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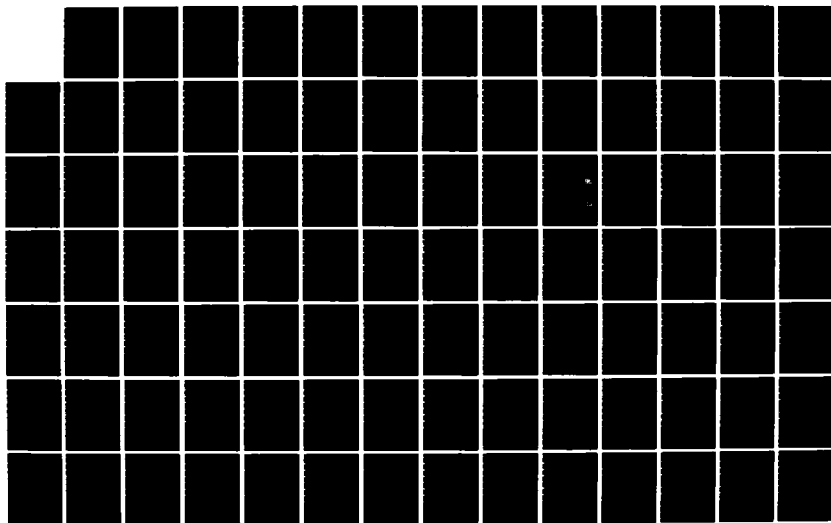
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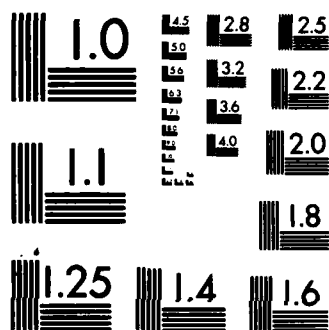
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A HIGH FREQUENCY RADIO TECHNIQUE
FOR MEASURING PLASMA DRIFTS IN
THE IONOSPHERE

Claude G. Dozois

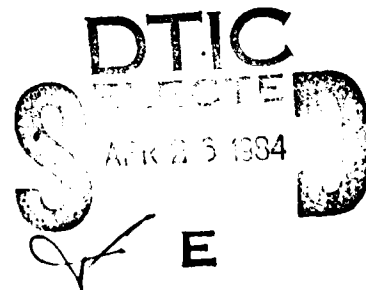
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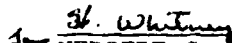
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the reflection areas are determined from the Doppler shifts, and a resultant plasma-drift velocity is calculated from these components. The analysis technique is first tested with computer-simulated drift data; then calculations using Goose Bay data from night observations of the F region verify the technique by showing a westerly drift in late evening, shifting to an easterly drift around midnight, in agreement with F-region drift measurements made by other observational techniques.

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1.0 INTRODUCTION

1.1 Thesis Topic

The subject of this thesis is the measurement of "drift" (i.e. plasma motion)¹ in the F region of the auroral (polar) ionosphere. In order to justify the role of drift measurements in the context of a scientific study of the ionosphere, a brief review of the history and present status of ionospheric investigation will be presented first. Since the method of observation used for gathering the data for this thesis is radio sounding (via radio waves reflected coherently off the ionosphere), emphasis will be placed on this method of investigation and what it reveals about the ionosphere.

¹In this thesis, when we speak of "drift" without qualification, we are referring to plasma drift, as opposed to current. (Some authors, in the context of fading measurements (see section 1.7.1), speak of drift velocity in reference to the "drifting" of the interference pattern on the ground.) When charged particles are accelerated by an applied force but are also continuously subject to collisions with neutral particles, the resulting motion of the charged particles is random, but there is also a net component of motion at some angle to the applied force (see section 1.6.2.1); the average speed of this net motion is called the drift speed. In this sense, electrons and positive ions each drift in some particular direction. If the electron and ion drifts are in the same direction, the plasma moves bodily: this is what we call plasma drift or simply drift. If the electron and ion drifts are in opposite directions, we speak of plasma currents. We also use the expression "Doppler drift" in reference to measurements of plasma drift using ULCAR's method of measuring the Doppler-frequency of the reflected echoes.

1.2 Summary

The discovery and scientific study of the ionosphere is relatively recent in the history of physics. Guglielmo Marconi's successful trans-Atlantic radio transmission in 1901 initiated speculation as to how radio waves which travel in nearly straight lines could be received at great distances beyond the horizon. The presence of ionized gases in the upper atmosphere had been postulated earlier as an explanation of the aurora ("northern lights") and of variations in the earth's magnetic field; belief in the existence of an ionized layer now gained further impetus as the possible explanation of electromagnetic-wave reflection. Scientific curiosity and the growing commercial use of radio for long-distance communications stimulated the development of methods for investigating various theories about the nature and structure of the ionized layer. A milestone was achieved in 1924 when vertical reflection of high-frequency radio waves was first used to study directly the electron content of the upper atmosphere; after that, knowledge of the ionosphere developed rapidly, although radio sounding was limited to heights of about 300 km. The study of the chemical structure of the entire atmosphere by various techniques added further to man's knowledge of the ionosphere, in particular after rockets and satellites came into use in the 1950's. The successful development in 1958 of Thomson scatter sounding with VHF and UHF radio waves (which measures the weak incoherent signals scattered back by the free-electron clusters in the ionosphere)² and the use of topside sounding by satellite (using HF radio waves transmitted from a satellite)³ since 1962, have made it possible to explore

²Hargreaves (1979), section 3.7.4.

³Hargreaves (1979), section 3.7.1.

the ionosphere above 300 km; satellites have also added important knowledge about the geomagnetic field (which extends much beyond the ionosphere) and solar radiation, and the influence of both on the ionosphere.

The various observation techniques employed in studying the ionosphere have measured continual changes in ionospheric structure. Knowledge of the dynamics behind the structure variations is a prerequisite for a more thorough understanding of ionospheric phenomena. Attempts have been made to measure ionospheric movements by analyzing the fading of radio signals (fading is due to the interference of multi-path signals reflecting off moving ionospheric irregularities), but interpretation of the resulting interference patterns has proven difficult. Another method, which determines plasma drift by measuring the Doppler shift of each reflected signal, has been under development since the late 1960's by the University of Lowell Center for Atmospheric Research (ULCAR) in cooperation with the Air Force Geophysics Laboratory (AFGL).

The purpose of "Doppler-drift" measurements is to determine general plasma motion from direct measurements of the moving irregularities. Some results have been obtained with this approach; but in order to take advantage of the full potential of drift measurements, it is necessary to develop the capacity to do 24-hour observations, leading to knowledge about the diurnal and seasonal variations in drift motion. With the recent advances in computer technology (in particular the development of microchips with greater memory capabilities), it has been possible for ULCAR to incorporate Doppler-drift measurements as a standard feature in its Digisonde.⁴ The raw drift data is stored on magnetic tape, to be interpreted later by computer analysis. This thesis is a report on the development of computer algorithms by the author for

⁴The Digisonde is a digital ionospheric sounder developed by ULCAR. See section 1.5.2.

calculating the speed and direction of drift motion. In view of the future goal of making 24-hour drift observations, it was necessary to develop a method of computing drift-velocity vectors in a completely automatic fashion, eliminating the need for separate visual inspection of the raw drift data, or hand-plotting of the calculated vectors. This was achieved by the reduction of systematic errors and by appropriate averaging and smoothing techniques; and by incorporating into the drift-calculation program an output format which plots the drift direction and the drift speed as a function of time on two side-by-side graphs. Doppler-drift measurements from a period of several hours at night were used to calculate the F-layer drift in fifteen-minute intervals over Goose Bay, Labrador; the results compared favorably with drift measurements made by other observational techniques.

1.3 Discovery and Early Investigations of the Ionosphere⁵

1.3.1 Early History

Until the early 1900's observations of the atmosphere were limited to measurements (chemical composition, pressure, temperature, geomagnetic field) of the region below 30 km (the highest that balloons could ascend to) and to a few observations of natural phenomena occurring at higher heights. Theoretical investigations of the air friction required for meteors to burn up gave an indication of the density of gases in the region of 100 km; spectral analysis of auroral light revealed some information about the chemical composition in the same region. From the temperature dependence of the velocity of sound, the temperatures at heights above 30 km were deduced from experiments with sky-wave sound transmissions. From the gas laws and principles of photochemistry, and what

⁵Ratcliffe (1970), Chapters 1 and 2.

was known of the lower atmosphere, some estimates about the physical structure and chemical composition of the upper atmosphere were extrapolated, but the conclusions were limited and not very accurate.

Early investigations also led to the suspicion of the presence of charged particles in the higher regions, to account for the aurora and for the minute diurnal variations in the earth's magnetic field. It was thought that the aurora was caused by electrons from the sun, which were deflected by the geomagnetic field to the polar regions, where they produced an effect similar to the electric discharge in a neon lamp. Gauss proposed, in 1839, that the fluctuations in the geomagnetic field could be explained by electric currents in the atmosphere, and Stewart developed this idea further in 1882. Stewart postulated a dynamo effect due to tidal motions of the atmosphere across the earth's magnetic field, resulting in currents at those heights where the gas pressure is low enough for the gas to conduct. When it was later realized from laboratory experiments that a gas at low pressure conducts only if first ionized by some external agent, it was postulated that the ionization was probably brought about during the day by particles or radiation from the sun, and persisted through the night, although with diminished strength.

1.3.2 Discovery of the Heaviside Layer

In 1901, Marconi transmitted a radio signal beyond the curvature of the earth. MacDonald's revision of the diffraction theory to account for this phenomenon was disproved by Lord Rayleigh. Heaviside and Kennelly independently invoked the notion of a layer of ionized gases acting as a reflector of electromagnetic waves. The reflecting layer was named the Heaviside layer by Eccles in 1912, in a paper on the effect of an ionized layer on radio transmission.

After the development of commercial radio communications across the Atlantic following Marconi's experiment, repeated measurements of the strength of long-distance radio transmissions manifested diurnal and seasonal variations in the attenuation of the signals. This was seen as evidence that the sun probably ionizes the upper atmosphere: the changes in signal strength could be explained by the ionization level varying with the inclination of the sun's rays. A statistical correspondence was also observed between solar sunspot activity on the one hand, and on the other hand, magnetic "storms" (stronger-than-usual variations in the geomagnetic field), intensified auroral activity, and unusually strong radio reception during magnetic storms, possibly resulting from intensified ionization at the reflection level. Furthermore, long-distance communications weakened considerably at sunrise and disappeared completely after a few hours, returning only at night. It was suggested that this might be due to increased ionization in the presence of solar radiation, ionization which penetrated to levels below the reflecting layer, where the high frequency of collisions between charged and neutral particles (due to greater particle density) would account for the increased absorption.⁶ Scientists became increasingly convinced that the sun plays a key role in the production of an ionized layer which determines radio-propagation conditions, and that a detailed study of radio waves reflected off this layer could reveal much about the charged-particle distribution and about the sun itself.

The phenomenon of fading (fluctuations in signal strength over short periods -- a few minutes or less) seemed to indicate the possibility of reflecting radio waves ver-

⁶Later, long-distance communications during the day became possible with the use of higher radio frequencies, since there is less absorption at higher frequencies.

tically off the Heaviside layer. If trans-Atlantic communication was due to the reflection of radio waves off an ionized layer (not everyone accepted this explanation in the early 1920's), these waves were reflected at very large oblique angles. However, fading was observed even at short distances that were within reach of the ground wave, so it seemed to result from the interference of a sky wave with the ground wave;⁷ this sky wave would have to be reflected at a sharp angle of incidence, suggesting that even vertical reflections might be possible. In 1924, Breit and Tuve in America tested this hypothesis by transmitting pulses vertically, and succeeded in picking up the echoes reflected from directly overhead. By timing the return time of each pulse, they calculated the height of reflection to be about 100 km. In the same year, Appleton and Barnett achieved the same result in England by varying the frequency of a continuous wave and timing the return time of the echo at a given frequency. These two achievements not only proved the existence of the Heaviside layer, but also opened the door to a systematic and quantitative study of the "ionosphere," as it later came to be known.

1.3.2.1 Virtual vs. Real Height

The height of reflection calculated by Breit and Tuve from the return time of the echo is called the "virtual" height. The difference between virtual height and the real height is explained as follows. The height at which a radio wave of a given frequency is reflected depends on the density N_e (number density, or concentration) of free electrons. The wave is reflected at the level where its frequency f is equal

⁷Fading can also result from the interference between sky waves. See section 1.7.1.

to the so-called "plasma frequency," ($f_p \sim \sqrt{N_e}$).⁸ The density of ionization in the upper atmosphere increases with height up to the level of the peak electron density. Higher frequencies penetrate deeper into the ionosphere before reaching the level where the density is sufficient for reflection; if the wave frequency is greater than the plasma frequency of the peak electron density, the wave is not reflected but radiates into space. As a wave travels through the ionization below the reflection level, its group velocity v_g decreases. The denser the ionization, the more the pulse is slowed down. (In fact, vertical reflection occurs because at the level of reflection, v_g becomes zero: the wave cannot propagate any further, so the energy carried by the radio wave is reflected back toward the earth.) Since the speed of light (in vacuum) is used for the group velocity of the waves in calculating the reflection height of the pulses, the calculated or virtual height h' is greater than the real height h .⁹

1.3.3 Discovery of the Appleton Layer

By using successively higher radio frequencies, Appleton attempted to measure the highest frequency reflected by the Heaviside layer, from which he could calculate the peak electron density of the layer. He expected that frequencies above the "penetration frequency" would radiate into space, but instead he discovered that they were reflected higher up from a denser layer of ionization. This layer was at first called the Appleton layer; later, the Heaviside and

⁸See the discussion of the magneto-ionic theory in section 1.5.1, and in particular, equation (14).

⁹The real-height profile can be calculated from the virtual heights using an appropriate inversion algorithm.

Appleton layers were renamed the E and F layers, respectively.¹⁰ The region below the E layer where absorption occurs during the day was called the D region.¹¹ At about the same time, the term "ionosphere" came into use to refer to the entire ionized region of the atmosphere.

1.3.4 Scientific Investigation of the Ionosphere:

The Ionosonde

Subsequently, Breit and Tuve originated a systematic technique for investigating the ionosphere by developing the "ionosonde" (ionospheric sounder), an apparatus which plots the virtual height of the reflected echoes vs. the frequency of the transmitted signal, as the frequency is increased. The resulting plot is called an "ionogram."¹² From the plasma frequencies, the electron densities can be calculated as a function of height up to the level of the F-layer peak, which is typically at about 300 km (real height) but can vary by ± 100 km or so. The electron-density profile above that can be estimated from theoretical considerations. From

¹⁰The letters E and F were chosen because the electric field reflecting off the Heaviside layer had originally been labeled E, and subsequently the field reflecting off the Appleton layer had been labeled F. This choice also conveniently left room for labeling other layers in alphabetical order, if any were later discovered.

¹¹D region rather than D layer, because the ionization in that region does not form a layer but merges into the bottom of the E layer. At times, however, the E layer also merges into the F layer, so that the distinction between "layer" and "region" is not strictly adhered to. We can also speak of the E and F regions in the sense of the height ranges at which the E and F layers are found.

¹²See Figure 2 and section 1.5.2.1.

records of the time variations in the peak densities and in the heights of the layers, knowledge about the diurnal and seasonal variations in ionospheric structure can be acquired.

Soon other scientists in different parts of the world began using ionosondes for continuous monitoring of the ionosphere. The ionosonde became the most widely used instrument for continuous investigation of the ionosphere. "Although complemented by many newer methods, the ionosonde has not been supplanted as the basic tool for ionospheric monitoring, and does not seem likely to be."¹³ It is relatively inexpensive to set up, and can be kept in operation 24 hours a day with little maintenance. Other observational techniques measure parameters which the ionosonde cannot measure (and as such the importance of these other techniques for the study of the ionosphere should not be underestimated), but their use is limited because of much higher cost (some of them require the use of rockets or satellites), or because they depend on the sporadic occurrence of natural phenomena (e.g. the observation of meteor trails). Even Thomson scatter sounding, which can measure the electron density at all heights and a variety of other plasma parameters, is much more expensive than ionosonde sounding because it requires very powerful transmitters and large sensitive antennas.

1.4 Vertical Structure of the Upper Atmosphere

1.4.1 The Ionosphere

The ionosphere is a "shell" of naturally occurring plasma (ionized gas) which surrounds the earth in the upper regions of the atmosphere, where the atmospheric density is sufficiently low that a significant number of positive ions

¹³Hargreaves (1979), p. 39.

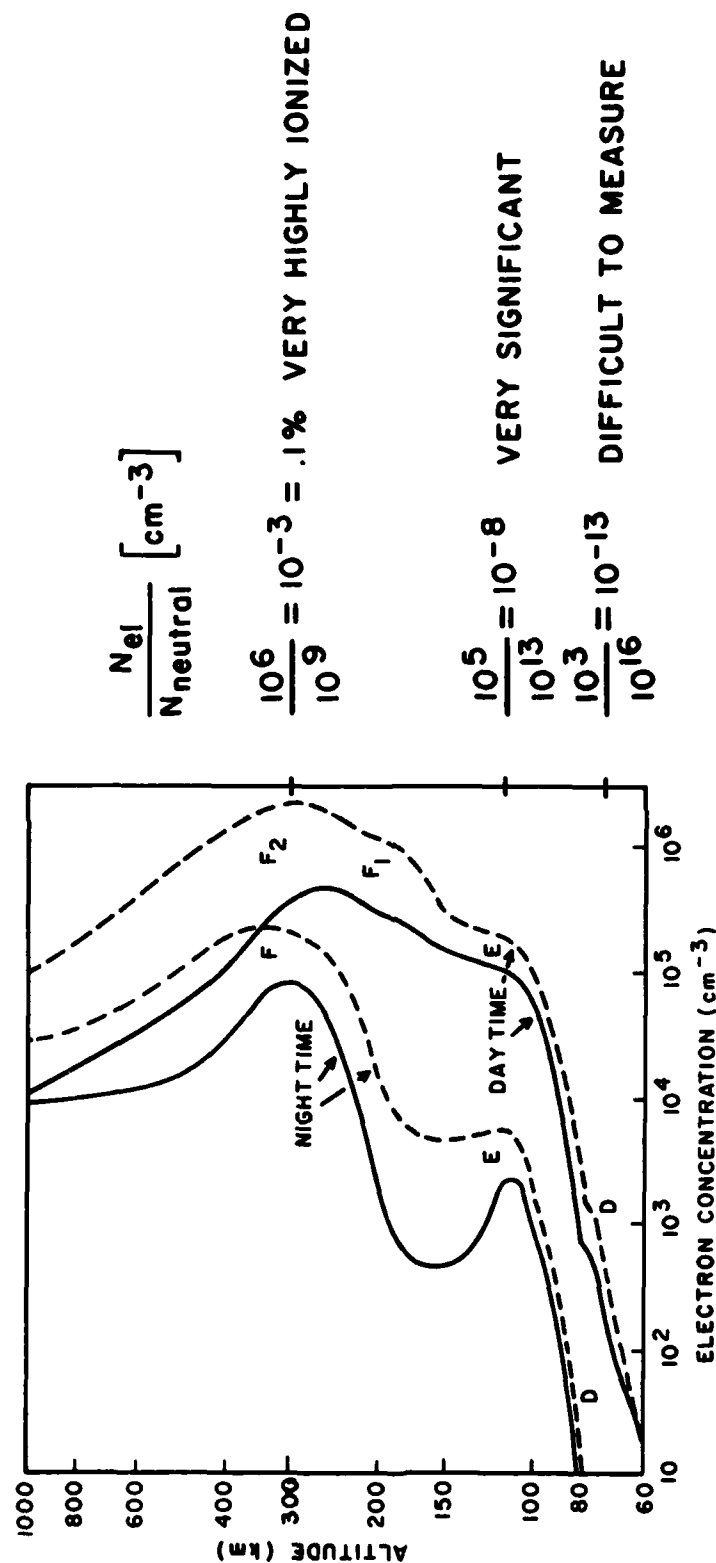
and free electrons (separated under the influence of the sun's energy) do not recombine but remain only loosely associated by electrostatic forces, giving the ionosphere the electrical nature characteristic of a plasma. Figure 1¹⁴ shows typical electron-density profiles in the mid-latitude ionosphere. Actual profiles are characterized by many temporal and geographical variations.¹⁵ The overlapping E and F layers approximate the shape of the so-called "Chapman layers" as predicted by Chapman in 1931.¹⁶ The nose of a Chapman layer (the region near the height of maximum electron density) approaches the shape of a parabola; at increasing heights, the profile decays into an exponential tail. (These tails are not shown in Figure 1: the E-layer tail merges into the F layer; the F-layer tail extends into the magnetosphere, beyond the range of the figure.) Despite several simplifying assumptions made by Chapman in his deductions, the electron-density profiles behave approximately as predicted. Historically, observed profiles have been compared to Chapman layers, and major departures from Chapman theory were called "anomalies."

The lower border of the ionosphere is considered to be the height at which the density of free electrons is sufficient to affect radio propagation; this height is somewhere

¹⁴Taken from a wall chart prepared by A. L. Carrigan and R. A. Skrivanek, Aerospace Environment (Hanscom Air Force Base, Mass.: Air Force Geophysics Laboratory, 1974), Figure 13, by W. Swider. The ratios of free-electron to neutral-particle concentrations were added by the present author. We speak of electron-density profiles because, even though the ionosphere is essentially neutral on a macroscopic scale (containing approximately equal numbers of free electrons and positive ions), it is the electrons that affect HF radio propagation.

¹⁵See Hargreaves (1979), Chapter 5.

¹⁶Davies (1965), section 1.4 and references therein.



Typical midlatitude daytime and nighttime electron profiles for sunspot maximum --- and minimum —.

DAY/NIGHTTIME ELECTRON CONCENTRATIONS

Figure 1

between 50 and 80 km (depending when and where it is measured). In the D and E regions, recombination of electrons and ions occurs more quickly because of the greater density of gases; the ionization in those regions is more closely dependent on the inclination of the sun's rays, and practically disappears at night. In the E region, a narrow layer of dense ionization called the sporadic E layer (Es) develops occasionally. The F layer can differentiate into two sub-layers called the F1 and F2 layers (see the two daytime profiles in Figure 1). This differentiation, which is sometimes pronounced, sometimes barely noticeable, occurs during the days of the summer season. In the F region also, a phenomenon called Spread-F can occur in the evening and at night. Spread-F manifests itself on ionograms as a widening of the trace, indicating reflections from many height ranges for the same wave frequency; this effect is probably due to patches of ionization covering a large height range.

1.4.2 The Magnetosphere¹⁷

Beyond the F layer, the electron density decreases exponentially with height. (The ratio of free electrons to neutral particles actually increases, but the total atmospheric density decreases exponentially.) In a broad sense, the ionosphere (the ionized region of the atmosphere) extends to tens of earth radii;¹⁸ however, the region above 800 or 1000 km is sometimes referred to as the magnetosphere, because there the geomagnetic field dominates plasma phenomena in determining the motion of charged particles: i.e., the energy density of the geomagnetic field exceeds the plasma energy density.

¹⁷Hargreaves (1979), section 7.1.

¹⁸The earth's radius is approximately 6370 km.

1.4.3 The Solar Wind¹⁹

Prior to the advent of artificial satellites, what was known of the atmospheric region beyond the peak of the F layer was limited to what could be inferred about the upper ionosphere and the magnetosphere from ground-based measurements and theoretical considerations. It was thought that beyond the magnetosphere and up to the sun's corona (outer atmosphere), there existed a vast region of "empty space," and that the influence of the sun on the earth's atmosphere was limited to photon radiation and occasional streams of plasma. In the early 1950's, it was suspected from observations of meteor trails and later from spectroscopic measurements of the sun's corona that the sun emits a steady stream of particles. Satellite measurements since then have shown that the sun's corona is not confined to a limited region near the sun but flows continuously outward to distances far beyond the earth; the earth is immersed in a sea of coronal plasma, which has been named the solar wind. The solar wind is pure plasma, which has the peculiar property of "freezing-in" the sun's magnetic field²⁰ and thus extending its influence to the regions of the earth. Since it is much easier for the charged particles from the solar wind to propagate along the earth's magnetic field lines than across them, and because of the nearly-vertical incidence of the geomagnetic field lines at the poles, the auroral ionosphere and magnetosphere are especially prone to the influence of the complex interactions between the solar wind (and the solar magnetic field) and the earth's upper atmosphere. The exact mechanism of how the solar wind particles enter into the magnetotail of the magnetosphere and from there into the polar ionosphere is the

¹⁹Ratcliffe (1970), Chapter 7.

²⁰Hargreaves (1979), section 2.3.6.

subject of current research and goes beyond the scope of this thesis.

1.4.4 The Dynamics of the Ionosphere

Variations in ionospheric structure are a function of the rate of change of plasma density, which in turn depends on the ionization rate, the recombination rate, and the loss (or gain) of plasma through movement.²¹ When Chapman calculated the theoretical shape of the ionospheric layers, he considered only the ionization and recombination rates, and he made simplifying assumptions about the nature of the ionizing radiation, the gas distribution in the atmosphere, and the photochemical processes involved in the ionization of the various gases.²² The anomalous behavior of the ionosphere can be explained in part by correcting these simplifications; but a complete picture of ionospheric variations requires knowledge of plasma motion, from which the scientist attempts to understand the forces governing the large-scale behavior of the ionosphere, as well as the origins of these forces. In particular, it is hoped that future drift measurements at Goose Bay, Labrador²³ will provide valuable information about the effects of the solar wind on the earth's atmosphere.

1.5 The Ionosonde

As mentioned above, a large part of our knowledge of the ionosphere before 1960 was acquired by remote sensing with

²¹Hargreaves (1979), section 4.2.

²²Davies (1965), sections 1.4.3 and 1.4.4.

²³Goose Bay is located about 25° south of the north geomagnetic pole.

ionosondes; and even in this age of artificial satellites, the ionosonde continues to play an indispensable role for continuous ionospheric monitoring.

1.5.1 The Magneto-Ionic Theory²⁴

The principles of ionosonde operation are based on the reflection properties of the plasma. Since the first suggestion of the existence of an ionized atmospheric layer by Heaviside and Kennelly, attempts were made to understand how radio waves are propagated by charged particles in the presence of the earth's magnetic field. Appleton and Lassen both developed the form of the magneto-ionic theory in common use today.

1.5.1.1 Radio Propagation in the Ionosphere

According to the magneto-ionic theory, electrons in the ionosphere oscillate under the influence of the electric field of the transmitted wave and then re-radiate wavelets of energy. The influence of the geomagnetic field causes the oscillating particles to gyrate around the magnetic field lines under the influence of the Lorentz force (see equation (24)), so that the electrons oscillate in a curve rather than in a straight line. As a result the re-radiated wavelets acquire a rotating polarization. The magneto-ionic theory shows that only waves with two particular polarizations, called "characteristic" polarizations, can propagate in the ionosphere: for the major part of the globe these polarizations are right-handed and left-handed circular. (Very close to the magnetic equator, where the field is horizontal, the characteristic modes for vertical propagation are linearly polarized

²⁴Davies (1965), section 2.3.

waves, parallel and perpendicular to the magnetic field.) A linearly polarized wave impinging on the ionosphere is split into these two characteristic waves, which propagate with different velocities. The two waves are called the ordinary (O) and extraordinary (X) waves.

1.5.1.2 The Appleton Formula

The speed of wave propagation in the ionosphere is expressed by the complex index of refraction

$$n = \frac{c}{v} = \mu - i\chi \quad (1)$$

where c is the speed of light in free space, v is the phase velocity of the transmitted wave, and μ and χ are respectively the real and imaginary parts of n . The effect of χ can be seen by expressing the wave equation for vertical propagation (along the z axis) in the following form (since $v = \omega/k$; here $e \equiv \exp$):

$$\begin{aligned} E &= E_0 e^{i(\omega t - kz)} \\ &= E_0 e^{i[\omega t - (\mu - i\chi) \frac{\omega}{c} z]} \\ &= E_0 e^{-\chi \frac{\omega}{c} z} e^{i(\omega t - \mu \frac{\omega}{c} z)} \end{aligned} \quad (2)$$

The term $e^{-\chi \frac{\omega}{c} z}$ represents a decay in the wave amplitude. In the ionosphere, the index of refraction takes the form of the so-called Appleton formula

$$n^2 = 1 - \frac{X}{1 - iZ - \frac{Y_T^2}{2(1-X-iZ)} \pm \left(\frac{Y_T^4}{4(1-X-iZ)^2} + Y_L^2 \right)^{1/2}} \quad (3)$$

where the upper sign is for the O wave, and the lower sign, for the X wave; and

$$X = \frac{Ne^2}{\epsilon_0 m \omega^2} = \frac{\omega_p^2}{\omega^2} = \frac{f_p^2}{f^2} \quad (4)$$

$$Y_{L,T} = \frac{|e| B_{L,T}}{m \omega} = \frac{\omega_{L,T}}{\omega} \quad (5)$$

$$Z = \nu/\omega \quad (6)$$

where: N is the electron density,

e is the electron charge,²⁵

ϵ_0 is the permittivity of free space,

m is the electron mass,

$\omega = 2\pi f$ where f is the radio frequency and ω is the corresponding angular frequency,

$\omega_p = 2\pi f_p$ where f_p is the plasma frequency (to be explained later),

$B_{L,T}$ are the components of the geomagnetic field $\vec{B}$ longitudinal to (along), and transverse to, the direction of wave propagation, i.e. $B_L = B \cos \theta$, $B_T = B \sin \theta$, θ being the angle between the geomagnetic field and the direction of propagation.

$\omega_{L,T}$ are the longitudinal and transverse components of the angular gyrofrequency $\omega_B = |e| B/m$,

ν is the frequency of electron collisions with other particles.

²⁵There is a confusion in the literature in the usage of the symbol e for denoting charge. Throughout this thesis, $e = \pm 1.6 \times 10^{-19}$ coul, i.e. $e = |e|$ for positive ions (neutrals stripped of one electron) and $e = -|e|$ for electrons.

The absorption due to collisions results in a decrease of the wave amplitude, as expressed in equation (2). Collisions are significant in the D region; but since D-region absorption is inversely proportional to the square of the radio frequency, waves of frequency above 1 or 2 MHz can penetrate into the E and F regions, where collisions can be neglected, so we will consider only the real part of n :

$$\mu^2 = 1 - \frac{2X(1-X)}{2(1-X) - Y_T^2 \pm \sqrt{Y_T^4 + 4(1-X)^2 Y_L^2}} \quad (7)$$

Just below the ionosphere, $N = 0$ so $X = 0$ and $\mu^2 = 1$. As N increases with height, μ^2 decreases. When μ^2 becomes negative, the index of refraction becomes a purely imaginary number; the wave does not propagate any further but becomes an evanescent wave, whose amplitude decays rapidly. For wave propagation in the ionosphere then, μ takes values between 1 and 0. At $\mu = 0$, the wave cannot propagate further but is reflected back towards the earth. If the direction of propagation of the incident wave is perpendicular to an iso-density surface (a surface of equal plasma density), the wave returns to the transmitter/receiver site and its virtual height or range is defined by the travel time of the signal.

1.5.1.3 Conditions of Reflection

Setting $\mu^2 = 0$ in equation (7) and solving for X , we get, with the + sign,

$$X = 1 \quad (8)$$

and with the - sign,

$$X = 1 - Y \quad (9)$$

$$X = 1 + Y \quad (10)$$

$$Y^2 = Y_T^2 + Y_L^2 \quad (11)$$

Note that, in the absence of the magnetic field ($Y_T = Y_L = 0$), equation (7) becomes, for all heights,

$$\mu^2 = 1 - X \quad (12)$$

which also yields $X = 1$ for $\mu = 0$ at the reflection height. Thus, one of the magneto-ionic waves is reflected as in the absence of the magnetic field; this is the ordinary wave. From (4) and (8), at the level of reflection,

$$\frac{Ne^2}{\epsilon_0 m} = \omega^2 \text{ or } \frac{Ne^2}{4\pi^2 \epsilon_0 m} = f^2 \quad (13)$$

$$\sqrt{\frac{Ne^2}{4\pi^2 \epsilon_0 m}} = \sqrt{80.5 N} \approx 9\sqrt{N} = f_p \quad (14)$$

i.e. reflection of the ordinary wave occurs at the level where the electron concentration is such that $f = 9\sqrt{N}$, which is why the quantity $9\sqrt{N}$ is called the plasma frequency f_p . Therefore we rewrite (8) as

$$f_p^2 = f^2 \text{ (reflection condition for the O wave)} \quad (15)$$

The reflection condition for the X wave is expressed by equation (9),²⁶ which can be written, using the definitions of X (equation (4)) and Y (equations (5) and (11)), and the gyrofrequency $f_B = \omega_B/2\pi$,

$$f_p^2 = f^2 \left(1 - \frac{f_B}{f}\right) \text{ (reflection condition for the X wave)} \quad (16)$$

To compare the densities at which the O and X waves are reflected, consider (using the definition (14) of f_p): from (15), the O wave is reflected at density

²⁶Equation (10) expresses the reflection condition for another type of wave, the so-called Z wave, which is rarely seen, so we will ignore it.

$$N = \frac{f^2}{80.5} \quad (17)$$

and from (16), and noting that $f_B < f$, the X wave is reflected at density

$$N = \frac{f^2 (1 - \frac{f_B}{f})}{80.5} < \frac{f^2}{80.5} \quad (18)$$

For a given radio frequency, the density required for reflection of the X wave is less than for reflection of the O wave; or, for a given N, the reflection frequency is higher for the X wave than for the O wave. For both ionograms and Doppler-drift measurements, it is the O wave that is normally used for analysis.

1.5.1.4 Phase Velocity vs. Group Velocity

From equation (1), as μ decreases, the phase velocity v increases and exceeds the speed of light. This does not contradict the special theory of relativity, since no energy is propagated by phase motion; it only means that in the ionosphere the wavelength is greater than in free space. Energy transport occurs at the group velocity of the pulses; in a dispersive medium (where each frequency component of the pulse travels at a different speed: $n = n(\omega)$, which is the case in the ionosphere; see equation (3)), the group velocity is different from the phase velocity. We can define a group index of refraction

$$\mu' = \frac{c}{v_g} \quad (19)$$

where v_g is the component of the group velocity in the direction of phase propagation; in the absence of a magnetic field or at the level of reflection of the O wave,

$$\mu' = \frac{c}{v_g} = \frac{1}{\mu} \quad (20)$$

or

$$\mu = \frac{v_g}{c} \quad (21)$$

so that as μ approaches zero the group velocity approaches zero. With the magnetic field and below the level of reflection of the O wave, the expression for μ' is much more complicated,²⁷ but v_g is less than c at all heights.

1.5.2 The Digisonde 128PS

ULCAR has developed its own model of the ionosonde, the Digisonde, which is an advanced digital ionosonde²⁸ capable of measuring and recording all the important wave parameters of the reflected echo: amplitude, phase, transmitted frequency, Doppler offset due to the motion of reflection areas, incidence angle and wave polarization (O, X). The Digisonde model presently in operation in Goose Bay, Labrador (where the drift measurements discussed later were made) is the DGS 128PS,²⁹ which implements many ideas suggested by experience with previous models. The DGS 128PS operates in two complementary modes: the ionogram and drift modes. In either mode, digital preprocessing and multiplexed output formatting reduces the data to manageable size, so that information about all the wave parameters can be stored on digital magnetic tapes, from which particular parameters can later be extracted for special research studies.

²⁷ See Davies (1965), equation 2.119.

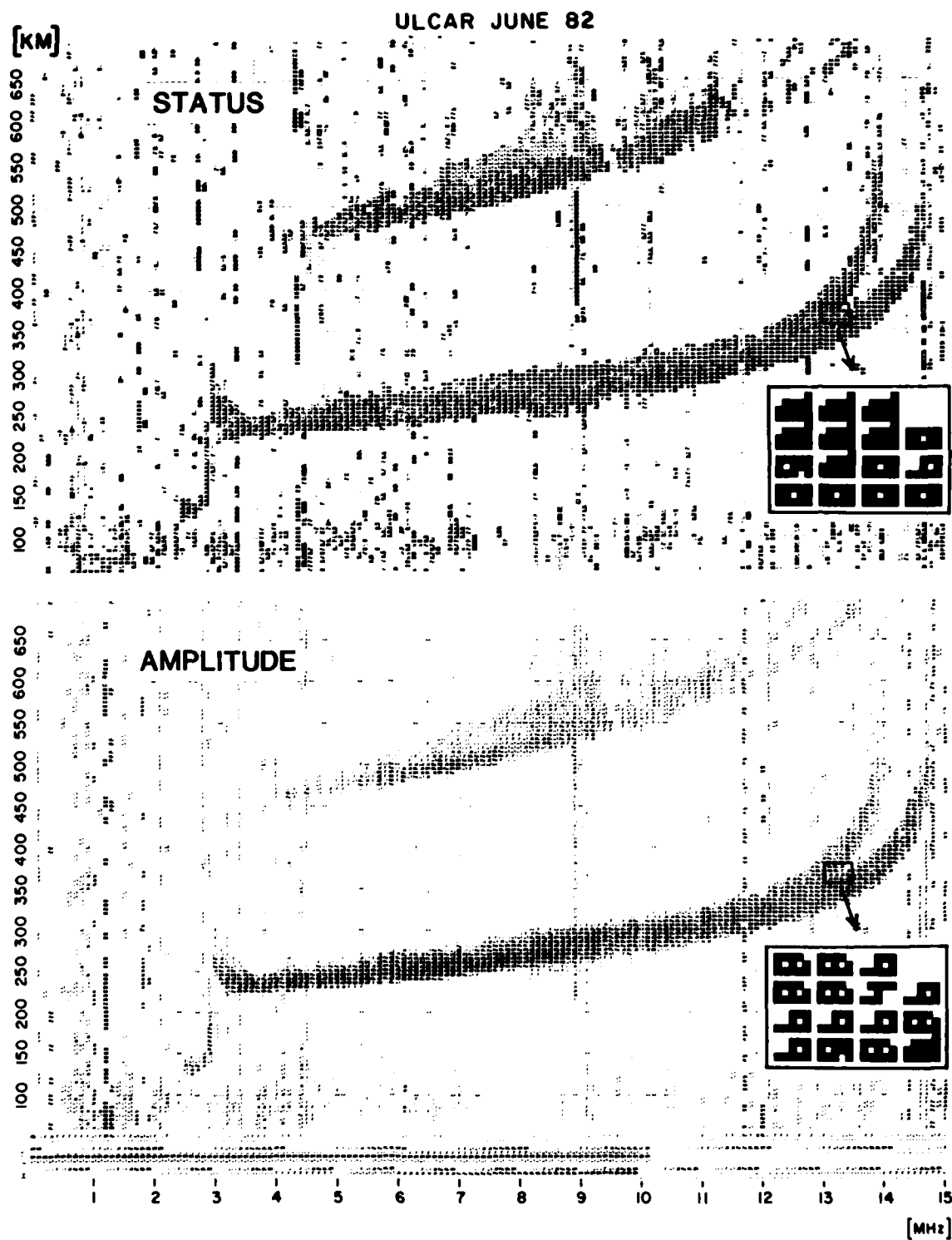
²⁸ Bibl and Reinisch (1978b).

²⁹ Bibl and Reinisch (1978a).

1.5.2.1 The Ionogram Mode

Figure 2 is a typical ionogram generated at Goose Bay in December of 1981. The height-vs-frequency trace is enhanced by the use of a special printing format³⁰ called the "Opti-Font" (optical font) in which the hexadecimal numbers of larger value are more prominent, as illustrated in the two inserts where some of the numbers are enlarged: the enlarged numbers 4, 6, 8 and 9 are easily recognizable; the thick 0 represents 10; and the other enlarged symbol represents 11. Similarly, recognizable symbols represent all numbers from 0 to 15, permitting the printing of all numbers representable by a 4 bit binary code by a single character presentation. The horizontal scale is the sounding frequency $f = f_p$ in 100 kHz steps for the selected band of frequencies; the vertical scale is the virtual height in increments of 5 km, starting at 60 km. The lower ionogram contains the amplitudes corresponding to each frequency-range bin (FRB); in order to improve the signal-to-noise ratio, the amplitudes are calculated by integrating, for each FRB, the echoes of several pulses (typically 64 pulses; the number is varied according to the encountered level of radio interference). The upper amplitude trace is due to the second echo: energy returning to earth from the ionosphere is reflected by the earth back to the ionosphere, from which it returns to the transmitter/receiver site; since the travel time of a double echo is twice that of a single echo, the lower trace is partially reproduced on the ionogram at twice the virtual height. For each FRB in the amplitude ionogram there is a corresponding status number in the upper ionogram, which provides information about the

³⁰Patenaude, Bibl and Reinisch (1973).



DIGISONDE IONOGRAM

GOOSE BAY 3 DEC 1981 11:00 AST

Figure 2

incidence angle,³¹ the Doppler shift and the polarization (0, X) of the strongest echo for each FRB. In this ionogram the major part of the trace is from the F layer; only a small section of the E layer shows up, the E-layer cusp, from 2.5 to 3 MHz (other numbers are due to noise; energy transmitted at the lower frequencies was absorbed in the D region). A cusp is formed near the critical frequency (penetration frequency) of each layer because near the peak of the layer the pulse stays longer in a region where μ is close to, though not quite, zero,³² i.e. the pulse travels very slowly for a relatively long time, so the time delay of the echo is increased much more. Of the two F-layer cusps, the one at the higher frequencies is from the extraordinary wave. This particular ionogram is a vertical ionogram; oblique ionograms (for which the transmitting and receiving antenna arrays are phased for maximum radiation at an oblique angle of incidence) are also made at Goose Bay to collect more specific information about the horizontal electron-density distribution.

1.5.2.2 The Drift Mode

Ionograms provide amplitude information for all FRB's within the selected limits of frequency and range, but only limited information about the incidence angles and Doppler frequencies of each FRB. In the drift mode, on the other hand, only 3 or 6 FRB's are chosen (FRB's with echo signals, as determined from an ionogram made immediately prior to the drift measurement); integration time is increased (providing

³¹Vertical sounding does not yield only vertical but also off-vertical echoes because of irregularities in the ionosphere. See section 1.6.1.

³²See the electron-density profiles in Figure 1: near the peaks of each layer the slope increases sharply, indicating that N changes much more slowly with height.

better Doppler resolution) and the complete discrete complex Fourier transform (amplitude and phase) of each signal from the four receiving antennas is recorded on magnetic tape. Each antenna signal is, in general, a composite of echoes received from different reflection points that are likely to move with a different radial velocity component. We will elaborate on this in later sections below.

1.6 Horizontal Structure of the Ionosphere

1.6.1 Horizontal Density Gradients³³

If the ionosphere were spherically symmetric about the earth, isodensity surfaces above a given site would be essentially horizontal; only radio waves that are propagated vertically would be reflected back to the site, and the study of horizontal movement in the ionosphere by the analysis of fading records or the measurement of Doppler frequencies would be impossible. There would be no fading of radio waves, since all echoes would come from the same area (directly overhead) and would therefore all be in phase; and since the Doppler-frequency shift imposed on reflected waves is proportional to the component of velocity along the direction of wave propagation, the Doppler-drift method would measure only vertical motion.

In fact, horizontal density gradients do exist in the ionosphere, so that off-vertical radio waves can be reflected back to the transmitter/receiver site by isodensity surfaces that are perpendicular to their direction of propagation. The density gradients are due to small-scale irregularities (in the order of 100's of meters) and large-scale travelling-wave disturbances (10's or 100's of kilometers). The fading of radio waves and the preliminary results obtained

³³Hargreaves (1979), Chapter 6.

from ULCAR's Doppler-drift measurements (see section 1.7.2.1) give evidence of the existence of the small and the large irregularities in both the E and F regions. F-region irregularities have been studied with ionosondes and by observing the fluctuations ("scintillations") imposed on signals from radio stars and satellites; they have also been measured directly by plasma probes placed on satellites. The large-scale density gradients fall in the category of acoustic-gravity waves, in which the restoring force is a combination of compressional and gravitational forces acting on the neutral air particles; the resulting motion is imparted to the charged particles through collisions. These waves or "travelling ionospheric disturbances" (TID's) have been observed in the distortion of meteor trails; they have been measured by ionosondes (for example, by continuous observations of virtual height at a fixed frequency),^{34a} by incoherent scatter, and by the Doppler-drift measurements made by ULCAR.

1.6.2 Movement of Irregularities³⁴

The small-scale irregularities move under the influence of neutral winds and electric fields. The movement of irregularities implies that the plasma is moving as a body, i.e. both electrons and positive ions³⁵ are moving in the

³⁴Risbeth and Garriott (1969), section 4.2; Ratcliffe (1972), sections 7.1 and 7.2; Hargreaves (1979), section 4.4.

^{34a}Techniques for the Study of TID's with Multi-Station Rapid-Run Ionosondes by M. G. Morgan, C. H. J. Calderon and K. A. Ballard, Radio Sci. 13, 4, 729-741, July 1978.

³⁵The concentration of negative ions (neutral particles to which free electrons have attached themselves) is generally negligible in the E and F regions. See Risbeth and Garriott (1969), p. 127.

same direction; motion in opposite directions constitutes a current, but does not result in any net movement of the plasma. The mechanical force $\vec{F}^U$ due to the wind, which transfers momentum to the charged particles through collisions, is

$$\vec{F}^U = m \nu \vec{U} \quad (22)$$

where m is the particle mass, ν is the collision frequency at which charged particles collide with neutrals and $\vec{U}$ is the wind velocity. The electrical force $\vec{F}^E$ is

$$\vec{F}^E = e \vec{E} \quad (23)$$

where e is the particle charge³⁶ and $\vec{E}$ is the electric field vector.

1.6.2.1 Charged-Particle Motion in the Geomagnetic Field

To determine under what conditions these forces result in plasma drift, we must include the effects of collisions and of the earth's magnetic field. We consider first the Lorentz force $\vec{F}^B$ exerted by the magnetic field $\vec{B}$, where $\vec{v}$

$$\vec{F}^B = e \vec{v} \times \vec{B} \quad (24)$$

is the velocity of the charged particle. For our considerations, we choose the z axis along the field, so that $|\vec{B}| = B_z$ and there is no Lorentz force in the z direction. A charged particle moving in the x - y plane and accelerated only by the Lorentz force rotates or gyrates around an axis parallel to the z axis with (angular) gyrofrequency ω ,

$$\omega = \frac{|e| B_z}{m} \quad (25)$$

³⁶See footnote 25 in section 1.5.1.2.

(particles of opposite charge rotating in opposite directions). To illustrate the resulting motion when there is also an applied force, consider a particle at rest at the origin of the coordinate system, to which is applied a force perpendicular to the magnetic field, say along the x axis. We consider both the electrical force $\vec{F}^E$ ($|\vec{E}| = E_x$) and the mechanical force $\vec{F}^U$ ($|\vec{U}| = U_x$) and neglect collisions for the moment.³⁷ The mechanical force F_x^U is in the direction of $+x$ for both positive and negative particles, but the Lorentz force is $|e| \vec{V} \times \vec{B}$ for ions and $-|e| \vec{V} \times \vec{B}$ for electrons. Both particles will start off in the $+x$ direction;³⁸ the positive ion will curve clockwise into an arc, coming to rest at some point down the $-y$ axis; the electron will curve counterclockwise and come to rest on the $+y$ axis; F_x impedes any further motion of either particle in the $-x$ direction. The motion of each particle then starts over again with an identical travel path. With the electrical force, F_x^E is $|e| E_x$ for ions, $-|e| E_x$ for electrons. Assuming that $|F_x^E| = |F_x^U|$, positive particles follow the same path as with the mechanical force; negative particles start off in the $-x$ direction and curve counterclockwise toward the $-y$ axis. The result is that under the influence of either force, both positive and negative particles drift with speed $F_x/|e|B_z$ in a direction perpendicular to the applied force and to the magnetic field.

³⁷ Strictly speaking, for the mechanical force we must consider the limit as v approaches zero, since $\vec{F}^U = m\vec{v}\vec{U}$ is zero if $v = 0$; as will be shown later, the result is the same as for $v \ll \omega$.

³⁸ See Figure 3, adapted from Risbeth and Garriott (1969), Figure 31, p. 133. The subscripts i and e refer to ions and electrons respectively; the heights in parentheses are the approximate heights at which the stated conditions apply. For simplicity of illustration, it is assumed in the drawing that $|F_x^U| = |F_x^E|$, $v_i = v_e$ and $\omega_e/\omega_i = m_i/m_e = 3$ instead of 10^4 .

The influence of collisions on the above motions is also illustrated in Figure 3; it is assumed that the charged particles collide with neutral particles with an average collision frequency ν ,³⁹ and start from rest after each collision. A component of particle drift is introduced in the direction of the applied force, at the expense of the drift perpendicular to that force, as expressed in the following equations (where we include the effect of an applied force along the magnetic field):

$$V_x = k_1 F_x \quad (26)$$

$$V_y = \mp k_2 F_x \quad (27)$$

$$V_z = k_0 F_z \quad (28)$$

$$k_1 = \frac{1}{|e|B_z} \frac{\omega\nu}{\nu^2 + \omega^2} \quad (29)$$

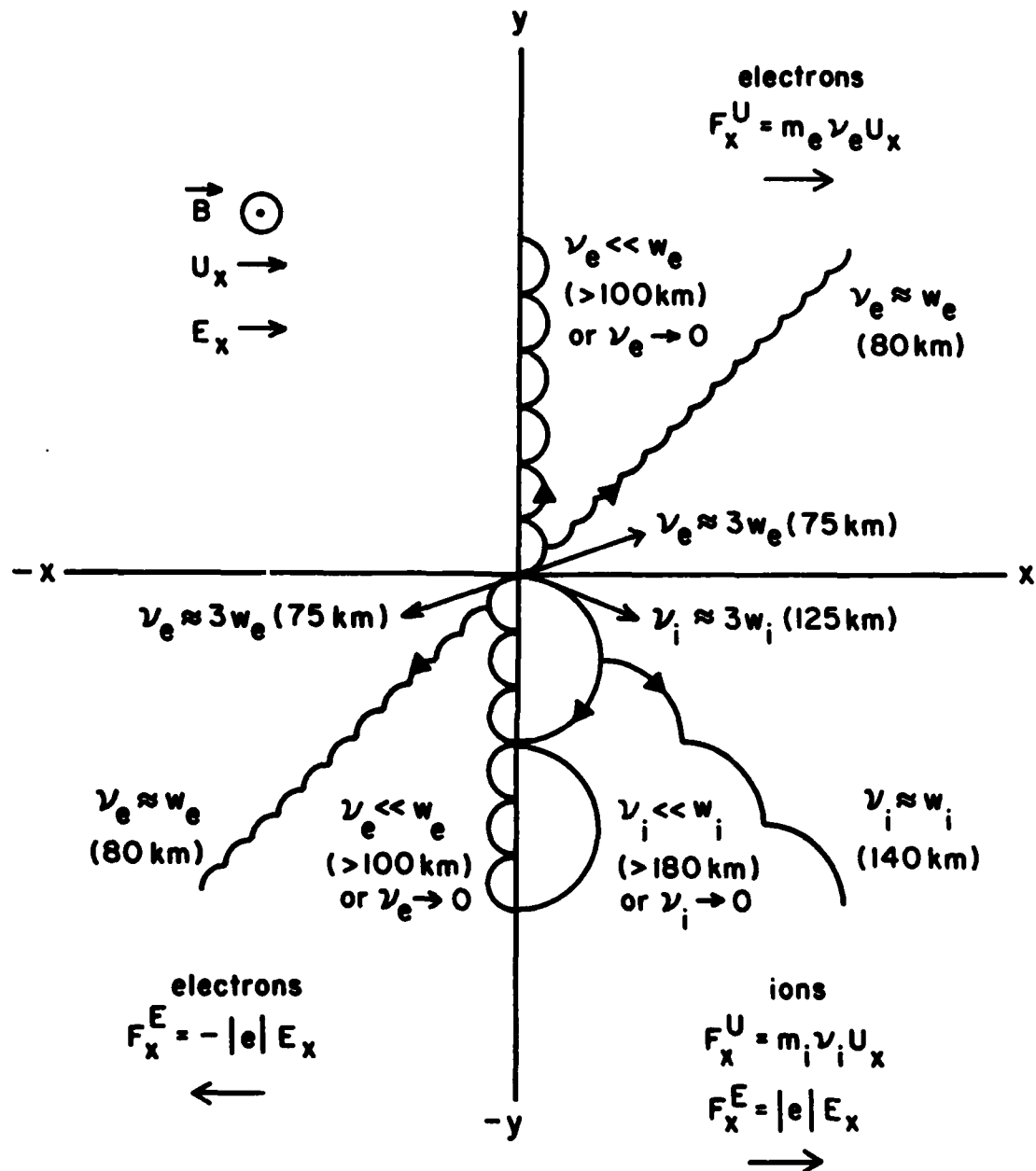
$$k_2 = \frac{1}{|e|B_z} \frac{\omega^2}{\nu^2 + \omega^2} \quad (30)$$

$$k_0 = \frac{1}{m\nu} = \frac{1}{|e|B_z} \frac{\omega}{\nu} \quad (31)$$

where the quantities ω , ν and m are, of course, different for positive ions and electrons. The signs in equation (27) indicate opposite results for positive and negative particles: here and below, the upper sign refers to positive ions; the lower sign, to electrons. Along the magnetic field, the wind causes the plasma to drift at velocity U_z :

$$V_z = \frac{m\nu U_z}{m\nu} = U_z \quad (32)$$

³⁹Or "effective" collision frequency; see Risbeth and Garriott (1969), section 4.12.



**CHARGED - PARTICLE MOTIONS IN A $\vec{B}$ FIELD
 UNDER THE INFLUENCE OF ELECTRICAL AND
 MECHANICAL FORCES**

Figure 3

whereas the electric field causes a current:

$$V_z = \frac{\pm |e| E_z}{mv} \quad (33)$$

For the component of the applied force perpendicular to the magnetic field, we consider two special cases. Below about 70-75 km, $v \gg \omega$ for both positive ions and electrons; to a first approximation, $k_1 = k_0 \gg k_2$, so that $V_y \approx 0$ and

$$V_x = \frac{F_x}{mv} \quad (34)$$

The effect of the magnetic field is negligible: the wind carries the plasma along at its own velocity,

$$V_x^U = \frac{mvU_x}{mv} = U_x \quad (35)$$

and the electric field produces a current parallel to itself,

$$V_x^E = \frac{\pm |e| E_x}{mv} \quad (36)$$

i.e. the results are the same as along the magnetic field. At heights above 180-200 km, $v \ll \omega$ for both types of particles: $k_1 \ll k_2 \approx 1/|e|B_z$ so $V_x \approx 0$; here, the wind produces a current perpendicular to itself and to the magnetic field,

$$V_y^U = \mp \frac{1}{|e|B_z} mvU_x = \mp \frac{v}{\omega} U_x \quad (37)$$

and the electric field causes plasma drift perpendicular to $\vec{E}$ and to $\vec{B}$,

$$V_y^E = (\mp)(\pm) \frac{1}{|e|B_z} |e| E_x = \frac{-E_x}{B_z} \quad (38)$$

1.6.2.2 Summary

Generally, the applied force can be in any direction. In the D region of the ionosphere, drift is due to the wind,

with drift velocity given by

$$\vec{v}^U = \vec{U} \quad (39)$$

In the F region, the field-aligned component of drift is due to the neutral wind, with velocity

$$\vec{v}^U = \frac{(\vec{U} \cdot \vec{B})\vec{B}}{B^2} \quad (40)$$

whereas the non-aligned drift is caused by an electric field, and its velocity is

$$\vec{v}^E = \frac{\vec{E} \times \vec{B}}{B^2} \quad (41)$$

with direction perpendicular to the plane containing $\vec{E}$ and $\vec{B}$. In the E region ($v_e < \omega_e$ but $v_i > \omega_i$) the situation is more complex; in general both winds and electric fields can produce drift velocities inclined to themselves, electron currents perpendicular to themselves, and ion currents parallel to themselves.

1.6.3 Plasma Drift in the F Region⁴⁰

The mechanical forces on charged particles in the ionosphere are divided into two classes: prevailing winds, and tides (which oscillate with a period related to the 24-hour daily cycle), both of which are primarily horizontal. The mechanism of prevailing winds is that of pressure gradients coming from the variation of solar heating with latitude, balanced by the Coriolis effect (as in the lower atmosphere); tides (which also exist in the lower atmosphere) are due primarily to the gravitational effects of the moon (as in the oceans--gravitational tides) and to the temperature differ-

⁴⁰Hargreaves (1979), section 6.4; Rishbeth and Garriott (1969), section 7.4; Ratcliffe (1972), section 5.1.

ences between the day and night sides of the earth (thermal tides), because of solar heating on the day side through absorption of solar radiation. The magnitude of the currents which can flow in any region of the ionosphere is dependent on the conductivity σ , which in turn is a function of the charged-particle density N and of the ratio v/ω . The conductivity is highest in the E region, so that an appreciable current flows at heights of about 110 km, under the influence of neutral winds; the separation of charges due to the different ion and electron drift directions ($v_e < \omega_e$ but $v_i > \omega_i$) results in an electric field, which further modifies the charged-particle motions. Since conductivity is greatest along magnetic field lines, which are oblique over most of the earth, the lines act as conductors between the E and F regions; thus (at low and middle latitudes) the electric field pattern of the E region is reproduced in the F region, which results in F-region plasma drift. The E region is referred to as the dynamo region, and the F region is compared to a motor driven by the dynamo. In the polar regions, F-region plasma drift⁴¹ is believed to arise from magnetospheric effects rather than from the neutral winds of lower altitudes. Several theories have been proposed to explain the interaction of the polar magnetosphere with the ionosphere.⁴² It is believed that interaction of the interplanetary field and the solar wind with the magnetosphere is the source of a large scale electric field across the magnetosphere, which maps down to F region heights across the polar cap, driving a large plasma convection system.^{42a} Satellite and UHF incoherent

⁴¹See Weber and Buchau (1981).

⁴²Stern (1977) gives an extensive review of the various theories.

^{42a}Evans et al, 1980 and references therein.

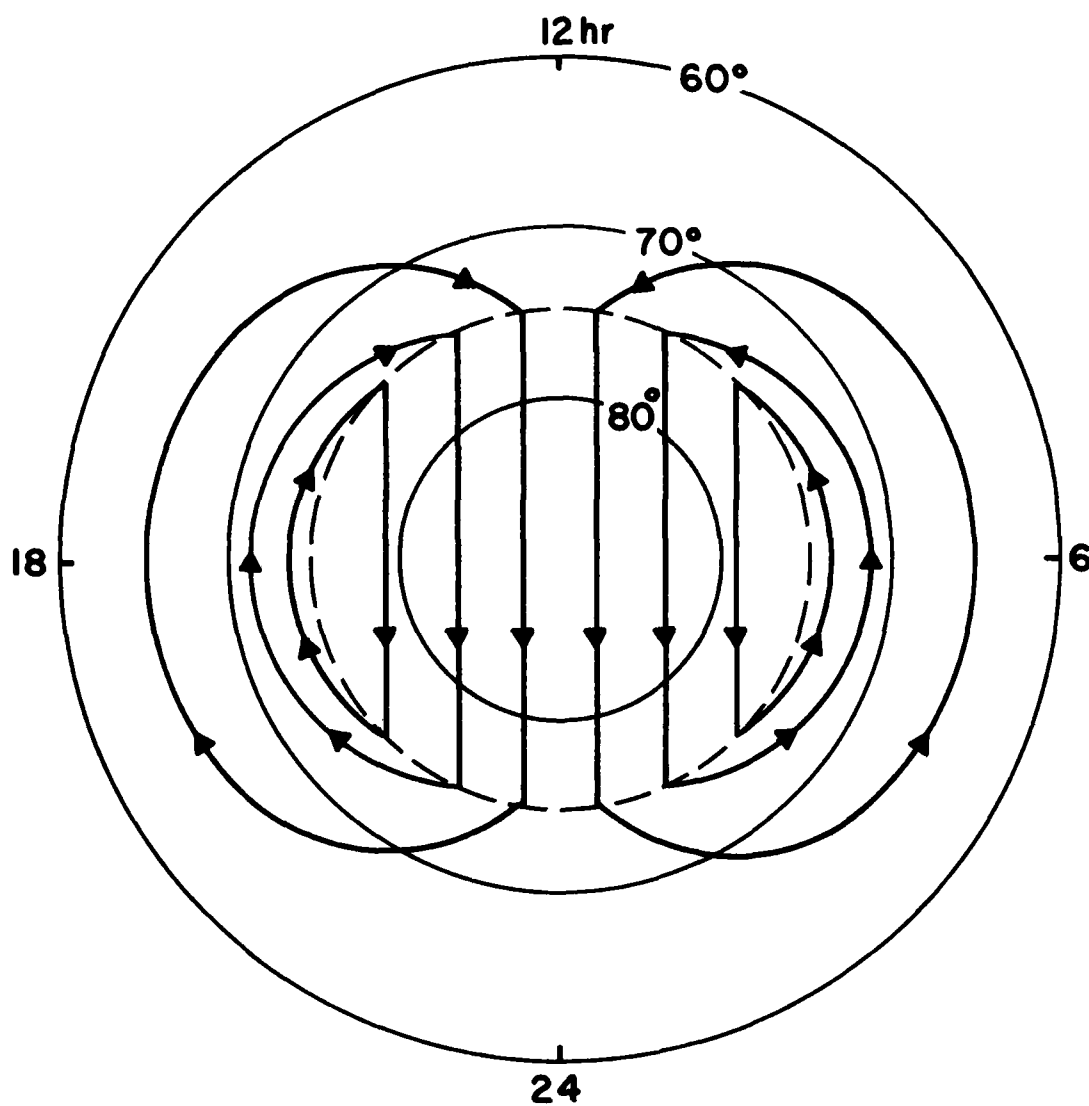
scatter (Thomson) radar measurements suggest a pattern of plasma drift motion over the polar cap from the day side to the night side, with sunward return flow at the lower latitudes, as shown in Figure 4.⁴⁴ Recent measurements made at Thule, Greenland (86° Corrected Geomagnetic Latitude) with the Digisonde and optical systems substantiate this flow pattern.⁴³ Measuring this convection from the ground at Goose Bay, one would expect a westerly flow of plasma prior to midnight, changing to an easterly flow after midnight. As will be shown below, the drift velocities calculated from the Doppler-drift data collected by ULCAR at Goose Bay are in agreement with these predictions.

1.6.4 Effects of TID's on Plasma Motion

The oscillating movement of plasma under the influence of acoustic-gravity waves reflects the phase velocity of a disturbance propagating through the ionosphere and not the true convection motion of the plasma as a whole, somewhat like ripples from a local disturbance in the current of a smoothly flowing stream of water. We do not know at present the precise effects of this ripple motion on the Doppler-drift measurements. As is typical of many scientific measurements, we make first a simple model, based on the assumption that our measurements reflect predominantly the true plasma drift, and we use a statistical approach for calculating the drift velocities, in order to smooth out the errors due to waves and to other factors discussed later. In this thesis, we are attempting only to prove that the results of ULCAR's Doppler-

⁴³Buchau et al. (1982).

⁴⁴From Spiro et al. (1978), Fig. 1a. See also Evans et al. (1982), section 5.3.



HIGH-LATITUDE PLASMA CONVECTION PATTERN

Figure 4

drift measurements are a step in the right direction, so that we may proceed with further drift measurements and thus collect a data base for more extensive analysis.

1.7 Measurement of Plasma Drift in the Ionosphere

1.7.1 Fading Measurements⁴⁵

The first attempts to measure ionospheric plasma drift were made by studying the fading of radio waves reflected off irregularities in the ionosphere. The study of fading is not to be confused with the incoherent scatter technique, where the radio waves are scattered off electron clusters smaller than the wavelength of the transmitted wave; since the electrons are in random motion, the resulting total echo is incoherent. Fading involves specular reflection of coherent waves off ionospheric irregularities larger than their wavelength. The difference in the path lengths of the coherent echoes from various directions results in phase interference and therefore a change in the amplitude of the signal received at a fixed site. As the irregularities move, the phase differences vary, causing the amplitude to fluctuate. At a different site "downwind" from the movement of the irregularities, the corresponding fluctuations should appear at a time t later, where t depends on the distance between the two receiving sites and the speed (on the ground) of the diffraction pattern produced by the interference of the several echoes. To measure drift in any direction, a minimum of three receivers is required (usually placed at the corners of the right triangle) in order to measure both components of the horizontal drift motion.

In a paper which is considered a classic in the

⁴⁵Hargreaves (1979), sections 6.2.1 and 6.3.1.

study of fading, Briggs et al.⁴⁶ pointed out that the changes in the diffraction pattern are due not only to the motion of the irregularities as a whole (so that the same fading pattern would be measured, at different times, at several spaced receivers -- "similar fade") but also to random motions of the irregularities relative to each other (so that the shape of the fading pattern would vary between sites). They also discuss how to calculate the rate at which the pattern is changing and the velocity with which the pattern moves over the ground. These calculations involve a statistical correlation analysis of the fading records measured by three (or more) spaced receivers; several techniques of correlation analysis were subsequently developed in the 1950's and 60's by various authors.⁴⁷

1.7.2 Doppler-Drift Measurements

1.7.2.1 History

By the late 1960's, the insufficiency of the fading technique was becoming apparent. W. Pfister of AFGL published a paper in 1971⁴⁸ in which he introduced the concept of adding phase measurements to HF radio sounding and using Doppler analysis to distinguish several signals reflected simultaneously off a moving ionosphere, an approach which "allows to look at the distribution of rays as they emerge from the ionosphere and not merely at the diffraction pattern on the

⁴⁶ Briggs, Phillips and Shinn (1950).

⁴⁷ For a summary of the four major techniques developed before 1960, see Sales (1960), Appendices A, B, C, D. For further references, see Pfister (1971), p. 999.

⁴⁸ Pfister (1971).

ground."⁴⁹ The paper is a report on results obtained for E-layer measurements made in 1967 and 1969 in Billerica, Mass., in cooperation with ULCAR personnel and using phase-recording instrumentation developed by ULCAR. Analysis of the data showed evidence of both wave motion and motion of irregularities in the ionosphere. Also, a limited number of discrete reflected signals were measured, disproving the assumption of Briggs et al. that the diffraction pattern on the ground is produced by a random distribution of many irregularities in the ionosphere.

In succeeding years, personnel from ULCAR and AFGL continued the collaborative work of improving the Doppler method for measuring drift. The bibliography lists several publications which describe the progress in the development of the instrumentation and measurement techniques. We note in particular the measurements of E-layer ionospheric motion made at Eglin, Florida, and of F-layer motion at Goose Bay, Labrador, in the early 1970's.⁵⁰ Narrow reflection regions were observed, which changed position at a different rate than indicated by the Doppler shifts. This change in position seemed to be controlled by medium- and large-scale TID's: as the wavelike structures moved over the observation site, the portion of the ionosphere satisfying the perpendicularity condition changed position. The Doppler shifts, on the other hand, indicated a movement of the reflecting irregularities independent of the wave motion, and probably due to a large-scale convection of the plasma.

The method of analysis used in interpreting the data from the Doppler-drift measurements involves a Fourier trans-

⁴⁹Ibid., p. 999.

⁵⁰Bibl et al. (1975).

form from the time domain into the frequency domain to determine the Doppler spectrum. Calculation of the transform consumed too much computer time, so in order to develop the capability for the rapid analysis required for 24-hour observations, a hardware transform had to be designed which could perform the spectral analysis as the drift data was collected. This has become possible in recent years due to the advancement of hardware memory technology.

1.7.2.2 The Present

The on-line Fourier transform and other improvements based on past experience⁵¹ have been incorporated into the DGS 128PS, which is in operation at Goose Bay. The primary function of the Digisonde at present is to monitor the diurnal and seasonal variations in ionospheric structure, but it is also equipped with the capability for Doppler-drift measurements. This capability is not yet fully automatic, but requires the presence of a skilled operator. ULCAR personnel occasionally travel to Goose Bay for specialized scientific experiments, and during the past few years they have on those occasions made drift measurements from which to calculate the drift velocity. After considerable efforts, which revealed technical problems in the data and led to their correction, a limited data base of correct data was collected; analysis of these data is discussed below.

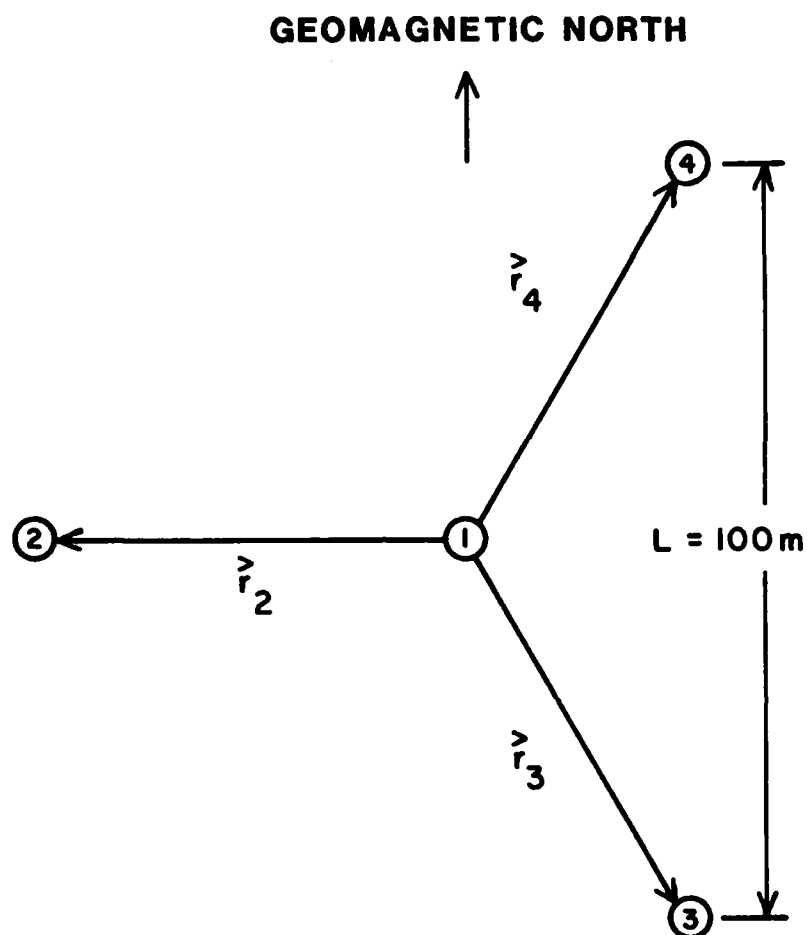
⁵¹ Including the addition of a fourth (center) antenna to the triangular receiving array, so as to be able to distinguish signals reflected from two distinct areas with the same Doppler-frequency shift. See section 2.4.3.

2.0 EXPERIMENTAL PROCEDURE

2.1 Summary

For Doppler-drift measurements at Goose Bay, Digisonde operation is alternated between the ionogram and drift modes (see section 1.5.2). The ionograms scan the relevant frequency range from 1 to 16 MHz and sample the virtual height from 60 to 700 km. Three or six frequencies and corresponding echo ranges are selected from the ionograms for the drift measurements.⁵² Doppler-shifted echoes from moving isodensity areas that are perpendicular to the direction of wave propagation are received at four antennas (see Figure 5). Spectral analysis of the composite signal received by each antenna yields the amplitude and phase of each echo; from the amplitudes and phases the frequency-wavenumber power density (FWPD) calculation determines the incidence angle of each echo. Since the range R is known, the angles of incidence of the echoes determine the positions of the various reflection areas. The coordinates of the reflection areas are displayed on a sky map; they are also used, together with the corresponding Doppler frequencies, to determine the radial component of motion of each reflection area, from which a resultant plasma-drift velocity is calculated.

