Goddard Space Flight Center

Land Information System

J4.1 Preparing to assimilate current and future land surface products at GMAO, AFWA, NCEP, and NRL using a common data assimilation infrastructure

Christa D. Peters-Lidard[1], S. V. Kumar[2], Y. Liu[3], R. H. Reichle[4], C. Draper[4], G. J. M. De Lannoy[4], J. B. Eylander[5], J. D. Cetola[6], M. B. Ek[7], X. Zhan[8], and T. R. Holt[9]

[1]Hydrological Sciences Laboratory, NASA/GSFC

[2]SAIC at Hydrological Sciences Laboratory, NASA/GSFC

[3]ESSIC at Hydrological Sciences Laboratory, NASA/GSFC

[4]Global Modeling and Assimilation Office, NASA/GSFC

[5]Army Cold Regions Research & Engineering Lab, Engineer Research & Development Center

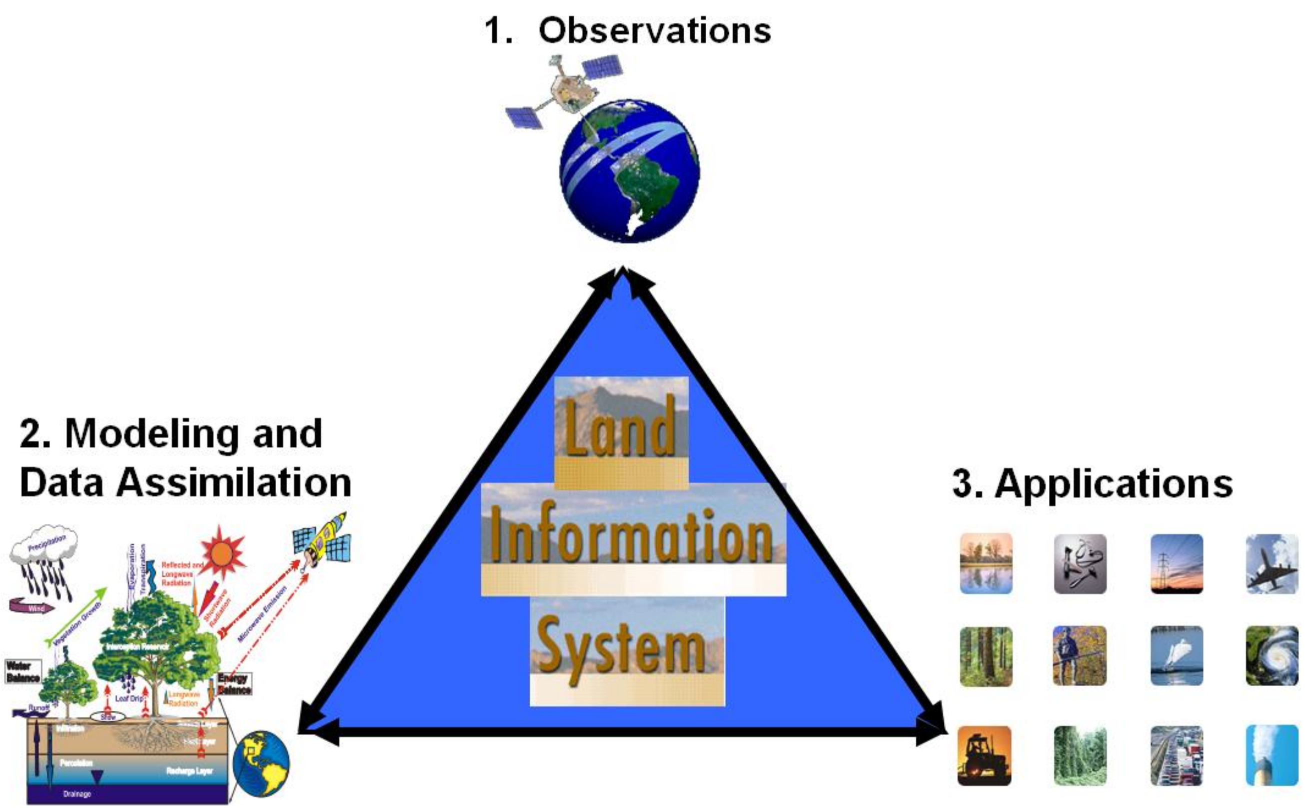
[6]16th Weather Squadron (16WS/WXE), 2nd Weather Group (Air Force Weather Agency)

[7]Environmental Modeling Center, NCEP/NOAA

[8]NESDIS, NOAA

[9]Naval Research Laboratory

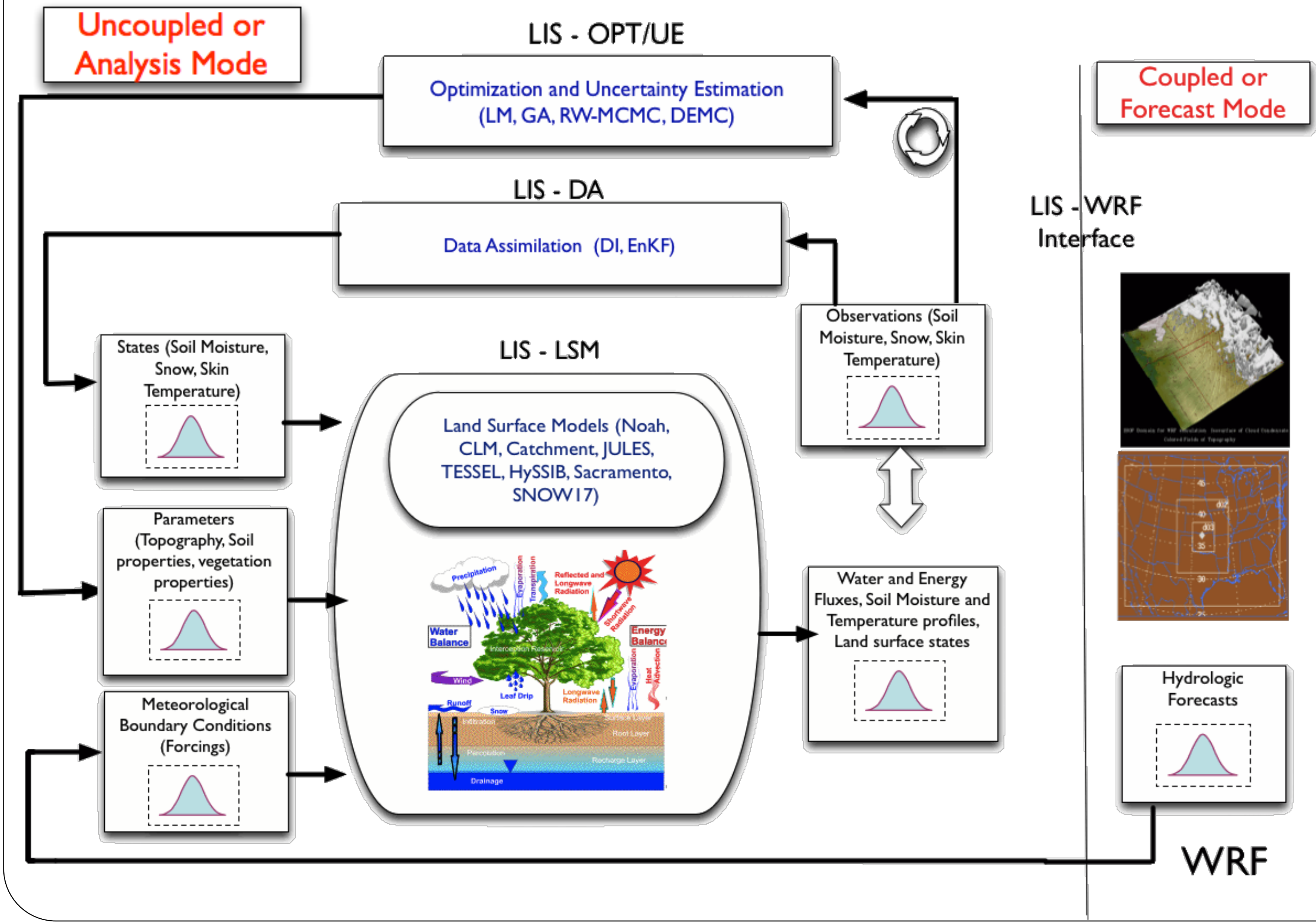
The Land Information System (LIS; http://lis.gsfc.nasa.gov)is a common land data assimilation infrastructure for NASA/DoD/NOAA



