International Satellite Cloud Climatology Project (ISCCP) Radiance Calibration Report

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GLOSSARY OF ACRONYMS

AVHRR	Advanced Very High Resolution Radiometer
ESA	European Space Agency
GMS	Geostationary Meteorological Satellite
GOES	Geostationary Operational Environmental Satellite
ICSU	International Council of Scientific Unions
IFOV	Instantaneous Field of View
INSAT	Indian National Satellite System
IR	Infrared
ISCCP	International Satellite Cloud Climatology Project
JMA	Japan Meteorological Agency
NOAA	National Oceanic and Atmospheric Administration
TIROS-N	Television Infrared Operational Satellite
VAS	VISSR Atmospheric Sounder
VHRR	Very High Resolution Radiometer
VIS	Visible
VISSR	Visible Infrared Spin-Scan Radiometer
WCRP	World Climate Research Program
WMO	World Meteorological Organization
WV	Water Vapor

1. INTRODUCTION

The International Satellite Cloud Climatology Project (ISCCP) was established in 1982 as part of the World Climate Research Program (WCRP), jointly sponsored by the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU), to collect a globally uniform satellite radiance dataset and to derive from it a climatology of cloud properties that could be used to improve climate models (Schiffer and Rossow 1983).

The ISCCP radiance data are obtained from the imaging radiometers on a suite of operational weather satellites, which have in common a narrowband spectral channel at about 0.6 µm, near the peak of the solar spectrum, and one in the atmosphere's thermal opacity "window" near 11 µm. Some of these radiometers have additional channels. The spatial resolution of the original images ranges between 1-4 km (visible channel) and between 4-11 km (infrared channel), but the ISCCP Stage B3 data are reduced to the infrared resolution and sampled to a pixel spacing of about 30 km. Imaging frequency (for a specific low latitude location) varies from 48 to 14 times per day for geostationary satellites to twice daily at the equator for each polar orbiting satellite, but the ISCCP Stage B3 data are sampled once every three hours (except for polar orbiter data). Currently operating satellite systems are the geostationary METEOSAT, GOES, GMS and INSAT and the NOAA (TIROS-N) polar orbiters.

This document describes the radiance calibrations used for all ISCCP Stage B3 data for the period July 1983 through June 1991 (Schiffer and Rossow 1985; Rossow et al. 1987; Brest and Rossow 1992; Desormeaux et al. 1992). Calibration is reported in three stages, called nominal, normalized and absolute. Equations and tables in the following sections define each of these calibrations.

1.1. NOMINAL CALIBRATION

The nominal calibration (first set of tables on Stage B3 data tapes) represents the best information available at the start of processing of data from a particular satellite, usually the pre-launch calibration supplied by the satellite operator for the visible (VIS) channel (and other channels at solar wavelengths) and an equation or table used to interpret on-board calibration information for the infrared (IR) channel (and other channels at thermal infrared wavelengths). Specific details are given for each satellite in sections to follow.

In this document, VIS radiances are given as "scaled radiances", L^*, defined as

$$L^* = \pi L_V / E_o. \quad (1.1)$$

L^* is the scaled radiance expressed as a fraction from zero to one, where L_v is the VIS radiance in the watts m^{-2} sr^{-1} measured by the instrument, and E_o/π is the "solar constant" of the instrument in watts m^{-2} sr^{-1}, representing the radiance that would be measured by the instrument when viewing a surface with unit (Lambertian) albedo illuminated by the (annual mean) sun.

IR radiances are given as brightness temperatures, TB, representing the temperature of a black body that emits the same radiance in the radiometer bandpass. The IR radiance, L_I, is given by

$$L_I = \int_0^\infty \phi_\lambda \, B(\lambda, TB) \, d\lambda \quad (1.2)$$

where ϕ_λ is the spectral response of the radiometer and $B(\lambda, TB)$ is the Planck function. The value of TB is obtained by inverting the integral using tables relating L_I to TB calculated with (1.2).

1.2. NORMALIZED CALIBRATION

Special image data sets are collected 3-5 times each month that provide nearly simultaneous (within 15 minutes) and co-located image pairs from each geostationary satellite and the afternoon polar orbiting satellite. A number of homogeneous ocean-cloud targets, approximately 50 km in dimension, are selected in both images of each pair; corresponding radiance values form the coordinates in a scatter plot. A linear least-squares fit to the points representing all targets in one month (usually about 50-100) gives coefficients (BC data) to normalize the radiances measured by the geostationary satellites to those measured by the afternoon polar orbiter. This procedure is carried out once every three months for the VIS (≈ 0.6 μm) and IR (≈ 11 μm) channels (Desormeaux et al. 1992). Other spectral channels have only nominal calibration.

The BC data are used to produce a second set of calibration tables for the radiance count values on Stage B3 data tapes. The reported slope and intercept values from the radiance regressions are used to alter the nominal calibration values by:

$$L_N^* = A_1(L^*) + B_1 \quad \text{(visible channel)} \tag{1.3}$$

$$TB_N = A_2(TB) + B_2 \quad \text{(IR channel)} \tag{1.4}$$

where L_N^* and TB_N are the normalized geostationary values of scaled radiance and brightness temperature with respect to the current AVHRR measurements. Normalized calibrations for the two intervening months between normalizations are generally obtained by linear interpolation; if large changes are detected, individual monthly values are obtained. The records of BC coefficients are given in tables for each satellite in later sections.

The afternoon polar orbiter has been replaced several times since the beginning of data collection in July 1983; hence BC coefficients are required for subsequent polar orbiters in the series to normalize them to the first satellite in the series, NOAA-7.

1.3. ABSOLUTE CALIBRATION

The absolute calibration for geostationary satellite radiances includes adjustments for (1) changes of the afternoon polar orbiter calibration with time and (2) short-term (less than one month) changes of the geostationary calibration. The former adjustments remove slow drifts or sudden changes in calibration of the polar orbiter radiometers that are detected by requiring the global, monthly mean radiances to be constant (Brest and Rossow 1992). Additional small adjustments are required to eliminate image-to-image variations of geostationary calibration that occasionally occur. The most common problem is small diurnal variations in IR calibration of geostationary radiometers during the seasons of the year when the satellites enter total solar eclipse every day (Desormeaux et al. 1992). Equations (1.3) and (1.4) are used to make these adjustments.

The absolute calibration for polar orbiting satellite radiances includes corrections for slow drifts and for sudden, short-term changes in calibration (Brest and Rossow 1992).

The absolute radiometric calibration standard for ISCCP Stage B3 radiances was defined by the performance of the NOAA-7 AVHRR in July 1983. Subsequently, aircraft calibration flights were conducted to calibrate the NOAA-9 AVHRR over its lifetime, 1985-1988 (Whitlock et al. 1990). Comparison of the ISCCP calibration of VIS radiances to these results led to adoption of a correction (Brest and Rossow 1992):

NEW VIS = 1.2 * OLD VIS

The remaining uncertainty in the absolute VIS radiance is estimated to be < 10%.

No correction to the IR calibration has been made; the estimated uncertainty is absolute brightness temperatures is 1-2 K.

1.4. SOLAR CONSTANT TABLE

The table of solar spectral irradiance used to calculate the effective solar spectral irradiance, E_o, for all satellite radiometers is an adaptation of the compilation of Neckel and Labs (1984). This table is created by averaging or interpolating to irradiance values for 100 Å intervals centered on the indicated wavelengths (the interval becomes 500 Å wide beyond 1 μm wavelength). The integrated solar constant for the Neckel and Labs table, which is based on ground-based observations, is 1372 watts m^{-2}. A review of spacecraft measurements suggests a slightly lower value (Willson 1984), 1368 watts m^{-2}; however, most of the difference probably lies in the UV and near IR parts of the spectrum.

TABLE 1.1. Solar Spectral Irradiance (watts m^{-2} μm^{-1}).

Wavelength (µm)	Irradiance	Wavelength	Irradiance	Wavelength	Irradiance
0.400	1479	0.545	1865	0.690	1456
0.405	1690	0.550	1878	0.695	1439
0.410	1700	0.555	1857	0.700	1410
0.415	1727	0.560	1844	0.705	1399
0.420	1728	0.565	1847	0.710	1386
0.425	1668	0.570	1846	0.715	1365
0.430	1593	0.575	1842	0.720	1345
0.435	1676	0.580	1848	0.725	1342
0.440	1840	0.585	1815	0.730	1327
0.445	1934	0.590	1785	0.735	1311
0.450	1998	0.595	1792	0.740	1285
0.455	2038	0.600	1772	0.745	1278
0.460	2046	0.605	1759	0.750	1269
0.465	2023	0.610	1736	0.755	1256
0.470	1999	0.615	1705	0.760	1240
0.475	2016	0.620	1696	0.765	1220
0.480	2032	0.625	1690	0.770	1201
0.485	1934	0.630	1668	0.775	1200
0.490	1895	0.635	1654	0.780	1188
0.495	1959	0.640	1637	0.785	1182
0.500	1921	0.645	1609	0.790	1160
0.505	1911	0.650	1584	0.795	1147
0.510	1929	0.655	1538	0.800	1138
0.515	1837	0.660	1528	0.805	1123
0.520	1824	0.665	1557	0.810	1113
0.525	1871	0.670	1530	0.815	1104
0.530	1876	0.675	1515	0.820	1082
0.535	1900	0.680	1490	0.825	1078
0.540	1876	0.685	1475	0.830	1063
0.835	1051	0.900	943	0.965	820
0.840	1041	0.905	933	0.970	812
0.845	1021	0.910	923	0.975	802
0.850	971	0.915	914	0.980	794
0.855	973	0.920	904	0.985	786
0.860	996	0.925	894	0.990	777
0.865	964	0.930	884	0.995	769
0.870	950	0.935	875	1.000	760
0.875	994	0.940	866	1.050	676
0.880	984	0.945	856	1.100	612
0.885	974	0.950	848	1.150	560
0.890	964	0.955	838	1.200	514
0.895	953	0.960	830		

1.5. CALIBRATION CHANGES

All of the calibration tables for individual images on Stage B3 data tapes have been compiled into a separate calibration history dataset for each satellite. These digital datasets are available from the ISCCP Central Archives (NOAA/NESDIS in Washington, DC). Continued studies of these data provide refined estimates of calibration. Rather than re-produce the whole Stage B3 dataset, calibration will be changed by issuing a new version of the calibration datasets. At the time of this report (1992), one new version (version No. = 1) is planned for early 1993.

2. NOAA (TIROS-N)

This satellite program is a cooperative effort of the USA, the United Kingdom and France for providing global environmental observations. The National Oceanic and Atmospheric Administration (NOAA) is the operating agency. TIROS-N was the NASA prototype R-and-D spacecraft launched in late 1978. The operational system consists of two polar orbiting, sun-synchronous satellites crossing the equator during local morning and afternoon (and corresponding nighttimes). NOAA-A, C, E, F, G and H were renamed as NOAA-6, 7, 8, 9, 10 and 11, respectively; NOAA-D became NOAA-12. At the start of ISCCP data collection in July 1983, NOAA-7 was the afternoon satellite supplying imaging data. NOAA-8 data were collected from October 1983 through May 1984 to augment observation of the Indian Ocean sector. These two satellites were replaced by NOAA-9 (afternoon) in January 1985 and NOAA-10 (morning) in December 1986. NOAA-11 replaced NOAA-9 in November 1988 and NOAA-12 replaced NOAA-10 in September 1991. (See Rossow et al. 1987 for details.)

Data were initially obtained from NOAA-7 which carries a five-channel AVHRR (some other satellites in this series have four-channel AVHRR's, e.g., NOAA-8 and 10). Table 2.1 shows the instrument characteristics (Lauritson et al. 1979; Kidwell 1991). The normalized spectral responses of the channels on NOAA-7, NOAA-8, NOAA-9, NOAA-10, NOAA-11 and NOAA-12 are given in Section 2.2. ISCCP calibration information is provided only for Channel 1 and Channel 4.

TABLE 2.1. Characteristics of AVHRR

	Bandwidth (μm)			
Channel	TIROS-N	NOAA-6, 8, 10	NOAA-7, 9, 11, 12	IFOV (mrad)
1	0.55 - 0.90	0.58 - 0.68	0.58 - 0.68	1.39
2	0.725 - 1.10	0.725 - 1.10	0.725 - 1.10	1.41
3	3.55 - 3.93	3.55 - 3.93	3.55 - 3.93	1.51
4	10.5 - 11.5	10.5 - 11.5	10.5 - 11.3	1.41
5	(Ch. 4 repeated)	(Ch. 4 repeated)	11.5 - 12.5	1.41

2.1. NOMINAL CALIBRATION

(1) SOLAR CHANNELS

Pre-launch calibration of the solar channels (Ch. 1 and 2) was performed with a standard calibration lamp viewed through an aperture in an integrating sphere; the calibration lamp is a standard traceable to NBS standards (Lauritson 1979). The spectral output for the source lamp is known, allowing for correction of the calibration to the solar spectrum.

The pre-launch calibration establishes a relation between count values (representing instrument output voltage) and percent scaled radiance for each channel:

$$L_i^* = G_i (CT) + Y_i \qquad (2.1)$$

where CT = 0 - 255. The coefficients in (2.1) are shown in Table 2.2. Uncertainties are estimated to be about 5-10%.

To obtain radiances the effective solar spectral irradiance for each channel is calculated by integrating over the product of the spectral response functions in Section 2.2 and the solar irradiance, Table 1.1 (Neckel and Labs 1984). Thus

$$L_i = (E_{oi}/\pi) L_i^* / 100 \text{ watts } m^{-2} \text{ sr}^{-1} \tag{2.2}$$

where values of E_{o1}/π are given in Table 2.2.

TABLE 2.2. Nominal calibration constants for solar channels on NOAA satellites. See equations (2.1) and (2.2).

Satellite	G_1	Y_1(%)	E_{o1}/π (watts m^{-2} sr^{-1})	G_2	Y_2	E_{o2}/π (watts m^{-2} sr^{-1})
NOAA-7	0.4272	-3.440	56.66	0.4276	-3.488	81.81
NOAA-8	0.4242	-4.162	56.70	0.4240	-4.149	76.96
NOAA-9	0.4254	-3.846	60.91	0.4300	-3.877	79.87
NOAA-10	0.4283*	-4.114*	56.89	0.4231	-3.454	73.20
NOAA-11	0.3624*	-3.730*	58.02	0.3308	-3.390	76.38
NOAA-12	0.4080	-4.130	63.43	0.4120	-4.210	83.13

* On 26 May 1989, NOAA changed the channel 1 nominal calibration coefficients for NOAA-10 to G_1 = 0.4235, Y_1 = -3.528 and G_2 = 0.4243, Y_2 = -3.477. On 27 September 1992, NOAA changed the nominal calibration coefficients for NOAA-11 to G_1 = 0.3800, Y_1 = -3.780 and G_2 = 0.3600, Y_2 = -3.600.

(2) INFRARED CHANNELS

Calibration of the infrared channels is done actively on the spacecraft, once per scan, by having the radiometer view space and a standard black-body with a known temperature. Pre-launch measurements of a precision calibration black-body with the radiometer are used to relate the output counts from four thermistors to the temperature of the reference black-body with a fourth order polynomial. This temperature is converted to a radiance by integrating the product of the Planck function and the spectral response functions shown in Section 2.2. NOAA documentation provides calibration in terms of radiance per unit wavelength, J, i.e., L_I = JB, where B is the radiometer bandwidth. From the spectral response functions in Section 2.2, bandwidths are calculated; results are shown in Table 2.3.

TABLE 2.3. Nominal calibration constants for infrared channels on NOAA satellites.

Satellite	BW_3 (cm^{-1})	J_{sp}^3 (counts)	BW_4 (cm^{-1})	J_{sp}^4 (counts)	BW_5 (cm^{-1})	J_{sp}^5 (counts)
NOAA-7	287.0	0.0	73.06	-1.176	61.29	-1.346
NOAA-8	262.9	0.0	69.64	-2.784	-	-
NOAA-9	289.0	0.0	73.96	-3.384	62.18	-2.313
NOAA-10*	272.0	0.0	64.30	0.0	-	-
NOAA-11	279.0	0.0	77.90	0.0	65.21	0.0
NOAA-12	270.4	0.0	81.10	0.0	64.30	0.0

*Incorrect bandwidths were used for the nominal calibration of NOAA-10 data from December 1986 through December 1988: B_3 = 27.70 cm^{-1} and B_4 = 66.14 cm^{-1}. This error was eliminated by the normalization coefficients.

The radiometer counts for measurements of space, CT_{sp}, and the on-board black-body, CT_{bb}, are used to calibrate the radiometer by calculating a gain, G_i, and intercept, Y_i:

$$G_i = (J_{sp}^{\ i} - J_{bb}^{\ i})(CT_{sp}^{\ i} - CT_{bb}^{\ i})^{-1} \tag{2.3}$$

$$Y_i = J_{sp}{}^i - G(CT_{sp}{}^i) \quad (2.4)$$

$J_{bb}{}^i$ is the reference black-body radiance calculated from its measured temperature and $J_{sp}{}^i$ is the radiance of space, adjusted to account for slight non-linearity in the radiometer response. In October 1987, NOAA discontinued use of negative values of $J_{sp}{}^i$ to correct for the non-linearity of the IR channels; however, the replacement scheme requires use of tables of values not made widely available. An alternative scheme for the calibration of the infrared channels provides better correction for the non-linear responses (Brown et al. 1985; Brown et al. 1992). Thus, the nominal calibration (using the formulation discussed here) appears to change; however, the normalization to NOAA-7 "corrects" for this effect.

TABLE 2.4. Sample values of G_i and Y_i in mwatts m^{-2} sr^{-1} cm.

Satellite	G_3	G_4	G_5	Y_3	Y_4	Y_5
NOAA-7	-0.00617	-0.62141	-0.72617	1.53945	152.93695	178.54785
NOAA-8	-0.00640	-0.65270	——	1.59280	159.2977	——
NOAA-9	-0.00580	-0.66520	-0.78488	1.44247	164.30469	194.97711
NOAA-10	-0.00589	-0.59292	——	1.46467	147.34045	——
NOAA-11	-0.00588	-0.67650	-0.69958	1.45564	167.94104	174.24371
NOAA-12	-0.00625	-0.62144	-0.69932	1.55300	154.54205	174.65582

Radiance measurements can be converted to brightness temperatures by inverting the relation

$$L_i = \int B(\nu,T)\ \phi_i(\nu)\ d\nu \quad (2.5)$$

where $B(\nu,T)$ is the Plank function of temperature and frequency, $\nu(cm^{-1}$, and $\phi_i(\nu)$ is the normalized spectral response of the radiometer. The conversion table used for ISCCP to convert L_4 into TB_4 is described in Section 2.2. An approximate relation, equivalent to the above for three temperature ranges, is given by Kidwell (1991):

$$TB\ (J_i) = C_2\ \bar{\nu}_i\ \{\ \ln\ [1 + C_1\ \bar{\nu}_i{}^3\ (J_i)^1]\ \}^{-1} \quad (2.6)$$

where $C_1 = 1.1910659 \times 10^{-5}$ mwatts m^{-2} sr^{-1} cm^4 $C_2 = 1.438833$ cm K, and $\bar{\nu}_i$ represents an effective frequency of the radiometer for a specific temperature range. These values are given in Table 2.5 (in cm^{-1}).

For ISCCP Stage B3 data, the calibration coefficients (G_i and Y_i) for the first scan line in an orbit swath are used for all scan lines in that orbit. Since the calibration actually changes somewhat during the orbit (due to varying thermal environment), the count values are altered so that constant coefficients reproduce the original data. For channels 4 and 5, the change in calibration is no more than 2-3%, occurring primarily when the satellite passes from the night to day side of the Earth. Consequently only the lowest count values actually change. Channel 3 data occasionally exhibit much greater noise, reflected in rapidly changing calibration coefficients. NOAA-7 noise levels at the beginning of ISCCP data collection were as high as 5-10%; however, an outgassing procedure performed in September 1983 reduced the noise level to less than 1%.

TABLE 2.5. Effective frequency for infrared channels viewing targets with temperatures in three ranges.

		T = 180 - 225K	T = 225 - 275K	T = 275 - 320K
NOAA-7	$\bar{\nu}_3$ =	2668.70	2670.30	2671.90
	$\bar{\nu}_4$ =	926.20	926.80	927.22
	$\bar{\nu}_5$ =	840.10	840.50	840.87

NOAA-8	$\bar{\nu}_3$ =	2631.52	2636.05	2639.18
	$\bar{\nu}_4$ =	913.360	913.865	913.305
NOAA-9	$\bar{\nu}_3$ =	2670.93	2674.81	2678.11
	$\bar{\nu}_4$ =	928.50	929.02	929.46
	$\bar{\nu}_5$ =	844.41	844.80	845.19
NOAA-10	$\bar{\nu}_3$ =	2658.53	2657.60	2660.76
	$\bar{\nu}_4$ =	908.73	909.18	909.58
NOAA-11	$\bar{\nu}_3$ =	2663.50	2668.15	2671.40
	$\bar{\nu}_4$ =	926.80	927.34	927.80
	$\bar{\nu}_5$ =	837.75	838.08	838.40
NOAA-12*	$\bar{\nu}_3$ =	2632.71	2636.67	2639.61
	$\bar{\nu}_4$ =	920.02	920.55	921.03
	$\bar{\nu}_5$ =	836.68	837.03	837.36

* The effective frequencies for NOAA-12 are defined for slightly different temperature ranges than for the other satellites: 190-230K, 230-270K, and 270-310K, respectively.

A sample table in Section 2.2 illustrates the calibration information supplied with each NOAA image (one orbit) showing the conversion of solar and thermal channel counts to scaled radiance and brightness temperature, respectively. (Note the renumbering of channels in this table.)

2.2. NOAA SPECTRAL RESPONSE

The AVHRR spectral responses for each channel on NOAA-7, 8, 9, 10, 11 and 12 are given in Tables 2.6, 2.8, 2.10, 2.12, 2.14 and 2.16 and illustrated in Figs. 2.1, 2.2, 2.3, 2.4, 2.5 and 2.6. The tabular values were used in the calculation of all nominal calibration quantities.

To convert measured IR radiances to brightness temperatures, we interpolated in tables, relating these two quantities for each channel, that were calculated using the spectral response shown for each channel. The radiances for every 1 K in the interval from 150 to 350 K were calculated using

$$\int B(\lambda,T)\ \phi(\lambda)\ d\lambda \tag{2.7}$$

where $\phi(\lambda)$ is the response function normalized to unity at its maximum and the Planck function $B(\lambda,T)$ is given by

$$B(\lambda,T) = c_1\ \lambda^{-5}\ [\exp(c_2/\lambda T) - 1]^{-1} \tag{2.8}$$

with c_1 = 1.1910659 x 10^8 watts m^{-2} sr^{-1} μm^4, c_2 = 1.438833 x 10^4 μm K. In order to invert the table to obtain brightness temperatures for a given radiance, the radiance values were interpolated to 0.1 K intervals.

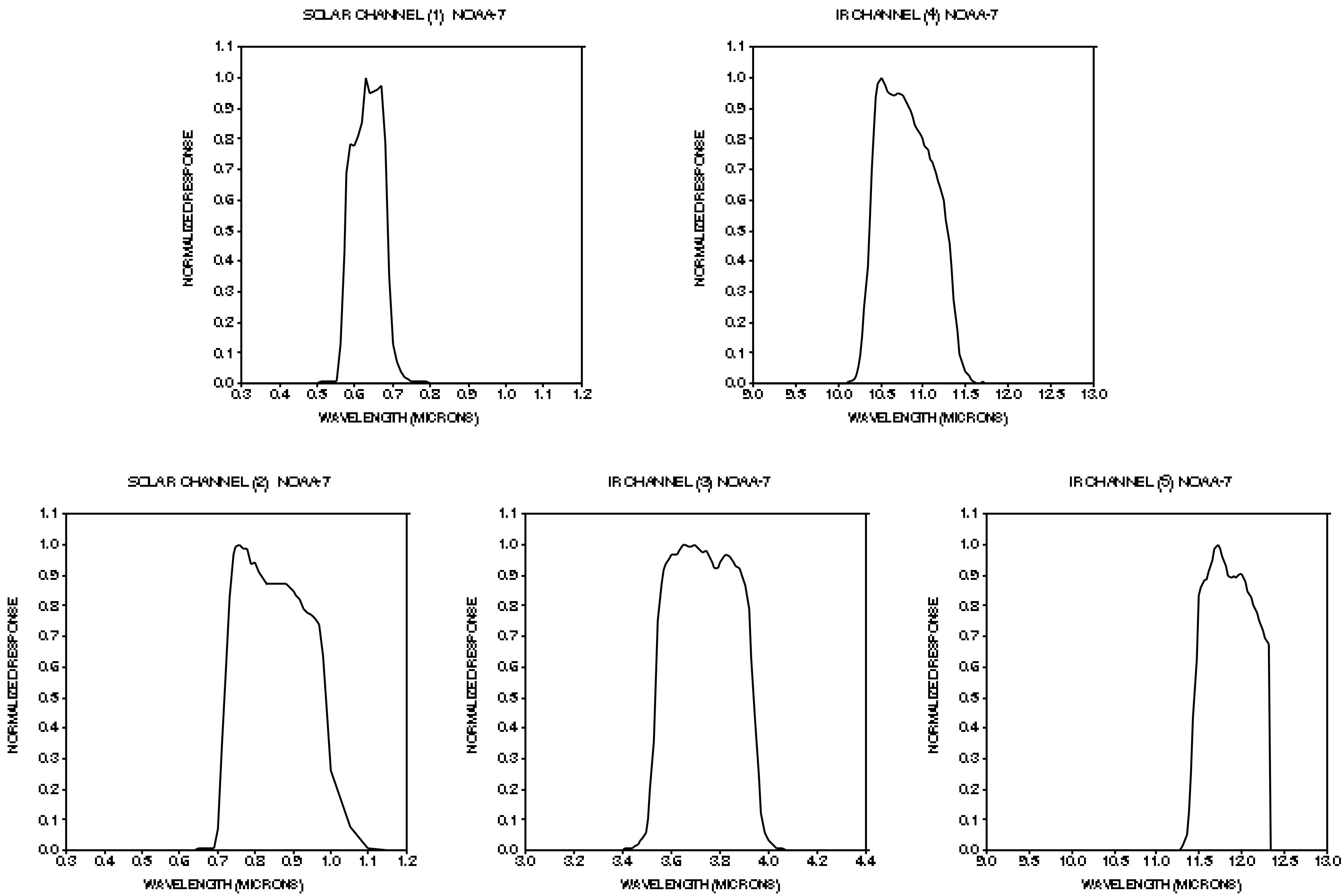

Fig. 2.1. Normalized spectral response functions for NOAA-7. The channels are shown in the order found on B3 data tapes.

TABLE 2.6. Solar Channel Normalized Spectral Responses for NOAA-7.

Channel 1		Channel 2	
Wavelength (μm)	Response	Wavelength (μm)	Response
0.500	0.000	0.640	0.000
0.510	0.005	0.650	0.005
0.520	0.005	0.660	0.005
0.530	0.005	0.670	0.005
0.540	0.005	0.680	0.005
0.550	0.005	0.690	0.010
0.560	0.127	0.700	0.070
0.570	0.427	0.710	0.340
0.580	0.687	0.720	0.580
0.590	0.782	0.730	0.830
0.600	0.780	0.740	0.965
0.610	0.812	0.750	0.995
0.620	0.855	0.760	1.000
0.630	1.000	0.770	0.990
0.640	0.950	0.780	0.990
0.650	0.955	0.790	0.935
0.660	0.960	0.800	0.940
0.670	0.975	0.810	0.910
0.680	0.790	0.830	0.870
0.690	0.350	0.830	0.870
0.700	0.130	0.840	0.870
0.710	0.070	0.850	0.870
0.720	0.040	0.860	0.870
0.730	0.020	0.870	0.870
0.740	0.015	0.880	0.870
0.750	0.010	0.890	0.860
0.760	0.010	0.900	0.845
0.770	0.010	0.910	0.835
0.780	0.010	0.920	0.820
0.790	0.010	0.930	0.790
0.800	0.000	0.940	0.780
		0.950	0.770
		0.960	0.760
		0.970	0.740
		0.980	0.640
		0.990	0.450
		1.000	0.260
		1.050	0.080
		1.100	0.005
		1.150	0.000

Infrared Channel Normalized Spectral Responses for NOAA-7.

Channel 3		Channel 4		Channel 5	
Wavelength (μm)	Response	Wavelength	Response	Wavelength	Response
3.390	0.00000	9.975	0.00000	10.974	0.00000
3.400	0.00400	10.000	0.00399	11.001	0.00150
3.410	0.00585	10.025	0.00331	11.029	0.00005
3.420	0.00742	10.050	0.00291	11.058	0.00000
3.430	0.00848	10.076	0.00307	11.086	0.00000
3.441	0.01008	10.101	0.00407	11.114	0.00000
3.451	0.01447	10.127	0.00623	11.143	0.00000
3.461	0.02268	10.153	0.00996	11.171	0.00000
3.472	0.03155	10.178	0.01638	11.200	0.00000
3.482	0.03844	10.205	0.02872	11.229	0.00000
3.493	0.05564	10.231	0.05154	11.259	0.00227
3.503	0.10503	10.257	0.09168	11.288	0.00753
3.514	0.20279	10.283	0.15616	11.317	0.02032
3.524	0.35513	10.310	0.25168	11.347	0.05340
3.535	0.55622	10.337	0.38049	11.377	0.12579
3.546	0.74977	10.363	0.53782	11.407	0.25400
3.557	0.87022	10.390	0.69869	11.437	0.43527
3.568	0.91795	10.418	0.82465	11.467	0.62417
3.579	0.93789	10.445	0.93753	11.497	0.83719
3.590	0.95494	10.472	0.98195	11.528	0.85999
3.601	0.96461	10.500	1.00000	11.559	0.88830
3.613	0.96504	10.527	0.98663	11.590	0.88307
3.624	0.96731	10.555	0.97384	11.621	0.91251
3.635	0.98100	10.583	0.95748	11.652	0.95109
3.647	0.99656	10.611	0.94893	11.683	0.98771
3.658	1.00000	10.640	0.94374	11.715	1.00000
3.670	0.99521	10.668	0.94257	11.747	0.98490
3.682	0.99483	10.697	0.94571	11.779	0.96001
3.694	0.99762	10.725	0.94601	11.811	0.92865
3.705	0.99145	10.754	0.94484	11.843	0.89900
3.717	0.97782	10.783	0.93278	11.875	0.89319
3.729	0.97345	10.813	0.91466	11.908	0.89533
3.741	0.97899	10.842	0.88924	11.941	0.88989
3.754	0.97081	10.872	0.87141	11.974	0.90419
3.766	0.94277	10.901	0.84935	12.007	0.90591
3.778	0.92214	10.931	0.83707	12.040	0.87717
3.791	0.92564	10.961	0.81322	12.074	0.84984
3.803	0.94412	10.991	0.80288	12.107	0.82820
3.816	0.96392	11.022	0.77621	12.141	0.80130
3.828	0.97078	11.052	0.76489	12.175	0.77629
3.841	0.95968	11.083	0.73537	12.210	0.74896
3.854	0.94369	11.114	0.72917	12.244	0.71723
3.867	0.93167	11.145	0.69068	12.279	0.69467
3.880	0.92131	11.176	0.66047	12.314	0.67773
3.893	0.90489	11.207	0.64197	12.349	0.66006
3.906	0.86804	11.239	0.60218	12.384	0.62827
3.919	0.78682	11.271	0.53797	12.420	0.50939

Infrared Channel Normalized Spectral Responses (continued).

Channel 3		Channel 4		Channel 5	
Wavelength (μm)	Response	Wavelength	Response	Wavelength	Response
3.932	0.63007	11.302	0.46186	12.455	0.32618
3.946	0.42469	11.335	0.37766	12.491	0.17621
3.959	0.24342	11.367	0.27743	12.527	0.08240
3.973	0.11935	11.399	0.17401	12.564	0.03675
3.987	0.05599	11.432	0.09750	12.600	0.02002
4.001	0.03127	11.465	0.05582	12.637	0.01306
4.014	0.01901	11.498	0.03689	12.674	0.00697
4.029	0.01295	11.531	0.02395	12.711	0.00131
4.034	0.01039	11.564	0.01289	12.748	0.00000
4.057	0.00710	11.598	0.00530	12.786	0.00000
4.071	0.00281	11.632	0.00229	12.824	0.00000
4.085	0.00118	11.667	0.00277	12.862	0.00038
4.100	0.00200	11.700	0.00499	12.900	0.00294
4.114	0.00000	11.735	0.00000	12.938	0.00000

Table 2.7 shows a sample of the conversion of count values to scaled radiance and brightness temperature for NOAA-7. Note the re-ordering of the channels: Ch. 2 below is Ch. 4 above, Ch. 3 below is Ch. 2 above and Ch. 4 below is Ch. 3 above. Zero temperature is recorded when the linear relationship between infrared radiance and count value gives a negative radiance.

TABLE 2.7. Sample Conversion Tables for NOAA-7.