⁵² There are five drift programs available in the drift mode of the DGS 128PS. The number of sounding frequencies (and ranges) used for drift measurements, as well as other parameters defined below such as the number N of quadrature samples, the time δt between quadrature samples, etc., vary according to the program used. The values of these parameters for each drift program will be specified in section 2.2.1.



RECEIVING - ANTENNA ARRAY

**GOOSE BAY, LABRADOR
(53.3° GEOGRAPHIC N, 60.5°W)**

Figure 5

2.1.1 The Time Sequence

Each reflection area is considered the source of a separate radio signal with propagation vector $\vec{k}$. Because the distance from the antenna array to the sources is much greater than the antenna separation, the wave at the antenna array can be considered a plane wave, so that the incidence angle of $\vec{k}$ is the same at all antennas. The instantaneous voltage at each antenna due to a given source is

$$V_{a,s}(t) = V_0(s) \cos [(\omega + \Delta\omega_s)t + \phi_{a,s}] \quad (42)$$

$$\phi_{a,s} = \vec{k}_s \cdot \vec{R}_{a,s} + \delta_s \quad (43)$$

$$a = 1, 2, 3, 4 \quad (44)$$

$$\omega = 2\pi f \quad (45)$$

$$\Delta\omega_s = 2\pi \Delta f_s \quad (46)$$

$$|\vec{k}_s| = k = \frac{2\pi}{\lambda}, \text{ all sources} \quad (47)$$

$$\lambda = \frac{c}{f} \quad (48)$$

where:

a is the antenna index;

s is the source index;

$V_0(s)$ is the amplitude or maximum voltage of the signal from source s ;

the argument of the cosine is the phase of the signal from source s received at antenna a , $\phi_{a,s}$ being the time-independent component of the phase;

f is the frequency of the transmitted wave (carrier frequency);

Δf_s is the Doppler shift or change in carrier frequency due to the motion of source s ;

t is the time;

$\vec{k}_s$ is the wave propagation vector for the signal from source s ;

λ is the wavelength of the carrier;⁵³

c is the speed of light in vacuum;

$\vec{R}_{a,s}$ is the position vector of source s relative to antenna a ;

δ_s is the initial phase of the signal at source s .

The phase term $\vec{k}_s \cdot \vec{R}_{a,s}$ is different at each antenna (see Figure 6):

$$\vec{k}_s \cdot \vec{R}_{a,s} = \vec{k}_s \cdot \vec{R}_{1,s} - \vec{k}_s \cdot \vec{r}_a \quad (49)$$

$$\vec{R}_{1,s} = R \hat{R}_s \quad (50)$$

$$\phi_{a,s} = \vec{k}_s \cdot \vec{R}_{1,s} - \vec{k}_s \cdot \vec{r}_a + \delta_s \quad (51)$$

where the magnitude of $\vec{R}_{1,s}$ is the range R and its direction is given by the unit source position vector $\hat{R}_s$; $\vec{r}_a$ is the position vector of antenna a relative to antenna 1 ($\vec{r}_1 \equiv 0$; see Figure 5). $V_{a,s}(t)$ differs from $V_{a',s}(t)$ only in the terms $\vec{k}_s \cdot \vec{r}_a$, $\vec{k}_s \cdot \vec{r}_{a'}$ ($a \neq a'$): the signal from a given source is the same at all antennas except for a constant phase difference, which is a function of the wavelength of the signal ($|\vec{k}_s| = 2\pi/\lambda$), the antenna separation $\vec{r}_a - \vec{r}_{a'}$, and the incidence angle of the source represented by $\hat{R}_s$. Since the wavelength and the antenna separation are known, the incidence angle can be calculated if $\phi_{a,s}$ is known for all antennas, as will be shown later.

⁵³Using $\lambda = c/f$ instead of $c/(f+\Delta f_s)$ results in an error of about 10^{-4} m, which can be neglected.



Figure 6

With several sources, the total signal $V_a(t)$ at antenna a is the sum (superposition) of the reflected signals,

$$V_a(t) = \sum_s V_{a,s}(t) = \sum_s V_0(s) \cos [(\omega + \Delta\omega_s)t + \phi_{a,s}] \quad (52)$$

$$s = s', s'', s''', \dots \quad (53)$$

$$V_a(t) = V(M_a(t), \phi_a(t)) \quad (54)$$

where the sum is over all sources; $M_a(t)$ is the magnitude (time-varying amplitude) of the composite signal at time t , and $\phi_a(t)$ is its phase.

At each antenna the composite analog signal $V_a(t)$ is sampled N times at intervals δt , i.e. at

$$t_n = n \delta t, n = -\frac{N}{2}, -\frac{N}{2} + 1, -\frac{N}{2} + 2, \dots, \frac{N}{2} - 1. \quad (55)$$

Each sample consists of two measurements X and Y obtained by quadrature sampling,⁵⁴

$$X_a(t_n) = V_a(t_n) = \sum_s V_0(s) \cos[(\omega + \Delta\omega_s) t_n + \phi_{a,s}] \quad (56)$$

$$Y_a(t_n) = -V_a(t_n + \frac{\pi}{2\omega}) = \sum_s V_0(s) \sin[(\omega + \Delta\omega_s) t_n + \phi_{a,s}] \quad (57)$$

$$\frac{\pi}{2\omega} = \frac{\tau}{4} \quad (58)$$

$$\tau = \frac{1}{f} = \frac{2\pi}{\omega} \quad (59)$$

where τ is the period of the carrier wave. X and Y are related to the amplitude M and phase ϕ of equation (54) by

$$M = \sqrt{X^2 + Y^2} \quad (60)$$

$$\phi = \arctan \frac{Y}{X} \quad (61)$$

⁵⁴In the phase of $Y_a(t_n)$, we are neglecting the term $\pi \Delta\omega_s / 2\omega \approx 10^{-6} \pi / 2$.

The quadrature samples are measured in phase with the carrier, i.e.

$$\delta t = m\tau = \frac{2m\pi}{\omega} \quad (62)$$

(where m is an integer), which effectively filters out the carrier frequency: remembering that $t_n = n \delta t$ (equation (55)),

$$\cos[(\omega + \Delta\omega_s) t_n] = \cos[(\omega + \Delta\omega_s) \frac{2nm\pi}{\omega}] \quad (63)$$

$$= \cos \Delta\omega_s t_n \quad (64)$$

and similarly for $\sin[(\omega + \Delta\omega_s) t_n]$; therefore

$$X_a(t_n) = \int_s V_0(s) \cos(\Delta\omega_s t_n + \phi_{a,s}) \quad (65)$$

$$Y_a(t_n) = \int_s V_0(s) \sin(\Delta\omega_s t_n + \phi_{a,s}) \quad (66)$$

The result is a digital time sequence which represents a signal whose frequency components are the frequencies of the Doppler shifts only.

2.1.2 The Frequency Spectrum

As the quadrature samples are measured, they are inputted in real time into a hardware processor which performs a direct discrete Fourier transform⁵⁵ with Hanning weighting by spectral averaging,⁵⁶ to reduce the $\sin x/x$ ringing and noise. For each spectral line of frequency ω_d ,

$$\omega_d = d \delta\omega \quad (67)$$

⁵⁵Bibl and Reinisch (1978b), p. 527.

⁵⁶See section 2.2.3 for references.

$$d = d', d'', d''', \dots \quad (68)$$

(where $\delta\omega$ is the angular Doppler-frequency resolution of the transform, and d is an integer, whose numerical values will be specified in section 2.2.1), the Fourier transform is defined as⁵⁷

$$F_a(d) = \sum_{n=-N/2}^{N/2-1} f_a(n) e^{-i \frac{2\pi}{N} dn} \quad (69)$$

$$f_a(n) = X_a(t_n) + i Y_a(t_n) = \int_s V_0(s) e^{i (D_s \delta\omega n \delta t + \phi_{a,s})} \quad (70)$$

$$D_s \delta\omega = \Delta\omega_s \quad (71)$$

where we have formed a complex time sequence from the quadrature measurements (X,Y); in the time sequence (70) the Doppler shift $\Delta\omega_s$ due to the motion of source s is written in terms of the Doppler-frequency resolution.

To illustrate the result of equation (69), consider two sources s' and s'' . If $D_{s'}$ and $D_{s''}$ are integers,

$$D_{s'} = d' \quad (72)$$

$$D_{s''} = d'' \quad (73)$$

then

$$\Delta\omega_{s'} = D_{s'} \delta\omega = \omega_{d'} = d' \delta\omega \quad (74)$$

$$\Delta\omega_{s''} = D_{s''} \delta\omega = \omega_{d''} = d'' \delta\omega \quad (75)$$

where d' and d'' are two different Doppler numbers, and⁵⁸

⁵⁷See section 2.2.2 for references.

⁵⁸See section 2.2.2 for the derivation of these results.

$$F_a(d') = N V_0(s') e^{i \phi_{a,s'}} \quad (76)$$

$$F_a(d'') = N V_0(s'') e^{i \phi_{a,s''}} \quad (77)$$

yielding the amplitude and the time-independent phase of the signal from each source. In general the Doppler shifts are not integral multiples of $\delta\omega$, and $F_a(d')$ and $F_a(d'')$ are modulated by the $\sin x/x$ ringing due to the limited sample length of the time sequence; Hanning weighting is applied to the frequency spectrum to reduce both the ringing and extraneous noise. Note that if

$$D_{s'} = -D_{s''} \quad (78)$$

equations (76) and (77) still hold (for integer D_s): the complex Fourier transform distinguishes positive and negative frequencies. In the present context, negative frequencies have a physical significance; they follow mathematically from the discrete quadrature sampling, which filters out the carrier frequency (see equations (65) and (66)). Negative Doppler frequencies correspond to a decrease in carrier frequency due to motion of the source away from the observation site; positive Doppler frequencies correspond to an increase in carrier frequency due to motion toward the observation site.

2.1.3 Sky-Map Calculations

A scanning method is used to determine the incidence angle of each echo. The area of the sky above the observation site is represented by a square sky map, with the corners of the map area at range R and with the maximum zenith angle $\zeta_{\max}$ (at the corners) defined so as to exclude from the sky map the major side lobes which follow from the periodicity of the FWPD calculation (the major side lobes have the same strength as the main lobe). In section 2.4.2 we will show that

$$\sin \zeta_{\max} = \frac{\lambda}{L} \quad (79)$$

where λ is the wavelength of the sounding frequency and L is the maximum antenna separation in the receiving array (see Figure 5); $\zeta_{\max}$ is limited to a maximum of 45° . The map is divided into 1681 locations defined by a 41×41 array of coordinates $(x_m, y_{m'})$,

$$x_m = m \delta x \quad (80)$$

$$y_{m'} = m' \delta y \quad (81)$$

$$\delta x = \delta y \quad (82)$$

$$m, m' = 0, \pm 1, \pm 2, \dots, \pm 20 \quad (83)$$

where δx is a function of R and $\zeta_{\max}$. Each coordinate $(x_m, y_{m'})$ defines the angle of incidence of the scanning vector $\vec{k}(x_m, y_{m'})$ whose magnitude is the same as that of $\vec{k}_s$ (equation (47)). For each Doppler number d , the frequency-wave-number power density P is calculated 1681 times, once for each map coordinate $(x_m, y_{m'})$:

$$P(d, x_m, y_{m'}) = \sum_{a=1}^4 \sum_{a'=1}^4 F_a(d) F_{a'}^*(d) e^{i \vec{k}(x_m, y_{m'}) \cdot (\vec{r}_a - \vec{r}_{a'})} \quad (84)$$

where $*$ denotes the complex conjugate; $F_a(d)$, $F_{a'}(d)$ are the frequency spectra (after spectral averaging) of antennas a and a' ; and $\vec{r}_a$, $\vec{r}_{a'}$ are the antenna position vectors relative to antenna 1. The factor $e^{i \vec{k}(x_m, y_{m'}) \cdot \vec{r}_a}$ introduces a computational phase "delay" in the signal spectrum from antenna a . When $\vec{k}(x_m, y_{m'})$ looks in the direction of the echo whose Doppler frequency is ω_d , the delayed phases of that echo are equal at all antennas, which makes $P(d, x_m, y_{m'})$ a maximum; thus the map coordinates $(x_m, y_{m'})$ for which P is a maximum

indicate the direction $\hat{k}_s$ of the corresponding source.⁵⁹ We re-write these map coordinates as the source coordinates

$$(x_s, y_s) = (x_m, y_m) \quad (85)$$

and define

$$P_s \equiv P(d, x_s, y_s) \quad (86)$$

as the power density of source s .

Two parallel sky maps are used to display the positions of the sources calculated in this manner: one map displays the power densities P_s at the corresponding source coordinates (x_s, y_s) ; the other map displays the Doppler numbers d at the same coordinates (see Figure 17).

2.1.4 Drift-Velocity Calculations

The sky map data (x_s, y_s, d, P_s) for all sources calculated from a given measurement are then used to determine the velocity of the plasma drift. The Doppler shift Δf_s due to the velocity $\vec{V}_s$ of source s is⁶¹

$$\Delta f_s = - 2 \frac{\vec{V}_s \cdot \hat{R}_s}{c} f \quad (87)$$

⁵⁹If there are two or more sources whose motion results in the same Doppler shift, the FWPD does not in general yield the correct source positions. See section 2.4.3.

⁶⁰In general, since the sky map is defined by a set of discrete coordinates, x_s is only approximately equal to x_m and y_s is only approximately equal to y_m ; we use the equal sign with the understanding that the equality is within the limits of the errors due to the digitizing of continuous functions.

⁶¹See section 2.5.1 for the derivation of (87).

where $\hat{R}_s$ is the unit source-position vector, f is the sounding frequency, and c is the speed of light in vacuum. Thus the radial component W_s of the source velocity is

$$W_s \equiv \vec{V}_s \cdot \hat{R}_s = -\frac{1}{2} \frac{\Delta f_s}{f} c \quad (88)$$

It is assumed that

$$\vec{V}_s \equiv \vec{V}, \text{ all } s \quad (89)$$

that is, all sources for a given measurement or case (a case is typically a measurement of 10 or 18 seconds; see Table 1) are moving at the same velocity $\vec{V}$. This velocity is calculated using a least-square fit procedure: the average square error ϵ^2 is defined as

$$\epsilon^2 = \frac{\sum_s w_s (\vec{V} \cdot \hat{R}_s - W_s)^2}{\sum_s w_s} \quad (90)$$

where w_s is a weighting factor proportional to P_s but normalized so that $\sum w_s$ is equal to the total number of sources. By setting the derivatives $\partial \epsilon^2 / \partial V_x$, $\partial \epsilon^2 / \partial V_y$ and $\partial \epsilon^2 / \partial V_z$ equal to zero, three simultaneous equations are obtained from which V_x , V_y and V_z are calculated; plugging $\vec{V}$ back into equation (90) yields the least square error.

The sources for a given case are sorted in descending order of the magnitude of P_s , then equation (90) is calculated several times: the first calculation uses only the first five sources; the second calculation, the first six sources; and so on. Each calculation of equation (90) is called an individual velocity calculation. A case velocity is calculated as the median of the individual velocities; the median of the case velocities from a group of four to six con-

AFTER SPECTRAL AVERAGING										
P	N _f	δt [msec]	T [sec]	CASE SPACING [sec]	N	δf [Hz]	N'	δf' [Hz]	DOPPLER SPECTRUM [Hz]	DOPPLER RANGE [Hz]
5	6	127.5	8.16	10	64	$\frac{1}{8}$	64	$\frac{1}{8}$	$\pm(0, \frac{1}{8}, \frac{1}{4}, \dots, \frac{31}{8})$	$\pm(0 \text{ to } 3 \frac{7}{8})$
6	6	127.5	16.32	18	128	$\frac{1}{16}$	64	$\frac{1}{8}$	$\pm(\frac{1}{16}, \frac{3}{16}, \frac{5}{16}, \dots, \frac{63}{16})$	$\pm(\frac{1}{16} \text{ to } 3 \frac{15}{16})$
7	6	127.5	32.64	34	256	$\frac{1}{32}$	128	$\frac{1}{16}$	$\pm(\frac{1}{32}, \frac{3}{32}, \frac{5}{32}, \dots, \frac{127}{32})$	$\pm(\frac{1}{32} \text{ to } 3 \frac{31}{32})$
8	3	63.75	8.16	10	128	$\frac{1}{8}$	128	$\frac{1}{8}$	$\pm(0, \frac{1}{8}, \frac{1}{4}, \dots, \frac{63}{8})$	$\pm(0 \text{ to } 7 \frac{7}{8})$
9	3	63.75	16.32	18	256	$\frac{1}{16}$	128	$\frac{1}{8}$	$\pm(\frac{1}{16}, \frac{3}{16}, \frac{5}{16}, \dots, \frac{127}{16})$	$\pm(\frac{1}{16} \text{ to } 7 \frac{15}{16})$

P = Program number
 N_f = # of sounding frequencies
 δt = sample spacing
 T = total sampling time/case
 Case spacing = T + dead time
 N = # of quadrature samples or Fourier components
 N' = # of spectral lines after spectral averaging
 δf = Doppler-frequency resolution in transform
 $\delta f'$ = Doppler resolution after averaging

δf , $\delta f'$, Doppler spectrum and range are rounded out to convenient fractions
 (for example, $\delta f = .122549$ Hz is rounded out to $1/8 = .125$ Hz)

DRIFT-MEASUREMENT PARAMETERS IN THE DGS 128PS

Table 1

secutive cases yields the group-norm velocity.⁶² Each case comprises simultaneous drift measurements at three or six sounding frequencies (and corresponding ranges); a velocity called the all-frequency velocity is also calculated as the median of the group-norm velocities which correspond to the three or six sounding frequencies.

The calculated drift velocities are displayed on two parallel graphs, one with a plot of the horizontal direction (azimuth graph) of a time sequence of drift velocities, the other with a plot of the magnitude of the horizontal drift, the vertical-drift magnitude being indicated by a + or - symbol (see Figure 22). Graphs of the individual, case and group-norm velocities were used for analyzing the effects of various weighting and smoothing techniques. After the best approach for calculating the drift velocities had been determined, a time sequence of all the group-norm and all-frequency velocities for a given time sequence of measurements was plotted on one pair of graphs, the direction and horizontal speed of the group-norm velocities being indicated by a number or letter specifying the range R of each measurement, and the direction and horizontal speed of the all-frequency velocities being indicated by a solid line drawn through the corresponding graph coordinates (see, for example, Figure 24).

2.2 Drift Measurements with the Digisonde 128PS

2.2.1 Drift-Measurement Parameters

Five drift programs are provided in the DGS 128PS, identified by the program number P,

⁶²The expression is awkward but was coined, for want of a better term, to avoid possible confusion with the "group velocity" of a wave.

$$P = 5, 6, 7, 8, 9 \quad (91)$$

with different drift parameters for each P (see Table 1). Drift measurements are made at three or six sounding frequencies as follows. The Digisonde transmits four 100 μ sec pulses 5 msec apart at the first frequency (see Figure 7) and receives with each of the four antennas successively, measuring the quadrature samples X and Y . The process is then repeated for the other sounding frequencies. After the measurements at the last frequency, the process starts over again at the first frequency. N such measurements are made, yielding a time sequence of N quadrature pairs (X, Y) for each sounding frequency at each antenna. The set of N quadrature measurements for all frequencies and antennas comprises one drift measurement or case.

The sample spacing δt (the time between successive samples at a given antenna and given frequency) is

$$\delta t = (1.25 \text{ msec} + 5 \text{ msec} \times N_a) N_f \quad (92)$$

where N_a is the number of antennas (four at Goose Bay; but the DGS 128PS provides for the possibility of up to 24 antennas for drift measurements) and N_f is the number of sounding frequencies. At Goose Bay,

$$\delta t = 21.25 \text{ msec} \times N_f \quad (93)$$

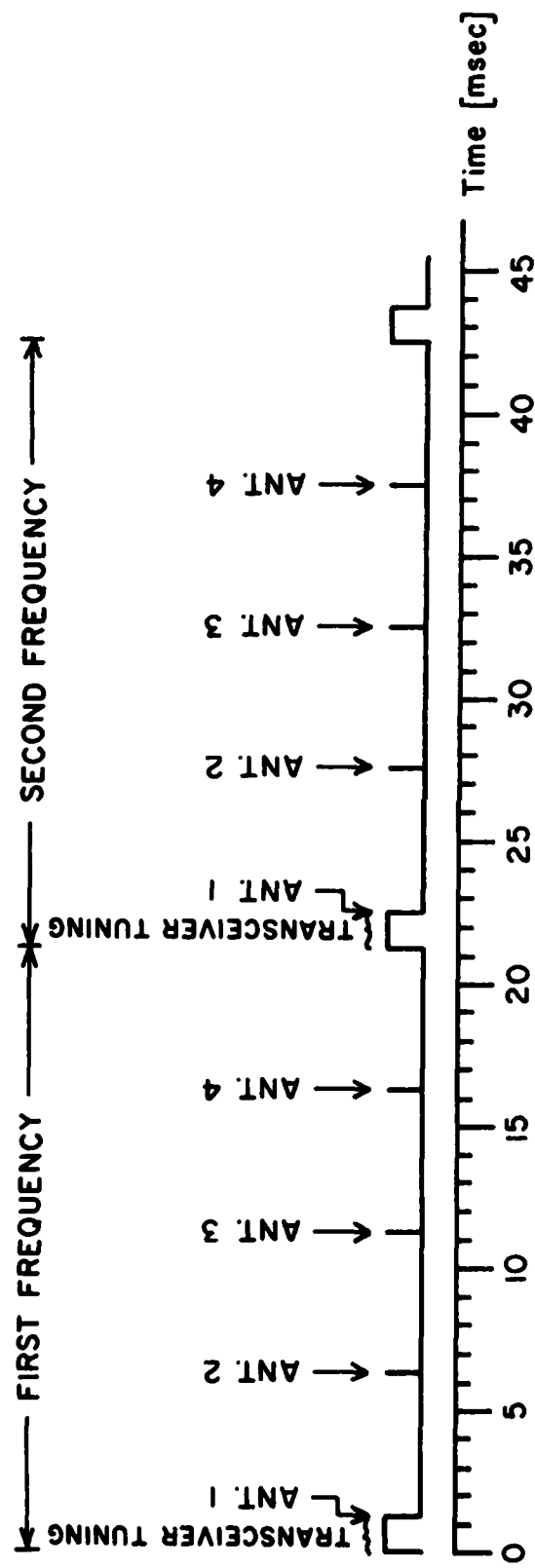
which gives the results shown in Table 1.

The Fourier transform yields a spectrum of N Doppler lines (see section 2.2.2) of frequency

$$f_d = d \delta f \quad (94)$$

$$-\frac{N}{2} \leq d \leq \frac{N}{2} - 1 \quad (95)$$

$$\delta f = \frac{1}{N \delta t} \quad (96)$$



1.25 msec is required for transceiver tuning.

Pulses are 100 msec long, spaced 5 msec apart.

The time indicated for each pulse is the time of transmission; the antenna number above each pulse indicates which antenna is used for receiving that pulse a few msec or less after transmission.

SEQUENCE OF QUADRATURE MEASUREMENTS

Figure 7

where N is the number of quadrature samples. Hanning weighting (see section 2.2.3) is applied to the frequency spectrum in either of two ways. For drift programs 5 and 8, all spectral lines are kept (the antenna index is omitted in the following equations):

$$F'(+0) = 2 F(0) + F(1) \quad (97)$$

$$F'(-0) = 2 F(0) + F(-1) \quad (98)$$

$$F'(d) = F(d-1) + 2 F(d) + F(d+1) \quad (99)$$

$$d = \pm 1, \pm 2, \pm 3, \dots, \pm(\frac{N}{2} - 1) \quad (100)$$

where F is the spectrum before spectral averaging and F' is the spectrum after averaging.⁶³ Equations (97) and (98) do not follow strictly from the definition of Hanning weighting, which would yield

$$F(+0) = F(-0) = F(-1) + 2F(0) + F(1). \quad (101)$$

Equations (97) and (98) were adopted in order to distinguish between positive and negative frequencies which are close to zero. For drift programs 6, 7 and 9, only the odd spectral lines are kept, the even spectral lines being used only in the average,

$$F'(d) = F(d-1) + 2F(d) + F(d+1)^{64} \quad (102)$$

⁶³See footnote 70 in section 2.2.3.

⁶⁴Note that in

$$F'(\frac{N}{2} - 1) = F(\frac{N}{2} - 2) + 2F(\frac{N}{2} - 1) + F(\frac{N}{2}) \quad (103)$$

the third term, $F(\frac{N}{2})$, is not within the transform spectrum (equation (95)); but from equation (140),

$$F(\frac{N}{2}) = F(-\frac{N}{2}) \quad (104)$$

$$d = \pm 1, \pm 3, \pm 5, \dots, \pm \left(\frac{N}{2} - 1\right) \quad (105)$$

The result is that for these three drift programs the spectral spacing is doubled, the number of spectral lines is halved, and the lowest Doppler frequency is $\pm \delta f$ instead of ± 0 . The spectrum for all five drift programs can be summarized as

$$f_d = \pm [f_0 + (|d| - 1) \delta f'] \quad (106)$$

$$d = \pm 1, \pm 2, \pm 3, \dots, \pm \frac{N'}{2} \quad (107)$$

where, for programs 5 and 8,

$$f_0 = 0 \quad (108)$$

$$N' = N \quad (109)$$

$$\delta f' = \delta f \quad (110)$$

and for programs 6, 7 and 9,

$$f_0 = \delta f \quad (111)$$

$$N' = \frac{N}{2} \quad (112)$$

$$\delta f' = 2\delta f \quad (113)$$

N and δf are as defined before spectral averaging, but note that d (equation (107)) is defined differently than in previous equations. The parameters defined in this section are summarized in Table 1.

2.2.2 The Fourier Transform⁶⁵

The definition of the Fourier transform used in the DGS 128PS has been given in Equation (69); with the time sequence (70) the transform becomes

⁶⁵Peled and Liu (1976), section 1.7.

$$F_a(d) = \sum_{n=-N/2}^{N/2-1} \left[\sum_s V_0(s) e^{i(D_s \delta\omega n \delta t + \phi_{a,s})} \right] e^{-i \frac{2\pi}{N} dn} \quad (114)$$

$$F_a(d) = \sum_s V_0(s) e^{i \phi_{a,s}} \sum_{n=-N/2}^{N/2-1} e^{i[(D_s - d) \frac{2\pi}{N}] n} \quad (115)$$

$$D_s \delta\omega = \Delta\omega_s \quad (116)$$

$$s = s', s'', s''', \dots \quad (117)$$

$$\delta\omega \delta t = \frac{2\pi}{N} \quad (118)$$

$$F_a(d) = \sum_s V_0(s) e^{i \phi_{a,s}} S(s, d) \quad (119)$$

$$S(s, d) = \sum_{n=-N/2}^{N/2-1} e^{i[(D_s - d) \frac{2\pi}{N}] n} \quad (120)$$

$$= e^{-i[(D_s - d)\pi]} \sum_{n=0}^{N-1} e^{i[(D_s - d) \frac{2\pi}{N}] n} \quad (121)$$

where (121) is a geometric progression of the form

$$r^{-N/2} \sum_{n=0}^{N-1} r^n = r^{-N/2} \frac{r^N - 1}{r - 1} = \frac{(r^{N/2} - r^{-N/2})}{r^{1/2}(r^{1/2} - r^{-1/2})} \quad (122)$$

so that

$$S(s, d) = \frac{\sin(D_s - d) \pi}{\sin(D_s - d) \pi / N} e^{-i(D_s - d)\pi / N} \quad (123)$$

$$\approx N \frac{\sin(D_s - d) \pi}{(D_s - d) \pi} e^{-i(D_s - d) \pi / N} \quad (124)$$

where (125) follows from the approximation for small angles,

$$\sin(D_s - d) \pi / N \approx (D_s - d) \pi / N \quad (125)$$

The Fourier transform must be evaluated for each value of d , so that (114) represents a sequence of N equations. To illustrate the result of calculating the transform, we write it for one of the values of d , say d' ,

$$\begin{aligned}
 F_a(d') &= V_0(s') e^{i \phi_{a,s'}} S(s', d') \\
 &+ V_0(s'') e^{i \phi_{a,s''}} S(s'', d') \\
 &+ V_0(s''') e^{i \phi_{a,s'''}} S(s''', d') \\
 &+ \dots
 \end{aligned} \tag{126}$$

If $\Delta\omega_s$ is an integral multiple of $\delta\omega$ for all sources, that is,

$$D_{s'} = d' \tag{127}$$

$$D_{s''} = d'' \tag{128}$$

etc.,⁶⁶ we use L'Hôpital's rule to evaluate $S(s', d')$, getting

$$\lim_{b \rightarrow 0} \frac{\sin b\pi}{\sin b\pi/N} e^{-ib\pi/N} = N \tag{129}$$

$$b = D_{s'} - d' \tag{130}$$

A straightforward evaluation of all other terms shows that they are all zero, since $(D_{s''}, -d')$, $(D_{s'''}, -d')$, etc. are all

⁶⁶In this section, we further assume that each echo has a different Doppler shift, i.e. that d' , d'' , etc. are all different Doppler numbers. Since the Doppler shift is proportional to the radial component of the velocity of the source (the component of velocity along $\hat{R}_s$), sources at different incidence angles will, in general, result in different Doppler shifts even if all sources move at the same velocity. There can, however, exist echoes with the same Doppler shift; this situation will be treated as a special case in section 2.4.3.

non-zero integers. Therefore

$$F_a(d') = N V_0(s') e^{i \phi_{a,s'}} \quad (131)$$

For $F_a(d'')$, only the second term is non-zero, so

$$F_a(d'') = N V_0(s'') e^{i \phi_{a,s''}} \quad (132)$$

and similarly for $F_a(d''')$, etc. Thus the Fourier transforms of the time sequence yield for each source the amplitude and time-independent phase at each antenna a , from which the location of each source can be calculated using the FWPD.

Returning to $F_a(d')$: if D_s is not an integer, then $S(s', d')$ is not equal to N : the amplitude is less than $N V_0(s')$, and the phase $\phi_{a,s}$ is shifted by $-(D_s - d') \frac{\pi}{N}$, although the first term is still the only non-zero term. If in addition $D_{s,1}$ (and/or $D_{s,2}$, etc.) is not an integer, the second (and/or third, etc.) term is non-zero: the first term dominates, but is modulated by the effect of the other term(s). The ringing effect of $D_s = 6.25$ on $F(0)$ to $F(12)$ is illustrated in the next section in Figure 8, which shows a comparison between unweighted and weighted Fourier transforms.

The spectral spacing or Doppler-frequency resolution δf of the N -term transform follows from equation (118),

$$\delta f = \frac{\delta \omega}{2\pi} = \frac{1}{N \delta t} \quad (133)$$

The frequency of each spectral line is

$$f_d = d \delta f \quad (134)$$

$$d = 0, \pm 1, \pm 2, \dots, \pm(\frac{N}{2} - 1), -\frac{N}{2} \quad (135)$$

so that the unambiguous frequency range is $-\frac{N}{2} \delta f$ to

$(\frac{N}{2} - 1) \delta f$.⁶⁷ The discrete Fourier transform is periodic, so that other frequencies are "aliased"⁶⁸ (folded in) and appear in the same frequency range; that is,

$$F(d + mN) = F(d) \quad (136)$$

$$m = 0, \pm 1, \pm 2, \dots \quad (137)$$

This can be seen from equation (120),

$$S(s, d + mN) = \sum_{n=-N/2}^{N/2-1} e^{i[(D_s - (d+mN)) \frac{2\pi}{N}] n} \quad (138)$$

$$= \sum_{n=-N/2}^{N/2-1} e^{i[(D_s - d) \frac{2\pi}{N}] n} e^{-i(m2\pi n)} \quad (139)$$

$$= S(s, d) \quad (140)$$

where the last step follows from the fact that both m and n are integers.

2.2.3 Hanning Weighting: Spectral Averaging⁶⁹

Defining the Fourier transform as a finite series has the effect of multiplying it by the box function, which results in the $\sin x/x$ ringing described in the previous section. This effect can be reduced significantly by weighting each term of the transform by $[.5 + .5 \cos (2\pi n/N)]$, which is called the von Hann (or Hanning) window or the raised cosine window. The weighted transform $F'_a(d)$ is therefore

⁶⁷Note that the above results are modified by the way spectral averaging is applied. See section 2.2.1.

⁶⁸Hamming (1977), section 2.2.

⁶⁹Hamming (1977), section 5.9.

$$F'_a(d) = \sum_s V_0(s) e^{i \phi_{a,s}} \sum_{n=-N/2}^{N/2-1} e^{i[(D_s-d) \frac{2\pi}{N}] n} \\ \times \left[\frac{1}{2} + \frac{1}{4} (e^{i \frac{2\pi}{N} n} + e^{-i \frac{2\pi}{N} n}) \right] \quad (141)$$

Since

$$e^{i[(D_s-d) \frac{2\pi}{N}] n} e^{\pm i \frac{2\pi}{N} n} = e^{i\{[D_s - (d \mp 1)] \frac{2\pi}{N}\} n} \quad (142)$$

the weighted transform is

$$F'_a(d) = \sum_s V_0(s) e^{i \phi_{a,s}} \left[\frac{1}{2} S(s,d) + \frac{1}{4} S(s,d-1) + \frac{1}{4} S(s,d+1) \right] \quad (143)$$

$$= \frac{1}{4} [F_a(d-1) + 2 F_a(d) + F_a(d+1)] \quad (144)$$

Hanning weighting can therefore be applied in the frequency domain by averaging three adjacent spectral lines with weights (1), (2), (1).⁷⁰

To evaluate the result of spectral averaging, we write equation (123) as

$$S(s, d) = \frac{\sin b}{\sin c} e^{-ic} = \sin b (\cot c - i) \quad (145)$$

$$b = (D_s - d) \pi \quad (146)$$

$$c = (D_s - d) \pi / N \quad (147)$$

$$S(s, d \mp 1) = \sin (b \pm \pi) [\cot (c \pm \pi / N) - i] \quad (148)$$

$$= -\sin b [\cot (c \pm \pi / N) - i] \quad (149)$$

Then the bracket in equation (143) becomes

⁷⁰The scaling factor 1/4 is ignored since it makes no difference in the FWPD calculation of the source positions.

$$\begin{aligned} & \sin b \left\{ \frac{\cot c}{2} - \frac{1}{4} [\cot (c+\pi/N) + \cot (c-\pi/N)] \right\} \\ &= \sin b \left\{ \frac{\cot c}{2} - \frac{1}{4} \frac{2 \sin c \cos c}{\sin^2 c - \sin^2 \pi/N} \right\} \end{aligned} \quad (150)$$

$$= \frac{1}{2} \frac{\sin b}{\sin c} \cos c \left\{ 1 - \frac{\sin^2 c}{\sin^2 c - \sin^2 \pi/N} \right\} \quad (151)$$

where the right side of (150) follows from the identity⁷¹

$$\cot (\alpha + \beta) + \cot (\alpha - \beta) = \frac{2 \sin \alpha \cos \alpha}{\sin^2 \alpha - \sin^2 \beta} \quad (152)$$

Therefore,

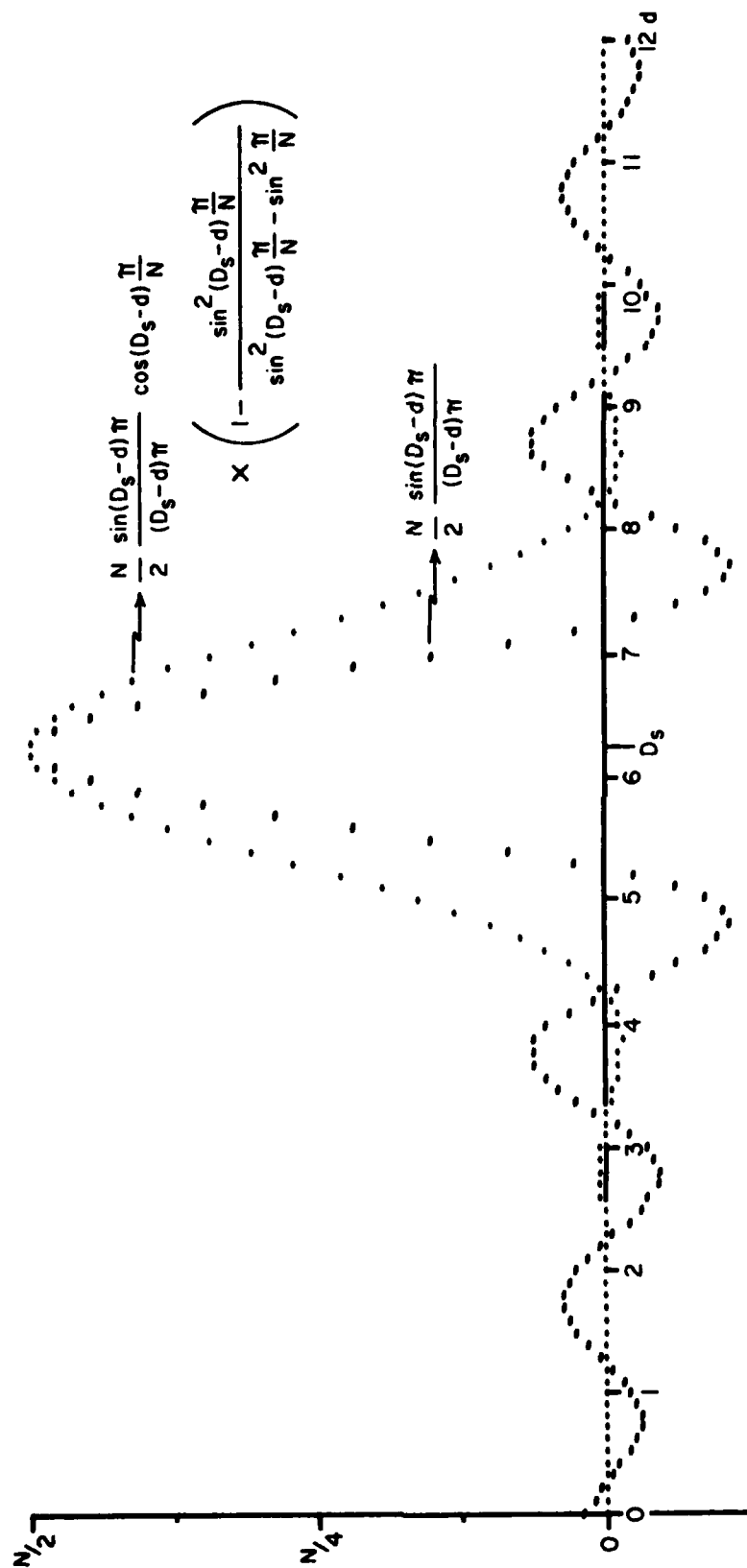
$$\begin{aligned} F'_a(d) &= \frac{1}{2} \int_s V_0(s) e^{i \phi_{a,s}} \frac{\sin (D_s - d) \pi}{\sin (D_s - d) \pi / N} \\ &\times \cos (D_s - d) \frac{\pi}{N} \left(1 - \frac{\sin^2 (D_s - d) \pi / N}{\sin^2 (D_s - d) \pi / N - \sin^2 \pi / N} \right) \end{aligned} \quad (153)$$

Figure 8 compares $\frac{1}{2} F_a(d)$ and $F'_a(d)$ for one source with $D_s = 6.25$, $V_0(s) = 1$, and $\phi_{a,s} = 0$. The widening of the spectral line $F'_a(6)$ -- i.e. $F'_a(5)$, $F'_a(7)$ are amplified -- is compensated by the significant reduction of the side lobes $F'_a(0)$ to $F'_a(4)$ and $F'_a(8)$ to $F'_a(12)$.

2.2.4 Data Recording

The data from each case of drift measurements is stored on digital tape in two or four records (see Table 2), the first record (the first two records for drift program

⁷¹Hamming (1977), section 5.9.



DOPPLER SHIFT $\Delta \omega_S = 6.25 \delta \omega$
 EFFECT OF HANNING WEIGHTING

Figure 6

PROGRAM N	RECORD #	CONTENTS		
5, 6, 8, 9	1	Negative Dopplers		
	2	Positive Dopplers		
7	1	Negative Dopplers, Frequency #'s 1-3		
	2	Negative Dopplers, Frequency #'s 4-6		
	3	Positive Dopplers, Frequency #'s 1-3		
	4	Positive Dopplers, Frequency #'s 4-6		
	# OF CHARACTERS	FORMAT OF EACH RECORD		
5, 6, 7, 8, 9	80	Preface*		
	160	Dummies		
		ANTENNA #	# OF SPECTRAL LINES**	
5, 6	80	1	32	Same for each of six sounding frequencies
	80	2	32	
	80	3	32	
	80	4	32	
7, 8, 9	160	1	64	Same for each of three sounding frequencies
	160	2	64	
	160	3	64	
	160	4	64	

*See Table 3.

**Two spectral lines coded into five six-bit characters.
See Table 4.

DRIFT-DATA RECORDING FORMAT

Table 2

7)⁷² including a preface and the negative-Doppler data; the second (third and fourth for program 7), a preface and the positive-Doppler data. The preface includes the identification number of the Digisonde station, the date and time of the measurement, and other relevant drift-measurement parameters (see Table 3). Each of the 80 digits of preface information is coded separately into 80 six-bit characters. (The station identification may contain two digits, but in this case the entire number is coded into one character.) The logarithmic amplitudes (maximum 63 dB) are also coded into six-bit characters. The phase accuracy of the data is more critical: negative phases are shifted by 2π to make them positive, and all phases are converted to nine-bit numbers,

$$\phi_{\text{new}} = \frac{\phi_{\text{old}}}{2\pi} \times 511 \quad (154)$$

(giving a phase resolution of $2\pi/511$), then two nine-bit phases are coded into three six-bit characters (see Table 4).

With all the information coded into six-bit characters, ten characters can be packed into one 60-bit computer word. Thus each record, which includes 2160 characters, is recorded on digital tape in only 216 computer words, so that one tape of Digisonde data can hold over a thousand cases (2000 records) of drift data and a comparable number of ionograms. (All data is recorded as it is measured, so the ionogram and drift data are inter-mixed on the tape.) Since no digit of preface information exceeds four bits, the fifth bit (the second MSB) is set to one in the preface of the drift data, in order to distinguish it from the ionogram data.

⁷²The program number, which was called P above to avoid confusion with the number N of quadrature samples, is called N in the following tables to conform with existing Digisonde documentation; see for example Bibl and Reinisch (1978a), p. 68.

CHARACTER #	SYMBOL	MEANING	
1	V	Station Identification	
2 - 6	YyΔDd	Calendar Year, Julian Day	
7 - 12	HhMmSs	Hour, Minute, Second	
21	R	Pulse Repetition Rate	
22	W	Pulse Width	
23, 24	Tt	Task # (Tt = 0 for Goose Bay)	
26	N	Program # (called P in text)	
		FREQ. #	
33 - 36	rFfg	1	Frequency in 10 kHz units, for each of the three or six sounding frequencies
37 - 40		2	
41 - 44		3	
45 - 48		4	
49 - 52		5	
53 - 56		6	
		RANGE #	
57 - 60	RrpG	1	Range [km] and Receiver Gain G in -10 dB units
61 - 64		2	
65 - 68		3	
69 - 72		4	
73 - 76		5	
77 - 80		6	

Parameters not listed are ionogram parameters.

DRIFT PREFACE

Table 3

CHARACTER #	1	2	3	4	5	6	7	.
6-BIT DATA	M_6^1	ϕ_9^1	ϕ_3^1	M_6^2	ϕ_9^2	M_6^3	ϕ_9^3	.
	M_5^1	ϕ_8^1	ϕ_2^1	M_5^2	ϕ_8^2	M_5^3	.	.
	M_4^1	ϕ_7^1	ϕ_1^1	M_4^2	ϕ_7^2	M_4^3	.	.
	M_3^1	ϕ_6^1	ϕ_3^2	M_3^2	ϕ_6^2	M_3^3	.	.
	M_2^1	ϕ_5^1	ϕ_2^2	M_2^2	ϕ_5^2	M_2^3	.	.
	M_1^1	ϕ_4^1	ϕ_1^2	M_1^2	ϕ_4^2	M_1^3	.	.

M_i^d is the i'th bit of the magnitude of $F(d)$.

ϕ_i^d is the i'th bit of the phase of $F(d)$.

CODING OF TWO SPECTRAL LINES INTO FIVE SIX-BIT CHARACTERS

Table 4

2.3 Digisonde-Data Simulation: Program TESTSKY

TESTSKY⁷³ is a Fortran-coded program which simulates the drift data outputted from the Digisonde. The program was started some years ago by AFGL and ULCAR, and was further developed by ULCAR for use in testing sky maps. The author has adapted TESTSKY to the University of Lowell's Cyber 71 computer system, and has modified and updated the program for use with the latest drift measurements. The program generates a simulated digital time sequence, transforms the time sequence into the frequency domain (with or without spectral averaging), and packs the data into two records in the same format as the Digisonde drift data.

The digital time sequence is calculated from sources of known incidence angles. The source information (azimuth, zenith, amplitude and Doppler frequency of the echo from each source; see Figure 12 in section 2.4.2 for the definition of the coordinate system) is specified on the input file TAPE1, which also includes the coordinates of the receiving antennas, the drift program number,⁷⁴ the sounding frequency, the task number (see Table 3), and the amplitude and seed (see below) of the noise to be added to each antenna. Arbitrary values for the Doppler frequencies can be inputted via TAPE1, or the frequencies can be calculated from the incidence angles of the sources and an assumed drift-velocity vector. The former choice is sufficient for testing the SKYMAP program (see section 2.4.4) in order to determine that SKYMAP calculates the correct source positions; the latter choice is necessary when it is desired to test program DRIFVEL (see section 2.5.3)

⁷³See program listing in Appendix A.

⁷⁴TESTSKY is coded only for drift programs 5, 6, 8 and 9.

which calculates the drift velocity on the assumption that all sources are moving at the same velocity. A binary-coded variable KPRINT (also inputted via TAPE1) determines whether to calculate the Doppler frequencies; it also determines whether to do the spectral averaging, whether to add noise to the time sequence, and which values (the time sequence, the frequency sequence, etc.) are to be printed (see comment statements in the program listing in Appendix A).

TESTSKY calculates for each antenna the digital time sequence

$$X_a(t_n) = \int_s V_0(s) \cos (\Delta\omega_s t_n - \vec{k}_s \cdot \vec{r}_a) \quad (155)$$

$$Y_a(t_n) = \int_s V_0(s) \sin (\Delta\omega_s t_n - \vec{k}_s \cdot \vec{r}_a) \quad (156)$$

$$|\vec{k}_s| = 2\pi/\lambda_s \quad (157)$$

$$\lambda_s = c/(f + \Delta f_s) \quad (158)$$

$$n = 0, 1, 2, \dots, N-1 \quad (159)$$

(The parameters not defined here are the same as in section 2.1.1.) The time-independent phase $-\vec{k}_s \cdot \vec{r}_a$ in (155) and (156) is different from $\phi_{a,s}$ of equations (65) and (66), which has the additional phase term $\vec{k}_s \cdot \vec{R}_{1,s} + \delta_s$ (see equation (51)); since this term cancels out in the FWPD calculation (see equation (179)), it can be omitted in the time-sequence simulation.⁷⁵ Also, compare the definition of $|\vec{k}_s|$ in (157) to equation (47): the latter is an approximation that we use in our calculations; TESTSKY uses the exact definition of $|\vec{k}_s|$.

⁷⁵ Except that δ_s is included when simulating drift data from more than one source at the same Doppler frequency. See section 2.4.3.

Note also that in (159), n starts at zero instead of $-N/2$ (compare equation (55)): adding $N/2$ to each of the values of n is equivalent to replacing $\Delta\omega_s t_n$ of equations (65) and (66) by (using equations (55), (116) and (118)):

$$\Delta\omega_s (n + N/2) \delta t = \Delta\omega_s t_n + D_s \pi \quad (160)$$

The phase constant $D_s \pi$ can be considered to be absorbed by δ_s .

If desired, noise can be added to the time sequence. For each of the simulated quadrature samples $X_a(t_n)$ and $Y_a(t_n)$, subroutine GAUSS1 calls a Fortran intrinsic function RANF, which is a random number generator, and uses the random numbers to generate a Gaussian noise sequence. The random number sequence can be varied by varying the seed of RANF. The noise is then added to the sequence of quadrature samples. Different noise sequences are added to the real parts $X_a(t_n)$ and to the imaginary parts $Y_a(t_n)$ of the time sequence. The result is not a Gaussian distribution of noise, but then neither is the noise in the real data. With an I.F. bandwidth of ± 10 kHz in the Digisonde receiver and a Doppler bandwidth of ± 4 Hz or ± 8 Hz (see Table 1), noise outside the Doppler range folds over and shows up within the Doppler range.

Subroutine FORER transforms the time sequence of each antenna into the frequency domain. The transform is defined as in equation (114), except that again n runs from 0 to $N-1$. The Doppler-frequency resolution and the Doppler range are the same as in section 2.2.1; $F_a(d)$ is the same as in section 2.2.2 except for a phase shift $(D_s - d)\pi$: $S(s, d)$ becomes (compare equation (124))

$$S(s, d) = N \frac{\sin (D_s - d)\pi}{(D_s - d)\pi} e^{i[(D_s - d)\pi - (D_s - d)\pi/N]} \quad (161)$$

The Fourier algorithm used in subroutine FORER is the Radix 2 Decimation-in-Frequency Fast Fourier Transform

(FFT),⁷⁶ taken from a program written by Michael Forman. The FFT is a discrete Fourier transform algorithm which calculates a transform of N points (for $N = 2^L$, with L an integer) by a suitable combination of two transforms, each of length $N/2$. An N -point transform is calculated from two $(N/2)$ -point transforms, each of which is computed using two $(N/4)$ -point transforms, and so on; in the final analysis, the N -point transform is calculated from $N/2$ two-point transforms. Whereas the direct transform employs N^2 complex multiplications to compute all N points, the FFT needs only $N \times L = N \log_2 N$ multiplications. For 64 and 128 points, this is a ratio of 4096/384 (over 10/1) and 16384/128 (over 18/1) respectively, resulting in a significant saving of computer time. With the FFT, the order of the sequence of points is shuffled and must be rearranged to produce the correct results. The Radix 2 Decimation-in-Time algorithm shuffles the input sequence, and the output is obtained in natural order. The algorithm used in TESTSKY takes the input in natural sequence so that the output must be reshuffled. The function IBRSH in TESTSKY determines the indices for the calculation of the $N/2$ two-point transforms, the combinations of half-length to full-length transforms, and the re-shuffling of the output into the correct order.

Spectral averaging is applied to the complex frequency spectrum by averaging three adjacent spectral lines with weights (-1) , (2) , (-1) instead of (1) , (2) , (1) , since for the Fourier transform defined with n starting at zero, the Hanning window is $[.5 - .5 \cos (2\pi n/N)]$.⁷⁷ The resulting weighted spectrum $F'_a(d)$ is the same as in equation (153), except for an added phase factor $(D_s - d)\pi$: i.e. $\phi_{a,s}$ of (153)

⁷⁶Peled and Liu (1976), sections 3.2 and 3.3.

⁷⁷Peled and Liu (1976), p. 99, exercise 2.6(c).

is replaced by $\phi_{a,s} + (D_s - d)\pi$.

After spectral averaging, the frequency spectrum is converted from (real, imaginary) to (amplitude, phase). Subroutine C720 then converts the amplitudes to $\log_{10}$ values and scales them to a maximum log value of 63 (six bits); the phases are converted as described in section 2.2.4 to nine-bit values. The preface and data for each case are then packed in the same format as in the Digisonde, and outputted on file TAPE9 by subroutine C2160 in two records (negative and positive Dopplers, in that order), with the 2160 six-bit characters for each record packed in 216 60-bit words. Program TESTSKY produces data for only one sounding frequency per case, but its output is otherwise identical to that of the Digisonde.

2.4 Analysis of the Drift Data: Locating the Sources

2.4.1 The Frequency-Wavenumber Power Density

The FWPD is a transform from the amplitude/phase domain into the spatial domain, using the cross-spectra between antennas to determine the angle of incidence of each spectral component.

The FWPD is defined as in equation (84), which is repeated here,

$$P(d, \vec{k}) = \sum_{a=1}^4 \sum_{a'=1}^4 F_a(d) F_{a'}^*(d) e^{i\vec{k} \cdot (\vec{r}_a - \vec{r}_{a'})} \quad (162)$$

$$\vec{k} \equiv \vec{k}(x_m, y_m) \quad (163)$$

$$P(d, \vec{k}) \equiv P(d, x_m, y_m) \quad (164)$$

$$P(d, \vec{k}) = \sum_{a=1}^4 F_a(d) e^{i\vec{k} \cdot \vec{r}_a} \sum_{a'=1}^4 [F_{a'}(d) e^{i\vec{k} \cdot \vec{r}_{a'}}]^* \quad (165)$$

$$= \left| \sum_{a=1}^4 F_a(d) e^{i\vec{k} \cdot \vec{r}_a} \right|^2 \quad (166)$$

where * denotes the complex conjugate; $F_a(d)$ and $F_{a'}(d)$ are the Fourier spectra at antennas a and a' respectively; and $\vec{k}$ is a scanning vector of constant magnitude $2\pi/\lambda$ but varying direction, as explained in section 2.1.3. $F_a(d) \times F_{a'}^*(d)$ is the cross-spectrum between a and a' , and $e^{i\vec{k} \cdot \vec{r}_a}$, $e^{i\vec{k} \cdot \vec{r}_{a'}}$ are computational phase delays.

If no two Doppler shifts fall on the same spectral line, then equation (153) yields (the prime has been dropped):

$$F_a(d) = V_{a,s} e^{i\phi_{a,s}} \quad (167)$$

$$F_{a'}(d) = V_{a',s} e^{i\phi_{a',s}} \quad (168)$$

$$V_{a,s} = V_{a',s} = \frac{N}{2} V_0(s) \frac{\sin b}{b} \cos c \left(1 - \frac{\sin^2 c}{\sin^2 c - \sin^2 \pi/N} \right) \quad (169)$$

$$b = (D_s - d) \pi \quad (170)$$

$$c = (D_s - d) \pi/N \quad (171)$$

We are neglecting the ringing contributions of neighboring Doppler lines, since spectral averaging has reduced their significance (see Figure 8). For each source whose Doppler shift $\Delta\omega_s$ is an integral multiple of $\delta\omega$, equation (169) becomes

$$V_{a,s} = V_{a',s} = \frac{N}{2} V_0(s) \quad (172)$$

Using (167) and (168), the FWPD becomes

$$P(d, \vec{k}) = \sum_{a=1}^4 \sum_{a'=1}^4 V_{a,s}^2 e^{i(\psi_{a,s} - \psi_{a',s})} \quad (173)$$

$$= \sum_{a=1}^4 V_{a,s}^2 + \sum_{a=1}^3 \sum_{a'=a+1}^4 V_{a,s}^2 [e^{i(\psi_{a,s} - \psi_{a',s})} + e^{-i(\psi_{a,s} - \psi_{a',s})}] \quad (174)$$

$$= \sum_{a=1}^4 V_{a,s}^2 + 2 \sum_{a=1}^3 \sum_{a'=a+1}^4 V_{a,s}^2 \cos(\psi_{a,s} - \psi_{a',s}) \quad (175)$$

$$\psi_{a,s} = \phi_{a,s} + \vec{k} \cdot \vec{r}_a \quad (176)$$

$$\psi_{a',s} = \phi_{a',s} + \vec{k} \cdot \vec{r}_{a'} \quad (177)$$

where the first term of (175) is the auto-correlation term.
From the definition of $\phi_{a,s}$ in equation (51),

$$\begin{aligned} \psi_{a,s} - \psi_{a',s} &= \vec{k}_s \cdot \vec{R}_{1,s} - \vec{k}_s \cdot \vec{r}_a + \delta_s + \vec{k} \cdot \vec{r}_a \\ &\quad - \vec{k}_s \cdot \vec{R}_{1,s} + \vec{k}_s \cdot \vec{r}_{a'} - \delta_s - \vec{k} \cdot \vec{r}_{a'}, \end{aligned} \quad (178)$$

$$= (\vec{k} - \vec{k}_s) \cdot (\vec{r}_a - \vec{r}_{a'}) \quad (179)$$

so that in the phase of the echo only the phase component which depends on the antenna separation matters. From (179), equation (175) is clearly a maximum when

$$\vec{k} = \vec{k}_s \quad (180)$$

that is, when the scanning vector $\vec{k}$ looks in the direction of the wave-propagation vector $\vec{k}_s$.

2.4.2 The Sky Map

As mentioned in section 2.1.3, the direction of the scanning vector $\vec{k}$ is defined by the Cartesian coordinates $(x_m, y_{m'})$, which vary in steps of equal increments on both horizontal axes of a square map. The north-west quadrant of the map area is sketched in Figure 9 and illustrated in more detail in Figure 10. Imagine a spherical cap formed by the set of all points at range R , zenith angle ζ and azimuth α ,

$$\zeta \leq \zeta_{\max} \quad (181)$$

$$0 \leq \alpha < 360^\circ \quad (182)$$

The sky map represents that area of the sky which is on the curved surface of the cap, and whose vertical projection onto a horizontal plane forms a square whose corners are at $(R, \zeta_{\max})$ and azimuth 45° (NE), 135° (SE), 225° (SW) and 315° (NW). (The azimuth α is defined as zero on the x axis, which points north, and increases towards the $-y$ axis, or east.)

The incremental steps δx and δy for the x - and y -axis coordinates are defined by R and $\zeta_{\max}$, as illustrated in Figure 11. The range vector at the corner of the map has x and y components both equal to $.707 R \sin \zeta_{\max}$. These components are divided into 20 equal increments so that

$$\delta x = \delta y = (.707 R \sin \zeta_{\max})/20 \quad (183)$$

Each of the sky map coordinates then corresponds to a point in the sky whose position vector $\vec{R}$ has components $x_m, y_{m'}, z$:

$$x_m = m \delta x = (.707 R \sin \zeta_{\max}) \frac{m}{20} \quad (184)$$

$$y_{m'} = m' \delta y = (.707 R \sin \zeta_{\max}) \frac{m'}{20} \quad (185)$$

$$z = (R^2 - x_m^2 - y_{m'}^2)^{1/2} \quad (186)$$

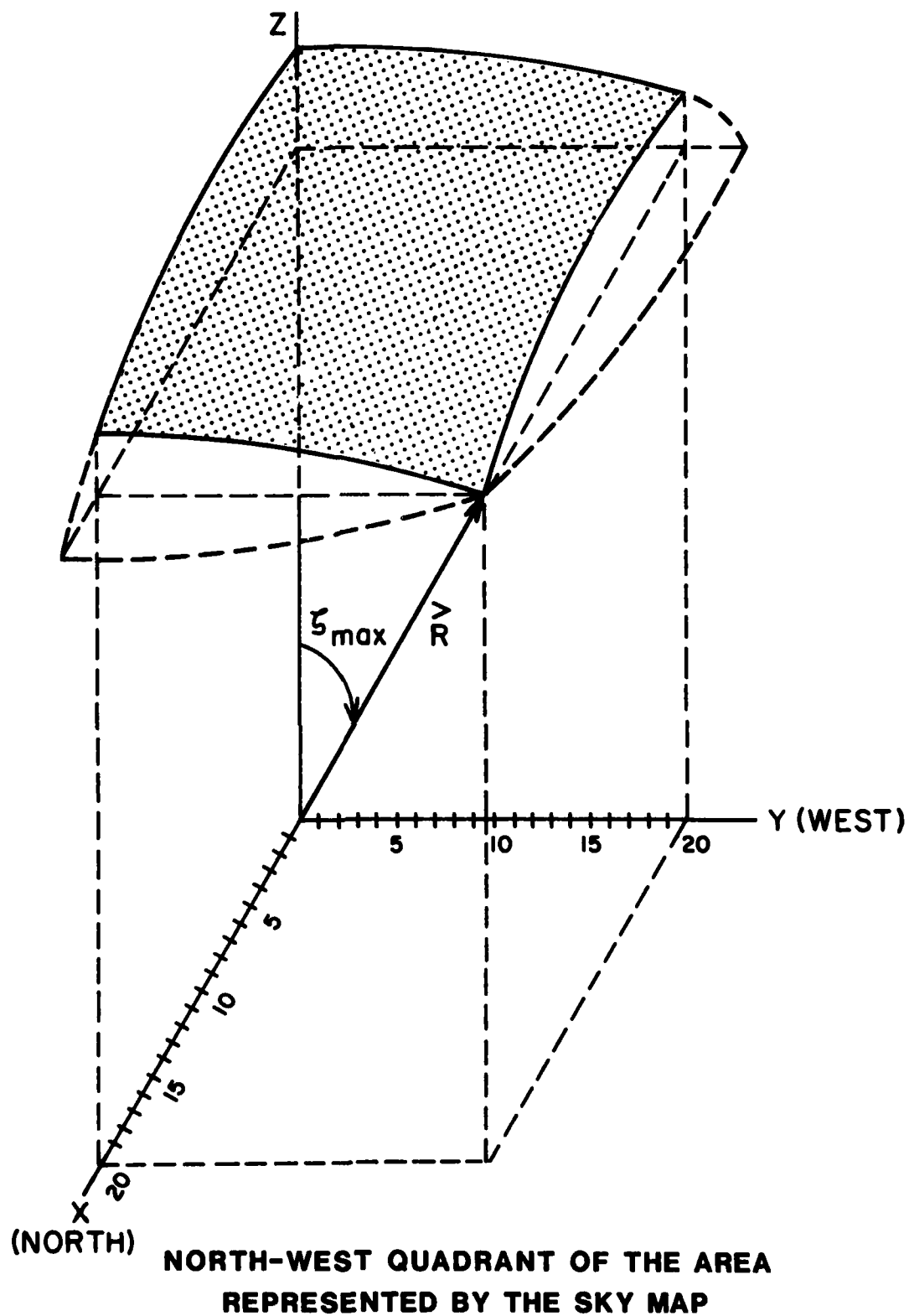
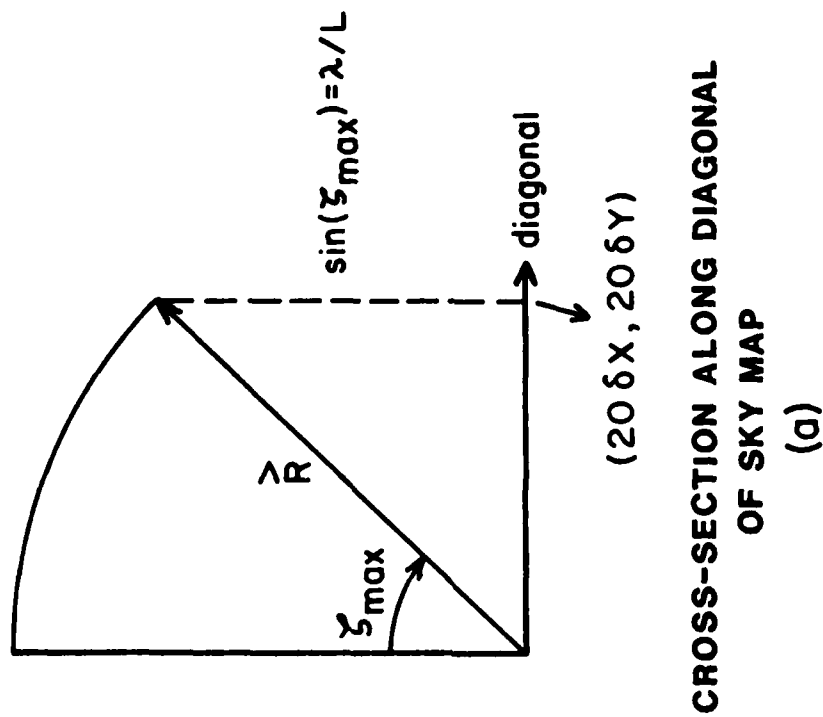
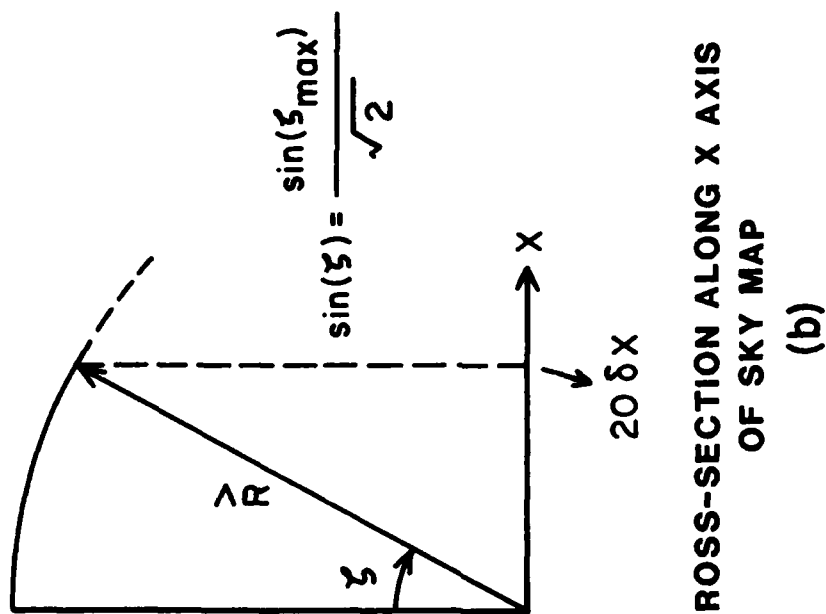


Figure 9



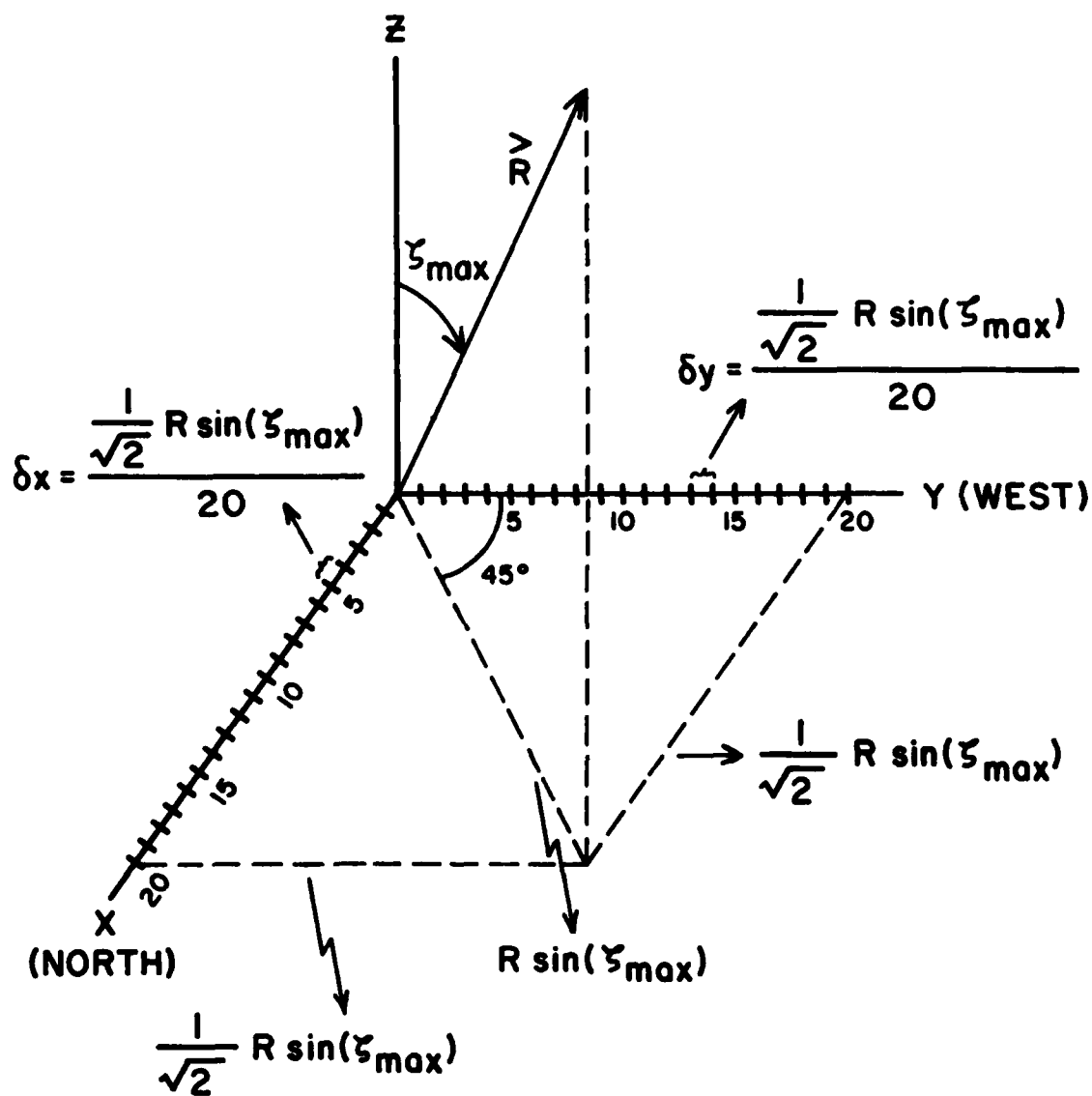
CROSS-SECTION ALONG DIAGONAL
OF SKY MAP



CROSS-SECTION ALONG X AXIS
OF SKY MAP

CROSS-SECTIONS OF SKY AREA REPRESENTED BY SKY MAP

Figure 10



MAP INCREMENTS δx AND δy IN TERMS OF R AND $\zeta_{\max}$

Figure 11

For drift-data simulation in program TESTSKY (see section 2.3), the source positions are inputted in terms of the angles α and ζ , which are related to x , y and z as follows (see Figure 12):

$$x = R \sin \zeta \sin (\alpha - 3\pi/2) \quad (187)$$

$$= R \sin \zeta \cos \alpha \quad (188)$$

$$y = R \sin \zeta \cos (\alpha - 3\pi/2) \quad (189)$$

$$= - R \sin \zeta \sin \alpha \quad (190)$$

$$z = R \cos \zeta \quad (191)$$

For a given Doppler number d , $P(d, \vec{k})$ is calculated for each of 1681 angles of $\vec{k}$ (x_m, y_m, z_m); since $\vec{k}$ and $\vec{R}$ are anti-parallel,

$$\vec{k} = k_x \hat{x} + k_y \hat{y} + k_z \hat{z} \quad (192)$$

$$\vec{R} = x \hat{x} + y \hat{y} + z \hat{z} \quad (193)$$

$$\vec{k} = k (-\hat{R}) = - \frac{k}{R} \vec{R} \quad (194)$$

$$= - \frac{k}{R} (x \hat{x} + y \hat{y} + z \hat{z}) \quad (195)$$

$$\vec{k}(x_m, y_m, z_m) = - \frac{k}{R} x_m \hat{x} - \frac{k}{R} y_m \hat{y} - \frac{k}{R} z_m \hat{z} \quad (196)$$

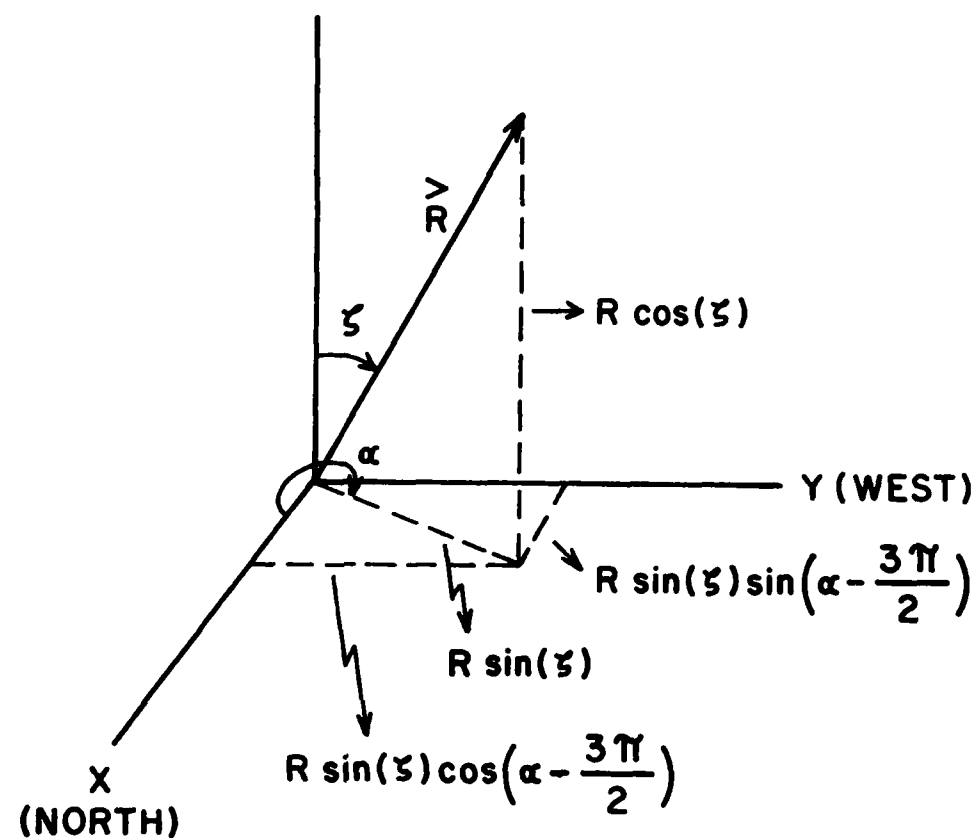
so that

$$k_x(m) = - (.707 k \sin \zeta_{\max}) \frac{m}{20} \quad (197)$$

$$k_y(m') = - (.707 k \sin \zeta_{\max}) \frac{m'}{20} \quad (198)$$

The z component of $\vec{k}$ (x_m, y_m, z_m) is not needed since in $P(d, \vec{k})$, $\vec{k}$ appears in the term $\vec{k} \cdot \vec{r}_a$, and the antenna position vector $\vec{r}_a$ has no z component.

