

## Microwave Radiometry of Snowpacks

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### Summary

The successful application of passive microwave sensors to remote sensing requires signatures for the unambiguous inversion of the observable data to useful geophysical information. Due to the large number of object types, large variability and heterogeneity, the inversion of satellite data from land surfaces is delicate. The situation gets even more complex with the addition of a seasonal snowcover with variable transparency. We would like the sensors to be able to

- discriminate snow-covered areas against any other surfaces,
- determine the snow-cover fraction in mixed situations,
- determine snow type,
- determine snow properties such as depth, water equivalent, liquid-water content, density, grain size, snowpack stability etc.
- estimate other physical properties such as ground temperature, soil moisture, presence of vegetation etc.

A necessary, but not sufficient condition is a detectable sensitivity of the observables to the above properties. It has been a long-term task of the terrestrial remote sensing group of our Institute to evaluate these sensitivities over a broad spectral range (1 to 100 GHz). The research has been concentrated on experimental studies with surface-based equipment. The present state of knowledge over the frequency range from 4.9 to 94 GHz was recently analyzed by Mätzler (1994). Most of these results were obtained with the multi-frequency radiometer system, PAMIR (Mätzler, 1987). Relevant results will be presented. Ambiguities of observables on the one hand and unexplained variations on the other limit the application of these results as direct signatures. Nevertheless we found that the majority of snow types can be discriminated against the considered snow-free surfaces. Difficulties exist with fresh snow at low density where only the 94 GHz brightness temperatures indicate a sensitivity due to slight volume scattering. The earlier difficulty with wet snow (Mätzler et al. 1982) has also found a solution; it is based primarily on the spectral behaviour of the polarization difference,  $T_{bv} - T_{bh}$ , between the brightness temperatures at vertical and horizontal polarization. The results have also shown that the state (frozen or unfrozen, wet or dry) of the soil under a grass cover hardly affects the observable brightness temperatures, because of the screening effect by the vegetation.

As illustrations of physical snow signatures we presented and discussed the time variations of brightness temperatures as observed during two different episodes at the alpine test site, Weissfluhjoch in Switzerland.

The first example was an interference phenomenon observed during the night of June 18 to 19, 1984 at 4.9 and 10.4 GHz, respectively, (Fig. 4.26 of Mätzler, 1987) which can be explained by the superposition of reflections at the refrozen snow surface and at the down-moving interface between refrozen and wet snow. The data allowed the determination of snow density



( $0.49\text{g/cm}^3$ ), thickness of refrozen crust (increase from 1 to 6.5cm), volumetric liquid-water content of the underlying layer (2.1%), and resulting heat loss of the snowpack (about  $15\text{W/m}^2$ ).

In a second example, which was observed in the evening of March 10, 1986, the 1.4m deep snowpack was almost completely dry with the exception of a slightly humid layer at 2 to 10 cm below the snow surface. We observed the decrease of the brightness temperatures due to the refreezing of the humid layer, which allowed the determination of the snowpack transmissivity as a function of time. At 4.9 and at 10.4 GHz, the data indicated that the freezing rate was  $0.12\text{mm/h}$  (or  $120\text{g water/m}^2/\text{h}$ ) in agreement with the thermodynamic estimate based on changes of the snow-temperature measurements. A larger value was estimated from the 21GHz data. A possible explanation for this discrepancy is an uncertainty of the frequency dependence of the dielectric loss factor of slightly wet snow, especially if the density is low.

For a better quantification of the influence of structural and physical snow parameters we started new work in cooperation with the Swiss Federal Snow and Avalanche Research Institute on Weissfluhjoch in the snow season 1993-94. On the modelling side this work is supported by a cooperation with Sylviane Surdyk, 'Laboratoire de Glaciologie et Géophysique de l'Environnement' of the University of Grenoble. The experimental setup consists of portable radiometers at frequencies of 11, 21, 35 and 48 GHz, and a further instrument at 94 GHz is under construction. These radiometers are operated from a sledge-like platform, 1.5m above the snow surface. In this way the snow samples to be investigated can be exactly positioned in front of each sensor. First results were presented.

#### References

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#### ABSTRA

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