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(ISCCP)

DOCUMENTATION OF CLOUD DATA

MARCH 1991

INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT (ISCCP)

DOCUMENTATION OF CLOUD DATA

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TABLE OF CONTENTS

Page No.

GLOSSARY OF ACRONYMS v

1. INTRODUCTION 1

1.1. ISCCP Scientific Objectives 1
1.2. Data Processing Strategy 2
1.3. ISCCP Working Group on Data Management 2
1.4. Description of Data Used 4
1.5. Algorithm Design Concepts 4
1.6. Description of Stage C Data 6
1.7. Validation Plans 6
1.8. Summary of Changes 6

2. DISCUSSION OF CLOUD ANALYSIS 9

2.1. Overview 9
2.2. Determination of Clear Sky Radiances 11

2.2.1. Definition of surface types and use of correlative data 12
2.2.2. Radiance angle corrections 12
2.2.3. Tests and statistics 13

2.2.3.1. IR clear tests 13
2.2.3.2. VIS clear tests 14

2.2.4. Composite logic 14

2.2.4.1. IR clear sky logic 15
2.2.4.2. VIS clear sky logic 17

2.3. Cloud Detection 19

2.3.1. Clear radiances 19
2.3.2. Thresholds 20
2.3.3. Threshold classes 20
2.3.4. Interpretations 23

2.4. Radiative Transfer Model Analysis 25

2.4.1. Radiance model descriptions 27

2.4.1.1. IR model 28
2.4.1.2. VIS model 30

2.4.2. Clear sky retrievals 31

2.4.2.1. Surface temperature 31
2.4.2.2. Surface reflectance 32

Page No.

2.4.3. Cloudy sky retrieval 33

2.4.3.1. Cloud top temperature and pressure (opaque limit) 33
2.4.3.2. Cloud optical thickness 33
2.4.3.3. Cloud altitude adjustment 33

2.5. Statistics 36

2.5.1. Definition of parameters 37
2.5.2. Averages and standard deviations 38
2.5.3. Cloud type information 39

2.6. Merging Results From Several Satellites 41

2.6.1. Definition of satellite hierarchy 41
2.6.2. Global coverage 41
2.6.3. Comparison of overlapping results 41

3. DESCRIPTION OF DATA TAPE CONTENTS 43

3.1. Data Organization 43
3.2. Map Grids 44

3.2.1. Equal-area grid for data storage 45
3.2.2. Equal-angle grid for data output 46
3.2.3. Geographic information 47

3.3. Coding of Parameter Values 47

4. DATA TAPE FORMAT 49

4.1. Tape Characteristics 49

4.1.1. IBM tape structure 49
4.1.2. Tape number 49
4.1.3. Reading the tape 50

4.1.3.1. Read program 50
4.1.3.2. Decoding bytes 50
4.1.3.3. Data record structure 51

4.2. Volume ID File 51
4.3. Table of Contents File 52
4.4. Read Program File 52
4.5. Ancillary Data Files 54

4.5.1. Conversion tables 54
4.5.2. Map grid information 54

Page No.

4.6. Data Files 54

4.6.1. Record prefix 55
4.6.2. Parameter arrangement 55
4.6.3. Location of specific values 59

4.7. Sample Volume ID File 60
4.8. Sample Table of Contents File 66
4.9. Conversion Tables 66

5. REFERENCES 72

5.1. General 72
5.2. Project Documents 75
5.3. Other Useful References 76

GLOSSARY OF ACRONYMS

ACLR	–	Clear sky composite values of VIS radiance
AMIN	–	Minimum VIS radiance over a 5,15 or 30-day period
AES	–	Atmospheric Environment Service, Downsview, Ontario, Canada
AVHRR	–	Advanced Very High Resolution Radiometer (flown on NOAA polar orbiters)
B3	–	Stage B3 data (reduced resolution VIS and IR radiance image data)
C1	–	Stage C1 data (cloud analysis results at 250 km for each 3 hr)
C2	–	Stage C2 data (cloud analysis results at 250 km for each month)
CMS	–	Centre de Météorologie Spatiale, Lannion, France
CSU	–	Colorado State University, Ft. Collins, Colorado, USA
ESA	–	European Space Agency
FOV	–	Field of view of satellite instrument
FRG	–	Federal Republic of Germany
GAC	–	Global Area Coverage data from AVHRR (4 km resolution)
GISS	–	NASA Goddard Space Flight Center Institute for Space Studies, New York, New York, USA
GMS	–	Geostationary Meteorological Satellite operated by JMA
GOES	–	Geostationary Operational Environmental Satellite (operated by NOAA)
GPC	–	Global Processing Center of ISCCP located at GISS
HIRS/2	–	High Resolution Infrared Sounder (flown on NOAA polar orbiters)
IAMAP	–	International Association of Meteorology and Atmospheric Physics
ICA	–	ISCCP Central Archive located at NOAA/NESDIS
ICSU	–	International Council of Scientific Unions
IMD	–	India Meteorological Department, New Delhi, India
IR	–	Infrared radiance in the wavelength range 10-12 μm
ISCCP	–	International Satellite Cloud Climatology Project
JMA	–	Japan Meteorological Agency, Tokyo, Japan
JPS	–	Joint Planning Staff for the JSC
JSC	–	Joint Scientific Committee for the World Climate Program
MSU	–	Microwave Sounding Unit (flown on NOAA polar orbiters)
NASA	–	National Aeronautics and Space Administration, Washington, DC, USA
NCAR	–	National Center for Atmospheric Research, Boulder, Colorado, USA
NCPO	–	U.S. National Climate Program Office
NESDIS	–	National Environmental Satellite Data and Information Service (NOAA), Washington, DC, USA
NOAA	–	National Oceanic and Atmospheric Administration, Washington, DC, USA
PC	–	Retrieved value of cloud top pressure
RS	–	Retrieved value of surface reflectance
RSA	–	Republic of South Africa
SAPC	–	Special Area Processing Center of ISCCP
SCC	–	Satellite Calibration Center of ISCCP located at CMS
SPC	–	Sector Processing Center of ISCCP located at ESA, NOAA, AES, CSU, JMA
SSU	–	Stratospheric Sounding Unit (flown on NOAA polar orbiters)
TAU	–	Retrieved value of cloud optical thickness at VIS wavelengths
TAVG	–	Average "CLEAR" temperature (IR radiance) over 5,15 or 30-day period
TC	–	Retrieved value of cloud top temperature
TCLR	–	Clear sky composite value of IR radiance

TMAX	–	Maximum IR radiance over a 5, 15 or 30-day period
TOVS	–	TIROS Operational Vertical Sounder (System composed of HIRS/2, SSU, MSU, flown on NOAA polar orbiters)
TS	–	Retrieved value of surface (brightness) temperature
UWS	–	University of Wisconsin, Madison, Wisconsin, USA
VAS	–	VISSR Atmospheric Sounder (flown on GOES satellites)
VIS	–	Visible radiance in the wavelength range 0.5-0.7 μm
VISSR	–	Visible and Infrared Spin-Scan Radiometer (flown on GMS and GOES)
WCP	–	World Climate Program
WCRP	–	World Climate Research Program
WMO	–	World Meteorological Organization, Geneva, Switzerland

1. INTRODUCTION

1.1. ISCCP Scientific Objectives

The International Satellite Cloud Climatology Project (ISCCP) was established as the first project of the World Climate Research Program (WMO, 1984), to collect and analyze satellite radiance measurements to infer the global distribution of cloud radiative properties and their diurnal and seasonal variations (WMO-35, 1982; Schiffer and Rossow, 1983). These data and analysis products will be used to improve the understanding and modeling of the effects of clouds on climate. The primary focus is the elucidation of the role of clouds in the radiation balance (top of the atmosphere and surface); however, the analysis should also improve understanding of the global hydrological cycle. Specific scientific objectives are:

(i) To produce a global, reduced resolution, infrared and visible, calibrated and normalized radiance data set containing basic information on the radiative properties of the atmosphere from which cloud parameters can be derived.

(ii) To stimulate and coordinate basic research on techniques for inferring the physical properties of clouds from the condensed radiance data set and to apply the resulting algorithms to derive and validate a global cloud climatology for improving the parameterization of clouds in climate models.

(iii) To promote research using ISCCP data and contributing to improved understanding of the Earth's radiation budget (top of atmosphere and surface) and hydrological cycle.

This document describes the cloud climatology data product produced by ISCCP (Stage C), along with two correlative data sets (Atmospheric and Ice/Snow data). The description of the reduced volume radiance data set (Stage B3) is given in Rossow et al. (1987). All of these ISCCP data sets are produced by

ISCCP Global Processing Center
NASA Goddard Space Flight Center
Institute for Space Studies
2880 Broadway
New York, NY 10025
USA

and are available from

ISCCP Central Archive
Satellite Data Services Division
NOAA/NESDIS
World Weather Building, Rm 100
Washington, DC 20233
USA

1.2. Data Processing Strategy

The strategy adopted for implementing the ISCCP reflects the diverse nature of the spaceborne observing system and the large volume of imaging and other data produced. The primary data processing is done by eight institutions (Fig. 1.1): a Sector Processing Center (SPC) for each satellite (nominally at least one polar orbiter and five geostationary satellites), the Satellite Calibration Center (SCC), and the Global Processing Center (GPC). Another center coordinates the delivery of other satellite and conventional weather data (correlative data) to the GPC for use in the cloud analysis and an additional center acts as the ISCCP Central Archive (ICA) for all data produced by the project. Table 1.1 shows the institutional commitments as of January 1991.

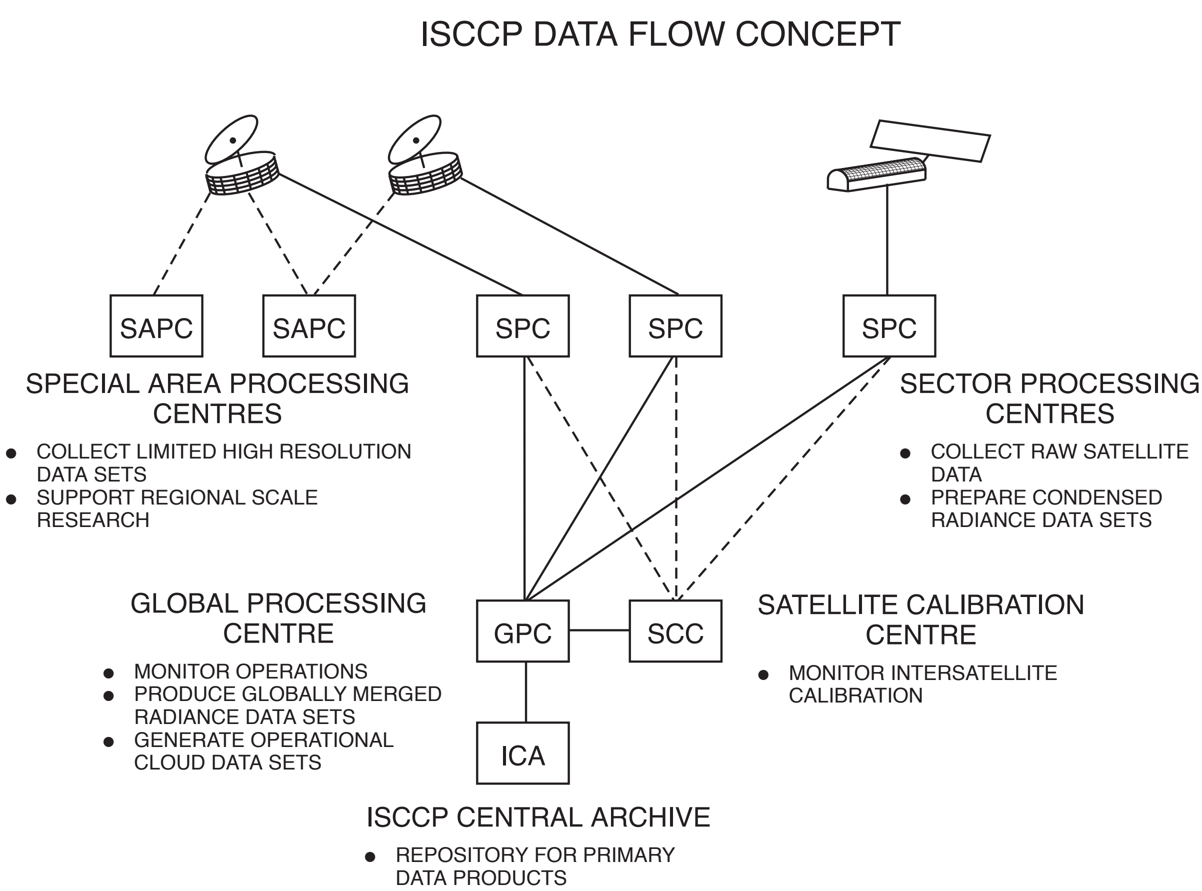

Figure 1.1. Schematic of ISCCP data processing.

1.3. ISCCP Working Group on Data Management

Representatives of the ISCCP Data Management Centers listed in Table 1.1 form the ISCCP Working Group on Data Management (WGDM) for the Joint Scientific Committee (JSC). Scientific guidance is provided to the project by the International Radiation Commission of IAMAP and by the JSC Working Group on Radiation Fluxes. Table 1.2 lists the WGDM membership as of January 1991.

Table 1.1. ISCCP Data Management Commitments

Type of Center	Primary Responsibility	Backup Responsibility
SPC for NOAA/TIROS-N	USA (NOAA/NESDIS)	+
SPC for METEOSAT	ESA	+
SPC for GOES-EAST	Canada (AES)*	USA (UWS)
SPC for GOES-WEST	USA (CSU)	USA (UWS)
SPC for GMS	Japan (JMA)	+
SPC for INSAT	India (IMD - tentative)	+
SCC	France (CMS)**	+
Correlative Data Center	USA (NOAA/NESDIS)	+
GPC	USA (NASA/GISS)	+
ICA	USA (NOAA/NESDIS)	+

\+ No commitment sought.
* USA (UWS) served as the SPC for GOES-EAST from 1 July 1983 to 31 July 1984.
** FRG (U. Koln) served as SCC for the Data Management Systems Test and assisted France (CMS) in the development of the radiance normalization technique.

Table 1.2. Membership of the ISCCP Working Group on Data Management

<u>Members from Data Management Centers</u>

F. Bowkett	Canada/AES	SPC GOES-EAST
G. Campbell	USA/CSU	SPC GOES-WEST
K. Kidwell	USA/NOAA/NESDIS	SPC NOAA, ICA
B. Mason	ESA	SPC METEOSAT
T. Nuomi	Japan/JMA	SPC GMS
W. Rossow	USA/GISS	GPC
Y. Desormeaux	France/CMS	SCC
D. Wylie	USA/UWS	SAPC GOES-EAST/WEST

<u>Members from JSC/CAS Working Group on Radiation Fluxes</u>

E. Raschke

<u>Ex-Officio Members</u>

R. Schiffer	Project Manager
S. Benedict	JPS for WCRP ICSU/WMO
R. Reeves	NOAA

<u>Previous Members</u>

N. Beriot	France/CMS	SCC
K. Black ICSU/RSA	SAPC METEOSAT	

H. Drahos	USA/NOAA/NESDIS	SPC NOAA, ICA
R. Fox USA/UWS	SPC GOES-EAST	
J. Gibson	USA/NOAA/NESDIS	SPC NOAA, ICA
S. Kadowaki	Japan/JMA	SPC GMS
T. Kaneshige	JPS for WCRP ICSU/WMO	
H. Jacobowitz	ISCCP Office NOAA	
I. Kubota	Japan/JMA	SPC GMS
A. Kurosaki	Japan/JMA	SPC GMS
S. Lapczak	Canada/AES	SPC GOES-EAST
M. Mignono	USA/NOAA/NESDIS	SPC NOAA, ICA
C. Norton	USA/UWS	SPC GOES-EAST
R. Saunders	ESA	SPC METEOSAT
T. Vonder Haar	IAMAP Radiation Commission	
S. Woronko	Canada/AES	SPC GOES-EAST

1.4. Description of Data Used

The primary data sets used to infer the cloud properties are the Stage B3, reduced resolution narrowband radiance (0.6 and 11 μm) measurements made by the imaging radiometers on operational weather satellites (Schiffer and Rossow, 1985; Rossow *et al.*, 1987). These data have a nominal spatial resolution of 30 km and temporal resolution of 3 hours produced by sampling the full resolution imaging data. Global coverage is provided by five geostationary satellites (METEOSAT, INSAT, GMS, GOES-EAST and GOES-WEST) and at least one polar orbiting NOAA satellite; however, no INSAT data have been obtained. The absolute radiometric calibration of all B3 radiances have been normalized to that of the AVHRR on NOAA-7 in July 1983. **Subsequent comparisons to aircraft data led to a revision of the VIS radiance calibration, accomplished by multiplying all values by a factor of 1.2.** This corrected calibration is used to produce the cloud products. No change was made in the IR absolute calibration.

In the analysis of these radiance data, two correlative data sets are utilized: from the TOVS operational system on the NOAA polar orbiting satellites and from the joint US NAVY/NOAA operational analyses of several satellite and surface measurements. The former provides daily, global atmospheric temperature and humidity profiles, plus ozone column abundances, while the latter provides weekly snow and sea ice coverage. These correlative data sets are described in Appendices A and B.

Additional correlative data sets are: (1) land/water/coast map at 10 minutes of latitude/longitude resolution (derived from Masaki, 1972), (2) topographic altitude at 10 minutes of latitude/longitude (NCAR), and (3) vegetation type and land-use classification at 1 degree resolution (Matthews, 1983).

1.5. Algorithm Design Concepts

The ISCCP cloud analysis has three fundamental parts: cloud detection, radiative transfer model analysis, and statistical analysis. The first part determines whether a particular radiance measurement is associated with cloudy or clear conditions. The second part compares the measured radiances, together with other correlative information about the atmosphere and surface, to a radiative model to retrieve several cloud (and surface) parameters. The third part accumulates spatial distribution information about the radiances and retrieved cloud and surface parameters to summarize the analysis, every 3 hours in C1 data and once per month in C2 data.

The cloud detection algorithm for ISCCP was developed from a three year pilot study that compared the performance of nine different algorithms applied to the same data (Rossow *et al.*, 1985). These tests showed that all methods can detect a majority of cloudiness on Earth because the spatial and temporal radiance changes produced by most clouds in both the visible and infrared bands are large compared to the total range of radiances observed. Indeed, the 0.6 and 11 μm bands were selected for weather satellite observations because the atmosphere is more nearly transparent and the contrast between the surface and clouds is generally high. However, these methods disagreed most in partially cloudy situations, where there are many radiance values that are only slightly different from those representing clear conditions, in locations where the surface is unusually cold or bright (e.g., winter land areas), which reduces the contrast with clouds, or for certain cloud types that do not cause very large changes in the observed radiances (cirrus in the visible or marine boundary layer clouds in the infrared). No one algorithm worked equally well for all cloud-surface conditions; thus, the ISCCP algorithm is composed of a series of tests, including some form of all of those tested in the pilot study, to provide the best chance of detecting clouds with similar reliability over the whole globe.

The pilot study also provided a practical way to define the accuracy of satellite cloud detections by focusing attention on the accuracy of the clear radiances, which are determined primarily by the properties of the Earth's surface. Since we have much more data and information about the surface of the Earth and about the large scale atmospheric properties than about the clouds and since our ability to model radiative transfer in the clear atmosphere is much better than that in cloudy conditions, the accuracy of the clear radiances can be validated more readily than that of cloudy radiances. Hence, the uncertainty of identifying clear conditions in the analysis of satellite measurements becomes the "noise" in the determination; the signal is the radiance difference caused by the presence of cloudiness. The practical limit on cloud detection is whether the signal exceeds the noise, i.e., whether the radiance difference with clear conditions caused by clouds is larger than the uncertainty in determining the radiance values associated with clear conditions. Verification of the accuracy of the clear radiances then provides a quantitative assessment of the detection accuracy of the analysis.

The subsequent development work on the ISCCP cloud detection algorithm focused on two issues: (1) how to combine the results from several different tests in a consistent and reliable way and (2) how to reduce uncertainties to improve detection of the "marginal" cloud types. Addressing both issues led to the use of a threshold decision process for cloud detection. Initially, the results of the multiple tests are used to identify clear, rather than cloudy, radiances, which allows the decisions to be combined by a simple, strict interpretation: all tests must agree on the identification. While this reduces the number of clear radiance values obtained early in the processing, it also increases the reliability of the identification under varying circumstances. Once clear radiances are determined, the cloud/clear distinction is made by a simple threshold decision: if the measured radiance is different enough from the clear values in either spectral channel, cloud is present. This concentrates the combined results at one point in the analysis and allows for simple control of the sensitivity of the detection by setting the magnitude of the thresholds. The accuracy of the cloud detection is also straightforwardly defined by assessing the accuracy of the clear radiances, which are determined primarily by the properties of the Earth's surface.

The key improvement in the algorithm that reduced the uncertainty in the clear radiances is the use of tests to detect *time* variations in radiances at each location. Although some early algorithms had used a simple form of this idea, by finding the extremum radiance for each location, the ISCCP algorithm extends this concept to tests of temporal contrast on several time scales, ranging from the image's immediate neighbors in time ("yesterday's" image, "tomorrow's" image) to groupings of five and fifteen successive images up to monthly composites. The goal is to capture the natural variability of cloudy and clear radiances under various circumstances.

Once the radiance data are divided into clear and cloudy populations, quantitative interpretation to infer specific properties of clouds requires a radiative model of the effects of clouds, as well as the atmosphere and surface, on the satellite radiances. To describe the variations of measurements in two spectral channels from pixel to pixel and time to time, we use the frequency of occurrence of clouds (number of cloudy image pixels) and their optical thickness and temperature (or vertical position in the atmosphere), and for the surface, the reflectance and temperature.

1.6. Description of Stage C Data

The cloud analysis products of ISCCP, called Stage C1 and C2 data, are constructed from the combination of the original B3 radiances, the results of the three parts of the cloud algorithm, and the correlative data used in the analysis. Stage C1 data represent the global, merged results reported every 3 hr with a spatial resolution of 250 km (nominal). These results provide a complete column description of the atmospheric temperature structure and composition and the cloud and surface properties present at each location. The Stage C2 data are the monthly averages and summary statistics of the Stage C1 quantities. The following sections describe the analysis steps, data contents, and data tape format of the Stage C1 data set; the contents and format of Stage C2 data are described in Appendix 6.3.

1.7. Validation Plans

Limitations of the satellite radiance measurements and other information, together with the experimental nature of the cloud analysis algorithm, make a research program a crucial component of the ISCCP. This research program will provide validation of the ISCCP cloud climatology and develop improved methods for remote sensing of clouds by comparisons of the ISCCP analysis products with other cloud observations. Validation of the ISCCP cloud climatology will address, not only the quantitative assessment of measurement errors, but also the refinement of the interpretation of the results in terms of atmosphere and cloud processes. This research will also lead to improved radiative models of cloudy atmospheres. In particular, a number of intensive field experiments are planned by various nations to collect special data sets for these purposes. Since deciding the most meaningful cloud statistics for climate studies beforehand is not possible, but is an expected outcome of the analysis of the ISCCP global and associated field experiment results, less statistics and more detail had to be retained in the C1 data to allow for the development and validation of these results. However, the C2 data derived from the C1 data provide a more compact summary of the cloud results containing the statistics thought to be most important at this time.

1.8. Summary of Changes

Several changes have been made to the ISCCP datasets since the first versions were issued; most of these are minor, but some are very important. All significant changes are summarized here.

a. Stage B3 VIS radiances are calibrated with respect to AVHRR Channel 1 on the NOAA-7 satellite in July 1983; however, subsequent aircraft calibration flights showed that this standard needs to be changed. This can be accomplished for all VIS radiances by multiplying by a factor of 1.2 before analysis.

b. An early test version of the ISCCP Stage C1 data for July 1983 was released to over 60 researchers in May 1987. The tape numbers are GPC946 and GPC948. These results were based on a different version of the cloud detection algorithm, used somewhat different optical parameters in the radiative analysis, and reported different statistics than in the final version of the Stage C1 data. The format of these tapes is entirely different from that of Stage C1 data. These data should no longer be used.

c. The first two months of the standard version of Stage C1 data that were produced were July 1983 and January 1984; these data were created in September 1987 with tape numbers

July 1983:	GPC.C1.0001.0.83182.83197.ISCCP
	GPC.C1.0002.0.83197.83212.ISCCP
January 1984:	GPC.C1.0003.0.84001.84016.ISCCP
	GPC.C1.0004.0.84017.84031.ISCCP.

