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ABSTRACT

The brightness temperature data from the Nimbus 5 Electrically Scanning microwave Radiometer (ESMR) was observed to have substantial time dependent shifts in 1973 and 1976. Temporal variations of the brightness temperature of selected regions representing ocean, sea ice, and ice sheets were studied. Shifts that could not be ascribed to geophysical effects were found to occur during the same time periods in the various regions. The procedures employed to correct for these shifts are described.

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CORRECTIONS FOR ANOMALOUS TIME DEPENDENT SHIFTS IN THE BRIGHTNESS TEMPERATURE FROM THE NIMBUS 5 ESMR

1. INTRODUCTION

The Nimbus 5 Electrically Scanning Microwave Radiometer (ESMR) data have been extensively used as a research tool in various disciplines (e.g., Allison, et al.(1979), Chang and Wilheit (1978), Gloersen and Salomonson (197) and Wilheit et al. (1975)), since launch in December 1972. The Ice Section of the Oceans and Ice Branch of the Goddard Laboratory for Atmospheric Sciences has compiled 3-day average polar stereographic maps of ESMR brightness temperature (T_B) data from launch till May 1977 for both the North and South Polar regions to support the research efforts on sea ice extent, open water within the ice pack, and polar ice sheets studies. Studies of the time distribution of T_B in various areas including open ocean, highly concentrated sea ice, and ice sheets have revealed unexpected shifts in brightness temperature during 1973 and 1976. Attempts to correlate these shifts with seasonal geophysical effects were not successful as will be discussed later. The purpose of this paper is to present the nature and extent of this problem and the procedure employed to normalize the data before it was used to generate the data sets for an Antarctic sea ice atlas (Zwally et al., in preparation). Two types of corrections have been made: 1) adjustments for abrupt changes of about 10° to 25° of brightness temperature around May to September 1976 and 2) month to month changes of about several degrees.

2. BRIGHTNESS TEMPERATURE TIME DISTRIBUTION

The polar stereographic maps used in this study consists of 293 x 293 elements (called pixels) with the 50° latitude enclosed. Each pixel represents a T_B for approximately 30 x 30 km^2 of area on the earth's surface. Color images of selected 3-day average maps in summer and winter for both North and South polar regions were published in Zwally and Gloersen (1977). To investigate the time dependence of the brightness temperature of the ocean, the data for each pixel between 55° and 65° latitudes of the Southern Ocean was binned and a typical distribution is shown in Figure 1. The contribution from the ocean comes out as a very strong narrow peak with an average width at half-maximum of about ±4°. The position of the ocean peaks for the monthly average maps were plotted and the results for the time periods in 1973, 1974, 1975, and 1976 are shown in Figure 2. In 1973, there is a dip of the order 8° from January to July. In contrast to this, the data for 1974 and 1975 show a fairly uniform distribution and no strong seasonal dependence. In 1976, a much stronger dip than in 1973 occurred in May, which was followed by a recovery in July, and then a general decrease for the remainder of the year.

The brightness temperature of the ocean is proportional to its physical temperature with the constant of proportionality being the emissivity for each physical temperature. The emissivity, at the ESMR wavelength of 1.55 cm on the other hand is inversely proportional to physical temperature as indicated by Wilheit (1972). It is therefore expected that the brightness temperature over the ocean is fairly constant throughout the year, as in 1974, except where there is abnormal surface roughness or unusually large variations in water vapor content in the atmosphere. The possible effect of these geophysical variations has been minimized by working with a selected ocean area that is sufficiently large to keep the average atmosphere and ocean activity uniform during the time period considered.

Investigation of the time variation of the brightness temperature of both ocean and sea ice areas was done using the 3-day averages maps and the results are shown in Figures (3a) and (3b). As would be expected for an instrumental or calibration problem, the shifts in brightness temperature in both ocean and ice areas occurred at about the same time period. Furthermore, although the initial downward shift is about 10° for the ocean and 8° for the sea ice, the recovery shift is about 18° for the ocean and 25° for the sea ice. The latter shift would require a change in physical temperature of about 27° on the ice and 40° in the water, assumming emissivity to be constant during the time period. Therefore, considering the abrupt nature of the shifts and their magnitude, it is not possible to attribute them to physical effects in the ocean or atmosphere.

Analysis of the calibration parameters used in calibrating the data set showed no obvious abnormality unique for this particular time period. What was observed is a corresponding shift in values for the raw uncalibrated data or radiometer counts. A sample distribution for ocean areas before and after the 1976 shift is shown in Figure 4. The magnitude of this shift when converted into brightness temperature compares favorably with that observed from the calibrated tape. It is not possible to give an adequate explanation for the observed shift in raw temperatures at this time. Although the problem is still being studied, it is worthy to note that the satellite was about 4-years old in 1976 and the instrument was operating well beyond its expected lifetime of one year.

