Use of ground-based radiometers for L-Band Freeze/Thaw retrieval

Alexandre Roy, Alain Royer, Chris Derksen, Peter Toose, Aaron Berg, Tracy Rowlandson, Alex Mavrovic, Michael Prince, Juha Lemmetyinen

UNIVERSITÉ DE SHERBROOKE

Environment Canada

Université de Montréal

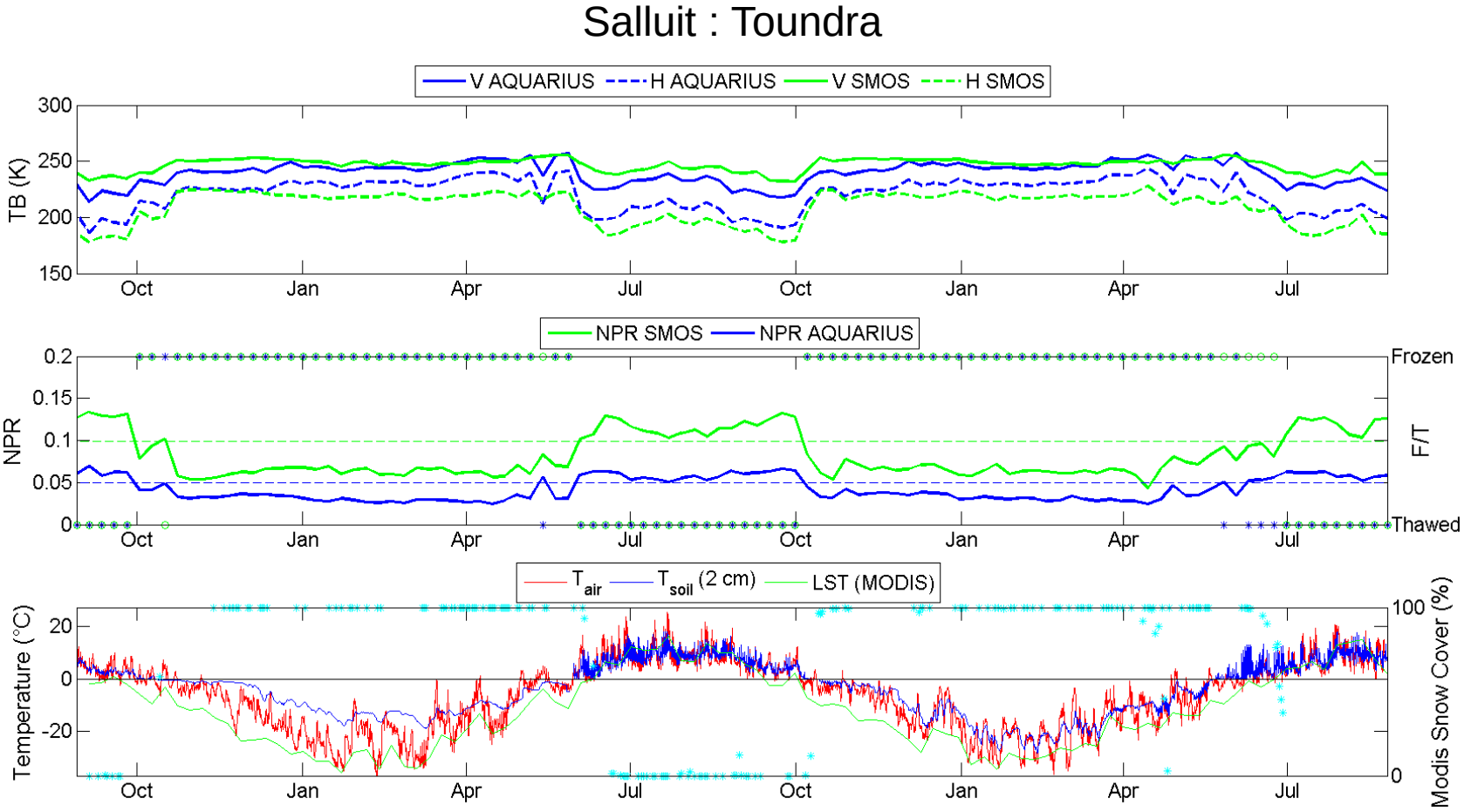
UNIVERSITY of GUELPH

CSA ASC

Plan

- Satellite-based analysis
- Ground-based results in prairie
- Ongoing experiment in boreal forest (old black spruce, northern Saskatchewan)
- Students projects

Satellite-based analysis (SMOS – Aquarius)

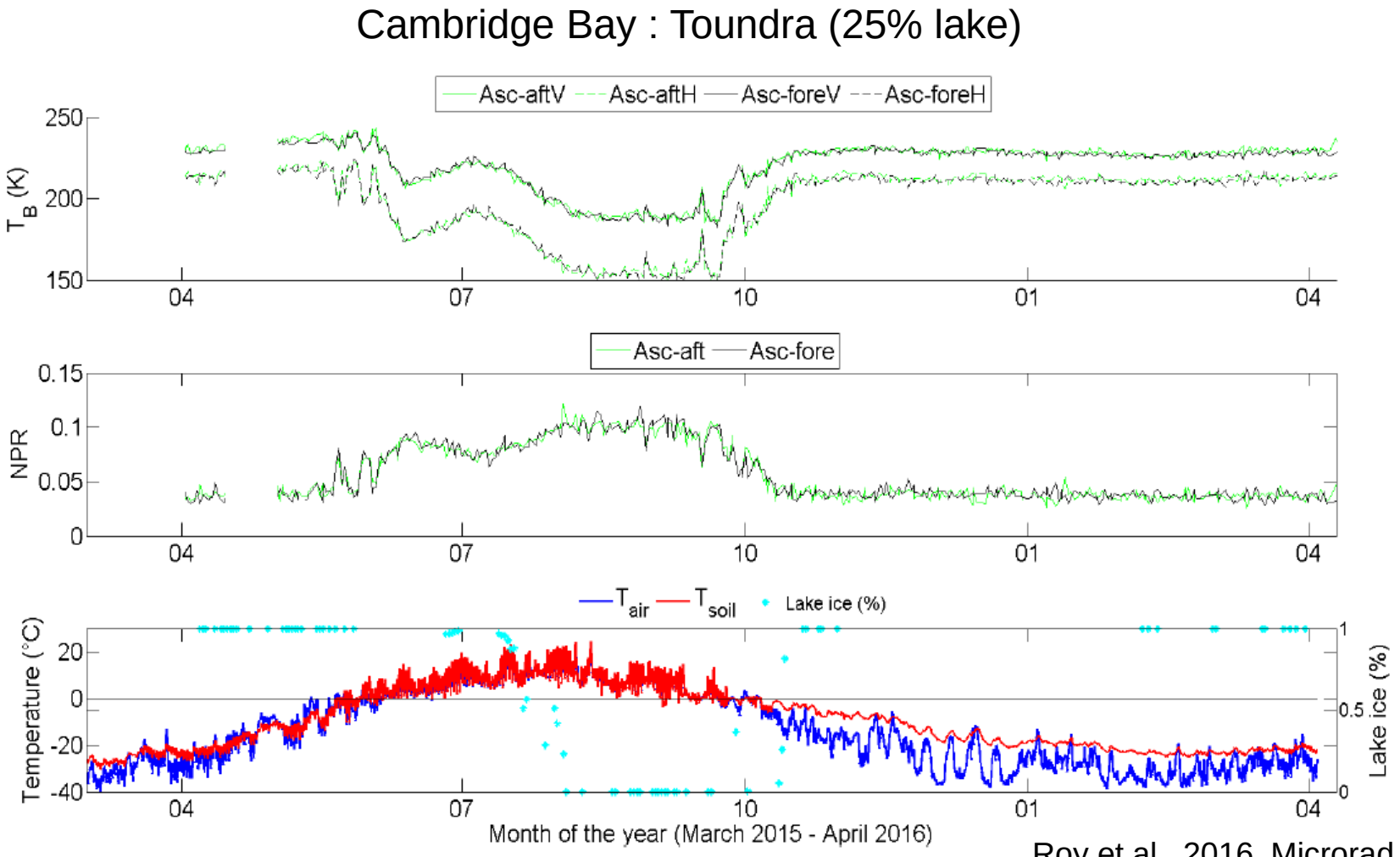


$$NPR = \frac{TB_V - TB_H}{TB_V + TB_H}$$

- Clear Freeze/Thaw signal in tundra
- SMOS at 55-60° and Aquarius at 38.9°

Roy et al., 2015, JSTARS.

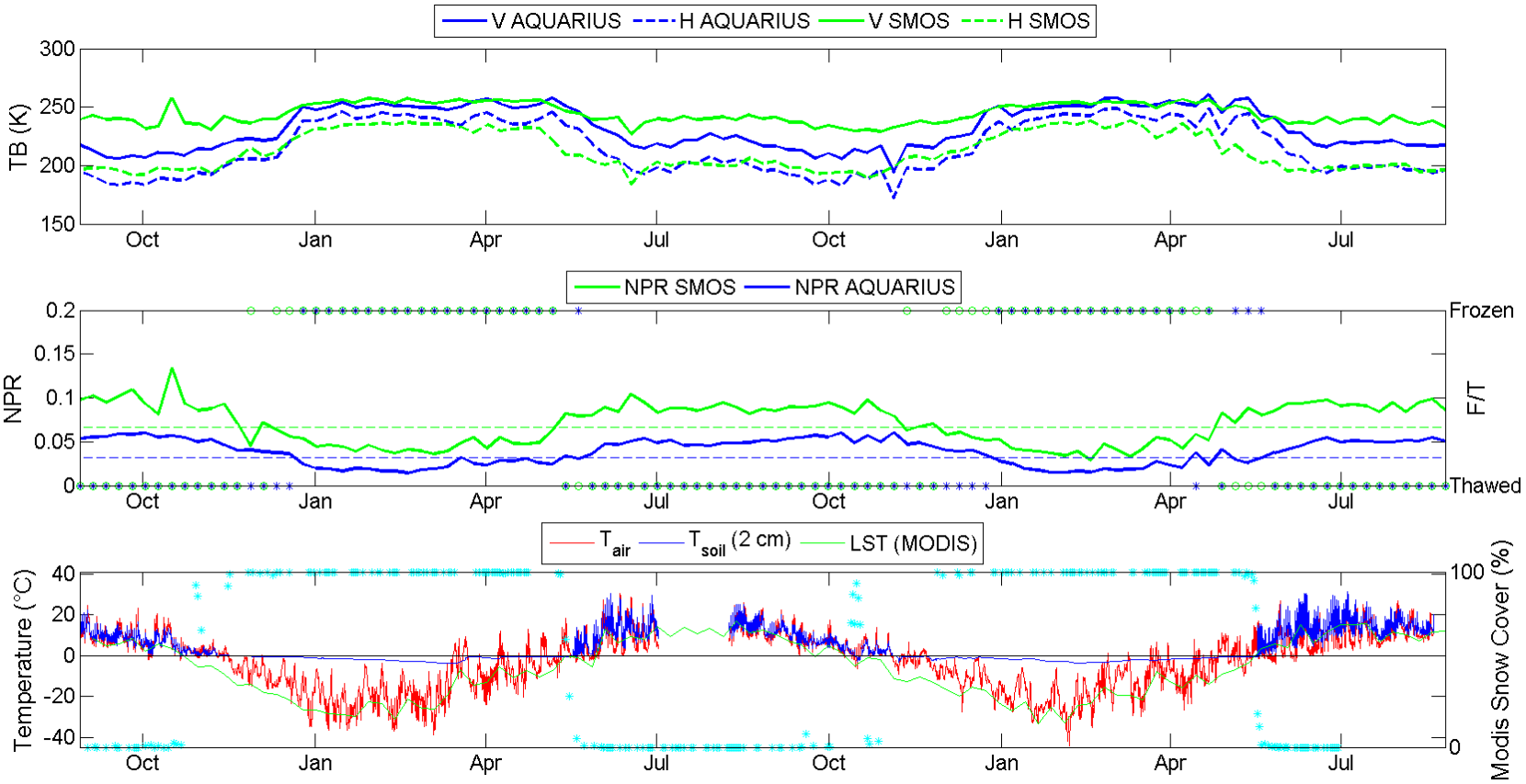
Satellite-based analysis (SMAP)



