Enabling GPM- and SMAP-based land data assimilation at AFWA, USACE, USGS, and NOAA with the Land Information System

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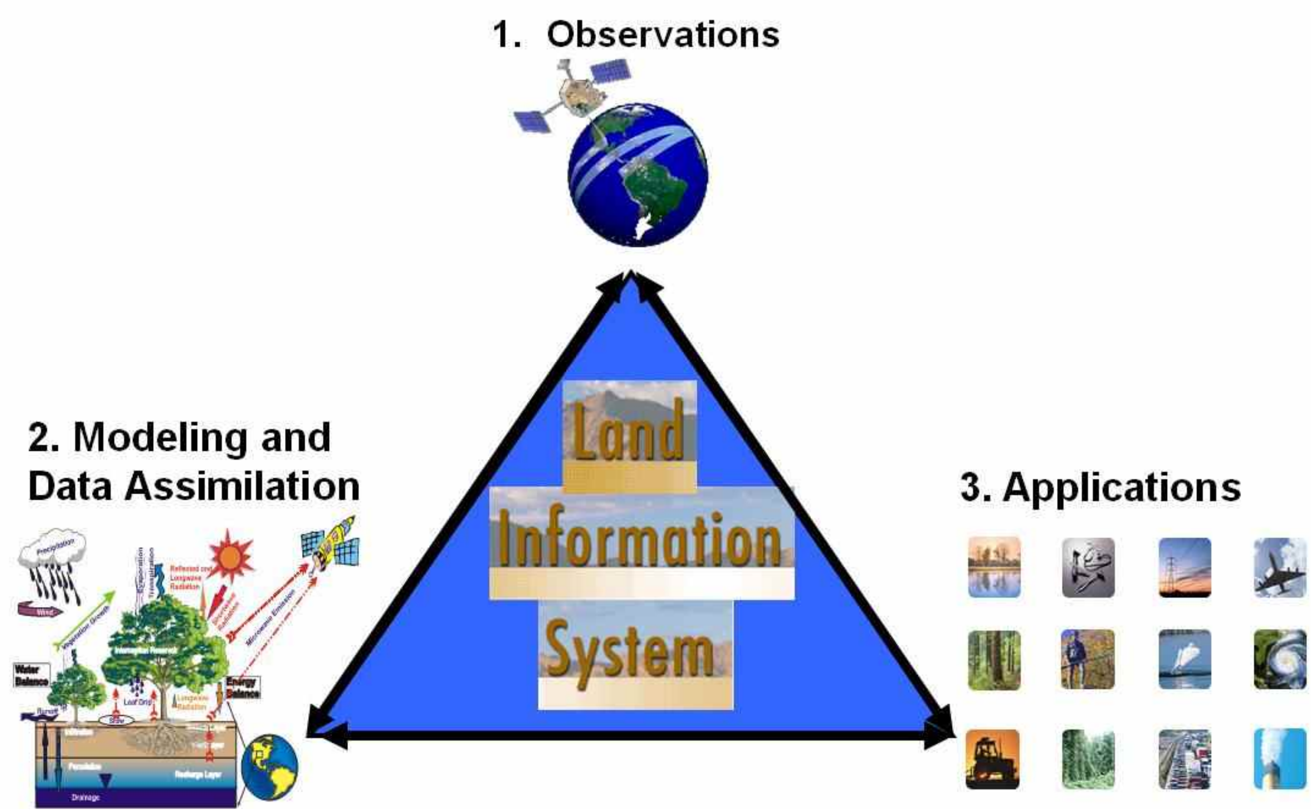
The Land Information System (LIS; http://lis.gsfc.nasa.gov) is a common land data assimilation infrastructure for NASA/DoD/NOAA and soon USGS



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.

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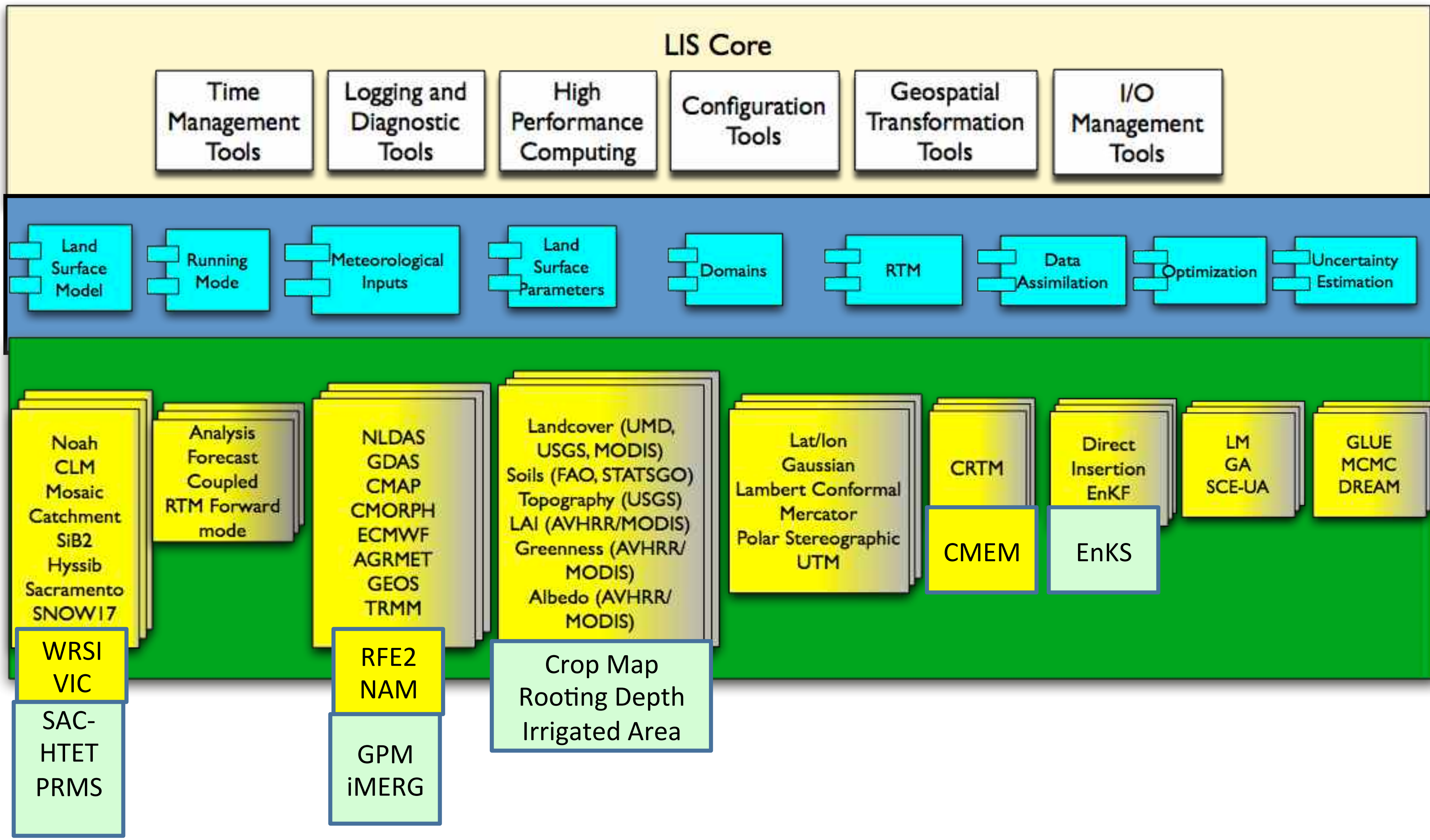
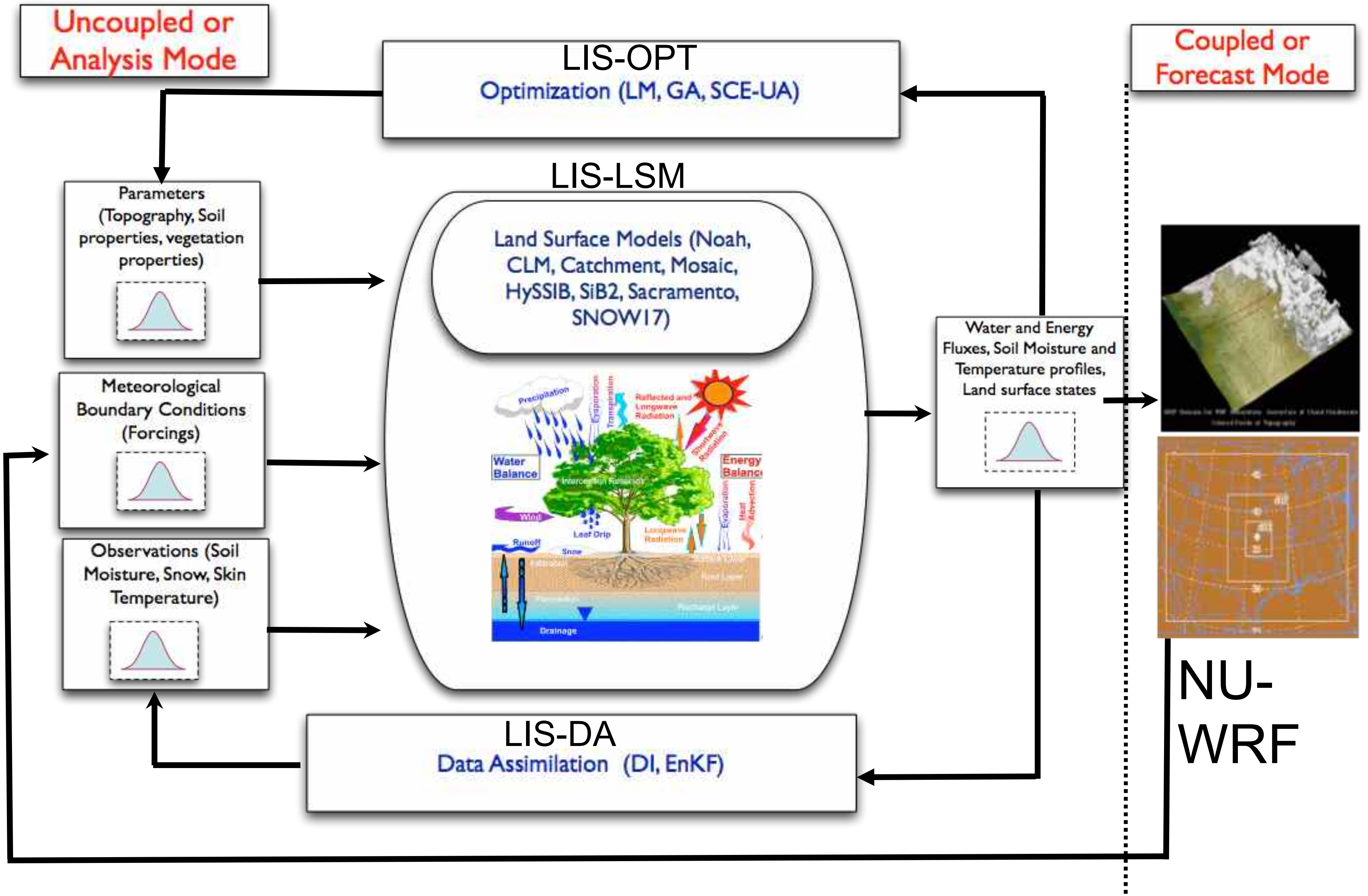
LIS Architecture



