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THE UNIVERSITY OF ALBERTA

The Application of Satellite and Radar data in Thunderstorm Research

by



James Grant Wieler

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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Date *28 August 1981*

Dedication

*To Shelley,
and my parents,
neither time nor distance,
could diminish their
loving support.*

Abstract

A technique is presented for determining cloud-top temperatures, cloud cover, and cloud type, from the combination of infrared and visible TIROS-N Automatic Picture Transmission (APT) data. These data are implemented in the study of convective storms over Alberta in July 1979 and 1980.

Infrared cloud-top temperatures, and associated heights derived from concurrent radiosonde ascents are compared to values derived by conventional methods such as the parcel method, and range-height indicators from radar data. Consideration of the possible errors involved in each method, imply that satellite derived cloud-top temperature and height measurements are the most accurate, economical, and representative estimates available.

Convective rain areas as determined from low-level PPI's are compared to the results of an algorithm combining visible and infrared data. The results, although encouraging, are dependent on both the season, and the thunderstorms stage of development.

The methods presented can provide a variety of products with detail sufficient for use in meso-scale analysis of cloud patterns.

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Table of Contents

Chapter	Page
1. The Observation of Thunderstorms from Satellites	1
1.1 Introduction	1
1.2 The Structure of Thunderstorms	2
1.3 The Utility of Satellite Data in Thunderstorm Studies	4
2. Satellite Instrumentation	5
2.1 Introduction	5
2.2 Satellite Scanning	5
2.3 Satellite Resolution	8
2.4 Internal Calibration	10
2.5 Errors in Satellite-derived Temperatures	13
3. Satellite Data Manipulation	14
3.1 Introduction	14
3.2 Identification of Study Area	14
3.3 Data Manipulation	17
3.4 Frequency Table Discussion	19
4. Thunderstorm Case Studies	21
4.1 Introduction	21
4.2 Radar Characteristics	23
4.3 Convective Cloud Top Estimates from Radiosonde Data	25
4.4 Estimation of Energy Available for Tropopause Modification	26
4.5 Ground-truthing on a Stratiform Day	28
4.6 Case Studies	30
4.6.1 Case Study #1 July 6, 1979	31
4.6.2 Case Study #2 July 7, 1979	37
4.6.3 Case Study #3 July 10, 1979	42
4.6.4 Case Study #4 July 21, 1979	47
4.6.5 Case Study #5 July 16, 1980	52
5. Rain Estimation from Satellite Data	57
5.1 Introduction	57

5.2 Rain Area Determination	57
6 Summary and Conclusions	64
6.1 Summary of Results	64
6.2 Applications	66
6.3 Recommendations for Future Study	66
Bibliography	68
A Appendix A Infrared Calibration Technique	71
B Appendix B Sample Output from Program SCAN	72
C Appendix C Computer Program Listings	74
C.1 Program SCAN	74
C.2 Program TAPERD	89
C.3 Program TELEM	94
C.4 Subroutine ITERA	95
C.5 Subroutine SMOO	97
C.6 Subroutine CALI	99
C.6.1 Subroutine PLANCK	101
C.7 Program PLT	102
C.8 Program GREY	104
C.9 Program RAIN	106
D Appendix D	107
D.1 Program FREQ	107
D.2 Frequency Histograms	109
D.2.1 Case study #1 TIROS-N Orbit 3758	109
D.2.2 Case study #2 TIROS-N Orbit 3772	110
D.2.3 Case study #3 TIROS-N Orbit 3814	111
D.2.4 Case study #4 TIROS-N Orbit 3970	112
D.2.5 Case study #5 TIROS-N Orbit 9063	113
D.3 Sample Output from Program TELEM	114

List of Tables

Table	Page
1.1 Thunderstorm Stages of Development	3
3.1 Frequency table description	20
4.1 Energy estimation from parcel method	27
4.2 Frequency table for orbit 3758	36
4.3 Frequency table for orbit 3772	41
4.4 Frequency table for orbit 3814	46
4.5 Frequency table for orbit 3970	51
4.6 Frequency table for orbit 9063	56
6.1 Cloud top height estimates	65

List of Figures

Figure	Page
2.1 APT Linearization regions and resolution	7
2.2 Example of one scan of TIROS-N APT data	9
2.3 Relationship between TIROS-N and recorded wedge levels	12
2.4 Digital count versus temperature	12
3.1 Alberta Hail Project Area (after Deibert 1978)	15
3.2 Visible data from orbit 3758, a) unsmoothed, b) smoothed	18
4.1 Infrared slicing algorithms	22
4.2 Beam width error in determining cloud height from radar	24
4.3 Infrared imagery from TIROS-N orbit 3828	29
4.4 500-mb and surface maps 2400Z July 6, 1979	31
4.5 Contoured image from orbit 3758, a) infrared, b) visible	32
4.6 Grey level image from orbit 3758, a) infrared, b) visible	33
4.7 Tephigram of Radiosonde ascents, a) CYQF, b) CYYC	34
4.8 Maximum echo top map 2229Z July 6, 1979	35
4.9 500-mb and surface maps 2400Z July 7, 1979	37
4.10 Contoured image from orbit 3772, a) infrared, b) visible	38
4.11 Grey level image from orbit 3772, a) infrared, b) visible	39
4.12 Tephigram of Radiosonde ascents, a) CYQF, b) CYEG	40
4.13 500-mb and surface maps 2400Z July 10, 1979	42
4.14 Contoured image from orbit 3814, a) infrared, b) visible	43
4.15 Grey level image from orbit 3814, a) infrared, b) visible	44
4.16 Tephigram of Radiosonde ascents, a) CYQF, b) CYRM	45
4.17 500-mb and surface maps 2400Z July 21, 1979	47
4.18 Contoured image from orbit 3970, a) infrared, b) visible	48
4.19 Grey level image from orbit 3970, a) infrared, b) visible	49
4.20 Tephigram of Radiosonde ascents, a) CYQF, b) CYEG	50
4.21 500-mb and surface maps 2400Z July 16, 1980	52
4.22 Contoured image from orbit 9063, a) infrared, b) visible	53
4.23 Grey level image from orbit 9063, a) infrared, b) visible	54
4.24 Tephigram of Radiosonde ascents, a) CYQF, b) CYRM	55

Figure

Page

5.1	July 6, 1979 2230Z. a) Rain area estimation, b) Radar PPI	61
5.2	July 21, 1979 2315Z. a) Rain area estimation, b) Radar PPI	62
5.3	July 16, 1980 2226Z. a) Rain area estimation, b) Radar PPI	63

1. The Observation of Thunderstorms from Satellites

1.1 Introduction

Thunderstorms have roused the imagination of man since time immemorial. The Greek God Zeus, the most powerful of the gods, was reputed to control lightning and thunder. Today thousands of man-hours and millions of dollars are spent each year so that we may someday understand and possibly control that phenomenon the ancients attributed to their gods.

With the launching of TIROS-1 on April 1, 1960, man entered into a new era of meteorological understanding. During the past twenty years, the data produced by meteorological satellites have steadily become more refined.

The first earth-orbiting satellites were able to produce imagery in the visible part of the spectrum only. As a result, early work with satellite data (Anderson and Veltishchev, 1973) consisted primarily of observing pictures to identify cloud and circulation patterns. Today meteorological satellite sensors transmit detailed visible, infrared, and microwave information covering the globe. From these data it is possible to determine cloud type (Harris and Barrett, 1978), estimate precipitation (Martin and Scherer, 1973), forecast precipitation (Bellon et al., 1980), and derive vertical temperature soundings (Phillips, 1979, Smith et al., 1979).

Most of the recent research in the area of satellite meteorology has concentrated on data from geosynchronous operational environmental satellites (GOES). The fine temporal resolution of GOES data is particularly useful in the study of cloud pattern movements. Fortunately, the work done with GOES data can be related to polar orbiting satellite data, provided the fine temporal resolution of the former is not considered.

The observation of convective storms over central Alberta by TIROS-N satellite data recorded at the University of Alberta, and S-band (10 cm) radar data collected in Penhold, Alberta by Alberta Research Council have provided a data base for this study. The derivation of a cloud-top temperature model using satellite data, its implications, and comparison between satellite products and radar data will be discussed in this thesis.

1.2 The Structure of Thunderstorms

Several categories of thunderstorms such as squall lines, multicell, supercell, and severely-sheared thunderstorms have been identified (Marwitz, 1972a,b,c). Of these, the squall line, which is composed of multi cell storms, is the most frequently observed over central Alberta. The severely-sheared storm is a subset of the supercell category; therefore, the majority of all thunderstorms fall into either the multicell or supercell category.

All thunderstorms consist of at least one updraft -downdraft pair, referred to as a convective cell. According to Byers and Braham (1949) these cells go through several stages of development as summarized in Table 1.1.

A multicell storm is simply a conglomerate of individual cells moving in an organized pattern. New cells develop periodically on the right-hand flank facing the direction of motion of the storm, growing to maturity as they move into, and become part of, the storm complex. Multicell storms appear to move to the right of the environmental wind due to this flanking development. Individual cells in a multicell storm tend to retain their identity and can be tracked by radar for up to thirty minutes.

In contrast to the highly time-dependent multicell storm, supercell storms retain their characteristics over a longer period of time, typically 30 to 60 minutes and, on occasion, as long as several hours. These supercell storms are most often characterized by a single persistent cell which generally travels to the right of the mid-tropospheric (700-300 mb) winds. The physical makeup of these storms permits the updraft and precipitation fallout (downdraft) to exist separately.¹ Thus, the resulting storm is what may be termed a "continuous flow" phenomenon (Chisholm and Renick, 1972), changing its air several times during its existence. During the mature stage of a supercell storm the storm top, as determined by radar, shows slight vertical variations, typically not more than one kilometer from the mean height.

Table 1.1 Thunderstorm stages of development.

Stage	Characteristics	Duration
Cumulus	updraft throughout cloud, cloud tops 25-30,000 feet	10-15 minutes between first radar echo and initiation of rain at ground.
Mature	strong updraft and downdraft, cloud tops 40-60,000 feet	15-30 minutes
Dissipating	updraft cut off at low levels by downdraft, falling cloud tops	approx. 30 minutes, after which vertical velocities are insignificant.

1.3 The Utility of Satellite Data in Thunderstorm Studies

Satellite data have the advantage over other meteorological observation systems in that they provide continuous spatial coverage over a very large area. These data can, moreover, provide information over areas where no conventional meteorological data are available.

Analyzed Automatic Picture Transmission (APT) data from TIROS-N can be a very useful tool in the study of convective storms. The derivation of cloud climatologies, cloud cover and type, cloud-top temperature and height, can be of great value in the study of interactions between the meso and synoptic scales. The combination of visible and infrared data to yield precipitation areas is useful in studying storm energetics, since precipitation is a fundamental indicator of the amount of latent heat released within a storm. The ability to monitor the coverage of rain over land is important because of its direct impact on crop production. Moreover, the destructive effects of heavy rainfall and hail could be reduced by more accurate forecasts based on satellite data.

The orbital period of TIROS-N is approximately 102 minutes, a period far greater than the lifetime of most multicell storms (30 to 60 minutes). Although the temporal resolution of the TIROS-N data is inadequate for studying cloud motions, its spatial resolution (4 km) at 51° north is far superior to that of the infrared GOES data (16-km) at 51° north.

2. Satellite Instrumentation

2.1 Introduction

The satellite information used in this study was obtained from TIROS-N, a third generation polar orbiting environmental satellite. Since a comprehensive discussion of the TIROS-N satellite system can be found in Schwalb (1978), only a general description of the TIROS-N Automatic Picture Transmission (APT) system will be given here.

The TIROS-N satellite series has been designed to operate in a sun-synchronous orbit at a height of 865 km. The satellite has a period of approximately 102 minutes, a westward nodal regression of 25.59° , and is inclined 98.8° from the equator. The satellite precesses eastward at a rate of one degree per day, so that the satellite maintains a nearly constant orientation over the course of the year.

2.2 Satellite Scanning

The satellite carries on board an Advanced Very High Resolution Radiometer (AVHRR); this is a four-channel scanning radiometer sensitive in the visible ($0.5-0.9 \mu\text{m}$), near infrared ($0.725-1.10 \mu\text{m}$), $(3.55-3.93 \mu\text{m})$ and far infrared ($10.5-11.5 \mu\text{m}$) window regions. The APT signal consists of the visible and far infrared channels from the AVHRR. These channels are time-division multiplexed into an output stream that is processed by the onboard computer to achieve both bandwidth reduction and geometric correction. The bandwidth reduction algorithm involves sending one of every three scan lines produced by the AVHRR to the APT transmitter. Each scan line consists of 700 individual pixels representing the radiometer's output while scanning from horizon to horizon. The geometric correction is performed to maintain constant resolution along the scan; this is accomplished by using a separate resolution reduction in each of five regions on either side of the satellite sub-point. The algorithm is summarized below and the results shown in Figure 2.1.

Region 1	($\pm 16.9^\circ$ from nadir): average four contiguous samples
Region 2	(16.9° to 34.8° either side of nadir): average two samples skip one and repeat
Region 3	(34.8° to 43.8° either side of nadir): average two samples
Region 4	(43.8° to 48.8° either side of nadir): average one and one half samples
Region 5	(48.8° to 55.4° either side of nadir): retain original resolution

All of this processing is accomplished in the digital domain before being converted into an analog signal for output on the APT transmitter.

The AVHRR contains a mirror which rotates at 360 revolutions per minute. However because of the bandwidth reduction the effective rotation for the APT signal is 120 scans per minute, or 2 scans per second. This rotation, perpendicular to the satellite's path, combined with the motion of the satellite gives complete coverage of the area in the field of view of the radiometer. The field of view of the scanning radiometer is restricted to be within 55.4° of the satellite sub-point in order to minimize the effect of atmospheric attenuation and limb darkening. These "artificial" horizons restrict the satellite scans to 27° of longitude at the equator (2997 km). Since the satellite regresses 25° per orbit, there is a 2° overlap between consecutive orbits at the equator. This overlap increases with the latitude such that the area over central Alberta is in the radiometer's view during four orbits each day.

2.3 Satellite Resolution

The TIROS-N APT data are corrected in such a way that the resolution is constant (4 km) along each scan. The distance between adjacent scans at the sub-point is given by,

$$\frac{360^\circ \times 111^\circ/\text{km} \times 1.017}{102 \text{ min/orbit} \times 2 \text{ scans/min} \times 60 \text{ s/min}} = 3.31 \text{ km}$$

where 1.017 represents the conversion factor from geocentric to geodetic coordinates. Hence, each digital value recorded represents the radiance averaged over a 4×3.3 km rectangle.

The University of Alberta satellite laboratory is equipped to receive the analog APT signal and convert it to digital values between 0 and 255 at a digitizing rate of 2400 Hz. Visible reflectance represented on this scale generally ranges from 30 digital counts (ground and water) to 230 digital counts (thick cloud). Warm and cold emitting layers and surfaces are represented in the infrared by high and low digital counts, respectively.

The output rate for the APT digital data is 4160 "words" per second, or 1600 digital values per scan. The infrared and visible data are represented along a scan by 700 digital values each, leaving 200 values in each scan for synchronization pulses and telemetry data. A sample of one scan of data can be seen in Figure 2.2.

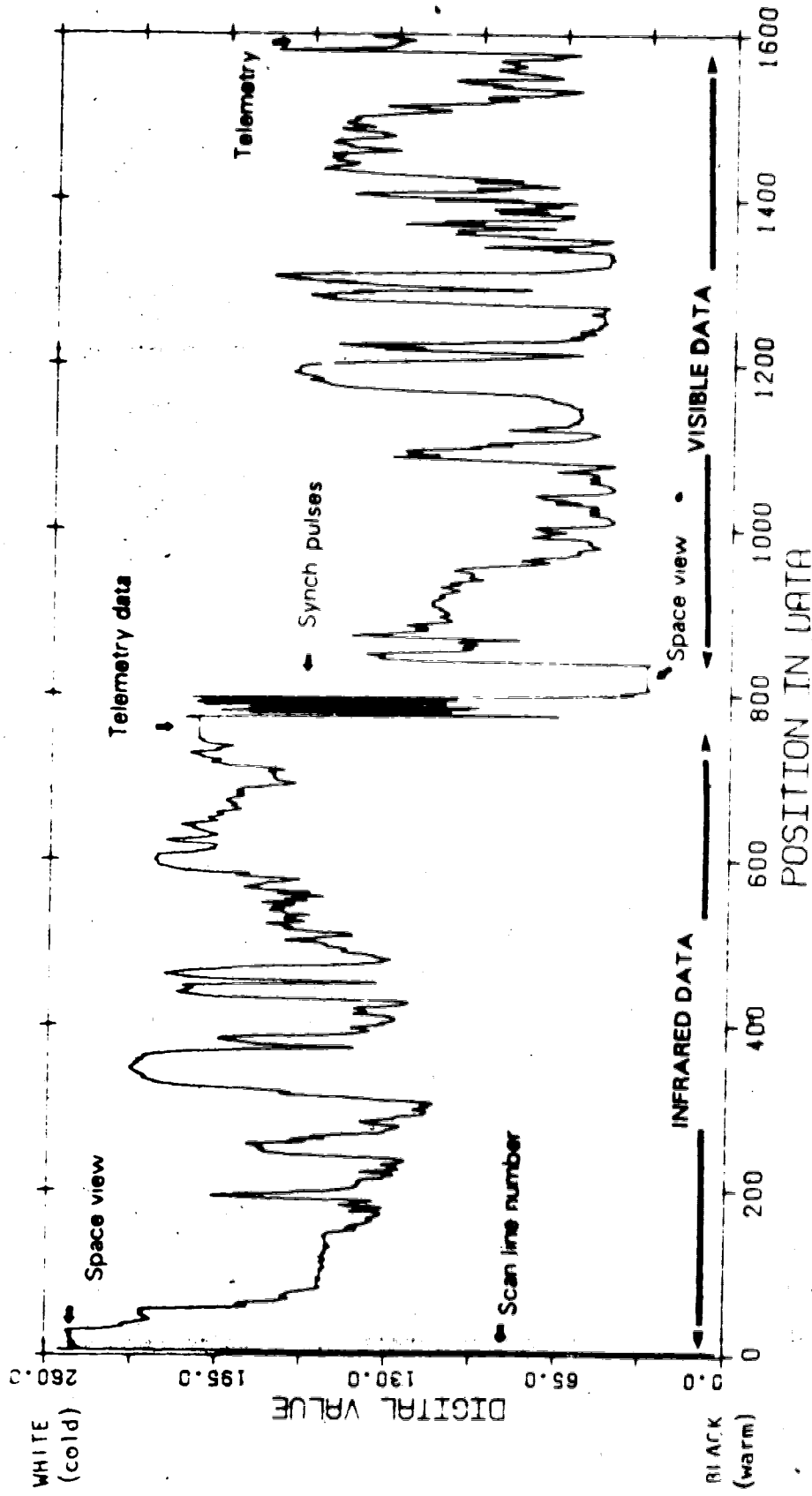


Figure 2.2 Example of one scan of TIROS-N APT data.

2.4 Internal Calibration

Calibration of the infrared channel of the AVHRR is possible because the output of the instrument is almost linear with input energy. During every scan, the radiometer views space (0 radiance) and its housing (approximately 290°K). The housing has been designed to be a black body target, with four platinum resistance thermometers (PRT's) embedded in it. By determining the radiometer's output while viewing the housing and space it is possible to ascertain the instrument's response curve.

In order to calibrate the infrared channel, it is necessary to relate the recorded APT signal to the AVHRR data. This is accomplished by determining the relative signal level using eight grey "wedges" as a scale. The output from the space view, housing PRT's, and representative values of all the wedge levels are located between the infrared and visible data in each scan. Wedge values are cyclically repeated over eight scans every 128 scans. In order to determine representative wedge level values the telemetry data output from program TAPERED (Appendix C.2) was used as input for program TELEM (Appendix C.3). The mean and standard deviation of 160 values over eight scans were computed to give the wedge level value. Sample output from program TELEM can be seen in Appendix D. The original data level of the signal was then determined by taking the average wedge levels and relating them to the original wedge levels which were recorded before the satellite was put into orbit.

The relationship between the TIROS-N wedge levels and those recorded for orbit 3758 is displayed in Figure 2.3. A polynomial fit between these two data sets was performed by the MIDAS (Fox and Gutre, 1976) statistical package available at the University of Alberta. The coefficients obtained from this procedure were then used in determining the average temperature of the PRT's. A second polynomial fit was then performed in order to find the recorded University of Alberta value corresponding to the average PRT temperature. The discrepancy between the University of Alberta digital values and the digital values transmitted by the satellite is due to a digital-analog-digital conversion.

The University of Alberta receiver at Ellerslie, Alberta is slightly dependent on temperature; to account for this the amplitude of the recorded signal can be arbitrarily adjusted at recording time by the technician operating the satellite receiver. The averaging technique and polynomial fitting just described were used to eliminate any effects that varying signal amplitude and temperature might have on the recorded data.

Once the relationship between the onboard calibration wedge levels and those recorded at the University of Alberta is known, the infrared data may be calibrated to obtain the temperature field using the technique described in Appendix A.

It was found through a number of tests that this calibration routine was on average accurate to 3°K in determining the temperature from the same digital count using different polynomial coefficients. However, on inspection of Figure 2.4, a plot of digital counts versus temperature for five different satellite orbits, one can see that in the worst case a single digital count may yield a temperature difference of up to 10°K. Hence, a separate polynomial fit is necessary for each orbit.

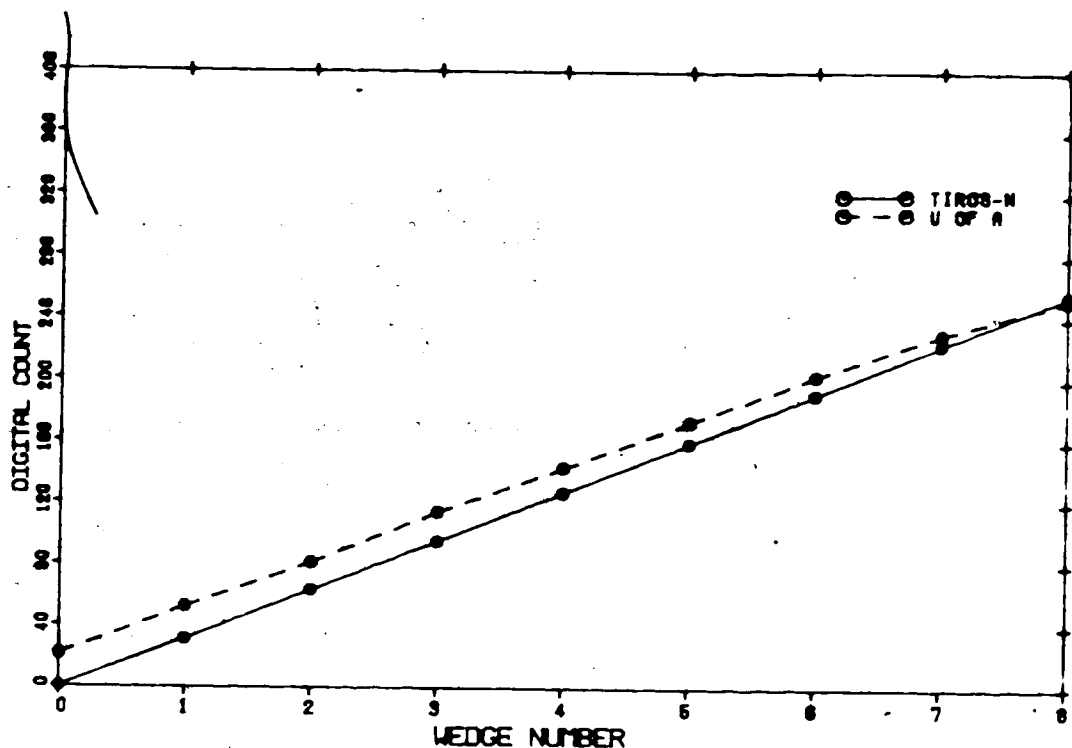


Figure 2.3 Relationship between TIROS-N transmitted wedge levels and those recorded at the University of Alberta.

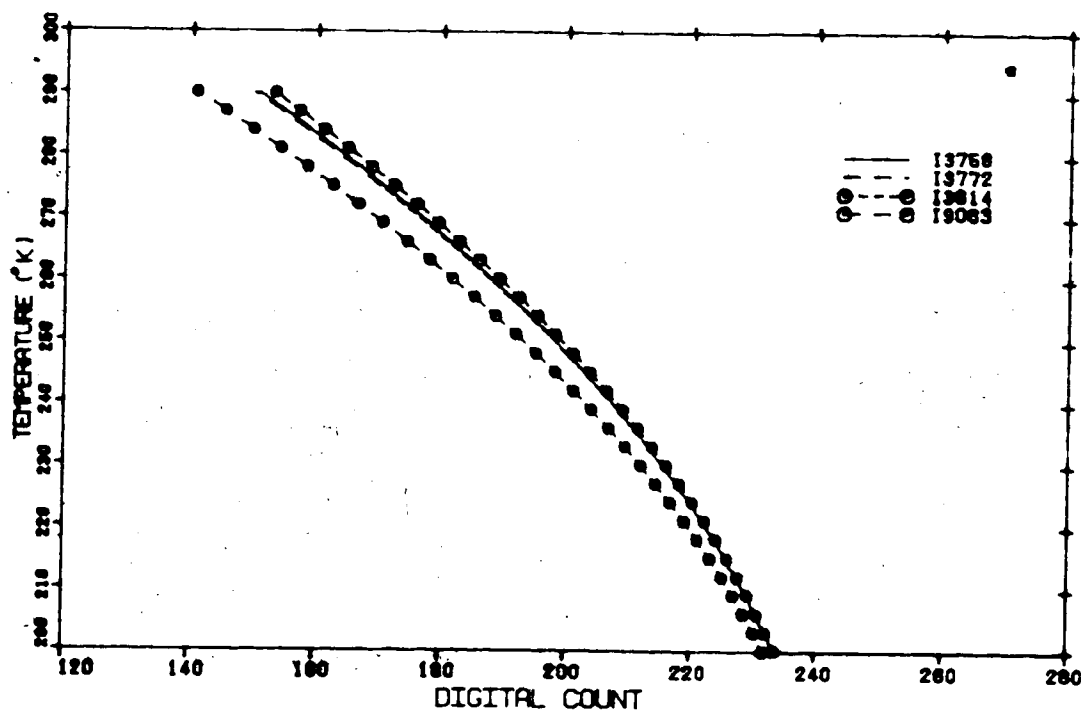


Figure 2.4 Temperature (°K) versus digital count for five case studies.

2.5 Errors in Satellite-derived Temperatures

According to Schwalb (1978) the non-linear response of the AVHRR is responsible for an error of approximately -1.7°K at 293°K decreasing to 0°K at 200°K . By a series of experiments it was determined that for a digital count difference of one, the calibration technique would, in the worst case, produce a temperature difference of 3°K for very low temperatures (200°K), and a difference of 1°K for temperatures near 293°K .

Perhaps the most complex problem in deriving temperatures from satellite data is accounting for longwave attenuation due to absorption by water vapor and carbon dioxide. Although the $11\text{ }\mu\text{m}$ band is a region of relatively little absorption by atmospheric constituents, under certain conditions this effect can be significant. For example, a moist atmosphere may attenuate the radiation emitted by the earth's surface by 5-10% (Weinreb, 1980). Because part of the thermal radiation emitted by the earth's surface is absorbed and re-emitted by the atmosphere, a radiant temperature measured from space will be lower than the true surface temperature. From experiments in the tropics Curtis and Rao (1969) estimated that at the satellite subpoint the brightness temperature measured by the satellite would be $2-4^{\circ}\text{K}$ colder than the actual radiating surface temperature. Since one would expect the water vapor content of the air over central Alberta ($2200-3500\text{ msl}$) to be far less than that in the tropics, a conservative estimate of attenuation from the surface might be 2°K . Ideally, one should apply a radiative transfer model such as LOWTRAN (Selby et al., 1978) to the data available in order to determine attenuation. In lieu of this rigorous method, the worst case for atmospheric attenuation will set the error limits for the accuracy of the satellite-derived temperatures in this study. These are:

$\pm 3^{\circ}\text{K}$ at 200°K

$\pm 4^{\circ}\text{K}$ at 293°K .

3. Satellite Data Manipulation

3.1 Introduction

During the summers of 1979 and 1980 the University of Alberta satellite laboratory recorded a minimum of two satellite passes over Alberta every afternoon. Assuming no lack of satellite data the case studies for this investigation were chosen from the Alberta Research Council's Hail Project hail size index. Three days in July 1979 and one day in July 1980, when the hail size was walnut size or greater, were chosen for case studies. In this chapter the development and implementation of the cloud top temperature model used in this study are examined.

3.2 Identification of Study Area

A map of the study area including both geographical and political boundaries can be seen in Figure 3.1. The area outlined in heavy black represents the Alberta Hail Project Area, and corresponds to the 80 mile range markers on the satellite contour and radar maps.

The topography of central Alberta is not characterized by any prominent surface features. Gently rolling hills and a few modest-sized lakes make visual identification of the study area by satellite data difficult even in the case of no cloud cover.

In order to eliminate the problems of no distinguishable land marks, or land marks obscured by cloud, Ormsby (1975) used gridded overlays of geographical and political boundaries. These overlays are calculated and drawn for specific satellite orbits and used for gridding all other orbits with similar characteristics. This method, although adequate for qualitative work, lacks the precision needed for quantitative work. A more accurate representation of latitude and longitude may be produced by calculating the latitude-longitude intersections from known satellite orbital parameters. These intersections can be transferred directly to satellite images in the form of fiducial marks (Reinelt et al., 1975).

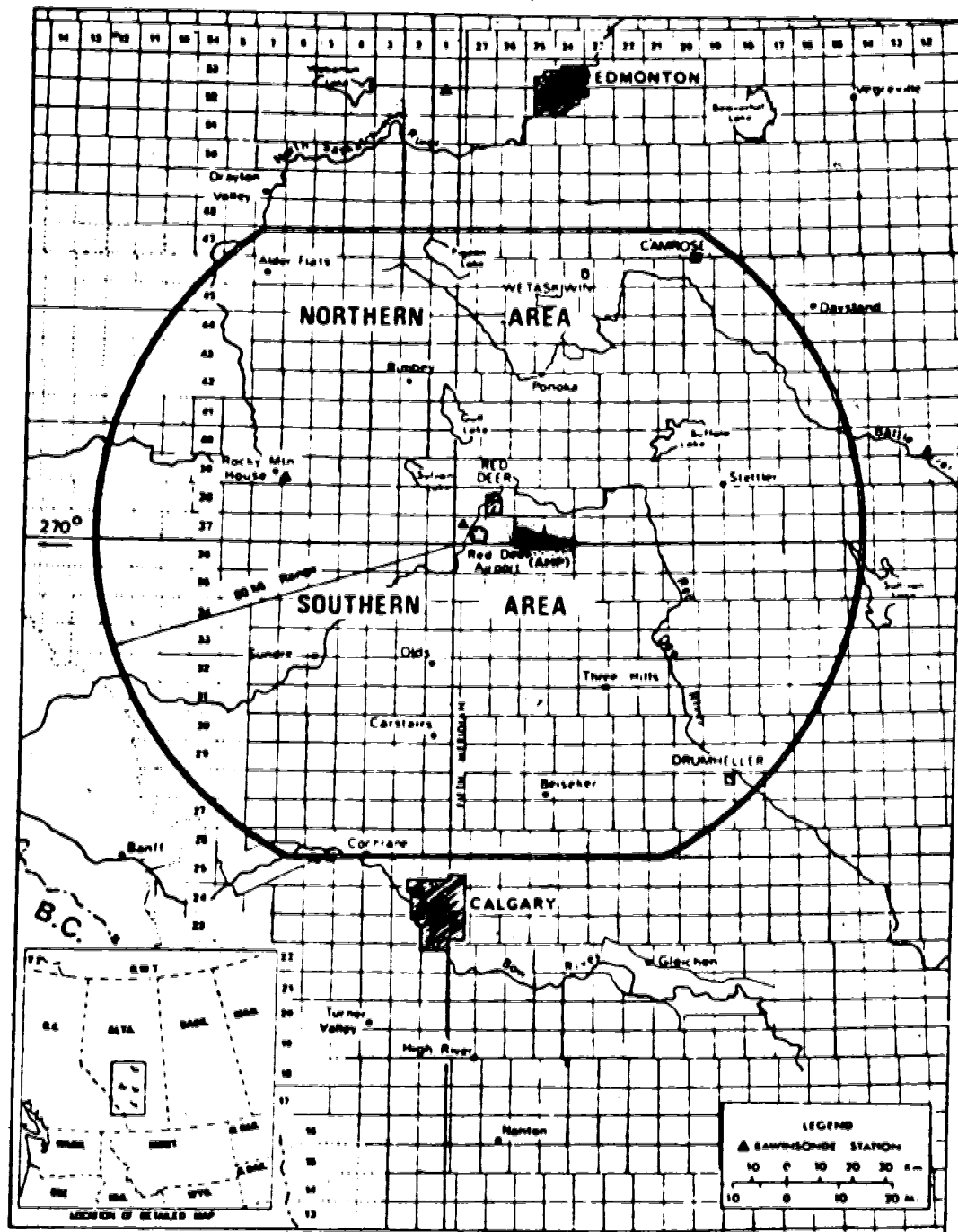


Figure 3.1

Alberta Hail Project Area. (after Deibert, 1979)

A combination of these two methods is used to correct the gridding errors for every satellite pass recorded at the University of Alberta. The pertinent information from this check is then recorded with the other orbital parameters, thus allowing for the accurate gridding of relatively small areas, such as the area around Penhold.

A variation of the scan-by-scan gridding procedure described by Reinelt et al. (1975) was used to produce the town site positions used in this study. The formulas used vary only in that they produce points on a geodetic (from the earth's foci) rather than geocentric (from the earth's center) grid. A listing of these equations is given in the computer program SCAN (Appendix C.1) and subroutine ITERA (Appendix C.4).

Since the TIROS-N satellite series has lower orbits than previous meteorological satellites, and their pitch, roll, and yaw are controlled within $\pm 0.1^\circ$, the gridding of their data is much more accurate than that of previous satellites. The largest gridding error discussed by Greaves (1980) is eliminated by using geodetic rather than geocentric gridding. The error due to variations in the satellite's attitude (pitch, roll, or yaw) is

$$\pm 0.1^\circ * 865 \text{ km} * 2 * \pi / 360^\circ = \pm 1.5 \text{ km},$$

a variation which is less than the resolution of the APT signal.

Another source of gridding error is in the timing of the satellite's equator crossing. Since this time is only accurate to the nearest second, and the satellite requires 102 minutes to scan the circumference of the earth, an error of

$$\pm 0.5^\circ * 2 * 6367 \text{ km} * 6120 \text{ s/orbit} = \pm 3.2 \text{ km}$$

is possible at the satellite subpoint.

3.3 Data Manipulation

The four steps necessary for procuring cloud-top temperature plots in the manner used in this study are described below.

- 1) The orbital parameters for each case study were used in conjunction with program SCAN (Appendix C.1) to determine the maximum and minimum scan and position numbers defining a box covering central Alberta, as well as the positions of various town sites within a one hundred mile range of Penhold.

- 2) Using this information, program TAPERED was run in order to copy the satellite tape data inside this box to a copy tape, and to read the telemetry data over the area of interest. The calibration wedge levels were then obtained by running TELEM on this telemetry data.

- 3) Program SCAN was then rerun in order to smooth, calibrate (in the infrared case) and write the data field into a file. Subroutines SMOO and CALI can be seen in Appendices C.5, and C.6 respectively.

- 4) These data were then output as either a contour or grey-level map using programs PLT or GREY, (Appendices C.7, and C.8 respectively).

The data field is smoothed by a simple three-point smoothing operation on the sides of the field, and a four-point smoothing operation in the interior of the field. It was found that two light smoothing operations resulted in the clearest representation of the temperature field while retaining all pertinent information. Noise lines and synchronization pulse problems were eliminated in the first smoothing operation by subtracting the smoothed from the unsmoothed fields, pixel by pixel. These differences were then summed up along each scan and the mean and standard deviation of each scan was computed. If the mean of any one scan was outside two standard deviations the scan was rejected and set equal to an adjacent scan.

