Nimbus-7 ERB Solar Analysis Tape (ESAT) User's Guide

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PREFACE

The Nimbus-7 Earth Radiation Budget (ERB) data set activity is being conducted by NASA, Goddard Space Flight Center. Launched on October 24, 1978, the Nimbus-7 satellite would have been considered successful if its several experiments had gathered useful data covering one complete year. Nine years later, half of the experiments are still operating. The ERB and the spacecraft are still in good condition; however, budget priorities may require the termination of the ERB experiment within the next year or so.

Monitoring the solar irradiance and its fluctuations is an important part of the ERB experiment. The ERB Solar Analysis Tape (ESAT) has been developed to make these solar observations available to the scientific community in a compact form. The present version of the ESAT contains 89 months (November 1978 to March 1986) of solar data, but additional data will be added in yearly increments as it is received and processed.

The Nimbus-7 ERB Experiment has been guided by the ERB Nimbus Experiment Team (NET) whose members are listed below. The original NET members were competitively chosen by a NASA Announcement of Opportunity issued in the fall of 1975. Later the NET elected to membership certain individuals who had made a considerable contribution to the scientific success of the experiment. The ERB solar sensors were furnished by Eppley Laboratory, Inc., and John Hickey, of Eppley Laboratory, has taken the lead in the quality control and analysis of the solar data. All the ERB orbital and daily mean solar data on the ESAT were provided by John Hickey. Solar active region data were provided by the NOAA (National Oceanic and Atmospheric Administration) World Data Center-A in Boulder, Colorado. The ERB Solar Analysis Tape and this User's Guide were put together at Goddard by Eugene Major of the Research and Data Systems Corporation, under NASA Contracts NAS5-27728 and NAS5-29373. This was done under the guidance of H. Lee Kyle, NASA/GSFC, and of John Hickey. This updated document supersedes the old version (Hickey, et al., 1984, NASA TM 86143). Additional background material about the sensors has been added, as well as a section on solar variability and additional data use references. The solar plots have been redone to show 89 months of solar data.

Since April 10, 1986, solar data have, from time to time, been taken in a special mode due to spacecraft power limitations. These limitations are caused by a combination of the aging of the spacecraft power system and special operating modes of other experiments on the Nimbus-7. In this mode, the ERB electronics are turned on only for a 20- or 30-minute period in the neighborhood of the south pole in order to obtain solar data. The solar sensors do not have time to warm up to normal operating temperature (18°C or warmer) before the measurements are taken. These measurements cannot, therefore, be accurately reduced by the algorithm described in this

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User's Guide. John Hickey has carried out an analysis of the problem and set up a new procedure for analyzing both these low temperature measurements and also the earlier measurements described here. This new analysis will be described in future papers. It does not affect the usefulness of the present ESAT data set, but will probably lead to the issuance of a more complete data set in a modified format in the future.

ERB NIMBUS EXPERIMENT TEAM (NET) MEMBERS

THE ORIGINAL TEAM

*Coulson, K. L.	University of California, Davis
Hickey, J. R.	Eppley Laboratory, Inc.
House, F. B.	Drexel University
*Ingersoll, A. P.	California Institute of Technology
**Jacobowitz, H.	NOAA/NESDIS
Smith, G. L.	NASA/LaRC
Stowe, L. L.	NOAA/NESDIS
Vonder Haar, T. H.	Colorado State University

ELECTED TEAM MEMBERS

Ardanuy, P. (1986)	Research and Data Systems Corporation
Arking, A. (1983)	NASA/GSFC
Campbell, G. G. (1983)	CIRA, Colorado State University
Kyle, H. L. (1983)	NASA/GSFC
Maschhoff, R. R. (1983)	Gulton Industries, Inc.

*Left the NET because of other commitments.
**Jacobowitz was elected team leader in 1976. He was succeeded in 1983 by Kyle.

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SECTION 1

INTRODUCTION

A compact Nimbus-7 ERB Solar Analysis Tape (ESAT) data set has been compiled to facilitate the solar science community's access to ERB solar measurements. These measurements include the total solar irradiance and six spectral regions (listed in Table 1-1) as of June 1987. The ESAT tape contains a collection of seven years plus five months of solar data derived from the ERB Solar and Earth Flux Data Tapes (SEFDTs). The ERB instrument is still taking data, and additional data will be added to the ESAT in yearly increments. This data set contains the orbital solar data as obtained from the SEFDT and the daily mean solar data computed from the SEFDT orbital data by Eppley Laboratory. The present data set covers the period November 16, 1978, through March 31, 1986. The ERB instrument is normally on 3 out of every 4 days and makes approximately 14 solar observations per day. The SEFDTs contain the raw counts and calibrated irradiances for each observation period whereas only one average irradiance value per channel per observation is given on the ESAT. For inclusion on the ESAT, the SEFDT data have been carefully sorted and questionable observations rejected. Certain common solar activity indicators are included on the ESAT to facilitate analysis of the data. Data will be available on one 1600 BPI Computer Compatible Tape (CCT). Revised ESAT tapes will be issued as the ERB data become available.

This document is intended to be both a user's guide for the ERB Solar Analysis Tape (ESAT) product and a guide to the history of ERB solar data processing.

Section 2.0 presents a brief review of the Nimbus-7 Earth Radiation Budget (ERB) experiment and a detailed account of the solar sensor construction, calibration (both pre and postlaunch), and degradation. Emphasis is placed on solar channel 10 (referred to as channel 10c); there are ten solar channels on the Nimbus-7 ERB experiment. Channel 10c is a self-calibrating cavity pyrheliometer which measures the total solar irradiance in the 0.2 μm to 50 μm spectral range. Section 2.3.3 discusses in detail degradation effects experienced by all ten solar channels. Emphasis, again, is on channel 10c, which has remained relatively free of degradation effects. The processing steps to generate ERB solar data are discussed in Section 2.4. The development of algorithms to compute solar irradiance is also discussed with emphasis on channel 10c. Section 2.5 presents a brief background of current research on solar irradiance variability. Recent analysis of channel 10c data is presented in examining short- and long-term solar irradiance variability.

The contents of ESAT are described in Section 3.0. A summary of statistics for all ten solar channels is presented in Section 3.6. The tape record formats are presented in Section 4.0, along with individual item descriptions for orbital, daily mean, and solar activity data files. A source code listing to read and extract data from ESAT is given in Appendix F.

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Table 1-1

Characteristics of ERB Solar Channels
(Jacobowitz, et al., 1978)

Channel	Sensor (c) Type	Wavelength Limits (μm)	Filter	Solar Irradiance (d) Air Mass Zero (Wm^{-2})	Gain	Noise Equivalent Irradiance (Wm^{-2})
1	N3	0.2-3.8	Suprasil W	1370	692.3	1.77×10^{-2}
2(a)	N3	0.2-3.8	Suprasil W	1370	685.8	1.77×10^{-2}
3	N3	<0.2 to> 50	None	1370	607.2	1.43×10^{-2}
4	N3	0.526-2.8	OG530	970	974.5	1.94×10^{-2}
5	N3	0.698-2.8	RG695	679	1339.4	1.91×10^{-2}
6	N3	0.395-0.508	Interference Filter	206	8512.7	3.58×10^{-2}
7	N3	0.344-0.460	Interference Filter	166	17964.7	5.73×10^{-2}
8	N3	0.300-0.410	Interference Filter	109	26985.3	7.55×10^{-2}
9	K2	0.275-0.360	Interference Filter	57	9808.6	0.94×10^{-2}
10C(b)	H-F	<0.2 to> 50	None	1370	2791.0	2.39×10^{-2}

Notes:

(a) Channels 1 and 2 are redundant. Channel 1 is normally shuttered and is opened periodically to adjust value of Channel 2.

(b) Channel 10C is a self-calibrating cavity channel added to Nimbus-7 and replacing a UV channel on Nimbus-6.

(c) All are types of Eppley wire wound thermopiles.

(d) Values obtained from adjusted Nimbus-6 results.

■ The unencumbered FOV for all channels is 10 degrees; the maximum field is 26 degrees for Channels 1 through 8 and 10C. The maximum FOV for Channel 9 is 28 degrees.

BACKGROUND'

2.1 Background of Nimbus-7 and ERB Experiment

A brief background of the Nimbus-7 ERB experiment is presented here. The user is referred to Jacobowitz et al. (1984) and Kyle et al. (1985) for more detailed descriptions of Nimbus-7 and the ERB experiment. The Nimbus-7 spacecraft was launched on October 24, 1978, and placed into a 955-km, Sun-synchronous polar orbit with ascending-node and descending-node equator crossings at noon and midnight, respectively. The orbital period is about 104 minutes.

The ERB experiment is one of eight experiments on board the Nimbus-7. The original objectives of the ERB experiment were twofold. First, to determine, over a one-year period, the radiation budget of the Earth by simultaneous measurement of: (1) incoming solar radiation and (2) outgoing Earth-reflected (shortwave) and Earth-emitted (longwave) radiation; and second, to develop angular models of the reflection and emission of radiation from clouds and Earth surfaces (Taylor and Stowe, 1984 and 1986). Both of these objectives have been fulfilled and, at present, over 8 1/2 years of solar and Earth flux measurements have been recorded.

2.2 Operational Schedule

Because of the competition for available power among the various Nimbus-7 experiments, the ERB instrument normally operates on a 3-day-on/1-day-off duty cycle. However, a number of other operational modes have also been used. For instance, the ERB was on full-time during the winters of 1984, 1985, and 1986. The first operational science data were available from November 16, 1978, and the first data year is defined to start on November 1, 1978. As of the spring of 1987, high quality solar data are still being received from the ERB instrument, which is still in excellent condition.

2.3 ERB Solar Channels

The solar sensor array on the ERB contains ten spectral channels in a single block which may be adjusted to acquire the Sun in the cross-orbit direction. However, at any one time, either channel 1 or channel 3 is closed. Solar measurements are taken when the Sun moves through the field of view (FOV) as the satellite crosses the southern terminator heading northward. The solar channel assembly is located on the side of the spacecraft facing the direction of spacecraft motion (see Figure 2-1). The assembly can be rotated in 1-degree steps up to 20 degrees on either side of the spacecraft's forward direction in order to acquire an on-axis view of the Sun under the expected variation of the satellite orbit plane with respect to the Sun.

When the ERB instrument is on, measurements of the solar irradiance by 9 of the 10 solar channels are made once per orbit as the Nimbus-7 spacecraft crosses the southern terminator, just before its northward movement over the sunlit side of the Earth. The instrument views space as a reference before and after each solar exposure. The mission allows for up to 14 measurements per day at approximately 104-minute intervals. For the channel 10c cavity radiometer, the solar disk is completely within the cavity FOV (10 degrees) for approximately 200 seconds during each 104-minute orbit. Therefore, a single orbit contains a solar record of 200 raw count samples which are digitized on an 11-bit quantization scale. The readings from channel 10c vary as the cosine of the Sun's off-axis angle. A smoothed estimate of solar irradiance for each solar measurement, approximately 14 values per day, can be averaged to generate a best daily estimate of the solar constant (Hickey and Alton, 1983).

Despite the fact that solar measurements are made only at the southern end of the orbit, the solar channel signals are monitored continually because of the way they enter the data stream
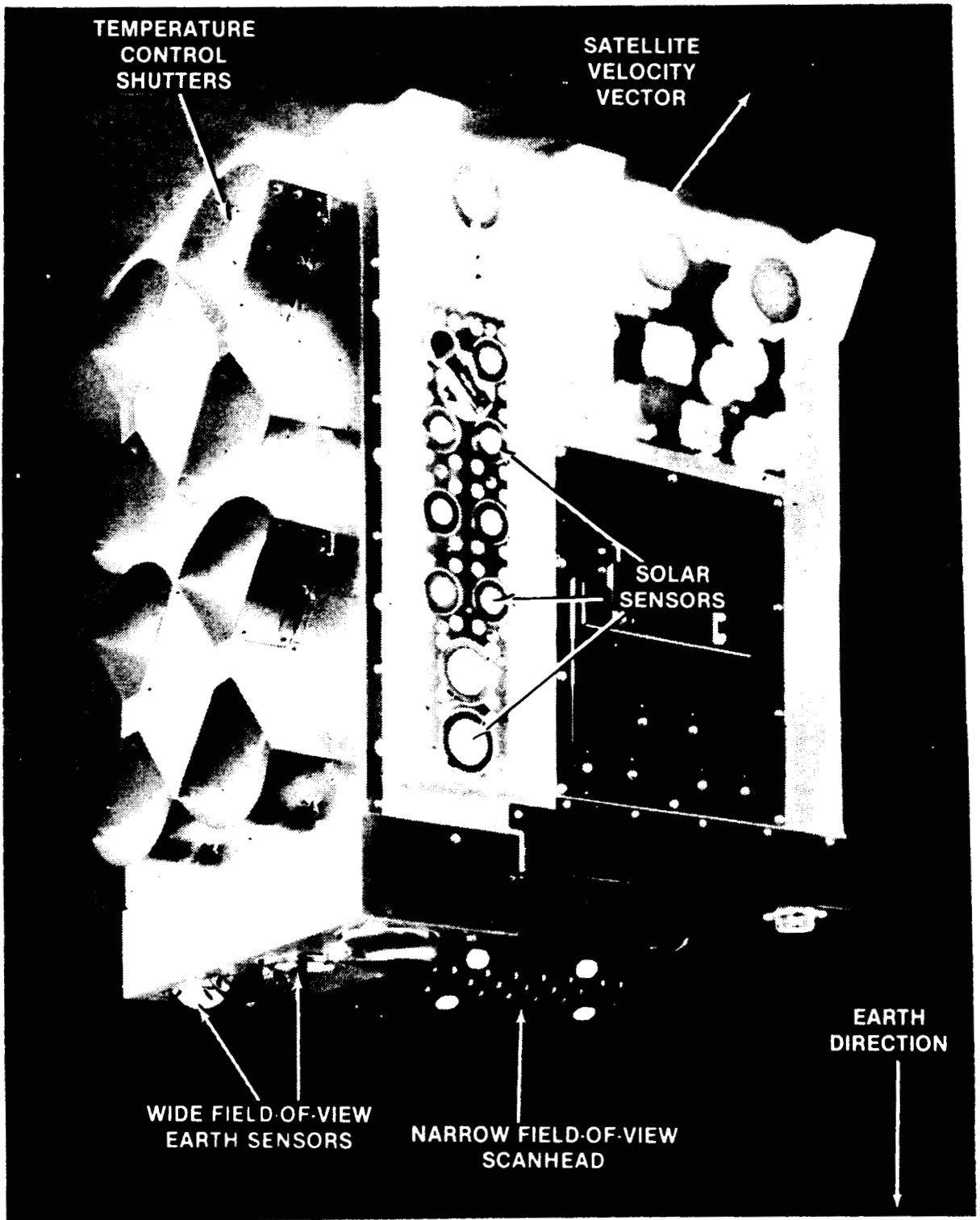
Figure 2-1. Complete ERB sensor assembly showing location of solar sensors

with data from the other sensors of ERB. The solar channels' digital count output is sensed every second, with an integration time of 0.8 seconds. That is to say that deep space is measured most of the time, except for channel 1, which normally views its closed shutter.

Table 1-1 lists the spectral characteristics of each of the solar channels. The spectral intervals, monitored by the ten ERB solar channels, are illustrated in Figure 2-2, superimposed on the 1971 NASA Standard Curve of Extraterrestrial Solar Spectral Irradiance.

The spectral intervals include--

■ necessary input data for heat budget calculations

■ bands in which deviations among various solar spectral curves exist

■ bands in which solar variability may be evident.

Channels 1 and 2 are duplicates, channel 1 being the reference for channel 2 for the inflight calibration program. Channel 1 is normally shuttered.

Channels 4 and 5 contain broad bandpass filters with transmittance spectra matching those of the standard Schott glasses, OG530, and RG695, of the World Meteorological Organization. The interference filters on channels 6 through 9 are deposited on Suprasil W (grade 3) fused silica substrates to minimize degradation. Blocking outside the primary transmission bands is achieved by interference layers only. No radiation absorbing glasses are used.

The spectral intervals in the 0.2 μm to 0.526 μm, 0.526 μm to 0.695 μm, and 0.20 μm to 0.695 μm range are obtained by differential treatment of the channels 4 and 5 data, together with readings obtained from channel 2. Channel 3 is closed when channel 1 is open. The channel 1 shutter acts as a secondary reference for channel 3. The primary reference for channel 3 and channel 10 is deep space, which the sensors view over most of the orbit.

Figure 2-3 shows a cross-sectional drawing of the typical filtered solar channel. Incoming radiation enters the sensor through a protective window. After passing through a spectral filter, it passes through a second window and strikes a 3M (Inc.), black-painted thermopile detector surface. The first protective window minimizes the effects of charged particles, whereas the second window reduces the effects of solar heating of the filter and reradiation to the detector. The whole interior of the cell was anodized to reduce the reflection of solar radiation onto the detector (Soule, 1983).

Each of the 10 solar channels is an independent, individual modular element with a mated amplifier as part of the unit. The sensors are advanced versions of wire-wound type thermopiles used in the Eppley-JPL radiometers (Drummond and Hickey, 1968). There are no imaging optics in the solar channels--only filters, windows, and apertures. No optical amplification is required to maintain high signal-to-noise ratios because of the high thermopile sensitivities and state-of-the-art electronics used.

There are two types of thermopiles: N3 and K2. Type N3 is used for solar channels 1 through 8 (and for the Earth flux channel 11 through 14). Type K2 is used for solar channel 9. (Type K2 is larger than N3, but similar in construction.) A typical thermopile is shown in Figure 2-4.

The thermopiles were constructed to react to a conductive thermal transient in such a way that both active and reference receivers would respond simultaneously and equally to the temperature offset, thus cancelling any offset in output signal. The time constants of the actual active and reference couples were also matched by position control during the plating operation. The receivers were matched, coated, and mounted to ensure a time constant balance. This
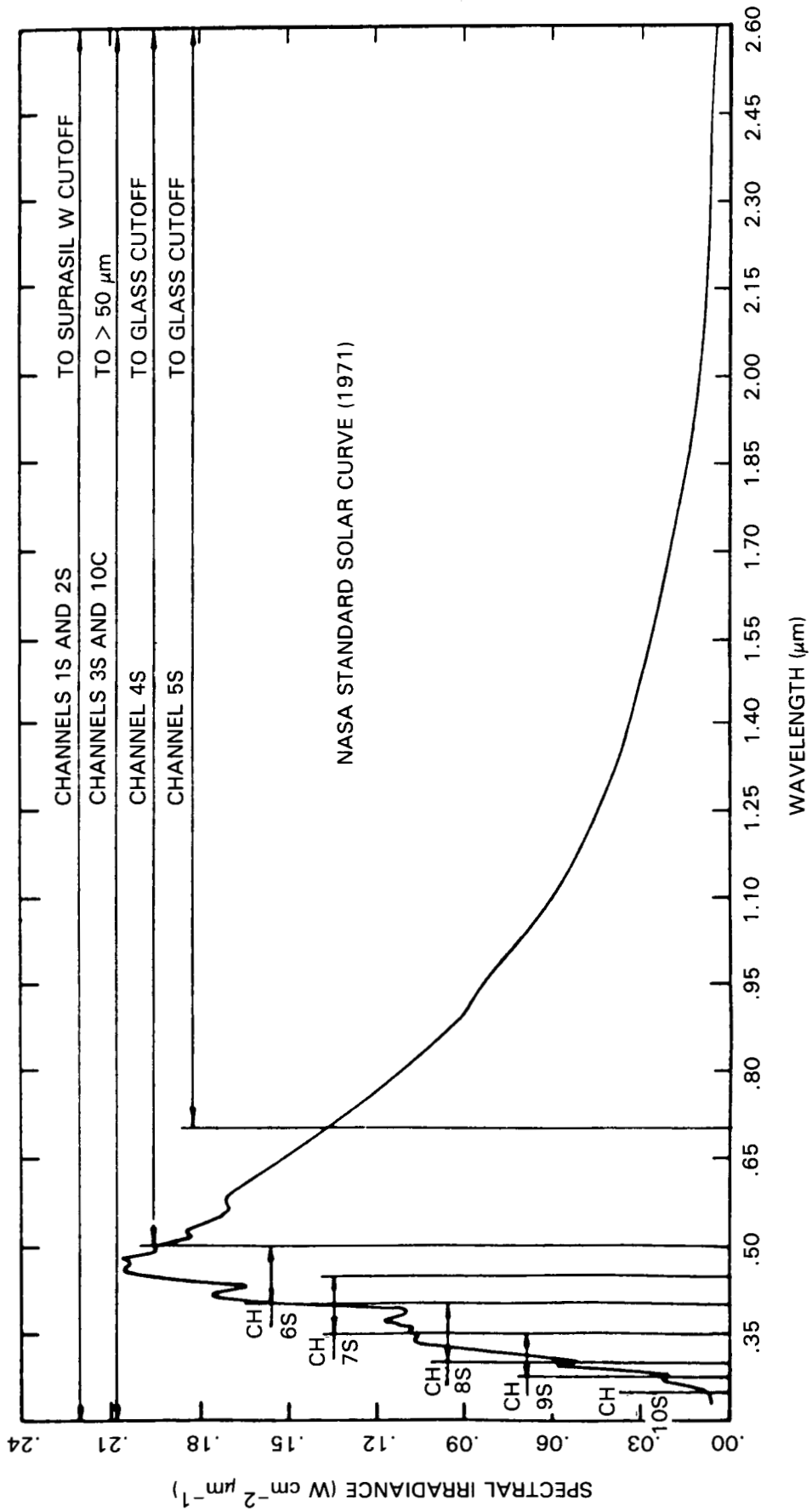
Figure 2-2. NASA Standard Curve of Extraterrestrial Solar Spectral Irradiance

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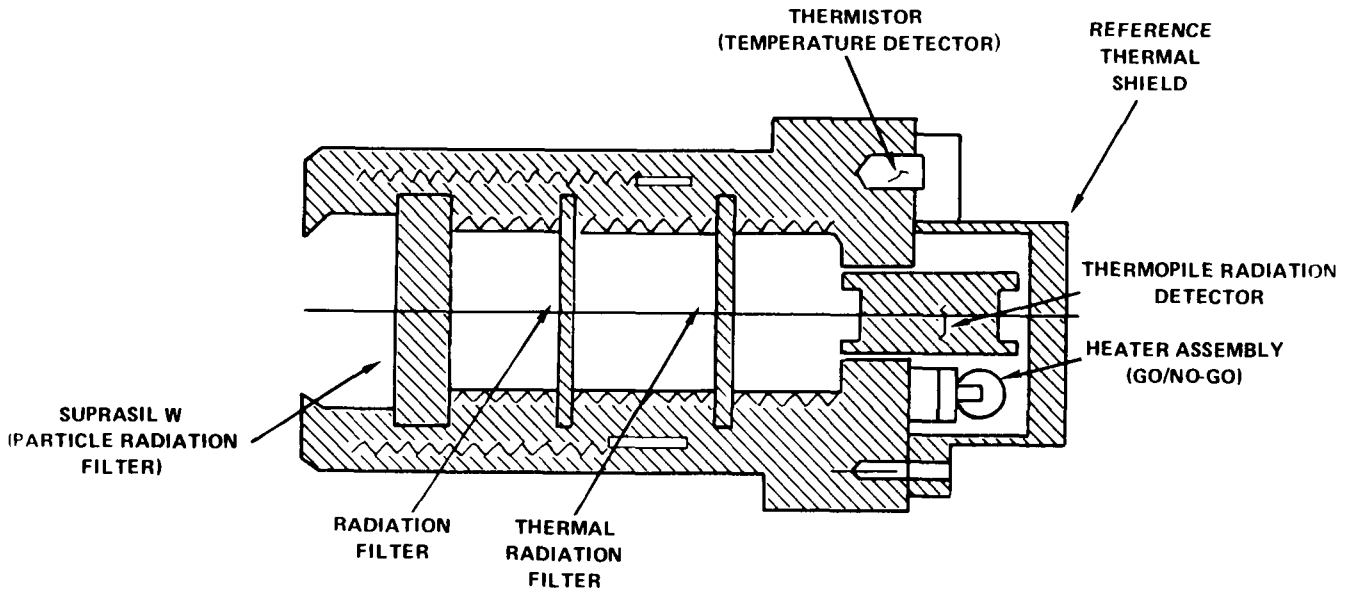
Figure 2-3. Typical Solar Channel Schematic (Soule, 1983)

requirement was extremely important because of the orbital characteristics of the experiment, since solar measurements were made during the thermal transient period due to the satellite crossing the terminator from darkness to full sunlight. See Hickey (1973) and Soule (1983) for additional details on individual solar channel construction.

2.3.1 Channel 10c Construction

The solar channel 10 on Nimbus-7 consists of a thermopile with a cavity radiometer receiver in front of it, referred to as a modified Hickey-Freiden self-calibrating cavity element.

Figure 2-5 shows the construction of channel 10c. As noted, its interior is circular and it has an aperture at A, together with baffles located along the interior of the cylinder at B. The inverted black-painted cone at C absorbs and also reflects some radiation to the surrounding wall.

The radiometer has a 10-degree FOV that allows the Sun to fully irradiate the cavity for about 3 minutes during each orbit. The angular response is a cosine function. This has been proven during flight by monitoring the off-axis response relative to the on-axis solar signal. Although the adherence to cosine response holds over the entire 10-degree field, the measurements are generally selected for an off-axis angle of less than 0.5 degree.