3. NORMALIZATION FACTOR AND ICE SHEET STUDIES

Although the reason behind the anomalous shift in brightness temperature has not been established from the instrumental point of view, it is apparent that the quality of the present set of calibrated data can be improved. As indicated earlier and as is evident in the 1974 data, the brightness temperature of the ocean is approximately uniform with time. The brightness temperature of the sea ice during the same time period looks reasonably uniform in the 1974 data as well. It is therefore possible to extract two well separated anchor points for normalization from a weighted average of 1974 data and the portion of the 1976 data which appears good. These points were determined to be 134.3° and 231.7° for ocean and sea ice, respectively. Each questionable data set could then be normalized by binning an area in the polar maps, containing substantial sea ice and water, like the Weddell Sea area. The resulting distribution provides the reference peaks (see Figure 1) which could be used to determine the normalization parameters for the particular data set. For the 1976 data set, the peaks for both ocean and ice indicated as x_O and x_I, respectively, and the corresponding half widths at half-maximum (σ_O and σ_I), are tabulated in Table 1. A slightly different reference peak for the ice was used for the October, November and December data to account for the increase of about 8° in the brightness temperature of the ice that occurs during the melting period. For these months, the brightness temperatures were adjusted to follow the same pattern of increase during the melt period as the 1974 data.

Initially, the substantial shift in brightness temperature in mid-1976 was the major concern while shifts less than 7° were ignored. Therefore, the normalization procedure discussed above was implemented only for the anomalous 1976 data. Studies in the ice sheet areas, however, indicated that further refinement in the data was possible, to reduce the smaller errors due to the uncertainty in the instrument calibration. The seasonal dependence of the brightness temperature of various areas of the Antarctic continent were plotted for the four years ESMR data were available, and are shown in Figure 5a. In each of the distributions for the various areas, the relative shift in brightness temperature from one year to the next was suspiciously similar. The distribution for 1973 shows conspicously a larger deviation from the mean than other years. The largest discrepancy occured in mid-winter, which is about the same time period when a shift in brightness temperature over the oceans was observed.

In the ice sheet, the most significant variable which could cause a seasonal or time dependent variation in brightness temperature is physical temperature. The brightness temperature observed from this region emanates from as far down as 10 meters as described in Chang et al. (1975) and Zwally (1977) and the interannual variability should be minimal. A comparison of seasonal physical temperatures at the Amundsen-Scott station (90° S) for 1973 and 1974 is shown in Figure 6. There is obviously no correlation between the marked deviation of the 1973 brightness temperature data from that of 1974 and the physical temperature profiles.

If the brightness temperatures for each data set are adjusted such that the ocean peak is maintained at a fixed value, of say 135°, a reconstruction of the distribution in Figure 5(a) is shown in Figure 5(b). An interannual distribution of ice sheet brightness temperatures, which are significantly more consistent and therefore more compatible with the expected minimal interannual variability was generated as a result. A comparison of yearly average maps of brightness temperature of the Antarctic ice sheet indicated that the adjusted data sets were significantly more

Table 1
Mean Brightness Temperatures at Ocean and Ice Areas in 1976

Date		Ocean		Ice	
		x_0	σ_0	x_I	σ_I
May	18	122.0	5.5	226.5	4.0
	21	122.0	5.5	223.0	5.5
	24	121.0	5.5	223.5	3.5
	27	121.5	5.0	222.0	3.0
	30	125.0	7.5	221.0	4.5
June	2	121.0	5.5	219.0	3.5
	5	123.0	4.5	220.5	3.0
	8	-	-	-	-
	11	122.5	5.0	222.0	2.5
	14	121.0	3.5	222.5	4.5
	17	122.0	4.5	222.5	2.5
	21	122.0	6.5	222.5	4.0
	23	123.0	4.5	223.0	3.5
	26	125.0	7.0	224.0	4.5
	29	124.0	6.5	223.0	3.5
July	2	-	-	-	-
	5	141.5	6.0	247.5	4.0
	8	140.0	4.5	248.5	7.0
	11	-	-	-	-
	14	136.0	6.0	241.5	6.0
	17	133.5	5.0	240.5	5.0
	20	131.5	5.0	240.0	6.5
	23	134.5	6.0	241.5	5.0
	26	134.0	5.5	241.0	4.5
	29	134.5	4.0	238.5	5.0
August	1	135.0	4.5	238.5	5.5
	4	131.0	4.5	240.0	4.5
	7	130.0	5.5	236.5	4.5
	10	133.0	5.5	238.5	4.5
	13	139.5	7.0	240.0	6.5
	16	137.0	4.5	240.0	3.5
	19	135.5	7.0	242.5	3.0
	22	136.0	5.5	239.0	6.5
	25	134.5	6.5	238.5	4.5
	28	134.5	5.5	240.0	4.5
	31	136.5	5.5	237.5	4.5
September	3	137.0	5.5	239.0	4.5
	6	137.5	5.0	243.0	4.5
	9	138.0	4.5	245.0	4.5
	12	138.5	5.5	243.0	3.5
	15	135.5	6.5	243.0	4.5
	18	133.5	6.0	238.5	5.0
	21	134.0	5.5	239.0	5.5
	24	135.0	5.0	235.0	5.0
	27	131.5	5.0	238.5	5.0
	30	130.5	7.0	239.5	4.5

Table 1 (continued)

