

Assimilation of MODIS Snow Cover and GRACE Terrestrial Water Storage Data through DART/CLM4

Yong-Fei Zhang¹, Zong-Liang Yang¹, Tim J. Hoar², Hua
Su¹, Jeffrey L. Anderson², Ally M. Toure^{3,4}, and
Matthew Rodell⁴

¹The University of Texas at Austin, Jackson School of Geosciences,
Austin, Texas

²The National Center for Atmospheric Research, Boulder, Colorado

³Universities Space Research Association (USRA), Columbia, MD, USA

⁴NASA Goddard Space Flight Center, Greenbelt, MD, USA

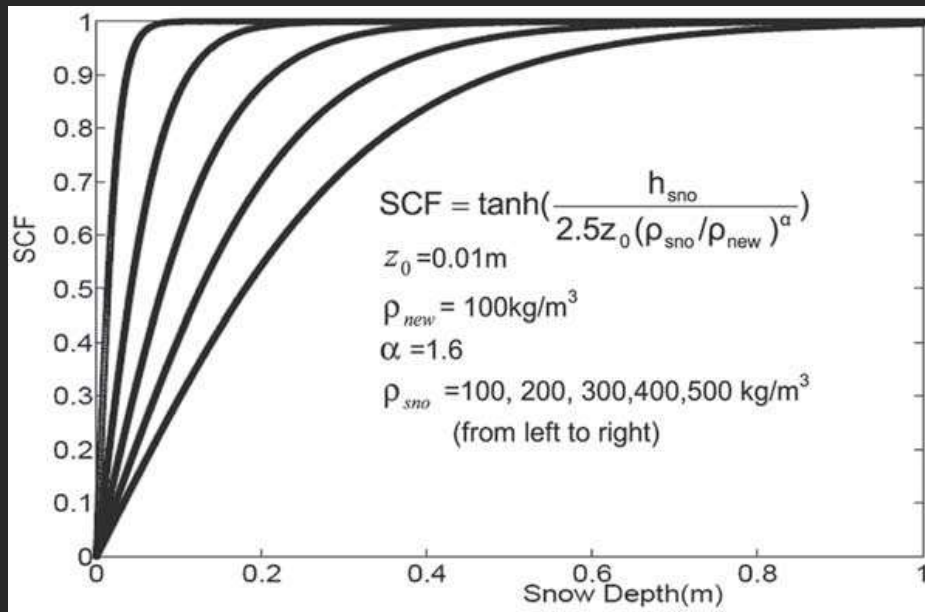


Content

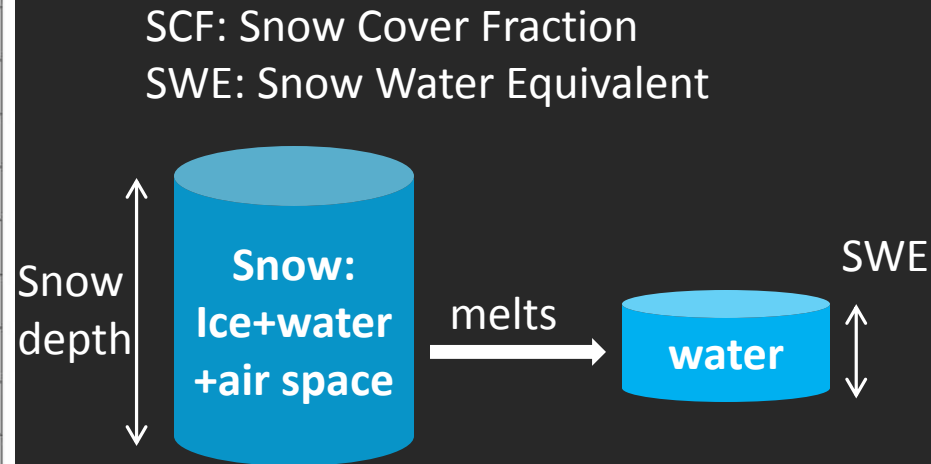
- DART/CLM4 land data assimilation system
- MODIS data assimilation
- MODIS and GRACE data assimilation
- New snow cover fraction parameterization scheme and its role in data assimilation

Community Land Model v.4 (CLM4)

- <http://www.cesm.ucar.edu/models/clm/>



Niu and Yang, 2007



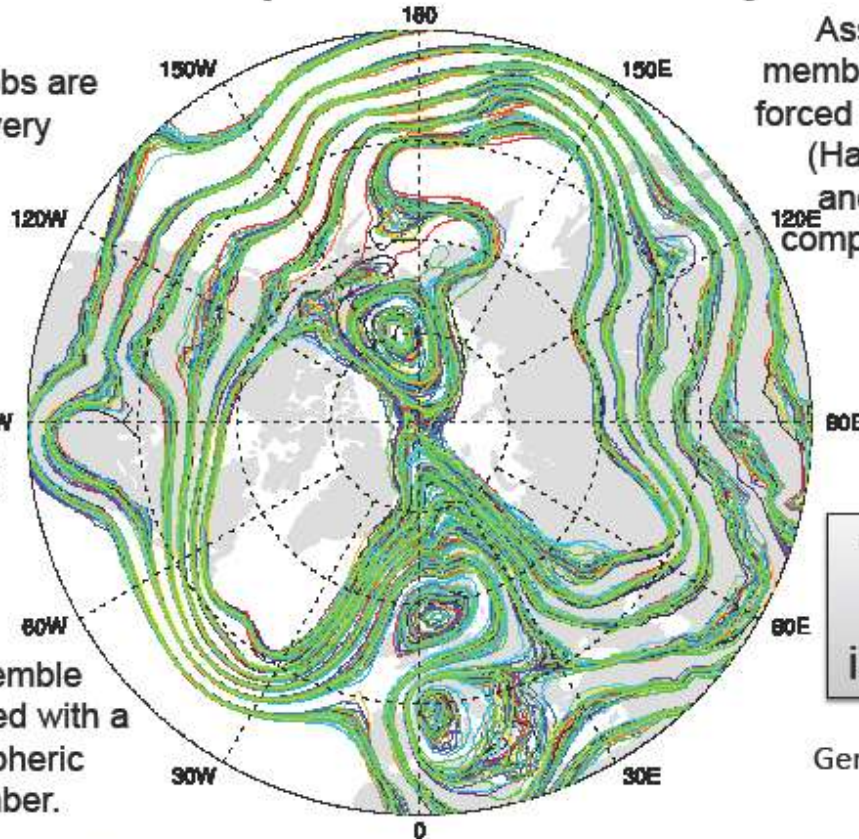
Data Assimilation Research Testbed (DART)

Atmospheric Reanalysis

O(1 million) atmospheric obs are assimilated every day.

Assimilation uses 80 members of 2° FV CAM forced by a single ocean (Hadley+ NCEP-OI2) and produces a very competitive reanalysis.

500 hPa GPH
Feb 17 2003



Each CLM ensemble member is forced with a different atmospheric reanalysis member.

1998-2010
4x daily
is available.

Generates spread in the land model.



