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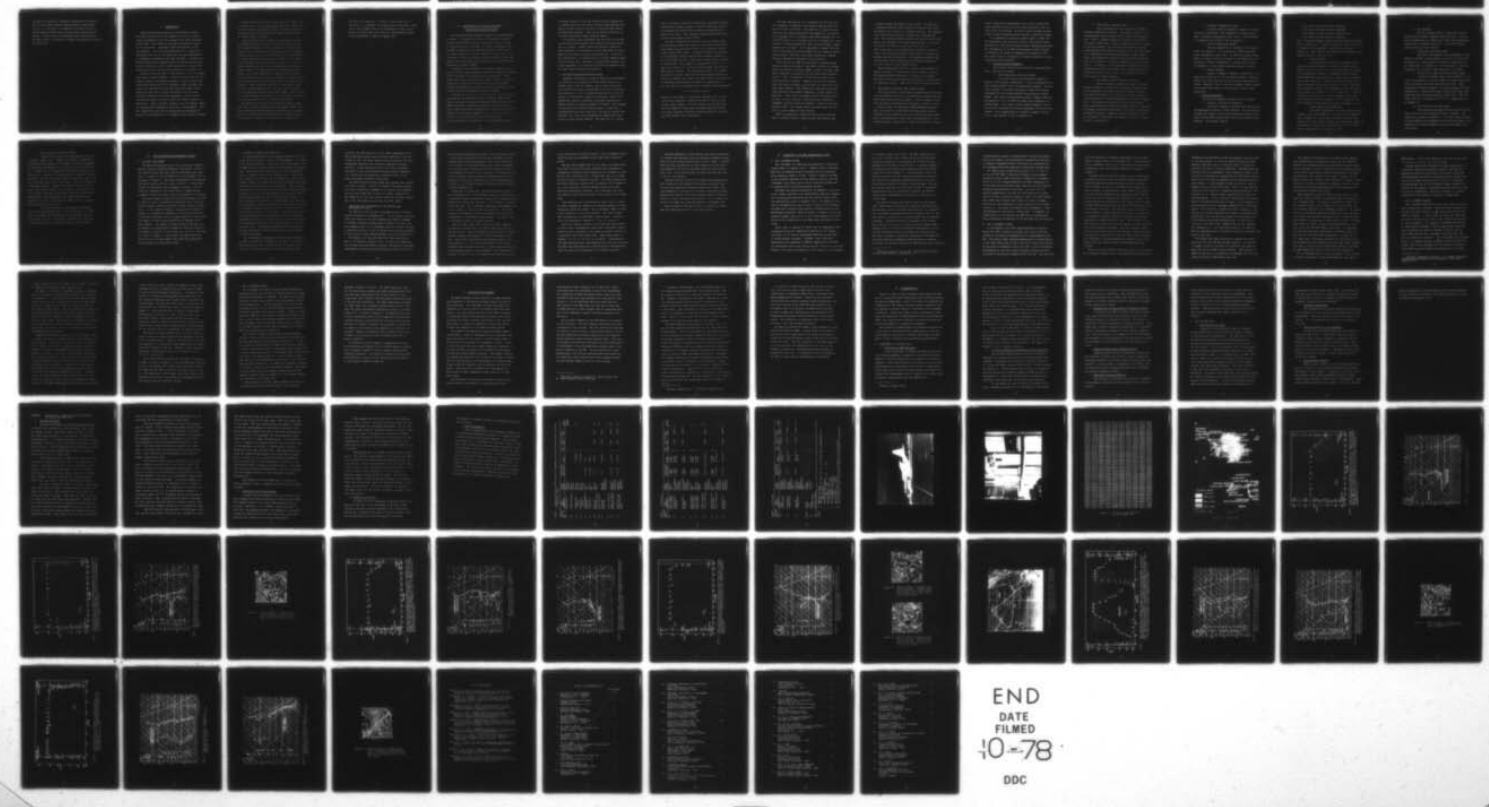

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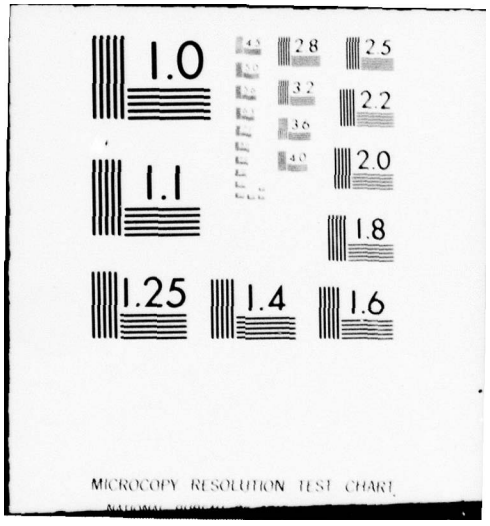
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THE AIRBORNE RESEARCH DATA SYSTEM (ARDS): DESCRIPTION AND AN EVALUATION OF METEOROLOGICAL DATA RECORDED DURING SELECTED 1977 ANTARCTIC FLIGHTS

by

Robert J. Renard and
Michael S. Foster

May 1978

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ABSTRACT

The paper describes the Airborne Research Data System (ARDS) and presents an evaluation of meteorological data recorded by it while installed aboard a United States Navy LC130R aircraft flown by the Antarctic Development Squadron Six (VXE-6), in support of the National Science Foundation's research programs in Antarctica. The evaluation consists of a comparison of wind, temperature and moisture data, collected on four flight missions during the period 8-12 November 1977, with similar data from Antarctic and New Zealand rawinsonde observations, as well as 50 kPa analyses from both Fleet Numerical Weather Central, Monterey, California and the National Meteorological Center, Washington, D. C. The results demonstrate some of the capabilities and limitations of the ARDS in logging meteorological data for operational as well as scientific research. Recommendations for improving the credibility of the sensed parameter data are included.

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The paper describes the Airborne Research Data System (ARDS) and presents an evaluation of meteorological data recorded by it while installed aboard a United States Navy LC130R aircraft flown by the Antarctic Development Squadron Six (VXE-6), in support of the National Science Foundation's research programs in Antarctica. The evaluation consists of a comparison of wind, temperature and moisture data, collected → next page

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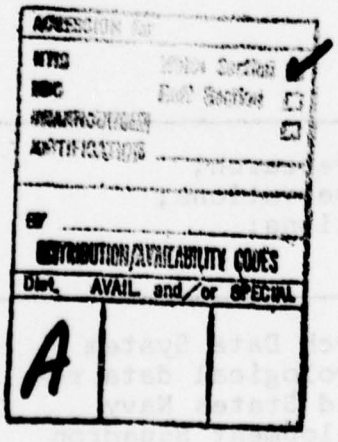
on four flight missions during the period 8-12 November 1977, with similar data from Antarctic and New Zealand rawinsonde observations, as well as 50 kPa analyses, from both Fleet Numerical Weather Central, Monterey, California and the National Meteorological Center, Washington, D. C. The results demonstrate some of the capabilities and limitations of the ARDS in logging meteorological data for operational as well as scientific research. Recommendations for improving the credibility of the sensed parameter data are included.



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LIST OF ABBREVIATIONS

ARDS	Airborne Research Data System
AWRS	Airborne Weather Reconnaissance System
BCD	Binary-Coded Decimal
BPI	Bits-per-inch
^{o}C	Degree Celsius (unit of temperature)
DALS	Data Acquisition and Logging System
FGGE	First GARP Global Experiment
FNWC	Fleet Numerical Weather Central, Monterey, Calif.
GARP	Global Atmospheric Research Program
GMT	Greenwich Mean Time
IBM	International Business Machines Corporation
IGY	International Geophysical Year
in Hg	Inches of Mercury (unit of pressure)
INS	Inertial Navigation System
Kaman	Kaman Aerospace Corporation
Knot	Nautical Mile per Hour (unit of wind speed)
kPa	Kilo-pascel (unit of pressure)
LED	Light-emitting Diode
LSD	Least Significant Digit
mb	Millibar (unit of pressure)
MSD	Most Significant Digit
NCAR	National Center for Atmospheric Research, Boulder, Colo.
NMC	National Meteorological Center, Washington, D.C.
NPS	Naval Postgraduate School, Monterey, Calif.
NSF	National Science Foundation, Washington, D.C.

NWC	Naval Weapons Center, China Lake, Calif.
POLEX	Polar Experiment
SCU	Signal Conversion Unit
TAS	True Airspeed
USAF	United States Air Force
VXE-6	United States Navy Antarctic Development Squadron Six

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provided the author with technical literature on the sensors used in the Airborne Weather Reconnaissance System (AWRS) of the U. S. Air Force. In addition, the staff of the W. R. Church Computer Center, NPS, have been most cooperative and helpful in their advice on programming and related matters. Ms. Marion Marks is thanked for typing, and sometimes retyping, the manuscript.

I. INTRODUCTION

Operational weather support for the Antarctic region has been and continues to be plagued by a lack of observational information from which accurate and timely forecasts can be made. This complaint has been persistently voiced in the literature. Lanterman (1960) and Mitchell (1970) are examples. Satellite technology has led to significant improvement but not in the sense that accurate measurements of atmospheric parameters have been provided. A widely dispersed observational network forces the operational weather analyst/forecaster to rely almost exclusively on experience and single-station forecasting techniques in the Antarctic.

Aircraft have been used in the Antarctic since 16 November 1928 when Sir Hubert Wilkins of Australia flew over the continent; however, Rear Admiral Richard E. Byrd of the United States Navy landed the first airplane on that continent and proved its compatibility with the harsh environment there. During the late 1950's, under the auspices of the International Geophysical Year (IGY) programs, aircraft became the principal means of contact with the interior regions of Antarctica. Today, aircraft continue to be the logical choice for long-distance transportation of men and equipment. The most important reason for the operational meteorologist's presence in the Antarctic is to support these flight missions.

Weather observations taken during Antarctic flights are an integral part of the observational data base. That these in-flight weather observations assume an added importance is underscored by the realization that other sources of data are either sparse or absent.

Limitations placed on scientific investigation of the polar atmosphere are due both to financial constraints and the inhospital habitat. Since aircraft have played an important role in atmospheric investigation in more temperate climates, and, since aircraft are being used in the Antarctic for routine re-supply and personnel transfer, it is reasonable to ask why these missions cannot serve as a source of quality atmospheric data to meet operational and scientific research needs. The National Science Foundation (NSF) has taken a step in this direction by funding the development and installation of the necessary equipment to enable collection of high-resolution data during aircraft flights in the Antarctic. This system was installed in the Navy's LC130R aircraft, Bureau number 159-131, in 1976, and is referred to as the Airborne Research Data System (ARDS). The aircraft is pictured in Figure 1; Kosar (1977 a,b) provides a description of the aircraft and its research capabilities.

The ARDS-collected data in the Antarctic region apparently have not been evaluated until the subject study. This effort follows the ARDS program from November 1976 to November 1977, at which time the data show an acceptable degree of consistency. However, on occasion, the credibility of

the data is in question. In order to make proper use of the data, it is important to recognize such situations. Hopefully, this document will be of assistance to other investigators in identifying those times and understanding certain of the limitations of ARDS in logging data.

II. DESCRIPTION OF THE LC130R AIRBORNE SENSING AND RECORDING SYSTEMS

The LC-130R airborne research system, incorporating ARDS, is unique. It combines the latest in electronic circuitry with well-established aircraft systems and sensors, proven in the earlier use of aircraft, to collect atmospheric data. The ARDS' versatility and compatibility with a wide variety of sensors will become readily apparent to the reader. It is convenient to view the airborne research system as being composed of two subsystems, the sensors and a monitoring/recording/display subsystem (ARDS).

A standard sensor package was installed aboard the aircraft in 1976 by Kaman Aerospace Corporation (Kaman). Gilchrist (1976) describes its installation and calibration. These sensors and their installation are almost identical to those installed by Kaman in the United States Air Force (USAF) weather reconnaissance aircraft and aircraft belonging to the National Center for Atmospheric Research (NCAR).

A system for collecting and recording the sensed data was developed for the National Science Foundation (NSF) by Mr. Samuel Schoenhals, Electronics Engineer, Naval Weapons Center, (NWC) China Lake, California and may be viewed in Figure 2. Sensor inputs and derived parameters are converted to digital signals for recording on magnetic tape. In addition, direct readout, using light-emitting diode (LED) displays and a line-printer, are provided. This recording system is

an updated version of the Data Acquisition and Logging System (DALS) which was once used to record meteorological data aboard aircraft flown by the Navy on hurricane and typhoon reconnaissance missions. What is now known as ARDS was, in its early development stage, known as DALS-II.

To facilitate easy maintenance and mobility, the recording and monitoring equipment are compactly rack-mounted and rest on a pallet. Sensor inputs are received, digitized (when required), and recorded at a scan rate which is determined by the number of inputs being collected. Accuracy of the recorded data is limited only by a 6-digit maximum number size and sensor lag. The data, including key navigation and flight parameters, are available on nine-track magnetic tape for post-flight reduction and analysis.

A. THE ARDS MONITORING/RECORDING SYSTEM

Parameter information recorded by ARDS may be conveniently divided into two groups; (a) those sensed directly as voltage inputs from the sensors, and (b) those derived by other aircraft systems, as described in Section B following. Each parameter is fed to a Signal Conversion Unit (SCU) designed to condition the signal for recording. Some of the signals are analog in character, requiring conversion to digital form by an analog-to-digital converter. The elements of the system are linked by three busses, a clock bus, a synchronization bus and a data bus. The master control unit generates the clock and synchronization signals which are passed to other system elements. The data bus is a two-way

link. The master control unit generates a two-digit channel-identification number, passes it down the data bus, and the SCU assigned that number code responds by transmitted its current data value. The two-digit channel number limits the system to one-hundred inputs (0-99).

The data transmitted by the SCU's are in positive logic serial-digital format and consist of the channel identification number and six digits of data, all in four-bit Binary-Coded Decimal (BCD) format. A channel of ARDS data consists of the two-digit channel-identification number followed by up to six digits of data. The total of eight digits occupies 32 binary bits. Each channel is separated by one bit. A data scan consists of a series of 32-bit words, one for each ARDS channel recorded. The transmission rate is 3.3 milliseconds per channel. The time (in milliseconds) required to collect a complete data scan of all ARDS channels in operation is obtained by multiplying the number of channels by 3.3. The scan rate per second may then be obtained from the equation

$$F = (1/3.3)(1/n) \times 10^3 ,$$

where n is the number of operational channels and F is the scan rate or frequency. More often than not the scan rate is not a whole number. For this reason, the user may find that the number of whole scans recorded during one second will vary, creating a difficulty during statistical processing which should not be overlooked.

The high sampling rate is illustrated by realizing that the scanning of a maximum of one-hundred channels would allow 3.03 scans per second. This high rate is more than adequate for the sensors presently being sampled by the system. As of November 1977, 38 channels were being recorded (F = 8.0 seconds^{-1}) which is an increase over the 29 channels (F = 10.4 seconds^{-1}) recorded during the 1976/77 Austral summer flights examined by the author. It is reasonable to expect the scan rate to vary among the future flights as the number of sensor inputs change. Efficient post-flight processing software should be designed to recognize this possibility.

SCU's used in the ARDS are tailored to perform several different processing chores. Some SCU's receive two voltage inputs and create a six-digit number in which the upper three digits represent one quantity and the lower three represent another. This is convenient for data which require less than three-digit accuracy. Examples are the true airspeed (TAS) and compass heading, each of which are never more than three-digit numbers. This combination, preceded by the two-digit identification number, comprises a single channel of ARDS data. Other SCU's are simple devices for manual entry of data. In this instance a calculator-like keyboard or thumbwheel switches allow the operator to enter the desired numerical data. The channel which contains month, day and year is a good example of this feature.

ARDS can permanently record the data in the following modes: a printed output, a master analog tape record, and

a computer-compatible magnetic tape record. The printer is a Datamatrix Model MC 3000, capable of printing 1500 lines per minute with as many as 7 channels per line. The scanning rate limits the printing to a maximum of 64 channels per scan. The interval between printed scans can be varied. The master tape recorder is an Ampex, Model AR-700. It records the digital information passed along the data bus and, in addition, voice communication internal to the aircraft. The computer-compatible tape output is created by a Kennedy tape unit, Model 9000. The maximum recording times for the master tape recorder and the computer-compatible unit are 4 and 6.9 hours, respectively.

The recording gear rests on a pallet which measures 1.6 meters in height, 1.4 meters wide and 0.6 meters in depth. The supporting pallet measures 2.7 meters by 2.0 meters. Heaters and blowers are strategically placed to ensure proper environmental control. Power is received from the aircraft.

B. THE SENSING SYSTEM AND ARDS CHANNELIZATION

Data from aircraft and navigation systems and non-specialized environmental sensors are consistently assigned the same ARDS-channel identification numbers. These assignments and selected signal characteristics are given in Table I, which is current except for additional higher-numbered channels used on occasion to record data from specialized sensors. Hinkleman (1976) stratified the data inputs into three categories, hydrodynamical, radiational and navigational. The radiation group, consisting of a down-viewing Barnes infrared

surface temperature sensor, Model 14-325 and an unspecified solar radiation sensor, have not been installed in the aircraft as of this writing. Gilchrist (1976) provides descriptions of those components which have been installed by Kaman.

It is expedient to group the sensor inputs to ARDS into two categories, those received directly from sensor instrumentation and those derived from aircraft operational systems. The thoroughness of the descriptive material which follows is limited by the desire to emphasize the behavior of the data rather than to accomplish an in-depth discussion of complicated electronic devices.

