Using JULES to understand the SMOS freeze/thaw product over a boreal landscape

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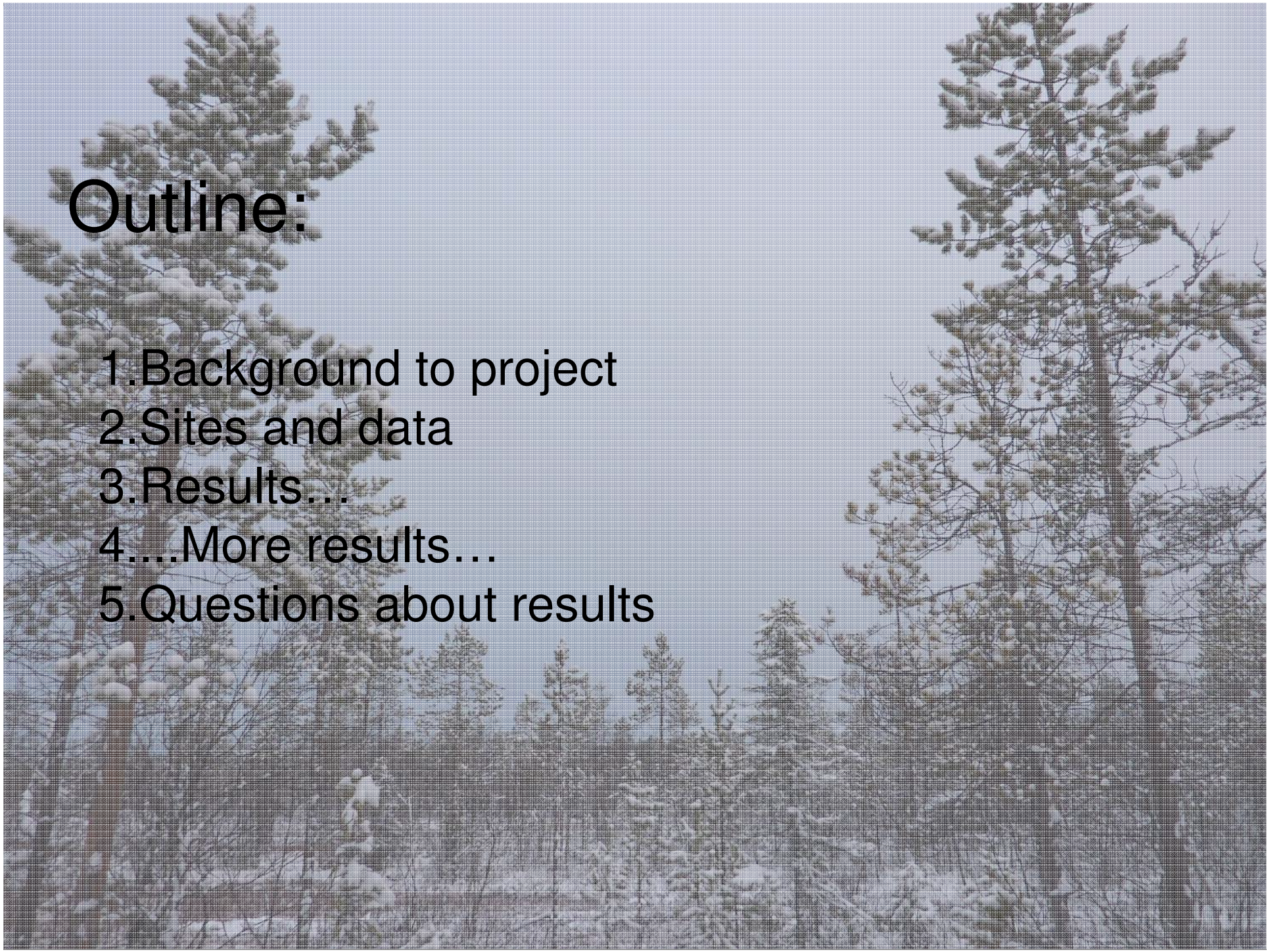


Outline:

1. Background to project
2. Sites and data
3. Results…
4. ….More results…
5. Questions about results

SMOS

ESA SMOS (Soil Moisture Ocean Salinity) mission

ESA's "water mission" to improve our understanding of the water cycle.

Measures microwave radiation at L-band

Soil moisture maps:

- Spatial resolution: ~ 43km, EASE-grid = 25 km
- Temporal resolution: 3 days

SMOS+ Innovation Permafrost

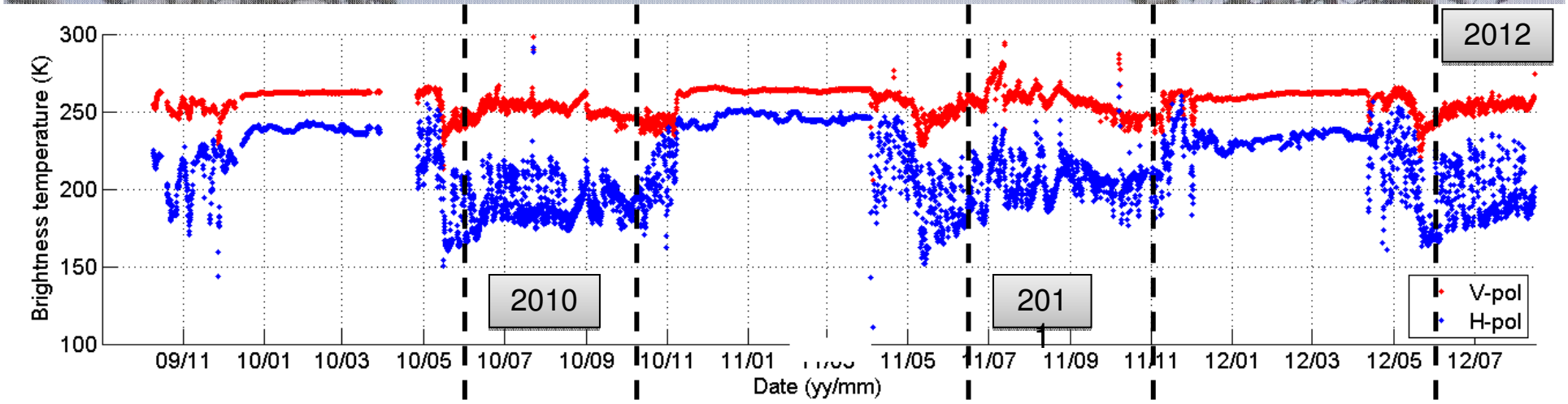
Aim: To investigate the feasibility of L-band space-borne radiometry to monitor soil processes in boreal/sub-arctic environments and to develop methods for such monitoring.

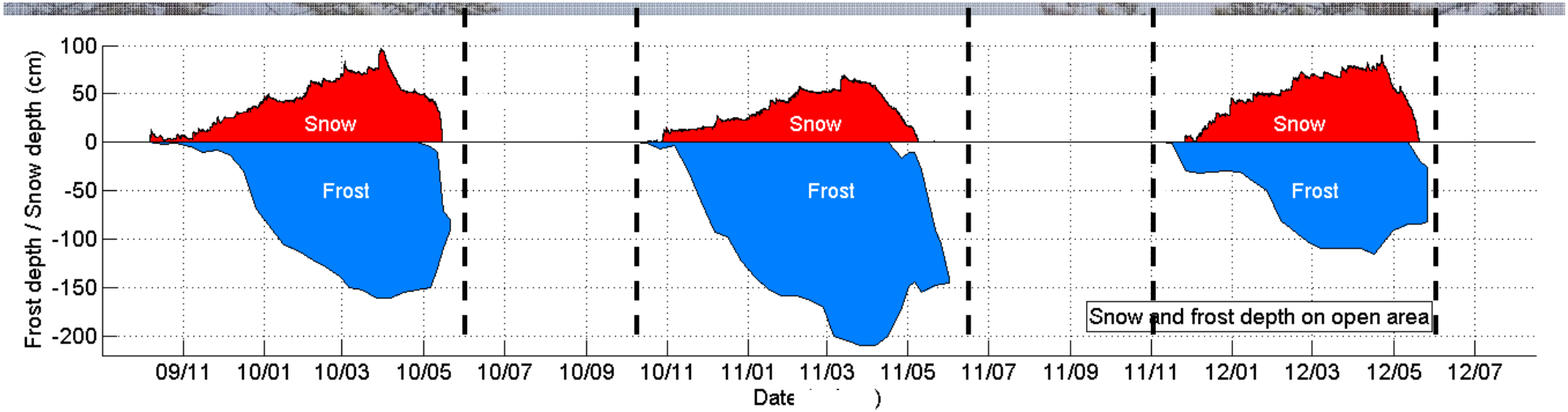
Objective: Monitoring freezing/thawing processes by means of remote sensing.

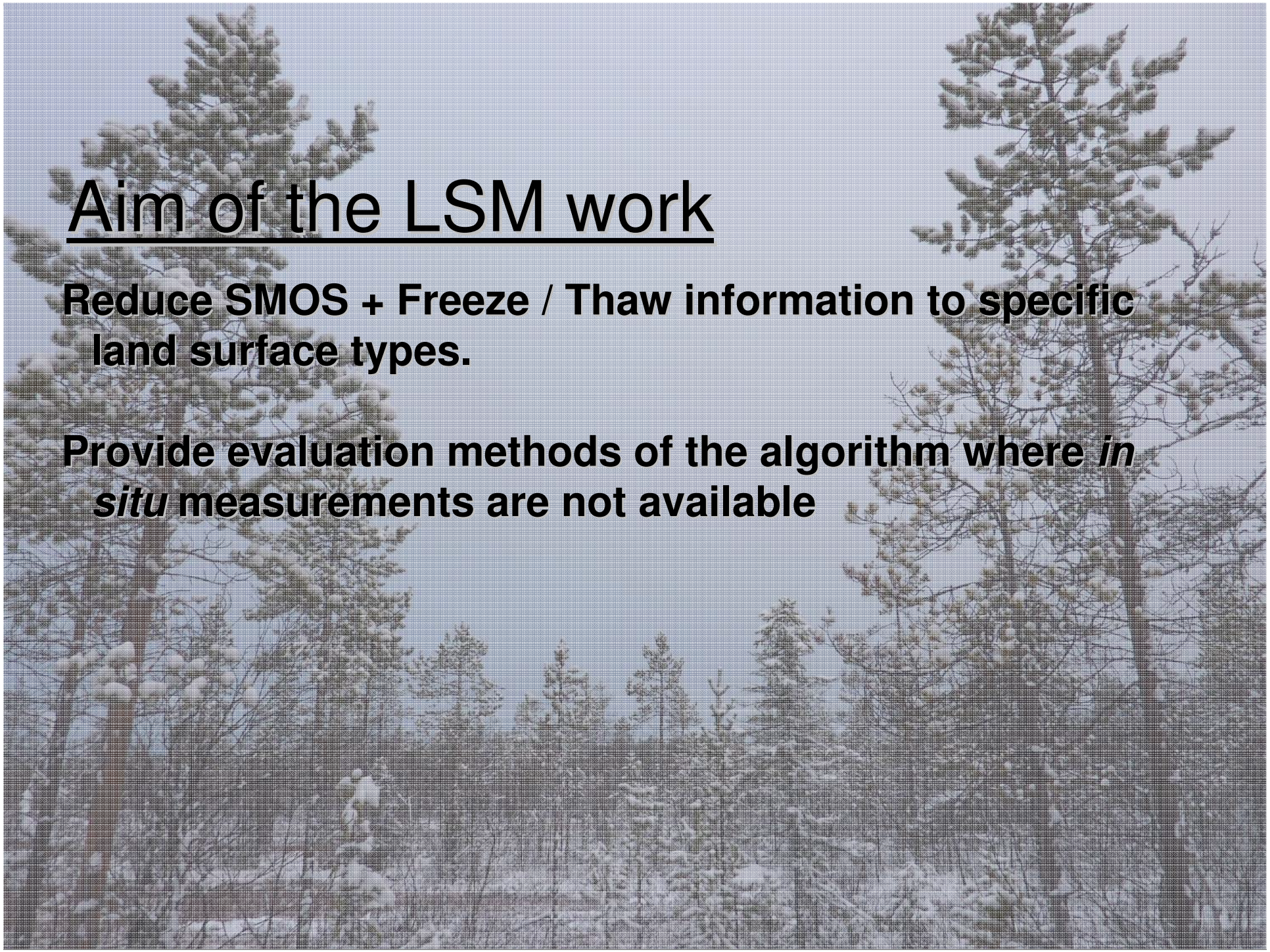
Simple algorithm to determine the state of the soil using SMOS –frost, no frost ?