Date (1976)		Ocean		Ice	
		x_0	σ_0	x_I	σ_I
October	3	131.5	5.0	240.0	5.5
	6	128.5	6.0	237.5	5.0
	9	133.5	6.0	239.0	4.5
	12	132.0	5.5	239.0	5.0
	15	133.5	5.0	242.0	3.5
	18	-	-	-	-
	21	134.0	5.5	245.0	2.5
	24	-	-	-	-
	27	-	-	-	-
	30	-	-	-	-
November	2	-	-	-	-
	5	-	-	-	-
	9	-	-	-	-
	11	-	-	-	-
	14	-	-	-	-
	17	130.0	6.5	239.5	4.0
	20	131.0	5.0	239.5	4.0
	23	130.0	5.0	243.0	2.5
	26	129.5	5.0	243.5	2.0
	29	-	-	-	-
December	2	132.5	5.0	245.0	5.0
	5	130.0	5.5	245.0	3,5
	8	130.5	4.0	242.0	3.5
	11	128.0	4.5	241.0	2.5
	14	-	-	-	-
	17	-	-	-	-
	20	129.5	5.0	243.0	2.5
	23	-	-	-	-
	26	127.5	4.0	241.0	3.0
	29	128.5	5.5	239.0	4.0

consistent on the interannual basis than the previous data sets. Except for a few cases, the magnitude of adjustment which needed to be made to maintain the ocean peak at a fixed value was comparable to the fluctuation of the 3-day average ocean peaks, as can be observed in Figure 2, and the width of the ocean peak shown in Figure 1. For the monthly average maps, this width was reduced to about half the size, because much of the short term temperature and atmospheric variability was averaged out. For the purpose of enhancing the data sets, the normalization factors were therefore applied only to the monthly average maps.

To determine the position of the monthly ocean peak, a Gaussian plus a polynomial fit was applied on each distribution. A typical result of this procedure is shown in Figure 7. The effectiveness in locating the peak is quite good except for a few cases when the width was substantially wider than average. The result of this analysis is tabulated in Table 2. The changes (indicated as T_B-135°), are not large except for 1973, when the ocean brightness temperature fluctuated from 138° in January to 129° in July, and in September, 1974. It should be noted that these normalization factors apply in 1976 after adjustment for the abrupt shift shown in Figure 3.

4. CONCLUSION

The preparation of the sea ice data sets required brightness temperatures with a more consistent calibration than the one actually achieved in producing the archived calibrated brightness temperature tapes. The ESMR Nimbus 5 instrument was carefully calibrated on the ground but after launch, an unforeseen change in the antenna properties caused the ground calibration to be practically useless. A calibration procedure which relied heavily on models and ground truth was therefore implemented. Unfortunately, an instrument is always subject to some deterioration after a period of time. This paper shows that some enhancements to the calibration can be made to compensate for the effect of instrument deterioration. For users of uncorrected ESMR data this should also serve as a guide for implementing correction before doing any analysis.

Table 2

Adjustments to Monthly Surface Temperature

Date	T_B Ocean Peak	σ_0	T_B-135°
January 1973	138.4	1.2	3.4
February	137.4	1.4	2.4
June	131.0	1.9	-4.0
July	129.6	2.4	-5.4
September	134.7	2.4	-0.3
October	132.8	1.2	-2.2
November	134.0	1.9	-1.0
December	135.7	1.8	0.7
January 1974	134.6	1.3	-0.4
February	135.7	1.4	0.7
March	136.2	1.7	1.2
April	136.6	1.4	1.6
May	136.2	1.4	1.2
June	136.0	1.3	1.0
July	136.3	1.4	1.3
August	136.6	2.0	1.6
September	138.8	1.8	3.8
October	136.6	2.0	1.6
November	135.1	1.3	0.1
December	135.1	1.2	0.1
January 1[illegible]	133.2	1.4	-1.8
February	133.8	1.6	-1.2
March	133.9	1.5	-1.1
April	134.7	1.8	-0.3
May	134.1	1.3	-0.9
September	135.3	3.4	0.3
October	135.7	2.9	0.7
November	133.8	2.4	-1.2
December	133.4	1.8	-1.6
January 1976	132.1	1.8	-2.9
February	134.5	1.7	-0.5
March	133.9	1.9	-1.1
April	133.5	1.4	-1.5
May	133.3	1.8	-1.7
June	132.8	1.7	-2.2
July	133.1	1.9	-1.9
August	134.7	1.9	-0.3
September	134.3	1.6	-0.7
October	134.3	2.2	-0.7
November	135.7	3.2	0.7
December	134.7	1.7	-0.3

