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# RAIN OBSERVATIONS IN TROPICAL STORM CORA

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Passive microwave observations were made in tropical storm Cora at 19.35 and 94GHz. These observations suggest that 94GHz is appropriate for mapping the extent of rain over either land or ocean backgrounds and that some rainfall intensity measurement is also possible.

## INTRODUCTION

With the launch of the Electrically Scanned Microwave Radiometer (ESMR) aboard the Nimbus-5 satellite, it became possible to map rain over the oceans globally (Wilheit et al. 1977). The technique depends on observing rain in emission against cold space as reflected off the ocean. Thus, the ESMR depends on the large and predictable reflectivity of the ocean surface for mapping rain and cannot be so-used over land, a severe limitation for many applications. Appropriate measurement frequencies for this approach to rain mapping are in the 10–20GHz (3–1.5cm) range.

Figure 1 shows brightness temperature calculated according to the model discussed by Wilheit et al. (1977) for 19.35GHz over both typical land and water surfaces and for both horizontal and vertical polarizations. For rain measurements over ocean, one would use horizontal polarization which gives good sensitivity to rain from about 1 to 20mm/hr. Over land, on the other hand, there is little sensitivity in either polarization to rain intensity over this same dynamic range. When one allows for the extreme variability of land backgrounds, it becomes obvious that the use of radiometry at this frequency for rain mapping over land is hopeless.

The use of higher frequencies for mapping of rain over land was suggested by Savage and Weinman (1975). This approach depends on the scattering of microwave radiation by the larger hydrometeors and causes rain areas to appear colder than the non-raining background. A detailed study of the Nimbus-6 Electrically Scanned Microwave Radiometer (ESMR) data by Rodgers et al. (1978) has demonstrated this possibility in a quantitative manner but the results must be considered marginal for operational applications. Still higher frequencies might well provide a useful tool for the measurement of rain over land. Also the use of higher frequencies makes possible high resolution which in the 10–20GHz range is difficult from low Earth orbit and prohibitive from geosynchronous orbit. Thus, in order to address both these problems, rain over land and spatial resolution, airborne measurements at 94GHz have been initiated.

OBSERVATIONS

During the summer of 1978, the NASA CV-990 aircraft was equipped with a complement of microwave radiometers which included a 94GHz radiometer which viewed 45° to the right hand side of the aircraft and the aircraft ESMR which scans from 50° to the left, through nadir to 50° to the right in 39 discrete steps and measures microwave brightness temperature at 19.35GHz. Other measurement frequencies ranged from 6.6 to 183GHz. Relevant systems routinely carried aboard the 990 include an inertial navigation system, a nadir viewing 10μ infrared radiometer and an atmospheric temperature probe.

The best opportunity to observe rain with this system came on August 11, 1978. Tropical Storm Cora had passed the Lesser Antilles and was decaying off the coast of Venezuela. The Convair 990 flew out of San Juan, P.R. and flew the pattern indicated in Figure 2. The storm was entered from the north at about 1700GMT and a north-to-south traverse was flown across the reported eye followed by a clockwise octagon pattern around the reported eye position. The aircraft then proceeded to the northern sector, where the most intense rain had been found, to observe individual rain cells. The triangles indicate the direction of flight at two minute intervals and the flight level winds are indicated by conventional meteorological symbols. As can be seen here, the storm no longer had a closed circulation and was only an open wave with about 30kt winds at the 13km flight level. Figures 3 and 4 show observations for two short time segments during the period in which the aircraft was overflying individual rain cells. The calibrations are preliminary and could be off by as much as 20°K, but, nevertheless, qualitative relationships are detectable. There is a clear tendency for increases in the 19.35 GHz brightness to be related to decreases in the 94GHz brightness. That is, an increase in rain intensity as indicated by the ESMR is accompanied by a decrease in the 94GHz brightness caused by scattering in the upper portions of the rain cell. The relationship is not precisely one-to-one but a general trend holds. Because the two sensors observe the rain in different manners and because of imperfections in the experimental situation, one would not expect a one-to-one relationship.

The data of Figures 3 and 4 and from another similar time segment were combined and displayed in Figure 5. Here the 94GHz brightness temperature is plotted as a function of the corresponding 19.35GHz brightness temperature for each observation. When the data are so displayed, a general relationship as indicated by the line segments A, B, and C becomes obvious. It may be interpreted as follows:

A. These data represent a no-rain situation. The choice of vertical polarization causes the 94GHz brightness temperature to be fairly high and constant. A land background would be similar or even warmer. The 19 GHz brightness shows more variability due to variation in cloudiness and surface winds.

B. This is a transition from no rain to rain. Non-raining clouds have few particles with greater than 50μ radius. As the dropsize grows toward the 100μ to 1 mm range, typical of rain drops, scattering begins to occur at 94GHz while the drops are still small enough to be within the Rayleigh absorption (cloud-like) region for 19GHz.