2.3.2 ERB Solar Channel Calibration

2.3.2.1 Prelaunch

The reference for the preflight absolute calibration of the ERB solar channels was the World Radiometric Reference (WRR) scale, which is embodied in a number of self-calibrating cavity radiometers. Solar channel 10c of the ERB is such a device. This new scale can be referenced to previous scales, such as the International Pyrheliometric Scale (IPS) of 1956 (Hickey and Karoli, 1974). The four major solar channels (1, 2, 3, and 10c) have been directly intercompared with self-calibrating cavity instruments of the JPL-PACKRAD and Eppley model H-F types.
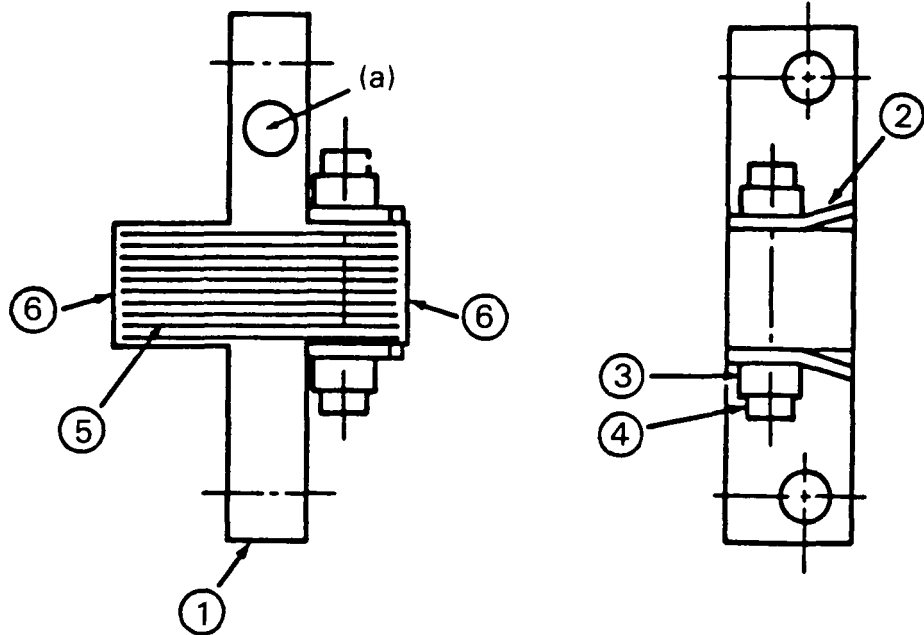
① THERMOPILE BODY (THE TWO MOUNTING LUGS EXTEND TO EITHER SIDE OF THE MAIN BODY; THE TOP SURFACE OF THE LUGS IS THE THERMAL TRANSFER CONTROL SURFACE TO THE CHANNEL BODY)

THE HOLE IN THE RIGHT LUG AT (a) WAS FOR MOUNTING THE MONITORING THERMISTER

② CONTACTS

③ INSULATOR THAT ELECTRICALLY ISOLATES THE CONTACT MOUNTING SCREW

④ CONTACT MOUNTING SCREW

⑤ WOUND AND PLATED COPPER-CONSTANTAN THERMOCOUPLE WIRES (THE COUPLES ARE MADE BY PLATING COPPER OVER A WOUND CONSTANTAN COIL IN A PARTICULAR MANNER)

⑥ ACTIVE (UPPER) AND REFERENCE (LOWER) RECEIVERS

Figure 2-4. Schematic of Construction of a Typical Solar Sensor Thermopile (Soule, 1983)

THERMOPILE (D)

CONE (C)

BAFFLES (B)

APERATURE (A)

CONSTANT TEMPERATURE SHIELD

SIDE VIEW
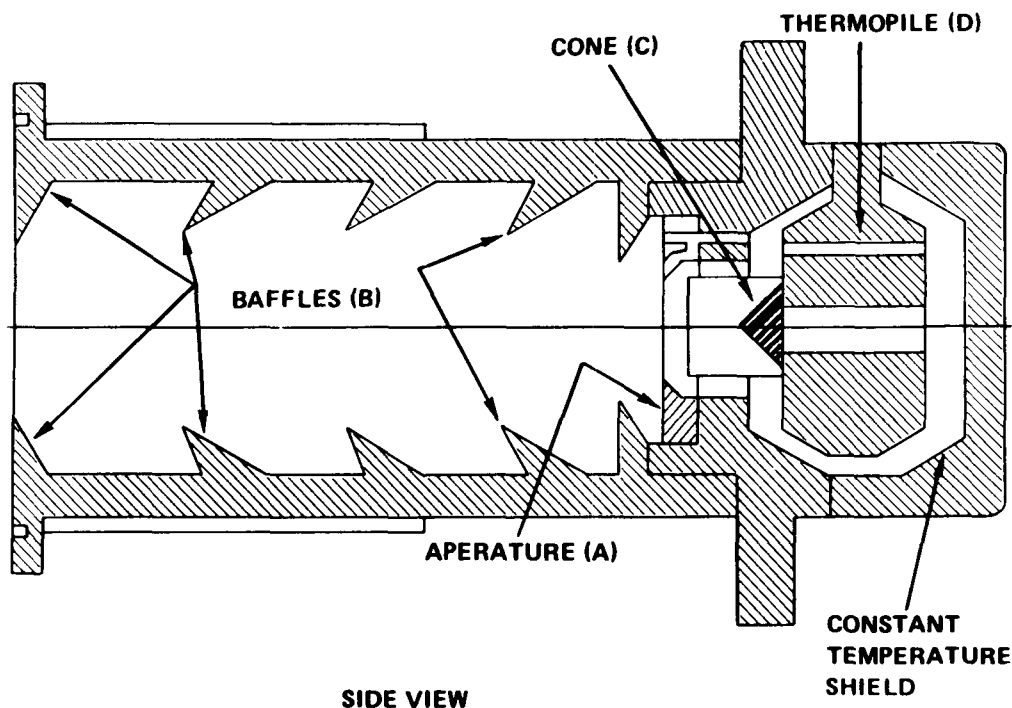
Figure 2-5. Cross-Section of Nimbus-7 ERB Solar Channel 10c
Construction (extracted from an Eppley Laboratory blueprint
(Soule, 1983))

For transfer operations, a solar simulator was used as a source and a Normal Incidence Pyrheliom-
eter (NIP) was employed, both traceable to the WRR. When calibrating the filtered channels (4, 5,
6, 7, 8, and 9), the NIP was fitted with a filter wheel containing filters matching the flight set.
The incident irradiance is calculated using the measured irradiance and the appropriate filter
factor for the particular filter.

The ERB Reference Sensor Model (RSM), which is a duplicate of the flight instruments relative to
the solar channels, has been employed as a transfer and checking device throughout the Nimbus-6
and -7 calibration program. All vacuum calibrations of the Nimbus-6 and -7 ERB solar channels
can be referenced through the RSM, as can many of the calibrations performed at atmospheric
pressure.

2.3.2.2 In-flight

In-flight calibration for the solar channels does not exist, except for channel 10c, whose cavity is
heated by a precision resistance heater. Accurate monitoring of the voltage and current of the
heater, as well as the detector response, yields the calibration sensitivity. This led to very
precise determinations of the total solar irradiance (Hickey et al., 1981). All thermopile channels
are equipped with the same heaters which were used during prelaunch activities to check whether
the channels are functioning properly. The heaters are used as a rough check in the analysis of
operational data. These channels are also equipped with an electrical calibration, which inserts a
precision voltage staircase at the input to the entire signal conditioning stream. While the elec-
tronic calibration cannot be used to infer changes in the sensor or optics characteristics, it
prevents misinterpretation of electronic measurements. Analysis of the electronic calibration data
has yielded no abnormalities. Channels 1 through 3 can be directly compared with channel 10c to
access their in-flight calibration. In addition, the degradation of channel 2 is checked by the
occasional exposure of its duplicate (channel 1), which is normally shuttered. Further details of
ERB sensor calibration can be found in Soule (1983).

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2.3.2.3 Channel 10c Calibration

A precision electrical heater, attached to the cavity assembly, is turned on about once every 2 weeks during calibration sequences while the instrument "views" deep space. This is initiated by a "Go/No-Go" heater command. The sensor output is sampled once each second when the experiment is in its operational mode.

To make very high accuracy irradiance measurements, it is necessary to measure the cavity electrical heating power. In addition, the nonequivalence in sensor response to radiative and electrical heating must be measured. Thus, it is necessary to measure channel 10c cavity heater currents and voltage in addition to the sensor response. This is initiated by the "E-CAL" command. The thermopile output, heater current, and heater voltage are submultiplexed into the channel 10c data system; however, during solar measurements, the thermopile signal is the only sensed value (Soule, 1983).

It was decided not to include the processing of this calibration in the SEFDT generating program, since the values had remained stable for the first two years of operation and efficiencies in processing were required. It was decided to obtain real-time printouts of the calibration data from the ground station in Subsystem Display (Sub-D) format. These Sub-D printouts were checked out by the Eppley Laboratory. Values over the 7 1/2-year period have been logged. Since there has been no change of greater than ~1 count for any of the three variables, the instrument is said to be stable at the resolution limit. It had been planned to use this calibration as the basis for adjusting the channel 10c sensitivity, if a calibration change or drift was noted. However, no such change has been found and, therefore, no change has been made to the channel 10c value used in SEFDT processing. It should be noted that the channel 10c temperature coefficient for flight conditions (as well as the reference temperatures of 22°C) was determined, using the initial calibration orbit analysis, prior to reprocessing of the SEFDT tapes. Further information on channel 10c calibration can be found in Hickey (1985).

2.3.3 ERB Solar Channel Degradation

The degradation, with time, of the solar channels 1 through 9 is depicted for the first eight months of flight in Figure 2-6. The solar channels are shown in detail through March 1986 in Figures 2-7 through 2-15. The plots are shown as solar irradiance (Wm^{-2}) versus number of days (2,692 days), month and year for 89 months. Particular attention should be given to channels 6 through 9, which contain the interference filters. Their curves show that a high rate of degradation occurred during the first two months, followed by a short period of relative stability. After this, the channels reversed the earlier trend and began to recover. After a little over four months in orbit, three of the channels completely recovered while the remaining one (channel 7) almost recovered.

Shortly thereafter, channels 7 and 8 began to degrade again with rates that were much slower than those encountered initially. This contamination/recovery event, exhibited in channels 6 through 9, is associated with the outgassing or deposition of contaminants at launch and their subsequent cleansing as a result of impingement of active ions on the front surface of the sensors (Predmore et al., 1982). This effect has been experienced by forward-looking sensors on other spacecraft, including the ERB on Nimbus-6. The changes in the spectral channels after the recovery exhibit trends similar to those experienced by the matching channels on Nimbus-6. Channels 2, 4, 7, and 8 (Figures 2-8, 2-10, 2-13, and 2-14) show a downward trend, while channels 6 and 9 (Figures 2-12 and 2-15) show readings at or above their initial values until 1984, when slow declines started. The shifts are associated with solarization of the Suprasil W filter substrates and the Suprasil W IR blockers behind the filters, as well as changes in the deposited filter layers themselves, which will probably change the effective pass bands. The flight filters were "burned-in" by exposure to UV in vacuum, prior to insertion in the instrument, but the
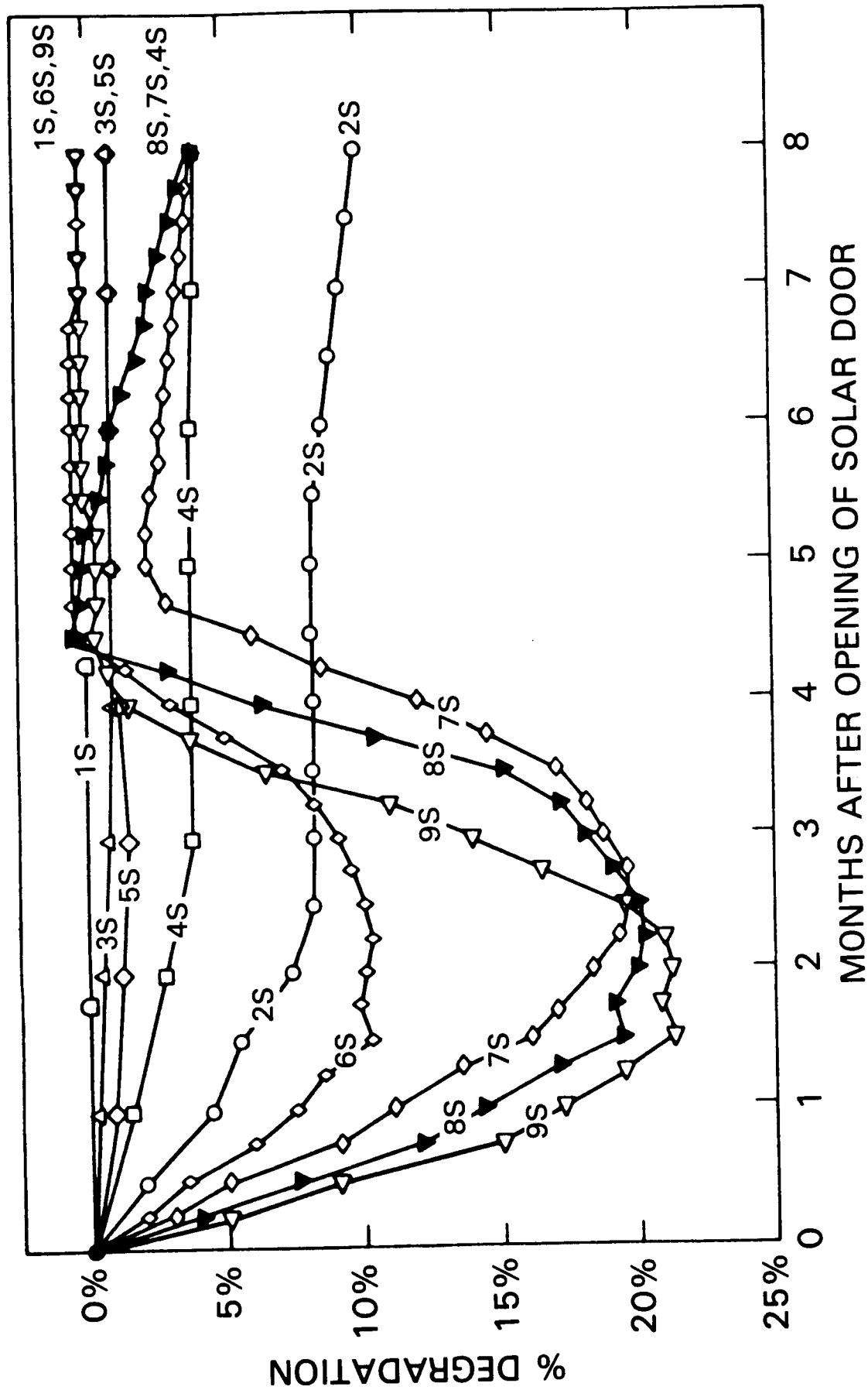
Figure 2-6. Percent degradations of solar channels (Jacobowitz, et al., 1984)

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NIMBUS 7 CH1 IRRADIANCES
NOV 1978-MAR 1986
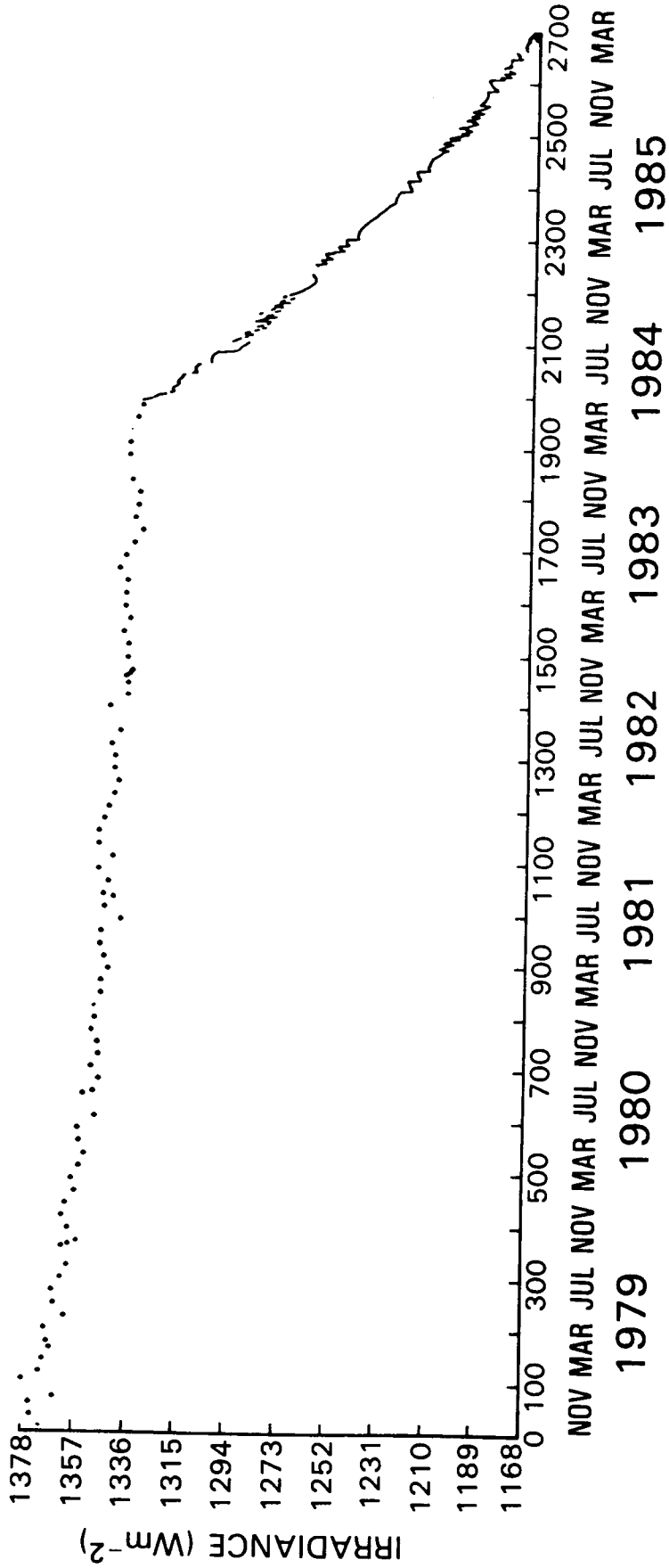
Figure 2-7.   Channel 1 Irradiance for 89 Months

NIMBUS 7 CH2 IRRADIANCE
NOV 1978-MAR 1986
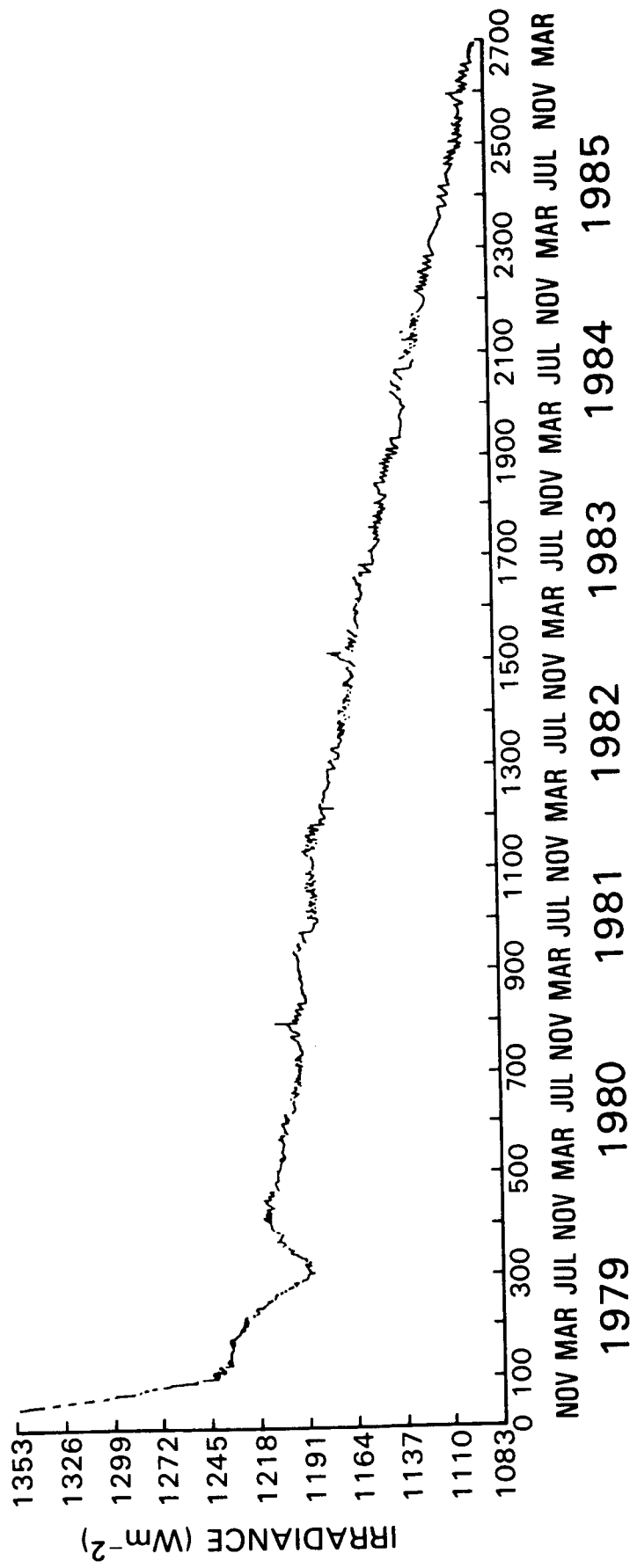
Figure 2-8.   Channel 2 Irradiance for 89 Months

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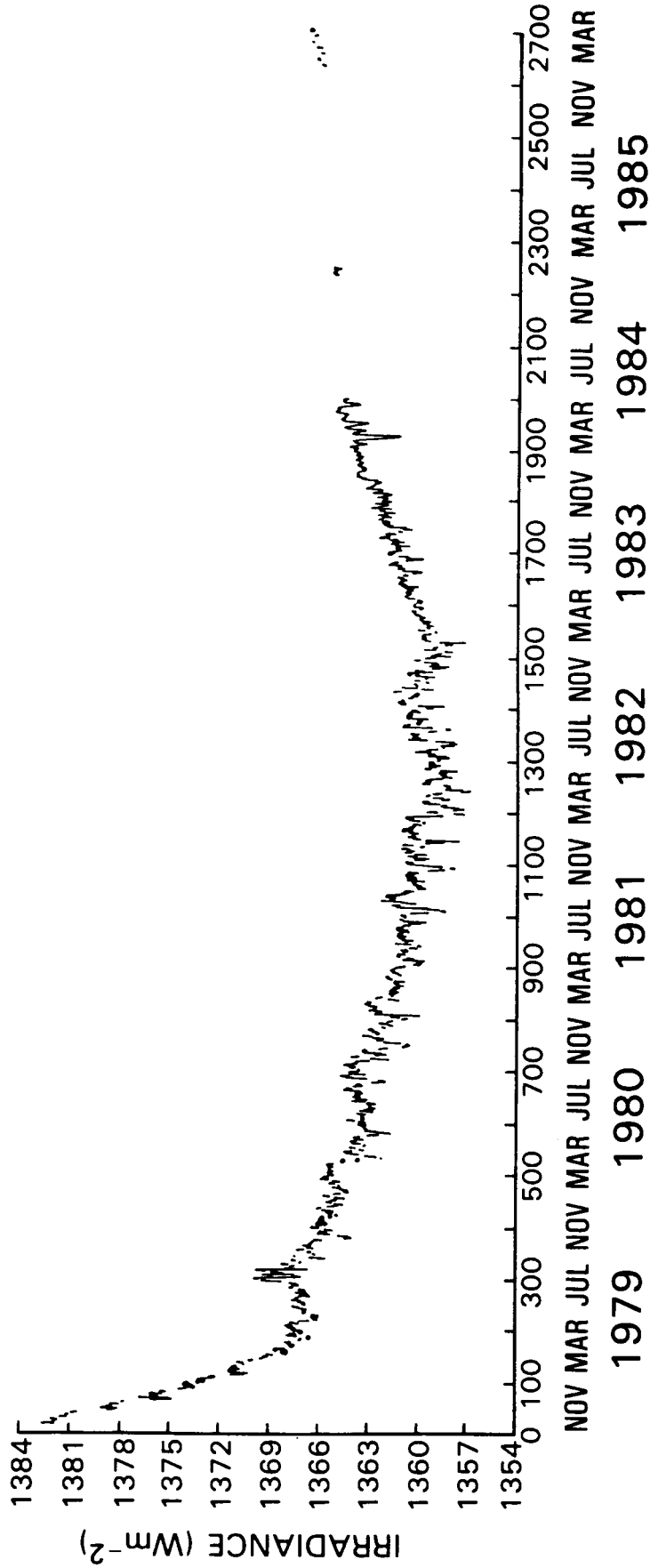
Figure 2-9. Channel 3 Irradiance for 89 Months

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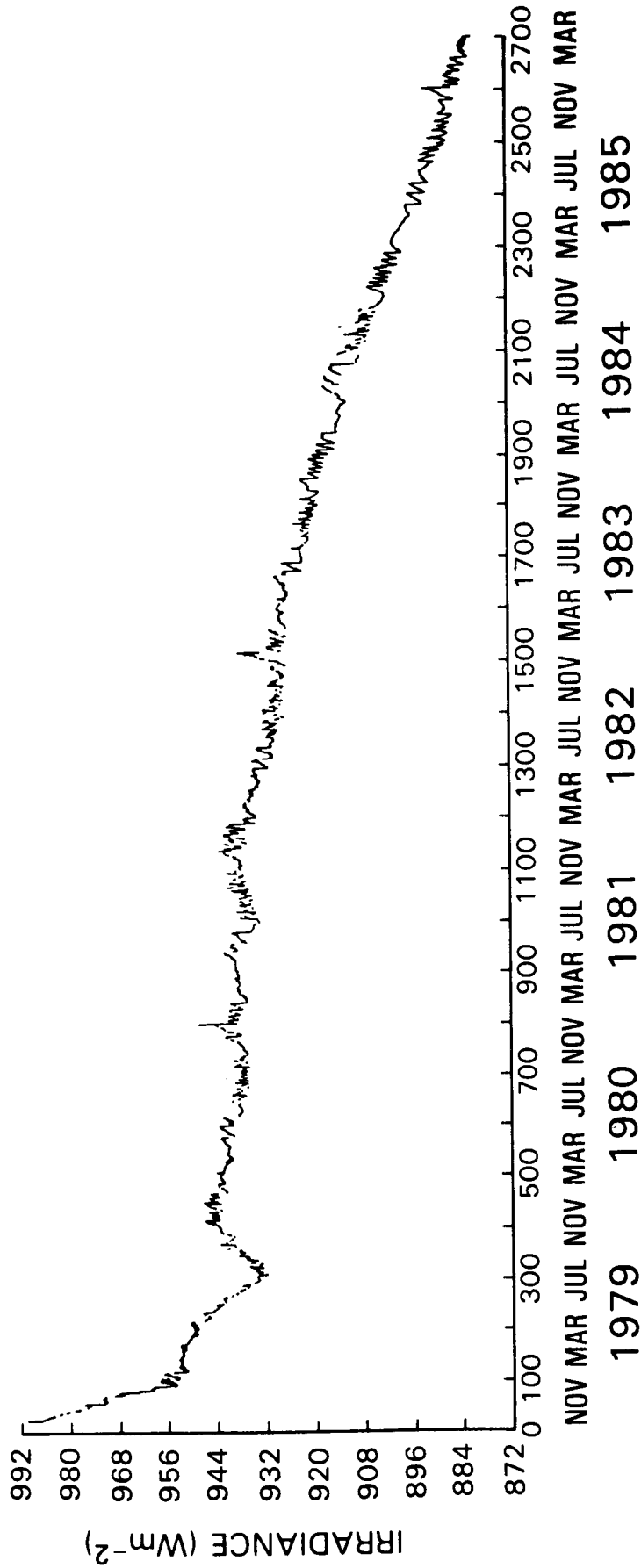
Figure 2-10. Channel 4 Irradiance for 89 Months

