Improving Climate Forecast System (CFS) through Enhancing the Noah-MP community land model

- PI: Fei Chen, NCAR
- Co-PI:
  - NCAR: Michael Barlage
  - University of Texas at Austin: Zong-Liang Yang
  - NCEP/EMC: Michael Ek, Rongqian Yang, Jesse Meng

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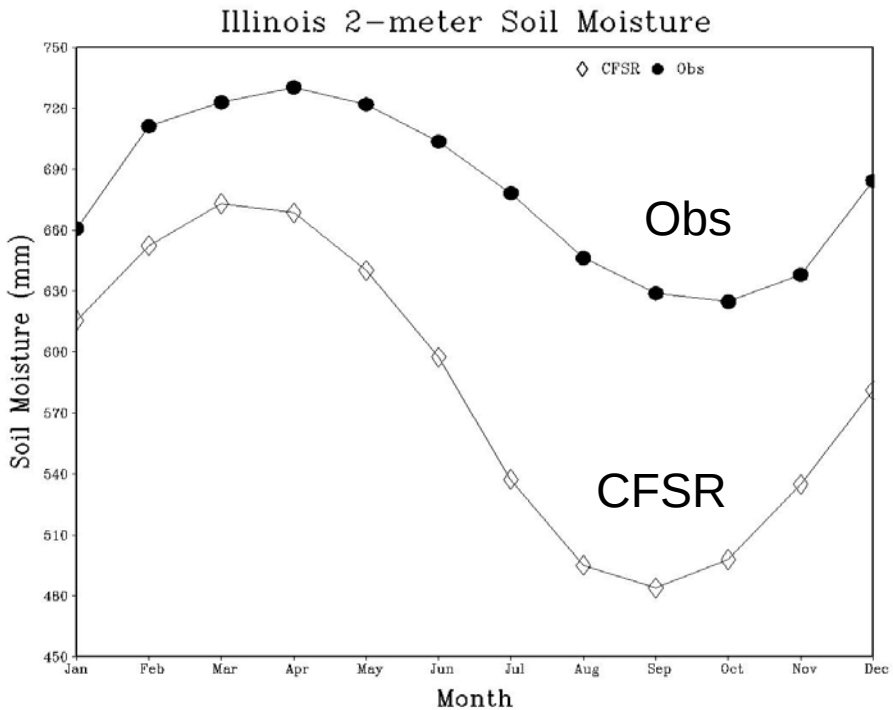
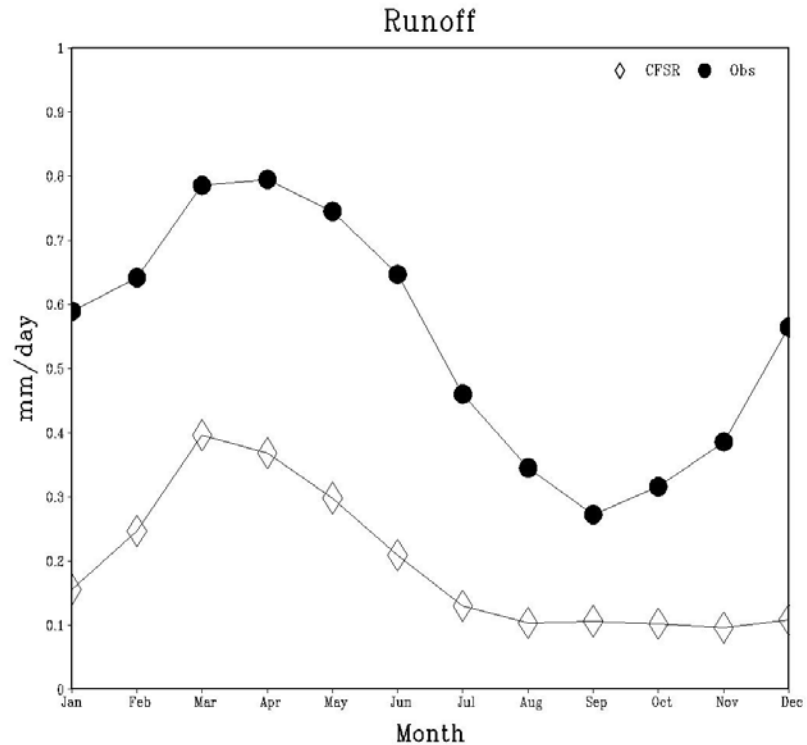
Improving Climate Forecast System (CFS) through Enhancing the Noah-MP community land model

- Motivations
- Project Accomplishments (08/01/2014 - 07/31/2016)
- R2O transition

