1.0 **Polar Orbiter System Description**

The Satellite Services Branch (SSB) of the National Climatic Data Center, under the auspices of the National Environmental Satellite, Data, and Information Service (NESDIS), has established a digital archive of data collected from the current generation of NOAA operational polar orbiting satellites. This series of satellites commenced with TIROS-N (launched in October 1978) and continued with NOAA-A (launched in June 1979 and renamed NOAA-6), NOAA-C (launched in June 1981 and renamed NOAA-7), NOAA-E (launched in March 1983 and renamed NOAA-8), NOAA-F (launched in December 1984 and renamed NOAA-9), NOAA-G (launched in September 1986 and renamed NOAA-10), NOAA-H (launched in September 1988 and renamed NOAA-11), NOAA-D (launched in May 1991 and renamed NOAA-12), NOAA-I (launched in August 1993 and renamed NOAA-13) and NOAA-J (launched in December 1994 and renamed NOAA-14). This series of satellites (TIROS-N and NOAA-6 through NOAA-14) will henceforth be referred to in this document as the TIROS-N series. [Technically, TIROS-N through NOAA-D are called the TIROS-N series and NOAA-E through -N= are called the TIROS ATN series (Advanced TIROS-N).] This complete TIROS series will eventually include NOAA-A through -N=. However, this document covers only the TIROS-N, NOAA-6 through NOAA-14 satellites.

This document can be found on the Internet at the following Uniform Resource Locator (URL): http://www2.ncdc.noaa.gov/docs/. Also, the document is available in both WordPerfect 6.1 and Postscript for downloading through ftp (file transfer protocol) at: ftp2.ncdc.noaa.gov/pub/doc/podguide/.

This section describes the characteristics of the TIROS-N series instruments, orbits, and data. Section 1.1 summarizes the instrument characteristics and general properties of the orbit. Section 1.2 contains specific information regarding the orbits, such as Brouwer mean orbital elements and how to make a "spinner". Section 1.3 contains information on the procedures for scheduling high resolution LAC (Local Area Coverage) AVHRR data over a specific area of interest. Section 1.4 provides specific information for each satellite, including operational date ranges, abnormalities, AVHRR and TOVS spectral responses, HIRS/2 thermal band-correction coefficients and AVHRR central wave numbers.

1.1 **System Summary**

This section summarizes the characteristics of the NOAA polar orbiter satellite instruments and properties of the satellite orbit. A detailed description of the NOAA Polar Orbiter instrumentation may be found in NOAA Technical Memoranda NESS 95 and 116, entitled respectively, *The TIROS-N/NOAA-A-G Satellite Series*, and *Modified Version of the TIROS-N/NOAA A-G Satellite Series (NOAA E-J) - Advanced TIROS-N (ATN)*. These documents are available from SSB.

The satellite system includes the following instrument package:

AVHRR - Advanced Very High Resolution Radiometer, from which is obtained:

a. HRPT - High Resolution Direct Readout AVHRR
b. LAC - Recorded HRPT AVHRR
c. GAC - Reduced Resolution Recorded AVHRR

TOVS - TIROS Operational Vertical Sounder, which includes:

a. MSU - Microwave Sounding Unit
b. SSU - Stratospheric Sounding Unit
c. HIRS/2 - High Resolution Infrared Radiation Sounder/2

The TIROS-N/NOAA A-G (6-10) series of satellites have been modified to add payload capacity without changing the basic environmental mission of the series. Seven additional satellites (NOAA-H, -I, -J, -K, -L, -M, -N and -N=) were added to the initial procurement to extend the lifetime of the program to the end of the century. Incrementally

added to the payload was a Search and Rescue Demonstration System (SAR), an Earth Radiation Budget Experiment (ERBE) flown on NOAA-9 and NOAA-10 only, and an operational Solar Backscatter Ultraviolet Radiometer (SBUV/2) to monitor the distribution of ozone in the atmosphere (flown on NOAA-9, -11, -13 and -14).

The NOAA-E through -N= spacecraft, also called the Advanced TIROS-N (ATN), are similar to the NOAA-A through -D satellites that preceded them with the exception that the Equipment Support Module has been enlarged to allow integration of new payloads. A change from the TIROS-N through NOAA-8 spacecraft is that the spare word locations of the low bit rate data system TIROS Information Processor (TIP) is used for special instruments such as the ERBE and SBUV/2. The SAR system will be independent, utilizing a special frequency for transmission of data to the ground.

As the satellite orbits the Earth, data are both broadcast continually (direct readout mode) and recorded on board for later playback. NOAA/NESDIS operates two Command and Data Acquisition (CDA) stations, one in Wallops Island, Virginia and one in Fairbanks, Alaska (formerly Gilmore Creek before 1984), to receive both recorded and direct readout environmental data from the satellite and send these data to Suitland, Maryland, via satellite relay. However, during two (sometimes three) sequential orbits of the Earth, the satellite remains out of contact with any of these sites.

The NOAA/NESDIS ground stations in Wallops, VA and Fairbanks, AK receive Direct Readout High Resolution Picture Transmission (HRPT) data. Fairbanks maintains a 90-day rotating pool of these data, while Wallops keeps a 60-day pool. As of January 1, 1997, both CDA stations reduced their rotating pools to 30 days. The data are in Field Station format which is described in Appendix C. These data may be ordered through SSB. The Field Station data **do not have appended Earth location and calibration information**, and are 8-bit precision rather than 10-bit precision. The amount of HRPT data received during one pass of the satellite over the ground station is limited to the acquisition range of the station. A satellite pass directly over an antenna site will be within view of that antenna (horizon to horizon) for about 15.5 minutes when the satellite is at 833 km and 16 minutes when it is at 870 km. Figures 1.1-1 and 1.1-2 depict the overall HRPT coverage from each of the NESDIS ground stations over the Northern and Southern hemispheres, respectively.

In addition to providing direct readout, the TIROS-N series satellites carry five digital tape recorders, each with a single electronic module and dual tape transport, to record data for subsequent transmission through the CDA to the data processing facility. Each transport has the capacity to record one of the following:

1) 115 minutes (slightly more than a full orbit) of GAC with embedded TIP data. (TIROS Information Processor is the on board computer system that formats the sensor data for transmission. TIP includes TOVS and auxiliary data.)

2) Eleven and one half minutes of HRPT data (called LAC when recorded), or

3) 230 minutes of TIP data only (called stored TIP).

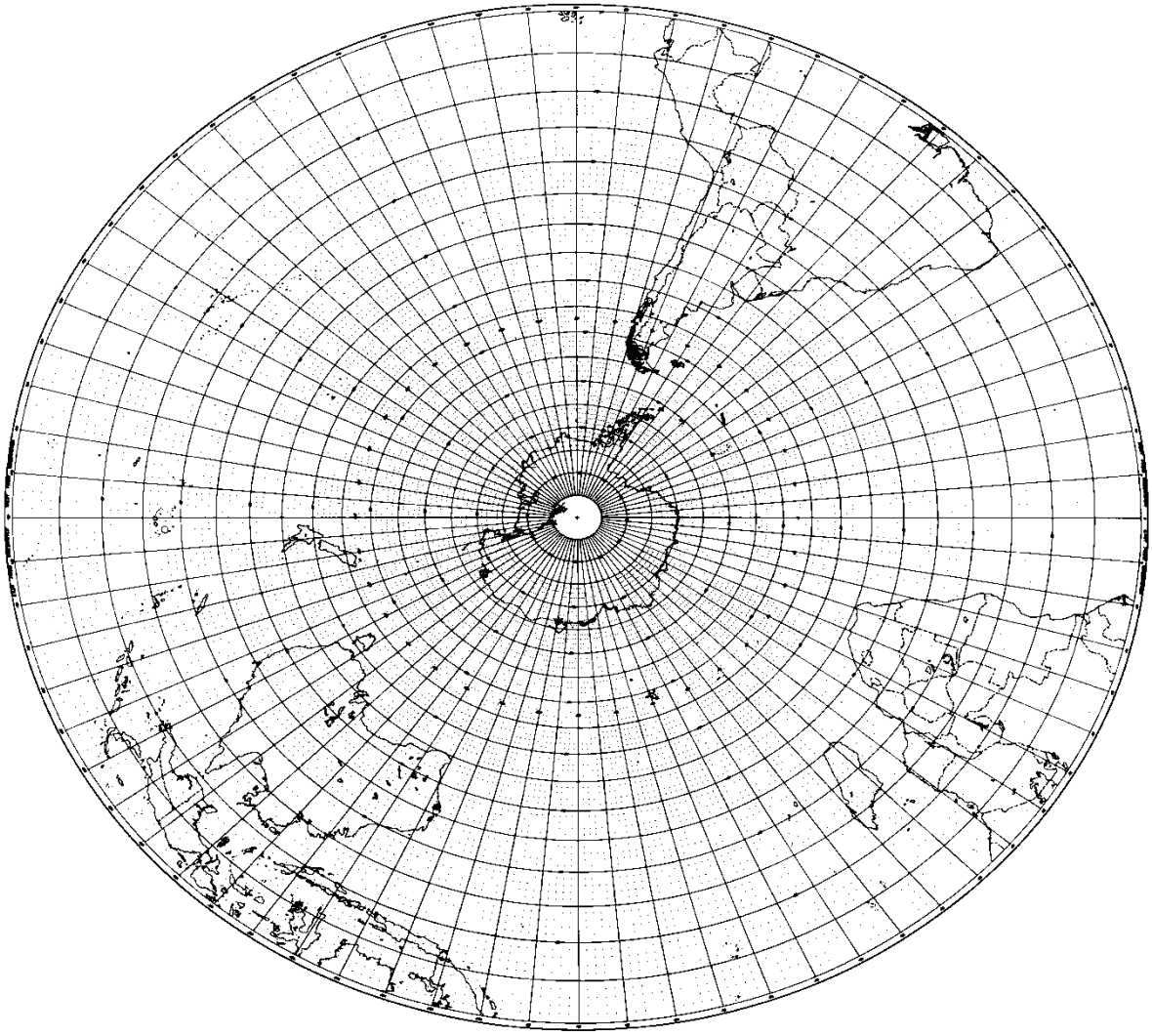
Between October 1978 and April 11, 1985, direct readout HRPT and recorded GAC, LAC, and TIP data were ingested by NESDIS computers and stored temporarily on staging disks used as work space and for interfacing these computers with the NESDIS Terabit Memory (TBM) mass storage system. The ingested data were then retrieved from disk storage on a time-available basis, processed to Level 1b format (which included appending of Earth location and calibration information) and returned to the disks for subsequent transfer to the TBM for NESDIS product processing and the SSB archive.

On April 11, 1985, NESDIS abandoned the TBM system as a means of storing ingested polar orbiter data. Over the years, SSB=s hardware complement has changed with advancing technology, but the corresponding media changes remain transparent to the satellite data user.

During the period of conversion from TBM tapes, SSB attempted to transfer as much of the data from TBM tapes as possible (while simultaneously servicing user requests). Priority was given to recovering the GAC data sets and

88% of these were saved. Similarly, 49% of the TOVS and 6% of the LAC/HRPT were saved. Users should contact SSB for the availability of any Level 1b data which were ingested between October 1978 and April 1985.

Figure 1.1-1 Overall HRPT coverage for the Southern Hemisphere.



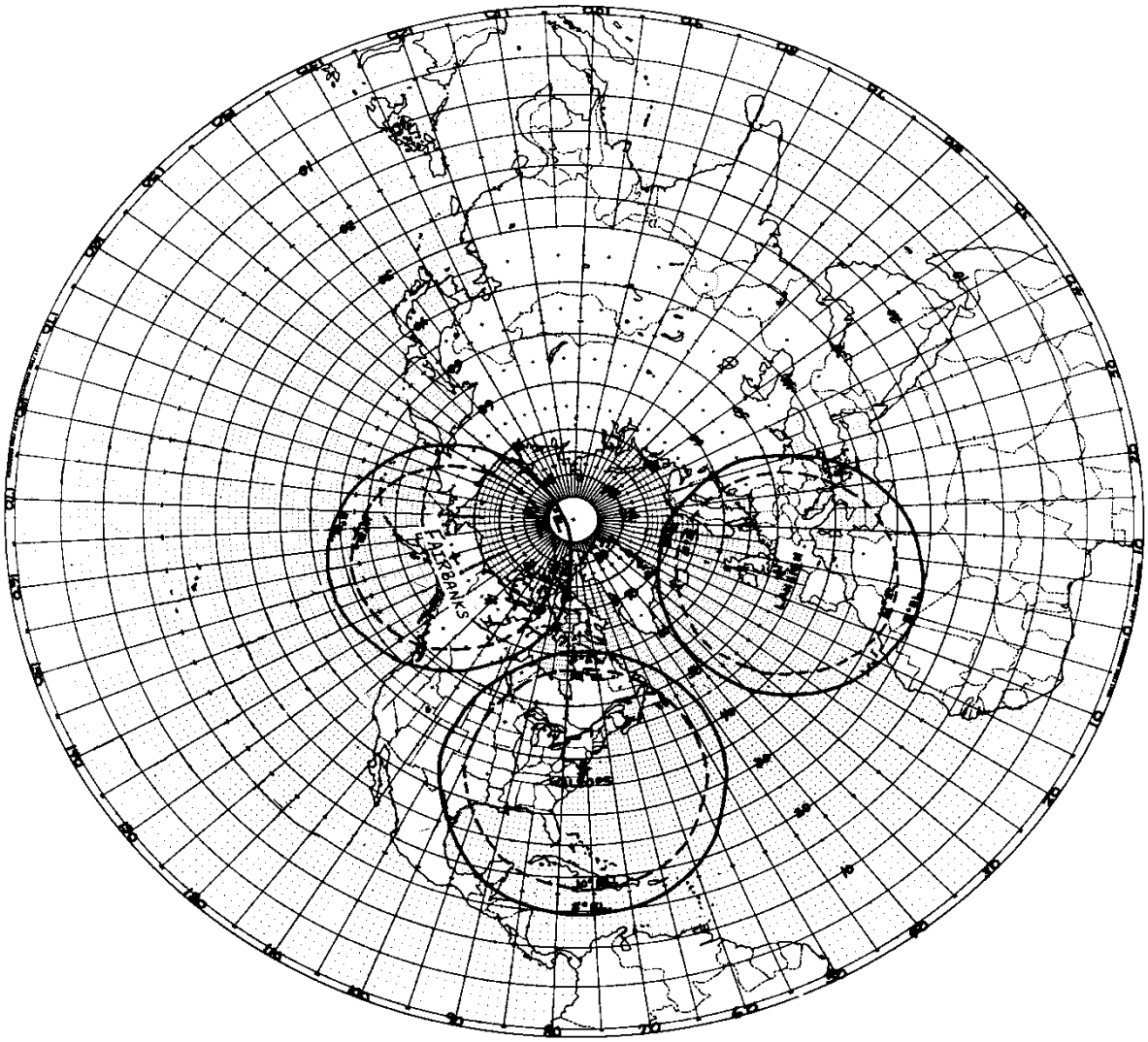


Figure 1.1-2 Overall HRPT coverage for the Northern Hemisphere.

As mentioned above, Earth location and calibration data are appended to the data as part of the Level 1b processing. The Earth location data are read from CCTs which contain up to 29 hours of information. These data are updated every 24 hours. These Earth location tapes (called GELDS data) were archived by SSB between March 8, 1985 and Sept. 7, 1992. On Sept. 8, 1992, NESDIS/IPD discontinued generating the GELDS data since the data were redundant with the Level 1b data.

For purposes of clarification, Figure 1.1-3 will be used as the definition of Solar Zenith angle, local zenith angle, and satellite scan angle. These angles are referred to throughout this guide and have the relationships shown in the figure.

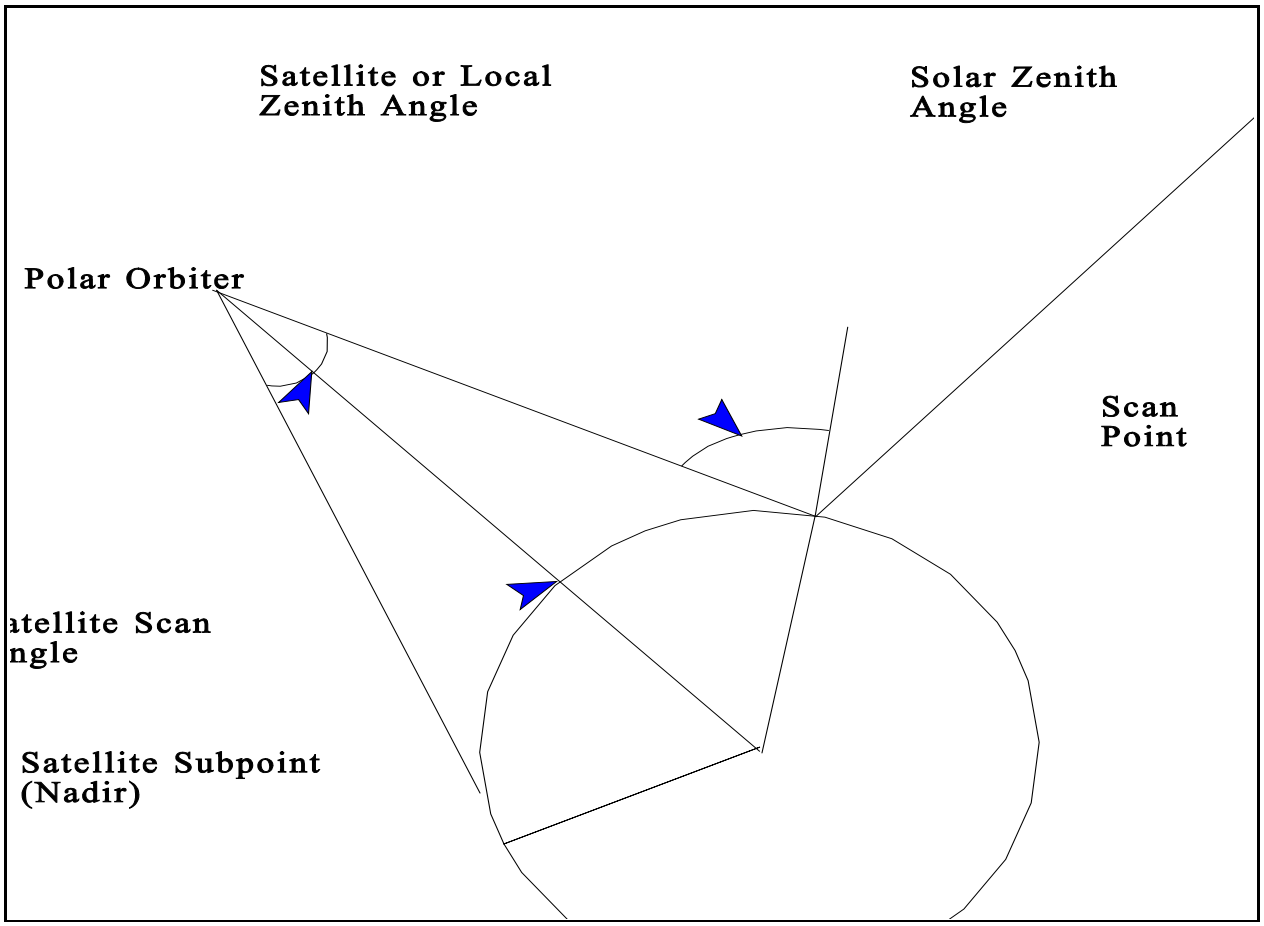


Figure 1.1-3. Relationship of sub-satellite point to Earth.

1.2 Orbital Information

The TIROS-N series satellites were designed to operate in a near-polar, sun-synchronous orbit. The orbital period is about 102 minutes which produces 14.1 orbits per day. Because the number of orbits per day is not an integer, the sub-orbital tracks do not repeat on a daily basis, although the local solar time of the satellite's passage is essentially unchanged for any latitude.

