VIII. RADIO ASTRONOMY

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A. RETRIEVAL OF ATMOSPHERIC TEMPERATURE PROFILES BY A SCANNING MICROWAVE SPECTROMETER

National Aeronautics and Space Administration (Contract NAS5-21980)

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Early data from the Scanning Microwave Spectrometer (SCAMS) on the Nimbus-6 satellite were presented in RLE Progress Report No. 117 (pp. 31-33). The accuracy of remotely sensed temperature profiles achieved by using this instrument has now been evaluated, by using conventional (radiosonde-based) measurements for comparison.

The SCAMS is an improvement of the Nimbus-5 Microwave Spectrometer.[1,2] It views the Earth at 13 equally spaced angular positions extending to 43° on either side of nadir at the satellite. The antennas step at 1-s intervals. The incidence angle at the Earth thus ranges from 0° (vertical) to 53°. Horizontal resolution near the suborbital track is ~150 km (see Fig. VIII-1). The spectrometer has 5 channels, centered at 22.23 GHz

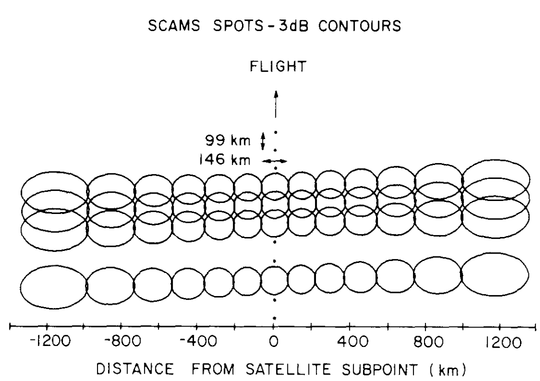

Fig. VIII-1. Contours of the antenna half-power points on the Earth. All three antennas have approximately the same pattern.

(water-vapor line), 31.65 GHz (window), and 52.85, 53.85, 55.45 GHz (oxygen band). The weighting functions of the three oxygen-band channels (Fig. VIII-2) peak at heights of 0, 5, and 13 km (pressure levels 1000, 540, and 180 mb) in order of frequency, for vertical incidence. The altitudes sensed by the weighting functions (Fig. VIII-3) increase gradually with angle of incidence, reaching ~2 km higher at the extremes of the scan.

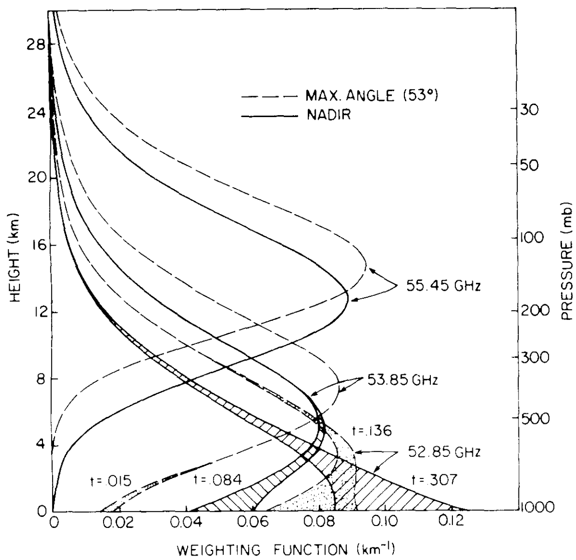

Fig. VIII-2.

Weighting functions for the oxygen-band channels. Shaded areas represent the reflected contribution when the surface is a smooth ocean (t = transmittance). The U. S. Standard Atmosphere with 2 cm precipitable water vapor was used for the calculations.

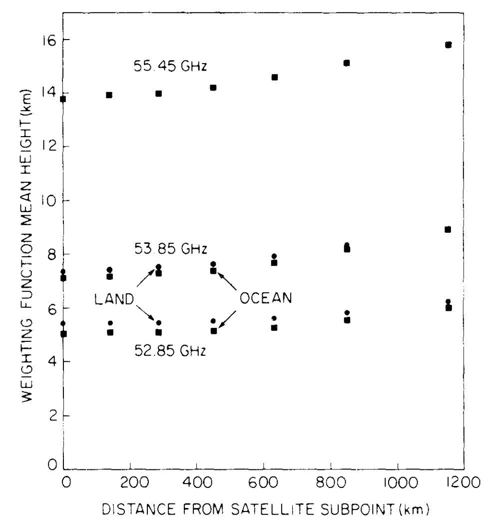

Fig. VIII-3.