Problem in NCEP CFS land/hydrology modeling

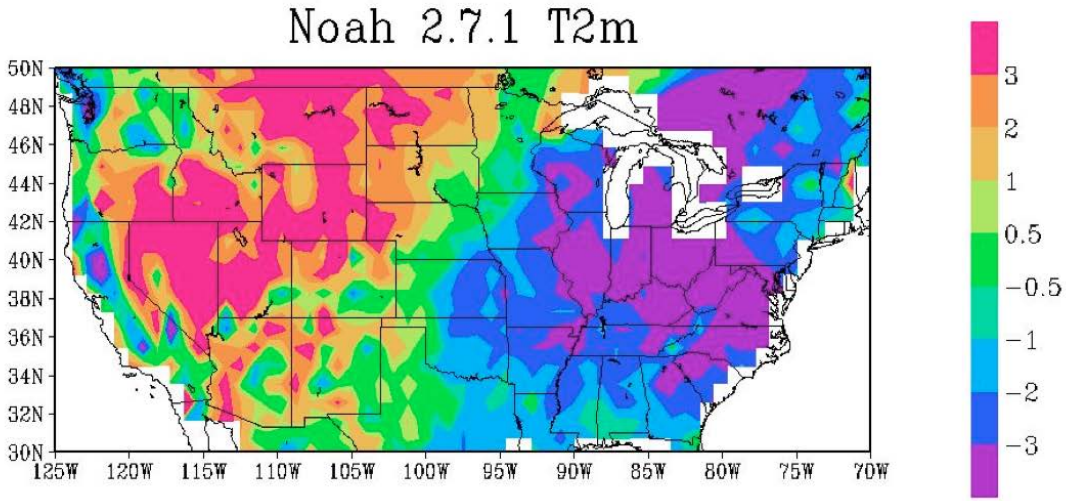


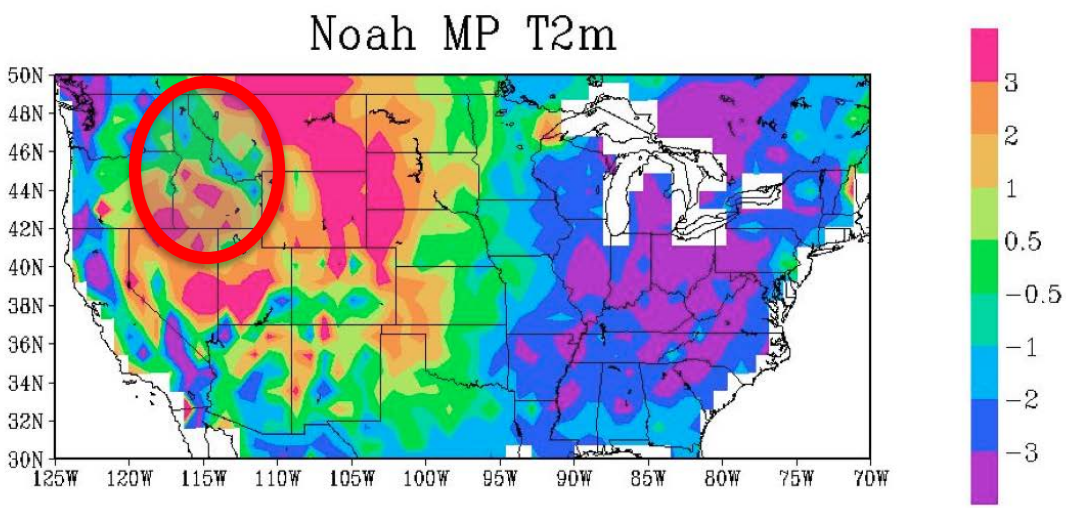
Seasonal cycle of soil moisture (mm) averaged over the state of Illinois from the CFSR (◊), and observation (●) for the period from Jan 1981 to Dec 2004.



Seasonal cycle of surface runoff (mm/day) averaged over the Mississippi River basin from the CFSR and observations. Observed runoff climatology based on the stream flow at Vicksburg, Mississippi. from Oct 1979 to Sep 1999.

Impacts of land/hydrology modeling on CFS forecast biases

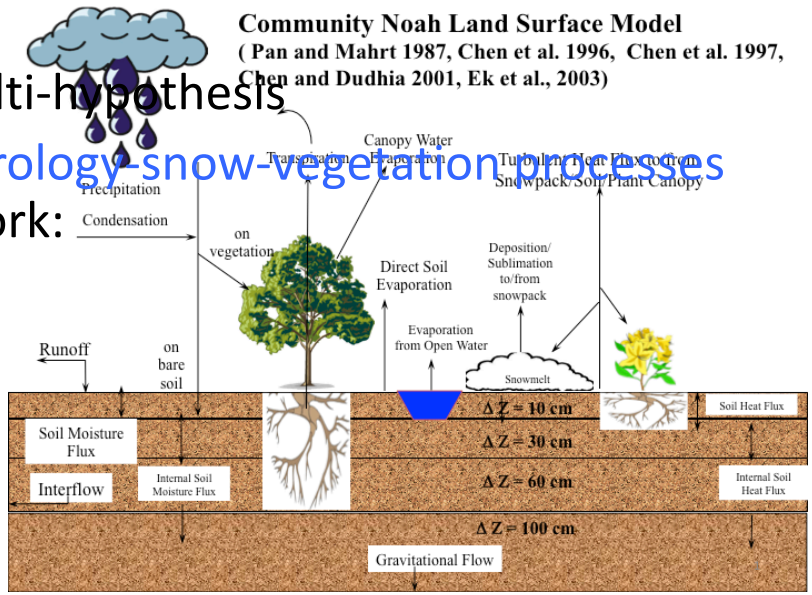




Monthly mean 2-meter temperature bias for May 1982 (unit: K) produced by the CFS v2 coupled with Noah v2.7.1 (top panel) and coupled with Noah-MP v1 (bottom panel), which effectively reduces warm biases in the western domain.

New Generation Noah-MP (Multi-parameterization)

- Multi-parameterization=Multi-physics ≡ Multi-hypothesis
- Multiple parameterizations to treat key hydrology-snow-vegetation processes paradigm in a single land modeling framework:
  - Canopy turbulence (2 schemes)
  - Canopy radiation (3 schemes)
  - Canopy resistance (2 schemes)
  - Frozen ground physics (2 schemes)
  - Snow physics (2 schemes)
  - runoff/water table (4 schemes)



Limiting ability for seasonal prediction

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 116, D12109, doi:10.1029/2010JD015139, 2011

The community Noah land surface model with multiparameterization options (Noah-MP): 1. Model description and evaluation with local-scale measurements

