Multi-Sensor Snow Data Assimilation: Part 1: Assimilation of the MODIS Snow Cover Fraction the Community Land Model (CLM04)

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OBJECTIVES

Assimilate the MODIS Snow Cover Fraction (Hall et al. 2002) Dataset through the Coupled Data Assimilation Research Testbed (DART) and the Community Land Model version 04 (CLM04)

In this study , we first assessed the CLM04 (Lawrence et al. 2011) snow fraction estimates to serve as a benchmark to evaluate the multisensor data assimilation(DA) into the land model.

The overall goal of the multisensor DA is to develop an optimized approach for merging Terra MODIS snow cover, Aqua AMSR-E radiance, and GRACE terrestrial water storage change observations to generate spatially and temporally continuous global snow water equivalent (SWE) fields, at high resolutions (~1/8 degree).

EXPERIMENTAL SETUP

a. Data Assimilation Framework

The Data Assimilation Research Testbed(DART)(http://www.image.ucar.edu/DAReS/DART/) is an ensemble-based data assimilation framework developed at the National Center for Atmospheric Research (NCAR).
➢ The assimilation uses 80 instances of CLM04.
➢ Each instance of CLM04 is forced by a unique realistic atmosphere (from an offline CAM assimilation)
➢ When observations (MODIS/GRACE/AMSR-E) are available, DART performs an assimilation once a day using all the observations +/- 12 hours from the model stopping time.
➢ The updated state variables are used as the restart variables for the next CLM04 model advance.
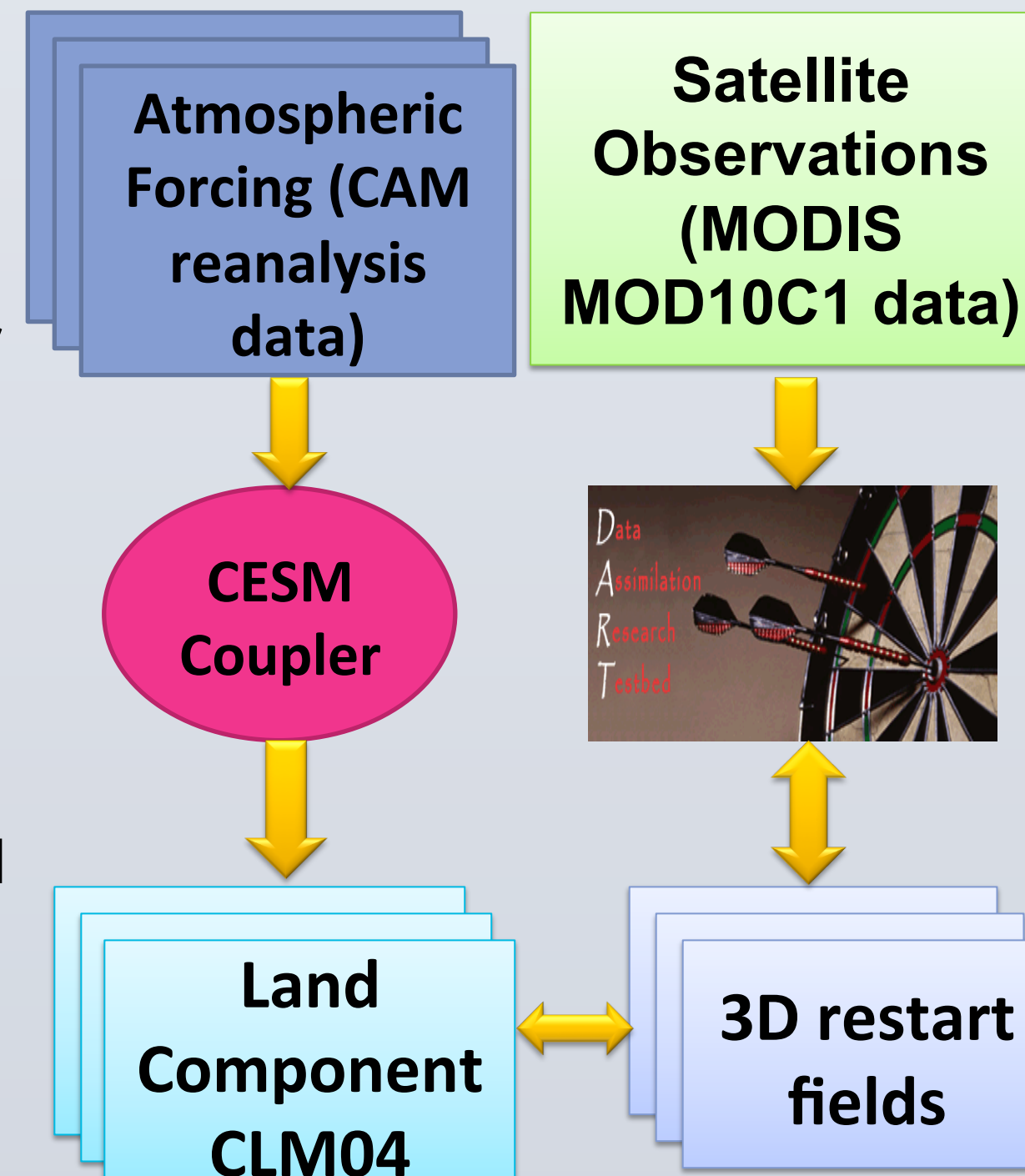
Fig: Diagram of the coupled DART and CLM04: The assimilation is performed using : Ensemble Adjustment Kalman Filter (Anderson, 2001)