Counts	Ch 1 S. Rad.	Ch 2 Temp.	Ch 3 S. Rad.	Ch 4 Temp.	Ch 5 Temp.
0	0.000	325.380	0.000	324.350	317.430
25	0.064	317.140	0.064	321.500	308.890
50	0.170	308.390	0.170	318.290	299.740
75	0.277	298.970	0.276	314.770	290.000
100	0.383	288.700	0.382	310.910	279.410
125	0.489	277.360	0.488	306.200	267.760
150	0.595	264.500	0.594	300.750	254.560
175	0.701	249.330	0.700	294.000	239.130
200	0.807	230.000	0.806	284.750	219.640
225	0.913	201.130	0.912	270.330	190.670
250	1.019	000.000	1.018	221.000	000.000

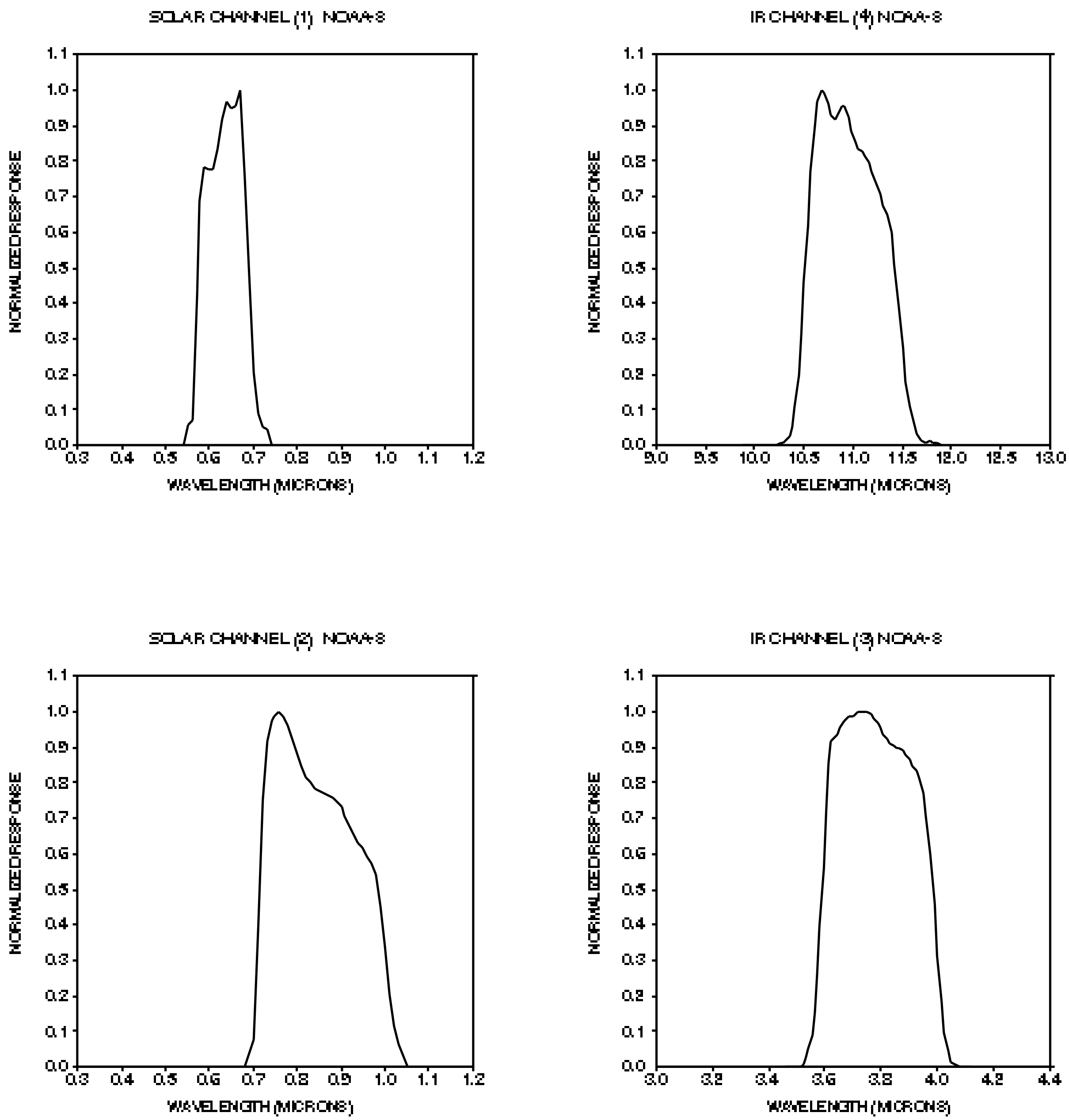

Fig. 2.2. Normalized spectral response functions for NOAA-8. The channels are shown in the order found on B3 data tapes.

TABLE 2.8. Solar Channel Normalized Spectral Responses for NOAA-8.

Channel 1		Channel 2	
Wavelength (µm)	Response	Wavelength (µm)	Response
0.540	0.000	0.680	0.000
0.550	0.056	0.690	0.040
0.560	0.073	0.700	0.075
0.570	0.426	0.710	0.394
0.580	0.690	0.720	0.752
0.590	0.782	0.730	0.918
0.600	0.775	0.740	0.974
0.610	0.775	0.750	0.990
0.620	0.833	0.760	1.000
0.630	0.920	0.770	0.985
0.640	0.971	0.780	0.960
0.650	0.946	0.790	0.924
0.660	0.957	0.800	0.885
0.670	1.000	0.810	0.850
0.680	0.760	0.820	0.814
0.690	0.476	0.830	0.800
0.700	0.203	0.840	0.785
0.710	0.090	0.850	0.780
0.720	0.050	0.860	0.770
0.730	0.047	0.870	0.766
0.740	0.000	0.880	0.757
		0.890	0.746
		0.900	0.732
		0.910	0.710
		0.920	0.680
		0.930	0.655
		0.940	0.630
		0.950	0.615
		0.960	0.593
		0.970	0.572
		0.980	0.540
		0.990	0.450
		1.000	0.338
		1.010	0.205
		1.020	0.117
		1.030	0.062
		1.040	0.032
		1.050	0.000

Infrared Channel Normalized Spectral Responses for NOAA-8.

Channel 3		Channel 4	
Wavelength (µm)	Response	Wavelength (µm)	Response
3.457	0.00000	9.871	0.00000
3.466	0.00000	9.900	0.00000
3.475	0.00184	9.929	0.00004
3.485	0.00274	9.958	0.00014
3.495	0.00180	9.987	0.00034
3.504	0.00007	10.016	0.00069
3.514	0.00131	10.046	0.00111
3.524	0.00926	10.075	0.00142
3.533	0.02560	10.105	0.00143
3.543	0.05049	10.135	0.00113
3.553	0.09021	10.165	0.00093
3.563	0.15560	10.195	0.00130
3.573	0.25931	10.226	0.00268
3.583	0.39786	10.257	0.00519
3.593	0.55865	10.288	0.00884
3.603	0.72160	10.319	0.01398
3.614	0.85086	10.350	0.02628
3.624	0.91457	10.381	0.05546
3.634	0.92953	10.413	0.11123
3.645	0.93626	10.445	0.19825
3.655	0.95467	10.477	0.31469
3.666	0.97368	10.509	0.45829
3.676	0.98270	10.541	0.61902
3.687	0.98512	10.577	0.77307
3.698	0.98772	10.607	0.89513
3.708	0.99222	10.640	0.96936
3.719	0.99650	10.673	1.00000
3.730	0.99913	10.707	0.99401
3.741	1.00000	10.740	0.96302
3.752	0.99876	10.774	0.92932
3.763	0.99369	10.808	0.91665
3.774	0.98301	10.843	0.93294
3.786	0.96816	10.877	0.95474
3.797	0.95204	10.912	0.95530
3.808	0.93653	10.947	0.92591
3.820	0.92233	10.982	0.88511
3.831	0.91049	11.017	0.85314
3.843	0.90258	11.053	0.83615
3.854	0.89885	11.089	0.82557
3.866	0.89601	11.125	0.81283
3.878	0.89051	11.161	0.79430
3.890	0.88052	11.198	0.76931
3.902	0.86535	11.235	0.73825
3.914	0.84849	11.272	0.70531
3.926	0.83350	11.309	0.67595
3.938	0.81278	11.347	0.64718
3.950	0.77392	11.385	0.59945

Infrared Channel Normalized Spectral Responses (continued).

Channel 3		Channel 4	
Wavelength (µm)	Response	Wavelength (µm)	Response
3.962	0.70500	11.423	0.51309
3.975	0.59651	11.461	0.39576
3.987	0.45860	11.499	0.27655
4.000	0.31335	11.538	0.17994
4.012	0.18449	11.577	0.10870
4.025	0.09439	11.617	0.05991
4.038	0.04297	11.656	0.03011
4.051	0.01722	11.696	0.01517
4.063	0.00674	11.736	0.01072
4.076	0.00314	11.777	0.01111
4.090	0.00198	11.818	0.01041
4.103	0.00109	11.859	0.00615
4.116	0.00000	11.900	0.00000

Note the re-ordering of the channels from Table 2.7 to 2.8: Ch. 2 below is Ch. 4 above, Ch. 3 below is Ch. 2 above, and Ch. 4 below is Ch. 3 above.

TABLE 2.9. Sample Conversion Tables for NOAA-8.

Counts	Ch 1 S. Rad.	Ch 2 Temp.	Ch 3 S. Rad.	Ch 4 Temp.
0	0.000	323.660	0.000	321.750
25	0.064	315.420	0.064	318.930
50	0.170	306.650	0.170	315.770
75	0.277	297.210	0.276	312.250
100	0.383	286.920	0.382	308.300
125	0.489	275.540	0.488	303.780
150	0.595	262.650	0.594	298.250
175	0.701	247.440	0.700	291.500
200	0.807	228.230	0.806	282.500
225	0.913	199.290	0.912	268.000
250	1.019	000.000	1.018	220.000

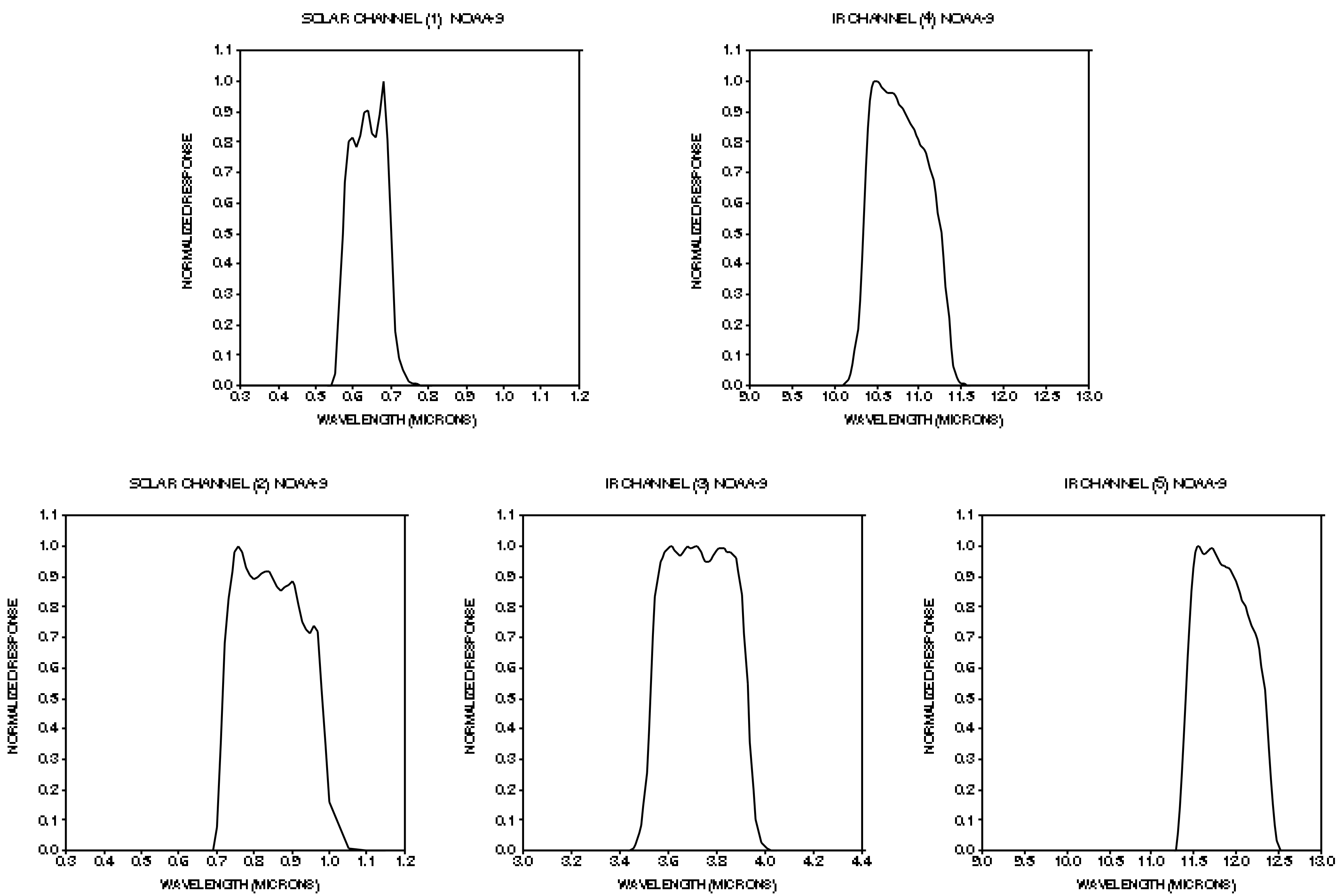

Fig. 2.3. Normalized spectral response functions for NOAA-9. The channels are shown in the order found on B3 data tapes.

TABLE 2.10. Solar Channel Normalized Spectral Responses for NOAA-9.

Channel 1		Channel 2	
Wavelength (μm)	Response	Wavelength (μm)	Response
0.530	0.000	0.680	0.000
0.540	0.001	0.690	0.001
0.550	0.040	0.700	0.080
0.560	0.270	0.710	0.360
0.570	0.500	0.720	0.680
0.580	0.670	0.730	0.830
0.590	0.800	0.740	0.920
0.600	0.815	0.750	0.980
0.610	0.785	0.760	1.000
0.620	0.820	0.770	0.980
0.630	0.895	0.780	0.930
0.640	0.905	0.790	0.905
0.650	0.825	0.800	0.890
0.660	0.815	0.810	0.895
0.670	0.890	0.820	0.908
0.680	1.000	0.830	0.915
0.690	0.810	0.840	0.915
0.700	0.500	0.850	0.890
0.710	0.180	0.860	0.865
0.720	0.090	0.870	0.855
0.730	0.050	0.880	0.865
0.740	0.025	0.890	0.875
0.750	0.015	0.900	0.883
0.760	0.010	0.910	0.870
0.770	0.005	0.920	0.810
0.780	0.003	0.930	0.750
0.790	0.001	0.940	0.725
0.800	0.001	0.950	0.712
0.810	0.000	0.960	0.740
		0.970	0.720
		0.980	0.530
		0.990	0.350
		1.000	0.160
		1.050	0.010
		1.100	0.002
		1.150	0.000

Infrared Channel Normalized Spectral Responses for NOAA-9.

Channel 3		Channel 4		Channel 5	
Wavelength (μm)	Response	Wavelength	Response	Wavelength	Response
3.434	0.00000	10.000	0.00000	11.265	0.00000
3.443	0.00217	10.024	0.00039	11.286	0.00238
3.453	0.00907	10.048	0.00100	11.308	0.05711
3.462	0.02149	10.072	0.00204	11.330	0.14169
3.471	0.03770	10.096	0.00374	11.352	0.24893
3.481	0.05639	10.120	0.00654	11.374	0.37099
3.490	0.08714	10.145	0.01228	11.397	0.50008
3.499	0.14805	10.169	0.02339	11.419	0.62840
3.509	0.25262	10.194	0.04230	11.441	0.74831
3.519	0.39162	10.219	0.07174	11.464	0.85217
3.528	0.54911	10.244	0.11711	11.486	0.93246
3.538	0.70499	10.269	0.18517	11.509	0.98172
3.548	0.83303	10.294	0.28269	11.531	1.00000
3.558	0.91026	10.319	0.41437	11.554	0.99764
3.567	0.94561	10.344	0.56721	11.577	0.98557
3.577	0.96367	10.370	0.71912	11.600	0.97487
3.587	0.98036	10.396	0.84795	11.623	0.97382
3.597	0.99373	10.421	0.93477	11.646	0.97991
3.607	1.00000	10.447	0.98166	11.669	0.98812
3.618	0.99827	10.473	0.99970	11.693	0.99328
3.628	0.98923	10.499	1.00000	11.716	0.99073
3.638	0.97666	10.526	0.99238	11.740	0.98097
3.648	0.96999	10.552	0.98166	11.763	0.96754
3.659	0.97698	10.579	0.97138	11.787	0.95398
3.669	0.99050	10.605	0.96487	11.811	0.94378
3.680	0.99766	10.632	0.96361	11.835	0.93799
3.690	0.99558	10.659	0.96428	11.859	0.93476
3.700	0.99341	10.686	0.96302	11.883	0.93221
3.711	0.99671	10.713	0.95592	11.907	0.92842
3.722	0.99677	10.741	0.94261	11.931	0.92207
3.733	0.98374	10.768	0.92612	11.956	0.91287
3.744	0.96306	10.796	0.90955	11.980	0.90049
3.755	0.94836	10.824	0.89565	12.005	0.88482
3.766	0.94611	10.852	0.88367	12.030	0.86591
3.777	0.95425	10.880	0.87162	12.054	0.84477
3.788	0.96907	10.908	0.85757	12.079	0.82256
3.799	0.98417	10.936	0.84085	12.104	0.80030
3.810	0.99359	10.965	0.82310	12.129	0.77903
3.822	0.99581	10.993	0.80632	12.155	0.75938
3.833	0.99113	11.022	0.79189	12.180	0.74209
3.844	0.98354	11.051	0.77836	12.205	0.72766
3.856	0.97877	11.080	0.76246	12.231	0.71435
3.867	0.97415	11.110	0.74116	12.257	0.69488
3.879	0.95876	11.139	0.71216	12.282	0.66124
3.891	0.91953	11.169	0.67462	12.308	0.60562
3.903	0.84071	11.198	0.62773	12.334	0.52643
3.915	0.71401	11.228	0.57057	12.360	0.43228

Infrared Channel Normalized Spectral Responses (continued).

Channel 3		Channel 4		Channel 5	
Wavelength (µm)	Response	Wavelength	Response	Wavelength	Response
3.926	0.54701	11.258	0.50173	12.386	0.33272
3.938	0.35939	11.289	0.41961	12.413	0.23716
3.951	0.19880	11.319	0.32331	12.439	0.15236
3.963	0.10226	11.350	0.22147	12.466	0.08229
3.975	0.05301	11.380	0.12961	12.492	0.03073
3.987	0.02633	11.411	0.06322	12.519	0.00095
4.000	0.01269	11.442	0.02747	12.546	0.00000
4.012	0.00669	11.473	0.01261		
4.024	0.00423	11.505	0.00778		
4.037	0.00219	11.536	0.00477		
4.050	0.00000	11.568	0.00266		
		11.600	0.00000		

Note the re-ordering of the channels from Table 2.8 to Table 2.9: Ch. 2 below is Ch. 1 above, Ch. 3 below is Ch. 2 above, and Ch. 4 below is Ch. 3 above.

TABLE 2.11. Sample Conversion Tables for NOAA-9.

Counts	Ch 1 S. Rad.	Ch 2 Temp.	Ch 3 S. Rad.	Ch 4 Temp.	Ch 5 Temp.
0	0.000	323.190	0.000	321.730	330.060
25	0.070	315.000	0.070	318.930	320.940
50	0.170	306.270	0.180	315.770	311.230
75	0.280	296.870	0.280	312.360	300.890
100	0.390	286.640	0.390	308.400	289.680
125	0.490	275.280	0.500	303.880	277.360
150	0.600	262.360	0.610	298.570	263.500
175	0.710	247.000	0.710	291.800	247.310
200	0.810	227.380	0.820	283.000	227.170
225	0.920	197.000	0.930	268.500	197.630
250	1.020	000.000	1.040	222.000	000.000

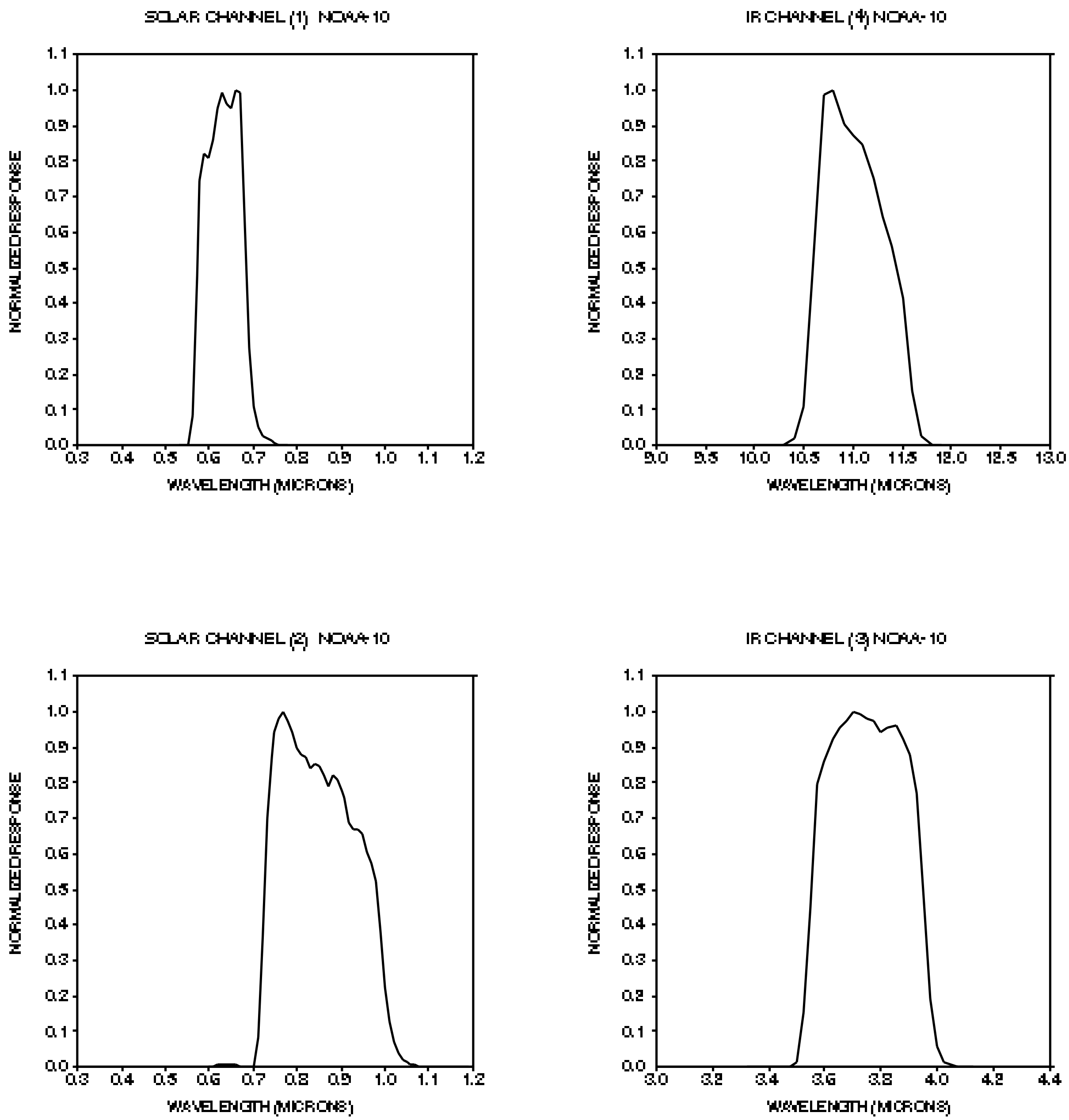

Fig. 2.4. Normalized spectral response functions for NOAA-10. The channels are shown in the order found on B3 data tapes.

TABLE 2.12. Solar Channel Normalized Spectral Responses for NOAA-10.

Channel 1		Channel 2	
Wavelength (µm)	Response	Wavelength (µm)	Response
0.530	0.00000	0.600	0.00000
0.540	0.00200	0.610	0.00240
0.550	0.00300	0.620	0.00480
0.560	0.08660	0.630	0.00510
0.570	0.48100	0.640	0.00530
0.580	0.74500	0.650	0.00550
0.590	0.82100	0.660	0.00570
0.600	0.80980	0.670	0.00440
0.610	0.85800	0.680	0.00310
0.620	0.94900	0.690	0.00330
0.630	0.99560	0.700	0.00340
0.640	0.96300	0.710	0.08550
0.650	0.94900	0.720	0.36800
0.660	1.00000	0.730	0.69900
0.670	0.99200	0.740	0.87500
0.680	0.62900	0.750	0.94200
0.690	0.27300	0.760	0.97800
0.700	0.10700	0.770	1.00000
0.710	0.05300	0.780	0.97330
0.720	0.02800	0.790	0.94450
0.730	0.01800	0.800	0.89800
0.740	0.01200	0.810	0.88000
0.750	0.00800	0.820	0.87500
0.760	0.00420	0.830	0.83800
0.770	0.00100	0.840	0.85200
0.780	0.00000	0.850	0.84700
		0.860	0.82300
		0.870	0.79000
		0.880	0.82300
		0.890	0.80700
		0.900	0.77500
		0.910	0.76000
		0.920	0.69000
		0.930	0.67200
		0.940	0.66800
		0.950	0.65800
		0.960	0.60800
		0.970	0.57300
		0.980	0.52200
		0.990	0.38300
		1.000	0.22500
		1.010	0.13100
		1.020	0.06900
		1.030	0.03800
		1.040	0.02100
		1.050	0.01260
		1.060	0.00790

Solar Channel Normalized Spectral Responses (continued).

Channel 1		Channel 2	
Wavelength (µm)	Response	Wavelength (µm)	Response
		1.070	0.00540
		1.080	0.00410
		1.090	0.00360
		1.100	0.00320
		1.110	0.00290
		1.120	0.00260
		1.130	0.00240
		1.140	0.00210
		1.150	0.00170
		1.160	0.00150
		1.170	0.00140
		1.180	0.00150
		1.190	0.00000

Infrared Channel Normalized Spectral Responses for NOAA-10.

Channel 3		Channel 4	
Wavelength (µm)	Response	Wavelength (µm)	Response
3.325	0.00000	10.000	0.00000
3.350	0.00070	10.100	0.00060
3.375	0.00070	10.200	0.00060
3.400	0.00000	10.300	0.00180
3.425	0.00000	10.400	0.01800
3.450	0.00000	10.500	0.10750
3.475	0.00200	10.600	0.48840
3.500	0.01600	10.700	0.98600
3.525	0.15600	10.800	1.00000
3.550	0.44700	10.900	0.90700
3.575	0.79500	11.000	0.87250
3.600	0.86100	11.100	0.85000
3.625	0.92600	11.200	0.75270
3.650	0.95600	11.300	0.64500
3.675	0.97620	11.400	0.56220
3.700	1.00000	11.500	0.41350
3.725	0.99600	11.600	0.15200
3.750	0.98200	11.700	0.02700
3.775	0.97300	11.800	0.00200
3.800	0.94250	11.900	0.00000
3.825	0.95300		
3.850	0.96200		
3.875	0.92300		
3.900	0.87800		

Infrared Channel Normalized Spectral Responses for NOAA-10 (continued).

Channel 3		Channel 4	
Wavelength (μm)	Response	Wavelength (μm)	Response
3.925	0.77100		
3.950	0.48250		
3.975	0.19300		
4.000	0.05600		
4.025	0.01700		
4.050	0.00540		
4.075	0.00280		
4.100	0.00090		
4.125	0.00000		

Note the re-ordering of the channels from Table 2.11 to Table 2.12: Ch. 2 below is Ch. 1 above, Ch. 3 below is Ch. 2 above, and Ch. 4 below is Ch. 3 above.

TABLE 2.13. Sample Conversion Tables for NOAA-10.

Counts	Ch 1 S. Rad.	Ch 2 Temp.	Ch 3 S. Rad.	Ch 4 Temp.
0	0.00	327.31	0.00	323.06
25	0.06	318.53	0.07	320.21
50	0.16	309.19	0.18	317.00
75	0.26	299.15	0.28	313.50
100	0.36	288.29	0.39	309.60
125	0.46	276.30	0.50	305.00
150	0.55	262.76	0.60	299.63
175	0.65	246.97	0.71	292.83
200	0.75	227.37	0.81	283.75
225	0.85	199.08	0.92	269.50
250	0.95	000.00	1.03	221.00

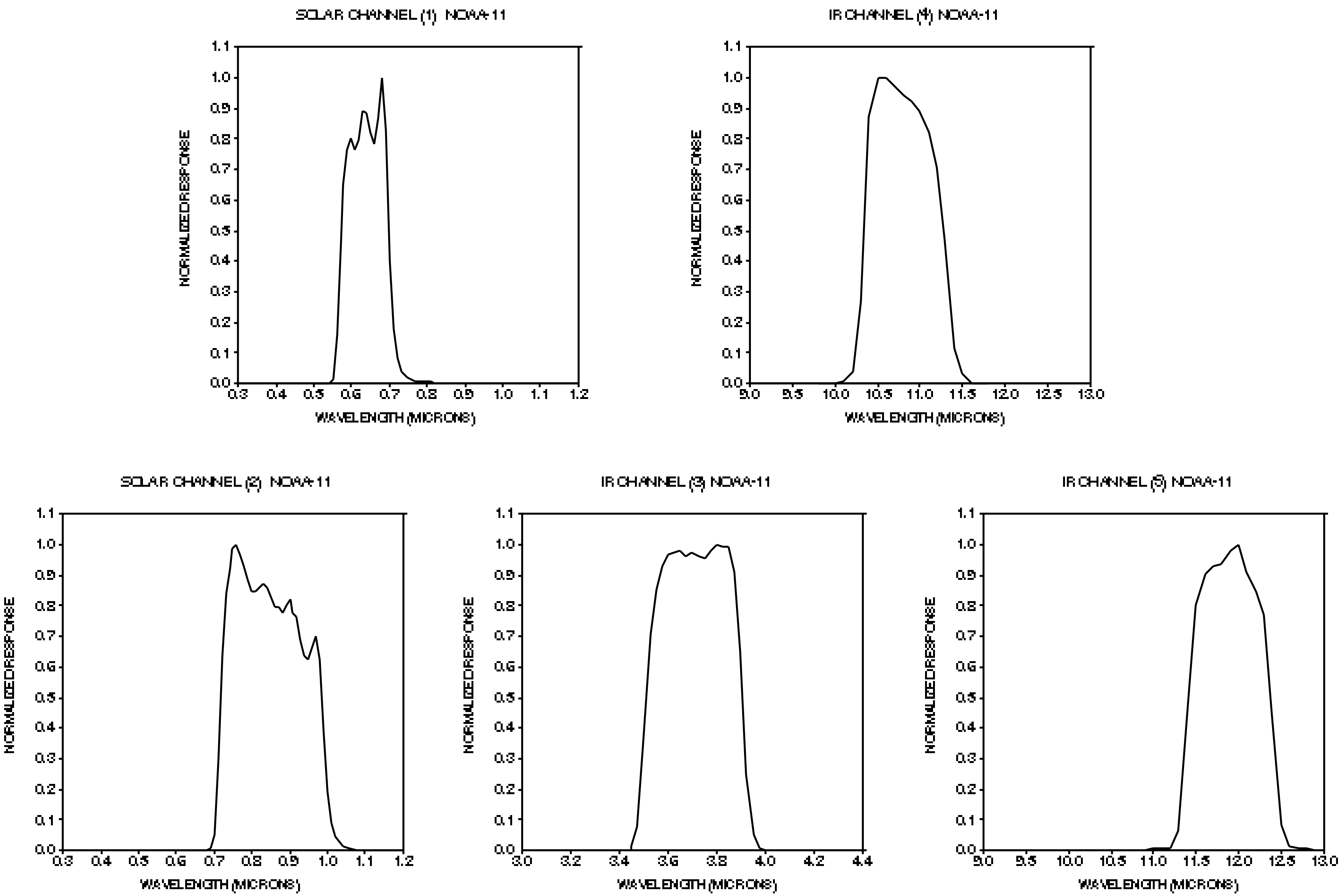

Fig. 2.5. Normalized spectral response functions for NOAA-11. The channels are shown in the order found on B3 data tapes.

TABLE 2.14. Solar Channel Normalized Spectral Responses for NOAA-11.

Channel 1		Channel 2	
Wavelength (µm)	Response	Wavelength (µm)	Response
0.500	0.00000	0.600	0.00000
0.510	0.00000	0.620	0.00400
0.520	0.00000	0.640	0.00300
0.530	0.00000	0.660	0.00200
0.540	0.00000	0.680	0.00200
0.550	0.01300	0.690	0.00500
0.560	0.16100	0.700	0.05400
0.570	0.47100	0.710	0.29800
0.580	0.64700	0.720	0.63500
0.590	0.76600	0.730	0.84100
0.600	0.80000	0.740	0.92600
0.610	0.76700	0.750	0.98800
0.620	0.79800	0.760	1.00000
0.630	0.89200	0.770	0.97000
0.640	0.88700	0.780	0.93000
0.650	0.82000	0.790	0.88700
0.660	0.78400	0.800	0.84700
0.670	0.86800	0.810	0.85000
0.680	1.00000	0.820	0.85700
0.690	0.82500	0.830	0.87000
0.700	0.40200	0.840	0.85900
0.710	0.18100	0.850	0.82500
0.720	0.08400	0.860	0.79800
0.730	0.04200	0.870	0.79900
0.740	0.02600	0.880	0.77700
0.750	0.01900	0.890	0.80300
0.760	0.01500	0.900	0.82100
0.770	0.01000	0.910	0.78000
0.780	0.00500	0.920	0.76700
0.790	0.00600	0.930	0.68800
0.800	0.00600	0.940	0.63800
0.810	0.00600	0.950	0.62600
0.820	0.00000	0.960	0.66000
		0.970	0.69800
		0.980	0.62200
		0.990	0.39200
		1.000	0.19200
		1.010	0.09100
		1.020	0.04500
		1.040	0.01400
		1.060	0.00500
		1.080	0.00300
		1.100	0.00200
		1.120	0.00200
		1.140	0.00200
		1.160	0.00200
		1.180	0.00200
		1.200	0.00200
		1.220	0.00000

Infrared Channel Normalized Spectral Responses for NOAA-11.