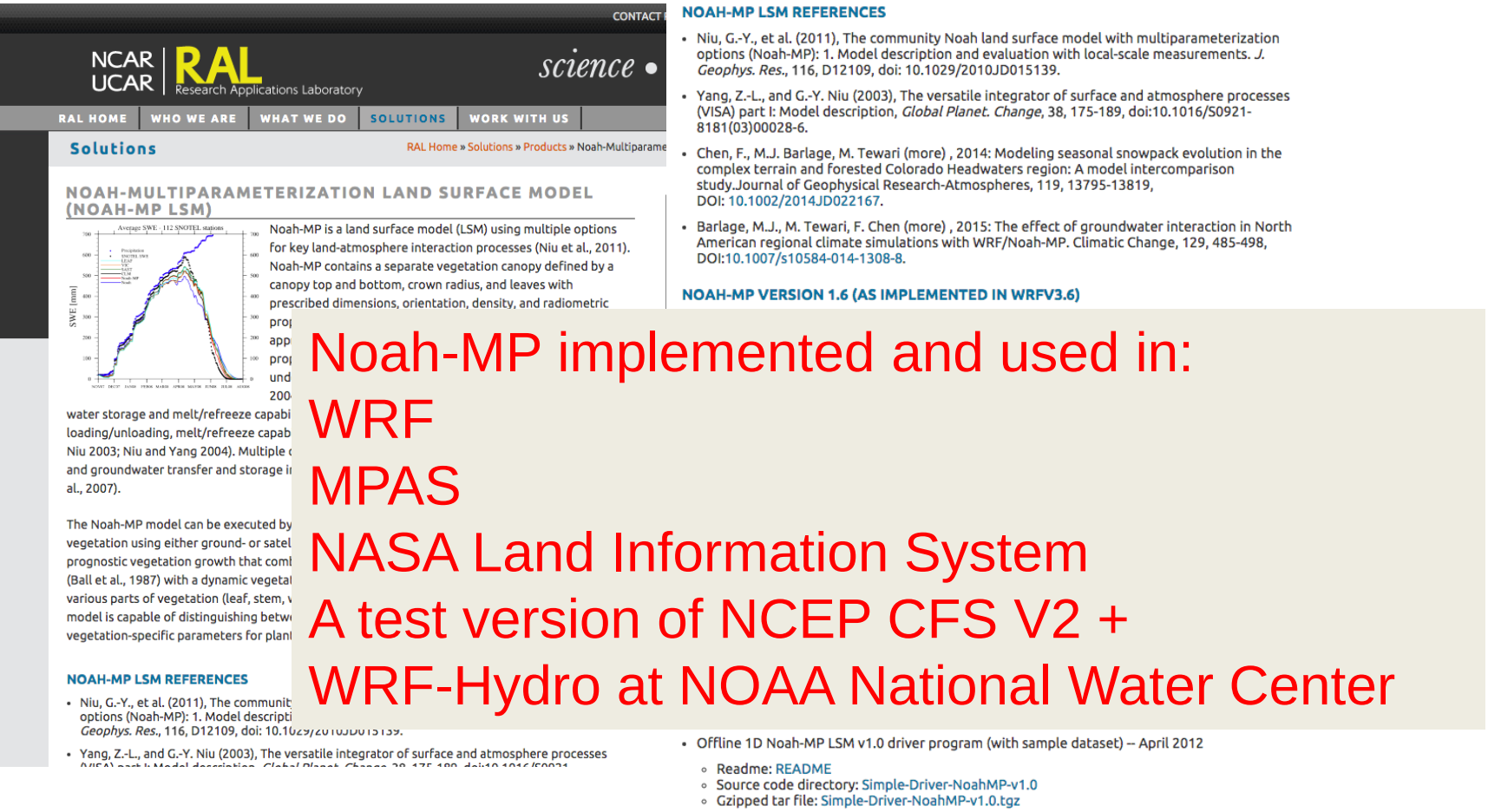
Guo-Yue Niu,[1] Zong-Liang Yang,[2] Kenneth E. Mitchell,[3] Fei Chen,[4] Michael B. Ek,[3] Michael Barlage,[4] Anil Kumar,[5] Kevin Manning,[4] Dev Niyogi,[6] Enrique Rosero,[1,7] Mukul Tewari,[4] and Youlong Xia[3]

Noah-MP a powerful tool for assessing land physics uncertainties and for physics ensemble prediction!

Received 4 October 2010; revised 3 February 2011; accepted 27 March 2011; published 24 June 2011.

Noah-MP Official Release Site at NCAR/RAL

https://www.ral.ucar.edu/solutions/products/noah-multiparameterization-land-surface-model-noah-mp-lsm



Noah-MP implemented and used in:

WRF

MPAS

NASA Land Information System

A test version of NCEP CFS V2 +

WRF-Hydro at NOAA National Water Center

Most recent development code available to community via http://github.com/NCAR/NoahMP_release

Science Questions

- *To what degree can the enhanced Noah-MP model improve CFS seasonal prediction skill?*

- *Is there an optimal set of Noah-MP physics options for improving CFS seasonal predictions, especially precipitation and near-surface temperature?*

- *Which are the key soil-hydrology-vegetation interactions contributing to CFS intra-seasonal and interannual prediction skill?*

Major Accomplishments

1. **Improved specification of vegetation and soil types in CFS**
   - **Implemented the 1-km global MODIS-based IGBP-NCEP land cover dataset**
   - **Implemented the 5-min global (1-km CONUS) soil texture dataset**

2. **Implemented Noah LSM v3.4 in CFS**
   - **Compared to Noah V.2.7.1 (cir 2000s) used in operational CFS,** Noah 3.4 (released in August 2012) has a number of bug fix and improved physical treatments such as soil-saturation slope, background emissivity, snow albedo, etc

Major Accomplishments (Continued)

3. Enhanced the community Noah-MP land model and released the new Noah-MP V2 in April 2017

- new capability of specifying spatially-varying soil properties;
- two new crop-growth-model (corn and soybean) modules;
- new options to specify seasonal vegetation parameter (leaf area index and vegetation fraction);
- new surface resistance option (treating soil/snow evap/sub resistance);
- Bug fixed patchy-snow surface temperature option.

4. Incorporated Noah-MP V2 in the test version of CFS V2+:

- The CFS used here (so-scalled V2+) is based on the operational CFSv2 but with many physics enhancements. The atmospheric component of the CFS is the operational GFS model (operational GFS as of May 2012).