Roy et al., 2016, Microrad

Satellite-based results (SMOS – Aquarius)

Kuujjuarapik : Forêt Boréale



$$NPR = \frac{TB_V - TB_H}{TB_V + TB_H}$$

- Smoother transition in boreal forest
- SMOS at 55-60° and Aquarius at 38.9°

Roy et al., 2015, JSTARS.

Satellite-based analysis

Strong Freeze/Thaw signal with satellite-based L-Band radiometer

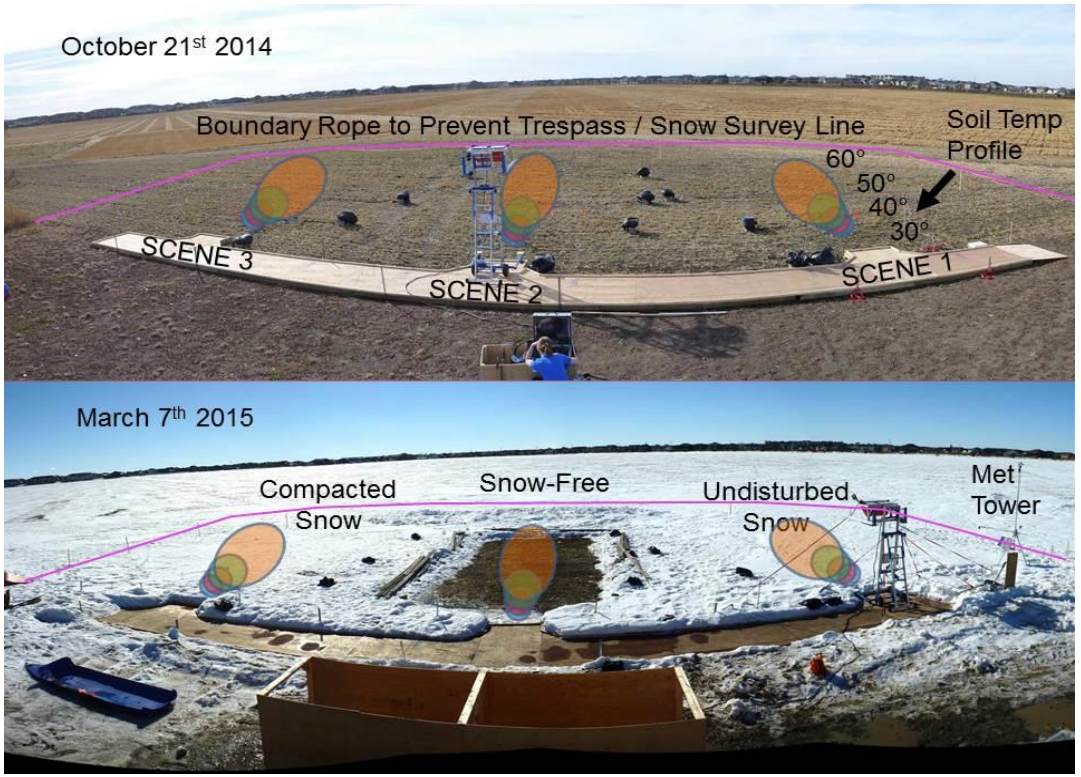
However…

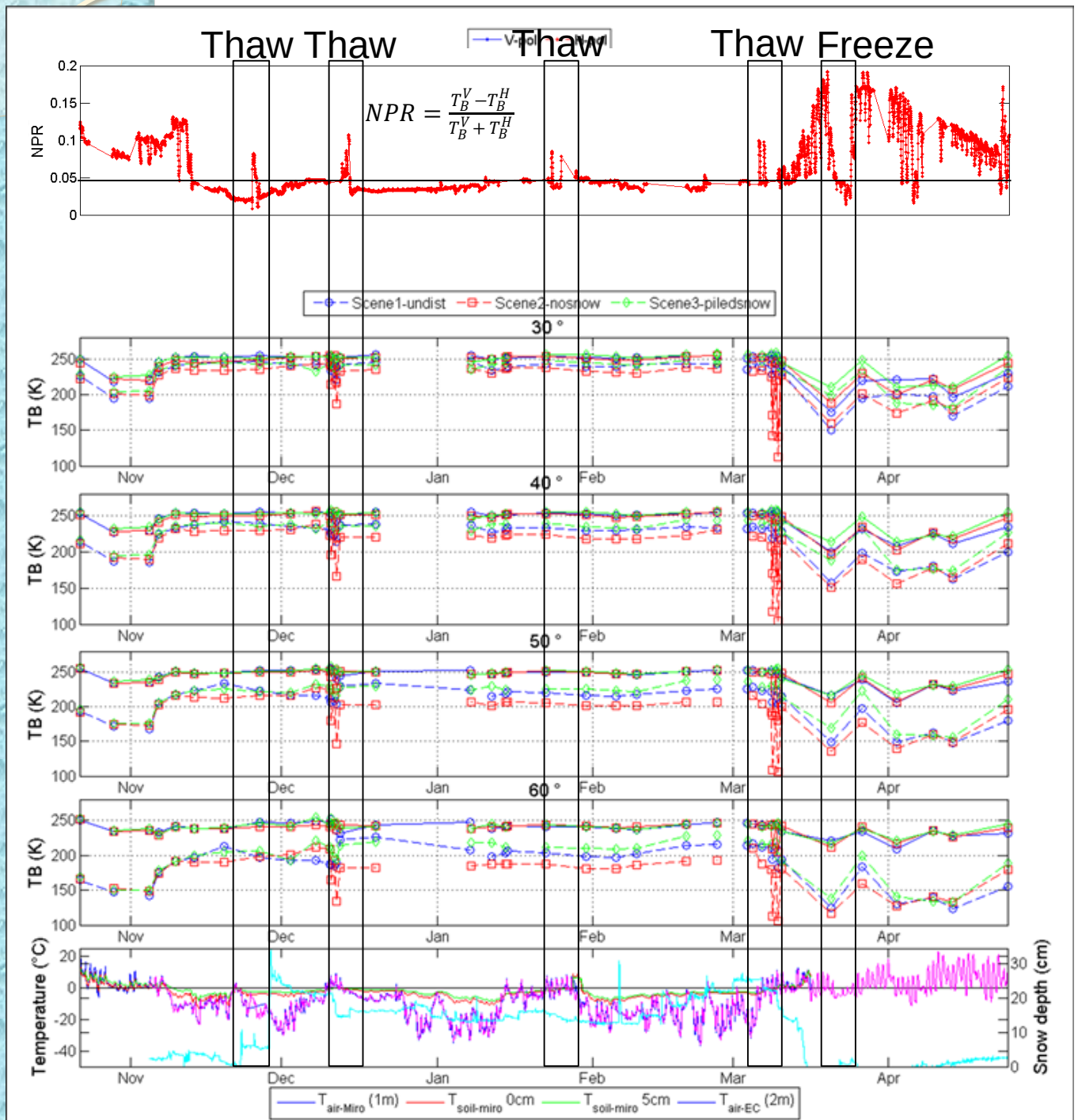
- Snow
- Liquid water in snow
- Vegetation

Ground-based results in prairie

Observation at 3 different SCENES (~12m x 6m) :

- Scene 1 - undisturbed snow
- Scene 2 - snow-free
- Scene 3 - compacted snow





Kernen Farm

October to April

- TB (V and H) very sensitive to FT (snow AND soil).
- Higher H-pol TB for dense (SCENE3) vs undisturbed snow (SCENE1).
- Strong diurnal FT signal in spring.

Roy et al., 2017, RSE.

