

The CoReH₂O Data Assimilation Study



Richard Essery
School of GeoSciences
University of Edinburgh

Acronyms

Cold Regions Hydrology High-Resolution Observatory (CoReH₂O)

Proposed satellite with dual-frequency SAR for mapping SWE at 250-500 m spatial resolution and 3 or 15 day revisit

Nordic Snow Radar Experiment (NoSREx)

Acquisition of radar backscatter data from snow at Sodankylä, winters of 2009-2010 and 2010-2011

CoReH₂O Snow Retrieval Study

Development and validation of algorithms to retrieve SWE from dual-frequency radar backscatter from dry snow

CoReH₂O Data Assimilation Study (CoSDAS)

Quantify the impact of remotely-sensed SWE estimates on the accuracy of analyses and subsequent forecasts of snow properties

CoSDAS Requirements

Build a modular sequential SWE analysis system operating in single column mode

Quantify the impact of remotely sensed SWE estimates on accuracy of analyses and subsequent model forecasts

Using:

- a database for model driving, evaluation, calibration and assimilation
 - at least two winters at two sites (**Sodankylä** and Col de Porte)
- two snow models of differing complexity
 - composite model with constant density and no snow hydrology
 - **multi-layer model with prognostic density and liquid water**
- an advanced data assimilation system with batch processing
 - Extended or **Ensemble Kalman Filter**

CoSDAS Motivation

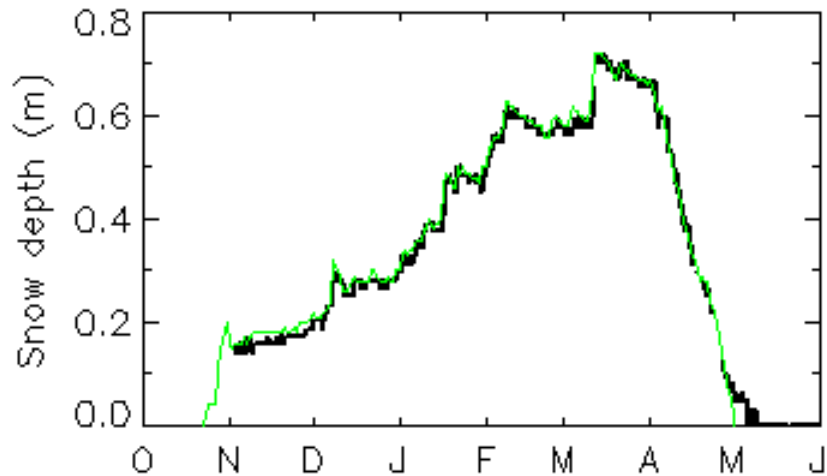
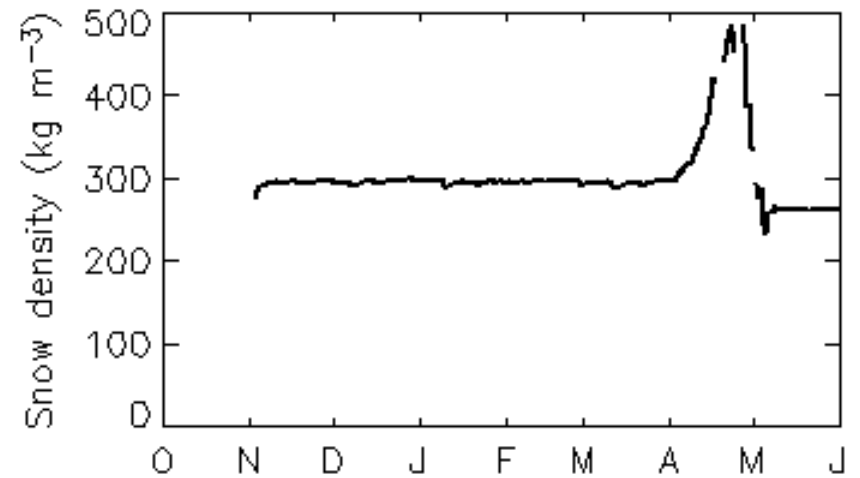
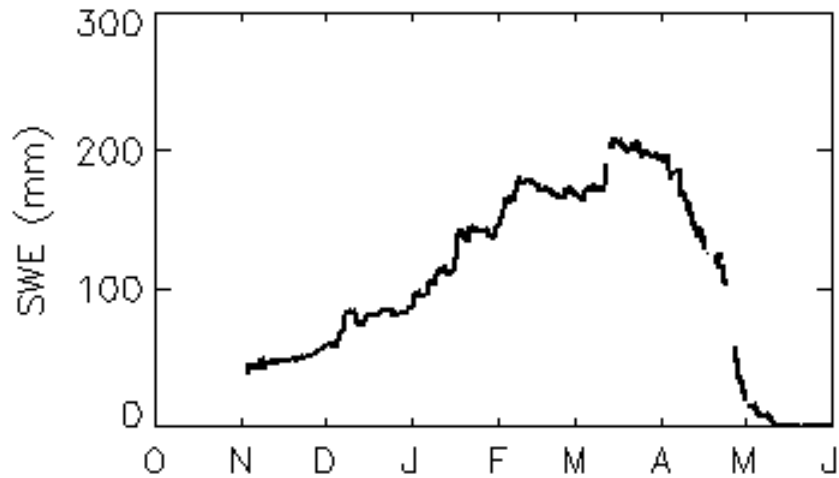
Snow:

- strongly affects surface energy balance
- stores water
- initialization of snow mass and extent important for NWP and hydrology

Operational analyses often assimilate satellite snow extent and ground snow depth data (observation model required to obtain snow mass state variable) ...