1. Directly Sensed Parameters

The directly sensed group consists of six sensor systems. They are as follows:

a. Total-Temperature Probe and Sensor

This sensor system was installed by Kaman and measures total dynamic temperature. It has a platinum-resistance sensing element with a de-icing heater element. The system is similar to the ones installed in USAF C130 aircraft configured for the Airborne Weather Reconnaissance System (AWRS). The output voltage passes through a signal conditioning amplifier, also installed by Kaman, which generates an analog signal. This signal varies linearly between 0 and 10 volts and is corrected for the heat generated by the de-icing element. Total temperature is recorded in degrees Celsius (^{o}C), to the nearest 0.01^{o}C, on channel 22.

b. Pitot-Static Pressure Probe

This instrument was also installed by Kaman according to AWRS specifications. The device consists of a strut-mounted, ported cylinder and includes a de-icing element. Total or dynamic pressure is sensed at the nozzle-like head of the probe. Static or ambient pressure is sensed at the exit portals. An associated differential pressure sensor measures the difference between static and total pressure, producing a linearly-varying analog voltage signal. Static and differential pressures are recorded in millibars (mb), to the nearest 0.01 mb, on channels 20 and 21, respectively. In addition, static pressure is recorded in inches of mercury (in Hg),to the nearest 0.001 in Hg,on channel 18. Pressure altitude to the nearest foot (channel 08) is obtained from the static pressure.

c. Flow Angle Pressure Sensors and Probes

Angle of sideslip pressure and angle of attack pressure forces are measured by two identical sensors which receive pressures via tubes from their respective probes. The probes are mounted on the exterior aircraft frame at locations selected to allow measurements of pressure differences. The sensors are physically inside the aircraft. These components were installed by Kaman along with appropriate signal conditioning electronics to provide a linear measurement of pressure. Angle of attack and sideslip angle are recorded as pressures to the nearest 0.01 mb on channels 10 and 11, respectively.

d. Frostpoint Temperature Sensor

A General Eastern hygrometer, Model 1011, senses frostpoint temperature. The frostpoint is readily convertible to dewpoint temperature (List, 1963). This parameter is recorded to the nearest 0.1°C on channel 23.

e. Free-Air Temperature Sensor

Free-air temperature is recorded to the nearest 0.01°C on channel 24. It is sensed by a Hewlett-Packard quartz thermometer, Model 2801. An identical quartz thermometer is located inside the aircraft on the ARDS pallet for sensing the "indoor" temperature. A manual switch allows the operator to choose which instrument signal to record.

f. Compass Heading

Compass or magnetic heading is obtained as a voltage output from each of the two onboard magentic compasses (Model C-12) which are part of the aircraft navigation subsystem. Numbered 1 and 2, they are recorded in whole degrees as the first three digits of the channel 13 and 14 data, respectively.

2. Derived Parameters

The derived parameters consist of the following:

a. Quadrant, Latitude and Longitude

The earth's quadrant, latitude and longitude give the geographical position of the aircraft. This information is among the outputs of the Litton Industries Inertial Navigation System (INS), Model LTN51, and its associated Micro-D computer. The quadrant code is

1, for north latitude and east longitude,

3, for south latitude and east longitude,

5, for south latitude and west longitude, and

7, for north latitude and west longitude.

One of these odd numbers occupies the most significant digit (MSD) of channel 04. Latitude occupies the last five digits of channel 04 and longitude occupies all six digits of channel 05. Both latitude and longitude are recorded to the nearest tenth of a minute of arc.

b. Radar Altitude

As originally envisioned by Hinkleman (1976), there would be two channels to record the radar altitude. Channel 06 was to record the low-level altitude and channel 07 the high-level altitude. A Honeywell radar altimeter, Model AN/APN-194, was installed to obtain altitude measurements below 5,000 feet. The Stewart Warner high-altitude radar altimeter has not been installed to date. Presently, ARDS records the output of the AN/APN-194, upon the operator's command, on channel 06 to the nearest foot. When the altimeter is turned off or when the flight level is more than 5,000 feet above the ground a "9" is recorded in the MSD of channel 06 and each of the last four digits is zero.

c. Drift Angle and True Heading

The LTN-51 INS derives the drift angle and true heading. Both are recorded to the nearest whole degree of arc on channel 12. Drift angle occupies the upper three digits while true heading occupies the lower three digits of the channel. Left drift is indicated by a "9" in the MSD while a right drift is indicated by a "0".

d. True Airspeed

The true airspeed (TAS) is computed by the Air Research true airspeed computer, Model A/A 24G-9. The output is recorded twice by ARDS as the three least significant digits (LSD) of channels 13 and 14. Units are in whole nautical miles per hour (knots).

e. Track Angle and Ground Speed

The LTN-51 INS provides these parameters. Track angle is recorded in whole degrees of arc as the three MSD's of channel 15. Ground speed is recorded in whole knots as the three LSD's of channel 15. The track angle is the true heading of the aircraft's track relative to the earth.

f. Doppler Drift Angle and Doppler Ground Speed

A Honeywell doppler radar, Model AN/APN-147, provides a measurement of the drift angle and ground speed separate and distinct from that provided by the INS. These values are recorded on channel 16 in whole degrees and knots, respectively. Doppler drift angle occupies the upper three digits and doppler ground speed the lower three. Left and right drift are indicated by a "9" or "0", respectively, as on channel 12.

g. Wind Direction and Wind Speed

Wind direction and speed are derived by the software within the Litton Industries Micro-D computer. The values are recorded on channel 19. The three digits occupied by each parameter are arranged in the order given above. Wind direction is in whole degrees of arc and wind speed is in whole knots.

h. Master Control and Manual Inputs

Channels 00 through 03 are recorded directly from the Master Control Unit. Channel 00 contains a synchronization signal which appears as the number 777777 and conveniently identifies the beginning of a new scan of the system's inputs. Channel 01 is a manually-entered 6-digit number, normally used to identify the flight mission. Channel 02 contains the month, day and year, each of which occupies two digits and fills the data space in the order given. The date information is manually entered. Channel 03 records the time of day in hours, minutes and seconds, in that order. The source of the time of day is the same clock within the Master Control Unit which monitors and synchronizes the complete ARDS system. Channels 07, 09 and 17 are used as spares or can be manually entered with data, as desired.

The preceding sensor and parameter information does not include descriptions of special sensors, e.g. those used to determine the concentration of atmospheric particulate matter or ozone. Such sensors are under the cognizance of specific principal investigators and not treated here.

III. DATA DESCRIPTION AND TREATMENT OF DATA

A. THE ARDS DATA FORMAT

The ARDS recorded data used in this study were obtained from the computer-compatible magnetic tape record. Copies of the original flight data were received from NWC, China Lake, Calif. A sample of the raw ARDS data for 10 November 1977 is presented in Figure 3. The format corresponds to the description given earlier and the listing in Table I. The raw data consist of consecutive scans arranged in records. The records are a maximum of 512 32-bit words in length and are arranged in data files which contain a maximum of 512 records.

The exact number of words per record and number of records in each file may be determined by executing one of the tape utility software routines available at most computer installations. In the sample of Figure 3, each scan is 38 words in length. By dividing the maximum of 512 words per record by 38 and then retaining only the integer portion of the quotient, the number of scans in each record can be obtained (13 in this example). The number of words in each record then can be obtained by multiplying the number of scans per record by the number of channels in each scan; e.g., 13 x 38 = 494 words per record in Figure 3. All records on a given tape were found to be of the same length since each tape represented data recorded on an individual flight.

B. OBTAINING A WORKING ARDS DATA SET

A detailed discussion of the computer software developed during the investigation is given in the Appendix. In essence, it was first necessary to convert the 4-bit BCD format of the raw ARDS data into binary form to allow mathematical manipulation. The binary values were written on a second magnetic tape in a format similar to the original data. Other than unit conversions for several of the parameters, the only significant change in the data was the time averaging of all raw data scans occurring during the same second. This procedure resulted in the creation of a one-second time interval between successive scans in the output data, each scan consisting of time-averaged parameters over the one-second interval. It also eliminated the problem of a non-integral scan rate and was justified by visual inspection which showed the resolution of frequencies higher than one second to be unnecessary for any envisioned purpose of this study. The only exception to the preceding generality was retention of the latitude and longitude, obtained in the last data scan of each second, as the geographical position of the time-averaged scan in the processed data. Calculations showed that any inaccuracy in position introduced by this artificiality was still within the INS error range.

Test voltages were eliminated from the data by checking for test values with a tolerance of $\pm$ 5 units. A simpler method would have been to check the MSD of channel 02 for the digit "9" (high voltage) or "8" (low voltage) which

indicates the ARDS system is in test mode (Schoenhals, 1976). The processing software could have been modified to take advantage of this test mode indicator but the presence of other anomalously excessive data variations required a broader solution. It was found that the ± 5 unit test tolerances (see Table I) were occasionally exceeded causing contamination of the data and requiring a screening filter in the later statistical treatment of the data.

The working data for each flight were grouped into records 493 words in length. Whereas the original data were grouped into files containing a maximum of 512 records, the processed data for each flight were placed in a single, labeled file. The length of the file for a given flight was variable according to the time spanned by the data for that flight.

C. PROCESSING AND PRESENTATION OF THE WORKING-ARDS METEOROLOGICAL DATA

The ARDS data used for this investigation were collected during the period 8-12 November 1977. In the authors' opinion, these data represent the most complete and credible examples of inflight atmospheric observations by ARDS up to that time. Data examined prior to 8-12 November consists of data collected in Antarctica between 12 and 15 January 1977 and data collected in the vicinity of New Zealand between 29 and 31 October 1977.

The January 1977 data were the first ever collected by ARDS in the Antarctic (Desko, 1977). At that time, ARDS was still being tested and several aircraft systems were inoperable. Investigation of these earlier data was set aside in favor of

data collected during Austral summer 1977/78; however, access to these early test data did facilitate development of the software which created working data sets. Even though the 29-31 October 1977 data were from an area other than Antarctica, the plan was to proceed with their evaluation if the 8-12 November data could not be obtained. The preference for the 8-12 November data was clearly established when it was learned that wind speed and direction, which apparently were in error in all previous flights, had been corrected between 8 and 10 November 1977.

There were four ARDS data collection missions between 8 and 12 November 1977. On 8 November, data were collected on a round-trip flight from McMurdo, Antarctica to Amundsen-Scott (South Pole), Antarctica and back. On 10 November, a similar flight was made. The 11 November flight was from McMurdo station to Camp J9 on the Ross Ice Shelf and back. The final flight on 12 November collected data during the return trip from McMurdo to Christchurch, New Zealand. See Figure 4 for the relative location of flight terminals.

Data for each flight were divided into three segments, the ascent to flight level, the main flight-level portion, and the descent. Computer software were developed to perform variable running time averages of selected segments of the data. The ascents and descents were processed using a 30-second period; i.e., 30 one-second elements of the chosen parameter were averaged to produce a single representative 30-second average value for that parameter. The flight-level portions of the 8, 10 and 12 November missions were processed

using a 900-second (15-minute) period. The 11 November flight-level portions were averaged using a 300-second (5-minute) period.

Running time-averaged data for all ascent and descent portions were listed at 30-second intervals which produced an average-data resolution which appeared to be suitable for comparison with rawinsonde data. Flight-level data on 11 November were listed at 5-minute intervals. All other flight-level data were listed by latitude with an interval of 15 minutes of arc, since they were collected during flights which were generally meridionally oriented. The 11 November data were not treated in this manner because of the nature of the flight path.

Cross-sections were constructed for each flight to depict the wind, temperature, dewpoint and pressure/pressure altitude variations during the flight. The 11 November flight to Camp J9 was treated as a time cross-section. All other flights were reconstructed as meridional cross-sections. Cross-sections are presented in Figures 5, 7, 10, 13, 18 and 22.

Ascent and descent portions of the ARDS data were plotted on Skew T-log P thermodynamic charts when conventional rawinsonde data were available at the ascent or descent station for a reasonably close observation time. These plots appear in Figures 6, 8, 11, 12, 14, 19, 20, 23 and 24. Unfortunately, 1200 GMT rawinsonde data from Amundsen-Scott were not available. The ARDS time associated with a descent(ascent) sounding represents the time of the beginning of the descent (ascent).

Southern Hemisphere 50 kPa (500 mb) analyses for the dates of interest were obtained from Fleet Numerical Weather Central (FNWC) and the National Meteorological Center (NMC). Selected ARDS data were overplotted on these charts for levels generally between 60 kPa and 40 kPa within three-to-four hours of chart time. It is believed that the ARDS data were not used in the 50 kPa analyses.

Pressure altitude curves for the ARDS ascent/descent data were constructed and compared with pressure altitude curves derived from appropriate rawinsonde data (not shown). The close agreement of the two sets of curves indicated the ARDS pressure and pressure altitude to possess levels of accuracy similar to their rawinsonde counterparts. This statement applies to all ARDS data collected during 8-12 November 1977.

There follows in the next section a discussion of these ARDS and rawinsonde data in a case study format.

IV. EVALUATION OF THE ARDS METEOROLOGICAL DATA

A. THE 8 NOVEMBER FLIGHTS

The 8 November 1977 ARDS data are presented in cross-sectional format in Figures 5 and 7. Figures 6 and 8 illustrate ARDS Pole and McMurdo descent soundings and the associated rawin soundings nearest in time. Figure 9 presents the FNWC 50 kPa automated analysis for the Antarctic area at 1200 GMT 8 November; such charts are an aid in relating the ARDS data to synoptic-scale circulation/thermal features.

The ARDS wind speeds collected on the McMurdo to Pole and return flights appeared to be exceptionally high when compared with corresponding rawinsonde data and thereby omitted from the cross-section plots in Figures 5 and 7. An example of this type of incompatibility may be seen in Figure 8 which presents the ARDS data recorded during descent to McMurdo and the 1200 GMT McMurdo rawinsonde. Their inclusion in Figure 8 is for comparative purposes only and it is not to be regarded as an indication of the credibility of all ARDS winds evaluated in this study.

While there is absence of "truth" for the temperature data documented during the flight-level portions of the flights, such data, in the form of radiosonde observations, may exist at ascent/descent locations. Figures 6 and 8 indicate a reasonably close agreement of ambient temperatures from ARDS and rawinsonde observations during aircraft descents at Pole and McMurdo. The flight from McMurdo to Pole (Figure 5) was primarily

at a pressure level near 45 kPa. The ARDS temperatures at and close to flight level closely match the corresponding rawinsonde temperatures near McMurdo (at 45 kPa) and near Amundsen-Scott (between 50 and 55 kPa). A similar agreement in temperature was noted at/near McMurdo during the return flight (at 40 kPa) (Figure 7). The smoothness of the temperature variation for the flight-level portion of Figure 5 was verified by computing standard deviations of the one-second values from each 15-minute flight average. The maximum standard deviation is only 0.43°C, which is considered significantly low since Hinkleman[1] indicated the Hewlett-Packard quartz thermometer was unproven in operational use of this type.

The dewpoint temperature (derived from the ARDS frostpoint temperature) showed greater variation from rawinsonde observations as well as greater time variation, in comparison with the ambient temperature behavior (Figures 6 and 8). However, there is similarity in pattern between the two moisture soundings. Standard deviations calculated for the flight-level portion of the data (15-minute running average) gave a maximum value of 1.76°C for frostpoint temperature. If space and time differences between the ARDS and rawinsonde data sets are considered, a subjective comparison of the ARDS and rawinsonde dewpoint temperature profiles does not indicate any reason to seriously question the ARDS moisture data. Specific

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[1]Personal communication with Mr. Jack Hinkleman, Federal Aviation Administration, Washington, D. C.

incompatibility factors of unknown effect involve the difference in the sensor's and rawinsonde's trajectory in relation to regional topography/surface variations and differences in the averaging techniques applied to rawinsonde and ARDS data.

The temperatures overplotted at points "a", "b" and "c" on the 1200 GMT FNWC 50 kPa chart (Figure 9) were obtained during the return flight from Pole to McMurdo on 8 November. Point "a" in this figure represents the ARDS temperature at 50 kPa about one hour before chart time and fits the computer-analyzed isotherm pattern quite well. At point "b", the plotted temperature is for the 39.2 kPa level and is colder than at 50 kPa, as would be expected. Point "c", which represents ARDS data collected very close to 50 kPa, is warmer than the 50 kPa temperature at that location, but not significantly so. The three and one-half hour difference in chart time/observation time may be a factor here. In general, the compatibility of the analysis and ARDS data is surprisingly good considering the sparsity of the data base for the analysis.

B. THE 10 NOVEMBER FLIGHTS

On 10 November, the LC130R departed McMurdo at approximately 0427 GMT, climbed to a flight level near 46 kPa and arrived on the ground at Amundsen-Scott at approximately 0809 GMT. The return flight departed Amundsen-Scott at approximately 0924 GMT, flew close to the 37 kPa level enroute and arrived on the ground at McMurdo at about 1227 GMT. Prior to departure from McMurdo on this date, newly developed software had been installed in the Micro-D computer within the INS. The resulting

wind data represent an apparent improvement over the ARDS winds on flights prior to 10 November 1977. Characteristics of the 10 November data set are illustrated by cross-section, thermodynamic chart and synoptic analysis in Figures 10 through 16.

The ARDS wind data for the aircraft ascent from McMurdo show good consistency with the 0000 GMT McMurdo rawinsonde winds although the former wind speeds are less than the latter (Figures 10 and 11). The ARDS winds during the aircraft's descent to Amundsen-Scott were notably inconsistent with the 0000 GMT Amundsen-Scott rawinsonde winds (Figures 10 and 12), even considering the differences in times. The same inconsistency, especially in wind speed, exists between the ARDS McMurdo descent data and the 1200 GMT McMurdo sounding (Figures 13 and 14). The ARDS wind speed for both descents exhibit a higher magnitude than would be expected due to atmospheric processes during the interim period between rawinsonde and ARDS observation times. The validity of the wind direction during these descent portions is also questionable (see paragraph following). The wind problem is most marked at the lowest levels of the descent. These discrepancies raise the question as to why the ascent winds are generally believable, although apparently relatively low in wind speed, while the descent winds are not meteorologically credible.