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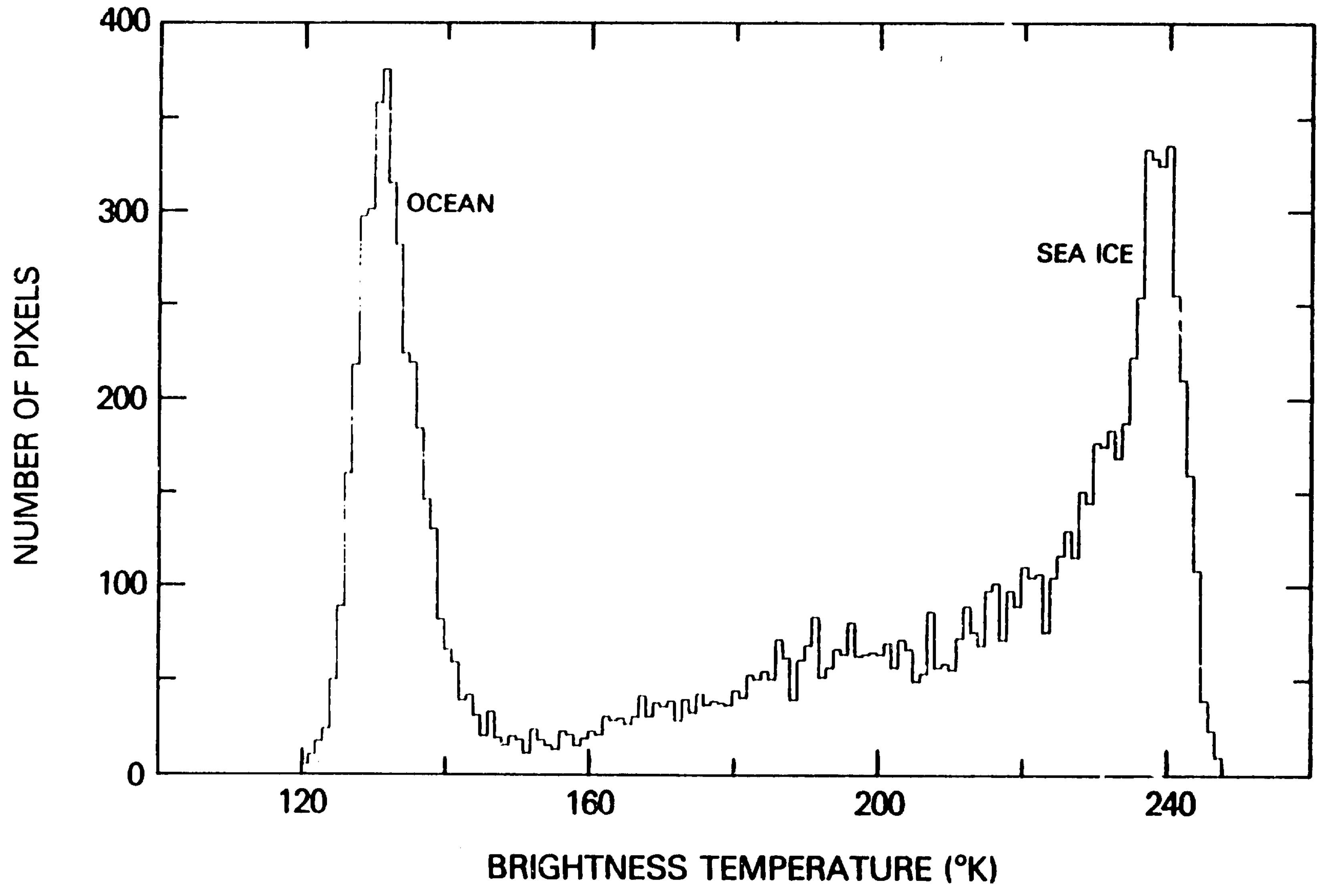

Figure 1. Typical brightness temperature distributions in selected areas in the southern ocean.

