LIS-JULES Benchmarking in the NLDAS Testbed

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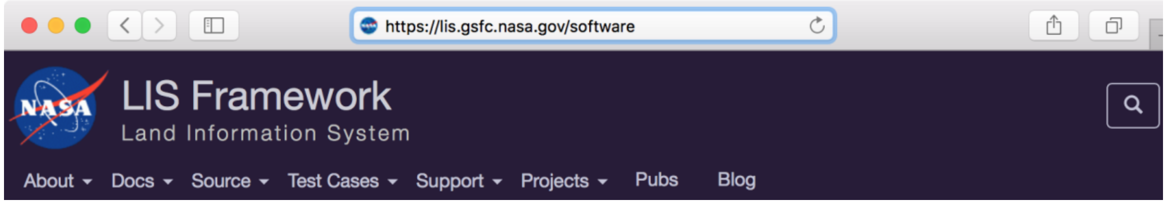
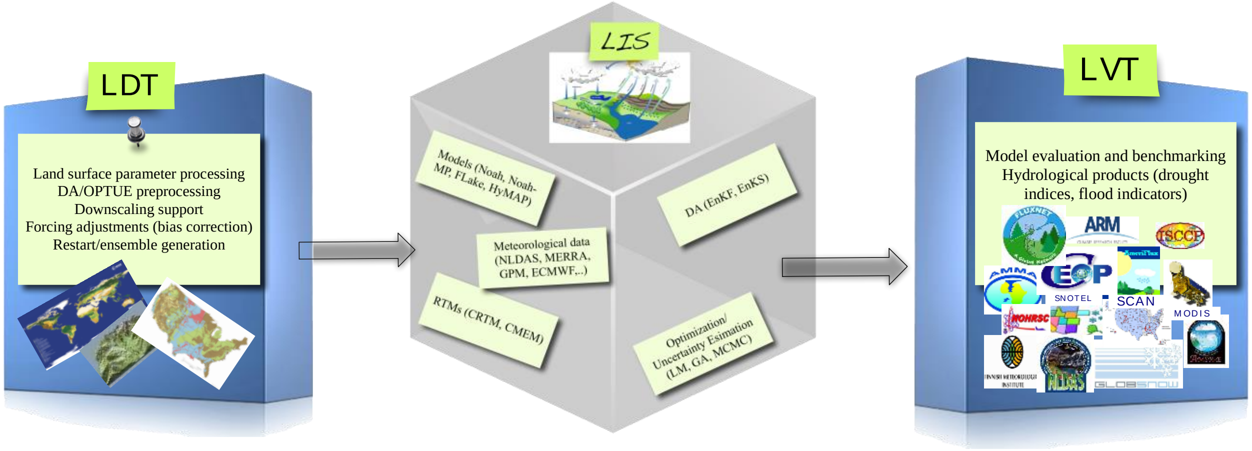

https://lis.gsfc.nasa.gov/software

LIS Framework

Land Information System



LDT

Land surface parameter processing
DA/OPTUE preprocessing
Downscaling support
Forcing adjustments (bias correction)
Restart/ensemble generation

LIS

Models (Noah, Noah-MP, FLake, HyMAP)
Meteorological data (NLDAS, MERRA, GPM, ECMWF,..)
RTMs (CRTM, CMEM)
DA (EnKF, EnKS)
Optimization/ Uncertainty Esimation (LM, GA, MCMC)

LVT

Model evaluation and benchmarking
Hydrological products (drought indices, flood indicators)

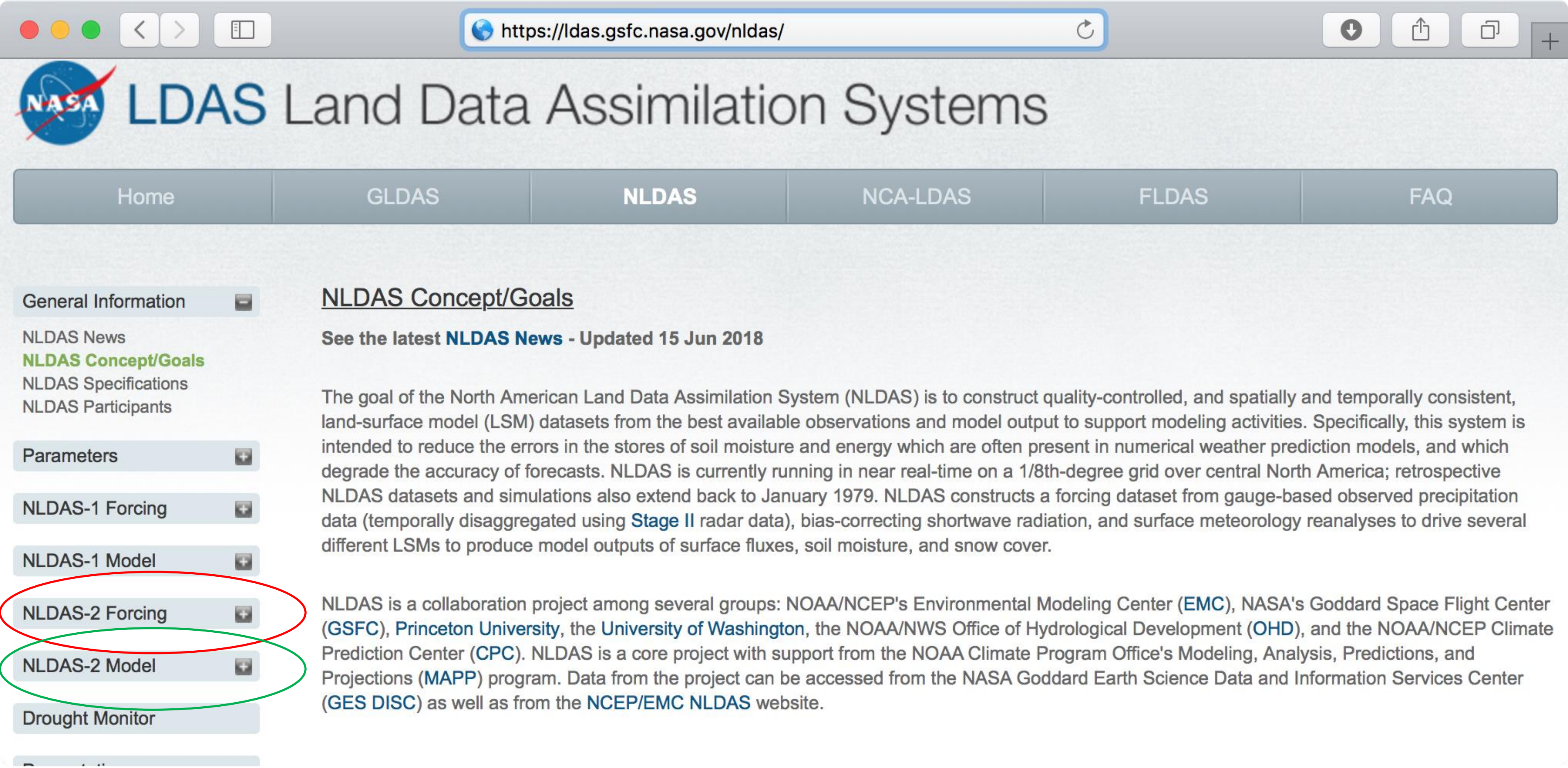
Land data assimilation platform of the U.S. Air Force 557th Weather Wing

JULES 5.0 has been integrated into LIS.

Land Verification Toolkit (LVT)

A range of evaluation metrics
Land model diagnostics
Data assimilation and uncertainty diagnostics
Spatial scale analysis
Support for non-LIS data

- Open source software
- Support for a range of data products (in-situ, remote sensing and model/reanalysis)
- Supports a range of metrics (diagnostics, deterministic, information-theory, decision-theory, scale-decomposition based metrics)
- Capability to generate hydrological products (drought/flood percentiles, indicators)
- In summary, LVT is a benchmarking and verification environment.



NLDAS Concept/Goals

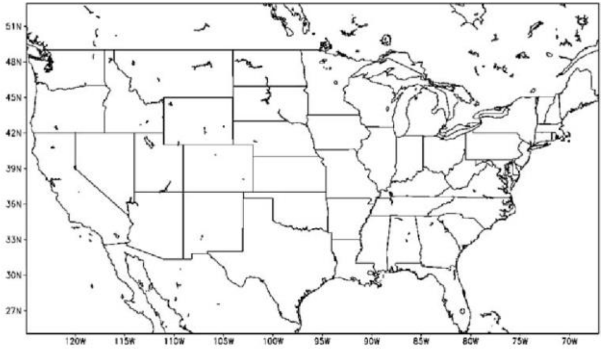
See the latest NLDAS News - Updated 15 Jun 2018

The goal of the North American Land Data Assimilation System (NLDAS) is to construct quality-controlled, and spatially and temporally consistent, land-surface model (LSM) datasets from the best available observations and model output to support modeling activities. Specifically, this system is intended to reduce the errors in the stores of soil moisture and energy which are often present in numerical weather prediction models, and which degrade the accuracy of forecasts. NLDAS is currently running in near real-time on a 1/8th-degree grid over central North America; retrospective NLDAS datasets and simulations also extend back to January 1979. NLDAS constructs a forcing dataset from gauge-based observed precipitation data (temporally disaggregated using Stage II radar data), bias-correcting shortwave radiation, and surface meteorology reanalyses to drive several different LSMs to produce model outputs of surface fluxes, soil moisture, and snow cover.

NLDAS is a collaboration project among several groups: NOAA/NCEP's Environmental Modeling Center (EMC), NASA's Goddard Space Flight Center (GSFC), Princeton University, the University of Washington, the NOAA/NWS Office of Hydrological Development (OHD), and the NOAA/NCEP Climate Prediction Center (CPC). NLDAS is a core project with support from the NOAA Climate Program Office's Modeling, Analysis, Predictions, and Projections (MAPP) program. Data from the project can be accessed from the NASA Goddard Earth Science Data and Information Services Center (GES DISC) as well as from the NCEP/EMC NLDAS website.

the NLDAS Testbed

NLDAS



$125^\circ W, 67^\circ W, 25^\circ N, 53^\circ N$

0.125° Resolution

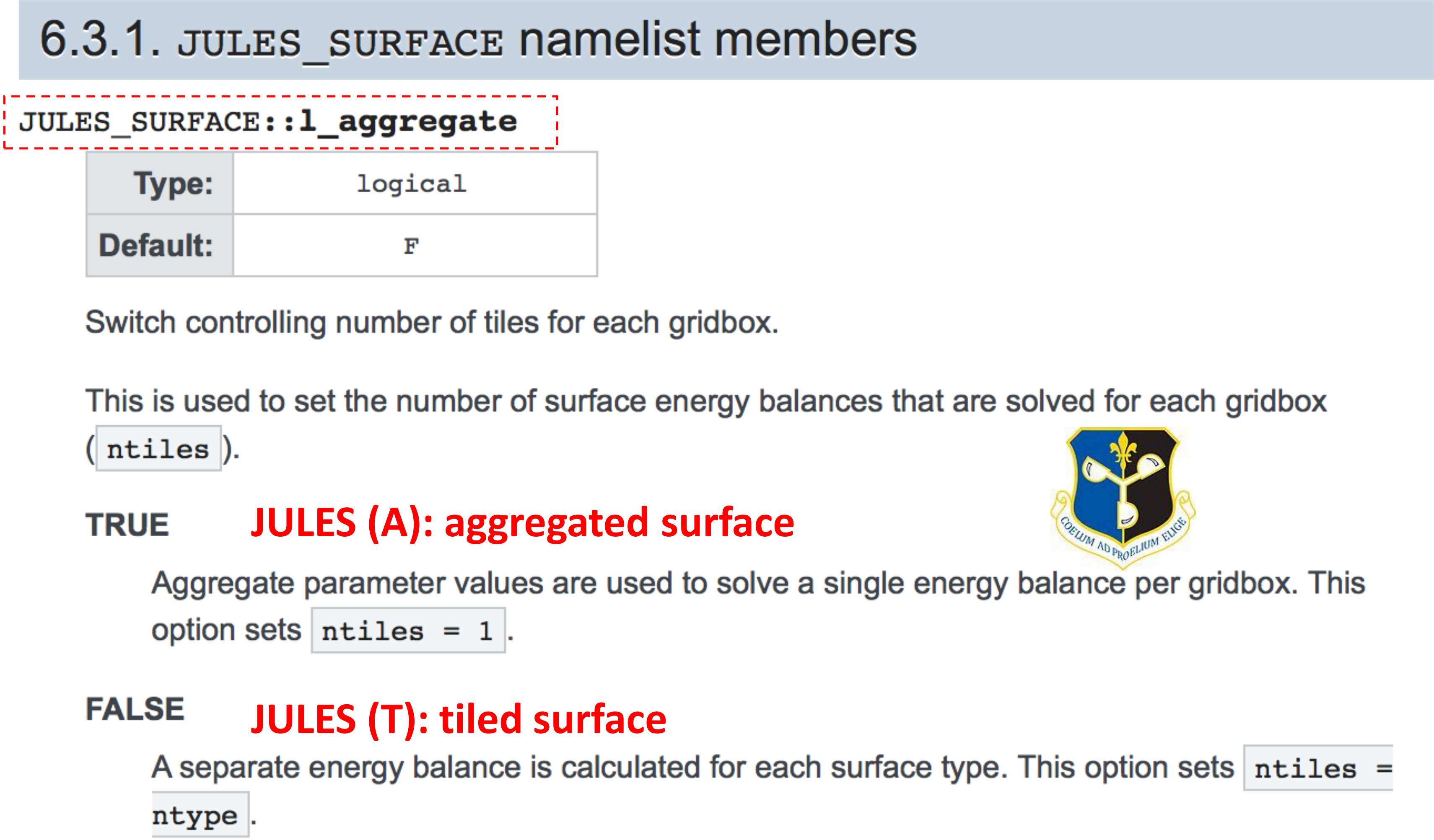
Hourly NLDAS-2 forcing, 15-min time step, daily average output

LIS

- JULES (A): l_aggregate=True
- JULES (T): l_aggregate=False
- Noah 3.6
- Noah-MP 3.6 dynamic vegetation
- Catchment 2.5
- VIC 4.1.2.l

LVT

- Soil moisture
    - NRCS Soil Climate Analysis Network (SCAN)
    - U.S. Climate Reference Network (USCRN)
- Snow depth
    - Canadian Meteorological Centre (CMC) daily snow depth analysis
    - NSIDC Snow Data Assimilation System (SNODAS) data product
- Latent heat flux
    - FLUXNET MTE
- Sensible heat flux
    - FLUXNET MTE



6.3.1. `JULES_SURFACE` namelist members

`JULES_SURFACE::l_aggregate`

Type:	`logical`
Default:	`F`

Switch controlling number of tiles for each gridbox.

This is used to set the number of surface energy balances that are solved for each gridbox (`ntiles`).

TRUE **JULES (A): aggregated surface**

Aggregate parameter values are used to solve a single energy balance per gridbox. This option sets `ntiles = 1` .

