SnowSTAR2002 Transect Reconstruction Using a Multilayered Energy and Mass Balance Snow Model

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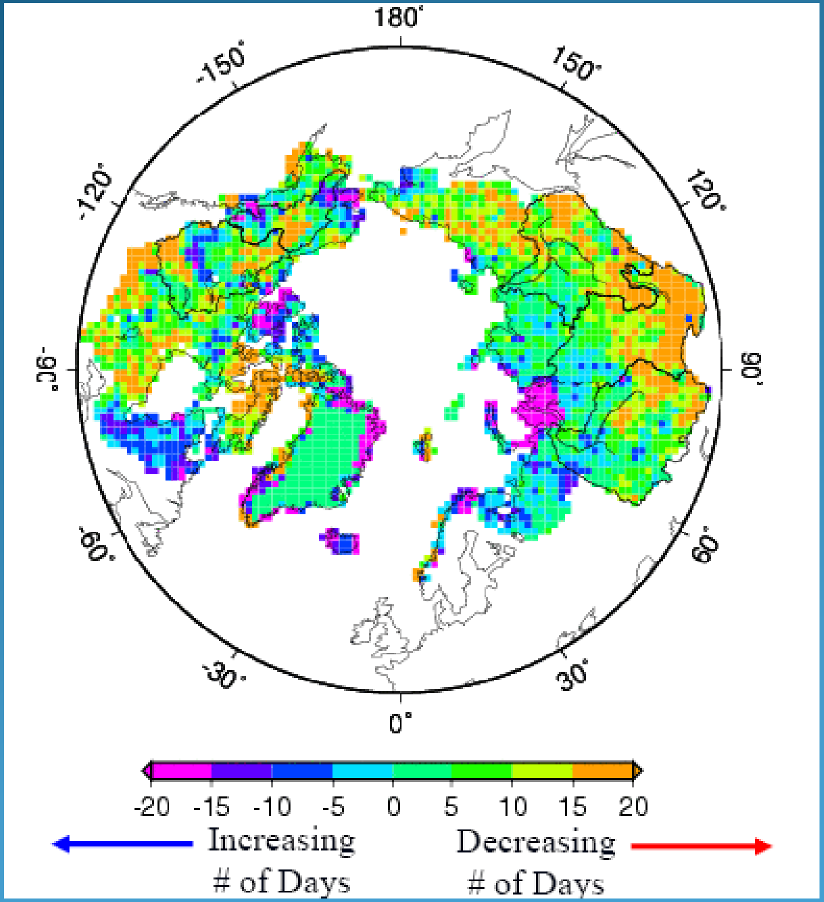
Motivation

Changes in Snow Cover Extent

VIC simulation (1950-1995)



(Adam et al. 2004)

- Snow cover extent (duration and depth) is decreasing in the Arctic.
- Current ground snow observations in the Arctic:

  1) sparse observation network

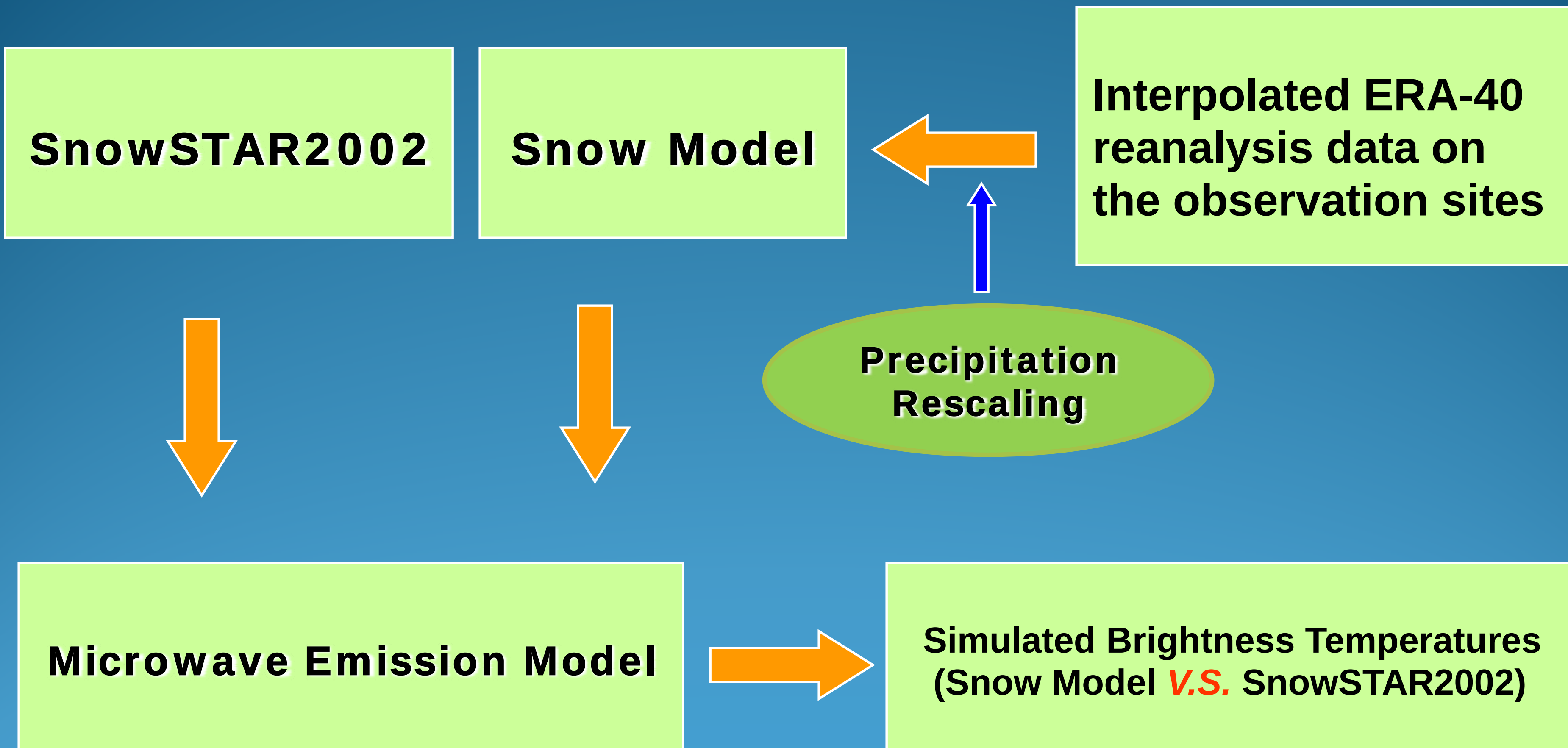
  2) unable to capture the spatial variability of snow over large areas.
- Retrieval of SWE is complicated by the dependence of microwave emission signal on snow microphysical properties, in particular, snow temperature, density, and grain size.
- The measured snow profiles along the SnowSTAR2002 transect can provide a unique opportunity to improve our understanding for this important source of error in SWE retrieval algorithm.