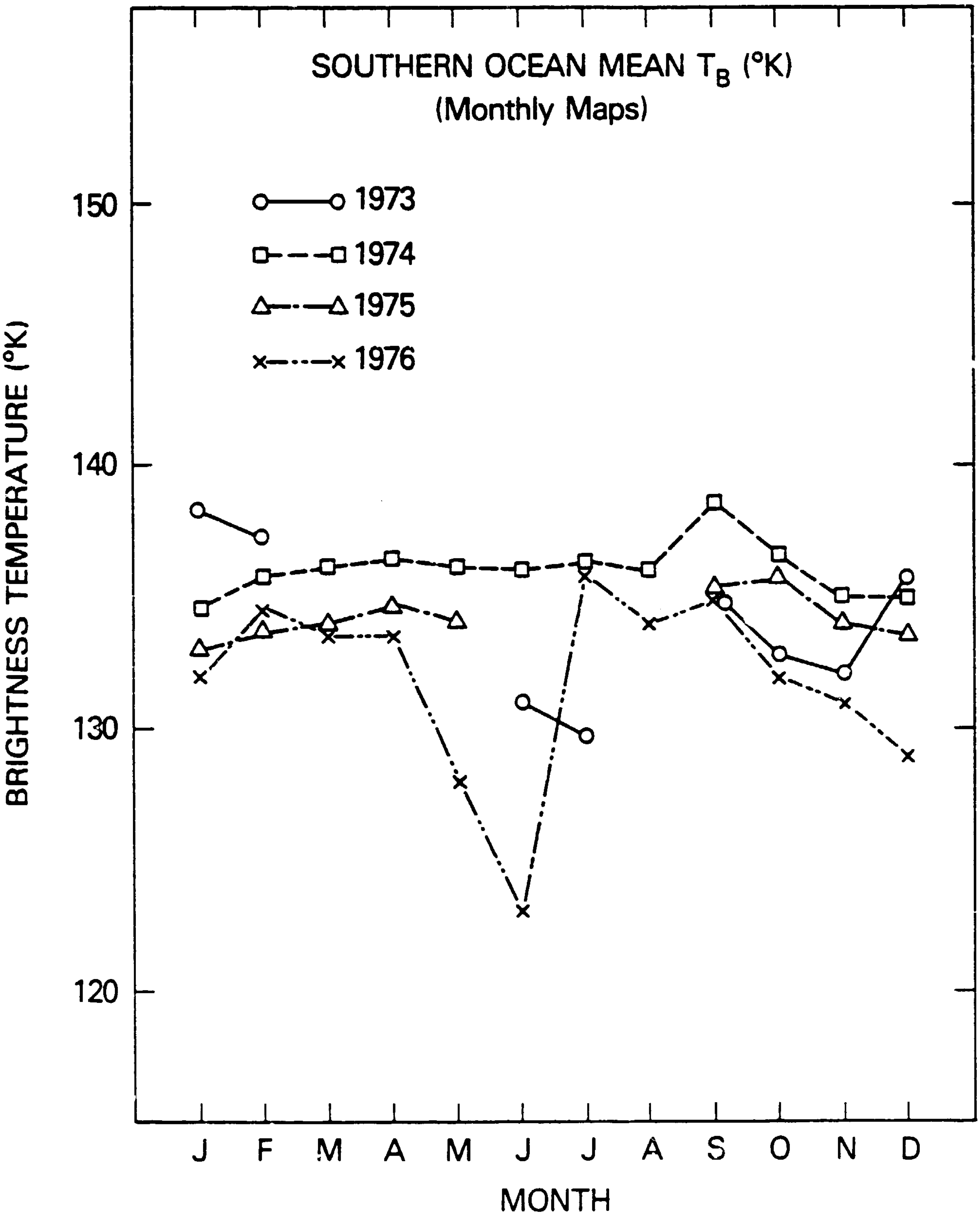

Figure 2. Mean brightness temperatures for ocean from monthly average maps for 1973-1976.

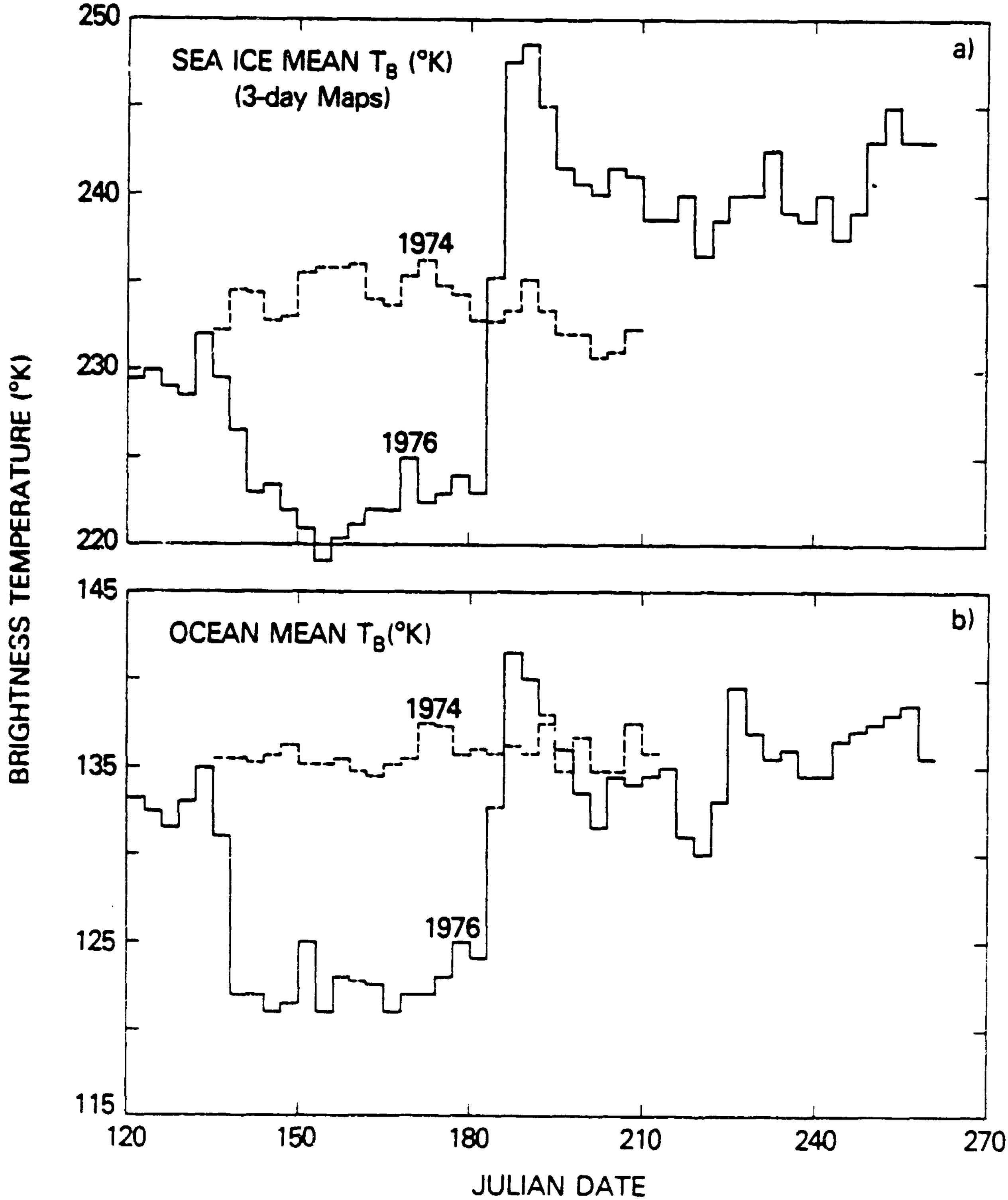

Figure 3. A comparison of mean brightness temperature from 3 day average maps a) sea ice and b) ocean areas between 1974 and 1976.

