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L-Band Radiometry for Freeze/Thaw Applications: Ongoing SMOS Activities and Potential for SMAP

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FINNISH METEOROLOGICAL INSTITUTE

Outline

1. Current SMOS+ project overview
2. Available instrumentation (Environment Canada; ESA)
3. Deployment ideas for Canada

Background

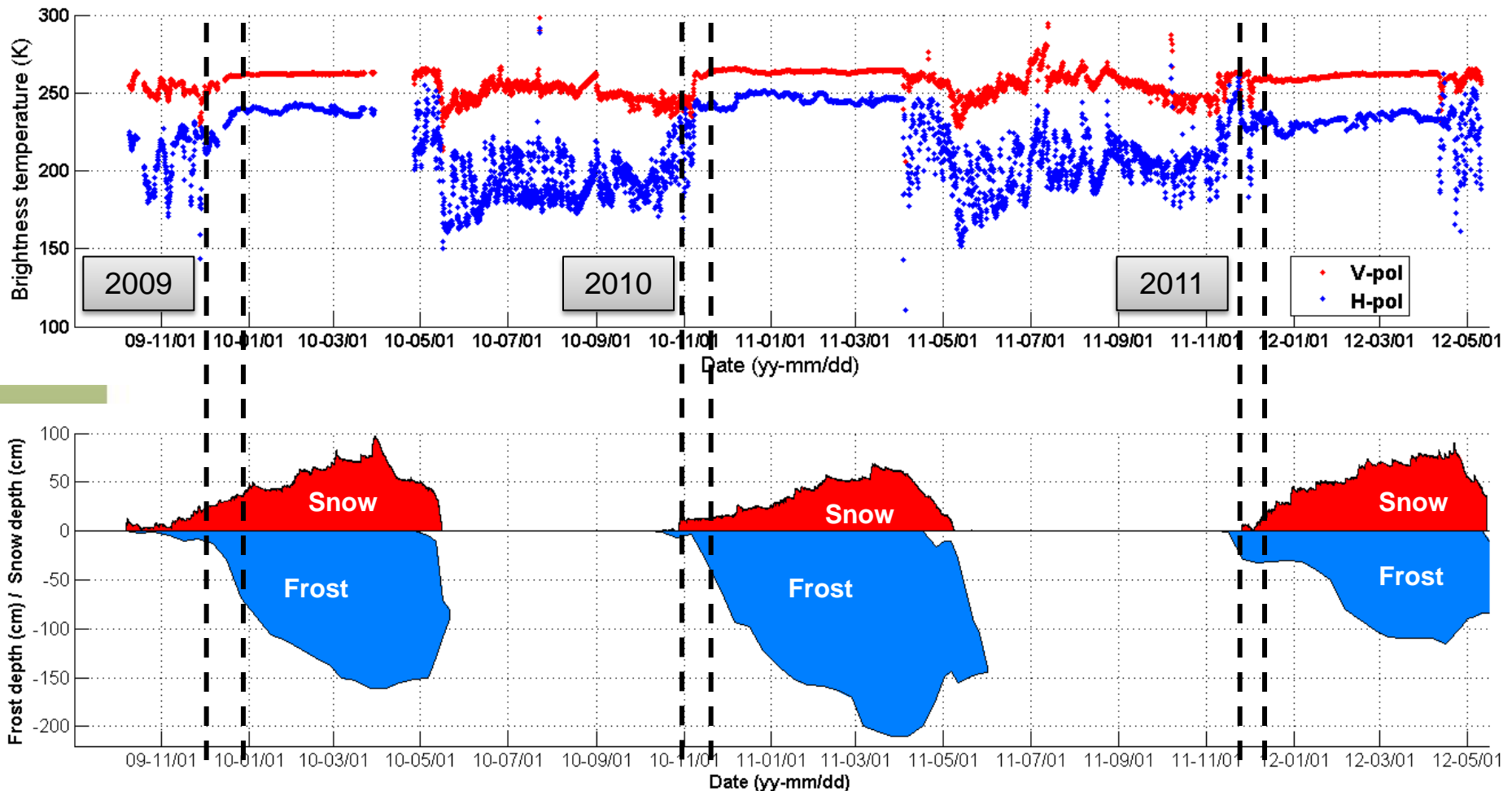
Tower-based SMOS reference radiometer ELBARA-II deployed in Sodankylä, Finland since October 2009.

- First three years on a forest opening site.
- Since August 2012 on a wetland site.

ESA funded SMOS+ Permafrost project aiming to demonstrate global freeze/thaw maps using SMOS data (collaboration between Finnish Meteorological Institute and Gamma Remote Sensing)



Freeze-up: rapid increase from summer values, strong correlation with soil frost depth