Research Questions

1) Does the snow model have the ability to recover observed microphysical structures of snowpack in the study domain?

2) What's the sensitivity of microwave emission model to difference in simulated and observed snowpack microphysical properties? What's the magnitude of error for brightness temperatures?

Experimental Design



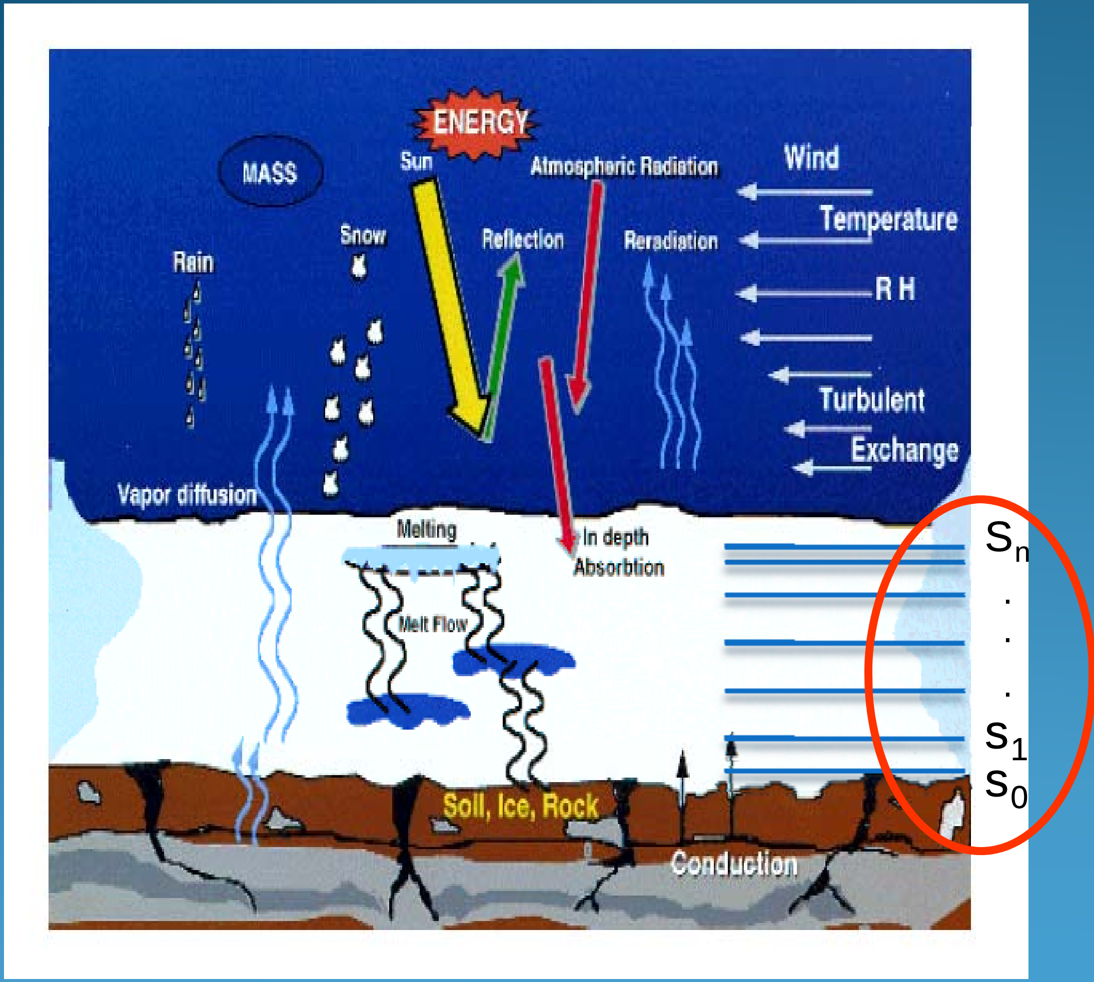
SNOWSTAR-2002 Nome to Barrow Alaska

SnowSTAR2002

- Route Length: about 1200 kilometers
- Period: March 24 - April 26 , 2002
- Data: SWE and profiles of snow properties

Snow Model---SNTHERM

(Jordan 1991)

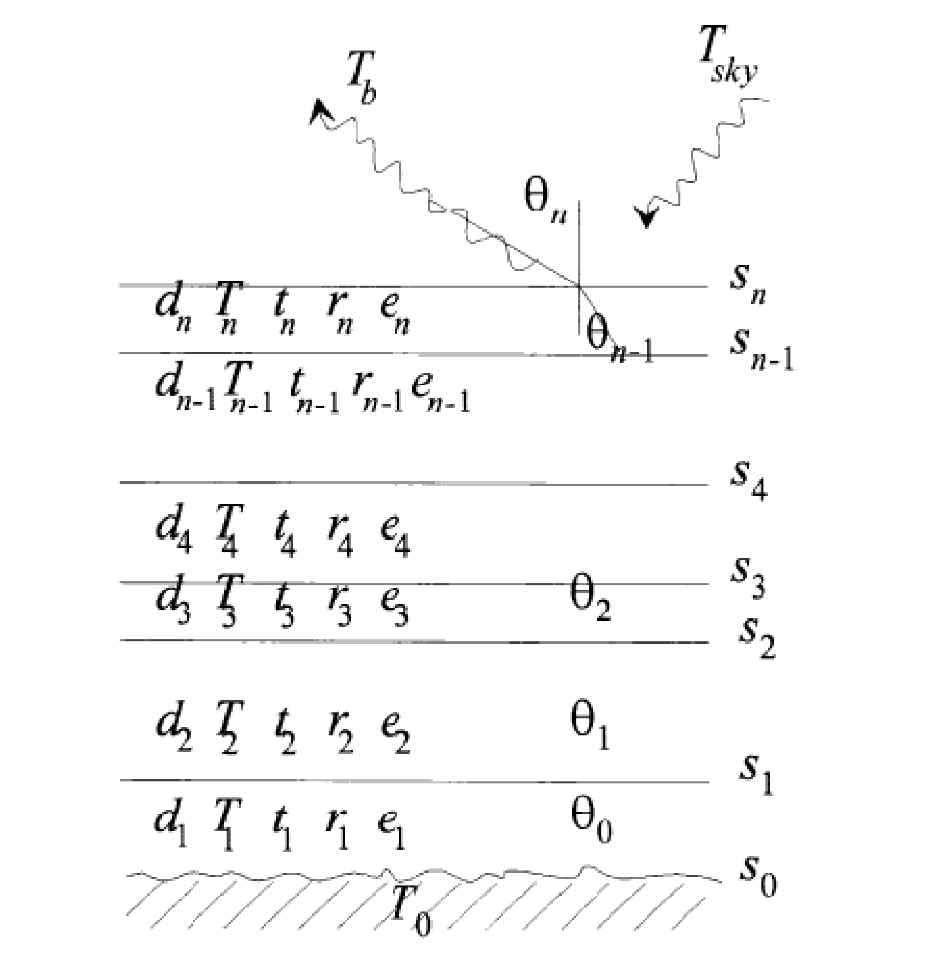


Schematic diagram of SNTHERM model

- Physically-based 1-D snow model.
- Accounts for the snowpack mass and energy balance in multiple layers.
- Simulates profiles of snow microphysical properties, such as snow density, grain size, and temperature.
- Initial conditions of snow and soil: the run starts from the date without snowfall.