... but almost never in situ or remote mass data

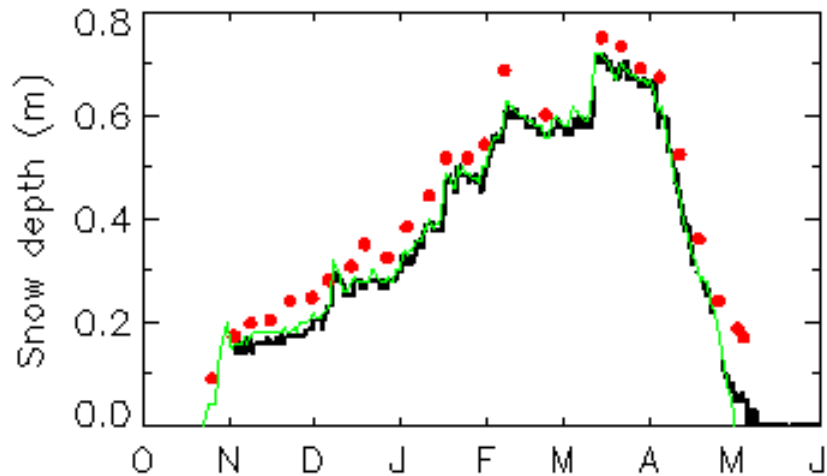
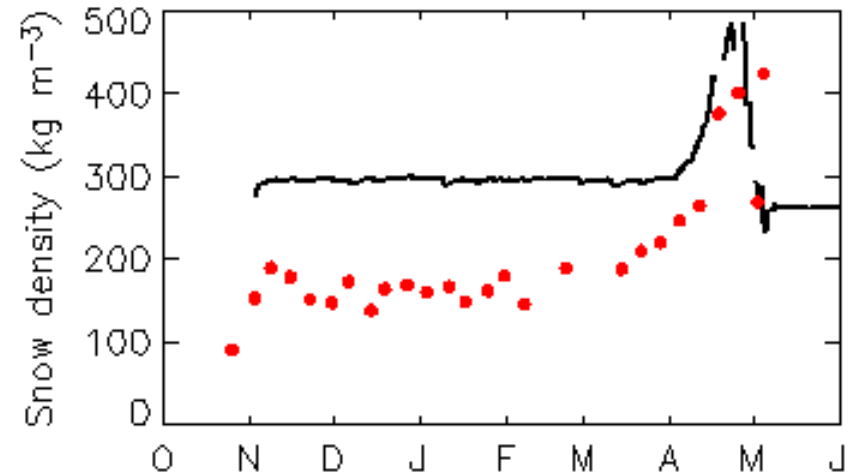
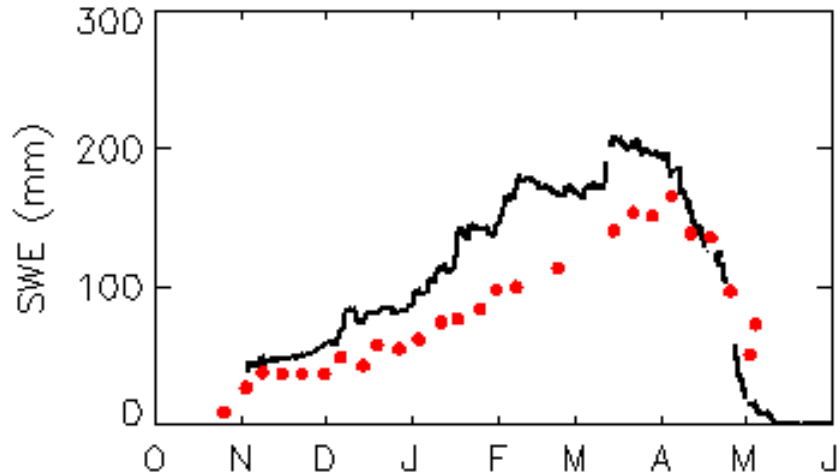
Sodankylä Snow 2010-2011



HIRLAM analyses

Sodankylä synop reports

Sodankylä Snow 2010-2011

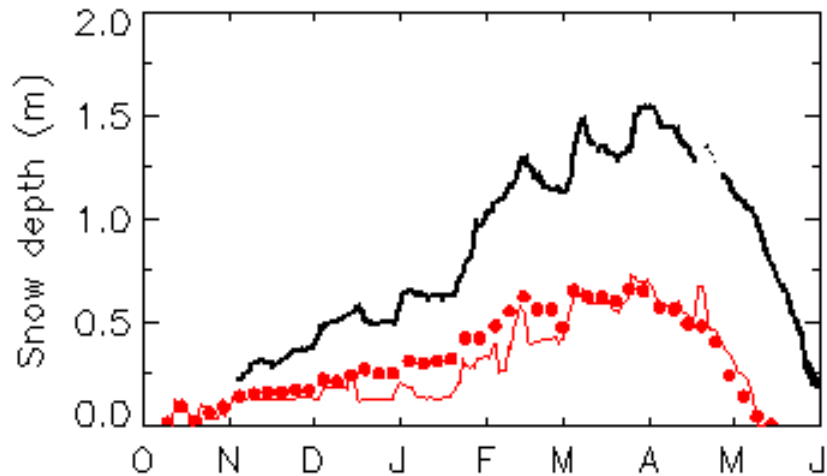
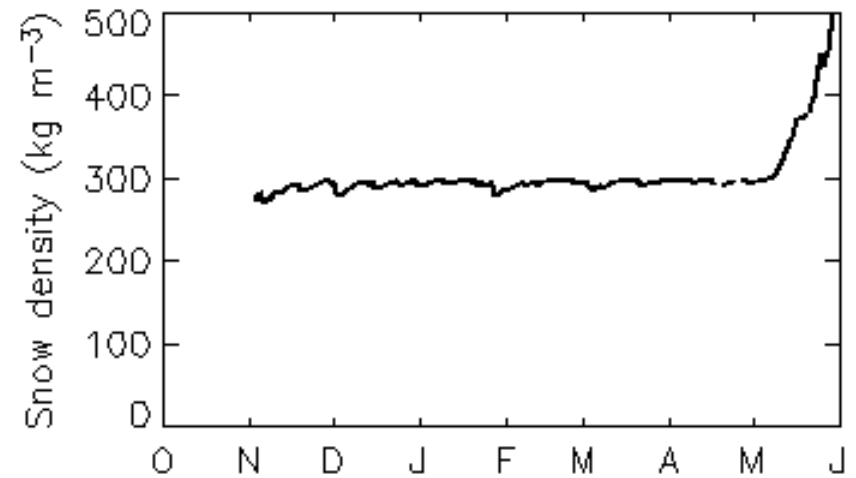
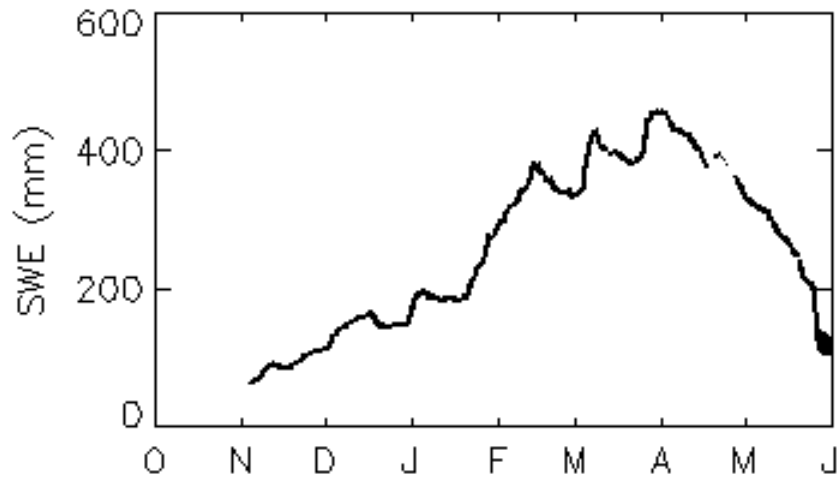