Channel 3		Channel 4		Channel 5	
Wavelength (μm)	Response	Wavelength	Response	Wavelength	Response
3.450	0.00000	9.800	0.00000	10.900	0.00000
3.475	0.01100	9.900	0.00010	11.000	0.00500
3.500	0.07500	10.000	0.00010	11.100	0.00500
3.525	0.33700	10.100	0.00500	11.200	0.00600
3.550	0.71000	10.200	0.03800	11.300	0.06200
3.575	0.85200	10.300	0.27100	11.400	0.47800
3.600	0.93300	10.400	0.87400	11.500	0.80400
3.625	0.96600	10.500	1.00000	11.600	0.90400
3.650	0.97700	10.600	0.99800	11.700	0.92800
3.675	0.98000	10.700	0.97400	11.800	0.93400
3.700	0.96400	10.800	0.94500	11.900	0.98200
3.725	0.97200	10.900	0.92100	12.000	1.00000
3.750	0.96100	11.000	0.89400	12.100	0.91200
3.775	0.95500	11.100	0.82200	12.200	0.84500
3.800	0.97800	11.200	0.70600	12.300	0.77200
3.825	1.00000	11.300	0.46900	12.400	0.45600
3.850	0.99100	11.400	0.11500	12.500	0.08600
3.875	0.99500	11.500	0.03300	12.600	0.01700
3.900	0.90800	11.600	0.00400	12.700	0.01000
3.925	0.65300	11.700	0.00100	12.800	0.00900
3.950	0.24900	11.800	0.00000	12.900	0.00000
3.975	0.05300				
4.000	0.00900				
4.025	0.00000				

Note the re-ordering of the channels from Table 2.13 to Table 2.14: Ch. 2 below is Ch. 1 above, Ch. 3 below is Ch. 2 above, and Ch. 4 below is Ch. 3 above.

TABLE 2.15. Sample Conversion Tables for NOAA-11.

Counts	Ch 1 S. Rad.	Ch 2 Temp.	Ch 3 S. Rad.	Ch 4 Temp.	Ch 5 Temp.
0	0.00	336.44	0.00	322.00	327.91
25	0.05	327.42	0.05	319.20	319.00
50	0.14	317.81	0.14	316.00	309.57
75	0.23	307.53	0.23	312.50	299.46
100	0.32	296.40	0.32	308.60	288.58
125	0.41	284.14	0.41	304.00	276.67
150	0.50	270.28	0.50	298.57	263.29
175	0.59	254.10	0.59	291.80	247.78
200	0.68	233.95	0.68	282.75	228.69
225	0.77	205.07	0.77	268.00	201.78
250	0.86	000.00	0.86	222.00	000.00

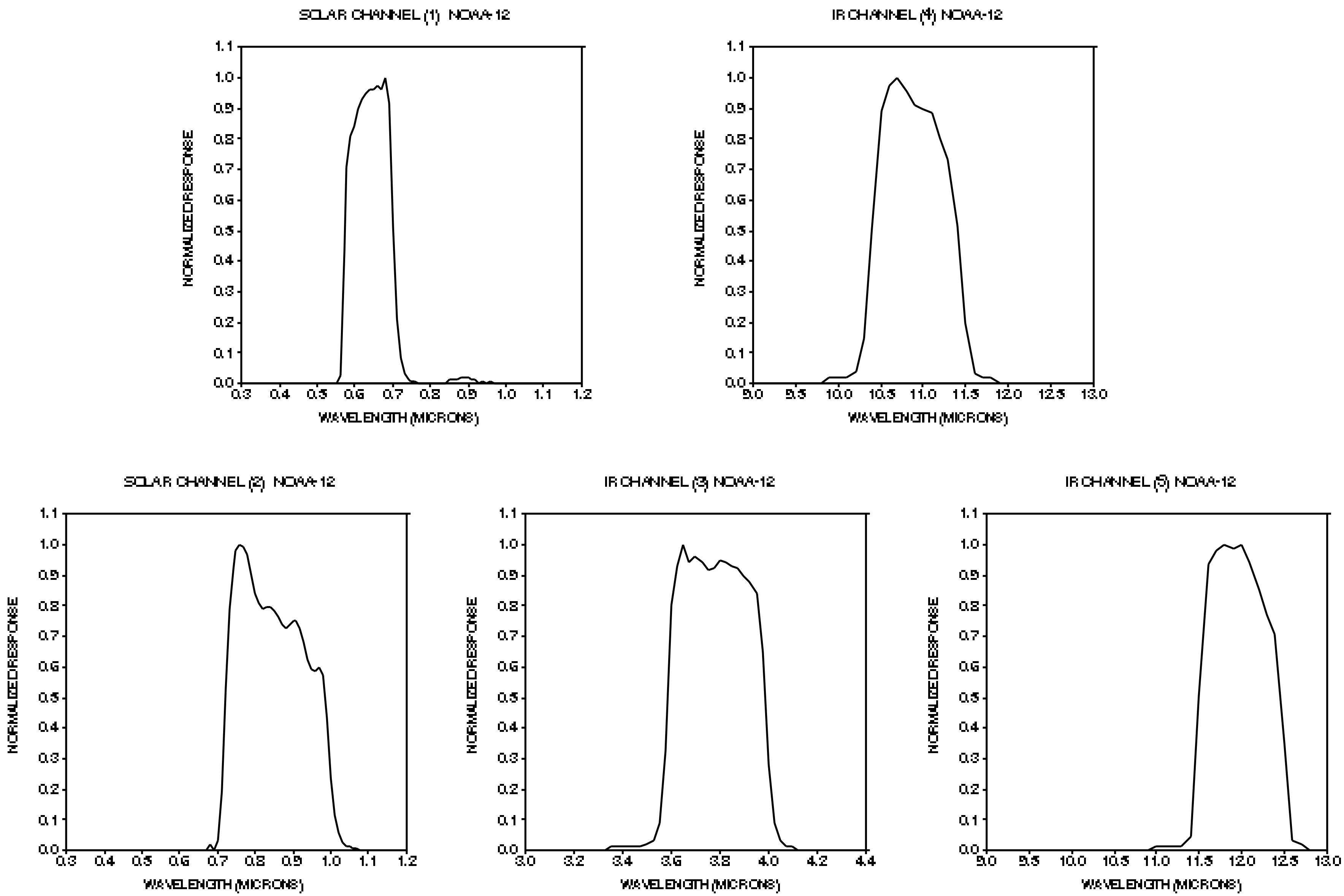

Fig. 2.6. Normalized spectral response functions for NOAA-12. The channels are shown in the order found on B3 data tapes.

TABLE 2.16. Solar Channel Normalized Spectral Responses for NOAA-12.

Channel 1		Channel 2	
Wavelength (µm)	Response	Wavelength (µm)	Response
0.550	0.00000	0.670	0.00000
0.560	0.02700	0.680	0.01800
0.570	0.43600	0.690	0.00000
0.580	0.70900	0.700	0.03300
0.590	0.81100	0.710	0.18900
0.600	0.83800	0.720	0.53000
0.610	0.89900	0.730	0.79200
0.620	0.93200	0.740	0.92200
0.630	0.95100	0.750	0.97800
0.640	0.96200	0.760	1.00000
0.650	0.95900	0.770	0.99200
0.660	0.97300	0.780	0.96500
0.670	0.96400	0.790	0.90300
0.680	1.00000	0.800	0.84100
0.690	0.91800	0.810	0.80600
0.700	0.51200	0.820	0.78800
0.710	0.21400	0.830	0.79400
0.720	0.08500	0.840	0.79600
0.730	0.03600	0.850	0.78200
0.740	0.01600	0.860	0.76500
0.750	0.00800	0.870	0.73700
0.760	0.00800	0.880	0.72900
0.770	0.00000	0.890	0.73800
0.780	0.00000	0.900	0.74900
0.790	0.00000	0.910	0.74900
0.800	0.00000	0.920	0.72900
0.810	0.00000	0.930	0.68200
0.820	0.00000	0.940	0.62400
0.830	0.00000	0.950	0.59200
0.840	0.00000	0.960	0.58600
0.850	0.01100	0.970	0.60000
0.860	0.01100	0.980	0.57500
0.870	0.01600	0.990	0.43400
0.880	0.01900	1.000	0.23600
0.890	0.02200	1.010	0.11300
0.900	0.02200	1.020	0.05600
0.910	0.01600	1.030	0.02900
0.920	0.01400	1.040	0.01700
0.930	0.00000	1.050	0.01100
0.940	0.00500	1.060	0.00700
0.950	0.00000	1.070	0.00500
0.960	0.00500	1.080	0.00000
0.970	0.00000	1.090	0.00400
		1.100	0.00000

Infrared Channel Normalized Spectral Responses for NOAA-12.

Channel 3		Channel 4		Channel 5	
Wavelength (µm)	Response	Wavelength	Response	Wavelength	Response
3.325	0.00000	9.800	0.00000	10.900	0.00000
3.350	0.01300	9.900	0.01900	11.000	0.01400
3.375	0.01300	10.000	0.01900	11.100	0.01400
3.400	0.01300	10.100	0.02300	11.200	0.01400
3.425	0.01300	10.200	0.03700	11.300	0.01400
3.450	0.01200	10.300	0.14700	11.400	0.04500
3.475	0.01500	10.400	0.50600	11.500	0.50100
3.500	0.01800	10.500	0.89200	11.600	0.93600
3.525	0.03500	10.600	0.97300	11.700	0.98300
3.550	0.08900	10.700	1.00000	11.800	0.99800
3.575	0.32500	10.800	0.95800	11.900	0.98400
3.600	0.80200	10.900	0.90800	12.000	1.00000
3.625	0.93200	11.000	0.89600	12.100	0.94400
3.650	1.00000	11.100	0.88400	12.200	0.85400
3.675	0.94400	11.200	0.80300	12.300	0.77100
3.700	0.95900	11.300	0.73000	12.400	0.70700
3.725	0.94100	11.400	0.51800	12.500	0.35400
3.750	0.91900	11.500	0.20000	12.600	0.03600
3.775	0.92300	11.600	0.03300	12.700	0.02200
3.800	0.94900	11.700	0.01900	12.800	0.00000
3.825	0.94300	11.800	0.01900		
3.850	0.92800	11.900	0.00000		
3.875	0.92200				
3.900	0.89600				
3.925	0.88100				
3.950	0.84300				
3.975	0.65300				
4.000	0.28300				
4.025	0.09100				
4.050	0.03000				
4.075	0.01300				
4.100	0.01200				
4.125	0.00000				

TABLE 2.17. Sample Conversion Tables for NOAA-12.

Counts	Ch 1 S. Rad.	Ch 2 Temp.	Ch 3 S. Rad.	Ch 4 Temp.	Ch 5 Temp.
0	0.00	321.95	0.00	320.13	324.36
25	0.06	314.00	0.06	317.33	315.61
50	0.16	305.53	0.16	314.17	306.33
75	0.26	296.45	0.27	310.67	296.43
100	0.37	286.60	0.37	306.80	285.72
125	0.47	275.67	0.47	302.25	274.00
150	0.57	263.38	0.58	297.00	260.90
175	0.67	249.00	0.68	290.33	245.69
200	0.77	231.07	0.78	281.25	226.92
225	0.88	205.33	0.88	267.50	200.63
250	0.98	000.00	0.99	220.00	000.00

2.3. NORMALIZED CALIBRATION

Table 2.18 gives the coefficients for Equations (1.3) and (1.4) that normalize all other polar orbiter calibrations to that of NOAA-7 in July 1983. The values shown apply only for the dates shown, additional adjustments may occur (see Section 2.4).

TABLE 2.18. Normalization coefficients for polar orbiters.

	VIS		IR		
Satellite	Slope (A_1)	Intercept (B_1)	Slope (A_2)	Intercept (B_2)	Date
NOAA-8	1.000	0.000	1.000	0.0	OCT 83
NOAA-9	0.835	0.002	1.000	0.0	JAN/FEB 85
NOAA-10	0.850	0.002	1.065	-20.5	DEC 86
NOAA-10*	0.850	0.002	1.076	-21.9	JAN 89
NOAA-11	0.940	0.001	1.067	-19.0	OCT/NOV 88
NOAA-12	——	——	——	——	SEP 91

* Incorrect bandwidths were used for NOAA-10 data from DEC 86 through DEC 88; when the correct bandwidths were employed, starting in JAN 89, the normalization changed as shown.

2.4. ABSOLUTE CALIBRATION

No significant calibration drifts were detected for NOAA-7 AVHRR during the 19 month period from July 1983 through January 1985; however, a study of a longer time record does indicate a 1.5% per year drift of Channel 1 (Staylor 1990). No trend corrections were made to NOAA-7 data (Brest and Rossow 1992). All NOAA-7 VIS data on B3 data tapes should be multiplied by 1.2.

No drift of calibration was detected for NOAA-8 AVHRR over the eight month period from October 1983 through May 1984; no corrections were made. All NOAA-8 VIS data on B3 data tapes should be multiplied by 1.2.

Significant changes of calibration for Channels 1 and 4 were found for NOAA-9 AVHRR (cf., Staylor 1990) and adjustments were made (Brest and Rossow 1992). Table 2.19 shows the coefficients used to remove the effects of a slow degradation of Channel 1 sensitivity; the total correction, including the factor of 1.2, is also shown. Table 2.20 shows adjustments made to Channel 4 calibration.

Tables 2.21 and 2.22 show the calibration adjustments made to NOAA-10 AVHRR.

Tables 2.23 and 2.24 show the calibration adjustments made to NOAA-11 AVHRR.

TABLE 2.19. NOAA-9 VIS corrections (fraction). Total correction includes the factor of 1.2, not included on B3 data tapes.

	Trend Correction Factor	Total Correction	
Month	1.00362 per month	Slope	Intercept
JAN 85	1.000	1.002	0.002
FEB 85	1.000	1.002	0.002
MAR 85	1.004	1.006	0.002
APR 85	1.007	1.009	0.002
MAY 85	1.011	1.013	0.002
JUN 85	1.015	1.018	0.002
JUL 85	1.018	1.020	0.002
AUG 85	1.022	1.024	0.002
SEP 85	1.026	1.028	0.002
OCT 85	1.029	1.031	0.002
NOV 85	1.033	1.036	0.002
DEC 85	1.037	1.039	0.002
JAN 86	1.041	1.043	0.002
FEB 86	1.044	1.046	0.002
MAR 86	1.048	1.050	0.002
APR 86	1.052	1.054	0.002
MAY 86	1.056	1.058	0.002
JUN 86	1.060	1.062	0.002
JUL 86	1.063	1.066	0.002
AUG 86	1.067	1.069	0.002
SEP 86	1.071	1.073	0.002
OCT 86	1.075	1.078	0.002
NOV 86	1.079	1.081	0.002
DEC 86	1.083	1.085	0.002
JAN 87	1.087	1.090	0.002
FEB 87	1.091	1.093	0.002
MAR 87	1.095	1.097	0.002
APR 87	1.099	1.102	0.002
MAY 87	1.103	1.105	0.002
JUN 87	1.107	1.109	0.002
JUL 87	1.111	1.114	0.002
AUG 87	1.115	1.117	0.002
SEP 87	1.119	1.121	0.002
OCT 87	1.123	1.126	0.002
NOV 87	1.127	1.129	0.002
DEC 87	1.131	1.133	0.002

NOAA-9 VIS corrections (fraction).

Month	Trend Correction Factor 1.00362 per month	Total Correction Slope	 Intercept
JAN 88	1.135	1.138	0.002
FEB 88	1.139	1.141	0.002
MAR 88	1.143	1.145	0.002
APR 88	1.147	1.150	0.002
MAY 88	1.151	1.153	0.002
JUN 88	1.156	1.158	0.002
JUL 88	1.160	1.163	0.002
AUG 88	1.164	1.166	0.002
SEP 88	1.168	1.170	0.002
OCT 88	1.172	1.175	0.002
NOV 88	1.177	1.180	0.002

TABLE 2.20. NOAA-9 IR corrections

Month	IR Calibration Adjustments	Slope	Intercept (K)
FEB 85		1.000	0.00
:			
OCT 86	(IR 10-percentile, mean and 90-percentile changed, also detected in normalization results - adjusted to long-term means)	1.028	-8.50
NOV 86		1.00	0.00
:			
MAR 87	(IR 90-percentile changed - no adjustment made)		
:			
OCT 87	(IR 10-percentile, mean and 90-percentile changed as a sudden step, also detected in normalization results - group means adjusted to long-term means)	1.038	-11.50
NOV 87	- -	1.038	-11.50
:			
NOV 88	- -	1.038	-11.50

TABLE 2.21. NOAA-10 VIS corrections (fraction). Total correction includes the factor of 1.2 not included on B3 data tapes.

Month	Trend Correction Factor 1.00370 per month	Total Correction Slope	Total Correction Intercept
DEC 86	1.000	1.020	0.002
JAN 87	1.004	1.024	0.002
FEB 87	1.007	1.031	0.002
MAR 87	1.011	1.031	0.002
APR 87	1.015	1.036	0.002
MAY 87	1.019	1.039	0.002
JUN 87	1.022	1.043	0.002
JUL 87	1.026	1.046	0.002
AUG 87	1.030	1.051	0.002
SEP 87	1.034	1.055	0.002
OCT 87	1.038	1.058	0.002
NOV 87	1.041	1.062	0.002
DEC 87	1.045	1.066	0.002
JAN 88	1.049	1.070	0.002
FEB 88	1.053	1.074	0.002
MAR 88	1.057	1.079	0.002
APR 88	1.061	1.082	0.002
MAY 88	1.065	1.086	0.002
JUN 88	1.069	1.091	0.002
JUL 88	1.073	1.094	0.002
AUG 88	1.077	1.099	0.002
SEP 88	1.081	1.103	0.002
OCT 88	1.085	1.106	0.002
NOV 88	1.089	1.111	0.002
DEC 88	1.093	1.115	0.002
JAN 89	1.097	1.119	0.002
FEB 89	1.101	1.123	0.002
MAR 89	1.105	1.127	0.002
APR 89	1.109	1.131	0.002
MAY 89	1.113	1.135	0.002
JUN 89	1.000	1.117	-0.005
JUL 89	1.000	1.117	-0.005
AUG 89	1.000	1.117	-0.005
SEP 89	1.000	1.117	-0.005
OCT 89	1.000	1.117	-0.005
NOV 89	1.000	1.117	-0.005
DEC 89	1.000	1.117	-0.005
JAN 90	1.000	1.117	-0.005
FEB 90	1.000	1.117	-0.005
MAR 90	1.000	1.117	-0.005
APR 90	1.000	1.117	-0.005
MAY 90	1.000	1.117	-0.005
JUN 90	1.000	1.117	-0.005
JUL 90	1.000	1.117	-0.005
AUG 90	1.000	1.117	-0.005
SEP 90	1.000	1.117	-0.005

NOAA-10 VIS corrections (fraction - continued).

Month	Trend Correction Factor 1.00370 per month	Total Correction Slope	Total Correction Intercept
OCT 90	1.000	1.117	-0.005
NOV 90	1.000	1.117	-0.005
DEC 90	1.000	1.117	-0.005
JAN 91	1.000	1.117	-0.005
FEB 91	1.000	1.117	-0.005
MAR 91	1.000	1.117	-0.005
APR 91	1.000	1.117	-0.005
MAY 91	1.000	1.117	-0.005
JUN 91	1.000	1.117	-0.005
JUL 91	1.000	1.117	-0.005
AUG 91	1.000	1.117	-0.005

TABLE 2.22. NOAA-10 IR corrections.

Month	IR Calibration Adjustments	Slope	Intercept (K)
DEC 86		1.065	-20.5
⋮			
JAN 89	(change of bandwidth value used for nominal calibration required change of normalization)		
⋮		1.076	-21.9
AUG 91		1.076	-21.9

TABLE 2.23. NOAA-11 VIS corrections (fraction). Total correction includes the factor of 1.2 not included on B3 data tapes.

Month	Trend Correction Factor 1.00000 per month	Total Correction Slope	Total Correction Intercept
OCT 88	1.000	1.128	0.001
NOV 88	1.000	1.128	0.001
DEC 88	1.000	1.128	0.001
JAN 89	1.000	1.128	0.001
FEB 89	1.000	1.128	0.001
MAR 89	1.000	1.128	0.001
APR 89	1.000	1.128	0.001
MAY 89	1.000	1.128	0.001

NOAA-11 VIS corrections (fraction - continued).

Month	Trend Correction Factor 1.00000 per month	Total Correction Slope	Total Correction Intercept
JUN 89	1.000	1.128	0.001
JUL 89	1.000	1.128	0.001
AUG 89	1.000	1.128	0.001
SEP 89	1.000	1.128	0.001
OCT 89	1.000	1.128	0.001
NOV 89	1.000	1.128	0.001
DEC 89	1.000	1.128	0.001
JAN 90	1.000	1.128	0.001
FEB 90	1.000	1.128	0.001
MAR 90	0.995	1.122	0.001
APR 90	0.990	1.117	0.001
MAY 90	0.984	1.110	0.001
JUN 90	0.979	1.104	0.001
JUL 90	0.974	1.099	0.001
AUG 90	0.969	1.093	0.001
SEP 90	0.964	1.087	0.001
OCT 90	0.959	1.082	0.001
NOV 90	0.954	1.076	0.001
DEC 90	0.949	1.070	0.001
JAN 91	0.944	1.065	0.001
FEB 91	0.939	1.059	0.001
MAR 91	0.934	1.054	0.001
APR 91	0.929	1.048	0.001
MAY 91	0.925	1.043	0.001
JUN 91	0.920	1.038	0.001
JUL 91	0.915	1.032	0.001
AUG 91	0.910	1.026	0.001
SEP 91	0.906	1.022	0.001
OCT 91	0.901	1.016	0.001
NOV 91	0.896	1.011	0.001
DEC 91	0.891	1.005	0.001

TABLE 2.24. NOAA-11 IR corrections.

Month	IR Calibration Adjustments	Slope	Intercept (K)
NOV 88	(normalization to NOAA-7)	1.067	-19.00
:			
DEC 91		1.067	-19.00

3. METEOSAT

This satellite system, operated by the European Space Agency (ESA), has been in geostationary orbit since December 1977. METEOSAT is a spin-stabilized spacecraft, stationed on the Greenwich meridian. At the beginning of ISCCP data collection in July 1983, imaging data were obtained from METEOSAT-2. The first of the operational series (MOP-1) replaced METEOSAT-2 in August 1988 and was renamed METEOSAT-3. METEOSAT-4 became operational in May 1989; however, temporary problems caused a switch back to METEOSAT-3 from January to April 1990 (see Rossow et al. 1987 for more details). Some METEOSAT-3 data were also collected to supplement METEOSAT-4 from October 1990 through January 1991. In August 1991, METEOSAT-3 was moved to 50°W to supplement coverage by GOES-7 after the failure of GOES-6. METEOSAT-5 was launched in 1991 and is being held in reserve.

The radiometers on METEOSAT-2, 3, 4 and 5 have three channels with nominal center wave-lengths of 0.75 µm, 6.5 µm and 11.7 µm (Morgan 1978). ISCCP calibration information is provided only for the visible and thermal infrared (11 µm) channels. Radiometer spectral responses are illustrated in Section 3.2. Instrument characteristics are shown in table 3.1.

TABLE 3.1. METEOSAT radiometer characteristics

Channel	VIS1/VIS2	IR1/IR2	IR3
Spectral band (µm)	0.4 - 1.1	10.5 - 12.5	5.7 - 7.1
Nadir resolution (km)	2.5	5.0	5.0

3.1. NOMINAL CALIBRATION

(1) SOLAR CHANNEL

Pre-launch calibration tests were performed to define the spectral response of the solar channel and to relate voltage output from the instrument to a known radiance (Hollier 1977). For a given gain setting, i, the sensitivity, $S_{i\lambda}$, is defined by

$$S_{i\lambda} = V_{i\lambda} \; L_{\lambda}^{-1} \tag{3.1}$$

where the instrument voltage, $V_{i\lambda}$, when illuminated by radiance L_λ, is

$$V_{i\lambda} = K_s \; (1.2)^i \; \tau_\lambda \; r_\lambda \; L_\lambda \tag{3.2}$$

K_s is the combined sensitivity of the optics and electronics when the gain i = 0, τ_λ is the optics transmittance and r_λ is the detector sensitivity. Thus the total spectral response is given by

$$S_{i\lambda} = K_s \; (1.2)^i \; \tau_\lambda \; r_\lambda \tag{3.3}$$

Pre-launch measurements were made with a monochromatic source, λ = 0.65 µm and L_λ = 31.6 watts m^{-2} sr^{-1}. Using a gain setting of 3, K_s is found to be 0.0280 volts $watts^{-1}$ m^2 sr. The value of $S_{i\lambda}$, normalized by its maximum value, is shown in Tables 3.3, 3.5, 3.7 and 3.9. The uncertainty of these measurements is estimated to be about 10%. Integration of $S_{i\lambda}$ times the solar irradiance gives the voltage output of the instrument corresponding to its effective solar spectral irradiance. Voltage readings from the spacecraft are related to (8-bit) counts by

$$1 \; CT = 0.085 \; volts \tag{3.4}$$

Post-launch comparisons of the METEOSAT-2 solar channel output with aircraft measurements by a precision radiometer gave the following results by K.T. Kriebel:

TABLE 3.2. Calibration factors for METEOSAT-2 in watts m^{-2} sr^{-1} $count^{-1}$. Counts are 8-bit integers.

Surface Type /	Date of Observation	Calibration Factor
La Mancha /	3 Nov. 1981	1.07
Desert (Tunisia) /	12 Nov. 1981	0.97
Cloud (Altostratus) /	20 Nov. 1981	1.13
Ocean /	3-20 Nov. 1981	1.6 - 2.0

The calibration factors obtained by Kriebel vary because of the difference in the spectral responses of the METEOSAT and aircraft radiometers and their interaction with the differing radiation spectra reflected from different scenes.

Koepke (1982) combined measurements of atmospheric and surface optical properties with radiative transfer calculations to obtain the effective radiances measured by the METEOSAT-1 radiometer. Effective radiances represent the energy actually sensed by the instrument by weighting the signal spectrum by the instrument response function. On the other hand, the calibration values obtained by Kriebel represent calibrations which attempt to remove the effects of the varying instrument spectral sensitivity; however, these calibration coefficients depend on the spectrum of the signal. Our calibration to effective radiances assumes a constant signal spectrum, namely, the solar spectrum at the top of the atmosphere. We adopt Koepke's result for METEOSAT-1 (which compares reasonably with Kriebel's results for specific scenes), but scale to METEOSAT-2 using the ratio of sensitivities suggested by Kriebel, namely 0.87 (see Rossow et al. 1987 for more details). Note that this ratio is scene independent. Therefore, the ISCCP calibration relation used for METEOSAT-2, 3, 4 and 5 is

$$L = 0.58(CT - 2) \text{ watts } m^{-2} \text{ sr}^{-1} \qquad (3.5)$$

where CT is an 8-bit count value. The scaled radiance L^* is obtained by dividing by the effective solar irradiance, E_o/π = 159.28 watts m^{-2} sr^{-1} for METEOSAT-2, 197.32 watts m^{-2} sr^{-1} for METEOSAT-3, and 201.80 watts m^{-2} sr^{-1} for METEOSAT-4, and 197.71 watts m^{-2} sr^{-1} for METEOSAT-5.

(2) INFRARED CHANNELS

Pre-launch calibration of both the IR channel (11.7 µm) and the WV (water vapor) channel (6.5 µm) established a linear relation between output voltage (represented by counts) and radiance (Hollier 1977). The spectral response, defined as for the solar channel, was also measured:

$$S_{i\lambda} = K_T \, (1.2)^i \, \tau_\lambda r_\lambda \qquad (3.6)$$

where $K_T = K_{IR}$ or K_{WV} depending on the channel. The normalized values of $S_{i\lambda}$ are given in Tables 3.3, 3.5, 3.7 and 3.9 for both channels. K_T is obtained from pre-launch measurements of a calibrated black-body at a standard reference temperature of 290K for the IR channel and 260K for the WV channel:

$$K_T = V_{T,i,\Theta} \left[(1.2)^i \int \tau_\lambda \, r_\lambda \, B(\lambda,\Theta) \, d\lambda \right]^{-1} \qquad (3.7)$$

where Θ is the temperature of the black-body, B(λ,Θ) is the Planck function and $V_{T,i,\Theta}$ is the output voltage at gain i. For the IR channel, $V_{T,8,290}$ = 3.09 volts for a detector temperature of 85K and 1.65 volts for a detector temperature of 110K. This gives K_{IR} = 0.11 volts watts^{-1} m^{2} sr at 90K. For the WV channel, $V_{T,5,260}$ = 3.35 volts for a detector temperature of 85K and 2.82 volts for a detector temperature of 110K. This gives K_{WV} = 0.91 volts watts^{-1} m^{2} sr at 90K. Section 3.2 shows the calculated spectral response for these two channels with the detector temperature maintained at 90K.

Post-launch calibration is monitored in two ways because the on-board calibration procedure does not provide an absolute calibration. The IR channel views the on-board black-body standard by means of a mirror introduced into the optical pathway in the instrument. Consequently, the calibration source is not viewed through the main optics as is the Earth and the Earth view does not involve the mirror used to view the calibration source. The WV channel does not view the calibration source at all.

The IR channel calibration is obtained twice daily by viewing space and the Earth's ocean in cloud free areas. Conventional sea surface temperature measurements by ships, together with a radiative transfer model calculation of atmospheric attenuation, are compared to these IR channel measurements to obtain the second calibration point (a space view provides the first point). Instrument output voltage is converted to count values by a factor 170 $(1.2)^{-i}$counts volt^{-1}, where i is the gain. The two calibration points give a gain, G_{IR}; and an intercept, Y_{IR}. Sample values reported are G_{IR} = 0.046 watts m^{-2} sr^{-1} count^{-1} and Y_{IR} = 5.0 counts. These calibration values are not changed unless the mean bias between the METEOSAT observations and the conventional ship measurements of sea surface temperature exceeds ± 0.5K. However, because the radiative transfer model used in this procedure assumes a sea surface emissivity of unity, instead of the correct value of 0.98, this procedure biases METEOSAT brightness temperatures by about + 2.5K (Koepke 1980).

The diurnal heating/cooling cycle that the satellite undergoes in orbit introduces shorter term variations in instrument response. In particular, the detector spectral sensitivity varies strongly with temperature. This effect is removed by thermostatic control of the detector temperature to 90K and twice daily observations of the on-board black-body calibration source. The on-board calibration procedure is used to determine a fine adjustment of gain factor, f_{IR}, by

$$f_{IR} = \frac{110}{CT_N} \tag{3.8}$$

where CT_N is the normalized count value measured when the instrument views the on-board black-body which is assumed to be at a temperature of 290K. A typical reported value of f_{IR} is 0.94.

Telemetry count values are converted to radiance units by

$$L_{IR} = f_{IR}\ G_{IR}\ (CT - Y_{IR})\ \text{watts m}^{-2}\ \text{sr}^{-1}. \tag{3.9}$$

The spectral response function of the IR channel, together with the Planck function of temperature, is used to calculate radiances measured by this channel when observing a black-body with various temperatures. A table of such values, provided by ESA, is used to convert radiance values to brightness temperatures. To make METEOSAT IR data consistent with all other satellites, the count values in Stage B3 data have been changed to (255-CT), so that high count values represent low radiance or brightness temperature.

The WV channel calibration is performed by comparing simultaneous measurements of high clouds (usually large cumulonimbus towers) by the WV and IR channels. Using the IR channel calibration information and the spectral response functions for the two channels, the radiance measured by the WV channel is calculated from the Planck function. This observation fixes the upper point of the calibration while the lower point is determined from a space view. The gain, G_{WV}, and the intercept, Y_{WV}, are then used to obtain a measure of upper tropospheric humidity from WV channel observations. The humidity is compared to the (arithmetic) mean humidity measured at all standard pressure levels between 700 and 300 mb by co-located radiosonde data. Eliminating any bias between the WV channel and radiosonde humidity provides the calibration of the WV channel. Sample reported values are G_{WV} = 0.00865 watts m^{-2} sr^{-1} $count^{-1}$ and Y_{WV} = 6.0 counts. No fine adjustment of gain is made for the WV channel.

Telemetry count values are converted to radiance units by

$$L_{WV} = G_{WV}\,(CT - Y_{WV})\ \text{watts m}^{-2}\ \text{sr}^{-1} \tag{3.10}$$

The spectral response function of WV channel, together with the Planck function of temperature, is used to calculate radiances measured by this channel when observing a black-body with various temperatures. Count values are recorded as (255-CT).

Sample tables in Section 3.2 illustrate the conversion of solar and thermal channel counts to scaled radiances and brightness temperatures.

3.2. METEOSAT SPECTRAL RESPONSE

The spectral responses for each channel on METEOSAT-2, 3, 4 and 5 are given in Tables 3.3, 3.5, 3.7 and 3.9 and illustrated in Figs. 3.1, 3.2, 3.3 and 3.4.

Tables relating temperature and infrared radiance are used to convert radiance values to brightness temperatures. This table is supplied by ESA; however, radiances values were divided by 0.533 for METEOSAT-2, 3 and 4 to make the response function normalization consistent with the definition in Eq. (2.7).