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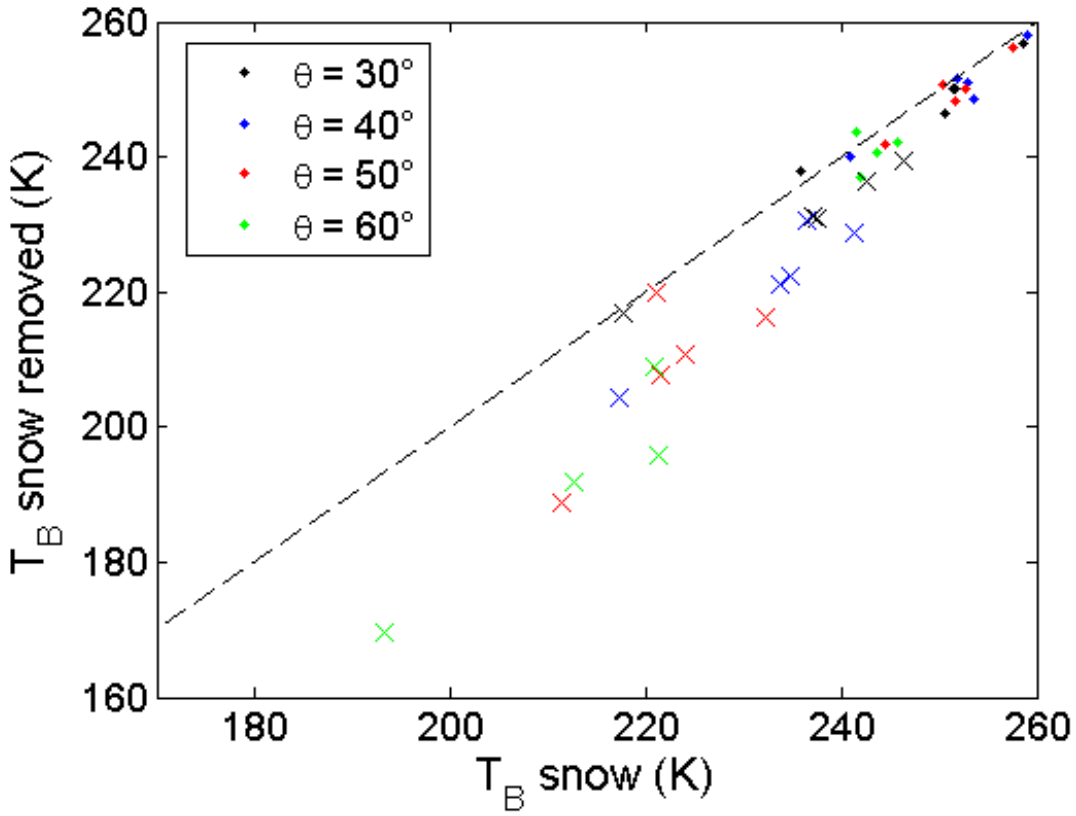
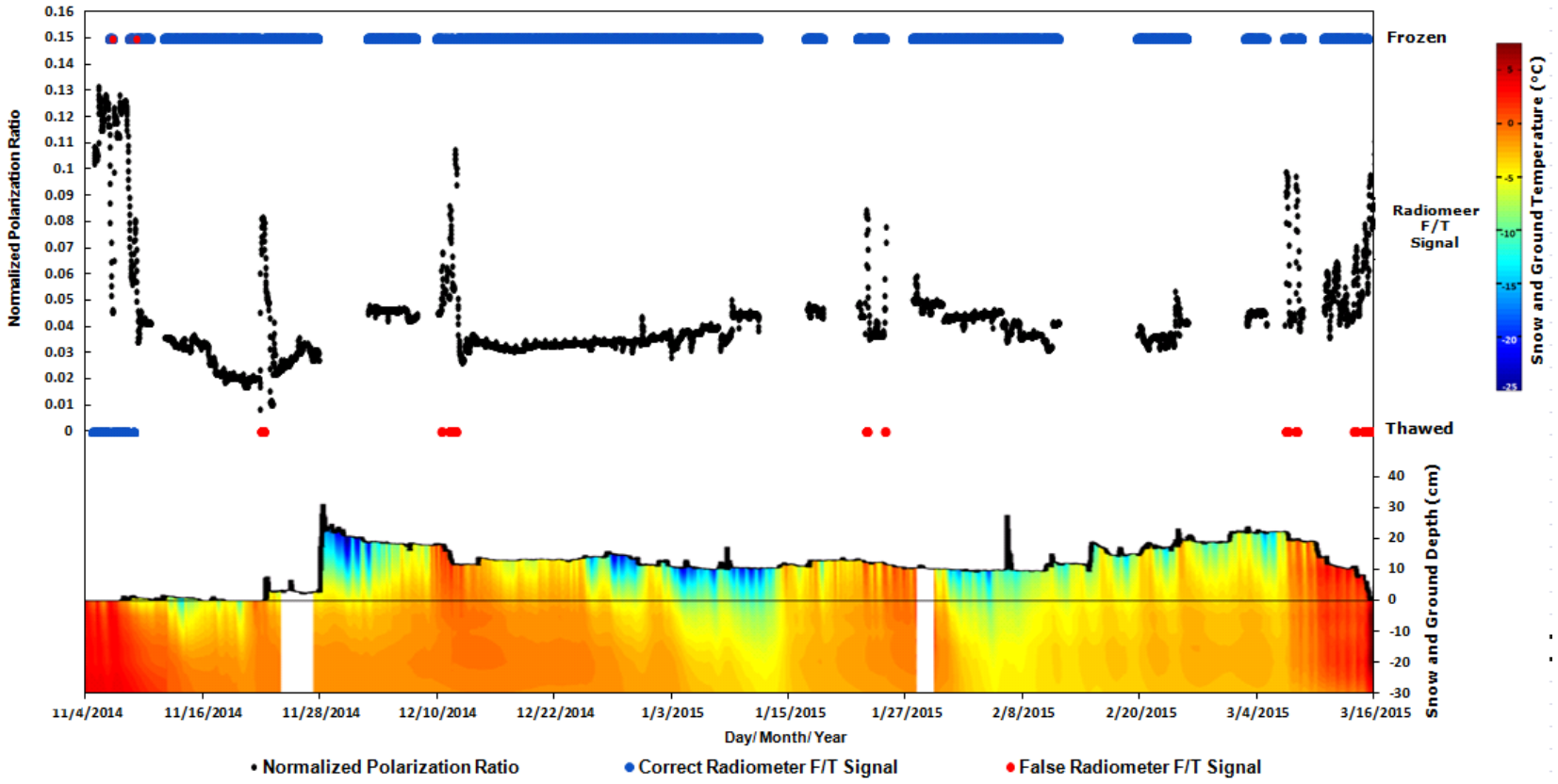
Ground-based results in prairie



- Non negligible effect of snow at H-pol (refraction and impedance matching).
- Sensitivity to snow density (Lemmetyinen et al., 2016, RSE) and snow layering.

Roy et al., 2017, RSE.

Ground-based results in prairie

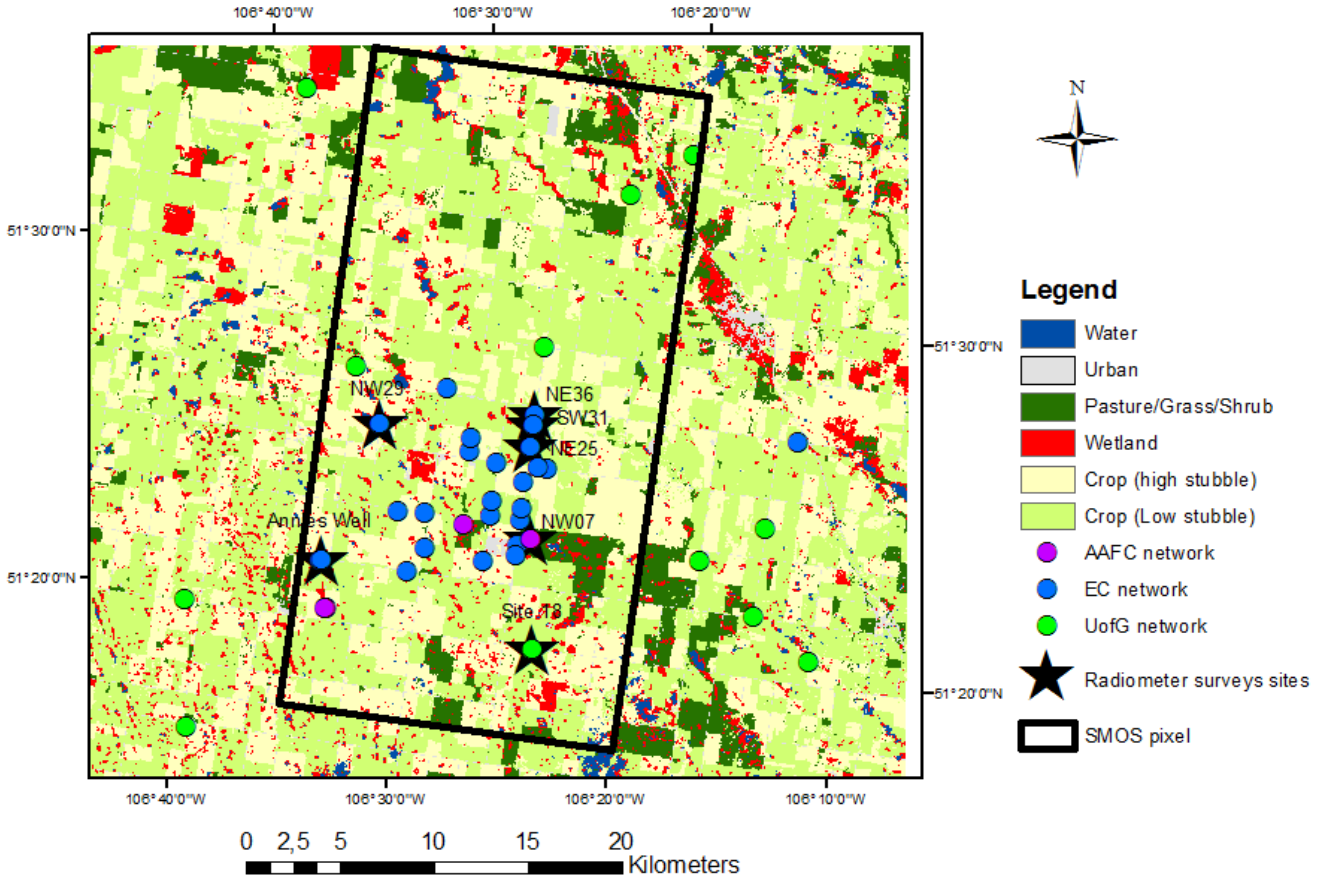


- Liquid water in snow gives similar signal to soil FT (false identification of soil thaw).
- Tair overestimates the thawing.

Roy et al., 2017, RSE.

