NASA LIS-based NLDAS status and future plans

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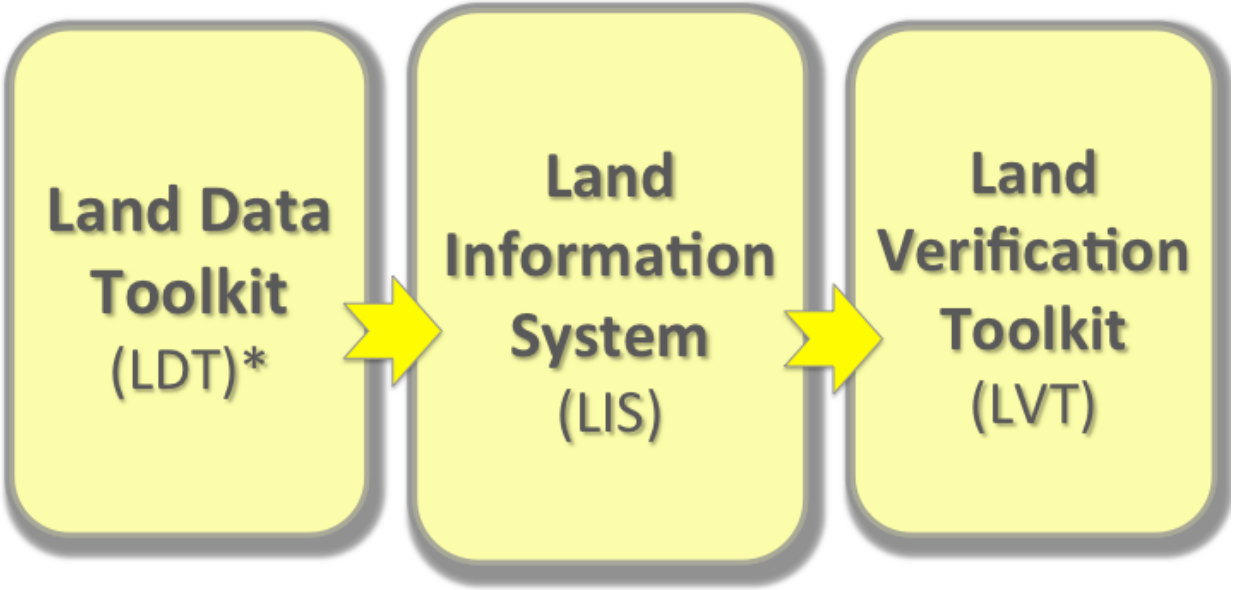
Current LIS (version 7) configuration



* *NOTE: LIS version 7 requires LDT processed inputs before its run-time execution …*

LDT – handles all the LSM (e.g., parameters) and data assimilation pre-processing needs of LIS

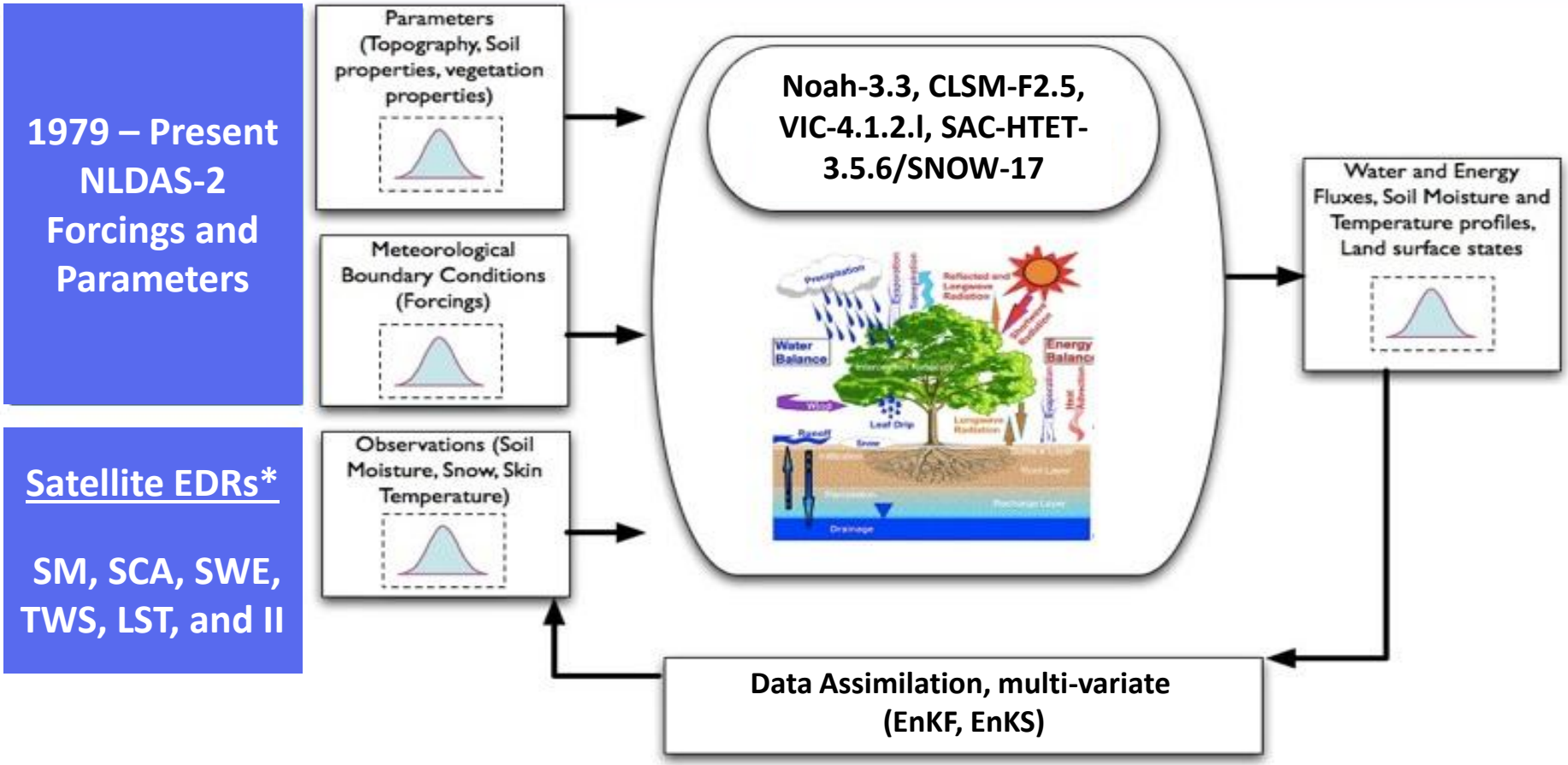
LIS – modeling and data assimilation environment