However, the satellite's orbits drift over time (Price 1991). This drift causes a systematic change of illumination conditions and local time of observation which is the major source of non-uniformity in multi-annual satellite time series.

Table 1.2-1 contains the approximate times of the ascending node (northbound Equator crossing) and the descending node (southbound Equator crossing) in Local Solar Time (LST) for the TIROS-N series when the satellites were launched. This table also contains the ascending and descending nodes as of March 1995 for the active satellites.

Table 1.2-1. Ascending and descending node times in LST.

Satellite	Ascending Node (Launch)	Descending Node (Launch)	Ascending Node (3/95)	Descending Node (3/95)
TIROS-N	1500	0300	n/a	n/a
NOAA-6	1930	0730	n/a	n/a
NOAA-7	1430	0230	n/a	n/a
NOAA-8	1930	0730	n/a	n/a
NOAA-9	1420	0220	2116	0916
NOAA-10	1930	0730	1753	0553
NOAA-11	1330	0130	1723	0523
NOAA-12	1930	0730	1915	0715
NOAA-13	1340	0140	n/a	n/a
NOAA-14	1330	0130	1330	0130

Table 1.2-2 summarizes the important dates for the satellites which have already been launched from the TIROS-N series. The date range in this table is at best an approximation. There may be scattered data sets available before or after these dates.

Table 1.2-2. Launch and data available dates for the TIROS-N series satellites.

Satellite	Launch Date	Date Range
TIROS-N	October 13, 1978	October 19, 1978-January 30, 1980
NOAA-6	June 27, 1979	June 27, 1979-March 5, 1983 July 3, 1984-November 16, 1986
NOAA-B	May 29, 1980	Failed to achieve orbit
NOAA-7	June 23, 1981	August 19, 1981-June 7, 1986
NOAA-8	March 28, 1983	June 20, 1983-June 12, 1984 July 1, 1985-October 31, 1985
NOAA-9	December 12, 1984	February 25, 1985-November 7, 1988
NOAA-10	September 17, 1986	November 17, 1986-September 16, 1991
NOAA-11	September 24, 1988	November 8, 1988-April 11, 1995
NOAA-12	May 14, 1991	May 14, 1991-present
NOAA-13	August 9, 1993	August 9, 1993-August 21, 1993
NOAA-14	December 30, 1994	April 11, 1995-present

SSB has available specific orbital reference information regarding each orbit of the polar orbiters. This information consists of the orbit number, longitude of ascending and descending nodes, height of satellite at each node, and date

and local time. SSB routinely receives this nodal information from SOCC two or three weeks in advance of the actual orbit.

A user may want to know the sub-orbital track and areal coverage available for a polar orbiter. The following paragraph describes how to make a "spinner" which would show the user this information. A spinner consists of a base map which is overlaid with a piece of clear acetate containing the sub-orbital track of the satellite. The acetate track is rotated over the base map as desired.

To make a spinner, the polar-stereographic map of the Northern Hemisphere in Figure 1.1-1 should be mounted on stiff cardboard or similar material. The sub-orbital track and width of the orbital swath for the TIROS-N series which is shown in Figure 1.2-1 should be traced onto a piece of clear acetate and overlaid on the base map. Note for Figures 1.2-1 and 1.2-2, the outer solid lines indicate a 15 degree swath (the actual width of an orbital swath is approximately 25 degrees). The area under the 15 degree swath contains good, usable data with little or no distortion at the edges. A small map pin should be inserted through the "x" on the acetate and into the center (North Pole) of the base map. The numbers indicated on the sub-orbital track are the minutes after the ascending node. The user need only rotate the acetate around the map base until the orbital track is over the desired area and read off the ascending node longitude. Or, conversely, if the orbit number and ascending node longitude are known, then the spinner can be rotated to the proper longitude and the orbital coverage will be shown as that area covered by the spinner. Similarly, a Southern Hemisphere spinner can be made using the base map in Figure 1.1-2 and the sub-orbital track in Figure 1.2-2.

Users now have the option of downloading a self-extracting file XTRCTORB.EXE to their PC=s hard drive. This file generates a program, GNRLORB.EXE and associated files which is the equivalent of making the spinner described in this section. By inputting the longitude of the ascending node (which is also available on the same WWW site), GNRLORB will display the subtrack of a nominal TIROS-N series satellite with marks at five minute intervals from the ascending node and the limits of an AVHRR scan on a choice of map bases: 1) rectangular equal spaced projection from 70S to 70N latitude; 2) Northern Hemisphere Polar Stereographic projection; and 3) Southern Hemisphere Polar Stereographic projection. Users may access this software from NOAA/NESDIS= Product Systems Branch (PSB) Home Page which has a URL of: http://psbsgi1.nesdis.noaa.gov:8080/ISB/NAVIGATION/navpage.html. Users should click on the AGraphical Orbit Locator@ to initiate the ftp download process. This same site also contains an overview of the NESDIS polar earth location process, polar satellite equator crossing information and clock drift files for polar satellites, as well as links to TBUS information and the Brouwer/Lyddane Software package.

Another excellent source of satellite navigation information is located at the NOAA Satellite Information System (NOAASIS) Internet site which has the following URL: http://140.90.207.25:8080/noaasis.html. Users should click on the ANavigation@ button to access TBUS bulletins, equator crossings, orbital elements and two line elements for both GOES and POES satellites. Also included is the navigation summary for the GOES satellites and the Monthly Predict elements for the POES. Further information on NOAASIS is included in Appendix G.

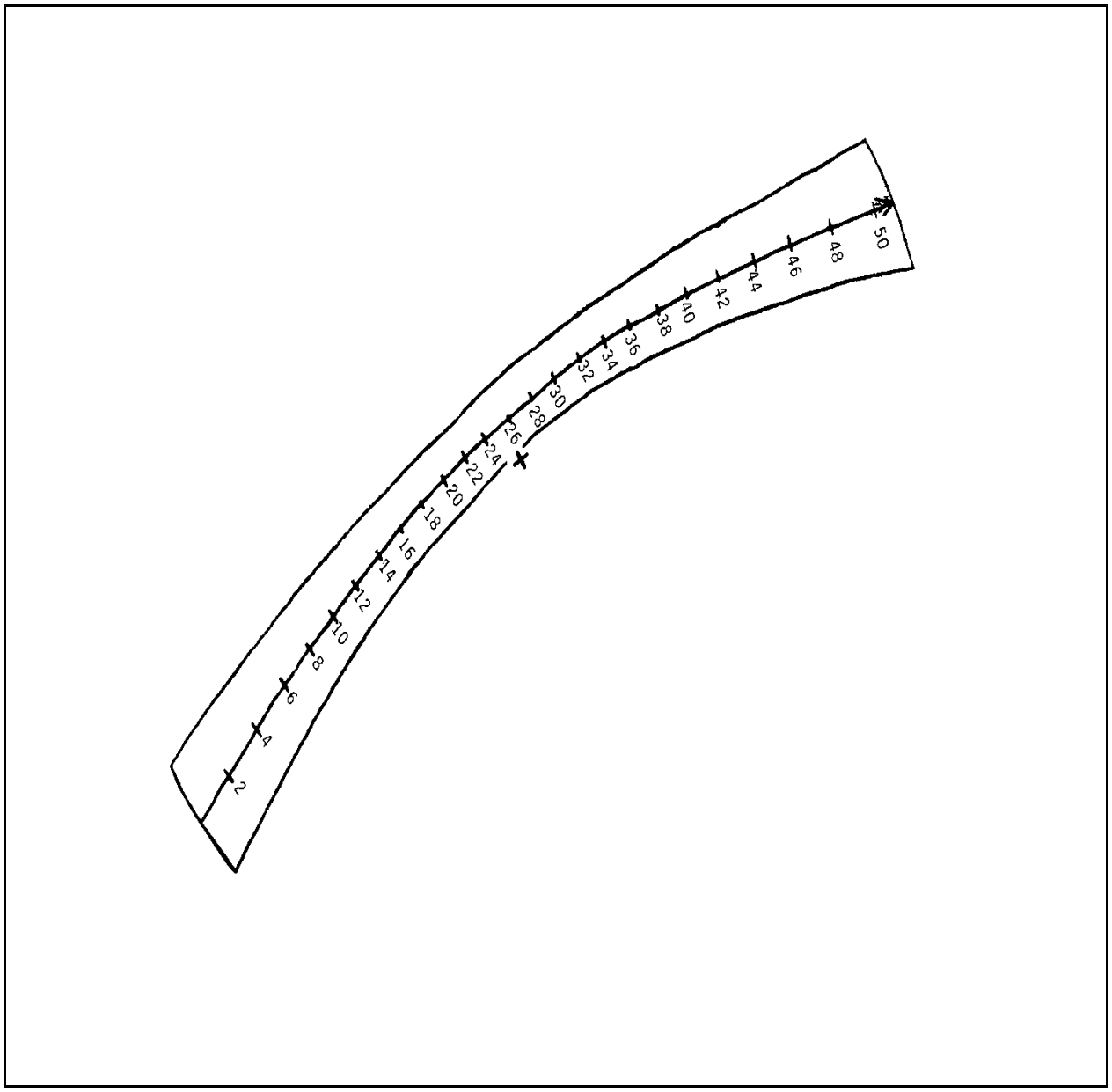


Figure 1 2-1Sub-orbital track overlay (Northern Hemisphere.

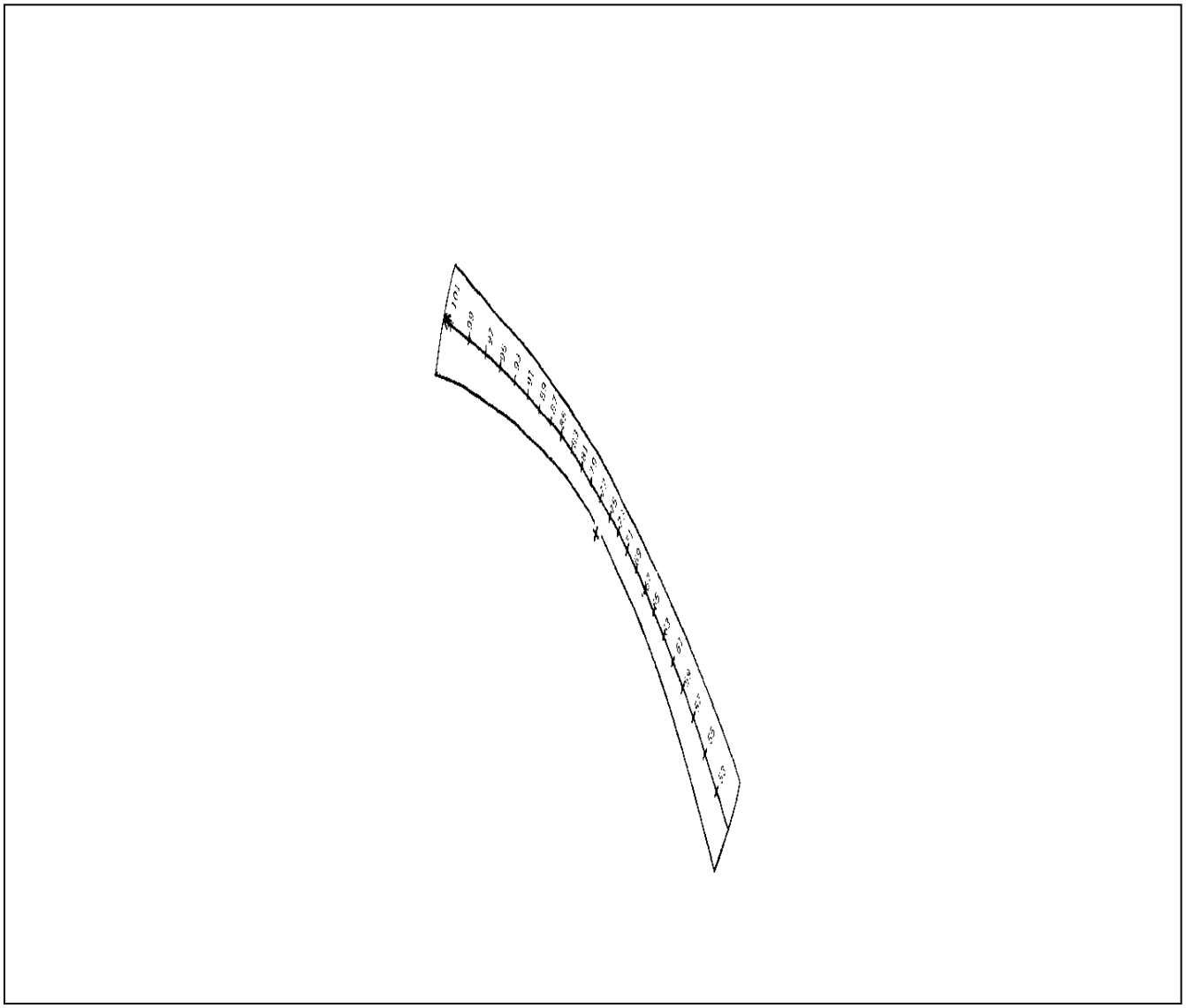


Figure 1 2-2Sub-orbital track overlay (Southern Hemisphere.

The United States Space Command (USSC, formerly NORAD) tracks TIROS-N series satellites for NESDIS. USSC sends orbital information to NESDIS each day. NESDIS regularly produces Brouwer mean orbital elements for its polar orbiting satellites and SSB archives them weekly (in hardcopy form). An example of the Brouwer mean orbital elements for TIROS-N (as of October 24, 1978 at 0000 UTC) is contained in Table 1.2-3.

Table 1.2-3. Brouwer mean orbital elements for TIROS-N on Oct. 24, 1978 at 0000 UTC.

Parameter	Value
Semi-Major Axis	7231.8505 km
Eccentricity	0.0011
Inclination	98.9127 degrees
Right ascension of ascending node	257.4741 degrees
Anomalistic period	102.0065 minutes
Argument of perigee	253.5599 degrees
Mean anomaly	126.4732
Height of perigee	845.67 km
Height of apogee	861.62 km

SOCC began recording TBUS (APT predict bulletin) messages on magnetic tape beginning on June 1, 1990. These TBUS messages contain information about each operational polar orbiter satellite. Specifically, TBUS Part IV contains the Brouwer mean elements which can be used in a stand alone Brouwer-Lyddane orbit prediction package to determine orbit position information at any time t-t_0 where t_0 represents the time of the Brouwer mean elements in Part IV and t represents the user request time. The Brouwer-Lyddane algorithm is an analytical solution of satellite motion for a simplified disturbing potential field limited to zonal harmonic coefficients for J_2 through J_5. Lyddane modified Brouwer's formulation to obtain algorithms applicable for zero eccentricity and zero inclination. This stand alone software package is included in Appendix F. Users may also request TBUS messages in hardcopy form from SSB.

Based on the information in Table 1.2-3, orbital reference information (ephemeris data) for the first operational TIROS-N orbit on November 1, 1978 is given in Table 1.2-4.

Table 1.2-4. Orbital reference information (Ephemeris data) for TIROS-N Orbit 262.

Parameter	Value
Satellite	TIROS-N
Orbit no.	262
Date/time	0042.70
Longitude of ascending node	145.56 W
Nodal period	102.1241 minutes
Increment between orbits	25.53 degrees

The ephemeris data is updated regularly and maintained on file (hardcopy) at SSB. Since June 1, 1992, SSB has also maintained an archive of ephemeris data containing 4-line elements and the PSCEAR initialization reports that IPD and Satellite Operations Control Center (SOCC) use to precisely locate each NOAA operational polar orbiting spacecraft for navigational purposes. These data are available from SSB.

The 4-line elements are generated by the NAVY's U.S. Space Command (USSC, formerly NORAD) and are transmitted to SOCC around 0000Z each day. IPD uses them to reinitialize or update the user ephemeris files each day. The 4-line elements contain the following parameters: the satellite ID, epoch time, epoch revolution number, the x,y,z components of the position and velocity vectors (Cartesian coordinates), ballistic coefficients, daily solar flux, average solar flux for 90 days, planetary magnetic index, drag modulation coefficient, radiation pressure coefficient, time of ascending node, revolution number at time of ascending node, the universal time correction and the universal time correction rate.

The PSCEAR initialization reports contain information from the User Ephemeris Files (UEF) header. The PSCEAR reports contain osculating Keplerian elements at epoch, the inertial Cartesian elements, the Brouwer mean elements at epoch, the anomalistic and nodal periods, orbit number at epoch, plus the first time derivatives of: the right ascension of the ascending node, argument of perigee and the mean anomaly. Contact SSB (see Section 6) to order these ephemeris data.

Users may access NOAA's Electronic Bulletin Board (NOAA.SIS) for information such as weekly HRPT/LAC coverage areas, TBUS messages, USSC 2-line elements (weekly), Keplerian orbital elements (weekly), recorder schedules (daily), weekly spacecraft events, polar status reports (monthly), and general information regarding NOAA's satellites. Much of the same information contained in NOAA.SIS resides on the Internet at URL: psbsgi1.nesdis.noaa.gov:8080/
noaasis.html. See Appendix G for specific procedures for telecommunication access to NOAA.SIS.

1.3 Procedure for Scheduling AVHRR LAC Data

Users may request scheduling of Local Area Coverage (LAC) data which are recorded outside the direct readout range of Wallops Island, Virginia or Fairbanks, Alaska. Because recorder space and transmission time must be shared by many requestors, requests must be received at least one month prior to the data acquisition period. Requests will be considered on a first-come, first-served basis, and according to the following priority considerations:

1. National emergencies, as specified in the various national emergency plans

2. Situations where human life is in immediate danger (i.e., search and rescue operations)

3. U.S. strategic requirements

4. Commercial requirements

5. Scientific investigations and studies

6. Other miscellaneous activities

Requests must also be accompanied by the following:

a. Brief description of application

b. Geographical area (i.e., East Greenland, Korea Straits, etc.)

c. Latitude and longitude coordinates bounding the area of interest

d. Desired frequency of coverage (i.e., once weekly, etc.)

e. Spectral channels required for image processing - Channel 1 or 2 = visible; Channel 3, 4, or 5 = infrared. Include range of expected brightness values or temperatures for image enhancement purposes.

f. Type of data - digital data available on computer compatible tape (CCT), and/or analog data, available as photographic prints.

g. Beginning and ending dates of the study period.

h. Satellite preference: NOAA-12 - daylight descending, nighttime ascending; NOAA-14 - daylight ascending, nighttime descending.

i. Name, address, and telephone number of requestor.

Failure to provide this information at the time of the request may cause a delay in scheduling of the LAC data. Requests for AVHRR LAC data may be emailed (preferred) or if phoned in, must be followed by written documentation. Submit requests to:

Mr.Tom Snell
NOAA/NESDIS/SOCC
Federal Office Building #4, Room 0220
Suitland, MD 20746-1701
Phone #: 301-457-5208
Fax #: 301-457-5175
Email: tsnell@nesdis.noaa.gov

Every effort is made to accommodate each request, for example, by combining requests of overlapping areas. However, because the number of requests for LAC coverage always surpasses scheduling resources, NESDIS does not guarantee complete or even partial fulfillment of LAC requirements. When lack of scheduling resources severely limit the acquisition of LAC coverage, requestors will be notified by SOCC LAC scheduling personnel. Users are not charged a fee for scheduling services.

Users should be aware that a request for LAC scheduling with SOCC is not an implicit request for data. Users must also contact SSB and meet all prepayment requirements before the actual processing of a data request can begin (see Section 6 for more details on ordering products from SSB).

1.4 Miscellaneous Parameters for the Polar Orbiter Satellites

This section provides specific information for each satellite. Each subsection contains a satellite's operational date range(s), any abnormalities associated with the satellite, tables for TOVS channel spectral response and HIRS/2 thermal band-correction coefficients, tables for AVHRR infrared channel central wave numbers as a function of temperature, and the spectral response curves for the AVHRR instrument. Many of these parameters are needed for calibration purposes.

