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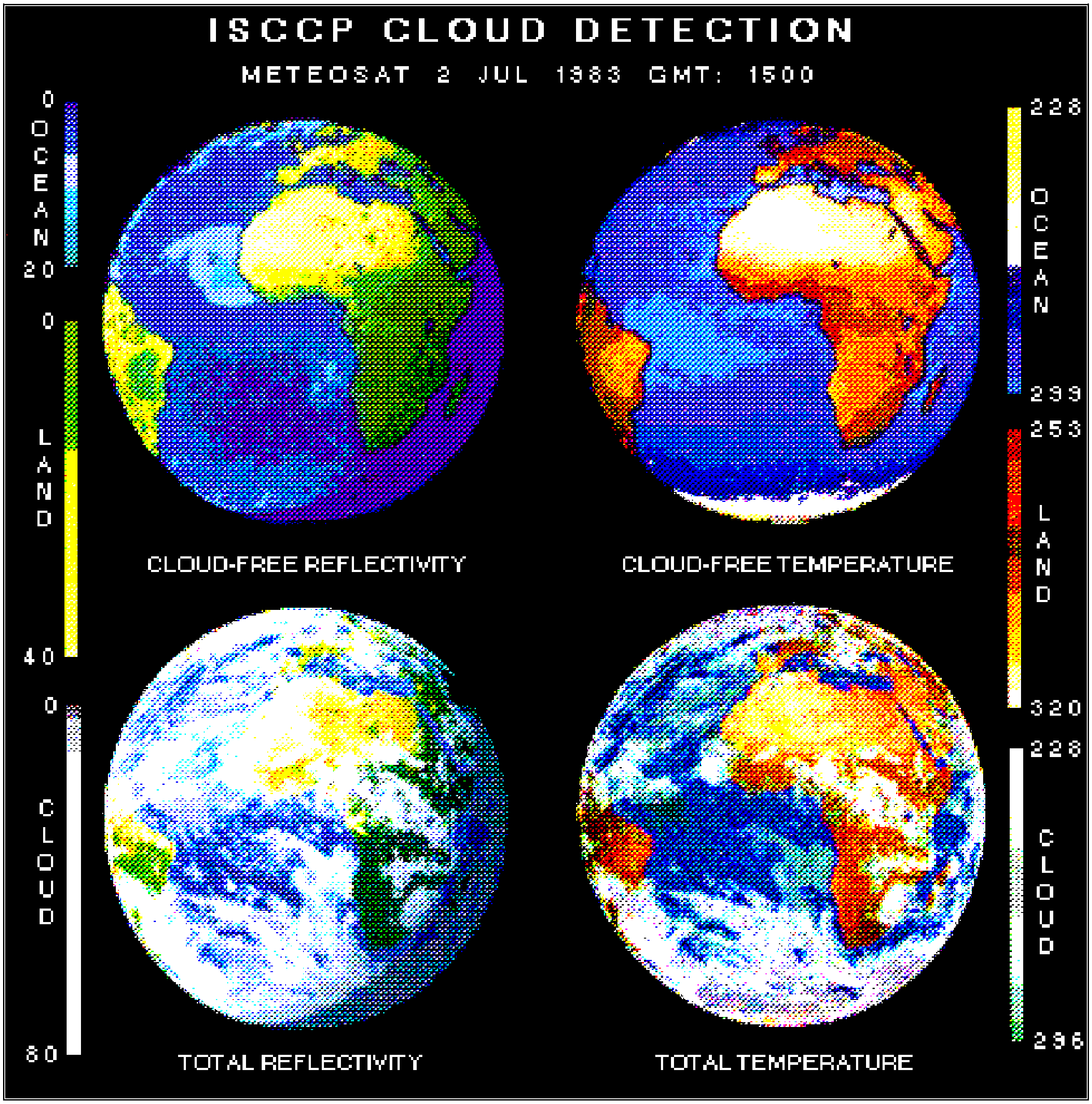

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ISCCP Global Radiance Data Set: A New Resource for Climate Research

R.A. Schiffer[1] and
W.B. Rossow[2]

Abstract

The operational data-collection phase of the International Satellite Cloud Climatology Project (ISCCP) began in July 1983 as an element of the World Climate Research Program (WCRP). Since then, raw images from an international network of operational geostationary and polar-orbiting meteorological satellites have been routinely processed to develop a global data set of calibrated radiances and derived cloud parameters for climate research. This report outlines the key steps involved in producing the basic ISCCP reduced-resolution global radiance (B3) data set, describes the main features of the data set, and indicates the principal point of contact for obtaining copies of the data tapes. A future paper will focus on the derived cloud properties and their utilization.