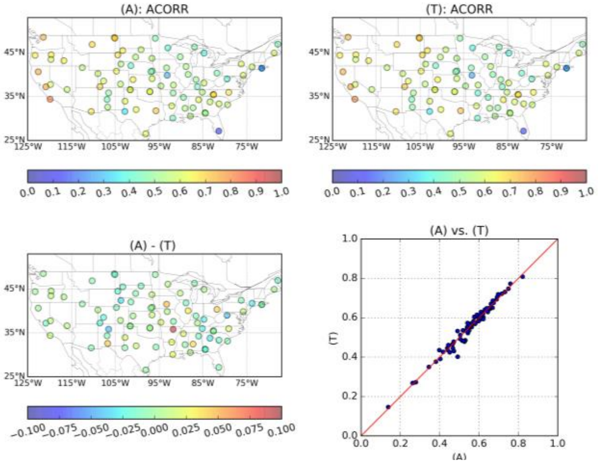
FALSE **JULES (T): tiled surface**

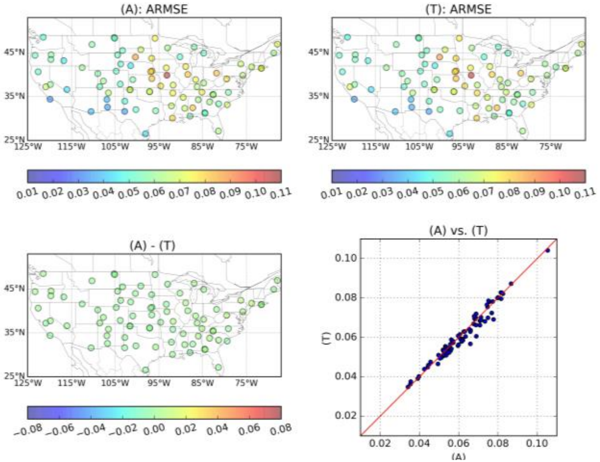
A separate energy balance is calculated for each surface type. This option sets `ntiles = ntype` .

Anomaly Correlation

Anomaly RMSE

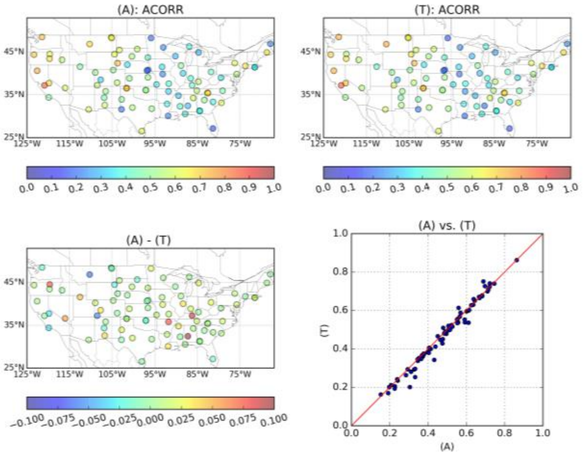
1st layer soil moisture
SMC_1 (0-10 cm)

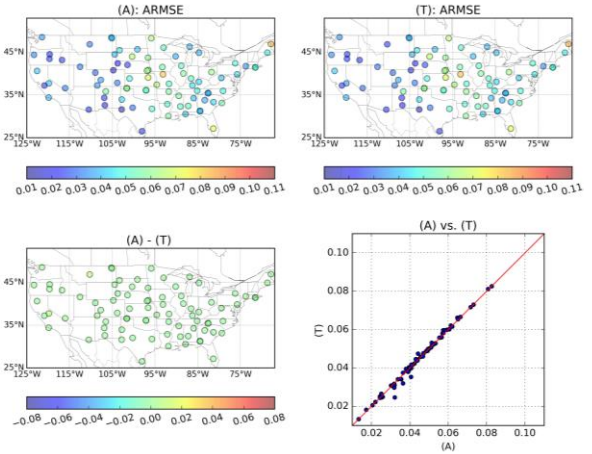




USCRN
2010-2018

Root zone soil moisture
SMC_R (0-100 cm)



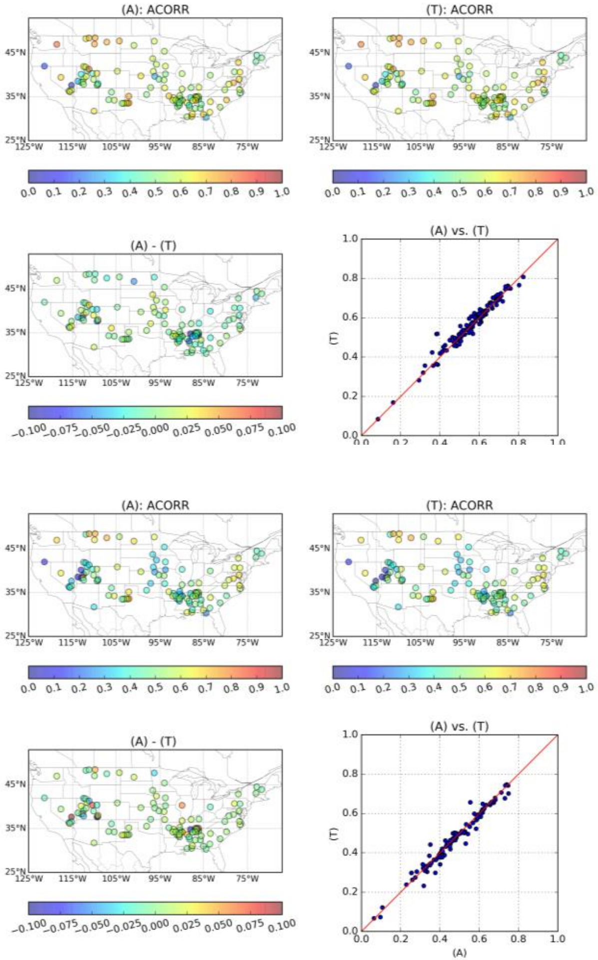


SCAN 2000-2017

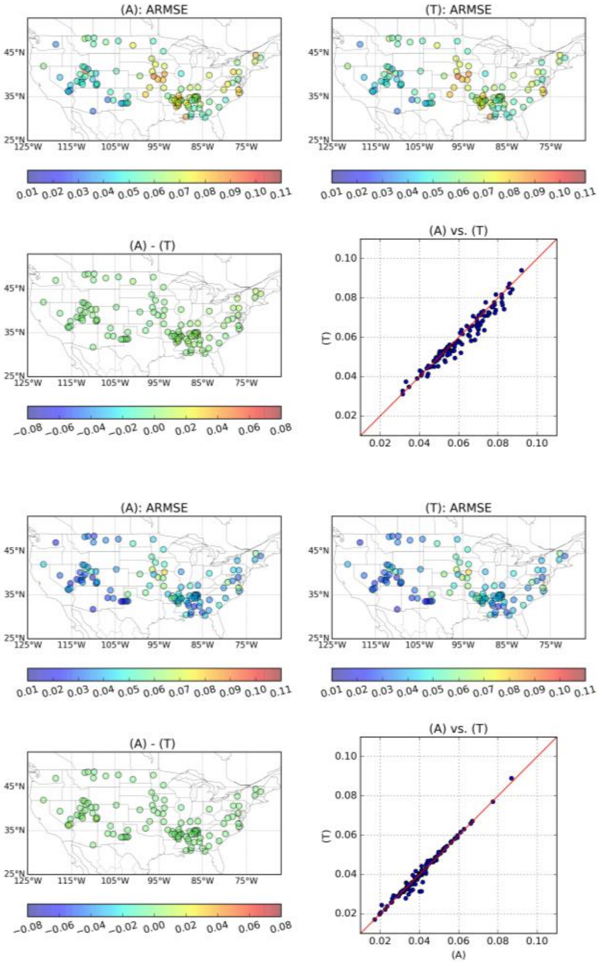
1st layer soil moisture SMC1 (0-10 cm)

Root zone soil moisture SMC_R (0-100 cm)

Anomaly Correlation

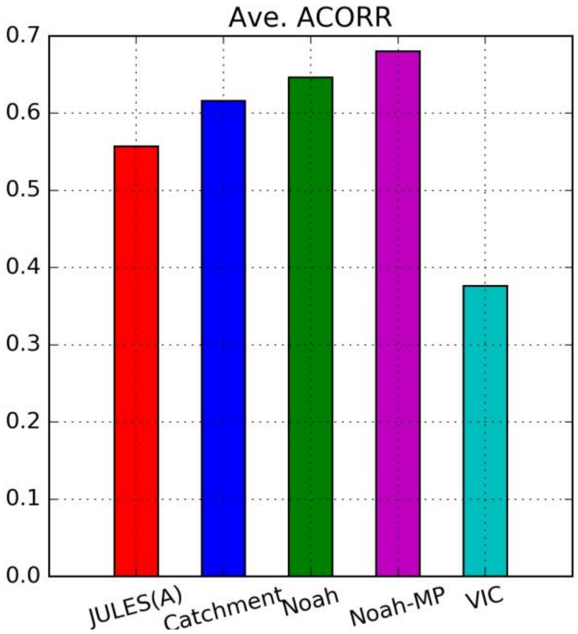


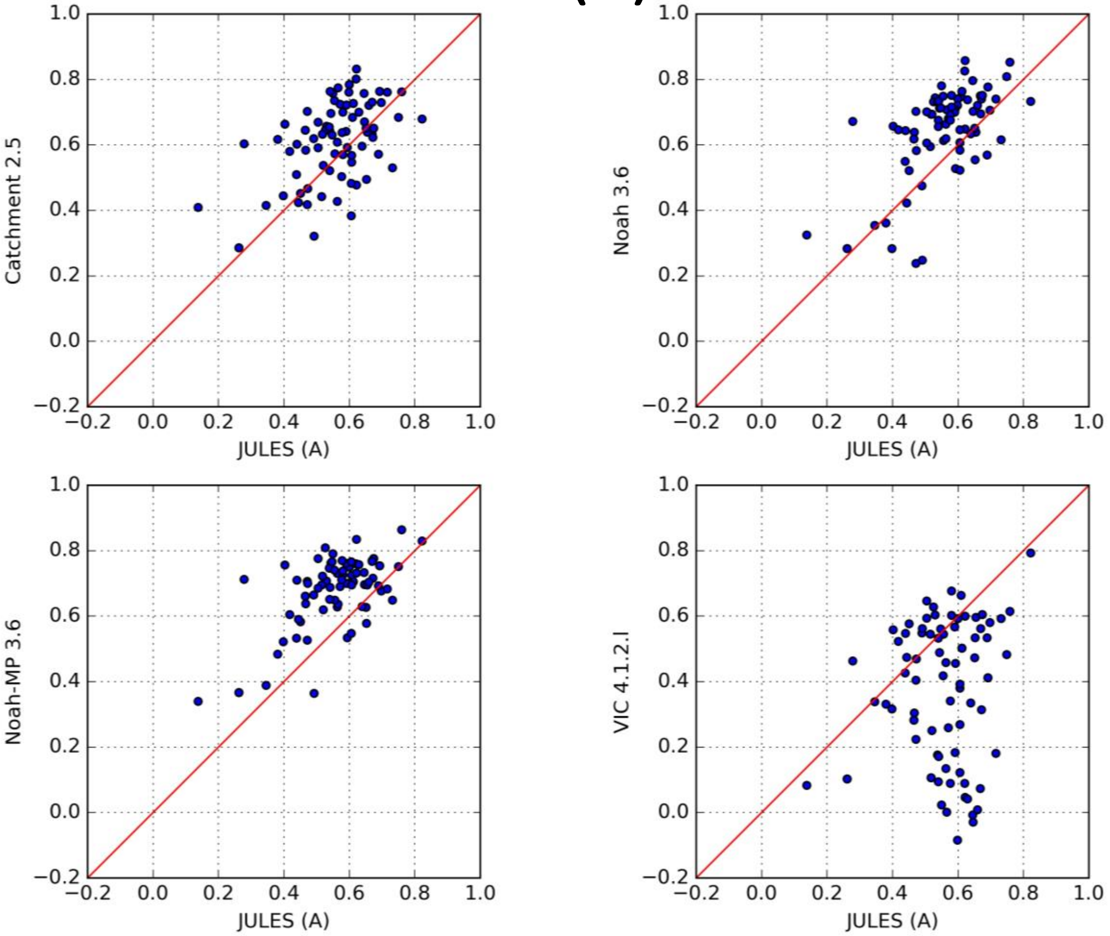
Anomaly RMSE



USCRN SMC$_1$ Anomaly Correlation – JULES (A)

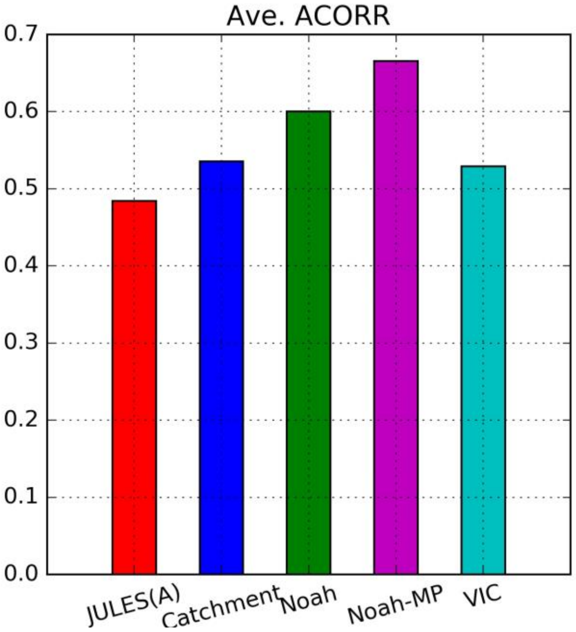
- JULES (A) is significantly different from the 4 models, especially VIC.
- For domain average, JULES (A) is higher than VIC but lower than the other 3 models.

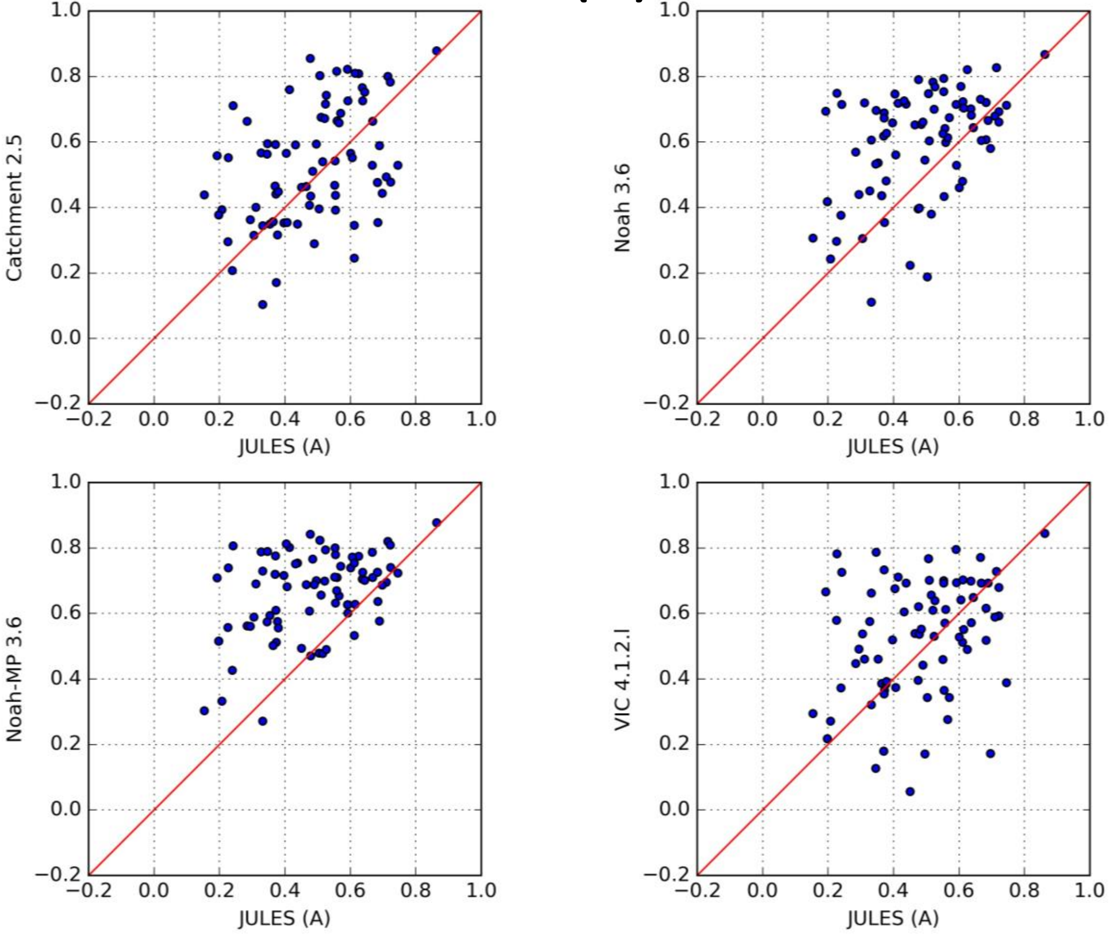




USCRN SMC$_R$ Anomaly Correlation – JULES (A)

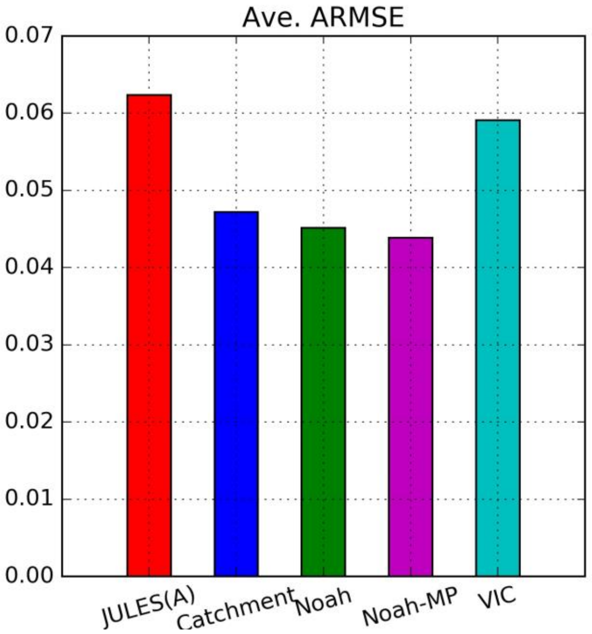
- JULES (A) is significantly different from the 4 models.
- For domain average, JULES (A) is lower than Noah and Noah-MP, about the same level of Catchment and VIC.