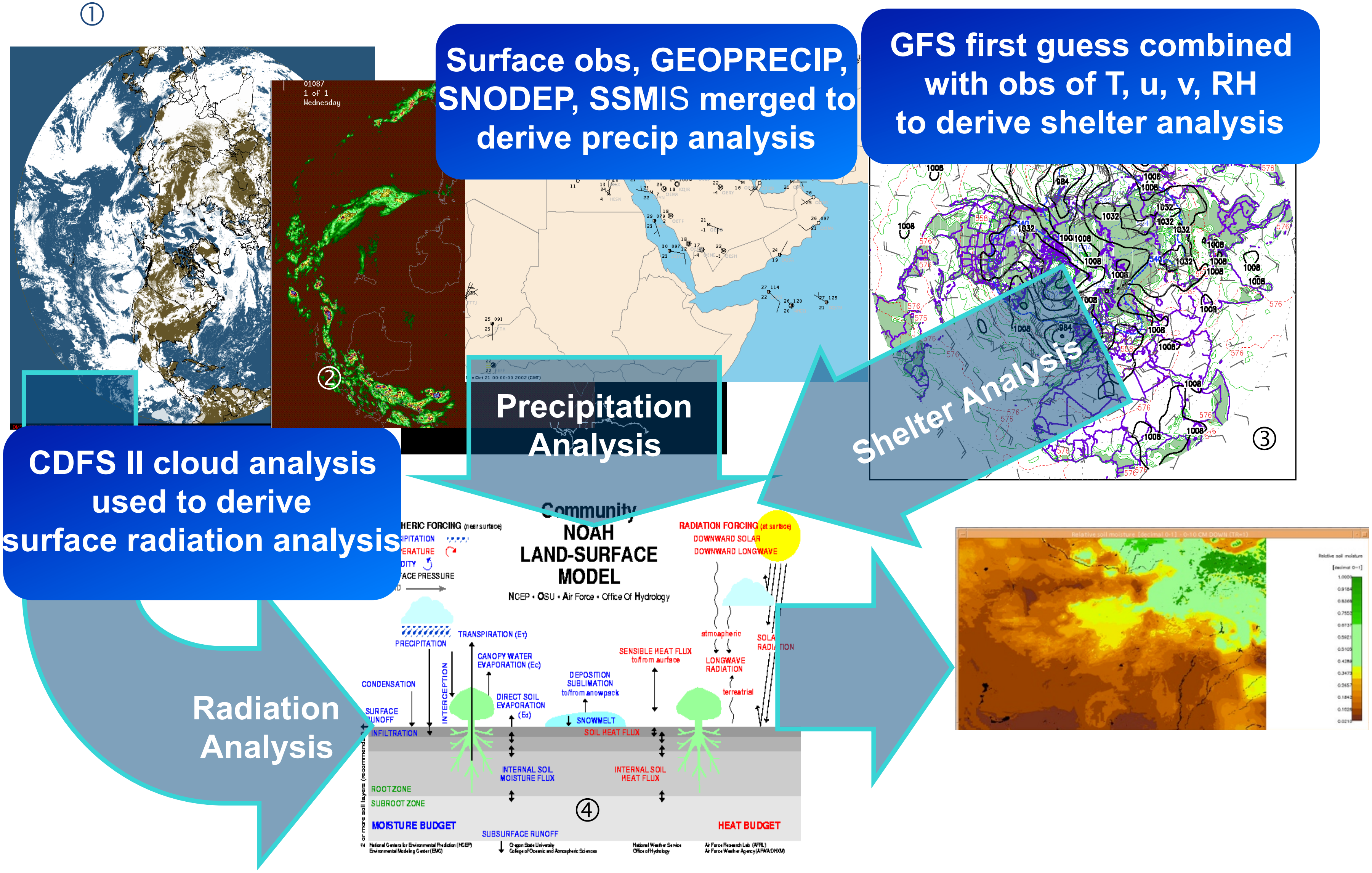
Kumar, S. V., C. D. Peters-Lidard, Y. Tian, P. R. Houser, J. Geiger, S. Olden, L. Lighty, J. L. Eastman, B. Doty, P. Dirmeyer, J. Adams, K. Mitchell, E. F. Wood and J. Sheffield, 2006. Land Information System - An Interoperable Framework for High Resolution Land Surface Modeling. *Environmental Modelling & Software,* Vol. 21, 1402-1415.

Peters-Lidard , C.D., P.R. Houser, Y. Tian, S.V. Kumar, J. Geiger, S. Olden, L. Lighty, B. Doty, P. Dirmeyer, J. Adams, K. Mitchell, E.F. Wood and J. Sheffield, 2007: High-performance Earth system modeling with NASA/GSFC's Land Information System. *Innovations in Systems and Software Engineering.* 3(3), 157-165. DOI:10.1007/s11334-007-0028-x

Background: LIS subsystems

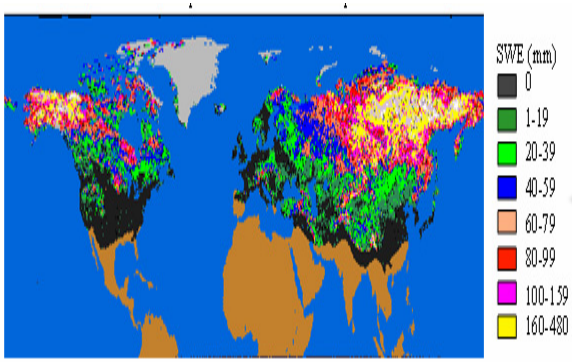


LIS at AFWA

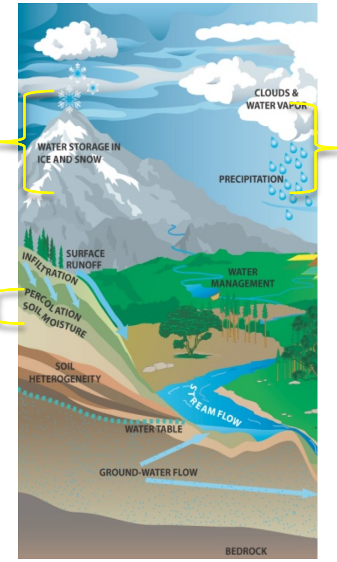


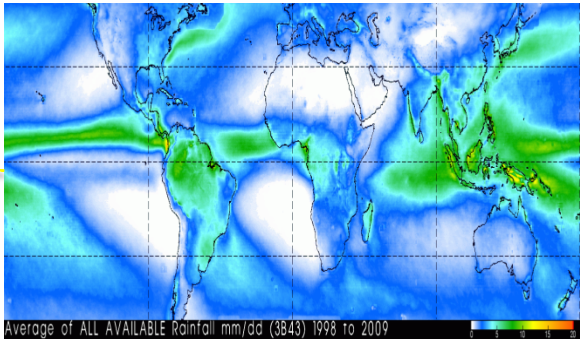
①
Surface obs, GEOPRECIP, SNODEP, SSMIS merged to derive precip analysis
GFS first guess combined with obs of T, u, v, RH to derive shelter analysis
②
Precipitation Analysis
Shelter Analysis
③
CDFS II cloud analysis used to derive surface radiation analysis
Radiation Analysis
Community NOAH LAND-SURFACE MODEL
NCEP • OSU • Air Force • Office Of Hydrology
RADIATION FORCING (at surface)
DOWNWARD SOLAR
DOWNWARD LONGWAVE
PRECIPITATION
TRANSPIRATION (Et)
CANOPY WATER EVAPORATION (Ec)
CONDENSATION
INTERCEPTION
DIRECT SOIL EVAPORATION (Ed)
DEPOSITION SUBLIMATION to/from snowpack
SENSIBLE HEAT FLUX to/from surface
LONGWAVE RADIATION
SNOWMELT
INFILTRATION
SOIL HEAT FLUX
INTERNAL SOIL MOISTURE FLUX
INTERNAL SOIL HEAT FLUX
ROOTZONE
SUBROOT ZONE
MOISTURE BUDGET
SUBSURFACE RUNOFF
HEAT BUDGET
④