Part of the wind problem at the Pole is due to the different coordinate systems used in calculating the wind direction.

Rawinsonde wind observations taken at Amundsen-Scott are given in the grid system; i.e. North is directed along the Prime Meridian from Pole, East is along 90E, South is along the dateline, and West is directed along 90W. The ARDS winds are derived in the true geographic north coordinate system. Great care must be exercised in coevaluating the directional characteristics of the ARDS and Amundsen-Scott rawinsonde winds for these reasons. A good example of what can occur is seen in Figures 10 and 12 at/near the Pole. Here it is seen that the South Pole wind direction is generally from grid-north. The aircraft is, in a general sense, approaching the South Pole from grid-south. In this situation, what appear as southerly winds in the ARDS descent data of Figure 12 are comparable to grid-north winds in the comparable Amundsen-Scott rawinsonde report. This situation, coupled with rapid changes in longitude as the aircraft maneuvers for landing at Amundsen-Scott, is believed to be the principal reason for directional conflicts between rawinsonde and ARDS winds, at least in the vicinity of the South Pole. McMurdo winds do not exemplify this problem,that is the coordinate system is the same for ARDS and rawinsonde and the longitude variation is minimal compared to near Pole.

The flight-level ARDS winds may be compared for consistency with the 1200 GMT NMC and FNWC analyses. As depicted in Figures 15 and 16, the ARDS wind direction data seem to agree best with the FNWC contour analysis. NMC isotachs in Figure 16 are seen to be generally in agreement with the wind speeds collected by ARDS except near Pole.

The upper-air data from which the FNWC and NMC analyses were constructed are notoriously scarce over the Antarctic. Moreover all radiosonde/aircraft observations were not necessarily available to both or either one of the analysis centers. On this basis alone caution should be exercised in declaring one analysis to be superior to the other. However, if the ARDS wind data are credible, their potential to create a better analysis is vividly illustrated in Figures 15 and 16, by comparing the vector geostrophic/gradient winds implied by the contours with the ARDS wind plots.

ARDS temperature data were found to have about the same level of accuracy relative to rawinsonde data as observed in the 8 November data. The absolute instability in ARDS data in two layers below 850 mb (Figure 11) is questionable, as was a similar depiction for 8 November (Figure 8). In Figures 11 and 14, the McMurdo rawinsonde temperature data are generally warmer than the ARDS temperature data, a tendency somewhat apparent on other days in this period as well. The ARDS ascent data of Figure 11 were collected approximately four hours after the 0000 GMT McMurdo rawinsonde. In comparing the 1200 GMT rawinsonde temperatures at McMurdo (Figure 14) with the 0000 GMT rawinsonde temperatures of Figure 11, it is evident that cooling was occurring over the McMurdo area. This establishes more credibility for the ARDS ascent temperature data, as does the close relationship between rawinsonde and ARDS temperature data at/near 1200 GMT of Figure 14.

As on 8 November there is some consistency in the pattern of vertical variations in moisture between the two types of

observations. However, the absolute differences between ARDS and rawinsonde dewpoints are quite variant.

Standard deviations calculated for these flight data, including the flight-level portions, indicate less than 1°C temperature deviation during ascent and descent (30-second running-average) and only an occasional deviation larger than that for the flight-level portions of the data (15-minute running-average). As on the 8 November flight, standard deviations of the dewpoint temperature are about twice as large as those for temperature, indicative, perhaps, of a greater stratification of moisture in relation to temperature.

C. THE 11 NOVEMBER FLIGHTS

The 11 November ARDS data did not lend itself to meridional cross-section treatment. These data were collected over the Ross Ice Shelf enroute to Camp J9 and during the return flight to McMurdo. It was elected to display the ARDS data in a time cross-section in view of the difficulties peculiar to other treatments. The complete 11 November ARDS mission is illustrated in Figures 17 and 18; appropriate rawinsonde data for McMurdo are shown in Figures 19 and 20; and the 50 kPa FNWC analysis for 11 November, with ARDS data overplots, is depicted in Figure 21. The investigator was informed by Dr. A. W. Hogan,[2] who was a working scientist aboard the flight, that it was necessary for the aircraft to perform a slow spiraling ascent during the mid-portion of the flight

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[2]Personal communication from Dr. A. W. Hogan, Atmospheric Sciences Research Center, State University of New York, Albany, N. Y.

to Camp J9 (vicinity of J9 in Figure 17) in order to calibrate instruments for measuring ozone concentration.

The ARDS wind data for 11 November exhibits the same behavior with respect to the McMurdo soundings as occurred on 10 November; i.e., the ascent portion of the ARDS wind data agrees quite well with the rawinsonde winds although speeds are less for ARDS, while the descent winds are excessive, especially at lower levels. The ascent and descent winds collected by ARDS near Camp J9 differ significantly from each other, but without comparative data no judgement of their accuracy can be made. The variation of geographical location of the ARDS wind data during the McMurdo ascent portion is quite large but there is still close agreement with the 0000 GMT McMurdo rawinsonde winds.

Temperature data during all phases of the flight seemed to exhibit the greatest credibility of all the parameters being evaluated. Of particular interest is the point labeled "b" in Figures 17, 18 and 19, where the aircraft overflew McMurdo. In Figure 19 the ARDS and radiosonde temperature profiles intersect at point "b", with the ARDS temperature data relatively warmer at lower levels and to the north but relatively colder at higher levels and to the south. Also noteworthy was the evidence in Figure 19 of stratospheric penetration near 39 kPa; the tropopause near this level is verified by the rawinsonde temperature profile. Although colder, the ARDS temperature profile above point "b" (in Figure 19) follows the same trend as the rawinsonde temperature data. The ARDS temperature data collected near the end

of the round trip flight (Figure 20) display an even closer agreement with the rawinsonde data than the data of Figure 19 and also show tropopause penetration. In Figure 20, the portion of the ARDS sounding geometrically above 42.5 kPa was collected during the main flight portion (5-minute running-average). The data for levels below 51.5 kPa were collected after the 1120 GMT data cutoff time (end of tape) in Figure 17. The missing portion in Figure 18 represents a brief period in which the aircraft circled several times near Mount Erebus, during which time the data were not evaluated. Figure 17 does not show the short distance flown from the Mount Erebus area to McMurdo which is depicted below the missing portion of the descent in Figures 18 and 20.

The moisture relation between the two sets of observations on this data shows nothing new in comparison with the 8 and 10 November cases. However, the ARDS data do indicate the atmosphere to be much drier than suggested by the rawinsonde data (Figures 19 and 20). Further, a first order discontinuity in moisture occurs at the tropopause level as defined by temperature.

The 50 kPa synoptic situation at 1200 GMT, as analyzed by FNWC, is shown in Figure 21. The only ARDS data available to plot, considering time, flight level and scale of chart, are those for 0953 GMT at the 51.6 kPa level, close to Camp J9. The temperature ($-39^{\circ}C$) agrees quite well with the isotherm pattern; the wind datum shows fair agreement with the wind derived from the isohyptic pattern.

D. THE 12 NOVEMBER FLIGHT

On 12 November the LC130R aircraft departed McMurdo at approximately 1200 GMT and flew to Christchurch, New Zealand, arriving at approximately 2200 GMT. The ARDS data collected during this flight were treated in the same manner as the 8 and 10 November data. The beginning and end of the flight correspond closely to the 1200 GMT McMurdo sounding and the 0000 GMT 13 November Christchurch sounding. Figure 22 illustrates the ARDS data in meridional cross-section form. Figures 23 and 24 depict the rawinsonde/ARDS ascent and descent data for McMurdo and Christchurch, respectively. Figure 25 is the FNWC analysis for 1200 GMT 12 November with selected ARDS data overplotted for comparison.

The aircraft climbed steeply after departing McMurdo (Figure 22) and the ARDS wind data (Figure 23) closely match the 1200 GMT McMurdo rawinsonde winds (Figure 23). During the descent at Christchurch, the ARDS wind data were expected to differ significantly from the rawinsonde winds (Figure 24), as based on previous analyses. The flight-level (about 38 kPa) data show a jet maximum near 58S, a feature which is well-depicted by the strong gradient in that area on the 1200 GMT FNWC analysis (Figure 25). The ARDS data overplots in Figure 25 indicate a minor jet axis poleward of McMurdo. The cross-sectional winds plotted in Figure 22 agree well with the synoptic situation given in Figure 25, a fact which supports the credibility of the ARDS data.

ARDS temperature profiles, when compared with those of the McMurdo and Christchurch soundings, show remarkable

agreement (Figures 23 and 24). The ARDS temperature data for the Christchurch descent are hardly distinguishable from the rawinsonde temperature below 60 kPa (Figure 24) even though there was a one-hour time difference between the times of the two data collections. The ARDS temperatures recorded at flight level have a maximum standard deviation of 2.43°C, near 72S, where considerable temperature gradient is evident (Figure 22). As noted in Figure 22, the ARDS wind data near 72S have considerable shear in both magnitude and direction. Standard deviation calculations for the wind in this region indicate an increase in spatial wind variability, mainly due to changes in the westerly wind component as a function of latitude. However, the greatest wind variability was found to exist in the vicinity of the jet maximum near 58S, as would be expected.

In comparison with the dewpoint temperature data from the three previous November cases, the ARDS dewpoint profiles for 12 November (Figures 23 and 24) reveal nothing extraordinarily different. The pattern relationship between ARDS and rawinsonde, as given by the vertical moisture gradient, is quite good at McMurdo (Figure 23).

V. CONCLUSIONS AND COMMENTS

The ARDS recording system represents a highly sophisticated approach to solving the problems usually involved in data collection. Once recorded, the data are immediately available for study in any of the several forms discussed earlier. The high sensor scan rate of the ARDS is capable of accepting sensors which possess even finer scale resolution than the sensors currently being used in the aircraft. This points to a need for acquiring or developing sensors to match the capability of the ARDS recording system.

The volume of data generated during each ARDS flight is considerable. Unless an investigator has a requirement for finer scale data and the sensors to provide them, there is little need for so massive an accumulation of data. There is a distinct need for post-flight statistical treatment of the data to limit the sample size and make it more manageable for most meteorological purposes. The biggest processing problem encountered in this study was the need to convert from the serial-digital 4-bit BCD format to a binary format using the IBM 360 computer, which recognizes the 8-bit BCD format. This may not be a problem for investigators who have access to other computers or other forms of the ARDS data output.

The difficulty of acquiring a reasonable amount of comparative data in the Antarctic is appreciated by those

meteorologists whose interests lie in that area. While rawinsonde data are considered too gross for establishing the credibility of ARDS data beyond doubt, these data were accepted as the only data available with continuity in the Antarctic. If the rawinsonde data are viewed with the same caution as the ARDS data, the view may be taken that the ARDS data are no less accurate than the rawinsonde data used in the comparison, except for certain aspects of the wind data.

The wind data computed by the INS appear to be accurate in most instances. The most obvious wind errors occur during descent of the aircraft. Why this should occur has been the subject of much scrutiny. Wind errors similar to those observed during the aircraft's descent were also observed during periods of rapid aircraft heading change. The problem has been discussed with personnel of Litton Industries,[3] the developers of the wind generating software used in the Micro-D computer of the INS. It was verified that rapid maneuvering of the aircraft could generate wind errors but the reason why these errors should occur primarily during aircraft descent remains elusive at this writing.

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[3]Personal communication with Mr. Arthur Gleason and Mr. Abdul Tahere, Litton Industries.

In general, there appears to be considerably more aircraft maneuvering during descents than during ascents, simply because of the need to align the aircraft with the runway. However, although less noticeable, there may be problems during aircraft ascent as well, as evidenced by the slightly lower wind speed during ascent on several occasions. In any event, a good criterion for accuracy of the ARDS wind data is an examination of TAS and aircraft heading variations. While in level flight and/or during a slowly executed maneuver, the ARDS wind data appear to be credible.

The ARDS temperature data appear to be good. The accuracy of ARDS frostpoint observations is not clear from this limited sample. The fact that ARDS data and rawinsonde data do not correspond as closely as might be expected is believed to be due to different times of collection, variations in height and nature of underlying surface around the rawinsonde stations, differences in the averaging techniques employed, differences in instrument responses and possible calibration errors in both the ARDS and rawinsonde sensors. Hinkleman[4] has stressed the need for frequent recalibration and testing of the ARDS sensors if accuracy is to be expected. Hogan[5] has indicated his distrust of the frostpoint temperature data in most circumstances. Hogan (1977) also has reported a larger concentration of moisture in the Antarctic stratosphere than previously suspected. The data examined by this investigator do not refute that possibility (e.g., see Figures 19 and 20).

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[4]Personal communication. [5]Personal communication.

As noted in an earlier section, the pressure and pressure altitude data seem to agree quite well with their counterparts in rawinsonde observations, indicating these ARDS parameters are credible. Other than the wind data problem when the aircraft undergoes rapid acceleration, the only other feature of the ARDS data which proved to be detrimental was the occasional contamination of the data by test voltages and, specifically, the switching of the temperature measurement from the exterior to the interior sensor. This problem is an annoyance which can be easily overcome in the data processing software.

As indicated earlier the subject study represents a very limited evaluation of ARDS. As such there is no reason to reject any of the sensed data on the basis of inaccuracy, except for the qualifications noted in the case of wind and perhaps moisture. The full capability of the ARDS system is yet to be realized; the appreciation of its value to the community of Antarctic researchers will grow rapidly and along with it its use. It is hoped that this investigation has been of some value in furthering this realization.

VI. RECOMMENDATIONS

There is a need for more intensive study before the ARDS and its associated sensor subsystems can be definitely labeled accurate and dependable. Much of the effort to establish the credibility of the subject aircraft research capability must be supplied by persons skilled in electronics and instrument calibration. During the course of this investigation, many ideas for application of ARDS-monitered data have surfaced but these, too, depend upon the ability to provide accepted and proven measurements of atmospheric parameters.

The following recommendations and proposals are proferred in the hope of creating a better understanding of the aircraft research system and to indicate areas where the ARDS may be of use to research and operational meteorologists.

A. IMPROVEMENT OF THE ARDS DATA

1. Correction of ARDS Wind Data

Litton Industries' Mr. Arthur Gleason[6] has indicated that wind measurements as computed in the LTN-51 INS can be improved by further modification of software in the Micro-D computer. These modifications are necessary if accurate wind measurements are desired while the aircraft is being maneuvered, particularly during aircraft descents and tight turns. Accurate wind measurements are an integral part of most meteorological investigations and the capability to

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[6]Personal communication.

acquire them is well worth the effort. It is recommended that the wind accuracy problem receive swift attention, either by contracting commercially for improved software, or, by developing the algorithms to allow post-flight computation of winds from other ARDS data such as TAS, ground speed, drift angle and slideslip angle. The first approach would be more economical in a long-term sense while the second approach is a better short-term or interim solution. The second approach should be at least developed, if not implemented, in order to allow post-flight derivation of wind speed and direction as a back-up during periods of INS malfunction.

Also, it may be advisable to consider funding development of INS software which can derive wind direction in the grid system for use on flights to or near the South Pole. Otherwise, it is expected that difficulties are sure to arise in interpreting the winds collected there. The example in Figures 10 and 12 supports this need.

2. Technical Evaluation Requirements for the ARDS DATA

The on-board research system should be evaluated to determine the accuracy of sensors and derived-parameter measurements. Preferably this evaluation should be conducted in a polar environment using control sensors of known response for comparison. Sensor response and accuracy of information obtained during this evaluation should be made available to investigators in order that they may have a complete understanding of the limitations of the data being collected.

In the absence of time or funding to accomplish the above, information provided by the developers of the sensors

should be collected to provide a definitive description of each sensor and its capability. This documentation could be easily developed into an ARDS Users' Guide in which the answers to the many questions about the accuracy and ranges of the sensors can be found.

3. Recalibration and Maintenance of Airborne Sensors

In order for the ARDS to realize its fullest potential, sensor recalibration and maintenance must be accomplished at regular and frequent intervals. The degree to which this is being accomplished is presently unknown. Knowledge that a system is definitely maintained is an important factor in developing confidence in that system's capabilities. For this reason, it is suggested that the maintenance and calibration/testing program for the sensors be reassessed for its impact on the credibility of the data being collected.

4. Hewlett-Packard Quartz Thermometer Data

Temperature data should be improved by altering the SCU circuitry to prevent the interior aircraft temperature from being recorded on the same channel as the exterior temperature. A spare channel is suggested as the proper place to record the interior temperature rather than contaminate the exterior temperature sample.

5. Additional Sensing Capability

The usefulness of the ARDS can be greatly increased by providing a high-altitude radar altimeter and radiation sensors.

These additions would allow the ARDS to collect the data necessary to more completely define the atmosphere. The radar altimeter would allow a determination of the actual heights associated with the observed atmospheric parameters and give D-values for use in constant-pressure surface analysis. Radiation sensors would provide satellite-truth data and allow expanded heat budget studies for the Antarctic.

B. USES OF ARDS DATA

1. Operational Use of ARDS

In general, the observations from the research - oriented ARDS system have not been made readily available to the operational meteorologist. The importance of such an additional data source for the meteorologists with analysis/forecasting responsibilities in the Antarctic is all too evident. To be of operational value, the data must be made available immediately after completion of an ARDS data-collection flight. To accomplish this, the ARDS line-printer output (or a copy of it) should be routed to the local operational meteorologists for use in their weather analysis and forecasting procedures. ARDS data could well be the only data available to them for a broad area of Antarctica. Facsimiles of the ARDS data thus acquired should be relayed by message to the weather services which provide support for the Antarctic. For the United States, NMC and FNWC should receive the data facsimiles reformatted in an

appropriate aircraft weather report code. In this way the ARDS data will contribute to analyses of enhanced accuracy in the Antarctic, with its consequent positive effect on prognoses initiated from such analyses.