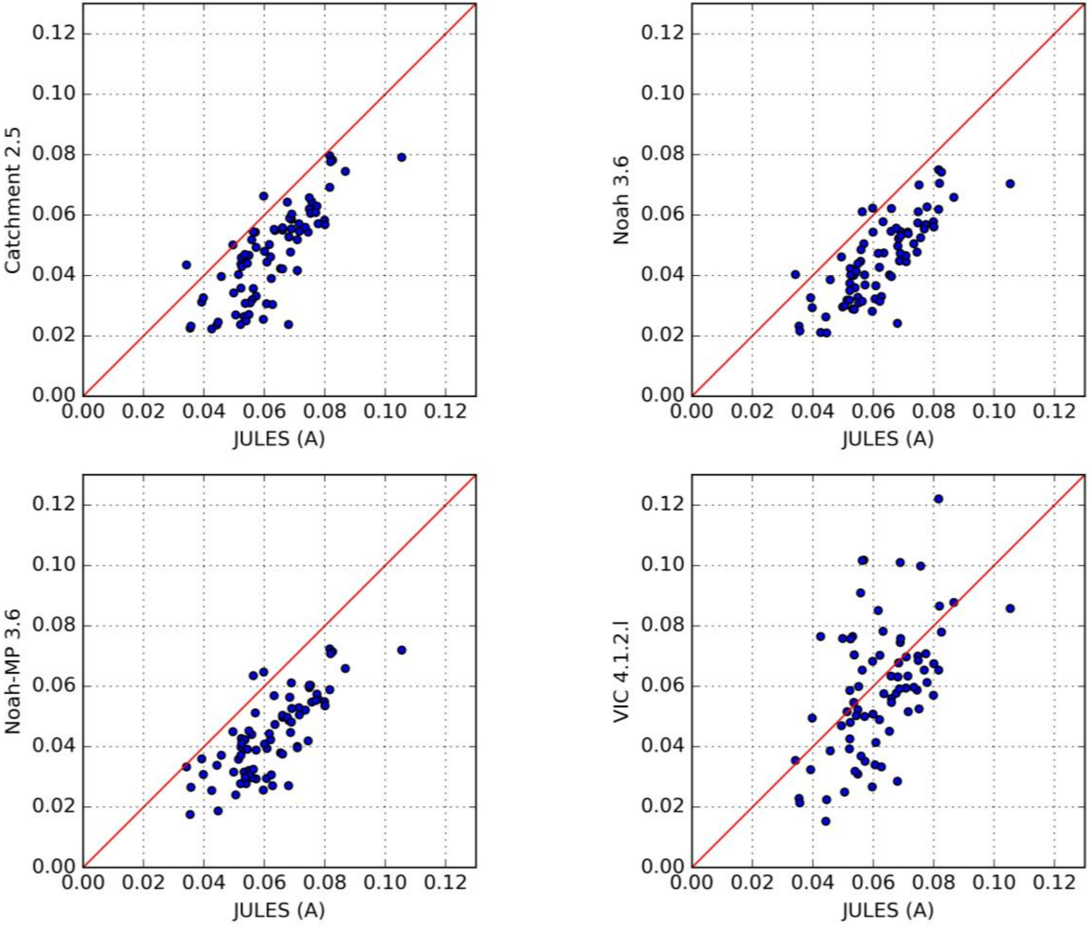




USCRN SMC_1 Anomaly RMSE – JULES (A)

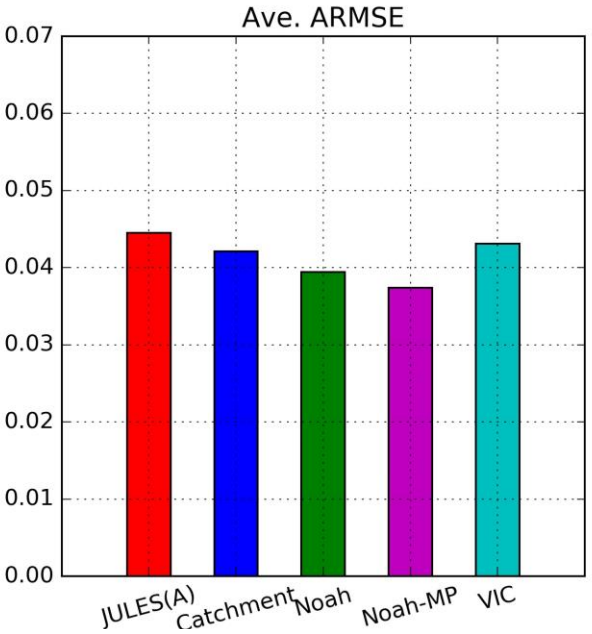
- For most of grid boxes, JULES (A) is higher than Catchment, Noah, and Noah-MP.
- For domain average, JULES (A) is similar to VIC but higher than other 3 models.

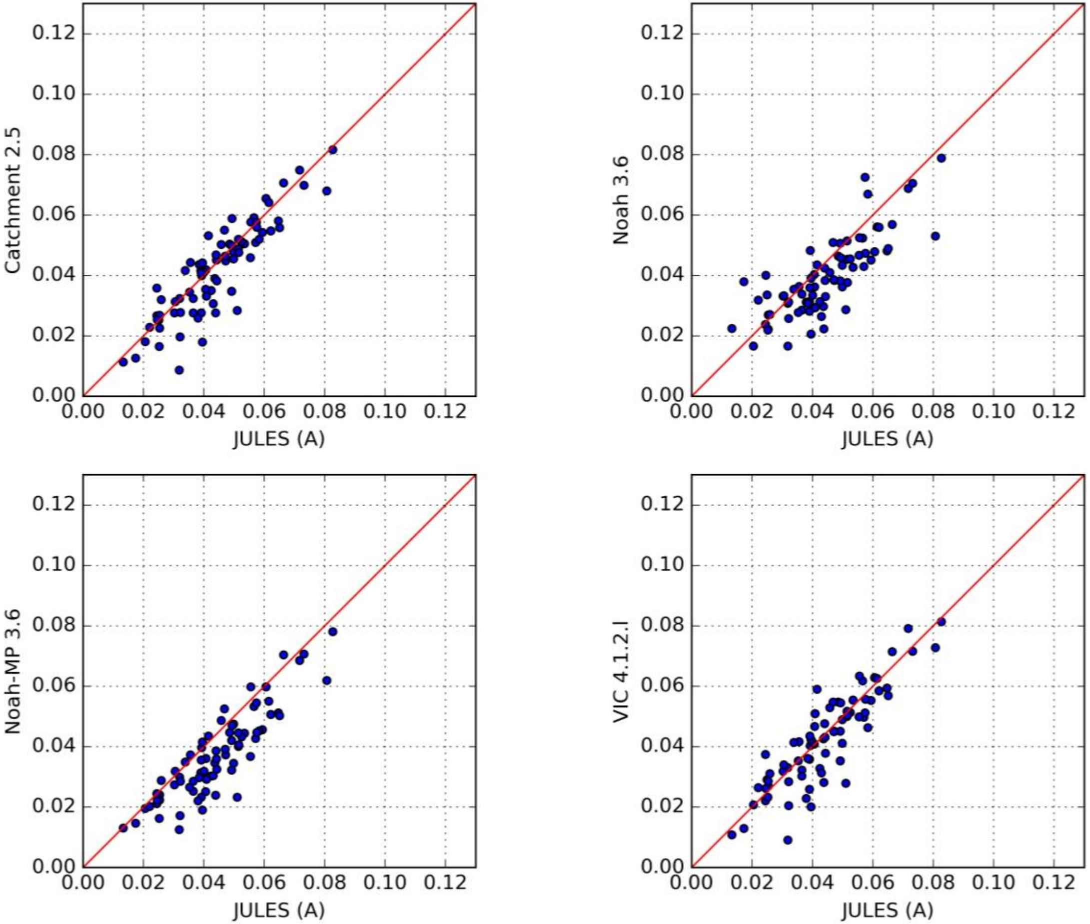




USCRN SMC$_R$ Anomaly RMSE – JULES (A)

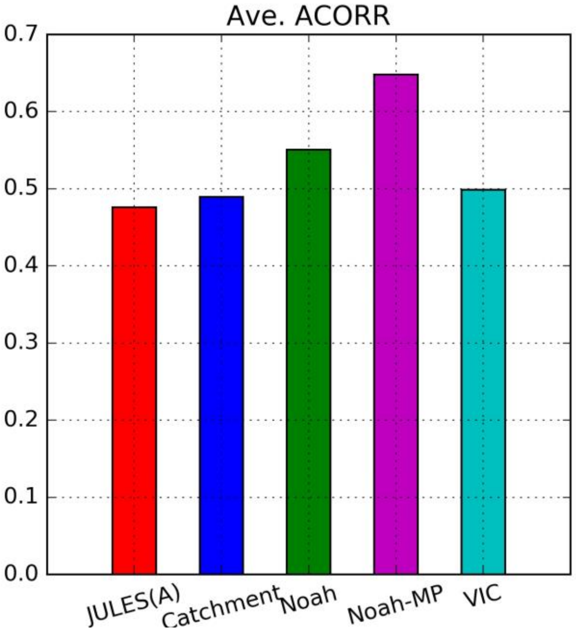
- JULES (A) is similar to the 4 models.
- JULES (A) ARMSE is more correlated to the 4 models for root zone soil moisture than the 1st layer soil moisture.

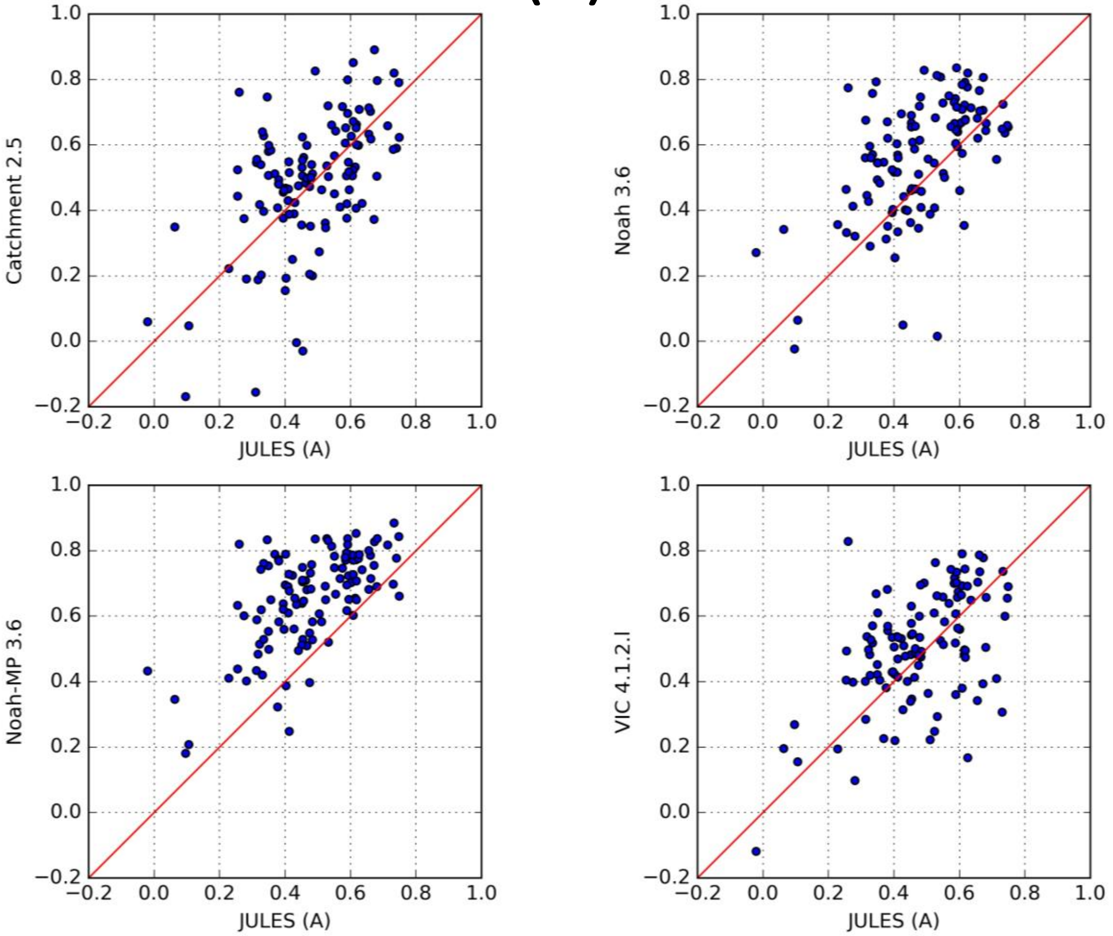




SCAN SMC$_1$ Anomaly Correlation – JULES (A)

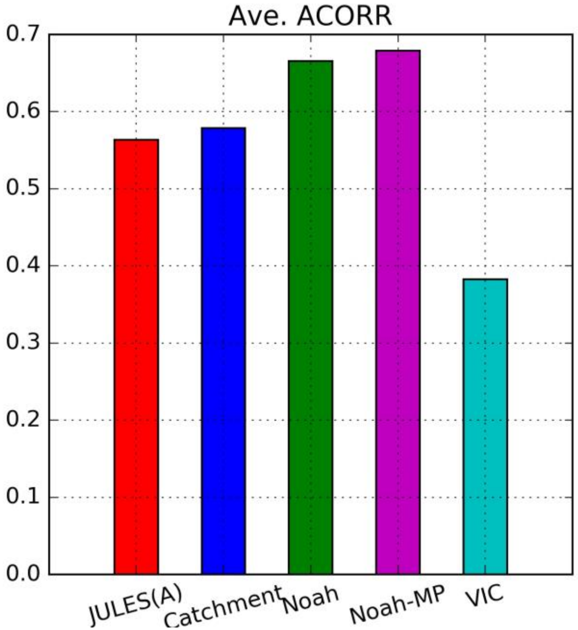
- JULES (A) is significantly different from the 4 models.
- For domain average, JULES (A) is close to Catchment and VIC but lower than Noah and Noah-MP.