NIMBUS 7 CH5 IRRADIANCE
NOV 1978-MAR 1986
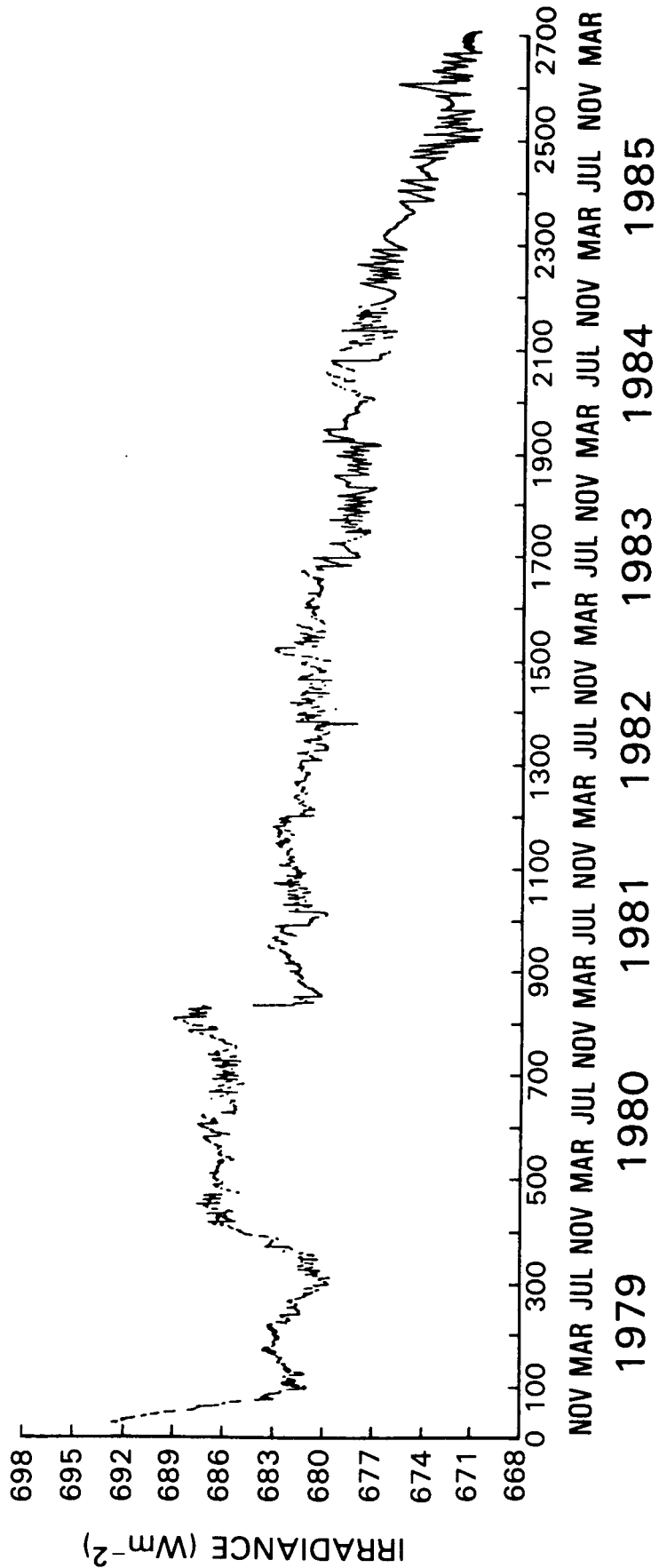
Figure 2-11. Channel 5 Irradiance for 89 Months
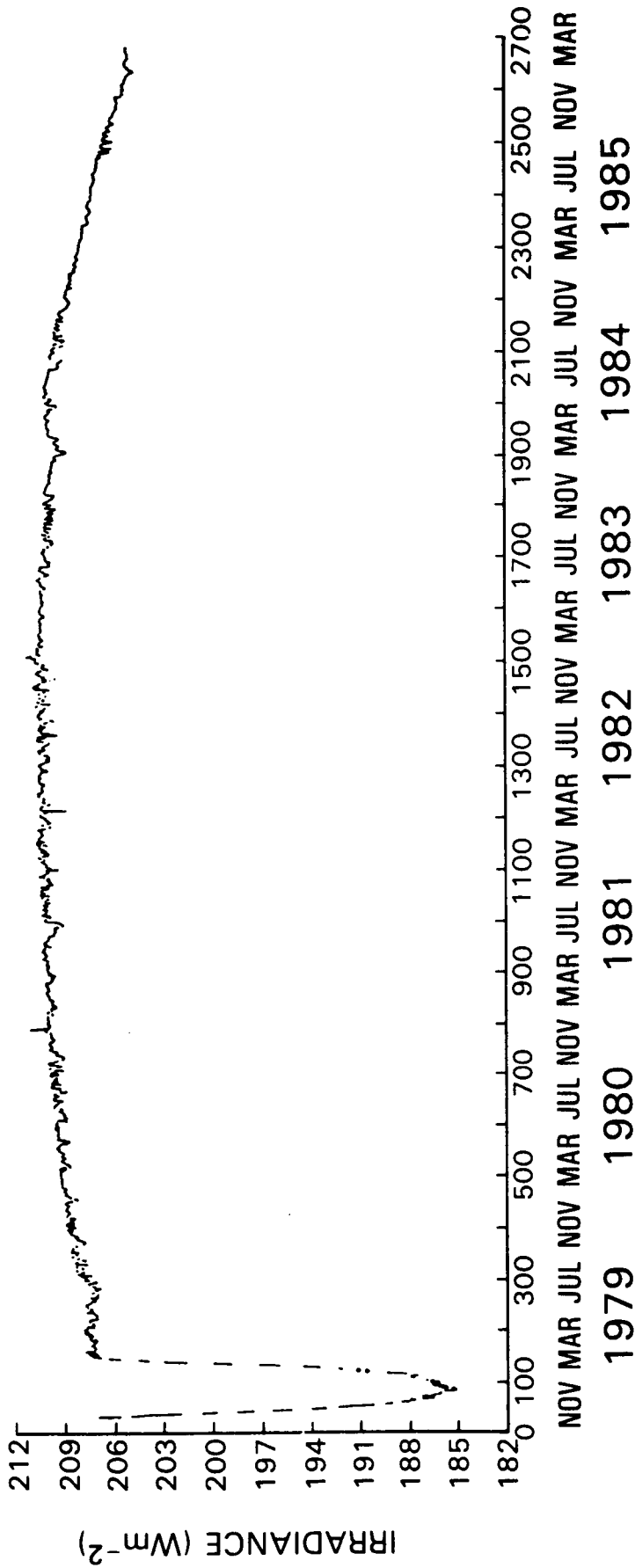
Figure 2-12.   Channel 6 Irradiance for 89 Months

NIMBUS 7 CH7 IRRADIANCE
NOV 1978-MAR 1986
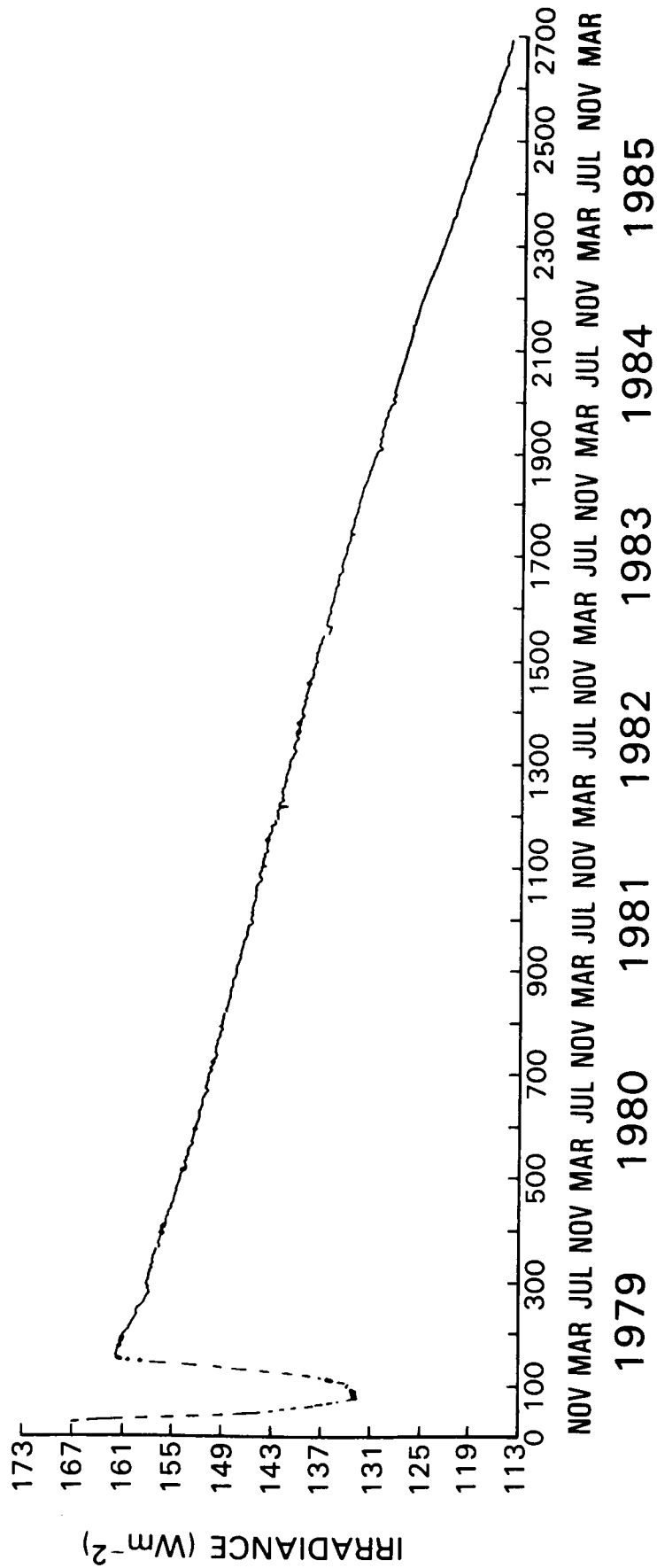
Figure 2-13. Channel 7 Irradiance for 89 Months

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NIMBUS 7 CH8 IRRADIANCES
NOV 1978-MAR 1986
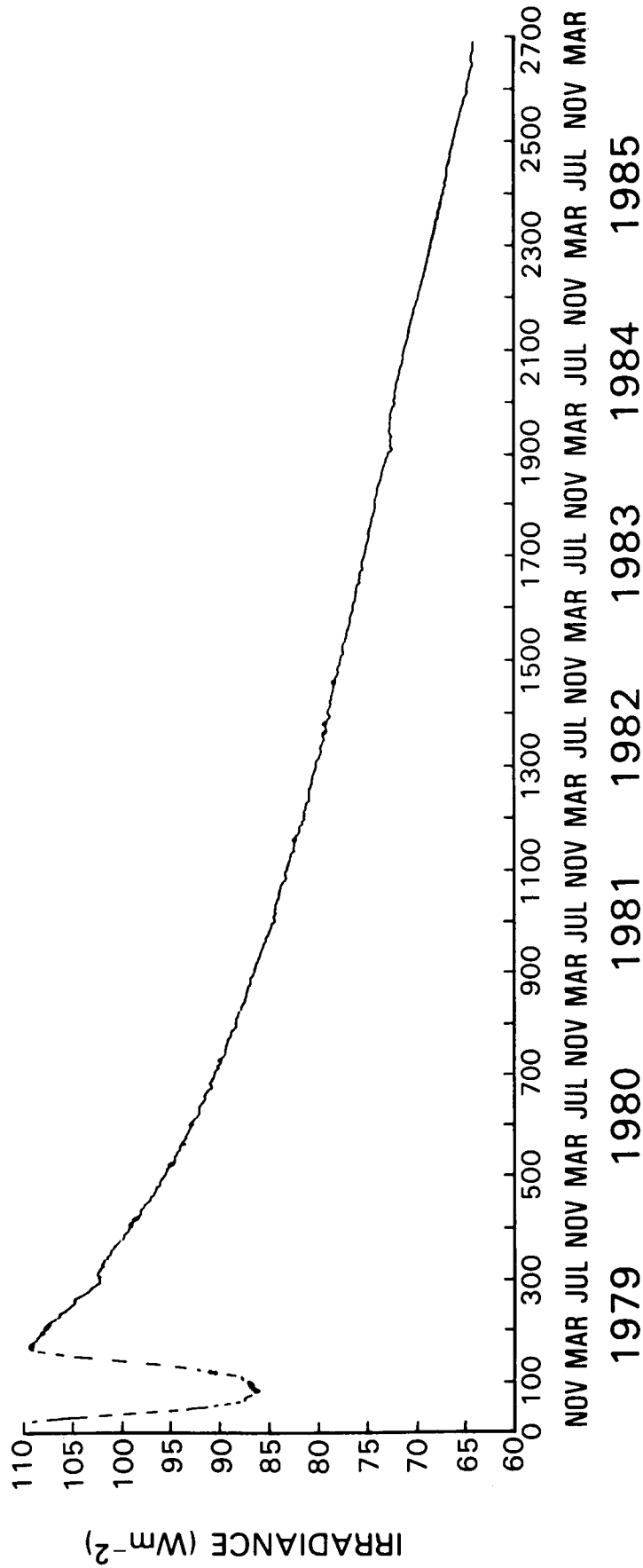
Figure 2-14. Channel 8 Irradiance for 89 Months

NIMBUS 7 CH9 IRRADIANCE
NOV 1978-MAR 1986
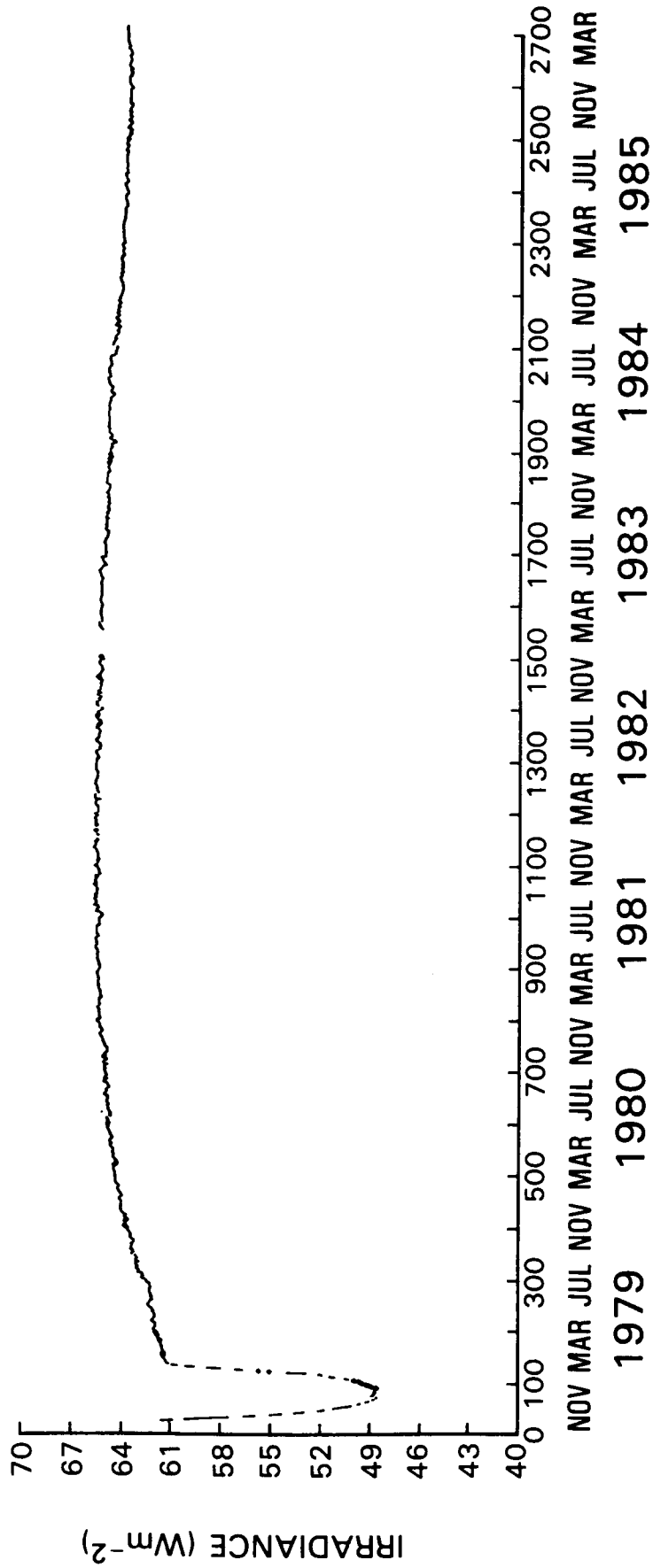
IRRADIANCE (Wm-2)

Figure 2-15. Channel 9 Irradiance for 89 Months

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blockers were not. It is possible that the upward trend of channels 6 and 9 could be due to development of pinholes in the filter coatings (Hickey et al., 1986).

The only other channel with no optical filtering is channel 3, which matches the total irradiance sensor on Nimbus-6. Channel 3 suffered some degradation at the start of the mission, followed by a small downward drift through 1982, then in 1983 a small upward drift set in. In 1984, channel 3 was closed. The shutters on the comparison channels 1 and 11 are opened and closed by the same command signal; further, when channel 1 is opened its shutter moves into a position blocking channel 3. In 1984, it was decided to keep channel 11 open most of the time, and this effectively closed channel 3. For the first several years, channel 1 was normally shuttered so that any possible degradation was not detected. After channel 1 was opened full-time, the degradation became apparent. Notice in Figure 2-6 and the other figures that degradation appears strongest in the ultraviolet. The contaminant layer on the Suprasil-W windows appears to act as a strong shortwave length blocker. Channel 5 in the near infrared is only mildly affected. The spectrally integrated effect of the contaminant layer can be judged from the degradation in channel 2 (0.2 μm to 3.8 μm). Further details on the degradation of the ERB filtered solar channels can be found in Hickey et al., (1986).

In order to maintain the uniformity and precision of the channel 10c solar irradiance data, only the central 44 seconds of each solar view are used, as well as a comparison with deep space. The sensor output is read once per second, with an integration time of 0.8 second. The data are separated into major frames of 16 seconds each. From the central three major frames, the central 44 seconds (out of 48) readings (counts) are averaged to obtain the "on-sun" reading for that orbit. The on-sun counts are corrected to a deep space reference by applying the average of the offset of the radiometer when viewing deep space before and after the solar reading. The deep space values are also 44-second averages taken at 13 minutes before and after the solar pass. The details of the algorithm are given in Section 2.4.

Channel 10c has remained relatively free of the degradation effects experienced by the other channels (see Figure 2-16). The calibration parameters have remained at the 0.5-percent resolution level throughout year 7. The space-load signal offset has also remained within ± 0.5 count when corrected for instrument temperature (Hickey et al., 1986).

2.4 ERB Solar Data Processing

A first analysis of the total solar irradiance was made using a preliminary data set called the "engineering level" data (Hickey et al., 1980). These data are obtained in near-real-time directly from the Nimbus ground station and are not available as an archived product. Other solar parameters are obtained from the ERB Master Archival Tapes (MATs). After preliminary review of the processed flight data from the Nimbus-7 ERB, certain changes were made in the processing algorithms, and the solar data were reprocessed. This new high-quality data set for the ERB solar channels (plus Earth flux channel data) was made available on a set of special digital tapes referred to as the Solar-Earth Flux Data Tapes (SEFDT). A user's guide for the SEFDT data has been made available (Ray et al., 1984). As described in Section 2.4.2, the ESAT is derived from the SEFDT. Figure 2-17 illustrates the solar data processing scenario.

2.4.1 ERB Solar Channel Algorithms

The algorithms used to determine the solar irradiance from the 10 ERB solar channels were derived based on early data returns from the Nimbus-7 (Smith et al., 1983; Hickey et al., 1980). The algorithms are as follows:

The Temperature Sensitivity Correction Factors:

$$S(T) = S_V[1 + A(T - L)] \tag{1}$$

21
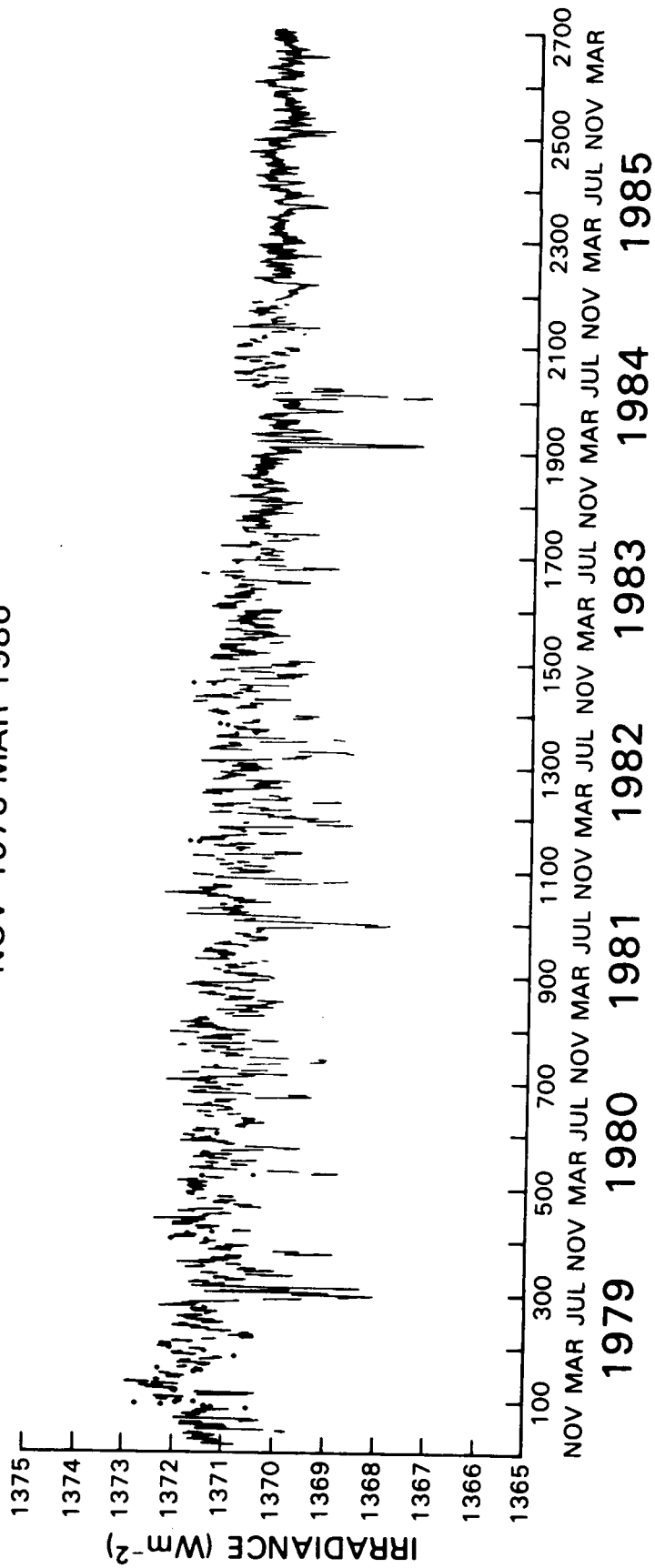
Figure 2-16. Channel 10c Irradiance for 89 Months

22
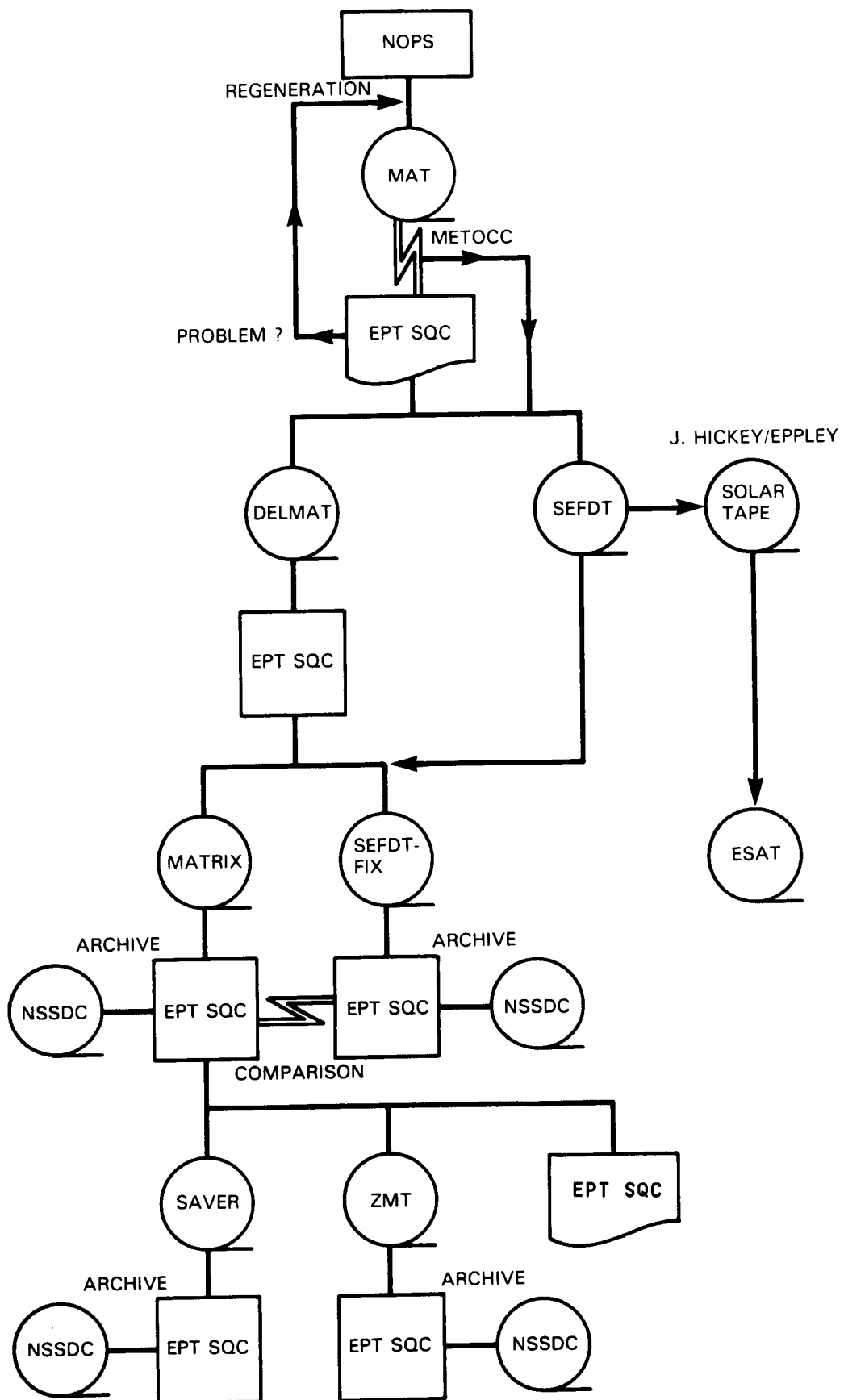
Figure 2-17.   Schematic of ERB Data Processing

where

S_V = Channel sensitivity in a vacuum at 25°C (22°C for channel 10c only) in counts per watts/m² (see Table 2-1).

A = Temperature sensitivity at 25°C (22°C for channel 10c only) in °C⁻¹ (see Table 2-1).

T = Temperature in °C.

L = Reference temperature: Channels 1 through 9: 25°C, Channel 10c: 22°C.

The channel sensitivity (S_V) was determined from laboratory measurements at an average temperature (L) for the calibrations (Hickey, 1985).

Table 2-1
Channel Coefficients

CHANNEL	S_V	A
1	1.299	0.0007
2	1.275	0.0008
3	1.214	0.0008
4	1.719	0.0007
5	2.424	0.0006
6	6.931	0.0007
7	9.588	0.0003
8	12.715	-0.0004
9	30.170	-0.0011
10c	1.3013	0.000524

The Uncorrected Net Solar Irradiance:

$$R = [V_o - 1/2 (V_- + V_+)] /S (T) \tag{2}$$

where

V_o = Solar channel detector output in counts at T_o, where T_o = time of minimum solar elevation, i.e., when the telescope is pointing most directly at the Sun.

V_- = Solar channel detector output in counts at T_o - 13 minutes.

V_+ = Solar channel detector output in counts at T_o + 13 minutes.

S(T) = Temperature sensitivity correction factor.

Adjustment of Channel 10c for Reflectance. (Note: This correction is applied to channel 10c only):

$$R_{10c} = U_{10c} * 0.998 \tag{3}$$

U_{10c} = Unadjusted channel 10c net solar irradiance.
R_{10c} = Adjusted channel 10c net solar irradiance.

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Note: At this point, all the net solar irradiances must be corrected for Sun-Earth distance.

Correction of Net Solar Irradiance for Sun-Earth Distance:

$$NSR = R * R_{SE}^2 \qquad (4)$$

R $\quad = \quad$ Instantaneous net solar irradiance.

$R_{SE} \quad = \quad$ Instantaneous Sun-Earth distance in astronomical units. The semi-major axis of the Earth's orbit about the Sun is defined to be 1.0 astronomical units.

NSR $\quad = \quad$ The final corrected net solar irradiance that appears in the SEFDT solar orbital summary records.

NSR is the value for the irradiance that also appears in the orbital and daily mean files of the ESAT.

In addition, a separate cosine-corrected channel 10c value is given in the ESAT orbital and daily mean files. This is a correction for the off-axis angle (γ_{o-a}). The off-axis angle measures the angular deviation of the pointing vector of the solar channel assembly from the position of the Sun. The gamma angle (γ) is adjusted by ground commands in order to account for changes in the Digital Solar Aspect Sensor (DSAS) solar azimuth angle (β). The off-axis angle as used in the SEFDT is defined as (Ray et al., 1984):

$$\gamma_{\text{off-axis}} = \gamma + {}^*\beta_{\text{DSAS}} \qquad (5)$$

This angle is then used by the Eppley Laboratory to obtain the cosine-corrected channel 10c irradiance:

$$NSR' \ (10c) = NSR \ (10c)/\cos \ (\gamma_{\text{off-axis}}) \qquad (6)$$

The off-axis angle is calculated under the assumption that the spacecraft orientation is known exactly and the calculated off-axis angle is normally less than 0.5 degree. However, the average error in the assumed spacecraft orientation may be of the order of 0.5 degree. It is questionable whether the cosine-corrected irradiances are, in most cases, actually more accurate than the uncorrected values.

2.4.1.1 Time of Minimum Solar Elevation

The time of minimum solar elevation is defined to be the relative minimum of the ERB solar channel 5 counts for each orbit as shown in Figure 2-18. Channel 5 is the solar alignment indicator because it suffers the least degradation of those channels (1, 2, 4, and 5) that have the proper angular response function.

The time of minimum solar elevation was labelled T_o for all of the ten solar channels. The algorithm for determining T_o was a 3-step process:

1. Search the channel 5 counts for the orbit and tabulate the occurrence of counts between 1000 and 2000. Counts greater than 1000 indicate Sun is in the FOV.