The effects of this smoothing and noise elimination routine on the visible data from orbit 3758 can be seen in Figures 3.2, a and b. The mean and standard deviation, as well as the scan number rejected, were output in order to observe the effect of the smoothing. From inspection of these parameters (see SCAN output, Appendix B), one can see that the average temperature change due to smoothing is small when compared to the $\pm 3.0^\circ\text{K}$ uncertainty of the temperature measurements discussed in Chapter 2.

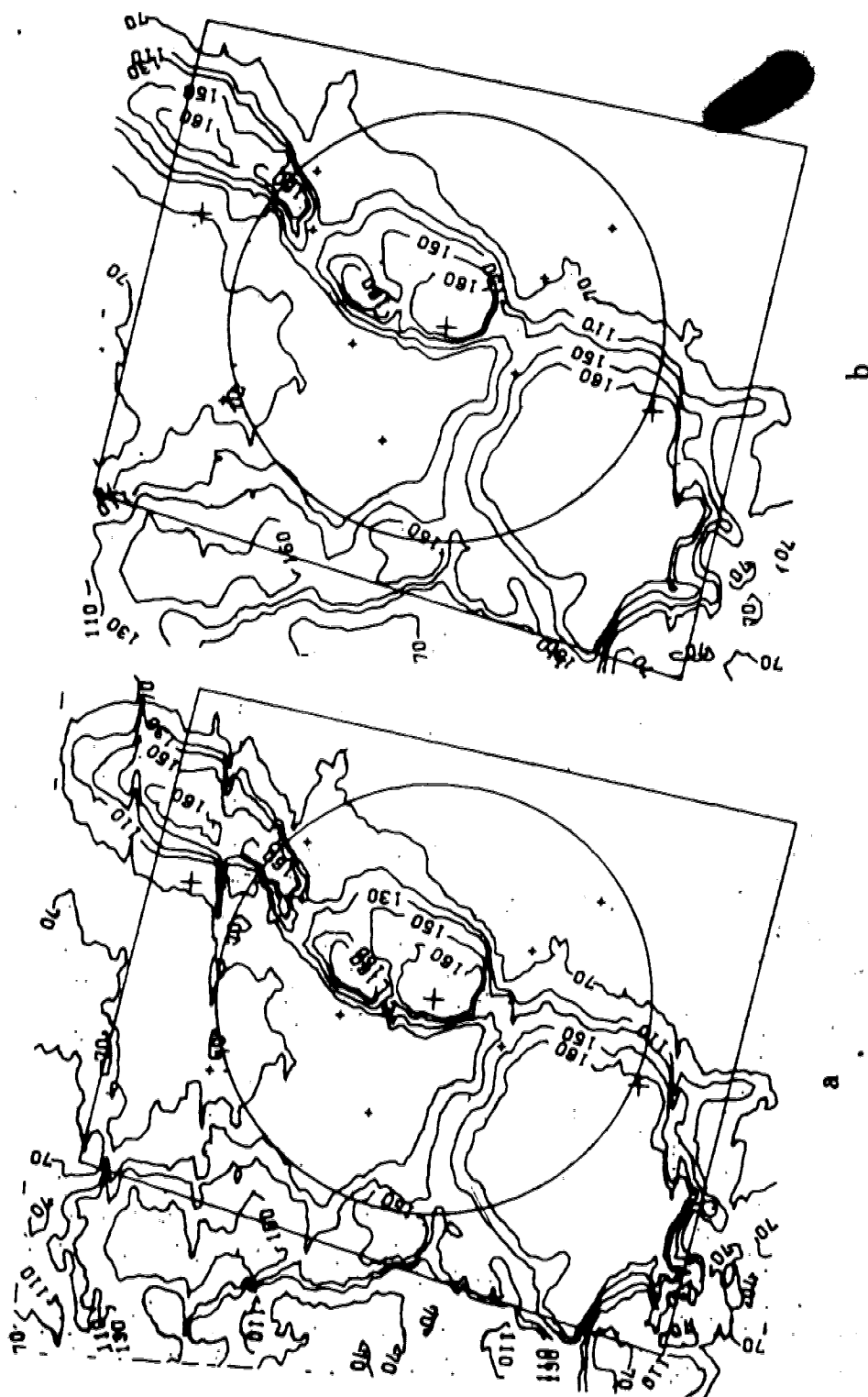


Figure 3.2 Visible imagery from orbit 3758
a) unsmoothed
b) smoothed.

3.4 Frequency Table Discussion

Satellite data, because of their large areal coverage, lend themselves easily to cloud classification methods. Early work in this area involved only visible-range imagery (Anderson et al., 1966, Aber and Taggart, 1969), then later both visible and infrared imagery (Anderson et al., 1969). More recent attempts to determine the spatio-temporal evolution of cloud patterns involve the use of only visible or infrared data in monodimensional histograms (Szejwach and DeBois, 1978). Reynolds and VonderHaar (1979) use both visible and infrared data in their "bi-spectral" method for determining cloud amount and height, while Harris and Barrett (1978) discuss the use of a brightness/texture approach for an objective nephanalysis.

In this study both visible data to detect cloud thickness and infrared data to determine cloud top temperature are used to classify cloud types. The concluding remarks of a review paper on rain estimates from satellite data, by Martin and Sherer (1973) support this combination of data: "Based on a bivariate frequency distribution of bright versus temperature, Gruber (1973) concluded that brightness enhancing or infrared technique alone might be inadequate to deduce details of convective activity." This statement reinforces some observations that the brightest part of the cloud may not be the coldest because of shear or the distribution of radiative properties of hydrometeors. This implies that a better estimate of cloud type may be made from a combination of visible and infrared data.

An objective determination of cloud type was accomplished by the implementation of program FREQ (Appendix D). Critical levels defining cloud borders were assumed to be 70 digital counts in the visible, and 0°C in the infrared data. Using this information the cloud frequency program simultaneously looks at both the visible and infrared data for each pixel and groups that pixel into a 5°C and 5 digital count "family." The percentage of each "family" is then output in the form of a frequency table.

Table 3.1 gives a description of the type of cloud found in the four different regions of the frequency Tables 4.2 to 4.6

The frequency of the 5°C and 5 digital count groups were also output separately in histogram form (Appendix D) in order to determine the contour values and "slicing" in the digital plotting programs PLT and GREY

Table 3.1 Frequency table description

Region	Characteristics	Cloud Type
Upper left	very cold, high visible reflectance (great vertical extent)	cumulonimbus, towering cumulus
Lower left	very cold, low visible reflectance, (high thin layer)	cirrus, cirrostratus, cirrus anvil
Upper right	warm, high visible reflectance, (low thick cloud)	cumulus, stratocumulus
Lower right	warm, low visible reflectance, (low thin cloud)	stratus, fog

4. Thunderstorm Case Studies

4.1 Introduction

The characteristics of radar and radiosonde data and the problems of "ground truthing" satellite derived cloud-top temperatures with both of these will be discussed and illustrated in this chapter.

Contour maps of infrared and visible data for accurate geographical orientation, and grey-level, visible and sliced infrared data to emphasize cloud structure are presented for each case study. The locations of Edmonton, Penhold and Calgary are marked on the grey-shade maps by either a white or a black cross. Contour maps mark the locations of Edmonton, Calgary, Drayton Valley, Camrose, Wetaskiwin, Rimbey, Rocky Mountain House, Olds, Three Hills, and Drumheller as well as north-south, east-west cross hairs intersecting at Penhold. It may be noted that these cross hairs are not perpendicular; this is due to the fact that the earth is rotating under the satellite as it scans. The various infrared slicing algorithms determined from the frequency tables of the passes are displayed in Figure 4.1.

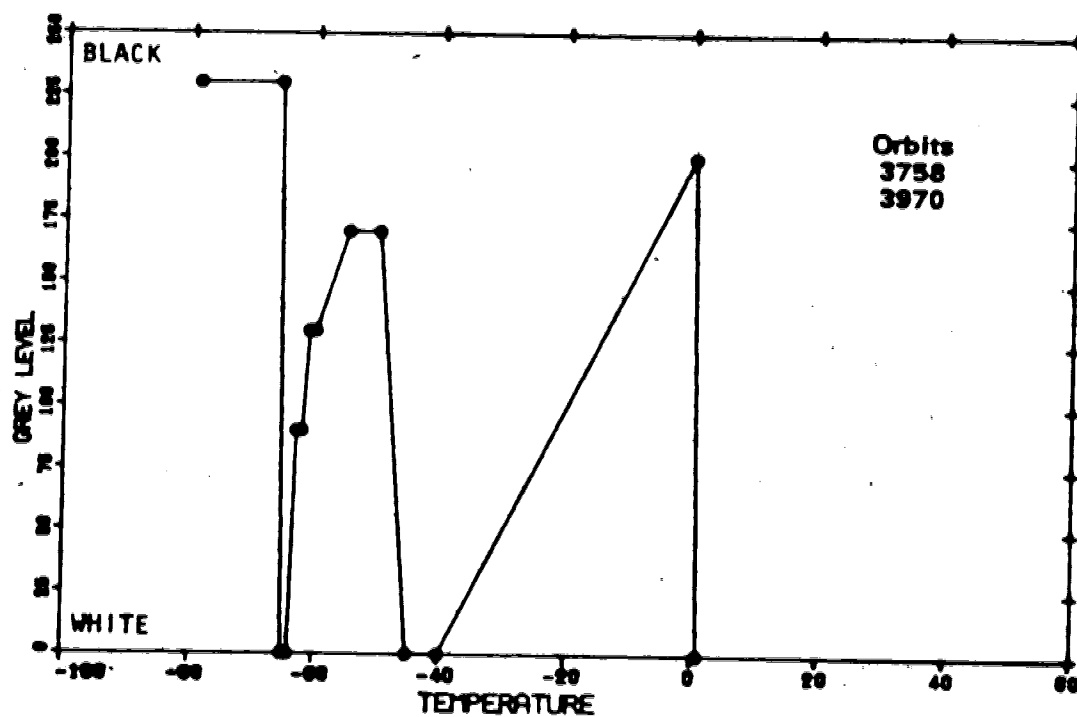
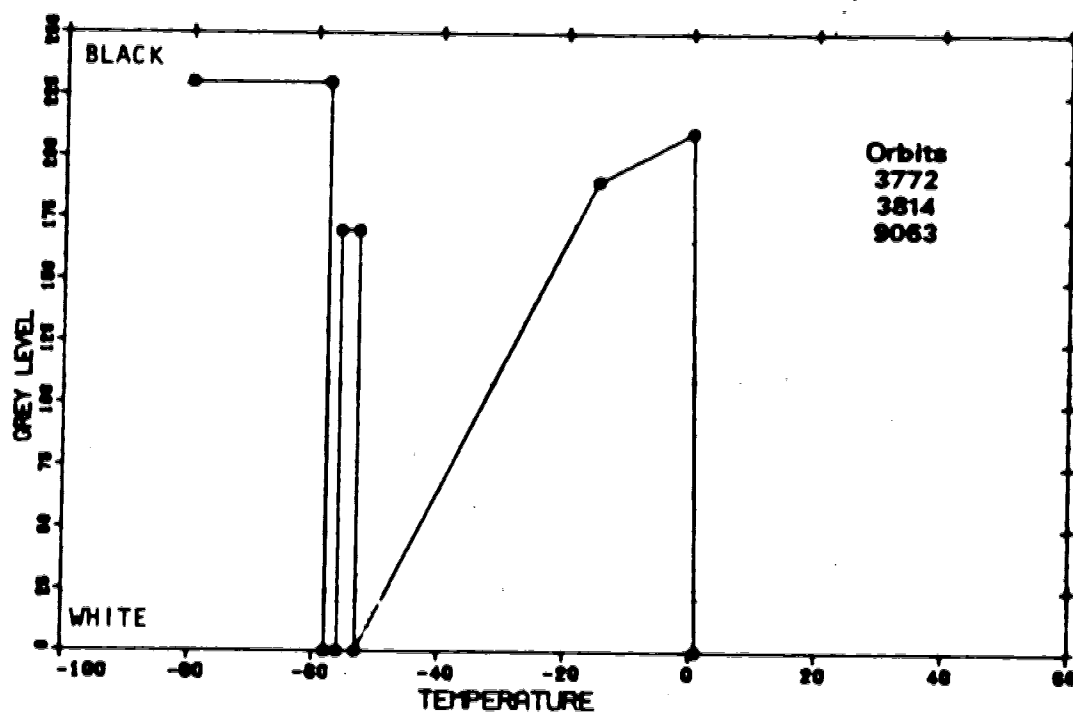


Figure 4.1

Infrared slicing algorithms.

4.2 Radar Characteristics

The detection of cloud droplets, rain droplets, snow, ice pellets and hail by radar (radio detection and ranging) has become an invaluable tool to meteorologists. Radar is based on the principle that an electromagnetic wave propagates along straight lines at the speed of light ($3 \times 10^8 \text{ ms}^{-1}$). Hence, by means of an antenna producing a narrow beam of radio energy and receiving a reflection from that beam, one can determine the direction of the reflecting object. The range of the reflecting object can be determined by recording the time interval between the transmission of the radio energy and the reception of its reflected signal. Hydrometeor detection capabilities are critically dependent on the wave length of the radar. In general, the smaller the particle, the shorter the wave length must be to detect it.

The Alberta Hail Project's S-band (10 cm) radar is capable of detecting raindrops and hail. The system's temporal resolution of three minutes and its spatial resolution of one kilometer make the study of thunderstorms within a one hundred kilometer range possible (Chisholm and Renick, 1972).

The radar data used in this study correspond in time with the satellite's scanning of the Penhold area. However, in a few cases (orbits 3772, 3814), there were brief breaks in the radar data, in which case radar data closest to the time of the satellite pass were used. The low-level Plan Position Indicators (PPI's) used for comparison of rain areas in Chapter 5, and the maximum echo tops used in sections 4.5 and 4.6 to estimate cloud-top height were readily available from the Atmospheric Sciences Department (ASD) of the Alberta Research Council.

Direct comparison of satellite and S-band radar data is difficult largely because radar views only a small cross-section of a cloud and is sensitive to precipitation size particles ($> 0.1 \text{ mm}$), not cloud droplets ($4\text{--}100 \text{ }\mu\text{m}$), while the satellite data consist of reflectance and radiance from cloud droplets and precipitation size particles measured from the cloud-top.

The height of the highest echo during the time of the satellite pass was taken from ASD output, this height was then compared to the height derived from the satellite temperature estimate and the radiosonde ascent in the area.

Accurate determination of cloud height by radar is difficult because the echo top does not necessarily coincide with the visible cloud top. Radar estimates of cloud top are dependent on both the beam width of the radar and the range of the target. Saunders and Ronne (1962) in their study of simultaneous measurements of convective cloud by theodolite and radar, found that in almost every case the radar beam gave a higher elevation angle than the theodolite when looking at the same cloud turret. They found that by subtracting a height increment equal to one-half the beam width (α) times the range (R) from the radar echo top, the height of the visible cloud exceeded the height of the "corrected" echo top. Figure 4.2 is an illustration of this error. Taking the radar range to be 130 km (80 miles) and the beam width to be 1.1° may yield an error of 1.2 km in the estimation of the height of the echo.

$$E_r = 0.5 \cdot R \cdot \sin(\alpha)$$

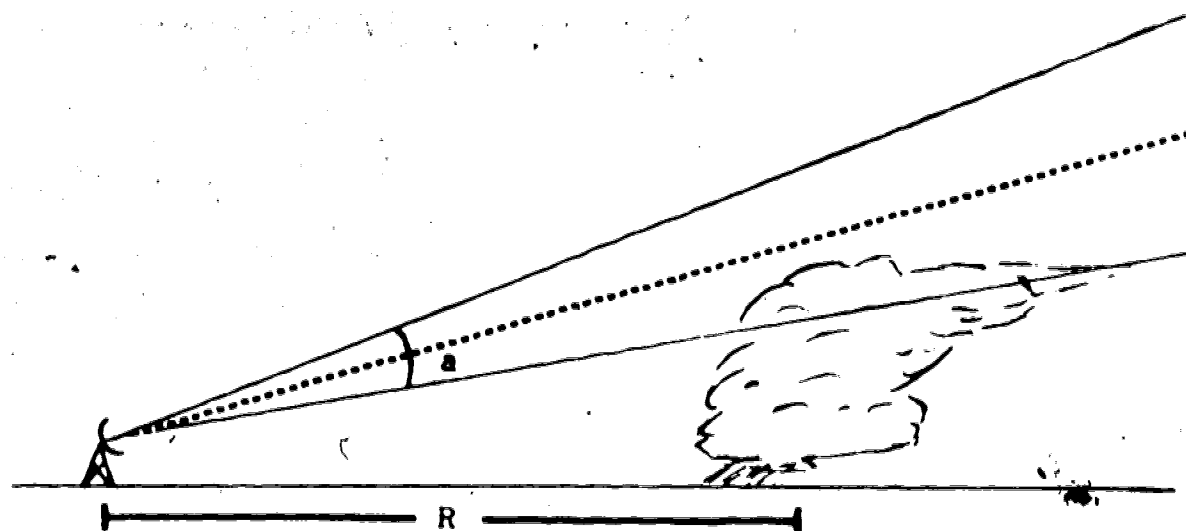


Figure 4.2 Illustration of error in deriving cloud top measurements with radar.

4.3 Convective Cloud Top Estimates from Radiosonde Data

Convective cloud-top temperature estimates from radiosonde data close to the time of a satellite pass were made in each of the case studies discussed in this section.

A schematic representation of the radiosonde data is plotted on a tephigram for each case study. The temperature and moisture profiles are represented on the tephigram by a solid and dashed line, respectively. The convective condensation level and the pseudo-adiabatic line are represented by a dotted line.

The normal procedure for estimating cloud-top temperature is to find the convective condensation level of the airmass and follow a line representing moist adiabatic ascent through the atmosphere until it crosses the environmental temperature curve, usually at the tropopause inversion. The convective condensation level is found at the intersection of the constant mixing ratio line leading up from the surface wet-bulb temperature, and a dry adiabatic line up from the surface temperature at the time convection was initiated.

There are several limitations to the procedure described above.

- 1) Radiosonde estimates of cloud-tops are point measurement, whereas the satellite-inferred value is representative of average conditions over a 4 km² area.
- 2) A representative surface wet-bulb temperature is difficult to obtain in the case of scattered showers. Determination of the cloud-base height from aircraft eliminates this problem and gives a more representative value of the convective condensation level.
- 3) Since standard radiosondes are not designed for release into thunderstorms, possible instrument error must be considered. Washout of the humidity duct, restricted flow through the humidity duct, and inaccuracies in the unshielded thermometer due to wetting and icing are a few of the possible instrument problems.
- 4) Variable balloon ascent rates due to updrafts, downdrafts, and icing further complicate the accurate determination of cloud-top heights.

Instrument and time resolution problems aside, another area of concern is the local modification of the atmosphere by thunderstorms. Davies-Jones and Henderson (1973), in their study of 33 different high plains thunderstorms found that the soundings taken in the updrafts of thunderstorms tended to be about 5°C warmer than the environmental soundings. From this it may be concluded that in a strong updraft, warm,

moist air ascends virtually undiluted, therefore modifying the tropopause in the vicinity of the thunderstorm. However, radiosondes are used operationally to yield a first guess at the cloud top height despite this local modification of the tropopause, instrument problems, graphical inaccuracies and positioning problems.

4.4 Estimation of Energy Available for Tropopause Modification

The energies available for local modification of the tropopause were calculated for each case study. These energies were computed graphically from a representative tephigram using the parcel method. The results of these calculations are displayed in table 4.1.

From inspection of the large vertical velocities in table 4.1 it is obvious that the parcel method is inadequate for the determination of energies in a thunderstorm. The parcel method is very sensitive to the computed area between the temperature profile displayed on the tephigram and the moist adiabatic line describing the saturated parcel's ascent through the atmosphere. This area can be altered significantly by a small graphical error or a poor estimation of the cloud-base height.

The assumption made in deriving the vertical velocity from the energy was that all the buoyant energy available in the cloud is transformed into kinetic energy of vertical motion. Clearly this is not so, the average vertical velocity determined by this method was about 50 ms^{-1} (100 mph). A reasonable vertical velocity as measured by aircraft might be close to 20 ms^{-1} (Musil, et al., 1976). The parcel method is simplified as it does not contain any terms accounting for low level mixing, entrainment of dry environmental air, nor viscous drag.

Even if the values in table 4.1 are assumed to be 100% too large because of the assumptions involved in their computation, one can see that these numbers are still indicative of severe thunderstorms. One interesting point about these rough estimates is that they are consistent relative to one another, that is, the larger and colder of these storms as indicated by the contour plots (Figures 4.10, and 4.18), Cases #1 and #4, have larger energies, and hence greater vertical velocities.

Table 4.1 Energy estimation from parcel method.

Storm	Energies J kg^{-1}	Vertical Velocities ms^{-1}
Case #1 July 6, 1979 CYYC	1570	56
Case #2 July 7, 1979 CYEG	1457	54
Case #3 July 10, 1979 CYRM	1240	50
Case #4 July 21, 1979 CYEG	3245	80
Case #5 July 16, 1980 CYRM	1050	46

4.5 Ground-truthing on a Stratiform Day

In order to avoid the instrument icing and tropopause modification problems discussed in section 4.3, the cloud-top temperature model was run and verified on a day in which most of the cloud was stratiform.

The synoptic situation on the afternoon of July 11, 1979 was characterized by a surface low-pressure system just to the north-east of Edmonton. No hail reports were received on an afternoon dominated by stratus, altocumulus, and stratocumulus clouds, and light rain showers.

Satellite orbit number 3828 scanned over the study area at approximately 2130Z. The radiosonde ascent through the cloud deck for the 2200Z sounding at Penhold (CYQF)¹ yielded a cloud-top temperature estimate of -12°C at a height of 5.1 km (16,500 ft). Although the exact position of the balloon as it broke through the cloud is in doubt, one can see from Figure 4.3 that the area over Penhold was largely covered by cloud with temperatures between -10 and -20°C .

Radiosonde ascents from Edmonton (CYEG)², Calgary (CYYC), and Rocky Mountain House (CYRM), all yielded cloud-top temperature estimates close to those expected from the satellite-derived temperatures. The time-integrated maximum echo top map for this period indicated a cloud-top of 3.4 to 4.6 km (11,000–15,000 ft), just under the estimates from both the satellite and radiosonde data.

¹The correct identifier for the Penhold (Red Deer Airport) upper air station is CYAF as of August 1981.

²The correct identifier for the Edmonton (Stony Plain) upper air station is CWSE as of August 1981.

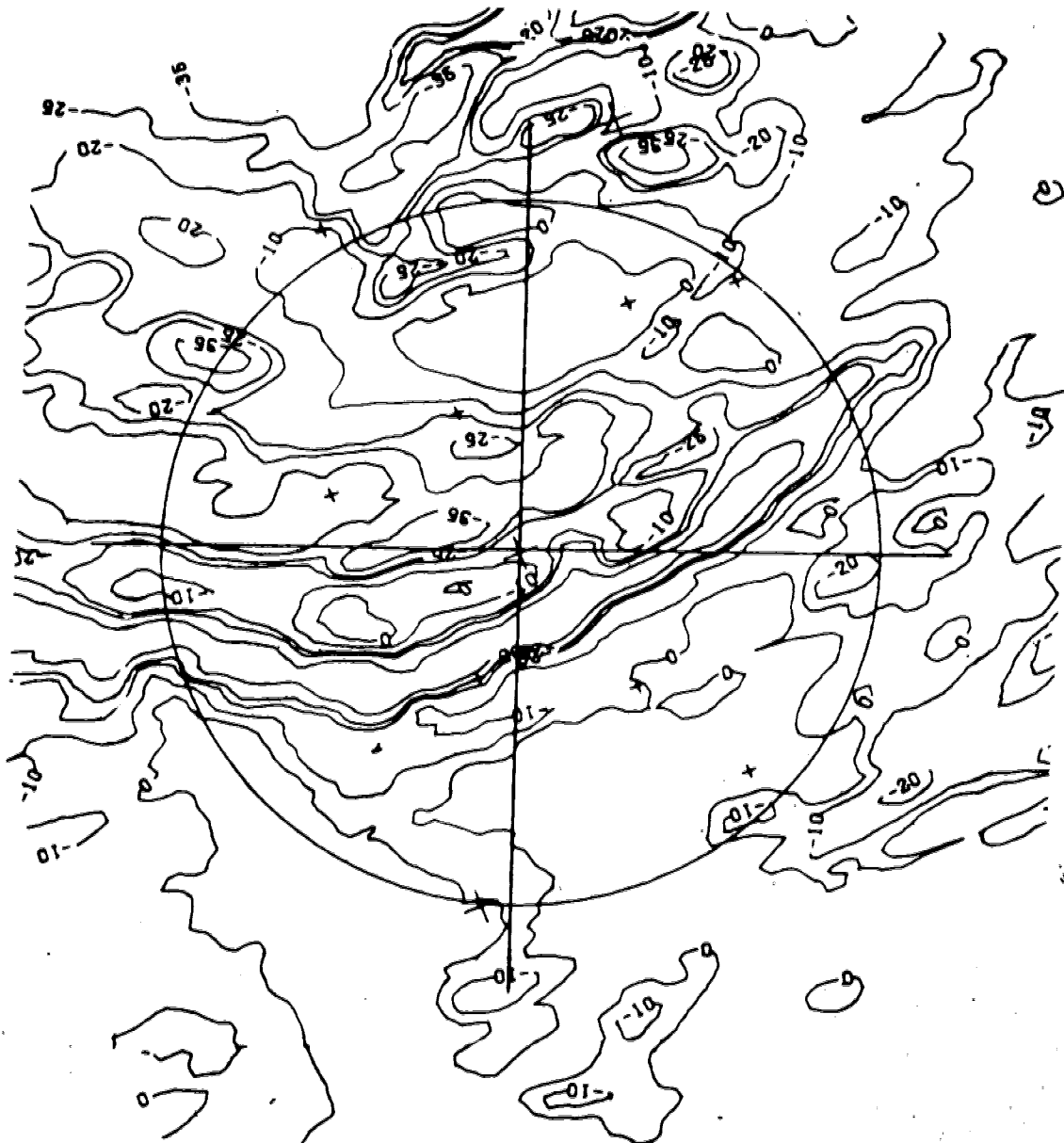


Figure 4.3 Infrared derived temperatures ($^{\circ}\text{C}$)
from TIROS-N orbit 3828.

4.6 Case Studies

The discussion of each case study includes: 1) a 500-mb height and vorticity analysis for 2400Z (1800 MDT), 2) two representative upper air soundings displayed on tephigrams, with the winds of one plotted on a hodograph; 3) a surface analysis for 2400Z (1800 MDT).

The solid isopleths on the 500-mb analyses are height contours in 60 m intervals, with the centers of the low's and high's marked by a crossed circle. Dashed isopleths are relative vorticity at $2 \times 10^{-5} \text{ s}^{-1}$ intervals. The maximum and minimum vorticity values relevant to the discussion are shown with an open circle. Short-wave ridges and troughs are indicated by heavy dashed lines.

For each case study soundings are shown from the radiosonde ascents at Penhold (CYQF), and one at either Rocky Mountain House (CYRM), Edmonton (CYEG), or Calgary (CYYC). The choice of a second sounding was made by considering which of the above locations would be more representative of the storm environment. These soundings show dry bulb (solid line) and wet bulb (dashed line) temperatures, and the moist adiabat that best represents a particular storm. Each moist adiabatic line was derived from values of maximum temperature and a mixing ratio. The mixing ratio was obtained by averaging the wet bulb temperature over the lowest 75-mb of the sounding. Two estimates of cloud-top height were derived from the tephigrams. The first of these assumes the cloud-top to be at the intersection of the moist adiabatic curve and the environmental temperature curve; the second estimate was obtained using the equal area or parcel method.

In an attempt to adjust cloud top height estimates to the current synoptic situation the "Wieler Standard Atmosphere" (WSA) was conceived. The WSA approximates the change in the height of the 250-mb surface based on the current 500-mb map. The adjustment to the 250-mb height from the standard atmosphere is taken to be twice the difference between the observed height of the 500-mb surface and the standard 500-mb height. This adjustment was used in all cloud top height estimates made in this study, except those derived from radar data.

4.6.1 Case Study #1 July 6, 1979

The synoptic situation the afternoon of July 6, 1979 was dominated by a long-wave trough at 500-mb sitting off the coast of Oregon. The 500-mb flow was diffluent over central Alberta, and surface winds were light (Figure 4.4). Prior to a short-wave ridge passage from the southwest at 2400Z several severe thunderstorms broke out. The convective day category (CDC) was 4 (walnut size), and 246 cases of hail were reported with a median time of 2345Z.

From figures 4.5a and 4.5b, the contoured infrared and visible images from orbit 3758 (2214Z), it is evident that at least three cells existed at this time, aligning themselves in a NE-SW line with the most vigorous cell just west of Calgary. Figures 4.6a and 4.6b, are grey shade representations of the visible and infrared fields respectively.

Figure 4.5a indicates that the storm to the west of Calgary had a minimum top temperature of -66°C (12.6 km), and a large anvil area colder than -55°C . The 0000Z radiosonde ascent at Calgary (YYC) (figure 4.7b) indicated cloud-tops at -56°C (11.7 km), (parcel method -70°C , 13.4 km). The 2000Z ascent at Penhold (YQF) (figure 4.7a) gave an estimate of cloud-tops at -60°C (12.2 km). Assuming these to be representative of the environmental air at 2130Z one might infer that overshooting cloud turrets had locally modified the tropopause by 0.5 km, creating a "convective bulge". The maximum echo top at this time over Calgary was estimated from figure 4.8 to be 12.6–13.8 km (41–45,000 ft).



Figure 4.4 500-mb and Surface maps July 6, 1979

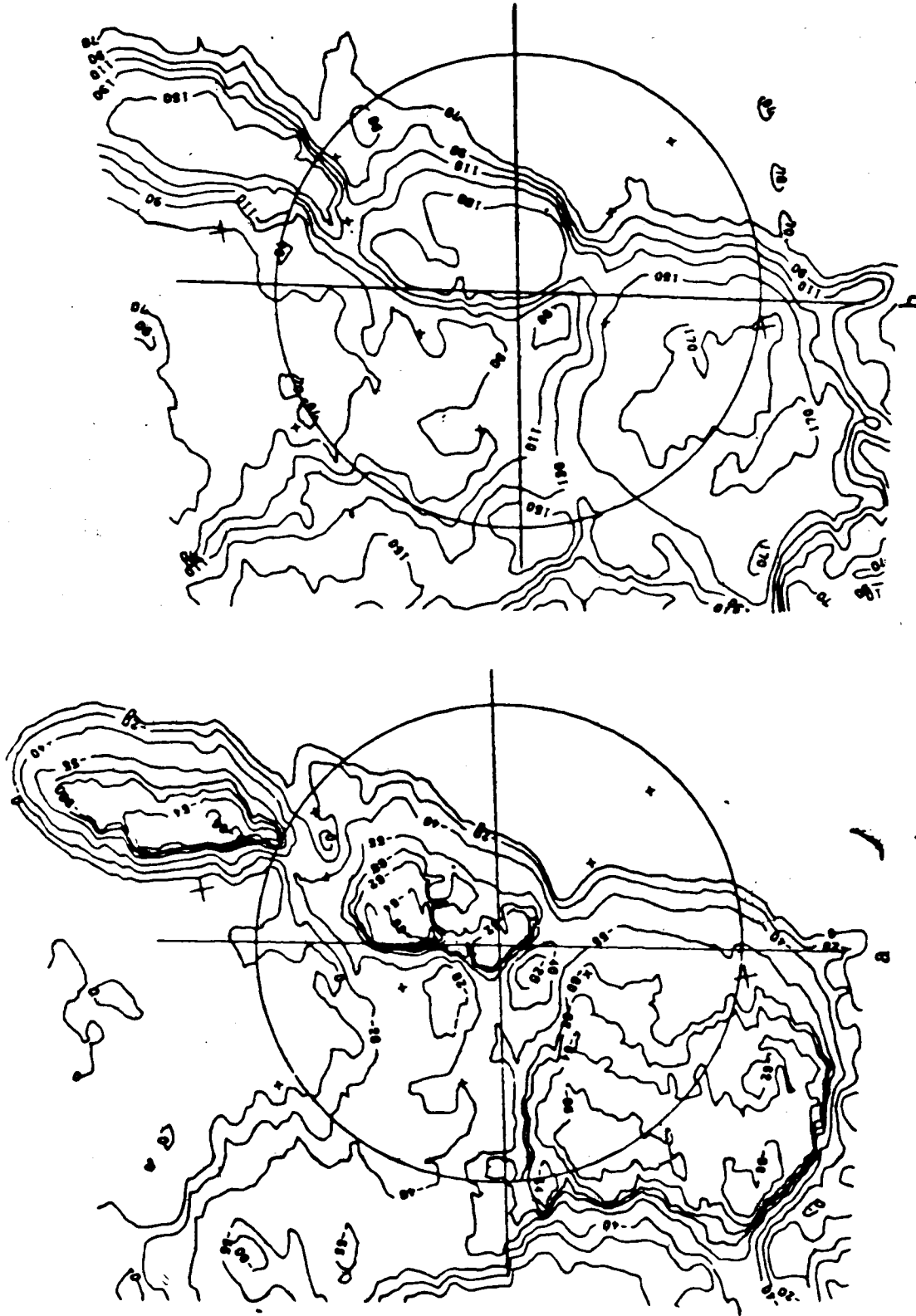


Figure 4.5 Contoured image from TIROS-N orbit 3758
a) Infrared, b) Visible.



Figure 4.6 Grey level image from TIROS-N orbit 3758
a) Infrared, b) Visible

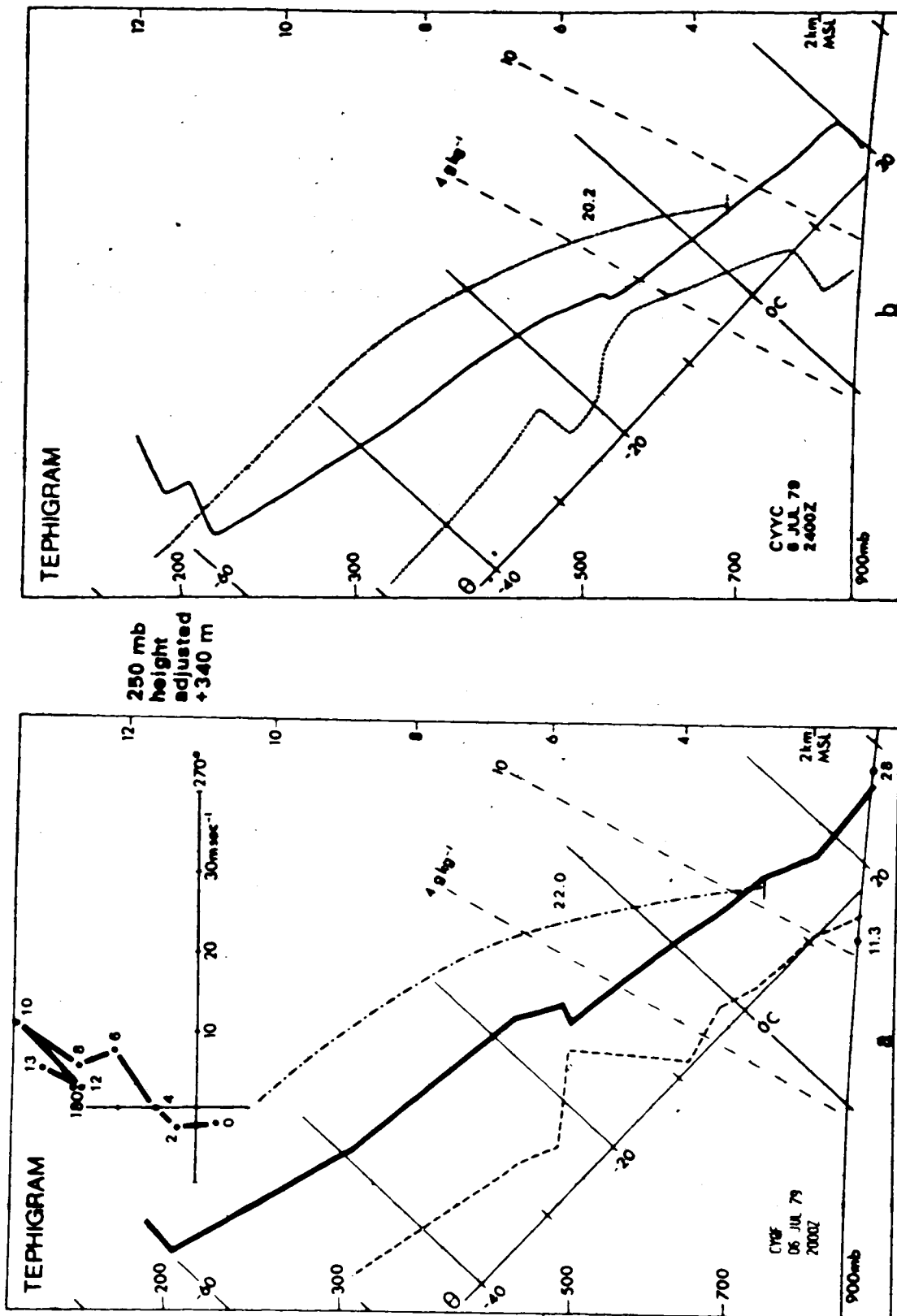


Figure 4.7 Tephigrams of radiosonde ascents, a) CYQF, b) CYVC.