1. Introduction

The objectives and strategy for the ISCCP were first described by Schiffer and Rossow (1983). ISCCP will collect and analyze satellite radiance data to infer the global distribution of cloud radiative properties in order to improve the modeling of cloud effects on climate. The basic ISCCP scientific objectives given in the "Preliminary Implementation Plan" (World Climate Program, 1982) are:

1) to produce a global, reduced-resolution, calibrated and normalized, infrared- and visible-radiance data set, along with basic information on the radiative properties of the atmosphere, from which cloud parameters can be derived;
2) to coordinate basic research on techniques for inferring the physical properties of clouds from satellite radiance data, and to derive and validate a global cloud climatology;
3) to promote research using ISCCP data to improve parameterizations of clouds in climate models, and to improve understanding of the earth's radiation budget (top-of-the-atmosphere and surface) and hydrological cycle.

Data specifications (goals) for the ISCCP data products are summarized in Table 1. Global coverage for the ISCCP is provided by the five geostationary meteorological satellites (*GOES-East, GOES-West,* GMS, *INSAT*, and *METEOSAT*), and at least one polar-orbiting NOAA satellite. The primary data are from the two standard visible (0.6 μm) and infrared (11 μm) channels common (roughly) to all of the satellites; however, all channels available on the imaging radiometers are saved. The polar orbiter is essential to the project for providing coverage of the polar regions not viewed by the geostationary satellites, a basis for normalization of the radiances observed by the different geostationary satellites, global coverage (although at the expense of diurnal sampling) that may help mitigate the occasional loss of one or more geostationary satellites, and multispectral observations for discriminating cloud properties not derivable from the primary two-channel data.

The strategy adopted for implementing the ISCCP reflects the diverse nature of the spaceborne observing system and the extremely large volume of image data produced routinely by the operational weather satellites. Primary data processing is the responsibility of eight institutions: a Sector Processing Center (SPC) for each satellite (nominally one polar orbiter and five geostationary satellites), the Satellite Calibration Center (SCC), and the Global Processing Center (GPC). Additional Special Area Processing Centers (SAPC) provide limited high-resolution data from designated satellites for regional research projects. Another center coordinates the delivery of conventional meteorological data and the other satellite data (correlative data) to the GPC for use in the cloud

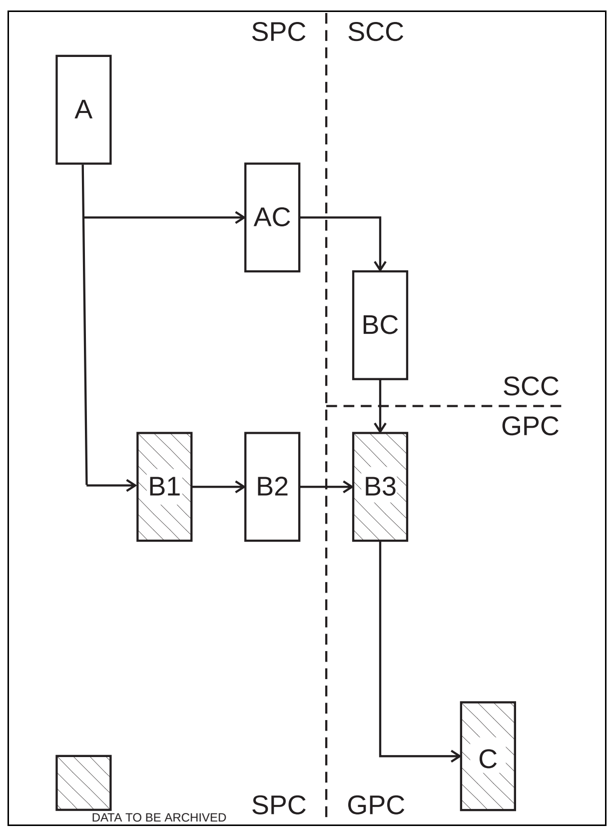

FIG. 1. ISCCP Data Stages *A* and *B* refer to levels of processing described in the text.

[1]ISCCP Project Manager, Joint Planning Staff for WCRP, WMO Secretariat, Geneva, Switzerland, and NASA Headquarters, Washington, D.C. 20546.

[2]NASA/Goddard Institute for Space Studies, New York, N.Y. 10025.

TABLE 1. Data specification for the International Satellite Cloud Climatology Project (ISCCP). Spatial and temporal averages and variances (or another statistical measure of the shape of the temporal distribution) are required for each of the following parameters.