2. Find, in the table, the smallest count value occurring more than four consecutive times (occurring n times).

**Channel 5
Counts**

T_0 Time
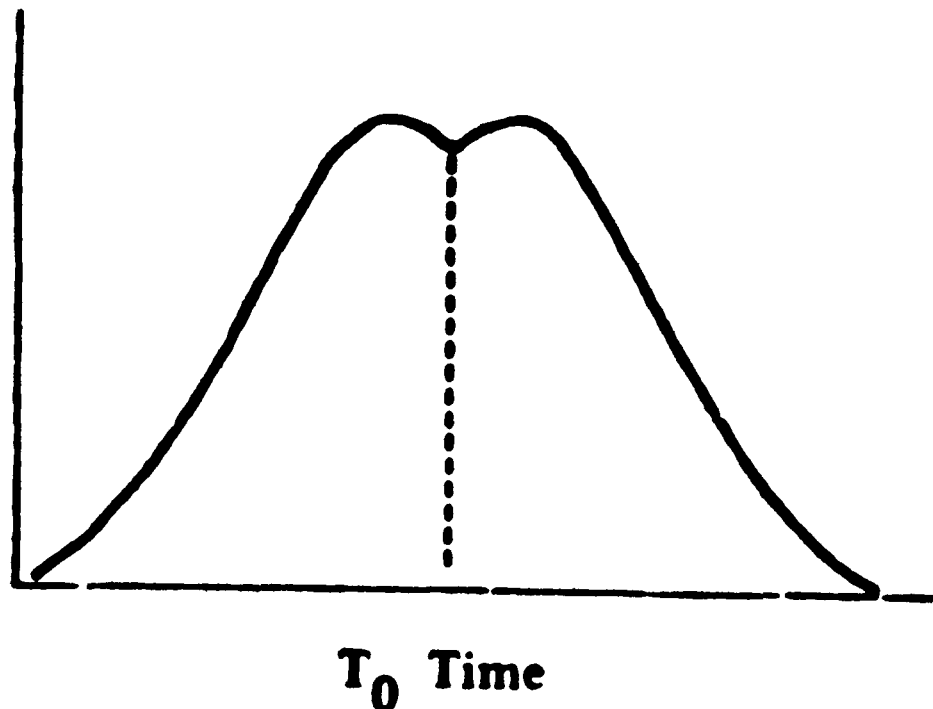
Figure 2-18. Time of Minimum Solar Elevation

3. T_0 is the time associated with the median of the possible smallest count values (n/2) (i.e., if the smallest count values occur eight times, T_0 will be the time associated with the fourth occurrence).

If no time of minimum solar elevation was found, T_0 was set to the southern terminator time for selection of solar data records.

It should be noted that the processing involved in transforming the SEFDT orbital summary data to the final solar data set used in ESAT is not performed in exactly the same manner as described by Smith et al., (1983). The main distinctions are (1) that the low temperature orbits are screened out in the solar data set generated by Eppley Laboratory, as opposed to applying the temperature correction then employed to obtain the SEFDT orbital summary and (2) that the cosine correction is applied using the off-axis angle at the time of the peak solar pass, as determined by the angular response of channel 5. This is because the data are immediately available on the SEFDT orbital summary and do not require recalculation of the time of peak response. The algorithm determined by the ERB NET (see Section 2.3.3.1) was employed in calculating the best on-sun value for the SEFDT orbital summary. The more detailed method discussed by Smith et al., (1983), would require recalculation from the raw data.

2.4.2 ESAT Solar Data Processing

A complete and high precision data set for the Nimbus-7 ERB solar channels was made available on a set of special digital tapes referred to as the SEFDTs. The ERB solar data on these tapes were used by Eppley Laboratory to derive the solar data for the ESAT. Appendix B shows the SEFDTs used to generate the ESAT data. With the exception of channel 10c (see Section 2.4.2.2), all of the ERB solar channel data on the ESAT are the same as on the SEFDT.

2.4.2.1 Differences Between ESAT and SEFDT

The purpose of ESAT is to present a complete ERB solar data set free of the Earth flux data and other information on the SEFDT that is not used by the solar community. Although the solar data used to generate the ESAT data set was derived from the SEFDTs, there are some differences between the two data sets.

- Solar data are corrected or deleted for bad orbits and/or missing or incorrect data (see Section 2.4.2.2).

- Daily mean and statistics derived from "cleaned" orbital information are included on the ESAT.

- Calculated off-axis angle, mission day, and Earth-Sun distance are included on ESAT. The Earth-Sun distance was included on the SEFDTs.

- Cosine-corrected channel 10c (see Section 3.3) is included on the ESAT.

- ESAT includes solar activity indicators.

2.4.2.2 Corrections to SEFDT Data

The solar data for the ESAT represents a higher order data set than the already high quality SEFDT data. For the ESAT data set, orbits and/or variables that are incorrect or beyond certain limits were deleted or corrected by Eppley Laboratory from the SEFDT orbital summary records. Limit criteria were based on the off-axis angle and temperatures of channels 3 and 10c. If the off-axis angle exceeded 3.1 degrees, then those orbits were deleted. If the temperature of either channel 3 or channel 10c fell below 18°C, then those orbits were deleted. The daily mean solar data and statistics were generated after screening of the orbital data.

The ESAT data set includes a cosine-corrected channel 10c. This correction is a first-order correction performed by Eppley Laboratory and is simply the cosine of the off-axis angle applied to the mean channel 10c irradiance calculated in the SEFDT (see Section 2.4.1).

The ESAT data set also includes the calculated mission day (mission day 1 is November 16, 1978) and the calculated off-axis angle (solar azimuth + gamma angle). Figure 2-19 illustrates the processing scenario for the ESAT data.

2.5 Observations of Solar Variability

The solar sensors on the Nimbus-7 ERB experiment have been returning high-quality measurements of the solar irradiance, "solar constant," since November 16, 1978. Analysis of solar data from the self-calibrating radiometer, channel 10c, has revealed variations in the solar irradiance by up to 0.2 percent on time scales from days to weeks (well within the sensor precision uncertainty of 0.02 percent). These solar irradiance variations have been found to be due to the passage of sunspots across the Sun's disc (Hickey et al., 1980; Smith et al., 1983). The Solar Maximum Mission (SMM) launched in February 1980, with the Active Cavity Radiometer Irradiance Monitor (ACRIM) has also monitored solar irradiance variations (Willson et al., 1981). The discovery of solar irradiance variations by the Nimbus-7 ERB and the SMM ACRIM has precipitated a number of technical papers launching a debate on the nature of solar irradiance variations, which was the subject of two NASA-sponsored workshops (Sofia, 1981; LaBonte et al., 1983), a special issue of the Journal of Geophysical Research on January 20, 1987 (Vol. 92, No. D1), and a recent review by Hudson (1987).
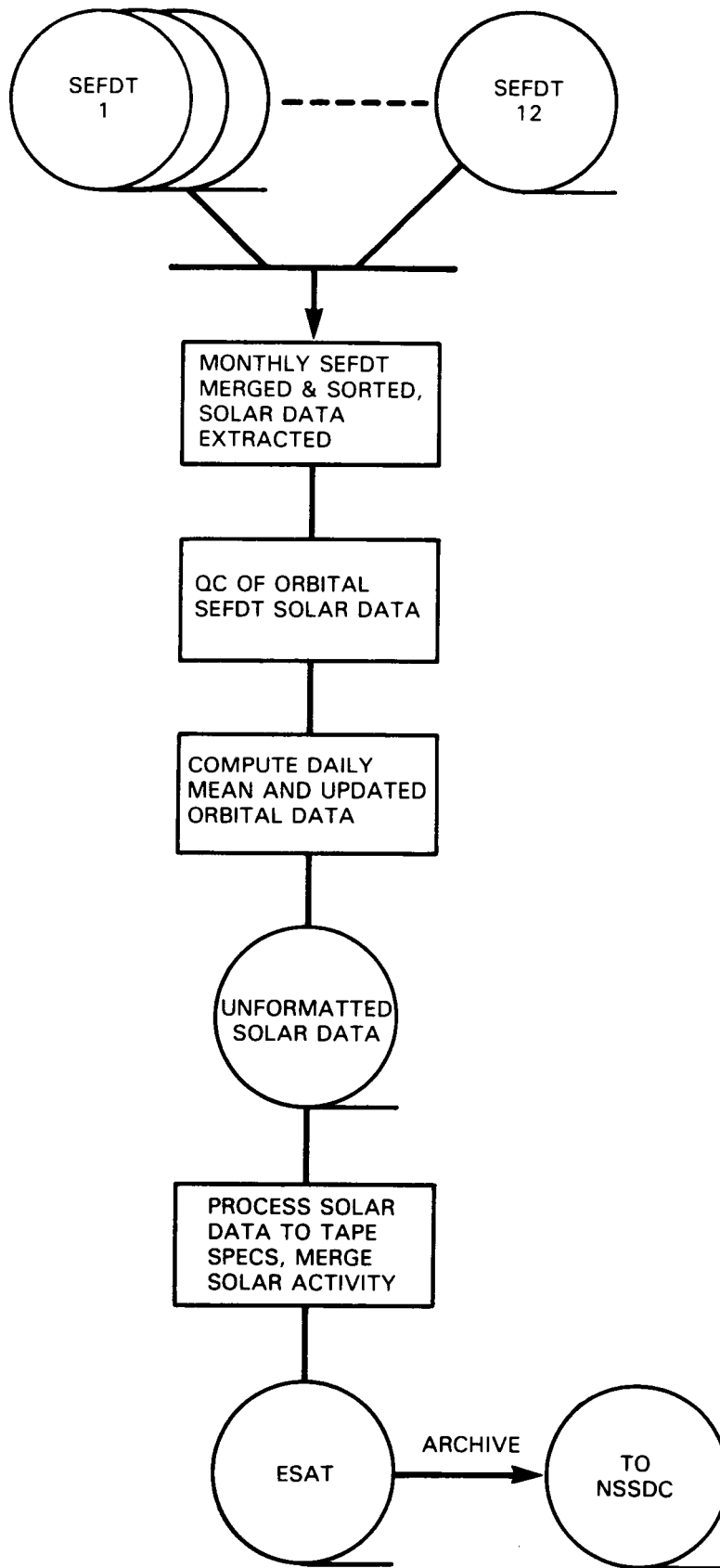
Figure 2-19. Schematic of Steps Taken in Generating ESAT

Observations of solar irradiance variations have important implications in our current understanding of solar physics, including the growth and decay of solar active regions, solar energy transportation, solar luminosity changes and possible long-term effects on the Sun-Earth system and Earth's climatology.

2.5.1 Properties of the Sun

The Sun is the closest star, and can be studied in detail. Observations indicate that the Sun has a radius of 700,000 km and emits energy at a rate of 4×10^{26} watts. Basically, the Sun consists of a core, radiative zone, photosphere, chromosphere, and corona (see Figure 2-20). The core contains most of the mass of the Sun and over 99 percent of the energy production. Energy is produced by thermonuclear reaction, fusing two hydrogen nuclei to form helium and a release of energy in what is known as the proton-proton reaction. Theoretical models indicate that such energy production has been occurring for about five billion years and will continue for another five billion years, thus, restraining the Sun to a relatively stable state as a typical main-sequence star.

Observations and models indicate that, from the core out to about 0.85, solar radii energy is transported by radiation. From about 0.85 solar radii and out (~150,000 km), energy is transported by convection--turbulent, circulating currents of gas; each element of rising gas takes energy directly to the surface. At the surface, radiation is again the dominant mode of energy transport. The solar atmosphere consists of the chromosphere, which extends from the photosphere to about 2000 km and merges with the corona, a region of low density and high temperature.

2.5.1.1 <u>Convection Cells</u>

The circulating convection cells are believed to consist of giant cells, which are about 200,000 km across and are deeper than the smaller cells. Next in the tier are the super-granular cells, which are about 30,000 km across. The final tier are the smaller currents, which are about 1000 km across and 2000 km deep. This tier marks the surface of the Sun.

The visible surface of the Sun is the photosphere. Telescopic observations reveal a mottled solar surface (granulation) that is a manifestation of the upper-level tier of circulating cells. Disturbances deep in the convection zone may be related to the observed 5-minute oscillation (Woodard and Hudson, 1983).

Oscillations in the Sun may be created in response to gravitational forces and gas pressure gradients (Christensen-Dalsgaard et al., 1985). Pressure gradients give rise to acoustic or pressure waves called p-modes. Gravity gives rise to buoyancy that could lead to the formation of gravity modes or g-modes. Such modes can be used to probe the Sun's interior much in the same way seismic waves are used to probe the Earth's interior. Both Nimbus-7 and SMM data have been used to detect p- and g-modes (Frohlich, 1987; Wolff, 1983; Wolff and Hickey, 1987a,b).

2.5.2 Solar Activity and Solar Cycles

We tend to think of the Sun as a static ball of gas; energy is created in the core and is radiated out to space through the convection zone, photosphere, and solar atmosphere. However, the Sun is a highly dynamic body, exhibiting a considerable amount of detectable phenomena.

Solar activity is caused by the interplay between strong solar magnetic fields and the Sun's differential rotation. Rotation at the solar poles takes about 37 days, while at the solar equator the rotation period is on the order of 26 days.

The appearance of sunspots in the photosphere is but one phenomena associated with solar activity. Sunspots appear and disappear on a daily basis, reaching a maximum every 11 years--the
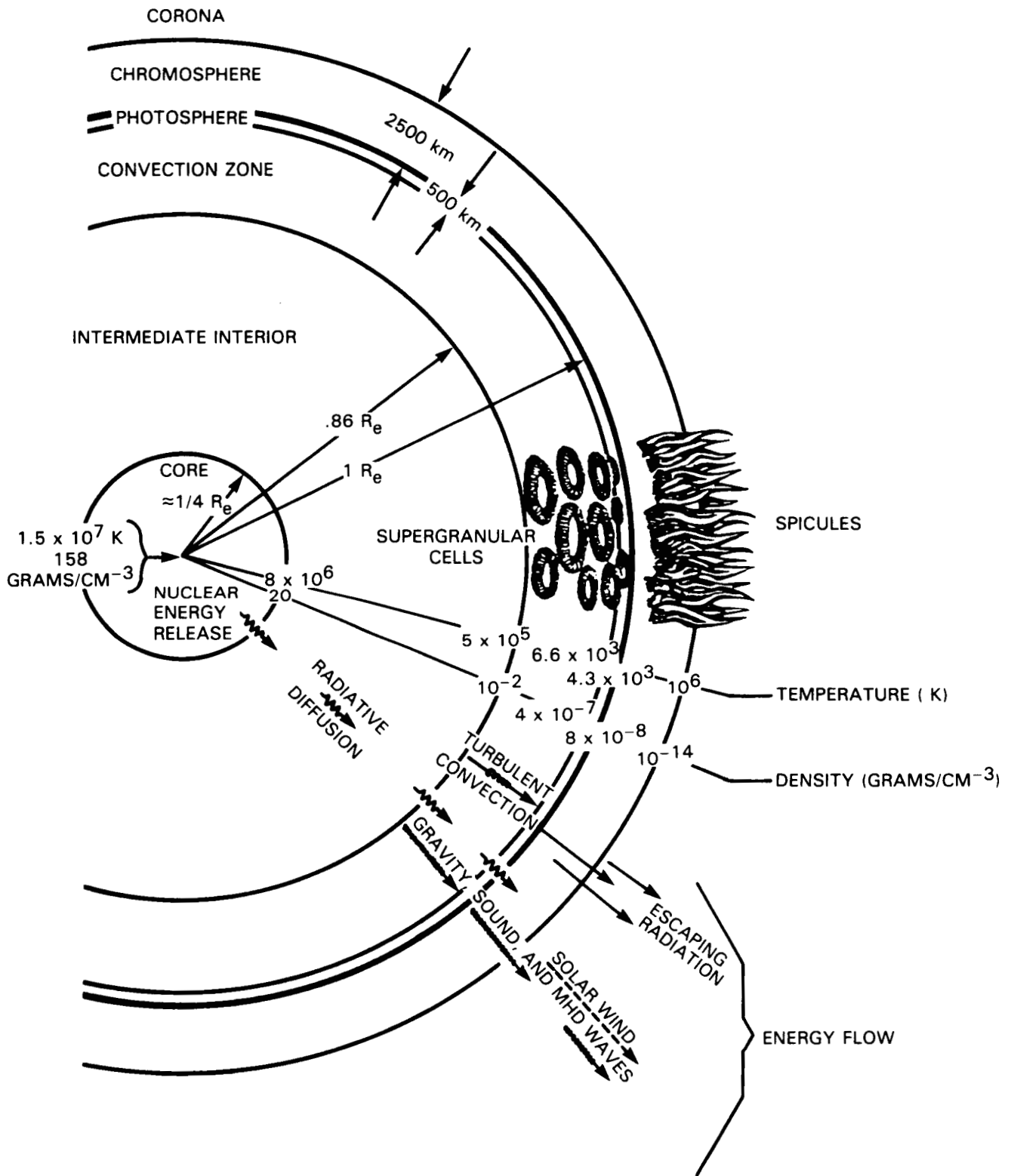
Figure 2-20. General Solar Properties, Structure, and Modes of Outward Energy Flow (not to scale). From Gibson, E. G., "The Quiet Sun," NASA SP-303, NASA, Washington, DC, 1973.

famous sunspot cycle. However, this cycle is but a part of a longer 22-year solar cycle associated with the Sun's magnetic field (Babcock, 1961). Internal magnetism rises due to convection and differential rotation and then collapses. This takes about 11 years. After the collapse of the magnetic field, the field reverses polarity and, during the next 11 years, differential rotation winds up the magnetic strength until the reversed field collapses. During each 11-year cycle, magnetic energy builds up as rotation amplifies the field. The energy is released through the appearance of sunspots, solar active regions, and flares. The sunspot or solar cycle may be much more complicated than Babcock envisioned. Recent evidence suggests there may be two overlapping solar cycles (Robinson, 1987).

2.5.2.1 Sunspots

Sunspots had been observed by early Chinese and Greek astronomers and were rediscovered by the Europeans in 1611. A sunspot appears black against the bright photosphere because it is about 30 percent cooler than the surrounding region. The average size of a sunspot is about 10,000 km, and some are as large as 150,000 km. Sunspots consist of a dark central region, called the umbra, surrounded by a less dark region called the penumbra. Sunspots are regions of intense magnetic fields. Differential rotation builds a shell of a strong magnetic field, under the photosphere, where convection eventually twists the field. Eventually the magnetic pressure is strong enough to make the field buoyant; it wells up and bursts through the photosphere and forms sunspots.

Sunspots have been systematically recorded for at least 300 years. Detailed analysis by H. Schwabe in 1843 and R. Wolff in 1856 first noticed that the sunspots' activity reaches a maximum about every 11 years. Over the last 50 years, the sunspot cycle has averaged 10.4 years and can be as short as 7 years and as long as 17 years (see Figure 2-21). Further analysis by R. Carrington and G. Sporer identified the latitude of occurrence of sunspots during maximum and minimum, which consequently led to the identification of the magnetic nature of the sunspot groupings by G. E. Hale.

2.5.2.2 Solar Active Regions

Solar active regions, in addition to sunspots, include plages, prominences, faculae and flares. Common to all are a strong magnetic field. Plages are highly disturbed zones in the chromosphere. Plages are bright and usually appear prior to the appearance of sunspots and live longer than sunspot groups. Faculae are a bright region around a solar active region in the photosphere. Prominences are regions of locally enhanced density. These are the most spectacular of solar displays. Flares are highly concentrated, explosive releases of energy, usually in the X-ray region. Flares usually appear in the vicinity of an active region. It has been suggested that there is a possible 154-day periodicity in the occurrence of solar flares (Rieger et al., 1984; Bogart and Bai, 1985).

2.5.3 Solar Variability

Newkirk (1983), in a review of current research in solar luminosity variations, indicates that fluctuations in luminosity may occur on time scales of days or weeks associated with specific sunspot groups, of 11 or 22 years associated with the solar cycle, of many decades associated with a modulation of the solar cycle, or of much longer periods associated with episodic mixing in the Sun's interior as the Sun evolves off the main sequence. The 11-year sunspot cycle has long been suspected as modulating the total solar radiative output. The 11-year cycle is known to have irregular variations in between cycles, and this would seem to indicate that the processes of nuclear generation and convection or rotation are not as exact as once thought (evidenced by the solar-neutrino discrepancy). A detailed historical analysis by Eddy (1976) has shown that solar activity was drastically reduced during the years 1645 to 1715 in which virtually no sunspots were detected. This period has been referred to as the Maunder minimum and is also associated with
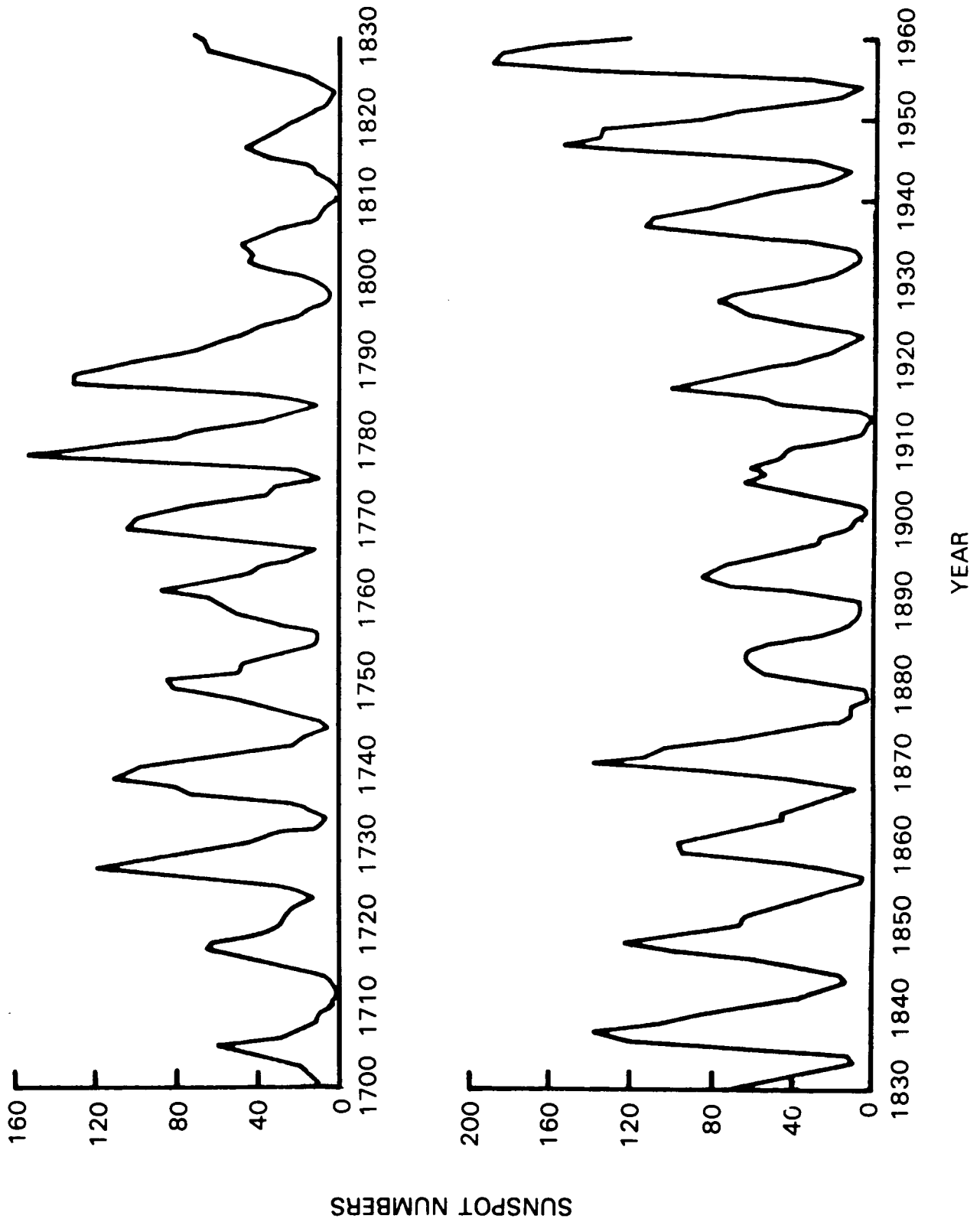
Figure 2-21. Annual Mean Sunspot Number, R, from 1700 to 1960 (Eddy, 1976)

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the "Little Ice Age" in North America and Europe. The cause of this reduction may be related to differential rotation anomalies (Eddy et al., 1976) and strongly suggests that variations in the solar cycle may lead to variations in the total solar luminosity, which can affect the Earth's climate. A recent paper by Ribes et al. (1987) suggests that the Sun was actually larger during the Maunder minimum and had a slower rotation.

On short time scales, early studies by Foukal and Vernazza (1979) and Foukal et al. (1977) suggest that variations of 0.01 percent in the Sun's luminosity correlate with the 11-year cycle. These studies suggest that luminosity variations are caused by magnetic field activity of sunspots and faculae that redistribute the flow of convective energy.

Prior to the launch of Nimbus-7, ground-based observations to monitor the solar constant (or changes in the solar constant) have been attempted without much success because observations cannot be corrected for atmospheric extinctions to the degree necessary to detect solar irradiance variations. Balloon, rocket, and aircraft flights have also made attempts to monitor the solar constant, but not on a continuous daily basis (Willson, 1984). Our knowledge of the total solar irradiance has grown significantly as a result of the radiometers on board the Nimbus-7 and SMM spacecraft.

Observed irradiance variations on time scales associated with solar active regions is based on days. It is believed that the presence of sunspots blocks the emerging radiant flux from the Sun. The blocked energy may be re-emitted immediately by the brighter and hotter faculae surrounding the active region, or the energy may be stored in the convection zone to be released slowly and unobserved over a long period of time.

Theoretical models of sunspot blocking, using Nimbus-7 and SMM solar irradiance data, have been developed to determine the mechanism that causes irradiance variations. It is not clear what role the faculae play in solar irradiance variations. Some modelers (Eddy et al., 1982; Foukal and Lean, 1986; Foukal, 1987) have evidence that the energy contribution from faculae is insufficient to balance the radiation blocked by the sunspots, and that the remainder of the energy is probably stored within the convective layer. Other modelers (Oster et al., 1982; Schatten et al., 1985; Schatten et al., 1987) have suggested that the energy is reradiated through faculae. In either case, the physical nature of the mechanism involved is undoubtedly a complex interplay of magnetic fields, convection, and rotation, as evidenced by complex relationships between irradiance observations and solar activity indicies (Pap, 1986; Hoyt and Eddy, 1983; Smith et al., 1983; Willson, 1984). Other unexplained features may be due to complexities of solar oscillations (Frohlich, 1987; Wolff and Hickey, 1987a,b). Short-term solar irradiance variations have also been observed in the ultraviolet and correlated with active regions (Lean, 1987). Figure 2-22 shows a plot of channel 10C solar irradiance for 1979 compared with Zurich sunspot numbers and 2800 MHz solar flux.

2.5.3.1 Long-Term Solar Variability

An examination of the slopes of solar irradiance measurements has revealed a persistent long-term, downward trend in the solar irradiance that seems to be associated with the 11-year sunspot or 22-year solar cycle. Over the 89-month span of ERB solar incidence measurements, a downward slope of -0.011 percent per year has been observed with a mean solar irradiance at 1 astronomical unit of 1370.4 W/m^2. A year-by-year statistical analysis has been made for the ERB solar irradiance data as shown in Table 2-2. As can be seen, the first year of observation (November 1978 to October 1979) experiences the largest slope, which may be related to the degradation observed in the filtered channels (Hickey et al., 1985). It is interesting to note that years 4, 6, and 7 all show a positive slope.