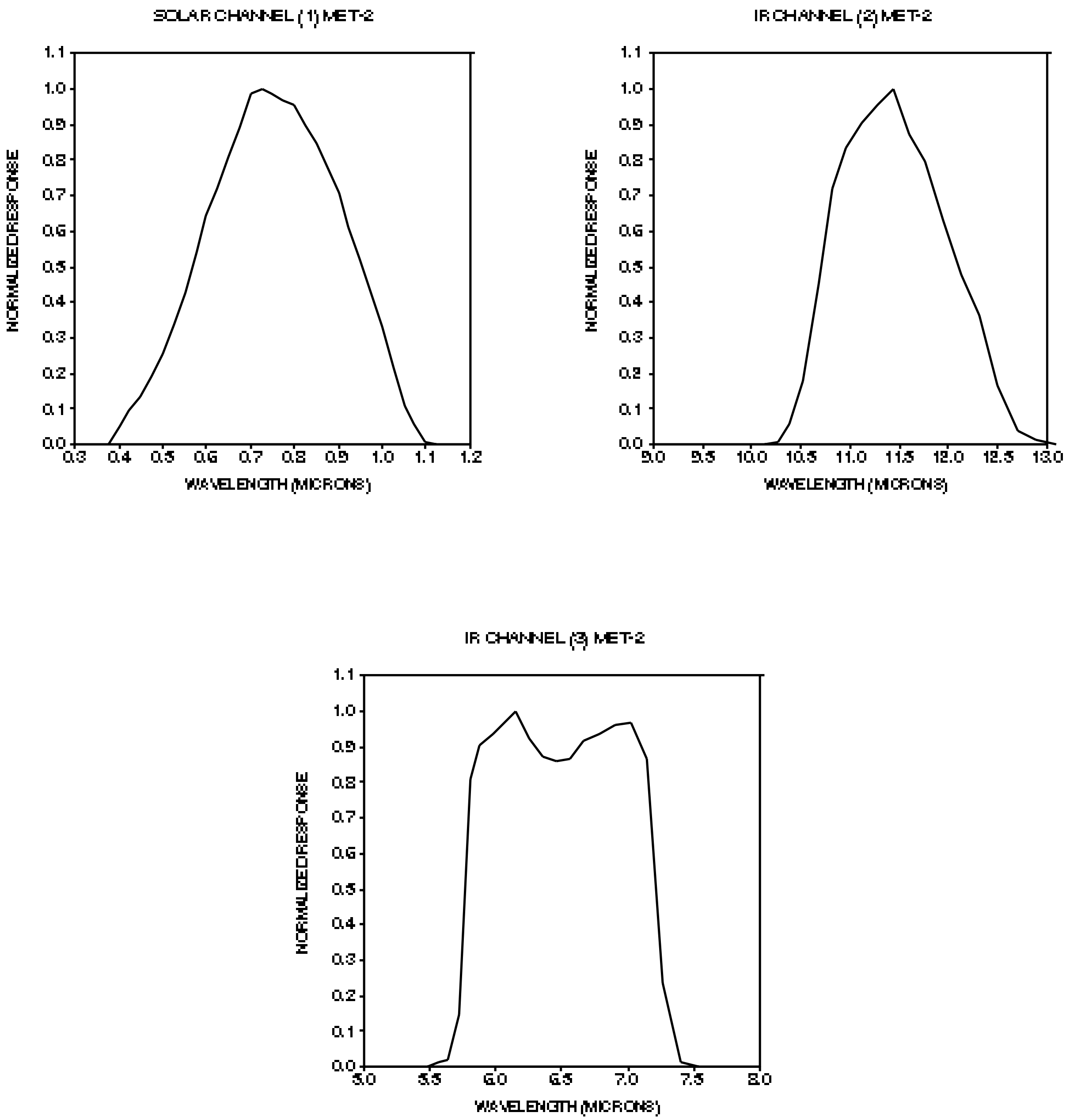

Fig. 3.1. Normalized spectral response functions for METEOSAT-2.

TABLE 3.3. Normalized Spectral Responses for METEOSAT-2.

Channel 1		Channel 2		Channel 3	
Wavelength (µm)	Response	Wavelength	Response	Wavelength	Response
0.375	0.000	10.130	0.000	5.480	0.000
0.400	0.053	10.260	0.010	5.560	0.015
0.425	0.097	10.390	0.058	5.630	0.021
0.450	0.136	10.530	0.177	5.710	0.145
0.475	0.192	10.670	0.455	5.800	0.811
0.500	0.255	10.810	0.722	5.880	0.904
0.525	0.339	10.960	0.837	5.970	0.935
0.550	0.428	11.110	0.906	6.060	0.968
0.575	0.542	11.270	0.952	6.150	1.000
0.600	0.644	11.430	1.000	6.250	0.923
0.625	0.719	11.590	0.870	6.350	0.874
0.650	0.808	11.760	0.797	6.450	0.862
0.675	0.892	11.940	0.629	6.560	0.869
0.700	0.990	12.120	0.475	6.670	0.915
0.725	1.000	12.310	0.361	6.780	0.937
0.750	0.987	12.500	0.166	6.900	0.961
0.775	0.965	12.700	0.042	7.020	0.967
0.800	0.956	12.900	0.016	7.140	0.868
0.825	0.901	13.100	0.000	7.270	0.236
0.850	0.847			7.410	0.013
0.875	0.779			7.550	0.000
0.900	0.704				
0.925	0.612				
0.950	0.520				
0.975	0.425				
1.000	0.330				
1.025	0.220				
1.050	0.110				
1.075	0.058				
1.100	0.005				
1.125	0.000				

TABLE 3.4. Sample Conversion Tables for METEOSAT-2.

Counts	Ch. 1 Scaled Radiance	Ch. 2 Temperature	Ch. 3 Temperature
0	0.000	336.060	0.000
25	0.119	327.090	206.000
50	0.239	317.580	224.330
75	0.358	307.410	235.200
100	0.477	296.460	243.200
125	0.596	284.460	249.830
150	0.716	270.950	255.440
175	0.835	255.280	260.500
200	0.954	236.000	264.550
225	1.074	209.000	268.450
250	1.193	000.000	272.150

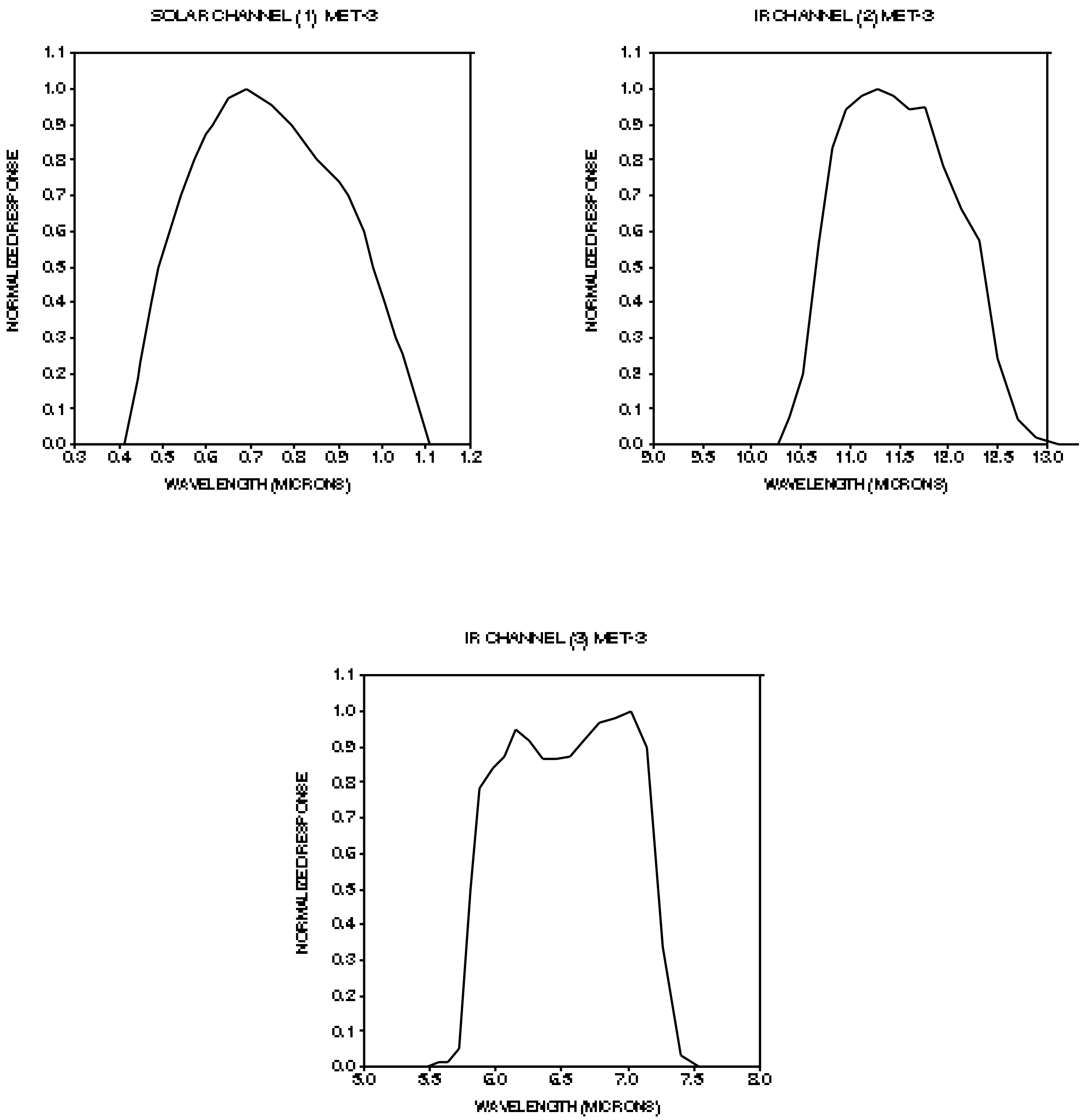

Fig. 3.2. Normalized spectral response functions for METEOSAT-3.

TABLE 3.5. Normalized Spectral Responses for METEOSAT-3.

Channel 1		Channel 2		Channel 3	
Wavelength (μm)	Response	Wavelength	Response	Wavelength	Response
0.414	0.00000	10.260	0.00000	5.480	0.00000
0.443	0.18400	10.390	0.07900	5.560	0.01200
0.450	0.22800	10.530	0.19700	5.630	0.01200
0.475	0.40000	10.670	0.56500	5.710	0.05200
0.492	0.50000	10.810	0.83700	5.800	0.50000
0.513	0.60000	10.960	0.94500	5.880	0.78300
0.540	0.70000	11.110	0.98200	5.970	0.84000
0.572	0.80000	11.270	1.00000	6.060	0.87500
0.600	0.87400	11.430	0.98000	6.150	0.94900
0.612	0.90000	11.590	0.94500	6.250	0.91500
0.650	0.97200	11.760	0.95000	6.350	0.86700
0.693	1.00000	11.940	0.78400	6.450	0.86400
0.750	0.95600	12.120	0.66200	6.560	0.87500
0.794	0.90000	12.310	0.57600	6.670	0.92000
0.853	0.80000	12.500	0.24200	6.780	0.96500
0.900	0.73600	12.700	0.06900	6.900	0.97900
0.922	0.70000	12.900	0.02000	7.020	1.00000
0.957	0.60000	13.110	0.00400	7.140	0.89500
0.982	0.50000	13.330	0.00000	7.270	0.33700
1.006	0.40000			7.410	0.03000
1.033	0.30000			7.550	0.00000
1.048	0.25600				
1.110	0.00000				

TABLE 3.6. Sample Conversion Tables for METEOSAT-3.

Counts	Ch. 1 Scaled Radiance	Ch. 2 Temperature	Ch. 3 Temperature
0	0.00	327.32	267.23
25	0.08	318.72	263.75
50	0.17	309.59	260.08
75	0.27	299.84	255.90
100	0.36	289.31	251.33
125	0.45	277.73	246.13
150	0.54	264.70	240.00
175	0.63	249.47	232.60
200	0.72	230.67	222.67
225	0.81	204.00	207.50
250	0.90	000.00	000.00

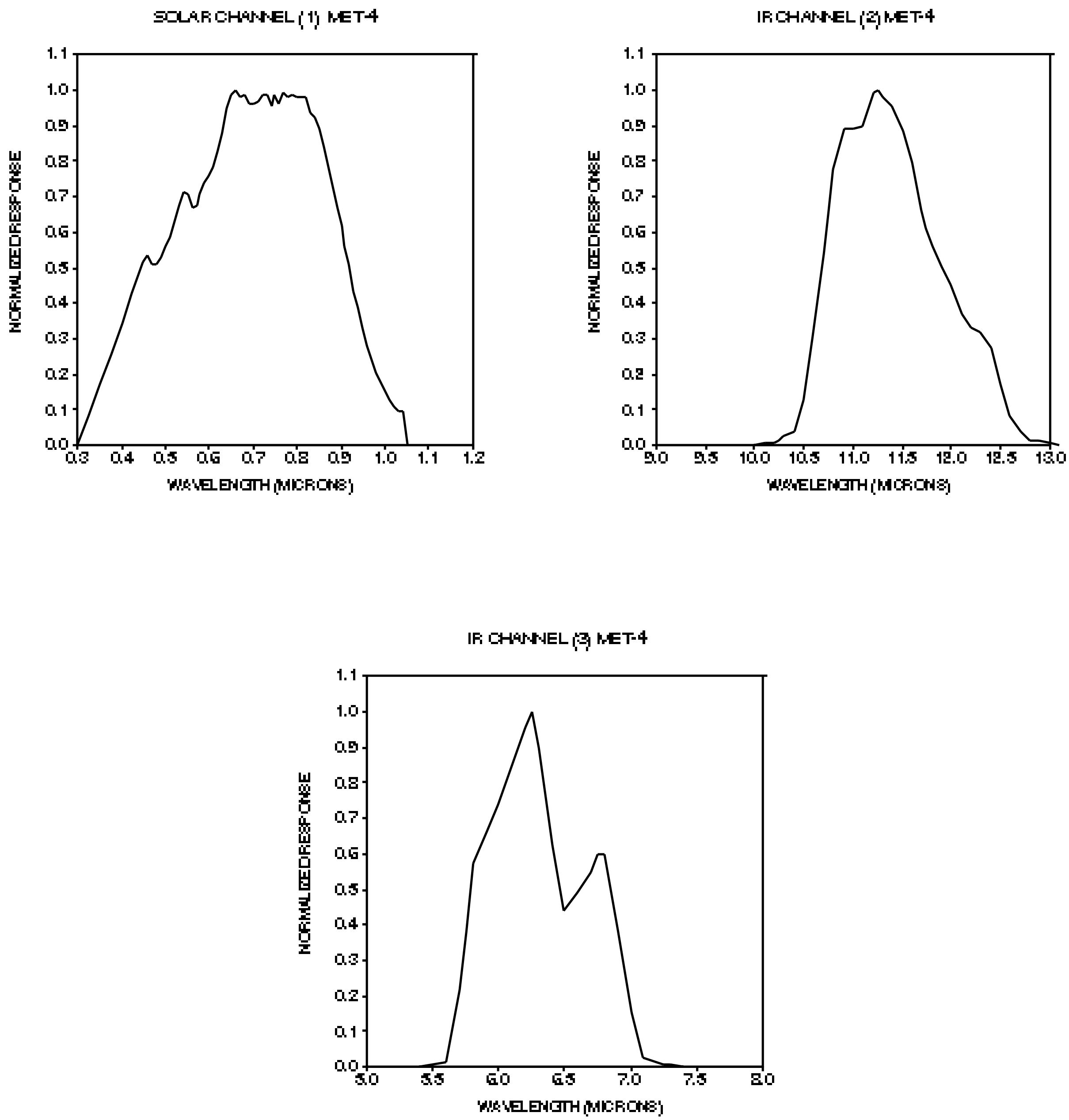

Fig. 3.3. Normalized spectral response functions for METEOSAT-4.

TABLE 3.7. Normalized Spectral Responses for METEOSAT-4.

Channel 1		Channel 2		Channel 3	
Wavelength (μm)	Response	Wavelength	Response	Wavelength	Response
0.300	0.00000	10.000	0.00000	5.400	0.00000
0.325	0.08600	10.100	0.00900	5.500	0.01000
0.350	0.17200	10.200	0.00900	5.600	0.01700
0.375	0.25800	10.250	0.01700	5.700	0.21600
0.400	0.34400	10.300	0.02500	5.750	0.38200
0.425	0.43000	10.400	0.04200	5.800	0.57200
0.450	0.51600	10.500	0.12700	5.900	0.66000
0.460	0.53600	10.600	0.30700	6.000	0.73700
0.470	0.51000	10.700	0.54400	6.100	0.84900
0.480	0.50800	10.750	0.65500	6.200	0.95600
0.490	0.53200	10.800	0.77700	6.250	1.00000
0.500	0.56100	10.900	0.89100	6.300	0.89700
0.510	0.58900	11.000	0.89200	6.400	0.62500
0.520	0.62900	11.100	0.89700	6.500	0.43800
0.530	0.67700	11.200	0.99200	6.600	0.49000
0.540	0.71200	11.250	1.00000	6.700	0.54900
0.550	0.70500	11.300	0.97900	6.750	0.59800
0.560	0.67100	11.400	0.95700	6.800	0.60200
0.570	0.67700	11.500	0.88700	6.900	0.38600
0.580	0.70500	11.600	0.79700	7.000	0.15500
0.590	0.74100	11.700	0.66300	7.100	0.02800
0.600	0.76100	11.750	0.60900	7.200	0.01600
0.610	0.78200	11.800	0.56000	7.250	0.01000
0.620	0.82700	11.900	0.50300	7.300	0.00500
0.630	0.87900	12.000	0.45000	7.400	0.00000
0.640	0.94600	12.100	0.37200		
0.650	0.98500	12.200	0.33500		
0.660	1.00000	12.250	0.32600		
0.670	0.98100	12.300	0.32000		
0.680	0.98800	12.400	0.27600		
0.690	0.96400	12.500	0.17600		
0.700	0.96400	12.600	0.08500		
0.710	0.96900	12.700	0.03800		
0.720	0.99000	12.750	0.02800		
0.730	0.98600	12.800	0.01600		
0.740	0.95600	12.900	0.01100		
0.750	0.99000	13.000	0.00600		
0.760	0.96400	13.100	0.00000		
0.770	0.99300				
0.780	0.97900				
0.790	0.98400				
0.800	0.98000				
0.810	0.98100				
0.820	0.97800				
0.830	0.93900				
0.840	0.92500				
0.850	0.88900				

Normalized Spectral Responses for METEOSAT-4 (continued).

Channel 1		Channel 2		Channel 3	
Wavelength (µm)	Response	Wavelength	Response	Wavelength	Response
0.860	0.84100				
0.870	0.78400				
0.880	0.72900				
0.890	0.67000				
0.900	0.61900				
0.910	0.56200				
0.920	0.51200				
0.930	0.43100				
0.940	0.38900				
0.950	0.33100				
0.960	0.28400				
0.970	0.24500				
0.980	0.20700				
0.990	0.18200				
1.000	0.15300				
1.010	0.13000				
1.020	0.11200				
1.030	0.09900				
1.040	0.09600				
1.050	0.00000				

TABLE 3.8. Sample Conversion Tables for METEOSAT-4.

Counts	Ch. 1 Scaled Radiance	Ch. 2 Temperature	Ch. 3 Temperature
0	0.00	335.09	265.58
25	0.08	326.19	262.40
50	0.17	316.77	258.80
75	0.27	306.70	254.89
100	0.36	295.88	250.50
125	0.45	283.95	245.57
150	0.54	270.55	239.50
175	0.63	255.00	232.40
200	0.72	235.85	222.67
225	0.81	208.89	208.00
250	0.90	000.00	000.00

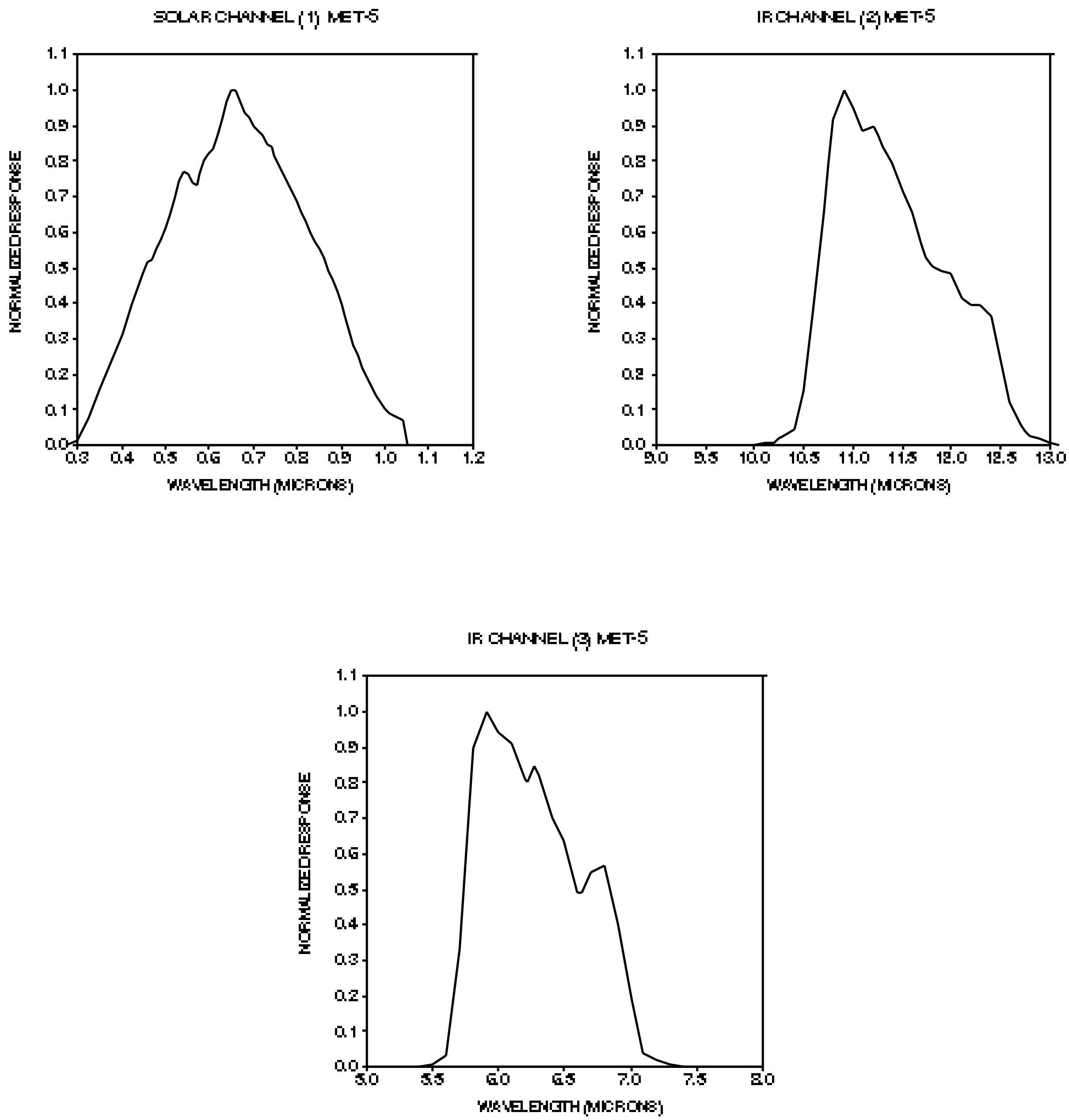

Fig. 3.4. Normalized spectral response functions for METEOSAT-5.

TABLE 3.9. Normalized Spectral Responses for METEOSAT-5.

Channel 1		Channel 2		Channel 3	
Wavelength (μm)	Response	Wavelength	Response	Wavelength	Response
0.275	0.00000	10.000	0.00000	5.400	0.00000
0.300	0.01450	10.100	0.00900	5.500	0.01000
0.325	0.08050	10.200	0.00900	5.600	0.03000
0.350	0.15850	10.250	0.01900	5.700	0.33000
0.375	0.23700	10.300	0.02900	5.800	0.90000
0.400	0.31450	10.400	0.04900	5.900	1.00000
0.425	0.39250	10.500	0.15200	6.000	0.94000
0.450	0.48550	10.600	0.37100	6.100	0.91000
0.460	0.51750	10.700	0.65900	6.200	0.81000
0.470	0.52350	10.750	0.79500	6.225	0.80000
0.480	0.55200	10.800	0.91700	6.275	0.85000
0.490	0.57950	10.900	1.00000	6.300	0.82000
0.500	0.61400	11.000	0.94900	6.400	0.70000
0.510	0.65050	11.100	0.88200	6.500	0.64000
0.520	0.69350	11.200	0.89900	6.600	0.49000
0.530	0.74250	11.250	0.87000	6.625	0.49000
0.540	0.77250	11.300	0.83900	6.700	0.55000
0.550	0.76650	11.400	0.79500	6.800	0.57000
0.560	0.73600	11.500	0.71200	6.900	0.40000
0.570	0.73550	11.600	0.65700	7.000	0.19000
0.580	0.76250	11.700	0.56500	7.100	0.04000
0.590	0.80100	11.750	0.52700	7.200	0.02000
0.600	0.81900	11.800	0.50400	7.300	0.01000
0.610	0.83400	11.900	0.48900	7.400	0.00000
0.620	0.87450	12.000	0.48200		
0.630	0.91950	12.100	0.41600		
0.640	0.96650	12.200	0.39500		
0.650	0.99800	12.250	0.39400		
0.660	0.99700	12.300	0.39800		
0.670	0.96600	12.400	0.36300		
0.680	0.93600	12.500	0.24300		
0.690	0.92100	12.600	0.12500		
0.700	0.89600	12.700	0.05800		
0.710	0.88800	12.750	0.04200		
0.720	0.87500	12.800	0.02600		
0.730	0.85000	12.900	0.01800		
0.740	0.83950	13.000	0.00900		
0.750	0.81650	13.100	0.00000		
0.760	0.78950				
0.770	0.76750				
0.780	0.73800				
0.790	0.71450				
0.800	0.68900				
0.810	0.65950				
0.820	0.63300				
0.830	0.60200				
0.840	0.57600				

Normalized Spectral Responses for METEOSAT-5 (continued).

Channel 1		Channel 2		Channel 3	
Wavelength (µm)	Response	Wavelength	Response	Wavelength	Response
0.850	0.55350				
0.860	0.52800				
0.870	0.49100				
0.880	0.46600				
0.890	0.43200				
0.900	0.39650				
0.910	0.36750				
0.920	0.32750				
0.930	0.28350				
0.940	0.25500				
0.950	0.21800				
0.960	0.19150				
0.970	0.16600				
0.980	0.14200				
0.990	0.12400				
1.000	0.10500				
1.010	0.09250				
1.020	0.08400				
1.030	0.07500				
1.040	0.07150				
1.050	0.00000				

TABLE 3.10. Sample Conversion Tables for METEOSAT-5.

Counts	Ch. 1 Scaled Radiance	Ch. 2 Temperature	Ch. 3 Temperature
0	0.00	329.45	264.85
25	0.08	320.84	261.64
50	0.17	311.73	258.09
75	0.27	301.96	254.22
100	0.36	291.42	249.89
125	0.45	279.83	244.88
150	0.54	266.80	239.14
175	0.63	251.65	231.80
200	0.72	233.00	222.50
225	0.81	206.63	207.50
250	0.90	000.00	000.00

3.3. NORMALIZED CALIBRATION

The following tables give the normalization coefficients (Desormeaux et al. 1992) to normalize METEOSAT calibrations to the current NOAA polar orbiter (changes of NOAA satellites are indicated in the tables). These coefficients do not account for any changes in the NOAA calibrations.

Normalized radiances are given by Eqs. (1.3) and (1.4), where visible slope and intercepts are the coefficients, A_1, and B_1, in Eq. (1.3) and infrared slope and intercepts are the coefficients, A_2 and B_2, in Eq. (1.4), respectively. Other values in the tables indicate the range of radiances used for normalization, as well as the rms deviations of individual target radiances from the best linear fit.

TABLE 3.11. Normalization for METEOSAT-2.

		Visible (fraction)					Infrared (Kelvin)				
Month		Slope	Interc	rms	Min	Max	Slope	Interc	rms	Min	Max
JUL	83	1.068	0.000	0.015	0.05	0.56	1.030	- 9.47	0.25	282	293
AUG	83	1.070	0.001	-	-	-	1.044	-13.33	-	-	-
SEP	83	1.073	0.001	-	-	-	1.058	-17.19	-	-	-
OCT	83	1.075	0.002	0.022	0.04	0.79	1.072	-21.05	0.86	206	294
NOV	83	1.046	0.004	-	-	-	1.054	-16.06	-	-	-
DEC	83	1.016	0.006	0.011	0.05	0.85	1.037	-11.07	1.53	216	293.5
JAN	84	0.997	0.007	0.019	0.06	0.58	1.025	- 7.83	2.04	232	297
FEB	84	1.002	0.003	-	-	-	1.041	-11.74	-	-	-
MAR	84	1.006	0.000	-	-	-	1.058	-15.64	-	-	-
APR	84	1.011	-0.004	0.013	0.06	0.91	1.074	-19.55	1.40	199	299.5
MAY	84	1.017	-0.001	-	-	-	1.074	-20.20	-	-	-
JUN	84	1.024	0.003	-	-	-	1.075	-20.85	-	-	-
JUL	84	1.030	0.006	0.021	0.04	0.75	1.075	-21.50	0.96	199.5	295.5
AUG	84	1.033	0.003	-	-	-	1.080	-22.89	-	-	-
SEP	84	1.037	0.001	-	-	-	1.085	-24.27	-	-	-
OCT	84	1.040	-0.002	0.015	0.04	0.77	1.090	-25.66	0.62	194.5	295
NOV	84	1.031	-0.001	-	-	-	1.075	-21.06	-	-	-
DEC	84	1.022	0.001	-	-	-	1.060	-16.46	-	-	-
JAN	85	1.013	0.002	0.011	0.05	0.63	1.045	-11.86	1.06	209.5	295
***	change from NOAA-7 to NOAA-9 as normalization standard										
FEB	85	1.309	0.002	-	-	-	1.101	-29.60	-	-	-
MAR	85	1.244	0.003	-	-	-	1.094	-27.00	-	-	-
APR	85	1.178	0.004	0.012	0.03	0.90	1.086	-24.40	1.30	198	301.5
MAY	85	1.172	0.004	-	-	-	1.080	-22.83	-	-	-
JUN	85	1.167	0.003	-	-	-	1.074	-21.27	-	-	-
JUL	85	1.161	0.003	0.017	0.04	0.86	1.068	-19.70	0.90	204	295
AUG	85	1.152	0.004	-	-	-	1.057	-16.87	-	-	-
SEP	85	1.144	0.005	-	-	-	1.047	-14.03	-	-	-
OCT	85	1.135	0.006	0.016	0.04	0.82	1.036	-11.20	0.60	269	298
NOV	85	1.117	0.008	-	-	-	1.046	-13.53	-	-	-
DEC	85	1.099	0.009	-	-	-	1.055	-15.87	-	-	-
JAN	86	1.081	0.011	0.014	0.04	0.90	1.065	-18.20	1.20	201	305
FEB	86	1.092	0.009	-	-	-	1.078	-21.97	-	-	-
MAR	86	1.102	0.008	-	-	-	1.091	-25.73	-	-	-
APR	86	1.113	0.006	0.011	0.03	0.86	1.104	-29.50	1.30	196	297

Normalization for METEOSAT-2 (continued).

Month		Visible (fraction) Slope	Interc	rms	Min	Max	Infrared (Kelvin) Slope	Interc	rms	Min	Max
MAY	86	1.114	0.008	-	-	-	1.105	-29.90	-	-	-
JUN	86	1.115	0.010	-	-	-	1.105	-30.30	-	-	-
JUL	86	1.116	0.012	0.012	0.05	0.74	1.106	-30.70	1.40	205	294
AUG	86	1.127	0.007	-	-	-	1.101	-29.30	-	-	-
SEP	86	1.139	0.002	-	-	-	1.096	-27.90	1.36	200	293.5
OCT	86	1.150	-0.003	0.013	0.03	0.89	1.022	- 6.20	0.90	212	295
NOV	86	1.125	-0.002	-	-	-	1.114	-32.50	1.20	196	295
DEC	86	1.101	-0.001	-	-	-	1.096	-27.05	-	-	-
JAN	87	1.076	0.000	0.010	0.035	0.88	1.079	-21.60	0.90	205	295.5
FEB	87	1.079	0.001	-	-	-	1.082	-22.80	-	-	-
MAR	87	1.081	0.003	-	-	-	1.084	-24.00	-	-	-
APR	87	1.084	0.004	0.020	0.03	0.80	1.087	-25.20	1.60	195	297
***	gain change in VIS channel on MET-2										
MAY	87	0.907	0.002	-	-	-	1.100	-28.63	-	-	-
JUN	87	0.911	0.001	-	-	-	1.112	-32.07	-	-	-
JUL	87	0.915	0.000	0.016	0.03	0.77	1.125	-35.50	1.29	203	294.5
AUG	87	0.901	0.002	-	-	-	1.110	-31.13	-	-	-
SEP	87	0.888	0.003	-	-	-	1.096	-26.77	-	-	-
OCT	87	0.874	0.005	0.023	0.03	0.79	1.081	-22.40	1.42	197	296
NOV	87	0.876	0.004	-	-	-	1.071	-19.03	-	-	-
DEC	87	0.879	0.002	-	-	-	1.060	-15.67	-	-	-
JAN	88	0.881	0.001	0.018	0.03	0.81	1.050	-12.30	1.20	201.5	295
FEB	88	0.864	0.000	-	-	-	1.049	-12.44	-	-	-
MAR	88	0.847	0.000	-	-	-	1.048	-12.57	-	-	-
APR	88	0.830	-0.001	-	-	-	1.047	-12.71	-	-	-
MAY	88	0.813	-0.001	-	-	-	1.046	-12.84	-	-	-
JUN	88	0.796	-0.002	0.013	0.04	0.66	1.045	-12.98	1.10	195.5	295.5
JUL	88	0.796	-0.002	0.013	0.04	0.66	1.045	-12.98	1.10	195.5	295.5
AUG	88	0.796	-0.002	-	-	-	1.045	-12.98	-	-	-

TABLE 3.12. Normalization for METEOSAT-3.

