Development of the next phase of NLDAS for improved drought monitoring and progress towards its operational transition

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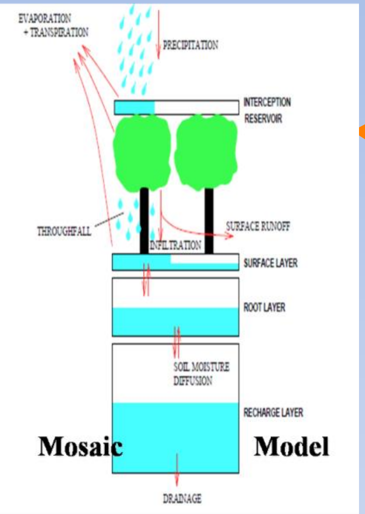
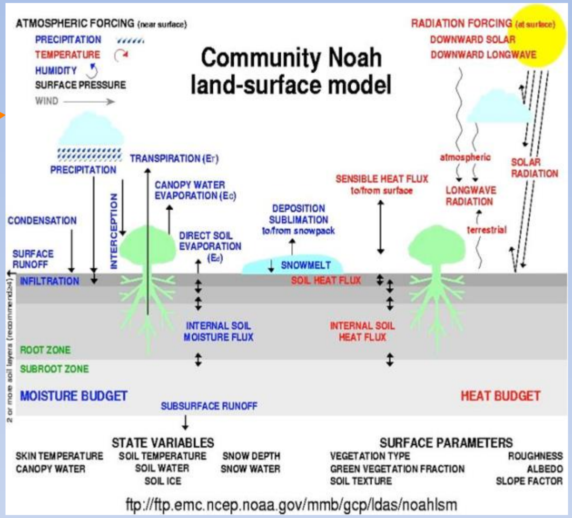
The **North American Land Data Assimilation System (NLDAS)** is a collaborative project between NOAA/NCEP and NASA/GSFC, and is supported by the NOAA Climate Program Office's Modeling Analysis, Predictions, and Projections (MAPP) Program.

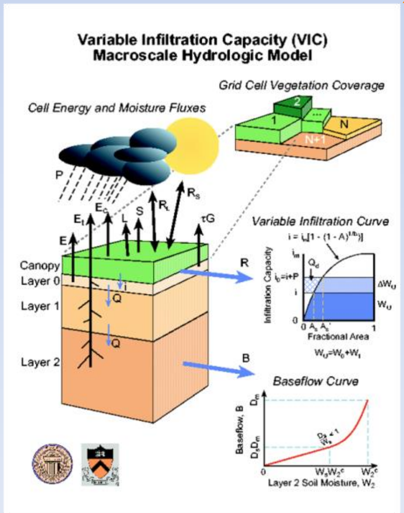
Collaboration between NOAA/NCEP/EMC and NASA/GSFC w/ other groups; it runs 4 LSMs (Noah, Mosaic, VIC, & SAC)



Mosaic (GSFC)

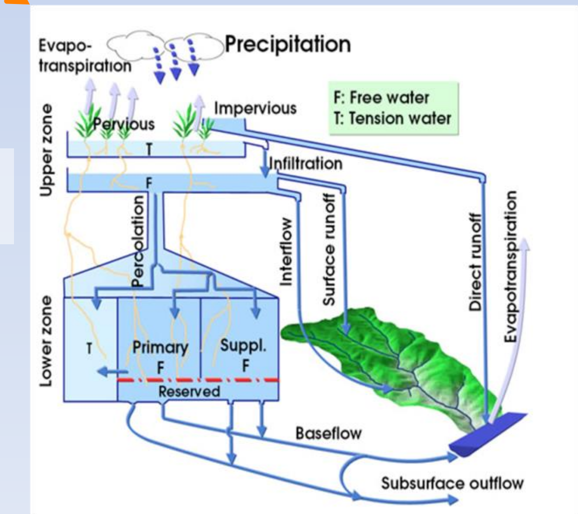
Noah (NCEP)





VIC (Princeton Univ. and Univ. of Washington)

SAC (OHD)



https://ldas.gsfc.nasa.gov/nldas/

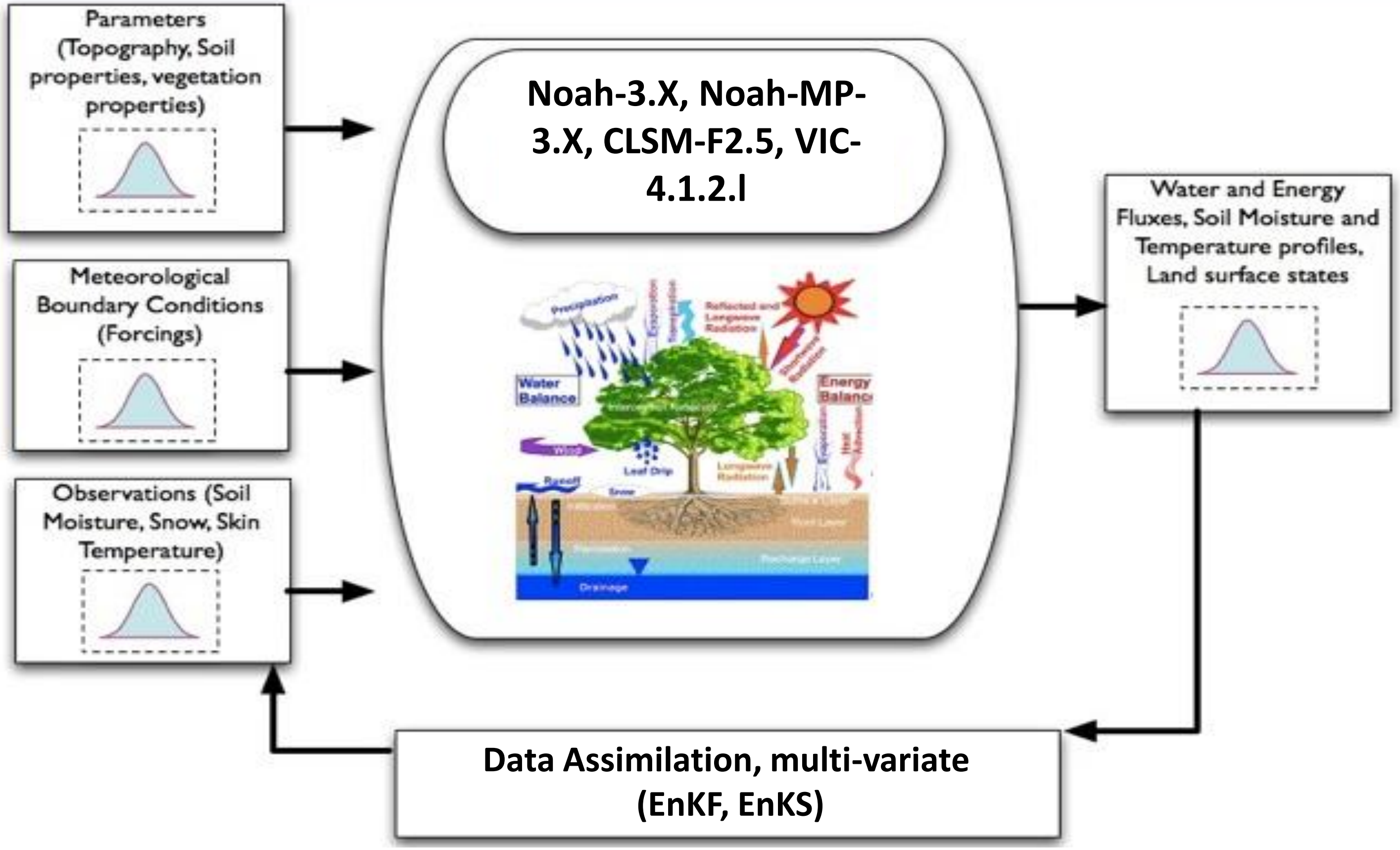
The next phase of NLDAS will use updated models and data assimilation using NASA’s Land Information System

LIS-based next phase of NLDAS

1979 – Present To be Updated w/ Larger Domain Forcings and Parameters at finer-scale