Further testing of the cloud algorithm revealed some difficulties with slow surface temperature variations during one month. Other small errors in numerical coefficients were also discovered. The July 1983 and January 1984 data were re-done with the modified algorithm and new data tapes issued in July 1988 with identical tape numbers and version numbers = 1 (the version number is the single digit following the sequence number).

d. Beginning in October 1988, Stage C1 data were then produced for the period July 1983 through April 1984 and for April 1985. An additional problem with GOES-WEST data for January 1984 required the replacement of the C1 data; new tapes have the same numbers with version number = 2. It was discovered that the effect of sea ice on surface reflectance was not properly included in the analysis, causing spurious detections of clouds over sea ice, but only when solar illumination was present. All of the Stage C1 data were replaced in April 1989 to correct this error. A similar difficulty occurred when processing the Stage C1 data for January 1987; these data were replaced in December 1990. Thus, the final versions of Stage C1 data that should be used have the following version numbers:

July 1983:	Version number = 2
January 1984:	Version number = 3
August 1983 - April 1984:	Version number = 1
April 1985:	Version number = 1
January 1987:	Version number = 1
May 1984 - June 1987:	Version number = 0

e. A small error in the water vapor absorption coefficients used in the IR radiance model was discovered and corrected. This affects all Stage C1 results prior to August 1985. The effect is to overestimate cloud top temperatures by < 0.2 K and surface temperatures by < 0.5 K.

f. An error in processing of TOVS data, which caused a mis-reading of the topography dataset, produces a few instances when the atmospheric temperature profiles are inconsistent with the reported surface pressure. This problem was corrected in the Stage C1 data when it was replaced in April 1989. This error was corrected in a new version of the TOVS correlative datasets (version numbers = 1); final versions of TOVS data have the following tape numbers:

GPC.TV.0001.1.83182.83365.ISCCP
GPC.TV.0002.1.84001.84366.ISCCP
GPC.TV.0003.1.85001.85365.ISCCP
GPC.TV.0004.1.86001.86365.ISCCP
GPC.TV.0005.1.87001.87365.ISCCP
GPC.TV.0006.1.88001.88366.ISCCP
GPC.TV.0007.0.89001.89365.ISCCP
GPC.TV.0008.0.90001.90365.ISCCP

g. The first version of the sea ice/snow dataset (data for 1983 - 1987, version number = 0) did not report any condition for Antarctica; however, the cloud analysis assumed that Greenland and Antarctica are always covered by land ice, which is treated the same as snow cover. A new version (data for 1983 - 1987, version number = 1) of the sea ice/snow correlative datasets was created in October 1989 to add permanent snow cover over Antarctica (Greenland was already reported as permanently snow covered). This change had no affect on Stage C1 data. Beginning with 1987 data, the US Navy/NOAA sea ice dataset was changed to report Arctic results in two sectors, east and west, with different date ranges. This change required alteration of the Volume Table of Contents and the data file header records (Bytes 9 - 14 in the data record prefix) to report the extra date range. Since this extra information used previously blank space in the records, the change does not actually alter the data format. The data tape for 1986 -1987 (GPC.IS.0002.1.86003.88003.ISCCP) is a mixture of old and new. Final versions of these data have the following tape numbers:

GPC.IS.0001.1.83184.85363.ISCCP
GPC.IS.0002.1.86003.88003.ISCCP
GPC.IS.0003.0.88003.88363.ISCCP
GPC.IS.0004.0.89002.89362.ISCCP

h. Stage C2 datasets (version number = 0) were delivered for the period July 1983 through 1985. A small error was discovered in the corrections of some variables for undersampling of the diurnal variations and corrected; the new version (version number = 1) of Stage C2 data was produced in October 1990. Stage C2 data for 1986 (version number = 0) were also delivered.

i. The initial definition of parameter 20, PATH, in Stage C2 datasets was misleading; in fact, this parameter was called ALBEDO, which suggested a radiative significance that was not intended. A new version of Stage C2 data was created in January 1991 to change the documentation of this quantity and to alter its treatment in the C2 READ program (for 1983 - 1985, version number = 2 and for 1986, version number = 1). An ERRATUM document that describes the change and how to alter usage of older versions of Stage C2 data is also available. Final versions of Stage C2 data have the following tape numbers:

GPC.C2.0001.2.83182.83365.ISCCP
GPC.C2.0002.2.84001.84366.ISCCP
GPC.C2.0003.2.85001.85365.ISCCP
GPC.C2.0004.1.86001.86365.ISCCP
GPC.C2.0005.0.87001.87365.ISCCP

2. DISCUSSION OF CLOUD ANALYSIS

2.1. Overview

The overall structure of the ISCCP cloud analysis is shown schematically in Fig. 2.1. This analysis procedure is applied separately to the data from each satellite at each of eight time periods in a day.

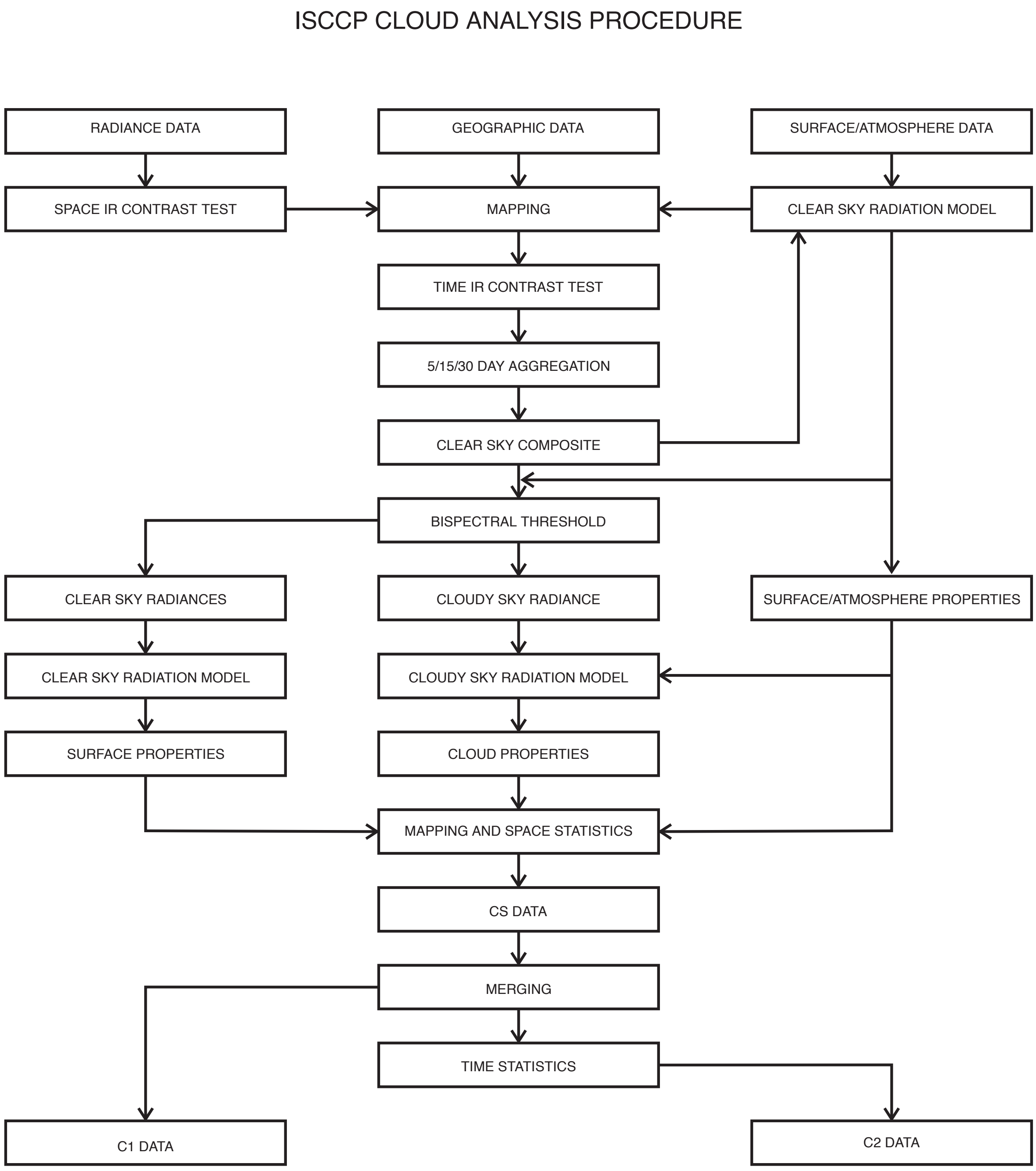

Figure 2.1. Schematic of ISCCP cloud analysis.

The cloud detection step analyzes the radiance data twice: first to determine an estimate for the radiance values that represent clear conditions at each place and time and second to determine which radiance measurements deviate from these clear sky values by an amount greater than the uncertainty in the estimated clear radiances (threshold step). Cloudy conditions are defined by those radiances that are sufficiently different from the clear values in either spectral channel.

To determine clear sky radiance values, the radiance data are searched over several different spatial and temporal domains; tests of pixel-to-pixel radiance contrasts and time variations for each pixel are intercompared and used to eliminate radiance values that may be cloud "contaminated." These tests are conservative in that any "hint" of contamination is used to discard values, meaning that some actual clear values may also be discarded to insure the accuracy of the resulting clear sky radiance values. This approach presumes the relatively low variability of clear radiances. Spatial scales considered range from 25 km up to an entire latitude zone and are different for land and ocean areas. Time scales examined range from one day up to one month. A unique aspect of the time comparisons is that data are arranged in daily sequences for each GMT, separately; results are obtained for each GMT independently to avoid the generally larger diurnal variations of the surface and of the solar illumination. The final clear sky composite represents an estimate of the clear radiances at a spatial resolution of 75 km (IR) or 25 km (VIS) and a time resolution of five days (IR) or 30 days (VIS) at each time of day.

The radiation analysis first retrieves the properties of the surface from the clear sky radiances and the atmospheric data for each pixel (ranging from 4 to 8 km in size). These surface properties are then used, along with the same atmospheric properties, to analyze individual pixel radiances. Surface properties are retrieved from individual pixel radiances labeled CLEAR by the threshold step, whereas cloud properties are retrieved from pixel radiances labeled CLOUD. When both VIS and IR data are available (daytime), the IR retrieval is modified to include the effects of variable cloud optical thickness on the radiances; when only IR data are available (nighttime), all clouds are assumed to be completely opaque to IR radiation.

To avoid spurious diurnal variations of cloudiness caused by changes in methodology associated with the presence or absence of VIS data, the results of two separate analyses are reported during the daytime: one dependent on both VIS and IR information and one dependent only on IR information. Clear sky IR radiances are determined independently of clear sky VIS radiances and threshold decisions are recorded separately. Daytime is defined by solar zenith angles $\leq 78.5°$.

The original satellite radiance data represent measurements over fields of view (FOV) ranging from 4 to 8 km in size; however, the ISCCP B3 data are sampled to a spacing of about 25-30 km. Although navigation accuracy may be higher for some satellites, overall accuracy is confirmed to be about ± 25 km. The analysis to determine clear radiances works with these data mapped to 25 km resolution; hence, we consider the smaller individual image pixels to represent a sample of the distribution of surface (and cloud) conditions over this spatial scale. Although the variability of surfaces and clouds is generally smaller at such small scales than at scales $\gtrsim$ 100 km (Sèze and Rossow, 1991), all pixel-level quantities are treated as having a certain amount of intrinsic variation about an average value representing a spatial resolution of 25 km. The clear sky analysis procedure *estimates* the clear radiances for every 25 km scene every three hours; however, the actual space/time resolution attained is 75 km (IR) or 25 km (VIS) and 5-days (IR) or 30-days (VIS). If cloudiness is frequent, the actual time resolution for IR clear radiances may be reduced to 15 or 30 days. Diurnal variations are resolved, however, by conducting the analysis separately at eight diurnal phases. When considering the validity of the radiative analysis, especially the assumption of horizontal homogeneity, the relevant spatial scale for cloudy scenes (assuming little actual variation of the surface at 25 km) is that of the original satellite FOV. However, the results are obtained (sampled) at 25 km resolution and summarized in C1 data at a spatial resolution of 250 km (nominal) for C1 data and time resolution of three hours. Time resolution is one month for C2 data.

2.2. Determination of Clear Sky Radiances

Clear radiance values are needed for every scene (this word will be used to refer to each cell of the 25 km gridded data) at each time (each day for each 3 hour period, separately). Since clouds obscure the view of the surface at some times and do so more or less frequently in different climate regimes, the object of the analysis is to infer the "missing" values from the observed values. To first order the accuracy of this procedure is dependent on the frequency of cloudiness at each location.

Three basic premises are used to identify clear scenes from an examination of the spatial and temporal variations of radiances. First, clear scenes are assumed to exhibit less spatial and/or temporal variability than cloudy scenes, as suggested by many studies (Coakley and Bretherton, 1982; Minnis and Harrison, 1984; Rossow *et al.*, 1985; Sèze and Desbois, 1987; Gutman *et al.*, 1987; Rossow *et al.*, 1989b; Sèze and Rossow, 1991a; Sèze and Rossow, 1991b). Based on our studies, we have concluded that the time variability is a much more reliable indicator of cloudiness than the space variability. Second, clear scenes are assumed to be warmer and/or darker than cloudy scenes (Arking, 1964; Reynolds and Vonder Haar, 1977; Koffler *et al.*, 1976; Coakley and Baldwin, 1984; Desbois and Sèze, 1982; Simmer *et al.*, 1982; Saunders, 1986). This premise may not always hold for low-level, thin stratus clouds in temperature inversions over polar ice (cf., Raschke *et al.*, 1986). Third, we assume that no single test is reliable under all conditions for all cloud types (Rossow *et al.*, 1985; Coakley and Baldwin, 1984; Saunders, 1986; Rossow *et al.*, 1989b; Sèze and Rossow, 1991a). This also implies that, even if a test usually works, there will be circumstances where it will not and some alternative approach or estimate must be available.

The clear sky radiances are obtained as the result of two tests and the accumulation of three kinds of statistics over two spatial domains and three time periods. The success of the tests for variability and the intercomparisons of statistics was significantly improved by allowing for the differences in these statistics in different climate regimes. In particular, different cloud and surface types exhibit different amounts of spatial and temporal variability; so, although the same tests are conducted at all locations, the decision parameters vary with location to give preference to one type of test over another depending on local characteristics.

2.2.1. Definition of surface types and use of correlative data

Several correlative data sets are used to determine the different surface types: (1) land/water/coast, (2) topography, (3) land vegetation type, and (4) sea ice/snow cover. The first data set identifies the surface at each scene (with known latitude and longitude) as water, land or coast; scenes actually on the coast are dropped. Proximity (within 200 km) to a coastline is also indicated. The second data set indicates both mean height and a measure of topographic "roughness" on a regional scale (~400 km resolution). The third data set classifies land areas by type of vegetative cover.

The IR clear sky logic uses different criteria for four different surface types, in order of increasing variability: Type 1 is low variability water, Type 2 is high variability water, Type 3 is low variability land, and Type 4 is high variability land. All water is Type 1 except near-coastal water, defined to be within 200 km of land, is defined to be Type 2. Scenes covered by sea ice or within 100 km of sea ice are also classified Type 2. All land is Type 3, except high (height > 2500 m) or rough topography regions, high topography scenes (height > 1750 m), and permanently-ice-covered land locations (Iceland, Greenland and Antarctica).

For determining the clear VIS radiances, the surface is classified as water or as one of eight land surface types by the density of vegetation cover: tropical rainforest, deciduous forest, woodland, shrubland, grassland, tundra, desert, and ice-covered land. Sea ice and snow-covered land are treated as additional types.

2.2.2. Radiance angle corrections

To compare radiances observed at different times, approximate corrections must be made to eliminate radiance variations caused by the larger changes in satellite viewing geometry or solar illumination geometry. Since the time comparisons are performed independently for each 3-hr interval of the day (i.e., constant diurnal phase), solar geometry is approximately constant for all comparisons within one month; however, variations of actual image time of up to 1.5 hours about the nominal time can occur. The viewing geometry is also constant for each location in images from geostationary satellites. Thus, the angle corrections, though performed for geostationary data, are nearly reversible and have little effect on their analysis. The polar orbiters, though nominally sun-synchronous, actually observe each location with varying viewing and solar illumination geometries, though the range of angles at each location is limited. The geometry variations of the radiances are removed after spatial contrast tests are performed, but before temporal contrast tests are conducted.

For the IR, the radiances (brightness temperatures) are corrected to a nadir view using (μ is the cosine of the satellite zenith angle):

$$T(1) = T(\mu) + C_0(\mu) + C_1(\mu)\,[\,T(\mu) - 250\,]$$

$$C_0(\mu) = -\,(1.93 + 2.52\mu)\,(1/\mu - \mu)\,/\,4.8$$

$$C_1(\mu) = (0.267 + 0.053\mu)\,(1/\mu - \mu)\,/\,4.8$$

where the coefficients used were derived from radiative calculations using global TOVS temperatures and humidities for all seasons. The second factor in the coefficients is the function used to interpolate between two brightness temperature values in the cloud analysis; the extra factors involving μ arise because the correction procedure must approximate the dependence on T(1) or the surface temperature by using the observed brightness temperature, $T(\mu)$. The radiative model is the same one used in the analysis of the satellite IR radiances (see Section 2.4.1.1). Small variations of the coefficients with latitude and season do occur; but the formula above fits all the data to within one standard deviation, about 1-2 K for the most extreme geometries in the tropics. Since the polar orbiter data are limited to $\mu > 0.45$, the errors in using the same formula for all latitudes and seasons are actually $\leq$ 1 K.

For the VIS, the radiances are corrected to nadir sun using (μ_0 is the cosine of the solar zenith angle):

$$A(\mu_0) = \mu_0 \, A(1)$$

where μ_0 is the value for the actual image pixel time and location. This correction neglects the weak anisotropy of land surface reflectances and the μ-dependence of Rayleigh scattering and ozone absorption, which partially offset each other. However, tests of the errors introduced by neglecting these effects show that they are $\leq$ 1-2% (absolute) for the range of geometries encountered by the polar orbiter at any one location. Only the very dark oceans are effected noticeably by this approach; however, we compare the resulting clear VIS radiances to an ocean reflectance model to eliminate cloud contamination, so that this effect is also removed. The corrected values are reflectances.

2.2.3. Tests and statistics

2.2.3.1. *IR clear tests*

The first step tests the spatial variability of the IR radiances within small regions (about 100 km on land and 300 km over ocean). This test is performed in the original satellite image coordinates for convenience. All pixels determined to be colder (by 3.5 K over ocean and 6.5 K over land) than the warmest pixel are labeled CLOUDY; all others (including the warmest) are labeled UNDECIDED.

The radiance images are then corrected for viewing geometry effects and mapped onto a constant grid with a resolution approximating the nadir resolution of the original images (25 km). The second step then tests the time variability of the IR radiances over three days at the same GMT. All scenes determined to be colder (by 3.5 K over ocean and 8.0 K over land) than the values at the same location on the previous or following day are labeled CLOUDY; all scenes found to have a similar temperature (to within 1.1 K over ocean and 2.5 K over land) as they have on the previous or following day are labeled CLEAR. (Performing the comparison at the same local time each day avoids the larger diurnal variations of land surface temperatures.) The remaining scenes with intermediate variability are labeled UNDECIDED. On some occasions, the test result for one direction in time will conflict with the result in the other direction; if the conflict is strong (i.e., both CLOUDY and CLEAR are determined), these cases are labeled MIXED. The UNDECIDED result is not considered a strong conflict.

The final classification of the IR radiance for each scene is determined by the following logic:

		SPACE TEST: CLOUDY	SPACE TEST: UNDECIDED
TIME TEST	CLOUDY	CLOUDY	CLOUDY
	UNDECIDED	CLOUDY	UNDECIDED
	MIXED	MIXED	MIXED
	CLEAR	MIXED	CLEAR

The IR clear sky composite logic (see below) makes use of a comparison of several statistics calculated for every scene for individual 5-day, 15-day and 30-day periods:

(i) the number of CLEAR observations, NCLEAR, in a spatial domain, centered on each scene and including its nearest neighbors (a region about 75 km in size),

(ii) the average IR brightness temperature, TAVG, for all CLEAR observations in this domain, and

(iii) the maximum IR brightness temperature, TMAX, for all observations in this domain.

These three statistics are collected for a short-term period (NCLEAR-ST, TAVG-ST and TMAX-ST) and for a long-term period (NCLEAR-LT, TAVG-LT, and TMAX-LT). For surface Type 1, short-term is taken to be 15 days and long-term is 30 days; for surface Types 2,3, and 4, short-term is 5 days and long-term is 15 days. (If the total number of observations available is less than 3, out of 45 per 5 days, for a particular location, then no analysis is performed for that location.) In addition, the mode of the differences between the 15-day values of TMAX in each 10° latitude zone is used to calculate a trend correction for each latitude zone; this correction is used to estimate a clear sky IR radiance for each 5-day period from the long-term values, whenever needed, by assuming a linear variation over the month.

2.2.3.2. *VIS clear tests*

For each daytime scene the value of AMIN is calculated from all the VIS radiances for each 5-day period (AMIN-ST) and for a 30-day period (AMIN-LT); Amin is calculated for 5-day and 15-day periods poleward of 55° latitude. Daytime conditions are defined by values of $\mu_0 \geq 0.2$. If any nighttime data are found in the record within the 30-day (or 15-day) period for a particular scene, no AMIN value is reported and the condition of that scene is changed to "nighttime" for all days within the month.

2.2.4. Composite logic

The intercomparison of all the scene statistics determines the estimate

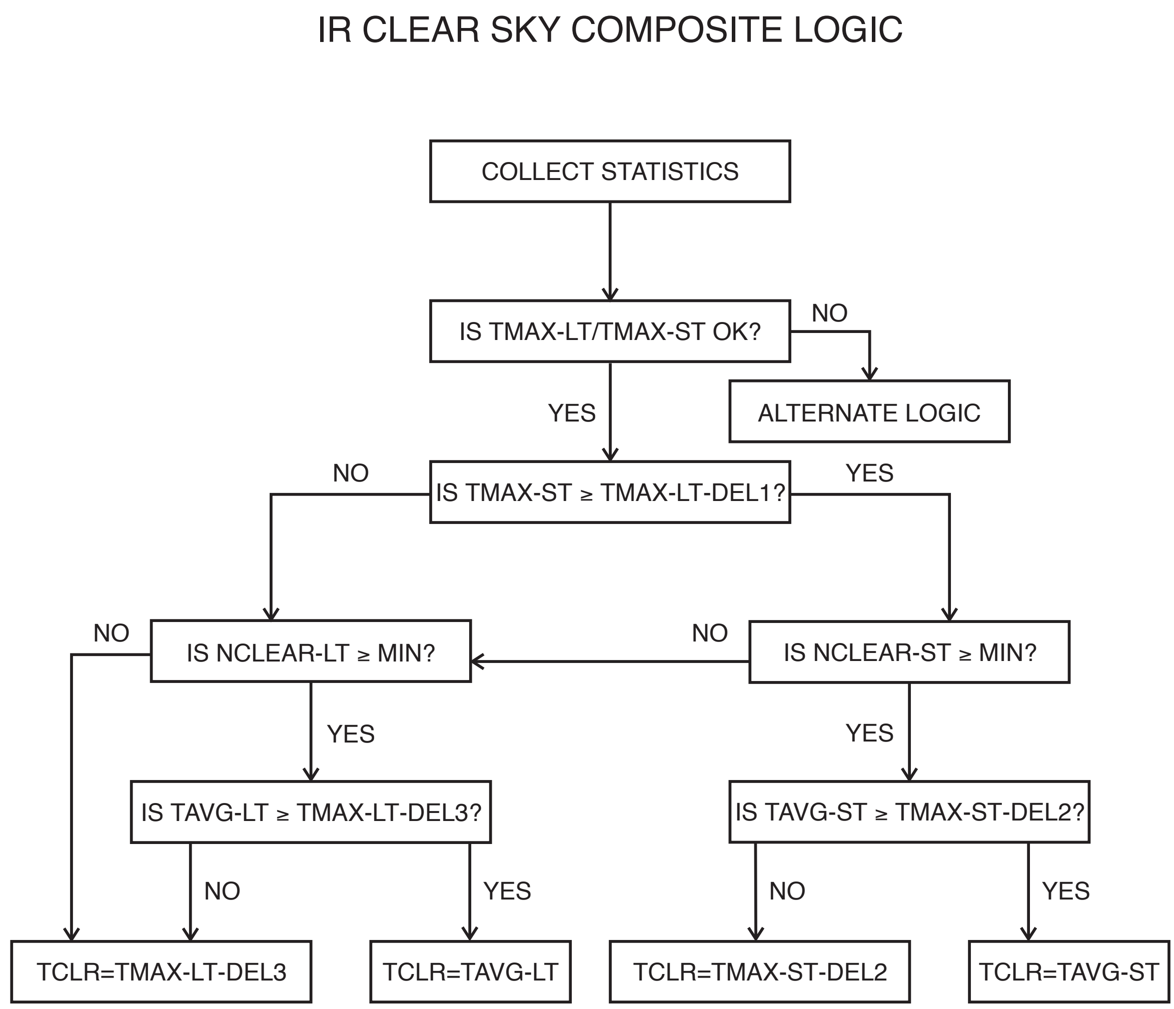

Figure 2.2. Infrared clear sky radiance processing logic.

of the clear radiances for each scene every five days, separately at each diurnal phase. These radiance values are called the clear sky composite; the comparison logic is illustrated in Figs. 2.2 and 2.3.

2.2.4.1. *IR clear sky logic*

The IR clear sky composite logic assumes that the intrinsic, relatively small variations of surface temperature (at constant diurnal phase) and their (almost global) tendancy to be larger than cloud temperatures produce a characteristic shape of the warmer part of the IR radiance distribution (Seze and Rossow, 1991a). This shape appears to be predictable, varying in association with the surface type. The composite logic tests the shape of the IR radiance distribution using the differences between TMAX-LT and TMAX-ST and between TMAX and TAVG (either short- or long-term). If the differences exceed their specified magnitudes, this is interpreted to indicate cloud contamination of one or more of these quantities. An additional use of this "shape assumption" is to reduce TMAX values, whenever they are used for the clear radiance, to approximate the TAVG values, using the assumed maximum difference between TMAX and TAVG.

Five situations may occur.

(i) The scene is partially cloudy but the cloudy-clear contrast is very low and/or the cloudiness is complete and constant with cloudy radiances that exhibit little space *and* time variability.

(ii) The scene is mostly cloudy and the cloudy-clear contrast is relatively small, but still larger than that of the surface, or the cloud persistence and extent are large but not total.

(iii) The scene is mostly cloudy but the cloudy radiances exhibit relatively large variability in space and/or time.

(iv) The scene is partly cloudy (spatially) or almost totally cloudy occasionally and the cloudy-clear contrast is relatively large.

(v) The scene is relatively clear.