2. Satellite Observations

The interpretation of weather satellite observations in the Antarctic can be improved by using ARDS data as truth measurements. ARDS and satellite data can be mutually supportive. It is recommended that studies in this area be initiated.

3. Vertical Profiles of the Atmosphere

For the most part ARDS flights have been flown at a constant flight level. A significant data set could be created by flight missions designed to establish vertical profiles at several points along a reference line. From these data much could be learned about the dynamics/thermodynamics of the polar atmosphere. Experiments of this type along the ice-water interface in polar regions should be especially valuable.

4. International Programs

ARDS may play a useful role in providing atmospheric data for current and future multi-national meteorological experiments in polar regions. Examples are the Polar Experiment (POLEX), First Global Atmospheric Research Program (GARP) Global Experiment (FGGE), and the international climate research effort planned for the 1980's. The use of the ARDS

should be maximized in these programs since the ARDS represents an asset already in operation, thus requiring little in the way of further developmental costs.

APPENDIX - Description of Computer Software Developed for Processing ARDS Data.

1. Raw Data Processor

The IBM 360 FORTRAN G processing program developed to process the raw ARDS data uses tape-based input except for several control cards which allows the user to choose the output mode and where, in the raw data, to begin the processing task. It is only necessary for the user to know the number of records in each file before executing the processor routine. This information may be obtained by a brief execution of a utility program which counts the number of records and files on an input tape.

The processor accepts an ARDS input tape written in odd parity at 800 bits-per-inch (BPI). The raw ARDS data tape is an unlabeled tape and is read as variably blocked records. The logical record length is 2052 8-bit bytes; block size is 2056 bytes; and density code is 3. A subroutine, "TAPRD", available from the W. R. Church Computer Center, NPS, was used to read the raw ARDS data records.

The user is given the option of printer output, magnetic tape output, or both. If tape output is chosen, the output is written at 1600 bits-per-inch, in records 1972 bytes (493 words) in length. Only one data file is written on output for each ARDS input tape processed. Labeled output files of processed data are shorter in length than the input data stream and several may be placed on a single output tape. The printer option prints the output record in a hexadecimal format. This option has been retained from the

period of processor development and has admittedly lost its usefulness now that the processor is operational.

The time required to process an input tape depends upon its length. A full six-hour data sample requires about an hour of computer time. It was inconvenient to request such a large block of computer time; therefore, the program was equipped with the ability to terminate itself after a user-determined period by monitoring the computer's time clock. The processing then may be restarted, at a later time, at the point where the previous processing was terminated. This capability proved extremely useful when the computer workload was high.

The reason for what may be considered an extraordinarily lengthy processing time is the need to convert the data to a binary form for mathematical manipulation. The only way to access a 4-bit BCD digit of raw ARDS data using IBM 360 FORTRAN G is by use of the "LOGICAL*1" variable type for each raw data 4-bit BCD digit. A six-digit number requires six multiplications by multiples of ten in order to convert it to binary form. The complication of several different channel formats in the raw ARDS data required an exceptional number of "IF" statements which are notoriously slow to execute. This, coupled with the desire to average all data scans for the same time (in seconds), and the need to check for test voltages, resulted in the lengthy run time.

The first control card contains a printer/tape option code and the total number of files on the raw ARDS data tape.

The cards which follow the initial control card are in the order of the files on the input tape. There are either one or two cards. The first card contains the number of records in the file corresponding to that control card and a code which determines whether the file is processed or by-passed. If the file is to be processed, the code determines where, within that file, to begin the processing. If the processing is to begin at an interior point in the file rather than at the beginning of the file, a second control card must follow the first card for that file. This second card contains the record and word within that record where processing is to begin; it also contains positioning information for the output tape to allow processing to commence at the same location where termination occurred earlier. The input and output positioning information for a restart is obtained from the computer printout of the previously terminated processing run.

Each channel of the raw ARDS data is treated in a manner designed to make it compatible with later statistical treatment.

2. Statistical Processing Program

A single software program was used to obtain the running averages and standard deviations of ARDS processed data. This program operates on a single ARDS parameter such as pressure, temperature, etc., during a single reading of a data file. The program possesses the capability to loop back and make as many passes as the user may desire, each time computing the statistics of a single ARDS channel.

This program can direct the output to the printer, magnetic tape, or both. The user can easily modify the time interval over which the averaging takes place. He can also change the output mode by specifying output at discrete time intervals or output at increasing or decreasing latitude spacing. The averaging interval and the printing cycle are independently controlled. The standard deviation is computed only for those averages and sample groups which are to be printed.

The maximum time of a sample is 900 seconds (15 minutes). The running average progresses by dropping the oldest 1-second datum in the sample array and adding the next one in succession. Only those data which fall within pre-established tolerances are included in the averaged sample. This "filter" prevents the possibility of test voltages or spurious signals contaminating the output. The printout lists the number of data points which compose the average in order that the user may judge the representativeness of the sample and statistics. The user determines the beginning and ending times for each series of running averages by control card entries.

3. Utilitarian Software

In order to fully investigate occasional erratic behavior in the data, it was necessary to develop a simple routine to provide a printer listing of one or more parameters over a specified time span or spatial interval. This routine was modified as the need arose to allow the

investigator to examine the data in the manner dictated by the situation.

4. Wind Investigation

When it appeared that the investigation might have to proceed with unrealistic wind data, an attempt was made to derive the wind from other parameters. This work was halted when the 8-12 November 1977 data were received. However, some software were developed after researching classical aerodynamic theory and the techniques used in the AWRS to obtain wind speed and direction. Several approaches were tried, some showing promise, others not. The biggest problem encountered was the unavailability of appropriate constants of proportionality needed in the mathematical relationships. The merit in pursuing this effort is contingent on the proposed improvement in ARDS-derived winds and the desirability of a back-up procedure to compute wind.

TABLE I. Ordered Listing of ARDS Channel Assignments and Data Characteristics (after Schoenhals, 1976).

CHANNEL NO.	ARDS PARAMETER	SIGNAL SOURCE	RESOLUTION AND UNITS	RANGE	SIG. FIGS.	TEST VOLTAGE HIGH	TEST VOLTAGE LOW	NOTES
00	Frame Sync	Master Control			6			Always 777777
01	Identification	Master Control			6			1
02	Mo/Day/Year (Date)	Master Control		0-123199	6			1,2
03	Hr/Min/Sec (Time)	Master Control		0-235959	6			
04	Quadrant(MSD)/ Latitude	LTN-51 INS	0.1 min.	0-90	6			3
05	Longitude	LTN-51 INS	0.1 min.	0-180	6			
06	Absolute Altitude (low)	APN-194 Radar	1 ft.	0-5000	4	4096	0512	4,6
07	Spare (Manual)							1,7
08	Pressure Altitude	Garrett Pressure Transducer	1 ft.	0-80000	5	33333	11111	
09	Spare (Manual)							1,7
10	Angle of Attack Pressure Force	Rosemont Pressure Transducer	0.01 mb.	$\pm$ 92.00	6	5000	905000	4,6
11	Angle of Side-slip Pressure Force	Rosemont Pressure Transducer	0.01 mb.	$\pm$ 92.00	6	5000	905000	4,6

TABLE I. (continued)

CHANNEL NO.	ARDS PARAMETER	SIGNAL SOURCE	RESOLUTION AND UNITS	RANGE	SIG. FIGS.	TEST VOLTAGE HIGH	TEST VOLTAGE LOW	NOTES
12	Drift Angle/ True Heading	LTN-51 INS	1 deg./ 1 deg.	± 39/ 0-360	3 3			5
13	Heading/True Airspeed	C12 Compass #1/TAS Computer A/A 24G-9	1 deg./ 1 knot	0-360/ 70-450	3 3	24033	120167	6
14	Heading/True Airspeed	C12 Compass #2/TAS Computer A/A 24G-9	1 deg./ 1 knot	0-360/ 70-450	3 3	24033	120167	6
15	Track Angle/ Ground Speed	LTN-51 INS	1 deg./ 1 knot	0-360/ 0-999	3 3			5
16	Drift Angle/ Ground Speed	APN-147 Doppler Radar	1 deg./ 1 knot	0-360/ 0-999	3 3			5
17	Spare (Manual)							1,7
18	Static Pressure	Garrett Pressure Transducer	0.001 in Hg.	3-31.000	5	33333	11111	6
19	Wind Direction/ Wind Speed	LTN-51 INS	1 deg./ 1 knot	0-360/ 0-379	3 3			
20	Static Pressure	Garrett Pressure Transducer	0.01 mb.	100-1050	6			
21	Differential Pressure	Rosemont Pressure Transducer	0.01 mb.	0-204.00	6	016490	003990	6

TABLE I. (continued)

CHANNEL NO.	ARDS PARAMETER	SIGNAL SOURCE	RESOLUTION AND UNITS	RANGE	SIG. FIGS.	TEST VOLTAGE HIGH	TEST VOLTAGE LOW	NOTES
22	Total Temperature	Rosemont Pressure Transducer	0.01C	-99.00 to +64.00	6	002530	906030	4,6
23	Frostpoint Temperature	General Eastern Hygrometer 1011	0.1°C	-75.00 to +50.0	6	00 777	9 0888	4,6
24	Free-Air Temperature	Hewlett-Packard Quartz Thermometer 2801	0.01°C	-80.00 to +99.99	5	0 8324	9 4884	4,6
25,26, 27	Nuclei Count	Nuclei Counter			4			
28	Ozone Concentration	Unknown			6			
29-	Special Sensors							8

NOTES:
1. Manually entered
2. MSD set to 8 for LOW test; set to 9 for HIGH test; otherwise set to MSD of month.
3. MSD determines quadrant
   1 = NE 3 = SE 5 = SW 7 = NW
4. MSD determines sign
   9 = minus 0 = plus
5. MSD determines direction
   9 = left 0 = right
6. Test tolerance ± 5 units
7. Specialized sensor data may be recorded for these channels
8. For recording of data from sensors supplied by principal investigators

Figure 1. The ARDS-equipped LC130R Aircraft.

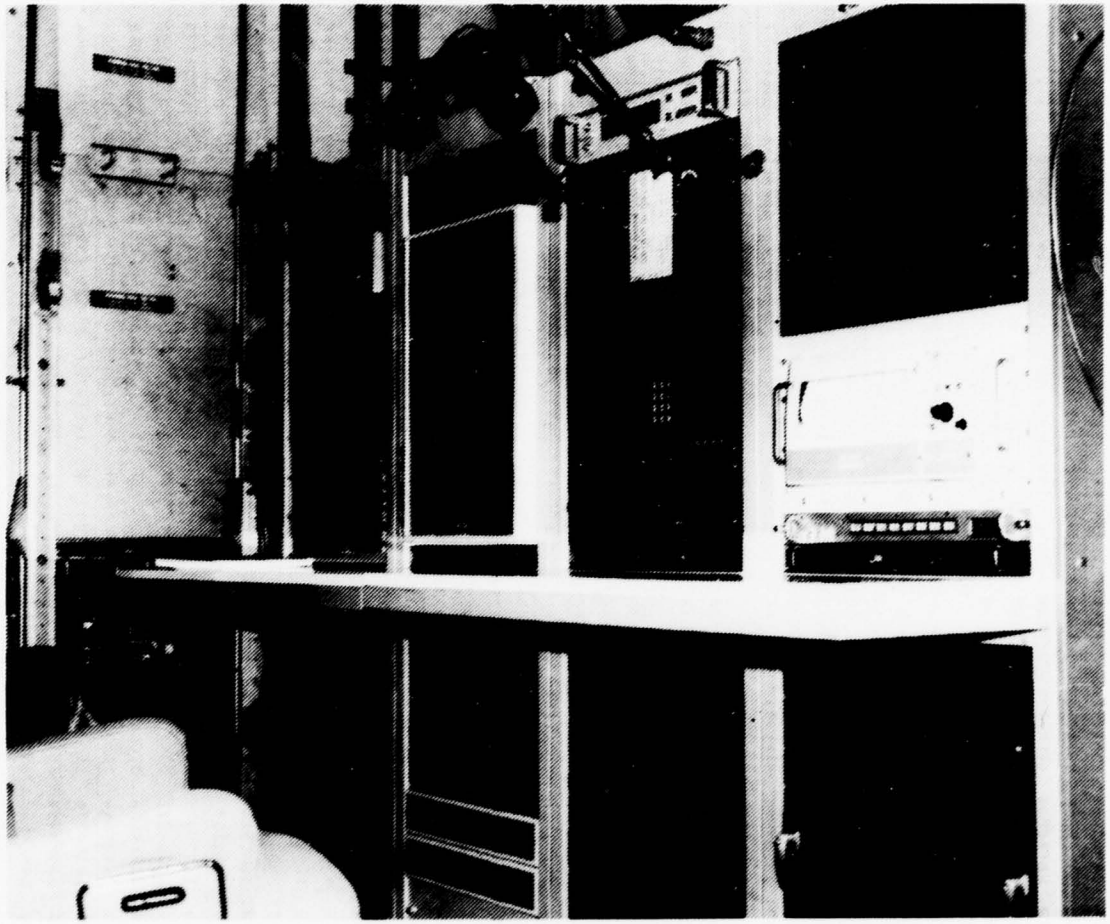

Figure 2. The Palletized ARDS Monitoring and Recording System.

00777777	01015019	02111077	03091936	04589546	05031178	06FF0005	07FFFFFF	08F11078	09090909	
10900041	11900227	12000075	13044071	14044069	15075004	16013509	17003390	18F19729	19076275	
20066781	21000000	22904210	239FF385	249F3988	25FFFFFF	26FFFFFF	27FFFFFF	28000000	29000000	
30011250	31FFFFFF	32FFFFFF	33000000	34FFFFFF	35FFFFFF	36FFFFFF	37FFFFFF	00777777	01015019	
02111077	03091935	04589546	05031178	06FF0006	07FFFFFF	08F11078	09090909	10900041	11900224	
12000075	13044069	14044070	15075004	16014557	17003340	18F19729	19076275	20066781	21000000	
22904209	239FF384	249F3988	25FFFFFF	26FFFFFF	27FFFFFF	28000000	29000000	30011249	31FFFFFF	
32FFFFFF	33000000	34FFFFFF	35FFFFFF	36FFFFFF	37FFFFFF	00777777	01015019	02111077	03091935	
04589546	05031178	06FF0003	07FFFFFF	08F11078	09090909	10900037	11900224	12000075	13044071	
14043069	15075004	16014593	17003308	18F19729	19076275	20066781	21000000	22904209	239FF385	
249F3988	25FFFFFF	26FFFFFF	27FFFFFF	28000000	29000000	30011249	31FFFFFF	32FFFFFF	33000000	
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36FFFFFF	37FFFFFF	00777777	01015019	02111077	03091936	04589546	05031178	06FF0000	07FFFFFF	
08F11079	09090909	10900037	11900224	12000075	13043071	14042071	15075004	16014530	17003295	
18F19729	19076275	20066781	21000000	22904210	239FF385	249F3988	25FFFFFF	26FFFFFF	27FFFFFF	
28000000	29000000	30011249	31FFFFFF	32FFFFFF	33000000	34FFFFFF	35FFFFFF	36FFFFFF	37FFFFFF	
00777777	01015019	02111077	03091936	04589546	05031178	06FF0006	07FFFFFF	08F11079	09090909	
10900037	11900218	12000075	13042070	14042071	15075004	16013510	17003295	18F19729	19076275	
20066781	21000000	22904210	239FF385	249F3988	25FFFFFF	26FFFFFF	27FFFFFF	28000000	29000000	
30011250	31FFFFFF	32FFFFFF	33000000	34FFFFFF	35FFFFFF	36FFFFFF	37FFFFFF	00777777	01015019	
02111077	03091936	04589546	05031178	06FF0002	07FFFFFF	08F11080	09090909	10900038	11900218	
12000075	13043070	14042070	15075004	16013426	17003271	18F19728	19076275	20066777	21000000	
22904210	239FF385	249F3988	25FFFFFF	26FFFFFF	27FFFFFF	28000000	29000000	30011250	31FFFFFF	
32FFFFFF	33000000	34FFFFFF	35FFFFFF	36FFFFFF	37FFFFFF	00777777	01015019	02111077	03091936	
04589546	05031178	06FF0003	07FFFFFF	08F11080	09090909	10900039	11900219	12000075	13042071	
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16014575	17003404	18F19727	19076275	20066773	21000000	22904212	239FF385	249F3988	25FFFFFF	
26FFFFFF	27FFFFFF	28000000	29000000	30011249	31FFFFFF	32FFFFFF	33000000	34FFFFFF	35FFFFFF	
36FFFFFF	37FFFFFF	00777777	01015019	02111077	03091936	04589546	05031178	06FF0003	07FFFFFF	
08F11081	09090909	10900039	11900205	12000075	13042071	14041070	15075004	16014332	17003404	
18F19727	19076275	20066773	21000000	22904213	239FF385	249F3988	25FFFFFF	26FFFFFF	27FFFFFF	
28000000	29000000	30011249	31FFFFFF	32FFFFFF	33000000	34FFFFFF	35FFFFFF	36FFFFFF	37FFFFFF	
00777777	01015019	02111077	03091936	04589546	05031178	06FF0002	07FFFFFF	08F11061	09090909	
10900040	11900205	12000075	13041070	14040070	15075004	16014061	17003390	18F19727	19073275	
20066773	21000040	22904213	239FF385	249F3988	25FFFFFF	26FFFFFF	27FFFFFF	28000000	29000000	
30011245	31FFFFFF	32FFFFFF	33000000	34FFFFFF	35FFFFFF	36FFFFFF	37FFFFFF	00777777	01015019	
02111077	03091937	04589546	05031178	06FF0005	07FFFFFF	08F11080	09090909	10900040	11900204	
12000071	13041071	14040071	15071004	16014545	17003390	18F19727	19073275	20066773	21000044	
22904214	239FF385	249F3988	25FFFFFF	26FFFFFF	27FFFFFF	28000000	29000000	30011244	31FFFFFF	
32FFFFFF	33000000	34FFFFFF	35FFFFFF	36FFFFFF	37FFFFFF	00777777	01015019	02111077	03091937	
04589546	05031178	06FF0005	07FFFFFF	08F11079	09090909	10900040	11900204	12000071	13041070	
14040071	15071004	16014274	17003354	18F19728	19073275	20066777	21000008	22904214	239FF385	
249F3989	25FFFFFF	26FFFFFF	27FFFFFF	28000000	29000000	30011244	31FFFFFF	32FFFFFF	33000000	
34FFFFFF	35FFFFFF	36FFFFFF	37FFFFFF	00000000	00000000	00000000	00000000	00000000	00000000	
00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000	00000000	

Figure 3. A Sample of Raw ARDS Data for 10 November 1977.