Satellite EDRs*

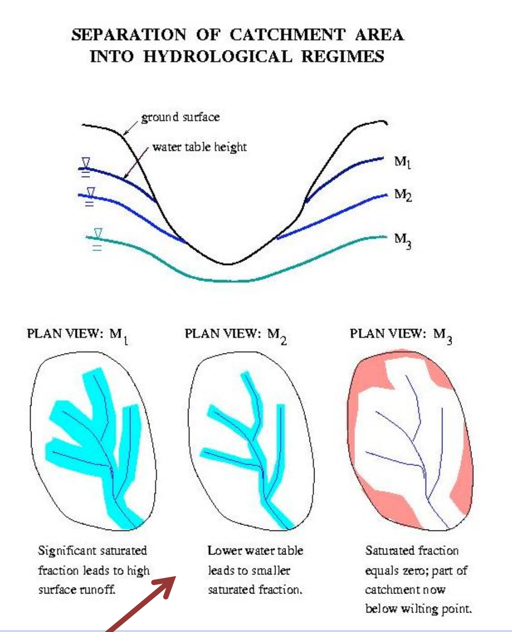
SM, SCA, SWE, TWS, and II



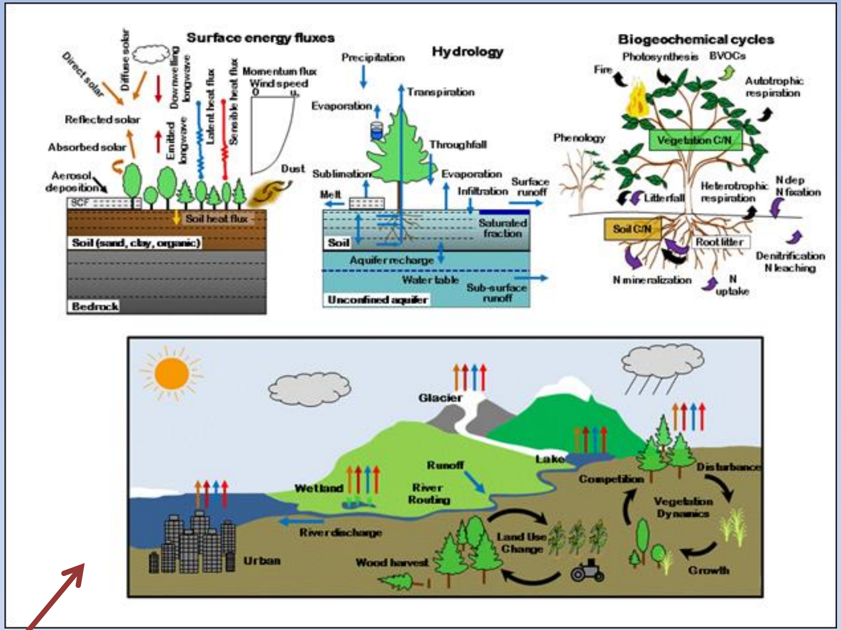
* Satellite-based Environmental Data Records (EDRs): soil moisture (SM), snow-covered area (SCA), snow water equivalent (SWE), terrestrial water storage (TWS), & irrigation intensity (II)

The **Land Information System (LIS)** is a flexible land-surface modeling and data assimilation framework developed with the goal of integrating satellite- and ground-based observed data products with land-surface models.

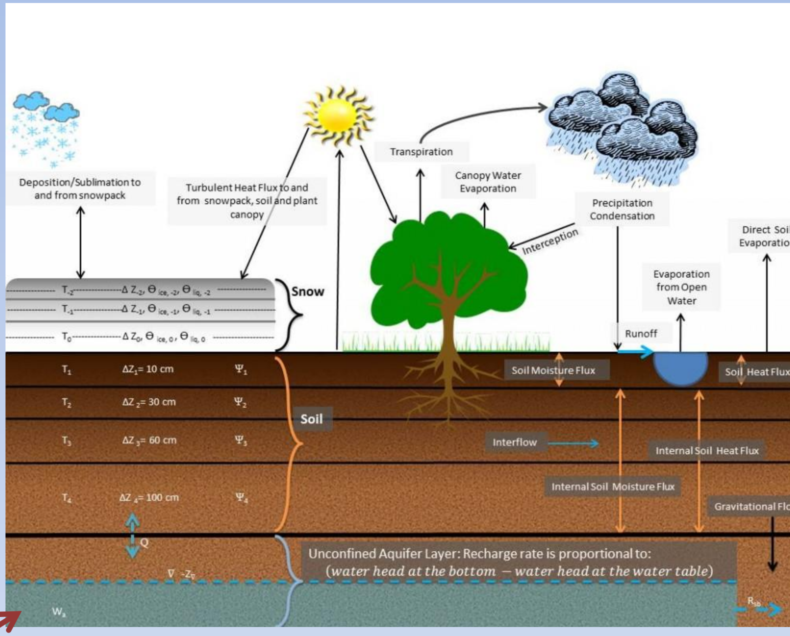
NASA's Catchment LSM as well as CLM are being added, with the other LSMs being upgraded to their latest versions



Catchment LSM (CLSM) is developed by NASA/GMAO, and is the land-surface component of the NASA GEOS-5 GCM.



Community Land Model (CLM-4.5) is maintained by NCAR, and is the land-surface model for the Community Earth System Model (CESM).

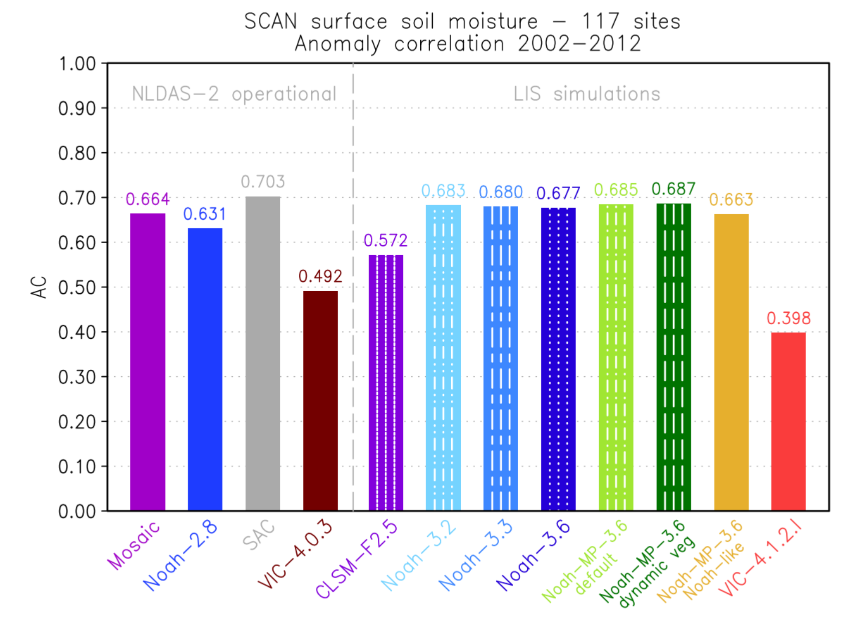


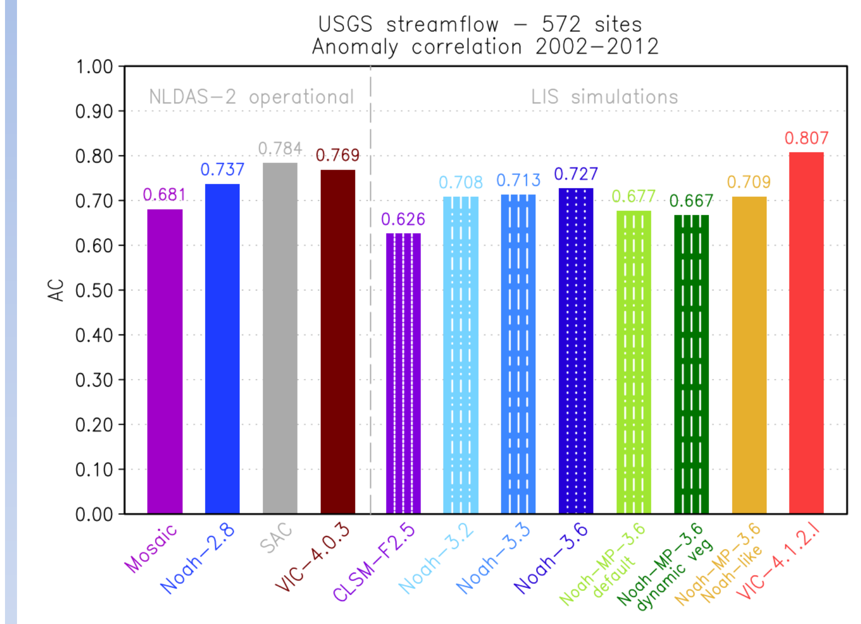
Noah-MP-3.6 is a LSM option within WRF, with Multiple Physics options, including dynamic vegetation & groundwater modules.

