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A MULTISPECTRAL METHOD OF DETERMINING SEA SURFACE TEMPERATURES

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There are two basic problems in remotely measuring sea surface temperature. The first and perhaps most important problem is establishing that you have a cloud-free line of sight, and the second problem is determining the effects of the atmosphere on the emission in an infrared atmospheric window.

In this investigation, three channels of the Nimbus 2 medium resolution infrared radiometer (MRIR) were used. The first channel measured the 10- to 11-μm emission. This channel, in the absence of clouds, sensed the radiance from the sea surface and the intervening atmosphere, and the other two channels tested for the presence of clouds. The other two channels were a broadband reflectance channel from 0.2 to 4.0 μm, and another channel sensitive to water vapor emission from 6.4 to 6.9 μm. If the reflectivity over the ocean was low, cloudiness would either be absent or confined to thin cirrus. Therefore, it was necessary to consider the 6.4- to 6.9-μm measurements that indicated if the upper troposphere was dry. If it was, then the probability of cirrus was low. Thus, when the thresholds of these two channels were met, the registered window measurement that was concurrently made was accepted as coming from the sea surface and the intervening atmosphere.

Figure 1 shows the establishment of the reflectance threshold for which the data were taken on four relatively clear days over the western North Atlantic during a 1-month period from mid-June to mid-July 1966. Normalized reflectances are plotted along the abscissa and frequency of observation is shown along the ordinate. The maximum frequency was associated with a spectral albedo of 6; and, considering the magnitude of instrument noise, a threshold of 9 was accepted as being associated with cloud-free conditions. A similar procedure was used to establish the thresholds for the 6.4- to 6.9-μm channel.

For results that were not corrected for the effects of the atmosphere, there is a difference between the sea surface temperatures as observed by ships and the equivalent blackbody temperature as determined by the radiometer. These differences are depicted in Figure 2 for four different latitude bands. The band nearest the tropics indicates a mean difference of about 8 K. To the north, the effects of a lower atmospheric water vapor content and the lower sea surface temperatures resulted in a smaller mean difference between the measurements of 4 to 5 K.