HIRLAM analyses

Sodankylä synop reports

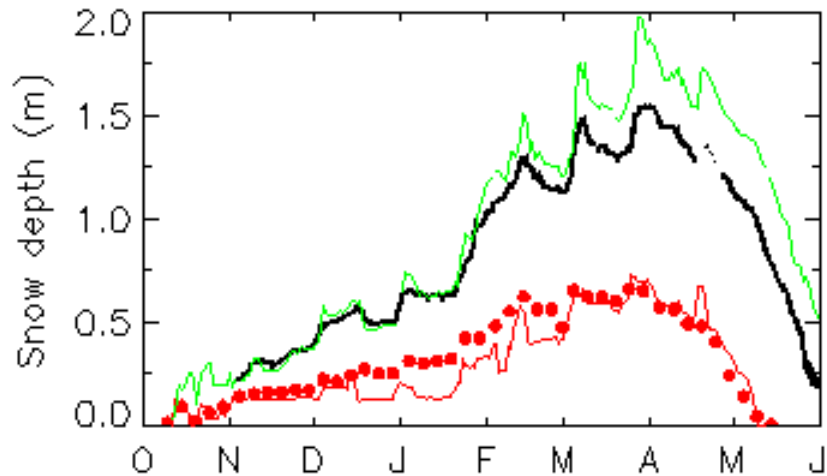
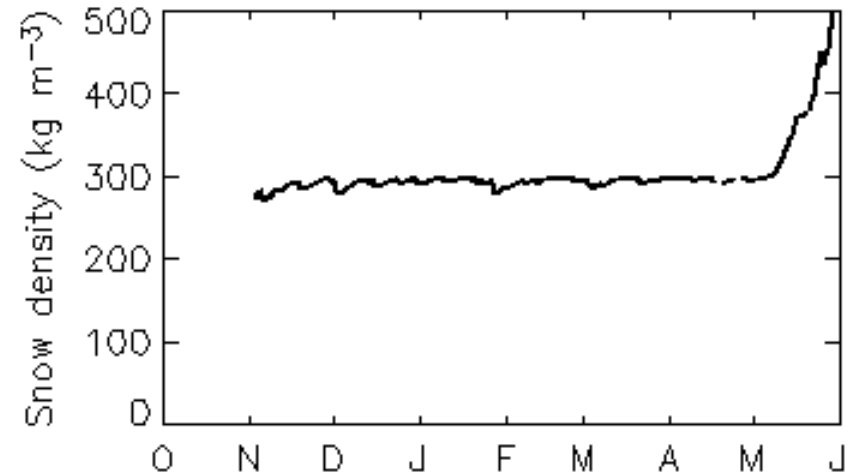
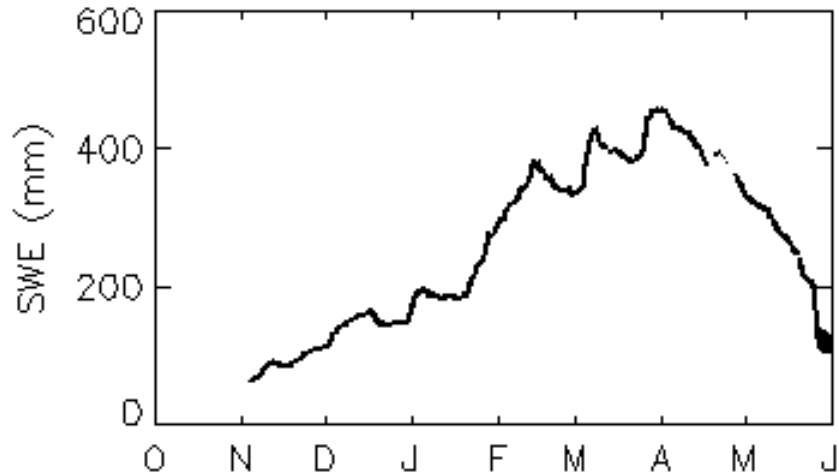
FMI snow pits

Abisko Snow 2010-2011



HIRLAM analyses (750 m)
ANS snow stake (388 m)
and 10-point transect

Abisko Snow 2010-2011



HIRLAM analyses (750 m)
ANS snow stake (388 m)
and 10-point transect
Katterjakk synop report
(515 m, 35 km from Abisko)

Data Assimilation

Analysis equation $\mathbf{x}^a = \mathbf{x}^b + \mathbf{K}(\mathbf{y} - \mathbf{H}\mathbf{x}^b)$

Kalman gain $\mathbf{K} = \mathbf{B}\mathbf{H}^T (\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R})^{-1}$

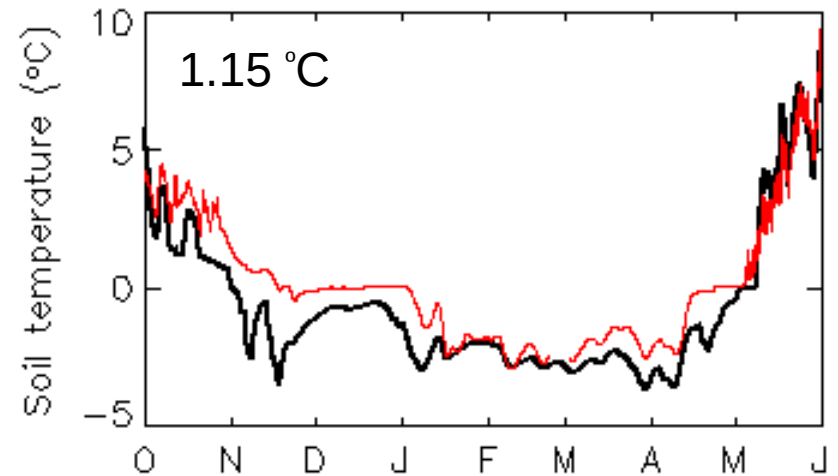
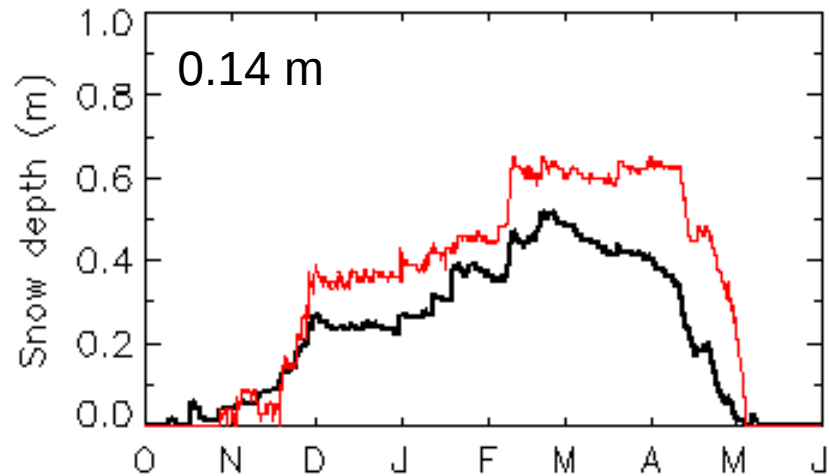
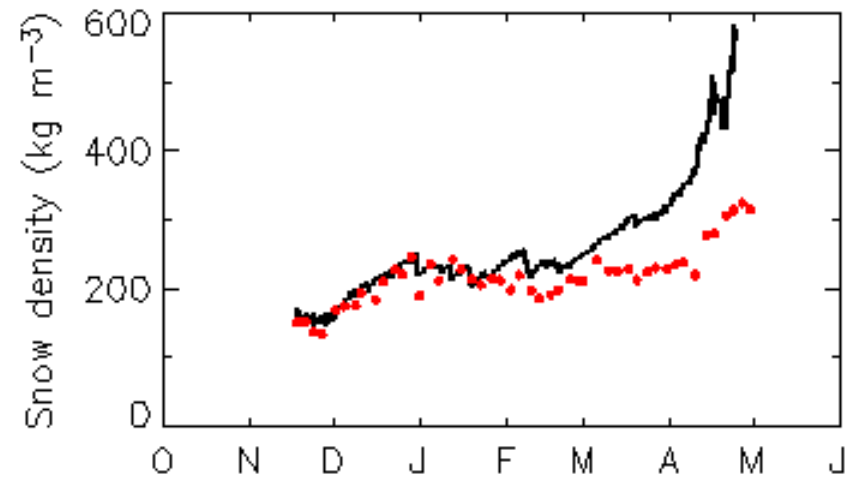
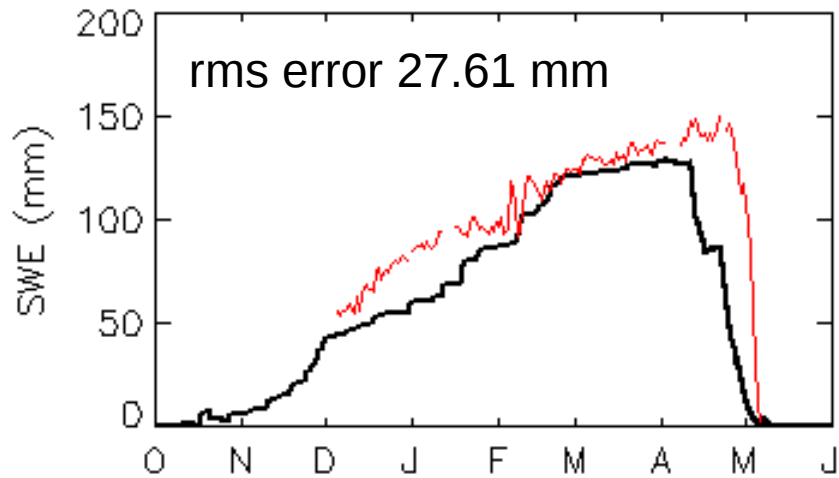
Assimilation of a state variable \rightarrow trivial observation operator