C. This is rain. The increase in brightness temperature at 19.35GHz with increasing rain rate has been well documented (Wilheit et al. 1977). It appears that there is a concommitant decrease in the 94GHz brightness. This may permit the use of 94GHz for the mapping of rain intensity but there may be too little accuracy for the intensity estimates to be useful. This remains to be settled.

D. This group of points clearly does not follow the overall trend observed in the rest of the data, yet they appear to cluster in a self-consistent manner suggesting a meteorological phenomenon rather than experimental errors. Further investigation, hopefully, will identify the phenomonon. Given the calibration uncertainties, it could be explained by large concentrations ($\gtrsim 0.1$ gm/cm$^2$) of supercooled water.

Although these observations were made over water, they suggest the usefulness of 94GHz measurements for mapping rain over land. With any non-trivial rain rate ($\gtrsim 1$ mm/hr) the rain column will be opaque at 94GHz and the background, land or water, will not influence the observed brightness temperature directly. It is possible, however, that drop size distributions are significantly different in land and ocean rain. If the cluster of points at D in Figure 5 does, in fact, turn out to be large concentrations of supercooled water, the combination of 19 and 94GHz measurements planned for the NASA B-57 aircraft would be useful indeed.

REFERENCES

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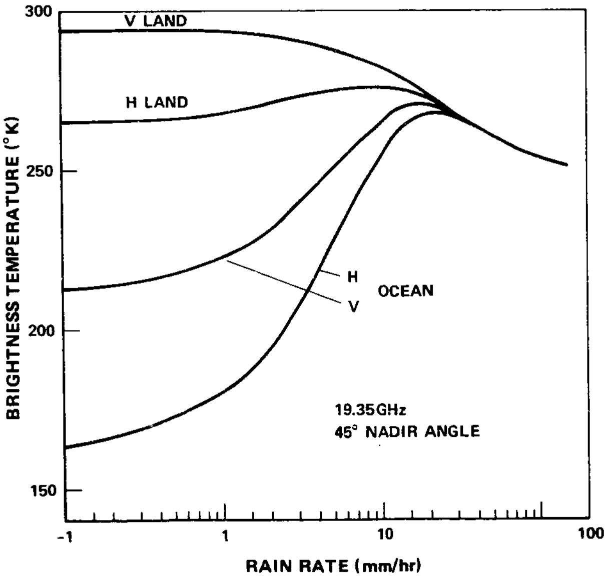


Fig. 1-Brightness temperature as a function of rain rate for ocean and land backgrounds viewed at 45° calculated according to Wilheit et al. (1977)

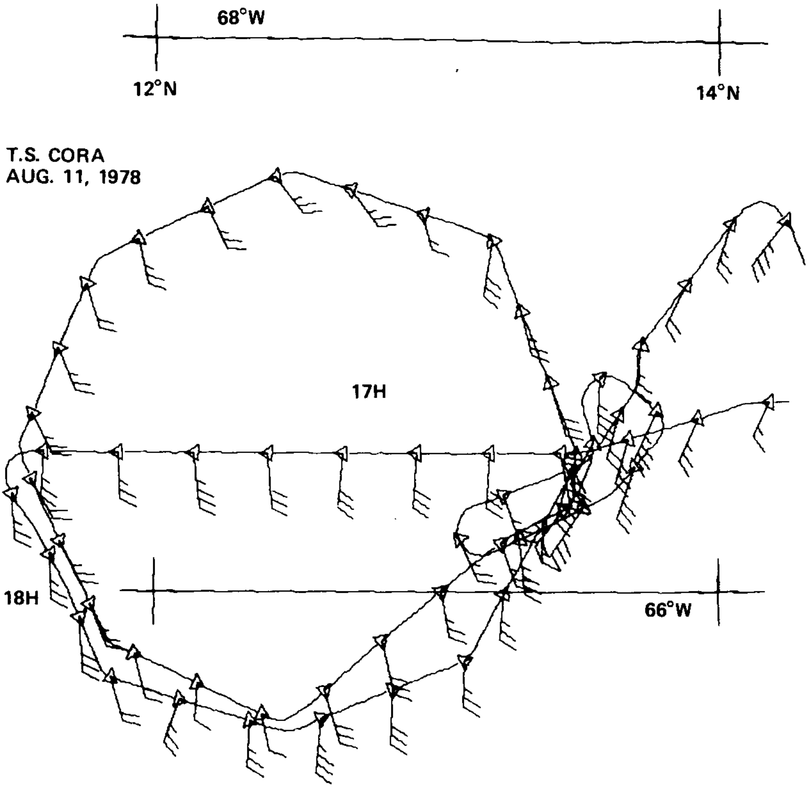


Fig. 2–Plot of CV-990 aircraft flight path through tropical storm Cora at 13 km altitude with wind barbs