Major Accomplishments (Continued)

5. Evaluated performance of CFS v2+ hindcast using different land models:

- T126 CFS reforecast experiments are carried out for selected eleven years (1982, 1987, 1996, 1988, 2000, 2007, 1986, 1991,1999, 2011, 2012) with four ensemble members (00z of May 1 to May 4).
- **Experiments:**
  - **Using operational Noah v2.7.1, Noah V3.4, Noah-MP**
  - **Different Noah-MP options**
  - **Different approach (climatology, realtime, table-based) to specify seasonal cycle of vegetation**

Old USGS AVHRR vs New MODIS IGBP-BU-NCEP Land-cover and land-use data sets

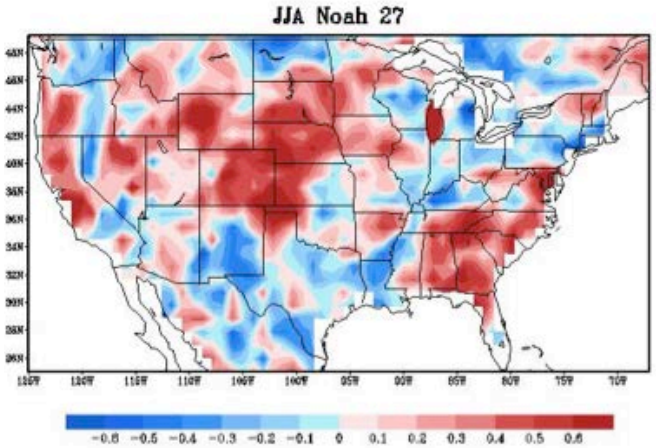
	AVHRR	MODIS
Data Collection Instrument	**AVHRR** (Advanced Very High Resolution Radiometer)	**MODIS** (MODerate resolution Imaging Spectroradiometer)
Channels	5 channels	15 land surface/vegetation dedicated channels
Data Collection Dates	April 1992 – March 1993	January 2001 – December 2001 • Reflecting recent change in land-use (Agriculture, urbanization, etc)
Data Provider	USGS/ORNL	Boston University
Classification Scheme	Modified USGS	Modified IGBP-BU-NCEP • Inland water
# of Categories	25*	19*

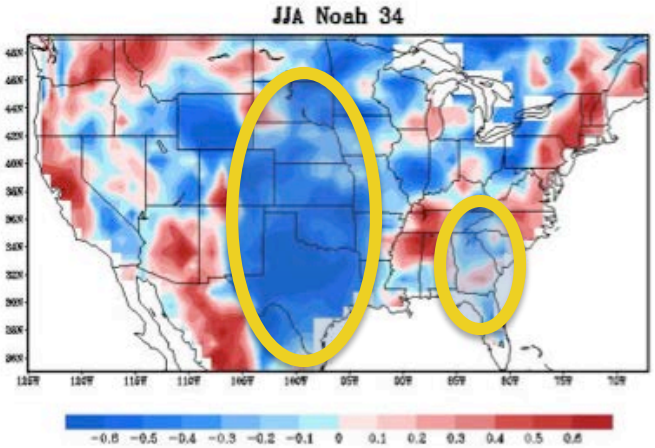
Impacts of land modeling on CFS seasonal forecast

Rongqian Yang conducted T126 CFS reforecasts using different land models: eleven years (1982, 1987, 1996, 1988, 2000, 2007, 1986, 1991,1999, 2011, 2012) with four ensemble members (00z of May 1 to May 4).