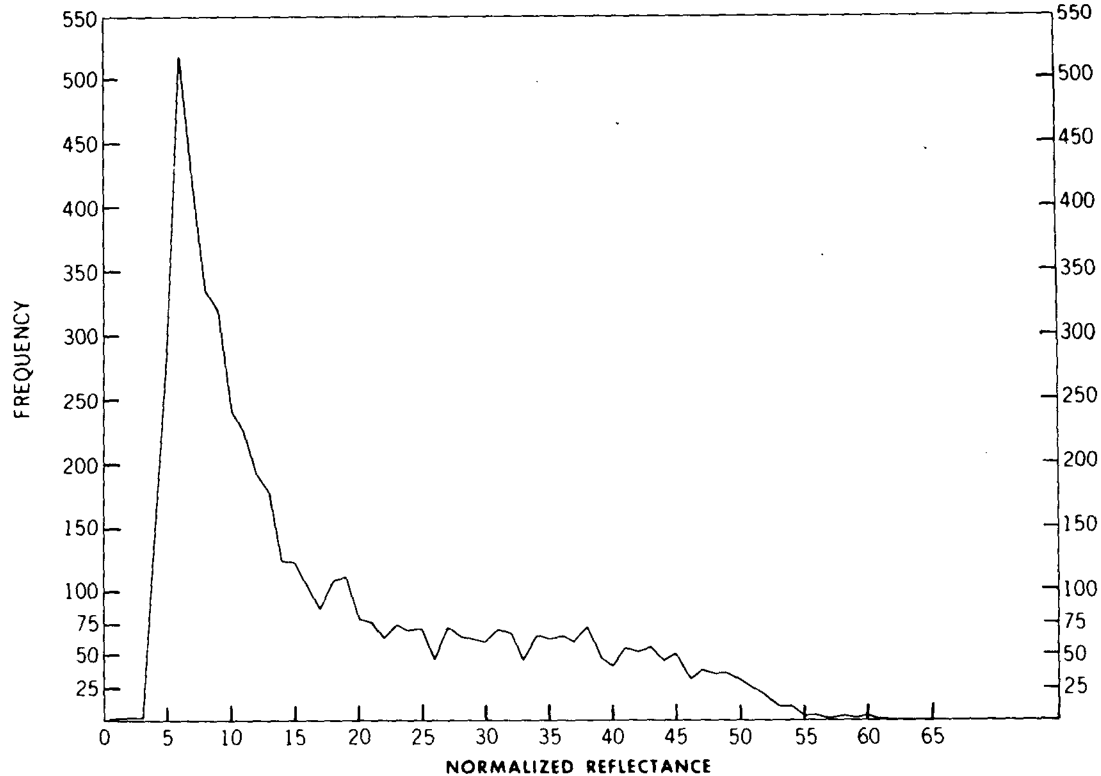

Figure 1–Reflectance threshold over the western North Atlantic.

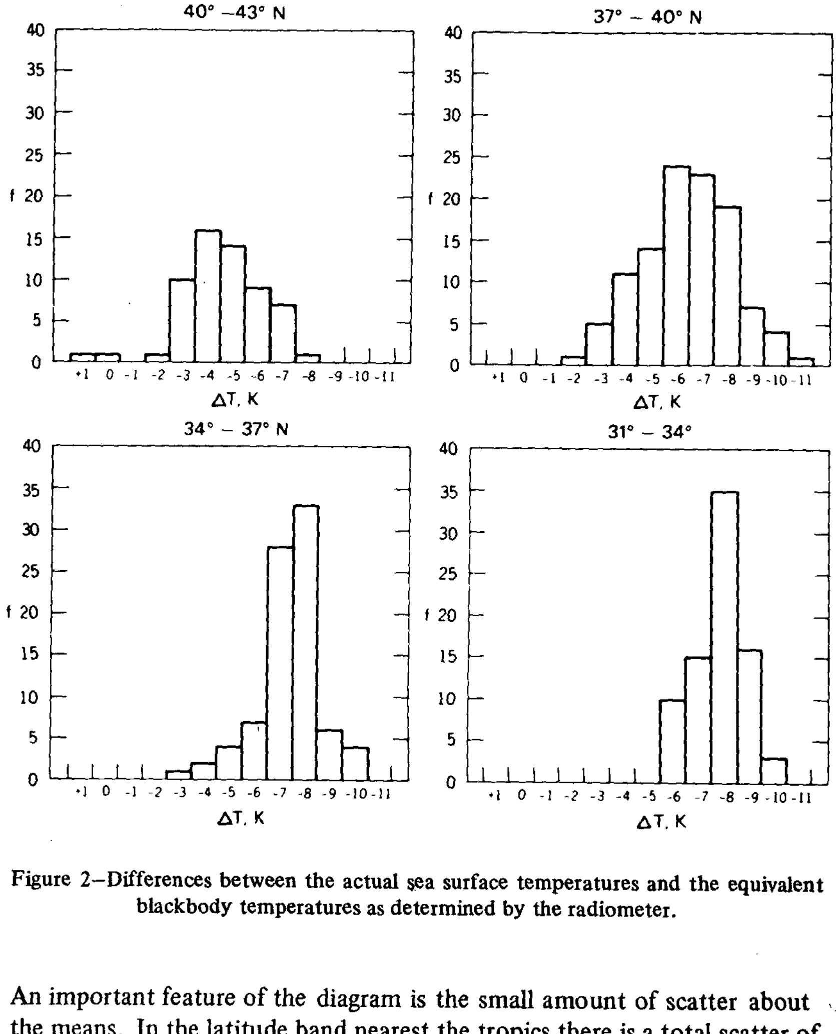

Figure 2–Differences between the actual sea surface temperatures and the equivalent blackbody temperatures as determined by the radiometer.

An important feature of the diagram is the small amount of scatter about the means. In the latitude band nearest the tropics there is a total scatter of 2° on either side of the mean. The scatter becomes slightly larger further north. This most likely occurred because the MRIR measurements had to be acquired over a 1-month period, for which the variability of sea surface temperature is greater. The 1-month period was necessary because of the low spatial resolution of the sensor which meant that relatively few cloud-free measurements could be acquired. A statistical method for correcting for the atmosphere was employed where a regression equation was developed between the radiances and the ship temperatures. The regression equation considered the effects of viewing angle, water vapor (the 6.4- to 6.9-μm measurements were used to provide information on atmospheric water vapor content), and any possible clouds (with the reflectance channel).