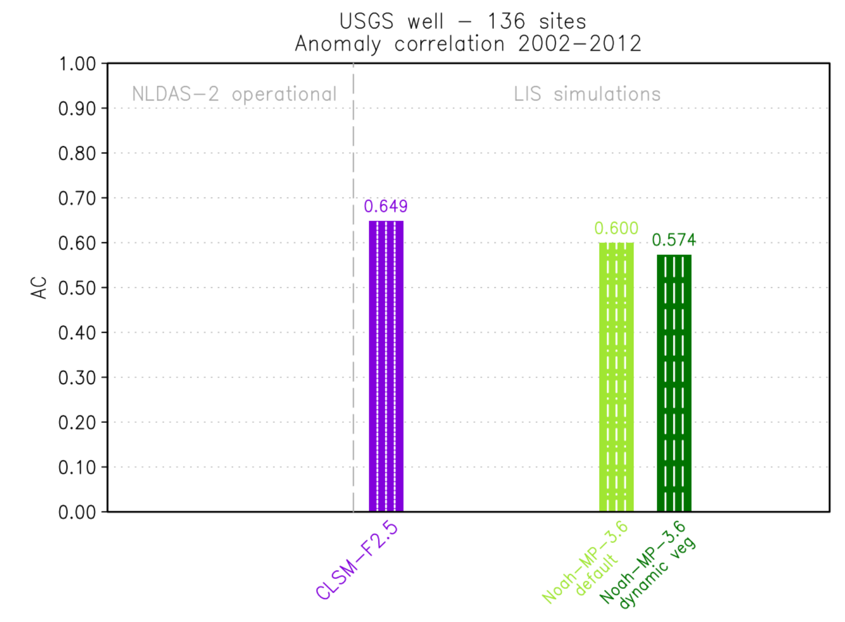
VIC-4.1.2.l, Noah-3.6, RUC, & other LSMs are also in LIS and contain numerous upgrades.

NLDAS Science Testbed evaluation

The new and upgraded LSMs for the next phase of NLDAS have been run using the LIS software framework, and the new results and the NLDAS-2 operational LSMs have been evaluated against observations using the LVT software.





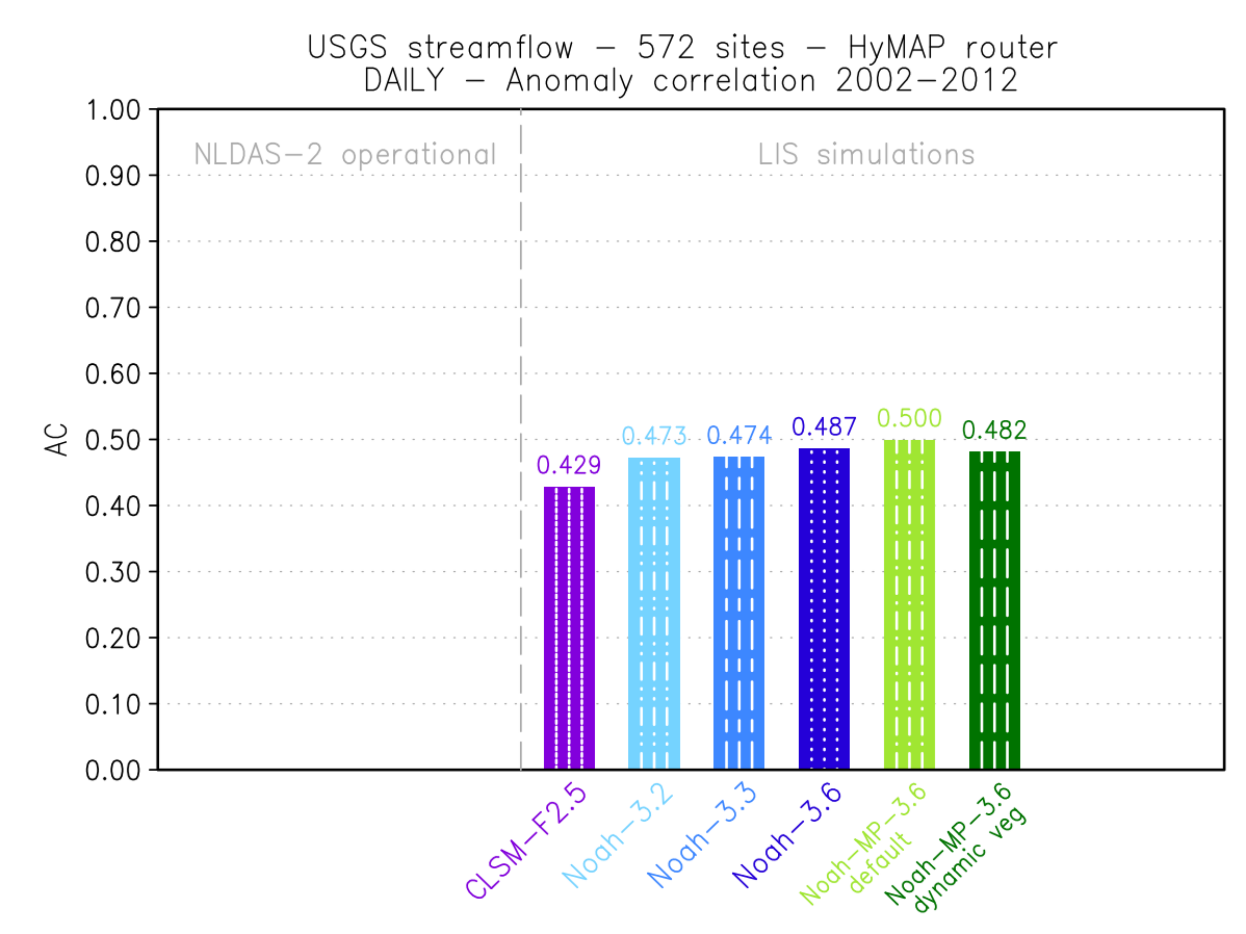


Surface soil moisture **Streamflow** **Groundwater**

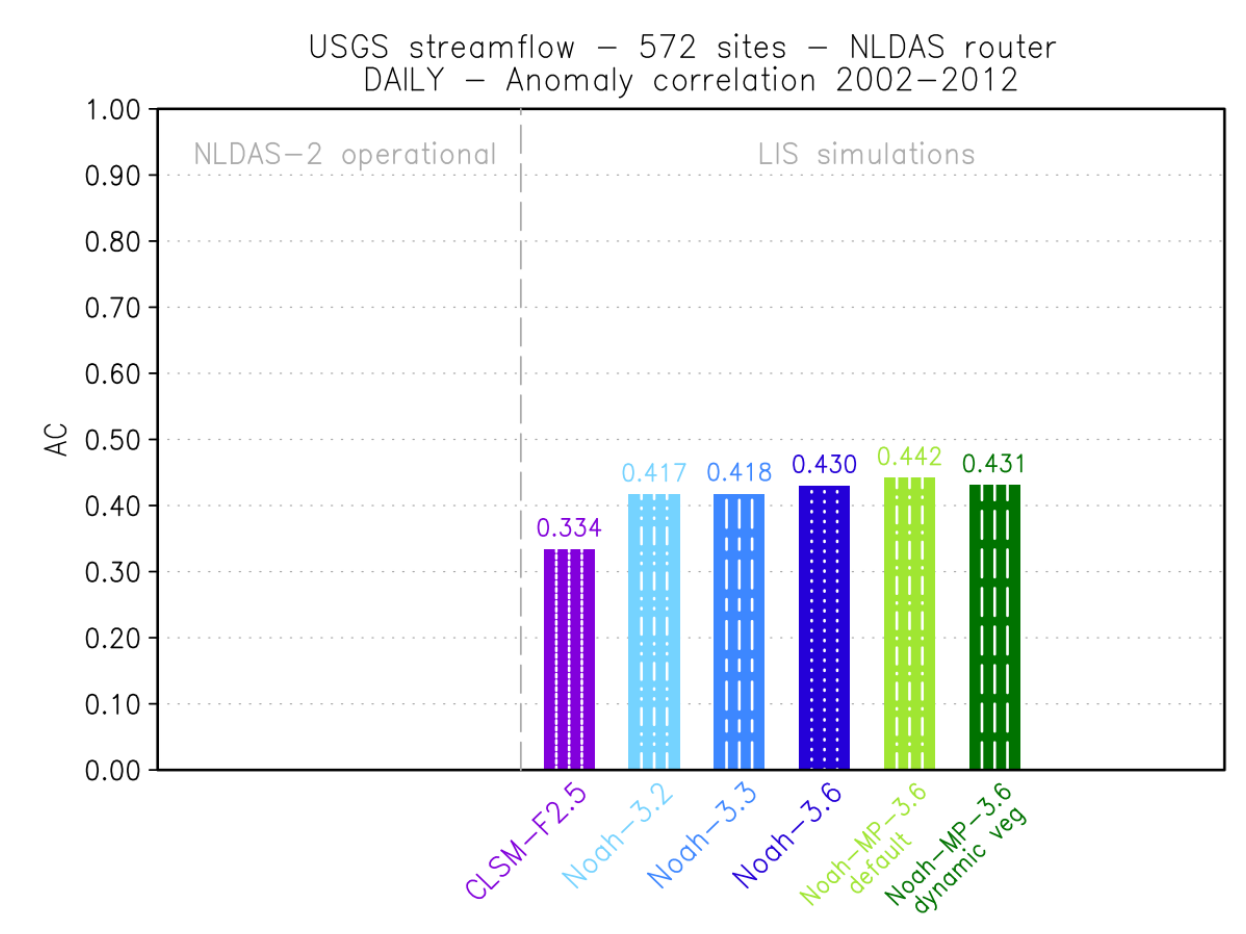
Anomaly correlations are shown for the 4 NLDAS-2 LSMs (left of the dashed line) and various instances/options of the LIS LSMs (right of the dashed line). Against 117 quality-controlled SCAN soil moisture sites (left panel), the new versions of Noah and Noah-MP are improved over NLDAS-2's Noah. For routed streamflow (middle) against USGS observations at 572 small, unregulated basins, the LSMs do well, particularly the new version of VIC. Groundwater anomaly correlation is shown (right) against 136 USGS well observations. Groundwater is not available in any of the NLDAS-2 LSMs, while two of the new LSMs in LIS calculate groundwater. Fluxes, snow, TWS are also in evaluation.