LVT – provides a comprehensive environment for model evaluation and data analysis

Reference(s): Kumar et al. (2006) in *Environmental Modelling & Software*
Peters-Lidard et al. (2007) in *Innovations in Systems and Software Engineering*

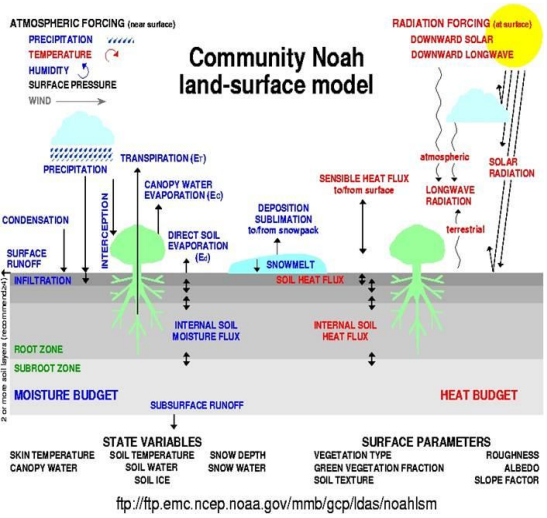
LIS-based NLDAS System Design

LIS-based next phase of NLDAS



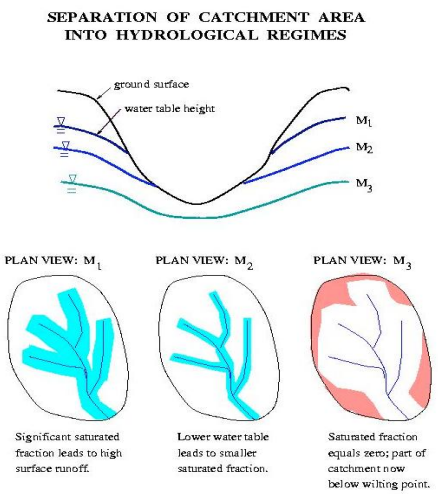
* Satellite-based Environmental Data Records (EDRs): soil moisture (SM), snow-covered area (SCA), snow water equivalent (SWE), terrestrial water storage (TWS), land surface temperature (LST), and irrigation intensity (II)

Land surface models



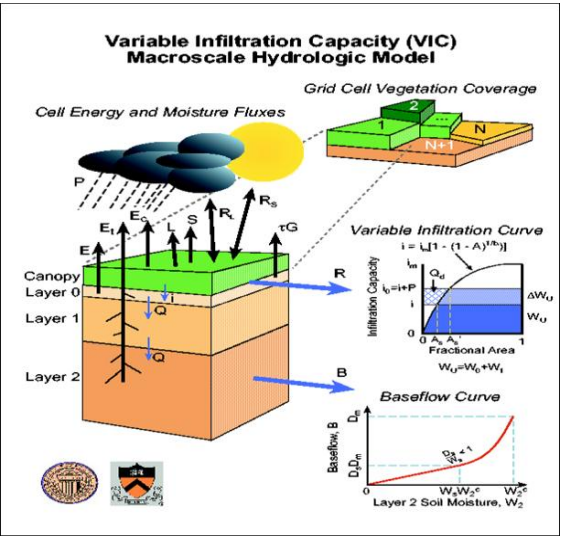
Noah-3.3 (including warm season updates as well as snow-physics upgrades), **Noah-3.6** (Univ. Arizona's snow-physics option), and **Noah-MP**

Soil moisture, snow DA tested for Noah-3.3 and Noah-3.6



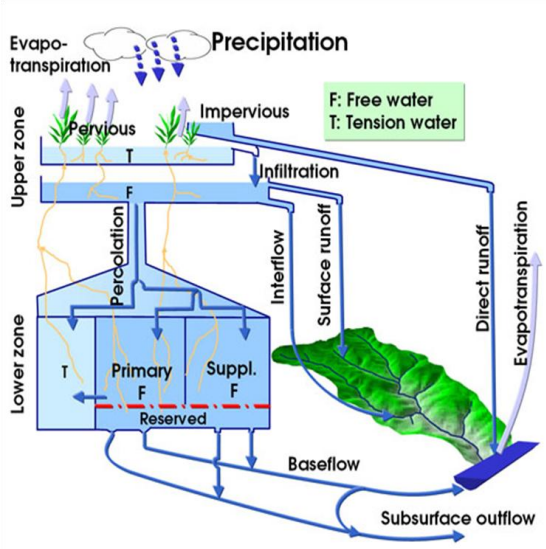
CLSM-F2.5 (Fortuna-2.5) version (same version used in MERRA-Land)

Soil moisture, snow, and TWS DA tested for CLSM-F2.5



VIC-4.1.2.l (numerous fixes and upgrades, including to soil temperatures)

VIC is computationally more intensive compared to Noah/CLSM. No DA implementation yet.



SAC-HTET-3.5.6 (RDHM-3.5.6) includes updates to the treatment of heat and to vegetation effects. Coupled to SNOW-17.

Still working on the full implementation and support of NLDAS parameters. No DA implementation yet.

Reference(s): Chen et al. (1996, JGR); Ek et al. (2003, JGR); Wei et al. (2012, HP); Livneh et al. (2010, JHM)

Next phase of LIS-NLDAS status

LSM	In LIS-7	Parameters in LDT	Configured for DA	Time to run 1 year in the NLDAS domain
Noah-3.3/3.6	Yes	Yes	Yes	1 hr, 20 mins
CLSM-F2.5	Yes	Yes	Yes	1 hr, 18 mins
VIC-4.1.2.l	Yes	No Read NLDAS-VIC pars	No	7 hrs, 45 mins
SAC-HTET-3.5.6	Yes	No Need to implement Victor Koren's code for parameters based on soil textures in LDT	No	TBD
Noah-MP-3.6.1	Yes	Yes	No	TBD, although should be similar to Noah-3.3/3.6

"Time to Run" is average time to run one calendar year of simulation on the NASA/GSFC NCCS's Discover platform, using 240 processors. Noah and CLSM were run with a 15-minute timestep, and VIC was run with a 1-hour timestep. VIC is slower in winter due to frozen soil calculations.