Planned LIS-based assimilation at AFWA

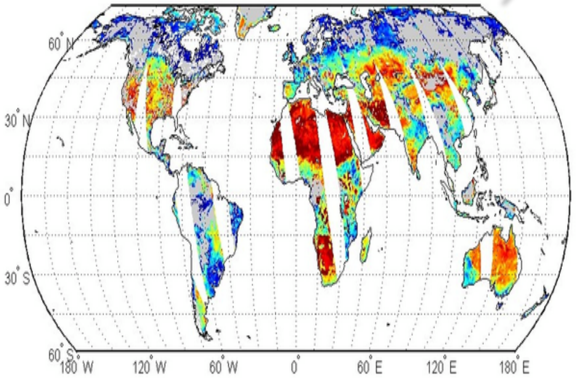


SNODEP snow depth





TRMM-based AMPS



SMOPS (ASCAT) Soil Moisture

Experimental Setup:

- Domain: Global
- Resolution: 0.125 deg.
- Period: 2014-
- Forcing: AMPS CDFSII+GFS
- LSM: Noah 3.3

Data Assimilation:

- SMOPS ASCAT soil moisture
- SNODEP snow depth

SMOPS ASCAT DA Evaluation over CONUS

Model domain: Continental United States (CONUS) at ¼th degree spatial resolution

Forcing data: AGRMET retrospective forcing

Land surface model: Noah LSM version 3.3

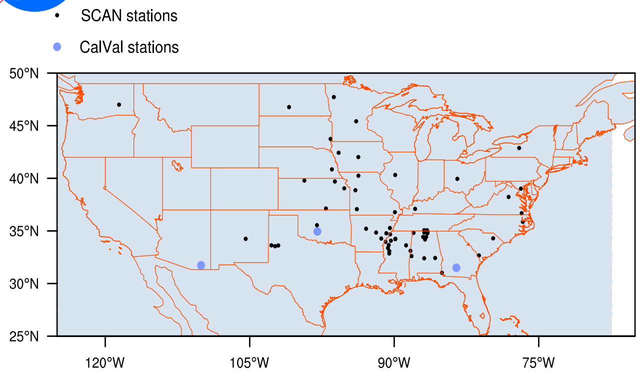
Data assimilation method: Ensemble Kalman Filter (EnKF). The observation error standard deviations were defined in the climatology of the datasets and were scaled (locally) into the Noah model climatology by the ratio of the model and observation time series standard deviations. A CDF-scaling approach was used to scale the observations into the Noah model climatology.

Time period: Jan 1, 2007, to Jan 1, 2012

Quality control: Data screened for dense vegetation, snow/rain, frozen soil, and using the estimated soil moisture error flag provided with the ASCAT data.

Evaluation: using SCAN/ARS networks. 60 SCAN sites and 3 ARS calval sites were used.

Soil moisture DA : Evaluation of soil moisture fields



Marginal, but statistically significant improvements in surface soil moisture and root zone soil moisture as a result of RTSMOPS/TUW

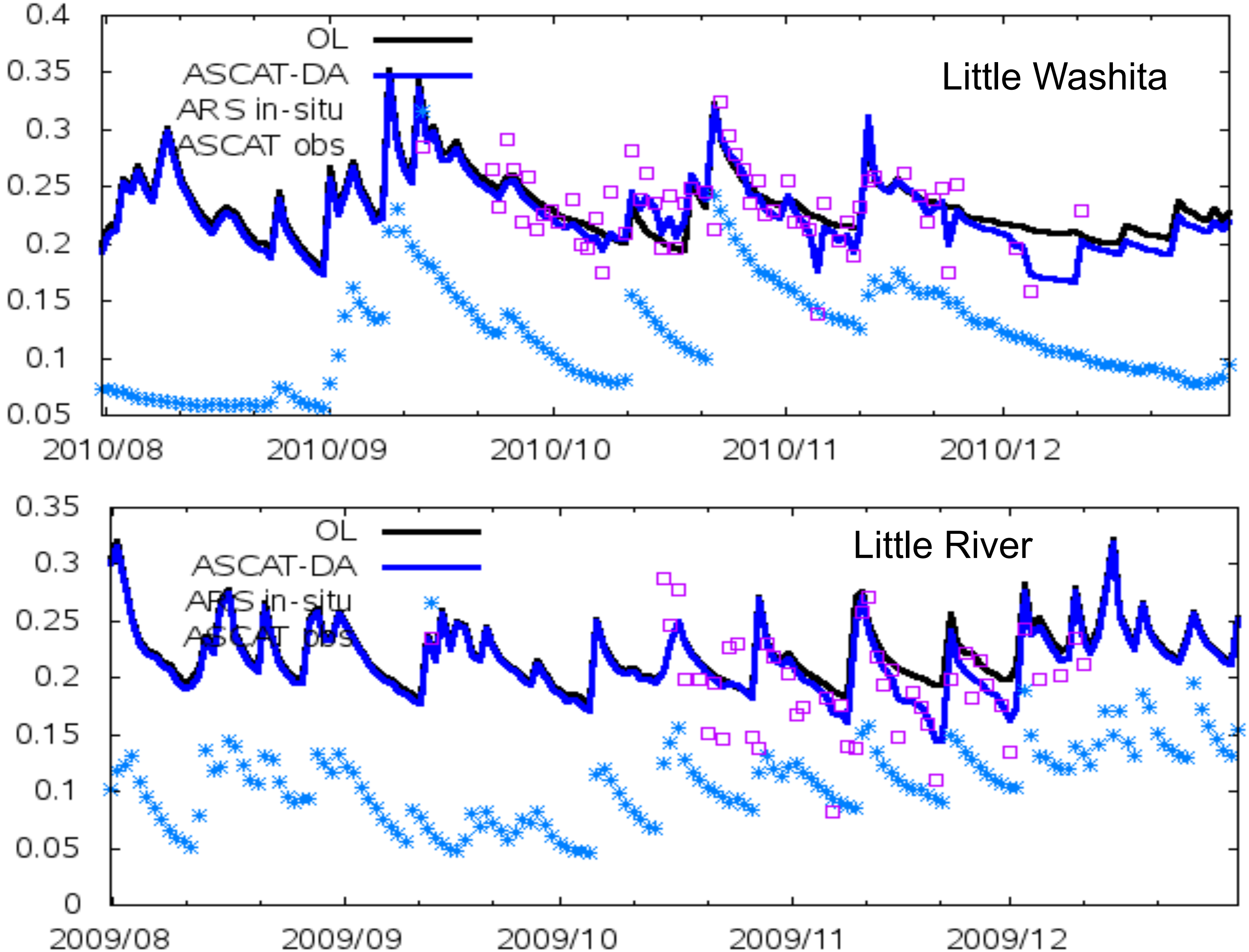
Anomaly R increases, Anomaly RMSE reduces and unbiased RMSE reduces with assimilation.

ARS CalVal (surface soil moisture)	Open loop (no DA)	TUWein DA	RTSMOPS DA
Anomaly R	0.53 +/- 0.01	0.56 +/- 0.01	0.55 +/- 0.01
Anomaly RMSE (m3/m3)	0.037 +/- 0.001	0.036 +/- 0.001	0.035 +/- 0.001
ubRMSE (m3/m3)	0.046 +/- 0.002	0.044 +/- 0.002	0.044 +/- 0.002

SCAN (surface soil moisture)	Open loop (no DA)	TUWein DA	RTSMOPS DA
Anomaly R	0.53 +/- 0.02	0.56 +/- 0.02	0.56 +/- 0.02
Anomaly RMSE (m3/m3)	0.048+/- 0.002	0.047 +/- 0.002	0.047 +/- 0.002
ubRMSE (m3/m3)	0.062 +/- 0.003	0.058 +/- 0.003	0.060 +/- 0.003

SCAN (root zone soil moisture)	Open loop (no DA)	TUWein DA	RTSMOPS DA
Anomaly R	0.54 +/- 0.02	0.55 +/- 0.02	0.56 +/- 0.02
Anomaly RMSE (m3/m3)	0.040 +/- 0.002	0.039 +/- 0.002	0.039 +/- 0.002
ubRMSE (m3/m3)	0.052 +/- 0.003	0.050 +/- 0.003	0.050 +/- 0.003