Assimilation of one value at a time \rightarrow trivial analysis equations

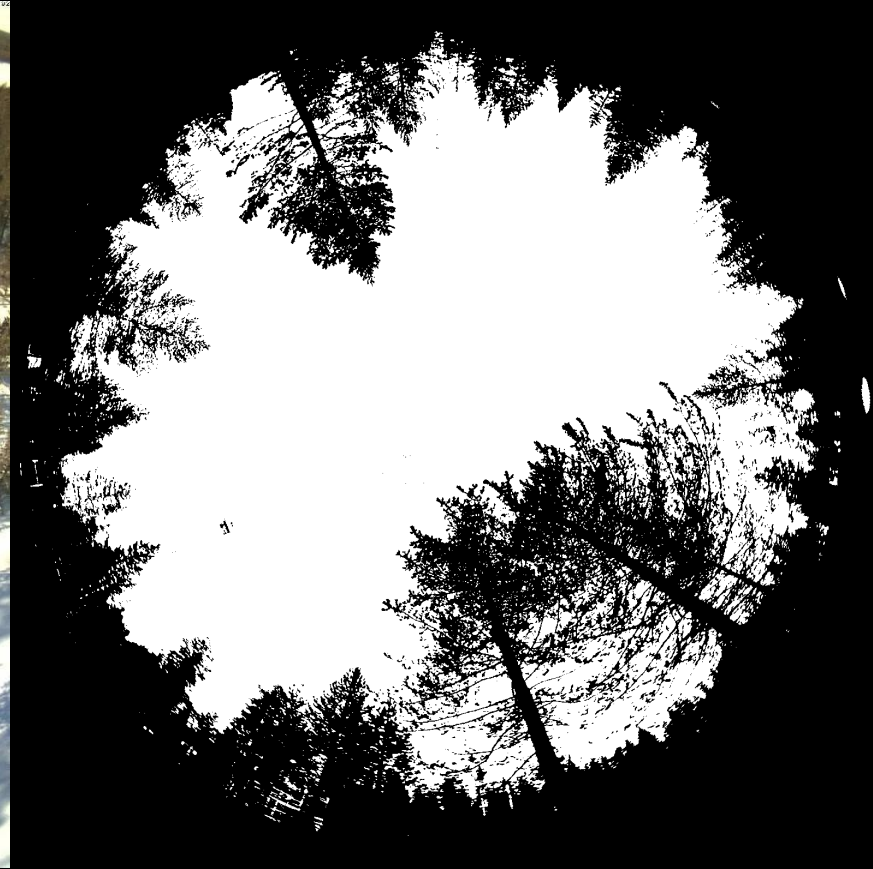
$$x_1^a = x_1^b + \frac{B_{11}}{B_{11}^{ob} + \sigma_1^2} (y_1^{ob} + \varepsilon - x_1^{ob})$$
$$x_2^a = x_2^b + \frac{B_{12}}{B_{11}^{ob} + \sigma_1^2} (y_1^{ob} + \varepsilon - x_1^{ob}) \quad \dots$$

