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Joint Services 5D-2 Microwave Scanner Definition Study

J. P. Hollinger, R. M. Lerner, B. E. Troy
and M. M. Wisler

Advanced Space Sensing Application Branch
Space Science Division

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August 1978

NAVAL RESEARCH LABORATORY
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This progress report presents the results obtained to date by the Naval Research Laboratory from their participation in the Joint-Services Microwave Definition Study. This is a joint Navy/Air Force effort to develop a microwave scanning system for the Defense Meteorological Satellite Program (DMSP) to provide all weather, global measurements of the sea surface winds, temperature and ice cover, precipitation over land and sea, and atmospheric liquid water and water vapor to support Department of Defense world-wide military operations.

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Three tasks are addressed. Task I is a sensor performance analysis, system trade-off study and algorithm development program utilizing a theoretical/empirical environmental model and a statistical description of the environmental parameters. Results are presented of a comparison of selected candidate sensor system with regard to their relative accuracy in measuring the desired surface and atmospheric environmental properties.

Task II is to develop a complete set of statistics necessary for Task I. It consists of deriving the means and covariance matrix for all of the desired environmental parameters. In all twelve matrices are being computed corresponding to arctic, temperature and tropic latitudes under spring, summer, fall and winter conditions.

Task III is to conduct a flight program using the NRL RP3-A aircraft and sensor complement to obtain microwave measurements of marine wind speed, atmospheric liquid water and water vapor, and precipitation over land and ocean to evaluate sensor performance models and data reduction algorithms. The results of the flight program in September 1977 to measure precipitation over land and sea are presented.

CONTENTS

JOINT SERVICES 5D–2 MICROWAVE SCANNER DEFINITION STUDY

INTRODUCTION

The Defense Meteorological Satellite Program (DMSP) provides global weather information to support Department of Defense world-wide military operations. Passive microwave sensors offer the advantages, over devices operating at infrared and optical wavelengths, that they can view the earth's surface through a cloud cover and that they have sensitivities to surface features and atmospheric properties that are unique to this part of the spectrum. They can thus provide information about the environment unobservable at other shorter wavelengths. For these reasons a microwave scanner is being developed for the DMSP.

This progress report presents the results obtained to date by the Naval Research Laboratory from their participation in the Joint-Services Microwave Scanner Definition Study. Three tasks have been undertaken.

Task I is a sensor performance analysis, system trade-off study and algorithm development program. It is intended to be responsive to analysis of new or innovative system configuration ideas and compromises dictated by engineering development of the sensor hardware as well as the development of data processing algorithms. As such it is a continuing program. It is constrained to the frequency range of 14 to 90 GHz and provides estimations of measurement accuracies of marine wind speed, sea ice boundary, integrated atmospheric liquid water and water vapor, precipitation rates over land and ocean, and soil moisture. It utilizes a theoretical approach and environmental model but relies on an empirical ocean roughness model and a statistical description of the environmental conditions for a range of geographic locations and sensors. Precipitation and soil moisture models are provided by the Air Force. The results of this continuing study, to date, are described in the second section of this report.

Task II is to develop the statistics necessary for Task I. It consists of deriving the means and covariance matrix for the following environmental parameters:

Note: Manuscript submitted June 15, 1978.

1. Surface Air Temperature
2. Air temperature vertical lapse rate
3. Columnar density of water vapor
4. Scale height of the water vapor profile
5. Surface pressure
6. Columnar density of non-precipitating liquid water
7. Surface rain rate
8. Surface wind speed
9. Sea surface water temperature.

In all, twelve matrices were computed corresponding to arctic, temperate, and tropic latitudes under spring, summer, fall and winter conditions. The data base used contains rawinsonde measurements, ground based weather station observations, and ship observations at or near Jan Mayen (70°57'N, 8°40'W) for arctic, Azores (38°44'N, 27°05'W) for temperate and Truk (7°28'N, 151°51'E) for tropic maritime conditions. This effort has been subcontracted to Frank J. Wentz and Associates. The covariance and the correlation matrices along with the mean standard deviations of each environmental parameter are given in the third section of this report.

Task III is to conduct a flight program using the NRL RP3-A aircraft and sensor complement to obtain microwave measurements of marine wind speed, atmospheric liquid water and water vapor, and precipitation over land and ocean to evaluate sensor performance models and data reduction algorithms. The results of the flight program in September 1977 to measure precipitation are described in the first section of this report.

AIRCRAFT FLIGHT PROGRAM

Measurements were made during the period 12 through 30 September 1977 with the NRL RP3-A aircraft. The objective was to obtain measurements of precipitation over both land and water. A decision to fly or cancel was made prior to each tentative flight based on weather information obtained from Weather/Flight Operations at Patuxent Naval Air Test Center (PAXNATC) and from Major Richard Savage at Air Force Global Weather Center (AFGWC), Offutt Air Force Base. All flights were from and return to PAXNATC.

Measurements were obtained with the following microwave radiometers:

14 GHz Tunnel Diode Amp (13.5-15.0 GHz) H&V Pol
19.3 GHz Xtal Mixer (20-300 MHz IF, DSB) H&V Pol
22.2 GHz Xtal Mixer (5-500 MHz IF, DSB) H only

31.3 GHz Xtal Mixer (5-500 MHz IF, DSB) V only
89.5 GHz Xtal Mixer (1-2 GHz IF, DSB) V only.

All of the radiometers have antennas with a 7 degree half-power beamwidth except the 90 GHz which is 2 degrees. The 90 GHz was primarily used in an imaging configuration (1) where the beam is scanned at a rate of 10 scans per second, ±32 degrees in the cross-track direction. All of the radiometers, except the 90 GHz, were mounted on a palette which can be rotated in flight to vary the direction of view from nadir to 55 degrees from vertical in the aft direction. The 90 GHz was mounted on the palette in place of the 14 GHz for all flights after 19 September.

In addition to the radiometers, a PRT-5 Barnes infrared thermometer operating in the 9.5 to 11.5 micron band was used to measure cloud top temperatures. Outside air temperature, dew point temperature, and barometric pressure were recorded. The inertial navigator outputs of latitude, longitude, true heading, ground speed, and wind speed and direction were logged.

Flights were conducted on the 13, 14, 15, 19, 20, and 23 of September. Measurements of precipitation over land were obtained on the 13th, 15th, and 20th and of precipitation over ocean on the 14th. No precipitation was encountered on the 19th and 23rd. The ground tracks for the flights of 13, 14, 15, and 20 September are shown in Figures 1, 2, 3, and 4 respectively.

A complete description of the conditions along the ground track for all flights is being assembled and prepared by Major Richard Savage using the resources of AFGWC but is not yet available. The following conditions along the flight path were determined by measurement and observation from the aircraft and by interrogating weather stations along the route at the time of the flights.

On the 13th broken Cumulus clouds were observed at 15:20 GMT. By 15:44 GMT the sky was completely undercast. A definite rain patch was overflown in the time period 16:13-16:31 GMT. Another rain cell was overflown at about 17:27 GMT. Clearing was gradually observed during overflight of Lake Michigan at 17:41 GMT. From the National Weather Service Map conditions on Lake Michigan were as follows:

Surface Pressure:	1009.4 mb
Surface Air Temperature:	14°C
Relative Humidity:	94%
Wind Speed:	10 knots

