Interaction of North American Land Data Assimilation System and National Soil Moisture Network: Soil Products and Beyond

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Current Operational NLDAS Land Surface Models: NCEP/Noah, NASA/Mosaic, NWC/SAC, and Princeton/Washington/VIC

- **NLDAS Products**:

  water fluxes – precipitation, runoff, routed streamflow, snowmelt, sublimation, ET;

  energy fluxes – downward/upward shortwave and longwave radiation, net radiation, sensible heat flux, latent heat flux, ground heat flux;

  state variables – soil temperature, soil moisture (liquid, frozen, total), skin temperature, SWE, snow cover and fraction, terrestrial water storage.

- **Product evaluation/validation**
  Using in situ observations, remote sensing data, and reanalysis data to compressively evaluate almost all NLDAS products for different spatial and temporal scales. For more details, please see NASA NLDAS website:

http://ldas.gsfc.nasa.gov/nldas/NLDAS2valid.php

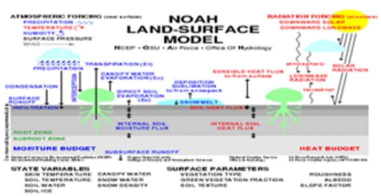
http://ldas.gsfc.nasa.gov/nldas/NLDASpublications.php

• NLDAS is a multi-model land modeling and data assimilation system…
• …run in uncoupled mode driven by atmospheric forcing (using surface meteorology data sets)…
• …with *"long-term"* retrospective and near real-time output of
land-surface **water** and **energy** budgets.

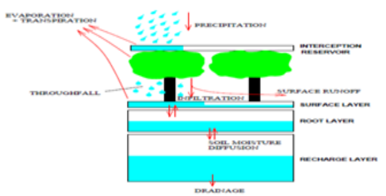
NLDAS Configuration: Land models

- Uncoupled ("offline") simulations.
- Input: atmospheric forcing.
- Output: water/energy budgets (surface fluxes, land states)

Atmospheric Community



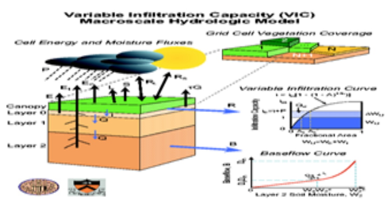
Noah
NCEP operational land model



Mosaic
NASA GSFC

Hydrology Community

SAC
NWS operational hydrological model

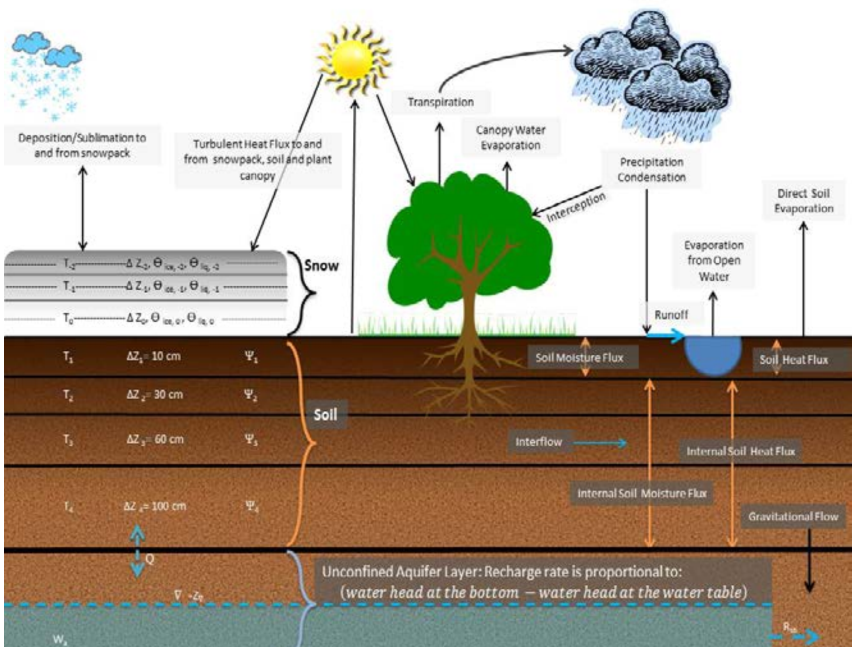


VIC
Princeton & U. Washington

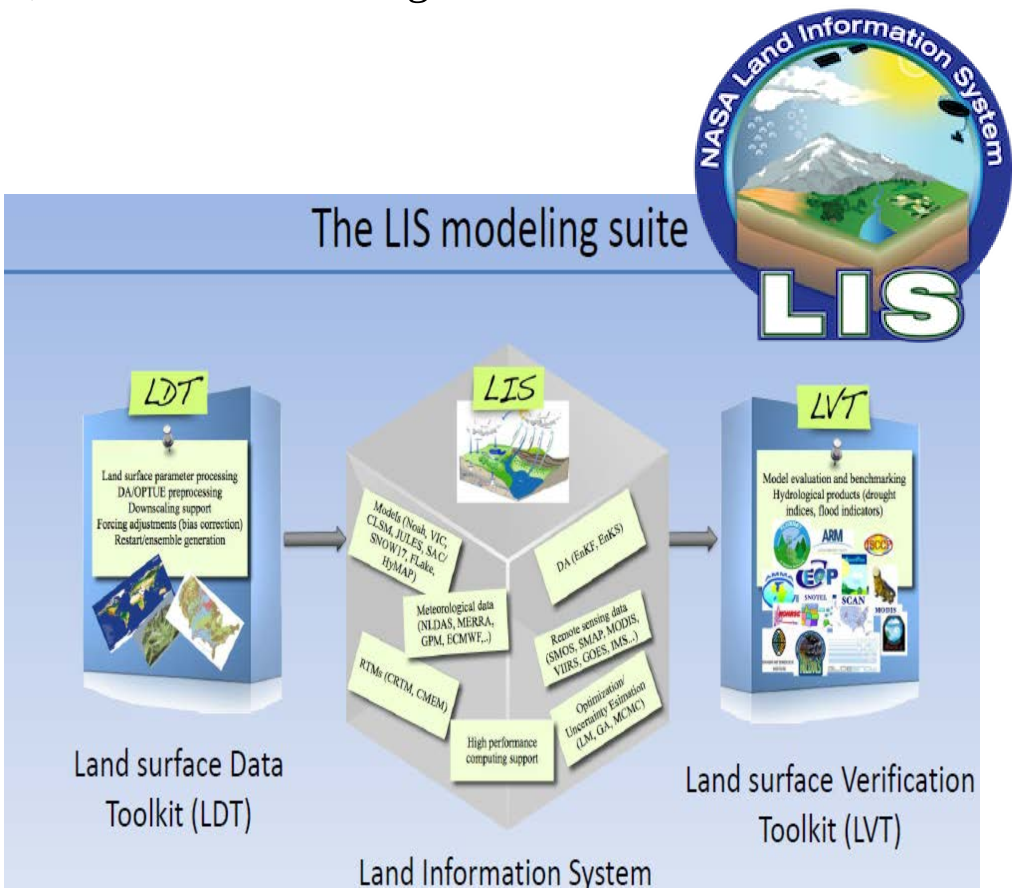
Next Phase NLDAS System – LIS-Based Framework

- NASA Land Information System (LIS) Framework
- Assimilation of soil moisture, snowpack, and GRACE terrestrial water storage
- Models: Catchment, Noah-MP, CLM4.5(??), Noah3.6, VIC4.1.2
- Addition of groundwater and dynamic vegetation module
- Output: groundwater storage, carbon flux, leaf area index and greenness fraction (simulated)

Noah-MP3.6



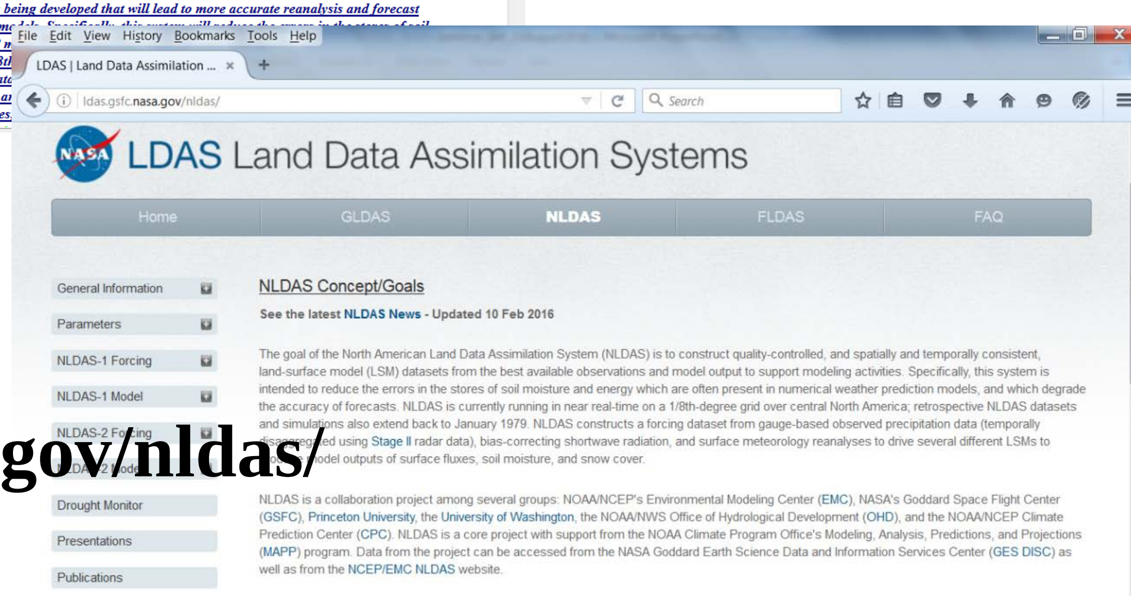
Groundwater



NLDAS Website

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

More details can see NCEP and NASA NLDAS website

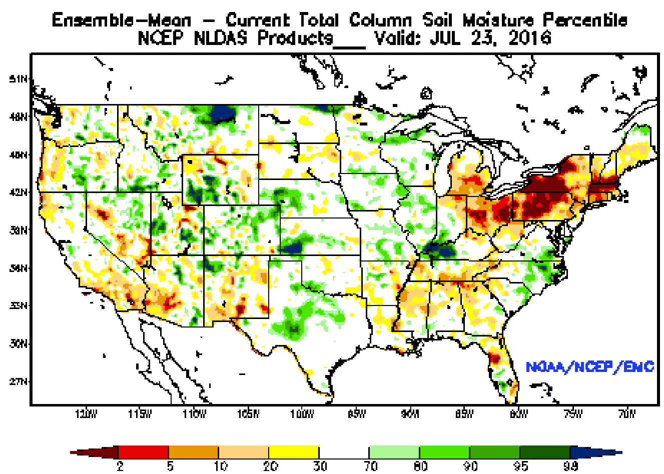


http://ldas.gsfc.nasa.gov/nldas/

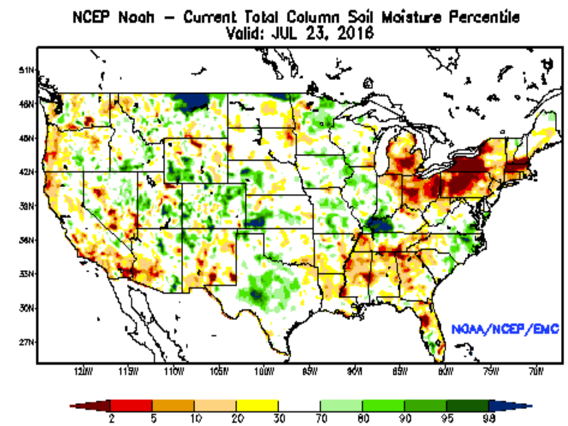
Contributions of NLDAS Product to National Integrated Drought Information System (NIDIS, drought.gov)