Soil moisture DA : ARS watershed locations



AFWA SNODEP DA Evaluation over CONUS

Model domain: Continental United States (CONUS) at ¼th degree spatial resolution

Forcing data: AGRMET and NLDAS2 retrospective forcing

Land surface model: Noah LSM version 3.3

Data assimilation method: Ensemble Kalman Filter (EnKF) and Direct Insertion (DI)

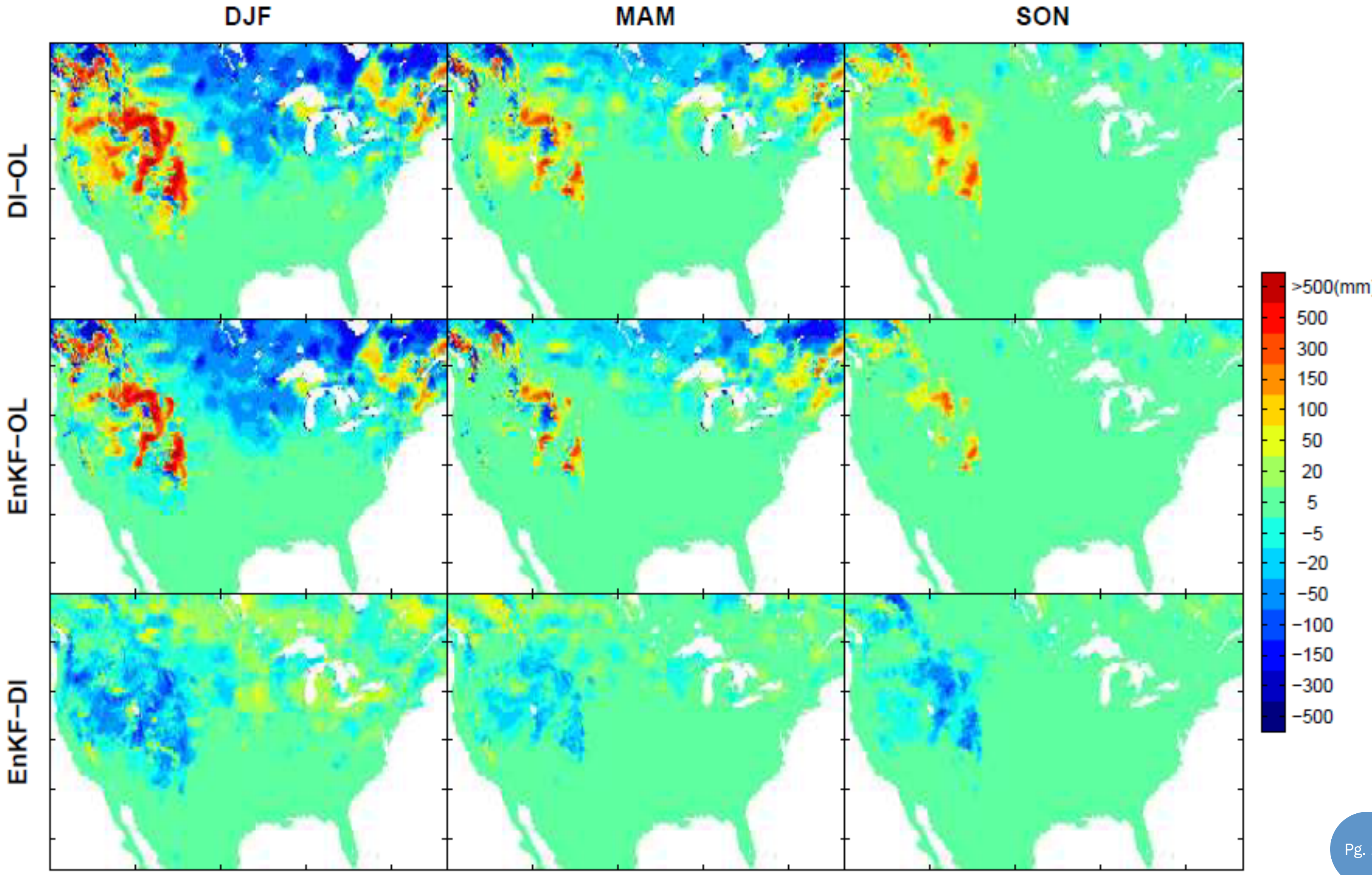
Time period: Jan 1, 2007, to Jan 1, 2012

Evaluation: using CMC, MODIS

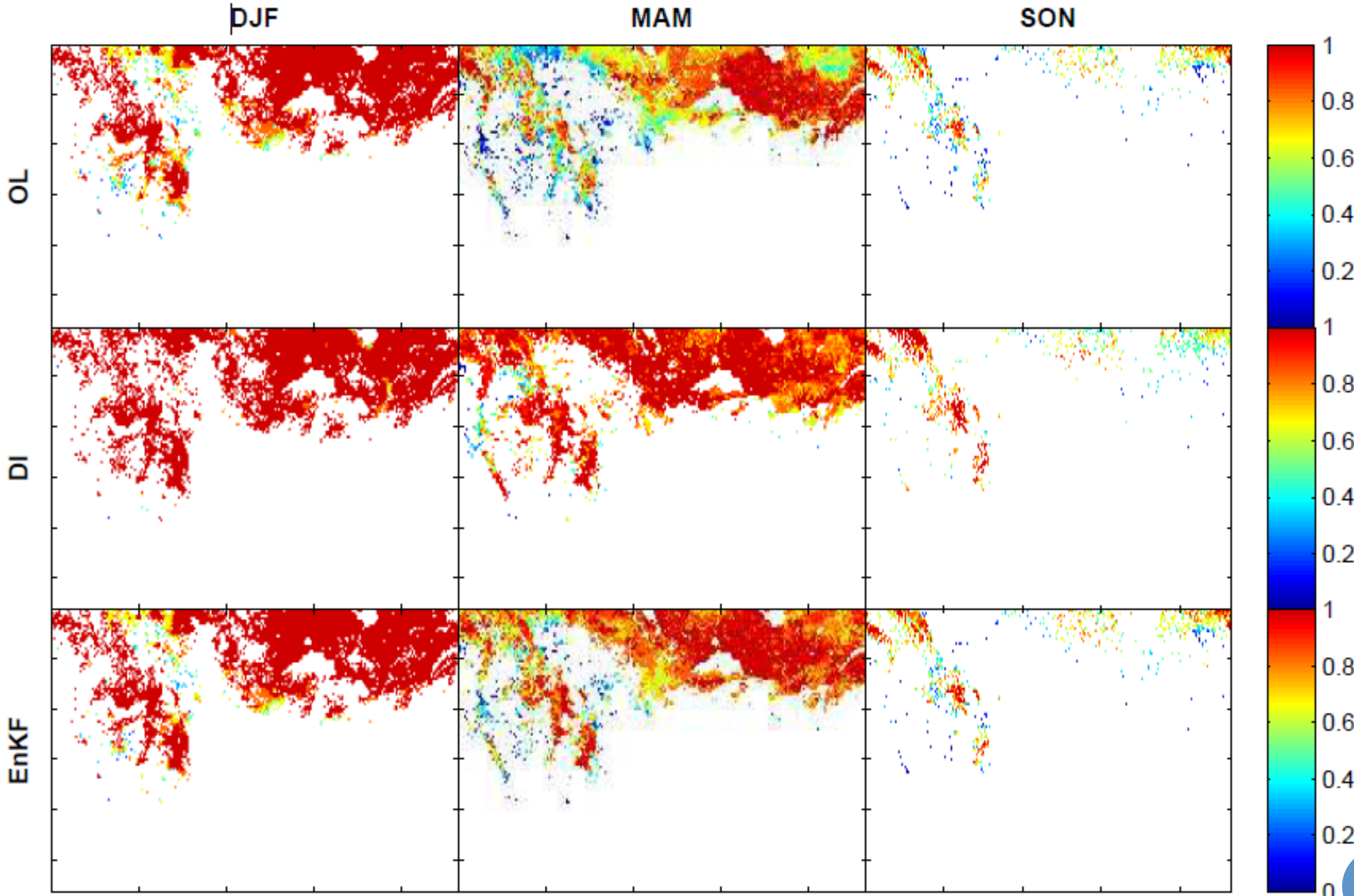
AFWA SNODEP DA:

Snow Depth – RMSE Difference vs. CMC

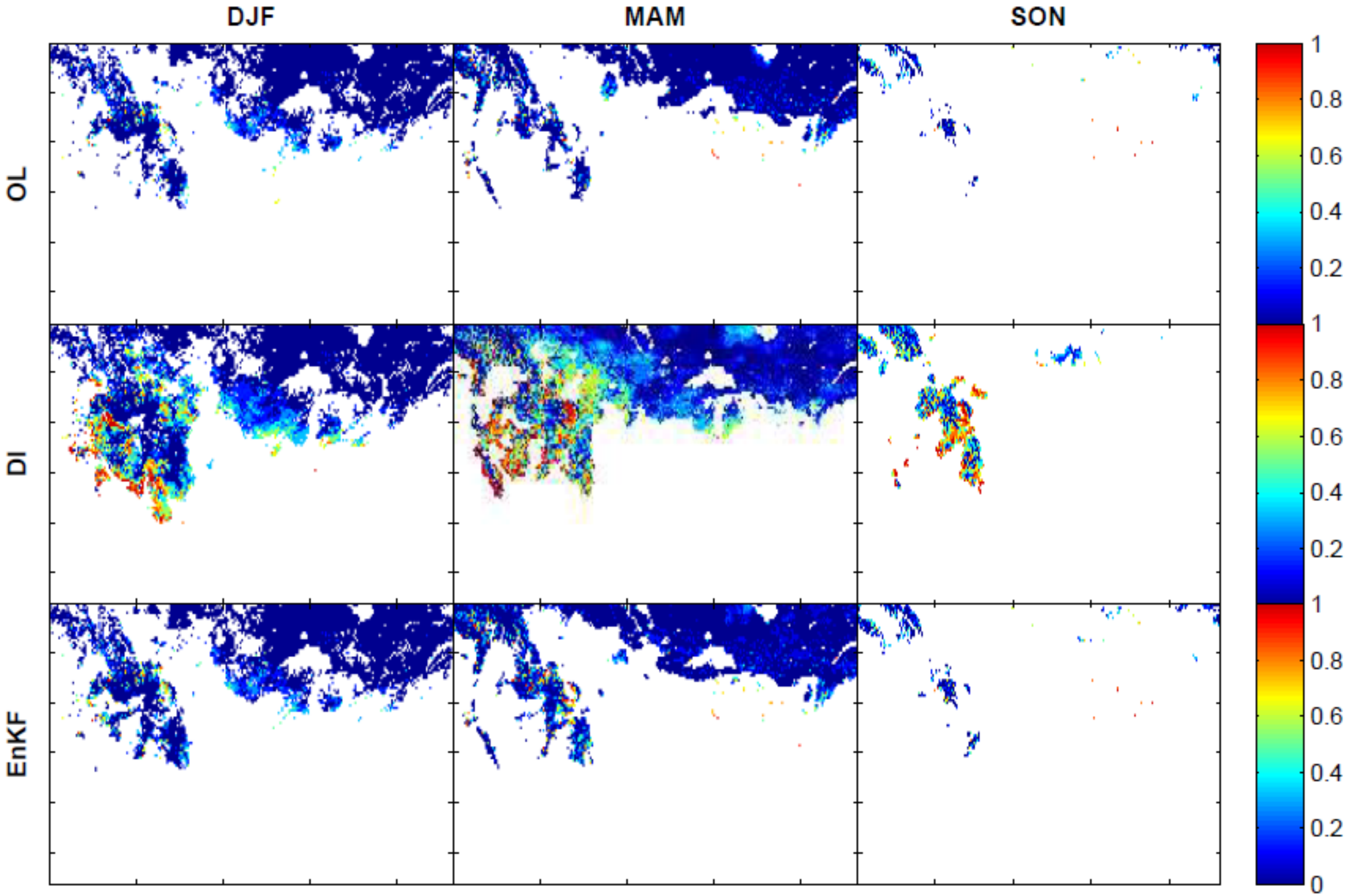
OL vs. DI vs. EnKF



AFWA SNODEP DA:
Snow Cover POD vs. MODIS



AFWA SNODEP DA: Snow Cover FAR vs. MODIS

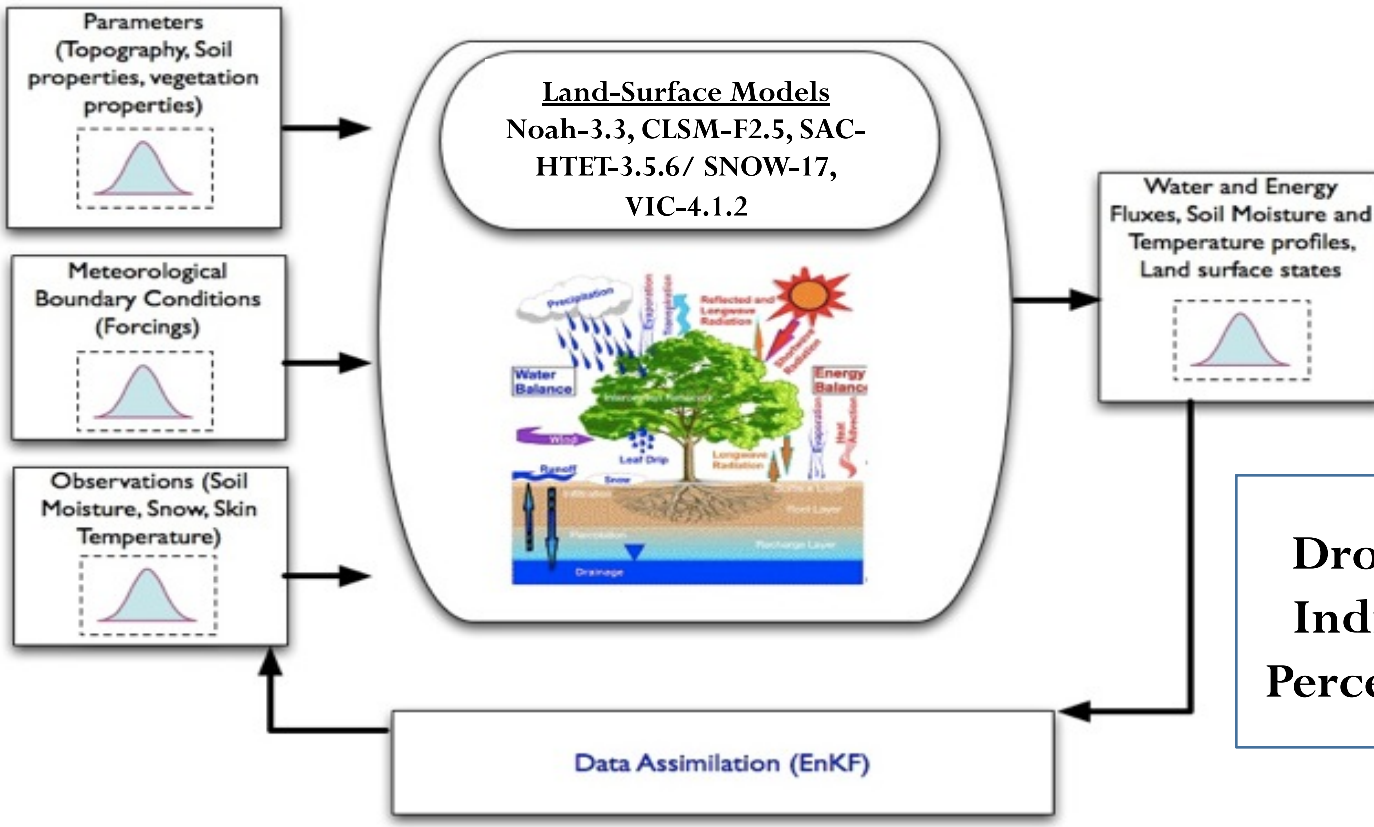


LIS at NOAA: NLDAS

CFS-LDAS and GFS-LDAS (not discussed)

1979-present NLDAS-2 Forcing and Parameters

Soil Moisture, SWE,TWS

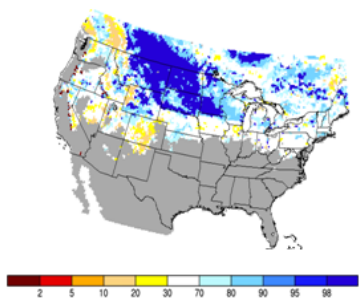


Drought Indices/ Percentiles

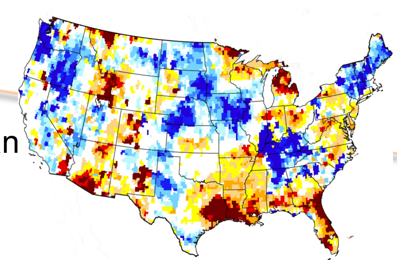
Kumar, S.V., C.D. Peters-Lidard, D. Mocko, R. Reichle, Y. Liu, K.A. Arsenault, Y. Xia, M. Ek, G. Riggs, B. Livneh, M. Cosh (2014), "Assimilation of remotely sensed soil moisture and snow depth retrievals for drought estimation" ***Journal of Hydrometeorology,*** **in revision**

Data assimilation for the next phase of NLDAS

- J10.4 Benchmarking the next phase of the North American Land Data Assimilation System (NLDAS) using the Land Verification Toolkit (LVT) by Mocko et al.
- J12.6 Assimilation of passive microwave-based soil moisture and snow depth retrievals for drought estimation by Kumar et al.