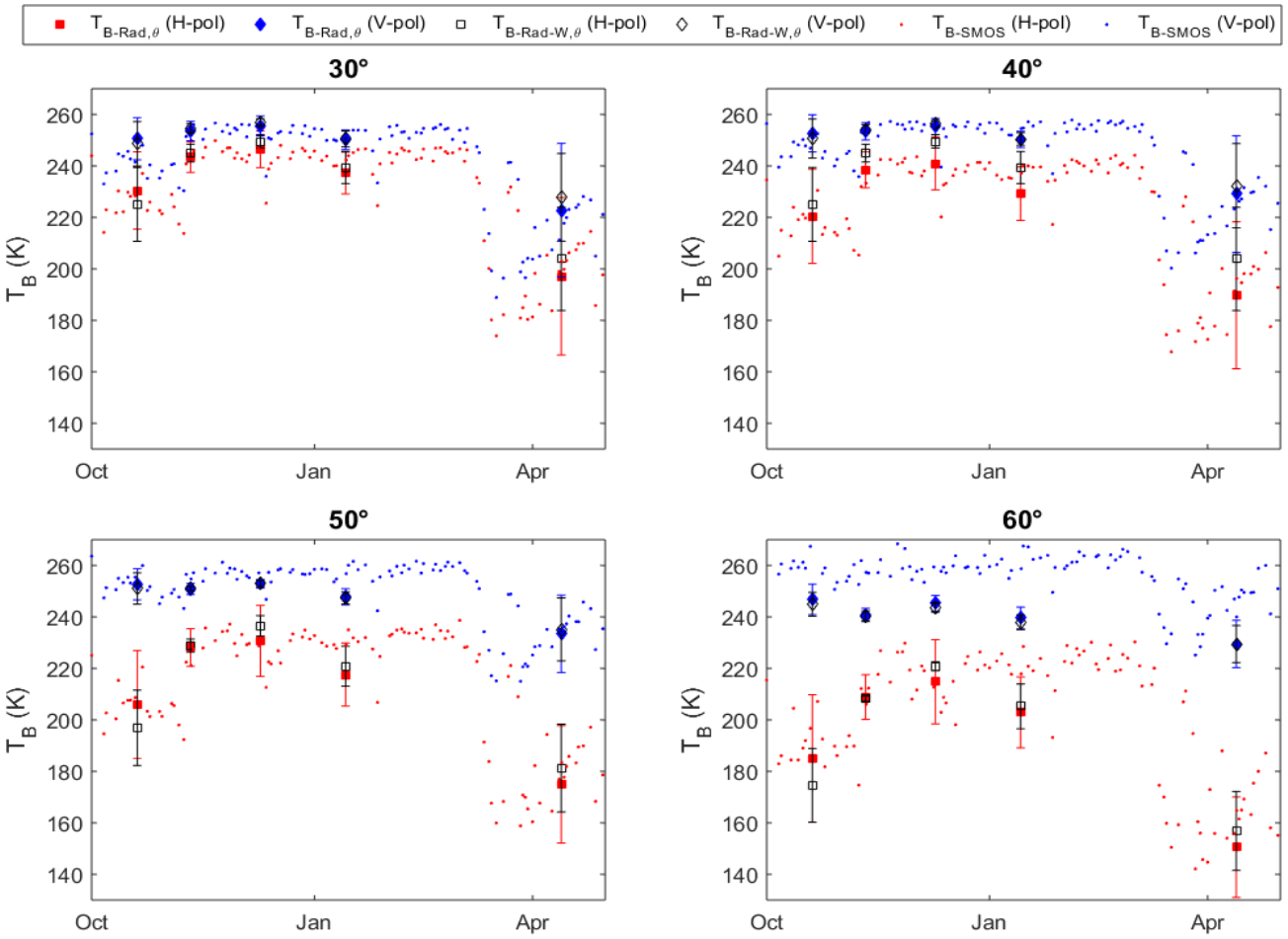
Ground-based results in prairie

Kenaston, Sasktchewan



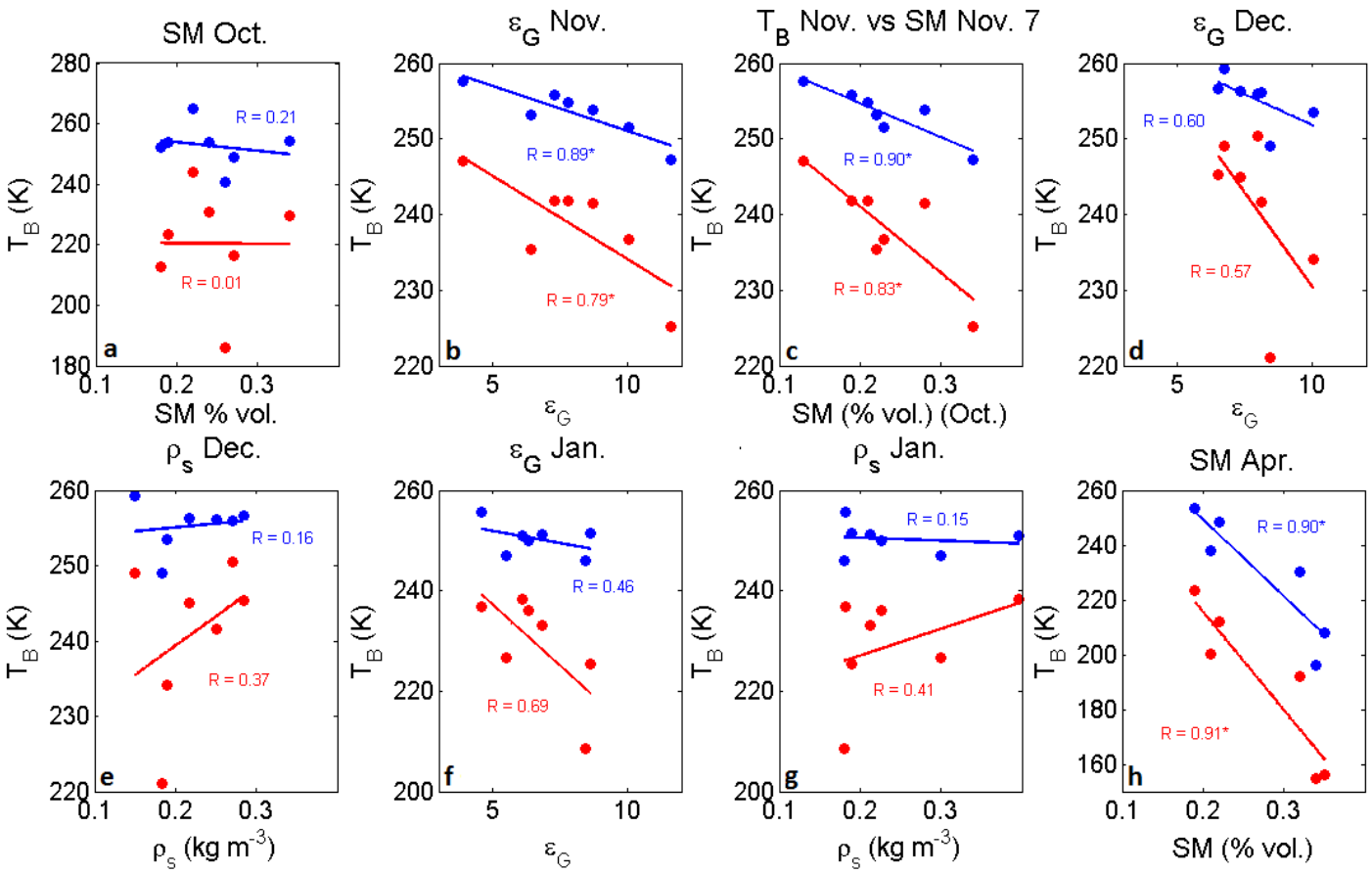
Roy et al., in redaction.

Ground-based results in prairie



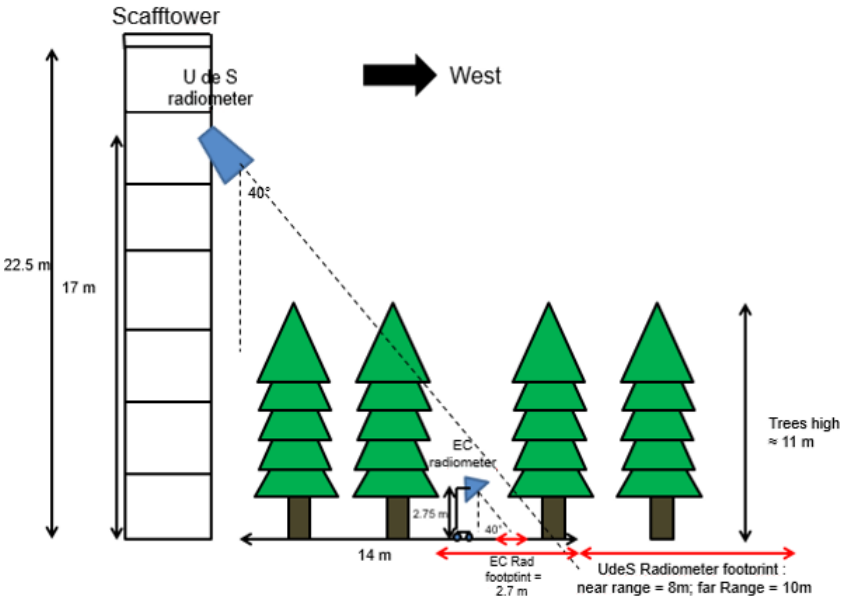
Roy et al., in redaction.

Ground-based results in prairie

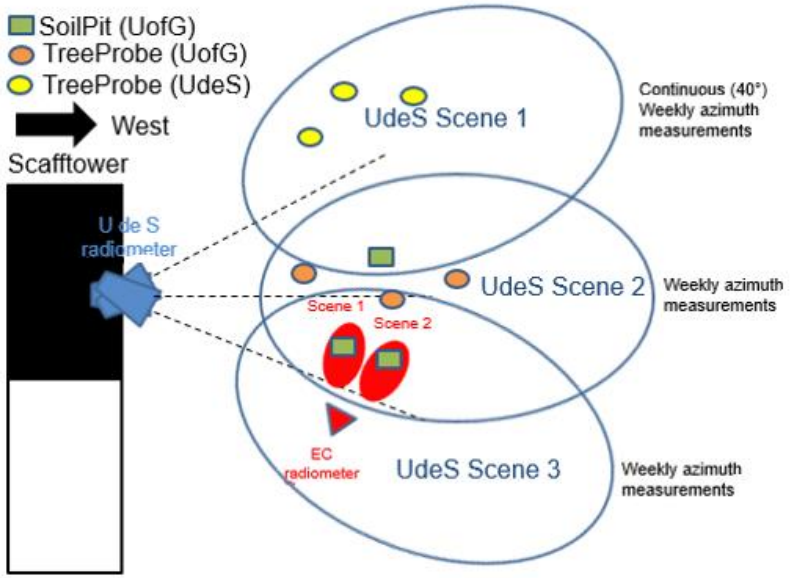


Roy et al., in redaction.