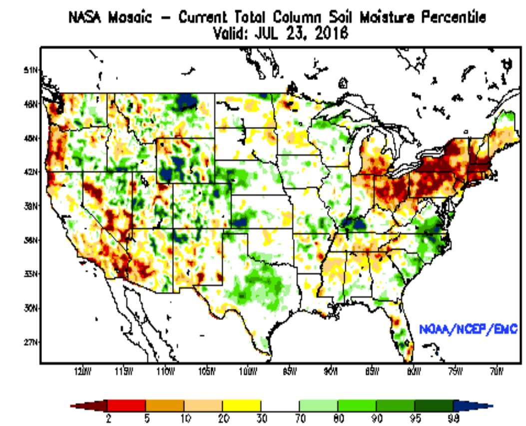
NLDAS Drought Monitor

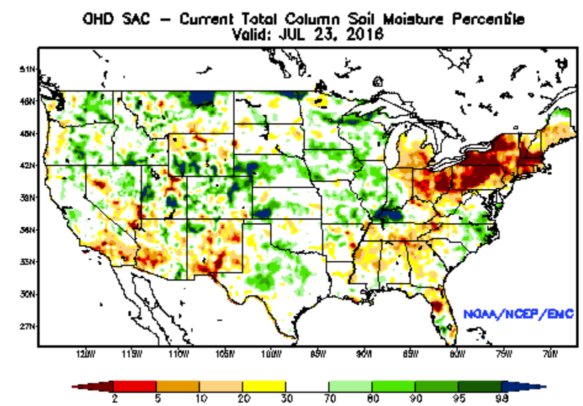
http://www.emc.ncep.noaa.gov/mmb/nldas/drought/

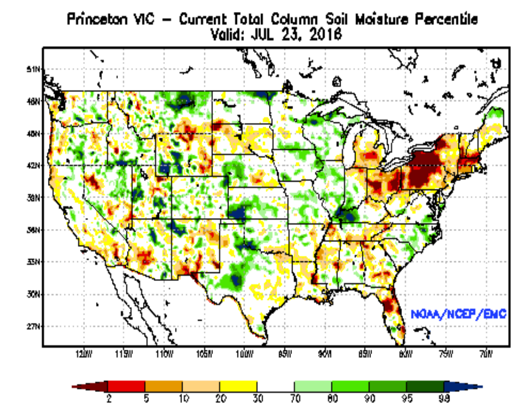


These products have been widely used by U.S. drought monitor author group, CPC, various regional climate centers and river forecast centers.









NLDAS Soil Moisture and Temperature

- **NLDAS Reliability:** NCEP operational product with a 4-day lag
  Resolution: spatial – 0.125 degree (~12-14 km), temporal –hourly (daily, monthly, yearly)
- **Vertical Soil Depth**: 0-10 cm (5cm at mid-soil layer), 10-40 cm (25 cm), 40-100 cm (70 cm), 100-200 cm (150cm). SAC and VIC use their post-processes to convert simulated soil moisture to Noah soil layers. Only Noah and VIC has four layers soil temperature.
- **Covering Period**: 02 January 1979 - present

Next phase NLDAS Update –NLDAS2.5 and NLDAS3.0

Achieve Actual Real-time by Closing the 4-day lag (~ 1-2 years)

Upgrade Land Surface Models: Noah-2.8 → Noah-3.6; Mosaic → Catchment Model; VIC-4.0.3 → VIC-4.1.2; and Noah-MP . All models will include soil temperature output (~1-2 years)

Achieve Actual Data Assimilation by using remotely sensed soil moisture, snowpack and GRACE TWS data (~2 years)

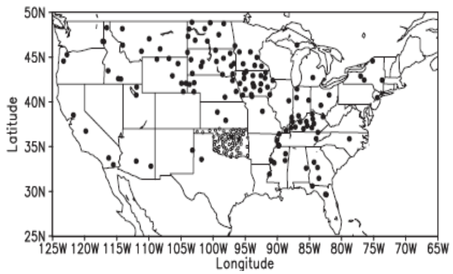
NLDAS white paper including design, plan and work schedule is nearly ready!

NLDAS Noah Soil Temperature Validation

J. Appl. Meteorol. Climatol.,52, 455-471 , 2013

Validation of Noah-Simulated Soil Temperature in the North American Land Data Assimilation System Phase 2

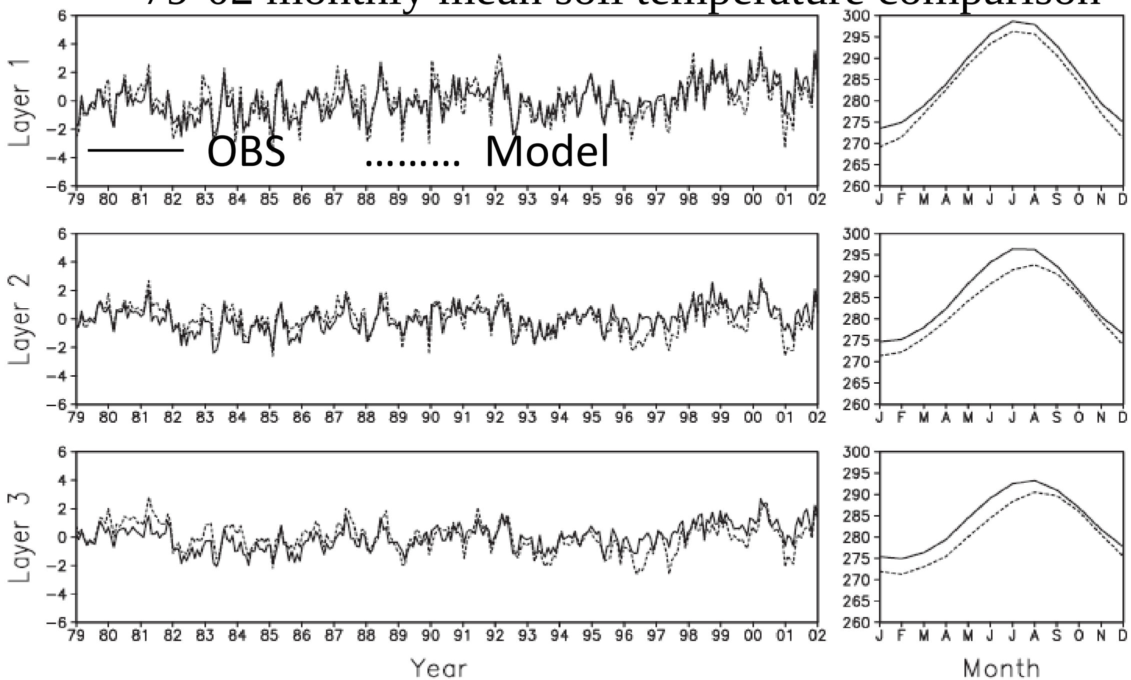
YOULONG XIA,*,+ MICHAEL EK,+ JUSTIN SHEFFIELD,# BEN LIVNEH,@ MAOYI HUANG,& HELIN WEI,*,+ SONG FENG,** LIFENG LUO,++ JESSE MENG,*,+ AND ERIC WOOD#

