Comparison analysis between operational and LIS-based NLDAS drought monitor

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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.

Acknowledgements: Numerous members of both the NLDAS and LIS teams over the last 15+ years

1 – NASA/GSFC; 2 – SAIC; 3 – NOAA/NCEP/EMC; 4 – IMSG

Goals/Outline

What is the value of each model to the ensemble when monitoring drought?

How does each individual model depict drought through case studies?

Outline:

1) Comparison between operational and LIS-based NLDAS drought monitoring
2) Similarity of drought depiction and correlation to USDM
3) Closer look at Noah-MP physics options with respect to drought depiction
4) Quick look at behavior of new Noah SOILPARM parameter values

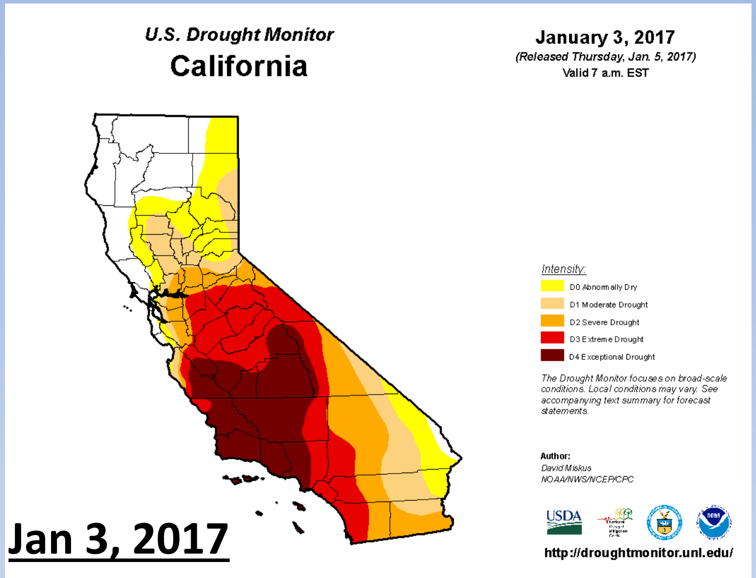
NLDAS Science Testbed

The LIS group has developed an NLDAS Science Testbed, designed to test LSMs, parameters, and data assimilation within the **Land Information System (LIS)** using the NLDAS configuration. These simulations are also being evaluated against the four operational LSMs running in NLDAS Phase 2.

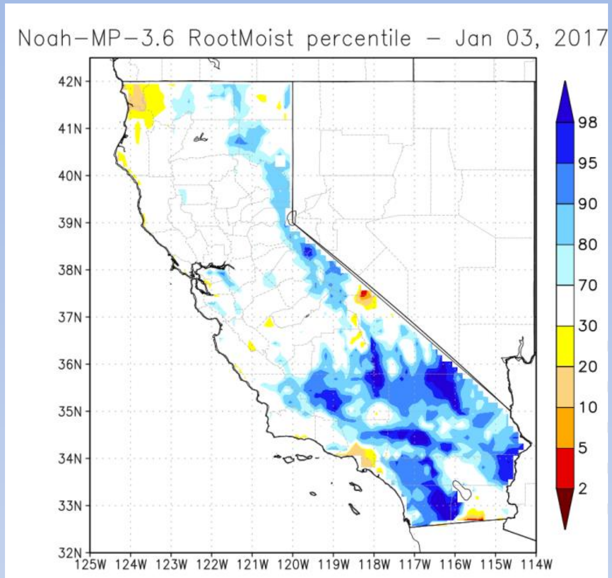
- Spin-Up #1: 35 years (1979 to 2014) – climatological average states of the last 30 years of the run used to initialize the next spin-up
- Spin-Up #2: 35 years (1979 to 2014) – climatological average states of the last 30 years of the run used to initialize the final run
- Final output: 38 years (1979 to 1 March 2017)
- Climatological period for percentiles: 1 Mar 1979 to 1 Mar 2017 (38 years)
- Evaluation: Using the **Land Verification Toolkit (LVT)** to evaluate snow, soil moisture, ET/fluxes, surface radiation, runoff, streamflow, groundwater, etc.

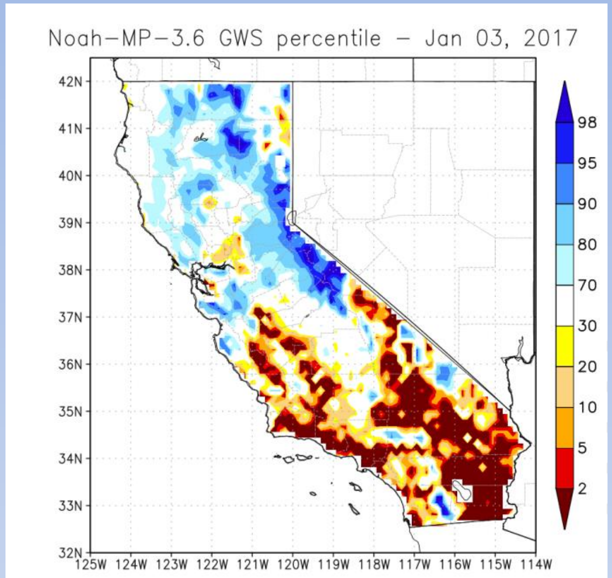
California winter drought reduction 2016-2017

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.