The first and last case resemble each other in that the magnitude of the cloudy radiance variability in case 1 is similar to that in case 5 or the cloud cover is complete for 30 days with little variation in cloudy radiances. If this resemblance is strong enough, there is no way to detect such clouds using satellite data alone. Two schemes have been tried with little success: regional intercomparisons on spatial scales large enough to detect the presence of the clouds and use of conventional surface temperature observations to determine the clear IR radiances. Neither of these schemes was found to be accurate enough to detect the most difficult examples of such clouds (see discussion in next section).

In case 2, either the radiance variations caused by cloudiness are relatively small or almost no observation represents completely clear conditions. This is indicated by the fact that TMAX-LT is warmer than TMAX-ST (by more than DEL1) and TAVG-LT by more than expected (by more than DEL3), in which case the estimate of clear radiance is TCLR = TMAX-LT - DEL3. The value of TMAX-LT used has been corrected for any zonal mean trend. The larger variability of land surface temperatures makes this test much less effective than it is over oceans, however.

In case 3, in contrast to case 2, the cloudy radiance variability is large enough that the space/time tests detect the clouds. That the scene is mostly cloudy is indicated by a very low number of CLEAR values. If this condition persists for most of the 30-day period (NCLEAR-LT < 10%), then the estimate of TCLR = TMAX-LT - DEL3, where TMAX-LT is for 30-days, even for surface Types 2,3, and 4. If the condition only occurs on the short-term (NCLEAR < 10%), then the estimate of TCLR = TAVG-LT. In both case 2 or 3 (when the long-term information is used for TCLR), the consistency of the result is maintained by insuring that the value of TCLR obtained is ≥ TMAX-ST - DEL2.

In case 4, while there are enough CLEAR values available on the short-term, there is still enough cloud contamination that TMAX-ST is warmer than TAVG-ST by more than expected (by more than DEL2), in which case TCLR = TMAX-ST - DEL2.

In case 5, the CLEAR values provide an accurate measure of the clear radiances; the best estimate for the whole 5-day period is TCLR = TAVG-ST.

The difference values (DEL1, DEL2, DEL3 and DEL4) in Kelvins, used for these tests, are listed below for the four surface types.

Surface Type	DEL1	DEL2	DEL3	DEL4
1	2.0	2.0	2.5	4.0
2	3.0	3.0	4.0	6.0
3	6.0	5.0	8.0	8.0
4	9.0	7.0	11.0	10.0

The composite logic employs one additional procedure. Since the tests rely on the relationships with maxima of the data distribution, some protection is required to prevent false results because of a few spurious data values that represent very large temperatures. This procedure compares the value of TMAX-LT for each scene against the regional distribution of values: if the particular value is much warmer (by more than DEL4) than most of the other values in the region *and* also much warmer than TAVG-LT, then this value is replaced using the regional distribution. If a value of TMAX-LT is determined to be too large, any value of TMAX-ST that is too close to TMAX-LT is also avoided.

A final spatial filter is applied to regions about 250 km in size, which are more than half covered by surface types 1 and 3, to smooth out the effects of radiometer noise and residual cloud contamination. If any region is found to have a range, MAX-TCLR - MIN-TCLR > DEL2 (excluding any scenes classified as surface types 2 and 4), then the values < (MAX-TCLR - MIN-TCLR)/2 are replaced by (MAX-TCLR - MIN-TCLR)/2.

2.2.4.2. *VIS clear sky logic*

The VIS clear sky composite logic (Fig. 2.3) assumes that the small intrinsic variations of surface reflectance (at approximately constant viewing and illumination geometry) and their almost global tendancy to be smaller than cloud reflectances produce a characteristic shape of the darker part of the VIS radiance distribution (Sèze and Rossow, 1991a). Time variations for surface reflectances for most surface types are generally much smaller than the spatial variations (Sèze and Rossow, 1991a,b; Rossow *et al.*, 1989a,b); however, the spatial variations are also small at 0.6 μm for densely vegetated locations (Matthews and Rossow, 1987). The relatively simpler time/space behavior of surface reflectances allows use of a simple statistic: the minimum VIS radiance over a sufficiently long time period to insure that clear conditions occur. However, this approach, which has been used in many other methods, does bias the actual clear radiance value (Matthews and Rossow, 1987; Rossow *et al.*, 1989a), so the same shape assumption is used to increase the minimum value by an amount representing the typical separation of the minimum and the mean value.

The surface is classified into five types: (i) variable water, (ii) rapidly (time) varying land, (iii) temporally constant, spatially heterogeneous land, (iv) constant water, and (v) spatially/temporally constant land.

(i, ii) Variable water and rapidly varying land are determined by the presence of sea ice cover on the former and snow cover on the latter (permanently ice covered land is treated as snow covered land). These two surfaces also have reflectances that are more nearly the same as those of clouds; i.e., the VIS radiance

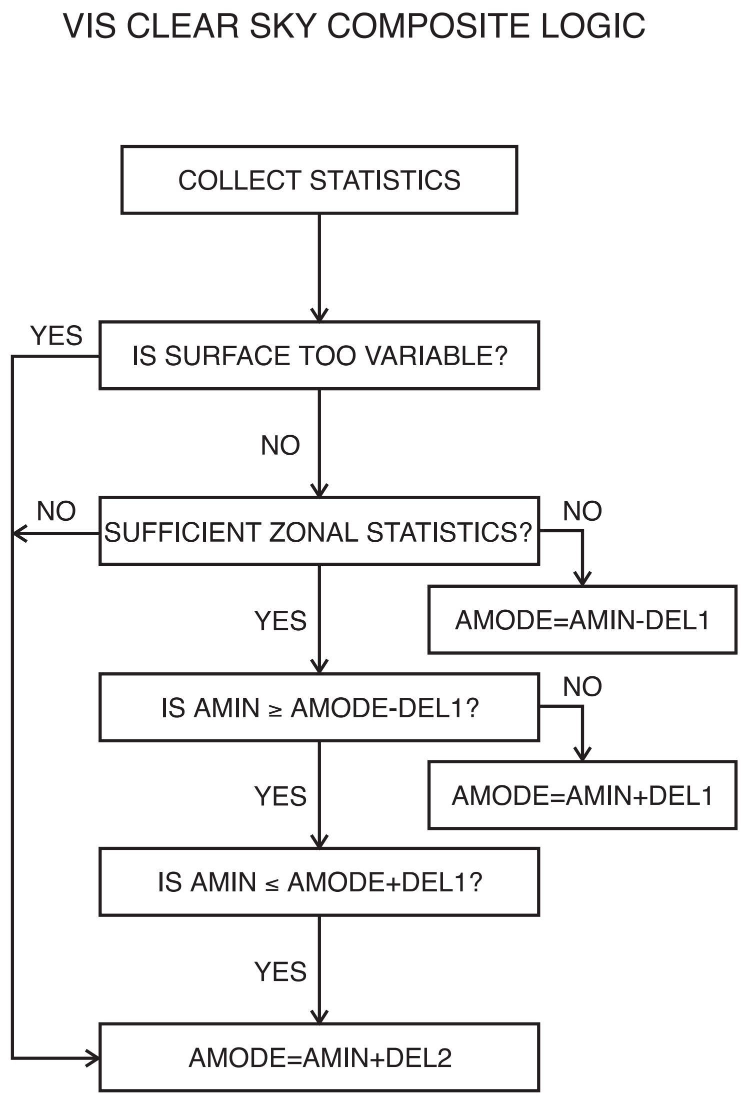

Figure 2.3. Visible clear sky radiance processing logic.

contrast is very low. The clear radiance ACLR = AMIN-ST + DEL1.

(iii) Some locations exhibit relatively large spatial variations of surface reflectance but small time variations (Sèze and Rossow, 1991a): these types are high topography regions (because of stronger solar zenith angle dependence and shadowing effects), deserts, tundra, and grasslands. ACLR = AMIN-LT + DEL2.

(iv) Open water generally exhibits constant reflectance in time and space at constant viewing/illumination geometry; however, since the viewing/illumination geometry for satellites varies (especially for the polar orbiter), the observed reflectance varies more because of the strong anisotropy of the surface. In particular, the reflectance of sun glint is highly variable because of the variation of surface roughness with surface winds. ACLR = AMIN-LT + DEL3; however, away from glint conditions, this value is not allowed to deviate from an empirical model of ocean VIS reflectance (derived from the model of Minnis and Harrison, 1984). For a conservative estimate of the reflectance, AMODEL + DEL4 ≥ ACLR ≥ AMODEL.

(v) The surface types that are spatially as well as temporally homogeneous are vegetated land surfaces: shrubland, woodland, forest and tropical rainforest. ACLR = AMIN-LT + DEL2; however, the individual values are compared to the distribution of values for the same surface type in 10° latitude zones and are required to meet the condition: AMODE + DEL5 ≥ ACLR ≥ AMODE - DEL5. AMODE is the peak value of the distribution; if ACLR for a particular scene is outside the range, it is re-set to the nearest value in the range.

The DEL values in percent reflectance are: DEL1 = 5.0, DEL2 = 3.5, DEL3 = 1.5, DEL4 = 3.0 and DEL5 = 6.0.

2.3. Cloud Detection

The final decision of the status of an image pixel is made by a bi-spectral threshold test (IR-only threshold at night, determined by $\mu_0 < 0.2$). Using the clear sky radiances derived for each location and time, all image pixels with radiance values in either spectral channel that are sufficiently different from clear sky conditions are declared to be CLOUDY. In order to improve the detection of cirrus and low-level clouds, single channel detections are allowed. Thus, if the VIS radiance <u>or</u> the IR radiance is different from the clear sky values, the pixel is called CLOUDY. The magnitude of the difference required is set by the estimate of the uncertainty in the clear radiance values. All remaining pixels are called CLEAR; there is no UNDECIDED category at this stage. The threshold decision is made without regard to the previous composite analysis labels.

2.3.1. Clear radiances

The clear sky composites are constructed for every scene for every 5-day period. Note, however, that the IR clear sky composite procedure uses some nearest-neighbor information; thus, the effective spatial resolution of this composite is about 75 km. These values have had most of the viewing geometry dependence removed before compositing. Prior to the threshold decision for a particular satellite image, the appropriate clear sky composite is selected (nearest in time) and the <u>inverse</u> angle corrections applied, using the specific viewing geometry for each pixel in that image. Thus, although the values in the clear sky composites are held constant over 5-day periods, the clear radiances used to detect clouds can undergo some day-to-day variation as viewing geometry varies.

In near-glint geometry over oceans (determined by a solid angle between the solar illumination vector and the satellite view vector ≤ 37°), a model of ocean reflectance is used to brighten the VIS clear sky radiances. The magnitude of this brightening is proportional to the cosine of the angle between the illumination and view vectors; maximum added reflectance is 0.3 This additional reflectance prevents most, but not all spurious detections in the VIS channel as it is generally somewhat larger than the reflectance observed at glint geometries.

2.3.2. Thresholds

The threshold values in the IR vary for the four surface types, whereas the VIS threshold values differ only for water and land surfaces (sea ice is treated as a land surface in VIS). VIS radiances are represented as percentages of the instrument response obtained when measuring the full solar flux; IR radiances are represented as brightness temperatures in Kelvins. The values used are:

Threshold Value	Surface Type			
	1	2	3	4
IR (K)	2.5	3.5	6.0	8.0
VIS (%)	3.0	3.0	6.0	6.0

There are a few specific exceptions to these threshold values. Because of their larger clear radiance variability and uncertainty no VIS-ONLY CLOUDY pixels are allowed over ocean in glint geometry and near sea ice margins or over land near snow margins; i.e., both spectral channels are required to detect clouds under these confusing circumstances. Use of the short-term value of AMIN over snow and sea ice introduces less confidence; hence over snow and sea ice the VIS threshold is 6.0%. No MARGINAL VIS-ONLY CLOUDY pixels are allowed over snow and sea ice.

The surface temperatures of shallow or near-coastal waters are more variable than for deeper water, as reflected in the larger IR threshold value. However, small navigation errors in the satellite images occasionally "move" the coastlines. The time analyses used to infer IR-CLEAR are particularly vulnerable to the effects of warmer land pixels being mistaken for water pixels. Thus, in coastal waters, no MARGINAL IR-ONLY CLOUDY pixels (category 7 below) are allowed. Since land-water temperature contrasts are much reduced at night and in winter, this problem does not arise as frequently.

2.3.3. Threshold classes

The actual relationship between the pixel radiances and the clear radiances is recorded for each pixel by a two-part code: each part records a value from 0 to 5 representing the VIS and IR results separately.

VIS code = 0 no data (nighttime; if daytime, pixel discarded)
VIS code = 1 less than CLEAR VIS by more than threshold
VIS code = 2 less than CLEAR VIS by less than threshold
VIS code = 3 greater than CLEAR VIS by less than threshold
VIS code = 4 greater than CLEAR VIS by more than threshold

S code = 5 greater than CLEAR VIS by more than 2 × threshold

IR code = 0 no data (pixel discarded)
IR code = 1 greater than CLEAR IR by more than threshold
IR code = 2 greater than CLEAR IR by less than threshold
IR code = 3 less than CLEAR IR by less than threshold
IR code = 4 less than CLEAR IR by more than threshold
IR code = 5 less than CLEAR IR by more than 2 × threshold

In the diagrams below, various combinations of these categories are illustrated, where the division between categories defined by codes 2 and 3 is the clear sky radiance value and the widths of categories 2, 3, and 4 are determined by the magnitude of the thresholds.

Bright							
	5	0	1	1	1	2	2
	4	0	1	1	1	2	2
VIS	3	0	3	3	3	2	2
	2	0	3	3	3	2	2
	1	0	3	3	3	2	2
	0	0	3	3	3	2	2
Dark							
		0	1	2	3	4	5
		Warm			IR		Cold

This diagram illustrates the basic division of the radiance distribution into TOTAL CLOUDY (categories 1 and 2) and CLEAR (category 3). Nighttime data have a VIS THR FLG = 0. To provide a data set that has identical properties day or night, the number of IR-CLOUDY (category 2) pixels is also reported (at night the TOTAL CLOUDY and IR-CLOUDY numbers are equal). The number in category 3 is not reported directly; rather, the total number of pixels with good data is reported and category 3 can be determined by subtraction.

Bright							
	5	0	1	1	1	2	2
	4	0	5	5	5	6	2
VIS	3	0	3	3	3	7	8
	2	0	3	3	3	7	8
	1	0	3	3	3	7	8
	0	0	3	3	3	4	2
Dark							
		0	1	2	3	4	5
		Warm			IR		Cold

The number of pixels with radiances near the clear values is often an indication of the presence of broken cloudiness and partially covered image pixels. Some analysis schemes use these pixels to estimate corrections to the cloud cover amount (Coakley and Bretherton, 1982; Koffler *et al.*, 1973; Reynolds and Vonder Haar, 1977; Arking and Childs, 1985; Stowe *et al.*, 1988).

However, as these radiance values can also be produced by optically thin clouds, there is, as yet, no way to distinguish reliably between these two effects (Rossow *et al.*, 1985). The analysis encounters special difficulties when the contrast between cloudy and clear conditions is very low; these situations are indicated by a large number of pixels with radiances near the clear sky values. Notable areas where this occurs are the marine boundary layer cloud regimes (IR only), thin cirrus over deserts (VIS only) and the polar regions (both IR and VIS). To provide an estimate of the sensitivity of the results to the magnitude of the radiance threshold, to indicate broken cloudiness or low contrast situations, and to provide a means for estimating the uncertainty in the results, the number of pixels lying near the clear radiance values is reported. The MARGINAL IR-CLOUDY pixels (categories 4, 6 and 7) represent the first derivative in cloud amount, defined for both day and night. The MARGINAL VIS/IR-CLOUDY pixels (categories 5, 6 and 7) represent the combined VIS/IR first derivative.

Since one channel detections are allowed to capture more cirrus and low level clouds during the day, the amount of single-channel detections is highlighted by reporting them separately. The IR-ONLY CLOUDY pixels (categories 7 and 8) are those that are detected only in the IR channel during the day; these occur in regions where thin cirrus is common or over snow and ice covered locations. The number of VIS-ONLY CLOUDY pixels (categories 1 and 5) can be determined by subtracting the number of IR-CLOUDY pixels (categories 2,4,6,7 and 8) from the TOTAL CLOUDY pixel number.

Bright							
	5	0	C	B	A	2	2
	4	0	C	B	A	2	2
VIS	3	0	C	B	A	2	2
	2	0	C	B	A	2	2
	1	0	C	B	A	2	2
	0	0	C	B	A	2	2
Dark							
		0	1	2	3	4	5
		Warm			IR		Cold

The accuracy of the cloud detection algorithm depends on the accuracy of the clear radiances. One way to assess the performance is to check the validity of two assumptions: (1) that the clear radiance values found by the analysis represent the mode value (and mean) of the intrinsic distribution of values that would be observed for that location if no clouds occurred and (2) that the width of this distribution is smaller than the magnitude of the thresholds used. To provide an assessment of these two propositions, the number of pixels with radiance values just above and below the clear radiance value is reported, along with the number of pixels that are farther away from the clear value than the threshold amount on the "non-cloudy" side (i.e., darker than VIS CLEAR and warmer than IR CLEAR). Category A, above, contains the pixels that are only slightly cooler than IR CLEAR; category B pixels are slightly warmer and category C pixels are much warmer. The equivalent daytime values are illustrated below: category D pixels are slightly brighter than VIS CLEAR and are also determined to be clear by the IR channel; category E pixels are slightly darker and category F pixels are much darker.

	VIS	IR 0	IR 1	IR 2	IR 3	IR 4	IR 5
Bright	5	0	1	1	1	2	2
	4	0	1	1	1	2	2
VIS	3	0	D	D	D	2	2
	2	0	E	E	E	2	2
	1	0	F	F	F	2	2
Dark	0	0	3	3	3	2	2

Warm IR Cold

2.3.4. Interpretations

The threshold labeling of pixels as cloudy or clear is performed without regard to the previous labels derived from the clear sky composite analysis, since the purpose of the two analyses is different. In the clear sky composite analysis, the objective is to find the most accurate values of clear radiance; hence, the tests for clear conditions are very strict and probably overestimate the cloud frequency. Because of the relatively low variability of the surface properties, not all measurements need to be included to get a good estimate of the clear radiance values. In practice, the image pixels are generally about equally divided between the CLOUDY and UNDECIDED categories, with the CLEAR category being smaller than either of the others. The MIXED category is usually very small, except when the algorithm is having difficulty distinguishing the clouds in ambiguous situations; this confirms the basic premises used in the compositing logic.

In the detection step, the purpose is to determine the number of pixels with radiance values significantly different from the clear values, a less strict test. The success of the overall cloud detection is indicated by whether the composite and threshold labels generally agree or disagree. Early results show that more than 90% of pixels labeled as CLOUDY or CLEAR in the clear sky composite analysis are similarly labeled by the threshold decision. The pixels in the UNDECIDED category, that have radiances that are too ambiguous to decide reliably in the composite analysis, are usually divided into CLOUDY and CLEAR in rough proportion to the number of pixels already labeled as CLOUDY or CLEAR.

The primary supposition behind the whole analysis design is that the actual clear radiances vary somewhat on time scales smaller than retained in the analysis, both because of real variations of the surface and atmosphere and because of analysis errors. If the threshold category A to B ratio (see above) and the category D to E ratio are greater than or about one, then the clear radiance values are near the center of the distribution of radiances labeled as CLEAR. (These ratios are expected to be greater than one because the threshold magnitude is somewhat larger than the actual width of the clear sky radiance distribution, thereby including some cloudy pixels in category A and D.) If the number of category C or F pixels is very small, then not only is the clear radiance probably about right, but also the threshold magnitude is not too small. These results do not guarantee the correctness of the analysis in all cases (the polar regions, in particular may occasionally violate the assumptions used in this analysis), but they do indicate consistency. Another circumstance where these statistics may not indicate the accuracy of the method is in areas that are persistently and almost totally cloud covered: in such cases the number of clear pixels is so small that the numbers in these categories will not be significant. Our experience with data so far suggests, however, that the A to B and D to E ratios are about two and the ratio of category C to A (or B) and F to D (or E) is much smaller than 0.1 for most of the Earth, which suggests good accuracy of the results.

ISCCP C1 data report results for a global grid of equal-area cells defined by the area of a 2.5° latitude by 2.5° longitude cell at the equator. Cloud amount is defined in the ISCCP data as the number of CLOUDY pixels within a region and represents, strictly, only the frequency of occurrence of clouds in that region at that time. However, the radiative analysis assumes that the cloud, atmospheric and surface properties are uniform on the scale of a satellite image pixel (about 5-10 km); hence, for consistency with the retrieved parameter values, the frequency of occurrence of cloudiness is also the cloud amount, which is DEFINED by these assumptions. This value can also be interpreted to indicate the variation of actual cloud amount on a scale > 5-10 km. Although this interpretation is thought to overestimate "actual" cloud cover amount, when using "low" resolution satellite data (e.g., Coakley and Bretherton, 1982; Arking and Childs, 1985; Stowe *et al.*, 1988), no technique is yet available that determines fractional cover of individual pixels for ALL cases. This approach was selected for the ISCCP analysis for reasons of uniformity and simplicity (Rossow *et al.*, 1985). Nevertheless, this is still an open issue, particularly since it is not certain that cloud cover amount is a meaningful parameter on scales smaller than those over which the radiation interacts with the clouds, scales < 1-10 km (Rossow, 1989). This possibility is also suggested by the fact that the magnitude of radiance variations is much smaller at scales < 30 km than at larger scales (Sèze and Rossow, 1991a, b). Resolving these issues is an objective of the research component of ISCCP.

The first derivative in cloud amount can be interpreted in a number of ways. The most straightforward interpretation is that this value indicates the sensitivity of the analysis by the number of pixels with an ambiguous status. Since the relationship between cloud and surface properties varies widely among the various climate regimes, the sensitivity of the analysis also varies. This value can also be used as an estimate of the uncertainty in cloud amount, in the sense that it defines the formal uncertainty in the detection of cloudiness.

Since the accuracy of the results depends directly on the accuracy of the clear radiance values and on the threshold magnitudes in relation to the actual variability of the clear radiances and errors in their estimation, the first derivative can be used to correct for any systematic errors discovered in these quantities in the validation of the ISCCP results. For example, if it is found that either the clear radiances are biased by some amount or the thresholds are the wrong magnitude, estimated corrections for the ISCCP results can be obtained by using these values as literal first derivatives of the cloud properties with threshold or clear radiance values.

A large first derivative also indicates a low contrast situation where cloudy radiances are only slightly different from clear values (in fact, early results show that the largest values of the first derivative occur in only a few areas that are all well-known for very low level cloudiness). This can occur because the clouds are very low level or highly broken (very small cloud elements and little total cover) or both (e.g., trade-wind or fair weather cumulus over the oceans). The clouds can also have very low optical thickness (e.g., cirrus and fogs), producing only small radiance perturbations. In some regions, the surface properties are more nearly the same as clouds in one or both spectral bands. This is particularly true of dust and cirrus clouds over the brighter deserts (e.g., Saharan and Arabian) in the visible and of many low level stratus clouds over the ocean and polar regions in the IR. Although the analysis for these situations probably cannot be improved with only the standard VIS and IR data, if some procedure is found to correct for these effects, then the first derivative values may also be useful for this purpose.

2.4. Radiative Transfer Model Analysis

Once pixels are classified as CLOUDY or CLEAR, the radiances are compared to radiative transfer model calculations designed to simulate the measurements of the AVHRR channels (to which all the radiometers have been normalized). These comparisons are used to calculate the surface reflectances and temperatures from clear radiances and the cloud optical thickness and top temperature from cloudy radiances. Atmospheric properties that affect the satellite measured radiances are specified from correlative data.

The cloud detection step is a relative process in that clouds are detected by contrast to clear radiances determined separately for each satellite and time period. Hence, the cloud frequency is independent of longer-term (> one month) changes in radiometer calibration. Shorter-term changes, especially those producing warmer or darker radiances, can affect the cloud frequency. In contrast, the retrieval of physical quantities from the radiances depends directly on radiometer calibration. The ISCCP B3 radiance values are normalized to a specific relative standard to a precision of better than 5%. For the C1 data production, the VIS radiances are multiplied by a factor of 1.2 and the IR radiances are unchanged. The VIS radiance calibration is altered based on a comprehensive absolute calibration of the NOAA-9 radiometer, using both direct aircraft measurements and several indirect calculations (Whitlock et al. 1990), together with the ISCCP normalization of NOAA-9 to the standard (NOAA-7 in July 1983). This calibration is estimated to be accurate to within ± 7%. The IR calibration is estimated to be accurately maintained by NOAA to about ± 5%.

The radiative model analysis proceeds in five steps (Fig. 2.4).

(i) Retrieval of surface temperature from the clear IR radiance obtained from the IR clear sky composite for the particular image pixel. The effects of atmospheric water vapor absorption are removed, using the atmospheric data for the particular location and time.

(ii) Retrieval of surface reflectance from the clear VIS radiance obtained from the VIS clear sky composite for the particular image pixel. The effects of Rayleigh scattering and ozone absorption are calculated, using ozone abundance data for the particular location and time. No retrieval is performed at night.

