General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Produced by the NASA Center for Aerospace Information (CASI)

X-622-69-372
PREPRINT

NASA TM X- 63708

PERFORMANCE OF THE NIMBUS II MEDIUM RESOLUTION RADIOMETER

MUSA PASTERNAK

SEPTEMBER 1969

GSFC

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

FACILITY FORM 602

N6 -40197
(ACCESSION NUMBER)
(THRU)
27
(PAGES)
1
(CODE)
NASA-TMX-#63708
(NASA CR OR TMX OR AD NUMBER)
14
(CATEGORY)

X-622-69-372

PERFORMANCE OF THE NIMBUS II MEDIUM RESOLUTION RADIOMETER

Musa Pasternak

September 1969

GODDARD SPACE FLIGHT CENTER

Greenbelt, Maryland

PRECEDING PAGE BLANK NOT FILMED.

PERFORMANCE OF THE NIMBUS II MEDIUM RESOLUTION RADIOMETER

Musa Pasternak

ABSTRACT

Average radiation values for a 10° latitude-15° longitude global grid were obtained for all five channels of the Nimbus II Medium Resolution Radiometer for the lifetime of the radiometer May 15, 1966 to July 30, 1966. The temperature measurements from the 10-11μ and the 5-30μ channels showed respective average day-night temperature differences of 3.2°K and 1.9°K. The average temperature measurements for the 6.4-6.9μ, 10-11μ, and the 5-30μ channels associated with 25°-45° nadir angles were 2.2°K less than those associated with 0-25° nadir angles. However the total outgoing long-wave radiation calculated from the 5-30μ data did not show any significant limb effect. The meridional temperature profiles of the channels measuring long-wave radiation showed a temperature minimum near 5°N, a temperature maximum near 25°N, and a higher temperature maximum near 15°S. The meridional reflectance profiles for the 0.2-4.0μ channel generally showed reflectance trends in an opposite direction from those of the long-wave radiation, except that the reflectance minimum near 15°N was displaced from the long-wave maximum at 25°N.

PRECEDING PAGE BLANK NOT FILMED.

CONTENTS

	Page
ABSTRACT	iii
I. INTRODUCTION	1
II. METHOD OF ANALYSIS	2
III. RESULTS	4
A. Day-Night Temperature Differences	4
B. Limb-Darkening	5
C. Degradation	5
D. Global Radiation Values	6
E. Meridional Profiles	6
IV. CONCLUSION	9
REFERENCES	9

ILLUSTRATIONS

Figure		Page
1	Nimbus II Channel 2 (10-11μ) day and night temperatures . . .	13
2	Nimbus II Channel 4 (5-30μ) day and night temperatures. . . .	14
3	Nimbus II Channel 2 (10-11μ) day-night temperature differences for May 15-July 30, 1966. The differences generally represent measurements taken when the sensor nadir angle was less than 25°. Encircled values were obtained when the sensor nadir angle was in the range 25°-45°. A negative temperature difference means the night temperature is greater than the day temperature	15
4	Nimbus II Channel 1 (6.4-6.9μ) meridional temperature profiles	16
5	Nimbus II Channel 2 (10-11μ) meridional temperature profiles	17
6	Nimbus II Channel 4 (5-30μ) meridional temperature profiles	18
7	Average Nimbus II total outgoing long-wave radiation and reflectance for lifetime of radiometer. The long-wave flux is derived from channel 4 measurements. The reflectance is derived from Channel 5 measurements	19

Figure		Page
8	Nimbus II Channel 3 (14-16μ) meridional temperature profiles	20
9	Nimbus II Channel 5 (0.2-4.0μ) measured short-wave reflectance profiles	21

TABLES

Table		Page
1	Nimbus II Weighted Day and Night Lifetime Global Values	10
2	Nimbus II Approximate Monthly Weighted Global Values	11
3	Comparison of Total Global Outgoing Long-Wave Radiation and Reflectance Global Averages	12

PERFORMANCE OF THE NIMBUS II

MEDIUM RESOLUTION RADIOMETER

I. INTRODUCTION

The Nimbus II meteorological satellite was equipped with a five-channel Medium Resolution Radiometer which received data from May 15, 1966 to July 27, 1966. Each radiometer channel measured the electromagnetic radiation emitted or reflected from the earth and its atmosphere in a selected wavelength interval. These five wavelength regions were 6.4-6.9μ, 10-11μ, 14-16μ, 5-30μ and 0.2-4μ. The five channels for these wavelength intervals measured the following:[1]

Channel 1 (6.4-6.9μ)

This channel, covering the 6.7μ peak of the 6.3μ water vapor absorption band, measured temperatures in the upper troposphere, and provided information on water vapor distribution in the upper troposphere and in conjunction with the other channels provided data concerning relative humidities at these altitudes.

Channel 2 (10-11μ)

This channel operating in the atmospheric window measured surface or near-surface temperatures over clear portions of the atmosphere.

Channel 3 (14-16μ)

This channel centered about the strong absorption band of CO_2 at 15μ, measured radiation emanating primarily from the stratosphere.

Channel 4 (5-30μ)

This channel measured the emitted long wavelength infrared energy and, in conjunction with the reflected solar radiation furnished data for a heat budget for the planet.

Channel 5 (0.2-4.0μ)

This channel measured the intensity of reflected solar energy from the earth and its atmosphere.

In order to study the trend of the radiometer data, the average, daily, weekly, biweekly, monthly, and lifetime radiation values for a 10° latitude-15° longitude grid were obtained for all five channels.

II. METHOD OF ANALYSIS

For each channel the radiometer measured the effective radiance $\bar{N}$ which is expressed in terms of equivalent blackbody temperature T_{BB} for Channels 1 to 4, and in reflectance R for Channel 5.

The relationship between effective radiance, spectral radiance, and blackbody temperature for Channels 1 to 4 is the following:

$$\bar{N} = \int_0^\infty N_\lambda \phi_\lambda \, d_\lambda = \int_0^\infty B_\lambda \left(T_{BB}\right) \phi_\lambda \, d_\lambda$$

where

N_λ is the spectral radiance in the direction of the satellite from the earth and its atmosphere.

ϕ_λ is the spectral response of the instrument

λ is the wavelength

$B_\lambda(T_{BB})$ is the Planck radiance, a function of the equivalent temperature T_{BB} of a blackbody filling the field of view of the channel.