Users should be aware that AVHRR Channel 3 data on TIROS-N series spacecraft have been very noisy due to an instrument problem and may be unusable at times.

1.4.1 TIROS-N

Operational dates: October 19, 1978 to January 30, 1980

Afternoon orbit: 1500 LST ascending node, 0300 LST descending node

AVHRR instrument: 4 channels

Spacecraft ID: 1

Table 1.4.1-1 contains the central wave numbers for the AVHRR IR channels for TIROS-N.

Table 1.4.1-2 contains the TOVS channel spectral response and HIRS/2 thermal band-correction coefficients for TIROS-N. Non-linearity errors for TIROS-N AVHRR Channel 4 are contained in Table 1.4.1-3. Table 1.4.1-4 contains values of the corrected radiance of space, N_{sp} (which includes the non-linearity correction) for the TIROS-N AVHRR IR channels.

Figures 1.4.1-1 through 1.4.1-4 contain the spectral response curves for the TIROS-N AVHRR channels 1 through 4, respectively.

Table 1.4.1-1. TIROS-N Central Wave Numbers for AVHRR IR Channels.

Temperature Range (K)	Ch. 3 (cm-1)	Ch. 4 (cm-1)
180-225	2631.81	911.13
225-275	2635.15	911.54
275-320	2638.05	912.01

Table 1.4.1-2. TIROS-N TOVS Channel Spectral Response and HIRS/2 Thermal Band-Correction Coefficients.

Instrument	Channel #	Central Wave #	Description	HIRS/2 Band-Correction Coefficients	
				b	c
HIRS/2	1	668.00 cm-1	15 micrometers	0.047	0.99986
	2	679.23 cm-1	CO2 Band	0.067	0.99979
	3	691.12 cm-1	CO2 Band	0.131	0.99962
	4	703.56 cm-1	CO2 Band	0.015	0.99991
	5	716.05 cm-1	CO2 Band	0.010	0.99993
	6	732.38 cm-1	CO2 Band	0.092	0.99974
	7	748.27 cm-1	CO2 Band	-0.101	1.00015
	8	897.71 cm-1	Window	-0.252	1.00013
	9	1027.87 cm-1	Ozone	0.118	0.99978
	10	1217.10 cm-1	Water Vapor	-0.132	0.99908
	11	1363.69 cm-1	Water Vapor	0.136	0.99982
	12	1484.35 cm-1	Water Vapor	0.424	0.99948
	13	2190.43 cm-1	4.3 micrometers	-0.015	0.99969
	14	2212.65 cm-1	CO2 Band	0.041	1.00011
	15	2240.15 cm-1	CO2 Band	0.074	1.00032
	16	2276.27 cm-1	CO2 Band	0.143	1.00057
	17	2360.63 cm-1	CO2 Band	0.060	1.00025
	18	2511.95 cm-1	Window	0.110	1.00020
	19	2671.18 cm-1	Window	0.650	1.00175
	20	14367.00 cm-1	Visible Window	n/a	n/a
MSU	1	1.6778 cm-1			
	2	1.7926 cm-1			
	3	1.8333 cm-1			
	4	1.9330 cm-1			
SSU	1	669.988 cm-1/15 mb			
	2	669.628 cm-1/5 mb			
	3	669.357 cm-1/1.5 mb			

Table 1.4.1-3. Non-linearity errors for TIROS-N Channel 4.	
Target temperature (K)	**Error (K)**
304.9	1.25
294.9	0.98
285.0	0.0
275.1	-0.03
264.9	-0.08
255.1	-0.10
234.9	-0.75
224.9	-0.95
204.9	-1.67
0.0	0.0

Table 1.4.1-4. Corrected values for TIROS-N Nsp.	
Channel	**Nsp (mW/(m2-sr-cm-1))**
3	0.0
4	-1.151

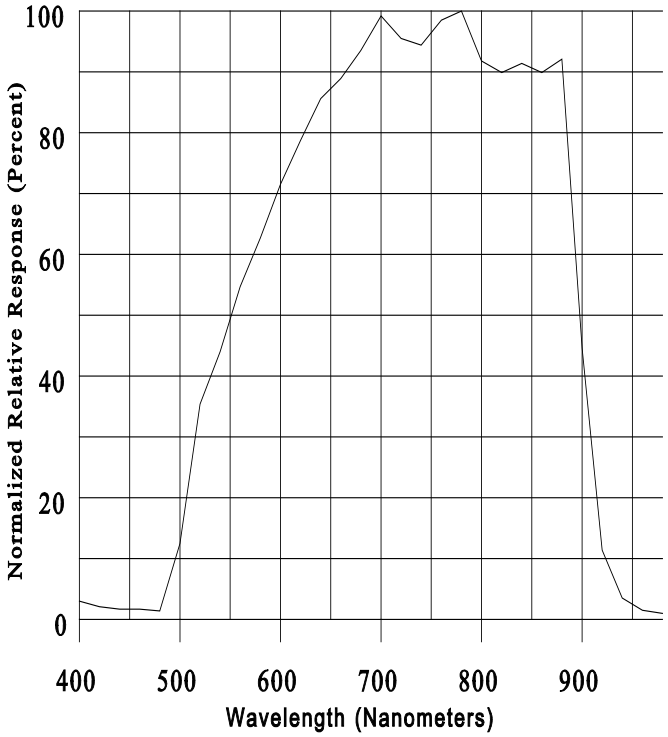


Figure 1.4.1-1 Spectral Response Curve TIROS-N AVHRR Channel 1**.**

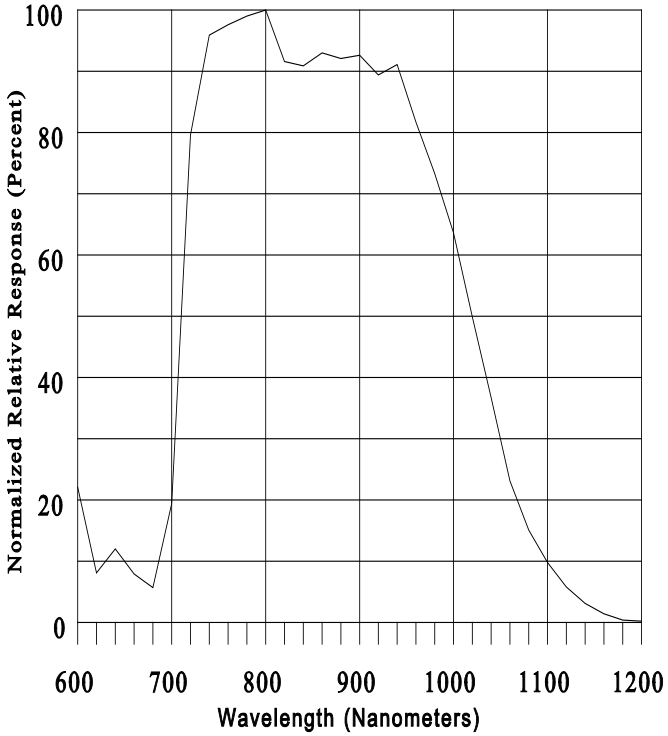


Figure 1.4.1-2 Spectral Response Curve TIROS-N AVHRR Channel 1**.**

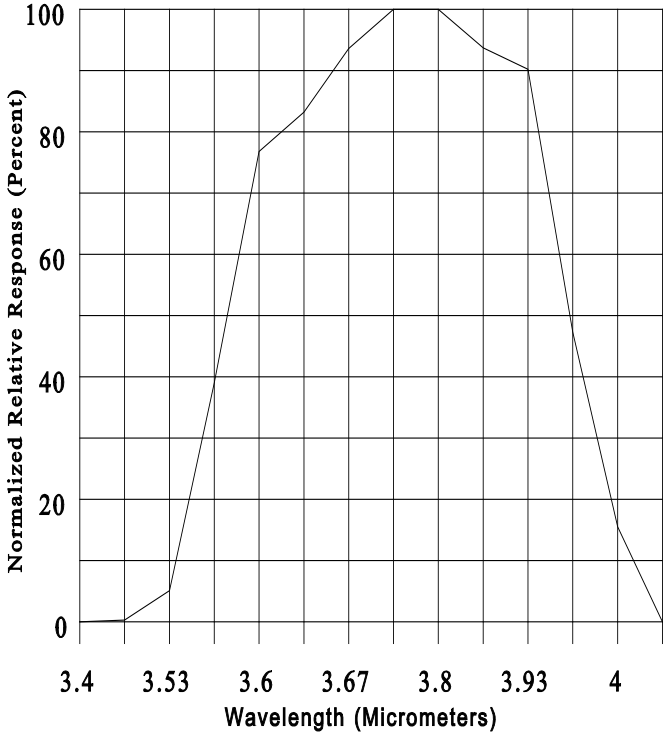


Figure 1.4.1-3 Spectral Response Curve TIROS-N AVHRR Channel 1**.**

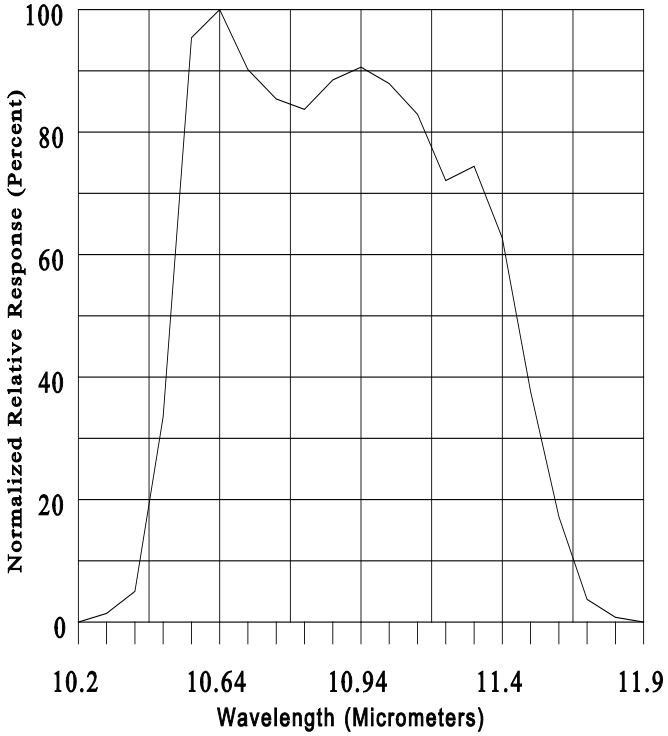


Figure 1.4.1-4 Spectral Response Curve TIROS-N AVHRR Channel 4**.**

1.4.2 **NOAA-6**

Operational dates: June 27, 1979 - March 5, 1983
July 3, 1984 - November 16, 1986

Morning orbit: 1930 LST ascending node, 0730 LST descending node

AVHRR instrument: 4 channels

Spacecraft ID: 2

Abnormalities:NOAA-6 was reactivated on July 3, 1984 to collect selected LAC/HRPT data because of the loss of NOAA-8.

Table 1.4.2-1 contains the central wave numbers for the AVHRR IR channels for NOAA-6. Table 1.4.2-2 contains the TOVS channel spectral response and HIRS/2 thermal band-correction coefficients for NOAA-6. Non-linearity errors for NOAA-6 AVHRR Channel 4 are contained in Table 1.4.2-3. Table 1.4.2-4 contains values of the corrected radiance of space, N_{sp} (which includes the non-linearity correction) for the NOAA-6 AVHRR IR channels.

Figures 1.4.2-1 through 1.4.2-4 contain the spectral response curves for NOAA-6 AVHRR channels 1 through 4, respectively.

Table 1.4.2-1. NOAA-6 Central Wave Numbers for AVHRR IR Channels.

Temperature Range (K)	**Ch. 3 (cm-1)**	**Ch. 4 (cm-1)**
180-225	2649.90	910.72
225-275	2653.90	911.41
275-320	2658.05	912.14

Table 1.4.2-2. NOAA-6 TOVS Channel Spectral Response and HIRS/2 Thermal Band-Correction Coefficients.

Instrument	Channel #	Central Wave #	Description	HIRS/2 Band-Correction Coefficients	
				b	c
HIRS/2	1	668.02 cm-1	15 micrometers	0.025	0.99992
	2	679.94 cm-1	CO2 Band	0.151	0.99900
	3	690.44 cm-1	CO2 Band	0.115	0.99970
	4	704.69 cm-1	CO2 Band	0.041	0.99984
	5	717.43 cm-1	CO2 Band	-0.035	1.00000
	6	732.47 cm-1	CO2 Band	0.066	0.99980
	7	748.48 cm-1	CO2 Band	-0.101	1.00012
	8	900.64 cm-1	Window	0.185	0.99961
	9	1029.48 cm-1	Ozone	0.268	0.99990
	10	1217.77 cm-1	Water Vapor	-0.205	0.99877

	11	1368.05 cm-1	Water Vapor	0.073	0.99966
	12	1485.76 cm-1	Water Vapor	0.597	1.00026
	13	2190.60 cm-1	4.3 micrometers	0.022	1.00000
	14	2210.09 cm-1	CO2 Band	-0.001	0.99978
	15	2237.76 cm-1	CO2 Band	0.029	0.99999
	16	2269.43 cm-1	CO2 Band	0.015	0.99991
	17	2360.42 cm-1	CO2 Band	0.011	0.99984
	18	2514.97 cm-1	Window	0.051	0.99985
	19	2654.58 cm-1	Window	0.482	1.00042
	20	14453.14 cm-1	Visible indow	n/a	n/a
MSU	1	1.6778 cm-1			
	2	1.7926 cm-1			
	3	1.8333 cm-1			
	4	1.9330 cm-1			
SSU	1	669.998 cm-1/15 mb			
	2	669.620 cm-1/5 mb			
	3	669.357 cm-1/1.5 mb			

Table 1.4.2-3. Non-linearity errors for NOAA-6 Channel 4.

Target temperature (K)	Error (K)
315	0.8
305	0.5
295	0.3
285	0.0
275	-0.4
255	-0.8
245	-1.4
235	-1.4
225	-2.0
215	-2.0
205	-2.8
195	-2.6
185	-2.0
0	0.0

Table 1.4.2-4. Corrected values for NOAA-6 Nsp.	
Channel	**Nsp (mW/(m2-sr-cm-1))**
3	0.0
4	-2.18222

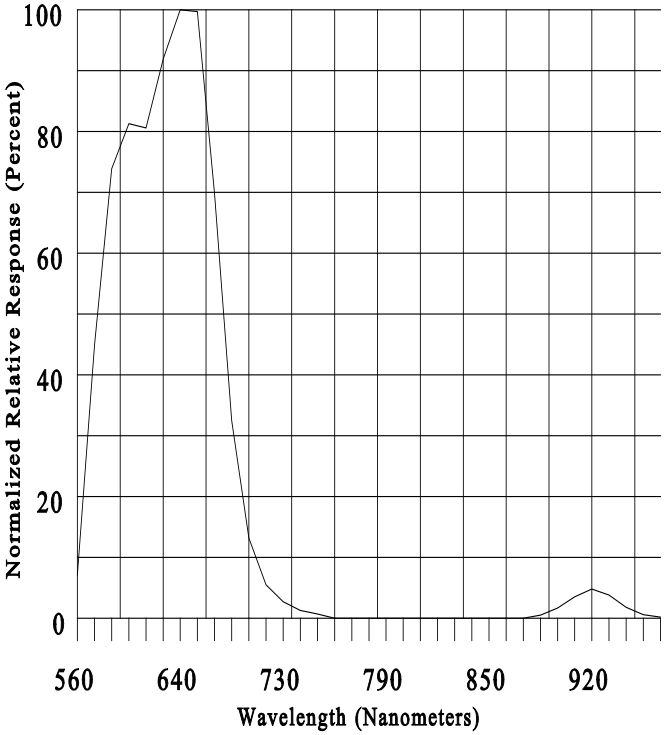


Figure 1.4.2-1 Spectral Response Curve NOAA-6 AVHRR Channel 1**.**

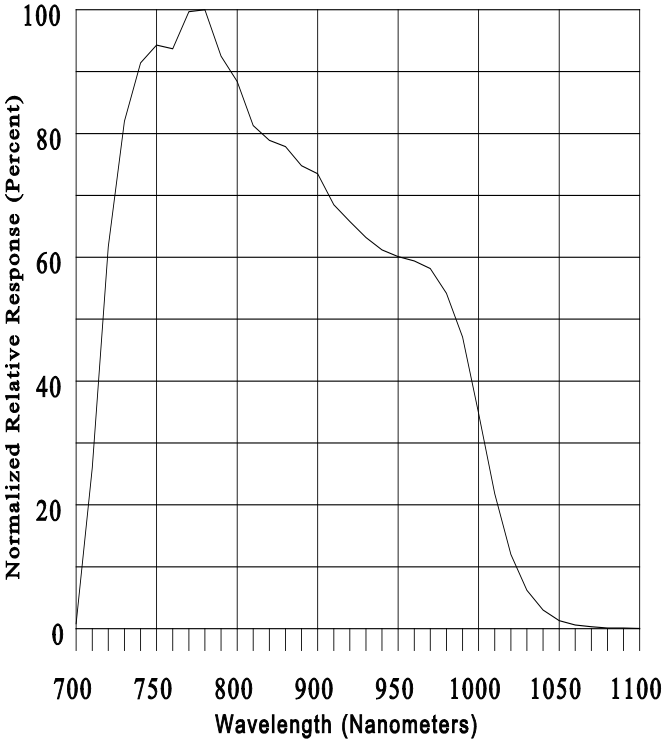


Figure 1.4.2-2 Spectral Response Curve NOAA-6 AVHRR Channel 2**.**

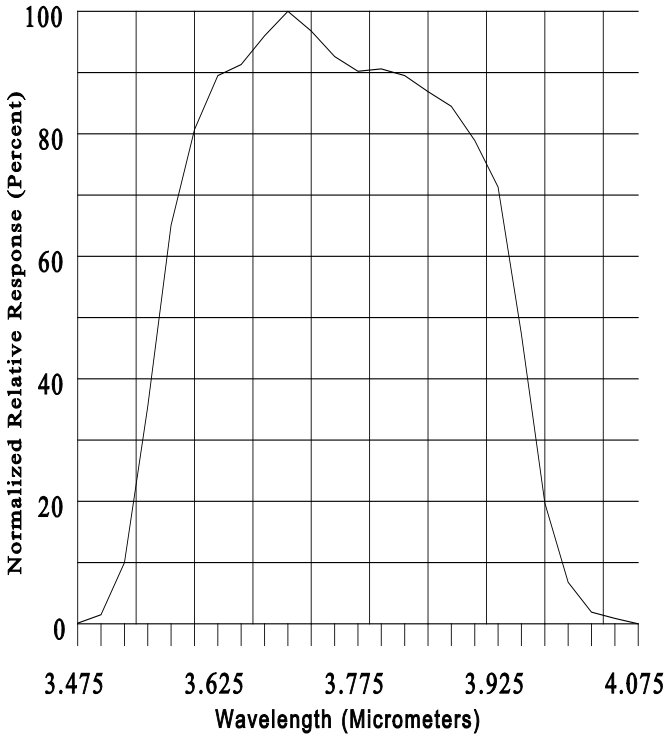


Figure 1.4.2-3 Spectral Response Curve NOAA-6 AVHRR Channel 3**.**

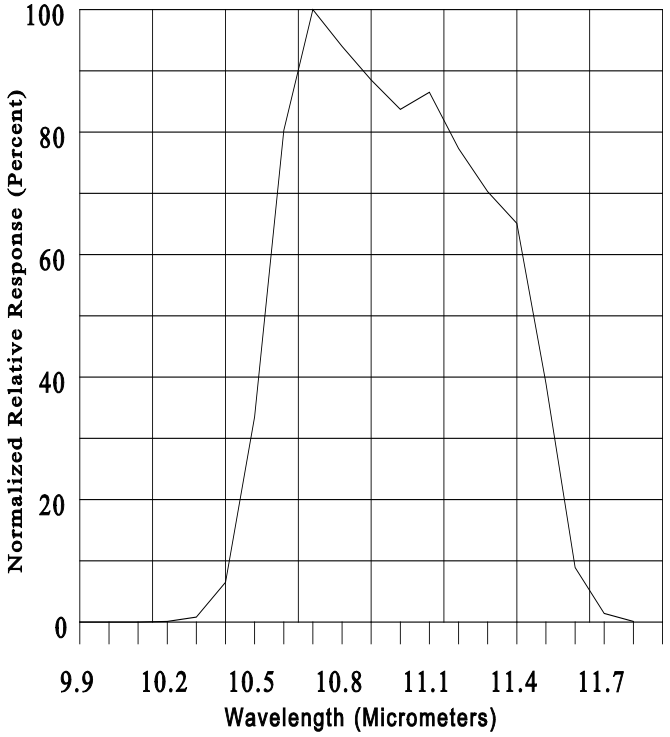


Figure 1.4.2-4 Spectral Response Curve NOAA-6 AVHRR Channel 4**.**

1.4.3 NOAA-7

Operational dates: August 24, 1981 - February 1, 1985

Afternoon orbit: 1430 LST ascending node, 0230 LST descending node

AVHRR instrument: 5 channels

Spacecraft ID: 4

Table 1.4.3-1 contains the central wave numbers for the AVHRR IR channels for NOAA-7. Table 1.4.3-2 contains the TOVS channel spectral response and HIRS/2 thermal band-correction coefficients for NOAA-7. Non-linearity errors for NOAA-7 AVHRR Channels 4 and 5 are contained in Table 1.4.3-3. Table 1.4.3-4 contains values of the corrected radiance of space, N_{sp} (which includes the non-linearity correction) for the NOAA-7 AVHRR IR channels.