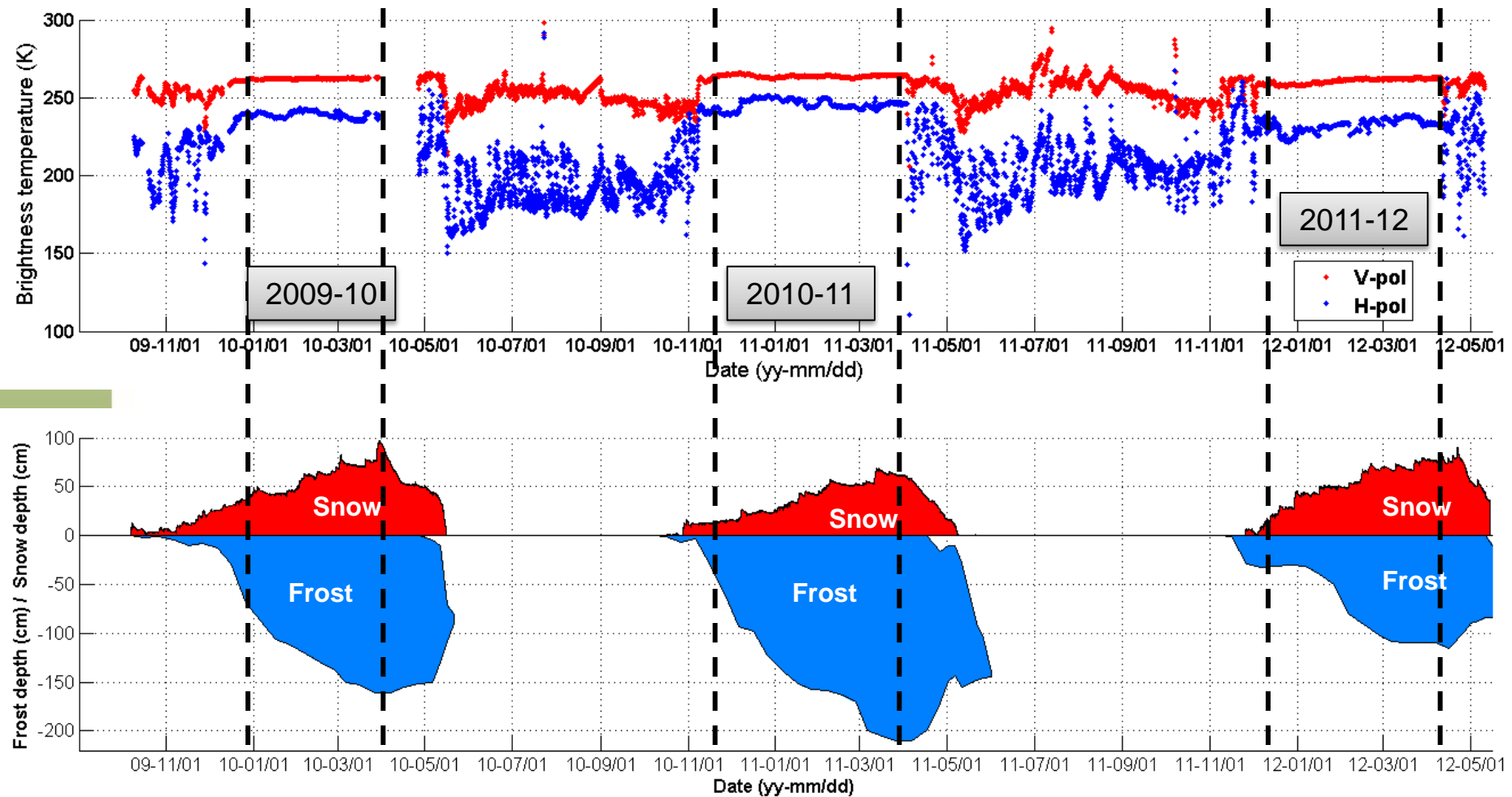
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Winter period: saturated brightness temperature (T_b) signal,
winter average higher than summer, reduced polarization gradient



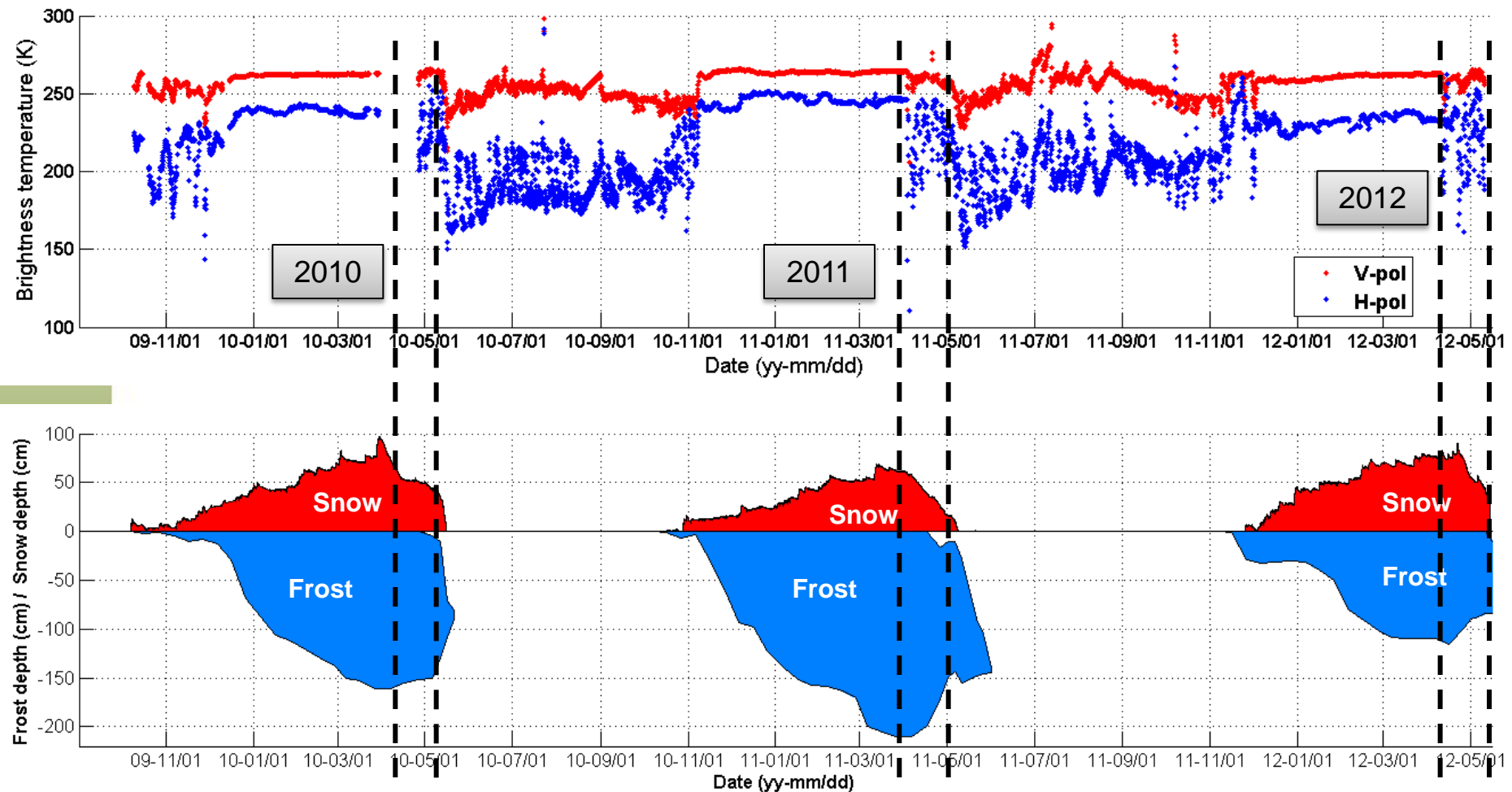
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Early spring: strong diurnal variations due to snow melt and re-freeze, High Tb during night