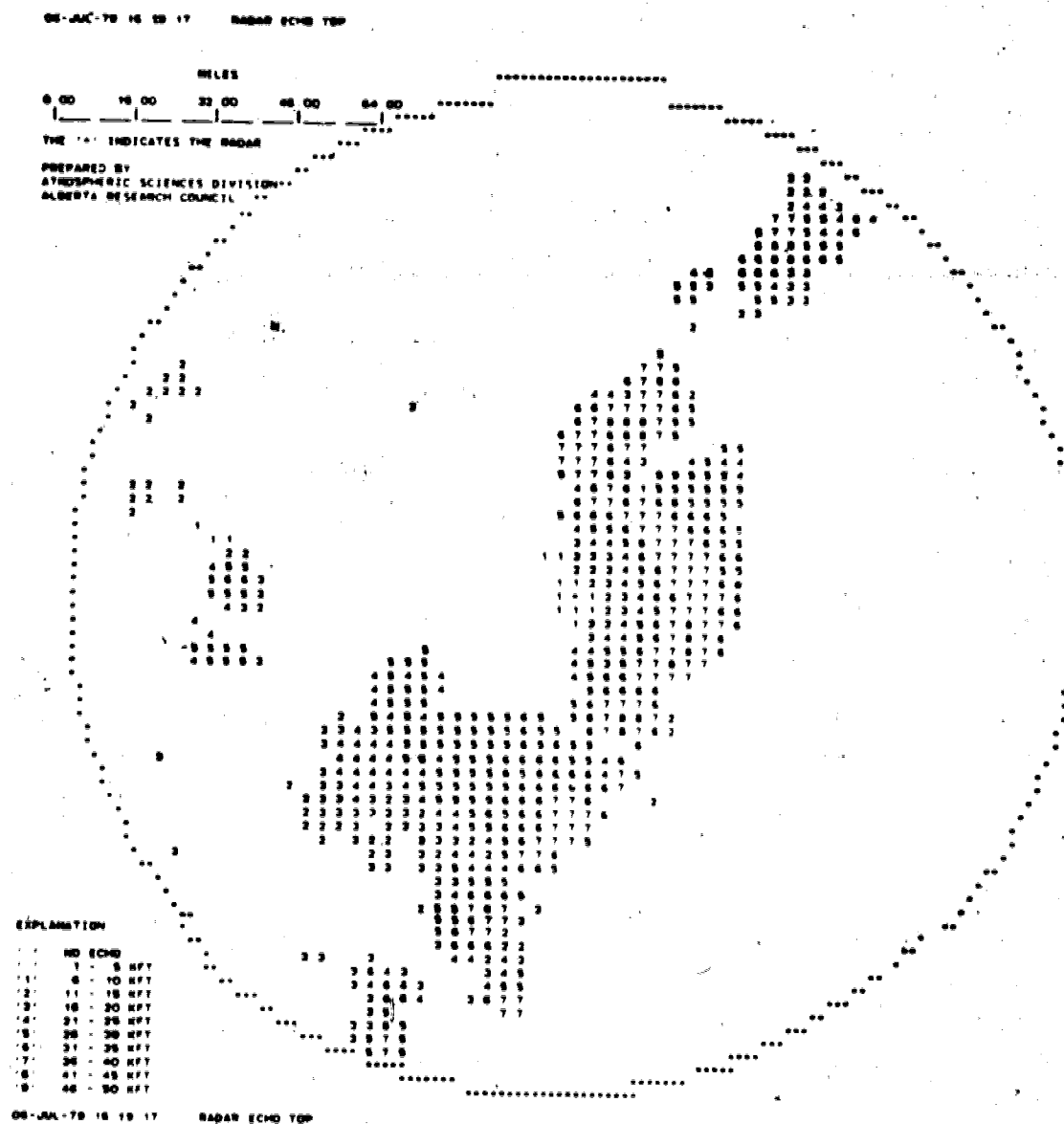


Figure 4.8 Maximum echo top map 22 19Z July 6, 1979.

VALUES GIVEN IN PERCENT OF TOTAL CLOUD COVER
54 OX CLOUD COVER OVER 38562 SQUARE KILOMETERS

Visible Reflectance	-70.	-65.	-60.	-55.	-50.	-45.	-40.	-35.	-30.	-25.	-20.	-15.	-10.	-5.	0.	5.	10.
Temperature (°C)																	
180																	
175																	
170																	
165																	
160																	
155																	
150																	
145																	
140																	
135																	
130																	
125																	
120																	
115																	
110																	
105																	
100																	
95																	
90																	
85																	
80																	
75																	
70																	

Table 4.2 Frequency table for orbit 3758.

4.6.2 Case Study #2 July 7, 1979

The general synoptic situation on the afternoon of July 7, 1979 was characterized by the passage of a short-wave trough-ridge pair. The 500-mb flow was diffluent from the southwest, while the surface winds over central Alberta were from the northwest (figure 4.9). The CDC was 4, and 143 cases of hail with a median time of 2300Z were reported.

Figures 4.10 and 4.11 are the contour and grey level maps for orbit 3772 which scanned over Penhold at 2218Z. At this time the major storm in the study area consisted of two cells, one to the west of Wetaskiwin, and the second more vigorous one to the northwest of Edmonton.

Looking at the tephigram figure 4.12a for the 2000Z ascent at CYQF yields a cloud-top estimate of -52°C (11.1 km). The tephigram for the 0000Z ascent at CYEG (figure 4.12b) yields an estimate of -55°C (11.5 km), (parcel method -68°C , 13.3 km). The radar maximum echo top map for the storm near Wetaskiwin gives a height of 11.1–12.3 km (36–40,000 ft). The cloud-top temperature of the cell west of Wetaskiwin as derived by satellite is -55°C (11.5 km). The data were contoured at -58°C , and -60°C , as the cell northwest of Edmonton shows, hence the -55°C estimate is not an artifact of the contour levels.

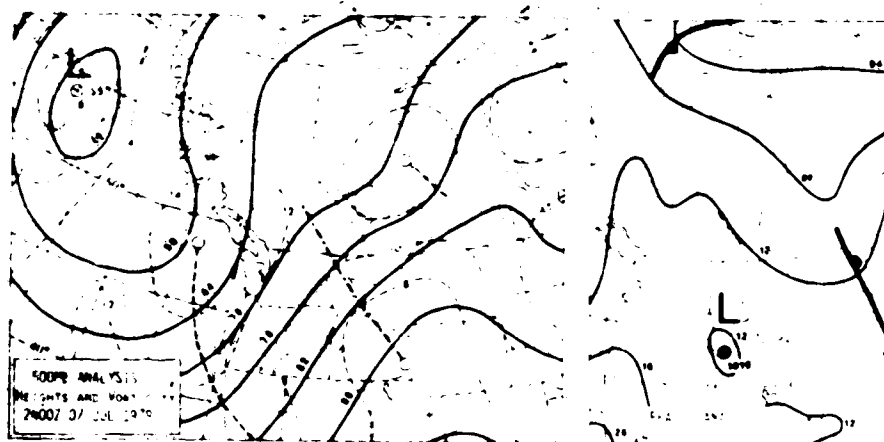


Figure 4.9 500-mb and Surface maps July 7, 1979

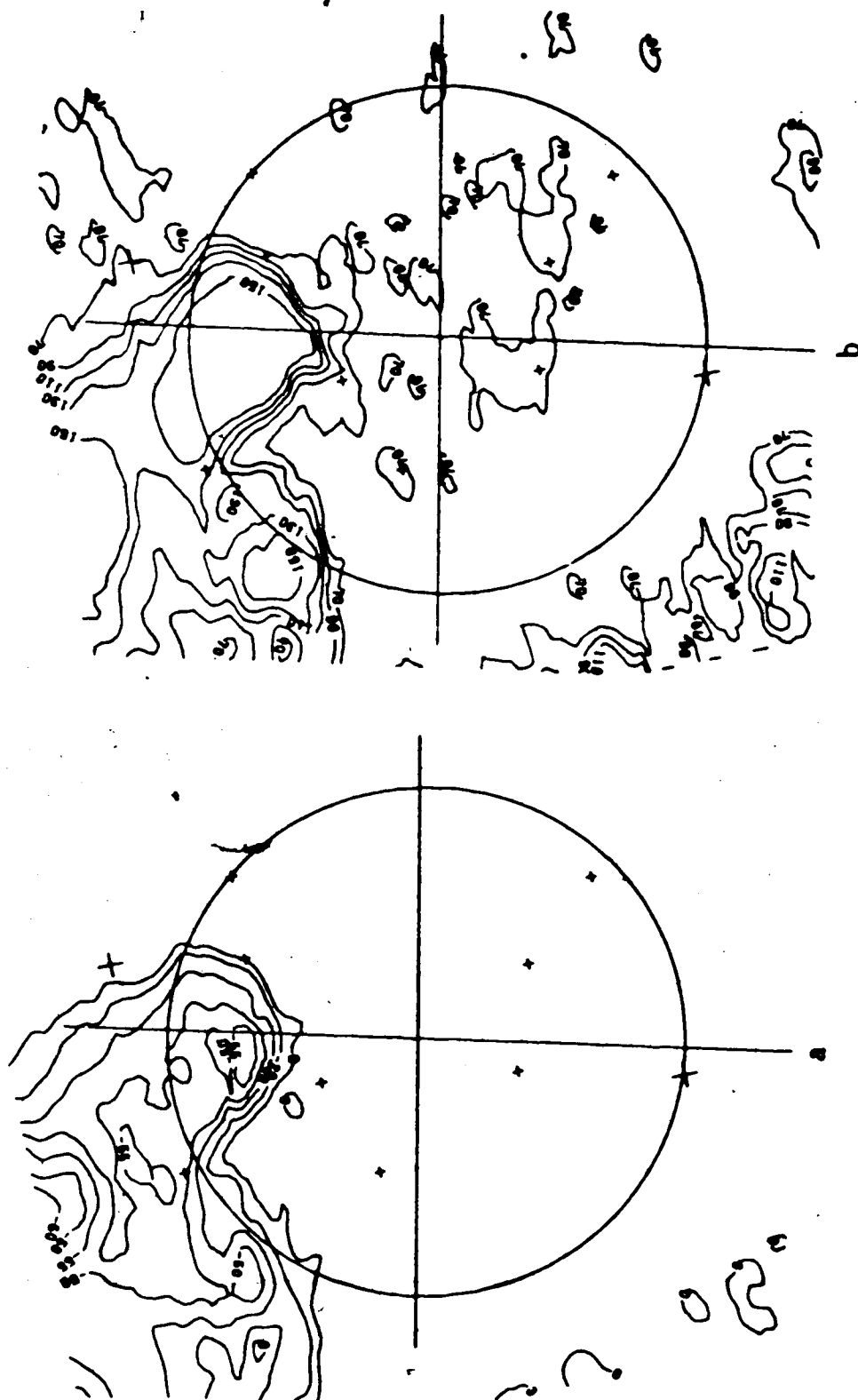


Figure 4.10 Contoured image from TIROS-N orbit 3772
a) Infrared, b) Visible.

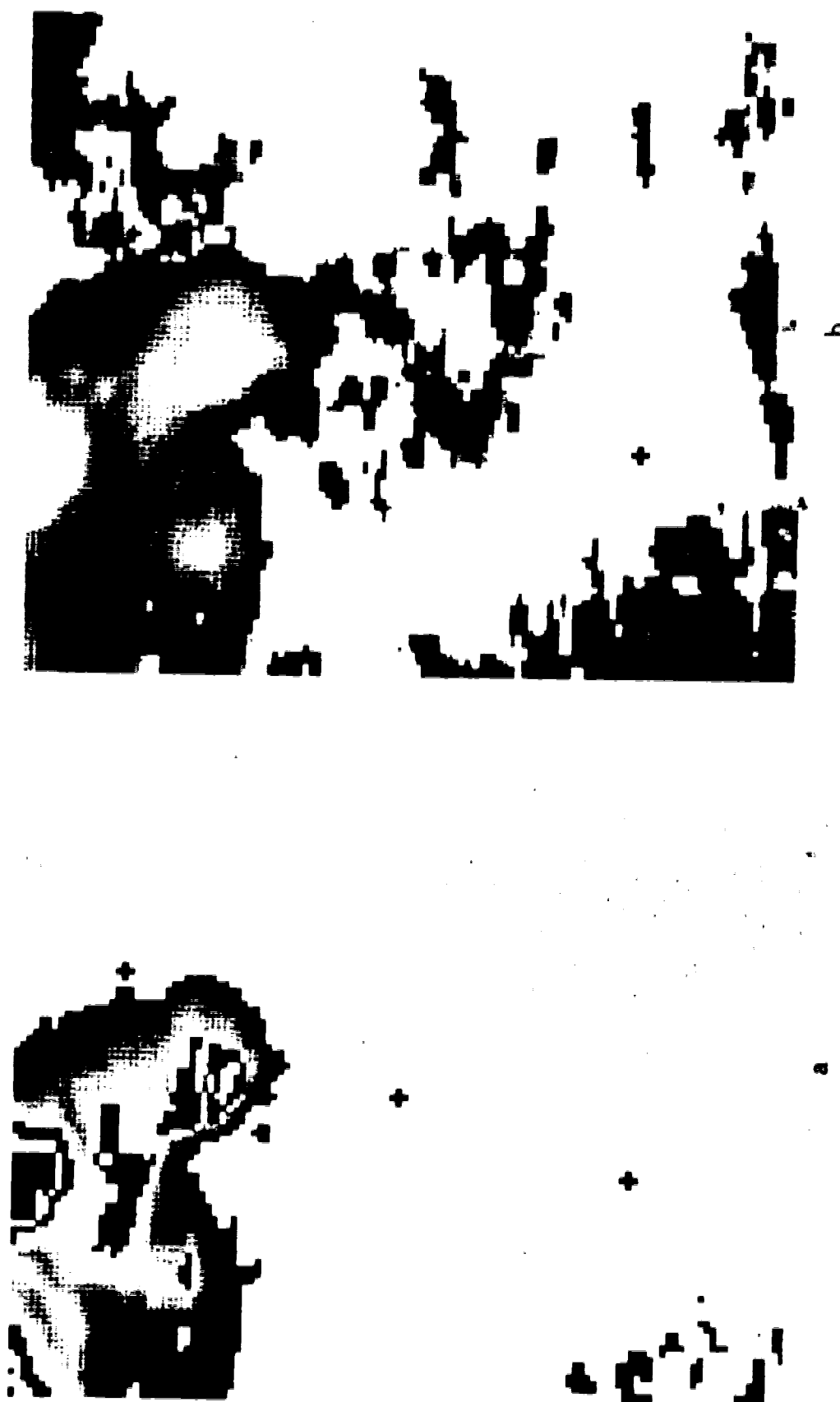


Figure 4.11 Gray level image from TIROS-N orbit 3772

a) Infrared, b) Visible.

VALUES GIVEN IN PERCENT OF TOTAL CLOUD COVER
18-2% CLOUD COVER OVER 41696 SQUARE KILOMETERS

Visible Reflectance	-70	-65	-60	-55	-50	-45	-40	-35	-30	-25	-20	-15	-10	-5	0	5	10
Temperature (°C)																	
180																	
175																	
170																	
165																	
160																	
155																	
150																	
145																	
140																	
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130																	
125																	
120																	
115																	
110																	
105																	
100																	
95																	
90																	
85																	
80																	
75																	
70																	

Table 4.3 Frequency table for orbit 3772.

4.6.3 Case Study #3 July 10, 1979

At 2400Z on July 10, 1979, the 500-mb flow was from the southwest with a short-wave trough just to the southwest of the study area at 2400Z. The surface map for that evening indicated a light northwesterly wind (figure 4.13). The CDC was 4 and there were 234 hail reports with a median time of 2200Z.

Figures 4.14 and 4.15 are the contour and grey level maps from orbit 3814 which crossed the study area at 2145Z. From these figures it is evident that there were four or possibly five convective cells aligning themselves perpendicular to the 500-mb flow.

The tephigrams for CYQF (2000Z) and CYRM (2400Z) (figure 4.16) indicate cloud-tops at -49°C (10.3 km) and -46°C (10.2 km), (parcel method -64°C , 12.6 km), respectively. The radar-top estimate was 8.0–9.2 km (26–30,000 ft). The satellite estimate of cloud-top temperature was -50°C (10.4 km) as seen in figure 4.14a.

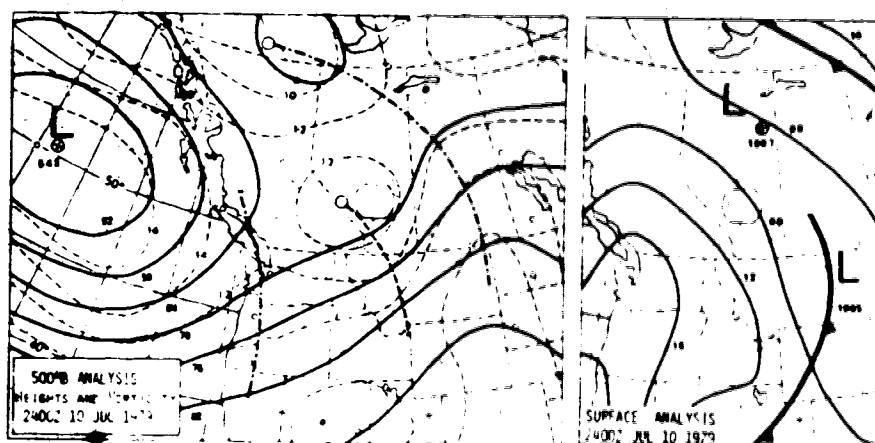


Figure 4.13 500-mb and Surface maps July 10, 1979

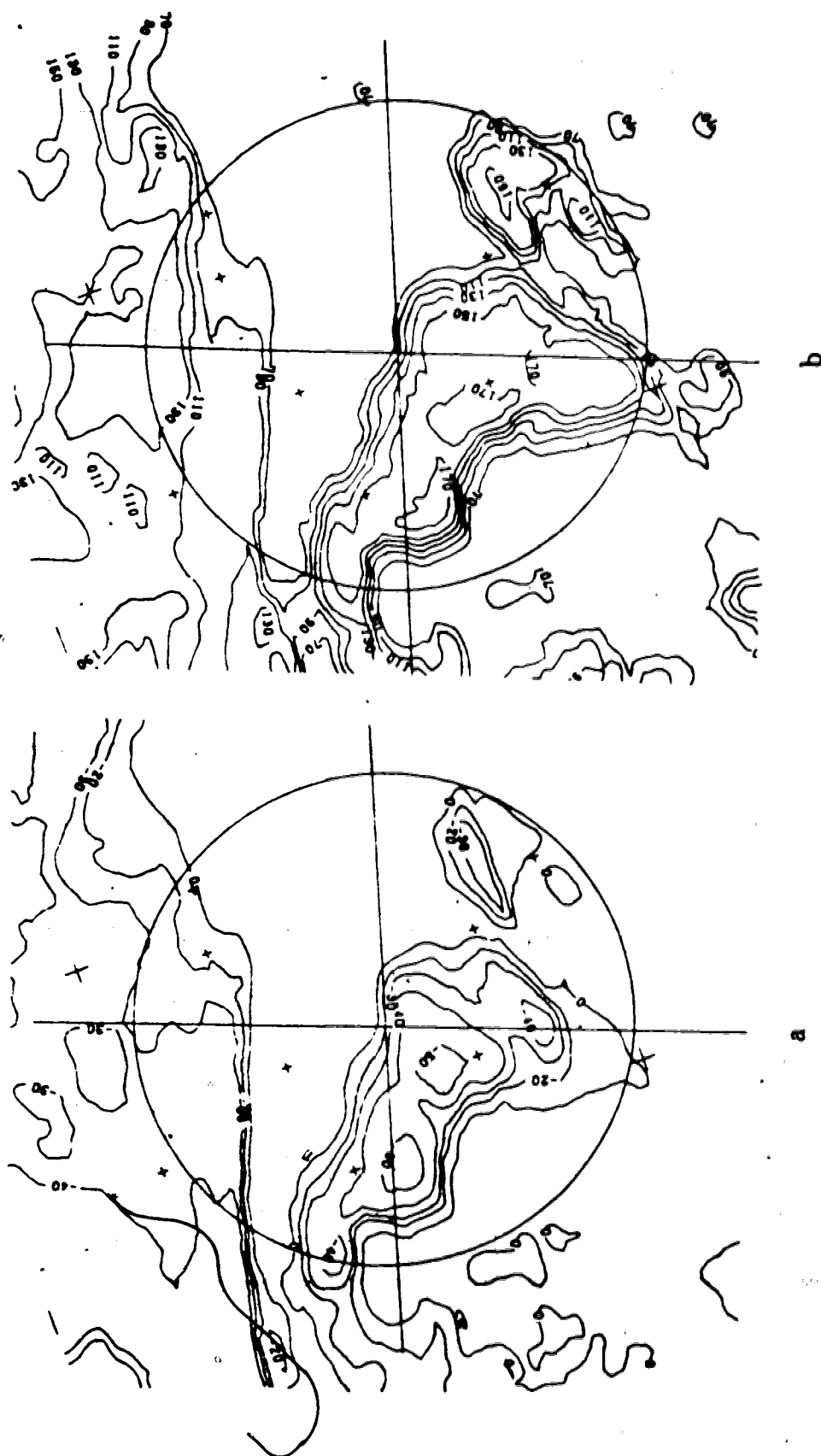


Figure 4.14 Contoured image from TIROS-N orbit 3814

a) Infrared, b) Visible.



Figure 4.15 Grey level image from TIROS-N orbit 3814

a) Infrared, b) Visible.

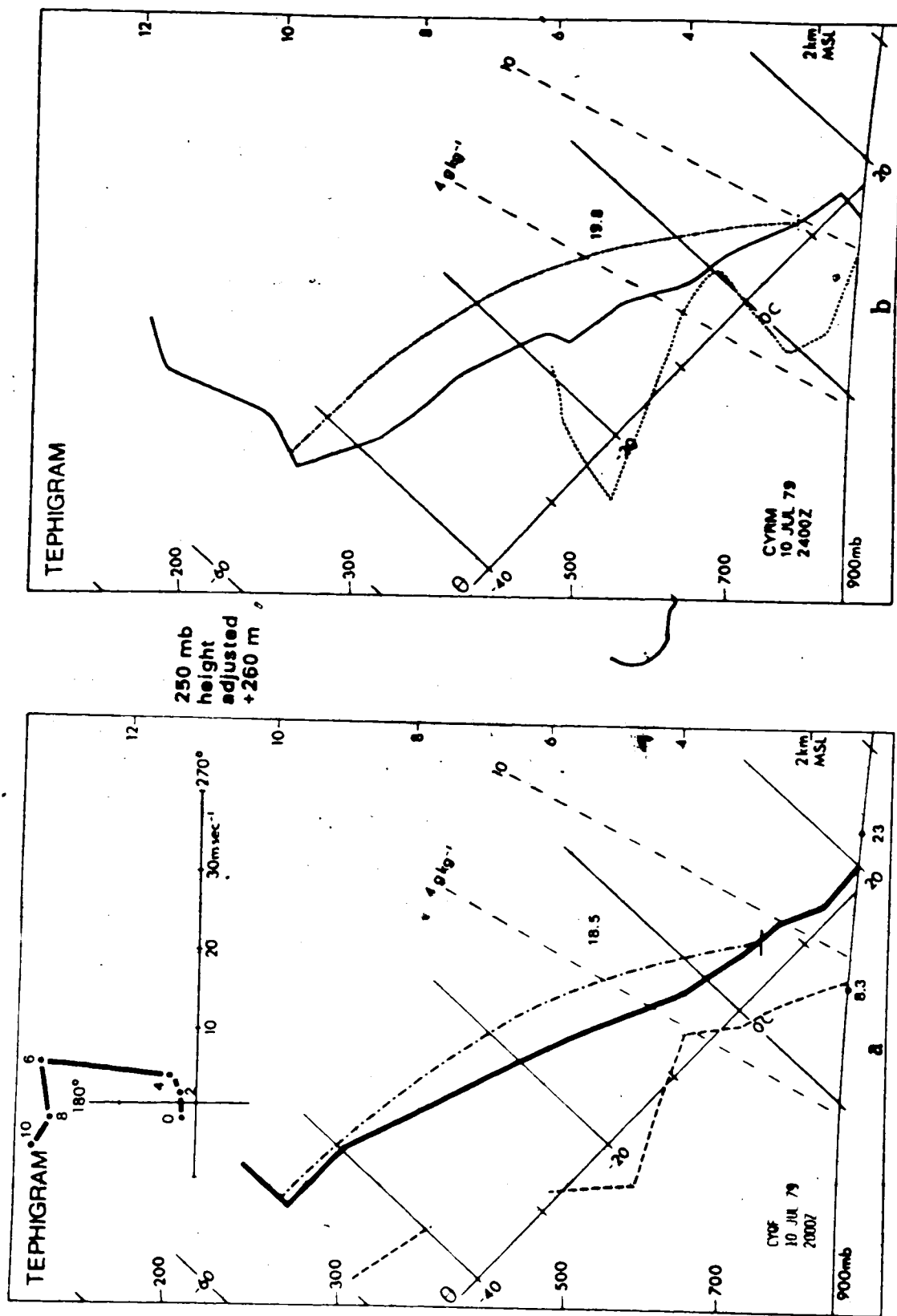


Figure 4.16 Tephigrams of radiosonde ascents, a) CYOF, b) CYRM.

VALUES GIVEN IN PERCENT OF TOTAL CLOUD COVER
45.8% CLOUD COVER OVER 46923 SQUARE KILOMETERS

Visible Reflectance	-70	-65	-60	-55	-50	-45	-40	-35	-30	-25	-20	-15	-10	-5	0	5	10
180																	
175																	
170	0.1	0.3	0.4	0.5	0.2	0.2	0.2	0.2	0.1								
165	0.1	0.4	0.6	0.6	0.3	0.3	0.3	0.2	0.2								
160			0.6	1.0	1.1	0.5	0.3			0.2							
155		0.1	0.4	1.0	1.0	0.8	0.3	0.1	0.1	0.3	0.3						
150			0.2	1.0	1.1	0.8	0.4	0.1	0.1	0.2	0.2						
145		0.1	0.2	0.9	1.3	1.2	0.7	0.5		0.1	0.6	0.2					
140		0.4	0.7	1.0	1.0	1.0	0.9	1.1	0.1	0.1	0.4	0.2					
135		0.2	1.1	1.5	1.2	1.5	1.5	0.4									
130			0.9	1.4	1.6	1.6	1.2	0.9	0.3	0.2	0.2	0.4					
125			1.6	1.3	1.8	1.3	0.6	0.9	0.2	0.3	0.3	0.5	0.2				
120			2.0	1.1	1.0	0.8	0.7	0.6	0.4	0.2	0.6	0.2	0.5	0.2			
115			1.2	1.7	0.7	0.9	0.4	0.5	0.3	0.3	0.3	0.5	0.3	0.5	0.2		
110			0.6	0.9	0.9	0.7	0.4	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.2	
105			0.5	1.4	0.7	0.9	0.9	0.5	0.7	0.3	0.2	0.4	0.4	0.8	0.4	0.4	
100			0.1	1.4	1.3	0.6	0.4	0.5	0.5	0.2	0.3	0.8	0.4	0.4	0.4	0.4	
95				0.3	1.0	0.7	0.2	0.4	0.5	0.3	0.3	0.7	0.7	0.7	0.7	0.7	
90						0.4	0.3	0.3	0.4	0.5	0.5	0.8	0.8	0.8	0.8	0.8	
85							0.2	0.3	0.3	0.3	0.6	0.4	0.7	1.0	1.0	1.0	
80										0.3	0.5	0.4	0.4	0.4	0.4	0.7	
75											0.1	0.2	0.4	0.6	0.7	0.7	
70												0.1	0.4	0.8	0.7	0.7	

Table 4.4 Frequency table for orbit 3814.

4.6.4 Case Study #4 July 21, 1979

The synoptic situation (figure 4.17) on July 21, 1979 was characterized by a low-pressure system centered over the southern project area; the 500-mb flow was from the southwest with a short-wave trough over central British Columbia. The CDC was 5 (golf ball size), and there were 247 reports of hail with a median time of 2335Z. From figures 4.18 and 4.19 (the contour and grey level maps for orbit 3970 at 2314Z), it is evident that two cells with tops to -64°C existed over the study area. Since the 2000Z ascent at YQF (figure 4.20a) was not recorded over 250-mb, the extrapolated height of the tropopause from the 2400Z CYEG, CYYC, and CYRM soundings was determined to be at -52°C (11.9 km). The ascent from CYEG at 2400Z (figure 4.20b) indicated a cloud-top at -55°C (12.4 km), (parcel method -74°C , 14.6 km). On inspection of figure 4.20a one can see that there were large areas of cloud colder than -62°C (13.2 km). The radar for this case gave an estimate of 126–138 km (41–45,000 ft).

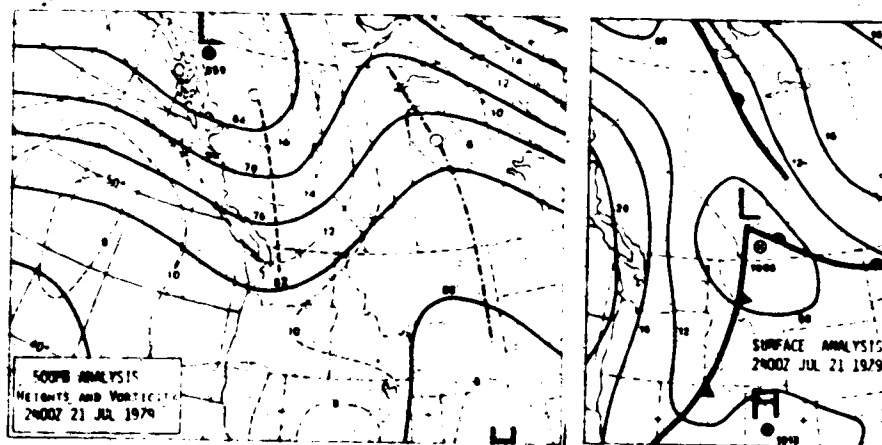


Figure 4.17 500-mb and Surface maps July 21, 1979



Figure 4.19 Gray level image from TIROS-N orbit 3970
a) Infrared, b) Visible.

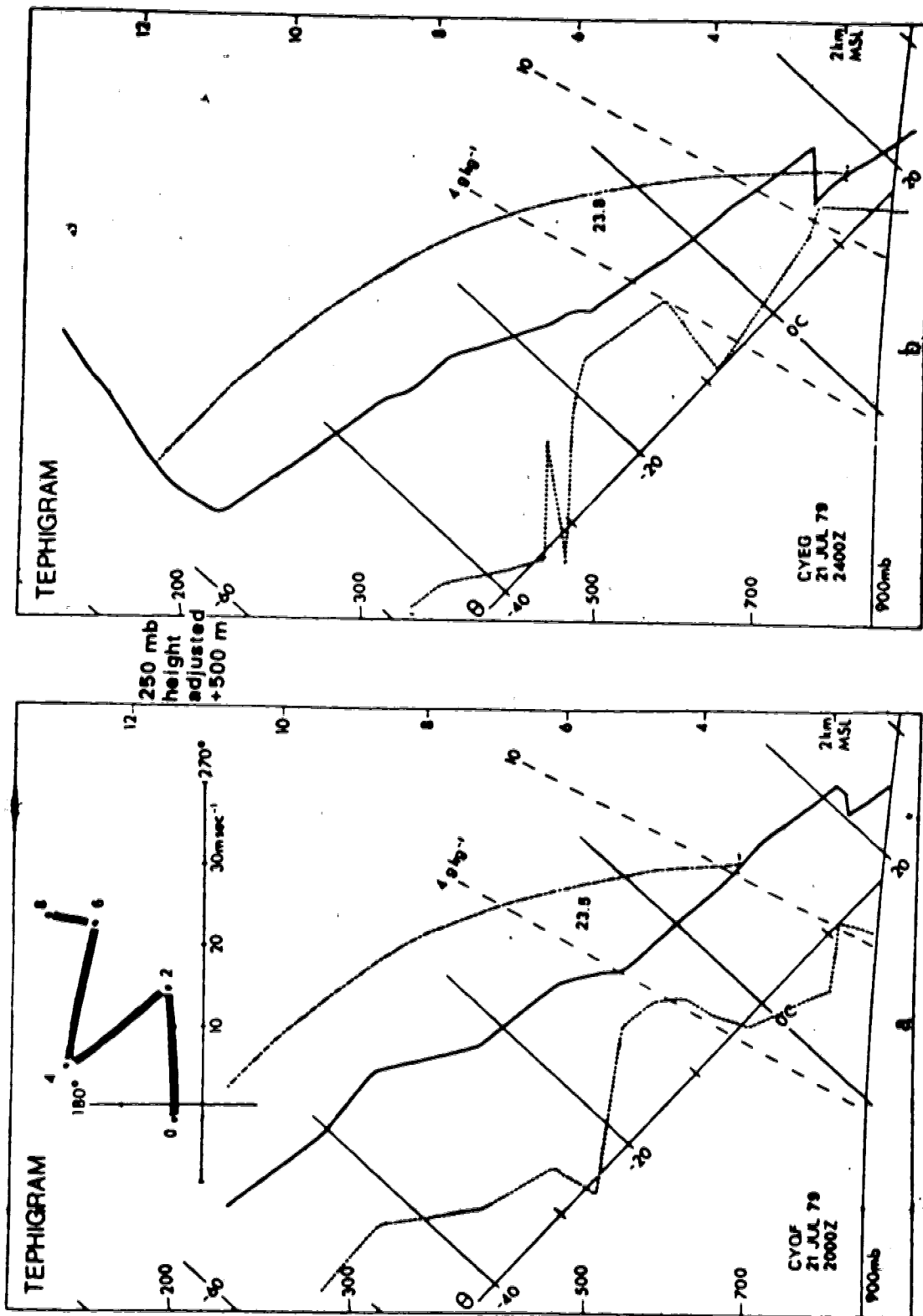


Figure 4.20 Tephigrams of radiosonde ascents. a) CYQF, b) CYEG.

4.6.5 Case Study #5 July 16, 1980

The synoptic situation the afternoon of July 16, 1980 was dominated by a 500-mb low-pressure system centered over Slave Lake, Alberta (Figure 4.21). At this time a short wave trough was oriented NE-SW just west of the project area. A surface low was located in northeastern Saskatchewan, surface winds over the project area at 2400Z were light and from the north. The CDC was 5, there were 410 cases of hail reported with a median time of 2300Z.