LIS-NLDAS routing status

- LIS is configured (in the NLDAS domain) to be able to run either the NLDAS router or the HyMAP router (Getirana et al., 2012, 2013)

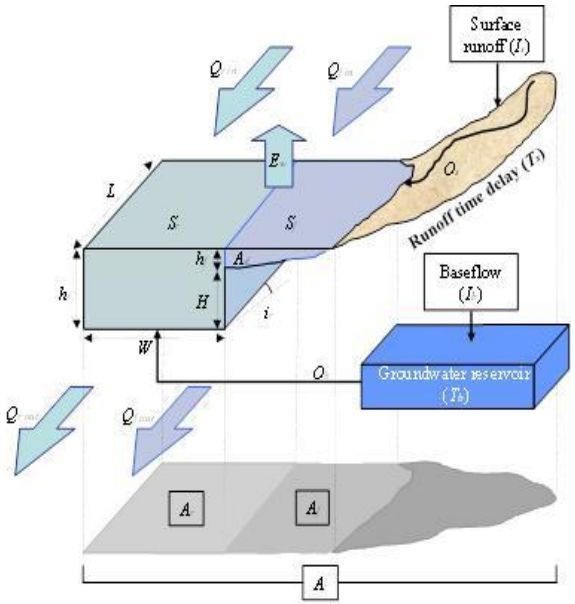
The Hydrological Modeling and Analysis Platform (HyMAP):

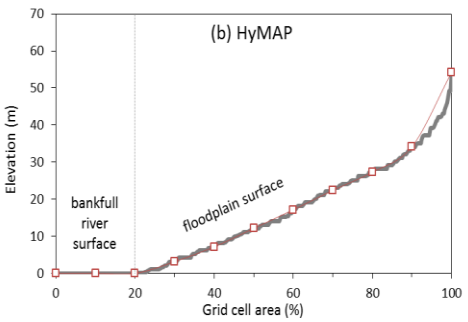
- Global scale;
- Adjustable spatial and temporal resolutions;
- Composed of four modules accounting for:

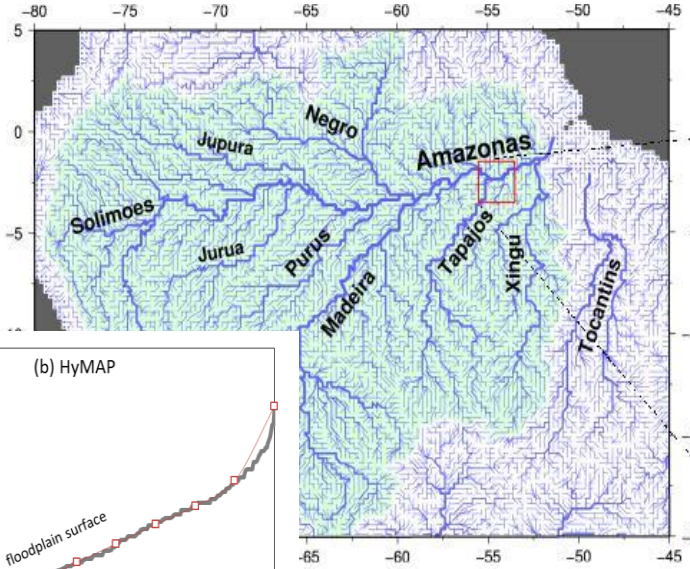
(1) surface runoff and baseflow time delays;
(2) a river-floodplain interface;
(3) flow routing in river channels and floodplains; and
(4) evaporation from open water surfaces

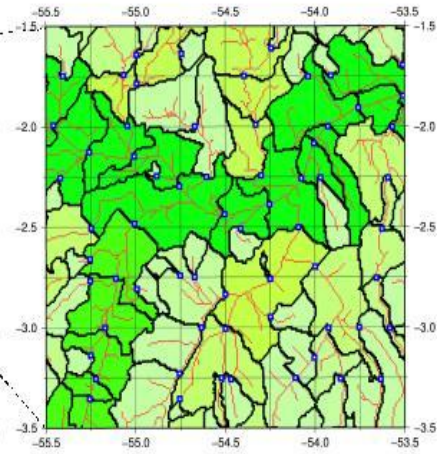
Model outputs:

- **Water volume** stored in rivers and floodplains;
- **Water depth** of rivers and floodplains;
- **Streamflows** in rivers and floodplains;
- **Flow velocity** in rivers and floodplains;
- **Flooded area**;
- **Evaporation** from open water surfaces.