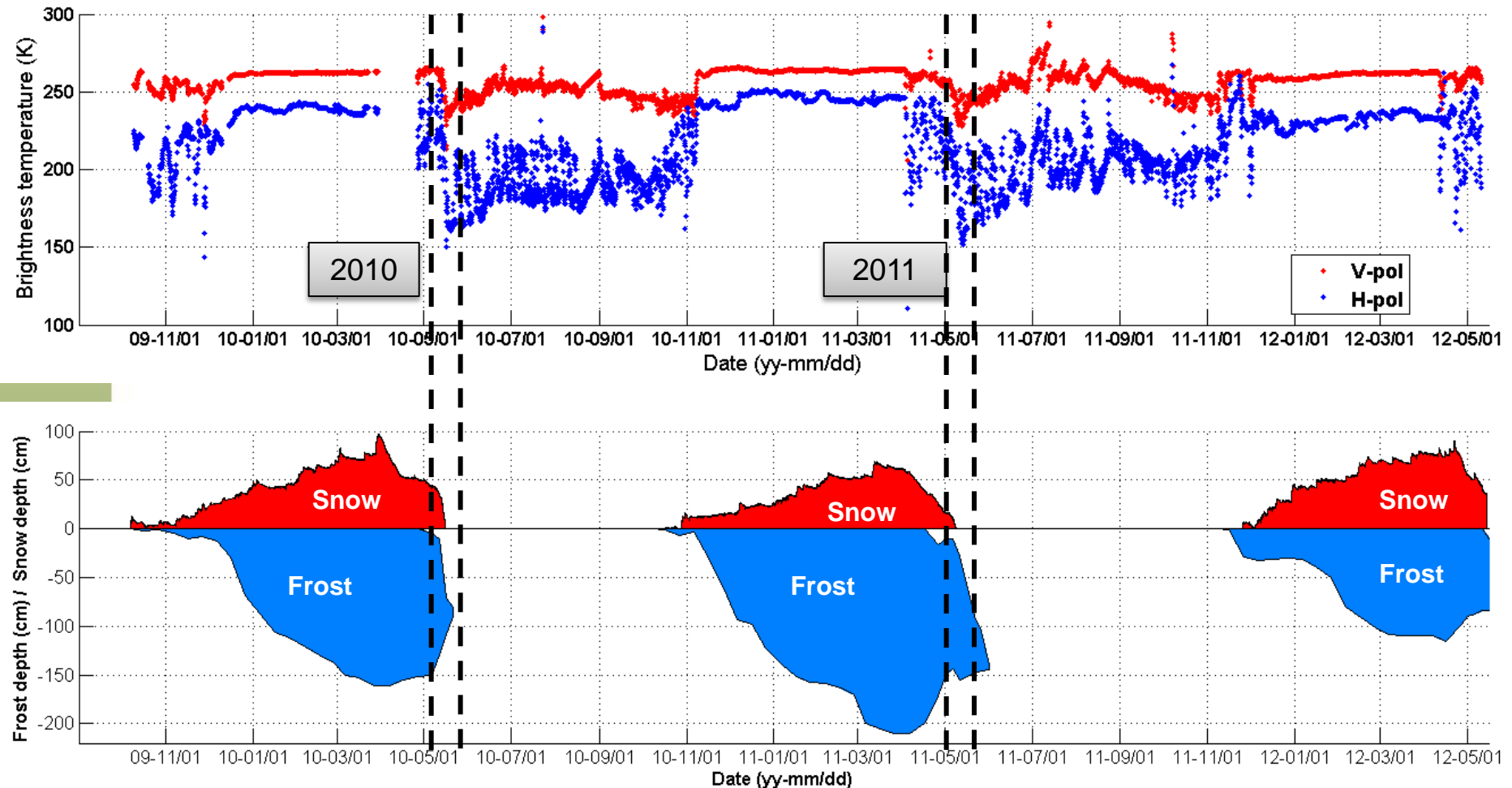
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Snow melt: local minima due to very wet soil conditions,
Rapid Tb increase follows drying of soil