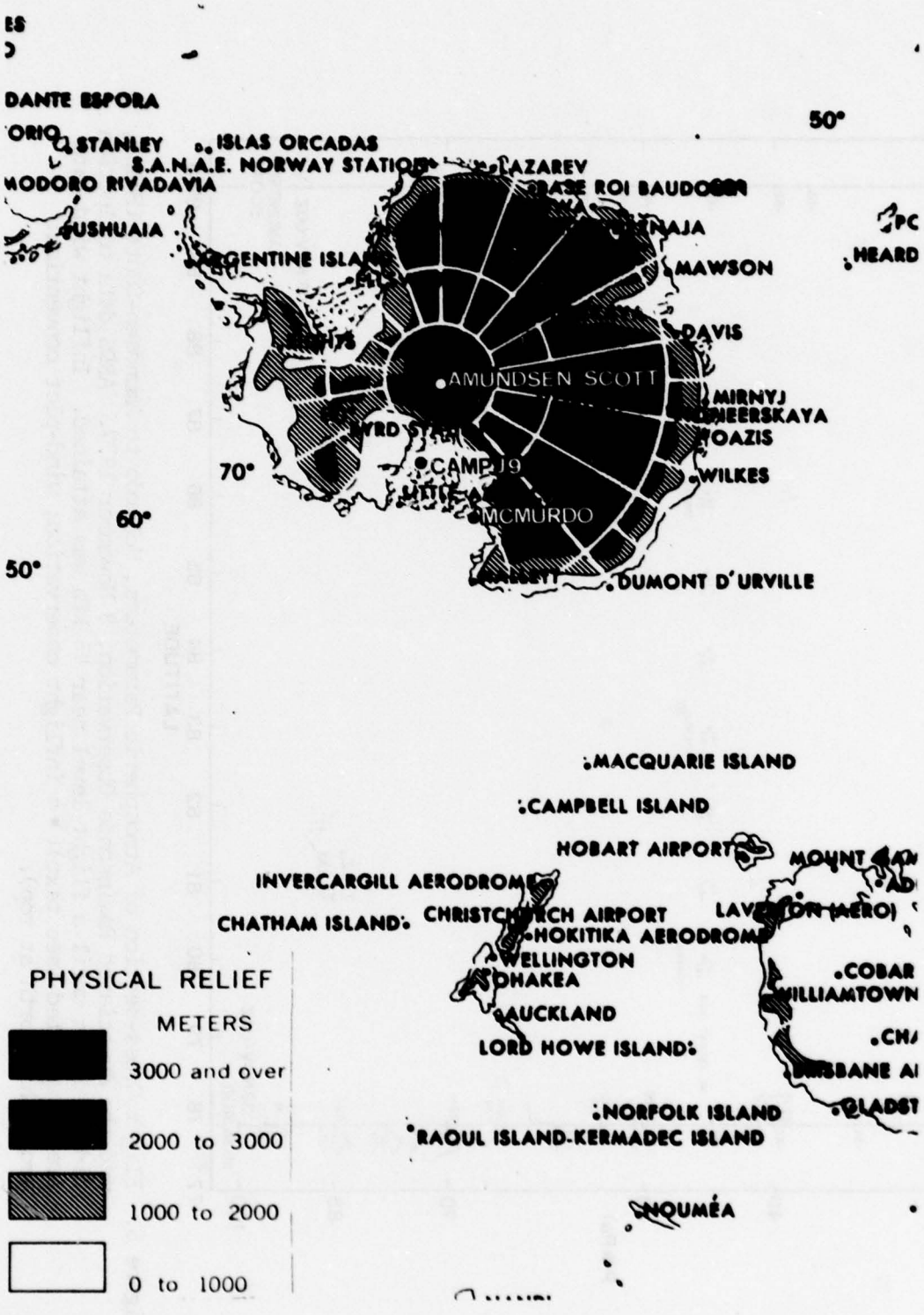

Figure 4. Locator Chart.

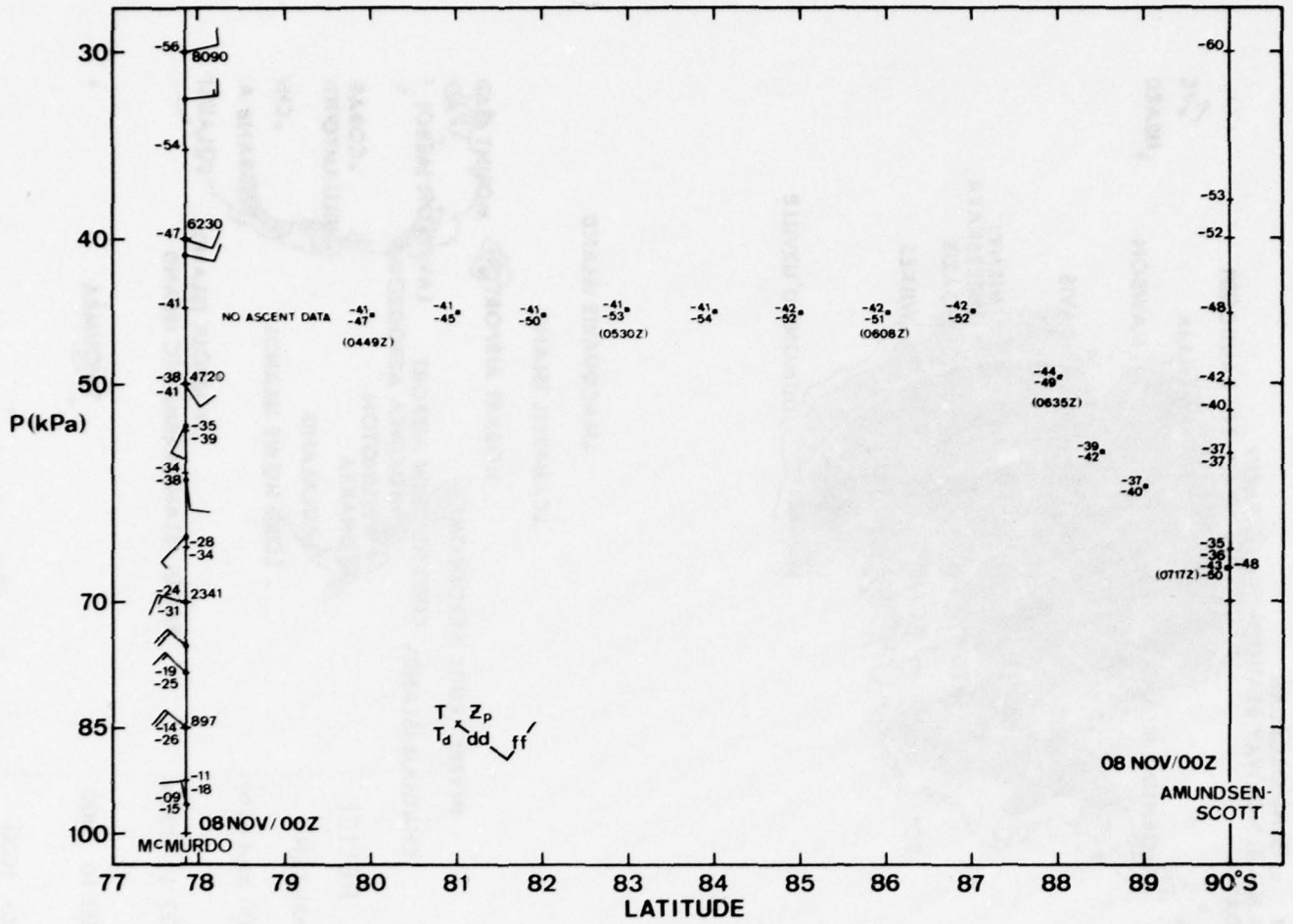

Figure 5. Flight Cross-section of Atmospheric Parameters, McMurdo to Amundsen-Scott (Pole), and the Associated Rawinsonde Observation, 8 November 1977. ARDS data collection did not begin until a flight level near 45 kPa was attained. Inflight wind data are not plotted (see text)(■ = inflight observation; wind-plot convention: geographic north at top).

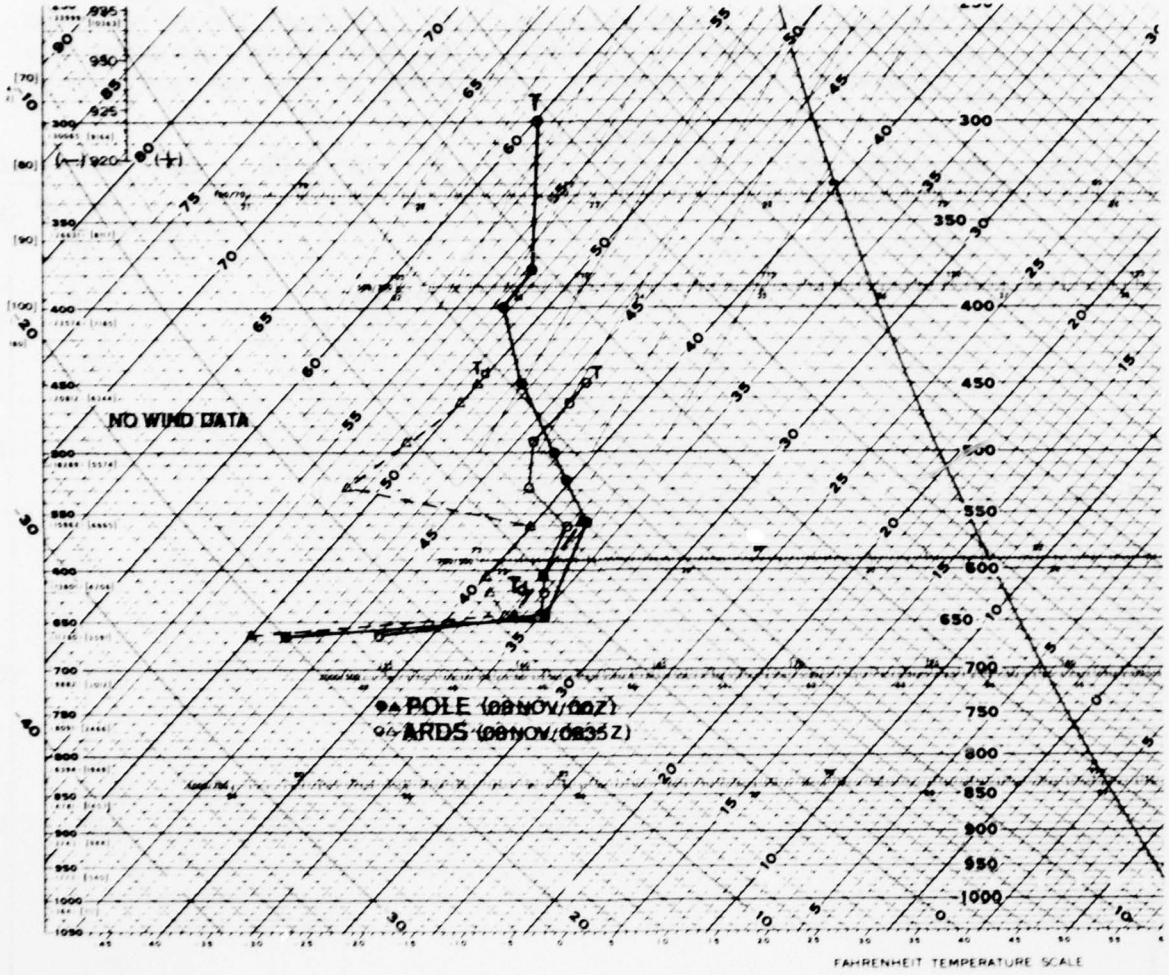

Figure 6. ARDS Descent and 00Z (GMT) 8 November 1977 Rawinsonde Data at Amundsen-Scott (Pole).

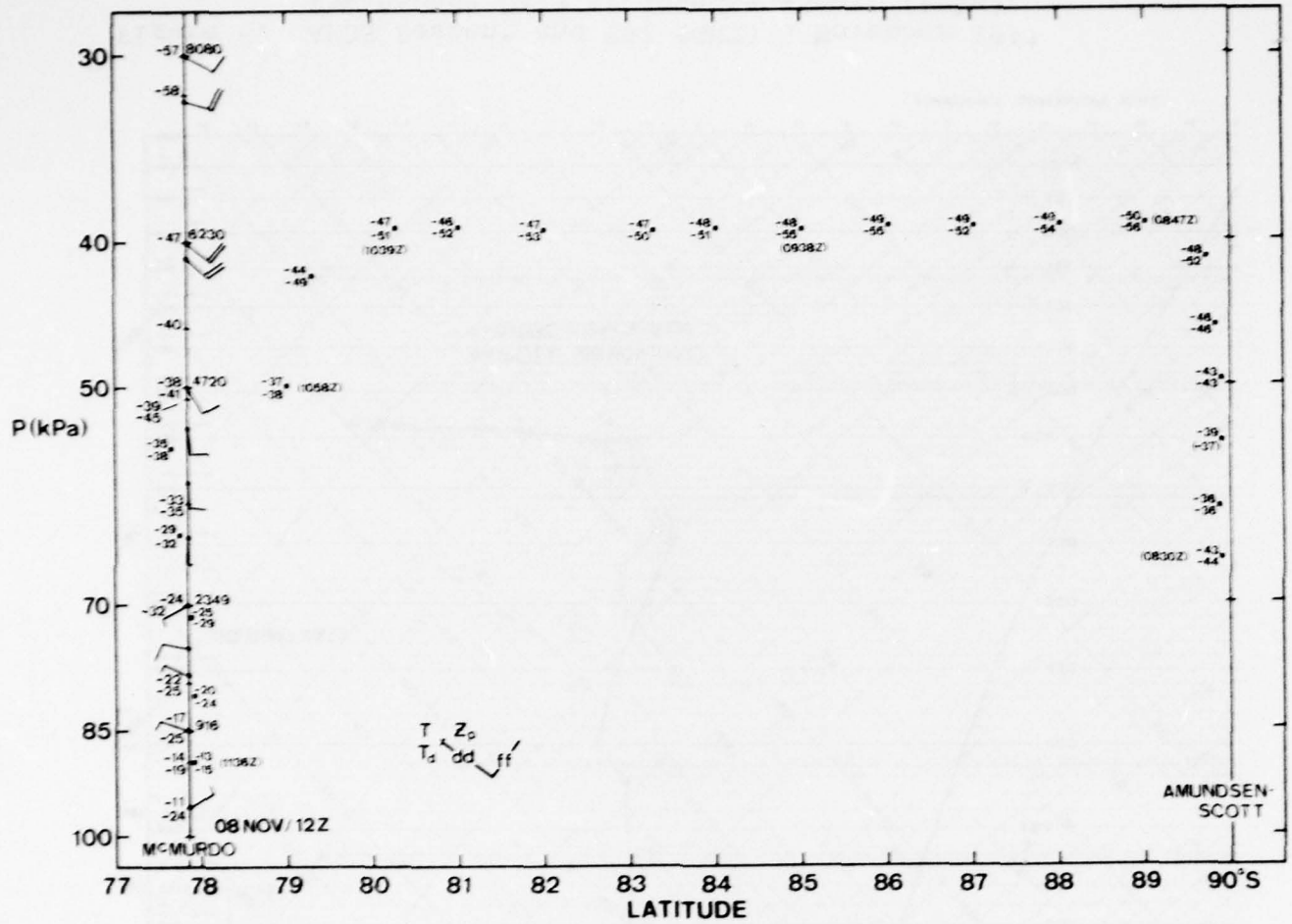

Figure 7. Flight Cross-section of Atmospheric Parameters, Amundsen-Scott (Pole) to McMurdo, and Associated Rawinsonde Observation, 8 November 1977. "No Data" portion occurred during loading of fresh magnetic tape. (■ = inflight observation; wind-plot convention: geographic north at top.)