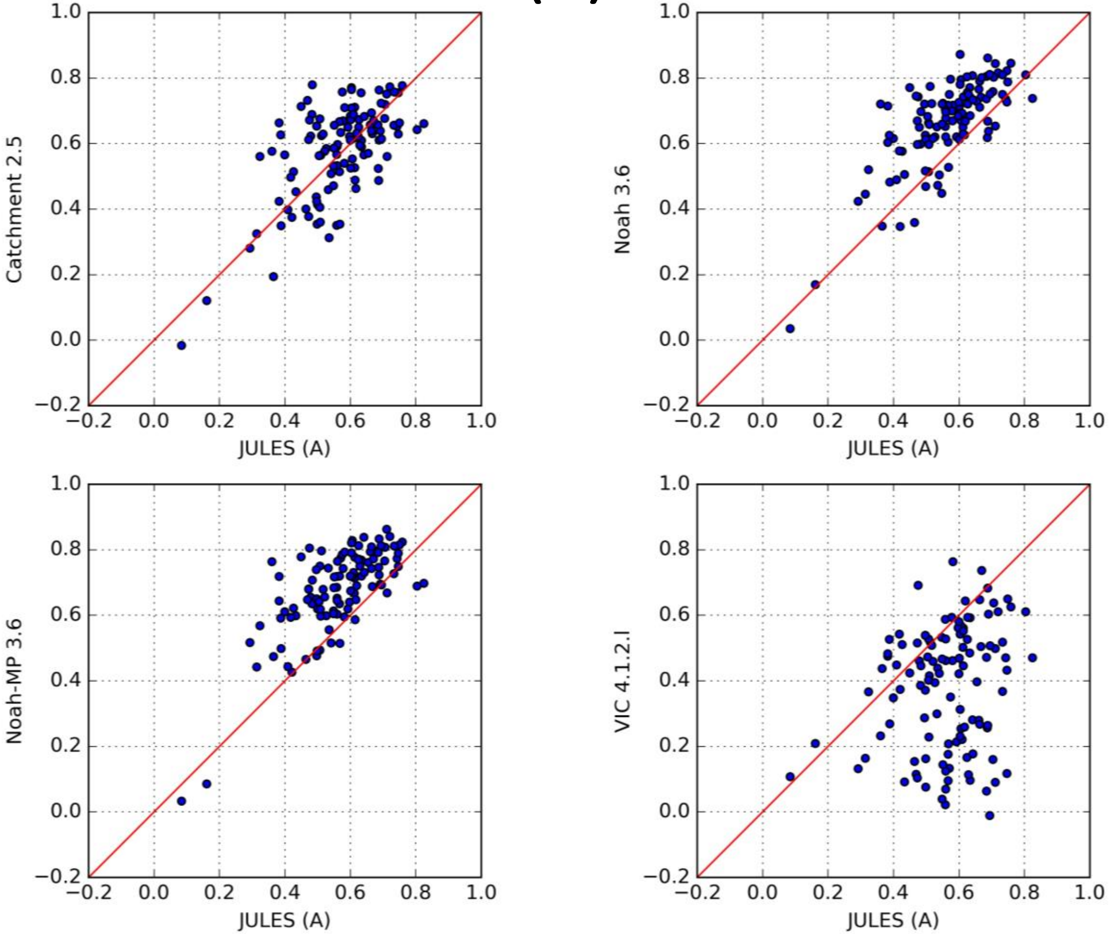




SCAN SMC_R Anomaly Correlation – JULES (A)

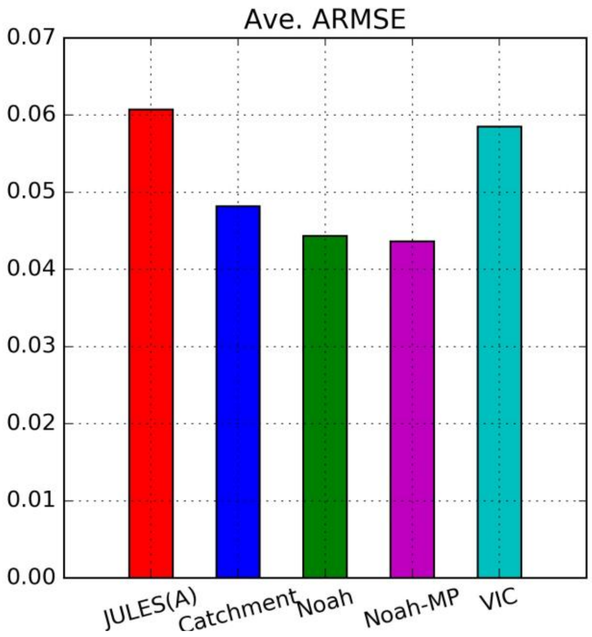
- There are significant differences between JULES (A) and the 4 models.
- For domain average, JULES (A) is similar to Catchment, higher than VIC, and lower than Noah and Noah-MP.

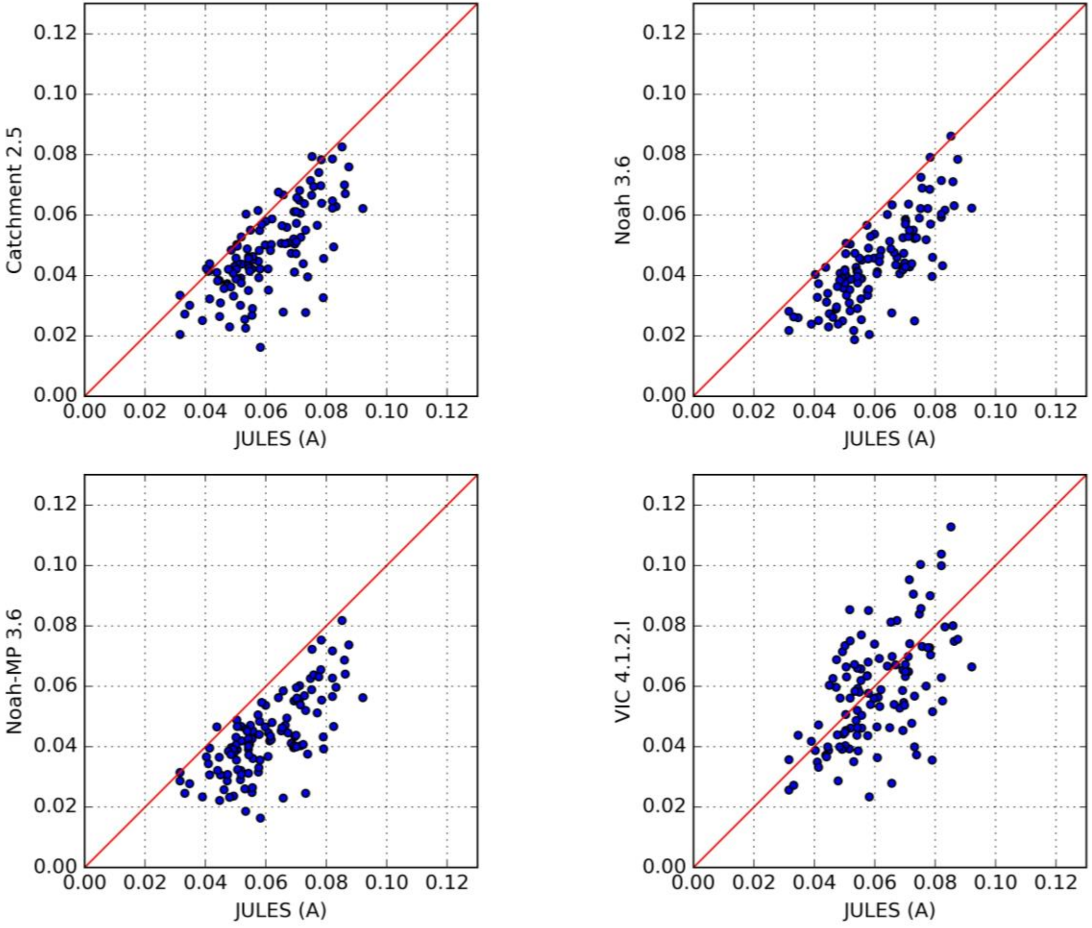




SCAN SMC$_1$ Anomaly RMSE – JULES (A)

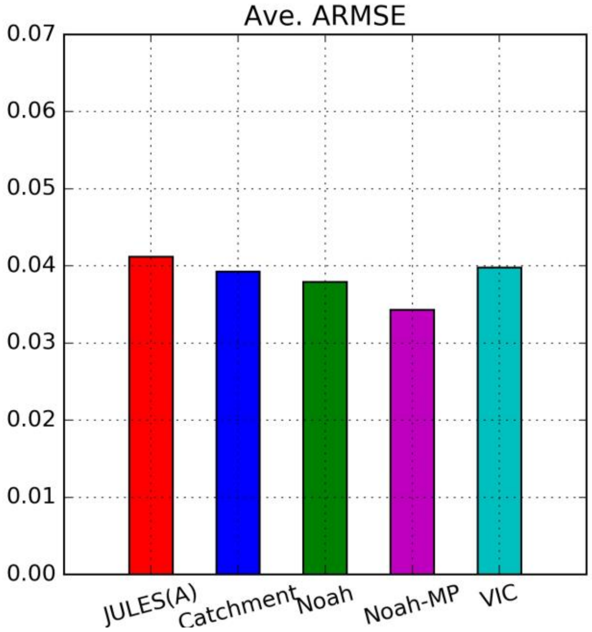
- There are significant differences between JULES (A) and the 4 models.
- For domain average, JULES (A) is similar to VIC but it is higher than Catchment, Noah and Noah-MP.

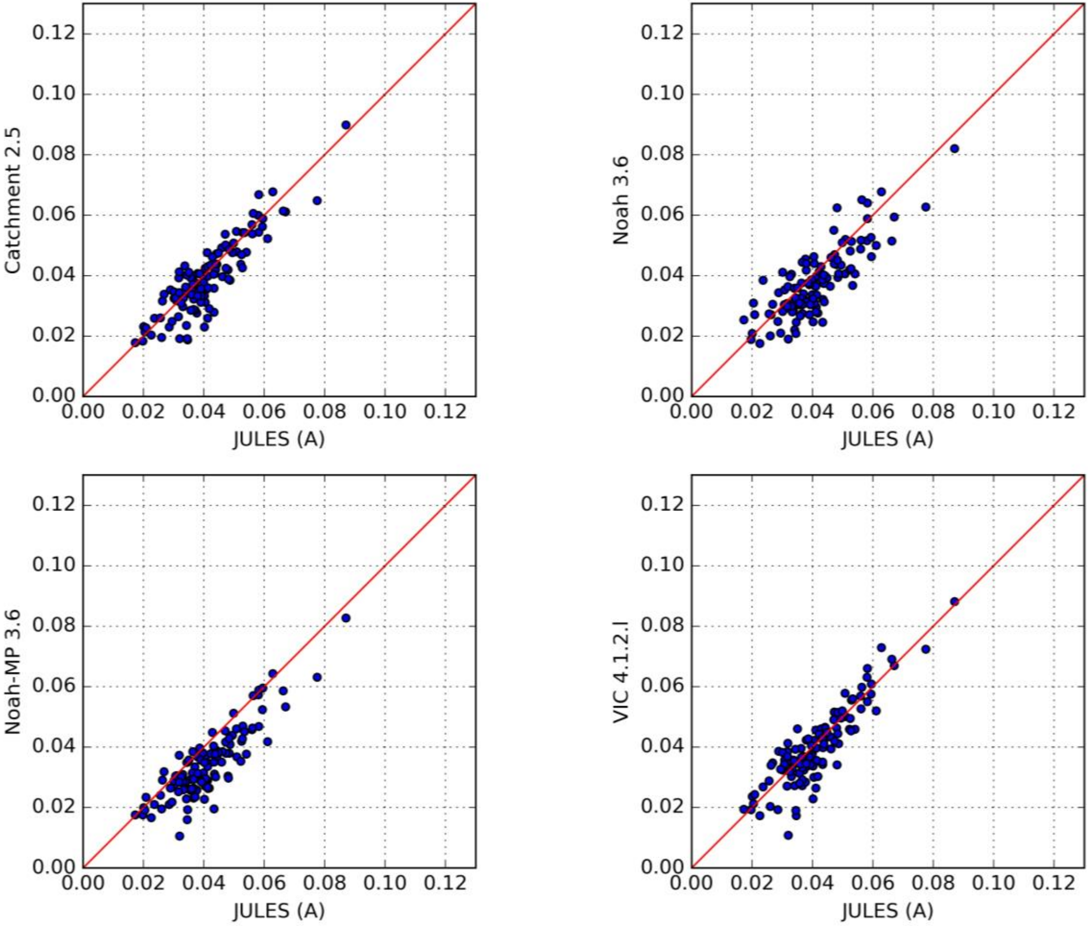




SCAN SMC$_R$ Anomaly RMSE - JULES (A)

- JULES (A) is relatively similar to the 4 models for ARMSE.
- For domain average, JULES (A) is similar to Catchment, Noah, and VIC but it is higher than Noah-MP.



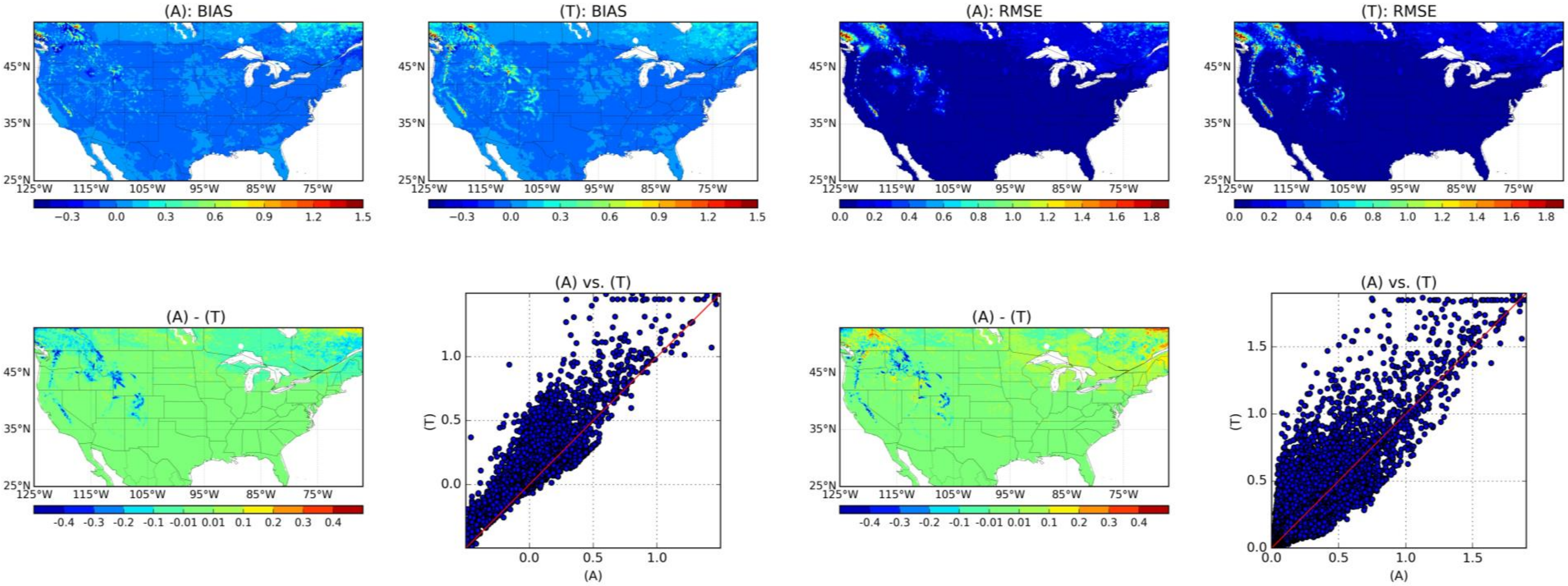


Summary 1 – Soil moisture contents

- **JULES (A) and JULES (T) produce similar soil moisture simulations.**
- **For the reference soil moisture datasets (USCRN and SCAN),**
    - **Noah 3.6 and Noah-MP 3.6 generally have better consistencies than JULES (A).**
    - **However, JULES (A) beats Catchment and VIC sometimes.**