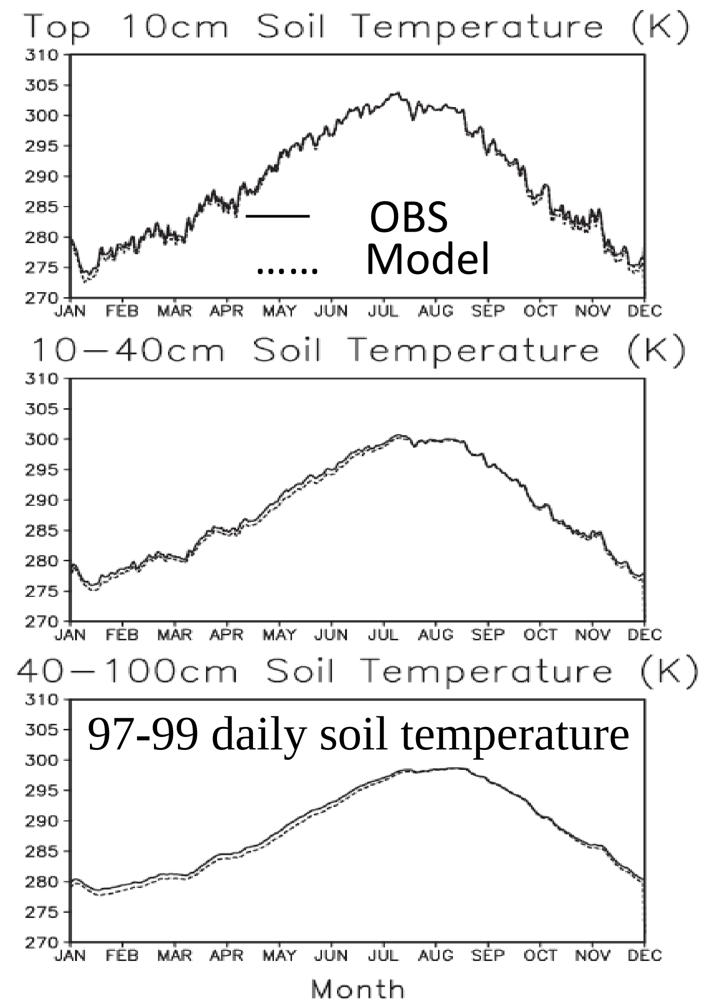


137 US cooperative station and 72 Oklahoma Mesonet stations

Errors < 3°C for most cases

79-02 monthly mean soil temperature comparison



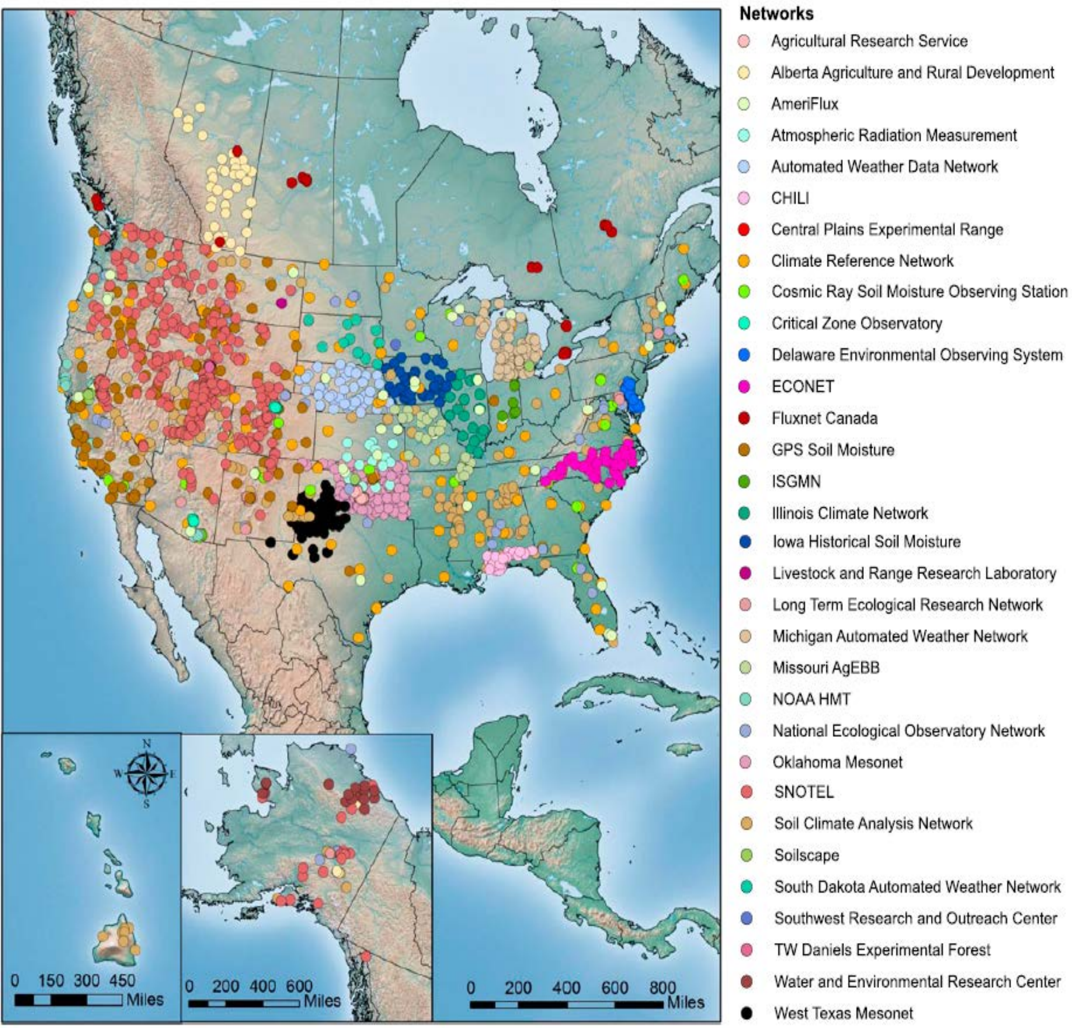


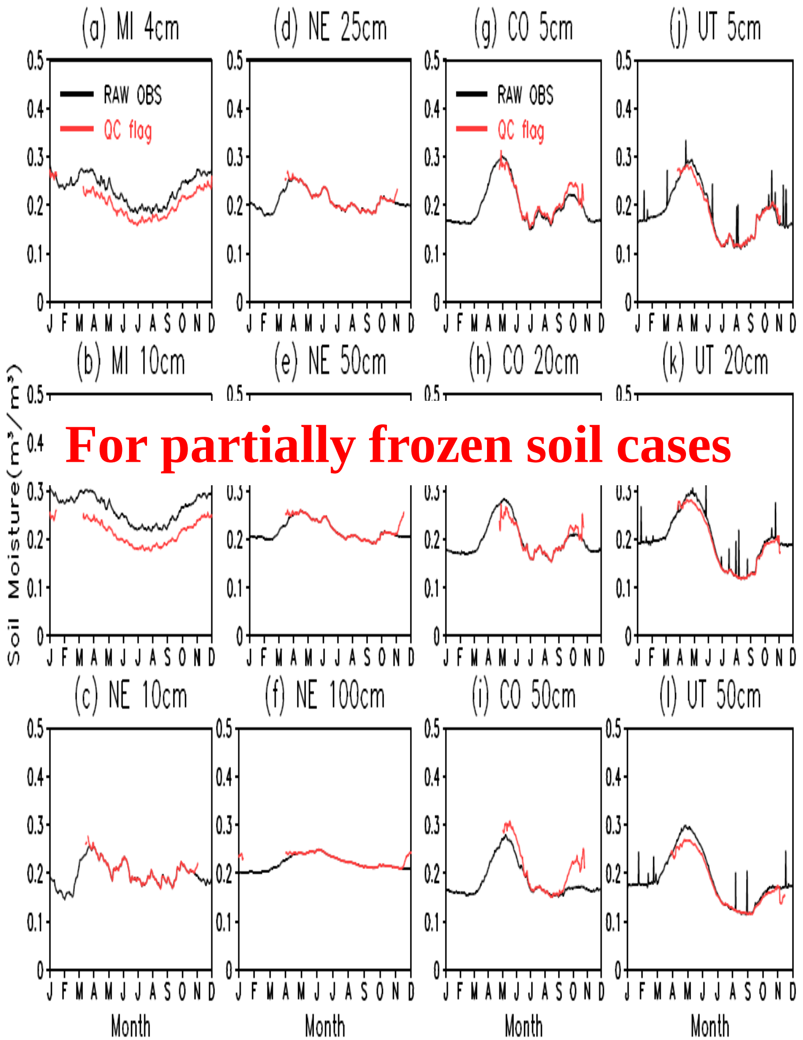
NLDAS soil temperature helps control NASMD data

J. Appl. Meteorol. Climatol., 54, 1267-1282, 2015

Automated Quality Control of In Situ Soil Moisture from the North American Soil Moisture Database Using NLDAS-2 Products

YOULONG XIA, TRENT W. FORD, YIHUA WU, STEVEN M. QUIRING, AND MICHAEL B. EK



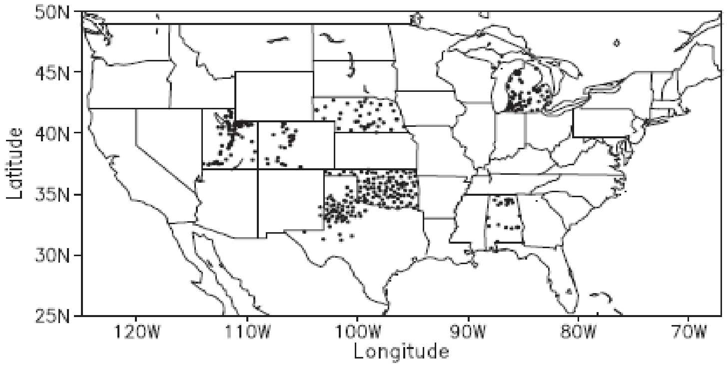


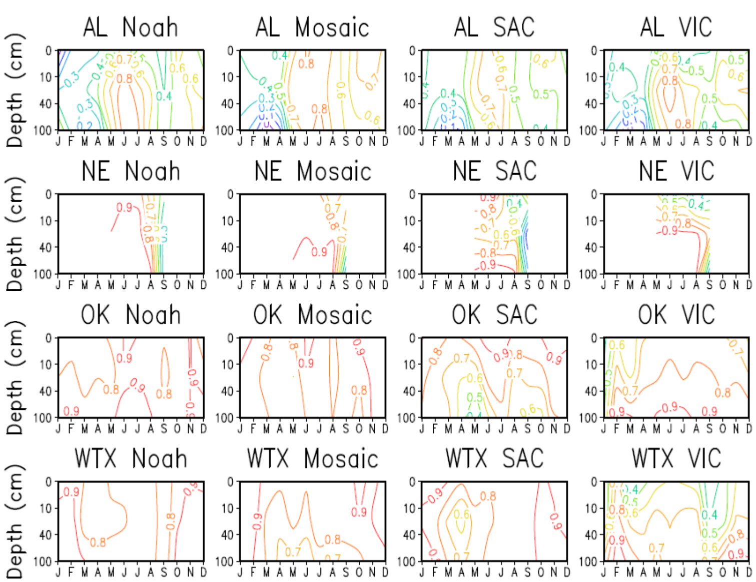
NLDAS soil moisture evaluation in North American Soil Moisture Database (NASMD)

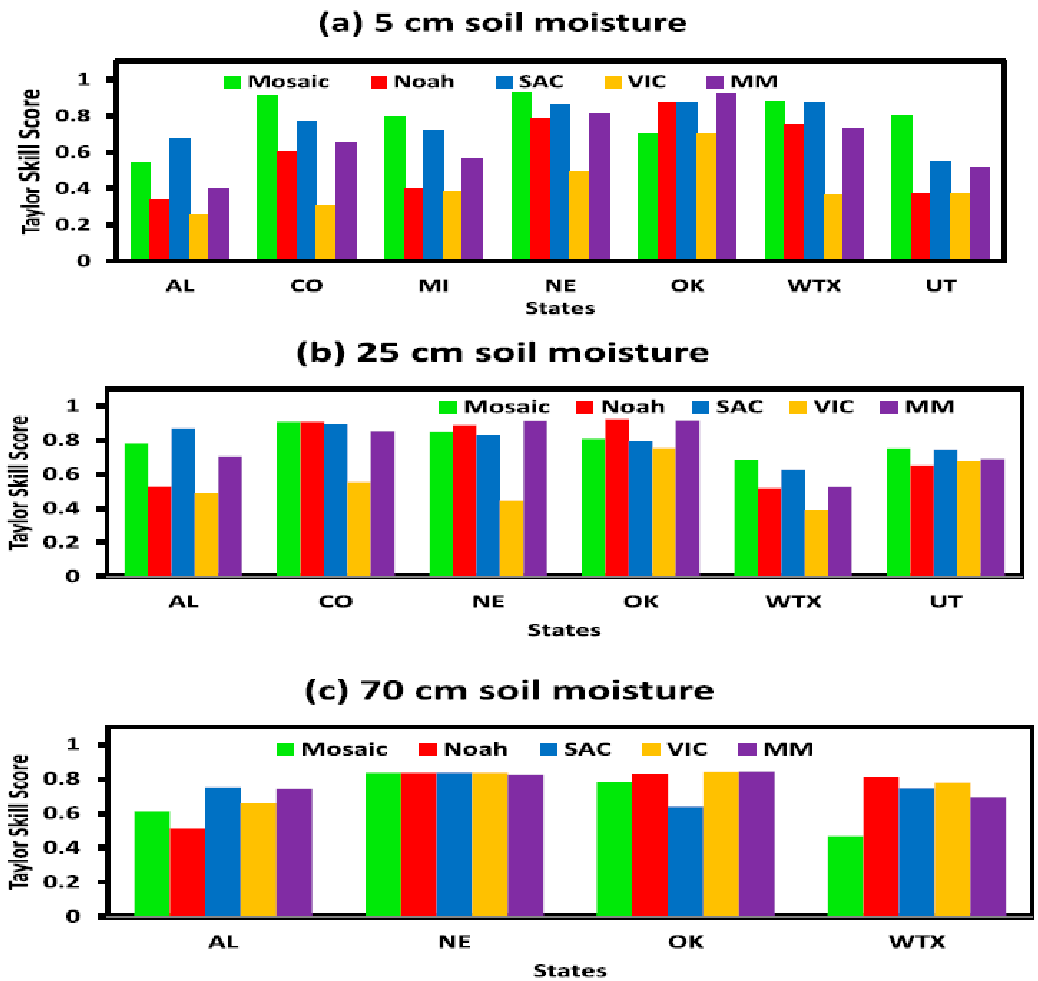
J. Hydrometeor., 16, 1962-1980, 2015

Comparison of NLDAS-2 Simulated and NASMD Observed Daily Soil Moisture. Part I: Comparison and Analysis