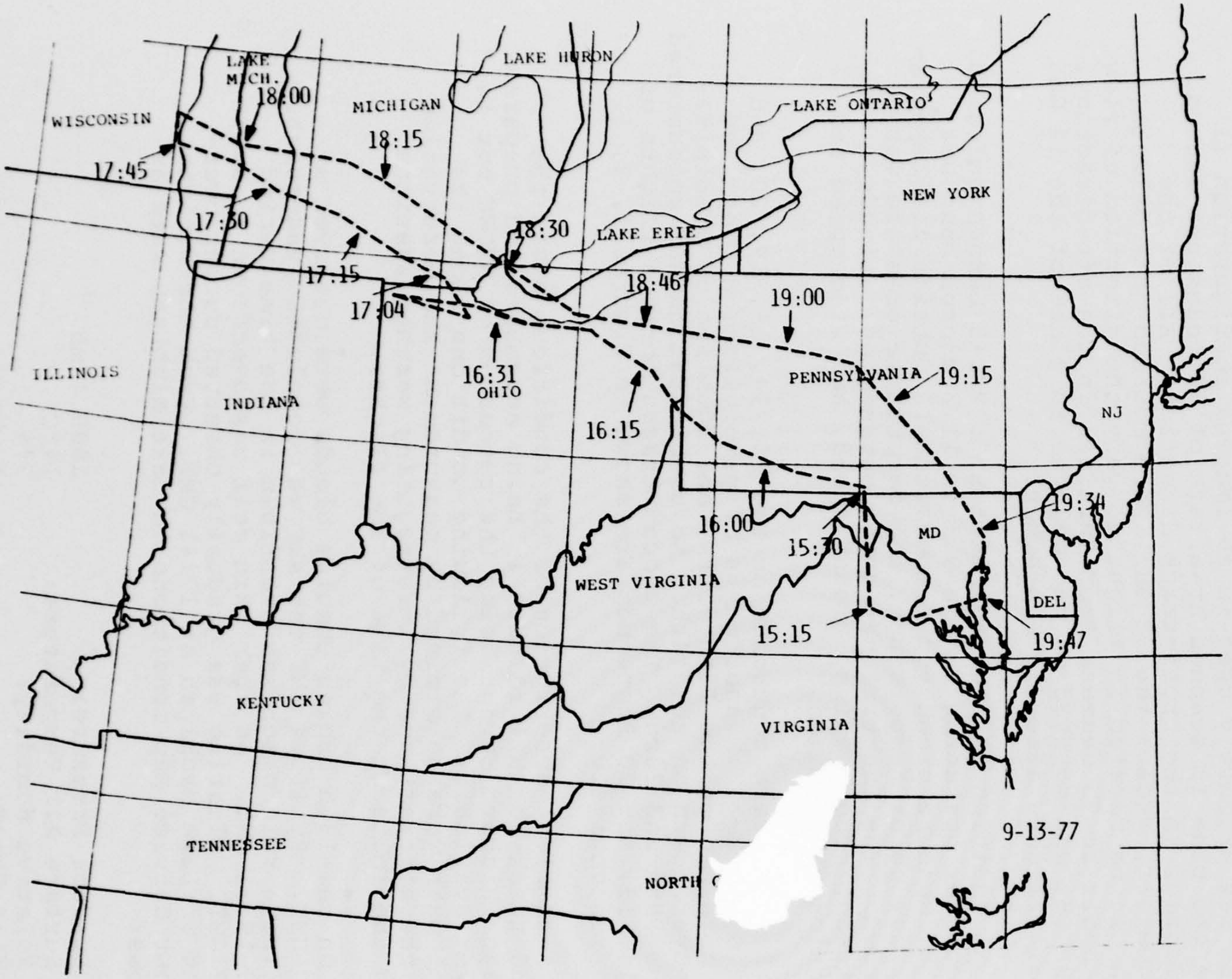


Fig. 1 — Ground track for the 13 September flight

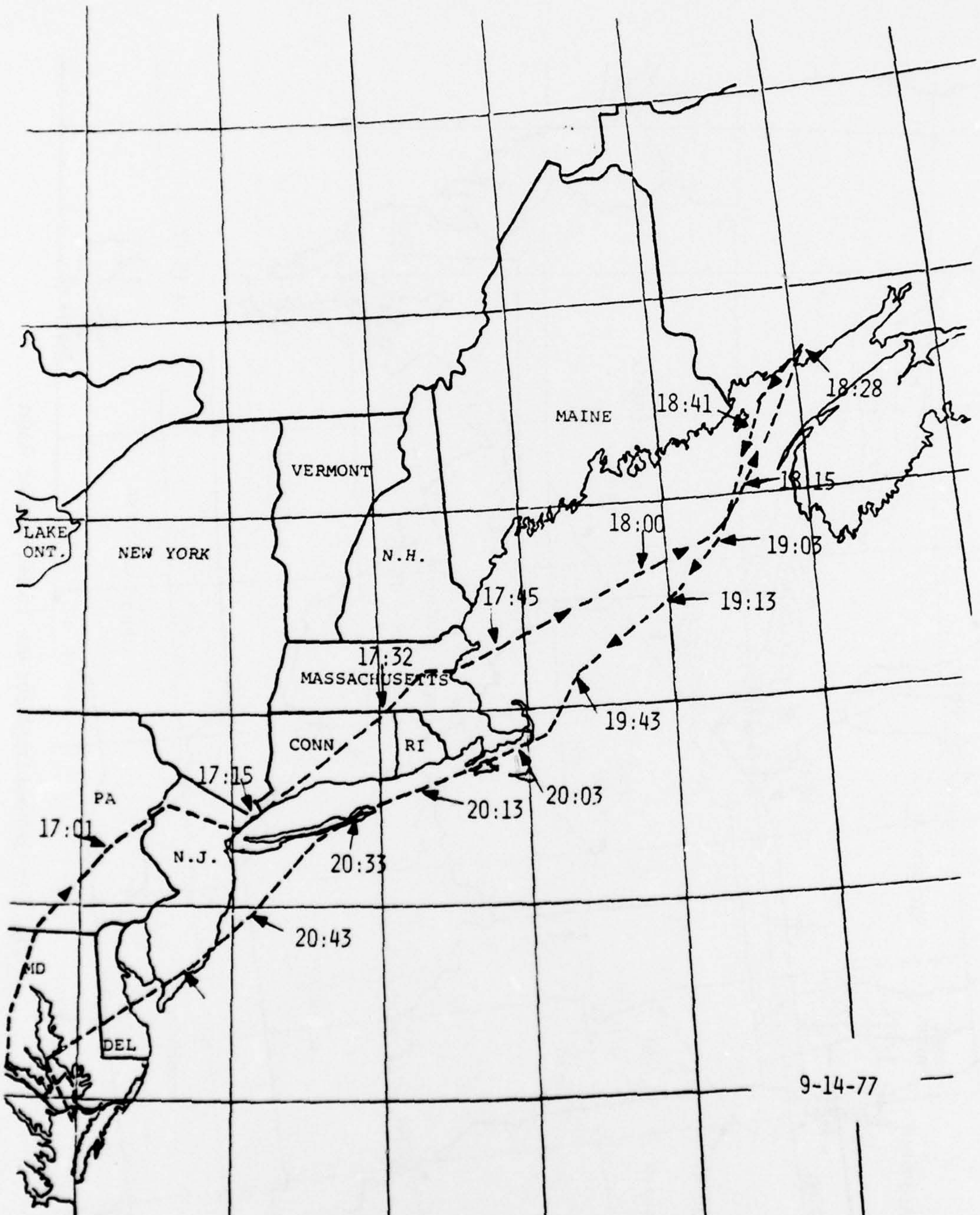


Fig. 2 — Ground track for the 14 September flight

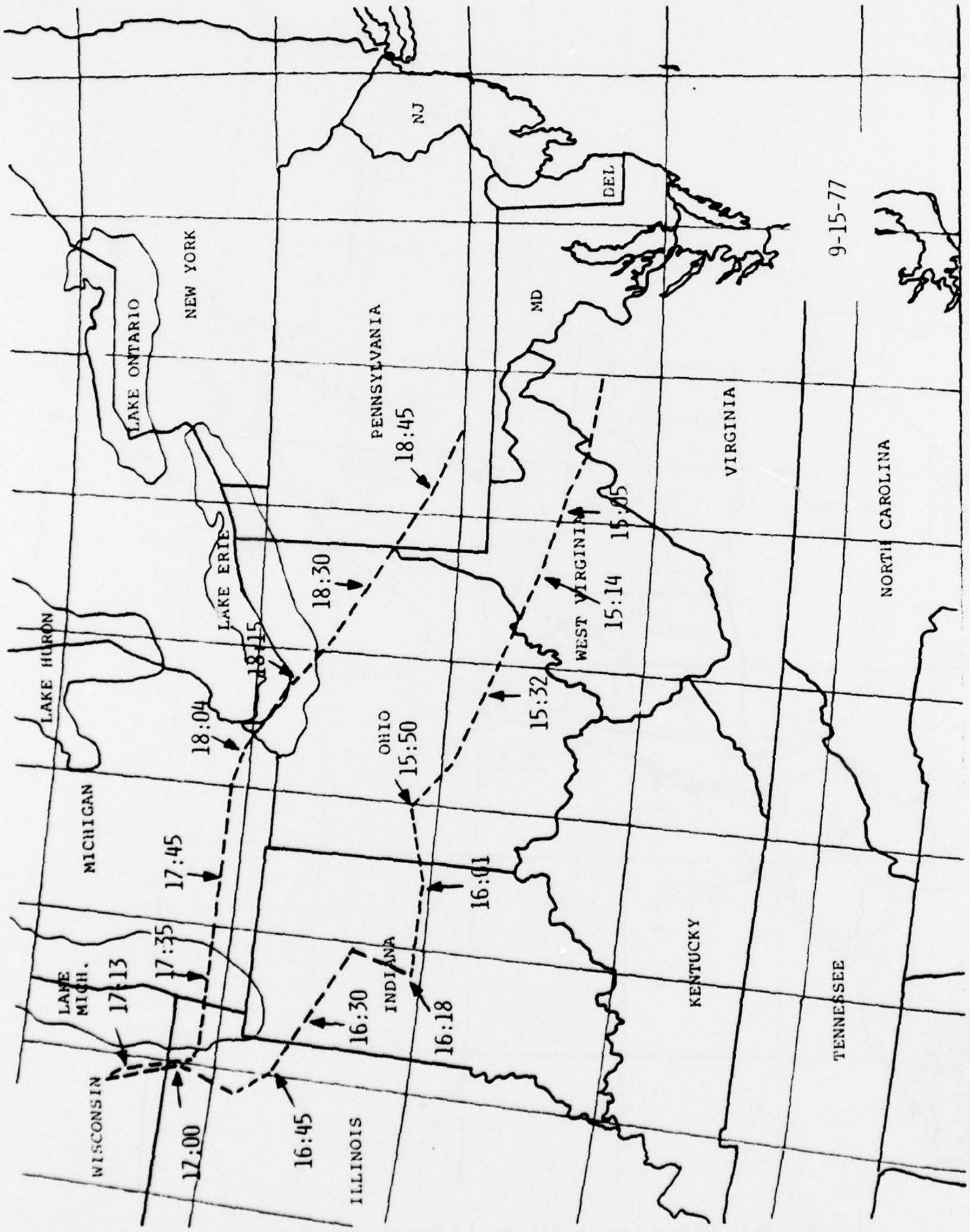


Fig. 3 — Ground track for the 15 September flight

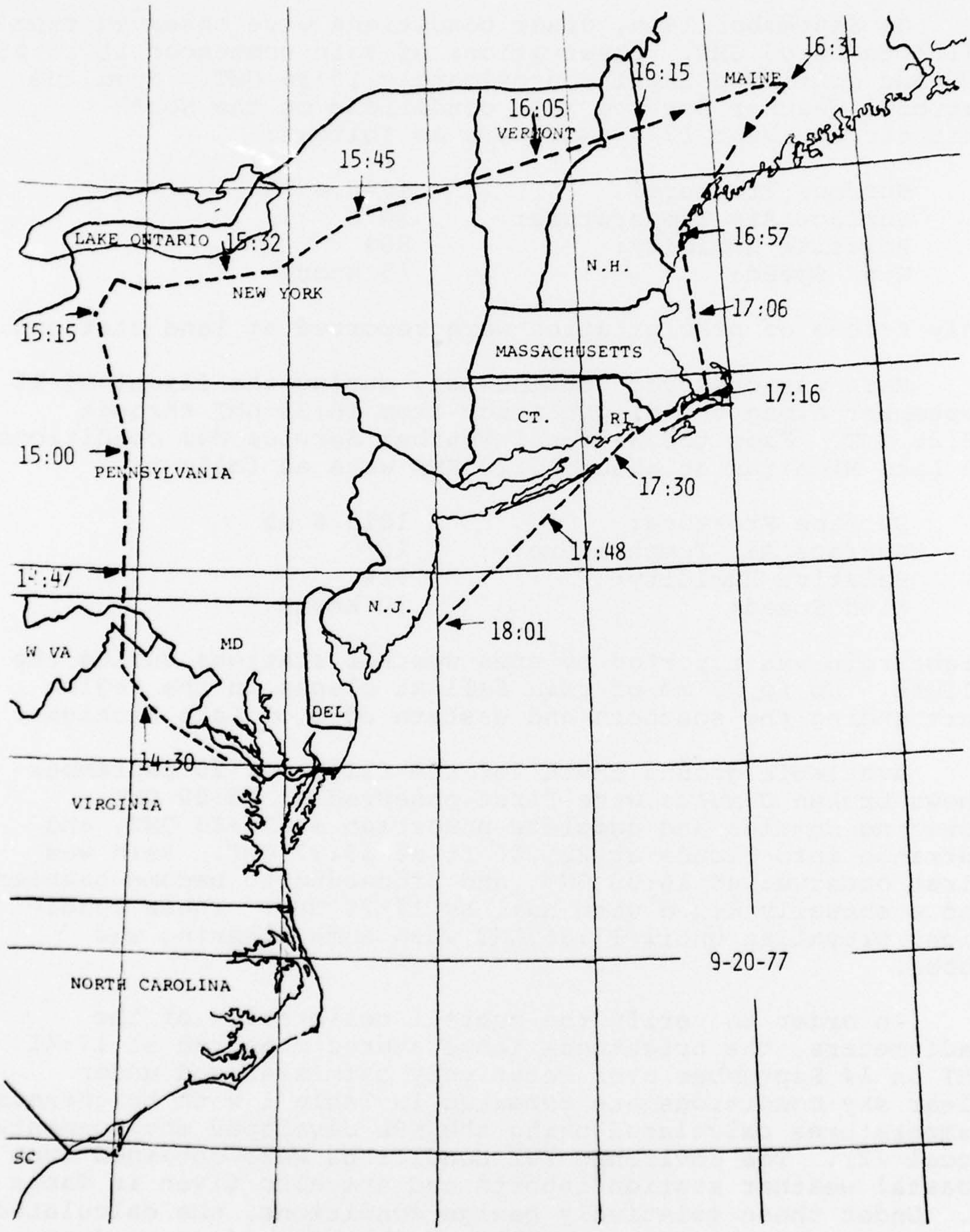


Fig. 4 — Ground track for the 20 September flight

Rain was again observed from 17:50 GMT to 18:10 GMT. Weather stations in the area reported light showers. Approximately 10 mm of rain fell in the area during the 24-hour period.

On September 14th, clear conditions were observed from 17:24 to 18:03 GMT. Observations of rain commenced at 18:05 GMT and continued until approximately 19:30 GMT. From the National Weather Service Map, conditions on the North Atlantic at about 17:40 GMT were as follows:

Surface Pressure:	1006.4 mb
Surface Air Temperature:	18°C
Relative Humidity:	80%
Wind Speed:	15 knots

Only traces of precipitation were reported at land stations.

Rain was observed continuously during the flight of 15 September along the flight track from 16:35 GMT through 18:20 GMT. From the National Weather Service Map conditions on Lake Michigan at about 17:20 GMT were as follows:

Surface Pressure:	1015.6 mb
Surface Air Temperature:	16°C
Relative Humidity:	91%
Wind Speed:	10 knots.

Light rain was reported by area weather stations during the flight. Up to 25 mm of rain fell at places in the region surrounding the southern and eastern edge of Lake Michigan.

Available ground truth for the flight of 20 September shows broken Cumulus were first observed at 15:00 GMT, towering Cumulus and complete undercast at 15:23 GMT, and entrance into clouds at 22,000 ft at 15:37 GMT. Rain was first observed at 16:00 GMT and proceeded to become heavier and eventually mixed with hail by 17:22 GMT. These conditions prevailed until 17:36 GMT when some clearing was noted.

In order to verify the overall calibration of the radiometers, the brightness temperatures measured at 17:41 GMT on 14 September over relatively calm seas and under clear sky conditions are compared in Table 1 with brightness temperatures calculated using the NRL developed environmental model (2). The environmental conditions were obtained from coastal weather station reports and are also given in Table 1. Under these relatively benign conditions, the calculated values should be most accurate and thus provide a good test of the accuracy of the measurements. As can be seen, there

TABLE 1

Comparison of Measured and Calculated Brightness Temperature for a Calm Sea

Date:	9-14-77
Time:	17:41 GMT
Altitude:	23,000 ft
Surface Pressure:	1006.40 mb
Surface Air Temperature:	18°C
Surface Relative Humidity:	80%
Surface Absolute Humidity:	12.28 gm/M^3
Scale Height:	2.2 km
Total H_2O Vapor:	2.88 gm/cm^2
No Clouds	
Sea Surface Salinity:	35.0 ppt
Sea Surface Temperature:	16°C
Surface Wind Speed:	15 knots

Frequency in GHz	14	19	22	31	90
Measured T_B (°K)	125.9	140.6	175.4	158.4	233.0
Calculated T_B (°K)	125.2	142.8	175.8	158.0	233.1

is good agreement between the measured and calculated values; the difference being less than 1°K except at 19 GHz where it is 2.2°K.

Three portions of the data of approximately one hour duration were selected for each of the flights of the 13, 14, and 15th as being representative of the precipitation measurements. The aircraft was above the cloud system for all of these measurements at altitudes of 26,000, 23,000, and 22,000 feet respectively. The nadir brightness temperatures at 14, 19, 22, 31, and 90 GHz are given as a function of time in Figures 5, 6, and 7 for 13, 14, and 15 September respectively. The 90 GHz data shown is the average of the central four beam positions obtained from the imager. This results in an eight degree nadir field of view for comparison with the other profile radiometric data. The full 90 GHz image is given for these same periods in Figures 8A, 8B, 9A, 9B, 10A and 10B. The field of view is 64 degrees and the flight track runs continuously from left to right along eight successive rows. The first figure in each set describes the color coded brightness temperature image which follows. Very roughly green corresponds to the brightness temperature of land, blue to water, and white to clouds. This is not, of course, strictly true since rain over water can have a brightness temperature high enough to resemble land.

The data for 13 September corresponds to a portion of the flight track over Michigan, preceeding across Lake Michigan to Wisconsin and then returning back across the lake. A river and various surface features are seen on all channels except 90 GHz over Michigan. The eastern edge of the lake is totally obscured at 90 GHz; however, conditions slowly clear as Lake Michigan is crossed, and the surface is nearly clear by the western edge. These brightness temperatures are consistent with a 2 mm/hr rain rate (3) over Michigan and the eastern edge of the lake to an absence of precipitation at the western edge. This is in agreement with available ground truth.

The entire section of the flight track shown for 14 September is over the Atlantic off the northeast coast except for a short turn around over Saint John, New Burnswick. Again various land features in the vicinity of Saint John are apparent on all channels except 90 GHz which is obscured. The rain continues to be opaque at 90 GHz well out into the Atlantic, south of Saint John with occasional individual rain cells visible on all channels. These cells appear green on the 90 GHz image of Figure 9B and are not to be confused with land. The brightness temperatures of the rain area over and south of Saint John as well as the isolated cells are consistent with very light rain; probably 1 mm/hr or less (3).

The flight path taken on 15 September is very similar to that of the 13th. Conditions are also similar. The rain is mostly to the east and south of Lake Michigan. The rain rate on the 15th is probably greater than on the 13th. This is indicated by the greater rain accumulation in the area, by the weather stations report of light rain rather than light showers and by the visual observations at the time from the aircraft. and observations from the aircraft at the time. The greater rain rate is suggested by the microwave data as well. The lake is totally obscured at 90 GHz and there is an apparent more intense region of rain at about 17:16 GMT and again near the eastern edge of the lake at 17:34 GMT. The 90 GHz shows a slight depression of about 8°K at 17:16 GMT while the 31 GHz shows a slight increase of about 4°K. The other channels also show a relative absence of surface features indicating an increased opacity at the lower frequencies. This indicates a more intense region of rain over land of about 4 mm/hr (3). The rain cell over the lake at 17:34 GMT is about 6°K warmer than the one at 17:30 GMT on the 13th at 31 GHz indicating more intense rain on the 15th. The brightness temperature of about 244°K at 31 GHz for the cell at 17:34 GMT indicates a rain rate in excess of 2 mm/hr (3). There is also a rain cell at 17:44 GMT. Here the 90 GHz brightness temperature is depressed to 252°K where land with little or no precipitation has a brightness temperature of closer to 280°K; e.g. in the region of 16:40 GMT. There is also a relative absence of surface features as during the cell at 17:16 GMT. Therefore rain rates of 2 to 4 mm/hr are indicated.

These measurements substantiate the need for a 90 GHz channel to detect very low rain rates and demonstrate the ability of microwave radiometry to quantify precipitation over both water and land surfaces.

SENSOR PERFORMANCE ANALYSIS

In this section, candidate SSM/I systems are compared with regard to their relative accuracy in measuring certain atmospheric and earth's surface parameters. The radiometric environmental model available at this time does not include the environmental parameters of rain and soil moisture. The parameters that were selected are thereby restricted to a marine environment and are: surface wind speed, sea surface temperature, precipitable water (integrated water vapor), and integrated liquid water in the form of clouds.