This downward trend has been given much attention and is obviously of great importance to solar physicists (Kerr, 1986). The trend also appears in the ACRIM record (Willson et al., 1986), and it

NIMBUS 7 CHIOC IRRADIANCE
JAN 1979-DEC 1979
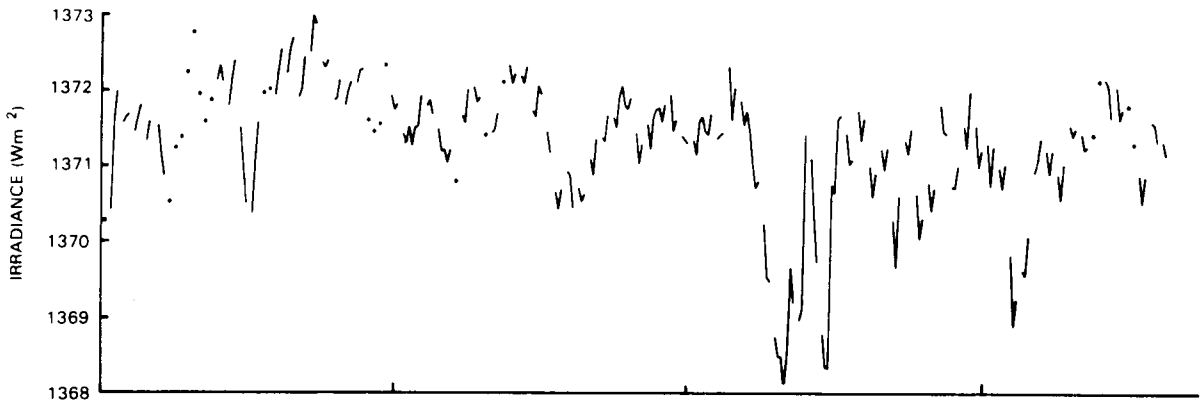
ZURICH SUNSPOT NUMBERS
JAN 1979-DEC 1979
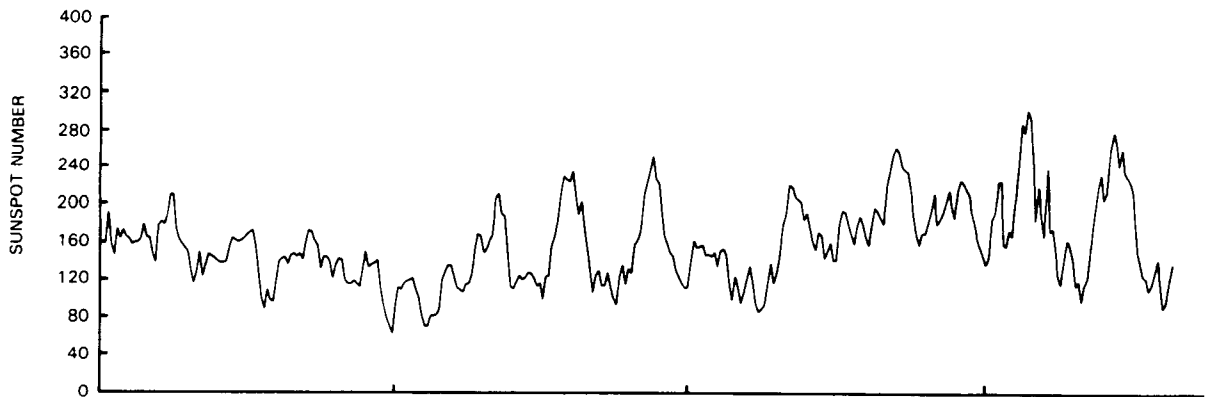
**OTTAWA 2800 MHz SOLAR FLUX**
JAN 1979-DEC 1979
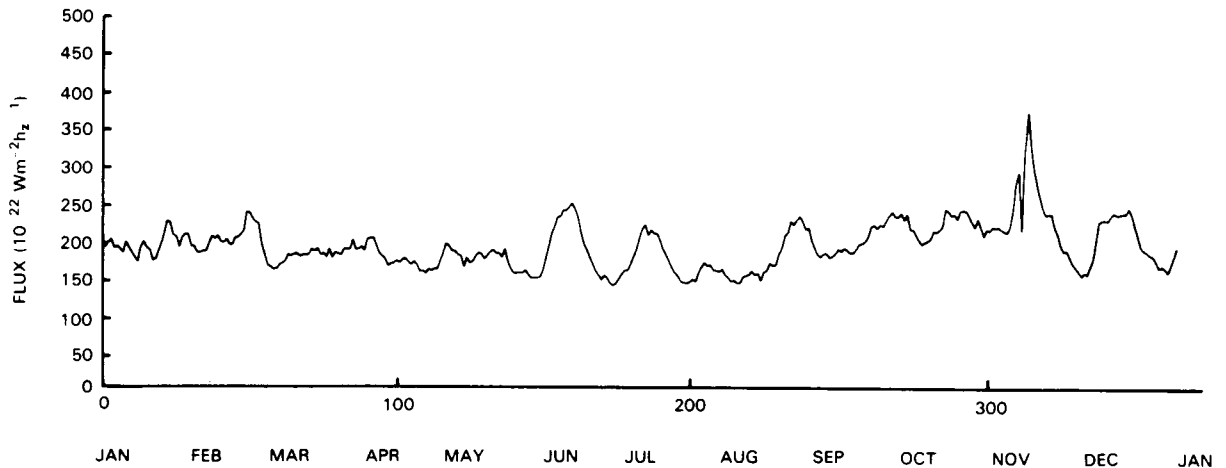
Figure 2-22.   Correlation between Nimbus-7 channel 10c irradiance, Zurich sunspot numbers, and Ottawa 2800 MHz solar flux for the period January to December 1979, during an active period

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is uncertain whether this trend will continue or whether it is of solar origin. Such a downward trend, if it is real, could be related to actual luminosity changes associated with the solar cycle and could have possible climatological significance. Although this does not appear to be the case at the present time, changes in solar luminosity associated with the solar cycle could explain such anomalies as the Maunder minimum (Foukal and Lean, 1986; Foukal, 1987). The ERB channel 10c has the longest existing continuous record of accurate extraterrestrial monitoring, and it started measurements before the current solar maximum (solar cycle 21, 1980). As the solar cycle passed through its minimum (which occurred in September 1986), a change in the trend was expected (Hickey et al., 1986). A flattening of the trend has been observed in the 10c data and appears associated with the solar minimum. The next question is this: Will the ERB 10c and SMM ACRIM measure an increase in the solar irradiance as the next solar activity maximum approaches?

Table 2-2
Year-by-Year Solar Irradiance Measurements

	NOBS	MEAN	SLOPE	%/ YEAR	STD. ERROR
Nov 1978-Oct 1979	263	1371.26	-0.0025	-0.066	0.0005
Nov 1979-Oct 1980	271	1371.06	-0.0006	-0.017	0.0004
Nov 1980-Oct 1981	284	1370.74	-0.0006	-0.015	0.0004
Nov 1981-Oct 1982	275	1370.57	+0.0002	+0.004	0.0004
Nov 1982-Oct 1983	291	1370.53	-0.0009	-0.024	0.0003
Nov 1983-Oct 1984	318	1370.13	+0.0006	+0.017	0.0003
Nov 1984-Oct 1985	365	1370.09	+0.0001	+0.026	0.0001
Nov 1985-Mar 1986	150	1370.07	-0.0001	-0.003	0.0004
Nov 1978-Mar 1986	2217	1370.44	-0.0004	-0.011	0.00002

2.5.3.2 Comparisons with SMM/ACRIM

The ACRIM on the SMM satellite began receiving data on February 16, 1980. A comparison between the ERB and ACRIM slopes reveals that the same long-term trends are evident (see Figure 2-23). The ACRIM also exhibits a positive slope for years 1982 and 1984. Since the ERB operates on a 3-day-on/1-day-off duty cycle, a comparison was made between the two instruments on those days when the ERB was on. The results are shown in Table 2-3. In general, the ERB solar measurements are on the order of 0.2 percent higher than the ACRIM over a similar period in time. This difference can probably be assigned to unknown calibration problems; however, the same short- and long-term trends are evident.

NIMBUS 7 CH10C AND SMM-ACRIM
NOV 1978-MAR 1986
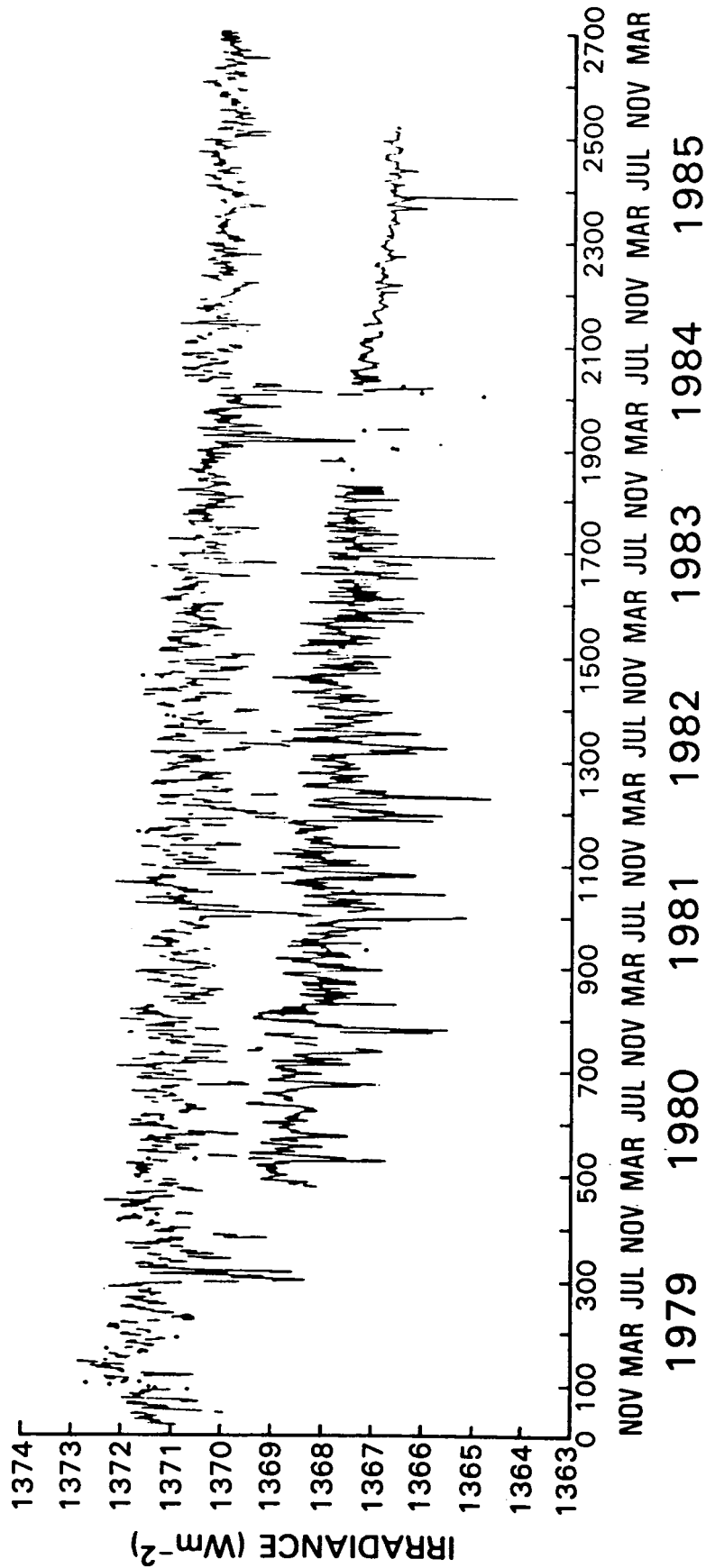
Figure 2-23. Complete solar data sets from Nimbus-7 ERB (top) and SMM/ACRIM (bottom). Note the correlation in the primary irradiance dips and the slow, long-term downward trend in both data sets.

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Table 2-3

Nimbus-7 ERB Channel 10c and SMM/ACRIM
Statistics on Identical Days

	Date	NOBS	Mean	Slope	%/Year	Std. Err. Slope
N7	FEB 1980	1453	1370.451	-0.00038	-0.010	0.00002
SMM	SEP 1985		1367.191	-0.00080	-0.021	0.00002
N7	FEB 1980	221	1370.960	-0.00143	-0.0381	0.00049
SMM	DEC 1980		1368.161	-0.00280	-0.075	0.00047
N7	JAN 1981	262	1370.752	-0.00082	-0.0218	0.00038
SMM	DEC 1981		1367.645	-0.00105	-0.0280	0.00039
N7	JAN 1982	269	1370.524	+0.00064	+0.0170	0.00042
SMM	DEC 1982		1367.333	+0.00061	+0.0162	0.00043
N7	JAN 1983	234	1370.534	-0.00138	-0.0368	0.00030
SMM	DEC 1983		1367.189	-0.00027	-0.0072	0.00038
N7	JAN 1984	197	1370.210	-0.00003	-0.0008	0.00041
SMM	DEC 1984		1366.811	-0.00005	-0.0014	0.00030
N7	JAN 1985	270	1370.130	-0.00005	-0.00140	0.000217
SMM	SEP 1985		1366.464	-0.000047	-0.0127	0.000219

SECTION 3

DESCRIPTION OF ESAT CONTENTS

The ERB ESAT consists of ERB solar channel data and solar activity indicators as described in the following sections.

3.1 ERB Solar Channel Data

The ERB solar channel data on ESAT, derived from the SEFDTs, are comprised of two parts: (1) the orbital solar data and (2) the daily mean solar data which consists of the mean, standard deviation, minimum, and maximum. The daily mean data were derived by Eppley Labs from the filtered orbital data using the Statistical Analysis System (SAS) software package.

The contents of the orbital ERB solar data are as follows:

- Orbit number, year, day of year
- Solar azimuth and elevation
- Instrument status word (ISW)
- Gamma angle
- Earth-Sun distance (least significant bit, most significant bit)
- Channel 3 and Channel 10c temperatures
- Channels 1 through 10c irradiances
- Southern terminator crossing time
- Mission day since November 16, 1978
- Off-axis angle
- Cosine corrected channel 10c irradiance

The contents of the daily mean ERB solar data (which includes the mean, standard deviation, minimum and maximum measurements, and the number of orbits for each parameter) is as follows:

- Orbit number, year, day of year
- Solar azimuth and elevation
- Gamma angle
- Channel 3 and 10c temperatures
- Channel 1 through 10c irradiances
- Mission day since November 16, 1978
- Off-axis angle
- Cosine corrected channel 10c irradiance

3.2 Origin of Solar Activity Indicators

The solar activity indicators defined on ESAT were derived from the NOAA/National Geophysical Data Center (NGDC) Solar Geophysical Data Reports (SGD) (NOAA/NGDC, 1982). Solar active region data were obtained from Dr. Ken Schatten at NASA/GSFC and were originally obtained from NOAA/NGDC World Data Center-A and published in the SGD. Daily calcium plage index and geomagnetic index were obtained directly from the SGD prompt reports.

A detailed description of the solar activity indicators is as follows:

Zurich Relative Sunspot Numbers. A measure of visible daily solar activity. This number is derived from several observatories and combines the number of single spots and groups of spots on the solar disk. The formula is

$$R_z = k(10g + s) \tag{7}$$

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where

10g	=	Number of spots and groups (weighted by 10).
s	=	Total number of distinct single spots.
k	=	Factor that depends on the observer and is used to convert measure from the original Wolff sunspot scale.

The Zurich Relative Sunspot Numbers comprise a complete daily record of solar activity for the period November 16, 1978, through March 31, 1986.

Ottawa 2800 MHz Solar Flux. A measure of daily radio solar activity. These measurements are the daily observations of the 2800 MHz radio emissions that originate from the solar disk and from any active region. Measurements are made at the Algonquin Radio Observatory (ARO) of the National Research Council of Canada with a 1.8-m diameter reflector. Measurements are in flux units of 10^{-22} Wm^{-2} Hz^{-1}.

The Ottawa 2800 MHz Solar Flux comprises a complete daily record of solar activity for the period November 16, 1978, to March 31, 1986.

Daily Calcium Plage Index. An index of solar activity based on the solar plage area and coordinates. The index as given by W. R. Swartz and modified in the SGD is as follows:

$$C_A II_{index} = [\Sigma I_i A_i \cos \theta_i \cos \phi_i]/1000 \tag{8}$$

where the summation includes all plages visible on that day.

I_i	=	Intensity of plage i.
A_i	=	Corrected area of plage i in millionths of solar hemisphere.
θ_i	=	Central meridian distance of plage i in degrees.
ϕ_i	=	Latitude of plage i.

The Daily Calcium Plage Index data are available on a daily basis from November 16, 1978, through March 31, 1986. Missing data or where no observations were made are defined as 0.

Geomagnetic Index. A daily index of magnetic activity due to solar events recorded on a linear scale. The daily Ap series is used and is an average of eight values of an intermediate 3-hourly index.

The Geomagnetic Ap Series Index is available on a daily basis from November 16, 1978, through December 1982. Missing data are defined as 0.

Solar Active Region Data. Solar active region data are comprised of two parts: calcium plage data and sunspot group data. Plage regions are the bright areas on the solar disk sometimes preceeding the appearance of sunspots. The calcium plage data contain seven parameters that were derived from the NOAA solar active region tape:

1. McMath-Hale Region Number. This is the active region number assigned in order of appearance on the solar disk. More than one region number can appear on a day.

2. Central Meridian Passage Date. The date of central meridian passage of the region, at 12^hUT and corrected for whether before noon or after noon.

3. Latitude. The latitude of the region center of mass, north or south of solar equator. Negative latitudes are south.

4. Central Meridian Distance. Distance of the region center of mass east or west of the central meridian at 12^{h}UT. Distance is in degrees, measured to the west 0° to 360°.

5. Area. The corrected area (corrected for distance from the center of the solar disk) in millionths of the solar hemisphere.

6. Intensity. The intensity of the plage region on a scale of 1 (very faint) to 5 (very bright). Solar plage data are available from November 16 to June 1982. The number of plage regions per day is noted on the ESAT tape so that the proper number of page region records can be read. If no observations were made, then the solar plage parameters are 0.

7. Carrington Longitude. An internationally-agreed central meridian that passed through the apparent center of the solar disc on January 1, 1854, at 12^h Universal Time (UT). From this Carrington-central meridian, heliographic longitude is measured to the west 0° to 360°. The zero meridian (L = 0°) becomes established on completion of a solar rotational period (synodic period) observed from the Earth and of mean duration of 27.2753 days.

Sunspot group data contain six parameters, which also were derived from the NOAA solar active region tape:

1. Mount Wilson Region Number. The sunspot group number is assigned by Mount Wilson Observatory as groups appear on solar disc.

2. Latitude. Same as for calcium plage data.

3. Central Meridian Distance. Same as for calcium plage data.

4. Class. Magnetic classification in numerical format as follows: A=1; AP=2; AF=3; BP=4; B=5; BF=6; BG or BY=7; G or Y=8; D=9; No Class=0.

5. Area. Same as for calcium plage area.

6. Carrington Longitude. Same as for calcium plage data.

3.3 Solar Activity Indicators

The solar activity indicators on the ESAT are not the most comprehensive, but do constitute a long-time series of the more common and useful indicators. A description of the contents of the solar activity data set is as follows:

- Zurich Relative Sunspot Number (daily)
- Daily Calcium Plage Index
- Geomagnetic Index (Ap)
- Solar active regions including:

  - McMath-Hale region number
  - Coordinates of plage region including CM and latitude
  - Corrected area of plage region
  - Intensity of plage region
  - Mount Wilson sunspot group number
  - Coordinates of sunspot group area
  - Magnetic classification of sunspot area
  - Corrected area of sunspot group

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3.4 Missing Data

Missing data in the orbital and mean data sets are flagged with -9999. Data gaps and ERB off days in the mean data are flagged with -9999. Gaps in the solar activity records are not flagged, but are simply missing as indicated by 0.

3.5 ESAT Tape Structure

The ESAT has three data files. Data File 1 contains the orbital data set, Data File 2 contains the daily mean data set, and Data File 3 contains the solar activity data. The physical structure of the tape is shown in Figure 3-1.

3.6 Summary of ESAT Solar Channel Uncertainties

The ESAT represents the highest level of precision of the ERB solar data currently available. The SEFDTs have been carefully screened for bad orbits, low temperatures (less than 18°C), and excessive off-axis angle (greater than 3.1 degrees). Along with quality controlled orbital data, the inclusion of daily mean solar data represents a significant improvement over the solar data available on the SEFDT. The degradation effects experienced by nine of the ten solar channels are retained on ESAT with no adjustments or corrections. The ERB off days (due to the ERB duty cycle of 3-days-on/1-day-off) are retained on ESAT as missing values.

A summary of the solar channels is presented below:

Channel	NOBS	Mean	Std. Dev.	Minimum	Maximum	Range
1	731	1246.32	55.810	1168.32	1377.07	208.75
2	2217	1164.83	44.959	1083.82	1357.26	273.44
3	1588	1363.37	3.982	1357.31	1382.55	25.24
4	2217	922.07	21.376	878.11	990.42	112.31
5	2217	679.92	4.187	670.66	692.82	22.16
6	2217	208.00	3.745	185.22	211.00	25.78
7	2217	136.79	13.367	114.17	166.87	52.70
8	2217	81.50	11.211	66.41	109.28	42.87
9	2153	64.38	2.746	48.27	66.26	17.99
10	2217	1370.44	0.692	1367.10	1372.95	5.85

```
┌─────────┐
│Standard │
│Header   │ <─────────────        Standard Header Record
│File     │
└─────────┘


┌─────────┐                       ERB Solar Orbital Mission Day 1
│Data     │                           .
│File     │ <─────────────            .
│1        │                       ERB Solar Orbital Mission Day 2692
└─────────┘                       Last Mission Day on Tape*


┌─────────┐                       ERB Solar Mean Data Mission Day 2
│Data     │                           .
│File     │ <─────────────            .
│2        │                       Mission Day 2692 to Last Mission Day
└─────────┘                       on Tape*


┌─────────┐
│Data     │
│File     │ <─────────────        Solar Activity Indicators**
│3        │
└─────────┘
```
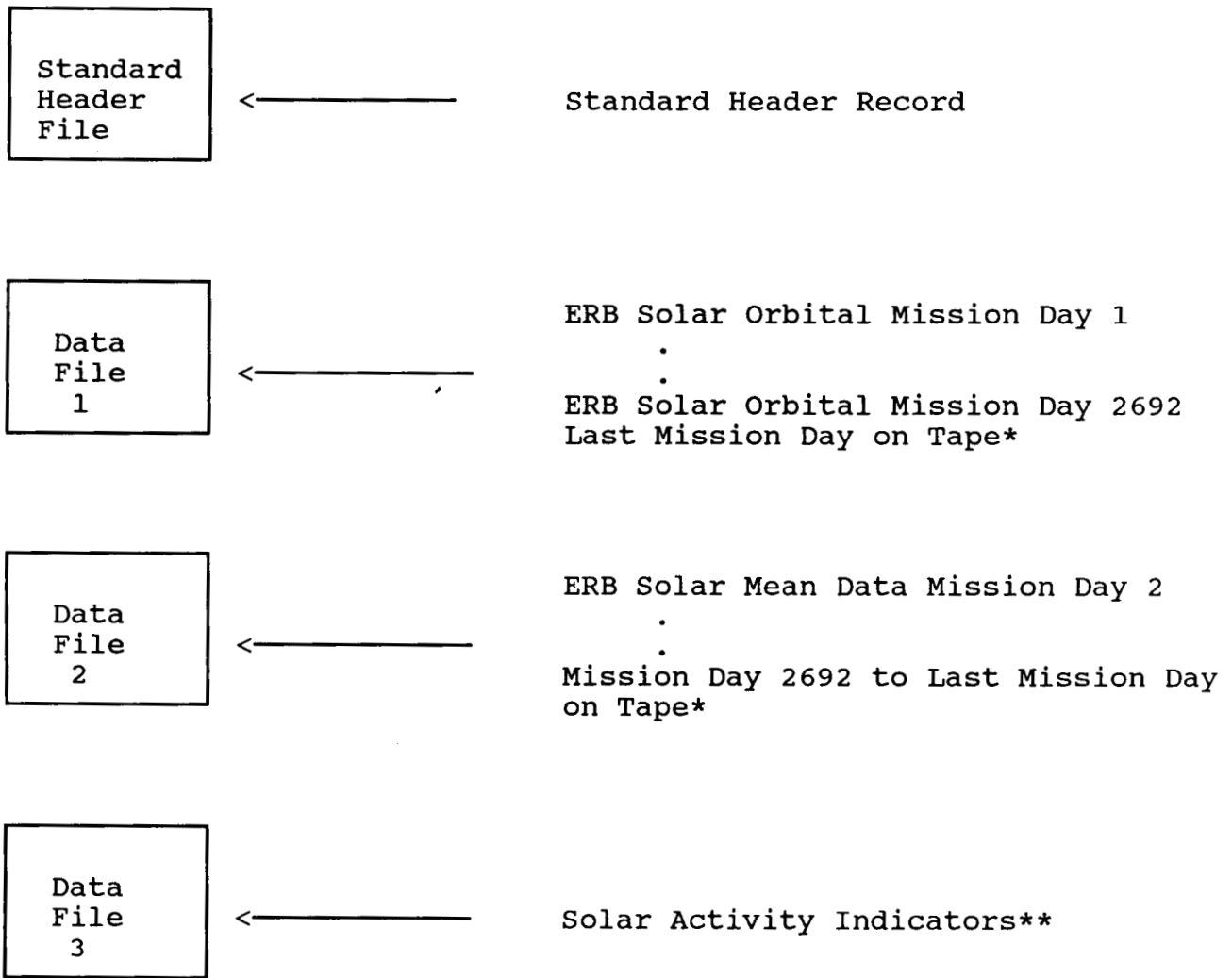
 *March 31, 1986 is mission day 2692.
**Not all solar activity indicators are available for all 89 months.

Figure 3-1.   Physical Structure of ESAT Tape

SECTION 4

PHYSICAL STRUCTURE OF ESAT TAPE

4.1 Tape Organization

The ESAT Tape is a 9-track, unlabeled, 1600-BPI compatible tape. The first file contains the Nimbus Observation Processing System (NOPS) Standard Header. The second file contains the ERB solar orbital data for 89 months. The third file contains the ERB solar daily mean data for 89 months. The fourth file contains the solar activity indicator data. The NOPS Standard Header file is described in Appendix A.

4.2 Tape and File Specifications

Tape Specifications: 1600-BPI, 9-track, non-labeled tape

File Specifications:

	Header File	Data File 1	Data File 2	Data File 3
File Location	1	2	3	4
Record Length (bytes)	630	84[1]	376[2]	48[3]
Record Format	unblocked	UT	UT	UT
Data Type	EBCDIC	binary	binary	binary
REC ID No.	none	100	200	300

[1] 84 bytes per observations by 27,671 observations = 2,324,364 bytes
[2] 376 bytes per day by 2,692 days = 1,012,192
[3] 48 bytes per observation by 2,692 days = 129,216 bytes minimum
The total number of bytes for the solar activity data set 559,324 bytes.

4.3 ESAT Data File Specifications

Tables 4.1, 4.2, and 4.3 and the accompanying information describe in detail the word location of each data item in each data file. A description of each data item is also included. Appendix C includes the scale factors used to generate the ESAT data set.

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Table 4-1
ESAT Orbital Data
Record Format

WORDS	32 0		BITS
1	RECORD NUMBER	RECORD ID	32
2	ORBIT NO.	SPARE	64
3	YEAR	DAY OF YEAR	96
4	SOLAR AZIMUTH	SOLAR ELEVATION	128
5	INSTRUMENT STATUS WORD	GAMMA ANGLE	160
6	EARTH-SUN DISTANCE (MSB)	EARTH-SUN DISTANCE (LSB)	192
7	CHANNEL 3 TEMPERATURE		224
8	CHANNEL 10C TEMPERATURE		256
9-18	CHANNEL 1-10C IRRADIANCE		576
19	SOUTH TERM. (HRS/MIN)	SOUTH TERM. (SECS)	608
20	MISSION DAY	OFF-AXIS ANGLE	640
21	COSINE-CORRECTED CHANNEL 10C IRRADIANCES		672

WORDS 1-6 AND 19-20 ARE IBM INTEGER *2 FORMAT
WORDS 7-18 AND 21 ARE IBM INTEGER *4 FORMAT

Table 4-2
ESAT Daily Mean Data
Record Format

WORDS	32		BITS
1	RECORD NUMBER	RECORD ID	32
2-6	ORBIT NO. (MEAN, STD. DEV., MIN., MAX., NO.)		192
7	YEAR		224
8	DAY OF YEAR		256
9-13	SOLAR AZIMUTH (MEAN, STD. DEV., MIN., MAX., NO.)		416
14-18	SOLAR ELEVATION (MEAN, STD. DEV., MIN., MAX., NO.)		576
19-23	GAMMA ANGLE (MEAN, STD. DEV., MIN., MAX., NO.)		736
24-28	CHANNEL 3 TEMPERATURE (MEAN, STD. DEV., MIN., MAX., NO.)		896
29-33	CHANNEL 10C TEMPERATURE (MEAN, STD. DEV., MIN., MAX., NO.)		1056
34-83	CHANNEL 1-10C IRRADIANCE (MEAN, STD. DEV., MIN., MAX., NO.)		2656
84	MISSION DAY		2688
85-89	OFF-AXIS ANGLE (MEAN, STD. DEV., MIN., MAX., NO.)		2848
90-94	COSINE-CORRECTED CHANNEL 10C IRRADIANCE (MEAN, STD. DEV., MIN., MAX., NO.)		3008

WORD 1 IS IBM INTEGER *2 FORMAT
WORDS 2-94 ARE IBM INTEGER *4 FORMAT

Table 4-3
ESAT Solar Activity Data
Record Format

WORDS	32		BITS
1	RECORD NUMBER	RECORD ID	32
2	YEAR	DAY OF YEAR	64
3	NO. PLAGE REGIONS (NPR)	NO. SUNSPOT GROUPS (NSG)	96
4	ZURICH SUNSPOT NO.	2800 MHz SOLAR FLUX	128
5	DAILY CALCIUM PLAGE INDEX	GEOMAGNETIC AP INDEX	160
6	CMP DATE	MH REGION NO.	224
7	LAT (PLAGE)	LON (PLAGE)	288
8	AREA	INTENSITY	352
9	CAR. LON (PLAGE)	BLANK (9999)	416
10	MT. WILSON (GROUP NO.)	LAT (SUNSPOT)	480
11	LON (SUNSPOT)	CAR. LON (SUNSPOT)	544
12	AREA (SUNSPOT)	MAG. CLASS (SUNSPOT)	608

*MINIMUM OF 608 BITS, DEPENDS ON NUMBER OF PLAGE REGIONS AND SUNSPOT GROUPS PER DAY.