The antenna pattern produced by the variations of $P(d, \vec{k})$ as $\vec{k}$ (x_m, y_m, z_m) scans the sky contains not only the



COMPONENTS OF THE RANGE VECTOR $\vec{R}$

Figure 12

main lobe (whose values increase to a maximum as $\vec{k}$ approaches the source vector $\vec{k}_s$ from any direction) but also two types of side lobes, which we call the major and minor side lobes: the major side lobes have a peak value equal to the peak of the main lobe; the minor side lobes have a maximum 6 dB below that of the main lobe. Both types of lobes are illustrated in Figure 13, which is the antenna pattern for a source directly overhead (the main lobe is in the center), at a sounding frequency of 10 MHz. The numbers labeled IX and IY to the right of and below the map respectively are the indices of the map coordinates; the other indices IXMAX and IYMAX will be explained in section 2.4.4. IX and IY are more properly array indices as defined in program SKYMAP but we consider them as map indices corresponding to m and m' as follows:

$$m = 21 - IX \quad (199)$$

$$m' = 21 - IY \quad (200)$$

$$IX, IY = 1, 2, 3, \dots, 41 \quad (201)$$

$$m, m' = 20, 19, 18, \dots, 0, \dots, -18, -19, -20 \quad (202)$$

For example,

$$\vec{k}(IX = 1, IY = 1) = \vec{k}(x_{20}, y_{20}) \quad (203)$$

$$\vec{k}(IX = 41, IY = 41) = \vec{k}(x_{-20}, y_{-20}) \quad (204)$$

(Note that the positive quadrant (+x, +y) is the NW quadrant of the sky map; see Figure 9). At each coordinate of the antenna pattern, $P(d, \vec{k})$ for each $\vec{k}(IX, IY)$ and any given d (the result is the same no matter which Doppler number is used) is indicated in dB. Note the six minor side lobes of peak density 67 dB around the main lobe, and the six major side lobes further out, of the same peak density (73 dB) as the main lobe. The angles shown are the zenith angles; the reason for their uneven spacing will be explained below.



844



FREQUENCY 10 MHZ
WAVELENGTH 30 METERS
VALUES IN dB

UNIVERSITY of LOWELL
CENTER for ATMOSPHERIC RESEARCH
LOWELL, MASSACHUSETTS

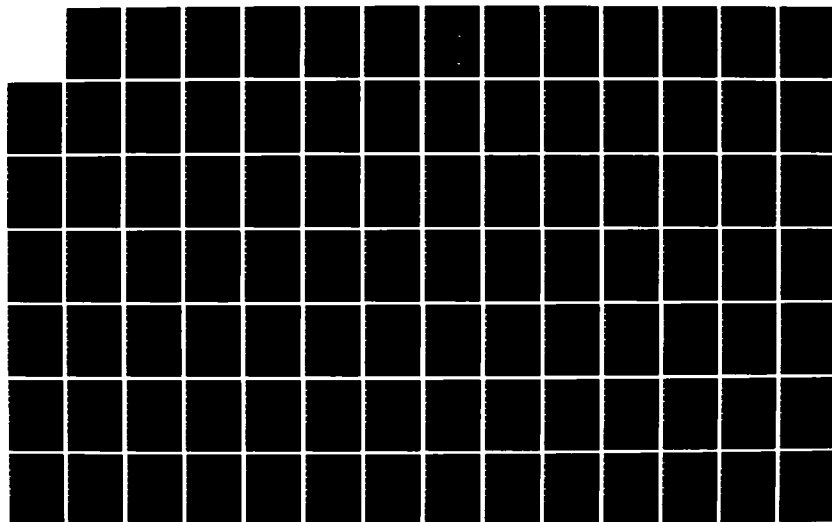
AD-A140 509

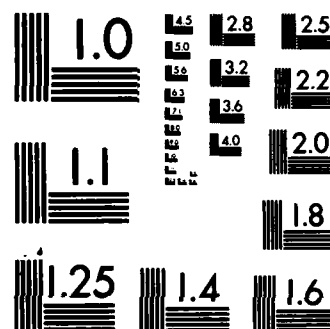
A HIGH FREQUENCY RADIO TECHNIQUE FOR MEASURING PLASMA
DRIFTS IN THE IONOS. (U) LOWELL UNIV MA CENTER FOR
ATMOSPHERIC RESEARCH C G DOZOIS JUL 83 ULRF-424/CAR
AFGL-TR-83-0202 F19628-80-C-0064 F/G 4/1

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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

With a proper choice of $\zeta_{\max}$, the map area can be limited so as to exclude the center (peak value) of the first major side lobe. A coarse approximation for $\zeta_{\max}$ can be derived by considering two antennas 1 and 2. The term in the FWPD (equation 175) which includes $\psi_{1,s}$ and $\psi_{2,s}$ is (ignoring the constants):

$$\cos(\psi_{1,s} - \psi_{2,s}) = \cos(\vec{k}_s \cdot \vec{r}_2 - \vec{k} \cdot \vec{r}_2) \quad (205)$$

where the right side follows from equation (179) with $\vec{r}_1 = 0$. The maxima of (205) are at

$$\vec{k}_s \cdot \vec{r}_2 - \vec{k} \cdot \vec{r}_2 = 0, \pm 2\pi, \pm 4\pi, \dots \quad (206)$$

Figure 14 illustrates the relationship between the zenith angle ζ and the angle θ (where θ is between $\vec{k}$ and $\vec{r}$) for $\vec{k}$ in the same vertical plane as $\vec{r}$, the antenna-position vector. In quadrant I,

$$\vec{k} \cdot \vec{r} = \frac{2\pi}{\lambda} |\vec{r}| \cos(90^\circ - \zeta) \quad (207)$$

$$= \frac{2\pi}{\lambda} r \sin \zeta \quad (208)$$

and in quadrant II,

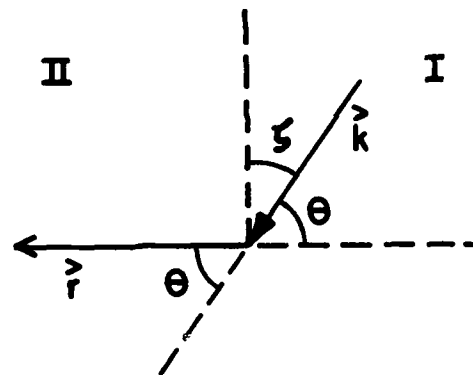
$$\vec{k} \cdot \vec{r} = \frac{2\pi}{\lambda} |\vec{r}| \cos(90^\circ + \zeta) \quad (209)$$

$$= -\frac{2\pi}{\lambda} r \sin \zeta \quad (210)$$

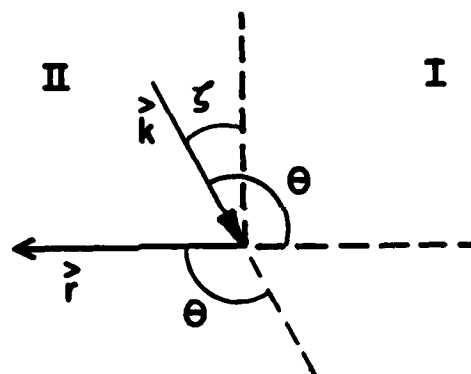
Now suppose that ζ_s (the zenith angle of $\vec{k}_s$) is in quadrant I, and

$$\sin \zeta_s = \lambda/2r \quad (211)$$

and ζ_k (the zenith angle of the scanning vector) is at the same zenith but in quadrant II, then from (208) and (210), equation (206) yields in this example



(a) $\vec{k}$ IN QUADRANT I



(b) $\vec{k}$ IN QUADRANT II

RELATIONSHIP BETWEEN ZENITH ANGLE ζ , AND ANGLE θ BETWEEN $\vec{k}$ AND $\vec{r}$, FOR $\vec{k}$ AND $\vec{r}$ IN THE SAME PLANE

Figure 14

$$\vec{k}_s \cdot \vec{r}_2 - \vec{k} \cdot \vec{r}_2 = \frac{2\pi}{\lambda} r \sin \zeta_s - (-\frac{2\pi}{\lambda} r \sin \zeta_k) \quad (212)$$

$$= \frac{2\pi}{\lambda} r \left(\frac{\lambda}{2r} + \frac{\lambda}{2r} \right) \quad (213)$$

$$= 2\pi \quad (214)$$

so that the FWPD (for two antennas) is a maximum in the direction of the source (main lobe) and at the same zenith angle but diametrically opposite in azimuth (side lobe). To exclude this side lobe, the searching angle (with only two antennas) must be limited to

$$\sin \zeta_{\max} < \lambda/2r \quad (215)$$

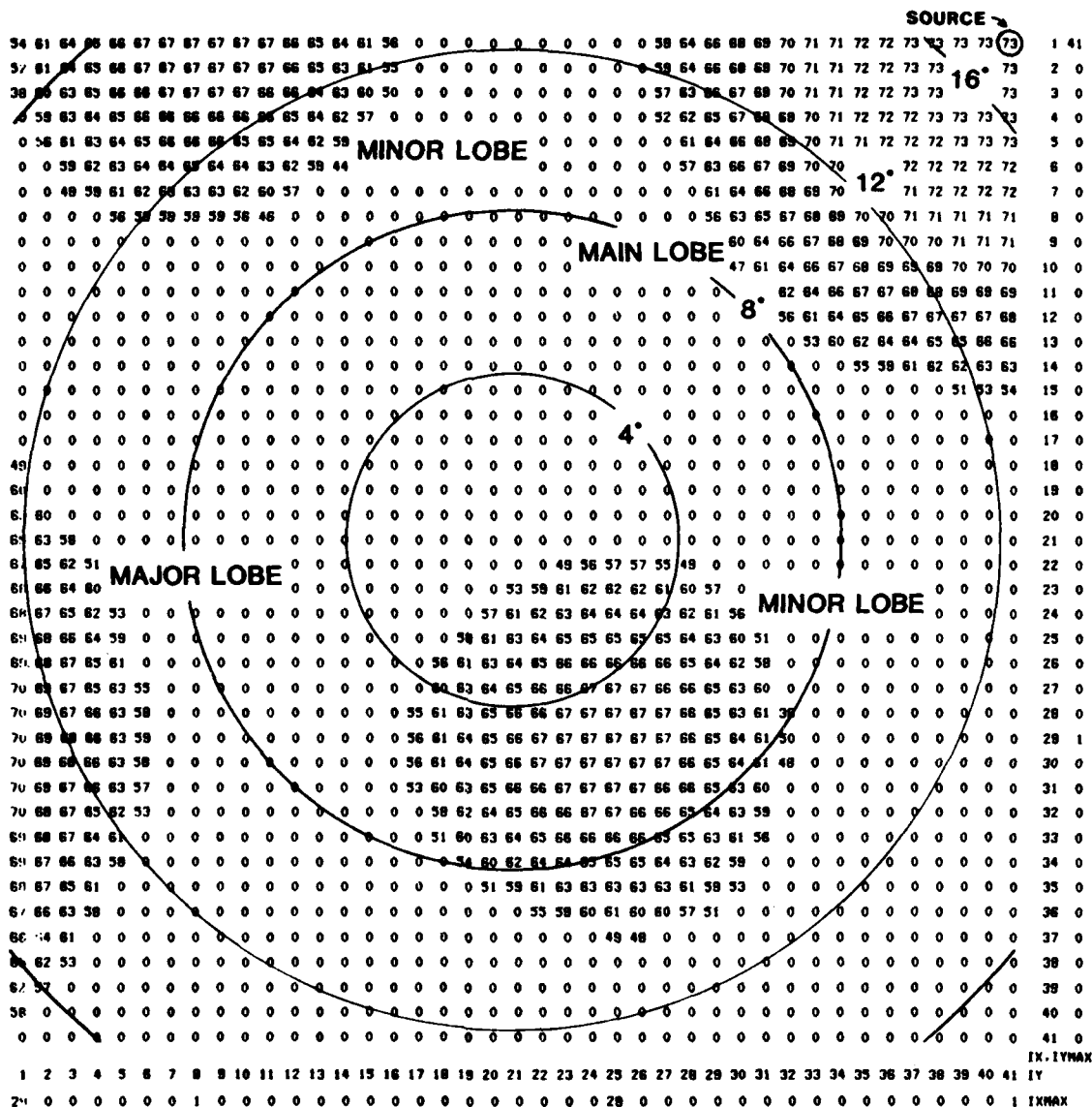
The determination of $\zeta_{\max}$ with four antennas was done numerically, and it was found that setting

$$\sin \zeta_{\max} = \lambda/L \quad (216)$$

(where L is the maximum antenna separation -- see Figure 5) eliminates the peak of the first major side lobe. This is illustrated in Figure 15 which shows the antenna pattern at a sounding frequency of 10 MHz, for a source placed at the extreme upper right-hand corner of the map, at zenith angle

$$\zeta_{\max} = 17.42^\circ \quad (217)$$

Part of the major side lobe appears near the bottom, on the left. Its maximum value at (IX = 29, IY = 1) is 3 dB below the peak of the main lobe; its own peak value is outside the map, which justifies the value of $\zeta_{\max}$ in (217) calculated according to (216). Two minor side lobes show up with peaks at (1, 8) and at (29, 25); these are 6 dB below the peak of the main lobe. Thus it is possible to determine the actual source position from the maximum value of P(IX, IY). Note, however, that if a source is outside $\zeta_{\max}$, the peak of one of its major side lobes may appear on the map.



FREQUENCY 10 MHZ
 WAVELENGTH 30 METERS
 $\zeta_{\max} = 17.42^\circ$
 SIDE LOBES WITH $\sin(\zeta_{\max}) = \lambda/L$,
 SOURCE AT ZENITH ANGLE $\zeta_{\max}$

Figure 15

$\zeta_{\max}$ is a function of λ ; at lower sounding frequencies, the lobes are spread further apart, so $\zeta_{\max}$ is larger. Up to about 4 MHz, $\zeta_{\max}$ as defined in (216) is greater than 45° , but the program SKYMAP sets it to 45° since it is not expected that the receiving pattern of the antenna array at Goose Bay will pick up sources beyond a zenith angle of 45° .

With the sky map coordinates as defined above, the angular increments for the zenith angles at a given azimuth are not equally spaced (as can be seen in the antenna pattern of Figure 13), which explains the apparent asymmetry of some of the side lobes in the antenna pattern. This uneven spacing of the zenith angles is illustrated in Figure 16, which shows a vertical cross-section of the sky along the map diagonal ξ , for $\zeta_{\max}$ at 45° (the maximum for the sky maps) and at 90° (the maximum for the antenna pattern of Figure 13). From equation (183), the diagonal map increment $\delta\xi$ is

$$\delta\xi = (\delta x^2 + \delta y^2)^{1/2} \quad (218)$$

$$= \delta x \sqrt{2} \quad (219)$$

$$= (R \sin \zeta_{\max})/20 \quad (220)$$

which yields the scale values given in the figure.

The range vectors $\vec{R}$ are drawn for the values of m ($= m'$) which are multiples of 2. Since the increments of arc length are proportional to the increments in zenith angle, a comparison of the arc-length increments near the center of the map with those near the edge gives a qualitative picture of the variations in zenith. The distortion near the edge is much less for the sky maps than for the antenna pattern in Figure 13. A few specific values of angular increments are indicated in Figure 16; these were calculated from

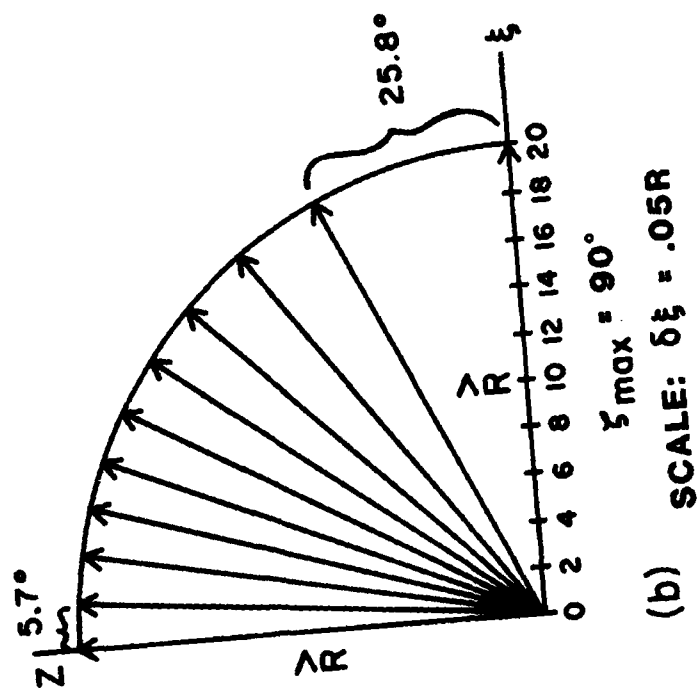


Figure 16

LE: $\delta\xi = .035H$

ZENITH-ANGLE INCREMENTS ALONG THE MAP DIAGONAL ξ

$$\sin \zeta(\vec{R}) = \xi/R \quad (221)$$

$$= m \delta \xi / R \quad (222)$$

$$= (m \sin \zeta_{\max})/20 \quad (223)$$

where $\zeta(\vec{R})$ is the zenith angle of the range vector $\vec{R}$.

2.4.3 More Than One Echo at the Same Doppler Line

To illustrate the result of the FWPD calculation when more than one source has the same Doppler shift, let us assume two sources s' and s'' with

$$\Delta \omega_{s'} = \Delta \omega_{s''} = d' \delta \omega \quad (224)$$

$$\Delta \omega_{s'} = D_{s'} \delta \omega \quad (225)$$

$$\Delta \omega_{s''} = D_{s''} \delta \omega \quad (226)$$

$$D_{s'} = D_{s''} = d' \quad (227)$$

where d' is one of the Doppler numbers d . In the more general case, $D_{s'}$ and $D_{s''}$ may not be integers (i.e. may not be exactly equal to d') and may not even be equal to each other; if they are both approximately equal to d' , then they fall on the same Doppler line d' . The principle to be illustrated below is the same with or without assumption (224); but this assumption makes the algebra considerably simpler.

With $D_{s'} (= D_{s''})$ an integer, the spectrum is the same before and after spectral averaging except for a scaling factor, so let us consider first equation (126), which is the spectrum before averaging: in (126), only the first two terms are non-zero, since it is assumed that there are only two sources; and from equation (129),

$$S(s', d') = S(s'', d') = N \quad (228)$$

$$D_{s'} = D_{s''} = d' \quad (229)$$

so that

$$F_a(d') = N V_0(s') e^{i\phi_{a,s'}} + N V_0(s'') e^{i\phi_{a,s''}} \quad (230)$$

A comparison of equations (119) and (143) shows that spectral averaging replaces $S(s,d)$ by the bracket in (143), which yields equation (151); it can be shown that with D_s an integer, (151) becomes $N/2$, so that (after averaging),

$$F_a(d') = \frac{N}{2} [V_0(s') e^{i\phi_{a,s'}} + V_0(s'') e^{i\phi_{a,s''}}] \quad (231)$$

To make the FWPD analytically tractable, we make the simplifying assumption that the amplitude V_0 of both sources is the same, and write

$$F_a(d') = \frac{N}{2} V_0 [e^{i\phi_{a,s'}} + e^{i\phi_{a,s''}}] \quad (232)$$

$$V_0 = V_0(s') = V_0(s'') \quad (233)$$

$$e^{i\phi_{a,s'}} + e^{i\phi_{a,s''}} = 2 \cos [(\phi_{a,s'} - \phi_{a,s''})/2] \times e^{i(\phi_{a,s'} + \phi_{a,s''})/2} \quad (234)$$

$$F_a(d') = V_a e^{i(\phi_{a,s'} + \phi_{a,s''})/2} \quad (235)$$

$$V_a \equiv V_a(s',s'') = N V_0 \cos [(\phi_{a,s'} - \phi_{a,s''})/2] \quad (236)$$

The last equation expresses the fact that with two (or more) echoes on the same Doppler line, the amplitude of that Doppler is in general different at each antenna. We write also $F_{a'}(d')$ as

$$F_{a'}(d') = V_{a'} e^{i(\phi_{a',s'} + \phi_{a',s''})/2} \quad (237)$$

$$V_{a'} = N V_0 \cos [(\phi_{a',s'} - \phi_{a',s''})/2] \quad (238)$$

(To avoid confusion, remember that as defined consistently above,

$$a, a' = 1, 2, 3, 4 \quad (239)$$

$$s = s', s'', s''', \dots \quad (240)$$

$$d = d', d'', d''', \dots \quad (241)$$

that is, the antenna index a' is a running index and not a specific value of a .) Then the FWPD (equation (162) evaluated for $d = d'$) becomes

$$P \equiv P(d', \vec{k}) = \sum_{a=1}^4 \sum_{a'=1}^4 V_a V_{a'} e^{i(\Psi_a - \Psi_{a'})} \quad (242)$$

$$\Psi_a \equiv \Psi_a(s', s'') = (\phi_{a,s'} + \phi_{a,s''})/2 + \vec{k} \cdot \vec{r}_a \quad (243)$$

$$\Psi_{a'} \equiv \Psi_{a'}(s', s'') = (\phi_{a',s'} + \phi_{a',s''})/2 + \vec{k} \cdot \vec{r}_{a'} \quad (244)$$

$$P = \sum_{a=1}^4 V_a^2 + \sum_{a=1}^3 \sum_{a'=a+1}^4 \{V_a V_{a'} [e^{i(\Psi_a - \Psi_{a'})} + e^{-i(\Psi_a - \Psi_{a'})}]\} \quad (245)$$

$$P = \sum_{a=1}^4 V_a^2 + \sum_{a=1}^3 \sum_{a'=a+1}^4 2 V_a V_{a'} \cos(\Psi_a - \Psi_{a'}) \quad (246)$$

Using (236), (238), (243), (244) and the definition (51) of $\phi_{a,s}$, equation (245) becomes:

$$\begin{aligned} P = N^2 V_0^2 \sum_{a=1}^4 \cos^2 \left[\frac{\vec{k}_{s''} - \vec{k}_{s'}}{2} \cdot \vec{r}_a + \delta \right] \\ + 2 N^2 V_0^2 \left\{ \sum_{a=1}^3 \sum_{a'=a+1}^4 \cos \left[\frac{\vec{k}_{s''} - \vec{k}_{s'}}{2} \cdot \vec{r}_a + \delta \right] \right. \\ \times \cos \left[\frac{\vec{k}_{s''} - \vec{k}_{s'}}{2} \cdot \vec{r}_{a'} + \delta \right] \\ \times \cos \left[\left(\vec{k} - \frac{\vec{k}_{s'} + \vec{k}_{s''}}{2} \right) \cdot (\vec{r}_a - \vec{r}_{a'}) \right] \left. \right\} \quad (247) \end{aligned}$$

$$\delta = \frac{\delta_{s'} - \delta_{s''}}{2} \quad (248)$$

Thus with two (or more) echoes at the same Doppler frequency, the initial phase of each echo does not cancel out. Examples of the effects of various values of δ will be shown in section 3.1.

2.4.4 Program SKYMAP

The SKYMAP program⁷⁸ is used to calculate sky maps using Doppler-drift data from either the Digisonde or program TESTSKY. The original SKYMAP program was developed a few years ago by ULCAR. In its present form, it retains the original routines for unpacking and decoding the data; but the rest of the program has been modified and expanded extensively by the present author.

The drift data is inputted via file TAPE1. At the beginning of each run, the program requests the value of KPRINT, the record number, the frequency number(s), and whether negative, positive or both Dopplers are to be processed. KPRINT is, as in program TESTSKY, a binary-coded variable which determines the functions to be performed (see below). The record number determines whether to start processing the data with the first record found on input file TAPE1 or with a later record. The frequency number (or numbers) indicates whether the data for all three or six sounding frequencies is to be processed, or only the data from one of the sounding frequencies.

The functions performed by the SKYMAP program are of three types:⁷⁹ data checks; separating the drift data from

⁷⁸See listing in Appendix B.

⁷⁹See program comments at the beginning of the program listing for more details.

the ionogram data; and calculating or printing sky maps or antenna patterns. The data checks include printing the drift data in its various forms (raw data, unpacked data, amplitudes, phases); these checks were used in the early testing stages to verify the format of the simulated data from TESTSKY, and for a preliminary examination of the measured drift data from Goose Bay. The second type of function is used to separate the drift data from the ionogram data on a physical tape and store it in a computer file, in order to use the allotted computer-memory space more efficiently. Of the four sky-map functions, three include the calculation of the sky maps (i.e. calculating the FWPD of each map coordinate, for each Doppler line), with options for printing the sky maps (via subroutine PRIN) as they are calculated, printing the antenna patterns for each Doppler line, and/or saving the map data (the map indices IX and IY of each source, the source density P_s (IX, IY), and the Doppler number d of each source) on file TAPE50. This last function is performed by subroutine MAPDATA. The fourth function involves printing the sky maps from the data on TAPE50. If the value of KPRINT indicates this function, the FWPD calculation is skipped and subroutine MAPSEQ is called. The subroutine requests information as to the starting time (the time of the first case to be printed; or "zero", to start at the beginning of TAPE50), whether negative, positive or both Dopplers are to be printed; the minimum density in dB of the sources to be included on the map (with the option of setting the minimum density at a fixed value for all maps, or at a fixed number of dB below the maximum density of each map); and whether to print each case on a separate map or to compress several consecutive cases onto one map ("time sequence"). With the latter choice, the densities P_s are replaced on the map by the numbers 0, 1, 2, ... to indicate the time sequence of the cases.

When calculating sky maps, the program buffers in one record of drift data from TAPE1 and unpacks the 216 char-

acters into 2160 computer words (see section 2.2.4). Then the next record is buffered in and unpacked, and the date and time in the preface of both records are compared to determine whether both records belong to the same case. If the date and time are not identical, the next record is buffered in; if they are identical, both records are stored temporarily on TAPE99, so that processing can continue with each record separately.

Next the preface parameters that are relevant to drift measurements (see Table 3) are decoded: the appropriate preface characters are combined to form the station number, the year, etc.; and the decoded sounding frequencies, ranges and receiver gains are assigned an index number for identification. The frequencies are incremented by 12.5 kHz, because the sounding frequencies in the DGS 128PS are offset by 12.5 kHz from the indicated frequencies in order to diminish possible interference with commercial short-wave stations, which generally broadcast at multiples of 100 kHz. It was found that for technical reasons the data transfer from the Digisonde to digital tape is not done correctly for drift measurements at ranges greater than 510 km, so the program skips to the next case if the range is too high.

Subroutine ANT is then called to determine, from the task number, the number of antennas used, and to define the indices for identifying the antenna sequence. For drift data from the Goose Bay station, the task number is always zero and the four-antenna array is used for all measurements; but the DGS 128PS is designed for processing drift data from receiving arrays of up to twenty-four antennas (using all antennas in the array or submultiples of 24 in various combinations). Subroutine ANT also determines from the drift program number the parameters of Table 1, and calculates the components of $\vec{k} \cdot \vec{r}/m$ for each antenna-position vector $\vec{r}_a$,

$$\frac{k_x r_x}{m} = \frac{-.707 k \sin(\zeta_{\max}) r_x}{20} \quad (249)$$

$$\frac{k_y r_y}{m} = \frac{-.707 k \sin(\zeta_{\max}) r_y}{20} \quad (250)$$

$$\vec{r} = r_x \hat{x} + r_y \hat{y} \quad (251)$$

where k_x and k_y were defined in equations (197) and (198).

Subroutine SPLIT sorts out the two six-bit amplitudes and two nine-bit phases from each group of five six-bit characters (see Table 4), converting the log amplitudes to linear amplitudes.

Next, subroutine FOU is called to calculate the FWPD of each Doppler line. In order to save computing time, we define an estimated power density $P'(d)$ for each Doppler,

$$P'(d) = \left[\sum_{a=1}^4 |V_a(d)| \right]^2 \quad (252)$$

where $|V_a(d)|$ is the measured amplitude of spectral line d ($V_a(d) \equiv V_{a,s}$ if all sources are at different Dopplers); and we skip the calculation of the FWPD for all Dopplers for which $P'(d)$ is more than 20 dB below the maximum $P'(d)$. Also, no FWPD is calculated when $P'(d)$ is less than 6 dB or when $|V_a(d)|$ is less than 1 at any antenna.

The FWPD is calculated from equation (166). $F_a(d)$ and $e^{i\vec{k} \cdot \vec{r}_a}$ are calculated separately and then combined: $e^{i\vec{k} \cdot (x_m, y_m) \cdot \vec{r}_a}$ is first calculated for each of the 1681 (41×41) coordinates, for antennas 2 to 4 ($\vec{r}_1 \equiv 0$); then at each Doppler, the measured amplitudes $V_a(d)$ and phases $\phi_a(d)$ ($\equiv \phi_{a,s}$ if all sources are at different Dopplers) are used to calculate $F_a(d)$ as $V_a(d) e^{i\phi_a(d)}$ for each antenna. $F_a(d)$ and $e^{i\vec{k} \cdot \vec{r}_a}$ are then combined as in (166) to yield the FWPD for each (x_m, y_m) . The FWPD algorithm in the original SKYMAP program combined the two exponentials as $e^{i[\phi_a(d) + \vec{k} \cdot \vec{r}_a]}$ and calculated this term 1681 times for each of the four antennas

at each Doppler number, which used more computing time. Also, in the current SKYMAP program, the cosine and sine values for the exponentials are determined by the program function COSINE, from a table (calculated at the beginning of the main program) of the values of $\cos(0)$ to $\cos(\pi/2)$, in angular increments of $2\pi/1024$. The original program calculated the trigonometric values with a Fortran library subroutine, which yields more exact values but takes more time. A comparison was made of the two algorithms, using a drift measurement with 64 Doppler lines (2 records: 32 positive and 32 negative Dopplers). The CPU time used for all 107,584 (64×1681) FWPD calculations with the original algorithm was 180 seconds. This was cut down to 40 seconds by using the cosine table and calculating the $e^{i\vec{k} \cdot \vec{r}}$ array only once. Skipping the FWPD calculations of the weaker Doppler lines as explained earlier further reduces the CPU time in varying amounts, depending how many strong sources there are; for the data used in the comparison, the time was reduced to 16 seconds.

Subroutine FOU subtracts from each value of $P(d, \vec{k})$ the constant auto-correlation term (the first sum in equations (175) and (246)) and sets the negative values to zero. As a result, when the antenna patterns are printed, only the values within a limited radius of the local peaks are non-zero, which makes it easier to identify the lobes.

For each Doppler, the map coordinates of the source(s) are determined from the maximum linear values of $P(d, \vec{k})$ of each row IX and the maximum of each column IY; these indices are stored as (IX, IYMAX) and (IXMAX, IY). (See Figure 13, to the right of and below the antenna pattern.) The densities $P_s(d)$ and the Doppler numbers d of those peaks whose row and column indices are equal ($IX_{\text{row}} = IXMAX_{\text{column}}$, $IYMAX_{\text{row}} = IY_{\text{column}}$) are stored for the final sky map, unless the densities are more than 3 dB below the maximum density for that Doppler (thus eliminating the minor side lobes). The final sky map consists of two parallel maps, one with the

logarithmic densities at the coordinates of the sources, the other with the corresponding Doppler numbers at the same coordinates.

As mentioned above, if subroutine MAPDATA is called, the map data is stored on TAPE50. The data on TAPE50 can be used either for printing sky maps or for calculating the drift velocities; the latter will be discussed in the next section.

2.5 Determining the Drift Velocity

2.5.1 Relationship between the Source Velocity and the Doppler Shift

The Doppler shift Δf_s of source s is proportional to the radial component (the component parallel to the source-position vector $\vec{R}_s$) of the velocity of the source, and is determined as follows. Consider first a radio signal of frequency f impinging on a reflector which is moving at a non-relativistic speed W towards or away from the transmitter; the signal is observed by the reflector as though it were at frequency f' ⁸⁰

$$f' = f \frac{1 \pm W/c}{[1 - (W/c)^2]^{1/2}} \quad (253)$$

$$f' \approx f (1 \pm W/c), \quad W \ll c \quad (254)$$

where c is the speed of light in vacuum, the upper sign is for approaching motion, and the lower sign is for receding motion. The reflected signal is then observed at the transmitting site at frequency f''

$$f'' = f' (1 \pm W/c) \quad (255)$$

$$= f (1 \pm W/c)^2 \quad (256)$$

⁸⁰Halliday and Resnick (1966), section 40-5.

$$f'' \approx f (1 \pm 2 \frac{W}{c}), W \ll c \quad (257)$$

with Doppler shift

$$\Delta f = f'' - f = \pm 2 \frac{W}{c} f \quad (258)$$

We consider the reflector as the source of a signal with Doppler shift Δf ; since the source motion can be in any direction, W is the radial component of the source velocity $\vec{V}$,

$$\vec{V} \cdot \hat{R} = \mp W \quad (259)$$

where with our choice of coordinate system, $\vec{V} \cdot \hat{R}$ is negative for motion towards the transmitter/receiver site (motion along $-\hat{R}$) and positive for motion away from the site (along $+\hat{R}$). Adding the source index s and combining (258) and (259) yields equation (87) given in section 2.1.4,

$$\Delta f_s = - 2 \frac{\vec{V}_s \cdot \hat{R}_s}{c} f \quad (260)$$

2.5.2 Calculation of the Median and Average Drift Velocities

It was stated in section 2.1.4 that the so-called case velocity is determined as the median of the individual velocities of the case; the group-norm velocity is the median of several case velocities; etc. For testing purposes, two other types of central-tendency calculations were also used: the weighted median and the weighted average.

All central tendencies are calculated separately for the velocity components V_x , V_y and V_z . The weighted average $\bar{V}_x$ (and similarly for $\bar{V}_y$ and $\bar{V}_z$) is defined as⁸¹

⁸¹Selby (1971).

$$\bar{V}_x = \frac{\sum_{j=1}^n \tilde{w}_j V_x(j)}{n} \quad (261)$$

$$n = \sum_j \tilde{w}_j \quad (262)$$

$$w_j = \text{MIN} [(1/\epsilon_j^2), 1] \quad (263)$$

where the index j refers to the velocities being averaged; w_j is the j th weighting factor, defined in (263) where MIN means the minimum of the values in the bracket; $\tilde{w}_j$ is the same weight but normalized such that the sum of the normalized weights equals the total number of velocities n . When the case velocity is being calculated, the least square error ϵ_j^2 is calculated for each individual velocity as in equation (90). For the calculation of the group-norm velocity, ϵ_j^2 of the j th case velocity is the average of the least square errors of the individual velocities of case j ; the group-norm velocities are not weighted when calculating the all-frequency velocities ($w_j \equiv 1$). With the average, the variance (the square of the standard deviation)

$$\sigma_x^2 = \frac{\sum_j \tilde{w}_j [V_x(j) - \bar{V}_x]^2}{n - 1} \quad (264)$$

is calculated using the faster computational form

$$\sigma_x^2 = \frac{\sum_j \tilde{w}_j V_x(j)^2 - \frac{[\sum_j \tilde{w}_j V_x(j)]^2}{n}}{n - 1} \quad (265)$$

Program DRIFVEL provides the option of calculating the weighted average once or twice: if the average is calculated twice, the second calculation bypasses those velocity vectors that are outside the standard deviation, according to the following definition:

$$V_j > \sigma \quad (266)$$

$$V_j = [V_x^2(j) + V_y^2(j) + V_z^2(j)]^{1/2} \quad (267)$$

$$\sigma = (\sigma_x^2 + \sigma_y^2 + \sigma_z^2)^{1/2} \quad (268)$$

The weighted median is determined as follows. The un-normalized weight w_j is rounded out to an integer after being multiplied by 10^4 , and is then treated as the frequency-of-occurrence of $V_x(j)$. The $V_x(j)$ for all j are sorted into descending order of magnitude; each occurrence of $V_x(j)$ is considered a separate value, and the median is defined as the center value if there is an odd number of values, or as the average of the two center values if the number of values is even. A variance for the weighted median is also calculated as

$$\sigma_x^2 = \frac{\sum_{j=1}^n \tilde{w}_j [V_x(j) - v_x^{\text{med}}]^2}{n - 1} \quad (269)$$

where v_x^{med} is the x component of the median velocity. The above procedure is also used to determine the y and z components of the median velocity. For the unweighted median, the weights w_j are all set to 1.

2.5.3 Program DRIFVEL

Program DRIFVEL⁸² was developed by the author to calculate the drift velocities from the sky-map data on file TAPE50. Some of the program options (calculations and output formats) indicated in the comments of the program listing will not be discussed here because they are not directly relevant to the presentation of the results in section III; they in-

⁸²See Appendix C.

volve preliminary efforts which were later supplanted by the calculations and data-presentation formats discussed below.

At the beginning of a run, DRIFVEL requests information about the program options desired. The value inputted for KPRINT determines which velocities are to be outputted. Since TAPE50 can include several files of map data (calculated by program SKYMAP) merged into a single file for storage, the starting date, time and frequency number determine which portion of the data on TAPE50 is to be used for velocity calculations. The program starts the calculations with the data of the indicated date, time and frequency number, and continues until the frequency number changes, unless zero is inputted, in which case all the data on TAPE50 is processed. The choice of central-tendency calculation for determining the case, group-norm and all-frequency velocities is also inputted, as well as the variable parameters for the least-square-error calculation.

The least-square-error calculation can be varied in several ways. It was indicated in section 2.1.4 that the source density is used as the weighting factor w_s in equation (90), and that the sources for a given case are sorted in descending order of the magnitude of P_s before the individual velocities are calculated; other weights and sorting orders can also be used. The least-square-error calculation can also be limited to sources with $|d|$ between chosen minimum and maximum values; and the result of the calculation is ignored if the least-square-error and/or the absolute value of V_z is greater than the inputted values for those parameters. These options will be discussed in section 3.2.

The main program calculates the individual velocity vectors, using function DET to calculate the determinants for solving for V_x , V_y and V_z . If further calculations are called for, subroutines MED, WHTMED or AVE calculate the central tendencies, using the sorting subroutine VSORT for the median

calculations. Subroutine VEL calculates from V_x , V_y and V_z the magnitude V of the drift vector, the horizontal component V_h and the azimuth and elevation. Subroutine GRAPH prints the two parallel graphs (azimuth and speed graphs) of the individual, case, group-norm or all-frequency velocities. All-frequency velocities need one run per frequency number; the group-norm velocities are calculated for each frequency number separately and stored by subroutine ALLFREQ on file TAPE49; during the run at the last frequency number, ALLFREQ calculates the all-frequency velocities from the group-norm velocities. The output then consists of two sets of graphs: one set with the all-frequency velocity results; the other with the group-norm velocities of all frequency numbers printed together. For the latter set of graphs, subroutine IDENT is called to "spread out" values that are at the same graph coordinates, so that none of the values will be lost: for example, if the azimuth of three group-norm velocities is 90° , IDENT will spread them out to 85° , 90° and 95° (the azimuth axis is in 5° increments).

3.0 RESULTS AND DISCUSSION

3.1 Simulated Data: Two Sources at the Same Doppler Frequency

In this section, we present some examples of sky-map and drift-velocity calculations with simulated drift data calculated from pairs of sources at the same Doppler number, with various initial phase differences δ (see equation 248). These examples serve the double purpose of verifying the validity of the sky maps and of the calculated drift velocities, and of illustrating the effects of multiple sources falling on the same Doppler line.

A horizontal drift velocity of 200 m/s due south is assumed. The correct source positions are shown in Figure 17 with an identifying source number (circled) next to the Doppler number of each source. The Doppler frequencies f_d are indicated by the Doppler number d as (see Table 1, for drift program number 9)

$$f_d = \pm 1/16, \pm 3/16, \pm 5/16, \dots [\text{Hz}] \quad (270)$$

$$d = 1, 2, 3, \dots \text{ for negative frequencies} \quad (271)$$

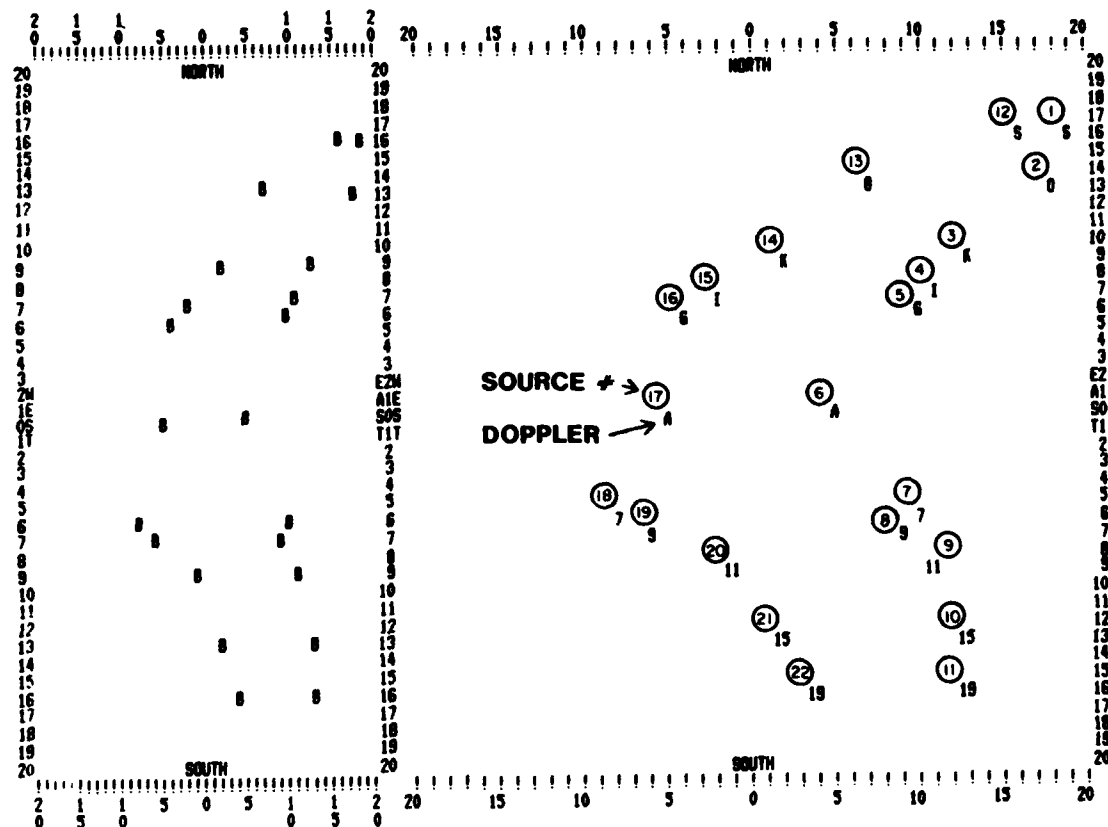
$$d = A, B, C, \dots \text{ for positive frequencies} \quad (272)$$

The hexadecimal numbers in the map on the left indicate the density P_s of each source in 6 dB increments, at the same coordinates as the corresponding Doppler numbers on the right. Note that the densities are single-digit numbers, whereas the Doppler numbers may be double-digit, which is why the map on the right is twice as wide. The absolute value of the map indices m and m' are indicated around the periphery of each map. The map scale and maximum zenith angle are

$$\delta x = \delta y = 7.3 \text{ km} \quad (273)$$

$$\zeta_{\text{max}} = 29.9^\circ \quad (274)$$

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RANGE: 412 KM SCALE: 7.3 KM/DIVISION
 FREQ: 6.0 MHZ $\zeta_{\max} = 29.9^\circ$
 LEFT MAP: DENSITIES (6 dB INCREMENTS)
 RIGHT MAP: DOPPLER NUMBERS
 NEG DOPP: NUMERIC POS DOPP: ALPHA
 DOPPLER RESOLUTION: .1225 HZ

SIMULATED DATA: SOURCE POSITIONS
 FOR TESTS OF EQUAL-DOPPLER ECHOES

Figure 17

where δx follows from the value of $\zeta_{\max}$ and an (arbitrary) range of 412 km (see equation 183) and $\zeta_{\max}$ follows from the sounding frequency of 6 MHz (see equation 216).

Table 5 lists the source parameters for all 22 sources. Each of the source pairs (1, 12), (2, 13), (3, 14), ... (11, 22) is at the same Doppler frequency. The Doppler frequencies were chosen to be integral multiples of $\delta\omega$. The source coordinates X and Y are not integers; the sky map calculation places them at the closest integral multiples of m and m' (remember that +X is north, +Y is west). Fourteen cases of data were calculated; the map in Figure 17 is a superposition of the maps from the first two cases, each calculated from sources that are all at different Doppler frequencies: the first map was calculated from sources 1 to 11, the second from sources 12 to 22.

Sky maps calculated from all 22 sources together (cases 3 to 14) show the effects of double sources at the same Doppler number. Since δ is the difference in phase between the two sources at the same Doppler, the first set of sources (1 to 11) were given an initial phase of zero for all cases, and the phases were varied in the second set (12 to 22). The values of δ in Table 5 ("INIT PH") are those of case 3: all pairs of sources have a phase difference of 30° . In the succeeding cases, δ was incremented by 30° for each new case,

$$\delta = 30^\circ, 60^\circ, 90^\circ, \dots, 330^\circ \text{ all source pairs} \quad (275)$$

$$\text{case} = 3, 4, 5, \dots, 13 \quad (276)$$

except that for the last case (case 14), each source pair has a different δ ,

$$\delta = 0^\circ, 30^\circ, 60^\circ, \dots, 330^\circ \quad (277)$$

$$\text{sources} = (1, 12), (2, 13), (3, 14), \dots, (11, 22) \quad (278)$$

Case 3 is shown in Figure 18: with a 30° phase difference, each pair of identical-Doppler sources is seen as one source

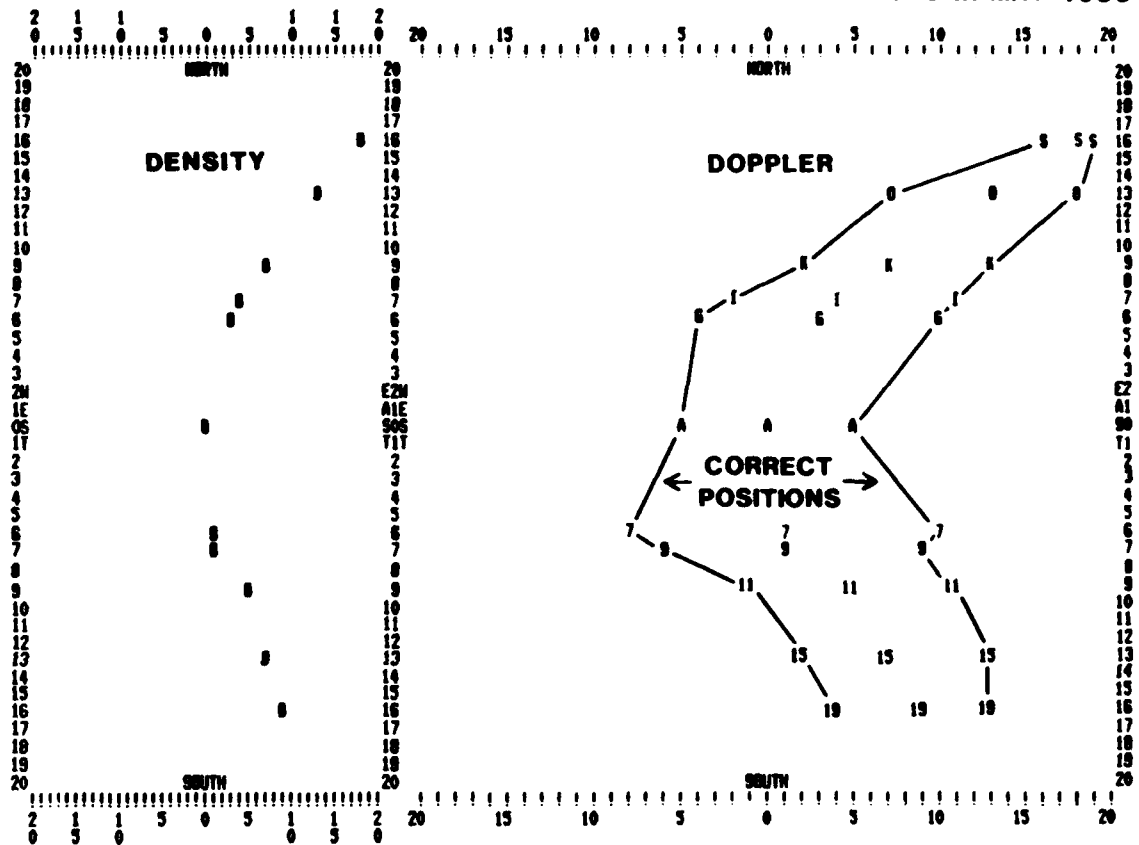
ULCAR MAY 1983

SOURCE	UX	UY [m/sec]	UZ	AZIM [deg]	ZEN	X	Y	AMPL	DOPFREQ [Hz]	INIT PH [deg]	DOPP. NO.
1	-200.00	0.00	0.00	50.00	26.08	16.0	-19.1	1.00	2.2670	0.00	19.00
2	-200.00	0.00	0.00	53.00	22.72	12.6	-17.9	1.00	1.7772	0.00	15.00
3	-200.00	0.00	0.00	53.00	16.24	9.1	-13.0	1.00	1.2868	0.00	11.00
4	-200.00	0.00	0.00	53.00	13.08	7.4	-10.5	1.00	1.0413	0.00	9.00
5	-200.00	0.00	0.00	60.00	11.45	5.6	-9.8	1.00	.7963	0.00	7.00
6	-200.00	0.00	0.00	85.00	5.03	.4	-5.0	1.00	.0613	0.00	1.00
7	-200.00	0.00	0.00	120.00	11.45	-5.6	-9.8	1.00	-.7963	0.00	-7.00
8	-200.00	0.00	0.00	130.00	11.65	-7.4	-8.8	1.00	-1.0413	0.00	-9.00
9	-200.00	0.00	0.00	130.00	14.45	-9.1	-10.8	1.00	-1.2867	0.00	-11.00
10	-200.00	0.00	0.00	135.00	18.26	-12.6	-12.6	1.00	-1.7774	0.00	-15.00
11	-200.00	0.00	0.00	140.00	21.65	-16.0	-13.5	1.00	-2.2672	0.00	-19.00
12	-200.00	0.00	0.00	45.00	23.56	16.0	-16.0	1.00	2.2674	30.00	19.00
13	-200.00	0.00	0.00	30.00	14.82	12.6	-7.3	1.00	1.7770	30.00	15.00
14	-200.00	0.00	0.00	10.00	9.37	9.1	-1.6	1.00	1.2862	30.00	11.00
15	-200.00	0.00	0.00	345.00	7.73	7.4	2.0	1.00	1.0423	30.00	9.00
16	-200.00	0.00	0.00	325.00	6.96	5.6	3.9	1.00	.7963	30.00	7.00
17	-200.00	0.00	0.00	275.00	5.03	.4	5.0	1.00	.0613	30.00	1.00
18	-200.00	0.00	0.00	235.00	9.97	-5.6	8.0	1.00	-.7966	30.00	-7.00
19	-200.00	0.00	0.00	220.00	9.76	-7.4	6.2	1.00	-1.0418	30.00	-9.00
20	-200.00	0.00	0.00	185.00	9.27	-9.1	.8	1.00	-1.2874	30.00	-11.00
21	-200.00	0.00	0.00	170.00	13.00	-12.6	-2.2	1.00	-1.7772	30.00	-15.00
22	-200.00	0.00	0.00	165.00	17.01	-16.0	-4.3	1.00	-2.2668	30.00	-19.00

SOURCE PARAMETERS FOR TESTS OF EQUAL-DOPPLER ECHOES

Table 5

ULCAR MAY 1983



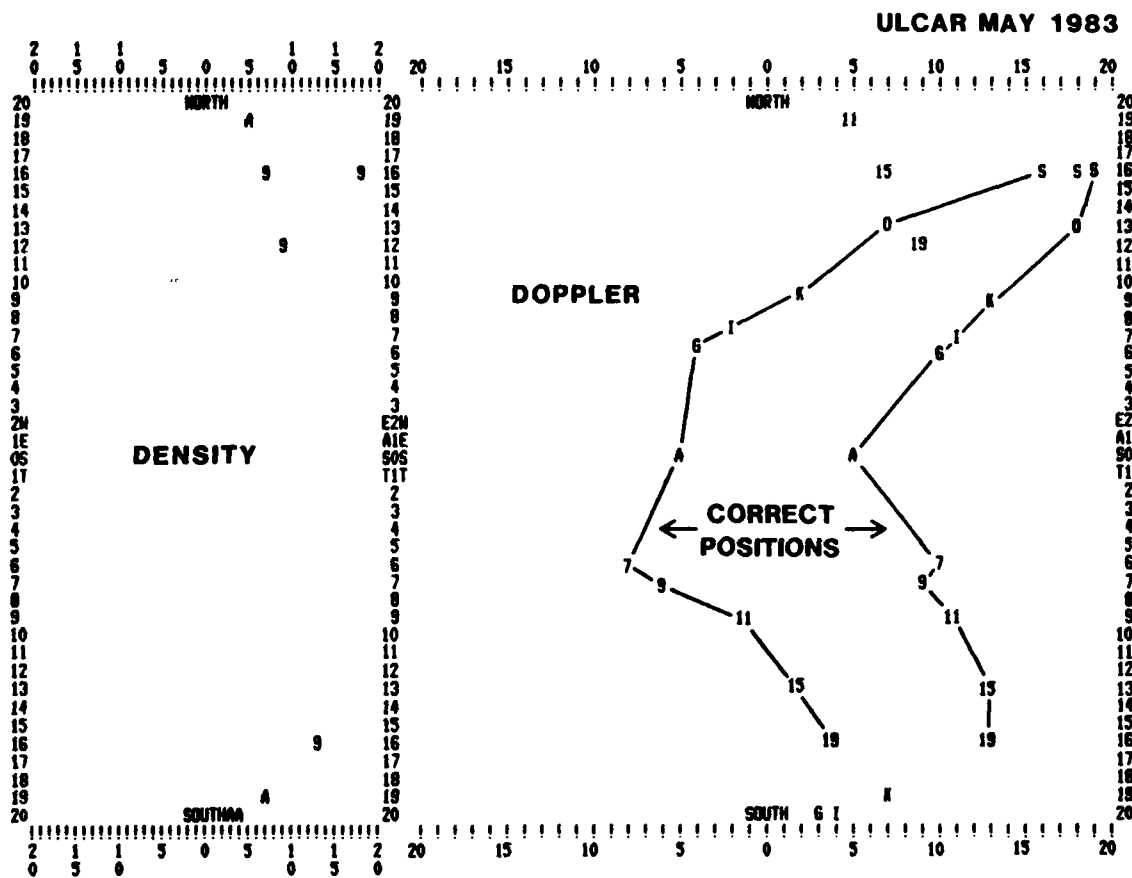
NEGATIVE DOPP = NUMERIC POSITIVE DOPP = ALPHA
DOPPLER RESOLUTION = .1225 HZ

POSITIONS OF SOURCES CALCULATED FROM
EQUAL-DOPPLER ECHOES, WITH $\delta = 30^\circ$

Figure 18

near the center of the correct positions. Some values of δ give the same results as others except for a difference in the densities; for example, the positions for 60° and 90° are the same as for 30° . Higher initial-phase differences shift the source positions. Figure 19 is an extreme example of what can happen: with a δ of 150° , most of the calculated or "apparent" sources are shifted outside the sky map; we suspect that those sources which appear on the map are probably side lobes rather than the main lobe. This suspicion is based on a comparison of Figures 20 and 21. Figure 20 is a composite map of the results of all 14 cases; the map on the left now contains the case numbers in hexadecimal notation, starting at zero for case 1. The sources for some of the cases are lost, since they fall at the same coordinates as those of previous cases. Figure 21 shows the Doppler numbers that result at each map coordinate with the assumed velocity of 200 m/s due south; those positions that are on a line perpendicular to the velocity vector are all at the same Doppler number. In Figure 20, we can see that most of the calculated source positions that are not correct have been shifted along a line perpendicular to the velocity vector; that is, most of the shifted sources are still at locations which result in the same Doppler number as do the correct source locations. The source positions indicated in Figure 19, on the other hand, seem to be due to the side lobes of sources whose positions have been shifted completely out of the map.

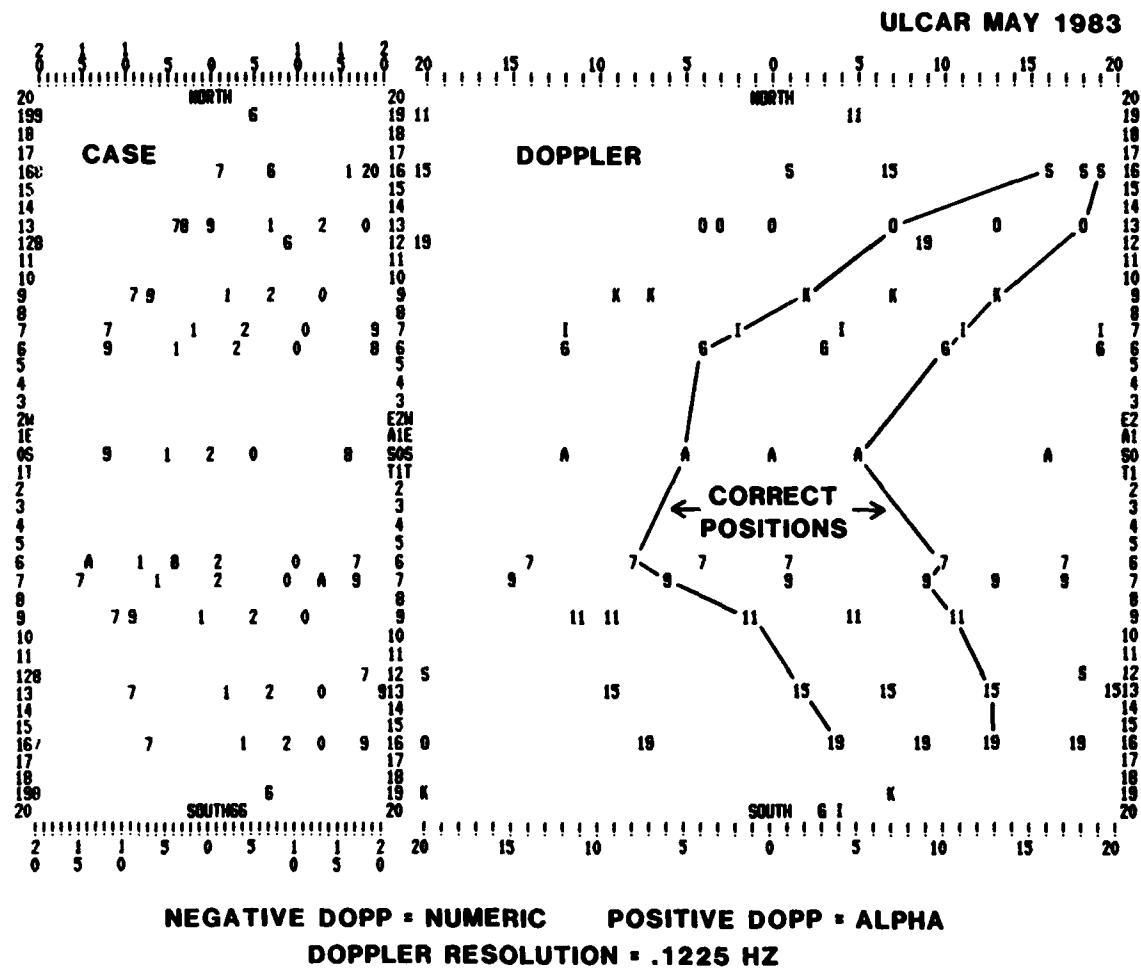
Those sources that appear on the same line (perpendicular to the velocity vector) as the correct source positions yield the correct velocities, as can be seen in Figure 22, which is a computer plot of the case velocities for all 14 cases. In the graph on the left, the "#" symbols indicate the azimuth of the velocity in 5° increments, the "+" signs indicate σ (see equation (268)) in 5 m/s increments. In the graph on the right, the horizontal speed is indicated by "#",



NEGATIVE DOPP = NUMERIC POSITIVE DOPP = ALPHA
 DOPPLER RESOLUTION = .1225 HZ

POSITIONS OF SOURCES CALCULATED FROM
 EQUAL-DOPPLER ECHOES, WITH $\delta = 150^\circ$

Figure 19



POSITIONS OF SOURCES CALCULATED FROM EQUAL -
DOPPLER ECHOES, $\delta = 30^\circ, 60^\circ, 90^\circ, \dots, 330^\circ$

Figure 20

	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!	!
20-	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-20	
19-	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	v	-19	
18-	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	u	-18	
17-	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	t	-17		
16-	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s	-16	
15-	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	-15	
14-	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	q	-14		
13-	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	p	-13		
12-	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	-12		
11-	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	-11		
10-	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	l	-10		
9-	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	k	-9		
8-	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	j	-8		
7-	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i	-7			
6-	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	-6		
5-	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	-5		
4-	e	e	e	e																																						

FREQUENCY = 6.0 MHZ
 $V_x = -200$ $V_y = 0$ $V_z = 0$
 NEGATIVE DOPP = NUMERIC
 LOWEST DOPP FREQ = 1/16 HZ

MAX ZENITH ANGLE = 29.9°
 PROGRAM NO. 9
 POSITIVE DOPP = ALPHA
 DOPP-FREQ RESOLUTION = 1/8 HZ

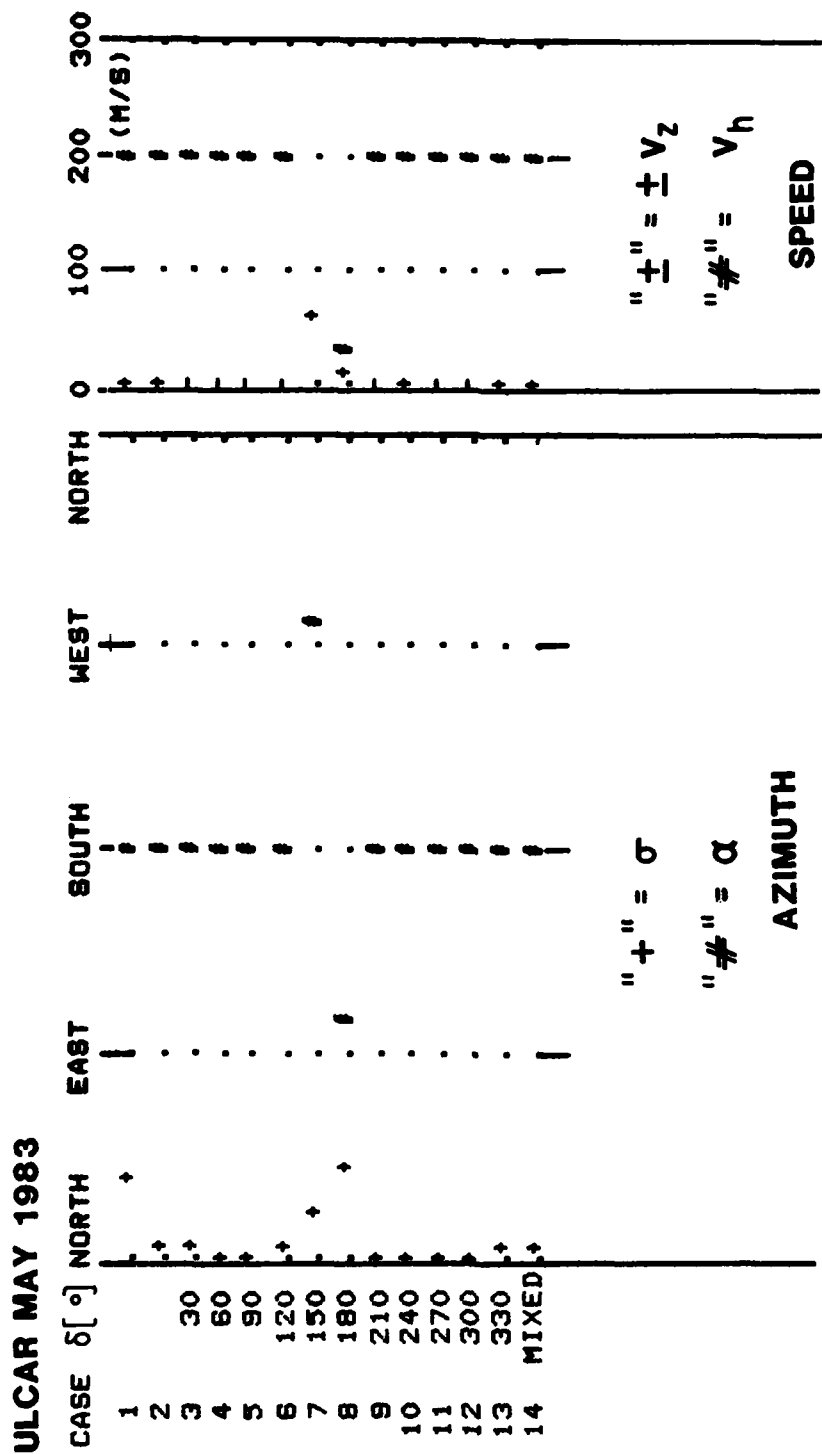
Figure 21

and the vertical speed by a "+" ($V_z = \text{up}$) or "-" ($V_z = \text{down}$) in increments of 10 m/s. As shown in Table 5, the velocity inputted into the test program was a horizontal velocity of 200 m/s south; so with the values of δ that were tested and with the chosen original source positions, only two cases yield velocities that are significantly incorrect. The initial phase difference in those two cases were 150° and 180° .

The most realistic case is number 14 where the phase differences δ vary from pair to pair. For a 6 MHz signal a range difference of 25 meters will cause a 2π shift in the phase of the echoes. It must therefore be assumed that the phase differences for a set of equal Doppler pairs are random. Figure 22 shows that for this situation, as simulated in case 14, the velocity is reproduced exactly.

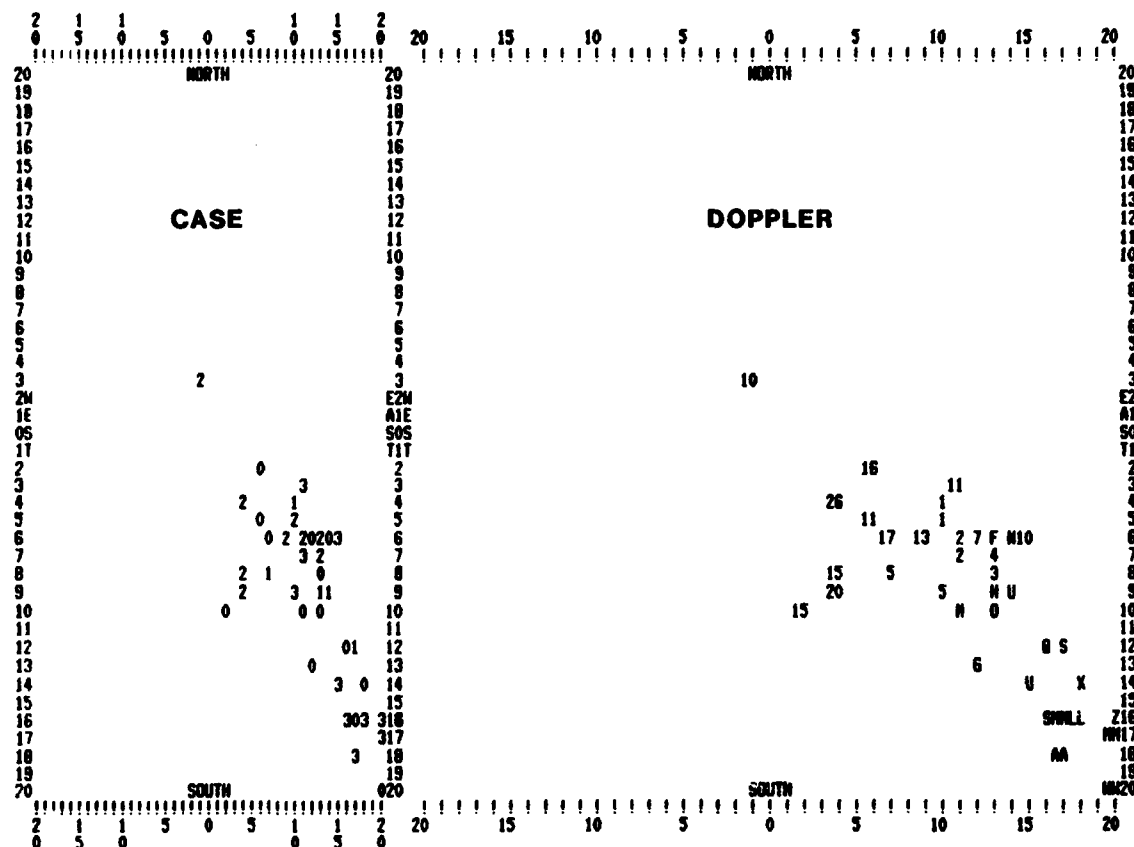
3.2 Tests of Measured Drift Data from Goose Bay

After the drift-measurement technical problems in the Digisonde had been corrected (see section 1.7.2.2), several sky maps were calculated with the available F-region drift data from Goose Bay. Efforts were made to determine from the information on the map, the general shape of the ionospheric iso-density surfaces above the measuring station as well as the direction of the drift motion. Analysis of maps with data from individual cases did not yield any satisfying results. A determination of the direction of the drift motion by analyzing successive cases was then attempted. This was done by composing "time sequence" maps of the sources with densities within 4 dB of the maximum density for each case, like the map in Figure 23, which compresses four successive cases (covering 72 seconds) of data. (The map legend is explained in the previous section; here the positive Doppler numbers run higher than 26, so the symbols AA, BB, CC, ... are used for Dopplers +27, +28, +29, ...) The resulting map displays a good consistency in the locations of the sources;



**DRIFT VELOCITIES CALCULATED FROM
EQUAL-DOPPLER ECHOES**

Figure 22



NEGATIVE DOPP = NUMERIC POSITIVE DOPP = ALPHA
 DOPPLER RESOLUTION = .1225 HZ
 SCALE: 9.4 KM/DIVISION $\zeta_{\max} = 45^\circ$

DOPPLER SKY MAP

26 JAN 1982 GOOSE BAY, LABRADOR
 20:18 AST 3 MHZ 375 KM

Figure 23

however, the sequence of cases (indicated by the numbers 0 to 3 in the map on the left) do not show a very clear progression of the reflection areas with time. This map is typical of most maps that were generated. Even if the movement of the reflection areas could be determined from the maps, this movement may be due to medium- and large-scale TID's and may not reflect the large-scale convection of the plasma. Analysis of earlier drift measurements made in the early 1970's supported this distinction of the two types of motions (see section 1.7.2.1). It was then decided to calculate the drift velocities directly from the map data, using the least-square-error method described earlier.