For Channel 4 (5-30μ) the blackbody temperatures can also be expressed in terms of total outgoing long-wave flux by a method developed by Wark, Yamamoto, and Lienesch.[2]

The relationship between reflectance and effective radiance $\bar{N}$ for Channel 5 is the following:

$$R = \pi \bar{N} r_0^2 / \bar{H}^* \cos \mathcal{L}$$

where

$\mathcal{L}$ is the solar zenith angle

$\bar{H}^*$ is the effective solar irradiance at the "top" of the atmosphere

r_0 is the ratio of the actual earth-sun distance to the mean earth-sun distance.

This reflectance calculation did not consider the anisotropy of the back-scattered solar radiation. The reason was that the author did not think that completely adequate formulas considering anisotropy were available at the time.

For each grid point in a 10° latitude-15° longitude global grid, the average day and night blackbody temperatures were obtained for Channels 1 to 4 and the average reflectances for Channel 5. The maximum nadir angle for the measurements was 45°. The maximum solar zenith angle for Channel 5 measurements

was 70°. The Channel 1 to 4 results were subdivided into measurements associated with nadir angles 0°-25° and 25°-45°.

III. RESULTS

Some of the results obtained from analyzing the radiation values from a 10° latitude-15° longitude global grid were the following:

A. Day-Night Temperature Differences*

Data from Channels 2 and 4 showed respective average day-night differences of 3.2°K and 1.9°K. Data from Channels 1 and 3 showed no appreciable day-night changes. In the Channel 2 meridional temperature profiles (Figure 1) the day values approach the night values in the Southern hemisphere due to the preponderance of oceans there. In the Channel 4 meridional temperature profile (Figure 2) the day-night differences are less south of 40°S than in a more northerly direction due to the ocean influence.

Data from Channels 2 and 4 showed that the Pacific night temperatures are sometimes greater than the day temperatures. In these cases the Pacific is probably more cloudy in the daytime. The average Channel 2 day-night temperature differences for the lifetime of the Nimbus II radiometer are shown in Figure 3. For latitudes 50°N-50°S in this figure, the temperature differences for

*In this report day and night values were differentiated on the basis of local time. Day values were those measured at local times 6 A.M. to noon and noon to 6 P.M. Night values were those measured at all other local times.

the Pacific, Atlantic, and Indian oceans were respectively 0.3°K, 1.1°K and 1.2°K. The average continent temperature difference was 13.2°K.

B. Limb Darkening

Data from Channels 1, 2, and 4 showed limb effects in temperature. Measurements associated with 25°-45° nadir angles were less than those associated with 0°-25° nadir angles by an average value of 2.2°K. Channel 3 data did not show any appreciable limb effect.

The Channel 4 fluxes (the effective outgoing long-wave radiation which was determined from the Channel 4 measurements by the Lienesch temperature-flux conversion method[2] did not show any significant limb effect; in fact, the fluxes associated with nadir angles 25°-45° were higher by 0.004 langleys/min than those associated with 0°-25° nadir angles. This result is, of course, not surprising since the conversion method incorporates limb effects and is designed to yield the total flux from an effective radiance observed under any zenith angle.

C. Degradation

The monthly averages for Channels 1 to 4 did not change significantly with time, showing that these channels either had no degradation or had been adequately corrected for changes in instrument response by the method of on-board instrument calibration. The monthly quasi-global Channel 5 reflectance averages (90°N-50°S) showed a slight dip of 0.8% in the third month of data (July), but this does not necessarily signify degradation.

D. Global Radiation Values

The global Nimbus II lifetime and monthly radiometer values obtained from a 10° latitude-15° longitude global grid are summarized in Tables I and II.

The Channel 4 global total long-wave outgoing radiation flux for May 15-July 27, 1966 (obtained from a 10° latitude-15° longitude global grid) was .344 langleys/min. The corresponding Channel 5 global reflectance value* was 24.3%, which was less than London's[3] value for the same season. The magnitude of Nimbus II global averages cannot be compared precisely with London's theoretical values or TIROS VII averages. (London's values are only for the Northern Hemisphere, and the Southern Hemisphere values have to be inferred from London's Northern Hemisphere winter values. TIROS VII had less zonal coverage than Nimbus II, and more approximations for missing zonal values have to be made to obtain a value for the global reflectance.)

However, for comparison purposes interpolated TIROS VII, Nimbus II, and London's values are listed in Table III. To obtain the global averages in this table, approximations were made for the missing TIROS VII values.

E. Meridional Profiles

Meridional radiation profiles for Channels 1 to 5 are shown in Figures 4 to 8. Each figure shows the following three time periods in 1966: May 15-June 4, June 5-July 2, and July 3-July 27.

(1) Channel 1 (6.4-6.9μ)

The meridional profiles for this channel have two temperature maxima on both sides of a temperature minimum. For each monthly profile the lower

temperature maximum is near 25°N, the higher maximum is near 15°S. The temperature minimum is near 5°N, in the vicinity of the intertropical convergence zone. (Figure 4).

The same relationship for the temperature maxima and minimum exists for the temperature profiles of Channel 2 (10-11μ) and Channel 4 (5-30μ).

The temperature profiles are asymmetrical. As expected, the Southern Hemisphere subpolar and polar values are colder in the May-July months than the corresponding Northern Hemisphere values. There is a much greater difference between the minimum polar values and the maximum value in the Southern Hemisphere than between the corresponding values in the Northern Hemisphere.

From 40° to the poles the variation of May data from July data is greater in the Nortnern Hemisphere than in the Southern. The smaller variation in the Southern Hemisphere is probably caused by the preponderance of oceans there.

For each hemisphere, the trend of the temperature variation from May to July is different in the subtropics than near the poles.

(2) Channel 2 (10-11μ)

The meridional profiles of Channel 2 are similar to those of Channel 1, except that the proportion of the temperature variation between the two subtropical maxima to the total temperature variation in the Southern Hemisphere is less than in Channel 1 (Figure 5).

(3) Channel 4 (5-30μ)

The meridional temperature profiles of Channel 4 are similar to those of Channel 2 (Figure 6). The Channel 4 measurements were converted to flux

(total long-wave outgoing radiation) by the Lienesch conversion formula.[2] The meridional flux profile for the lifetime of Nimbus II is shown in Figure 7.

(4) Channel 3 (14-16μ)

The Channel 1 temperature profiles are relatively level from 24°N to 25°S. From 30° to the poles, the Northern Hemisphere values increase and the Southern Hemisphere values decrease. The decrease of temperature in a poleward direction in the Southern Hemisphere from the level portion of the profile is greater than the corresponding increase of temperature in a poleward direction in the Northern Hemisphere (Figure 8).