Ongoing experiment in boreal forest



Side view

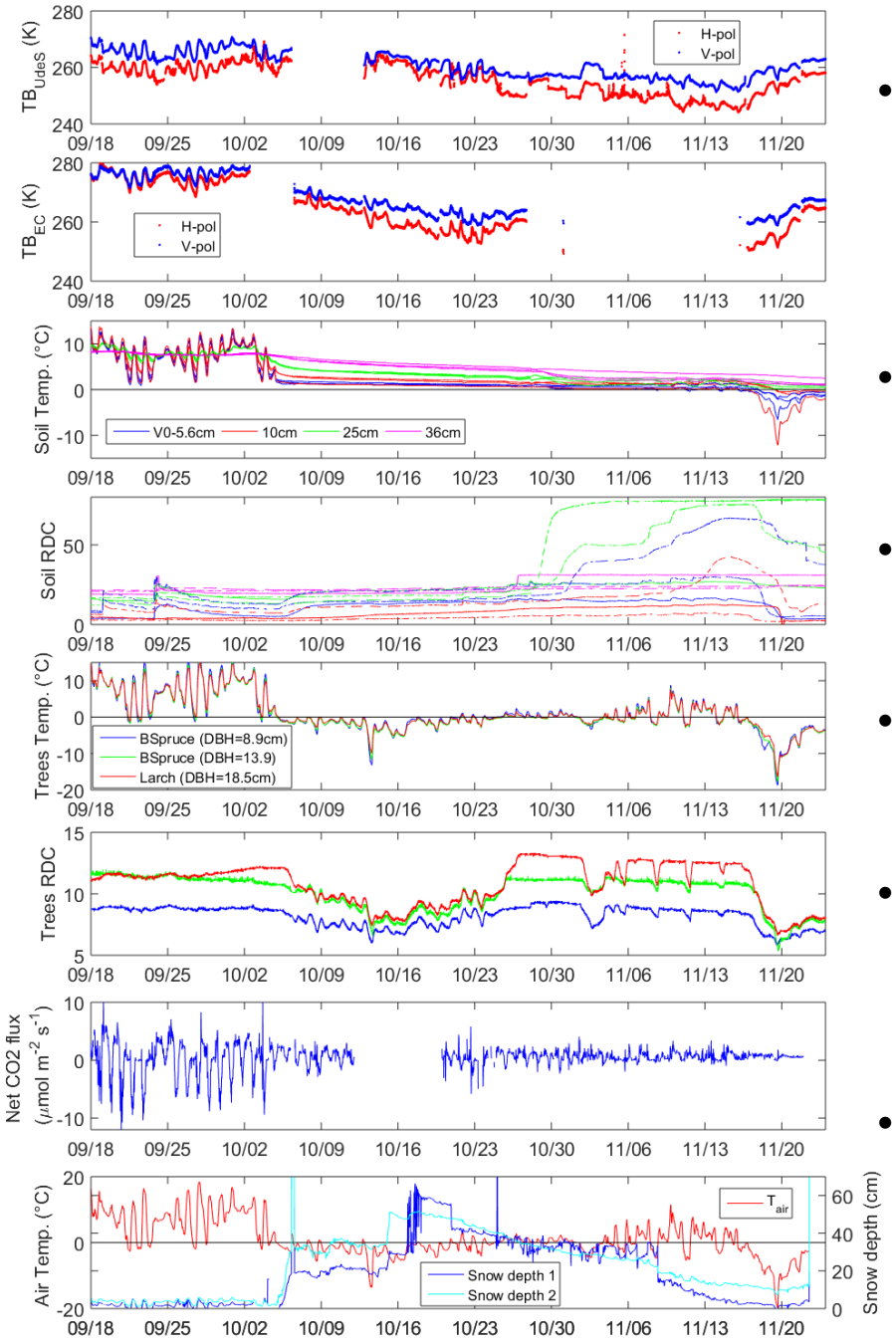


Bird view

Ongoing experiment in boreal forest

Well intrumented site :

- 2 ground-based L-band radiometers
- Soil moisture probes
- Soil moisture probes in trees (liqui water content in trees
- Sap flow measurements (Umontrea
- Dendro.
- Tree temperature bore holes
- PhenoCam
- NDVI (SRS)
- Snow depth
- eddy covariance
- albedo
- L-Band permittivity of soil and trees
- Terrestrial Lidar scan
- Thermal camera (Kyle McDonald)



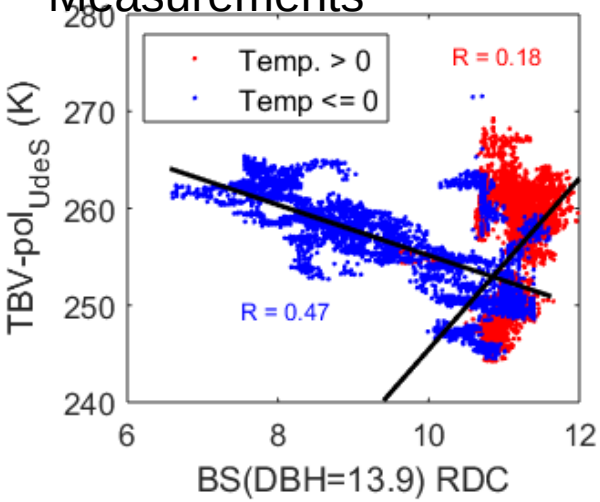
- SoilPit : HydraProbes (RDC: relative dielectric constant and soil temperature [0-5 vertical, 10 cm, 25cm and mineral soil])
- TreeProbe : HydraProbes inserted in trees
- Both radiometers made continuous measurements at 40°.
- Very high TB in September because of dry surface
- FT signal with both radiometers (delayed) after Nov. 15 (frozen soil = TB increase)
- Strong signal of Tree RDC to freeze/thaw (probably related to vegetation liquid/solid water content)