Parameter	Precision (30-day averages)
Amounts (fractions)	
Total cloud amount*	±0.03
Cirrus cloud amount*	±0.05
Middle cloud amount	±0.05
Low cloud amount*	±0.05
Deep convective cloud amount	±0.05
Heights (km)	
Cirrus cloud-top height*	±1.00
Middle-level cloud-top height	±1.00
Low-level cloud-top height	±0.50
Deep convective cloud-top height	±1.00
Cloud-top temperature (*K*) for each cloud category*	±1.00
Cloud optical depth	
Cloud-size distribution	
Average Narrow-band radiances (VIS and IR)*	
Spatial averaging−the information is to be averaged over approximately 250-km × 250-km boxes	
Time sampling−every three hours, i.e., 8 times a day, centered around the synoptic observation times	
Time averaging−the global cloud climatology should consists of 30-day averages for each of the 8 observing times per day	
Length of time series−5 years	

*Highest priority.

TABLE 2. ISCCP international commitments.

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

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

analysis. Key data are archived at the ISCCP Central Archive (ICA). International commitments to the project are summarized in Table 2. [As of this date, the SPC for *INSAT* is not yet operational.]

Figure 1 describes the data stages involved in collecting and analyzing the vast quantity of satellite data and reducing it to a manageable volume with globally uniform properties. The SPC's task is to collect raw satellite-image data (stage A) and reduce its volume in four steps. First, time sampling of geostationary images reduces the frequency of observation to synoptic three-hour intervals. Second, the higher-resolution visible-channel data are averaged (if necessary) to match the lower resolution of the infrared-channel data. Third, overlapping image pixels are removed. Fourth, spatial sampling of images is performed (if necessary) to reduce the resolution to approximately 10 km. The resulting image data (stage B1) is sent to the GPC for further processing and archived at the ICA. Some SPCs also produce stage B2 data (further reduced in volume by sampling to approximately 30 km); these data are sent to the GPC in place of B1 data, but all B1 data are archived.

The SCC routinely receives special high-resolution-image data (stage AC) from each of the SPCs. These data, which correspond to regions viewed simultaneously by the polar

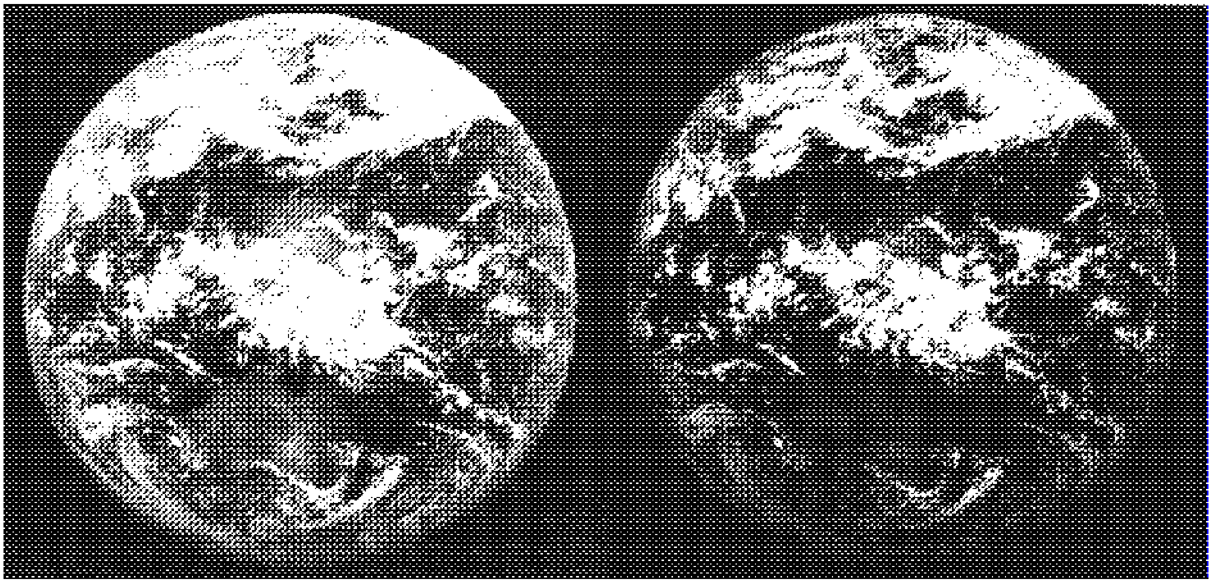

FIG. 2 Reduced-resolution (B3 ≈ 30 km) images of the earth from *GMS-2*; left: visible channel, right: infrared channel

orbiter and each geostationary satellite, are used to normalize the calibrations of each geostationary satellite to the polar orbiter. The resulting normalization coefficients (stage BC) are sent to the GPC.

Calibration of the infrared (IR) channels on the polar orbiter (and all geostationary satellites) is monitored by repeated observations of space and a reference blackbody target. Calibration of the visible channels is not monitored after launch; however, the GPC utilizes a statistical comparison of the satellite-measured surface reflectivity over the whole earth's surface to monitor the relative calibration of the polar orbiter's visible channel.