ESAT SOLAR ANALYSIS TAPE--DATA FILE 1
ORBITAL ITEM DESCRIPTIONS

ITEM NO.	WORD	TYPE	DETAILED DESCRIPTION OF DATA ITEMS
			NOTE: Scaling factor for the data contained within the data array is as follows: True Values = Integer Value/Scaling Factor.
1	1	I*2	RECORD NO: Number of this record in this file.
2	1	I*2	RECORD ID: Record identification number. 100 = Orbital File.
3	2	I*2	ORBIT NO: Data orbit number.
4	2	---	Spare (-9999).
4	3	I*2	YEAR: 4-digit year.
5	3	I*2	DAY OF YEAR: Day number.
6	4	I*2	SOLAR AZIMUTH: Azimuth of sun relative to the spacecraft axes. Ranges from -180 to +180. Stored in tenths of a degree. Same as DSAS alpha angle.
7	4	I*2	SOLAR ELEVATIONS: Elevation of sun relative to the spacecraft axes. Ranges from -180 to +180. Stored in tenths of a degree. Same as DSAS beta angle, in tenths of a degree.
8	5	I*2	INSTRUMENT STATUS WORD: Determined from VIP MF.

Units Decimal Digit (indicates position of scanhead)

0 = Scan mode	3 = LW check position
1 = Nadir position	4 = SW check position
2 = Space position	9 = Transition mode

Tens Decimal Digit (indicates status of shutters, channels 1, 11, and 12)

0 = Reference channels CLOSED, Channel 12 OPEN
1 = Reference channels CLOSED, Channel 12 CLOSED
2 = Reference channels OPEN, Channel 12 OPEN
3 = Reference channels OPEN, Channel 12 CLOSED
9 = Status unknown

Hundreds Decimal Digit (indicates status of Channel 12 FOV)

0 = Channel 12 FOV Wide
1 = Channel 12 FOV narrow
9 = Status unknown

ITEM NO.	WORD	TYPE	DETAILED DESCRIPTION OF DATA ITEMS
			Thousands Decimal Digit (indicates status of Electrical Calibration (ECAL), and Go/No-Go heater) 0 = Go/No-Go heater OFF, ECAL OFF 1 = Go/No-Go heater OFF, ECAL ON 2 = Go/No-Go heater ON, ECAL OFF 9 = Status unknown
9	5	I*2	GAMMA ANGLE: Solar channel subassembly position at middle of major frame (MF).
10	6	I*2	EARTH-SUN DISTANCE: MSB Earth-Sun distance in AU (see Appendix E).
11	6	I*2	EARTH-SUN DISTANCE: LSB Earth-Sun distance in AU (see Appendix E).
12	7	I*4	CHANNEL 3 TEMPERATURE: Temperature in degrees centigrade, in tenths of a degree.
13	8	I*4	CHANNEL 10c TEMPERATURE: Temperature in degrees centigrade, in tenths of a degree.
14-24	9-18	I*4	CHANNELS 1 through 10c IRRADIANCES: Channels 1 through 10c irradiances are in W/m². Channels 1 through 5 and 10c are in tenths of a W/m² (e.g., 13705 on ESAT is actually 1370.5 W/m²); channels 6 through 9 are in hundredths of a W/m².
25	19	I*2	SOUTHERN TERMINATOR (HRS/MIN): GMT hours/minutes of southern terminator crossing.
26	19	I*2	SOUTHERN TERMINATOR (SECS): GMT seconds of southern terminator crossing (1-60).
27	20	I*2	MISSION DAY: Mission day number starting with 1 on 16 November 1978.
28	20	I*2	OFF-AXIS ANGLE: Calculated sum of solar azimuth and gamma angles, in tenths of a degree.
29	21	I*4	COSINE-CORRECTED CHANNEL 10c: Channel 10c irradiance corrected with cosine of off-axis angle, in tenths of a W/m².

ITEM NO.	WORD	TYPE	DETAILED DESCRIPTION OF DATA ITEMS
			NOTE: Scaling factor for the data contained within the data array is as follows: True Values = Integer Value/Scaling Factor.
1	1	I*2	RECORD NO: The number of this record in this file.
2	1	I*2	RECORD ID: The record identification for this file. 200 = daily mean.
3	2-6	I*4	ORBIT NO: Data orbit number. MEAN: Scaled by 10. STD. DEV.: Scaled by 10,000. MINIMUM: Minimum orbit number. MAXIMUM: Maximum orbit number. NUMBER: Number of orbits to calculate mean per day.
4	7	I*4	YEAR: 4-digit year.
5	8	I*4	DAY OF YEAR: Day number.
6	9-13	I*4	SOLAR AZIMUTH: Azimuth of sun relative to spacecraft axes. Value in degrees (-180 to +180). MEAN: Scaled by 10,000. STD. DEV.: Scaled by 1,000,000. MINIMUM: Minimum solar azimuth, scaled by 10. MAXIMUM: Maximum solar azimuth, scaled by 10. NUMBER: Number to calculate mean solar azimuth per day.
7	14-18	I*4	SOLAR ELEVATION: Elevation of sun relative to spacecraft axes. Value in degrees (-180 to +180). MEAN: Scaled by 100,000. STD. DEV.: Scaled by 1,000,000. MINIMUM: Minimum solar elevation, scaled by 10. MAXIMUM: Maximum solar elevation, scaled by 10. NUMBER: Number to calculate mean solar elevation per day.
8	19-23	I*4	GAMMA ANGLE: Solar channel subassembly position at middle of MF. MEAN: Scaled by 100,000. STD. DEV.: Scaled by 1,000,000. MINIMUM: Minimum gamma angle. MAXIMUM: Maximum gamma angle. NUMBER: Number to calculate mean gamma angle per day.
9	24-28	I*4	CHANNEL 3 TEMPERATURE: Temperature of channel 3 in degrees centigrade. MEAN: Scaled by 10,000. STD. DEV.: Scaled by 100,000. MINIMUM: Minimum channel 3 temperature, scaled by 10. MAXIMUM: Maximum channel 3 temperature scaled by 10. NUMBER: Number to calculate mean channel 3 temperature per day.

ITEM NO.	WORD	TYPE	DETAILED DESCRIPTION OF DATA ITEMS

10   29-33   I*4   **CHANNEL 10c TEMPERATURE:** Temperature of channel 10c in degrees centigrade.
MEAN: Scaled by 10,000.
STD. DEV.: Scaled by 100,000.
MINIMUM: Minimum channel 10c temperature, scaled by 10.
MAXIMUM: Maximum channel 10c temperature, scaled by 10.
NUMBER: Number to calculate mean channel 10c temperature per day.

11   34-83   I*4   **IRRADIANCES:** Channels 1 through 10c irradiances in W/m^2.
MEAN: Channels 1 through 3, 10c scaled by 100; channels 4 through 7 scaled by 1000; channels 8 through 9 scaled by 10,000.
STD. DEV.: Channels 2, 4, and 10c scaled by 100,000; channels 1, 3 scaled by 1,000,000; channels 7 through 9 scaled by 10,000,000.
MINIMUM: Minimum channels 1 through 10c irradiances. Channels 1 through 5, 10c scaled by 10; channels 6 through 9 scaled by 100.
MAXIMUM: Maximum channels 1 through 10c irradiances. Channels 1 through 5, 10c scaled by 10; channels 6 through 9 scaled by 100.
NUMBER: Number to calculate mean channels 1 through 10c irradiances per day.

NOTE: Irradiances are stored as channel 1 (MEAN, STD. DEV., MIN, MAX, NUMBER), ..., channel 10c (MEAN, STD. DEV., MIN, MAX, NUMBER)

12   84   I*4   **MISSION DAY:** Day number starting with 1 on 16 November 1978.

13   85-89   I*4   **OFF-AXIS ANGLE:** Calculated sum of solar azimuth and gamma angle.
MEAN: Scaled by 1,000,000.
STD. DEV.: Scaled by 10,000.
MINIMUM: Minimum off-axis angle, scaled by 10.
MAXIMUM: Maximum off-axis angle, scaled by 10.
NUMBER: Number to calculate mean off-axis angle per day.

14   90-94   I*4   **COSINE-CORRECTED CHANNEL 10C:** Channel 10c irradiance corrected by cosine of off-axis angle.
MEAN: Scaled by 100.
STD. DEV.: Scaled by 100,000.
MINIMUM: Minimum corrected channel 10c irradiance scaled by 100.
MAXIMUM: Maximum corrected channel 10c irradiance scaled by 100.
NUMBER: Number to calculate mean corrected channel 10c irradiance per day.

ITEM NO.	WORD	TYPE	DETAILED DESCRIPTION OF DATA ITEMS
			NOTE: Scaling factor for the data contained within the data array is as follows: True Values = Integer Value/Scaling Factor
1	1	I*2	RECORD NO.: The number of this record in this file.
2	1	I*2	RECORD ID: The record identification of this file. Solar Activity = 300.
3	2	I*2	YEAR: 4-digit year.
4	2	I*2	DAY OF YEAR: Day number.
5	3	I*2	PLAGE REGION NO.: Number of plage regions for this day. If 0, then no observations are available for this day.
6	3	I*2	SUNSPOT GROUP NO.: Number of sunspot groups for this day. If 0, then no observations are available for this day.
7	4	I*2	ZURICH RELATIVE SUNSPOT NO.: Daily index of solar activity. Daily sunspot numbers.
8	4	I*2	OTTAWA 2800 MHz SOLAR FLUX: Daily index of solar activity. Daily radio emissions from active regions in 10 to ^{22} Wm^{-2} Hz^{-1} in tenths of a degree.
9	5	I*2	DAILY CALCIUM PLAGE INDEX: Summation of all plages visible on solar disk, corrected for distance from center, in tenths of a degree.
10	5	I*2	GEOMAGNETIC INDEX: Geomagnetic Ap series measurement of magnetic activity due to solar activity, in tenths of a degree.
11	6-9	I*2	SOLAR PLAGE REGION DATA: Consists of the following seven parameters: MCMATH-HALE REGION NUMBER: Number assigned to region of solar activity. CENTRAL MERIDIAN PASSAGE DATE: Greenwich date of central meridian passage at time of observation in hours from $12^{h}UT$, in tenths of a degree. LATITUDE: Latitude of region in degrees north or south of solar equator. South latitudes are negative. CENTRAL MERIDIAN DISTANCE: Distance east or west of central meridian of region. Measured 0° to 90° west is negative.

ITEM NO.	WORD	TYPE	DETAILED DESCRIPTION OF DATA ITEMS

AREA: Area of region corrected for distance from the center of the solar disk in millionths of solar hemisphere.

INTENSITY: Intensity of region on a scale of 1 = faint to 5 = very bright, in tenths of a degree.

CARRINGTON LONGITUDE: Central meridian that passed through solar disk on January 1, 1854 at 12^hUT. Measured 0° to 360° to the west. Note: More than one solar plage region per day may be visible.

BLANK FIELD: Filled with 9999.

12	10-12	I*2	SOLAR SUNSPOT GROUP DATA: Consists of the following parameters:

MT. WILSON GROUP NUMBER: Number assigned to sunspot group.

LATITUDE: Latitude of group north or south of solar equator. South latitudes are negative.

CENTRAL MERIDIAN DISTANCE: Distance east or west of central meridian of group. Measured 0° to 90° west is negative.

CARRINGTON LONGITUDE: Same description as above for sunspot group.

AREA: Area of group in millionths of solar hemisphere.

MAGNETIC CLASSIFICATION: Magnetic classification of sunspot configuration on a numerical scale of 0 to 9. Note: More than one sunspot group per day may be visible.

SECTION 5

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LIST OF ACRONYMS, INITIALS, AND ABBREVIATIONS

ACRIM	Active Cavity Radiometer Irradiance Monitor
ARO	Algonquin Radio Observatory
bpi	bits per inch
CCT	computer-compatible tape
Ch	Channel
CIRA	Cooperative Institute for Research in the Atmosphere
DSAS	Digital Solar Aspect Sensor
ECAL	Electrical Calibration
EPT	ERB Processing Team
ERB	Earth Radiation Budget
ESAT	ERB Solar Analysis Tape
FOV	field of view
GSFC	Goddard Space Flight Center
H-F	Hickey-Frieden
ID	identification
IPS	International Pyrheliometric Scale
IR	infrared
ISW	Instrument Status Word
JPL	Jet Propulsion Laboratory
LaRC	Langley Research Center
lsb	least significant bit
lw	longwave
MAT	Master Archival Tape
max	maximum
mf	major frame
min	minimum
msb	most significant bit
NASA	National Aeronautics and Space Administration
NESDIS	National Environmental Satellite, Data, and Information Service
NET	Nimbus Experiment Team
NGDC	National Geophysical Data Center
NIP	Normal Incidence Pyrheliometer
NOAA	National Oceanic and Atmospheric Administration
NOPS	Nimbus Observation Processing System
NPR	Number of Plage Regions
NSG	Number of Sunspot Groups
NSSDC	National Space Science Data Center
PCDS	Pilot Climate Data System

QC	Quality Control
RSM	Reference Sensor Model
SAS	Statistical Analysis System
SAVER	Seasonal Average (tape)
SEFDT	Solar and Earth Flux Data Tape
SGD	Solar Geophysical Data
SMM	Solar Maximum Mission
So	Southern
SQC	Science Quality Control
Std. Dev.	Standard Deviation
Sub-D	Subsystem display
SW	Shortwave
TDF	Trailer Documentation File
UT	Universal Time
UV	Ultraviolet
WRR	World Radiometric Reference
ZMT	Zonal Means Tape

APPENDIX A

NOPS STANDARD HEADER FILE AND TRAILER DOCUMENTATION FILE (TDF)

Every individual derivative products tape contains a Standard Header File and a Trailer Documentation File.* Each is written in a format common to all archival tapes produced by the Nimbus Observation Processing System (NOPS).

The Standard Header File is the first file on any tape. It is used to define key characteristics of the tape.

The Trailer Documentation File (TDF) is the last file on any tape. It is intended to provide a geneology of the current product by providing data relating to previous products that went into the making of the current product.

A.1 Standard Header File

The standard header file contains two identical blocks (physical records) of 630 characters, written in EBCDIC. Each block consists of five 126-character lines.

Lines 1 and 2 are written according to a standardized format called the NOPS Standard Header Record.

Line 1:

COLUMNS	DESCRIPTION
1	An indicator to show that a TDF will be found at the end of a tape (blank = no TDF; * = TDF present).
2-24	Label: NIMBUS-7$_b$NOPS$_b$SPEC$_b$No$_b$T.
25-30	Tape Specification Number. See Appendix D.
31-37	Label: $_b$SQ$_b$NO$_b$.
38-39	PDF Code:
	AS = ESAT.
40-45, 47	Tape sequence number, defined as follows:
40	The last digit of the year in which the data were acquired.
41-43	Day of the year in which the data were acquired.
44	Sequence number for this particular product.

*Trailer Documentation File not included on ESAT Tape.
b = blank

COLUMNS	DESCRIPTION

COLUMNS   **DESCRIPTION**

45   The existing hyphen remains unless there is a remake of the tape for any reason. In this case, an ascending alpha character will replace the hyphen, and the most recent reasons for remake will be recorded in logical record 4 of the header.

47   This will remain as a blank unless it is needed to remove ambiguities in character 40. This may occur if data are being acquired on or after October 24, 1988.

46   Copy Number:
1 = original
2 = copy.

47-52   Subsystem ID (with leading and trailing blank). For ERB code is 1.

53-56   Generation (Source) Facility (see page 64).

57-60   Label: $_b TO_b$

61-64   Destination Facility (see page 64).

65-87   Start year, day, hour, minute, second for data coverage on this tape, in the form:

$_b START_b 19YY_b DDD_b HHMMSS_b$

88-106   End year, day, hour, minute, second for data coverage on this tape, in the form:

$TO_b 19YY_b DDD_b HHMMSS_b$

In order to avoid unnecessary processing complications, the true ending date does not appear in the header record. Instead a fill date is used:

$1999_b 365_b 240000$

107-126   Generation year, day, hour, minute, second that the tape was created in the form:

$GEN_b 19YY_b DDD_b HHMMSS_b$

COLUMNS	DESCRIPTION

Line 2:

1-12	Software program name and version number.
13-18	Program documentation reference number, if it exists.
19	Blank.
20-126	User-defined comments that may be more relevant to the user than the preceding ones.

Lines 3-5:

May contain further descriptive information about the tape, such as which software was used (program name, version number, and version date) or how this version of the data differs from the previous version.

NOPS PRODUCT SPECIFICATION CODES

Tapes: A six-digit number prefixed with a T to denote TAPE will be used.

$$T \quad X_1 \quad X_2 \quad X_3 \quad X_4 \quad X_5 \quad X_6$$

X_1	Subsystem
	1 = ERB
	2 = SMMR
	3 = THIR
	4 = SAM II
	5 = LIMS
	6 = SBUV/TOMS
	7 = CZCS
	8 = SAMS
	9 = ILT

X_2 Source Facility (Same code as Destination Facility)

X_3	Destination Facility
	1 = NOC (Pre-NOPS)
	2 = MDHS (NOPS)
	3 = SACC
	4 = IPD
	5 = LARC
	6 = NCAR
	7 = NOAA
	8 = OXFD
	9 = USER

X_4, X_5 Tape number in sequence for subsystem (code to be derived depending on how many tapes are needed)

X_6	Tape Description:
	1 = 9 Trk 1600 BPI
	2 = 9 Trk 800 BPI
	3 = 7 Trk 800 BPI
	4 = 7 Trk 556 BPI
	5 = HDT (IPD)
	6 = 9 Trk 6250 BPI

APPENDIX B

SEQUENCE NUMBERS OF THE SEFDT TAPES USED TO GENERATE SOLAR DATA AT EPPLEY LABORATORIES FOR THE ERB SOLAR ANALYSIS TAPE (ESAT)

NOV 1978	AD83051-3	NOV 1981	AD13051-3	NOV 1984	AD43061-3
DEC 1978	AD83351-3	DEC 1981	AD13361-3	DEC 1984	AD43361-3
JAN 1979	AD90011-3	JAN 1982	AD20011-3	JAN 1985	AD50011-3
FEB 1979	AD90330-3	FEB 1982	AD20321-3	FEB 1985	AD50321-3
MAR 1979	AD90601-3	MAR 1982	AD20601-3	MAR 1985	AD50601-3
APR 1979	AD90911-3	APR 1982	AD20911-3	APR 1985	AD50911-3
MAY 1979	AD91211-3	MAY 1982	AD21211-3	MAY 1985	AD51211-3
JUN 1979	AD91521-3	JUN 1982	AD21521-3	JUN 1985	AD51521-3
JUL 1979	AD91821-3	JUL 1982	AD21831-3	JUL 1985	AD51821-3
AUG 1979	AD92131-3	AUG 1982	AD22441-3	AUG 1985	AD52131-3
SEP 1979	AD92441-3	SEP 1982	AD22441-3	SEP 1985	AD52441-3
OCT 1979	AD92741-3	OCT 1982	AD22751-3	OCT 1985	AD52741-3
NOV 1979	AD93051-3	NOV 1982	AD23051-3	NOV 1985	AD53051-3
DEC 1979	AD05771-3	DEC 1982	AD23361-3	DEC 1985	AD53351-3
JAN 1980	AD06241-3	JAN 1983	AD30011-3	JAN 1986	AD60011-3
FEB 1980	AD06661-3	FEB 1983	AD30321-3	FEB 1986	AD60321-3
MAR 1980	AD07111-3	MAR 1983	AD30601-3	MAR 1986	AD60601-3
APR 1980	AD07531-3	APR 1983	AD30911-3		
MAY 1980	AD07951-3	MAY 1983	AD31211-3		
JUN 1980	AD08421-3	JUN 1983	AD31521-3		
JUL 1980	AD08831-3	JUL 1983	AD31831-3		
AUG 1980	AD09261-3	AUG 1983	AD32131-3		
SEP 1980	AD09731-3	SEP 1983	AD32441-3		
OCT 1980	AD00141-3	OCT 1983	AD32751-3		
NOV 1980	AD03061-3	NOV 1983	AD33051-3		
DEC 1980	AD03361-3	DEC 1983	AD33361-3		
JAN 1981	AD10011-3	JAN 1984	AD40011-3		
FEB 1981	AD19321-3	FEB 1984	AD40321-3		
MAR 1981	AD10601-3	MAR 1984	AD40611-3		
APR 1981	AD10921-3	APR 1984	AD40921-3		
MAY 1981	AD11211-3	MAY 1984	AD41221-3		
JUN 1981	AD11521-3	JUN 1984	AD41531-3		
JUL 1981	AD11821-3	JUL 1984	AD41831-3		
AUG 1981	AD12131-3	AUG 1984	AD42141-3		
SEP 1981	AD12441-3	SEP 1984	AD42451-3		
OCT 1981	AD12741-3	OCT 1984	AD42751-3		

APPENDIX C

TABLE OF SCALE FACTORS
DAILY MEAN DATA

DATA ITEM		MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM	NUMBER OF ORBITS
1.	Orbit No.	10	100,000	I	I	I
2.	Year	I				
3.	Day of year	I				
4.	Solar Azimuth	10,000	1,000,000	10	10	I
5.	Solar Elevation	100,000	1,000,000	10	10	I
6.	Gamma Angle	100,000	100,000	I	I	I
7.	Ch. 3 Temp	10,000	1,000,000	10	10	I
8.	Ch. 10c Temp	10,000	1,000,000	10	10	I
9.	Ch. 1 Irrad.	100	10,000,000	10	10	I
10.	Ch. 2 Irrad.	100	10,000,000	10	10	I
11.	Ch. 3 Irrad.	100	10,000,000	10	10	I
12.	Ch. 4 Irrad.	1000	100,000	10	10	I
13.	Ch. 5 Irrad.	1000	100,000	10	10	I .
14.	Ch. 6 Irrad.	1000	100,000	100	100	I
15.	Ch. 7 Irrad.	1000	1,000,000	100	100	I
16.	Ch. 8 Irrad.	10,000	1,000,000	100	100	I
17.	Ch. 9 Irrad.	10,000	1,000,000	100	100	I
18.	Ch. 10c Irrad.	100	1,000,000	10	10	I
19.	Mission Day	I				
20.	Off-Axis Angle	1,000,000	10,000	10	10	I
21.	Cosine Corrected Ch. 10c Irrad.	100	100,000	100	100	I

I = Integer value; not scaled

NOTE: All data items on ESAT are in integer format and must be divided by the appropriate factor to obtain the actual real value.

TABLE OF SCALE FACTORS
ORBITAL DATA

DATA ITEM	SCALE FACTOR
1. Orbit Number	I
2. Year	I
3. Day of Year	I
4. Solar Azimuth	10
5. Solar Elevation	10
6. ISW	I
7. Gamma Angle	I
8. MSB E-S Distance	I
9. LSB E-S Distance	I
10. Ch. 3 Temp	10
11. Ch. 10c Temp	10
12. Ch. 1 Irrad.	10
13. Ch. 2 Irrad.	10
14. Ch. 3 Irrad.	10
15. Ch. 4 Irrad.	10
16. Ch. 5 Irrad.	10
17. Ch. 6 Irrad.	100
18. Ch. 7 Irrad.	100
19. Ch. 8 Irrad.	100
20. Ch. 9 Irrad.	100
21. Ch. 10c Irrad.	10
22. So. Term (hrs/min)	I
23. So. Term (secs)	I
24. Mission Day	I
25. Off-Axis Angle	10
26. Cosine Corrected Ch. 10c Irrad.	10

I = Integer value; not scaled

NOTE: All data items on ESAT are in integer format and must be divided by the appropriate factor to obtain the actual real value.

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APPENDIX D

DATA AVAILABILITY

To obtain archived data, or information about it, call or write to--

> National Space Science Data Center
> Code 633.4
> Goddard Space Flight Center
> Greenbelt, Maryland 20771
> Telephone: (301) 286-6695
> Telex: 89675 NASCOM GBLT
> TWX: 7108289716
> SPAN: NSSDC::REQUEST

A user's guide should be ordered by all first-time users of the data. Researchers who reside outside the USA should direct their request to--

> World Data Center A for Rockets and Satellites
> Code 630.2
> Goddard Space Flight Center
> Greenbelt, Maryland 20771
> Telephone: (301) 286-6695
> Telex: 89675 NASCOM GBLT
> TWX: 7108289716
> SPAN: NSSDC::REQUEST

The data will also be made available on the NASA/GSFC Pilot Climate Data System (PCDS). This is a scientific information system for selected climate data sets. Users of the system may access the data and information about the data via local (i.e., at the GSFC) and remote computer terminals. They may learn about climate data, its availability, the details of the PCDS holdings, access, select and subset data sets of interest; perform data manipulation and comparisons; and obtain a wide variety of graphical representations of data.

The PCDS has many climate data sets, most of spacecraft origin. Data sets from the following experiments are supported in the PCDS.

- Nimbus-4 Backscatter Ultraviolet (BUV)

- Nimbus-4/5 Selective Chopper Radiometer (SCR)

- Nimbus-5 Electrically Scanning Microwave Radiometer (ESMR)

- Nimbus-7 Limb Infrared Monitor of the Stratosphere (LIMS)

- Nimbus-7 Solar Backscatter Ultraviolet (SBUV)

- Nimbus-7 Total Ozone Mapping Spectrometer (TOMS)

- Nimbus-7 Earth Radiation Budget (ERB)

- Nimbus-7 Stratospheric Aerosol Measurement (SAM II)

- AEM-2 Stratospheric Aerosol and Gas Experiment (SAGE)

- National Meteorological Center (NMC) Daily Analyses of Atmospheric Parameters

- World Monthly Surface Station Climatology

- First Global Atmospheric Research Program Global Experiment (FGGE)

- NOAA Heat Budget Data

- Middle Atmosphere Electrodynamics (MAD) miscellaneous data sets

In addition to the ERB Solar Analysis data set, the PCDS will also make available, in the future, selected data sets produced for the International Satellite Cloud Climatology Project (ISCCP).

Those interested in utilizing the PCDS should contact--

> Ms. Lola Olsen
> PCDS User's Support Office
> National Space Science Data Center
> Code 634
> NASA/Goddard Space Flight Center
> Greenbelt, Maryland 20771
> Telephone: (301) 286-9760

APPENDIX E

UNPACKING EARTH-SUN DISTANCE

The Earth-Sun distance is stored on the ESAT Orbital Data File (2) as two 16-bit words. These words are referred to as the most significant bit (MSB) Earth-Sun distance and the least significant bit (LSB) Earth-Sun distance.