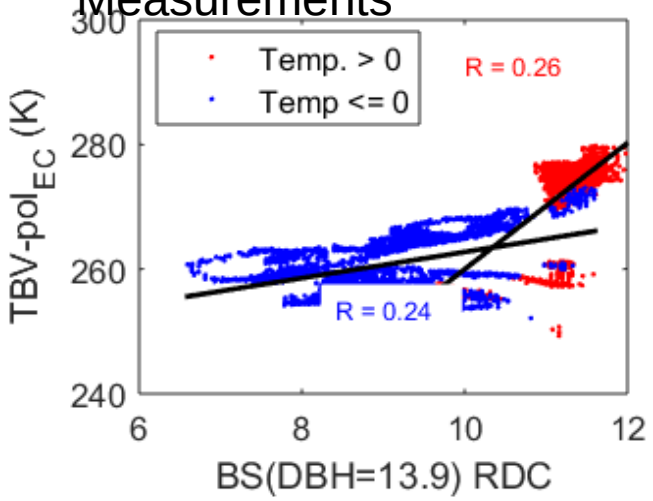
Ongoing experiment in boreal forest

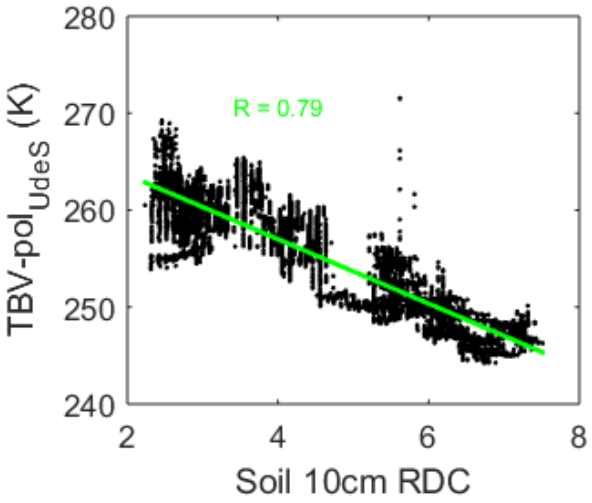
Above Canopy Measurements

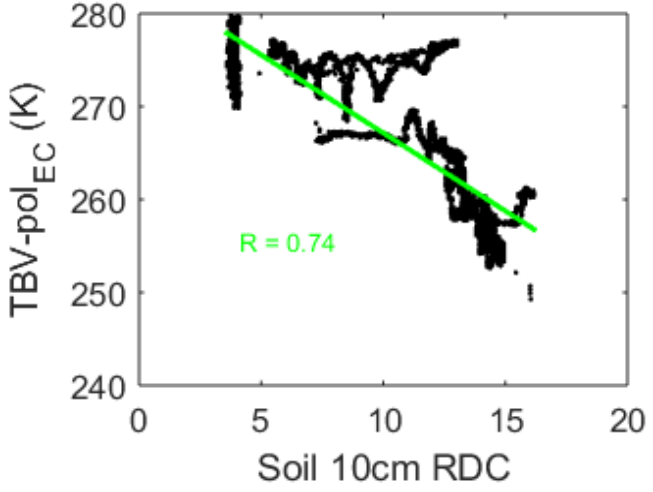
Below Canopy Measurements

Unfrozen soil

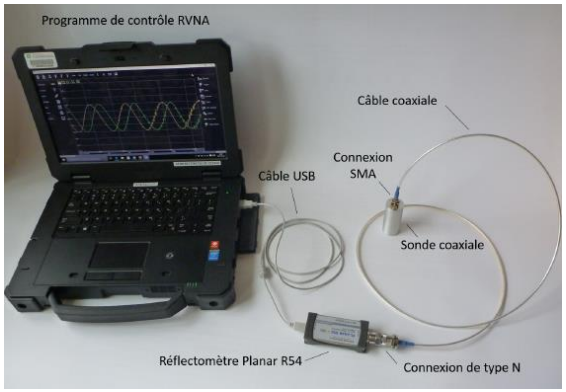


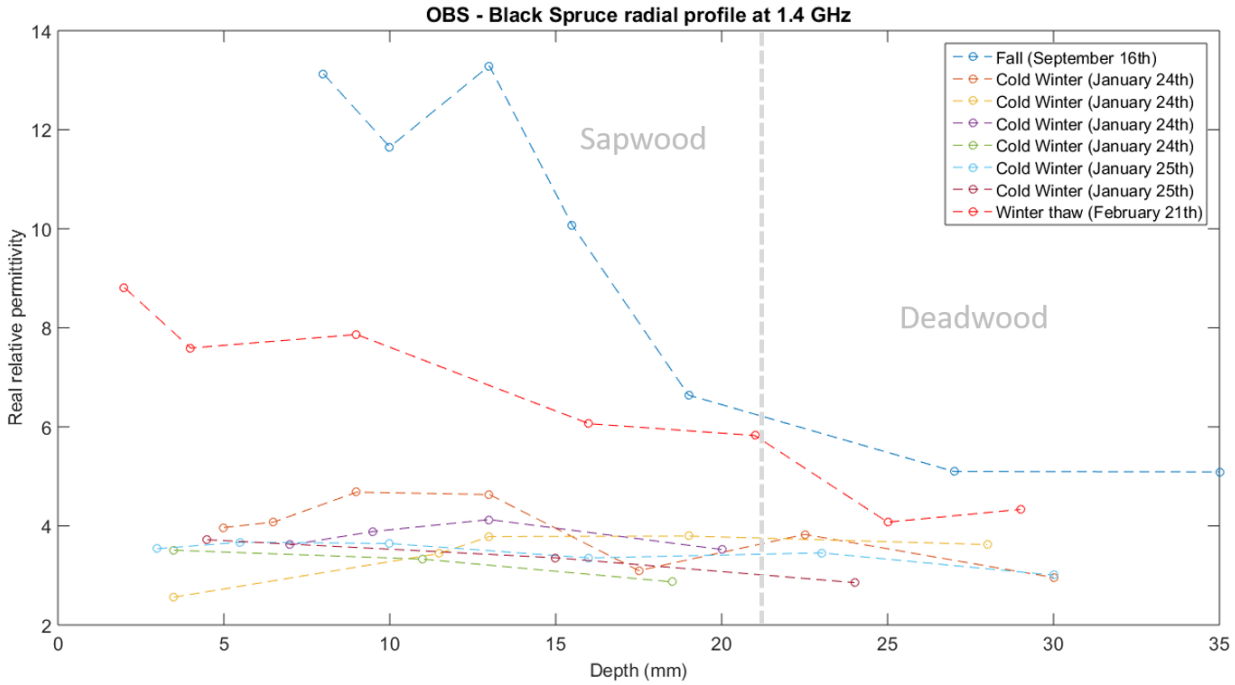






Ongoing experiment in boreal forest





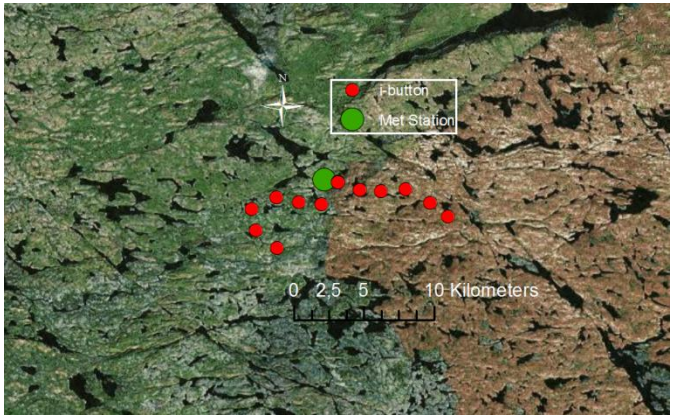
Alex Mavrovic, Master student

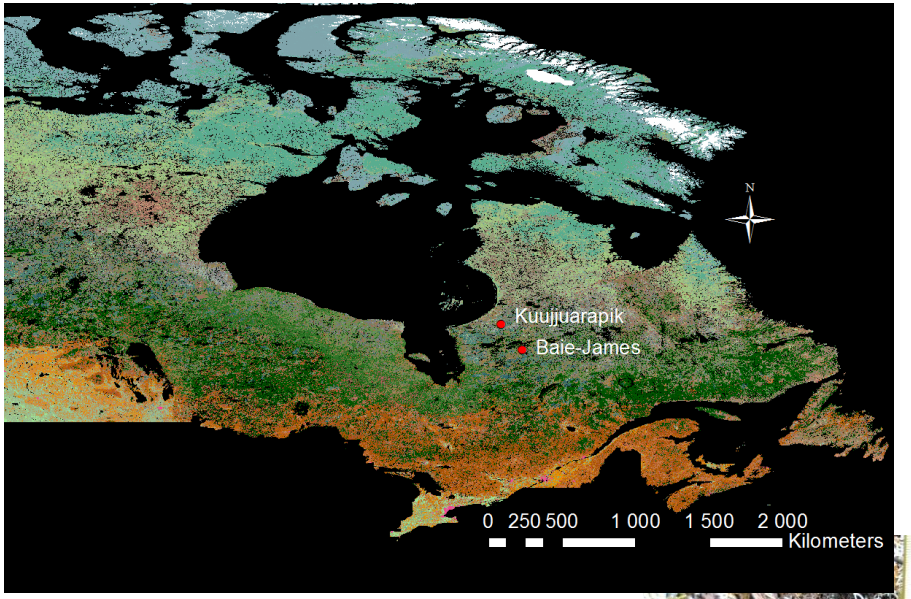
Ongoing experiment in boreal forest

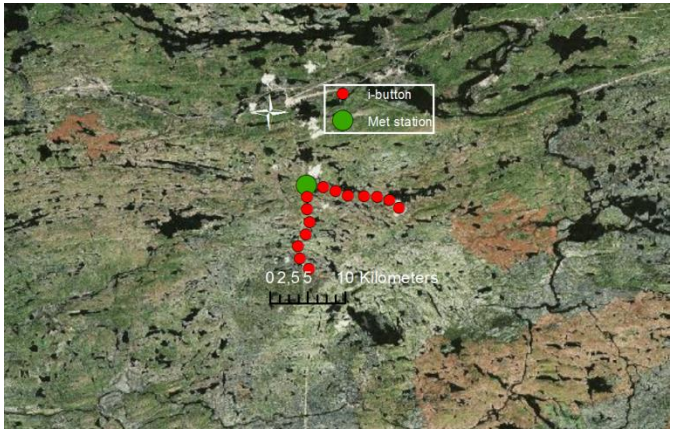
What next:

- Measurements still ongoing!
- Calibration of tree probes for stem water storage.
- Use bi-monthly multi-angular measurements to invert the τ-ω vegetation radiative transfer model to decouple the effect of soil and vegetation.
- Upscale the information to satellite observations (SMAP and SMOS)
- Link tree L-Band emissivity with coaxial L-Band RDC probe measurements
- Measure soil L-Band permittivity with coaxial probe
- Summer retrieval : soil moisture and total liquid water in trees

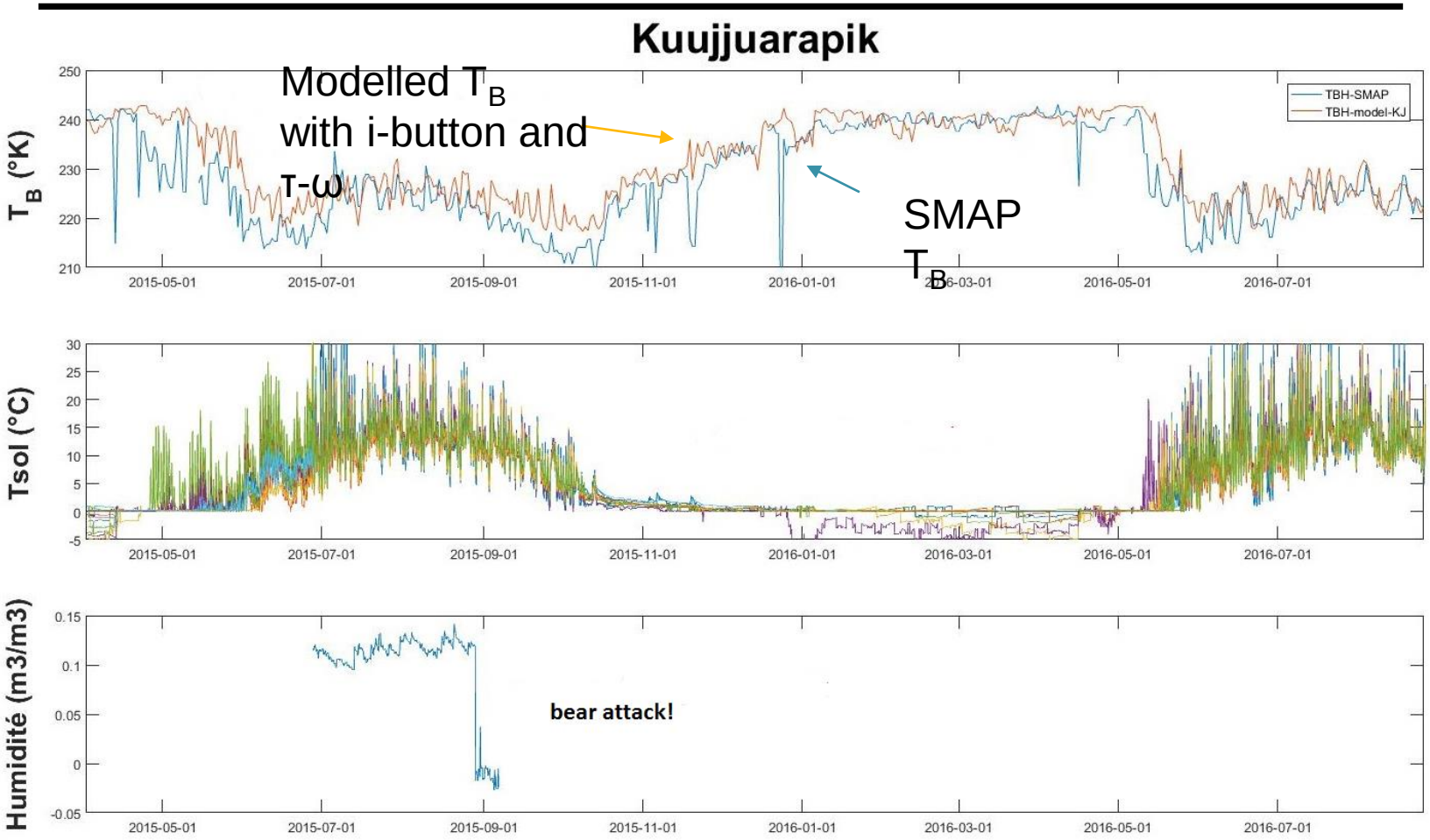
Freeze/Thaw spatial variability in boreal forest







Freeze/Thaw spatial variability in boreal forest



Michael Prince
Master
student

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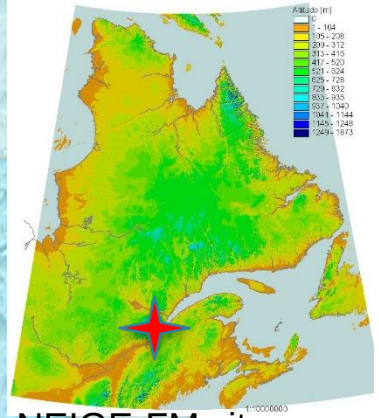