YOULONG XIA, MICHAEL B. EK, YIHUA WU, TRENT W. FORD, AND STEVEN M. QUIRING

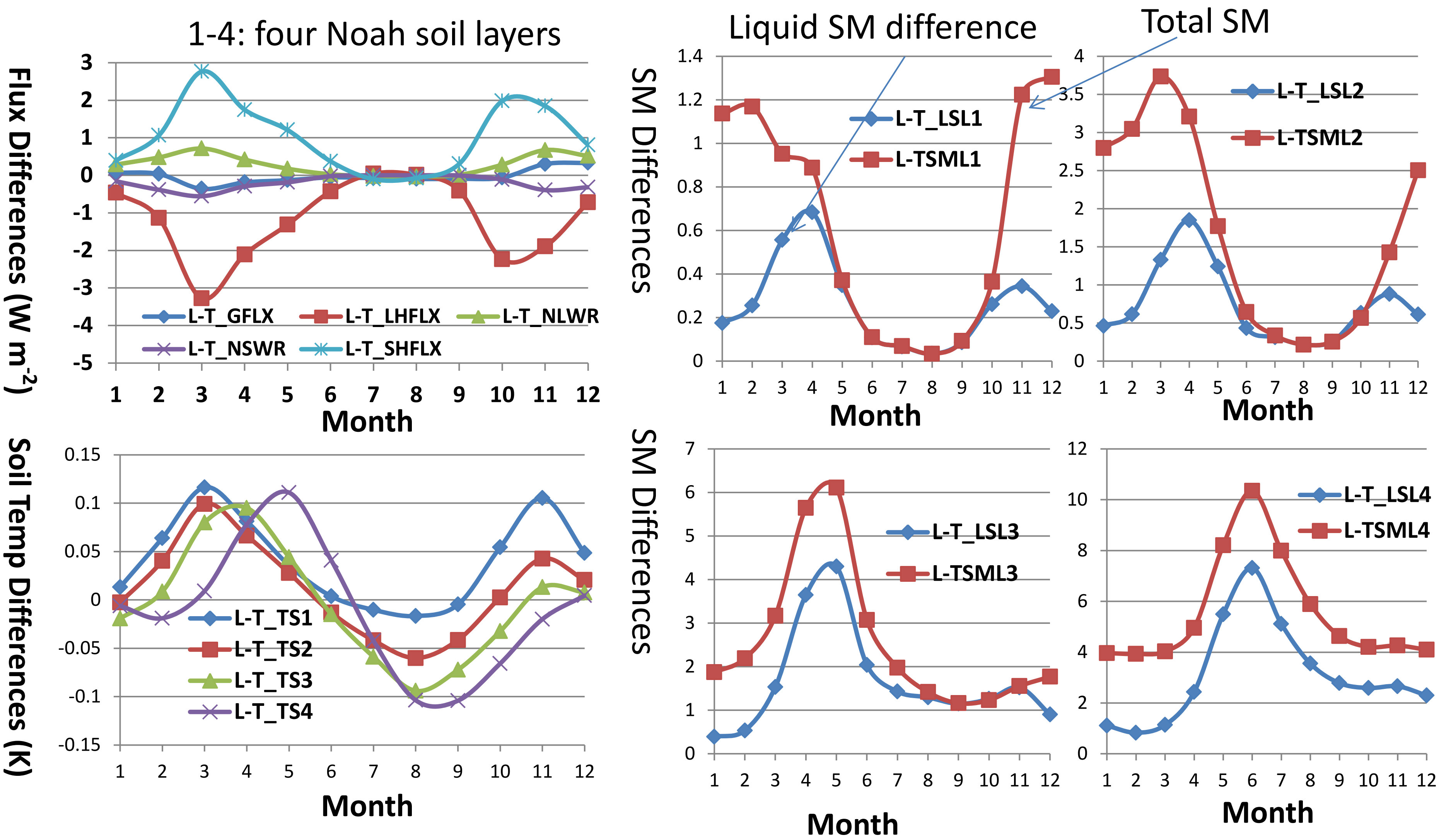






In model parameterization, the differences due to transpiration formula using liquid or total (liquid + ice) soil moisture. Soil physics plays an important role in particular spring time.

Outputs for Tenderfoot Creek
(Lat: 46.95, Lon-110.89, Elevation 2255 m)

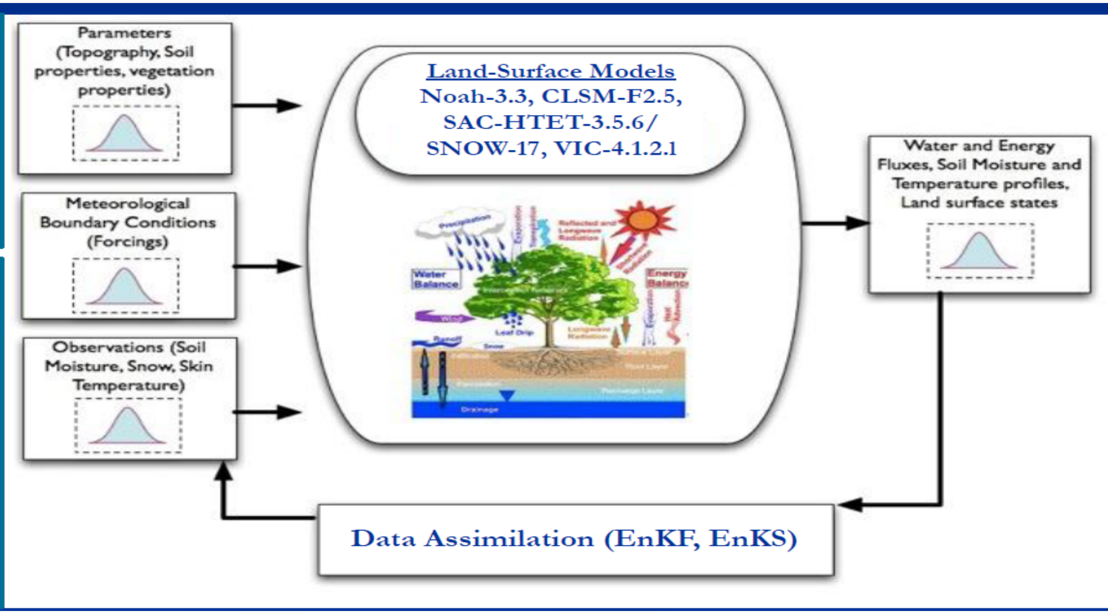


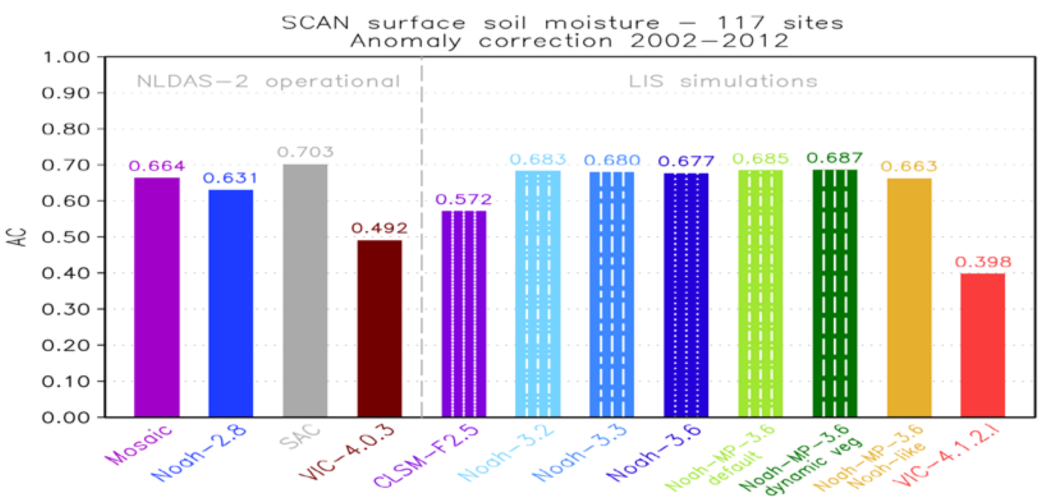
Improvement of NLDAS soil moisture via (1) upgrading model physics and (2) adding actual assimilation process

Kumar et al., 2016, J. Hydrometeor.,17, 1951-1972

1979-present NLDAS-2 Forcing and Parameters

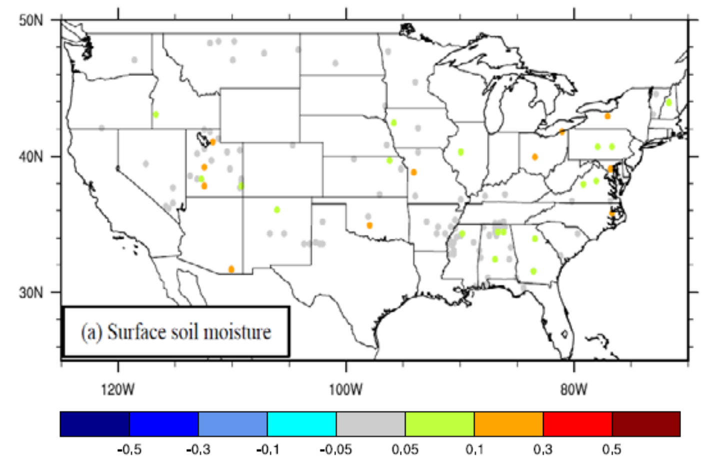
Data assimilation of: soil moisture, snow depth/area, terrestrial water storage (TWS), and irrigation intensity





5 cm soil moisture evaluation

CLSM-F2.5 with GRACE DA



Warm color - significant improvement

Energy and Water Fluxes Evaluation in NLDAS

AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Atmospheres

RESEARCH ARTICLE

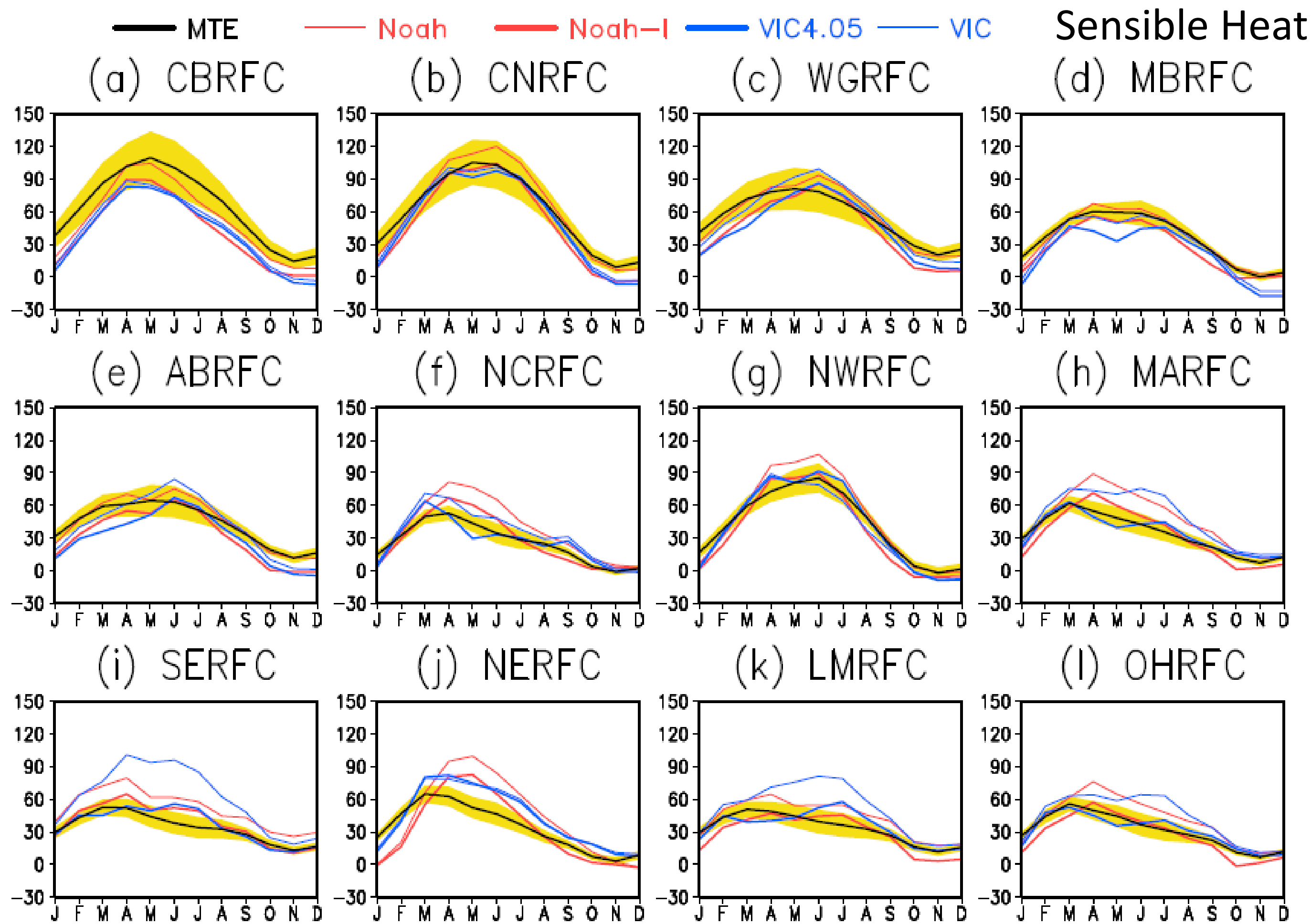
Basin-scale assessment of the land surface energy