Assemble batch of observations in augmented state vector

Sodankylä 2008-2009: default simulation

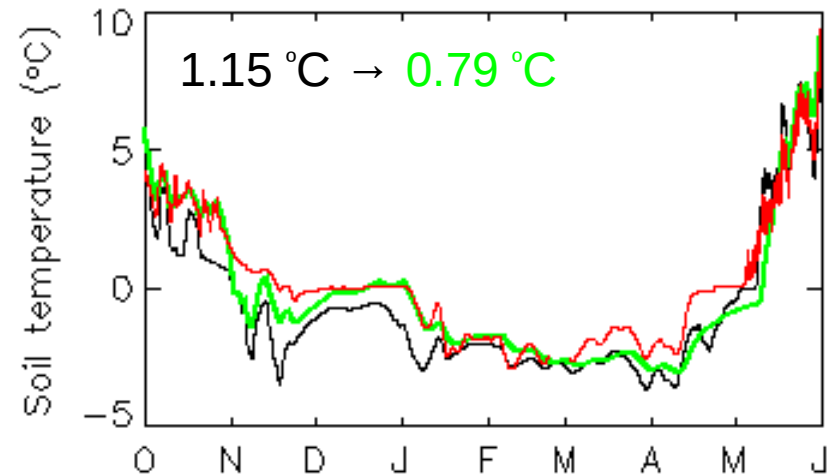
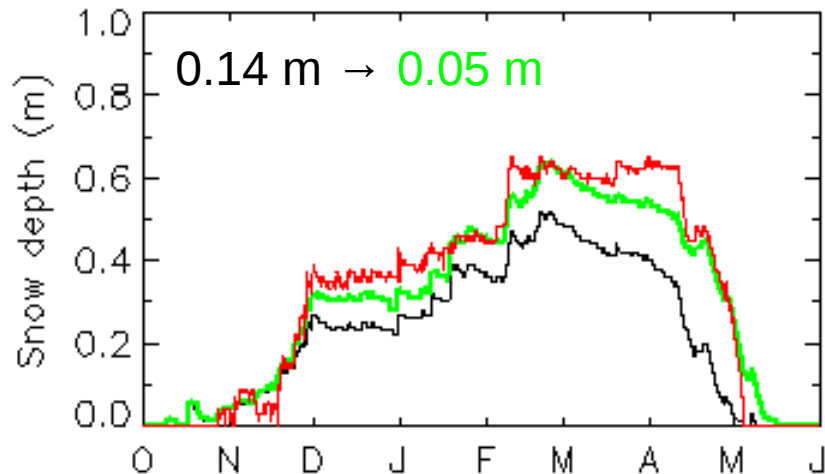
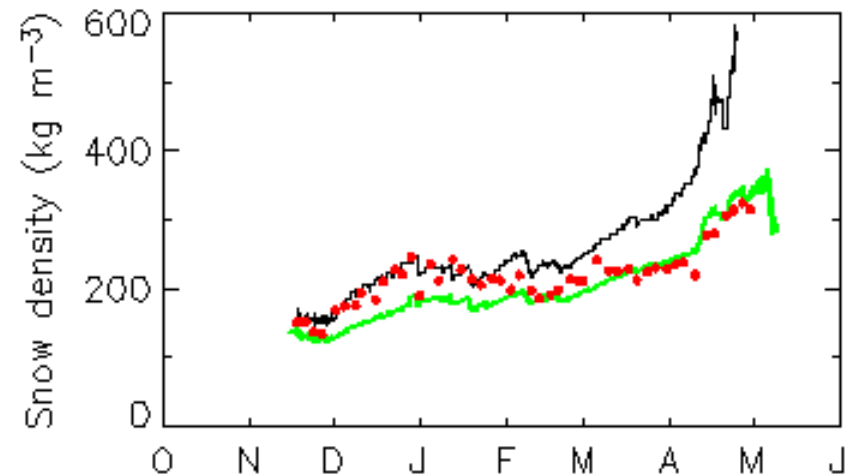
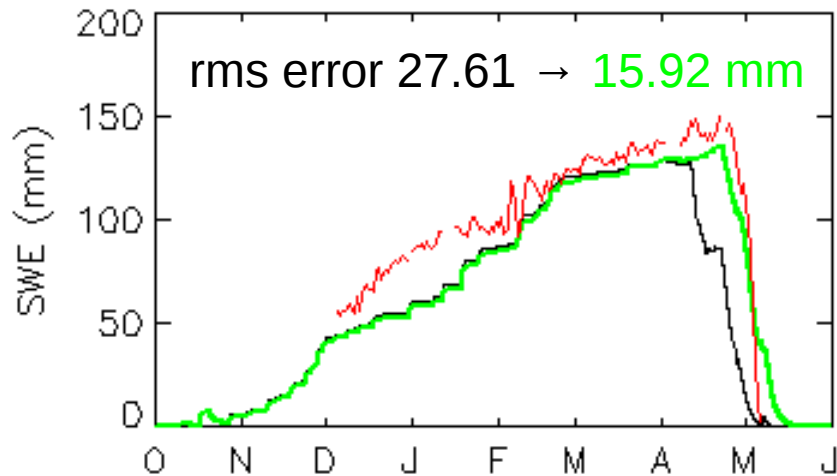


Shading of the NoSREx Site



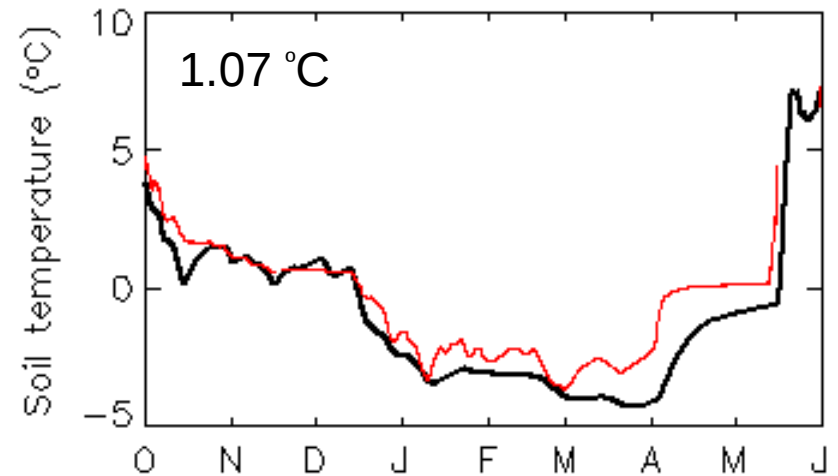
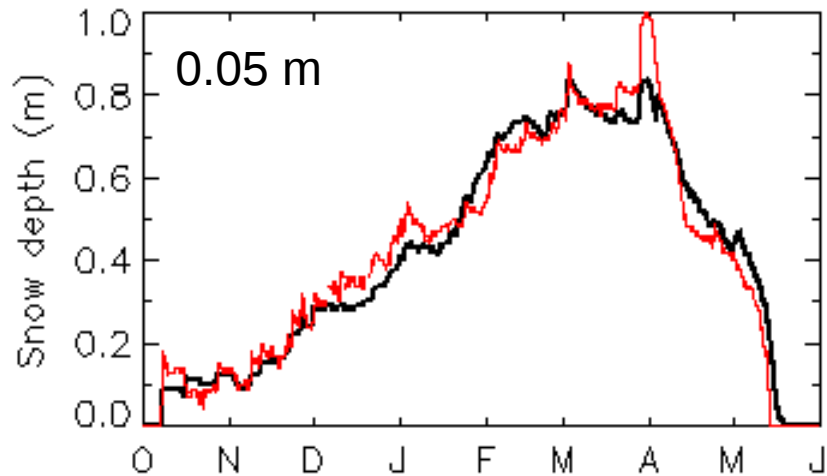
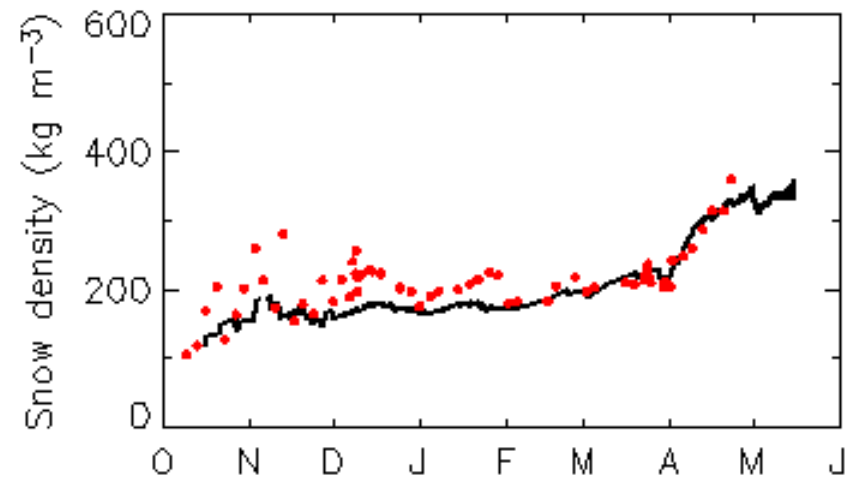
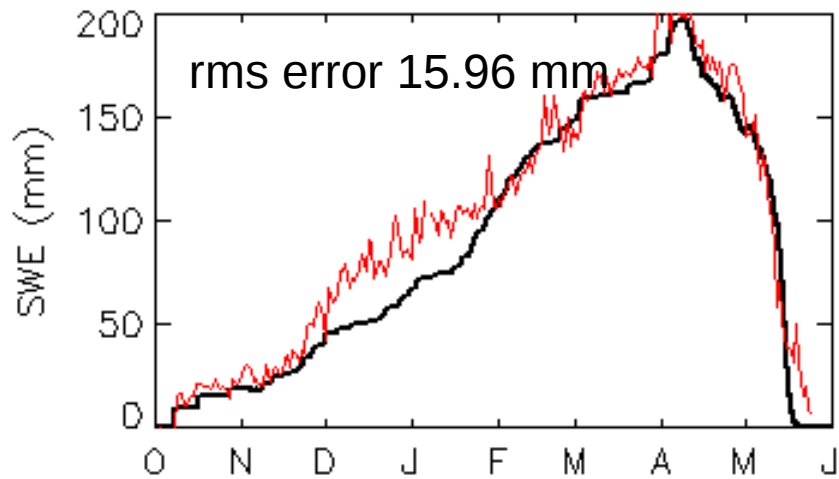
Sodankylä 2008-2009: calibrated simulation