Anomaly Correlation (AC) skill of averaged JJA precipitation

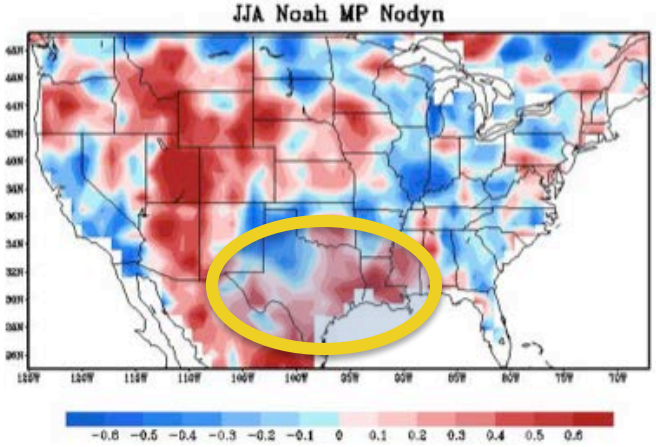
Noah 2.7

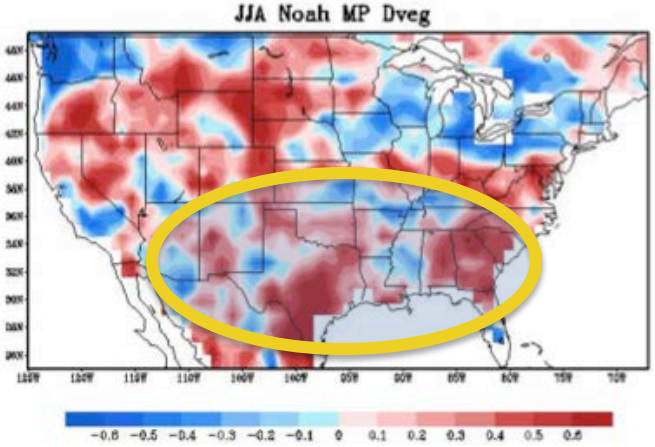




Noah 3.4

Noah-MP

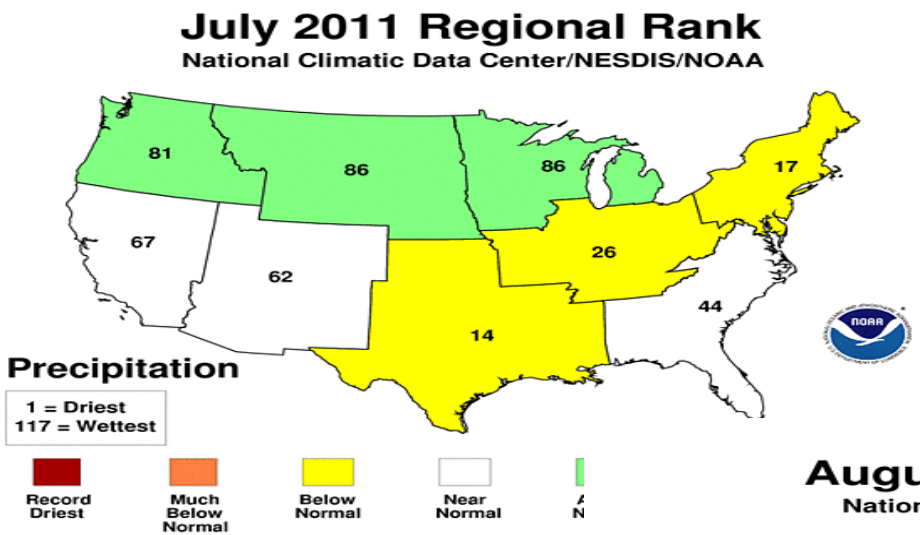


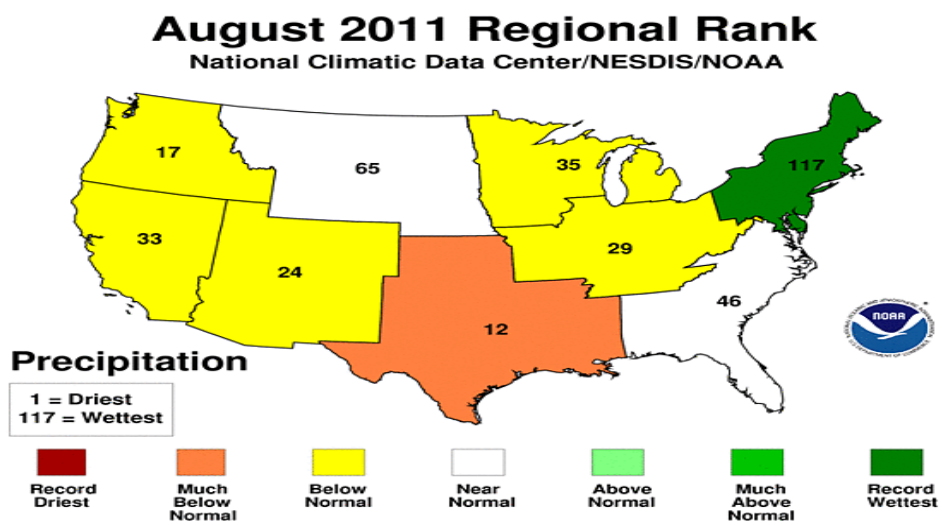


Noah-MP dyn veg.

Impacts of land modeling on CFS seasonal forecast

Comparison of <u>precipitation</u> and <u>T2m</u> from CFS with two different vegetation data and with Noah-MP V1 and V2. 2011 Texas Drought

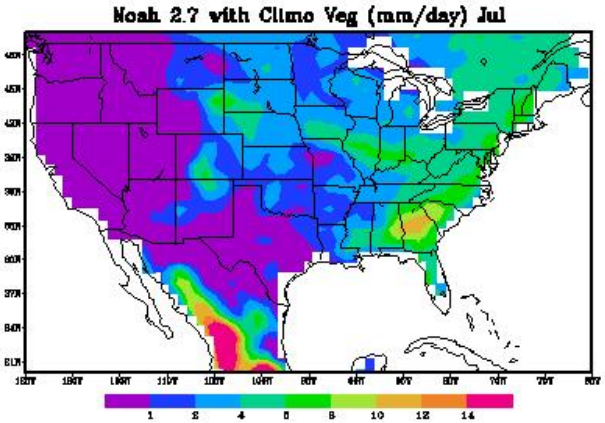




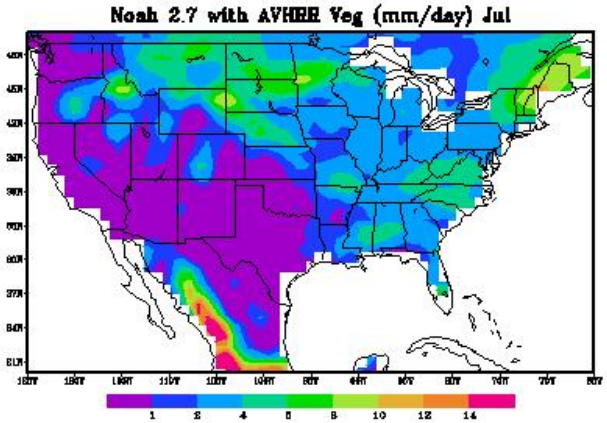
Impacts of land modeling on CFS seasonal forecast

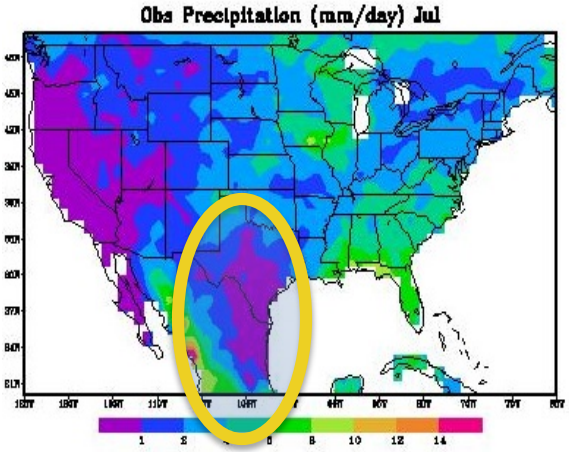
2011 Texas Drought

Noah 2.7 Climo GVF



Noah 2.7 AVHRR GVF





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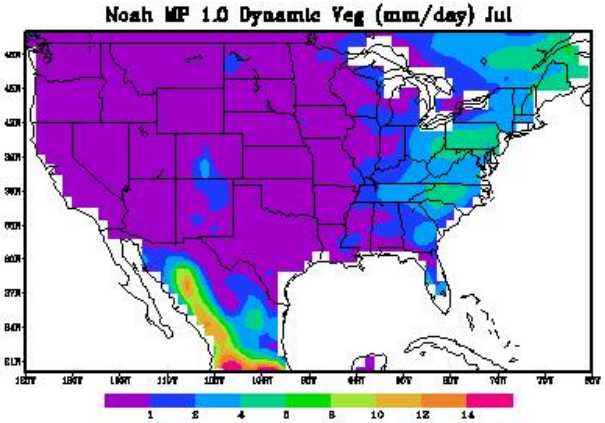
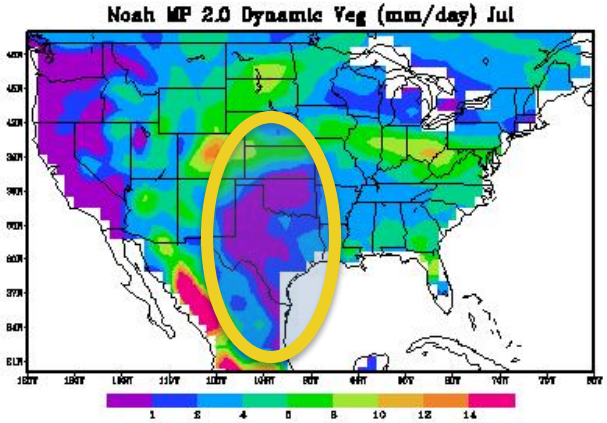