The procedure to unpack the Earth-Sun distance (in FORTRAN) is as follows:

```
        INTEGER * 2 ESD(1), MSB, LSB
        INTEGER * 4 ESD1
        EQUIVALENCE (ESD1, ESD(1))
             .
             .
             .

        ESD(1)      =      MSB
        ESD(2)      =      LSB

        ESD(1)      =      ESD1/10000
             .
             .
             .
```

APPENDIX F

SOURCE CODE

```
C                                                                      00000010
C**********************************************************************00000020
C          FUNCTION - THIS PROGRAM READS THE ERB SOLAR ANALYSIS TAPE (ESAT)00000030
C          AND DUMPS THE NOPS STANDARD HEADER FILE, THE FIRST 10       00000040
C          RECORDS OF THE DAILY MEAN FILE, THE FIRST 10 RECORDS        00000050
C          OF THE ORBITAL FILE, AND THE FIRST 10 RECORDS OF THE        00000060
C          SOLAR ACTIVITY FILE FOR EACH YEAR.                          00000070
C           THIS PROGRAM CAN BE MODIFIED TO DUMP AS MANY OR AS FEW     00000080
C           RECORDS DESIRED FROM ANY FILE BY SPECIFYING THE            00000090
C           FILE NUMBER TO BE READ AND THE START AND  END DATES TO DUMP.00000100
C                                                                      00000110
C          DETAILS OF THIS TAPE CAN BE FOUND IN THE "USER'S GUIDE      00000120
C          FOR THE NIMBUS 7 ERB SOLAR ANALYSIS TAPE (ESAT)", BY        00000130
C          J.R.HICKEY, E.R.MAJOR, AND H.L.KYLE, NASA TECH. MEMO.       00000140
C          86143,NASA/GSFC,GREENBELT,MD 20771,AUGUST 1984.            00000150
C                                                                      00000160
C          THE REVISED USER'S GUIDE FOR ESAT WILL BE                   00000170
C          "USER'S GUIDE FOR THE NIMBUS 7 ERB SOLAR ANALYSIS           00000180
C          TAPE (ESAT)", BY E.R.MAJOR, J.R.HICKEY, AND H.L.KYLE,       00000190
C          NASA REFERENCE PUBLICATION XXXX,NASA/GSFC,GREENBELT,        00000200
C          MD 20771,AUGUST 1987.                                       00000210
C                                                                      00000220
C                                                                      00000230
C                                                                      00000240
C          ARGUMENT LIST - NONE.                                       00000250
C          --------- ----                                              00000260
C                                                                      00000270
C          LOCAL VARIABLES:                                            00000280
C          ----- ----------                                            00000290
C          VARIABLE      TYPE      DESCRIPTION                          00000300
C          --------      ----      -----------                         00000310
C           IFILE        I*4       FILE NUMBER TO BE READ:             00000320
C                                  IFILE=1 - NOPS STANDARD LABEL        00000330
C                                  IFILE=2 - ORBITAL SOLAR DATA         00000340
C                                  IFILE=3 - DAILY MEAN SOLAR DATA      00000350
C                                  IFILE=4 - SOLAR ACTIVITY INDICATORS  00000360
C                                                                      00000370
C           YYDDD1       I*4       DATE TO BEGIN READING ESAT DATA      00000380
C                                   YY=2 DIGIT YEAR DDD=3 DIGIT DAY OF YEAR 00000390
C           YYDDD2       I*4       DATE TO END READING ESAT DATA        00000400
C                                                                      00000410
C                                                                      00000420
C          CALLED FROM: NONE. THIS IS THE MAIN PROGRAM                 00000430
C                                                                      00000440
C          CALLS TO:                                                   00000450
C                  NOPS     -  READS THE NOPS STANDARD HEADER FILE      00000460
C                  DMEAN    -  READS THE DAILY MEAN SOLAR DATA FILE     00000470
C                  ORBTAL   -  READS THE ORBITAL SOLAR DATA FILE        00000480
C                  SOLAR    -  READS THE SOLAR ACTIVITY DATA FILE       00000490
C                                                                      00000500
C          INPUT TAPE: 9-TRACK,1600 BPI, RECFM=U, BLKSIZE=32760        00000510
C                                                                      00000520
C          PROGRAMMER: G. MAJOR, RESEARCH & DATA SYSTEMS, INC.         00000530
C                                                                      00000540
C          LANGUAGE/COMPUTER: VS FORTRAN/IBM 3081 AT NASA/GSFC         00000550
C                                                                      00000560
```

```fortran
C        VERSION DATE: JULY 1984                              00000570
C                                                             00000580
C        MODIFIED SEPTEMBER 1985; GRM-RDS,INC.                00000590
C                                                             00000600
C        INCLUDES DATA THROUGH YEAR 6 (NOVEMBER 1978 - OCTOBER 1984) 00000610
C                                                             00000620
C        MODIFIED JUNE 1985; GRM-RDS,CORP. TO INCLUDE YEAR 6 ESAT 00000630
C                                                             00000640
C        MODIFIED JULY 1987 TO INCLUDE NEW SOLAR ACTIVITY FILE AND 00000650
C        89 MONTHS OF NIMBUS 7 SOLAR DATA (NOV 1978 - MARCH 1986). 00000660
C                                                             00000670
C                                                             00000680
C                                                             00000690
Cxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx00000700
C                                                             00000710
C        READ FILE AND RECORD INFORMATION FROM UNIT 5         00000720
C                                                             00000730
       INTEGER*4 YYDDD1,YYDDD2                                00000740
   10  READ(5,1000,END=999) IFILE,YYDDD1,YYDDD2               00000750
 1000  FORMAT(3I10)                                           00000760
       IF(IFILE.EQ.0) GO TO 10                                00000770
       WRITE(6,1001) YYDDD1,YYDDD2                            00000780
 1001  FORMAT(/1X,' START DATE:',I10,2X,' END DATE:',I10/)    00000790
       YR1=YYDDD1/1000.                                       00000800
       IY1=YR1                                                00000810
       ID1=((YR1-IY1)*1000)+1                                 00000820
       YR2=YYDDD2/1000.                                       00000830
       IY2=YR2                                                00000840
       ID2=((YR2-IY2)*1000)+1                                 00000850
       WRITE(6,1002) IY1,IY2,ID1,ID2                          00000860
 1002  FORMAT(/4I10)                                          00000870
C                                                             00000880
       IF(IFILE.EQ.1) CALL NOPS(IFILE)                        00000890
       IF(IFILE.EQ.2) CALL ORBTAL(IFILE,IY1,IY2,ID1,ID2)      00000900
       IF(IFILE.EQ.3) CALL DMEAN(IFILE,IY1,IY2,ID1,ID2)       00000910
       IF(IFILE.EQ.4) CALL SOLAR(IFILE,IY1,IY2,ID1,ID2)       00000920
       GO TO 10                                               00000930
  999  CONTINUE                                               00000940
       STOP                                                   00000950
       END                                                    00000960
Cxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 00000970
C                                                          ..  00000980
       SUBROUTINE NOPS(IF)                                    00000990
C                                                             00001000
Cxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx00001010
C        FUNCTION - NOPS READS THE NOPS STANDARD HEADER LABEL ON 00001020
C                   THE ERB SOLAR ANALYSIS TAPE (ESAT) AND    00001030
C                   PRINTS THE LABEL.                         00001040
C                   SEE APPENDIX A OF THE ESAT USER'S GUIDE.  00001050
C                                                             00001060
C        ARGUMENT LIST:                                       00001070
C        -------- ----                                        00001080
C        VARIABLE   IO  TYPE  DESCRIPTION                     00001090
C        --------   --  ----  -----------                     00001100
C        IF         I   I*4   ESAT FILE POSITION              00001110
C                                                             00001120
C        LOCAL VARIABLES:                                     00001130
C        ----- ----------                                     00001140
C        VARIABLE   TYPE  DESCRIPTION                         00001150
C        --------   ----  -----------                         00001160
```

```
C          LABEL      L*1    CONTENTS OF NOPS STANDARD LABEL          00001170
C                                                                     00001180
C          CALLED FROM - MAIN                                         00001190
C                                                                     00001200
C          CALLS TO:                                                  00001210
C                POSN   -  FTIO TAPE POSITIONING ROUTINE              00001220
C                FREAD  -  FTIO TAPE READ ROUTINE                     00001230
C                                                                     00001240
C          PROGRAMMER - G. MAJOR, RESEARCH & DATA SYSTEMS, INC.       00001250
C                                                                     00001260
C          COMPUTER/LANGUAGE -  VS FORTRAN/IBM 3081 AT NASA/GSFC      00001270
C                                                                     00001280
C          VERSION DATE - JULY 1984                                   00001290
C                                                                     00001300
C*********************************************************************** 00001310
       LOGICAL*1 LABEL(630),LABEL2(126)                               00001320
C                                                                     00001330
C          POSITION TAPE TO FILE 1                                    00001340
C                                                                     00001350
       CALL POSN(1,10,IF)                                             00001360
C                                                                     00001370
       WRITE(6,1000)                                                  00001380
 1000  FORMAT(/' OPEN FILE 1 TO READ DATA'//10X,'NOPS STANDARD HEADER', 00001390
      1    ' LABEL'/)                                                 00001400
C                                                                     00001410
C          READ FIRST FILE                                           00001420
C                                                                     00001430
       DO 20 L=1,2                                                    00001440
       CALL FREAD(LABEL,10,LENGTH,900,900)                            00001450
       K=0                                                            00001460
       DO 10 I=1,5                                                    00001470
         DO 15 J=1,126                                                00001480
           K=K+1                                                      00001490
           LABEL2(J)=LABEL(K)                                         00001500
   15    CONTINUE                                                     00001510
C                                                                     00001520
C          WRITE HEADER                                               00001530
C                                                                     00001540
         WRITE(6,2000) LABEL2                                         00001550
 2000    FORMAT(1X,126A1)                                             00001560
   10  CONTINUE                                                       00001570
C      GO TO 20                                                       00001580
 20    CONTINUE                                                       00001590
 900   WRITE(6,3000)                                                  00001600
 3000  FORMAT(//' END OF FILE 1 PROCESSING'//)                        00001610
       RETURN                                                         00001620
       END                                                            00001630
C***********************************************************************00001640
C                                                                     00001650
       SUBROUTINE ORBTAL(IF,IY1,IY2,ID1,ID2)                          00001660
C                                                                     00001670
C*********************************************************************** 00001680
C                                                                     00001690
C          FUNCTION - THIS ROUTINE WILL DUMP SELECTED RECORDS FROM    00001700
C                     THE ORBITAL DATA FILE OF THE ESAT TAPE (FILE    00001710
C                     2 OF THE ESAT).                                 00001720
C                                                                     00001730
C                     THE DATA IN THE ORBITAL FILE IS AS FOLLOWS:     00001740
C                     RECORD NUMBER                                   00001750
C                     RECORD ID                                       00001760
```

```
C                    ORBIT                                        00001770
C                    YEAR                                         00001780
C                    DAY OF YEAR                                  00001790
C                    SOLAR AZIMUTH ANGLE                          00001800
C                    SOLAR ELEVATION ANGLE                        00001810
C                    INSTRUMENT STATUS WORD (ISW)                 00001820
C                    GAMMA ANGLE                                  00001830
C                    MSB - EARTH-SUN DISTANCE                     00001840
C                    LSB - EARTH-SUN DISTANCE                     00001850
C                    CHANNEL 3 TEMPERATURE                        00001860
C                    CHANNEL 10C TEMPERATURE                      00001870
C                    CHANNELS 1-10C IRRADIANCE                    00001880
C                    COSINE-CORRECTED CHANNEL 10C IRRADDIANCE     00001890
C                                                                 00001900
C                    THIS FILE CONTAINS 276671 DATA POINTS        00001910
C                    WITH EACH DAY CONSISTING OF 84 BYTES         00001920
C                                                                 00001930
C        ARGUMENT LIST -                                          00001940
C        -------- ----                                            00001950
C        VARIABLE TYPE IO DESCRIPTION                             00001960
C        -------- ---- -- -----------                             00001970
C        IF       I*4  I  FILE NUMBER                             00001980
C        IY1,ID1  I*4  I  FIRST DATE TO DUMP ESAT DATA            00001990
C        IY2,ID2  I*4  I  SECOND DATE TO DUMP ESAT DATA           00002000
C                                                                 00002010
C     CALLED FROM: MAIN                                           00002020
C                                                                 00002030
C     CALLS TO:                                                   00002040
C     POSN - FTIO TAPE POSITION ROUTINE                           00002050
C     FREAD - FT10 TAPE READ ROUTINE                              00002060
C                                                                 00002070
C     PROGRAMMER/DESIGNER: G.MAJOR RESEARCH & DATA SYSTEMS, INC.  00002080
C                                                                 00002090
C     LANGUAGE/COMPUTER: VS FORTRAN/IBM 3081                      00002100
C                                                                 00002110
C     VERSION DATE: DECEMBER 1984                                 00002120
C                                                                 00002130
C     MODIFIED SEPTEMBER 1985 BY GRM-RDS,INC.                     00002140
C                                                                 00002150
C     MODIFIED JUNE 1985 BY GRM-RDS,CORP. TO INCLUDE YEAR 6 ESAT  00002160
C                                                                 00002170
C     MODIFIED JULY 1987 TO INCLUDE 89 MONTHS OF ESAT             00002180
C                                                                 00002190
C                                                                 00002200
C                                                                 00002210
Cxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx  00002220
      DIMENSION KYEAR(2),KDAY(2),KMSDAY(2)                        00002230
C                                                                 00002240
      INTEGER*2 SOLORB(42),ISOLRB(42)                             00002250
      INTEGER*4 IR1(12)                                           00002260
      REAL*4 R2(12)                                               00002270
      INTEGER*4 R10C                                              00002280
      EQUIVALENCE(IR1(1),SOLORB(13))                              00002290
      EQUIVALENCE(R10C,SOLORB(41))                                00002300
C                                                                 00002310
      LENGTH=84                                                   00002320
      IN=0                                                        00002330
      J1 = 9999                                                   00002340
      J2=0                                                        00002350
      NOBS=27671                                                  00002360
```

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```
C                                                             00002370
        WRITE(6,1000)                                         00002380
 1000   FORMAT(//' OPEN FILE 2 FOR PROCESSING'//20X,'ORBITAL SOLAR',  00002390
      1 ' DATA FROM ESAT'//)                                  00002400
C                                                             00002410
C         POSITION ESAT TAPE TO FILE 2                        00002420
C                                                             00002430
        CALL POSN(1,10,IF)                                    00002440
C                                                             00002450
C         LOOP OVER ALL OBSERVATIONS AND READ ESAT ORBITAL FILE  00002460
C                                                             00002470
        DO 105 KREC=1,NOBS                                    00002480
          CALL FREAD(ISOLRB,10,LENGTH,*900,*902)              00002490
C                                                             00002500
C         STORE DATA IN TEMPORARY ARRAY                       00002510
C                                                             00002520
          DO 10 I=1,42                                        00002530
            SOLORB(I)=ISOLRB(I)                               00002540
  10      CONTINUE                                            00002550
C                                                             00002560
C         UNPACK AND DESCALE THE ORBITAL DATA                 00002570
C                                                             00002580
          IREC=ISOLRB(1)                                      00002590
          IRECID=ISOLRB(2)                                    00002600
          SOLAZ=SOLORB(7)/10.                                 00002610
          SOLEL=SOLORB(8)/10.                                 00002620
C                                                             00002630
          DO 50 J3=1,7                                        00002640
            R2(J3)=FLOAT(IR1(J3))/10.                         00002650
  50      CONTINUE                                            00002660
C                                                             00002670
          DO 51 J4=8,11                                       00002680
            R2(J4)=FLOAT(IR1(J4))/100.                        00002690
  51      CONTINUE                                            00002700
C                                                             00002710
          R2(12)=FLOAT(IR1(12))/10.                           00002720
C                                                             00002730
          C10CC=FLOAT(R10C)/10.                               00002740
          OFFAX=SOLORB(40)/10.                                00002750
C                                                             00002760
C         ORGANIZE ARRAYS TO KEEP TRACK OF YEAR, DAY AND MISSION DAY  00002770
C                                                             00002780
          IF(KREC.EQ.1) THEN                                  00002790
            KYEAR(2)=SOLORB(5)                                00002800
            KDAY(2)=SOLORB(6)                                 00002810
            KMSDAY(2)=SOLORB(39)                              00002820
          ELSE                                                00002830
            KYEAR(1)=KYEAR(2)                                 00002840
            KDAY(1)=KDAY(2)                                   00002850
            KMSDAY(1)=KMSDAY(2)                               00002860
            KYEAR(2)=SOLORB(5)                                00002870
            KDAY(2)=SOLORB(6)                                 00002880
            KMSDAY(2)=SOLORB(39)                              00002890
          ENDIF                                               00002900
C                                                             00002910
C         FILL IN FOR MISSING DAYS                            00002920
C                                                             00002930
 391      CONTINUE                                            00002940
          MSDCK=0                                             00002950
          IF(KMSDAY(2).EQ.-9999) THEN                         00002960
```

```
              KMSDAY(2)=KMSDAY(1)                                     00002970
              KYEAR(2)=KYEAR(1)                                       00002980
              KDAY(2)=KDAY(1)                                         00002990
              MSDCK=1                                                 00003000
            ENDIF                                                     00003010
          IF(DTACK.EQ.1) THEN                                         00003020
            KMSDAY(1)=FMSDAY                                          00003030
            KYEAR(1)=FYEAR                                            00003040
            KDAY(1)=FDAY                                              00003050
          ENDIF                                                       00003060
           DTACK=0                                                    00003070
           IF(KMSDAY(2).GT.KMSDAY(1)+1) THEN                          00003080
            IF(KDAY(1).NE.365.AND.KDAY(1).NE.366)THEN                 00003090
              FYEAR=KYEAR(1)                                          00003100
              FDAY=KDAY(1)+1                                          00003110
            ELSE                                                      00003120
              FYEAR=KYEAR(1)+1                                        00003130
              FDAY=1                                                  00003140
            ENDIF                                                     00003150
            FMSDAY=KMSDAY(1)+1                                        00003160
            DTACK=1                                                   00003170
           ENDIF                                                      00003180
C                                                                     00003190
           IF(STPCK.EQ.1.AND.KMSDAY(2).GT.J2) GO TO 900              00003200
C                                                                     00003210
C         CHECK FOR FIRST AND LAST DAYS                              00003220
C                                                                     00003230
           IF(DTACK.EQ.0) THEN                                        00003240
             IF(IY1.EQ.KYEAR(2).AND.ID1.EQ.KDAY(2))                   00003250
     1       J1=KMSDAY(2)                                             00003260
             STPCK=0                                                  00003270
             IF(IY2.EQ.KYEAR(2).AND.ID2.EQ.KDAY(2)) THEN              00003280
               J2=KMSDAY(2)                                           00003290
               STPCK=1                                                00003300
             ENDIF                                                    00003310
           ELSE                                                       00003320
             IF(IY1.EQ.FYEAR.AND.ID1.EQ.FDAY)                         00003330
     1       J1=FMSDAY                                                00003340
             STPCK=0                                                  00003350
             IF(IY2.EQ.FYEAR.AND.ID2.EQ.FDAY) THEN                    00003360
               J2=FMSDAY                                              00003370
               STPCK=1                                                00003380
             ENDIF                                                    00003390
           ENDIF                                                      00003400
C                                                                     00003410
C         FORMAT DATA FOR OUTPUT                                      00003420
C                                                                     00003430
C         DUMP ONLY THE RECORDS INDICATED                            00003440
C                                                                     00003450
           IF(KMSDAY(2).GE.J1) THEN                                   00003460
             IN=IN+1                                                  00003470
             IF(IN.GT.1) GO TO 390                                    00003480
             WRITE(6,4900)                                            00003490
 4900        FORMAT(//20X,'89 MONTHS OF ESAT ORBITAL DATA'//)         00003500
 390         CONTINUE                                                 00003510
C                                                                     00003520
C         TEST FOR MISSING DATA                                      00003530
C                                                                     00003540
           IF(DTACK.EQ.1) THEN                                        00003550
             WRITE(6,4151)                                            00003560
```

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 4151     FORMAT(//1X,'DAY',1X,'YEAR',1X,'MISDAY')              00003570
          WRITE(6,4152) FDAY,FYEAR,FMSDAY                       00003580
 4152     FORMAT(1X,I3,2X,I2,3X,I5)                             00003590
          WRITE(6,7000)                                         00003600
 7000     FORMAT(//20X,'*********NO DATA',                      00003610
     1      ' AVAILABLE***********'//)                          00003620
        GO TO 391                                               00003630
        ELSE                                                    00003640
C                                                               00003650
C       WRITE SPECIFIED RECORDS                                 00003660
C                                                               00003670
        WRITE(6,4150)                                           00003680
 4150     FORMAT(//49X,'EARTH-SUN DIS SO.TERM.OFF-'/            00003690
     1    1X,'DAY',1X,'YEAR',1X,'ORBIT',1X,'MISDAY',1X,'SOLAZ', 00003700
     2    2X,'SOLEL',3X,'ISW',1X,'GAMMA',2X,'MSB',5X,'LSB',3X,  00003710
     3    'H/M',1X,'SEC',1X,'AXIS'/)                            00003720
C                                                               00003730
        WRITE(6,5000) KDAY(2),KYEAR(2),SOLORB(3),               00003740
     1  KMSDAY(2),                                              00003750
     1  SOLAZ,SOLEL,(SOLORB(K),K=9,12),(SOLORB(K1),K1=37,38),OFFAX, 00003760
     2  (R2(K),K=1,12),CH10CC                                   00003770
 5000     FORMAT(1X,I3,2X,I2,3X,I5,3X,I4,1X,F7.2,1X,F7.2,1X,I4, 00003780
     1    1X,I3,1X,I7,1X,I7,1X,I4,1X,I2,1X,F4.1/6X,F6.2,1X,F6.2,1X, 00003790
     2    11(F7.2,1X))                                          00003800
C                                                               00003810
        WRITE(6,5001)                                           00003820
 5001     FORMAT(/7X,'TEMPERATURE',22X,'IRRADIANCE',50X,'COS.COR.'/ 00003830
     1    6X,'CH.3',3X,'CH.10C',2X,'CH.1',4X,'CH.2',4X,'CH.3',4X, 00003840
     2    'CH.4',4X,'CH.5',4X,'CH.6',4X,'CH.7',4X,'CH.8',4X,'CH.9', 00003850
     3    4X,'CH.10C',1X,'CH.10C'/)                             00003860
C                                                               00003870
        WRITE(6,5002) (R2(K),K=1,12),C10CC                      00003880
 5002     FORMAT(6X,F6.2,1X,F6.2,1X,11(F7.2,1X))                00003890
C                                                               00003900
C         WRITE(20,8000) SOLORB(3),KYEAR(2),KDAY(2),SOLORB(11), 00003910
C    1     SOLORB(12),SOLORB(37),SOLORB(38)                     00003920
C8000      FORMAT(I7,2X,I2,2X,I3,2X,I7,2X,I7,2X,I4,2X,I2)       00003930
        ENDIF                                                   00003940
      ENDIF                                                     00003950
 105    CONTINUE                                                00003960
        GO TO 900                                               00003970
 902    WRITE(6,2001)                                           00003980
 2001   FORMAT(//' ERROR IN TAPE READ'//)                       00003990
        GO TO 999                                               00004000
 900    CONTINUE                                                00004010
        WRITE(6,2000)                                           00004020
 2000   FORMAT(//' END OF FILE 2 PROCESSING'//)                 00004030
 999    RETURN                                                  00004040
        END                                                     00004050
C****************************************************************00004060
C                                                               00004070
        SUBROUTINE DMEAN(IFILE,IY1,IY2,ID1,ID2)                 00004080
C                                                               00004090
C****************************************************************00004100
C                                                               00004110
C       FUNCTION - THIS ROUTINE WILL OUTPUT DAILY MEAN SOLAR    00004120
C                  DATA FROM THE ESAT TAPE.                     00004130
C                  THE DATA CONTAINS THE MEAN, MAXIMUM, MINIMUM, 00004140
C                  STANDARD DEVIATION AND NUMBER OF ORBITS. THE 00004150
C                  DAILY MEAN SOLAR DATA IS AS FOLLOWS:         00004160
```

```
C                                                                    00004170
C              RECORD NUMBER                                         00004180
C              RECORD ID                                             00004190
C              ORBIT (MEAN,SD,MIN,MAX,N)                             00004200
C              YEAR                                                  00004210
C              DAY OF YEAR                                           00004220
C              SOLAR AZIMUTH ANGLE (MEAN,SD,MIN,MAX,N)               00004230
C              SOLAR ELEVATION ANGLE (MEAN,SD,MIN,MAX,N)             00004240
C              GAMMA ANGLE (MEAN,SD,MIN,MAX,N)                       00004250
C              CHANNEL 3 TEMPERATURE (MEAN,SD,MIN,MAX,N)             00004260
C              CHANNEL 10C TEMPERAURE (MEAN,SD,MIN,MAX,N)            00004270
C              CHANNELS 1-10C IRRADIANCE (MEAN,SD,MIN,MAX,N)         00004280
C              MISSION DAY                                           00004290
C              OFF-AXIS ANGLE (MEAN,SD,MIN,MAX,N)                    00004300
C              COSINE-CORRECTED CHANNEL 10C IRRADIANCE(MEAN,SD,MIN,  00004310
C              MAX,N)                                                00004320
C                                                                    00004330
C              THE DATA IS LOCATED IN THE 3RD FILE OF THE ESAT       00004340
C              TAPE AND CONTAINS 376 BYTES.                          00004350
C                                                                    00004360
C                                                                    00004370
C      ARGUMENT LIST -                                               00004380
C      -------- ----                                                 00004390
C      VARIABLE  IO  TYPE DECSRIPTION                                00004400
C      --------  --  ---- -----------                                00004410
C      IFILE      I   I*4 FILE POSITION                              00004420
C      IY1,ID1    I   I*4 FIRST DATE TO DUMP ESAT DATA               00004430
C      IY2,ID2    I   I*4 SECOND DATE TO DUMP ESAT DATA              00004440
C                                                                    00004450
C      OUTPUT VARIABLES -                                            00004460
C      ------ ---------                                              00004470
C      VARIABLE  TYPE DESCRIPTION                                    00004480
C      --------  ---- -----------                                    00004490
C      XMEAN     R*4  ARRAY OF MEAN SOLAR DATA                       00004500
C      XMIN      R*4  ARRAY OF MINIMUM SOLAR DATA VALUES             00004510
C      XMAX      R*4  ARRAY OF MAXIMUM SOLAR DATA VALUES             00004520
C      NO        I*4  ARRAY OF NUMBER OF ORBITS                      00004530
C      XSD       R*4  ARRAY OF STANDARD DEVIATIONS                   00004540
C      IYEAR     I*4  YEAR                                           00004550
C      IDOY      I*4  DAY OF YEAR                                    00004560
C      MISDAY    I*4  MISSION DAY                                    00004570
C                                                                    00004580
C      CALLED FROM: MAIN                                             00004590
C                                                                    00004600
C      CALLS TO:                                                     00004610
C      POSN - FTIO TAPE POSITION ROUTINE                             00004620
C      FREAD - FTIO TAPE READ ROUTINE                                00004630
C                                                                    00004640
C      PROGRAMMER/DESIGNER: G. MAJOR RESEARCH AND DATA SYSTEMS,INC.  00004650
C                                                                    00004660
C      LANGUAGE/COMPUTER: VS FORTRAN/IBM 3081                        00004670
C                                                                    00004680
C      VERSION DATE: DECEMBER 1984                                   00004690
C                                                                    00004700
C      MODIFIED SEPTEMBER 1985 BY GRM-RDS,INC.                       00004710
C                                                                    00004720
C      MODIFIED JUNE 1985 BY GRM-RDS,CORP. TO INCLUDE YEAR 6 ESAT    00004730
C                                                                    00004740
C      MODIFIED JULY 1987 TO INCLUDE 89 MONTHS OF ESAT              00004750
C                                                                    00004760
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C                                                                    00004770
C                                                                    00004780
C************************************************************************00004790
C                                                                    00004800
      DIMENSION IMEAN(18),ISD(18),MIN(18),MAX(18),NO(18),XMEAN(18),  00004810
     1 XMIN(18),XMAX(18),XSD(18),IDATA(18,5),IYEAR(2692),IDOY(2692),  00004820
     2 MISDAY(2692)                                                  00004830
C                                                                    00004840
      INTEGER*4 RMEAN(94)                                           00004850
      INTEGER*2 R1(2),IREC,IRECID                                    00004860
C                                                                    00004870
      EQUIVALENCE(R1(1),RMEAN(1))                                    00004880
C                                                                    00004890
      LENGTH=376                                                    00004900
      IN=0                                                          00004910
      J1=9999                                                       00004920
      J2=0                                                          00004930
      NOBS=2692                                                     00004940
C                                                                    00004950
      WRITE(6,1000) IFILE                                           00004960
 1000 FORMAT(//' OPEN FILE',I3,' TO READ ESAT DAILY MEAN SOLAR',    00004970
     1 ' DATA'//)                                                   00004980
C                                                                    00004990
C      POSITION TAPE TO FILE 3                                      00005000
C                                                                    00005010
      CALL POSN(1,10,IFILE)                                         00005020
C                                                                    00005030
C      LOOP OVER NUMBER OF OBSERVATIONS IN THIS FILE                00005040
C                                                                    00005050
      DO 105 KREC=1,NOBS                                            00005060
        CALL FREAD(RMEAN,10,LENGTH,900,902)                         00005070
        IREC=R1(1)                                                 00005080
        IRECID=R1(2)                                               00005090
C                                                                    00005100
C      STORE DATA IN ARRAY IDATA(18,5)                              00005110
C                                                                    00005120
        J=1                                                        00005130
        K=0                                                        00005140
        DO 10 I=2,6                                                00005150
          K=K+1                                                    00005160
          IDATA(J,K)=RMEAN(I)                                      00005170
   10   CONTINUE                                                   00005180
C                                                                    00005190
        IYEAR(KREC)=RMEAN(7)                                       00005200
        IDOY(KREC)=RMEAN(8)                                        00005210
C                                                                    00005220
        J=J+1                                                      00005230
        K=0                                                        00005240
        DO 20 I=9,83                                               00005250
          K=K+1                                                    00005260
          IF(K.EQ.6) THEN                                          00005270
            K=0                                                    00005280
            K=K+1                                                  00005290
            J=J+1                                                  00005300
          ENDIF                                                    00005310
          IDATA(J,K)=RMEAN(I)                                      00005320
   20   CONTINUE                                                   00005330
C                                                                    00005340
        MISDAY(KREC)=RMEAN(84)                                     00005350
C                                                                    00005360
```