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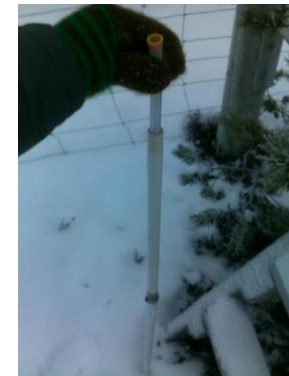
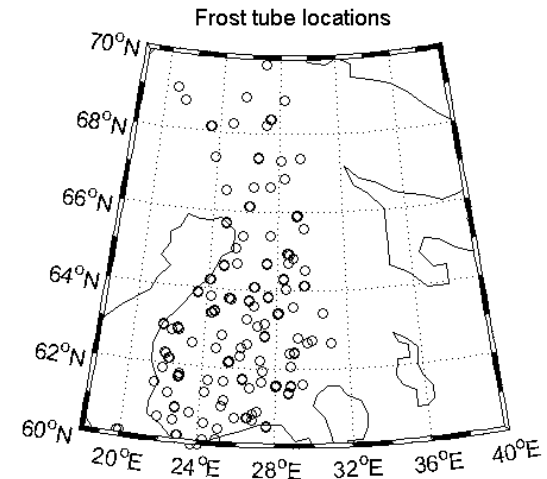
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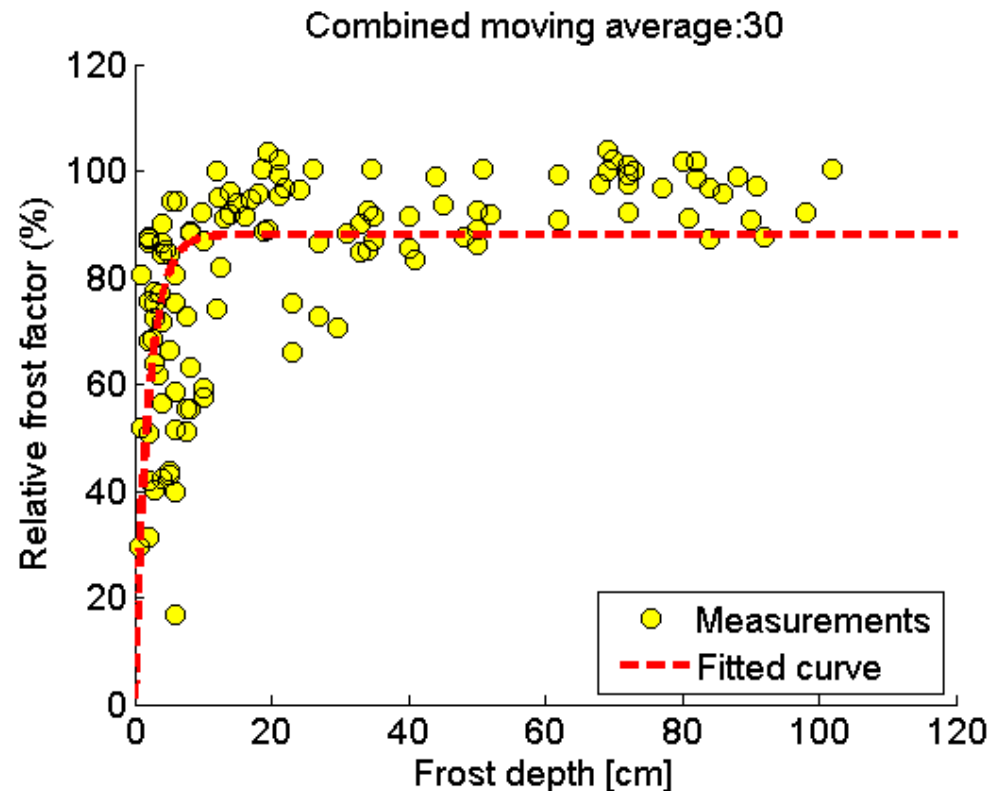
Freeze-Thaw Detection Algorithm for SMOS

- **Soil freezing detection algorithm developed for passive L-band observations**
 - First developed for ELBARA-II three-year observations at a forest clearing site: homogeneous target with many *in situ* observations
- **Algorithm further tuned for SMOS using data over Northern Finland**
 - *In situ* data: Finnish Environment Institute's Soil Frost Observation network
- **Detection algorithm is based on (1) increase in observed brightness temperature and (2) decrease in polarization difference due to soil freezing**
 - Several Frost Factor formulations tested
 - Combined use of polarization difference and H-pol Tb provided best results
 - Moving average optimized to categorize soil state



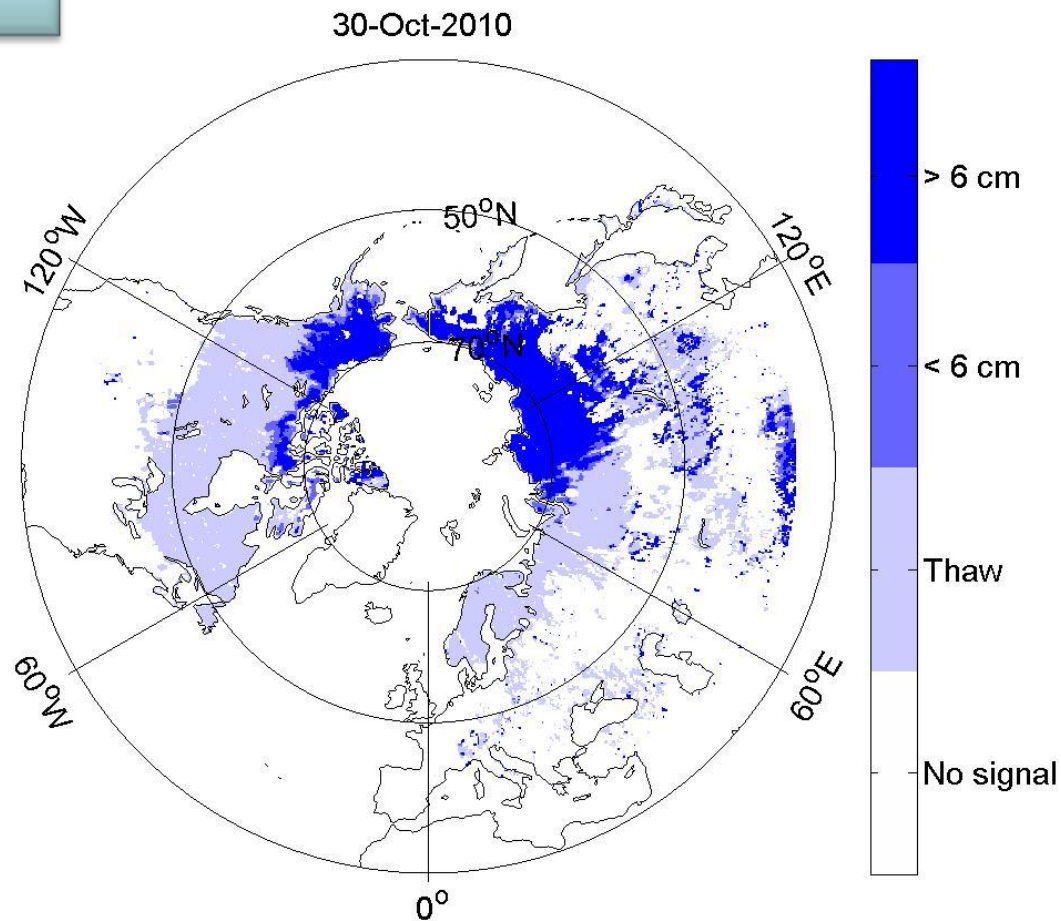
Freeze-Thaw Detection Algorithm for SMOS