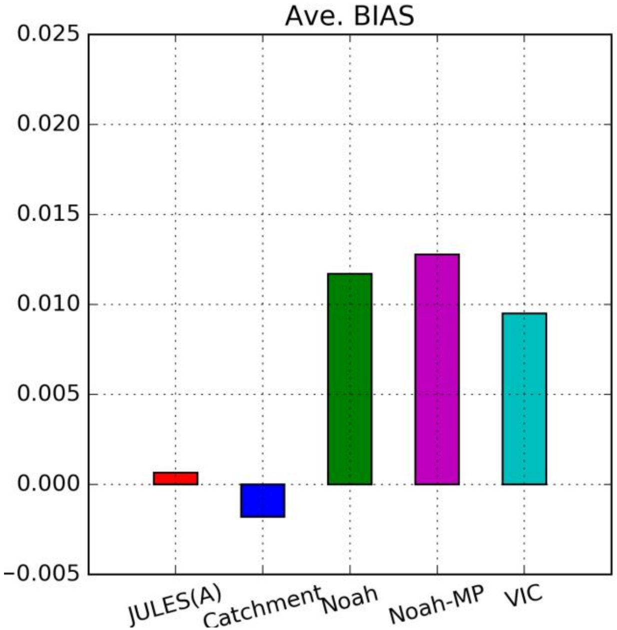
CMC Snow Depth JULES (A) vs. JULES (T)

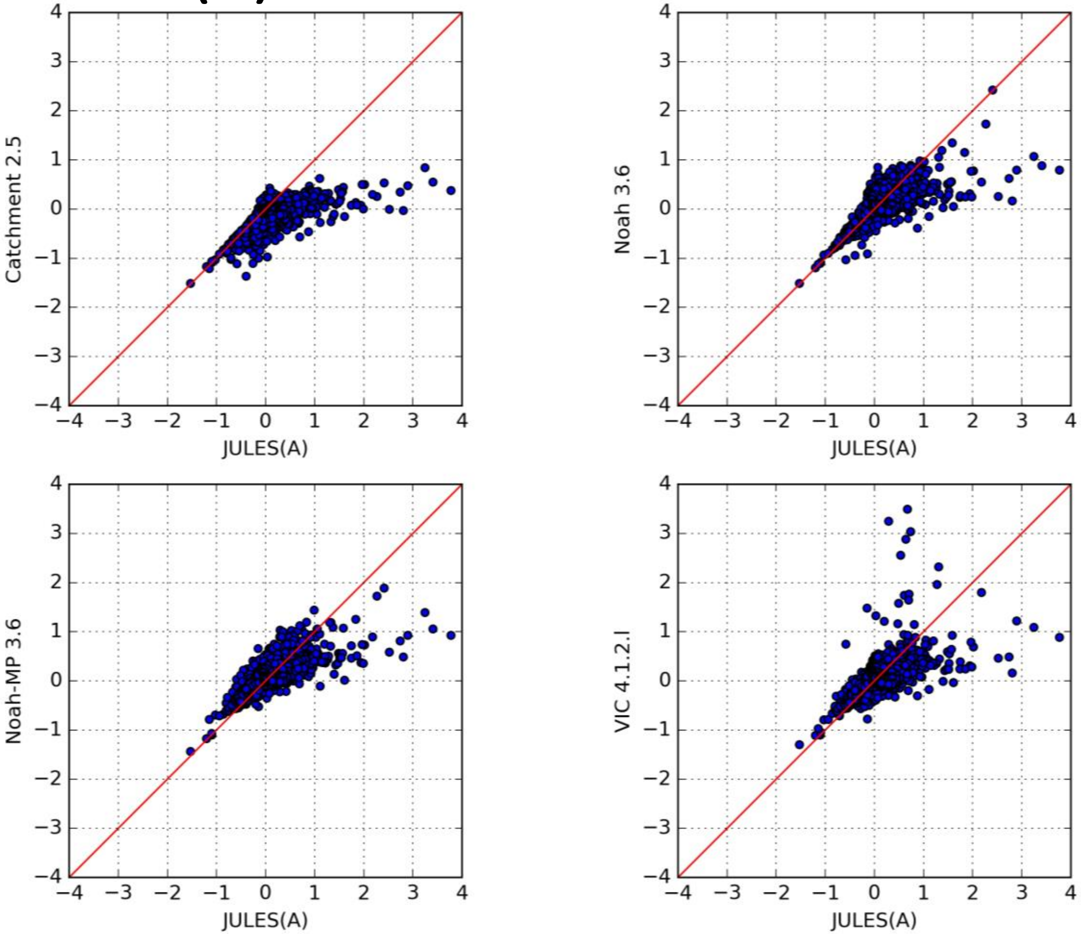
- **Data period:1998 – 2017**
- **JULES (T) has higher biases than JULES (A) in most of grid boxes.**
- **JULES (T) has larger RMSE than JULES (A) in most of grid boxes.**



CMC Snow Depth BIAS - JULES (A)

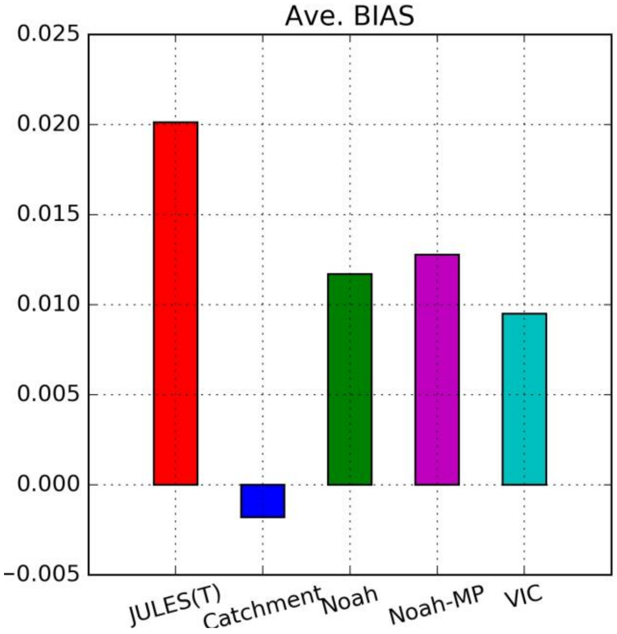
- JULES (A) has much lower average bias than Noah, Noah-MP and VIC
- JULES (A) has very high positive biases (e.g. >2m) over some grid boxes. This is similar to VIC.

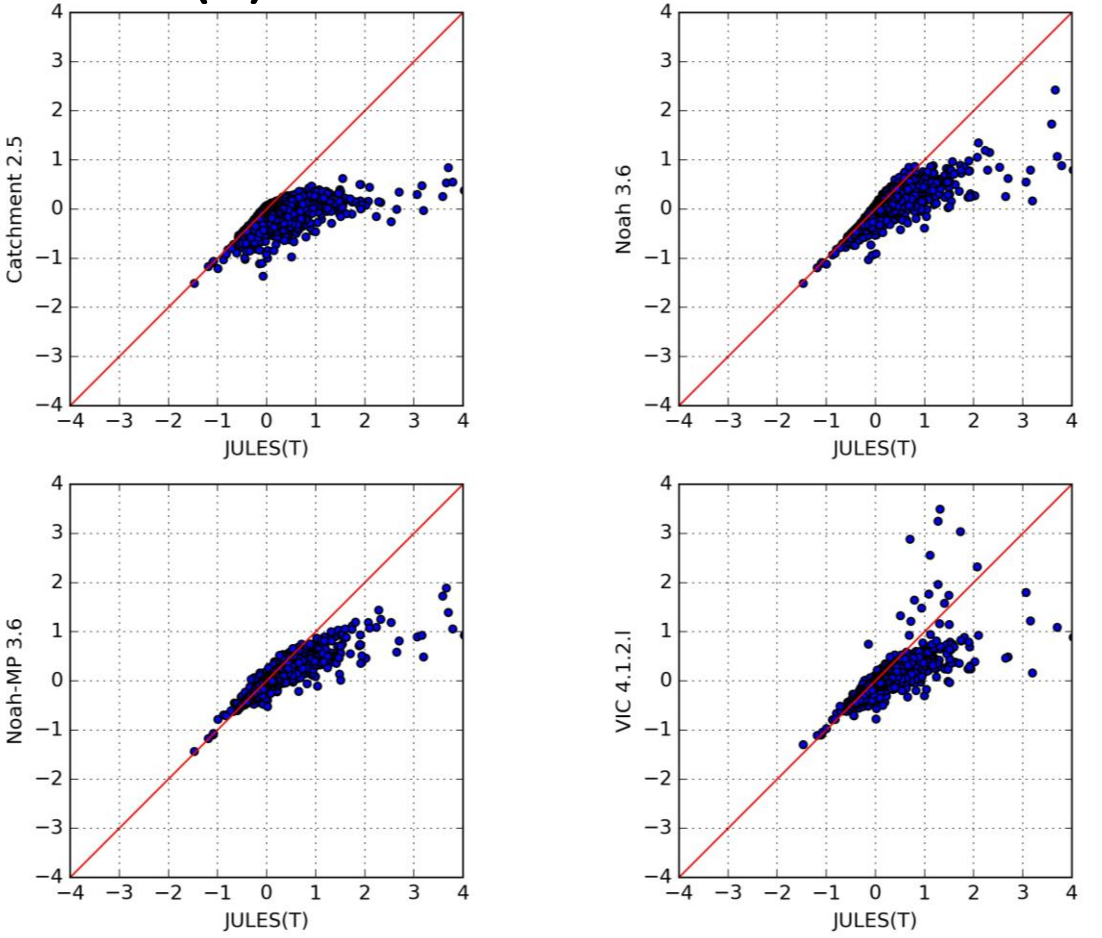




CMC Snow Depth BIAS - JULES (T)

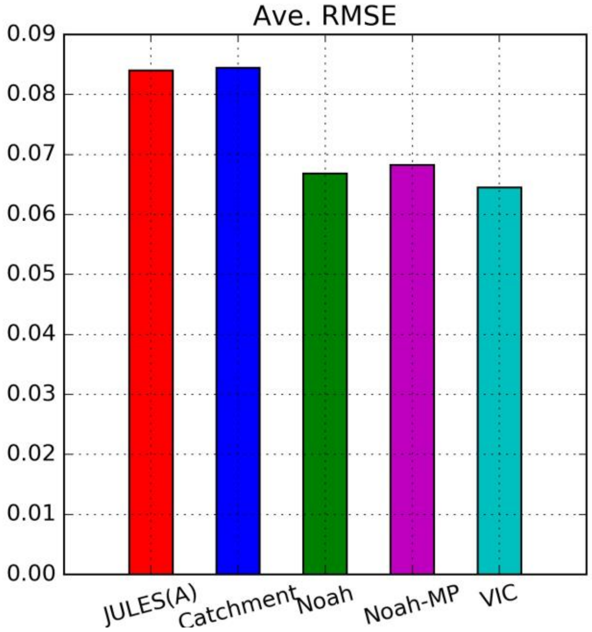
- On average, JULES (T) is higher than the 4 models.
- JULES (T) has very high positive biases (>2m) over a few grid boxes. This is similar to VIC.

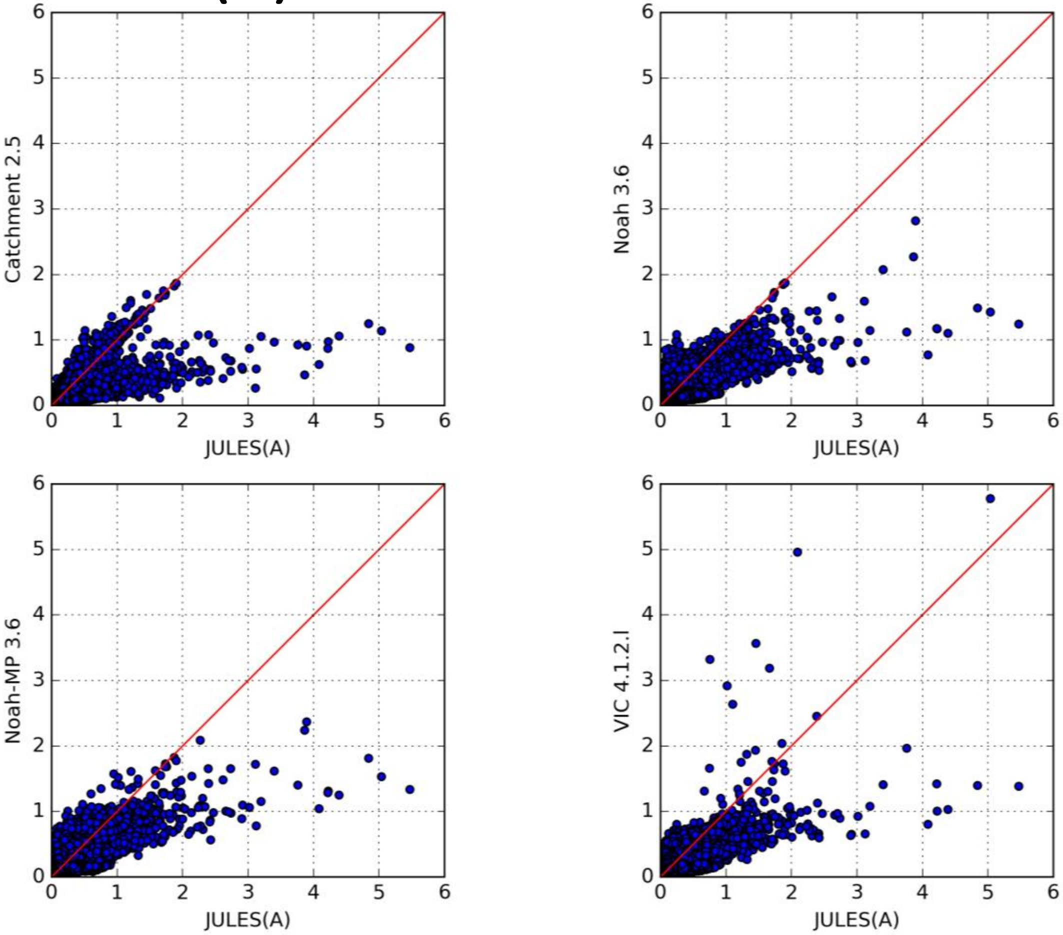




CMC Snow Depth RMSE - JULES (A)

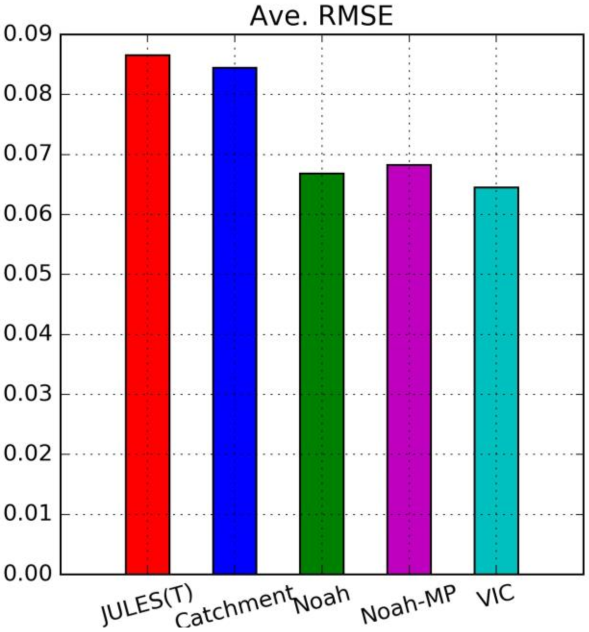
- JULES (A) is higher than the 4 models over more gird boxes.
- JULES (A) has very high RMSE (>2m) over a few grid boxes, which is similar to VIC.