From the contour and grey level maps (Figures 4.22, and 4.23 respectively) one can see that the main storm feature at 2225Z was one well organized storm over Rocky Mountain House. The contour map yields an estimate of -53°C (10.2 km) for the storm's top. The CYRM radiosonde ascent (figure 4.24b) yielded an estimate of -47°C (9.7 km), (parcel method -66°C , 11.7km). The concurrent radar estimate for this storm was 9.3-11.9 km (35-41000 ft).

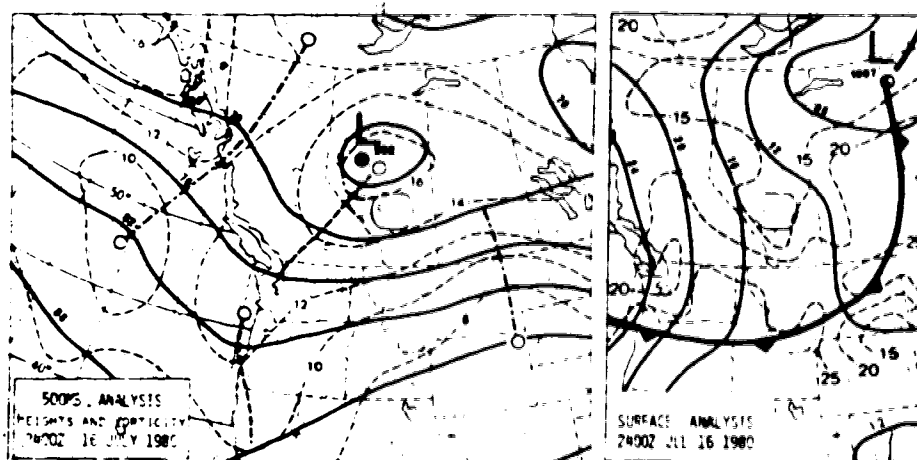


Figure 4.21 500-mb and Surface maps July 16, 1980

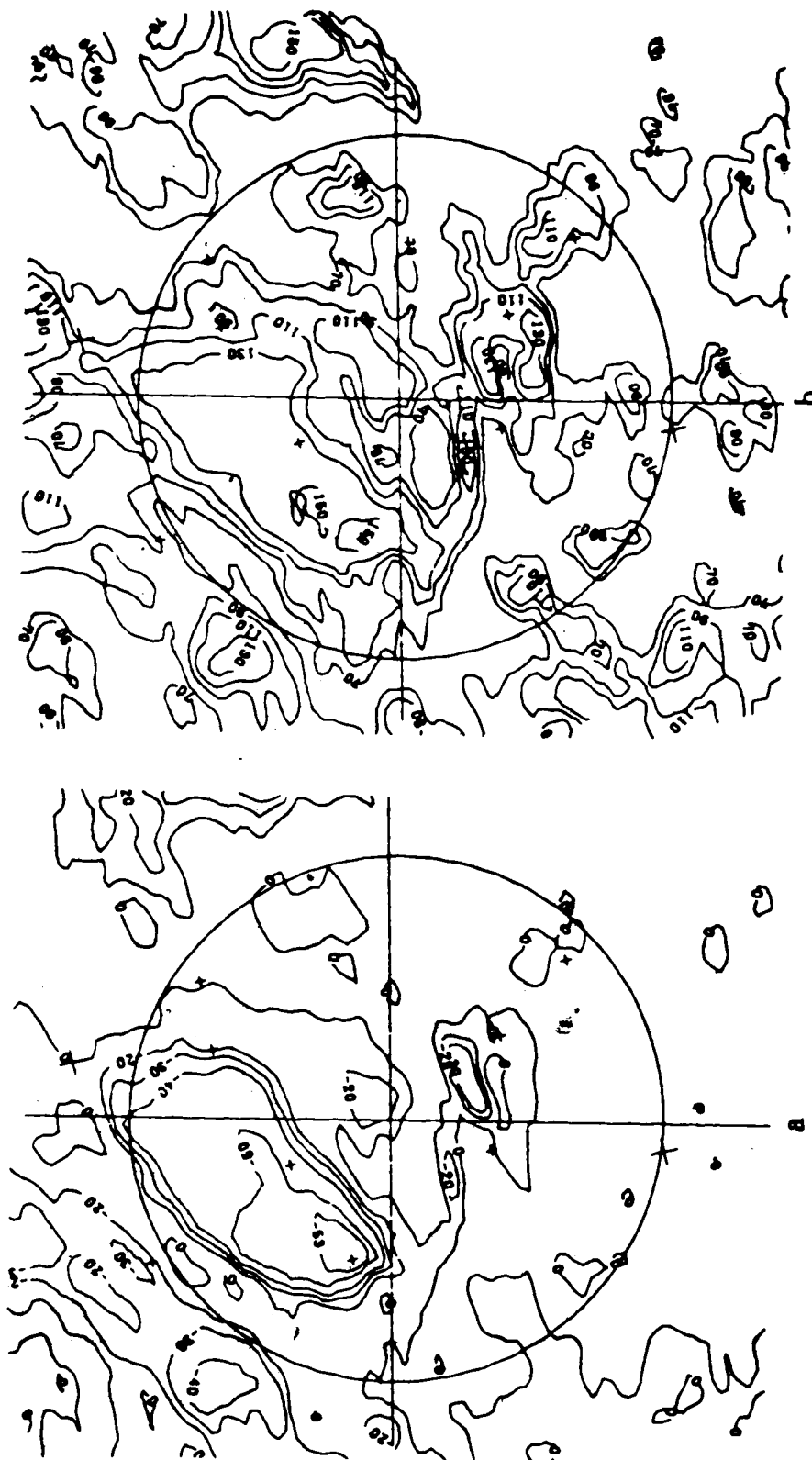


Figure 4.22 Contoured image from TIROS-N orbit 9063

a) Infrared, b) Visible.

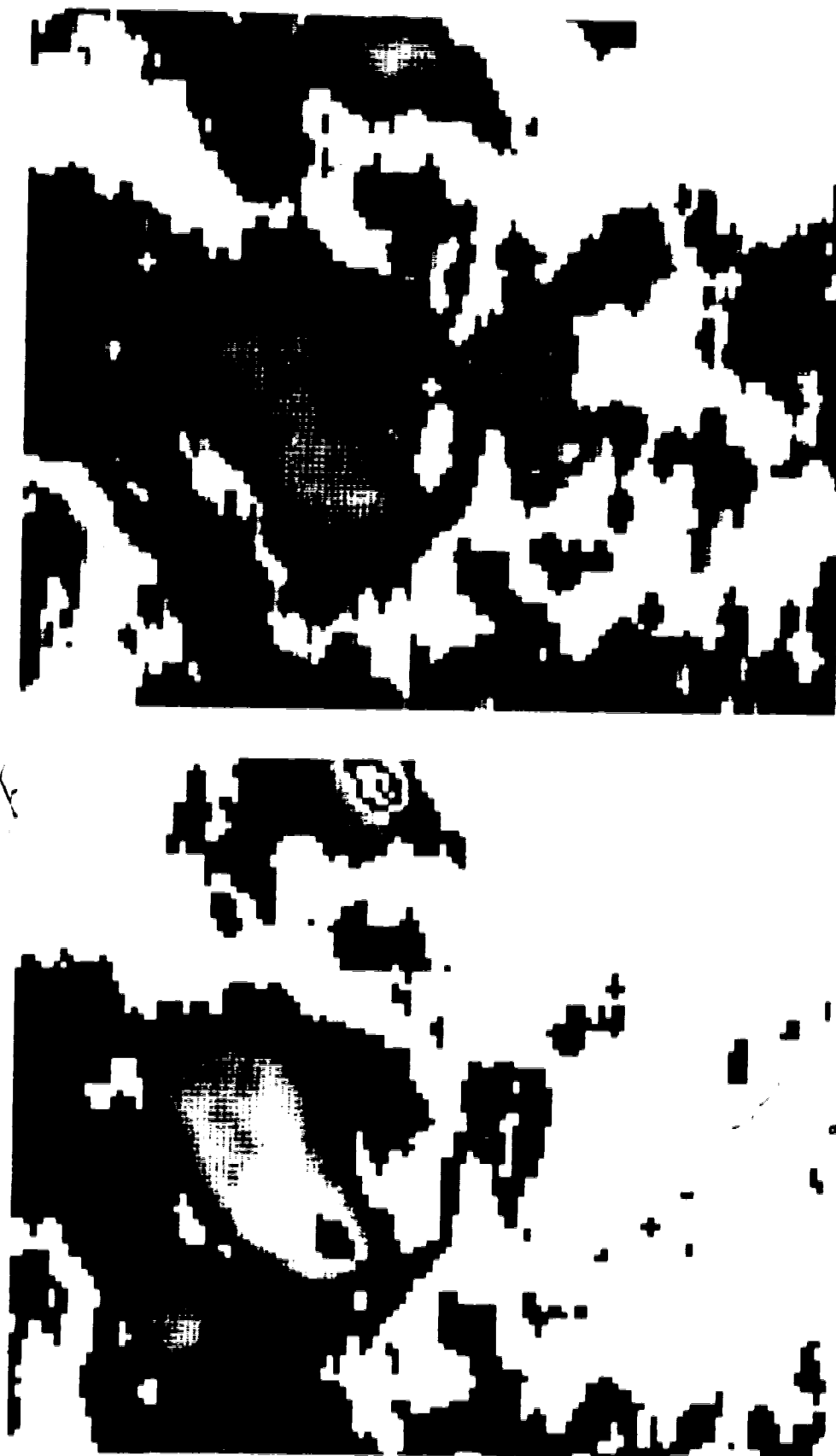
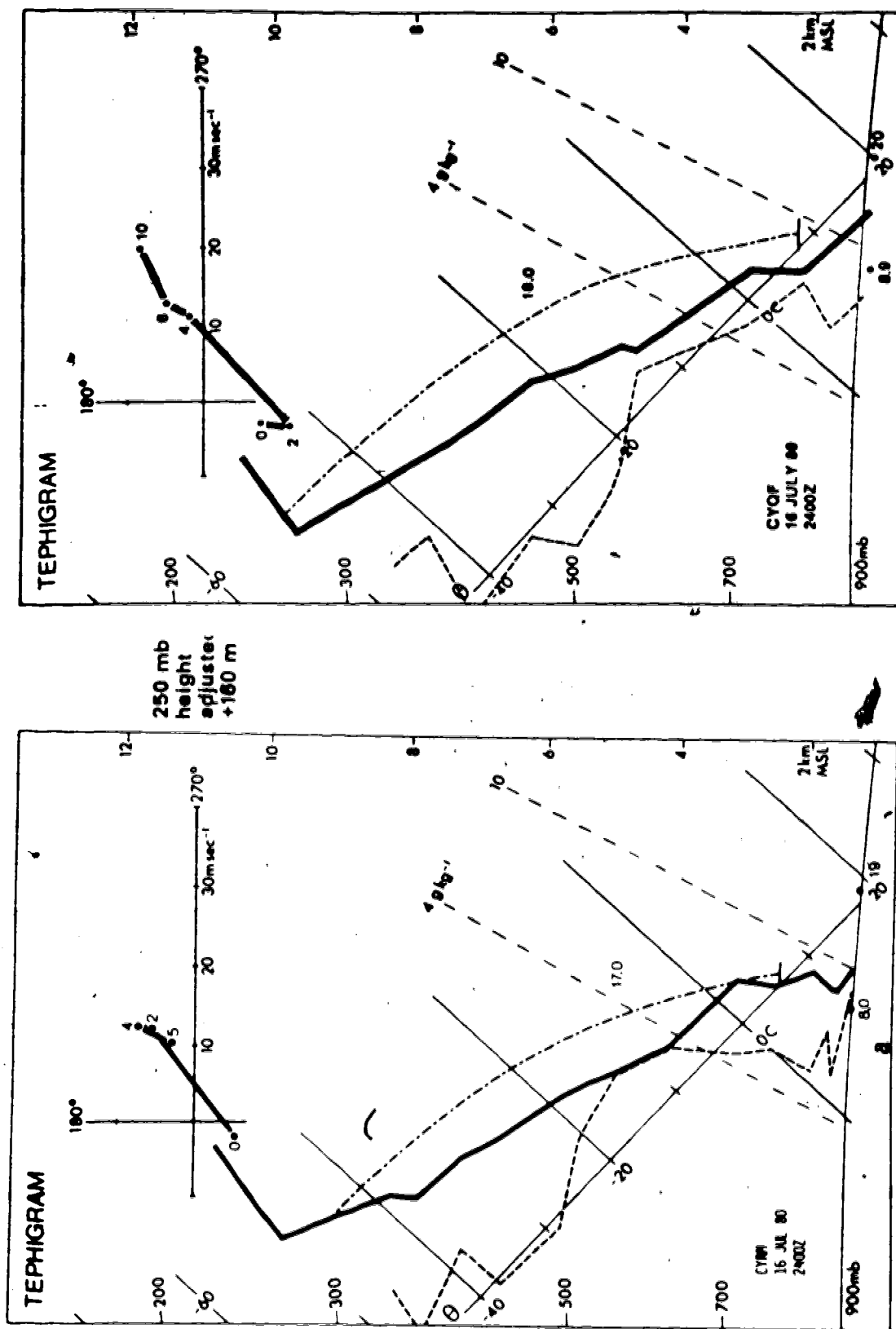


Figure 4.23 Gray level image from TIROS-N orbit 9063
a) Infrared, b) Visible.



VALUES GIVEN IN PERCENT OF TOTAL CLOUD COVER.
36.2% CLOUD COVER OVER 42369 SQUARE KILOMETERS

Visible Reflectance	-70.	-65.	-60.	-55.	-50.	-45.	-40.	-35.	-30.	-25.	-20.	-15.	-10.	-5.	0.	5.	10.
Temperature (°C)																	
180																	
175																	
170																	
165																	
160																	
155																	
150																	
145																	
140																	
135																	
130																	
125																	
120																	
115																	
110																	
105																	
100																	
95																	
90																	
85																	
80																	
75																	
70																	

Table 4.8 Frequency table for orbit 9063.

5. Rain Estimation from Satellite Data

5.1 Introduction

The estimation of rainfall over extensive areas is important in several ways. For example, such estimates are needed for improved calculations of both the water balance over oceans and continents, and the heat balance of the atmosphere.

Several attempts have been made to estimate rainfall from satellite data. A comprehensive review of satellite rainfall estimation methods is given by Martin and Scherer (1973). It has been well established that the area of convective rain (as determined from radar) is closely related to precipitation areas. Gruber (1973) indicated that the area of the radar echo return is well defined on satellite imagery by cold (i.e., high) clouds. Lethbridge (1967) compared TIROS-IV visible and infrared radiation for several localities with the occurrence of precipitation three to twelve hours following the satellite pass. It was found that the probability of rain for a twelve-hour period is higher than that for a three-hour period. Woodley and Sancho (1971) in their paper comparing satellite and rainfall data state: "The correspondence between echo and brightness area is best when the cloud system is young and vigorous, and worst when it is old and decaying." This is most likely due to the fact that mature clouds are colder and brighter than young ones because of their cirrus canopies.

Research suggests a generally positive relationship between rainfall and bright, cold clouds. However, it is also apparent that the use of time-integrated data of satellite imagery will produce a better correlation with the radar-determined rainfall areas than can be produced by instantaneous values.

5.2 Rain Area Determination

Although a majority of the research involving the estimation of rain intensity from satellite data is inconclusive, several tests were performed in order to determine what combinations of visible and infrared data correspond best with concurrent radar PPI's.

The first of these tests was run using cut-off values from previous research trying to determine rain areas from satellite data. Assuming that the visible digital counts

for GOES and TIROS-N data represent the same visible reflectance, values found by Griffiths (1978) were used to define the cut-off between the rain - no rain areas. The no rain area is defined by pixels with an infrared temperature higher than -20°C and a visible digital count of less than 80. According to Griffiths (1978), 88% of the clouds with a temperature of less than -20°C and digital counts greater than 80 will have radar echos. Thus, the rain area is assumed to be described by all pixels with temperatures lower than -20°C and digital counts greater than 80. Heavy rain areas were chosen to be all those pixels having a digital count of 120 or greater and a temperature of -50°C or less. Cheng (1977) found, 84.3% of the total rain area and 92.2% of the total rain amount will be within this area when using TIROS-N data.

The results given by the above values showed poor correlation with the radar PPI's, generally yielding larger "rain areas" than those inferred from the concurrent PPI's. The reason for this discrepancy may be due to a variety of factors. The first explanation that comes to mind is the possibility that the assumptions made regarding the correspondence between the GOES and TIROS-N visible data are poor.

A second reason might be the difference in geographical location. Both Griffiths and Cheng used data from Florida thunderstorms (27°N), while the data in this study involved storms over central Alberta (51°N). Although both studies were conducted in early summer within a few hours of local noon, the sun elevation angle varies by at least 26° . In all of these studies overhead lighting is assumed in order to simplify the sun elevation angle problem in the calibration of visible data. This overhead lighting assumption may not be valid over central Alberta where the sun elevation angle is 60° in early July.

The most likely reason for the apparent difference in results is the altitude difference between central Alberta (2200'-3500' msl) and the area around Miami, Florida (0'-20' msl). Miami's close proximity to the ocean and lower elevation, and Alberta's location on the leeward side of a mountain barrier indicate a larger amount of water vapour is available over Miami than is available over central Alberta. It is due to these differences that clouds at low elevations produce precipitation at lower heights and higher temperatures than clouds over higher elevations (Battan and Braham, 1956).

Two methods, chosen for their consistency and operational simplicity, were tested in order to determine the cut-off values for the rain areas. Program RAIN (Appendix C.9) was run with experimental cut-off values, and the data were contoured on a map in order to compare the resultant "rain area" with it's corresponding low-level PPI.

The first cut-off determination method involved contouring the brightest and coldest 5% of the cloud as the "heavy rain area", and the top 10% as the remaining "rain area". The percentages were determined from the frequency tables for each pass (Tables 4.2-4.5). This attempt yielded varied results for all cases tested. These results were thought to be influenced by the possibility of "sun glint" (ie. low sun elevation angle) skewing the visible digital counts in some cases. This skewing would only have to be very slight in order to make a significant difference in the reflectance of the top 10% of the cloud.

The second cut-off determination method involved using the same cut-off values for all satellite passes. After several attempts it was found that cut-off's of

-35°C, 134	"Rain area"
-50°C, 145	"Heavy rain area"

best approximated the PPI's.

It appears that the over-estimate of rain areas by Griffith's values is due more to the difference in the visible reflectance cut-off than to a difference in temperature cut-off. This may be due to the assumption made about GOES and TIROS-N visible data, and may support the argument that the sun elevation angle is in fact crucial in this type of data analysis. It is interesting to note that the differences in the cut-off values found by Cheng and those found in these tests may be explained solely by the difference in the geographical location.

Two of the problems associated with the "across the board" cut-off method are: 1) if the values are chosen too high the method will eliminate some information in a few of the passes; 2) if they are chosen too low, unusually large "rain areas" will result. The values obtained in these tests were a compromise of these two conditions while considering four separate data sets.

Figures 5.1, 5.2, and 5.3 are the plots of both "rain area" and PPI's. Although the estimated rain area seems to overestimate the low-level PPI's area, the basic shape and location of the rain areas is close to that of the PPI's.

The PPI's in Figures 5.1 and 5.2 are marked with a heavy black line representing the spatial integration of the 1° to 4° elevation angle positions of the 20 DBZ contour. This combination seems to give the best agreement with the satellite-derived "rain areas".

It must be stressed that these cut-off values are dependent on the stage of development of the thunderstorm, and would be of little use in non-convective rain estimation. This conclusion was also reached by Lovejoy and Austin (1979), who stated: "For widespread rain (stratus) days and convective rain days for Montreal, the optimum (rain no-rain) boundry is significantly different."

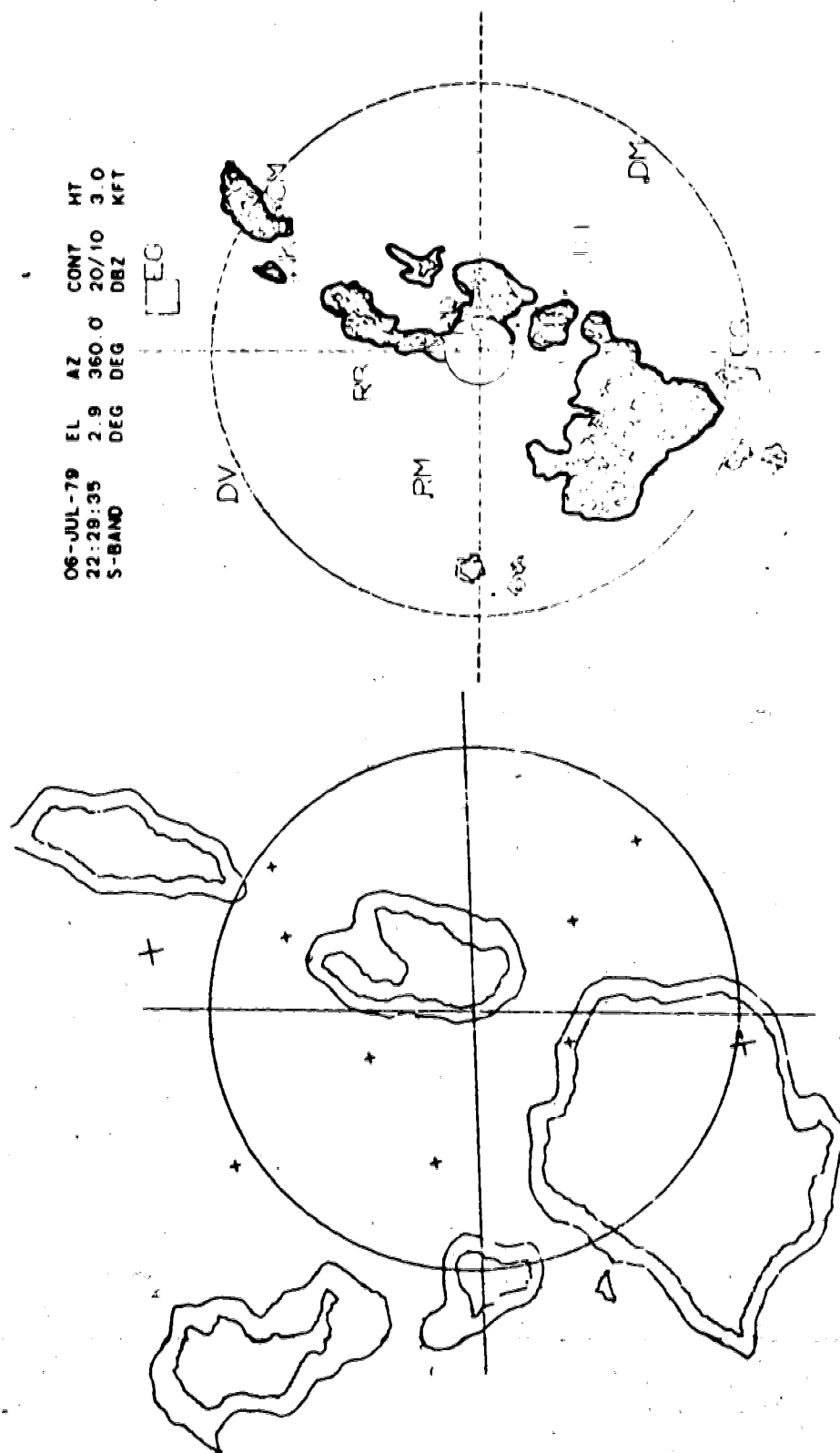


Figure 5.1 July 6, 1979 2230Z a) Satellite rain area estimation
 b) Radar PPI.

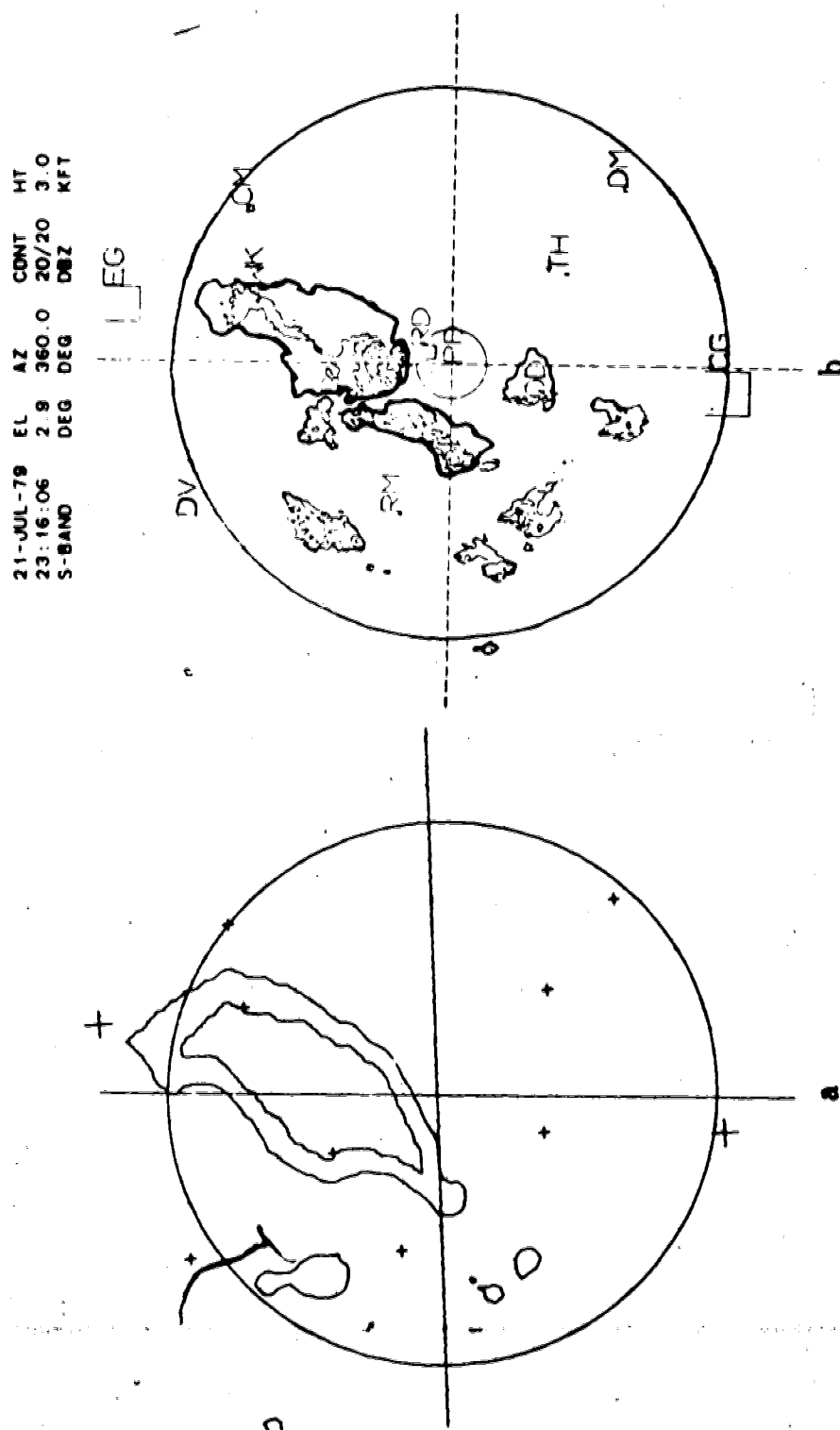


Figure 5.2 July 21, 1979 2315Z a) Sattelite rain area estimation
b) Radar PPI.

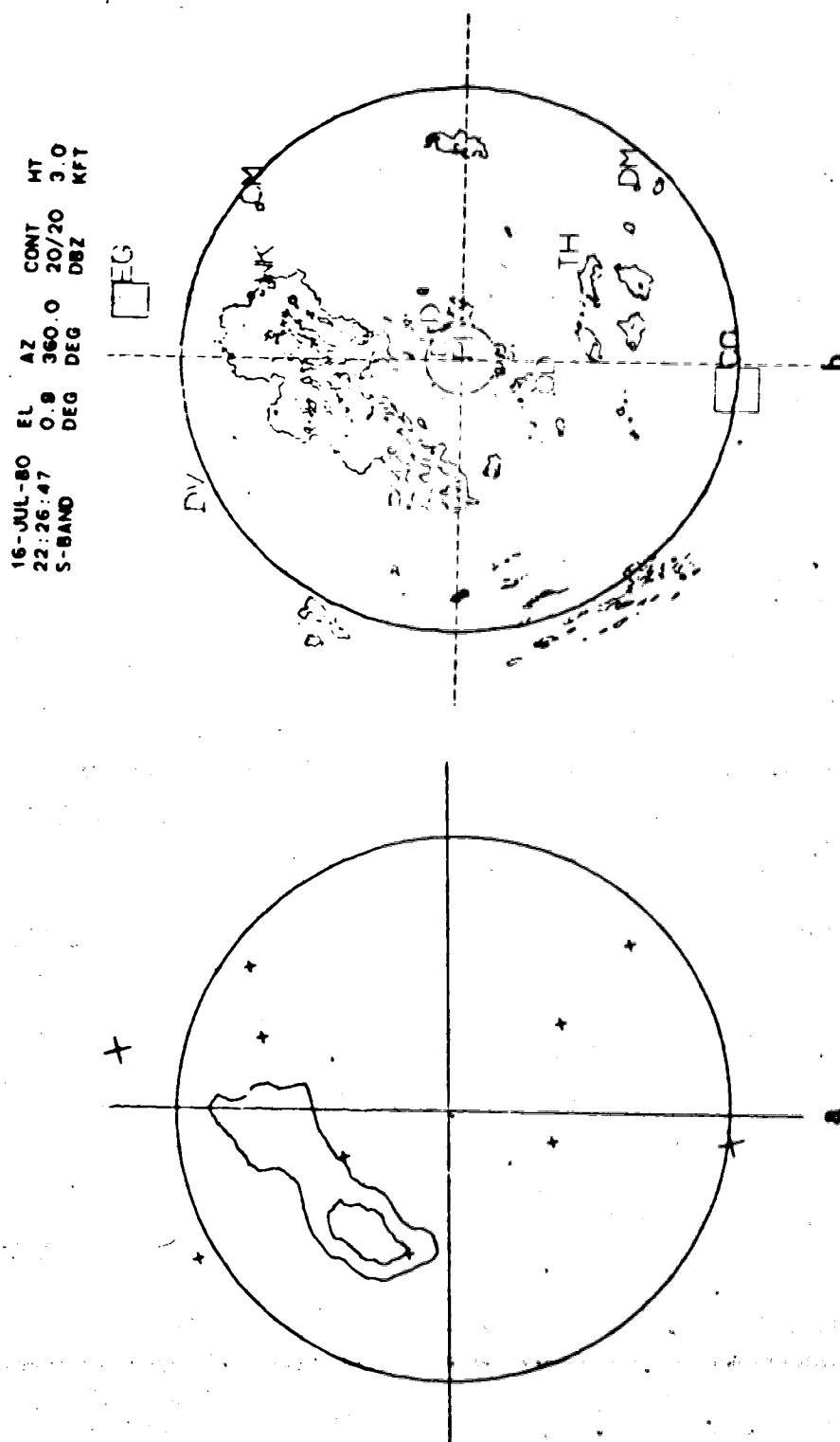


Figure 5.3 July 16, 1980 2226Z a) Satellite rain area estimation
 b) Radar PPI.

6. Summary and Conclusions

6.1 Summary of Results

The results found in Chapter 4 reveal that TIROS-N satellite data may yield the most accurate and economical estimation of cloud-top temperature available today.

The resolution of TIROS-N APT data (4 km²) is sufficient for use in the study of mesoscale cloud patterns, and therefore it can be used as a tool in the study of thunderstorms. This 4 km² resolution is fine enough to detect the "convective bulge" due to local tropopause modification by penetrating turrets, yet it is unable to detect these individual turrets as they are usually no larger than 2 km².

The temperatures derived in the manner discussed in Chapter 2 are calculated to be within $\pm 3^{\circ}\text{C}$ of the true temperature of the radiating surface. This error in temperature can be translated to a maximum error of approximately 450 m in cloud top height.

In comparing the cloud-top height estimates from all case studies (Table 6.1), it is evident that all estimates are close to one another relative to the error limits of each of the individual cloud-top height estimation methods.

The results in Table 6.1 indicate that the satellite estimates were close to all the conventional estimates for cloud top height. Generally, the cloud-top height associated with the satellite data was slightly underestimated by the tephigram method when not using the parcel method, and highly overestimated by an average of 1.5 km when using the parcel method. The satellite estimate was at the low end of the radar estimate range in Case #1, in the middle of the radar estimate range in Cases #2 and #4, and higher than the upper radar estimate in Cases #3 and #5. Consideration of the possible errors and assumptions involved in determining cloud-top height by conventional methods implies that satellite data may provide a more accurate estimate of cloud-top temperatures and height than any other method available, short of direct aircraft measurements.

Besides being more accurate, satellite data are more representative of the meso-scale and synoptic-scale conditions than the few point measurements one obtains from radiosonde data. The satellite data are area-averaged, which eliminates any chance for an unrepresentative point estimate, as can be the case for a radiosonde sounding.

Table 6.1 Cloud top height estimates (km)

Case study	Satellite	Tephigram	Tephigram parcel method	Radar
Case #1	12.6	11.7-12.2	13.4	12.6-13.8
Case #2	11.5	11.1-11.5	13.3	11.1-12.3
Case #3	10.5	10.3-10.2	12.6	8.0-9.2
Case #4	13.2	11.9-12.4	14.6	12.6-13.8
Case #5	12.0	9.3-9.8	11.7	9.5-10.7

The fact that the satellite infrared data originate from the radiating surface make satellite cloud-top height estimates more accurate than a radar estimate, as radar cannot detect the top of the cloud, except in special circumstances, (eg. airborne, very short wave-length radar).

The rain area determination method discussed in Chapter 5 proved to yield a rain area estimation close the estimation from the low-level PPI in each case studied. Generally, the rain area as determined from the satellite data overestimated the rain area, which was assumed to be equivalent to the area enclosed by the 20 DBZ contour on a low-level PPI. These tests agree well with former work in this area, in that it was found that a short (5 min) time-integrated PPI yields the best correspondence with the satellite-derived rain area.

6.2 Applications

The potential applications of these satellite data are as wide-spread as the satellite's areal coverage. Accurate cloud-top temperatures are valuable to the cloud physicist for evaluation of cloud physics models, and to help assess the effectiveness of cloud seeding both of thunderstorms for hail suppression, and of winter orographic clouds for snow pack augmentation.

These data can also be used for "truthing" other methods of cloud-top temperature measurement, such as cloud seeding or research aircraft. The large areal coverage of satellite data makes it possible to develop cloud climatologies over specific regions. Cloud cover and cloud size distributions of cloud greater than 4 km² may be numerically calculated over a given area far more accurately and economically than by any other method available. Infrared data alone can yield grid-point surface temperature data in data-sparse regions for input into heat budget and climate models. The mapping of natural disasters such as forest fires to assess damage is also possible from these data. *

The rain area determination method derived in this study can be used to map rain areas over regions where no rain gauge or radar data is available. This routine is also of value in deriving cloud climatologies of precipitating clouds.

6.3 Recommendations for Future Study

The need for further work in this area is evident. More accurate methods for "ground truthing" and temperature retrieval would be a definite asset to the use and implementation of satellite data in cloud physics research.

The effects of long-wave atmospheric attenuation has only been briefly mentioned in this work. The application of a radiation transfer model, based on current atmospheric conditions, would yield a far more accurate satellite product.

The "ground truthing" of satellite data could be greatly improved over the rough estimates of cloud-top height used in this study by the implementation of a thunderstorm cloud model which considers the effects of viscous drag, entrainment, and precipitation processes.

It is evident that both the infrared and visible cut-off values for the rain area determination method discussed in this study will be dependent on the stage of development of the thunderstorm, as well as the time of year. Hence there would be a need to establish the relationship of these cut-off values for the different stages of a thunderstorm's life cycle, and for different seasons, if this method were to be used operationally.

The derivation of a model for determining cloud-size distribution would be invaluable for meso-scale research, and would provide a systematic and objective record for establishing cloud climatologies.