10.1002/2015JD02

Key Points:
- To assess basin-scale components in NCEP research NLDAS-2
- To jointly use GEWEX/ and gridded FLUXNET fluxes
- To directly evaluate NI products at 12 CONUS Centers

Supporting Informatio
- Text S1

Correspondence to:
Y. Xia,



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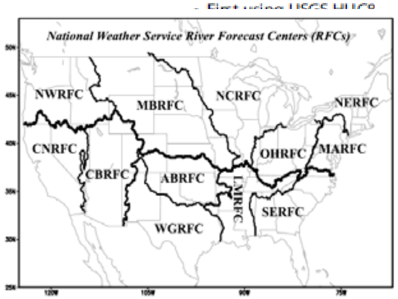
Journal o

RESEARCH A

10.1002/2015JD02

Key Points:
- Evaluation of the wate components in NCEP research NLDAS-2 syst
- Focus on 12 National W River Forecast Centers



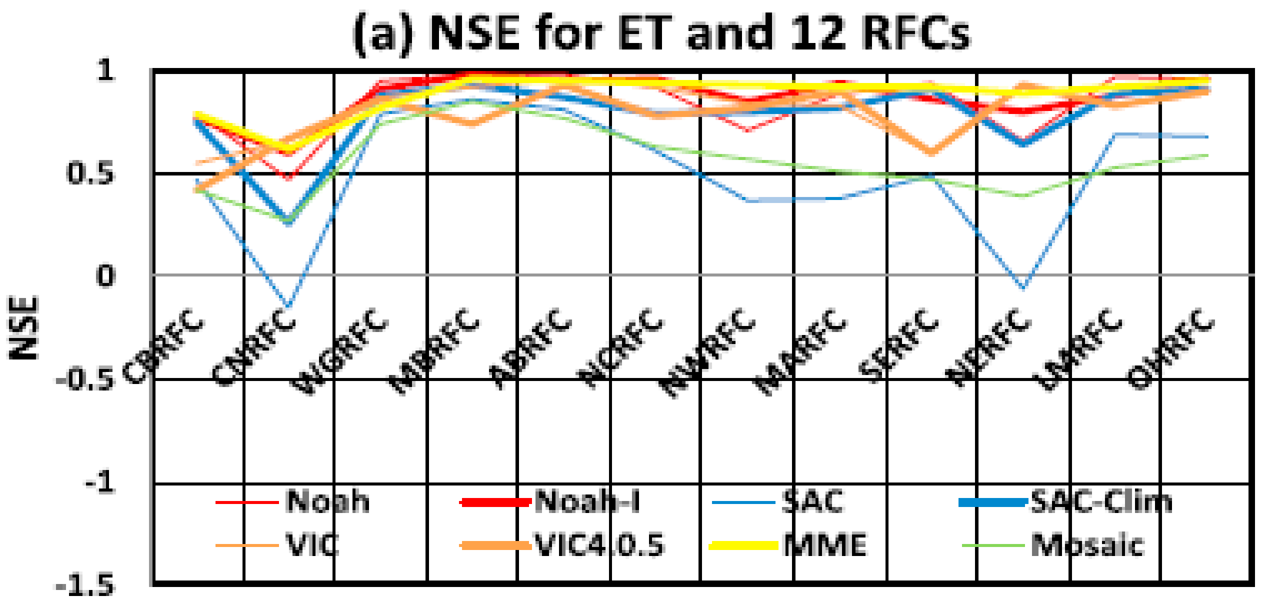
dget in the

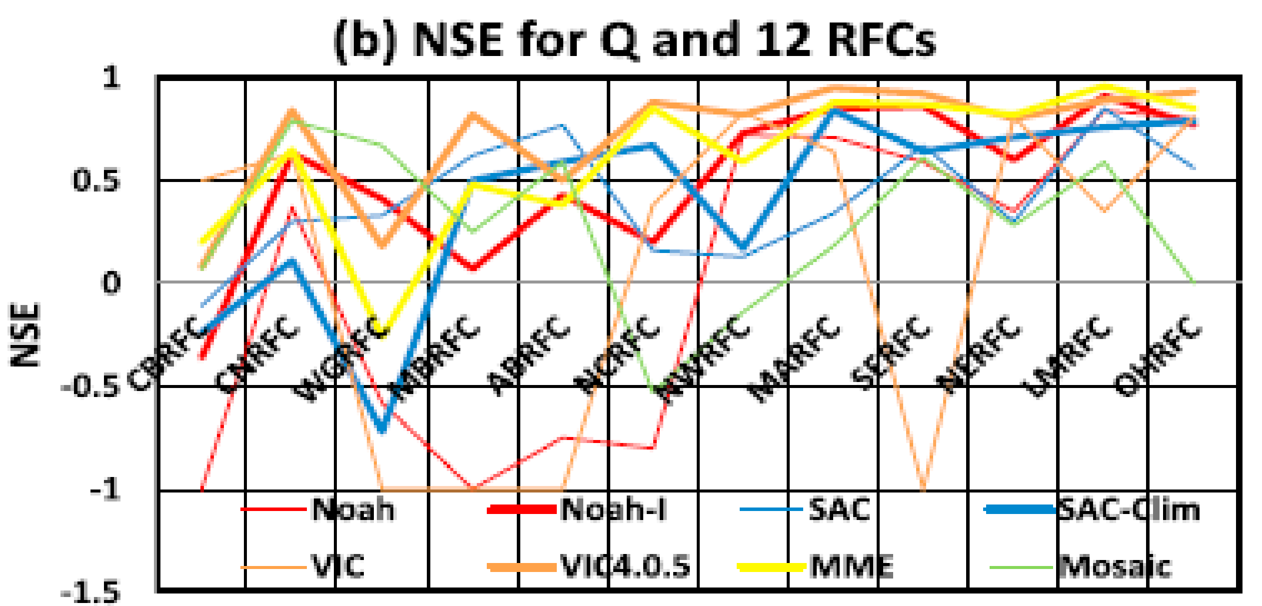
four land surface models (Noah, SAC-Sacramento Soil Moisture Accounting Model, (VIC) Variable Infiltration Capacity Model, and Mosaic) applied in the newly implemented National Centers for Environmental Prediction