New HyMAP router in LIS shows improvements

Both the HyMAP router (Getirana et al., 2012) and the NLDAS router (Lohmann et al., 2004) are included within LIS. However, the NLDAS router is tied to the current NLDAS grid, while HyMAP supports finer-scale and global domains. Also, HyMAP provides river depth as well as discharge, considers floodplains among many other physics upgrades.



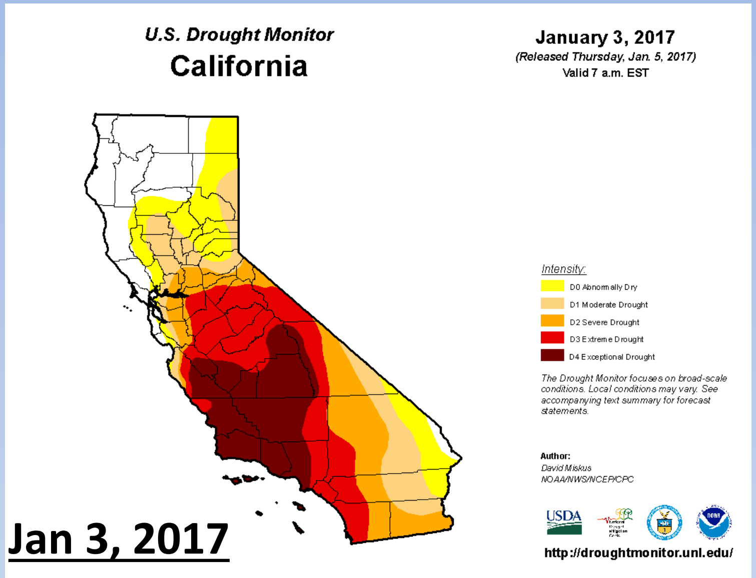
LEFT) Experiments with HyMAP router

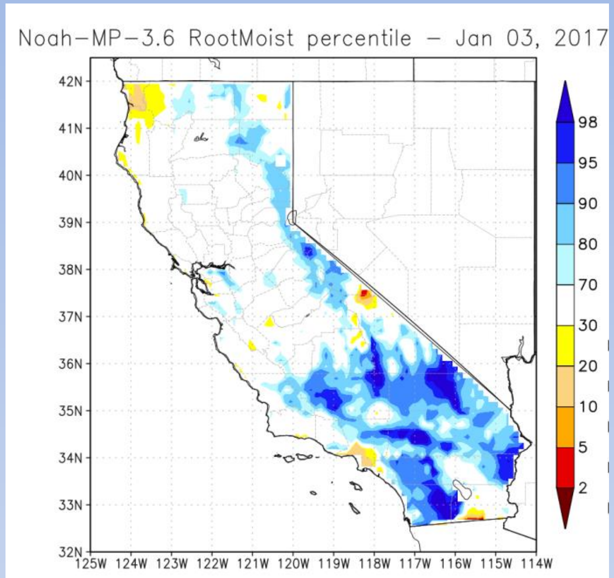


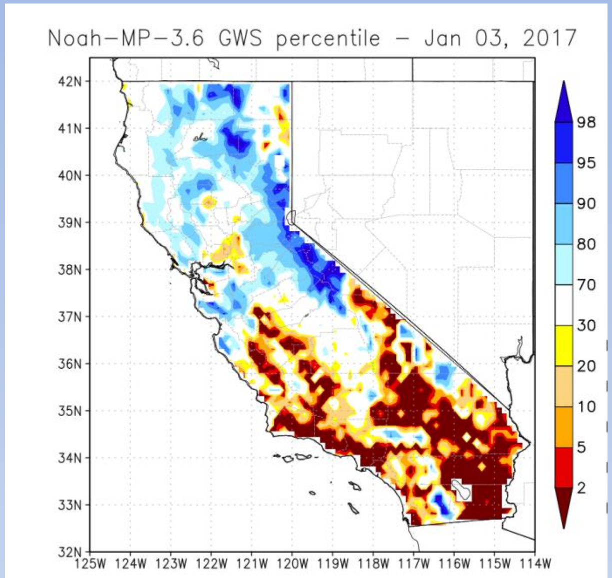
RIGHT) Experiments with NLDAS router

California winter drought reduction 2016-2017

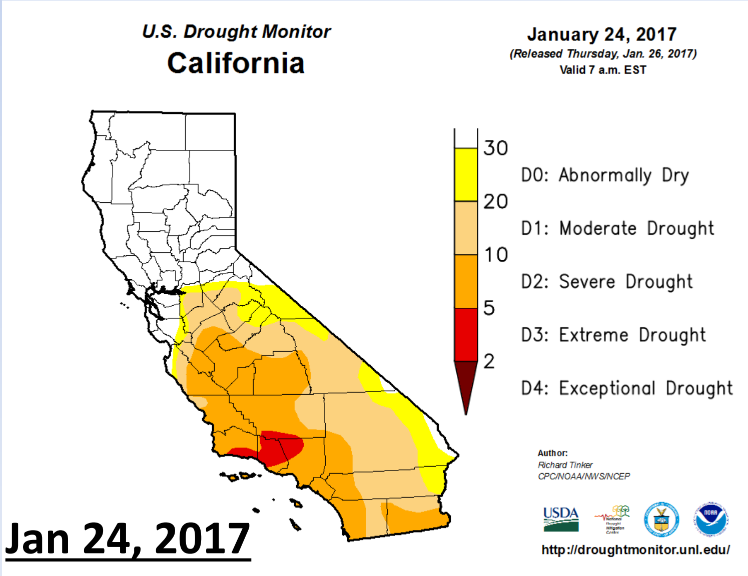
Comparisons to the U.S. Drought Monitor on Jan 3 and Jan 24, 2017 are shown. The percentiles of groundwater from Noah-MP in LIS show dryness despite many winter storms. The USDM noted the dry groundwater well observations in many areas of Southern California in issuing the USDM maps for these dates. The root zone soil moisture percentiles do not tell the entire story.