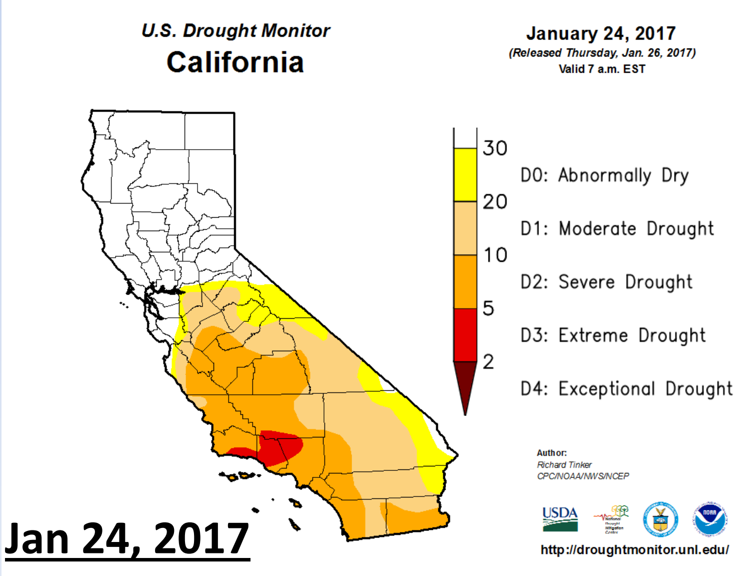


Jan 3, 2017

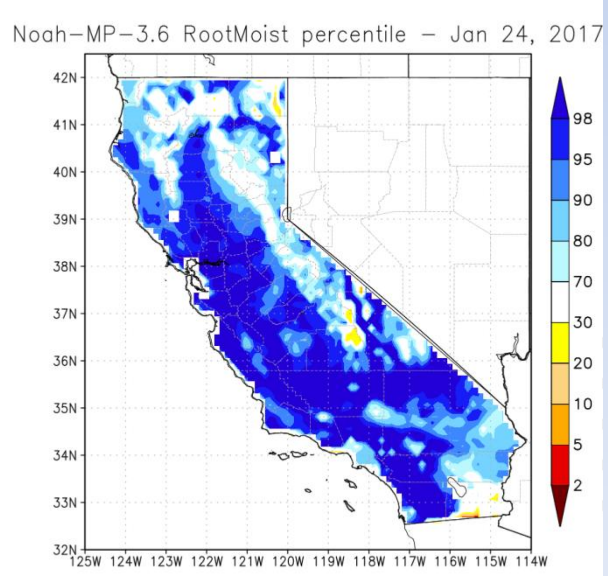


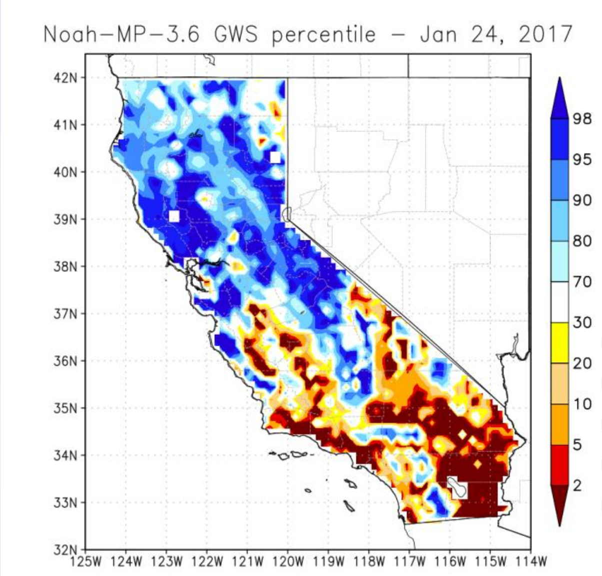


U.S. Drought Monitor **LIS Noah-MP Top 1-m soil moisture**



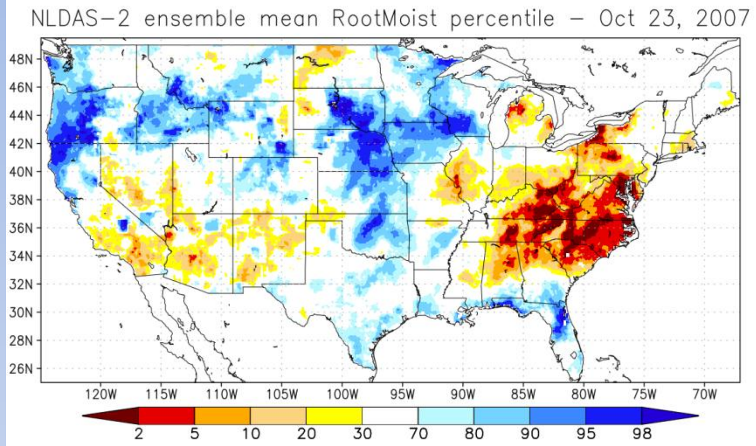
Jan 24, 2017

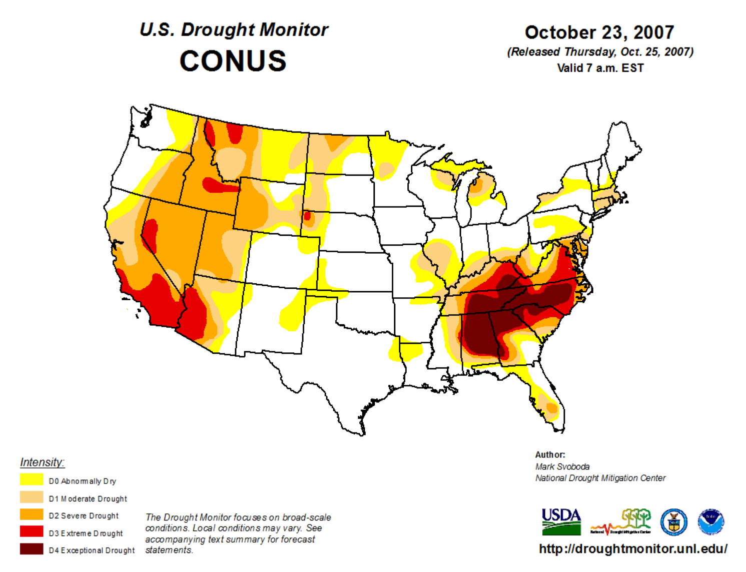




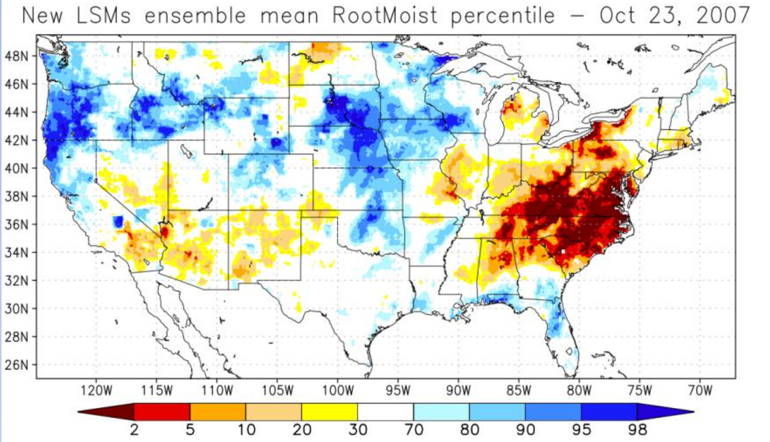
Oct 23, 2007 – Southeast Drought

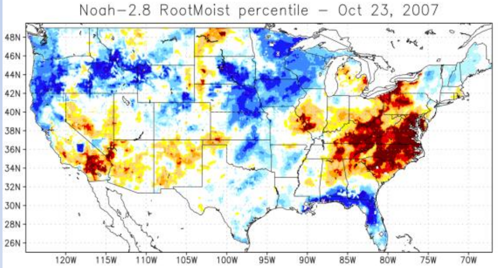
NLDAS-2 operational LSMs

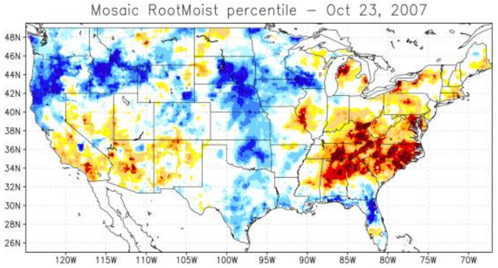


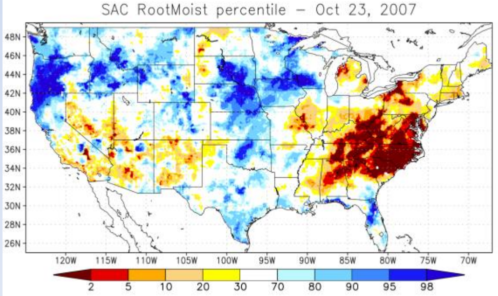


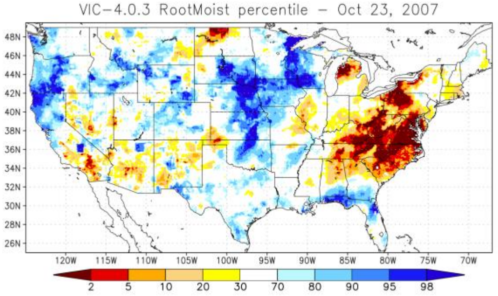
LIS LSMs for next phase

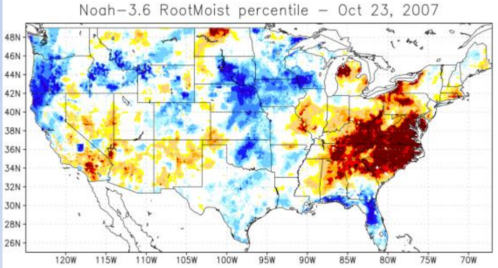


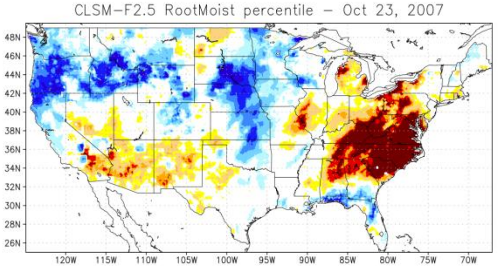


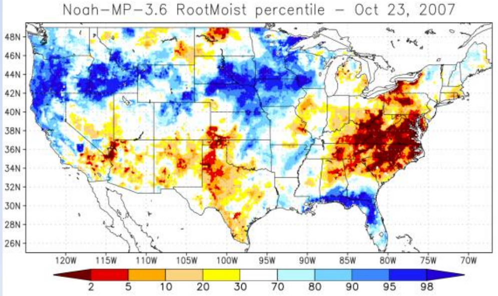


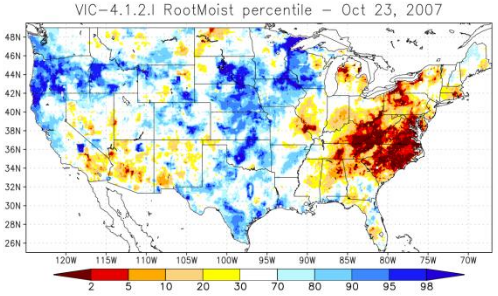






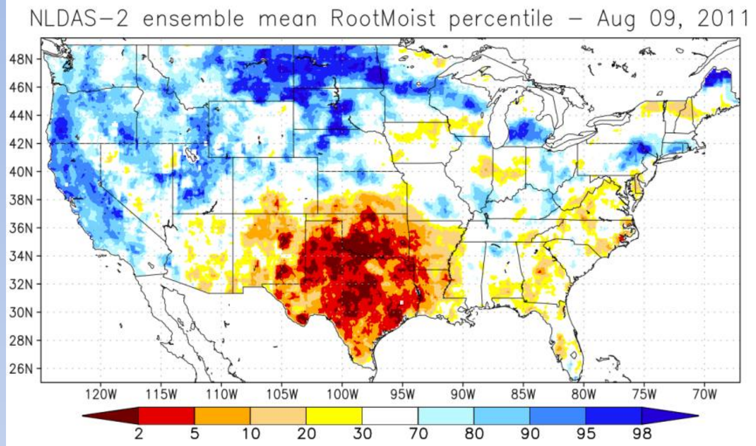


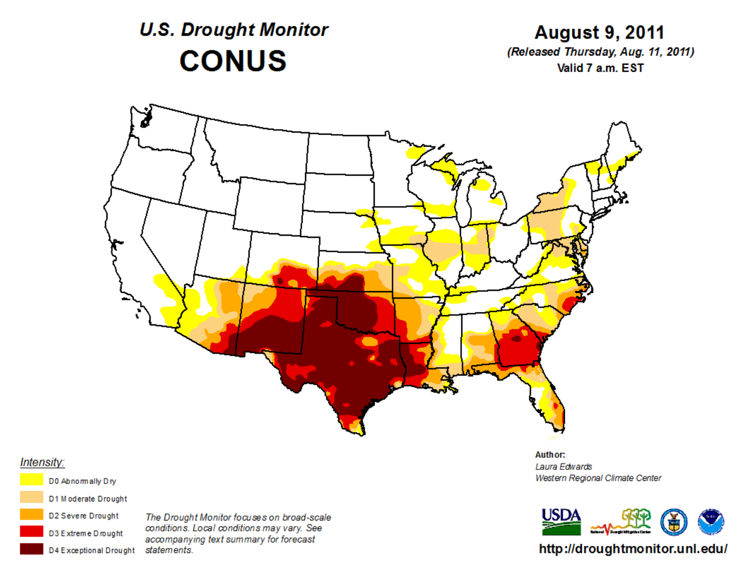




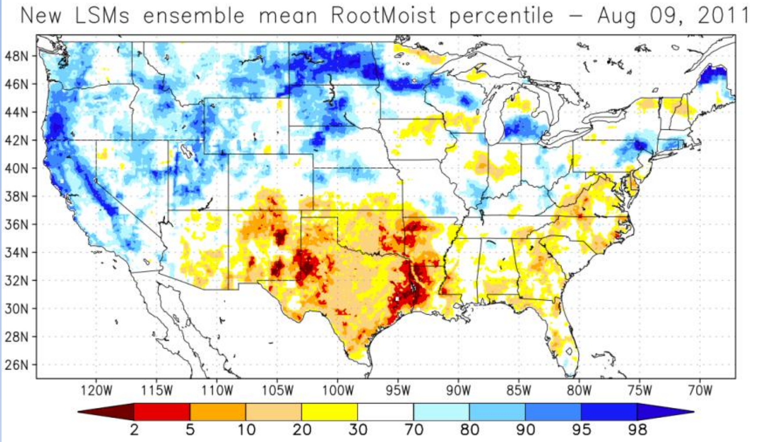
Aug 09, 2011 – Texas Drought

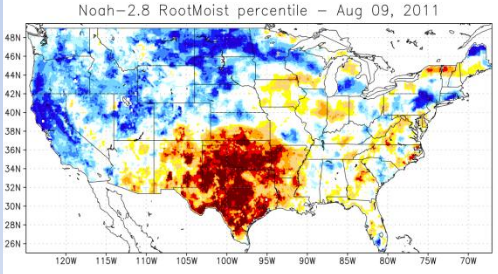
NLDAS-2 operational LSMs

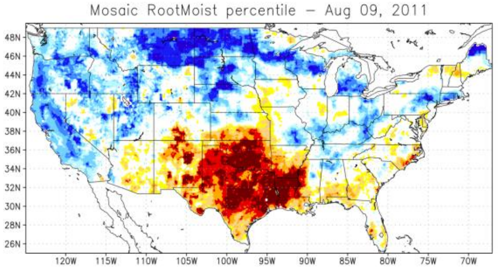


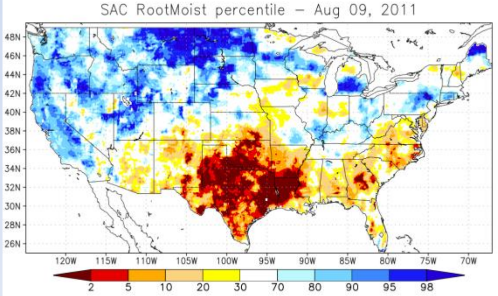


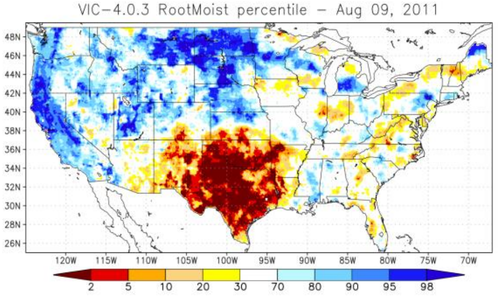
LIS LSMs for next phase

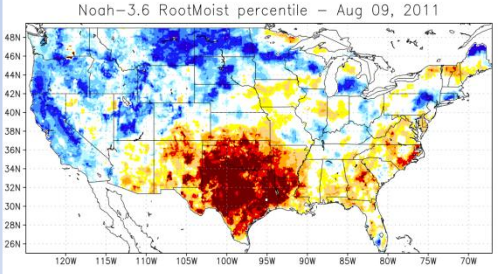


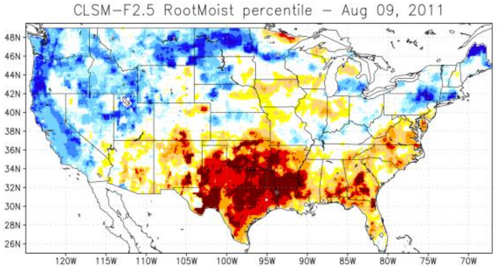


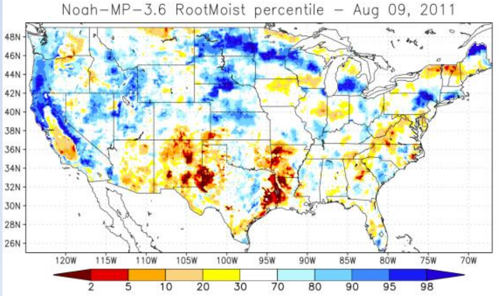


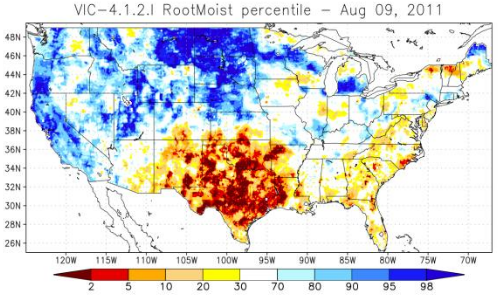






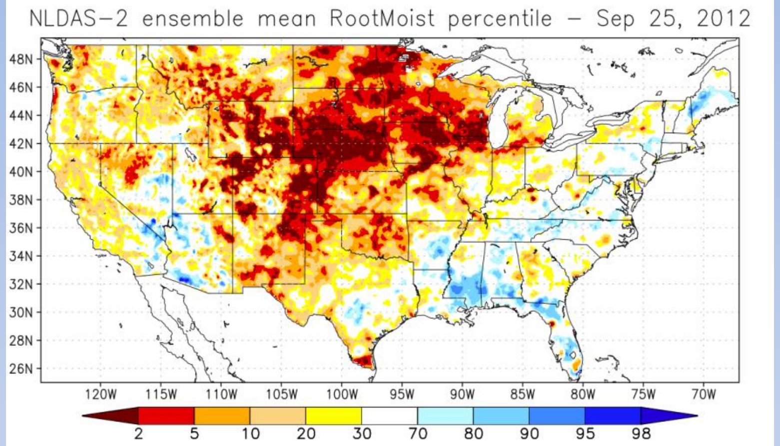


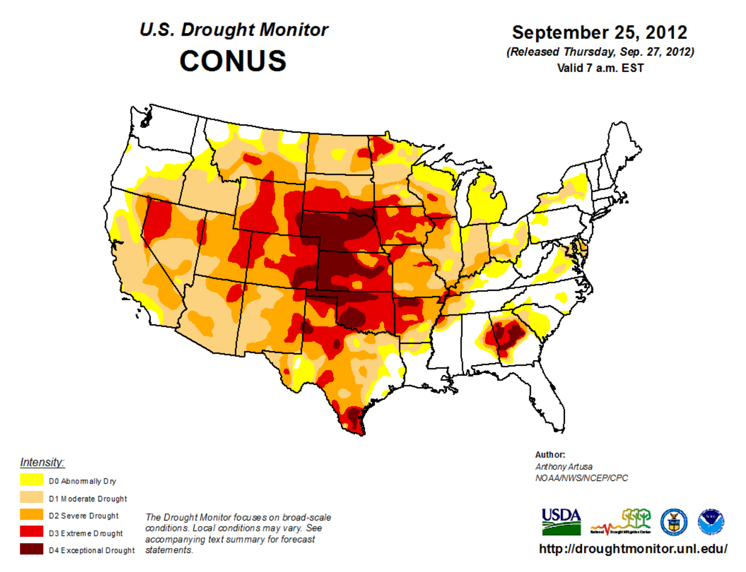




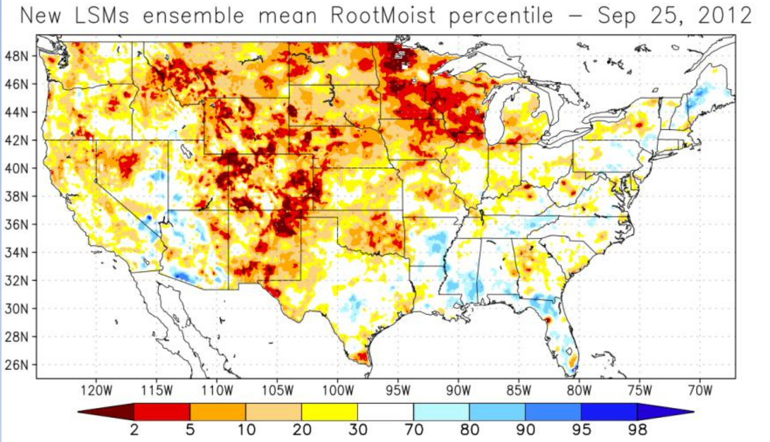
Sep 25, 2012 – Great Plains Drought

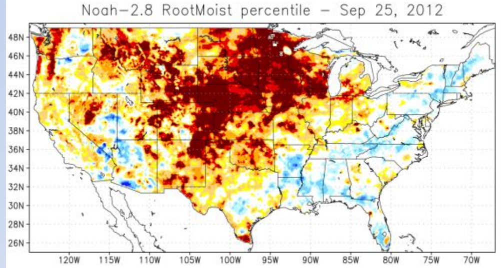
NLDAS-2 operational LSMs

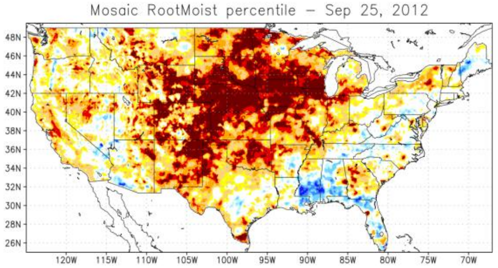


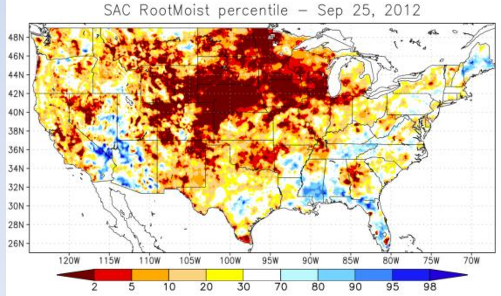


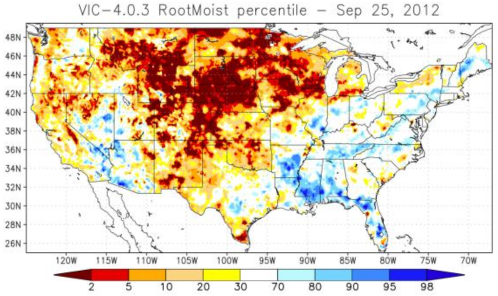
LIS LSMs for next phase

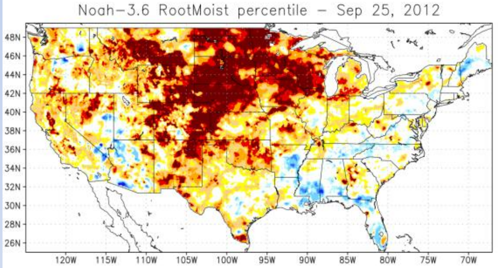


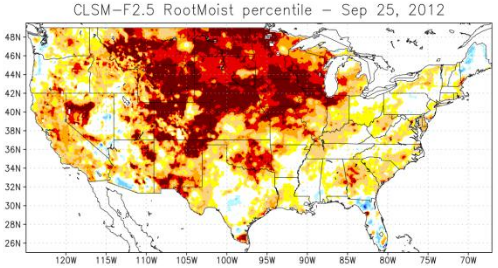


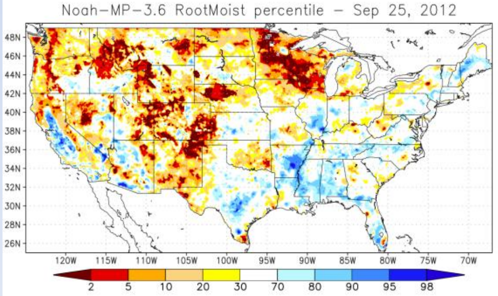


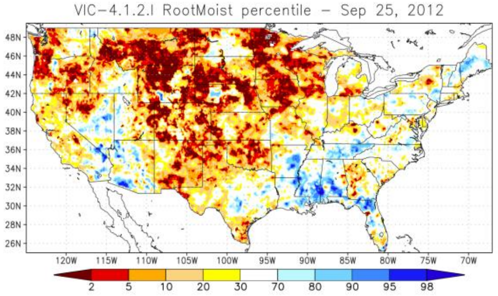










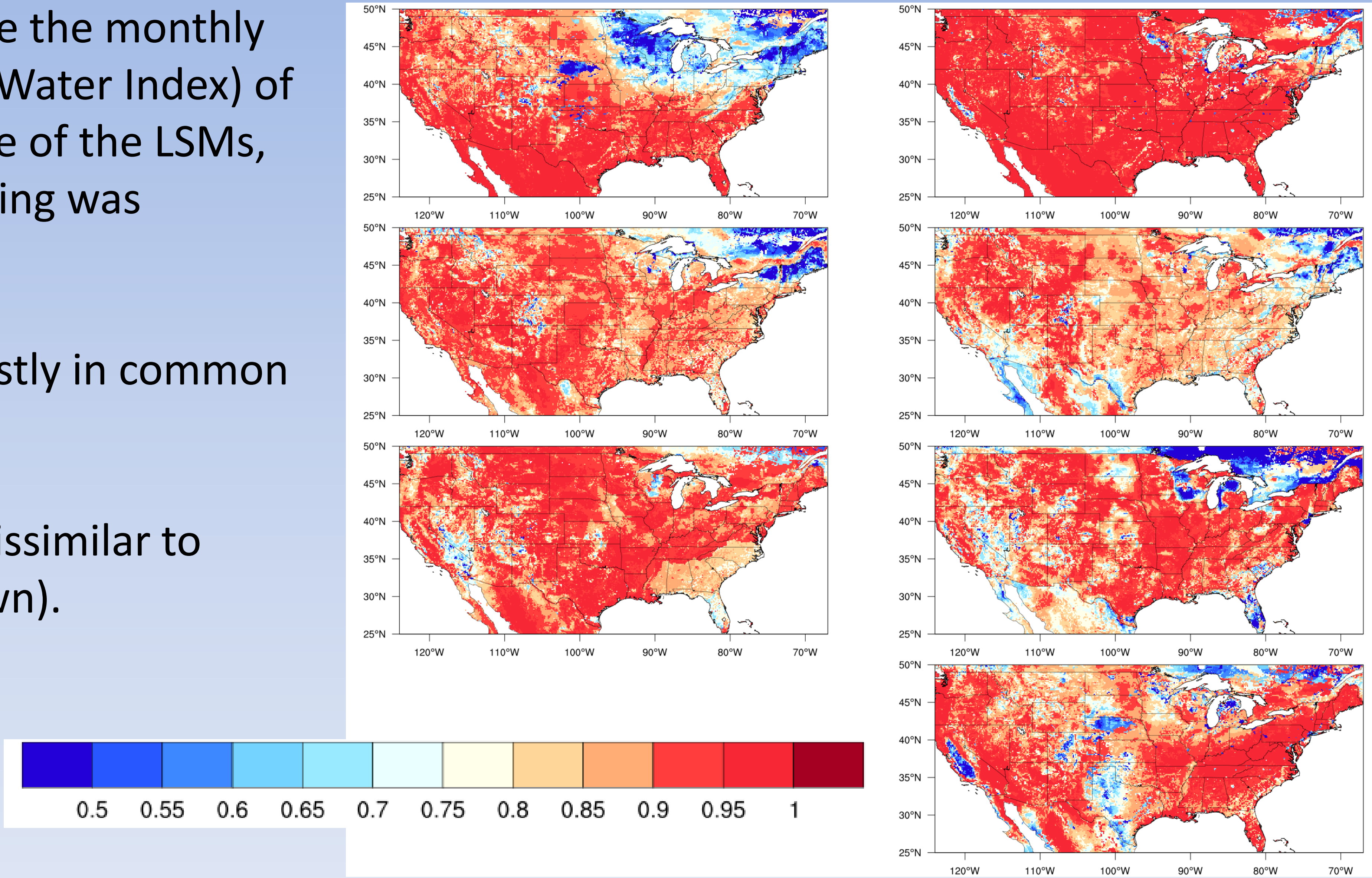


Monthly SSWI similarity

LVT was used to calculate the monthly SSWI (Standardized Soil Water Index) of the top 1-m soil moisture of the LSMs, and then the factor loading was calculated.

Noah-3.6 results are mostly in common with other models.

SAC results are mostly dissimilar to other models (now shown).

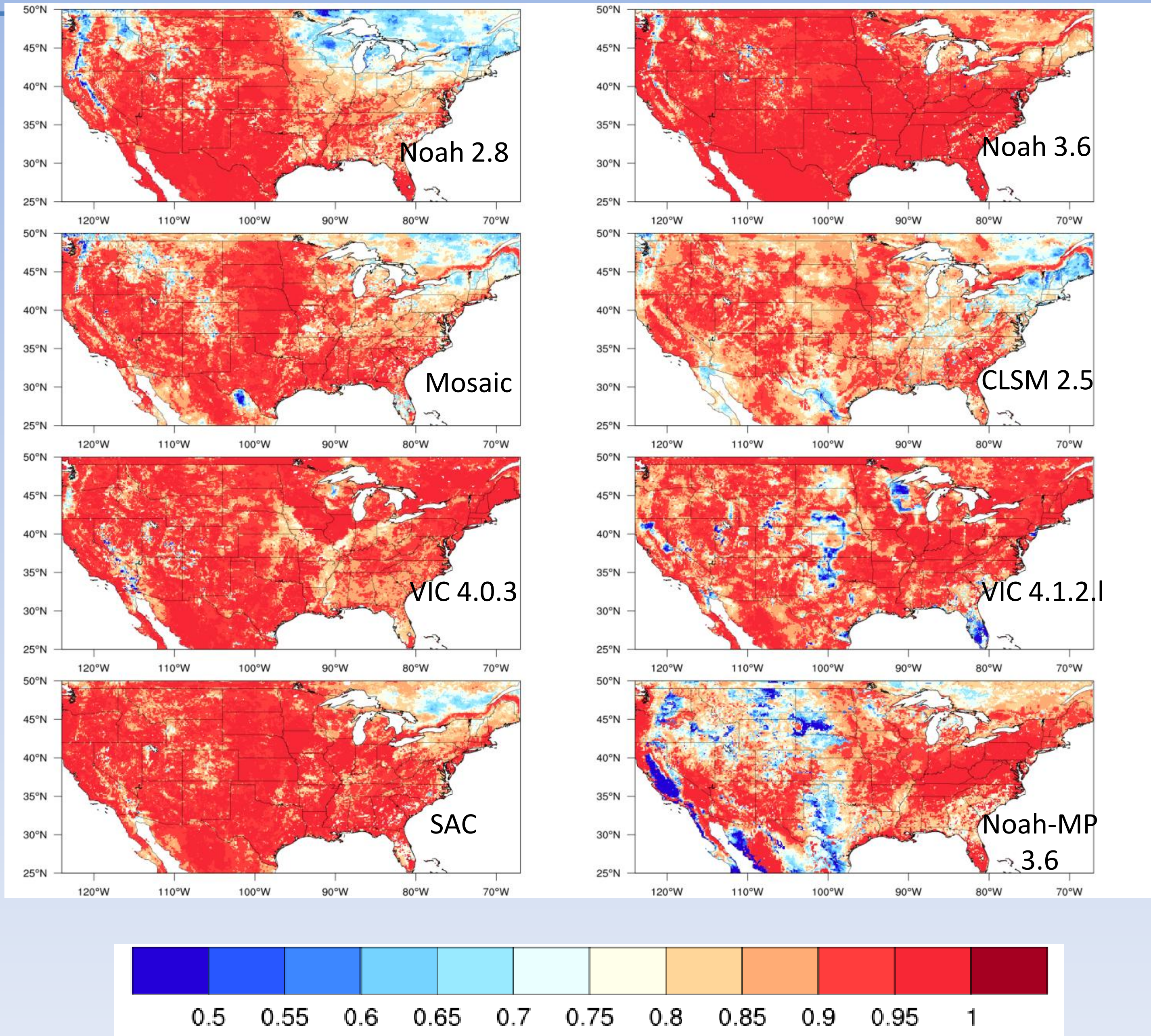


Daily factor loading of top 1-m SM percentiles

These figures show the similarity of the top 1-meter soil moisture percentiles over a 38-year period. Values close to one indicate that that particular LSM is similar to the common factor of all 8 of the LSMs.