The GPC then produces the primary global-radiance-data product (stage B3), which has a nominal spatial resolution of approximately 30 km, a time resolution of three hours, and radiance values normalized to a single standard radiometer. The GPC also analyzes the B3 data to derive cloud properties (stage C). All of these data are archived at the ICA. Figure 2 illustrates a typical geostationary image at B3 resolution.

2. Documentation

A report will be published in 1985 containing a detailed description of the B3 radiance data and the data-tape format. The format of the data tapes has been designed to accomplish three objectives: 1) maximizing format uniformity while preserving the original data character, 2) enhancing the data value by providing complete calibration and navigation information while minimizing data volume, and 3) providing easy, flexible access to the large volume of data. The following sections summarize the key features of the B3 data format that accomplish these objectives.

3. Data characteristics

The ISCCP global data set is derived from the array of operational satellite radiometers which have in common a narrowband channel near the peak of the solar spectrum at about 0.6 μm, and one in the atmosphere's thermal window near 11 μm. Some of these radiometers have additional channels which are also included in the ISCCP data set. The spatial resolution of the raw images ranges between 1-4 km (visible channel) and 4-12 km (infrared channels). Imaging frequency (at any geographical location) varies from 14 to 48 times per day for geostationary satellites to twice daily for polar-orbiting satellites. Details of the characteristics of the radiometers are described in the "ISCCP Data Management Plan" (World Climate Program, 1984a) and in the "ISCCP Preliminary Implementation Plan" (World Climate Program, 1982).

Table 3 summarizes those characteristics of the operational imaging radiometers and the estimated data volumes relevant to the ISCCP. Although the visible-channel data resolution is reduced (if necessary) to match the lower resolution of the IR-channel data, the original satellite measurements are, in all other respects, preserved in the reduced-resolution data sets, since volume reduction is accomplished by the sampling shown in Table 3. Original count values in the original image coordinates are preserved for each satellite. Thus, these data sets represent a "climatology" of the raw satellite imagery.

4. Radiance calibration

Integer count values (CT = 0 to 255) on ISCCP radiance-data tapes represent the original radiances, L ($W \cdot m^{-2} \cdot sr^{-1}$), measured by satellite imaging radiometers and supplied to the GPC by the SPCs. These radiometers are narrow band, making measurements in limited ranges of the solar and thermal infrared spectra. In the shortwave (solar) wavelength region of the spectrum, radiances can also be expressed as a normalized radiance, L^*, by dividing L by the effective solar irradiance for that spectral region. Dividing L^* by the cosine of the zenith angle yields a (bidirectional) reflectance, R. High count values correspond to high radiance or reflectance.

TABLE 3. Characteristics of operational imaging radiometers and estimated ISCCP data volumes.

Characteristics	Satellite				
	NOAA	*METEOSAT*	*GOES-East*	*GOES-West*	GMS
VIS resolution (km at nadir)	4.0	2.5	0.9	0.9	1.25
IR resolution	4.0	5.0	6.9	6.9	5.0
other channel resolution[a]	4.0	5.0	--	--	--
IR resolution (μrad)	1300[b]	140	192	192	140
IR east-west pixel step (μrad)	--	125	84	84	48
IR north-south step (μrad)	--	125	192	192	140
VIS pixels in line	409[c]	5000	15288	15288	13376
VIS lines in image	12240[c]	2500	14568	14568	10000
IR pixels in line	409[c]	2500	3822	3822	6688
IR lines in image	12240[c]	2500	1821	1821	2500
IR select factor for B1					
along a line	1	2	2	3	6
line to line	1	2	1	1	2
Full 10-km resolution (IR/VIS)					
pixels in line	409[c]	1250	1911	1274	1114
lines in image	12240[c]	1250	1821	1821	1250
Approximate B1 archive					
pixels in line	409[c]	1250	1911	1230	1100
lines in image	12240[c]	1250	1821	1700	1100
IR select factor for B2					
along a line	6	3	4	3	3
line to line	8	3	4	4	3
B2 archive (trimmed)					
pixels in line	65	416	477	413	367
lines in image	1530	416	455	455	367
B2 east-west spacing at nadir (km)	24	27	25	28	31
Data volume (10^9 bits/yr)					
A	1640	2200	25000	25000	4600
B1[d]	1640[e]	92.4[f]	126	82	48
B2[g]	32	11.0	9.5	7.8	6.0

[a]*METEOSAT* has three spectral channels; NOAA has five.
[b]Intrinsic field of view of instruments; on-board averaging reduces resolution from 1.1 km to nominal 4.0-km resolution shown.
[c]NOAA numbers are for one orbit swath, whereas other satellite numbers are for whole earth image.
[d]Assumes 5% overhead is balanced by 5% data loss. All pixels stored in eight bits, except for NOAA. The volume of visible data is reduced by 37% by deleting three night images for *GOES-East*, *GOES-West*, GMS, and *METEOSAT*.
[e]Radiances stored as 10-bit numbers.
[f]Based on actual format but with overhead offset by data loss.
[g]Assumes 20% overhead.