(5) Channel 5 (0.2-4.0μ)

From 30°N to 30°S the maximum and the minimum trends in the meridional profiles for the short-wave channel are in the opposite direction from those of the long-wave channels (Figures 7 and 9). In each monthly profile the reflectance maximum at 5°N and the reflectance minimum at 15°S correspond to the long-wave maximum and minimum at these approximate locations. The other reflectance minimum is near 15°N, which is displaced from the longwave maximum near 25°N. On the other hand, there is a direct correlation between the reflectance minima zones and the zones of maximum evaporation over oceans,[4] and the converse is true with the zone of maximum reflectance.

Between 30° and the poles, the reflectance profiles have much greater symmetry between the Northern and Southern Hemisphere values than the profiles for the long-wave Channels 1 to 4.

IV. CONCLUSION

The Medium Resolution Radiometer data in Nimbus II showed significant advantages over that of the TIROS satellites due to the wide global coverage of the satellite and the lack of instrumental degradation. Unfortunately, the lifetime of the radiometer was only ten weeks. More valuable meteorological information is anticipated from future Nimbus satellites having a longer lifetime radiometer.

REFERENCES

1. Nimbus II Users Guide, NASA Project, Goddard Space Flight Center, July 1966.
2. Lienesch, J. H., "Methods of Estimating Infrared Flux From Nimbus II Data," personal communication, July 1966. Wark, D., Yamamoto, G., and Lienesch, F. H., Methods of Estimating Infrared Flux and Surface Temperature from Meteorological Satellites, J. Atmos. Sci., 19, 369-384, 1962.
3. London, Julius, "A Study of the Atmospheric Heat Balance," Final Report, New York, New York University College of Engineering, Dept. of Meteorology and Oceanography, AFCRC TR-57-287; AD-117, 227, July 1957.
4. Budyko, M. I., Editor, Atlas of the Heat Balance of the Earth, Moscow, 1963, plates 59-61.

Table I

Nimbus II Weighted Day and Night Lifetime Global Values

Time Nadir Angles		May 15-July 27, 1966									Differences	
Channel No.	μ	Day C.*	Day L.*	Day C.*+L.*	Night C.*	Night L.*	Night C.*+L.*	24-hour C.*	24-hour L.*	24-hour C.*+L.*	24 hr. C. values– 24 hr. L. values	(Day–Night)
1.	6.4-6.9	239.0	236.3	237.5	238.6	236.2	237.4	238.7	236.3	237.6	2.4	0.1
2.	10-11	275.7	273.1	274.2	271.9	270.1	271.0	274.0	272.0	273.1	2.0	3.2
3.	14-16	223.3	223.0	223.1	223.3	223.1	223.2	223.3	223.1	223.2	0.2	-0.1
4.	5-30	260.5	257.6	258.8	258.0	255.8	256.9	259.3	257.0	258.3	2.3	1.9
5.	0.2-4.0†	23.8	24.7	24.3	—	—	—	23.8	24.7	24.3	-.9%	—
4.	5-30	.348	.351	.349	.335	.340	.337	.342	.346	.344	-.004	.018

Unit: 1. °K; 2. °K; 3. °K; 4. °K; 5. %; 4. FLUX Langleys/Min.

*Notation C. means measurements associated with (0°-25°) nadir angles. Notation L. means measurements associated with (25°-40°) nadir angles.

†This Channel 5 average consists of reflectances in the 90°N-50°S zones only. The day average for all nadir angles is equal to the average using extrapolated values for 50°S-90°S and the measurement values from 90°N-50°S.

Table II

Nimbus II Approximate Monthly Weighted Global Values

Date 1966			May 15-June 4	June 5-July 2	July 3-July 27	Lifetime: May 15-July 27
Channel No.	μ	Unit				
1.	6.4-6.9	°K	237.1	237.7	238.1	237.6
2.	10-11	°K	272.6	273.3	273.1	273.1
3.	14-16	°K	223.4	223.4	223.0	223.2
4.	5-30	°K	257.8	258.5	258.3	258.3
5.	0.2-4.0*	%	24.6	24.5	23.8	24.3
4.	5-30	FLUX Langleys/Min.	.341	.345	.343	.344

*The solar constant used was 2.00 langleys/min. A more recent solar constant of 1.942 would increase the May, June, July, and lifetime global reflectances to 25.3%, 25.2%, 24.5%, and 25.1% respectively.

Table III

Comparison of Total Outgoing Long-Wave Radiation and Reflectance Global Averages

Total Global Outgoing Long-Wave Radiation (langleys/min)				
	Nimbus II*	TIROS VII†	TIROS VII†	Calculation by London(3)
Period	May 15-July 27, 1966	June-August 1963	July-August 1963	June-August
Channel	#4 (5-30μ)	#2 (8-12μ)	#4 (5-30μ)	—
Weighted Flux Average	.344 (obtained from 10° lat.-15° long. grid)	.351	.336	.324
Global Reflectance (%)‡				
Period	May 15-July 27, 1966	June-August 1963	June-August 1963	June-August
Channel	#4 (0.2-4μ)	#5 (0.55-0.75μ)	#3 (0.2-4μ)	—
Weighted Reflectance Average	24.3	21.3	19.5	34.8

*Nimbus II reflectance measurements were in zones 90°N-50°S. To compute global averages, reflectances were interpolated for the remaining zones.

†The TIROS VII reflectance values listed here have been corrected for change of instrument response with time.

‡Global reflectances used solar constant of 2.00 langleys/min. using a newer value of the solar constant of 1.942 langleys/min. raises the global reflectance of NIMBUS II to 25.1%.