Noah-MP V1



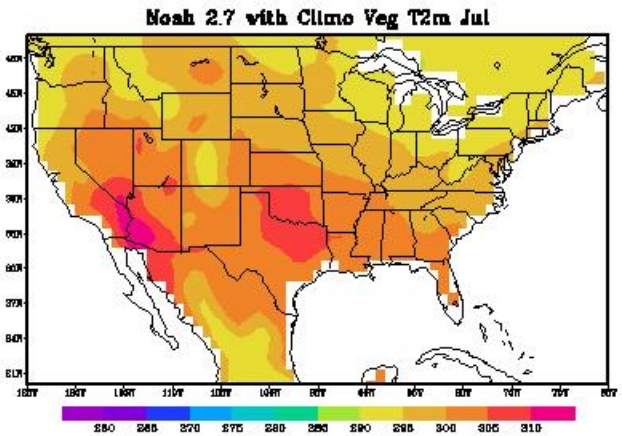
Noah-MP V2

Predicted Precipitation for July 2011

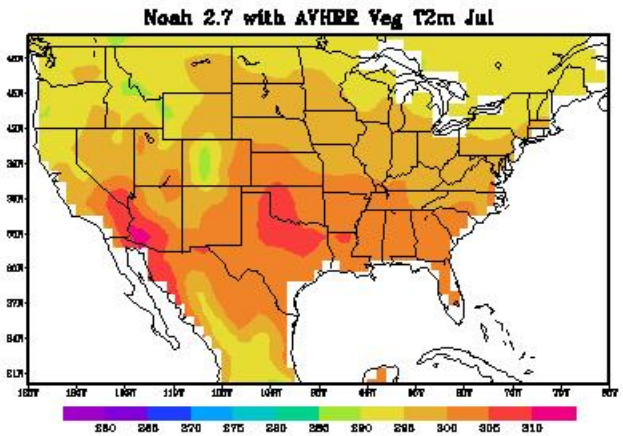
Impacts of land modeling on CFS seasonal forecast