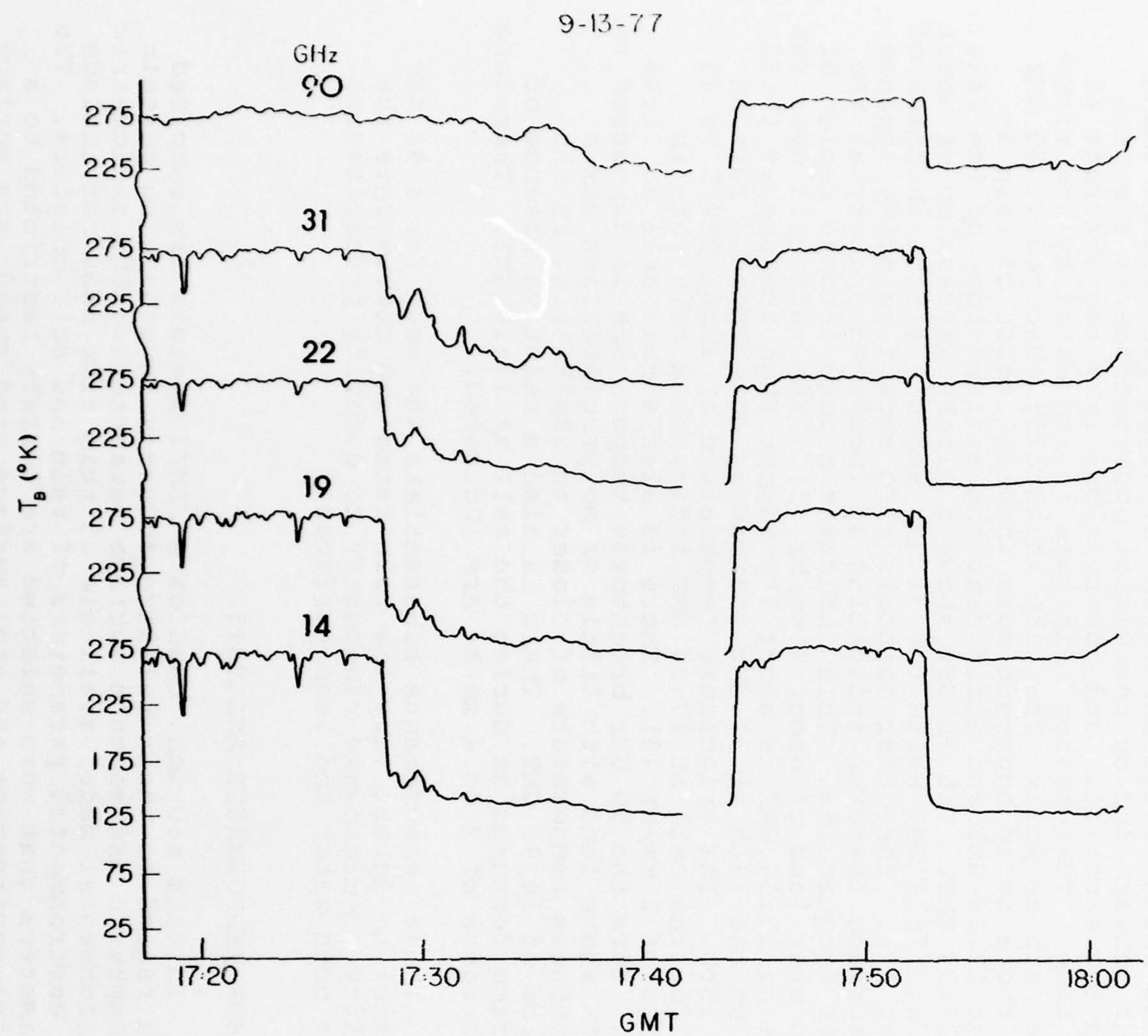


Fig. 5 — Radiometer data obtained on 13 September from 26,000 feet altitude

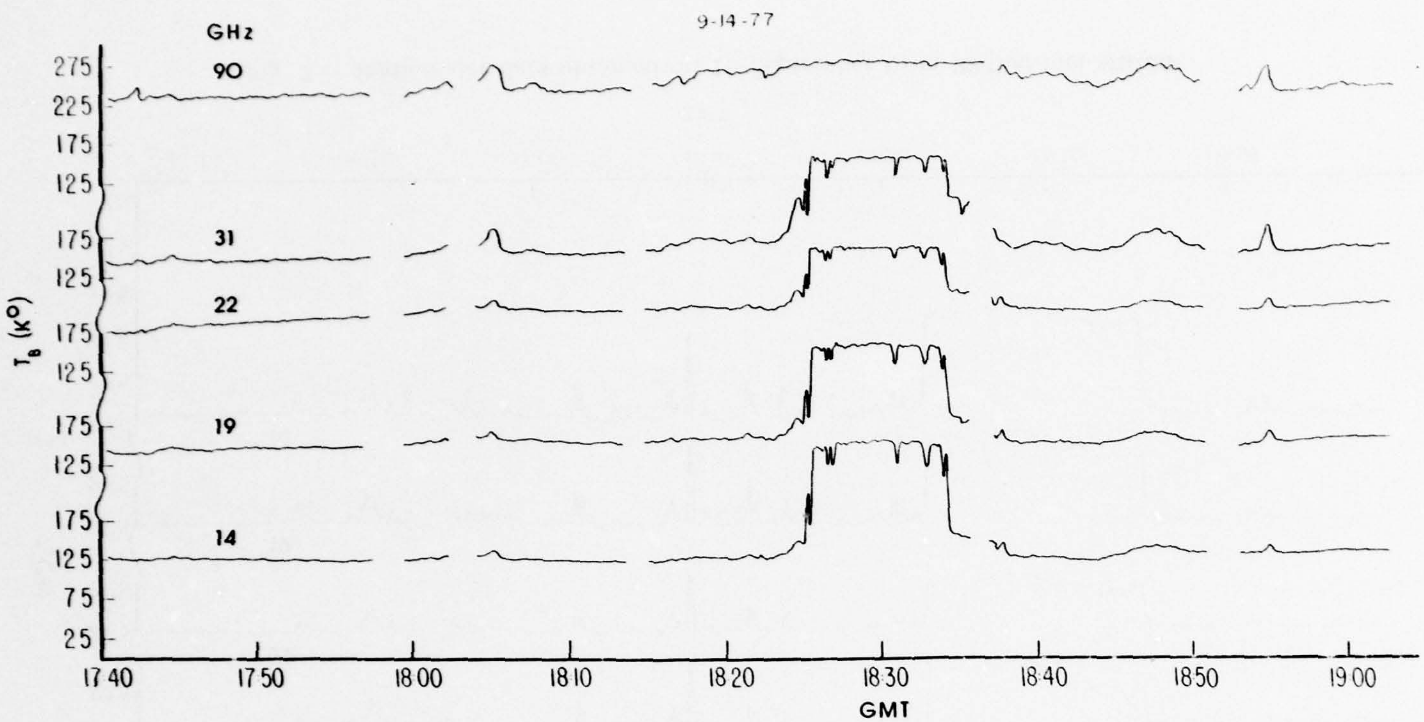


Fig. 6 — Radiometer data obtained on 14 September from 23,000 feet altitude

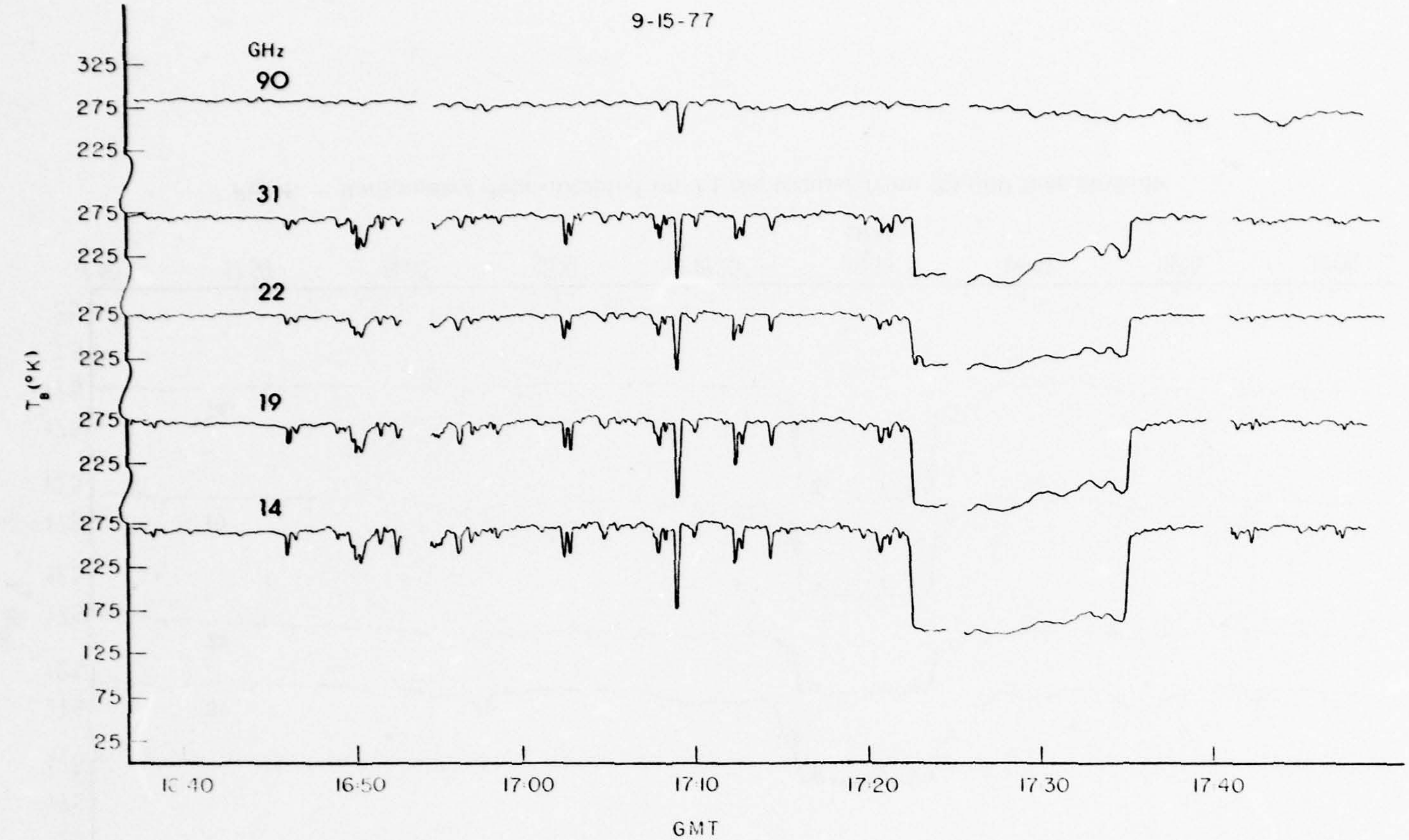


Fig. 7 — Radiometer data obtained on 15 September from 22,000 feet altitude

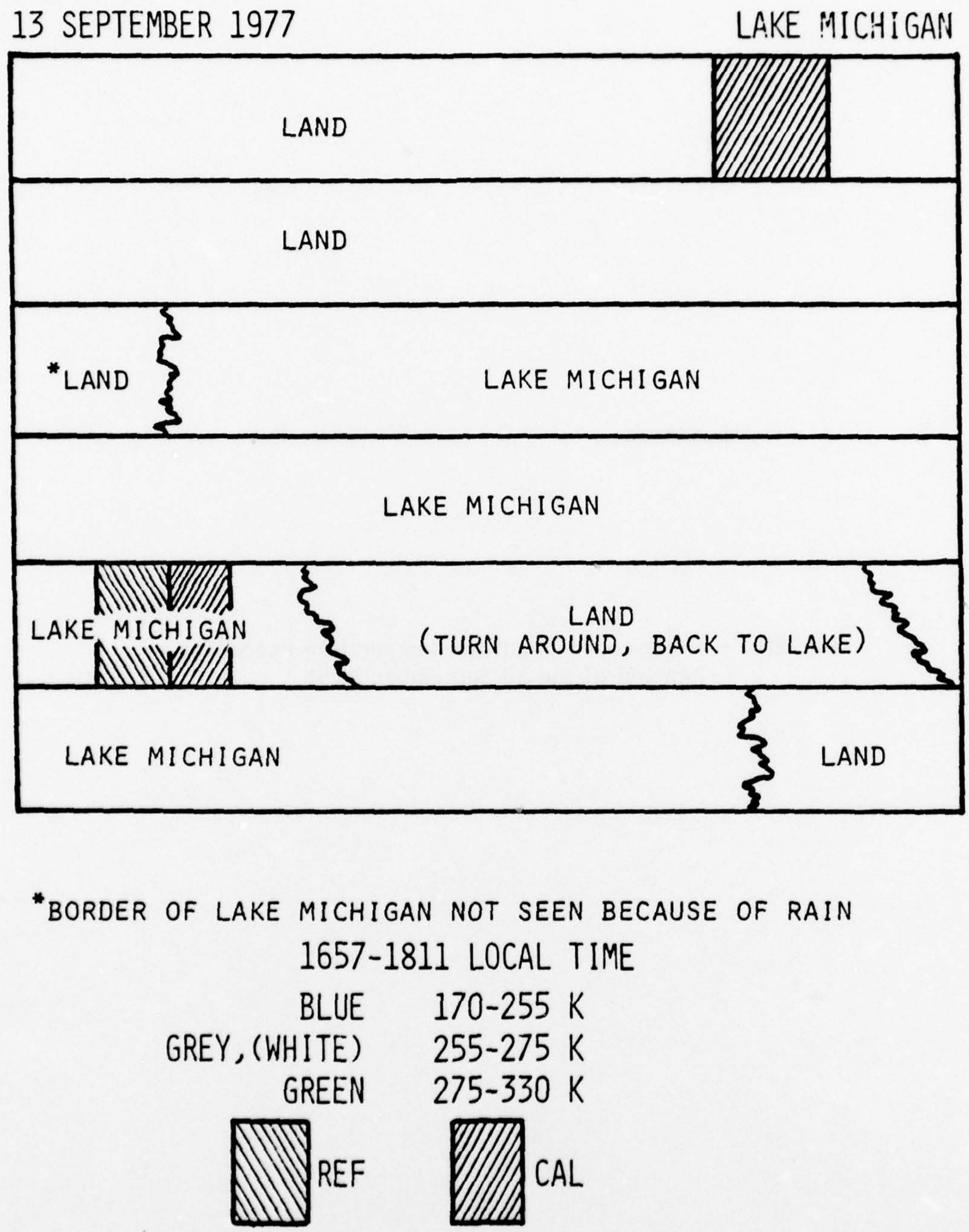
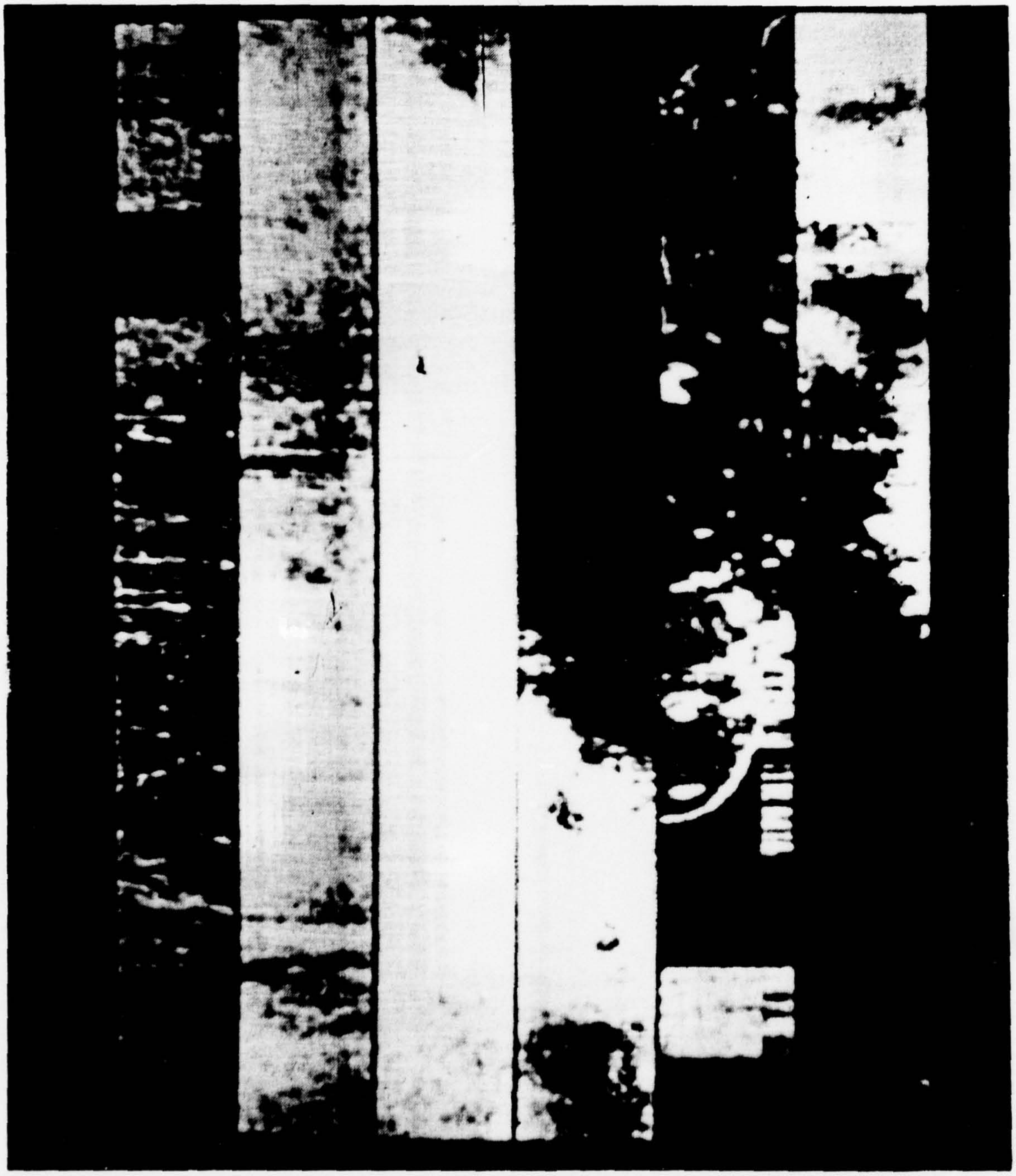


Fig. 8(a) — Schematic description of the 13 September color coded brightness temperature images in Fig. 8(b). Data reads left to right top to bottom.

Fig. 8(b) — Color coded brightness temperature images for a portion of the 13 September flight



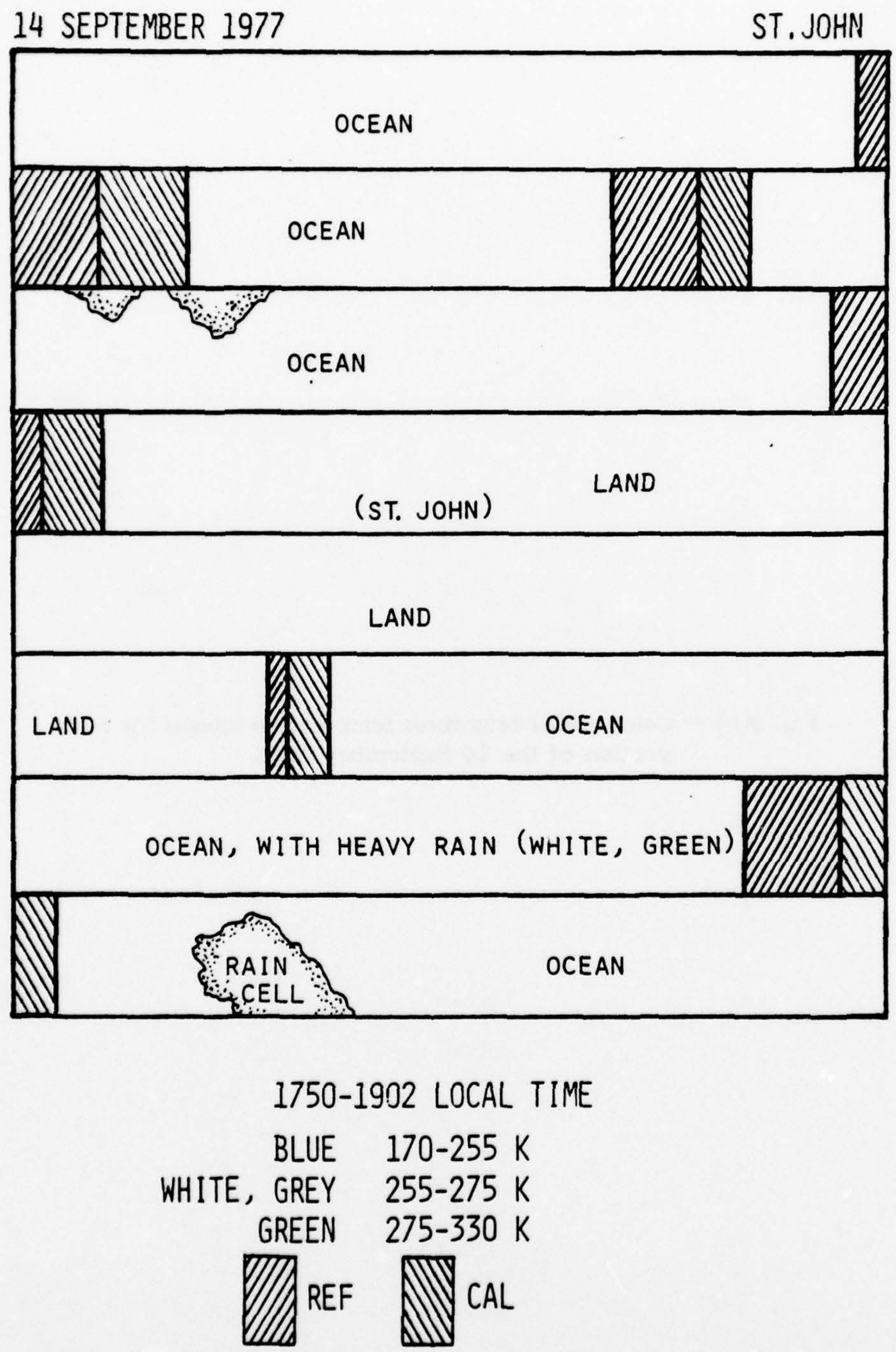


Fig. 9(a) — Schematic description of the 14 September color coded brightness temperature images in Fig. 9(b)