LIS Subsystems



Land Data Assimilation Objectives

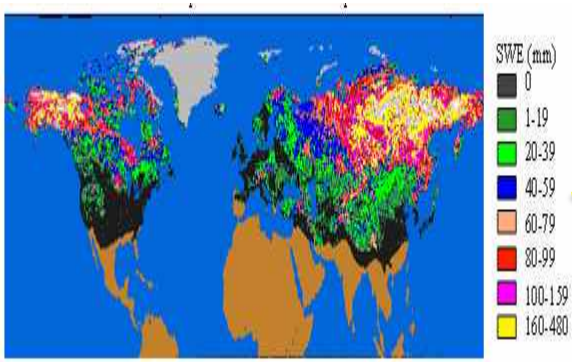
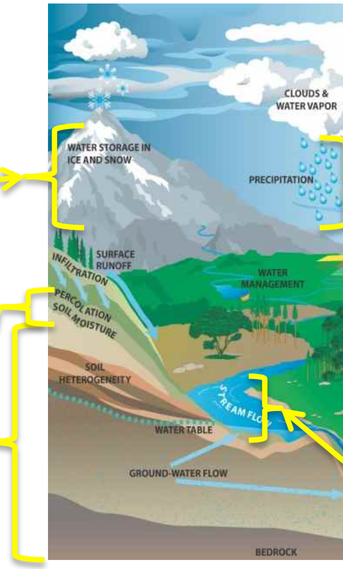


Figure 1: Snow water equivalent (SWE) based on Terra/MODIS and Aqua/AMSR-E. Future observations will be provided by JPSS/VIIRS and DWSS/MIS.



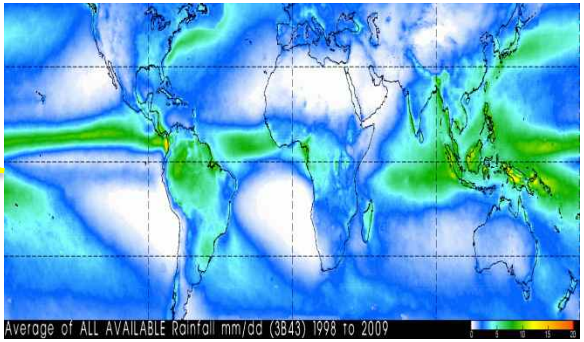


Figure 2: Annual average precipitation from 1998 to 2009 based on TRMM satellite observations. Future observations will be provided by GPM.

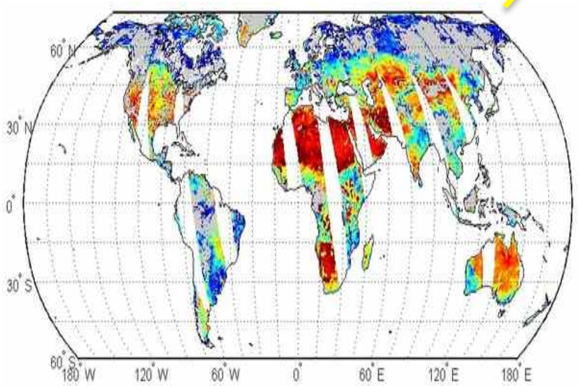


Figure 3: Daily soil moisture based on Aqua/AMSR-E. Future observations will be provided by SMAP.

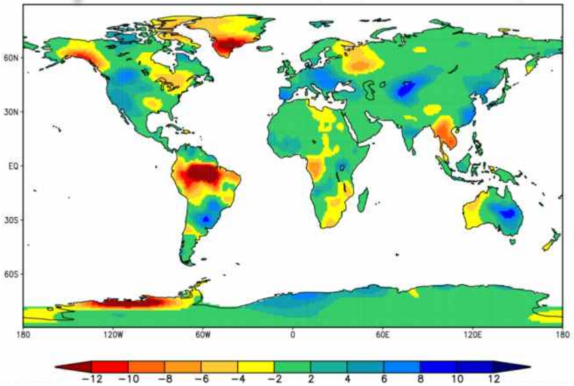


Figure 4: Changes in annual-average terrestrial water storage (the sum of groundwater, soil water, surface water, snow, and ice, as an equivalent height of water in cm) between 2009 and 2010, based on GRACE satellite observations. Future observations will be provided by GRACE-II.

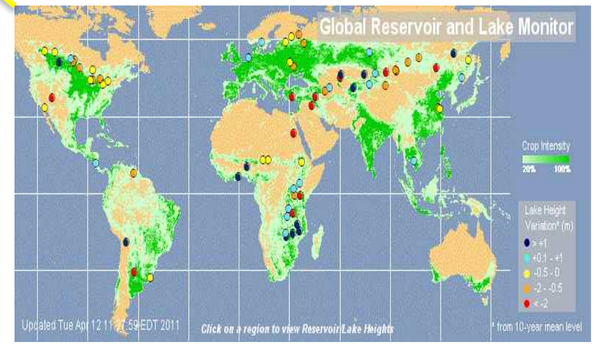
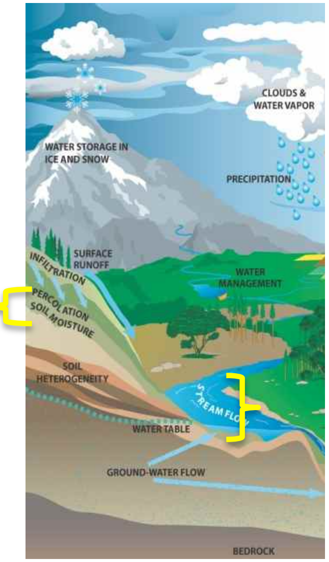


Figure 5: Current lakes and reservoirs monitored by OSTM/Jason-2. Shown are current height variations relative to 10-year average levels. Future observations will be provided by SWOT.

Soil Moisture Data Assimilation



Impact Assessment:

- Drought

Variables Analyzed:

- Soil Moisture
- Evapotranspiration
- Steamflow

Experimental Setup:

- Domain: CONUS, NLDAS
- Resolution: 0.125 deg.
- Period: 2002-01 to 2010-01
- Forcing: NLDASII
- LSM: Noah 3.2

Data Assimilation:

- AMSR-E LPRM soil moisture
- AMSR-E NASA soil moisture

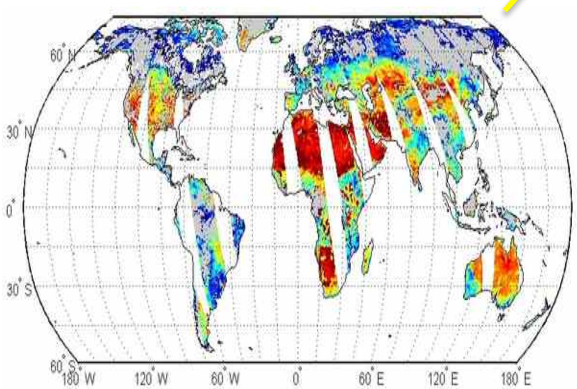
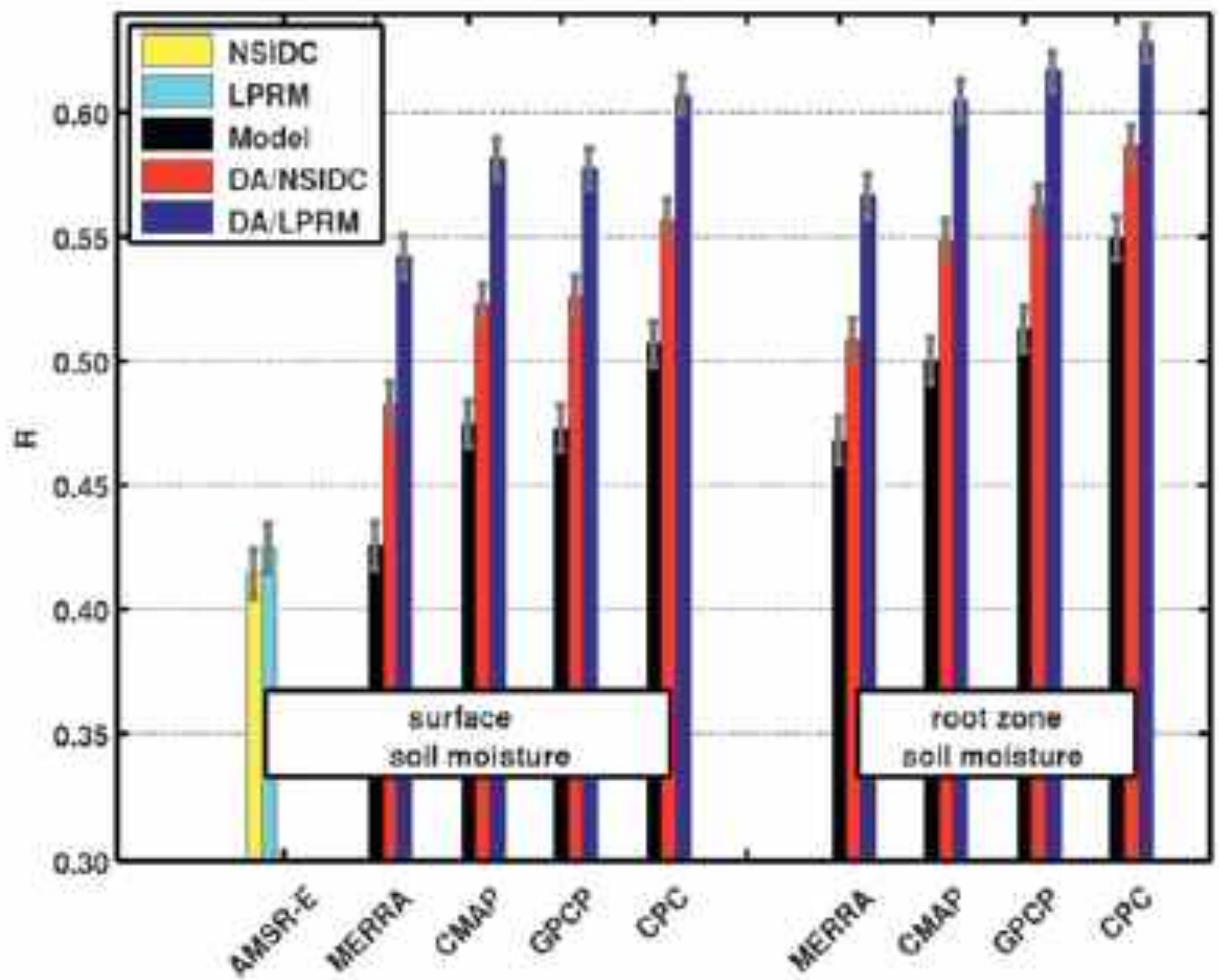