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C          REPLACE -9999'S WITH REAL VALUES FOR YEAR, DAY AND MISDAY       00005370
C                                                                          00005380
           DATACK=0                                                        00005390
           IF(IYEAR(KREC).EQ.-9999) THEN                                   00005400
            IF(IDOY(KREC-1).NE.365.AND.IDOY(KREC-1).NE.366)THEN            00005410
             IYEAR(KREC)=IYEAR(KREC-1)                                     00005420
             IDOY(KREC)=IDOY(KREC-1)+1                                     00005430
            ELSE                                                           00005440
             IYEAR(KREC)=IYEAR(KREC-1)+1                                   00005450
             IDOY(KREC)=1                                                  00005460
            ENDIF                                                          00005470
           MISDAY(KREC)=MISDAY(KREC-1)+1                                   00005480
           DATACK=1                                                        00005490
           ENDIF                                                           00005500
C                                                                          00005510
           J=J+1                                                           00005520
           K=0                                                             00005530
           DO 21 I=85,94                                                   00005540
             K=K+1                                                         00005550
             IF(K.EQ.6) THEN                                               00005560
               K=0                                                         00005570
               K=K+1                                                       00005580
               J=J+1                                                       00005590
             ENDIF                                                         00005600
             IDATA(J,K)=RMEAN(I)                                           00005610
      21     CONTINUE                                                      00005620
C                                                                          00005630
C          UNPACK THE DATA INTO REAL DATA. STORE THE DATA IN               00005640
C          THE MEAN, STANDARD DEVIATION, MINIMUM, MAXIMUM, AND             00005650
C          NUMBER ARRAYS.                                                  00005660
C                                                                          00005670
           DO 50 I=1,18                                                    00005680
             IMEAN(I)=IDATA(I,1)                                           00005690
             IF(IMEAN(I).EQ.-9999) IMEAN(I)=0                              00005700
             ISD(I)=IDATA(I,2)                                             00005710
             IF(ISD(I).EQ.-9999) ISD(I)=0                                  00005720
             MIN(I)=IDATA(I,3)                                             00005730
             IF(MIN(I).EQ.-9999) MIN(I)=0                                  00005740
             MAX(I)=IDATA(I,4)                                             00005750
             IF(MAX(I).EQ.-9999) MAX(I)=0                                  00005760
             NO(I)=IDATA(I,5)                                              00005770
             IF(NO(I).EQ.-9999) NO(I)=0                                    00005780
      50     CONTINUE                                                      00005790
C                                                                          00005800
C          DESCALE THE MEAN DATA                                           00005810
C                                                                          00005820
           XMEAN(1)=FLOAT(IMEAN(1))/10.                                    00005830
             XMEAN(2)=FLOAT(IMEAN(2))/10000.                               00005840
             XMEAN(3)=FLOAT(IMEAN(3))/100000.                              00005850
           XMEAN(4)=FLOAT(IMEAN(4))/100000.                                00005860
           DO 52 I=5,6                                                     00005870
             XMEAN(I)=FLOAT(IMEAN(I))/10000.                               00005880
      52   CONTINUE                                                        00005890
           XMEAN(7)=FLOAT(IMEAN(7))/100.                                   00005900
           DO 53 I=8,9                                                     00005910
             XMEAN(I)=FLOAT(IMEAN(I))/100.                                 00005920
      53   CONTINUE                                                        00005930
           DO 54 I=10,13                                                   00005940
             XMEAN(I)=FLOAT(IMEAN(I))/1000.                                00005950
      54   CONTINUE                                                        00005960
```

```
      XMEAN(14)=FLOAT(IMEAN(14))/10000.                            00005970
      XMEAN(15)=FLOAT(IMEAN(15))/10000.                            00005980
      XMEAN(16)=FLOAT(IMEAN(16))/100.                              00005990
      XMEAN(17)=FLOAT(IMEAN(17))/1000000.                          00006000
      XMEAN(18)=FLOAT(IMEAN(18))/100.                              00006010
C                                                                  00006020
C     DECSALE THE STANDARD DEVIATIONS                              00006030
C                                                                  00006040
      XSD(1)=FLOAT(ISD(1))/100000.                                 00006050
      XSD(2)=FLOAT(ISD(2))/1000000.                                00006060
      XSD(3)=FLOAT(ISD(3))/1000000.                                00006070
        XSD(4)=FLOAT(ISD(4))/100000.                               00006080
        XSD(5)=FLOAT(ISD(5))/1000000.                              00006090
        XSD(6)=FLOAT(ISD(6))/1000000.                              00006100
        XSD(7)=FLOAT(ISD(7))/10000000.                             00006110
        XSD(8)=FLOAT(ISD(8))/10000000.                             00006120
        XSD(9)=FLOAT(ISD(9))/10000000.                             00006130
      DO 56 I=10,12                                                00006140
        XSD(I)=FLOAT(ISD(I))/100000.                               00006150
   56 CONTINUE                                                     00006160
      DO 57 I=13,16                                                00006170
        XSD(I)=FLOAT(ISD(I))/1000000.                              00006180
   57 CONTINUE                                                     00006190
      XSD(17)=FLOAT(ISD(17))/10000.                                00006200
      XSD(18)=FLOAT(ISD(18))/100000.                               00006210
C                                                                  00006220
C     DESCALE THE MINIMUM AND MAXIMUM DATA                         00006230
C                                                                  00006240
      XMIN(1)=MIN(1)                                               00006250
      XMAX(1)=MAX(1)                                               00006260
      DO 60 I=2,11                                                 00006270
        IF(I.EQ.4) THEN                                            00006280
          XMIN(4)=MIN(4)                                           00006290
          XMAX(4)=MAX(4)                                           00006300
        ELSE                                                       00006310
        XMIN(I)=FLOAT(MIN(I))/10.                                  00006320
        XMAX(I)=FLOAT(MAX(I))/10.                                  00006330
        ENDIF                                                      00006340
   60 CONTINUE                                                     00006350
      DO 61 I=12,15                                                00006360
        XMIN(I)=FLOAT(MIN(I))/100.                                 00006370
        XMAX(I)=FLOAT(MAX(I))/100.                                 00006380
   61 CONTINUE                                                     00006390
      XMIN(16)=FLOAT(MIN(16))/10.                                  00006400
      XMAX(16)=FLOAT(MAX(16))/10.                                  00006410
      XMIN(17)=FLOAT(MIN(17))/10.                                  00006420
      XMAX(17)=FLOAT(MAX(17))/10.                                  00006430
      XMIN(18)=FLOAT(MIN(18))/100.                                 00006440
      XMAX(18)=FLOAT(MAX(18))/100.                                 00006450
C                                                                  00006460
C                                                                  00006470
C     CHECK WHICH RECORDS TO DUMP                                  00006480
C                                                                  00006490
      IF(IY1.EQ.IYEAR(KREC).AND.ID1.EQ.IDOY(KREC)) J1=MISDAY(KREC) 00006500
      STOPCK=0                                                     00006510
      IF(IY2.EQ.IYEAR(KREC).AND.ID2.EQ.IDOY(KREC)) THEN            00006520
        J2=MISDAY(KREC)                                            00006530
        STOPCK=1                                                   00006540
      ENDIF                                                        00006550
C                                                                  00006560
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          IF(MISDAY(KREC).GE.J1) THEN                               00006570
          IF(J2.GT.0.AND.MISDAY(KREC).GT.J2) GO TO 105              00006580
          IN=IN+1                                                   00006590
          IF(IN.GT.1) GO TO 390                                     00006600
          WRITE(6,4900)                                             00006610
 4900     FORMAT(20X,'SEVEN YEARS+5 MONTHS OF ESAT DAILY MEAN SOLAR 00006620
     1        DATA'/)                                               00006630
  390     CONTINUE                                                  00006640
          WRITE(6,4920) IREC,IRECID                                 00006650
 4920     FORMAT(/' RECORD NUMBER=',I10,5X,'RECORD ID=',I10/)       00006660
          WRITE(6,5001) IYEAR(KREC),IDOY(KREC),MISDAY(KREC)         00006670
 5001     FORMAT(//15X,'YEAR=',I10,5X,'DAY OF YEAR=',I10,5X,'MISSION', 00006680
     1    ' DAY=',I10/)                                             00006690
C                                                                   00006700
C         TEST FOR MISSING DATA OR ERB OFF DAY                      00006710
C                                                                   00006720
          IF=0                                                      00006730
          IF(DATACK.EQ.1) THEN                                      00006740
            WRITE(6,7000)                                           00006750
 7000       FORMAT(//20X,'*********ERB OFF DAY - NO DATA',          00006760
     1      ' AVAILABLE**********'//)                               00006770
            IF=IF+1                                                 00006780
          ENDIF                                                     00006790
          IF(IF.GT.0) GO TO 899                                     00006800
C                                                                   00006810
          WRITE(6,4930)                                             00006820
 4930     FORMAT(42X,'MEAN',11X,'MIN',11X,'MAX',11X,'N',11X,'STD.DEV') 00006830
C                                                                   00006840
C                                                                   00006850
          WRITE(6,5002) (XMEAN(J),XMIN(J),XMAX(J),NO(J),XSD(J),J=1,18) 00006860
 5002     FORMAT(1X,'ORBIT NUMBER',26X,F10.3,5X,F10.3,4X,F10.3,6X,  00006870
     1    I2,8X,F12.4/1X,'SOLAR AZIMUTH',25X,F10.3,5X,F10.3,4X,F10.3,6X,00006880
     2    I2,8X,F12.4/1X,'SOLAR ELEVATION',23X,F10.3,5X,F10.3,4X,F10.3, 00006890
     3    6X,I2,8X,F12.4/1X,'GAMMA ANGLE',27X,F10.3,5X,F10.3,4X,F10.3,  00006900
     4    6X,I2,8X,F12.4/1X,'CHAN.3 TEMP',27X,F10.3,5X,F10.3,4X,F10.3,  00006910
     5    6X,I2,8X,F12.4/1X, 'CHAN.10C TEMP',25X,F10.3,5X,F10.3,4X,     00006920
     6    F10.3,6X,I2,8X,F12.4/1X,'CHAN.1 IRRAD',26X,F10.3,5X,F10.3,    00006930
     7    4X,F10.3,6X,I2,8X,F12.4/1X,'CHAN.2 IRRAD',26X,F10.3,5X,F10.3, 00006940
     8    4X,F10.3,6X,I2,8X,F12.4/1X,'CHAN.3 IRRAD',26X,F10.3,5X,F10.3, 00006950
     9    4X,F10.3,6X,I2,8X,F12.4/1X,'CHAN.4 IRRAD',26X,F10.3,5X,F10.3, 00006960
     A    4X,F10.3,6X,I2,8X,F12.4/1X,'CHAN.5 IRRAD',26X,F10.3,5X,F10.3, 00006970
     B    4X,F10.3,6X,I2,8X,F12.4/1X,'CHAN.6 IRRAD',26X,F10.3,5X,F10.3, 00006980
     C    4X,F10.3,6X,I2,8X,F12.4/1X,'CHAN.7 IRRAD',26X,F10.3,5X,F10.3, 00006990
     D    4X,F10.3,6X,I2,8X,F12.4/1X,'CHAN.8 IRRAD',26X,F10.3,5X,F10.3, 00007000
     E    4X,F10.3,6X,I2,8X,F12.4/1X,'CHAN.9 IRRAD',26X,F10.3,5X,F10.3, 00007010
     F    4X,F10.3,6X,I2,8X,F12.4/1X,'CHAN.10C IRRAD',24X,F10.3,5X,     00007020
     G    F10.3,4X,F10.3,6X,I2,8X,F12.4/1X,'OFF AXIS ANGLE',24X,F10.3,  00007030
     I    5X,F10.3,4X,F10.3,6X,I2,8X,F12.4/1X,'COSINE CORRECT.',       00007040
     J    'CHAN.10C IRRAD',10X,F10.3,5X,F10.3,4X,F10.3,6X,I2,8X,F12.4/) 00007050
C                                                                   00007060
          CH10C=XMEAN(16)                                           00007070
          IF(CH10C.LT.0.0) CH10C=0.0                                00007080
C         WRITE(20,8000) KREC,IYEAR(KREC),IDOY(KREC),CH10C          00007090
C8000     FORMAT(3I10,F10.2)                                        00007100
C                                                                   00007110
  899     CONTINUE                                                  00007120
          ENDIF                                                     00007130
          IF(STOPCK.EQ.1) GO TO 900                                 00007140
C                                                                   00007150
  105     CONTINUE                                                  .00007160
```

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      GO TO 900                                                      00007170
902   WRITE(6,2001)                                                  00007180
2001  FORMAT(//'ERROR IN TAPE READ'/)                                00007190
      GO TO 999                                                      00007200
900    CONTINUE                                                      00007210
      WRITE(6,2000)                                                  00007220
2000  FORMAT(//' END OF FILE 3 PROCESSING'//)                       00007230
999   RETURN                                                         00007240
      END                                                            00007250
C*************************************************************************00007260
C                                                                    00007270
      SUBROUTINE SOLAR(IF,IY1,IY2,ID1,ID2)                           00007280
C************************************************************************ 00007290
C       FUNCTION - THIS PROGRAM READS THE SOLAR ACTIVITY INDICATORS FILE00007300
C                  OF THE ERB SOLAR ANLAYSIS TAPE (ESAT).            00007310
C                  SELECTED RECORDS ARE PRINTED OUT.                 00007320
C                                                                    00007330
C       ARGUMENT LIST:                                               00007340
C       -------- -----                                               00007350
C       VARIABLE  TYPE  IO  DESCRIPTION                              00007360
C       --------  ----  --  -----------                             00007370
C       IF        I*4   I   FILE POSITION                            00007380
C       IY1,ID1   I*4   I   FIRST DATE TO DUMP ESAT DATA             00007390
C       IY2,ID2   I*4   I   LAST DATE TO DUMP ESAT DATA              00007400
C                                                                    00007410
C       LOCAL VARIABLES USED:                                        00007420
C       ----- --------- -----                                        00007430
C       VARIABLE  TYPE  DESCRIPTION                                  00007440
C       --------  ----  -----------                                  00007450
C       ACTREG    I*2   ARRAY OF SOLAR PLAGE AND SUNSPOT DATA        00007460
C       SOLACT    I*2   ARRAY CONTAINS SOLAR ACTIVITY DATA FOR 1 RECORD 00007470
C       IREC      I*2   RECORD NUMBER                                00007480
C       IRECID    I*2   RECORD ID                                    00007490
C       YEAR      I*2   YEAR OF OBSERVATION                          00007500
C       DAY       I*2   DAY OF OBSERVATION                           00007510
C       NPR       I*2   NUMBER OF PLAGE REGION OBSERVATIONS PER DAY  00007520
C       NSG       I*2   NUMBER OF SUNSPOT REGION OBSERVATIONS PER DAY 00007530
C       ISS       I*2   ZURICH SUNSPOT NUMBER                        00007540
C       MHZ       R*4   2800 MHZ SOLAR FLUX                          00007550
C       CAL       R*4   DAILY CALCIUM PLAGE INDEX                    00007560
C       IGEO      I*2   GEOMAGNETIC INDEX (AP SERIES)                00007570
C       PLAG      I*2   PLAGE REGION DATA. CONTAINS:                 00007580
C                       CMPD - CENTRAL MERIDIAN PASSAGE DATE         00007590
C                       MHRN - MCMATH-HALE REGION NUMBER             00007600
C                       LAT  - LATITUDE OF REGION                    00007610
C                       LON  - LONGITUDE OF REGION                   00007620
C                       AREA - AREA OF REGION IN MILLIONTHS OF SOL. HEM.00007630
C                       INT  - INTENSITY OF REGION (1=FAINT,5=BRIGHT) 00007640
C                       CLN - CARRINGTON LONGITUDE NUMBER            00007650
C       SPOT      I*2   SUNSPOT REGION DATA. CONTAINS:               00007660
C                       MHRN - MCMATH-HALE REGION NUMBER             00007670
C                       LAT  - LATITUDE OF REGION                    00007680
C                       LON  - CARRINGTON LONGITUDE OF REGION        00007690
C                       INT  - INTENSITY OF REGION (1=FAINT,5=BRIGHT) 00007700
C                       AREA - AREA OF REGION IN MILLIONTHS OF SOL. HEM.00007710
C                       CLN - CARRINGTON LONGITUDE NUMBER            00007720
C                                                                    00007730
C       NOTE: THERE MAY BE MORE THAN ONE PLAGE REGION OBSERVATION    00007740
C             OBSERVATION PER DAY. THEREFORE PLAGE REGION RECORDS ARE 00007750
C             READ SEPERATELY DEPENDING ON THE VALUE OF NPR AND NSG. 00007760
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C                                                                 00007770
C          CALLED FROM: MAIN                                      00007780
C                                                                 00007790
C          CALLS TO:                                             00007800
C                   POSN   -   FTIO TAPE POSITIONING ROUTINE       00007810
C                   FREAD  -   FTIO TAPE READ ROUTINE             00007820
C                                                                 00007830
C          PROGRAMMER: G. MAJOR, RESEARCH & DATA SYSTEMS, INC.    00007840
C                                                                 00007850
C          LANGUAGE/COMPUTER: VS FORTRAN/IBM 3081 AT NASA/GSFC    00007860
C                                                                 00007870
C          VERSION DATE: JULY 1984                                00007880
C                                                                 00007890
C          MODIFIED SEPTEMBER 1985 BY GRM-RDS,INC                 00007900
C                                                                 00007910
C          MODIFIED JUNE 1985 BY GRM-RDS,CORP. TO INCLUDE YEAR 6 ESAT  00007920
C                                                                 00007930
C          MODIFIED JULY 1987 TO INCLUDE 89 MONTHS OF SOLAR DATA  00007940
C          (WHERE AVAILABLE) AND TO REVISE THE SOLAR ACTIVITY FILE. 00007950
C                                                                 00007960
C                                                                 00007970
C                                                                 00007980
C*******************************************************************00007990
C                                                                 00008000
       INTEGER*2 SOLACT(1000),ACTREG(1000),IREC,IRECID,YEAR,DAY    00008010
C      INTEGER*2 NPR(2700),NSG(2700)                              00008020
       REAL*4 CAL,MHZ,PLAG(50,8),SPOT(50,6)                        00008030
C                                                                 00008040
        EQUIVALENCE(SOLACT(11),ACTREG(1))                         00008050
C                                                                 00008060
       WRITE(6,3000)                                              00008070
 3000  FORMAT(//' OPEN FILE 4 FOR PROCESSING'//' DAILY SOLAR ACTIVITY', 00008080
      1  ' INDICATORS'//)                                         00008090
C                                                                 00008100
       JT1=9999                                                   00008110
       JT2=0                                                      00008120
C                                                                 00008130
C       POSITION TAPE TO FILE 4 FOR PROCESSING                    00008140
C                                                                 00008150
       CALL POSN(1,10,IF)                                         00008160
C                                                                 00008170
C       WRITE HEADER FOR PRINTOUT                                 00008180
C                                                                 00008190
       WRITE(6,1000)                                              00008200
 1000  FORMAT(20X,'ERB SOLAR ANALYSIS TAPE (ESAT)'/               00008210
      1        20X,'SOLAR ACTIVITY INDICATORS'/                   00008220
      2        20X,' FILE # 3'/)                                  00008230
C                                                                 00008240
C       LOOP OVER ALL OBSERVATIONS                                00008250
C                                                                 00008260
       IUNIT=10                                                   00008270
       IN=0                                                       00008280
       DO 100 I=1,2692                                            00008290
C                                                                 00008300
C         READ SOLAR ACTIVITY DATA                                00008310
C                                                                 00008320
         CALL FREAD(SOLACT,IUNIT,LENGTH)                          00008330
         IREC=SOLACT(1)                                           00008340
         IRECID=SOLACT(2)                                         00008350
         YEAR=SOLACT(3)                                           00008360
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          DAY=SOLACT(4)                                                 00008370
          NPR=SOLACT(5)                                                 00008380
          NSG=SOLACT(6)                                                 00008390
          ISS=SOLACT(7)                                                 00008400
          MHZ=(SOLACT(8))/10.                                           00008410
          CAL=(SOLACT(9))/10.                                           00008420
          IGEO=SOLACT(10)                                               00008430
C                                                                       00008440
C         UNPACK PLAGE REGION DATA                                      00008450
C                                                                       00008460
          K=0                                                           00008470
          IF(NPR.GT.0)THEN                                              00008480
          DO 112 J=1,NPR                                                00008490
            DO 113 J2=1,8                                               00008500
              K=K+1                                                     00008510
              IF(J2.EQ.1) PLAG(J,J2)=(ACTREG(K))/10.                    00008520
              IF(J2.GT.1.AND.J2.LT.6) THEN                              00008530
                PLAG(J,J2)=ACTREG(K)                                    00008540
              END IF                                                    00008550
              IF(J2.EQ.6) PLAG(J,J2)=(ACTREG(K))/10.                    00008560
              IF(J2.EQ.7) PLAG(J,J2)=ACTREG(K)                          00008570
              IF(J2.EQ.8) PLAG(J,J2)=ACTREG(K)                          00008580
  113       CONTINUE                                                    00008590
  112     CONTINUE                                                      00008600
          ELSE                                                          00008610
          J=1                                                           00008620
          DO 119 J2=1,8                                                 00008630
            K=K+1                                                       00008640
            PLAG(J,J2)=(ACTREG(K))                                      00008650
  119     CONTINUE                                                      00008660
          ENDIF                                                         00008670
C                                                                       00008680
C         UNPACK SUNSPOT DATA                                           00008690
C                                                                       00008700
          IF(NSG.GT.0)THEN                                              00008710
          DO 115 J=1,NSG                                                00008720
            DO 116 J2=1,6                                               00008730
              K=K+1                                                     00008740
                SPOT(J,J2)=ACTREG(K)                                    00008750
  116       CONTINUE                                                    00008760
  115     CONTINUE                                                      00008770
          ELSE                                                          00008780
          J=1                                                           00008790
          DO 120 J2=1,6                                                 00008800
            K=K+1                                                       00008810
            SPOT(J,J2)=(ACTREG(K))                                      00008820
  120     CONTINUE                                                      00008830
          ENDIF                                                         00008840
C                                                                       00008850
          IF(IY1.EQ.YEAR.AND.ID1.EQ.DAY) JT1=I                         00008860
          IF(IY2.EQ.YEAR.AND.ID2.EQ.DAY) JT2=I                         00008870
C                                                                       00008880
C         WRITE SPECIFIED RECORDS                                       00008890
C                                                                       00008900
          IF(I.GE.JT1) THEN                                             00008910
            IF(JT2.GT.0.AND.I.GT.JT2) GO TO 101                        00008920
            IN=IN+1                                                     00008930
C                                                                       00008940
            WRITE(6,2002)                                               00008950
 2002       FORMAT(6X,'RECORD',28X,'SOLAR',2X,' DAILY',2X,' GEOM',2X/   00008960
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   1      1X,' OBS',2X,' ID ',' YEAR',2X,'DAY',2X,' NPR',2X,' NSG',    00008970
   2      1X,'SSN',2X,'FLUX',2X,' CALCM',2X,' INDX')                   00008980
C                                                                      00008990
          WRITE(6,1005) IREC,IRECID,YEAR,DAY,NPR,NSG,ISS,MHZ,CAL,      00009000
   1      IGEO                                                         00009010
1005      FORMAT(3(I4,2X),I3,2X,2(I4,2X),I3,3X,F5.1,2X,                00009020
   1      F5.1,3X,I4)                                                  00009030
          WRITE(6,2000)                                                00009040
2000      FORMAT(/'SOLAR PLAGE DATA)'/                                 00009050
   2      48X,' CMP',2X,'MHREG.NO',2X,'LATIT',2X,' LON',               00009060
   3      5X,' AREA',2X,' INTEN',2X,' CLN',2X,'BLANK'/)                00009070
C                                                                      00009080
          IF(NPR.GT.0)THEN                                             00009090
           DO 114 J9=1,NPR                                             00009100
            WRITE(6,1006) (PLAG(J9,J6),J6=1,8)                         00009110
1006       FORMAT(48X,F5.1,2X,F8.0,2X,2(F5.0,2X),F8.0,2X,             00009120
   1       F6.1,2X,2(F5.0,2X))                                         00009130
114        CONTINUE                                                    00009140
          ENDIF                                                        00009150
          IF(NPR.EQ.0) THEN                                            00009160
           J7=1                                                        00009170
             WRITE(6,1006) (PLAG(J7,J8),J8=1,8)                        00009180
          END IF                                                       00009190
       WRITE(6,2001)                                                   00009200
2001   FORMAT('(SOLAR SUNSPT DATA)'/                                   00009210
   2 48X,'MHREG.NO',2X,'LATIT',3X,'LON',                              00009220
   3 5X,'INTEN',5X,' AREA',4X,'CLN'/)                                 00009230
C                                                                      00009240
          IF(NSG.GT.0)THEN                                             00009250
           DO 118 J10=1,NSG                                            00009260
            WRITE(6,1008) (SPOT(J10,J11),J11=1,6)                      00009270
1008       FORMAT(48X,F8.0,2X,2(F5.0,2X),F7.0,2X,F8.0,2X,F5.0)        00009280
118        CONTINUE                                                    00009290
          ENDIF                                                        00009300
           IF(NSG.EQ.0) THEN                                           00009310
           J12=1                                                       00009320
             WRITE(6,1008) (SPOT(J12,J13),J13=1,6)                     00009330
          END IF                                                       00009340
101      CONTINUE                                                      00009350
          END IF                                                       00009360
 100   CONTINUE                                                        00009370
       WRITE(6,3001)                                                   00009380
3001   FORMAT(//' END OF FILE 4 PROCESSING'//)                        00009390
       RETURN                                                          00009400
       END                                                            00009410
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		14. Sponsoring Agency Code

16. Abstract

Seven years and five months of Nimbus-7 ERB solar data are available on a single ERB Solar Analysis Tape (ESAT). The period covered is November 16, 1978 through March 31, 1986. The Nimbus-7 satellite performs approximately 14 orbits per day and the ERB solar telescope observes the Sun once per orbit as the satellite crosses the southern terminator. The solar data have been carefully calibrated and screened. Orbital and daily mean values are given for the total solar irradiance plus other spectral intervals (10 solar channels in all). In addition, selected solar activity indicators are included on the ESAT. The ESAT User's Guide is an update of the previous ESAT User's Guide (NASA TM 86143) and includes more detailed information on the solar data calibration, screening procedures, updated solar data plots, and applications to solar variability. Details of the tape format, including source code to access ESAT, are included.

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