b. Data

1) MODIS/Terra daily snow cover fraction : MOD10C1; 0.05 ° resolution; northern hemisphere; 2001 to 2010). Regridded to 0.9°x 1.25° CLM04 resolution using algorithm developed at NASA Global Modeling and Assimilation Office.

2) Interactive Multisensor Snow and Ice Mapping System (IMS) data (NOAA/NESDIS/OSDPD/SSD, 2004). It provides estimates of daily snow and ice cover extent over the northern hemisphere at ~1/4° resolution.

IMS 01-Feb-2001

No snow   snow
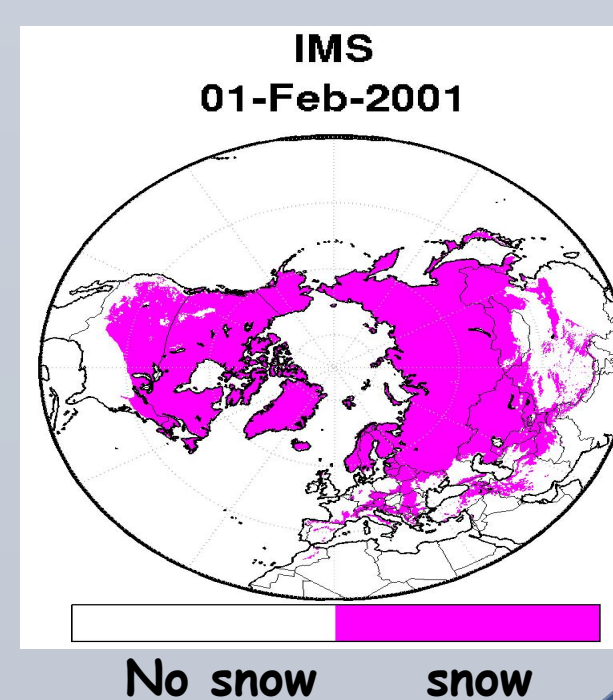
c. Prognostic Model: CLM version 04

The CLM 04, the land model for the Community Earth System Model(CESM v1.0.4) (Vertenstein et al., 2011) is a spatially distributed one-dimensional vertical model that provides the lower boundary condition for the Community Atmosphere Model (CAM). CLM04 include a state-state-of-art snow model which simulate snow as a 5-layer medium and each layer is characterized by its depth, density, temperature, effective grain size and liquid water content.
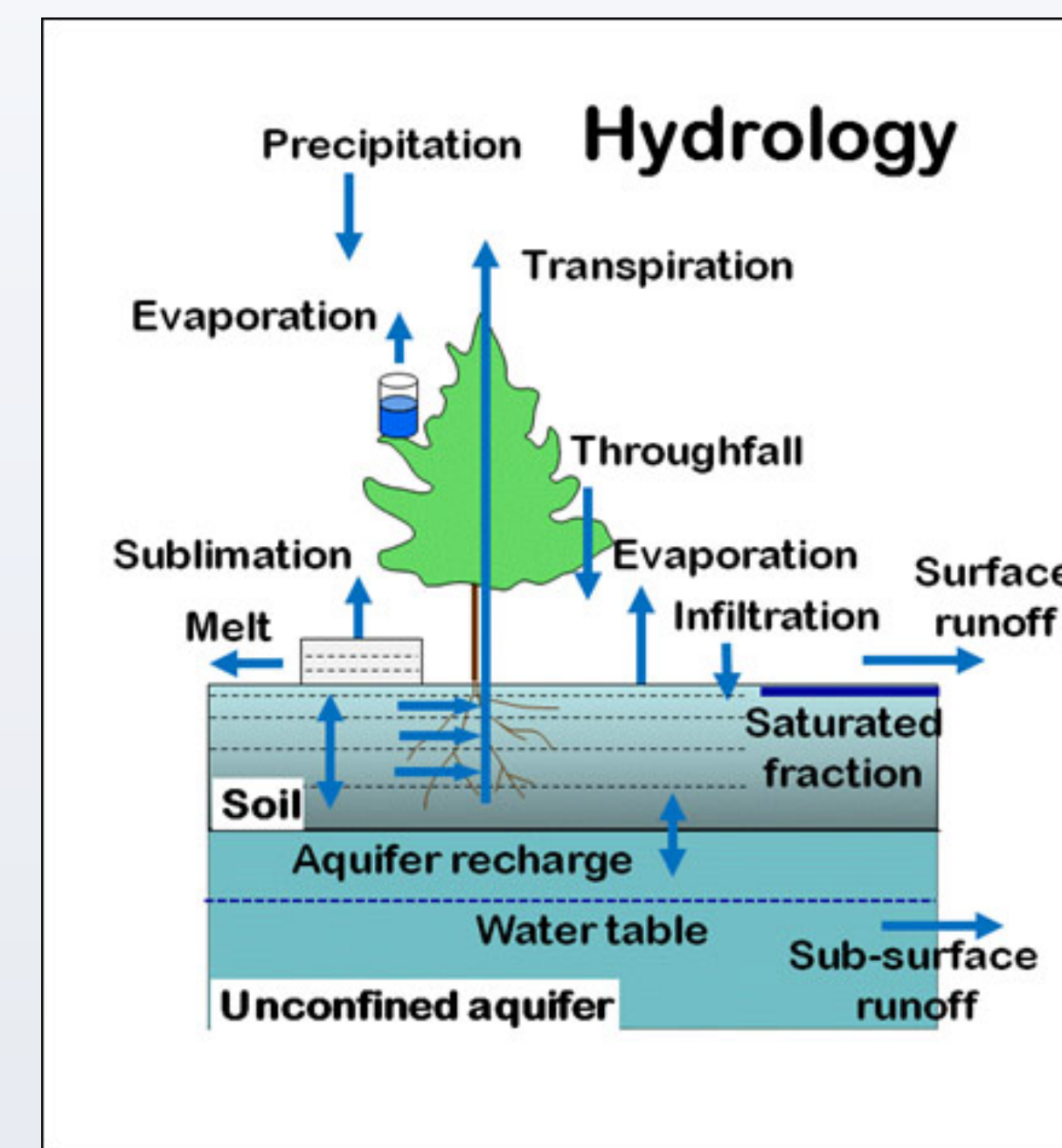
Fig: Hydrologic cycle over land in CLM04 (http://www.cesm.ucar.edu/models/clm/hydrologic.html)