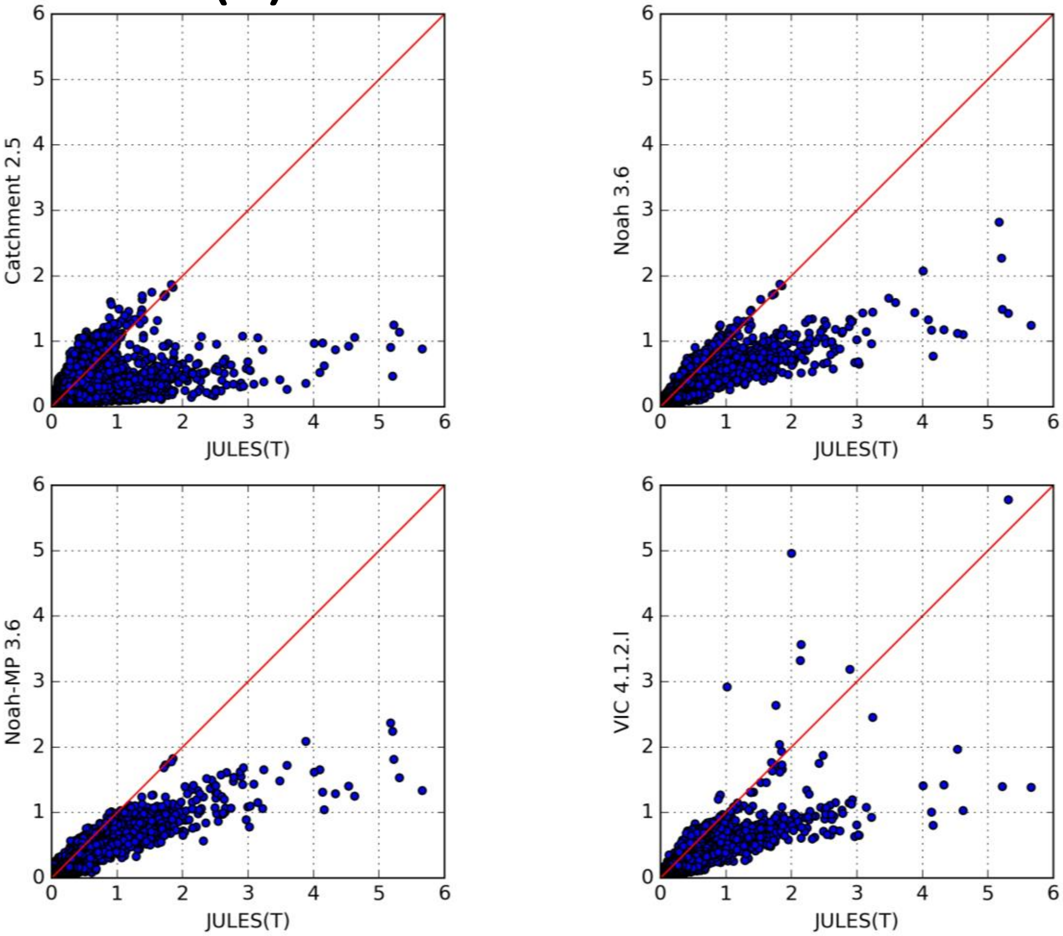




CMC Snow Depth RMSE - JULES (T)

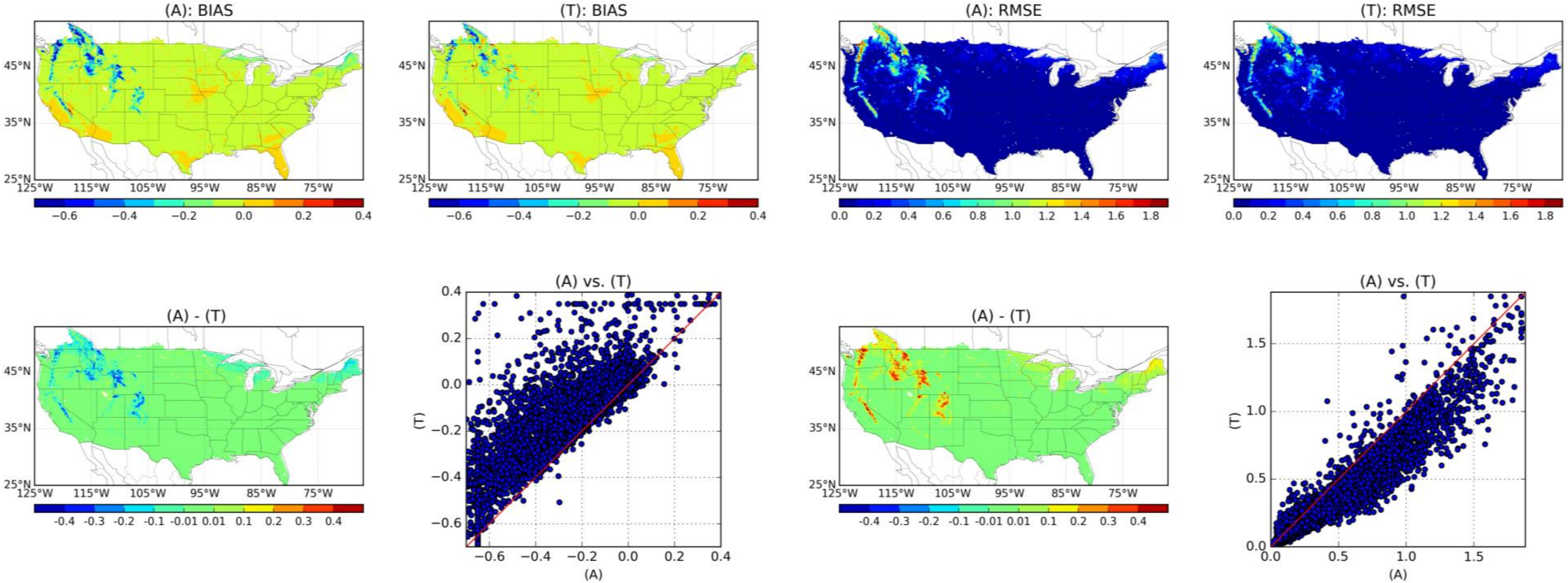
- JULES (T) is higher than Noah, Noah-MP and VIC in most of grid boxes.
- JULES (T) has every high RMSE (>2m) over a number of grid boxes. This is similar to VIC.





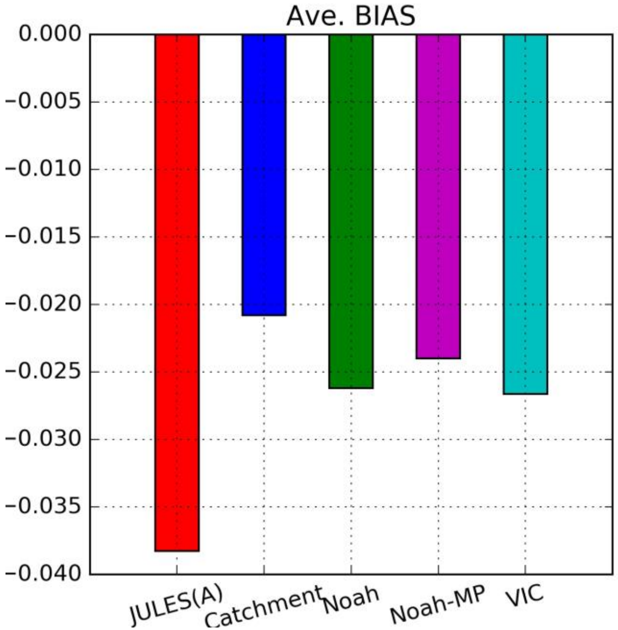
SNODAS Snow Depth JULES (A) vs. JULES (T)

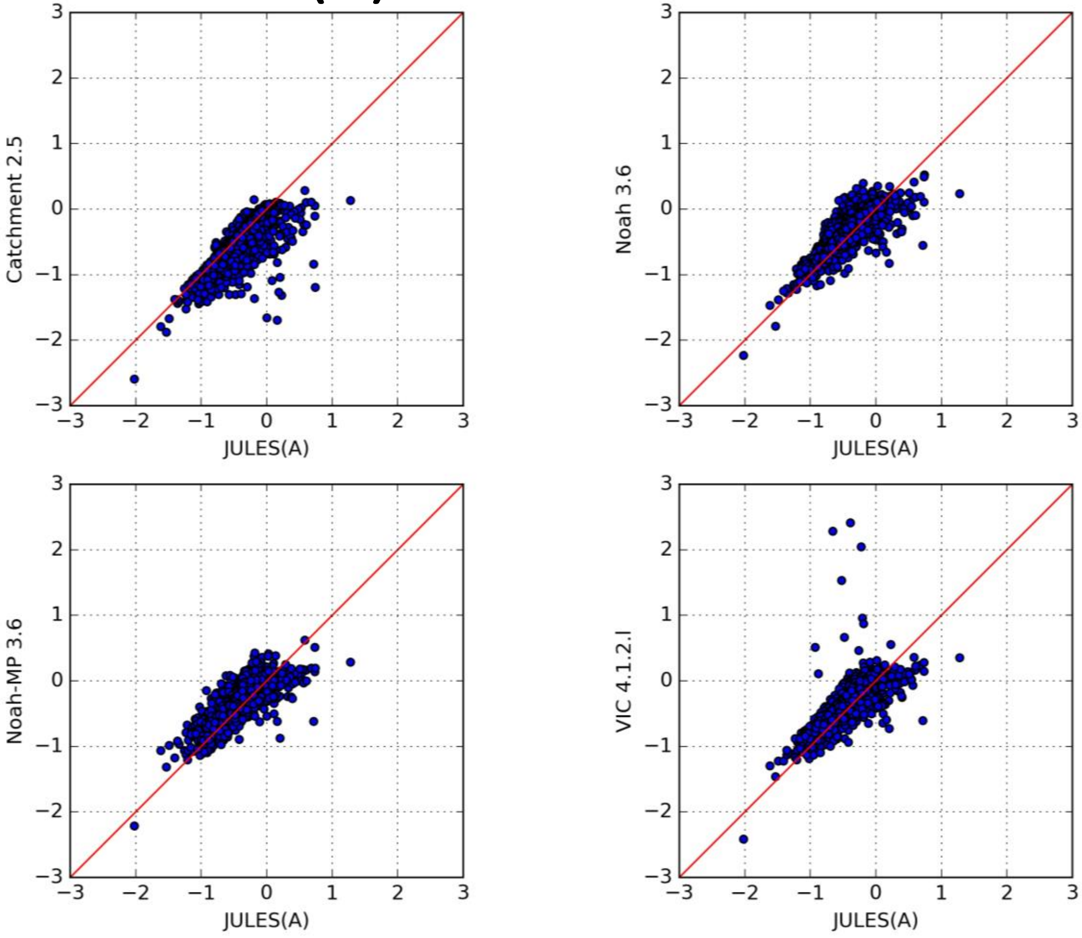
- **Data period: 2003 - 2017**
- **Both JULES (A) and JULES (T) have negative biases over most grid boxes.**
  - **JULES (T) has higher biases than JULES (A) in most of grid boxes.**
- **JULES (T) has smaller RMSE than JULES (A) in most of grid boxes.**



SNODAS Snow Depth BIAS - JULES (A)

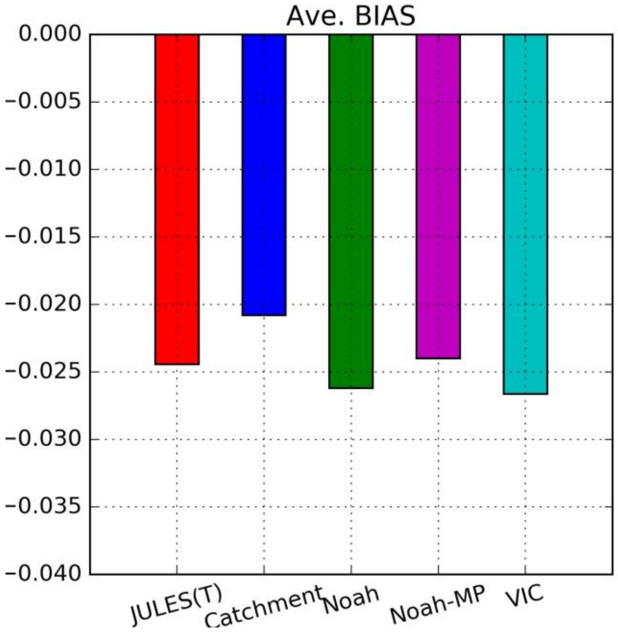
- JULES (A) is linearly correlated to the other 4 models.
- For most of grid boxes, all the model have negative biases, while JULES (A) has the lowest domain average.

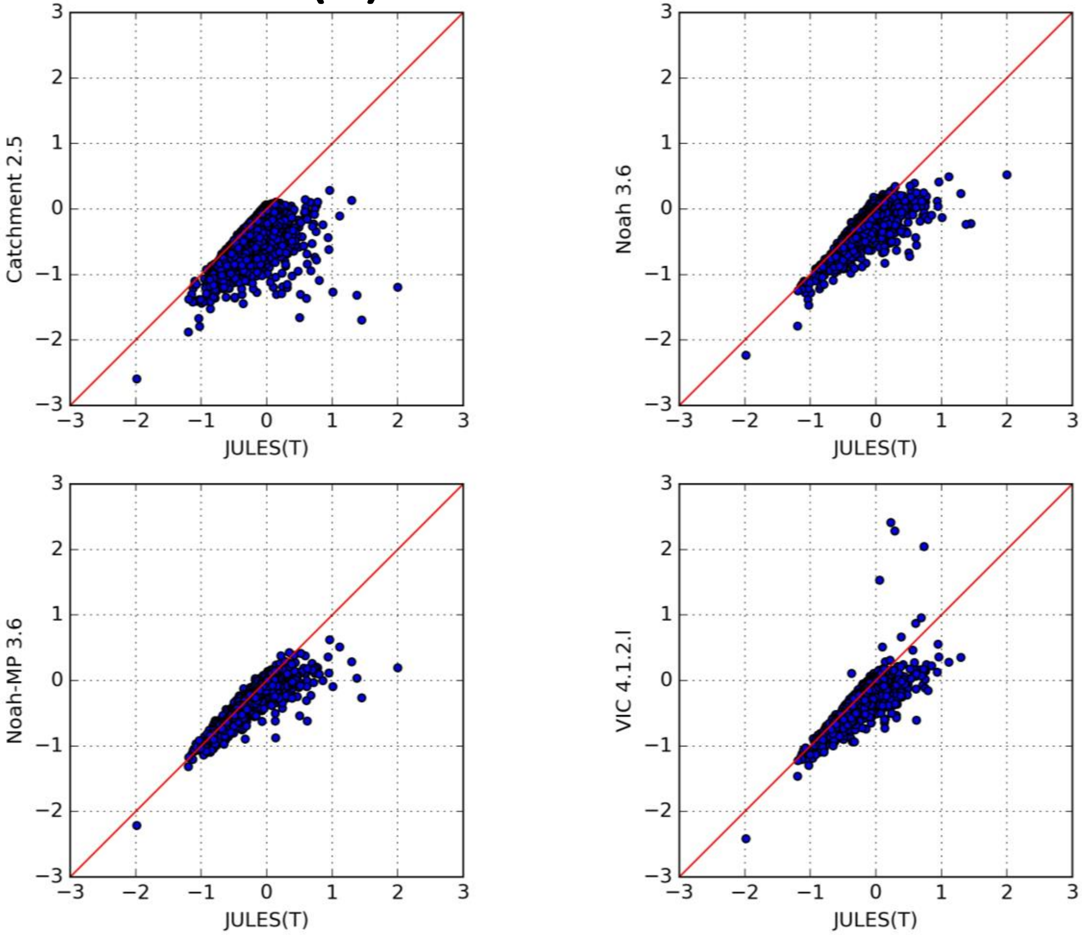




SNODAS Snow Depth BIAS - JULES (T)