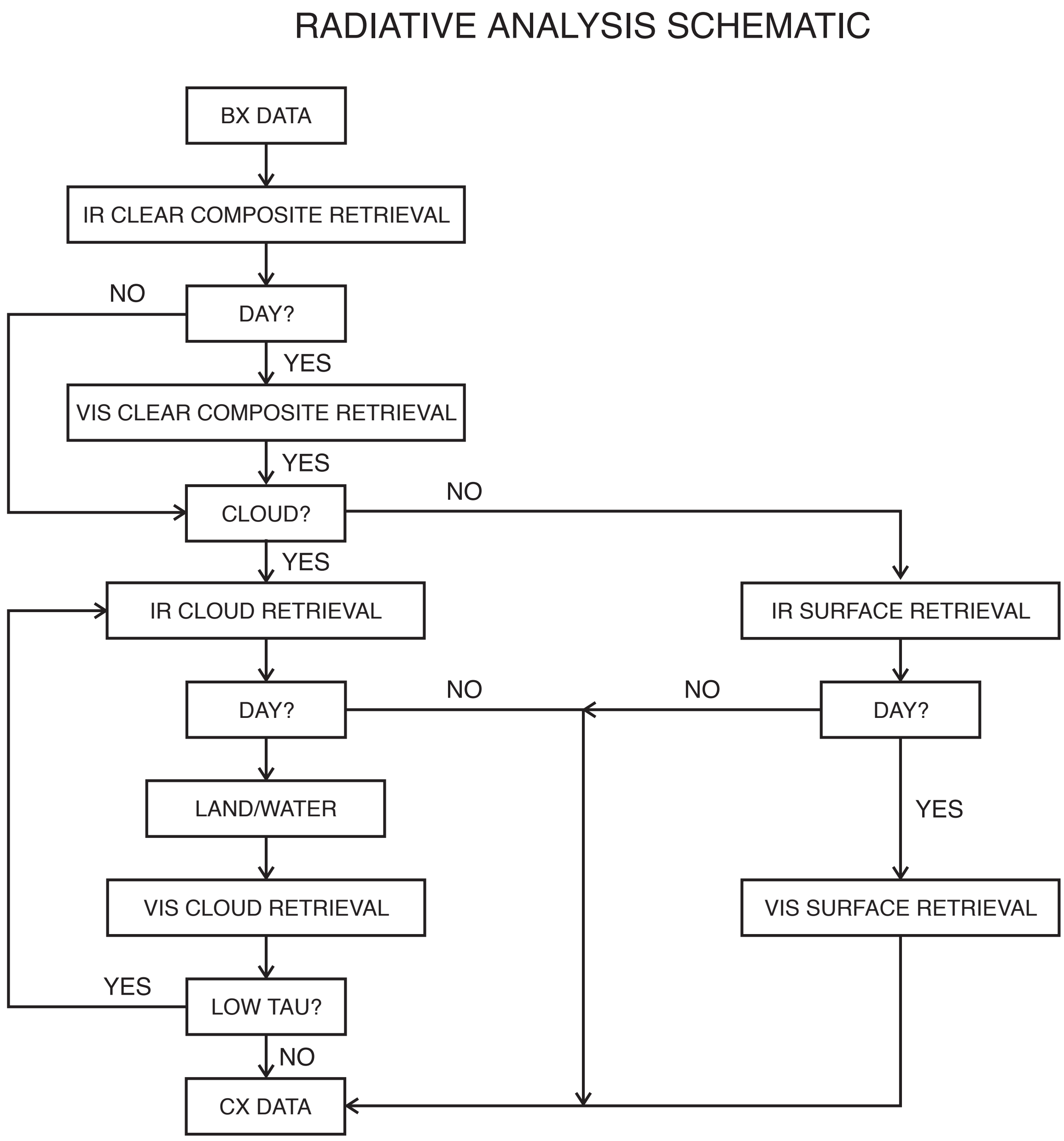

Figure 2.4. Radiative model analysis logic.

(iii) Retrieval of surface temperature from the IR radiance, if the pixel is labeled CLEAR, or of cloud top temperature, if the pixel is labeled CLOUDY. The effects of atmospheric water vapor absorption are removed, using the atmospheric data for the particular location and time. Cloud top pressure is inferred (assuming that all clouds are opaque to IR radiation) from the atmospheric temperature profile for the particular location and time and the surface temperature retrieved in Step 1.

(iv) Retrieval (if it is daytime) of surface reflectance from the VIS radiances, if the pixel is labeled CLEAR, or of cloud optical thickness, if the pixel is labeled CLOUDY. The effects of Rayleigh scattering and ozone absorption are calculated; for a cloudy pixel the Rayleigh scattering is calculated, using the cloud top pressure retrieved in Step 3. Calculation of cloud optical thickness also uses the surface reflectance from the clear VIS composite, obtained in Step 2, for land and sea ice surfaces or from a model for water surfaces.

(v) If the optical thickness of the cloud is small, the cloud top temperature is re-calculated to account for transmission of radiation from the surface using the retrieved optical thickness. The revised cloud top pressure is then used to re-calculate the optical thickness. No adjustment is performed at night.

2.4.1. Radiance model descriptions

All retrieved parameters are model-dependent quantities. The accuracy with which they represent real quantities depends on two factors:

(i) the extent to which variations of other cloud and surface characteristics, which are held constant in the model, change the radiances, and

(ii) the importance of effects neglected in the model.

The first of these factors will effect the accuracy of a specific observation, but will not, generally, affect the statistical results (climatology) as long as the estimated values for these parameters are "climatologically" correct. The variations in the satellite-measured radiances that are caused by changes of other cloud properties will be included as variations of optical thickness and top temperature. Since all clouds must be treated as opaque at night, optical thickness variations are included in top temperature variations in the IR-ONLY results; however, the importance of this can be assessed by comparing the IR-ONLY results with the VIS/IR results in daytime.

The second of these factors may introduce important biases into these results. The most uncertain issue in this category is the assumption of optical homogeneity (of clouds and surfaces) at pixel spatial scales. The research part of ISCCP will address these questions.

The next sections describe the detailed assumptions made about the cloud, atmosphere, and surface characteristics. Key highlights are:

(i) Surface and atmospheric optical properties are assumed to be uniform over the image pixels (5-10 km, but actually interpreted to be uniform over the scene scale of 25 km for VIS and 75 km for IR).

(ii) No aerosol effects are included in the radiative models; hence, the mean properties of the surface include the climatological effects of aerosols. Variations in aerosols that change the radiances enough in time, particularly dust storms, will be detected as clouds.

(iii) All surface types are assumed to be black bodies in modeling IR radiances; hence, the retrieved temperatures are brightness temperatures that are slightly lower than the actual skin temperatures of the surface. These values will differ from near-surface air temperatures by an amount that varies with time of day and season.

(iv) Land and sea ice surfaces are assumed to be isotropic reflectors. The ocean reflectance is represented by a model derived from satellite observations (Minnis and Harrison, 1984; see also Rossow *et al.*, 1989a).

(v) Cloud optical properties are assumed to be uniform over the image pixels; hence, cloud cover of pixels, if present, is assumed to be complete.

(vi) Clouds are assumed to be single, physically thin layers (no vertical temperature gradients) that are pure absorbers of IR radiation. The effects of IR radiation scattering by the cloud are neglected except in the empirical relation between the visible and infrared optical thicknesses.

(vii) Clouds are assumed to be single, thin layers that are pure (conservative) scatters of VIS radiation. No gaseous absorption or scattering is included in the cloud layer. Scattering is calculated as Mie scattering from a size distribution of water spheres.

2.4.1.1. *IR model*

The infrared radiance model is very similar to that described in Rossow *et al.* (1989a), with optical constants adjusted to the spectral response of Channel 4 on the NOAA-7 AVHRR (see Rossow *et al.*, 1987). The model represents the clear atmosphere as seven layers of absorbing gas (the pressure intervals are the same as in the temperature profile defined below) above a black-body surface; no aerosol effects are included. Each pixel is assumed to correspond to a column of gas with horizontally uniform properties; the surface and any cloud layers are also assumed to be horizontally uniform over the image pixels (5-10 km).

Clear gas layers in the model are not isothermal; rather the gas temperature varies from top to bottom of the layer so that the Planck function is linear (this is equivalent, however, to a nearly linear temperature variation with pressure for the relatively thin layers used). Radiances (brightness temperatures) are calculated as a function of satellite zenith angle. Absorption is due to water vapor; the total amount of water vapor in each pressure layer is vertically distributed with a constant mixing ratio.

Water absorption has two contributions: continuum and weak line absorption. The formulation of the continuum absorption follows that of Roberts *et al.* (1976) and includes the effects of self-broadening and foreign-broadening. The temperature dependence of the self-broadening is included, that of foreign-broadening is not because it is weaker than the uncertainty in the foreign-broadening effect. The optical thickness of continuum absorption is given by

$$\tau = (6.3859 \times 10^{-6})\ U\ \{ e \times \exp [1800\ (1/T - 1/296)] + \delta\ (p - e) \}$$

where U is the amount of water vapor in centimeters-STP, e is the partial pressure of water vapor in mb, and p is the total atmospheric pressure in mb. The ratio of foreign- to self-broadening, δ, is uncertain; we use δ = 0.001. The optical thickness of line absorption is obtained, using a fit to calculations with a Malkmus model for very narrow spectral intervals and weighted by the response function of AVHRR. Using the line strengths given by Rothman *et al.* (1983), we get

$$\tau = U \times \frac{0.000067 + 0.0081\ U}{1 + 109\ U + 1.3\ U^{1.6}}$$

Figure 2.5 shows the variation of these two optical thicknesses with the amount of water in a layer, expressed in precipitable centimeters.

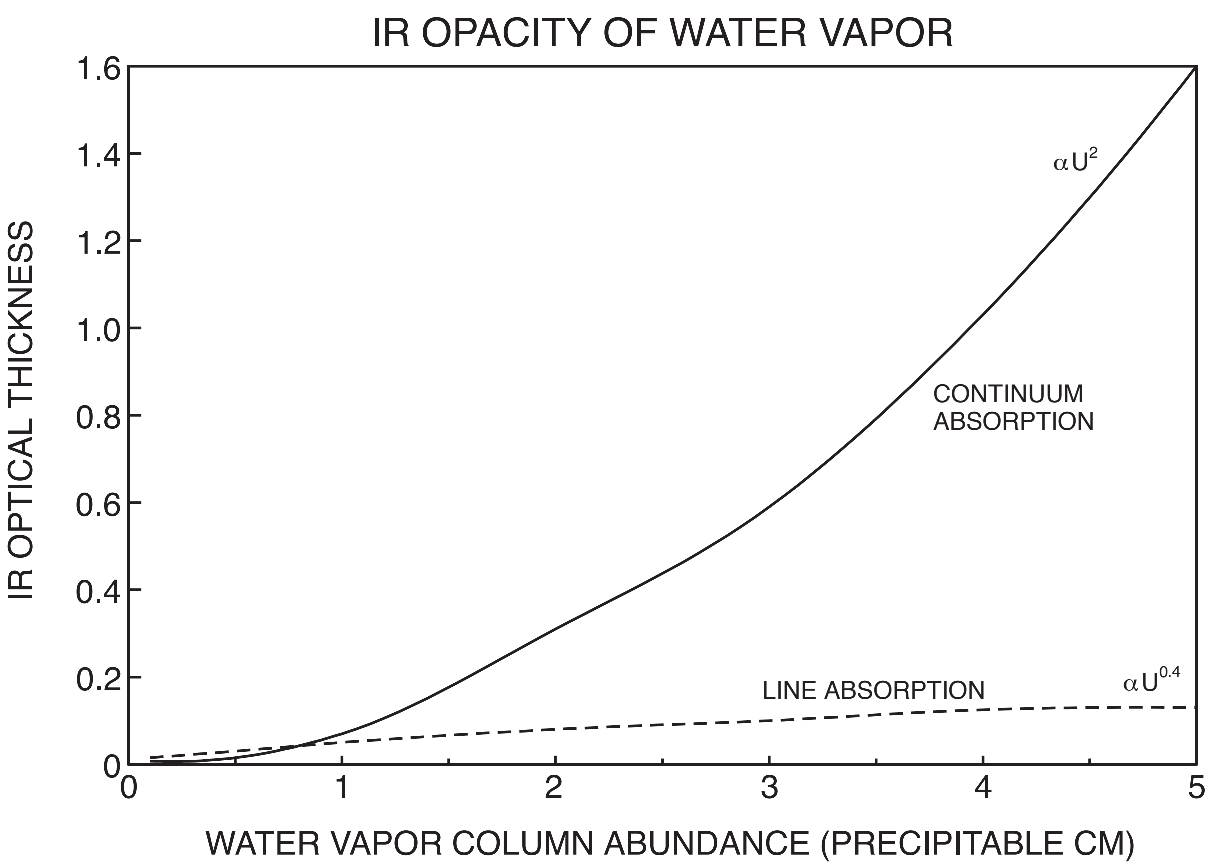

Figure 2.5. Variation of water vapor infrared opacity at 10.5 μm with total water layer amount.

An error in calculation of the coefficients for line absorption was discovered and corrected for all Stage C1/C2 data for September 1985 onwards. The altered expression is

$$\tau = U \times \frac{0.000067 + 0.0065U}{1 + 115U + 1.3U^{1.6}}$$

As Fig. 2.5 shows, this contribution to the water vapor absorption is very small anyway; thus, the effect of this change is to reduce cloud top temperatures by < 0.2 K and surface temperatures by < 0.5 K.

Clouds are assumed to be single, physically thin layers (no vertical temperature gradients) that are pure absorbers of IR radiation. The effects of IR radiation scattering by the cloud are neglected except for the empirical relation between the visible and infrared optical thicknesses (discussed below). The actual albedo of clouds at 10.5 μm (see VIS model description below for microphysical characteristics) is 2%, using the optical constants for liquid water from Hale and Querry (1973) for VIS wavelengths and Downing and Williams (1975) for IR wavelengths, and about 0.2% for ice, using Warren (1984).

2.4.1.2. *VIS model*

VIS radiances are expressed as a fraction of the solar constant of the radiometer (the amount of energy intercepted in the instrument bandpass per unit solid angle, see Rossow *et al.*, 1987, for details). Before comparison to the VIS model, the measured radiances are corrected to a constant sun-Earth distance.

The visible radiance model is very similar to that described in Rossow *et al.* (1989a), with optical constants adjusted to the spectral response of Channel 1 on the NOAA-7 AVHRR (see Rossow *et al.*, 1987); however, none of the calculations are very sensitive to the precise spectral dependence or wavelength used, over the range from 0.55 to 0.7 μm covered by the satellite radiometers (the exception is the surface reflectance for vegetated land surfaces). The model represents the clear atmosphere as two gas layers above a reflecting surface; no aerosol effects are included. Each pixel is assumed to correspond to a column of gas with horizontally uniform properties; the surface and any cloud layers are also assumed to be horizontally uniform over the image pixels (5-10 km).

The two gas layers are an absorbing layer at the top, representing ozone effects, and a Rayleigh scattering layer (total gas amount represented by a maximum surface pressure of 1000 mb). Ozone absorption is calculated, using a fit to line-by-line calculations weighted by the spectral response of the AVHRR:

$$\tau = U \, [\, 0.085 - (0.00052 \, U) \,]$$

where U is the column amount of ozone in cm-STP. Continuum absorption strengths in the Chappuis band are from Inn and Tanaka (1953).

Land and sea ice covered surfaces are assumed to be isotropic reflectors; reflection from the ocean is specified by a model obtained by removing the atmospheric effects from the clear radiance model of Minnis and

Harrison (1984). The consistency of this model has been checked by comparing it to directly retrieved surface reflectances for a summer and winter month from both polar and geostationary satellites, using the VIS retrieval model. The retrieval agrees with the model to within 2% (random error) except near glint conditions. In glint geometry the model is found to be too bright by ≈5% in a majority of cases, but too dark in many other cases. This large variability of the glint reflectance is accounted for in the cloud detection by requiring confirmation of cloud presence by the IR channel.

Clouds are assumed to be single, thin layers that are pure (conservative) scatterers of VIS radiation. No gaseous absorption or scattering is included in the layer. When clouds are present, the VIS radiances are calculated from the individual scattering and absorption layers using the doubling-adding procedure (Hansen and Travis, 1974); the amount of gas above the cloud is determined by the cloud top pressure and the remaining gas is below the cloud.

Reflectance from clouds is calculated as complete, multiple Mie-scattering from water spheres. The optical constants of liquid water are used (from Hale and Querry, 1973, for VIS and Downing and Williams, 1975, for IR); the particle effective radius and variance are 10 μm and 0.15, respectively (see Hansen and Travis, 1974).

2.4.2. Clear sky retrievals

2.4.2.1. *Surface temperature*

The IR model calculations are performed separately from the cloud algorithm; the model is used to convert the TOVS atmospheric profiles of physical temperature and humidity into profiles of observed brightness temperature as a function of satellite zenith angle, location and time. The cloud radiative processing uses these results as data sets. The water vapor values provided in the TOVS data set are rather noisy (quoted estimates of error are about 25-35%, Smith et al., 1979). To reduce this noise somewhat, all water vapor values are averaged over a 5-day period centered on the day being analyzed.

As part of this off-line calculation, the observed brightness temperature corresponding to the TOVS surface temperature is also obtained. Two sets of information are saved as a function of satellite zenith angle, location and time: the atmospheric transmission and emission and the difference between the surface physical temperature and the calculated brightness temperature. The surface temperature corresponding to the observed clear IR radiance (brightness temperature) is given by

$$BTS = [\ BTOBS - EMISS\ ] \ /\ TRANS$$

where BTS is the Planck radiation of a black body (weighted by the response function of the AVHRR) at surface temperature, TS, BTOBS is the observed clear IR radiance, EMISS is the total atmospheric emission and TRANS is the transmission fraction for surface radiation through the whole atmosphere. Note that the effective wavelength of the AVHRR radiometer channel is about 0.5 μm shorter than that of the geostationary satellite radiometers, but this difference is ignored in the analysis.

Although this formula is theoretically correct, when the water opacity becomes very large, TRANS becomes very small. Then the errors in the observed radiances, in the inference of the clear IR radiance and in the properties of the atmosphere are multiplied by a very large number, (1/TRANS). This is equivalent to saying that, when TRANS is small, the measured signal contains little actual information about the surface and is dominated by the atmospheric emission. We have found that when TRANS < 0.2, the errors dominate the above equation and the values of TS diverge rapidly, especially when satellite zenith angles are relatively large in the tropics. Since little real information about the surface temperature is present in the observation under these conditions, we use an alternate procedure for these cases. For TRANS < 0.2, the surface temperature is obtained from

$$BTS = BTOBS + [BTST - BTBT]$$

where BTST is the TOVS surface temperature and BTBT is the corresponding brightness temperature calculated for the TOVS temperature/humidity profile at the same viewing geometry. In other words, we assume, in cases of large water vapor opacity, that the difference between the observed brightness temperature and the actual surface temperature is the same as it is for the TOVS values. This is approximately equivalent to assuming that the atmospheric and surface temperatures vary together, i.e., that if the actual surface temperature is higher than the TOVS value, so is the atmospheric temperature which dominates the observed radiances.

2.4.2.2. *Surface reflectance*

The measured VIS radiances are corrected to a constant sun-Earth distance. Since ozone causes an attenuation of the VIS radiation as it passes through the ozone layer from the sun to the atmosphere/surface/cloud and as it passes again from the atmosphere below to the satellite, the change in the radiance is dependent on both the solar and satellite zenith angles. The transmission is calculated for many narrow spectral intervals over the NOAA-7 Channel 1 bandpass, weighted by the spectral response of the instrument (Rossow *et al.*, 1987), and fit with an empirical function of ozone amount. The transmission is given by

$$Tr = \exp \{ - U [0.085 - 0.00052 U] / \mu \}$$

where U is the total ozone column abundance in cm-STP and μ can be the cosine of either solar or satellite zenith angle. The ozone absorption is removed by dividing by the two transmission factors (for the solar and satellite pathlengths).

To calculate the effects of Rayleigh scattering, the VIS model is run off-line to produce a table of VIS radiance values (normalized to the mean solar constant of the instrument) as a function of isotropic surface reflectance and viewing/illumination geometry. This table is inverted for use in the cloud analysis to provide surface reflectance as a function of VIS radiance and viewing/illumination geometry (cosine of solar and satellite zenith angles and relative azimuth angle). Given a VIS radiance, corrected for varying sun-Earth distance and ozone absorption, and the geometry, the table provides a corresponding value of isotropic surface reflectance.

The effects of the atmosphere on the broader "visible" channel on METEOSAT are slightly overestimated by the analysis. In general this difference in spectral response is insignificant, except for the retrieved surface reflectances for vegetated land areas, which will be significantly larger in areas observed by METEOSAT.

2.4.3. Cloudy sky retrieval

2.4.3.1. *Cloud top temperature and pressure (opaque limit)*

The first step in the analysis of a cloudy pixel is to retrieve the cloud top temperature, assuming that the cloud is opaque to IR radiation. The brightness temperatures that correspond to the physical atmospheric temperatures at various pressure levels are first interpolated to the particular satellite zenith angle of the pixel, using

$$T(\mu) = T(1) + (1/\mu - \mu) \times [\ T(0.2) - T(1)\ ] / 4.8$$

where T(0.2) and T(1) are brightness temperatures at $\mu = 0.2$ and 1 previously calculated by the IR model using the TOVS atmospheric temperature and humidity profiles for the particular location and time.

The brightness temperature of the cloudy pixel is compared to these values to find a match at some pressure level; the corresponding physical temperature at that pressure level is then reported as the cloud top temperature. If the observed cloudy IR radiance (brightness temperature) is less than any value in the profile, then the cloud top temperature is set equal to the brightness temperature (since there is no significant amount of water above the tropopause) and the cloud top pressure is set equal to the tropopause pressure. If the observed brightness temperature is warmer than any value on the profile (the surface temperature is the warmest value and is obtained by extrapolating the atmospheric profile to the surface, but this may not correspond to the temperature inferred from the satellite-measured clear sky IR radiance), then the cloud top pressure is set equal to the surface pressure and the cloud top temperature is retrieved using the clear pixel procedure described above.

At night the cloudy pixel analysis ends with this step.

2.4.3.2. *Cloud optical thickness*

The VIS model is also run off-line to calculate VIS radiances as a function of viewing/illumination geometry, surface reflectance, cloud optical thickness and top pressure. The resulting table is inverted for use in the second step of the cloud analysis. Given a VIS radiance, corrected for sun-Earth distance and ozone absorption, the viewing/illumination geometry, a surface reflectance (from the retrieval using the VIS radiance value from the clear sky composite) and the cloud top pressure from the first step, the table returns a value of cloud optical thickness. Interpolation errors in this table are less than 10%, relative.

Figure 2.6 shows the model relationships between TAU and the cloud spherical albedo (over a black surface) and IR (narrowband) emissivity.

2.4.3.3. *Cloud altitude adjustment*

In the third step of the analysis, the value of the cloud optical thickness is checked for consistency with the assumption in the first step that the clouds are opaque to IR radiation. The optical thickness value,

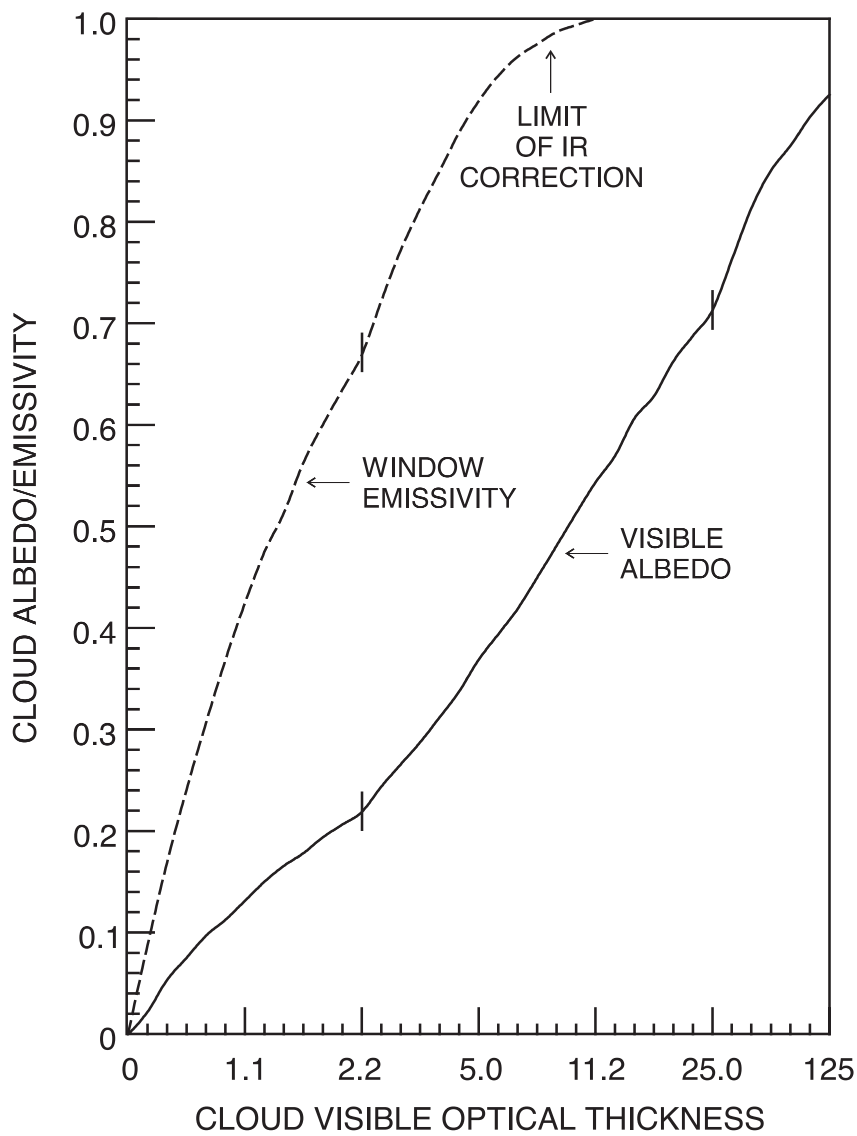

Figure 2.6. Relation of cloud visible (0.6 μm) albedo (scene albedo over black surface with no atmosphere) and infrared (10.5 μm) emissivity as a function of optical depth at 0.6 μm in the ISCCP radiative analysis model.

calculated in the VIS model, is the value at 0.6 μm; the opacity of the cloud to IR radiation at 10.5 μm must be judged by the optical thickness at this wavelength.