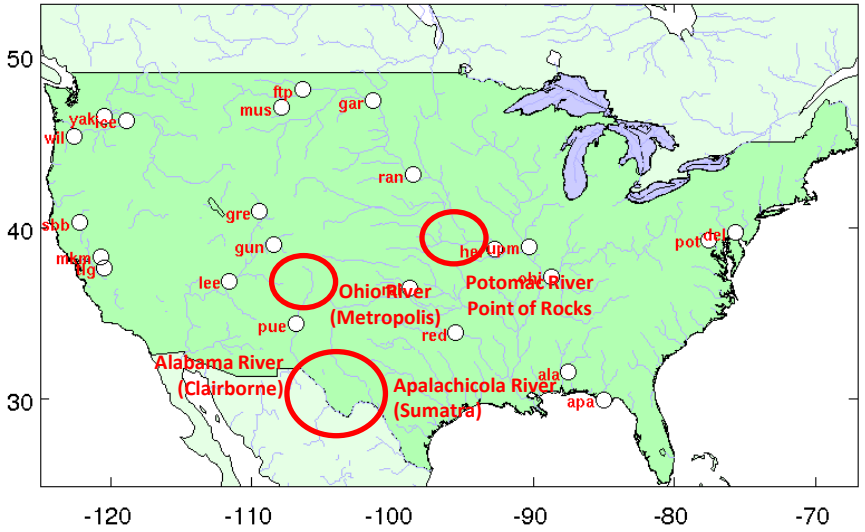


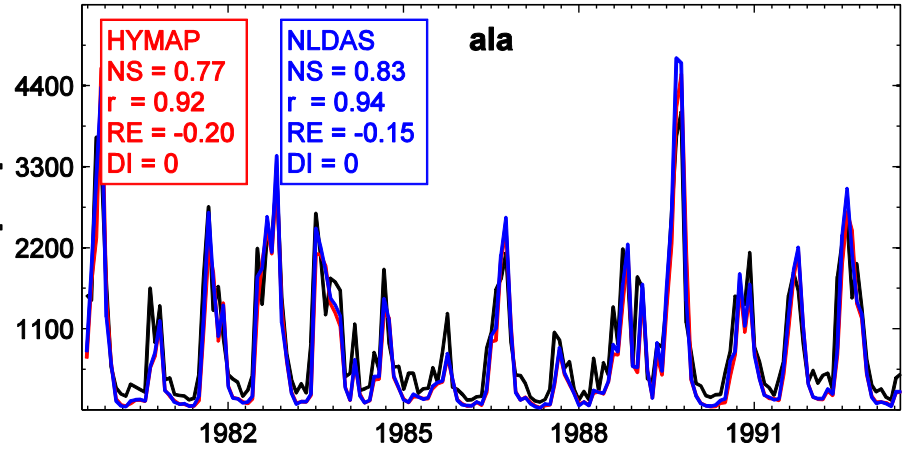


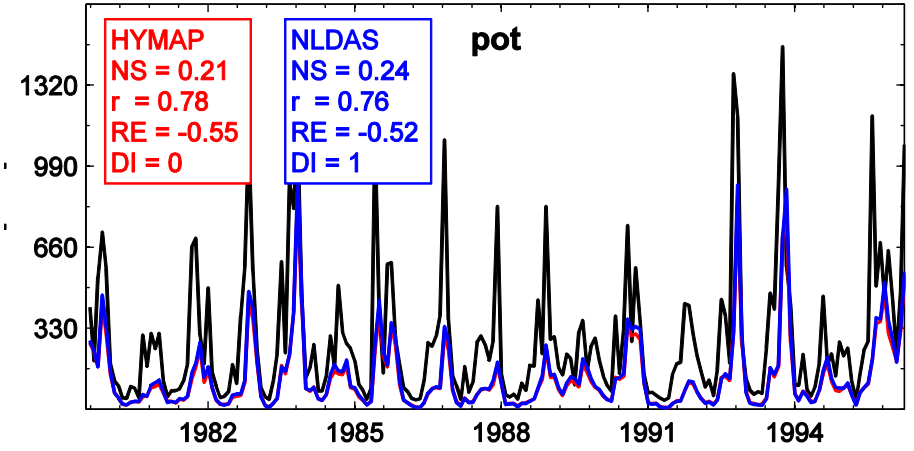


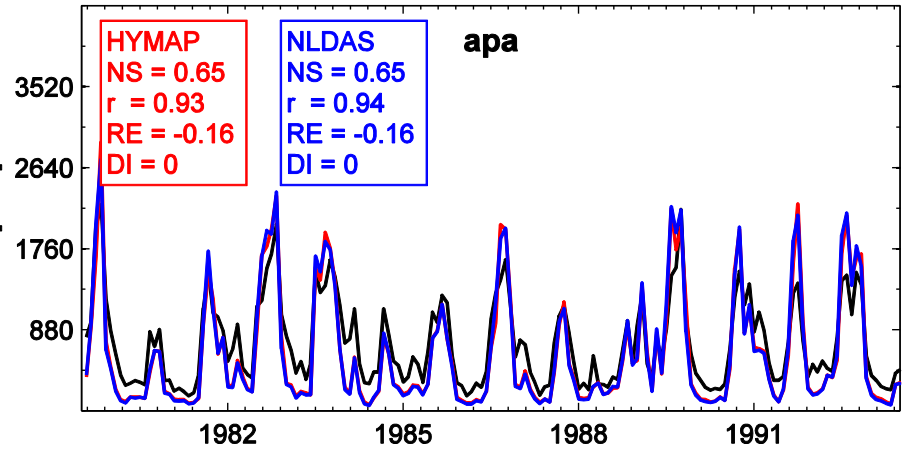
Noah-3.3 + NLDAS

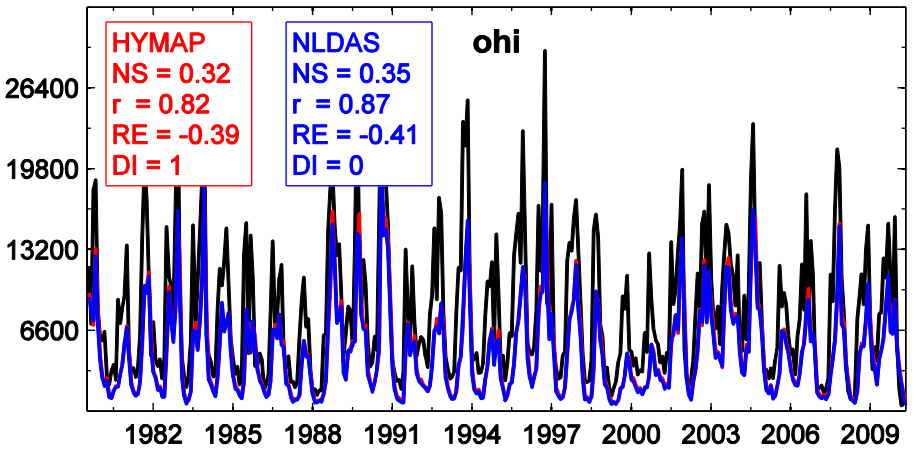
HyMAP router compared against NLDAS router