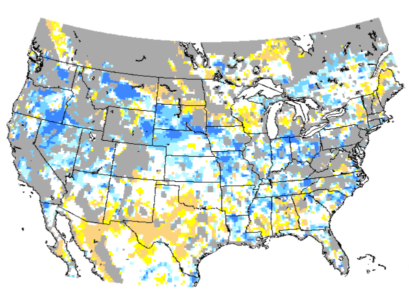


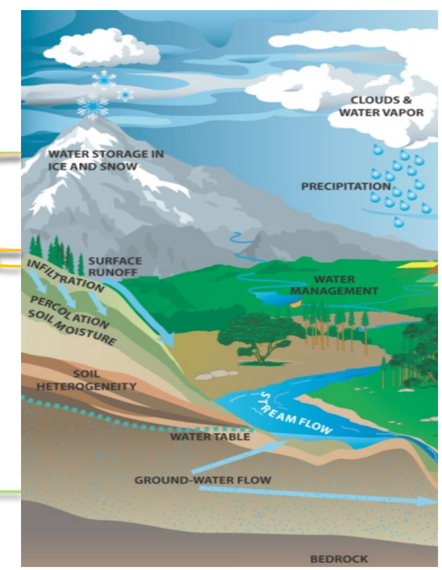
March 2011 SWE Mean Percentile from LPRM v5 – NASA Aqua/ AMSR-E EDR (2003-2011).



March 2011 GRACE-based Groundwater Percentile from GRACE TWS EDR (2002-present).

March 2011 Surface SM Percentile from LPRM v5 – NASA Aqua/AMSR-E EDR (2003-2011).





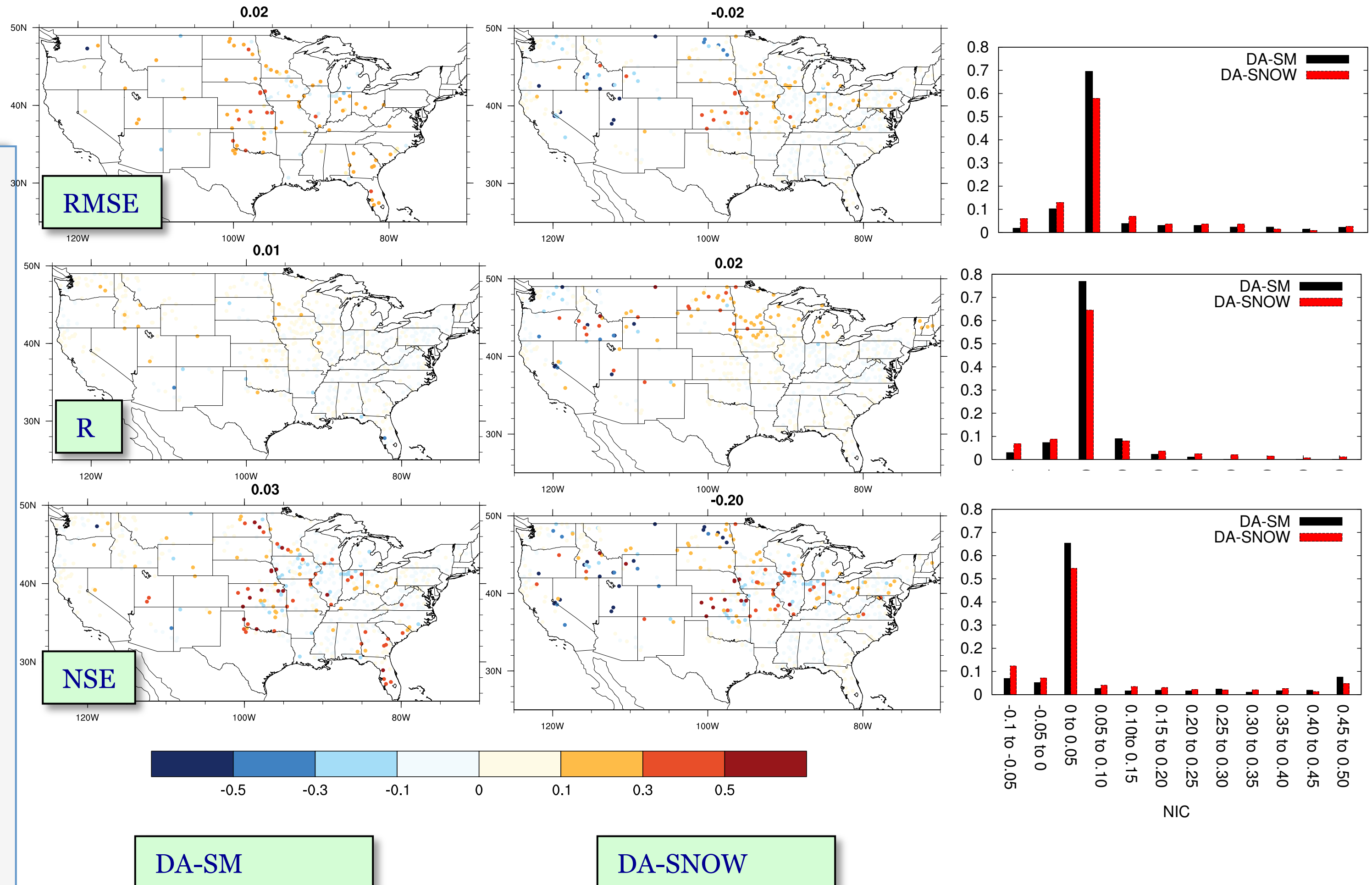
Soil moisture and snow depth DA: Evaluation of streamflow

The improvements are expressed using an Normalized Information Contribution (NIC) metric that measures the skill improvement from DA as a fraction of the maximum possible skill improvement