Figure 3: Daily soil moisture based on Aqua/ AMSR-E. Future observations will be provided by SMAP.

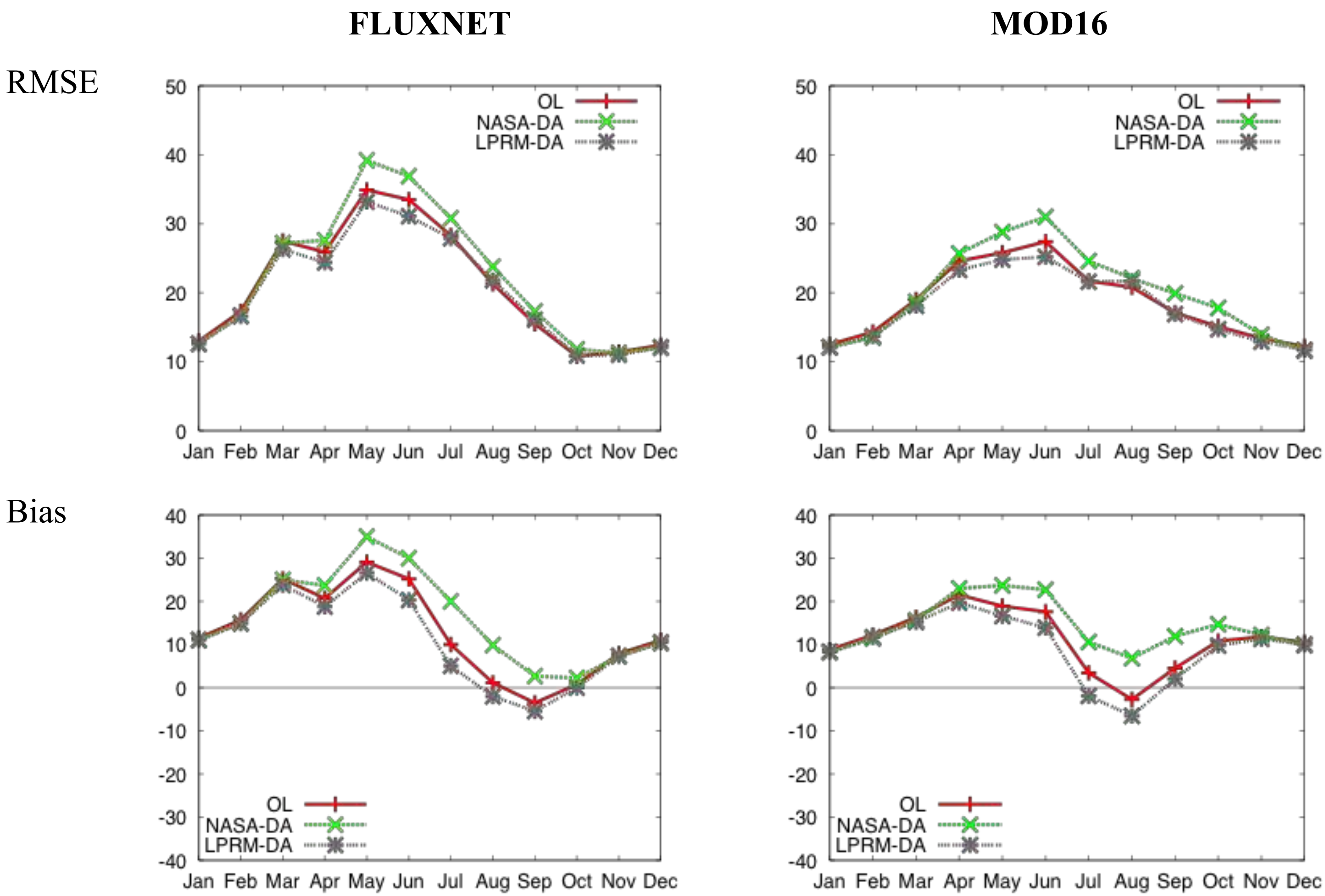
Peters-Lidard, C.D, S.V. Kumar, D.M. Mocko, Y. Tian, 2011: Estimating evapotranspiration with land data assimilation systems, Hydrological Processes, 25(26), 3979--3992, DOI: 10.1002/hyp.8387

Soil Moisture Assimilation <- Precipitation Impact



Liu, Q., R. H. Reichle, R. Bindlish, M. H. Cosh, W. T. Crow, R. de Jeu, G. J. M. De Lannoy, G. J. Huffman, and T. J. Jackson: 2011,The contributions of precipitation and soil moisture observations to the skill of soil moisture estimates in a land data assimilation system. *J. Hydrometeor., 12*, 750-765, doi:10.1175/JHM-D-10-05000.1.

Soil Moisture Assimilation -> Latent Heat Flux



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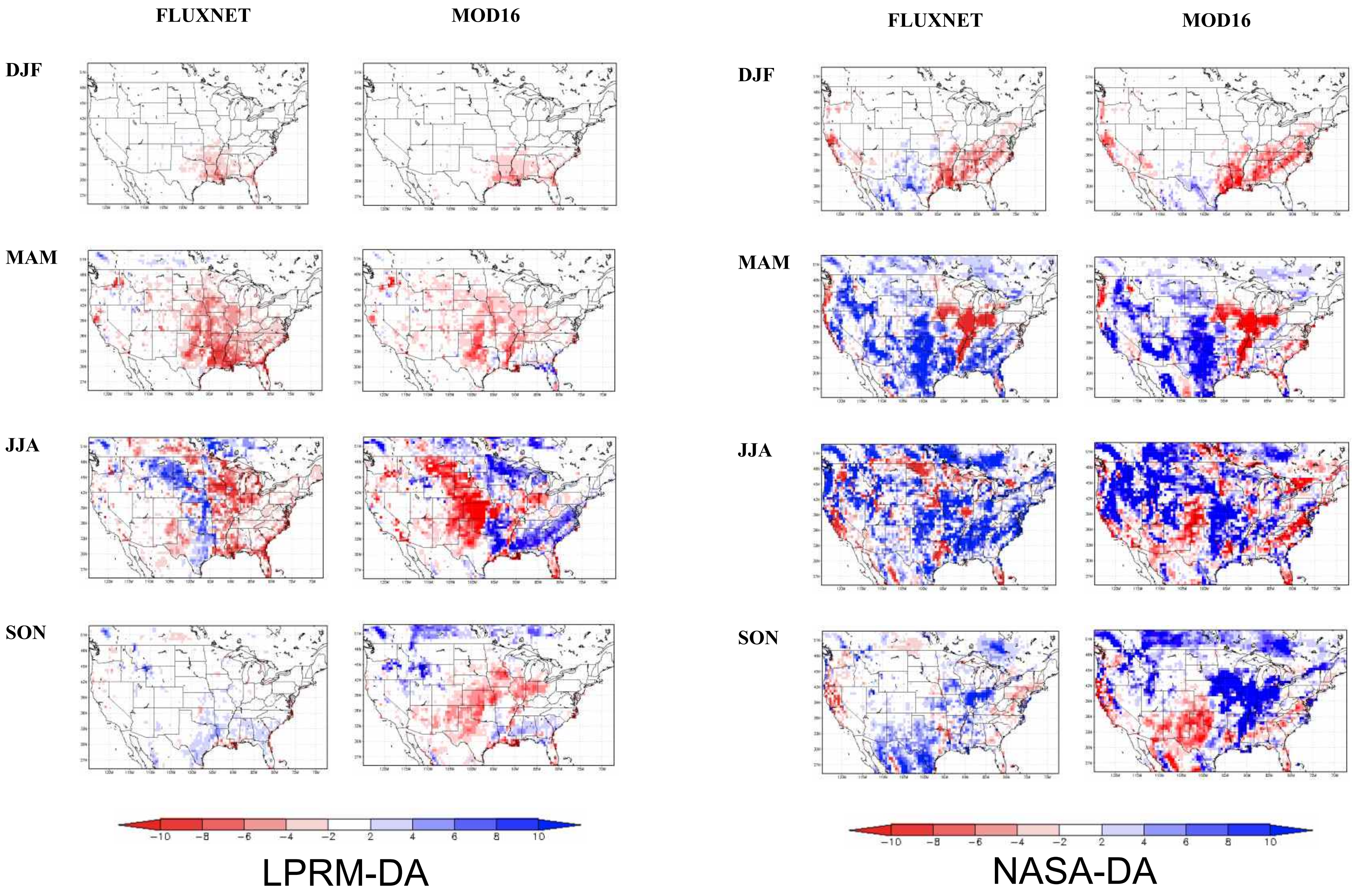
Where Does Soil Moisture Assimilation Help Improve Qle (i.e. Reduce RMSE) ?