Fig. 9(b) — Color coded brightness temperature images for a portion of the 14 September flight

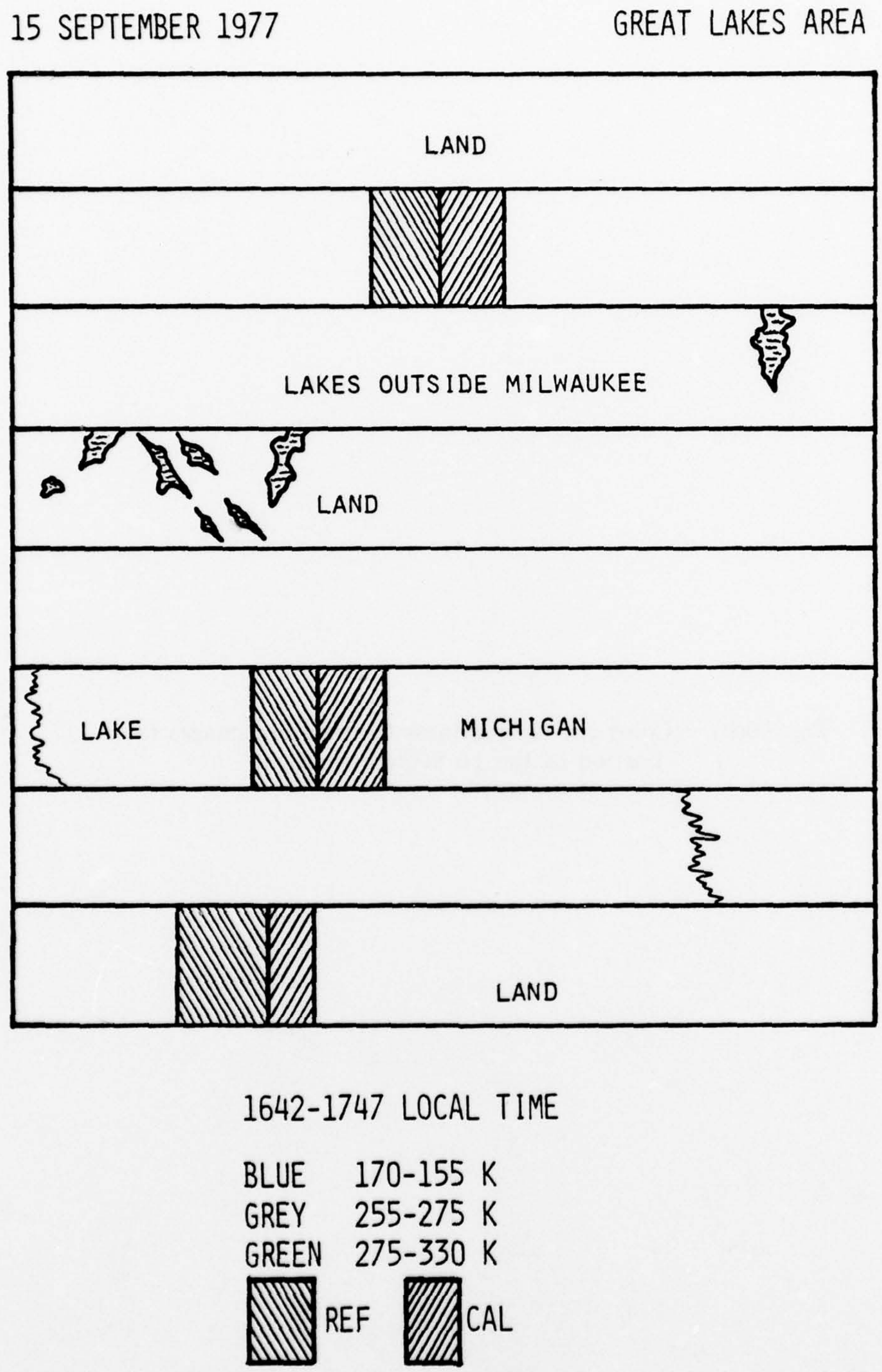
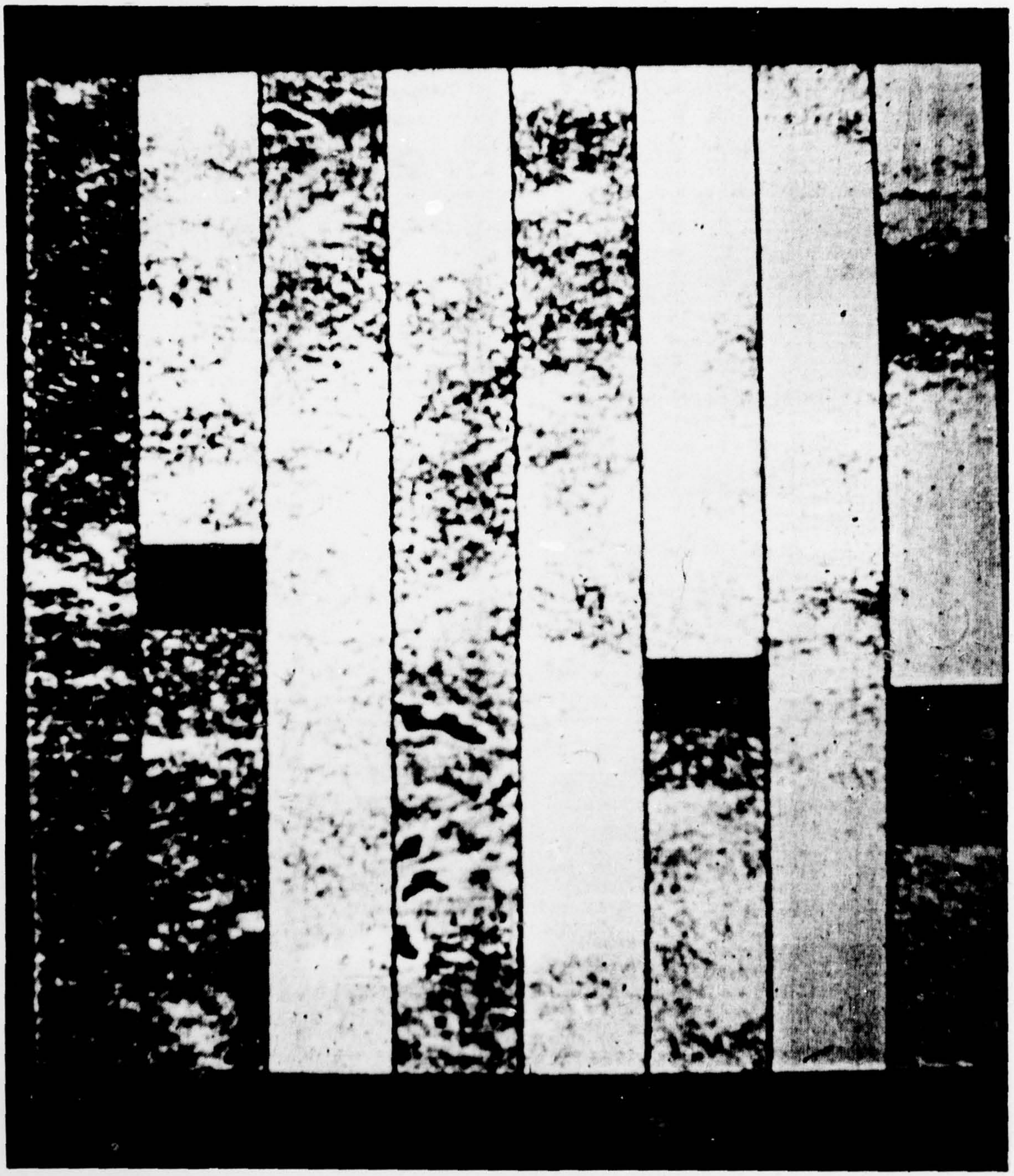


Fig. 10(a) — Schematic description of the 15 September color coded brightness temperature images in Fig. 10(b)

Fig. 10(b) — Color coded brightness temperature images for a portion of the 15 September flight



Because of the over water measurement conditions, the radiometric earth incidence angle was chosen to be 55 deg. for maximum separation of the horizontal and vertical channels during a variety of sea states (4). The radiometric measurement noise was varied and the frequencies and polarizations were changed and their effects on estimation precision were recorded using the NRL developed estimation techniques (2).

A major input to the estimation technique is a set of parameters which appreciably affect radiometric brightness temperatures. As previously mentioned, a complete set of these will be available at the end of May. For this report, an interim set of covariance matrices was constructed from available seasonal statistics. In these matrices the cross terms were set equal to zero due to the lack of information about cross correlations in our data sources. The effect of this simplification is unknown at present, but it is believed that it will not appreciably affect the results qualitatively. The climate chosen for analysis will be a worst case 45°N latitude mid-North Atlantic in July with a thick (1 Km) cloud and no rain.

There are an infinity of possible cases consisting of various environmental parameters, and possible radiometric channel combinations which may be considered. At this stage, to narrow down the task, the analysis is restricted to combinations of environmental parameters and system configurations suggested for the SSM/I. The environmental parameters considered are sea surface temperature, marine wind speed, precipitable water vapor and liquid water in the form of clouds. The sea/ice boundary presents a strong constrast signal and is generally less than 3 Km, and usually less than 1 Km, wide and thus its location depends primarily on the system resolution and does not require the present trade-off analysis. The system configurations considered include combinations of the strawman system suggested in the SSM/I Specification Document, containing channels at 19.5, 22.2, 37.0 and 90 GHz, as well as the inclusion of a 14.5 GHz channel. Although the 90 GHz channel is included in the analysis here, it should be kept in mind that its value primarily rests upon its ability to detect low rain rates over water and land and its higher resolution for sea/ice boundary location which are not part of this analysis. Therefore, a lower utility of this channel relative to the lower frequencies in the present analysis does not mean it should not be given strong consideration as part of the final system configuration. A final consideration in this study is the relative merits of 18 versus 19 GHz and 21 versus 22 GHz for the determination of wind speed, sea surface temperature and water vapor.

The radiometric measurement noise is, of course, a large factor in the environmental parameter estimation error, the lower limit on the precision will probably be around 0.1K and an upper limit on the accuracy is possibly 2K. In what follows, this should be kept in mind in analyzing the graphs.

Figure 11 shows the ability of a five-frequency radiometer system to measure sea surface temperature as a function of the radiometer noise (all radiometers assumed to have the same noise). The sea surface temperature estimate is perfect if the ability to measure is 1 and useless if the ability to measure is 0. In between 0 and 1, the ability to measure is one minus the ratio of the rms residual error to the rms a priori error. So, for the case in Figure 11 the rms a priori error is 2.3K, and for curve 1 and no radiometer noise, the sea surface can be measured to a residual accuracy of 0.97K. Curve 1 is for a radiometer system consisting of both polarizations at each of the frequencies 14.5, 19.4, 22.3, 31.4, and 90 GHz. Curve 2 is also for a five-frequency radiometer system, but with only one polarization measured at each frequency. Specifically, there are 14.5V, 19.4H, 22,2H, 31.4V, and 90V GHz, where the V refers to vertical polarization (E field in the plane of incidence) and H refers to horizontal polarization.

There is some question as to the usefulness of a 22.2 GHz radiometer as opposed to a 21 GHz radiometer and an 18 GHz as opposed to a 19.4 GHz radiometer. Figure 12 shows there to be advantage to using the 22.2 rather than the 21. In both Figures 12a and 12b, X's below the frequency and polarization column indicate that a measurement is made at that frequency and polarization. The rows of X's then correspond to a particular system and the point on the graph colinear with the X's is the residual error for that particular system. In the columns of X's, it is noted that the 22.2 GHz is removed (going from top to bottom) before the 21 GHz, this corresponds to the dotted graph line. Interchange the columns under the 21 and 22.2 GHz headings to obtain the configuration of X's which corresponds to the solid line graph. The a priori error is the error in estimating the precipitable water with only a knowledge of its average value available.

Figure 13 is a set of graphs designed to show the effect on estimating surface winds and sea surface temperature of removing the 18 or the 19.4 GHz radiometer. However, here it was found that although eliminating the 18 GHz had a slightly greater effect than eliminating the 19.4, the difference could not be graphed on this scale. So interchanging the columns headed by 18 GHz and 19.4 GHz will have negligible effect on these graphs.

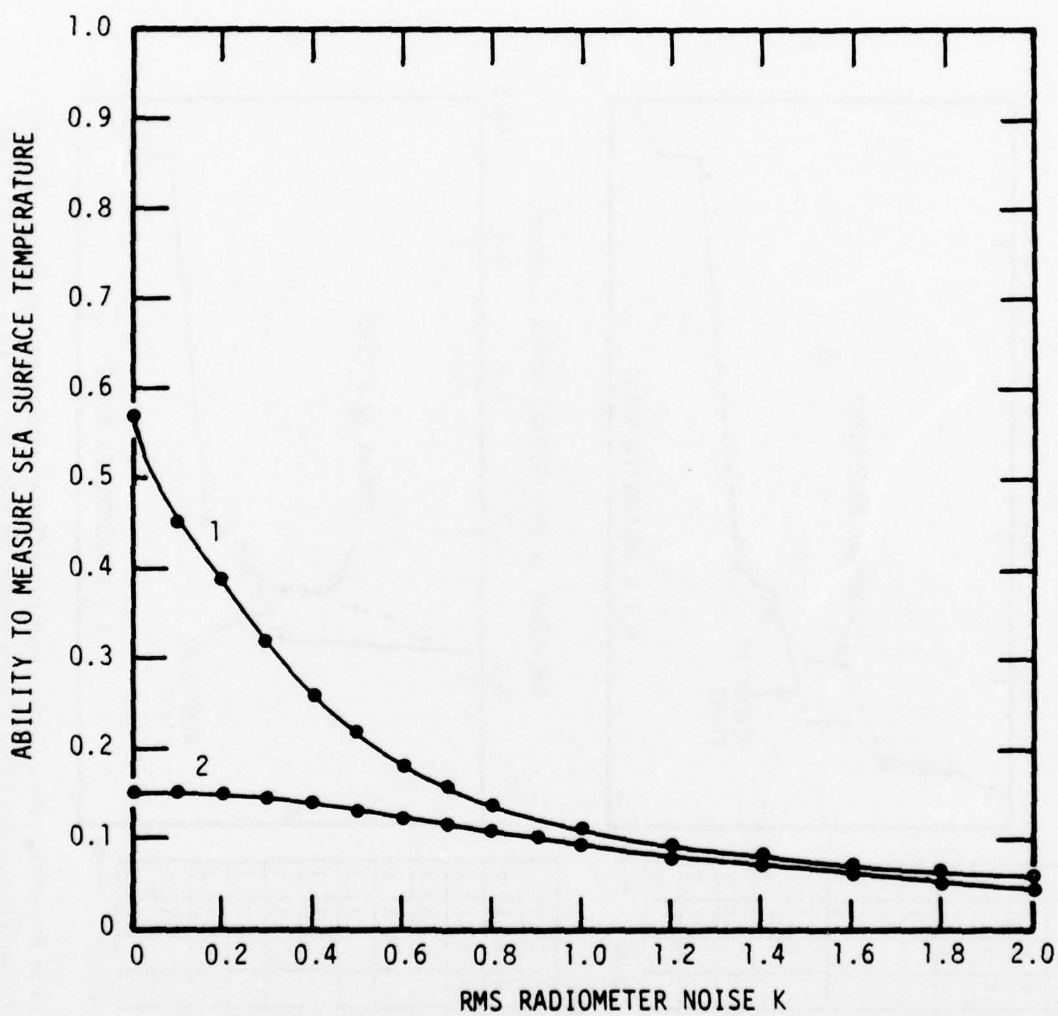


Fig. 11 — Ability to measure sea surface temperature as a function of radiometer noise. Curve 1 corresponds to a radiometer system measuring both polarizations at each of the frequencies 14.5, 19.4, 22.2, 31.4, and 90 GHz. Curve 1 corresponds to a system with only one polarization at each of 5 frequencies 14.5V, 19.4H, 22.2H, 31.4V, and 90V GHz. The V refers to vertical polarization and H to horizontal polarization.