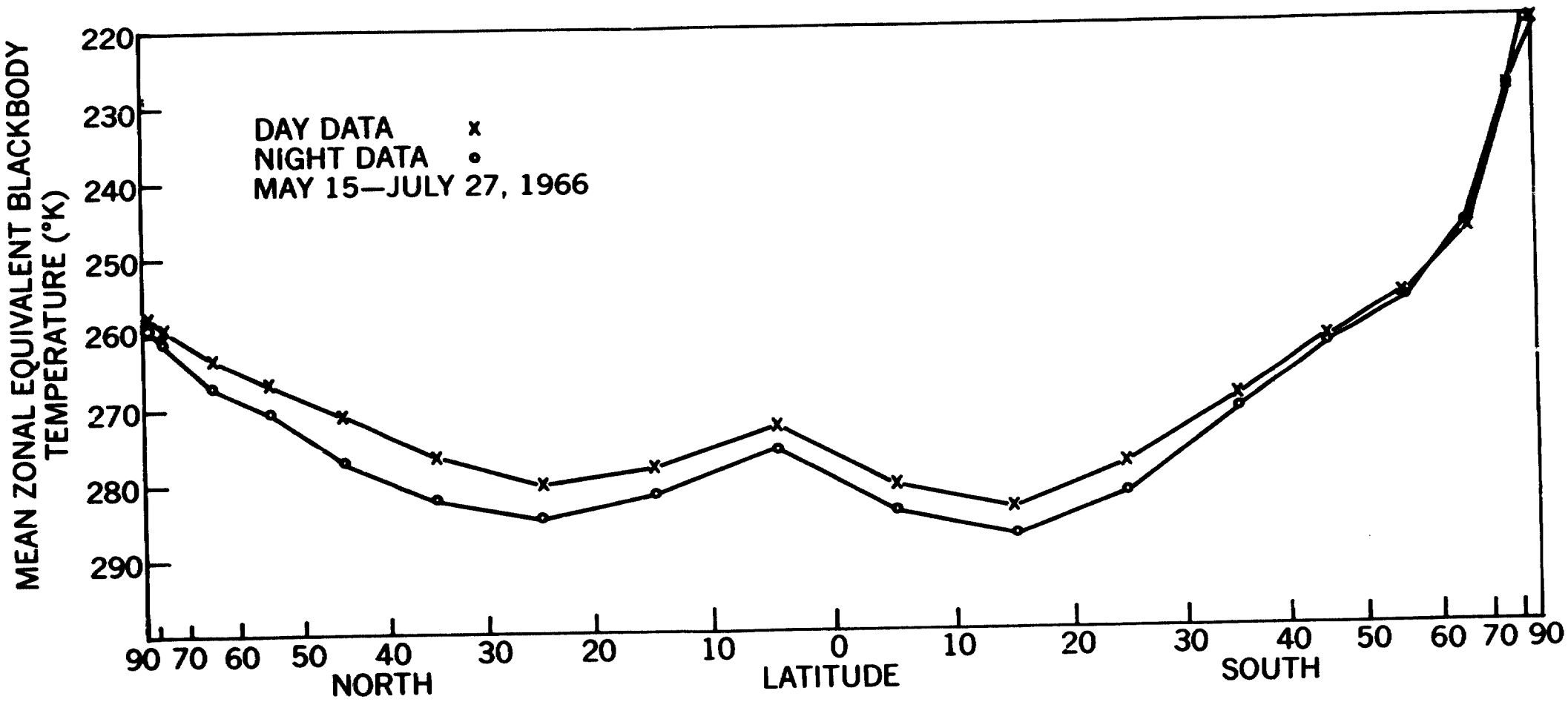

Figure 1. Nimbus II Channel 2 (10-11μ) day and night temperatures.

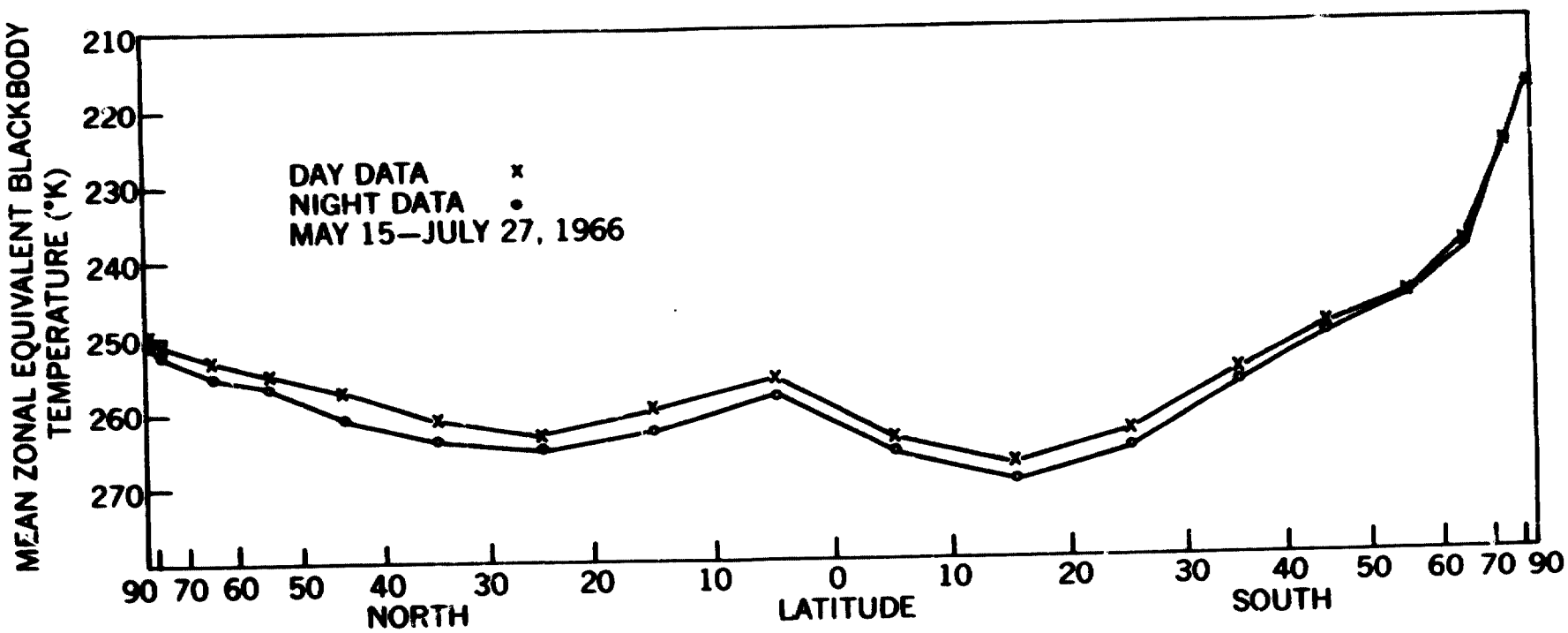

Figure 2. Nimbus II Channel 4 (5-30μ) day and night temperatures.