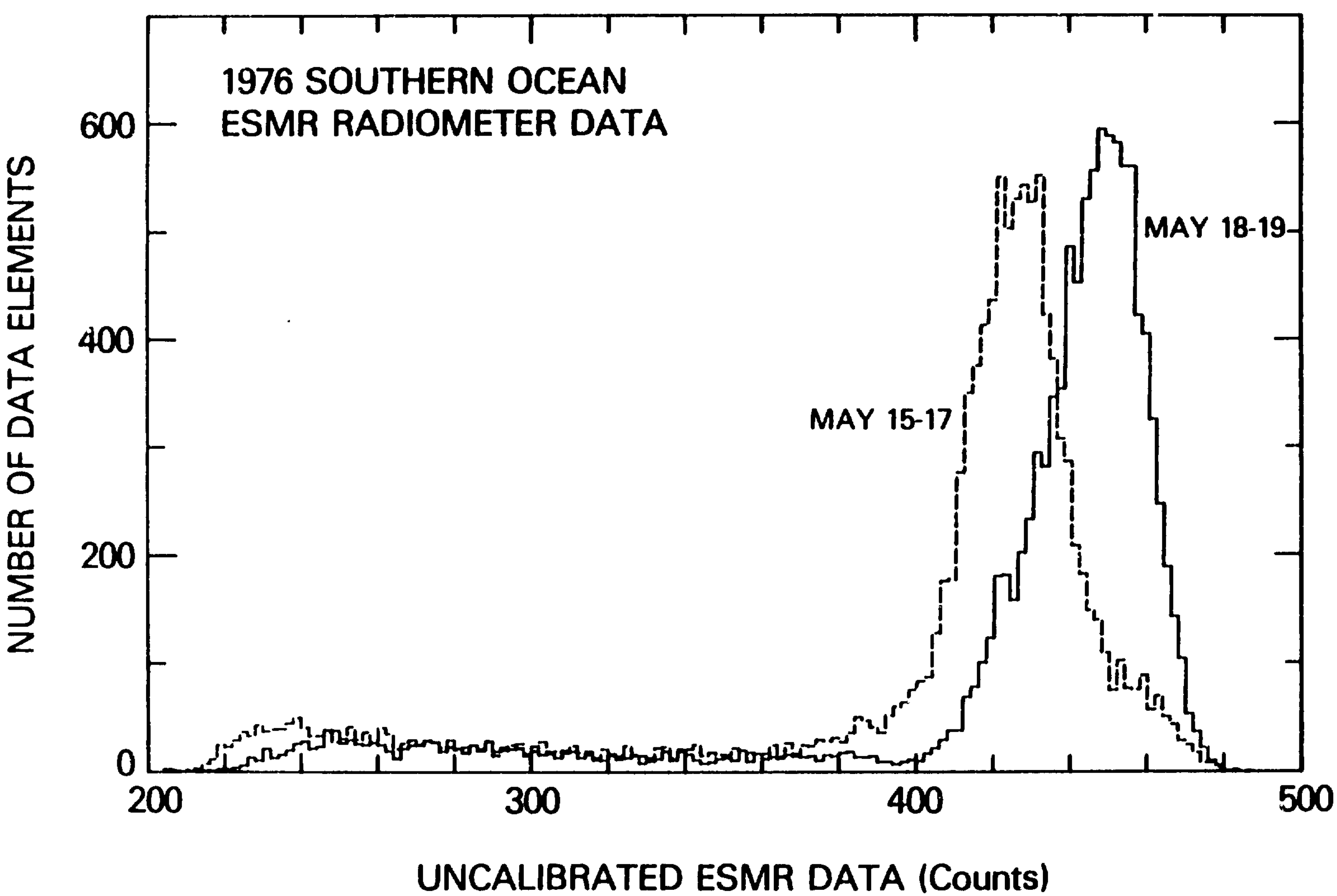

Figure 4. A comparison of radiometric data (counts) in ocean area before and after the observed shift in brightness temperature.