In years to come, the numerical combination of remote sensing devices, such as radar and satellite data, will undoubtedly give man the tools to develop a better understanding of our atmosphere and its most dramatic displays of convection.

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A. Appendix A Infrared Calibration Technique

Since the radiometer on board TIROS-N has an output which is a linear function of the sensed radiance. Then:

$$N = GX + I$$

describes the relationship between digital counts (X) and radiance (N), where G and I are channel gain and intercept respectively. The channel gain is calculated by,

$$G = \frac{N_{sp} - N_t}{X_{sp} - X_t}$$

where G is the channel gain in radiance per unit count, N_{sp} is the radiance of space, N_t is the radiance of the internal target, and X_{sp} and X_t are the mean output count values when the radiometer views space and the internal target respectively.

The channel intercept is calculated by,

$$I = N_{sp} - G * X_{sp}$$

In reality the response of the radiometer in the 11 μ m region is slightly non-linear due to the physical properties of the radiometer. In order to compensate for these non-linearities the radiance of space is taken to be -1.151, as recommended by Schwalb (1978).

The Planck function is then integrated with the spectral response function of the radiometer and evaluated every 3°C in the -70°C to +30°C range. This process gives a digital count value for each temperature. The temperature of each pixel is then found by a linear interpolation on the temperature versus digital count curve.

Appendix B

Sample Output from Program SCAN

INFRARED INFORMATION FROM ORBIT 3758 OF SATELLITE TIROS-N ON JULY 6 1979
TIME OF FIRST SCAN 22:13:55 Z

SATELLITE SCANNED PENHOLD AT TIME 22:14:26Z.

LOCATION OF PENHOLD IN GRID
SCAN 63. POSITION 42.

SATELLITE HEADING IS NORTH

968.0 SCANS PASSED SINCE SATELLITE LAST CROSSED EQUATOR
AT LONGITUDE 104.82 DEGREES WEST

REFERENCE ORBIT 3740

CROSSED EQUATOR AT LONGITUDE 354.58 DEGREES EAST
AT TIME 15:31:31 Z

ORBITAL PERIOD = 102.09171 MIN

LONGITUDINAL INCREMENT = 25.52 DEGREES TO WEST

HEIGHT OF SATELLITE AT EQUATOR = 868. KM RADIUS OF EARTH = 6365. KM

ORBITAL INCLINATION = 98.95 DEG SCANNING RATE = 360. SCANS PER MINUTE

SCANNING BEGINS AT 744 AND ENDS AT 866

OUTPUT TAKES UP 233 TO 320 OF AVAILABLE WIDTH

SATELLITE SUBPOINT PIXEL NUMBER = 375.00

DISTANCE BETWEEN SCANS = 3.31 KM

SCALING = 7.6737E+01 GRID UNITS PER INCH IN X DIRECTION

DISTANCE BETWEEN POINTS = 4.28 KM

SCALING = 5.9346E+01 GRID UNITS PER INCH IN Y DIRECTION

MAP SCALE = 1 : 10.00 MILLION

DATA FIELD PARAMETERS

SMOOTHING PARAMETERS

SMOOTHING OPERATION NUMBER 1 SMOOTHING PARAMETER = 0.75

MEAN OF FIELD DIFFERENCES = 1.001

STANDARD DEVIATION = 0.723

NUMBER OF SCANS IN WINDOW = 123

SCAN LINES REJECTED DUE TO SYNCH PROBLEM = 6

SCAN LINES REJECTED = 10. 20. 71.
81. 102. 118.

SMOOTHING OPERATION NUMBER 2 SMOOTHING PARAMETER = 0.75

CALIBRATION PARAMETERS

CALIBRATION CURVE :	DATA LEVELS	TEMPERATURES (IN DEG K)
	233.51	200.00
	225.72	215.00
	215.62	230.00
	203.07	245.00
	188.03	260.00
	170.52	275.00
	150.64	290.00
	128.54	305.00

O. BAD DATA POINTS IN DATA FIELD

GRID DIMENSIONS : COLUMNS 1 TO 123 ROWS 1 TO 88

GRID SIZE = 10.82K ELEMENTS

EXTREME VALUES OF DATA FIELD
MINIMUM = -68.7 MAXIMUM = 52.7

NO LATITUDE LONGITUDE LINES GENERATED

OUTLINE PARAMETERS

LAT-LON POINTS FROM UNIT 1

15 GRID COORDINATE POINTS OF OUTLINE TRANSFERRED TO UNIT 16

OUTLINE OCCUPIES BOX CONTAINING SCANS 9. TO 115. AND POSITIONS 6. TO 82.

GRID POINT POSITIONS OF OUTLINE TRANSFERRED TO UNIT 16

Appendix C

Computer Program Listings

C.1 Program SCAN

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1      C      PROGRAM SCAN
2      C
3      C      PROGRAM TO CONVERT TIROS-N TAPE INFORMATION TO A GRIDDED
4      C      FIELD. GENERATE GRID POINT LOCATIONS OF LATITUDE AND
5      C      LONGITUDE LINES FOR USE IN PLOTTING ROUTINES. CALL
6      C      SMOOTHING AND CALIBRATION SUBROUTINES WHEN NECESSARY.
7      C      AND TO WRITE DATA FIELD TO TEMPORARY FILE.
8      C
9      C
10     C      INPUT FROM   UNITS 1,2 AND 3 : LATITUDE - LONGITUDE COORDINATES
11     C                      OF OUTLINES TO BE COMPUTED
12     C                      UNIT 4 : RAW VALUES OF SATELLITE INFORMATION
13     C                      (PRODUCED BY PROGRAM TAPERD)
14     C                      UNIT 5 : PROGRAM PARAMETERS
15     C
16     C      OUTPUT TO    UNIT 6 : PROGRAM PARAMETERS, CALCULATED VALUES,
17     C                      AND ERROR STATEMENTS
18     C                      UNIT 7 : AVERAGED CALIBRATION COEFFICIENTS
19     C                      UNIT 11 : GRID COORDINATES OF LATITUDE AND
20     C                      LONGITUDE LINES
21     C                      UNIT 13 : OUTPUT OF DATA FIELD
22     C                      UNIT 15 : POSTING OF NORTH POLE AND OTHER LOCATIONS
23     C                      UNIT 16 : GRID COORDINATES OF OUTLINES
24     C                      (UNITS 17, 18 AND 19 ALSO USED IF NECESSARY)
25     C
26     LOGICAL*1 LFMT(1) /'.'/
27     LOGICAL*1 LA(760)
28     INTEGER RORBIT, RQ, RHR, RMIN, RSEC, LOUT2(3)
29     INTEGER*2 HSCAN, BSCAN, ESCAN
30     REAL LAINC, LOINC, SLAT(500), SLONG(500)
31     REAL*8 IROV, POSI, IR, VISIBL, BLANK
32     REAL*8 QUAD, EAST, WEST, HEAD, NOR, SOU, POL, MONTH(12)
33     DATA POSI /BHPOSITION/, IR /BHIRFRED/, VISIBL /8H VISIBLE/
34     DATA EAST /8H EAST /, WEST /8H WEST /
35     DATA NOR /8H NORTH /, SOU /8H SOUTH /, POL /8H AT POLE/
36     DATA MONTH /8H JANUARY, 8HFEBRUARY, 8H MARCH, 8H APRIL, 8H
37     1 MAY, 8H JUNE, 8H JULY, 8H AUGUST, 8HSEPTEMBER, 8H OCTOBER,
38     2 BHNNOVEMBER, BHDECEMBER/
39     C
40     COMMON* /TFIELD/ TEMP(301,400)
41     COMMON /CALIB/ COF(11)
42     COMMON /CONSTO/ PIT2, PIB2, SB, XKB
43     COMMON /CONSTS/ RTSC, H, SSPP, SRPM, SINC, CINC
44     COMMON /VARI/ RRL
45     COMMON /VARID/ SCAN(500), POSN(500)
46     COMMON /PLT/ SCALP, SCALS, SCANMN, POSNMN, IPDS, MAXSC, LCHK1,
47     1 LOUT1, KINP
48     C

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49 C .....
50 C
51 C   CONSTANTS AND CHECKS
52 C
53 C   COMMON /BLOCK/ R, PI, C1, C2, C4, C5
54 C   R = 6367.65
55 C   PI = 3.1415927
56 C   PIT2 = PI * 2.
57 C   PIB2 = PI / 2.
58 C   C1 = PIT2 / 360.0
59 C   C2 = 1.0 / C1
60 C   DATA C3 /2.54/, MZERO /0/, ZERO /0.0/
61 C   SRPM = 360.0
62 C   EFFECTIVE SRPM
63 C   ESRPM = 120.
64 C
65 C   R   = RADIUS OF EARTH IN KM
66 C   PI  = PI
67 C   PIT2 = PI*2
68 C   PIB2 = PI/2
69 C   C1  = CONVERSION FACTOR DEGREES TO RADIAN
70 C   C2  = CONVERSION FACTOR RADIAN TO DEGREE
71 C   DIGF = DIGITIZING FREQUENCY OF SATELLITE IN DATA VALUES
72 C   PER SECOND
73 C   SRPM = SCAN RATE OF SATELLITE IN REVOLUTIONS PER MINUTE
74 C   (ONE REVOLUTION EQUALS ONE SCAN)
75 C   C3  = CONVERSION FACTOR CM TO INCHES
76 C   C4  = CONVERSION FACTOR (AHVRR RADIAN SCAN ANGLE TO DATA
77 C   VALUE POSITION). THE ZERO DEGREE REFERENCE FOR
78 C   SATELLITE IS DIRECTLY ABOVE THE SUBPOINT AT DATA VALUE
79 C   SSPP. SCANNING IS RESTRICTED TO WITHIN 54' OF SATELLITE
80 C   SUBPOINT FOR TIROS-N / NOAA A-6 SATELLITES.
81 C   EACH DATA RECORD (EITHER IR OR VISIBLE DATA) CONTAINS
82 C   699 DATA VALUES (PLUS A SCAN NUMBER). MIDPOINT IS AT
83 C   DATA VALUE SSPP. THEREFORE, ALL VALUES MEASURED
84 C   FROM ZERO DEGREE REFERENCE ARE CONVERTED TO DATA
85 C   VALUE POSITIONS BY MULTIPLYING BY C4 AND ADDING
86 C   SSPP. C4 IS INITIALIZED IN 'ENTRY EONS' IN ITERA
87 C
88 C .....
89 C
90 C   INPUT DATA
91 C
92 C   INPUT DATA IS READ FROM UNITS 1, 2, 4 AND 5. ALL INPUT DATA IS
93 C   FORMAT FREE. VALUES ARE DIVIDED BY BLANKS OR COMMAS. FORTRAN G
94 C   COMPILER INSERTS MISSING DECIMAL PLACES FOR REAL DATA AND DELETES
95 C   UNNECESSARY DECIMAL PLACES FOR INTEGER DATA INCORRECTLY ENTERED
96 C
97 C   THERE ARE ELEVEN READ STATEMENTS FOR UNIT 5
98 C
99 C 1 INPUT TYPE AND INCREMENTS
100 C
101 C   KINP = INPUT TYPE
102 C   KINP=0 NO INPUT FROM UNIT 3. USED TO CHECK POSITIONS OR
103 C   OUTPUT LAT-LON LINES ONLY
104 C   KINP=1 IR DATA FROM FILE SOURCE
105 C   KINP=2 VISIBLE DATA FROM FILE SOURCE
106 C   KINP=3 IR DATA FROM MAG TAPE SOURCE
107 C   KINP=4 VISIBLE DATA FROM MAG TAPE SOURCE
108 C   BSCAN = SCAN NUMBER TO BEGIN OUTPUT
109 C   ESCAN = SCAN NUMBER TO END OUTPUT
110 C
111 C   PARAMETER HSCAN IS READ DIRECTLY FROM UNIT 3 FOR EACH SCAN.
112 C   IT REPRESENTS THE NUMBER OF SCANS SINCE FIRST ARRIVAL OF
113 C   SATELLITE SIGNAL, FROM PROGRAM TAPERD. IF SCAN NUMBER CORRES-
114 C   PONDING WITH BSCAN IS NOT AVAILABLE FROM UNIT 3, PROGRAM
115 C   WILL BEGIN READING FIRST SCAN AVAILABLE. IF ESCAN
116 C   IS LARGER THAN THE LAST SCAN TRANSFERRED BY PROGRAM TAPERD-1
117 C   TO UNIT 3, AN END OF FILE MARK WILL BE ENCOUNTERED. BOTH
118 C   CASES RESULT IN PROGRAM FAILURE.
119 C

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120 C KB = POSITION TO BEGIN OUTPUT
121 C KE = POSITION TO END OUTPUT
122 C
123 C LENGTH OF OUTPUT (NUMBER OF COLUMNS) IS GIVEN BY PARAMETER
124 C MAXSC. MAXIMUM LENGTH IS 400 SCANS
125 C WIDTH OF OUTPUT (NUMBER OF ROWS) IS GIVEN BY IPOS (AND XPOS).
126 C MAXIMUM WIDTH IS 301 POSITIONS, WHICH CORRESPONDS TO
127 C SLIGHTLY LESS THAN ONE HALF THE SCAN WIDTH.
128 C SIZE OF OUTPUT IS GIVEN BY MTMAT (MAXSC*IPOS).
129 C
130 C SF = MAP SCALING FACTOR (1:10,000,000 INPUTTED AS 10E6)
131 C
132 C 2 ORBITAL DATA
133 C
134 C NORBIT = NUMBER OF ORBIT
135 C NYR = YEAR OF ORBIT
136 C NMO = MONTH OF ORBIT
137 C NDY = DAY OF ORBIT
138 C GRID = NUMBER OF SCANS BETWEEN LAST EQUATOR CROSSING AND
139 C FIRST ARRIVAL OF SATELLITE
140 C
141 C 3 ORBITAL DATA FOR REFERENCE ORBIT
142 C
143 C RORBIT = NUMBER OF REFERENCE ORBIT
144 C RHR = HOUR OF REFERENCE ORBIT (Z)
145 C RMIN = MINUTE OF REFERENCE ORBIT
146 C RSEC = SECOND OF REFERENCE ORBIT
147 C RQ = QUADRANT OF REFERENCE ORBIT EQUATOR CROSSING
148 C RQ=0 (5) 0 TO 90 DEGREES LONGITUDE WEST
149 C RQ=1 (6) 90 TO 180 DEGREES LONGITUDE WEST
150 C RQ=2 (7) 90 TO 180 DEGREES LONGITUDE EAST
151 C RQ=3 (8) 0 TO 90 DEGREES LONGITUDE EAST
152 C 0,1,2,3 ARE QUADRANTS FOR NORTHERN HEMISPHERE
153 C 5,6,7,8 ARE QUADRANTS FOR SOUTHERN HEMISPHERE
154 C RLONG = 'LONGITUDE' OF REFERENCE ORBIT EQUATOR CROSSING
155 C RQ AND RLONG ARE CODED VALUES READ DIRECTLY FROM T-BUS.
156 C THE PROGRAM CALCULATES RLONGC FROM THESE VALUES BY ASSUMING
157 C RIGHT ASCENSION OF THE ORBIT, THAT IS, LONGITUDE IS TAKEN
158 C TO BE POSITIVE TO EAST AND NEGATIVE TO WEST (T-BUS CODE
159 C ASSUMES 0 TO 180 DEGREES BOTH EAST AND WEST)
160 C
161 C 4 SATELLITE PARAMETERS
162 C
163 C PER = ORBITAL PERIOD IN MINUTES
164 C REG = LONGITUDINAL DISPLACEMENT PER ORBIT IN DEG LONG TO WEST
165 C H = HEIGHT OF SATELLITE AT FIRST SCAN IN KM
166 C ORIN = INCLINATION OF SATELLITE AT FIRST SCAN IN DEGREES
167 C SSPP = SATELLITE SUB-POINT PIXEL NUMBER (NADIR POINT IN SCAN)
168 C
169 C 5 CHECKING PARAMETERS
170 C
171 C LCHK1 = FIRST LATITUDE-LONGITUDE CHECKING PARAMETER
172 C LCHK1=0 LAT-LON LINES ARE NOT COMPUTED
173 C LCHK1=1 LAT-LON LINES ARE COMPUTED
174 C LOUT1 = OUTLINE CHECKING PARAMETER
175 C LOUT1=0 NO OUTLINES ARE COMPUTED
176 C LOUT1=1,2 OR 3 ONE, TWO OR THREE OUTLINES ARE COMPUTED
177 C (MAXIMUM OF THREE OUTLINES ALLOWED)
178 C
179 C 6 OUTLINE TYPE (NOT REQUIRED IF LOUT1=0)

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180 C      NOTE : EACH OUTLINE REQUIRES A SEPARATE LOUT2 PARAMETER
181 C
182 C      LOUT2 = OUTLINE TYPE PARAMETER
183 C      LOUT2=1 INPUTTED POINTS OUTPUTTED TO UNIT 6.
184 C              CALCULATED GRID POINT LOCATIONS OUTPUTTED
185 C              TO UNIT 16 (17, 18 AND 19)
186 C      LOUT2=2 NO OUTPUT OF INPUTTED POINTS.
187 C              CALCULATED GRID POINT LOCATIONS OUTPUTTED
188 C              TO UNIT 16 (17, 18 AND 19) MAXIMUM AND
189 C              MINIMUM ROW AND COLUMN OF GRID LOCATIONS
190 C              CALCULATED AND OUTPUTTED
191 C      LOUT2=3 NO OUTPUT OF INPUTTED POINTS.
192 C              MAXIMUM AND MINIMUM ROW AND COLUMN OF
193 C              GRID LOCATIONS CALCULATED AND OUTPUTTED
194 C      LOUT2=4 INPUTTED POINTS OUTPUTTED TO UNIT 6.
195 C              CALCULATED GRID POINT LOCATIONS OUTPUTTED
196 C              TO UNIT 15 FOR POSTING
197 C      LOUT2=5 INPUTTED POINTS WITHIN GRID FIELD OUTPUTTED TO UNIT 6.
198 C              CALCULATED GRID POINT LOCATIONS OUTPUTTED
199 C              TO UNIT 6
200 C
201 C      7 LATITUDE AND LONGITUDE INCREMENTS (NOT REQUIRED IF LCHK1=0)
202 C
203 C      LAINC = INCREMENT FOR LATITUDE LINES (IN DEGREES)
204 C      LOINC = INCREMENT FOR LONGITUDE LINES (IN DEGREES)
205 C      LCHK2 = SECOND LATITUDE-LONGITUDE CHECKING PARAMETER
206 C      LCHK2=0 DEFAULT VALUES FOR LATITUDE AND LONGITUDE
207 C              PLOTTING USED
208 C      LCHK2=1 VALUES FOR LATITUDE AND LONGITUDE PLOTTING
209 C              MUST BE INPUTTED
210 C
211 C      THE DEFAULT VALUES ARE LATITUDES FROM 0 TO 90 DEGREES NORTH,
212 C      LONGITUDES FROM 0 TO 360 DEGREES EAST. POINTS ARE CALCULATED
213 C      FOR EVERY LATITUDE-LONGITUDE INTERSECTION, BUT IF THE
214 C      OUTPUTTED AREA IS SMALL, MOST OF THESE POINTS ARE NOT USED.
215 C      THEREFORE, JUDICIOUS CHOICE OF LATITUDE AND LONGITUDE
216 C      PARAMETERS LEADS TO GREAT TIME SAVING
217 C
218 C      8 LATITUDE AND LONGITUDE PLOTTING VALUES
219 C      (NOT REQUIRED IF LCHK1=0 OR LCHK2=0)
220 C
221 C      LAB = LATITUDE TO BEGIN PLOTTING
222 C      LAE = LATITUDE TO END PLOTTING
223 C      LOB = LONGITUDE TO BEGIN PLOTTING
224 C      LOE = LONGITUDE TO END PLOTTING
225 C      LHEM = LONGITUDE HEMISPHERE
226 C      LHEM=1 BOTH LONGITUDES INPUTTED AS DEGREES EAST
227 C      LHEM=2 BOTH LONGITUDES INPUTTED AS DEGREES WEST
228 C
229 C      LATITUDES ARE EXPRESSED IN DEGREES NORTH
230 C      LONGITUDES ARE EXPRESSED IN DEGREES EAST OR WEST
231 C      NOTE: LATITUDE (LONGITUDE) TO BEGIN PLOTTING MUST
232 C      BE SMALLER THAN LATITUDE (LONGITUDE) TO END PLOTTING
233 C
234 C      A MAXIMUM OF 500 POINTS ALLOWED FOR EACH LINE
235 C
236 C      9 DATA INPUT PARAMETERS (NOT REQUIRED IF KINP=0)
237 C
238 C      NSKIP = NUMBER OF SCANS OF INPUT TO BE SKIPPED (FOR USE WITH MAG
239 C              TAPE INPUT ONLY. FOR FILE INPUT, PROGRAM WILL READ EACH

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240 C          SCAN OF DATA, AND BEGIN OUTPUT WHEN BSCAN IS REACHED)
241 C
242 C      LSMT = SMOOTHING CHECKING PARAMETER
243 C      LSMT=0 NO SMOOTHING IS DONE
244 C      LSMT=1 SMOOTHING IS CARRIED OUT
245 C      LCAL = CALIBRATION CHECKING PARAMETER
246 C      LCAL=0 NO CALIBRATION IS DONE
247 C      LCAL=1 CALIBRATION IS CARRIED OUT
248 C          COEFFICIENTS MUST BE READ IN ON UNIT 7.
249 C
250 C 10 SMOOTHING PARAMETERS (NOT REQUIRED IF KINP=0 OR LSMT=0)
251 C      (SEE SUBROUTINE $MOO)
252 C
253 C
254 C      THERE IS ONE READ STATEMENT FOR UNIT 4, WHICH IS CALLED
255 C      ESCAN-BSCAN+1 TIMES. UNIT 4 IS EITHER A FILE OR A MAG TAPE UNIT.
256 C
257 C
258 C      THERE IS ONE READ STATEMENT FOR UNITS 1, 2 AND 3. EACH CARD OR
259 C      LINE OF EACH UNIT CONSISTS OF A SINGLE LATITUDE-LONGITUDE
260 C      INTERSECTION WHICH THE PROGRAM CONVERTS TO GRID POINT COORDINATES.
261 C      THE PROGRAM CONTINUES TO READ UNTIL 500 POINTS ARE INPUTTED OR
262 C      AN END OF FILE MARK IS ENCOUNTERED. DEPENDING ON LOUT2,
263 C      GRID COORDINATES OF THE OUTLINE ARE OUTPUTTED EITHER TO
264 C      UNIT 6 OR TO UNIT 16 (17, 18 AND 19). THIS OUTLINE CAN
265 C      THEN USED WITH THE GRID FIELD IN PLOTTING
266 C
267 C      XLATD = LATITUDE COORDINATE OF POINT (IN DEGREES)
268 C      XLATM = LATITUDE COORDINATE OF POINT (AND MINUTES)
269 C      XLOND = LONGITUDE COORDINATE OF POINT (IN DEGREES)
270 C      XLONM = LONGITUDE COORDINATE OF POINT (AND MINUTES)
271 C      LHEM = LONGITUDE HEMISPHERE
272 C      LHEM=1 LONGITUDE INPUTTED IN DEGREES EAST
273 C      LHEM=2 LONGITUDE INPUTTED IN DEGREES WEST
274 C
275 C .....
276 C
277 C      READ (5,LFMT) KINP, BSCAN, ESCAN, KB, KE, SE
278 C      READ (5,LFMT) NORBIT, NYR, NMO, NDY, GRID
279 C      READ (5,LFMT) RORBIT, RHR, RMIN, RSEC, RO, RLONG
280 C      READ (5,LFMT) PER, REG, H, ORIN, SSPP
281 C      READ (5,LFMT) LCHK1, LOUT1
282 C      IF (LOUT1 .GT. 0) READ (5,LFMT) (LOUT2(I), I=1, LOUT1)
283 C      IF (LCHK1 .EQ. 0) GO TO 10
284 C      READ (5,LFMT) LINC, LOINC, LCHK2
285 C      IF (LCHK2 .EQ. 0) GO TO 50
286 C      READ (5,LFMT) LAB, LAE, LOB, LOE, LHEM
287 C 10 IF (KINP .NE. 0) READ (5,LFMT) NSKIP, LSMT, LCAL
288 C      IF (LCAL .EQ. 1) READ (7,LFMT) (COF(I), I=1, 11)
289 C
290 C
291 C
292 C
293 C      CONVERT LONGITUDE TO DEGREES EAST AND CONVERT
294 C      BEGINNING AND ENDING LATITUDES AND LONGITUDES
295 C      TO VALUES USED IN DO LOOPS
296 C      IF (LCHK1 .EQ. 0) GO TO 60
297 C      IF (LAE .LT. LAB) GO TO 820
298 C 20 LAB = LAB * 10 + 10
299 C      LAE = LAE * 10 + 10

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300      IF (LOE .LT. LOB) GO TO 840
301      30 IF (LHEM .NE. 2) GO TO 40
302      LOST = LOE
303      LOE = 360 - LOB
304      LOB = 360 - LOST
305      40 LOB = LOB * 10 + 10
306      LOE = LOE * 10 + 10
307      GO TO 60
308      50 LAB = 10
309      LAE = 910
310      LOB = 10
311      LOE = 3610
312      C
313      C      DETERMINE OUTPUT TYPE
314      60 IF (KINP .LT. 0 .OR. KINP .GT. 4) GO TO 860
315      IROV = POSI
316      IF (KINP .EQ. 1 .OR. KINP .EQ. 3) IROV = IR
317      IF (KINP .EQ. 2 .OR. KINP .EQ. 4) IROV = VISIBL
318      C
319      C      CALCULATE PROGRAM CONSTANTS FROM INPUT PARAMETERS
320      C
321      IF (RQ .EQ. 0 .OR. RQ .EQ. 5) RLONGC = 360. - RLONG
322      IF ((RQ .EQ. 1 .OR. RQ .EQ. 6) .AND. RLONG .GE. 90.)
323      1RLONGC = 360. - RLONG
324      IF ((RQ .EQ. 1 .OR. RQ .EQ. 6) .AND. RLONG .LT. 90.)
325      1RLONGC = 360. - RLONG - 100.
326      IF ((RQ .EQ. 2 .OR. RQ .EQ. 7) .AND. RLONG .LT. 90.)
327      1RLONGC = RLONG + 100.
328      IF ((RQ .EQ. 2 .OR. RQ .EQ. 7) .AND. RLONG .GE. 90.)
329      1RLONGC = RLONG
330      IF (RQ .EQ. 3 .OR. RQ .EQ. 8) RLONGC = RLONG
331      C      CALCULATE LONGITUDE OF LAST EQUATOR CROSSING
332      RL = RLONGC - (NORBIT - RORBIT) * REG
333      RL = AMOD(RL, 360.0)
334      IF (RL .LT. 0.0) RL = RL + 360.0
335      RRL = RL * C1
336      C      CONVERT TO EAST-WEST LONGITUDE FOR OUTPUT ONLY
337      QUAD = EAST
338      RLOUT = RL
339      IF (180.0 - RL) 70, 80, 90
340      70 QUAD = WEST
341      RLOUT = 360. - RL
342      GO TO 90
343      80 QUAD = BLANK
344      C      DETERMINE TIME AT FIRST OUTPUTTED SCAN OF ORBIT
345      90 RTIME = RHR * 60. + RMIN + RSEC / 60.
346      STIME = RTIME + (NORBIT - RORBIT) * PER + (GRID + BSCAN) / SRPM
347      SHR = AMOD(STIME, 1440.0)
348      IF (SHR .LT. 0.0) SHR = SHR + 1440.0
349      NHR = SHR / 60.
350      TIMIN = SHR - NHR * 60.
351      NMIN = TIMIN
352      SSEC = TIMIN - NMIN
353      NSEC = SSEC * 60.
354      XKB = FLOAT(KB)
355      C      DETERMINE GRID LENGTH, WIDTH AND SIZE OF FINAL OUTPUT
356      IPOS = (KE - KB) + 1
357      XPOS = FLOAT(IPOS)
358      MAXSC = ESCAN - BSCAN + 1
359      IF (KINP .EQ. 0) GO TO 100

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360      IF (MAXSC .GT. 400) GO TO 900
361      IF (IPOS .GT. 301) GO TO 920
362      MTMAT = MAXSC * IPOS
363      RTMAT = MTMAT / 1000.
364      SCANMN = 0.0
365      POSNMN = 0.0
366      C      DETERMINE NUMBER OF SCANS PER RADIAN OF ORBIT,
367      C      AND CONVERT BSCAN AND ESCAN TO RADIAN ANGLES
368      100 RTSC = PER * ESRPM / (PI*2)
369      SB = (BSCAN + GRID) / RTSC
370      SE = (ESCAN + GRID) / RTSC
371      C      DETERMINE LIMITS FOR POSITIONS AND SCANS OF LAT-LON LINES
372      DPOS = 0.050 * XPOS
373      PB1 = 1.0 - DPOS
374      PB2 = PB1 - 2. * DPOS
375      PE1 = XPOS + DPOS + 1
376      PE2 = PE1 + 2 * DPOS
377      DSCAN = 0.050 * (SE - SB)
378      SB1 = SB - DSCAN
379      SB2 = SB1 - 2. * DSCAN
380      SB3 = SB2 - 2 * DSCAN
381      SE1 = SE + DSCAN
382      SE2 = SE1 + 2. * DSCAN
383      SE3 = SE2 + 2. * DSCAN
384      C      DETERMINE SATELLITE HEADING
385      HEAD = POL
386      IF (SB .LT. PIB2 AND SE .LT. PIB2) HEAD = NOR
387      IF (SB .GT. PIB2 AND SE .GT. PIB2) HEAD = SOU
388      C      DETERMINE SCALING FACTORS (IN GRID UNITS PER INCH)
389      C      THESE FACTORS DUE TO FACT THAT PIXELS ARE NOT SQUARE.
390      SF = SF * 1E-6
391      SCALP = SF * 10. * C3 * 0.233645
392      SCALS = SF * 10. * C3 * 0.302115
393      DISTS = 3.31
394      DISTP = 4.28
395      C      DETERMINE IF OUTPUT WIDTH IS TOO WIDE.
396      IF (XPOS/SCALP .GT. 32.) GO TO 920
397      C      SATELLITE INCLINATION
398      110 RINC = (ORIN) * C1
399      SINC = SIN(RINC)
400      CINC = COS(RINC)
401      C
402      C
403      C      COMPUTE SCAN LINE # AND TIME PENHOLD WAS SCANNED.
404      C      PENHOLD COORDINATES ,52.2 N 246.1 DEGREES EAST
405      MCHK = 0
406      PLAT = 52.2
407      PLONG = 246.1
408      CALL EQNS(REG)
409      CALL ITERL(PLAT)
410      CALL ITERA(PLONG,PSCAN,PPOSN,MCHK,SB2,SB3,SE2,SE3,PB2,PE2)
411      C      PSCAN IS THE SCAN OVER PENHOLD
412      C
413      C      TIME CALCULATIONS
414      TPSC = PSCAN / ESRPM
415      NPHR = (SHR+TPSC) / 60.
416      PMIN = (SHR+TPSC) - NPHR * 60.
417      NPMIN = PMIN
418      PSEC = PMIN - NPMIN
419      NPSEC = PSEC * 60.