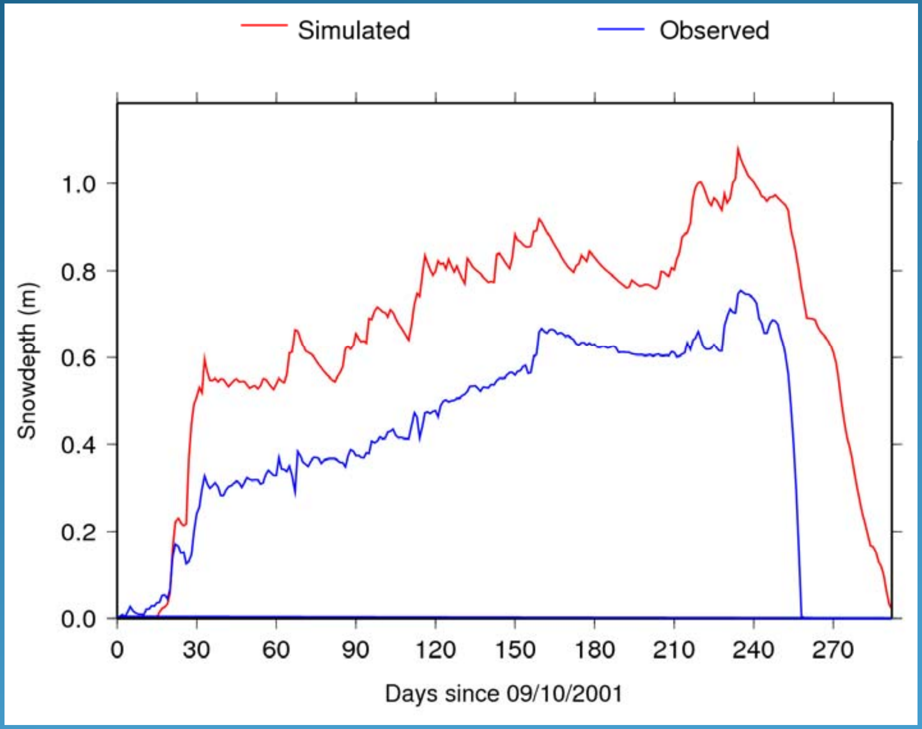
Microwave Emission Model---MEMLS

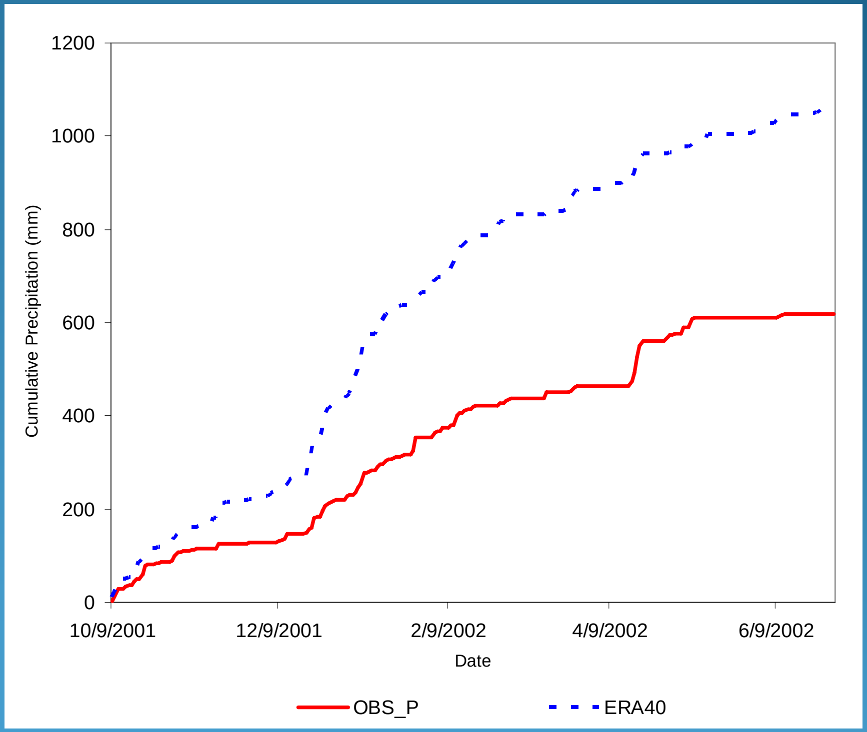
(Mätzler et al. 1999)



1. Calculates brightness temperature from a multi-layer snow medium.
2. The absorption coefficient is derived from snow density, frequency and temperature.
3. The scattering coefficient depends on the correlation length, density, and frequency.
4. Inputs include snow depth, temperature, density, ground temperature and correlation length for each layer.

Cumulative precipitation comparison between the ERA-40 and observed data at Indian Pass





Rescaling ERA-40 precipitation Data

1. For the day of a SnowSTAR2002 observation, we defined a ratio ***R**** of the observed SWE ***SWE**** to the accumulated ERA-40 precipitation ***P**** up to the measurement date:

$$R^* = SWE^*/P^*$$

2. This ratio ***R**** was applied to rescale ERA-40 precipitation on all days starting with the beginning of the winter season so as to produce a rescaled ERA-40 precipitation time series.

3. We assume that all winter precipitation either adds to SWE or is sublimated (i.e., we assume that the effect of winter melt is negligible), therefore SWE on the measurement date is given by:

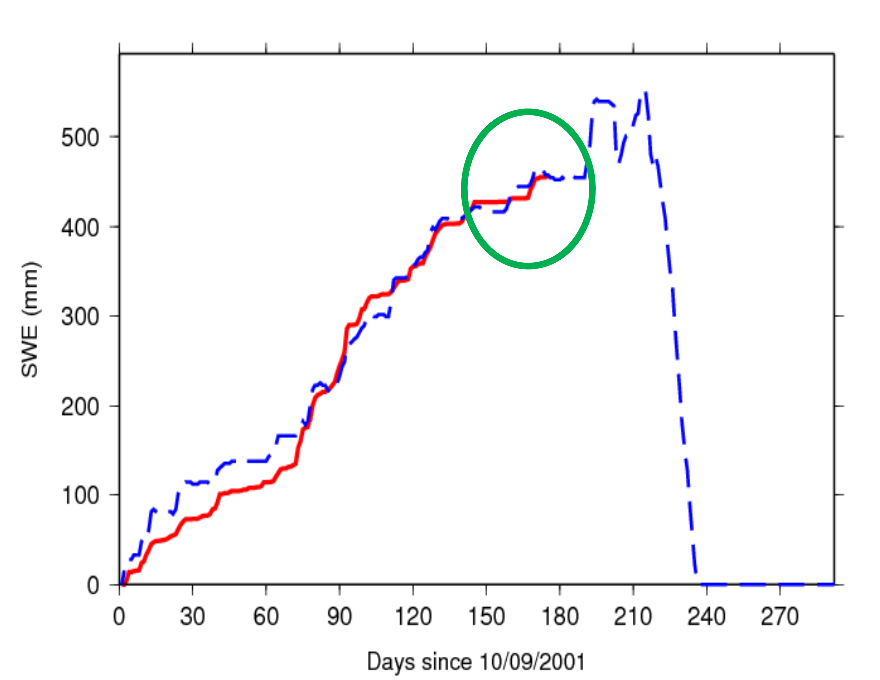
$$SWE = \sum P - \sum S$$

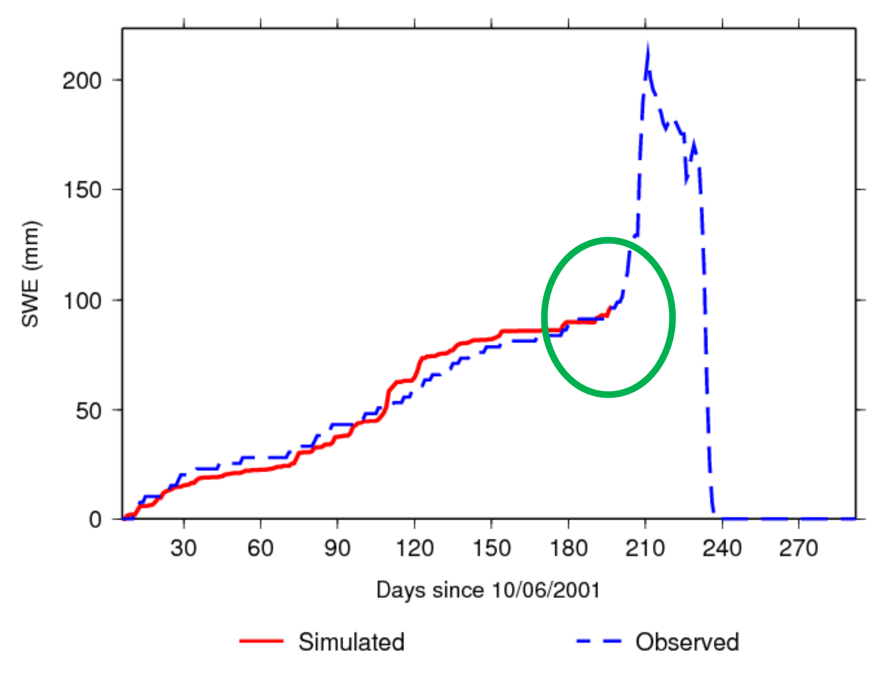
4. The rescaled precipitation at any time is given by:

$$P = \Delta SWE \times (1 + \sum S/SWE)$$

where S is the sublimation rate. ΔSWE is the successive difference of SWE over the time step (e.g., daily). Adjusting the ratio of the sublimation to snow water equivalent ($\sum S/SWE$) allows solution for the rescaled precipitation from ERA-40, and in particular, we force the predicted SWE to match on the observation date.