There re some differences amongst the models (particularly in the Northeast and in parts of the Great Plains), but there is much more similarity in the soil moisture percentiles.

Noah-MP-3.6 often shows the most dissimilarity, particularly in areas with a deep groundwater storage (California Central Valley, West Texas, Great Plains).

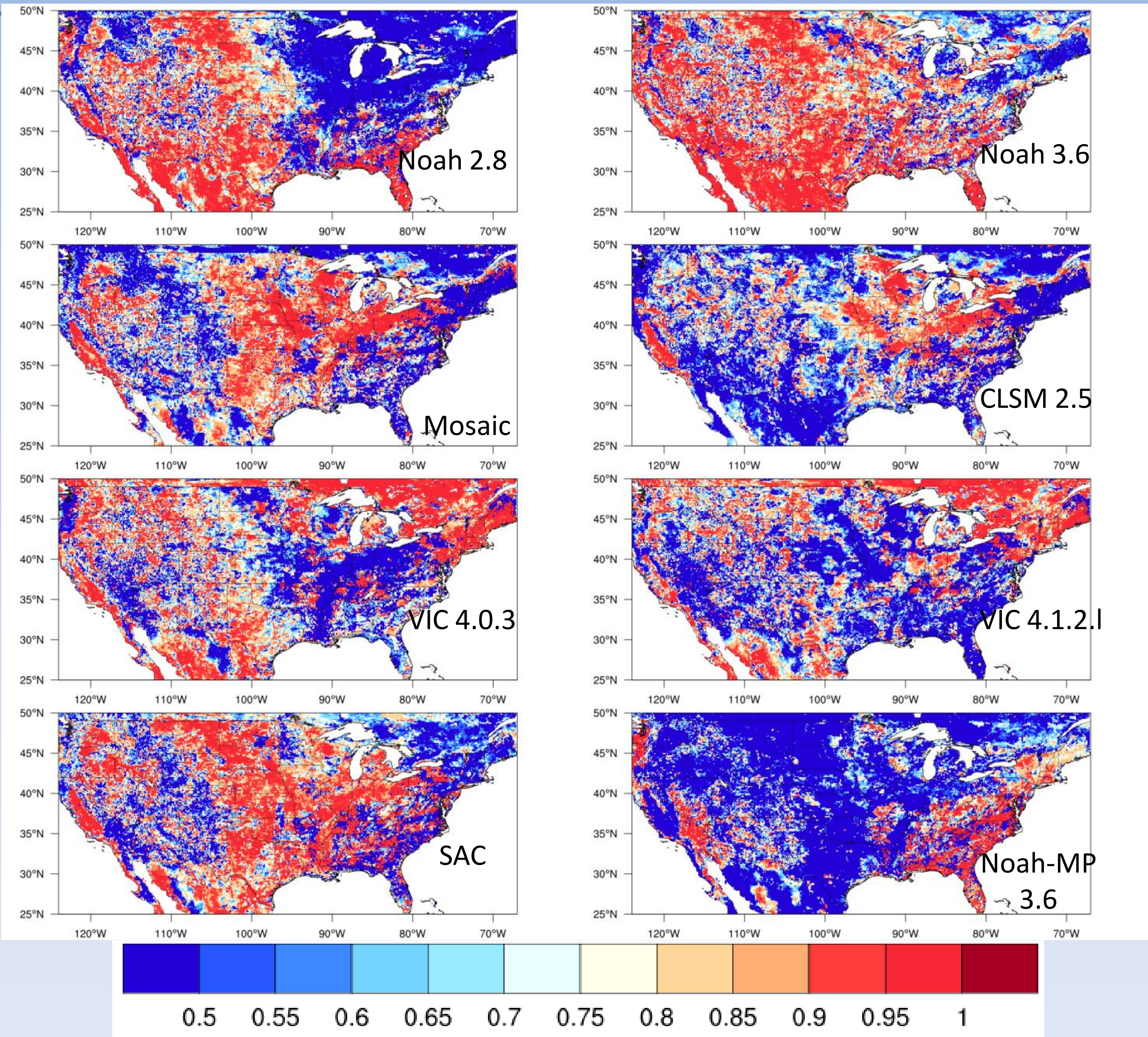


Daily factor loading of only driest 5th percentile

Data selection is conducted grid box by grid box. For the 8 models, if any of them have percentile value <= 0.05, then the percentile outputs of the 8 models are selected. This means that the record number of selected data are different among the NLDAS grid boxes. Factor analysis is conducted if the record number of data is >= 30. For a grid box, at least one value of percentile is less than or equal to 0.05 for a selected day.

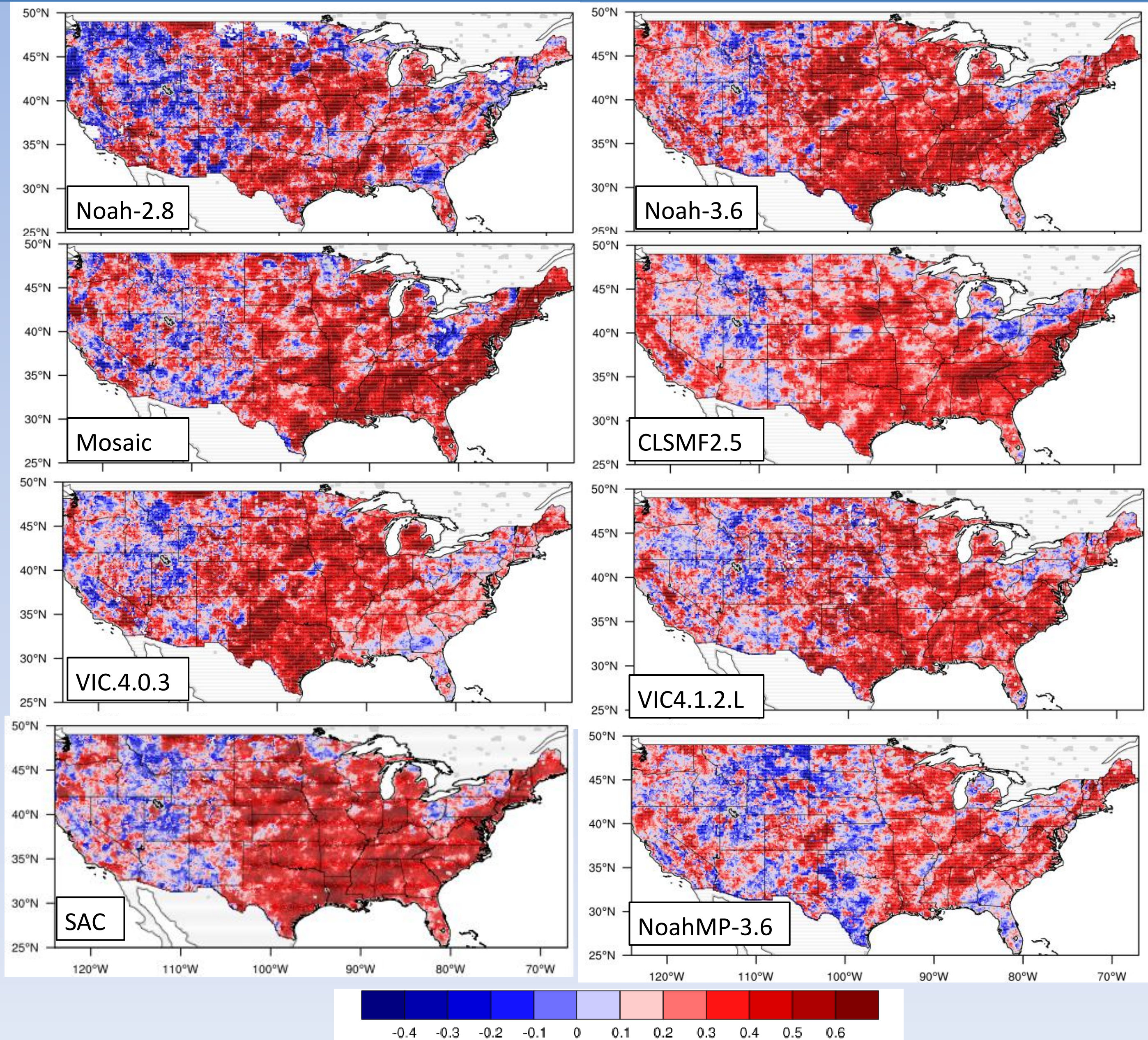
We see much bigger differences than the full distribution.

5^{th} percentile or drier = D3 or D4 drought

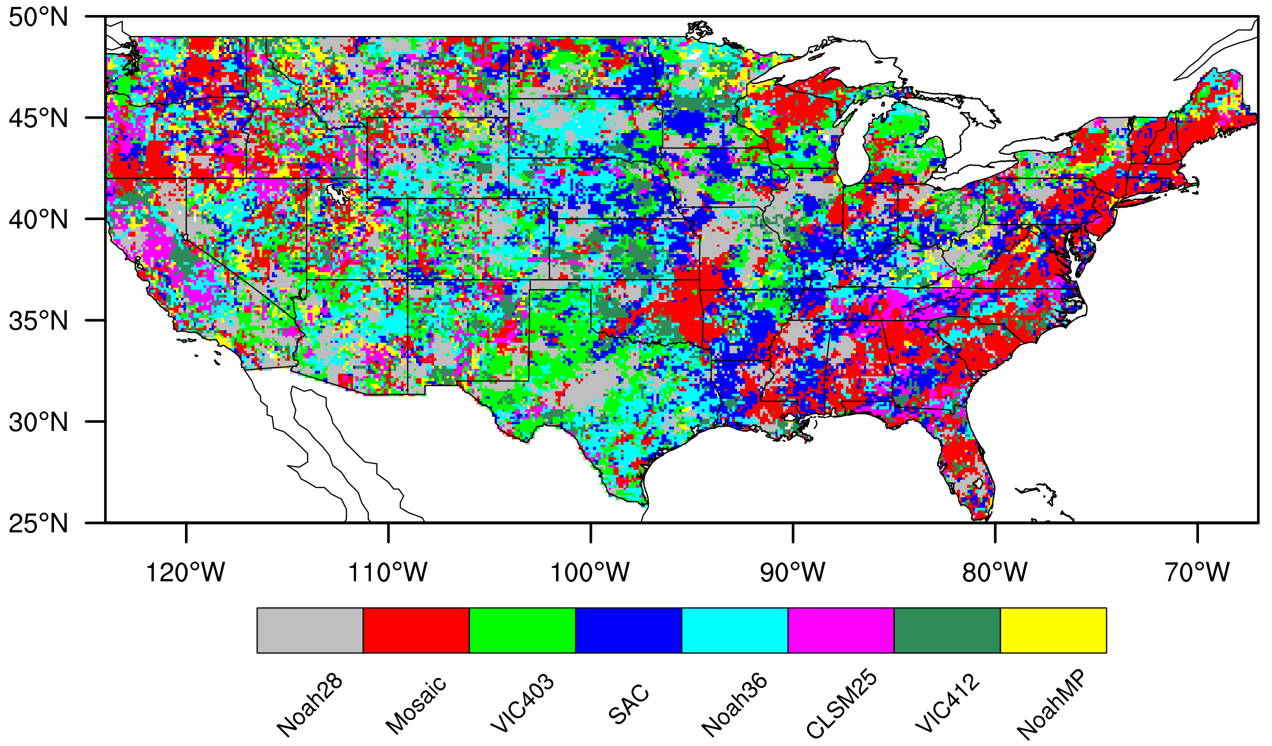


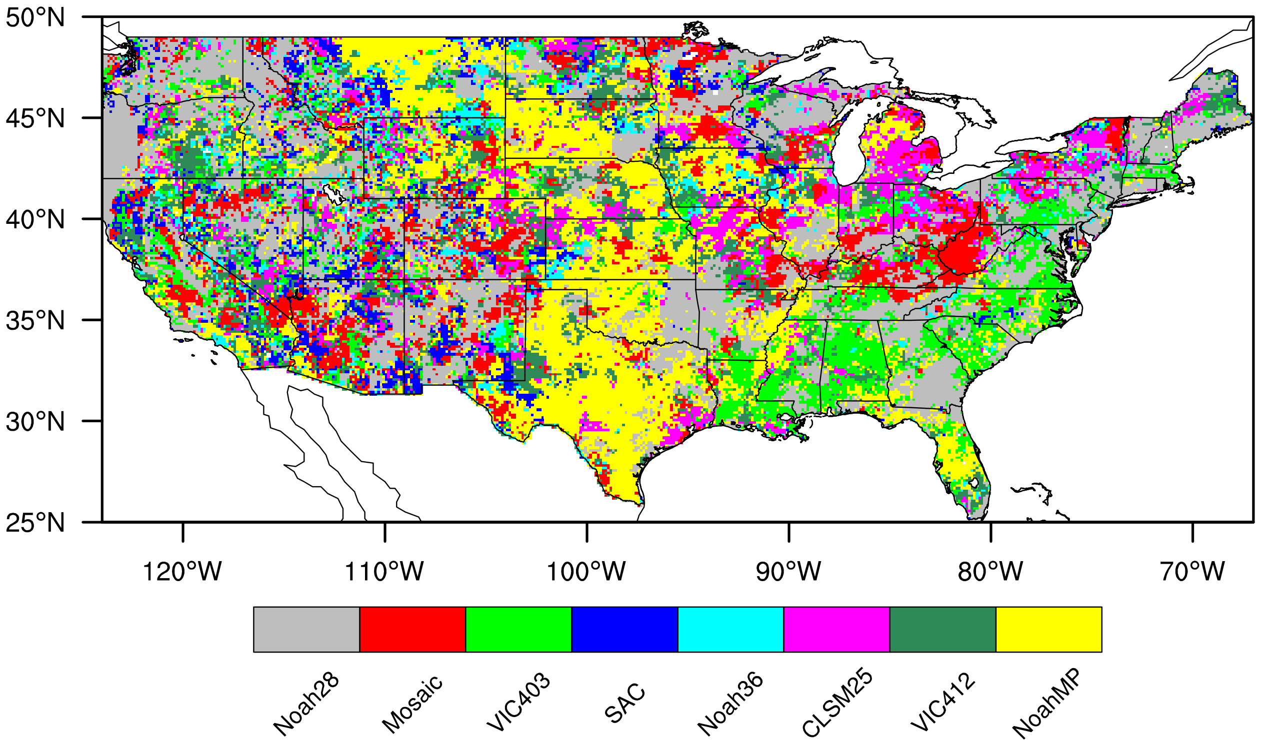
Correlation of USDM and top 1-m SM percentiles

Using LVT, the correlation of digitized USDM drought categories and of drought categories from the top 1-m soil moisture percentiles of each LSM were calculated.



Correlation of USDM and top 1-m SM percentiles





Best correlation to USDM

Worst correlation to USDM

These figures depict the model with the best correlation (left) and the worst correlation (right) amongst all 8 LSMs as compared to USDM. The comparison is between the top 1-meter soil moisture percentiles calculated from each LSM.

Description of the Noah-MP experiments

Noah-MP-3.6:

- This is the run that was used in the previous results
- Dynamic vegetation
- Groundwater (SIMGM) – TOPMODEL with groundwater

Noah-MP-3.6.WRF:

- WRF default (Table LAI and maximum GVF)
- Groundwater (SIMGM) – TOPMODEL with groundwater

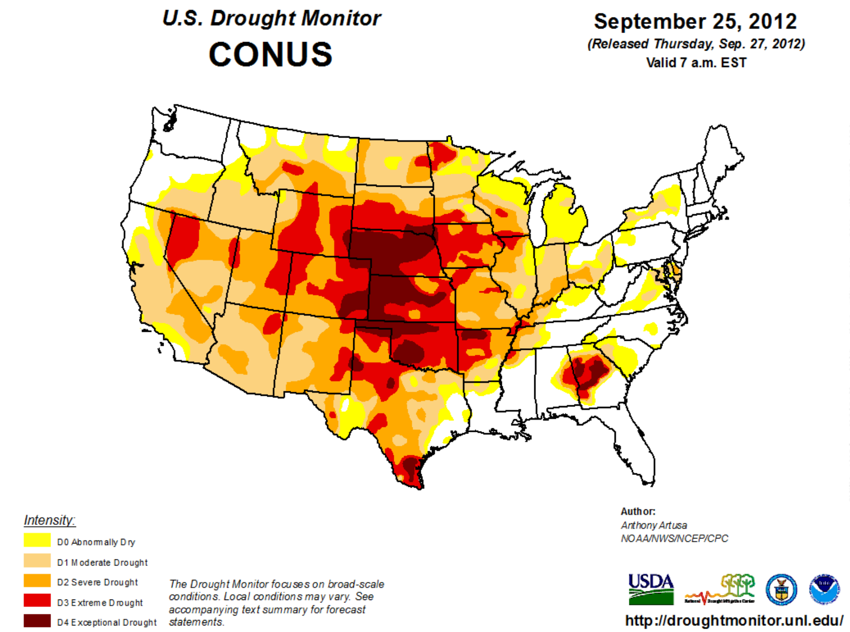
Noah-MP-3.6.SIMTOP:

- WRF default (Table LAI and maximum GVF)
- SIMTOP – TOPMODEL with equilibrium water table

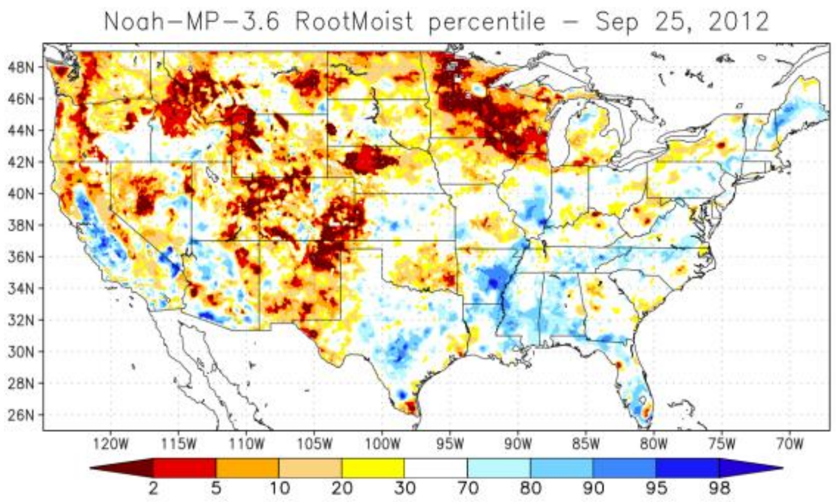
Noah-MP-3.6.Noah:

- WRF default (Table LAI and maximum GVF)
- Noah surface and subsurface runoff (free drainage)

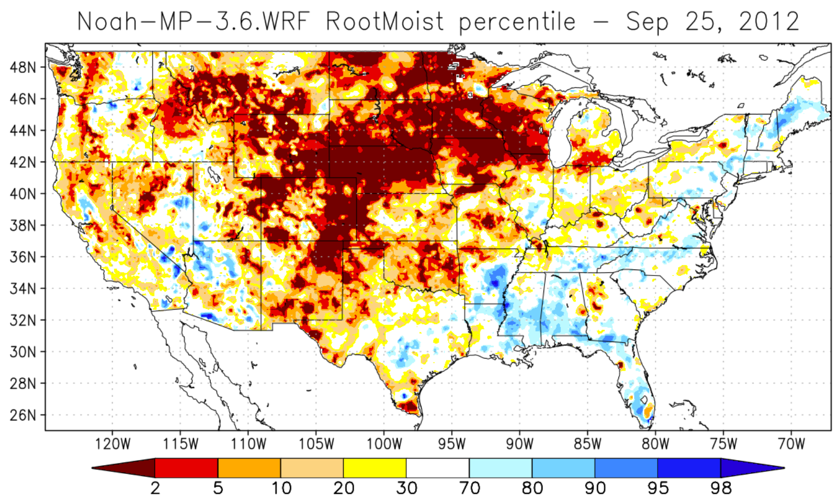
Sep 25, 2012 – Great Plains Drought



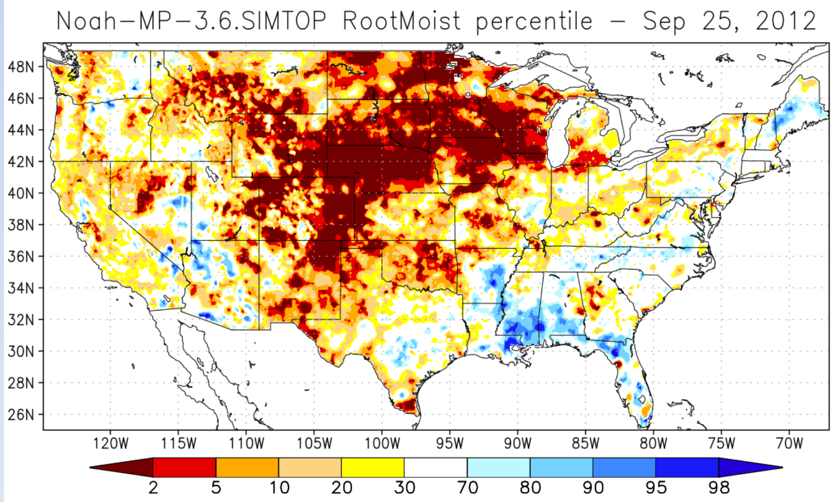
Dynamic vegetation with GW



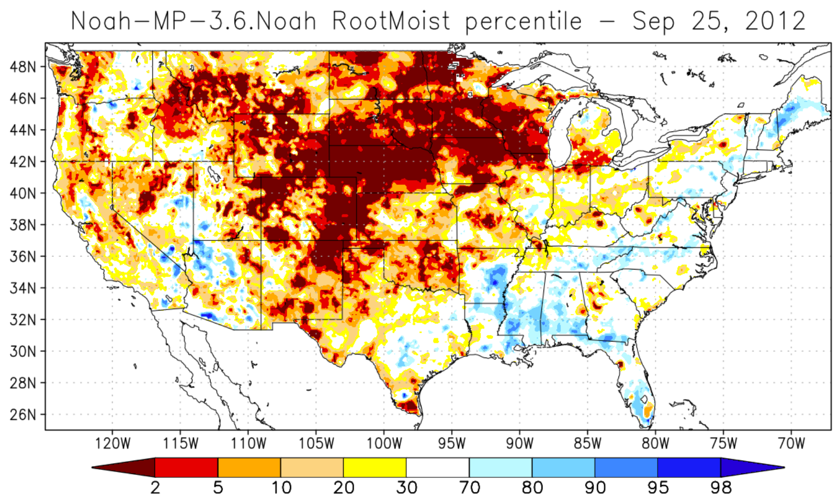
WRF default vegetation with GW



Equilibrium water table

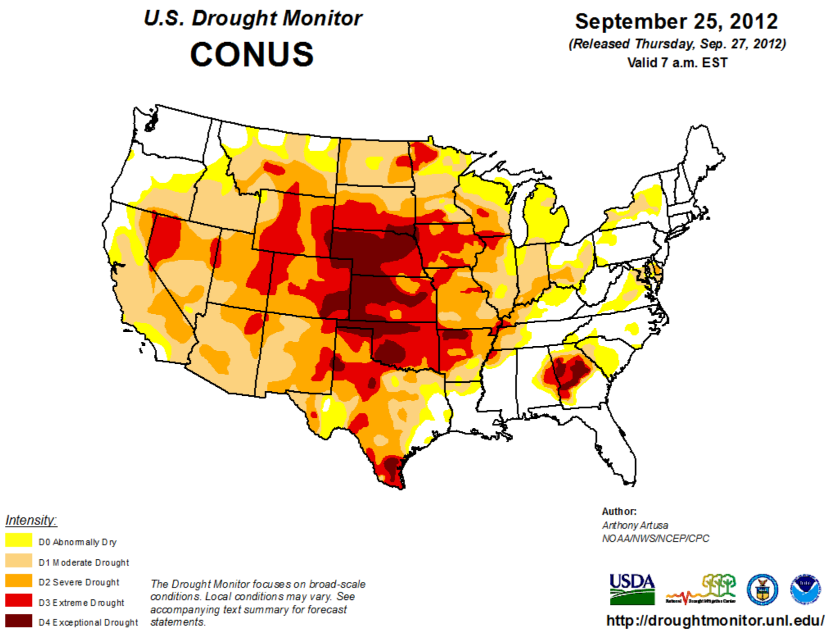


Noah free drainage

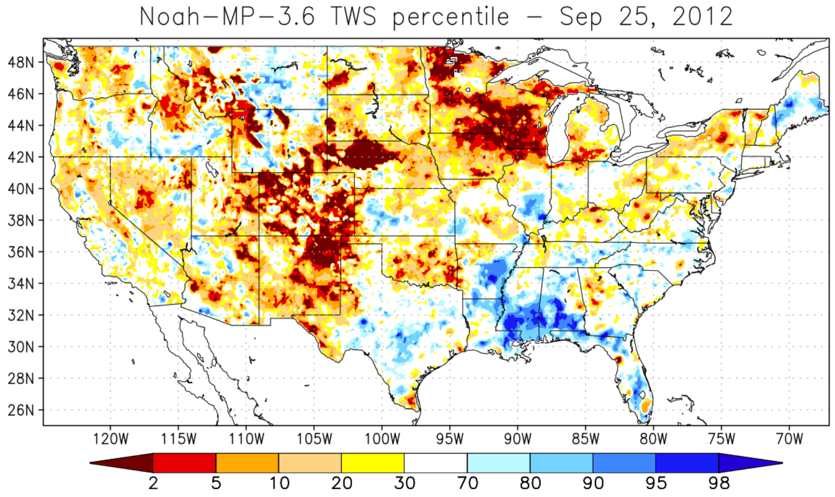


Looking at the difference between the top two LIS outputs, it's clear that the dynamic vegetation is causing the weak drought over the northern Great Plains in the **top 1-m soil moisture**. The bottom two results are generally similar to the WRF with GW (all three runs use the default vegetation), showing that the groundwater does not have a big effect on the top 1-m soil moisture percentiles.

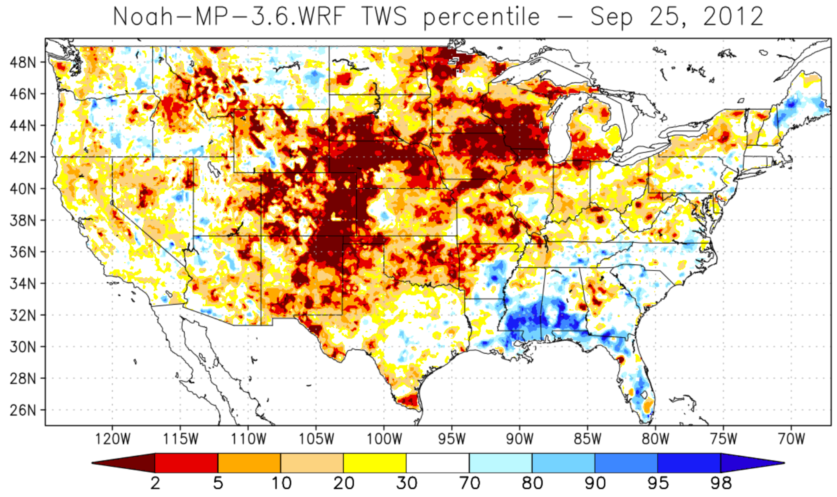
Sep 25, 2012 – Great Plains Drought



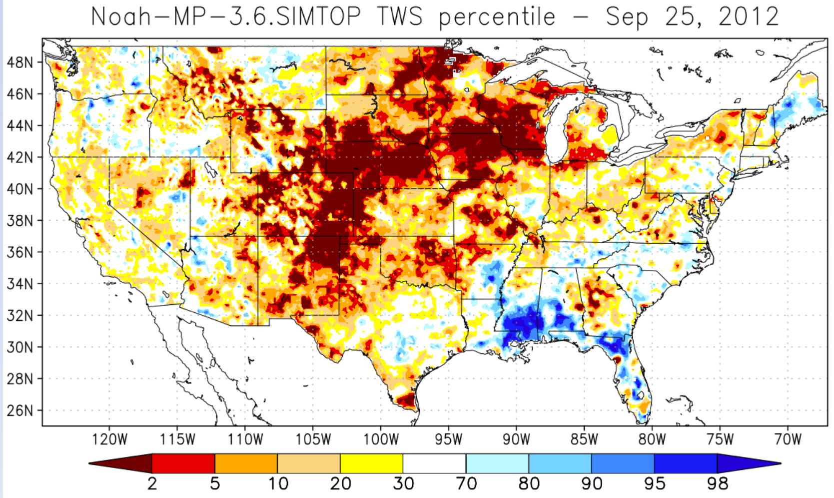
Dynamic vegetation with GW



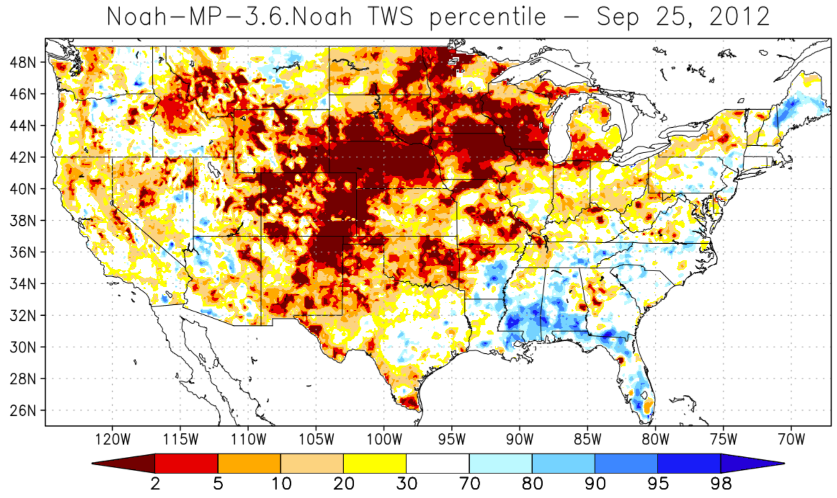
WRF default vegetation with GW



Equilibrium water table

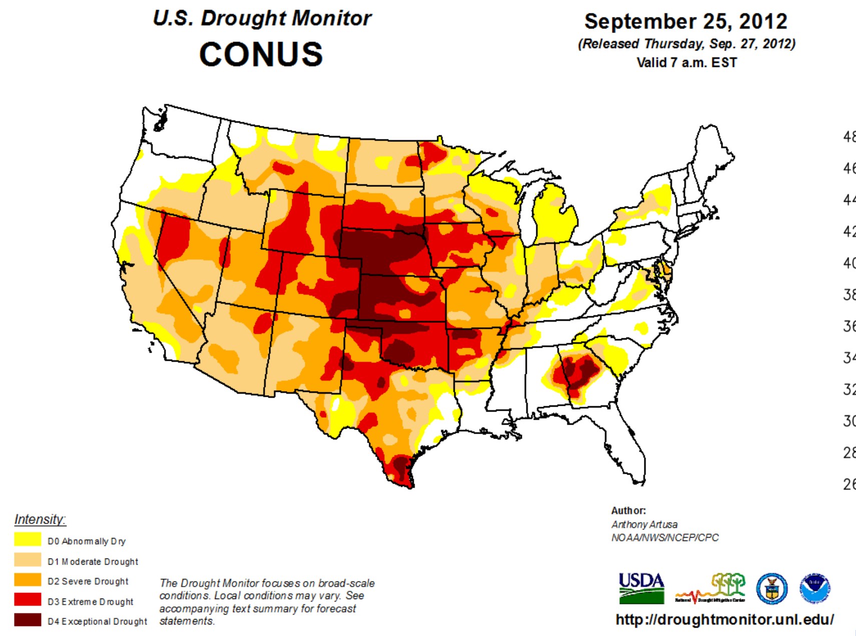


Noah free drainage

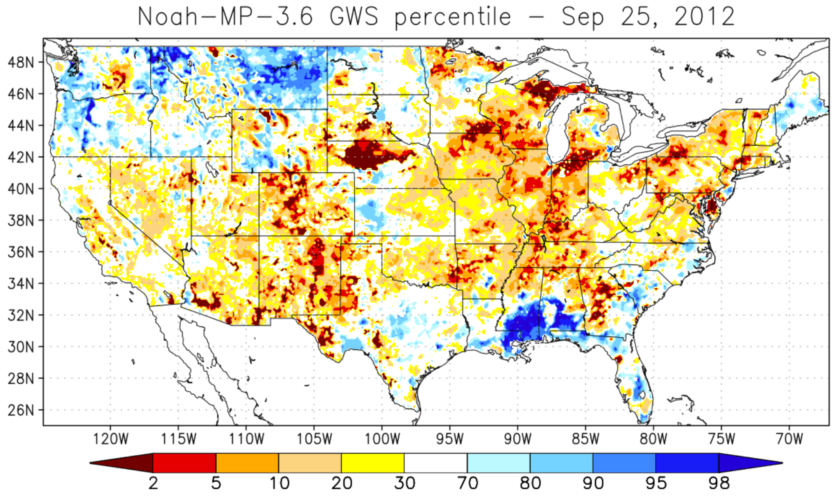


These figures are for the **terrestrial water storage (TWS)**. TWS is the sum of the soil moisture, groundwater, mass of the snow cover and mass of water/snow on the canopy. The bottom two options do not have a separate groundwater storage, and depict a slightly stronger drought than the WRF default run with groundwater.

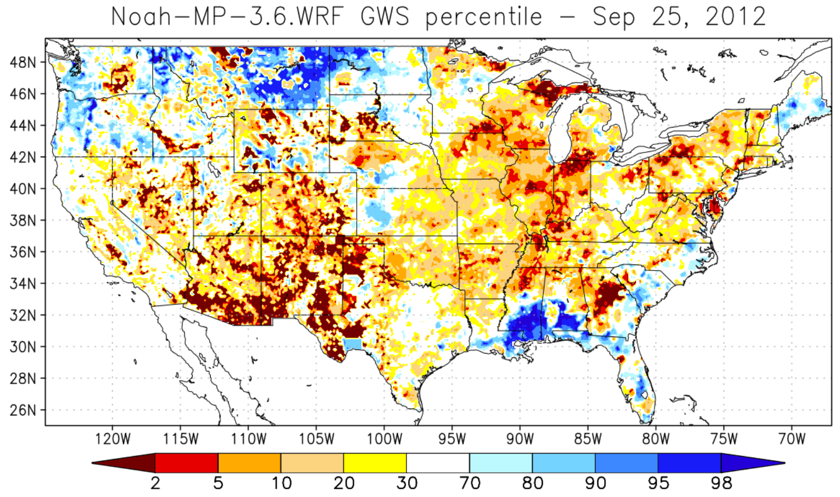
Sep 25, 2012 – Great Plains Drought



Dynamic vegetation with GW



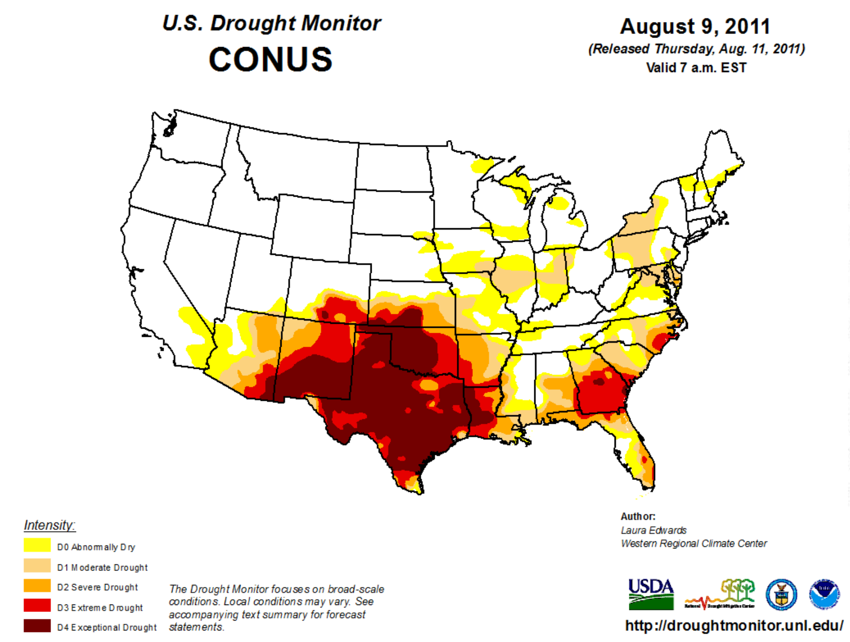
WRF default vegetation with GW



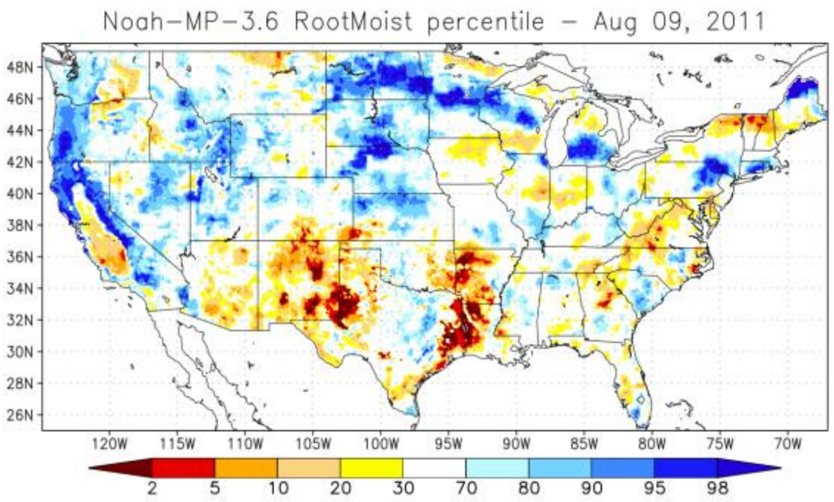
These figures are for the **ground water storage (GWS)**. The bottom two options do not have a separate groundwater storage.