- Relative Frost factor from SMOS data vs Northern Finland Frost tube observation for each SMOS data grid cell containing a frost tube (forest fraction > 50% based on GlobCover)



Freeze-Thaw Maps for Northern Hemisphere

30-Oct-2010



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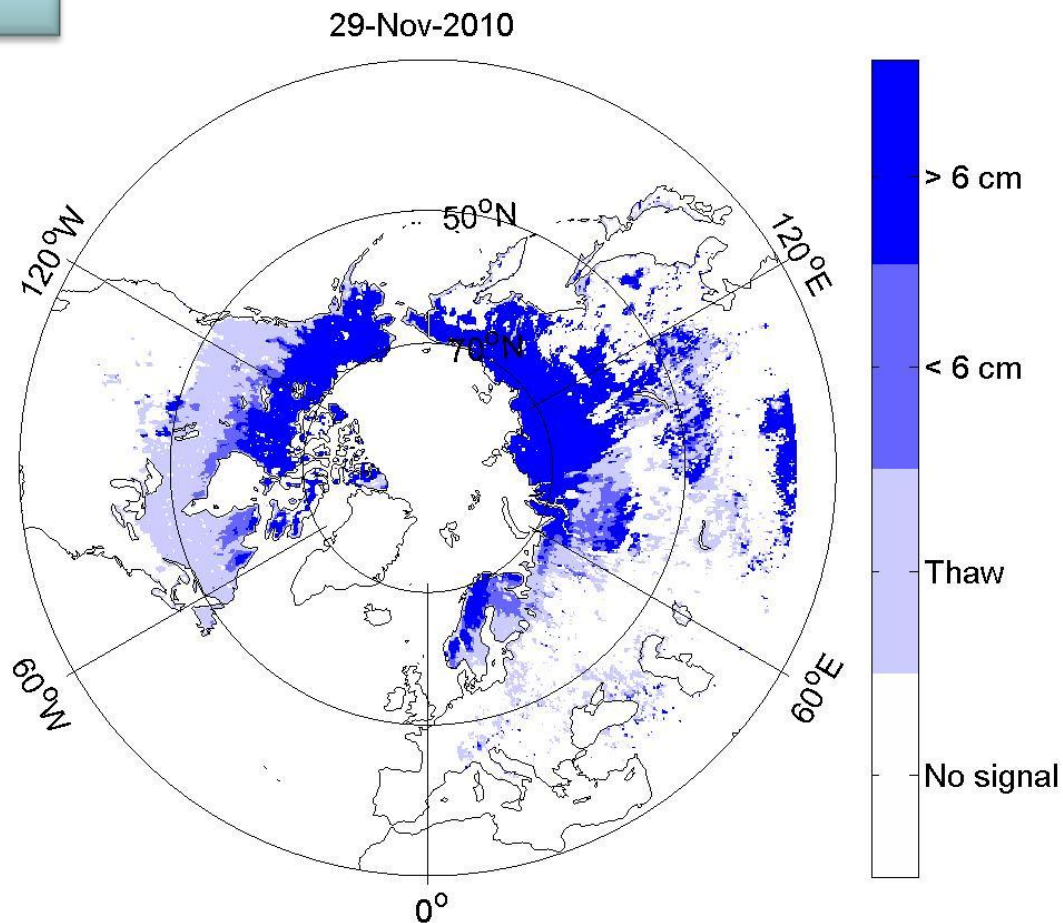
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Freeze-Thaw Maps for Northern Hemisphere