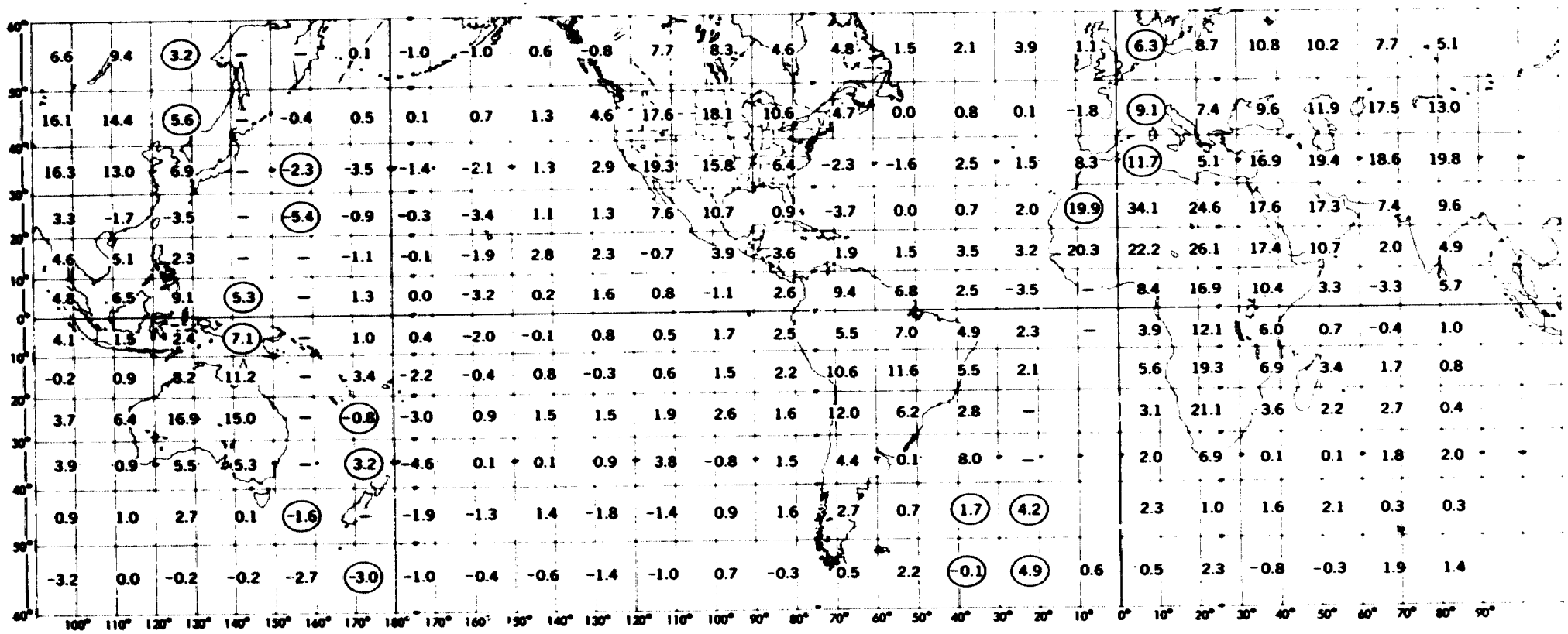

Figure 3. Nimbus II Channel 2 (10-11μ) day-night temperature differences for May 15-July 30, 1966. The differences generally represent measurements taken when the sensor nadir angle was less than 25°. Encircled values were obtained when the sensor nadir angle was in the range 25°-45°. A negative temperature difference means the night temperature is greater than the day temperature.

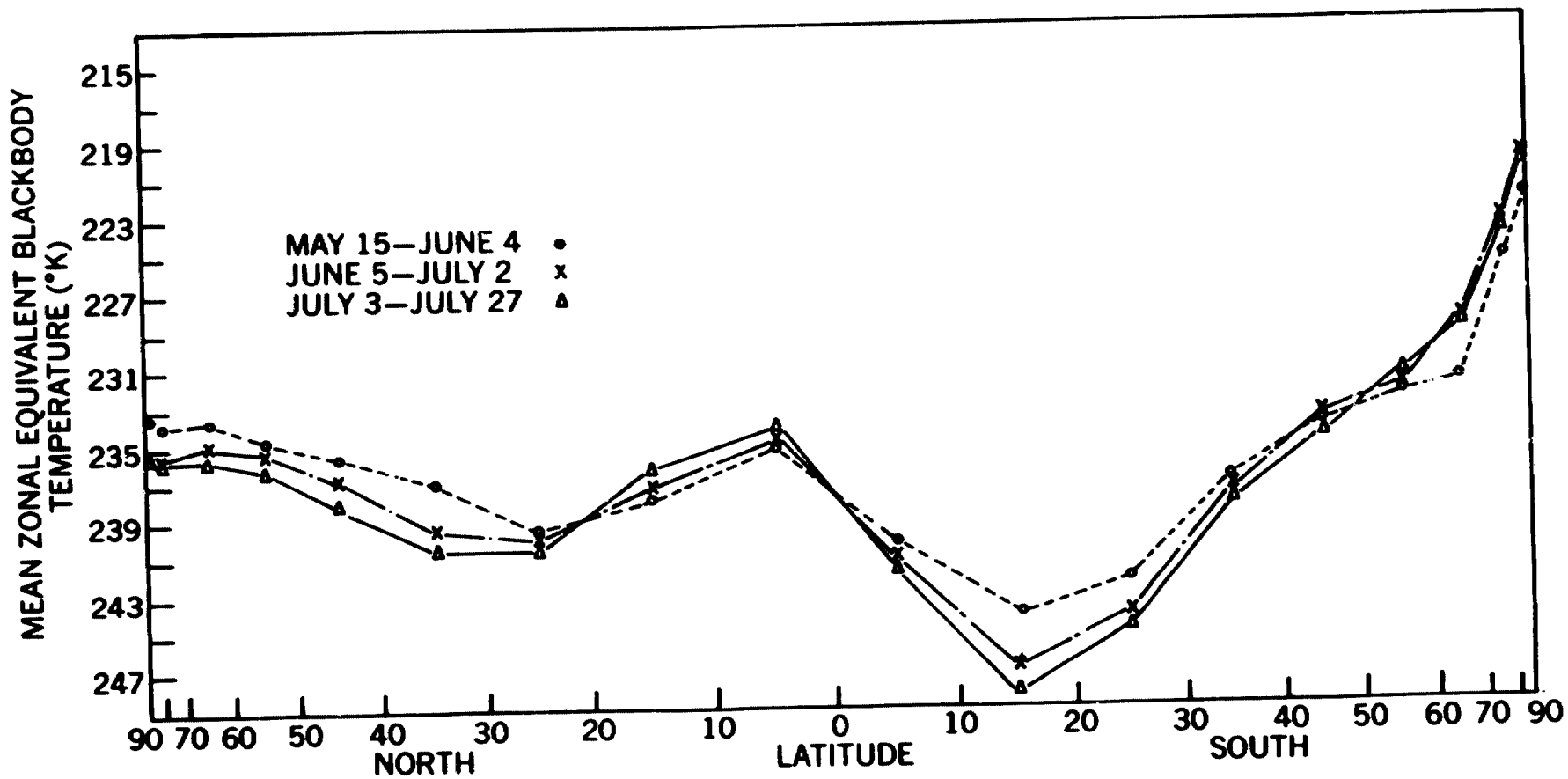

Figure 4. Nimbus II Channel 1 (6.4-6.9μ) meridional temperature profiles.