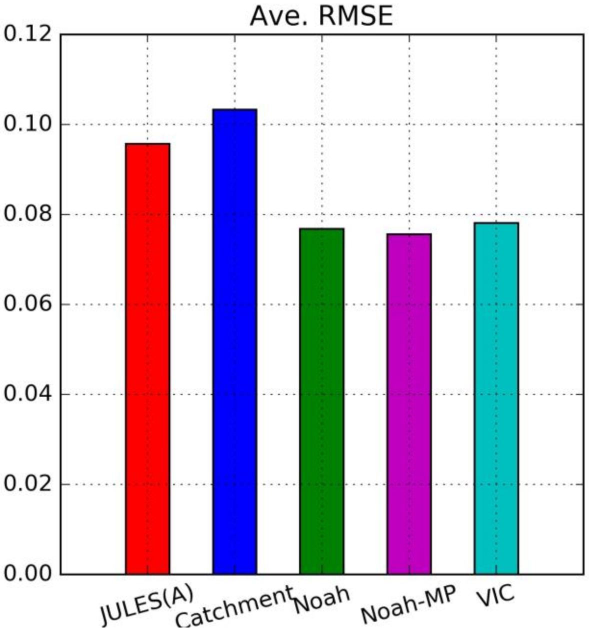
- JULES (T) and all the other models have negative biases over most of grid boxes.
- For domain average, JULES (T) is similar to other models

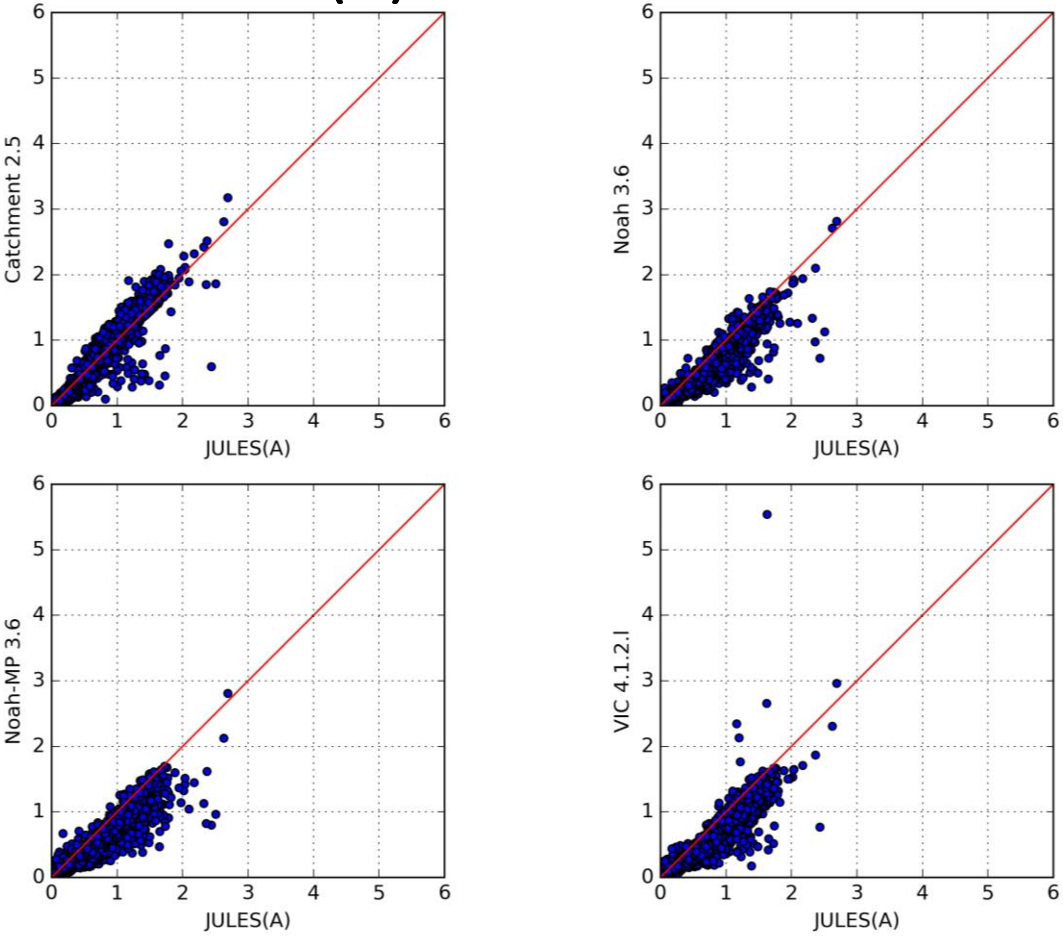




SNODAS Snow Depth RMSE - JULES (A)

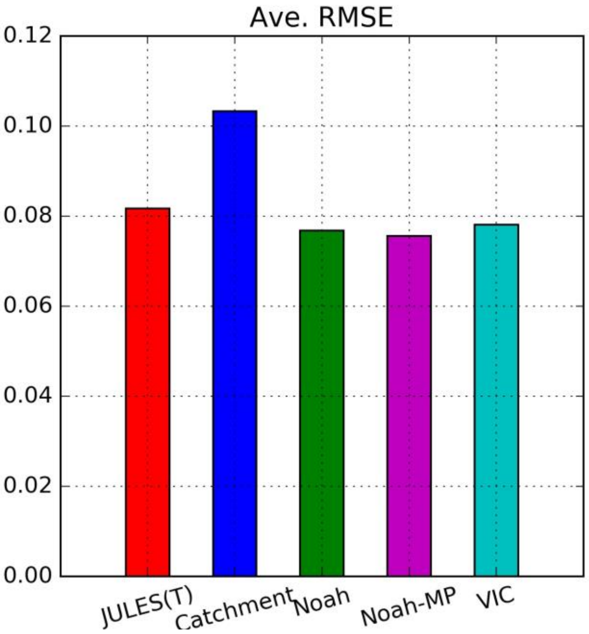
- JULES (A) is significantly correlated to the other 4 models.
- For domain average, JULES (A) is lower than Catchment but higher than Noah, Noah-MP and VIC.

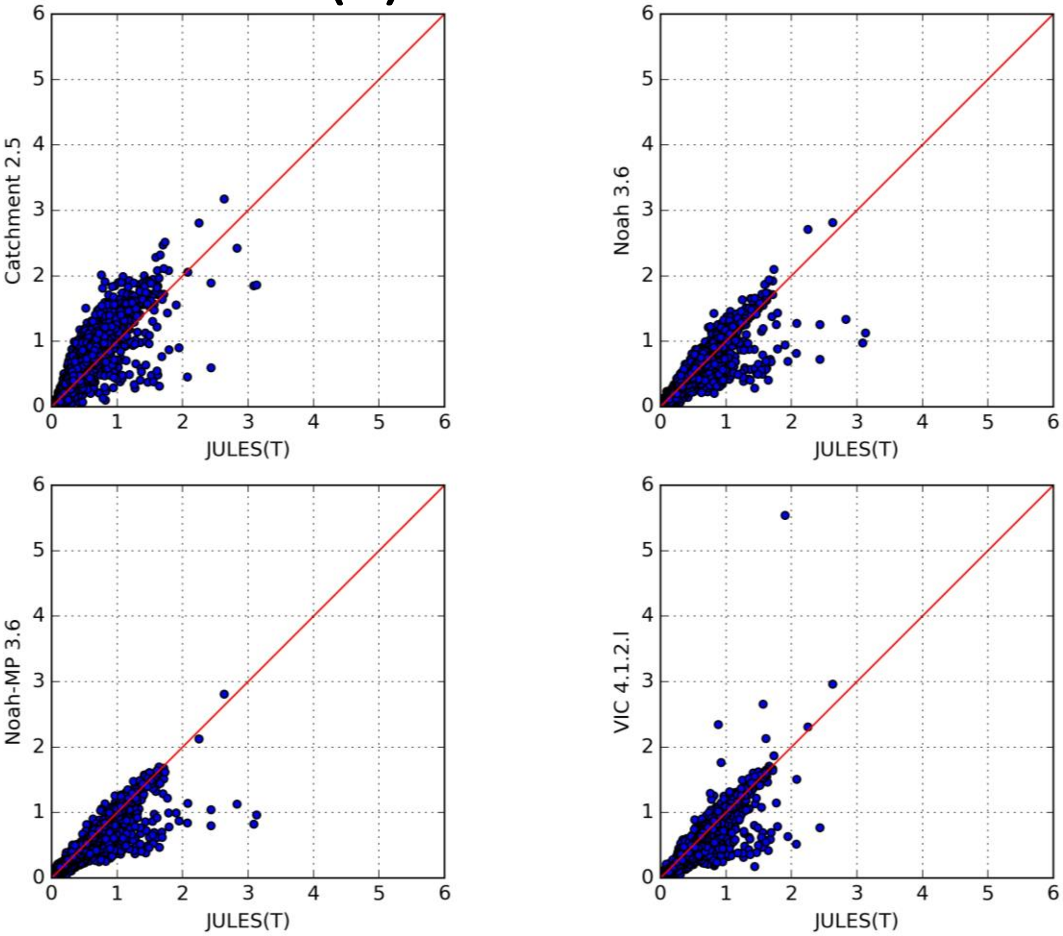




SNODAS Snow Depth RMSE - JULES (T)

- JULES (T) is less correlated to the 4 models than JULES (A).
- For domain average, JULES is about the same as Noah, Noah-MP and VIC but lower than Catchment.



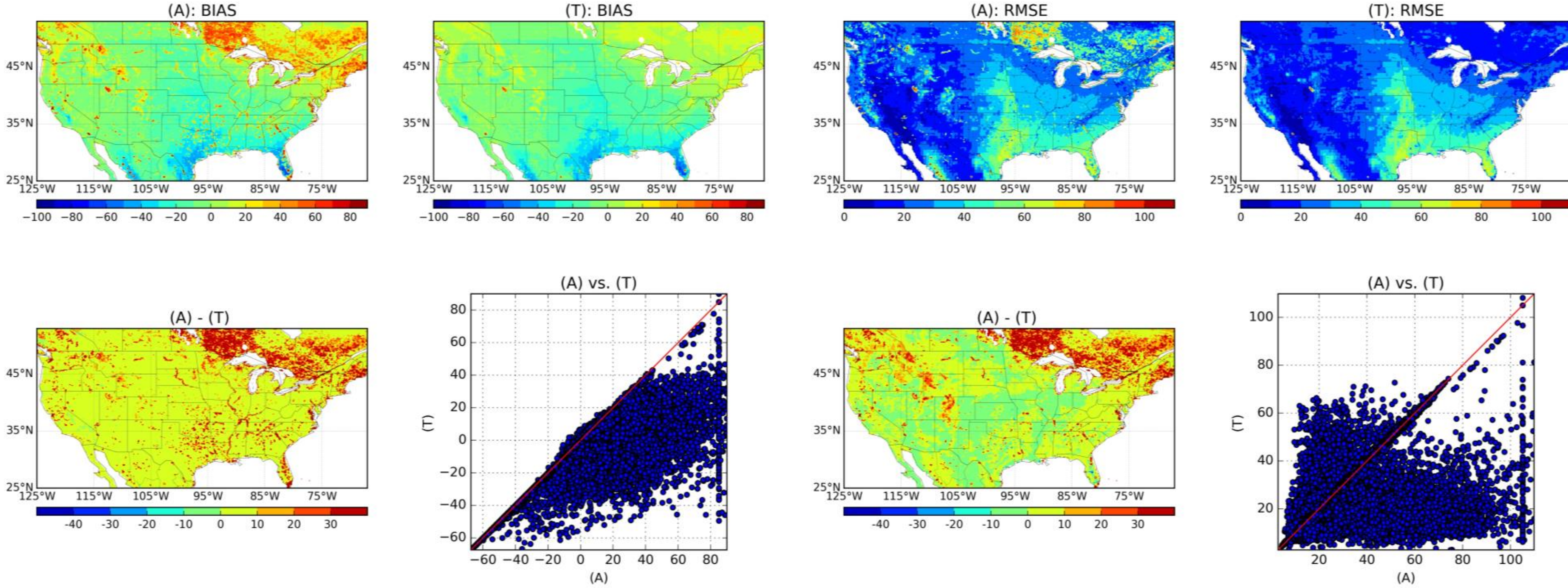


Summary 2 – Snow Depth

- **JULES (A) and JULES (T) produce significantly different snow depth simulations.**
  - **For the CMC snow depth dataset, JULES (A) has about the same negative biases and positive biases, while JULES (T) has much more positive biases.**
  - **For the SNODAS snow depth dataset, both JULES (A) and JULES (T) has more negative biased, while JULES (T) is lager than JULES (A) on average.**
- **Both JULES (A) and JULES (B) produce significantly different snow depth simulation than Catchment, Noah, Noah-MP, and VIC.**
  - **Generally, both JULES (A) and JULES (T) are next to (Noah-MP, Noah, VIC) and better than Catchment in terms of consistency to the reference datasets.**

FLUXNET MTE Latent Heat Flux JULES (A) vs. JULES (T)

- **Data period: 1982 – 2008**
- **JULES (A) has higher biases than JULES (T) for most of grid boxes**
- **JULES (A) also has larger RMSE than JULES (T) for more grid boxes**



(A): BIAS

(T): BIAS

(A): RMSE

(T): RMSE

(A) - (T)

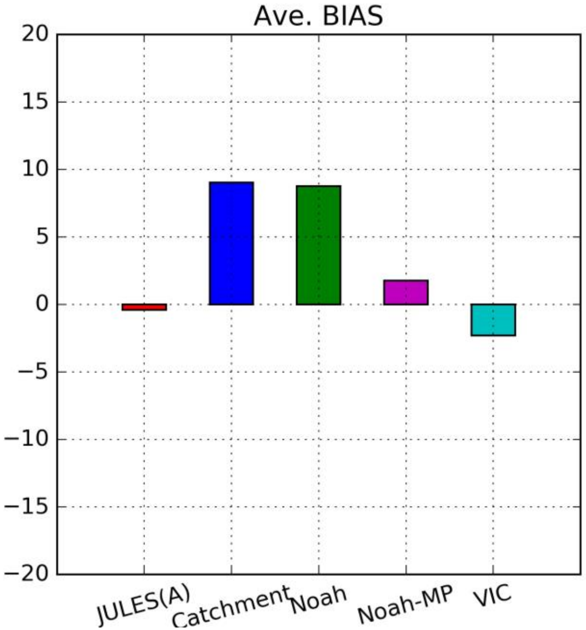
(A) vs. (T)

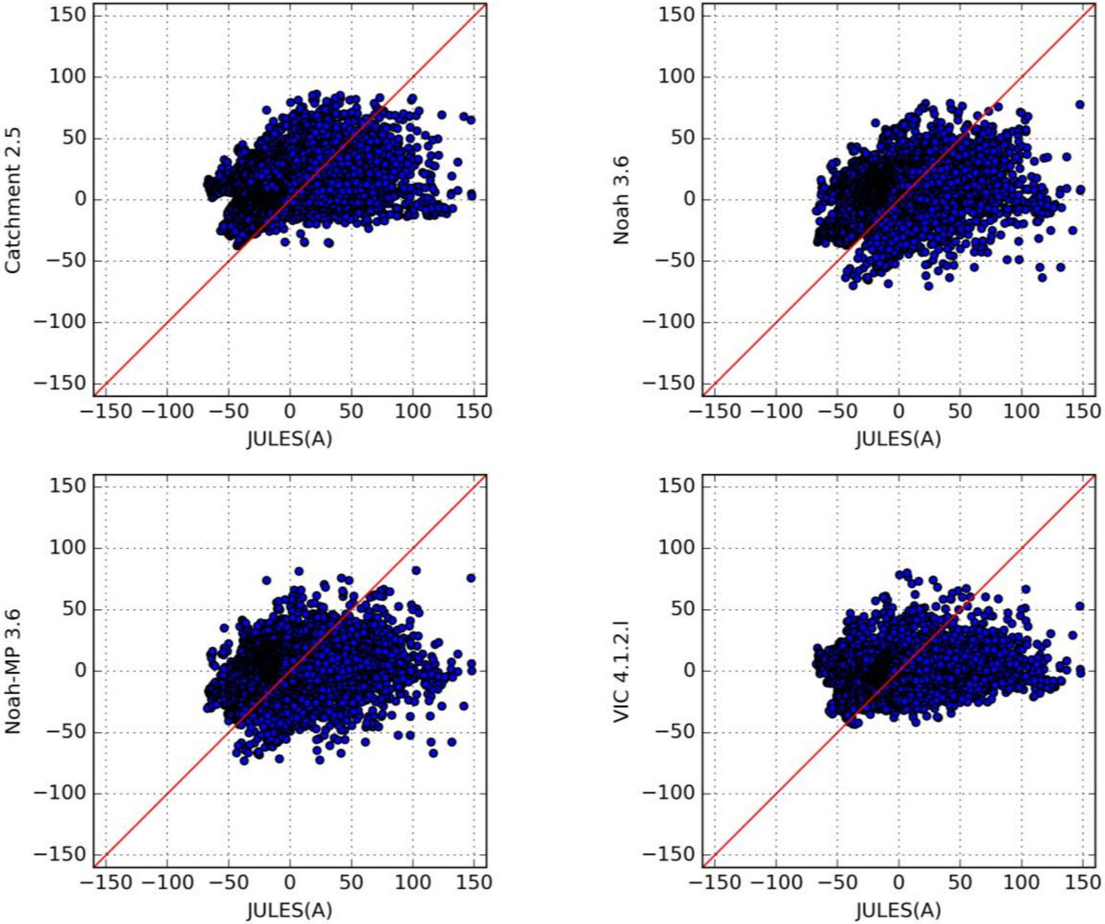
(A) - (T)