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420      C      PRINT INPUT DATA AND PRELIMINARY CALCULATIONS
421      WRITE (6,120) IROV, NORBIT, MONTH(NMO), NDY, NYR, NHR, NMIN, NSEC,
422      1 NPHR, NPMIN, NPSEC, PSCAN, PPOSN, HEAD, GRID,
423      1 RLOUT, QUAD, RORBIT, RLONGC, RHR, RMIN, RSEC,
424      2 PER, REG, H, R, ORIN, SRPM
425      WRITE (6,130) BSCAN, ESCAN, KB, KE, SSPP, DIST, SCALS, DISTP,
426      1 SCALP, SF
427      120 FORMAT (1H1, /, 4X, A8, 1X, 'INFORMATION FROM ORBIT', 16, 2X,
428      1 'OF SATELLITE TIROS-N ON', 2X, A8, 1X, 12, 2X, 14, /, 5X, 'TIME OF
429      2 OF FIRST SCAN',
430      2 13, 1H, 12, 1H, 12, 2H Z, /, 5X,
431      1 'SATELLITE SCANNED PENHOLD AT TIME', 13, 1H, 12, 1H, 12, 2H Z, /,
432      15X, 'LOCATION OF PENHOLD IN GRID', /, 5X, 'SCAN', F6.0, 5X,
433      1 'POSITION',
434      2 F6.0, /, 5X, 'SATELLITE HEADING IS',
435      3 A8, /, 5X, F7.1, 'SCANS PASSED SINCE SATELLITE
436      3 LAST CROSSED EQUATOR',
437      4 /, 5X, 'AT LONGITUDE', F7.2, 'DEGREES', A8, /,
438      1 5X, 'REFERENCE ORBIT',
439      5 16, /, 5X, 'CROSSED EQUATOR AT LONGITUDE', F7.2, 'DEGREES
440      6 EAST', /, 5X, 'AT TIME', 13, 1H, 12, 1H, 12, 2H Z, /, 5X,
441      1 'ORBITAL PERIOD =',
442      7 F10.5, 'MIN', /, 5X, 'LONGITUDINAL INCREMENT =', F6.2,
443      8 'DEGREES TO WEST', /, 5X, 'HEIGHT OF SATELLITE AT EQUATOR =',
444      9 F6.0, 'KM', 5X, 'RADIUS OF EARTH =', F6.0, 'KM', /, 5X,
445      * 'ORBITAL INCLINATION =', F7.2, 'DEG', 5X, 'SCANNING RATE =
446      1', F4.0, 'SCANS PER MINUTE')
447      130 FORMAT (1H-, /, 5X, 'SCANNING BEGINS AT', 16, 2X, 'AND ENDS AT', 16,
448      1 /, 5X, 'OUTPUT TAKES UP', 14, 'TO', 14, 'OF AVAILABLE WIDTH
449      2', /, 5X, 'SATELLITE SUBPOINT PIXEL NUMBER =', F7.2, /, 5X, 'DIS
450      3 TANCE BETWEEN SCANS =', F6.2, 1X,
451      4 'KM', /, 5X, 'SCALING =', 1PE11.4, 'GRID UNITS PER INCH IN X DIRECTI
452      1 ON', /, 5X, 'DISTANCE BETWEEN POINTS =', OPF6.2, 'KM', /, 5X,
453      1 'SCALING =',
454      2 1PE11.4, 'GRID UNITS PER INCH IN Y DIRECTION', /, 5X,
455      3 'MAP SCALE =', 1, 'OPF5.2, 'MILLION')
456
457      C      IF (KINP .EQ. 0) GO TO 290
458      C      *****
459      C
460      C      INPUT LOOP FOR DATA FIELD
461      C
462      C      SKIP NSKIP SCANS OF DATA (FOR MAG TAPE ONLY)
463      IF (KINP .EQ. 3 .OR. KINP .EQ. 4) CALL SKIP(0, NSKIP, 4, 8940)
464      C      READ AND INPUT SCANS BETWEEN BSCAN AND ESCAN
465      180 READ (4,END=1220) HSCAN, LA
466      IF (HSCAN .LT. BSCAN) GO TO 150
467      IF (HSCAN .GT. ESCAN) GO TO 170
468      MSCAN = HSCAN - BSCAN + 1
469      ICNT = 0
470      DO 160 JP = KB, KE
471      ICNT = ICNT + 1
472      DATUM = FLOAT(1BYTE(LA(JP)))
473      IF (DATUM .LT. 1.) DATUM = 1.OE35
474      TEMP(ICNT, MSCAN) = DATUM
475      160 CONTINUE
476      IF (ICNT .NE. IPOS) GO TO 960
477      GO TO 150
478      170 IF (MAXSC - MSCAN) 980, 180, 980
479      180 WRITE (6,190)

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480 190 FORMAT (1H-, /, 10X, 'DATA FIELD PARAMETERS')
481 C .....
482 C
483 C      SMOOTHING OF DATA FIELD
484 C
485 C      IF (LSMT .EQ. 0) GO TO 200
486 C      CALL SMOO(MAXSC, IPDS)
487 C      GO TO 220
488 C
489 C      200 WRITE (6,210)
490 C      210 FORMAT (1H-, 14X, 'NO SMOOTHING OF DATA FIELD USED')
491 C .....
492 C
493 C      CALIBRATION OF DATA FIELD
494 C
495 C      220 IF (LCAL .EQ. 0) GO TO 230
496 C      CALL CALI(MAXSC, IPDS, &250, &230)
497 C
498 C      230 WRITE (6,240)
499 C      240 FORMAT (1H-, 14X, 'NO CALIBRATION OF DATA FIELD USED')
500 C .....
501 C
502 C      WRITE CALIBRATED FIELD TO UNIT 13
503 C
504 C      250 WRITE (13) IPDS, MAXSC
505 C      DO 260 JJ = 1, MAXSC
506 C      260 WRITE (13) (TEMP(IJ,JJ), IJ=1, IPDS)
507 C
508 C      CHECK DATA FIELD FOR MAX AND MIN VALUES.
509 C
510 C      TMIN = 500.0
511 C      TMAX = -500.0
512 C      FIND MAXIMUM AND MINIMUM OF DATA FIELD
513 C      DO 270 JJ = 1, MAXSC
514 C      DO 270 II = 1, IPDS
515 C      IF (TEMP(II,JJ) .LT. TMIN) TMIN = TEMP(II,JJ)
516 C      IF (TEMP(II,JJ) .GT. TMAX) TMAX = TEMP(II,JJ)
517 C
518 C      270 CONTINUE
519 C      WRITE (6,280) MAXSC, IPDS, RTMAT, TMIN, TMAX
520 C      280 FORMAT (1H-, //, 5X, 'GRID DIMENSIONS : COLUMNS 1 TO', 15, 5X,
521 C      1 'ROWS 1 TO', 15, //, 5X, 'GRID SIZE =', F6.2, 'K ELEMENTS',
522 C      2 '//, 5X, 'EXTREME VALUES OF DATA FIELD', /, 5X, 'MINIMUM =',
523 C      3 F6.1, 5X, 'MAXIMUM =', F6.1)
524 C
525 C      290 IF (LCHK1 .EQ. 0) GO TO 490
526 C .....
527 C
528 C      DETERMINE INCREMENTS FOR FINDING LATITUDE AND LONGITUDE CURVES
529 C      (INCREMENTS MUST BE AT LEAST 1)
530 C
531 C      LALAT = LAINC * 10
532 C      IF (LALAT .LT. 1) LALAT = 1
533 C      LOLAT = LAINC * 2
534 C      IF (LOLAT .LT. 1) LOLAT = 1
535 C      LOLON = LOINC * 10
536 C      IF (LOLON .LT. 1) LOLON = 1
537 C      LALON = LOINC * 1
538 C      IF (LALON .LT. 1) LALON = 1
539 C      WRITE (6,300) LAINC, LOINC
540 C      300 FORMAT (1H-, /, 10X, 'LATITUDE-LONGITUDE PARAMETERS', ///, 5X, 'LA

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540      1TITUDE  LINES GENERATED EVERY', F5.1, ' DEGREES', 5X, '500 POINTS
541      2ALLOWED FOR EACH LINE', //, 5X, 'LONGITUDE LINES GENERATED EVERY',
542      3      F5.1, ' DEGREES', 5X, '500 POINTS ALLOWED FOR EACH LINE')
543      C
544      C
545      C .....
546      C .....
547      C
548      C OUTLINES AND LATITUDE, LONGITUDE LINE COMPUTATIONS.
549      C (THE FOLLOWING MAY BE SIGNIFICANTLY SIMPLIFIED BY
550      C RESTRICTING THE INPUT-OUTPUT OPTIONS.)
551      C
552      CALL EONS(REG)
553      JUNIT = 11
554      WRITE (6,310) JUNIT
555      310 FORMAT (1H-, 14X, 'LATITUDE-LONGITUDE LINES OUTPUTTED TO UNIT',
556      1      14)
557      KCHK = 0
558      C .....
559      C
560      C DETERMINE POINTS FOR LATITUDE LINES
561      C
562      WRITE (6,320)
563      320 FORMAT (1H0, 7X, 'LATITUDE LINES', /)
564      MLL = 1
565      C MLL=1 DENOTES LATITUDE LINES IN OUTPUT
566      C
567      C INCREMENT LATITUDE LINES TO BE FOUND
568      - DO 390 LAT = LAB, LAE, LALAT
569      ALAT = (LAT - 10) / 10
570      LLAT = IFIX(ALAT)
571      LOLATA = LOLAT
572      C ONLY ONE-FIFTH NUMBER OF POINTS USED IN
573      C LATITUDE LINES NORTH OF 80 DEGREES
574      IF (ALAT .GT. 80.) LOLATA = 5 * LOLAT
575      IF (ALAT .GT. 90.) GO TO 1060
576      MM = 1
577      C
578      C INCREMENT LONGITUDE INTERSECTIONS TO DETERMINE
579      C EACH LATITUDE LINE
580      CALL ITERL(ALAT)
581      DO 340 LONG = LOB, LOE, LOLATA
582      BLONG = (LONG - 10) / 10
583      CALL ITERA(BLONG, SCAN(MM), POSN(MM), MCHK, SB1, SB2, SE1,
584      1      SE2, PB1, PE1)
585      IF (MCHK .EQ. 1) GO TO 330
586      IF (MM .EQ. 1) GO TO 340
587      KCHK = KCHK + 1
588      GO TO 350
589      330 IF (SCAN(MM) .LT. SCANMN) SCANMN = SCAN(MM)
590      IF (SCAN(MM) .GT. SCANMX) SCANMX = SCAN(MM)
591      IF (POSN(MM) .LT. POSNMN) POSNMN = POSN(MM)
592      IF (POSN(MM) .GT. POSNMX) POSNMX = POSN(MM)
593      MM = MM + 1
594      340 CONTINUE
595      350 MM = MM - 1
596      IF (MM .LE. 2) GO TO 390
597      C OUTPUT LATITUDE LINE SEGMENT
598      WRITE (6,360) ALAT, MM
599      360 FORMAT (1H, 5X, 'LATITUDE =', F5.1, ' DEGREES NORTH', 6X, 'POIN

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600      ITS IN LATITUDE LINE = ' ', I4)
601      WRITE (JUNIT,370) MM, MZERO, MLL, LLAT
602      370 FORMAT (4I4)
603      WRITE (JUNIT,380) (SCAN(I), POSN(I), I=1, MM)
604      380 FORMAT (2F7.2)
605      KCHK = KCHK + 1
606      390 CONTINUE
607      400 FORMAT (3F7.2)
608      C
609      C .....
610      C
611      C      DETERMINE POINTS FOR LONGITUDE LINES
612      C
613      410 WRITE (6,420)
614      420 FORMAT (1HO, 7X, 'LONGITUDE LINES', /)
615      MLL = 2
616      C      MLL=2 DENOTES LONGITUDE LINES IN OUTPUT
617      C
618      C      INCREMENT LONGITUDE LINES TO BE FOUND
619      DO 470 LONG = LOB, LOE, LOLON
620      ALONG = (LONG - 10) / 10
621      LLONG = IFIX(ALONG)
622      IF (ALONG .GT. 360.) GO TO 1080
623      VLONG = ALONG / (2.*LOLON) - IFIX(ALONG/(2.*LOLON))
624      MM = 1
625      C
626      C      INCREMENT LATITUDE INTERSECTIONS TO DETERMINE
627      C      EACH LONGITUDE LINE
628      DO 440 LAT = LAB, LAE, LALON
629      BLAT = (LAT - 10) / 10
630      C      EXTEND ONLY EVERY SECOND LONGITUDE LINE
631      C      PAST 85 DEGREES NORTH TO AVOID CROWDING
632      IF (BLAT .GT. 85 .AND. VLONG .GT. 0.1) GO TO 470
633      CALL ITERL(BLAT)
634      CALL ITERA(ALONG, SCAN(MM), POSN(MM), MCHK, SB2, SB3, SE2,
635      SE3, PB2, PE2)
636      IF (MCHK .EQ. 1) GO TO 430
637      IF (MM .EQ. 1) GO TO 440
638      KCHK = KCHK + 1
639      GO TO 450
640      430 IF (SCAN(MM) .LT. SCANNM) SCANNM = SCAN(MM)
641      IF (SCAN(MM) .GT. SCANMX) SCANMX = SCAN(MM)
642      IF (POSN(MM) .LT. POSNMN) POSNMN = POSN(MM)
643      IF (POSN(MM) .GT. POSNMX) POSNMX = POSN(MM)
644      MM = MM + 1
645      440 CONTINUE
646      MM = MM - 1
647      IF (MM .LE. 2) GO TO 470
648      C      OUTPUT LONGITUDE LINE SEGMENT (ONLY ONE SEGMENT
649      C      POSSIBLE FOR EACH LONGITUDE LINE)
650      WRITE (6,460) ALONG, MM
651      460 FORMAT (1H, 5X, 'LONGITUDE = ', F6.1, ' DEGREES EAST', 5X, 'POIN
652      ITS IN LONGITUDE LINE = ' ', I4)
653      WRITE (JUNIT,370) MM, MZERO, MLL, LLONG
654      WRITE (JUNIT,380) (SCAN(I), POSN(I), I=1, MM)
655      470 CONTINUE
656      C
657      WRITE (6,480) KCHK, JUNIT, SCANNM, SCANMX, POSNMN, POSNMX
658      480 FORMAT (1HO, 7X, I4, ' LATITUDE-LONGITUDE LINES OUTPUTTED TO UNIT
659      1      . 13, //, 5X, 'LAT LON LINES FORM BOX : COLUMNS', F5.0, 'TO

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660      2. F5.0, 5X, 'ROWS', F5.0, 'TO', F5.0)
661      GO TO 510
662
663      C 490 WRITE (6,500)
664      500 FORMAT (1H-, //, 10X, 'NO LATITUDE LONGITUDE LINES GENERATED')
665      C .....
666      C
667      C DETERMINE GRID COORDINATES OF INPUTTED LAT-LON POINTS
668      C
669      510 IF (LOUT1 .EQ. 0) GO TO 790
670      MLL = 3
671      C MLL=3 DENOTES OUTLINE IN OUTPUT
672      WRITE (6,520)
673      520 FORMAT (1H-, //, 10X, 'OUTLINE PARAMETERS', //)
674      C
675      KUNIT = 16
676      CALL EONS(REG)
677      DO 780 LUNIT = 1, LOUT1
678      IF (LUNIT .GT. 3) GO TO 1100
679      WRITE (6,530) LUNIT
680      530 FORMAT (1H-, 14X, 'LAT-LON POINTS FROM UNIT', I3, //)
681      IF (LOUT2(LUNIT) .LT. 1 .OR. LOUT2(LUNIT) .GT. 5) GO TO 1140
682      C
683      IF (KUNIT .GT. 19) GO TO 1040
684      II = 0
685      MM = 0
686      KCHK = 0
687      C INPUT LOOP FOR LAT-LON OUTLINE INTERSECTIONS
688      540 II = II + 1
689      MM = MM + 1
690      MCHK = 0
691      READ (LUNIT,LFMT,END=660,ERR=1120) XLATD, XLATM, XLOND, XLONM
692      LHEM
693      SLAT(II) = XLATD + XLATM / 60.0
694      SLONG(II) = XLOND + XLONM / 60.0
695      IF (LHEM .EQ. 2) SLONG(II) = 360.0 - SLONG(II)
696      CALL ITERL(SLAT(II))
697      CALL ITERA(SLONG(II), SCAN(MM), POSN(MM), MCHK, SB2, SB3, SE2,
698      SE3, PB2, PE2)
699      IF (MCHK .EQ. 1 .OR. MM .LE. 1) GO TO 540
700      IF (LOUT2(LUNIT) .EQ. 3) GO TO 1200
701      C OUTPUT OUTLINE SEGMENT
702      KCHK = KCHK + 1
703      MM = MM - 1
704      IF (LOUT2(LUNIT) - 4) 550, 580, 600
705      550 WRITE (6,560) MM, KUNIT
706      560 FORMAT (1H0, 4X, I4, ' GRID COORDINATE POINTS OF OUTLINE', ' TRA
707      1NSFERRED TO UNIT', I3)
708      WRITE (KUNIT,570) MM
709      570 FORMAT (I4)
710      WRITE (KUNIT,580) (SCAN(I), POSN(I), I=1, MM)
711      GO TO 650
712      580 WRITE (6,590) MM, KUNIT
713      590 FORMAT (1H0, 4X, I4, ' GRID COORDINATE POINTS', ' CONTAINED IN U
714      1NIT', I4, ' OUTPUT AREA', ' TRANSFERRED TO UNIT 15 FOR POSTING')
715      WRITE (15,400) (SCAN(I), POSN(I), ZERO, I=1, MM)
716      GO TO 650
717      600 WRITE (6,610)
718      610 FORMAT (1H0, 4X, 'INPUTTED POINTS', //)
719      WRITE (6,620) (SLAT(I), SLONG(I), I=1, MM)

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720 \ 620 FORMAT (1H, 8(F6.2,F7.2,3X))
721 WRITE (6,630)
722 630 FORMAT (1HO, 4X, 'GRID COORDINATES', /)
723 WRITE (6,640) (SCAN(I), POSN(I), I=1, MM)
724 640 FORMAT (1H, 8(F7.1, F6.1, 3X))
725 650 MM = 0
726 GO TO 540
727 C END OF OUTLINE FILE GO ON
728 660 II = II - 1
729 IF (MCHK .EQ. 0 .AND. MM .LE. 1) GO TO 740
730 KCHK = KCHK + 1
731 IF (LOUT2(LUNIT) - 4) 670, 680, 700
732 670 IF (LOUT2(LUNIT) .EQ. 3) GO TO 710
733 MM = MM - 1
734 WRITE (6,560) MM, KUNIT
735 WRITE (KUNIT,570) MM
736 WRITE (KUNIT,380) (SCAN(I), POSN(I), I=1, MM)
737 IF (LOUT2(LUNIT) - 2) 690, 710, 710
738 680 WRITE (6,590) MM, KUNIT
739 WRITE (15,400) (SCAN(I), POSN(I), ZERO, I=1, MM)
740 690 WRITE (6,610)
741 WRITE (6,620) (SLAT(I), SLONG(I), I=1, II)
742 GO TO 740
743 700 WRITE (6,610)
744 WRITE (6,620) (SLAT(I), SLONG(I), I=1, MM)
745 WRITE (6,630)
746 WRITE (6,640) (SCAN(I), POSN(I), I=1, MM)
747 GO TO 740
748 C DETERMINE MAXIMUM AND MINIMUM SCAN AND POSITION VALUES
749 C OF LAT-LON INTERSECTIONS WITHIN EXTENDED LIMITS OF GRID
750 710 SCANMN = 1900
751 SCANMX = -1000
752 POSNMN = 1900
753 POSNMX = -1000
754 DO 720 JI = 1, MM
755 IF (SCAN(JI) .LT. SCANMN) SCANMN = SCAN(JI)
756 IF (SCAN(JI) .GT. SCANMX) SCANMX = SCAN(JI)
757 IF (POSN(JI) .LT. POSNMN) POSNMN = POSN(JI)
758 IF (POSN(JI) .GT. POSNMX) POSNMX = POSN(JI)
759 720 CONTINUE
760 WRITE (6,730) SCANMN, SCANMX, POSNMN, POSNMX
761 730 FORMAT (1HO, 4X, 'OUTLINE OCCUPIES BOX CONTAINING SCANS', F5.0,
762 1 ' TO', F5.0, 4X, 'AND POSITIONS', F5.0, ' TO', F5.0)
763 C
764 740 IF (KCHK .EQ. 0) GO TO 1180
765 IF (LOUT2(LUNIT) .EQ. 1 .OR. LOUT2(LUNIT) .EQ. 2) WRITE (6,
766 1 750) KUNIT
767 750 FORMAT (1HO, 4X, 'GRID POINT POSITIONS OF OUTLINE TRANSFERRED
768 1 TO UNIT', I4)
769 IF (LOUT2(LUNIT) .EQ. 3 .OR. LOUT2(LUNIT) .EQ. 5) GO TO 760
770 760 WRITE (6,770)
771 770 FORMAT (1HO)
772 KUNIT = KUNIT + 1
773 C
774 C
775 780 CONTINUE
776 790 STOP
777 C
778 800 WRITE (6,810)
779 810 FORMAT (1H, /, 10X, 'NO OUTLINES GENERATED', //)

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780      GO TO 1240
781      .....
782      C
783      C      ERROR DEFAULT STATEMENTS
784      C
785      C      IN SOME CASES PROGRAM WILL PRINT ERROR AND TRY TO
786      C      CORRECT FOR IT AUTOMATICALLY.
787      C
788      820 WRITE (6,830)
789      830 FORMAT (1H0, '***** ERROR   LATITUDE TO BEGIN PLOTTING   GREATER
790      1 THAN LATITUDE TO END PLOTTING *****')
791      LAST = LAE
792      LAE = LAB
793      LAB = LAST
794      GO TO 20
795      840 WRITE (6,850)
796      850 FORMAT (1H0, '***** ERROR   LONGITUDE TO BEGIN PLOTTING   GREATER
797      1R THAN LONGITUDE TO END PLOTTING *****')
798      LOST = LOE
799      LOE = LOB
800      LOB = LOST
801      GO TO 30
802      860 WRITE (6,870) KINP
803      870 FORMAT (1H0, '***** ERROR   INPUT TYPE INCORRECTLY SPECIFIED   3X,
804      1 KINP = 13, INPUTTED, 0 TO 4 ONLY ALLOWED *****')
805      GO TO 1240
806      880 WRITE (6,890)
807      890 FORMAT (1H0, '***** ERROR   INVALID PARAMETERS FOR WIDTH OF   OU
808      1TPUT FIELD *****')
809      GO TO 1240
810      900 WRITE (6,910) MAXSC
811      910 FORMAT (1H0, '***** ERROR   OUTPUT TOO LONG   5X, 16,
812      1 SCANS IN   OUTPUT.   FORMAT ALLOWS ONLY 400 SCANS *****')
813      2
814      GO TO 1240
815      920 WRITE (6,930) IPO5
816      930 FORMAT (1H0, '***** ERROR   OUTPUT TOO WIDE   5X, 16,   POSITIONS
817      1IN   OUTPUT.   FORMAT ALLOWS ONLY 301 POSITIONS *****')
818      GO TO 1240
819      940 WRITE (6,950)
820      950 FORMAT (1H0, '***** ERROR, IN SCAN SKIP *****')
821      GO TO 1240
822      960 WRITE (6,970) HSCAN
823      970 FORMAT (1H0, '***** ERROR   INCORRECT DATA LENGTH FOR SCAN   16,
824      1 *****')
825      GO TO 1240
826      980 WRITE (6,990) MSCAN
827      990 FORMAT (1H0, '***** ERROR   INCORRECT DATA LENGTH   5X, 17,   SCAN
828      1S IN OUTPUT *****')
829      IF (MSCAN .GT. 400) GO TO 1240
830      MAXSC = MSCAN
831      GO TO 180
832      1000 WRITE (6,1010)
833      1010 FORMAT (1H0, '***** ERROR   TOO MANY OUTPUT UNITS CALLED   FOR D
834      1ATA FIELD OUTPUT *****')
835      GO TO 290
836      1020 WRITE (6,1030)
837      1030 FORMAT (1H0, '***** ERROR   TOO MANY OUTPUT UNITS CALLED   FOR L
838      1AT-LON LINE OUTPUT *****')
839      GO TO 490

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840      1040 WRITE (6,1050)
841      1050 FORMAT (1H0, '***** ERROR   TOO MANY OUTPUT UNITS CALLED   FOR O
842            1UTLINE OUTPUT *****')
843            GO TO 800
844      1060 WRITE (6,1070)
845      1070 FORMAT (1H0, '***** ERROR   END VALUE FOR FINAL LATITUDE LINE
846            1LARGER THAN 90 DEGREES *****')
847            GO TO 410
848      1080 WRITE (6,1090)
849      1090 FORMAT (1H0, '***** ERROR   END VALUE FOR FINAL LONGITUDE LINE
850            1LARGER THAN 360 DEGREES *****')
851            GO TO 1240
852      1100 WRITE (6,1110)
853      1110 FORMAT (1H0, '***** ERROR   TOO MANY INPUT UNITS CALLED   FOR OU
854            1TLINE PROCEEDURE *****')
855            GO TO 1240
856      1120 WRITE (6,1130) LUNIT
857      1130 FORMAT (1H0, '***** ERROR IN UNIT 12. READ *****')
858            GO TO 1240
859      1140 WRITE (6,1150) LOUT2(LUNIT)
860      1150 FORMAT (1H0, '***** ERROR   OUTLINE TYPE LOUT2 INCORRECTLY   SPE
861            1CIFIED AS 16 *****')
862            GO TO 1240
863      1160 WRITE (6,1170)
864      1170 FORMAT (1H0, '***** ERROR   MORE THAN 500 POINTS IN OUTLINE *****')
865            GO TO 660
866      1180 WRITE (6,1190)
867      1190 FORM (1H0, '***** ERROR   FAILURE IN OUTLINE PROCEEDURE, NO
868            1POINTS FOUND WITHIN GRID LIMITS *****')
869            GO TO 1240
870      1200 WRITE (6,1210)
871      1210 FORMAT (1H0, '***** ERROR   OUTLINE EXCEEDS LIMITS OF   DATA FILE
872            1LD *****')
873            GO TO 740
874      1220 WRITE (6,1230)
875      1230 FORMAT (1H0, '***** ERROR END OF FILE ON UNIT 4 *****')
876            STOP 99
877      1240 STOP
878            END
879
880 C .....
881 C
882 C      FUNCTION IBYTE(NUM)
883 C
884 C      CONVERTS ONE BYTE NUMBER TO TWO BYTE INTEGER
885 C      LOGICAL*1 NUM, INT(2)
886 C      INTEGER*2 I /O/
887 C      EQUIVALENCE (I,INT)
888 C      INT(2) = NUM
889 C      IBYTE = I
890 C      RETURN
891 C      END

```

END OF FILE

C.2 Program TAPERD

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1      C      PROGRAM TAPERD
2      C
3      C      PROGRAM FOR IDENTIFYING SATELLITE SCAN INFORMATION
4      C      AND CONVERTING MAG TAPE INFORMATION TO COMPUTER USABLE FORM
5      C
6      C      INPUT FROM UNIT 1 : RAW TAPE DATA IN ONE BYTE INTEGER FORM
7      C      UNIT 5 : PROGRAM PARAMETERS
8      C
9      C      OUTPUT TO UNIT 3 : (RAW TAPE DATA IN ONE BYTE FORM)
10     C      UNIT 6 : PROGRAM PARAMETERS, TAPE DOCUMENTATION,
11     C      (TAPE DATA IN INTEGER FORM),
12     C      UNIT 7 : CALIBRATION WEDGE LEVELS.
13     C
14     C      TAPE PARAMETERS
15     C
16     C      SPB = NUMBER OF SCANS PER DATA BLOCK (5)
17     C      BPS = NUMBER OF BYTES PER SCAN (1530)
18     C      LDR = LENGTH OF DATA RECORD (ONE SCAN)
19     C      (BPS BYTES PLUS TWO BYTES CONTAINING SCAN NUMBER)
20     C      LDB = LENGTH OF DATA BLOCK (SPB SCANS)
21     C      LEN = LENGTH OF ANY BLOCK
22     C      LRN = INTERNAL COUNTER FOR DATA INPUT
23     C
24     C      OUTPUT PARAMETERS
25     C
26     C      ID(J) = OUTPUT IN INTEGER FORM (UNIT 6)
27     C      LA(J) = OUTPUT IN ONE BYTE FORM (UNIT 3)
28     C      NSC(N) = TWO BYTE NUMBER OF SCAN OUTPUTTED
29     C      MINSCL = FIRST SCAN OUTPUTTED
30     C      MAXSC = LAST SCAN OUTPUTTED
31     C      NSOUT = NUMBER OF SCANS OUTPUTTED
32     C      .....
33     C
34     C      LOGICAL*1 LFMT(1) /'.'/
35     C      LOGICAL*1 FL(18), DTXT(52), LA(8192)
36     C      INTEGER*2 IA(4096), HTXT(26), LREV(5), LFWD(3)
37     C      EQUIVALENCE (IA(1),DTXT,HTXT,FL,LA)
38     C      INTEGER*2 LEN, ISC(64), BL(18), DOC(52), NSC(12), ID(2512)
39     C      INTEGER*4 LRN
40     C      INTEGER BPS, SPB, NX(10)
41     C      REAL*8 IROV(2)
42     C
43     C      DATA IROV /8H      IR , 8HVISIBLE /
44     C
45     C      DATA ISC /1H , 1H1 , 1H2 , 1H3 , 1H4 , 1H5 , 1H6 , 1H7 , 1H8 , 1H9 , 1H0 , 1H1 , 1H2 , 1H3 , 1H4 , 1H5 , 1H6 ,
46     C      1H7 , 1H8 , 1H9 , 1H0 , 1H1 , 1H2 , 1H3 , 1H4 , 1H5 , 1H6 ,
47     C      1H7 , 1H8 , 1H9 , 1H0 , 1H1 , 1H2 , 1H3 , 1H4 , 1H5 , 1H6 ,
48     C      1H7 , 1H8 , 1H9 , 1H0 , 1H1 , 1H2 , 1H3 , 1H4 , 1H5 , 1H6 ,
49     C      1H7 , 1H8 , 1H9 , 1H0 , 1H1 , 1H2 , 1H3 , 1H4 , 1H5 , 1H6 ,
50     C      1H7 , 1H8 , 1H9 , 1H0 , 1H1 , 1H2 , 1H3 , 1H4 , 1H5 , 1H6 ,
51     C      .....
52     C
53     C
54     C      INPUT DATA IS FORMAT FREE, DIVIDED BY COMMAS
55     C
56     C      NFS = NUMBER OF FILES TO BE SKIPPED
57     C      NBS = NUMBER OF BLOCKS TO BE SKIPPED
58     C      NBR = NUMBER OF BLOCKS TO BE READ AND OUTPUTTED
59     C      KOUT= OUTPUT OPTION

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60      C      KOUT=6  OUTPUTS FORMATTED BLOCKS TO UNIT 6
61      C      KOUT=3  OUTPUTS UNFORMATTED BLOCKS TO UNIT 3
62      C      FILE OR MAG TAPE FOR USE IN PROGRAM
63      C      SCAN. IN THE INFRARED CASE THE
64      C      TELEMETRY DATA IS OUTPUT TO UNIT 7.
65      C
66      C      INPUT DATA: FOR UNIT 3 OUTPUT ONLY
67      C
68      C      ITYPE = OUTPUT TYPE OPTION
69      C      ITYPE=1  OUTPUTS IR DATA
70      C      ITYPE=2  OUTPUTS VISIBLE DATA
71      C
72      C      .....
73      C
74      C      READ TAPE INPUT DATA
75      C      READ (5,LFMT,END=470) NORBIT, NFS, NBS, NBR, KOUT, ITYPE,BPS,SPB
76      C
77      C      WRITE (6,20)
78      C      20 FORMAT (1H1, 10X, 'INPUT PARAMETERS')
79      C      WRITE (6,30) NFS, NBS, NBR, KOUT
80      C      30 FORMAT (1H0, 5X, 'FILES SKIPPED =', I3, 5X, 'BLOCKS SKIPPED =',
81      C      '13, 5X, 'BLOCKS READ =', I4, 5X, 'OUTPUT OPTION =', I2)
82      C
83      C      READ UNIT 3 INPUT DATA
84      C      IBGN = 0
85      C      THERE ARE 800 SAMPLES PER CHANNEL (IR&VIS)
86      C      IF (ITYPE .EQ. 2) IBGN = 800
87      C      IF (KOUT .NE. 6) GO TO 50
88      C      WRITE (6,40) IROV(ITYPE)
89      C      40 FORMAT (1H0, 5X, A8, 'INFORMATION TRANSFERRED TO UNIT 3')
90      C
91      C      50 REWIND 1
92      C
93      C      SKIP TO FILE
94      C
95      C      CALL SKIP(NFS, 0, 1, &390)
96      C
97      C      READ AND INTERPRET FILE LABEL
98      C
99      C      96 CALL READ(FL, LEN, 0, LRN, 1, &290)
100     C      DO 60 L = 1, LEN
101     C      ID(L) = IBYTE(FL(L))
102     C      INDX = ID(L) - 31
103     C      IF (INDX .LT. 1) INDX = 1
104     C      IF (INDX .GT. 64) INDX = 1
105     C      LL(L) = ISC(INDX)
106     C
107     C      60 CONTINUE
108     C
109     C      PROGRAM CHECKS FOR CORRECT PASS NUMBER
110     C      PROGRAM WILL SEARCH TAPE UNTIL IT'S FOUND
111     C      NPASS = LL(2)*1000 + LL(1)*100 + LL(4)*10 + LL(3)
112     C      IF (NPASS-NORBIT) 98,99,97
113     C      97 CALL CNTRL('BSF 2',LREV,1,RET)
114     C      98 CALL CNTRL('FSF',LFWD,1,RET)
115     C      GO TO 96
116     C
117     C      99 WRITE (6,70) (LL(K),K=1,4), LL(2), LL(1), LL(4), LL(3), LEN, LRN
118     C      70 FORMAT (1H0, 5X, 'FILE LABEL: ', 4A1, 5X, 'ORBIT ', 4A1, 5X, 'LENGT
119     C      1H', I3, 5X, 'LRN=', I5)

```

```

120 C      READ AND INTERPRET FILE DOCUMENTATION
121 C
122 80 CALL READ(DTXT, LEN, O, LRN, 1, 8310)
123 C      BPS AND SPB ARE READ IN. IF EITHER ARE 0 USE VALUES FROM TAPE.
124 C      USED IN CASE OF TAPE ERROR
125 IF (BPS GT 0 AND SPB GT 0) GO TO 85
126 BPS = HTXT(1)
127 SPB = HTXT(2)
128 85 DO 90 L = 5, LEN
129 ID(L) = BYTE(DTXT(L))
130 INDX = ID(L) - 31
131 IF (INDX LT 1) INDX = 1
132 IF (INDX GT 64) INDX = 1
133 DOC(L) = ISC(INDX)
134 90 CONTINUE
135 WRITE (6,100) (DOC(K), K=5, LEN), LEN, LRN
136 100 FORMAT (1H0, 5X, 'DOCUMENTATION: ', 48A1, 5X, 'LENGTH= ', 13, 5X, 'L
137 1RN= ', 15)
138 WRITE (6,110) BPS, SPB
139 110 FORMAT (1H0, 5X, 15, ' BYTES PER SCAN', 4X, 12, ' SCANS PER BLOCK'
140 1)
141 LDR = BPS + 2
142 LDB = SPB * LDR
143 NS = LDR / 2
144 C
145 C      SKIP NBS BLOCKS OF DATA
146 C
147 120 CALL SKIP(0, NBS, 1, 8450)
148 ISCAN = SPB * NBS
149 MINSC = ISCAN
150 NSOUT = 0
151 C
152 C
153 C      READ AND CONVERT NBR BLOCKS OF DATA
154 C
155 DO 270 KK = 1, NBR
156 NRCNT = NBS + KK
157 C      READ ONE BLOCK OF DATA
158 CALL READ(IA, LEN, O, LRN, 1, 8330)
159 C      CHECK TO SEE IF BLOCK LENGTH CORRECT (BLOCKS
160 C      OF INCORRECT LENGTH ARE NOT OUTPUTTED)
161 IF (LEN NE LDB) GO TO 350
162 C
163 DO 180 N = 1, SPB
164 IX = (N - 1) * NS + 1
165 NSC(N) = IA(IX)
166 C      CHECK TO SEE IF SCAN NUMBER CORRECT (MISSED SCANS ARE NOTED)
167 IF (NSC(N) EQ ISCAN) GO TO 170
168 IF (NSC(N) - ISCAN GT 1) GO TO 140
169 WRITE (6,130) ISCAN
170 130 FORMAT (1H0, 5X, 'MISSED SCAN = ', 15)
171 GO TO 160
172 140, NSS = NSC(N) - 1
173 WRITE (6,150) ISCAN, NSS
174 150 FORMAT (1H0, 5X, 'SCANS', 15, 2X, 'TO', 15, 2X, 'MISSED')
175 160 ISCAN = NSC(N)
176 170 ISCAN = ISCAN + 1
177 180 CONTINUE
178 IF (KOUT NE 6) GO TO 230
179 C

```

```

180 C      UNIT 6 DATA OUTPUT
181 C
182 C      WRITE BLOCK DOCUMENTATION
183 C      WRITE (6,190) LEN, LRN, (NSC(N),N=1,SPB)
184 190 FORMAT (1H0, 5X, 'DATA BLOCK LENGTH=', 15, 5X, 'LRN=', 15, 5X,
185 1SCANS', 10I5)
186 C
187 C      THE FOLLOWING MAY BE USED TO WRITE OUT ONE BLOCK OF DATA..
188 C      DO 220 I = 1, SPB
189 C      NJ = (I - 1) * LDR
190 C      DO 200 J = 1, LDR
191 C      ID(J) = IBYTE(LA(J + NJ))
192 C 200 CONTINUE
193 C      OUTPUT ONE SCAN OF DATA
194 C      WRITE(6,210)I,J,ID(1),ID(2)
195 C      WRITE (6,210) (ID(J),J=3,LDR)
196 C210 FORMAT (20I4)
197 C      NSOUT = NSOUT + 1
198 C 220 CONTINUE
199 C      GO TO 270
200 C
201 C      UNIT 3 DATA OUTPUT
202 C
203 C      NOTE FOR MAG TAPE OUTPUT: UNIT 1 IS REWOUND
204 C      AT BEGINNING OF PROGRAM. UNIT 3 IS NOT REWOUND.
205 C      THEREFORE, SECTIONS OF SEVERAL FILES FROM UNIT 1
206 C      CAN BE TRANSFERRED TO SUCCESSIVE FILES OF UNIT 3
207 C      BY RE-RUNNING TAPERD, USING NEW INPUT PARAMETERS FOR
208 C      EACH RUN.
209 C
210 230 DO 260 I = 1, SPB
211 C      JB = 3 + (I - 1) * LDR + IBGN
212 C      JE = JB + 759
213 C      WRITE (3) NSC(I), (LA(J),J=JB,JE)
214 C      NSOUT = NSOUT + 1
215 261 IF (ITYPE .NE. 1) GO TO 260
216 C      JB = JB + 735
217 C      JE = JB + 19
218 C      KKK = 0
219 C      DO 240 MNN = JB, JE
220 C      KKK = KKK + 1
221 C      NX(KKK) = IBYTE(LA(MNN))
222 C 240 CONTINUE
223 C      IF (KK .LT. 5 OR KK .GT. 60) GO TO 260
224 C      WRITE (7,250) (NX(KKK),KKK=1,20)
225 C 250 FORMAT (20I4)
226 C 260 CONTINUE
227 C
228 C 270 CONTINUE
229 C
230 C      PRINT OUTPUT PARAMETERS
231 C
232 C      MAXSC = NSC(SPB)
233 C      WRITE (6,280) MINSC, MAXSC, NSOUT
234 280 FORMAT (1H0, 5X, 'FIRST SCAN OUTPUTTED =', 15, 5X, 'LAST SCAN',
235 10OUTPUTTED =', 15, 5X,
236 1 'NUMBER OF SCANS OUTPUTTED =', 15)
237 C      IF (KOUT .EQ. 6) GO TO 470
238 C      END FILE 3
239 C