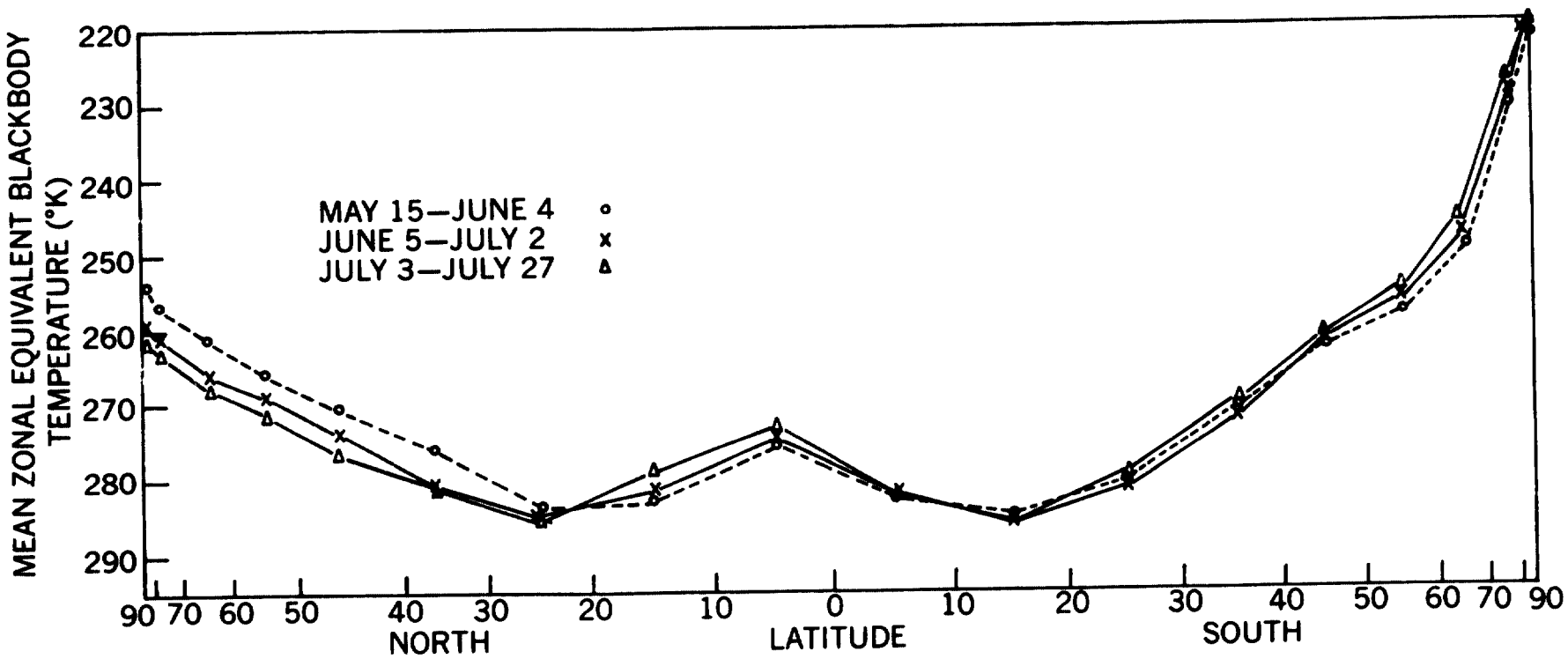

Figure 5. Nimbus II Channel 2 (10-11μ) meridional temperature profiles.