SMOS

Summer period: higher variability in the signal, larger polarization difference







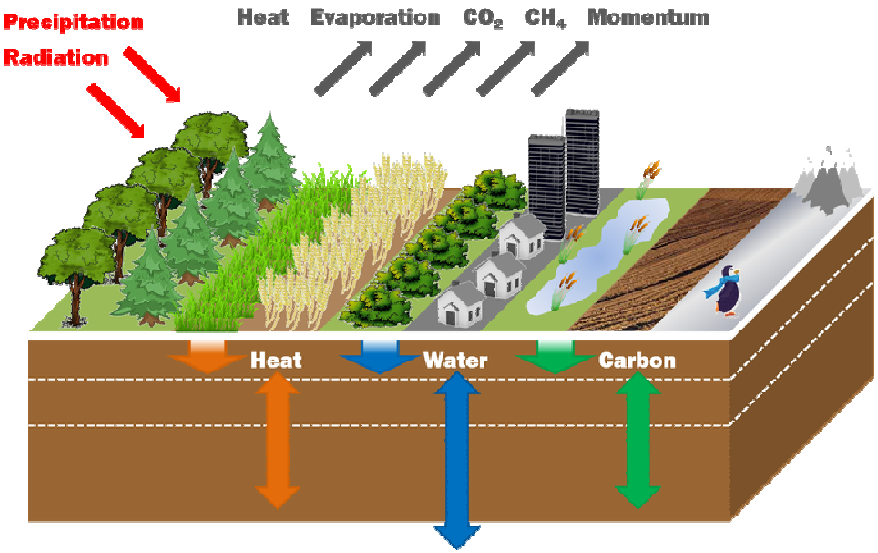
Aim of the LSM work

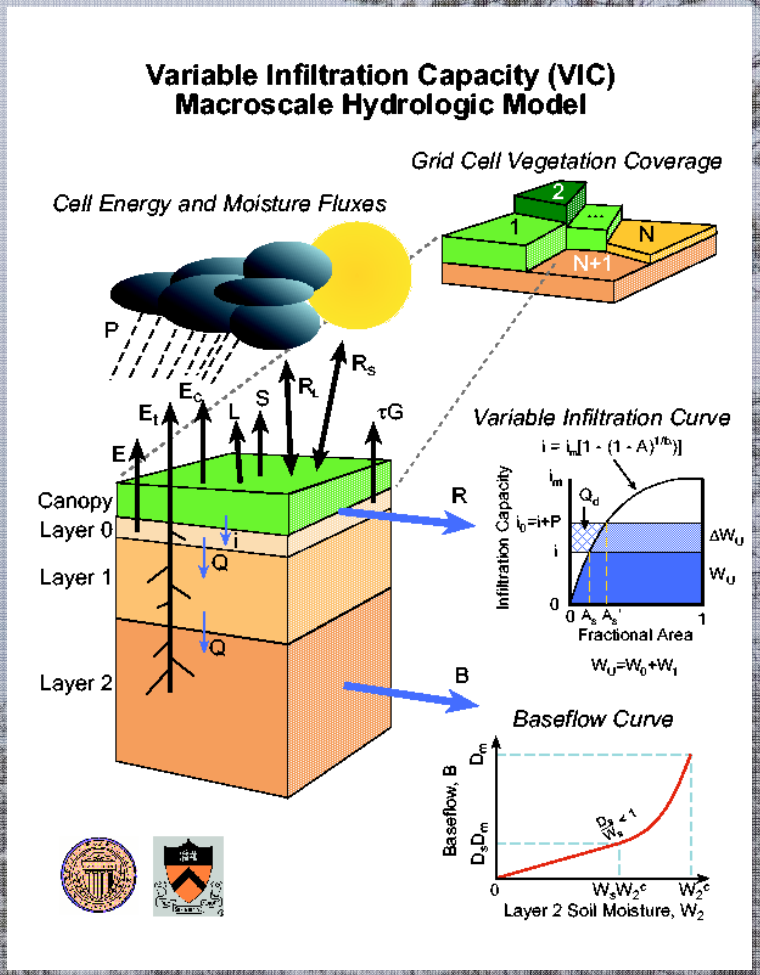
Reduce SMOS + Freeze / Thaw information to specific land surface types.

Provide evaluation methods of the algorithm where *in situ* measurements are not available

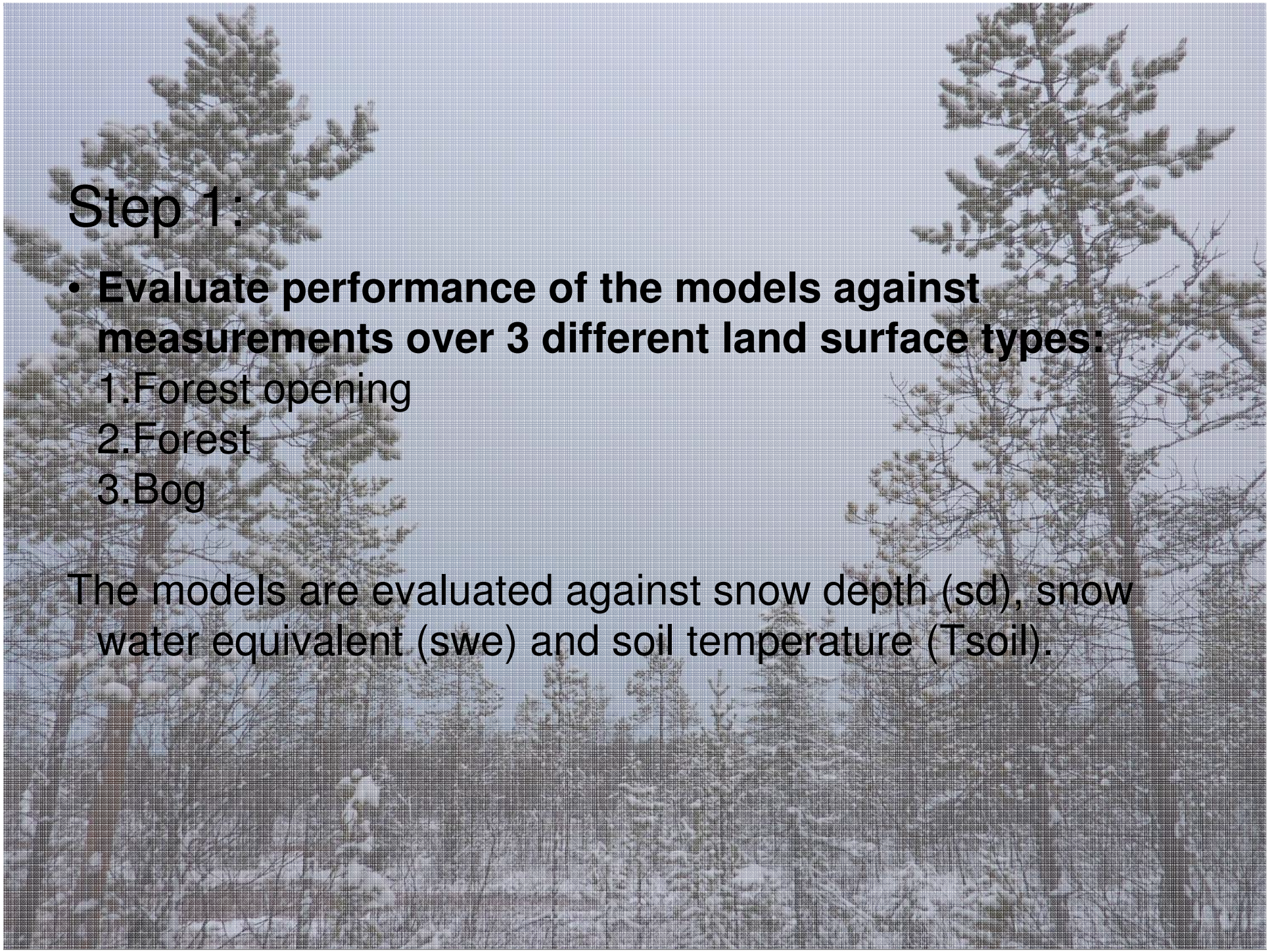
The Models:

JULES





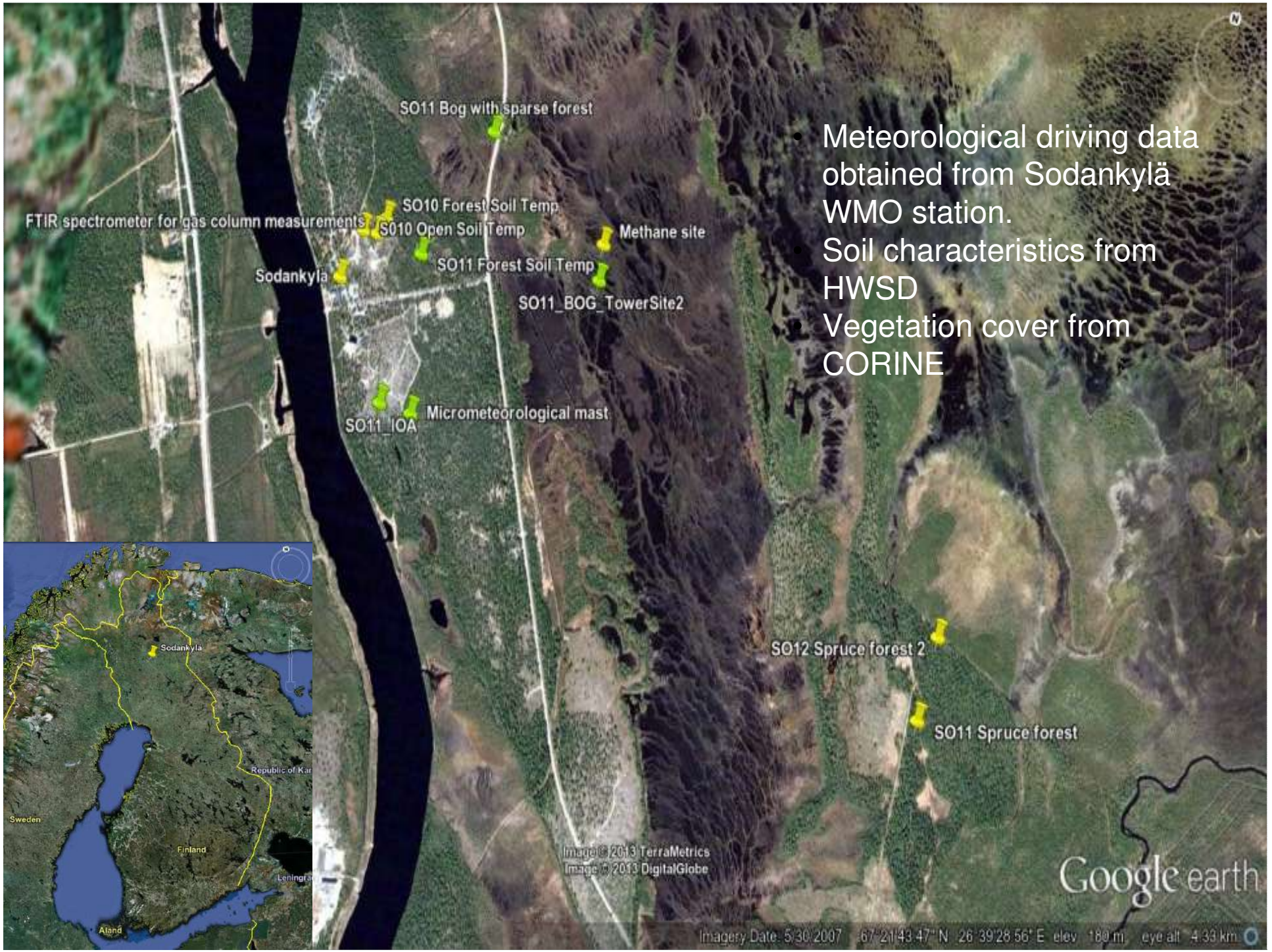
From http://www.hydro.washington.edu/Lettenmaier/Models/VIC/images/VIC_grid_cell_schematic.gif



Step 1:

- **Evaluate performance of the models against measurements over 3 different land surface types:**
  1. Forest opening
  2. Forest
  3. Bog

The models are evaluated against snow depth (sd), snow water equivalent (swe) and soil temperature (Tsoil).



- Meteorological driving data obtained from Sodankylä WMO station.
- Soil characteristics from HWSD
- Vegetation cover from CORINE

The sites:

<u>Forest opening</u>

Sd, SWE, Tsoil, Soil moisture, Microwave Tb

The sites:

Forest

Sd,Tsoil,
soil moisture

The sites:

<u>Bog (Peatland) site</u>

Sd, SWE (2 years)
Tsoil (1 year)
Elbara Tb since 08/12

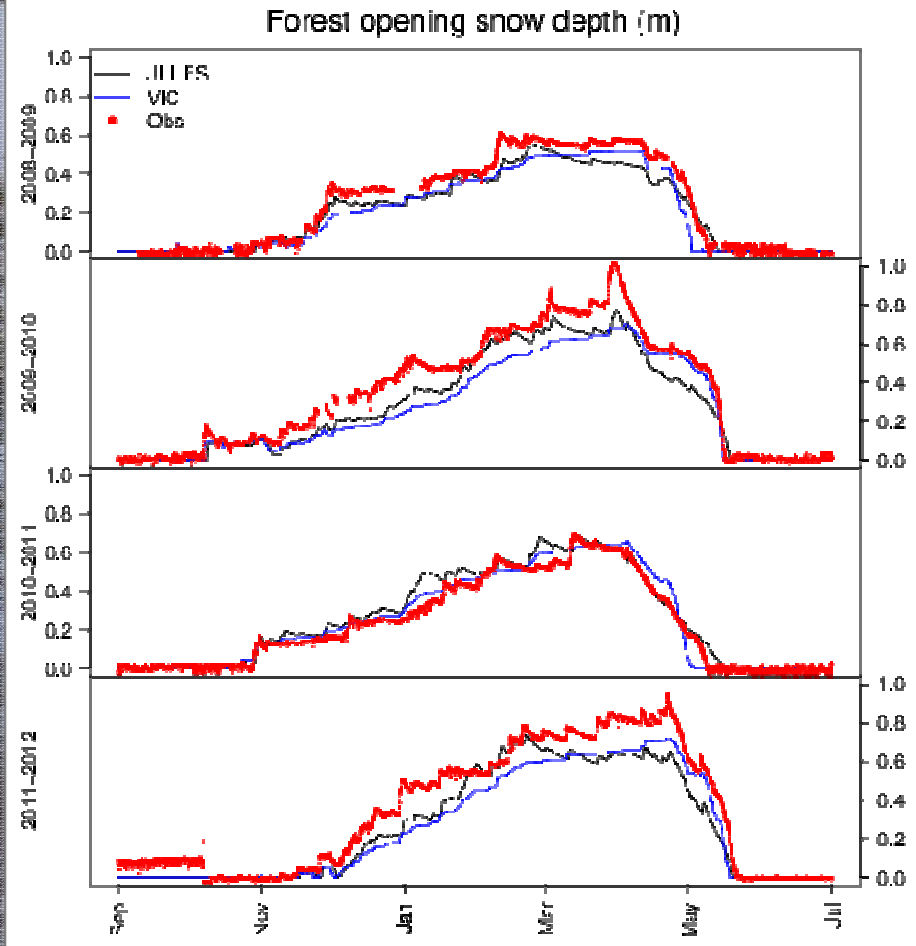
The data

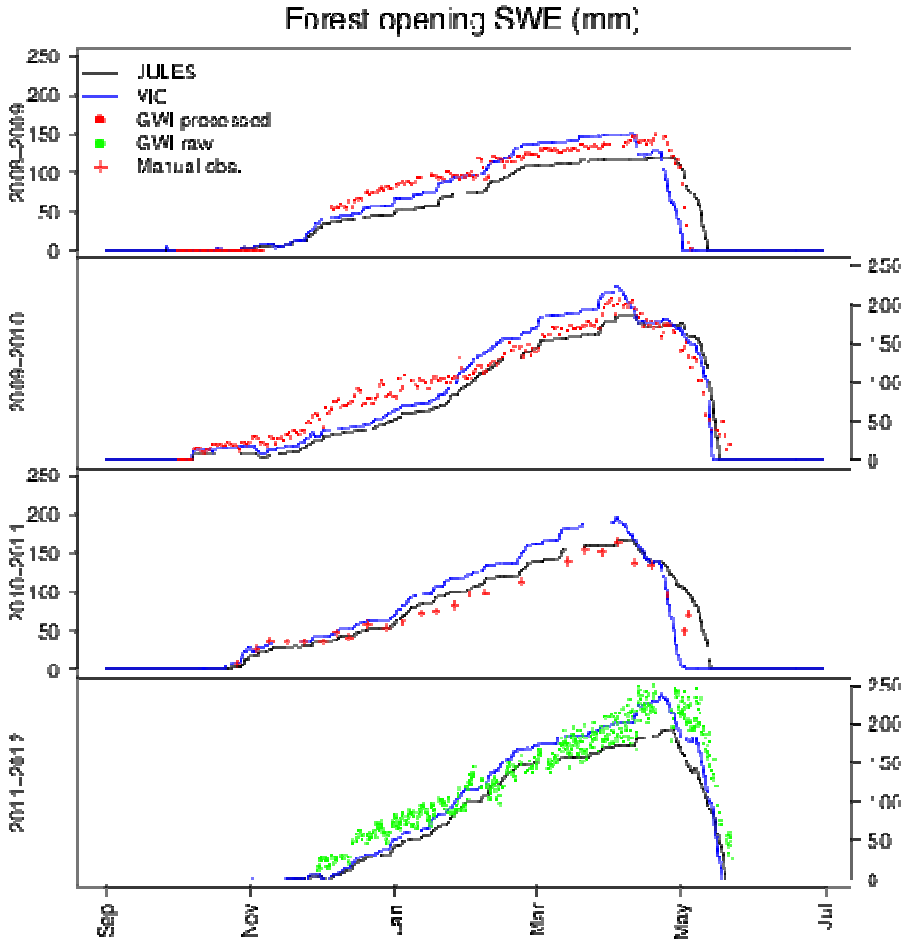
	Season	30 -year average	2009-2010	2010-2011	2011-2012
Soil conditions	Onset of soil freezing (DOY)	298	289	289	320
Date of maximum frost depth (DOY)	91	91	90	107	
Onset of soil thaw (DOY)	132	126	116	132	
Date of soil thaw (DOY)	148	141	152	147	
Max. frost depth	160 cm	161 cm	210 cm	115 cm	
Snow conditions	Date of permanent snow cover (DOY)	299	279	300	329
Date of SWE maximum (DOY)	109	88	72	112	
Date of snow melt onset (DOY)	Not available	90	92	115	
Date of snow melt-off (DOY)	129	134	128	140	
Max SWE	186.5 +/- 41.9 mm (min 120 mm; max 267 mm)	225mm	165 mm	240 mm	