Mean heights of the weighting functions as a function of the scan position.

The spectrometer is calibrated by viewing cold space and ambient temperature targets in two additional positions at the end of each scan. The three oxygen-band channels share the same antenna and calibration target. Difference mode errors among these three channels are thereby minimized.

Residual system errors were investigated by comparing brightness temperatures (corrected for antenna sidelobes) measured October 22-25, 1975, with brightness temperatures computed from the National Meteorological Center objective analysis (NMC grid) for the regions of North America, Europe, and Japan, excluding locations where the surface was higher than 1 km (Fig. VIII-4). The oxygen absorption coefficient was computed from expressions given by Rosenkranz[3] using recent measurements of the resonant linewidths by Liebe et al.[4] These comparisons revealed mean errors that were

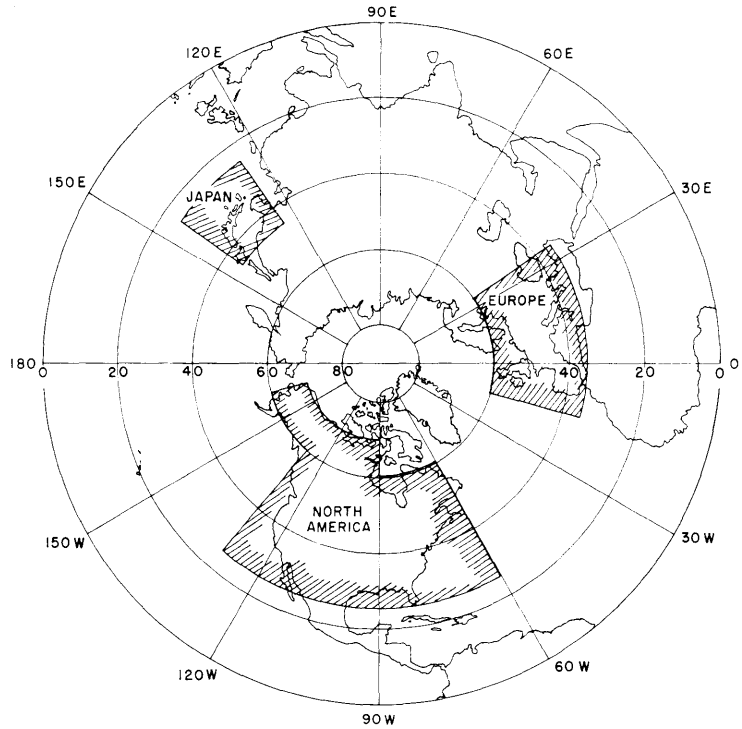

Fig. VIII-4. Regions used to compare SCAMS measurements with National Meteorological Center data.

removed by assuming that the radiometric temperature of the calibration target was 1.2 K ± 0.6 K colder than the physical temperature measured by imbedded thermistors. Root-mean-square errors about the mean were typically ~0.8 K at 53.85 and 55.45 GHz, of which 0.5 K is accounted for by instrument noise. The 52.85 GHz channel is strongly influenced by the terrestrial surface; consequently, errors on this channel were greater, approximately 1.5 K rms.

Atmospheric temperature profiles were retrieved from the SCAMS measurements by a linear statistical method[5] that optimizes the retrieval on a set of a priori statistics. These statistics comprised 354 radiosonde records from stations at Weather Ship Papa, Peoria, Illinois, Pt. Mugu, California, San Juan, Puerto Rico, and Point Barrow, Alaska, in the period 1966-1970. Matrices of coefficients for the retrieval were determined separately from these statistics for land and ocean surfaces. These matrices were applied globally.