FREQUENCY GHz

18		19.4		21		22.2		37	
V	H	V	H	V	H	V	H	V	H
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
	X			X	X			X	X
				X	X			X	X
					X			X	X
								X	X
									X

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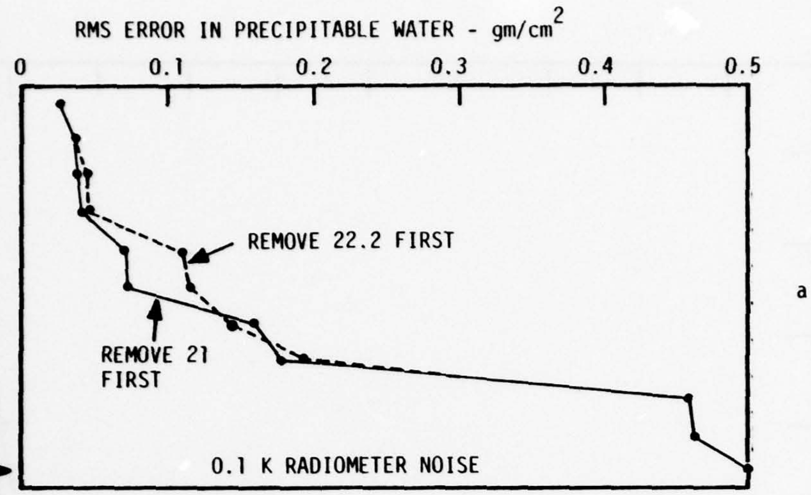

FREQUENCY GHz

18		19.4		21		22.2		37	
V	H	V	H	V	H	V	H	V	H
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
	X			X	X			X	X
				X	X			X	X
					X			X	X
								X	X
									X

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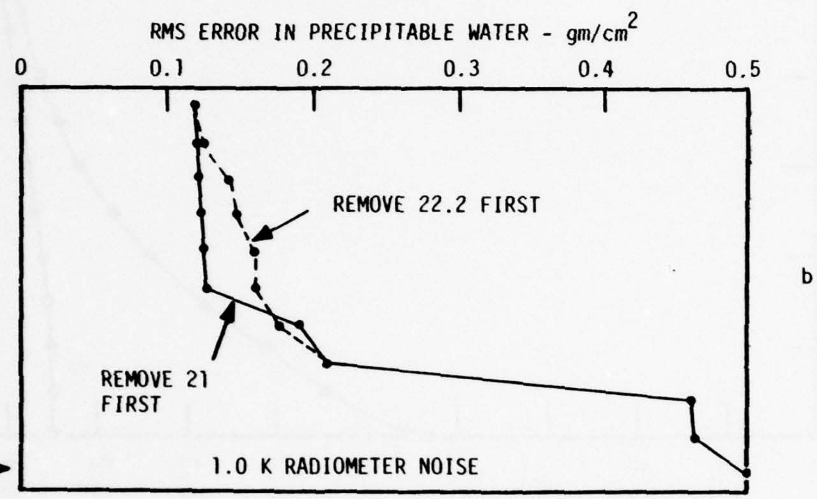


Fig. 12 — Error in measuring precipitable water for different radiometric systems. For the solid line graph interchange the two columns under 21 GHz for the two under 22.2 GHz. The bottom figure assumes 1°K radiometer noise and the top figure 0.1°K radiometer noise.

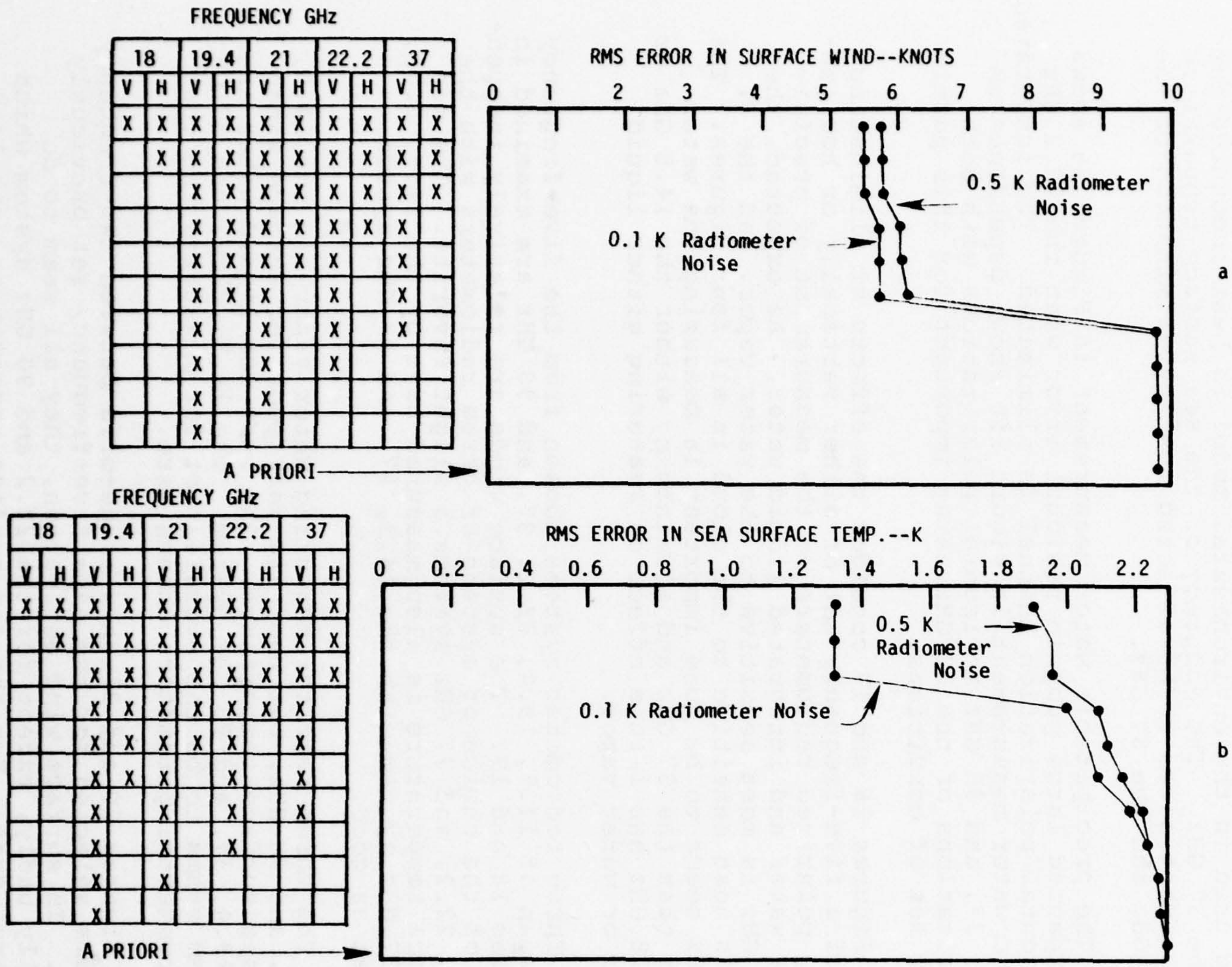


Fig. 13 — Error in measuring surface wind speed and sea surface temperature as a function of radiometric systems

Figures 14 and 15 show the effects of eliminating each of the radiometers from a five-frequency strawman system of 14.5, 18, 22.2, 37 and 90 GHz. For this system, the 37 GHz appears to affect the accuracy of the surface wind measurement more than the other frequencies; probably because the 18 and 14.5 measure nearly the same parameters and the large cloud used in the environmental model is best accounted for by the 37 GHz. The accuracy of the sea surface temperature measurement seems to be affected most by elimination of the 14.5 GHz and the 37 GHz.

The precipitable water measurement in Figure 15a shows an expected large jump in residual error when the 22.2 GHz horizontal polarization channel is eliminated. The integrated liquid water measurement in Figure 15b shows dependence on 22.2, 37, and 90 GHz horizontal polarizations with both polarizations of the 37 GHz being important for this particular set of conditions.

Figures 16 and 17 consider the effects of eliminating one of a five-frequency set of either vertically or horizontally polarized radiometers on the measurement of precipitable water and integrated liquid water. As expected, the 22.2 GHz is most sensitive to the water vapor, and the 37 GHz is most sensitive to the cloud in all four figures. The 90 GHz seems to be more important in measuring the water vapor than the 37 GHz and eliminating either the 14.5 GHz or the 18 GHz has little effect on measuring either liquid water or water vapor.

Three radiometer systems chosen from the five-frequency strawman of 14.5, 19.4, 22.2, 37, and 90 GHz are examined in Figures 18 and 19. The surface winds are relatively independent of the choice of systems of three radiometers with the 14.5, 22.2, and 37 GHz systems a slight favorite. The sea surface temperature is also measured best by the 14.5, 22.2, and 37 GHz system with the 14.5, 37, and 90 GHz system almost as good.

The three best for measuring water vapor are the 14.5, 22.2, and 90 GHz, but they are very poor for surface winds and sea surface temperature. The best for liquid water are the 19.4, 37, and 90 Ghz system. The 14.5, 22.2, and 37 GHz system seems to be the overall best for measuring the four environmental parameters chosen here.

Figures 20 and 21 show trade-offs between two-frequency systems selected for the same five-frequency set previously used. In surface wind estimation, they all seem to do equally badly, except for the 22.2 and 90 GHz system which appears worst. For the sea surface temperature, the 14.5

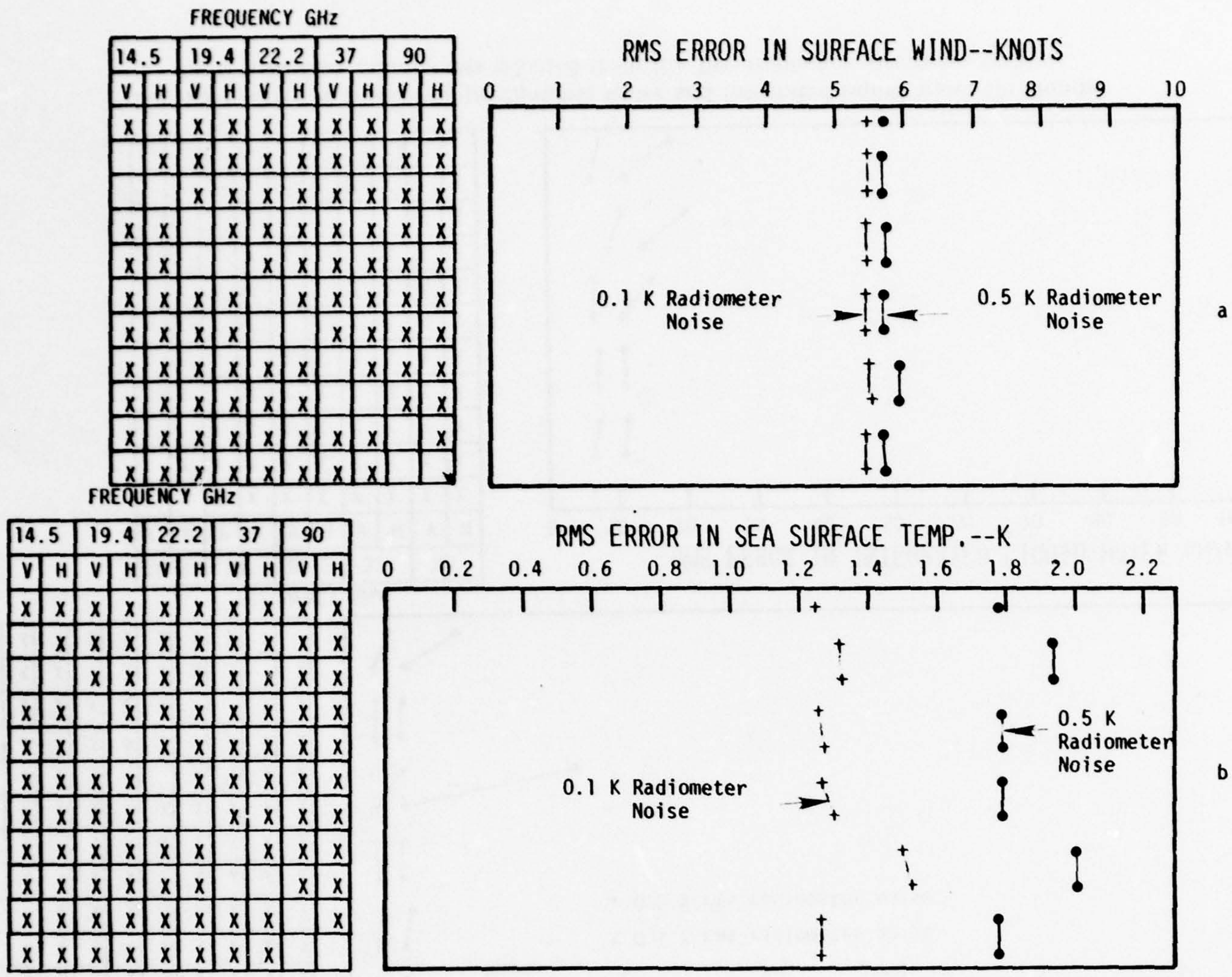
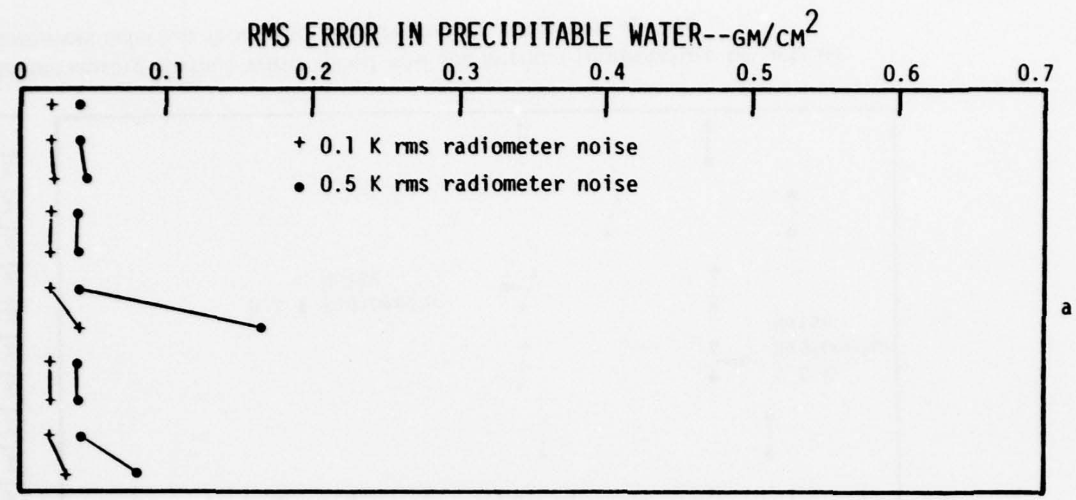


Fig. 14 — Error in measuring surface wind speed and sea surface temperature by sets of four radiometers selected from the five frequency strawman system

FREQUENCY GHz

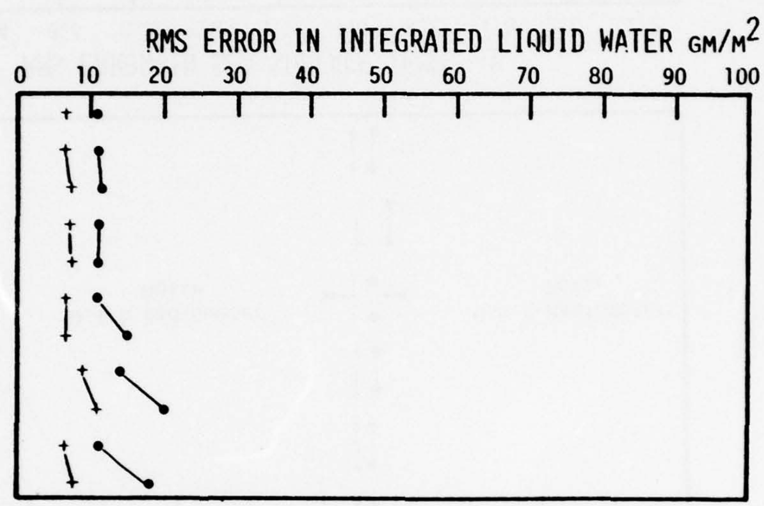
14.5		18		22.2		37		90	
H	V	H	V	H	V	H	V	H	V
X	X	X	X	X	X	X	X	X	X
	X	X	X	X	X	X	X	X	X
		X	X	X	X	X	X	X	X
X	X		X	X	X	X	X	X	X
X	X			X	X	X	X	X	X
X	X	X	X		X	X	X	X	X
X	X	X	X			X	X	X	X
X	X	X	X	X	X		X	X	X
X	X	X	X	X	X			X	X
X	X	X	X	X	X	X	X		X
X	X	X	X	X	X	X	X		



a

FREQUENCY GHz

14.5		18		22.2		37		90	
V	H	V	H	V	H	V	H	V	H
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	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	X	X	X	X	X	X		X
X	X	X	X	X	X	X	X		

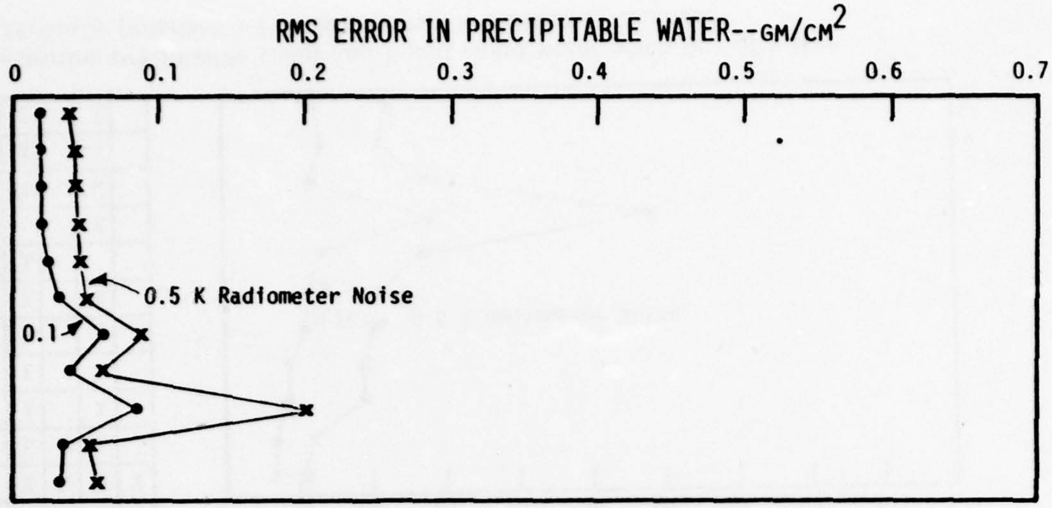


b

Fig. 15 — Error in measuring precipitable water and integrated liquid water (in clouds) by sets of four radiometers selected from the five frequency strawman system