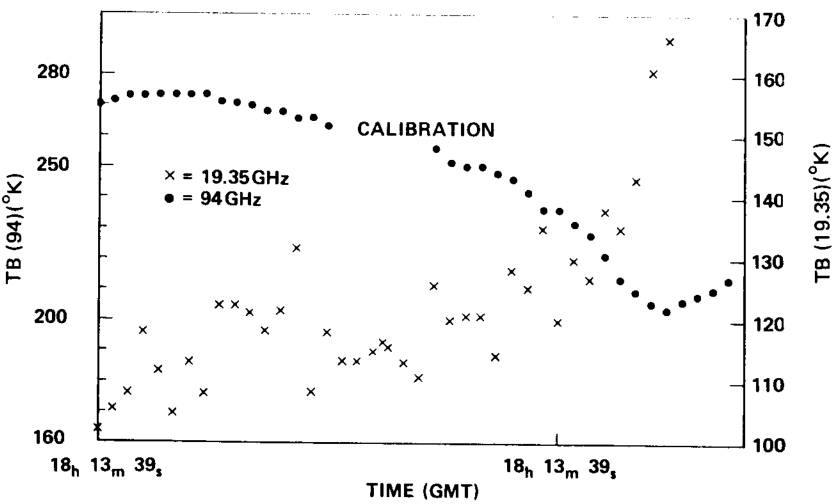


Fig. 3–Brightness temperature observations at 19.35 and 94GHz in tropical storm Cora

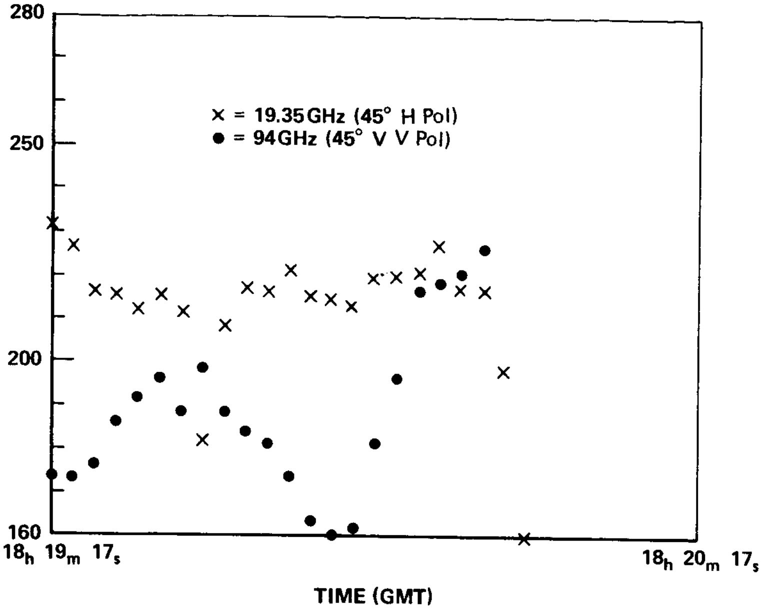


Fig. 4–Brightness temperature observations at 19.35 and 94GHz in tropical storm Cora

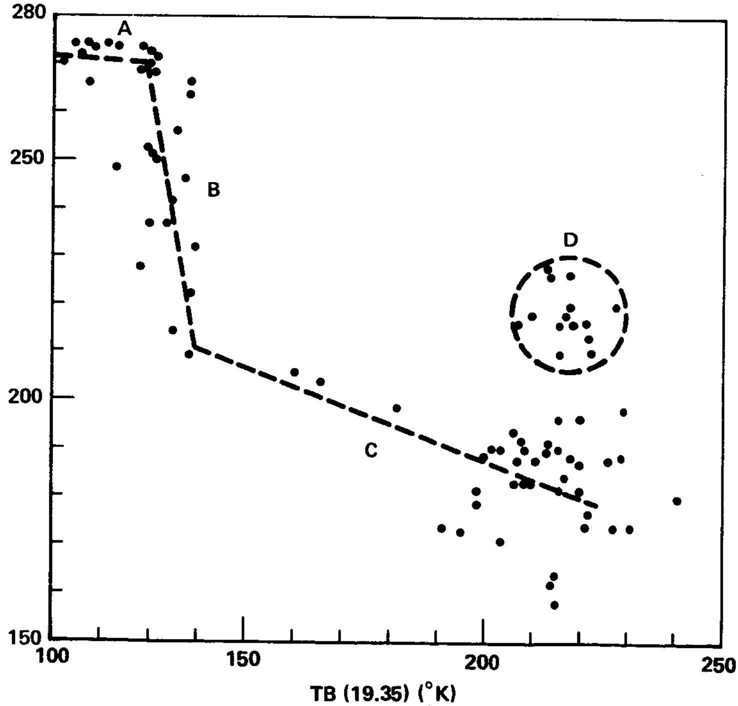


Fig. 5–Simultaneous observations 7 19.35 and 94GHz brightness temperature