From

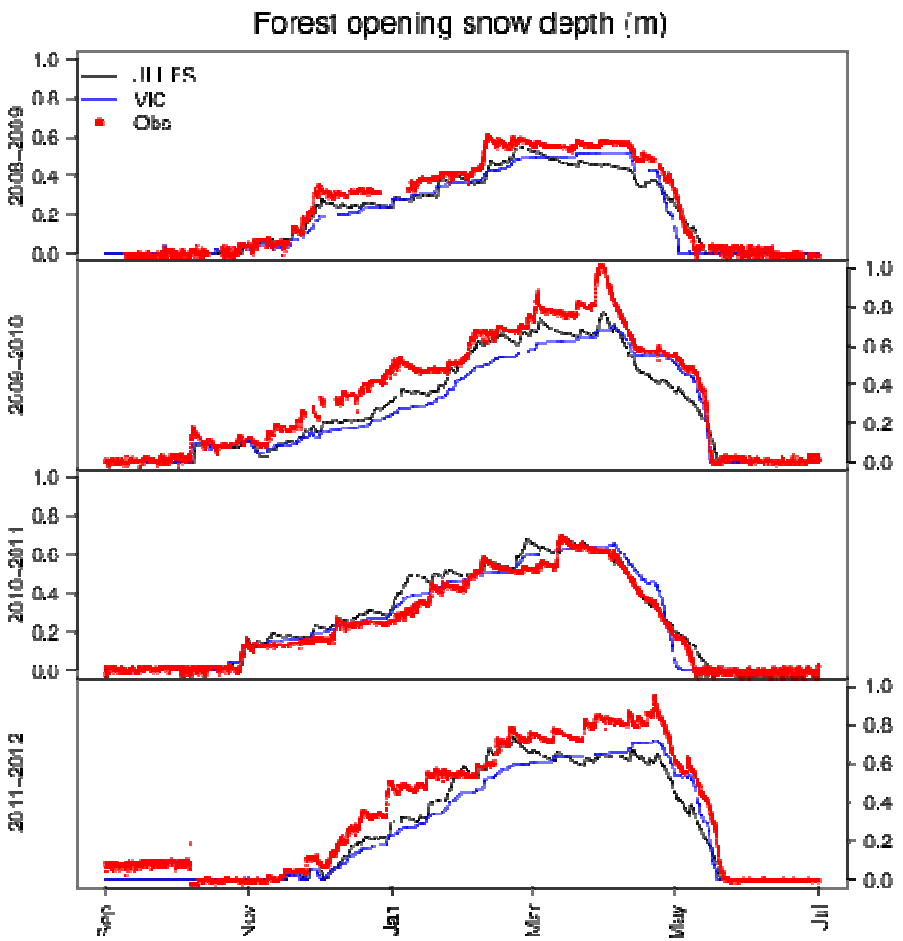
The results

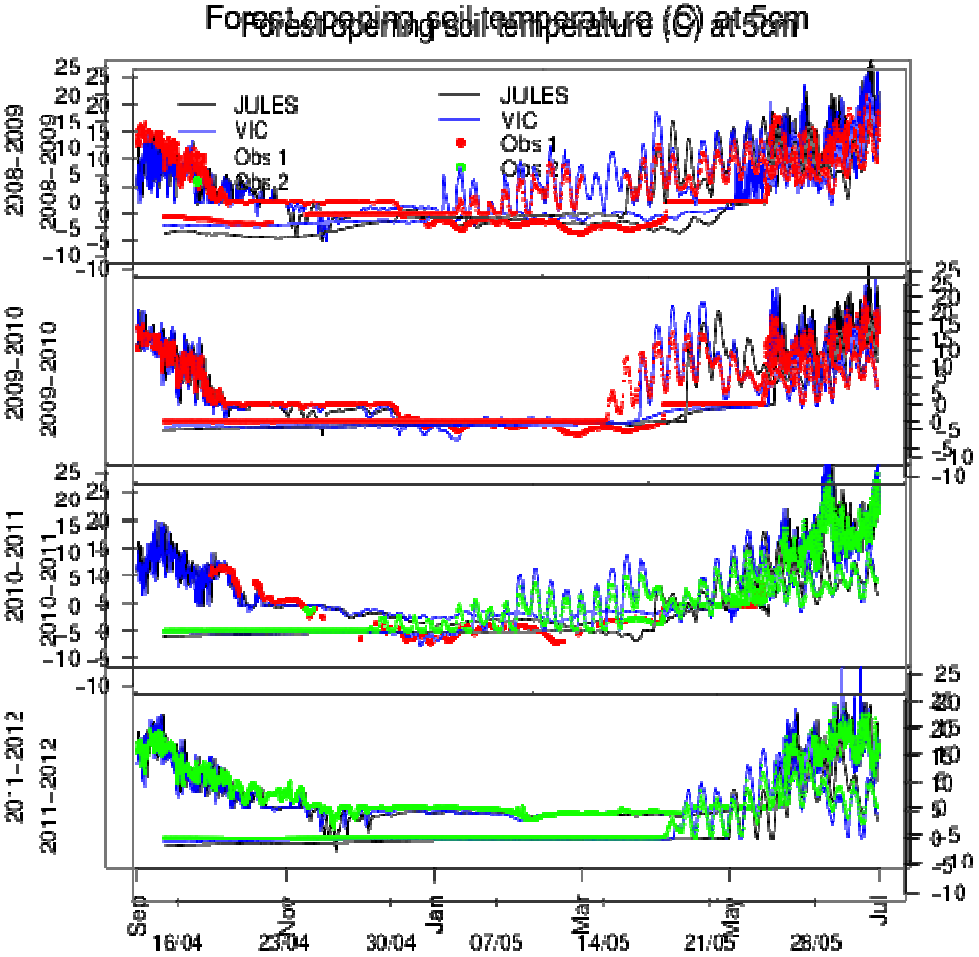
Results: Forest opening



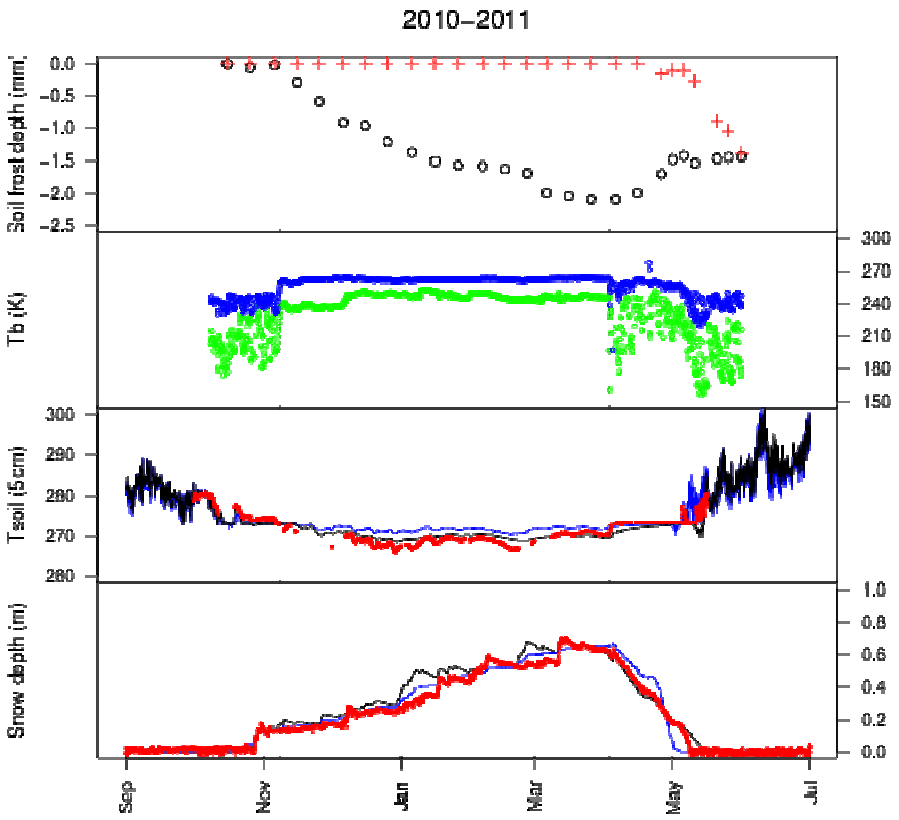


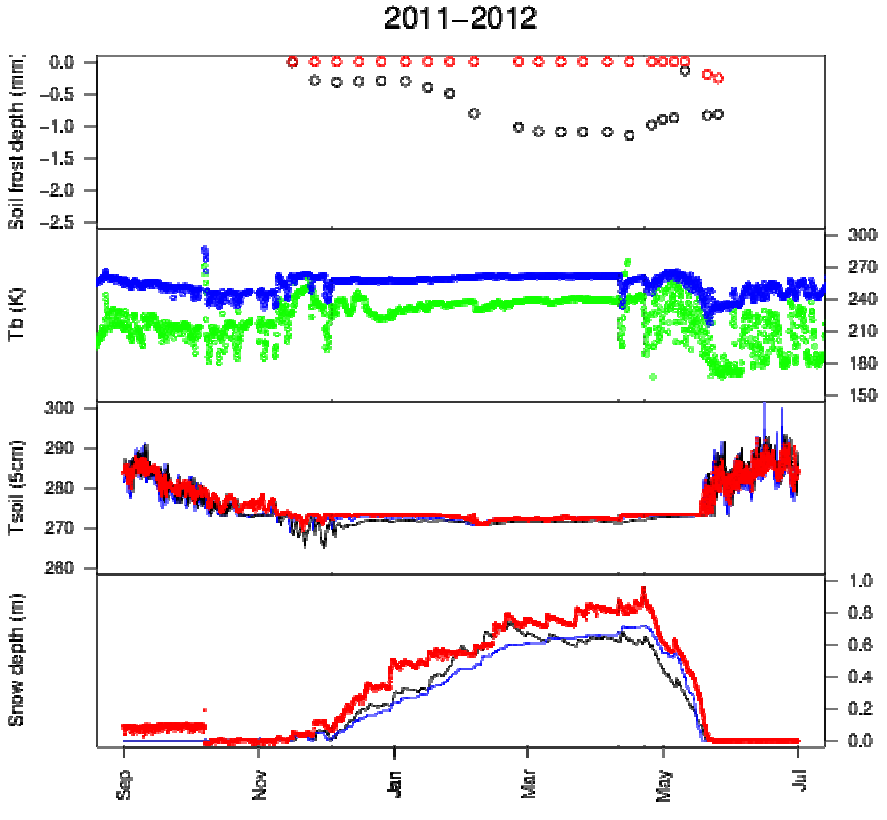
Results: Forest opening



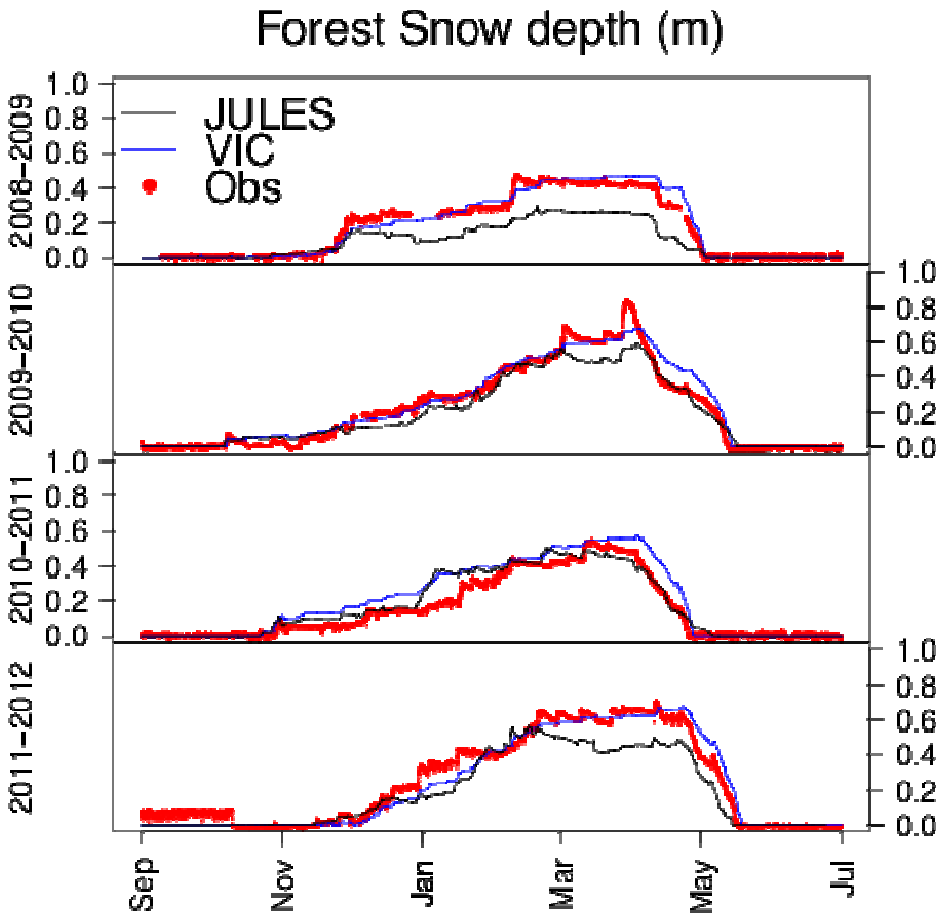


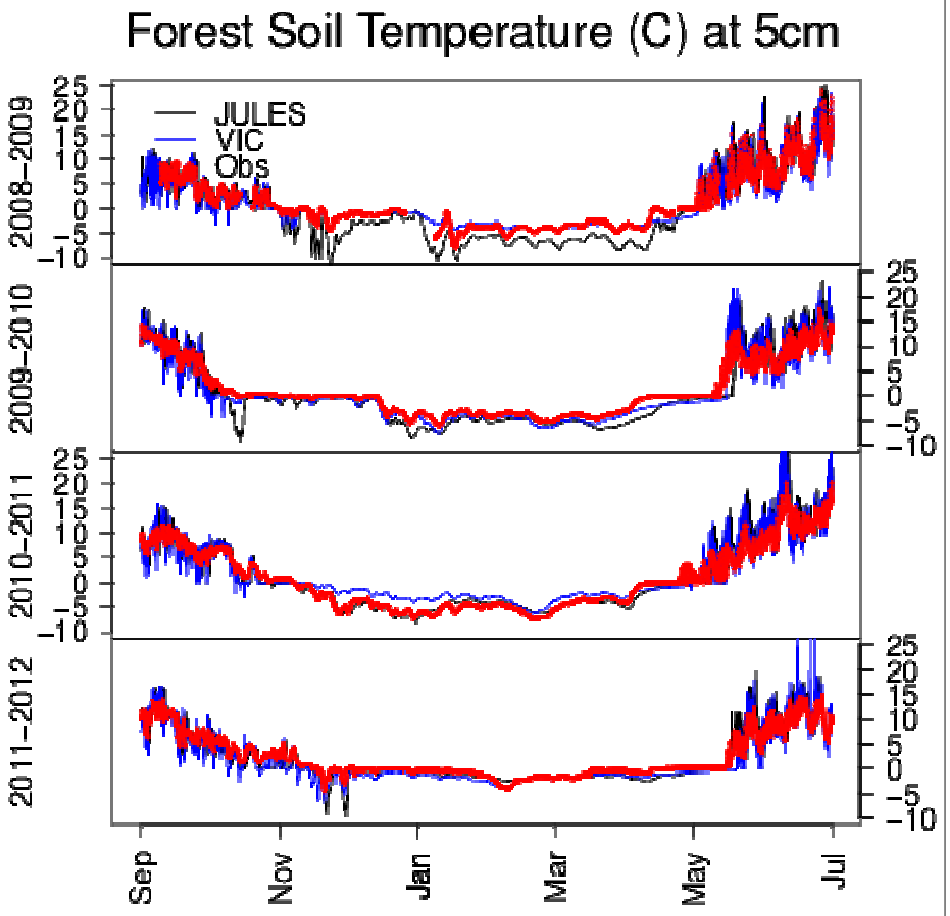
Results:
Comparison with ELBARA Tb



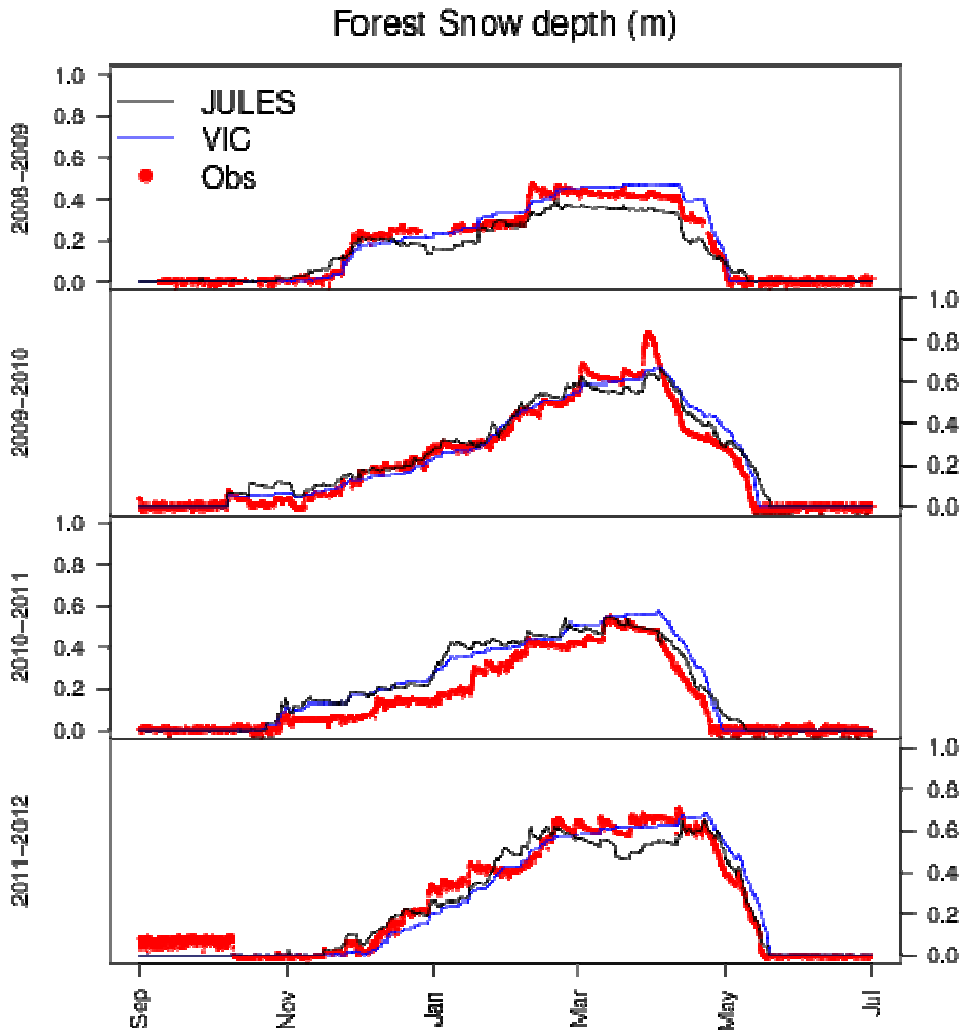


Results: Forest site





Results: Forest site