In the infrared region of the spectrum, L can be expressed as a brightness temperature, TB, the temperature of a blackbody radiating the same amount of energy as measured by the radiometer. High count values correspond to low radiance or brightness temperature. Reflectance and brightness-temperature units are more convenient because they are more directly comparable when measured by radiometers with slightly different spectral responses.

The type of information available to convert the count values to radiances (or their alternate units) varies from radiometer to radiometer and ranges from prelaunch calibration to active on-board calibration. The nominal calibration given for each satellite on B3 data tapes utilizes this independent calibration information. A second calibration for each radiometer is based on a normalization of the geostationary radiometers to the AVHRR sensor carried on the NOAA polar orbiter. This normalization procedure is performed every three months by the SCC. The GPC monitors the relative calibration of the visible channel on the AVHRR. These results provide a normalized calibration which is also given for each satellite on B3 data tapes.

Absolute calibration of the radiometers requires postlaunch observations for the solar channels. The infrared channels are well calibrated by on-board sources. The lack of regular monitoring of the absolute calibration of the visible channels on any of the operational satellites and the importance of data precision (repeatability) to climate studies led to a NASA-sponsored pilot study by the Scripps Institution of Oceanography to provide a periodic absolute calibration of the GOES VISSR Atmospheric Sounder (VAS) shortwave detectors for

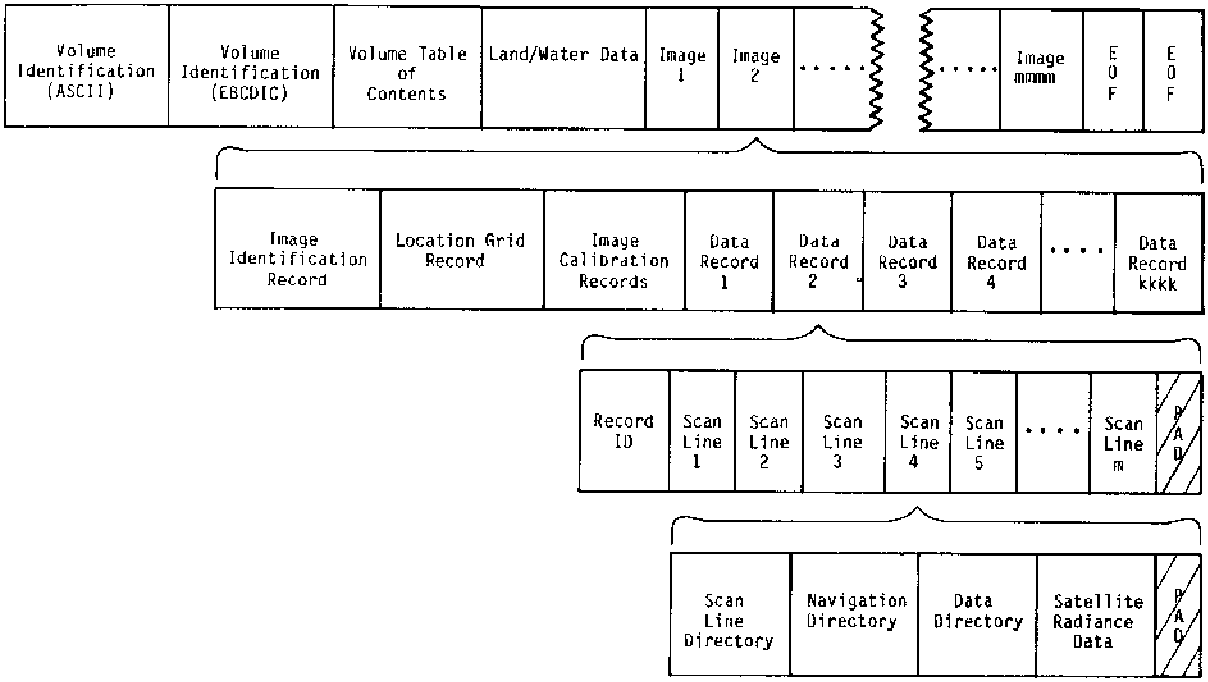

FIG. 3 Structure and organization of B3 data tapes.

the duration of the ISCCP. Once absolute calibrations are obtained, the entire ISCCP radiance data set can be calibrated using the normalization coefficients.