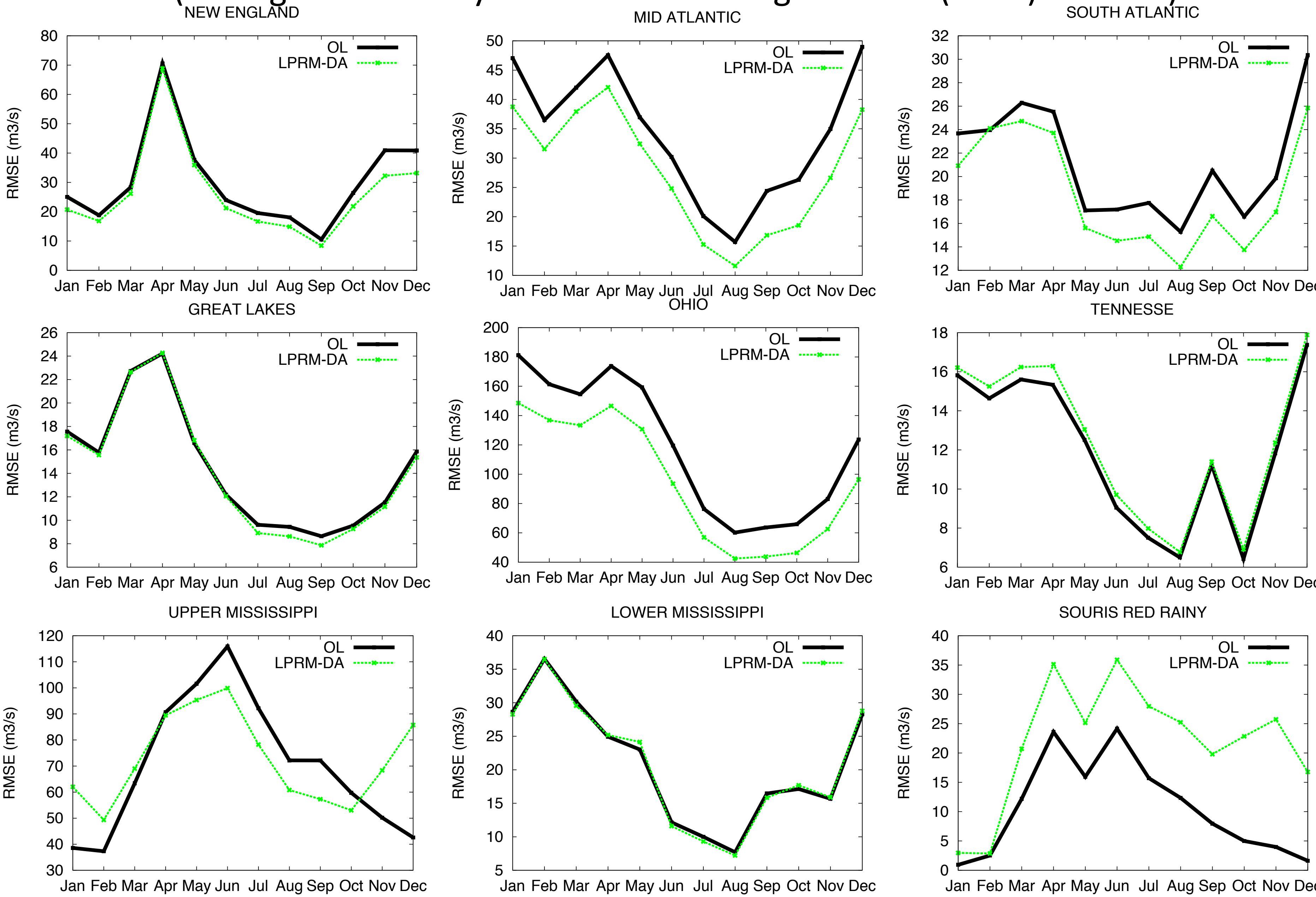
Where Does Soil Moisture Assimilation Help Improve Qle (i.e. Reduce RMSE) ?

Qle RMSE % Difference (DA-OL)	FLUXNET		MOD16	
Landcover type	**NASA-DA (Wm^{-2})**	**LPRM-DA (Wm^{-2})**	**NASA-DA (Wm^{-2})**	**LPRM-DA (Wm^{-2})**
Evergreen needleleaf forest	17.6	7.9	10.5	-3.6
Deciduous broadleaf forest	3.2	12.7	0.3	0.7
Mixed forest	1.8	8.0	-0.7	-0.9
Woodlands	16.4	18.9	11.5	-5.9
Wooded grassland	8.8	-0.5	9.6	0.3
Closed shrubland	7.3	3.4	2.5	8.9
Open shrubland	9.0	7.4	3.6	12.1
Grassland	23.9	7.1	32.9	46.4
Cropland	12.3	34.7	30.9	40.8
Bare soil	-0.1	0.6	-0.8	1.4
Urban	-0.1	-0.1	-0.2	-0.3

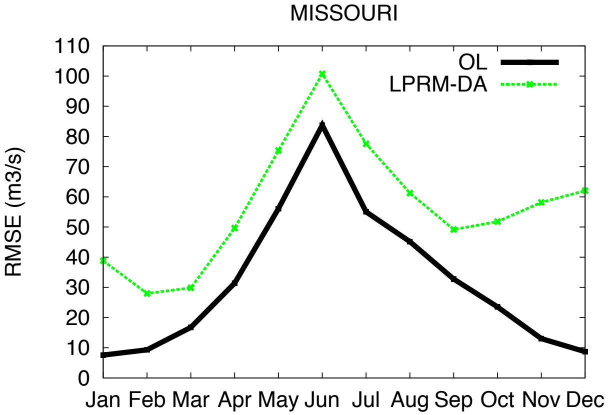
Peters-Lidard, C.D, S.V. Kumar, D.M. Mocko, Y. Tian, 2011: Estimating evapotranspiration with land data assimilation systems, Hydrological Processes, 25(26), 3979--3992, DOI: 10.1002/hyp.8387

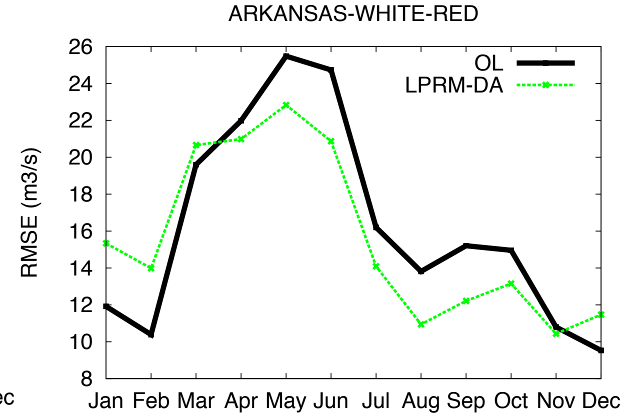
Soil Moisture Assimilation -> Streamflow Evaluation vs. USGS gauges – by major basins

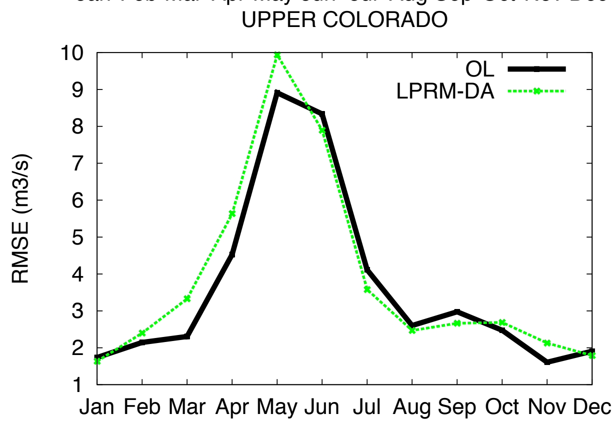
Soil Moisture Assimilation -> Streamflow
(average seasonal cycles of RMSE– using Xia et al. (2011) stations)

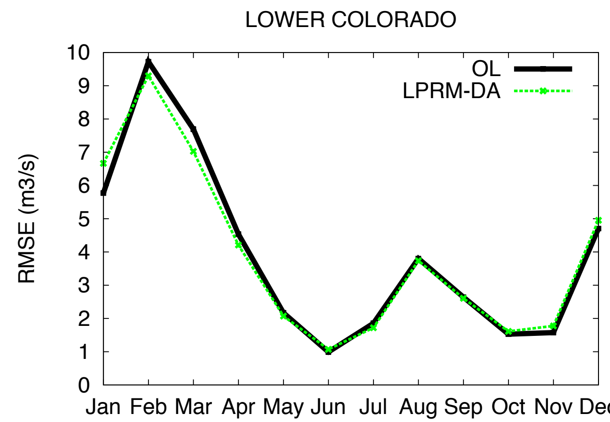


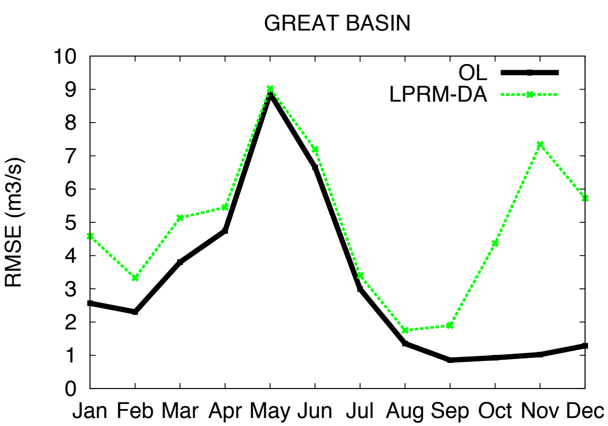
Soil Moisture Assimilation -> Streamflow
(average seasonal cycles of RMSE– using Xia et al. (2011) stations)