```

```

240      GO TO 470
241  C .....
242  C
243  C      ERROR DEFAULT STATEMENTS
244  C
245      290 WRITE (6,300)
246      300 FORMAT (1H0, 5X, '***ERROR IN FILE LABEL INPUT***')
247      GO TO 80
248      310 WRITE (6,320)
249      320 FORMAT (1H0, 5X, '***ERROR IN DOCUMENTATION INPUT***')
250      GO TO 120
251      330 WRITE (6,340) NBCNT
252      340 FORMAT (1H0, 5X, '***ERROR IN RECORD INPUT AT BLOCK', I5, '***')
253      STOP
254      350 WRITE (6,360) NBCNT, LDB, LEN, LDR, BPS, SPB
255      360 FORMAT (1H0, 5X, '***ERROR IN LENGTH OF DATA BLOCK', I5, '***', //
256      1      5X, 'LDB =', I7, 5X, 'LEN =', I6, 5X, 'LDR =', I6, 5X, 'B
257      2PS =', I6, 5X, 'SPB =', I3)
258      GO TO 270
259      370 WRITE (6,380) NBCNT
260      380 FORMAT (1H0, 5X, '***ERROR IN CALIBRATION INPUT BLOCK', I5, '***')
261      390 WRITE (6,400)
262      400 FORMAT (1H0, 5X, '***ERROR ON FILE SKIP***')
263      STOP
264      410 WRITE (6,420)
265      420 FORMAT (1H0, 5X, '***ERROR ON FIRST FILE RETURN***')
266      STOP
267      430 WRITE (6,440)
268      440 FORMAT (1H0, 5X, '***ERROR ON SECOND FILE RETURN***')
269      STOP
270      450 WRITE (6,460)
271      460 FORMAT (1H0, 5X, '***ERROR ON DATA BLOCK SKIP***')
272      470 STOP
273      END
274  C
275  C
276  C      FUNCTION IBYTE(NUM)
277  C
278  C      CONVERTS ONE BYTE NUMBER TO TWO BYTE INTEGER
279  C
280      LOGICAL*1 NUM, INT(2)
281      INTEGER*2 I (0/
282      EQUIVALENCE (I,INT)
283      INT(2) = NUM
284      IBYTE = I
285      RETURN
286      END

```

END OF FILE

C.3 Program TELEM

```

1      C      PROGRAM TELEM
2      C
3      C      DETERMINE AVERAGE DATA VALUES OF CALIBRATION LEVELS
4      C      THIS PROGRAM READS FORM UNIT 5, WRITES THEMISTER AVERAGES
5      C      TO UNIT 7, AND TO UNIT 8, MEAN'S TO UNIT 6
6      C
7      DIMENSION EAN(16)
8      INTEGER TELM(160)
9      REAL CMIRP(8)/31.,63.,95.,127.,159.,191.,223.,255./
10     LOGICAL*1 LFMT(1) /'.'/
11     C
12     DO 20 JWDG=1,16
13     TD=0.0
14     SUM=0.0
15     READ(5,900) TELM
16     900  FORMAT(20I4)
17     DO 10 I=1,160
18     SUM=SUM+TELM(I)
19     10  CONTINUE
20     EAN(JWDG)=SUM/160
21     DO 11 K=1,160
22     TD=TD+(TELM(K)-EAN(JWDG))**2
23     11  CONTINUE
24     STD=SQRT(TD/159.)
25     C      OUTPUT CALIBRATION WEDGES MEANS AND STD DEVIATIONS
26     WRITE(6,225) JWDG,EAN(JWDG),STD
27     225  FORMAT(1H-.5X,' WEDGE NUMBER',I3.4X,' MEAN',F7.2,
28     1 4X,' STD DEVIATION',F7.2)
29     20  CONTINUE
30     C
31     C      DUMP THEMISTER AVERAGES AND SPACE VIEW TO UNIT 9.
32     C
33     EAN(14)=EAN(15)
34     WRITE(9,LFMT)(EAN(J),J=10,14)
35     C
36     WRITE (7,901)(CMIRP(I),I=1,8)
37     WRITE (7,901)(EAN(I),I=1,8)
38     WRITE (8,901)(EAN(I),I=1,8)
39     WRITE (8,901)(CMIRP(I),I=1,8)
40     901  FORMAT(8F6.2)
41     STOP
42     END

```

END OF FILE

C.4 Subroutine ITERA

```

1      C      SUBROUTINE ITERA
2      C
3      C      SUBROUTINE FOR DETERMINING IF LAT-LON INTERSECTION
4      C      IS WITHIN EXTENDED LIMITS OF GRID, AND FOR
5      C      DETERMINING EXACT LOCATION IF IT IS.
6      C
7      C      SUBROUTINE ITERA(ALONG, SCAN, POSN, MCHK, SBA, SBAA, SEA, SEAA,
8      C      XPOSB, XPOSE)
9      C      COMMON /CONSTO/ PIT2, PIB2, SB, XKB
10     C      COMMON /CONSTS/ RTSC, H, ZDRP, SRPM, SI, CI
11     C      COMMON /VARI/ RRL
12     C      COMMON /BLOCK/ R, PI, C1, C2, C4, C5
13     C
14     C      DIMENSION XNR(4), XAV(5)
15     C
16     C      ALAT = LATITUDE OF LAT-LON INTERSECTION
17     C      ALONG = LONGITUDE OF LAT-LON INTERSECTION
18     C      MCHK = LOCATION PARAMETER
19     C      MCHK=0 POINT OUTSIDE EXTENDED LIMITS OF GRID
20     C      MCHK=1 POINT INSIDE EXTENDED LIMITS OF GRID
21     C      SBA = EXTENDED SCAN TO BEGIN OUTPUT
22     C      SBAA = OVEREXTENDED SCAN TO BEGIN OUTPUT
23     C      (FIRST CHECK ONLY)
24     C      SEA = EXTENDED SCAN TO END OUTPUT
25     C      SEAA = OVEREXTENDED SCAN TO END OUTPUT
26     C      (FIRST CHECK ONLY)
27     C      XPOSLAT = EXTENDED POSITION TO BEGIN OUTPUT
28     C      XPOSE = EXTENDED POSITION TO END OUTPUT
29     C      SCAN = SCAN LOCATION OF ITH POINT IN LINE
30     C      POSN = POSITION LOCATION OF ITH POINT IN LINE
31     C
32     C      APT GEOMETRIC CORRECTION DATA
33     C      DATA XNR /312.0, 330.0, 166.0, 93.0/
34     C      DATA XAV /4.0, 3.0, 2.0, 1.5, 1.0/
35     C
36     C      MCHK = 0
37     C      THETA = RRL - ALONG * C1
38     C      CHANGE IN EARTHS RADIUS VERY SMALL FACTOR.
39     C      R=6367.65 +10.738*COS(2.0*SP)
40     C      H=AA-R
41     C      X1 = SI * SLAT + SIN(THETA - TPL*SP) * (-CI) * CLAT
42     C      X2 = COS(THETA - TPL*SP) * CLAT
43     C      SNT = ATAN2(X1,X2)
44     C      IF (SNT .LT. 0.0 .AND. SP .GT. PIB2) SNT = SNT + PIT2
45     C      IF (SNT .GE. SBAA .AND. SNT .LE. SEAA) GO TO 10
46     C      SP = SNT
47     C      RETURN
48     C
49     C
50     C      ITERATE TO FIND SATELLITE PATH LENGHT
51     C      FROM EQUATOR
52     C      10 DO 20 J = 1, 10
53     C          ST = THETA - TPL * SNT
54     C          CT = COS(ST)
55     C          ST = SIN(ST)
56     C          CSNT = COS(SNT)
57     C          SSNT = SIN(SNT)
58     C          X1 = CLAT * (SSNT*CT + CI*CSNT*ST) - SI * SLAT * CSNT
59     C          X2 = CLAT * ((1.0 - TPL*CI)*CSNT*CT + (TPL - CI)*SSNT*ST) + SI *

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60      1 SLAT = SSNT
61      SP = SNT - X1 / X2
62      C
63      C SIN(EARTH ARC LENGTH FROM SUBPOINT)
64      ST = SIN(THETA + TPL*SP) * SI * CLAT + CI * SLAT
65      C CHECK TO SEE IF NADIR ANG. > FALSE MORISON
66      IF (ABS(ST) .GT. SGN) RETURN
67      IF (ABS(SNT - SP) .LT. 1E-6) GO TO 40
68      SNT = SP
69      20 CONTINUE
70      WRITE (6,30) ALAT, ALONG
71      30 FORMAT (1H, '***** ERROR NO CONVERGENCE TO POINT AT, ' LATITUD
72      1E', F7.1, 2X, 'AND LONGITUDE', F7.1, 2X, 'DEGREES *****')
73      RETURN
74      C
75      40 IF (SNT .LT. SBA .OR. SNT .GT. SEA) RETURN
76      C CALC SENSOR NADIR ANGLE (FROM SUBPOINT)
77      C ANGLE AT EARTH'S CENTER
78      X3 = R * ST
79      X4 = H + R * (1. - SORT(1.0 - ST*ST))
80      -Y = ATAN(X3/X4)
81      C
82      C TIROS-N : DATA POSN. ALONG AVHRR SCAN. 39936HZ @ 6SCANS/SEC
83      C FIND (4160HZ) APT POSN. FROM AVERAGED AVHRR DATA
84      C CONVERT TO 3200HZ DIGITIZE RATE (USING C5), CENTER=350,
85      C RESTRICT 0 < IPOS < 700 =(2*ZDRP).
86      C
87      Y = C4 * ABS(Y)
88      IF (Y .GT. 1025.0) RETURN
89      SNT = 0.0
90      DO 50 J = 1, 4
91      SGN = XNR(J)
92      IF (Y .LT. SGN) GO TO 60
93      SNT = SNT + SGN / XAV(J)
94      Y = Y - SGN
95      50 CONTINUE
96      J = 5
97      60 Y = SNT + Y / XAV(J)
98      IF (ST .LT. 0.0) Y = -Y
99      C
100     C TIROS-N : CALC POSN. FOR DIGITIZING FREQ.
101     C
102     SCAN = (SP - SB) * RTSC + 1.
103     POSN = Y * C5 + ZDRP - XKB
104     IF (POSN .LT. XPOSB .OR. POSN .GT. XPOSE) RETURN
105     MCHK = 1
106     RETURN
107     C
108     ENTRY EONS(REG)
109     C HORIZON ANGLE
110     TPL = REG / 360.0
111     C SIN(HORIZON EARTH ARC)
112     SGN = SIN(C1*15.0)
113     C4 = 39936.0 / (12.0 * PI)
114     C5 = 3200.0 / 4160.0
115     AA = R + H
116     RETURN
117     C CHANGE GEODETIC LATITUDE TO GEDCENTRIC
118     ENTRY ITERL(ALAT)
119     SP = C1 * ALAT
120     TANSP = TAN(SP)
121     TEM = 1.0 + 43.02466 / AA
122     IF (ALAT .LT. 90.0) SP = ATAN(TANSP/TEM)
123     CLAT = COS(SP)
124     SLAT = SIN(SP)
125     R = 6367.65 + 10.738 * COS(2.*SP)
126     H = AA - R
127     RETURN
128     END

```

END OF FILE

C.5 Subroutine SMOO

```

1      C      SMOOTHING SUBROUTINE
2      C
3      C      SUBROUTINE TO SMOOTH AND ELIMINATE NOISE FROM DATA FIELD.
4      C
5      C      SUBROUTINE SMOO(MAXSC,IPOS)
6      C
7      C      LOGICAL*1 LFMT(1)/'.'/
8      REAL SMT(10),CORR(301,400),RESID(400),STEMP(301,400),BS(30)
9      C
10     COMMON/TFIELD/TEMP(301,400)
11     C
12     C      MAXSC = NUMBER OF COLUMNS IN DATA FIELD
13     C      IPOS  = NUMBER OF ROWS IN DATA FIELD
14     C      TEMP(I,J) = DATA VALUE AT EACH POINT (I,J)
15     C
16     C      INPUT DATA
17     C
18     C      NSMT  = NUMBER OF SMOOTHING OPERATIONS TO BE CARRIED
19     C              OUT ON GRID FIELD BEFORE OUTPUT
20     C      SMT(I)= SMOOTHING PARAMETER FOR EACH OPERATION
21     C
22     READ(5,LFMT) NSMT,(SMT(I),I=1,NSMT)
23     C
24     WRITE(6,520)
25     520 FORMAT(1H-,14X,'SMOOTHING PARAMETERS')
26     C
27     C      BEGIN SMOOTHING LOOP
28     C
29     DO 100 KK=1,NSMT
30     SM=SMT(KK)+1
31     SMT4=SMT(KK)/4
32     SMT3=SMT(KK)/3
33     SMT2=SMT(KK)/2
34     IPOSM=IPOS-1
35     MXSCM=MAXSC-1
36     C
37     C      TWO POINT SMOOTHING IS USED AT CORNERS OF GRID
38     C
39     CORR(1,1)=SMT2*(TEMP(2,1)+TEMP(1,2))
40     CORR(1,MAXSC)=SMT2*(TEMP(2,MAXSC)+TEMP(1,MXSCM))
41     CORR(IPOS,1)=SMT2*(TEMP(IPOSM,1)+TEMP(IPOS,2))
42     CORR(IPOS,MAXSC)=SMT2*(TEMP(IPOSM,MAXSC)+TEMP(IPOS,MXSCM))
43     C
44     C      THREE POINT SMOOTHING IS USED ON SIDES OF GRID
45     C
46     DO 30 J=2,MXSCM
47     CORR(1,J)=SMT3*(TEMP(1,J-1)+TEMP(2,J)+TEMP(1,J+1))
48     CORR(IPOS,J)=SMT3*(TEMP(IPOS,J-1)+TEMP(IPOSM,J)+TEMP(IPOS,J+1))
49     30 CONTINUE
50     DO 40 I=2,IPOSM
51     CORR(I,1)=SMT3*(TEMP(I+1,1)+TEMP(I,2)+TEMP(I-1,1))
52     CORR(I,MAXSC)=SMT3*(TEMP(I+1,MAXSC)+TEMP(I,MXSCM)+TEMP(I-1,MAXSC))
53     40 CONTINUE
54     C
55     C      FOUR POINT SMOOTHING IS USED IN INTERIOR OF GRID
56     C
57     DO 50 J=2,MXSCM
58     DO 50 I=2,IPOSM
59     CORR(I,J)=SMT4*(TEMP(I+1,J)+TEMP(I,J+1)+TEMP(I-1,J)+TEMP(I,J-1))

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60      50 CONTINUE
61      C
62      C      SMOOTHING CORRECTION IS APPLIED TO EACH GRID POINT
63      C      AND THE DIFFERENCES BETWEEN ORIGINAL AND SMOOTHED
64      C      TEMPERATURE FIELDS IS FOUND
65      C
66      KOUNT=0
67      S=0.0
68      DO 75 J=1,MAXSC
69      SUM=0.0
70      DO 70 I=1,IPOS
71      STEMP(I,J)=(TEMP(I,J)+CORR(I,J))/SM
72      DT=ABS(TEMP(I,J)-STEMP(I,J))
73      SUM=SUM+DT
74      70 CONTINUE
75      C      RESID IS THE MEAN DIFFERENCE BETWEEN FIELDS.
76      C
77      RESID(J)=SUM/IPOS
78      S=S+RESID(J)
79      75 CONTINUE
80      C
81      C
82      C      COMPUTE THE MEAN AND STD DEV. OF SMOOTH VS. ORIGINAL FIELDS
83      C      IN ORDER TO DISTINGUISH NOISE, AND OBSERVE THE EFFECTS
84      C      OF SMOOTHING.
85      SSO=0.0
86      AVE=S/MAXSC
87      DO 77 J=1,MAXSC
88      SSO=SSO+(RESID(J)-AVE)*(RESID(J)-AVE)
89      77 CONTINUE
90      STDEV=SQRT(SSO/(MAXSC-1))
91      ERR=AVE+2*STDEV
92      C
93      C      FIRST SMOOTHING USED TO ELIMINATE NOISE.
94      IF (KK .GT. 1)GO TO 199
95      DO 76 J=1,MAXSC
96      IF(RESID(J) .LT. ERR) GO TO 399
97      KOUNT=KOUNT+1
98      BS(KOUNT)=J
99      DO 78 II=1,IPOS
100     78 TEMP(II,J)=STEMP(II,J-1)
101     GO TO 76
102     399 DO 79 I=1,IPOS
103     79 TEMP(I,J)=STEMP(I,J)
104     76 CONTINUE
105     GO TO 74
106     C
107     199 DO 99 J=1,MAXSC
108     DO 99 I=1,IPOS
109     TEMP(I,J)=STEMP(I,J)
110     C
111     WRITE(6,521) KK,SMT(KK)
112     GO TO 100
113     C
114     74 WRITE(6,521) KK,SMT(KK)
115     521 FORMAT(1H0,4X,'SMOOTHING OPERATION NUMBER',13,5X,
116     1 'SMOOTHING PARAMETER =',F6.2)
117     C
118     WRITE(6,522) AVE,STDEV
119     WRITE(6,525) MAXSC
120     WRITE(6,524) KOUNT
121     IF(KOUNT .GT. 0) WRITE(6,526) (BS(J),J=1,KOUNT)
122     522 FORMAT(1H0,4X,'MEAN OF FIELD DIFFERENCES =',F8.3,
123     1 '//,5X,'STANDARD DEVIATION',9X,'=',F8.3)
124     523 FORMAT(/,50(10F6.2,/))
125     524 FORMAT(1H0,4X,'SCAN LINES REJECTED DUE TO SYNCH PROBLEM =',14)
126     525 FORMAT(1H0,4X,'NUMBER OF SCANS IN WINDOW =',18)
127     526 FORMAT(1H0,4X,'SCAN LINES REJECTED =',5X,10(3F6.0/,31X))
128     100 CONTINUE
129     RETURN
130     END

```

END OF FILE

C.6 Subroutine CALI

```

1  C   CALIBRATION SUBROUTINE
2  C
3  C   SUBROUTINE CALI(MAXSC, IPDS,*,*)
4  C
5  C
6  C   THIS SUBROUTINE IS USED TO CALIBRATE THE INFRARED DATA
7  C   OBTAINED FROM TIROS-N. THE ONBOARD COMPUTER IS CALLED
8  C   A MANIPULATION INFORMATION PROCESSOR OR MIRP FOR SHORT.
9  C   A DIGITAL COUNT FROM MIRP IS WHAT IS CONVERTED TO AN
10 C   ANALOG SIGNAL AND TRANSMITTED TO AP7 STATIONS. THE
11 C   PROBLEM INVOLVED IN CALIBRATING THE INFRARED DATA IS
12 C   DETERMINING THE RELATIONSHIP BETWEEN THE U OF A DIGITAL
13 C   COUNT AND THE MIRP DIGITAL COUNT.
14 C
15 C
16 C   LOGICAL*1 LFMT(1) /'*/
17 C   REAL T(80), CA(80), CMR(80)
18 C
19 C   COMMON /TFIELD/ TEMP(301,400)
20 C   COMMON /CALIB/ COF(11)
21 C
22 C   MAXSC = NUMBER OF COLUMNS IN DATA FIELD
23 C   IPDS = NUMBER OF ROWS IN DATA FIELD
24 C   RETURN1 = CALIBRATION PROGRAM SUCCEEDS
25 C   RETURN2 = CALIBRATION PROGRAM FAILS
26 C   TEMP(I,J) = DATA VALUE AT EACH POINT (I,J)
27 C
28 C   INPUT DATA
29 C   NCAL = 36
30 C   BP = 0.0
31 C   REAL IN
32 C
33 C   NCAL = NUMBER OF CALIBRATION LEVELS USED
34 C   CA(I),T(I) = DATA VALUES AND CORRESPONDING TEMPERATURE
35 C   VALUES FOR EACH CALIBRATION LEVEL (IN PAIRS)
36 C
37 C   DETERMINE RELATION BETWEEN UOFA DIGITAL VALUE AND BB. TEMP.
38 C
39 C   THE FIRST 3 VALUES IN COF ARE THE COEFFICIENTS FITTING THE
40 C   U OF A WEDGE LEVELS TO THE MIRP WEDGE LEVELS. THE SECOND 3
41 C   VALUES ARE COEFFICIENTS FITTING MIRP VALUES TO U OF A VALUES.
42 C   THE LAST 5 VALUES IN COF(11) ARE B. B. THEMISTER
43 C   AVERAGES AND SPACE VIEW.
44 C
45 C   USE QUADRATIC FIT TO GET MIRP COUNT CORRESPONDING
46 C   TO THE RECORDED VALUES IN COF(7 THRU 11)
47 C
48 C   DO 10 J = 7, 11
49 C       COF(J) = COF(1) + COF(2) * COF(J) + COF(3) * COF(J) ** 2
50 C
51 C
52 C   CONVERT FROM 8 TO 10 BIT NUMBER
53 C       COF(J) = 4 * COF(J)
54 C   10 CONTINUE
55 C
56 C   CONVERT COF(J) TO TEMPERATURE
57 C   COEFFICIENTS OBTAINED BEFORE SATELLITE IS LAUNCHED.
58 C   T1 = 277.73 + 0.047752 * COF(7) + 8.29E-6 * COF(7) ** 2
59 C   T2 = 277.41 + 0.046637 * COF(8) + 11.01E-6 * COF(8) ** 2
60 C   T3 = 277.14 + 0.045188 * COF(9) + 14.77E-6 * COF(9) ** 2

```

```

61      T4 = 277.42 + 0.046387 * COF(10) + 10.59E-6 * COF(10) ** 2
62      C
63      C TAKE AVERAGE OF PRT TEMP'S
64      C TBB IS THE ACTUAL TEMPERATURE OF THE RADIOMETER HOUSING.
65      C
66      TBB = (T1 + T2 + T3 + T4) / 4.
67      C
68      CALL PLANCK(TBB, ON)
69      C
70      C TO ACCOUNT FOR NON-LINEARITIES
71      C ASSUME THE RADIANCE OF SPACE=-1.151. CMSP=250
72      C
73      SP = -1.151
74      CMSP = 250.
75      C FROM N=G*CM+IN
76      G = (SP - ON) / (CMSP - COF(11)/4.)
77      IN = SP - G * CMSP
78      C
79      C NOW WORK BACKWARDS- FIND N FOR EVERY 3' INTERVAL FROM -70' TO 30'C
80      C
81      J = 0
82      DO 20 K = 200, 305, 3
83      J = J + 1
84      T(J) = K
85      CALL PLANCK(T(J), ON)
86      CMR(J) = (ON - IN) / G
87      C
88      C INTERPOLATE TO GET U OF A COUNT FROM MIRP COUNT
89      C
90      CA(J) = COF(4) + COF(5) * CMR(J) + COF(6) * CMR(J) ** 2
91      20 CONTINUE
92      C
93      WRITE (6,30) (CA(I),T(I),I=1,NCAL,5)
94      30 FORMAT (1H-, 14X, 'CALIBRATION PARAMETERS', //, 5X, 'CALIBRATION C
95      URVE ', 5X, 'DATA LEVELS', 5X, 'TEMPERATURES (IN DEG K)', //,
96      2 '70(31X,F8.2,14X,F7.2,/)')
97      C
98      C
99      C CALIBRATE EACH GRID POINT
100     C
101     DO 70 J = 1, MAXSC
102     DO 70 I = 1, IPO5
103     C SET VALUES OUTSIDE OF TEMP RANGE TO EXTREME VALUES
104     IF (TEMP(I,J) .LE. CA(1) .OR. TEMP(I,J) .GE. CA(NCAL))
105     1 GO TO 40
106     BP = BP + 1
107     IF (TEMP(I,J) .GT. CA(1)) TEMP(I,J) = CA(1)
108     IF (TEMP(I,J) .LT. CA(NCAL)) TEMP(I,J) = CA(NCAL)
109     TEMP(I,J) = TEMP(I,J) - 273.15
110     GO TO 70
111     40 DO 50 K = 1, 35
112     IF (TEMP(I,J) .LT. CA(K) .AND. TEMP(I,J) .GE. CA(K + 1))
113     1 GO TO 60
114     50 CONTINUE
115     C
116     C PERFORM LINEAR INTERPOLATION
117     C
118     60 DUM = (TEMP(I,J) - CA(K + 1)) / (CA(K) - CA(K + 1))
119     DUM2 = DUM * (T(K) - T(K + 1)) + T(K)
120     C

```

```

121 C      CONVERT TO °C
122      TEMP(I,J) = DUM2 - 273.15
123 70 CONTINUE
124      WRITE (6,90) BP
125      RETURN 1
126 C
127 80 WRITE (6,100)
128 90 FORMAT (F20.0, 5X, 'BAD DATA POINTS IN DATA FIELD')
129 100 FORMAT (1H0, '***** ERROR CALIBRATION FAILURE *****')
130      RETURN 2
131      END
132 C
133 C
134      SUBROUTINE PLANCK(TEMP, QN)
135      DIMENSION PHI(60)
136 C
137 C      THIS SUBROUTINE DETERMINES THE RADIANCE OF A BLACK BODY
138 C      WITH TEMPERATURE T IN THE 11MICRON BAND. (ALL CONSTANTS
139 C      WERE OBTAINED FROM TIROS-N WRITE UP)
140 C
141      DATA PHI /0.0, 0.33701E-4, 0.73654E-4, 0.10611E-3, 0.14390E-3,
142      10.24906E-3, 0.50024E-3, 0.95828E-3, 0.15939E-2, 0.23496E-2,
143      10.31779E-2, 0.40893E-2, 0.51155E-2, 0.62748E-3, 0.74753E-2,
144      20.85702E-2, 0.94211E-2, 0.10012E-1, 0.10418E-1, 0.10718E-1,
145      30.10961E-1, 0.11164E-1, 0.11335E-1, 0.11489E-1, 0.11635E-1,
146      40.11786E-1, 0.11954E-1, 0.12147E-1, 0.12374E-1, 0.12644E-1,
147      50.12877E-1, 0.12887E-1, 0.12539E-1, 0.12331E-1, 0.12071E-1,
148      60.11931E-1, 0.11982E-1, 0.12175E-1, 0.12387E-1, 0.12766E-1,
149      70.13462E-1, 0.14131E-1, 0.14239E-1, 0.13355E-1, 0.11367E-1,
150      80.87492E-2, 0.60630E-2, 0.38563E-2, 0.23495E-2, 0.13991E-2,
151      90.84093E-1, 0.51723E-3, 0.33615E-3, 0.24878E-3, 0.20690E-3,
152      *0.16664E-3, 0.11659E-3, 0.59942E-4, 0.61584E-8, 0.0/
153 C
154 C
155 C      INITIAL VALUE OF V
156 C      IS      V=840.0337
157 C      TO ACCOUNT FOR INCREMENTING
158      V = 837.61981
159      DV = 2.41389
160      QN = 0.0
161 C
162 C      CALCULATE PLANK FN.
163      DO 20 I = 1, 60
164 C
165      V = V + DV
166 C
167      PLANK = (1.1910659E-5*(V**3)) / (EXP(1.438833*V/TEMP) - 1)
168      QN = QN + PLANK * PHI(I) * DV
169 20 CONTINUE
170 C
171      RETURN
172      END

```

END OF FILE

C.7 Program PLT

```

1  C  PROGRAM PLT
2  C  PROGRAM TO PLOT TEMPERATURE OR REFLECTANCE FIELDS,
3  C  POST TOWNSITE LOCATIONS, DRAW LAT-LON LINES AND
4  C  OUTLINE ALBERTA. (PROGRAM COULD BE CONSIDERABLY SHORTER
5  C  IF I-O OPTIONS WERE RESTRICTED.)
6  C
7  C  INPUT - OUTPUT
8  C  UNIT 5 : PROGRAM PARAMETERS
9  C  UNIT 9 : PLOT OUTPUT FOR CALCOMPO PLOTTING
10 C  UNIT 13 : DATA FIELD
11 C  UNIT 16 : OUTLINES WITH ORIGIN OF (0,0)
12 C
13 C  NCON = NUMBER OF CONTOUR INTERVALS
14 C  (CONTOUR INTERVALS STORED IN CTR(I))
15 C  BUP = BLOW-UP FACTOR
16 C  MTNS = PLOT B.C. - ALBERTA BORDER
17 C  O = NO, 1 = YES
18 C  LCHK1= LAT-LON LINES DESIRED ?
19 C  O = NO, 1 = YES
20 C  LOGICAL*1 LFMT(1) /'/'
21 C  REAL CTR(10)
22 C
23 C  READ (5,LFMT) NCON, BUP, LCHK1, MTNS
24 C  READ (5,LFMT) (CTR(I),I=1,NCON)
25 C  SCALP = 59.346
26 C  SCALS = 76.737
27 C
28 C  REAL TFLD(400,301)
29 C  REAL VP(8) /4*0.0, -1.0, 2*0.0, 0.2/
30 C  IP(4)=0 NO CONTOUR VALUES ARE PLOTTED
31 C  IP(4)=2 CONTOUR VALUES ARE PLOTTED 3IN. APART
32 C  INTEGER IP(8) /0, 1, 0, 2, 1, 1, 0, 0/
33 C  CALL PLOTS
34 C
35 C
36 C  READ (13) IPDS, MAXSC
37 C  DO 10 JJ = 1, MAXSC
38 C  10 READ (13) (TFLD(JJ,II),II=1,IPDS)
39 C
40 C  READ (16,120) MM
41 C  CALCULATE SYMBOL AND MAP SIZE.
42 C  RADAR RANGE RR=.5 INCHES CORRESPONDS TO 80 MILES
43 C  MAP SCALE IS 1:10E6
44 C  SX = (MAXSC/SCALS) * BUP
45 C  SY = (IPDS/SCALP) * BUP
46 C  RR = 0.50 * BUP
47 C  CHT = 0.05 * BUP
48 C  THT = 0.02 * BUP
49 C
50 C
51 C  CALL PLOT(1.0, 1.0, -3)
52 C  CALL CONTUR(SX, SY, TFLD, 400, MAXSC, IPDS, CTR, NCON, IP, VP)
53 C
54 C  20 READ (16,110) XP, YP
55 C  XP = (XP/SCALS) * BUP
56 C  YP = (YP/SCALP) * BUP
57 C  CALL CIRCL2(XP, YP, 0., 360., RR)
58 C  POST EDMONTON AND CALGARY
59 C  READ (16,110) XE, YE

```

```

60      XE = (XE/SCALS) * BUP
61      YE = (YE/SCALP) * BUP
62      CALL SYMBOL(XE, YE, CMT, 3, 0., -1)
63      READ (16,110) XC, YC
64      XC = (XC/SCALS) * BUP
65      YC = (YC/SCALP) * BUP
66      CALL SYMBOL(XC, YC, CMT, 3, 0., -1)
67      C READ AND POST TOWNSITES IN RADAR RANGE
68      DO 30 J = 1, 8
69          READ (16,110) XT, YT
70          XT = (XT/SCALS) * BUP
71          YT = (YT/SCALP) * BUP
72          CALL SYMBOL(XT, YT, THT, 3, 0., -1)
73      30 CONTINUE
74      IF (MTNS .EQ. 1) GO TO 40
75      C N.S.E.W. LINES ARE DRAWN
76      READ (16,110) X, Y
77      X = (X/SCALS) * BUP
78      Y = (Y/SCALP) * BUP
79      CALL PLOT(X, Y, 3)
80      READ (16,110) X, Y
81      X = (X/SCALS) * BUP
82      Y = (Y/SCALP) * BUP
83      CALL PLOT(X, Y, 2)
84      READ (16,110) X, Y
85      X = (X/SCALS) * BUP
86      Y = (Y/SCALP) * BUP
87      CALL PLOT(X, Y, 3)
88      READ (16,110) X, Y
89      X = (X/SCALS) * BUP
90      Y = (Y/SCALP) * BUP
91      CALL PLOT(X, Y, 2)
92      C
93      GO TO 90
94      C
95      C DRAW ROCKIES
96      40 MM = MM - 11
97      DO 50 I = 1, MM
98          READ (16,110,END=60) X, Y
99          X = (X/SCALS) * BUP
100         Y = (Y/SCALP) * BUP
101         IF (I .EQ. 1) CALL PLOT(X, Y, 3)
102         IF (I .NE. 1) CALL PLOT(X, Y, 2)
103     50 CONTINUE
104     C
105     C ARE LAT LON LINES DESIRED?
106     60 IF (LCHK1 .EQ. 0) GO TO 90
107     C PROGRAM TO PRODUCE LAT LON LINE PLOT.
108     C
109     70 READ (11,100,END=90) J, MZERO, MLL, LLAT
110     DO 80 I = 1, J
111         READ (11,110) XL, YL
112         XL = (XL/SCALS) * BUP
113         YL = (YL/SCALP) * BUP
114         IF (I .EQ. 1) CALL PLOT(XL, YL, 3)
115         IF (I .NE. 1) CALL PLOT(XL, YL, 2)
116     80 CONTINUE
117     GO TO 70
118     90 CALL PLOT(0.0, 0.0, 999)
119     100 FORMAT (4I4)
120     110 FORMAT (2F7.2)
121     120 FORMAT (I4)
122     130 FORMAT (34F4.0)
123     STOP
124     END
END OF FILE

```

C.8 Program GREY

```

1      C      PROGRAM GREY
2      C
3      C      PROGRAM TO PRODUCE GREY-LEVEL MAP OF DATA FIELD
4      C      ON THE ESPP. THIS PROGRAM WORKS IN CONJUNCTION
5      C      WITH PROGRAM JMON GREY
6      C
7      LOGICAL*1 LFMT(1) /'.'/
8      LOGICAL*1 LFLD(150,150), P(2)
9      DIMENSION YSCAN(3), XPOS(3)
10     INTEGER ITRANS(256)
11     REAL*4 LINE(78)
12     INTEGER*2 NLEV
13     EQUIVALENCE(NLEV,P)
14     ISIZE=1
15     C
16     C      READ IN CITY LOCATIONS
17     READ(16,LFMT)(YSKAN(I),XPOS(I),I=1,3)
18     C
19     C
20     C      SET UP TRANSLATION TABLE (ITRANS)
21     C
22     1      REWIND 13
23     DO 5 J=1,256
24     ITRANS(J)=J-1
25     5      CONTINUE
26     IP=-1
27     C
28     READ(5,LFMT,END=100) IR
29     KORR=1
30     IF(IR.EQ.1) KORR=81
31     C
32     20     READ(5,LFMT,END=100) II,IO
33     II=II+KORR
34     IF(II.LT.1.OR.II.GT.256.OR.IO.LT.0.OR.IO.GT.255)GO TO 95
35     IF(IP.LT.0) GO TO 90
36     IF(II-IP) 95, 90, 30
37     30     SLOPE=FLOAT(IO-IOP)/FLOAT(II-IP)
38     DO 40 J=IP,II
39     ITRANS(J)=IOP+INT(0.5+(J-IP)*SLOPE)
40     40     CONTINUE
41     90     IP=II
42     IOP=IO
43     GO TO 20
44     95     WRITE(6,999) II,IO,IP,IOP
45     999     FORMAT(' ***ERROR IN ORDINATE VALUES FOR TRANSLATE TABLE***',
46     1      4I4)
47     STOP 99
48     100    IF(IP.LT.0)STOP
49     C
50     READ(13) IPOS,MAXSC
51     WRITE(6,99) IPOS,MAXSC
52     99     FORMAT(2I5)
53     C
54     C      CONVERT REAL*4 TO INTEGER*2 THEN TO LOGICAL*1
55     C
56     DO 11 JJ=1,MAXSC
57     READ(13) LINE
58     II=1
59     KOUNT=0

```

```

60      DO 11 I=1,IPOS
61      C
62      ILINE=KORR+INT(SIGN(0.5,LINE(I))+LINE(I))
63      NLEV =ITRANS(ILINE)
64      C
65      KOUNT=KOUNT+1
66      C
67      IF(KOUNT.NE.4) GO TO 10
68      LFLD(II,JJ)=P(2)
69      II=II+1
70      KOUNT=0
71      C
72      10  LFLD(II,JJ)=P(2)
73      II=II+1
74      11- CONTINUE
75      C
76      C  PLOT CITIES YEG,YQF,YYC
77      C
78      DO 220 ICITY=1,3
79      IXPOS=IFIX(XPOS(ICITY)*1.25+.2)
80      IYSCAN=IFIX(YSCAN(ICITY)+.5)
81      IT1=IXPOS-ISIZE
82      IT2=IXPOS+ISIZE
83      C - BLACK + SYMBOL ON WHITE BACKGROUND & VICE VERSA
84      NLEV=0
85      P(2)=LFLD(IXPOS,IYSCAN)
86      I=0
87      IF(NLEV.LT.100) I=235
88      NLEV=I
89      C
90      STRIPE ALONG SCAN
91      DO 200 I=IT1,IT2
92      200 LFLD(I,IYSCAN)=P(2)
93      C
94      STRIPE ACROSS SCAN
95      IT1=IYSCAN-ISIZE
96      IT2=IYSCAN+ISIZE
97      DO 210 J=IT1,IT2
98      210 LFLD(IXPOS,J)=P(2)
99      220 CONTINUE
100      CALL GREY (LFLD,150,MAXSC,2)
101      C
102      GO TO 1
103      END
END OF FILE