5. Image navigation

Navigation refers to the procedure for determining the earth location (latitude-longitude) of each satellite image pixel and the three angles that define the observation geometry; namely, the satellite and solar zenith angles near the earth's surface and the relative azimuth. The satellites involved in the ISCCP provide two types of navigation information. The *METEOSAT* and NOAA systems provide direct earth-location information for every image pixel and indicate the subsatellite pixel in the image. The orbital altitude of the satellite is also known. The GOES and GMS systems provide coordinates that describe the spacecraft orbit, attitude, and the relationship between the image pixel and the spacecraft geometry. The position of the earth and sun in celestial coordinates is also known. All of this information is used to locate the satellite in its orbit and to determine the pointing of the radiometer. The GPC uses these different types of navigation information to calculate the earth location and viewing geometry; the results are provided on the B3 data tapes in the same format for all satellites.

The accuracy of image-pixel locations varies depending on the procedure and information quality, but estimates place the uncertainty for all satellites at less than 20 km or approximately 0.2° near nadir. Routine checks are made on the B3 data to monitor the navigation accuracy. Four complete days of images per month are examined manually by superimposing the continental outlines, a latitude-longitude grid, the limb, and the terminator in their calculated positions onto the image data. This verifies the navigation accuracy to within one B3 pixel or about 24-30 km.

Detailed information on the navigation procedures is contained in the "ISCCP Data Management Plan" referred to earlier.

6. Data-tape format

Each B3 data tape contains a chronological sequence of multispectral images from a single satellite starting on a particular day of each month (1st, 9th, 17th, and 25th for the polar orbiter and 1st and 17th for geostationary-satellite data). The tape number, in the form III.DD.NNNN.V.YYDDD.-YYDDD.SATID, uniquely identifies the contents by source data center (III = GPC), data type (DD = B3), unique sequence number (NNNN = 0001-9999), version number (V = 0-9), year and day-of-year of the first and last image (YYDDD), and the satellite providing the data (SATID).

Each B3 data tape is constructed entirely with 8000-byte records organized into a number of files as illustrated in Figure 3. The first two files contain duplicate descriptive information summarizing the data processing and tape contents. All of the software required to read, copy, and decode any information on the tape is also provided in these two files. The third file contains a file-by-file index of the tape contents, allowing for selection of images based on location and time criteria. An example of the table of contents, printed by one

```
    ISCCB3 TAPE VOLUME HEADER INFORMATION
    -------------------------------------

TAPE NUMBER :  GPC.B3.0019.1.83244.83251.NOAA-7
ISCCP
B2 INPUT TAPE NUMBERS :  C00099 C00100 C00101 C00102 C00103 C00104
                         C00105 C00106 C00107 C00108
SATELLITE :   NOAA-7                       IMAGE HEADER CODE NUMBER :    11
SPC :         NOA                          IMAGE HEADER CODE NUMBER :     1
DATE OF FIRST IMAGE : 83244                LAST IMAGE :  83251
GPC TAPE CREATION DATE : 10/14/88          B3 SOFTWARE VERSION NUMBER :  880930

CHANNEL IDENTIFICATION
----------------------
VIS      (   .58  -    .68  )  MICRONS      IMAGE HEADER CODE NUMBER :   1
IR       ( 10.5   -  11.3   )  MICRONS      IMAGE HEADER CODE NUMBER :   2
.725     (   .725 -   1.10  )  MICRONS      IMAGE HEADER CODE NUMBER :   3
3.55     (  3.55  -   3.93  )  MICRONS      IMAGE HEADER CODE NUMBER :   4
11.5     ( 11.5   -  12.5   )  MICRONS      IMAGE HEADER CODE NUMBER :   5

CALIBRATION COEFFICIENTS       SLOPE   INTERCEPT    RMS     MINIMUM   MAXIMUM
------------------------      -------  ---------  --------  -------   -------
VIS NORMALIZED CALIBRATION    001.000   000.000    -1.000   000.000   000.000
IR  NORMALIZED CALIBRATION    001.000   000.000    -1.000   000.000   000.000
VIS  ABSOLUTE  CALIBRATION    001.000   000.000    -1.000   000.000   000.000
IR   ABSOLUTE  CALIBRATION    001.000   000.000    -1.000   000.000   000.000

ERROR INFORMATION
-----------------
NAVIGATION FIT ERROR IN  LATITUDE   (DEGREES)            .06
NAVIGATION FIT ERROR IN  LONGITUDE  (DEGREES)            .06
NAVIGATION FIT ERROR IN  COSINE SATELLITE ZENITH         .01
NAVIGATION FIT ERROR IN  COSINE SOLAR ZENITH             .01
NAVIGATION FIT ERROR IN  RELATIVE AZIMUTH  (DEGREES)     .50

TOTAL NUMBER OF IMAGES :  14
```