Adjust LAI, compactive viscosity and 1 October soil moisture



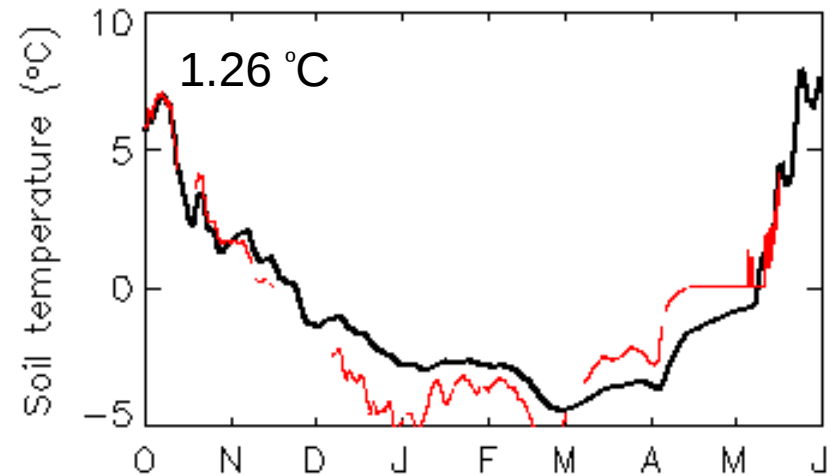
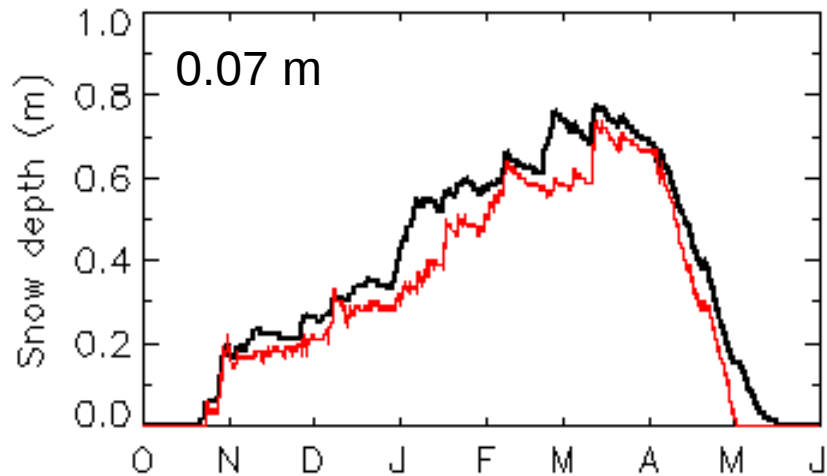
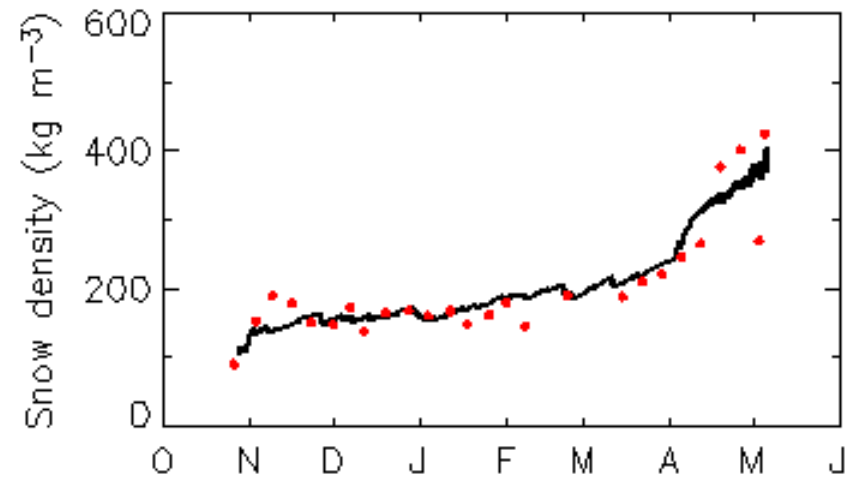
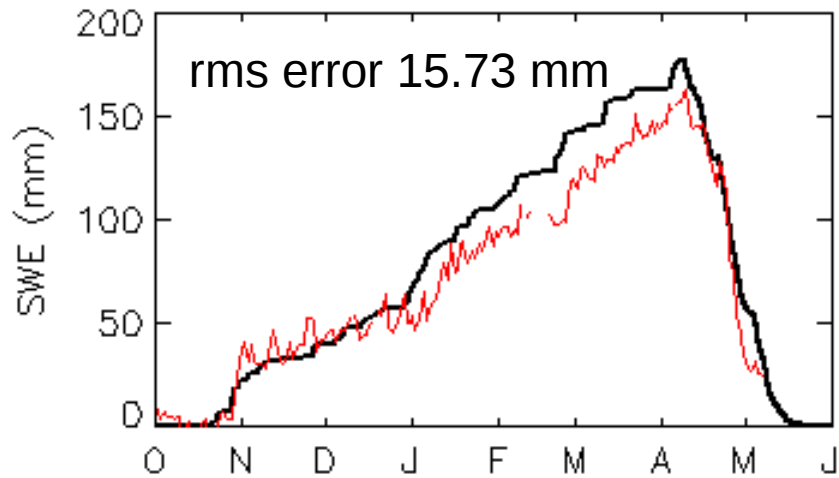
Sodankylä 2009-2010