Evaluation of the rescaling method

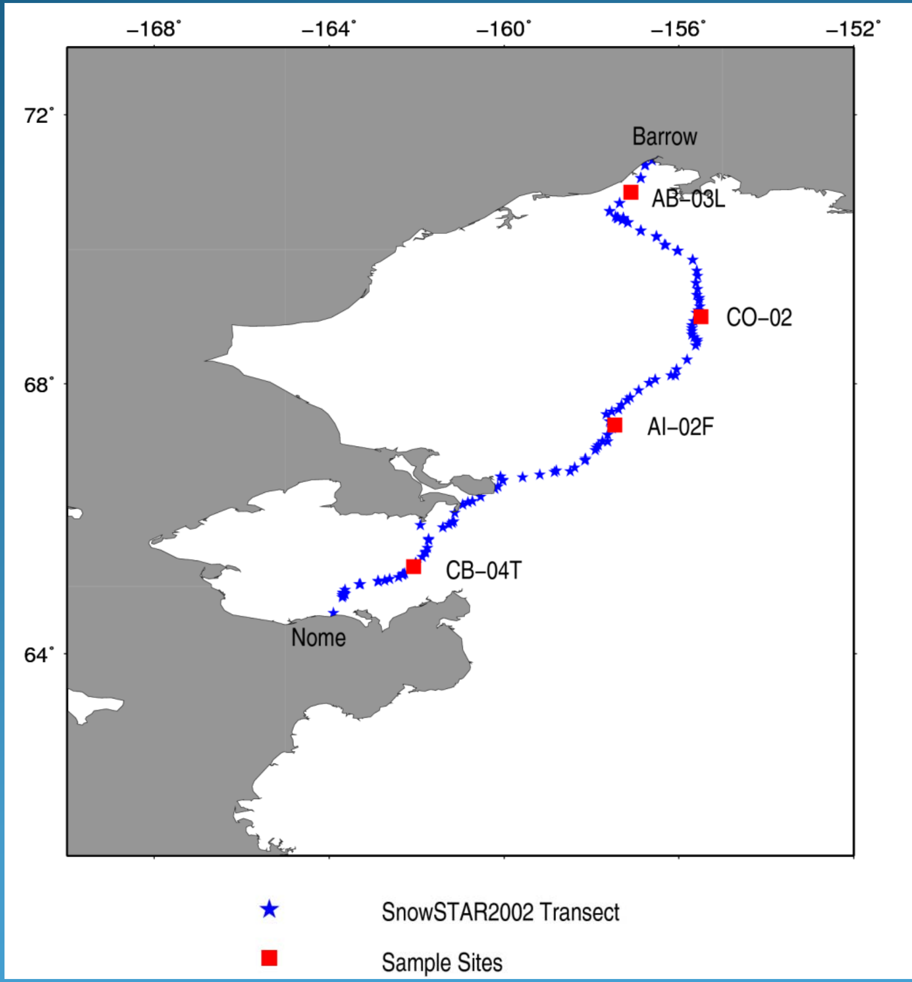




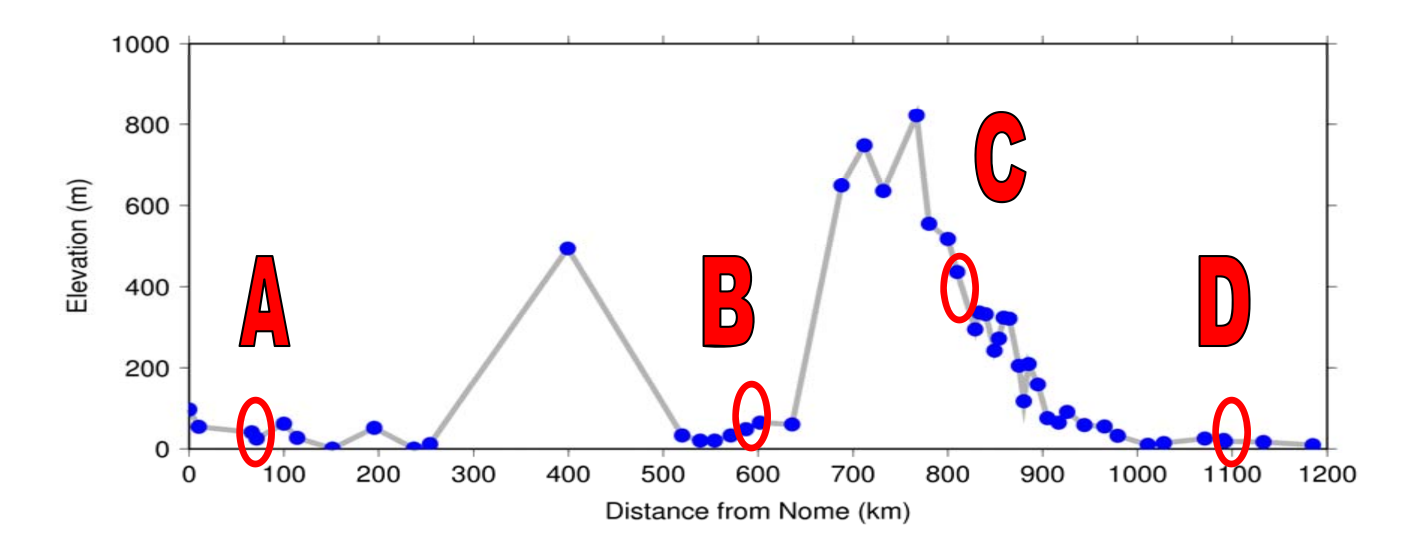
Indian Pass (61.07N,149.49W)
April 1, 2002
Relative RMSE: 8.9%

Munson Ridge (64.85N,146.21W)
April 15, 2002
Relative RMSE: 9.8%

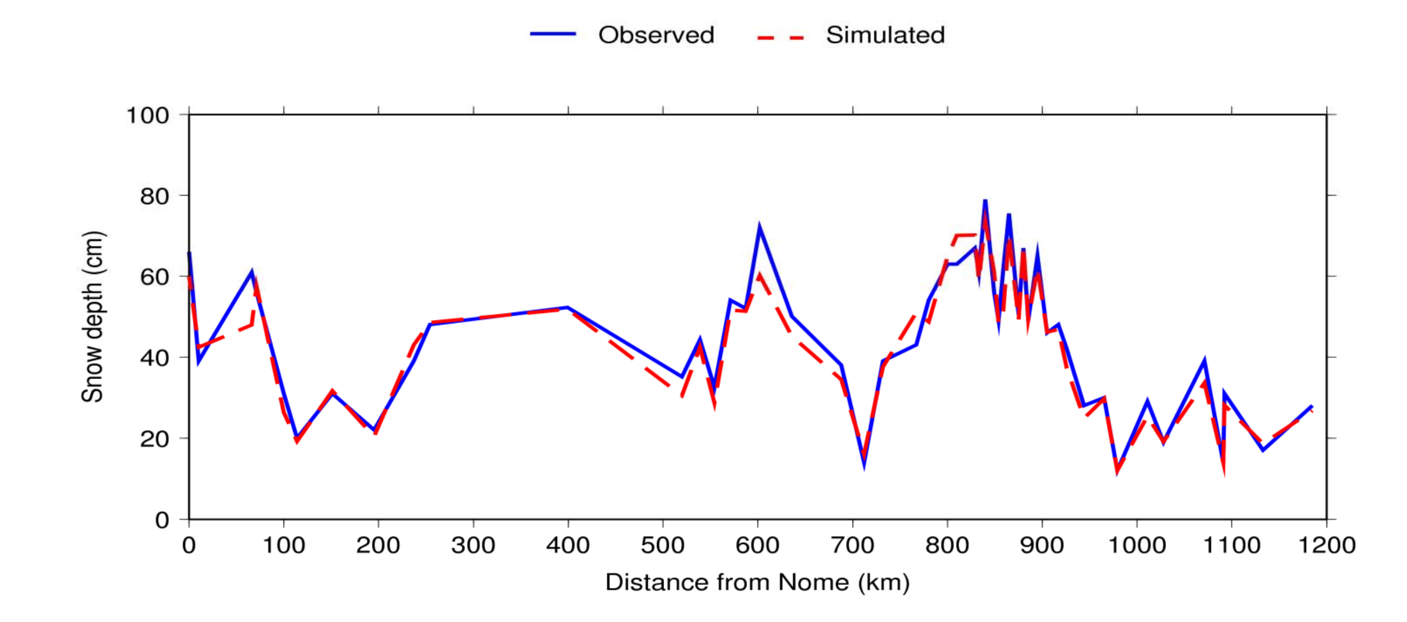
SNTHERM *V.S.* SnowSTAR2002



1. The comparison of snowpack profiles at 4 sample stations evenly distributed on the transect.
2. The mean absolute error (MAE) between model simulation and field measurements along the SnowSTAR2002 transect.