Program DRIFVEL was then written to calculate several drift velocities for each case. Calculating only one velocity per case using all the map data from that case could lead to large errors, since the map data are probably not all equally reliable. It is expected that the measured Doppler frequencies and calculated positions of the strongest sources are probably more accurate (this assumption is evaluated below); the weakest calculated sources may actually be due to noise rather than to echoes from real sources. On the other hand, since all map data have some error (for example, the digitizing error), using only a few sources to calculate the velocity can also lead to large errors; with more sources (provided they are reliable), the errors smooth out somewhat. Therefore, the procedure used was to calculate the first so-called individual drift velocity with the five strongest sources of a given case, then the second velocity with the six strongest sources, etc. By starting with the strongest sources (using a minimum of five sources in order to eliminate excessively large errors) and adding one more source to each calculation, we hoped that each succeeding velocity would be relatively consistent with the previous one until we hit unreliable map data. The last "good" velocity would then probably

be the most accurate one. Several cases of data were calculated in this way, but some of the results were not as simple to interpret as had been expected. An effort was made to evaluate each velocity by its least-square-error ϵ^2 ; this was also difficult to do since ϵ^2 increases as more sources are added, even if they are reliable sources. That is, with more sources the errors smooth out (the positive errors are compensated by negative errors), but ϵ^2 is a sum of the squares of the errors. A weighting factor was added to the least-square-error calculation (several different factors were tried, as explained below), but there were still cases whose individual velocities varied too drastically (in speed and/or direction) to be considered valid. Also, the velocities from case to case sometimes varied more than would be expected over periods of 10 or 18 seconds.

It was then decided to determine the case velocity by a weighted average of the individual velocities, in an effort to smooth out the effects of the bad data; and to apply further smoothing by averaging the velocities of four to six consecutive cases, yielding the group-norm velocity. The number of cases per group was restricted by the choice to use only groups for which the frequencies and ranges remained constant for all cases of the group (frequencies and/or ranges were changed during drift measurements as ionospheric conditions changed). Later results have shown that this restriction can be removed in the future. Both types of averages (averaging once or twice; see section 2.5.2) were calculated. Later, the same calculations were also tried with a median, and with a weighted median, instead of the average. The output of DRIFVEL at the time was in the form of a list of the velocity components (both Cartesian and spherical), and it was difficult to draw definite conclusions about the differences among the results of the four central-tendency calculations. The different smoothing methods did not affect the trend of the velocities, but showed in the standard deviation

of the values; all calculations showed some cases and groups whose velocities varied drastically from the general trend.

Meanwhile, drift measurements covering longer time periods than the previous measurements did became available, so a larger amount of data could be calculated to see if a trend in the velocities would be observed over several hours. Groups of drift measurements made about every fifteen minutes from 18:00 to 05:00 AST (217 18-second cases; drift program number 9 had been used) on 26/27 January 1982, were chosen for analysis. The case and group-norm velocities were calculated; an average source position was also calculated from the source positions (negative- and positive-Doppler sources separately) of each case, as well as an average position for each group of cases. The results of both the position and velocity calculations were hand-plotted to permit easier analysis. Each group position and velocity was plotted on a separate graph, with vectors indicating the drift direction and speed, and plus and minus signs indicating the positive- and negative-Doppler average source positions. The velocity results were very promising, showing the expected westward drift in the late evening, shifting towards the east around midnight; and the results were very similar for all three ranges (heights) and the different sounding frequencies. The effects of the velocities with large discrepancies were not smoothed out satisfactorily by any of the central-tendency calculations, but at least we could tell which groups were departures from the general trend.

No general trend could be determined in the averaged source positions. This may be due in part to the shift in the virtual position of the sources due to the interaction of the sources whose Doppler shifts fall on the same Doppler line, as discussed in the previous section. Note that sources close to each other but far enough apart to be at slightly different Doppler frequencies may still fall on the same Doppler line and therefore still affect each other's calculated positions.

This is especially true since the Doppler line is widened by spectral averaging. Spectral averaging helps the determination of the drift velocity by diminishing side lobes and noise; but its effect on the determination of the positions of reflection areas in the ionosphere is less clear.

Program DRIFVEL was then modified to print the drift-calculation results in the form of an azimuth graph and a speed graph, and to print a separate graph of the root-mean-square error ϵ ,

$$\epsilon = (\epsilon^2)^{1/2} \quad (279)$$

where ϵ^2 is the least-square error for the individual velocity calculations. This concise format made it much easier to compare the results of various calculations using different statistical weighting and smoothing; it also cut down drastically the time involved in plotting the calculated velocity vectors since this step is done by the computer.

Drift data from F-region measurements made in Goose Bay on 20/21 January 1982, from 20:30 to 12:00 AST, were used for the following test. Groups of four to six successive 18-second cases from measurements made approximately 15 minutes apart were chosen from the available data, for a total of 280 cases. The data of the first frequency number was used. Four separate graphs of the individual velocities were calculated, with the sources sorted in decreasing order of P_s , increasing order of P_s , decreasing $|d|$ and increasing $|d|$. In each run, the first individual velocity for each case was calculated using the first four sources instead of the first five, in order to re-evaluate our choice of the minimum number of sources to be used. All least-square-error calculations were done without weighting. The purpose of this test was to determine if there was any relationship between the error ϵ (we call it error from now on, but we mean RMS error) and the density of the sources, or between the error and the Doppler

number, in order to determine the validity of using the density and/or the absolute value of the Doppler number as a weighting factor in the least-square-error calculation. Also, if it turned out that the weaker sources caused large errors, we would set a higher minimum density threshold for the FWPD calculation in program SKYMAP (where the threshold is set to 20 dB below the strongest source, as explained in section 2.4.4).

Examination of the error graphs of the above four runs showed that when we started with the strongest sources or the lowest $|d|$, the error increased as more sources were added (which is to be expected, as explained above), but also there were occasionally some sudden jumps in the increase. In the error graphs from the calculations starting with the weakest sources or with the highest $|d|$, some cases had errors starting quite high and decreasing as more sources were added. Closer examination showed that the large errors were caused by sources with $|d|$ around 25 or higher. (These sources have generally small amplitudes.) Typical errors for cases without any Dopplers higher than 20 were between 5 to 20 m/s; with higher Doppler numbers, the errors jumped to 100-150 m/s. The cases with high Dopplers were relatively few in this group of data, so we tested a two-hour portion of the 26/27 January data, which included about 55 cases, most of which had high Dopplers. Velocity calculations were made using only those sources with $|d|$ above 20; most of these cases yielded errors in the order of 90 to 100 m/s. It seems that the calculated sources with these high Doppler numbers are due to noise and/or to reflection areas whose motion is not the same as the large-scale plasma drift that we are trying to measure. Velocities were also calculated with the sources limited to $|d|$ from 11 to 20. Some of these results had errors of the order of 40 to 70 m/s; but many cases had much lower errors. Later calculations of the group-norm velocities with a weighted

ϵ^2 calculation, and using the median as the central-tendency determination of the case and group-norm velocities, showed that velocities calculated with $|d|$ from 1 to 20 or with $|d|$ from 1 to 10 were not significantly different. Therefore, it was decided to use sources with $|d|$ up to 20 for all future calculations.

Once the large errors were removed by eliminating the higher Doppler numbers, there was no conclusive evidence that the minimum density threshold should be changed for the FWPD calculation in program SKYMAP; nor was it clear which weighting factor should be used in the ϵ^2 calculation. Originally, six different factors had been tried for the least-square-error weights:

1. log density P_s ;
2. log density $\times |d|$;
3. linear P_s ;
4. linear $P_s \times |d|$;
5. $|d|$;
6. no weighting.

It had already become clear from the handplotted graphs of the 26/27 January data that the linear density was superior to the log density. The last four weights were compared using the 20/21 January data by printing together on the same set of graphs the individual velocities calculated with each weight, with the resulting errors. (Program DRIFVEL was modified temporarily for this purpose; the version of the program listed in Appendix C does not have this option.) The calculated velocities were more consistent with each other within each case, and the errors were smaller, with the linear density alone used as the weighting factor. In most cases, the results with the other three weights were not drastically different; but there were several cases where the difference

was significant enough to justify preferring the linear-density weight.

With the cause of the large errors removed, the minimum number of sources for the first individual velocity calculation could be set higher; but setting the minimum too high eliminates many cases which yield only a few sources. It was finally decided after examination of the data that a minimum of five sources appeared to be a good compromise.

Before the discovery that the large discrepancies in some of the velocities were due to high Doppler numbers, it had been observed that some of these velocities had a vertical component V_z of several hundred meters per second. It is known from various experiments that the vertical drift in the ionosphere is generally more of the order of tens of m/s; even under the most disturbed conditions, vertical velocities cannot be expected to be greater than 150-200 m/s. Therefore, sources which yielded velocities with $|V_z|$ greater than 200 m/s were ignored. The tests discussed above were done without this limitation; and with the data tested, the vertical velocities have reasonable values when the sources are limited to those with lower Dopplers. However, in the final results shown in the next section (as well as in future drift calculations), this limitation is kept since it can do no harm.

Once we were satisfied with the results of the individual velocity calculations, we proceeded to evaluate the weighted average (calculated once or twice), the median and the weighted median in determining the case velocities and the group-norm velocities. All resulting group-norm graphs were essentially the same, so it was decided to use the median in future calculations.

The last variation that we tried in the drift calculations was ignoring those sources which result in values of ϵ^2 greater than a chosen maximum. The group-norm velocities

were calculated for all three sounding frequencies with the data from 26/27 January, with a maximum ϵ^2 of $250 \text{ m}^2/\text{s}^2$ (i.e. a RMS error of about 16 m/s) and compared to the same calculations without any limit on ϵ^2 ; the resulting graphs did not show any significant differences. Apparently, velocities with larger errors are filtered out by the median calculation.

3.3 Final Results

Drift velocities were calculated from measurements of four different days: 29 August 1981, 20/21 January 1982, 23 January 1982 and 26/27 January 1982 (see Figures 24 to 27). As explained in the previous section, the map data were first sorted in order of decreasing source density, and the individual velocities were calculated with a minimum of five sources, using only sources with Doppler numbers between -20 and +20. The linear density was used as a weighting factor in the least-square-error calculation. Any map data yielding $|V_z|$ greater than 200 m/s, if there were any, were ignored.

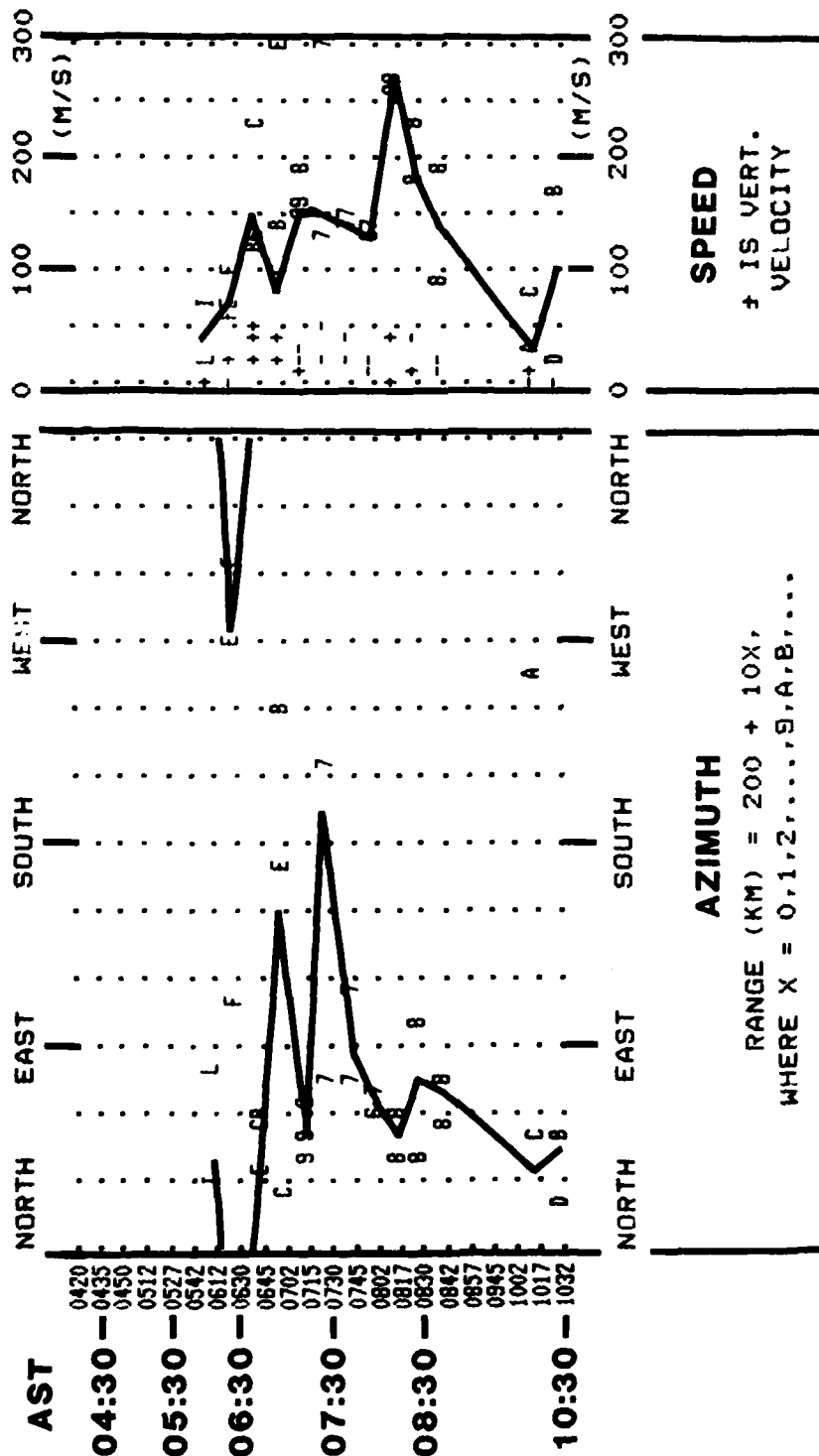
The graphs in this section display the group-norm velocities for the three simultaneous drift measurements (at three different sounding frequencies and ranges; drift program number 9 had been used for these drift measurements), in terms of the ranges:

$$R = 200 + 10X \text{ [km]} \quad (280)$$

$$X = 0, 1, 2, \dots, 9, A, B, \dots \quad (281)$$

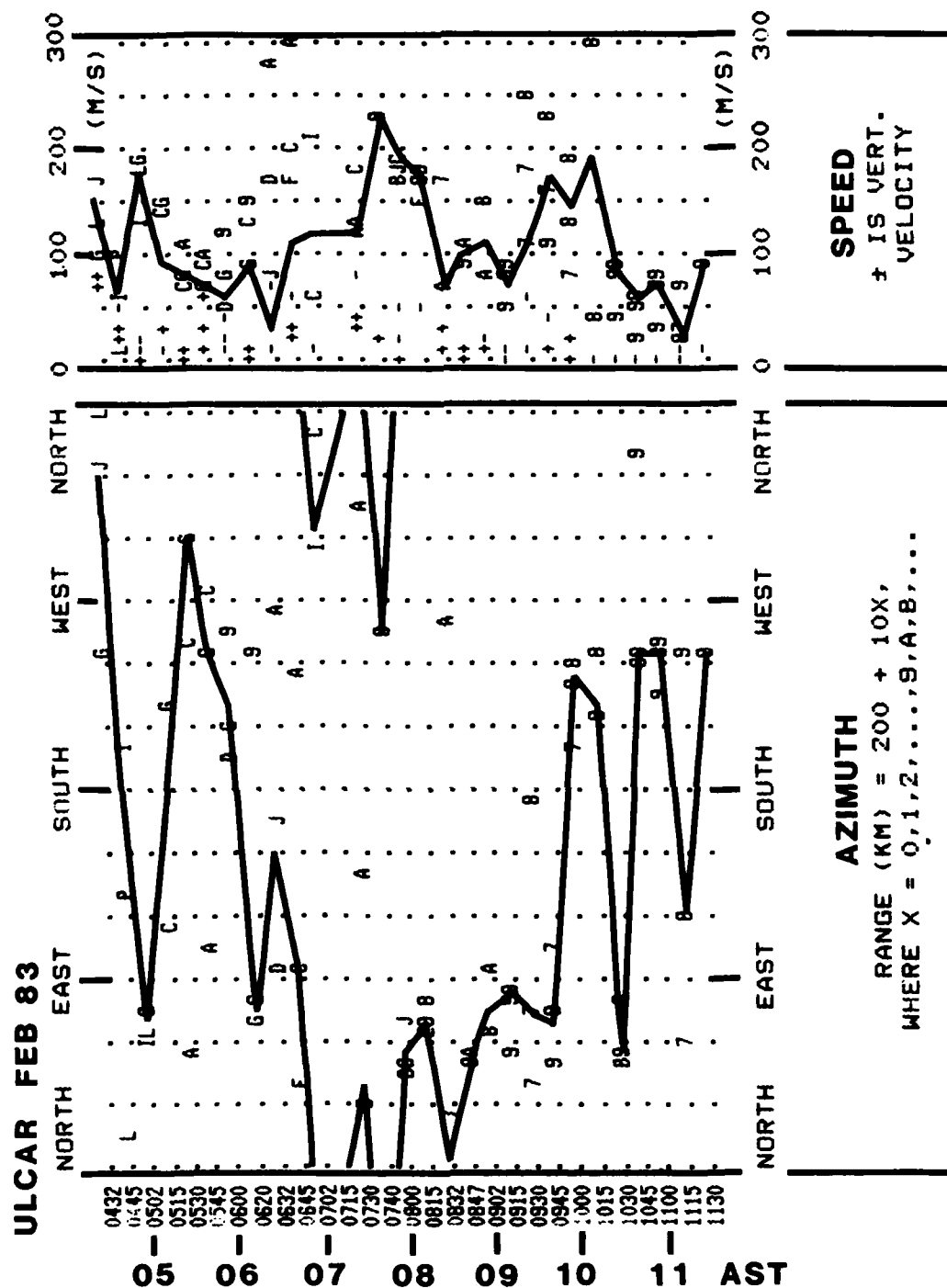
where the letters A to V are used for the numbers 10 to 31; as explained in section 2.4.4, measurements at ranges above 510 km ($200 + 10 \cdot 31$) are not calculated in program SKYMAP. Each group-norm velocity is the median of the case velocities of the group, and the case velocity is the median of the individual velocities of the case. The solid line in the graphs indicates the all-frequency velocities, each of which is the median of the three corresponding group-norm velocities.

ULCAR FEB 83



F - REGION DRIFT
DIGISONDE OBSERVATIONS AT GOOSE BAY, LABRADOR
29 AUG 81 04:20 TO 10:30 AST

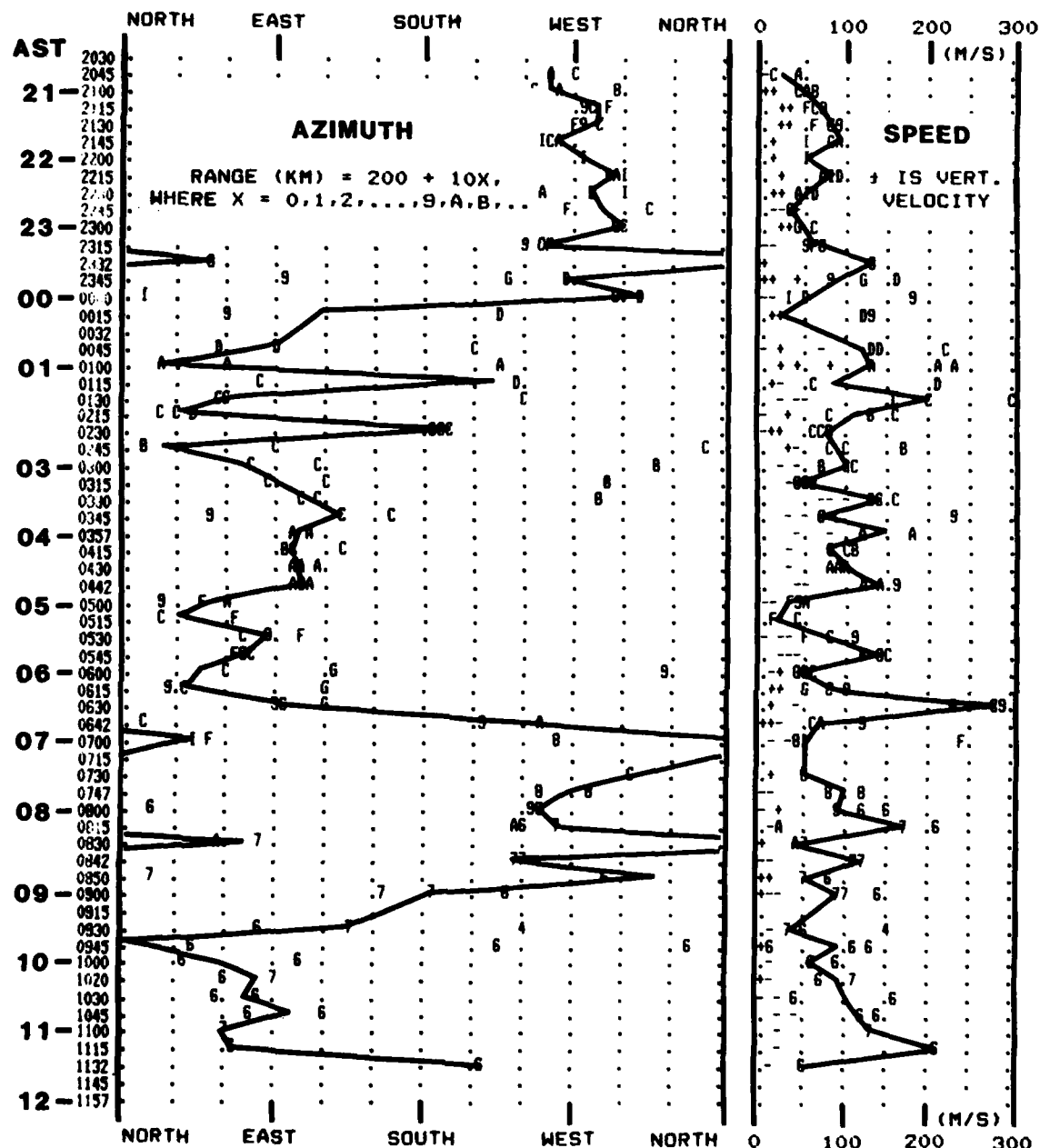
Figure 64



F - REGION DRIFT
DIGISONDE OBSERVATIONS AT GOOSE BAY, LABRADOR
23 JAN 82 04:30 TO 11:30 AST

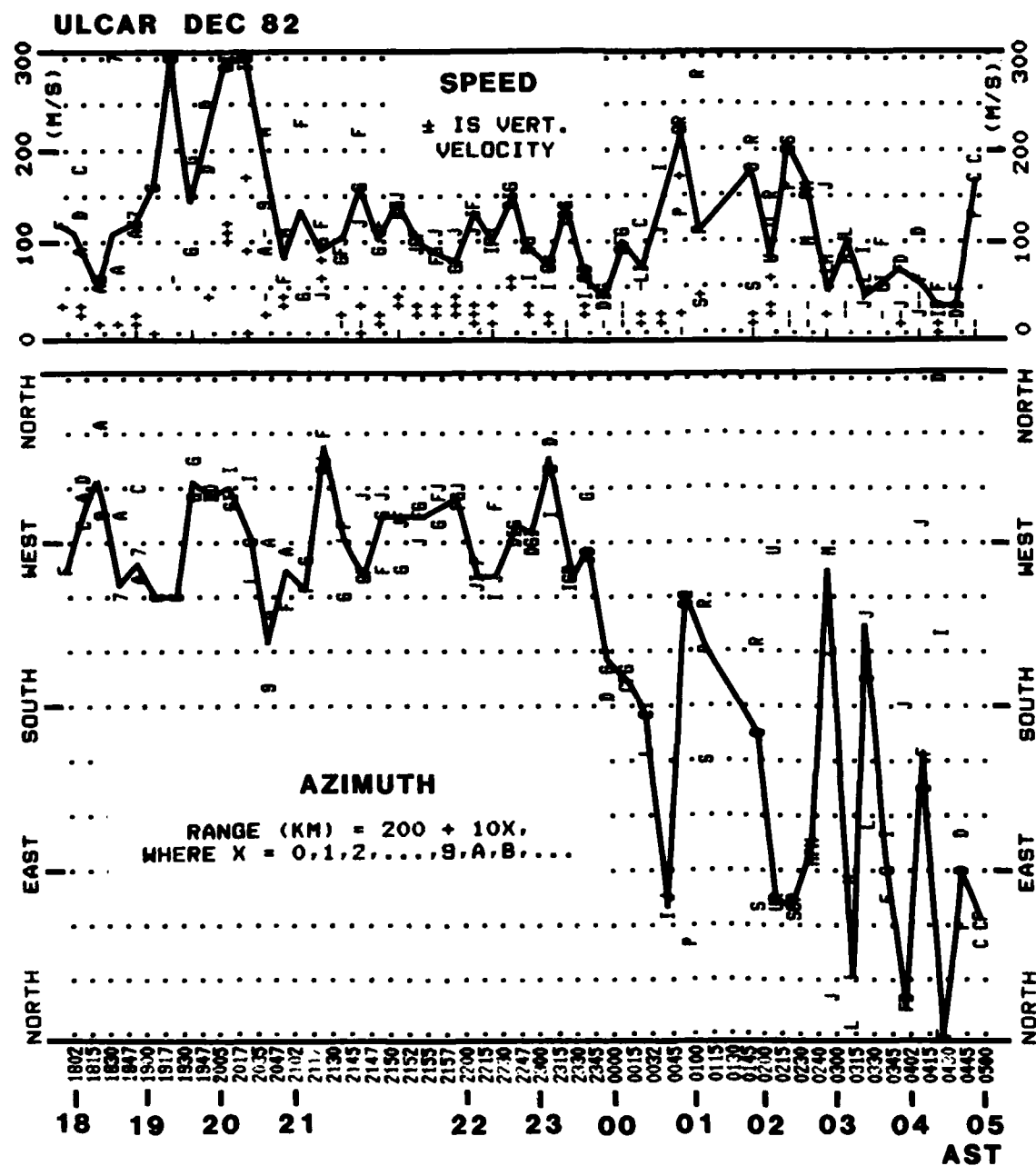
Figure 25

ULCAR FEB 83



F - REGION DRIFT
DIGISONDE OBSERVATIONS AT GOOSE BAY, LABRADOR
20/21 JAN 82 20:30 TO 12 AST

Figure 26



F - REGION DRIFT
DIGISONDE OBSERVATIONS AT GOOSE BAY, LABRADOR
26/27 JAN 82 18 TO 05 AST

Figure 27

We consider first the results in Figures 26 and 27, where the drift observations start before midnight. The plasma drifts in a generally westward direction until midnight, then shifts towards the east; this is what we would expect (see section 1.6.3 and references therein).^{82A} Before midnight, both the direction and speed are similar for all three ranges of each group, although after midnight there are groups where the velocities are not as consistent for all ranges. Most measurements are fifteen minutes apart, so it is quite possible that the calculated-velocity variations as a function of time reflect true variations. Because of a fortunate typing mistake in punching computer cards when choosing the drift data to be calculated, a series of seven drift measurements only two or three minutes apart were also calculated (see Figure 27, 21:45 to 22:00); these velocities show relatively little variation during the fifteen-minute period.

The first three graphs include drift velocities calculated from data measured after sunrise. The first graph starts at 04:20 because no earlier drift measurements were made that day. The blanks from 04:20 to 05:42 indicate that the sky map calculation yielded less than five sources for each case of drift measurements during that time period. (The data from cases yielding less than five sources are not used to calculate drift velocities; see section 3.2.) On this and the other graphs, some times have less than three velocities for the same reason. The second graph starts at 04:32 because even though drift measurements were started the previous evening, all F-region echoes before 04:32 were blanketed by a strong Es layer. The median of the three velocities is more

^{82A} The results of 20/21 and 26/27 January 1982 also compare favorably with drift direction and velocity shown for averaged data from the Millstone Hill Incoherent Scatter Radar (Oliver et. al., 1983).

jagged during this time period. At sunrise, there is a sudden surge of ionizing energy in the ionosphere; the changes in electron concentration along the wave propagation path causes the high-frequency phase to change. This apparent Doppler shift is interpreted as motion of the reflecting ionization.

4.0 CONCLUSIONS

The Doppler method of measuring plasma drift seems to be valid if we evaluate the results in the light of statements by Hargreaves and by Rawer and Suchy (the latter is in the context of fading measurements):

The small-scale structure of the atmosphere tends to be irregular and unpredictable in detail -- though predictions of a statistical kind may be possible. The distinction can be illustrated by reference to meteorology, in which the forecaster might predict the average wind speed and direction, but it would be a hopeless task to attempt a prediction of the precise wind vector for a stated place and instant of time.⁸³

... individual determinations with neighbouring antennae triangles may give considerable differences. So the fluctuations in time and space are another reason to disregard individual observations and accept only the median of several of these as a reasonable determination.⁸⁴

⁸³Hargreaves (1979), p. 107.

⁸⁴Rawer and Suchy (1967), p. 407.

5.0 RECOMMENDATIONS

The next step in the study of high-latitude ionospheric plasma motion is to analyze the drift measurements of a large number of days in order to determine if there are typical features which are repeated from day to day in the drift-movement pattern, and to distinguish the diurnal and seasonal variations in these features. Also, by analyzing all drift measurements made instead of small groups of measurements fifteen minutes apart, it should be possible to evaluate the validity of the data for those time periods (for example, the morning measurements) which yielded large variations in the velocities, by determining whether the calculated velocity changes with time in a steady or random manner.

The drift convection pattern (discussed in section 1.6.3) characteristic of the polar cap⁸⁵ has been observed in the F region with ionograms and optical techniques from the AFGL Airborne Ionospheric Observatory (AIO)⁸⁶ during flights from Thule, Greenland (which is about 23° of latitude north of Goose Bay) and while the AIO was on the ground at Thule. During periods of high magnetic activity the auroral oval, which bounds the polar cap, extends down to mid-latitudes and, at night, Goose Bay may be directly below or poleward to the oval. During more quiet periods Goose Bay is south of the equatorward edge of the oval. In order to determine if and when the plasma drift at Goose Bay forms part of the polar cap convection pattern, it would be extremely useful if another

⁸⁵The polar cap is the region where the geomagnetic-field lines are vertical or nearly vertical. It is along these magnetic lines that energetic solar particles penetrate deep into the atmosphere. See Hargreaves (1979), section 8.2.2.

⁸⁶See Euchau et al (1982).

Digisonde station with the capability of making multi-antennae drift measurements were put into operation at Thule, so that the drift measurements from Goose Bay could be correlated with those from Thule.

6.0 BIBLIOGRAPHY

- Banks, P. M. and G. Kockarts (1973), Aeronomy, Part A, New York: Academic Press.
- Beer, T. (1974), Atmospheric Waves, New York: John Wiley and Sons.
- Bibl, K. (1956), "Automatic Recording of Ionospheric Characteristics," J. Atmos. Terr. Phys., 8:295.
- Bibl, K. (1973), Doppler Angle of Arrival Spectral Measurement System, Final Report AFCRL-TR-73-0759, LTIRF-363/IP, Lowell, Massachusetts: Lowell Technological Institute Research Foundation, ADA002306.
- Bibl, K. (1974), "Velocity of the Reflection Points Reveals Structure and Motions in the Ionosphere," COSPAR, Methods of Measurements and Results of Lower Ionosphere Structure, ed. K. Rawer, Berlin: Akademie-Verlag.
- Bibl, K. et al. (1975), "Velocities of Small and Medium Scale Ionospheric Irregularities Deduced from Doppler and Arrival Angle Measurements," COSPAR, Space Research XV, ed. M. J. Rycroft, Berlin, Akademie-Verlag.
- Bibl, K., J. E. Gorman, and B. W. Reinisch (1973), Complex Amplitude Multifrequency Scanner Operation and Circuitry, Final Report AFCRL-TR-73-0556, LTIRF-358/IP, Lowell, Massachusetts: Lowell Technological Institute Research Foundation, AD775751.
- Bibl, K., D. F. Kitrosser, and B. W. Reinisch (1979), Digisonde System for Multi-Dimensional Structure Studies of the Ionosphere, Final Report DAAB07-76-C-1953, ULRF-401/CAR, Lowell, Massachusetts: University of Lowell Center for Atmospheric Research.
- Bibl, K., J. A. Patenaude, and B. W. Reinisch (1970), Digital Integrating Goniometric Ionospheric Sounder - Digisonde 128, Final Report AFCRL-71-0002, Hanscom Air Force Base, Massachusetts: Air Force Geophysics Laboratory. AD A886624
- Bibl, K., W. Pfister, and B. W. Reinisch (1975), "Spectral Analysis of E-Region 'Drift' Measurements in Eglin, Florida," paper presented at U.R.S.I. Meeting, University of Illinois, June 5.

- Bibl, K. and B. W. Reinisch (1972), Digital Technique of Complex Amplitude Multifrequency Scanning for Ionospheric Spatial Doppler Measurements, Final Report AFCRL-72-0468, LTIRF-347/IP, Lowell, Massachusetts: Lowell Technological Institute Research Foundation. AD 779669
- Bibl, K. and B. W. Reinisch (1974), "Separation of Wave and Drift Motions in the E-Region," paper presented at the Conference on the E-Region at Boulder, Colorado, August 14.
- Bibl, K. and B. W. Reinisch (1978a), Digisonde 128PS for Ionospheric Dynamics and Three-Dimensional Structure Studies: System Description and Manual, Lowell, Massachusetts: University of Lowell Center for Atmospheric Research.
- Bibl, K. and B. W. Reinisch (1978b), "The Universal Digital Ionosonde," Radio Science, 13, No. 3:519-530.
- Blackman, R. B. and J. W. Tuckey (1958), The Measurement of Power Spectra, New York: Dover Publications.
- Briggs, B. H., G. J. Phillips, and D. H. Shinn (1950), "The Analysis of Observations on Spaced Receivers of the Fading of Radio Signals," Proc. Phys. Soc., 63B:106-121.
- Booker, H. G., J. A. Ratcliffe, and D. H. Shinn (1950), "Diffraction from an Irregular Screen with Applications to Ionospheric Problems," Phil. Trans. Roy. Soc., 242:579.
- Buchau, J. et al. (1978), "Remote Ionospheric Monitoring," Proceedings of 1978 Symposium on the Effects of the Ionosphere on Space and Terrestrial Systems, Paper 5-5.
- Buchau, J. et al. (1982), Structure and Dynamics of the Winter Polar Cap Region, Environmental Research Paper No. 792, AFGL-TR-82-0258, Hanscom Air Force Base, Massachusetts: Air Force Geophysics Laboratory, and Radio Science (1983), in print. AD A123706
- Buchau, J., J. A. Whalen, and S. I. Akasofu (1969), "Airborne Observation of the Midday Aurora," J. Atmos. Terr. Phys., 31:1021-1026.
- Chapman, S. and R. S. Lindzen (1970), Atmospheric Tides: Thermal and Gravitational, New York: Gordon Breach Science Publishers.
- Danilov, A. D. (1970), Chemistry of the Ionosphere, ed. R. W. Fairbridge, Monographs in Geoscience Series, New York: Plenum Press.

- Davies, K. (1965), Ionospheric Radio Propagation, National Bureau of Standards Monograph 80, rpt. with corrections, October 1966, Washington: Government Printing Office.
- Elkins, T. J. (1973), "An Empirical Model of the Polar Ionosphere," Survey in Geophysics, No. 267.
- Evans, J. V. et al. (1980), "Millstone Hill Incoherent Scatter Observations of Auroral Convection Over $60^\circ < \lambda < 75^\circ$, 2. Initial Results, J. Geophys. Res., 85, 41-54."
- Evans, J. V. et al. (1982), Studies of the Midlatitude and High Latitude Ionosphere from Millstone Hill during Solar Maximum Conditions, Final Report to the NSF, Grant ATM79-09189, Westford, Massachusetts: Haystack Observatory.
- Feldstein, Y. I. and G. V. Starkov (1967), "Dynamics of Auroral Belt and Polar Geomagnetic Disturbances," Planet. Space Sci., 15:209-229.
- Gorman, J. E., K. Bibl, and K. H. Olson (1967), Investigation of the Turbulent Structure and Drift Motions in the Ionosphere, Final Report LTIRF-265/IP, AFCRL-67-0188, Lowell, Massachusetts: Lowell Technological Institute Research Foundation, AD651483.
- Halliday, D. and R. Resnick (1966), Physics, Parts I and II, New York: John Wiley and Sons.
- Hamming, R. W. (1977), Digital Filters, Englewood Cliffs, New Jersey: Prentice-Hall.
- Hannan, E. J. (1960), Time Series Analysis, New York: John Wiley and Sons.
- Hargreaves, J. K. (1979), The Upper Atmosphere and Solar-Terrestrial Relations: An Introduction to the Aerospace Environment, New York: Van Nostrand Reinhold.
- Heelis, R. A. and W. B. Hanson (1980), "High Latitude Ion Convection in the Nighttime F Region," J. Geophys. Res., 85:1995.
- Heppner, J. P. et al. (1981), "The Cameo Barium Releases: E₁ Fields over the Polar Cap," J. Geophys. Res., 86: 3519.
- Hultqvist, B. and G. Gustafsson (1960), "On the Magnetic Time Dependence of the Auroral Zone Currents," J. Atmos. Terr. Phys., 19:246-259.

- Jenkins, G. M. and D. G. Watts (1968), Spectral Analysis and Its Applications, Holden-Day.
- Jones, A. V. (1974), Aurora, ed. B. M. McCormac, Geophysics and Astrophysics Monographs, Vol. 9, Boston: D. Reidel Publishing Company.
- MacLeod, M. A., T. J. Keneshea, and B. W. Reinisch (1973), "The ALADDIN II Ionosphere: A Comparison of Theoretical Calculations with Digisonde Observations (abstract)," EOS Trans. AGU, 54:381.
- McNish, A. G. (1936), "Geomagnetic Coordinates for the Entire Earth," Terr. Magn., 41:37-43.
- Mende, S. B., R. H. Eather, and E. K. Aamodt (1977), "Instrument for the Monochromatic Observation of All Sky Auroral Images," Appl. Opt., 16:1691.
- Morgan, M. G., C. H. J. Calderon, and K. A. Ballard (1978), "Techniques for the Study of TID's with Multi-Station Rapid-Run Ionosondes," Radio Sci., 13, 4, 729-741.
- Murphy, J. A., G. J. Bailey, and R. J. Moffet (1980), "A Theoretical Study of the Effects of Quiet-Time Electromagnetic Drifts on the Behavior of Thermal Plasma at Mid-Latitudes," J. Geophys. Res., 85, No. A5:1979-1986.
- Oliver, W. L., J. M. Holt, R. H. Wand and J. V. Evans (1983), "Millstone Hill Incoherent Scatter Observations of Auroral Convection over $60^\circ < \lambda < 75^\circ$, 3. Average Patterns Versus Y_p ," J. Geophys. Res., 88, 5505-5516.
- Patenaude, J., K. Bibl, and B. W. Reinisch (1973), "Direct Digital Graphics - The Display of Large Data Fields," American Laboratory, 15:95-101.
- Peled, A. and B. Liu (1976), Digital Signal Processing: Theory, Design, and Implementation, New York: John Wiley and Sons.
- Pfister, W. (1971), "The Wave-Like Nature of Inhomogeneities in the E-Region," J. Atmos. Terr. Phys., 33, 7:999-1025.
- Pfister, W. (1974), "Drift Measurement with Spectral Analysis during Periods of Chemical Releases into the Ionosphere," COSPAR, Methods of Measurements and Results of the Lower Ionosphere Structure, Berlin: Akademie Verlag.
- Pfister, W. et al. (1968-75), Pulse Sounding with Closely Spaced Receivers as a Tool for Measuring Atmospheric Motions and Fine Structure in the Ionosphere, Vols. I-VIII, Bedford, Massachusetts: Air Force Cambridge Research Laboratories.

- Pfister, W. and K. Bibl (1972), "A Modernized Technique for Ionospheric Drift with Spectral Analysis," COSPAR, Space Research XII, pp. 975-982.
- Pfister, W. and G. S. Sales (n.d.), Spectral Analysis of F-Region "Drift" Measurements in Goose Bay, Labrador, Hanscom Air Force Base, Massachusetts: Air Force Cambridge Research Laboratories (Mimeographed).
- Phillips, M. L. (1974), "Ground-Based Vertical-Incidence Ionograms," IEEE Transactions on Antennas and Propagation, AP-22, 6:785-795.
- Rastogi, R. G. (1977), "Coupling Between Equatorial and Auroral Ionospheres During Polar Substorms," Proc. Indian Acad. Sci., 86A, 4:409-416.
- Ratcliffe, J. A. (1970), Sun, Earth and Radio: An Introduction to the Ionosphere and Magnetosphere, World University Library Series, New York: McGraw-Hill.
- Ratcliffe, J. A. (1972), An Introduction to the Ionosphere and Magnetosphere, London: Cambridge University Press.
- Rawer, K. and K. Suchy (1967), Radio Observations of the Ionosphere, ed. S. Flügge, Handbuch der Physik, Vol. XLIX/2, Berlin: Springer-Verlag.
- Reinisch, B. W. (1973), "Burnt-Out Rocket Punches Holes Into Ionosphere," Space Res., 13:503-506.
- Reinisch, B. W. and K. Bibl (1977), "Real-Time Spectra for Incidence Angle Spread in Multipath Propagation Caused by Ionosphere," paper presented at U.R.S.I., International Symposium on Measurements in Telecommunications, October 3-7, Lannion, France.
- Reinisch, B. W. and Huang Xueqin (1983), "Automatic Calculation of Electron Density Profiles from Digital Ionograms. Part 3: Processing of Bottomside Ionograms," Radio Science, 18, 3:477-492.
- Richards, D. W. (1972), Twenty-Element Receive Array for the DAASM Experiment, Instrumental Paper No. 178, AFCRL-72-0475, Hanscom Air Force Base, Massachusetts: Air Force Cambridge Research Laboratories, AD751873.
- Rishbeth, H. and O. K. Garriott (1969), Introduction to Ionospheric Physics, ed. J. V. Miegheem, International Geophysics Series, Vol. 14, New York: Academic Press.

- Sales, G. S. (1960), Low Frequency Radio Studies of Apparent Ionospheric Motions, Ph.D. dissertation, Pennsylvania State University.
- Sales, G. S., J. I. Videberg, and R. Varad (1975), DAASM Project - High Latitude Aircraft HF Propagation Experiment, Environmental Research Paper No. 516, AFCRL-TR-75-0290, Hanscom Air Force Base, Massachusetts: Air Force Cambridge Research Laboratories, ADA015764.
- Selby, S. M. (1971), ed. "Probability and Statistics," Standard Mathematical Tables, pp. 554-557, Cleveland, Ohio: The Chemical Rubber Company.
- Spiro, R. W., R. A. Heelis, and W. B. Hanson (1978), "Ion Convection and the Formation of the Mid-Latitude F Region Ionization Trough," J. Geophys. Res., 83, A9:4255-4264.
- Stern, D. P. (1977), "Large-Scale Electric Fields in the Earth's Magnetosphere," Rev. of Geophys. and Space Phys., 15, 2:156-188.
- Varad, R. and W. C. McComish (1975), The Maximum Likelihood Method: Applications to DAASM Studies, Final Report AFCRL-TR-75-0551, Chestnut Hill, Massachusetts: Boston College Space Data Analysis Laboratory.
- Weber, E. J. et al. (1977), Large-Scale Optical Mapping of the Ionosphere, AFGL-TR-77-0236, Hanscom Air Force Base, Massachusetts: Air Force Geophysics Laboratory, ADA051122.
- Weber, E. J. and J. Buchau (1981), "Polar Cap F-Layer Auroras," Geophys. Res. Lett., 8, 1:125-128.
- Wright, J. W. (1975), "Development of Systems for Remote Sensing of Ionospheric Structure and Dynamics," Preprint 206, Environmental Research Laboratories, Boulder, Colorado: National Oceanic and Atmospheric Administration.

A P P E N D I X A

PROGRAM TESTSKY

TESTSKY (ULCAR)

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00100      PROGRAM TESTSKY(INPUT,OUTPUT,TAPE1,TAPE3,TAPE8,TAPE9)
00110C
00120C=====
00130C
00140C      THIS PROGRAM GENERATES A TIME SEQUENCE OF DATA POINTS WHICH
00150C SIMULATES DRIFT DATA RECEIVED FROM ONE OR MORE SOURCES BY A SET OF
00160C ANTENNAS IN THE COMPLEX PLANE, IN THE SAME FORMAT AS THE DGS 128PS
00170C IN GOOSE BAY, LABRADOR. THE TIME SEQUENCE IS TRANSFORMED INTO THE
00180C FREQUENCY DOMAIN BY SUBROUTINE FORER. SPECTRAL AVERAGING (HANNING
00190C WEIGHTING APPLIED TO THE FREQUENCY DOMAIN) IS DONE IN THE COMPLEX
00200C DOMAIN: FROM EACH SPECTRAL LINE WEIGHTED BY A FACTOR OF TWO, THE
00210C ADJACENT SPECTRAL LINES ARE SUBTRACTED. FOR PROGRAM NUMBERS IN=5
00220C OR 8, ALL SPECTRAL LINES ARE KEPT; THE FIRST SPECTRAL LINE (OF
00230C DOPPLER FREQ. ZERO) IS DOUBLED, BUT ONLY THE SECOND SPECTRAL LINE
00240C IS SUBTRACTED. FOR IN=6,7,9, ONLY THE ODD-FREQUENCY (E.G.: 1/16,3/16
00250C HZ,ETC.) SPECTRAL LINES ARE KEPT, THE INFORMATION FROM THE EVEN-FREQ.
00260C LINES (0 HZ,2/16 HZ, ETC.) BEING INCLUDED ONLY IN THE AVERAGING. THE
00270C RESULT IS TRANSFORMED FROM (REAL,IMAG) TO (AMPLITUDE,PHASE), AND IS
00280C THEN PACKED AND BUFFERED OUT ONTO TAPE9 BY SUBROUTINES C720 AND
00290C C2160, IN THE SAME FORMAT AS THE DATA ON TAPES GENERATED BY THE
00300C DIGISONDE, EXCEPT THAT DATA IS GENERATED FOR ONLY ONE FREQUENCY AND
00310C RANGE. (THE DGS 128PS MEASURES DRIFT AT THREE FREQUENCIES AND RANGES
00320C FOR IN=8,9 AND AT SIX FOR IN=5,6,7.) ALSO, TESTSKY IS NOT FULLY
00330C CODED FOR PROGRAM IN=7, WHICH REQUIRES FOUR OUTPUT RECORDS PER
00340C CASE INSTEAD OF TWO.
00350C
00360C      FR,FI,HAMPLTD,HPHASE, MUST BE DIMENSIONED AT LEAST TO NMAX, NMAX=
00370C =NPTS IF NPTS IS A POWER OF 2, NMAX=NEXT HIGHER POWER OF 2 OTHERWISE.
00380C FOR DGS 128PS, NMAX=NPTS. DIM OF SINS AT LEAST ((DIM OF FI)/4)+1.
00390C HFR,HFI, DIMENSIONED AT LEAST TO NSL. THESE ARRAYS, AND ARRAYS
00400C FM TO IBUF1 IN SUBROUTINE C720, AND ARRAY IBUF IN C2160, ARE
00410C DIMENSIONED TO THE MAXIMUM PRESENTLY REQUIRED, BUT MAY NEED LARGER
00420C DIMENSIONS IF DIGISONDE PARAMETERS ARE CHANGED.
00430C (DIMENSION REQUIREMENTS ARE DEFINED IN C720 AND C2160 COMMENTS).
00440C
00450C      FOR DGS 128PS DATA, NPTS=NO. OF POINTS IN THE TIME SEQUENCE=NMAX
00460C =NO. OF SPECTRAL LINES BEFORE SPECTRAL AVE'G=64 FOR IN=5; 128 FOR
00470C IN=6,8; 256 FOR IN=7,9. AFTER SPECTRAL AVE'G, NSL=NO. OF SPECTRAL
00480C LINES=64 FOR IN=5,6; 128 FOR IN=7,8,9.
00490C
00500C      BEFORE SPECTRAL AVERAGING, FREQ. SPECTRUM IS APPROXIMATELY:
00510C      IN          DOPFREQ [HZ]          I=1 TO NMAX DF
00520C      5  0,-1/8,-2/8,...,-31/8,32/8,31/8,...,1/8.      1 TO 64  1/8
00530C      6  0,-1/16,-2/16,...,-63/16,64/16,63/16,...,1/16.  1 TO 128 1/16
00540C      7  0,-1/32,-2/32,...,-127/32,128/32,127/32,...,1/32. 1 TO 256 1/32
00550C      8  0,-1/8,-2/8,...,-63/8,64/8,63/8,...,1/8.      1 TO 128 1/8
00560C      9  0,-1/16,-2/16,...,-127/16,128/16,127/16,...,1/16. 1 TO 256 1/16
00570C WHERE DF=DOPP-FREQ RESOLUTION [HZ] BEFORE SPECTRAL AVERAGING.
00580C
00590C      AFTER SPECTRAL AVE'G, AND AFTER AFTER NEG & POS DOPPLERS HAVE
00600C BEEN SEPARATED AND ORDER OF POS DOPPLERS HAS BEEN REVERSED (IN

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TESTSKY (ULCAR)

00610C SUBROUTINE C720), THE ABSOLUTE VALUE OF THE NEG AND POS DOPPLER
00620C FREQUENCIES ARE APPROXIMATELY:

00630C	IN	DOPFREQ [HZ]	I=1 TO NSL/2	DFR [HZ]
00640C	5	0, 1/8, 2/8, ..., 31/8	1 TO 32	1/8
00650C	6	1/16, 3/16, ..., 63/16	1 TO 32	1/8
00660C	7	1/32, 3/32, ..., 127/32	1 TO 64	1/16
00670C	8	0, 1/8, 2/8, ..., 63/8	1 TO 64	1/8
00680C	9	1/16, 3/16, ..., 127/16	1 TO 64	1/8

00690C WHERE DFR=DOPP-FREQ RESOLUTION AFTER SPECTRAL AVERAGING.

00700C

00710C EXPLANATION OF KPRINT USAGE:

00720C (FUNCTIONS CAN BE CALLED SIMULTANEOUSLY BY SETTING KPRINT EQUAL

00730C TO THE SUM OF THE INDIVIDUAL KPRINTS)

00740C

00750C KPRINT: PROGRAM FUNCTION:

00760C	1	CALCULATE DOPPLER FREQUENCIES FROM DRIFT VELOCITY SPECIFIED ON TAPE1. (OTHERWISE, DOPP. FREQ'S MUST BE DEFINED ON TAPE1; SEE FREQ. SPECTRUM ABOVE; REPLACE 1/8 BY .12254902, AND MULTIPLES OR SUB- MULTIPLES OF 1/8 BY MULT. OR SUB-MULT. OF .12254902)
00810C	2	PRINT VALUES (TAPE1)
00820C	4	PRINT ANTENNA NO., LOCATION, NOISE PARAMETERS
00830C	8	PRINT SOURCE NO., ANT. PHASE, TOTAL PHASE (TOT. PH.=ANT. PH. + PHINIT, WHERE PHINIT IS INITIAL PHASE AT THE SOURCE)
00860C	16	PRINT TIME SEQUENCE (REAL, IMAG)
00870C	32	PRINT FREQ. SEQUENCE (REAL, IMAG)
00880C	2048	SKIP SPECTRAL AVE'G (THE SAME DOPPLER LINES APPEAR AT THE OUTPUT, BUT THE ADJACENT SPECTRAL LINES ARE NOT SUBTRACTED)
00910C	64	PRINT AVERAGED SPECTRAL LINES (REAL, IMAG)
00920C	128	PRINT AVE'D SPECTRAL LINES (AMPLITUDE, PHASE)
00930C	256	PRINT NEG & POS DOPPLERS AFTER THEY ARE SEPARATED AND ORDER OF POS DOPP HAS BEEN REVERSED
00940C	512	PRINT NEG & POS DOPPLERS AFTER SCALING
00960C	1024	PRINT DATA AFTER PACKED INTO TWO RECORDS

00970C=====

00980C

00990C COMMON KPRINT, RADIANT

01000C COMMON FR(256), FI(256), SINS(65)

01010C DIMENSION HAMPLTD(256), HPHASE(256), HFR(128), HFI(128)

01020C COMPLEX ANT2

01030C DIMENSION ANT3(3) \$ EQUIVALENCE(ANT3, ANT2)

01040C DIMENSION S3(3)

01050C

01060C=====

01070C SOURCE INFORMATION.

01080C DIRECTION AND INITIAL PHASE AT THE SOURCE IN DEGREES.

01090C=====

01100C

01110C DIMENSION VX(32), VY(32), VZ(32), VXYZ(3)

TESTSKY (ULCAR)

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01120      DIMENSION SAZMTH(32),SZENITH(32),AMPLTDE(32),DOPFREQ(32)
01130+      ,PHINIT(32)
01140      DIMENSION RX(32),RY(32),RZ(32)
01150C
01160C=====
01170C ANTENNA INFORMATION.
01180C ANTENNA LOCATION IN METERS.
01190C RADIAN=RADIANS/DEGREE.
01200C=====
01210C
01220      COMPLEX ANT(10)
01230      REAL NOISE(10)
01240      DIMENSION TINIT(10),TINCR(10)
01250      COMMON /BLK/FMAXMAG,TWOPI
01260C
01270      NAMELIST/VALUES/CASE,KPRINT,IN,KSOURCE,VX,VY,VZ,
01280+      SAZMTH,SZENITH,AMPLTDE,DOPFREQ,PHINIT,FREQ,
01290+      NANT,ITT,ANT,NOISE,SEED
01300      DATA TINIT/10*0.0/
01310      DATA C/2.997925EB/
01320      DATA TWOPI/6.283185307179586/
01330      DATA ANT3/3*0.0/,NSWITCH/0/
01340      REWIND 1
01350      REWIND 3
01360      REWIND 8
01370      REWIND 9
01380C
01390C=====
01400C READ VALUES.
01410C DETERMINE:
01420C      ITIME=TIME OF EACH MEASUREMENT (CASE);
01430C      TINCR=DELTA-T FOR TIME SAMPLES;
01440C      NPTS=NO. OF DATA POINTS IN TIME SEQUENCE,
01450C      =NO. OF SPEC. LINES BEFORE SPEC. AVE'G;
01460C      NSL=NO. OF SPEC. LINES AFTER SPEC. AVE'G;
01470C      DFR=DOPP-FREQ RESOLUTION AFTER SPECTRAL AVERAGING;
01480C      DF2=DOPP. FREQ. OF FIRST SPECTRAL LINE;
01490C      USCALE=.707*SINZMAX/20
01500C      =COORD.-SYSTEM SCALE FOR THE UNIT VECTORS;
01510C      RX,RY,RZ=X,Y,Z COMPONENTS OF THE UNIT SOURCE-POSITION
01520C      VECTOR R;
01530C      DOPPLER FREQUENCIES.
01540C      OUTPUT OF DOT=VR=DOT PRODUCT OF VELOCITY VECTOR V
01550C      AND UNIT SOURCE-POSITION VECTOR R.
01560C      PRINT VALUES.
01570C=====
01580C
01590      ITIME=KT=0
01600      RADIAN=.0174532925199433
01610      1 CONTINUE
01620      NPTS=0

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TESTSKY (ULCAR)

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01630      READ (1,VALUES)
01640      IF(CASE.LT.0) GO TO 28
01650      KT=KT+1 $ IF(KT.EQ.7)KT=1
01660      ITIME=ITIME+10+((KT/6)*40)
01670      DO 17 I=1,NANT
01680      17 TINC(I)=.1275/(1+IN/8)
01690      NPTS=64+((IN/6)*64) $ IF(IN.EQ.7.OR.IN.EQ.9)NPTS=256
01700      NSL=64+64*(IN/7)
01710      DFR=.12254902 $ IF(IN.EQ.7) DFR=DFR/2
01720      DF2=DFR/2 $ IF(IN.EQ.5.OR.IN.EQ.8) DF2=0
01730      USCALE=(.707/20)*AMIN1(.707,(C/(FREQ*100)))
01740C
01750      DO 4 IS=1,KSOURCE
01760      ZENRAD=SZENITH(IS)*RADIAN $ AZIMRAD=SAZMTH(IS)*RADIAN
01770      RX(IS)=SIN(ZENRAD)*COS(AZIMRAD)
01780      RY(IS)=-SIN(ZENRAD)*SIN(AZIMRAD)
01790      4 RZ(IS)=COS(ZENRAD)
01800C
01810      IF((KPRINT.AND.1).EQ.0) GO TO 14
01820C
01830      DO 16 IS=1,KSOURCE
01840      VXYZ(1)=VX(IS) $ VXYZ(2)=VY(IS) $ VXYZ(3)=VZ(IS)
01850      S3(1)=RX(IS) $ S3(2)=RY(IS) $ S3(3)=RZ(IS)
01860      CALL DOT(VXYZ,S3,VR)
01870      16 DOPFREQ(IS)=-2*(VR/C)*FREQ
01880C
01890      14 IF((KPRINT.AND.2).EQ.0) GO TO 15
01900C
01910      PRINT 105, CASE,KPRINT,IN,KSOURCE
01920      105 FORMAT(" CASE=",F3.0," KPRINT=",I5," IN=",I1,
01930+      " NO. OF SOURCES=",I3)
01940C
01950      IF((KPRINT.AND.1).EQ.0) GO TO 100
01960      PRINT 110
01970      110 FORMAT(/," SOURCE",6X,"VX",7X,"VY",7X,"VZ",6X,"AZIM",5X," ZEN",5X,
01980+      "X",6X,"Y",4X,"AMPL",3X,"DOPFREQ",1X," INIT PH",2X,"DOPP. NO.")
01990C
02000      DO 120 IS=1,KSOURCE
02010      120 PRINT 130,IS,VX(IS),VY(IS),VZ(IS),SAZMTH(IS),SZENITH(IS),
02020+      (RX(IS)/USCALE),(RY(IS)/USCALE),AMPLTDE(IS),
02030+      DOPFREQ(IS),PHINIT(IS),(((ABS(DOPFREQ(IS))-DF2)/DFR+1)*
02040+      ((DOPFREQ(IS)+.0000001)/ABS((DOPFREQ(IS)+.0000001))))
02050      130 FORMAT(I5,2X,5F9.2,2F7.1,F7.2,F10.4,2F9.2)
02060      GO TO 140
02070C
02080      100 PRINT 150
02090      150 FORMAT(/," SOURCE",5X,"AZIM",6X,"ZEN",5X,"X",6X,"Y",4X,"AMPL",3X,
02100+      "DOPFREQ",1X," INIT PH",2X,"DOPP. NO.")
02110C
02120      DO 160 IS=1,KSOURCE
02130      160 PRINT 170,IS,SAZMTH(IS),SZENITH(IS),(RX(IS)/USCALE),

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TESTSKY (ULCAR)

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02140+      (RY(IS)/USCALE),AMPLTDE(IS),DOPFREQ(IS),
02150+      PHINIT(IS),(((ABS(DOPFREQ(IS))-DF2)/DFR+1)*((DOPFREQ(IS)+
02160+      .0000001)/ABS((DOPFREQ(IS)+.0000001))))
02170  170 FORMAT(I5,2X,2F9.2,2F7.1,F7.2,F10.4,2F9.2)
02180C
02190  140 PRINT 180,(FREQ/(1E+6)),NANT,ITT
02200  180 FORMAT(/" SOUNDING FREQ=",F8.4," MHZ, NO. OF ANT=",I2," ITT="
02210+      ,I2/)
02220C
02230      PRINT*,"ANT. COORD.(X,Y)= ",(ANT(IA),IA=1,NANT)
02240      PRINT*," "
02250      PRINT*,"NOISE= ",(NOISE(IA),IA=1,NANT)
02260      PRINT*," "
02270      PRINT*,"T-INIT= ",(TINIT(IA),IA=1,NANT)
02280      PRINT*," "
02290      PRINT*,"DELTA-T= ",(TINCR(IA),IA=1,NANT)
02300      PRINT*," "
02310      PRINT*,"TIME= ",ITIME," SEED= ",SEED
02320C
02330C=====
02340C SET INITIAL PARAMETERS
02350C=====
02360C
02370  15 IF(NPTS.EQ.NPTS0) GO TO 2 $ NPTS0=NPTS $ NMAX=0
02380      FMAXMAG=1.E-6
02390  2 IA=0
02400      W=TWOPI*FREQ
02410      IF(SEED.NE.0.) CALL RANSET(SEED)
02420C
02430C=====
02440C INITIALIZE ANTENNA PARAMETERS.
02450C PRINT ANTENNA PARAMETERS.
02460C=====
02470C
02480  3 IA=IA+1 $ IS=0
02490      ANT2=ANT(IA) $ SDN=NOISE(IA) $ TI=TINIT(IA) $ DT=TINCR(IA)
02500C
02510      IF((KPRINT.AND.4).EQ.0) GO TO 5
02520      PRINT*," " $ PRINT*," " $ PRINT*," "
02530      PRINT*,"ANTENNA NO.=",IA," LOCATION=",ANT2," NOISE=",SDN
02540      PRINT*," "
02550C
02560C=====
02570C INITIALIZE SOURCE PARAMETERS.
02580C=====
02590C
02600  5 IS=IS+1
02610      AMP=AMPLTDE(IS) $ DFREQ=DOPFREQ(IS)
02620      DELTA=PHINIT(IS)*RADIAN
02630      WD=TWOPI*DFREQ
02640C

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TESTSKY (ULCAR)

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02650C=====
02660C COMPUTE ARRIVAL PHASE DIFFERENCE DUE TO ANTENNA LOCATION.
02670C OUTPUT OF DOT=Q=DOT PRODUCT OF UNIT PROPAGATION VECTOR K
02680C AND ANTENNA-POSITION VECTOR A.
02690C PRINT SOURCE PARAMETERS.
02700C=====
02710C
02720      S3(1)=-RX(IS) $ S3(2)=-RY(IS) $ S3(3)=-RZ(IS)
02730      CALL DOT(ANT3,S3,Q)
02740      PHI=(W+WD)*Q/C
02750C
02760      IF((KPRINT.AND.8).EQ.0) GO TO 7
02770      IF(IS.EQ.1) PRINT*," SOURCE ANT.PHASE TOT.PHASE(DEG)"
02780      PRINT 6,IS,(PHI/RADIAN),((PHI+DELTA)/RADIAN)
02790      6 FORMAT(I5,F11.2,F10.2)
02800C
02810C=====
02820C COMPUTE TIME SEQUENCE FOR THIS SOURCE.
02830C=====
02840C
02850      7 T=TI $ I=1
02860      8 IF(IS.EQ.1) FR(I)=FI(I)=0.
02870CCC      Q=PHI+WD*T+DELTA
02880      Q=WD*T-PHI-DELTA
02890      FR(I)=FR(I)+AMP*COS(Q) $ FI(I)=FI(I)+AMP*SIN(Q)
02900      IF(I.EQ.NPTS) GO TO 9 $ I=I+1 $ T=T+DT $ GO TO 8
02910      9 IF(IS.LT.KSOURCE) GO TO 5
02920      IF(SDN.EQ.0.) GO TO 20
02930C
02940C=====
02950C ADD NOISE TO THE TIME SEQUENCE.
02960C PRINT TIME SEQUENCE.
02970C=====
02980C
02990      DO 10 I=1,NPTS
03000      CALL GAUSS1(0.,SDN,Q)
03010      FR(I)=FR(I)+Q
03020      CALL GAUSS1(0.,SDN,Q)
03030      10 FI(I)=FI(I)+Q
03040C
03050      20 IF(KPRINT.AND.16)21,22
03060      21 PRINT 32,TI,DT
03070      32 FORMAT(/," TIME SEQUENCE: T=INIT=",F6.5," DELTA-T=",
03080+          F6.5,/,6(4X,"I",3X,"REAL",4X,"IMAG",2X))
03090      PRINT 13,(I,FR(I),FI(I),I=1,NPTS)
03100      13 FORMAT(25(I5,2F8.2,,5(I6,2F8.2/))
03110C
03120C=====
03130C COMPUTE THE FOURIER SPECTRUM.
03140C PRINT FREQ. SPECTRUM (REAL,IMAG).
03150C=====

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TESTSKY (ULCAR)

```

03160C
03170 22 CALL FORER(NPTS,FR,FI,SINS,NSWTC,NMAX)
03180C
03190 IF((KPRINT.AND.32).EQ.0) GO TO 31
03200 PRINT 30
03210 30 FORMAT(/," FREQUENCY SEQUENCE (REAL,IMAG)",/,
03220+ 6(4X,"I",3X,"REAL",4X,"IMAG",2X))
03230 PRINT 13,(I,FR(I),FI(I),I=1,NMAX)
03240C
03250C=====
03260C DO SPECTRAL AVERAGING.
03270C IF SKIPPING SPECTRAL AVE'G, ADJACENT SPECTRAL LINES ARE NOT
03280C SUBTRACTED. MULTIPLYING SPECTRAL LINES BY 2 CHANGES NOTHING
03290C SINCE SPECTRAL LINES ARE SCALED LATER TO SIX BITS.
03300C
03310C PRINT AVERAGED SPECTRAL LINES (REAL,IMAG).
03320C=====
03330C
03340 31 O1=1.
03350 IF((KPRINT.AND.2048).NE.0) O1=0.
03360 IF(IN.NE.5.AND.IN.NE.8) GO TO 25
03370C
03380 HFR(1)=2*FR(1)-O1*FR(2)
03390 HFI(1)=2*FI(1)-O1*FI(2)
03400C
03410 NS2=NSL/2 $ NS3=NS2+1 $ NS4=NSL-2
03420 DO 40 I=2,NS2
03430 HFR(I)=-O1*FR(I-1)+2*FR(I)-O1*FR(I+1)
03440 40 HFI(I)=-O1*FI(I-1)+2*FI(I)-O1*FI(I+1)
03450C
03460 DO 50 I=NS3,NS4
03470 HFR(I)=-O1*FR(I)+2*FR(I+1)-O1*FR(I+2)
03480 50 HFI(I)=-O1*FI(I)+2*FI(I+1)-O1*FI(I+2)
03490C
03500 HFR(NSL-1)=-O1*FR(1)+2*FR(NSL)-O1*FR(NSL-1)
03510 HFI(NSL-1)=-O1*FI(1)+2*FI(NSL)-O1*FI(NSL-1)
03520 HFR(NSL)=2*FR(1)-O1*FR(NSL)
03530 HFI(NSL)=2*FI(1)-O1*FI(NSL)
03540 GO TO 60
03550C
03560 25 NS1=NSL-1
03570 DO 70 I=1,NS1
03580 J=2*I
03590 HFR(I)=-O1*FR(J-1)+2*FR(J)-O1*FR(J+1)
03600 70 HFI(I)=-O1*FI(J-1)+2*FI(J)-O1*FI(J+1)
03610 HFR(NSL)=-O1*FR(1)+2*FR(2*NSL)-O1*FR(2*NSL-1)
03620 HFI(NSL)=-O1*FI(1)+2*FI(2*NSL)-O1*FI(2*NSL-1)
03630C
03640 60 IF((KPRINT.AND.64).EQ.0) GO TO 24
03650 IF((KPRINT.AND.2048).NE.0) PRINT*," "
03660 IF((KPRINT.AND.2048).NE.0) PRINT*," NO SPECTRAL AVE'G; ",

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TESTSKY (ULCAR)

```

03670+      "WHAT FOLLOWS IS FREQ. SEQ."
03680      PRINT 61
03690      61 FORMAT(/," AVERAGED SPECTRAL LINES (REAL,IMAG)
03700+      " ,/,6(4X,"I",3X,"REAL",4X,"IMAG",2X))
03710      PRINT 13,(I,HFR(I),HFI(I),I=1,NSL)
03720C=====
03730C=====
03740C CONVERT TO AMPLITUDE AND PHASE.
03750C PRINT AVERAGED SPECTRAL LINES (AMPL & PHASE).
03760C=====
03770C=====
03780      24 DO 26 I=1,NSL
03790      TEMP=(HFR(I)*HFR(I)+HFI(I)*HFI(I))
03800      IF(TEMP.EQ.0.0)GO TO 27
03810      HAMPLTD(I)=SQRT(TEMP)
03820      HPHASE(I)=ATAN2(HFI(I),HFR(I))
03830      GO TO 26
03840      27 HAMPLTD(I)=0.0
03850      HPHASE(I)=0.0
03860      26 CONTINUE
03870C=====
03880      DO 55 I=1,NSL
03890      55 IF(HAMPLTD(I).GT.FMAXMAG) FMAXMAG=HAMPLTD(I)
03900C=====
03910      IF((KPRINT.AND.128).EQ.0) GO TO 62
03920      IF((KPRINT.AND.2048).NE.0) PRINT*," "
03930      IF((KPRINT.AND.2048).NE.0) PRINT*," NO SPECTRAL AVE'G; ",
03940+      "WHAT FOLLOWS IS FREQ. SEQ."
03950      PRINT 23
03960      23 FORMAT(/," AMPLITUDE & PHASE(DEG) OF AVERAGED SPECTRAL LINES " ,/,
03970+      6(4X,"I",3X,"AMPL",3X,"PHASE",2X))
03980      PRINT 13,(I,HAMPLTD(I),(HPHASE(I)/RADIAN),I=1,NMAX)
03990C=====
04000C=====
04010C WRITE THE SPECTRAL AMPLITUDES & PHASES ON TAPE3.
04020C=====
04030C=====
04040      62 WRITE(3) NSL,(HAMPLTD(I),HPHASE(I),I=1,NSL)
04050      IF(IA.LT.NANT) GO TO 3
04060C=====
04070      PRINT*," "
04080      PRINT*,"MAX HAMPLTD=",FMAXMAG
04090      PRINT*," "
04100C=====
04110      IF((KPRINT.AND.2048).NE.0)PRINT*," ***** NO SPECTRAL AVE'G *****"
04120C=====
04130C=====
04140C THIS CASE IS COMPLETED.
04150C=====
04160C SCALE DATA AND PACK PREFACE AND DATA INTO 2 RECORDS IN SAME FORMAT
04170C AS DIGISONDE OUTPUT.