Figures 1.4.3-1 through 1.4.3-5 contain the spectral response curves for NOAA-7 AVHRR Channels 1 through 5, respectively.

Table 1.4.3-1. NOAA-7 Central Wave Numbers for AVHRR IR Channels.

Temperature Range (K)	Channel 3 (cm-1)	Channel 4 (cm-1)	Channel 5 (cm-1)
180-225	n/a	926.20	840.100
225-275	2670.3	926.80	840.500
275-320	2671.9	927.22	840.872

Table 1.4.3-2. NOAA-7 TOVS Channel Spectral Response and HIRS/2 Thermal Band-Correction Coefficients.

Instrument	Channel #	Central Wave #	Description	HIRS/2 Band-Correction Coefficients	
				b	c
HIRS/2	1	667.92 cm-1	15 micrometers	-0.010	1.00001
	2	679.21 cm-1	CO2 Band	0.100	0.99973
	3	691.56 cm-1	CO2 Band	-0.018	0.99997
	4	704.63 cm-1	CO2 Band	0.026	0.99989
	5	717.05 cm-1	CO2 Band	-0.009	0.99995
	6	733.20 cm-1	CO2 Band	-0.081	1.00008
	7	749.20 cm-1	CO2 Band	-0.054	1.00003
	8	898.94 cm-1	Window	0.332	0.99942
	9	1027.38 cm-1	Ozone	0.205	0.99987
	10	1224.89 cm-1	Water Vapor	0.469	0.99994
	11	1363.85 cm-1	Water Vapor	0.114	0.99983
	12	1489.06 cm-1	Water Vapor	0.573	1.00028

	13	2183.05 cm-1	4.3 micrometers	0.047	1.00013
	14	2208.28 cm-1	CO2 Band	0.060	1.00028
	15	2239.84 cm-1	CO2 Band	0.021	0.99993
	16	2271.33 cm-1	CO2 Band	0.032	1.00008
	17	2357.55 cm-1	CO2 Band	0.032	1.00005
	18	2512.83 cm-1	Window	0.026	0.99968
	19	2663.79 cm-1	Window	0.637	1.00171
	20	14453.14 cm-1	Visible Window	n/a	n/a
MSU	1	1.6779 cm-1			
	2	1.7927 cm-1			
	3	1.8337 cm-1			
	4	1.9331 cm-1			
SSU	1	669.988 cm-1/15 mb			
	2	669.628 cm-1/5 mb			
	3	669.357 cm-1/1.5 mb			

Table 1.4.3-3. Non-linearity errors for NOAA-7 Channels 4 and 5.

Target temperature (K)	Channel 4 Error (K)	Channel 5 Error (K)
315	1.66	1.08
305	1.05	0.64
295	0.49	0.31
285	0.0	0.0
275	-0.38	-0.22
255	-0.66	-0.55
235	-0.73	-0.86
225	-0.61	-0.71
205	-0.19	-0.86
0	0.0	0.0

Table 1.4.3-4. Corrected values for NOAA-7 Nsp.

Channel	Nsp (mW/(m2-sr-cm-1))
3	0.0
4	-1.176
5	-1.346

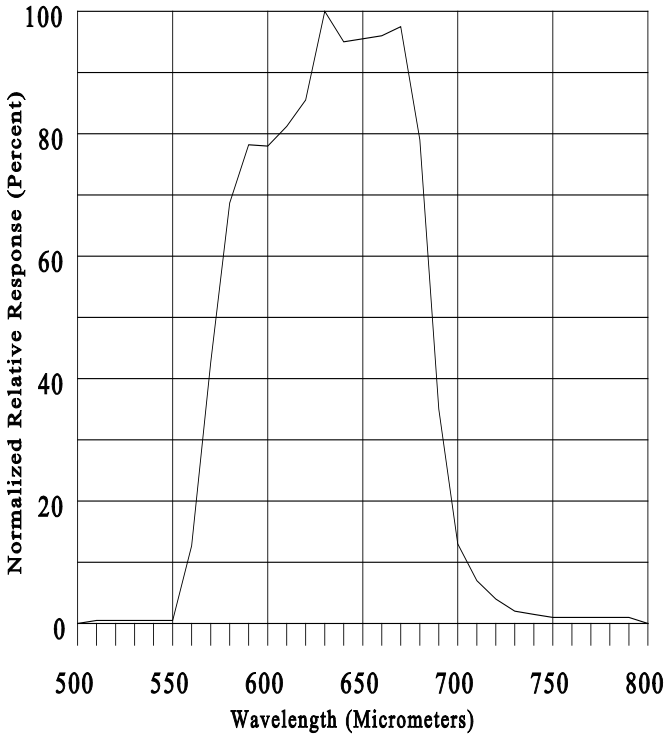


Figure 1.4.3-1 Spectral Response Curve NOAA-7 AVHRR Channel 1**.**

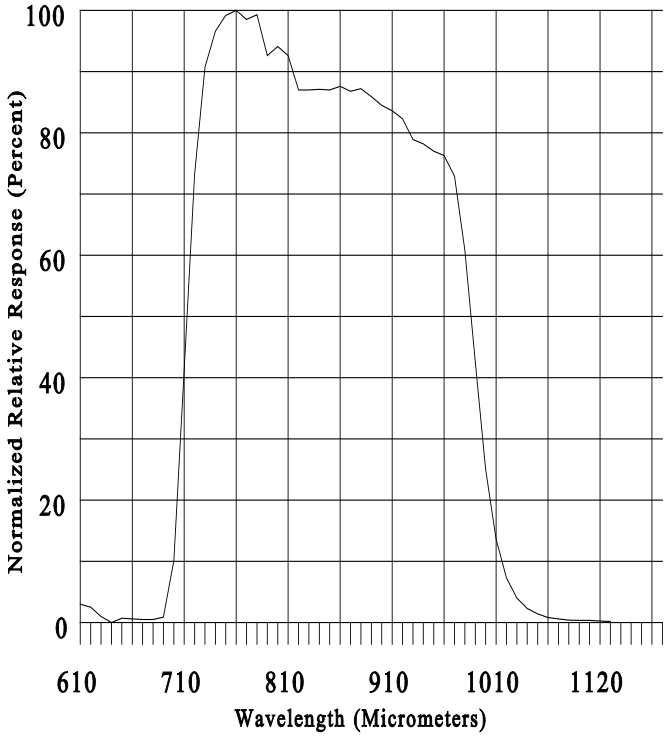


Figure 1.4.3-2 Spectral Response Curve NOAA-7 AVHRR Channel 2**.**

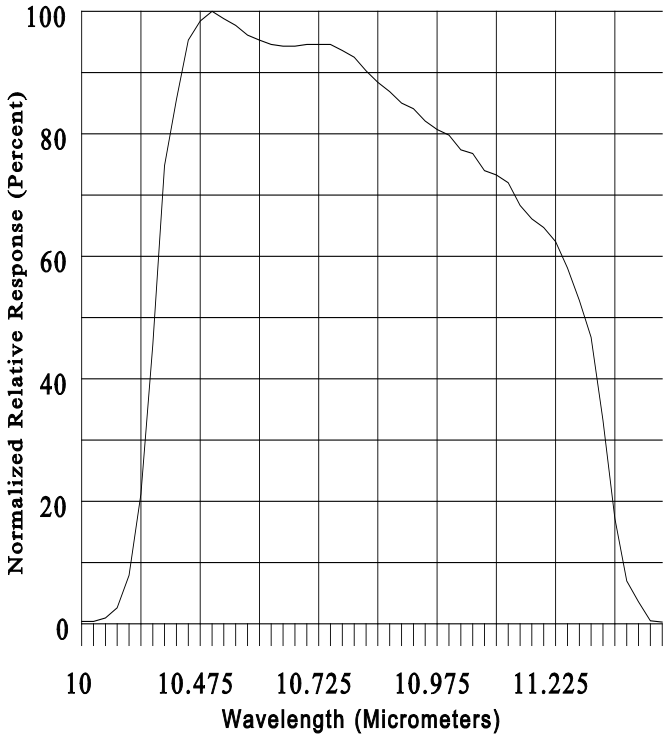


Figure 1.4.3-3 Spectral Response Curve NOAA-7 AVHRR Channel 3**.**

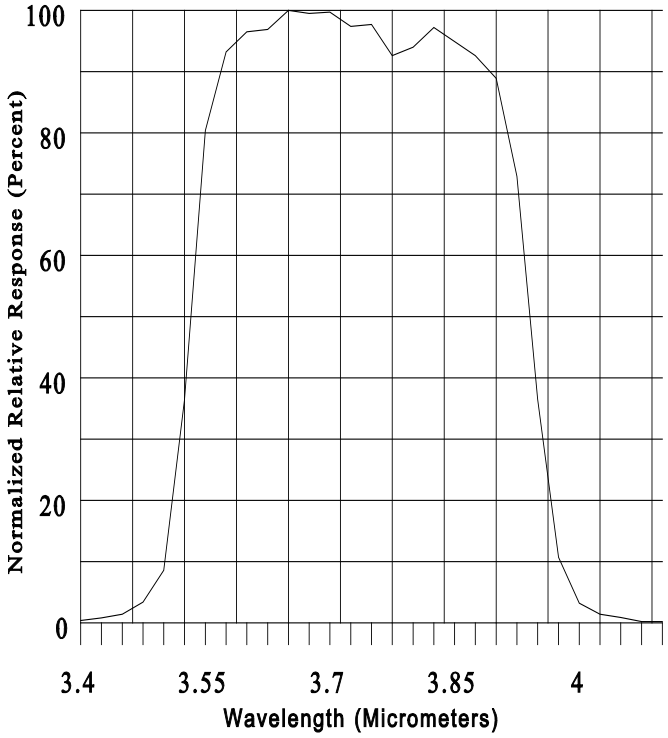


Figure 1.4.3-4 Spectral Response Curve NOAA-7 AVHRR Channel 4**.**

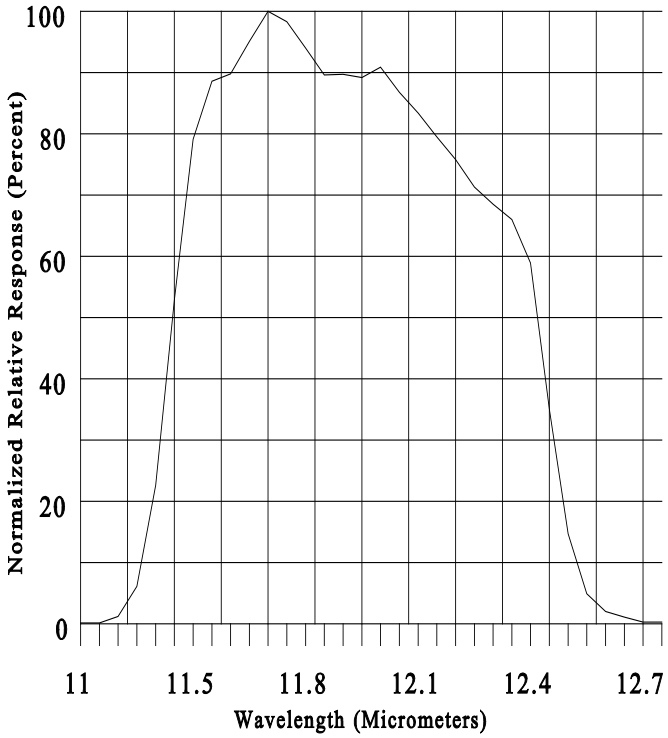


Figure 1.4.3-5 Spectral Response Curve NOAA-7 AVHRR Channel 5**.**

1.4.4 NOAA-8

Operational dates: May 3, 1983 - June 21, 1984
July 1, 1985 - October 31, 1985

Morning orbit: 1930 LST ascending node, 0730 LST descending node

AVHRR instrument: 4 channels

Spacecraft ID: 6

Abnormalities: Primary oscillator began to operate sporadically on June 12, 1984. Between June 12 and 21, 1984, a small amount of GAC, LAC, and TOVS data were recorded. At this point NOAA-8 was turned off. It was not until July 1, 1985 that NOAA-8 was reactivated and all instruments checked out except the HIRS/2 instrument. Due to detector heating while the spacecraft tumbled, channels 1-12 of the HIRS/2 were lost.

Table 1.4.4-1 contains the central wave numbers for the AVHRR IR channels for NOAA-8. Table 1.4.4-2 contains the TOVS channel spectral response and HIRS/2 thermal band-correction coefficients for NOAA-8. Non-linearity errors for NOAA-8 AVHRR Channel 4 are contained in Table 1.4.4-3. Table 1.4.4-4 contains values of the corrected radiance of space, N_{sp} (which includes the non-linearity correction) for the NOAA-8 AVHRR IR channels.

Figures 1.4.4-1 through 1.4.4-4 contain the spectral response curves for NOAA-8 channels 1 through 4, respectively.

Table 1.4.4-1. NOAA-8 Central Wave Numbers for AVHRR IR Channels.

Temperature Range (K)	Channel 3 (cm-1)	Channel 4 (cm-1)
180-225	2631.52	913.360
225-275	2636.05	913.865
275-320	2639.18	914.305

Table 1.4.4-2. NOAA-8 TOVS Channel Spectral Response and HIRS/2 Thermal Band-Correction Coefficients.

Instrument	Channel #	Central Wave #	Description	HIRS/2 Band-Correction Coefficients	
				b	c
HIRS/2	1	667.41 cm-1	15 micrometers	0.099	0.99971
	2	679.45 cm-1	CO2 Band	0.147	0.99962
	3	690.90 cm-1	CO2 Band	0.143	0.99964
	4	702.97 cm-1	CO2 Band	0.010	0.99991
	5	717.56 cm-1	CO2 Band	-0.001	0.99994
	6	732.97 cm-1	CO2 Band	0.193	0.99955
	7	747.90 cm-1	CO2 Band	-0.104	1.00013

	8	901.08 cm-1	Window	0.429	0.99931
	9	1027.11 cm-1	Ozone	0.140	0.99984
	10	1224.05 cm-1	Water Vapor	0.450	0.99988
	11	1366.17 cm-1	Water Vapor	0.108	0.99978
	12	1486.92 cm-1	Water Vapor	0.530	1.00008
	13	2189.28 cm-1	4.3 micrometers	0.051	1.00022
	14	2211.71 cm-1	CO2 Band	0.063	1.00029
	15	2238.06 cm-1	CO2 Band	0.015	0.99992
	16	2271.43 cm-1	CO2 Band	0.029	1.00004
	17	2357.11 cm-1	CO2 Band	0.018	0.99993
	18	2515.53 cm-1	Window	0.080	1.00007
	19	2661.85 cm-1	Window	0.489	1.00061
	20	14355.00 cm-1	Visible Window	n/a	n/a
MSU	1	1.6779 cm-1			
	2	1.7927 cm-1			
	3	1.8334 cm-1			
	4	1.9331 cm-1			
SSU	1	669.988 cm-1/15 mb			
	2	669.628 cm-1/5 mb			
	3	669.357 cm-1/1.5 mb			

Table 1.4.4-3. Non-linearity errors for NOAA-8 Channel 4.

Target temperature (K)	Error (K)
315	0.8
305	0.3
295	-0.1
285	-0.3
275	-0.4
255	-0.4
235	0.2
225	0.7
205	2.2
0	0.0

Table 1.4.4-4. Corrected values for NOAA-8 Nsp.