Month		Visible (fraction) Slope	Interc	rms	Min	Max	Infrared (Kelvin) Slope	Interc	rms	Min	Max
AUG	88	0.841	-0.022	0.023	0.03	0.55	1.015	- 4.70	1.95	220	295
SEP	88	0.864	-0.022	-	-	-	1.028	- 7.25	-	-	-
OCT	88	0.888	-0.023	0.019	0.04	0.72	1.041	- 9.80	1.00	198	295.5
NOV	88	0.888	-0.023	0.019	0.04	0.72	1.041	- 9.80	1.00	198	295.5
***	change from NOAA-9 to NOAA-11 as normalization standard										
NOV	88	0.847	-0.007	0.015	0.03	0.82	1.017	- 3.31	1.21	205	296
DEC	88	0.832	-0.006	-	-	-	1.021	- 4.49	-	-	-
JAN	89	0.816	-0.006	0.018	0.03	0.82	1.025	- 5.67	1.09	195.5	298.5
FEB	89	0.820	-0.006	-	-	-	1.026	- 5.33	-	-	-
MAR	89	0.823	-0.007	0.010	0.03	0.83	1.026	- 4.99	1.27	190	296
APR	89	0.823	-0.007	-	-	-	1.026	- 4.99	-	-	-
MAY	89	0.823	-0.007	0.010	0.03	0.83	1.026	- 4.99	1.27	190	296
JUN	89	0.810	-0.003	0.009	0.04	0.78	1.017	-3.64	1.02	195.5	295
JAN	90	0.963	-0.002	0.010	0.03	0.83	1.021	-4.28	1.15	187.5	297
FEB	90	0.963	-0.002	0.010	0.03	0.83	1.021	-4.28	1.15	187.5	297
MAR	90	0.962	-0.006	-	-	-	1.020	-4.38	-	-	-
APR	90	0.961	-0.009	0.012	0.03	0.72	1.018	-4.48	1.01	203	296.5
OCT	90	0.961	-0.009	-	-	-	1.018	-4.48	-	-	-
NOV	90	0.992	-0.012	0.009	0.03	0.33	0.990	3.38	0.61	267	294.5
NOV	90	0.961	-0.009	-	-	-	1.018	-4.48	-	-	-
DEC	90	0.961	-0.009	-	-	-	1.018	-4.48	-	-	-
JAN	91	0.961	-0.009	-	-	-	1.018	-4.48	-	-	-
METEOSAT-3 at 50° West											
AUG	91	0.859	-0.002	0.011	0.05	0.78	1.013	-3.70	0.86	207	295.5

TABLE 3.13. Normalization for METEOSAT-4.

Month		Visible (fraction) Slope	Interc	rms	Min	Max	Infrared (Kelvin) Slope	Interc	rms	Min	Max
MAY	89	0.896	-0.028	-	-	-	1.022	- 4.40	-	-	-
JUN	89	0.896	-0.028	0.010	0.04	0.79	1.022	- 4.40	0.88	194.5	294.5
JUL	89	0.870	-0.015	0.009	0.03	0.78	1.023	- 5.78	1.20	200	295.5
AUG	89	0.892	-0.017	-	-	-	1.023	- 5.37	-	-	-
SEP	89	0.913	-0.018	-	-	-	1.022	- 4.97	-	-	-
OCT	89	0.935	-0.020	0.013	0.02	0.78	1.022	- 4.56	1.00	206.5	294.5
NOV	89	0.917	-0.018	-	-	-	1.022	- 4.81	-	-	-
DEC	89	0.899	-0.016	-	-	-	1.023	- 5.07	-	-	-
JAN	90	0.881	-0.014	0.012	0.03	0.80	1.023	- 5.32	0.91	199.5	295.5
APR	90	0.923	-0.017	0.010	0.02	0.81	1.024	-5.43	1.25	186.5	296.5
MAY	90	0.923	-0.017	0.010	0.02	0.81	1.024	-5.43	1.25	186.5	296.5
JUN	90	0.916	-0.018	-	-	-	1.010	-2.27	1.15	208	295
JUL	90	0.910	-0.020	0.011	0.03	0.66	1.001	0.79	0.86	225.5	294
AUG	90	0.940	-0.021	-	-	-	1.005	-0.35	-	-	-
SEP	90	0.970	-0.021	-	-	-	1.009	-1.50	-	-	-
OCT	90	1.000	-0.022	0.012	0.03	0.87	1.013	-2.64	0.94	200	294.5
NOV	90	0.990	-0.018	-	-	-	1.014	-3.26	-	-	-
DEC	90	0.980	-0.014	-	-	-	1.015	-3.87	0.88	204.5	296
JAN	91	0.970	-0.010	0.012	0.03	0.83	1.005	-0.82	0.87	205.5	297
FEB	91	0.978	-0.013	-	-	-	1.011	-2.35	-	-	-
MAR	91	0.986	-0.016	-	-	-	1.016	-3.87	-	-	-
APR	91	0.994	-0.019	0.008	0.03	0.82	1.022	-5.40	1.19	186	296
MAY	91	0.980	-0.018	-	-	-	1.016	-4.01	-	-	-
JUN	91	0.967	-0.018	-	-	-	1.011	-2.61	-	-	-
JUL	91	0.953	-0.017	0.006	0.04	0.71	1.005	-1.22	0.54	218.5	294.5

3.4. ABSOLUTE CALIBRATION

The final calibration of METEOSAT radiances is obtained by applying to the normalized calibration the same corrections as applied to the relevant NOAA satellite, shown in Tables 2.18 through 2.24. No changes are required when METEOSAT is normalized to NOAA-7, except for multiplying all VIS radiances by 1.2. Table 3.14 gives the final calibration coefficients used for METEOSAT, including the corrections for changes in NOAA calibration and the factor of 1.2 for VIS radiances (from Desormeaux et al. 1992).

TABLE 3.14. History of visible and infrared normalization coefficients for METEOSAT.

METEOSAT-2

Month	Visible (fraction) Slope	Visible (fraction) Interc	Infrared (Kelvin) Slope	Infrared (Kelvin) Interc
JUL 83	1.282	0.000	1.030	- 9.47
AUG 83	1.284	0.001	1.044	-13.33
SEP 83	1.288	0.001	1.058	-17.19
OCT 83	1.290	0.002	1.072	-21.05
NOV 83	1.255	0.005	1.054	-16.06
DEC 83	1.219	0.007	1.037	-11.07
JAN 84	1.196	0.008	1.025	- 7.83
FEB 84	1.202	0.004	1.041	-11.74
MAR 84	1.207	0.000	1.058	-15.64
APR 84	1.213	-0.005	1.074	-19.55
MAY 84	1.220	-0.001	1.074	-20.20
JUN 84	1.229	0.004	1.075	-20.85
JUL 84	1.236	0.007	1.075	-21.50
AUG 84	1.240	0.004	1.080	-22.89
SEP 84	1.244	0.001	1.085	-24.27
OCT 84	1.248	-0.002	1.090	-25.66
NOV 84	1.237	-0.001	1.075	-21.06
DEC 8	0.001	1.060	-16.46	
JAN 85	1.216	0.002	1.045	-11.86
** change from NOAA-7 to NOAA-9 as normalization standard				
FEB 85	1.312	0.005	1.101	-29.60
MAR 85	1.250	0.006	1.094	-27.00
APR 85	1.189	0.006	1.086	-24.40
MAY 85	1.187	0.006	1.080	-22.83
JUN 85	1.188	0.006	1.074	-21.27
JUL 85	1.184	0.006	1.068	-19.70
AUG 85	1.180	0.006	1.057	-16.87
SEP 85	1.176	0.007	1.047	-14.03
OCT 85	1.170	0.008	1.036	-11.20
NOV 85	1.157	0.011	1.046	-13.53
DEC 85	1.142	0.012	1.055	-15.87
JAN 86	1.127	0.014	1.065	-18.20
FEB 86	1.142	0.012	1.078	-21.97
MAR 86	1.157	0.011	1.091	-25.73
APR 86	1.172	0.008	1.104	-29.50
MAY 86	1.180	0.011	1.105	-29.90
JUN 86	1.184	0.013	1.105	-30.30
JUL 86	1.189	0.016	1.106	-30.70
AUG 86	1.205	0.010	1.101	-29.30
SEP 86	1.222	0.005	1.096	-27.90
OCT 86	1.240	-0.001	1.051	-14.87
NOV 86	1.217	0.000	1.114	-32.50
DEC 86	1.194	0.001	1.096	-27.05
JAN 87	1.172	0.002	1.079	-21.60
FEB 87	1.180	0.004	1.082	-22.80
MAR 87	1.186	0.006	1.084	-24.00

METEOSAT-2 (continued)

Month		Visible (fraction) Slope	Interc	Infrared (Kelvin) Slope	Interc
APR	87	1.194	0.007	1.087	-25.20
	** gain change in VIS channel on MET-2				
MAY	87	1.002	0.005	1.100	-28.63
JUN	87	1.010	0.004	1.112	-32.07
JUL	87	1.019	0.002	1.125	-35.50
AUG	87	1.007	0.005	1.110	-31.13
SEP	87	0.995	0.006	1.096	-26.77
OCT	87	0.984	0.008	1.122	-34.75
NOV	87	0.989	0.007	1.112	-31.25
DEC	87	0.996	0.005	1.100	-27.77
JAN	88	1.002	0.004	1.090	-24.27
FEB	88	0.986	0.002	1.089	-24.41
MAR	88	0.970	0.002	1.088	-24.55
APR	88	0.954	0.001	1.087	-24.69
MAY	88	0.937	0.001	1.086	-24.83
JUN	88	0.922	0.000	1.085	-24.97
JUL	88	0.925	0.000	1.085	-24.97
AUG	88	0.929	0.000	1.085	-24.97

METEOSAT-3

Month		Visible (fraction) Slope	Interc	Infrared (Kelvin) Slope	Interc
AUG	88	0.980	-0.023	1.054	-16.38
SEP	88	1.010	-0.023	1.067	-19.03
OCT	88	1.043	-0.025	1.081	-21.67
	** change from NOAA-9 to NOAA-11 as normalization standard				
NOV	88	0.955	-0.007	1.085	-22.53
DEC	88	0.938	-0.006	1.089	-23.79
JAN	89	0.920	-0.006	1.094	-25.05
FEB	89	0.925	-0.006	1.095	-24.69
MAR	89	0.929	-0.007	1.095	-24.32
APR	89	0.929	-0.007	1.095	-24.32
MAY	89	0.929	-0.007	1.095	-24.32
JUN	89	0.913	-0.002	1.085	-22.88
JAN	90	1.086	-0.001	1.089	-23.57
FEB	90	1.086	-0.001	1.089	-23.57
MAR	90	1.085	-0.006	1.088	-23.67
APR	90	1.084	-0.008	1.086	-23.78
OCT	90	1.084	-0.008	1.086	-23.78
NOV	90	1.084	-0.008	1.086	-23.78
DEC	90	1.084	-0.008	1.086	-23.78

Month		Visible (fraction) Slope	Visible (fraction) Interc	Infrared (Kelvin) Slope	Infrared (Kelvin) Interc
JUN	89	1.010	-0.032	1.090	-23.69
JUL	89	0.982	-0.016	1.092	-25.17
AUG	89	1.006	-0.018	1.092	-24.73
SEP	89	1.030	-0.019	1.090	-24.30
OCT	89	1.055	-0.022	1.090	-23.87
NOV	89	1.034	-0.019	1.090	-24.13
DEC	89	1.014	-0.017	1.092	-24.41
JAN	90	0.994	-0.014	1.092	-24.68
APR	90	1.031	-0.018	1.093	-24.79
MAY	90	1.025	-0.018	1.093	-24.79
JUN	90	1.012	-0.019	1.078	-21.42
JUL	90	1.001	-0.020	1.068	-18.16
AUG	90	1.027	-0.022	1.072	-19.37
SEP	90	1.055	-0.022	1.077	-20.60
OCT	90	1.081	-0.023	1.081	-21.82
NOV	90	1.066	-0.018	1.082	-22.48
DEC	90	1.049	-0.013	1.083	-23.13
JAN	91	1.032	-0.010	1.072	-19.87
FEB	91	1.037	-0.012	1.079	-21.51
MAR	91	1.039	-0.016	1.084	-23.13
APR	91	1.042	-0.019	1.090	-24.76
MAY	91	1.024	-0.018	1.084	-23.28
JUN	91	1.003	-0.018	1.079	-21.78

4. GOES

The USA Geostationary Operational Environmental Satellite (GOES) system consists of two spacecraft in geostationary orbit, called GOES-EAST and GOES-WEST, operated by NOAA. The initial series of these satellites, starting with the NASA prototypes SMS-1 and 2 and continuing with GOES-1, 2, 3, were improved by the addition of a temperature sounding capability first flown on GOES-4. GOES-4 data were collected during the ISCCP Data Management Systems Test, but GOES-5 (EAST) and GOES-6 (WEST) were supplying imaging data at the start of ISCCP data collection in July 1983. GOES-5 failed in July 1984 and was not replaced by GOES-7 until April 1987. GOES-6 failed in January 1989 and has not yet been replaced (see Rossow et al. 1987 for more details).

The imaging data come from the visible and infrared window channels of the Visible Infrared Spin-Scan Radiometer (VISSR; the combination of VISSR and the Atmospheric Sounder is known as VAS). The nominal center wavelengths are 0.68 µm and 11.6 µm. The spectral responses for GOES-5 (EAST), GOES-6 (WEST) and GOES-7 (EAST) are shown in Section 4.2. The solar channel of the VISSR is actually composed of eight separate detectors sweeping across the Earth in parallel. The infrared part of the instrument makes measurements in 12 spectral bands, with band 8 serving as the standard imaging channel.

4.1. NOMINAL CALIBRATION

(1) SOLAR CHANNEL

No pre-launch information is available for this channel. Since the VISSRs on GOES-4, 5, 6 and subsequent spacecraft are different instruments from previous VISSRs on SMS-1, 2 and GOES-1, 2, 3, none of the previous pre-launch and post-launch calibration information for GOES (Smith and Loranger 1977; Smith and Vonder Haar 1980; Norton et al. 1980; Smith et al. 1981; Muench 1981) is applicable. A recent calibration of the solar channel on GOES-6 has been provided by C. Gautier (see Rossow et al. 1987; Frouin and Gautier 1987). Observations of White Sands, New Mexico, which is assumed to have an albedo of 0.69 at 0.565 µm, and of space (CT_{sp} = 27) are combined with radiative transfer calculations of atmospheric effects to obtain the following relationship:

$$E = (0.0066818 \pm 0.00043)\ (CT)^2 - 5 \text{ watts m}^{-2} \tag{4.1}$$

where CT = 0-255. This result uses a spectral response function which is an average over the eight channel spectral response functions, giving an effective solar spectral irradiance of 315.83 watts m^{-2}. Subsequent analyses (Frouin and Gautier 1987) adopted a different calibration value; however, normalization of the GOES radiances to the NOAA values eliminates the dependence on this choice of nominal calibration as confirmed in a study by Whitlock et al. (1990) (see also Desormeaux et al. 1992).

Data from the eight separate solar channels are processed to normalize the output from all the channels to a single reference channel. This reference channel is selected as having a maximum dynamic range with little saturation. Observations of large homogeneous targets are used to construct tables relating each channel response to the response of the reference channel. The reference channel for GOES-5 is channel 8, for GOES-6 is channel 2 and for GOES-7 is channel 8. In ISCCP radiance data sets the output of the eight detectors is averaged to produce a single, lower resolution radiance measurement, which is treated as equivalent to measurements by the reference channel.

The conversion of telemetry count values to radiances makes use of the designed linearity of the instrument with measured radiance, the counts measured for a space view, and the calculated effective solar spectral irradiance based on the spectral responses shown in Section 4.2. Since the solar irradiance tables used here differ slightly from those used by Gautier, we rescale and adopt the following relation between radiance and counts for GOES-6:

$$L = (0.0020)\ (CT)_2 - 1.5 \text{ watts m}^{-2} \text{ sr}^{-1} \quad (4.2)$$

where CT is an 8-bit count. The scaled radiance is obtained using the solar spectral irradiance for GOES-6 of E_o/π = 94.29 watts m^{-2} sr^{-1}.

No equivalent calibration information is available for the solar channel on GOES-5. Comparison of one week of observations at the meridian halfway between GOES-5 and GOES-6 (namely 105°W) shows a ratio of solar channel counts = 0.965 and a bias of -10 counts. The space count value for GOES-6 is 27, while the space count value for GOES-5 is 26. Since the ratio is similar to that given by the slightly different spectral responses, the adopted nominal calibration for GOES-5 is that used for GOES-6 adjusted by the difference in solar spectral radiances of the two instruments. Radiance is obtained using the following expression:

$$L = (0.0019)\ (CT)^2 - 1.5 \text{ watts m}^{-2} \text{ sr}^{-2} \quad (4.3)$$

and scaled radiance is obtained using a solar spectral irradiance for GOES-5, E_o/π = 92.15 watts m^{-2} sr^{-1}.

Equation (4.2) is also used for GOES-7 with a solar spectral irradiance of E_o/π = 107.8 watts m^{-2} sr^{-1}.

A processing error occurred in the Stage B3 data for GOES-5 and GOES-6 from July 1983 through May 1984 that is equivalent to adding 0.5 watts m^{-2} sr^{-1} to all nominal VIS radiances or about 0.5% to scaled radiances. Since this "change" is well within the uncertainty of the calibration, no correction was made.

(2) INFRARED CHANNEL

Calibration of the IR channel is performed once per week using an on-board black-body source which is viewed directly by the detector (Menzel 1980, 1981, 1983; Menzel et al. 1981). However, the detector views Earth through telescope optics with a transmittance, τ, and an emittance, ε_{space}; thus, the on-board source measurements must be corrected to represent a black-body viewed through the telescope. Pre-launch measurements are used to model the relation between the radiance observed from the on-board source and an external source in terms of the temperatures of various components of the instrument measured by thermistors. The radiance measured by the instrument, which is assumed to be linear in response, is given by

$$E = \frac{V - V_{sp}}{V_{bb} - V_{sp}} \left\{ E_{bb} + \Sigma\ c_i\ (E_{bb} - E_i) \right\} \quad (4.4)$$

where V, V_{bb} and V_{sp} are the instrument voltages obtained when viewing an external target, the on-board black-body and space, respectively, and E_{bb} and E_i are the black-body irradiances of the on-board source and eight other instrument components, at temperatures T_b and T_i. The c_i coefficients are obtained from the pre-launch calibration measurements (see Menzel 1981, 1983).

The results of the on-board calibration sequence, expressed in terms of the measured temperatures, T_b and T_i, and voltages, V_{bb} and V_{sp}, are used to calculate tables relating telemetry count values to black-body temperatures. The black-body temperatures are related to the radiances obtained from Eq. (4.4) by integrating the Planck function times the spectral response function. Application of the calibration tables produces count values transmitted to users that are related to black-body temperatures by a constant relationship:

$$\begin{aligned} TB &= 330 - CT/2 \quad \text{for} \quad 0 \le CT < 176 \\ TB &= 418 - CT \quad \text{for} \quad 176 \le CT < 255 \end{aligned} \quad (4.5)$$

This conversion of count values is valid through March 1987. A table relating brightness temperatures to radiances can be used to obtain radiances.

In April 1987 NOAA changed the telemetry format for GOES data which increased the number of bits used to record VIS radiances from six to eight and IR radiances from eight to ten. In the ISCCP data processing, the extra IR radiance resolution was exploited to produce an eight bit representation with count values nearly linear in radiance rather than linear in brightness temperature. This change made GOES IR data more like data from all other satellites. Table 4.1 gives the brightness temperature values for all counts after and before the change; the change was made in April 1987 for GOES-6 and January 1989 for GOES-7. Since all calibration adjustments are applied to brightness temperatures, users of GOES data in its original format can use the following information to alter brightness temperature values.

Short time scale variations in the calibration, particularly those associated with diurnal heating/cooling cycles of the satellite, are not monitored for GOES (see Desormeaux et al. 1992).

Sample tables in Section 4.2 illustrate the relation of counts to scaled radiances and brightness temperatures.

TABLE 4.1. Infrared brightness temperature values corresponding to 8-bit count values used as nominal calibration for GOES-6 from April 1987 onwards and for GOES-7 from January 1989 onwards. Some GOES-6 data in 1987 used the second table, labelled "old".

NEW TABLE

Count Value	Brightness Temperature (K)	Count Value	Brightness Temperature (K)	Count Value	Brightness Temperature (K)
1	345.17	44	318.54	87	301.76
2	333.25	45	318.17	88	301.34
3	332.92	46	317.80	89	300.92
4	332.58	47	317.43	90	300.50
5	332.24	48	317.06	91	300.08
6	331.91	49	316.69	92	299.66
7	331.57	50	316.32	93	299.24
8	331.23	51	315.94	94	298.81
9	330.89	52	315.57	95	298.38
10	330.55	53	315.19	96	297.96
11	330.21	54	314.81	97	297.53
12	329.87	55	314.44	98	297.09
13	329.53	56	314.06	99	296.66
14	329.19	57	313.68	100	296.23
15	328.84	58	313.30	101	295.79
16	328.50	59	312.91	102	295.35
17	328.15	60	312.53	103	294.92
18	327.81	61	312.15	104	294.48
19	327.46	62	311.76	105	294.03
20	327.11	63	311.38	106	293.59
21	326.77	64	310.99	107	293.14
22	326.42	65	310.60	108	292.70
23	326.07	66	310.21	109	292.25
24	325.72	67	309.82	110	291.80
25	325.37	68	309.43	111	291.34
26	325.02	69	309.04	112	290.89
27	324.66	70	308.64	113	290.43
28	324.31	71	308.25	114	289.98
29	323.96	72	307.85	115	289.52
30	323.60	73	307.45	116	289.06
31	323.24	74	307.05	117	288.59
32	322.89	75	306.65	118	288.13
33	322.53	76	306.25	119	287.66
34	322.17	77	305.85	120	287.19
35	321.81	78	305.45	121	286.72
36	321.45	79	305.04	122	286.25
37	321.09	80	304.64	123	285.77
38	320.73	81	304.23		
39	320.37	82	303.82		
40	320.00	83	303.41		
41	319.64	84	303.00		
42	319.27	85	302.59		
43	318.91	86	302.17		

Count Value	Brightness Temperature (K)	Count Value	Brightness Temperature (K)	Count Value	Brightness Temperature (K)
124	285.29	169	261.11	214	227.11
125	284.81	170	260.50	215	226.13
126	284.33	171	259.88	216	225.13
127	283.85	172	259.25	217	224.12
128	283.36	173	258.63	218	223.08
129	282.87	174	257.99	219	222.03
130	282.38	175	257.36	220	220.96
131	281.89	176	256.71	221	219.87
132	281.40	177	256.07	222	218.76
133	280.90	178	255.41	223	217.62
134	280.40	179	254.76	224	219.46
135	279.90	180	254.09	225	215.28
136	279.39	181	253.43	226	214.07
137	278.89	182	252.75	227	212.83
138	278.38	183	252.07	228	211.56
139	277.87	184	251.39	229	210.26
140	277.35	185	250.69	230	208.93
141	276.84	186	250.00	231	207.55
142	276.32	187	249.29	232	206.14
143	275.79	188	248.58	233	204.69
144	275.27	189	247.87	234	203.19
145	274.74	190	247.14	235	201.64
146	274.21	191	246.41	236	200.04
147	273.68	192	245.67	237	198.38
148	273.14	193	244.93	238	196.66
149	272.60	194	244.18	239	194.86
150	272.06	195	243.42	240	192.98
151	271.51	196	242.65	241	191.01
152	270.97	197	241.87	242	188.95
153	270.41	198	241.09	243	186.76
154	269.86	199	240.29	244	184.45
155	269.30	200	239.49	245	181.98
156	268.74	201	238.68	246	179.33
157	268.17	202	237.86	247	176.46
158	267.61	203	237.02	248	173.32
159	267.04	204	236.18	249	169.83
160	266.46	205	235.33	250	165.90
161	265.88	206	234.47	251	161.34
162	265.30	207	233.59	252	155.85
163	264.71	208	232.71	253	148.76
164	264.12	209	231.82	254	138.17
165	263.53	210	230.90	255	118.44
166	262.93	211	229.97		
167	262.33	212	229.03		
168	261.72	213	228.08		

OLD TABLE

Count Value	Brightness Temperature (K)	Count Value	Brightness Temperature (K)	Count Value	Brightness Temperature (K)
1	343.56	48	306.72	95	283.20
2	329.76	49	306.25	96	282.71
3	329.24	50	305.78	97	282.22
4	328.79	51	305.24	98	281.73
5	328.27	52	304.70	99	281.23
6	327.75	53	304.23	100	280.73
7	327.29	54	303.75	101	280.23
8	326.77	55	303.27	102	279.73
9	326.24	56	302.79	103	279.23
10	325.78	57	302.24	104	278.72
11	325.25	58	301.76	105	278.21
12	324.72	59	301.27	106	277.70
13	324.25	60	300.71	107	277.18
14	323.78	61	300.22	108	276.75
15	323.24	62	299.73	109	276.32
16	322.71	63	299.24	110	275.79
17	322.23	64	298.74	111	275.27
18	321.75	65	298.24	112	274.74
19	321.27	66	297.74	113	274.21
20	320.79	67	297.24	114	273.77
21	320.25	68	296.73	115	273.32
22	319.70	69	296.23	116	272.78
23	319.21	70	295.72	117	272.24
24	318.72	71	295.21	118	271.70
25	318.23	72	294.77	119	271.24
26	317.74	73	294.25	120	270.78
27	317.25	74	293.74	121	270.23
28	316.75	75	293.29	122	269.77
29	316.25	76	292.77	123	269.30
30	315.75	77	292.25	124	268.74
31	315.25	78	291.80	125	268.27
32	314.75	79	291.27	126	267.80
33	314.25	80	290.74	127	267.23
34	313.74	81	290.28	128	266.75
35	313.23	82	289.75	129	266.27
36	312.72	83	289.21	130	265.78
37	312.21	84	288.75	131	265.30
38	311.70	85	288.28	132	264.71
39	311.25	86	287.74	133	264.22
40	310.79	87	287.19	134	263.73
41	310.28	88	286.72	135	263.23
42	309.75	89	286.25		
43	309.23	90	285.77		
44	308.71	91	285.29		
45	308.25	92	284.81		
46	307.78	93	284.25		
47	307.25	94	283.69		

Count Value	Brightness Temperature (K)	Count Value	Brightness Temperature (K)	Count Value	Brightness Temperature (K)
136	262.73	180	239.08	224	195.16
137	262.23	181	237.99	225	193.93
138	261.72	182	237.02	226	192.98
139	261.21	183	236.04	227	192.01
140	260.80	184	235.04	228	191.02
141	260.29	185	234.03	229	190.00
142	259.77	186	233.00	230	188.95
143	259.25	187	231.96	231	187.87
144	258.73	188	230.90	232	186.77
145	258.31	189	229.97	233	186.01
146	257.78	190	229.03	234	185.24
147	257.25	191	228.08	235	184.05
148	256.82	192	227.11	236	182.86
149	256.28	193	226.13	237	181.99
150	255.74	194	225.13	238	181.13
151	255.31	195	224.12	239	180.24
152	254.76	196	223.08	240	179.34
153	254.20	197	222.03	241	178.41
154	253.76	198	220.96	242	177.45
155	253.31	199	219.87	243	176.47
156	252.75	200	218.94	244	175.46
157	252.19	201	218.00	245	174.41
158	251.73	202	217.05	246	173.33
159	251.27	203	216.07	247	172.21
160	250.81	204	215.08	248	171.05
161	250.35	205	214.07	249	169.85
162	249.76	206	213.04	250	168.60
163	249.18	207	211.99	251	167.94
164	248.70	208	210.92	252	167.29
165	248.23	209	210.04	253	165.92
166	247.75	210	209.15	254	165.21
167	247.26	211	208.02	255	164.49
168	246.78	212	206.85		
169	246.29	213	205.91		
170	245.80	214	204.94		
171	245.30	215	203.95		
172	244.80	216	202.94		
173	244.30	217	201.91		
174	243.80	218	200.85		
175	243.29	219	200.04		
176	242.78	220	199.22		
177	242.00	221	198.10		
178	240.95	222	196.95		
179	240.03	223	196.07		

4.2. GOES SPECTRAL RESPONSE

The spectral responses for the imaging channels on GOES-5, GOES-6 and GOES-7 are given in Tables 4.2 through 4.7 and illustrated in Figs. 4.1, 4.2 and 4.3.

Tables relating temperature and infrared radiances were calculated at 0.1 K intervals, as described for the NOAA satellites, and used to obtain radiance values from brightness temperatures.

TABLE 4.2. Normalized Spectral Responses for GOES-5.

Channel 1		Channel 2	
Wavelength (μm)	Response	Wavelength (μm)	Response
0.500	0.000	9.800	0.000
0.508	0.080	9.850	0.002
0.518	0.456	9.900	0.005
0.528	0.743	9.950	0.009
0.539	0.851	10.000	0.015
0.549	0.913	10.050	0.022
0.560	0.925	10.100	0.029
0.571	0.933	10.150	0.051
0.582	0.958	10.200	0.091
0.593	1.000	10.250	0.189
0.604	0.949	10.300	0.309
0.616	0.902	10.350	0.431
0.628	0.805	10.400	0.561
0.640	0.795	10.450	0.694
0.652	0.766	10.500	0.813
0.665	0.699	10.550	0.891
0.677	0.572	10.600	0.917
0.690	0.498	10.650	0.908
0.703	0.427	10.700	0.880
0.717	0.366	10.750	0.852
0.730	0.286	10.800	0.869
0.744	0.228	10.850	0.905
0.758	0.167	10.900	0.941
0.773	0.131	10.950	0.978
0.787	0.091	11.000	1.000
0.802	0.060	11.050	0.989
0.818	0.037	11.100	0.978
0.833	0.016	11.150	0.983
0.849	0.003	11.200	0.978
0.865	0.000	11.250	0.953
		11.300	0.928
		11.350	0.903
		11.400	0.888
		11.450	0.882
		11.500	0.876
		11.550	0.858
		11.600	0.837
		11.650	0.816
		11.700	0.793

Normalized Spectral Responses for GOES-5 (continued).

Channel 1		Channel 2	
Wavelength (μm)	Response	Wavelength (μm)	Response
		11.750	0.757
		11.800	0.722
		11.850	0.689
		11.900	0.680
		11.950	0.673
		12.000	0.630
		12.050	0.606
		12.100	0.504
		12.150	0.358
		12.200	0.163
		12.250	0.081
		12.300	0.038
		12.350	0.025
		12.400	0.015
		12.450	0.010
		12.500	0.008
		12.550	0.007
		12.600	0.003
		12.650	0.001
		12.700	0.000

TABLE 4.3. Sample Conversion Tables for GOES-5.

Counts	Ch. 1 Scaled Radiance	Ch. 2 Temperature
0	0.000	330.000
25	0.003	317.500
50	0.042	305.000
75	0.108	292.500
100	0.200	280.000
125	0.319	267.500
150	0.464	255.000
175	0.635	242.500
200	0.833	218.000
225	1.057	193.000
250	1.308	168.000

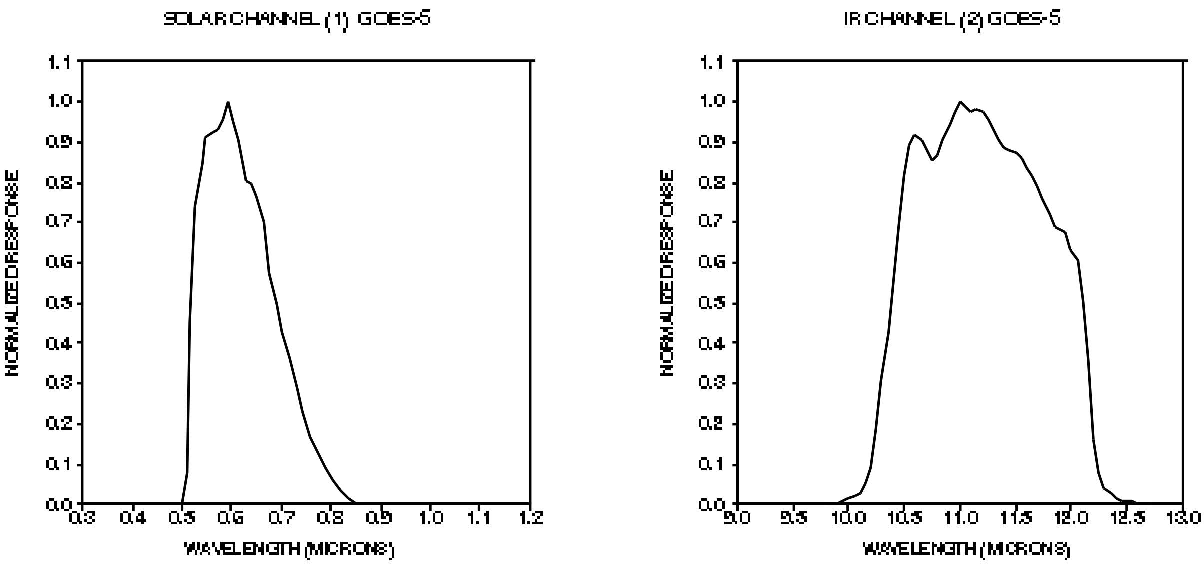

Fig. 4.1. Normalized spectral response functions for GOES-5.