FREQUENCY GHz

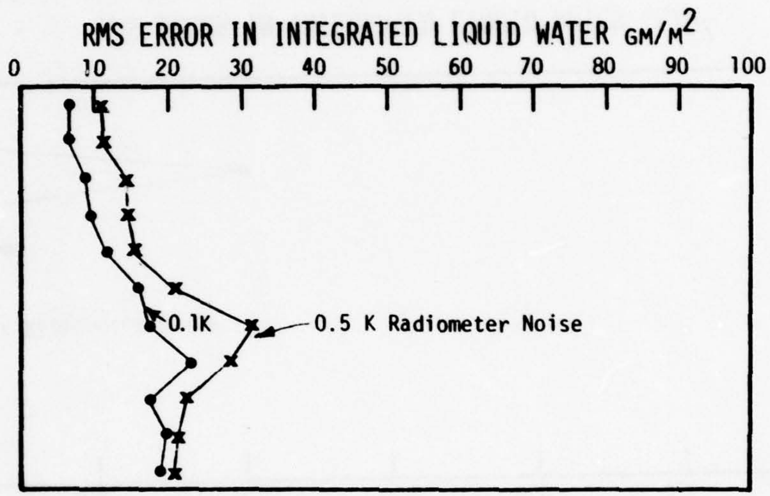
14.5		18		22.2		37		90	
V	H	V	H	V	H	V	H	V	H
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X		X
X	X	X	X	X	X		X		X
X	X	X	X		X		X		X
X	X		X		X		X		X
	X		X		X		X		X
	X		X		X		X		
	X		X		X				X
	X		X				X		X
	X				X		X		X
			X		X		X		X



a

FREQUENCY GHz

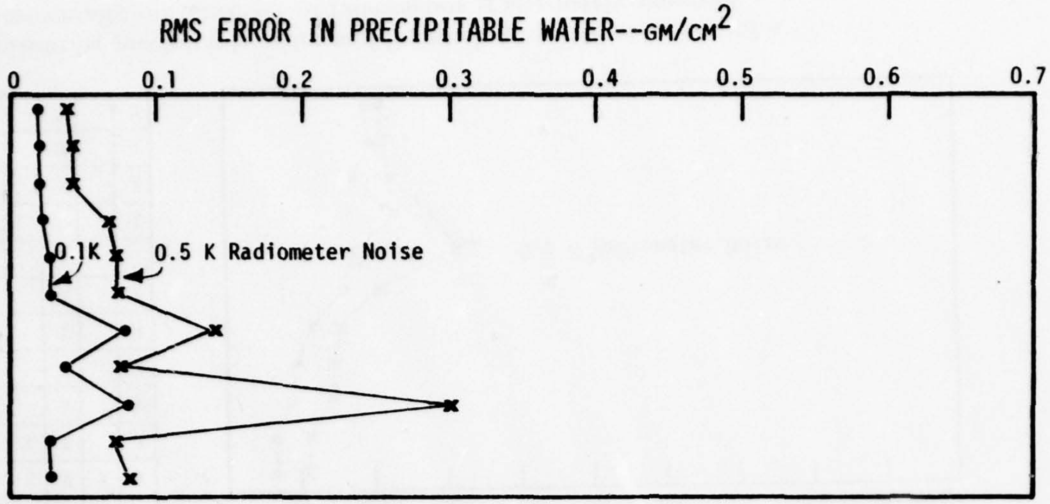
14.5		18		22.2		37		90	
V	H	V	H	V	H	V	H	V	H
X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X		X
X	X	X	X	X	X		X		X
X	X	X	X		X		X		X
X	X		X		X		X		X
	X		X		X		X		X
	X		X		X		X		
	X		X		X				X
	X		X				X		X
	X				X		X		X
			X		X		X		X



b

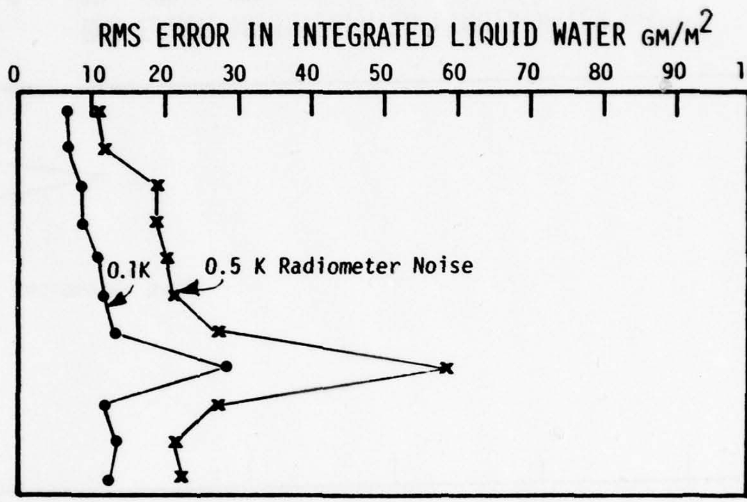
Fig. 16 — Error in measuring precipitable water and liquid cloud water when one of a five-frequency horizontally polarized set of radiometers is alternately removed

FREQUENCY GHz 14.5		18		22.2		37		90	
V	H	V	H	V	H	V	H	V	H
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	
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	



a

FREQUENCY GHz 14.5		18		22.2		37		90	
V	H	V	H	V	H	V	H	V	H
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	
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	



b

Fig. 17 — Error in measuring precipitable water and liquid cloud water when one of a five-frequency vertically polarized set of radiometers is alternately removed

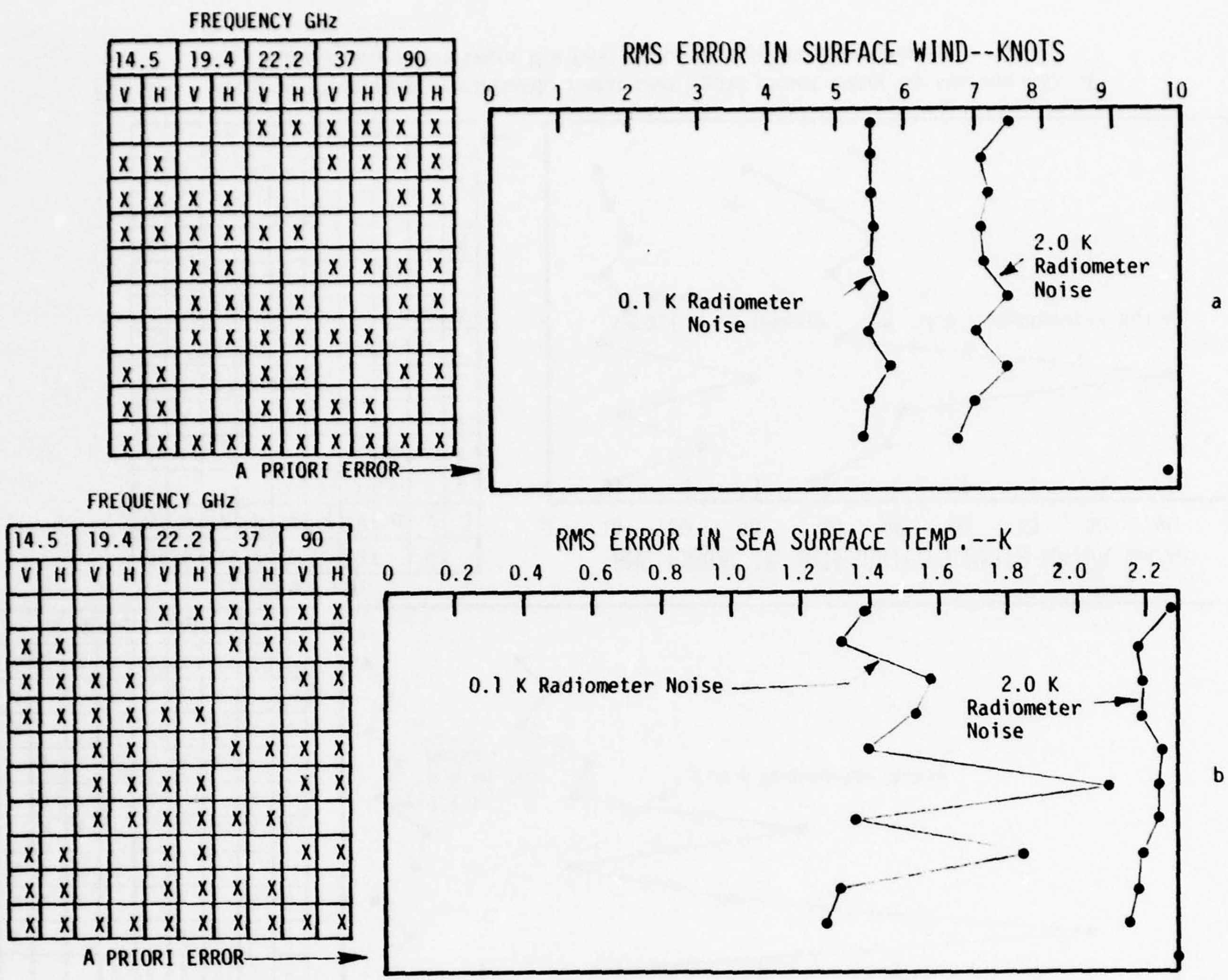
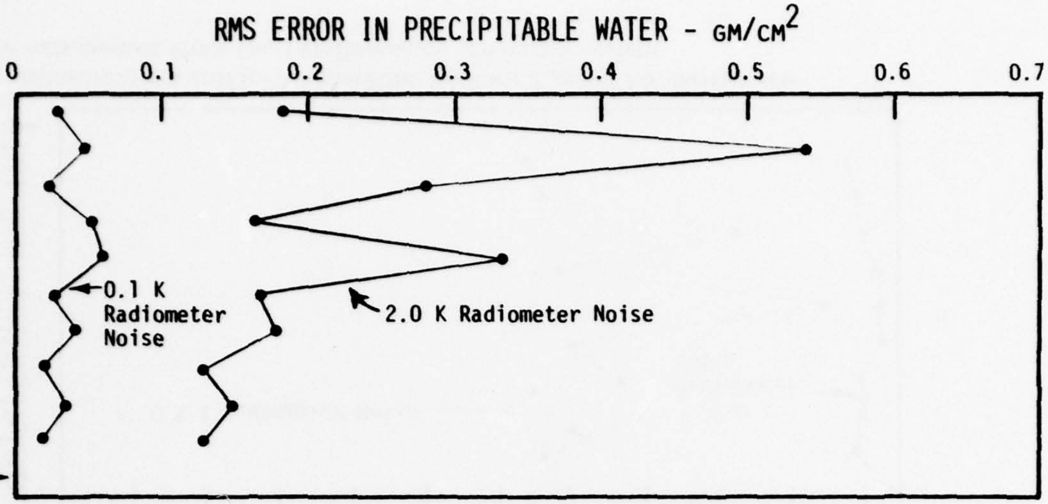


Fig. 18 — Error in measuring sea surface temperature and wind speed by various sets of three radiometers from the five-frequency strawman system

FREQUENCY GHz

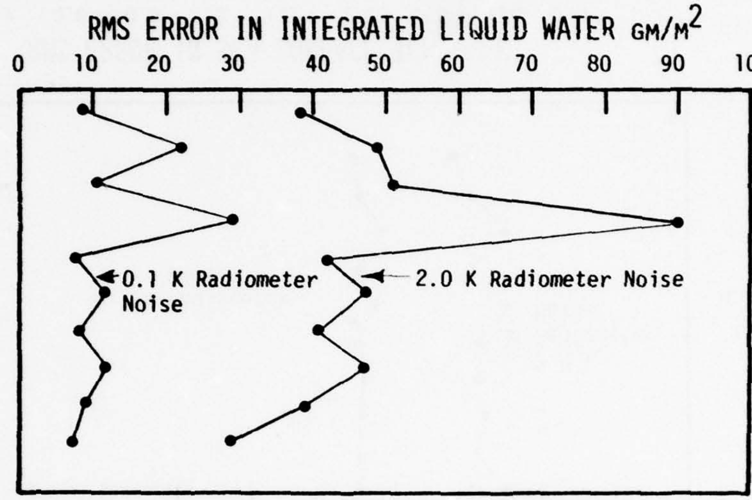
14.5		19.4		22.2		37		90	
V	H	V	H	V	H	V	H	V	H
				X	X	X	X	X	X
X	X					X	X	X	X
X	X	X	X					X	X
X	X	X	X	X	X				
		X	X			X	X	X	X
		X	X	X	X			X	X
		X	X	X	X	X	X		
X	X			X	X			X	X
X	X			X	X	X	X		
X	X	X	X	X	X	X	X	X	X
A PRIORI ERROR →									



a

FREQUENCY GHz

14.5		19.4		22.2		37		90	
V	H	V	H	V	H	V	H	V	H
				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	X	X		
X	X			X	X			X	X
X	X			X	X	X	X		
X	X	X	X	X	X	X	X	X	X
A PRIORI ERROR →									



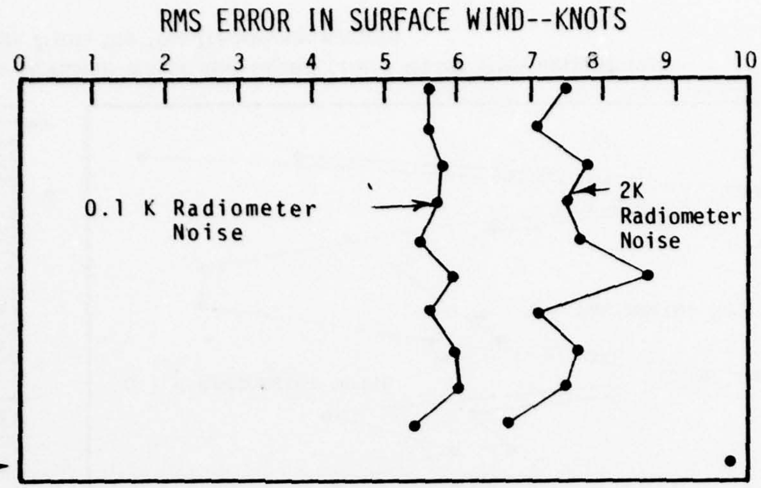
b

Fig. 19 — Error in measuring precipitable water and liquid cloud water by various sets of three radiometers from the five-frequency strawman system

FREQUENCY GHz

14.5		19.4		22.2		37		90	
V	H	V	H	V	H	V	H	V	H
				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				
X	X	X	X	X	X	X	X	X	X