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TESTSKY (ULCAR)

```

04180C=====
04190C
04200      CALL C720(FREQ,IN,ITT,ITIME,NSL,NANT,NWORD,IOUT)
04210C
04220      CALL C2160(NWORD,IOUT)
04230C
04240      GO TO 1
04250      28 STOP
04260      END
04270C
04280C
04290C
04300C
04310C
04320C
04330C
04340C=====
04350C SUBROUTINE FORER
04360C=====
04370C
04380      SUBROUTINE FORER (NPTS,FR,FI,SINS,NSWTC,NMAX)
04390C
04400C=====
04410C COMPUTE FOURIER COEFFICIENTS OF ARRAY OF DATA
04420C
04430C TAKEN FROM A PROGRAM WRITTEN BY MICHAEL FORMAN
04440C
04450C NPTS IS THE NUMBER OF INPUT POINTS
04460C
04470C FR IS INPUTED AS THE REAL PART OF THE INPUT DATA ARRAY
04480C (FOR SIMPLE OPERATION INPUT DATA ARRAY)
04490C FR IS OUTPUTED AS THE ARRAY OF COSINE COEFFICIENTS
04500C
04510C FI IS INPUTED AS THE IMAGINARY PART OF THE INPUT DATA ARRAY
04520C (FOR SIMPLE OPERATION ARRAY OF ZEROS)
04530C FI IS OUTPUTED AS THE ARRAY OF SINE COEFFICIENTS
04540C
04550C GIVEN THE ORIGINAL TIME SEQUENCE ( FR(I),FI(I) ) FOR I=1,...,NPTS,
04560C THE RESULTING FREQUENCY SEQUENCE ( FR(J),FI(J) ) FOR J=1,...,NMAX
04570C IS DEFINED:
04580C
04590C      NMAX
04590C      ( FR(J),FI(J) ) = SUM ( FR(I),FI(I) ) ( COS(K),SIN(K) )
04600C      I=1
04610C WHERE K = (J-1)(2*PI/NMAX)(I-1).
04620C
04630C SINS IS AN ERASABLE ARRAY (MUST BE DIMENSIONED AT LEAST M/4+1
04640C WHERE M IS THE DIMENSION OF FI)
04650C
04660C NSWTC=0 FORWARD TRANSFORM
04670C NSWTC=1 BACKWARDS TRANSFORM
04680C

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TESTSKY (ULCAR)

```

04680C NMAX (ON INPUT) SET NMAX=0 ONLY WHEN NECESSARY TO COMPUTE
04700C          A NEW NMAX OR SINS ARRAY
04710C          (ON OUTPUT) THE NUMBER OF POINTS IN THE EXTENDED FUNCTION
04720C          (EXTENDED WITH ZEROS TO THE NEXT POWER OF 2)
04730C=====
04740C
04750          COMMON KPRINT,RADIAN
04760          DIMENSION FR(1),FI(1),SINS(1)
04770          DATA TWOPI/6.283185307179586/
04780C          PRINT 10,(I,FR(I),FI(I),I=1,NPTS)
04790          IF(NMAX.NE.0) GO TO 650
04800C
04810C=====
04820C COMPUTE NEXT HIGHER POWER OF 2 ABOVE NPTS
04830C=====
04840C
04850          NBIT = ALOG(FLOAT(NPTS))/ .693147180559945
04860          NMAX = 2**NBIT
04870          IF (NMAX.GE.NPTS) GO TO 200
04880          NBIT = NBIT+1
04890          NMAX = 2*NMAX
04900          200 FNMAX = NMAX
04910          NP = NPTS+1
04920          KR = NMAX/4+1
04930C
04940C=====
04950C COMPUTE 1/4 CYCLE SINE FUNCTION
04960C=====
04970C
04980          DO 600 I=1,KR
04990          XI = I-1
05000          600 SINS(I) = SIN(TWOPI*XI/FNMAX)
05010          650 IF(NMAX.LE.NPTS) GO TO 675
05020C
05030C=====
05040C CLEAR REMAINDER OF REAL AND IMAGINARY PARTS
05050C=====
05060C
05070          DO 300 I=NP,NMAX
05080          FR(I) = 0.
05090          300 FI(I) = 0.
05100          675 JMAX = NMAX
05110          JHALF = NMAX/2
05120          LXY = 2*KR
05130C
05140C=====
05150C COMPUTE FOURIER COEFFICIENTS
05160C=====
05170C
05180          DO 1300 K=1,NBIT
05190          JP = NBIT-K

```

TESTSKY (ULCAR)

```

05200      DO 1200 J=1,NMAX,JMAX
05210      JT = J+JHALF-1
05220      JJ = IBSH(J-1,NBIT,JP)
05230      KK = KR-JJ-1
05240      IF (KK) 900,800,700
05250 700  WI = SINS(JJ+1)
05260      WR = SINS(KK+1)
05270      GO TO 1000
05280 800  WI = 1.0
05290      WR = 0.0
05300      GO TO 1000
05310 900  JB = LXY-(JJ+1)
05320      WI = SINS(JB)
05330      KK = -KK
05340      WR = -SINS(KK+1)
05350 1000 CONTINUE
05360      IF(NSWTCHE.0) WI=-WI
05370      DO 1100 L=J,JT
05380      LK = L+JHALF
05390      AR = FR(L)
05400      AI = FI(L)
05410      BR = FR(LK)*WR-FI(LK)*WI
05420      BI = FR(LK)*WI+FI(LK)*WR
05430      FR(L) = AR+BR
05440      FI(L) = AI+BI
05450      FR(LK) = AR-BR
05460 1100 FI(LK) = AI-BI
05470 1200 CONTINUE
05480      JMAX = JMAX/2
05490 1300 JHALF = JHALF/2
05500C
05510C=====
05520C SWAP COEFFICIENTS INTO CORRECT ORDER
05530C=====
05540C
05550      DO 1400 I=1,NMAX
05560      JJ = IBSH(I-1,NBIT,0)
05570      IF (JJ.LE.I-1) GO TO 1400
05580      FX = FR(I)
05590      FR(I) = FR(JJ+1)
05600      FR(JJ+1) = FX
05610      FX = FI(I)
05620      FI(I) = FI(JJ+1)
05630      FI(JJ+1) = FX
05640 1400 CONTINUE
05650C      PRINT 10,(I,FR(I),FI(I),I=1,NMAX)
05660 10  FORMAT(3(2X,*SUB*4X*I*7X*FR*13X*FI*6X)/3(I10,1P2E15.7))
05670      IF(NSWTCHE.0) RETURN
05680      TMAX=1.0/FLOAT(NMAX)
05690      DO 2 I=1,NMAX
05700      FR(I)=FR(I)*TMAX

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TESTSKY (ULCAR)

```
05710      FI(I)=FI(I)*TMAX
05720      2 CONTINUE
05730      RETURN
05740      END
```

05750C

05760C

05770C

05780C

05790C

05800C

05810C

05820C=====

05830C FUNCTION IBRSH

05840C=====

05850C

05860 FUNCTION IBRSH (K,NP,JP)

05870 NS=2*(NP-1)

05880 NM=2*JP

05890 JC=2*JP

05900 KST=K

05910 KV=0

05920 DO 1 I=JC,NP

05930 KIN=KST/NS

05940 KV=KV+KIN*NM

05950 KST=KST-NS*KIN

05960 NS=NS/2

05970 NM=NM*2

05980 1 CONTINUE

05990 IBRSH=KV+KST*NM

06000 RETURN

06010 END

06020C

06030C

06040C

06050C

06060C

06070C

06080C

06090C=====

06100C SUBROUTINE GAUSS1

06110C THIS SUBROUTINE COMPUTES A NORMALLY DISTRIBUTED

06120C RANDOM VARIABLE V WITH GIVEN MEAN AND STANDARD

06130C DEVIATION

06140C=====

06150C

06160 SUBROUTINE GAUSS1(AM,S,V)

06170C

06180 1 P=RANF(DUM)

06190 IF(P) 1,1,2

06200 2 D=P

06210 IF(P.GT.0.5) D=1.0-D

TESTSKY (ULCAR)

```

06220      T2=ALOG(1.0/(D*D))
06230      T=SGRT(T2)
06240      V=T-(2.515517+0.802853*T+0.010328*T2)/(1.0+1.432788*T+0.189269*T2
06250+      +0.001308*T*T2)
06260      IF(P.LE.0.5) 3,4
06270      3 V=-V
06280      4 V=V*S+AM
06290      RETURN
06300      END
06310C
06320C
06330C
06340C
06350C
06360C
06370C
06380C=====
06380C SUBROUTINE VECTORS
06400C=====
06410C
06420      SUBROUTINE VECTORS(A,B,C)
06430      DIMENSION A(3),B(3),C(3)
06440C
06450      ENTRY CROSS
06460      C(1)=A(2)*B(3)-A(3)*B(2)
06470      C(2)=A(3)*B(1)-A(1)*B(3)
06480      C(3)=A(1)*B(2)-A(2)*B(1)  $ RETURN
06490C
06500      ENTRY DOT
06510      C(1)=A(1)*B(1)+A(2)*B(2)+A(3)*B(3)  $ RETURN
06520C
06530      ENTRY LENGTHV
06540      C(1)=SGRT(A(1)**2+A(2)**2+A(3)**2)  $ RETURN
06550      END
06560C
06570C
06580C
06590C
06600C
06610C
06620C
06630C=====
06640C SUBROUTINE C720
06650C=====
06660C
06670      SUBROUTINE C720(FREQ,IN,ITT,ITIME,NSL,NANT,NWORD,IOUT)
06680C
06690C=====
06700C TO SCALE AND PACK THE OUTPUT (AMPLITUDE, PHASE) FROM THE TEST
06710C FUNCTION SUCH THAT EACH DATUM WILL APPEAR AS STORED IN THE
06720C 8-BIT WORD WITH AMPLITUDE RANGE (0-63) AND PHASE RANGE

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TESTSKY (ULCAR)

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06730C (0-511). THE MAX AMPLITUDE HAS BEEN SORTED OUT IN MAIN PROGRAM.
06740C
06750C NSL=NO. OF SPECTRAL LINES
06760C      =NO. OF DOPPLER FREQUENCIES
06770C NANT=NO. OF ANTENNAS
06780C NHALF=NO. OF NEGATIVE DOPPLERS
06790C      =NO. OF POSITIVE DOPPLERS
06800C NTOT=NANT*NHALF
06810C      =TOTAL NO. OF NEG-DOPP VALUES OVER ALL ANTENNAS
06820C      =TOTAL NO. OF POS-DOPP VALUES OVER ALL ANTENNAS
06830C NCHAR=NO. OF 6-BIT CHARACTERS INTO WHICH THE NEG (OR POS) DATA IS
06840C      CODED: 2 AMPLITUDES AND 2 PHASES ARE CODED INTO 5 CHARACTERS
06850C NWORD=NO. OF COMPUTER WORDS CONTAINING THE NEG (OR POS) PACKED DATA:
06860C      10 6-BIT CHARACTERS ARE PACKED INTO EACH 60-BIT COMPUTER WORD
06870C IOUT=TOTAL NO. OF PACKED COMPUTER WORDS: 8 PREFACE, NWORD-NUMBER OF
06880C      NEG-DOPP, NWORD-NUMBER OF POS-DOPP
06890C
06900C FM,PHI,FMN,PHIN MUST BE DIMENSIONED AT LEAST TO NTOT; TM,TPHI, TO NSL;
06910C      IBUF, TO NCHAR; IBUF2, TO NWORD; IBUF1, TO IOUT.
06920C=====
06930      DIMENSION FM(256),PHI(256),FMN(256),PHIN(256),TM(128),
06940+      TPHI(128)
06950      DIMENSION IBUF(640),IBUF2(64),IBUF1(136),IPREF(80)
06960      COMMON /BLK/FMAXMAG,TWOPI
06970      COMMON KPRINT,RADIAN
06980C
06990      NHALF=NSL/2 $ NTOT=NANT*NHALF $ NCHAR=(NTOT/2)*5
07000      NWORD=NCHAR/10 $ IOUT=2*NWORD+8
07010C
07020C===== P R E F A C E =====
07030C
07040C STATION IDENT,YR,DAY,HR,MIN,SEC; LAST 4 DIGITS NOT USED
07050C (IDENT=0 IDENTIFIES THIS DATA AS TEST DATA IN SKYMAP)
07060      DATA IPREF /0, 7,8, 0,8,2, 0,0, 0,0, 0,0, 0,0,0,0,
07070C FOR MICROCOMPUTER ONLY
07080+      0,0,0,0,
07090C FIRST DIGIT=IREP; 2ND,IDB; 3RD & 4TH,ITT
07100+      4,3,0,0,
07110C IQ,IN; NEXT 6 DIGITS NOT USED
07120+      1,0,0,0,0,0,0,0,
07130C SOUNDING FREQUENCIES 1 TO 6, IN 10-KHZ UNITS
07140+      0,0,0,0, 0,0,0,0, 0,0,0,0, 0,0,0,0, 0,0,0,0, 0,0,0,0,
07150C FIRST 3 DIGITS: CORRESPONDING RANGES (1.5-KM UNITS); 4TH DIGIT: IGAIN
07160+      2,7,5,4, 0,0,0,0, 0,0,0,0, 0,0,0,0, 0,0,0,0, 0,0,0,0,
07170C
07180C=====
07190C DETERMINE IN, ITT AND HR,MIN,SEC FROM NAMELIST VALUES
07200C=====
07210C
07220      IPREF(26)=IN
07230      IPREF(23)=ITT/10

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TESTSKY (ULCAR)

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07240      IPREF(24)=ITT-IPREF(23)*10
07250      IPREF(7)=ITIME/100000
07260      IPREF(8)=MOD(ITIME,100000)/10000
07270      IPREF(9)=MOD(ITIME,10000)/1000
07280      IPREF(10)=MOD(ITIME,1000)/100
07290      IPREF(11)=MOD(ITIME,100)/10
07300      IPREF(12)=MOD(ITIME,10)
07310C
07320C=====
07330C SET SOUNDING FREQ EQUAL TO FREQ FROM NAMELIST VALUES
07340C
07350C TEST FUNCTION USES ONLY FIRST FREQ, WHEREAS DIGISONDE DATA
07360C CAN INCLUDE DRIFT DATA FOR UP TO 6 FREQUENCIES
07370C=====
07380C
07390      IFREQ=FREQ-12.5E+3
07400      IFREQ=IFREQ/10000
07410      IPREF(33)=MOD(IFREQ,10000)/1000
07420      IPREF(34)=MOD(IFREQ,1000)/100
07430      IPREF(35)=MOD(IFREQ,100)/10
07440      IPREF(36)=MOD(IFREQ,10)
07450C
07460      DO 11 I=1,80
07470      11 IPREF(I)=IPREF(I).OR.16
07480C
07490C===== F R E Q U E N C Y   S E Q U E N C E =====
07500C
07510C READ FREQUENCY SEQUENCE FROM TAPE3
07520C
07530C PUT FIRST HALF OF THE DOPPLERS (NEG. DOPPLERS) FROM ALL ANTENNAS
07540C INTO FM,PHI; 2ND HALF (POS. DOPPLERS) IN REVERSE ORDER INTO FMN,PHIN.
07550C PRINT NEGATIVE AND POSITIVE DOPPLERS, ALL ANTENNAS
07560C=====
07570C
07580      DO 66 I=1,NANT
07590      BACKSPACE 3
07600      66 CONTINUE
07610C
07620      DO 15 IA=1,NANT
07630      READ (3) NPT64,(TM(I),TPHI(I),I=1,NPT64)
07640      IF(EOF(3))100,10
07650      10 II=IA-1
07660C
07670      DO 15 K=1,NHALF
07680      KK=II*NHALF+K
07690      FM(KK)=TM(K)
07700      PHI(KK)=TPHI(K)
07710      FMN(KK)=TM(NSL+1-K)
07720      PHIN(KK)=TPHI(NSL+1-K)
07730      15 CONTINUE
07740C

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TESTSKY (ULCAR)

```

07750      IF((KPRINT.AND.258).EQ.0) GO TO 26
07760      PRINT 27
07770      27 FORMAT(/," NEGATIVE DOPPLERS, ALL ANTENNAS (PHASE IN DEGREES)",/,
07780+        6(5X,"I",3X,"AMPL",2X,"PHASE"))
07790      PRINT 28,(I,FM(I),(PHI(I)/RADIAN),I=1,NTOT)
07800      28 FORMAT(6(I6,2F7.1))
07810      PRINT 29
07820      29 FORMAT(/," POSITIVE DOPPLERS, ALL ANTENNAS (PHASE IN DEGREES)",/,
07830+        6(5X,"I",3X,"AMPL",2X,"PHASE"))
07840      PRINT 28,(I,FMN(I),(PHIN(I)/RADIAN),I=1,NTOT)
07850C
07860C=====
07870C PACK PREFACE AND STORE RESULT IN IBUF1
07880C=====
07890C
07900      26 CALL COMPACT(IPREF,80,IBUF1,8)
07910C
07920C=====
07930C SCALE THE AMPLITUDES AND PHASES AND STORE IN IBUF1 WITH PREFACE:
07940C      ICOUNT=1:
07950C          CALL SCAST TO SCALE NEG-DOPPLER AMPL. & PHASES; AND TO STORE
07960C          SETS OF 2 6-BIT AMPLITUDES AND 2 9-BIT PHASES INTO ARRAY
07970C          IBUF IN SETS OF 5 6-BIT CHARACTERS.
07980C          CALL COMPACT TO PACK GROUPS OF 10 6-BIT CHARACTERS FROM IBUF INTO
07990C          60-BIT COMPUTER WORDS IN IBUF2.
08000C          APPEND NEG. DOPPLERS TO PREFACE IN IBUF1.
08010C      ICOUNT=2:
08020C          DO SAME FOR POS. DOPPLERS, APPENDING THEM TO PREFACE AND NEG.
08030C          DOPPLERS IN IBUF1.
08040C=====
08050C
08060      DO 45 ICOUNT=1,2
08070C
08080      CALL SCAST(FM,PHI,NTOT,IBUF,NCHAR,ICOUNT)
08090C
08100      CALL COMPACT(IBUF,NCHAR,IBUF2,NWORD)
08110C
08120      K=8
08130      IF(ICOUNT.EQ.2) K=8+NWORD
08140      DO 35 I=1,NWORD
08150      35 IBUF1(K+I)=IBUF2(I)
08160      IF(ICOUNT.EQ.2) GO TO 45
08170      DO 40 J=1,NTOT
08180      FM(J)=FMN(J)
08190      PHI(J)=PHIN(J)
08200      40 CONTINUE
08210      45 CONTINUE
08220C
08230C=====
08240C OUTPUT DATA WITH BUFFEROUT TO TAPEB
08250C=====

```

TESTSKY (ULCAR)

```

08260C
08270      70 BUFFEROUT(8,1)(IBUF1(1),IBUF1(IOUT))
08280      IF(UNIT(8))95,80,70
08290      80 STOP 2
08300      95 CONTINUE
08310      GO TO 100
08320      4 PRINT 3,(IBUF1(I),I=1,IOUT)
08330      3 FORMAT (6(1X,020))
08340      100 RETURN $ END
08350C
08360C
08370C
08380C
08390C
08400C
08410C
08420C=====
08430C SUBROUTINE COMPACT
08440C PACK NN 6-BIT CHARACTERS FROM IBUFIN INTO N=NN/10 60-BIT COMPUTER
08450C WORDS IN IBUFOUT
08460C=====
08470C
08480      SUBROUTINE COMPACT(IBUFIN,NN,IBUFOUT,N)
08490      DIMENSION IBUFIN(NN),IBUFOUT(N)
08500      DO 65 IM=1,N
08510      IBUFOUT(IM)=IBUFOUT(IM).AND.0
08520      DO 65 IBY=1,10
08530      IB=10*IM+IBY-10 $ IBB=60-IBY*6
08540      IBUFOUT(IM)=(IBUFIN(IB).AND.77B).OR.
08550+      (SHIFT(IBUFOUT(IM),6).AND.(.NOT.77B))
08560      65 CONTINUE
08570      RETURN $ END
08580C
08590C
08600C
08610C
08620C
08630C
08640C
08650C=====
08660C SUBROUTINE SCAST
08670C=====
08680C
08690      SUBROUTINE SCAST(FM,PHI,NTOT,IBUF,NCHAR,ICOUNT)
08700C
08710C=====
08720C INPUT      FM: AMPLITUDES
08730C          PHI: PHASES
08740C          NTOT: NUMBER OF POINTS TO BE SCALED
08750C OUTPUT:    IBUF: SCALED FM,PHI STORED IN ARRAY IBUF
08760C=====

```

TESTSKY (ULCAR)

```

08770C
08780      DIMENSION FM(NTOT),PHI(NTOT),IBUF(NCHAR)
08790      COMMON /BLK/FMAXMAG,TWOPI
08800      COMMON KPRINT,RADIAN
08810C
08820C=====
08830C SCALE THE AMPLITUDES TO A MAXIMUM OF 63.999 DB, SETTING NEGATIVE
08840C   AMPLITUDES TO ZERO
08850C SHIFT NEG. PHASES(RAD) BY +TWOPI AND SCALE PHASES TO MAX OF 511.999
08860C PRINT NEG. & POS. DOPPLERS, ALL ANT., AFTER SCALING
08870C=====
08880C
08890      CONST=FMAXMAG/10**((63.999/20.))
08900      DO 45 I=1,NTOT
08910      IF(FM(I).EQ.0.0)GO TO 20
08920      FM(I)=20*ALOG10(FM(I)/CONST)
08930      IF (FM(I).LT.0) FM(I)=0
08940  20 IF(PHI(I).EQ.0.0) GO TO 45
08950      IF(PHI(I).GT.0.0) GO TO 30
08960      PHI(I)=(TWOPI+PHI(I))/TWOPI*511.999
08970      GO TO 45
08980  30 PHI(I)=PHI(I)/TWOPI*511.999
08990C
09000      45 CONTINUE
09010C
09020      IF((KPRINT.AND.512).EQ.0) GO TO 31
09030      IF(ICOUNT.EQ.1) PRINT 27
09040  27 FORMAT(/," NEGATIVE DOPPLERS, ALL ANTENNAS, AFTER SCALING",
09050+      " ; RADIANS SCALED TO 511",/,
09060+      6(4X,"I",3X,"AMPL",3X,"PHASE",2X))
09070      IF(ICOUNT.EQ.2) PRINT 29
09080  29 FORMAT(/," POSITIVE DOPPLERS, ALL ANTENNAS, AFTER SCALING",
09090+      " ; RADIANS SCALED TO 511",/,
09100+      6(4X,"I",3X,"AMPL",3X,"PHASE",2X))
09110      PRINT 28,(I,FM(I),PHI(I),I=1,NTOT)
09120  28 FORMAT(25(I5,2F8.2,5(I6,2F8.2)/))
09130C
09140C=====
09150C STORE THE AMPLITUDES AND PHASES IN ARRAY IBUF, PUTTING 2 AMPL. & 2
09160C PHASES INTO 5 ELEMENTS OF ARRAY IBUF:
09170C   FM(I); 6 MSB OF PHI(I); 3 LSB OF PHI(I) AND 3 LSB OF PHI(I+1);
09180C   FM(I+1); 6 MSB OF PHI(I+1)
09190C=====
09200C
09210      31 NN=NTOT/2
09220      DO 55 I=1,NN
09230      I5=I*5 & I2=I*2
09240      IBUF(I5-4)=FM(I2-1)
09250      IBUF(I5-3)=PHI(I2-1)/8
09260      IBUF(I5-2)=(IFIX(PHI(I2)).AND.7)+SHIFT(IFIX(PHI(I2-1)).
09270+      AND.7,3)

```

TESTSKY (ULCAR)

```

09280      IBUF(15-1)=FM(I2)
09290      IBUF(15)=PHI(I2)/8
09300      SS CONTINUE
09310      RETURN $ END
09320C
09330C
09340C
09350C
09360C
09370C
09380C
09390C=====
09400C SUBROUTINE C2160
09410C=====
09420C
09430      SUBROUTINE C2160(NWORD,IOUT)
09440C
09450C=====
09460C OUTPUT DATA WITH 2160 8-BIT CHARACTERS PER RECORD
09470C   IN 216 10-CHARACTER WORDS
09480C DIMENSION OF IBUF MUST BE AT LEAST IOUT
09490C=====
09500C
09510      COMMON KPRINT,RADIAN
09520      DIMENSION IOUTPT2(216),IBUF(136)
09530C
09540C=====
09550C READ DATA FROM TAPE8
09560C=====
09570C
09580      BACKSPACE 8
09590      IRECRD=2
09600      4 BUFFERIN (8,1)(IBUF(1),IBUF(IOUT))
09610      IF(UNIT(8))10,5,4
09620      5 STOP 1
09630C
09640C=====
09650C INITIALIZE IOUTPT2 TO 0
09660C=====
09670C
09680      10 DO 15 I=1,216
09690      15 IOUTPT2(I)=IOUTPT2(I).AND.0
09700C
09710C=====
09720C OUTPUT 2 RECORDS OF 216 WORDS:
09730C   REC 1: 8 PREFACE, 16 DUMMIES, NWORD-NUMBER OF NEG DOPPLERS, REST 0
09740C   REC 2: 8 PREFACE, 16 DUMMIES, NWORD-NUMBER OF POS DOPPLERS, REST 0
09750C PRINT DATA AFTER PACKED INTO 2 RECORDS
09760C=====
09770C
09780      DO 45 IR=1,IRECRD

```

TESTSKY (ULCAR)

```

09790C
09800      DO 25 II=1,8
09810      25 IOUTPT2(II)=IBUF(II)
09820C
09830      K=8 $ KK=24
09840      IF(IR.EQ.2)K=8+NWORD
09850      DO 35 J=1,NWORD
09860      35 IOUTPT2(KK+J)=IBUF(K+J)
09870      39 BUFFEROUT(9,1)(IOUTPT2(1),IOUTPT2(216))
09880      IF(UNIT(9))46,40,39
09890      40 STOP 2
09900      46 IF ((KPRINT.AND.1024).EQ.0) GO TO 45
09910      PRINT*," "
09920      IF(IR.EQ.1)PRINT*," PACKED DATA: 1ST RECORD"
09930      IF(IR.EQ.2)PRINT*," PACKED DATA: 2ND RECORD"
09940      IJ=24+NWORD
09950      PRINT 1,(IOUTPT2(I),I=1,IJ)
09960      PRINT*," "
09970      45 CONTINUE
09980      1 FORMAT(6(1X,020))
09990      RETURN $ END

```

A P P E N D I X B

PROGRAM SKYMAP

SKYMAP (ULCAR)

```

00100      PROGRAM SKYMAP(INPUT,TAPE1,OUTPUT,TAPE30
00110+      ,TAPE50,TAPE90,TAPE91,TAPE97,TAPE98,TAPE99)
00120C
00130C=====
00140C GOOSE BAY
00150C CALCULATES SKYMAP FROM DRIFT TAPE DATA, USING THE FREQUENCY-WAVENUMBER
00160C   POWER DENSITY (FWPD).
00170C
00180C
00190C TAPE1: INPUT FOR ALL FUNCTIONS EXCEPT MAPSEQUENCE (KPRINT=128)
00200C TAPE30: OUTPUT FOR KPRINT=4
00210C TAPE50: OUTPUT OF MAPDATA (KPRINT=64)
00220C   INPUT FOR MAPSEQUENCE (KPRINT=128)
00230C TAPE90,91: SCRATCH FILES FOR TEMPORARY STORAGE OF FWMAX(I),
00240C   FM(I,J),PHI(I,J); SEE SUBROUTINE SPLIT
00250C TAPE97,98: OUTPUT OF MAXIMUM AMPLITUDE (KPRINT=8192) OF NEGATIVE
00260C   AND POSITIVE DOPPLERS RESPECTIVELY
00270C   MAX AMPL OF BOTH NEG AND POS DOPPLERS ARE PRINTED OUT
00280C   TOGETHER AT THE SAME TIME AS THEY ARE WRITTEN SEPARATELY
00290C   ON TAPE
00300C TAPE99: SCRATCH FILES FOR TEMPORARY STORAGE OF ARRAYS IB216 AND
00310C   IB216T WHILE SORTING OUT NEG- AND POS-DOPPLER DRIFT DATA
00320C
00330C
00340C EXPLANATION OF KPRINT USAGE (SEE FURTHER COMMENTS WITH EXPLANATION
00350C   OF INPUT PARAMETERS BELOW):
00360C   (COMPATIBLE FUNCTIONS CAN BE CALLED SIMULTANEOUSLY BY SETTING KPRINT
00370C   EQUAL TO THE SUM OF THE INDIVIDUAL KPRINTS)
00380C
00390C KPRINT   PROGRAM FUNCTION:
00400C
00410C   DATA CHECKS
00420C
00430C     1     PRINTS OCTAL DUMP OF RAW DATA.
00440C     8     PRINTS UNPACKED DUMP (IN DECIMAL), WITH MASKED PREFACE.
00450C    256    PRINTS RECORD NUMBER AND MASKED PREFACE.
00460C   1024    PRINTS COMPARISON OF THE PHASES (0 TO 2*PI) AT THE FOUR
00470C           ANTENNAS FOR EACH OF THE FIRST 32 DOPPLERS.
00480C   4096    PRINTS THE AVERAGE OF THE LOG AMPLITUDES OF THE FOUR
00490C           ANTENNAS FOR EACH OF THE FIRST 32 DOPPLERS
00500C    16     PRINTS COMPARISON OF THE LOG AMPLITUDES AT THE FOUR
00510C           ANTENNAS FOR EACH OF THE FIRST 32 DOPPLERS.
00520C           (ALL DATA CHECKS ABOVE ARE COMPATIBLE)
00530C
00540C   8192    PRINTS A GRAPH OF THE MAXIMUM LOG AMPLITUDE AT EACH
00550C           FREQUENCY. (NOT COMPATIBLE WITH ANY OTHER FUNCTION)
00560C    512    ANTENNA CORRELATION THROUGH COMPARISON OF PHASE
00570C           DIFFERENCES. (NOT COMPATIBLE WITH ANY OTHER FUNCTION)
00580C
00590C
00600C   SORTING DRIFT DATA

```

SKYMAP (ULCAR)

00610C
00620C 4 USING INPUT TAPE CONTAINING BOTH IONOGRAM AND DRIFT
00630C DATA, SORTS OUT 252 RECORDS OF DRIFT AND BUFFERS THEM
00640C ONTO TAPE30, WHICH CAN BE SAVED ON FILE. ALSO PRINTS
00650C RECORD NUMBER AND PREFACE.
00660C (NOT COMPATIBLE WITH ANY OTHER FUNCTION)
00670C
00680C
00690C
00700C SKYMAP CALCULATIONS AND PRINTOUTS
00710C
00720C 2 PRINTS SINGLE SKYMAPS, ONE RECORD AT A TIME (NEG OR
00730C POS DOPPLERS), AS THEY ARE CALCULATED. IF BOTH NEG
00740C AND POS DOPPLERS ARE REQUESTED, PRINTS NEG- AND
00750C POS-DOPPLER MAPS SEPARATELY; DOPPLER NUMBERS ARE
00760C REPRESENTED BY NUMERALS ON BOTH MAPS.
00770C 32 PRINTS ANTENNA PATTERNS, FOR THOSE DOPPLERS WHERE THE
00780C ANT. PATTERN CONTAINS NON-ZERO VALUES.
00790C 64 MAPDATA: WRITES FMPD'S, THEIR COORDINATES, AND THEIR CORRES-
00800C PONDING DOPPLER NUMBERS ON TAPE FOR LATER USE IN PRINTING
00810C SKYMAPS (SEE KPRINT 128 BELOW).
00820C 16384 AVERAGE THE RAW DRIFT DATA (IN COMPLEX DOMAIN)
00830C OVER SEVERAL CASES (ADD TO 2,32 OR 64).
00840C (16384 NEEDS TO BE MODIFIED IF TO BE RUN IN BATCH
00850C MODE. PRESENTLY STOPS WHEN TIME CONTINUITY OF CASES
00860C IS BROKEN.)
00870C (ABOVE 4 CALCULATIONS ARE COMPATIBLE; 2 AND/OR 32 CAN BE RUN
00880C FOR A SINGLE FREQUENCY NUMBER AND/OR FOR ONLY NEG OR ONLY
00890C POS DOPPLERS. IF 64 IS RUN, WITH OR WITHOUT 2 AND/OR 32,
00900C ALL FREQUENCY NUMBERS AND BOTH NEG AND POS DOPPLERS
00910C ARE CALCULATED).
00920C
00930C 128 MAPSEQUENCE:
00940C IF REQUEST "FMPD", EACH CASE IS PRINTED ON A SEPARATE
00950C SKY MAP.
00960C IF REQUEST "TIME", COMPRESSES A TIME SEQUENCE OF UP TO
00970C 16 CASES ON ONE MAP (SEE COMMENTS IN SUBROUTINE
00980C MAPSEQ FOR DETERMINATION OF NUMBER OF CASES IN EACH
00990C SEQUENCE); THE FMPD'S ARE REPLACED BY NUMBERS 0 TO 15,
01000C INDICATING THE SEQUENCE OF CASES.
01010C IF REQUEST "BOTH" (BOTH NEG AND POS DOPPLERS),
01020C BOTH ARE PRINTED ON THE SAME MAP, WITH NEG DOPPLERS
01030C REPRESENTED BY NUMERALS, POS DOPPLERS BY LETTERS.
01040C IF REQUEST "NEG" (OR "POS"), ONLY NEG (OR POS)
01050C DOPPLERS ARE PRINTED; POS DOPPLERS ARE STILL
01060C REPRESENTED BY LETTERS.
01070C (INCOMPATIBLE WITH ANY OTHER FUNCTION)
01080C
01090C
01100C EXPLANATION OF INPUT PARAMETERS REQUIRED:
01110C (ALL "QUOTED" PARAMETERS ARE TO BE INPUTTED WITHOUT QUOTES)

SKYMAP (ULCAR)

01120C
 01130C A: KPRINT (SEE ABOVE).
 01140C IF KPRINT=128, IGNORE INPUT PARAMETERS LISTED BELOW; BUT
 01150C SEE SUBROUTINE MAPSEQ FOR OTHER INPUT PARAMETERS.
 01160C
 01170C B: STARTING RECORD NO.:
 01180C INPUT "1" TO START AT BEGINNING OF TAPE1. TO START AT
 01190C A SPECIFIC DRIFT RECORD, FIRST RUN KPRINT=256 TO FIND THE
 01200C RECORD NO. OF THE DRIFT RECORD WANTED.
 01210C WITH KPRINT 64, IF ONE RUN IS NOT SUFFICIENT TO PROCESS
 01220C ALL DRIFT DATA ON TAPE1, CHECK THE END OF THE OUTPUT TO
 01230C DETERMINE THE RECORD NUMBER AT WHICH TO START THE NEXT RUN.
 01240C SKYMAP ONLY PROCESSES DRIFT DATA FOR WHICH IT FINDS BOTH
 01250C RECORDS OF A CASE, SO STARTING RECORD NUMBER MUST BE THAT
 01260C OF THE FIRST RECORD OF THE FIRST CASE WANTED.
 01270C
 01280C C: CPU TIME LIMIT (IN DECIMAL SECONDS):
 01290C USED WITH KPRINT 64. THE TIME IS CHECKED AFTER EACH CASE
 01300C (2 RECORDS, ALL FREQUENCIES). IF THERE ARE 300 OR LESS
 01310C SECONDS LEFT, SKYMAP CALCULATIONS ARE STOPPED AND THE
 01320C RECORD NO. (DECIMAL) AND THE FIRST TWO WORDS (OCTAL) ARE
 01330C PRINTED FOR EACH DRIFT RECORD ON TAPE1 NOT YET PROCESSED,
 01340C UNTIL END OF TAPE OR ONLY 5 CPU SECONDS ARE LEFT.
 01350C
 01360C D: FIRST FREQ. NO., LAST FREQ. NO.:
 01370C E.G. "1,3" FOR FREQUENCIES 1,2,3;
 01380C E.G. "2,2" FOR FREQ. 2;
 01390C E.G. "0" (ZERO) FOR ALL FREQ. NOS., EVEN IF THE NUMBER OF
 01400C FREQUENCIES CHANGES DURING THE RUN.
 01410C
 01420C E: "NEG", "POS", OR "BOTH" DOPPLERS.
 01430C RECORDS NOT CHOSEN ARE IGNORED; EXCEPT THAT FOR KPRINT 2
 01440C OR 32, BOTH RECORDS OF A CASE ARE UNPACKED FOR DETERMINING
 01450C FMAXX (=THE MAXIMUM ESTIMATED FMPD FOR A CASE; SEE SUB-
 01460C ROUTINES SPLIT AND FOU), BUT THE SKYMAPS OR ANTENNA PATTERNS
 01470C ARE CALCULATED ONLY FOR THE DESIRED RECORDS.
 01480C
 01490C F: NO. OF CASES TO BE AVERAGED (ODD NO.); WEIGHT FACTORS:
 01500C USED WITH KPRINT 16384. E.G. "3,1,2,1": EACH CASE IS
 01510C DOUBLED AND AVERAGED WITH ITS NEIGHBORS. FIRST CASE
 01520C (DETERMINED BY "STARTING RECORD NO.") IS NOT CALCULATED;
 01530C CASE 2 WILL BE AVERAGED WITH CASES 1 AND 3; CASE 3 AVE'D
 01540C WITH 2 AND 4; ETC.
 01550C
 01560C G: MINIMUM SOURCE (LOG) AMPLITUDE TO BE USED:
 01570C USED WITH KPRINT=512. PURPOSE: TO CHOOSE ONLY HIGH-
 01580C AMPLITUDE SIGNALS (SOURCES, AS OPPOSED TO NOISE) IN
 01590C DOING ANTENNA CORRELATION.
 01600C
 01610C
 01620C IF RUNNING SKYMAP ON A TERMINAL, THE REQUIRED INPUT PARAMETERS

SKYMAP (ULCAR)

01630C WILL BE REQUESTED BY THE TERMINAL.

01640C

01650C IF A BATCH RUN:

01660C	IF KPRINT INCLUDES	BUT DOES NOT INCLUDE	INPUT
01670C	ONE OR MORE OF THESE	ANY OF THESE	
01680C	1,8,256	16,1024,4096	A,B,E
01690C	1024,4096,16		A,B,D,E
01700C	8192		A,B,D,E
01710C	512		A,B,D,E,G
01720C	4		A,B
01730C	2,32	64,16384	A,B,D,E
01740C	64	16384	A,B,C
01750C	16384	64	A,B,D,E,F
01760C	16384 WITH 64		A,B,C,F
01770C	128		A

01780C (SEE ALSO SUBROUTINE MAPSEG FOR KPRINT 128 INPUT PARAMETERS)

01790C

01800C

01810C ARRAYS X,Y DIMENSIONED FOR ONLY 4 ANTENNAS

01820C

01830C VARIABLE FORMATS (REDEFINED AS NEEDED IN THE PROGRAM) IFORMAT,

01840C JFORMAT, KFORMAT USED WITH KPRINT 512; LFORMAT, WITH KPRINT 8192

01850C=====

01860C

01870 DIMENSION IFORMAT(20),JFORMAT(28),KFORMAT(3),LFORMAT(36)

01880 DIMENSION SUM(6),NUMBR(6,18),AVE(32)

01890 DIMENSION FACT(11),X(64,4,2),IBTEMP(12),Y(64,4,2)

01900 DIMENSION KPTEST(6)

01910 COMMON/PIE/NPI,N2PI,N3PI2,NPI2,TMOPI,PI2,PI512,CSN(257)

01920 COMMON IB2160(2160),JSEQ(7),RJX(7,6),RJY(7,6)

01930+ ,IB216(216),IB216T(216),NANTND(7),MAXFMPD(41,41),IMAX(41,41)

01940+ ,FMPD(41,41),PHI(64,7),FMX(64),FM(64,7),PI,RADIAN,KPRINT

01950+ ,FREQ(6),RANG(6),IGAIN(6),FMXX(6)

01960C

01970 INTEGER SHIFT

01980C

01990 DATA KPTEST/4,128,512,8192,5401,16482/

02000 DATA IFORMAT/4H(T2,,4H*0*,,7HT5,*-*,,3HT6,,4H*0*,,

02010+ 8HT10,*+*,,0,4H*1*,,0,4H*2*,,0,4H*3*,,0,4H*4*,,0,4H*5*,,

02020+ 0,4H*6*,,7H3(/T10,,5H*!*))//

02030 DATA JFORMAT/4H(T3,,8H*NUMBER*,,8HT10,*0*,,4HT19,,0,4HT29,,0,

02040+ 4HT39,,0,4HT49,,0,4HT59,,0,4HT69,,0,4HT79,,0,4HT89,,0,

02050+ 4HT99,,0,5HT109,,0,5HT119,,0,5HT129,,0,1H)/

02060 DATA KFORMAT/8H(9X,*+*,,9H12(*----*,,10H*-----+*))//

02070 DATA LFORMAT/9H(T22,*!*,,8HT32,*!*,,8HT42,*!*,,8HT52,*!*,,

02080+ 8HT62,*!*,,8HT72,*!*,,8HT82,*!*,,8HT92,*!*,,

02090+ 9HT102,*!*,,9HT112,*!*,,9HT122,*!*,,3HT2,,0,4H,T7,,

02100+ 0,5H,T13,,0,6*(2H,T,1H1,1H),1H)/

02110 REWIND 1

02120 REWIND 30

02130 REWIND 50

SKYMAP (ULCAR)

```

02140      REWIND 97
02150      REWIND 98
02160      REWIND 99
02170C
02180      CALL SECOND (START)
02190      PRINT 10
02200      10 FORMAT(*1*)
02210      PRINT*," START TIME (SECONDS)=" ,START
02220      PRINT*," "
02230C
02240      PI=2.*ASIN(1.)
02250      RADIAN=.0174532925199433
02260C
02270C=====
02280C RADIAN=RADIANS/DEGREE
02290C
02300C READ INPUT PARAMETERS
02310C KPRINT 30258=2+16+32+512+1024+4096+8192+16384
02320C KPRINT 30523=1+2+8+16+32+256+512+1024+4096+8192+16384
02330C=====
02340C
02350      MDTFLAG=0
02360      IALL=0
02370      NSIGN=3
02380C
02390      PRINT*," KPRINT?"
02400      READ*,KPRINT
02410C
02420      DO 15 I=1,5
02430      JI=I+1
02440      DO 15 J=JI,6
02450      IF(((KPRINT.AND.KPTEST(I)).EQ.0).OR.
02460+      ((KPRINT.AND.KPTEST(J)).EQ.0)) GO TO 15
02470      PRINT*," INCOMPATIBLE KPRINTS"
02480      STOP
02490      15 CONTINUE
02500C
02510      IF(KPRINT.EQ.128) CALL MAPSEQ
02520C
02530C===== REST OF MAIN PROGRAM NOT USED IF KPRINT=128 =====
02540C
02550      PRINT*," STARTING RECORD NO.?"
02560      READ*,IREC
02570C
02580      IF((KPRINT.AND.64).EQ.0) GO TO 20
02590      PRINT*," CPU TIME LIMIT (DECIMAL SECONDS)?"
02600      READ*,TOTAL
02610      PRINT 18
02620      18 FORMAT(*1*//1X,7B(" ")/1X,7B(" ")/1X,"PREFACE FORMAT:"/
02630+      3X,"REC STAT",39X,"FREQ"/3X,"NO.",2X,"NO.",
02640+      " DATE TIME UUUS UUUU RWTT GNXZ UUUU NO.",

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SKYMAP (ULCAR)

```

02650+      " FREQ   RANGE GAIN"//1X,"U: UNUSED"/
02660+      1X,"S: 1 FOR NEG. DOPPLERS, 2 FOR POS. DOPPLERS"/
02670+      1X,"(S IS NOT IN ORIGINAL PREFACE; DEFINED BY SKYMAP",
02680+      " PROGRAM)"//1X,78("**")/1X,78("**")///)
02690C
02700      20 IF((KPRINT.AND.68).NE.0) GO TO 50
02710C
02720      IF((KPRINT.AND.30258).EQ.0) GO TO 30
02730      PRINT*," FIRST FREQ. NO., LAST FREQ. NO.?"
02740      PRINT*,"      (OR 0 (ZERO) FOR ALL FREQ. NOS.)"
02750      READ*,IALL
02760      IF(IALL.EQ.0) GO TO 30
02770      IBEGIN=IALL
02780      READ*,IEND
02790C
02800      30 IF((KPRINT.AND.30523).EQ.0) GO TO 50
02810      PRINT*," NEG, POS, OR BOTH DOPPLERS?"
02820      READ 40,NSIGN
02830      40 FORMAT(A4)
02840      IF(NSIGN.EQ."NEG")NSIGN=1
02850      IF(NSIGN.EQ."POS")NSIGN=2
02860      IF(NSIGN.EQ."BOTH")NSIGN=3
02870      IF((KPRINT.AND.34).EQ.0) GO TO 50
02880      NSIG=NSIGN
02890      NSIGN=3
02900C
02910      50 IF((KPRINT.AND.16384).EQ.0) GO TO 55
02920      PRINT*," NO. OF CASES TO BE AVERAGED (ODD NO.);",
02930+      " WEIGHT FACTORS?"
02940      READ*,NCASES,(FACT(I),I=1,NCASES)
02950      MDL=FLOAT(NCASES)/2.+.5
02960      NCASE=0
02970C
02980      55 IF((KPRINT.AND.8192).EQ.0) GO TO 70
02990      PRINT 60 $ WRITE(97,60) $ WRITE(98,60)
03000      60 FORMAT(/T22,*0*,T41,*10*,T61,*20*,T81,*30*,T101,*40*,
03010+      T121,*50*)
03020C
03030      70 IF((KPRINT.AND.512).EQ.0) GO TO 80
03040      PRINT*," MINIMUM SOURCE (LOG) AMPLITUDE TO BE USED?"
03050      READ*,FMIN
03060      DO 75 M=1,6
03070      DO 75 N=1,18
03080      75 NUMB(M,N)=0
03090      MAXNUM=0
03100C
03110      80 IR=0
03120      DO 100 K=1,6
03130      100 SUM(K)=0
03140C
03150C=====

```

SKYMAP (ULCAR)

```

03160C CALCULATE COSINE TABLE FOR 0 TO PI/2, IN INCREMENTS OF 2PI/1024
03170C KPRINT 98=2+32+64
03180C=====
03190C
03200      IF((KPRINT.AND.98).EQ.0) GO TO 120
03210      NPI=512 $ N2PI=2*NPI $ N3PI2=3*NPI/2 $ NPI2=NPI/2
03220      TWOPI=2.*PI $ PI2=PI/2. $ PI512=PI/512.
03230      CSN(1)=1. $ CSN(257)=0.
03240      DO 110 MN=2,256
03250      110 CSN(MN)=COS(FLOAT(MN-1)*PI512)
03260C
03270C=====
03280C INPUT DRIFT DATA WITH BUFFERIN FROM TAPE 1
03290C
03300C IF "16" BIT NOT ON IN PREFACE, DATA IS NOT DRIFT DATA;
03310C   BUFFERIN NEXT RECORD
03320C
03330C IF BUFFERING OUT DATA ONTO TAPE30 (KPRINT=4), STOP AFTER 252
03340C   RECORDS TO AVOID EXCEEDING PRU LIMIT
03350C=====
03360C
03370      120 IF(IREC.EQ.1) GO TO 135
03380      LSKIP=IREC-1
03390      DO 130 ISKIP=1,LSKIP
03400      BUFFERIN(1,1)(IB216(1),IB216(1))
03410      IF(UNIT(1)) 130,135,130
03420      130 CONTINUE
03430C
03440      135 DO 1290 NMAP=IREC,10000
03450      IF((IR.GT.252).AND.((KPRINT.AND.4).NE.0)) STOP
03460      140 BUFFERIN (1,1)(IB216(1),IB216(216))
03470      IF (UNIT(1)) 280,150,140
03480      150 IF(KPRINT.AND.512)160,270
03490C
03500C=====
03510C STOP AT END OF DRIFT DATA TAPE, UNLESS DOING ANTENNA CORRELATION
03520C   (KPRINT=512), IN WHICH CASE PRINT OUT THE RESULTS
03530C=====
03540C
03550      160 K=0
03560CCC      NMINUS1=NANT-1
03570CCC      DO 180 J=1,NMINUS1
03580CCC      JPLUS1=J+1
03590CCC      DO 180 JJ=JPLUS1,NANT
03600CCC      K=K+1
03610CCC      PRINT 170,(J,JJ,(NUMBR(K,IDELPHI),IDELPHI=1,18))
03620CCC      170 FORMAT(/1X,*PHI(*,I1,*,*,I1,*)*,2X,18I6)
03630CCC      180 CONTINUE
03640C
03650      PRINT 185
03660      185 FORMAT(////* SUM OF THE SQUARE OF THE PHASE DIFFERENCES*,

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SKYMAP (ULCAR)

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03670+      * (RADIAN) BETWEEN ANTENNA PAIRS*/)
03680C
03690      PRINT 190,(SUM(K),K=1,6)
03700      190 FORMAT(*      1-2      1-3      1-4      2-3      *,
03710+      *2-4      3-4*/8(F9.1)////)
03720C
03730      MAXNUM=((MAXNUM/12)+1)*12
03740      JVF=3
03750      DO 230 M=10,120,10
03760      JVF=JVF+2
03770      MM=IFIX(FLOAT(MAXNUM*M)/120.)
03780      IF(MM.GT.99) GO TO 210
03790      ENCODE(5,200,JFORMAT(JVF))MM
03800      200 FORMAT(1H*,I2,2H*,)
03810      GO TO 230
03820C
03830      210 ENCODE(6,220,JFORMAT(JVF))MM
03840      220 FORMAT(1H*,I3,2H*,)
03850      230 CONTINUE
03860C
03870      PRINT 235
03880      235 FORMAT(* NUMBER OF OCCURRENCES OF INDICATED PHASE *,
03890+      *DIFFERENCES AT ANTENNA PAIRS 1-2,....,3-4,*,
03900+      *REPRESENTED BY 1,....,6*/)
03910      PRINT JFORMAT
03920      PRINT KFORMAT
03930      PRINT*," DEGREES!"
03940      PRINT*," PHASE !"
03950      ND=-10
03960      DO 260 IDELPHI=1,18
03970      IVF=5
03980      ND=ND+10      $ NT=ND+10
03990      ENCODE(10,220,IFORMAT(2))ND
04000      ENCODE(10,220,IFORMAT(5))NT
04010      DO 250 K=1,6
04020      IVF=IVF+2
04030      FRCTN=FLOAT(NUMBR(K, IDELPHI))/FLOAT(MAXNUM)
04040      NN=FRCTN*120.+10.5
04050      ENCODE(10,240,IFORMAT(IVF))NN
04060      240 FORMAT(1HT,I3,1H,)
04070      250 CONTINUE
04080C      PRINT*,(IFORMAT(KJK),KJK=1,18)
04090      PRINT IFORMAT
04100      260 CONTINUE
04110C
04120      270 PRINT*," "
04130      IF((KPRINT.AND.8192).NE.0)PRINT*," NEG. DOPP. ON TAPE 97;",
04140+      " POS. DOPP. ON TAPE 98."
04150      PRINT*," "
04160      PRINT*," STOPPED AT END OF TAPE1."
04170      STOP

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SKYMAP (ULCAR)

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04180C
04190 280 IF((IB216(1).AND.16).EQ.0) GO TO 1290
04200C
04210C=====
04220C TEMPORARILY SORT OUT NEG DOPPLERS INTO IB216T AND POS
04230C DOPPLERS INTO IB216
04240C=====
04250C
04260 IF((IB216(1).NE.IB216T(1)).OR.
04270+ (IB216(2).NE.IB216T(2))) GO TO 310
04280 IR=IR+2
04290 GO TO 320
04300 310 CALL MOVLEV (IB216,IB216T,216)
04310 GO TO 1290
04320C
04330 320 REWIND 99
04340C
04350 330 BUFFEROUT(99,1)(IB216T(1),IB216T(216))
04360 IF(UNIT(99)) 350,350,330
04370 350 BUFFEROUT (99,1)(IB216(1),IB216(216))
04380 IF(UNIT(99)) 360,360,350
04390 360 REWIND 99
04400C
04410C
04420C
04430 DO 1230 IJ=1,2
04440 390 BUFFERIN(99,1)(IB216(1),IB216(216))
04450 IF(UNIT(99)) 400,400,390
04460C
04470C=====
04480C UNPACK 2160 6-BIT CHARACTERS FROM 216 60-BIT WORDS;
04490C PUT "1" FOR NEG, "2" FOR POS INTO PREFACE (IB2160(16))
04500C=====
04510C
04520 400 DO 410 IM=1,216
04530 DO 410 IBY=1,10
04540 IB=10*IM+IBY-10 $ IBB=IBY*6
04550 410 IB2160(IB)=63.AND.SHIFT(IB216(IM),IBB)
04560 ISIGN=IB2160(16)=IJ
04570C
04580 IF(NSIGN.EQ.3.AND.ISIGN.EQ.1) NCASE=NCASE+1
04590 IF(NSIGN.EQ.3) GO TO 420
04600 IF(ISIGN.NE.NSIGN) GO TO 1230
04610 NCASE=NCASE+1
04620 420 IF(NCASE.GT.NCASES) NCASE=1
04630C
04640C=====
04650C OCTAL DUMP
04660C=====
04670C
04680 IF((KPRINT.AND.1).EQ.0) GO TO 440

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SKYMAP (ULCAR)

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04680      PRINT 430,(IB216(I),I=1,216)
04700      430 FORMAT (6(1X,020))
04710      PRINT*," "
04720C=====
04730C MASK PREFACE
04740C=====
04750C
04760      440 DO 450 K=1,80
04770          IB216(K)=IB216(K).AND.15
04780      450 CONTINUE
04790          IB216(7)=IB216(7).AND.3
04800          IB216(8)=IB216(8).AND.3
04810          IB216(9)=IB216(9).AND.7
04820          IB216(11)=IB216(11).AND.7
04830C
04840C=====
04850C BUFFER OUT DRIFT DATA ONTO TAPE 30 (KPRINT=4)
04860C      AND PRINT RECORD # AND PREFACE
04870C=====
04880C
04890          IF(KPRINT.NE.4) GO TO 480
04900          IRR=IR-1 $ NRR=NMAP-1
04910          IF(IJ.EQ.2)IRR=IRR+1 $ IF(IJ.EQ.2)NRR=NRR+1
04920          PRINT 460,IRR,NRR,(IB216(M),M=1,80)
04930      460 FORMAT(1X,2I6,I3,1X,5I1,1X,6I1,17(1X,4I1))
04940      470 BUFFEROUT(30,1) (IB216(1),IB216(216))
04950          IF(UNIT(30))1230,1230,470
04960C
04970C=====
04980C PRINT RECORD NUMBER AND MASKED PREFACE
04990C=====
05000C
05010      480 IF(KPRINT.AND.256)490,510
05020      490 PRINT 500,(NMAP-2+IJ),(IB216(I),I=1,80)
05030      500 FORMAT(1X,I6,1X,I3,1X,5(I1),1X,6(I1),17(1X,4(I1)))
05040C
05050C=====
05060C PRINT UNPACKED DUMP, WITH MASKED PREFACE
05070C=====
05080C
05090      510 IF(KPRINT.AND.8)520,540
05100      520 PRINT 530,(IB216(I),I=1,216)
05110      530 FORMAT(54(1X,40I3/))
05120C
05130      540 IF(KPRINT.EQ.1.OR.KPRINT.EQ.8.OR.KPRINT.EQ.256.OR.KPRINT.EQ.
05140+      4) GO TO 1230
05150C
05160C=====
05170C DECODE PREFACE IF NOT ALREADY DECODED FOR THIS CASE
05180C=====
05190C

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SKYMAP (ULCAR)

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05200      IF((NSIGN.EQ.3).AND.(ISIGN.EQ.2)) GO TO 698
05210C
05220      IVSTAT=IB2160(1)
05230      IYEAR=10*IB2160(2)+IB2160(3)
05240      LDAY=IDAY $ LHR=IHR $ LMIN=IMIN $ LSEC=ISEC
05250      IDAY=100*IB2160(4)+10*IB2160(5)+IB2160(6)
05260      IHR=10*IB2160(7)+IB2160(8)
05270      IMIN=10*IB2160(9)+IB2160(10)
05280      ISEC=10*IB2160(11)+IB2160(12)
05290      IREP=50+((IB2160(21).AND.2)*25+((IB2160(21).AND.4)*75)/2
05300+      +((IB2160(21).AND.2)*(IB2160(21).AND.4)*75)/4
05310C
05320C=====
05330C IDB=20 FOR 1 DB INCREMENTS
05340C IDB=40 FOR 1/2 DB INCREMENTS
05350C ITT=TASK (FOR ANTENNA SEQUENCE SPECIFICATION; SEE SUBROUTINE ANT)
05360C      GOOSE BAY: ITT=0
05370C IN: PROGRAM NUMBER
05380C=====
05390C
05400      IDB=(IB2160(22).AND.4)*5+20
05410      ITT=0
05420CCC      ITT=10*IB2160(23)+(IB2160(24).AND.3)
05430      IQ=IB2160(25)
05440      IN=IB2160(26)
05450C
05460C=====
05470C IF AVERAGING DATA OVER SEVERAL CASES(KPRINT=16384),
05480C      STOP IF TIME CONTINUITY OF CASES IS BROKEN; OTHERWISE,
05490C      STORE DATE AND TIME (BOTH DECODED AND NON-DECODED FORMS)
05500C      IF THIS IS THE MIDDLE CASE
05510C=====
05520C
05530      IF(((KPRINT.AND.16384).EQ.0).OR.
05540+      ((NMAP-IREC).LE.2)) GO TO 600
05550      KASESEQ=10
05560      IF(IN.EQ.6.OR.IN.EQ.9)KASESEQ=18 $ IF(IN.EQ.7)KASESEQ=34
05570      IF((IDAY-LDAY).GT.1) GO TO 570
05580      IIHR=IHR+24*(IDAY-LDAY)
05590      IF((IIHR-LHR).GT.1) GO TO 570
05600      IIMIN=IMIN+60*(IIHR-LHR)
05610      IF((IIMIN-LMIN).GT.1) GO TO 570
05620      IISEC=ISEC+60*(IIMIN-LMIN)
05630      IF((IISEC-LSEC).GT.KASESEQ) GO TO 570
05640      GO TO 580
05650      570 PRINT*,"SEQUENCE OF CASES NOT CONTINUOUS." $ STOP
05660      580 IF(NCASE.NE.MDL) GO TO 600
05670      MDLYR=IYEAR $MDLDAY=IDAY $MDLHR=IHR
05680      MDLMIN=IMIN $MDLSEC=ISEC
05690      DO 590 I=1,12
05700      590 IBTEMP(I)=IB2160(I)

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SKYMAP (ULCAR)

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05710C
05720C=====
05730C FREQUENCY IN PREFACE IN 10 KHZ UNITS; CONVERTED TO FREQ(K) IN KHZ
05740C RANGE IN KM
05750C
05760C IF KPRINT=16384, STOP IF FREQ, RANGE, OR GAIN CHANGES; OR IF RANGE
05770C   GREATER THAN 510 KM
05780C
05790C IF RANGE G.T. 510 AND KPRINT NOT 16384, SKIP THAT RECORD AND CONTINUE
05800C=====
05810C
05820   600 DO 595 K=1,6
05830       RANG(K)=0.
05840       FREQ(K)=0.
05850   595 IGAIN(K)=0
05860       KL=6
05870       IF(IN.GE.8) KL=3
05880C
05890       DO 670 K=1,KL
05900       RA=RANG(K) $ IGA=IGAIN(K) $ FRE=FREQ(K)
05910       FREQ(K)=12.5 $ RANG(K)=0.
05920       DO 620 KK=1,4
05930       KKK=4*K-KK+33 $ KK10=10*K*KK $ KKKK=4*K-KK+56
05940       IF(KK.EQ.1) IGAIN(K)=(-10)*IB2160(KKKK+1)
05950       FKK =IB2160(KKK)*KK10
05960       FREQ(K)=FREQ(K)+FKK
05970       IF(KK.EQ.4)GO TO 620
05980       FKK=IB2160(KKKK)*KK10
05990       RANG(K)=RANG(K)+.15*FKK
06000   620 CONTINUE
06010       IF(IG.EQ.5.AND.((K/2)*2).EQ.K)630,640
06020   630 FREQ(K)=FREQ(K-1)
06030       RANG(K)=RANG(K-1)
06040C
06050   640 IF(RANG(K).GT.510.)650,660
06060   650 PRINT*,"RANGE(",K,") IS TOO HIGH; RANGE=",RANG(K)
06070       IF((KPRINT.AND.16384).NE.0) STOP
06080       PRINT*,"RECORDS ",(NMAP-1)," AND ",(NMAP)," SKIPPED. "
06090       GO TO 1290
06100   660 IF((KPRINT.AND.16384).EQ.0.OR.(RA.EQ.RANG(K).AND.IGA.EQ.
06110+   IGAIN(K).AND.FRE.EQ.FREQ(K)).OR.(NMAP-IREC).LE.2) GO TO 670
06120       PRINT*," CHANGE OF FREQ, RANGE OR GAIN." $ STOP
06130C
06140   670 CONTINUE
06150C
06160       CALL ANT(IFF,ITT,IN,NF,NANT,NDOPP,SINZMAX,1)
06170C
06180       IF(IVSTAT.EQ.0) NF=1
06190       DO 690 K=NF,6
06200       IF (K.EQ.NF.OR.NF.EQ.6) GO TO 690
06210       RANG(K)=0. $ FREQ(K)=0.

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SKYMAP (ULCAR)

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06220      690 CONTINUE
06230C
06240      IF(IALL.NE.0) GO TO 694
06250      IBEGIN=1
06260      IEND=NF
06270      GO TO 698
06280      694 IF((IBEGIN.NE.IEND).OR.
06290+      (IEND.LE.NF)) GO TO 696
06300      PRINT*," NO FREQ. NUMBER ",IEND," IN PROGRAM NUMBER ",IN
06310      STOP
06320      696 IF(IEND.LE.NF) GO TO 698
06330      PRINT*," 'LAST FREQ. NO.' ",IEND," IS TOO HIGH FOR "
06340      PRINT*," PROGRAM NO. ",IN,"; HAS BEEN RESET TO ",NF
06350      IEND=NF
06360C
06370      698 KX=16
06380      DO 1170 IFF=IBEGIN,IEND
06390      IF(FREQ(IFF).LE.12.5) GO TO 1170
06400C
06410C
06420      IF(((KPRINT.AND.98).EQ.0).OR.(ISIGN.EQ.1))
06430+      CALL ANT(IFF,ITT,IN,NF,NANT,NDOPP,SINZMAX,2)
06440C
06450      CALL SPLIT(NDOPP,NANT,IFF,IDB,ISIGN,IBEGIN)
06460      IF((KPRINT.AND.16384).EQ.0) GO TO 820
06470C
06480C=====
06490C AVERAGE THE RAW DRIFT DATA (IN COMPLEX DOMAIN) OVER SEVERAL CASES
06500C (KPRINT=16384). NO. OF CASES (MUST BE ODD NO.) AND THE WEIGHT FACTOR
06510C OF EACH IS ASKED FOR AT BEGINNING OF PROGRAM.
06520C=====
06530C
06540      IF((NCASE.NE.1).OR.(NSIGN.EQ.3.AND.ISIGN.NE.1))GO TO 750
06550C
06560      DO 740 I=1,NDOPP
06570      DO 740 J=1,NANT
06580      DO 740 K=1,2
06590      740 X(I,J,K)=Y(I,J,K)=0
06600C
06610      750 DO 760 I=1,NDOPP
06620      DO 760 J=1,NANT
06630      X(I,J,ISIGN)=FACT(NCASE)*FM(I,J)*COS(PHI(I,J))+X(I,J,ISIGN)
06640      760 Y(I,J,ISIGN)=FACT(NCASE)*FM(I,J)*SIN(PHI(I,J))+Y(I,J,ISIGN)
06650C
06680      IF(NCASE.LT.NCASES) GO TO 1170
06670C
06680      DIV=0
06690      DO 770 L=1,NCASES
06700      770 DIV=DIV+FACT(L)
06710C
06720      DO 780 I=1,NDOPP

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SKYMAP (ULCAR)

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06730      DO 790 J=1,NANT
06740      FM(I,J)=SQRT((X(I,J,ISIGN))**2+(Y(I,J,ISIGN))**2)/DIV
06750      IF(X(I,J,ISIGN).EQ.0.0) GO TO 780
06760      PHI(I,J)=ATAN2(Y(I,J,ISIGN),X(I,J,ISIGN))
06770      GO TO 790
06780      780 PHI(I,J)=0
06790      790 CONTINUE
06800C
06810      IYEAR=MDLYR $IDAY=MDLDAY $ IHOURL=MDLHR
06820      IMIN=MDLMIN $ISEC=MDLSEC
06830      DO 800 I=1,12
06840      800 IB2160(I)=IBTEMP(I)
06850C
06860      IF(NSIGN.EQ.3.AND.ISIGN.NE.2) GO TO 820
06870      NCAS=2*NCASES-2
06880      DO 810 I=1,NCAS
06890      810 BACKSPACE 1
06900C
06910C=====
06920C TO PRINT THE AVERAGE OF THE LOG AMPLITUDES ON THE 4 ANT.AT EACH
06930C DOPPLER (KPRINT=4096) AND/OR PRINT THE MAXIMUM LOG AMPLITUDE OF
06940C EACH FREQ. (KPRINT=8192) AND/OR COMPARE LOG AMPLITUDES (KPRINT=16)
06950C AND/OR PHASES IN DEG (KPRINT=1024) OF EACH DOPPLER ON THE 4 ANT.
06960C (FIRST 32 DOPP ONLY FOR 4096,16,1024; 8192 PRINTED AFTER "DO 1170" LOOP)
06970C
06980C KPRINT 13328=16+1024+4096+8192
06990C KPRINT 1040=16+1024
07000C=====
07010C
07020      820 IF((KPRINT.AND.13328).EQ.0) GO TO 950
07030      LSIGN="NEG" $ IF(IJ.EQ.2) LSIGN="POS"
07040C
07050      IF((KPRINT.AND.4096).EQ.0) GO TO 850
07060      DO 830 I=1,32
07070      AVE(I)=0.
07080      DO 825 J=1,NANT
07090      825 AVE(I)=AVE(I)+FM(I,J)
07100      830 AVE(I)=AVE(I)/NANT
07110      PRINT 840,(IB2160(I),I=2,12),FREQ(IFF),RANG(IFF),LSIGN,
07120+      ((IFIX(AVE(I))),I=1,32)
07130      840 FORMAT(1X,5I1,1X,6I1,1X,2(F6.1),1X,A3,3X,32I3)
07140      IF((KPRINT.AND.1040).EQ.0.AND.IFF.EQ.IEND) PRINT*," "
07150C
07160      850 IF((KPRINT.AND.8192).EQ.0) GO TO 890
07170      XAM=0
07180      DO 860 I=1,NDOPP
07190      DO 860 J=1,NANT
07200      860 XAM=AMAX1(XAM,FM(I,J))
07210      KX=KX+3
07220      NXAM=2*IFIX(XAM)+22
07230      ENCODE(4,870,LFORMAT(KX))NXAM

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SKYMAP (ULCAR)

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07240 870 FORMAT(I3,1H,)
07250 ENCODE(3,880,LFORMAT(KX+1))IFF
07260 880 FORMAT(1H*,I1,1H*)
07270C
07280 890 IF(KPRINT.AND.16)900,920
07290 900 PRINT 910,(IB2160(I),I=2,12),FREQ(IFF),RANG(IFF),LSIGN,
07300+ ((IFIX(FM(I,J)),I=1,32),J=1,NANT)
07310 910 FORMAT(1X,5I1,1X,6I1,1X,2(F6.1),1X,A3,3X,32I3/,6(33X,32I3/))
07320C
07330 920 IF(KPRINT.AND.1024)930,1170
07340 930 IF((KPRINT.AND.16).EQ.0) PRINT 910,(IB2160(I),I=2,12),
07350+ FREQ(IFF),RANG(IFF),LSIGN
07360 PRINT 940,(((FIX(PHI(I,J)/RADIAN)),I=1,32),J=1,NANT)
07370 940 FORMAT(7(1X,32I4/))
07380 GO TO 1170
07390C
07400C=====
07410C CHECK ANTENNA CORRELATION (KPRINT=512).
07420C K=1,...,6 REPRESENTS ANTENNA PAIRS 1-2,1-3,1-4,2-3,2-4,3-4.
07430C SUM(K) IS THE SUM OF THE SQUARE OF THE PHASE DIFFERENCES (IN RADIAN)
07440C BETWEEN BOTH ANTENNAS OF A PAIR.
07450C NUMBR(K,IDELPHI) COUNTS FOR EACH ANTENNA PAIR THE NUMBER OF TIMES THE
07460C PHASE DIFFERENCE IS THE ABSOLUTE VALUE OF 0-10,10-20,...,170-180
07470C DEGREES (FOR -180 TO +180 DEGREES).
07480C THE PHASES ARE COMPARED AT ALL DOPPLER NUMBERS WHOSE AMPLITUDES ARE
07490C AT LEAST FMIN ON ALL ANTENNAS, FOR POS, NEG, OR BOTH TYPES OF
07500C DOPPLERS (ACCORDING TO THE CHOICE INDICATED AT THE BEGINNING OF
07510C THE RUN) AND FOR THE FREQUENCY NUMBER(S) INPUTTED AT THE BEGINNING
07520C OF THE RUN.
07530C THE RESULTS ARE PRINTED WHEN TAPE1 RUNS OUT OF DATA
07540C (SEE STATEMENT 160 ABOVE).
07550C=====
07560C
07570 950 IF((KPRINT.AND.512).EQ.0) GO TO 1010
07580C
07590 DO 990 I=1,NDOPP
07600 DO 970 II=1,NANT
07610 970 IF(FM(I,II).LT.FMIN) GO TO 990
07620 K=0
07630 NMINUS1=NANT-1
07640 DO 980 J=1,NMINUS1
07650 JPLUS1=J+1
07660 DO 980 JJ=JPLUS1,NANT
07670 K=K+1
07680 SUM(K)=SUM(K)+(PHI(I,J)-PHI(I,JJ))*2
07690 DELPHI=ABS((PHI(I,J)-PHI(I,JJ))/(RADIAN*10.))
07700 IF(DELPHI.GT.18.) DELPHI=ABS(DELPHI-36.)
07710 IDELPHI=IFIX(DELPHI+1.) * IF(IDELPHI.EQ.19)IDELPHI=18
07720 NUMBR(K,IDELPHI)=NUMBR(K,IDELPHI)+1
07730 980 MAXNUM=MAX0(MAXNUM,NUMBR(K,IDELPHI))
07740 990 CONTINUE

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SKYMAP (ULCAR)

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07750      GO TO 1170
07760C
07770C=====
07780C CALL FOU TO CALCULATE FWP
07790C
07800C KPRINT 98=2+32+64
07810C=====
07820C
07830 1010 IFOU2=1
07840      IF((KPRINT.AND.98).EQ.0) GO TO 1020
07850      IF(ISIGN.EQ.1) GO TO 1170
07860      IFOU2=2
07870C
07880 1020 DO 1165 IFOU=1,IFOU2
07890      IF((KPRINT.AND.98).EQ.0) GO TO 1040
07900      IF(((KPRINT.AND.34).NE.0).AND.
07910+      ((NSIG.AND.ISIGN).EQ.0)) GO TO 1040
07920C
07930CCC      DPTIM=SECOND(CO)
07940CCC      PRINT*,"START FOU=",DPTIM
07950      CALL FOU(ISIGN,NDOPP,NANT,IFF,IBEGIN,IFOU)
07960CCC      DPTIM=SECOND(CP)
07970CCC      PRINT*,"END FOU=",DPTIM
07980      IF((KPRINT.AND.64).NE.0) CALL MAPDATA(IFF,MDTFLAG,IFOU,NMAP)
07990 1040 IF((KPRINT.AND.2).EQ.0) GO TO 1165
08000      IF(((KPRINT.AND.2).NE.0).AND.
08010+      ((NSIG.AND.ISIGN).EQ.0)) GO TO 1165
08020C
08030C=====
08040C OUTPUT SKYMAP
08050C ZMAX=ZENITH ANGLE OF FURTHEST K VECTOR IN SKYMAP
08060C (AT THE CORNERS OF THE SQUARE MAP)
08070C RADIAN=RADIANS/DEGREE)
08080C SCALE=INCREMENT OF SKYMAP COORDINATES IN KM
08090C=====
08100C
08110C
08120C===== MAP HEADING FOR KPRINT 2 =====
08130 1050 PRINT 1110,(K,K=1,6),IVSTAT,IYEAR,IDAY,IHOUR,
08140+      IMIN,ISEC,IREF,IDB,NDOPP,NANT,FREQ,IFF,
08150+      FREQ(IFF),RANG(IFF),RANG,(NANTNO(K),K=1,NANT),IGAIN
08160C
08170      CALL PRIN(IN,ISIGN,IFWP,SINZMAX,IFF)
08180C
08190 1110 FORMAT(1H1,10X*VSTAT YEAR DAY HOUR MIN SEC REP IDB NDOPP *,
08200+      *NANT NF*,4X,6(I4,4X)/8X,2I6,I5,3I4,I5,I4,2I5
08210+      * FREQ*6F8.1* KHZ*/11X*FREQ. NO. *
08220+      I1*, AT*F8.1* KHZ; RANGE=*F7.1,* KM *,*RANG*6F8.1
08230+      * KM*/11X*ANTENNA SEQUENCE *4I3,17X*GAIN*I6,5I8* DB*)
08240C
08250C

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SKYMAP (ULCAR)

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08260C
08270 1165 CONTINUE
08280 1170 CONTINUE
08290C
08300C=====
08310C PRINT THE MAXIMUM LOG AMPLITUDE FOR EACH FREQUENCY (KPRINT=8192)
08320C=====
08330C
08340      IF((KPRINT.AND.8192).EQ.0) GO TO 1230
08350      LSIGN="NEG"  $ IF(IJ.EQ.2) LSIGN="POS"
08360      ENCODE(6,1180,LFORMAT(13))LSIGN
08370 1180 FORMAT(1H*,A3,2H*,)
08380      ENCODE(7,1190,LFORMAT(15))(IB2160(K),K=2,6)
08390 1190 FORMAT(1H*,5I1,1H*)
08400      ENCODE(10,1200,LFORMAT(17))(IB2160(K),K=7,12)
08410 1200 FORMAT(1H*,2I1,I2,I1,I2,I1,1H*)
08420      IF(IB2160(16).EQ.2) GO TO 1210
08430      WRITE(97,LFORMAT)  $ GO TO 1220
08440 1210 WRITE(98,LFORMAT)
08450 1220 PRINT LFORMAT
08460      IF(IB2160(16).EQ.2) PRINT*,"  "
08470C
08480 1230 CONTINUE
08490C
08500      IF((KPRINT.AND.64).EQ.0) GO TO 1290
08510      CALL SECOND(ACTUAL)
08520      IF((TOTAL-(ACTUAL-START)).GT.300.0) GO TO 1290
08530C
08540      NREC=NMAP
08550      PRINT 1240
08560 1240 FORMAT(///1X,*RECORD NO. AND FIRST 2 WORDS OF EACH*,
08570+      * DRIFT RECORD NOT YET PROCESSED:*/)
08580 1250 BUFFERIN(1,1)(IB216(1),IB216(2))
08590      IF(UNIT(1)) 1260,270,1250
08600 1260 NREC=NREC+1
08610      IF((IB216(1).AND.16).NE.0)
08620+      PRINT 1270,NREC,IB216(1),IB216(2)
08630 1270 FORMAT(1X,I6,2(1X,020))
08640      CALL SECOND(ACTUAL)
08650      IF((TOTAL-(ACTUAL-START)).GT.5.0) GO TO 1250
08660      PRINT 1280
08670 1280 FORMAT(///1X,*RAN OUT OF TIME; THERE MAY BE MORE*,
08680+      * DRIFT DATA ON TAPE1.*/)
08690      STOP
08700C
08710 1290 CONTINUE
08720C
08730      STOP
08740      END
08750C
08760C

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SKYMAP (ULCAR)

