Reply

KUO-NAN LIOU AND ALAN D. DUFF[1]

Department of Meteorology, University of Utah, Salt Lake City 84112

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Dr. Schmugge's comments (1980) on the surface emissivity of wet soils are well taken. He correctly points out that the emissivity values of wet bare soils for SCAMS frequencies should be generally on the order of 0.8.

In our analyses of the liquid water content inference over land utilizing Nimbus 6 SCAMS data, we first carried out comparisons between the observed and computed brightness temperatures for a number of stations in the region from 40–55°N and from 85–110°W for 22 and 25 August 1975. The computed brightness temperatures for precipitating conditions require information on temperature and relative humidity profiles from radiosonde, and on rainfall rates from surface reports. The microwave radiative transfer program, which has been developed by our group in the past years, was used in the simulation studies in which effects of multiple scattering and absorption due to hydrometeors were included. In order to have a reasonable comparison with the observed data for the aforementioned area, we found that the best emissivity values for the water vapor and window channels were about 0.92 and 0.93, respectively, while for the oxygen channels, they were about 0.95. On the basis of the comparison program, we used these emissivity values in the empirical-theoretical analysis for the liquid water content.

In conjunction with our continuous effort to derive the liquid water content over land from satellite microwave sounders, we recently carried out comprehensive comparisons between the observed and computed brightness temperatures when the surface report indicates precipitation under the satellite pass. The Nimbus 6 SCAMS data covering the period of 20–30 August 1975 were again used in the present analysis. Listed in Table 1 are the observed data and the computed values using the emissivities assumed in our previous paper (Liou and Duff, 1979) for two radiosonde stations: Green Bay, Wisconsin and Peoria, Illinois. Also listed are the emissivities derived from an objective method proposed by Waters *et al.* (1975) utilizing the window and water vapor channels. It is apparent that the assumed emissivities used in our previous paper are not unreasonable.

The high emissivities over wet surfaces may be explained by the following facts. First, we note that the ground resolution of SCAMS is approximately 145 km at nadir and 330 km at 43° from nadir. Thus, satellite observed brightness temperatures arise from large surface areas. Second, a large portion of the area over which the mapping of the liquid water content was performed is covered by vegetation during

TABLE 1. Comparisons between observed and computed brightness temperatures.

a. Green Bay, Wisconsin (44.48°N, 88.13°W)

Nimbus 6 passing time 1642:24 GMT 21 August 1975
Radiosonde observation 1200 GMT 21 August 1975
Rainfall rate 1 mm h^{-1}

Channel	Frequency (GHz)	Brightness observed (K)	Temperature computed (K)	Emissivity	
				Used	Derived
1	22.235	277.77	276.88	0.92	0.928
2	31.4	273.18	273.53	0.93	0.929
3	52.85	266.78	269.09	0.95	0.938
4	53.85	252.55	254.02	0.95	0.938
5	55.45	219.95	222.11	0.95	0.938

b. Peoria, Illinois (40.67°N, 89.68°W)

Nimbus 6 passing time 1719:12 GMT 25 August 1975
Radiosonde observation 0000 GMT 26 August 1975
Rainfall rate 1 mm h^{-1}

Channel	Frequency (GHz)	Brightness observed (K)	Temperature computed (K)	Emissivity	
				Used	Derived
1	22.235	279.65	278.63	0.92	0.929
2	31.4	276.06	276.48	0.93	0.930
3	52.85	268.78	269.00	0.95	0.939
4	53.85	255.29	253.35	0.95	0.939
5	55.45	219.63	221.03	0.95	0.939

[1] Present affiliation: Second Weather Squadron, Patrick Air Force Base, FL 32925.

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the summer growth season. The emissivity in the case of the vegetative cover is close to one and is unaffected by the soil moisture as indicated by Dr. Schmugge. With regard to the surface temperature problem, it is true that radiosonde observations do not provide the ground temperature but the air temperature above the ground. In nonprecipitating atmospheres the ground temperature may be significantly higher than the air temperature. However, in precipitating conditions, the mixing of the atmosphere and the surface through hydrometeors is likely to prevent large temperature differential between the ground and the air above it.

In Section 4 of our paper we stated "It should be noted that the SCAMS data base from which the samples were taken was limited to a two-week period in August, and the effects of certain surface conditions, such as snow cover, mountain terrain and a combination of water and land surfaces, were not considered and examined. Thus, the success of the present investigation regarding the retrieval of the liquid water content over mesoscale land surfaces must be noted in the context of these limitations."

We are in complete agreement with Dr. Schmugge that further research on the problem of inferring liquid water content over land surfaces is needed. We are also pleased to learn that Nimbus 7 and the Seasat Scanning Multichannel Microwave Radiometer carry an additional channel at 10.69 GHz (2.8 cm), which is less affected by atmospheric conditions and which may be used to distinguish between various surface characteristics.

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