A PRIORI ERROR ——→

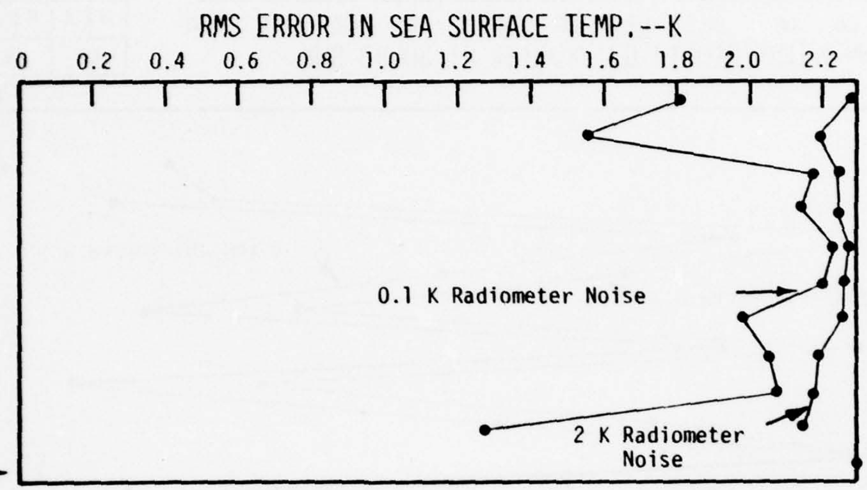


a

FREQUENCY GHz

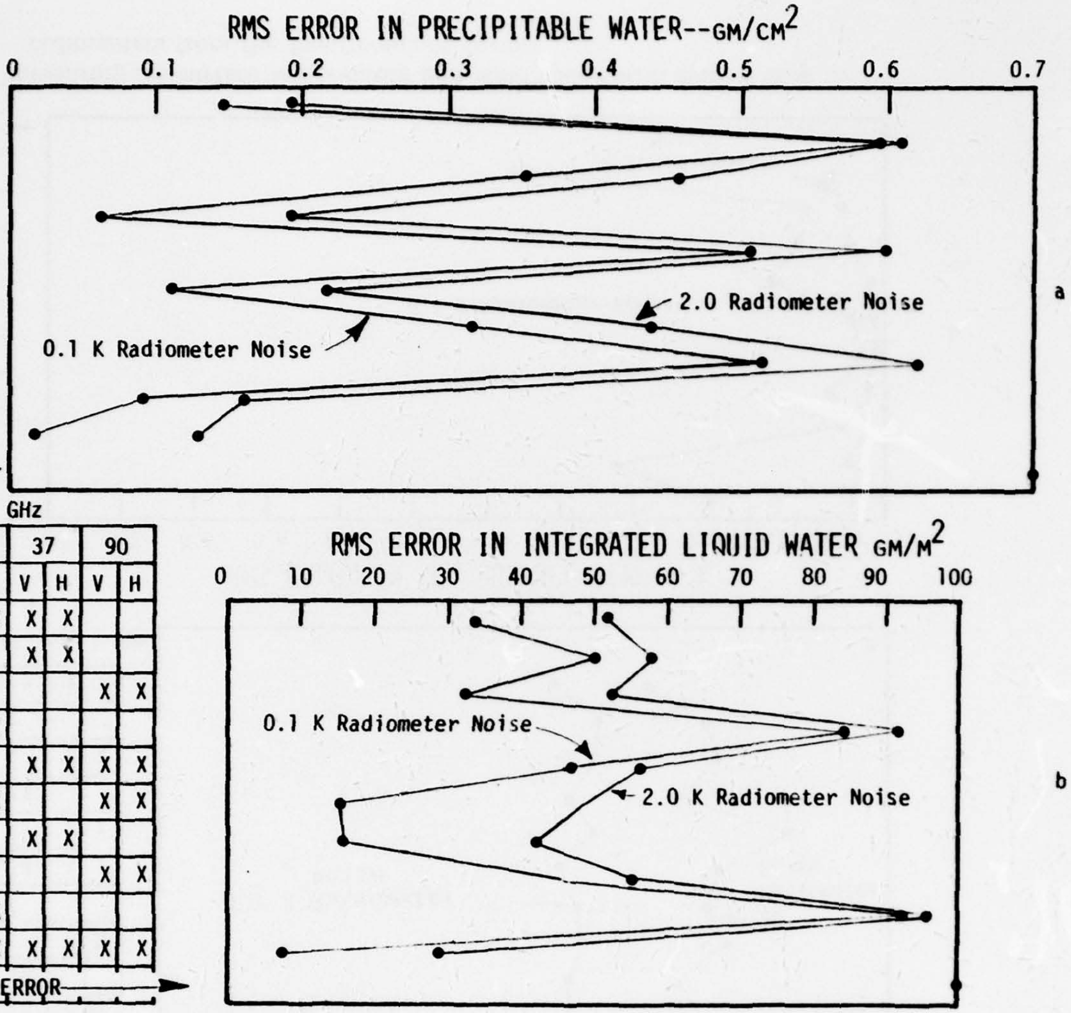
14.5		19.4		22.2		37		90	
V	H	V	H	V	H	V	H	V	H
				X	X	X	X		
X	X					X	X		
		X	X					X	X
		X	X	X	X				
						X	X	X	X
				X	X			X	X
		X	X			X	X		
X	X							X	X
X	X		X	X					
X	X	X	X	X	X	X	X	X	X

A PRIORI ERROR ——→



b

Fig. 20 — Error in measuring sea surface temperature and wind speed with sets of two radiometers from the five-frequency system



14.5		19.4		22.2		37		90	
V	H	V	H	V	H	V	H	V	V
				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	X	X	X	X	X	X
A PRIORI ERROR									

14.5		19.4		22.2		37		90	
V	H	V	H	V	H	V	H	V	H
				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	X	X	X	X	X	X
A PRIORI ERROR									

Fig. 21 — Error in measuring precipitable water and liquid cloud water with sets of two radiometers from the five-frequency system

and 37 GHz system is clearly the best, but also one of the worst for precipitable water and liquid water. Conversely, the 22.2 and 90 GHz system appears best for the precipitable water and liquid water estimates.

ENVIRONMENTAL STATISTICS

The following printout give the covariance and the correlation matrices along with the mean and standard deviations of each environmental parameter.

REFERENCES

1. Hollinger, J.P., Kenney, J.E., and Troy, B.E., "A Versatile Millimeter-Wave Imaging System," IEEE Transactions on Microwave Theory and Techniques, MTT-24, pg 786-793, November 1976.

2. Wisler, M.M. and Hollinger, J.P., "Estimation of Marine Environmental Parameters Using Microwave Radiometric Sensing Systems," NRL Memorandum Report 3661, November 1977.

3. Savage, R.C., "The Transfer of Thermal Microwaves Through Hydrometeors," Thesis, University of Wisconsin, 1976.

4. Hollinger, J.P., "Passive Microwave Measurements of Sea Surface Roughness," IEEE Transactions on Geoscience Electronics, Vol. GE-9, pg 165-169, July 1971.

JAN MEYEN

	DEG MIN	
LATITUDE	70 57 N	WINTER, 1972
LONGITUDE	08 40 W	77 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	-3.519	5.418
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-5.851	.6915
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	.6217	.2859
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	3.394	1.292
X5	SURFACE AIR PRESSURE (MILLIBARS)	1009.2	11.93
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.4365E-01	.5685E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.1147	.1982
X8	SURFACE WIND SPEED (METERS/SECOND)	6.519	4.077
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	.1989	.2030

COVARIANCE MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
29.36	-2.889	1.006	6.568	-5.031	-.7095E-01	-.3502E-01	-3.437	-.1650	X1
	.4781	-.7154E-01	-.6495	1.004	.5983E-02	.8571E-02	.1856	.1730E-01	X2
		.8172E-01	.2559	-.2377	-.2069E-02	.1629E-01	-.2219	-.4795E-02	X3
			1.669	-1.355	-.1216E-01	.1816E-01	-1.106	-.5288E-01	X4
				142.4	-.1343	-.5436	-11.15	-.5941E-01	X5
					.3232E-02	.5598E-02	.4841E-01	.3229E-02	X6
						.3930E-01	.2624E-01	.4436E-02	X7
							16.62	.2309	X8
								.4121E-01	X9

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SAN FRANCISCO, CA.

JAN MEYEN

	DEG MIN	
LATITUDE	70 57 N	SPRING, 1972
LONGITUDE	08 40 W	99 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	-.1717	3.531
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-5.447	.4545
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	.8677	.3935
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	4.075	1.103
X5	SURFACE AIR PRESSURE (MILLIBARS)	1013.4	11.64
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.2183E-01	.3357E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.5892E-01	.1459
X8	SURFACE WIND SPEED (METERS/SECOND)	4.939	4.589
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	1.345	.7783

COVARIANCE MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
12.47	-.5795	.9748	3.448	-3.216	-.3643E-01	.2808E-01	-7.021	1.570	X1
	.2065	-.1571E-01	-.1267	.7221	.4709E-03	-.1092E-01	.4955	-.1392E-01	X2
		.1549	.3498	-.7219	-.2480E-02	.7429E-02	-.3896	.2125	X3
			1.216	-2.344	-.9065E-02	.2876E-01	-1.807	.5540	X4
				135.4	-.1018	-.5978	-18.45	-2.261	X5
					.1127E-02	.1529E-02	.6458E-01	-.3531E-02	X6
						.2129E-01	.4783E-01	.1735E-01	X7
							21.06	-.2622	X8
								.6058	X9

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SAN FRANCISCO, CA.

JAN MEYEN

	DEG MIN
LATITUDE	70 57 N
LONGITUDE	08 40 W

SUMMER, 1972

82 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	4.159	2.070
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-5.572	.4876
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	1.352	.5441
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	5.530	1.057
X5	SURFACE AIR PRESSURE (MILLIBARS)	1011.7	6.171
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.3176E-01	.5214E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.9248E-01	.1667
X8	SURFACE WIND SPEED (METERS/SECOND)	4.768	3.080
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	5.349	.5953

COVARIANCE MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
4.283	-.1846	.7564	1.937	-2.192	-.1584E-01	.4483E-01	.8657E-01	-.4091	X1
	.2377	.4988E-01	-.8551E-01	1.517	-.2883E-02	.5664E-02	-.2722	-.3606E-01	X2
		.2960	.4080	-.6322	.2032E-03	.2923E-01	-.2628	-.1680	X3
			1.116	-1.906	-.3263E-02	.5334E-01	-.1774	-.1627	X4
				38.08	-.5048E-01	-.2274	-1.111	-.7419	X5
					.2718E-02	.2835E-02	.4367E-01	.1102E-02	X6
						.2778E-01	-.4027E-02	.3633E-02	X7
							9.489	.2879	X8
								.3543	X9

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SAN FRANCISCO, CA.

JAN MEYEN

	DEG MIN	
LATITUDE	70 57 N	AUTUMN, 1972
LONGITUDE	08 40 W	68 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	-1.309	2.944
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-5.763	.7759
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	.7203	.3253
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	3.541	1.129
X5	SURFACE AIR PRESSURE (MILLIBARS)	1001.9	13.12
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.7291E-01	.7351E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.1752	.3082
X8	SURFACE WIND SPEED (METERS/SECOND)	7.765	3.469
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	2.895	1.267

COVARIANCE MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
8.664	-.3785	.6971	2.954	-10.18	-.1153E-01	.2353	3.105	1.224	X1
	.6021	.1388E-02	-.1982	2.895	-.7185E-02	.9737E-02	-.4323	.4432	X2
		.1058	.3056	-1.379	.1152E-02	.5679E-01	.3657	.7980E-01	X3
			1.275	-6.655	.1155E-01	.1496	1.370	.2422	X4
				172.1	-.1713	-1.094	-13.90	5.788	X5
					.5404E-02	.9934E-02	.7080E-01	-.2045E-02	X6
						.9497E-01	.2844	.5156E-02	X7
							12.03	.5015	X8
								1.604	X9

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SAN FRANCISCO, CA.

AZORES

	DEG MIN	
LATITUDE	38 44 N	WINTER, 1972
LONGITUDE	27 05 W	54 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	12.91	2.357
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-6.403	.3822
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	1.372	.4332
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	8.405	1.727
X5	SURFACE AIR PRESSURE (MILLIBARS)	1024.3	8.138
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.4016E-01	.3373E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.2701	1.157
X8	SURFACE WIND SPEED (METERS/SECOND)	5.259	3.410
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	15.51	.3403

COVARIANCE MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
5.557	-.1951E-01	.4525	2.994	-.1346	-.3371E-02	.1780	1.515	.1810	X1
	.1460	.1812E-01	-.1308E-02	-.1334	.2287E-02	-.2378E-01	.1049	-.1937E-01	X2
		.1877	.4542	-.6352	-.1375E-02	-.6994E-02	.5681E-01	.3980E-01	X3
			2.982	-.9073	.3305E-02	.4654	.2721E-01	.2928E-01	X4
				66.22	-.5411E-01	-1.890	-10.11	-.3978	X5
					.1138E-02	.2300E-01	.7268E-01	-.2291E-02	X6
						1.338	1.254	-.2160E-01	X7
							11.63	-.1864	X8
								.1158	X9

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AZORES

	DEG MIN	
LATITUDE	38 44 N	SPRING, 1972
LONGITUDE	27 05 W	74 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	17.88	2.745
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-6.298	.3419
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	1.876	.5523
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	11.74	2.030
X5	SURFACE AIR PRESSURE (MILLIBARS)	1028.1	4.226
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.3414E-01	.2499E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.1914E-01	.7107E-01
X8	SURFACE WIND SPEED (METERS/SECOND)	3.757	2.163
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	17.63	1.493

COVARIANCE MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
7.533	.1973E-01	.3515	3.834	.8295	.3925E-02	.1263E-01	2.011	2.904	X1
	.1169	.5686E-01	.1318	.3715	.1379E-03	.2130E-02	-.8458E-01	.1235	X2
		.3050	.7581	-.1542E-01	.2888E-02	.8738E-02	-.8841E-01	.4537	X3
			4.121	.9949	.1020E-01	.3784E-01	.3883	2.131	X4
				17.86	-.2007E-01	-.6994E-01	-3.877	1.598	X5
					.6245E-03	.8612E-03	.1479E-02	.6065E-02	X6
						.5051E-02	-.9873E-03	.1077E-01	X7
							4.680	-.2289E-04	X8
								2.228	X9

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AZORES

	DEG MIN	
LATITUDE	38 44 N	SUMMER, 1972
LONGITUDE	27 05 W	71 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	22.80	2.561
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-6.271	.3388
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	2.577	.5283
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	14.90	2.070
X5	SURFACE AIR PRESSURE (MILLIBARS)	1024.0	4.943
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.3318E-01	.2650E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.4695E-01	.1080
X8	SURFACE WIND SPEED (METERS/SECOND)	3.549	2.103
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	21.99	.7615

COVARIANCE MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
6.561	-.1824	.1696	2.893	.6008E-01	.3586E-02	.3201E-01	2.567	-.2427	X1
	.1148	.1386E-01	-.5542E-01	.5615	-.5497E-03	.7069E-02	-.3446E-01	.1796E-01	X2
		.2791	.6006	.3534E-01	.2244E-02	.9939E-02	-.2362	.5055E-01	X3
			4.283	-.4842	.1182E-01	.9440E-01	.2917	-.1105	X4
				24.43	.4361E-02	.2056E-02	-.1449E-02	-.8741	X5
					.7023E-03	.1464E-02	.1820E-01	.4890E-03	X6
						.1165E-01	.4646E-01	.8245E-02	X7
							4.423	-.7439E-01	X8
								.5799	X9

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AZORES

	DEG MIN
LATITUDE	38 44 N
LONGITUDE	27 05 W

AUTUMN, 1972

52 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	17.37	1.657
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-6.197	.4859
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	2.045	.5393
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	10.98	1.951
X5	SURFACE AIR PRESSURE (MILLIBARS)	1022.5	5.837
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.4895E-01	.4091E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.2131	.7014
X8	SURFACE WIND SPEED (METERS/SECOND)	4.731	3.056
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	18.99	1.385

COVARIANCE MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
2.746	-.3163	.2680	1.951	-5.204	.7961E-02	.1395	2.296	.9956	X1
	.2361	-.4253E-01	-.2731	.9673	-.1489E-02	.1147E-02	-.2389	-.1518	X2
		.2908	.7718	-.8790	.9009E-02	.1829	.3414	-.9885E-01	X3
			3.808	-4.863	.3670E-01	.6547	1.127	-.2807E-01	X4
				34.07	-.6212E-01	-1.024	-9.828	-2.455	X5
					.1674E-02	.2371E-01	.3113E-01	.1099E-02	X6
						.4919	.1141	-.4343E-01	X7
							9.338	1.938	X8
								1.917	X9

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TRUK

	DEG MIN	
LATITUDE	07 28 N	WINTER, 1972
LONGITUDE	151 51 E	54 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	27.72	1.446
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-5.878	.2214
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	3.836	.9616
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	20.99	1.155
X5	SURFACE AIR PRESSURE (MILLIBARS)	1009.5	2.093
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.5232E-01	.4871E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.7006	1.747
X8	SURFACE WIND SPEED (METERS/SECOND)	5.333	1.737
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	28.22	.2127

COVARIANCE MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
2.091	-.1264	-.5862	.2461	.7825	-.2466E-01	-.5218	.8679	-.5678E-01	X1
	.4901E-01	.7119E-01	.5558E-01	-.1901	.3979E-02	.1295	-.9814E-01	.6657E-02	X2
		.9247	.6388	-.4004E-01	.2335E-01	.8627	-.3863	-.3743E-01	X3
			1.333	.2725	.1212E-01	.9283	-.6888E-01	-.5801E-01	X4
				4.380	-.5071E-02	-.1011	1.038	-.2907	X5
					.2372E-02	.5587E-01	-.1586E-01	.3512E-03	X6
						3.052	-.4644	-.3441E-02	X7
							3.019	-.1260	X8
								.4526E-01	X9

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TRUK

	DEG MIN	
LATITUDE	07 28 N	SPRING, 1972
LONGITUDE	151 51 E	65 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	27.85	1.372
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-5.838	.2094
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	4.929	.9032
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	22.22	1.227
X5	SURFACE AIR PRESSURE (MILLIBARS)	1010.1	2.161
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.7082E-01	.8316E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.9397	1.802
X8	SURFACE WIND SPEED (METERS/SECOND)	4.892	2.405
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	28.48	.2628

COVARIANCE MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
1.882	-.1342	-.5637	.5956	-.5417	-.3807E-01	-.5172	-.1683E-01	-.2991E-03	X1
	.4387E-01	.9754E-01	.5765E-02	-.6420E-02	-.3033E-03	-.1847E-01	.3764E-01	.1316E-01	X2
		.8158	.1526	-.1126	.4415E-02	.6204E-01	-.2608	.1203	X3
			1.507	-1.007	.3394E-02	.3756	.1649	.6117E-01	X4
				4.672	.2308E-01	-.1089	-.8153	-.1282	X5
					.6915E-02	.1059	.5714E-01	-.1083E-02	X6
						3.247	1.432	-.3638E-01	X7
							5.785	-.1894	X8
								.6908E-01	X9