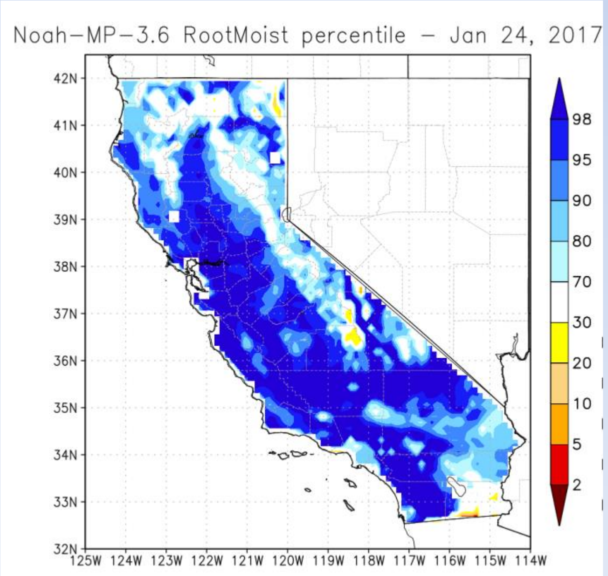


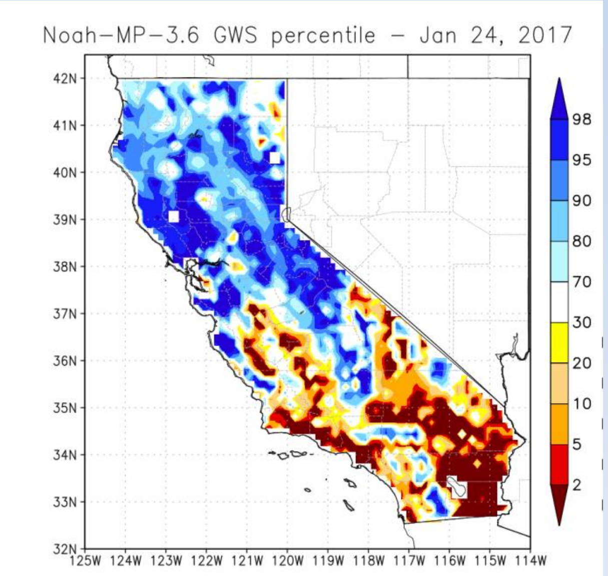




U.S. Drought Monitor **LIS Noah-MP Top 1-m soil moisture**



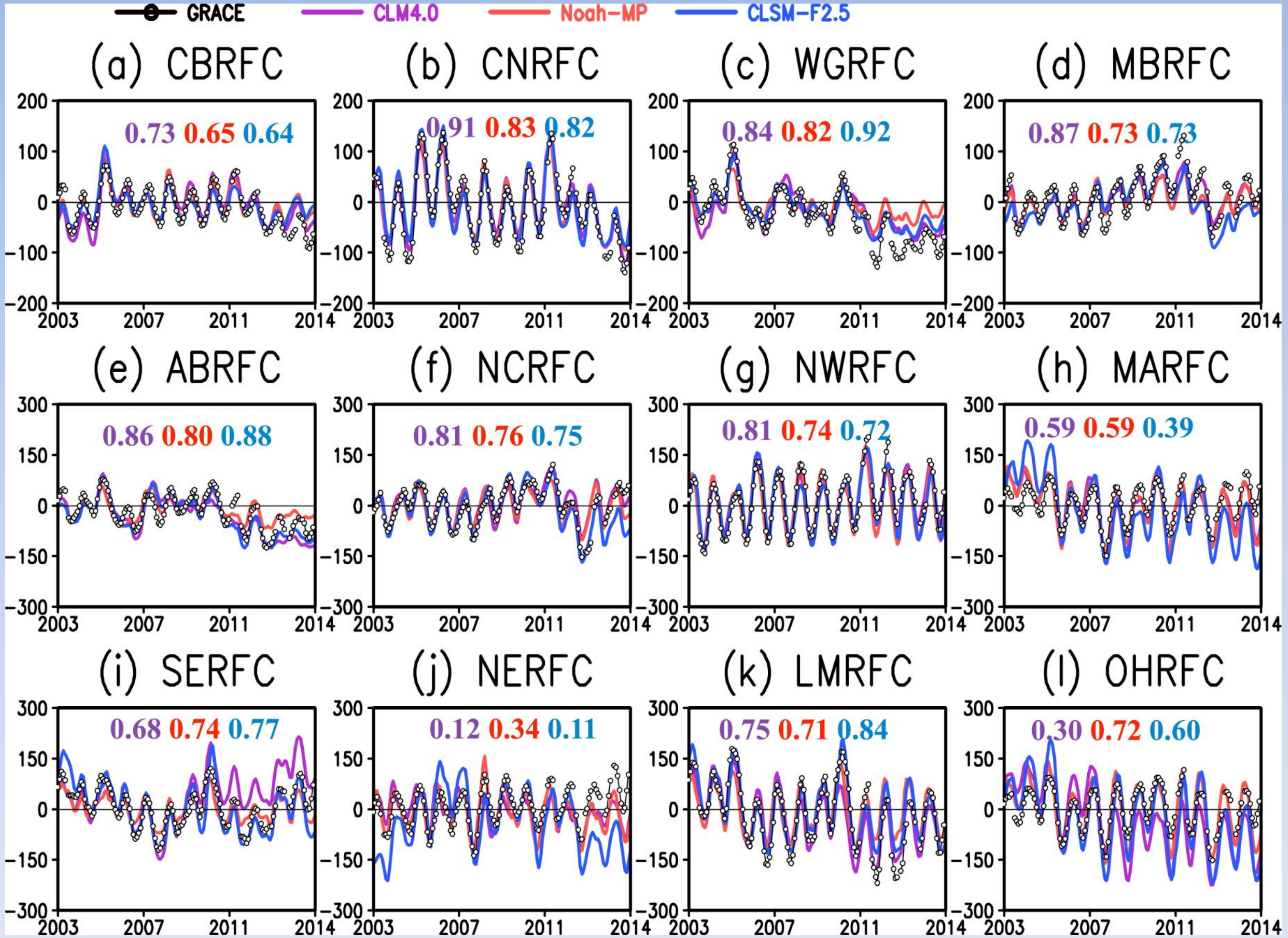




Comparison of TWS against GRACE observations

Noah-MP-3.6 and CLSM-F2.5 within LIS were evaluated for various terrestrial water storage (TWS) components (including groundwater) against CLM-4.0 LSM. This figure compares GRACE TWS anomalies for various River Forecast Centers (RFCs) in the NLDAS domain.

The CLM-4.5 LSM has been integrated into LIS and work is underway to run and evaluate it for the NLDAS Science Testbed.

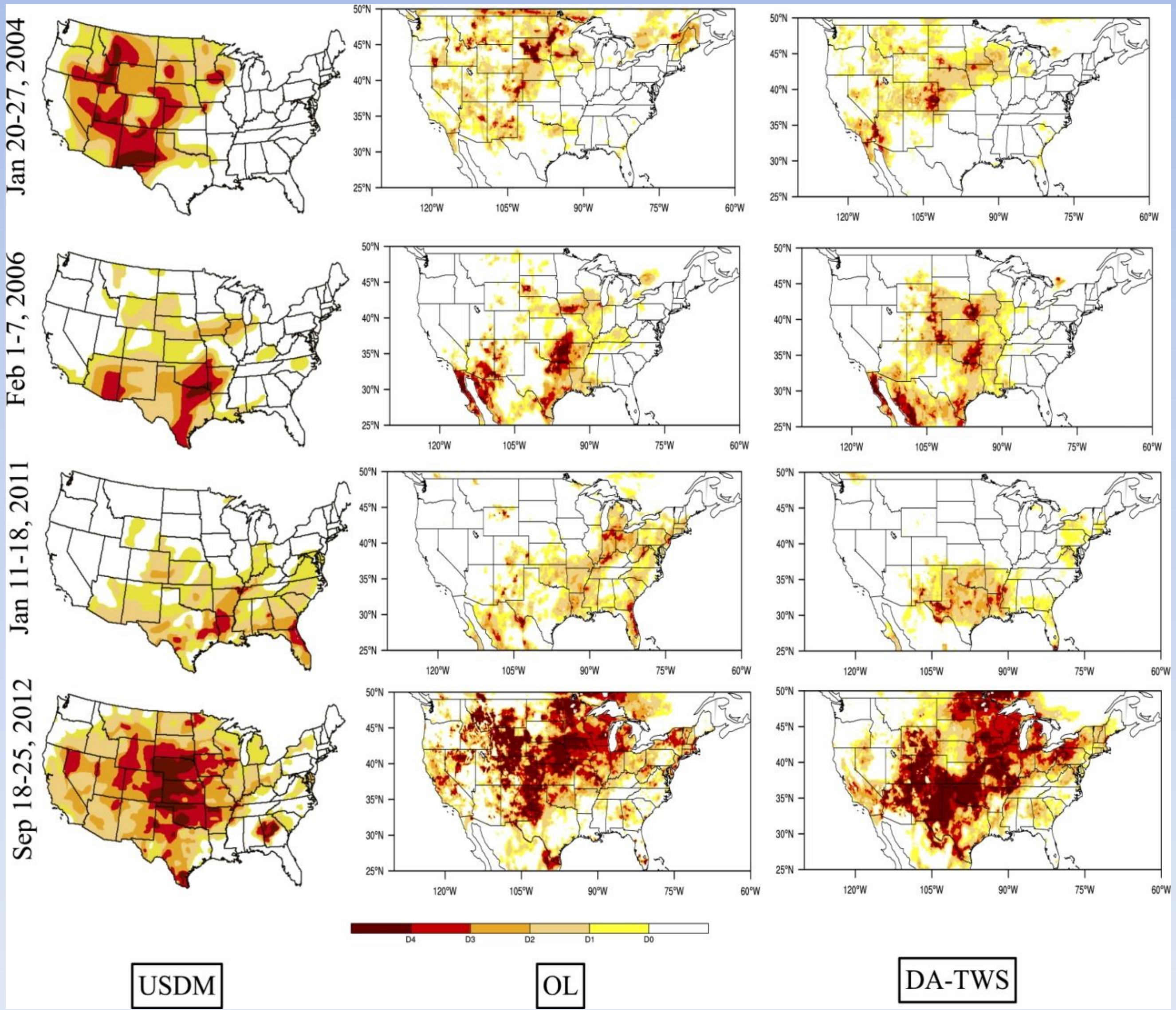


Xia, Mocko, Huang, Li, Rodell, Mitchell, Cai, and Ek, 2017: J. Hydrometeorology, doi:10.1175/jhm-d-16-0112.1

Data assimilation of GRACE terrestrial water storage anomalies can help with the depiction of drought

Comparison of the drought percentile maps from CLSM-F2.5 (center) without and (right) with assimilation of GRACE against (left) the corresponding U.S. Drought Monitor (USDM) estimate for four representative cases.