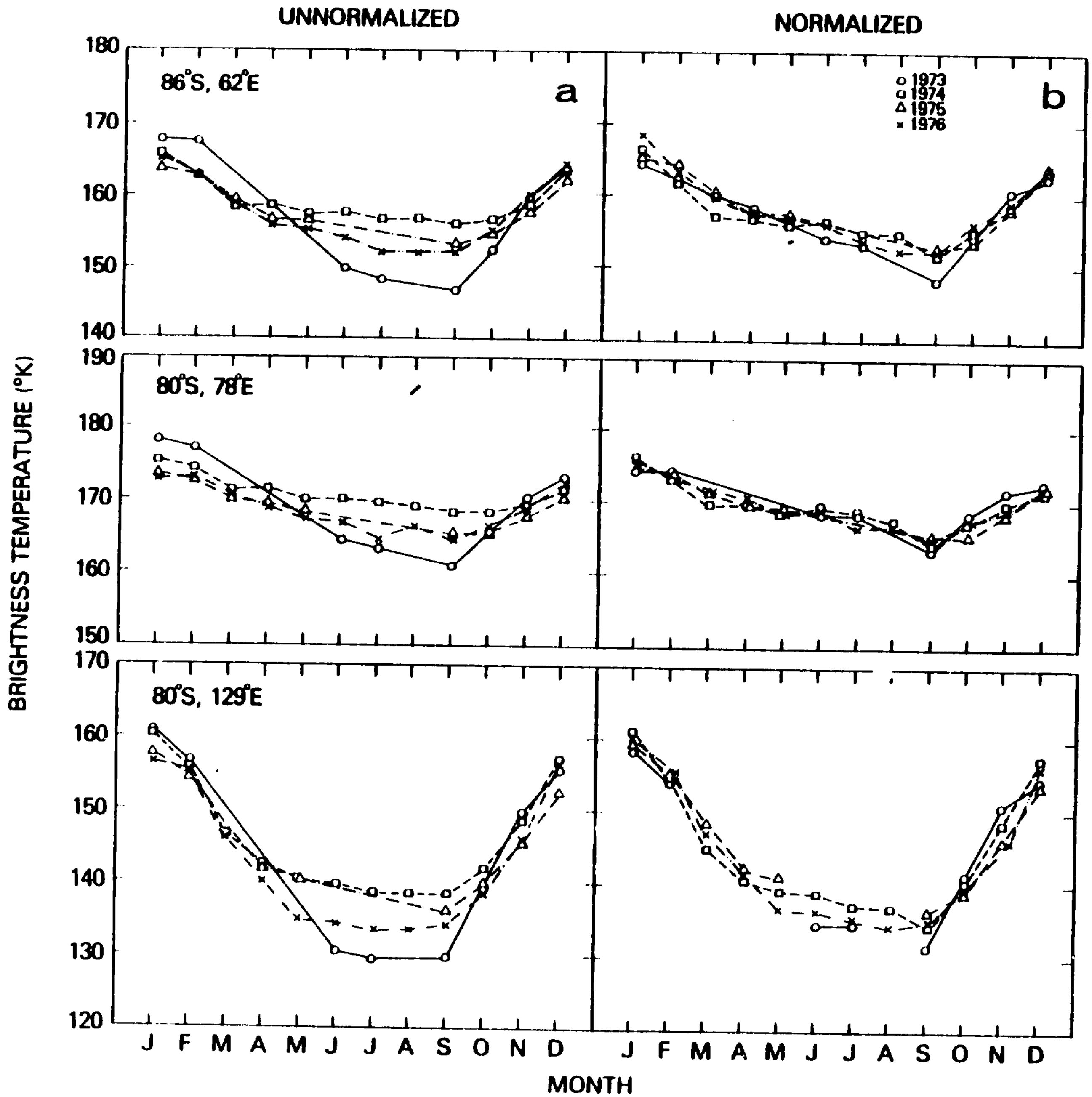

Figure 5. A comparison of seasonal and interannual distribution of brightness temperature in selected ice sheet regions, before and after the data was normalized.