Parameters transferred from 2008-2009 calibration

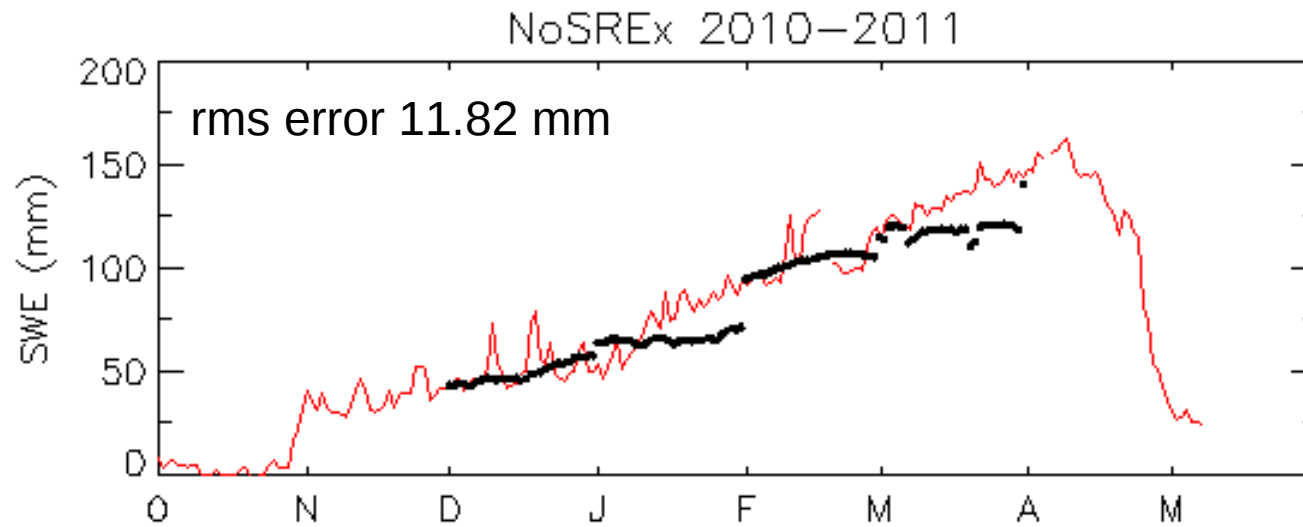
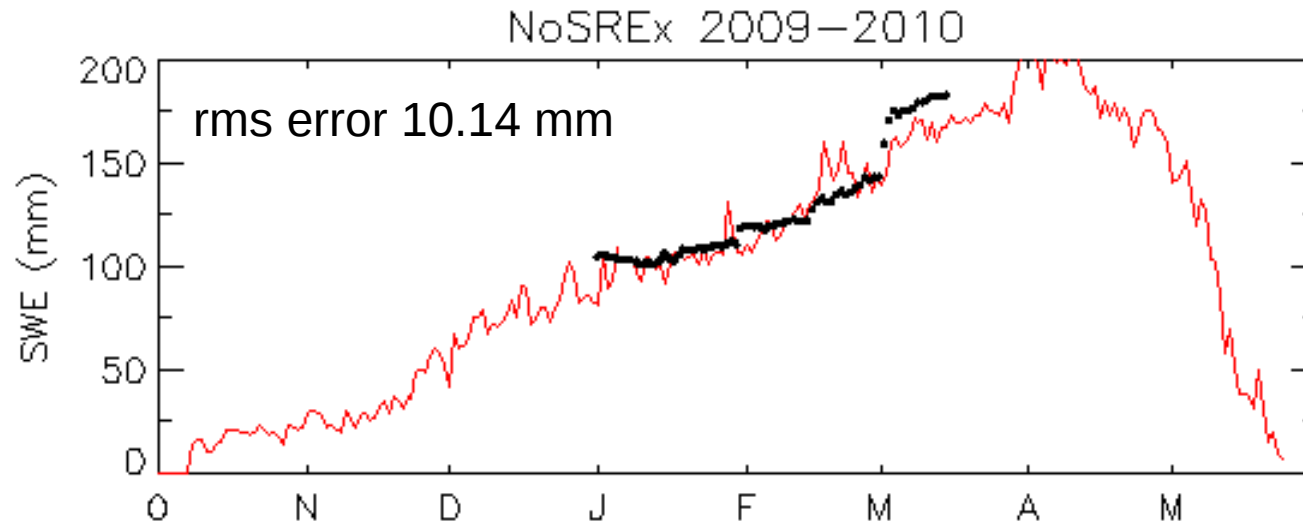


