AMSR-E brightness temperatures over tundra and taiga: Implications for snow water equivalent retrievals

Chris Derksen[1], Matthew Sturm[2], Claude Duguay[3], Anne Walker[1], and Stéphane Bélair[4]

[1]Climate Research Division, Environment Canada, Toronto, Ontario [2]Cold Regions Research and Engineering Laboratory, Fort Wainwright, Alaska
[3]Interdisciplinary Centre on Climate Change, University of Waterloo, Waterloo, Ontario [4]Meteorological Research Division, Environment Canada, Dorval, Quebec

Introduction

> Information on sub-Arctic (taiga and tundra) snow cover across Canada is limited by a sparse conventional observing network that has a strong coastal bias.

> The measurements themselves are also often flawed: snowfall data require corrections and station snow depth measurements can poorly represent the surrounding area.

> Satellite measurements provide systematic observations, but with varying levels of effectiveness and uncertainty.

> A series of field experiments conducted in the taiga and tundra of Manitoba, the Northwest Territories, and Nunavut, Canada (2003-2007) have provided the necessary in situ observations to characterize passive microwave brightness temperature response to snow water equivalent (SWE).

> A new version of the Canadian Land Data Assimilation System (CaLDAS) is being developed to include remote sensing measurements of snow, in preparation for eventual implementation in Canadian operational environmental prediction systems. Resolving brightness temperature relationships with SWE across observation pixel regions is a necessary step in this process.

Boreal Forest Measurements

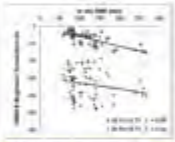
Measurements of snow distribution and physical properties were made at a network of sites across northern Manitoba during late winter 2004 through 2007.

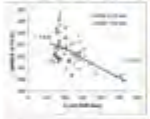
Tundra Measurements

> During April 2007, five American and two Canadian scientists made a series of snow measurements across the Northwest Territories and Nunavut, Canada, during a 4,000km snowmobile traverse from Fairbanks, Alaska, to Baker Lake, Nunavut.

> Recorded measurements at each site included 200-500 snow depths, 10 ESC-30 SWE measurements, snow density, stratigraphy and grain size, and chemical analysis of black carbon (soot) content and deposition of mercury.

Results: Boreal Forest





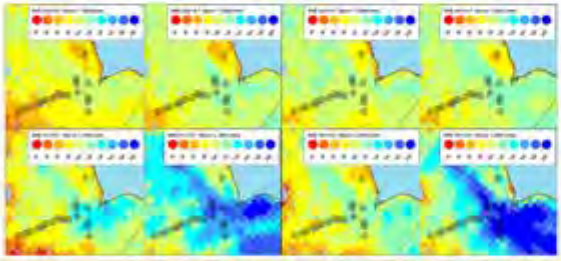
Volume scatter extent at 19.7 GHz when SWE exceeds 125mm

19.7 GHz measurements provide a non-shifting background regardless of SWE

18.7–19.7 difference easily associated with forest transmissivity compared to 36.5 GHz measurements

36.5 GHz: seasonal linear relationships shifted from year to year over the same TB range regardless of SWE

18.7–19.7 GHz: statistically significant relationship with SWE over multiple years



18.7V–19.7V difference provides sensitivity to the deep snowpacks observed during 2004/05 and 2006/07

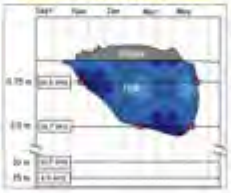
Results: Tundra

While highly variable locally, no longitudinal gradients in snow distribution, magnitude, or structure were detected.

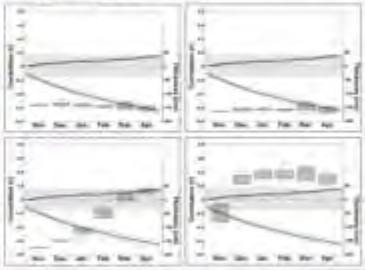
Observed spatial variability in passive microwave brightness temperatures related to sub-grid fractional lake cover.

> At low frequencies (6.9, 10.7 GHz) correlations with lake fraction are consistent through the winter season.

> At higher frequencies (18.7, 36.5 GHz) the strength and direction of the correlations evolve consistent with the penetration depth as the influence of the subnivo water was replaced by emission from the ice and snowpack.

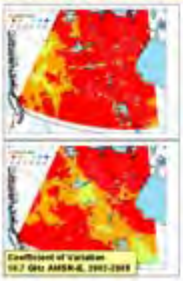


Scatplots of correlation between vertically polarized AMSR-E brightness temperatures and lake fraction, 2002/03 – 2006/07, for the domain shown above. Lines show simulated lake ice and snow-on-lake ice thickness (mean, +/- 1 standard deviation) from the Canadian Lake Ice Model driven by observations at Baker Lake also for the 2002/03 – 2006/07 period. Shading denotes insignificant correlations at 95%.



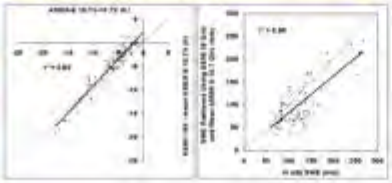
Future Direction and Conclusions

18.7 GHz measurements required for sensitivity to deep snow across the boreal forest are not available on SSM/I, however, they are highly relevant through the AMSR-E record.

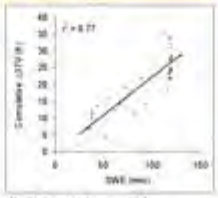


Coefficient of Variation 18.7 GHz AMSR-E, 2002-2005

Assessment at field sites (2004-2007) suggests mean AMSR-E 18.7 and SSM/I 19 GHz can be used with minimal impact on SWE retrievals.



The seasonally evolving influence of lake ice must be accounted for in the tundra. Options include examining single frequencies.



Monthly averaged measurements from Dove/STAR sites (2007) and Baker Lake climate station (2003-2007) vs. cumulative first derivative of 37 GHz brightness temperatures.

The conventional approach to operational SWE retrieval (the difference between 37 and 19 GHz measurement frequencies) is not appropriate across sub-Arctic Canada.

In the boreal forest:
Relationships with SWE at 37 GHz are largely indirect and circumstantial because the forest density and SWE relationship varies in the same direction as the forest density and brightness temperature relationship.

In the tundra:
Measurements in lake rich areas are influenced by water beneath (ice) or part of the season, but by the isolated overlying snowpack by the end of the season.

Acknowledgments

AMSR-E brightness temperatures were acquired from the National Snow and Ice Data Center.
Thanks to Dove/STAR 2007 colleagues: Glen Liston, Arvide Situ, Jon Holmgren, Henry Huntington and Dan Sale. Thanks to Peter Toose, Dave Mitchell, and Dell Bayne for assistance in the field.

For further details see:

Derksen, C.H., 2007. The contribution of AMSR-E 18.7 and 10.7 GHz measurements to improved boreal snow water equivalent retrievals. Remote Sensing of Environment, 112: 2916-2930.

Sturm, M., Holmgren, J., König, M., Morris, K., 2007. The Dry Snow Line of the Arctic Alaska Coastal Plain and Its Ecological Implications. Journal of Glaciology, April 2007.

Environment Canada Environnement Canada