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TRUK

	DEG MIN	
LATITUDE	C7 28 N	SUMMER, 1972
LONGITUDE	151 51 E	105 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	27.45	1.286
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-5.778	.2160
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	5.558	.5065
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	22.52	.9349
X5	SURFACE AIR PRESSURE (MILLIBARS)	1009.9	1.185
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.7384E-01	.7661E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	1.365	2.042
X8	SURFACE WIND SPEED (METERS/SECOND)	5.743	4.341
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	28.95	.8222E-01

COVARIANCE MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
1.653	-.1911	-.2056	.5673	.9271E-01	-.2285E-01	-.8717	1.030	.1500E-01	X1
	.4666E-01	.4532E-01	-.4804E-01	-.4614E-01	.1473E-02	.9427E-01	-.9479E-01	-.3840E-03	X2
		.2565	.2188E-03	-.2252	.4037E-02	.1904	-.3788	-.1092E-02	X3
			.8740	-.2331	-.2388E-02	-.3100	.1690	.2868E-01	X4
				1.405	-.1136E-03	-.1409	.1174	-.2260E-01	X5
					.5868E-02	.1263	.2079E-02	.8465E-03	X6
						4.168	.6754E-01	.1308E-01	X7
							18.85	.8091E-01	X8
								.6759E-02	X9

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TRUK

	DEG MIN	
LATITUDE	07 28 N	AUTUMN, 1972
LONGITUDE	151 51 E	84 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	28.10	1.402
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-5.864	.2341
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	4.938	.7200
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	22.62	1.161
X5	SURFACE AIR PRESSURE (MILLIBARS)	1010.7	1.494
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.5240E-01	.3722E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.7560	1.762
X8	SURFACE WIND SPEED (METERS/SECOND)	4.429	2.180
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	29.23	.2576

COVARIANCE MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
1.967	-.1699	-.2654	.5918	.2050	-.2533E-02	-.1150	1.007	.9249E-01	X1
	.5482E-01	.3478E-01	-.2593E-01	-.8193E-01	.1848E-02	.7545E-01	-.1064	-.2059E-02	X2
		.5184	.2310	-.1598	.8613E-02	.5047	.2070	-.1153E-01	X3
			1.348	-.1924	.5105E-02	.1533	.5443	-.5020E-01	X4
				2.233	-.1027E-01	-.3233	-.6351	-.4947E-01	X5
					.1385E-02	.4161E-01	.1482E-01	-.4038E-03	X6
						3.103	.1380	.1653E-01	X7
							4.754	-.8190E-01	X8
								.6635E-01	X9

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JAN MEYEN

	DEG MIN	
LATITUDE	70 57 N	WINTER, 1972
LONGITUDE	08 40 W	77 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	-3.519	5.418
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-5.851	.6915
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	.6217	.2859
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	3.394	1.292
X5	SURFACE AIR PRESSURE (MILLIBARS)	1009.2	11.93
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.4365E-01	.5685E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.1147	.1982
X8	SURFACE WIND SPEED (METERS/SECOND)	6.519	4.077
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	.1989	.2030

CORRELATION MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
1.000	-.7710	.6494	.9384	-.7780E-01	-.2303	-.3260E-01	-.1556	-.1500	X1
	1.000	-.3619	-.7271	.1217	.1522	.6253E-01	.6584E-01	.1233	X2
		1.000	.6930	-.6969E-01	-.1273	.2875	-.1904	-.8264E-01	X3
			1.000	-.8788E-01	-.1656	.7092E-01	-.2100	-.2016	X4
				1.000	-.1980	-.2319	-.2291	-.2452E-01	X5
					1.000	.4967	.2089	.2798	X6
						1.000	.3247E-01	.1102	X7
							1.000	.2791	X8
								1.000	X9

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JAN MEYEN

	DEG MIN	
LATITUDE	70 57 N	SPRING, 1972
LONGITUDE	08 40 W	99 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	-.1717	3.531
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-5.447	.4545
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	.8677	.3935
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	4.075	1.103
X5	SURFACE AIR PRESSURE (MILLIBARS)	1013.4	11.64
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.2183E-01	.3357E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.5892E-01	.1459
X8	SURFACE WIND SPEED (METERS/SECOND)	4.939	4.589
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	1.345	.7783

CORRELATION MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
1.000	-.3611	.7014	.9852	-.7826E-01	-.3073	.5449E-01	-.4333	.5712	X1
	1.000	-.8783E-01	-.2527	.1365	.3087E-01	-.1647	.2376	-.3934E-01	X2
		1.000	.8060	-.1577	-.1877	.1294	-.2157	.6936	X3
			1.000	-.1827	-.2449	.1787	-.3571	.6454	X4
				1.000	-.2606	-.3521	-.3455	-.2497	X5
					1.000	.3122	.4219	-.1352	X6
						1.000	.7142E-01	.1528	X7
							1.000	-.7341E-01	X8
								1.000	X9

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JAN MEYEN

	DEG MIN	
LATITUDE	70 57 N	SUMMER, 1972
LONGITUDE	C8 40 W	82 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	4.159	2.070
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-5.572	.4876
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	1.352	.5441
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	5.530	1.057
X5	SURFACE AIR PRESSURE (MILLIBARS)	1011.7	6.171
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.3176E-01	.5214E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.9248E-01	.1667
X8	SURFACE WIND SPEED (METERS/SECOND)	4.768	3.080
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	5.349	.5953

CORRELATION MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
1.000	-.1829	.6717	.8860	-.1717	-.1468	.1300	.1358E-01	-.3321	X1
	1.000	.1880	-.1660	.5043	-.1134	.6970E-01	-.1812	-.1242	X2
		1.000	.7098	-.1883	.7163E-02	.3223	-.1568	-.5187	X3
			1.000	-.2923	-.5924E-01	.3029	-.5450E-01	-.2587	X4
				1.000	-.1569	-.2211	-.5843E-01	-.2020	X5
					1.000	.3263	.2719	.3550E-01	X6
						1.000	-.7844E-02	.3662E-01	X7
							1.000	.1570	X8
								1.000	X9

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JAN MEYEN

	DEG MIN
LATITUDE	70 57 N
LONGITUDE	08 40 W

AUTUMN, 1972

68 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	-1.309	2.944
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-5.763	.7759
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	.7203	.3253
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	3.541	1.129
X5	SURFACE AIR PRESSURE (MILLIBARS)	1001.9	13.12
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.7291E-01	.7351E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.1752	.3082
X8	SURFACE WIND SPEED (METERS/SECOND)	7.765	3.469
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	2.895	1.267

CORRELATION MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
1.000	-.1657	.7281	.8889	-.2638	-.5329E-01	.2594	.3041	.3283	X1
	1.000	.5498E-02	-.2262	.2845	-.1260	.4072E-01	-.1606	.4509	X2
		1.000	.8321	-.3232	.4816E-01	.5665	.3241	.1937	X3
			1.000	-.4494	.1392	.4300	.3499	.1694	X4
				1.000	-.1777	-.2706	-.3055	.3483	X5
					1.000	.4385	.2776	-.2196E-01	X6
						1.000	.2660	.1321E-01	X7
							1.000	.1141	X8
								1.000	X9

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AZORES

	DEG MIN	
LATITUDE	38 44 N	WINTER, 1972
LONGITUDE	27 05 W	54 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	12.91	2.357
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-6.403	.3822
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	1.372	.4332
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	8.405	1.727
X5	SURFACE AIR PRESSURE (MILLIBARS)	1024.3	8.138
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.4016E-01	.3373E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.2701	1.157
X8	SURFACE WIND SPEED (METERS/SECOND)	5.259	3.410
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	15.51	.3403

CORRELATION MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
1.000	-.2166E-01	.4431	.7354	-.7018E-02	-.4238E-01	.6528E-01	.1885	.2256	X1
	1.000	.1094	-.1982E-02	-.4251E-01	.1774	-.5379E-01	.8052E-01	-.1490	X2
		1.000	.6071	-.1802	-.9407E-01	-.1396E-01	.3846E-01	.2699	X3
			1.000	-.6456E-01	.5673E-01	.2330	.4619E-02	.4981E-01	X4
				1.000	-.1971	-.2008	-.3642	-.1436	X5
					1.000	.5894	.6318	-.1996	X6
						1.000	.3180	-.5487E-01	X7
							1.000	-.1606	X8
								1.000	X9

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AZORES

	DEG MIN
LATITUDE	38 44 N
LONGITUDE	27 05 W

SPRING, 1972

74 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	17.88	2.745
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-6.298	.3419
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	1.876	.5523
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	11.74	2.030
X5	SURFACE AIR PRESSURE (MILLIBARS)	1028.1	4.226
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.3414E-01	.2499E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.1914E-01	.7107E-01
X8	SURFACE WIND SPEED (METERS/SECOND)	3.757	2.163
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	17.63	1.493

CORRELATION MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
1.000	.2103E-01	.2319	.6882	.7151E-01	.5723E-01	.6477E-01	.3387	.7089	X1
	1.000	.3012	.1899	.2571	.1615E-01	.8765E-01	-.1144	.2421	X2
		1.000	.6762	-.6606E-02	.2093	.2226	-.7400E-01	.5504	X3
			1.000	.1160	.2011	.2623	.8842E-01	.7033	X4
				1.000	-.1901	-.2329	-.4240	.2533	X5
					1.000	.4849	.2737E-01	.1626	X6
						1.000	-.6422E-02	.1015	X7
							1.000	-.7089E-05	X8
								1.000	X9

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AZORES

	DEG MIN	
LATITUDE	38 44 N	SUMMER, 1972
LONGITUDE	27 05 W	71 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	22.80	2.561
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-6.271	.3388
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	2.577	.5283
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	14.90	2.070
X5	SURFACE AIR PRESSURE (MILLIBARS)	1024.0	4.943
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.3318E-01	.2650E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.4695E-01	.1080
X8	SURFACE WIND SPEED (METERS/SECOND)	3.549	2.103
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	21.99	.7615

CORRELATION MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
1.000	-.2102	.1254	.5457	.4746E-02	.5283E-01	.1158	.4766	-.1244	X1
	1.000	.7744E-01	-.7903E-01	.3352	-.6121E-01	.1933	-.4836E-01	.6960E-01	X2
		1.000	.5493	.1353E-01	.1603	.1743	-.2126	.1267	X3
			1.000	-.4733E-01	.2155	.4225	.6703E-01	-.7010E-01	X4
				1.000	.3329E-01	.3853E-02	-.1354E-03	-.2322	X5
					1.000	.5118	.3266	.2423E-01	X6
						1.000	.2047	.1003	X7
							1.000	-.4645E-01	X8
								1.000	X9

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AZORES

	DEG MIN
LATITUDE	38 44 N
LONGITUDE	27 05 W

AUTUMN, 1972
52 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	17.37	1.657
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-6.197	.4859
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	2.045	.5393
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	10.98	1.951
X5	SURFACE AIR PRESSURE (MILLIBARS)	1022.5	5.837
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.4895E-01	.4091E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.2131	.7014
X8	SURFACE WIND SPEED (METERS/SECOND)	4.731	3.056
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	18.99	1.385

CORRELATION MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
1.000	-.3928	.2999	.6033	-.5380	.1174	.1201	.4535	.4339	X1
	1.000	-.1623	-.2880	.3481	-.7491E-01	.3366E-02	-.1609	-.2257	X2
		1.000	.7334	-.2793	.4084	.4836	.2072	-.1324	X3
			1.000	-.4270	.4597	.4784	.1891	-.1039E-01	X4
				1.000	-.2601	-.2501	-.5510	-.3038	X5
					1.000	.8262	.2490	.1940E-01	X6
						1.000	.5322E-01	-.4471E-01	X7
							1.000	.4579	X8
								1.000	X9

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TRUK

	DEG MIN	
LATITUDE	07 28 N	WINTER, 1972
LONGITUDE	151 51 E	54 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	27.72	1.446
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-5.878	.2214
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	3.836	.9616
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	20.99	1.155
X5	SURFACE AIR PRESSURE (MILLIBARS)	1009.5	2.093
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.5232E-01	.4871E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.7006	1.747
X8	SURFACE WIND SPEED (METERS/SECOND)	5.333	1.737
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	28.22	.2127

CORRELATION MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
1.000	-.3947	-.4216	.1474	.2585	-.3501	-.2066	.3454	-.1846	X1
	1.000	.3344	.2190	-.4103	.3690	.3347	-.2551	.1413	X2
		1.000	.5754	-.1989E-01	.4986	.5136	-.2312	-.1830	X3
			1.000	.1128	.2156	.4603	-.3434E-01	-.2362	X4
				1.000	-.4975E-01	-.2765E-01	.2655	-.6528	X5
					1.000	.6566	-.1875	.3389E-01	X6
						1.000	-.1530	-.9259E-02	X7
							1.000	-.3410	X8
								1.000	X9

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TRUK

	DEG MIN
LATITUDE	07 28 N
LONGITUDE	151 51 E

SPRING, 1972

65 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	27.85	1.372
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-5.838	.2094
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	4.929	.9032
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	22.22	1.227
X5	SURFACE AIR PRESSURE (MILLIBARS)	1010.1	2.161
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.7082E-01	.8316E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.9397	1.802
X8	SURFACE WIND SPEED (METERS/SECOND)	4.892	2.405
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	28.48	.2628

CORRELATION MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
1.000	-.4671	-.4549	.3478	-.1827	-.3337	-.2092	-.5099E-02	-.8294E-03	X1
	1.000	.5156	.2243E-01	-.1418E-01	-.1741E-01	-.4894E-01	.7473E-01	.2391	X2
		1.000	.1377	-.5767E-01	.5878E-01	.3812E-01	-.1200	.5069	X3
			1.000	-.3795	.3325E-01	.1698	.5586E-01	.1896	X4
				1.000	.1284	-.2797E-01	-.1568	-.2257	X5
					1.000	.7070	.2857	-.4957E-01	X6
						1.000	.3304	-.7681E-01	X7
							1.000	-.2996	X8
								1.000	X9

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TRUK

	DEG MIN	
LATITUDE	07 28 N	SUMMER, 1972
LONGITUDE	151 51 E	105 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	27.45	1.286
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-5.778	.2160
X3	COLUMNAR DENSITY OF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	5.558	.5065
X4	SURFACE ABSOLUTE HUMIDITY (GRAMS/CUBIC METER)	22.52	.9349
X5	SURFACE AIR PRESSURE (MILLIBARS)	1009.9	1.185
X6	COLUMNAR DENSITY OF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.7384E-01	.7661E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	1.365	2.042
X8	SURFACE WIND SPEED (METERS/SECOND)	5.743	4.341
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	28.95	.8222E-01

CORRELATION MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
1.000	-.6880	-.3157	.4719	.6084E-01	-.2320	-.3321	.1845	.1419	X1
	1.000	.4143	-.2379	-.1803	.8904E-01	.2138	-.1011	-.2162E-01	X2
		1.000	.4620E-03	-.3751	.1040	.1842	-.1723	-.2623E-01	X3
			1.000	-.2104	-.3334E-01	-.1624	.4164E-01	.3732	X4
				1.000	-.1251E-02	-.5826E-01	.2281E-01	-.2320	X5
					1.000	.8076	.6253E-02	.1344	X6
						1.000	.7620E-02	.7794E-01	X7
							1.000	.2267	X8
								1.000	X9

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TRUK

	DEG MIN
LATITUDE	C7 28 N
LONGITUDE	151 51 E

AUTUMN, 1972
84 OBSERVATIONS

VARIABLE	DESCRIPTION	MEAN	ST. DEV.
X1	SURFACE AIR TEMPERATURE (DEGREES CENTIGRADE)	28.10	1.402
X2	AIR TEMPERATURE VERTICAL LAPSE RATE (DEGREES CENTIGRADE/KILOMETER)	-5.864	.2341
X3	COLUMNAR DENSITY CF WATER VAPOR (GRAMS/SQUARE CENTIMETER)	4.938	.7200
X4	SURFACE ABSCLUTE HUMIDITY (GRAMS/CUBIC METER)	22.62	1.161
X5	SURFACE AIR PRESSURE (MILLIBARS)	1010.7	1.494
X6	COLUMNAR DENSITY CF LIQUID CLOUD WATER (GRAMS/SQUARE CENTIMETER)	.5240E-01	.3722E-01
X7	SURFACE RAIN RATE (MILLIMETERS/HOUR)	.7560	1.762
X8	SURFACE WIND SPEED (METERS/SECOND)	4.429	2.180
X9	SEA SURFACE WATER TEMPERATURE (DEGREES CENTIGRADE)	29.23	.2576

CORRELATION MATRIX

X1	X2	X3	X4	X5	X6	X7	X8	X9	
1.000	-.5175	-.2628	.3635	.9785E-01	-.4853E-01	-.4656E-01	.3293	.2560	X1
	1.000	.2063	-.9541E-01	-.2342	.2121	.1829	-.2085	-.3481E-01	X2
		1.000	.2763	-.1485	.3214	.3979	.1319	-.6218E-01	X3
			1.000	-.1109	.1181	.7494E-01	.2150	-.1679	X4
				1.000	-.1847	-.1228	-.1949	-.1285	X5
					1.000	.6346	.1827	-.4212E-01	X6
						1.000	.3592E-01	.3643E-01	X7
							1.000	-.1458	X8
								1.000	X9

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