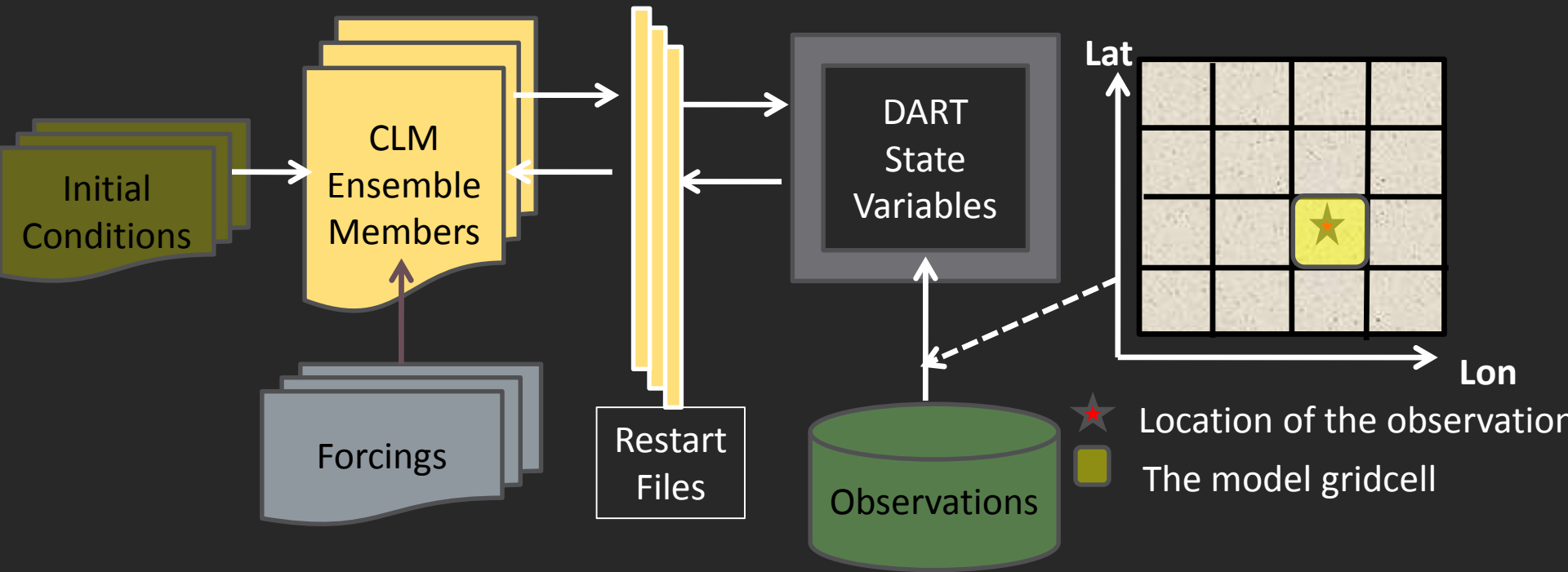
AMS New Orleans 2012



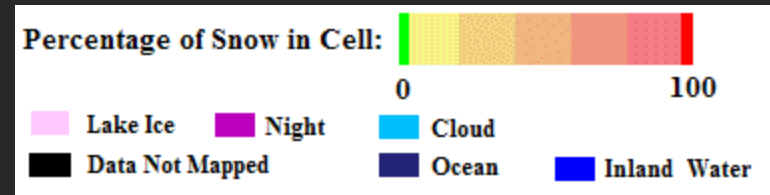
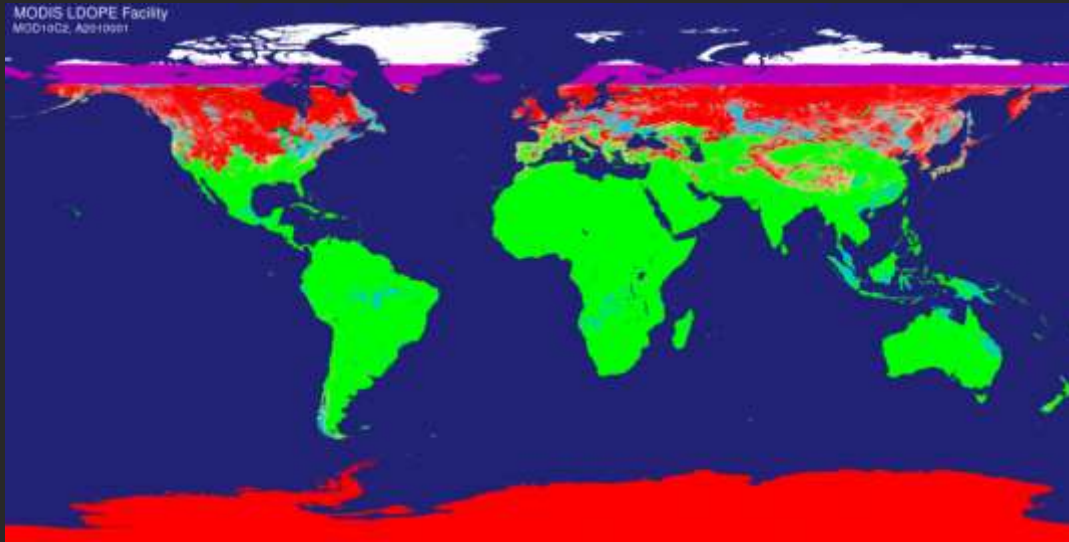
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Hoar et al.,
2012 AMS

The Coupled DART and CLM4



MODIS SCF data



<http://landweb.nascom.nasa.gov/animation/>

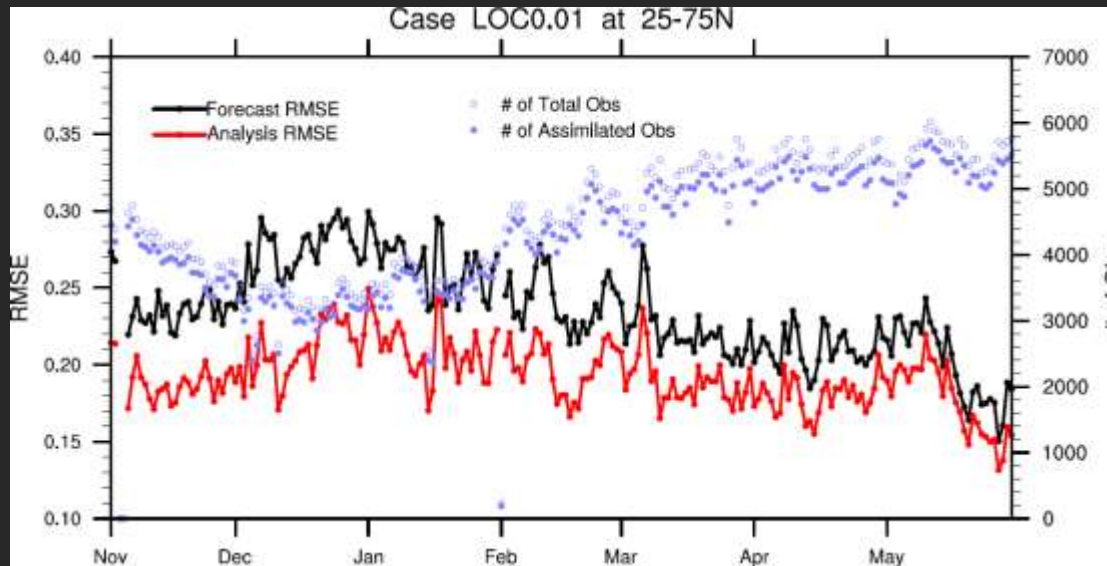
Daily MODIS observation

- MODIS/Terra daily snow cover (MOD10C2; 0.05° resolution; northern hemisphere)
 - Retrieved using NDSI

$$\text{NDSI} = \frac{\text{band 4} - \text{band 6}}{\text{band 4} + \text{band 6}}$$

- Preprocessed to 0.9° x 1.25° “Level 4” data
 - Pixels with lower than 20% confidence index (percentage of clear sky over certain grid) will be discarded.