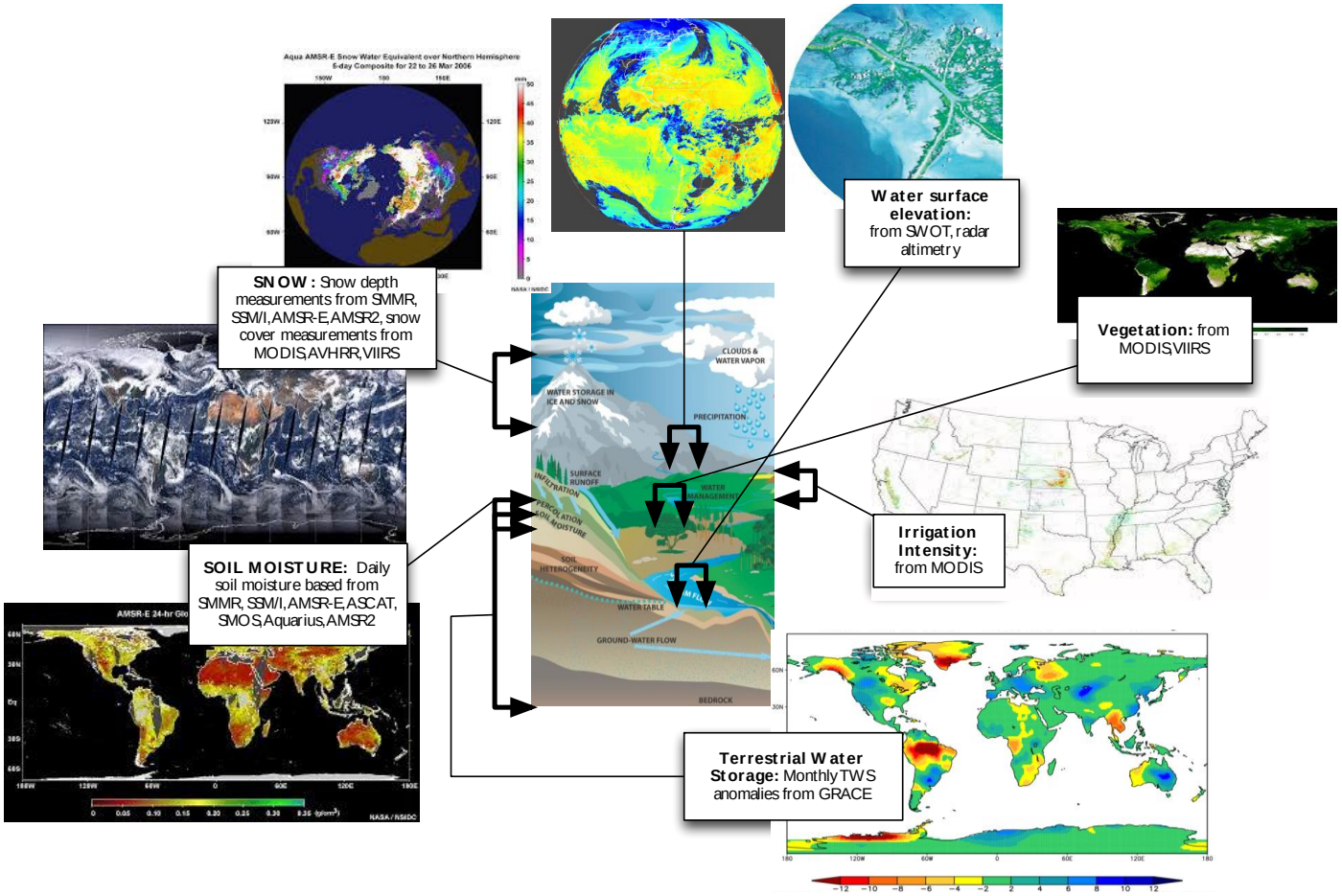








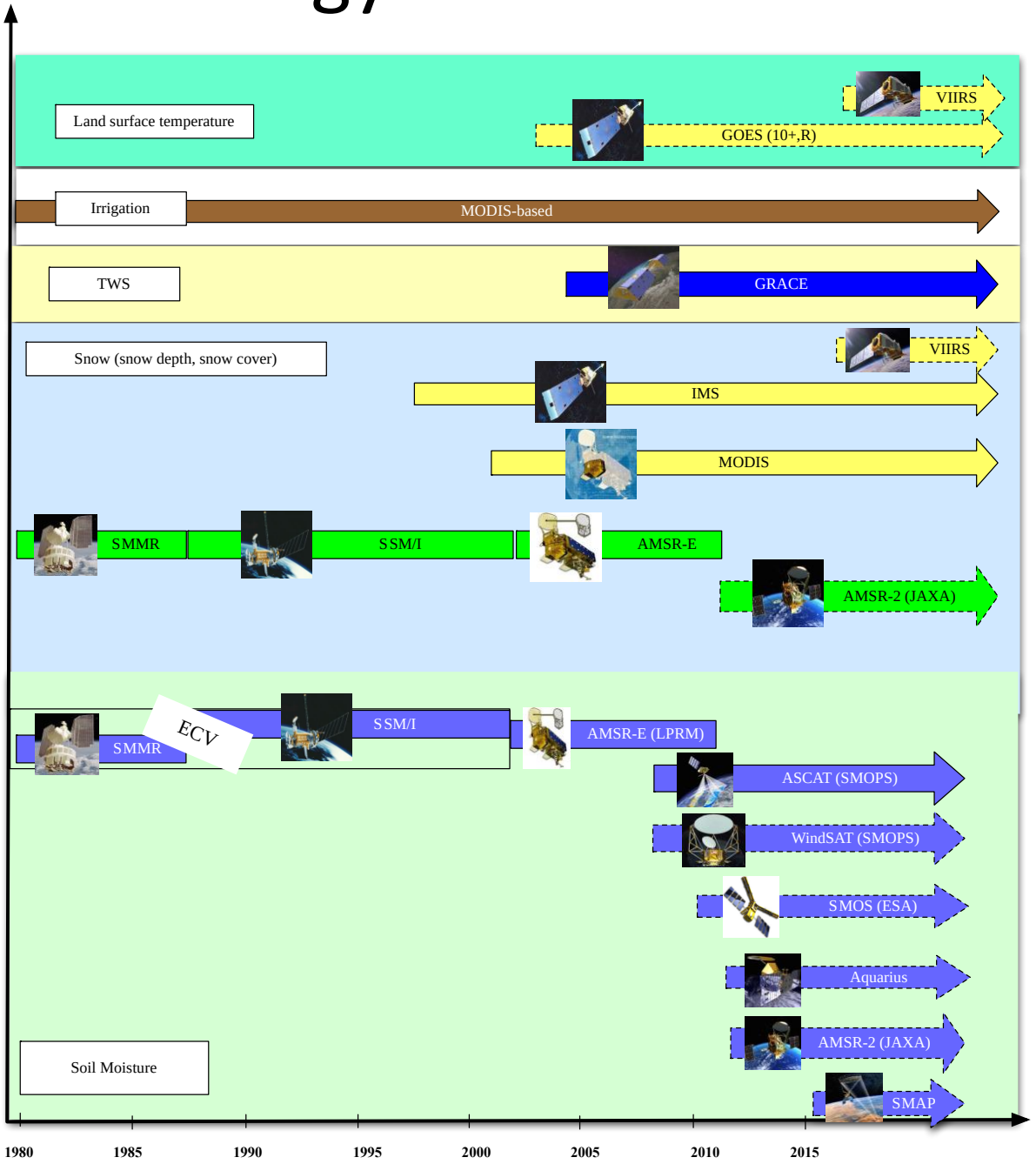
Vision for data assimilation within NLDAS



NLDAS to-date, has not included the assimilation of remote sensing datasets. The focus of the new phase of NLDAS is to enable the "DA" in NLDAS.

As part of this new phase of NLDAS, we examine the assimilation of various terrestrial hydrological datasets, from 1979 onwards

Chronology of land remote sensing datasets



Data assimilation method: 1-d Ensemble Kalman Filter (EnKF) and 3-d Ensemble Kalman Smoother (EnKS)

Time period: Jan 1, 1979 to 1 Jan 2013.