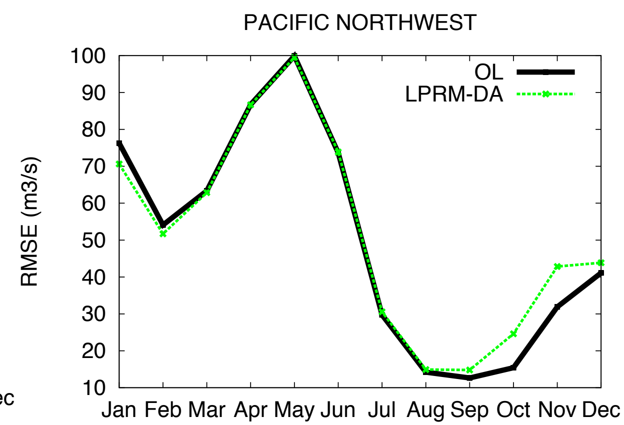


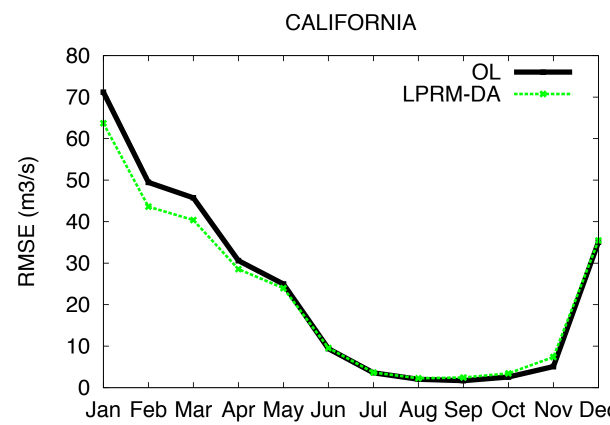










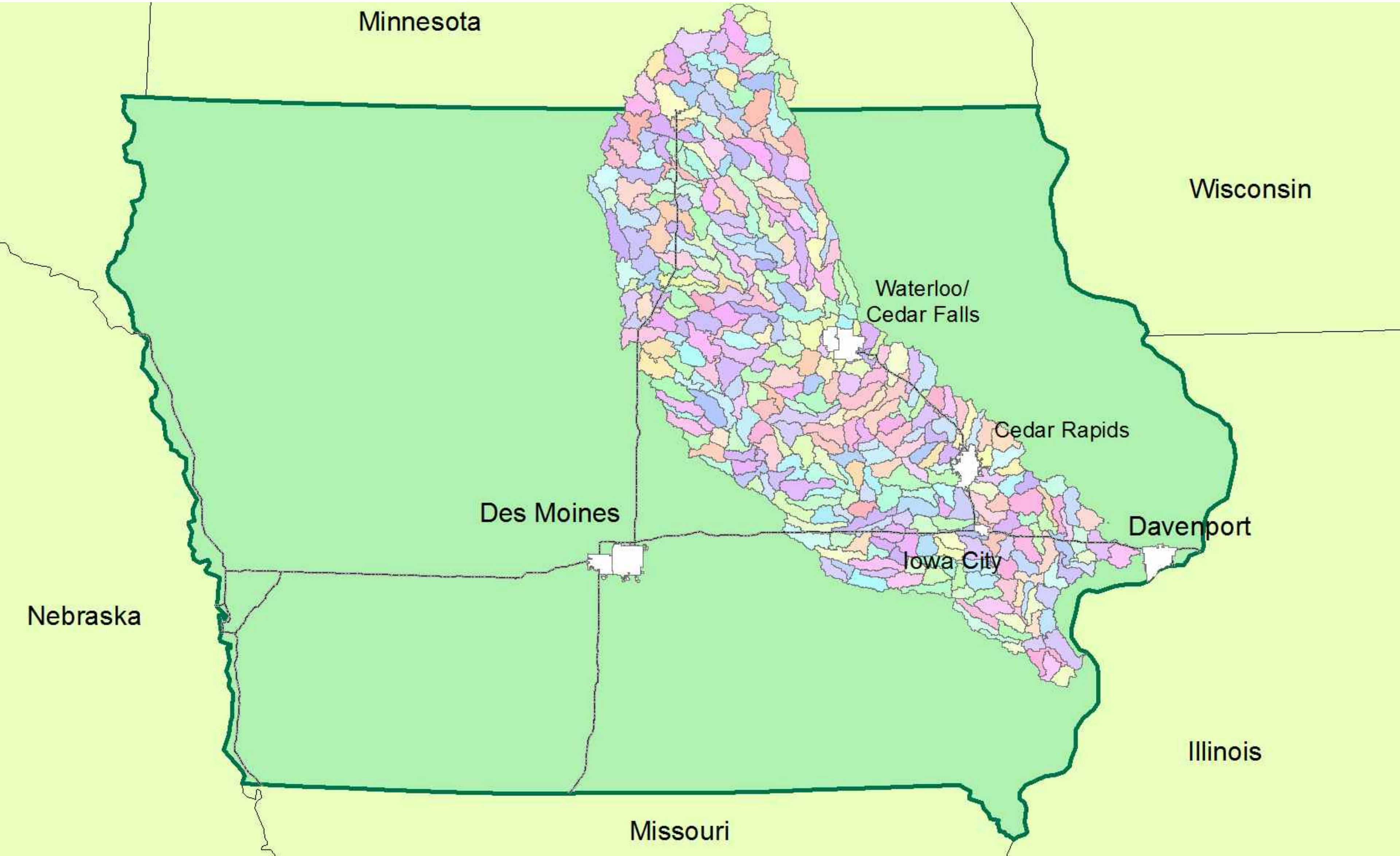


Summary

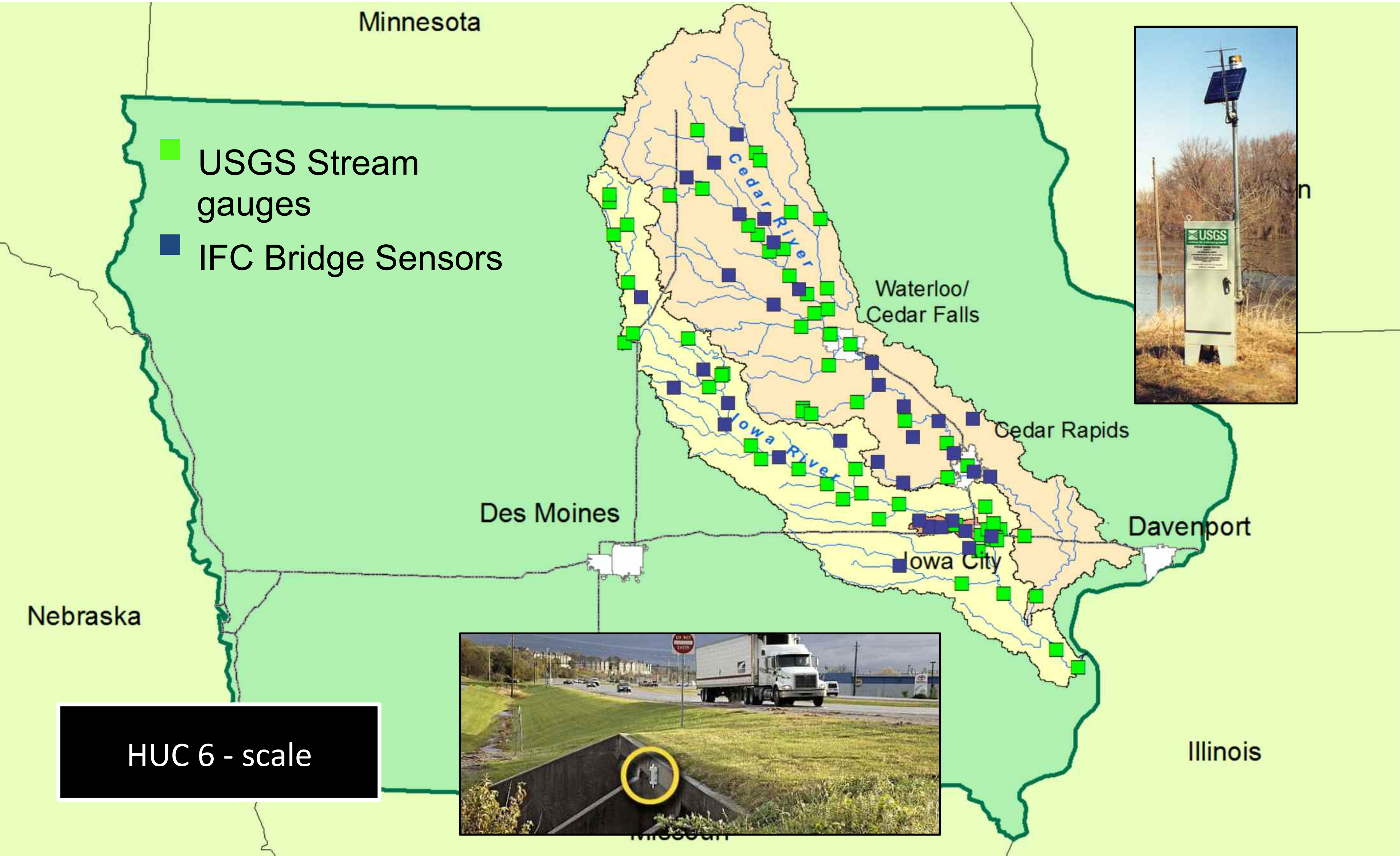
- The combination of improved precipitation from GPM and improved soil moisture from SMAP should significantly improve surface and root zone soil moisture states
- Soil moisture assimilation can also improve streamflow and evapotranspiration

- Opportunities:
  - Operational LIS implementations at AFWA, NOAA/NCEP,NOAA/NOHRSC
  - Testing CMORPH at AFWA—should be ready for iMERG from GPM
  - Developing capabilities for FEWS-NET and IWRSS
  - Near-term GPM Field Campaigns with Hydrology Focus:
    - iFLOODS'13: Large Scale Flood: Iowa, May-July, 2013
    - HMT-SE: Orographically-Enhanced Convection: HydroMeteorological Testbed (HMT)-Southeast (joint with NOAA), North Carolina, May-July 2014
    - SMAPex: Arid Monsoon: San Pedro-Walnut Gulch, Arizona, Jul-Aug., 2015 (dependent on SMAP validation plans).
    - OLYMPEX: Snow-Rain transition/Orographic/Flooding: western Olympic Peninsula, Washington, Nov-Dec. 2015.