29-Nov-2010



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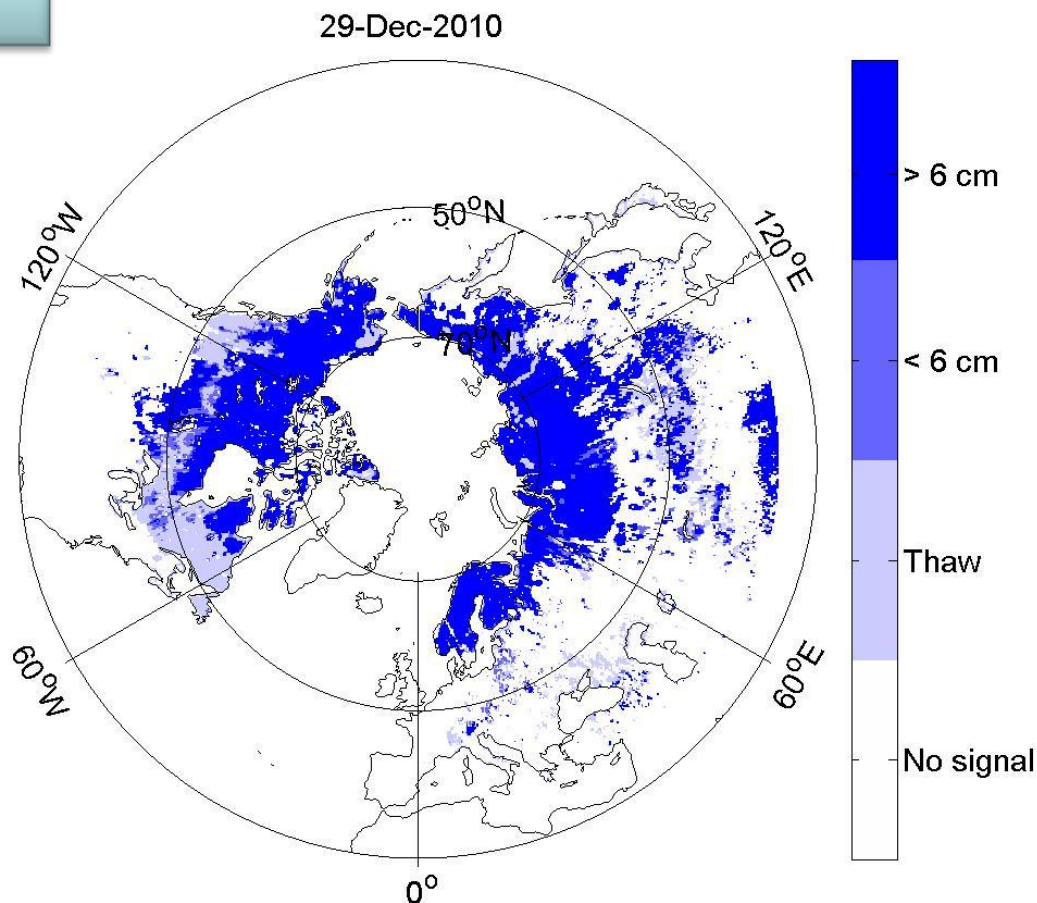
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Freeze-Thaw Maps for Northern Hemisphere

29-Dec-2010



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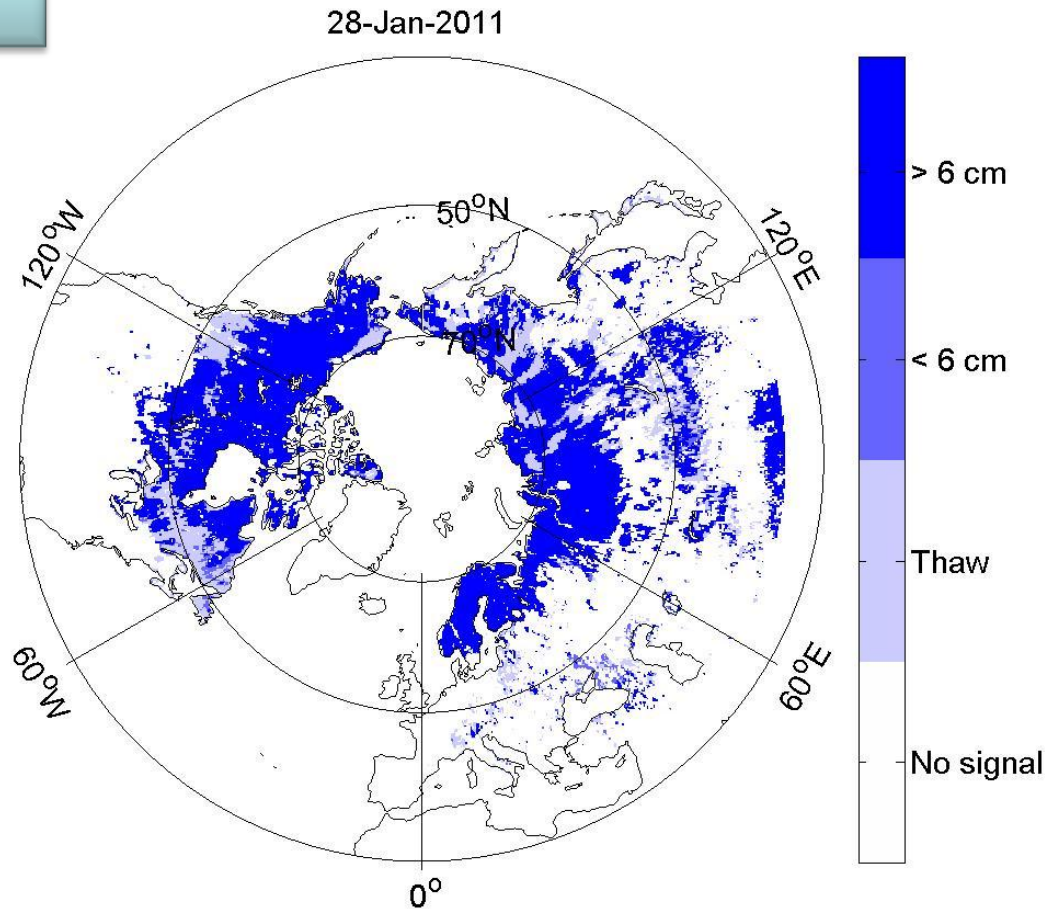
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Freeze-Thaw Maps for Northern Hemisphere

28-Jan-2011



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Freeze-Thaw Retrievals with SMOS: Moving Forward

- **Soil state is defined from relative frost factor value, which requires good summer and winter references for each SMOS grid pixel**
 - Experimental winter reference may not be realistic for lower latitudes
 - Emission models under development to have physical means of determining reference values for different soil types
 - ELBARA-II and other tower-based measurements required in subarctic and midlatitude regions
 - Use of ancillary data to detect and avoid false alarms
- **Peculiar phenomena in Siberia requires further attention**
- **Extensive evaluation and verification work still required**
 - Comparison with *in situ* data around the globe
 - Comparison with other available global products
 - Distributed high resolution airborne measurements