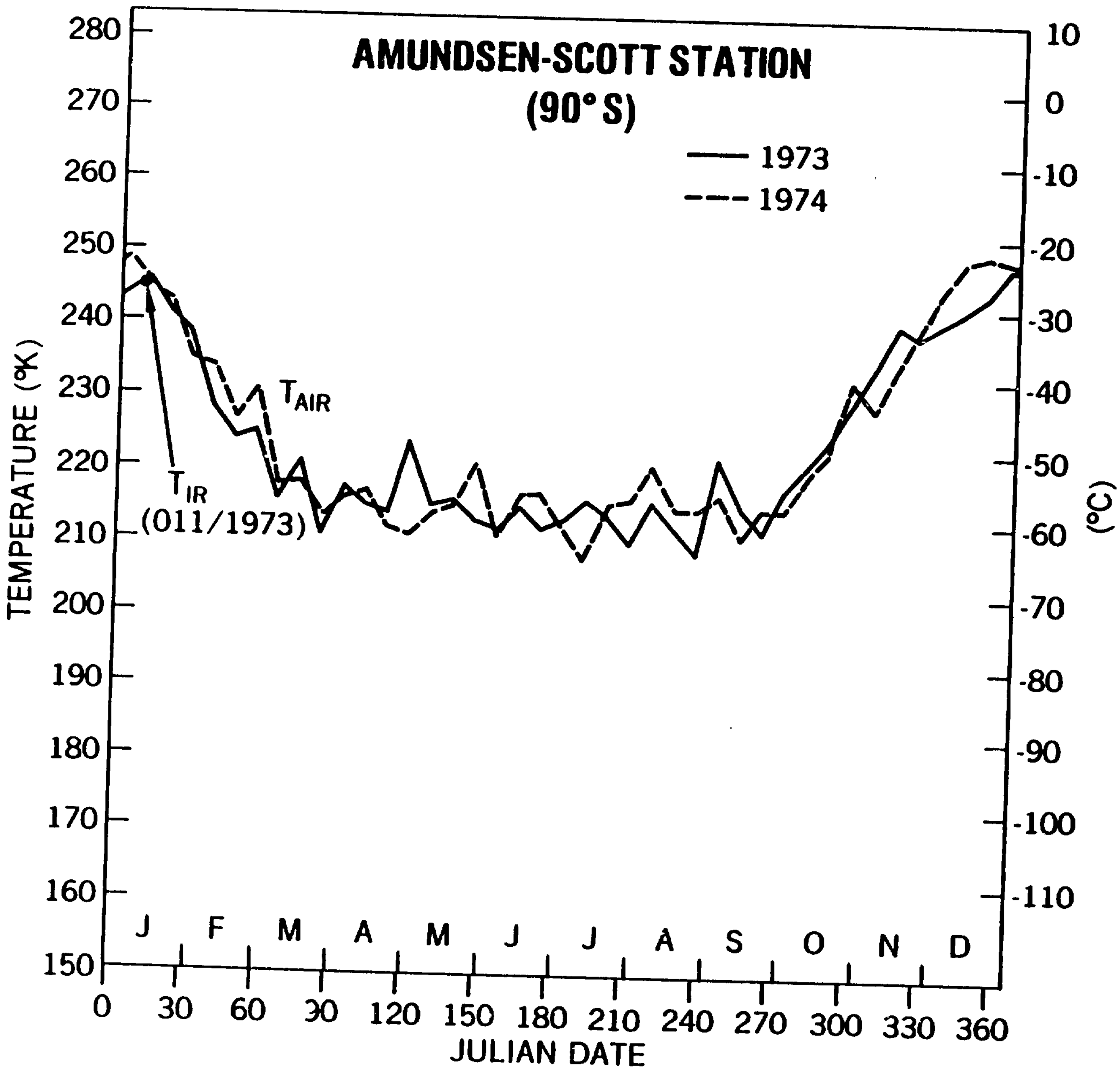

Figure 6. A comparison of seasonal surface air temperatures in Amundsen-Scott station during 1973 and 1974.

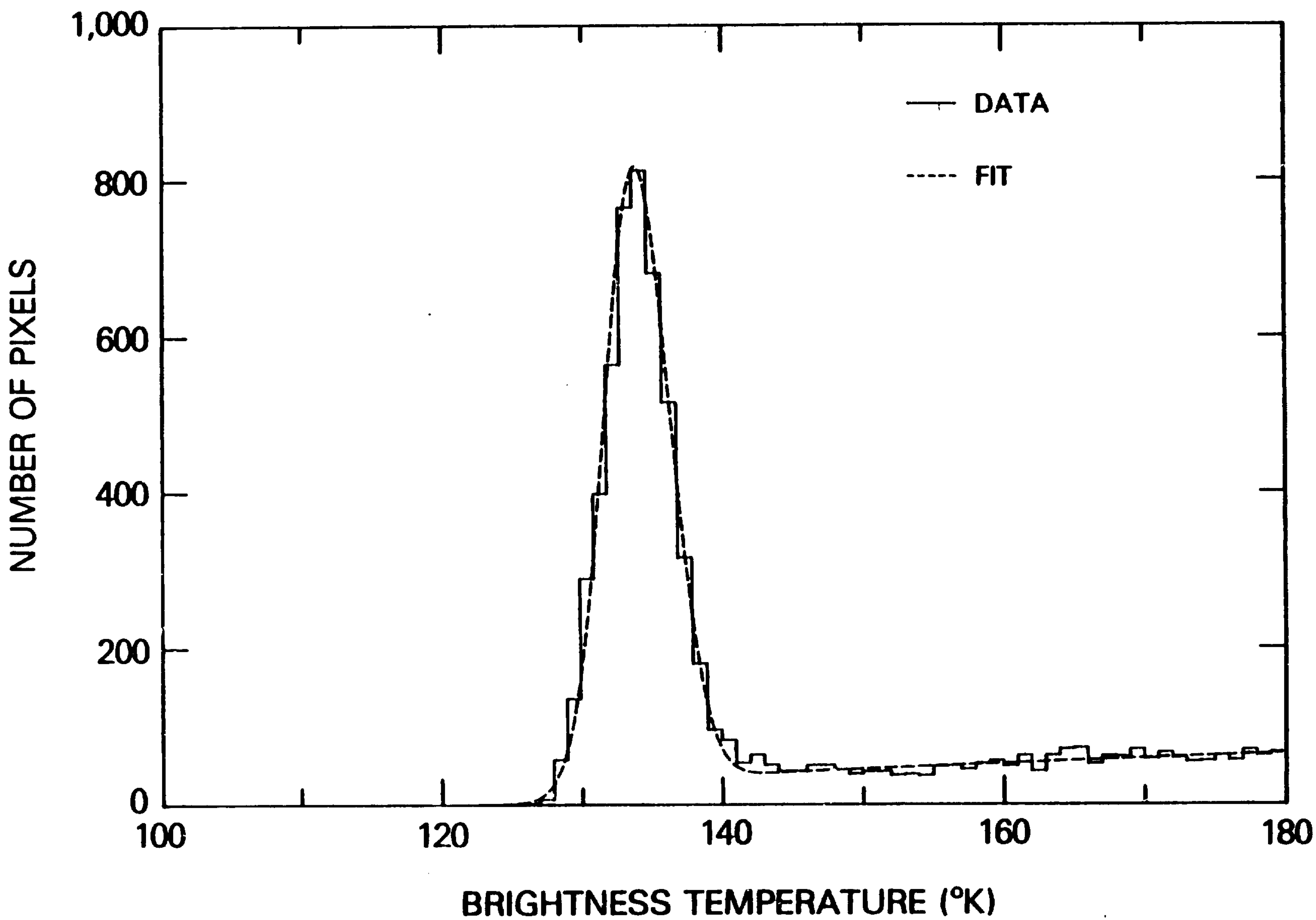

Figure 7. Functional fit of brightness temperature in predominantly ocean areas.