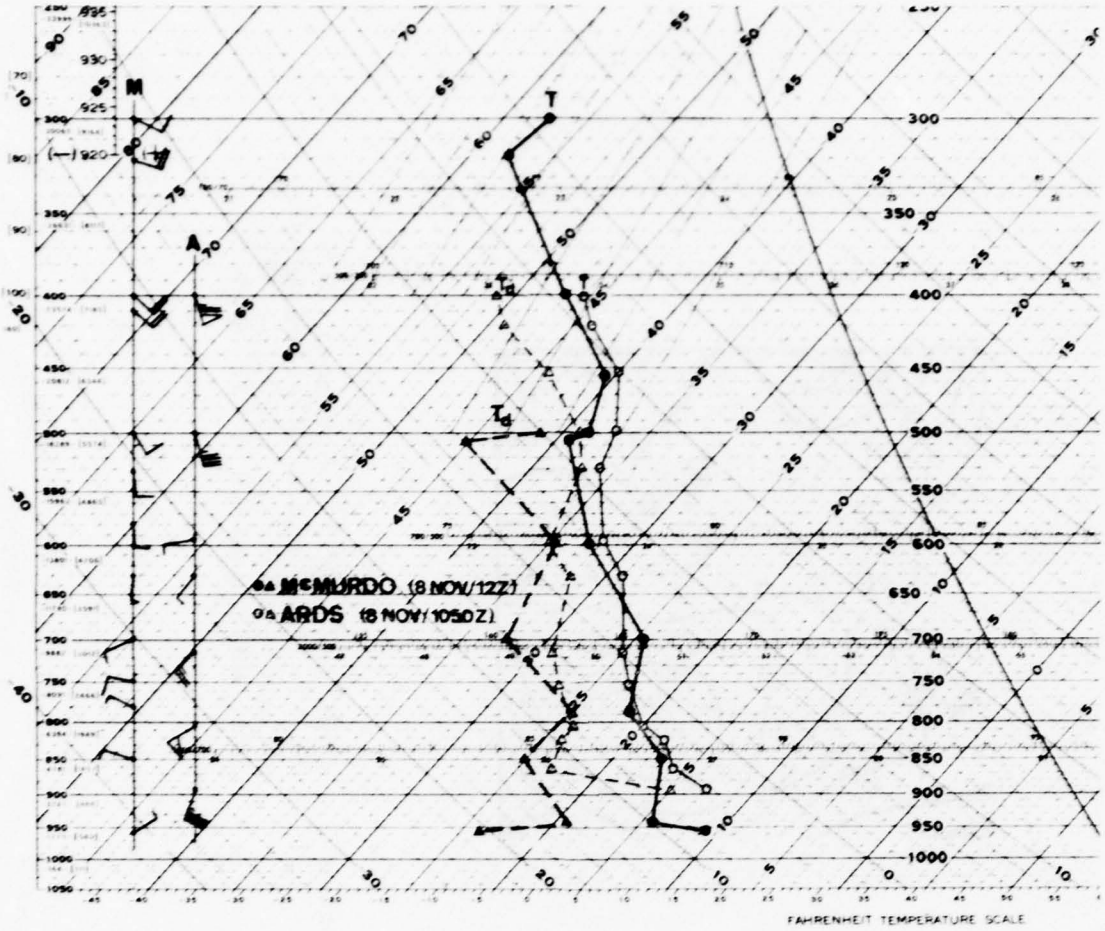

Figure 8. ARDS Descent and 12Z (GMT) 8 November 1977 Rawinsonde Data at McMurdo. ARDS winds illustrate wind problem encountered during this and other flights prior to this time. (Wind-plot convention: geographic north at top.)

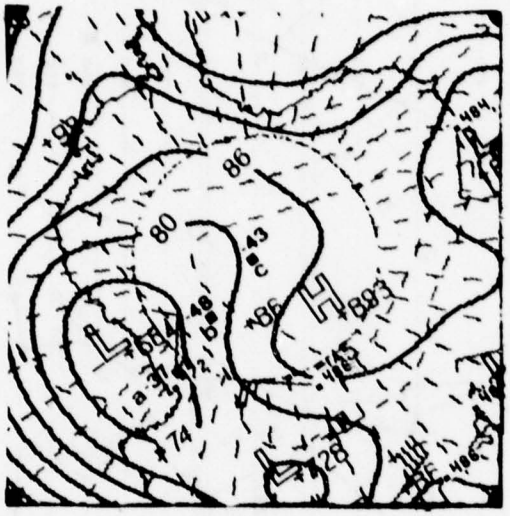

Figure 9. FNWC 12Z (GMT) 8 November 1977 50 kPa Analysis. Selected ARDS data: a- 50 kPa, 1058Z; b- 39.2 kPa, 0951Z; c- 49.8 kPa, 0834Z.

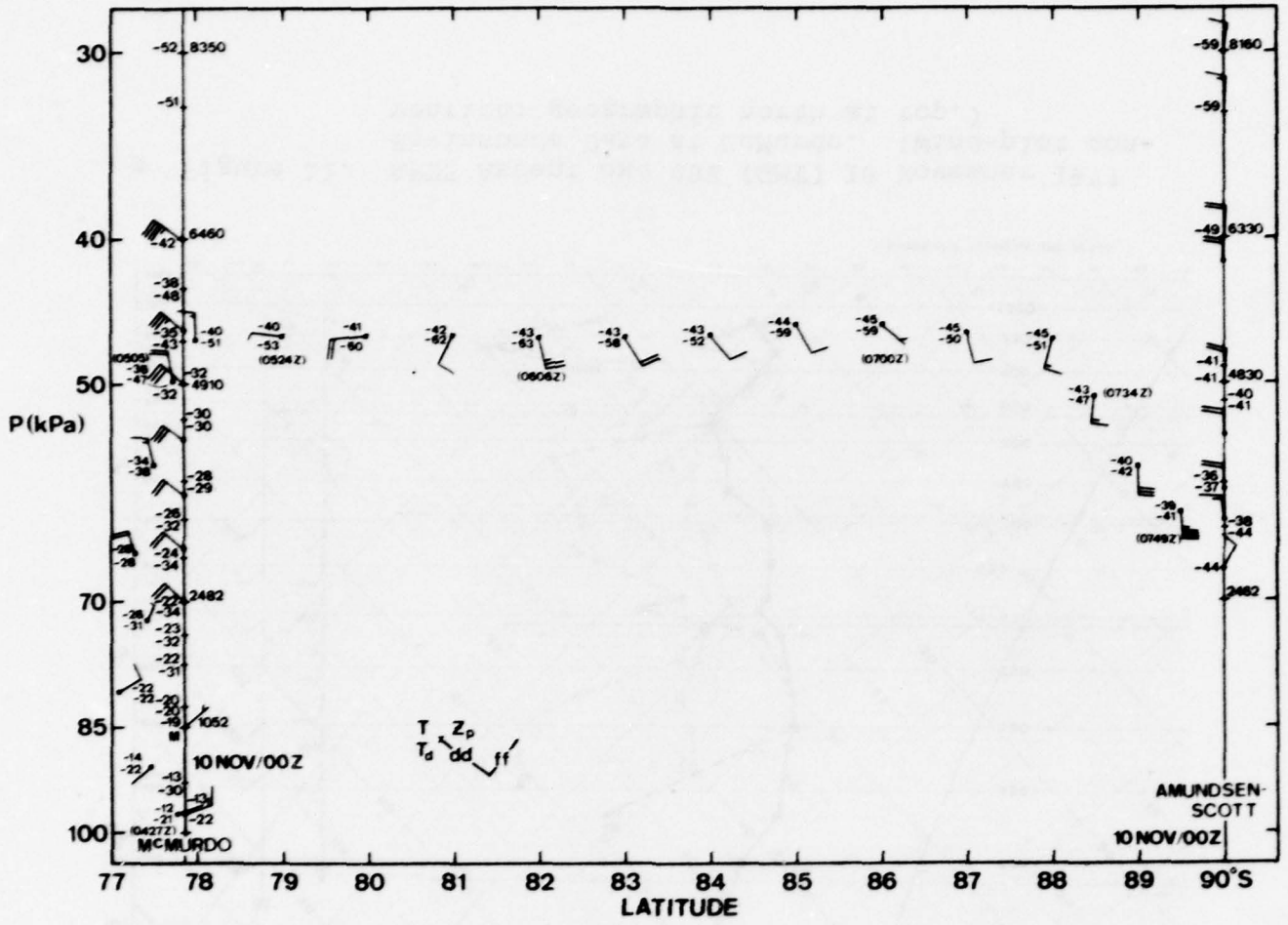

Figure 10. Flight Cross-section of Atmospheric Parameters, McMurdo to Amundsen-Scott (Pole), and Associated Rawinsonde Observations, 10 November 1977. ARDS winds this date represent the first use of new software in the LTN-51 INS computer. (■ = inflight observation; wind-plot convention: geographic north at top except grid north at top for Pole rawinsonde winds.)

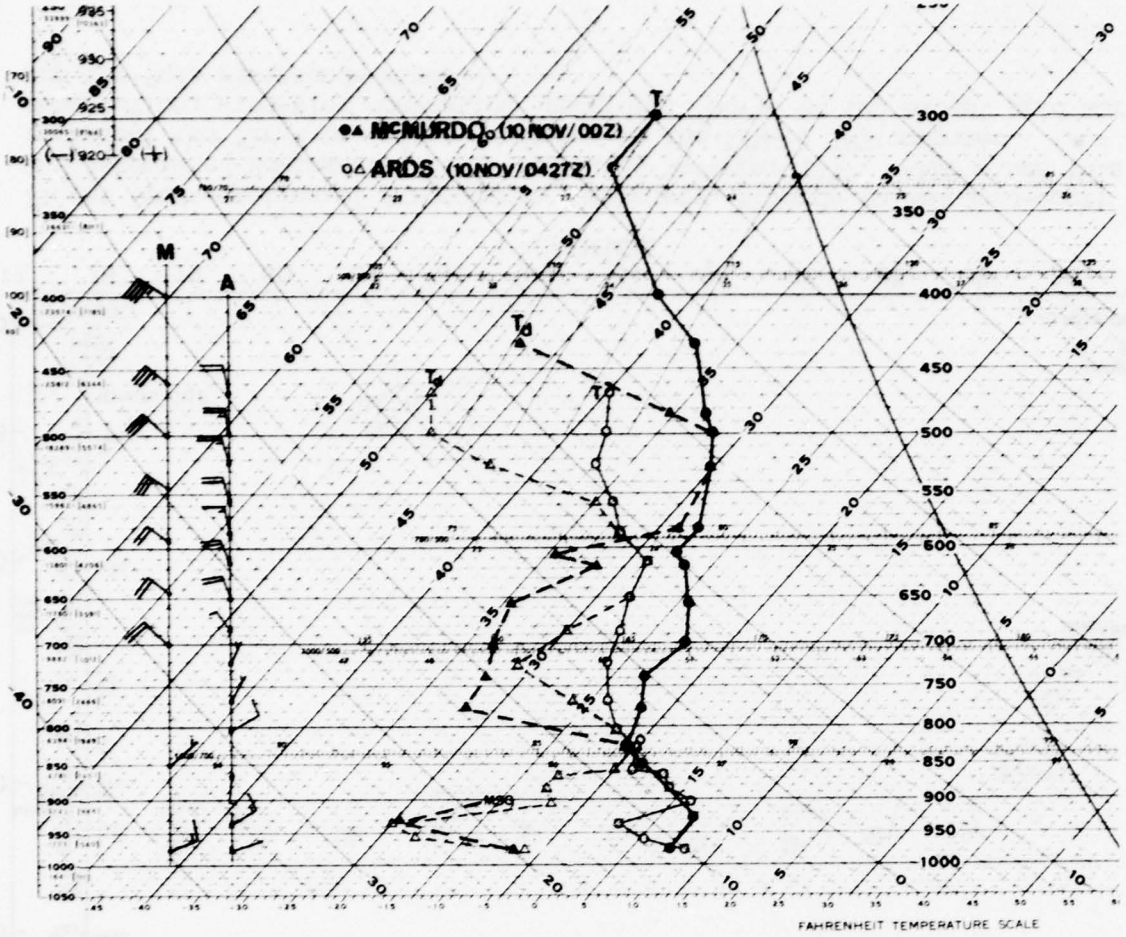

Figure 11. ARDS Ascent and 00Z (GMT) 10 November 1977 Rawinsonde Data at McMurdo. (Wind-plot convention: geographic north at top.)

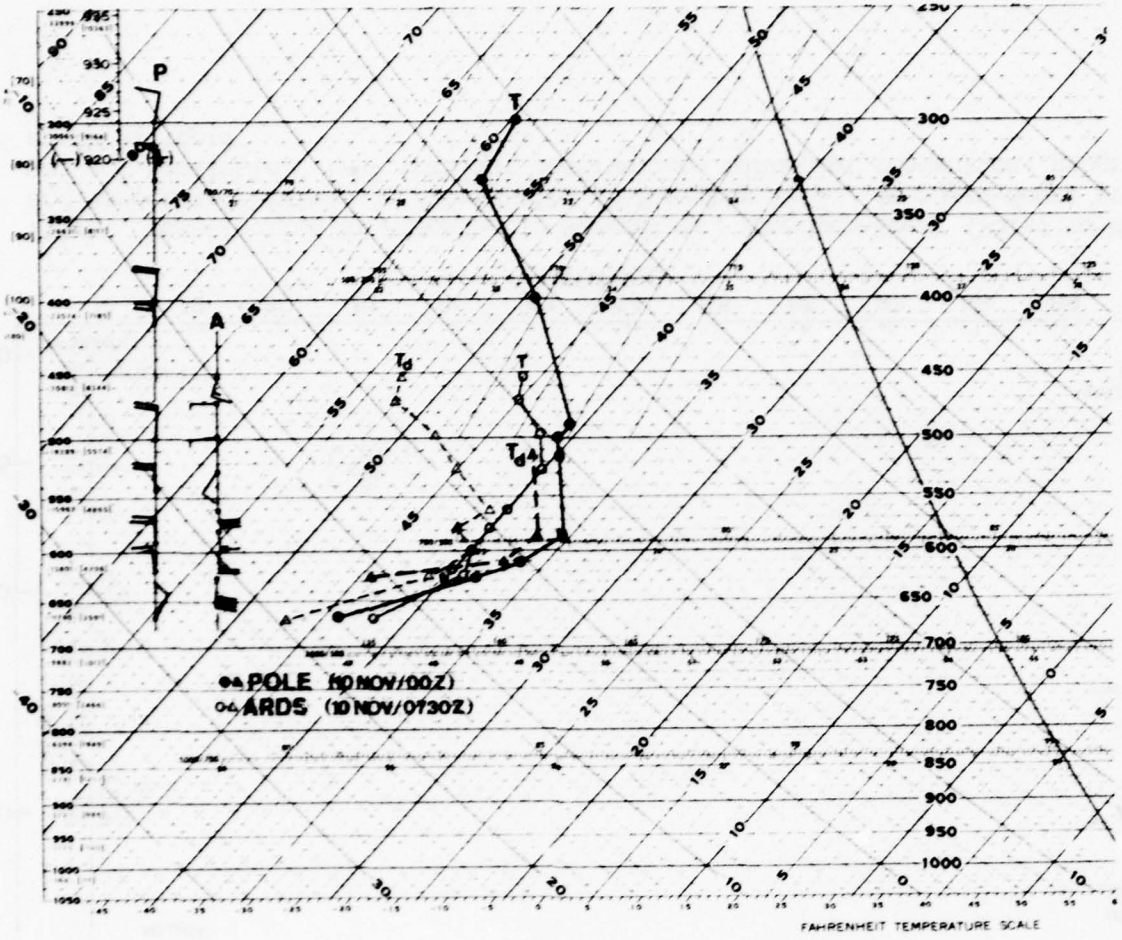

Figure 12. ARDS Descent and 00Z (GMT) 10 November 1977 Rawinsonde Data at Amundsen-Scott (Pole). (Wind-plot convention for ARDS: geographic north at top; for Pole rawinsonde winds: grid north at top.)

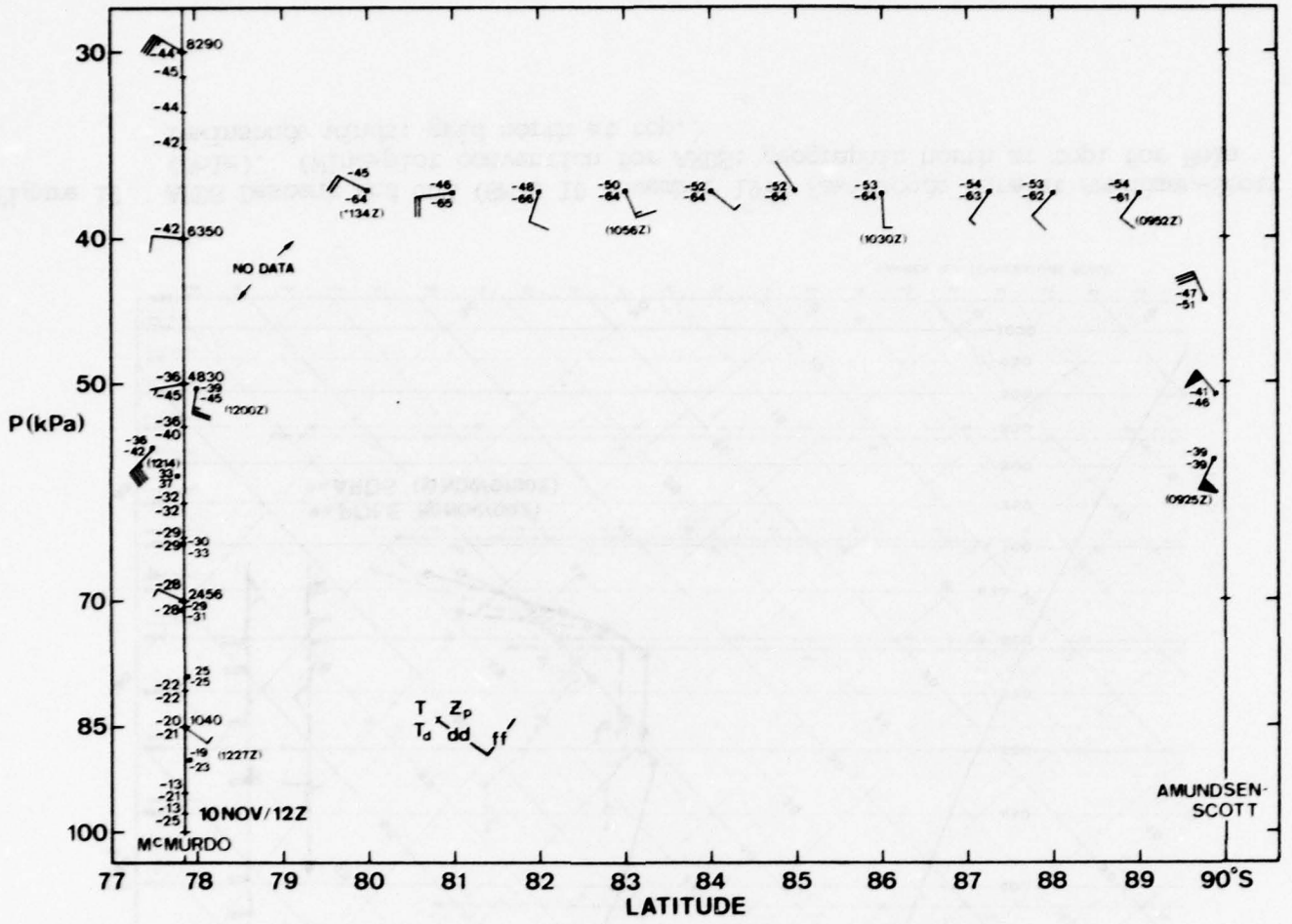

Figure 13. Flight Cross-section of Atmospheric Parameters, Amundsen-Scott (Pole) to McMurdo, and Associated Rawinsonde Observation, 10 November 1977. Amundsen-Scott sounding was not available. (■ = inflight observation; wind-plot convention: geographic north at top.)

