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SOIL MOISTURE MEASUREMENTS WITH MICROWAVE RADIOMETERS

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There is considerable interest in the measurement of the moisture content of soils. For example, meteorologists are interested in monitoring moisture content of soils over large areas to learn more about the energy exchange of the air/soil interface.

One technique of measuring moisture content that appears promising is that of microwave radiometry. In the microwave region of the spectrum, the emissivity of water is approximately 0.4, whereas that of dry soil is approximately 0.9. Therefore, the emissivity of the soil can range from about 0.6 to 0.9 as the soil changes from a wet to a dry condition. Recent ground base measurements have demonstrated emissivity changes of this magnitude.

To test the use of this approach for remote sensing of soil moisture, the NASA Convair 990 was flown over agricultural test sites in the vicinity of Phoenix, Ariz., during late February 1971. On the same day, soil moisture measurements were made on the ground for 200 fields. On board the aircraft were six microwave radiometers, ranging in wavelength from 21 cm to 8 mm. The results of one of these radiometers is shown in Figure 1.

This is a false-color image produced by the 1.55-cm mapping microwave radiometer similar to that scheduled for Nimbus E. The flightpath was from south to north along a line about 8 km west of Phoenix.

The rectangular pattern of the fields is quite apparent, and we are clearly able to distinguish between a wet field *A*, which in this case has about 35 percent water content (expressed as weight percent) and, for example, the dry field *B*, which has a moisture content of approximately 6 percent.

The other radiometers were nonscanning and looked at the fields along the aircraft's flightpath, that is, those directly along the center of the map shown in Figure 1.

Figure 2 is an example of the results from these radiometers. It is the plot of the microwave brightness temperature versus the soil moisture for the 21-cm-wavelength radiometer, and the straight line is a linear regression fit of the data; the fit is reasonably good.

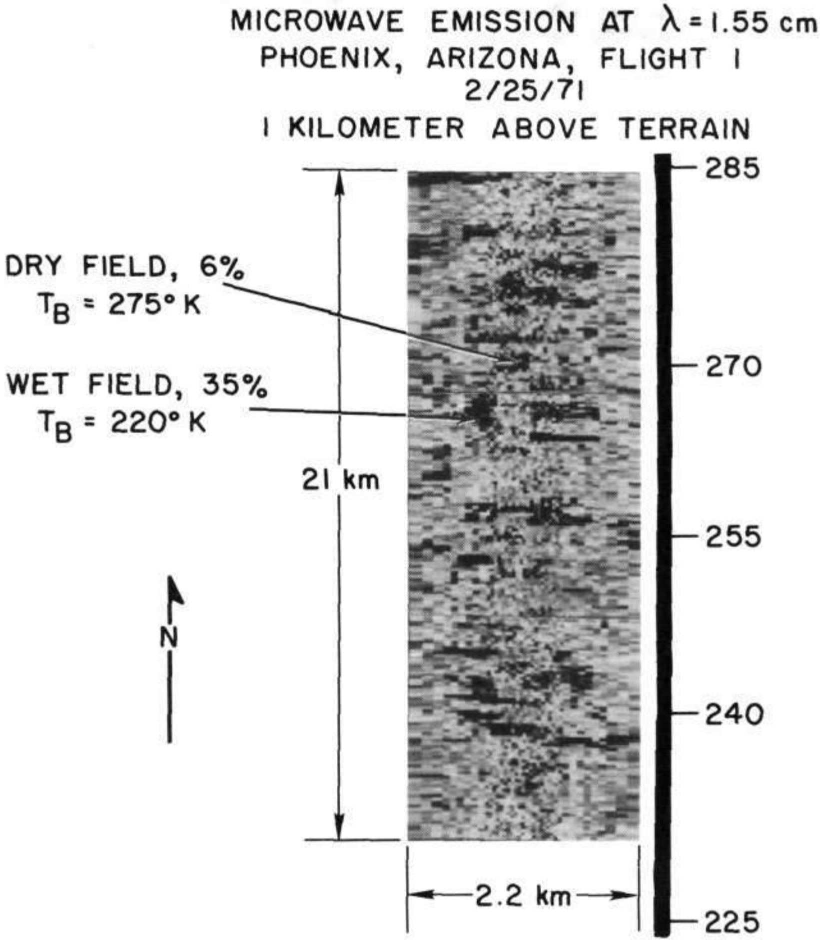

Figure 1–Microwave emission at 1.55-cm wavelength, 1 km above the terrain; flight 1, February 25, 1971, at Phoenix, Ariz. Field *A* is a wet field with a moisture content of 35 percent and microwave brightness temperature of 220 K. Field *B* is dry with 6 percent moisture content and microwave brightness temperature of 275 K.