Although the same radiation code can calculate a theoretical value for the ratio of TAU-VIS/TAU-IR, there are three factors that argue against using this value. First, although there is scattering of 10.5 μm radiation, it is highly concentrated in the forward direction; hence, it is a good approximation (accurate to within about 5%) to consider the opacity of the cloud as its absorption opacity only. This simplifies the analysis considerably, but it is an approximation. Second, the calculated scattering and absorption opacities in the range 10 – 12 μm, the range of wavelengths covered by the radiometers, are sensitive to the particular wavelength used. This does not affect the results when the cloud is opaque, however. Third, the sensitivity to wavelength also means that the ratio of TAU-VIS/TAU-IR is also sensitive to the particle size assumed. Since the majority of clouds that are not opaque are likely to be cirrus clouds, the dependence of the ratio on particle size and shape may be stronger. Hence, we have adopted for this ratio the empirical value (where TAU-IR is absorption optical thickness), TAU-VIS/TAU-IR = 2, determined for cirrus clouds by intercomparison of lidar and satellite measurements (Platt and Stephens, 1980; Stephens and Webster, 1981). The model value of this ratio for 10 μm spheres and the AVHRR channel wavelength is 2.704; a larger size or non-spherical shape would reduce this value.

The observed radiance is modeled as the sum of two contributions: the emission from the cloud layer and the transmitted radiation from the surface. We use the surface brightness temperature to account for the water vapor absorption, which is assumed to be below the cloud:

$$\text{BTOBS} = (1 - \text{TRANS}) \times \text{BTC} + \text{TRANS} \times \text{BTS}$$

where BTOBS is the observed radiance (Planck function for a temperature, TOBS, weighted by the spectral response function of the instrument), BTC is the radiance emitted by a cloud with temperature, TC, and emissivity (1 - TRANS), and BTS is the clear sky (surface) brightness temperature. The transmission of the cloud is given by

$$\text{TRANS} = \exp \left[- \text{TAU-IR} / \mu \right]$$

Thus, if TAU-IR/μ > 4.5, the cloud is considered opaque (since TRANS < 1%) and no further calculations are made. If TAU-IR/μ ≤ 4.5, then the above formula is used to retrieve an adjusted cloud top temperature:

$$\text{BTC} = \left[\text{BTOBS} - \text{TRANS} \times \text{BTS} \right] / (1 - \text{TRANS})$$

The adjusted cloud top pressure that corresponds to TC is found from the temperature profile. If TC is smaller than any value on the profile, the cloud top pressure is set to the tropopause pressure.

This procedure encounters difficulties with very thin clouds because of errors in the VIS radiance measurements, uncertainties in the determination of the clear radiances and the retrieved surface reflectances, and in the retrieval of TAU-VIS and TAU-IR. In other words, even though the cloud may be "obvious" in the IR image, its VIS radiance effect may be negligible, making an accurate determination of its optical thickness (which is near zero) difficult. This can lead to non-physical relations in the above equation for TC. Also when (1-TRANS) is too small, all of these errors are amplified.

Thus, we also solve the equation for a minimum value of TAU-IR by assuming TC to be the coldest possible cloud top temperature (cloud top at the tropopause with a temperataure 5 K colder than the tropopause temperature):

$$\text{TRANS-MAX} = \left[\text{BTOBS} - \text{BTC-MIN} \right] / \left[\text{BTS} - \text{BTC-MIN} \right]$$

where TAU-MIN is obtained from TRANS-MAX. If the retrieved optical thickness is less than this minimum value, then the cloud top temperature is set to the coldest possible value and the optical thickness is set to its minimum value. If BTOBS < BTC-MIN, then the cloud top temperature is set to BTOBS and the optical thickness is set to the minimum value.

If the values of the cloud top temperature and pressure are adjusted and the value of TAU has not been re-set to the minimum value, then the retrieval of TAU-VIS is repeated with the new cloud top pressure. The cycle of retrievals is repeated until the values converge (usually no more than one iteration is needed). Such adjustment of the values of cloud top temperature and pressure is performed only during the daytime.

A number of consistency checks are made to determine if the radiative analysis is performing as expected. These checks generally detect infrequent problems with the data or errors in the cloud decision. Only the number of cases indicating possible cloud contamination in the clear IR radiance values is reported.

2.5. Statistics

The individual pixel results are summarized as a gridded set of statistics to limit the volume of the C1 dataset. The map grid is an EQUAL-AREA grid with grid cell areas equal to the area of a 2.5° × 2.5° cell at the equator; this map grid is described in more detail in Section 3.3.

Each grid cell is labeled as land/water/coast and day/night. The former is defined by:

- if land cover fraction ≥ 65 %, then cell is labeled "land",
- if land cover fraction ≤ 35 %, then cell is labeled "water",
- if land cover fraction > 35 and < 65 %, then cell is labeled "coast".

A cell is labeled as day/night by:

- if number of day pixels ≥ 50% and 20, then cell is labeled "day",
- otherwise, if number of pixels ≥ 20, then cell is labeled "night".

A "day" pixel is defined by cosine of the solar zenith angle ≥ 0.2 (zenith angle ≤ 78.5°), with complete VIS-dependent information. Occasionally, some VIS-dependent information may be unavailable: if the cosine of the solar zenith angle is still < 0.3, then this is called a night pixel; however, if the cosine of the zenith angle is ≥ 0.3, then the pixel is discarded. If a cell is a "day" cell, then only day pixels (those with both IR and VIS information) are used to calculate statistics and both IR- and VIS-dependent results are reported. If a cell is a "night" cell, then all pixels are used to calculate statistics, but only the IR-dependent information is used and reported.

An additional constraint on the observations is that the cosine of the satellite zenith angle for any pixel must be ≥ 0.3 (zenith angle ≤ 72.5°).

No results are reported for a cell containing less than 20 pixels.

2.5.1. Definition of parameters

The reported physical quantities and their units are:

IR = infrared radiance expressed as brightness temperature in Kelvins
T = temperatures in Kelvins

- ST = stratospheric temperature
- TT = tropopause temperature
- T = tropospheric temperature at some pressure level
- TC = cloud top temperature
- TS = surface temperature (black body)

PW = layer precipitable water amount in centimeters
P = pressure in mb

- PT = tropopause pressure
- P = atmospheric pressure
- PC = cloud top pressure
- PS = surface pressure (≤1000 mb)

VIS = visible radiance expressed as a fraction of the solar constant, weighted by instrument response (= μ_0 R)
O3 = ozone column abundance in Dobson units
R = visible reflectance as fraction from 0 to 1

- RS = surface reflectance
- RC = cloud reflectance (not reported)

TAU = cloud optical thickness (visible wavelength unless otherwise indicated)

- TAU-VIS = visible wavelength cloud optical thickness (scattering)
- TAU-IR = infrared wavelength cloud optical thickness (absorption)

I/S = ice/snow cover fraction
MUE = cosine of satellite zenith angle from 0 to 1
MU0 = cosine of solar zenith angle from 0 to 1
PHI = relative azimuth angle in degrees

Temperatures are reported for seven tropospheric pressures:

900, 740, 620, 500, 375, 245, 115 mb

representing the centers of seven layers, defined by the pressures 1000 or PS, 800, 680, 560, 440, 310, 180, and 50 or PT. Seven troposphere layers are always present in the data, but the actual extent of the bottom and top layers in the troposphere is variable, depending on the values of PS and PT. The former depends primarily on surface topography. As examples, if PS = 850 mb and PT = 100 mb, then the first layer will extend from 850 to 800 mb with a center pressure of 825 mb and the last layer will extend from 180 to 100 mb with a center pressure of 140 mb; if PS = 750 mb and PT = 200 mb, then the first and last layers have no reported values (code value set = 255), the second layer will extend from 750 to 680 mb with a center pressure of 715 mb, and the sixth layer will extend from 310 to 200 mb with a center pressure of 255 mb. As illustrated, the temperatures correspond to the calculated center pressures of these variable layers.

The two stratospheric temperatures are reported at 50 and 15 mb, representing the centers of two layers with fixed extent from 70 to 30 mb and 30 to 5 mb, independent of the location of the tropospause.

PW is reported only for the lowest five layers and represents layer water amount.

Sea ice and snow cover are reported as the fraction of the region, without regard for land or water classification, that is covered by either snow or ice. Cover is reported in increments of 10%. An absence of data is also reported as zero coverage.

Cloud types are defined by their values of PC and TAU. The categories used to define these cloud types are:

for PC = 1000 (or surface)	-	800 mb	approximately	0.0 - 2.0 km
800	-	680 mb	equivalent to	2.0 - 3.3 km
680	-	560 mb		3.3 - 4.8 km
560	-	440 mb		4.8 - 6.6 km
440	-	310 mb		6.6 - 9.1 km
310	-	180 mb		9.1 - 12.7 km
180	-	50 (tropopause) mb		12.7 - 20.7 km

The center values of the pressure classes are 900, 740, 620, 500, 375, 245, and 115 mb (approximately heights of 1.0, 2.6, 4.0, 5.6, 7.8, 10.9, and 16.7 km). The classes

for TAU =	0	-	1.3	approximately equivalent to	0 - 15%
	1	-	3.6	albedos of	15 - 30%
	4	-	9.4		30 - 50%
	9	-	23		50 - 70%
	23	-	125		70 - 93%

The center values of the TAU classes are 0.5, 2.3, 6.0, 14.5, and 30 (approximately albedos of 7.5, 22.5, 40, 60, and 75%, see Fig. 2.6).

2.5.2. Averages and standard deviations

From the distribution of cloud and surface parameter values for the pixels in each map grid cell, representing their variations on small spatial scales (from about 10 to 250 km, cf., Sèze and Rossow, 1991a,b), the mean and standard deviation (SIGMA) are calculated. SIGMA in C1 data indicates the magnitude of the small scale spatial variability of these parameters. The total number of pixels used to calculate both these statistics is also reported.

Since the primary objective of ISCCP is to determine the statistical properties of the clouds (and surface) that influence the radiation balance of the Earth, a description of the average properties and their variability must assign proper weight to the cloud and surface values according to their contribution to the total radiation. For example, warmer objects contribute more to the total IR flux than colder objects. Additionally, since the basic measurements used to infer these values are radiance measurements, themselves, the relative precision of the measurements is linear in energy rather than in the retrieved parameter. Hence, the averages of the cloud and surface properties are performed using representations of the values that are linear in their equivalent energy amounts. For example, the temperatures are represented in increments that are linear in the related Planck radiance and the cloud optical thicknesses have linear increments in reflectance. This method of calculating the mean and standard deviation is not appropriate for all problems, but better represents the information content of the satellite radiance data.

2.5.3. Cloud type information

Since the mean and standard deviation cannot represent all of the characteristics of a distribution and since other ways of averaging the values may be desirable, the C1 data also include some information about the explicit distribution of cloud properties in each map grid cell.

Original ISCCP plans called for reporting the properties of five cloud types: low, middle, high, cirrus, and deep convective clouds. The latter two types were qualitatively defined to be optically thin and thick high clouds, respectively. Consideration of how best to define these types precisely, as well as studies of the adequacy of this classification scheme to represent the actual cloud structures, was part of a one year pilot study on the uses of ISCCP data. Recommendations from that study were to make the definitions more flexible and to preserve greater resolution in cloud top location and cloud optical thickness. Thus, "cloud type" information is presented in the C1 data by the distribution of cloud properties, rather than by reporting results for (arbitrary) classifications of these parameters. In effect, the "cloud types" are identified by their values of PC and TAU, but given as frequencies in a complete distribution. There are several additional advantages of this approach to classification.

(i) Definitions of low clouds, for example, can be formulated from the distribution informatian by the user by combining (or interpolating between) the seven cloud top pressure categories provided. In particular the height categories can be adjusted to the levels in a climate model. Since the information provided in C1 data is actually a low resolution representation of the actual distribution of PC values, which is statistically continuous, linear interpolation to any other pressure value will represent the proper value as long as no higher resolution variations are present.

(ii) Different definitions that depend on the optical thickness, such as cirrus (= "thin", "high" clouds) can also be adopted in the same way. Users can construct their own cloud classes.

(iii) The mean values of PC and TAU for each category can be assumed to be equal to the central value with reasonable accuracy, especially if calculating statistics like the monthly mean values. The center values are less accurate on an instantaneous basis; but their statistics over a month capture the monthly mean properties well (cf., Sèze and Rossow, 1991b).

(iv) Linear averages of TAU and PC values, not weighted by radiative contribution, can be obtained by using the center values of the PC/TAU categories, if desired.

(v) The cloud top temperature for each category can also be obtained from the corresponding atmospheric temperature reported at the center pressure.

(vi) To allow for diurnal studies and to study the effects of the cloud top adjustment procedure, the PC distribution determined by the IR-ONLY (nighttime) algorithm is also reported during the daytime, along with the PC distribution determined by the VIS/IR (daytime) algorithm but without the cloud top adjustment.

(vii) Past treatments of cloud radiative effects considered only the variation of "cloud amount" with fixed cloud optical properties or the variation of cloud amount and height with fixed solar wavelength properties. The distribution of properties provided in Cl data extends the treatment of cloud-radiation variations to a full distribution representation.

The cloud type (PC/TAU) categories are defined above. The figure below illustrates the distribution. The actual extent of the lower and upper layers depends on the values of PS and PT as explained above.

```
   tropo or 50  --------------------------------------------------
          (115) |   7    |   7    |   7    |   8    |   9    |
           180  --------------------------------------------------
          (245) |   7    |   7    |   7    |   8    |   9    |
           310  --------------------------------------------------
          (375) |   7    |   7    |   8    |   8    |   9    |
           440  --------------------------------------------------
   PC     (500) |   4    |   5    |   5    |   5    |   6    |
           560  --------------------------------------------------
          (620) |   4    |   5    |   5    |   5    |   6    |
           680  --------------------------------------------------
          (740) |   1    |   2    |   2    |   2    |   3    |
           800  --------------------------------------------------
          (900) |   1    |   1    |   1    |   1    |   1    |
surface or 1000 --------------------------------------------------
                0 (0.5)  1.3 (2.3) 3.6 (6.0) 9.4 (14.5) 23 (30)   125

(TAU = 0 is 0.02)                  TAU

                0 (7.5)  15 (22.5)  30 (40)  50  (60)   70 (75)   93
                                   ALB
```

2.6. Merging Results From Several Satellites

The final form of the C1 data is constructed by combining the analysis results from several satellites, nominally at least one polar orbiting and five geostationary satellites, to obtain complete global coverage every 3 hrs. Since the polar orbiter provides complete global observations twice daily and adjacent geostationary satellites view some overlapping portions of the globe, there are many coincident observations available. Rather than average two or more measurements, usually obtained at somewhat different times within the 3 hr slots and under different viewing geometries, only one observation from a specific satellite is reported for each grid cell in a 3 hr period.

2.6.1. Definition of satellite hierarchy

To maintain as much continuity and uniformity as possible, a hierarchy of satellites is specified for each map grid cell on Earth, indicating the order of preference when several observations are available. This hierarchy is defined by two general rules: geostationary data are preferred over polar orbiter data equatorward of 55° (polar orbiter data are really the only option at high latitudes, but if no polar orbiter data are available, some geostationary data are reported) and preference should be given to the best viewing geometry (smallest satellite zenith angle). The transition between geostationary and polar regimes at high latitudes is selected as a compromise between the rapidly increasing satellite zenith angles of the geostationary observations and obtaining sufficient orbit overlap to provide complete diurnal coverage with polar orbiter observations.

Since the preferred satellite data may not always be available, each cell has a specified order of preference for any other satellites that may observe that location.

2.6.2. Global coverage

Fig. 2.7 shows the global coverage provided by the primary satellites and indicates the next level of the hierarchy of other satellites at each location. At low latitudes, the two polar orbiters do not actually observe the same location at the same time. The figure assumes no INSAT data are available; the "morning" polar orbiter is used to supplement the "afternoon" polar orbiter coverage. If no data are available at a particular location and time, no values are reported. No form of interpolation or "bogusing" is used. Users wishing to fill in missing observations can apply their own schemes.

2.6.3. Comparison of overlapping results

The overlap of observations from different satellites provides an opportunity to check the algorithm, since the analysis of each data set is perform independently. Some studies have already shown that the cloud amount, defined as the frequency of cloudy pixels, tends to grow as the satellite zenith angle increases (Arking and Vemury, 1984). In the C1 data, the difference between the cloud amounts and satellite zenith angles are reported whenever two observations are available. We find that, when the zenith angle difference is small, the cloud amounts determined are generally similar (±10%).

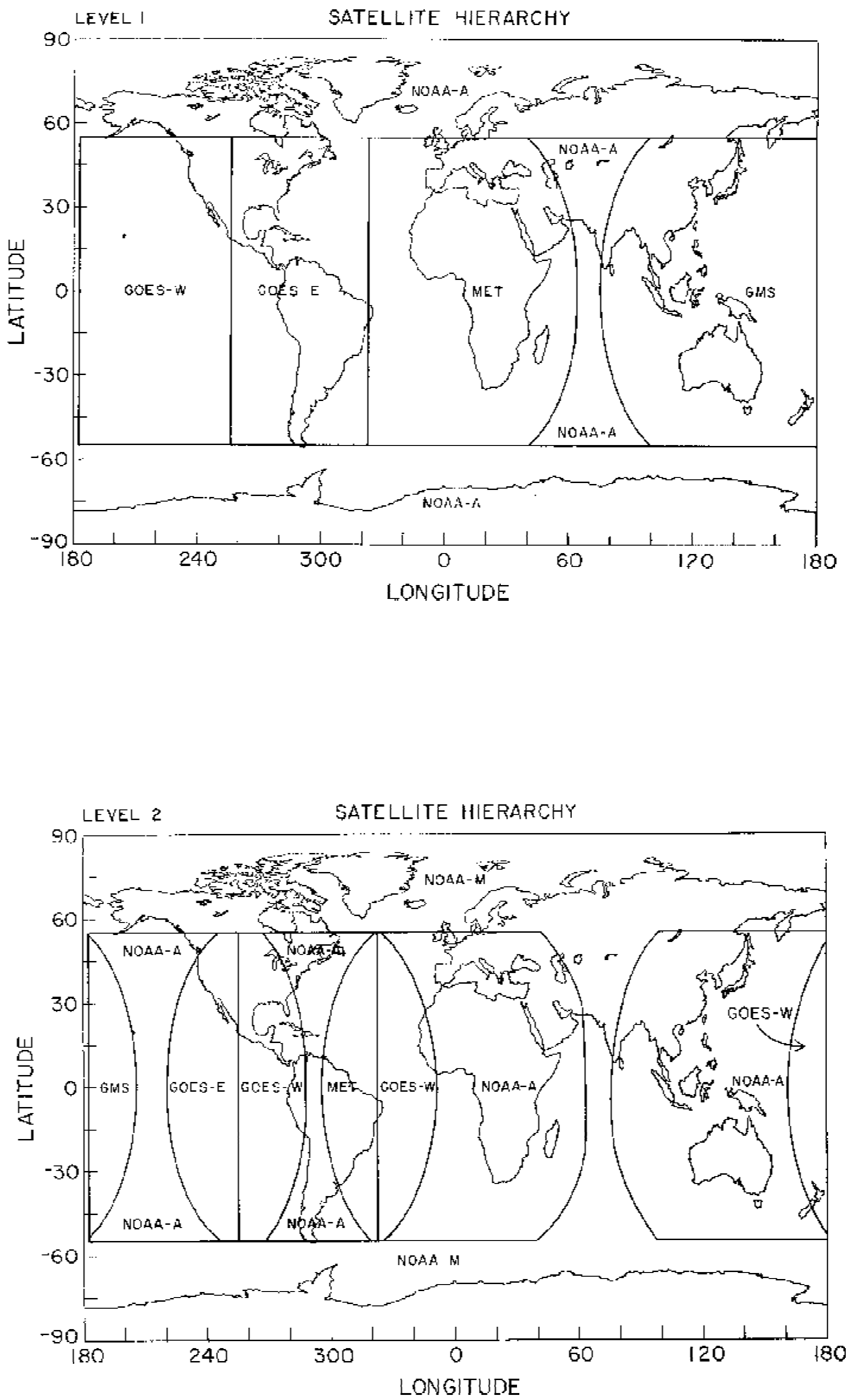

Figure 2.7. Regional coverage provided by satellites used for ISCCP: Level 1 ofhierarchy indicates the preferred satellite for each location while Level 2 indicates the second choice used if the preferred satellite is not available.

3. DESCRIPTION OF DATA TAPE CONTENTS

3.1. Data Organization

ISCCP data collection began on 1 July 1983 and is currently planned to continue through June 1995 (Rossow and Schiffer, 1991). The C1 data will cover this twelve year period. Data are obtained and analyzed every 3 hours during this time period. Even though the actual availability of data at a particular time and place depends on the success of capturing the particular satellite image, a C1 data set exists for every 3 hour period (approximately 248 data sets per month). C2 data provide a monthly mean summary of the C1 data in the form of eight separate monthly averages for each 3 hour time period and the average over all diurnal phases. Thus, there are nine C2 data sets per month covering the whole time period, (see Appendix 6.3 for more details of C2 data).

Each month of C1 data is contained on two data tapes; the first tape for each month contains the first 16 days of data, while the second tape contains the remainder of the days in that month. Tapes are numbered sequentially from July 1983 onwards. The structure of a C1 data tape is illustrated in Figure 3.1.

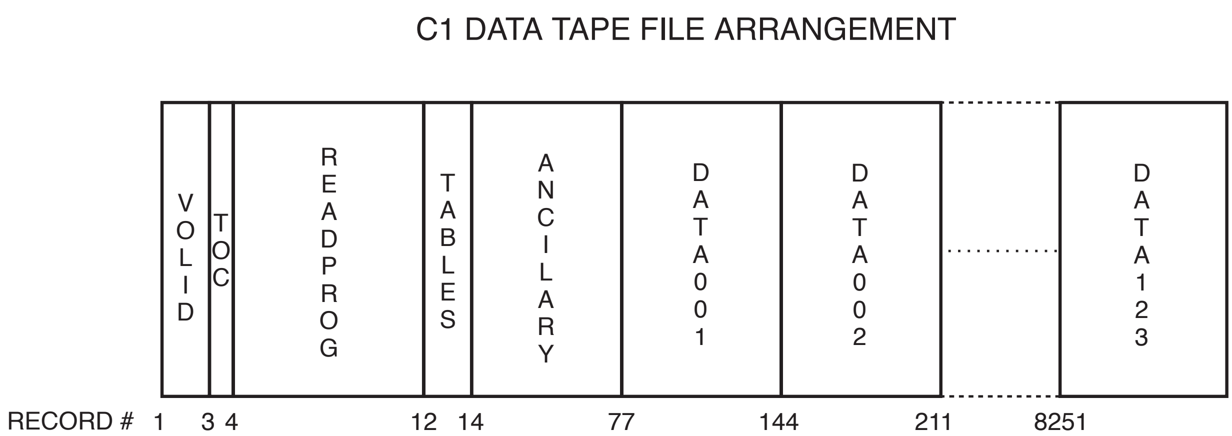

Figure 3.1. File arrangement on C1 data tapes.

Each C1 data file on a tape represents a global set of results for a specific 3 hour time period on a specific date (all data within ± 1.5 hours of the nominal time are included). These files are arranged sequentially in time on each data tape, starting with 0000 GMT on the first or 17th day of the month to 2100 GMT of the 16th or last day of the month. All time periods are represented by a data file, even if no data are available for that time period (such a case has not yet occurred).

Each C1 data set represents a complete global distribution of results. The same number of values is always reported in each data file, even if some data are missing for some locations; missing data values are always represented by count values of 255. The nominal resolution of the map grid is 250 km: each map cell represents an area equal to that of a 2.5° × 2.5° latitude/longitude cell at the equator (actually the dimensions of this cell at the equator are about 278 km, square). The latitude increment in the map grid is 2.5°; the longitude increment in the EQUAL-AREA map grid is variable to preserve a constant cell area (see description of map grids below).

A single C1 data file represents the merging of analysis results from all available satellites within the 3 hour time period; however, in one map cell the values from only one satellite are reported. Each location has an established hierarchy of satellite observations (see Fig. 2.7) based on the variations of viewing geometry and time coverage characteristic of each satellite. For low latitudes, observations from the nearest geostationary satellite are preferred, while in the polar regions (poleward of 55° latitude) the polar orbiter data are preferred. If data from the primary geostationary satellite are not available, then a secondary geostationary satellite may be used if the viewing geometry is not too extreme. If no geostationary data are available at low latitudes, then polar orbiter data are used if available. If no polar orbiter data are available at latitudes poleward of 55°, geostationary data may be reported, if available. Since the time period covered by each data set is 3 hours, anywhere from none to two polar orbiter observations may be reported within this time period. The satellite that contributes the specific results is identified with a code number which is defined in the Volume ID file. The Volume ID indicates which satellites contributed to the tape and the Table of Contents shows contributions for each data file.

Data within a single C1 data file are organized to provide all quantities at each map location. (If no data are available for a particular location, all quantities will be coded as 255.) In C1 data files 132 quantities are reported for each map cell (see description in section 4.6). The sequence of values within a data file gives the 132 quantities for the first map cell (latitude 88.75° S, longitude 1.25° E), then the next cell (latitude 88.75° S, longitude 3.75° E), and so on. The map cells progress in longitude increasing eastward and latitude increasing northward. Each latitude zone is completed before moving to the next latitude zone.

3.2. Map Grids

Two related map grids are used for ISCCP C data sets, an EQUAL-AREA grid and an EQUAL-ANGLE grid. These grids are identical at the equator. The collection of statistics from the satellite analysis, which produces global information at about 30 km resolution, is conducted using an EQUAL-AREA map to maintain a nearly constant statistical weight for results at all locations (see Rossow and Garder 1984). For economy of data storage on the data tapes, the results are also recorded in the same EQUAL-AREA grid. However, since data manipulation on computers and in image displays is more convenient using rectangular arrays, the C1READ program provided with the data will automatically put the data into an EQUAL-ANGLE map grid of 2.5° resolution. This grid is identical to the grid used for ERBE data. The data are transformed to the EQUAL-ANGLE grid by replication, which preserves all of the original statistics (Rossow and Garder 1984), since the grid cells of the EQUAL-ANGLE grid at higher latitudes represent higher resolution (in the longitudinal direction) than in the original data set. If a user wishes to re-map the data to some other projection, the EQUAL-AREA form of the data is most convenient, since the area-weights are all equal.