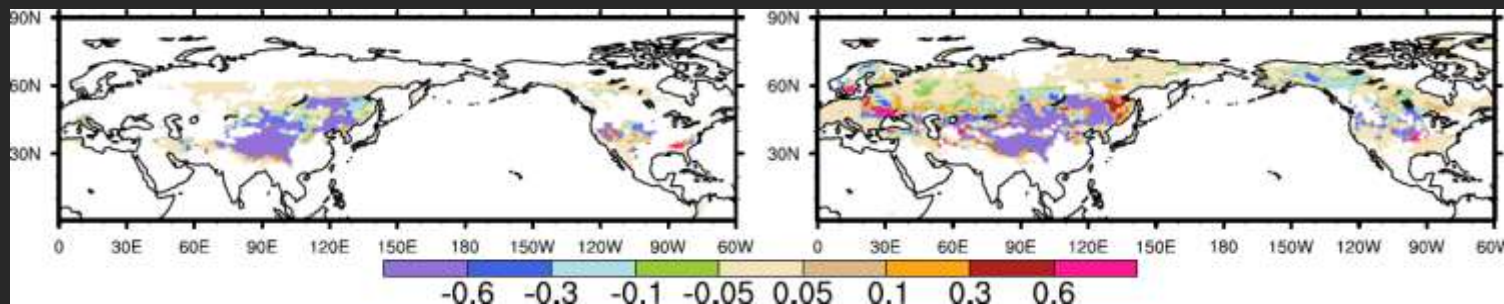
RMSE against MODIS data is reduced at each data assimilation step



Zhang et al., 2014

DJF 2002-2003

MAM2002-2003



Differences (data assimilation minus open loop) of normalized absolute bias of SCF against MODIS
 Cold color: improvements
 Warm color: degradation

DART/CLM4

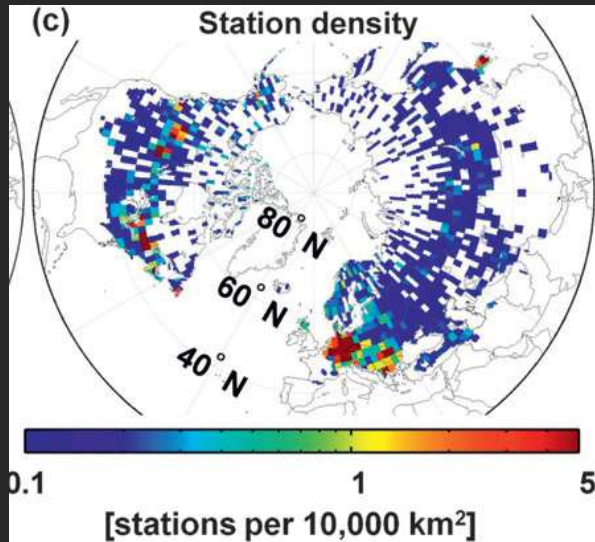
MODIS

GRACE

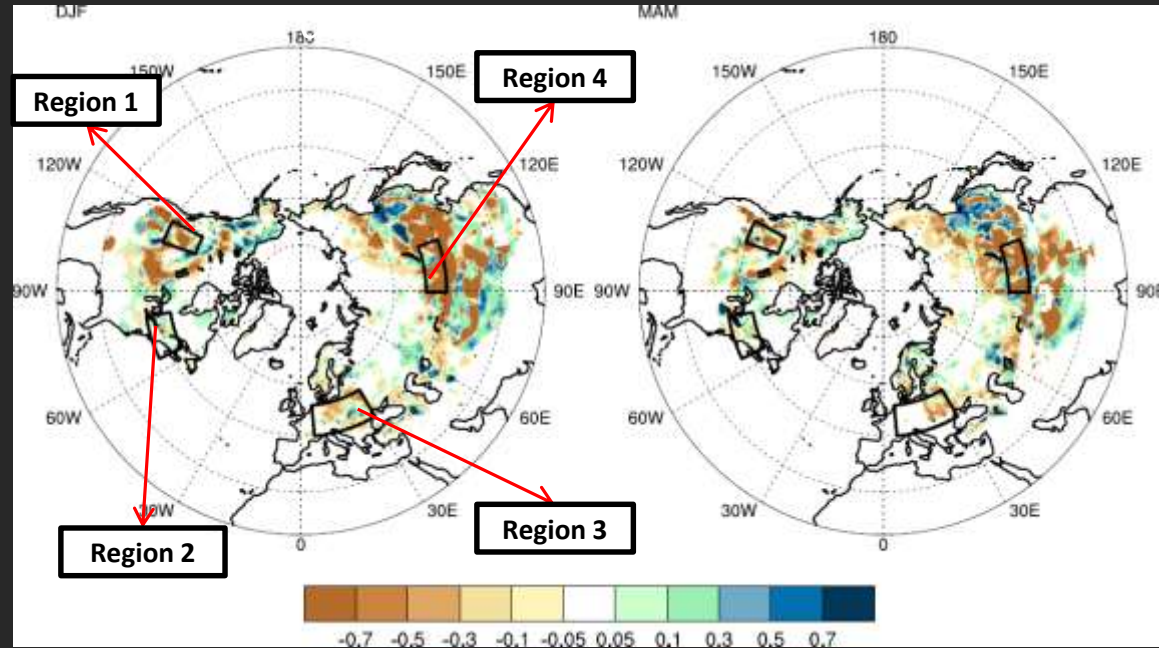
NewSCF

Comparison with CMC snow depth

Site density map (*Reichle et al., 2011*)

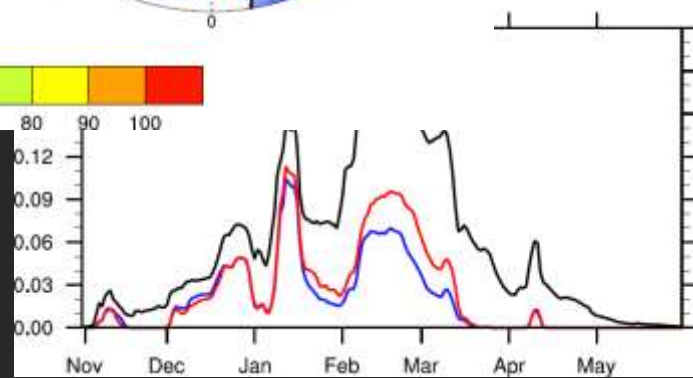
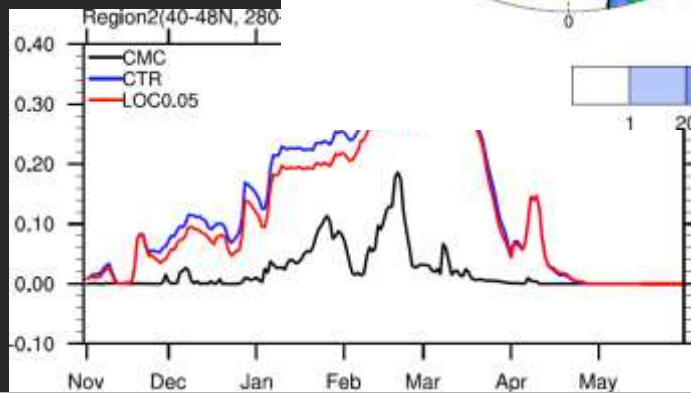
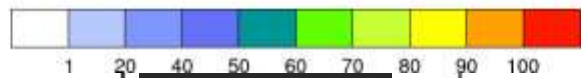
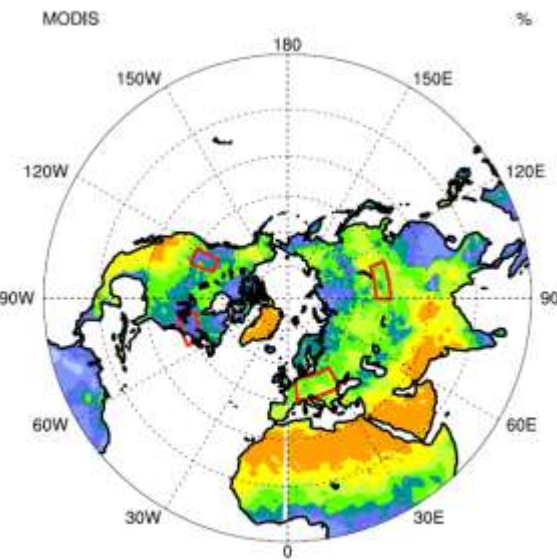
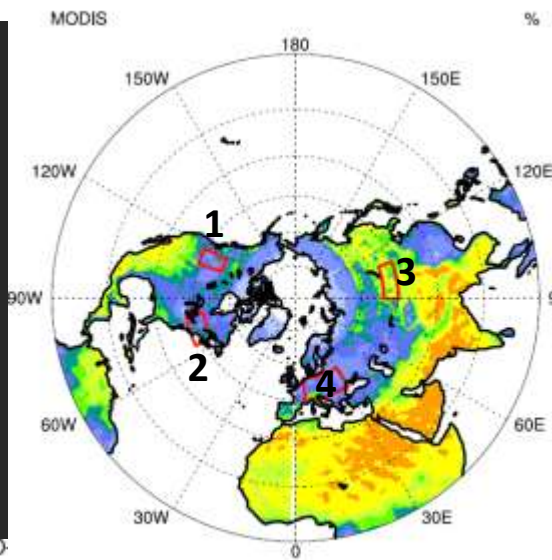
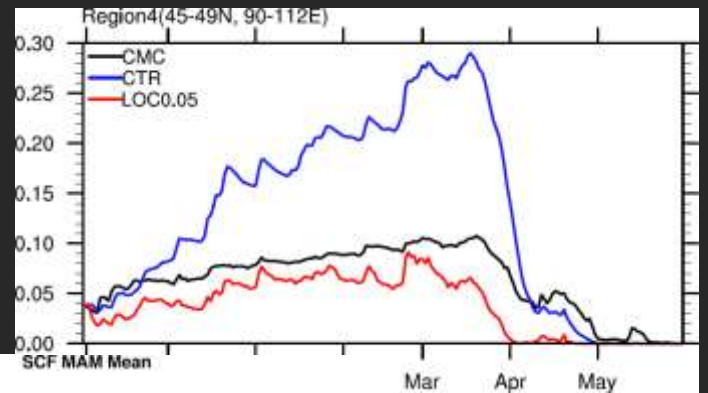
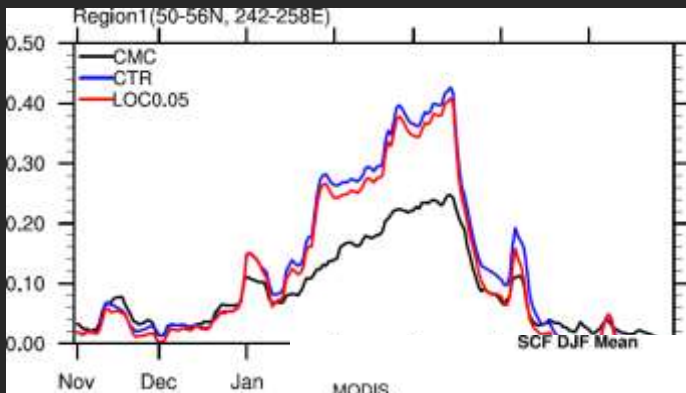