NSE – Nash-Sutcliffe Efficiency

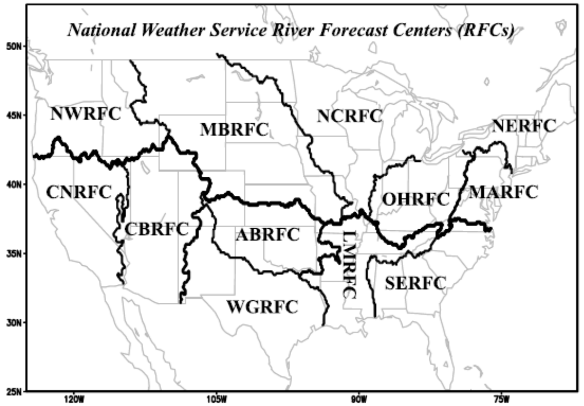
Q- USGS
ET- Gridded FUXNET

Research version improved Q and ET simulations for most RFCs





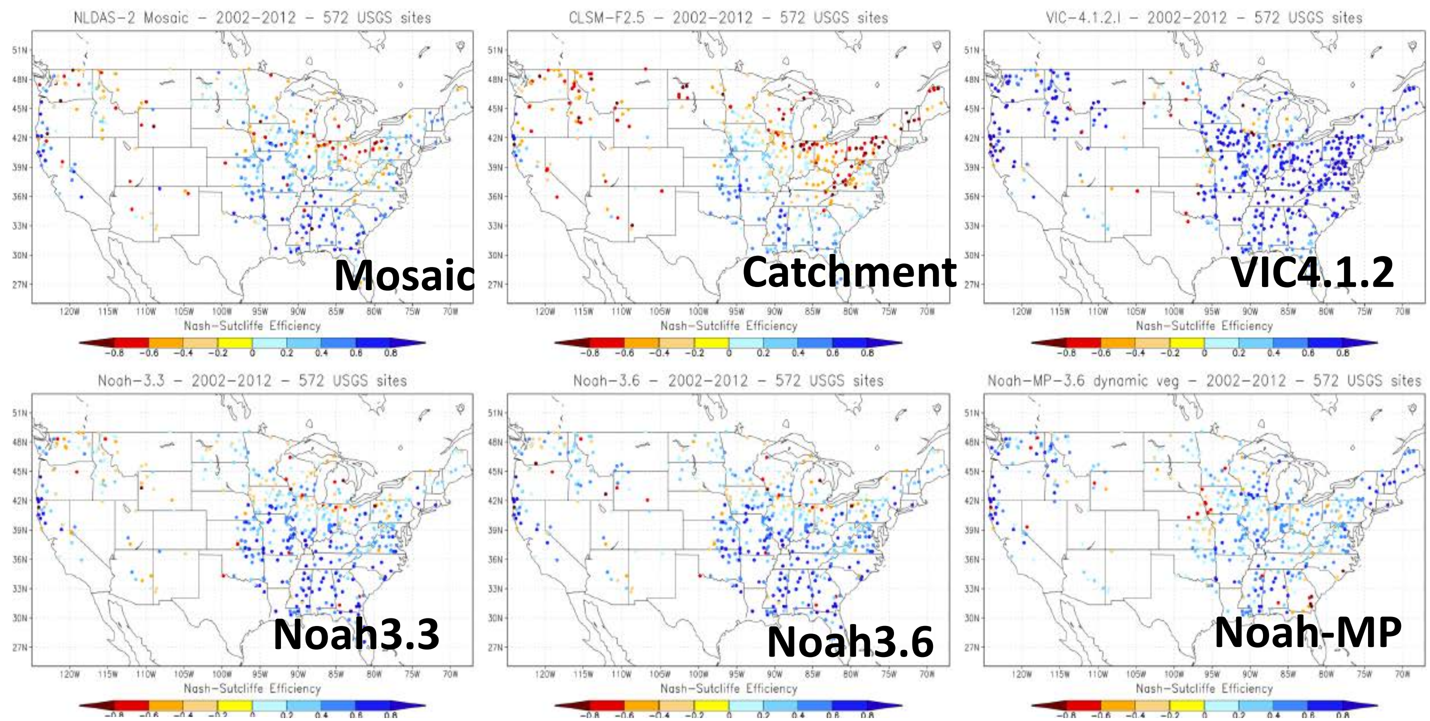
12 River Forecast Centers

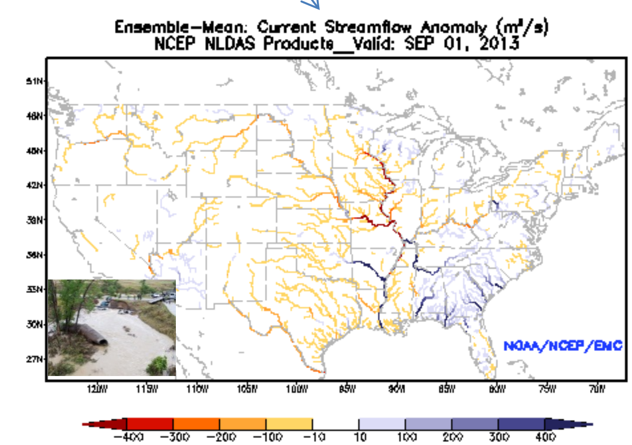


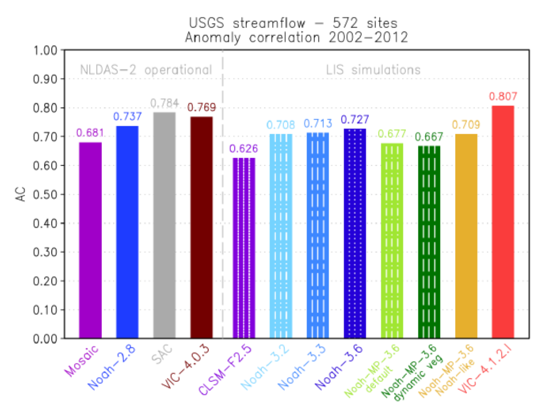
Xia et al, JGR, 2016b

Daily streamflow evaluation in NLDAS
Nash-Sutcliffe Efficiency (NSE)

Operational NLDAS Router (*Xia et al., 2021, JGR-Atmos.*) – ***Colorado Front Ridge Flooding in September 2013***





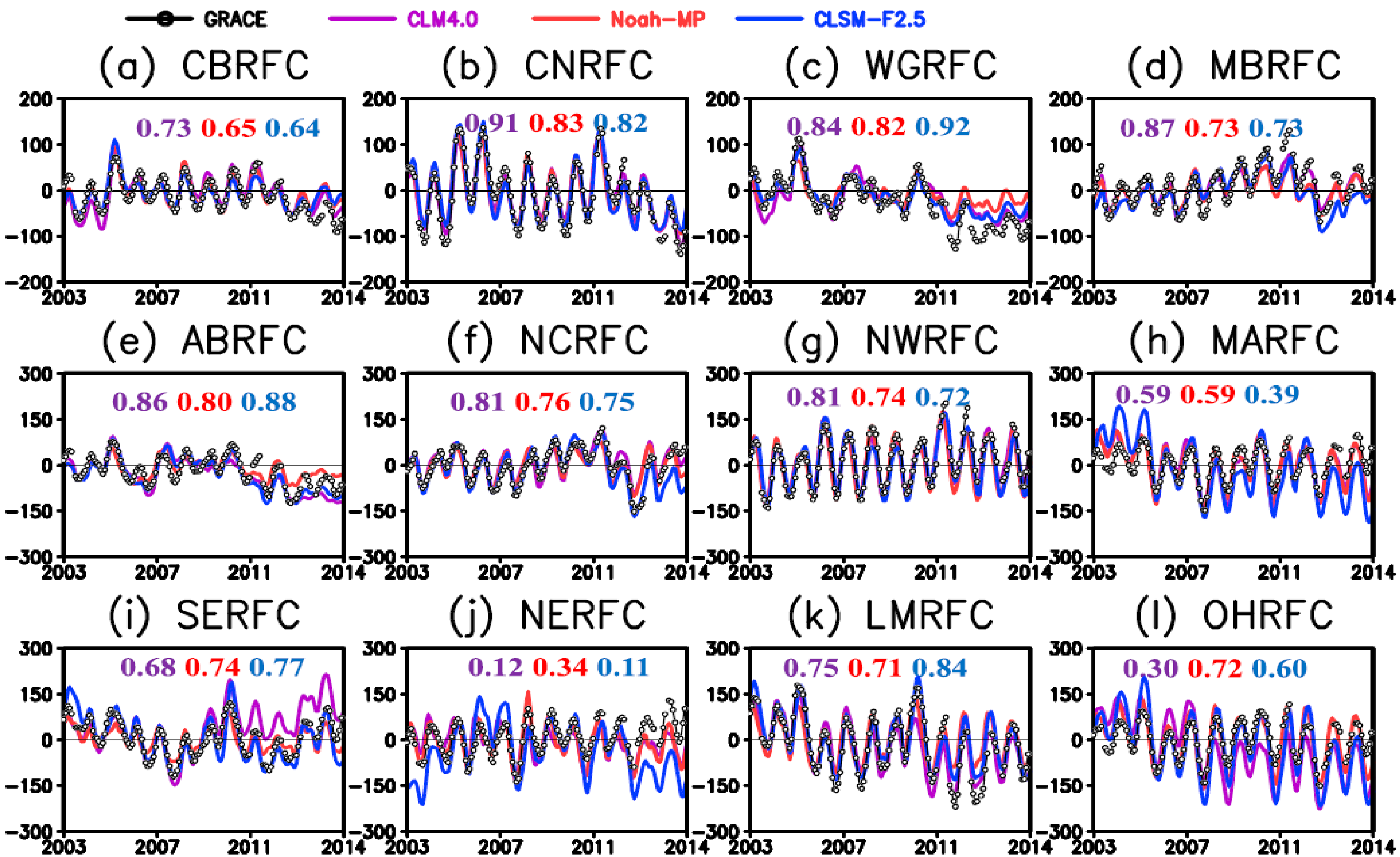


VIC4.1.2 performs best and CLSM-F2.5 performs worst.

Larger NSE appears in southeast and west coast where there are large precipitation. Small NSE appears in interior US region as there is less precipitation.

Terrestrial Water Storage (TWS) Anomaly Evaluation

(TWS=SMC+SWE+GWS), SMC-soil moisture content,
SWE – snow water equivalent, GWS-ground water storage



Xia et al., JHM, 2017

SWE Evaluation in LIS-Based NLDAS

CLSM-F2.5 has too little SWE when compared with SNODAS SWE. The reason is large sublimation. Further investigation (leading to large sublimation) is ongoing.

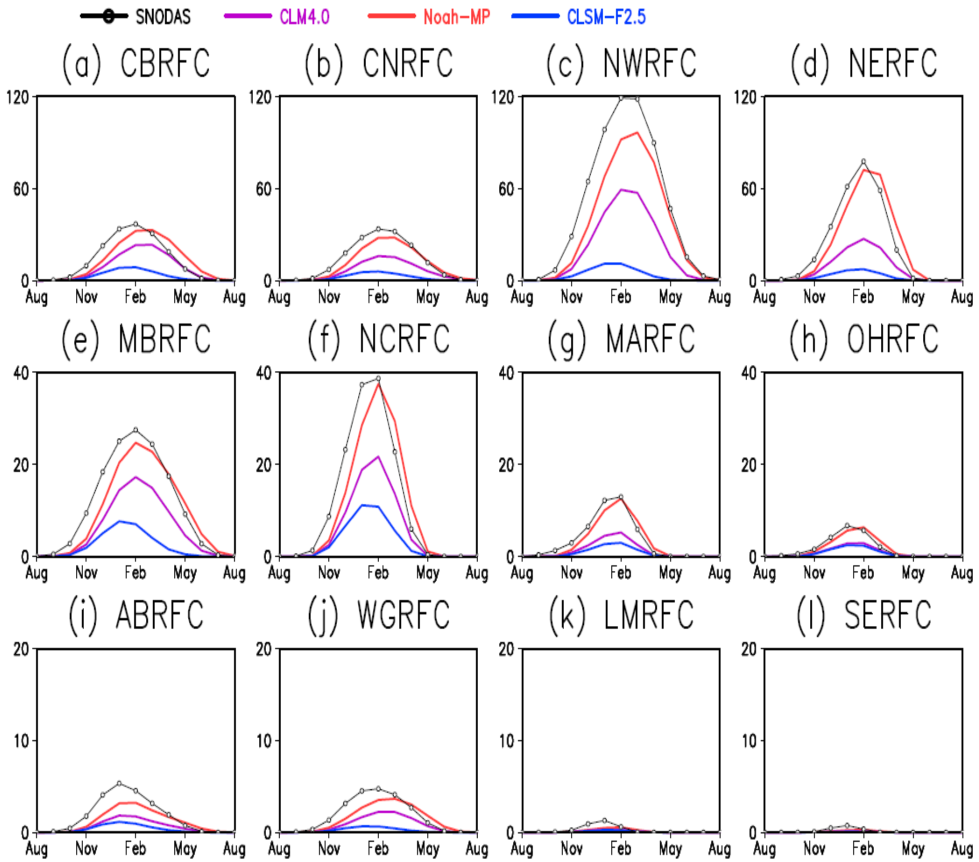


FIG. 8. Mean annual cycle of monthly mean SWE (mm) for each of 12 RFCs for the three models and SNODAS reanalysis calculated for the 11-yr period of 2004–14 (thin black line with open circles, SNODAS; purple line, CLM4.0; red line, Noah-MP; blue line, CLSM-F2.5). Note that the *y*-axis ranges from 0 to 120 in (a)–(d), from 0 to 40 in (e)–(h), and from 0 to 20 in (i)–(l).

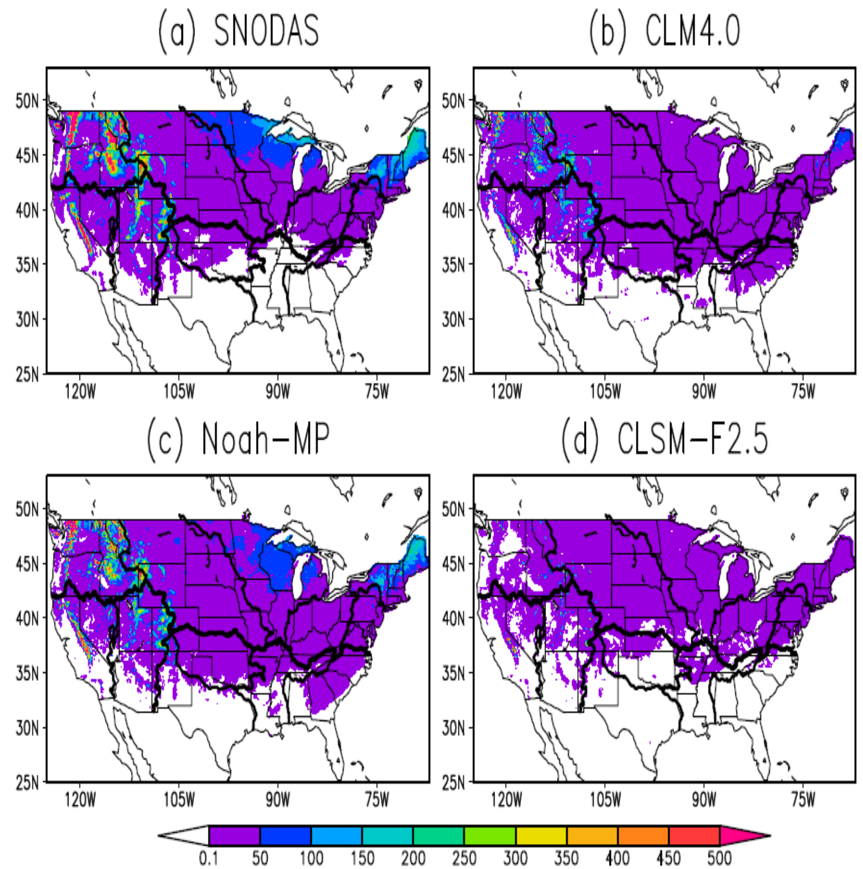


FIG. 9. Spatial distribution of 11-yr (2004–14) averaged February SWE (mm) derived from (a) SNODAS, (b) CLM4.0, (c) Noah-MP, and (d) CLSM-F2.5.