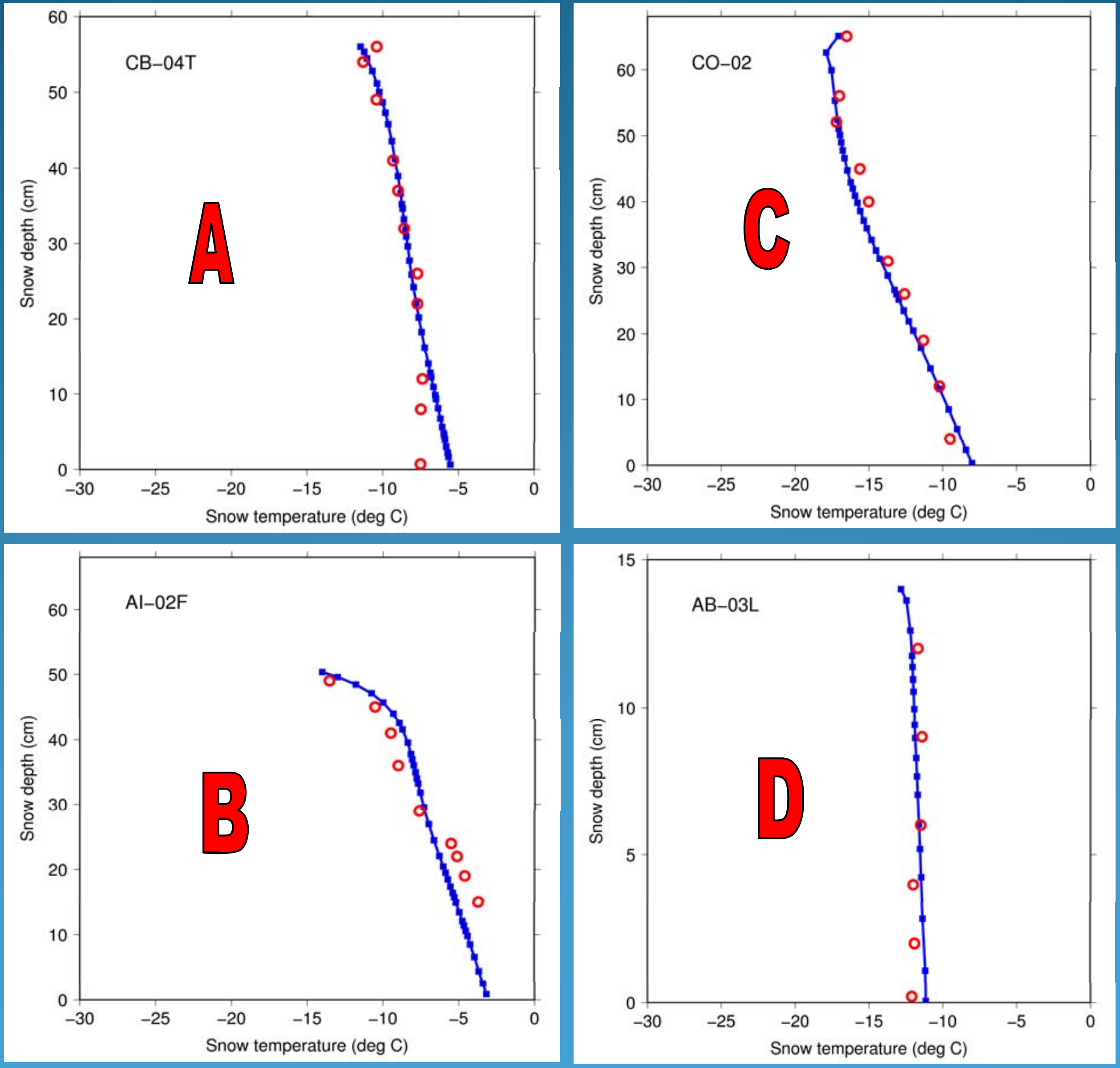


Elevation

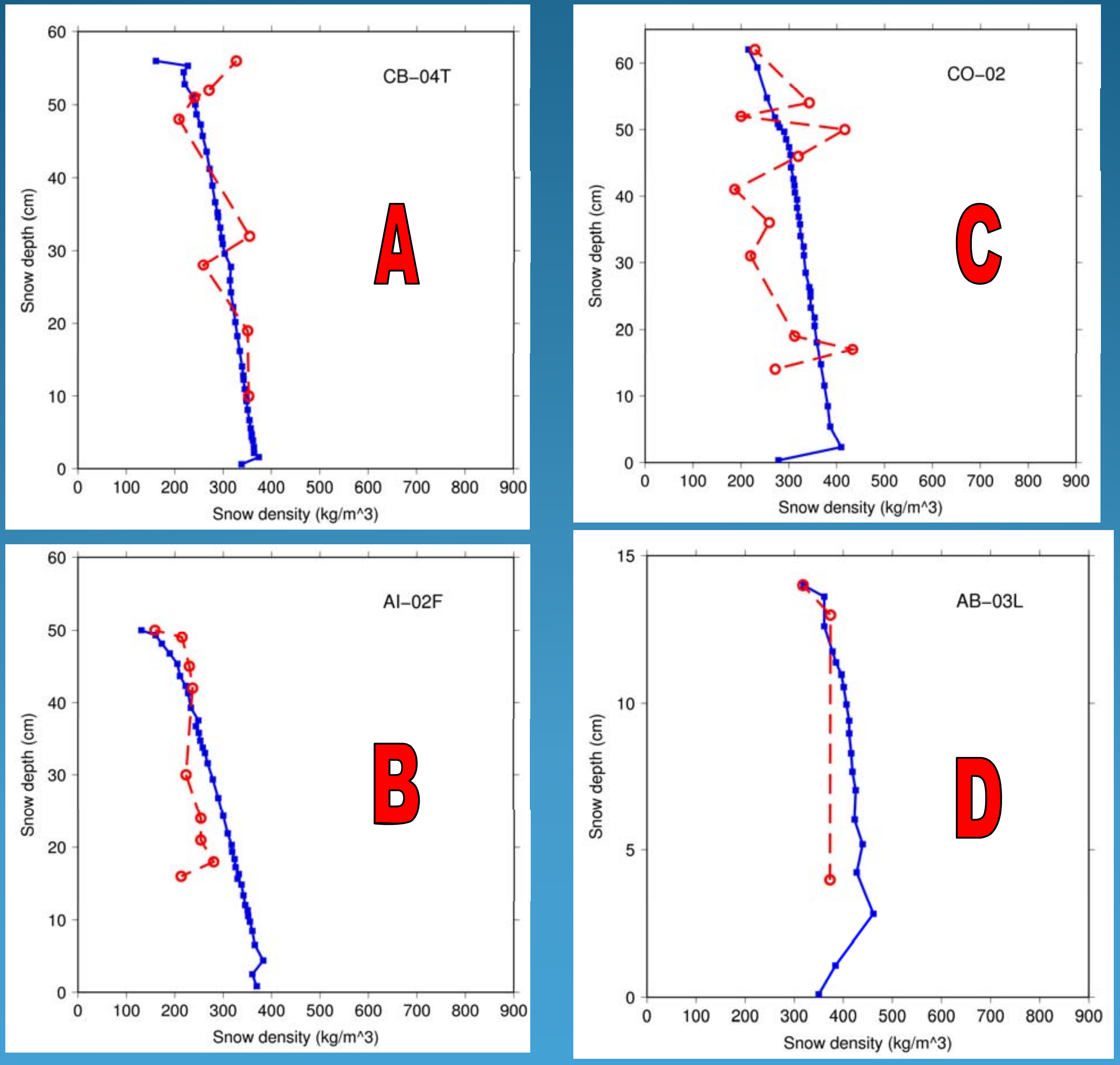