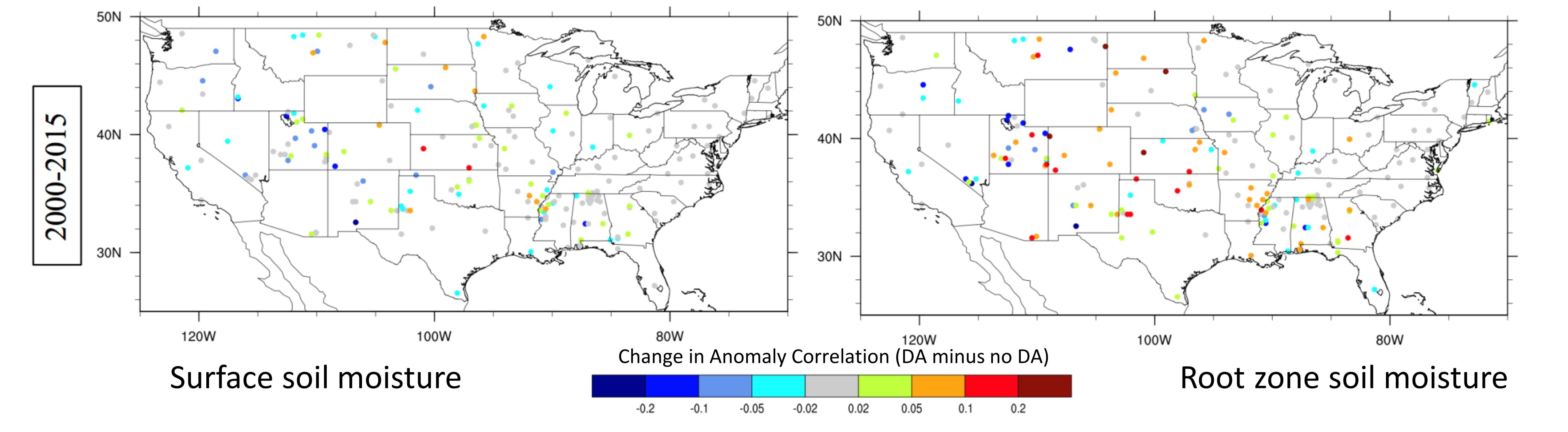
Evaluations against in situ observations also showed improvements in simulated groundwater and soil moisture.



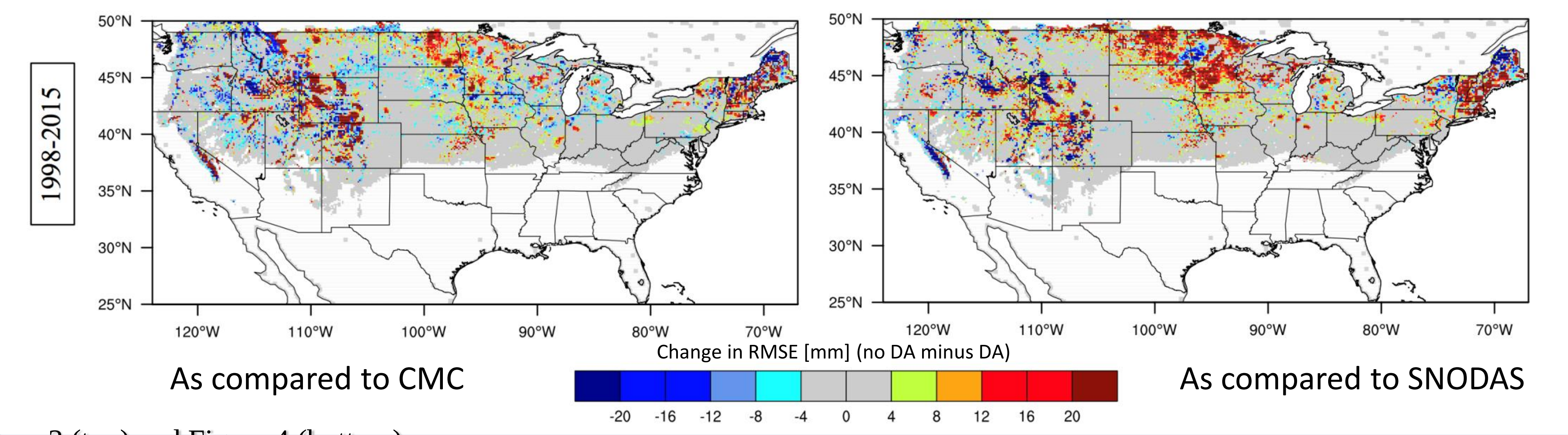
Kumar et al., 2016, JHM, Figure 12, doi:10.1175/jhm-d-15-0157.1

Multi-variate data assimilation of remotely-sensed snow and soil moisture improves modeled stats against obs.

- **Soil moisture** against USDA ARS, NRCS SCAN, and USCRN station network data (change in AC)



- **Snow depth** against CMC and SNODAS (change in [mm] of RMSE)

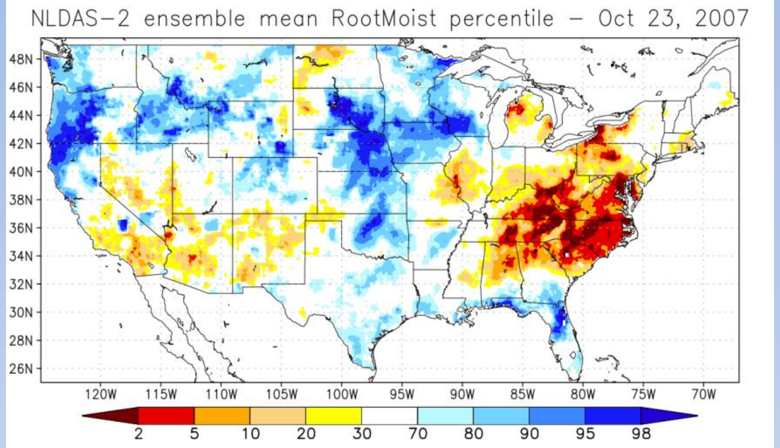


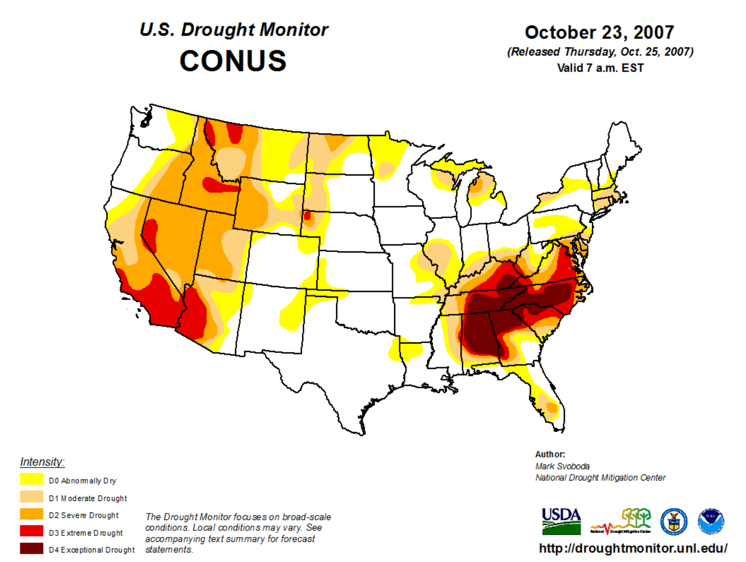
Warm = improvement
Cool = degradation

Kumar et al., 2017, submitted, Figure 3 (top) and Figure 4 (bottom)