Results

1. Assessment of CLM04 snow model estimates

a. Comparison against MODIS SCF Observations

Snow cover extent

Mean SCE: MODIS = 11.00 [x10⁶ km²] CLM = 11.38 [x10⁶ km²]
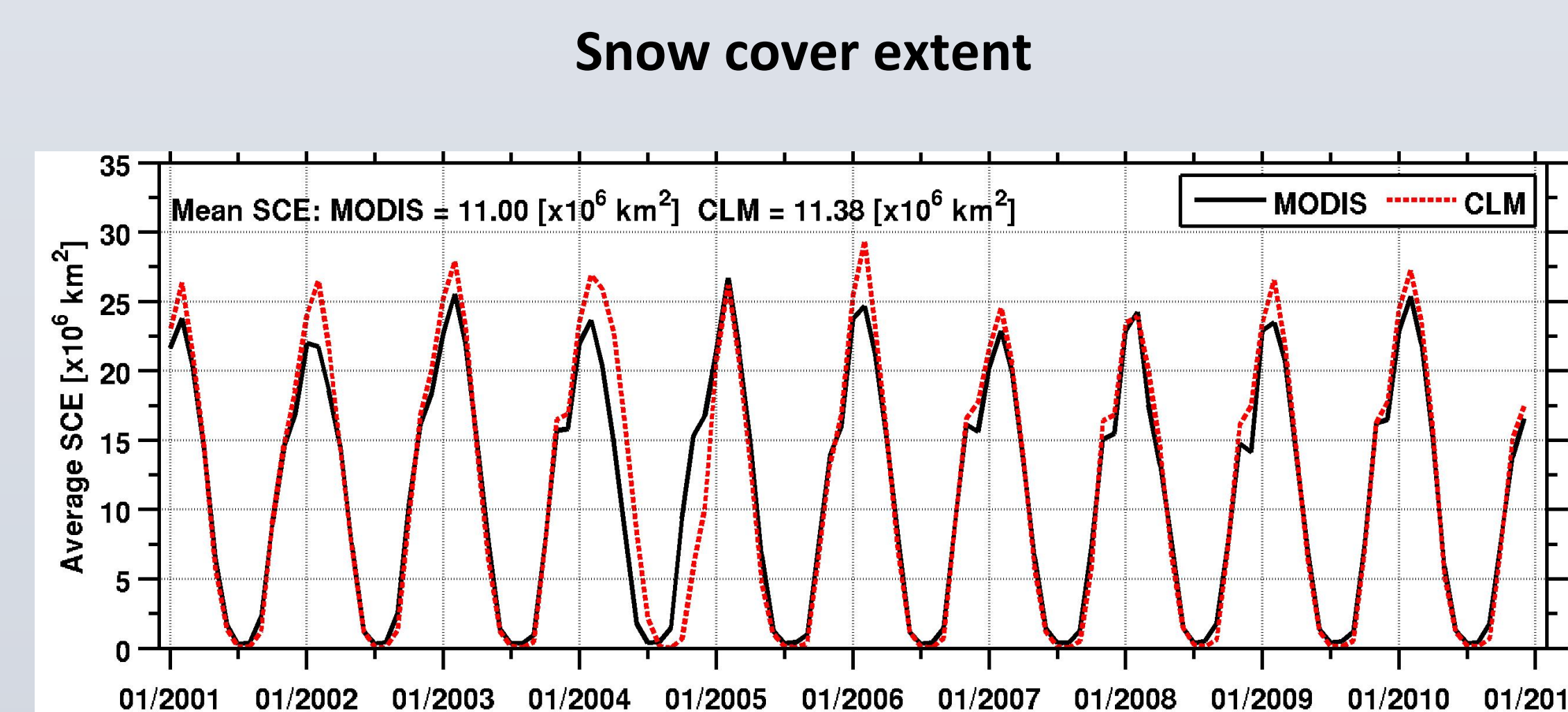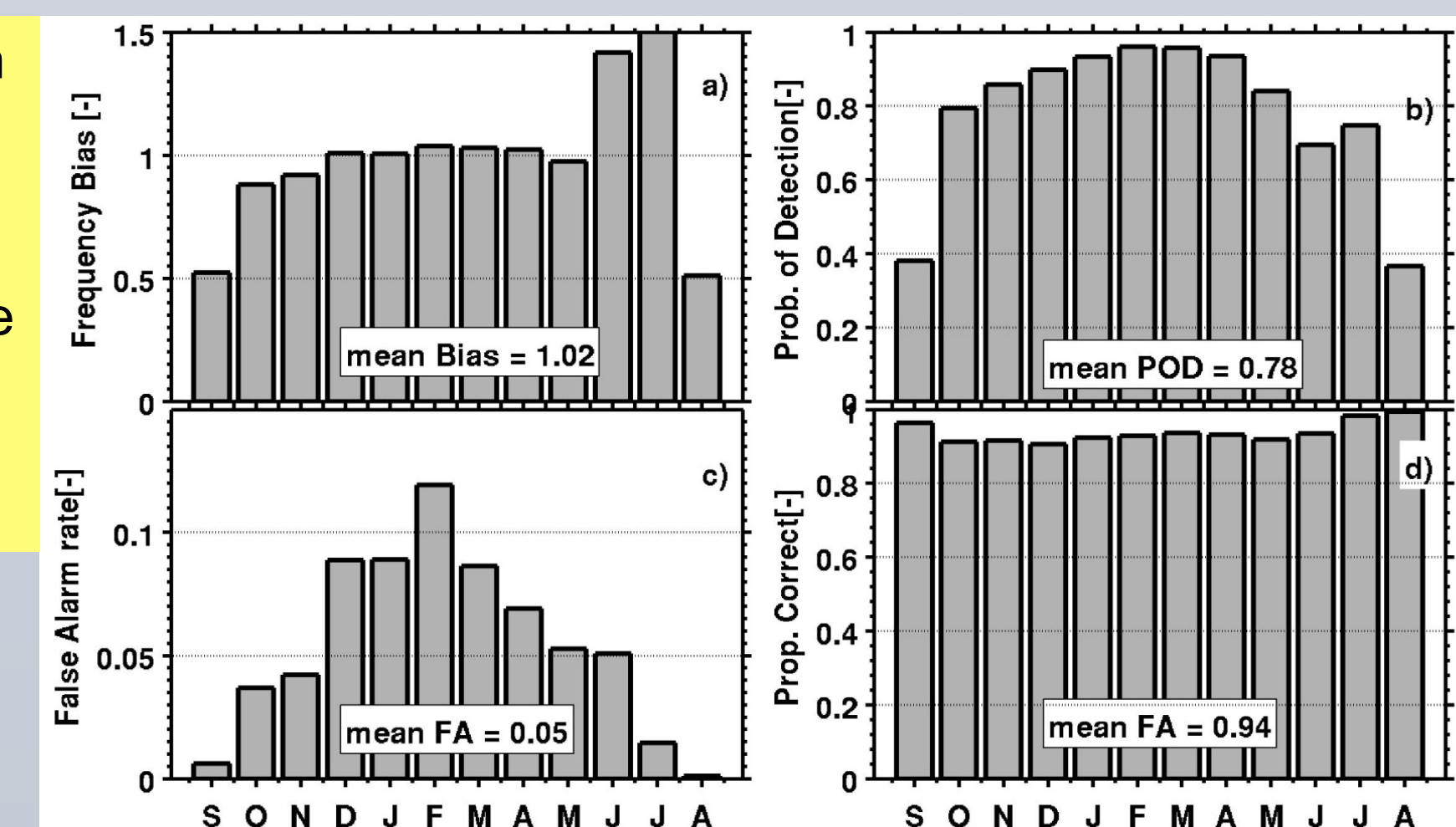
Fig : Comparison of CLM04 against MODIS snow cover extent (SCE) for Northern Hemisphere. (RMSE was normalized with the maximum annual SCE).