GWS is much more similar between dynamic vegetation and WRF default

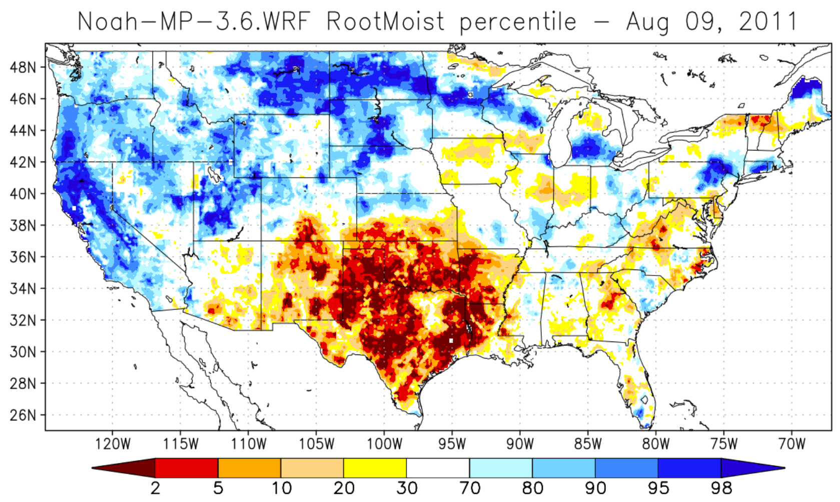
Aug 09, 2011 – Texas Drought



Dynamic vegetation with GW

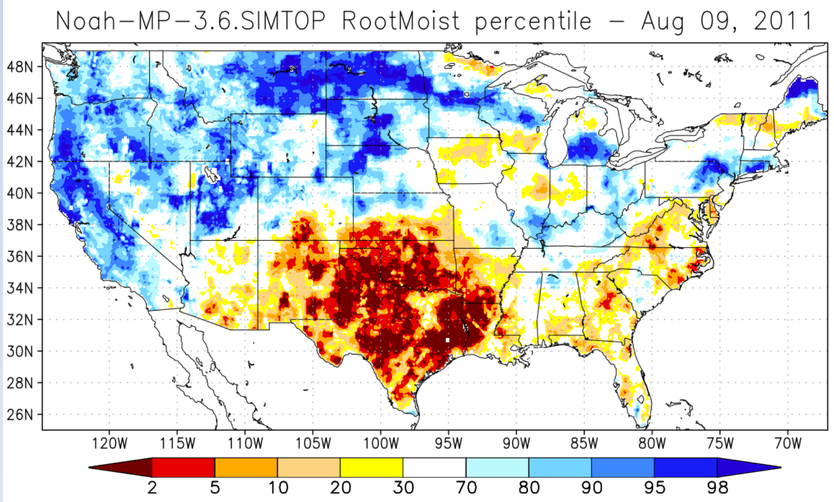


WRF default vegetation with GW

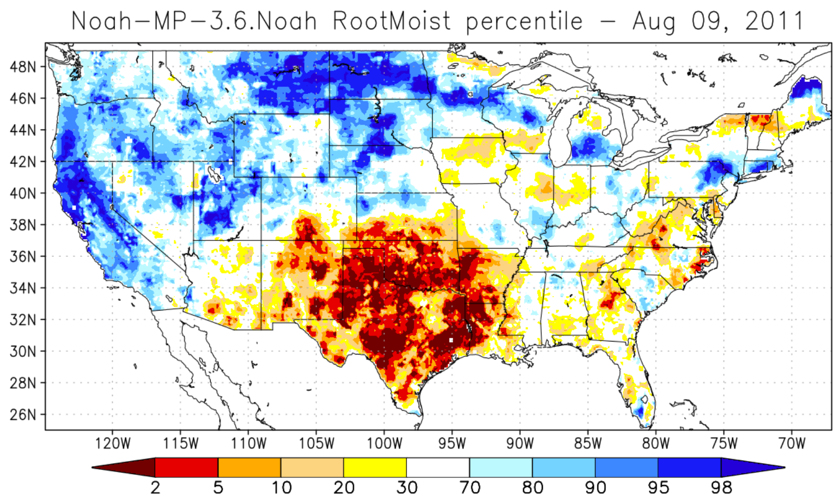


Looking at the difference between the top two LIS outputs, it's clear that the dynamic vegetation is causing the weak drought over Texas in the **top 1-m soil moisture**. The bottom two results are generally similar to the WRF with GW (all three runs use the default vegetation), showing that the groundwater does not have a big effect on the top 1-m soil moisture percentiles.

Equilibrium water table



Noah free drainage



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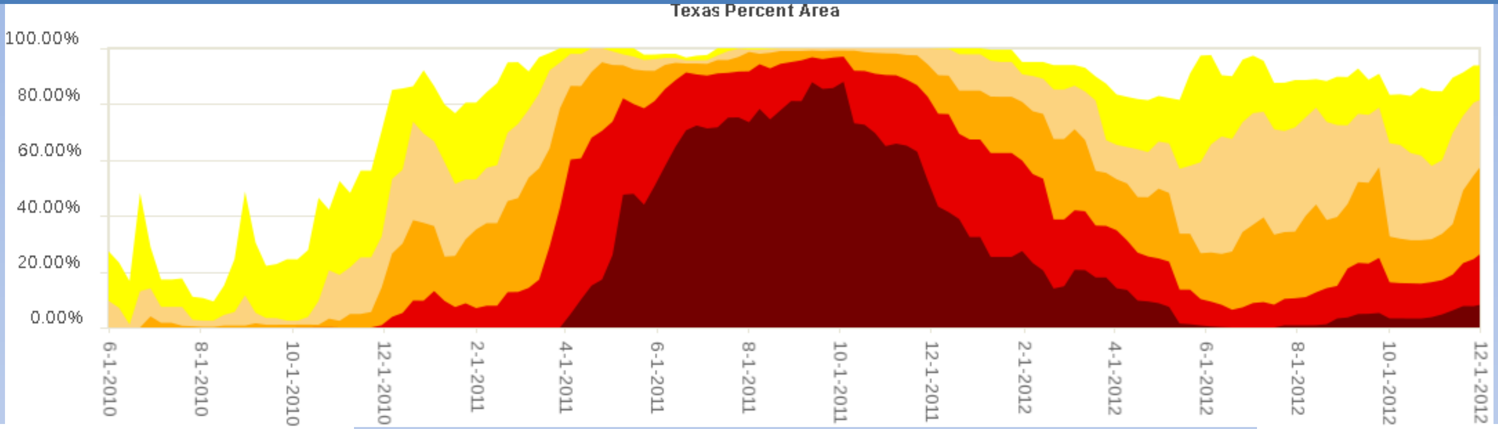
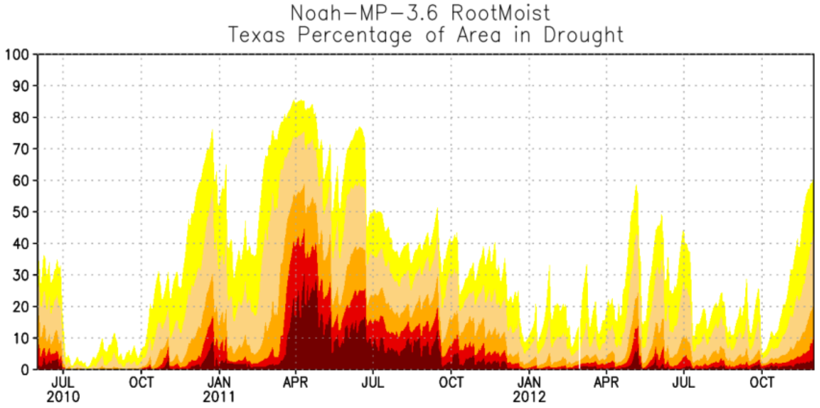
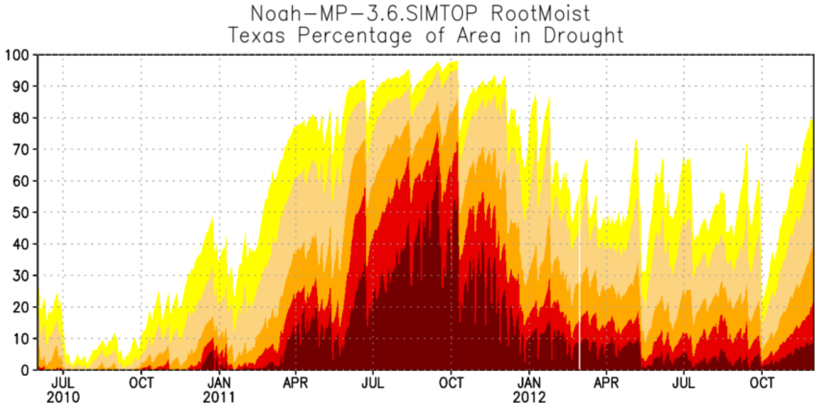
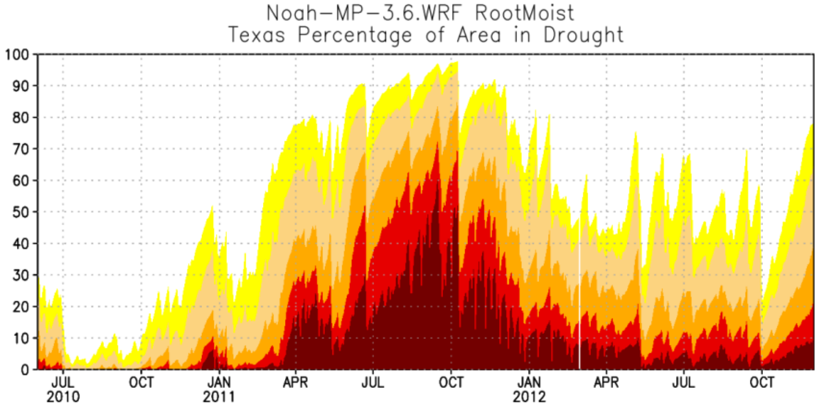
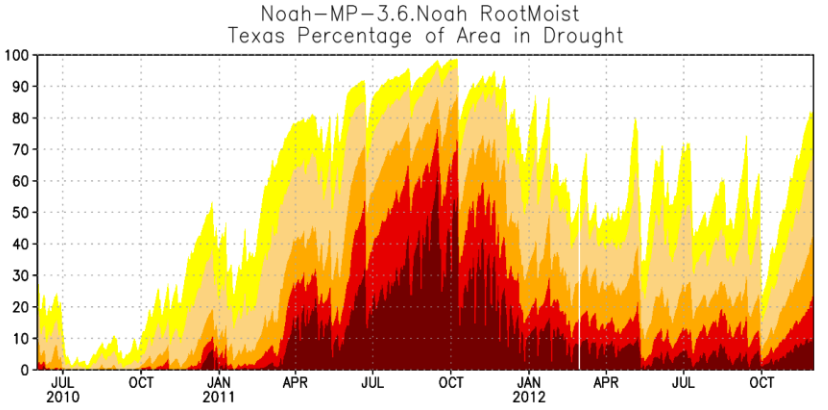






The dynamic vegetation run (upper left) misses the summer 2011 TX drought in the top 1-m soil moisture. The runs that use WRF default vegetation do a better job, and are similar to each other, despite using groundwater, equilibrium water table, or free drainage.





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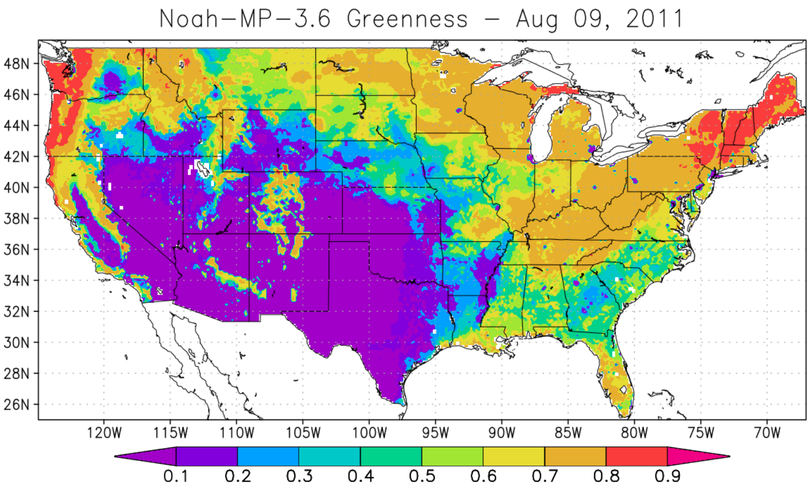
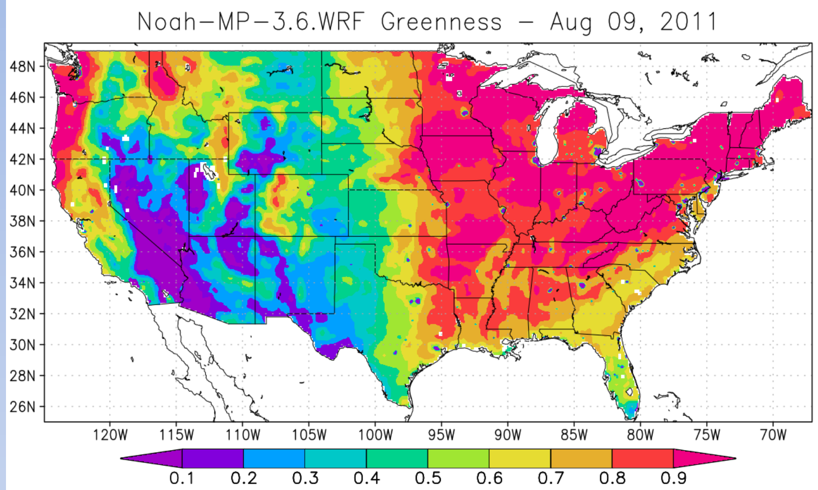
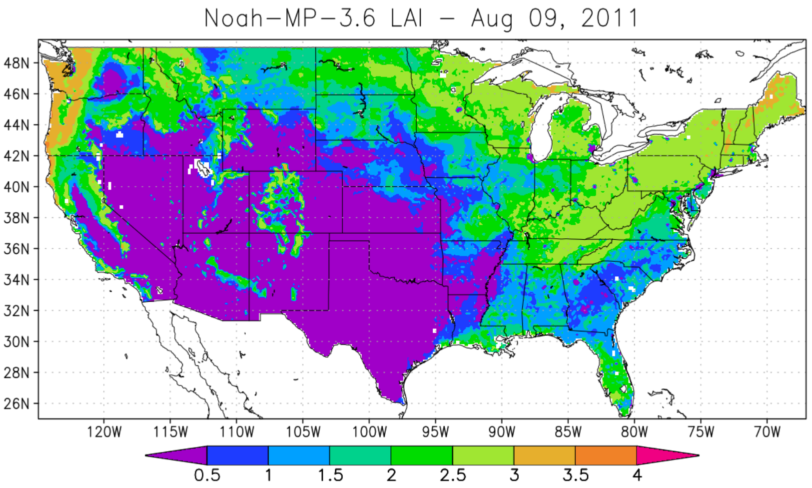
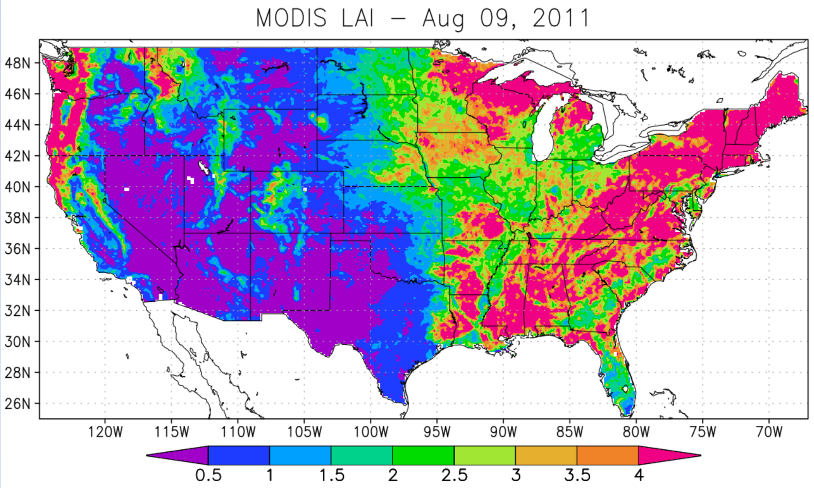


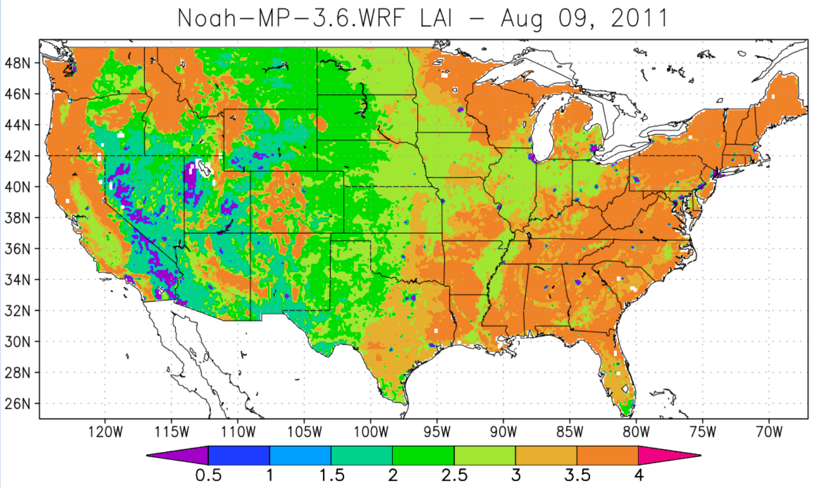
The dynamic vegetation run (left) has very low greenness and LAI in Texas during summer 2011. WRF default vegetation run (right) uses table LAI and maximum GVF. The dynamic vegetation has lower LAI than MODIS (bottom middle), but is closer to MODIS than the WRF LAI is.