Channel	Nsp (mW/(m2-sr-cm-1))
3	0.0
4	-2.784

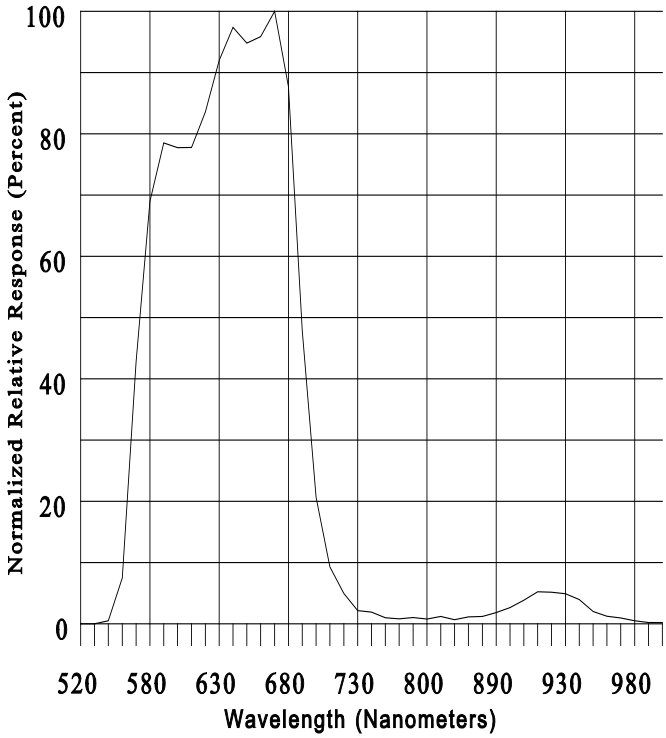


Figure 1.4.4-1 Spectral Response Curve NOAA-8 AVHRR Channel 1**.**

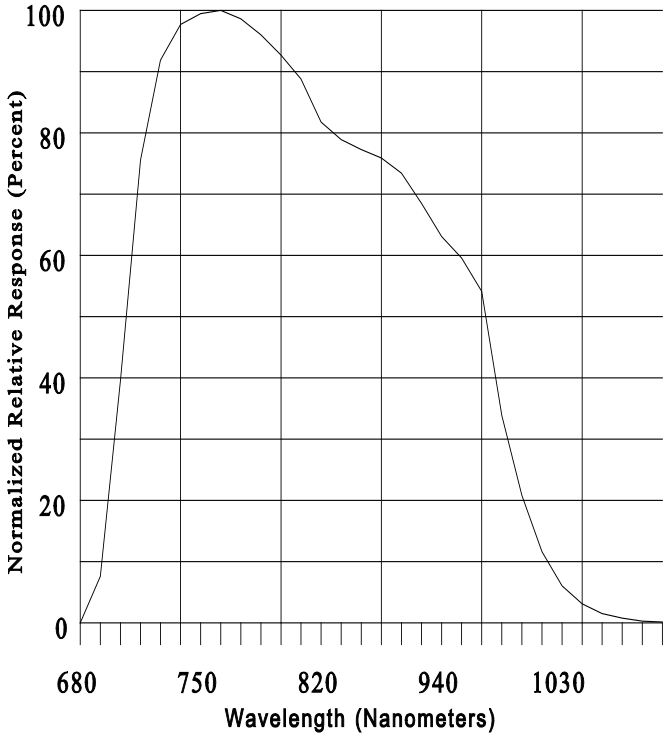


Figure 1.4.4-2 Spectral Response Curve NOAA-8 AVHRR Channel 2**.**

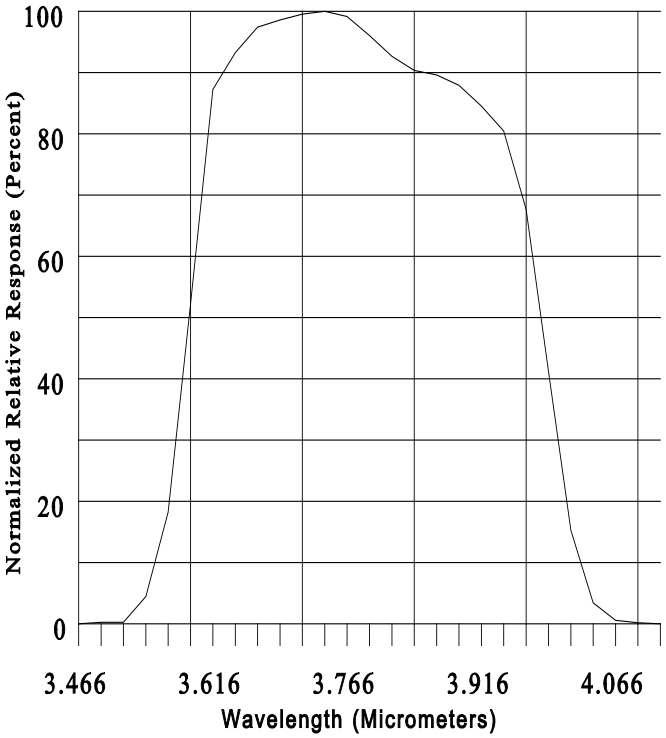


Figure 1.4.4-3 Spectral Response Curve NOAA-8 AVHRR Channel 3**.**

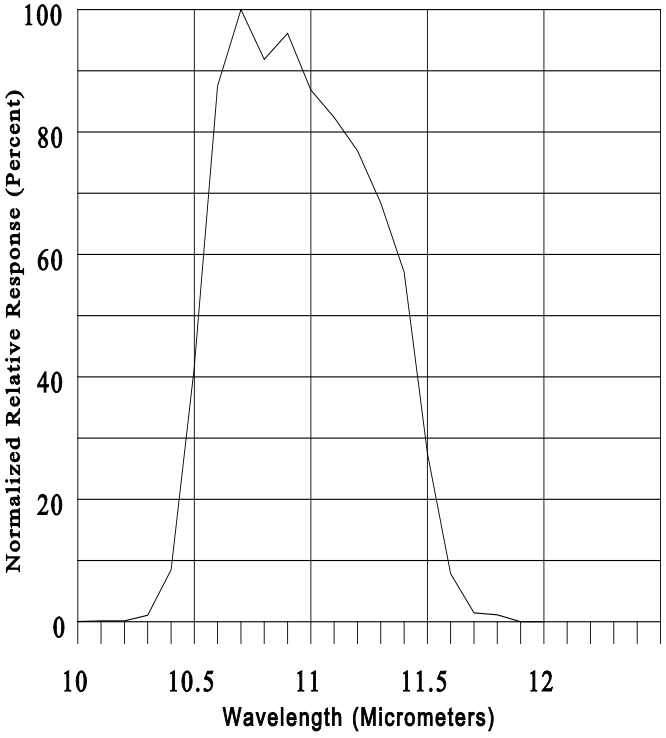


Figure 1.4.4-4 Spectral Response Curve NOAA-8 AVHRR Channel 4**.**

1.4.5 NOAA-9

Operational dates: February 25, 1985 - November 7, 1988

Afternoon orbit: 1420 LST ascending node, 0220 LST descending node

AVHRR instrument: 5 channels

Spacecraft ID: 7

Table 1.4.5-1 contains the central wave numbers for the AVHRR IR channels for NOAA-9. Table 1.4.5-2 contains the TOVS channel spectral response and HIRS/2 thermal band-correction coefficients for NOAA-9. Non-linearity errors for NOAA-9 AVHRR Channels 4 and 5 are contained in Table 1.4.5-3. Table 1.4.5-4 contains values of the corrected radiance of space, N_{sp} (which includes the non-linearity correction) for the NOAA-9 AVHRR IR channels.

Figures 1.4.5-1 through 1.4.5-5 contain the spectral response curves for NOAA-9 AVHRR channels 1 through 5, respectively.

Table 1.4.5-1. NOAA-9 Central Wave Numbers for AVHRR IR Channels.

Temperature Range (K)	Channel 3 (cm-1)	Channel 4 (cm-1)	Channel 5 (cm-1)
180-225	2670.93	928.50	844.41
225-275	2674.81	929.02	844.80
275-320	2678.11	929.46	845.19

Table 1.4.5-2. NOAA-9 TOVS Channel Spectral Response and HIRS/2 Thermal Band-Correction Coefficients.

Instrument	Channel #	Central Wave #	Description	HIRS/2 Band-Correction Coefficients	
				b	c
HIRS/2	1	667.67 cm-1	15 micrometers	0.034	0.99989
	2	679.84 cm-1	CO2 Band	0.024	0.99991
	3	691.46 cm-1	CO2 Band	0.092	0.99975
	4	703.37 cm-1	CO2 Band	0.002	0.99993
	5	717.16 cm-1	CO2 Band	0.013	0.99991
	6	732.64 cm-1	CO2 Band	-0.023	0.99997
	7	749.48 cm-1	CO2 Band	-0.006	0.99995
	8	898.53 cm-1	Window	0.126	0.99969
	9	1031.61 cm-1	Ozone	0.187	0.99987
	10	1224.74 cm-1	Water Vapor	0.569	1.00010
	11	1365.12 cm-1	Water Vapor	0.033	0.99961
	12	1483.24 cm-1	Water Vapor	0.353	0.99911

	13	2189.97 cm-1	4.3 micrometers	-0.001	0.99980
	14	2209.18 cm-1	CO2 Band	0.007	0.99984
	15	2243.14 cm-1	CO2 Band	0.027	1.00003
	16	2276.46 cm-1	CO2 Band	0.099	1.00038
	17	2359.05 cm-1	CO2 Band	0.004	0.99977
	18	2518.14 cm-1	Window	0.084	1.00012
	19	2667.80 cm-1	Window	0.448	1.00040
	20	14549.27 cm-1	Visible Window	n/a	n/a
MSU	1	1.6779 cm-1			
	2	1.7927 cm-1			
	3	1.8334 cm-1			
	4	1.9331 cm-1			
SSU	1	669.988 cm-1/15 mb			
	2	669.628 cm-1/5 mb			
	3	669.357 cm-1/1.5 mb			

Table 1.4.5-3. Non-linearity errors for NOAA-9 Channels 4 and 5.

Target temperature (K)	Channel 4 Error (K)	Channel 5 Error (K)
315	1.8	1.0
305	0.9	0.6
295	0.2	0.2
285	-0.4	-0.1
275	-0.9	-0.5
255	-1.4	-0.8
245	-1.6	-1.0
225	-1.5	-1.3
205	-1.0	-1.4

Table 1.4.5-4. Corrected values for NOAA-9 Nsp.

Channel	Nsp (mW/(m2-sr-cm-1))
3	0.0
4	-3.384
5	-2.313

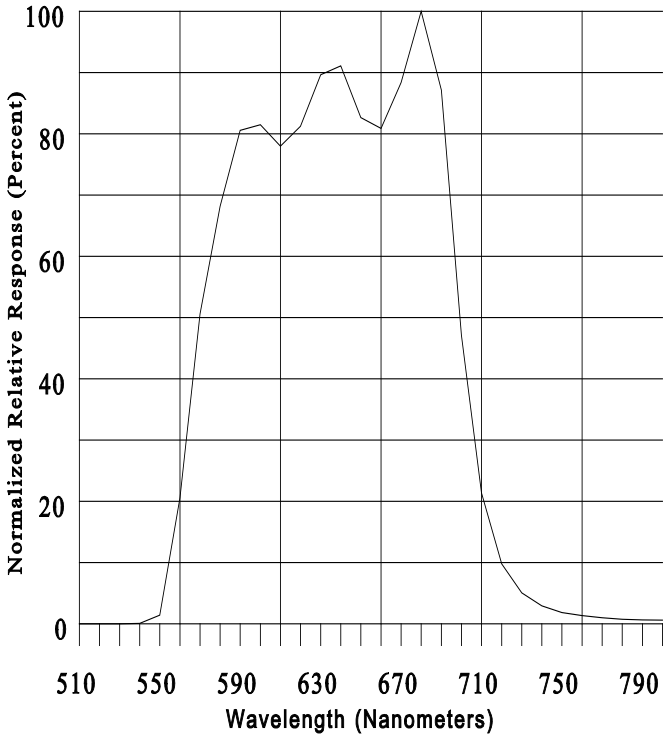


Figure 1.4.5-1 Spectral Response Curve NOAA-9 AVHRR Channel 1**.**

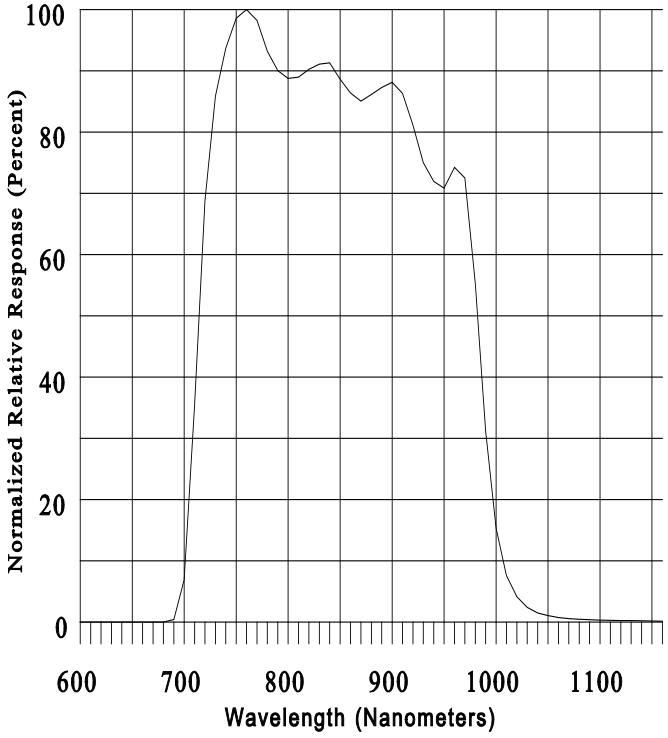


Figure 1.4.5-2 Spectral Response Curve NOAA-9 AVHRR Channel 2**.**

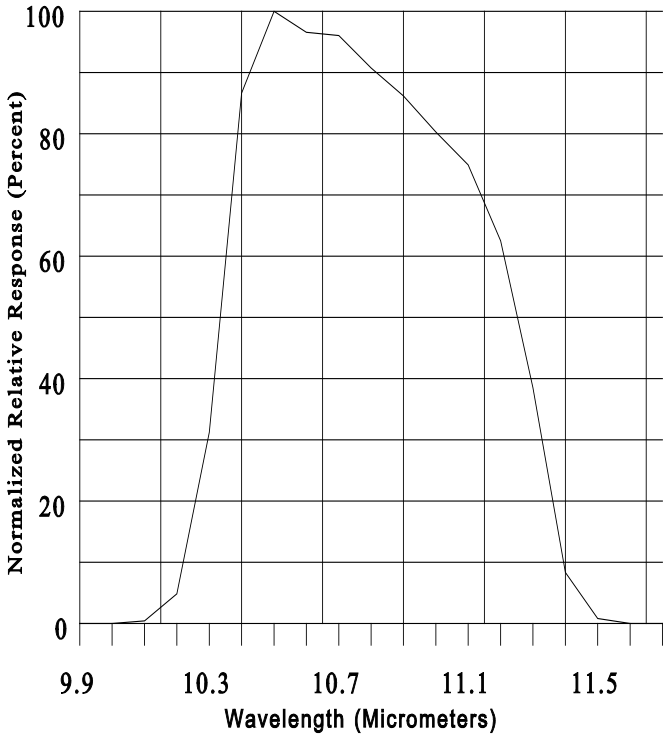


Figure 1.4.4-3 Spectral Response Curve NOAA-9 AVHRR Channel 3**.**

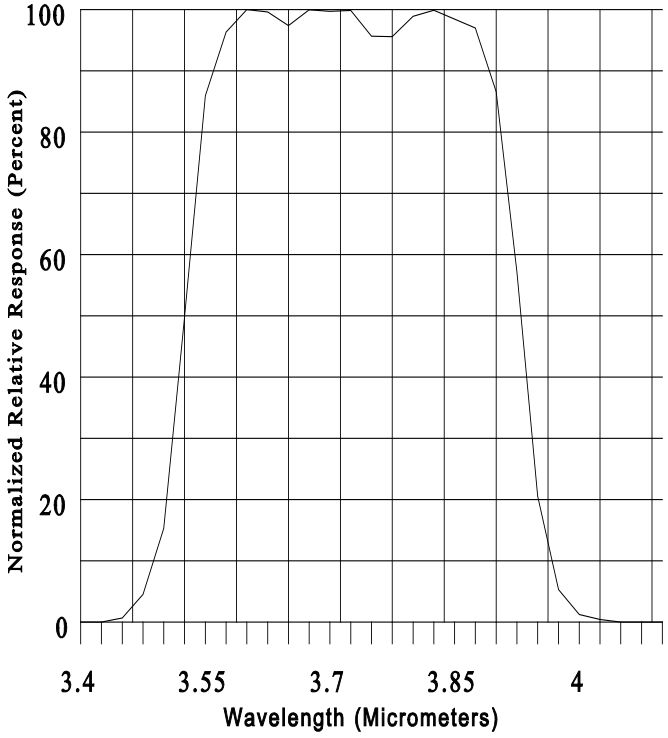


Figure 1.4.5.4 Spectral Response Curve NOAA-9 AVHRR Channel 4**.**

1.4.6 **NOAA-10**

Operational dates: Nov. 17, 1986 to Sept. 16, 1991

Morning orbit: 1930 LST ascending node, 0730 LST descending node

AVHRR instrument: 4 channels

Spacecraft ID: 8

Abnormalities: Last ERBE instrument; no SSU and SBUV instruments flown. HIRS/2 instrument had a problem with filter wheel which was corrected with a software patch. The TOVS data became operational Dec. 16, 1986. The AVHRR has a northern latitude ascending spacelook apparent sunlight intrusion that affects the channel 3 space look and calibration for brief periods.

Table 1.4.6-1 contains the central wave numbers for the AVHRR IR channels for NOAA-10. Table 1.4.6-2 contains the TOVS channel spectral response and HIRS/2 thermal band-correction coefficients for NOAA-10. Non-linearity corrections for NOAA-10 AVHRR Channel 4 are contained in Table 1.4.6-3. The non-linearity corrections are the difference between the measured target temperature and that temperature derived from a two-point linear calibration using a radiance of space of zero. Table 1.4.6-4 contains values of the corrected radiance of space, N_{sp} (which includes the non-linearity correction) for NOAA-10 AVHRR Channel 4.

Figures 1.4.6-1 through 1.4.6-4 contain the spectral response curves for NOAA-10 AVHRR channels 1 through 4.

Table 1.4.6-1. NOAA-10 Central Wave Numbers for AVHRR IR Channels.

Temperature Range (K)	Channel 3 (cm-1)	Channel 4 (cm-1)
180-225	2658.53	908.73
225-275	2657.60	909.18
275-320	2660.76	909.58
270-310	2660.35	909.52
Note: The 270-310 K range is applicable for sea surface temperatures.		

Table 1.4.6-2. NOAA-10 TOVS Channel Spectral Response and HIRS/2 Thermal Band-Correction Coefficients.

				HIRS/2 Band-Correction Coefficients	
Instrument	**Channel #**	**Central Wave #**	**Description**	**b**	**c**
HIRS/2	1	667.70 cm-1	15 micrometers	0.033	0.99989
	2	680.23 cm-1	CO2 Band	0.018	0.99992
	3	691.15 cm-1	CO2 Band	-0.006	0.99994

	4	704.33 cm-1	CO2 Band	-0.002	0.99994
	5	716.30 cm-1	CO2 Band	-0.064	1.00007
	6	733.13 cm-1	CO2 Band	0.065	0.99980
	7	750.72 cm-1	CO2 Band	0.073	0.99979
	8	899.50 cm-1	Window	0.218	0.99957
	9	1029.01 cm-1	Ozone	0.195	0.99987
	10	1224.07 cm-1	Water Vapor	0.327	0.99965
	11	1363.32 cm-1	Water Vapor	0.046	0.99963
	12	1489.42 cm-1	Water Vapor	0.645	1.00064
	13	2191.38 cm-1	4.3 micrometers	0.072	1.00036
	14	2208.74 cm-1	CO2 Band	0.079	1.00045
	15	2237.49 cm-1	CO2 Band	-0.026	0.99947
	16	2269.09 cm-1	CO2 Band	0.041	1.00019
	17	2360.00 cm-1	CO2 Band	0.040	1.00019
	18	2514.58 cm-1	Window	0.098	1.00025
	19	2665.38 cm-1	Window	0.462	1.00067
	20	14453.14 cm-1	Visible Window	n/a	n/a
MSU	1	1.6779 cm-1			
	2	1.7927 cm-1			
	3	1.8334 cm-1			
	4	1.9331 cm-1			
SSU	Instrument not flown on NOAA-10				

Table 1.4.6-3. Non-linearity errors for NOAA-10 Channel 4.