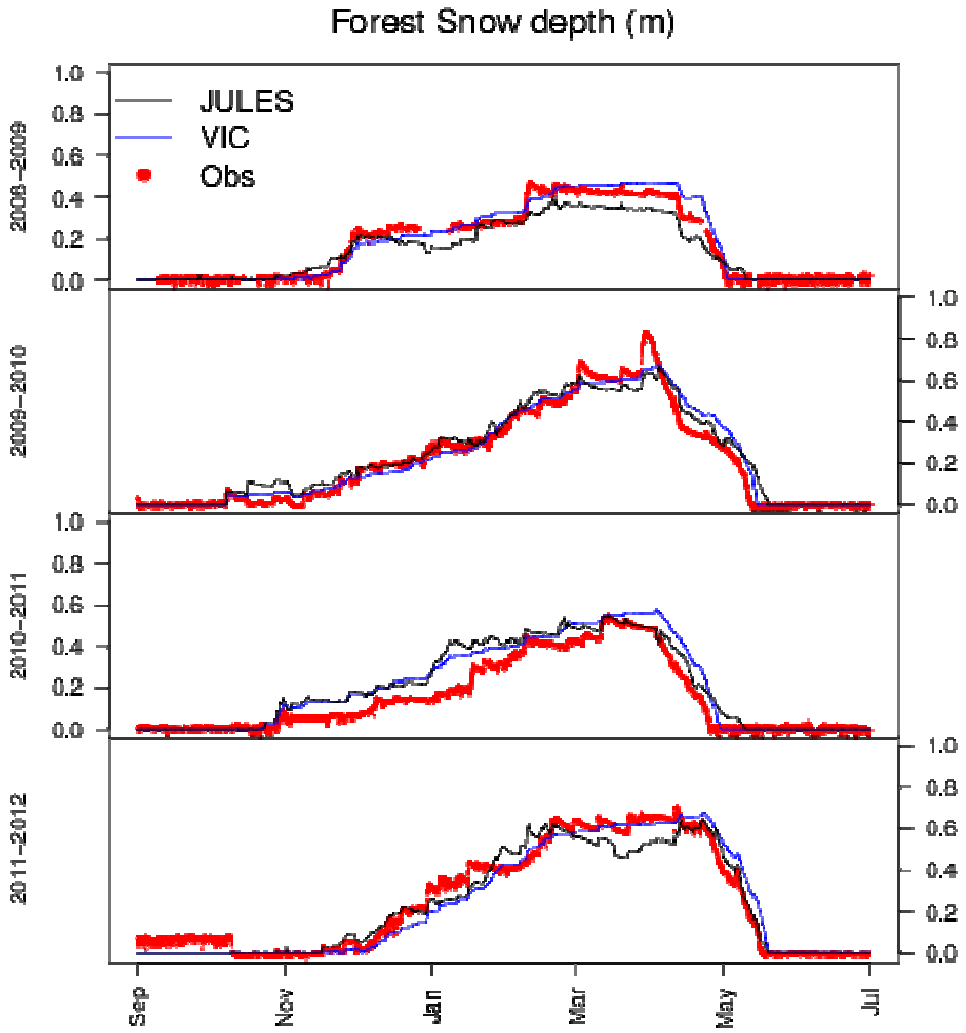
Snow parameters
(from Hedstrom and Pomeroy, 1998 & Essery et al. 2003)

Snowinterceptfact “Constant in relationship between mass of intercepted snow and snowfall rate”. Default: 0.7

Snowloadlai: ratio of maximum canopy snow load to LAI. Default: 4.4

Snowunloadfact: constant in relationship between canopy snow unloading and canopy snow melt rate”. Default: 0.4

Results: Forest site



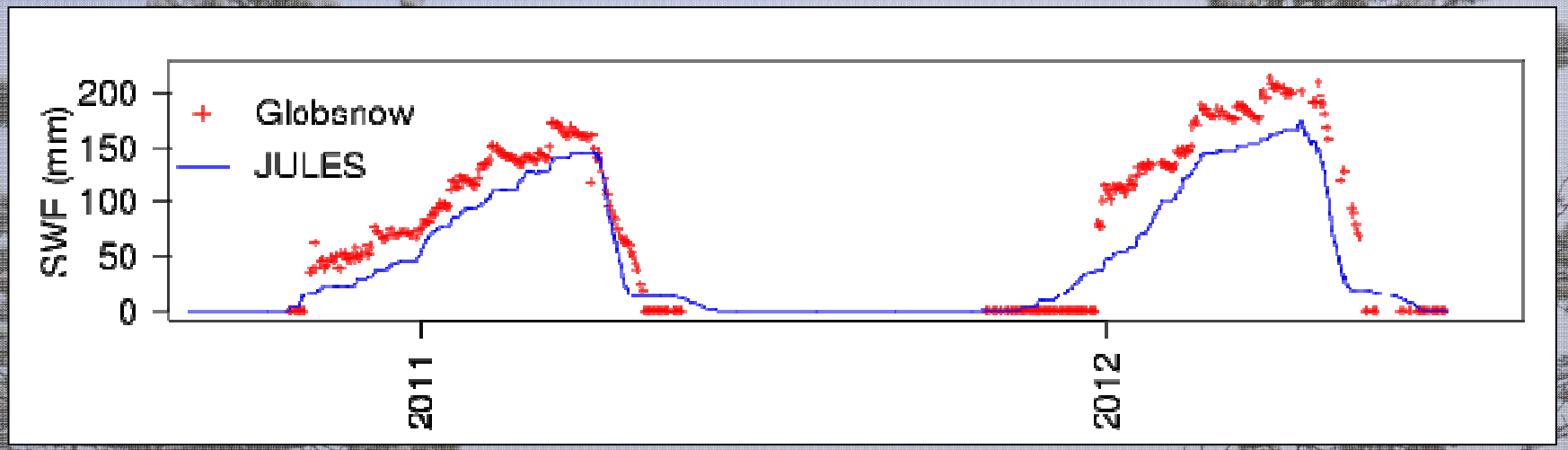
Snow parameters:

Snowinterceptfact “Constant in relationship between mass of intercepted snow and snowfall rate”. Default: 0.7 Changed to 0.2

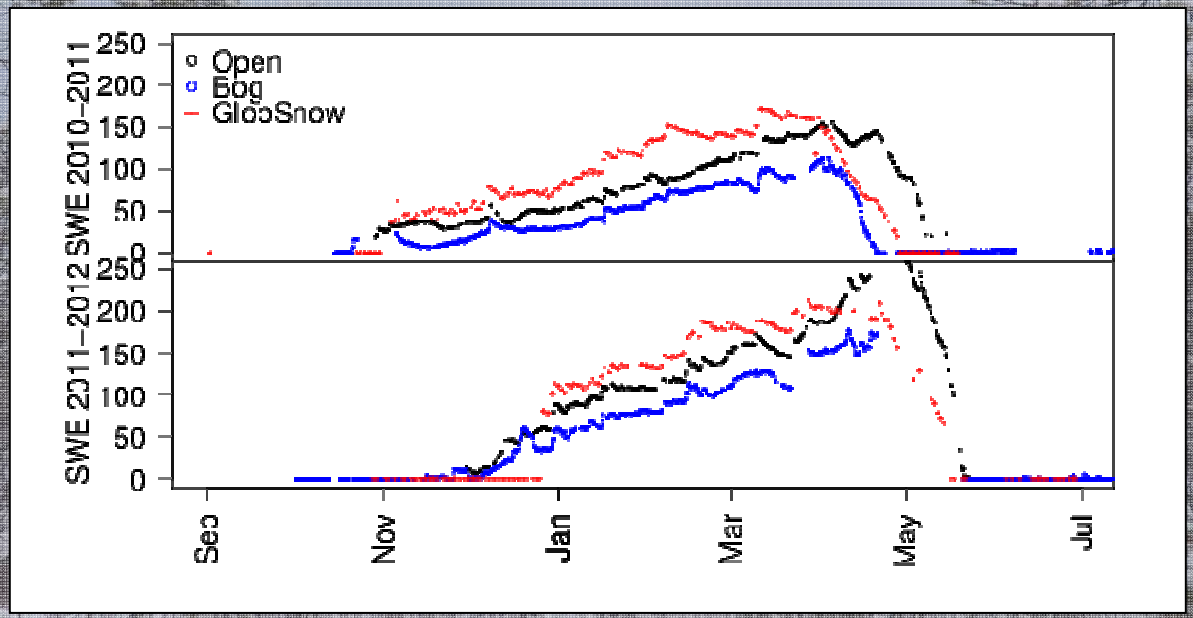
- 0.7 was measured on a weekly basis

- Fairly open canopy

JULES vs. Globsnow



Globsnow vs. in situ data



Results: Bog site

1.JULES represents wetlands but…

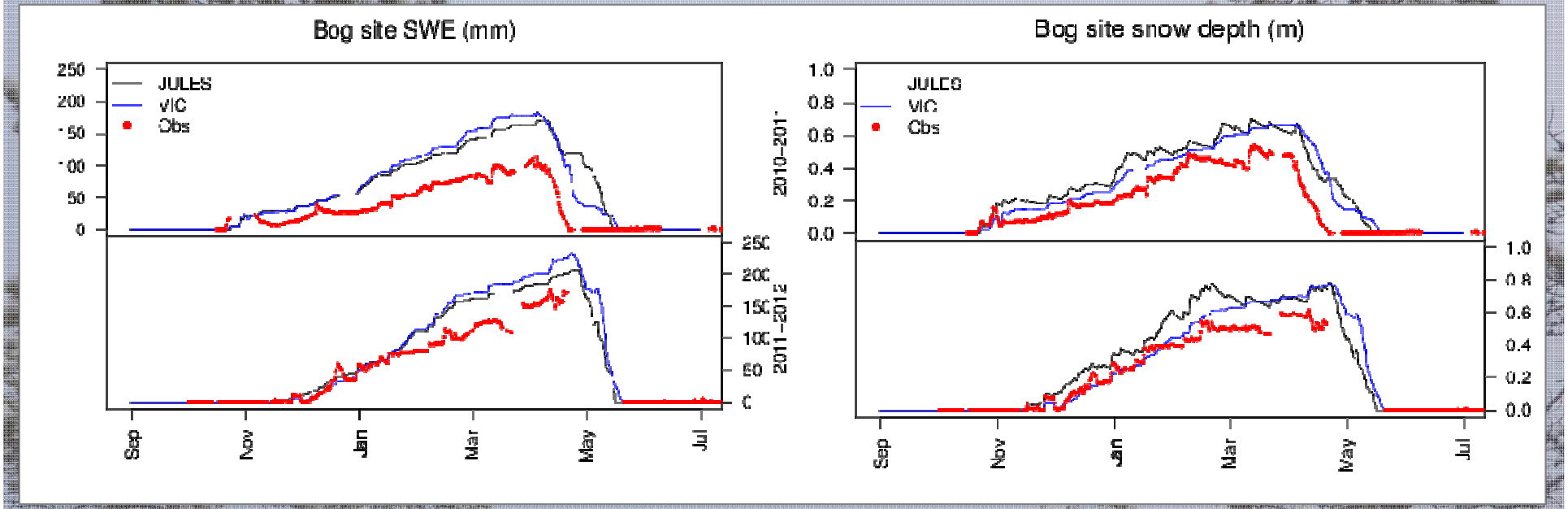
Results: Bog site

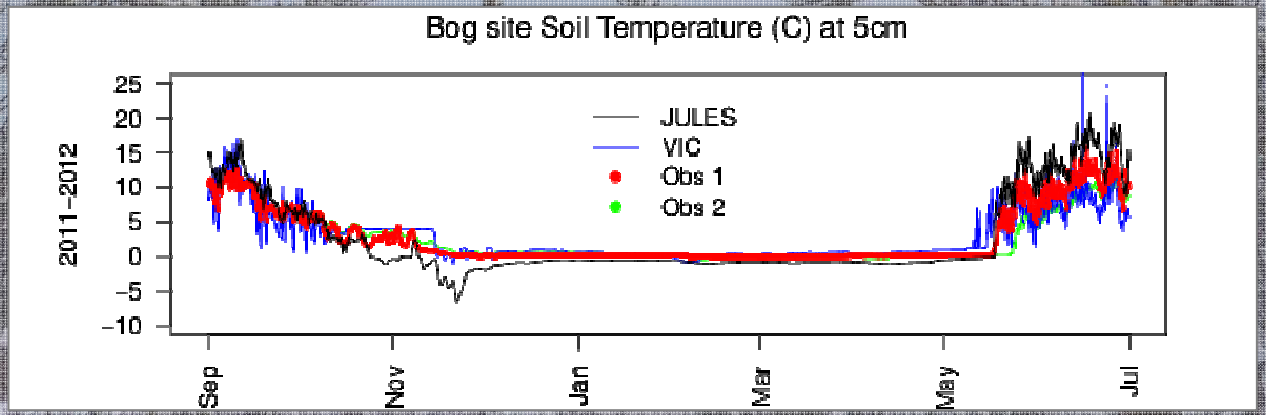
1.JULES represent wetlands but…
2.… are they more like lakes?

Results: Bog site

1.JULES represents wetlands but…
2.… are they more like lakes?
3.Organic soil in a mineral gridbox