Figure 3 shows a sea surface temperature map constructed over the western North Atlantic for the same 1-month period; the results have been corrected by the regression equation for the effects caused by the atmosphere. The continent of North America is shown as a dark area. The warm tongue of the Gulf Stream is seen sweeping northeastward off the U.S. coast and the north wall of the Gulf Stream is clearly visible. This temperature gradient is less than it generally would be on an individual day because of the 1-month averaging period of observation and the spatial resolution of the sensor (55 km). Also, the Sargasso Sea is seen below the Gulf Stream as an area with small temperature gradients.

The accuracy we have achieved is about 1- to 1.5 K. The best results were achieved nearest the tropics. With improved information on water vapor content and with higher spatial resolution, even better results can be anticipated. This technique has the advantage of providing an independent test for the presence of clouds and using every measurement.

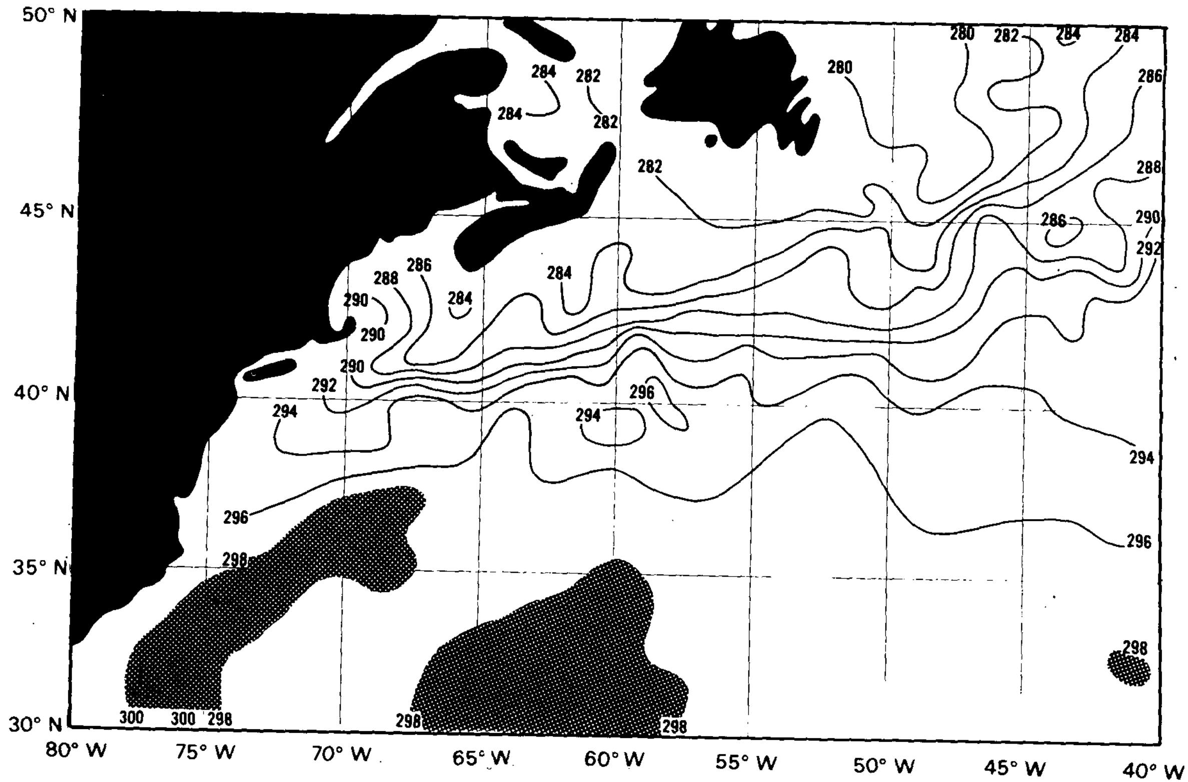

Figure 3–Sea surface temperature map.