All data arrays are listed in order from the south pole to the north pole. All longitudes for each latitude zone are listed in order from Greenwich meridian, eastward (longitudes are given in the range 0-360°), before listing the next latitude zone.

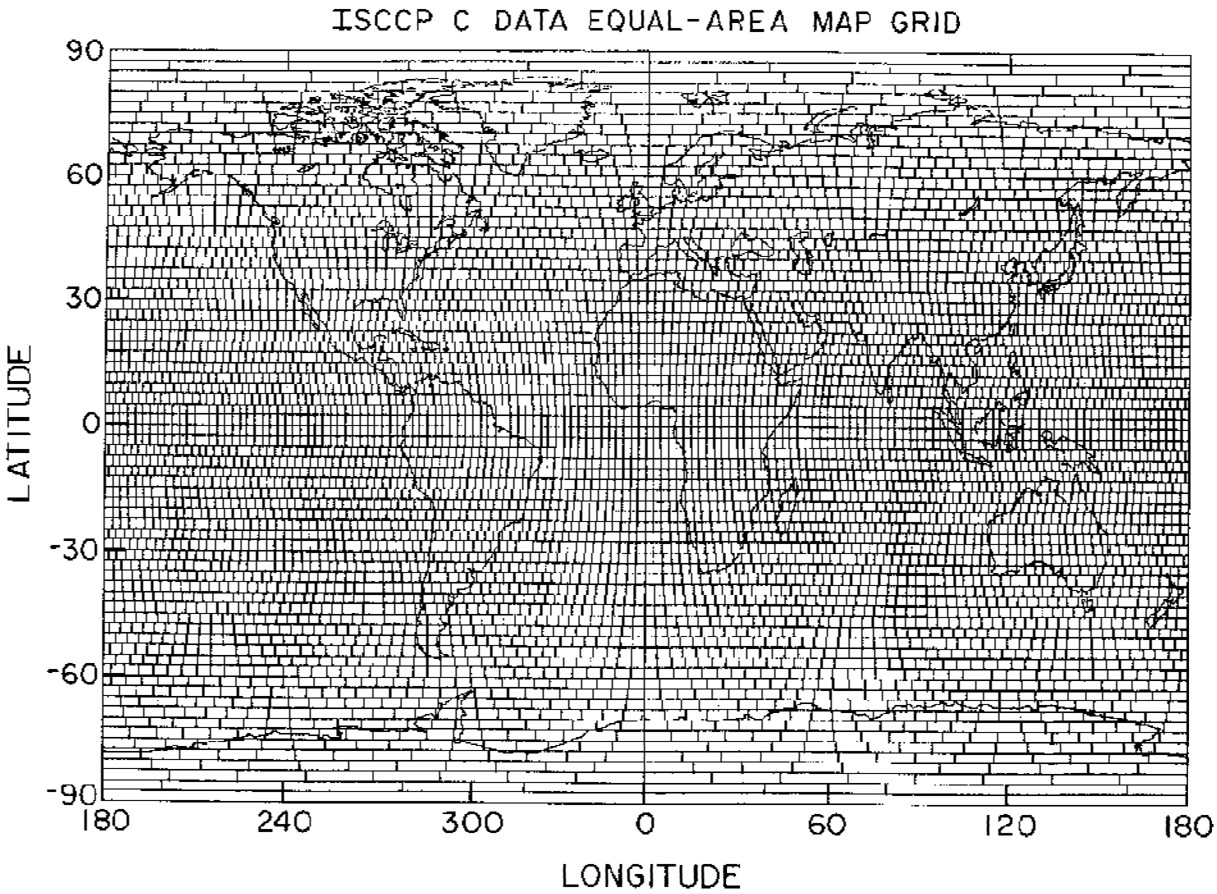

Figure 3.2a. Equal-area map grid used for ISSPC data.

3.2.1. Equal-area grid for data storage

The EQUAL-AREA map (Fig. 3.2) is defined by the area of a 2.5° latitude × 2.5° longitude cell at the equator; the intersection of the Greenwich meridian and the equator is a cell corner. There are 6596 cells in this map grid.

All map cells are determined by a constant 2.5° increment in latitude and a variable longitude increment. The longitude increment is selected to provide an integer number of cells in a latitude zone and to give a cell area as close to that of the equatorial cell as possible. The number of longitude increments for each latitude (first number of each pair is latitude index from 1 to 72) is given below.

1	-	3	19	-	104	37	-	144	55	-	100
2	-	9	20	-	108	38	-	144	56	-	95
3	-	16	21	-	112	39	-	143	57	-	90
4	-	22	22	-	116	40	-	142	58	-	85
5	-	28	23	-	120	41	-	141	59	-	80

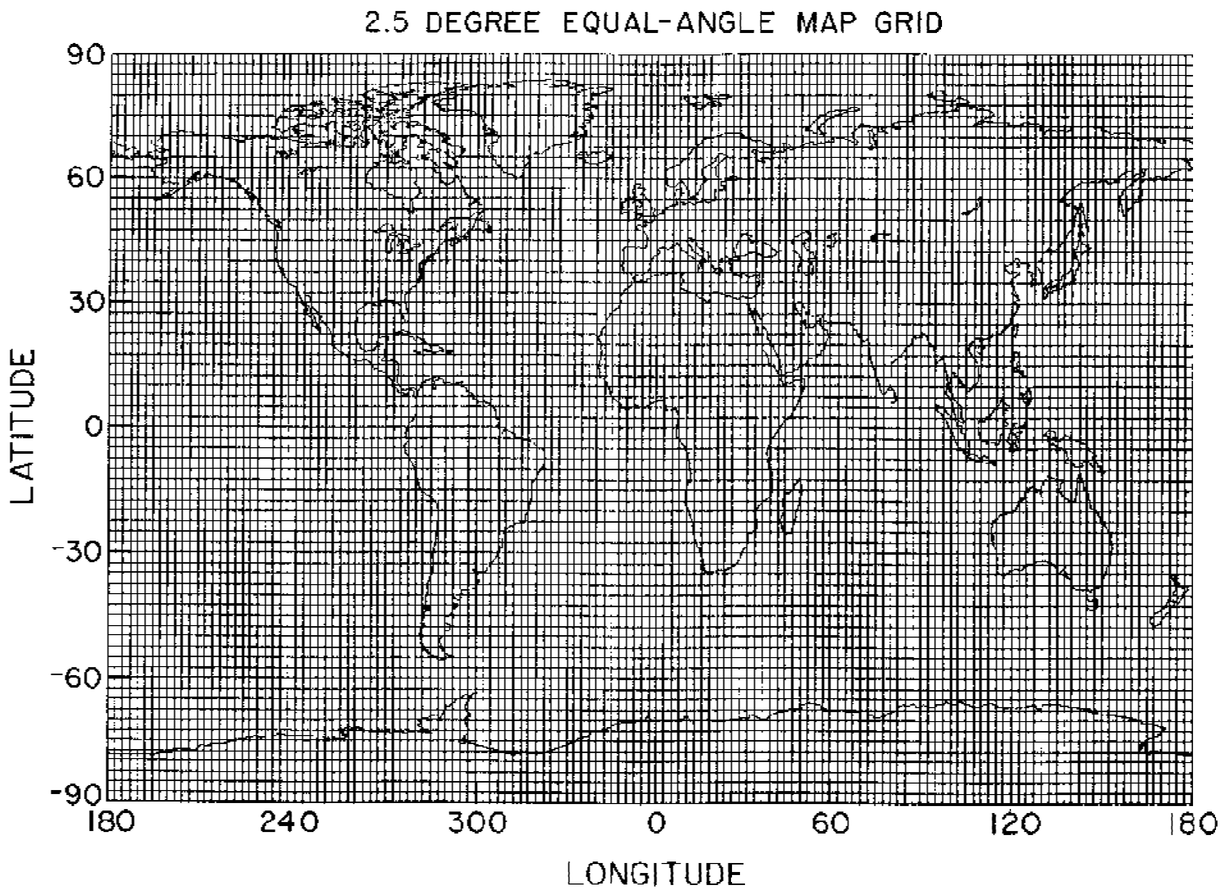

Figure 3.2b. Equal-angle map grid used for ISCCP data.

6	-	34	24	-	123	42	-	140	60	-	75
7	-	40	25	-	126	43	-	138	61	-	69
8	-	46	26	-	129	44	-	136	62	-	64
9	-	52	27	-	132	45	-	134	63	-	58
10	-	58	28	-	134	46	-	132	64	-	52
11	-	64	29	-	136	47	-	129	65	-	46
12	-	69	30	-	138	48	-	126	66	-	40
13	-	75	31	-	140	49	-	123	67	-	34
14	-	80	32	-	141	50	-	120	68	-	28
15	-	85	33	-	142	51	-	116	69	-	22
16	-	90	34	-	143	52	-	112	70	-	16
17	-	95	35	-	144	53	-	108	71	-	9
18	-	100	36	-	144	54	-	104	72	-	3

3.2.2. Equal-angle grid for data output

The C1READ program, provided to read the data files, will automatically replicate the data from the 6596 EQUAL-AREA cells to an EQUAL-ANGLE map grid (Fig. 3.2). This map grid has equal 2.5° increments in latitude and longitude;

there are 10368 cells in this grid (72 latitude zones and 144 longitude intervals). The intersection of the Greenwich meridian and equator is a cell corner; coordinates are given as latitudes from -90° to 90° and longitudes from 0° to 360° (positive eastward).

3.2.3. Geographic information

The fifth file on every C1 data tape contains additional information, reported for each EQUAL-ANGLE map cell: the EQUAL-AREA map grid, the land cover fraction and topography of the surface, and the satellite hierarchy. The map grid information consists of the latitude and longitude indices of the EQUAL-ANGLE map cell, the latitude and longitude of the EQUAL-ANGLE map cell center, the center-longitude of the EQUAL-AREA map cell replicated to that particular EQUAL-ANGLE cell, the EQUAL-AREA cell number (1 to 6596), the location of the cell in all data files (record number within the file and byte number within the record), and the actual area (in km^2) of the original EQUAL-AREA cell. The land cover fraction (0 to 100%) and the mean topographic altitude above mean sea level in meters are also reported. The satellite hierarchy is given by listing the satellites that are the first, second, third and fourth preferences.

Geographic information, such as the land/water/coast classification, topographic altitude, and map cell areas, is defined for the EQUAL-AREA map grid, but reported for each EQUAL-ANGLE map grid cell. Thus, for example, the average topography, when reported in the EQUAL-ANGLE map grid does not represent information with 2.5° longitude resolution at high latitudes.

3.3. Coding of Parameter Values

All quantities in the C data set are reported in the form of positive integer code values, called COUNT values and represented in the data files as one BYTE (8-bit) BINARY values. The 132 quantities reported for each map cell are arranged into two groups: the first 74 values are counts representing integer quantities, while the last 58 values are counts representing physical quantities. The C1READ program automatically converts the first group of count values to integers (I*4 form) and the second group of count values to physical units (R*4 form), where appropriate. Users may wish to retrieve the count values directly for image display purposes, however.

The reported physical parameters are defined in Section 2.5; temperatures are given in Kelvins, pressures in mb, reflectances as a fraction from 0.0 to 1.12, cloud optical thickness as values from 0.02 to 119.59, precipitable water amounts in centimeters, and ozone abundances in Dobson units. IR radiances are reported as brightness temperatures, using the same scale as for other temperatures; VIS radiances are reported in the same units as reflectances (however, a reflectance is not a radiance).

Since most of the parameters derived in the analysis are obtained from measurements of satellite radiances, the precision of such measurements, though roughly constant over the response range of the radiometer, is not constant over the range of some parameters. For example, a radiometer measurement of IR radiances with constant precision does not provide temperature values with constant precision: colder temperatures are not measured with as much precision as warmer temperatures. Hence, the relation between the code values and physical values is not always linear and represents the proper proportionality between the derived parameter and the original radiance measurement. The two instances of a non-linear relation are temperatures and cloud optical thicknesses: the linear variation of count values parallels the linear variation of the amount of energy measured by the radiometer.

Averaging of quantities from C data can be done in two ways, depending on what is appropriate to the purpose. For most quantities with a linear relation between count values and physical values, these two approaches produce identical results. For temperatures and optical thicknesses, however, averaging before conversion to physical units will produce a different result than averaging after conversion.

Input data errors and model errors can result in derived values that are non-physical, especially near zero, or are much smaller/larger than anticipated. To limit the count values to a 1-byte representation requires establishing limits for all quantities. If these limits are violated, then either underflow or overflow occurs. Special count values have been reserved for the physical quantities to indicate these possibilities: count = 0 represents underflow and count = 254 represents overflow. Count 255 is reserved to mean NO DATA, exclusively. For physical quantities, count = 0 is converted to -100.0, count = 254 is converted to -200.0, and count = 255 is converted to -1000.0. (Overflow occurs at lower counts for pressures and cloud optical thicknesses.)

The fourth file on every C1 data tape contains the conversion tables used to translate the COUNT values to physical values; the C1READ program contains the same table and automatically converts all data to physical units.

The standard tropospheric pressure levels used to define the seven atmospheric layers and cloud height categories are 1000 (or PS), 800, 680, 560, 440, 310, 180, and 50 (or PT) mb. The center pressures for these layers, which may be taken to be the pressure locations for the reported quantities, are 900, 740, 620, 500, 375, 245, 115 mb; the actual center pressure of the lowest and highest layers depends on the value of PS and PT (see Section 2.5.1).

In the C1 data, cloud type information is given in the form of the distribution of pixels falling into each of seven tropospheric pressure layers and into each of five optical thickness categories. The five optical thickness categories are defined by the values: 0 to 1.3, 1.3 to 3.6, 3.6 to 9.4, 9.4 to 23, and 23 to 125. The center values, which may be taken to represent the average value of all pixels in each category, are: 0.5, 2.3, 6.0, 14.5, and 30.

4. DATA TAPE FORMAT

4.1. Tape Characteristics

4.1.1. IBM tape structure

The C1 data tapes are written in "IBM Standard Label" format. In this format each actual data file is accompanied by additional, very short, "Header" and "Trailer" files that describe the contents of the actual file. Some computer systems use these files to obtain the "data set name." Users whose computer systems do not use these additional files should read the tape from the second actual file on the tape and read every third file after that. In the discussion to follow, the file numbers referred to are those of actual data files, ignoring the extra Header/Trailer files. The file numbers given at various places in the C1 data also ignore these extra files.

Each C1 data tape consists of the following files with the indicated lengths.

File Number	Data Set Name	Length (Records)	Contents
1	VOLID	2	Volume ID
2	TOC	1	Table of Contents
3	READPROG	8	READ Program
4	TABLES	2	Conversion Tables
5	ANCILARY	63	Ancillary information
6-133	DATA001-DATA123	67	C1 Data

All files on C1 data tapes are separated by standard end-of-file (EOF) marks. The first five files on all tapes provide an assortment of identification and ancillary information; these files are coded entirely as ASCII character data, arranged in groups of 80-character strings representing individual lines of text. The contents of these files are meant to be printed as text. The remaining files on each tape contain the C1 data coded entirely as 1-BYTE BINARY integers; the contents of these files are not meant to be printed as text.

All files are composed of records that are separated by standard inter-record gaps. All records are 13200 BYTES in length.

4.1.2. Tape number

C1 data tapes are numbered consecutively as follows:

GPC.C1.NNNN.V.YYDDD.YYDDD.ISCCP

GPC = Global Processing Center, producer of C1 data,
NASA Goddard Space Flight Center
Institute for Space Studies
New York, NY USA

C1 = type of data

NNNN	=	unique sequence number within the C1 data set
V	=	version number, original version = 0, if a new version of a tape is issued the version number is increased
YYDDD	=	year and Julian day of first data file on tape
YYDDD	=	year and Julian day of last data file on tape
ISCCP	=	International Satellite Cloud Climatology Project, first project of the World Climate Research Programme of the World Meteorological Organization and the International Council of Scientific Unions

The tape number is recorded as ASCII characters in the first 80 bytes of the first (Volume ID) file on every tape.

4.1.3. Reading the tape

4.1.3.1. *Read program*

The third tape file on all C1 tapes contains a program (C1READ) which can be used to read and decode the C1 data files. The program also serves as a guide to the data structure, which is also described completely below. The program, used as a subroutine for a user program, reads one data record at a time to retrieve data for the latitude/longitude range specified by the user program. The count values are converted to INTEGER*4 and REAL*4, as appropriate, and re-mapped to the 2.5° map grid. This program is written in ANSI Standard FORTRAN 77.

4.1.3.2. *Decoding bytes*

Most computer systems cannot perform arithmetic operations with individual BYTES; hence, some form of decoding is necessary to use the information contained in the C1 data files, which are coded exclusively in this form (CHARACTER*1). In C1READ, the subroutine UNPACK performs the conversion from CHARACTER*1 to INTEGER*4 and the subroutine CONVRT translates the code integers to physical quantities in REAL*4.

The conversion of the BYTE values to INTEGER*4 values is performed using the FORTRAN function called ICHAR; this function is declared to be INTRINSIC in the subroutine, UNPACK, so that if the particular computer does not support this procedure, an error message will be generated at LINK time.

If a computer system cannot use this approach or has incompatible definitions of numerical values, the C1 data should be directly decoded, using a local procedure to transform each set of 8 bits in a record into the local representation of positive integers. This local decoding process should replace the subroutine UNPACK, which is clearly labeled in the software listing. Each data record can then be identified as an integer array, called C1INTS (NBYTES, NUMBOX) in the UNPACK subroutine. NBYTES is the number of variables reported for each map cell (= 132 in C1 data) and NUMBOX is the number of map cells in a record, plus one, reported in one record (= 99 + 1 in C1 data). Once this has been done, the rest of the C1READ program should run successfully on all computers.

Another feature of the C1READ program that may cause difficulties is the use of EQUIVALENCE declarations for arrays in BLOCK DATA. Since there are limits on the length of data statements, these declarations are used to assemble the complete conversion tables in COMMON BLOCK CNTTAB from several smaller arrays, which are defined in this subprogram. Users with systems that do not support this process will need to alter BLOCK DATA to initialize COMMON BLOCK CNTTAB. Another way to initialize the table values in COMMON BLOCK CNTTAB is to read the fourth file on each data tape that contains the same conversion tables, represented as ASCII text.

4.1.3.3. *Data record structure*

Each data record (in Files 6-133 for C1 data) begins with a numerical prefix that identifies the record and its contents. This is followed by the parameter values for 99 map cells for C1 data. The prefix is the same length as the data for one map cell and contains:

BYTE	CONTENTS	C1 VALUE
1	Record number within file	(1-67)
2	File number on tape	(6-133)
3	Year of data set	(83-95)
4	Month	(1-12)
5	Day	(1-31)
6	GMT	(0,3,6...21)
7	Latitude index of first cell in record	
8	Equal-area longitude index of first cell in record	
9	Latitude index of last cell in record	
10	Equal-area longitude index of last cell in record	
11-132	= 255	

4.2. Volume ID File

The VOLUME ID (File 1) is coded entirely as ASCII characters, arranged into 80-character groups representing individual lines of text, and meant to be printed as text. This file provides a complete description of the tape structure and data format, as well as identification of the sources of data. The contents are listed below (each item ends in a blank line). The Volume ID file for the first C1 tape is shown in Section 4.7. Later data tapes list in this file the input Stage B3 data tape numbers used to produce the particular Stage C1 data.

Line Number	Contents
1 - 2	Tape number
3 - 6	Data type and project name
7 - 9	Date and time of first and last data files on tape
10 - 15	Address of originating center
16 - 17	Tape creation date
18 - 23	Address of archives for data
24 - 32	Satellites contributing data to the particular tape (unused lines left blank)

Line Number	Contents
33 - 40	Definition of satellite types
41 - 45	Sources and types of correlative data used
46 - 58	Description of file order and record characteristics
59 - 95	Description of tape files and contents
96 - 111	Description of data record structure
112 - 163	Description of map grids and geographic information
164 - 168	Definition of land/water/coast surface types
169 - 319	Variable definitions
320 - 330	Blank

4.3. Table of Contents File

The TABLE OF CONTENTS (File 2) provides a file-by-file listing for each data file and is coded entirely as ASCII characters. The first two lines (80-characters each or 160 BYTES) are the headings for the table of numerical values to follow. Each one line summary lists the file number, the year, month, day, and GMT of the data, percent of the map cells with data, and the code numbers of the specific satellites contributing data to that file.

4.4. Read Program File

The READ PROGRAM (File 3) file provides the C1READ subroutine which can be used to read, decode, and re-map the C1 data files. The file is coded entirely as ASCII characters, meant to be printed as text. This subroutine retrieves the data from one record at a time. To illustrate the use of the C1READ program, a SAMPLE MAIN program is provided that prints all the quantities from one particular longitude for all latitudes. A schematic of the program is shown in Fig. 4.1; documentation contained in the software listing explains the functions of each component of the program.

(i) For the initial call to the subroutine C1READ, the subroutine "EQUARE" calculates quantities needed to re-map the data from the EQUAL-AREA map grid to the 2.5° EQUAL-ANGLE (latitude/longitude) map grid. The first data record is read, using the subroutine C1REC.

(ii) In C1REC the C1 data record is read and translated from CHARACTER*1 to INTEGER*4 by the subroutine UNPACK. Note that this subroutine calls the function ICHAR. The data record prefix is decoded in the subroutine PREFIX.

(iii) Output variable arrays are initialized so that missing data will be reported as an integer value of 255 or a real value of -1000.0.

(iv) The data records are searched until the first latitude specified by the user is found. If the desired cell is not in the "current" record, the next data record is read and decoded by subroutines C1REC, UNPACK and PREFIX.

(v) If the desired cell is present, the count values, which have been converted from CHARACTER*1 form to INTEGER*4 form, are converted to physical units where appropriate in the subroutine CONVRT. The first 74 quantities are integer values and are not

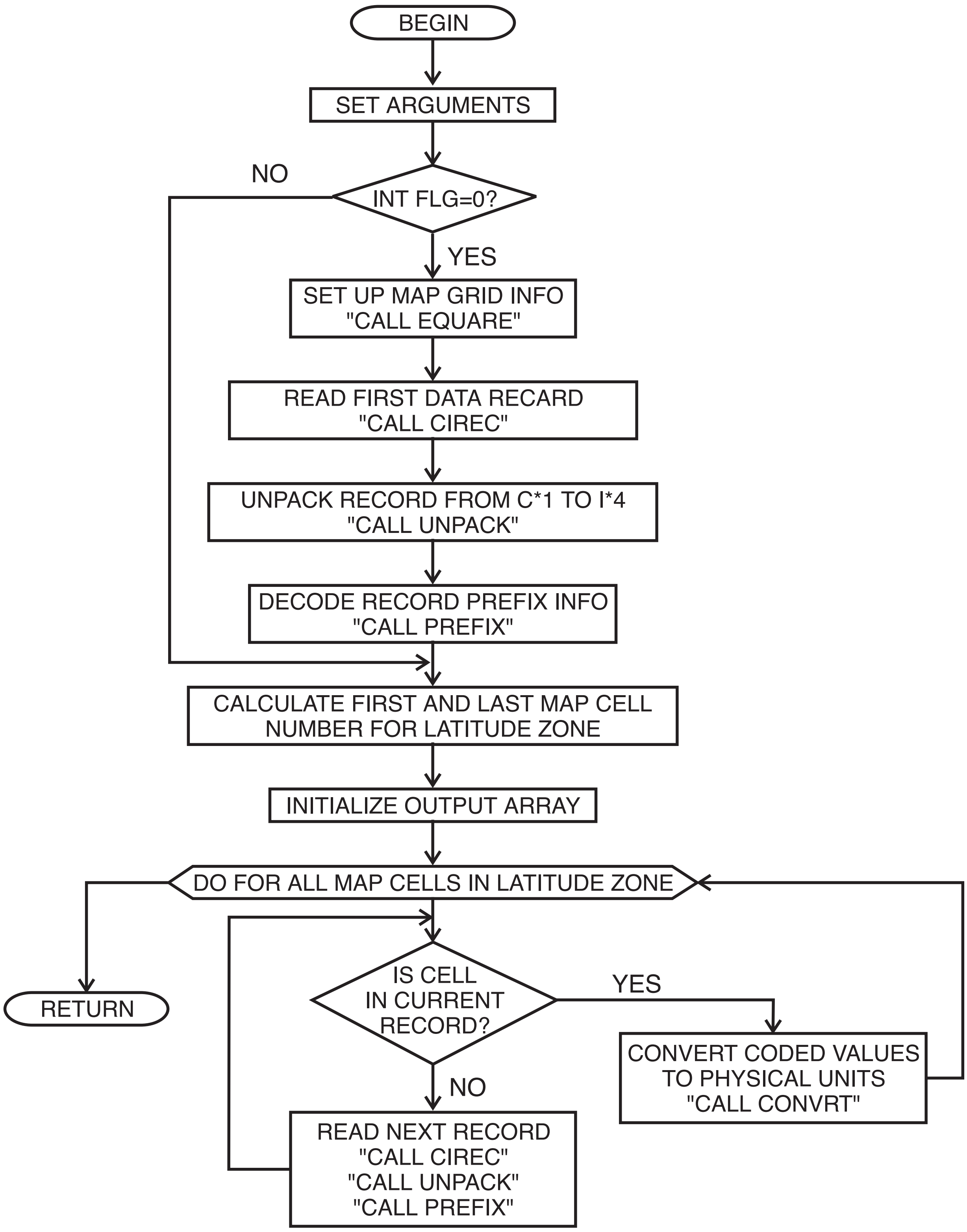

Figure 4.1. Program schematic for SUBROUTINE CIREAD.

converted; the remaining 58 values are changed to REAL*4. The conversion tables are initialized in a BLOCK DATA subprogram that defines the arrays in COMMON BLOCK CNTTAB. These tables are used as lookup arrays by CONVRT. Note the use of EQUIVALENCE declarations in this subprogram.