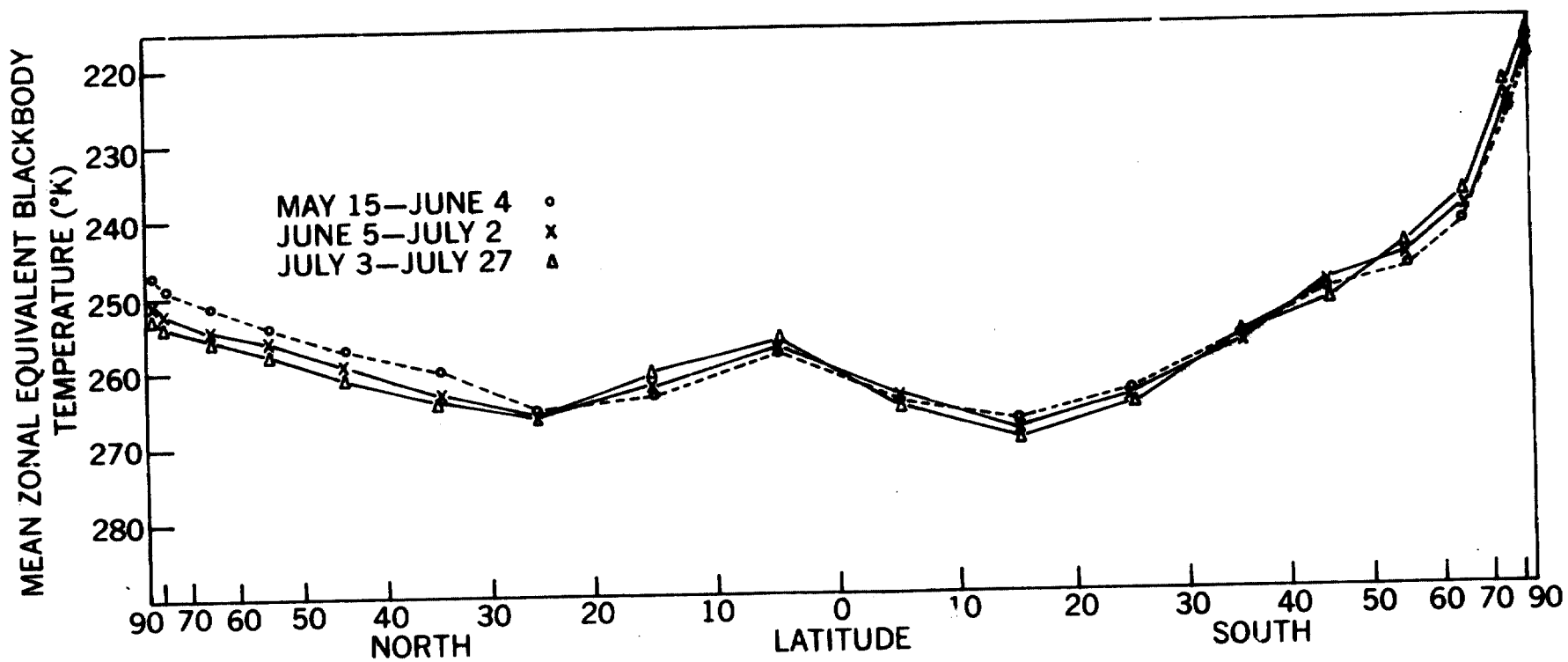

Figure 6. Nimbus II Channel 4 (5-30μ) meridional temperature profiles.

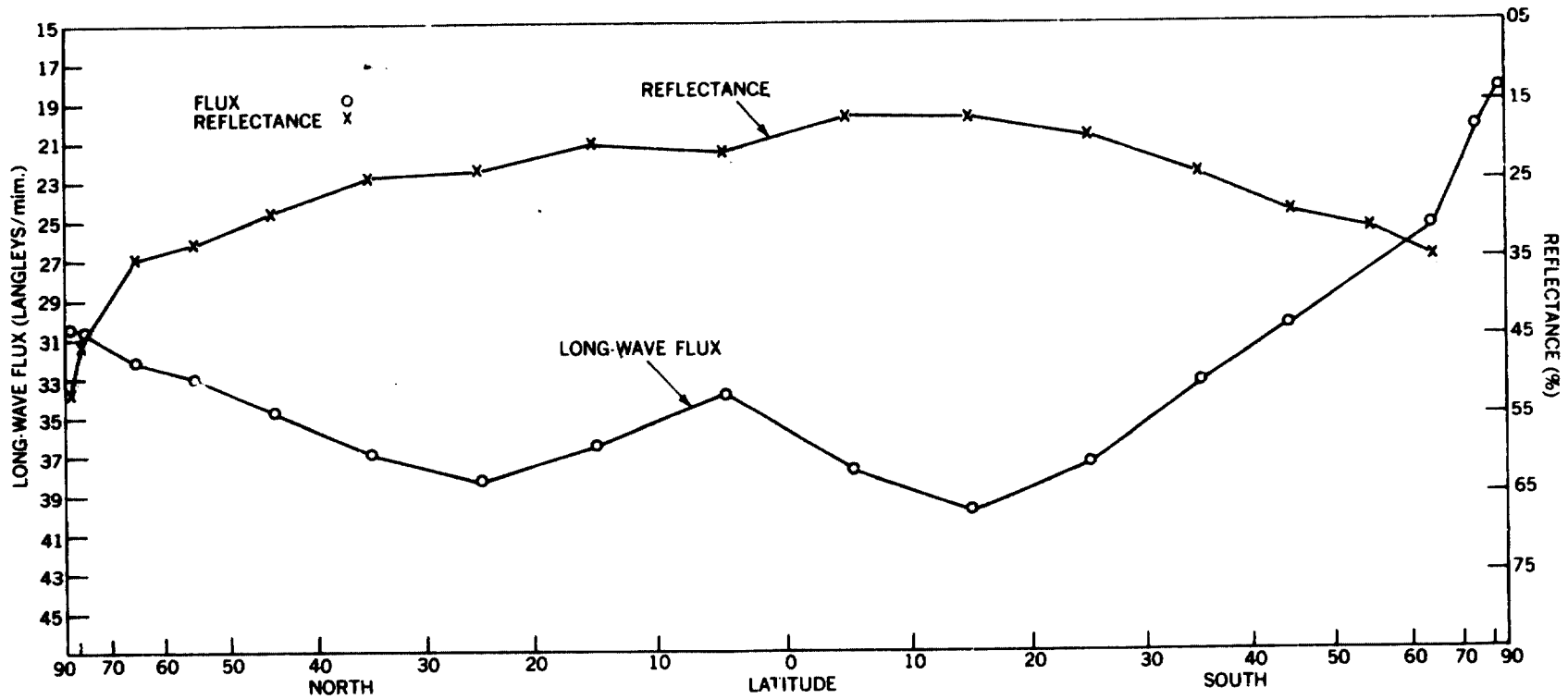

Figure 7. Average Nimbus II total outgoing long-wave radiation and reflectance for lifetime of radiometer. The long-wave is derived from Channel 4 measurements. The reflectance is derived from Channel 5 measurements.