All simulations performed using the **NASA Land Information System (LIS; http://lis.gsfc.nasa.gov)**

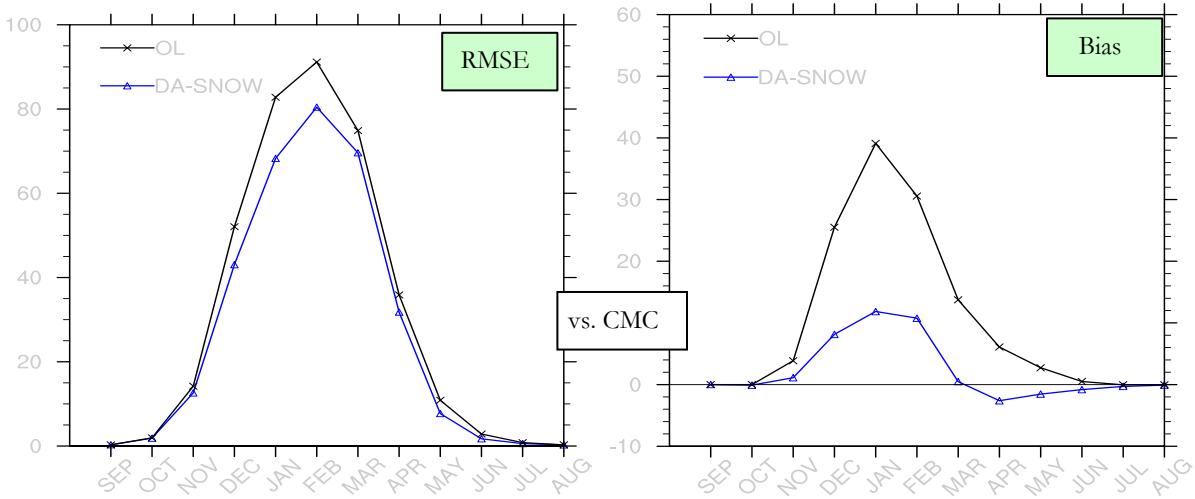
Univariate assimilation: soil moisture and snow depth

A recent study examined the **individual** assimilation of soil moisture (ECV, LPRM) and snow (SMMR, SSMI, AMSR-E) data sets, into the Noah LSM (Kumar et al., JHM 2014).

The open loop soil moisture skills are high and assimilation improvements in soil moisture were small and barely at the statistically significant levels.

The assimilation of snow depth datasets were found to generally improve the snow fields.

ARS CalVal (surface soil moisture)	**Open Loop (no DA)**	**DA-SM**
Anomaly R	0.84 +/- 0.02	**0.86 +/- 0.02**
SCAN (surface soil moisture)	**Open Loop (no DA)**	**DA-SM**
Anomaly R	0.67 +/- 0.02	0.67 +/- 0.02
SCAN (root zone soil moisture)	**Open Loop (no DA)**	**DA-SM**
Anomaly R	0.60 +/- 0.02	0.59 +/- 0.02



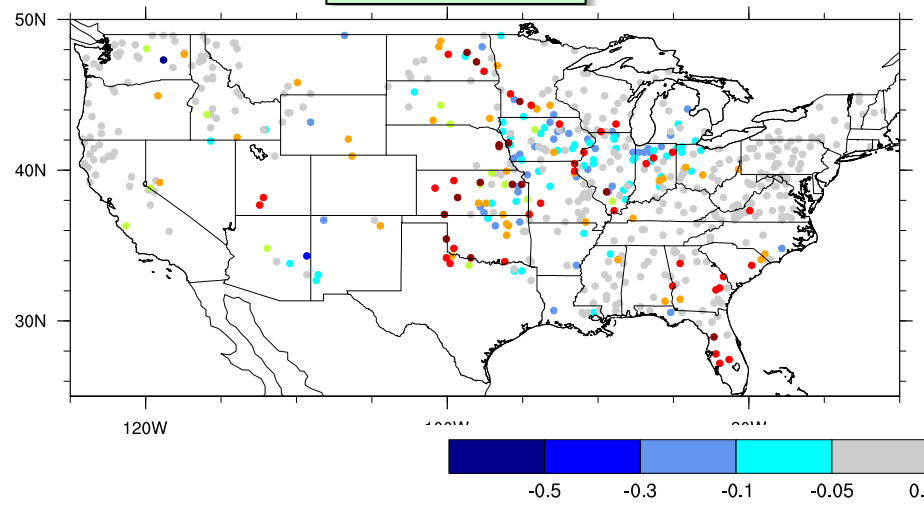
Kumar, S.V., C.D. Peters-Lidard, D. Mocko, R. Reichle, Y. Liu, K.A. Arsenault, Y. Xia, M. Ek, G. Riggs, B. Livneh, M. Cosh (2014), "Assimilation of remotely sensed soil moisture and snow depth retrievals for drought estimation" *Journal of Hydrometeorology*, 15, 2446-2469.

Evaluation of streamflow

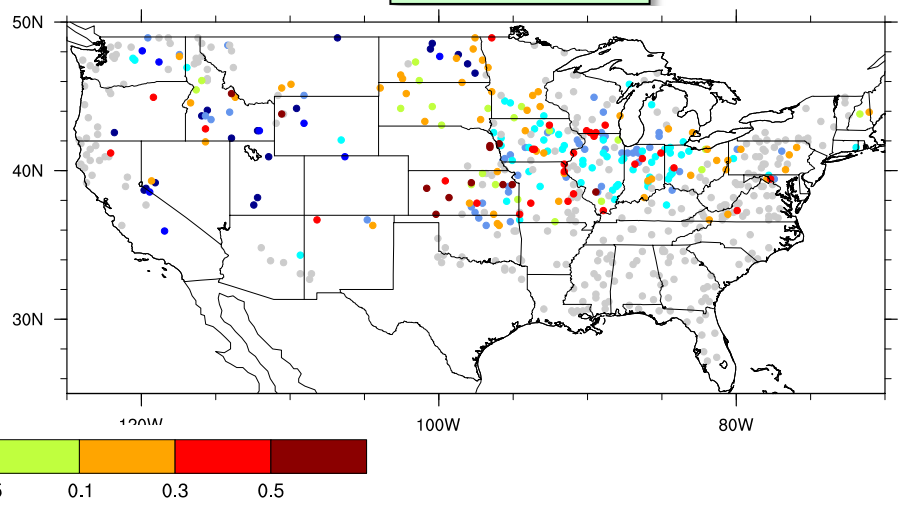
The improvements are expressed using an Normalized Information Contribution (NIC) metric that measures the skill improvement from DA as a fraction of the maximum possible skill improvement

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

DA-SM



DA-SNOW



Minor improvements 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.