Snow Depth

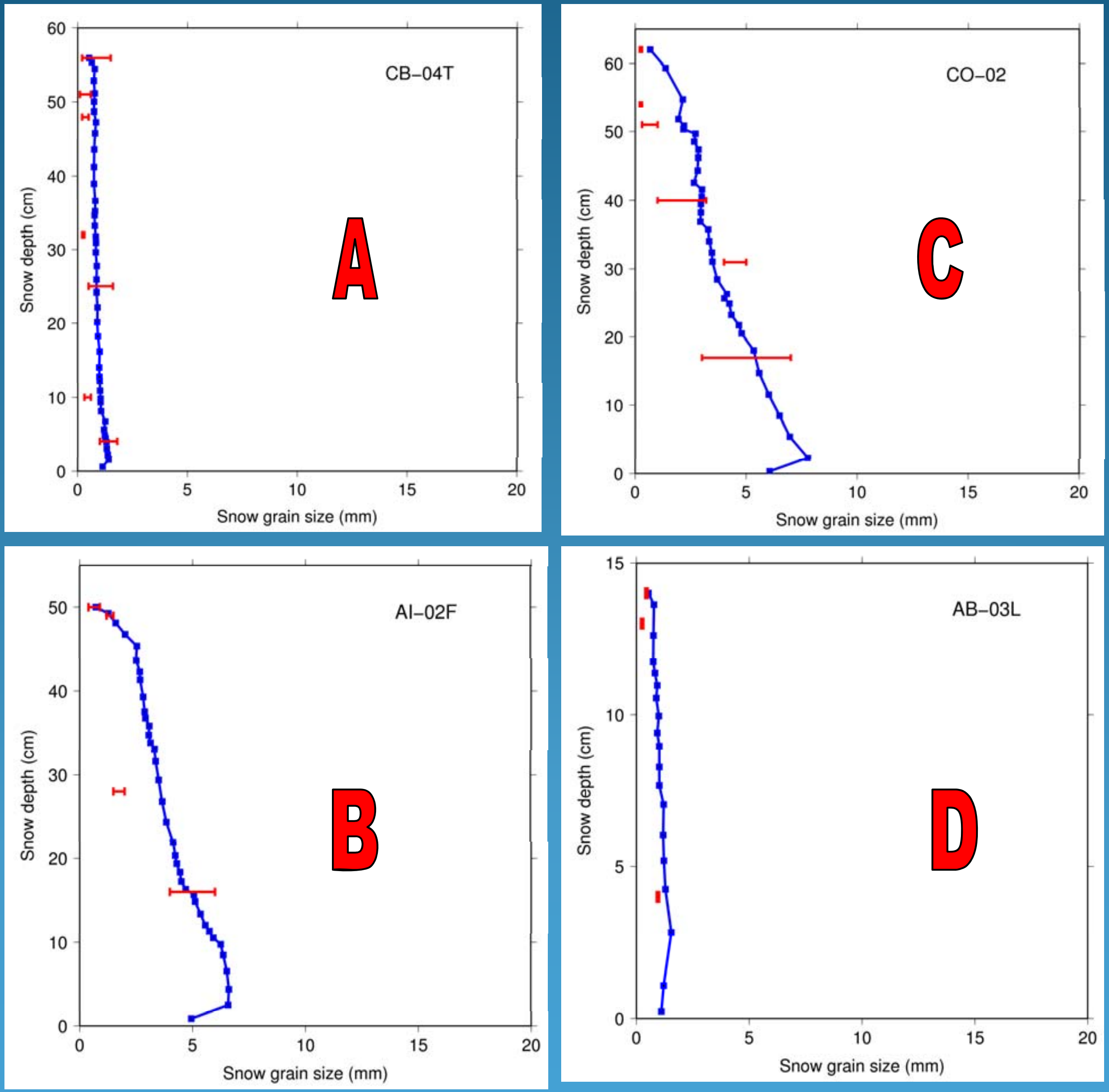
Comparison of snowpack temperature profiles