NEIGE-FM site
Forêt Montmorency

Atmospheric forcings: GEM LAM 2.5 km (and CaPA at 2.5 km); hourly forcings

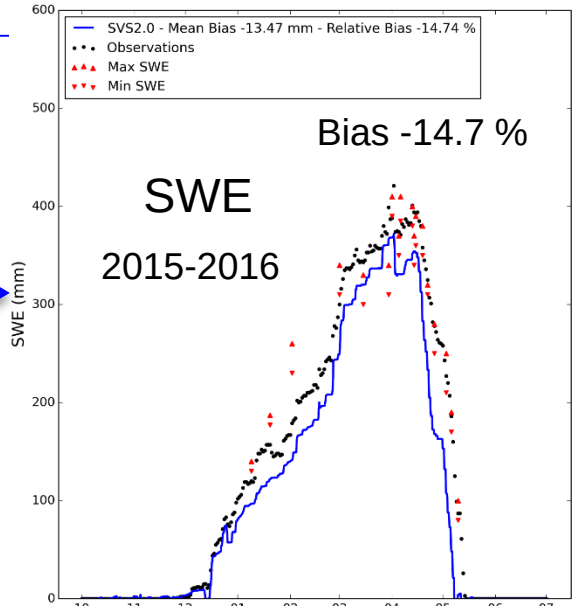
Snow model : SVS2.0-ES, 6 layers

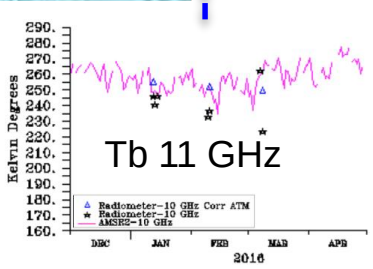
Radiative transfert model: DMRT-ML and CMEM

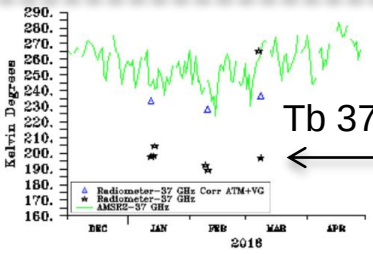
Tb 1.4, 11, 19, 37, 89 GHz

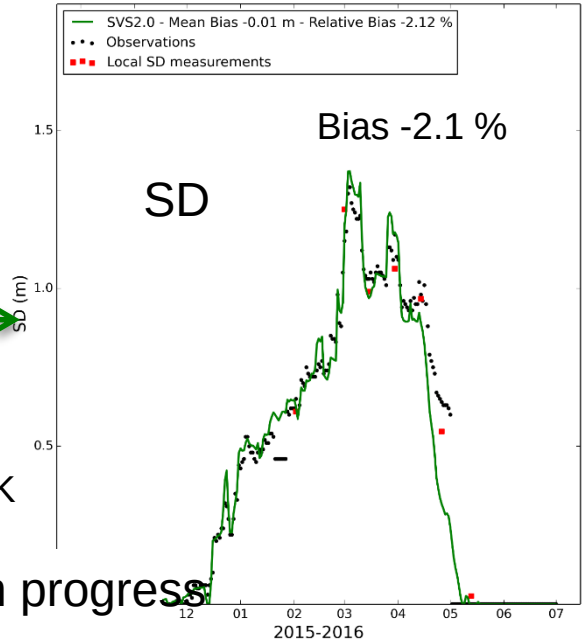
CALDAS

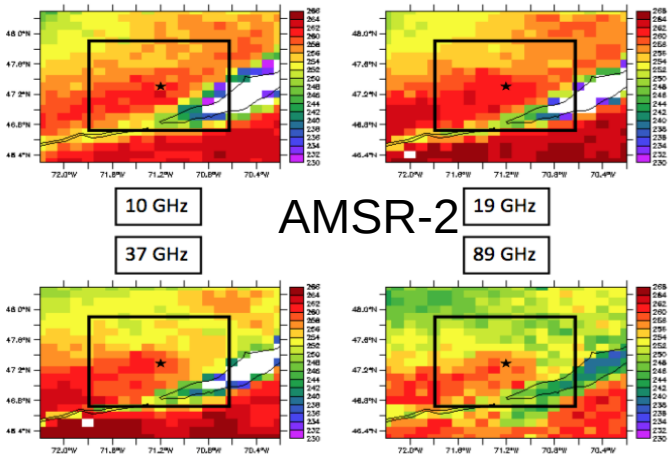
6-Hourly SWE data (GMON CS725 sensor) and in in-situ

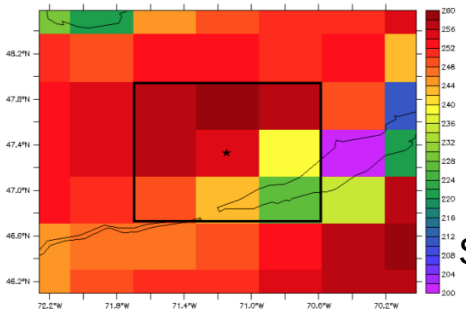












STD=2.2 K

Mélody Poncin, PhD, work in progress

Conclusion

- Strong F/T signal with L-Band radiometer
- In spring the signal come from the liquid water in the snow
- Snow is not totally transparent at L-Band at H-pol
- Refraction and impedance matching caused by snow is related to snow density (Lemmetyinen et al., 2016)
- The amount of ice in the soil impact the TB in winter
- At OBS, we saw a small F/T signal from the vegetation
- Tree F/T signal also well capture with permittivity probe
- But the strongest F/T signal come from the soil
- The smoother F/T signal in boreal forest probably come from soil freezing spatial variability

Merci !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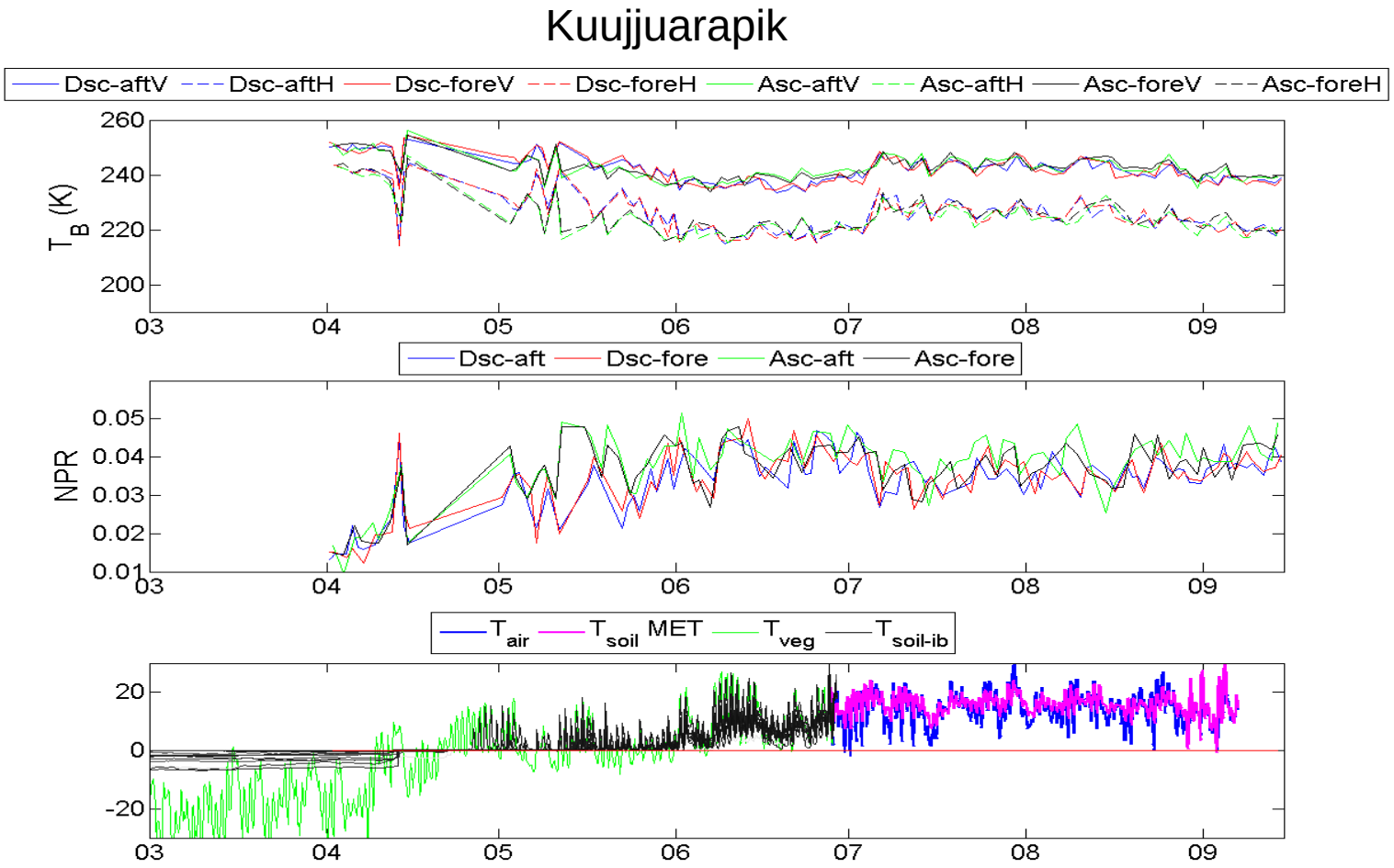
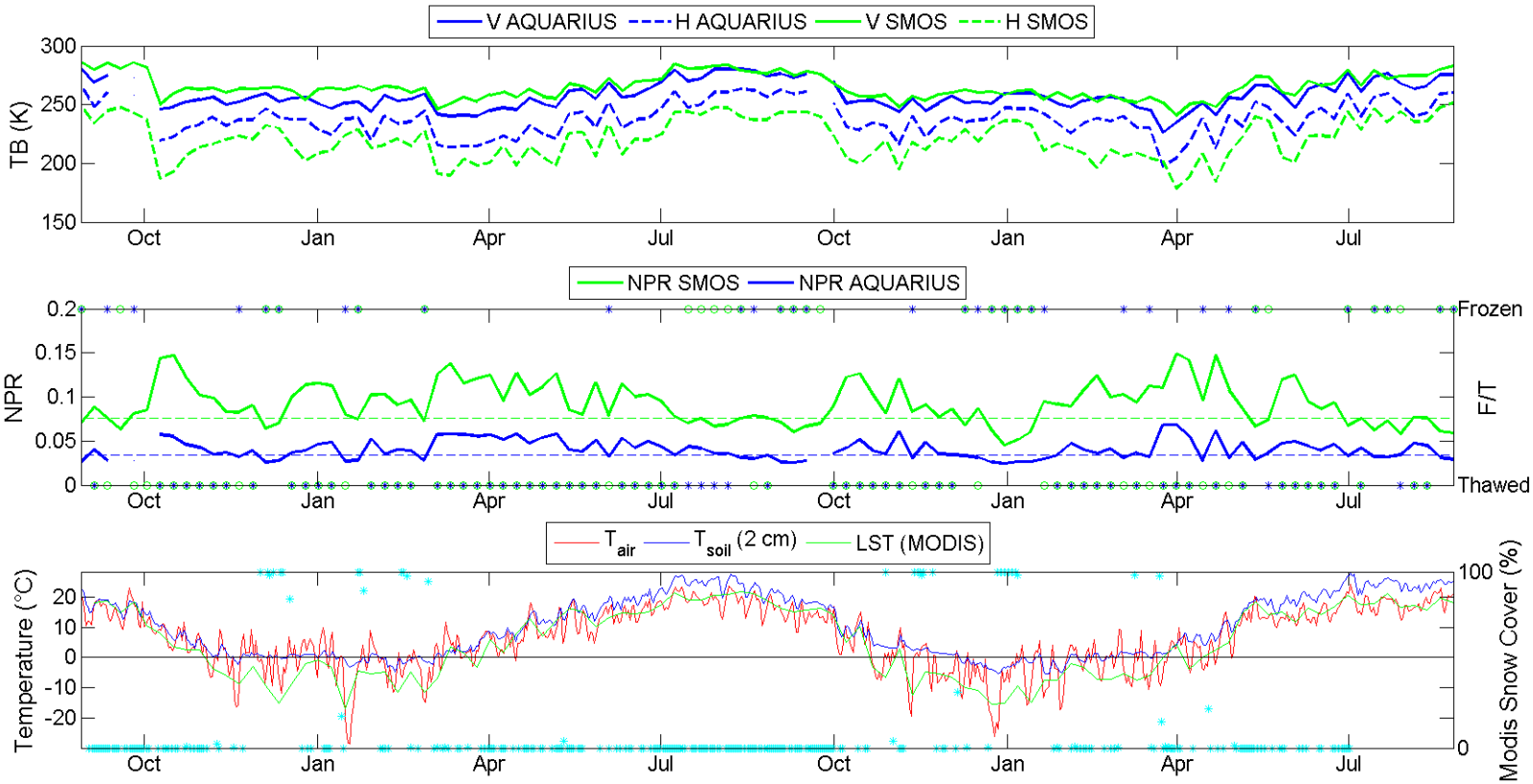
Expérimentations
Gel/Dégel vu des satellites (SMAP)