Categorical analysis

Fig : Comparison of CLM04 binary model estimates (snow/no snow) vs. MODIS for the Northern Hemisphere (2001-2010).

mean Bias = 1.02
mean POD = 0.78
mean FA = 0.05
mean FA = 0.94

b. Comparison against IMS snow cover product

Fig: Comparison of CLM04 binary model estimates (snow/no snow) vs. IMS daily Snow cover fraction for the Northern Hemisphere. Error bars show the standard deviation of the 10 years (2001-2010).
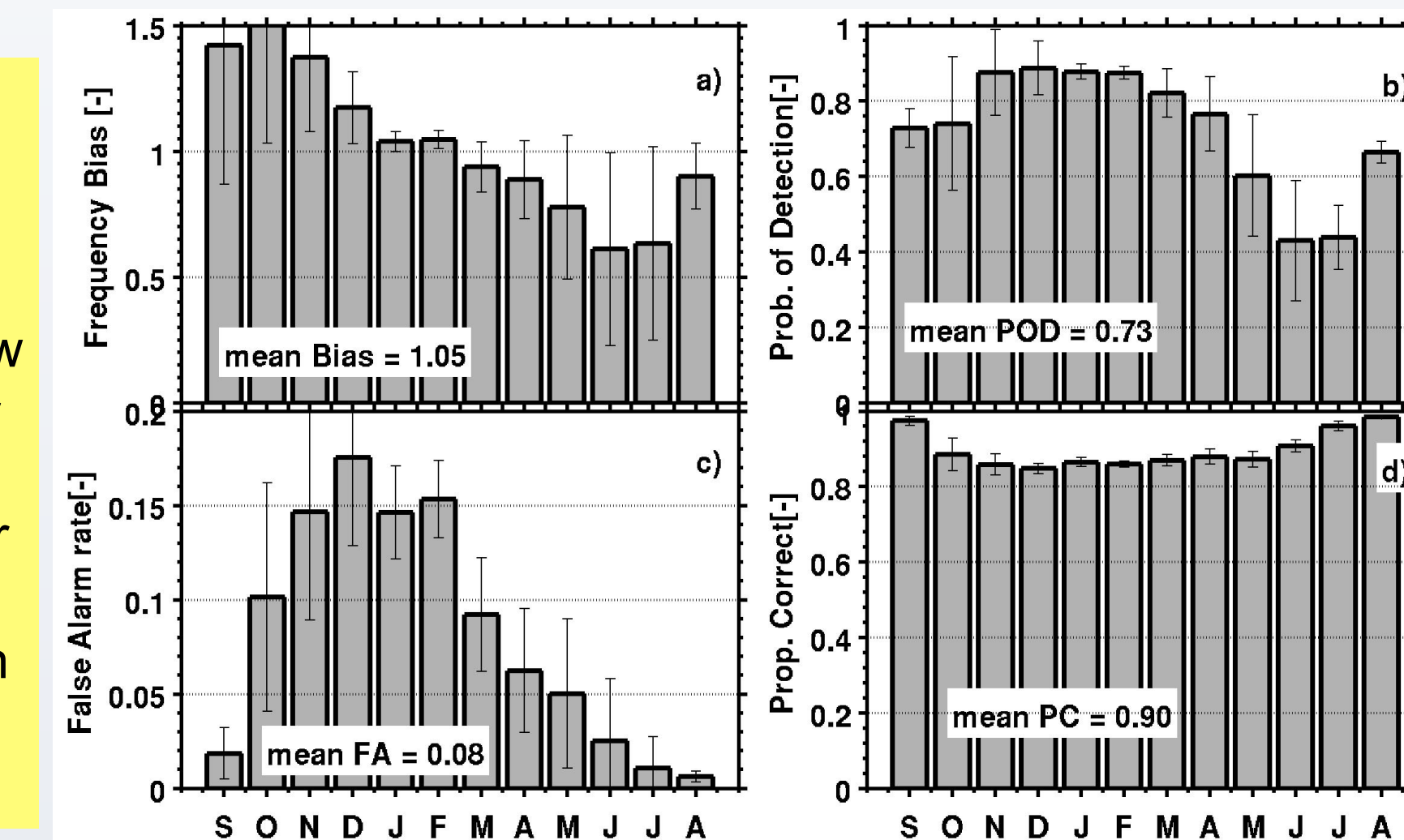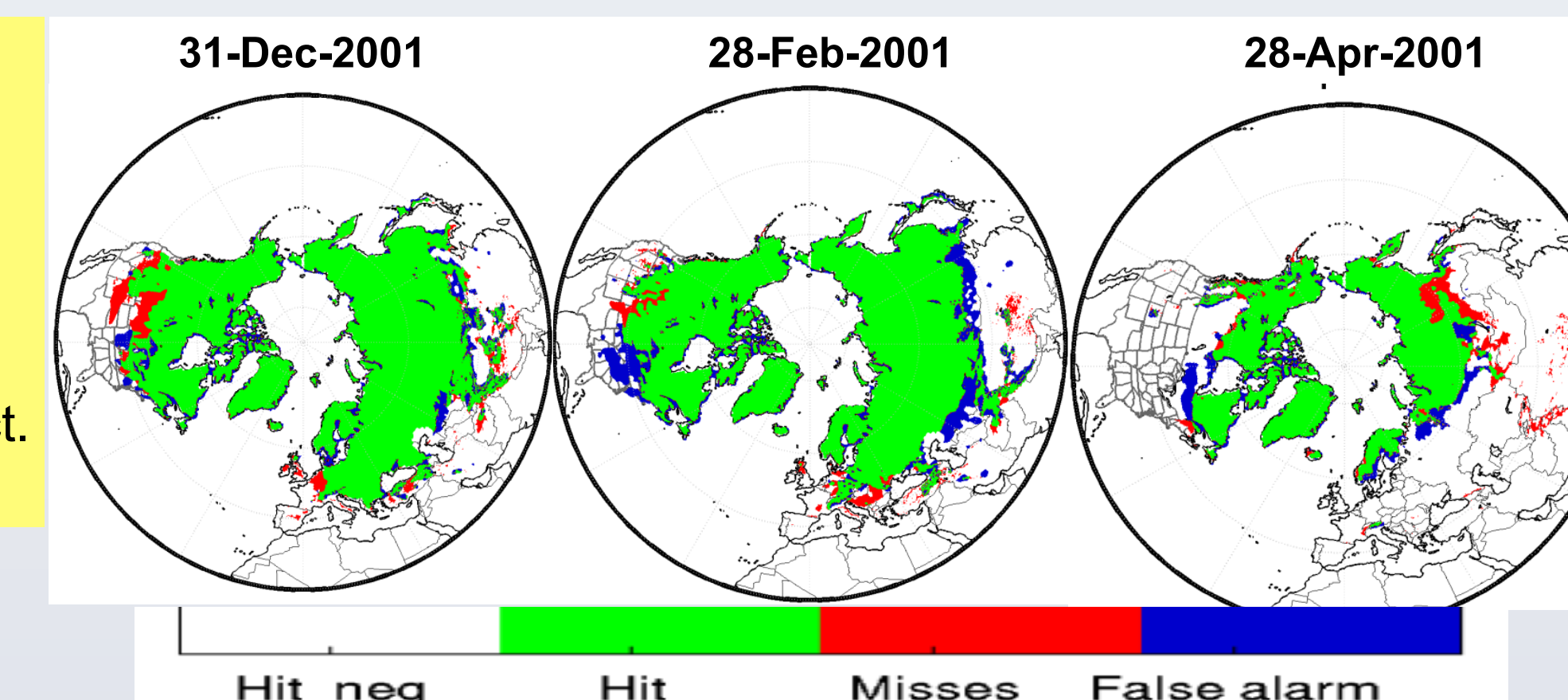
mean Bias = 1.05
mean POD = 0.73
mean FA = 0.08
mean PC = 0.90