```

08770C
08780C
08790C
08800      SUBROUTINE ANT(IFF,ITT,IN,NF,NANT,NDOPP,SINZMAX,NUM)
08810C
08820      INTEGER AN
08830      DIMENSION ANTY(7),ANTX(7),AN(5,8)
08840      COMMON IB2160(2160),JSEQ(7),RJX(7,6),RJY(7,6)
08850+      ,IB216(216),IB216T(216),NANTNO(7),MAXFWPD(41,41),IMAX(41,41)
08860+      ,FWPD(41,41),PHI(64,7),FWMAX(64),FM(64,7),PI,RADIAN,KPRINT
08870+      ,FREQ(6),RANG(6),IGAIN(6),FWMAXX(6)
08880C
08890C=====
08900C ANTENNA COORD IN METERS
08910C      ANTY= Y COORD
08920C      ANTX= X COORD
08930C      X AXIS=NORTH=AZIMUTH ZERO DEG
08940C      (-Y) AXIS=EAST=AZIMUTH 90 DEG
08950C=====
08960C
08970      DATA ANTY /0.,57.73502,-28.86751,-28.86751,
08980+      0.,28.86751,-28.86751/
08990      DATA ANTX /0.,0.,-50.,50.,
09000+      33.3333,-16.6667,-16.6667/
09010C
09020C=====
09030C GENERATE JSEQ: ARRAY OF SEQUENCE NO'S FOR ANTENNAS
09040C
09050C      CAN USE UP TO 7 ANTENNAS
09060C      FOR EACH ANTENNA SEQUENCE, DEFINE:
09070C      DATA(AN(KT,J),J=1,8)/SEQUENCE-OF-ANTENNAS,99/
09080C      WHERE KT IS DETERMINED FROM ITT (SEE BELOW)
09090C      98 SIGNIFIES BLANK, 99 SIGNIFIES END OF SEQUENCE
09100C
09110C      GOOSE BAY: ITT=0, KT=1, ALL 4 ANTENNAS USED
09120C=====
09130C
09140      DATA(AN( 1,J),J=1,8)/1,2,3,4,99/
09150      DATA(AN( 2,J),J=1,8)/1,2,3,4,5,6,7,99/
09160      DATA(AN( 3,J),J=1,8)/1,98,98,98,5,6,7,99/
09170C
09180      IF(NUM.EQ.2) GO TO 40
09190C
09200C=====
09210C DETERMINE KT
09220C=====
09230C
09240      KT=ITT/10
09250      KT=ITT-6*KT+1
09260C
09270C=====

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SKYMAP (ULCAR)

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09280C GENERATE JSEQ (ANTENNA SEQ.); DETERMINE NANT (NO. OF ANTENNAS)
09290C=====
09300      JS=0
09310      DO 20 J=1,8
09320      IF (AN(KT,J)-98)10,20,30
09330      10 JS=JS+1
09340      JSEQ(JS)=J
09350      NANT=JS
09360      20 CONTINUE
09370C
09380C=====
09390C DETERMINE:
09400C      NDOPP: NO.OF DOPPLERS
09410C      NF: NO. OF SOUNDING FREQ.
09420C      NC: NO.OF CHANNELS
09430C      SS: SAMPLE SPACING [SEC]=TIME BETWEEN SAMPLES AT ONE FREQ, ONE ANT
09440C      SW: SPECTRAL WIDTH [HZ]=RANGE OF NEG OR POS DOPPLER FREQUENCIES
09450C      DFR: SPECTRAL SPACING [HZ]=DOPPLER-FREQ RESOLUTION
09460C=====
09470C
09480      30 NDOPP=32+32*(IN/7)
09490      NC=24/((IN/8)+1)
09500      NF=NC/NANT
09510CCC      SS=.07125*NF
09520CCC      SW=.5/SS
09530CCC      DFR=SW/NDOPP
09540      RETURN
09550C
09560C=====
09570C TO LIMIT SKYMAP TO THE MAIN ANT. LOBE, DEFINE THE X AND Y
09580C COMPONENTS OF THE FURTHEST K VECTOR AS:
09590C
09600C      -.707*VK*SIN(MAXIMUM ZENITH)
09610C
09620C      WITH: VK=ABS.VALUE OF WAVE PROPAGATION VECTOR K
09630C              =2*PI/WAVELENGTH
09640C      SIN(MAX. ZEN.)=WAVELENGTH/(MAXIMUM ANT. SPACING)
09650C      (BUT LIMIT THE MAX. ZENITH TO 45 DEGREES)
09660C
09670C      THUS THE X COMPONENTS OF THE (41X41) ARRAY OF K VECTORS ARE:
09680C
09690C      -.707*VK*SIN(MAX. ZEN.)*(XIX/20)=RJ*XIX
09700C      WHERE XIX=+20,...,+1,0,-1,...,-20
09710C
09720C      Y COORDINATES ARE: -.707*VK*SIN(MAX. ZEN.)*(YIY/20)=RJ*YIY
09730C      WHERE YIY=+20,...,+1,0,-1,...,-20
09740C
09750C      AK= DOT PRODUCT (K,A)=(RJ*XIX*ANTX+RJ*YIY*ANTY)
09760C
09770C      WAVELENGTH IN METERS
09780C=====

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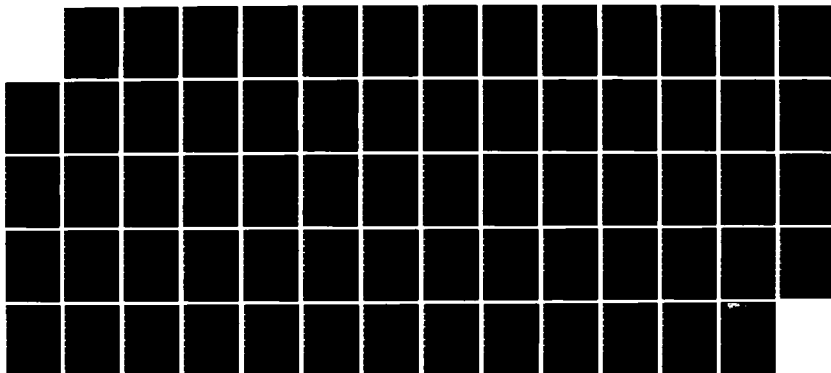
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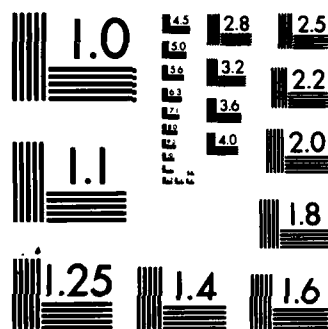
A HIGH FREQUENCY RADIO TECHNIQUE FOR MEASURING PLASMA
DRIFTS IN THE IONOS. (U) LOWELL UNIV MA CENTER FOR
ATMOSPHERIC RESEARCH C G DOZOIS JUL 83 ULRF-424/CAR
AFGL-TR-83-0202 F19628-88-C-0064 F/G 4/1

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MICROCOPY RESOLUTION TEST CHART
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SKYMAP (ULCAR)

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09790C
09800      40 WAVELEN=299792.5/FREQ(IFF)
09810      VK=2.*PI/WAVELEN
09820      SINZMAX=WAVELEN/100.
09830      IF(KT.GT.2) SINZMAX=WAVELEN/200.
09840      IF(SINZMAX.GT.0.707) SINZMAX=.707
09850      RJ=-.707*VK*SINZMAX/20.
09860      DO 50 J=1,NANT
09870      JS=JSEQ(J)
09880      NANTNO(J)=AN(KT,JS)
09890      RJY(J,IFF)=RJ*ANTY(NANTNO(J))
09900      50 RJX(J,IFF)=RJ*ANTX(NANTNO(J))
09910      RETURN
09920      END
09930C
09940C
09950C
09960C
09970C
09980C
09990C
10000C
10010      SUBROUTINE SPLIT(NDOPP,NANT,IFF,IDB,ISIGN,IBEGIN)
10020C
10030C=====
10040C GOOSE BAY
10050C SPLITS IB2160 FROM BUFFERIN INTO PHASES AND MAGNITUDES
10060C INPUTS  IB2160  UNPACKED RAW DRIFT DATA
10070C          NDOPP   NO. OF DOPPLERS USED IN CALCULATION
10080C          NANT    NO. OF ANTENNA'S USED IN CALCULATION
10090C          IFF     FREQUENCY NO.
10100C          IDB     NO. OF LSB'S IN A BEL OF MAGNITUDE
10110C OUTPUTS PHI     NDOPP X NANT ARRAY OF PHASES IN RADIANS
10120C          FM      NDOPP X NANT ARRAY OF LOG 10 MAGNITUDES
10130C                  CONVERTED TO LINEAR AMPLITUDES
10140C
10150C FOR KPRINT 16,512,4096 OR 8192, LEAVE AMPLITUDES AS LOG VALUES
10160C=====
10170C
10180      COMMON IB2160(2160),JSEQ(7),RJX(7,6),RJY(7,6)
10190+      ,IB216(216),IB216T(216),NANTNO(7),MAXFMPD(41,41),IMAX(41,41)
10200+      ,FMPD(41,41),PHI(64,7),FMMAX(64),FM(64,7),PI,RADIAN,KPRINT
10210+      ,FREQ(6),RANG(6),IGAIN(6),FMMAXX(6)
10220C
10230      DB=IDB
10240      NK=NDOPP*NANT/2
10250      DO 20 K=1,NK
10260      J=(2*K-2)/NDOPP+1
10270      I=2*K-(J-1)*NDOPP
10280      K5=5*(K+(IFF-1)*NK+(JSEQ(J)-J)*NDOPP/2)+240
10290      FM(I-1,J)=FLOAT(IB2160(K5-4))

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SKYMAP(ULCAR)

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10300      FM(I ,J)=FLOAT(IB2160(K5-1))
10310      IF((KPRINT.AND.12816).NE.0) GO TO 10
10320      FM(I-1,J)=FM(I-1,J)/DB
10330      FM(I,J)=FM(I,J)/DB
10340      FM(I-1,J)=10.**FM(I-1,J)-1.
10350      FM(I,J)=10.**FM(I,J)-1.
10360      10 IPHI=8*IB2160(K5-3)+(IB2160(K5-2).AND.56)/8
10370      PHI(I-1,J)=2.*PI*FLOAT(IPHI)/512.
10380      IPHI=8*IB2160(K5)+(IB2160(K5-2).AND.7)
10390      PHI(I,J)=2.*PI*FLOAT(IPHI)/512.
10400      20 CONTINUE
10410      IF((KPRINT.AND.98).EQ.0) RETURN
10420C
10430C=====
10440C FOR KPRINT 2,32 OR 64, DEFINE:
10450C
10460C      NANT
10470C      FWMAX(I)= SUM FM(I,J)
10480C      J=1
10490C
10500C AS THE SQRT OF THE ESTIMATED MAGNITUDE OF THE MAXIMUM FMPD(I).
10510C (FWMAX(I)**2 IS EXACTLY THE MAGNITUDE OF THE MAXIMUM FMPD(I)
10520C IF THERE IS ONLY ONE SOURCE AT DOPPLER I).
10530C
10540C SET FWMAX(I)=0 IF FM(I,J).LT.1 FOR ANY ANTENNA J.
10550C FWMAXX(IFF)=MAXIMUM FWMAX(I) OVER ALL DOPPLERS I OF A CASE,
10560C      FOR A GIVEN FREQUENCY NUMBER IFF.
10570C FWMAX, FWMAXX USED IN SUBROUTINE FOU.
10580C
10590C STORE FWMAX(I), FM(I,J), PHI(I,J) FOR ALL FREQUENCY NUMBERS, IF
10600C PROCESSING FIRST RECORD OF A CASE; IF SECOND RECORD, STORE ONLY
10610C THOSE OF THE FREQUENCY BEING CALCULATED, AND MAIN PROGRAM CALLS FOU
10620C TWICE, ONCE FOR THE NEGATIVE DOPPLERS, ONCE FOR THE POSITIVE
10630C DOPPLERS, OF THE GIVEN FREQUENCY.
10640C=====
10650C
10660      IF(ISIGN.EQ.1) FWMAXX(IFF)=0.
10670      DO 50 I=1,NDOPP
10680      FWMAX(I)=0
10690      AMN=FM(I,1)
10700      DO 30 J=2,NANT
10710      30 AMN=AMIN1(AMN,FM(I,J))
10720      IF(AMN.LT.1.0) GO TO 50
10730      DO 40 J=1,NANT
10740      40 FWMAX(I)=FWMAX(I)+FM(I,J)
10750      50 FWMAXX(IFF)=AMAX1(FWMAXX(IFF),FWMAX(I))
10760C
10770      IF(ISIGN.EQ.2) GO TO 60
10780      IF(IFF.EQ.IBEGIN) REWIND 90
10790      WRITE (90) (FWMAX(I),I=1,NDOPP),
10800+      ((FM(I,J),PHI(I,J),I=1,NDOPP),J=1,NANT)

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SKYMAP (ULCAR)

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10810      RETURN
10820      GO REWIND 91
10830      WRITE (91) (FWMAX(I),I=1,NDOPP),
10840+      ((FM(I,J),PHI(I,J),I=1,NDOPP),J=1,NANT)
10850      RETURN
10860      END

10870C
10880C
10890C
10900C
10910C
10920C
10930C
10940C
10950C
10960      SUBROUTINE MAPSEQ
10970C
10980C=====
10990C READS MAPDATA (IY,IX,FMPD,DOPP) FROM TAPE30 AND PUTS THE FMPD'S AND
11000C DOPPLERS WANTED (ACCORDING TO THE CHOICES INDICATED AT THE BEGINNING
11010C OF THE RUN) INTO ARRAYS MAXFMPD AND IMAX FOR PRINTING SINGLE SKY MAPS
11020C OR TIME-SEQUENCE SKY MAPS
11030C=====
11040C
11050      DIMENSION MAPDAT(4,80),MPDT(52),M1(64),M2(64),KOUNT(41,41)
11060      COMMON IB2160(2160),JSEQ(7),RJX(7,6),RJY(7,6)
11070+      ,IB216(216),IB216T(216),NANTND(7),MAXFMPD(41,41),IMAX(41,41)
11080+      ,FMPD(41,41),PHI(64,7),FWMAX(64),FM(64,7),PI,RADIAN,KPRINT
11090+      ,FREQ(6),RANG(6),IGAIN(6),FWMAXX(6)
11100C
11110      INTEGER SHIFT
11120C
11130      DATA M1/" 1"," 2"," 3"," 4"," 5"," 6"," 7"," 8"," 9","10",
11140+      "11","12","13","14","15","16","17","18","19","20","21","22",
11150+      "23","24","25","26","27","28","29","30","31","32","33","34",
11160+      "35","36","37","38","39","40","41","42","43","44","45","46",
11170+      "47","48","49","50","51","52","53","54","55","56","57","58",
11180+      "59","60","61","62","63","64"/
11190      DATA M2/" A"," B"," C"," D"," E"," F"," G"," H"," I"," J",
11200+      " K"," L"," M"," N"," O"," P"," Q"," R"," S"," T"," U"," V",
11210+      " W"," X"," Y"," Z","AA","BB","CC","DD","EE","FF","GG","HH",
11220+      "II","JJ","KK","LL","MM","NN","OO","PP","QQ","RR","SS","TT",
11230+      "UU","VV","WW","XX","YY","ZZ","A+","B+","C+","D+","E+","F+",
11240+      "G+","H+","I+","J+","K+","L+"/
11250      DATA KBLANK1/1H /,KBLANK2/2H /
11260C
11270C=====
11280C INPUTS REQUIRED: (ALL "QUOTED" PARAMETERS ARE TO BE INPUTTED
11290C      WITHOUT QUOTES)
11300C --TIME (E.G."121832") OF THE FIRST CASE WANTED
11310C OR "0" (ZERO) TO START AT THE BEGINNING OF TAPE30

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SKYMAP (ULCAR)

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11320C --FREQUENCY NUMBER (ONLY ONE FREQ. NO. CAN BE PROCESSED AT A TIME)
11330C --WHETHER WANT "NEG", "POS", OR "BOTH" DOPPLERS
11340C --"FMPD" IF WANT A SINGLE CASE ON EACH MAP; OR "TIME" IF WANT
11350C SEVERAL SUCCESSIVE CASES (TIME SEQUENCE)
11360C --THE MINIMUM FMPD (IN DB) OF THE SOURCES TO BE INCLUDED IN THE
11370C MAP:
11380C --"0" (ZERO) IF WANT ONLY THE MAX FMPD OF EACH RECORD
11390C --POSITIVE NO. (E.G."30") IF WANT THE SAME MINIMUM FOR ALL RECORDS
11400C --NEG. NO. IF WANT THE MINIMUM FOR EACH RECORD TO BE A GIVEN
11410C NUMBER OF DB BELOW THE MAX OF THAT RECORD: E.G. IF INPUT "-3",
11420C MINIMUM OF EACH RECORD IS 3 DB BELOW THE MAX
11430C=====
11440C
11450 PRINT*," START TIME?"
11460 PRINT*," (OR 0 (ZERO) TO START AT THE BEGINNING)"
11470 READ*,ITIME
11480 PRINT*," FREQUENCY NUMBER?"
11490 READ*,IFREQ
11500 PRINT*," NEG, POS, OR BOTH DOPPLERS?"
11510 READ 10,ISIGN
11520 10 FORMAT(A4)
11530 PRINT*," FMPD OR TIME SEQUENCE?"
11540 READ 10,IFMPD
11550 IF(ISIGN.EQ."NEG")ISIGN=1 $ IF(ISIGN.EQ."POS")ISIGN=2
11560 IF(ISIGN.EQ."BOTH")ISIGN=3
11570 PRINT*," MINIMUM FMPD?"
11580 PRINT*," (POS. NO.: CONSTANT IDBMIN)"
11590 PRINT*," (0: IDBMIN=IDBMAX)"
11600 PRINT*," (NEG. NO.: AMOUNT BY WHICH IDBMIN IS L.T. IDBMAX)"
11610 READ*,MNN
11620C
11630C
11640C=====
11650C AT BEGINNING OF A RUN (NRUN=0) CHECK THE TIME UNTIL FIND FIRST
11660C CASE WANTED, UNLESS ITIME ("START TIME") IS ZERO.
11670C FOR EACH RECORD, SKIP THE RECORD IF THAT FREQ. NO. IS NOT WANTED,
11680C OR IF THAT SIGN ("1" FOR NEG DOPPLERS, "2" FOR POSITIVE) IS
11690C NOT WANTED.
11700C KREC=1: FIRST RECORD OF A GIVEN SEQUENCE (OR GIVEN MAP).
11710C=====
11720C
11730 KREC=1
11740 NRUN=0
11750 20 DO 30 I=1,52
11760 30 MPDT(I)=MPDT(I).AND.0
11770C
11780 BUFFERIN(50,1)(MPDT(1),MPDT(52))
11790 IF(UNIT(50))50,40,20
11800 40 IF (KREC.EQ.1) STOP $ GO TO 360
11810 50 IF(KREC.EQ.1.AND.NRUN.EQ.0.AND.MPDT(3).NE.ITIME
11820+ .AND.ITIME.NE.0) GO TO 20

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SKYMAP (ULCAR)

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11830      IF(IFREQ.NE.MPDT(9)) GO TO 20
11840      JSIGN=1 $ IF(((MPDT(4)/2)*2).EQ.MPDT(4)) JSIGN=2
11850      IF(ISIGN.NE.3.AND.JSIGN.NE.ISIGN) GO TO 20
11860      NRUN=1
11870C
11880      IF(KREC.EQ.2) GO TO 70
11890C
11900C===== INITIALIZE; PRINT FIRST PREFACE OF THIS SEQUENCE =====
11910C
11920      IHR=MPDT(3)/10000 $ IMIN=MPDT(3)/100-IHR*100
11930      ISEC=MPDT(3)-IHR*10000-IMIN*100
11940      ITOTSEC=LTOTSEC=IHR*3600+IMIN*60+ISEC
11950C
11960      NFREQ=MPDT(9)
11970      FREQ(NFREQ)=FLOAT(MPDT(10))/10.
11980      SINZMAX=AMIN1(.707,(2997.925/FREQ(NFREQ)))
11990      RANG(NFREQ)=FLOAT(MPDT(11))/10.
12000      IGAIN(NFREQ)=MPDT(12)
12010C
12020      NUMBER=-1
12030      IOVER=0
12040      DO 240 IX=1,41
12050      DO 240 IY=1,41
12060      MAXFMPD(IY,IX)=KBLANK1
12070      IMAX(IY,IX)=KBLANK2
12080      240 KOUNT(IY,IX)=0
12090C
12100      MSIGN="NEG" $ IF(JSIGN.EQ.2) MSIGN="POS"
12110      PRINT 250
12120      250 FORMAT(1H1,31X,"SEG DOPP VSTAT DATE TIME RMTT GNXZ ",
12130+      "FREQ.NO. FREQ(KHZ) RANGE(KM) GAIN(DB)")
12140      PRINT 260,(NUMBER+1),MSIGN,(MPDT(I),I=1,3),MPDT(6),MPDT(7),
12150+      NFREQ,FREQ(NFREQ),RANG(NFREQ),IGAIN(NFREQ)
12160      260 FORMAT(22X,"BEGIN AT: ",Z1,3X,A3,3X,I2,2X,I5.5,1X,
12170+      I6.6,2(1X,I4.4),4X,I1,6X,F7.1,3X,F6.1,6X,I3)
12180C
12190      KREC=2
12200      GO TO 270
12210C
12220C=====
12230C DETERMINE IF END OF THE SEQUENCE:
12240C IF TIME LAPSE SINCE FIRST PREFACE IS G.T. 5 MIN., OR TIME LAPSE
12250C BETWEEN PREFACES IS G.T. 18 SEC. (INDICATING THE TIME SEQUENCE
12260C OF CASES IS BROKEN), GO TO 360 TO PRINT THE MAP.
12270C IF, COMPARED TO THE FIRST PREFACE, FREQ. NO. CHANGES, OR RANGE
12280C DIFFERENCE IS G.T. 10 KM, OR FREQ. DIFFERENCE IS G.T. 0.5 MHZ,
12290C PRINT A MESSAGE AND PRINT THE MAP.
12300C IF GAIN IS DIFFERENT, PRINT A MESSAGE BUT CONTINUE READING DATA.
12310C=====
12320C
127330      70 JHR=MPDT(3)/10000 $ JMIN=MPDT(3)/100-JHR*100

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SKYMAP (ULCAR)

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12340      JSEC=MPDT(3)-JHR*10000-JMIN*100
12350      JTOTSEC=JHR*3600+JMIN*60+JSEC
12360      IF(JTOTSEC.LT.LTOTSEC) JTOTSEC=JTOTSEC+24*3600
12370      IF((JTOTSEC-LTOTSEC).GT.18) GO TO 170
12380      LTOTSEC=JTOTSEC
12390      IF((JTOTSEC-ITOTSEC).GT.300) GO TO 170
12400      IF(MPDT(9).NE.NFREQ) GO TO 80
12410      IF((ABS((FLOAT(MPDT(10))/10.)-FREQ(NFREQ))).GT.500.)GOTO 100
12420      IF((ABS((FLOAT(MPDT(11))/10.)-RANG(NFREQ))).GT.10.)GOTO 120
12430      IF(MPDT(12).NE.IGAIN(NFREQ))GO TO 140
12440      GO TO 270
12450      80 PRINT*," DIFFERENT FREQ. NO. ENCOUNTERED"
12460      GO TO 170
12470      100 PRINT*," FREQ. DIFFERENCE G.T. 0.5 MHZ"
12480      GO TO 170
12490      120 PRINT*," RANGE DIFFERENCE G.T. 10 KM"
12500      GO TO 170
12510      140 PRINT 150,IGAIN(NFREQ),MPDT(12)
12520      IGAIN(NFREQ)=MPDT(12)
12530      150 FORMAT(" NOTE GAIN CHANGE FROM ",I3," TO ",I3)
12540      GO TO 270
12550      170 BACKSPACE 50
12560      GO TO 360
12570C
12580C=====
12590C DETERMINE PARAMETERS OF LATEST PREFACE FOR PRINTING
12600C
12610C UNPACK IY,IX,FWD,AND DOPPLER NO. INTO ARRAY MAPDAT
12620C=====
12630C
12640      270 IST=MPDT(1)
12650      MNUM=NUMBER $ IF(ISIGN.LE.2) MNUM=NUMBER+1
12660      MSIGN="NEG" $ IF(JSIGN.EQ.2) MSIGN="POS"
12670      MDATE=MPDT(2)
12680      MTIME=MPDT(3)
12690      MRN=MPDT(6) $ MGN=MPDT(7)
12700      MFRQ=MPDT(9) $ FRQ=FLOAT(MPDT(10))/10
12710      RNG=FLOAT(MPDT(11))/10
12720      IGN=MPDT(12)
12730C
12740      DO 280 NROW=1,4
12750      DO 280 NCOL=1,80
12760      280 MAPDAT(NROW,NCOL)=0
12770C
12780      DO 290 IM=13,52
12790      IBF=0
12800      DO 290 IBY=1,8
12810      IMM=8*IM+IBY-104 $ IBG=3+3*((IBY+1-4*(IBY/5))/2)
12820      IBF=IBF+IBG $ NCOL=(IMM+3)/4 $ NROW=IMM-(4*(NCOL-1))
12830      290 MAPDAT(NROW,NCOL)=(63+448*(IBG/9)).AND.SHIFT(MPDT(IM),IBF)
12840C

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SKYMAP (ULCAR)

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12850C===== IDBMAX=MAX. FMPD OF EACH RECORD (NEG OR POS DOPPLERS) =====
12860C
12870      IDBMAX=0
12880      DO 300 NCOL=1,80
12890  300 IDBMAX=MAX0(MAPDAT(3,NCOL),IDBMAX)
12900      IF(MNN.GT.0) IDBMIN=MNN
12910      IF(MNN.LT.0) IDBMIN=IDBMAX+MNN
12920      IF(MNN.EQ.0) IDBMIN=IDBMAX
12930      IF(IDBMIN.LT.3) IDBMIN=3
12940      IF((ISIGN.EQ.3.AND.JSIGN.EQ.1).OR.(ISIGN.LE.2))
12950+      NUMBER=NUMBER+1
12960C
12970C
12980C=====
12990C SELECT THE CASES WITH FMPD .GE. IDBMIN.
13000C
13010C PUT THE DOPPLER NO. INTO ARRAY IMAX.
13020C IF IFMPD(INPUTTED AT BEGINNING OF RUN)="TIME",PUT A TIME SEQUENCE
13030C   NO. (0 TO 15) INTO ARRAY MAXFMPD.
13040C IF IFMPD="FMPD", PUT THE FMPD INTO ARRAY MAXFMPD.
13050C
13060C IF THE SAME COORDINATES HAVE MORE THAN ONE FMPD, KEEP THE FIRST ONE
13070C   IN THE MAP, AND PRINT THE INFORMATION ABOUT THE EXTRA ONES.
13080C (PRINTING THIS INFO NOT PRESENTLY OPERATIVE; ONLY COUNTING
13090C   THE NUMBER OF "OVERFLOWS")
13100C=====
13110C
13120      DO 340 NCOL=1,80
13130      IF(MAPDAT(3,NCOL).LT.IDBMIN) GO TO 340
13140      IY=MAPDAT(1,NCOL)
13150      IX=MAPDAT(2,NCOL)
13160      IF(IMAX(IY,IX).NE.KBLANK2)310,330
13170  310 IOVER=IOVER+1
13180C
13190CCC      KOUNT(IY,IX)=KOUNT(IY,IX)+1
13200CCC      IYC="W"  $ IF(IY.GT.21) IYC="E"
13210CCC      IXC="N"  $ IF(IX.GT.21) IXC="S"
13220CCC      PRINT 320,NUMBER,KOUNT(IY,IX),IABS(21-IY),IYC,IABS(21-IX),IXC,
13230CCC+      (((-1)**JSIGN)*MAPDAT(4,NCOL)),MAPDAT(3,NCOL)
13240CCC  320 FORMAT(IX,Z1," OVERFLOW ("I2") AT ("I2,A1","I2,A1");  DOPPLER"I4,
13250CCC+      " FMPD="I3" DB")
13260C
13270      GO TO 340
13280  330 MAXFMPD(IY,IX)=NUMBER
13290      IF(IFMPD.EQ."FMPD")MAXFMPD(IY,IX)=(MAPDAT(3,NCOL)-3)/6
13300      IMAX(IY,IX)=M1(MAPDAT(4,NCOL))
13310      IF(JSIGN.EQ.2) IMAX(IY,IX)=M2(MAPDAT(4,NCOL))
13320  340 CONTINUE
13330C
13340      IF(IFMPD.EQ."TIME") GO TO 350
13350      IF(ISIGN.EQ.3.AND.JSIGN.EQ.2.AND.NUMBER.EQ.0) GO TO 360

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SKYMAP (ULCAR)

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13360      IF(ISIGN.LE.2.AND.NUMBER.EQ.0) GO TO 360
13370C
13380      350 IF(ISIGN.EQ.3.AND.JSIGN.EQ.2.AND.NUMBER.EQ.15) GO TO 360
13390      IF(ISIGN.LE.2.AND.NUMBER.EQ.15) 360,20
13400C
13410C===== PRINT LAST PREFACE OF THIS SEQUENCE =====
13420C      AND CALL PRIN TO PRINT THE MAP
13430C
13440      360 PRINT 370,MNUM,MSIGN,IST,MDATE,MTIME,MRW,
13450+      MGN,MFRQ,FRQ,RNG,IGN
13460      370 FORMAT(22X,"END AT:  ",Z1,3X,A3,3X,I2,2X,I5.5,1X,
13470+      I6.6,2(1X,I4),4X,I1,6X,F7.1,3X,F6.1,6X,I3)
13480      PRINT*,"      ",IOVER," OVERFLOW(S)"
13490C
13500      IF(NUMBER.GE.0) CALL PRIN(IN,ISIGN,IFWPD,SINZMAX,NFREQ)
13510C
13520      KREC=1
13530      GO TO 20
13540      END
13550C
13560C
13570C
13580C
13590C
13600C
13610      SUBROUTINE FOU(ISIGN,NDOPP,NANT,IFF,IBEGIN,IFOU)
13620C
13630C=====
13640C CALCULATES FOURIER TRANSFORMS FOR SKY MAP
13650C REQUIRED INPUTS ARE
13660C      NDOPP  NO.OF DOPPLERS USED IN CALCULATIONS
13670C      NANT   NO.OF ANTENNAS USED IN CALCULATION
13680C      RJY    NANT ARRAY SCALED Y ANTENNA COORDINATES
13690C      RJX    NANT ARRAY SCALED X ANTENNA COORDINATES
13700C      PHI   NDOPP X NANT ARRAY OF PHASES
13710C      FM     NDOPP X NANT ARRAY OF MAGNITUDES
13720C OUTPUTS ARE
13730C MAXFWD  41X41 ARRAY SKYMAP W/FWPD
13740C IMAX 41X41 ARRAY SKYMAP W/DOPPLERS
13750C=====
13760C
13770      COMPLEX FMEXP(4),EXPAK(41,41,3),FSUM
13780      DIMENSION IXMAX(41),IYMAX(41),FXMAX(41),FYMAX(41)
13790      DIMENSION LOGFWD(41,41)
13800      COMMON IB2160(2160),JSEQ(7),RJX(7,6),RJY(7,6)
13810+      ,IB216(216),IB216T(216),NANTNO(7),MAXFWD(41,41),IMAX(41,41)
13820+      ,FWPD(41,41),PHI(64,7),FM(64,7),PI,RADIAN,KPRINT
13830+      ,FREQ(6),RANG(6),IGAIN(6),FM(64,7),PI,RADIAN,KPRINT
13840C
13850C
13860      DO 10 IX=1,41

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SKYMAP (ULCAR)

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13870      DO 10 IY=1,41
13880      MAXFWPD(IY,IX)=0.
13890      10 IMAX(IY,IX)=0
13900C
13910C=====
13920C FWMAX(I) DETERMINED IN SUBROUTINE ANT.
13930C FWMAX(I)=0 IF FM(I,J).LT.1 FOR ANY ANTENNA J.
13940C FWMAXX=MAXIMUM FWMAX(I) OVER ALL I, FOR A GIVEN FREQUENCY.
13950C FWMIN=FWMAXX/10 (20 DB BELOW FWMAXX) BUT AT LEAST 2 (6 DB).
13960C=====
13970C
13980      IF(IFOU.EQ.2) GO TO 20
13990      IF(IFF.EQ.IBEGIN) REWIND 90
14000      READ (90) (FWMAX(I),I=1,NDOPP),
14010+      ((FM(I,J),PHI(I,J),I=1,NDOPP),J=1,NANT)
14020      FWMIN=AMAX1((FWMAXX(IFF)/10.),2.)
14030      GO TO 30
14040C
14050      20 REWIND 91
14060      READ (91) (FWMAX(I),I=1,NDOPP),
14070+      ((FM(I,J),PHI(I,J),I=1,NDOPP),J=1,NANT)
14080      GO TO 45
14090C
14100C=====
14110C ARRAY COORDINATES IY,IX=1,...,41 CORRESPOND TO MAP
14120C COORDINATES YIY,XIX=+20,...,0,...,-20
14130C
14140C +YIY=WEST; +XIX=NORTH
14150C
14160C AK=K-DOT-A (SEE SUBROUTINE ANT).
14170C K=K(IY,IX)=WAVE PROPAGATION VECTOR (SCANNING VECTOR).
14180C A=A(J)=ANTENNA POSITION VECTOR; A=0 FOR ANTENNA J=1.
14190C EXPAK=EXPONENTIAL(II*AK); II=SQRT(-1)
14200C=====
14210C
14220      30 DO 40 IX=1,41
14230      XIX=21-IX
14240      DO 40 IY=1,41
14250      YIY=21-IY
14260      DO 40 J=2,NANT
14270      AK=(RJY(J,IFF)*YIY+RJX(J,IFF)*XIX)
14280      40 EXPAK(IY,IX,J-1)=CMPLX(COSINE(AK,SINE),SINE)
14290C
14300C=====
14310C SKIP DOPPLER I IF FWMAX(I).LT.FWMIN
14320C FMEXP(J)=FM(I,J)*EXP(II*PHI(I,J)); II=SQRT(-1)
14330C AUTOCOR=AUTOCORRELATION TERM
14340C=====
14350C
14360      45 DO 170 I=1,NDOPP
14370C

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SKYMAP (ULCAR)

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14380      IF(FWMAX(I).LT.FWMIN) GO TO 170
14390C
14400      DO 50 J=1,NANT
14410      50 FMEXP(J)=CMPLX((FM(I,J)*COSINE(PHI(I,J),SINE)),
14420+          (FM(I,J)*SINE))
14430C
14440      AUTOCOR=0
14450      DO 60 J=1,NANT
14460      60 AUTOCOR=AUTOCOR+FM(I,J)*FM(I,J)
14470C
14480C=====
14490C FOR A GIVEN DOPPLER (I), AT COORDINATES (IY,IX):
14500C
14510C      NANT
14520C      FSUM= SUM FM(I,J) * EXP(II*PHI(I,J)) * EXP(II*AK(IY,IX,J))
14530C          J=1
14540C          WHERE II=SQRT(-1)
14550C
14560C      FWPD=ABS(FSUM)**2
14570C          =(REAL(FSUM))**2+(IMAGINARY(FSUM))**2
14580C
14590C SUBTRACT THE CONSTANT AUTO-CORRELATION TERM FROM THE FWPD
14600C=====
14610C
14620      DO 80 IX=1,41
14630      DO 80 IY=1,41
14640      FSUM=FMEXP(1)
14650      DO 70 J=2,NANT
14660      70 FSUM=FSUM+FMEXP(J)*EXPAK(IY,IX,J-1)
14670      FWPD(IY,IX)=REAL(FSUM)**2+AIMAG(FSUM)**2-AUTOCOR
14680      80 CONTINUE
14690C
14700C=====
14710C SEARCH FOR MAXIMA AT THIS DOPPLER I
14720C
14730C      SEARCH FOR MAXIMA ALONG EACH HORIZONTAL LINE IX:
14740C      FYMAX(IX)=MAX FWPD OF LINE IX
14750C      IYMAX(IX) IS ITS IY INDEX
14760C      FYMAX(IX)=FWPD(IYMAX(IX),IX)
14770C      SET INDEX IYMAX TO ZERO IF FYMAX OF LINE IX IS NOT GREATER
14780C      THAN FYMAX OF LINES IX-1 AND IX+1
14790C=====
14800C
14810      DO 100 IX=1,41
14820      FYMAX(IX)=FWPD(1,IX) $ IYMAX(IX)=1
14830      DO 90 IY=2,41
14840      IF(FWPD(IY,IX).LT.FYMAX(IX)) GO TO 90
14850      FYMAX(IX)=FWPD(IY,IX)
14860      IYMAX(IX)=IY
14870      90 CONTINUE
14880      IF(IYMAX(IX).EQ.1) GO TO 100

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SKYMAP (ULCAR)

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14890      IF(FYMAX(IX).GT.FYMAX(IX-1)) IYMAX(IX-1)=0
14900      IF(FYMAX(IX).LT.FYMAX(IX-1)) IYMAX(IX)=0
14910      100 CONTINUE
14920C
14930C=====
14940C      SEARCH FOR MAXIMA ALONG EACH VERTICAL LINE IY:
14950C      FXMAX(IY)=MAX FWPD OF LINE IY
14960C      IXMAX(IY) IS ITS IX INDEX
14970C      FXMAX(IY)=FWPD(IY,IXMAX(IY))
14980C      SET INDEX IXMAX TO ZERO IF FXMAX OF COLUMN IY IS NOT
14990C      GREATER THAN FXMAX OF COLUMNS IY-1 AND IY+1
15000C
15010C DETERMINE:
15020C      MAX=MAXIMUM LOGFWPD OF THE ARRAY FOR A GIVEN DOPPLER I
15030C=====
15040C
15050C
15060      DO 120 IY=1,41
15070      FXMAX(IY)=FWPD(IY,1) $ IXMAX(IY)=1
15080      DO 110 IX=2,41
15090      IF(FWPD(IY,IX).LT.FXMAX(IY)) GO TO 110
15100      FXMAX(IY)=FWPD(IY,IX)
15110      IXMAX(IY)=IX
15120 110 CONTINUE
15130      IF(IY.EQ.1) GO TO 120
15140      IF(FXMAX(IY).GT.FXMAX(IY-1)) IXMAX(IY-1)=0
15150      IF(FXMAX(IY).LT.FXMAX(IY-1)) IXMAX(IY)=0
15160 120 CONTINUE
15170C
15180      BMAX=0
15190      DO 130 IY=1,41
15200      IF(IXMAX(IY).EQ.0) GO TO 130
15210      IF(IYMAX(IXMAX(IY)).NE.IY) GO TO 130
15220      BMAX=AMAX1(BMAX,FXMAX(IY))
15230 130 CONTINUE
15240      BMAX2=BMAX/2.
15250C
15260C=====
15270C DETERMINE MAXFWPD: ARRAY OF FWPD'S TO BE PRINTED ON THE SKYMAP:
15280C
15290C      FOR A GIVEN DOPPLER, SKIP FWPD'S LESS THAN OR EQUAL TO 1/2 THE
15300C      MAX FWPD FOR THAT DOPPLER (TO SUPPRESS WEAK SIDELOBES; STRONG
15310C      SIDELOBES ARE SUPPRESSED BY CHOICE OF MAX ZENITH ANGLE, AS
15320C      DETERMINED IN SUBROUTINE ANT)
15330C
15340C      IF MULTIPLE SOURCES AT ONE LOCATION, KEEP THE DOPPLER WITH
15350C      THE MAXIMUM INTEGER FWPD, OR KEEP THE LAST ONE IF TWO HAVE THE SAME
15360C      INTEGER VALUE
15370C=====
15380C
15390      DO 140 IY=1,41

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SKYMAP (ULCAR)

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15400      IF(IXMAX(IY).EQ.0) GO TO 140
15410      IF(IYMAX(IXMAX(IY)).NE.IY) GO TO 140
15420      IF(FXMAX(IY).LE.BMAX2) GO TO 140
15430      IF(MAXFWPD(IY,IXMAX(IY)).GT.(IFIX(FXMAX(IY)))) GO TO 140
15440      MAXFWPD(IY,IXMAX(IY))=IFIX(FXMAX(IY))
15450      IMAX(IY,IXMAX(IY))=I
15460      140 CONTINUE
15470C
15480      IF((KPRINT.AND.32).EQ.0)GO TO 170
15490      IFPRINT=0
15500      DO 150 IXX=1,41
15510      DO 150 IYY=1,41
15520      FWPDIYY,IXX)=AMAX1(1.,FWPD(IYY,IXX))
15530      LOGFWPD(IYY,IXX)=IFIX(10.*ALOG10(FWPD(IYY,IXX)))
15540      IF(LOGFWPD(IYY,IXX).LT.1) GO TO 150
15550      IFPRINT=1
15560      150 CONTINUE
15570      IF(IFPRINT.NE.1) GO TO 170
15580      PRINT 160, I,(((LOGFWPD(IYY,IXX),IYY=1,41),IXX,
15590+      IYMAX(IXX)),IXX=1,41),(IYY,IYY=1,41),(IXMAX(IYY),IYY=1,41)
15600      160 FORMAT(*1 DOPPLER=*,I3////,41(41I3,3X,I2,1X,I2/),
15610+      T125,*IX,IYMAX*/,41I3,T125,*IY*/,41I3,T125,*IXMAX*,17(/))
15620      170 CONTINUE
15630C
15640C=====
15650C CONVERT FINAL MAP TO DB VALUES
15660C=====
15670C
15680      IF(KPRINT.EQ.32) RETURN
15690      DO 180 IX=1,41
15700      DO 180 IY=1,41
15710      MAXFWPD(IY,IX)=MAX0(1,MAXFWPD(IY,IX))
15720      180 MAXFWPD(IY,IX)=IFIX(10.*ALOG10(FLOAT(MAXFWPD(IY,IX))))
15730C
15740      RETURN
15750      END
15760C
15770C
15780C
15790C
15800      FUNCTION COSINE(ARG,SINE)
15810C
15820C=====
15830C DETERMINE COSINE=COS(ARG) AND SINE=SIN(ARG) FROM TABLE
15840C CALCULATED AT BEGINNING OF MAIN PROGRAM
15850C=====
15860C
15870      COMMON/PIE/NPI,N2PI,N3PI2,NPI2,TWOPI,PI2,PI512,CSN(257)
15880      ARG=AMOD(ARG,TWOPI)
15890      IF(ARG.LT.0) ARG=ARG+TWOPI
15900      KUADRNT=IFIX(ARG/PI2)+1

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SKYMAP (ULCAR)

```

15910      KARG=IFIX(ARG/PI512+.5)
15920      GO TO (1,2,3,4)KUADRNT
15930      1 COSINE=CSN(KARG+1) $ SINE=CSN(NPI2-KARG+1) $ RETURN
15940      2 COSINE=-CSN(NPI-KARG+1) $ SINE=CSN(KARG+1-NPI2) $ RETURN
15950      3 COSINE=-CSN(KARG+1-NPI) $ SINE=-CSN(N3PI2-KARG+1) $ RETURN
15960      4 COSINE=CSN(N2PI-KARG+1) $ SINE=-CSN(KARG+1-N3PI2)
15970      RETURN
15980      END
15990C
16000C
16010C
16020C
16030      SUBROUTINE MAPDATA(NFREQ,MDTFLAG,IFOU,NMAP)
16040C
16050C=====
16060C STORES THE FWP'D'S, DOPPLER NUMBERS, AND THEIR COORDINATES
16070C FOR THE SKYMAPS
16080C=====
16090C
16100      DIMENSION MAPDAT(320),MPDT(52)
16110      COMMON IB2160(2160),JSEQ(7),RJX(7,6),RJY(7,6)
16120+      ,IB216(216),IB216T(216),NANTNO(7),MAXFWD(41,41),IMAX(41,41)
16130+      ,FWD(41,41),PHI(64,7),FWMAX(64),FM(64,7),PI,RADIAN,KPRINT
16140+      ,FREQ(6),RANG(6),IGAIN(6),FWMAXX(6)
16150C
16160      INTEGER SHIFT
16170C
16180C=====
16190C AT THE BEGINNING OF A RUN, READ TAPE50 UNTIL GET TO END OF DATA.  THUS
16200C IF TAPE50 ALREADY CONTAINS DATA, THE NEW DATA WILL BE APPENDED TO IT.
16210C IGNORE LAST RECORD IF MPDT(4) IS NOT AN EVEN NUMBER (SEE EXPLANATION
16220C OF MPDT(4) BELOW); I.E., IF LAST RECORD IS NOT THE SECOND RECORD
16230C OF A CASE.
16240C=====
16250C
16260      IF(MDTFLAG.EQ.1) GO TO 30
16270      10 BUFFERIN(50,1)(MPDT(1),MPDT(52))
16280      IF(UNIT(50)) 10,20,10
16290      20 MDTFLAG=1
16300      IF(((MPDT(4)/2)*2).NE.MPDT(4)) BACKSPACE 50
16310C
16320C=====
16330C CODE FIRST 32 PREFACE CHARACTERS INTO ARRAY MPDT:
16340C CHARACTER(S)      1= VSTAT      INTO MPDT(1)
16350C                   2-6= DATE      2
16360C                   7-12= TIME      3
16370C                   13-16: NOT USED; SEE NOTE 4
16380C                   17-20: NOT USED  5
16390C                   21-24= RWTT      6
16400C                   25-28= GNXZ      7
16410C                   29-32: NOT USED  8

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SKYMAP (ULCAR)

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16420C  NOTE: CHARACTER 16 SET TO 1 BY PROGRAM SKYMAP FOR
16430C      FIRST RECORD OF A CASE; SET TO 2 FOR SECOND RECORD.
16440C  ALSO: MPDT(9)=NFREQ=FREQUENCY NUMBER
16450C      MPDT(10)=FREQ(NFREQ), IN 100-HZ UNITS
16460C      MPDT(11)=RANG(NFREQ), IN 100-METER UNITS
16470C      MPDT(12)=IGAIN(NFREQ), IN DB
16480C  NOTE THAT PREFACE DOES NOT GET PACKED.
16490C
16500C  PRINT PREFACE.
16510C=====
16520C
16530      30 DO 40 I=1,52
16540      40 MPDT(I)=MPDT(I).AND.0
16550      DO 50 I=1,320
16560      50 MAPDAT(I)=0
16570C
16580      IB2160(16)=IFOU
16590      MPDT(1)=IB2160(1)
16600C
16610      II=100000
16620      DO 60 I=2,6
16630      II=II/10
16640      60 MPDT(2)=MPDT(2)+IB2160(I)*II
16650C
16660      II=1000000
16670      DO 70 I=7,12
16680      II=II/10
16690      70 MPDT(3)=MPDT(3)+IB2160(I)*II
16700C
16710      II=10000
16720      DO 80 I=13,16
16730      II=II/10 * JJ=-4
16740      DO 80 J=4,8
16750      JJ=JJ+4
16760      80 MPDT(J)=MPDT(J)+IB2160(I+JJ)*II
16770C
16780      MPDT(9)=NFREQ
16790      MPDT(10)=IFIX(FREQ(NFREQ)*10.)
16800      MPDT(11)=IFIX(RANG(NFREQ)*10.)
16810      MPDT(12)=IGAIN(NFREQ)
16820C
16830      PRINT 90,(NMAP-(MPDT(4)-(MPDT(4)/2)*2),
16840+          (MPDT(1),I=1,9),(FLOAT(MPDT(10))/10.),
16850+          (FLOAT(MPDT(11))/10.),MPDT(12)
16860      90 FORMAT(1X,I5,1X,I3,1X,I5.5,1X,I6.6,5(1X,I4.4),3X,I3,2F8.1,I5)
16870C
16880C=====
16890C  STORE DATA (IY, IX, FWP, DOPPLER NO.) INTO MAPDAT.
16900C  PRINT DATA.
16910C=====
16920C

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SKYMAP (ULCAR)

```

16930      I=-3
16940      DO 110 IX=1,41
16950      DO 110 IY=1,41
16960      IF(MAXFWPD(IY,IX).LT.1) GO TO 110
16970      I=I+4 $ IF(I.LT.320) GO TO 100
16980      PRINT*,"WARNING: AMOUNT OF DATA EXCEEDS SIZE OF ARRAY ",
16990+      "MAPDAT, AT (IY,IX)=(",IY," ",IX,"), WITH MAXFWPD=",
17000+      MAXFWPD(IY,IX)," IMAX=",IMAX(IY,IX)
17010      GO TO 110
17020      100 MAPDAT(I)=IY.AND.63 $ MAPDAT(I+1)=IX.AND.63
17030      MAPDAT(I+2)=MAXFWPD(IY,IX).AND.511
17040      MAPDAT(I+3)=IMAX(IY,IX).AND.511
17050      110 CONTINUE
17060      NPR=NPR+I $ IF(I.GT.157) NPR=157
17070      IF(I.GT.317) NPR=317
17080      NPR1=NPR+1 $ NPR2=NPR+2 $ NPR3=NPR+3
17090      NPRR1=NPRR+1 $ NPRR2=NPRR+2 $ NPRR3=NPRR+3
17100C
17110      PRINT 120,(MAPDAT(I),I=1,NPR,4)
17120      PRINT 130,(MAPDAT(I),I=2,NPR1,4)
17130      PRINT 140,(MAPDAT(I),I=3,NPR2,4)
17140      PRINT 150,(MAPDAT(I),I=4,NPR3,4)
17150      120 FORMAT(1X," IY",40I3)
17160      130 FORMAT(1X," IX",40I3)
17170      140 FORMAT(1X,"FWPD",40I3)
17180      150 FORMAT(1X,"DOPP",40I3)
17190C
17200      IF(MAPDAT(161).EQ.0) GO TO 160
17210CCC      PRINT*," "
17220      PRINT 120,(MAPDAT(I),I=161,NPRR,4)
17230      PRINT 130,(MAPDAT(I),I=162,NPRR1,4)
17240      PRINT 140,(MAPDAT(I),I=163,NPRR2,4)
17250      PRINT 150,(MAPDAT(I),I=164,NPRR3,4)
17260C
17270C=====
17280C PACK DATA INTO MPDT(13) TO (52).
17290C BUFFEROUT PREFACE AND DATA.
17300C=====
17310C
17320      160 DO 170 IA=1,320
17330      ILS=3+3*((IA+1-4*((IA-1)/4))/2)
17340      IG=((IA-1)/8)+13
17350      170 MPDT(IG)=(SHIFT(MPDT(IG),ILS).OR.(MAPDAT(IA)))
17360C
17370      180 BUFFEROUT(50,1)(MPDT(1),MPDT(52))
17380      IF(UNIT(50)) 190,190,180
17390C
17400      190 RETURN
17410      END
17420C
17430C

```

SKYMAP (ULCAR)

```

17440C
17450C
17460C
17470C
17480C
17490      SUBROUTINE PRIN(IN,ISIGN,IFWPD,SINZMAX,IFF)
17500C
17510C=====
17520C TO PRINT SKY MAP.
17530C INPUTS ARE:
17540C      MAXFWD=41X41 ARRAY OF MAXIMUM FWD'S;
17550C      IMAX=41X41 ARRAY OF DOPPLER NO'S, EACH DOPPLER I AT THE COORDINATES
17560C      (IY,IX) OF FWD(I,IY,IX).
17570C (SEE SUBROUTINES FOU AND MAPSEQ FOR MORE DETAILS.)
17580C=====
17590C
17600      DIMENSION IPR(94),IPRS(94)
17610      COMMON IB2160(2160),JSEQ(7),RJX(7,6),RJY(7,6)
17620+      ,IB216(216),IB216T(216),NANTNO(7),MAXFWD(41,41),IMAX(41,41)
17630+      ,FWD(41,41),PHI(64,7),FWMAX(64),FM(64,7),PI,RADIAN,KPRINT
17640+      ,FREQ(6),RANG(6),IGAIN(6),FWMAXX(6)
17650C
17660      DATA KBLANK1/1H /,KBLANK2/2H /
17670C
17680C===== IPR,IPRA1,IPRA2, CONTAIN FORMAT STATEMENTS =====
17690C
17700      DATA IPR/7H(1X,I2,,41*3HZ1,,6HI2,1X,,42*3HI2,,1H)/
17710      DATA IPRA1/3HA1,/,IPRA2/3HA2,/
17720C
17730C===== PRINT MAP LEGEND =====
17740C
17750      PRINT 150
17760C
17770      IF(ISIGN.EQ.3) GO TO 10
17780      DP1=DP4="      " $ DP3="RS      " $ DP2="NEG DOPPLE"
17790      IF(ISIGN.EQ.2) DP2="POS DOPPLE"
17800      GO TO 20
17810C
17820      10 DP1="NEG DOPP: " $ DP2="NUMERIC      "
17830      DP3="POS DOPP: " $ DP4="ALPHA      "
17840C
17850      20 IF(KPRINT.EQ.128.AND.IFWPD.EQ."TIME") GO TO 30
17860      PRINT*, "      FWD (6 DB INCREMENTS)"
17870      GO TO 40
17880C
17890      30 PRINT*, "      TIME SEQUENCE"
17900C
17910      40 ZMAX=ASIN(SINZMAX)/RADIAN
17920      SCALE=(.707*RANG(IFF)*SINZMAX)/20.
17930      DFR=.12254902 $ IF(IN.EQ.7) DFR=DFR/2.
17940      DF2=DFR/2. $ IF(IN.EQ.5.OR.IN.EQ.8) DF2=0.

```

SKYMAP (ULCAR)

```

17950      INVDFR=IFIX(1./DFR)
17960      INVDF2=0
17970      DP5="  "
17980      IF(DF2.EQ.0.) GO TO 50
17990      INVDF2=IFIX(1./DF2)
18000      DP5="1 /"
18010C
18020      50 PRINT 160, ZMAX,DP1,DP2,DP3,DP4,SCALE,DP5,INVDF2,INVDFR
18030C
18040C===== PRINT MAP WITH BORDERS =====
18050C
18060      PRINT 170
18070      PRINT 180
18080C
18090      DO 140 IX=1,41
18100      DO 60 IY=1,94
18110      60 IPRS(IY)=IPR(IY)
18120      DO 100 IY=1,41
18130      IF(KPRINT.EQ.128) GO TO 80
18140CCC      IF(IX.EQ.1.OR.IX.EQ.41.OR.IY.EQ.1.OR.IY.EQ.41)GO TO 70
18150      IF(MAXFMPD(IY,IX).NE.0.OR.IMAX(IY,IX).NE.0)GO TO 90
18160C
18170C=====
18180C PUT BLANKS INTO MAXFMPD,IMAX AND CHANGE CORRESPONDING
18190C      VARIABLE FORMAT (IPRS) TO HOLLERITH FORMAT
18200C=====
18210C
18220      70 MAXFMPD(IY,IX)=KBLANK1 $ IMAX(IY,IX)=KBLANK2
18230      80 IF(MAXFMPD(IY,IX).EQ.KBLANK1)IPRS(IY+1)=IPRA1
18240      IPRS(IY+43)=IPRA2
18250      GO TO 100
18260C
18270C=====
18280C EXPRESS MAXFMPD IN 6-DB INCREMENTS
18290C=====
18300C
18310      90 MAXFMPD(IY,IX)=(MAXFMPD(IY,IX)-3)/6
18320      100 CONTINUE
18330C
18340C=====
18350C FORMAT FOR BORDERS AND COMPASS DIRECTIONS
18360C=====
18370C
18380      IF(IX.NE.1) GO TO 110
18390      IPRS(86)=10HT22,*NORTH $ IPRS(87)=2H*,
18400      IPRS(88)=10HT87,*NORTH $ IPRS(89)=2H*)
18410      110 IF(IX.LT.19.OR.IX.GT.22) GO TO 120
18420      IPRS(86)=3HT3, $ IPRS(88)=4HT45,
18430      IPRS(90)=4HT47, $ IPRS(92)=5HT130,
18440      IF(IX.EQ.19) IPRS(87)=IPRS(91)=4H*W*,
18450      IF(IX.EQ.19) IPRS(89)=IPRS(93)=4H*E*,

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SKYMAP (ULCAR)

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18460      IF(IX.EQ.20) IPRS(87)=IPRS(91)=4H*E*,
18470      IF(IX.EQ.20) IPRS(89)=IPRS(93)=4H*A*,
18480      IF(IX.EQ.21) IPRS(87)=IPRS(89)=IPRS(91)=IPRS(93)=4H*S*,
18490      IF(IX.EQ.22) IPRS(87)=IPRS(89)=IPRS(91)=IPRS(93)=4H*T*,
18500      IPRS(94)=1H)
18510  120 IF(IX.NE.41) GO TO 130
18520      IPRS(86)=10HT22,*SOUTH $ IPRS(87)=2H*,
18530      IPRS(88)=10HT87,*SOUTH $ IPRS(89)=2H*)
18540  130 IXI=IABS(21-IX)
18550      IF(IXI.LT.10) IPRS(1)=7H(I2,1X,
18560C
18570C=====
18580C PRINT LINE IX
18590C=====
18600C
18610      PRINT IPRS,
18620+      IXI,(MAXFMPD(IY,IX),IY=1,41),IXI,(IMAX(IY,IX),IY=1,41),IXI
18630C
18640  140 CONTINUE
18650      PRINT 180
18660      PRINT 190
18670C
18680C===== FORMATS =====
18690  150 FORMAT(//)
18700  160 FORMAT (11X*MAXIMUM ZENITH=*F5.1* DEG*,T72,A10,T82,A10,
18710+      T92,A10,T102,A10/11X,*SCALE:*,F5.1,* KM/DIVISION*,
18720+      T36,*LOWEST DOPP. FREQ.= *,T77,A3,T80,I2,
18730+      T82,* HZ      DOPP.-FREQ. RESOLUTION= 1 /*,
18740+      T118,I2,T120,* HZ*)
18750  170 FORMAT (T4,*2*,T9,*1*,T14,*1*,T34,*1*,T39,*1*,T44,*2*/
18760+      3X,4(*0*,4X,*5*,4X),*0*,T48,*20*,T58,*15*,T68,*10*,T79,
18770+      *5*,T89,*0*,T99,*5*,T108,*10*,T118,*15*,T128,*20*)
18780  180 FORMAT(3X,41(1H!),3X,41(2H !))
18790  190 FORMAT (T4,*2*,T9,*1*,T14,*1*,T19,*5*,T24,*0*,T29,*5*,
18800+      T34,*1*,T39,*1*,T44,*2*,T48,*20*,T58,*15*,T68,*10*,T79,
18810+      *5*,T89,*0*,T99,*5*,T108,*10*,T118,*15*,T128,*20*/
18820+      T4,*0      5      0*,T34,*0      5      0*,8(/))
18830      RETURN
18840      END

```

A P P E N D I X C

PROGRAM DRIFVEL

DRIFVEL (ULCAR)

```

00100      PROGRAM DRIFVEL(INPUT,OUTPUT,TAPE48,TAPE49,TAPE50,TAPE69,
00110+      TAPE70,TAPE71,TAPE72)
00120C
00130C=====
00140C CALCULATION OF AVERAGE OR MEDIAN IONOSPHERIC-DRIFT VELOCITY VECTORS AND
00150C SOURCE POSITIONS FROM SKYMAP DATA.
00160C
00170C INPUT=TAPE50, GENERATED BY SUBROUTINE MAPDATA OF PROGRAM SKYMAP.
00180C MAPDATA OUTPUT IS STORED UNDER LABELS "YDDHHN", WHERE Y=T,U,...FOR
00190C YEARS 81,82,...; DDD=DAY; HH=STARTING HOUR; N=FREQUENCY NUMBER.
00200C (E.G.: U026181=YEAR 82, DAY 26, HOUR 18, FREQ. NO. 1)
00210C SEVERAL "SUB-FILES" (EACH SUB-FILE CONTAINING DATA AT ONE FREQUENCY
00220C NUMBER) MAY HAVE BEEN MERGED INTO ONE FILE AND LABELLED IN CON-
00230C SEQUENCE (E.G. U02618 IF ALL FREQ. NOS. ARE INCLUDED; OR U02618A
00240C AND U02618B). ALSO, DATA MAY BE ON PHYSICAL TAPES LABELLED MAPDAT.
00250C SEE PROGRAM MAPDATA FOR FURTHER DETAILS.
00260C (INPUT FILE MUST BE RENAMED TAPE50.)
00270C
00280C ONE SET OF BOTH NEGATIVE- AND POSITIVE-DOPPLER SOURCES (2 RECORDS)
00290C CALCULATED BY PROGRAM SKYMAP COMPRISES ONE CASE.
00300C
00310C SEVERAL VELOCITY VECTORS ARE CALCULATED FROM THE DATA OF EACH CASE:
00320C THE SOURCES ARE SORTED IN ORDER OF INCREASING OR DECREASING DENSITY
00330C (I.E., FMPD; SEE PROGRAM SKYMAP) OR DOPPLER NUMBER (AS DETERMINED BY
00340C "ISORT", INPUTTED AT BEGINNING OF THE RUN); THE FIRST VELOCITY
00350C CALCULATION USES THE MINIMUM NUMBER OF SOURCES "MINSRC" (ALSO
00360C INPUTTED AT BEGINNING), AND SUCCEEDING CALCULATIONS ADD ONE MORE
00370C SOURCE. (SOME SOURCES ARE SKIPPED; SEE BELOW.) EACH VELOCITY IS
00380C CALCULATED AS VX,VY,... AND STORED IN ARRAYS DBVX(NIVEL),DBVY(NIVEL),
00390C ... WHERE NIVEL=NUMBER OF INDIVIDUAL VELOCITY CALCULATIONS.
00400C
00410C AN AVE OR MEDIAN VELOCITY IS CALCULATED FROM THE INDIVIDUAL VELOCITIES
00420C FOR EACH CASE: CVX,CVY,...=CASEVX(KASE),CASEVY(KASE),... AND IS
00430C REFERRED TO AS CASE-NORM VELOCITY.
00440C
00450C AN AVERAGE NEG-DOPPLER SOURCE POSITION IS CALCULATED FOR EACH CASE:
00460C CNX,CNY,...=CASENX(KASE),CASENY(KASE),...,
00470C AND AN AVERAGE POS-DOPPLER SOURCE POSITION: CPX,CPY,...=CASEPX(KASE),
00480C CASEPY(KASE),...; THEY ARE REFERRED TO AS CASE-NORM POSITIONS.
00490C
00500C AN AVERAGE OR MEDIAN FOR GROUPS OF UP TO 6 CASES IS CALCULATED:
00510C GVX,GVY,...=GROUP-NORM VELOCITIES, AND
00520C GNX,GNY,...,GPX,GPY,...=GROUP-NORM NEG- AND POS-DOPP POSITIONS.
00530C
00540C THE DIGISONDE TAKES DRIFT MEASUREMENTS AT 3 OR 6 DIFFERENT FREQUENCIES
00550C (AND RANGES) SIMULTANEOUSLY. EACH MEASUREMENT IS LABELLED BY A
00560C FREQUENCY NUMBER (1-3 OR 1-6). AN AVE OR MEDIAN OF THE GROUP-NORM
00570C VELOCITIES FROM ALL 3 OR 6 SIMULTANEOUS MEASUREMENTS IS CALCULATED
00580C AND IS REFERRED TO AS ALL-FREQ VELOCITY.
00590C=====
00600C

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00610C
00620      COMMON MPDT(52),MAPDAT(4,160)
00630      COMMON/IGA/NN(35)
00640      DIMENSION XX(160),YY(160),ZZ(160),ONE(160)
00650      DIMENSION DBVX(60),DBVY(60),DBVZ(60),DBESQ(60)
00660      DIMENSION CASENX(16),CASENY(16),CASENZ(16),CASENS(16)
00670      DIMENSION CASEPX(16),CASEPY(16),CASEPZ(16),CASEPS(16)
00680      DIMENSION CASEVX(16),CASEVY(16),CASEVZ(16),CASEESQ(16),CASESIG(16)
00690      DIMENSION MTEMP(4),KPTST(15),KVV(3),KPT(3),IDT(5),NTAPE(5)
00700      DIMENSION IREAD(10)
00710      DATA NN/"1","2","3","4","5","6","7","8","9","A","B","C","D","E",
00720+      "F","G","H","I","J","K","L","M","N","O","P","Q","R","S","T","U",
00730+      "V","W","X","Y","Z"/
00740      DATA KPTST/1,2,4,8,16,24,34,36,40,48,66,68,72,80,88/
00750      DATA KVV/"(22X,"*WEIGHT: *","R6,A5)"/
00760      DATA IDT/"(6X,*START","ING DATE A","ND TIME:*,","A9","A1)"/
00770C
00780      REWIND 48
00790      REWIND 49
00800      REWIND 50 $ REWIND 69
00810      REWIND 70 $ REWIND 71 $ REWIND 72
00820C
00830      EOF50=0.
00840      IFLAG=IFHEAD=IFOUND=0
00850      DO 10 I=1,160
00860      10 ONE(I)=1.
00870C
00880C===== INPUTS REQUIRED =====
00890C  K P R I N T :
00900C      1=SUMMARY OF CASE-NORM AND GROUP-NORM POSITION AND VELOCITY VECTORS
00910C      2=LIST OF INDIVIDUAL VELOCITY CALCULATIONS
00920C      4=LIST OF CASE-NORM VELOCITIES
00930C      8=LIST OF GROUP-NORM VELOCITIES
00940C      16=LIST OF ALL-FREQ VELOCITIES
00950C          (KPRINT 16 REQUIRES SEVERAL RUNS, ONE AT EACH FREQUENCY NUMBER.
00960C           AFTER EACH RUN, RENAME TAPE48=TAPE49 (SEE SUBROUTINE ALLFREQ).
00970C           AFTER LAST RUN, LIST TAPE49 FOR REQUIRED OUTPUT.)
00980C      32+(2,4,8 OR 16)=LIST AND POLAR MAP.
00990C      64+(2,4,8,16)=GRAPH, NO LIST.
01000C          FOR KPRINT 2, AZIM-SPEED GRAPH IS WRITTEN ON TAPE69,
01010C              RMS ERROR GRAPH IS WRITTEN ON TAPE70.
01020C          FOR KPRINT 4,8, AZIM-SIGMA-SPEED GRAPH IS WRITTEN ON TAPE69.
01030C          FOR KPRINT 16, AZIM-SIGMA-SPEED GRAPH IS WRITTEN ON TAPE71.
01040C              ALSO,IF NO. OF FREQUENCIES IS .LE. 3, THE GROUP-NORM
01050C              VELOCITIES OF ALL 3 FREQ. NOS. AND THE ALL-FREQ
01060C              VEL. ARE WRITTEN ON ONE AZIM-SPEED GRAPH ON TAPE72.
01070C  NOTE: --32 OR 64 CANNOT BE USED ALONE BUT MUST BE ADDED TO 2,4,8 OR 16
01080C          --IF WANT BOTH GROUP-NORM AND ALL-FREQ OUTPUTS, SET KPRINT=8+16
01090C          FOR LIST ONLY, 8+16+64 FOR GRAPH. IF WANT LIST AND POLAR
01100C          MAP, MUST USE SEPARATE RUNS: 8+32 OR 16+32.
01110C