Difference (data assimilation – open loop) of normalized absolute bias of model-simulated snow depth against



Brown: improvements

Blue: degradation



DART/CLM4

MODIS

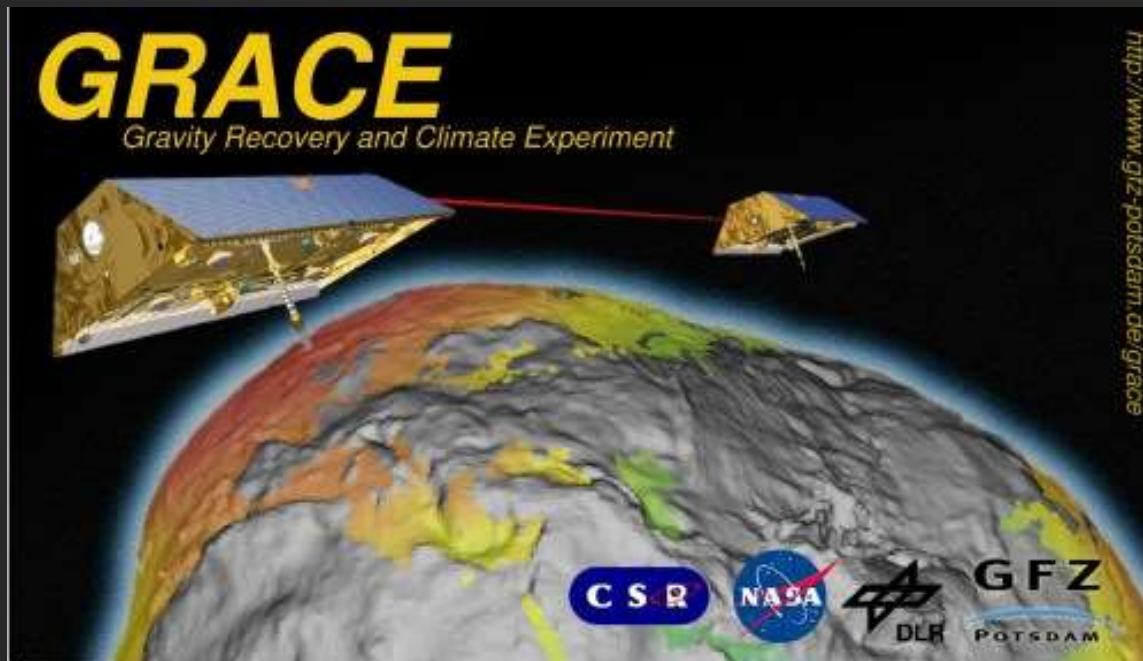
GRACE

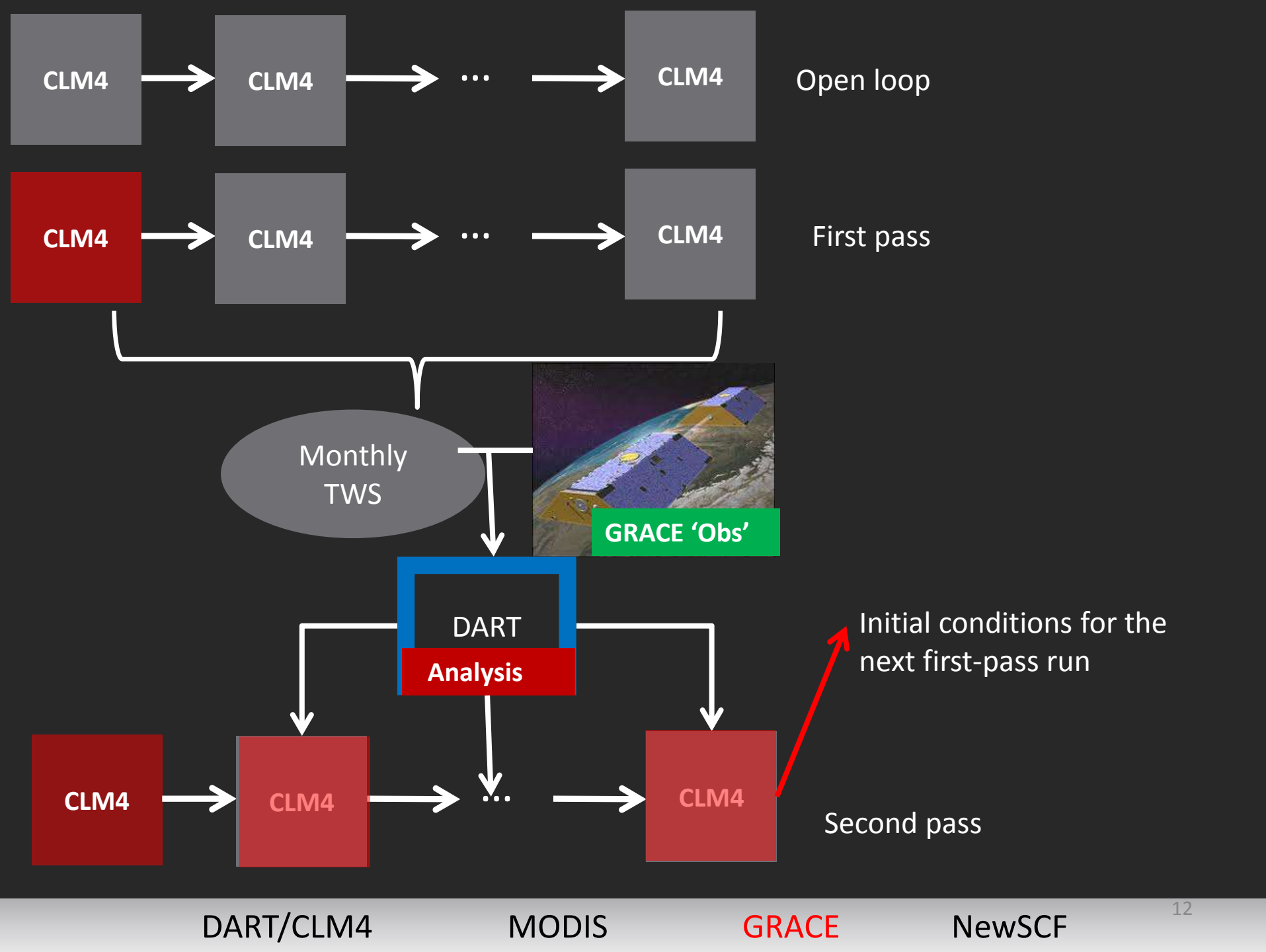
NewSCF

- The MODIS-only data assimilation results are generally closer to the CMC data in site-dense regions than the open loop case but are further away from the CMC data in some portions of the Northern Hemisphere where observations are sparse (e.g., in dense forests and high-elevation regions).
- Snow data assimilation has little impact on SCF at higher-middle and high latitudes in winter because SCF in CLM4 ensembles is close to unity with little ensemble spread.
- Limitations include:
 - Lack of observations due to sunlight and clouds
 - Can not provide more information when snowpack is full