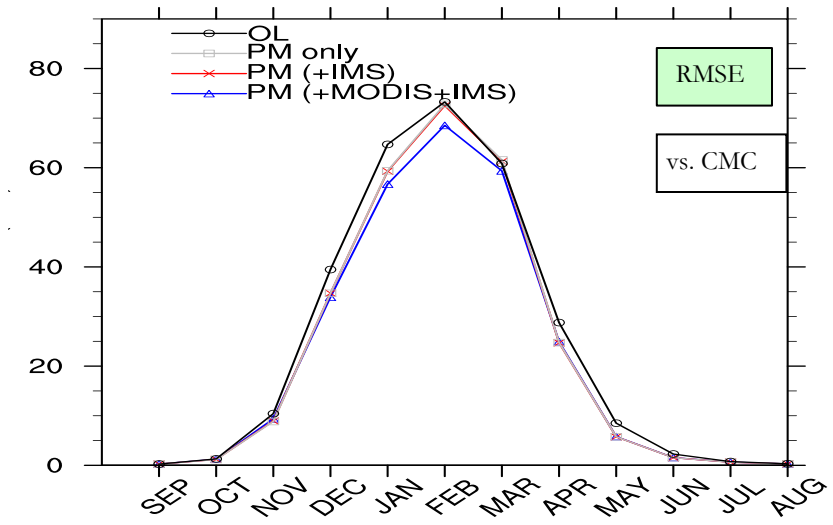
Added influence of snow cover measurements

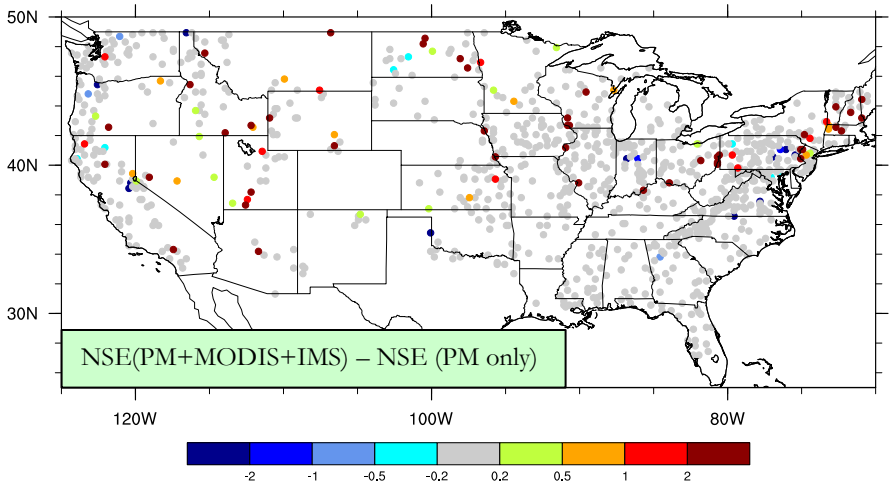
Snow DA approach was updated to use visible snow cover data (IMS/MODIS) as an added constraint.

SCA observations are used as the default for identifying the presence or absence of snow.

If SCA indicates no-snow, zero snow depth is assimilated. If SCA indicates non-zero snow and passive microwave data indicates no-snow, then snow depth data is not assimilated.

Non-zero snow depth from passive microwave data is assimilated only if SCA data also indicates non-zero snow.



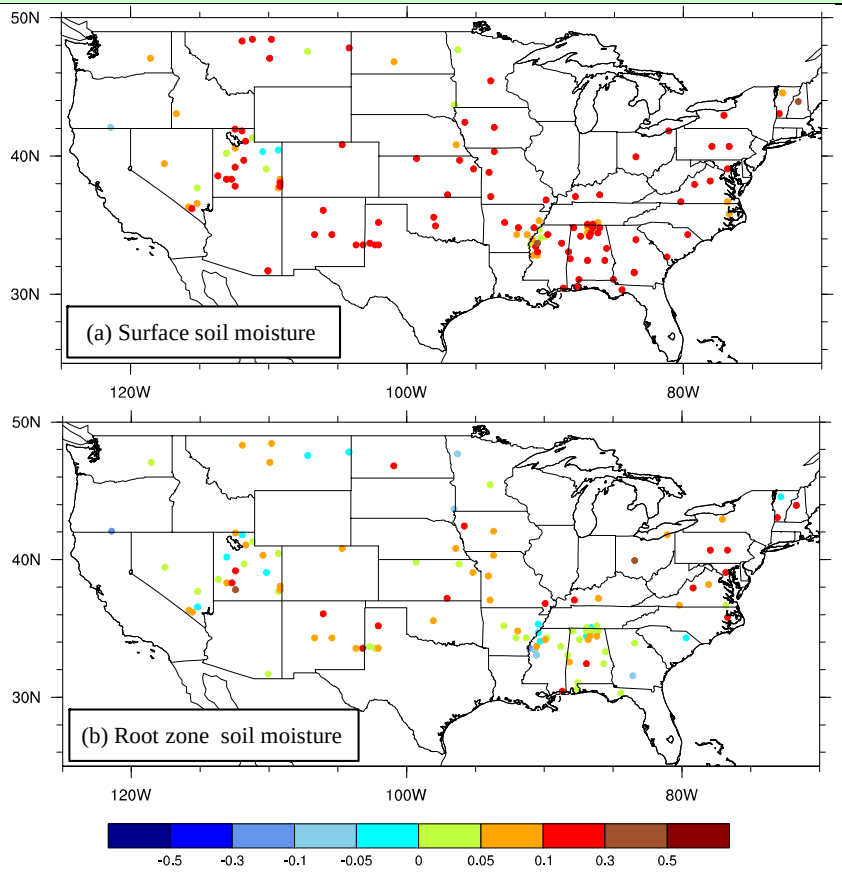


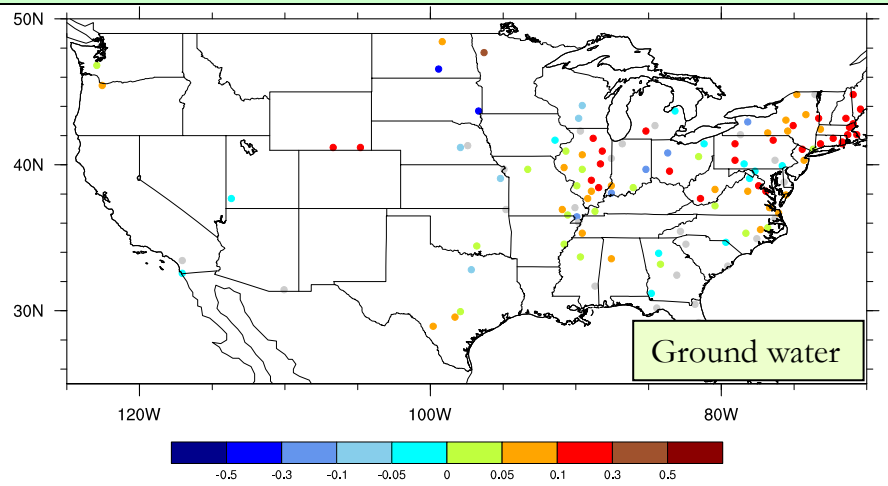
The use of SCA data is helpful in providing added improvements to the passive microwave snow data assimilation.