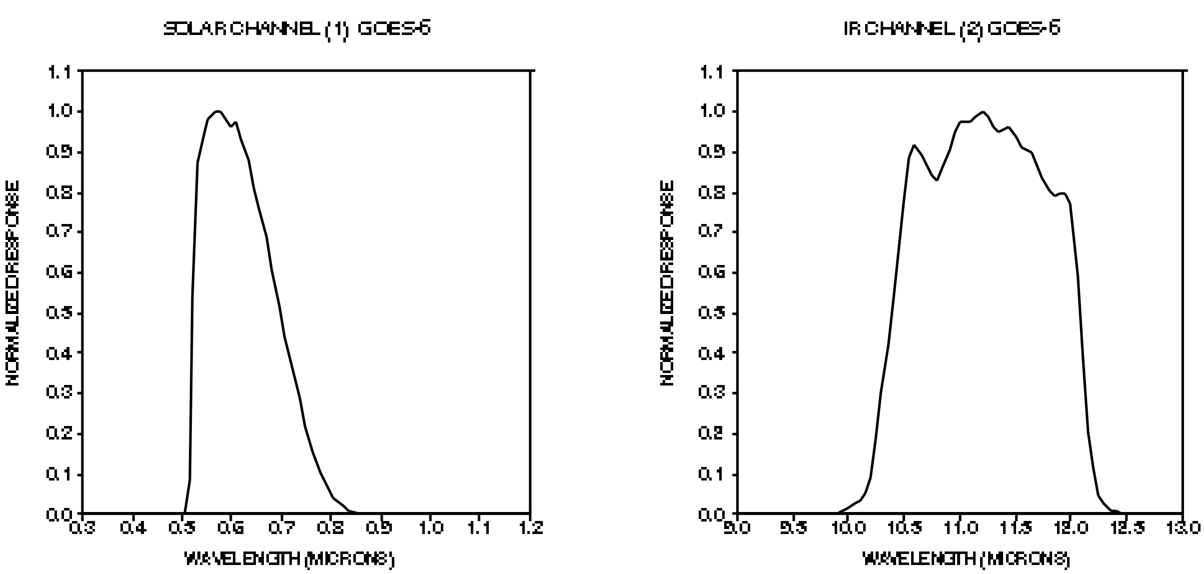

Fig. 4.2. Normalized spectral response functions for GOES-6.

TABLE 4.4. Normalized Spectral Responses for GOES-6.

Channel 1		Channel 2	
Wavelength (μm)	Response	Wavelength (μm)	Response
0.500	0.000	9.800	0.000
0.503	0.002	9.850	0.002
0.513	0.086	9.900	0.005
0.523	0.545	9.950	0.009
0.533	0.875	10.000	0.016
0.544	0.955	10.050	0.026
0.554	0.983	10.100	0.036
0.565	0.998	10.150	0.052
0.576	1.000	10.200	0.094
0.587	0.981	10.250	0.186
0.598	0.960	10.300	0.302
0.609	0.972	10.350	0.419
0.621	0.933	10.400	0.537
0.633	0.881	10.450	0.658
0.645	0.811	10.500	0.781
0.657	0.761	10.550	0.885
0.670	0.689	10.600	0.915
0.682	0.608	10.650	0.891
0.695	0.514	10.700	0.866
0.708	0.442	10.750	0.840
0.722	0.363	10.800	0.829
0.735	0.287	10.850	0.863
0.749	0.216	10.900	0.906
0.763	0.157	10.950	0.950
0.778	0.107	11.000	0.977
0.792	0.068	11.050	0.977
0.807	0.042	11.100	0.976
0.823	0.024	11.150	0.988
0.838	0.007	11.200	1.000
0.854	0.002	11.250	0.986
0.868	0.000	11.300	0.965
		11.350	0.951
		11.400	0.959
		11.450	0.962
		11.500	0.935
		11.550	0.912
		11.600	0.905
		11.650	0.896
		11.700	0.864
		11.750	0.832
		11.800	0.801
		11.850	0.788
		11.900	0.796
		11.950	0.796
		12.000	0.771
		12.050	0.595
		12.100	0.387

Normalized Spectral Responses for GOES-6 (continued).

Channel 1		Channel 2	
Wavelength (μm)	Response	Wavelength (μm)	Response
		12.150	0.208
		12.200	0.116
		12.250	0.046
		12.300	0.028
		12.350	0.011
		12.400	0.008
		12.450	0.005
		12.500	0.000

TABLE 4.5. Sample Conversion Tables for GOES-6.

Counts	Ch. 1 Scaled Radiance	Ch. 2 Temperature
0	0.000	330.000
25	0.003	317.500
50	0.042	305.600
75	0.108	292.500
100	0.200	280.000
125	0.319	267.500
150	0.464	255.000
175	0.635	242.500
200	0.833	218.000
225	1.057	193.000
250	1.308	168.000

TABLE 4.6. Normalized Spectral Responses for GOES-7.

Channel 1		Channel 2	
Wavelength (µm)	Response	Wavelength (µm)	Response
0.290	0.00000	9.800	0.00000
0.306	0.01080	9.850	0.00005
0.323	0.00930	9.900	0.00035
0.341	0.00790	9.950	0.00357
0.360	0.00680	10.000	0.01097
0.379	0.00650	10.050	0.02055
0.399	0.00280	10.100	0.04575
0.420	0.00090	10.150	0.09399
0.441	0.00060	10.200	0.18242
0.464	0.00130	10.250	0.32393
0.473	0.00150	10.300	0.48341
0.482	0.00130	10.350	0.58568
0.492	0.00170	10.400	0.65793
0.501	0.00450	10.450	0.70789
0.511	0.10140	10.500	0.73167
0.521	0.48100	10.550	0.74200
0.531	0.79080	10.600	0.74879
0.541	0.89340	10.650	0.75260
0.552	0.93680	10.700	0.75468
0.563	0.96640	10.750	0.76542
0.573	0.97280	10.800	0.78923
0.584	0.99820	10.850	0.81975
0.595	0.99730	10.900	0.84977
0.607	0.99470	10.950	0.87226
0.618	1.00000	11.000	0.89702

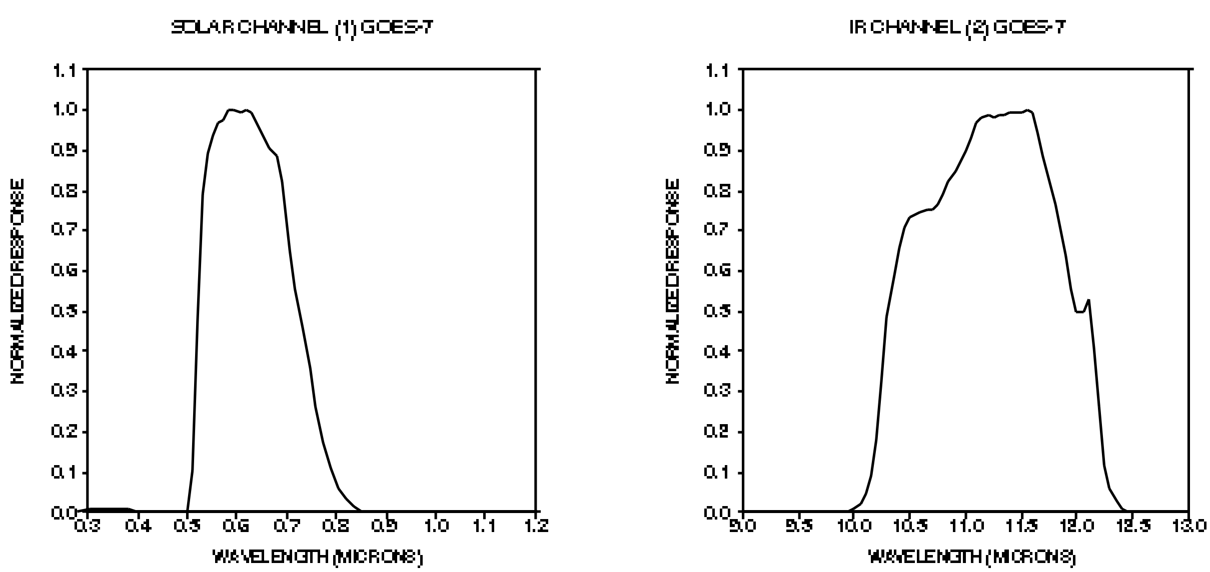

Fig. 4.3. Normalized spectral response functions for GOES-7.

Normalized Spectral Responses for GOES-7 (continued).

Channel 1		Channel 2	
Wavelength (μm)	Response	Wavelength (μm)	Response
0.630	0.99130	11.050	0.92959
0.642	0.95820	11.100	0.96983
0.654	0.92950	11.150	0.98371
0.667	0.90720	11.200	0.98751
0.679	0.88470	11.250	0.98028
0.692	0.82500	11.300	0.98695
0.705	0.65300	11.350	0.99079
0.719	0.55400	11.400	0.99444
0.732	0.46000	11.450	0.99185
0.746	0.36000	11.500	0.99507
0.760	0.26200	11.550	1.00000
0.775	0.17500	11.600	0.99332
0.790	0.10800	11.650	0.94202
0.805	0.06000	11.700	0.88602
0.820	0.03100	11.800	0.76815
0.836	0.01200	11.850	0.69898
0.852	0.00200	11.900	0.64084
0.868	0.00000	11.950	0.55832
0.884	0.00320	12.000	0.49836
0.901	0.00120	12.050	0.49623
0.000	0.00000	12.100	0.52759
		12.150	0.40961
		12.200	0.26218
		12.250	0.11368
		12.300	0.05816
		12.350	0.02633
		12.400	0.01126
		12.450	0.00397
		12.500	0.00039
		12.550	0.00001

TABLE 4.7. Sample Conversion Tables for GOES-7.

Counts	Ch. 1 Scaled Radiance	Ch. 2 Temperature
0	0.00	349.30
25	0.00	327.79
50	0.04	318.11
75	0.10	307.77
100	0.18	296.61
125	0.30	284.38
150	0.43	270.71
175	0.60	254.91
200	0.78	235.67
225	0.99	209.41
250	1.23	153.15

4.3 NORMALIZED CALIBRATION

The following tables give the normalization coefficients to normalize GOES calibrations to the current NOAA polar orbiter (changes of NOAA satellites are indicated in the tables). These coefficients do not account for any changes in the NOAA calibrations.

TABLE 4.8. Normalization for GOES-5.

	Visible (fraction)					Infrared (Kelvin)				
Month	Slope	Interc	rms	Min	Max	Slope	Interc	rms	Min	Max
JUL 83	0.665	-0.004	0.016	0.04	0.71	1.117	-30.92	1.00	195.5	299
AUG 83	0.653	0.000	-	-	-	1.111	-29.33	-	-	-
SEP 83	0.642	0.005	-	-	-	1.104	-27.74	-	-	-
OCT 83	0.630	0.009	0.022	0.09	0.80	1.098	-26.15	1.60	193	301
NOV 83	0.607	0.009	-	-	-	1.084	-22.62	-	-	-
DEC 83	0.583	0.009	-	-	-	1.069	-19.08	-	-	-
JAN 84	0.560	0.010	0.018	0.04	0.80	1.055	-15.55	1.20	193	302
FEB 84	0.580	0.009	-	-	-	1.066	-18.81	-	-	-
MAR 84	0.600	0.007	-	-	-	1.078	-22.08	-	-	-
APR 84	0.620	0.006	0.020	0.04	0.73	1.089	-25.34	1.50	195.5	303
MAY 84	0.625	0.006	-	-	-	1.102	-28.24	-	-	-
JUN 84	0.631	0.006	-	-	-	1.116	-31.14	-	-	-
JUL 84	0.636	0.006	0.013	0.04	0.73	1.129	-34.04	1.70	194.5	296

TABLE 4.9. Normalization for GOES-6.

	Visible (fraction)					Infrared (Kelvin)				
Month	Slope	Interc	rms	Min	Max	Slope	Interc	rms	Min	Max
JUL 83	0.675	-0.001	0.012	0.03	0.74	1.034	- 9.20	0.96	197.5	297
AUG 83	0.685	-0.004	-	-	-	1.041	-11.43	-	-	-
SEP 83	0.694	-0.007	-	-	-	1.049	-13.67	-	-	-
OCT 83	0.704	-0.010	0.022	0.04	0.77	1.056	-15.90	0.66	192.5	297
NOV 83	0.708	-0.004	-	-	-	1.059	-16.33	-	-	-
DEC 83	0.713	0.002	-	-	-	1.061	-16.77	-	-	-
JAN 84	0.717	0.008	0.010	0.035	0.73	1.064	-17.20	0.80	210.5	298
FEB 84	0.708	0.009	-	-	-	1.061	-16.63	-	-	-
MAR 84	0.699	0.009	-	-	-	1.059	-16.07	-	-	-
APR 84	0.690	0.010	0.020	0.03	0.78	1.056	-15.50	1.20	196	297
MAY 84	0.668	0.011	-	-	-	1.057	-15.43	-	-	-
JUN 84	0.645	0.011	-	-	-	1.059	-15.37	-	-	-
JUL 84	0.623	0.012	0.013	0.03	0.71	1.060	-15.30	1.17	193.5	296
AUG 84	0.645	0.011	-	-	-	1.061	-15.67	-	-	-
SEP 84	0.697	0.010	-	-	-	1.061	-16.03	-	-	-
OCT 84	0.750	0.009	0.009	0.04	0.51	1.062	-16.40	0.50	226.5	294
NOV 84	0.737	0.008	-	-	-	1.037	-10.20	-	-	-
DEC 84	0.724	0.007	0.015	0.04	0.68	1.012	- 4.00	1.70	205	296
JAN 85	0.724	0.007	0.015	0.04	0.68	1.012	- 4.00	1.70	205	296
*** change from NOAA-7 to NOAA-9 as normalization standard										
FEB 85	0.777	0.007	-	-	-	1.046	-14.70	-	-	-
MAR 85	0.777	0.007	0.016	0.03	0.88	1.046	-14.70	2.86	218.5	297.5

Normalization for GOES-6 (continued).

Month		Visible (fraction) Slope	Interc	rms	Min	Max	Infrared (Kelvin) Slope	Interc	rms	Min	Max
APR	85	0.805	0.004	0.010	0.03	0.90	1.070	-19.90	1.25	202.5	297
MAY	85	0.784	0.006	-	-	-	1.076	-21.23	-	-	-
JUN	85	0.762	0.008	-	-	-	1.083	-22.57	-	-	-
JUL	85	0.741	0.010	0.012	0.03	0.81	1.089	-23.90	1.58	200	294
AUG	85	0.774	0.009	-	-	-	1.091	-24.47	-	-	-
SEP	85	0.806	0.007	-	-	-	1.093	-25.03	-	-	-
OCT	85	0.839	0.006	0.015	0.03	0.86	1.095	-25.60	0.84	215.5	295
NOV	85	0.847	0.004	-	-	-	1.088	-23.45	-	-	-
DEC	85	0.856	0.003	-	-	-	1.080	-21.30	1.67	196	296.5
JAN	86	0.864	0.001	0.019	0.03	0.72	1.080	-21.30	1.67	196	296.5
FEB	86	0.839	0.003	-	-	-	1.079	-21.67	-	-	-
MAR	86	0.813	0.004	-	-	-	1.078	-22.03	-	-	-
APR	86	0.788	0.006	0.009	0.03	0.88	1.077	-22.40	1.55	206	296.5
MAY	86	0.769	0.008	-	-	-	1.074	-20.93	-	-	-
JUN	86	0.750	0.011	-	-	-	1.070	-19.47	-	-	-
JUL	86	0.731	0.013	0.017	0.03	0.80	1.067	-18.00	1.87	206.5	294.5
AUG	86	0.775	0.010	-	-	-	1.054	-13.83	-	-	-
SEP	86	0.820	0.008	-	-	-	1.040	- 9.67	-	-	-
OCT	86	0.864	0.005	0.015	0.03	0.70	1.027	- 5.50	1.02	230.5	294.5
NOV	86	0.830	0.009	-	-	-	1.052	-12.90	-	-	-
DEC	86	0.796	0.012	-	-	-	1.077	-20.30	-	-	-
JAN	87	0.762	0.016	0.020	0.03	0.86	1.102	-27.70	1.30	193.5	296.5
FEB	87	0.740	0.012	-	-	-	1.100	-28.60	-	-	-
MAR	87	0.717	0.007	0.012	0.02	0.86	1.098	-29.50	1.19	194.5	296.5
***	change to AAA format on GOES - new IR calibration coding introduced										
APR	87	0.729	0.008	-	-	-	1.112	-33.17	-	-	-
MAY	87	0.740	0.009	-	-	-	1.125	-36.83	-	-	-
JUN	87	0.752	0.010	0.009	0.03	0.77	1.139	-40.50	1.40	180.5	299
JUL	87	0.765	0.018	0.015	0.02	0.77	1.119	-33.90	1.30	194.5	298
AUG	87	0.788	0.016	-	-	-	1.106	-30.10	-	-	-
SEP	87	0.812	0.014	-	-	-	1.093	-26.30	-	-	-
OCT	87	0.835	0.012	0.015	0.03	0.71	1.080	-22.50	1.80	198	297.5
NOV	87	0.827	0.011	-	-	-	1.066	-18.57	-	-	-
DEC	87	0.818	0.011	-	-	-	1.052	-14.63	-	-	-
JAN	88	0.810	0.010	0.012	0.03	0.68	1.038	-10.70	0.80	220.5	296
FEB	88	0.754	0.011	-	-	-	1.034	- 9.43	-	-	-
MAR	88	0.698	0.011	-	-	-	1.029	- 8.17	-	-	-
APR	88	0.642	0.012	0.014	0.02	0.71	1.025	- 6.90	1.20	215	296.5
MAY	88	0.637	0.013	-	-	-	1.026	- 7.17	-	-	-
JUN	88	0.633	0.014	-	-	-	1.028	- 7.43	-	-	-
JUL	88	0.628	0.015	0.010	0.03	0.73	1.029	- 7.70	1.00	204.5	296
AUG	88	0.643	0.013	-	-	-	1.038	-10.37	-	-	-
SEP	88	0.658	0.012	-	-	-	1.048	-13.03	-	-	-
OCT	88	0.673	0.010	0.012	0.03	0.77	1.057	-15.70	1.40	198	296
***	change from NOAA-9 to NOAA-11 as normalization standard										
NOV	88	0.692	0.011	0.013	0.02	0.85	1.021	- 5.90	1.00	197	295.5
DEC	88	0.695	0.010	-	-	-	1.014	- 4.20	-	-	-
JAN	89	0.698	0.008	0.016	0.02	0.75	1.008	- 2.50	0.60	219.5	294.5

TABLE 4.10. Normalization for GOES-7.

		Visible (fraction)					Infrared (Kelvin)				
Month		Slope	Interc	rms	Min	Max	Slope	Interc	rms	Min	Max
APR	87	0.591	0.012	0.021	0.04	0.73	1.131	-34.94	2.36	183.5	298
***	trend present in April - change at 13th)										
APR	87	0.725	0.015	0.017	0.04	0.78	1.131	-34.94	2.36	183.5	298
MAY	87	0.725	0.015	0.017	0.04	0.78	1.131	-34.94	2.36	183.5	298
JUN	87	0.728	0.015	-	-	-	1.126	-34.21	-	-	-
JUL	87	0.731	0.015	0.011	0.03	0.70	1.122	-33.48	1.42	192	297
AUG	87	0.759	0.022	-	-	-	1.097	-26.30	-	-	-
SEP	87	0.786	0.029	-	-	-	1.071	-19.13	-	-	-
OCT	87	0.814	0.036	0.022	0.03	0.76	1.046	-11.95	1.24	188	298.5
NOV	87	0.827	0.028	-	-	-	1.046	-12.27	-	-	-
DEC	87	0.840	0.020	0.011	0.04	0.74	1.047	-12.59	1.11	188.5	301
JAN	88	0.699	0.014	0.011	0.03	0.78	1.047	-12.59	1.11	188.5	301
FEB	88	0.577	0.025	0.016	0.03	0.66	1.047	-12.59	1.11	188.5	301
MAR	88	0.716	0.007	0.004	0.07	0.62	1.050	-12.74	-	-	-
APR	88	0.737	0.016	0.010	0.05	0.74	1.052	-12.90	1.30	188	300
MAY	88	0.737	0.015	0.010	0.05	0.68	1.059	-15.25	-	-	-
JUN	88	0.728	0.023	-	-	-	1.066	-17.60	1.50	213.5	294.5
JUL	88	0.718	0.031	0.020	0.04	0.63	0.999	1.00	0.70	203	302
AUG	88	0.754	0.029	-	-	-	1.056	-14.70	1.30	194	298.5
SEP	88	0.789	0.028	-	-	-	1.057	-14.85	-	-	-
OCT	88	0.825	0.026	0.020	0.04	0.75	1.058	-15.00	1.40	189.5	297.5
***	change from NOAA-9 to NOAA-11 as normalization standard										
NOV	88	0.749	0.025	0.010	0.03	0.80	0.993	2.30	1.00	206.5	295.5
DEC	88	0.749	0.025	0.010	0.03	0.80	0.993	2.30	1.00	206.5	295.5
***	change to new AAA IR calibration coding										
JAN	89	0.731	0.012	0.013	0.03	0.81	1.023	- 6.10	1.00	200.5	297
FEB	89	0.755	0.013	0.020	0.02	0.80	1.003	- 0.70	0.70	214.5	295.5
MAR	89	0.754	0.013	-	-	-	1.008	- 1.70	-	-	-
APR	89	0.752	0.013	0.009	0.03	0.77	1.012	- 2.70	0.80	208.5	295.5
MAY	89	0.742	0.012	-	-	-	1.020	-5.20	-	-	-
JUN	89	0.732	0.012	-	-	-	1.029	-7.70	-	-	-
JUL	89	0.723	0.011	0.018	0.02	0.76	1.037	-10.20	1.00	207	295.5
AUG	89	0.745	0.012	-	-	-	1.033	-9.00	-	-	-
SEP	89	0.767	0.013	-	-	-	1.029	-7.80	-	-	-
OCT	89	0.789	0.014	0.011	0.02	0.62	1.025	-6.60	0.40	203	294
NOV	89	0.792	0.016	-	-	-	1.013	-3.43	-	-	-
DEC	89	0.794	0.017	-	-	-	1.002	-0.27	-	-	-
JAN	90	0.797	0.019	0.017	0.02	0.66	0.990	-2.90	0.70	222.5	295.5
FEB	90	0.794	0.015	-	-	-	0.997	1.17	-	-	-
MAR	90	0.791	0.012	-	-	-	1.004	-0.57	-	-	-
APR	90	0.788	0.008	0.010	0.02	0.78	1.011	-2.30	1.20	196	297.5
MAY	90	0.783	0.011	-	-	-	1.017	-3.90	-	-	-
JUN	90	0.779	0.014	-	-	-	1.022	-5.57	-	-	-
JUL	90	0.774	0.017	0.013	0.02	0.78	1.028	-7.20	1.10	204	295.5
AUG	90	0.757	0.020	0.013	0.02	0.78	1.020	-4.60	1.30	197.5	295.5
SEP	90	0.794	0.027	0.012	0.02	0.78	1.013	-2.80	1.00	211.5	295
OCT	90	0.857	0.023	0.015	0.02	0.80	1.019	-5.10	0.90	204.5	295.5

Normalization for GOES-7 (continued).

Month		Visible (fraction) Slope	Interc	rms	Min	Max	Infrared (Kelvin) Slope	Interc	rms	Min	Max
NOV	90	0.881	0.020	-	-	-	1.010	-2.75	-	-	-
DEC	90	0.905	0.016	0.012	0.03	0.64	1.001	-0.40	0.90	216.5	296.5
JAN	91	0.923	0.020	0.012	0.03	0.73	1.015	-4.30	1.10	213	296
FEB	91	0.857	0.018	0.010	0.02	0.82	0.999	0.60	0.70	216	297
MAR	91	0.860	0.022	0.013	0.02	0.80	1.036	-9.60	0.80	205.5	297.5
APR	91	0.851	0.017	0.006	0.02	0.81	1.023	-6.10	1.10	203.5	296.5
MAY	91	0.860	0.020	0.014	0.02	0.78	1.014	-2.90	1.10	198	297.5
JUN	91	0.833	0.026	0.016	0.02	0.80	1.009	-1.50	1.00	199.5	296.5
JUL	91	0.836	0.026	0.016	0.04	0.82	1.014	-2.80	1.20	196	295

4.4. ABSOLUTE CALIBRATION

The final calibration of GOES radiances is obtained by applying to the normalized calibration the same corrections as applied to the relevant NOAA satellite, shown in Tables 2.18 through 2.24. No changes are required when GOES is normalized to NOAA-7, except for multiplying all VIS radiances by 1.2. Table 4.11 gives the final calibration coefficients used for GOES, including the corrections for changes in NOAA calibration and the factor of 1.2 for VIS radiances (from Desormeaux et al. 1992). Table 4.12 shows additional VIS calibration adjustments made for GOES-7.

TABLE 4.11. History of visible and infrared normalization coefficients for GOES.

GOES-5

Month		Visible (fraction) Slope	Interc	Infrared (Kelvin) Slope	Interc
JUL	83	0.798	-0.005	1.117	-30.92
AUG	83	0.784	0.000	1.111	-29.33
SEP	83	0.770	0.006	1.104	-27.74
OCT	83	0.756	0.011	1.098	-26.15
NOV	83	0.728	0.011	1.084	-22.62
DEC	83	0.700	0.011	1.069	-19.08
JAN	84	0.672	0.012	1.055	-15.55
FEB	84	0.696	0.011	1.066	-18.81
MAR	84	0.720	0.008	1.078	-22.08
APR	84	0.744	0.007	1.089	-25.34
MAY	84	0.750	0.007	1.102	-28.24
JUN	84	0.757	0.007	1.116	-31.14
JUL	84	0.763	0.007	1.129	-34.04

Month		Visible (fraction) Slope	Visible (fraction) Interc	Infrared (Kelvin) Slope	Infrared (Kelvin) Interc
JUL	83	0.810	-0.001	1.034	- 9.20
AUG	83	0.822	-0.005	1.041	-11.43
SEP	83	0.833	-0.008	1.049	-13.67
OCT	83	0.845	-0.012	1.056	-15.90
NOV	83	0.850	-0.005	1.059	-16.33
DEC	83	0.856	0.002	1.061	-16.77
JAN	84	0.860	0.010	1.064	-17.20
FEB	84	0.850	0.011	1.061	-16.63
MAR	84	0.839	0.011	1.059	-16.07
APR	84	0.828	0.012	1.056	-15.50
MAY	84	0.802	0.013	1.057	-15.43
JUN	84	0.774	0.013	1.059	-15.37
JUL	84	0.748	0.014	1.060	-15.30
AUG	84	0.774	0.013	1.061	-15.67
SEP	84	0.836	0.012	1.061	-16.03
OCT	84	0.900	0.011	1.062	-16.40
NOV	84	0.884	0.010	1.037	-10.20
DEC	84	0.869	0.008	1.012	- 4.00
JAN	85	0.869	0.008	1.012	- 4.00
	** change from NOAA-7 to NOAA-9 as normalization standard				
FEB	85	0.779	0.010	1.046	-14.70
MAR	85	0.781	0.010	1.046	-14.70
APR	85	0.812	0.006	1.070	-19.90
MAY	85	0.794	0.008	1.076	-21.23
JUN	85	0.775	0.011	1.083	-22.57
JUL	85	0.756	0.012	1.089	-23.90
AUG	85	0.792	0.012	1.091	-24.47
SEP	85	0.829	0.010	1.093	-25.03
OCT	85	0.865	0.008	1.095	-25.60
NOV	85	0.877	0.006	1.088	-23.45
DEC	85	0.889	0.006	1.080	-21.30
JAN	86	0.901	0.004	1.080	-21.30
FEB	86	0.878	0.006	1.079	-21.67
MAR	86	0.853	0.007	1.078	-22.03
APR	86	0.830	0.008	1.077	-22.40
MAY	86	0.814	0.011	1.074	-20.93
JUN	86	0.797	0.014	1.070	-19.47
JUL	86	0.779	0.017	1.067	-18.00
AUG	86	0.829	0.013	1.054	-13.83
SEP	86	0.880	0.011	1.040	- 9.67
OCT	86	0.931	0.007	1.056	-14.15
NOV	86	0.898	0.012	1.052	-12.90
DEC	86	0.864	0.016	1.077	-20.30
JAN	87	0.830	0.020	1.102	-27.70
FEB	87	0.809	0.016	1.100	-28.60
MAR	87	0.786	0.010	1.098	-29.50
	** change to AAA format on GOES - new IR calibration coding introduced				
APR	87	0.803	0.011	1.112	-33.17
MAY	87	0.818	0.012	1.125	-36.83

GOES-6 (continued).

Month		Visible (fraction) Slope	Visible (fraction) Interc	Infrared (Kelvin) Slope	Infrared (Kelvin) Interc
JUN	87	0.834	0.013	1.139	-40.50
JUL	87	0.852	0.023	1.119	-33.90
AUG	87	0.881	0.020	1.106	-30.10
SEP	87	0.910	0.018	1.093	-26.30
OCT	87	0.940	0.016	1.121	-34.86
NOV	87	0.934	0.014	1.107	-30.78
DEC	87	0.926	0.014	1.092	-26.69
JAN	88	0.922	0.013	1.077	-22.61
FEB	88	0.860	0.014	1.073	-21.29
MAR	88	0.799	0.014	1.068	-19.98
APR	88	0.738	0.016	1.064	-18.66
MAY	88	0.734	0.017	1.065	-18.94
JUN	88	0.733	0.019	1.067	-19.21
JUL	88	0.731	0.020	1.068	-19.49
AUG	88	0.750	0.018	1.077	-22.26
SEP	88	0.770	0.017	1.088	-25.03
OCT	88	0.791	0.014	1.097	-27.80
	** change from NOAA-9 to NOAA-11 as normalization standard				
NOV	88	0.780	0.013	1.089	-25.30
DEC	88	0.784	0.012	1.082	-23.48
JAN	89	0.787	0.011	1.076	-21.67

GOES-7.

Month		Visible (fraction) Slope	Visible (fraction) Interc	Infrared (Kelvin) Slope	Infrared (Kelvin) Interc
APR	87	0.652	0.016	1.131	-34.94
	** trend present in April - change at 13th				
APR	87	0.799	0.019	1.131	-34.94
MAY	87	0.802	0.019	1.131	-34.94
JUN	87	0.808	0.019	1.126	-34.21
JUL	87	0.814	0.019	1.122	-33.48
AUG	87	0.848	0.026	1.097	-26.30
SEP	87	0.881	0.035	1.071	-19.13
OCT	87	0.917	0.043	1.086	-23.90
NOV	87	0.934	0.034	1.086	-24.26
DEC	87	0.952	0.025	1.087	-24.57
JAN	88	0.796	0.018	1.087	-24.57
FEB	88	0.659	0.031	1.087	-24.57
MAR	88	0.820	0.011	1.090	-24.72
MAY	88	0.850	0.019	1.099	-27.33
APR	88	0.847	0.020	1.092	-24.89
JUN	88	0.844	0.029	1.107	-29.77
JUL	88	0.835	0.038	1.037	-10.46
AUG	88	0.880	0.036	1.096	-26.76
SEP	88	0.923	0.035	1.097	-26.91

GOES-7 (continued).

Month		Visible (fraction) Slope	Visible (fraction) Interc	Infrared (Kelvin) Slope	Infrared (Kelvin) Interc
OCT	88	0.970	0.032	1.098	-27.07
	** change from NOAA-9 to NOAA-11 as normalization standard				
NOV	88	0.845	0.029	1.060	-16.55
DEC	88	0.845	0.029	1.060	-16.55
	** change to new AAA IR calibration coding				
JAN	89	0.824	0.014	1.092	-25.51
FEB	89	0.852	0.016	1.070	-19.75
MAR	89	0.851	0.016	1.076	-20.81
APR	89	0.848	0.016	1.080	-21.88
MAY	89	0.836	0.014	1.088	-24.55
JUN	89	0.826	0.014	1.098	-27.22
JUL	89	0.816	0.013	1.106	-29.88
AUG	89	0.840	0.014	1.102	-28.60
SEP	89	0.865	0.016	1.098	-27.32
OCT	89	0.890	0.017	1.083	-22.64
NOV	89	0.893	0.019	1.071	-19.29
DEC	89	0.895	0.020	1.059	-15.95
JAN	90	0.899	0.023	1.056	-22.09
FEB	90	0.895	0.018	1.064	-17.75
MAR	90	0.888	0.014	1.071	-19.61
APR	90	0.881	0.010	1.079	-21.45
MAY	90	0.869	0.013	1.085	-23.16
JUN	90	0.860	0.017	1.090	-24.94
JUL	90	0.851	0.020	1.097	-26.68
AUG	90	0.828	0.023	1.088	-23.91
SEP	90	0.863	0.030	1.081	-21.99
OCT	90	0.926	0.026	1.087	-24.44
NOV	90	0.948	0.023	1.078	-21.93
DEC	90	0.968	0.018	1.068	-19.43
JAN	91	0.983	0.023	1.083	-23.59
FEB	91	0.908	0.020	1.066	-18.36
MAR	91	0.906	0.024	1.105	-29.24
APR	91	0.892	0.019	1.092	-25.51
MAY	91	0.898	0.022	1.082	-22.09
JUN	91	0.865	0.028	1.077	-20.60

TABLE 4.12. GOES-7 VIS Calibration Adjustments.

Month	Day	Slope	Intercept
JAN 88	01 - 07:	1.200	0.003
JAN 88	29 - 31:	0.825	-0.009
FEB 88	21 - 29:	1.200	0.003
MAR 88	01 - 31:	1.000	0.010

5. GMS

The Geostationary Meteorological Satellite (GMS) is operated by the Japan Meteorological Agency (JMA). GMS-1 was launched in July 1977 and remained operational until replaced by GMS-2 in December 1981. GMS-2 supplied imaging data for the ISCCP beginning in July 1983. Problems with the GMS-2 scanner caused a switch back to GMS-1 in January 1984; however, the GMS-1 scanner failed in June 1984 requiring use of GMS-2 with a reduced imaging frequency. GMS-3 became operational in September 1984 and functioned without problems until replaced by GMS-4 in December 1989 (see Rossow et al. 1987 for more details).

Imaging data are from the Visible Infrared Spin-Scan Radiometer (VISSR), which consists of four visible and one infrared sensors as the primary set and an identical back-up set. The spectral response functions for the two channels, nominally at 0.65 µm and 11.5 µm, are shown in Section 5.2.