- Frozen soil with a certain T_{soil} variability in winter
- Catch some small F/T events

Expérimentations

Gel/Dégel vu des satellites (SMOS & Aquarius)



- TB increase during summers → seasonal crop growth cycle
- Many melt events in winter
- SMOS at 55-60° and Aquarius at 38.9°

Expérimentations
Gel/Dégel vu des satellites (SMOS & Aquarius)

- Évaluer la performance des algorithmes de détection du gel / dégel avec :
  - SMOS
  - Aquarius

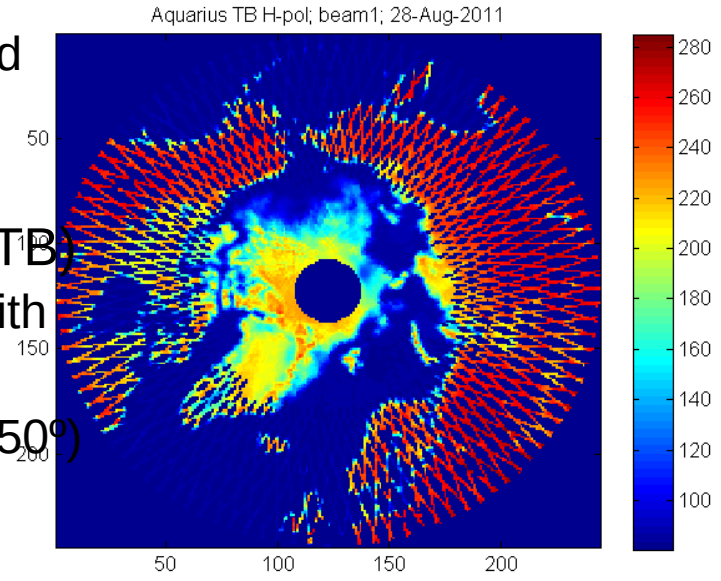
- Évaluer l'effet de la couverture du sol et des caractéristiques du radiomètre sur la détection du gel / dégel

Roy A., A. Royer, C. Derksen, L. Brucker, A. Langlois, A. Mialon, Y. H. Kerr (2015) Evaluation of Spaceborne L-band radiometer measurements for terrestrial Freeze/Thaw retrievals in Canada, IEEE JSTARS, DOI:10.1109/JSTARS.2015.2476358.

Expérimentations
Gel/Dégel vu des satellites (SMOS & Aquarius)

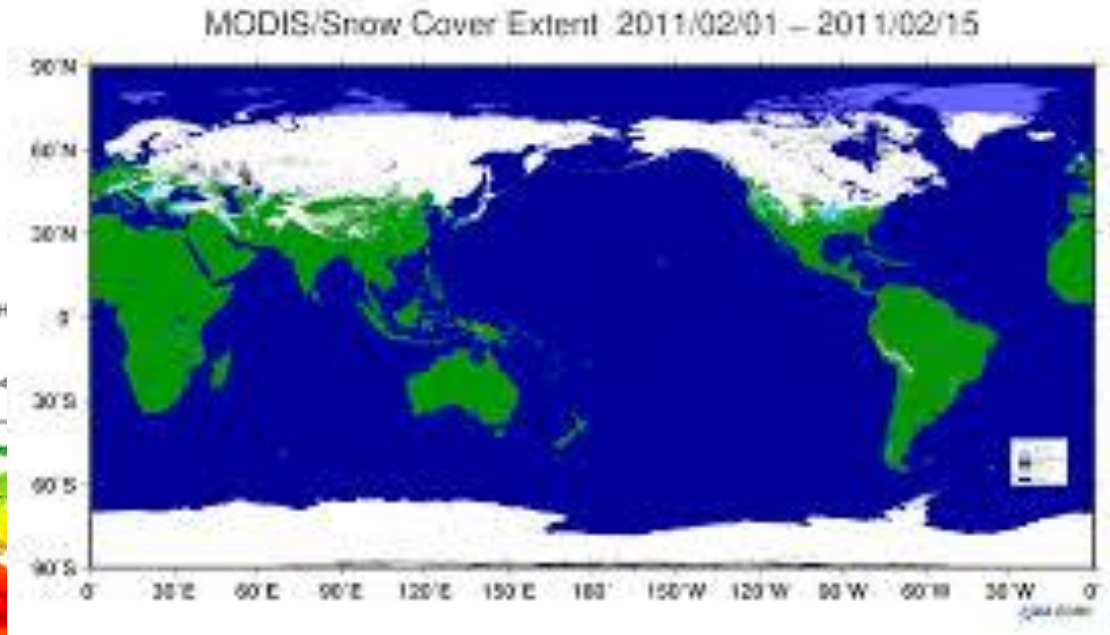
- Aquarius weekly-polar gridded T_B (Brucker et al., *The Cryosphere*, 2014)
  - 3 beams (29.2º; 38.4º; 46.3º)
  - Gridded on a 36 x 36 km EASE-grid
  - Revisit time ≈ 7 days

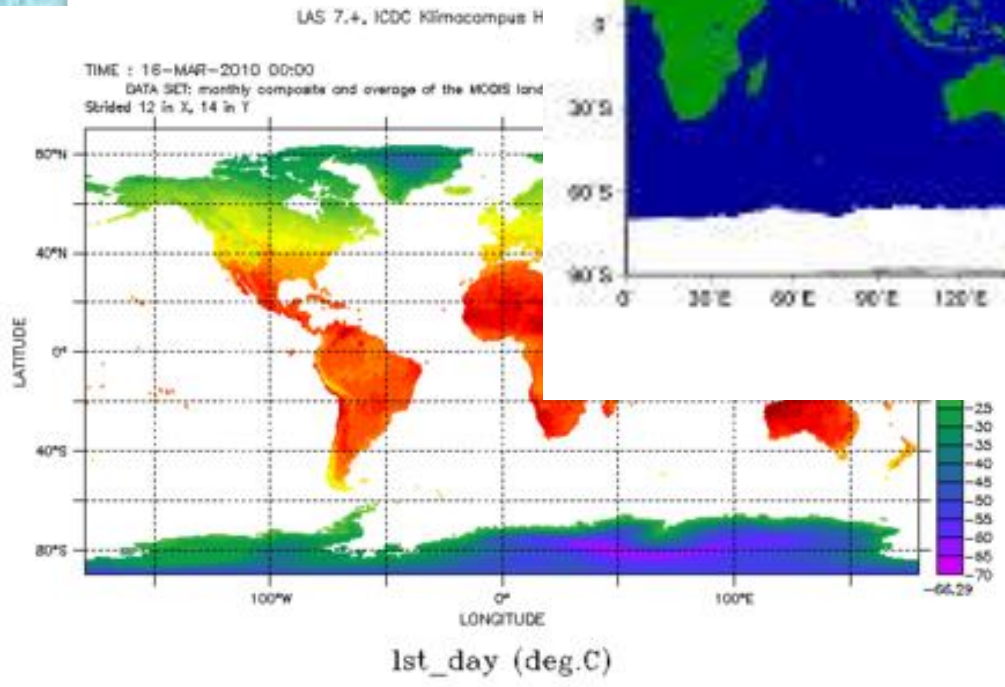
- SMOS daily reconstructed TB (L3TB)
  - Weekly averaged (for coherency with Aquarius)
  - 3 angle ranges (25-30º; 35-40º;45-50º)
  - (www.catds.fr/sipad/)



Expérimentations
Gel/Dégel vu des satellites (SMOS & Aquarius)

MODIS Snow cover (MOD10)

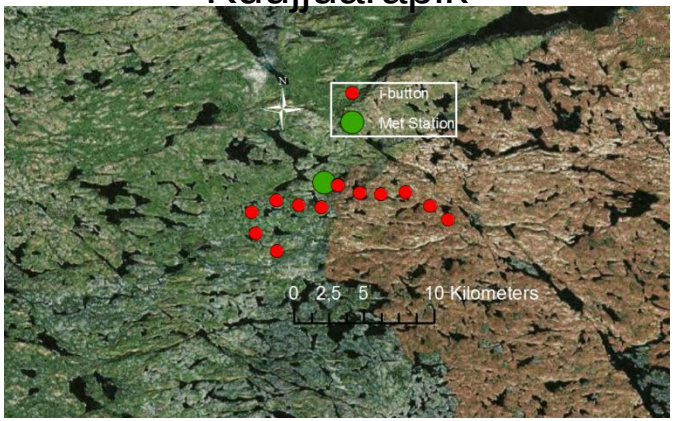




MODIS Land Surface Temperature (MOD11A1)

Expérimentations
Gel/Dégel vu des satellites (SMAP)

Kuujjuarapik



Baie-James

- Station météo “Near-real time” (données transmises hebdo.)
- Réseau de 13 sites avec i-button dans le sol (2 cm and 10 cm)
- Réseau de 4 i-button dans les arbres