The SIMTOP and Noah runs have the same LAI/GVF as the WRF run.

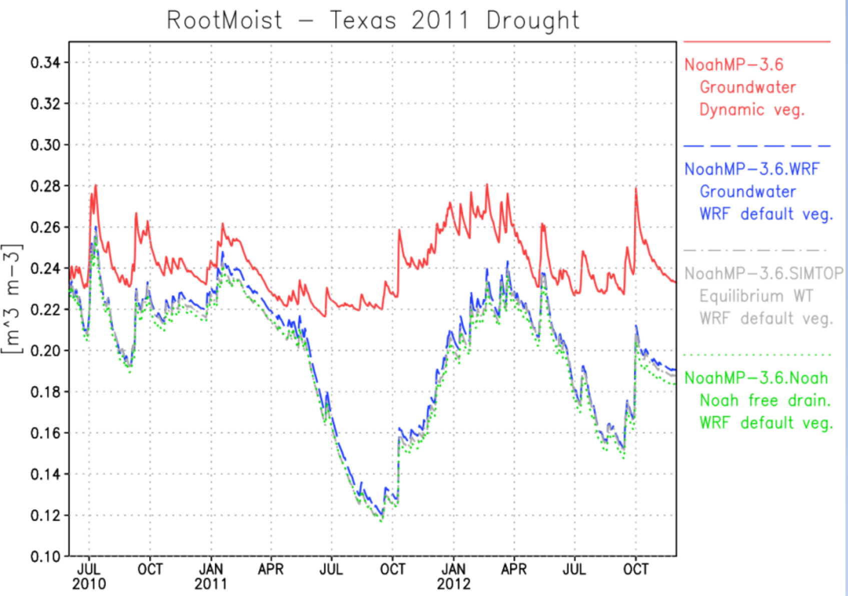


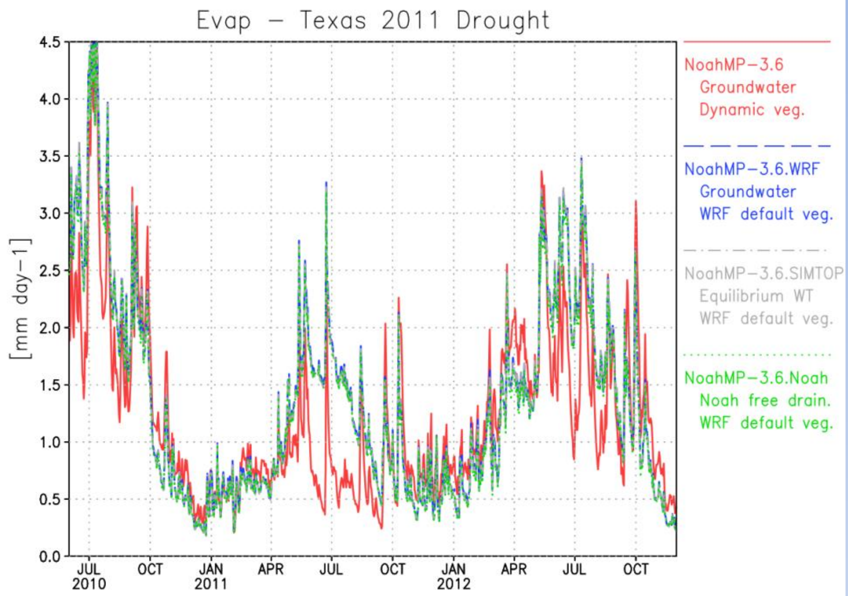


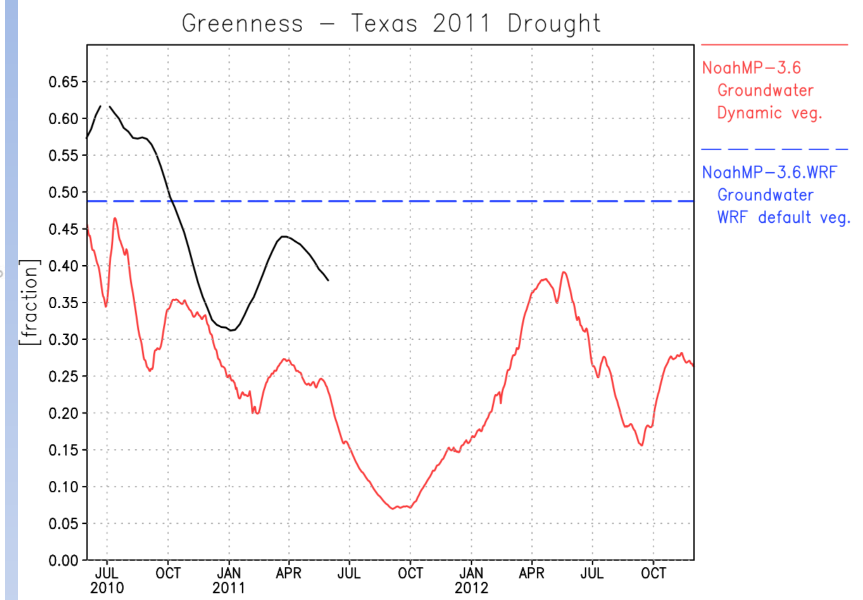


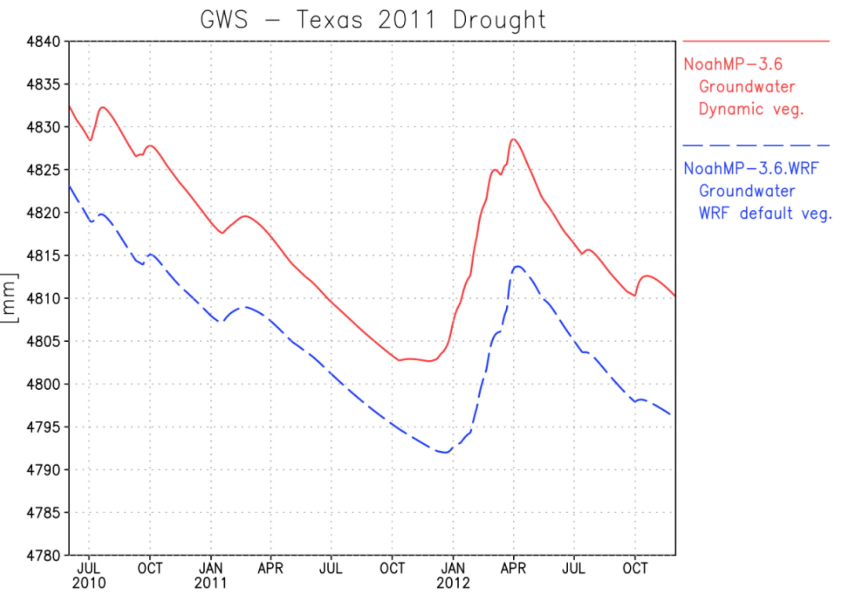


Aug 09, 2011 – Texas Drought

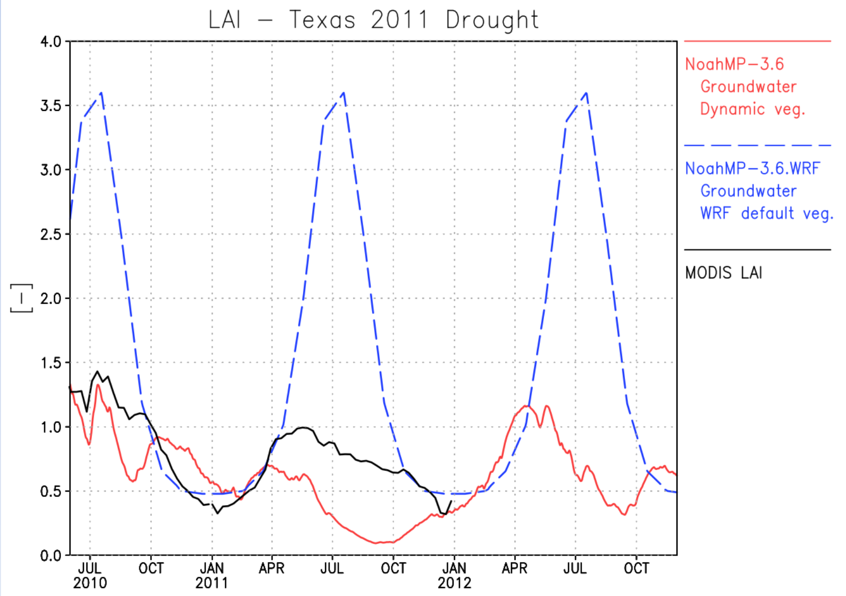




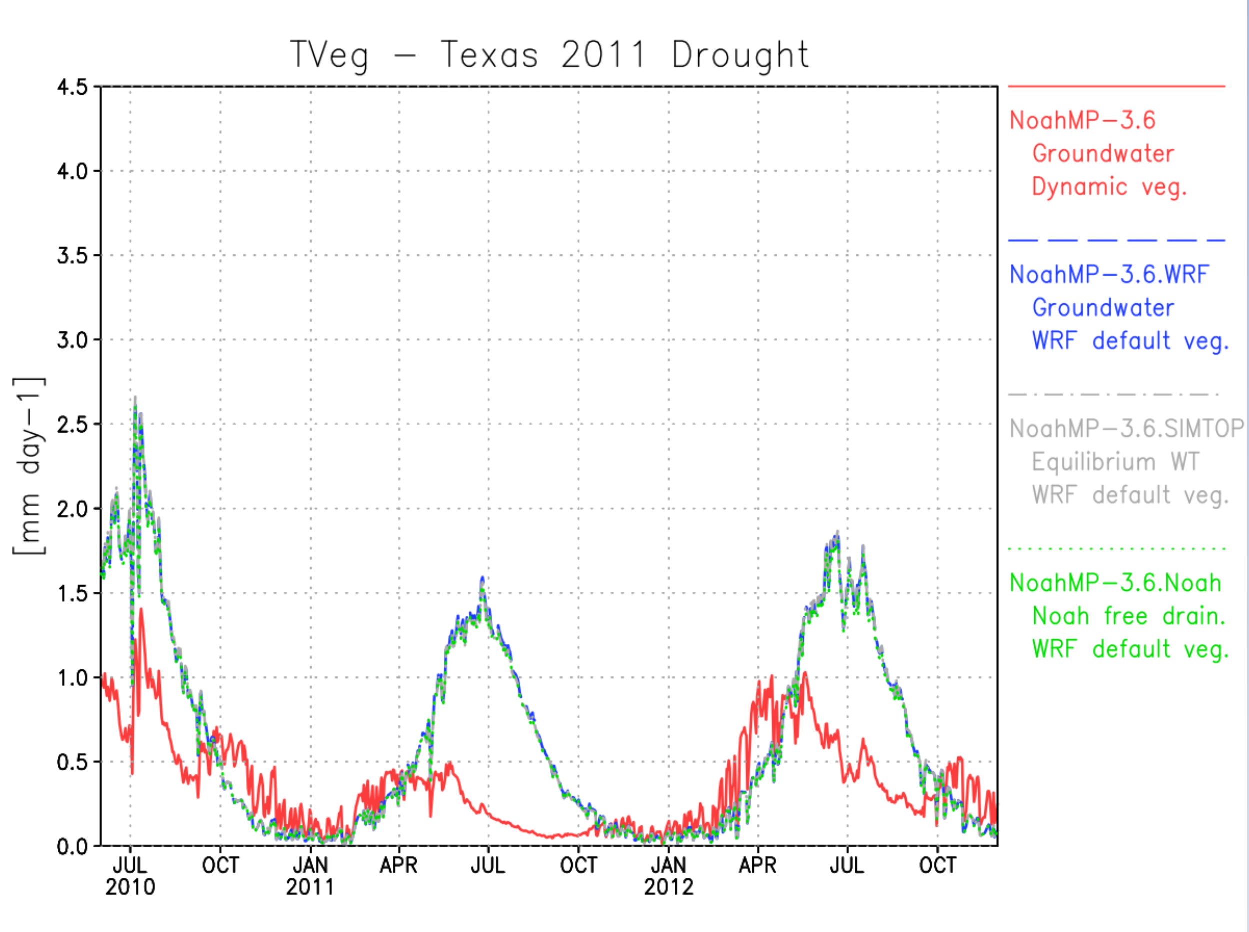


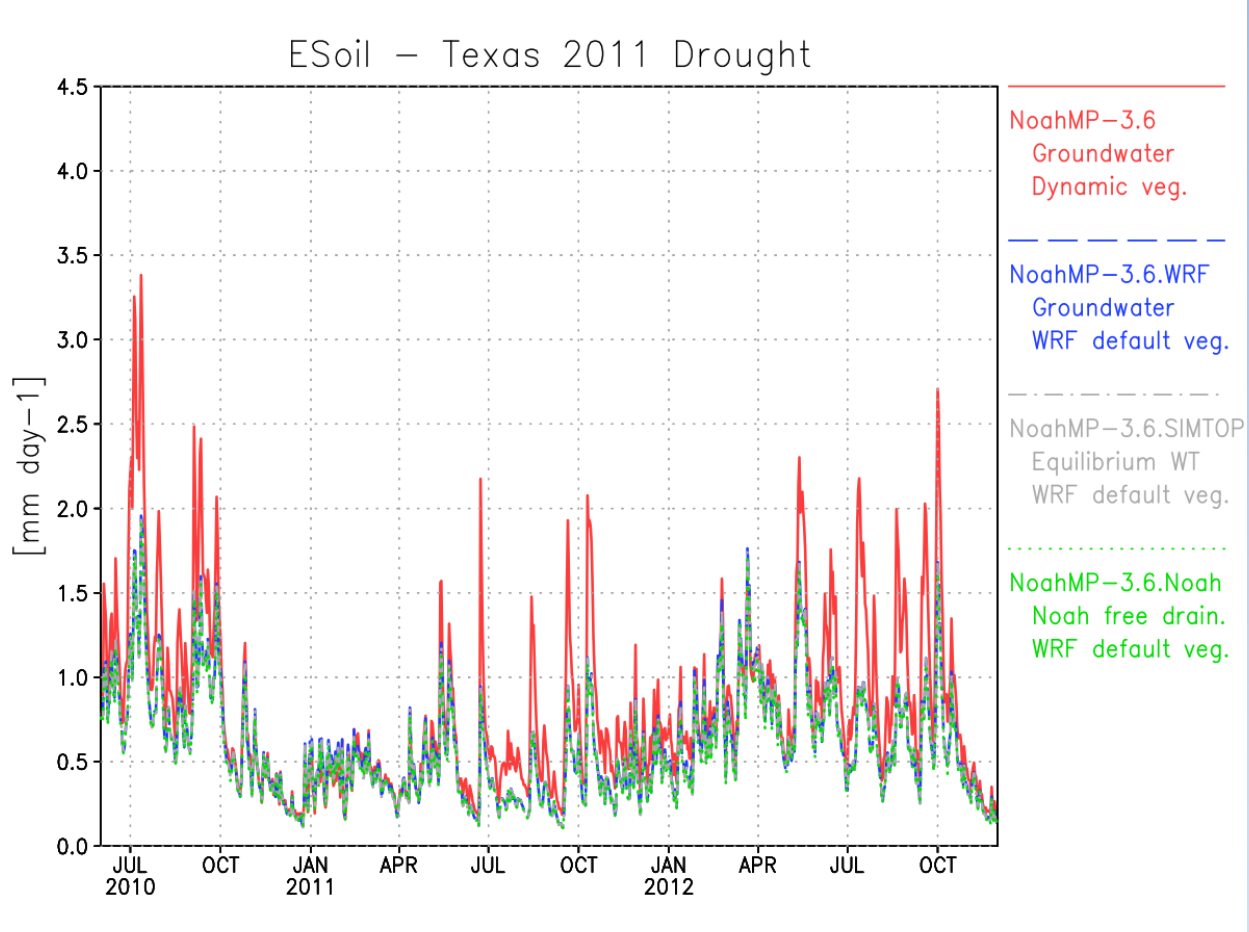


The top 1-m soil moisture does not decrease in TX during 2011 drought, compared to the other runs. GWS behaves similarly between dynamic vegetation and WRF default, although with slightly different mean values. Evaporation is much lower during the summer due to lower GVF and LAI from the dynamic vegetation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