5.1. NOMINAL CALIBRATION

(1) SOLAR CHANNEL

Conversion of radiometer output voltages to scaled radiances involves two sets of calibration coefficients (Meteorological Satellite Center 1984). Telemetry counts are related to instrument voltages by

$$CT = ß_0 + ß_1 \sqrt{V} \tag{5.1}$$

where the coefficients $ß_0$ and $ß_1$ are determined daily by insertion of a standard 0 to 5 - volt staircase signal in the telemetry. The instrument voltage is also related to scaled radiance by

$$V = \alpha_0 L^* + V_0 \tag{5.2}$$

where α_0 and V_0 are determined by viewing space and the sun, where the sun is viewed through an energy-reducing prism. Taking the radiance of the sun to be $L^*_{sn}$and that of space to be L_{sp} = 0, (5.1) and (5.2) can be combined to give

$$L^* = L^*_{sn} [(CT - CT_{sp})(CT + CT_{sp} - 2ß_0)][(CT_{sn} - CT_{sp})(CT_{sn} + CT_{sp} - 2ß_0)]^{-1} \tag{5.3}$$

where CT_{sp} and CT_{sn} are the telemetry counts when viewing these two targets.

Post-launch measurements showed two difficulties: differences in the sensitivity of the four primary and back-up sensors, causing stripes in the images, and rapid variability of the sun calibration signal. Therefore, the solar channel data are normalized to a reference channel (Ch. 7 on GMS-1, Ch. 1 on GMS-2, Ch. 5 on GMS-3 and Ch. 3 on GMS-4), where the calibration coefficients for the reference channel are fixed based on a combination of pre-launch and post-launch measurements. These equations are used to construct a table relating telemetry counts (6-bit) to scaled radiance for all solar channels; daily monitoring of the values of $ß_0$ and $ß_1$ can lead to replacement of tables.

Solar channel data for ISCCP represent an average of the measurements from channels 5, 7 and 8 for GMS-1, 1 - 4 for GMS-2, 5 - 8 for GMS-3, and 1-4 for GMS-4. These average values are rescaled to an 8-bit count scale using

$$L^* = (CT/255)^2 \tag{5.4}$$

These scaled radiance values are converted to radiances using the spectral response functions shown in Section 5.2; the solar spectral irradiances for the reference channels are E_o/π = 113.25 watts m^{-2} sr^{-1} for GMS-1, 114.50 watts m^{-2} sr^{-1} for GMS-2, 119.56 watts m^{-2} sr^{-1} for GMS-3, and 122.82 watts m^{-2} sr^{-1} for GMS-4, where

$$L = (E_o/\pi) L^* . \tag{5.5}$$

(2) INFRARED CHANNEL

Instrument voltage is related to telemetry counts (8-bit) in the same way as for the solar channel (Meteorological Satellite Center 1984):

$$CT = ß_0 + ß_1 \sqrt{V} \tag{5.6}$$

where $ß_0$ and $ß_1$ are determined daily from the on-board voltage reference signal. Instrument voltage is related to radiance, L, by

$$V = \alpha_0 L + V_0 \tag{5.7}$$

where α_0 and V_0 are determined from daily observations of space and an on-board black-body of known temperature. These two coefficients are thus given by $V_0 = V_{sp}$ and

$$\alpha_0 = (V_{sh} - V_{sp})/L_{bb} \tag{5.8}$$

where V_{sp} is the voltage recorded when viewing space (telemetry count CT_{sp} and radiance $L_{sp} = 0$) and V_{sh} is the voltage recorded when viewing the shutter which serves as the on-board reference. The radiance, L_{bb}, is the radiance at the sensor, which depends on the temperatures of various parts of the instrument. The effective temperature of the calibration source is determined by

$$T_{bb} = T_{sh} + k_1 (T_{sh} - T_a) + k_2 (T_{sh} - T_1) \tag{5.9}$$

where

$$T_{sh} = (T_{sh1} + T_{sh2})/2 \quad \text{mean shutter temperature} \tag{5.10}$$

$$T_a = (T_1 + T_2 + T_3)/3 \quad \text{mean scanner temperature} \tag{5.11}$$

A look-up table, calculated using the measured spectral response of the infrared channels and the Planck function, is used to convert T_{bb} to L_{bb}. The results of the daily calibration observations are used to produce a table relating count values (8-bit) to radiances and black-body temperatures; these tables are provided with the data. In operation, the backup IR channel is used on GMS-1 and the primary channel is used on GMS-2, GMS-3 and GMS-4 (see Section 5.2).

The coefficients k_1 and k_2 used in construction of the calibration tables were determined from pre-launch calibration measurements; $k_1 = 0.325$ and $k_2 = 0.175$ are used for GMS-1, GMS-2 and GMS-3. Post-launch comparisons of GMS-2 IR measurements and conventional sea surface temperature observations by ships were performed with a model for atmospheric corrections. A small bias (1-2K) was found which varied seasonally, apparently due to changing temperature gradients within the scanner. Because of the uncertainties in both the ship observations and the modeled corrections, no change in calibration was made.

Shorter period variations in calibration due to the diurnal heating/cooling cycle were not monitored for the GMS satellites before 1987; after 1987 diurnal corrections are applied to radiances.

Sample tables in Section 5.2 illustrate the conversion tables supplied with the data that are used to obtain scaled radiances and brightness temperatures from counts.

5.2. GMS SPECTRAL RESPONSE

The spectral responses for the VISSR channels on GMS-1, 2, 3 and 4 are given in Tables 5.1 through 5.8 and illustrated in Figs. 5.1, 5.2, 5.3 and 5.4.

Tables relating counts to temperature and counts to infrared radiances are provided by JMA; however, the radiances values are in units per wavelength. To obtain consistent radiance units, the values are multiplied by a bandwidth: 1.623 µm (GMS-1), 1.214 µm (GMS-2), 2.057 µm (GMS-3), and 1.103 µm (GMS-4).

TABLE 5.1. Normalized Spectral Responses for GMS-1.

Channel 1		Channel 2	
Wavelength (µm)	Response	Wavelength (µm)	Response
0.440	0.000	9.400	0.000
0.450	0.001	9.500	0.002
0.460	0.004	9.600	0.002
0.470	0.045	9.700	0.002
0.480	0.212	9.800	0.002
0.490	0.438	9.900	0.002
0.500	0.598	10.000	0.002
0.510	0.706	10.100	0.004
0.520	0.785	10.200	0.020
0.530	0.871	10.300	0.104
0.540	0.952	10.400	0.355
0.550	0.995	10.500	0.675
0.560	0.995	10.600	0.871
0.570	0.979	10.700	0.943
0.580	0.955	10.800	0.947
0.590	0.988	10.900	0.944
0.600	1.000	11.000	1.000
0.610	0.966	11.100	0.941
0.620	0.881	11.200	0.904
0.630	0.838	11.300	0.857
0.640	0.798	11.400	0.789
0.650	0.834	11.500	0.704
0.660	0.793	11.600	0.652
0.670	0.737	11.700	0.578
0.680	0.651	11.800	0.508
0.690	0.574	11.900	0.489
0.700	0.515	12.000	0.471
0.710	0.496	12.100	0.466
0.720	0.466	12.200	0.465
0.730	0.402	12.300	0.451
0.740	0.346	12.400	0.414
0.750	0.276	12.500	0.404
0.760	0.224	12.600	0.429
0.770	0.192	12.700	0.372
0.780	0.163	12.800	0.210

Normalized Spectral Responses for GMS-1 (continued).

Channel 1		Channel 2	
Wavelength (µm)	Response	Wavelength (µm)	Response
0.790	0.143	12.900	0.088
0.800	0.117	13.000	0.033
0.810	0.093	13.100	0.000
0.820	0.069		
0.830	0.055		
0.840	0.039		
0.850	0.028		
0.860	0.016		
0.870	0.009		
0.880	0.002		
0.890	0.001		
0.900	0.000		

TABLE 5.2. Sample Conversion Tables for GMS-1.

Counts	Ch. 1 Scaled Radiance	Ch. 2 Temperature
0	0.000	330.000
25	0.010	322.620
50	0.040	313.080
75	0.090	302.850
100	0.150	291.750
125	0.242	279.510
150	0.340	265.065
175	0.473	249.340
200	0.610	228.720
225	0.770	197.540
250	0.950	170.000

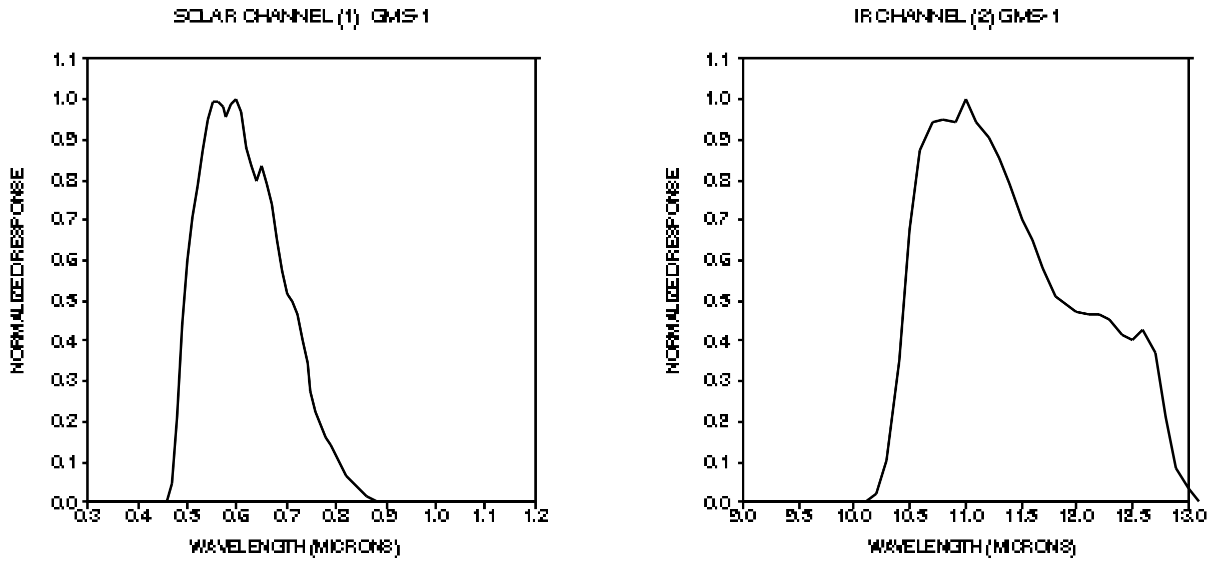

Fig. 5.1. Normalized spectral response functions for GMS-1.

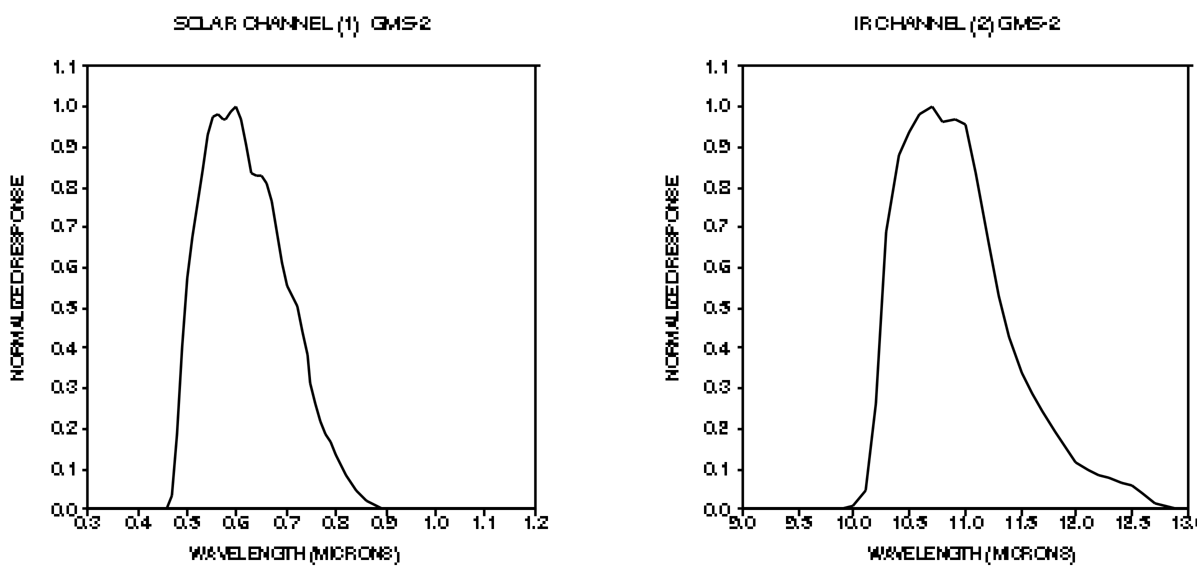

Fig. 5.2. Normalized spectral response functions for GMS-2.

TABLE 5.3. Normalized Spectral Responses for GMS-2.

Channel 1		Channel 2	
Wavelength (μm)	Response	Wavelength (μm)	Response
0.450	0.000	9.400	0.000
0.460	0.002	9.500	0.001
0.470	0.036	9.600	0.002
0.480	0.188	9.700	0.002
0.490	0.401	9.800	0.002
0.500	0.573	9.900	0.005
0.510	0.677	10.000	0.008
0.520	0.762	10.100	0.046
0.530	0.843	10.200	0.262
0.540	0.930	10.300	0.691
0.550	0.974	10.400	0.881
0.560	0.983	10.500	0.937
0.570	0.970	10.600	0.982
0.580	0.967	10.700	1.000
0.590	0.987	10.800	0.962
0.600	1.000	10.900	0.966
0.610	0.970	11.000	0.954
0.620	0.908	11.100	0.835
0.630	0.837	11.200	0.664
0.640	0.830	11.300	0.529
0.650	0.829	11.400	0.430
0.660	0.810	11.500	0.341
0.670	0.768	11.600	0.289
0.680	0.690	11.700	0.241
0.690	0.611	11.800	0.193
0.700	0.557	11.900	0.155
0.710	0.532	12.000	0.116
0.720	0.503	12.100	0.097
0.730	0.444	12.200	0.088
0.740	0.385	12.300	0.080
0.750	0.313	12.400	0.067
0.760	0.266	12.500	0.058
0.770	0.221	12.600	0.043
0.780	0.190	12.700	0.014
0.790	0.166	12.800	0.009
0.800	0.133	12.900	0.001
0.810	0.109	13.000	0.000
0.820	0.084		
0.830	0.065		
0.840	0.046		
0.850	0.035		
0.860	0.023		
0.870	0.015		
0.880	0.006		
0.890	0.003		
0.900	0.000		

TABLE 5.4. Sample Conversion Tables for GMS-2.

Counts	Ch. 1 Scaled Radiance	Ch. 2 Temperature
0	0.000	330.000
25	0.010	323.650
50	0.040	314.290
75	0.088	304.250
100	0.150	293.340
125	0.242	281.280
150	0.340	267.610
175	0.473	251.510
200	0.610	231.180
225	0.770	200.200
250	0.950	170.000

TABLE 5.5. Normalized Spectral Responses for GMS-3.

Channel 1		Channel 2	
Wavelength (µm)	Response	Wavelength (µm)	Response
0.460	0.000	9.400	0.000
0.470	0.043	9.500	0.001
0.480	0.154	9.600	0.001
0.490	0.314	9.700	0.001
0.500	0.429	9.800	0.001
0.510	0.525	9.900	0.003
0.520	0.614	10.000	0.007
0.530	0.695	10.100	0.045
0.540	0.740	10.200	0.225
0.550	0.804	10.300	0.534
0.560	0.850	10.400	0.637
0.570	0.896	10.500	0.686
0.580	0.944	10.600	0.764
0.590	0.973	10.700	0.822
0.600	0.979	10.800	0.881
0.610	0.989	10.900	0.946
0.620	1.000	11.000	1.000
0.630	0.981	11.100	0.988
0.640	0.983	11.200	0.959
0.650	0.963	11.300	0.967
0.660	0.953	11.400	0.957
0.670	0.924	11.500	0.953
0.680	0.876	11.600	0.957
0.690	0.801	11.700	0.949
0.700	0.734	11.800	0.913
0.710	0.727	11.900	0.849
0.720	0.690	12.000	0.813
0.730	0.623	12.100	0.793

Normalized Spectral Responses for GMS-3 (continued).

Channel 1		Channel 2	
Wavelength (µm)	Response	Wavelength (µm)	Response
0.740	0.546	12.200	0.796
0.750	0.468	12.300	0.763
0.760	0.395	12.400	0.787
0.770	0.335	12.500	0.749
0.780	0.287	12.600	0.456
0.790	0.239	12.700	0.196
0.800	0.191	12.800	0.073
0.810	0.158	12.900	0.027
0.820	0.124	13.000	0.012
0.830	0.098	13.100	0.008
0.840	0.072	13.200	0.004
0.850	0.055	13.300	0.009
0.860	0.037	13.400	0.014
0.870	0.025	13.500	0.009
0.880	0.013	13.600	0.005
0.890	0.008	13.700	0.005
0.900	0.002	13.800	0.000
0.910	0.001		
0.920	0.000		

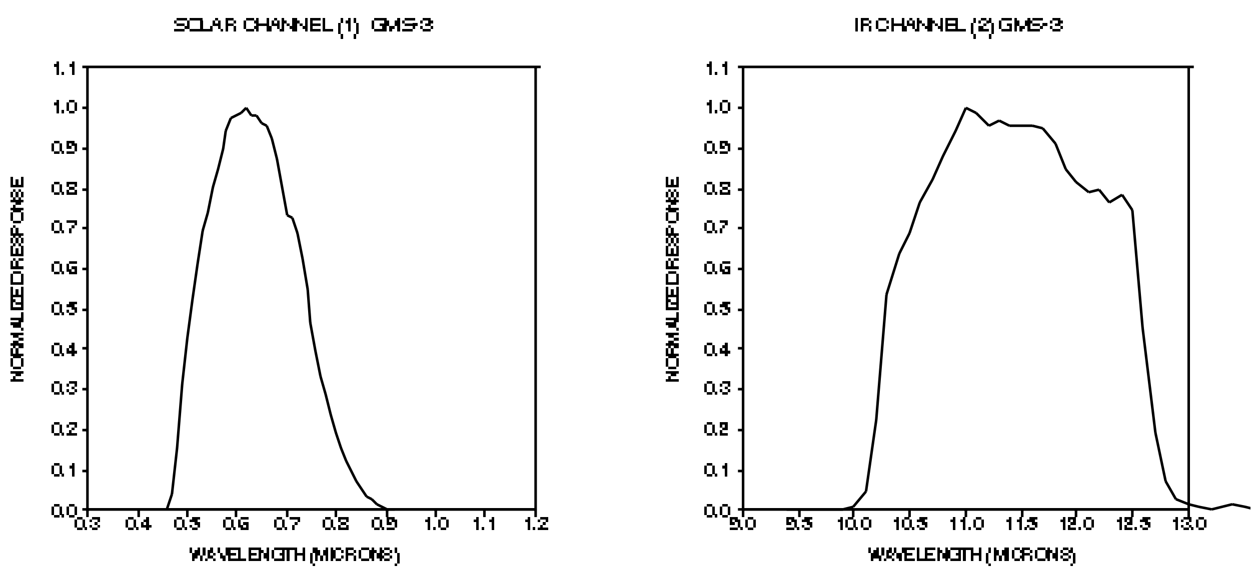

Fig. 5.3. Normalized spectral response functions for GMS-3.

TABLE 5.6. Sample Conversion Tables for GMS-3.

Counts	Ch. 1 Scaled Radiance	Ch. 2 Temperature
0	0.000	335.130
25	0.010	325.690
50	0.040	315.790
75	0.090	305.190
100	0.160	293.690
125	0.240	280.990
150	0.350	266.610
175	0.470	249.640
200	0.620	228.050
225	0.780	194.630
250	0.960	000.000

TABLE 5.7. Normalized Spectral Responses for GMS-4.

Channel 1		Channel 2	
Wavelength (µm)	Response	Wavelength (µm)	Response
0.4500	0.000	7.800	0.000
0.4600	0.005	8.000	0.004
0.4700	0.099	8.200	0.003
0.4800	0.341	8.400	0.004
0.4900	0.446	8.600	0.004
0.5000	0.603	8.800	0.007
0.5100	0.824	9.000	0.006
0.5200	0.889	9.200	0.007
0.5300	0.915	9.400	0.007
0.5400	0.924	9.600	0.008
0.5500	0.924	9.800	0.008
0.5600	0.946	10.000	0.013
0.5700	0.978	10.100	0.044
0.5800	0.944	10.200	0.242
0.5900	1.000	10.300	0.538
0.6000	0.995	10.400	0.824
0.6100	0.997	10.500	0.982
0.6200	0.985	10.600	1.000
0.6300	0.974	10.700	0.973
0.6400	0.946	10.800	0.856
0.6500	0.908	10.900	0.872
0.6600	0.882	11.000	0.799
0.6700	0.831	11.100	0.704
0.6800	0.797	11.200	0.570
0.6900	0.738	11.300	0.459
0.7000	0.670	11.400	0.368
0.7100	0.637	11.500	0.286
0.7200	0.560	11.600	0.222

Normalized Spectral Responses for GMS-4.

Channel 1		Channel 2	
Wavelength (μm)	Response	Wavelength (μm)	Response
0.7300	0.498	11.700	0.180
0.7400	0.432	11.800	0.150
0.7500	0.374	11.900	0.113
0.7600	0.297	12.000	0.097
0.7700	0.236	12.100	0.074
0.7800	0.182	12.200	0.053
0.7900	0.139	12.300	0.053
0.8000	0.102	12.400	0.047
0.8200	0.029	12.500	0.033
0.8400	0.016	12.600	0.029
0.8600	0.004	12.700	0.025
0.8800	0.003	12.800	0.027
0.9000	0.006	12.900	0.023
0.9200	0.000	13.000	0.021
0.9400	0.003	13.200	0.020
0.9600	0.001	13.400	0.020
0.9800	0.002	13.600	0.026
1.0000	0.000	13.800	0.020
		14.000	0.026
		14.200	0.000

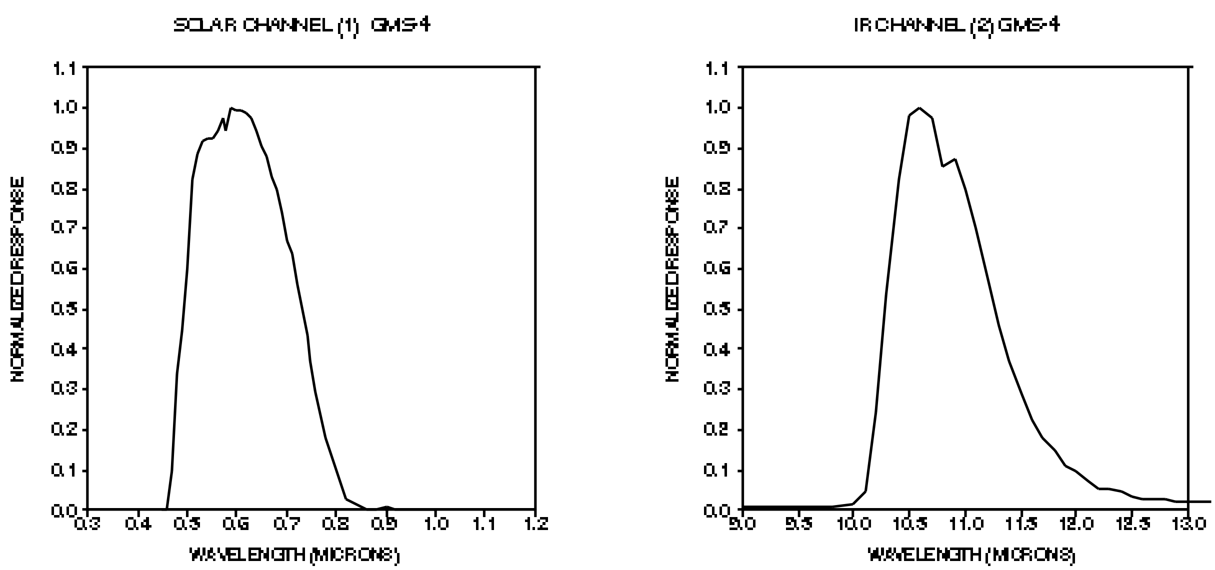

Fig. 5.4. Normalized spectral response functions for GMS-4.

TABLE 5.8. Sample Conversion Tables for GMS-4.

Counts	Ch. 1 Scaled Radiance	Ch. 2 Temperature
0	0.00	323.37
25	0.01	314.47
50	0.04	304.97
75	0.08	294.75
100	0.15	283.59
125	0.23	271.20
150	0.33	257.05
175	0.44	240.19
200	0.58	218.35
250	0.90	119.71

5.3. NORMALIZED CALIBRATION

The following tables give the normalization coefficients to normalize GMS calibrations to the current NOAA polar orbiter (changes of NOAA satellites are indicated in the tables). These coefficients do not account for any changes in the NOAA calibrations.

TABLE 5.9. Normalization for GMS-1.

	Visible (fraction)					Infrared (Kelvin)				
Month	Slope	Interc	rms	Min	Max	Slope	Interc	rms	Min	Max
JAN 84	1.328	-0.003	-	-	-	1.046	-11.38	-	-	-
FEB 84	1.328	-0.003	0.010	0.04	0.73	1.046	-11.38	1.10	204	295
MAR 84	1.341	-0.004	0.011	0.03	0.81	1.040	-10.08	1.03	200.5	299.5
APR 84	1.334	-0.004	0.023	0.03	0.84	1.035	- 8.44	1.60	204.5	294.5
MAY 84	1.334	-0.004	-	-	-	1.035	- 8.44	-	-	-
JUN 84	1.334	-0.004	-	-	-	1.035	- 8.44	-	-	-

TABLE 5.10. Normalization for GMS-2.

	Visible (fraction)					Infrared (Kelvin)				
Month	Slope	Interc	rms	Min	Max	Slope	Interc	rms	Min	Max
JUL 83	1.132	0.012	0.025	0.03	0.78	1.036	- 8.25	1.60	198	297
AUG 83	1.119	0.017	-	-	-	1.032	- 7.74	-	-	-
SEP 83	1.106	0.021	-	-	-	1.027	- 7.24	-	-	-
OCT 83	1.093	0.026	0.034	0.04	0.78	1.023	- 6.73	2.46	192	295
NOV 83	1.102	0.022	-	-	-	1.020	- 6.00	-	-	-
DEC 83	1.112	0.017	-	-	-	1.018	- 5.26	-	-	-
JAN 84	1.121	0.013	0.031	0.03	0.82	1.015	- 4.53	1.70	192	296.5

Normalization for GMS-2 (continued).

Month		Visible (fraction) Slope	Interc	rms	Min	Max	Infrared (Kelvin) Slope	Interc	rms	Min	Max
JUL	84	0.909	-0.014	-	-	-	1.058	-14.20	-	-	-
AUG	84	0.909	-0.014	0.013	0.03	0.81	1.058	-14.20	0.80	201.5	297.5
SEP	84	0.895	-0.015	0.013	0.03	0.73	1.058	-15.66	1.40	195.5	297.5

TABLE 5.11. Normalization for GMS-3.

Month		Visible (fraction) Slope	Interc	rms	Min	Max	Infrared (Kelvin) Slope	Interc	rms	Min	Max
SEP	84	0.991	-0.014	-	-	-	1.049	-12.90	-	-	-
OCT	84	0.991	-0.014	0.014	0.04	0.71	1.049	-12.90	1.30	194	297
NOV	84	1.003	-0.017	-	-	-	1.048	-12.40	-	-	-
DEC	84	1.016	-0.020	-	-	-	1.047	-11.90	-	-	-
JAN	85	1.028	-0.023	0.014	0.04	0.78	1.046	-11.40	1.80	194	295
***	change from NOAA-7 to NOAA-9 as normalization standard										
FEB	85	1.049	-0.002	-	-	-	1.068	-19.50	-	-	-
MAR	85	1.082	-0.006	-	-	-	1.070	-19.15	-	-	-
APR	85	1.114	-0.009	0.019	0.03	0.89	1.071	-18.80	1.53	194	295
MAY	85	1.099	-0.008	-	-	-	1.079	-20.98	-	-	-
JUN	85	1.083	-0.008	-	-	-	1.088	-23.17	-	-	-
JUL	85	1.068	-0.007	0.013	0.03	0.87	1.096	-25.35	1.40	194.5	296.5
AUG	85	1.079	-0.004	-	-	-	1.088	-23.39	-	-	-
SEP	85	1.089	-0.001	-	-	-	1.080	-21.44	-	-	-
OCT	85	1.100	0.002	0.020	0.03	0.90	1.072	-19.48	1.70	193.5	299.5
NOV	85	1.093	0.001	-	-	-	1.073	-19.92	-	-	-
DEC	85	1.087	-0.001	-	-	-	1.075	-20.36	-	-	-
JAN	86	1.080	-0.002	0.012	0.03	0.89	1.076	-20.80	1.30	194.5	296
FEB	86	1.075	-0.003	-	-	-	1.076	-20.66	-	-	-
MAR	86	1.069	-0.004	-	-	-	1.077	-20.52	-	-	-
APR	86	1.064	-0.005	0.012	0.03	0.89	1.077	-20.38	1.50	194	297.5
MAY	86	1.060	-0.005	-	-	-	1.079	-20.70	-	-	-
JUN	86	1.055	-0.004	-	-	-	1.082	-21.02	-	-	-
JUL	86	1.051	-0.004	0.015	0.03	0.86	1.084	-21.34	1.25	193	296
AUG	86	1.083	-0.005	-	-	-	1.061	-15.37	-	-	-
SEP	86	1.114	-0.005	-	-	-	1.038	- 9.39	-	-	-
OCT	86	1.146	-0.006	0.015	0.02	0.89	1.015	- 3.42	0.97	193	298.5
NOV	86	1.121	-0.004	-	-	-	1.034	- 8.92	-	-	-
DEC	86	1.095	-0.002	-	-	-	1.054	-14.42	-	-	-
JAN	87	1.070	0.000	0.018	0.03	0.90	1.073	-19.92	1.20	194	296
FEB	87	1.078	0.000	-	-	-	1.072	-19.65	-	-	-
MAR	87	1.087	0.000	-	-	-	1.071	-19.37	-	-	-
APR	87	1.095	0.000	0.013	0.02	0.82	1.070	-19.10	1.18	197	298.5
MAY	87	1.090	0.001	-	-	-	1.075	-20.10	-	-	-
JUN	87	1.084	0.001	-	-	-	1.079	-21.10	-	-	-

Normalization for GMS-3 (continued).

Month		Visible (fraction) Slope	Interc	rms	Min	Max	Infrared (Kelvin) Slope	Interc	rms	Min	Max
JUL	87	1.079	0.002	0.020	0.03	0.80	1.084	-22.10	1.40	195	297.5
AUG	87	1.110	-0.002	-	-	-	1.080	-21.62	-	-	-
SEP	87	1.141	-0.005	-	-	-	1.076	-21.15	1.20	197	297
OCT	87	1.172	-0.009	0.015	0.03	0.82	1.021	- 5.10	1.68	197	297.5
NOV	87	1.153	-0.008	-	-	-	1.013	- 2.63	1.40	196.5	297
DEC	87	1.134	-0.006	-	-	-	1.012	- 2.37	1.04	198	298.5
JAN	88	1.115	-0.005	0.013	0.02	0.76	1.008	- 1.20	1.18	195.5	298
FEB	88	1.138	-0.009	-	-	-	1.011	- 1.66	-	-	-
MAR	88	1.161	-0.013	-	-	-	1.013	- 2.11	-	-	-
APR	88	1.184	-0.017	0.013	0.02	0.72	1.016	- 2.57	1.36	197.5	297.5
MAY	88	1.187	-0.017	-	-	-	1.016	- 2.55	-	-	-
JUN	88	1.189	-0.017	-	-	-	1.017	- 2.52	-	-	-
JUL	88	1.192	-0.017	0.011	0.02	0.66	1.017	- 2.50	1.10	194	298.5
AUG	88	1.173	-0.017	-	-	-	1.017	- 2.77	-	-	-
SEP	88	1.154	-0.016	-	-	-	1.016	- 3.03	-	-	-
OCT	88	1.135	-0.016	0.010	0.03	0.60	1.016	- 3.30	1.20	202	298.5
***	change from NOAA-9 to NOAA-11 as normalization standard										
NOV	88	1.114	-0.001	0.017	0.02	0.87	0.996	1.90	1.10	193.5	296
DEC	88	1.091	0.003	-	-	-	0.992	2.95	-	-	-
JAN	89	1.068	0.007	0.013	0.03	0.84	0.987	4.00	1.30	189.5	297
FEB	89	1.073	0.006	-	-	-	0.993	2.73	-	-	-
MAR	89	1.079	0.006	-	-	-	0.999	1.45	-	-	-
APR	89	1.084	0.005	0.017	0.02	0.80	1.005	0.18	0.96	196	298
MAY	89	1.084	0.002	-	-	-	1.006	0.17	-	-	-
JUN	89	1.084	0.000	-	-	-	1.006	0.17	-	-	-
JUL	89	1.084	-0.003	0.014	0.02	0.79	1.007	0.16	1.10	196	296.5
AUG	89	1.096	0.000	-	-	-	1.004	0.54	-	-	-
SEP	89	1.107	0.002	-	-	-	1.002	0.92	-	-	-
OCT	89	1.119	0.005	0.017	0.02	0.79	0.999	1.30	1.00	189.5	298
NOV	89	1.131	0.003	0.012	0.02	0.82	1.001	0.10	1.00	189	297

TABLE 5.12. Normalization for GMS-4.