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01120C DATE, TIME, FREQUENCY NUMBER :
 01130C OR, TO START AT BEGINNING OF INPUT DATA, INPUT ZERO
 01140C UNLESS KPRINT INCLUDES 16 AND/OR 64;
 01150C E.G.: 82026,185910,2; OR: 0
 01160C IF IDATE=0, ALL RECORDS FROM 1ST TO LAST ARE CALCULATED.
 01170C IF IDATE NOT ZERO, STARTS AT FREQ. NO., DATE, TIME INPUTTED, THEN
 01180C CONTINUES UNTIL FREQ. NO. CHANGES.
 01190C
 01200C VEL - WEIGHT = VELOCITY-CALCULATION WEIGHT FACTOR
 01210C (USED IN LEAST SQUARE ERROR CALCULATION OF INDIVIDUAL VELOCITIES)
 01220C 1=LOG DENSITY
 01230C 2=LOG DENSITY*DOPPLER NO.
 01240C 3=LINEAR DENSITY
 01250C 4=LINEAR DENSITY*DOPPLER NO.
 01260C 5=DOPPLER NO.
 01270C 6=NO WEIGHTING
 01280C
 01290C SORTING ORDER :
 01300C "DECF": SOURCES ARE SORTED IN ORDER OF DECREASING FMPD
 01310C BEFORE CALCULATING THE SEVERAL INDIVIDUAL VELOCITIES,
 01320C THE FIRST CALCULATION USING "MINSRC" SOURCES, EACH
 01330C SUCCEEDING CALCULATION ADDING ONE MORE SOURCE.
 01340C "INCF": SOURCES SORTED IN ORDER OF INCREASING FMPD.
 01350C "DECD": SOURCES SORTED IN ORDER OF DECREASING DOPPLER NUMBER.
 01360C "INCD": SOURCES SORTED IN ORDER OF INCREASING DOPPLER NUMBER.
 01370C
 01380C MIN - SOURCES = MINIMUM NUMBER OF SOURCES TO BE USED FOR
 01390C CALCULATING A VELOCITY (LEAST SQUARE ERROR CALCULATION)
 01400C
 01410C MIN - DOPP : SOURCES WITH DOPPLER NUMBER LESS THAN
 01420C MIN-DOPP ARE BYPASSED IN VELOCITY CALCULATION
 01430C
 01440C MAX - DOPP : SOURCES WITH DOPPLER NUMBER GREATER THAN
 01450C MAX-DOPP ARE BYPASSED IN VELOCITY CALCULATION
 01460C
 01470C MAX - ESQ : CALCULATIONS WITH ESQ .GT. MAX-ESQ ARE BY-PASSED
 01480C
 01490C MAX - VZ : CALCULATIONS WITH ABS(VZ) .GT.MAX-VZ ARE BY-PASSED
 01500C
 01510C NOTE: FOR MIN-DOPP,MAX-DOPP,MAX-ESQ,MAX-VZ, ENTER 0 (ZERO) IF WANT ALL
 01520C
 01530C VEL - CHOICE :
 01540C "MED": CASE-NORM VELOCITY=MEDIAN OF THE DBVX,... OF ONE CASE;
 01550C GROUP-NORM VEL=MEDIAN OF THE CASE-NORM VELOCITIES;
 01560C ALL-FREQ VELOCITY=MEDIAN OF THE GROUP-NORM VELOCITIES FROM
 01570C ALL FREQUENCIES.
 01580C "WMED": WEIGHTED MEDIAN INSTEAD OF MEDIAN, EXCEPT ALL-FREQ
 01590C VELOCITY=NON-WEIGHTED MEDIAN.
 01600C "AVE" IJK: AVERAGE INSTEAD OF MEDIAN;
 01610C I,J,K=1 OR 2, AND INDICATE WHETHER CASE-NORM, GROUP-NORM
 01620C AND ALL-FREQ RESPECTIVELY ARE TO BE DETERMINED BY

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01630C          AVERAGING ONCE OR TWICE (IF TWICE, THE SECOND AVE'G
01640C          BY-PASSES VELOCITIES OUTSIDE THE STANDARD DEVIATION
01650C          OF THE FIRST AVERAGE)
01660C          "QUOTED" SYMBOLS ARE TO BE INPUTTED AS IS, BUT WITHOUT
01670C          QUOTE SIGNS E.G. AVE211
01680C=====
01690C
01700          PRINT 20
01710          20 FORMAT(" KPRINT"/" DATE,TIME,FREQ-NO."/" VEL-WEIGHT,MIN-SOURCES"/
01720+          " MIN-DOPP,MAX-DOPP,MAX-ESQ,MAX-VZ?")
01730C
01740          READ*,KPRINT,IDATE
01750C
01760          DO 30 K=1,15
01770          30 IF(KPRINT.EQ.KPTEST(K)) GO TO 40
01780          PRINT 110
01790          PRINT*," INVALID KPRINT." $ STOP
01800C
01810          40 IF((IDATE.NE.0).OR.((KPRINT.AND.80).EQ.0)) GO TO 50
01820          PRINT 110
01830          PRINT*," FOR THIS KPRINT, ENTER DATE,START TIME, FREQ. NO."
01840          STOP
01850C
01860          50 KD=0 $ KPT(1)=KPT(2)=KPT(3)=" "
01870          IF((KPRINT.AND.1).EQ.0) GO TO 55
01880          KD=1 $ KPT(1)=1
01890          55 DO 60 KB=1,6
01900          KC=2**KB
01910          IF((KPRINT.AND.KC).EQ.0) GO TO 60
01920          KD=KD+1 $ KPT(KD)=KC
01930          60 CONTINUE
01940C
01950          IF(IDATE.EQ.0) GO TO 70
01960          READ*,ITIME,IFREQNO
01970C
01980          70 READ*,INT,MINSRC,MINDOPP,MAXDOPP,MAXESQ,MAXVZ
01990          GO TO (71,72,73,74,75,76) INT
02000          71 MWT1=" LOG DE" $MWT2="NSITY" $ GO TO 80
02010          72 MWT1=" LOG DENS." $MWT2="*DOPP. NO." $ KVM(3)="R9,A10)" $ GO TO 80
02020          73 MWT1=" LINEAR A" $MWT2="AMPLITUDE" $ KVM(3)="R8,A8)" $ GO TO 80
02030          74 MWT1="LIN. DENS." $MWT2="*DOPP. NO." $ KVM(3)="2A10)" $ GO TO 80
02040          75 MWT1=" DOPPLER" $MWT2=" NUMBER" $ KVM(3)="R7,A7)" $ GO TO 80
02050          76 MWT1=" NO WEI" $MWT2="GHTING" $ KVM(3)="R6,A6)"
02060C
02070          80 PRINT*," SORTING ORDER?"
02080          READ 84,ISORT
02090          84 FORMAT(A4)
02100C
02110          IF((KPRINT.AND.29).EQ.0) GO TO 100
02120          PRINT*,"VELOCITY CHOICE?"
02130          READ 85,ICV

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02140      85 FORMAT(A6)
02150      IF(ICV.EQ."MED".OR.ICV.EQ."WMED") GO TO 95
02160      DECODE(6,90,ICV)ICVTEMP,ICV1,ICV2,ICV3
02170      90 FORMAT(A3,3I1)
02180      ICV=ICVTEMP
02190      95 IF(ICV.EQ."MED") ICV=1
02200      IF(ICV.EQ."WMED") ICV=2
02210      IF(ICV.EQ."AVE") ICV=3
02220C
02240      100 IDT1=" ALL DATA " $ IDT2=" "
02240      IF(IDATE.EQ.0) GO TO 105
02250      IDT1=IDATE $ IDT2=ITIME $ IDT(4)="I6," $ IDT(5)="1X,I6.6)"
02260      105 CONTINUE
02270      MINDO=MINDOPP $ IF(MINDO.EQ.0) MINDO="ALL"
02280      MAXDO=MAXDOPP $ IF(MAXDO.EQ.0) MAXDO="ALL"
02290      MAXES=MAXESQ $ IF(MAXES.EQ.0) MAXES="ALL"
02300      MAXV=MAXVZ $ IF(MAXV.EQ.0) MAXV="ALL"
02310      IF(ISORT.EQ."DECF") ISORT=1
02320      IF(ISORT.EQ."INCF") ISORT=2
02330      IF(ISORT.EQ."DECD") ISORT=3
02340      IF(ISORT.EQ."INCD") ISORT=4
02350C
02360C===== PRINT INPUT PARAMETERS CHOSEN, ON OUTPUT AND ON TAPES TO BE USED
02370C
02380C
02390      PRINT 110
02400      110 FORMAT(////)
02410      PRINT*,"                                KPRINT: ",KPT
02420      PRINT IDT,IDT1,IDT2
02430      IF(IDATE.NE.0) PRINT*,"                                FREQUENCY NUMBER: ",IFREGNO
02440      PRINT 111
02450      111 FORMAT(/13X,"INDIVIDUAL VELOCITY CALCULATION")
02460      PRINT KVM,MWT1,MWT2
02470      GO TO (112,113,114,115) ISORT
02480      112 PRINT*,"      ORDER OF SORTED SOURCES: DECREASING FWPD" $ GO TO 116
02490      113 PRINT*,"      ORDER OF SORTED SOURCES: INCREASING FWPD" $ GO TO 116
02500      114 PRINT*,"      ORDER OF SORTED SOURCES: DECREASING ABS(DOPPLER NUMBER)"
02510      GO TO 116
02520      115 PRINT*,"      ORDER OF SORTED SOURCES: INCREASING ABS(DOPPLER NUMBER)"
02530      116 PRINT*,"      MINIMUM NO. OF SOURCES: ",MINSRC
02540      PRINT*,"      MINIMUM DOPPLER NUMBER: ",MINDO
02550      PRINT*,"      MAXIMUM DOPPLER NUMBER: ",MAXDO
02560      PRINT*,"      MAXIMUM LEAST SQUARE ERROR: ",MAXES
02570      PRINT*,"      MAXIMUM ABS(VZ): ",MAXV
02580C
02590      DO 117 N=1,5
02600      117 NTAPE(N)=0
02610C
02620      IF((KPRINT.AND.80).EQ.0) GO TO 135
02630      IF((KPRINT.AND.14).NE.0) NTAPE(1)=69
02640      IF(KPRINT.EQ.66) NTAPE(2)=70

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DRIFUEL (ULCAR)

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02650      IF((KPRINT.AND.16).EQ.0) GO TO 125
02660      NTAPE(3)=49
02670      118 FORMAT(10A10)
02680      119 READ(48,118)(IREAD(I),I=1,10)
02690      IF(EOF(48).EQ.1) GO TO 121
02700      WRITE(49,118)(IREAD(I),I=1,10)
02710      IF(IREAD(6).NE."OUP-NORM V") GO TO 119
02720      DO 120 I=1,9
02730      120 BACKSPACE 49
02740      121 IF((KPRINT.AND.64).EQ.0) GO TO 125
02750      NTAPE(4)=71
02760      NTAPE(5)=72
02770      122 READ(71,118)(IREAD(I),I=1,10)
02780      IF(EOF(71).EQ.1) GO TO 125
02790      IF(IREAD(6).NE." GRAPH OF ") GO TO 122
02800      123 READ(72,118)(IREAD(I),I=1,10)
02810      IF(EOF(72).EQ.1) GO TO 125
02820      IF(IREAD(6).NE."OF GROUP-N") GO TO 123
02830      DO 124 I=1,9
02840      BACKSPACE 71
02850      124 BACKSPACE 72
02860C
02870      125 DO 131 N=1,5
02880      IF(NTAPE(N).EQ.0) GO TO 131
02890      NTP=NTAPE(N)
02900      PRINT(NTP,110)
02910      PRINT(NTP,*)"                                KPRINT: ",KPT
02920      PRINT(NTP,IDT)IDT1,IDT2
02930      IF(IDATE.NE.0) PRINT(NTP,*)"                                FREQUENCY NUMBER: ",
02940+      IFREQNO
02950      PRINT(NTP,111)
02960      PRINT(NTP,KVM)MWT1,MWT2
02970      GO TO (126,127,128,129) ISORT
02980      126 PRINT(NTP,*)"      ORDER OF SORTED SOURCES: DECREASING FWPD" $GOTO130
02990      127 PRINT(NTP,*)"      ORDER OF SORTED SOURCES: INCREASING FWPD" $GOTO130
03000      128 PRINT(NTP,*)"      ORDER OF SORTED SOURCES: DECREASING DOPPLER NUMBER"
03010      GO TO 130
03020      129 PRINT(NTP,*)"      ORDER OF SORTED SOURCES: INCREASING DOPPLER NUMBER"
03030      130 PRINT(NTP,*)"      MINIMUM NO. OF SOURCES: ",MINSRC
03040      PRINT(NTP,*)"      MINIMUM DOPPLER NUMBER: ",MINDO
03050      PRINT(NTP,*)"      MAXIMUM DOPPLER NUMBER: ",MAXDO
03060      PRINT(NTP,*)"      MAXIMUM LEAST SQUARE ERROR: ",MAXES
03070      PRINT(NTP,*)"      MAXIMUM ABS(VZ): ",MAXV
03080      131 CONTINUE
03090C
03100      135 IF((KPRINT.AND.29).EQ.0) GO TO 235
03110C
03120      140 FORMAT(/20X,"CHOICE OF VELOCITIES")
03130      145 FORMAT(8X,"CASE-NORM VELOCITIES: MEDIAN OF THE INDIVIDUAL",
03140+      " VELOCITIES")
03150      150 FORMAT(7X,"GROUP-NORM VELOCITIES: MEDIAN OF THE ",

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03160+      "CASE-NORM VELOCITIES")
03170 155 FORMAT(9X,"ALL-FREQ VELOCITIES: MEDIAN OF THE GROUP-NORM ",
03180+      "VELOCITIES FOR ALL FREQUENCY NUMBERS")
03190 160 FORMAT(8X,"CASE-NORM VELOCITIES: WEIGHTED MEDIAN OF THE"
03200+      " INDIVIDUAL VELOCITIES")
03210 165 FORMAT(7X,"GROUP-NORM VELOCITIES: WEIGHTED MEDIAN OF THE ",
03220+      "CASE-NORM VELOCITIES")
03230 170 FORMAT(9X,"ALL-FREQ VELOCITIES: MEDIAN OF THE GROUP-NORM ",
03240+      "VELOCITIES FOR ALL FREQUENCY NUMBERS")
03250 175 FORMAT(8X,"CASE-NORM VELOCITIES: WEIGHTED AVE OF INDIVIDUAL ",
03260+      "VELOCITIES CALCULATED ",A5)
03270 180 FORMAT(7X,"GROUP-NORM VELOCITIES: ",
03280+      "WEIGHTED AVE OF THE CASE-NORM VELOCITIES CALCULATED ",A5)
03290 185 FORMAT(9X,"ALL-FREQ VELOCITIES: AVERAGE OF THE GROUP-NORM ",
03300+      "VELOCITIES FOR ALL FREQUENCY NUMBERS CALCULATED ",A5)
03310      PRINT 140
03320      GO TO (190,195,200) ICV
03330 190 PRINT 145
03340      IF((KPRINT.AND.25).NE.0) PRINT 150
03350      IF((KPRINT.AND.16).NE.0) PRINT 155
03360      GO TO 205
03370 195 PRINT 160
03380      IF((KPRINT.AND.25).NE.0) PRINT 165
03390      IF((KPRINT.AND.16).NE.0) PRINT 170
03400      GO TO 205
03410 200 IF(ICV1.EQ.1) ICVN1="ONCE"  $ IF(ICV1.EQ.2) ICVN1="TWICE"
03420      IF(ICV2.EQ.1) ICVN2="ONCE"  $ IF(ICV2.EQ.2) ICVN2="TWICE"
03430      IF(ICV3.EQ.1) ICVN3="ONCE"  $ IF(ICV3.EQ.2) ICVN3="TWICE"
03440      PRINT 175,ICVN1
03450      IF((KPRINT.AND.25).NE.0) PRINT 180,ICVN2
03460      IF((KPRINT.AND.16).NE.0) PRINT 185,ICVN3
03470 205 IF((KPRINT.AND.80).EQ.0) GO TO 235
03480C
03490      DO 230 N=1,5
03500      IF(NTAPE(N).EQ.0) GO TO 230
03510      NTP=NTAPE(N)
03520      PRINT(NTP,140)
03530      GO TO (210,215,220) ICV
03540 210 PRINT(NTP,145)
03550      IF((KPRINT.AND.25).NE.0) PRINT(NTP,150)
03560      IF((KPRINT.AND.16).NE.0) PRINT(NTP,155)
03570      GO TO 225
03580 215 PRINT(NTP,160)
03590      IF((KPRINT.AND.25).NE.0) PRINT(NTP,165)
03600      IF((KPRINT.AND.16).NE.0) PRINT(NTP,170)
03610      GO TO 225
03620 220 PRINT(NTP,175)ICVN1
03630      IF((KPRINT.AND.25).NE.0) PRINT(NTP,180)ICVN2
03640      IF((KPRINT.AND.16).NE.0) PRINT(NTP,185)ICVN3
03650 225 PRINT(NTP,110)
03660 230 CONTINUE

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03670C

03680 235 PRINT 110

03690C

03700 IF((KPRINT.AND.64).EQ.0) GO TO 330

03710C

03720C===== G R A P H H E A D I N G =====

03730C

03740 273 FORMAT(///44X,"GRAPH OF INDIVIDUAL VELOCITY CALCULATIONS")

03750 276 FORMAT(///50X,"GRAPH OF CASE-NORM VELOCITIES")

03760 279 FORMAT(///50X,"GRAPH OF GROUP-NORM VELOCITIES")

03770 282 FORMAT(///51X,"GRAPH OF ALL-FREQ VELOCITIES")

03780 283 FORMAT(///44X,"GRAPH OF GROUP-NORM VELOCITIES FOR ALL RANGES")

03790 285 FORMAT(1X,"DATE:",16/" AST: HOUR,MINUTE")

03800 288 FORMAT(1X,"MINUTE ROUNDED OUT TO NEAREST 2.5 MINUTE"/

03810+ 3X,"(00,02,05,07,...=0, 2.5, 5, 7.5,... MIN.)")

03820 291 FORMAT(1X,"# = NUMBER OF SOURCES")

03830 294 FORMAT(1X,"# = NO. OF INDIVIDUAL VELOCITIES/CASE")

03840 297 FORMAT(1X,"# = NO. OF CASE-NORM VELOCITIES/GROUP")

03850 300 FORMAT(1X,"# = NO. OF FREQ. WITH NON-ZERO GROUP-NORM VELOCITY")

03860CCC 301 FORMAT(1X,"GROUP-NORM AZIM AND VH FOR FREQ. #1 = 1"

03870CCC+ /1X,"GROUP-NORM AZIM AND VH FOR FREQ. #2 = 2"

03880CCC+ /1X,"GROUP-NORM AZIM AND VH FOR FREQ. #3 = 4"

03890CCC+ /1X," ALL-FREQ AZIM AND VH = 8")

03900 301 FORMAT(1X,"GRAPH SYMBOLS REPRESENT RANGE:"

03910+ /3X,"RANGE(KM)=(200+10X), WHERE X=0,1,2,...,9,A,B,...")

03920 302 FORMAT(" FREQ (100KHZ UNITS) = (MAX FREQ) - (MIN FREQ)"

03930+ /" RANGE (KM) = (MAX RANGE) - (MIN RANGE)")

03940 303 FORMAT(" FREQUENCY IN 100KHZ UNITS; RANGE IN KM")

03950 304 FORMAT(/1X,"SEQ",3X,"FREQ",5X,"#",35X,"AZIMUTH",50X,"SPEED"/

03960+ 4X,"AST",3X,"RANGE",36X,"(DEGREES)",40X,

03970+ "VH=# +VZ=+ -VZ=- (M/S)"/

03980+ 19X,I1,3(4X,I2),1X,9(3X,I3),3X,I1,3X,I2,1X,5(2X,I3)/

03990+ 17X,"NORTH",13("."),"EAST",14("."),"SOUTH",13("."),

04000+ "WEST",14("."),"NORTH",2X,31("."),"X100")

04010 1304 FORMAT(/1X,"SEQ",3X,"FREQ",5X,"#",35X,"AZIMUTH",50X,"SPEED"/

04020+ 4X,"AST",3X,"RANGE",36X,"(DEGREES)",40X,

04030+ "VH=# +VZ=+ -VZ=- (M/S)"/

04040+ 19X,I1,3(4X,I2),1X,9(3X,I3),3X,I1,3X,I2,1X,5(2X,I3)/

04050+ 17X,"NORTH",13("."),"EAST",14("."),"SOUTH",13("."),

04060+ "WEST",14("."),"NORTH",2X,31("."),"X100")

04070CCC 305 FORMAT(/49X,"SIGMA=+ (M/S)"/

04080CCC+ 19X,I1,8(4X,I2),1X,4(3X,I3),16X,"SPEED"/

04090CCC+ 1X,"SEQ",3X,"FREQ",5X,"#",30X,"AZIMUTH=# (DEGREES)",34X,

04100CCC+ "VH=# +VZ=+ -VZ=- (M/S)"/

04110CCC+ 4X,"AST",3X,"RANGE",4X,I1,3(4X,I2),1X,9(3X,I3),3X,I1,3X,I2,1X,

04120CCC+ 5(2X,I3)/17X,"NORTH",13("."),"EAST",14("."),"SOUTH",13("."),

04130CCC+ "WEST",14("."),"NORTH",2X,31("."),"X100")

04140 305 FORMAT(/109X,"SPEED"/

04150+ 1X,"SEQ",3X,"FREQ",5X,"#",17X,"SIGMA=+ (M/S)",13X,"AZIMUTH",

04160+ "=# (DEGREES)",21X,"VH=# +VZ=+ -VZ=- (M/S)"/

04170+ 4X,"AST",3X,"RANGE",4X,I1,3(4X,I2),1X,9(3X,I3),3X,I1,3X,I2,1X,

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04180+      5(2X,I3)/17X,"NORTH",13("."),"EAST",14("."),"SOUTH",13("."),
04190+      "WEST",14("."),"NORTH",2X,31("."),"X100")
04200  308 FORMAT(/1X,"SEQ",3X,"FWPD",45X,"ROOT-MEAN-SQUARE ERROR ",
04210+      "(M/S)"/4X,"AST",3X,"DOPP")
04220  311 FORMAT(/3X,"SEQ AST",45X,"ROOT-MEAN-SQUARE ERROR (M/S)"/)
04230  314 FORMAT(15X,I1,4X,I1,18(3X,I2),1X,3(2X,I3)/15X,I11("."),"GT100")
04240C
04250      IF((KPRINT.AND.2).EQ.0) GO TO 317
04260      WRITE(69,273) $WRITE(70,273) $WRITE(69,285)IDATE $WRITE(70,285)IDATE
04270      WRITE(69,291) $ WRITE(69,303)
04280      WRITE(69,304)((I-1),I=1,361,30),((I-1),I=1,301,50)
04290      WRITE(70,308) $ WRITE(70,314)((I-1),I=1,111,5)
04300C
04310  317 IF((KPRINT.AND.4).EQ.0) GO TO 320
04320      WRITE(69,276) $WRITE(69,285)IDATE
04330      WRITE(69,294) $ WRITE(69,303)
04340CCC      WRITE(69,305)((I-1),I=1,145,12),((I-1),I=1,361,30),
04350CCC+      ((I-1),I=1,301,50)
04360      WRITE(69,305)((I-1),I=1,361,30),((I-1),I=1,301,50)
04370CCC      WRITE(70,276) $WRITE(70,285)IDATE
04380CCC      WRITE(70,311) $ WRITE(70,314)((I-1),I=1,111,5)
04390C
04400  320 IF((KPRINT.AND.8).EQ.0) GO TO 323
04410      WRITE(69,279) $WRITE(69,285)IDATE
04420      WRITE(69,288) $ WRITE(69,297) $ WRITE(69,303)
04430CCC      WRITE(69,305)((I-1),I=1,145,12),((I-1),I=1,361,30),
04440CCC+      ((I-1),I=1,301,50)
04450      WRITE(69,305)((I-1),I=1,361,30),((I-1),I=1,301,50)
04460CCC      WRITE(70,279) $WRITE(70,285)IDATE $WRITE(70,288)
04470CCC      WRITE(70,311) $ WRITE(70,314)((I-1),I=1,111,5)
04480C
04490  323 IF((KPRINT.AND.16).EQ.0) GO TO 330
04500      WRITE(71,282)
04510      WRITE(71,285)IDATE
04520      WRITE(71,288) $ WRITE(71,300) $ WRITE(71,302)
04530CCC      WRITE(71,305)((I-1),I=1,145,12),((I-1),I=1,361,30),
04540CCC+      ((I-1),I=1,301,50)
04550      WRITE(71,305)((I-1),I=1,361,30),((I-1),I=1,301,50)
04560      WRITE(72,283) $ WRITE(72,285)IDATE $ WRITE(72,288)
04570CCC      WRITE(72,311) $ WRITE(72,314)((I-1),I=1,111,5)
04580      WRITE(72,300) $ WRITE(72,301) $ WRITE(72,302)
04590      WRITE(72,1304)((I-1),I=1,361,30),((I-1),I=1,301,50)
04600CG
04610CG=====
04620CG THERE ARE 3 PRINCIPAL BLOCKS IN THE MAIN PROGRAM:
04630CG  1: INDIVIDUAL-VELOCITY-CALCULATION LOOP, WHICH IS INSIDE THE
04640CG  2: CASE LOOP, WHICH IS INSIDE THE
04650CG  3: GROUP LOOP.
04660CG THE "COMMENT INDICATORS" (COLUMN 6) IDENTIFY THE BLOCKS:
04670CG  "CV" FOR INDIVIDUAL VELOCITY CALCULATIONS;
04680CG  "CK" FOR CASE CALCULATIONS;

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04690CG  "CG" FOR GROUP CALCULATIONS.
04700CG  ALL-FREQ CALCULATIONS ARE DONE IN SUBROUTINE ALLFREQ.
04710CG===== G R O U P   L O O P =====
04720CG  INDEX NGRP=1 TO 35 COUNTS GROUPS,
04730CG  AND NN=1,2,...,9,A,...,Z IDENTIFIES GROUPS ON PRINTOUTS.
04740CG=====
04750CG
04760    330 NGVEL=NFVEL=0
04770        DO 1420 NGRP=1,35
04780            IGSEQ=NN(NGRP)
04790C
04800    340 NFCNTOT=NFCPTOT=NKVEL=NGIVEL=0
04810CG
04820        DO 350 I=1,16
04830            CASENX(I)=CASENY(I)=CASENZ(I)=CASENS(I)=0
04840            CASEPX(I)=CASEPY(I)=CASEPZ(I)=CASEPS(I)=0
04850    350 CASEVX(I)=CASEVY(I)=CASEVZ(I)=CASEESQ(I)=CASESIG(I)=0
04860CG
04870CK
04880CK===== C A S E   L O O P =====
04890CK  INDEX KASE=1 TO 6 COUNTS CASES PER GROUP.
04900CK  (KASE CAN BE INCREASED FROM 1,6 TO 1,15 SINCE HEXADECIMAL DIGITS
04910CK  (1 TO F) ARE USED TO IDENTIFY CASES ON PRINTOUTS.)
04920CK
04930CK  ARRAY MPDT CONTAINS ONE RECORD FROM TAPE 50:
04940CK      MPDT(1)=STATION IDENTIFICATION
04950CK          (2)=DATE
04960CK          (3)=TIME
04970CK          (6)=RWTT
04980CK          (7)=GNXZ
04990CK          (9)=FREQ. NO.
05000CK          (10)=FREQUENCY
05010CK          (11)=RANGE
05020CK          (12)=GAIN
05030CK          (4),(5),(8)=PREFACE PARAMETERS NOT USED HERE
05040CK          (13) TO (52)=PACKED SKYMAP DATA (1Y,1X,FWD,DOPPLER NO.--NEGATIVE
05050CK                      AND POSITIVE DOPPLERS IN SUCCESSIVE RECORDS)
05060CK
05070CK  ARRAY MAPDAT CONTAINS UNPACKED SKYMAP DATA FOR A COMPLETE CASE
05080CK  (BOTH NEGATIVE AND POSITIVE DOPPLERS).
05090CK=====
05100CK
05110        DO 1170 KASE=1,6
05120            NC=NR=0
05130            NICN=NFCN=NICP=NFCP=NICV=NFCV=0
05140CK
05150            IF(((KPRINT.AND.2).NE.0).AND.((KPRINT.AND.64).EQ.0)) PRINT*," "
05160CK
05170        DO 360 NRO=1,4
05180        DO 360 NCO=1,160
05190    360 MAPDAT(NRO,NCO)=0
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05200CK
05210 370 DO 380 I=1,52
05220 380 MPDT(I)=MPDT(I).AND.0
05230CK
05240CK=====BUFFERIN SKYMAP DATA FROM TAPE50
05250CK
05260 390 BUFFERIN(50,1)(MPDT(1),MPDT(52))
05270 IF(UNIT(50)) 420,400,390
05280C
05290C===== IF NOT END OF TAPE50, GO TO 420
05300C
05310 400 EOF50=1.
05320 IF(IFOUND.EQ.1) GO TO 405
05330 PRINT*," NO DATA FOUND TO SATISFY THE INPUT PARAMETERS."
05340 PRINT*," " $ PRINT*," " $ STOP
05350C
05360C===== IF VELOCITIES HAVE BEEN CALCULATED FOR AT LEAST ONE CASE IN
05370C THIS GROUP, EXIT CASE LOOP; IF NOT, PRINT INFO ABOUT WHERE
05380C OUTPUTS ARE TO BE FOUND, THEN STOP.
05390C
05400 405 IF(KASE.NE.1) GO TO 1175
05410 PRINT 407
05420 407 FORMAT(///)
05430 IF(LASFREQ.EQ.0.AND.(KPRINT.AND.16).NE.0) PRINT 410
05440 410 FORMAT(" LIST OF GROUP-NORM VELOCITIES FOR THE FREQUENCY ",
05450+ "NUMBER(S) ALREADY RUN IS ON TAPE 49."/
05460+ " PLEASE RENAME TAPE48=TAPE49, TO USE THE OUTPUT ",
05470+ "OF THIS RUN (TAPE49) AS INPUT (TAPE48) OF THE NEXT RUN."/
05480+ " BE SURE THAT FOR THE NEXT RUN, TAPE50 HAS MAP DATA",
05490+ " OF A DIFFERENT FREQUENCY NUMBER.")
05500 IF(LASFREQ.EQ.1.AND.(KPRINT.AND.16).NE.0) PRINT 415
05510 415 FORMAT(" LIST OF GROUP-NORM-VELOCITIES-FOR-ALL-",
05520+ "FREQUENCY-NUMBERS AND OF ALL-FREQ-VELOCITIES IS ON TAPE 49.")
05530 IF((KPRINT.AND.64).EQ.0) GO TO 419
05540 IF((KPRINT.AND.2).NE.0) PRINT 416,NFREQ
05550 416 FORMAT(" AZIM-SPEED GRAPH OF INDIVIDUAL VELOCITIES FOR FREQ. NO. ",
05560+ I1," IS ON TAPE69, AND RMS-ERROR GRAPH IS ON TAPE70.")
05570 IF((KPRINT.AND.4).NE.0)
05580+ PRINT*," GRAPH OF CASE-NORM VELOCITIES FOR FREQ. NO. ",
05590+ NFREQ," IS ON TAPE69."
05600 IF((KPRINT.AND.8).NE.0)
05610+ PRINT*," GRAPH OF GROUP-NORM VELOCITIES FOR FREQ. NO. ",
05620+ NFREQ," IS ON TAPE69."
05630 IF(((KPRINT.AND.16).NE.0).AND.(LASFREQ.EQ.1))
05640+ PRINT*," GRAPH OF ALL-FREQ VELOCITIES IS ON TAPE 71."
05650 IF(((KPRINT.AND.16).NE.0).AND.(LASFREQ.EQ.1).AND.(NUMFREQ.LE.3))
05660+ PRINT 414
05670 414 FORMAT(" GRAPH OF GROUP-NORM VELOCITIES FOR ALL ",
05680+ "RANGES IS ON TAPE 72.")
05690 IF(((KPRINT.AND.16).NE.0).AND.(LASFREQ.NE.1).AND.(NUMFREQ.GT.3))
05700+ PRINT 417

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05710 417 FORMAT(" IF SAVING RESULTS TO DO NEXT RUN LATER, SAVE TAPE48",
05720+ " AND TAPE71; GET BOTH TAPES, AS WELL AS TAPE50=(MAP DATA)," ,
05730+ "/" FOR THE NEXT RUN.")
05740 IF(((KPRINT.AND.16).NE.0).AND.(LASFREQ.NE.1).AND.(NUMFREQ.LE.3))
05750+ PRINT 418
05760 418 FORMAT(" IF SAVING RESULTS TO DO NEXT RUN LATER, SAVE TAPES 48," ,
05770+ " 71, AND 72; GET THE 3 TAPES, AS WELL AS TAPE50=(MAP DATA)," ,
05780+ "/" FOR THE NEXT RUN.")
05790 419 PRINT 407
05800 STOP
05810CK
05820CK=====CHECK IF WANT THIS SKYMAP DATA
05830CK
05840 420 IF(IDATE.EQ.0) GO TO 440
05850 IF(IFLAG.NE.0) GO TO 430
05860 IF(MPDT(9).NE.IFREQNO) GO TO 370
05870 IF(MPDT(2).NE.IDATE) GO TO 370
05880 IF(MPDT(3).NE.ITIME) GO TO 370
05890 IFLAG=1
05900CK
05910 430 IF(MPDT(9).NE.IFREQNO) GO TO 400
05920CK
05930 440 ISIGN=MPDT(4).AND.3
05940 IFOUND=1
05950CK
05960CK=====UNPACK DATA
05970CK IENDNEG=INDEX OF LAST NEG-DOPP SOURCE
05980CK =NUMBER OF NEG-DOPP SOURCES
05990CK IENDPOS=INDEX OF LAST POS-DOPP SOURCE
06000CK =TOTAL NUMBER OF SOURCES
06010CK
06020 CALL UNPACK(ISIGN,NR,NC)
06030 IF(ISIGN.EQ.1) IENDNEG=NC
06040 IF(ISIGN.EQ.2) IENDPOS=NC
06050 IF(ISIGN.EQ.1) GO TO 370
06060CK
06070CK===== C H E C K F O R E N D O F G R O U P =====
06080CK IF THIS CASE IS NOT THE FIRST ONE IN THE GROUP, CHECK IF IT SHOULD BE IN
06090CK THIS GROUP; IF NOT, BACKSPACE TAPE50 (2 RECORDS) SO THAT IT WILL BE
06100CK BUFFERED IN AGAIN IN NEXT GROUP.
06110CK
06120CK END THE GROUP WITH THE PREVIOUS CASE (LAST CASE CALCULATED) IF:
06130CK TIME LAPSE SINCE PREFACE OF FIRST CASE IN THE GROUP IS .GT. 5 MIN., OR
06140CK TIME LAPSE SINCE PREVIOUS CASE IS .GT. 18 SEC. (INDICATING THE TIME
06150CK SEQUENCE OF CASES IS BROKEN);
06160CK OR IF, COMPARED TO PREFACE OF FIRST CASE, FREQ. NO. CHANGES, OR RANGE
06170CK DIFFERENCE IS .GT. 10 KM, OR FREQ. DIFFERENCE IS .GT. 0.5 MHZ
06180CK (FOR THE LAST THREE CONDITIONS, ALSO PRINT A MESSAGE; EXCEPT,
06190CK MESSAGE IS SUPPRESSED FOR CERTAIN KPRINTS).
06200CK
06210CK OTHERWISE, CALCULATE THE LAST CASE BUFFERED IN.

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06220CK (PRINT MESSAGE IF GAIN CHANGES.)
06230CK
06240CK KIYR,ETC. REFER TO INITIAL (FIRST) CASE OF THE GROUP.
06250CK KLYR,ETC. REFER TO LAST CASE BUFFERED IN (NOT YET CALCULATED).
06260CK MYR,ETC. REFER TO CASE BEING CALCULATED.
06270CK KITIME,KLTIME,MTIME ARE HR-MIN-SEC IN SECONDS; ADD 24 HOURS TO KLTIME
06280CK IF INITIAL AND LAST DAYS ARE DIFFERENT.
06290CK IN=DRIFT-MEASUREMENT PROGRAM NUMBER.
06300CK DF2=DOPPLER FREQUENCY (HZ) OF DOPPLER NUMBER D=1.
06310CK DFR=SPECTRAL WIDTH(HZ)=DOPPLER-FREQ RESOLUTION.
06320CK NFREQ=FREQUENCY NUMBER.
06330CK NUMFREQ=NUMBER OF FREQUENCIES.
06340CK FREQ IN 100-HZ UNITS, CONVERTED TO KHZ.
06350CK RANGE IN 100-METER UNITS, CONVERTED TO KM.
06360CK ZMAX=MAXIMUM ZENITH ANGLE FOR SKYMAP.
06370CK SCALE=METERS-PER-DIVISION SCALE IN SKYMAP.
06380CK=====
06390CK
06400 IF(KASE.NE.1) GO TO 460
06410 KIYR=MPDT(2)/1000 $ KIDY=MOD(MPDT(2),(KIYR*1000))
06420 KIHHR=MPDT(3)/10000 $ KIMIN=MPDT(3)/100-KIHR*100
06430 KISEC=MPDT(3)-KIHHR*10000-KIMIN*100
06440 KITIME=KIHHR*3600+KIMIN*60+KISEC
06450 FREQKI=FLOAT(MPDT(10))/10 $ RANGKI=FLOAT(MPDT(11))/10
06460 KGAIN=MPDT(12) $ NFREQKI=MPDT(9)
06470 GO TO 555
06480CK
06490 460 KLYR=MPDT(2)/1000 $ KLDY=MOD(MPDT(2),(KLYR*1000))
06500 KLHR=MPDT(3)/10000 $ KLMIN=MPDT(3)/100-KLHR*100
06510 KLSEC=MPDT(3)-KLHR*10000-KLMIN*100
06520 KLTIME=KLHR*3600+KLMIN*60+KLSEC
06530 IF(KLDY.NE.KIDY) KLTIME=KLTIME+86400
06540 IF((KLTIME-MTIME).GT.18) GO TO 550
06550 IF((KLTIME-KITIME).GT.300) GO TO 550
06560CK
06570 IF(MPDT(9).NE.NFREQKI) 470,480
06580 470 IF((KPRINT.AND.64).EQ.0) PRINT*," DIFFERENT FREQ-NO ENCOUNTERED"
06590 GO TO 550
06600CK
06610 480 IF((ABS((FLOAT(MPDT(10))/10)-FREQKI)).GT.500.) 490,500
06620 490 IF((KPRINT.AND.64).EQ.0) PRINT*," FREQ. DIFFERENCE G.T. 0.5 MHZ"
06630 GO TO 550
06640CK
06650 500 IF((ABS((FLOAT(MPDT(11))/10)-RANGKI)).GT.10.) 510,520
06660 510 IF((KPRINT.AND.64).EQ.0) PRINT*," RANGE DIFFERENCE G.T. 10 KM"
06670 GO TO 550
06680CK
06690 520 IF(MPDT(12).NE.KGAIN)530,555
06700 530 IF((KPRINT.AND.80).EQ.0) PRINT 540,KGAIN,MPDT(12)
06710 KGAIN=MPDT(12)
06720 540 FORMAT(" NOTE GAIN CHANGE FROM ",I3," TO ",I3)

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```
06730      GO TO 555
06740CK
06750      550 BACKSPACE 50 $ BACKSPACE 50
06760      GO TO 1175
06770CK
06780CK===== D E T E R M I N E   P A R A M E T E R S   =====
06790CK                        O F   T H E   C A S E   B E I N G   C A L C U L A T E D
06800CK
06810      555 MSTAT=MPDT(1) $ KSEQ=NN(KASE)
06820      IF(KASE.NE.1) GO TO 560
06830      MYR=KIYR $MDY=KIDY $MHR=KIHR $MMIN=KIMIN $MSEC=KISEC $MTIME=KITIME
06840      GO TO 565
06850      560 MYR=KLYR $MDY=KLDY $MHR=KLHR $MMIN=KLMIN $MSEC=KLSEC $MTIME=KLTIME
06860      565 MRWTT=MPDT(6) $ MGNXZ=MPDT(7)
06870CK
06880CK=====IN: DIGISONDE PROGRAM NUMBER
06890CK      DFR: DOPPLER-FREQ RESOLUTION (SPECTRAL SPACING)
06900CK      DF2: DOPP-FREQ OF DOPPLER NO. 1
06910CK      NFREQ: ACTUAL FREQ. NO.; NUMFREQ: TOTAL NO. OF FREQUENCIES
06920CK      FREQ IN 100HZ UNITS CONVERTED TO KHZ
06930CK      RANGE IN 100M UNITS CONVERTED TO KM
06940CK
06950      IN=MGNXZ/100-(MGNXZ/1000)*10
06960      DFR=.12254902 $ IF(IN.EQ.7) DFR=DFR/2
06970      DF2=DFR/2 $ IF(IN.EQ.5.OR.IN.EQ.8) DF2=0
06980      NFREQ=MPDT(9)
06990      NUMFREQ=6-3*(IN/8)
07000      FREQ=FLOAT(MPDT(10))/10
07010      RANG=FLOAT(MPDT(11))/10
07020      SINZMAX=2997.925/FREQ
07030      IF(SINZMAX.GT.0.707) SINZMAX=.707
07040      SCALE=.707*RANG*SINZMAX/20
07050      R=RANG/SCALE
07060CK
07070CK===== P R I N T   H E A D I N G   =====
07080CK
07090      IF((KASE.NE.1).OR.((KPRINT.AND.84).NE.0)) GO TO 630
07100CK
07110      IF(((KPRINT.AND.7).NE.0).OR.(((KPRINT.AND.8).NE.0).AND.(NGRP.EQ.1)))
07120+      PRINT 570,MSTAT,MYR,MDY,MRWTT,MGNXZ,NFREQ,FREQ,RANG,
07130+      SCALE,MWT1,MWT2
07140      570 FORMAT(////*1*/1X,*STAT DATE RWTT QNXZ FREQ.NO. FREQ(KHZ) *,
07150+      *RANGE(KM) SCALE VEL WEIGHTING FACTOR */ ,
07160+      1X,I3,2X,I2,2,1H-,I3,3,2(1X,I4,4),I5,F13.1,F9.1,F7.1,3X,2A10//)
07170CK
07180      IF(KPRINT.EQ.1) PRINT 580, SCALE
07190      580 FORMAT(22X,"(POSITION UNITS: X,Y,Z *",F4.1      UX,
07200+      *+X,+UX=NORTH +Y,+UY=WEST)* /
07210+      17X,*NEG-DOPP SOURCE POSITION      POS-DOPP SOURCE POSITION*,
07220+      *      VELOCITY(M/S)* /
07230+      1X,*CASE TIME      X      Y      Z SIG NI NF      X      Y*,
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07240+      *   Z SIG NI NF      VX      VY      VZ      VH VEL AZIM ELEV*,
07250+      * SIG   ESQ NI NF*)
07260CK
07270      IF((KPRINT.AND.2).NE.0) PRINT 590
07280 590 FORMAT(20X,*(MAP COORD)*,3X,*( +VX=NORTH +VY=WEST ),13X,*NO. OF*
07290+      /1X,*CASE TIME   MIN DB   IVX IVY   VX(M/S) VY   VZ   VH*,
07300+      * VEL AZIM ELEV SOURCES   ESQ*)
07310CK
07320      IF((KPRINT.AND.4).NE.0) PRINT 600
07330 600 FORMAT(14X,*(MAP COORD) ( +VX=NORTH +VY=WEST )*/
07340+      1X,*CASE TIME      IVX IVY   VX(M/S) VY   VZ   VH VEL*,
07350+      * AZIM ELEV SIG   ESQ NI NF*)
07360CK
07370      IF((((KPRINT.AND.8).NE.0).AND.(NGRP.EQ.1)) PRINT 610
07380 610 FORMAT(36X,*(MAP COORD)*,3X,*( +VX=NORTH +VY=WEST )*/
07390+      1X,*GROUP TIME   FREQ(KHZ) RANGE(KM)*,
07400+      *   IVX IVY   VX(M/S) VY   VZ   VH VEL AZIM ELEV SIG*,
07410+      *   ESQ NI NF*)
07420CK
07430CK=====IF NO SOURCES, PRINT MESSAGE (UNLESS KPRINT INCLUDES 8,16, OR 64).
07440CK      IF PRINTING CASE-NORM, GROUP-NORM OR ALL-FREQ GRAPHS, SKIP
07450CK      INDIVIDUAL-VELOCITY CALCULATION LOOP; OTHERWISE, GO TO END
07460CK      OF CASE LOOP.
07470CK
07480 630 IF(IENDPOS.NE.0) GO TO 645
07490      IF((KPRINT.AND.88).EQ.0) PRINT 640,KASE,MHR,MMIN,MSEC
07500 640 FORMAT(2X,Z1,2X,Z2(I2.2,1H:),I2.2,3X,*NO SOURCES*)
07510      IF(((KPRINT.AND.64).NE.0).AND.((KPRINT.AND.2).EQ.0)) GO TO 955
07520      GO TO 1170
07530CK
07540CK=====FIND MAX AND MIN FMPD (LOG DENSITY) OF NEG- AND POS-DOPPLER
07550CK      SOURCES COMBINED FOR THIS CASE.
07560CK
07570      645 CONTINUE
07580CKKK 645 IDBMAX=IDBMIN=0
07590CKKK      IF(IENDPOS.EQ.0) GO TO 660
07600CKKK      DO 650 MCOL=1,IENDPOS
07610CKKK      IDBMIN=MIN0(MAPDAT(3,MCOL),IDBMIN)
07620CKKK 650 IDBMAX=MAX0(MAPDAT(3,MCOL),IDBMAX)
07630CKKK 660 CONTINUE
07640CK
07650CKKK      IDB6=MAX0((IDBMAX-5),0)
07660CK
07670      IF(KPRINT.NE.1) GO TO 760
07680CK
07690CK===== F I N D   C A S E - N O R M   S O U R C E   P O S I T I O N S   =====
07700CK      (NEG- AND POS-SOURCE POSITIONS SEPARATELY)
07710CK
07720      DO 750 J=1,2
07730      NC1=1 $ NC2=IENDNEG
07740      IF(J.EQ.1) GO TO 690

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07750      NC1=IENDNEG+1  $ NC2=IENDPOS
07760      690 NS=0
07770      DO 700 I=1,160
07780      700 XX(I)=YY(I)=ZZ(I)=0
07790      IF(NC2.LT.NC1) GO TO 720
07800      DO 710 NCOL=NC1,NC2
07810CKKK      IF(MAPDAT(3,NCOL).LT.IDB6) GO TO 710
07820      NS=NS+1
07830      YY(NS)=21-MAPDAT(1,NCOL)
07840      XX(NS)=21-MAPDAT(2,NCOL)
07850      ZZ(NS)=SQRT(R*R-XX(NS)*XX(NS)-YY(NS)*YY(NS))
07860      710 CONTINUE
07870      720 GO TO (730,740) J
07880      730 KASENEG=1
07890      CALL AVE(1,2,XX,YY,ZZ,ONE,NS,CNX,CNY,CNZ,CNS,DUM,NICN,NFCN)
07900      IF(NFCN.EQ.0) KASENEG=0
07910      CASENX(KASE)=CNX
07920      CASENY(KASE)=CNY
07930      CASENZ(KASE)=CNZ
07940      CASENS(KASE)=CNS
07950      GO TO 750
07960      740 KASEPOS=2
07970      CALL AVE(1,2,XX,YY,ZZ,ONE,NS,CPX,CPY,CPZ,CPS,DUM,NICP,NFCP)
07980      IF(NFCP.EQ.0) KASEPOS=0
07990      CASEPX(KASE)=CPX
08000      CASEPY(KASE)=CPY
08010      CASEPZ(KASE)=CPZ
08020      CASEPS(KASE)=CPS
08030      750 CONTINUE
08040CV
08050CV===== C A L C U L A T I O N   O F   V E L O C I T Y   =====
08060CV THE SOURCES FOR EACH CASE ARE SORTED IN ORDER OF DECREASING DENSITY,
08070CV INCREASING DENSITY, DECREASING ABS(DOPP. NO.), OR INCREASING
08080CV ABS(DOPP. NO.), AS REQUESTED IN INPUT PARAMETERS.
08090CV "MINSRC" (INPUTTED AT THE BEGINNING OF THE RUN) IS THE MINIMUM NUMBER
08100CV OF SOURCES REQUIRED FOR THE FIRST VELOCITY CALCULATION (USING TOO FEW
08110CV SOURCES CAN RESULT IN VERY LARGE ERRORS IN VELOCITY EVEN THOUGH ESQ
08120CV APPROACHES ZERO). EACH SUCCEEDING CALCULATION INCLUDES ONE MORE
08130CV SOURCE.
08140CV
08150CV NSRC COUNTS THE NUMBER OF SOURCES USED. A SOURCE IS SKIPPED IF:
08160CV --ITS DOPPLER NUMBER IS .LT. MINDOPP OR .GT. MAXDOPP
08170CV (MINDOPP,MAXDOPP ARE INPUTTED AT BEGINNING OF RUN);
08180CV --IT RESULTS IN A VELOCITY WHERE ABS(VZ).GT.MAXVZ, OR ESQ.GT.MAXESQ
08190CV (UNLESS THE SOURCE IS ONE OF THE "MINSRC" SOURCES USED IN THE
08200CV FIRST CALCULATION: IN THAT CASE, THE VELOCITY IS IGNORED, BUT
08210CV ALL MINSRC SOURCES ARE KEPT, SINCE THERE IS NO WAY IF KNOWING
08220CV WHICH SOURCE IS BAD).
08230CV
08240CV NIVEL COUNTS THE INDIVIDUAL VELOCITY CALCULATIONS FOR THIS CASE.
08250CV

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08260CV THE RESULTS ARE STORED IN ARRAYS DBUX(NIVEL), ETC.

08270CV

08280CV LEAST-SQUARE-ERROR CALCULATION:

08290CV

08300CV

08310CV
$$ESQ = \sum_I A(I) * [(V,R(I)) - (-C * DFREQ(I) / (2 * FREQ))]^2$$

08320CV

08330CV

08340CV

08350CV

08360CV

08370CV

08380CV

08390CV

08400CV

08410CV

08420CV

08430CV

08440CV SETTING DERIVATIVES (W.R.T. VX,VY,VZ) OF ESQ EACH EQUAL TO ZERO GIVES 3

08450CV EQUATIONS WHICH ARE SOLVED FOR VX,VY,VZ VIA CRAMER'S RULE;

08460CV ESQ IS THEN CALCULATED BY PLUGGING IN VX,VY,VZ.

08470CV=====

08480CV

08490 760 NIVEL=0

08500 IF(((KPRINT.EQ.66).AND.(IENDPOS.LT.4)).OR.

08510+ ((KPRINT.NE.66).AND.(IENDPOS.LT.MINSRC))) GO TO 955

08520CV

08530

08540

08550CV

08560

08570

08580

08590

08600

08610

08620

08630

08640

08650

08660

08670

08680

08690

08700

08710CV

08720

08730

08740

08750

08760CV

DO 765 I=1,60

765 DBUX(I)=DBUY(I)=DBVZ(I)=DBESQ(I)=0

IEND=IENDPOS-1

770 IFAGAIN=0

DO 790 KCOL=1,IEND

GO TO (771,772,773,774) ISORT

771 IF(MAPDAT(3,KCOL).GE.MAPDAT(3,KCOL+1)) 790,775

772 IF(MAPDAT(3,KCOL).LE.MAPDAT(3,KCOL+1)) 790,775

773 IF(IABS(MAPDAT(4,KCOL)).GE.IABS(MAPDAT(4,KCOL+1))) 790,775

774 IF(IABS(MAPDAT(4,KCOL)).LE.IABS(MAPDAT(4,KCOL+1))) 790,775

775 IFAGAIN=1

DO 780 KROW=1,4

MTEMP(KROW)=MAPDAT(KROW,KCOL)

MAPDAT(KROW,KCOL)=MAPDAT(KROW,KCOL+1)

780 MAPDAT(KROW,KCOL+1)=MTEMP(KROW)

790 CONTINUE

IF(IFAGAIN.EQ.1) GO TO 770

XSQ=YSQ=ZSQ=WSQ=XY=XZ=YZ=WX=WY=WZ=SUMA=NSRC=0

VX=0.

VY=0.

VZ=0.

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08770      DO 950 NCOL=1,IENDPOS
08780      IFWPD=MAPDAT(3,NCOL)
08790      IDOPP=MAPDAT(4,NCOL)
08800      FWPD=IFWPD
08810      DOPP=IDOPP
08820CV
08830CVVV      PRINT*, " NCOL,FWP,DOPP ",NCOL,FWP,DOPP
08840CVVV      PRINT 800,XSQ,YSQ,ZSQ,WSQ,XY,XZ,YZ,WX,WY,WZ,SUMA
08850      800 FORMAT(" XSQ...",6F15.3/7X,6F15.3)
08860CV
08870      IF(IABS(IDOPP).LT.MINDOPP) GO TO 910
08880      IF(IABS(IDOPP).GT.MAXDOPP.AND.MAXDOPP.NE.0) GO TO 910
08890CV
08900      Y=(21-MAPDAT(1,NCOL))
08910      X=(21-MAPDAT(2,NCOL))
08920      Z=SQRT(R*R-X*X-Y*Y)
08930      GO TO (820,830,840,850,860,870) INT
08940      820 A=FWPD $ GO TO 880
08950      830 A=FWPD*ABS(DOPP) $ GO TO 880
08960      840 A=10**((FWPD/10) $ GO TO 880
08970      850 A=(10**((FWPD/10))*ABS(DOPP) $ GO TO 880
08980      860 A=ABS(DOPP) $ GO TO 880
08990      870 A=1
09000      880 DFREQ=(DF2+(ABS(DOPP)-1)*DFR)*(DOPP/ABS(DOPP))
09010      W=-299792.5*DFREQ/(2*FREQ)
09020CV
09030      Y=SQRT(A)*Y/R
09040      X=SQRT(A)*X/R
09050      Z=SQRT(A)*Z/R
09060      W=SQRT(A)*W
09070CV
09080      XSQ=XSQ+X*X $ YSQ=YSQ+Y*Y $ ZSQ=ZSQ+Z*Z $ WSQ=WSQ+W*W
09090      XY=XY+X*Y $ XZ=XZ+X*Z $ YZ=YZ+Y*Z
09100      WX=WX+W*X $ WY=WY+W*Y $ WZ=WZ+W*Z $ SUMA=SUMA+A
09110CV
09120CVVV      PRINT 800,XSQ,YSQ,ZSQ,WSQ,XY,XZ,YZ,WX,WY,WZ,SUMA
09130CV
09140      NUMB=NSRC=NSRC+1
09150C
09160CVVV      IF(NCOL.EQ.IENDPOS) GO TO 895
09170CVVV      IF(IFWPD.EQ.MAPDAT(3,(NCOL+1))) GO TO 950
09180C
09190CVVV      895 IF(NSRC.GE.MINSRC) GO TO 897
09200      IF(NSRC.GE.MINSRC) GO TO 897
09210      IF((KPRINT.AND.64).NE.0) GO TO 920
09220      GO TO 950
09230CV
09240      897 DX=DET(WX,XY,XZ,WY,YSQ,YZ,WZ,ZSQ)
09250      DY=DET(XSQ,WX,XZ,XY,WY,YZ,XZ,WZ,ZSQ)
09260      DZ=DET(XSQ,XY,WX,XY,YSQ,WY,XZ,YZ,WZ)
09270      D=DET(XSQ,XY,XZ,XY,YSQ,YZ,XZ,YZ,ZSQ)

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09280CV
09290      VZ=DZ/D
09300      IF(IFIX(ABS(VZ)).GT.MAXVZ.AND.MAXVZ.NE.0) GO TO 900
09310CV
09320      VX=DX/D $ VY=DY/D
09330      ESQ=VX*VX*XSQ+VY*VY*YSQ+VZ*VZ*ZSQ+WSQ+2*VX*(VY*XY+VZ*XZ
09340+      -WX)+2*VY*(VZ*YZ-WY)-2*VZ*WZ
09350      ESQ=ESQ/SUMA
09360      IF(IFIX(ESQ).GT.MAXESQ.AND.MAXESQ.NE.0) GO TO 900
09370CV
09380      NIVEL=NIVEL+1
09390      DBVX(NIVEL)=VX
09400      DBVY(NIVEL)=VY
09410      DBVZ(NIVEL)=VZ
09420      DBESQ(NIVEL)=ESQ
09430      GO TO 920
09440CV
09450CVVV  900 CONTINUE
09460  900 XSQ=XSQ-X*X $ YSQ=YSQ-Y*Y $ ZSQ=ZSQ-Z*Z $ WSQ=WSQ-W*W
09470      XY=XY-X*Y $ XZ=XZ-X*Z $ YZ=YZ-Y*Z
09480      WX=WX-W*X $ WY=WY-W*Y $ WZ=WZ-W*Z $ SUMA=SUMA-A
09490      NSRC=NSRC-1
09500CV
09510CVVV  PRINT*, " SKIPPED: NCOL,FWPD,DOPP ",NCOL,FWPD,DOPP
09520CV
09530  910 NUMB=" "
09540      IF((KPRINT.AND.64).EQ.0) GO TO 950
09550CV
09560  920 IF((KPRINT.AND.2).EQ.0) GO TO 950
09570CV
09580      CALL VEL(VX,VY,VZ,VH,V,AZIM,ELEV)
09590      IF((KPRINT.AND.64).EQ.0) GO TO 930
09600      CALL GRAPH(KSEQ,MHR,MMIN,FREQ,RANG,NUMB,FWPD,DOPP,NCOL,KASE,
09610+      NGRP,VH,VZ,AZIM,DUM,ESQ,KPRINT,IDUM,MINSRC)
09620      GO TO 950
09630  930 CALL POLMAP(IDUM,KPRINT,KASE,VY,VX,IVY,IVX,1)
09640CV
09650      PRINT 940,KASE,MHR,MMIN,MSEC,IFWPD,IVX,IVY,VX,VY,VZ,
09660+      (IFIX(VH+.5)),(IFIX(V+.5)),AZIM,ELEV,NSRC,
09670+      (IFIX(ESQ+.5))
09680  940 FORMAT(2X,Z1,2X,2(I2.2,1H:),I2.2,I5,I7,I4,F8,F6,F5,
09690+      2I5,F6,F5,I5,I9)
09700CV
09710      IF(KPRINT.EQ.34)
09720+      CALL POLMAP(NGRP,KPRINT,KASE,DUM,DUM1,IVY,IVX,2)
09730CV
09740  950 CONTINUE
09750CV
09760CV=====END OF INDIVIDUAL-VELOCITY LOOP
09770CV      NGIVEL COUNTS THE INDIV. VELOCITIES IN THIS GROUP
09780CV

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09790      NGIVEL=NGIVEL+NIVEL
09800CV
09810CK
09820      IF(NIVEL.NE.0) GO TO 970
09830  955 IF((KPRINT.AND.89).EQ.0) PRINT 960,KASE,MHR,MMIN,MSEC
09840  960 FORMAT(2X,Z1,2X,2(I2.2,1H:),I2.2,3X,
09850+      *NOT ENOUGH SOURCES FOR VELOCITY CALCULATION*)
09860      KASEVEL=0 $ NIVEL=" "
09870      IF(KPRINT.EQ.68) GO TO 1000
09880      GO TO 1030
09890CK
09900  970 KASEVEL=4
09910CK
09920CK===== F I N D C A S E - N O R M V E L O C I T I E S =====
09930CK      BY CALCULATING THE AVE OR MEDIAN OF THE INDIVIDUAL VELOCITIES.
09940CK      NKVEL COUNTS THE CASE-NORM VELOCITIES IN THIS GROUP.
09950CK
09960      IF((KPRINT.AND.2).NE.0) GO TO 1170
09970      GO TO (980,985,990) ICV
09980  980 CALL MEDIAN(DBVX,DBVY,DBVZ,ONE,NIVEL,CVX,CVY,CVZ,CVS,CVE,NFCV)
09990      GO TO 995
10000  985 CALL MEDIAN(DBVX,DBVY,DBVZ,DBESQ,NIVEL,CVX,CVY,CVZ,CVS,CVE,NFCV)
10010      GO TO 995
10020  990 CALL AVE(NFREQ,ICV1,DBVX,DBVY,DBVZ,DBESQ,NIVEL,CVX,CVY,CVZ,CVS,
10030+      CVE,NICV,NFCV)
10040  995 NKVEL=NKVEL+1
10050      CASEVX(KASE)=CVX
10060      CASEVY(KASE)=CVY
10070      CASEVZ(KASE)=CVZ
10080      CASESIG(KASE)=CVS
10090      CASEESQ(KASE)=CVE
10100CK
10110      IF((KPRINT.AND.5).NE.0)
10120+      CALL VEL(CVX,CVY,CVZ,CVH,CV,CAZ,CEL)
10130      IF((KPRINT.AND.4).EQ.0) GO TO 1030
10140      IF((KPRINT.AND.64).EQ.0) GO TO 1010
10150CK
10160  1000 CALL GRAPH(KSEQ,MHR,MMIN,FREQ,RANG,NIVEL,DUM,DUM1,IDUM,KASE,
10170+      NDUM,CVH,CVZ,CAZ,CVS,DUM2,KPRINT,IDUM2,IDUM3)
10180      GO TO 1030
10190  1010 CALL POLMAP(IDUM,KPRINT,KASE,CVY,CVX,IVY,IVX,1)
10200      PRINT 1020,KASE,MHR,MMIN,MSEC,
10210+      IVX,IVY,CVX,CVY,CVZ,(IFIX(CVH+.5)),(IFIX(CV+.5)),
10220+      CAZ,CEL,(IFIX(CVS+.5)),(IFIX(CVE+.5)),NICV,NFCV
10230  1020 FORMAT(2X,Z1,2X,2(I2.2,1H:),I2.2,I6,I4,F7,F6,F5,2I4,
10240+      2F5,I5,I7,2I3)
10250      IF(KPRINT.EQ.36)
10260+      CALL POLMAP(NKVEL,KPRINT,KASE,DUM,DUM1,IVY,IVX,2)
10270CK
10280  1030 IF(KPRINT.NE.1) GO TO 1170
10290CK

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10300CK=====
10310CK PRINT CASE-NORM NEGATIVE- AND POSITIVE-DOPPLER SOURCE POSITIONS AND
10320CK VELOCITIES FOR THIS CASE. KASENEG, ETC., DETERMINE WHICH PRINT
10330CK STATEMENT TO USE: ONLY THE "NON-ZERO" RESULTS ARE PRINTED.
10340CK (IF THERE ARE NO SOURCES, SEE COMMENT PRECEDING STATEMENT 630 ABOVE.)
10350CK=====
10360CK
10370      NFCNTOT=NFCNTOT+NFCN
10380      NFCPTOT=NFCPTOT+NFCP
10390      GO TO(1040,1060,1080,1100,1110,1130,1150)(KASENEG+KASEPDS+KASEVEL)
10400CK
10410 1040 PRINT 1050,KASE,MHR,MMIN,MSEC,
10420+      CNX,CNY,CNZ,(IFIX(CNS+.5)),NICN,NFCN,NICP,NFCP,
10430+      NICV,NFCV
10440 1050 FORMAT(2X,Z1,2X,2(I2.2,1H:),I2.2,4X,3F5,3I3,23X,2I3,55X,2I3)
10450      GO TO 1170
10460CK
10470 1060 PRINT 1070,KASE,MHR,MMIN,MSEC,
10480+      NICN,NFCN,CPX,CPY,CPZ,(IFIX(CPS+.5)),NICP,NFCP,
10490+      NICV,NFCV
10500 1070 FORMAT(2X,Z1,2X,2(I2.2,1H:),I2.2,22X,2I3,5X,3F5,3I3,55X,2I3)
10510      GO TO 1170
10520CK
10530 1080 PRINT 1090,KASE,MHR,MMIN,MSEC,
10540+      CNX,CNY,CNZ,(IFIX(CNS+.5)),NICN,NFCN,
10550+      CPX,CPY,CPZ,(IFIX(CPS+.5)),NICP,NFCP,NICV,NFCV
10560 1090 FORMAT(2X,Z1,2X,2(I2.2,1H:),I2.2,4X,3F5,3I3,5X,3F5,3I3,55X,2I3)
10570 1100 GO TO 1170
10580CK
10590CK
10600 1110 PRINT 1120,KASE,MHR,MMIN,MSEC,
10610+      CNX,CNY,CNZ,(IFIX(CNS+.5)),NICN,NFCN,NICP,NFCP,
10620+      CVX,CVY,CVZ,(IFIX(CVH+.5)),(IFIX(CV+.5)),CAZ,
10630+      CEL,(IFIX(CVS+.5)),(IFIX(CVE+.5)),NICV,NFCV
10640 1120 FORMAT(2X,Z1,2X,2(I2.2,1H:),I2.2,4X,3F5,3I3,23X,2I3,4X,2F7,F6,2I5,
10650+      2F5,I5,I6,2I3)
10660      GO TO 1170
10670CK
10680 1130 PRINT 1140,KASE,MHR,MMIN,MSEC,
10690+      NICN,NFCN,CPX,CPY,CPZ,(IFIX(CPS+.5)),NICP,NFCP,
10700+      CVX,CVY,CVZ,(IFIX(CVH+.5)),(IFIX(CV+.5)),CAZ,
10710+      CEL,(IFIX(CVS+.5)),(IFIX(CVE+.5)),NICV,NFCV
10720 1140 FORMAT(2X,Z1,2X,2(I2.2,1H:),I2.2,22X,2I3,5X,3F5,3I3,4X,2F7,F6,2I5,
10730+      2F5,I5,I6,2I3)
10740      GO TO 1170
10750CK
10760 1150 PRINT 1160,KASE,MHR,MMIN,MSEC,
10770+      CNX,CNY,CNZ,(IFIX(CNS+.5)),NICN,NFCN,
10780+      CPX,CPY,CPZ,(IFIX(CPS+.5)),NICP,NFCP,
10790+      CVX,CVY,CVZ,(IFIX(CVH+.5)),(IFIX(CV+.5)),CAZ,
10800+      CEL,(IFIX(CVS+.5)),(IFIX(CVE+.5)),NICV,NFCV

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10810 1160 FORMAT(2X,Z1,2X,2(I2.2,1H:),I2.2,4X,3F5,3I3,5X,3F5,3I3,4X,2F7,F6,
10820+      2I5,2F5,I5,I6,2I3)
10830CK
10840 1170 CONTINUE
10850      GO TO 1180
10860CK
10870CK===== END OF CASE LOOP =====
10880CK
10890 1175 KASE=KASE-1
10900CK
10910CK=====PRINT POLAR MAP OF INDIVIDUAL OR CASE-NORM VELOCITIES
10920CK
10930 1180 IF(((KPRINT.EQ.34).AND.(NGIVEL.NE.0)).OR.
10940+      ((KPRINT.EQ.36).AND.(NKVEL.NE.0)))
10950+      CALL POLMAP(NDUM,KPRINT,IDUM,DUM,DUM1,IDUM1,IDUM2,3)
10960CK
10970      IF((KPRINT.AND.6).NE.0) GO TO 1420
10980      IF(KPRINT.NE.1) GO TO 1182
10990CG
11000CG=====FIND GROUP-NORM NEG- AND POS-DOPP SOURCE POSITIONS
11010CG
11020      KGRPNEG=1 $ KGRPPDS=2
11030      CALL AVE(NFREQ,1,CASENX,CASENY,CASENZ,ONE,KASE,GNX,GNY,GNZ,
11040+      GNS,DUM,NIGN,NFGN)
11050      IF(NFGN.EQ.0) KGRPNEG=0
11060CG
11070      CALL AVE(NFREQ,1,CASEPX,CASEPY,CASEPZ,ONE,KASE,GPX,GPY,GPZ,
11080+      GPS,DUM,NIGP,NFGP)
11090      IF(NFGP.EQ.0) KGRPPDS=0
11100CG
11110CG=====FIND GROUP TIME ROUNDED OUT TO NEAREST 2.5 MINUTES
11120CG
11130 1182 IF((KPRINT.AND.24).EQ.0) GO TO 1185
11140      KFTIME=MTIME
11150      KIT=IFIX(FLOAT(KITIME)/150+.5)*150
11160      KFT=IFIX(FLOAT(KFTIME)/150+.5)*150
11170      IF((IABS(KIT-KITIME)).GT.(IABS(KFT-KFTIME))) GO TO 1183
11180      NGRPDAT=KIYR*1000+KIDY
11190      NGRPTIM=KIT
11200      GO TO 1184
11210 1183 NGRPDAT=MPDT(2)
11220      NGRPTIM=KFT
11230 1184 IF(NGRPTIM.GT.86400) NGRPTIM=NGRPTIM-86400
11240      NGRPHR=NGRPTIM/3600 $ NMINSEC=NGRPTIM-NGRPHR*3600
11250      NGRPMIN=NMINSEC/60 $ NGRPSEC=NMINSEC-NGRPMIN*60
11260CG
11270 1185 IF(NKVEL.NE.0) GO TO 1187
11280CG
11290      KGRPVEL=0 $ NKVEL=" " $ GUX=GVY=GVZ=0 $ NIGU=NFGU=0
11300      IF(((KPRINT.AND.8).NE.0).AND.((KPRINT.AND.64).EQ.0))
11310+      PRINT 1186,NN(NGRP),NGRPHR,NGRPMIN,NGRPSEC,FREQ,RANG,NIGU,NFGU
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11320 1186 FORMAT(3X,A1,3X,2(I2.2,1H:),I2.2,F8.1,F10.1,60X,2I3)
11330      GO TO 1196
11340CG
11350 1187 KGRPVEL=4
11360CG
11370CG=====FIND GROUP-NORM VELOCITY
11380CG      NGVEL COUNTS THE NUMBER OF GROUP-NORM VELOCITIES
11390CG
11400      GO TO(1191,1192,1193) ICV
11410 1191 CALL MEDIAN(CASEVX,CASEVY,CASEVZ,ONE,KASE,GVX,GVY,GVZ,GVS,GVE,NFGV)
11420      GO TO 1194
11430 1192 CALL MEDIAN(CASEVX,CASEVY,CASEVZ,CASEESQ,KASE,GVX,GVY,GVZ,GVS,GVE,
11440+      NFGV)
11450      GO TO 1194
11460 1193 CALL AVE(NFREQ,ICV2,CASEVX,CASEVY,CASEVZ,CASEESQ,KASE,GVX,GVY,
11470+      GVZ,GVS,GVE,NIGV,NFGV)
11480 1194 NGVEL=NGVEL+1
11490CG
11500 1196 IF((KPRINT.AND.9).NE.0)
11510+      CALL VEL(GVX,GVY,GVZ,GVH,GV,GVZ,GEL)
11520CG
11530      IF(KPRINT.EQ.1) GO TO 1245
11540      IF((KPRINT.AND.8).EQ.0) GO TO 1230
11550      IF((KPRINT.AND.64).EQ.0) GO TO 1210
11560CG
11570 1200 CALL GRAPH(IGSEQ,NGRPHR,NGRPMIN,FREQ,RANG,NKVEL,DUM,DUM1,
11580+      IDUM,IDUM1,NDUM,GVH,GVZ,GAZ,GVS,DUM2,KPRINT,IDUM2,8)
11590      GO TO 1230
11600CG
11610 1210 IF(NKVEL.EQ." ") GO TO 1230
11620      CALL POLMAP(IDUM,KPRINT,NGRP,GVY,GVX,IVY,IVX,1)
11630      PRINT 1220,(NN(NGRP)),NGRPHR,NGRPMIN,NGRPSEC,FREQ,RANG,IVX,IVY,
11640+      GVX,GVY,GVZ,(IFIX(GVH+.5)),(IFIX(GV+.5)),GAZ,GEL,
11650+      (IFIX(GVS+.5)),(IFIX(GVE+.5)),NIGV,NFGV
11660 1220 FORMAT(3X,A1,3X,2(I2.2,1H:),I2.2,F8.1,F10.1,I8,I4,1X,2F6,F5,
11670+      2I4,2F5,I5,I7,2I3)
11680      IF(KPRINT.EQ.40)
11690+      CALL POLMAP(NGVEL,KPRINT,NGRP,DUM,DUM1,IVY,IVX,2)
11700 1230 IF((KPRINT.AND.16).EQ.0) GO TO 1240
11710CG
11720      IF((RANG.LT.200.).OR.(RANG.GT.510.)) GVX=GVY=GVZ=0
11730      CALL ALLFREQ(KPRINT,NGRP,NGRPDAT,NGRPHR,NGRPMIN,NGRPSEC,GVX,
11740+      GVY,GVZ,FREQ,RANG,NUMFREQ,NFREQ,ONE,ICV,ICV3,IFHEAD,LASFREQ,NFVEL)
11750 1240 GO TO 1410
11760CG
11770CG===== P R I N T   G R O U P   -   N O R M   =====
11780CG===== S O U R C E   P O S I T I O N S   A N D   V E L O C I T I E S   =====
11790CG      KG DETERMINES WHICH PRINT STATEMENT TO USE: ONLY THE "NON-ZERO"
11800CG      RESULTS ARE PRINTED. IF THERE ARE NO SOURCES, NOTHING IS PRINTED.
11810CG
11820 1245 KG=KGRPNEG+KGRPPOS+KGRPVEL