(vi) The data are returned to the calling MAIN program through the COMMON C1DATA.

4.5. Ancillary Data Files

4.5.1. Conversion tables

The CONVERSION TABLES (File 4), used to convert the integer count values to physical quantities, are also provided in this file. The file is written in ASCII characters that are meant to be printed as text. The first three lines of text (80-characters each or 240 BYTES) are headings for the table of numerical values to follow. Each subsequent 80-character string represents one line of the tables listing the COUNT value and the corresponding temperatures in Kelvins, pressures in millibars, reflectances and VIS radiances as dimensionless fractions, optical thickness as a dimensionless number, humidity in precipitable centimeters, and ozone abundance in Dobson units.

4.5.2. Map grid information

The ANCILLARY DATA (File 5) provides geographic and map grid information for each cell in the 2.5° map grid as a one line summary. The information is recorded as ASCII characters that are meant to be printed as text. The first two lines (80-characters each or 160 BYTES) are headings for the table of numerical values to follow. Listed on each line are the latitude index (same for both map grids, 1-72), the longitude index for the 2.5° map grid, latitude and longitude at the center of the 2.5° map cell, longitude at the center of the EQUAL-AREA map cell, the EQUAL-AREA cell number that is mapped to that EQUAL-ANGLE cell, the record number where that cell is found in ALL data files, the number of the first byte in the record that contains data for that cell, the EQUAL-AREA cell area in km^2, the land fraction in percent, the topographic altitude of the surface (meters), and the satellite hierarchy for that cell (first, second, third and fourth preference).

4.6. Data Files

All C1 data files are coded entirely as 1-BYTE BINARY values; these values are not meant to be printed as text. The first data file on C1 data tapes is always File 6. If the tape is the first C1 tape of the month, File 6 contains data for 0000 GMT on day 1; File 133 on that tape contains data for 2100 GMT on day 16. If the tape is the second C1 tape of the month, then File 6 contains data for 0000 GMT for day 17 and the last file (file number 101, 109, 117, or 125) contains data for 2100 GMT for the last day of that month.

Each data file is composed of 67 data records for C1, each 13200 BYTES in length. Each C1 data record begins with a 132 BYTE prefix that identifies the contents of that record. The prefix is followed by 99 map cells of data, each represented by 132 BYTES.

4.6.1. Record prefix

The record prefix for C1 data records contains the following:

BYTE NO.	CONTENTS	C1 VALUE
1	Record number within file	(1-67)
2	File number on tape	(6-133)

BYTE NO.	CONTENTS	C1 VALUE
3	Year of data set	(83-95)
4	Month	(1-12)
5	Day	(1-31)
6	GMT	(0,3,6...21)
7	Latitude index of first cell in record	
8	Equal-area longitude index of first cell in record	
9	Latitude index of last cell in record	
10	Equal-area longitude index of last cell in record	
11-132	= 255	

4.6.2. Parameter arrangement

For each map cell in a C1 data file, 132 quantities are reported as defined below (see also the Volume ID file). Each quantity is reported as a single byte, representing a BINARY code or COUNT value. These BYTE (or CHARACTER*1) values are converted into INTEGER*4 count values in the C1READ program.

C1 DATA PARAMETERS

Byte No.	Contents
Location information:	
1	Latitude index (equal-area)
2	Longitude index (equal-area)
3	Lower longitude index (2.5° lat/lon)
4	Upper longitude index (2.5° lat/lon)
Cloud amount:	
5	Total number of pixels
6	Number of cloudy pixels
7	Number of IR-cloudy pixels
8	Number of marginal IR-cloudy pixels
9(d)	Number of marginal VIS/IR-cloudy pixels
10(d)	Number of IR-only-cloudy pixels

Identification, snow/ice and viewing geometry:

11	Day/Night/Land/Water/Coast code
12	Satellite identification
13	Snow/ice cover percent
14(d)	Cosine of solar zenith angle (MU0 = 0-100)
15	Cosine of satellite zenith angle (MUE = 0-100)
16(d)	Relative azimuth angle (PHI = 0 - 180 degrees)

Clear sky quality information:

17	Number of pixels with long term statistics
18(d)	Number of pixels from cloud contaminated region (VIS)
19	Number of pixels cooler than clear IR
20	Number of pixels warmer than clear IR
21	Number of pixels much warmer than clear IR
22(d)	Number of clear IR pixels brighter than clear VIS
23(d)	Number of clear IR pixels darker than clear VIS
24(d)	Number of clear IR pixels much darker than clear VIS
25	Number of clear pixels showing IR cloud contamination in RAD ANAL

PC distribution (UNADJUSTED PC)

26	Number of pixels	5 < PC < 180 mb
27	Number of pixels	180 < PC < 310 mb
28	Number of pixels	310 < PC < 440 mb
29	Number of pixels	440 < PC < 560 mb
30	Number of pixels	560 < PC < 680 mb
31	Number of pixels	680 < PC < 800 mb
32	Number of pixels	800 < PC < 1000 mb

PC distribution (VIS-ONLY CLOUDY, UNADJUSTED PC)

33(d)	Number of pixels	5 < PC < 180 mb
34(d)	Number of pixels	180 < PC < 310 mb
35(d)	Number of pixels	310 < PC < 440 mb
36(d)	Number of pixels	440 < PC < 560 mb
37(d)	Number of pixels	560 < PC < 680 mb
38(d)	Number of pixels	680 < PC < 800 mb
39(d)	Number of pixels	800 < PC < 1000 mb

PC/TAU distribution (ADJUSTED PC)

40(d)	Number of pixels	5 < PC < 180 mb	0.02 < TAU < 1.27
41(d)	Number of pixels	5 < PC < 180 mb	1.27 < TAU < 3.55
42(d)	Number of pixels	5 < PC < 180 mb	3.55 < TAU < 9.38
43(d)	Number of pixels	5 < PC < 180 mb	9.38 < TAU < 22.63
44(d)	Number of pixels	5 < PC < 180 mb	22.63 < TAU < 119.59
45(d)	Number of pixels	180 < PC < 310 mb	0.02 < TAU < 1.27
46(d)	Number of pixels	180 < PC < 310 mb	1.27 < TAU < 3.55
47(d)	Number of pixels	180 < PC < 310 mb	3.55 < TAU < 9.38
48(d)	Number of pixels	180 < PC < 310 mb	9.38 < TAU < 22.63
49(d)	Number of pixels	180 < PC < 310 mb	22.63 < TAU < 119.59

50(d)	Number of pixels	310 < PC < 440 mb	0.02 < TAU < 1.27
51(d)	Number of pixels	310 < PC < 440 mb	1.27 < TAU < 3.55
52(d)	Number of pixels	310 < PC < 440 mb	3.55 < TAU < 9.38
53(d)	Number of pixels	310 < PC < 440 mb	9.38 < TAU < 22.63
54(d)	Number of pixels	310 < PC < 440 mb	22.63 < TAU < 119.59
55(d)	Number of pixels	440 < PC < 560 mb	0.02 < TAU < 1.27
56(d)	Number of pixels	440 < PC < 560 mb	1.27 < TAU < 3.55
57(d)	Number of pixels	440 < PC < 560 mb	3.55 < TAU < 9.38
58(d)	Number of pixels	440 < PC < 560 mb	9.38 < TAU < 22.63
59(d)	Number of pixels	440 < PC < 560 mb	22.63 < TAU < 119.59
60(d)	Number of pixels	560 < PC < 680 mb	0.02 < TAU < 1.27
61(d)	Number of pixels	560 < PC < 680 mb	1.27 < TAU < 3.55
62(d)	Number of pixels	560 < PC < 680 mb	3.55 < TAU < 9.38
63(d)	Number of pixels	560 < PC < 680 mb	9.38 < TAU < 22.63
64(d)	Number of pixels	560 < PC < 680 mb	22.63 < TAU < 119.59
65(d)	Number of pixels	680 < PC < 800 mb	0.02 < TAU < 1.27
66(d)	Number of pixels	680 < PC < 800 mb	1.27 < TAU < 3.55
67(d)	Number of pixels	680 < PC < 800 mb	3.55 < TAU < 9.38
68(d)	Number of pixels	680 < PC < 800 mb	9.38 < TAU < 22.63
69(d)	Number of pixels	680 < PC < 800 mb	22.63 < TAU < 119.59
70(d)	Number of pixels	800 < PC < 1000 mb	0.02 < TAU < 1.27
71(d)	Number of pixels	800 < PC < 1000 mb	1.27 < TAU < 3.55
72(d)	Number of pixels	800 < PC < 1000 mb	3.55 < TAU < 9.38
73(d)	Number of pixels	800 < PC < 1000 mb	9.38 < TAU < 22.63
74(d)	Number of pixels	800 < PC < 1000 mb	22.63 < TAU < 119.59

Mean cloud properties:

75	Mean PC for IR-cloudy pixels
76	Sigma-PC for IR-cloudy pixels
77	Mean PC for marginal IR-cloudy pixels
78(d)	Mean PC for VIS/IR-cloudy pixels
79(d)	Mean PC for marginal VIS/IR-cloudy pixels
80	Mean TC for IR-cloudy pixels
81	Sigma-TC for IR-cloudy pixels
82	Mean TC for marginal IR-cloudy pixels
83(d)	Mean TC for VIS/IR-cloudy pixels
84(d)	Mean TC for marginal VIS/IR-cloudy pixels
85(d)	Mean TAU for VIS/IR-cloudy pixels
86(d)	Sigma-TAU for VIS/IR-cloudy pixels
87(d)	Mean TAU for marginal IR-cloudy pixels
88(d)	Mean TAU for marginal VIS/IR-cloudy pixels

Mean surface properties:

89	Mean TS from clear sky composite
90	Mean TS for IR-clear pixels
91	Sigma-TS for IR-clear pixels
92(d)	Mean TS for VIS/IR-clear pixels
93(d)	Mean RS from clear sky composite
94(d)	Mean RS for VIS/IR-clear pixels
95(d)	Sigma-RS for VIS/IR-clear pixels
96(d)	Mean RS for IR-clear pixels

Mean radiances:

97	Mean IR for IR-cloudy pixels
98	Sigma-IR for IR-cloudy pixels
99(d)	Mean IR for VIS/IR-cloudy pixels
100	Mean IR for IR-clear pixels
101	Sigma-IR for IR-clear pixels
102(d)	Mean IR for VIS/IR-clear pixels
103	Mean IR from clear sky composite
104(d)	Mean VIS for VIS/IR-cloudy pixels
105(d)	Sigma-VIS for VIS/IR-cloudy pixels
106(d)	Mean VIS for IR-cloudy pixels
107(d)	Mean VIS for VIS/IR-clear pixels
108(d)	Sigma-VIS for VIS/IR-clear pixels
109(d)	Mean VIS for IR-clear pixels
110(d)	Mean VIS from clear sky composite

Coincident cloud amount differences:

111	Difference in mean MUE
112	Difference in mean cloud frequency

Atmospheric properties:

113	Atmospheric origin code
114	PS, surface pressure
115	TS, surface temperature
116	T, temperature 900 mb
117	T, temperature 740 mb
118	T, temperature 620 mb
119	T, temperature 500 mb
120	T, temperature 375 mb
121	T, temperature 245 mb
122	T, temperature 115 mb
123	PT, tropopause pressure
124	TT, tropopause temperature
125	ST, stratosphere temperature at 50 mb
126	ST, stratosphere temperature at 15 mb
127	PW, precipitable water for 1000-800 mb
128	PW, precipitable water for 800-680 mb
129	PW, precipitable water for 680-560 mb
130	PW, precipitable water for 560-440 mb
131	PW, precipitable water for 440-310 mb
132	O3, ozone abundance

The upper/lower longitude indices indicate the range of longitudes in the 2.5° map grid into which the particular cell will be replicated; the range of values for both longitude indices is 1 to 144. The combined day/night and land/water/coast code value indicates surface type (water, land, coast) and whether VIS data are used (day, night); codes 1, 2, and 3 indicate water, land, coast during the day and codes 101, 102, and 103 indicate the same three surface types at night. The satellite ID codes are explained in the Volume ID file; each map cell contains data from only one satellite. Snow and ice cover are represented as the fractional cover of the grid cell without regard to the mixing of land and water; i.e., this value represents the fractional cover of "solid water".

Abbreviations are TAU = optical thickness, PC = cloud top pressure, TC = cloud top temperature, PS = surface pressure, TS = surface temperature, RS = surface reflectance, T = atmospheric temperature, PT = tropopause pressure, TT = tropopause temperature, ST = stratospheric temperature, PW = atmospheric water vapor layer amount as precipitable centimeters, and O3 = ozone column abundance. RAD ANAL refers to the radiative model analysis step. The MEAN of a value for C1 data refers to an average of all pixel results in the grid cell at one time; SIGMA in C1 data refers to the standard deviation of a quantity within the cell, given in the same units as the mean value. ADJUSTMENT refers to the adjustment of cloud top pressure and temperature to account for the effects of low optical thickness. The atmospheric ORIGIN code refers to the TOVS data that follow and indicates the source of the values occurring in the particular cell (see Appendix A).

There are two types of quantities reported in C1 data: all-day quantities and daytime-only quantities. The former are values determined using only the IR radiance data in the analysis, so that their meaning is the same under day or night conditions; the latter are determined using both the VIS and IR radiance data in the analysis and are reported only during the daytime (at night these BYTES = 255). The daytime-only quantities are indicated by "(d)" following the byte number.

The first derivative of the cloud amount with radiance threshold magnitude is indicated by the term MARGINAL; this gives the number of pixels near the dividing value for CLEAR and CLOUDY and indicates the amount of change in the cloud amount caused by doubling the radiance threshold values. The prefixes, VIS/IR and IR, refer to which radiance data are used to obtain a value.

The magnitude of the effect of doubling the radiance thresholds on the cloud physical properties is also given: a larger threshold causes the cloud amount to decrease, the cloud top temperature to decrease (cloud top pressure will also decrease), and the optical thickness to increase. These first derivatives can be calculated by:

$$d\frac{\bar{X}}{dTHR} = \frac{N_m}{N - N_m} (\bar{X}-\bar{X}_m)$$

$$\bar{X}_{adj} = \bar{X} + \frac{d\bar{X}}{dTHR} = \frac{NX - N_m X_m}{N-N_m}$$

where $\bar{X}$ is the reported mean quantity (e.g., BYTE 78), dTHR is equal to the threshold magnitude (see Section 2.3.2), N_m is the number of "marginal" cloudy pixels (e.g., BYTE 9), N is the total number of cloudy pixels (e.g., BYTE 6), X_m is the mean quantity for the marginal cloudy pixels (e.g., BYTE 79), and X_{adj} is the new value of $\bar{X}$ if the radiance thresholds are doubled.

4.6.3. Location of specific values

Each quantity on a C1 tape is always found in exactly the same position within a data file for easy collection of samples of the full information. In other words, finding the same value for each grid cell, some few values for particular grid cells, or any other subset of the data is made simple by the fixed structure. In File 5, the location of a particular map cell within a data file is given for each latitude/longitude in the 2.5° map grid in the form of the record number and the number of the first byte of that cell within the record. Combining this information with the relative byte number of a particular value from the list above allows for the pre-calculation of the specific location (BYTE and record numbers) of any quantity at any location on Earth.

4.7. Sample Volume ID File

GPC.C1.0001.1.83182.83197.ISCCP

CLOUD CLIMATOLOGY PRODUCT
International Satellite Cloud Climatology Project
World Climate Research Program

First data file:	1983	7	1	00	(Year Month Day GMT)
Last data file:	1983	7	16	21	(Year Month Day GMT)

Tape Produced at: NASA Goddard Space Flight Center
Institute for Space Studies
2880 Broadway
New York, N.Y. 10025
USA

Creation date: 1988 7 25 (Year Month Day)

Tape archived at: Satellite Data Services Division
National Environmental Satellite Data
and Information Service
National Oceanic and Atmospheric Administration
Washington, DC 20233
USA

Contributing Satellites:			Processing Center:
Sat-ID-Code 11	Type 6	NOAA-7	National Oceanic & Atmosheric Admin.
Sat-ID-Code 21	Type 3	GOES-6	Colorado State University
Sat-ID-Code 31	Type 4	GOES-5	University of Wisconsin
Sat-ID-Code 41	Type 2	METEOSAT-2	European Space Agency
Sat-ID-Code 52	Type 1	GMS-2	Japan Meteorological Agency

Satellite types:	1	Western Pacific	Geostationary
	2	European	Geostationary
	3	Eastern Pacific	Geostationary
	4	American	Geostationary
	5	Asian	Geostationary
	6	Afternoon	Polar Orbiter
	7	Morning	Polar Orbiter

Correlative Data:	TOVS	NOAA/NESDIS
	Snow cover	NOAA/NESDIS
	Sea ice	US Navy/NOAA
	Topography	National Center for Atmospheric Research

Tape Format:			
	File 1 —	Volume ID	(2 records)
	File 2 —	Table of Contents	(1 record)
	File 3 —	READ program	(8 records)
	File 4 —	Variable Conversion Table	(2 records)
	File 5 —	Ancillary Data Table	(63 records)
	File 6 through 133 —	CLOUD DATA	(67 records/ file)

The logical record length for each file is 13200 bytes.

Files 1 through 5 are written in ASCII and are meant to be printed as text. They should be separated into logical records of 80 characters representing lines of text. The remaining data files are written as binary data, not meant to be printed.

Conversion Tables: (File 4 - ASCII) The seven tables convert the 8-bit counts in the data files to the appropriate physical units as given below. The count values represent positive integers from 0 to 254 (inclusive) with 255 always indicating no data.

Temperature	in Kelvin
Temperature variance	in Kelvin
Pressure	in Millibars
Reflectance	Fraction of Solar Constant
Optical Depth (Tau)	dimensionless
Humidity	in precipitable centimeters
Ozone Abundance	in Dobson Units

Ancillary Data: (File 5 - ASCII) Tabular format, for each Equal-Angle cell:

- Latitude Index of cell
- Longitude Index of cell
- Latitude of cell
- Longitude of cell
- Longitude of Equal-Area box mapped to this cell
- Cell number of Equal-Area box mapped to this cell
- Cell locator: Record number
- Cell locator: Byte number within record
- Area of Equal-Area box mapped to this cell
- Land Fraction of Equal-Area box mapped to this cell
- Topographic Altitude of Equal-Area box mapped to this cell
- Satellite Hierarchy: First
- Satellite Hierarchy: Second
- Satellite Hierarchy: Third
- Satellite Hierarchy: Fourth

Data: (Binary) Global data every three hours with spatial resolution of 250 km (nominal). One month of data resides on 2 tapes.

Tape 1:	file 6	is	Day 1	, GMT 00
	file 133	is	Day 16	, GMT 21
Tape 2:	file 6	is	Day 17	, GMT 00
	file NNN	is	Last Day	, GMT 21
				(where NNN <125)

Record Structure: Each record has a 132-byte prefix followed by 99 cells of 132 bytes each (adding up to 13200 bytes). The first 10 bytes of the prefix contain the following, reported as 8-bit positive integers:

Byte 1:	Record number in file	(1 - 67)
Byte 2:	File number on tape	(6 - 133)
Byte 3:	Year of dataset	(83 - 90)
Byte 4:	Month	(1 - 12)
Byte 5:	Day	(1 - 31)
Byte 6:	GMT	(0,3,6...,21)
Byte 7:	First Latitude Equal Area index in record	
Byte 8:	First Longitude Equal Area index in record	
Byte 9:	Last Latitude Equal Area index in record	
Byte 10:	Last Longitude Equal Area index in record	

Byte 11 through 132 are equal to 255 (no data)

Mapping: Data are stored on tape in Equal-Area Grid format 6596 Grid Boxes in Equal Area Map; (0,0) is a box corner. The sequential box numbering system assigns a number between 1 and 6596 to each Equal-Area box, starting from the South Pole at the Greenwich Meridian. Within each latitude belt the numbers then increase eastward from the zero degree meridian. Box numbers increase northward in latitude. In each hemisphere there are 3298 boxes.

Output from READ program is in Equal-Angle Grid format 10368 Grid Cells in Equal Latitude/Longitude Map Latitude begins at -90 degrees (South Pole) moving to +90 (North Pole). Longitude begins at 0 degrees and moves to 360 positive eastward.

Equal-Area Map:

Latitude Index	Number of Cells	Latitude Index	Number of Cells
1	3	37	144
2	9	38	144
3	16	39	143
4	22	40	142
5	28	41	141
6	34	42	140
7	40	43	138
8	46	44	136
9	52	45	134
10	58	46	132
11	64	47	129
12	69	48	126
13	75	49	123
14	80	50	120
15	85	51	116
16	90	52	112
17	95	53	108
18	100	54	104
19	104	55	100
20	108	56	95
21	112	57	90
22	116	58	85
23	120	59	80
24	123	60	75

25	126	61	69
26	129	62	64
27	132	63	58
28	134	64	52
29	136	65	46
30	138	66	40
31	140	67	34
32	141	68	28
33	142	69	22
34	143	70	16
35	144	71	9
36	144	72	3

Land/Water/Coast classification of Equal-Area Cells:
- Land cell has fraction 65 - 100%
- Coast cell has land fraction 36 - 64%
- Water cell has land fraction 0 - 35%

Variable Definitions for each cell:

Variables labeled with "d" are present only during local daytime.

Variable abbreviations:

IR	=	IR radiance
VIS	=	Visible radiance
SIGMA	=	Variance of quantity
PC	=	Cloud Top Pressure
PS	=	Surface Pressure
PT	=	Tropopause Pressure
TC	=	Cloud Top Temperature
TS	=	Surface Temperature
TT	=	Tropopause Temperature
T	=	Atmospheric Temperature
TAU	=	Cloud Optical Thickness
RS	=	Surface Reflectance
PW	=	Precipitable Water

Byte No.	Description
Location information:	
1	Latitude index (equal-area)
2	Longitude index (equal-area)
3	Lower longitude index (2.5° lat/lon)
4	Upper longitude index (2.5° lat/lon)
Cloud amount:	
5	Total number of pixels
6	Number of cloudy pixels
7	Number of IR-cloudy pixels
8	Number of marginal IR-cloudy pixels
9(d)	Number of marginal VIS/IR-cloudy pixels
10(d)	Number of IR-only-cloudy pixels
Identification, snow/ice and viewing geometry:	
11	Day/Night/Land/Water/Coast code
12	Satellite identification
13	Snow/ice cover percent
14(d)	Cosine of solar zenith angle (MU0 = 0-100)
15	Cosine of satellite zenith angle (MUE = 0-100)
16(d)	Relative azimuth angle (PHI = 0 - 180 degrees)

Clear sky quality information:

17	Number of pixels with long term statistics
18(d)	Number of pixels from cloud contaminated region (VIS)
19	Number of pixels cooler than clear IR
20	Number of pixels warmer than clear IR
21	Number of pixels much warmer than clear IR
22(d)	Number of clear IR pixels brighter than clear VIS
23(d)	Number of clear IR pixels darker than clear VIS
24(d)	Number of clear IR pixels much darker than clear VIS
25	Number of clear pixels showing IR cloud contamination in RAD ANAL

PC distribution (UNADJUSTED PC)

26	Number of pixels 5 < PC < 180 mb
27	Number of pixels 180 < PC < 310 mb
28	Number of pixels 310 < PC < 440 mb
29	Number of pixels 440 < PC < 560 mb
30	Number of pixels 560 < PC < 680 mb
31	Number of pixels 680 < PC < 800 mb
32	Number of pixels 800 < PC < 1000 mb

PC distribution (VIS-ONLY CLOUDY, UNADJUSTED PC)

33(d)	Number of pixels 5 < PC < 180 mb
34(d)	Number of pixels 180 < PC < 310 mb
35(d)	Number of pixels 310 < PC < 440 mb
36(d)	Number of pixels 440 < PC < 560 mb
37(d)	Number of pixels 560 < PC < 680 mb
38(d)	Number of pixels 680 < PC < 800 mb
39(d)	Number of pixels 800 < PC < 1000 mb

PC/TAU distribution (ADJUSTED PC)

40(d)	Number of pixels 5 < PC < 180 mb	0.02 < TAU < 1.27
41(d)	Number of pixels 5 < PC < 180 mb	1.27 < TAU < 3.55
42(d)	Number of pixels 5 < PC < 180 mb	3.55 < TAU < 9.38
43(d)	Number of pixels 5 < PC < 180 mb	9.38 < TAU < 22.63
44(d)	Number of pixels 5 < PC < 180 mb	22.63 < TAU < 119.59
45(d)	Number of pixels 180 < PC < 310 mb	0.02 < TAU < 1.27
46(d)	Number of pixels 180 < PC < 310 mb	1.27 < TAU < 3.55
47(d)	Number of pixels 180 < PC < 310 mb	3.55 < TAU < 9.38
48(d)	Number of pixels 180 < PC < 310 mb	9.38 < TAU < 22.63
49(d)	Number of pixels 180 < PC < 310 mb	22.63 < TAU < 119.59
50(d)	Number of pixels 310 < PC < 440 mb	0.02 < TAU < 1.27
51(d)	Number of pixels 310 < PC < 440 mb	1.27 < TAU < 3.55
52(d)	Number of pixels 310 < PC < 440 mb	3.55 < TAU < 9.38
53(d)	Number of pixels 310 < PC < 440 mb	9.38 < TAU < 22.63
54(d)	Number of pixels 310 < PC < 440 mb	22.63 < TAU < 119.59
55(d)	Number of pixels 440 < PC < 560 mb	0.02 < TAU < 1.27
56(d)	Number of pixels 440 < PC < 560 mb	1.27 < TAU < 3.55
57(d)	Number of pixels 440 < PC < 560 mb	3.55 < TAU < 9.38
58(d)	Number of pixels 440 < PC < 560 mb	9.38 < TAU < 22.63
59(d)	Number of pixels 440 < PC < 560 mb	22.63 < TAU < 119.59
60(d)	Number of pixels 560 < PC < 680 mb	0.02 < TAU < 1.27
61(d)	Number of pixels 560 < PC < 680 mb	1.27 < TAU < 3.55
62(d)	Number of pixels 560 < PC < 680 mb	3.55 < TAU < 9.38
63(d)	Number of pixels 560 < PC < 680 mb	9.38 < TAU < 22.63
64(d)	Number of pixels 560 < PC < 680 mb	22.63 < TAU < 119.59
65(d)	Number of pixels 680 < PC < 800 mb	0.02 < TAU < 1.27