$$NIC_{RMSE} = \frac{(RMSE_o - RMSE_a)}{RMSE_o}$$

$$NIC_R = \frac{(R_a - R_o)}{(1 - R_o)}$$

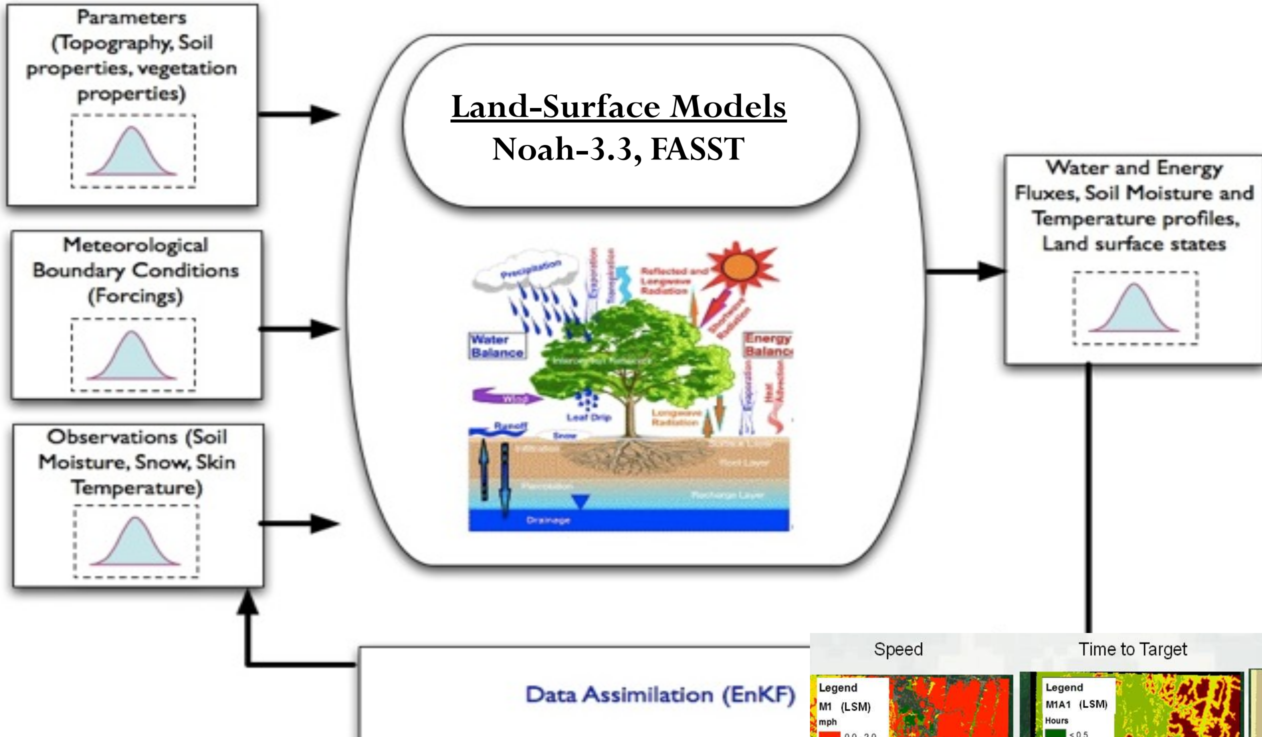
$$NIC_{NSE} = \frac{(NSE_a - NSE_o)}{(1 - NSE_o)}$$

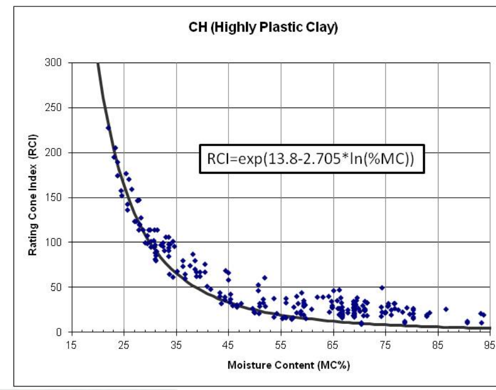


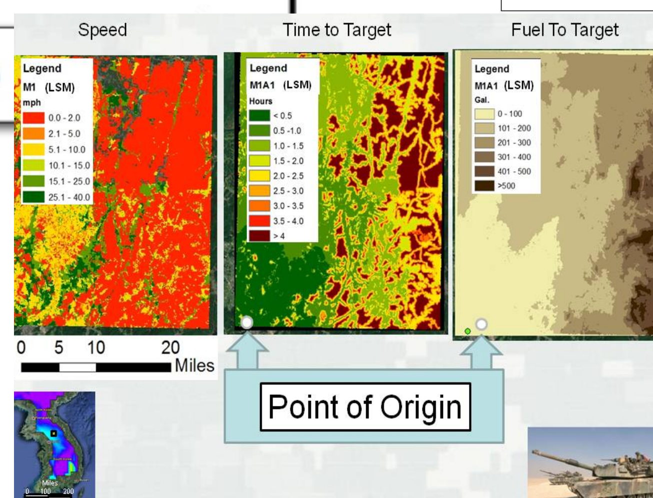
Minor improvements in all skill metrics (RMSE, R and NSE) are observed in streamflow estimates with soil moisture data assimilation. Snow DA indicates a slight overall degradation.

Skill improvements from soil moisture assimilation are mostly over parts of the Mississippi, Missouri and Arkansas-Red basins and parts of Southeastern U.S. Notable degradations due to snow DA are observed over Colorado headwater region and over Northwest U.S.

LIS at USACE/CRREL







Soil Strength, Vehicle Speed, Mobility, Trafficability

JCSDA Land Data Assimilation Objectives

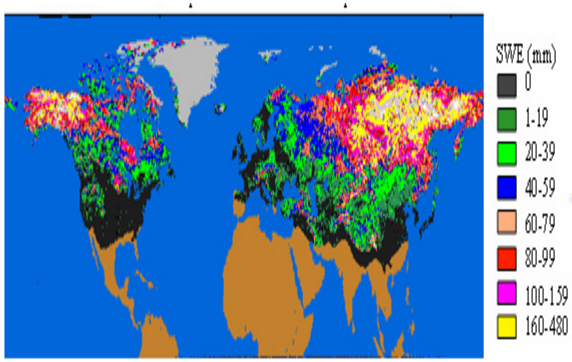
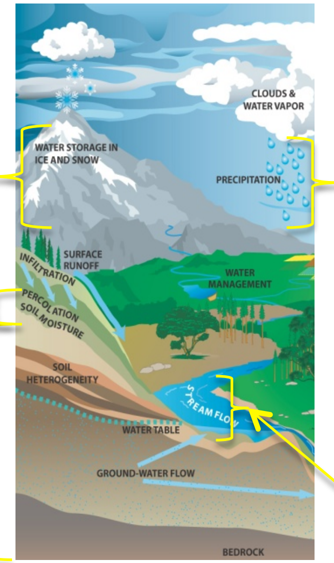


Figure 1: Snow water equivalent (SWE) based on Terra/MODIS and Aqua/AMSR-E. Future observations will be provided by JPSS/ VIIRS and DWSS/MIS.



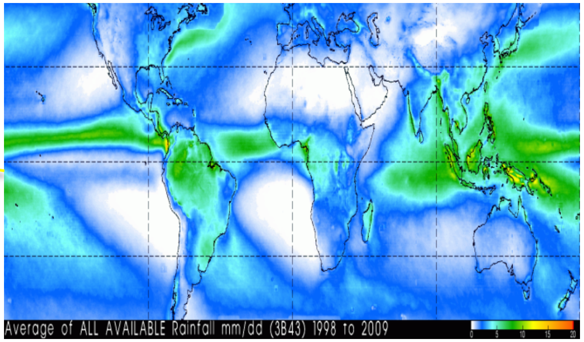


Figure 2: Annual average precipitation from 1998 to 2009 based on TRMM satellite observations. Future observations will be provided by GPM.

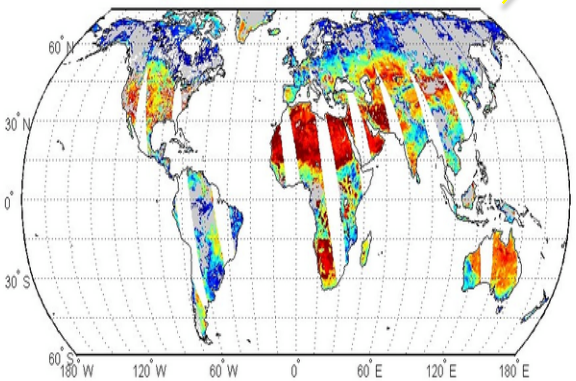


Figure 3: Daily soil moisture based on Aqua/ AMSR-E. Future observations will be provided by SMAP.

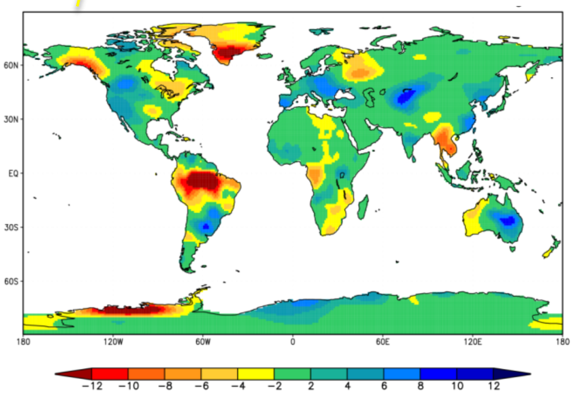


Figure 4: Changes in annual-average terrestrial water storage (the sum of groundwater, soil water, surface water, snow, and ice, as an equivalent height of water in cm) between 2009 and 2010, based on GRACE satellite observations. Future observations will be provided by GRACE-II.