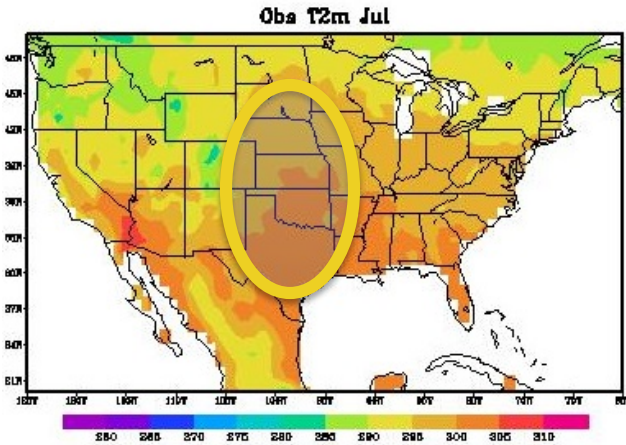
2011 Texas Drought

Noah 2.7 Climo GVF

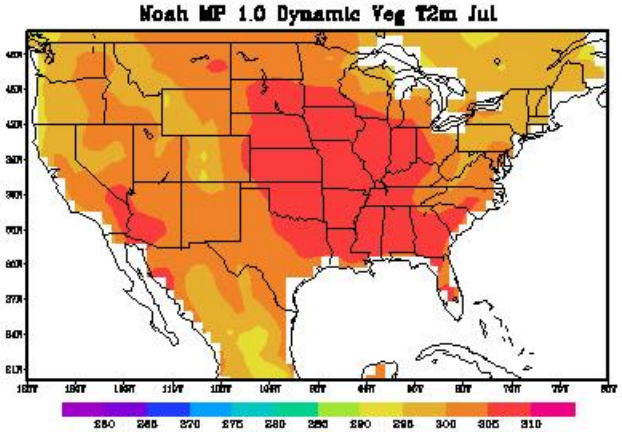


Noah 2.7 AVHRR GVF

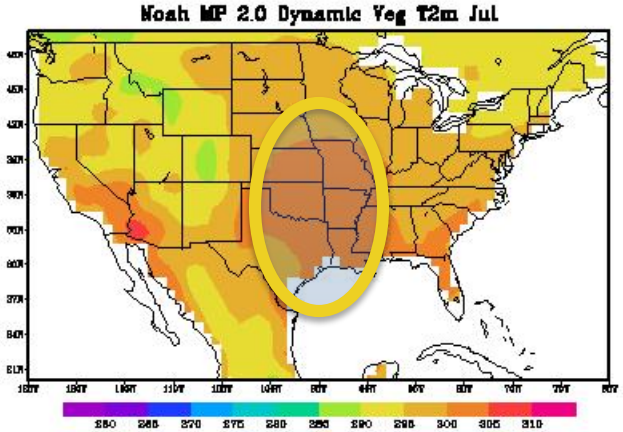




Obs



Noah-MP V1

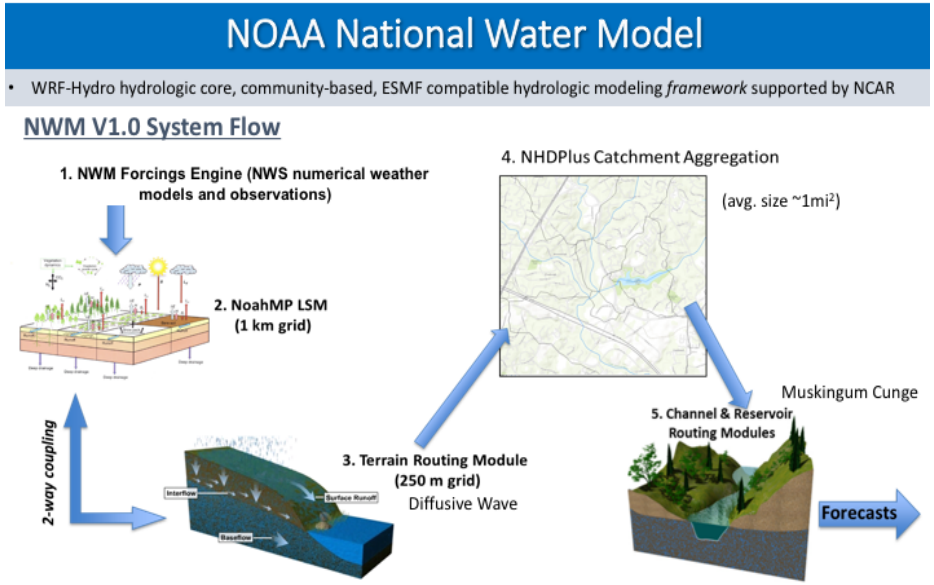


Noah-MP V2

Predicted T2m for July 2011

R2O transition

- The enhanced Noah-MP has been implemented in the NOAA operational National Water Model (NWM V1.2, fall of 2017)
- Provide NCEP/EMC with detailed documentation that includes model, data, and procedures to perform model runs
- Give NCEP/EMC staff hands-on training about Noah-MP software structure, input and output data, and trouble-shooting information and help them execute the coupled model



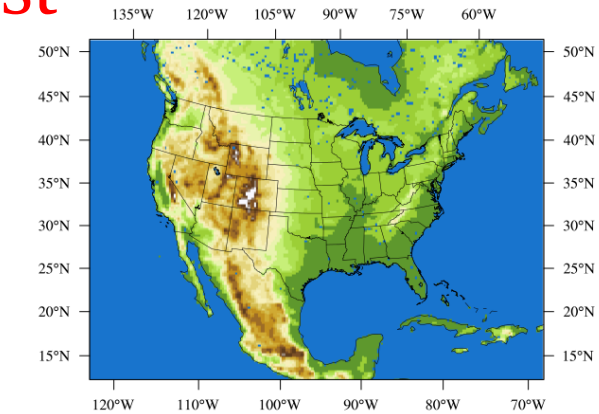
Courtesy of Brian Cosgrove and David Gochis

Summary

- The CFS test version is enhanced with the implementation of the community Noah-MP LSM and new global land-cover and land-use (LULC) and soil texture data, bringing CFS land component closer to recent community efforts.
- CFS reforecast results show positive impacts of using Noah-MP with ground-water and dynamic vegetation parameterizations in seasonal prediction skills in precipitation and surface temperature. The vegetation-crop-hydrology interactions are expected to be more significant in high-resolution NGGPS models
- This project elevated the Readiness levels (RL) of Noah-MP from 5 to 7. The enhanced Noah-MP has been transitioned to the operational National Water Model.
- Closer collaboration with NCEP beneficial to R2O and O2R.

Scale dependencies of groundwater effects on seasonal forecast

Noah-MP vs. Noah-MP w/groundwater



- Six-month 30km WRF simulations - 2010
- Spin-up soil for one year using offline HRLDAS
- IC/BC from NARR
- Verification against ~2600 surface stations

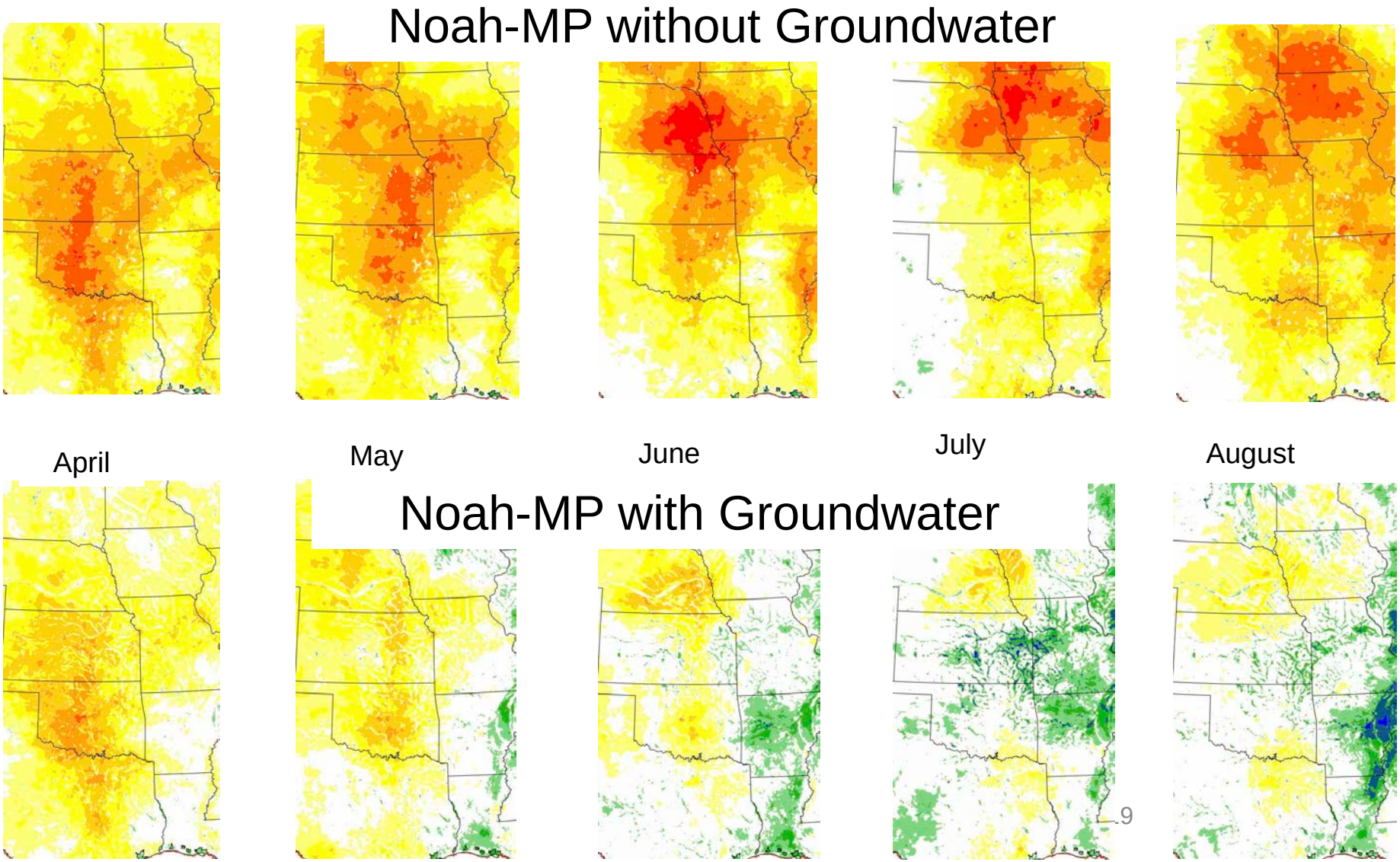
Green: Noah-MP w/GW improves Red: Noah-MP w/GW degrades