GRACE satellite data

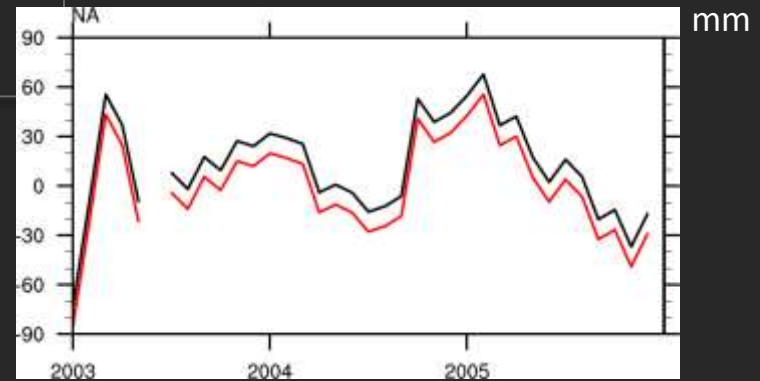
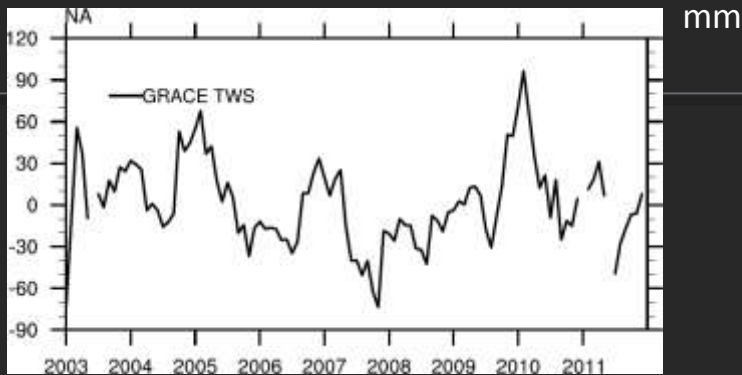
- Different from MODIS that measures radiances, GRACE measures the distance between two satellites and retrieves land abnormal quantities from that.



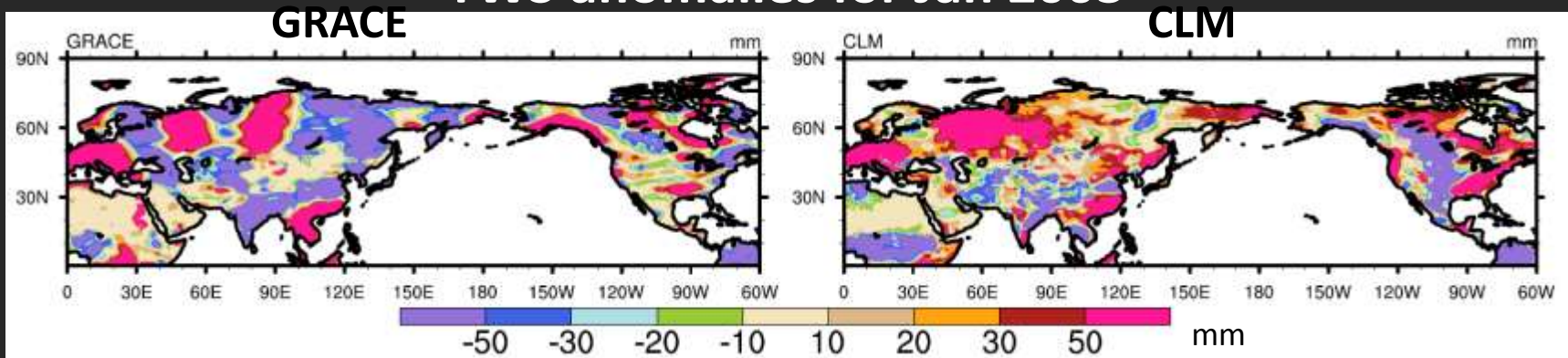


GRACE TWS assimilation

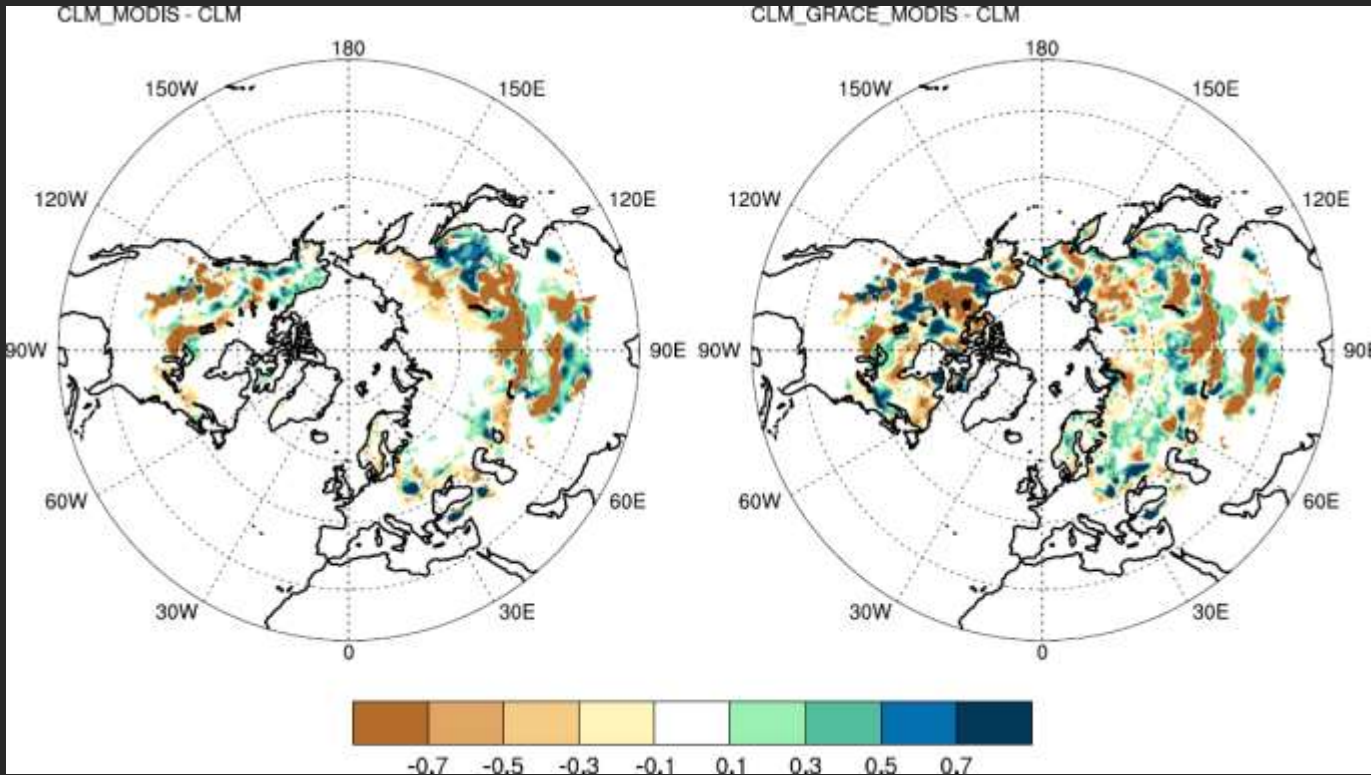
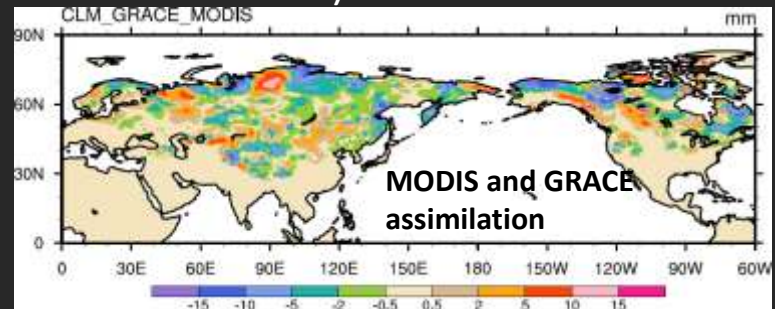
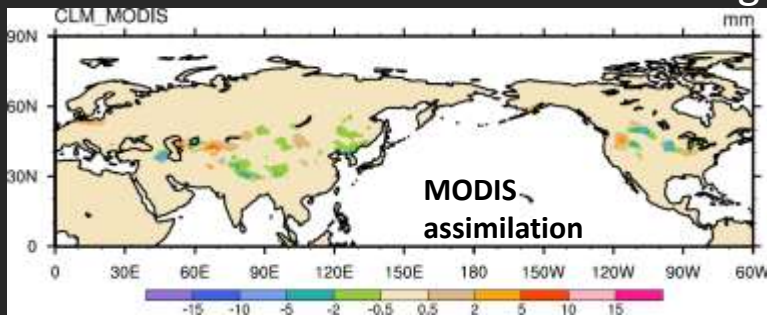
TWS anomaly over North America