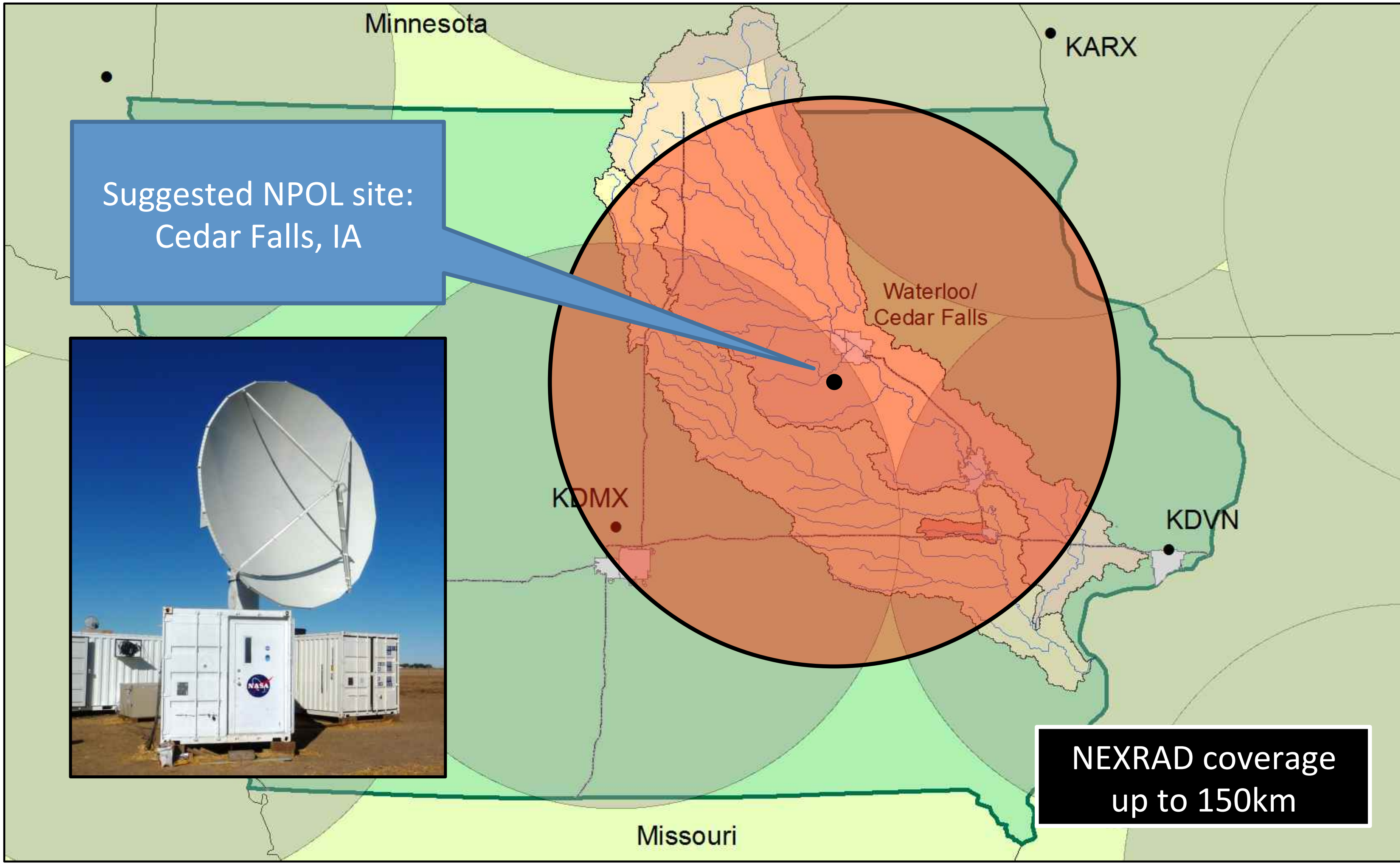
NASA GPM-GV FIELD CAMPAIGN IFLOODS'13
Sub-watershed Perspective



NASA GPM-GV FIELD CAMPAIGN IFLOODS'13
Existing Infrastructure



NASA GPM-GV FIELD CAMPAIGN IFLOODS'13
Instrument Deployment



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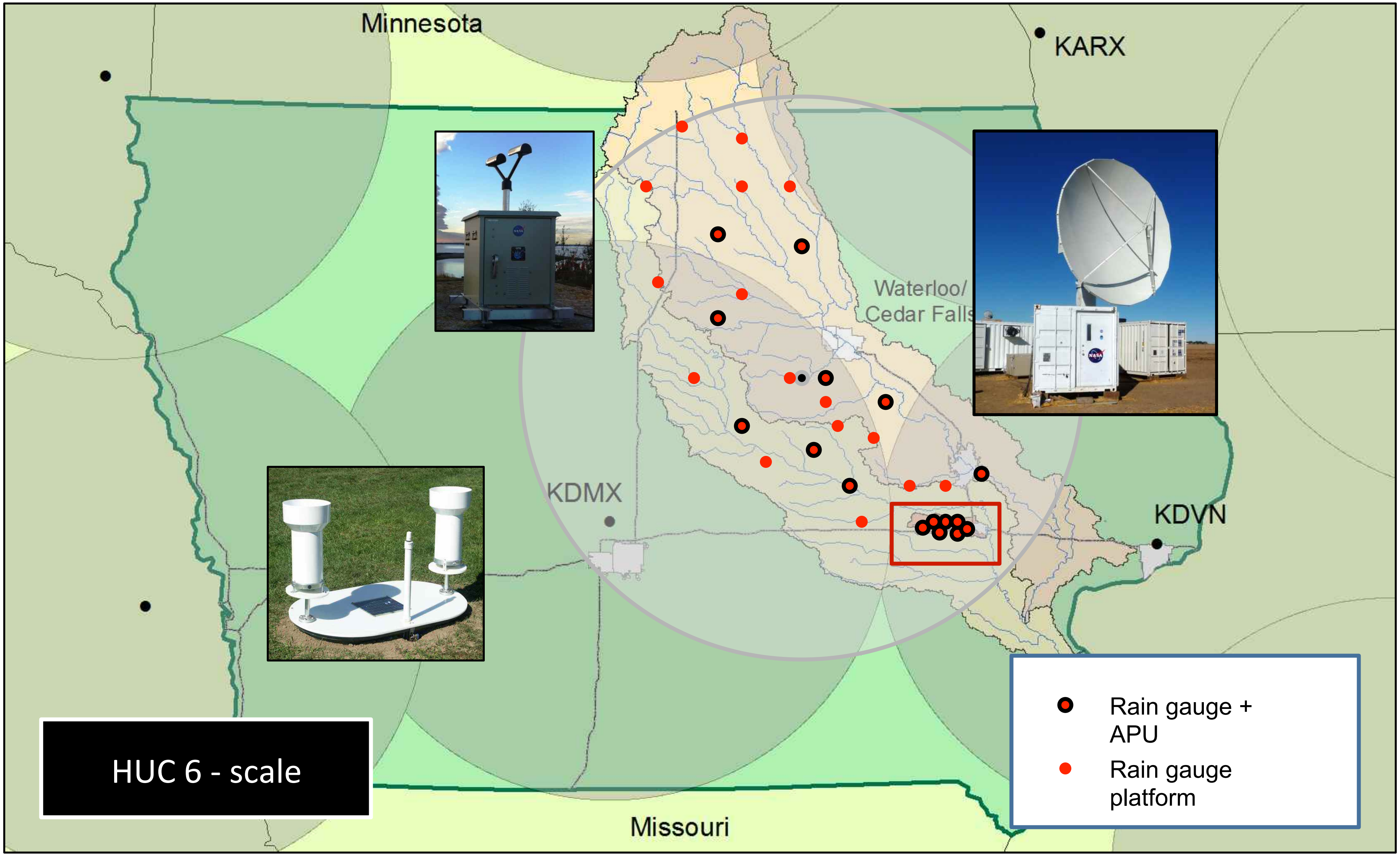