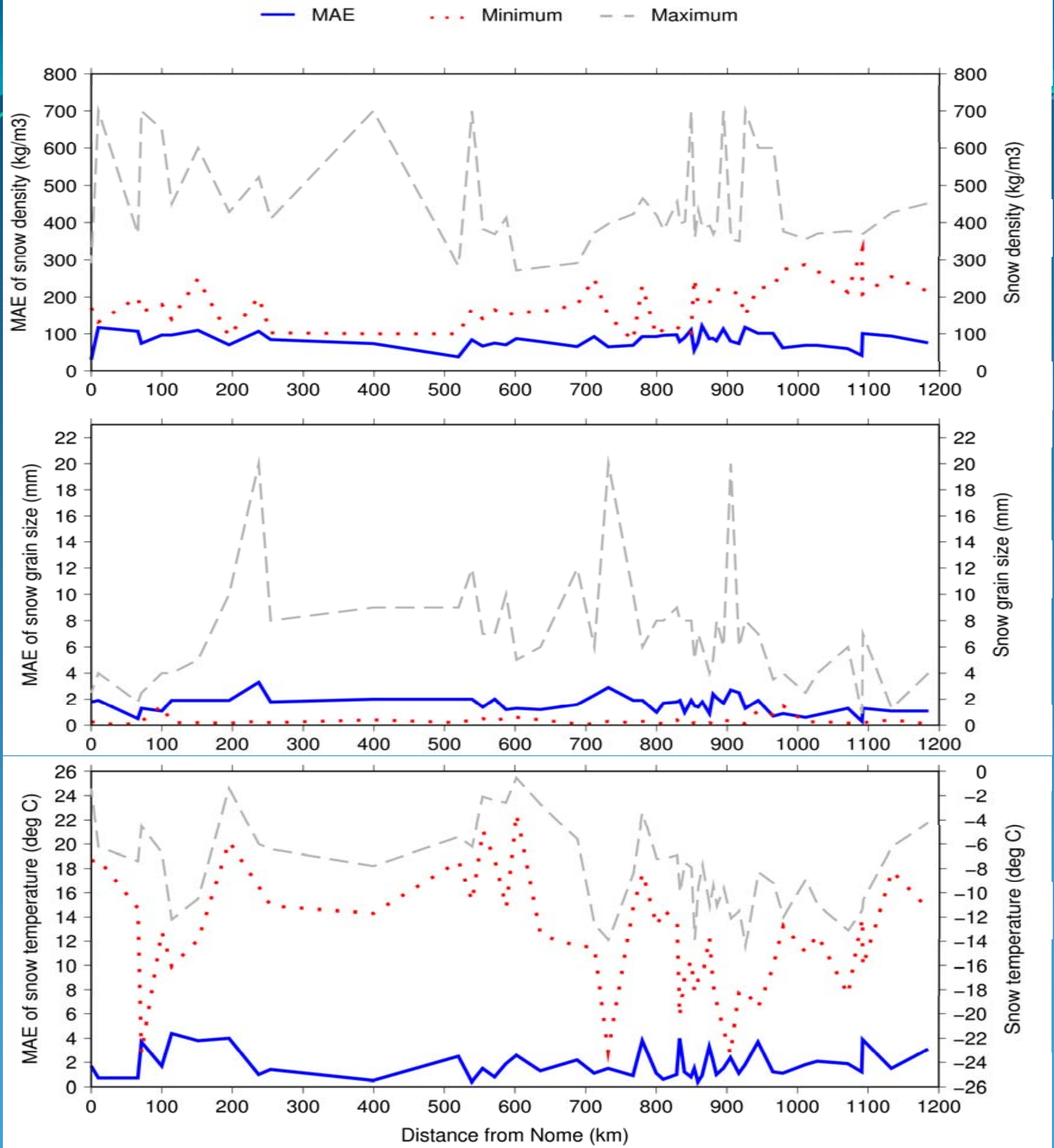


Comparison of snowpack density profiles



Comparison of snow grain size profiles





Maximum:700

Minmum:82

Mean (MAE):76

Maximum:20

Minmum:0.1

Mean (MAE):1.2

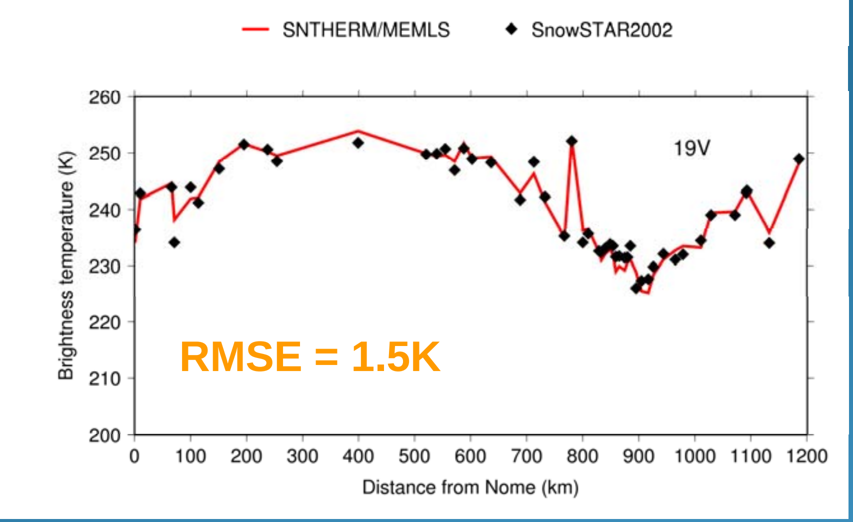
High:-0.5

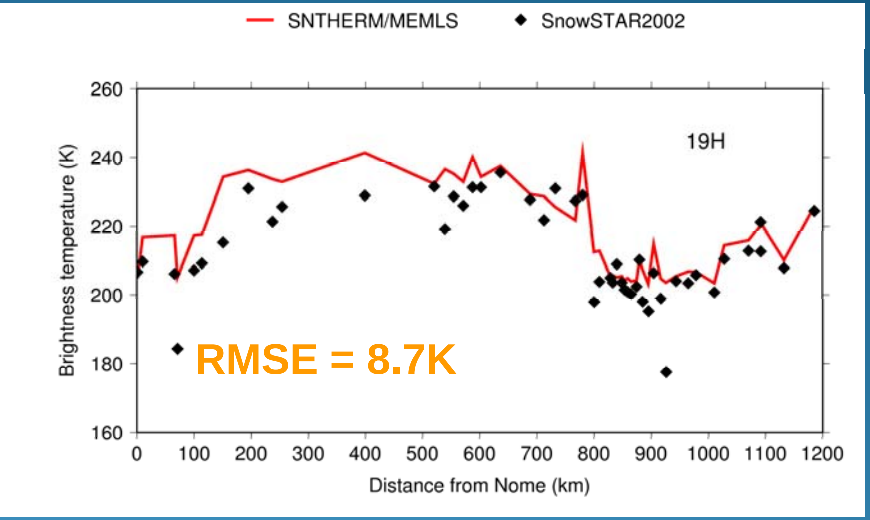
Low:-23.3

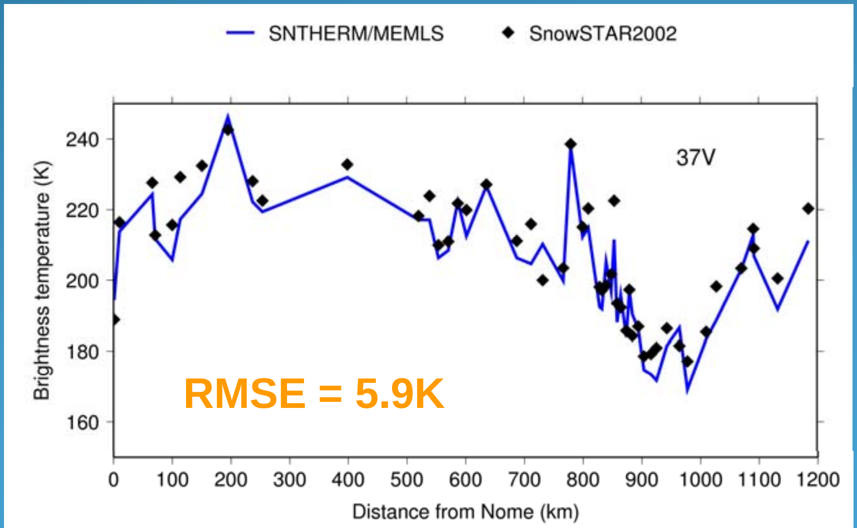
Mean (MAE):1.8

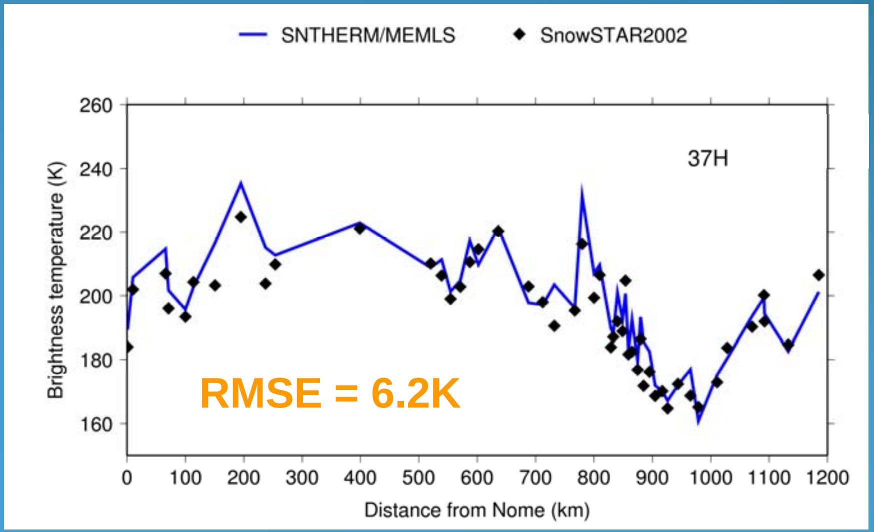
SNTHERM/MEMLS *V.S.* SnowSTAR2002/MEMLS

Comparison of modeled brightness temperatures









Conclusions

1. SNTHERM has the ability to recover observed snow microphysical structures along the SnowSTAR2002 transect. In particular, it does quite well for profile simulations of snow temperature, less well for snow density and snow grain size.

2. Comparison of simulated brightness temperatures showed quite good agreement between SNTHERM/MEMLS and SnowSTAR2002/MEMLS. The error is generally lower than the effects of mixed land cover types over large satellite footprints. These results are encouraging and imply that model simulation of snow microphysical profiles is a viable strategy for retrieval of SWE from passive microwave remote sensing data.

Reference:

Shi, X., M. Sturm, G. E. Liston, R. E. Jordan, and D. P. Lettenmaier, 2008: SnowSTAR2002 transect reconstruction using a multilayered energy and mass balance snow mode l, J. of Hydrometeorology (in review).