We have considerable amount of scatter in the low moisture content area, but we attribute this scatter to variations in such quantities as the temperature and moisture profiles in the soil, the soil type, the surface roughness, and the vegetative cover, all of which will affect the microwave emission and had not been taken into account in this plot.

It is interesting to note that some of the fields with vegetation cover lie reasonably close to the curve for the bare fields, indicating that it may be possible to measure the moisture content even with vegetation present.

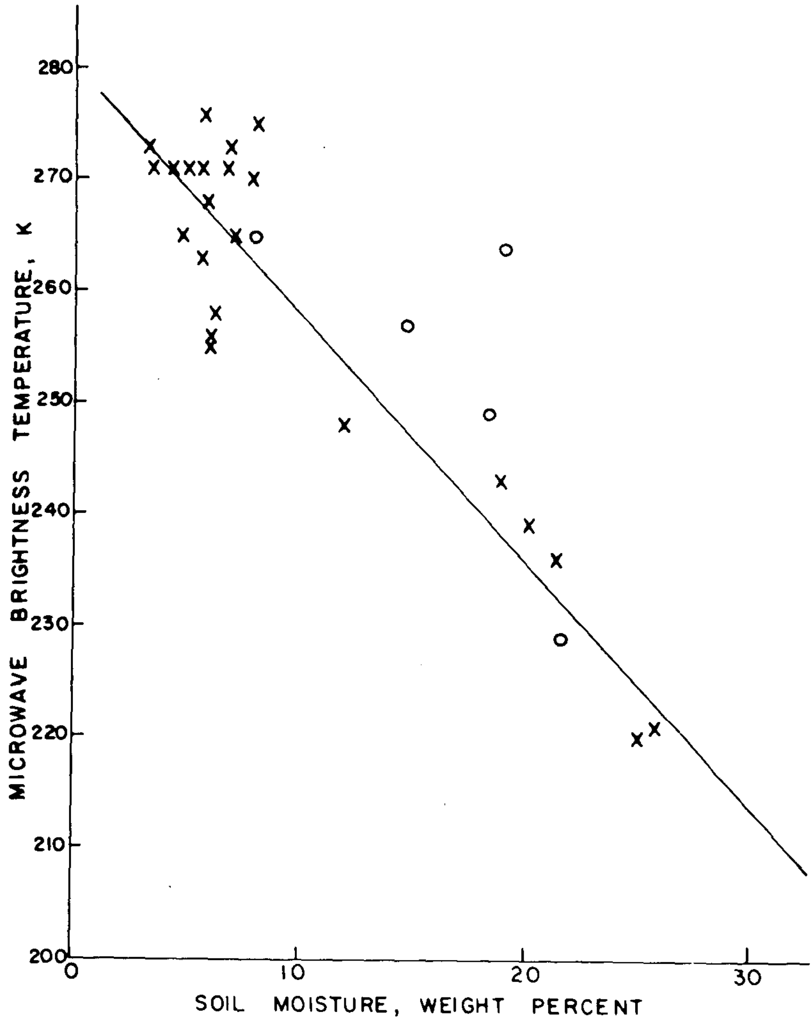

Figure 2–Plot of the microwave brightness temperature versus the soil moisture for the 21-cm wavelength radiometer, flight 1 over Phoenix, Ariz., February 25, 1971. X *indicates the bare fields;* o, *the vegetated fields.*

The results from three other radiometers are given in Table I, which is a table of regression results indicating the intercept of the curve, the slope of the curve, and the rms deviation of the data from the straight line. The results were calculated from the same 23 bare fields as were used in Figure 2. For

TABLE 1–Linear Regression Results of Microwave Brightness Temperature Versus Soil Moisture Content

Wavelength, cm	Intercept	Slope	Standard Error of estimate
21	280	-2.22	6.22
6	307	-1.65	5.46
1.55	281	-1.44	4.34
.8	292	-1.16	5.50

the scanning radiometer, which is the 1.55-cm radiometer, only those fields that were directly along the aircraft's flightpath were used. There is a general decrease in the negative slope of the curve with decreasing wavelength. This is to be expected because the difference between the emissivity of the water and the dry soil decreases with decreases in wavelength. This effect plus the fact that the longer wavelengths provide greater penetration depth in the soil and better atmospheric transmission characteristics indicate that they would be best for soil moisture sensing.

These results are encouraging and lead us to believe that it should be possible to remotely monitor soil moisture changes with the microwave radiometers.