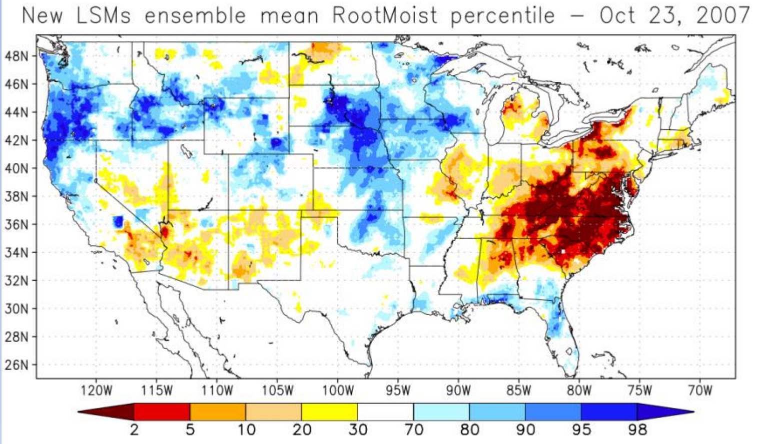
Oct 23, 2007 – Southeast Drought

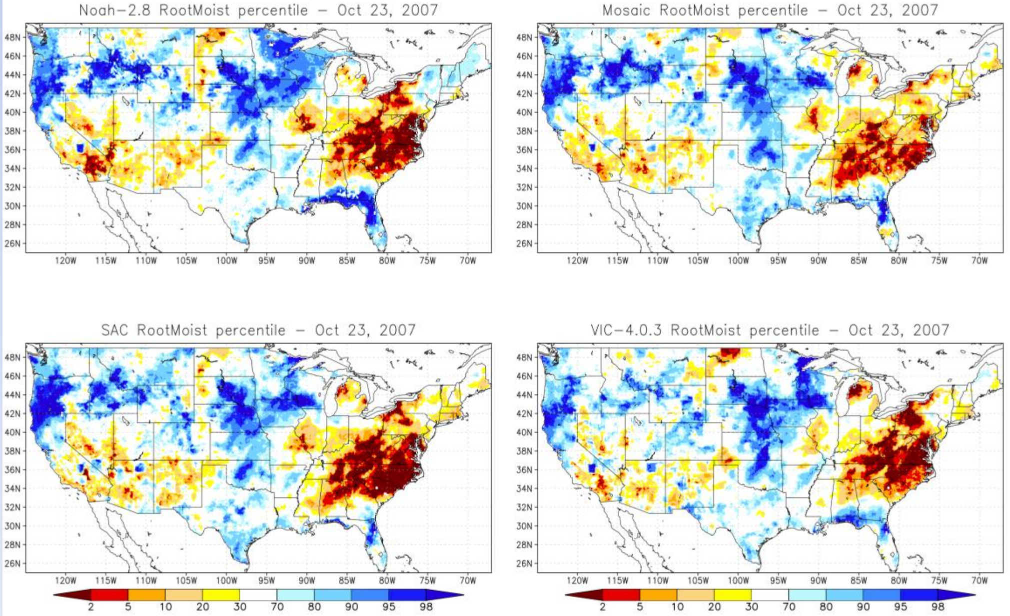
NLDAS-2 operational LSMs



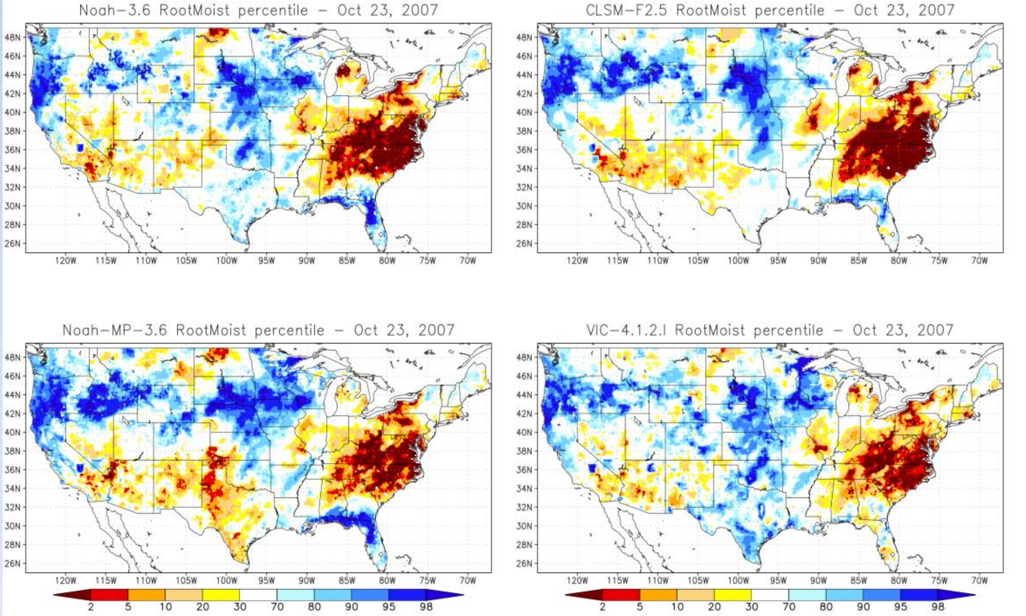


LIS LSMs for next phase





Top 1-meter soil moisture

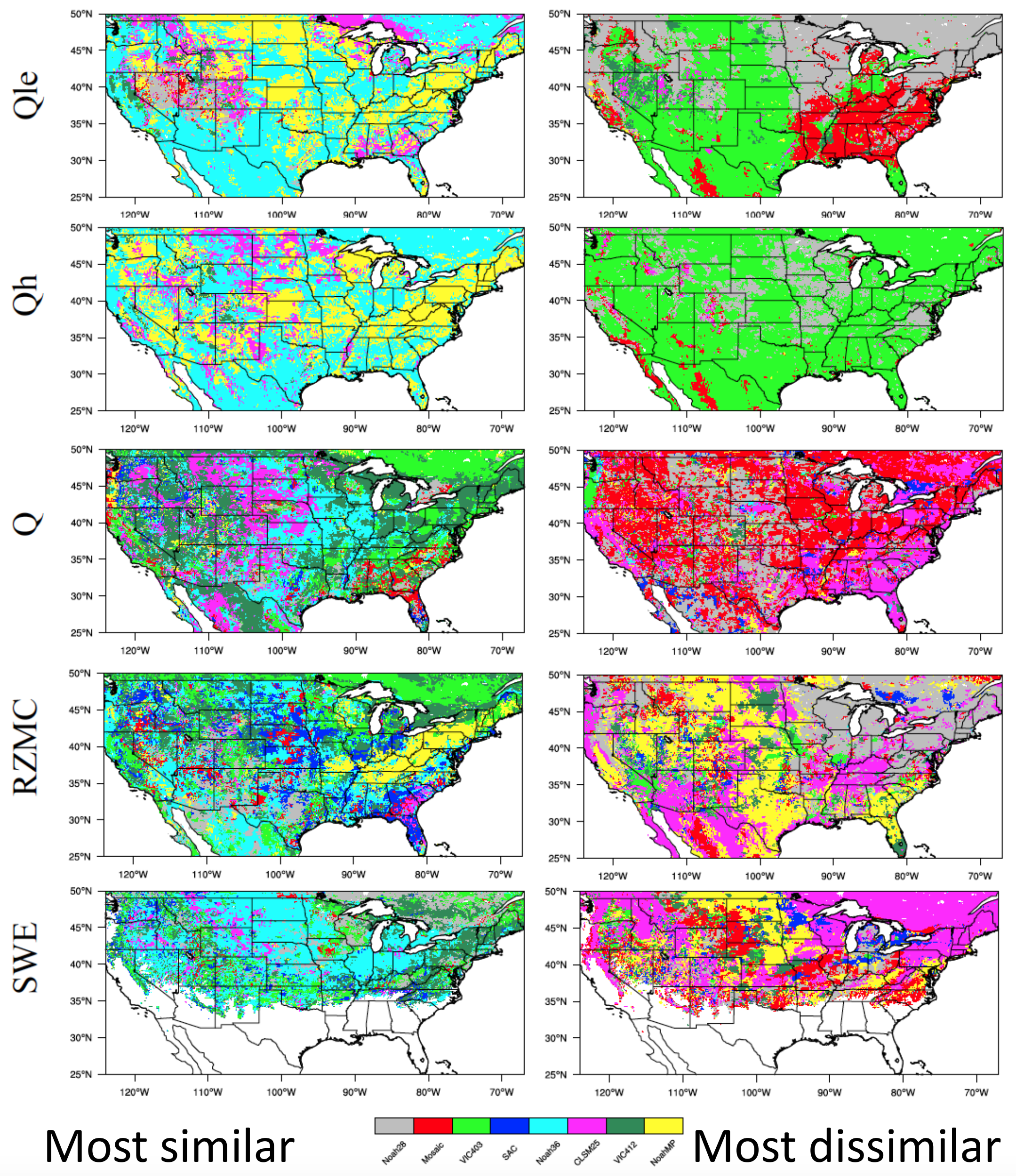


Similarity Assessment of new and old NLDAS LSMs

The 8 LSMs under evaluation (the 4 operational NLDAS-2 LSMs and 4 of the LIS LSMs) were included in a formal similarity assessment to assess their utility to the ensemble. The runoff estimates from the LSMs were shown to be most dissimilar, and the soil moisture shown to be the most similar.

The figure on the right show which of the 8 LSM is the most similar (left column) and the most dissimilar (right column) to the ensemble, for the latent (Qle) and sensible (Qh) heat fluxes, runoff (Q), root zone soil moisture (RZMD), and snow-water equivalent (SWE).