TWS anomalies for Jan 2003



Snow Water Storage (Posterior minus Prior)



DART/CLM4

MODIS

GRACE

NewSCF

TWS monthly anomaly from four data sources

- Reference time period: 2003–2005

GRACE

Open loop

First pass

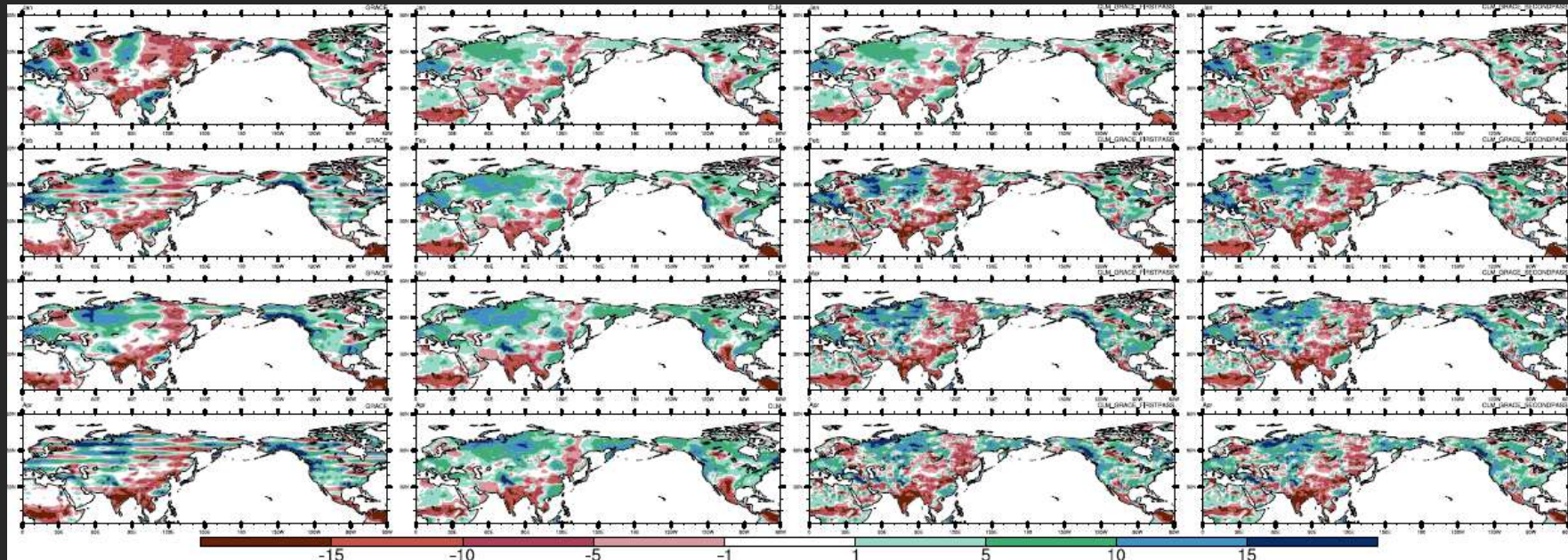
Second pass

Jan

Feb

Mar

Apr



cm

DART/CLM4

MODIS

GRACE

NewSCF

Model uncertainty

Open loop

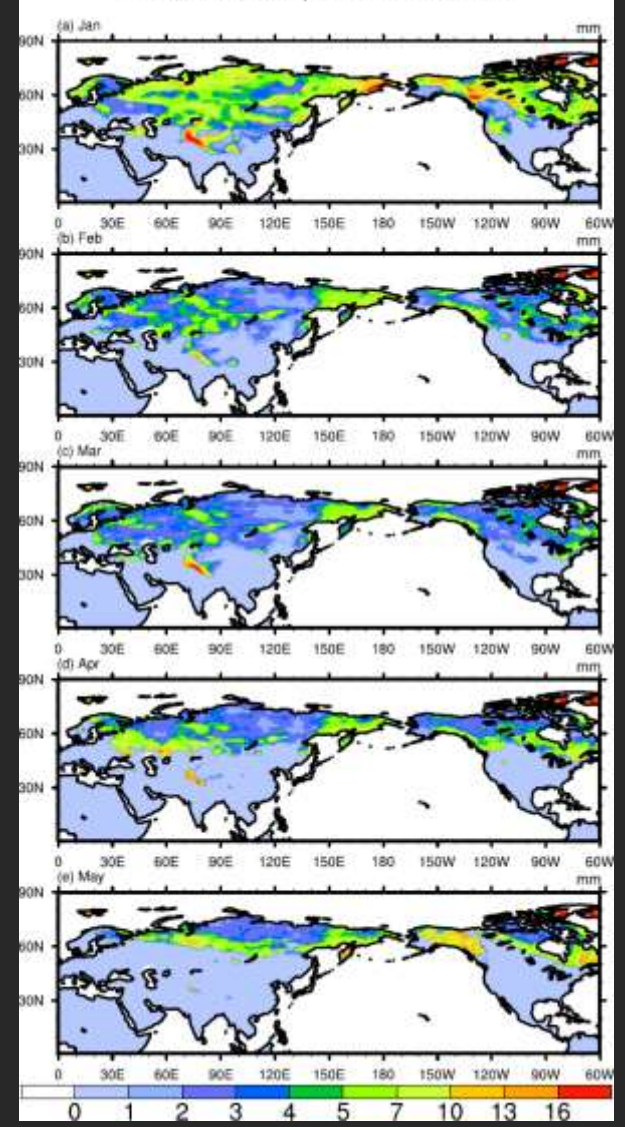
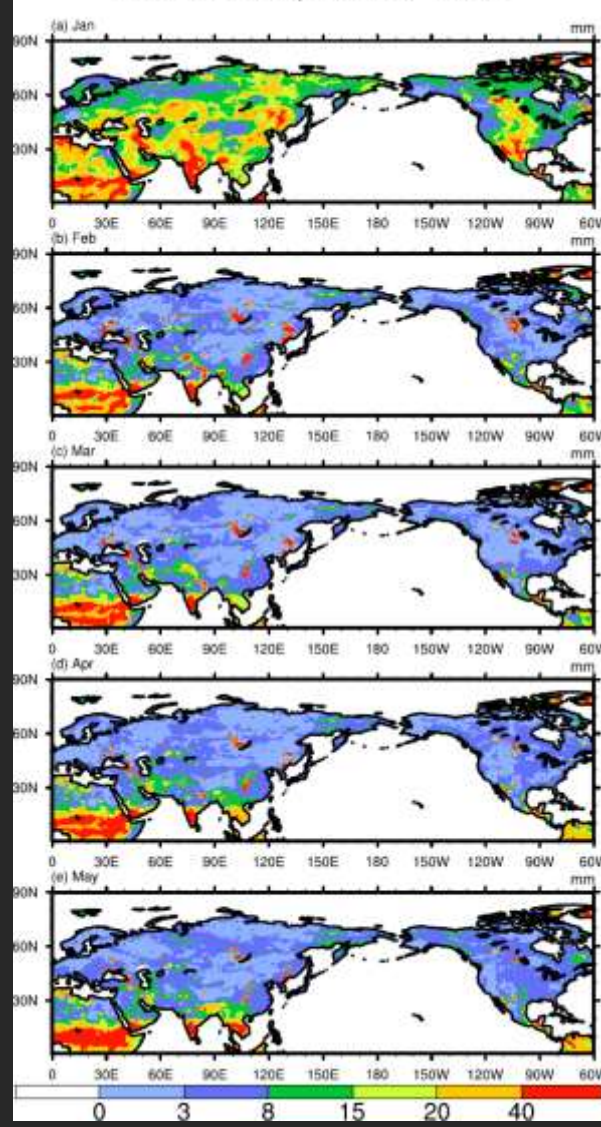
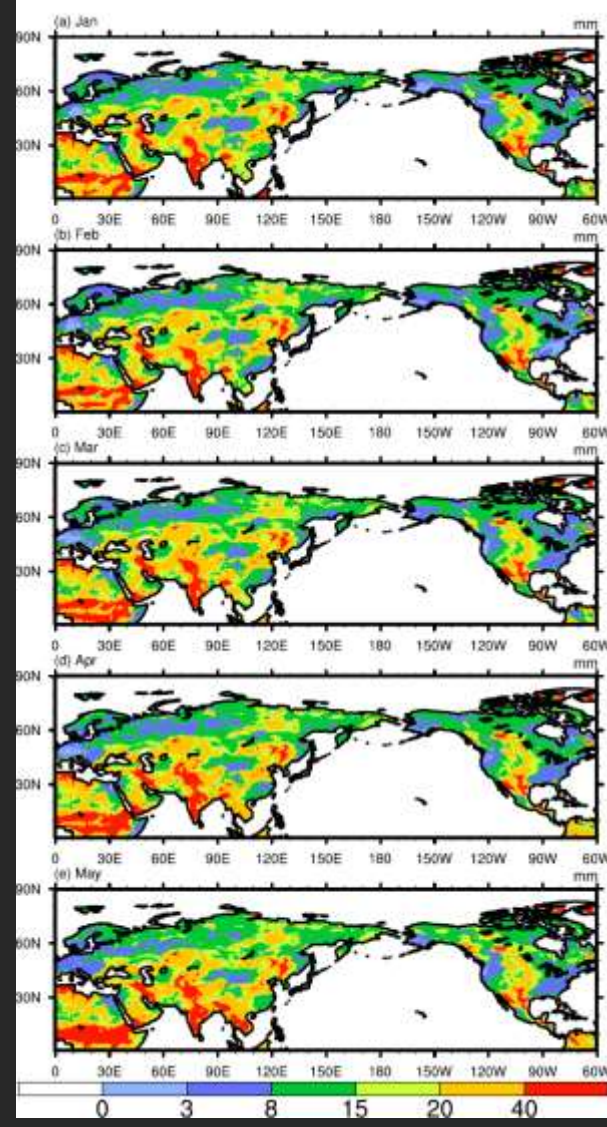