	Internal Target Temperature (Degrees C)		
Target temperature (K)	**10**	**15**	**20**
320	3.50	2.83	2.54
315	2.93	2.19	1.97
305	1.88	1.34	1.11
295	1.12	0.57	0.12
285	0.20	-0.15	-0.38
275	-0.46	-0.53	-1.08
265	-0.76	-0.93	-1.37
255	-1.33	-1.49	-1.77
245	-1.74	-2.09	-2.26
235	-1.79	-2.20	-2.53
225	-2.22	-2.51	-2.53
215	-2.58	-2.65	-2.80
205	-2.47	-2.88	-3.27

Table 1.4.6-4. Corrected values for NOAA-10 Nsp.	
Channel	**Nsp (mW/(m2-sr-cm-1))**
3	0.0
4	0.0

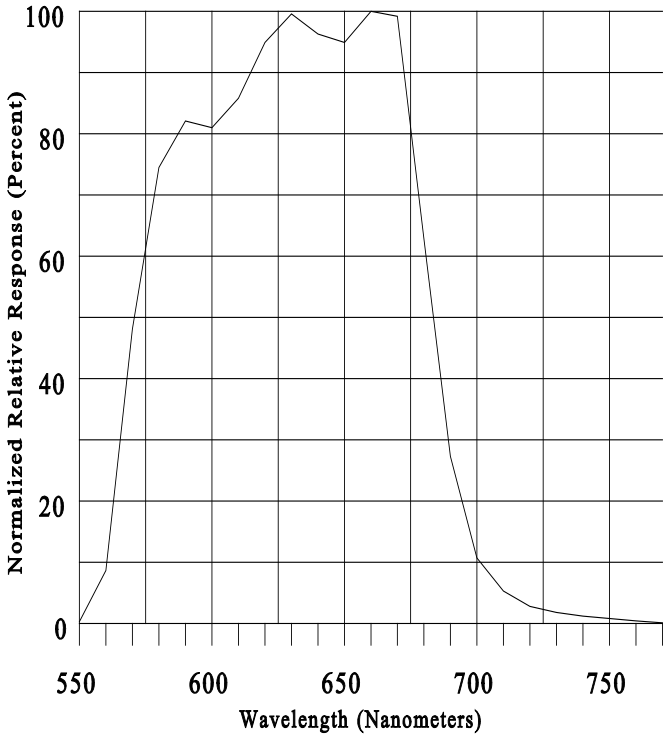


Figure 1.4.6-1 Spectral Response Curve NOAA-10 AVHRR Channel 1**.**

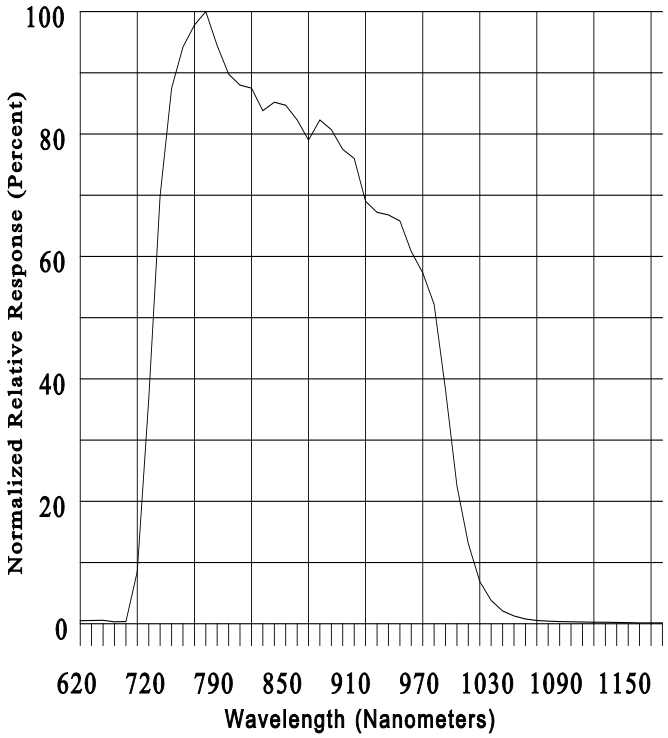


Figure 1.4.6-2 Spectral Response Curve NOAA-10 AVHRR Channel 2**.**

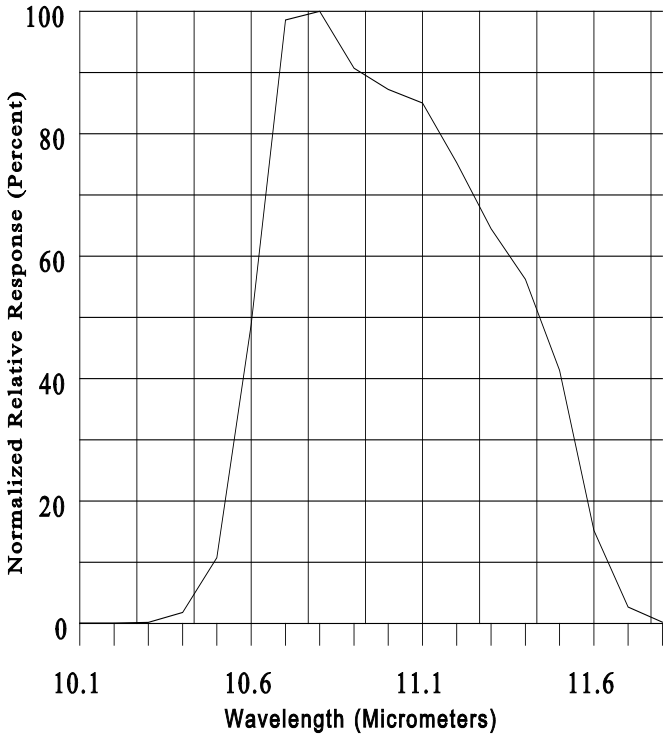


Figure 1.4.6-3 Spectral Response Curve NOAA-10 AVHRR Channel 3**.**

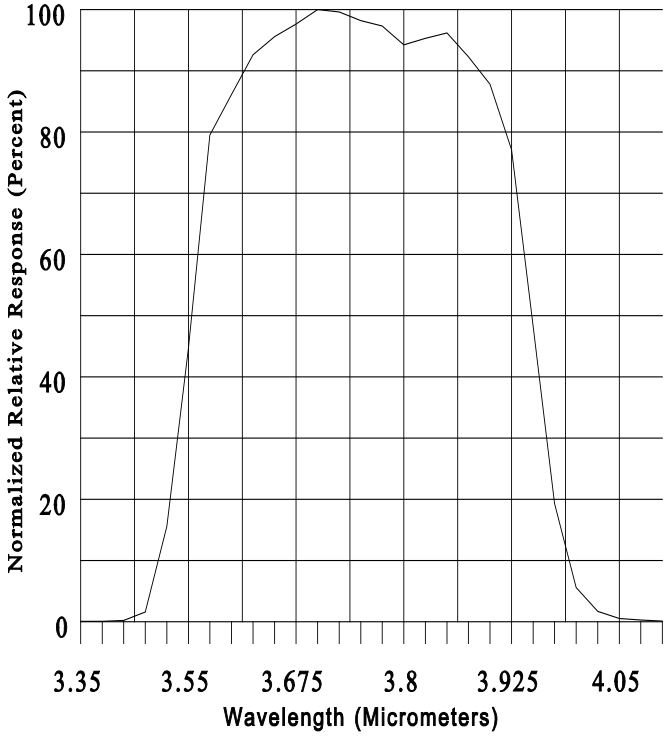


Figure 1.4.6-4 Spectral Response Curve NOAA-10 AVHRR Channel 4**.**

1.4.7 NOAA-11

Operational dates: November 8, 1988 to April 11, 1995

Afternoon orbit: 1340 LST ascending node, 0140 LST descending node

AVHRR instrument: 5 channels

Spacecraft ID: 1 (same as TIROS-N)

Abnormalities:AVHRR instrument failed on Sept. 13, 1994.

Table 1.4.7-1 contains the central wave numbers for the AVHRR IR channels for NOAA-11. Table 1.4.7-2 contains the TOVS channel spectral response and HIRS/2 thermal band-correction coefficients for NOAA-11. Non-linearity corrections for NOAA-11 AVHRR Channel 4 and 5 are contained in Tables 1.4.7-3 and 1.4.7-4, respectively. The non-linearity corrections are the difference between the measured target temperature and that temperature derived from a two-point linear calibration using a radiance of space (N_{sp}) of zero. The non-linearity correction can be obtained from Tables 1.4.7-3 and 1.4.7-4 by interpolation on the scene temperatures and the temperatures of the AVHRR's internal calibration target.

Figures 1.4.7-1 through 1.4.7-5 contain the spectral response curves for NOAA-11 AVHRR channels 1 through 5, respectively.

Table 1.4.7-1. NOAA-11 Central Wave Numbers for AVHRR IR Channels.

Temperature Range (K)	Channel 3 (cm-1)	Channel 4 (cm-1)	Channel 5 (cm-1)
180-225	2663.50	926.81	841.40
225-275	2668.15	927.36	841.81
275-320	2671.40	927.83	842.20
270-310	2670.96	927.75	842.14
Note: The 270-310 K range is applicable for sea surface temperatures.			

Table 1.4.7-2. NOAA-11 TOVS Channel Spectral Response and HIRS/2 Thermal Band-Correction Coefficients.

Instrument	Channel #	Central Wave #	Description	HIRS/2 Band-Correction Coefficients	
				b	c
HIRS/2	1	668.99 cm-1	15 micrometers	0.007	0.99996
	2	678.89 cm-1	CO2 Band	0.010	0.99994
	3	689.70 cm-1	CO2 Band	0.007	0.99992
	4	703.25 cm-1	CO2 Band	-0.003	0.99995
	5	716.83 cm-1	CO2 Band	0.014	0.99991
	6	732.11 cm-1	CO2 Band	0.019	0.99991

	7	749.48 cm-1	CO2 Band	0.032	0.99988
	8	900.51 cm-1	Window	0.077	0.99988
	9	1031.19 cm-1	Ozone	0.068	0.99975
	10	795.69 cm-1	Water Vapor	-0.001	0.99994
	11	1361.10 cm-1	Water Vapor	0.074	0.99972
	12	1479.86 cm-1	Water Vapor	0.288	0.99994
	13	2189.94 cm-1	4.3 micrometers	0.022	0.99994
	14	2209.66 cm-1	CO2 Band	0.018	0.99995
	15	2239.26 cm-1	CO2 Band	0.020	0.99995
	16	2267.80 cm-1	CO2 Band	0.015	0.99993
	17	2416.32 cm-1	CO2 Band	0.024	0.99991
	18	2511.83 cm-1	Window	0.045	0.99990
	19	2664.07 cm-1	Window	0.325	0.99949
	20	14453.14 cm-1	Visible Window	n/a	n/a
MSU	1	1.6779 cm-1			
	2	1.7927 cm-1			
	3	1.8334 cm-1			
	4	1.9331 cm-1			
SSU	1	669.988 cm-1/15 mb			
	2	669.628 cm-1/5 mb			
	3	669.357 cm-1/1.5 mb			

Table 1.4.7-3. Non-linearity errors for NOAA-11 Channel 4.

	Internal Target Temperature (Degrees C)		
Target temperature (K)	**10**	**15**	**20**
320	4.29	3.71	3.25
315	3.50	2.98	2.55
310	2.85	2.33	1.91
305	2.23	1.73	1.32
295	1.05	0.68	0.22
285	0.24	-0.21	-0.67
275	-0.45	-0.79	-1.15
265	-1.06	-1.37	-1.66
255	-1.41	-1.72	-2.03
245	-1.70	-1.96	-2.22
235	-1.87	-2.10	-2.28
225	-1.90	-2.14	-2.36
215	-1.82	-2.02	-2.20
205	-1.54	-1.76	-1.98

Table 1.4.7-4. Non-linearity errors for NOAA-11 Channel 5.			
	Internal Target Temperature (Degrees C)		
Target temperature (K)	**10**	**15**	**20**
320	1.43	1.28	1.12
315	1.23	1.03	0.89
310	1.05	0.84	0.70
305	0.85	0.64	0.47
295	0.43	0.28	0.09
285	0.07	-0.07	-0.23
275	-0.19	-0.34	-0.47
265	-0.37	-0.51	-0.60
255	-0.60	-0.77	-0.78
245	-0.72	-0.90	-0.92
235	-0.84	-1.02	-1.00
225	-0.94	-1.06	-1.16
215	-1.12	-1.24	-1.16
205	-1.15	-1.27	-1.23

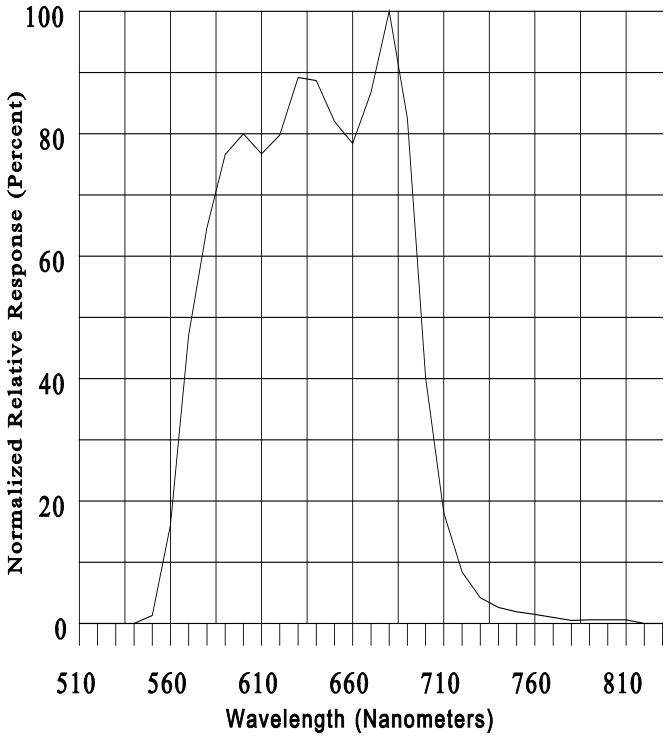


Figure 1.4.7-1 Spectral Response Curve NOAA-11 AVHRR Channel 1**.**

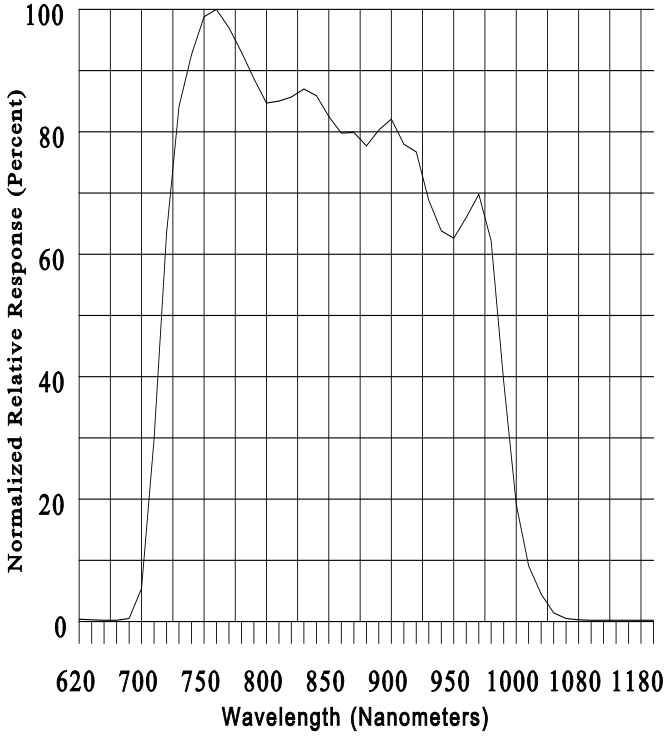


Figure 1.4.7-2 Spectral Response Curve NOAA-11 AVHRR Channel 2**.**

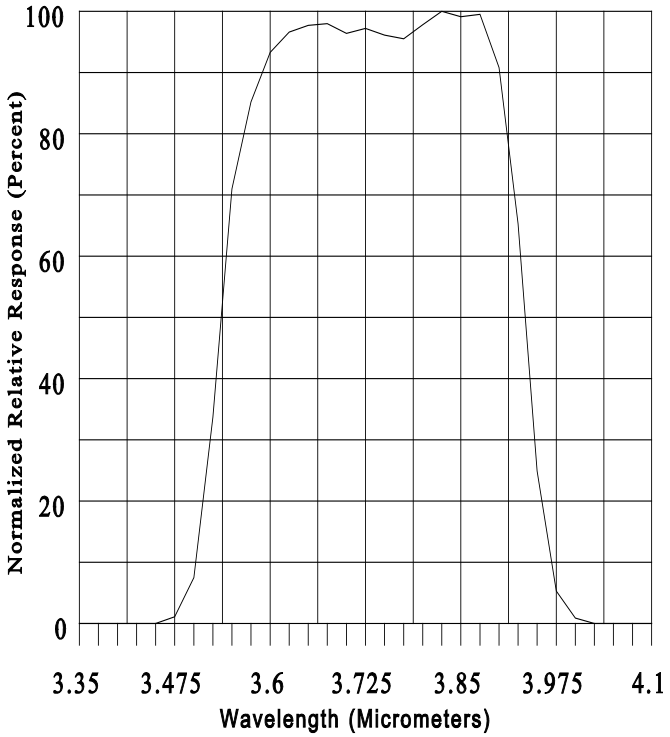


Figure 1.4.7-3 Spectral Response Curve NOAA-11 AVHRR Channel 3**.**

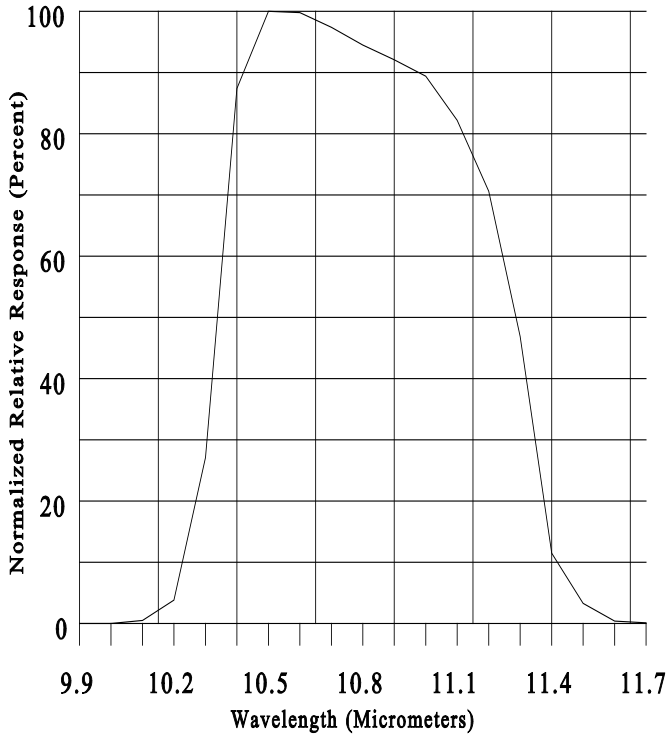


Figure 1.4.7-4 Spectral Response Curve NOAA-11 AVHRR Channel 4**.**

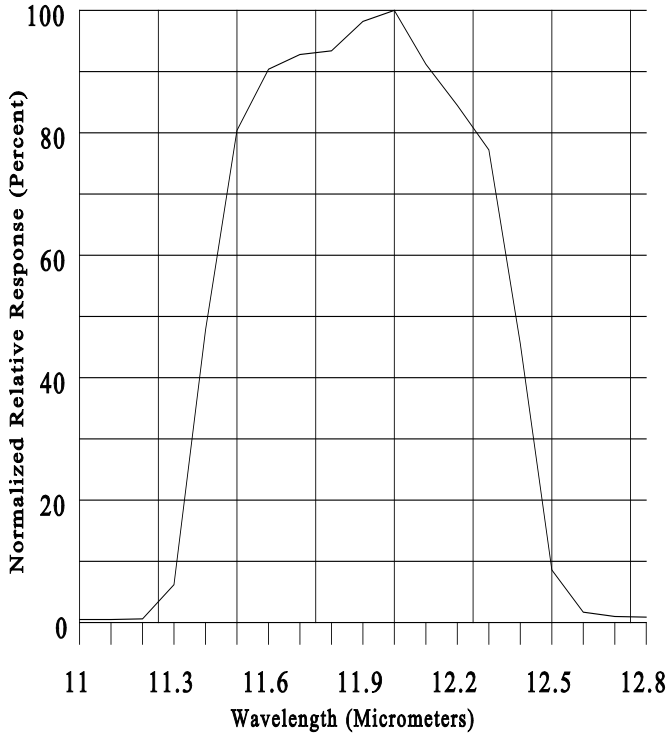


Figure 1.4.7-5 Spectral Response Curve NOAA-10 AVHRR Channel 5**.**

1.4.8 NOAA-12

Operational dates: September 16, 1991 to present

Morning orbit: 1930 LST ascending node, 0730 descending node

AVHRR instrument: 5 channels

Spacecraft ID: 5

Table 1.4.8-1 contains the central wave numbers for the AVHRR IR channels for NOAA-12. Table 1.4.8-2 contains the TOVS channel spectral response and HIRS/2 thermal band-correction coefficients for NOAA-12. Non-linearity corrections for NOAA-12 AVHRR Channels 4 and 5 are contained in Tables 1.4.8-3 and 1.4.8-4. The non-linearity corrections are the difference between the measured target temperature and that temperature derived from a two-point linear calibration using a radiance of space (N_{sp}) of zero. The non-linearity correction can be obtained from Tables 1.4.8-3 and 1.4.8-4 by interpolation on the scene temperatures and the temperatures of the AVHRR's internal calibration target.