Xia et al, JHM, 2017

GWS Evaluation in LIS-Based NLDAS

Xia et al., JHM, 2017

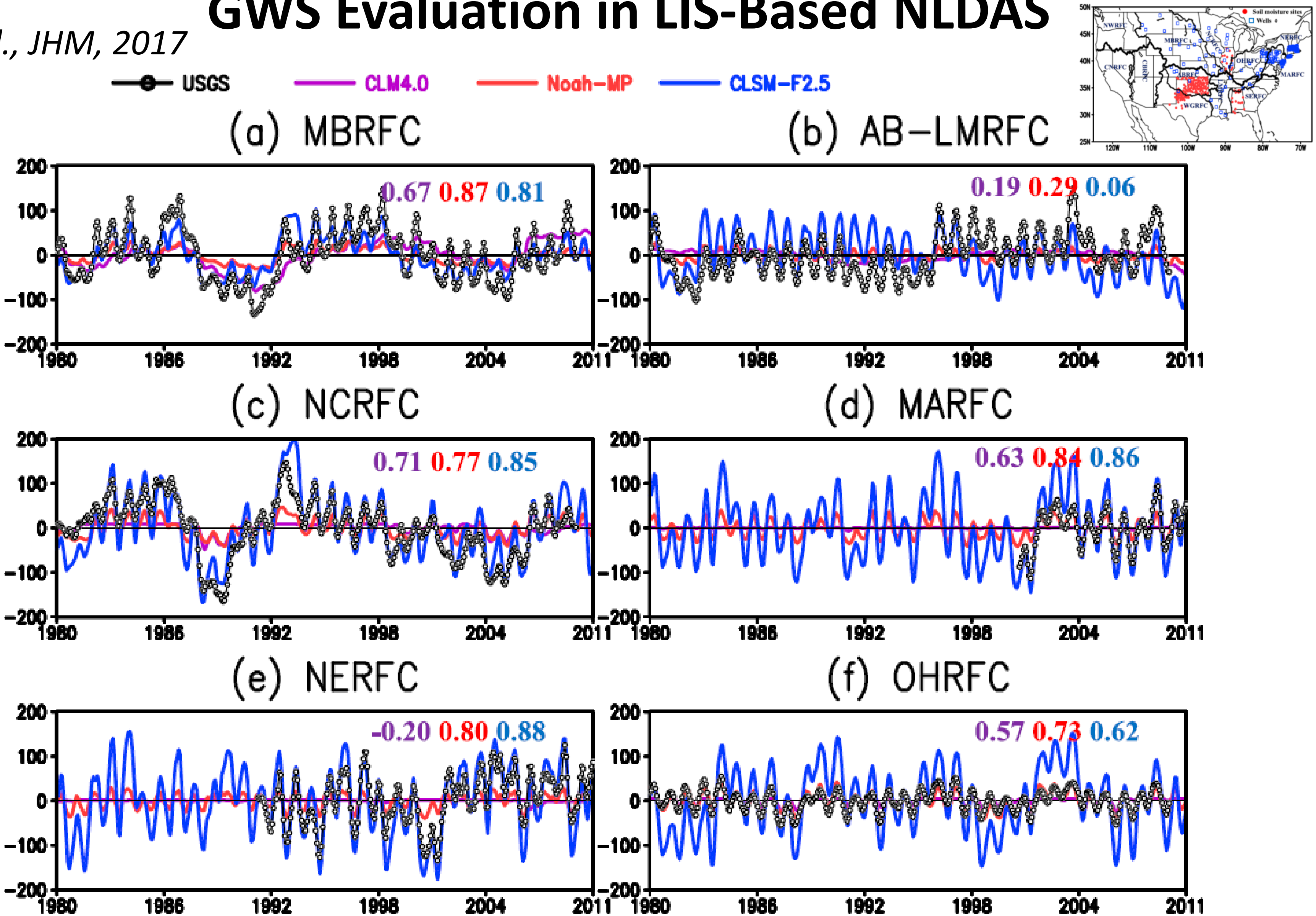
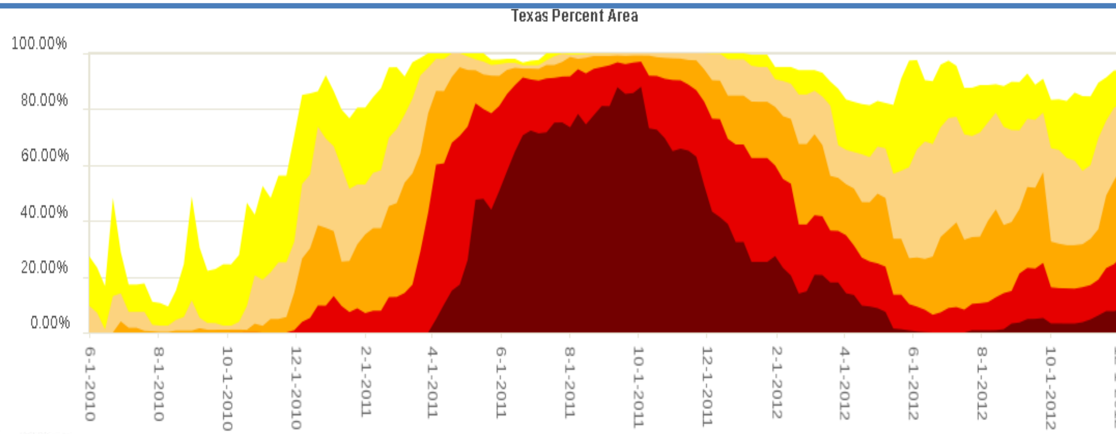
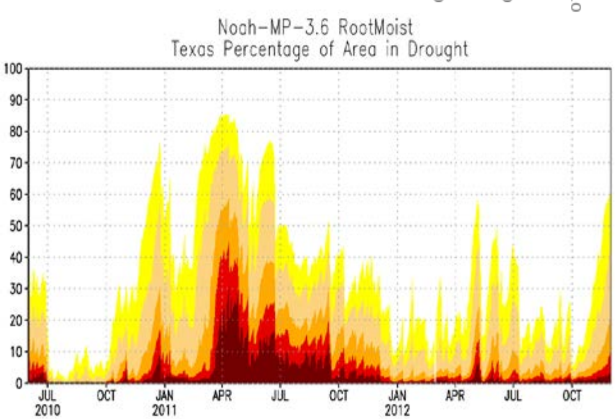


FIG. 7. Comparison of 32-yr time series of GWSA (mm) between USGS wells (thin black line with open circles) and the three models for six basins (purple line, CLM4.0; red line, Noah-MP; blue line, CLSM-F2.5). The model AC values given at the top of each frame correspond to model line color. The USGS values are unavailable before year 2002 (year 1992) for MARFC (NERFC).

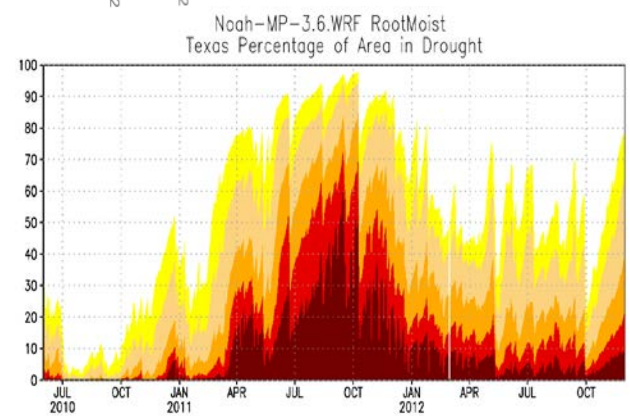
2011 Texas Drought (different options for Noah-MP)

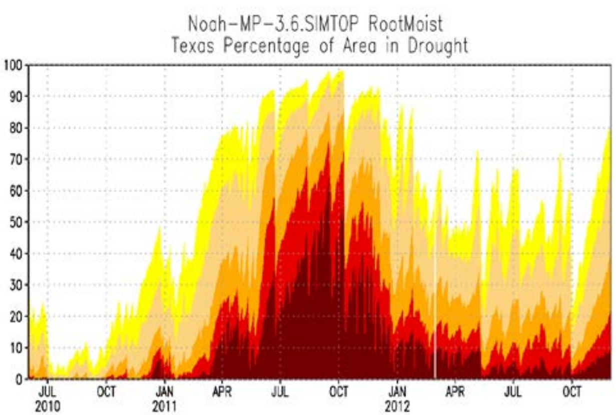


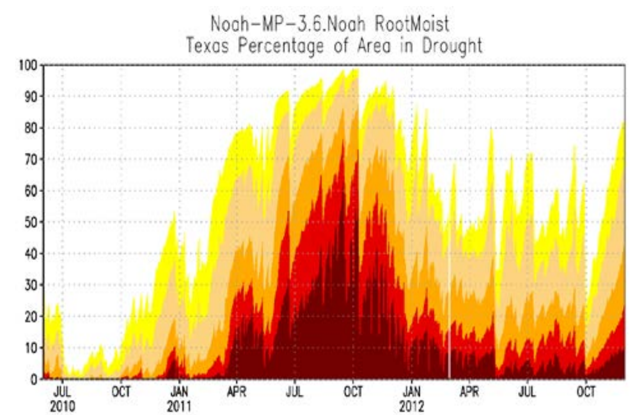
US
Drought Monitor



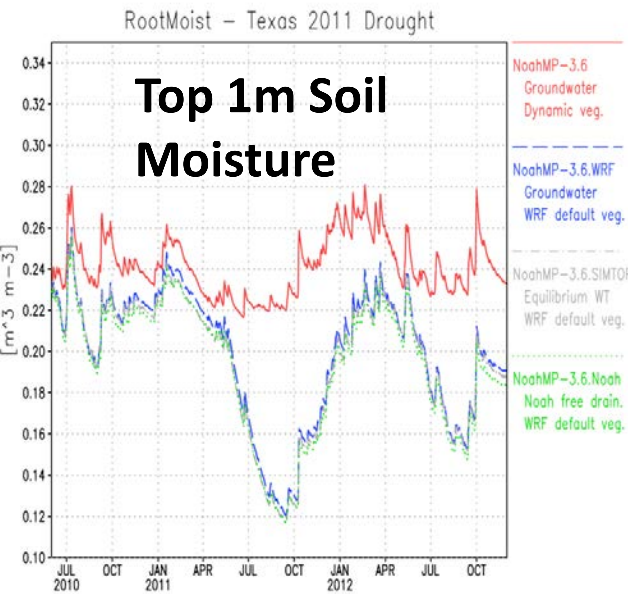
The **dynamic vegetation** run (upper left) completely misses the 2011 TX drought in the top 1-m soil moisture. **The other runs that use WRF default vegetation** do a better job, and are similar to each other, despite using groundwater, equilibrium water table, or free drainage.