VOLUME TABLE OF CONTENTS

FILE NUMBER	IMAGE NUMBER	NOMINAL DATE	NOMINAL GMT	LOCAT 1 / 2	GMT 1	GMT 2	NUMBER RECORDS	NUMBER SCANS	PERCENT BAD	NUMBER PIXELS	NUMBER CHANNELS	VISIBLE FLAG	IR FLAG
5	1	83244	0	-148/ 44	10716	1614	134	1601	0	65	5	1	1
6	2	83244	0	-173/ 18	24915	15813	145	1709	0	65	5	1	1
7	3	83244	30000	160/ -6	43113	34011	142	1683	0	65	5	1	1
8	4	83244	60000	135/ -32	61311	52209	144	1703	0	65	5	1	1
9	5	83244	60000	109/ -57	75509	70407	134	1598	0	65	5	1	1
10	6	83244	90000	84/ -83	93708	84606	133	1587	0	65	5	1	1
11	7	83244	90000	58/-108	111907	102805	126	1514	0	65	5	1	1
12	8	83244	120000	33/-134	130106	121004	131	1568	0	65	5	1	1
13	9	83244	120000	-1/-159	-1	135202	60	733	0	65	5	1	1
14	10	83244	150000	-17/ 174	162504	153359	131	1558	0	65	5	1	1
15	11	83244	180000	-43/ 149	180701	171559	114	1362	0	65	5	1	1
16	12	83244	180000	-68/ 123	194859	185757	129	1543	0	65	5	1	1
17	13	83244	210000	-68/ 98	194858	203954	143	1708	0	65	5	1	1

FIG. 4. Sample table of contents of a B3 data tape.

of the software modules provided, is shown in Figure 4. The fourth file contains a global data set, used by another of the software modules provided, to determine the underlying surface type (land, water, or coast) for each image pixel. The fifth and subsequent files contain the image data.

Each image file contains a single multispectral image as a sequence of fixed-length scan lines in the original image format. The Image Identification Record provides complete descriptive information about the image, including the source of the data, the radiometer channels that are active, and radiance-noise estimates. The Location Grid Records provides a coarse-resolution (10 degrees of latitude/longitude) summary of the geographic coverage provided by the image. Radiance values are stored as counts in the data records, but the calibration records provide tables for each active spectral channel to allow conversion of count values into two alternate physical quantities using up to three alternate calibrations. Each image pixel is labeled to indicate earth location and viewing geometry.

All B3 data tapes have an identical structure, except at the scan-line level; however, any set of the software modules provided can read any B3 data tape. The total number of B3 data tapes (6250-bpi density) covering one year is 24 for a geostationary satellite and 48 for a polar orbiter.

7. Cloud retrievals

Although the scientific community has expressed a strong interest in the narrow-band global radiances produced by the ISCCP for a variety of research applications, the ultimate goal of the project emphasizes the derivation of a global climatology of significant cloud radiative properties. The process of

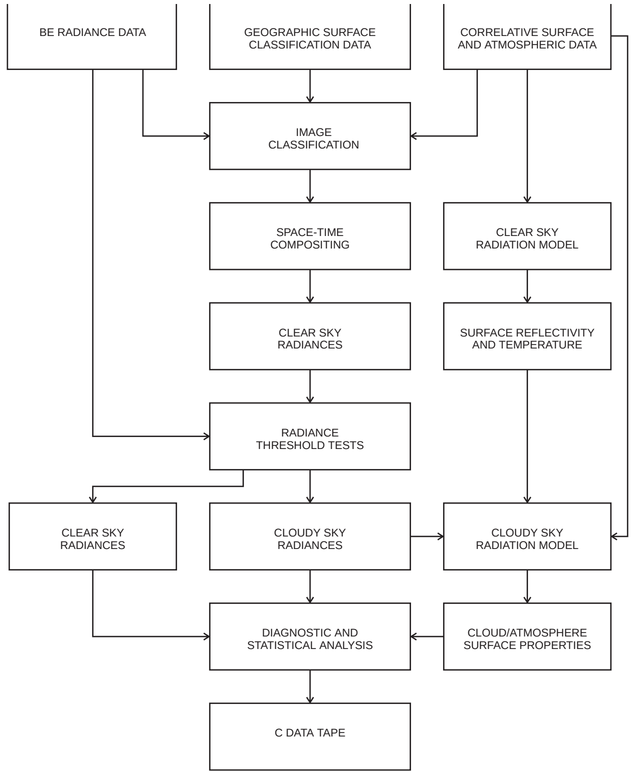

FIG. 5. Schematic of the ISCCP operational cloud algorithm.

selecting a practical operational cloud algorithm for ISCCP has been under way since 1981 through a systematic intercomparison of alternate cloud-retrieval techniques, all applied to a common-pilot radiance data set. The results of this study are outlined in World Climate Program (1984b) and Rossow *et al.* (1985).