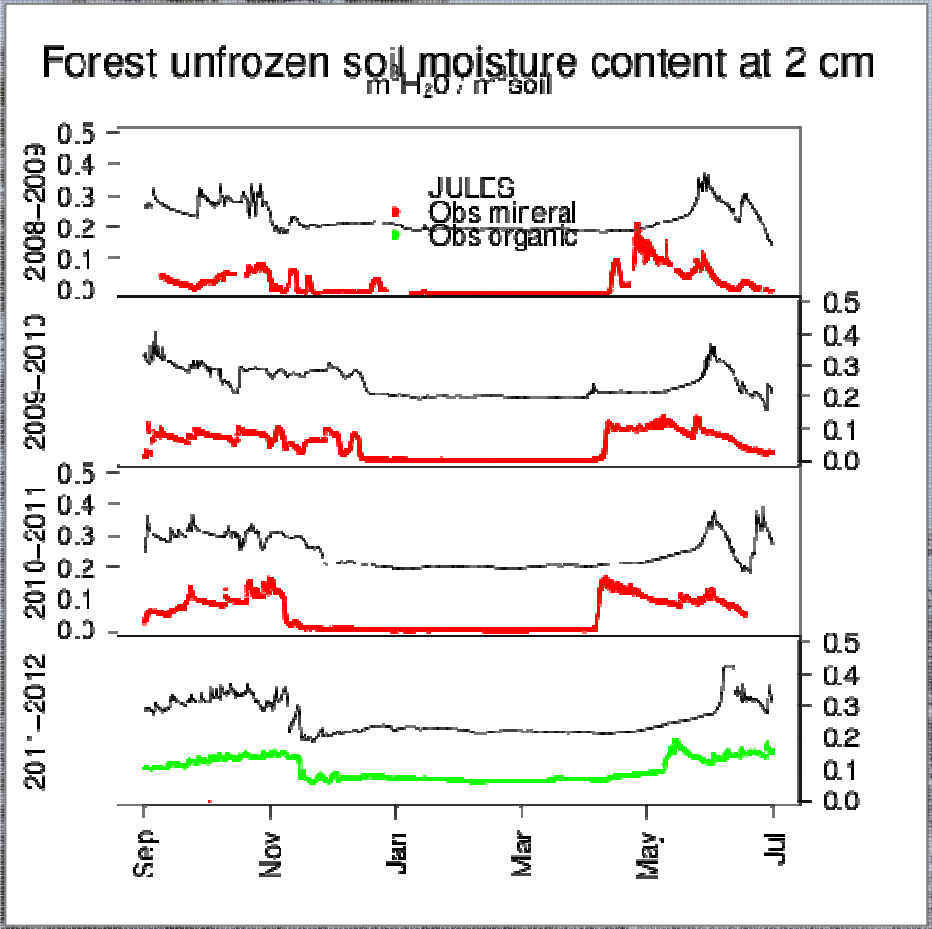
Results: Bog site

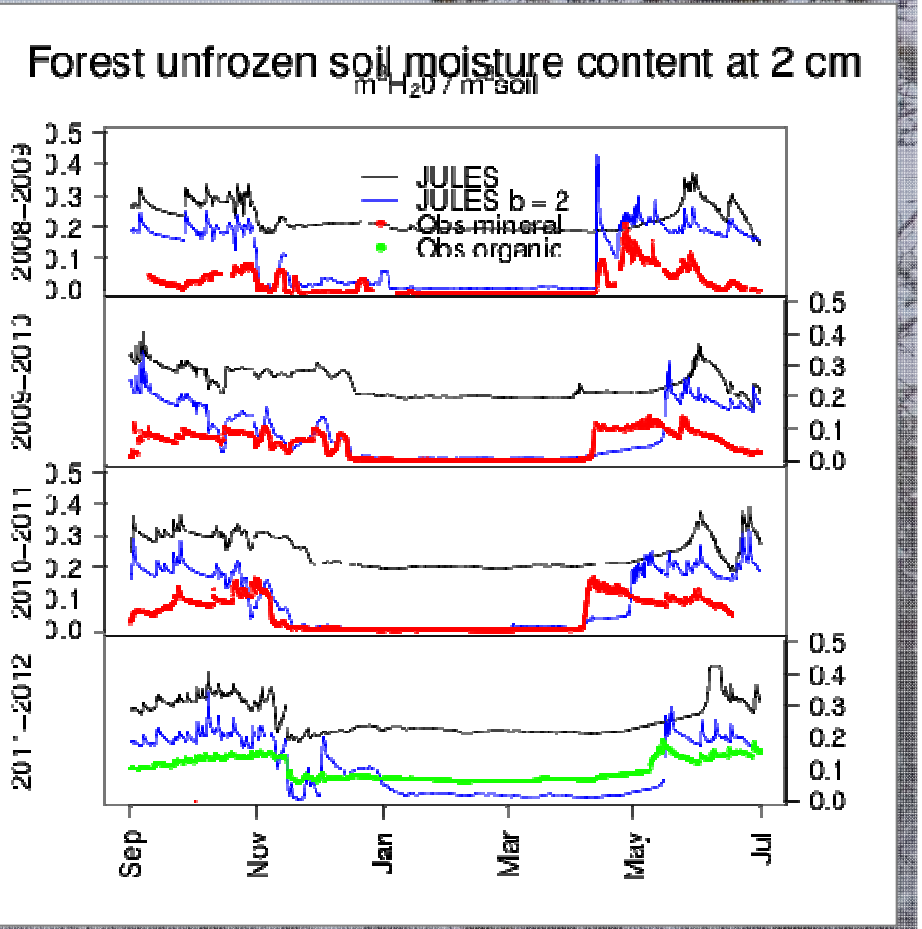




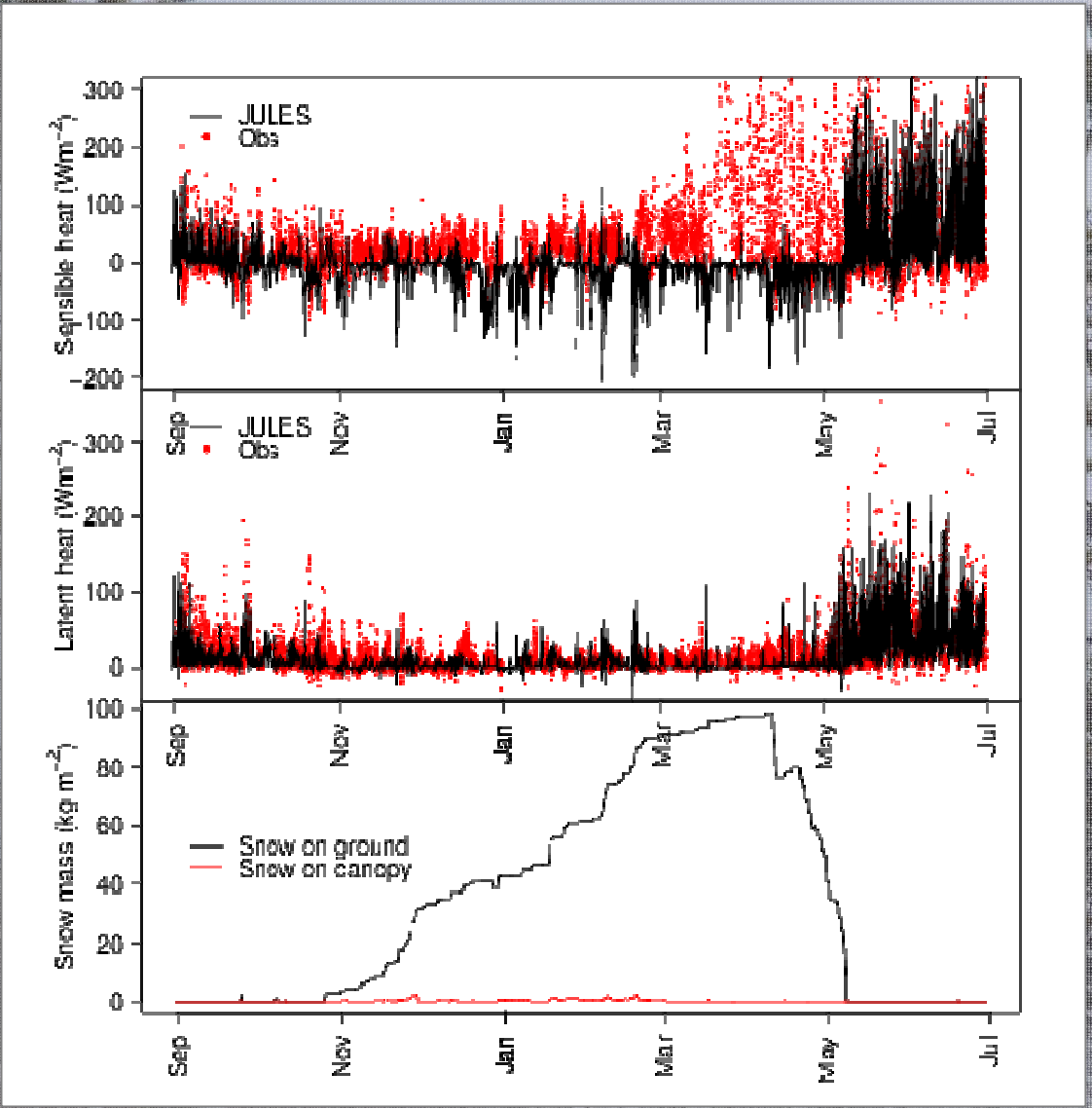
Results: Soil moisture

Soil texture from HWSD
Brooks and Corey / Clapp & Hornberger model
Regression analyses by Cosby et al. (1984) for hydraulic properties
Farouki (1981) for thermal conductivity