Tower Based L-band Radiometer Measurements by Environment Canada



Centre for Atmospheric Research
Experiments (CARE) south of Barrie, ON

Numerous ephemeral ground freeze/thaw
events over the 2012/13 winter

Typically shallow freezing depth (<10 cm)

Instrument measures brightness
temperature at 512 sub-frequencies
between 1.35 and 1.55 GHz for RFI
mitigation



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Capability for Airborne L-band Radiometer Measurements

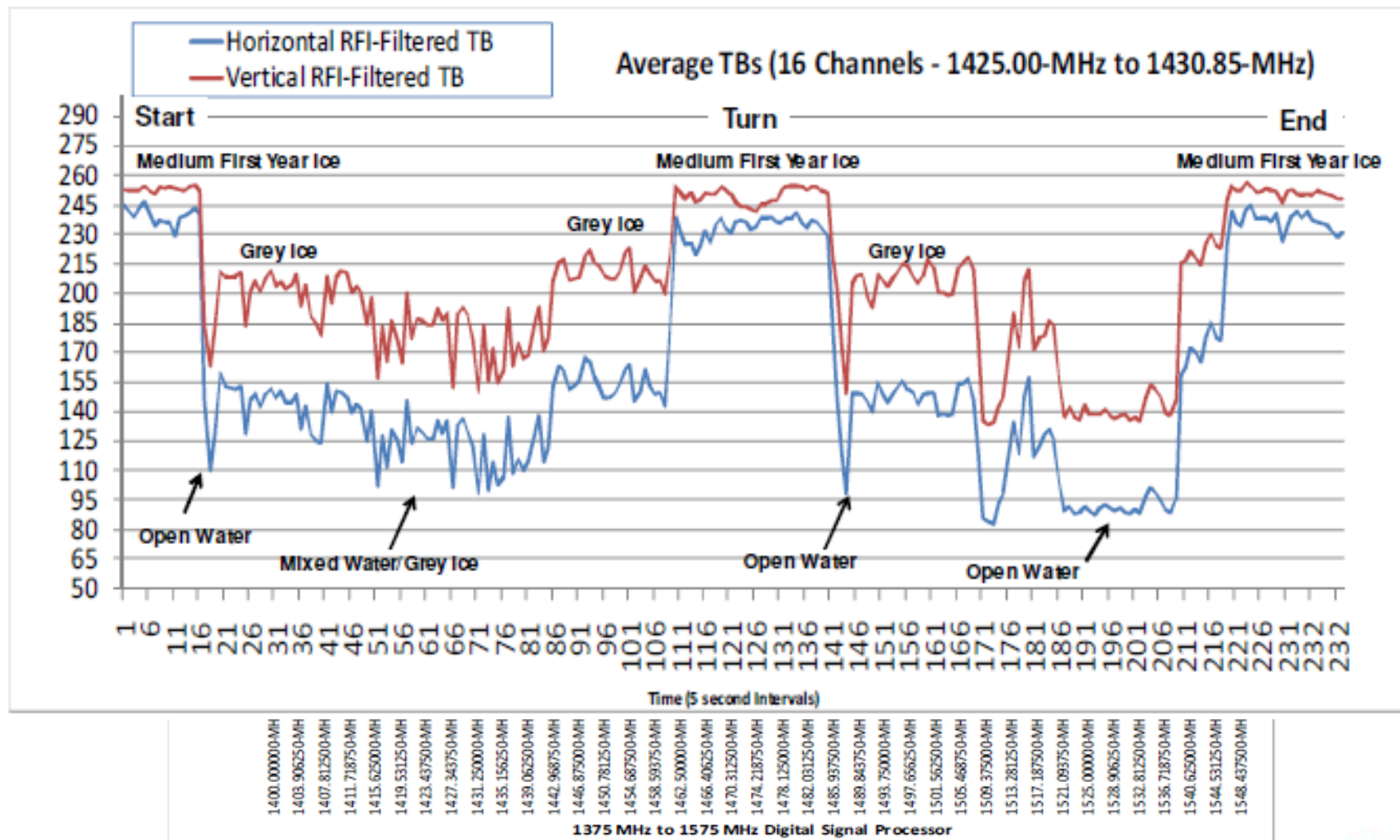


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Example Airborne L-band Measurements and RFI Mitigation