Figures 1.4.8-1 through 1.4.8-5 contain the spectral response curves for NOAA-12 AVHRR channels 1 through 5, respectively.

Table 1.4.8-1. NOAA-12 Central Wave Numbers for AVHRR IR Channels.

Temperature Range (K)	Channel 3 (cm-1)	Channel 4 (cm-1)	Channel 5 (cm-1)
190-230	2632.713	920.0158	836.6847
230-270	2636.669	920.5504	837.0251
270-310	2639.61	921.0291	837.3641
290-330	2640.817	921.2741	837.5612
Note: The 270-310 K range is applicable for sea surface temperatures.			

Table 1.4.8-2. NOAA-12 TOVS Channel Spectral Response and HIRS/2 Thermal Band-Correction Coefficients.

Instrument	Channel #	Central Wave #	Description	HIRS/2 Band-Correction Coefficients	
				b	c
HIRS/2	1	667.58 cm-1	15 micrometers	0.007	0.99996
	2	680.18 cm-1	CO2 Band	0.007	0.99995
	3	690.01 cm-1	CO2 Band	0.019	0.99989
	4	704.22 cm-1	CO2 Band	0.026	0.99988
	5	716.32 cm-1	CO2 Band	0.021	0.99990
	6	732.81 cm-1	CO2 Band	0.140	0.99964
	7	751.92 cm-1	CO2 Band	0.058	0.99982
	8	900.45 cm-1	Window	0.358	0.99940

	9	1026.66 cm-1	Ozone	0.181	0.99985
	10	1223.44 cm-1	Water Vapor	0.377	0.99975
	11	1368.68 cm-1	Water Vapor	0.175	0.99992
	12	1478.59 cm-1	Water Vapor	0.265	0.99863
	13	2190.37 cm-1	4.3 micrometers	0.078	1.00042
	14	2210.51 cm-1	CO2 Band	0.017	0.99995
	15	2236.62 cm-1	CO2 Band	-0.023	0.99950
	16	2267.62 cm-1	CO2 Band	0.021	0.99995
	17	2361.64 cm-1	CO2 Band	0.022	0.99997
	18	2514.68 cm-1	Window	0.058	0.99992
	19	2653.48 cm-1	Window	0.344	0.99950
	20	14453.14 cm-1	Visible Window	n/a	n/a
MSU	1	1.6799 cm-1			
	2	1.7927 cm-1			
	3	1.8334 cm-1			
	4	1.9331 cm-1			
SSU	Instrument not flown on NOAA-12				

Table 1.4.8-3. Non-linearity errors for NOAA-12 Channel 4.

Target temperature (K)	Internal Target Temperature (Degrees C)			
	10	**15**	**20**	**25**
320	3.21	2.88	2.27	1.91
315	2.58	2.39	1.72	1.43
310	2.04	1.94	1.28	0.98
305	1.6	1.42	0.8	0.52
295	0.8	0.53	0.13	-0.16
285	0.16	-0.23	-0.52	-0.7
275	-0.41	-0.84	-1.05	-1.19
265	-.071	-0.97	-1.19	-1.32
255	-1.04	-1.2	-1.53	-1.59
245	-1.18	-1.4	-1.58	-1.62
235	-1.05	-1.59	-1.51	-1.63
225	-1.33	-1.65	-1.58	-1.67
215	-1.24	-1.65	-1.49	-1.53
205	-1.58	-1.8	-1.31	-1.33

Table 1.4.8-4. Non-linearity errors for NOAA-12 Channel 5.

Target temperature (K)	Internal Target Temperature (Degrees C)			
	10	**15**	**20**	**25**
320	0.8	0.8	0.8	0.73
315	0.8	0.8	0.73	0.61

310	0.8	0.73	0.61	0.37
305	0.73	0.61	0.37	0.18
295	0.37	0.18	0.08	-0.08
285	0.08	-0.08	-0.21	-0.31
275	-0.21	-0.31	-0.37	-0.41
265	-0.37	-0.41	-0.47	-0.53
255	-0.47	-0.53	-0.63	-0.76
245	-0.63	-0.76	-0.88	-0.94
235	-0.88	-0.94	-1.01	-1.1
225	-1.01	-1.1	-1.15	-1.19
215	-1.15	-1.19	-1.17	-1.16
205	-1.17	-1.16	-1.19	-1.23

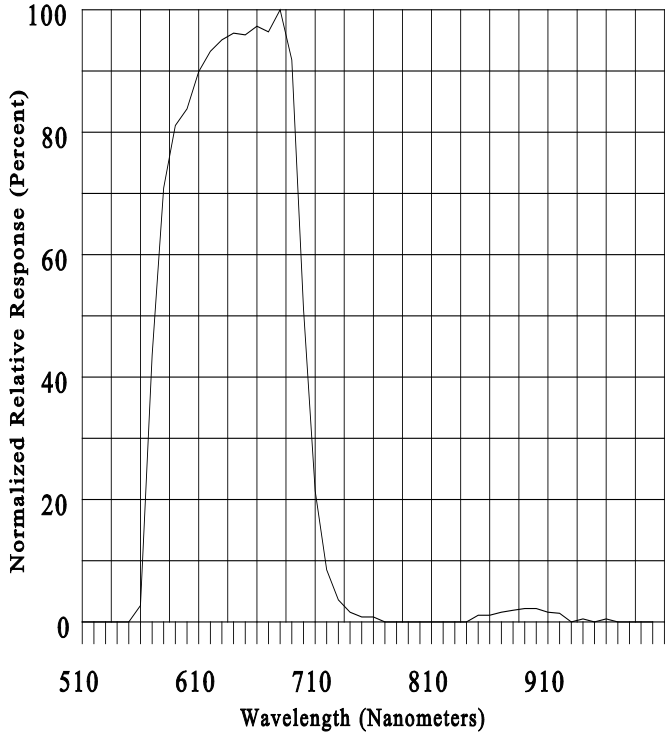


Figure 1.4.8-1 Spectral Response Curve NOAA-12 AVHRR Channel 1**.**

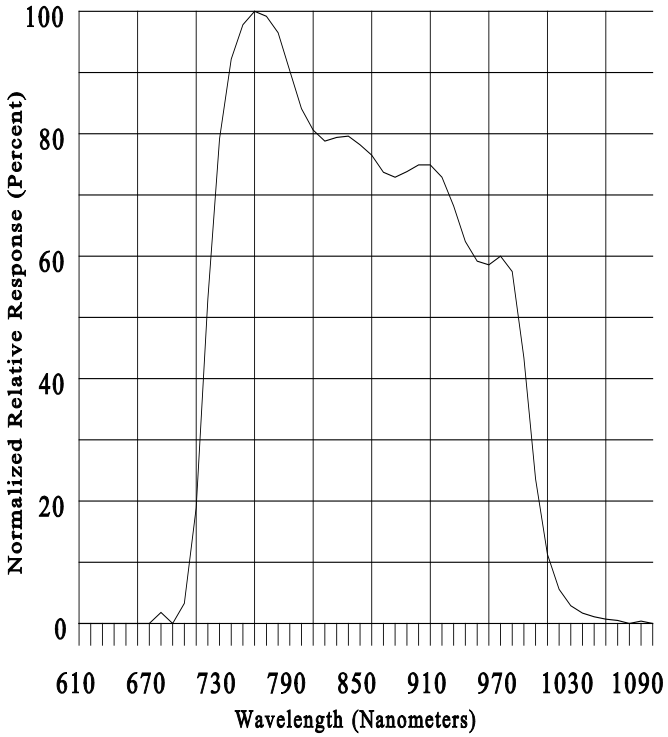


Figure 1.4.8-2 Spectral Response Curve NOAA-12 AVHRR Channel 2**.**

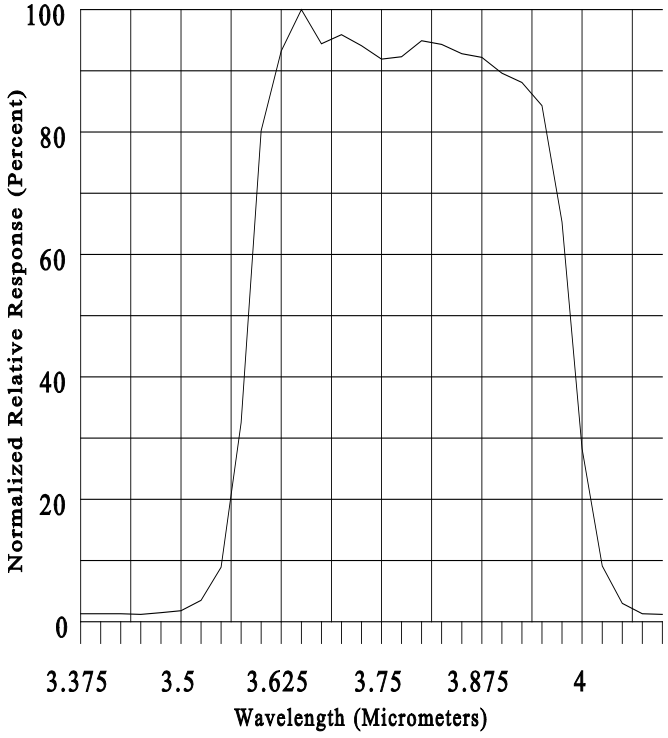


Figure 1.4.8-3 Spectral Response Curve NOAA-12 AVHRR Channel 3**.**

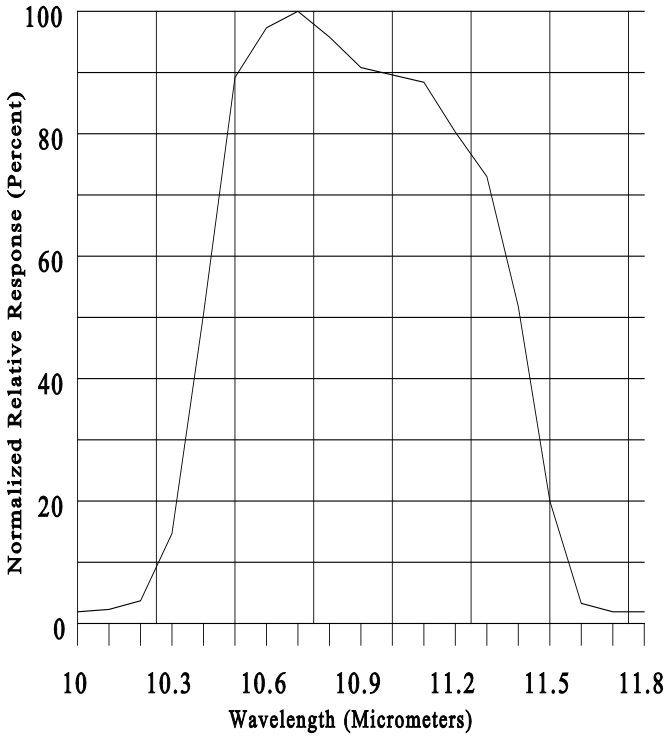


Figure 1.4.8-4 Spectral Response Curve NOAA-12 AVHRR Channel 1**.**

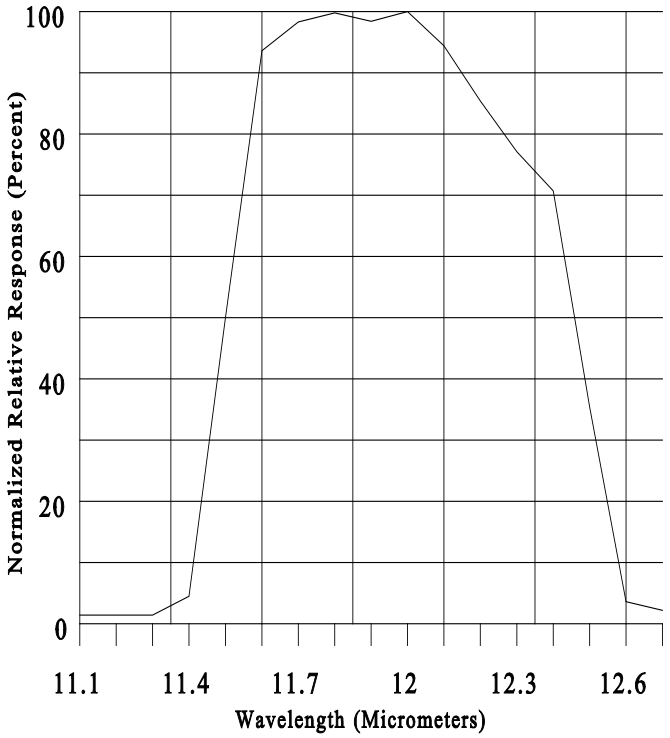


Figure 1.4.8-5 Spectral Response Curve NOAA-12 AVHRR Channel 5**.**

1.4.9 NOAA-13

Operational dates: Aug. 9, 1993 - Aug. 21, 1993

Afternoon orbit: 1340 LST ascending node, 0140 descending node

AVHRR instrument: 5 channels

Spacecraft ID: 3

Table 1.4.9-1 contains the central wave numbers for the AVHRR IR channels for NOAA-13. Table 1.4.9-2 contains the TOVS channel spectral response and HIRS/2 thermal band-correction coefficients for NOAA-13. Non-linearity corrections for NOAA-13 AVHRR Channels 4 and 5 are contained in Table 1.4.9-3. The non-linearity correction can be obtained from Table 1.4.9-3 by interpolation on the scene temperatures and the temperatures of the AVHRR's internal calibration target.

With the launch of NOAA-13, NESDIS changed their method of handling the non-linearity correction. See Section 3.3.1.2 for NESDIS' alternate method for calculating the non-linearity correction. Use Equation 3.3.1.2-1 to calculate the corrected radiance. Table 1.4.9-4 contains the coefficients A, B, and C for the quadratic equation in Equation 3.3.1.2-1 and the radiance of space which are required to calculate the corrected radiance.

Figures 1.4.9-1 through 1.4.9-5 contain the spectral response curves for NOAA-13 AVHRR channels 1 through 5, respectively.

Table 1.4.9-1. NOAA-13 Central Wave Numbers for AVHRR IR Channels.

Temperature Range (K)	Channel 3 (cm-1)	Channel 4 (cm-1)	Channel 5 (cm-1)
190-230	2636.124	924.0114	836.1164
230-270	2640.147	924.5165	836.4339
270-310	2643.153	924.9732	836.7651
290-330	2644.382	925.2164	836.9520
Note: The 270-310 K range is applicable for sea surface temperatures.			

Table 1.4.9-2. NOAA-13 TOVS Channel Spectral Response and HIRS/2 Thermal Band-Correction Coefficients.

Instrument	Channel #	Central Wave #	Description	HIRS/2 Band-Correction Coefficients	
				b	c
HIRS/2	1	668.81 cm-1	15 micrometers	-0.077	1.00019
	2	679.59 cm-1	CO2 Band	0.020	0.99992
	3	690.18 cm-1	CO2 Band	0.016	0.99993
	4	703.02 cm-1	CO2 Band	0.018	0.99991

	5	715.96 cm-1	CO2 Band	0.040	0.99986
	6	732.98 cm-1	CO2 Band	0.028	0.99987
	7	749.34 cm-1	CO2 Band	-0.034	1.00000
	8	902.39 cm-1	Window	0.544	0.99916
	9	1028.77 cm-1	Ozone	0.062	0.99979
	10	792.82 cm-1	Water Vapor	-0.005	0.99994
	11	1359.95 cm-1	Water Vapor	0.090	0.99972
	12	1479.90 cm-1	Water Vapor	0.292	0.99931
	13	2189.06 cm-1	4.3 micrometers	0.022	0.99997
	14	2212.55 cm-1	CO2 Band	0.021	0.99997
	15	2231.68 cm-1	CO2 Band	0.029	0.99993
	16	2267.04 cm-1	CO2 Band	0.022	0.99999
	17	2418.31 cm-1	CO2 Band	0.025	0.99992
	18	2516.80 cm-1	Window	0.058	0.99970
	19	2653.33 cm-1	Window	0.264	0.99927
	20	14453.14 cm-1	Visible Window	n/a	n/a
MSU	1	1.6779 cm-1			
	2	1.7927 cm-1			
	3	1.8334 cm-1			
	4	1.9331 cm-1			
SSU	1	669.988 cm-1/15 mb			
	2	669.628 cm-1/5 mb			
	3	669.357 cm-1/1.5 mb			

Table 1.4.9-3. Non-linearity errors for NOAA-13 AVHRR Channels 4 and 5.

	Temperature Corrections	
Scene temperature (K)	**Channel 4**	**Channel 5**
320	0.025	0.20
315	0.07	0.03
310	-0.01	-0.02
305	-0.09	-0.06
295	-0.00	0.01
285	0.07	0.01
275	0.24	0.13
265	0.87	0.40
255	1.47	0.70
245	2.14	1.05
235	3.32	1.43
225	4.53	2.27
215	5.93	3.02

205	9.42	3.96

Table 1.4.9-4. Non-linearity coefficients and radiance of space for NOAA-13 AVHRR Channels 4 and 5 (Alternate method).