66(d)	Number of pixels	680 < PC < 800 mb	1.27 < TAU < 3.55
67(d)	Number of pixels	680 < PC < 800 mb	3.55 < TAU < 9.38
68(d)	Number of pixels	680 < PC < 800 mb	9.38 < TAU < 22.63
69(d)	Number of pixels	680 < PC < 800 mb	22.63 < TAU < 119.59
70(d)	Number of pixels	800 < PC < 1000 mb	0.02 < TAU < 1.27
71(d)	Number of pixels	800 < PC < 1000 mb	1.27 < TAU < 3.55
72(d)	Number of pixels	800 < PC < 1000 mb	3.55 < TAU < 9.38
73(d)	Number of pixels	800 < PC < 1000 mb	9.38 < TAU < 22.63
74(d)	Number of pixels	800 < PC < 1000 mb	22.63 < TAU < 119.59

Mean cloud properties:

75	Mean PC for IR-cloudy pixels
76	Sigma-PC for IR-cloudy pixels
77	Mean PC for marginal IR-cloudy pixels
78(d)	Mean PC for VIS/IR-cloudy pixels
79(d)	Mean PC for marginal VIS/IR-cloudy pixels
80	Mean TC for IR-cloudy pixels
81	Sigma-TC for IR-cloudy pixels
82	Mean TC for marginal IR-cloudy pixels
83(d)	Mean TC for VIS/IR-cloudy pixels
84(d)	Mean TC for marginal VIS/IR-cloudy pixels
85(d)	Mean TAU for VIS/IR-cloudy pixels
86(d)	Sigma-TAU for VIS/IR-cloudy pixels
87(d)	Mean TAU for marginal IR-cloudy pixels
88(d)	Mean TAU for marginal VIS/IR-cloudy pixels

Mean surface properties:

89	Mean TS from clear sky composite
90	Mean TS for IR-clear pixels
91	Sigma-TS for IR-clear pixels
92(d)	Mean TS for VIS/IR-clear pixels
93(d)	Mean RS from clear sky composite
94(d)	Mean RS for VIS/IR-clear pixels
95(d)	Sigma-RS for VIS/IR-clear pixels
96(d)	Mean RS for IR-clear pixels

Mean radiances:

97	Mean IR for IR-cloudy pixels
98	Sigma-IR for IR-cloudy pixels
99(d)	Mean IR for VIS/IR-cloudy pixels
100	Mean IR for IR-clear pixels
101	Sigma-IR for IR-clear pixels
102(d)	Mean IR for VIS/IR-clear pixels
103	Mean IR from clear sky composite
104(d)	Mean VIS for VIS/IR-cloudy pixels
105(d)	Sigma-VIS for VIS/IR-cloudy pixels
106(d)	Mean VIS for IR-cloudy pixels
107(d)	Mean VIS for VIS/IR-clear pixels
108(d)	Sigma-VIS for VIS/IR-clear pixels
109(d)	Mean VIS for IR-clear pixels
110(d)	Mean VIS from clear sky composite

Coincident cloud amount differences:

111	Difference in mean MUE
112	Difference in mean cloud frequency

Atmospheric properties:

113	Atmospheric origin code
114	PS, surface pressure
115	TS, surface temperature
116	T, temperature 900 mb
117	T, temperature 740 mb
118	T, temperature 620 mb
119	T, temperature 500 mb
120	T, temperature 375 mb
121	T, temperature 245 mb
122	T, temperature 115 mb
123	PT, tropopause pressure
124	TT, tropopause temperature
125	ST, stratosphere temperature at 50 mb
126	ST, stratosphere temperature at 15 mb
127	PW, precipitable water at 900 mb
128	PW, precipitable water at 740 mb
129	PW, precipitable water at 620 mb
130	PW, precipitable water at 500 mb
131	PW, precipitable water at 375 mb
132	O3, ozone abundance

4.8. Sample Table of Contents File

The first ten lines of the second file on a C1 data tape look similar to the following.

FILE	YEAR	MONTH	DAY	GMT	DATA CELL STATS		SATELLITE TYPES IN DATA						
					%GOOD	%EMPTY	1	2	3	4	5	6	7
6	1983	7	1	0	78	22	52	41	21	31	0	0	0
7	1983	7	1	3	87	13	52	41	21	31	0	11	0
8	1983	7	1	6	88	12	52	41	21	31	0	11	0
9	1983	7	1	9	91	9	52	41	21	31	0	11	0
10	1983	7	1	12	91	9	52	41	21	31	0	11	0
11	1983	7	1	15	88	12	52	41	21	31	0	11	0
12	1983	7	1	18	71	29	52	0	21	31	0	11	0
13	1983	7	1	21	91	9	52	41	21	31	0	11	0

4.9. Conversion Tables

The fourth file on a C1 data tape contains the following table to convert coded BYTE values to physical quantities.

Note: Count value 255 always represents bad data

COUNT	TEMPERATURE	TEMP-VAR	PRESSURE	REFLECT	TAU	PRECIP WATER	OZONE
0	-100.000	-100.000	-100.000	-100.000	-100.000	-100.000	-100.0
1	165.000	0.075	1.000	0.000	0.020	0.000	0.0
2	169.000	0.300	5.000	0.008	0.040	0.030	2.0
3	172.000	0.600	10.000	0.012	0.060	0.060	4.0
4	175.000	0.900	15.000	0.016	0.090	0.090	6.0
5	177.800	1.200	20.000	0.020	0.110	0.120	8.0
6	180.500	1.500	25.000	0.024	0.140	0.150	10.0
7	183.000	1.800	30.000	0.028	0.160	0.180	12.0
8	185.500	2.100	35.000	0.032	0.190	0.210	14.0
9	187.800	2.400	40.000	0.036	0.220	0.240	16.0
10	190.000	2.700	45.000	0.040	0.240	0.270	18.0

11	192.000	3.000	50.000	0.044	0.270	0.300	20.0
12	194.000	3.300	55.000	0.048	0.300	0.330	22.0
13	195.700	3.600	60.000	0.052	0.330	0.360	24.0
14	197.500	3.900	65.000	0.056	0.370	0.390	26.0
15	199.200	4.200	70.000	0.060	0.400	0.420	28.0
16	201.000	4.500	75.000	0.064	0.430	0.450	30.0
17	202.700	4.800	80.000	0.068	0.460	0.480	32.0
18	204.500	5.100	85.000	0.072	0.500	0.510	34.0
19	206.200	5.400	90.000	0.076	0.530	0.540	36.0
20	208.000	5.700	95.000	0.080	0.570	0.570	38.0
21	209.700	6.000	100.000	0.084	0.600	0.600	40.0
22	211.500	6.300	105.000	0.088	0.640	0.630	42.0
23	212.800	6.600	110.000	0.092	0.680	0.660	44.0
24	214.100	6.900	115.000	0.096	0.720	0.690	46.0
25	215.400	7.200	120.000	0.100	0.750	0.720	48.0
26	216.700	7.500	125.000	0.104	0.790	0.750	50.0
27	217.900	7.800	130.000	0.108	0.830	0.780	52.0
28	219.200	8.100	135.000	0.112	0.870	0.810	54.0
29	220.500	8.400	140.000	0.116	0.920	0.840	56.0
30	221.800	8.700	145.000	0.120	0.960	0.870	58.0
31	223.100	9.000	150.000	0.124	1.000	0.900	60.0
32	224.400	9.300	155.000	0.128	1.040	0.930	62.0
33	225.400	9.600	160.000	0.132	1.090	0.960	64.0
34	226.500	9.900	165.000	0.136	1.130	0.990	66.0
35	227.500	10.200	170.000	0.140	1.180	1.020	68.0
36	228.600	10.500	175.000	0.144	1.220	1.050	70.0
37	229.600	10.800	180.000	0.148	1.270	1.080	72.0
38	230.600	11.100	185.000	0.152	1.320	1.110	74.0
39	231.700	11.400	190.000	0.156	1.370	1.140	76.0
40	232.700	11.700	195.000	0.160	1.420	1.170	78.0
41	233.800	12.000	200.000	0.164	1.470	1.200	80.0
42	234.800	12.300	205.000	0.168	1.520	1.230	82.0
43	235.700	12.600	210.000	0.172	1.570	1.260	84.0
44	236.600	12.900	215.000	0.176	1.620	1.290	86.0
45	237.500	13.200	220.000	0.180	1.670	1.320	88.0
46	238.400	13.500	225.000	0.184	1.730	1.350	90.0
47	239.200	13.800	230.000	0.188	1.780	1.380	92.0
48	240.100	14.100	235.000	0.192	1.830	1.410	94.0
49	241.000	14.400	240.000	0.196	1.890	1.440	96.0
50	241.900	14.700	245.000	0.200	1.950	1.470	98.0
51	242.800	15.000	250.000	0.204	2.000	1.500	100.0
52	243.700	15.300	255.000	0.208	2.060	1.530	102.0
53	244.500	15.600	260.000	0.212	2.120	1.560	104.0
54	245.300	15.900	265.000	0.216	2.180	1.590	106.0
55	246.100	16.200	270.000	0.220	2.240	1.620	108.0
56	246.900	16.500	275.000	0.224	2.300	1.650	110.0
57	247.700	16.800	280.000	0.228	2.360	1.680	112.0
58	248.500	17.100	285.000	0.232	2.430	1.710	114.0
59	249.300	17.400	290.000	0.236	2.490	1.740	116.0
60	250.100	17.700	295.000	0.240	2.550	1.770	118.0
61	250.900	18.000	300.000	0.244	2.620	1.800	120.0
62	251.700	18.300	305.000	0.248	2.690	1.830	122.0
63	252.400	18.600	310.000	0.252	2.750	1.860	124.0
64	253.100	18.900	315.000	0.256	2.820	1.890	126.0
65	253.900	19.200	320.000	0.260	2.890	1.920	128.0
66	254.600	19.500	325.000	0.264	2.960	1.950	130.0
67	255.300	19.800	330.000	0.268	3.030	1.980	132.0

68	256.000	20.100	335.000	0.272	3.100	2.010	134.0
69	256.700	20.400	340.000	0.276	3.180	2.040	136.0
70	257.500	20.700	345.000	0.280	3.250	2.070	138.0
71	258.200	21.000	350.000	0.284	3.320	2.100	140.0
72	258.900	21.300	355.000	0.288	3.400	2.130	142.0
73	259.500	21.600	360.000	0.292	3.480	2.160	144.0
74	260.200	21.900	365.000	0.296	3.550	2.190	146.0
75	260.800	22.200	370.000	0.300	3.630	2.220	148.0
76	261.500	22.500	375.000	0.304	3.710	2.250	150.0
77	262.100	22.800	380.000	0.308	3.790	2.280	152.0
78	262.800	23.100	385.000	0.312	3.880	2.310	154.0
79	263.400	23.400	390.000	0.316	3.960	2.340	156.0
80	264.100	23.700	395.000	0.320	4.040	2.370	158.0
81	264.700	24.000	400.000	0.324	4.130	2.400	160.0
82	265.400	24.300	405.000	0.328	4.220	2.430	162.0
83	266.000	24.600	410.000	0.332	4.300	2.460	164.0
84	266.600	24.900	415.000	0.336	4.390	2.490	166.0
85	267.200	25.200	420.000	0.340	4.480	2.520	168.0
86	267.800	25.500	425.000	0.344	4.570	2.550	170.0
87	268.400	25.800	430.000	0.348	4.670	2.580	172.0
88	269.100	26.100	435.000	0.352	4.760	2.610	174.0
89	269.700	26.400	440.000	0.356	4.850	2.640	176.0
90	270.300	26.700	445.000	0.360	4.950	2.670	178.0
91	270.900	27.000	450.000	0.364	5.050	2.700	180.0
92	271.500	27.300	455.000	0.368	5.150	2.730	182.0
93	272.100	27.600	460.000	0.372	5.250	2.760	182.0
94	272.700	27.900	465.000	0.376	5.350	2.790	186.0
95	273.200	28.200	470.000	0.380	5.450	2.820	188.0
96	273.800	28.500	475.000	0.384	5.560	2.850	190.0
97	274.400	28.800	480.000	0.388	5.660	2.880	192.0
98	275.000	29.100	485.000	0.392	5.770	2.910	194.0
99	275.600	29.400	490.000	0.396	5.880	2.940	196.0
100	276.100	29.700	495.000	0.400	5.990	2.970	198.0
101	276.700	30.000	500.000	0.404	6.110	3.000	200.0
102	277.300	30.300	505.000	0.408	6.220	3.030	202.0
103	277.800	30.600	510.000	0.412	6.340	3.060	204.0
104	278.400	30.900	515.000	0.416	6.450	3.090	206.0
105	278.900	31.200	520.000	0.420	6.570	3.120	208.0
106	279.500	31.500	525.000	0.424	6.690	3.150	210.0
107	280.000	31.800	530.000	0.428	6.820	3.180	212.0
108	280.500	32.100	535.000	0.432	6.940	3.210	214.0
109	281.100	32.400	540.000	0.436	7.070	3.240	216.0
110	281.600	32.700	545.000	0.440	7.190	3.270	218.0
111	282.200	33.000	550.000	0.444	7.330	3.300	220.0
112	282.700	33.300	555.000	0.448	7.460	3.330	222.0
113	283.200	33.600	560.000	0.452	7.590	3.360	224.0
114	283.700	33.900	565.000	0.456	7.730	3.390	226.0
115	284.200	34.200	570.000	0.460	7.870	3.420	228.0
116	284.700	34.500	575.000	0.464	8.010	3.450	230.0
117	285.200	34.800	580.000	0.468	8.150	3.480	232.0
118	285.800	35.100	585.000	0.472	8.300	3.510	234.0
119	286.300	35.400	590.000	0.476	8.440	3.540	236.0
120	286.800	35.700	595.000	0.480	8.590	3.570	238.0
121	287.300	36.000	600.000	0.484	8.740	3.600	240.0
122	287.800	36.300	605.000	0.488	8.900	3.630	242.0
123	288.300	36.600	610.000	0.492	9.060	3.660	244.0
124	288.800	36.900	615.000	0.496	9.220	3.690	246.0

125	289.300	37.200	620.000	0.500	9.380	3.720	248.0
126	289.800	37.500	625.000	0.504	9.540	3.750	250.0
127	290.200	37.800	630.000	0.508	9.710	3.780	252.0
128	290.700	28.100	635.000	0.512	9.880	3.810	254.0
129	291.200	28.400	640.000	0.516	10.050	3.840	256.0
130	291.700	38.700	645.000	0.520	10.230	3.870	258.0
131	292.200	39.000	650.000	0.524	10.410	3.900	260.0
132	292.700	39.300	655.000	0.528	10.590	3.930	262.0
133	293.200	39.600	660.000	0.532	10.780	3.960	264.0
134	293.600	39.900	665.000	0.536	10.970	3.990	266.0
135	294.100	40.200	670.000	0.540	11.160	4.020	268.0
136	294.600	40.500	675.000	0.544	11.350	4.050	270.0
137	295.000	40.800	680.000	0.548	11.550	4.080	272.0
138	295.500	41.100	685.000	0.552	11.760	4.110	274.0
139	296.000	41.400	690.000	0.556	11.960	4.140	276.0
140	296.500	41.700	695.000	0.560	12.170	4.170	278.0
141	296.900	42.000	700.000	0.564	12.390	4.200	280.0
142	297.400	42.300	705.000	0.568	12.600	4.230	282.0
143	297.800	42.600	710.000	0.572	12.830	4.260	284.0
144	298.300	42.900	715.000	0.576	13.050	4.290	286.0
145	298.700	43.200	720.000	0.580	13.280	4.320	288.0
146	299.200	43.500	725.000	0.584	13.520	4.350	290.0
147	299.600	43.800	730.000	0.588	13.760	4.380	292.0
148	300.100	44.100	735.000	0.592	14.000	4.410	294.0
149	300.500	44.400	740.000	0.596	14.250	4.440	296.0
150	301.000	44.700	745.000	0.600	14.510	4.470	298.0
151	301.400	45.000	750.000	0.604	14.770	4.500	300.0
152	301.900	45.300	755.000	0.608	15.030	4.530	302.0
153	302.300	45.600	760.000	0.612	15.300	4.560	304.0
154	302.800	45.900	765.000	0.616	15.580	4.590	306.0
155	303.200	46.200	770.000	0.620	15.860	4.620	308.0
156	303.600	46.500	775.000	0.624	16.150	4.650	310.0
157	304.000	46.800	780.000	0.628	16.440	4.680	312.0
158	304.500	47.100	785.000	0.632	16.740	4.710	314.0
159	304.900	47.400	790.000	0.636	17.050	4.740	316.0
160	305.300	47.700	795.000	0.640	17.360	4.770	318.0
161	305.800	48.000	800.000	0.644	17.690	4.800	320.0
162	306.200	48.300	805.000	0.648	18.020	4.830	322.0
163	306.600	48.600	810.000	0.652	18.350	4.860	324.0
164	307.000	48.900	815.000	0.656	18.700	4.890	326.0
165	307.500	49.200	820.000	0.660	19.050	4.920	328.0
166	307.900	49.500	825.000	0.664	19.410	4.950	330.0
167	308.300	49.800	830.000	0.668	19.780	4.980	332.0
168	308.700	50.100	835.000	0.672	20.160	5.010	334.0
169	309.100	50.400	840.000	0.676	20.540	5.040	336.0
170	309.600	50.700	845.000	0.680	20.940	5.070	338.0
171	310.000	51.000	850.000	0.684	21.350	5.100	340.0
172	310.400	51.300	855.000	0.688	21.770	5.130	342.0
173	310.800	51.600	860.000	0.692	22.200	5.160	344.0
174	311.200	51.900	865.000	0.696	22.630	5.190	346.0
175	311.600	52.200	870.000	0.700	23.080	5.220	348.0
176	312.000	52.500	875.000	0.704	23.550	5.250	350.0
177	312.400	52.800	880.000	0.708	24.030	5.280	352.0
178	312.900	53.100	885.000	0.712	24.520	5.310	354.0
179	313.300	53.400	890.000	0.716	25.020	5.340	356.0
180	313.700	53.700	895.000	0.720	25.540	5.370	358.0
181	314.100	54.000	900.000	0.724	26.070	5.400	360.0

182	314.500	54.300	905.000	0.728	26.620	5.430	362.0
183	314.900	54.600	910.000	0.732	27.190	5.460	364.0
184	315.300	54.900	915.000	0.736	27.770	5.490	366.0
185	315.700	55.200	920.000	0.740	28.370	5.520	368.0
186	316.100	55.500	925.000	0.744	28.990	5.550	370.0
187	316.400	55.800	930.000	0.748	29.630	5.580	372.0
188	316.800	56.100	935.000	0.752	30.290	5.610	374.0
189	317.200	56.400	940.000	0.756	30.970	5.640	376.0
190	317.600	56.700	945.000	0.760	31.670	5.670	378.0
191	318.000	57.000	950.000	0.764	32.400	5.700	380.0
192	318.400	57.300	955.000	0.768	33.160	5.730	382.0
193	318.800	57.600	960.000	0.772	33.940	5.760	384.0
194	319.200	57.900	965.000	0.776	34.740	5.790	386.0
195	319.500	58.200	970.000	0.780	35.580	5.820	388.0
196	319.900	58.500	975.000	0.784	36.450	5.850	390.0
197	320.300	58.800	980.000	0.788	37.350	5.880	392.0
198	320.700	59.100	985.000	0.792	38.290	5.910	394.0
199	321.100	59.400	990.000	0.796	39.260	5.940	396.0
200	321.400	59.700	995.000	0.800	40.260	5.970	398.0
201	321.800	60.000	1000.000	0.804	41.320	6.000	400.0
202	322.200	60.300	1005.000	0.808	42.420	8.030	402.0
203	322.600	60.600	1010.000	0.812	43.570	6.060	404.0
204	323.000	60.900	1015.000	0.816	44.760	6.090	406.0
205	323.300	61.200	1020.000	0.820	46.000	6.120	408.0
206	323.700	61.500	1025.000	0.824	47.310	6.150	410.0
207	324.100	61.800	1030.000	0.828	48.680	6.180	412.0
208	324.500	62.100	1035.000	0.832	50.110	6.210	414.0
209	324.900	62.400	1040.000	0.836	51.600	6.240	416.0
210	325.200	62.700	1045.000	0.840	53.170	6.270	418.0
211	325.600	63.000	1050.000	0.844	54.840	6.300	420.0
212	326.000	63.300	1055.000	0.848	56.590	6.330	422.0
213	326.400	63.600	1060.000	0.852	58.430	6.360	424.0
214	326.700	63.900	1065.000	0.856	60.360	6.390	426.0
215	327.100	64.200	1070.000	0.860	62.400	6.420	428.0
216	327.400	64.500	1075.000	0.864	64.590	6.450	430.0
217	327.800	64.800	1080.000	0.868	66.900	6.480	432.0
218	328.200	65.100	1085.000	0.872	69.360	6.510	434.0
219	328.500	65.400	1090.000	0.876	71.960	6.540	436.0
220	328.900	65.700	1095.000	0.880	74.720	6.570	438.0
221	329.200	66.000	1100.000	0.884	77.730	6.600	440.0
222	329.600	66.300	1105.000	0.888	80.940	6.630	442.0
223	329.900	66.600	1110.000	0.892	84.380	6.660	444.0
224	330.300	66.900	1115.000	0.896	88.060	6.690	446.0
225	330.600	67.200	1120.000	0.900	92.020	6.720	448.0
226	331.000	67.500	1125.000	0.904	101.010	6.750	450.0
227	331.300	67.800	1130.000	0.908	105.510	6.780	452.0
228	331.700	68.100	1135.000	0.912	109.870	6.810	454.0
229	332.000	68.400	1140.000	0.916	114.330	6.840	456.0
230	332.400	68.700	1145.000	0.920	119.590	6.870	458.0
231	332.700	69.000	1150.000	0.924	-200.000	6.900	460.0
232	333.100	69.300	1155.000	0.928	-200.000	6.930	462.0
233	333.400	69.600	1160.000	0.932	-200.000	6.960	464.0
234	333.800	69.900	1165.000	0.936	-200.000	6.990	466.0
235	334.100	70.200	1170.000	0.940	-200.000	7.020	468.0
236	334.500	70.500	1175.000	0.944	-200.000	7.050	470.0
237	334.800	70.800	1180.000	0.948	-200.000	7.080	472.0
238	335.200	71.100	1185.000	0.952	-200.000	7.110	474.0

239	335.500	71.400	1190.000	0.956	-200.000	7.140	476.0
240	335.900	71.700	1195.000	0.960	-200.000	7.170	478.0
241	336.200	72.000	1200.000	0.964	-200.000	7.200	480.0
242	336.600	72.300	-200.000	0.968	-200.000	7.230	482.0
243	336.900	72.600	-200.000	0.972	-200.000	7.260	484.0
244	337.300	72.900	-200.000	0.976	-200.000	7.290	486.0
245	337.600	73.200	-200.000	0.980	-200.000	7.320	488.0
246	338.000	73.500	-200.000	0.984	-200.000	7.350	490.0
247	338.300	73.800	-200.000	0.988	-200.000	7.380	492.0
248	338.600	74.100	-200.000	0.992	-200.000	7.410	494.0
249	339.000	74.400	-200.000	1.000	-200.000	7.440	496.0
250	339.300	74.700	-200.000	1.016	-200.000	7.470	498.0
251	339.700	75.400	-200.000	1.040	-200.000	7.500	500.0
252	340.000	78.000	-200.000	1.072	-200.000	7.650	505.0
253	345.000	85.000	-200.000	1.108	-200.000	8.000	515.0
254	-200.000	-200.000	-200.000	-200.000	-200.000	-200.000	-200.0
255	-1000.000	-1000.000	-1000.000	-1000.000	-1000.000	-1000.000	-1000.0

4.10. Sample of Map Grid Information

The first ten lines of the fifth file on a C1 data tape look like the following.

		Actual	Longitude		Cell Location						Sat Hier			
Lat	Lon	Lat	Square	Eq Area	Num	Rec	Byte	Area	Land	Topog	1	2	3	4
1	1	-88.75	1.25	60.00	1	1	133	80949.	100	2895	6	7	0	0
1	2	-88.75	3.75	60.00	1	1	133	80949.	100	2895	6	7	0	0
1	3	-88.75	6.25	60.00	1	1	133	80949.	100	2895	6	7	0	0
1	4	-88.75	8.75	60.00	1	1	133	80949.	100	2895	6	7	0	0
1	5	-88.75	11.25	60.00	1	1	133	80949.	100	2895	6	7	0	0
1	6	-88.75	13.75	60.00	1	1	133	80949.	100	2895	6	7	0	0
1	7	-88.75	16.25	60.00	1	1	133	80949.	100	2895	6	7	0	0
1	8	-88.75	18.75	60.00	1	1	133	80949.	100	2895	6	7	0	0

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