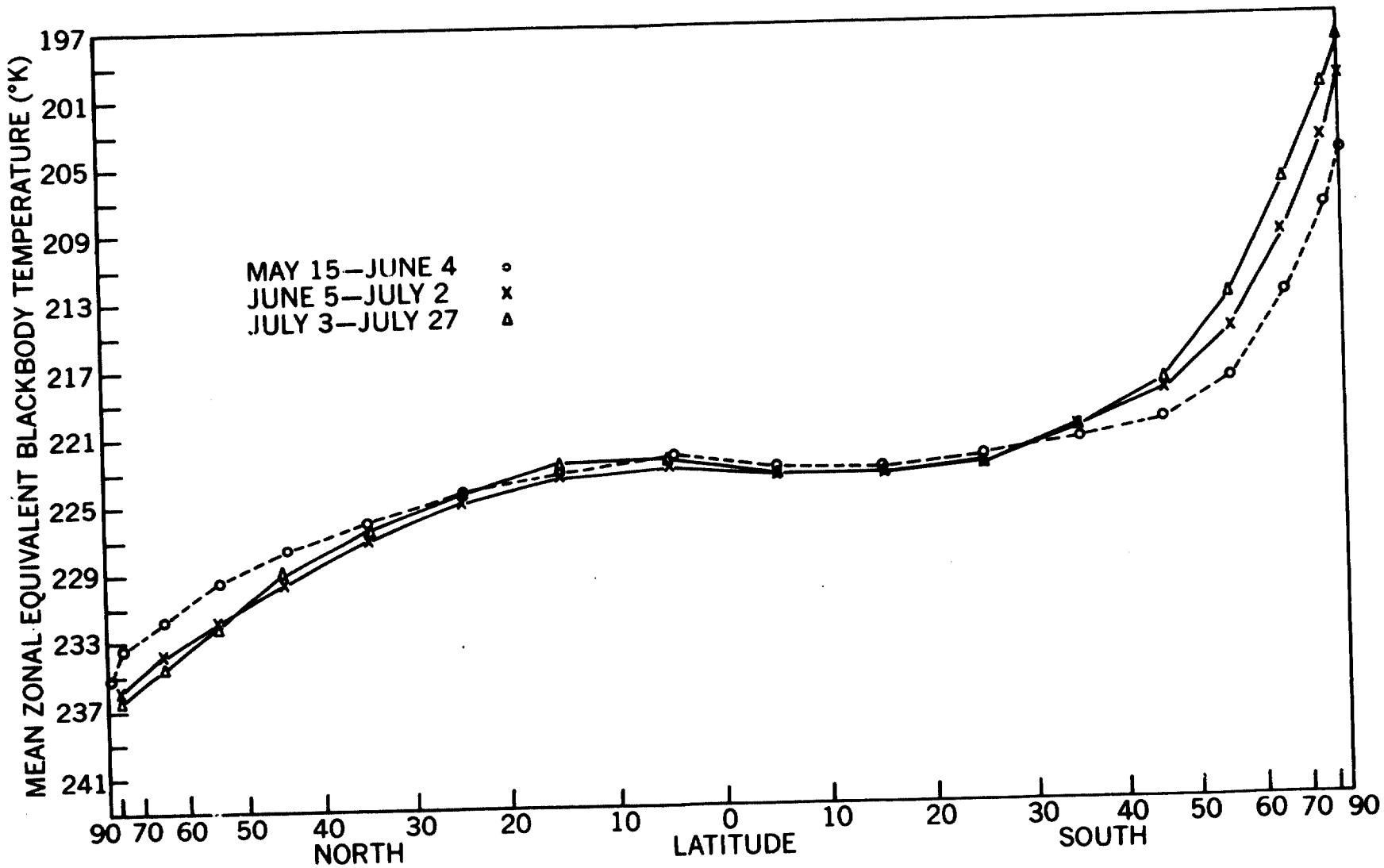

Figure 8. Nimbus II Channel 3 (14-16μ) meridional temperature profiles.

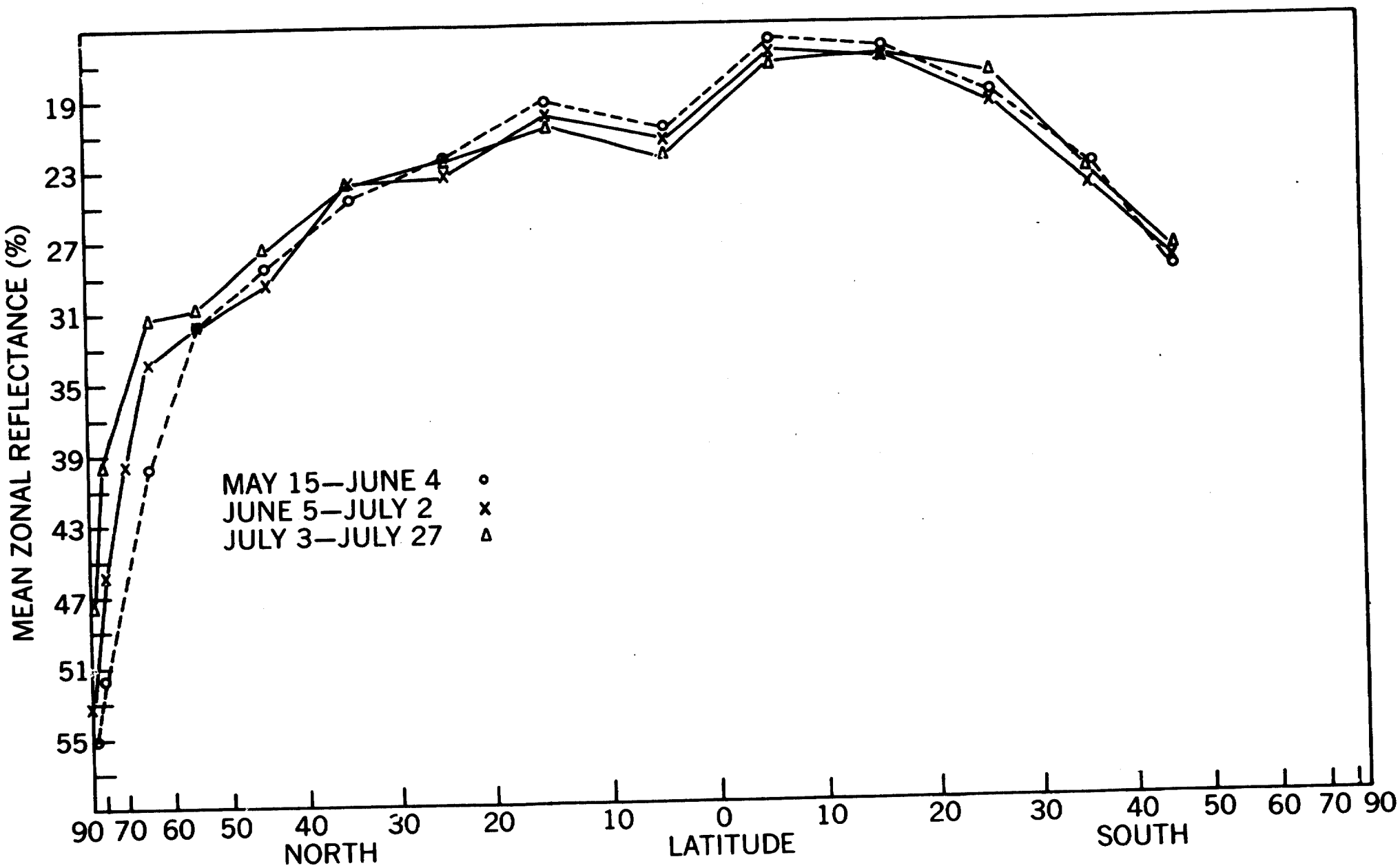

Figure 9. Nimbus II Channel 5 (0.2-4.0μ) measured short-wave reflectance profiles.