Kumar, Wang, Mocko, Peters-Lidard, and Xia:
WRR, revised version submitted



Most similar

Most dissimilar

Plans and timelines for new NLDAS phases

NOAA/NCEP/EMC and NASA/GSFC have written a **white paper** on the vision, requirements, and implementation of LDAS systems at NCEP. Here are some highlights w/r/t new NLDAS phases:

Phase	Highlights	Operational Date
NLDAS-2.5	• Close the 3.5-day latency gap to real-time • Same LSMs as NLDAS-2	~Fall 2017 to Spring 2018
NLDAS-3.0	• Running in NASA's LIS software framework • Upgrade Noah and VIC LSMs • Noah-MP replaces SAC • CLSM-F2.5 replaces Mosaic • Snow, soil moisture, GRACE data assimilation • HyMAP streamflow router • Irrigation scheme in MODIS-derived areas	~Fall 2018 to Spring 2019

How NLDAS-2.5 closes the 3.5-day latency gap

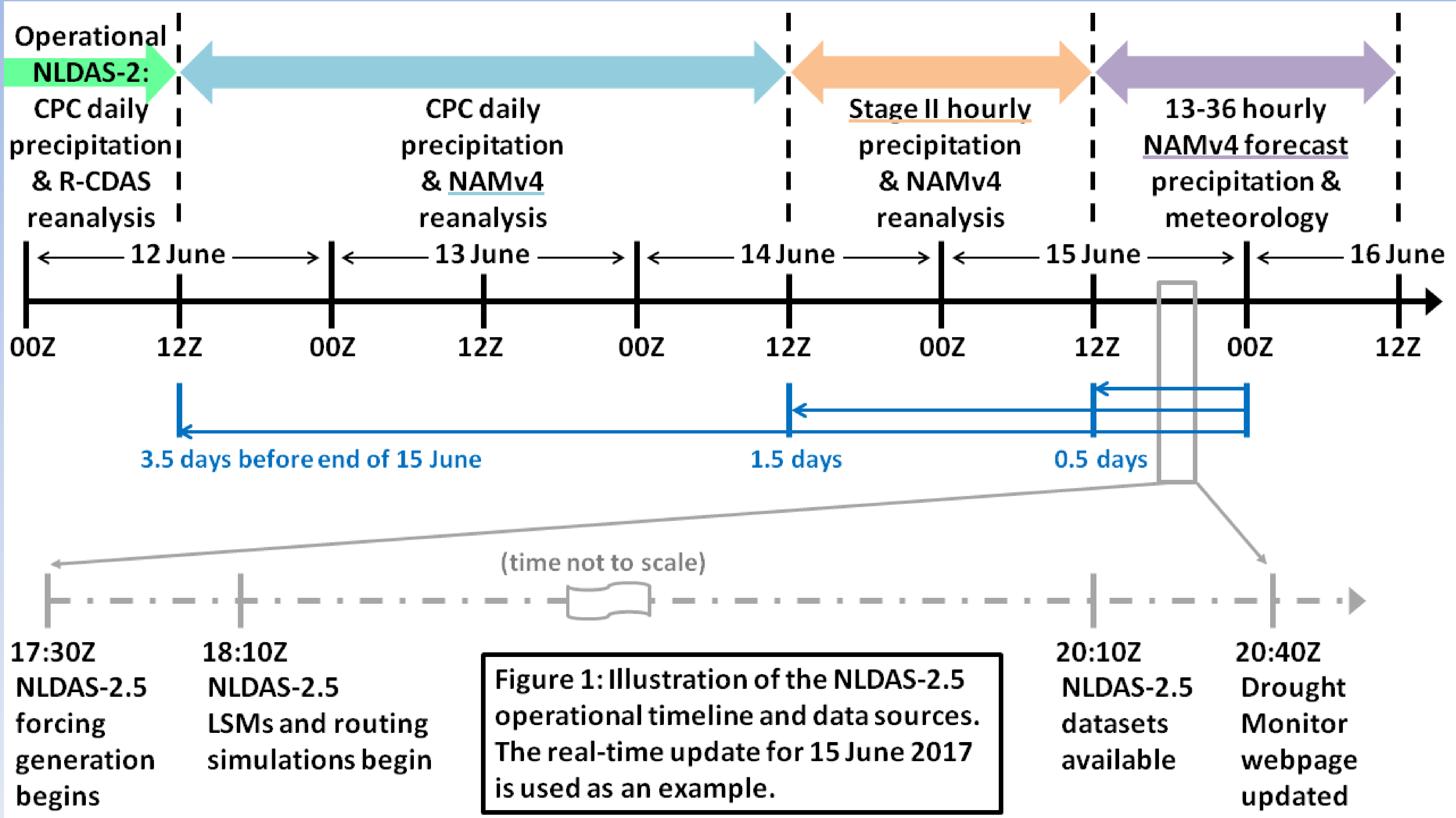


Figure 1: Illustration of the NLDAS-2.5 operational timeline and data sources. The real-time update for 15 June 2017 is used as an example.

Take-away Messages

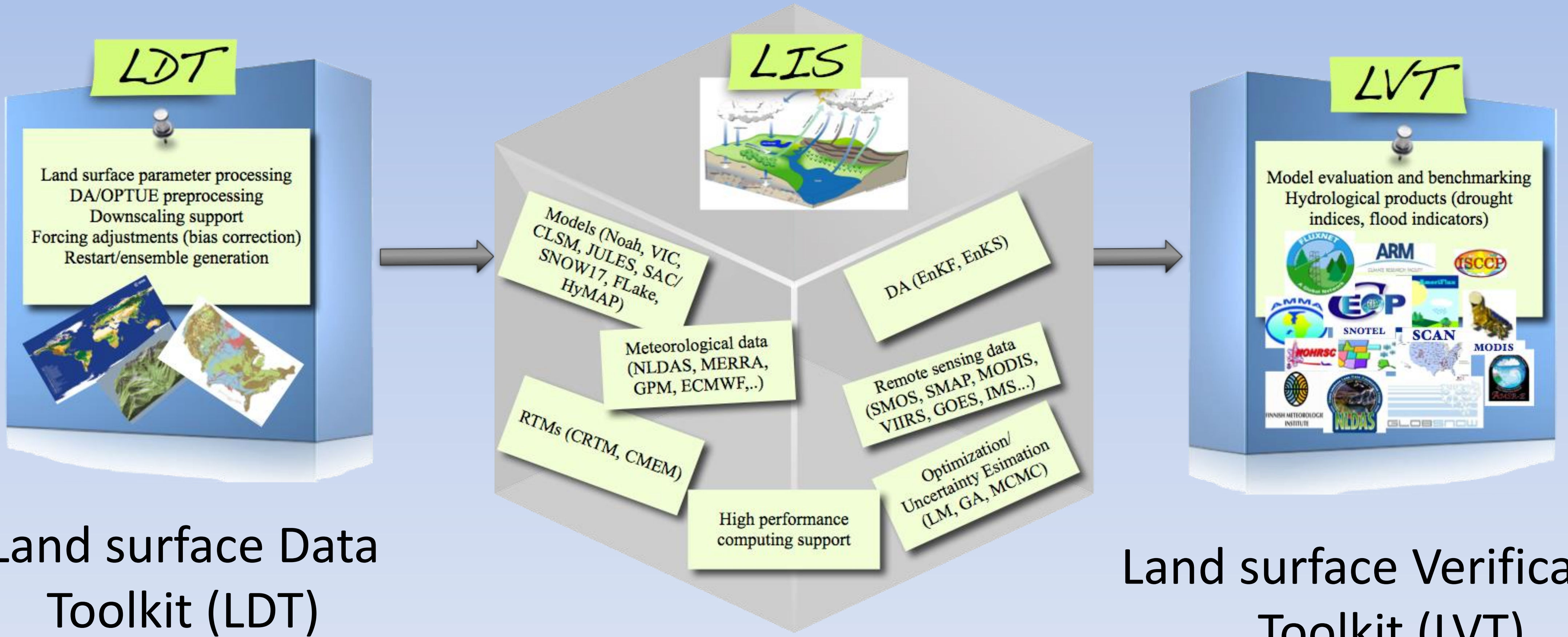
- NLDAS-2.5 will close the 3.5-day latency gap (using the same LSMs)
- NLDAS-3.0 will include new/updated LSMs running in NASA's LIS software framework with data assimilation of operational remotely-sensed products, along with an irrigation scheme and the HyMAP streamflow router
- Data assimilation has been shown to improve NLDAS depiction of soil moisture, snow, evaporation, and streamflow compared to in situ & gridded observations
- Similarity assessment of the operational and future NLDAS LSMs underway
- Many LSMs in NLDAS-3.0 consider groundwater; may help with drought depiction

@NASA_LIS

http://www.emc.ncep.noaa.gov/mmb/nldas/

https://ldas.gsfc.nasa.gov/ https://lis.gsfc.nasa.gov/

NASA's Land Information System (LIS) software framework is used to drive the models and perform data assimilation



Land surface Data Toolkit (LDT)

Land Information System (LIS)

Land surface Verification Toolkit (LVT)

https://lis.gsfc.nasa.gov/

@NASA_LIS