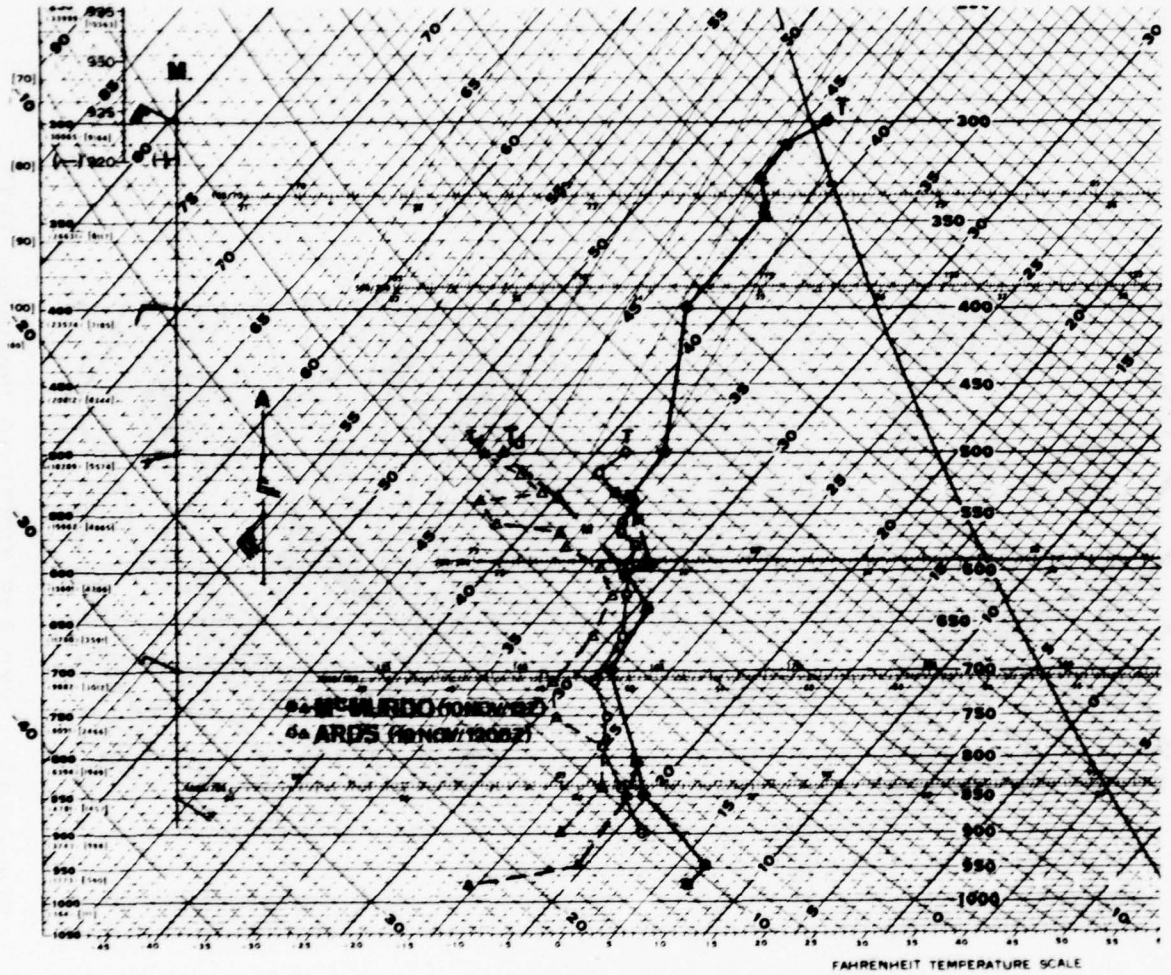

Figure 14. ARDS Descent and 12Z (GMT) 10 November 1977 Rawinsonde Data at McMurdo. (Wind-plot convention: geographic north at top.)

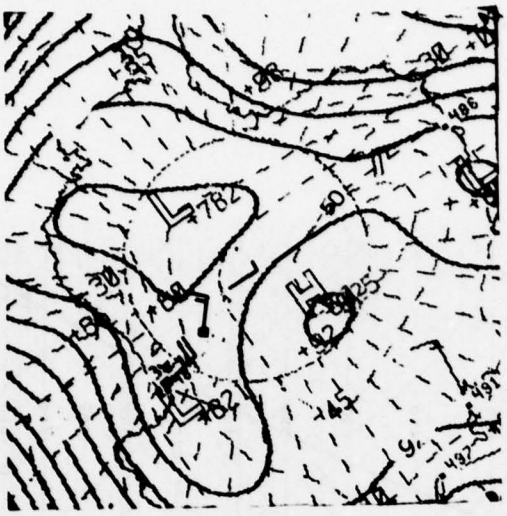

Figure 15. FNWC 12Z (GMT) 10 November 1977 50 kPa Analysis. Selected ARDS data: a- 50 kPa, 1203Z; b- 37.2 kPa, 1056Z; c- 37.3 kPa, 1004Z; d- 55.4 kPa, 0925Z.

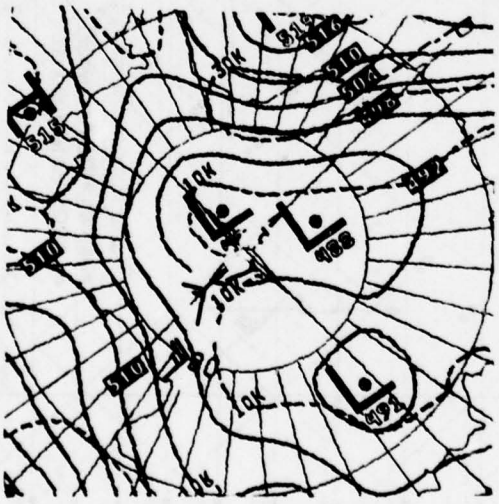

Figure 16. NMC 12Z (GMT) 10 November 1977 50 kPa Analysis. Selected ARDS data: a- 50 kPa, 1203Z; b- 37.2 kPa, 1056Z; c- 37.3 kPa, 1004Z; d- 55.4 kPa, 0925Z.

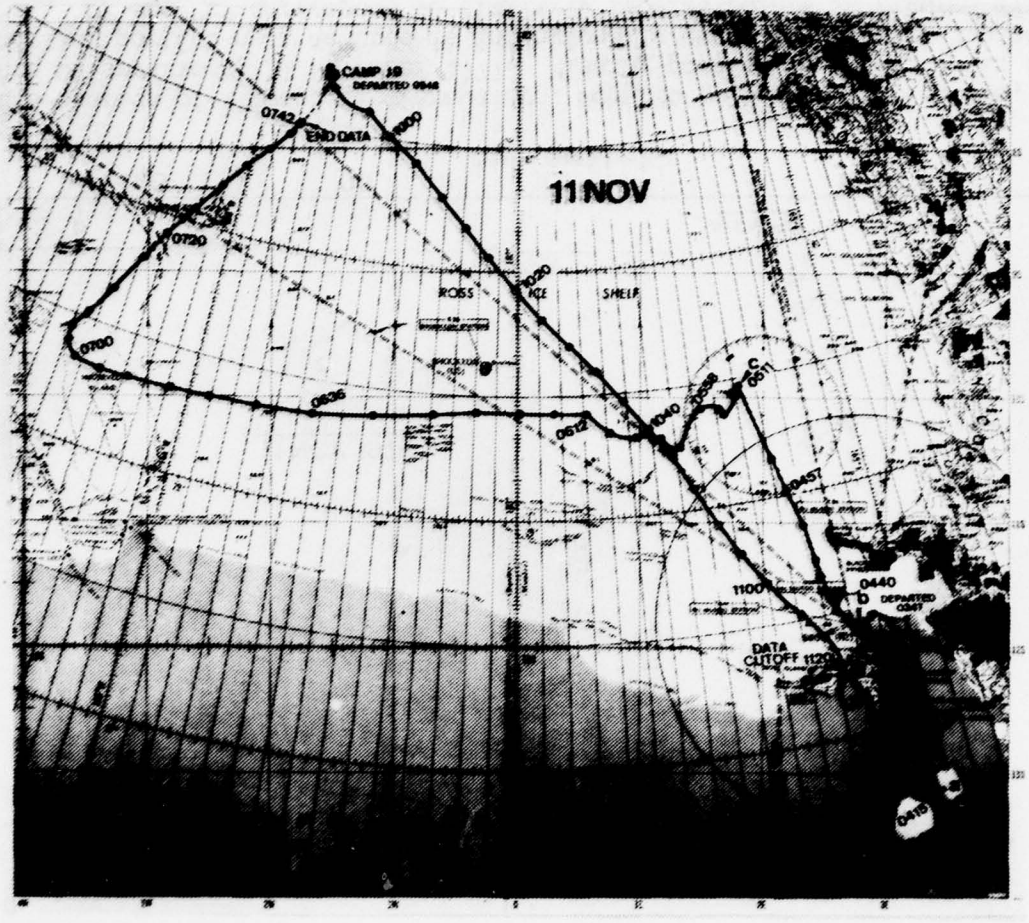

Figure 17. 11 November 1977 ARDS Flight from McMurdo to Camp J9 and Back. Points "a", "b" and "c" correspond to similarly labeled points in Figures 18 and 19.

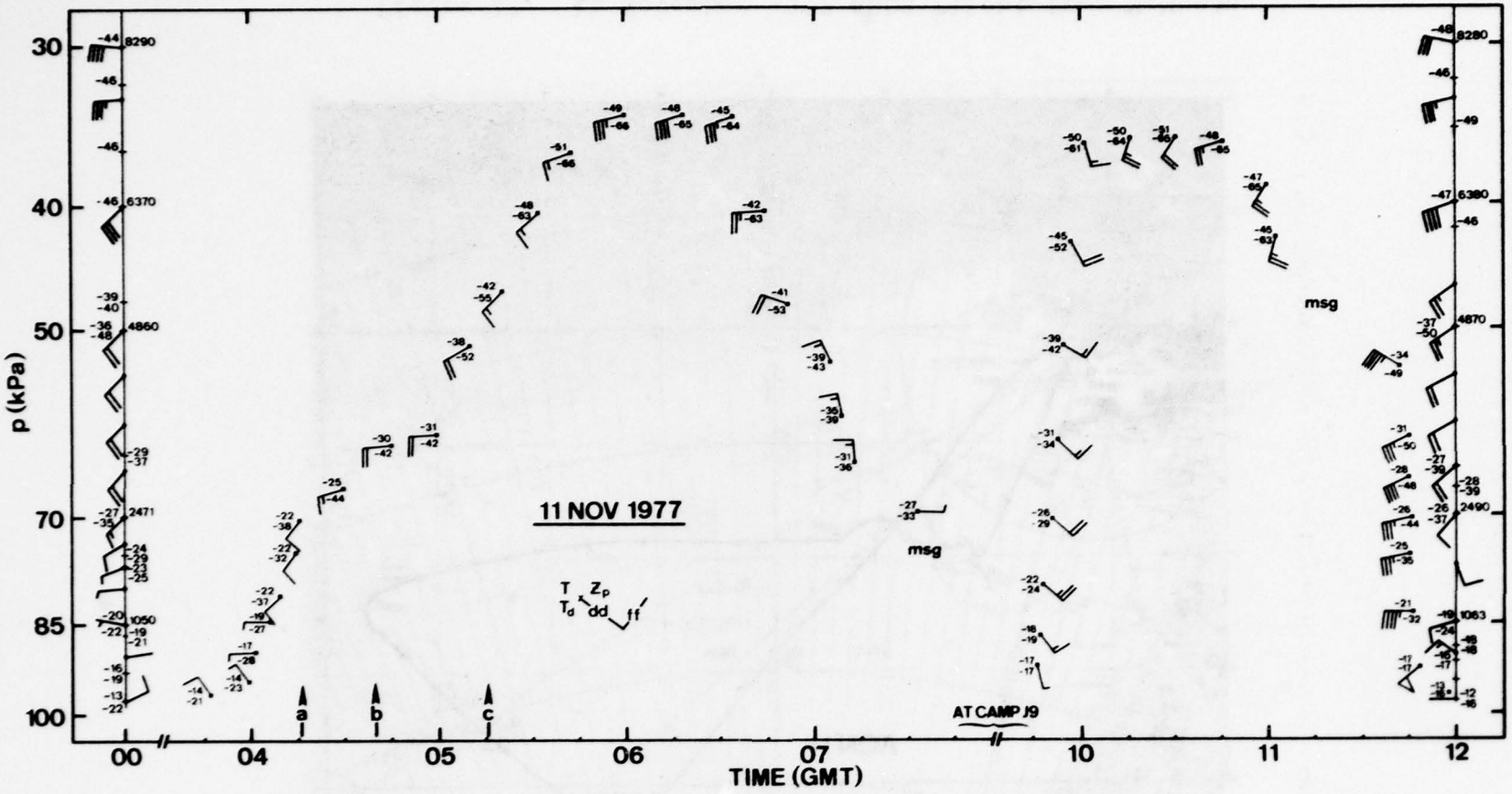

Figure 18. Time Cross-section of Atmospheric Parameters, McMurdo to Camp J9 and Return, and Associated Rawinsonde Observations, 11 November 1977. Missing portion near Camp J9 is due to end of data. Missing portion near McMurdo is intentionally created (aircraft "buzzed" Mount Erebus). Points "a", "b" and "c" correspond to similarly labeled points in Figures 17 and 19. (= inflight observation; wind-plot convention: geographic north at top.)

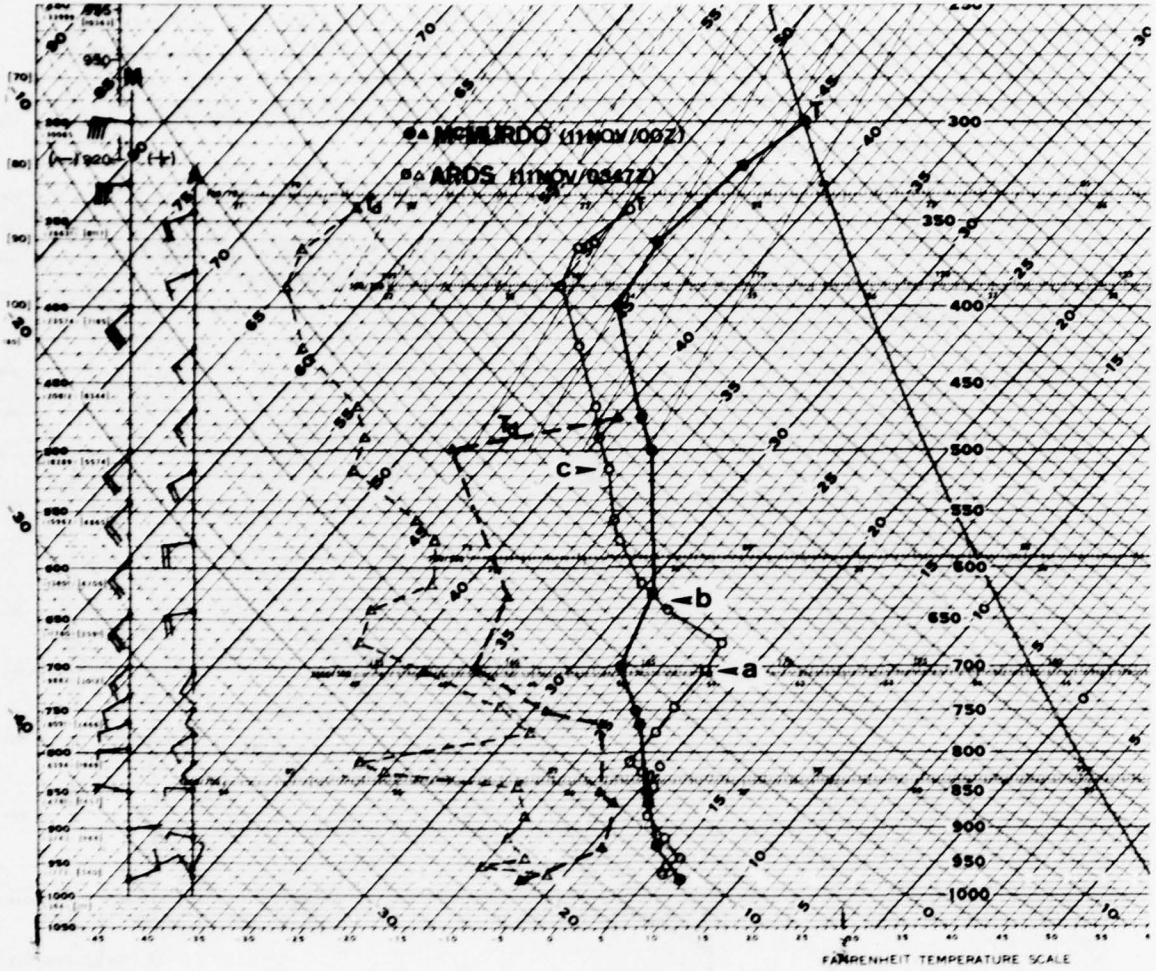

Figure 19. ARDS Ascent and 00Z (GMT) 11 November 1977 Rawinsonde Data at McMurdo. Points "a", "b" and "c" correspond to similarly labeled points in Figures 17 and 18. (Wind-plot convention: geographic north at top.)