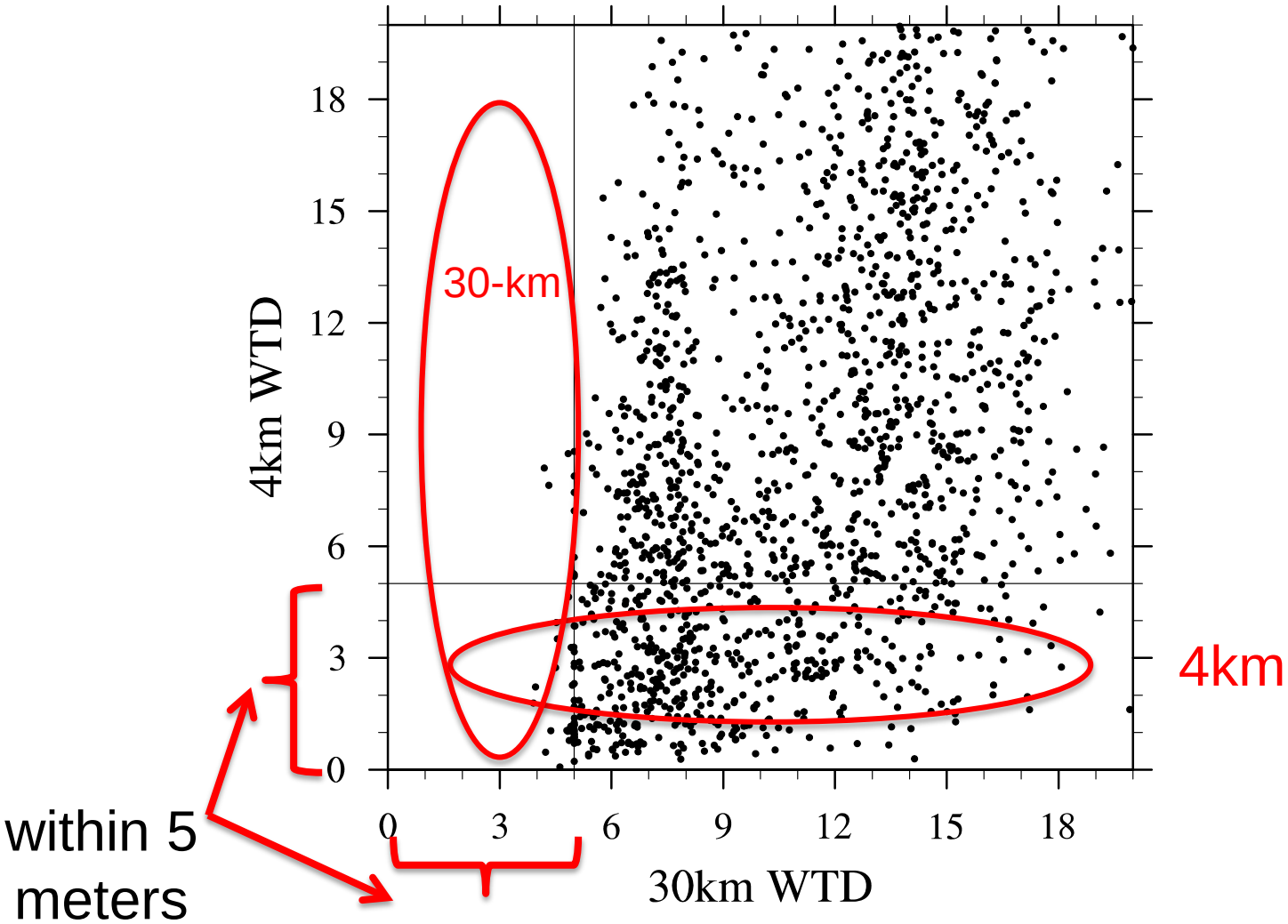
Model	Season	Output field	Day bias	Day RMSE	Night bias	Night RMSE
Noah-MP	MAM	T_{2m}	0.5	1.0	0.2	0.8
w/GW	MAM	T_{2m}	**0.4**	1.0	0.2	0.8
Noah-MP	JJA	T_{2m}	1.7	1.9	0.5	1.0
w/GW	JJA	T_{2m}	**1.1**	**1.6**	**0.1**	**0.9**

Regional bias improvements of 1.5° C on 30-km grids

Barlage, et al. 2015

At 1-km resolution, groundwater parameterization produces 3-6 °C differences.



The interactions of vegetation-hydrology are amplified at higher spatial resolution

- Significant sub-grid variability is missed when using coarse resolution