Second pass

Second pass

Ensemble Spread of TWS

Ensemble Spread of TWS

Ensemble Spread of SWE



DART/CLM4

MODIS

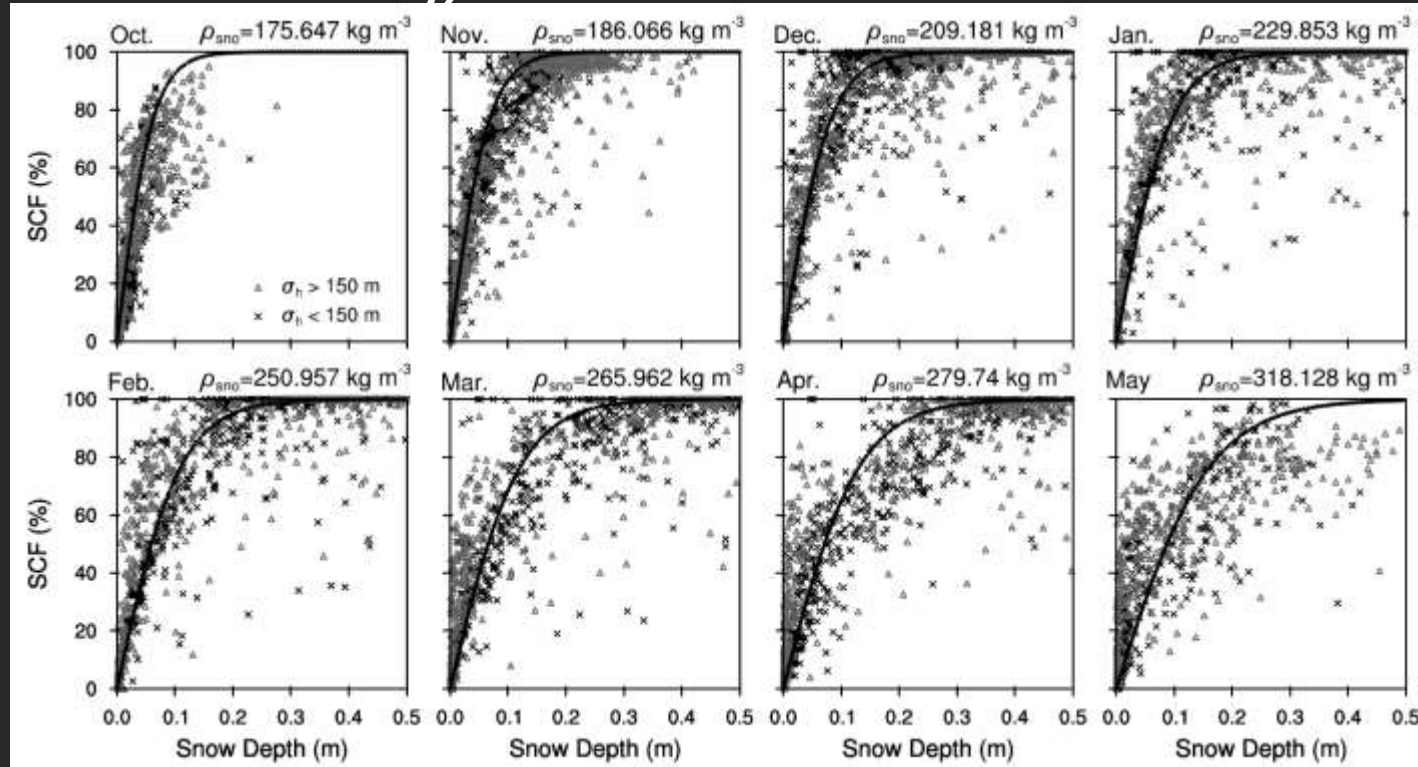
GRACE

NewSCF

- While MODIS data assimilation is mainly effective along the snowline, GRACE provides valuable information at higher latitudes. This is confirmed by comparing to CMC snow depth observations.
- Ensemble spread shrinks fast. The value of GRACE become small after first month's assimilation.