Fig : Snow cover hits, misses, and false alarms CLM04 vs. IMS snow cover product.

31-Dec-2001   28-Feb-2001   28-Apr-2001

Hit_neg   Hit   Misses   False alarm

2. Evaluation of the MODIS SCF assimilation

a) MODIS DJF Mean   b) DA DJF Mean
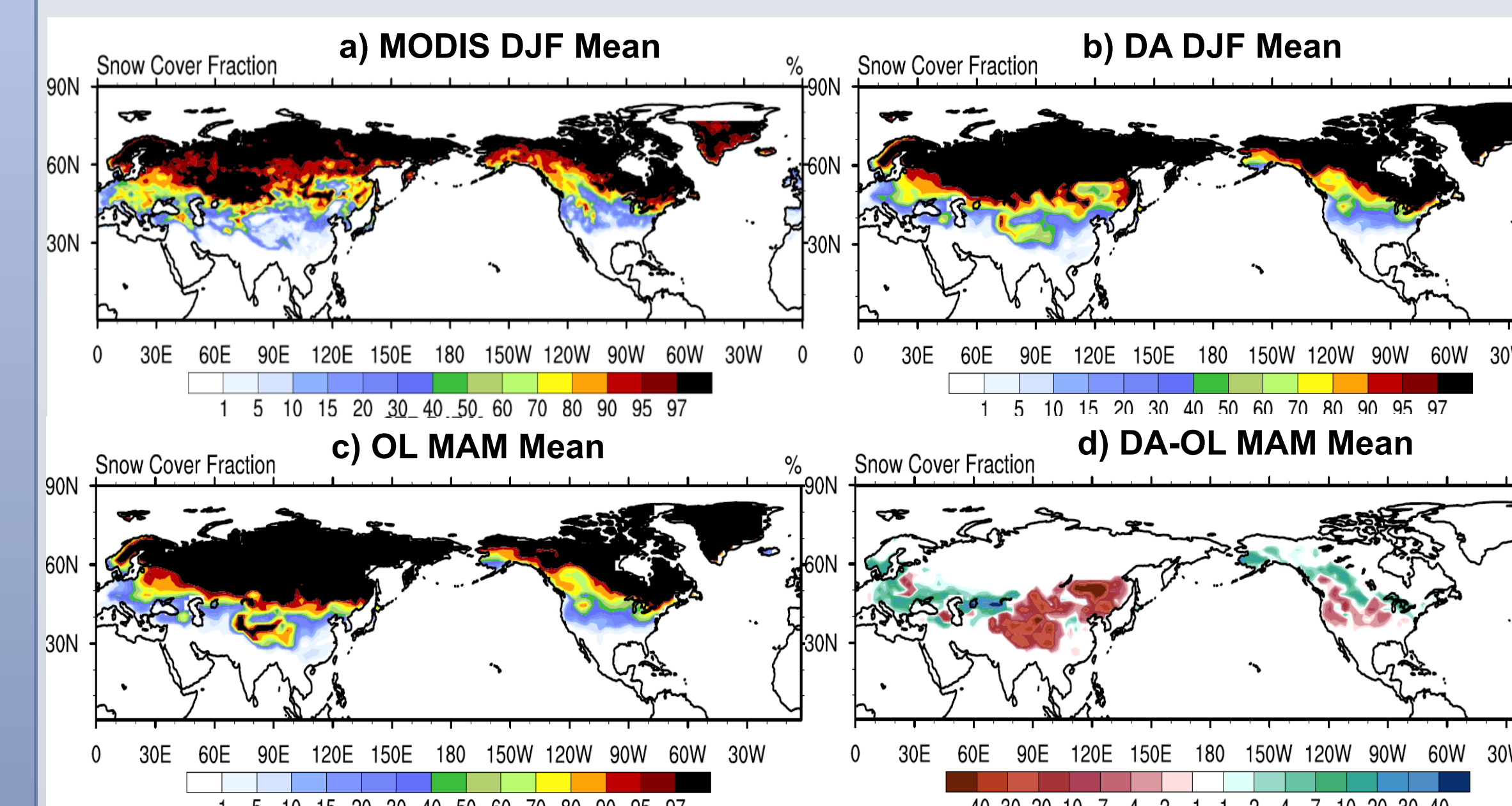c) OL MAM Mean   d) DA-OL MAM Mean

Fig : Average Snow cover fraction (SCF) field in Dec-Jan-Feb(DJF) 2002 -2003 for Northern Hemisphere: a) is MODIS SCF observations, b) is the data assimilation (DA), c) the control run (open-loop(OL)) and d) is DA-OL.