Potential Study Site: Trail Valley Creek near Inuvik, NT

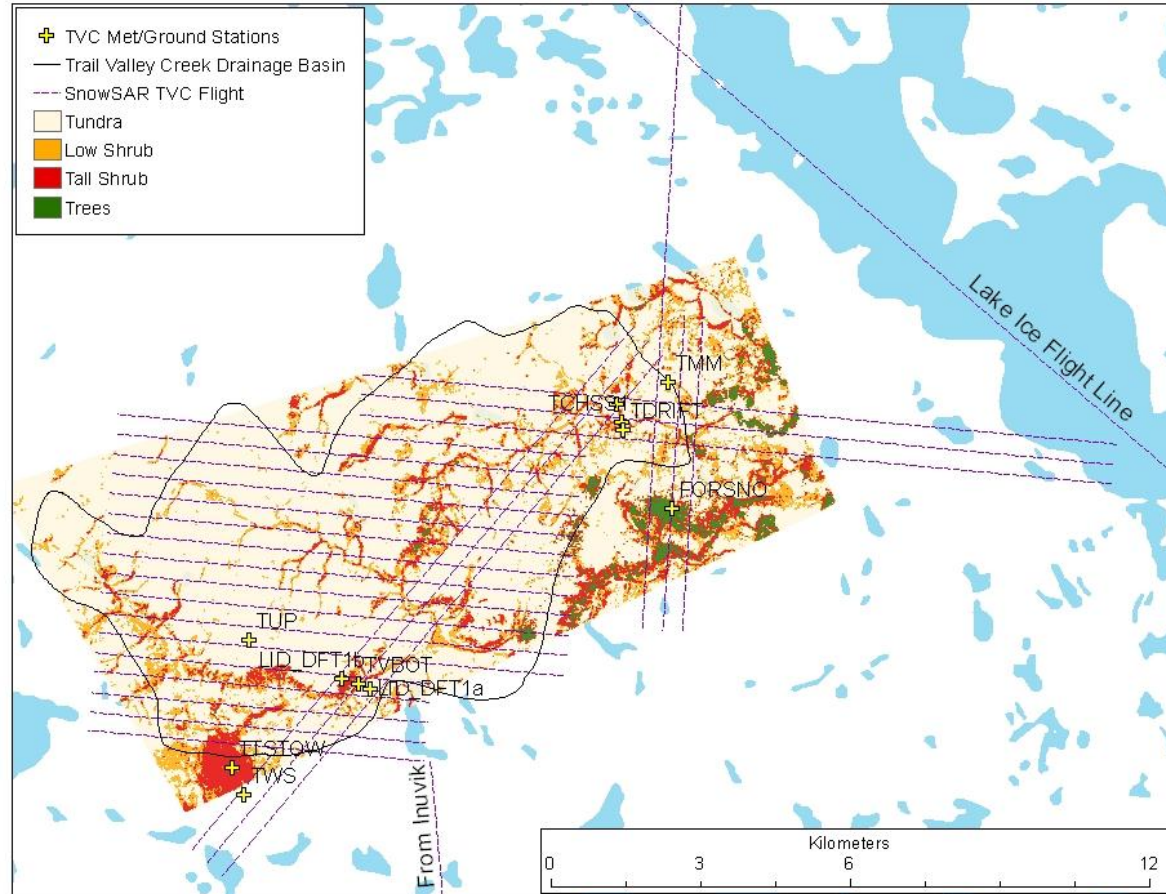
Site of ongoing Environment Canada hydrometeorological research for past two decades (led by P. Marsh).

Ground instrumentation in place.

Location of previous airborne passive microwave and snow radar campaigns.



Trail Valley Creek - Flight Lines

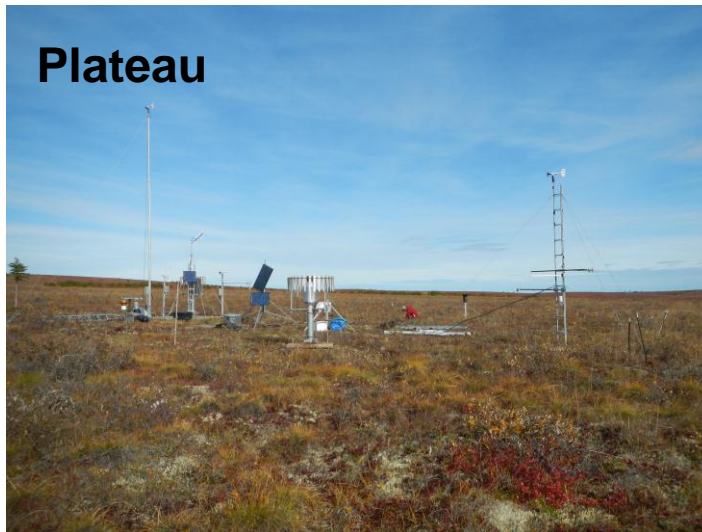
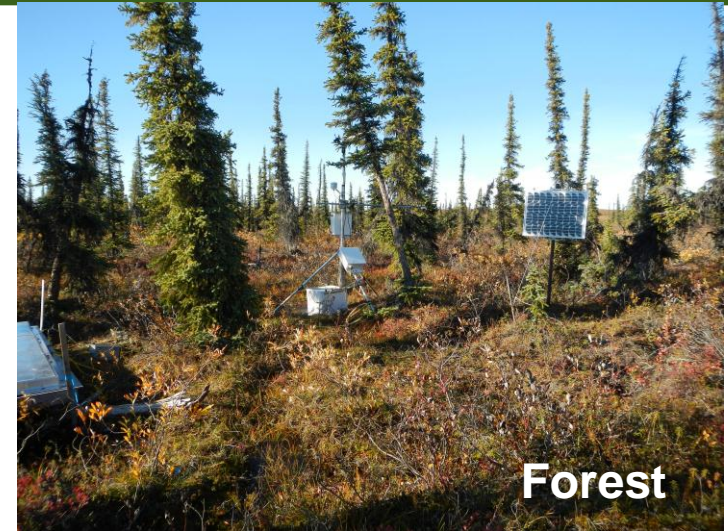
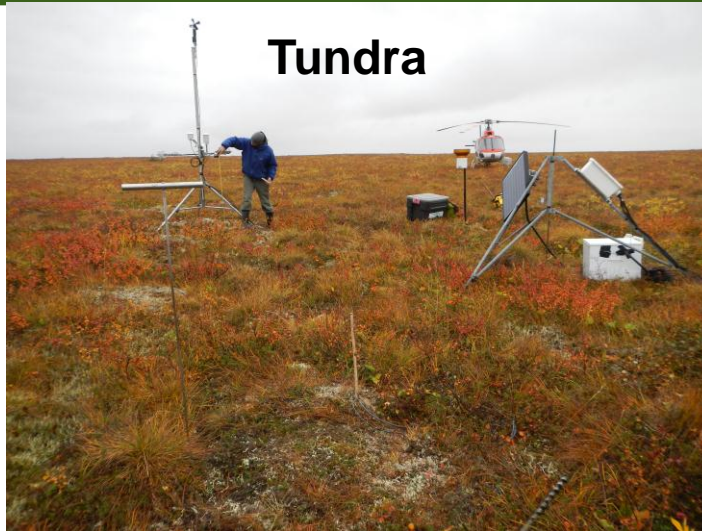


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Other Considerations?

Collaboration with ESA, including deployment of Elbara-II?

Funding support/timing for a freeze/thaw campaign?

Airborne L-band radar measurements?

Logistics of a fall season airborne campaign...