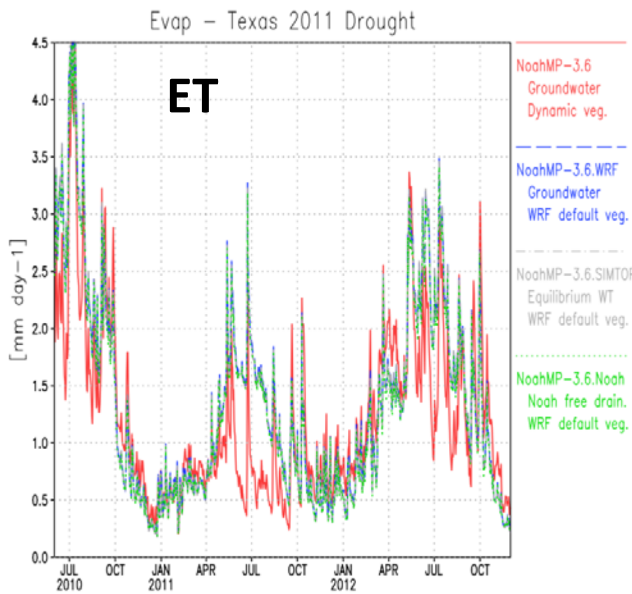


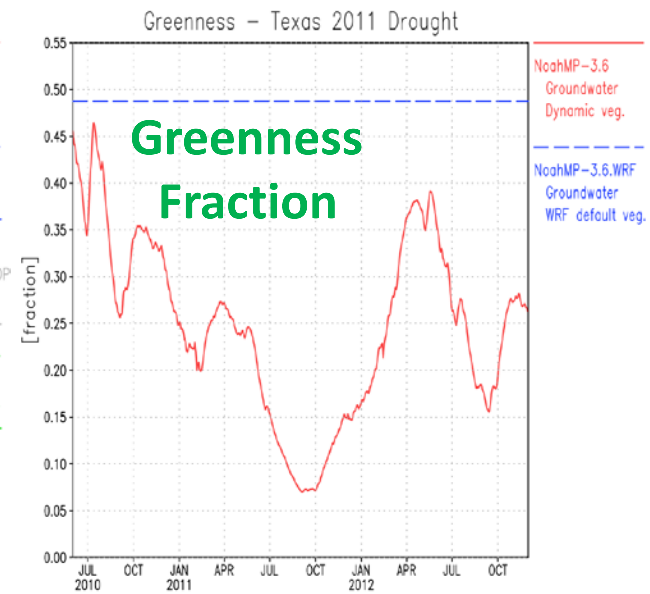


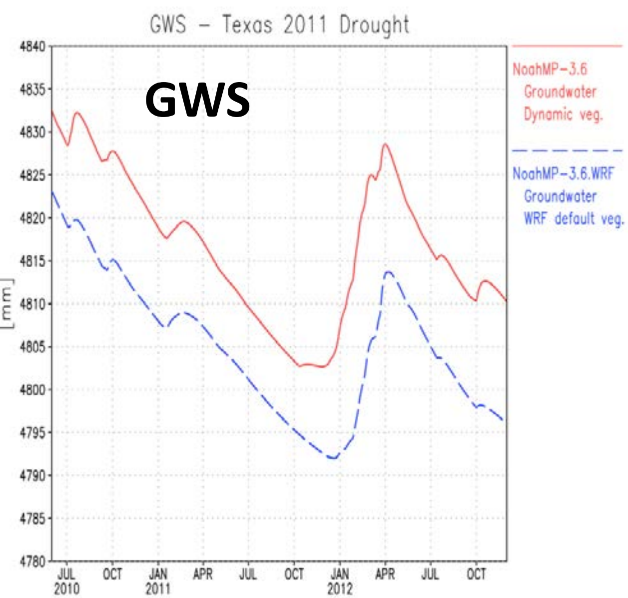


2011 Texas Drought

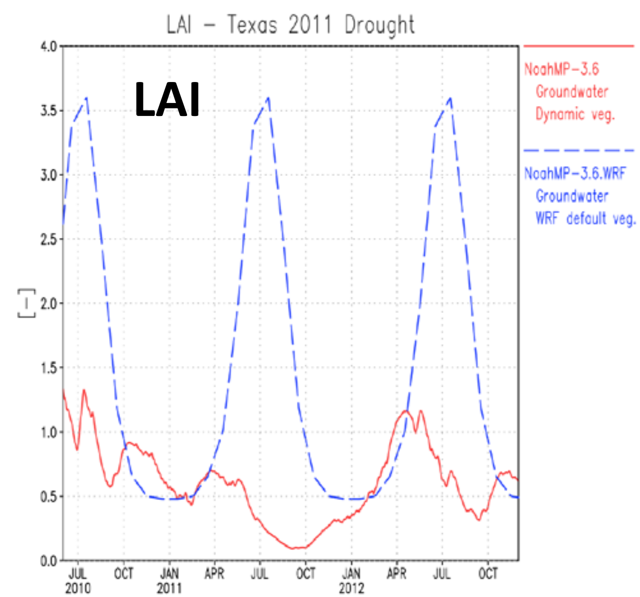




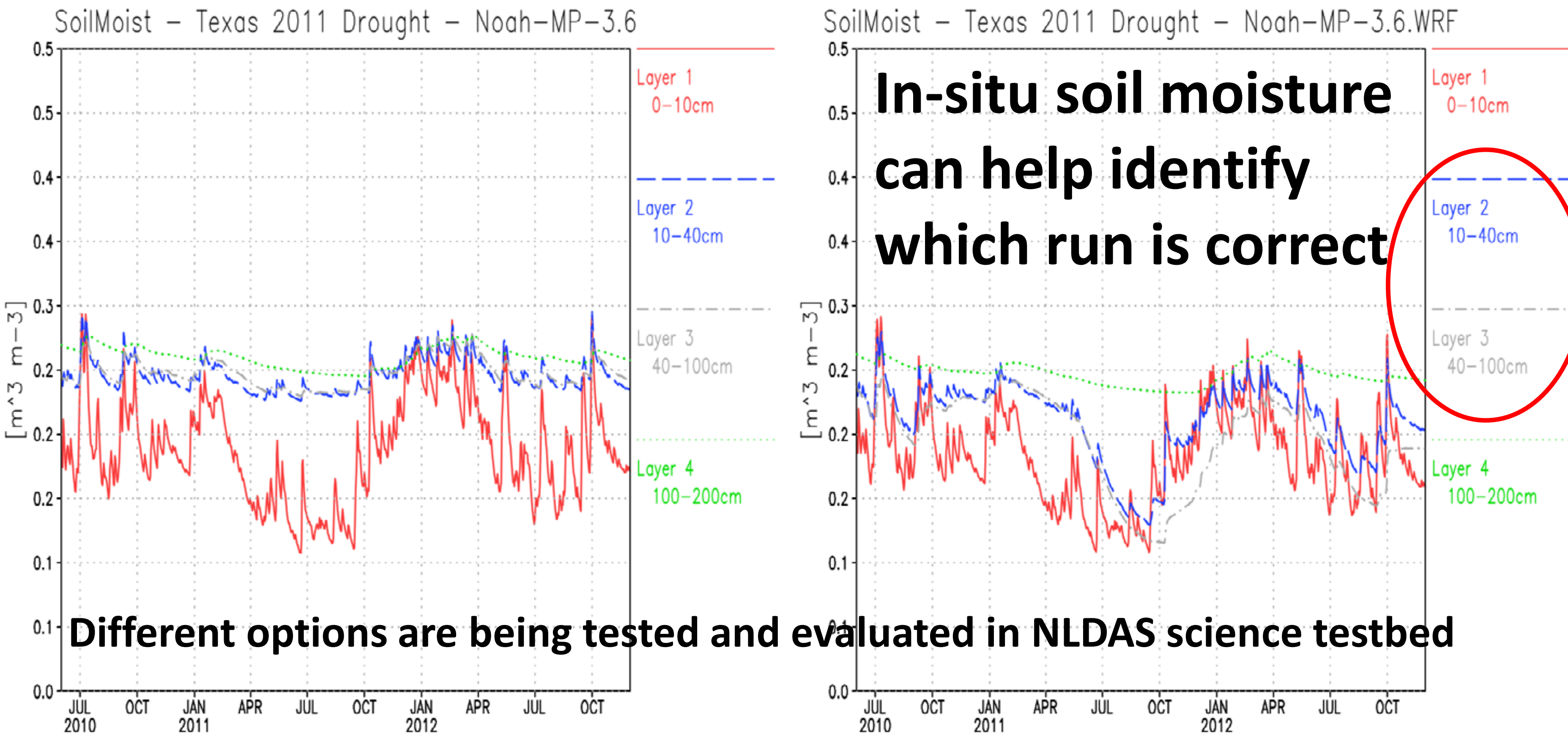




The top 1-m soil moisture does not decrease in TX during 2011 drought, compared to the other runs. GWS behaves similarly between dynamic vegetation and WRF default, although with slightly different mean values. Evaporation is much lower during the summer due to lower GVF and LAI from the dynamic vegetation run.



2011 Texas Drought



In-situ soil moisture can help identify which run is correct

Different options are being tested and evaluated in NLDAS science testbed

These figures now show the 4 soil moisture layers for (LEFT) dynamic vegetation and (RIGHT) WRF default vegetation. The **top layer SM is generally similar, but the 2nd and 3rd layers differ significantly between the runs.** In the dynamic vegetation, there is little drying of the SM, while in the WRF default runs, the soil moisture drops significantly in the late summer.

Future work plan

- **To enhance the collaboration with NSMN scientists to use observed soil data to improve NLDAS product quality and model physical processes understanding**
- **To efficiently use NASA/NCEP joint NLDAS science and evaluation testbed to help R2O task via O2R experiments**
- **To achieve real-time (zero day lag) NLDAS system to meet the public requirements – NLDAS2.5**
- **To transition LIS-based NLDAS system developed at NASA to NCEP to move toward operational implementation (R2O) –NLDAS3.0**
- **To extend NLDAS to North America and 1/8th degree to 1~3 km (NLDAS 3.5 and beyond)**
- **To unify NLDAS with GLDAS to form a unified LDAS system at NCEP**
- **To improve surface forcing, to upgrade soil and vegetation parameter datasets, to add irrigation, vegetation dynamics, groundwater dynamics, lake model , ecosystem processes, biochemistry, carbon and nitrogen dynamics, etc.**

Useful Datasets from NSMN for NCEP/NASA NLDAS team

1. Several example datasets have liquid and frozen soil moisture measurement separately. This will help our model team to check if model physical processes are correct for frozen soil simulation.
2. More soil moisture measurements in middle to east Texas will help us to check if our models can correctly capture soil moisture variation, such as 2011 Texas drought.
3. Harmonized and QC soil moisture and temperature measurement is helpful for NLDAS product evaluation/validation in future.
4. Human management impacts. There should be focused effort to capture the impact and seasonality from human management processes as part of NSMN (from Sujay Kumar)
5. Biases: Right now, the global soil moisture climatology is unknown. The NSMN should consider as part of its core mission to close this gap by bringing the in-situ, model, remote sensing communities together (from Sujay Kumar).

Potential contributions to NSMN from NLDAS Project

1. NLDAS is going to provide spatially and temporally continuous soil moisture estimates from latest models and remote sensing datasets
2. 12 km and high-resolution NLDAS (1-3 km) soil product, snow water equivalent, terrestrial water storage, groundwater, simulated/predicted LAI, greenness fraction, and ET
3. NLDAS soil products with reasonable soil physics explanations
4. Gridded data in national, North America, and global domain

Comments/Suggestions to:

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