Testing of the operational algorithm has been under way since 1984, leading to a refinement in the definition of the steps involved in the analysis. Figure 5 illustrates the key steps in the algorithm: 1) image classification, 2) space-time compositing, 3) bispectral radiance thresholding, 4) radiative model analysis, and 5) diagnostic calculations. The algorithm applies a series of analysis techniques, each of which provides part of the total answer. This approach takes advantage of the fact that cloud algorithms work better for different cloud situations, but uses an intercomparison of the results to avoid spurious cloud detection. This series of steps is referred to as image classification since it serves to divide each image into a clear and cloudy part. The clear portions are further analyzed to remove persistent or hard-to-detect clouds by compositing data over a several-day time period. The analysis culminates in a description of the clear-sky radiances corresponding to each image (the reverse of the cloud-detection problem). A bispectral threshold, based on this clear-sky image pair (visible and IR), is then applied to obtain the cloud amount. Algorithm sensitivity and error are controlled entirely by the choice of threshold magnitudes.

Coding of the ISCCP algorithm is complete and test production of cloud results is under way. An example of the cloud-detection analysis is illustrated in the cover picture, which shows an eight-day composite of the visible and IR radiances representing clear-sky values (upper panels) and the original image data colored according to the algorithm's determination of clear or cloud status. Clear sky is displayed with the same color scale (different for land and water) as in the composite images, while clouds are displayed with a grey-green-blue scale. Algorithm details will appear in a future publication.

8. Data-set availability

Figure 6 shows the data collected during the first two years of ISCCP operations by indicating which satellites contributed data. *NOAA-8* data will be processed only over the Indian Ocean sector to help compensate for the lack of *INSAT* data.

Information regarding the availability of ISCCP data sets, including the latest catalog of data and products, may be obtained by contacting the ISCCP Central Archive (ICA) located at: National Oceanic and Atmospheric Administration, National Climate Data Center, Satellite Data Services Division

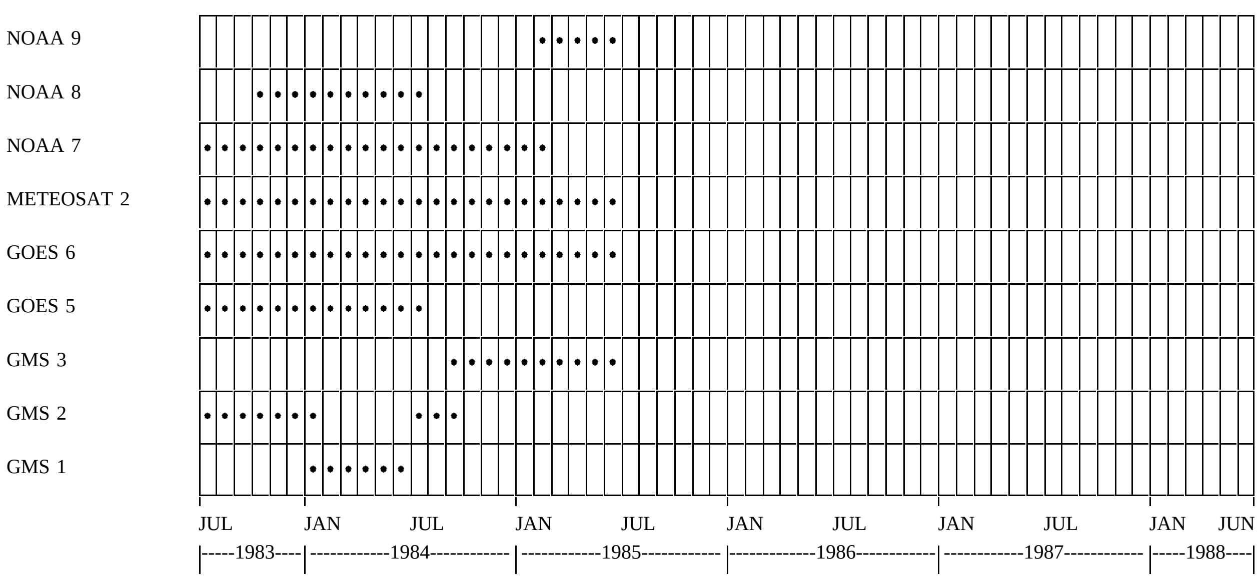

FIG. 6. Satellites contributing data during the first two years of ISCCP operations.

(SDSD), World Weather Building, Rm. 100, Washington, DC 20233. Telephone: 301-763-8111; Telex: 248376 OBSWUR.

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