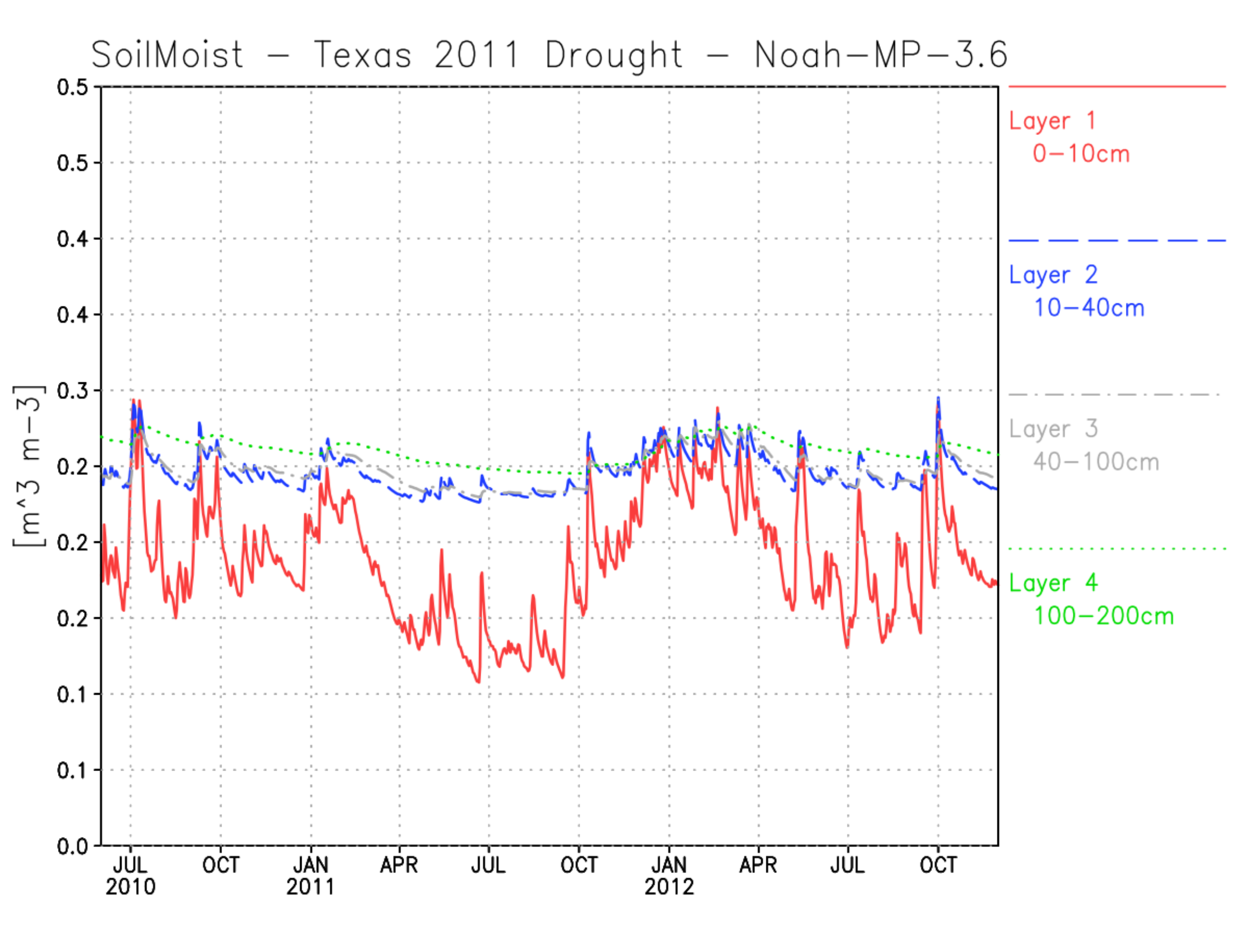
Aug 09, 2011 – Texas Drought

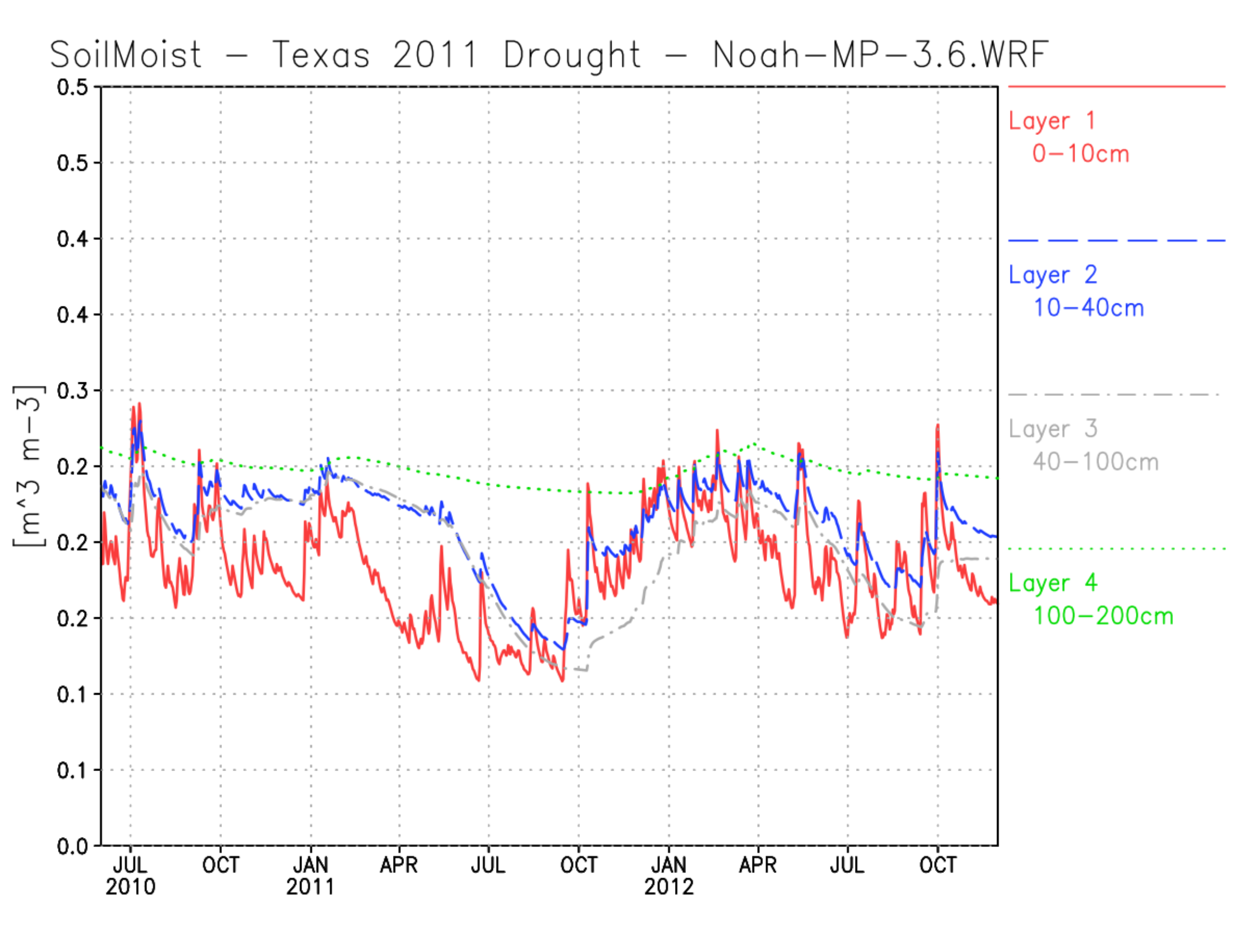




The transpiration (left) greatly reduces in late summer 2011 in Texas in the dynamic vegetation run compared to WRF default. The bare soil evaporation (right) is a little higher in the dynamic vegetation run, especially immediately following rain events.

Aug 09, 2011 – Texas Drought





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.

Description of the Noah-3.6 experiments

Noah-3.6 **[old SOILPARM]**:

- This SOILPARM was used up until Noah-3.5.

Noah-3.6 **[3.6 SOILPARM]**:

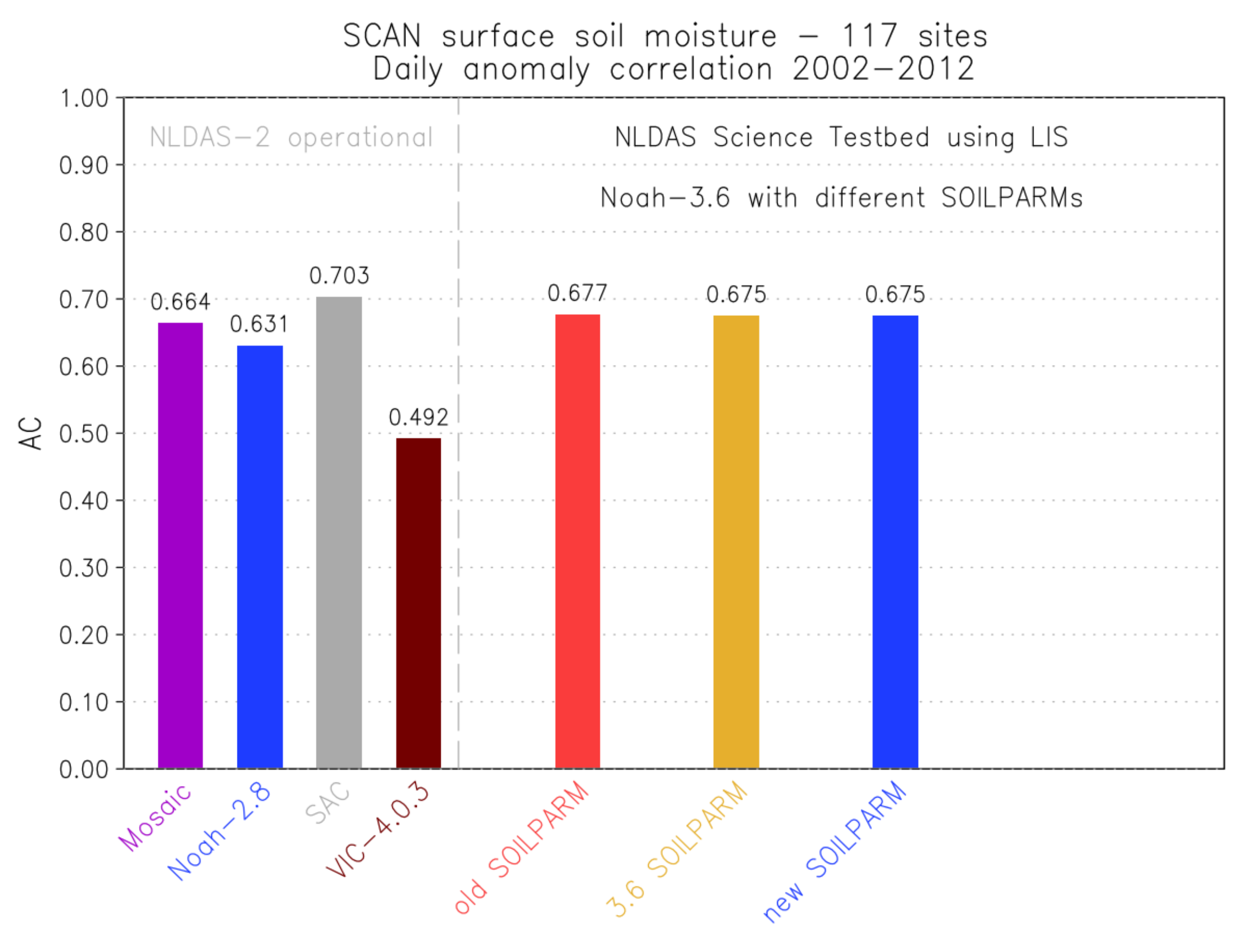
- This is the SOILPARM that has been used for Noah-3.6 so far.
- Biggest change from [old SOILPARM] is that SATDK for SAND went from 1.07E-6 to 4.66E-5. Very minor typo fixes for SANDY/SILTY CLAY LOAM.

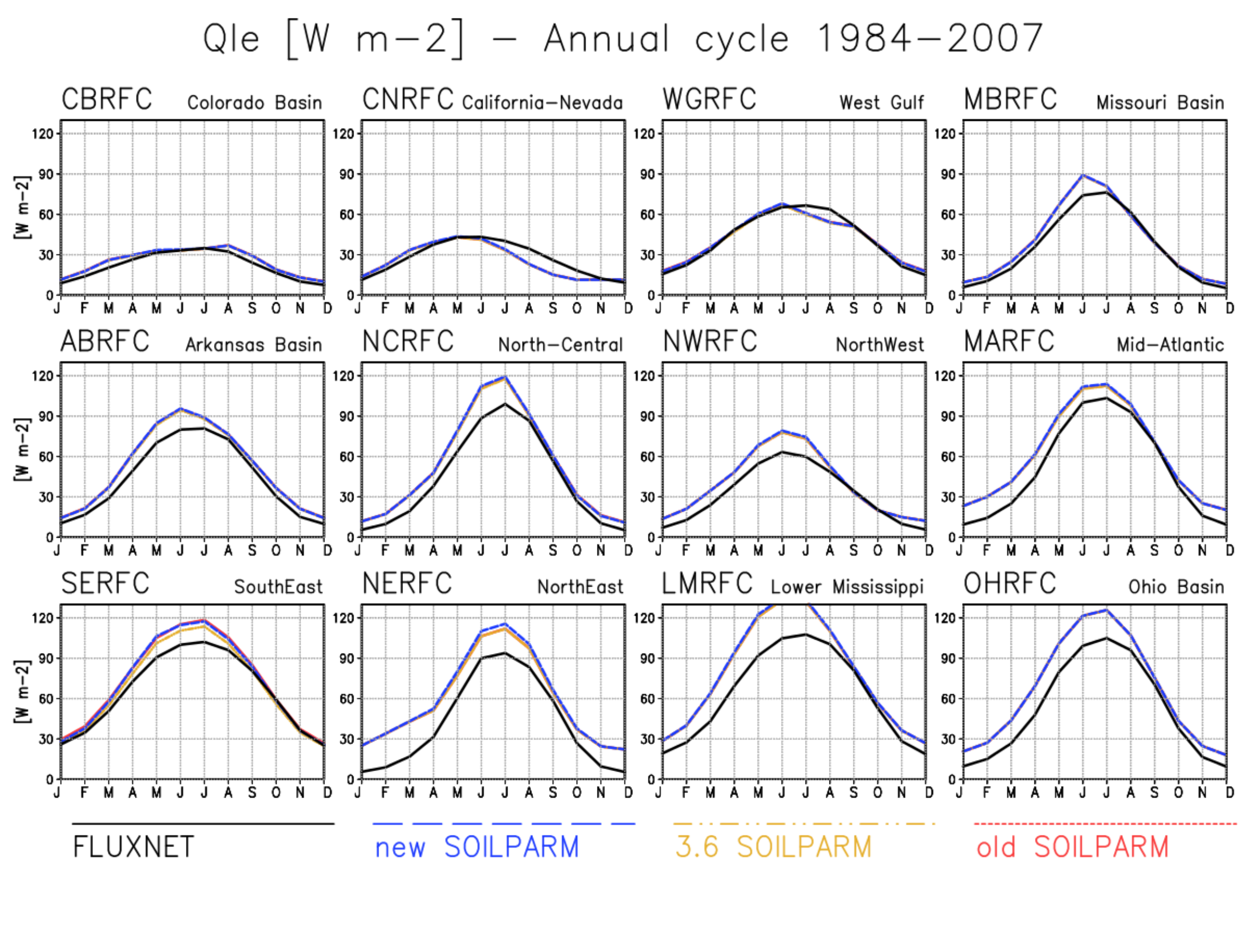
Noah-3.6 **[new SOILPARM]**:

- This is SOILPARM included in the Noah-3.9 release, and is recommended to be used with all previous/current versions of Noah and Noah-MP.

- SATDW and REFSMC for sand modified to account for previously-fixed SATDK (which was probably due to a sign error in the transcription from Cosby)
- SATDW, REFSMC, and WLTSMC for sandy clay loam modified for previously-fixed BB (which was probably transcribed incorrectly from Cosby)
- REFSMC for loamy sand changed from 0.383 (probably typo from calculated 0.283)
- REFSMC for sandy loam and SATDW for silty clay loam differ from calculated values (unknown reason; changed for consistency)
- calculated all parameters for silt category, previously they were just copied from soil loam (Cosby has no silt category)

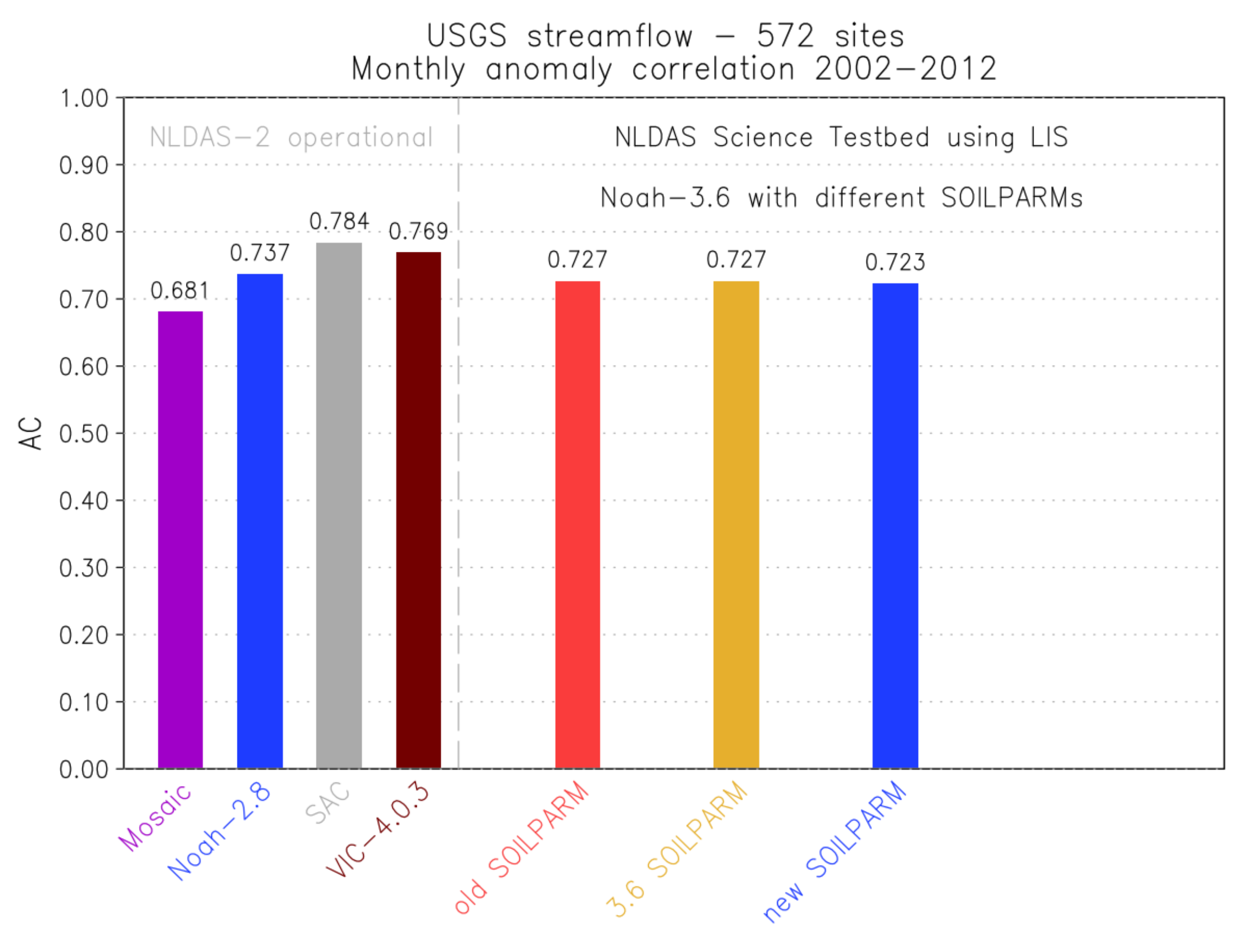
Noah-3.6 evaluations

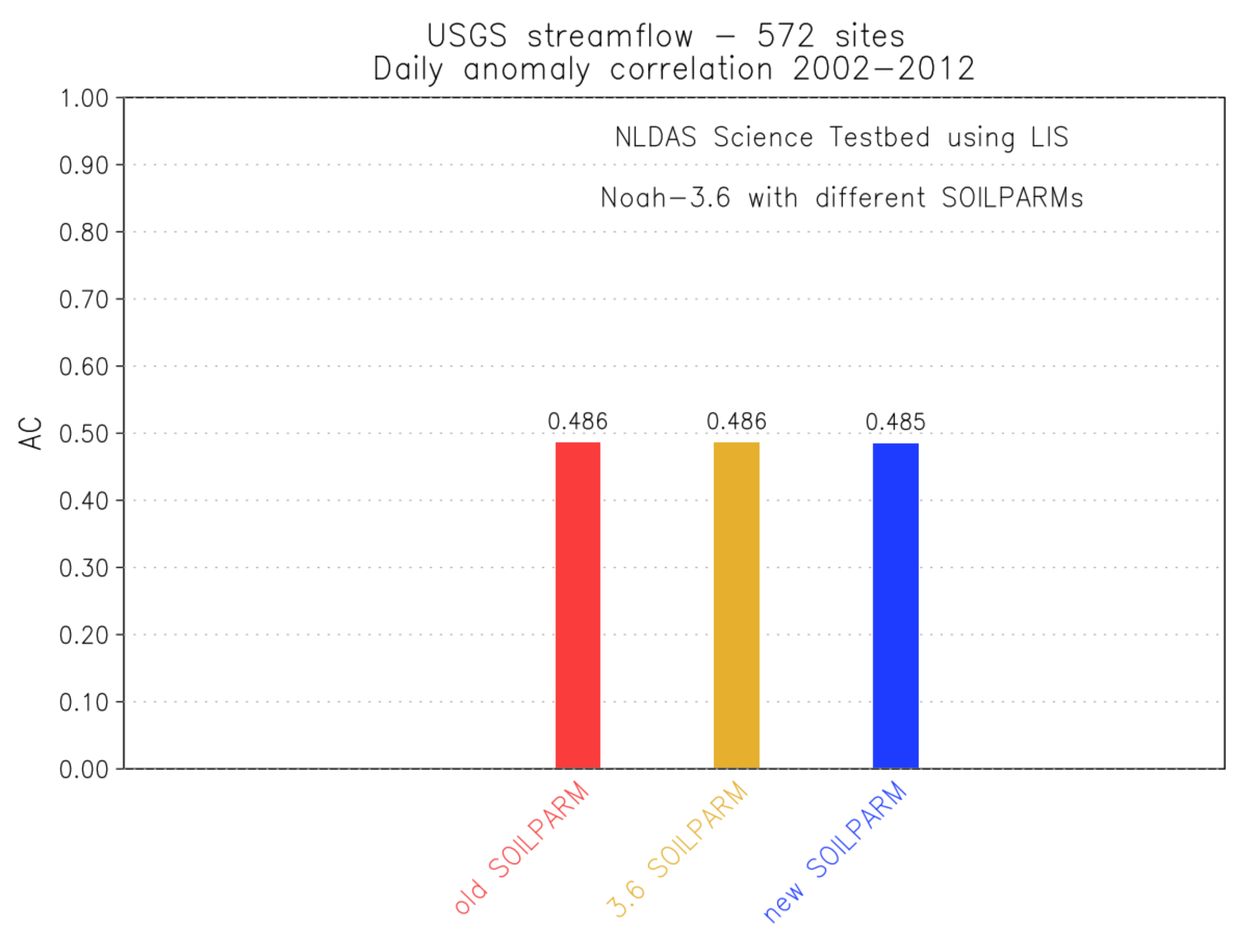




Average over 177 SCAN surface soil moisture observations, the anomaly correlation is essentially the same between the different SOILPARM tables. The latent heat flux annual cycle is similar for the RFCs – biggest differences are in the SouthEast RFC. Note that Qle is high compared to the FLUXNET product, but we have found calibration of CZIL greatly improves the agreement.

