The Importance of Snow Grain Size and Density in Measuring Snow Mass by Remote Sensing

Ian Davenport, Melody Sandells, Debbie Clifford, Robert Gurney
NERC Environmental Systems Science Centre, The University of Reading, UK

Why measure snow mass?
Snow is important as a source of water for agriculture, drinking and power generation for large parts of the world.

Siberian snow formation may be a factor in northern hemisphere atmospheric circulation.

Global monitoring of snow mass from remote sensing carried out by satellites is a vital tool in water resource management, environmental risk assessment and studying the sensitivity of climate to change.

Is there a problem with our estimates?
As illustrated to the right, the snow mass distribution predicted by numerical weather prediction models differs considerably from what we observe with instruments. Either our models or our measuring technique are inadequate, or possibly both. Here we investigate potential problems with the algorithm we use to interpret passive microwave emission in terms of snow mass.

How easy is it to measure snow grain size?
In the field, it is measured by scraping grains from the side of a snow pit. What is the effect of small errors?

Modelling the effect of snow size assumption errors
The Chang algorithm assumes snow grains to have a diameter of 0.8mm. What is the effect of an error in this assumption? By modelling snowpack emission, we can determine the accuracy of the algorithm over a range of grain sizes.

How much variation in snow grain size and density is typical, and what will be the effect?
We analysed the grain size measurements taken during CLPX, Colorado in 2002-3, and used them in the emission model, to see the effect on snow mass retrieval.

Future Work
Physical modelling is required to better characterise the physical properties of snow, using meteorological measurements, numerical weather predictions and a physical understanding of snow development. The model outputs will serve two objectives.

1. Drive the emission model, improving our interpretation of the real emission.
2. Show where physical conditions are such that the emission modelling will fail, e.g. where the snow will have partially or completely melted.

How do we measure snow mass globally?
Passive microwave satellites used

SMOS - 19, 22, 37, and 86 GHz, resolution >13km, on DMSP satellites,1987 - present
AMSR-E on AQUA platform, 7.11, 19, 24, 37, 89GHz, resolution >5km, 2002 - present

The Chang Algorithm
A simple relationship between the modelled emission at two frequencies and the snow mass is used.

These are the mean snow mass distributions in February according to a numerical weather prediction model and a reanalysis. They have very different spatial distributions to the satellite observations to the left. Why is there a problem with the models, or how do we make the observations?

How can we improve snow mass estimation?
To account for the sensitivity of microwave emission to physical properties, we need to estimate density and grain size, possibly via a physical model of snow, incorporating meteorological conditions and new observations.

Conclusions
The microwave emission of snow is strongly dependent on its grain size and density, making the current technique of snow mass estimation sensitive to variation in these characteristics.

For physically more realistic snow with multiple layers with a range of properties, ice layers and non-zero liquid water content, microwave emission will resemble even less the ideal model output required for this technique to work.

The infra-red reflectance of snow is a function of the surface grain size.