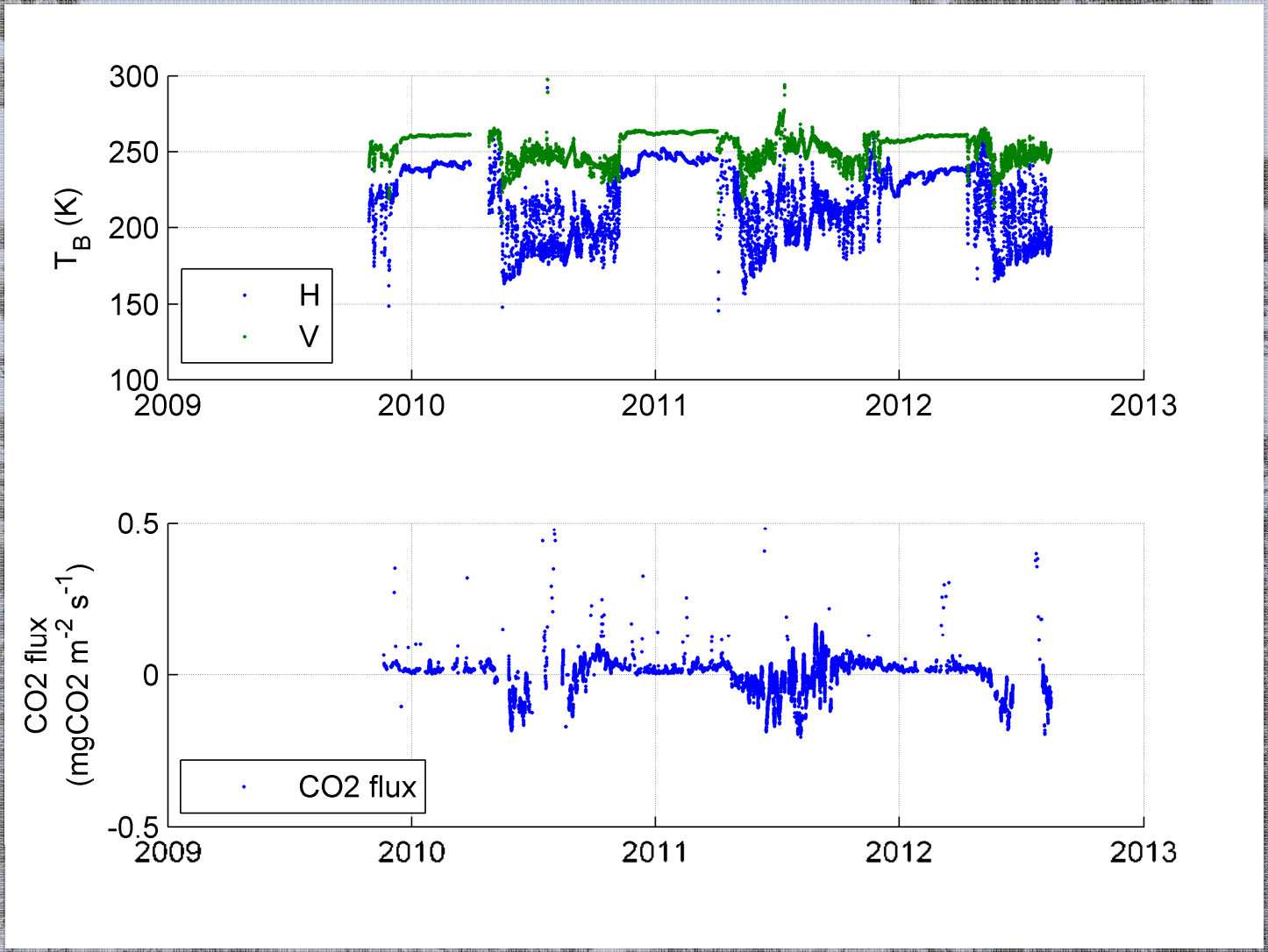


Results: Turbulent Fluxes

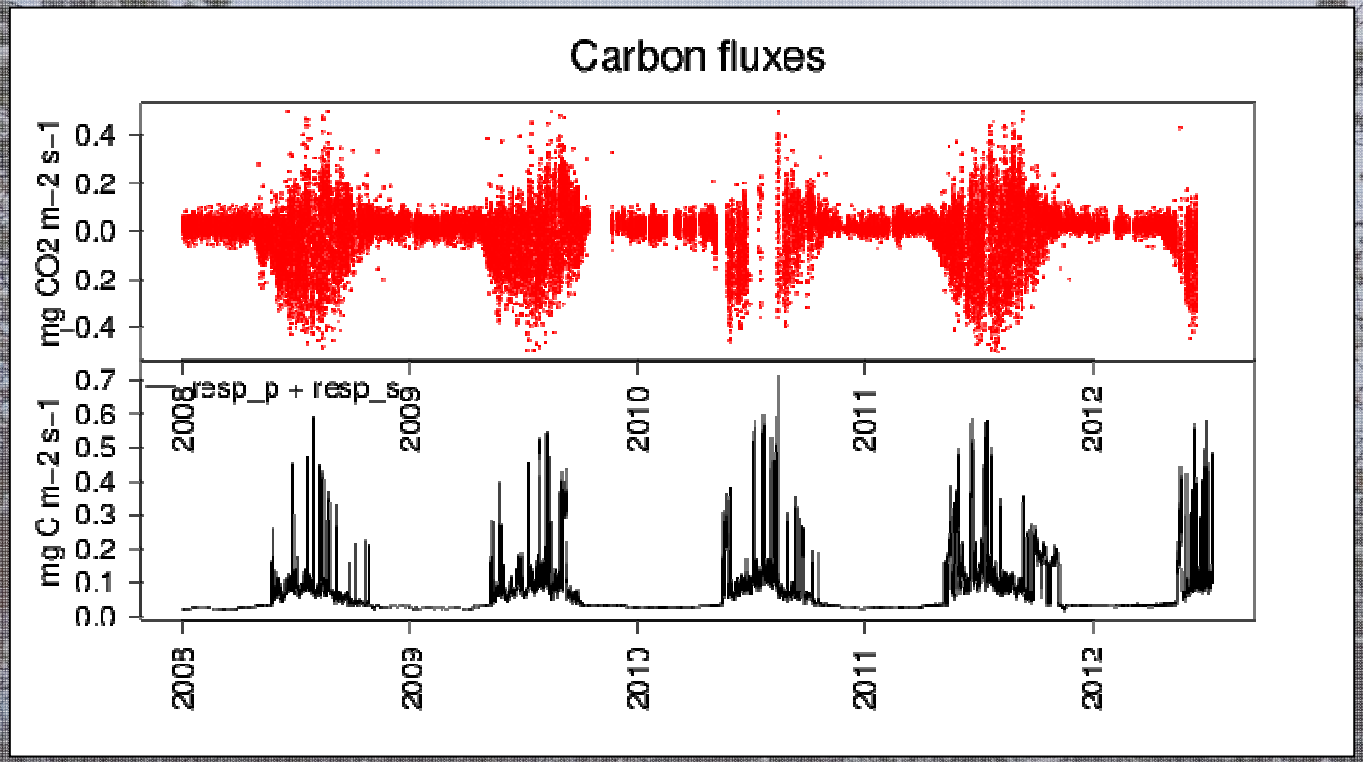


CO_2 in forest

- Three year time series of ELBARA in forest opening site and CO2 in forest
- CO2: 48 hour moving average



Carbon fluxes



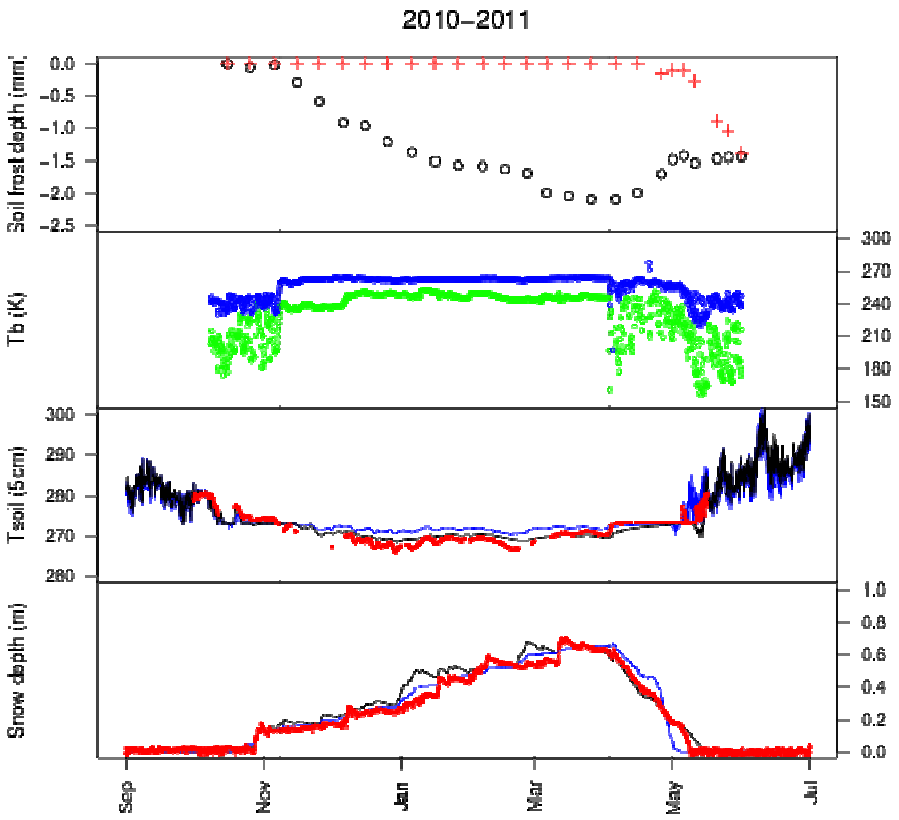
SUMMARY & QUESTIONS

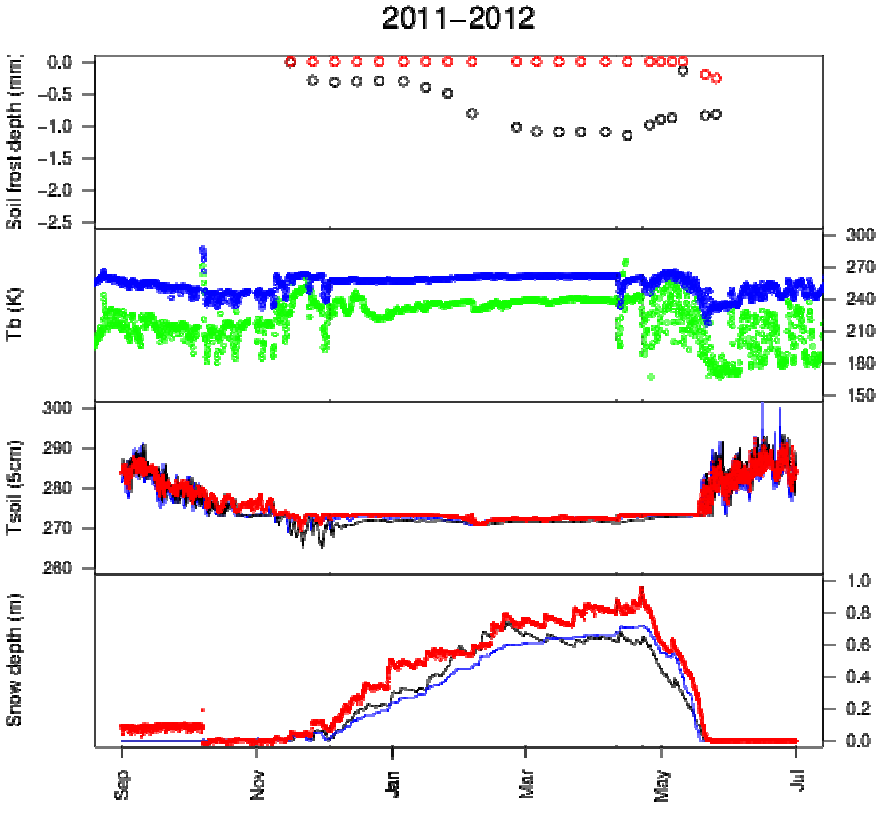
- JULES is able to simulate SWE, snow depth at a forest opening (low wind speeds) and at a forest site in Northern Finland.
- The errors in modelled soil temperatures are generally low during the winter but large errors can occur when the snow is shallow because of the snow / soil composite layer. This issue is problematic is JULES if to be used to assist the development of the soil freeze / thaw algorithm.
- The absence of blowing snow in the model causes large errors in SWE in point runs at an exposed site and (possibly) in the distributed run.
- The model is very sensitive to the Clapp & Hornberger b exponent. Is calibration acceptable?
- Sensible heat fluxes during winter and snow melt are generally in the wrong direction.
- CO_2 fluxes in summer are in the wrong direction. Can JULES be used at high latitude to model carbon fluxes at all?

Point scale model runs
Conclusions

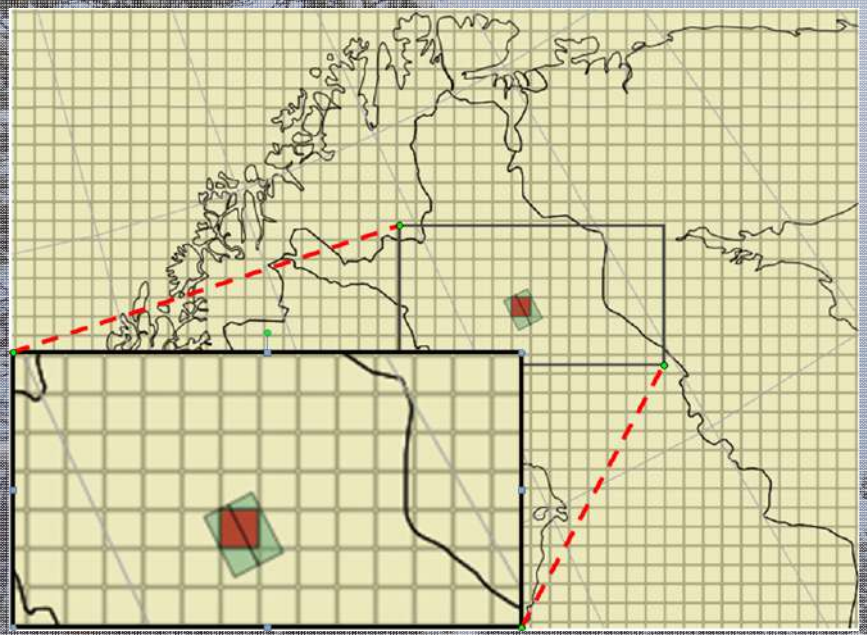
- Both models perform well against snow depth at the forest and forest opening sites and against soil temperature at the 3 sites.
- Both models capture the onset of snowmelt at the 3 sites.
- Snow melt-off to within 8 days maximum of observations in Forest opening.
- Snow melt-off to within 15 days maximum of observations in Forest opening.
- VIC consistently within 5 days of Tsoil > 0 during thaw.
- Tsoil model errors are greatest at the Forest opening.
- SD and SWE at the bog site need to be improved.

Results:
Comparison with ELBARA Tb





Distributed model set-up:



- VIC only.
- EASE-Grid 25 x 25 km SMOS product.
- 1 SMOS pixel over Sodankylä = 2* 0.4ox0.4o LSM pixels (Equal area vs. lat/long)
- Same forcing data as point runs.
- Vegetation cover form CORINE 2006