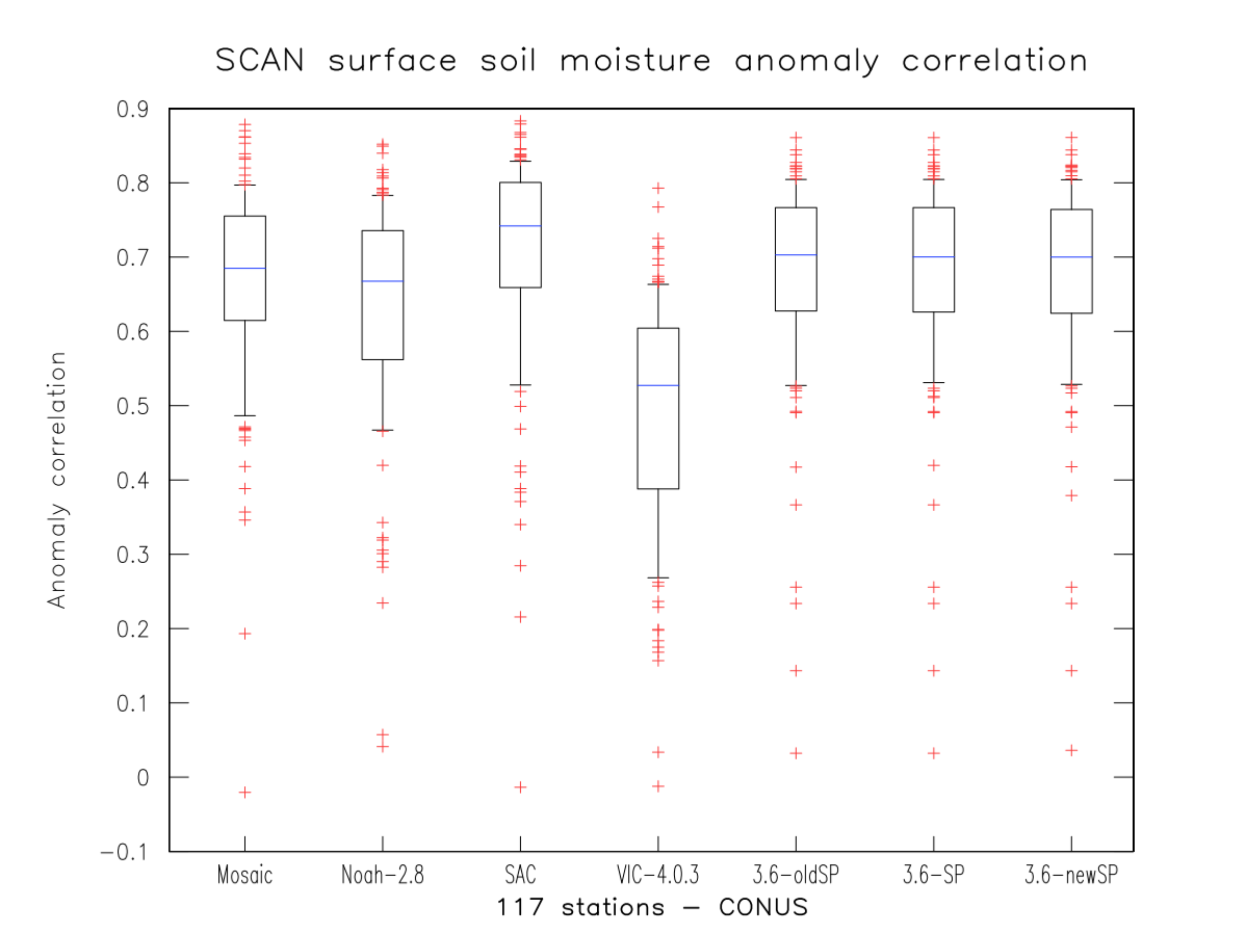
Noah-3.6 evaluations

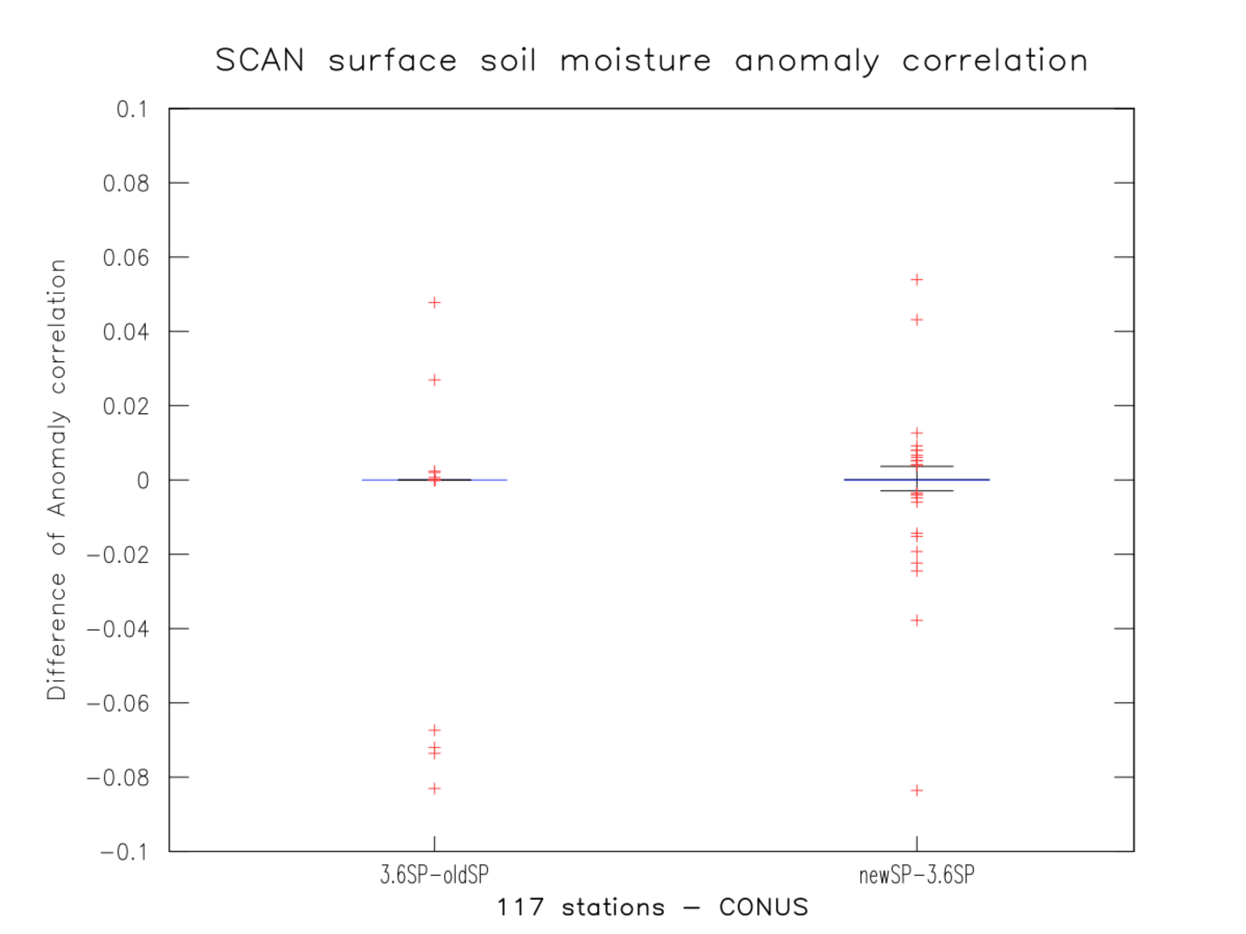




Average over 572 USGS streamflow observations in small, unregulated basins also shows very similar anomaly correlation between the different SOILPARM tables, for both monthly and daily.

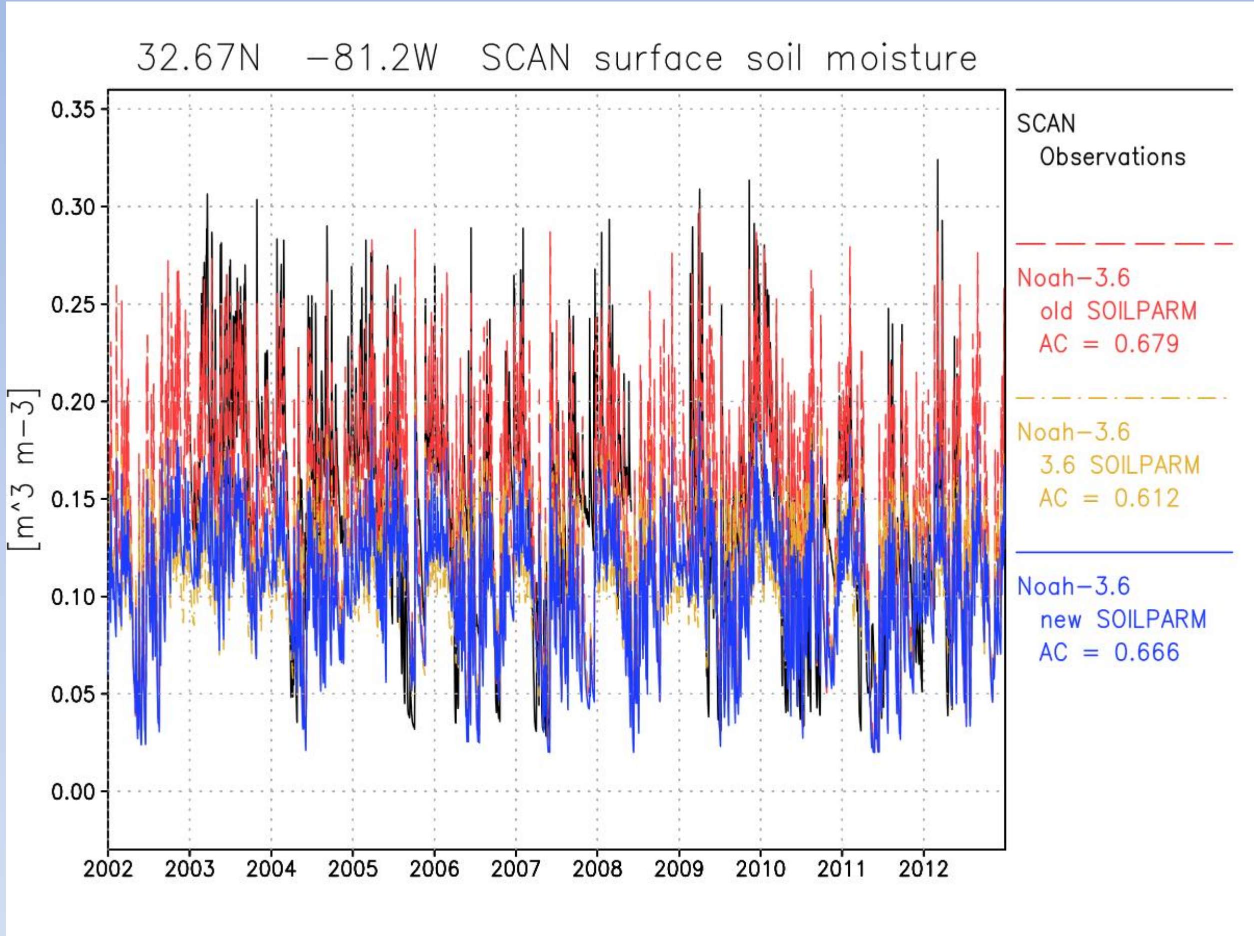
Noah-3.6 evaluations

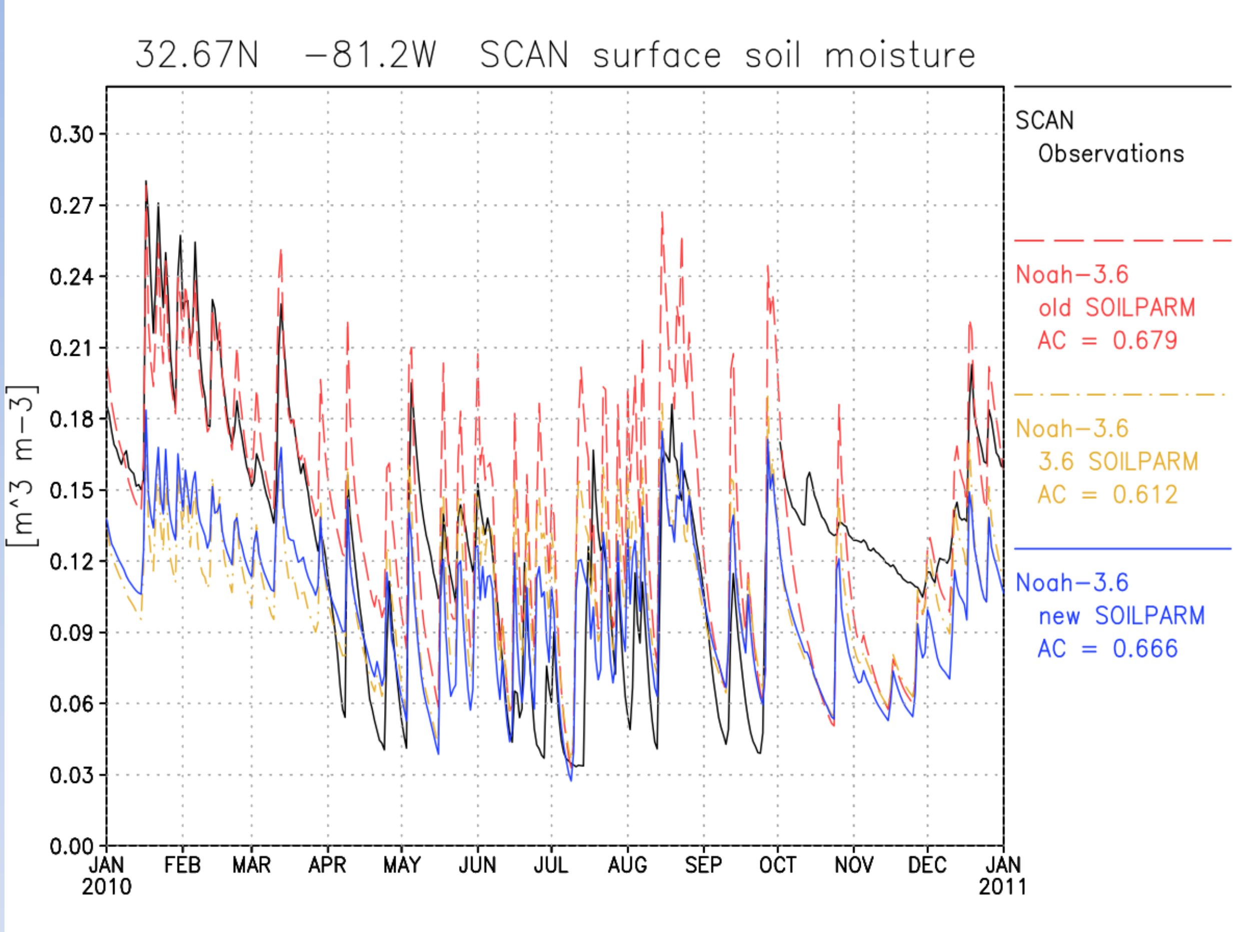




(LEFT) Box plot of the anomaly correlation at the 117 SCAN soil moisture sites. The majority of the individual sites have the same AC value regardless of the SOILPARM used. (RIGHT) This plot is a box plot of the difference in the AC for each individual site (left side is 3.6 SOILPARM minus old SOILPARM; right side is new SOILPARM minus 3.6 SOILPARM). Most differences are small.

Noah-3.6 evaluations





(LEFT) 2002-2012 of an individual site with SAND soil texture. Increasing SATDK has resulted in a drier surface soil moisture. The 3.6 SOILPARM table dropped the AC, but the new SOILPARM has an increase of the AC. (RIGHT) Same site, but only showing the year 2010. Note the change in the dry down after a rain event.

Summary and next steps

- Comparisons shown of drought depiction between operational NLDAS-2 LSMs, the new LIS-based LSMs for the next phase of NLDAS, and the USDM
- Groundwater in Noah-MP and CLSM-F2.5 in the new LIS-based LSMs can add value to the depiction of drought in NLDAS
- The dynamic vegetation option in Noah-MP needs additional evaluation with respect to its ability to properly depict extreme droughts
- Data assimilation of LAI/GVF in Noah-MP may help with depiction of drought
- For the most part, there are minor to no differences in the simulated output in Noah-3.6 when changing SOILPARM parameter values, although some types (e.g., SAND) do show more significant changes.
- Next steps:
  1) Continue Noah-MP dynamic vegetation evaluation/investigation
  2) Stratify SOILPARM changes by soil texture class
  3) Further analysis of similarity and correlation of drought depiction