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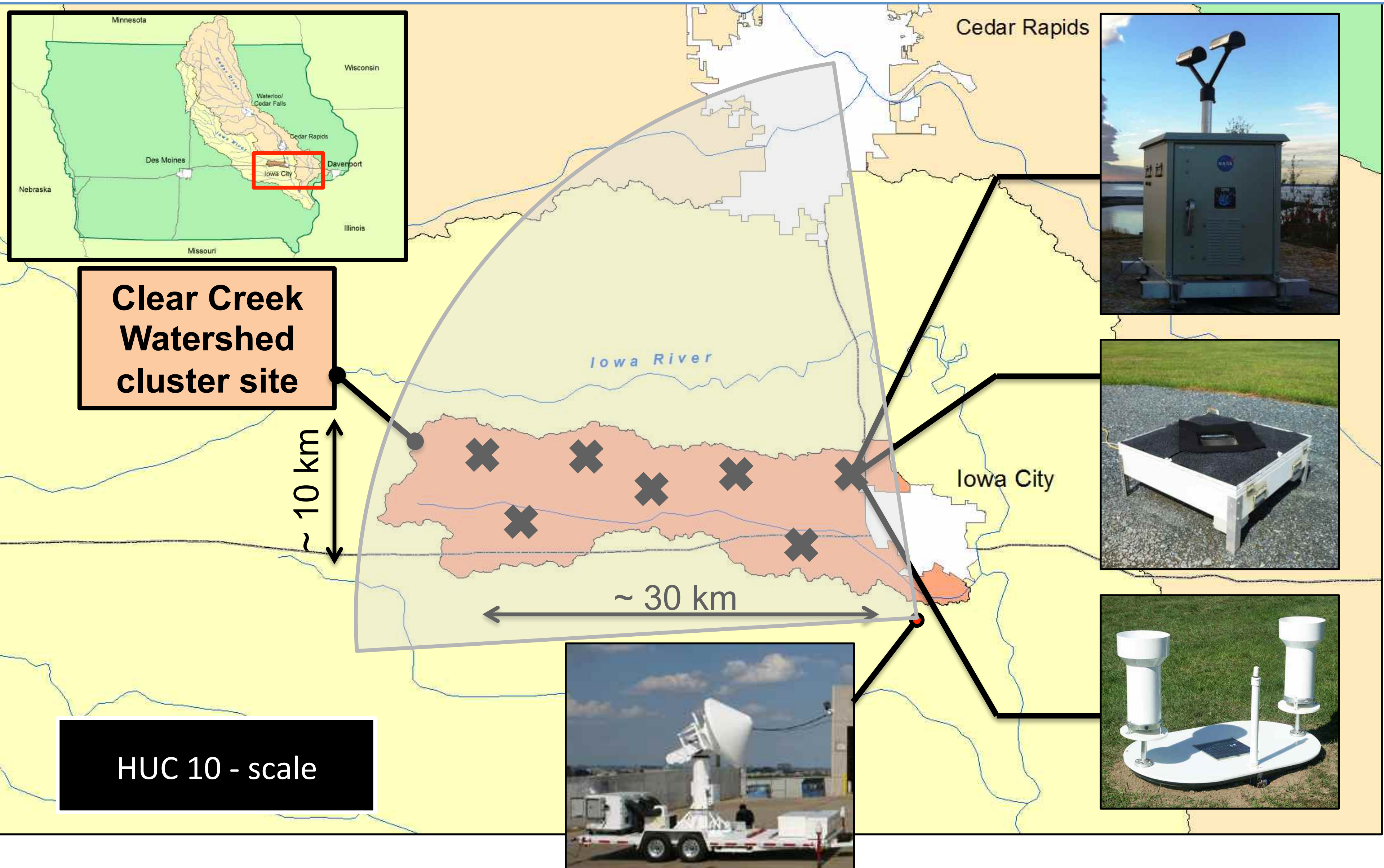


Backup

NASA's Land Information System Supports Alaska Snow Analysis for NOAA's Operational Hydrologic Remote Sensing Center (NOHRSC)

Christa D. Peters-Lidard, Sujay V. Kumar, Yuqiong Liu and the LIS Team, Code 617, NASA GSFC

NOAA's National Operational Hydrologic Remote Sensing Center (NOHRSC) recently implemented an experimental land surface model output for Alaska using NASA's Land Information System (LIS) software.

NOHRSC experimental LIS-based snowpack information for Alaska takes the form of a four-member "ensemble" consisting of two forcing data systems (GDAS and NAM) and two land surface models (CLM and Noah). Each forcing system is used to drive each model using NASA's Land Information System (LIS) software. Consequently, four independent sets of snowpack states are available: GDAS+CLM, GDAS+Noah, NAM+CLM, and NAM+Noah.

Key:
NAM= the North American Mesoscale (NAM) model
GDAS= Global Data Assimilation System,
CLM= Community Land Model version 2.0
Noah= The Community Noah land surface model version 3.2

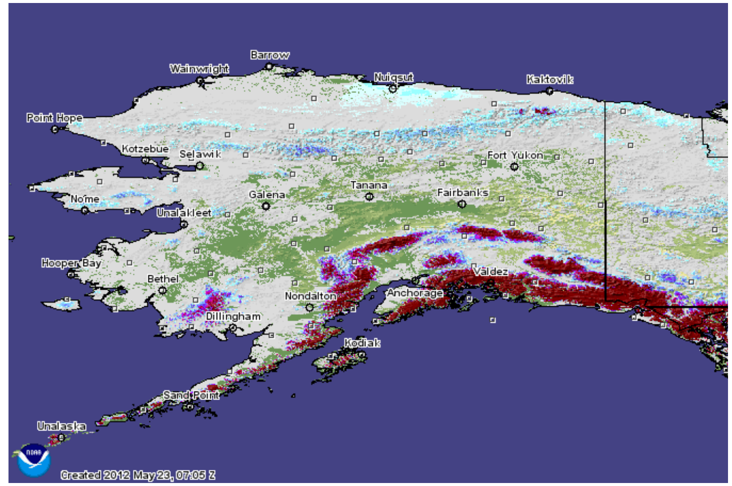


Figure 1: The experimental modeled (NAM+Noah) snow water equivalent for May 23, 2012, 0:00 Z.

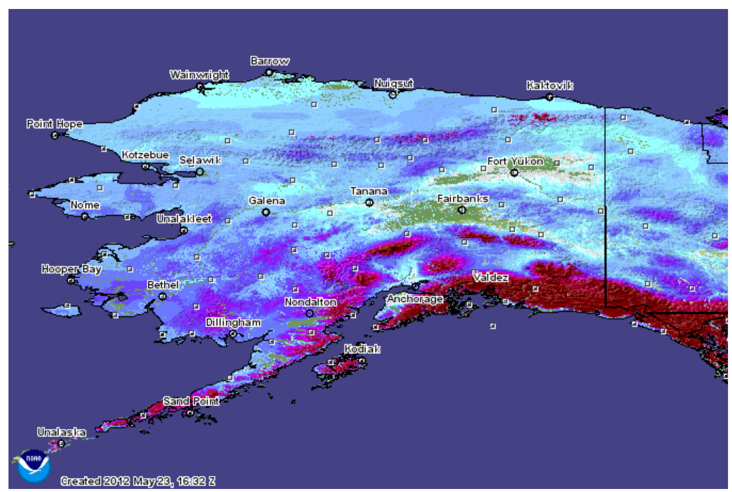
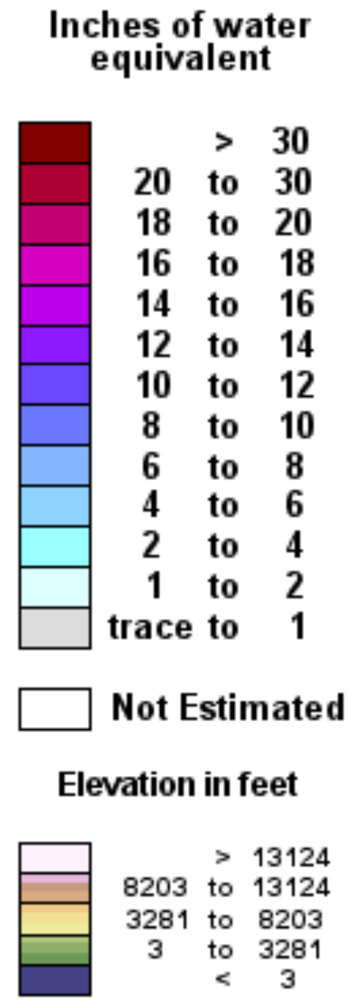


Figure 2: The experimental modeled (GDAS+CLM) snow water equivalent for May 23, 2012, 0:00 Z. Differences from Figure 1 are related to differences in snowfall and snowpack physics.



Name: Christa D. Peters-Lidard and the LIS team, NASA/GSFC, Code 617
E-mail: Christa.Peters@nasa.gov
Phone: 301-614-5811

References:

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Data Sources: LIS version 6 software, downloaded by agreement from lis.gsfc.nasa.gov by our partners at NOAA NOHRSC, including Gregory Fall on the NOHRSC team. Numerous other data sources used in the analysis, including NOAA's Global Data Assimilation System (GDAS) and the North American Mesoscale (NAM) model products, available at http://nomads.ncdc.noaa.gov/data.php.

Technical Description of Figures:

Figure 1: This figure is taken from the experimental NOHRSC page (http://www.nohrsc.noaa.gov/interactive/html/map.htm), and shows the experimental modeled (NAM+Noah) snow water equivalent for May 23, 2012, 0:00 Z.

Figure 2: This figure is taken from the experimental NOHRSC page (http://www.nohrsc.noaa.gov/interactive/html/map.htm), and shows the experimental modeled (GDAS+CLM) snow water equivalent for May 23, 2012, 0:00 Z.

Scientific significance: Improvements to land surface snowpack states, including snow water equivalent, snow depth, and snow cover, lead to direct improvements in streamflow and hydrological forecasting at NOAA River Forecast Centers supported by NOHRSC, such as the Alaska River Forecast Center. The flexibility and configurability of the LIS software infrastructure simplifies the process for improving snow and other hydrological analyses for our partners at NOAA/NOHRSC.

Relevance for future science and relationship to Decadal Survey: The adoption of the LIS infrastructure by our partners at NOHRSC (under funding from NASA's Earth Science Applications Program) sets them up to be early adopters of Decadal-Survey era data, including snowfall products from GPM, and freeze-thaw and/or soil moisture products from SMAP. The strongest interest is for snow-related products, which may be available from NPP/VIIIRS as well as ICESat-2, as well as eventually from the tier-3 SCLP mission.