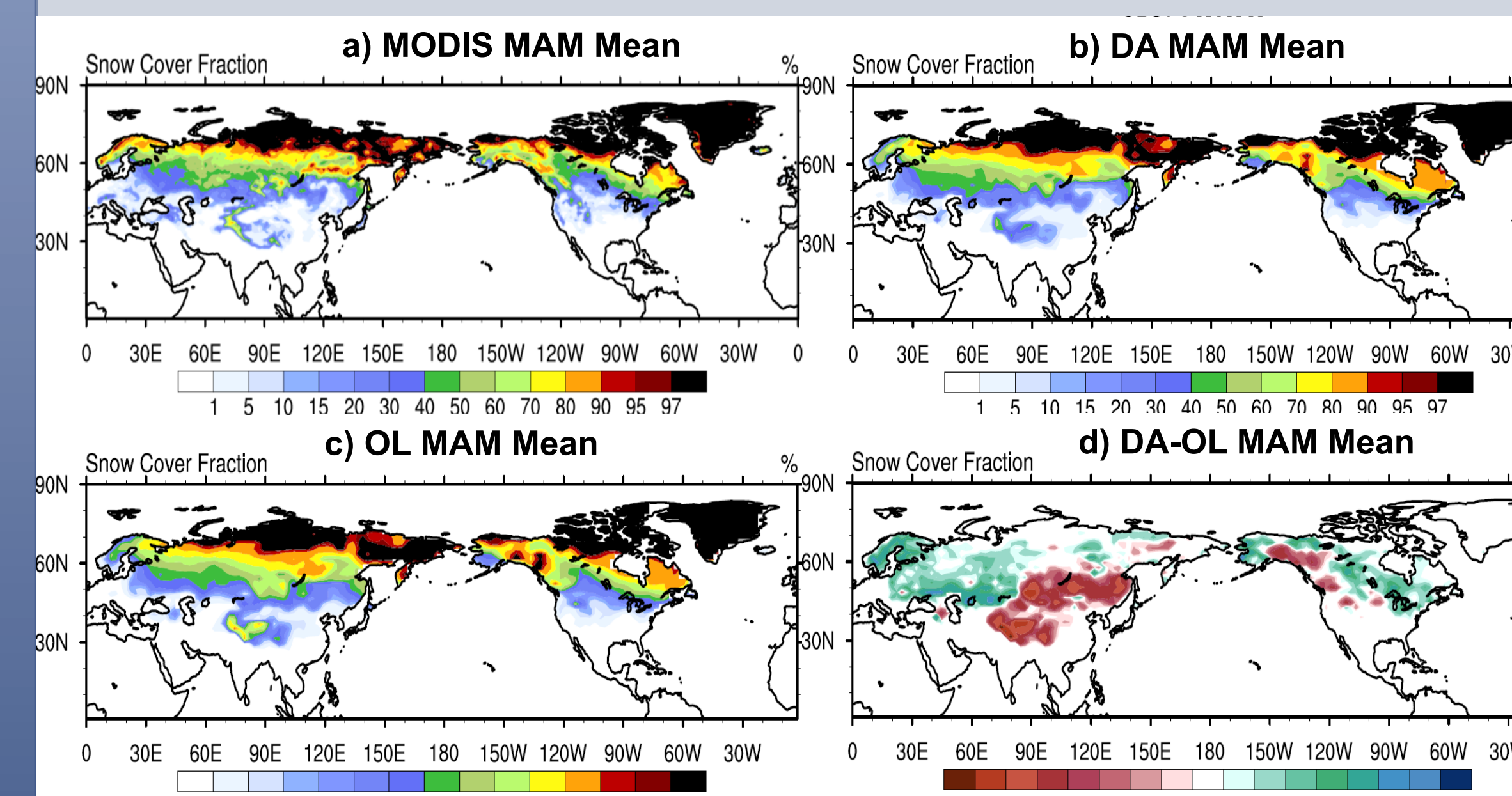a) MODIS MAM Mean   b) DA MAM Mean
c) OL MAM Mean   d) DA-OL MAM Mean

Fig : Average Snow cover fraction (SCF) field in March-April-May(MAM) 2003 for Northern Hemisphere: a) is MODIS SCF observations, b) is the data assimilation (DA), c) the control run (open-loop(OL)) and d) is DA-OL.

CONCLUSIONS

We assimilated MODIS MOD10C1 SCF observations into the Community Land Model version 04 using the Data Assimilation Research Testbed developed at the National Center for Atmospheric Research.

Key Findings

✓ CLM04 control run SCF agrees well with MODIS SCF observations and IMS snow cover product especially in February when snow cover extent is at it maximum.

✓ The control run overestimates SCF in the central Eurasia from 45° to 60°N, the western Russia, the Tibet Plateau, the western Canada, and the Rocky Mountain regions, and underestimate SCF in the western Europe and southern Alaska; underestimates SCF in the western Europe and southern Alaska.

✓ The DA SCF improved compared to the control run. The Assimilation removes snow in the areas where the model overestimates SCF(Tibet Plateau, northeastern China, eastern Russia, and along the Canadian western coast) and add snow in the areas where the model underestimates the SCF(southwestern Russia, the United Kingdom, and central and southeastern Canada).

Future work

Assimilation of AMSR-E radiance, and GRACE terrestrial water storage change observations into CLM04 through the Data Assimilation Research Testbed.

REFERENCES

Hall, D. K., G. A. Riggs, V. V. Salomonson, N. E. DiGirolamo and K. J. Bayr (2002), MODIS snow-cover products. Remote sensing of Environment, 83(2-Jan), 181-194.

Lawrence, D.M., K.W. Oleson, M.G. Flanner, P.E. Thornton, S.C. Swenson, P.J. Lawrence, X. Zeng, Z.-L. Yang, S. Levis, K. Sakaguchi, G.B. Bonan, and A.G. Slater (2011), Parameterization Improvements and Functional and Structural Advances in Version 4 of the Community Land Model. J. Adv. Model. Earth Sys., 3, DOI: 10.1029/2011MS000045.

NOAA/NESDIS/OSDPD/SSD(2004), updated 2006. IMS daily Northern Hemisphere snow and ice analysis at 4 km and 24 km resolution. Colorado USA: National Snow and Ice Data Center. Digital media.

Vertenstein, M., Craig, T., Middleton, A., Feddema, D., and C. Fischer, (2010), CESM1.0.3 User's Guide, available at: http://www.cesm.ucar.edu/models/cesm1.0/cesm/cesm doc/book1.html .

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