Radiance Correction Coefficients	Channel 4	Channel 5
A	0.91159	0.94784
B	0.0003820	0.0002057
C	5.01	3.24
Radiance of Space, Rsp	-5.31	-3.28

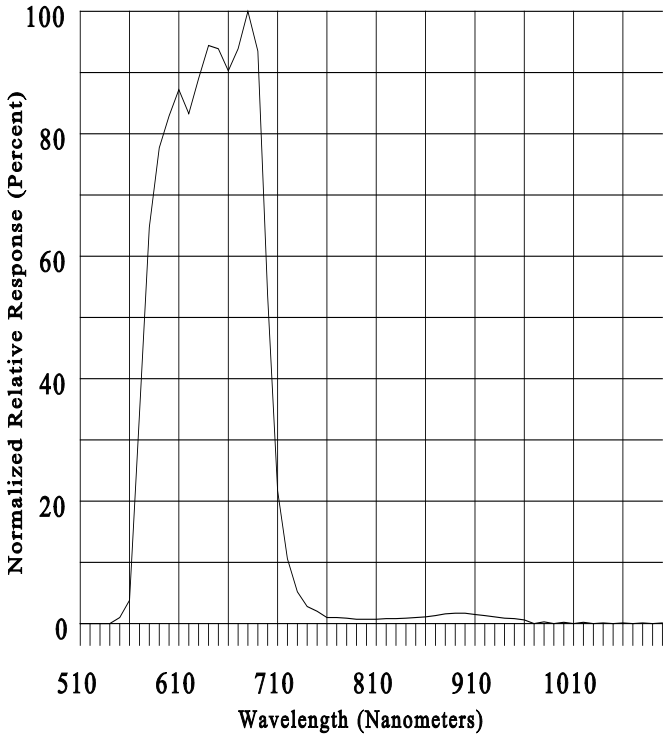


Figure 1.4.9-1 Spectral Response Curve NOAA-13 AVHRR Channel 1**.**

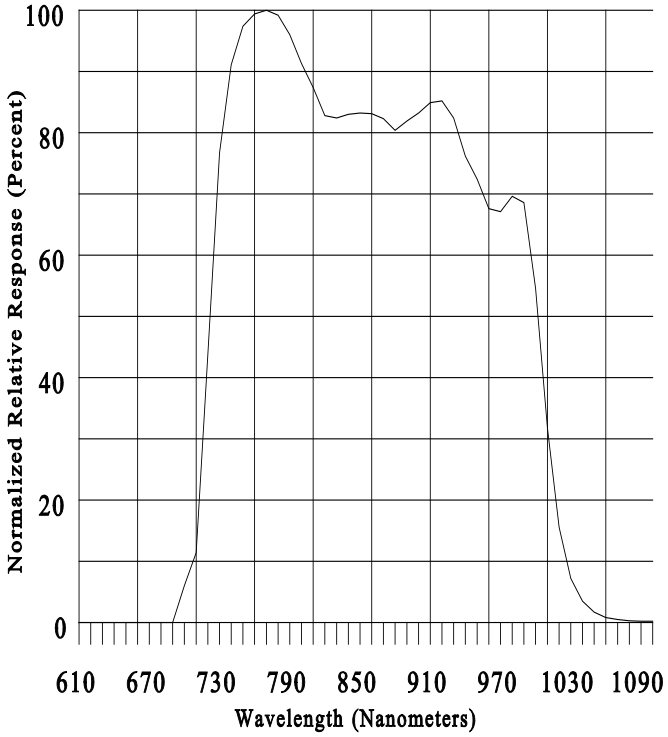


Figure 1.4.9-2 Spectral Response Curve NOAA-13 AVHRR Channel 2**.**

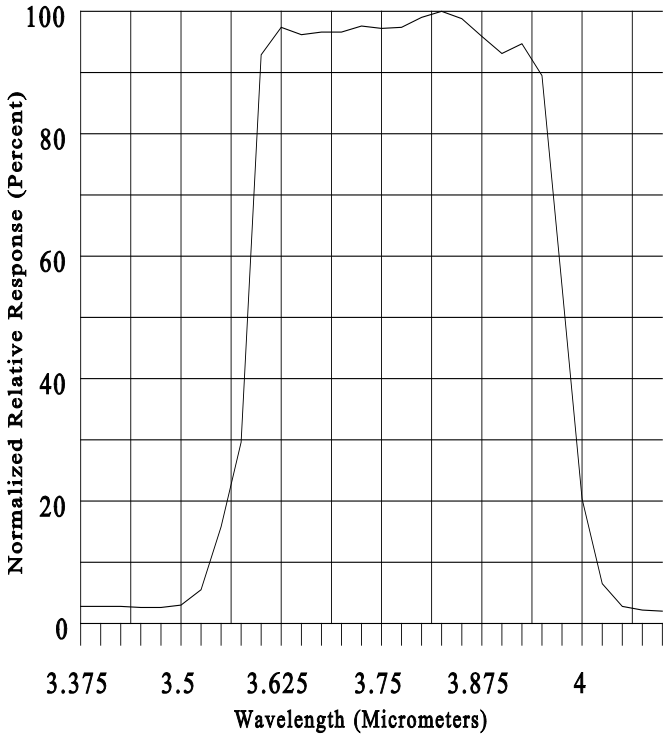


Figure 1.4.9-3 Spectral Response Curve NOAA-13 AVHRR Channel 3**.**

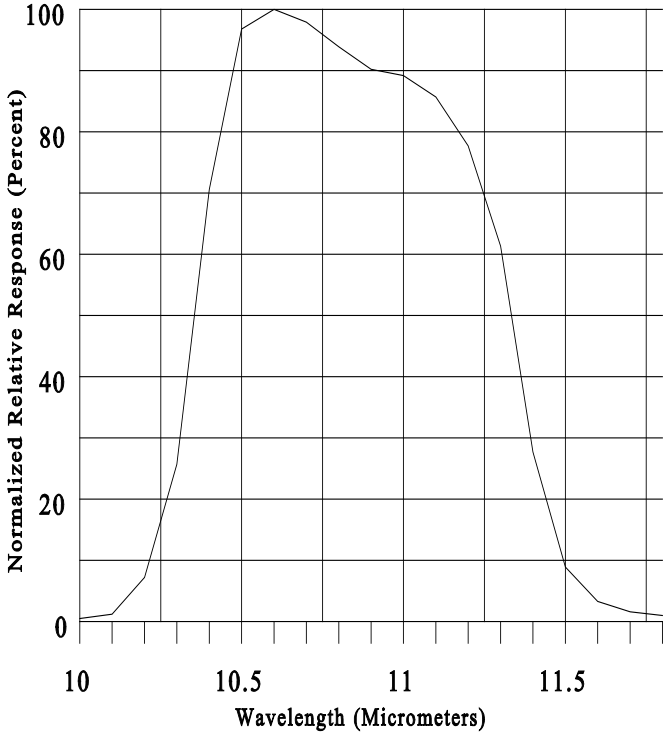


Figure 1.4.9-4 Spectral Response Curve NOAA-13 AVHRR Channel 4**.**

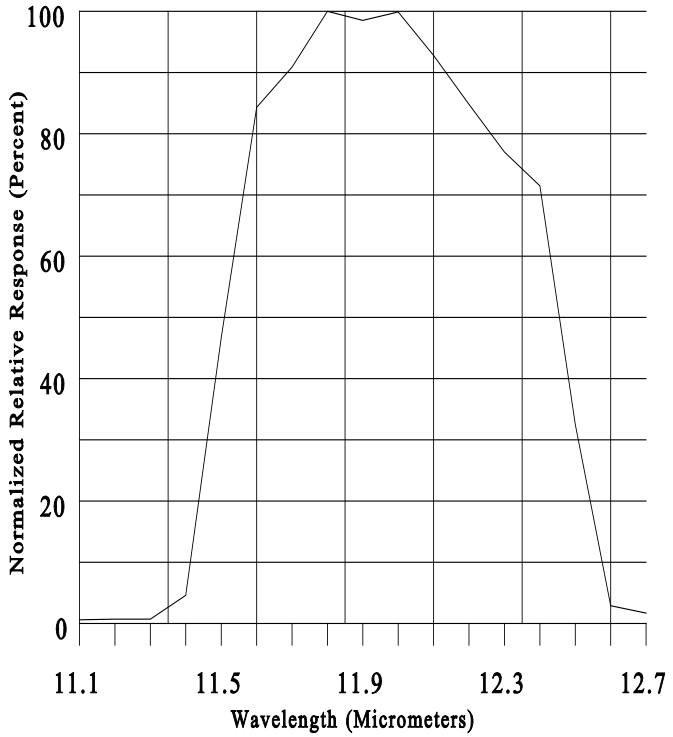


Figure 1.4.9-5 Spectral Response Curve NOAA-13 AVHRR Channel 5**.**

1.4.10 **NOAA-14**

Operational dates: Dec. 30, 1994 - present

Afternoon orbit: 1340 LST ascending node, 0140 LST descending node

AVHRR instrument: 5 channels

Spacecraft ID: 3

Abnormalities:The MSU instrument on NOAA-14 failed on March 3, 1995 at 0100 UTC, but was successfully turned back on March 30, 1995.

Table 1.4.10-1 contains the central wave numbers for the AVHRR IR channels for NOAA-14. Table 1.4.10-2 contains the TOVS channel spectral response and HIRS/2 thermal band-correction coefficients for NOAA-14.

Table 1.4.10-1. NOAA-14 Central Wave Numbers for AVHRR IR Channels.

Temperature Range (K)	Ch. 3 (cm-1)	Ch. 4 (cm-1)	Ch. 5 (cm-1)
190-230	2638.652	928.2603	834.4496
230-270	2642.807	928.8284	834.8066

270-310	2645.899	929.3323	835.1647
290-330	2647.169	929.5878	835.374
Note: The 270-310 K range is applicable for sea surface temperatures.			

Table 1.4.10-2. NOAA-14 TOVS Channel Spectral Response and HIRS/2 Thermal Band-Correction Coefficients.

Instrument	Ch #	Central Wave #	Description	HIRS/2 Band-Correction Coefficients	
				b	c
HIRS/2	1	668.90 cm-1	15 micrometers	0.002	0.99998
	2	679.36 cm-1	CO2 Band	-0.000	0.99997
	3	689.63 cm-1	CO2 Band	0.011	0.99994
	4	703.56 cm-1	CO2 Band	0.001	0.99994
	5	714.50 cm-1	CO2 Band	-0.014	0.99997
	6	732.28 cm-1	CO2 Band	0.026	0.99989
	7	749.64 cm-1	CO2 Band	0.019	0.99991
	8	898.67 cm-1	Window	0.067	0.99977
	9	1028.31 cm-1	Ozone	0.050	0.99980
	10	796.04 cm-1	Water Vapor	0.021	0.99990
	11	1360.95 cm-1	Water Vapor	0.073	0.99971
	12	1481.00 cm-1	Water Vapor	0.284	0.99931
	13	2191.32 cm-1	4.3 micrometers	0.021	0.99996
	14	2207.36 cm-1	CO2 Band	0.020	0.99997
	15	2236.39 cm-1	CO2 Band	0.024	0.99998
	16	2268.12 cm-1	CO2 Band	0.018	0.99996
	17	2420.24 cm-1	CO2 Band	0.026	0.99992
	18	2512.21 cm-1	Window	0.042	0.99993
	19	2647.91 cm-1	Window	0.313	0.99946
	20	14453.14 cm-1	Visible Window	n/a	n/a
MSU	1	1.6779 cm-1			
	2	1.7927 cm-1			
	3	1.8334 cm-1			
	4	1.9331 cm-1			
SSU	1	669.988 cm-1/15 mb			
	2	669.628 cm-1/5 mb			
	3	669.357 cm-1/1.5 mb			

Beginning with the NOAA-13 AVHRR instrument, a new radiance correction procedure is being

implemented at NESDIS which corrects both the non-linearity of AVHRR Channels 4 and 5 and the observed offset of the space point from the calibration curve for Channel 3. As was the case with previous instruments, gain and slope calibration coefficients for each channel are imbedded in the Level 1b data stream which allows the user to perform a linear calibration. However, these coefficients are derived using a non-zero radiance of space, R_{sp} which is a constant for each channel and which makes the radiance corrections independent of the internal calibration target

$$G = \frac{R_T - R_{sp}}{C_T - C_{sp}}$$

$$I = R_{sp} - G \times C_{sp}$$

temperature. The slope and intercept coefficients are derived with the following equations: where G is the slope, I is the intercept, R_T is the radiance of the target, C_T is the counts of the

$$R_{lin} = G \times C + I$$

target, and C_{sp} is counts of space. These coefficients provide a linear radiance, R_{lin}: where C is the counts of the channel.

This linear calibration procedure is described in more detail in *NOAA Technical Memorandum NESS 107*. The following equation provides a corrected radiance, RAD, for AVHRR channels 3, 4, and 5 which is a function only of the linear radiance derived from Eq. (3):
This radiance can be converted to temperatures using the energy tables or by using the inverse of the Planck function with the appropriate central wave numbers. No additional temperature correction should be applied. The regression coefficients (A, B and D) to apply this equation for NOAA-14 AVHRR Channels 3, 4 and 5 are contained in Table 1.4.10-3.

Table 1.4.10-3. Radiance correction coefficients for NOAA-14 AVHRR Channels 3, 4, and 5.

Radiance Correction Coefficients	Channel 3	Channel 4	Channel 5
A	1.00359	0.92378	0.96194
B	0.0	0.0003822	0.0001742
D	-0.0031	3.72	2.00
Radiance of Space, Rsp	0.0069	-4.05	-2.29

Figures 1.4.10-1 through 1.4.10-5 contain the spectral response curves for NOAA-14 AVHRR Channels 1 through 5, respectively.

Users of SSU data should note that the quality indicator for invalid blackbody position is **always** set on NOAA-14. Users should ignore this condition, assume the data are good and proceed with

processing as usual.

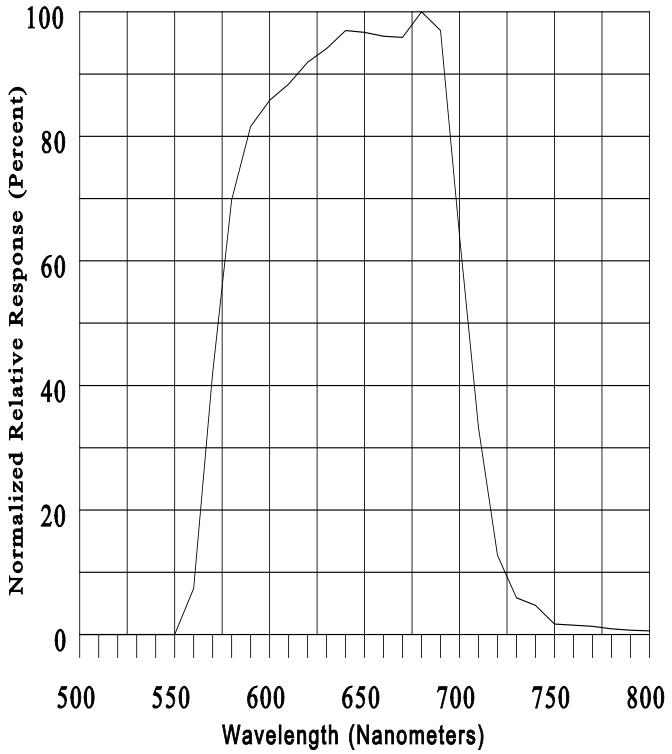


Figure 1.4.10-1 Spectral Response Curve NOAA-14 AVHRR Channel 1**.**

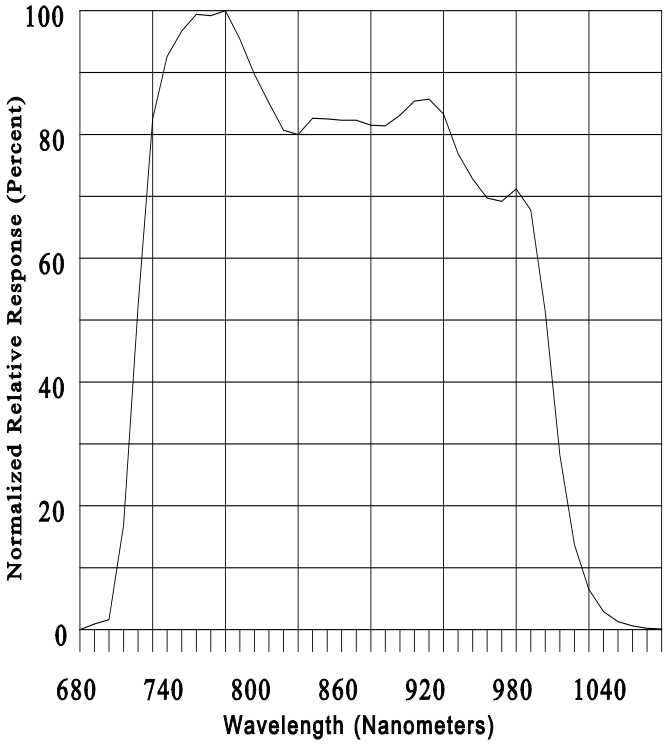


Figure 1.4.10-2 Spectral Response Curve NOAA-14 AVHRR Channel 2**.**

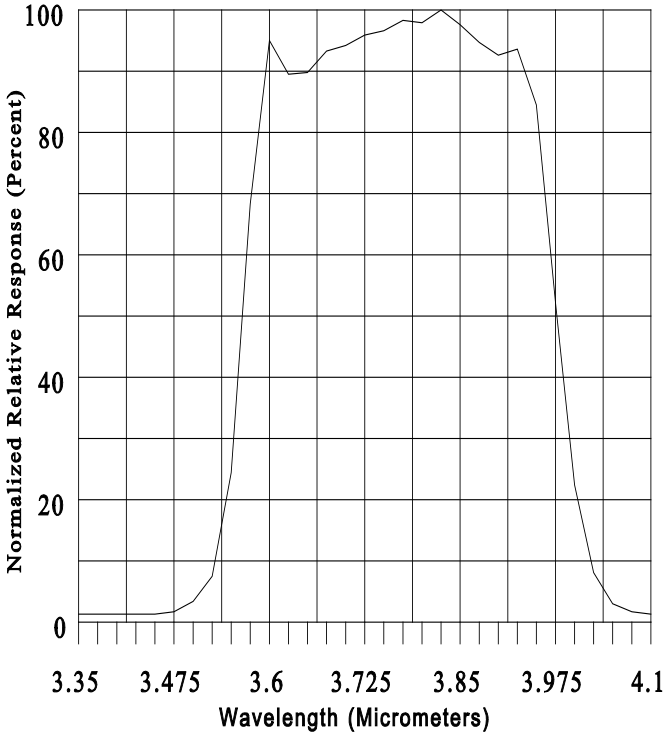


Figure 1.4.10-3 Spectral Response Curve NOAA-14 AVHRR Channel 3**.**

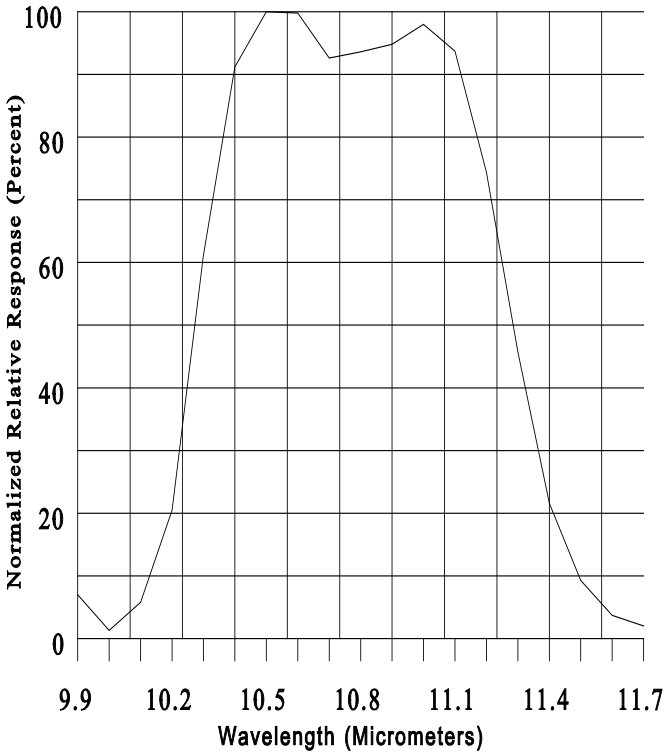


Figure 1.4.10-4 Spectral Response Curve NOAA-14 AVHRR Channel 4**.**

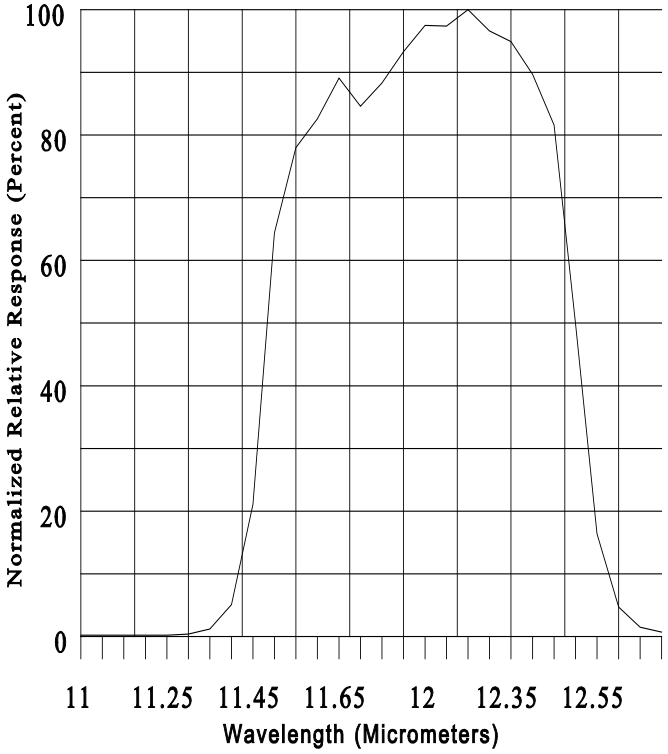


Figure 1.4.10-5 Spectral Response Curve NOAA-14 AVHRR Channel 5**.**