NASA's Land Information System Supports Land Analysis for NOAA's Climate Forecast System Reanalysis (CFSR)

Christa D. Peters-Lidard and the LIS Team, Code 617, NASA GSFC

NOAA's National Centers for Environmental Prediction (NCEP) recently completed a new coupled global reanalysis, known as CFSR, for the period 1979–present. This reanalysis has significantly higher temporal and spatial resolution than previous reanalyses, known as R1 and R2.

The NASA Land Information System (LIS) infrastructure is employed to execute the global land data analysis system (GLDAS) for CFSR. To support CFSR-GLDAS, NCEP took advantage of LIS' flexible grid and parameter support to configure LIS with the identical land model setup as in the fully coupled Climate Forecast System. Compared to R1 and R2, this CFSR-GLDAS uses observed global precipitation analyses as direct forcing to the land surface analysis, which leads to a more realistic soil moisture initial conditions for the coupled reanalysis system. CFSR-GLDAS interacts with the reanalysis once per day, instead of every time step.

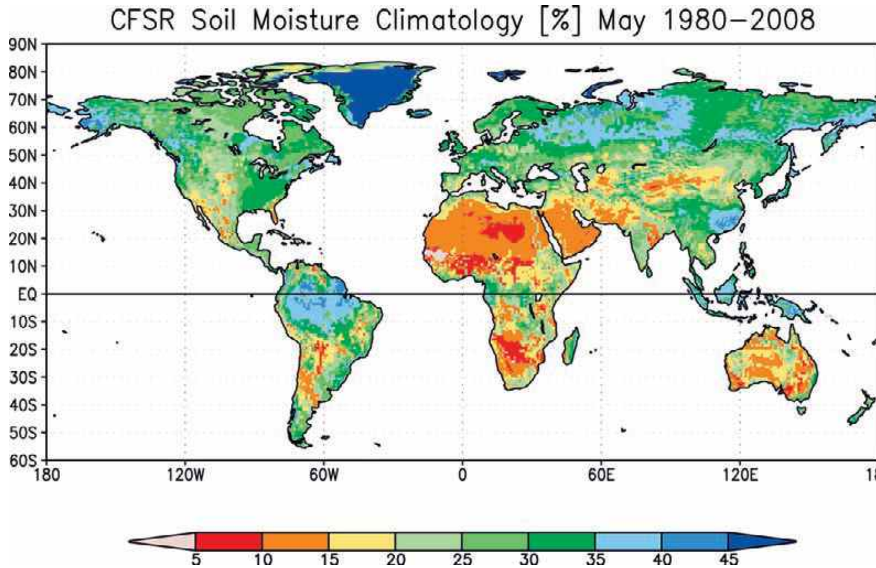

Figure 1: The 2-m volumetric soil moisture climatology of CFSR, from the LIS-based CFSR-GLDAS for May averaged over 1980–2008.

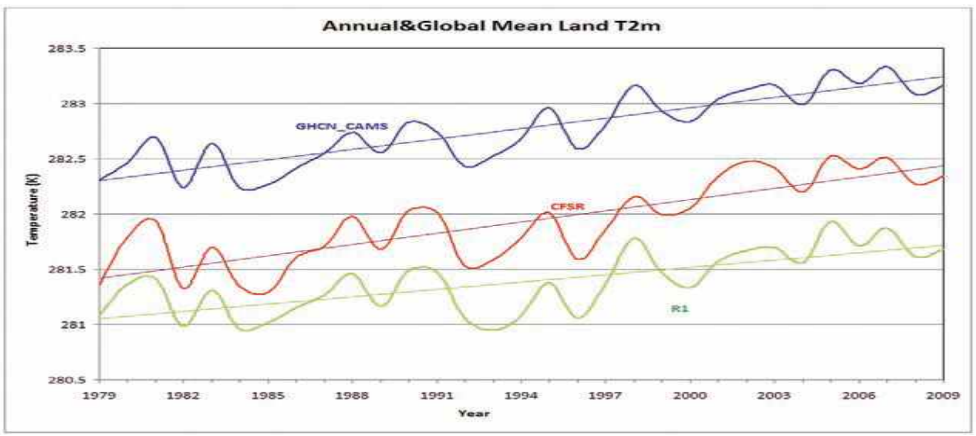

Figure 2: Time series of annual and global mean 2m temperatures over land, with R2 shown in green, CFSR in red and independent (non-assimilated) observations in blue. The 2m air temperature over land is sensitive to the land surface soil moisture.

Name: Christa D. Peters-Lidard and the LIS team, NASA/GSFC, Code 617
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References:

Saha, Suranjana, and Coauthors, 2010: The NCEP Climate Forecast System Reanalysis. *Bull. Amer. Meteor. Soc.*, **91**, 1015–1057. DOI: 10.1175/2010BAMS3001.1.

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

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Data Sources: LIS version 5 software, downloaded by agreement from lis.gsfc.nasa.gov by our partners at NOAA NCEP, including Michael Ek, Jesse Meng, and Heilin Wei on the NCEP Land Team. Numerous other data sources used in the reanalysis, including NASA's Aqua/AIRS, AMSR-E and AMSU-A, are described at http://cfs.ncep.noaa.gov/cfsr.

Technical Description of Figures:

Figure 1: This figure is taken from the CFSR BAMS article (Figure 17), and shows the 2-m volumetric soil moisture climatology of CFSR, from the LIS-based CFSR-GLDAS for May averaged over 1980–2008.

Figure 2: This figure is taken from the CFSR BAMS article (Figure 19), and shows time series of annual and global mean 2m temperatures over land, with R2 shown in green, CFSR in red and independent (non-assimilated) observations in blue. The 2m air temperature over land is sensitive to the land surface soil moisture.

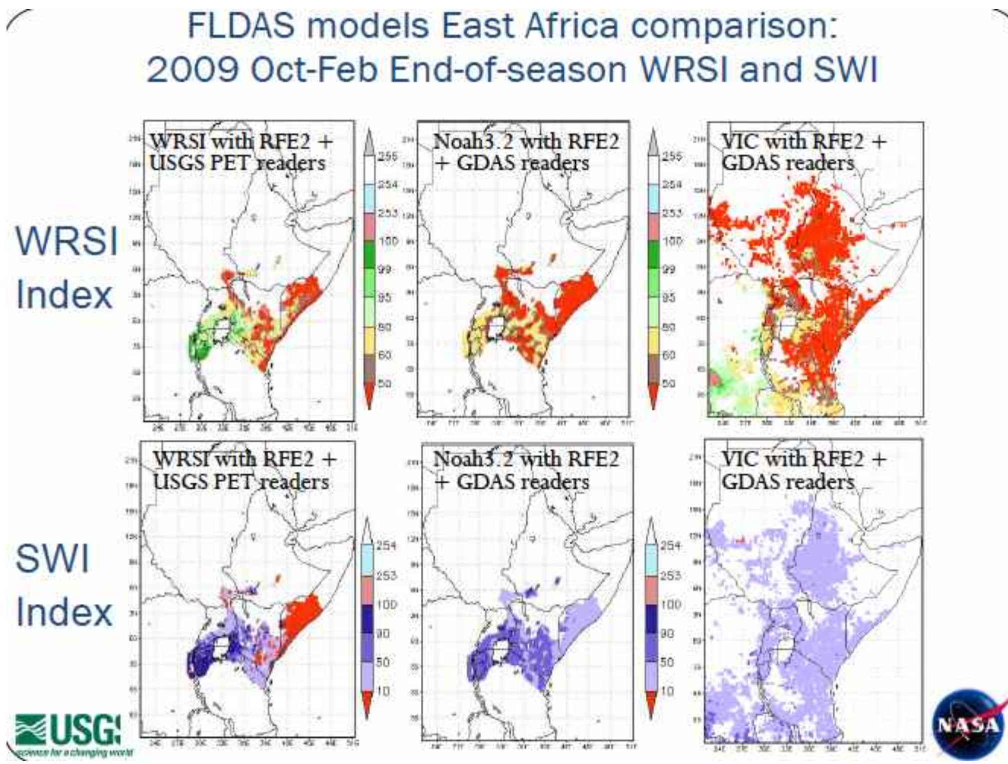
Scientific significance: Improvements to land surface states, including soil moisture, temperature , snow pack and vegetation, lead to direct improvements in land surface fluxes and atmospheric states such as 2m air temperature. The flexibility and configurability of the LIS software infrastructure simplifies the process for improving land analyses for our partners at NOAA/NCEP.

Relevance for future science and relationship to Decadal Survey: The adoption of the LIS infrastructure by our partners at NCEP sets them up to be early adopters of Decadal-Survey era data, including precipitation from GPM, and soil moisture from SMAP, among others.

A Land Data Assimilation System for Famine Early Warning

Co-PIs: James Verdin and Chris Funk, USGS;
Co-Is: Christa Peters-Lidard, Soni Yatheendradas, Sujay Kumar, Brad Wind, Jim Geiger, Shugong Wang and Kristi Arsenault, NASA/GSFC 617; Dennis Lettenmaier, UW; Molly Brown, NASA/GSFC 618; Michael Dettinger, USGS

Highlight: The recently developed FEWS NET Land Data Assimilation System (FLDAS) custom instance of NASA's Land Information System (LIS) software supports the use of multiple satellite inputs and land models to quantify their impacts on agricultural drought-related information. For example, characterizing uncertainties though the FLDAS multi-model ensemble helps to assess the resulting uncertainty of drought indices such as the Water Requirement Satisfaction Index (WRSI). See Fig. 1 using LIS/WRSI, LIS/Noah and LIS/VIC land surface models for East Africa.



Relevance: Information from multiple satellite-based inputs, land surface models and their relevant enhancement towards FEWS NET goals, fills a critical information gap towards better specification of losses to agricultural yields and related food insecurity. Uncertainty information helps to better quantify the value to society-relevant hazards like famine.

Additional References

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