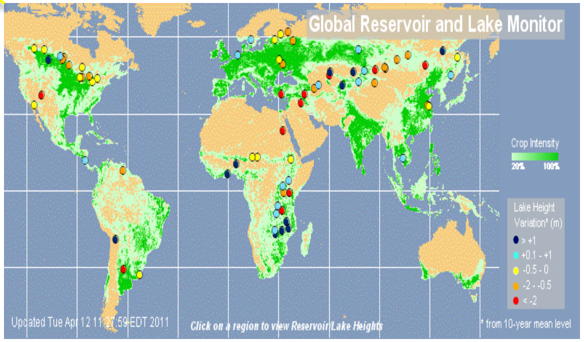
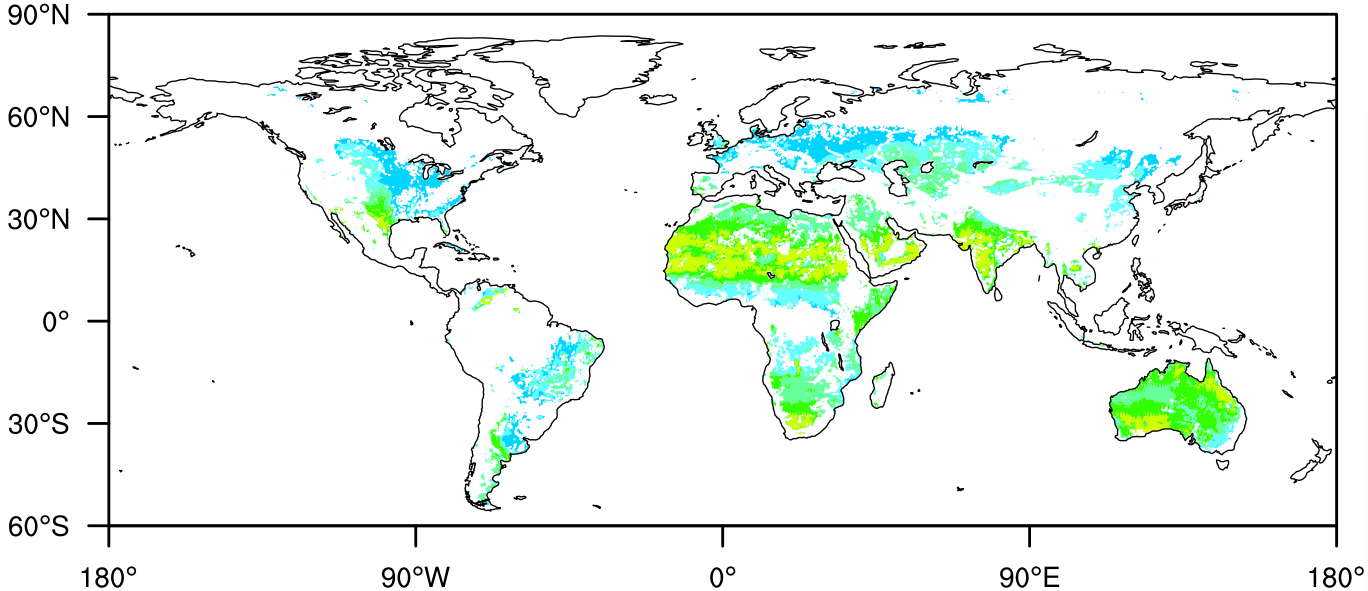


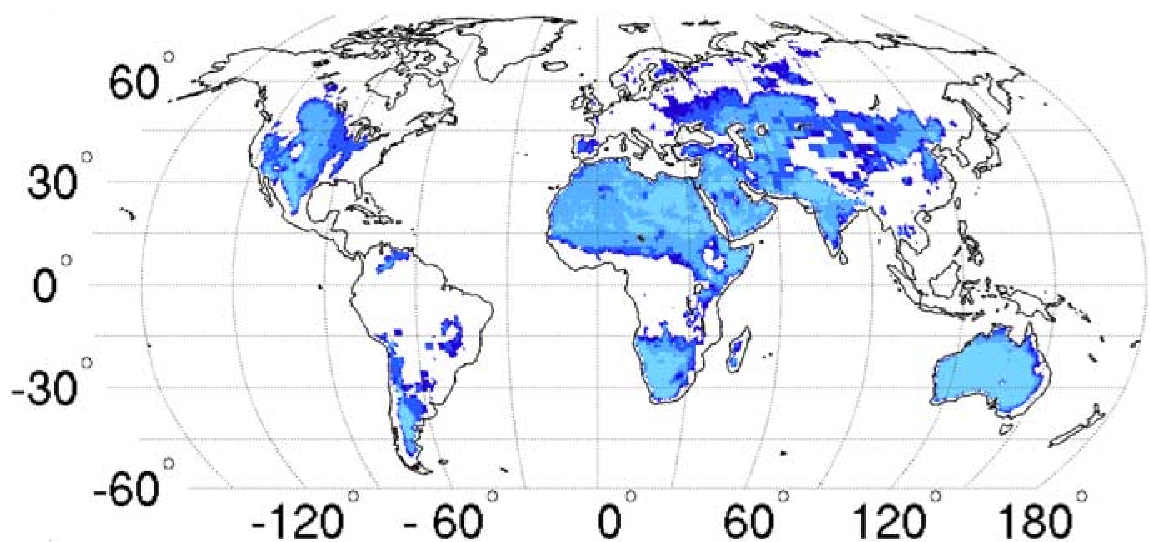
Figure 5: Current lakes and reservoirs monitored by OSTM/Jason-2. Shown are current height variations relative to 10-year average levels. Future observations will be provided by SWOT.

Additional References

- Kumar, S., C. Peters-Lidard, D. Mocko, and Y. Tian (2013). Multiscale evaluation of the improvements in surface snow simulation through terrain adjustments to radiation Journal of Hydrometeorology, 14(1), 220-232, doi:10.1175/JHM-D-12-046.1
- Liu, Y., Peters-Lidard C, Kumar S, Foster J , Shaw M, Y. Tian, and F.G. Hall (2013). Assimilating satellite-based snow depth and snow cover products for improving snow predictions in Alaska Advances in Water Resources, 54, 208–227, doi:10.1016/j.advwatres.2013.02.005
- Yatheendradas, S., C.D. Peters-Lidard, V.I. Koren, B. Cosgrove, L.G.G. de Goncalves, M.B. Smith, J. Geiger, Z. Cui, J. Borak, S. Kumar, D. Toll, G.A. Riggs and N. Mizukami, 2012 . Distributed assimilation of satellite-based snow extent for improving simulated streamflow in mountainous, dense forests: An example over the DMIP2 western basins. Water Resources Resarch DOI:10.1029/2011WR011347
- Kumar, S., C. D. Peters-Lidard, J. Santanello, K. Harrison, Y. Liu, and M. Shaw (2012). Land surface Verification Toolkit (LVT) – a generalized framework for land surface model evaluation Geoscientific Model Development Discuss., 5, 229-276, doi:10.5194/gmdd-5-229-2012
- Kumar, S., R.H. Reichle, K. W. Harrison, C.D. Peters-Lidard, S. Yatheendradas, and J.A. Santanello (2012). A comparison of methods for a priori bias correction in soil moisture data assimilation Water Resources Research, 48(W03515), 16, doi: 10.1029/2010WR010261
- De Lannoy, G., R.H. Reichle, K.R. Arsenault, P.R. Houser, S.V. Kumar, N.E.C. Verhoes, V.R.N. Pauwels , 2012: Assimilation of AMSR-E snow water equivalent and MODIS snow cover fraction in Northern Colorado. Water Resources Research, 48, W01522, 18 PP. doi:10.1029/2011WR010588
- Peters-Lidard, C., S. Kumar, D. Mocko, and Y. Tian (2011). Estimating evapotranspiration with land data assimilation systems. Hydrological Processes, 25(26 SI), 3979-3992, doi:10.1002/hyp.8387

RT SMOPS DA – Global assimilation





Colored areas show locations with retrievals available for input to the data assimilation system.

QC flags include rain/snow, frozen soil, dense vegetation, snow cover, frozen deep soil layers, etc.

For AMSR-E, from Reichle et al. (2007)