Again, the NMC grid was used to verify the temperature profile retrieval in the three regions. Problems involved in verification of remotely sensed temperature profiles are discussed elsewhere.[2] Retrieval errors are typically ~2 K rms in the mid troposphere, including the mean error, if any (see Figs. VIII-5, VIII-6, and VIII-7). Near the surface and around the tropopause the errors increase to >4 K, then decrease again

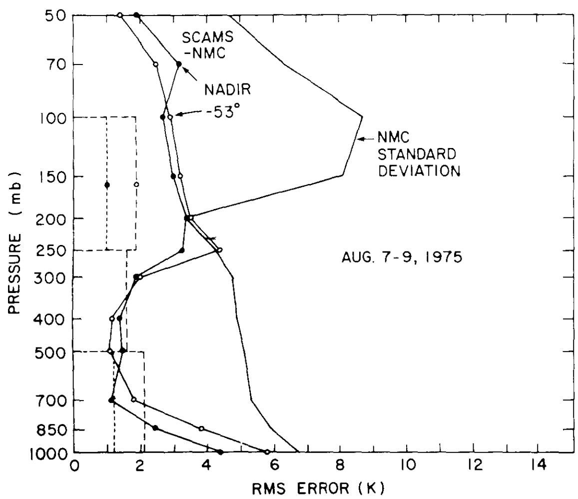

Fig. VIII-5.

Retrieval errors for August 7-9, 1975. Broken lines indicate errors for mean temperatures of layers.

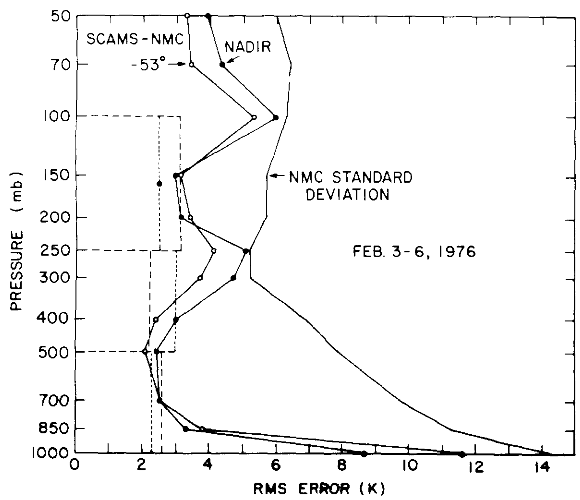

Fig. VIII-6.

Retrieval errors for February 3-6, 1975.

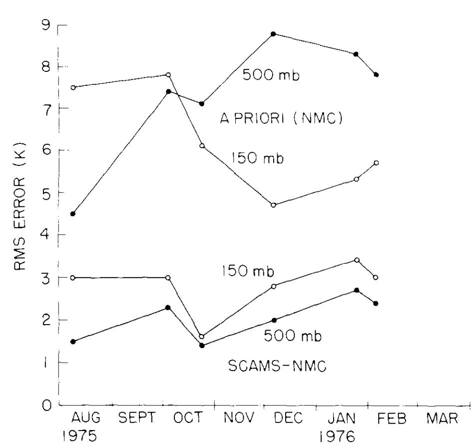

Fig. VIII-7.

Retrieval errors at two levels as a function of time.

in the stratosphere. These errors result from temperature profile structure that is finer than the vertical resolution of the weighting functions. This is illustrated by retrievals of the mean temperature of atmospheric layers, denoted by broken lines in Figs. VIII-5 and VIII-6. Errors for these retrievals are more uniform with altitude.

References

1. J. W. Waters, K. F. Kunzi, R. L. Pettyjohn, R. K. L. Poon, and D. H. Staelin, "Remote Sensing of Atmospheric Temperature Profiles with the Nimbus-5 Microwave Spectrometer," J. Atmos. Sci. 32, 1953-1969 (1975).

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3. P. W. Rosenkranz, "Shape of the 5 mm Oxygen Band in the Atmosphere," IEEE Trans. on Antennas and Propagation, Vol. AP-23, No. 4, pp. 498-506, July 1975.

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5. C. D. Rodgers, "Some Theoretical Aspects of Remote Sounding in the Earth's Atmosphere," J. Quant. Spec. Rad. Trans. 11, 767-777 (1971).