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11830      IF(KG.EQ.0) GO TO 1410
11840      IF((NFCNTOT+NFCPTOT).NE.0) PRINT 1250,NFCNTOT,NFCPTOT
11850 1250  FORMAT(6X,"(TOTAL)",25X,I3,26X,I3)
11860      GO TO(1260,1280,1300,1320,1330,1350,1370) KG
11870CG
11880 1260 PRINT 1270,"GROUP-NORM",":",
11890+      GNX,GNY,GNZ,(IFIX(GNS+.5)),NIGN,NFGN,NIGP,NFGP,
11900+      NIGV,NFGV
11910 1270 FORMAT(/1X,A10,A4,2X,3F5,3I3,23X,2I3,55X,2I3)
11920      GO TO 1390
11930CG
11940 1280 PRINT 1290,"GROUP-NORM",":",
11950+      NIGN,NFGN,GPX,GPY,GPZ,(IFIX(GPS+.5)),NIGP,NFGP,
11960+      NIGV,NFGV
11970 1290 FORMAT(/1X,A10,A4,20X,2I3,5X,3F5,3I3,55X,2I3)
11980      GO TO 1390
11990CG
12000 1300 PRINT 1310,"GROUP-NORM",":",
12010+      GNX,GNY,GNZ,(IFIX(GNS+.5)),NIGN,NFGN,
12020+      GPX,GPY,GPZ,(IFIX(GPS+.5)),NIGP,NFGP,NIGV,NFGV
12030 1310 FORMAT(/1X,A10,A4,2X,3F5,3I3,5X,3F5,3I3,55X,2I3)
12040 1320 GO TO 1390
12050CG
12060CG
12070 1330 PRINT 1340,"GROUP-NORM",":",
12080+      GNX,GNY,GNZ,(IFIX(GNS+.5)),NIGN,NFGN,NIGP,NFGP,
12090+      GUX,GUY,GVZ,(IFIX(GVH+.5)),(IFIX(GV+.5)),GAZ,
12100+      GEL,(IFIX(GVS+.5)),(IFIX(GVE+.5)),NIGV,NFGV
12110 1340 FORMAT(/1X,A10,A4,2X,3F5,3I3,23X,2I3,4X,2F7,F6,2I5,
12120+      2F5,I5,I6,2I3)
12130      GO TO 1390
12140CG
12150 1350 PRINT 1360,"GROUP-NORM",":",
12160+      NIGN,NFGN,GPX,GPY,GPZ,(IFIX(GPS+.5)),NIGP,NFGP,
12170+      GUX,GUY,GVZ,(IFIX(GVH+.5)),(IFIX(GV+.5)),GAZ,
12180+      GEL,(IFIX(GVS+.5)),(IFIX(GVE+.5)),NIGV,NFGV
12190 1360 FORMAT(/1X,A10,A4,20X,2I3,5X,3F5,3I3,4X,2F7,F6,2I5,
12200+      2F5,I5,I6,2I3)
12210      GO TO 1390
12220CG
12230 1370 PRINT 1380,"GROUP-NORM",":",
12240+      GNX,GNY,GNZ,(IFIX(GNS+.5)),NIGN,NFGN,
12250+      GPX,GPY,GPZ,(IFIX(GPS+.5)),NIGP,NFGP,
12260+      GUX,GUY,GVZ,(IFIX(GVH+.5)),(IFIX(GV+.5)),GAZ,
12270+      GEL,(IFIX(GVS+.5)),(IFIX(GVE+.5)),NIGV,NFGV
12280 1380 FORMAT(/1X,A10,A4,2X,3F5,3I3,5X,3F5,3I3,4X,2F7,F6,
12290+      2I5,2F5,I5,I6,2I3)
12300CG
12310 1390 CONTINUE
12320CGGG 1390 PRINT 1400,(GVX/20),(GVY/20),(GVZ/20)
12330 1400 FORMAT(1X,"(UNITS OF 20)",60X,2F7,F6)

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12340CG
12350 1410 IF(E0F50.EQ.1.) GO TO 1430
12360CG
12370 1420 CONTINUE
12380CG
12390 1430 IF(((KPRINT.EQ.40).AND.(NGVEL.NE.0)).OR.
12400+      ((KPRINT.EQ.48).AND.(NFVEL.NE.0)))
12410+      CALL POLMAP(NDUM,KPRINT,IDUM,DUM,DUM1,IDUM1,IDUM2,3)
12420      IF((KPRINT.EQ.40).AND.(NGVEL.NE.0)) PRINT 110
12430      IF((KPRINT.EQ.48).AND.(NFVEL.NE.0)) WRITE(49,110)
12440      GO TO 330
12450      END
12460C
12470C
12480C
12490C===== S U B R O U T I N E U N P A C K =====
12500C EACH 60-BIT WORD IN MPDT(13) TO MPDT(52) CONTAINS 2 SETS OF
12510C   IY, IX, FWP, DOPPLER NUMBER:
12520C   IY,IX: 6 BITS EACH;
12530C   FWP,DOPP. NO.: 9 BITS EACH.
12540C STORE EACH SET IN MAPDAT(NROW,NCOLUMN),NROW=1 TO 4.
12550C STORE 2 RECORDS TOGETHER:
12560C   1ST RECORD: NEGATIVE DOPPLERS (MAPDAT(4,NCOL)=DOPP. NO. IS STORED
12570C               AS A NEGATIVE NUMBER).
12580C   2ND RECORD: POSITIVE DOPPLERS.
12590C
12600C       FOR: IBY= 1, 2, 3, 4, 5, 6, 7, 8:
12610C           IBG= 6, 6, 9, 9, 6, 6, 9, 9, AND
12620C           IBF= 6, 12, 21, 30, 36, 42, 51, 60, AND
12630C "63+448*(IBG/9)"= 63, 63,511,511, 63, 63,511,511.
12640C=====
12650C
12660      SUBROUTINE UNPACK(ISIGN,NROW,NCOL)
12670      COMMON MPDT(52),MAPDAT(4,160)
12680      INTEGER SHIFT
12690C
12700      DO 30 IM=13,52
12710      IBF=0
12720      DO 30 IBY=1,8
12730      NROW=NROW+1 $ IF(NROW.EQ.5)NROW=1 $ IF(NROW.EQ.1)NCOL=NCOL+1
12740      IBG=3+3*((IBY+1-4*(IBY/5))/2) $ IBF=IBF+IBG
12750      MAPDAT(NROW,NCOL)=(63+448*(IBG/9)).AND.SHIFT(MPDT(IM),IBF)
12760      IF((NROW.EQ.4).AND.(MAPDAT(1,NCOL).EQ.0)) GO TO 40
12770      IF((NROW.EQ.4).AND.(MAPDAT(1,NCOL).EQ.1.OR.MAPDAT(1,NCOL).EQ.41
12780+      .OR.MAPDAT(2,NCOL).EQ.1.OR.MAPDAT(2,NCOL).EQ.41)) 10,20
12790      10 NCOL=NCOL-1 $ GO TO 30
12800      20 IF((NROW.EQ.4).AND.(ISIGN.EQ.1))MAPDAT(NROW,NCOL)=
12810+      -MAPDAT(NROW,NCOL)
12820      30 CONTINUE
12830      40 NROW=0 $ NCOL=NCOL-1
12840      RETURN
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12850      END
12860C
12870C
12880C
12890C===== FUNCTION DET =====
12900C=====CALCULATE DETERMINANT
12910C
12920      FUNCTION DET(A11,A12,A13,A21,A22,A23,A31,A32,A33)
12930      DET=A11*(A22*A33-A23*A32)-A12*(A21*A33-A23*A31)
12940+      +A13*(A21*A32-A22*A31)
12950      RETURN
12960      END
12970C
12980C
12990C
13000C===== SUBROUTINE AVE =====
13010C CALCULATE AVERAGE VECTOR BY AVE'G X,Y,Z COMPONENTS SEPARATELY.
13020C
13030C INPUTS:
13040C      I2: EQUALS 1 OR 2, FOR AVERAGING ONCE OR TWICE. THE SECOND AVERAGING
13050C          BYPASSES VECTORS OUTSIDE THE STANDARD DEVIATION CALCULATED
13060C          WITH THE FIRST AVERAGE.
13070C      ARRAYS X,Y,Z: INPUTTED AS POSITION COORDINATES OR VELOCITY COMPONENTS.
13080C      ARRAY ESQ: VALUES FOR WEIGHTING FACTOR. INPUTTED AS LEAST AVERAGE
13090C          SQUARE ERRORS FOR VELOCITIES, AS ARRAY ONE=1 FOR POSITIONS.
13100C          WEIGHT=1 FOR ESQ.LE.1,
13110C          =1/SQRT(ESQ) FOR ESQ.GT.1.
13120C      NVEC: NUMBER OF VECTORS INPUTTED, INCLUDING ZERO VECTORS IF ANY.
13130C
13140C OUTPUTS:
13150C      AVEX,AVEY,AVEZ.
13160C      SIG=STANDARD DEVIATION.
13170C      AVEESQ=AVE OF THE ESQ'S OF THE VECTORS USED IN FINDING AVEX,AVEY,AVEZ.
13180C      NI="NUMBER-INITIAL"=NUMBER OF VECTORS USED IN FIRST AVERAGING.
13190C      NI=NVEC IF NO INPUTTED VECTORS ARE IDENTICALLY 0. IF ANY VECTORS
13200C      HAVE ALL 3 COMPONENTS ZERO, THEY ARE NOT INCLUDED IN THE AVERAGE.
13210C      NF="NUMBER-FINAL"=NUMBER OF VECTORS LEFT AFTER EXCLUDING THOSE
13220C      OUTSIDE THE STANDARD DEVIATION, I.E., NUMBER OF VECTORS USED
13230C      IN THE SECOND AVERAGING. IF AVERAGE CALCULATED ONLY ONCE, NI=NF.
13240C=====
13250C
13260      SUBROUTINE AVE(NFREQ,I2,XX,YY,ZZ,EESQ,NVEC,AVEX,AVEY,AVEZ,SIG,
13270+          AVEESQ,NI,NF)
13280      DIMENSION XX(1),YY(1),ZZ(1),EESQ(1)
13290      DIMENSION X(160),Y(160),Z(160),ESQ(160)
13300      DIMENSION WHTP(160)
13310CCC      PRINT*," "
13320CCC      PRINT*," "
13330C
13340      IF(NVEC.EQ.0) GO TO 120
13350C
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13360      CALL MOVLEV(XX(1),X(1),NVEC)
13370      CALL MOVLEV(YY(1),Y(1),NVEC)
13380      CALL MOVLEV(ZZ(1),Z(1),NVEC)
13390      CALL MOVLEV(EESQ(1),ESQ(1),NVEC)
13400C
13410      DO 110 I=1,I2
13420CCC      PRINT*, "I=", I
13430      IRETURN=1
13440      SUMWHTP=0
13450      NF=SUMWX=SUMWY=SUMWZ=SUMWXSQ=SUMWYSQ=SUMWZSQ=SUMWHT=SUMESQ=0
13460C
13470      DO 10 K=1,NVEC
13480      10 WHTP(K)=0.0
13490C
13500C=====COUNT NON-ZERO VECTORS; DETERMINE WHTP=UN-NORMALIZED WEIGHTS
13510C
13520      DO 30 J=1,NVEC
13530      IF(X(J).EQ.0.0.AND.Y(J).EQ.0.0.AND.Z(J).EQ.0.0) GO TO 30
13540      NF=NF+1
13550      IF(ESQ(J).LE.1.0) WHTP(J)=1.
13560      IF(ESQ(J).GT.1.0) WHTP(J)=1/SQRT(ESQ(J))
13570CCC      PRINT 20,J,WHTP(J)
13580      20 FORMAT("WHTP(",I2,")=" ,F7.4)
13590      SUMWHTP=SUMWHTP+WHTP(J)
13600      30 CONTINUE
13610C
13620      IF(I.EQ.1) NI=NF
13630C
13640C=====FIND FACTOR TO NORMALIZE WEIGHTS SO THEIR SUM IS NF
13650C
13660      IF(NF.EQ.0) GO TO 130
13670C
13680      ANORM=NF/SUMWHTP
13690CCC      PRINT 40,NF,SUMWHTP,ANORM
13700      40 FORMAT("NF,SUMWHTP,ANORM ",I3,2F9.3)
13710C
13720C=====DETERMINE NORMALIZED PARAMETERS FOR CALCULATION OF AVERAGE AND
13730C      SIGMA (STANDARD DEVIATION)
13740C
13750      DO 60 J=1,NVEC
13760      IF((X(J).EQ.0.0).AND.(Y(J).EQ.0.0).AND.(Z(J).EQ.0.0)) GO TO 60
13770      WHT=ANORM*WHTP(J)
13780CCC      PRINT 50,J,X(J),Y(J),Z(J),WHT
13790      50 FORMAT(3X,"J=",I2,2X,"X,Y,Z,WHT ",4F9.3)
13800      SUMWX=SUMWX+WHT*X(J)
13810      SUMWY=SUMWY+WHT*Y(J)
13820      SUMWZ=SUMWZ+WHT*Z(J)
13830      SUMWXSQ=SUMWXSQ+WHT*X(J)*X(J)
13840      SUMWYSQ=SUMWYSQ+WHT*Y(J)*Y(J)
13850      SUMWZSQ=SUMWZSQ+WHT*Z(J)*Z(J)
13860      SUMWHT=SUMWHT+WHT

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13870      SUMESQ=SUMESQ+ESQ(J)
13880      80 CONTINUE
13890CCC   PRINT*, "SUMWHT, NF ", SUMWHT, NF
13900C
13910C=====
13920C      SUM(W*X)      WHERE: W=NORMALIZED WEIGHT
13930C      AVERAGE-X = -----
13940C      SUM(W)          SUM(W)=NF
13950C=====
13960C
13970      AVEX=SUMWX/SUMWHT $ AVEY=SUMWY/SUMWHT $ AVEZ=SUMWZ/SUMWHT
13980      AVEESQ=SUMESQ/NF
13990CCC   PRINT 80, AVEX, AVEY, AVEZ
14000      80 FORMAT(3X, "AVEX, AVEY, AVEZ  ", 3F9.3)
14010C
14020      IF(NF.EQ.1) GO TO 140
14030C
14040C=====
14050C
14060C      SUM(W*X)2      (SUM(W*X))2
14070C      SUM(W*X)2 - -----
14080C      NF
14090C      X-VARIANCE = (SIGMA-X)2 = -----
14100C      NF-1
14110C=====
14120C
14130      SIGXSQ=(SUMWXSQ-(SUMWX**2/SUMWHT))/(SUMWHT-1)
14140      SIGYSQ=(SUMWYSQ-(SUMWY**2/SUMWHT))/(SUMWHT-1)
14150      SIGZSQ=(SUMWZSQ-(SUMWZ**2/SUMWHT))/(SUMWHT-1)
14160      SIG=SQRT(SIGXSQ+SIGYSQ+SIGZSQ)
14170CCC   PRINT 90, SIGXSQ, SIGYSQ, SIGZSQ, SIG
14180      90 FORMAT(3X, "SIGXSQ, SIGYSQ, SIGZSQ, SIG ", 4F9.3)
14190C
14200C=====RETURN AFTER 1ST AVE'G IF I2=1; AFTER 2ND, IF I2=2.
14210C
14220      IF(I.EQ.I2) RETURN
14230C
14240      DO 100 K=1, NVEC
14250CCC   PRINT*, "K, X, Y, Z FOR XD ", K, X(K), Y(K), Z(K)
14260      IF(X(K).EQ.0.0.AND.Y(K).EQ.0.0.AND.Z(K).EQ.0.0) GO TO 100
14270      XD=(X(K)-AVEX)**2
14280      YD=(Y(K)-AVEY)**2
14290      ZD=(Z(K)-AVEZ)**2
14300      IF((SQRT(XD+YD+ZD)).LE.SIG) GO TO 100
14310      X(K)=Y(K)=Z(K)=0
14320      IRETURN=0
14330CCC   PRINT*, " ZERO VECTOR"
14340      100 CONTINUE
14350C
14360C=====IF I2=2, RETURN AFTER 1ST AVE'G IF ALL VECTORS ARE WITHIN SIGMA.
14370C

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14380      IF(IRETURN.EQ.1) RETURN
14390C
14400      110 CONTINUE
14410      120 NI=NF=0
14420CCC      PRINT*,"NI=NF=0"
14430      130 AVEX=AVEY=AVEZ=AVEESQ=0
14440CCC      PRINT*," AVEX=AVEY=AVEZ=AVEESQ=0"
14450      140 SIG=0
14460CCC      PRINT*,"SIG=ZERO"
14470      RETURN
14480      END
14490C
14500C
14510C
14520C===== S U B R O U T I N E   V E L   =====
14530C=====CALCULATE HORIZONTAL VELOCITY COMPONENT VH, MAGNITUDE V,
14540C      AZIMUTH AND ELEVATION.
14550C
14560      SUBROUTINE VEL(VX,VY,VZ,VH,V,AZIM,ELEV)
14570C
14580      VH=SQRT(VX*VX+VY*VY)
14590      V=SQRT(VH*VH+VZ*VZ)
14600      IF((VX.EQ.0.0).AND.(VY.EQ.0.0)) GO TO 10
14610      AZIM=ATAN2(VY,VX)/.0174532925199433
14620      IF(AZIM.GT.0.0) AZIM=360-AZIM
14630      IF(AZIM.LT.0.0) AZIM=-AZIM
14640      ELEV=ATAN(VZ/VH)/.0174532925199433
14650      RETURN
14660      10 IF(VZ.NE.0.0) GO TO 20
14670      AZIM=ELEV=0 $ RETURN
14680      20 AZIM=0
14690      ELEV=90 $ IF(VZ.LT.0.0) ELEV=-90
14700      RETURN
14710      END
14720C
14730C
14740C
14750C===== S U B R O U T I N E   P O L M A P   =====
14760C CALCULATE POLAR MAP OF HORIZONTAL COMPONENTS OF VELOCITY.
14770C
14780C IY,IX=Y AND X COMPONENTS OF VELOCITY IN UNITS OF 10.
14790C IY,IX=THE CORRESPONDING ADDRESSES OF ARRAY IMAP, INTO WHICH ARE STORED
14800C      THE SEQUENCE NUMBERS (HEXADECIMAL NUMBERS 1 TO F, IDENTIFYING
14810C      THE CASES; OR NUMBERS 1 TO 9, LETTERS A TO Z, IDENTIFYING
14820C      THE GROUPS). EACH SEQUENCE NUMBER IS AT THE POSITION OF
14830C      THE ARROWHEAD OF A VECTOR WITH ORIGIN AT THE CENTER OF THE
14840C      MAP. IF MORE THAN ONE VECTOR HEAD OCCUPIES ANY IMAP ADDRESS,
14850C      THE FIRST ONE IS KEPT IN THE MAP, THE OTHERS ARE INDICATED IN
14860C      AN "OVERFLOW" MESSAGE.
14870C=====
14880C
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14890      SUBROUTINE POLMAP(KV,KPRINT,KG,VY,VX,IVY,IVX,NM)
14900      COMMON MPDT(52),MAPDAT(4,160)
14910      COMMON/IGA/NN(35)
14920      DIMENSION NNN(103),IMAP(103,103)
14930      DATA NNN/" ", "500",9*" ", "400",9*" ", "300",9*" ", "200",9*" ",
14940+      "100",9*" ", " 0 ",9*" ", "100",9*" ", "200",9*" ", "300",9*" ",
14950+      "400",9*" ", "500", " "/
14960C
14970      IF(NM.EQ.3) GO TO 200
14980      IF(NM.EQ.2) GO TO 10
14990C
15000C===== F I R S T C A L L
15010C      DETERMINES IVY,IVX=VY/10,VX/10 ROUNDED TO INTEGERS, AND IY,IX=
15020C      THE CORRESPONDING COORDINATES FOR IMAP.
15030C      NEEDED IF PRINTING LIST ONLY, OR LIST AND POLAR MAP.
15040C
15050      SY=1 $ IF(VY.LT.0.0) SY=-1
15060      SX=1 $ IF(VX.LT.0.0) SX=-1
15070      IVY=IFIX(VY/10.+SY*.5)
15080      IVX=IFIX(VX/10.+SX*.5)
15090      IF(IABS(IVY).GT.50) IVY=50*SY
15100      IY=52-IVY
15110      IF(IABS(IVX).GT.50) IVX=50*SX
15120      IX=52-IVX
15130      RETURN
15140C
15150C===== S E C O N D C A L L
15160C
15170      10 IF(((KPRINT.EQ.34).AND.(KV.EQ.LASTKV)).OR.
15180+      ((KPRINT.NE.34).AND.(KV.NE.1))) GO TO 70
15190C
15200C=====INITIALIZE IMAP (BORDERS) IF FIRST CALCULATION.
15210C      NEEDED ONLY IF POLAR MAP TO BE PRINTED.
15220C
15230      DO 20 KY=1,103
15240      DO 20 KX=1,103
15250      20 IMAP(KY,KX)=" "
15260C
15270      DO 30 KY=2,102
15280      30 IMAP(KY,1)=IMAP(KY,52)=IMAP(KY,103)="-"
15290      DO 40 KY=2,102,10
15300      40 IMAP(KY,1)=IMAP(KY,52)=IMAP(KY,103)="+"
15310C
15320      DO 50 KX=2,102
15330      50 IMAP(1,KX)=IMAP(52,KX)=IMAP(103,KX)="-"
15340      DO 60 KX=2,102,10
15350      60 IMAP(1,KX)=IMAP(52,KX)=IMAP(103,KX)="+"
15360C
15370      IMAP(49,1)=IMAP(49,103)=IMAP(55,1)=IMAP(55,103)=" "
15380      IMAP(50,1)="N" $ IMAP(50,103)="S"
15390      IMAP(51,1)=IMAP(51,103)="O"

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15400      IMAP(52,1)="R"  $ IMAP(52,103)="U"
15410      IMAP(53,1)=IMAP(53,103)="T"
15420      IMAP(54,1)=IMAP(54,103)="H"
15430      IMAP(1,49)=IMAP(103,49)=IMAP(1,54)=IMAP(103,54)=" "
15440      IMAP(1,50)="W"  $ IMAP(103,51)="A"
15450      IMAP(1,51)=IMAP(103,50)="E"
15460      IMAP(1,52)=IMAP(103,52)="S"
15470      IMAP(1,53)=IMAP(103,53)="T"
15480C
15490C=====PUT SEQUENCE NUMBERS AT THE (IY,IX) COORDINATES OF IMAP,
15500C      OR PRINT OVERFLOW MESSAGE.
15510C
15520      70 LASTKV=KV
15530      IF(IMAP(IY,IX).EQ." ".OR.IMAP(IY,IX).EQ."-".OR.
15540+      IMAP(IY,IX).EQ."+") GO TO 90
15550      IF((KPRINT.AND.24).EQ.0) PRINT 80,NN(KG),IVX,IVY
15560      IF(KPRINT.EQ.40) PRINT 80,NN(KG),IVX,IVY
15570      IF(KPRINT.EQ.48) WRITE(49,81) IVX,IVY,NN(KG)
15580      80 FORMAT(2X,A1,37X,"OVERFLOW AT IVX=",I3," , IVY=",I3)
15590      81 FORMAT(97X,"OVERFLOW AT IVX=",I3," , IVY=",I3,5X,A1)
15600      RETURN
15610      90 IF((KPRINT.AND.24).EQ.0) IMAP(IY,IX)=NN(KG)
15620      IF((KPRINT.AND.24).NE.0) IMAP(IY,IX)=NN(KG)
15630      RETURN
15640C
15650C===== T H I R D C A L L
15660C      PRINT POLAR MAP
15670C
15680      110 FORMAT(///38X,*HORIZONTAL COMPONENTS OF IONOSPHERIC DRIFT*/)
15690      120 FORMAT(49X,*INDIVIDUAL VELOCITIES*/)
15700      130 FORMAT(49X,*CASE-NORM VELOCITIES*/)
15710      140 FORMAT(49X,*GROUP-NORM VELOCITIES*/)
15720      150 FORMAT(50X,*ALL-FREQ VELOCITIES*/)
15730      160 FORMAT(7X,9(A3,7X),A3,1X,"(M/S)",1X,A3)
15740      180 FORMAT(4X,A3,103A1,A3)
15750      200 IF(KPRINT.EQ.48) GO TO 220
15760      PRINT 110
15770      IF(KPRINT.EQ.34) PRINT 120
15780      IF(KPRINT.EQ.36) PRINT 130
15790      IF(KPRINT.EQ.40) PRINT 140
15800      PRINT 160,(NNN(I),I=2,102,10)
15810      INNN=0
15820      DO 210 IX=1,103
15830      INNN=INNN+1
15840      210 PRINT 180,NNN(INNN),(IMAP(IY,IX),IY=1,103),NNN(INNN)
15850      PRINT 160,(NNN(I),I=2,102,10)
15860      RETURN
15870C
15880      220 WRITE(49,110)  $ WRITE(49,150)
15890      WRITE(49,160)(NNN(I),I=2,102,10)
15900      INNN=0

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15910      DO 230 IX=1,103
15920      INNN=INNN+1
15930      230 WRITE(49,180) NNN(INNN),(IMAP(IY,IX),IY=1,103),NNN(INNN)
15940      WRITE(49,160)(NNN(I),I=2,102,10)
15950      RETURN
15960      END
15970C
15980C
15990C
16000C===== SUBROUTINE GRAPH =====
16010C
16020      SUBROUTINE GRAPH(ISEQ,KHR,KMIN,FREQ,RANG,NUMB,DB,DOPP,
16030+          NCOL,KASE,NGRP,VH,VZ,AZIM,SIG,ESQ,KPRINT,NUMFREQ,KP)
16040C
16050      COMMON/IR7/IRNG(7)
16060      COMMON/IGA/NN(35)
16070      COMMON/G/GVELZ(6),GVELH(6),GVELAZ(6)
16080      DIMENSION IAZMTH(73),ISPEED(32),IERR(112),KVV(8),KVE(6)
16090      DIMENSION IAZZ(6),IATMP(6),IAN(73),IVZZ(6),IVZTMP(6),IVHH(6),
16100+          IVHTMP(6),IVN(32)
16110C
16120C====KVV IS FORMAT FOR AZIMUTH-SPEED GRAPH
16130C      KVE IS FORMAT FOR ROOT-MEAN-SQUARE-ERROR GRAPH
16140C
16150      DATA KVV/“(1X,A1,“,“I3.2,“,“I2.2,“,“I3,I4,“,“I3,“,“2X,73A1,“,
16160+          “4X,31A1,“,“R3)”/
16170      DATA KVE/“(1X,A1,“,“I3.2,“,“I2.2,“,“I3,I4,“,“1X,111A1,“,“R4)”/
16180C
16190      IF(KPRINT.EQ.66) MINSRC=KP
16200      IF(IAZMTH(1).EQ.“.”) GO TO 40
16210C
16220      DO 10 I=2,72
16230      10 IAZMTH(I)=""
16240      IAZMTH(1)=IAZMTH(73)=""
16250C
16260      DO 20 I=2,32
16270      20 ISPEED(I)=""
16280      ISPEED(1)=ISPEED(31)=""
16290C
16300      DO 30 I=2,112
16310      30 IERR(I)=""
16320      IERR(1)=IERR(111)=""
16330C
16340C=====
16350C DEFINE VARIABLES AND GRID MARKERS FOR PRINTING (OR PUT BLANKS):
16360C
16370C FOR KPRINT 4,8,16, PRINT:
16380C     SEQ.NO.,HOUR,MIN,FREQ,RANGE,NUMB ON AZIM-SPEED GRAPH,
16390C     WITH GRID MARKERS;
16400C EXCEPT, FOR KPRINT 4, OMIT HOUR AND HALF OF THE GRID MARKERS IF NOT
16410C     FIRST CASE OF A GROUP (IF KASE.NE.1).

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16420C      NUMB=
16430C      NIVEL: NO. OF INDIVIDUAL VEL. CALCULATIONS PER CASE FOR KPRINT 4;
16440C      NKVEL: NO. OF CASE-NORM VELOCITIES PER GROUP FOR KPRINT 8;
16450C      NFF: NO. OF FREQUENCIES WHICH HAVE NON-ZERO GROUP-NORM VELOCITIES
16460C      FOR KPRINT 16.
16470C      FOR KPRINT 16:
16480C      IFREQ,IRANG ARE THE DIFFERENCES BETWEEN THE HIGHEST AND LOWEST
16490C      FREQUENCIES AND RANGES;
16500C      MINUTES ARE ROUNDED OUT TO NEAREST 2.5 (BUT SECONDS ARE NOT
16510C      PRINTED, SO 2=2.5, 7=7.5, ETC.)
16520C
16530C      FOR KPRINT 2:
16540C      AT BEGINNING OF EACH GROUP OF CASES (NGRP.NE.LASTGRP),PRINT:
16550C      SEQ.NO.,HOUR,MIN,FREQ,RANGE,NUMB(NO.OF SOURCES) ON AZIM-SPEED GRAPH,
16560C      SEQ.NO.,HOUR,MIN,FWD,DOPP.NO. ON ERROR GRAPH,
16570C      WITH GRID MARKERS ON BOTH GRAPHS.
16580C      IF BEGINNING A NEW CASE (NCOL=1) BUT NOT A NEW GROUP,
16590C      OMIT THE HOUR AND HALF OF THE GRID MARKERS.
16600C      ELSEWHERE (NCOL.NE.1), PRINT ONLY:
16610C      SEQ.NO.,NUMB ON AZIM-SPEED GRAPH,
16620C      SEQ.NO.,FWD,DOPP.NO. ON ERROR GRAPH.
16630C
16640C      NUMB COUNTS ONLY THOSE SOURCES USED FOR A VELOCITY CALCULATION,SO
16650C      WHEN THE SOURCE IS SKIPPED, NUMB IS OMITTED.
16660C=====
16670C
16680      40 IF((KPRINT.AND.2).NE.0) GO TO 70
16690      LHR=KHR $ LMIN=KMIN $ MGRID1=MGRID2="."
16700      IFREQ=IFIX(FREQ/100+.5) $ IRANG=IFIX(RANG+.5) $ KVV(4)="I3,I4,"
16710      IF((KP.NE.16.AND.KP.NE.99).OR.((NUMB.NE." ").AND.(NUMB.NE.1)))GOTO45
16720      IFREQ=IRANG=" " $ KVV(4)="A3,A4,"
16730      45 KVV(5)="I3," $ IF(NUMB.EQ." ") KVV(5)="A3,"
16740CCC      IDB=IDOPP=" " $ KVE(1)="5X,A1,1X," $ KVE(4)="2A1,"
16750      IF((KPRINT.AND.4).NE.0) GO TO 50
16760      IF(IAZMTH(19).EQ."") GO TO 130 $ GO TO 90
16770C
16780      50 IF(KASE.EQ.1) GO TO 60
16790      LHR=" " $ IF(KASE.GT.2) GO TO 130
16800CCC      KVE(2)="A3,"
16810      MGRID1=" " $ KVV(2)="A3," $ GO TO 90
16820C
16830      60 KVV(2)="I3.2,"
16840CCC      KVE(2)="I3.2,"
16850      GO TO 90
16860C
16870      70 KVV(5)="I3," $ IF(NUMB.EQ." ") KVV(5)="A3,"
16880      IDOPP=DOPP $ IDB=DB
16890      IF(NCOL.GT.2) GO TO 130
16900C
16910      IF(NCOL.EQ.2) GO TO 80
16920      IFREQ=IFIX(FREQ/100+.5) $ IRANG=IFIX(RANG+.5)

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16930      KVV(4)="I3,I4," $ LMIN=KMIN $ KVV(3)=KVE(3)="I2.2," $ MGRID2="."
16940      IF(NGRP.NE.LASTGRP) GO TO 75
16950      LHR=MGRID1=" " $ KVV(2)=KVE(2)="A3," $ GO TO 90
16960C
16970      75 MGRID1="." $ LHR=KHR $ KVV(2)=KVE(2)="I3.2," $ GO TO 90
16980C
16990      80 IFREQ=IRANG=" " $ KVV(4)="A3,A4,"
17000      MGRID1=MGRID2=LHR=LMIN=" "
17010      KVV(2)=KVE(2)="A3,"
17020      KVV(3)=KVE(3)="A2,"
17030C
17040      90 DO 100 I=1,55,18
17050      IAZMTH(I)=MGRID2
17060      100 IAZMTH(I+6)=IAZMTH(I+12)=MGRID1
17070      IAZMTH(1)="."
17080C
17090      DO 110 I=1,21,10
17100      ISPEED(I)=MGRID2
17110      110 ISPEED(I+5)=MGRID1
17120      ISPEED(1)="."
17130C
17140      DO 120 I=1,101,10
17150      IERR(I)=MGRID2
17160      120 IERR(I+5)=MGRID1
17170      IERR(1)="."
17180C
17190C=====PUT SYMBOLS INTO THE GRAPH COORDINATES WHICH CORRESPOND TO THE
17200C      VALUES TO BE GRAPHED
17210C
17220      130 LASTGRP=NGRP
17230      IF((NUMB.EQ." ").OR.((KPRINT.EQ.66).AND.(NUMB.LT.MINSRC))) GO TO 310
17240C
17250      IF(KP.NE.99) GO TO 270
17260      DO 140 I=1,NUMFREQ
17270      IAZZ(I)=0
17280      IF(GVELZ(I).EQ." ") GO TO 140
17290      IAZZ(I)=IFIX(GVELAZ(I)/5+1.5)
17300      140 CONTINUE
17310      NFG=NUMFREQ-1
17320      DO 150 I=1,NFG
17330      I1=I+1
17340      DO 150 J=I1,NUMFREQ
17350      IF((IAZZ(I).EQ.0).OR.(IAZZ(J).EQ.0)) GO TO 150
17360      IF(IAZZ(I).EQ.0) GO TO 160
17370      150 CONTINUE
17380      GO TO 170
17390      160 CALL IDENT(GVELAZ,IAZZ,NUMFREQ,1)
17400      170 DO 180 I=1,NUMFREQ
17410      IF(GVELZ(I).EQ." ") GO TO 180
17420      IATMP(I)=IAZMTH(IAZZ(I))
17430      IRG=IFIX((FLOAT(IRNG(I))-200)/10+.5)

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17440      IF(IRG.EQ.0) IAZMTH(IAZZ(I))="0"
17450      IF(IRG.NE.0) IAZMTH(IAZZ(I))=NN(IRG)
17460      180 CONTINUE
17470C
17480      DO 190 I=1,NUMFREQ
17490      IVZZ(I)=0
17500      IF(GVELZ(I).EQ." ") GO TO 190
17510      IF(GVELZ(I).LT.0) IVZZ(I)=MAX0(IFIX(GVELZ(I)/10-1.5),-31)
17520      IF(GVELZ(I).GE.0) IVZZ(I)=MIN0(IFIX(GVELZ(I)/10+1.5),31)
17530      IVZTMP(I)=ISPEED(IABS(IVZZ(I)))
17540      190 CONTINUE
17550      DO 200 I=1,NUMFREQ
17560      IVHH(I)=0
17570      IF(GVELZ(I).EQ." ") GO TO 200
17580      IVHH(I)=MIN0(IFIX(GVELH(I)/10+1.5),31)
17590      200 CONTINUE
17600      DO 210 I=1,NFQ
17610      I1=I+1
17620      DO 210 J=I1,NUMFREQ
17630      IF((IVHH(I).EQ.0).OR.(IVHH(J).EQ.0)) GO TO 210
17640      IF(IVHH(I).EQ.IVHH(J)) GO TO 220
17650      210 CONTINUE
17660      GO TO 230
17670      220 CALL IDENT(GVELH,IVHH,NUMFREQ,1)
17680      230 DO 240 I=1,NUMFREQ
17690      IF(GVELZ(I).EQ." ") GO TO 240
17700      IVHTMP(I)=ISPEED(IVHH(I))
17710      240 CONTINUE
17720      DO 250 I=1,NUMFREQ
17730      IF(GVELZ(I).EQ." ") GO TO 250
17740      IF(IVZZ(I).GT.0) ISPEED(IVZZ(I))="+"
17750      IF(IVZZ(I).LT.0) ISPEED(-IVZZ(I))="-"
17760      250 CONTINUE
17770      DO 260 I=1,NUMFREQ
17780      IF(GVELZ(I).EQ." ") GO TO 260
17790      IRG=IFIX((FLOAT(IRNG(I))-200)/10+.5)
17800      IF(IRG.EQ.0) ISPEED(IVHH(I))="0"
17810      IF(IRG.NE.0) ISPEED(IVHH(I))=NN(IRG)
17820      260 CONTINUE
17830      GO TO 310
17840C
17850      270 IF((KPRINT.EQ.66).OR.(NUMB.LT.2)) GO TO 280
17860      ISIG=MIN0(IFIX(SIG/5+1.5),73)
17870      ITEMP=IAZMTH(ISIG) * IAZMTH(ISIG)="+"
17880      280 IAZ=IFIX(AZIM/5+1.5)
17890      IATEMP=IAZMTH(IAZ) * IAZMTH(IAZ)="#"
17900C
17910      IF(VZ.LT.0) IVZ=MAX0(IFIX(VZ/10-1.5),-31)
17920      IF(VZ.GE.0) IVZ=MIN0(IFIX(VZ/10+1.5),31)
17930      IVH=MIN0(IFIX(VH/10+1.5),32)
17940      IVZTEMP=ISPEED(IABS(IVZ)) * IVHTEMP=ISPEED(IVH)

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17950      IF(IVZ.LT.0) ISPEED(-IVZ)="-" * IF(IVZ.GT.0) ISPEED(IVZ)="+"
17960      ISPEED(IVH)="#"
17970      IF(IVH.NE.32) GO TO 300
17980      IVH100=MIN0((IFIX(VH/100+.5)),999)
17990      ENCODE(10,290,ISPEED(IVH)) IVH100
18000 290 FORMAT(I10)
18010C
18020 300 IF(KPRINT.NE.66) GO TO 310
18030      IE=MIN0((IFIX(SQRT(ESQ)+1.5)),112)
18040      ITEMP=IERR(IE) * IERR(IE)="#"
18050      IF(IE.NE.112) GO TO 310
18060      IERR100=MIN0((IFIX(ESQ+.5)),9999)
18070      ENCODE(10,290,IERR(IE)) IERR100
18080C
18090 310 IF(KP.EQ.16) GO TO 320
18100      IF(KP.EQ.99) GO TO 330
18110      WRITE(69,KVV) ISEQ,LHR,LMIN,IFREQ,IRANG,NUMB,IAZMTH,ISPEED
18120      IF(KPRINT.EQ.66) WRITE(70,KVE) ISEQ,LHR,LMIN,IDB,IDOPP,IERR
18130      GO TO 340
18140 320 WRITE(71,KVV) ISEQ,LHR,LMIN,IFREQ,IRANG,NUMB,IAZMTH,ISPEED
18150      GO TO 340
18160 330 WRITE(72,KVV) ISEQ,LHR,LMIN,IFREQ,IRANG,NUMB,IAZMTH,ISPEED
18170CCC      WRITE(72,KVE) ISEQ,LHR,LMIN,IDB,IDOPP,IERR
18180 340 IF((NUMB.EQ." ").OR.((KPRINT.EQ.66).AND.(NUMB.LT.MINSRC))) RETURN
18190      IF(KP.EQ.99) GO TO 350
18200C
18210      IAZMTH(IAZ)=ITEMP * ISPEED(IVH)=IVHTEMP
18220      IF(KPRINT.EQ.66)IERR(IE)=ITEMP * ISPEED(IABS(IVZ))=IVZTEMP
18230      IF((KPRINT.NE.66).AND.(NUMB.GT.1)) IAZMTH(ISIG)=ITEMP
18240      RETURN
18250C
18260 350 DO 360 I=1,NUMFREQ
18270      IF(GVELZ(I).EQ." ") GO TO 360
18280      IAZMTH(IAZZ(I))=IATMP(I)
18290      ISPEED(IABS(IVZZ(I)))=IVZTMP(I)
18300      ISPEED(IVHH(I))=IVHTMP(I)
18310 360 CONTINUE
18320      RETURN * END
18330C
18340C
18350C
18360C===== S U B R O U T I N E   A L L F R E Q   =====
18370C FINDS AVERAGE (OR MEDIAN) OF GROUP-NORM VELOCITIES FOR ALL FREQUENCY
18380C NUMBERS. EACH RUN WRITES ON TAPE49 THE GROUP-NORM VELOCITIES
18390C CALCULATED FROM THE INPUT DATA ON TAPE50 (DATA FOR ONE FREQUENCY
18400C NUMBER) PLUS THE VELOCITIES FROM OTHER FREQUENCY NUMBERS ALREADY
18410C STORED ON TAPE48, IF ANY. IN THE LAST RUN (WHEN DATA OF LAST FREQ. NO.
18420C IS BEING RUN) THE SUBROUTINE CALCULATES THE AVE. OR MEDIAN OVER ALL
18430C FREQ. NO.'S, AND WRITES THE RESULT ON TAPE49, WITH THE POLAR MAP IF
18440C REQUESTED, AND WRITES THE GRAPHS, IF REQUESTED, ON TAPES 71 AND 72.
18450C AT THE END OF A RUN, IF NOT ALL FREQUENCY NUMBERS HAVE BEEN RUN, BE SURE

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18460C   TO RENAME TAPE48=TAPE49 TO USE TAPE48 (AS WELL AS TAPE50) AS INPUT FOR
18470C   THE RUN AT THE NEXT FREQUENCY NUMBER. (FREQUENCY NUMBERS DON'T HAVE
18480C   TO BE RUN IN ORDER.)
18490C=====
18500C
18510      SUBROUTINE ALLFREQ(KPRINT,NGRP,NGRPDAT,NGRPHR,NGRPMIN,NGRPSEC,GVX,
18520+      GVV,GVZ,FREQ,RANG,NUMFREQ,NFREQ,ONE,ICV,ICV3,IFHEAD,LASFREQ,NFVEL)
18530C
18540C=====NUMFREQ=THE TOTAL NUMBER OF FREQUENCIES;
18550C      NFREQ=THE ACTUAL FREQ. NO. FOR THIS RUN.
18560C
18570      COMMON/IR7/IRANG(7)
18580      COMMON/IGA/NN(35)
18590      COMMON/G/GVELZZ(6),GVELH(6),GVELAZ(6)
18600      DIMENSION GVELX(6),GVELY(6),GVELZ(6),KVD(13),KVH(24)
18610      DIMENSION GFREQ(7),MHZ(7),KM(7),KFR(22)
18620C
18630C=====KVH=FORMAT FOR HEADING; KVD: FOR DATA; KFR: FOR FREQ AND RANGE.
18640C
18650      DATA KVH/("////44X","4X","*GROUP*"," *-NORM ","VELOCITIES",
18660+      "*,34X,*/"," * AVE ","OR MED OF ","ALL*/101X","2X",
18670+      "*/*,6X","*FREQUENCI","ES*/9X","2X","6(","* / FREQ.",
18680+      " NO.*,I2)","* /*,25X","/2X","*DATE TIM","E*,7(* / V",
18690+      "X VY V","Z*),* SIGM","A NI NF*)"/
18700C
18710      NGTIME=NGRPHR*10000+NGRPMIN*100+NGRPSEC
18720      IF(KPRINT.EQ.48) KVH(19)="*SEQ*/2X,"
18730C
18740      KVD(1)="(1X," $ KVD(2)="I5,1X," $ KVD(3)="I6.6,"
18750      DO 4 K=4,10
18760      4 KVD(K)="3F5,"
18770      KVD(11)="F5," $ KVD(12)="2I3," $ KVD(13)="1X,A1,1X)"
18780C
18790      KFR(1)="(7X,I6.6,"
18800      DO 6 K=2,20,3
18810      KFR(K)="F4.1,A3," $ KFR(K+1)="I5,A2,"
18820      6 KFR(K+2)="1X,"
18830      KFR(22)=")"
18840C
18850      LASFREQ=KDATE=KTIME=NIF=NFF=0
18860      DO 5 K=1,6
18870      MHZ(K)=KM(K)=" "
18880      5 GVELX(K)=GVELY(K)=GVELZ(K)=GFREQ(K)=IRANG(K)=0
18890      FVX=FVY=FVZ=FSIG=GFREQ(7)=IRANG(7)=0 $ MHZ(7)=KM(7)=" "
18900C
18910C=====ADVANCE TAPE48 BEYOND HEADING; WRITE HEADING ON TAPE49.
18920C
18930      IF(IFHEAD.EQ.1) GO TO 80
18940      20 FORMAT(A6)
18950      21 READ(48,20) IREAD
18960      IF(EOF(48))25,24

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DRIFVEL (ULCAR)

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18970C
18980      24 IF(IREAD.NE." DATE") 21,35
18990      25 EOF48=1. $ GO TO 30
19000      35 EOF48=0.
19010      30 WRITE(49,KVH) (N,N=1,6)
19020          IFHEAD=1
19030C
19040      60 DO 61 K=1,NUMFREQ
19050      61 GVELZ(K)=999.
19060C
19070C=====READ DATE,TIME,AND DATA FROM TAPE48
19080C
19090      62 IF(EOF48.EQ.1.) GO TO 100
19100          READ(48,KVD) KDATE,KTIME,(GVELX(K),GVELY(K),
19110+              GVELZ(K),K=1,6),FVX,FVY,FVZ,FSIG,NIF,NFF
19120          IF(EOF(48))65,65
19130      65 READ(48,KFR)KTIME,(GFREQ(M),MHZ(M),IRANG(M),KM(M),M=1,7)
19140          IF(EOF(48))68,70
19150C
19160      68 EOF48=1.
19170          GO TO 100
19180C
19190C=====IF DATE AND TIME FROM TAPE48 DON'T MATCH THOSE OF THIS GROUP,
19200C      READ NEXT RECORD.
19210C
19220      70 IF((NGRPDAT.NE.KDATE).OR.(NGTIME.NE.KTIME)) GO TO 62
19230C
19240CCC          PRINT 75,KDATE,KTIME,NGRPDAT,NGTIME
19250CCC      75 FORMAT(" DATE AND/OR TIME DO NOT MATCH. TAPE48 IS AT ",
19260CCC+          15,1X,16.6,/" AND THIS RUN IS AT ",
19270CCC+          15,1X,16.6, ".")
19280CCC          STOP
19290C
19300C=====PUT VELOCITIES CALCULATED IN THIS RUN INTO ARRAYS GVELX, ETC.
19310C
19320      100 SX=1.
19330          SY=1.
19340          IF(GVX.NE.0.) SX=GVX/ABS(GVX)
19350          IF(GVY.NE.0.) SY=GVY/ABS(GVY)
19360          GVELX(NFREQ)=AMIN1(999.,ABS(GVX))*SX
19370          GVELY(NFREQ)=AMIN1(999.,ABS(GVY))*SY $ GVELZ(NFREQ)=GVZ
19380          IF(GVX.EQ.0.0.AND.GVY.EQ.0.0.AND.GVZ.EQ.0.0) GO TO 105
19390          GFREQ(NFREQ)=FREQ/1000 $ MHZ(NFREQ)="MHZ"
19400          IRANG(NFREQ)=IFIX(RANG+.5) $ KM(NFREQ)="KM"
19410C
19420      105 DO 110 K=1,NUMFREQ
19430      110 IF(GVELZ(K).EQ.999.) GO TO 130
19440C
19450C=====IF ALL FREQUENCIES HAVE BEEN RUN, FIND MEDIAN OR AVERAGE.
19460C      NFVEL COUNTS THE NUMBER OF GROUPS THAT HAVE A GROUP-NORM VELOCITY
19470C          FOR AT LEAST ONE FREQUENCY NUMBER.

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DRIFVEL (ULCAR)

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19480C
19490      LASFREQ=1
19500      GO TO (111,112,113) ICV
19510 111 CALL MEDIAN(GVELX,GVELY,GVELZ,ONE,NUMFREQ,FVX,FVY,FVZ,FSIG,DUM,NFF)
19520      GO TO 114
19530 112 CALL MEDIAN(GVELX,GVELY,GVELZ,ONE,NUMFREQ,FVX,FVY,FVZ,FSIG,DUM,NFF)
19540      GO TO 114
19550 113 CALL AVE(NFREQ,ICV3,GVELX,GVELY,GVELZ,ONE,NUMFREQ,FVX,FVY,FVZ,
19560+      FSIG,DUM,NIF,NFF)
19570C
19580 114 DELFREQ=DELRANG=0.
19590      IF(NFF.EQ.0) GO TO 120
19600      NFVEL=NFVEL+1 $ FREQMAX=MAXRANG=0 $ FREQMIN=MINRANG=9999
19610      DO 118 M=1,NUMFREQ
19620      IF(GFREQ(M).EQ.0.) GO TO 118
19630      FREQMAX=AMAX1(GFREQ(M),FREQMAX)
19640      FREQMIN=AMIN1(GFREQ(M),FREQMIN)
19650      MAXRANG=MAX0(IRANG(M),MAXRANG)
19660      MINRANG=MIN0(IRANG(M),MINRANG)
19670 118 CONTINUE
19680      DELFREQ=GFREQ(7)=FREQMAX-FREQMIN
19690      DELFREQ=DELFREQ*1000
19700      IRANG(7)=MAXRANG-MINRANG
19710      DELRANG=IRANG(7)
19720      MHZ(7)="MHZ" $ KM(7)="KM"
19730C
19740      IF(KPRINT.EQ.48) CALL POLMAP(IDUM,KPRINT,NGRP,FVY,FVX,IVY,IVX,1)
19750C
19760 120 IF((KPRINT.AND.64).EQ.0) GO TO 130
19770      CALL VEL(FVX,FVY,FVZ,FVH,FV,FAZ,FEL) $ IFSEQ=NN(NGRP)
19780      NFFF=NFF $ IF(NFFF.EQ.0) NFFF=" "
19790      CALL GRAPH(IFSEQ,NGRPHR,NGRPMIN,DELFREQ,DELRANG,NFFF,DUM,DUM1,
19800+      IDUM,IDUM1,NDUM,FVH,FVZ,FAZ,FSIG,DUM2,KPRINT,IDUM2,16)
19810CCC      IF(NUMFREQ.GT.3) GO TO 130
19820      IF(NFFF.EQ." ") GO TO 128
19830      DO 126 I=1,NUMFREQ
19840      GVELH(I)=SQRT(GVELX(I)**2+GVELY(I)**2)
19850      IF((GVELX(I).EQ.0.).AND.(GVELY(I).EQ.0.)) GO TO 125
19860      GVELAZ(I)=ATAN2(GVELY(I),GVELX(I))/0.174532925199433
19870      IF(GVELAZ(I).GT.0.0) GVELAZ(I)=360-GVELAZ(I)
19880      IF(GVELAZ(I).LT.0.0) GVELAZ(I)=-GVELAZ(I)
19890      GO TO 126
19900 125 GVELAZ(I)=0.
19910 126 CONTINUE
19920      DO 127 I=1,NUMFREQ
19930      GVELZZ(I)=GVELZ(I)
19940 127 IF((GVELX(I).EQ.0.).AND.(GVELY(I).EQ.0.).AND.(GVELZ(I).EQ.0.))
19950+      GVELZZ(I)=" "
19960CCC      GVELZZ(4)=FVZ $ GVELH(4)=FVH $ GVELAZ(4)=FAZ
19970 128 CALL GRAPH(IFSEQ,NGRPHR,NGRPMIN,DELFREQ,DELRANG,NFFF,DUM,DUM1,
19980+      IDUM,IDUM1,NDUM,FVH,FVZ,FAZ,FSIG,DUM2,KPRINT,NUMFREQ,99)

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DRIFVEL (ULCAR)

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19990C
20000C=====PREPARE VARIABLES FOR OUTPUT (PUT BLANKS IF APPROPRIATE,
20010C      AND RE-DEFINE FORMAT IN CONSEQUENCE; PUT BLANKS FOR SIGMA UNLESS
20020C      ALL-FREQ VEL IS AN AVE OR MEDIAN OF AT LEAST 2 GROUP-NORM VELOCITIES)
20030C
20040      130 DO 140 M=1,6
20050          IF((GVELX(M).NE.0.).OR.(GVELY(M).NE.0.).OR.(GVELZ(M).NE.0.))
20060+          GO TO 140
20070          GVELX(M)=GVELY(M)=GVELZ(M)=GFREQ(M)=" "
20080          MHZ(M)=IRANG(M)=KM(M)=" "
20090          KVD(M+3)="3A5," $ KFR(3*M-1)="A4,A3," $ KFR(3*M)="A5,A2,"
20100      140 CONTINUE
20110C
20120          IF(NFF.NE.0) GO TO 150
20130          FVX=FVY=FVZ=" "
20140          KVD(10)="3A5,"
20150      150 IF(NFF.GT.1) GO TO 160
20160          MHZ(7)=IRANG(7)=KM(7)=" " $ GFREQ(7)=" "
20170          KFR(20)="A4,A3," $ KFR(21)="A5,A2,"
20180C
20190      160 IF(NFF.GT.1) GO TO 170
20200          FSIG=" " $ KVD(11)="A5,"
20210C
20220C=====WRITE DATE, TIME, VELOCITIES, ETC ON TAPE49; ALSO SEQUENCE
20230C      NUMBERS (1-9,A-Z) IF WRITING POLAR MAP (KPRINT 32)
20240C
20250      170 ISEQ=" "
20260          IF((KPRINT.AND.32).NE.0) ISEQ=NN(NGRP)
20270          WRITE(49,KVD)NGRPDAT,NGTIME,(GVELX(M),GVELY(M),
20280+          GVELZ(M),M=1,6),FVX,FVY,FVZ,FSIG,NIF,NFF,ISEQ
20290          WRITE(49,KFR)NGTIME,(GFREQ(M),MHZ(M),IRANG(M),KM(M),M=1,7)
20300          IF((NFF.NE.0).AND.(LASFREQ.EQ.1).AND.(KPRINT.EQ.48))
20310+          CALL POLMAP(NFVEL,KPRINT,NGRP,DUM,DUM1,IVY,IVX,2)
20320          IF(LASFREQ.EQ.1) WRITE(49,180)
20330      180 FORMAT(" ")
20340C
20350C
20360      RETURN
20370      END
20380C
20390C
20400C
20410C===== SUBROUTINE MEDIAN =====
20420C
20430      SUBROUTINE MEDIAN(VX,VY,VZ,ESQ,NC,VXMED,VYMED,VZMED,SIG,ESGOUT,
20440+      KOUNT)
20450C
20460      DIMENSION VX(1),VY(1),VZ(1),ESQ(1)
20470      DIMENSION VXTEMP(60),VYTEMP(60),VZTEMP(60)
20480      DIMENSION IVXWHT(60),IVYWHT(60),IVZWHT(60)
20490      DIMENSION VYESQ(60),VYESQ(60),VZESQ(60)

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DRIFVEL (ULCAR)

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20500C
20510CCC      PRINT*, " "
20520CCC      PRINT*, "VX,VY,VZ,ESQ"
20530CCC      PRINT 200,(VX(I),I=1,NC)
20540CCC      PRINT 200,(VY(I),I=1,NC)
20550CCC      PRINT 200,(VZ(I),I=1,NC)
20560CCC      PRINT 200,(ESQ(I),I=1,NC)
20570 200 FORMAT(16F8.1)
20580C
20590C====NC INDICATES HOW MANY VECTORS (SOME OF WHICH MAY BE ZERO) ARE IN
20600C      ARRAYS VX,VY,VZ,ESQ
20610C
20620      IF(NC.LE.60) GO TO 10
20630      PRINT*, " ARRAYS VXTEMP, ETC., NOT LARGE ENOUGH." $ STOP
20640C
20650      10 IF(NC.EQ.0) GO TO 60
20660C
20670      DO 5 I=1,60
20680      IVXWHT(I)=!VYWHT(I)=IVZWHT(I)=0
20690      5 VXTEMP(I)=VYTEMP(I)=VZTEMP(I)=0.
20700C
20710C====PUT NON-ZERO VECTORS (VX,VY,VZ) AND THEIR ESQ'S AND WEIGHTS INTO
20720C      ARRAYS VXTEMP,ETC. MAXIMUM WEIGHT WT IS 1, ALL WT'S BEING 1 IF ESQ
20730C      IS INPUTTED AS "ONE" WHEN SUBROUTINE IS CALLED; IVXWHT,ETC.=WEIGHTS
20740C      ROUNDED OUT TO INTEGER AFTER MULTIPLICATION BY 10000.
20750C
20760      KOUNT=ISUMWHT=0
20770      DO 20 I=1,NC
20780      IF((VX(I).EQ.0.).AND.(VY(I).EQ.0.).AND.(VZ(I).EQ.0.)) GO TO 20
20790      KOUNT=KOUNT+1
20800      VXTEMP(KOUNT)=VX(I)
20810      VYTEMP(KOUNT)=VY(I)
20820      VZTEMP(KOUNT)=VZ(I)
20830      VYESQ(KOUNT)=VYESQ(KOUNT)=VZESQ(KOUNT)=ESQ(I)
20840      WT=AMIN1(1.,(1/(SQRT(ESQ(I)+.00000001))))
20850      IVXWHT(KOUNT)=IVYWHT(KOUNT)=IVZWHT(KOUNT)=IFIX((WT*10000)+.5)
20860      ISUMWHT=ISUMWHT+IVXWHT(KOUNT)
20870      20 CONTINUE
20880C
20890CCC      PRINT*, "VXTEMP,VYTEMP,VZTEMP"
20900CCC      PRINT 200,(VXTEMP(I),I=1,NC)
20910CCC      PRINT 200,(VYTEMP(I),I=1,NC)
20920CCC      PRINT 200,(VZTEMP(I),I=1,NC)
20930CCC      PRINT 220,ISUMWHT,(IVXWHT(I),I=1,NC)
20940 220 FORMAT("ISUMWHT ",I8/"WEIGHTS"/16I8)
20950C
20960      IF(KOUNT.EQ.0) GO TO 60
20970      IF(KOUNT.EQ.1) GO TO 50
20980C
20990C====SEPARATELY SORT VX,VY,VZ INTO DESCENDING ORDER, KEEPING TRACK
21000C      OF THEIR LEAST SQUARE ERRORS AND WEIGHTS.
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DRIFVEL (ULCAR)

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21010C
21020      CALL VSORT(VXTEMP,VXESQ,IVXWHT,KOUNT)
21030      CALL VSORT(VYTEMP,VYESQ,IVYWHT,KOUNT)
21040      CALL VSORT(VZTEMP,VZESQ,IVZWHT,KOUNT)
21050C
21060CCC      PRINT*,"SORTED V*TEMP,V*ESQ,IV*WHT,  *=X,Y,Z"
21070CCC      PRINT 200,(VXTEMP(I),I=1,NC)
21080CCC      PRINT 200,(VXESQ(I),I=1,NC)
21090CCC      PRINT 230,(IVXWHT(I),I=1,NC)
21100CCC      PRINT 200,(VYTEMP(I),I=1,NC)
21110CCC      PRINT 200,(VYESQ(I),I=1,NC)
21120CCC      PRINT 230,(IVYWHT(I),I=1,NC)
21130CCC      PRINT 200,(VZTEMP(I),I=1,NC)
21140CCC      PRINT 200,(VZESQ(I),I=1,NC)
21150CCC      PRINT 230,(IVZWHT(I),I=1,NC)
21160 230 FORMAT(16I8)
21170CCC      PRINT*,"KOUNT=",KOUNT
21180C
21190C=====FIND THE MIDDLE VALUE OF THE SUM OF THE WEIGHTS.  FIND WEIGHTED
21200C      OR UNWEIGHTED MEDIANS FOR VX,VY,VZ SEPARATELY. (SEE COMMENTS IN
21210C      SUBROUTINE WHTMED)
21220C
21230      CENTER=FLOAT(ISUMWHT)/2+.5
21240      MID=MID1=IFIX(CENTER)
21250      IF(FLOAT(MID).NE.CENTER) MID1=MID1+1
21260C
21270      CALL WHTMED(VXTEMP,VXESQ,IVXWHT,MID,MID1,VXMED,ESQX,KOUNT)
21280      CALL WHTMED(VYTEMP,VYESQ,IVYWHT,MID,MID1,VYMED,ESQY,KOUNT)
21290      CALL WHTMED(VZTEMP,VZESQ,IVZWHT,MID,MID1,VZMED,ESQZ,KOUNT)
21300      ESQOUT=(ESQX+ESQY+ESQZ)/3
21310C
21320C=====                2  KOUNT                2
21330C      X-VARIANCE = (SIGMA-X) =  SUM WX(I)*(VX(I)-VXMEDIAN)
21340C                        I=1
21350C                        -----
21360C                        KOUNT-1
21370C      WHERE WX(I) IS THE WEIGHT NORMALIZED SO THAT THE SUM OF THE
21380C      WEIGHTS EQUALS KOUNT.
21390C
21400      WX=WY=WZ=0
21410      ANORM=FLOAT(KOUNT)/FLOAT(ISUMWHT)
21420      SIG=SIGXSQ=SIGYSQ=SIGZSQ=0
21430      DO 70 I=1,KOUNT
21440CCC      PRINT*,"I=",I
21450      W=ANORM*FLOAT(IVXWHT(I))
21460      WX=WX+W
21470CCC      PRINT*,"W,VXTEMP(I) ",W,VXTEMP(I)
21480      SIGXSQ=SIGXSQ+W*((VXTEMP(I)-VXMED)**2)
21490      W=ANORM*FLOAT(IVYWHT(I))
21500      WY=WY+W
21510CCC      PRINT*,"W,VYTEMP(I) ",W,VYTEMP(I)

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21520      SIGYSQ=SIGYSQ+W*((VYTEMP(I)-VYMED)**2)
21530      W=ANORM*FLOAT(IVZWHT(I))
21540      WZ=WZ+W
21550CCC    PRINT*,"W,VZTEMP(I) ",W,VZTEMP(I)
21560      70 SIGZSQ=SIGZSQ+W*((VZTEMP(I)-VZMED)**2)
21570CCC    PRINT*,"WX,WY,WZ,KOUNT ",WX,WY,WZ,KOUNT
21580      SIGXSQ=SIGXSQ/(KOUNT-1)
21590      SIGYSQ=SIGYSQ/(KOUNT-1)
21600      SIGZSQ=SIGZSQ/(KOUNT-1)
21610      SIG=SQRT(SIGXSQ+SIGYSQ+SIGZSQ)
21620CCC    PRINT*,"SIG:XSQ,YSQ,ZSQ; SIG "
21630CCC    PRINT*,SIGXSQ,SIGYSQ,SIGZSQ,SIG
21640C
21650CCC    PRINT 210,VXMED,VYMED,VZMED,ESGOUT,SIG,KOUNT
21660      210 FORMAT("VXMED,VYMED,VZMED,ESGOUT,SIG,KOUNT ",5F8.1,I4)
21670      RETURN
21680C
21690C=====IF ONLY ONE VECTOR, IT BECOMES THE MEDIAN.
21700C
21710      50 VXMED=VXTEMP(1) $VYMED=VYTEMP(1) $VZMED=VZTEMP(1) $ESGOUT=VXESQ(1)
21720      SIG=0
21730CCC    PRINT 210,VXMED,VYMED,VZMED,ESGOUT,SIG,KOUNT
21740      RETURN
21750C
21760      60 VXMED=VYMED=VZMED=ESGOUT=SIG=0
21770CCC    PRINT 210,VXMED,VYMED,VZMED,ESGOUT,SIG,KOUNT
21780      RETURN
21790      END
21800C
21810C
21820C
21830C===== SUBROUTINE VSORT =====
21840C      SORT V,E,IWHT INTO DESCENDING ORDER OF V.
21850C
21860      SUBROUTINE VSORT(V,E,IWHT,ILAST)
21870C
21880      DIMENSION V(1),E(1),IWHT(1)
21890C
21900      IEND=ILAST-1
21910      10 IFAGAIN=0
21920      DO 20 I=1,IEND
21930      IF(V(I).GE.V(I+1)) GO TO 20
21940      IFAGAIN=1
21950      TEMP=V(I) $ V(I)=V(I+1) $ V(I+1)=TEMP
21960      TEMP=E(I) $ E(I)=E(I+1) $ E(I+1)=TEMP
21970      ITEMP=IWHT(I) $ IWHT(I)=IWHT(I+1) $ IWHT(I+1)=ITEMP
21980      20 CONTINUE
21990      IF(IFAGAIN.EQ.1) GO TO 10
22000C
22010      RETURN
22020      END
```

DRIFVEL (ULCAR)

```
22030C
22040C
22050C
22060C===== S U B R O U T I N E   W H T M E D   =====
22070C FIND WEIGHTED MEDIAN VMED (VMED=UNWEIGHTED MEDIAN IF ALL WEIGHTS ARE
22080C EQUAL) AND ITS LEAST SQUARE ERROR ESGV.
22090C CONSIDER WEIGHT AS "FREQUENCY OF OCCURRENCE" OF A VALUE. MID=MID1 IS
22100C THE MIDDLE NUMBER OF THE SUM OF THE FREQUENCIES (WEIGHTS) IF THERE ARE
22110C AN ODD NUMBER OF VALUES (EACH OCCURRENCE OF A VALUE BEING CONSIDERED A
22120C DIFFERENT VALUE). MID,MID1 ARE THE TWO MIDDLE NUMBERS IF THERE ARE AN
22130C EVEN NUMBER OF VALUES.
22140C VMED=VMED(MID) IF MID=MID1; VMED=AVERAGE OF VMED(MID),VMED(MID1) IF NOT.
22150C SIMILARLY FOR ESGV.
22160C=====
22170C
22180 SUBROUTINE WHTMED(V,ESQ,IWHT,MID,MID1,VMED,ESGV,KOUNT)
22190C
22200 DIMENSION V(1),ESQ(1),IWHT(1)
22210C
22220CCC PRINT*,"MID,MID1 ",MID,MID1
22230 ISUMWHT=0 $ VMED1=99999.
22240 DO 10 I=1,KOUNT
22250 ISUMWHT=ISUMWHT+IWHT(I)
22260CCC PRINT*,"ISUMWHT=",ISUMWHT
22270 IF(VMED1.NE.99999.) GO TO 5
22280 IF(ISUMWHT.LT.MID) GO TO 5
22290 VMED1=V(I) $ ESQ1=ESQ(I)
22300 5 IF(ISUMWHT.LT.MID1) GO TO 10
22310 VMED2=V(I) $ ESQ2=ESQ(I)
22320CCC PRINT*,"VMED1,ESQ1,VMED2,ESQ2 ",VMED1,ESQ1,VMED2,ESQ2
22330 GO TO 20
22340 10 CONTINUE
22350C
22360 20 VMED=(VMED1+VMED2)/2
22370 ESGV=(ESQ1+ESQ2)/2
22380CCC PRINT*,"VMED,ESGV ",VMED,ESGV
22390 RETURN
22400 END
22410C
22420C
22430C
22440C===== S U B R O U T I N E   I D E N T   =====
22450C=====CALLED BY SUBROUTINE GRAPH: IF 2 OR MORE GRAPH COORDINATES ARE
22460C IDENTICAL, IT "SPREADS" THEM OUT, KEEPING THEM AS CLOSE TO THE
22470C ORIGINAL COORDINATE(S) AS POSSIBLE.
22480C FOR EXAMPLE: COORDINATES 7,7,4,12 BECOME 6,7,4,12
22490C COORDINATES 10,10,10,10,10,10 BECOME 7,8,9,10,11,12
22500C
22510 SUBROUTINE IDENT(PARAM,INDEX,NUMFREQ,ICN)
22520C
22530 COMMON/G/GVELZ(6),GVELH(6),GVELAZ(6)
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DRIFUEL (ULCAR)

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22540      DIMENSION PARAM(6),INDEX(6),PAR(6),IND(6),IP(6)
22550C
22560      J=0
22570      DO 10 I=1,NUMFREQ
22580      PAR(I)=IND(I)=IP(I)=0
22590      IF(GVELZ(I).EQ." ") GO TO 10
22600      J=J+1
22610      PAR(J)=PARAM(I)  $ IND(J)=INDEX(I)  $ IP(J)=I
22620  10 CONTINUE
22630      JA=J  $ J1=J-1
22640C
22650      IF(ICN.EQ.2) GO TO 25
22660      DO 20 J=1,JA
22670      IF(IND(J).LE.(73-NUMFREQ)) GO TO 20
22680      IND(J)=IND(J)-72  $ PAR(J)=PAR(J)-360
22690  20 CONTINUE
22700C
22710  25 IFAGAIN=0
22720      DO 30 J=1,J1
22730      IF(PAR(J).LE.PAR(J+1)) GO TO 30
22740      IFAGAIN=1
22750      TEMP=PAR(J)  $ PAR(J)=PAR(J+1)  $ PAR(J+1)=TEMP
22760      ITEMP=IND(J)  $ IND(J)=IND(J+1)  $ IND(J+1)=ITEMP
22770      ITEMP=IP(J)  $ IP(J)=IP(J+1)  $ IP(J+1)=ITEMP
22780  30 CONTINUE
22790      IF(IFAGAIN.EQ.1) GO TO 25
22800C
22810      NT=IFIX(FLOAT(JA)/2+.5)
22820      JA1=JA-1  $ NTK=0
22830  40 IFAGAIN=0  $ NTK=NTK+1
22840      DO 50 J=1,JA1
22850      IF(IND(J).NE.IND(J+1)) GO TO 50
22860      IFAGAIN=1
22870      IND(J)=IND(J)-1
22880      GO TO 60
22890  50 CONTINUE
22900  60 IF(IFAGAIN.NE.1)GO TO 90
22910      IF(NTK.GT.NT) GO TO 80
22920      DO 70 J=1,JA1
22930      IBK=JA1+1-J
22940      IF(IND(IBK+1).NE.IND(IBK)) GO TO 70
22950      IFAGAIN=1
22960      IND(IBK+1)=IND(IBK+1)+1
22970      GO TO 80
22980  70 CONTINUE
22990  80 IF(IFAGAIN.EQ.1) GO TO 40
23000C
23010  90 IF(ICN.EQ.2) GO TO 110
23020      DO 120 J=1,JA
23030      IF(IND(J).LT.1) IND(J)=IND(J)+73
23040  120 IF(IND(J).GT.73) IND(J)=IND(J)-73

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23050C

23060 110 DO 100 J=1,JA

23070 100 INDEX(IP(J))=IND(J)

23080 RETURN

23090 END

BIOGRAPHICAL SKETCH

Claude G. Dozois was born on November 16, 1941 in Lewiston, Maine, where he attended elementary school. He graduated from St. Joseph's High School Seminary in Bucksport, Maine in 1960, and obtained a Bachelor of Arts degree in Philosophy from the Oblate College and Seminary in Natick, Massachusetts in 1965. After completing his theological preparation at the Boston Theological Institute in Cambridge, Massachusetts, he was ordained to the priesthood and served in church ministry for several years. After making up undergraduate physics pre-requisites as a special student at the University of Lowell, he was admitted in the fall of 1979 as a matriculated graduate student in the Master of Science program in the Department of Physics of the University of Lowell. During his studies he worked part time under the supervision of Prof. Reinisch at the University of Lowell Center for Atmospheric Research, first as a technician and later as a research assistant.

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