```

C.9 Program RAIN

```

1  PROGRAM RAIN
2  C
3  C      ALGORITHM FOR IR & VIS DATA TO DETERMINE RAIN AREAS.
4  C      DATA IS READ IN UNFORMATTED IS TESTED AND RESULT
5  C      IS WRITTEN ON UNIT 15.
6  C
7  LOGICAL*1 LFMT(1) /* */
8  C
9  COMMON/TEFIELD/TEMP(301,400)
10 DIMENSION T(200,200),VIS(200,200)
11 READ(5,LFMT)T1,V1,T2,V2
12 C
13 C
14 READ(13) IPOB,MAXSC
15 READ(14) JPOS,NAXSC
16 IF(IPOB .NE. JPOS .OR. MAXSC .NE. NAXSC) WRITE(6,99)
17 C
18 DO 11 JU=1,MAXSC
19 READ(13) (T(IJ,JU),IJ=1,IPOB)
20 READ(14) (VIS(IJ,JU),IJ=1,JPOS)
21 11 CONTINUE
22 C
23 DO 10 J=1,MAXSC
24 DO 10 I=1,IPOB
25 C
26 C      DATA TESTS
27 IF(T(I,J).GT. T1 .OR. VIS(I,J).LT.V1) GO TO 8
28 TEMP(I,J)=51
29 IF(T(I,J).LE. T2 .AND. VIS(I,J).GT.V2) TEMP(I,J)=85.
30 GO TO 10
31 C
32 8 TEMP(I,J)=0.
33 10 CONTINUE
34 C      SMOOTH FIELD
35 CALL SMOO(MAXSC,IPOB)
36 C
37 WRITE(15) IPOB,MAXSC
38 DO 12 J=1,MAXSC
39 WRITE(15)(TEMP(I,J),I=1,IPOB)
40 12 FORMAT('INPUT FILES NOT FROM SAME PASS.')
41 WRITE(6,LFMT)IPOB,MAXSC,JPOS,NAXSC
42 STOP
43 END
END OF FILE

```

Appendix D

D.1 Program FREQ

```

1 C PROGRAM FREQ
2 C
3 C PROGRAM TO DETERMINE THE FREQUENCY OF DIGITAL
4 C COUNTS IN GROUPS (EVERY 5 COUNTS).
5 C DATA READ IN UNFORMATTED IS TESTED AND COMBINED
6 C FREQUENCIES ARE OUTPUT ALONG WITH
7 C BOTH IR & VIS FREQUENCIES
8 C
9 C LOGICAL*1 LFMT(1) /'.'/
10 C LOGICAL*4 DASH/ZBFBFBF/. CNR/ZABABAB/. VLIN/'.'/
11 C
12 C DIMENSION T(200,200),VIS(200,200),DT(22)
13 C INTEGER IBOTH(40,40),ICT(40)/40*0/,ICV(40)/40*0/
14 C REAL BOTH(40,40)
15 C
16 C DO 5 I=1,40
17 C DO 5 J=1,40
18 C BOTH(I,J)=0.0
19 C IBOTH(I,J)=0
20 C
21 C WRITE(5,988)
22 988 FORMAT('PLEASE ENTER PASS NUMBER')
23 C READ(5,987)IPASS
24 987 FORMAT(I4)
25 C READ(13) IPOS,MAXSC
26 C READ(14) JPOS,MAXSC
27 C IF(IPOS.NE.JPOS.OR.MAXSC.NE.MAXSC) WRITE(6,99)
28 C GRID=IPOS*MAXSC
29 C AREA=GRID*3.655
30 C
31 C DO 11 JJ=1,MAXSC
32 C READ(13) (T(II,JJ),II=1,IPOS)
33 C READ(14) (VIS(II,JJ),II=1,JPOS)
34 11 CONTINUE
35 C
36 C DO 10 J=1,MAXSC
37 C DO 10 I=1,IPOS
38 C
39 C FREQUENCY TABLE CHECK
40 C IT=1 COLDER THAN -70
41 C IT=2 -65.1 TO -70.0 ETC.
42 C IT=20 WARMER THAN +20 CELCIUS
43 C
44 C
45 C IT=IFIX((T(I,J)+80.0)/5.)
46 C IT=MAXO(1,IT)
47 C IT=MINO(20,IT)
48 C
49 C ICT(IT)=ICT(IT)+1
50 C
51 C IV=IFIX(VIS(I,J)/5.)
52 C IV=MAXO(8,IV)
53 C IV=MINO(38,IV)
54 C
55 C ICV(IV)=ICV(IV)+1
56 C
57 C IBOTH(IT,IV)=IBOTH(IT,IV)+1
58 C
59 C
60 C SCALE LARGE COUNTS FOR PLOTTING

```

```

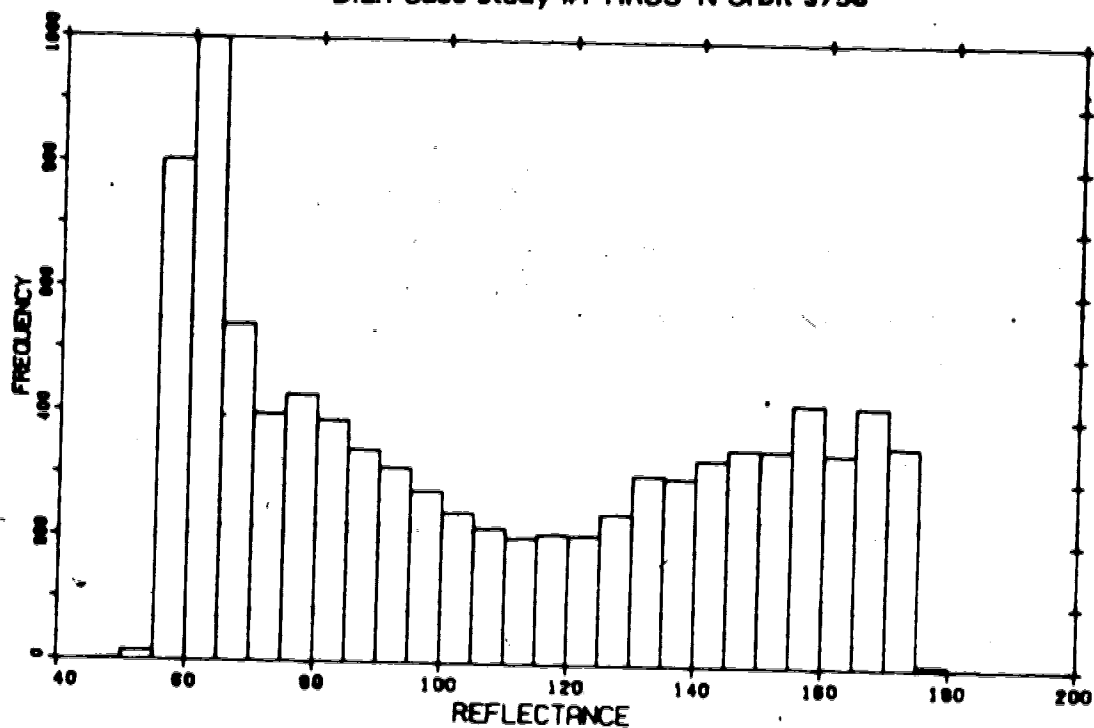
61      IF(ICT(IT).GT.1000)ICT(IT)=999
62      IF(ICV(IT).GT.1000)ICV(IT)=999
63      C
64      IF(IT.GT.15.OR.IV.LT.14)GO TO 10
65      CLDA=CLDA+1.
66      C
67      10  CONTINUE
68      C
69      DO 16 IV=8.38
70      DO 16 IT=1.20
71      BOTH(IT,IV)=100.*IBOTH(IT,IV)/CLDA
72      IF(BOTH(IT,IV).LT.0.1) BOTH(IT,IV) = 0.0
73      16  CONTINUE
74      PCNT=100.*CLDA/GRID
75      K=-75
76      C      K=80 FOR EXTENDED RANGE
77      DO 13 J=1.22
78      K=K+5
79      13  DT(J)=K
80      C
81      C
82      WRITE(6,989) IPASS,PCNT,AREA
83      989  FORMAT(1H1.46X,'FREQUENCY TABLE FOR ORBIT NUMBER',2X,I4.//
84      1    14X.36X,'Y AXIS = VISIBLE REFLECTANCE'//
85      1    14X.36X,'X AXIS = INFRARED TEMPERATURES'//
86      1    14X.30X,'VALUES GIVEN IN PERCENT OF TOTAL CLOUD COVER'//
87      1    42X.F4.1,'% CLOUD COVER OVER',2X,F7.0,1X,'SQUARE KILOMETERS'//)
88      C
89      C      THE LIMITS OF SEVERAL VARIABLES HAVE BEEN CHANGED FOR OUTPUT
90      C      THESE ARE IO=200,IV=39-K,IT=1.16,K=1.25
91      C      WRITE OUT COMBINED FREQ
92      IO=185
93      DO 12 K=1.22
94      IO=IO-5
95      IV=36-K
96      C      SUPPRESS ZEROS
97      CALL FTNCMD('SET ZEROSUPPRESS=ON;')
98      C
99      WRITE(6,999) IO ,VLIN, VLIN, (BOTH(IT,IV),IT=2,16)
100     12  CONTINUE
101     999  FORMAT(1H ,15.A1./,6X,A1,16F7.1)
102     CALL FTNCMD('SET ZEROSUPPRESS=OFF;')
103     ISVTY=70
104     WRITE(6,990) ISVTY,CNR,(DASH,I=1,28)
105     990  FORMAT(1H ,3X,I2,A1,28A4)
106     WRITE(6,991) (DT(I),I=1,17)
107     991  FORMAT(6X,F5.0,17(F7.0))
108     C
109     C
110     WRITE(3,994) IPASS
111     994  FORMAT(3X,'ORBIT',15,2X,'INFRARED DATA HISTOGRAM',13X,
112     1    'TEMPERATURE',7X,'FREQUENCY')
113     DO 14 K=1.21
114     WRITE(3,LFMT) DT(K+1),ICT(K)
115     14  CONTINUE
116     WRITE(3,993) IPASS
117     993  FORMAT(3X,'ORBIT',15,2X,'VISIBLE DATA HISTOGRAM',13X,
118     1    'REFLECTANCE',8X,'FREQUENCY')
119     IO=200
120     DO 15 K=1.31
121     IO=IO-5
122     J=39-K
123     WRITE(3,LPMT) IO,ICV(J)
124     15  CONTINUE
125     STOP
126     99  FORMAT('DILEXIC ? INPUT FILES NOT FROM SAME PASS')
127     WRITE(6,LFMT)IPOS,MAXSC,JPOS,MAXSC
128     STOP
129     END

```

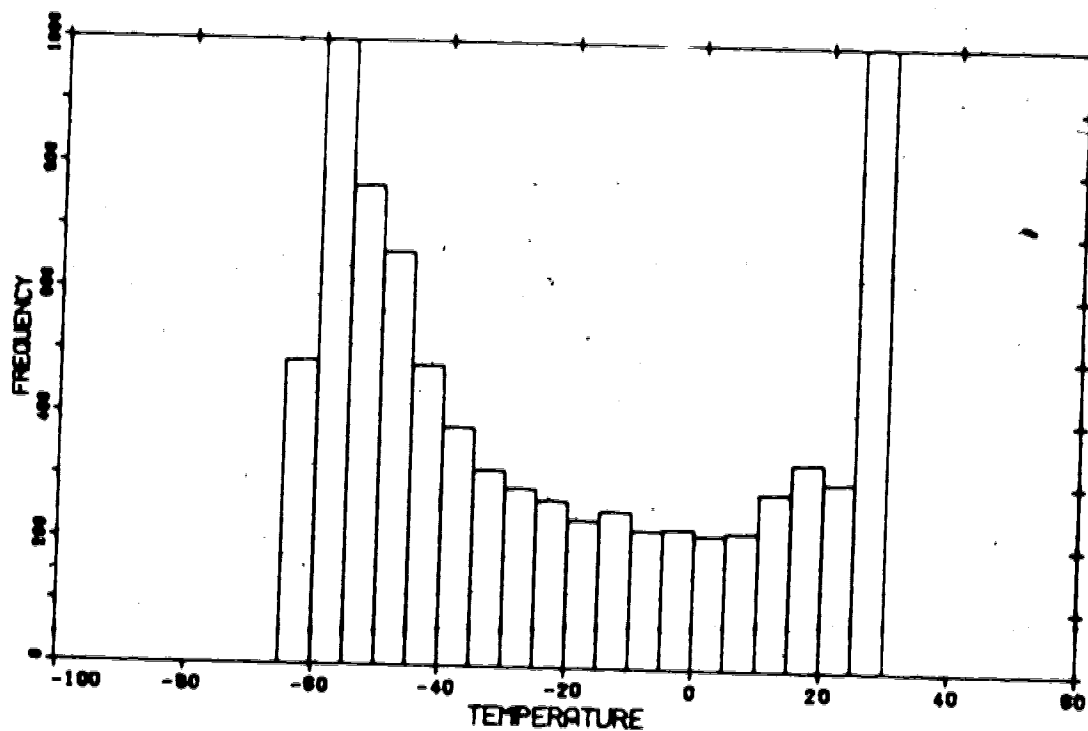
END OF FILE

D.2 Frequency Histograms

D.2.1 Case study #1 TIROS-N Orbit 3758

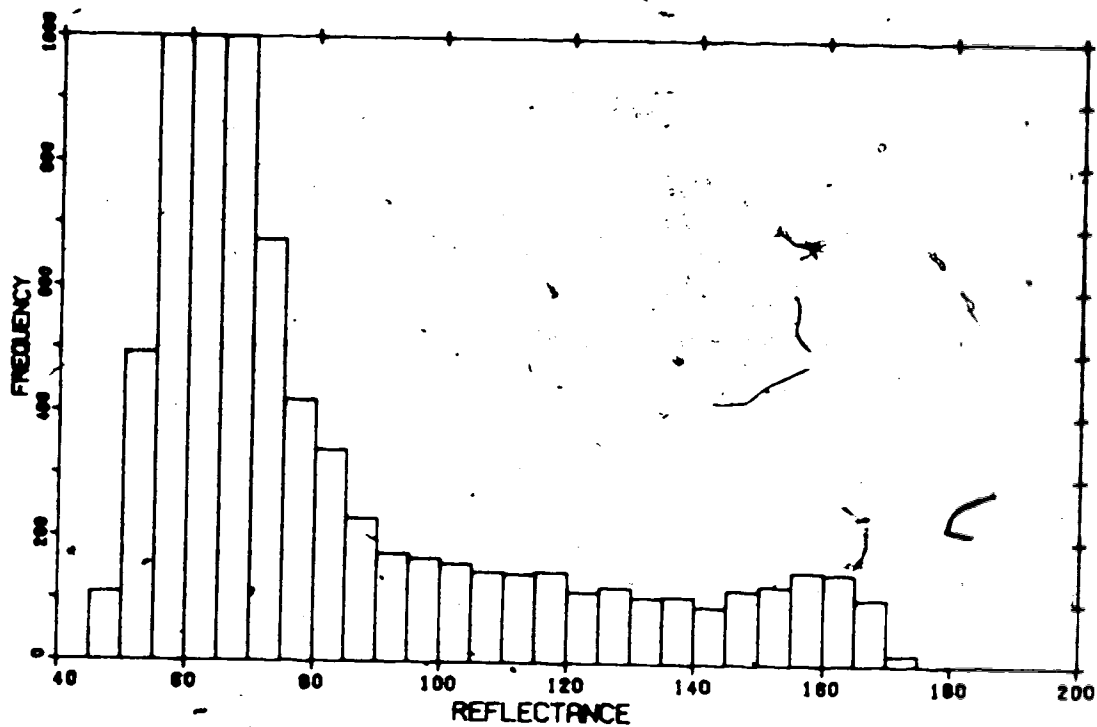


ORBIT 3758 VISIBLE DATA HISTOGRAM

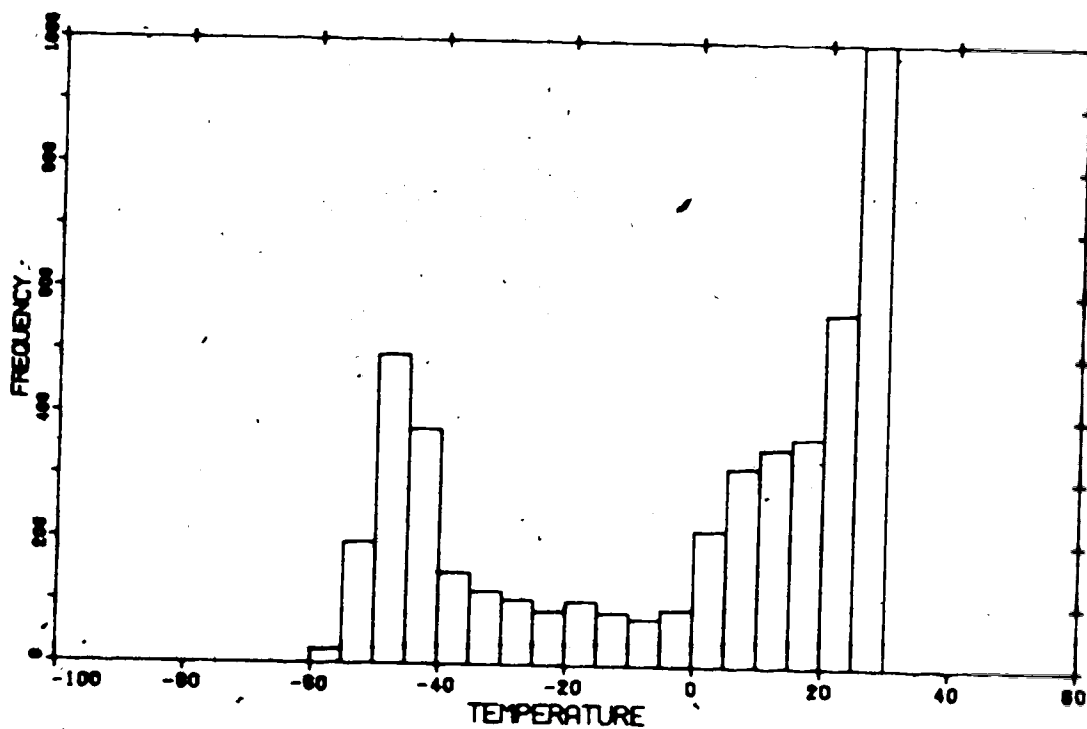


ORBIT 3758 INFRARED DATA HISTOGRAM

D.2.2 Case study #2 TIROS-N Orbit 3772

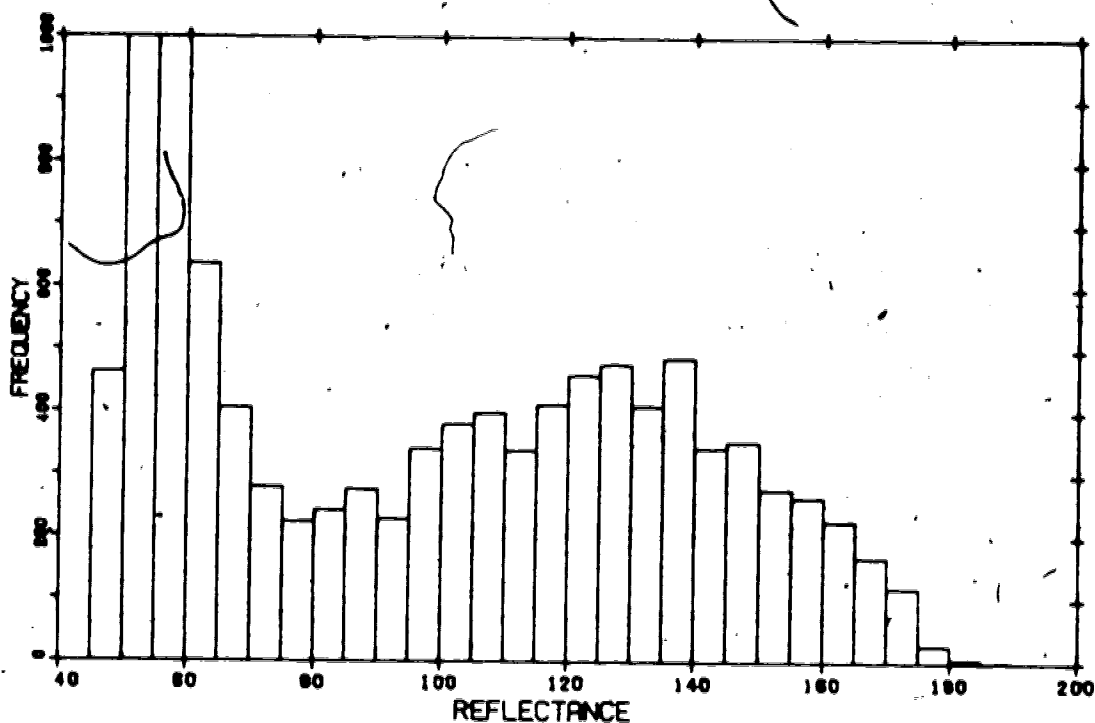


ORBIT 3772 VISIBLE DATA HISTOGRAM

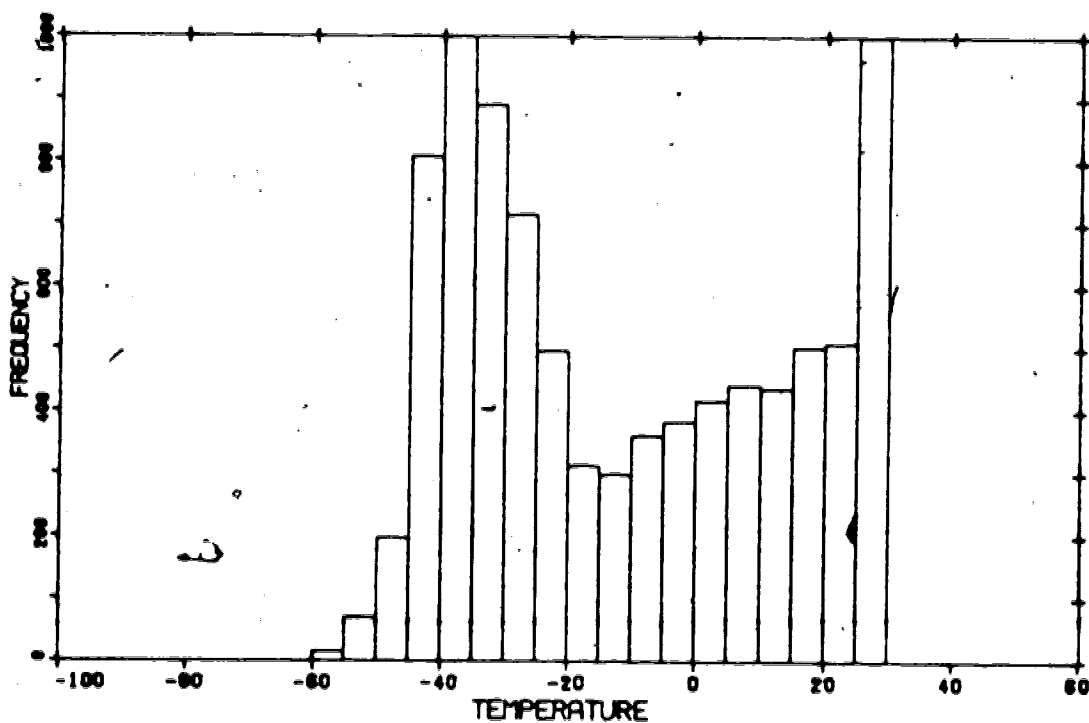


ORBIT 3772 INFRARED DATA HISTOGRAM

D.2.3 Case study #3 TIROS-N Orbit 3814

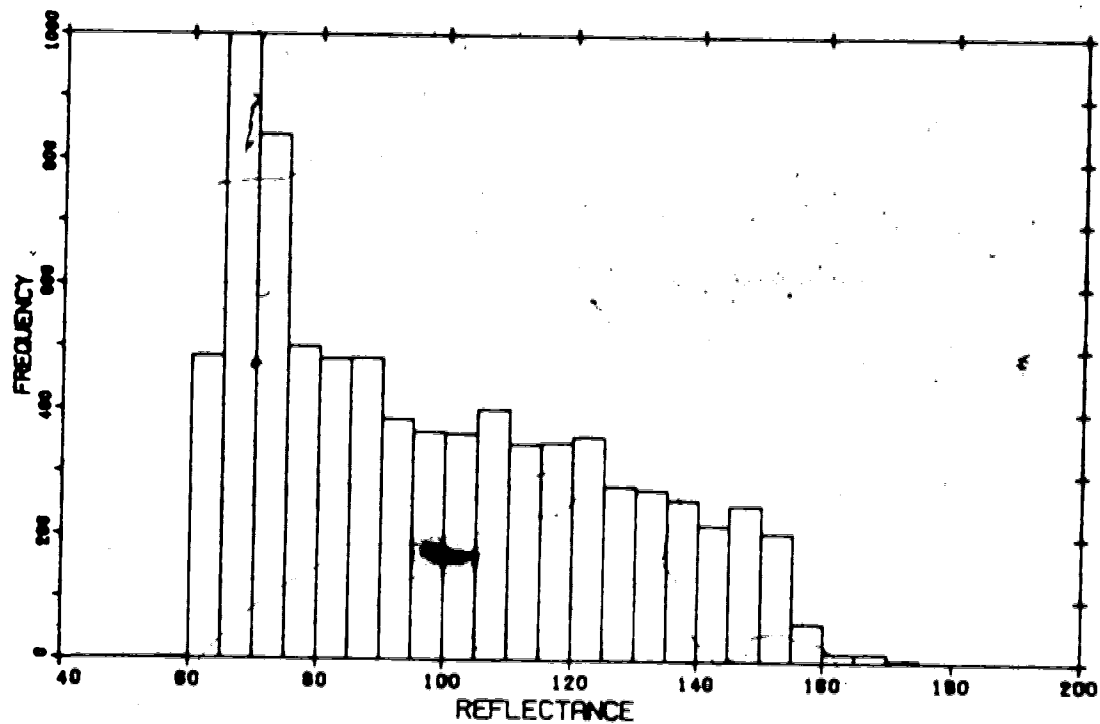


ORBIT 3814 VISIBLE DATA HISTOGRAM

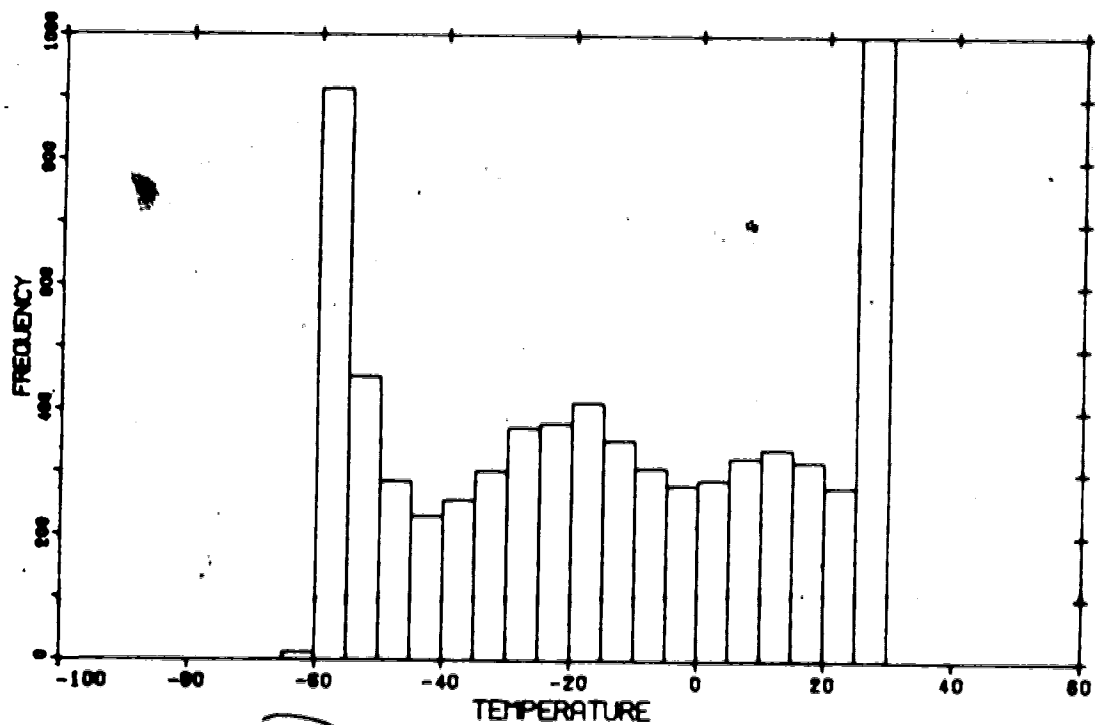


ORBIT 3814 INFRARED DATA HISTOGRAM

D.2.4 Case study #4 TIROS-N Orbit 3970

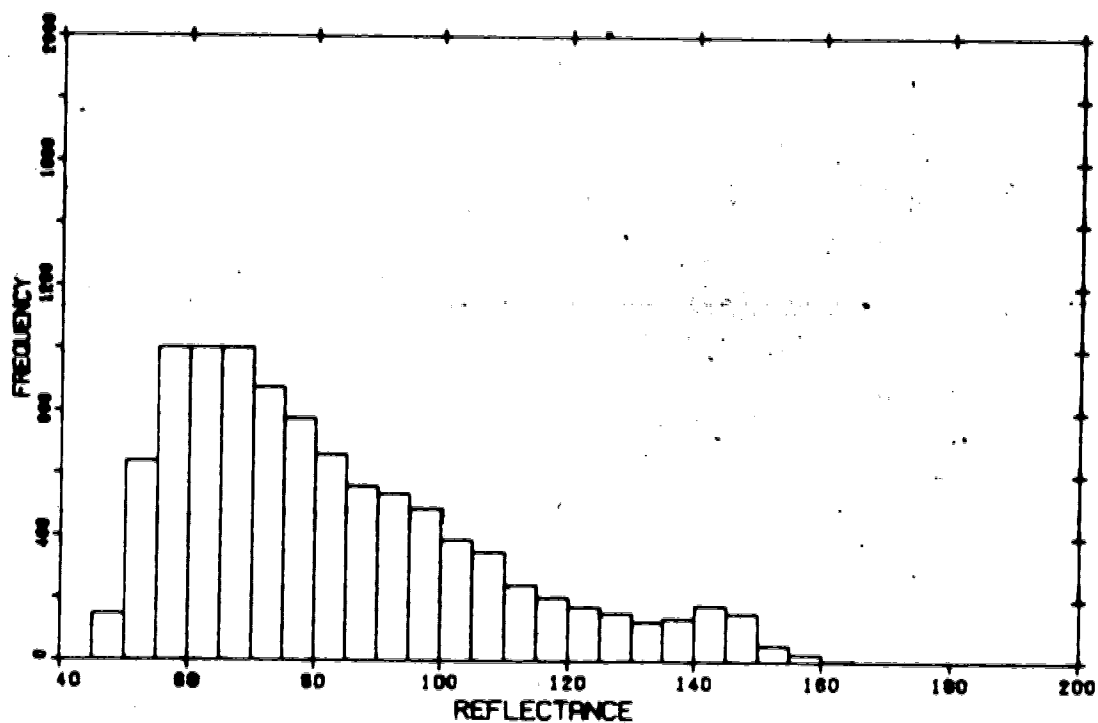


ORBIT 3970 VISIBLE DATA HISTOGRAM

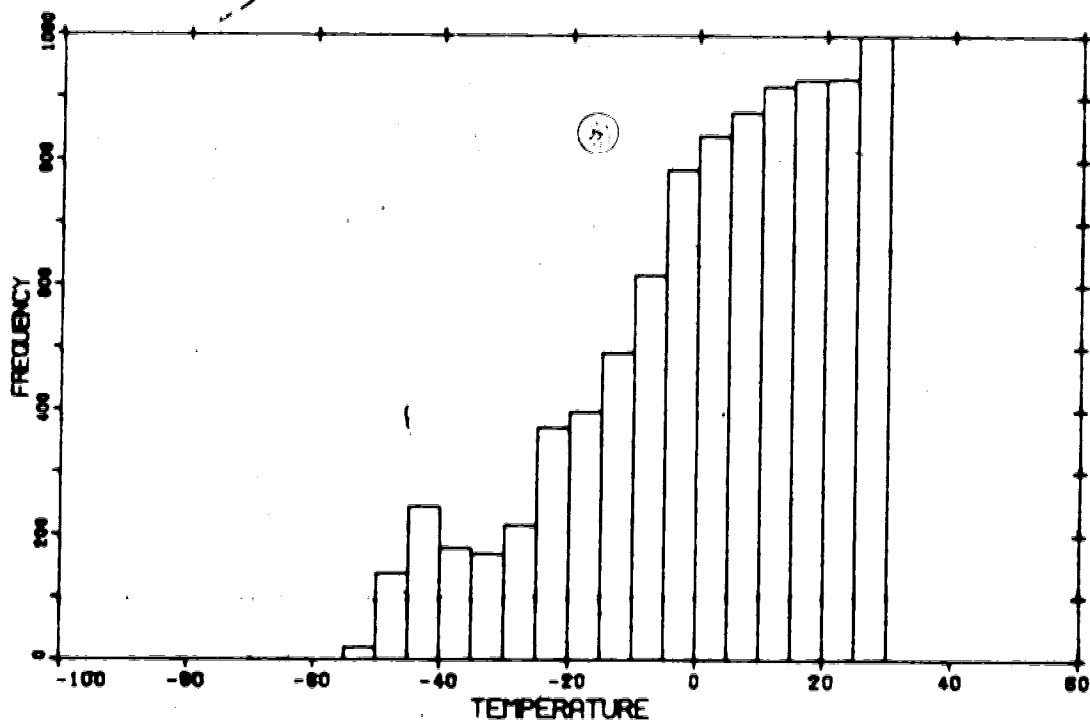


ORBIT 3970 INFRARED DATA HISTOGRAM

D.2.5 Case study #5 TIROS-N Orbit 9063



ORBIT 9063 VISIBLE DATA HISTOGRAM



ORBIT 9063 INFRARED DATA HISTOGRAM

D.3 Sample Output from Program TELEM

WEDGE NUMBER	1	MEAN	51.03	STD DEVIATION	0.28
WEDGE NUMBER	2	MEAN	81.35	STD DEVIATION	0.63
WEDGE NUMBER	3	MEAN	112.32	STD DEVIATION	0.57
WEDGE NUMBER	4	MEAN	142.84	STD DEVIATION	0.46
WEDGE NUMBER	5	MEAN	172.91	STD DEVIATION	0.41
WEDGE NUMBER	6	MEAN	203.40	STD DEVIATION	0.55
WEDGE NUMBER	7	MEAN	230.08	STD DEVIATION	0.70
WEDGE NUMBER	8	MEAN	254.54	STD DEVIATION	0.67
WEDGE NUMBER	9	MEAN	21.75	STD DEVIATION	1.08
WEDGE NUMBER	10	MEAN	98.46	STD DEVIATION	0.82
WEDGE NUMBER	11	MEAN	98.26	STD DEVIATION	0.69
WEDGE NUMBER	12	MEAN	100.89	STD DEVIATION	0.44
WEDGE NUMBER	13	MEAN	99.81	STD DEVIATION	0.91
WEDGE NUMBER	14	MEAN	137.74	STD DEVIATION	0.75
WEDGE NUMBER	15	MEAN	122.14	STD DEVIATION	0.55
WEDGE NUMBER	16	MEAN	143.21	STD DEVIATION	0.46