Month		Visible (fraction) Slope	Interc	rms	Min	Max	Infrared (Kelvin) Slope	Interc	rms	Min	Max
DEC	89	0.892	-0.005	0.012	0.02	0.82	0.997	1.00	1.10	190	298
JAN	90	0.884	-0.001	0.015	0.02	0.81	1.006	-1.10	1.30	190.5	294.5
FEB	90	0.926	-0.006	0.012	0.02	0.81	1.004	-0.53	-	-	-
MAR	90	0.946	-0.004	0.017	0.02	0.81	1.001	0.03	-	-	-
APR	90	0.990	-0.002	0.015	0.02	0.78	0.999	0.60	1.00	194	298
MAY	90	0.981	0.000	-	-	-	0.998	1.17	-	-	-
JUN	90	0.972	0.003	-	-	-	0.998	1.73	-	-	-

Normalization for GMS-4 (continued).

Month		Visible (fraction)					Infrared (Kelvin)				
		Slope	Interc	rms	Min	Max	Slope	Interc	rms	Min	Max
JUL	90	0.963	0.005	0.016	0.02	0.76	0.997	2.30	0.80	194.5	296
AUG	90	0.997	0.004	-	-	-	0.998	1.70	-	-	-
SEP	90	1.031	0.002	-	-	-	0.999	1.10	-	-	-
OCT	90	1.065	0.001	0.012	0.02	0.81	1.000	0.50	1.30	193.5	296.5
NOV	90	1.070	0.000	-	-	-	0.997	1.15	-	-	-
DEC	90	1.075	0.000	-	-	-	0.994	1.80	1.00	196.5	297.5
JAN	91	1.080	-0.001	0.014	0.02	0.84	0.991	2.60	1.00	196	297.5
FEB	91	1.088	-0.001	-	-	-	0.993	2.27	-	-	-
MAR	91	1.095	-0.002	-	-	-	0.995	1.93	-	-	-
APR	91	1.103	-0.002	0.015	0.02	0.82	0.997	1.60	1.00	192.5	296
MAY	91	1.102	-0.002	-	-	-	1.000	1.20	-	-	-
JUN	91	1.101	-0.001	-	-	-	1.002	0.80	-	-	-
JUL	91	1.100	-0.001	0.020	0.04	0.79	1.005	0.40	1.10	195.5	294
JUL	91	1.276	-0.022	-	-	-	*** starting 16 Jul 91				

5.4. ABSOLUTE CALIBRATION

The final calibration of GMS radiances is obtained by applying to the normalized calibration the same corrections as applied to the relevant NOAA satellite, shown in Tables 2.18 through 2.24. No changes are required when GMS is normalized to NOAA-7, except for multiplying all VIS radiances by 1.2. Table 5.13 gives the final calibration coefficients used for GMS including the corrections for changes in NOAA calibration and the factor of 1.2 for VIS radiances (from Desormeaux et al. 1992). Table 5.14 gives additional VIS calibration adjustments made for GMS-2.

TABLE 5.13. History of visible and infrared normalization coefficients for GMS.

GMS-1

Month		Visible (fraction)		Infrared (Kelvin)	
		Slope	Interc	Slope	Interc
JAN	84	1.594	-0.004	1.046	-11.38
FEB	84	1.594	-0.004	1.046	-11.38
MAR	84	1.609	-0.005	1.040	-10.08
APR	84	1.601	-0.005	1.035	- 8.44
MAY	84	1.601	-0.005	1.035	- 8.44
JUN	84	1.601	-0.005	1.035	- 8.44

GMS-2

Month		Visible (fraction) Slope	Interc	Infrared (Kelvin) Slope	Interc
JUL	83	1.358	0.014	1.036	- 8.25
AUG	83	1.343	0.020	1.032	- 7.74
SEP	83	1.327	0.025	1.027	- 7.24
OCT	83	1.312	0.031	1.023	- 6.73
NOV	83	1.322	0.026	1.020	- 6.00
DEC	83	1.334	0.020	1.018	- 5.26
JAN	84	1.345	0.016	1.015	- 4.53
JUL	84	1.091	-0.017	1.058	-14.20
AUG	84	1.091	-0.017	1.058	-14.20
SEP	84	1.074	-0.018	1.058	-15.66

GMS-3

Month		Visible (fraction) Slope	Interc	Infrared (Kelvin) Slope	Interc
SEP	84	1.189	-0.017	1.049	-12.90
OCT	84	1.189	-0.017	1.049	-12.90
NOV	84	1.204	-0.020	1.048	-12.40
DEC	84	1.219	-0.024	1.047	-11.90
JAN	85	1.234	-0.028	1.046	-11.40
	** change from NOAA-7 to NOAA-9 as normalization standard				
FEB	85	1.051	0.000	1.068	-19.50
MAR	85	1.088	-0.004	1.070	-19.15
APR	85	1.124	-0.007	1.071	-18.80
MAY	85	1.114	-0.006	1.079	-20.98
JUN	85	1.102	-0.006	1.088	-23.17
JUL	85	1.090	-0.005	1.096	-25.35
AUG	85	1.104	-0.001	1.088	-23.39
SEP	85	1.120	0.001	1.080	-21.44
OCT	85	1.134	0.005	1.072	-19.48
NOV	85	1.132	0.004	1.073	-19.92
DEC	85	1.129	0.001	1.075	-20.36
JAN	86	1.127	0.000	1.076	-20.80
FEB	86	1.124	-0.001	1.076	-20.66
MAR	86	1.122	-0.002	1.077	-20.52
APR	86	1.121	-0.002	1.077	-20.38
MAY	86	1.122	-0.002	1.079	-20.70
JUN	86	1.121	-0.002	1.082	-21.02
JUL	86	1.120	-0.002	1.084	-21.34
AUG	86	1.158	-0.002	1.061	-15.37
SEP	86	1.195	-0.002	1.038	- 9.39

Month		Visible (fraction) Slope	Interc	Infrared (Kelvin) Slope	Interc
OCT	86	1.235	-0.004	1.043	-12.02
NOV	86	1.212	-0.002	1.034	- 8.92
DEC	86	1.188	0.000	1.054	-14.42
JAN	87	1.166	0.002	1.073	-19.92
FEB	87	1.178	0.002	1.072	-19.65
MAR	87	1.193	0.002	1.071	-19.37
APR	87	1.206	0.002	1.070	-19.10
MAY	87	1.205	0.004	1.075	-20.10
JUN	87	1.202	0.004	1.079	-21.10
JUL	87	1.201	0.005	1.084	-22.10
AUG	87	1.240	0.000	1.080	-21.62
SEP	87	1.279	-0.004	1.076	-21.15
OCT	87	1.319	-0.007	1.060	-16.79
NOV	87	1.302	-0.007	1.051	-14.23
DEC	87	1.284	-0.005	1.050	-13.96
JAN	88	1.268	-0.004	1.046	-12.75
FEB	88	1.298	-0.008	1.049	-13.22
MAR	88	1.330	-0.012	1.051	-13.69
APR	88	1.361	-0.017	1.055	-14.17
MAY	88	1.369	-0.017	1.055	-14.15
JUN	88	1.376	-0.017	1.056	-14.12
JUL	88	1.386	-0.017	1.056	-14.10
AUG	88	1.368	-0.018	1.056	-14.38
SEP	88	1.350	-0.017	1.055	-14.65
OCT	88	1.333	-0.017	1.055	-14.93
	** change from NOAA-9 to NOAA-11 as normalization standard				
NOV	88	1.256	0.000	1.063	-16.97
DEC	88	1.231	0.005	1.058	-15.85
JAN	89	1.205	0.010	1.053	-14.73
FEB	89	1.211	0.008	1.060	-16.09
MAR	89	1.217	0.008	1.066	-17.45
APR	89	1.223	0.007	1.072	-18.81
MAY	89	1.223	0.004	1.073	-18.82
JUN	89	1.223	0.001	1.073	-18.82
JUL	89	1.223	-0.002	1.074	-18.83
AUG	89	1.236	0.001	1.071	-18.42
SEP	89	1.249	0.004	1.069	-18.02
OCT	89	1.262	0.007	1.056	-14.29
NOV	89	1.276	0.005	1.058	-15.55

GMS-4

Month		Visible (fraction) Slope	Interc	Infrared (Kelvin) Slope	Interc
DEC	89	1.006	-0.005	1.054	-14.60
JAN	90	0.997	0.000	1.073	-20.17
FEB	90	1.044	-0.006	1.071	-19.57
MAR	90	1.062	-0.004	1.068	-18.97
APR	90	1.106	-0.001	1.066	-18.36
MAY	90	1.088	0.001	1.065	-17.75
JUN	90	1.073	0.005	1.065	-17.15
JUL	90	1.058	0.007	1.064	-16.55
AUG	90	1.090	0.006	1.065	-17.19
SEP	90	1.121	0.004	1.066	-17.83
OCT	90	1.152	0.002	1.067	-18.47
NOV	90	1.152	0.001	1.064	-17.77
DEC	90	1.151	0.001	1.061	-17.08
JAN	91	1.150	0.000	1.057	-16.23
FEB	91	1.153	0.000	1.060	-16.58
MAR	91	1.153	-0.001	1.062	-16.94
APR	91	1.156	-0.001	1.064	-17.29
MAY	91	1.151	-0.001	1.067	-17.72
JUN	91	1.142	0.000	1.069	-18.15

TABLE 5.14. Special Calibration Adjustments

Month	slope	intercept		
JUL 84 (GMS-2)	2.420	0.000	-	-

(adjustment to absolute VIS calibration for failed detector in first 17 days)
(based on cloud results, adjustment should have had an additive factor of 0.001)

6. INSAT

The Indian National Satellite System (INSAT) was developed by the Indian Space Research Organization to provide, among other services, meteorological imagery to the Indian Meteorological Department. INSAT is a three-axis stabilized satellite operated in geostationary orbit with a sub-satellite longitude of 74.5° E since September 1983. INSAT-1B operated well into 1989 when it was replaced by INSAT-1C (INSAT-2 was launched in the summer of 1992). Only limited data have been obtained from INSAT-1B: twice-daily imagery for January 1986 - March 1988 and eight-times-daily imagery for April 1988 - March 1989.

The INSAT radiometer, called the Very High Resolution Radiometer (VHRR), has four VIS (0.55-0.75 µm) channels with a nadir resolution of 2.75 km and one IR (10.5-12.5 µm) channel with a nadir resolution of 11.0 km. There is also a back-up set of detectors. Radiometer spectral responses are illustrated in Section 6.2.

6.1. NOMINAL CALIBRATION

(1) SOLAR CHANNEL

Little detail is available concerning the pre-launch calibration; which detector set is operational is not known. Average results of pre-launch calibration give the scaled radiance (in percent):

$$L^{*} = G\ (CT - Y) \tag{6.1}$$

where CT is an 8-bit count (original INSAT VIS data are reported as 6-bit counts), G = 0.4122 (average primary detector set), G = 0.4203 (back-up detectors), Y = -0.375 (primary) and Y = 0.475 (back-up). Since this information was not available at the time of processing, the ISCCP nominal calibration is

$$L^{*} = 0.400 * CT\ . \tag{6.2}$$

Radiances are obtained by multiplying $L^{*}/100$ by the effective solar constant for the VHRR VIS channel, which is 105.7339 Watts m^{-2} sr^{-2} (for the average spectral response of the primary detector set).

(2) INFRARED CHANNEL

Pre-launch calibrations established relations between counts and radiances for a range of instrument operating temperatures. On-board calibration measurements are used to convert radiance counts into brightness temperature values; these values are converted into standard 8-bit count values with a fixed relationship to brightness temperatures:

$$\begin{aligned} TB &= 179 + (255 - CT_{IR})\ \ K & 150 \le CT_{IR} \le 253\ \ K \\ TB &= 284 + 0.127 * (150 - CT_{IR})\ \ K & 16 < CT_{IR} < 150\ \ K \\ TB &= 301 + (16 - CT_{IR})\ \ K & 0 \le CT_{IR} \le 16\ \ K \end{aligned} \tag{6.3}$$

The frequency of calibration by on-board measurements is not known.

6.2. INSAT SPECTRAL RESPONSE

The spectral responses for INSAT-1B are given in Table 6.1 and illustrated in Fig. 6.1. These values represent the average spectral response of the primary set of detectors.

Tables relating temperatures to infrared radiances, as described for NOAA, are use to get IR radiance values. A sample table that converts counts to scaled radiances or temperature is shown.

TABLE 6.1. Normalized Spectral Responses for INSAT-1B.

Channel 1		Channel 2	
Wavelength (µm)	Response	Wavelength (µm)	Response
0.470	0.00000	10.100	0.00000
0.480	0.00800	10.200	0.01000
0.490	0.01000	10.300	0.03000
0.500	0.00200	10.400	0.18000
0.510	0.00800	10.500	0.66000
0.520	0.00200	10.600	0.91000
0.530	0.01000	10.700	0.99000
0.540	0.10800	10.800	1.00000
0.550	0.51500	10.900	0.98000
0.560	0.75200	11.000	0.91000
0.570	0.84200	11.100	0.84000
0.580	0.90200	11.200	0.86000
0.590	0.96000	11.300	0.92000
0.600	1.00000	11.400	0.94000
0.610	0.99000	11.500	0.92000
0.620	0.98000	11.600	0.84000
0.630	0.97000	11.700	0.78000
0.640	0.98500	11.800	0.76000
0.650	0.97000	11.900	0.76000
0.660	0.93000	12.000	0.80000
0.670	0.90200	12.100	0.73000
0.680	0.89000	12.200	0.71000
0.690	0.90000	12.300	0.67000
0.700	0.89500	12.400	0.64000
0.710	0.82200	12.500	0.31000
0.720	0.74800	12.600	0.08000
0.730	0.66800	12.700	0.00000
0.740	0.65800		
0.750	0.66000		
0.760	0.56200		
0.770	0.32800		
0.780	0.13200		
0.790	0.06000		
0.800	0.00000		

TABLE 6.2. Sample Conversion Tables for INSAT-1B.

Counts	Ch. 1 Scaled Radiance	Ch. 2 Temperature
0	0.00	317.00
25	0.10	299.90
50	0.20	296.90
75	0.30	293.80
100	0.40	290.60
125	0.50	287.40
150	0.60	284.00
175	0.70	259.00
200	0.80	234.00
225	0.90	209.00
250	1.00	184.00

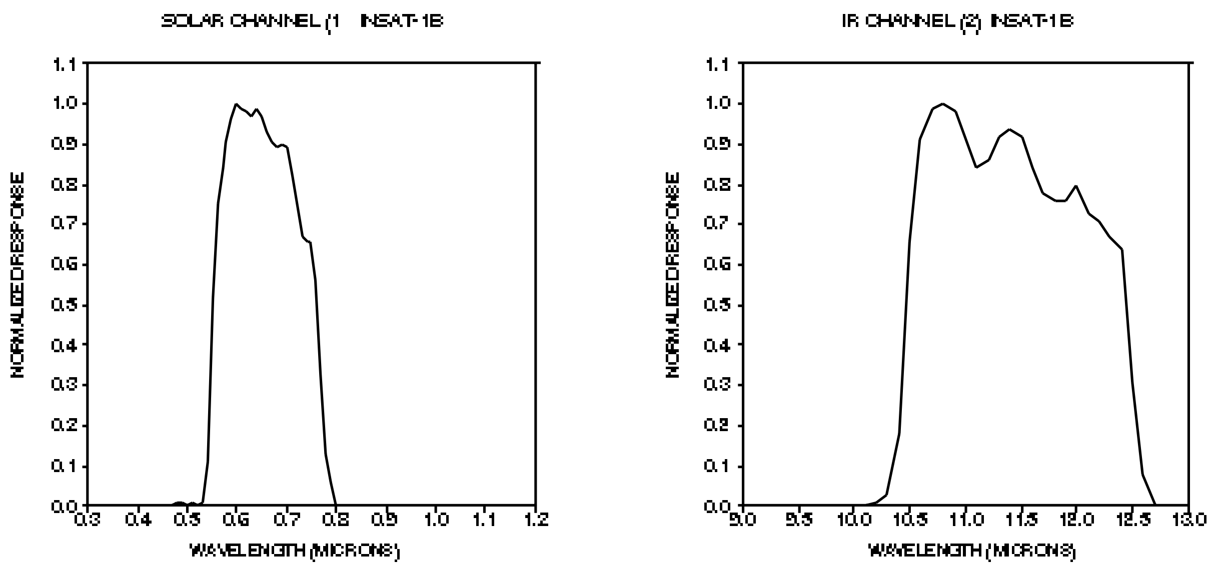

Fig. 6.1. Normalized spectral response functions for INSAT-1B.

6.3. NORMALIZED CALIBRATION

Unlike the other geostationary satellites used by ISCCP, the calibration of INSAT-1B could not be directly normalized to the AVHRR on the afternoon polar orbiter because the special normalization datasets were not collected. Instead, INSAT-1B radiances are compared to co-located and nearly coincident measurements by METEOSAT and GMS that have been normalized to the AVHRR (Desormeaux et al. 1992). The normalization coefficients were found to be relatively stable, so only annual values were obtained, based on the GMS comparisons (since the GMS and INSAT radiometer spectral responses are very similar in the VIS channels). Table 6.3 gives the normalization coefficients used.

TABLE 6.3. Normalization for INSAT-1B. Recommended values are marked by '*'.

Year	Comparison Satellite		Visible (fraction) slope - intercept	Infrared (Kelvin) slope - intercept	
1986	GMS	0600 UTC	1.008 (+0.018)	1.187 (-50.7 K)	*
	GMS	1200 UTC	---	1.209 (-55.4 K)	
	METEOSAT	0600 UTC	---	1.177 (-50.6 K)	
	METEOSAT	1200 UTC	---	1.191 (-53.4 K)	
1987	GMS	0600 UTC	1.003 (+0.022)	1.193 (-48.8 K)	*
	GMS	1200 UTC	---	1.219 (-55.5 K)	
	METEOSAT	0600 UTC	---	1.149 (-41.3 K)	
	METEOSAT	0600 UTC	---	1.179 (-48.6 K)	
1988	GMS	0600 UTC	1.058 (+0.000)	1.109 (-28.3 K)	*
	GMS	1200 UTC	---	1.129 (-34.0 K)	
	METEOSAT	0600 UTC	---	1.125 (-35.6 K)	
	METEOSAT	1200 UTC	---	1.146 (-41.5 K)	
1989	GMS	0600 UTC	1.093 (+0.022)	1.068 (-17.4 K)	

6.4. ABSOLUTE CALIBRATION

The final calibration of INSAT is obtained by applying to the normalized calibration the same corrections as applied to the relevant NOAA satellite, shown in Tables 2.18 through 2.24. Table 6.4 gives the final calibration coefficients used for INSAT including the corrections for changes in NOAA calibration and the factor of 1.2 for VIS radiances (from Desormeaux et al. 1992).

TABLE 6.4 History of visible and infrared normalization coefficients for INSAT.

	Visible (fraction)		Infrared (Kelvin)	
Month	Slope	Interc	Slope	Interc
JAN 86	1.051	0.021	1.187	-50.7
FEB 86	1.054	0.021	1.187	-50.7
MAR 86	1.058	0.021	1.187	-50.7
APR 86	1.062	0.021	1.187	-50.7
MAY 86	1.066	0.021	1.187	-50.7
JUN 86	1.070	0.021	1.187	-50.7
JUL 86	1.075	0.021	1.187	-50.7
AUG 86	1.078	0.021	1.187	-50.7
SEP 86	1.082	0.021	1.187	-50.7
OCT 86	1.087	0.021	1.187	-50.7
NOV 86	1.090	0.021	1.187	-50.7
DEC 86	1.094	0.022	1.187	-50.7
JAN 87	1.093	0.026	1.193	-48.8
FEB 87	1.096	0.026	1.193	-48.8
MAR 87	1.100	0.026	1.193	-48.8
APR 87	1.105	0.026	1.193	-48.8
MAY 87	1.108	0.026	1.193	-48.8
JUN 87	1.112	0.026	1.193	-48.8
JUL 87	1.117	0.027	1.193	-48.8
AUG 87	1.120	0.027	1.193	-48.8
SEP 87	1.124	0.027	1.193	-48.8
OCT 87	1.129	0.027	1.193	-48.8
NOV 87	1.132	0.027	1.193	-48.8
DEC 87	1.136	0.027	1.193	-48.8
JAN 88	1.204	0.002	1.151	-40.9
FEB 88	1.207	0.002	1.151	-40.9
MAR 88	1.211	0.002	1.151	-40.9
APR 88	1.217	0.002	1.151	-40.9
MAY 88	1.220	0.002	1.151	-40.9
JUN 88	1.225	0.002	1.151	-40.9
JUL 88	1.230	0.002	1.151	-40.9
AUG 88	1.234	0.002	1.151	-40.9
SEP 88	1.238	0.002	1.151	-40.9
OCT 88	1.243	0.002	1.151	-40.9
NOV 88	1.193	0.002	1.151	-40.9
DEC 88	1.193	0.002	1.151	-40.9
JAN 89	1.233	0.026	1.140	-37.6
FEB 89	1.233	0.026	1.140	-37.6
MAR 89	1.233	0.026	1.140	-37.6

7. HISTORY OF CALIBRATION

As part of the data analysis to produce the ISCCP cloud climatology, the overlapping observations by geostationary and polar orbiting satellites are again compared to monitor the normalization procedure. Small biases in physical quantities, produced by small residual calibration differences, are revealed. Table 6.1 shows the history of these corrections for visible surface reflectances and cloud top temperatures. These corrections overestimate the calibration differences, but do illustrate the approximate magnitude of the calibration uncertainties in Stage B3 radiances.

TABLE 7.1. Final bias removed from each month's values of visible surface reflectance (first number in percent) and of cloud top temperature (second number in Kelvins) from each geostationary satellite. Numbers in parentheses indicate the serial number of the active satellite.

Date		METEOSAT			GOES WEST			GOES EAST			GMS		
JUL	83	(2)	-0.6	-0.8	(6)	0.6	0.2	(5)	-0.7	-1.2	(2)	-2.8	-1.0
AUG	83	(2)	-0.4	0.2	(6)	1.2	0.5	(5)	-2.5	-1.4	(2)	-4.1	-1.1
SEP	83	(2)	-1.8	-0.6	(6)	3.2	0.5	(5)	-1.8	-1.0	(2)	-4.4	-1.0
OCT	83	(2)	-2.1	0.3	(6)	3.1	0.8	(5)	-3.4	0.2	(2)	-6.1	-1.0
NOV	83	(2)	-2.4	0.7	(6)	2.7	-0.4	(5)	-1.4	-0.8	(2)	-7.0	-1.0
DEC	83	(2)	-2.4	0.5	(6)	1.4	0.2	(5)	-0.8	-0.4	(2)	-4.9	-1.0
JAN	84	(2)	-2.3	-0.7	(6)	-0.5	-0.7	(5)	-0.9	-0.3	(2)	-1.3	-0.9
FEB	84	(2)	-1.7	0.5	(6)	-2.6	-0.5	(5)	-1.5	-0.2	(1)	0.4	-1.0
MAR	84	(2)	-1.7	-1.0	(6)	-2.0	-0.7	(5)	-1.5	0.5	(1)	0.1	0.3
APR	84	(2)	0.0	-1.5	(6)	-1.5	-0.7	(5)	-2.0	-0.8	(1)	0.0	0.3
MAY	84	(2)	-1.8	-1.5	(6)	-1.7	-0.1	(5)	-1.2	-0.3	(1)	-1.1	0.3
JUN	84	(2)	-2.2	-0.9	(6)	-1.6	-0.6	(5)	-1.5	-0.6	(-)	--	--
JUL	84	(2)	-3.8	-1.0	(6)	-2.6	-1.0	(5)	-1.4	-1.0	(2)	3.3	-1.1
AUG	84	(2)	-3.7	-1.0	(6)	-3.6	-1.2	(-)	--	--	(2)	2.5	-1.3
SEP	84	(2)	-2.0	-1.0	(6)	-3.6	-1.1	(-)	--	--	(2)	2.9	0.6
OCT	84	(2)	-1.5	0.4	(6)	-4.1	0.2	(-)	--	--	(3)	2.5	-1.3
NOV	84	(2)	-1.6	0.3	(6)	-3.8	0.1	(-)	--	--	(3)	3.2	-1.5
DEC	84	(2)	-1.7	0.2	(6)	-3.2	0.8	(-)	--	--	(3)	3.4	-2.6
JAN	85	(2)	-0.3	-1.0	(6)	-2.1	0.5	(-)	--	--	(3)	3.5	-2.2
FEB	85	(2)	-0.6	2.4	(6)	-1.4	0.7	(-)	--	--	(3)	0.2	-0.4
MAR	85	(2)	-0.6	-0.7	(6)	-1.1	0.8	(-)	--	--	(3)	0.1	-1.0
APR	85	(2)	-0.7	-1.0	(6)	-1.3	-0.5	(-)	--	--	(3)	0.6	-1.0
MAY	85	(2)	-0.6	-1.2	(6)	-1.9	0.7	(-)	--	--	(3)	0.6	-0.5
JUN	85	(2)	-0.7	-1.1	(6)	-2.1	0.7	(-)	--	--	(3)	0.5	-0.4
JUL	86	(2)	-2.4	-1.3	(6)	-3.1	0.5	(-)	--	--	(3)	0.0	-0.9
AUG	85	(2)	-0.6	-1.0	(6)	-2.4	0.4	(-)	--	--	(3)	-0.3	-0.8
SEP	85	(2)	-0.5	-0.6	(6)	-2.0	-0.5	(-)	--	--	(3)	-0.4	-0.5
OCT	85	(2)	-1.4	0.2	(6)	-2.0	-0.3	(-)	--	--	(3)	-1.2	-1.0
NOV	85	(2)	-0.4	-0.7	(6)	-1.5	-0.5	(-)	--	--	(3)	-0.7	-1.1
DEC	85	(2)	-0.5	-0.6	(6)	-1.4	-0.5	(-)	--	--	(3)	0.2	-1.1
JAN	86	(2)	-1.8	0.3	(6)	-0.5	-0.5	(-)	--	--	(3)	0.4	-1.1
FEB	86	(2)	-0.5	-0.5	(6)	-0.6	0.6	(-)	--	--	(3)	0.3	-1.2
MAR	86	(2)	-0.5	-1.0	(6)	-1.0	-0.4	(-)	--	--	(3)	0.4	-1.0
APR	86	(2)	-0.6	-1.1	(6)	-1.3	-0.3	(-)	--	--	(3)	0.7	-0.8
MAY	86	(2)	-1.8	-1.1	(6)	-1.6	1.0	(-)	--	--	(3)	0.8	0.4
JUN	86	(2)	-2.3	-1.1	(6)	-2.4	0.7	(-)	--	--	(3)	0.1	-0.7
JUL	86	(2)	-2.4	-1.3	(6)	-3.1	0.5	(-)	--	--	(3)	0.0	-0.9
AUG	86	(2)	-1.8	-1.0	(6)	-3.2	-0.8	(-)	--	--	(3)	-0.1	-0.8
SEP	86	(2)	-0.2	-0.9	(6)	-2.9	-0.5	(-)	--	--	(3)	0.1	-1.0

Date	METEOSAT			GOES WEST			GOES EAST			GMS		
OCT 86	(2)	0.2	-0.6	(6)	-2.0	0.3	(-)	--	--	(3)	0.3	-0.7
NOV 86	(2)	-0.1	-1.1	(6)	-2.3	-0.4	(-)	--	--	(3)	0.2	-0.5
DEC 86	(2)	-0.3	-0.9	(6)	-3.1	-0.4	(-)	--	--	(3)	0.3	-0.6
JAN 87	(2)	-0.2	-0.9	(6)	-3.0	-0.4	(-)	--	--	(3)	-0.5	-0.7
FEB 87	(2)	0.0	-0.9	(6)	-1.6	0.8	(-)	--	--	(3)	-0.7	-1.0
MAR 87	(2)	-0.2	-0.7	(6)	-0.6	0.8	(-)	--	--	(3)	-1.0	0.5
APR 87	(2)	-1.8	-1.0	(6)	1.0	1.0	(-)	--	--	(3)	-1.1	0.4
MAY 87	(2)	-0.3	-0.8	(6)	0.8	1.8	(7)	-1.0	-0.6	(3)	-1.3	-0.6
JUN 87	(2)	-0.5	-0.9	(6)	0.6	1.4	(7)	-1.2	1.8	(3)	-1.3	-1.0
JUL 87	(2)	-0.4	-1.7	(6)	-1.2	0.5	(7)	-1.0	1.7	(3)	-1.8	-1.2
AUG 87	(2)	-0.3	-1.6	(6)	-1.1	0.8	(7)	-3.3	0.6	(3)	-1.2	-1.2
SEP 87	(2)	-1.9	-0.9	(6)	-1.4	2.2	(7)	-4.5	2.1	(3)	-0.2	-1.3
OCT 87	(2)	-2.0	0.6	(6)	-0.9	1.3	(-)	--	1.0	(3)	0.5	0.4
NOV 87	(2)	-0.9	0.2	(6)	-2.5	1.8	(7)	-3.6	0.8	(3)	0.9	-1.0
DEC 87	(2)	-0.7	0.4	(6)	-2.4	0.5	(7)	-1.4	0.8	(3)	0.7	-1.0
JAN 88	(2)	-0.6	-0.9	(6)	-2.3	0.7	(7)	-0.4	0.6	(3)	0.5	-0.9
FEB 88	(2)	-0.5	0.3	(6)	-2.8	1.1	(7)	-5.3	1.0	(3)	0.8	-1.0
MAR 88	(2)	-0.1	0.4	(6)	-3.2	0.5	(-)	--	--	(3)	0.9	-0.6
APR 88	(2)	0.0	-0.9	(6)	-0.9	1.1	(7)	-1.1	0.5	(3)	2.3	-0.7
MAY 88	(2)	0.1	-1.0	(6)	-0.3	0.6	(7)	-1.1	-0.5	(3)	2.4	0.7
JUN 88	(2)	0.3	-1.2	(6)	-0.8	1.2	(7)	-3.7	2.1	(3)	2.1	0.3
JUL 88	(2)	0.2	-1.2	(6)	-1.3	1.2	(7)	-6.0	-0.3	(3)	2.1	-0.7
AUG 88	(3)	-1.7	-1.1	(6)	-1.7	1.1	(7)	-6.2	-0.4	(3)	2.1	-0.8
SEP 88	(3)	-1.6	-0.8	(6)	-2.3	1.1	(7)	-7.2	0.2	(3)	2.4	-0.5
OCT 88	(3)	-2.9	0.7	(6)	-1.3	0.8	(7)	-8.4	0.5	(3)	3.1	-0.5
NOV 88	(3)	-0.8	-0.6	(6)	-2.1	0.3	(7)	-3.7	0.4	(3)	-1.4	-1.2
DEC 88	(3)	-1.2	-0.7	(6)	-2.2	0.5	(7)	-3.7	-0.3	(3)	-1.9	-1.2
JAN 89	(3)	-1.2	-0.4	(6)	-2.5	1.5	(7)	-1.2	-0.4	(3)	-2.0	0.5
FEB 89	(3)	-1.3	-0.8	(-)	--	--	(7)	-1.4	-0.4	(3)	-2.0	-1.3
MAR 89	(3)	-1.3	-1.1	(-)	--	--	(7)	-1.4	-0.7	(3)	-2.2	-0.9
APR 89	(3)	-1.3	-1.5	(-)	--	--	(7)	-1.5	-0.7	(3)	-2.1	-0.8
MAY 89	(3)	-1.1	-1.6	(-)	--	--	(7)	-1.3	-0.5	(3)	-1.7	-0.5
JUN 89	(4)	-0.7	-0.9	(-)	--	--	(7)	-1.3	-0.7	(3)	-1.8	-0.5
JUL 89	(4)	-0.7	-0.6	(-)	--	--	(7)	-0.9	-0.6	(3)	-1.5	-0.7
AUG 89	(4)	-0.8	-0.8	(-)	--	--	(7)	-1.7	-0.7	(3)	-2.1	-0.8
SEP 89	(4)	-0.8	-0.6	(-)	--	--	(7)	-1.7	-0.7	(3)	-2.1	-0.9
OCT 89	(4)	-0.7	-1.1	(-)	--	--	(7)	-1.6	-0.8	(3)	-1.9	-0.9
NOV 89	(4)	-0.3	-0.7	(-)	--	--	(7)	-1.7	-0.6	(3)	-1.8	-0.8
DEC 89	(4)	-0.2	-1.0	(-)	--	--	(7)	-1.7	-0.6	(4)	0.0	-0.7
JAN 90	(3)	-0.5	-0.7	(-)	--	--	(7)	-2.0	-0.5	(4)	-0.2	-0.9
FEB 90	(3)	-2.3	-0.7	(-)	--	--	(7)	-1.3	-0.5	(4)	0.2	0.8
MAR 90	(3)	-1.0	-0.7	(-)	--	--	(7)	-0.6	-0.5	(4)	-0.2	-1.0
APR 90	(4)	-0.5	-0.8	(-)	--	--	(7)	-0.1	-0.8	(4)	-1.0	-0.7
MAY 90	(4)	-0.5	-1.2	(-)	--	--	(7)	-0.5	-0.7	(4)	-1.0	0.3
JUN 90	(4)	-0.3	-0.7	(-)	--	--	(7)	-1.3	-0.9	(4)	-1.5	-0.7
JUL 90	(4)	-0.1	-0.7	(-)	--	--	(7)	-1.8	-1.1	(4)	-2.1	-0.9
AUG 90	(4)	-0.4	-0.7	(-)	--	--	(7)	-2.2	-1.1	(4)	-2.2	-1.0
SEP 90	(4)	-0.4	0.4	(-)	--	--	(7)	-3.4	-0.9	(4)	-1.8	-1.2
OCT 90	(4)	0.0	0.2	(-)	--	--	(7)	-1.9	-0.3	(4)	-0.7	-1.2
NOV 90	(4)	0.1	-0.6	(-)	--	--	(7)	-1.7	-0.4	(4)	0.0	-0.9
DEC 90	(4)	-0.2	-0.5	(-)	--	--	(7)	-0.5	0.2	(4)	-0.2	-0.7

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