Sodankylä 2010-2011

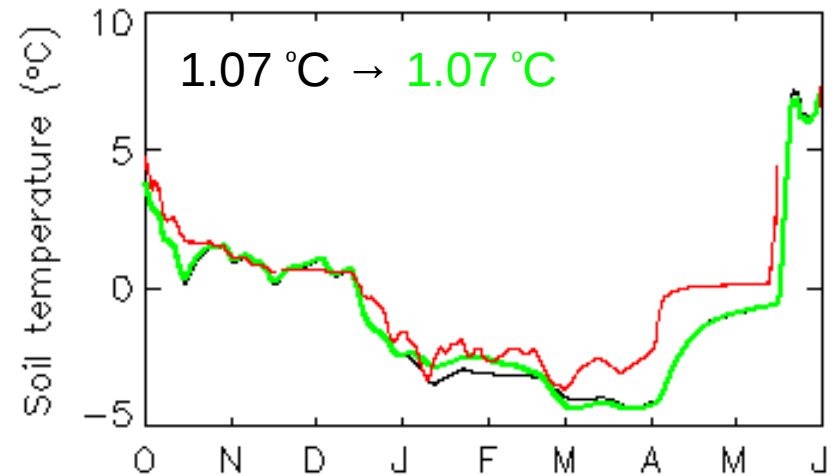
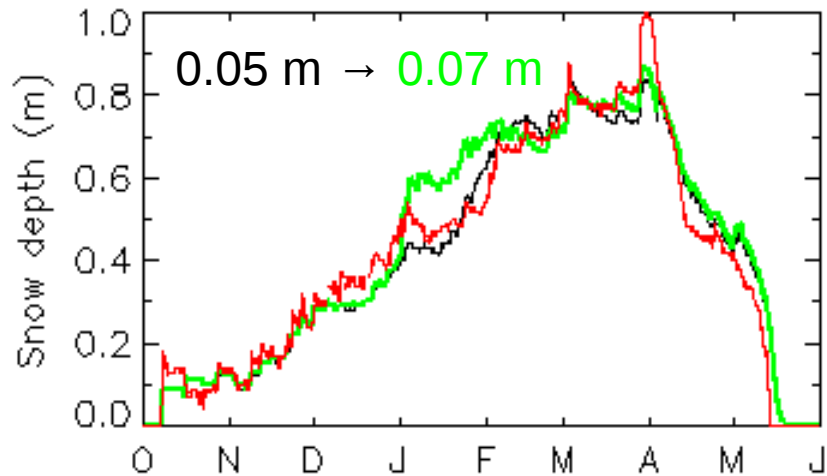
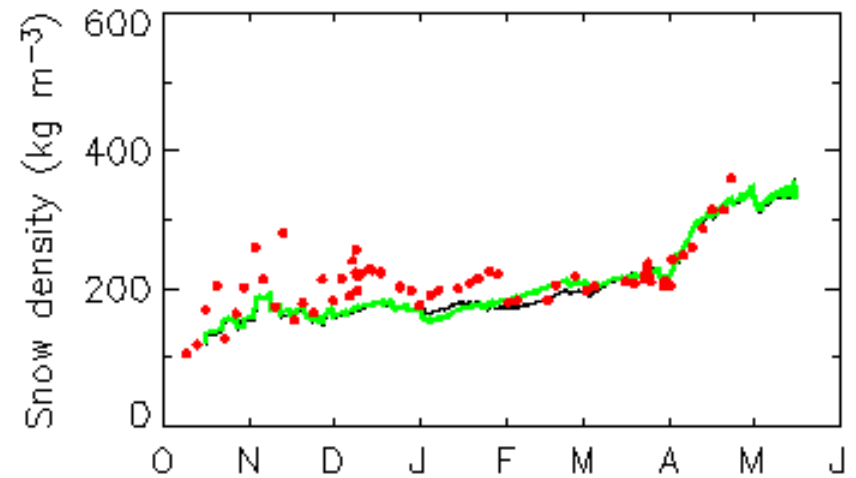
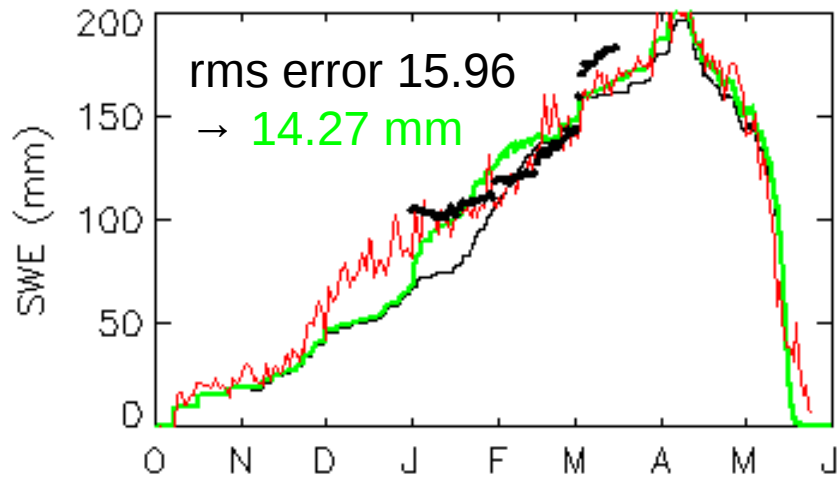
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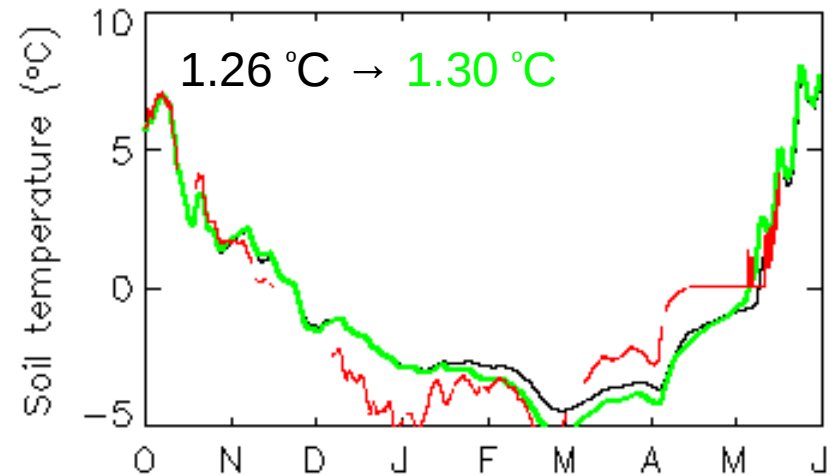
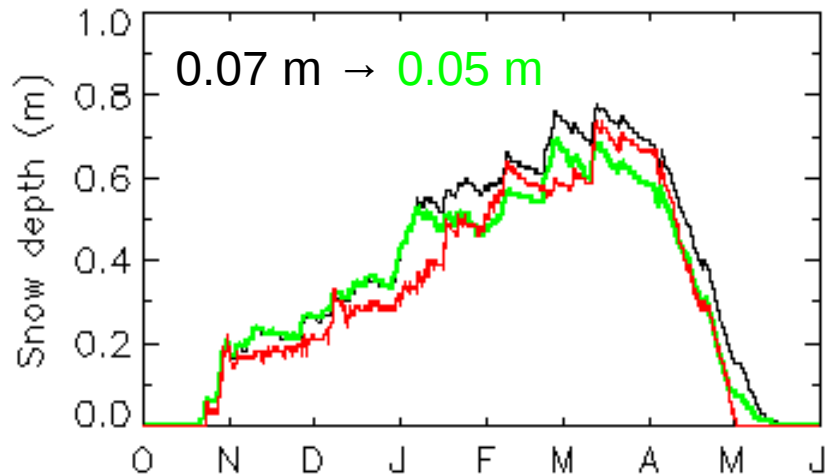
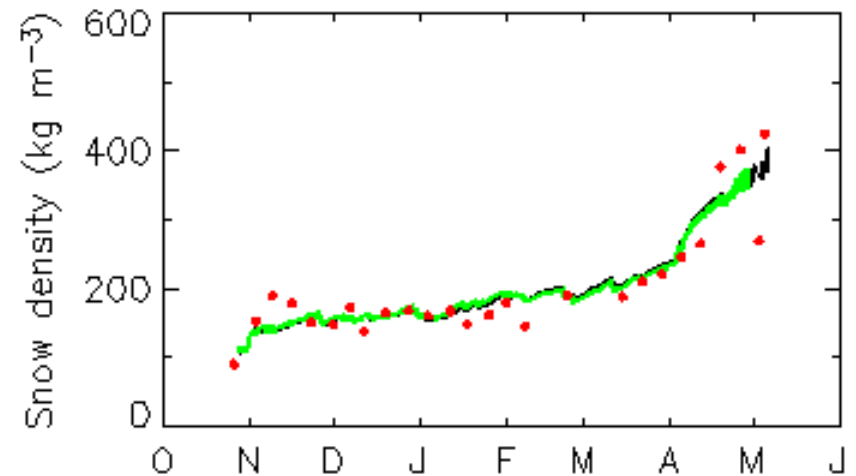
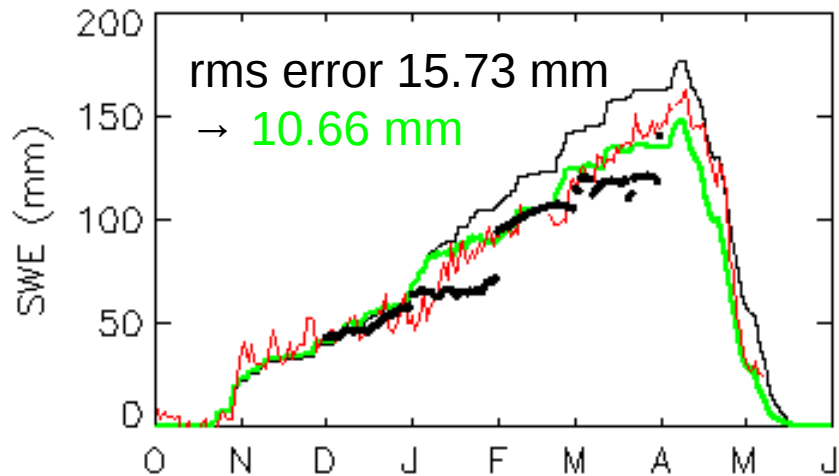
NoSREx SWE Retrievals



Sodankylä 2009-2010 Assimilation



Sodankylä 2010-2011 Assimilation



To Do

- Reconsider shading problem with hemispherical sky view and diffuse radiation
- Synthetic observation experiments to determine impact of frequency of observations, assimilation window length, variance, covariance and autocorrelation of perturbations
- Simulations with HIRLAM forcing
“The first guess will be based on inaccurate meteorological forcing data coming from the NWP model”
- Compare with GlobSnow
- Extended Kalman Filter with adjoint from perturbed forecasts