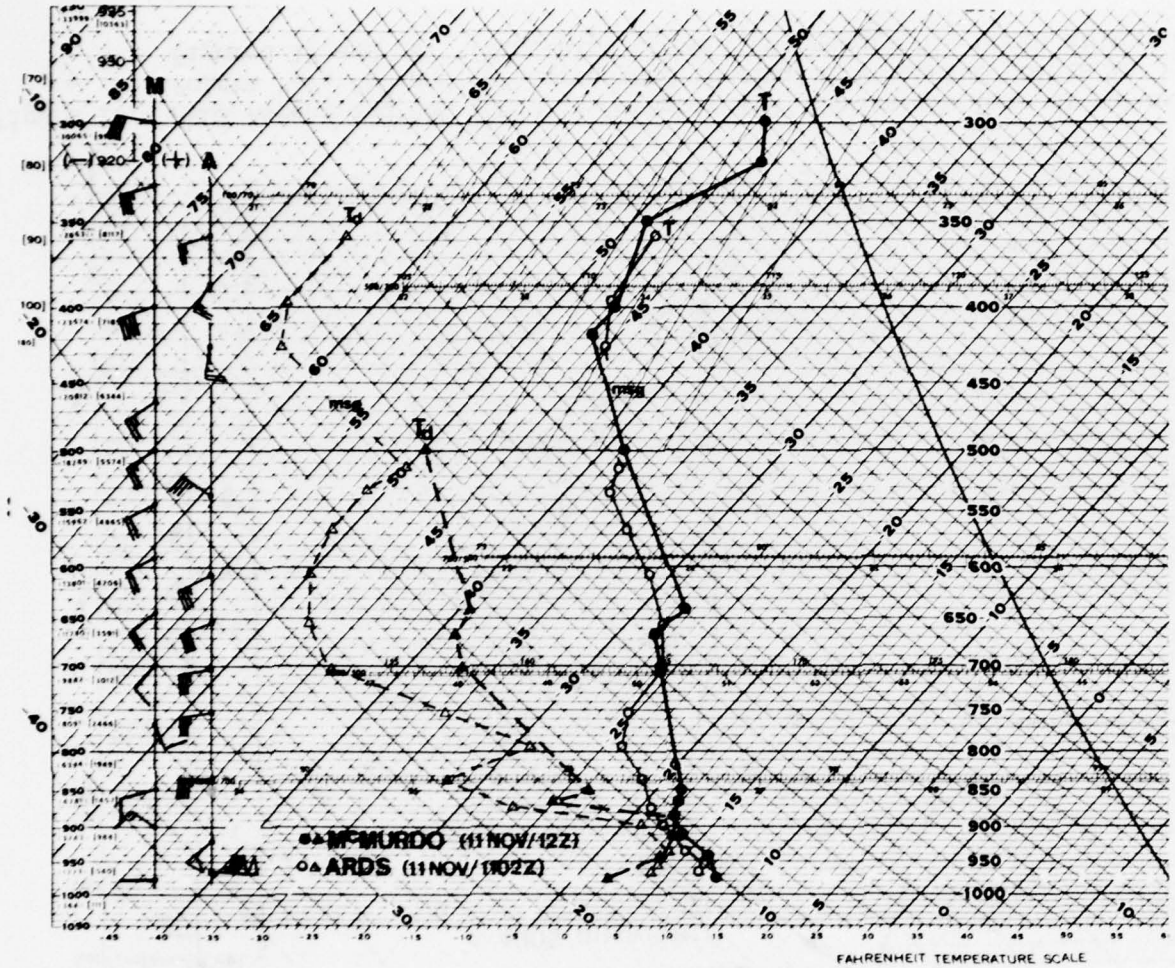

Figure 20. ARDS Descent and 12Z (GMT) 11 November 1977 Rawinsonde Data at McMurdo. Missing portion occurred during "buzzing" of Mount Erebus. 5-minute (30-second) averages above (below) missing portion of descent sounding. (Wind-plot convention: geographic north at top.)

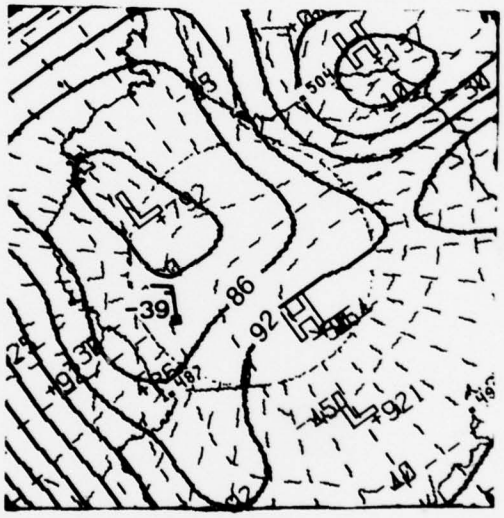

Figure 21. FNWC 12Z (GMT) 11 November 1977 50 kPa Analysis. Selected ARDS data: 51.6 kPa, 0953Z.

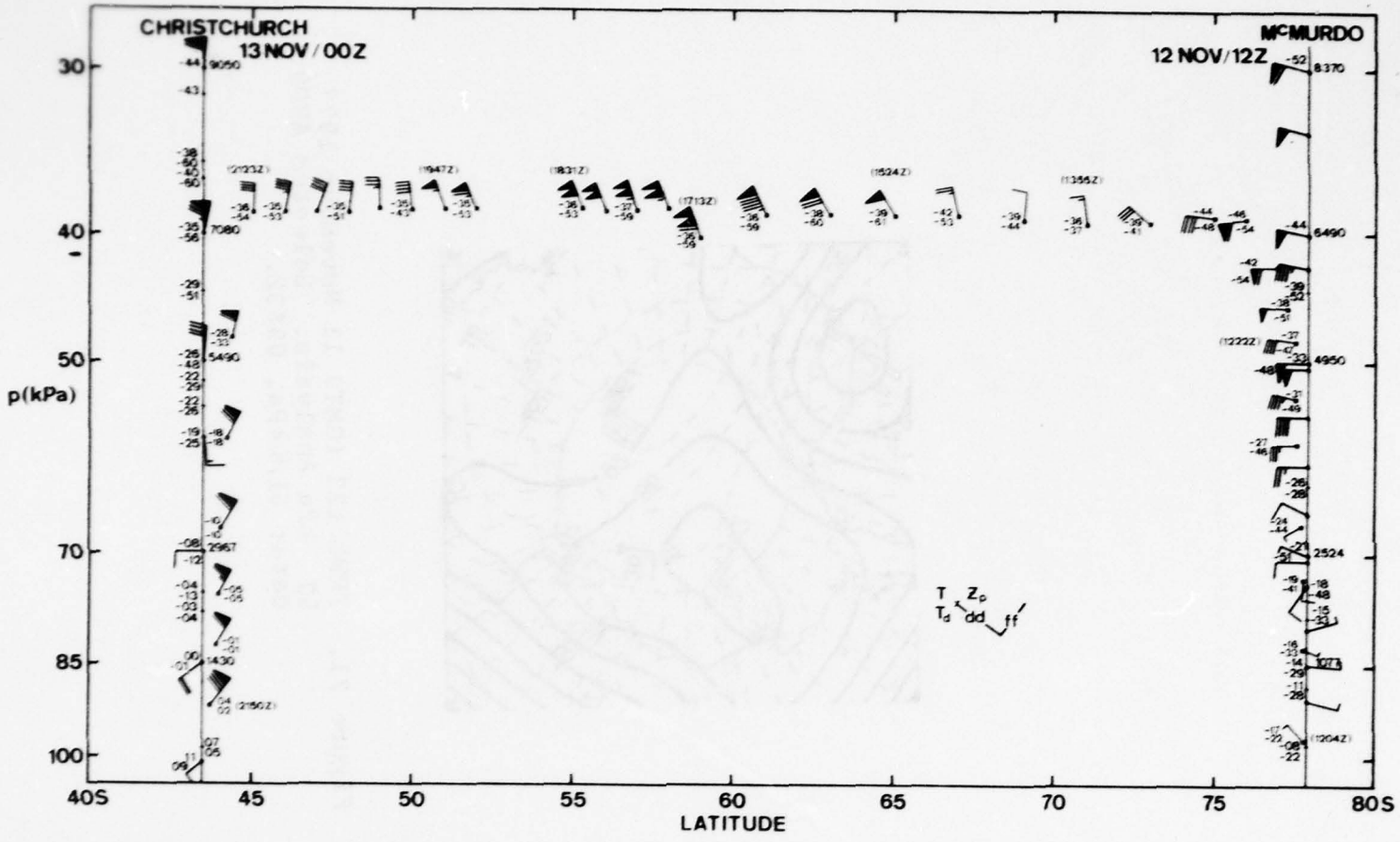

Figure 22. Flight Cross-section of Atmospheric Parameters, McMurdo to Christchurch, New Zealand, and Associated Rawinsonde Observations, 12/13 November 1977. (= inflight observation; wind-plot convention: geographic north at top)

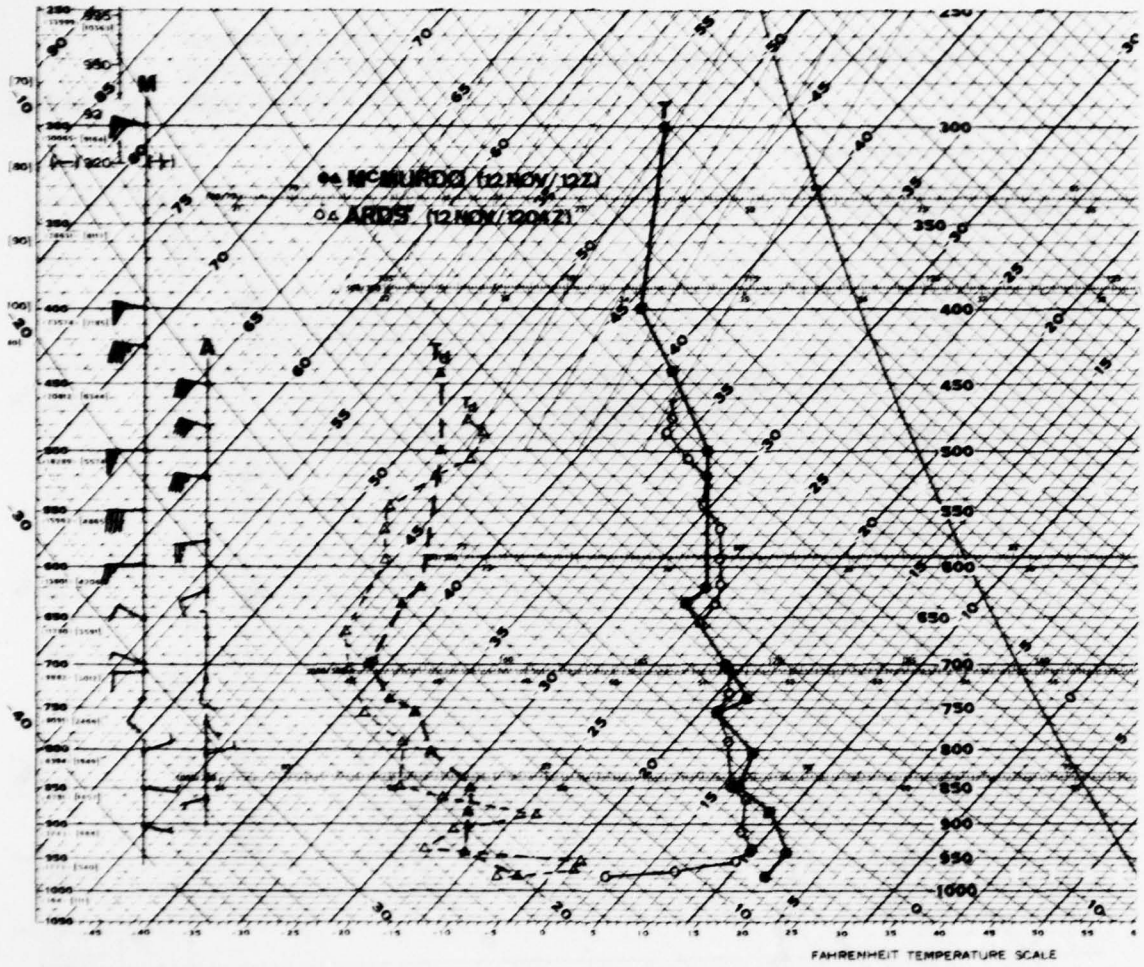

Figure 23. ARDS Ascent and 12Z (GMT) 12 November 1977 Rawinsonde Data at McMurdo. (Wind-plot convention: geographic north at top.)

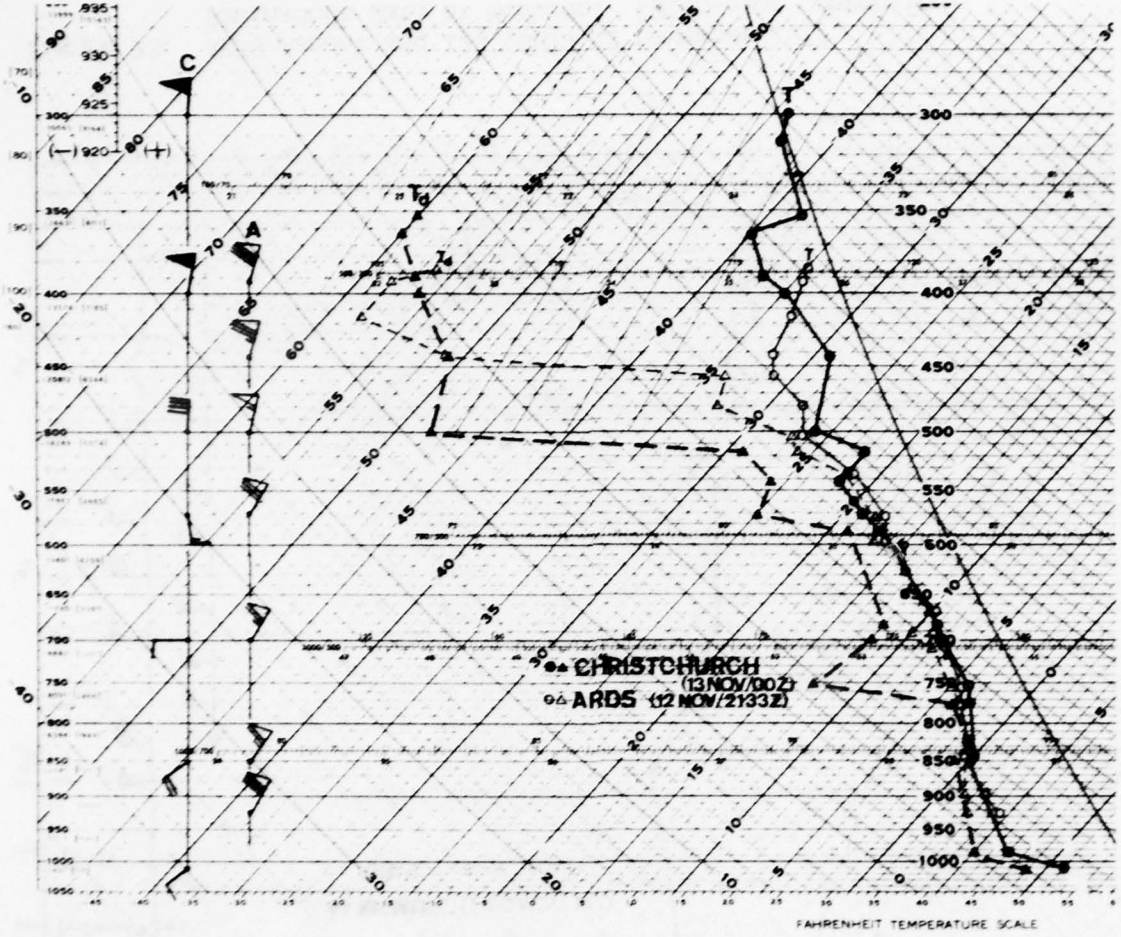

Figure 24. ARDS Descent and 00Z (GMT) 13 November 1977 Rawinsonde Data at Christchurch. (Wind-plot convention: geographic north at top.)

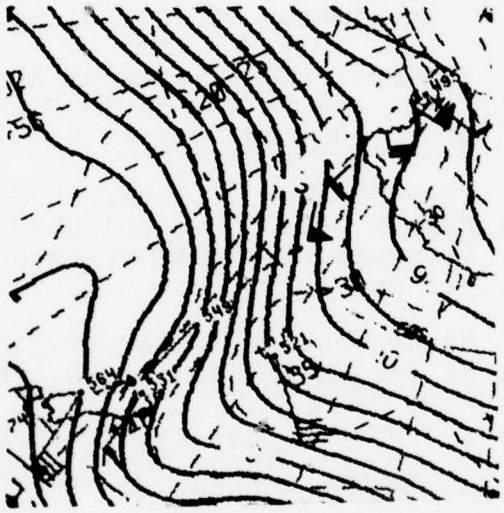

Figure 25. FNWC 12Z (GMT) 12 November 1977 50 kPa Analysis. Selected ARDS data: a- 38.6 kPa, 1524Z; b- 39 kPa, 1425Z; c- 39.1 kPa, 1326Z; d- 38.9 kPa, 1242Z.

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