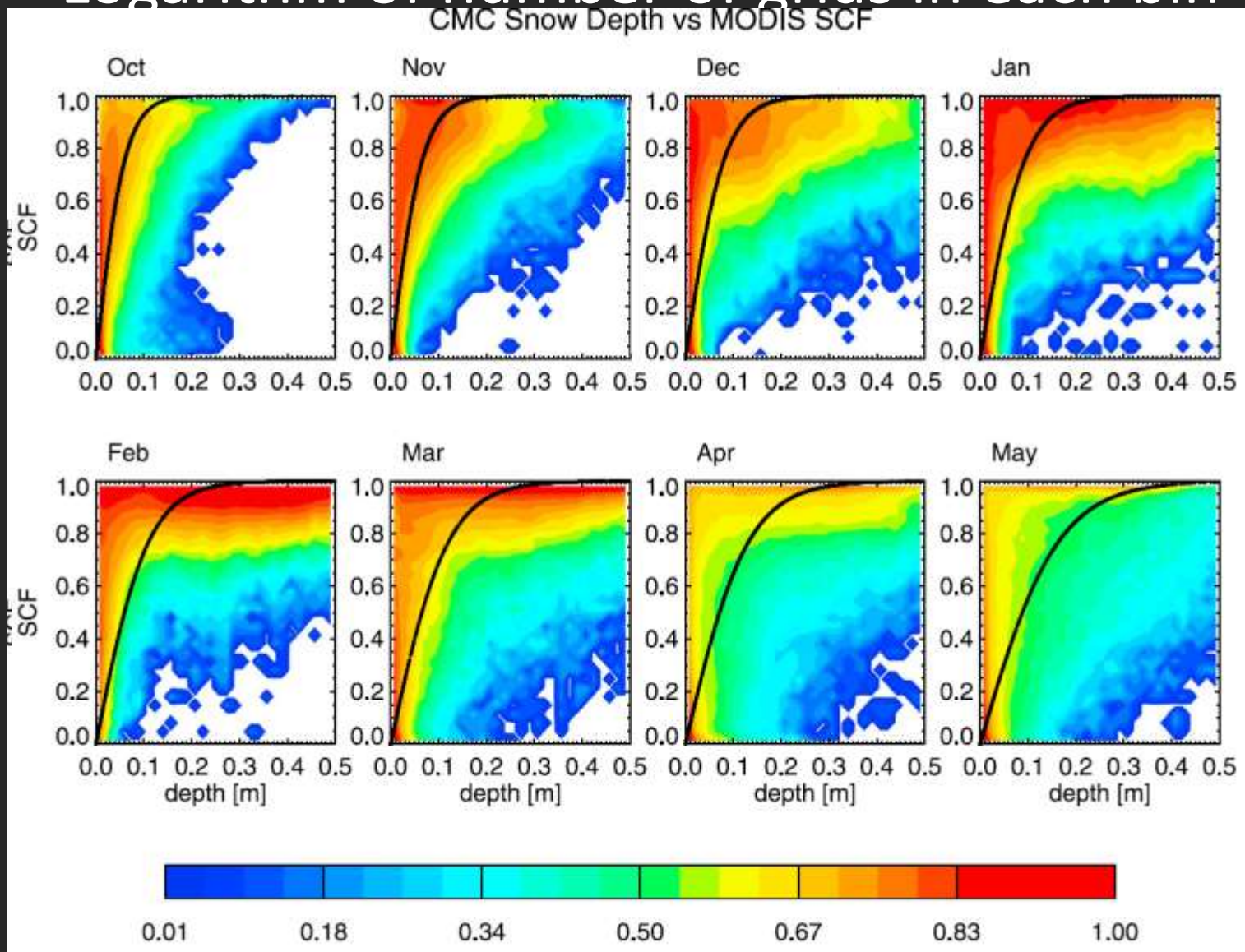
SCF parameterization scheme in CLM4

- *Niu and Yang, 2006*

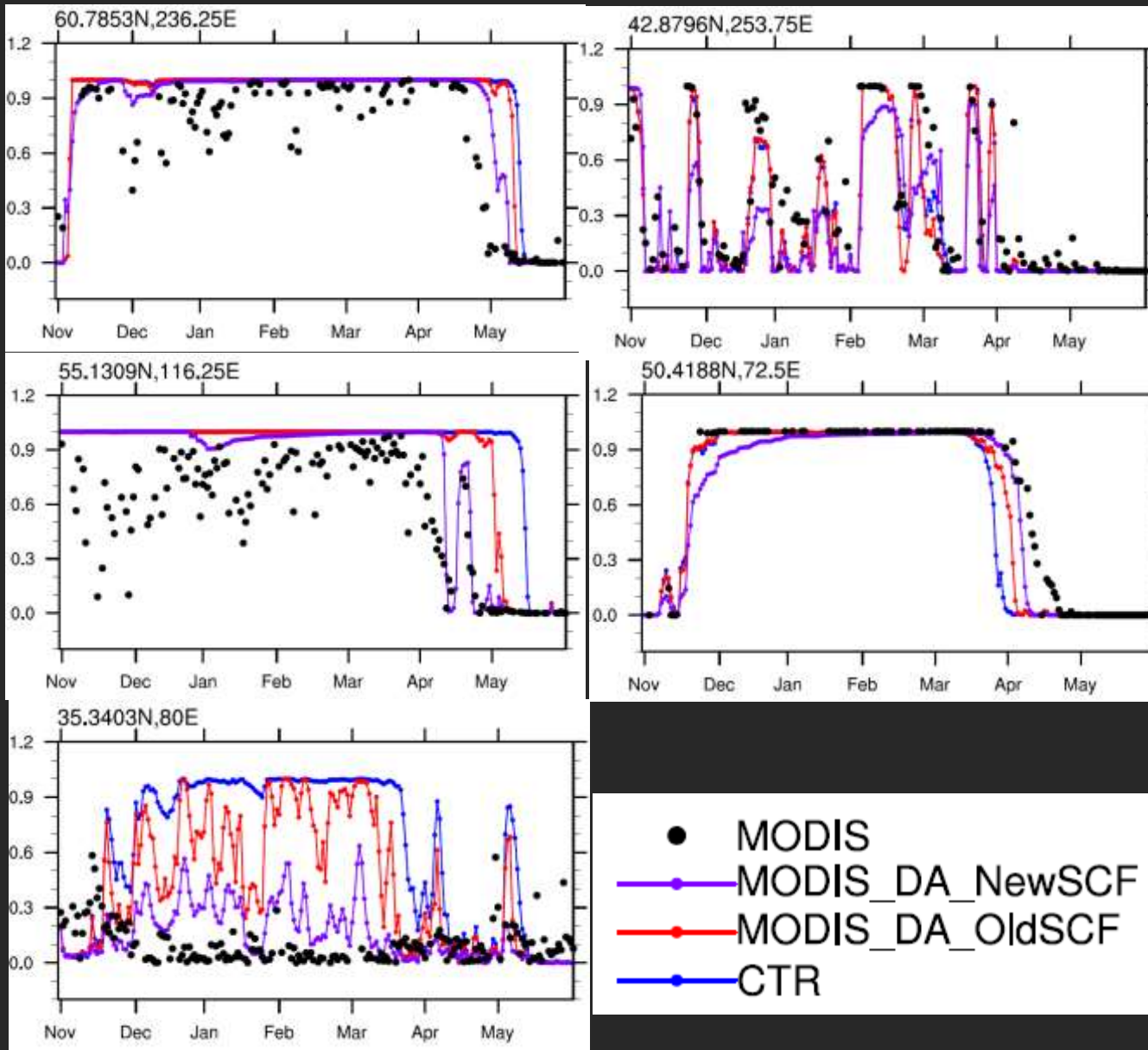


$$f_{sno} = \tanh\left(\frac{h_{sno}}{2.5z_{0g}(\rho_{sno}/\rho_{new})^m}\right)$$

- Logarithm of number of grids in each bin



Swenson and Lawrence, 2012



DART/CLM4

MODIS

GRACE

NewSCF

SCF parameterization scheme matters

- SCF Data assimilation results are very sensitive to snow cover fraction parameterization scheme
- SCF assimilation with the new SCF scheme shows better performance in the melting season, but not in the accumulation season

Thanks!
Questions?