Kumar, S.V., C.D. Peters-Lidard, K. Arsenault, A. Getirana, D. Mocko, Y. Liu, (2015), Quantifying the added value of snow cover area observations in passive microwave snow depth data assimilation, Journal of Hydromet., *in revisions*

Assimilation (univariate) of GRACE data

Maps show Anomaly R differences – Anomaly R(DA) – Anomaly R (OL); Warm colors indicate improvements and cool colors indicate degradations.





Anomaly R	OL	DA-TWS
Ground water	0.64 +/- 0.02	**0.69 +/- 0.02**
Surface soil moisture	0.44+/- 0.02	**0.58 +/- 0.02**
Root zone soil moisture	0.48 +/- 0.02	**0.54 +/- 0.02**

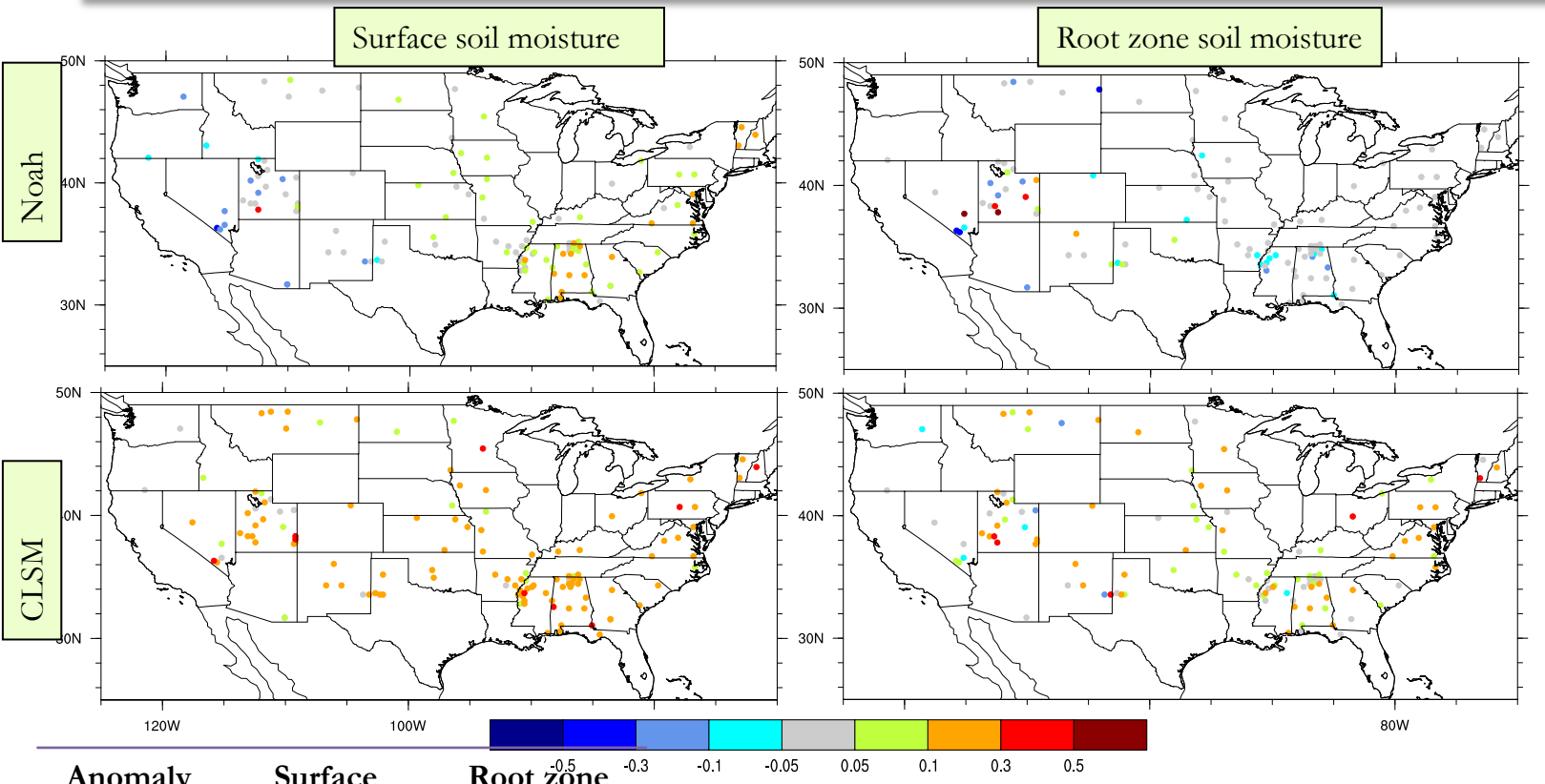
Statistically significant improvements in ground water and soil moisture fields from GRACE data assimilation

Kumar, S.V., B. F. Zaitchik, C.D. Peters-Lidard, M. Rodell, R. Reichle, B. Li, M. Jasinski, D. Mocko, A. Getirana (2015), Assimilation of gridded GRACE terrestrial water storage estimates in the North American Land Data Assimilation System (NLDAS), Water Resources Research, *submitted.*

Multivariate assimilation

Noah (soil moisture, snow depth, snow cover, irrigation)

CLSM (soil moisture, snow depth, snow cover, irrigation, terrestrial water storage)



Maps show Anomaly R differences – Anomaly R(DA) – Anomaly R (OL) (using SCAN data as reference) ; Warm colors indicate improvements and cool colors indicate degradations.

Anomaly R	Surface soil moisture	Root zone soil moisture
Noah OL	0.60	0.55
Noah DA	**0.65**	**0.55**
CLSM OL	0.43	0.48
CLSM DA	**0.61**	**0.58**

Noah – improvements in soil moisture fields are small, some degradation in the western locations observed

CLSM – more significant improvements in both surface and root zone fields

LIS-NLDAS plans

- Transfer LIS7 to Youlong and others at EMC
- Complete SAC-HTET parameters and Noah-MP (configuration TBD)
- NLDAS Benchmarking system using LVT
- Perform probabilistic drought analysis with LIS7-UE
- Add NCAR'S latest CLM model
- Test new satellite products/radiances for data assimilation (SMAP, IMS, AMSR-2, etc.)