(A) vs. (T)

FLUXNET MTE Latent Heat Flux BIAS - JULES (A)

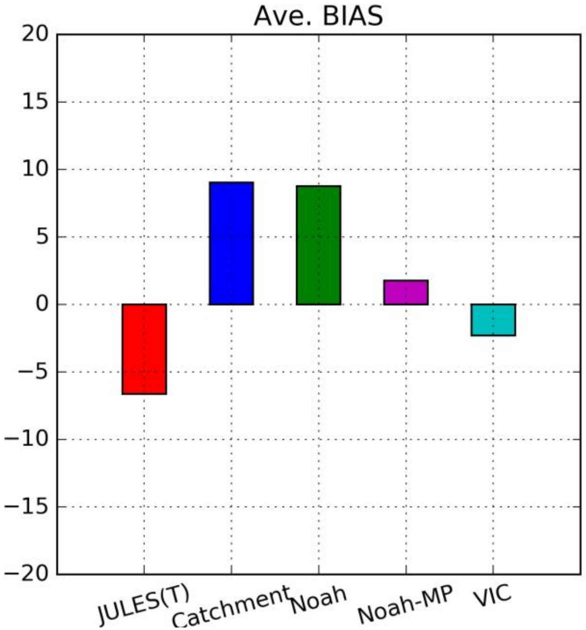
- JULES (A) has much wider distribution than the 4 models.
- The domain average of JULES (A) is very close to 0, while the domain averages of Catchment and Noah are much higher.

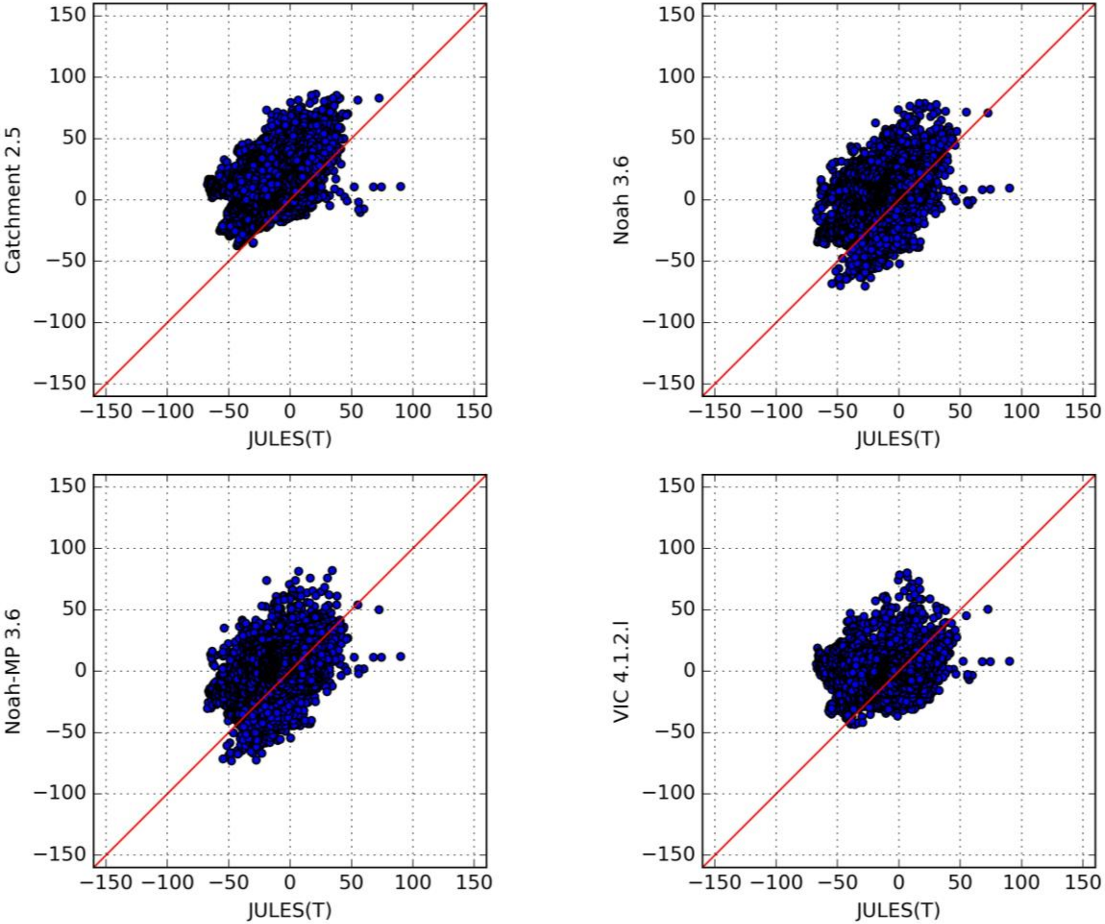




FLUXNET MTE Latent Heat Flux BIAS – JULES (T)

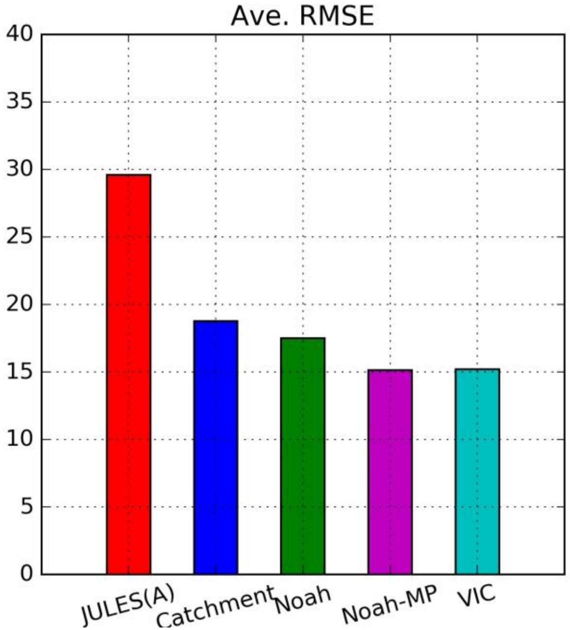
- JULES (T) has a much narrower distribution than JULES (A) and the domain average of JULES (T) is negative.
- JULES (T) is not much correlated with the 4 models regarding biases.

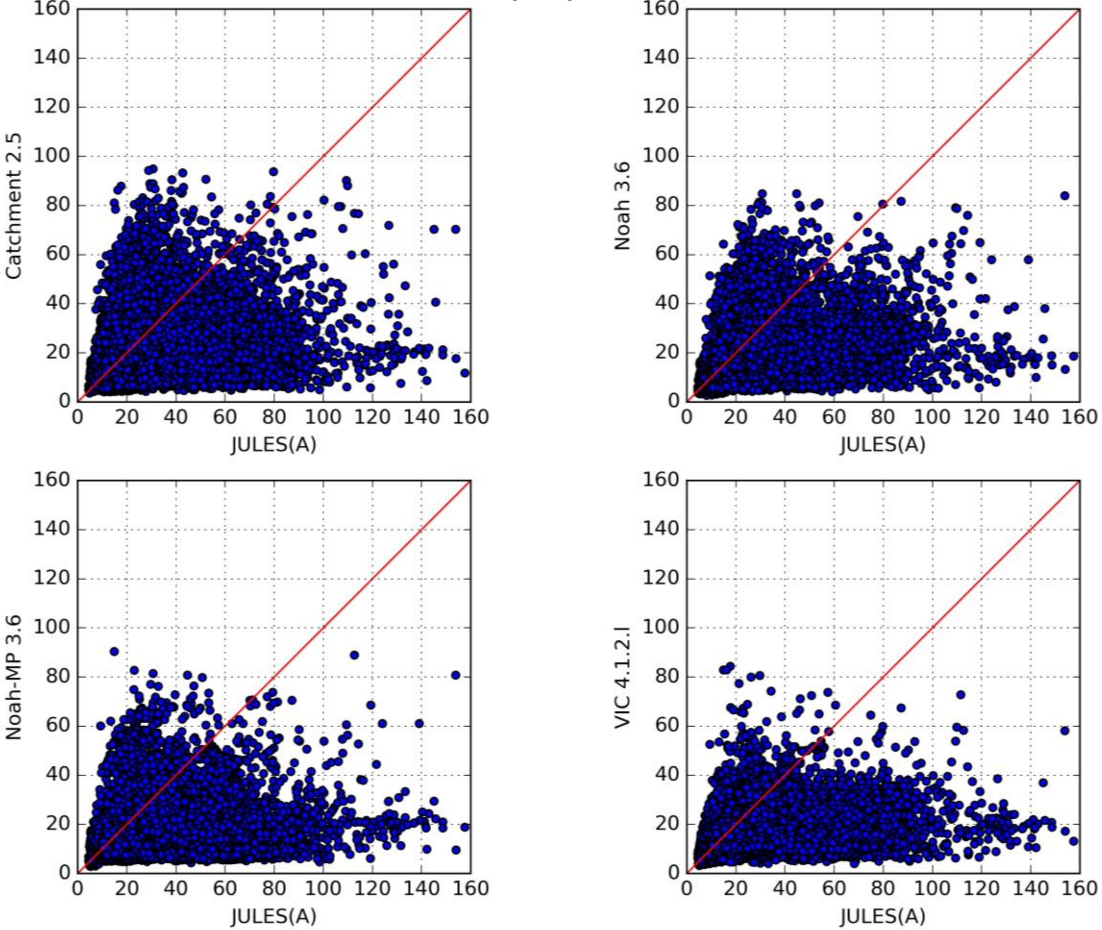




FLUXNET Latent Heat Flux RMSE – JULES (A)

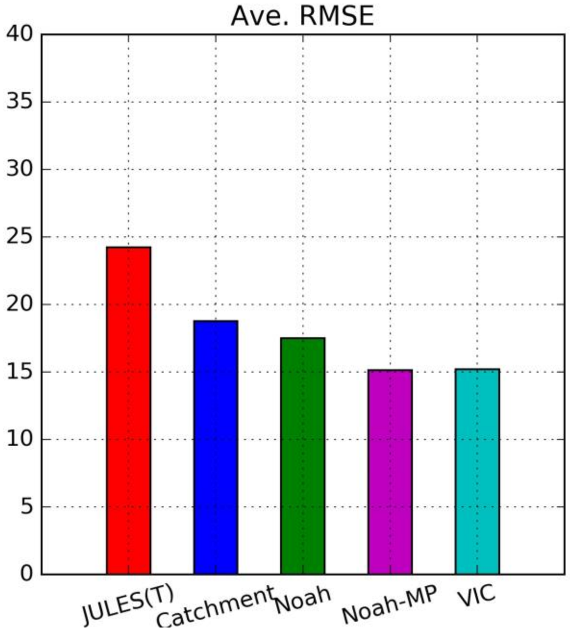
- JULES (A) is higher than the 4 models for most of grid boxes.
- JULES (A) is significantly higher than the 4 models for domain average.

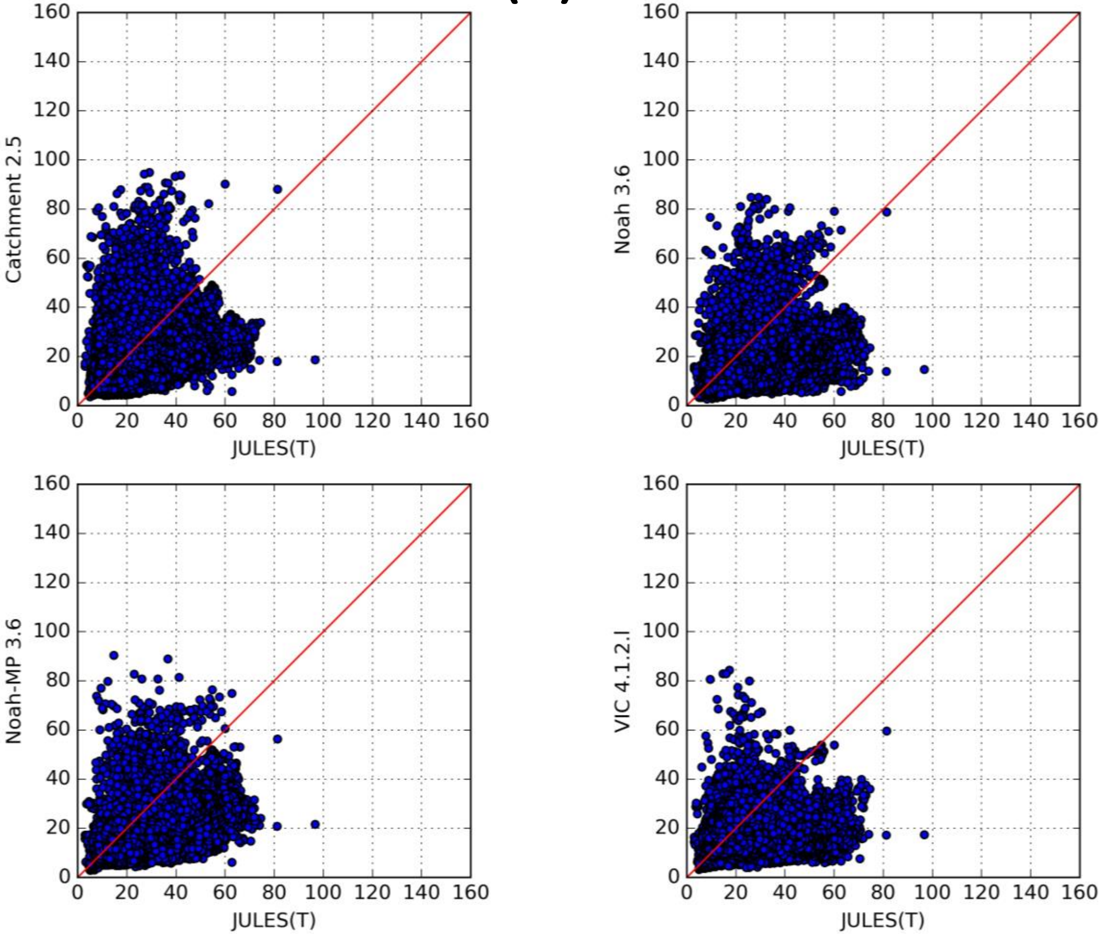




FLUXNET Latent Heat Flux RMSE – JULES (T)

- JULES (T) has similar value ranges with the 4 models in the scatter plots.
- For domain average, JULES (T) is higher than the 4 models but not as much as JULES (A)



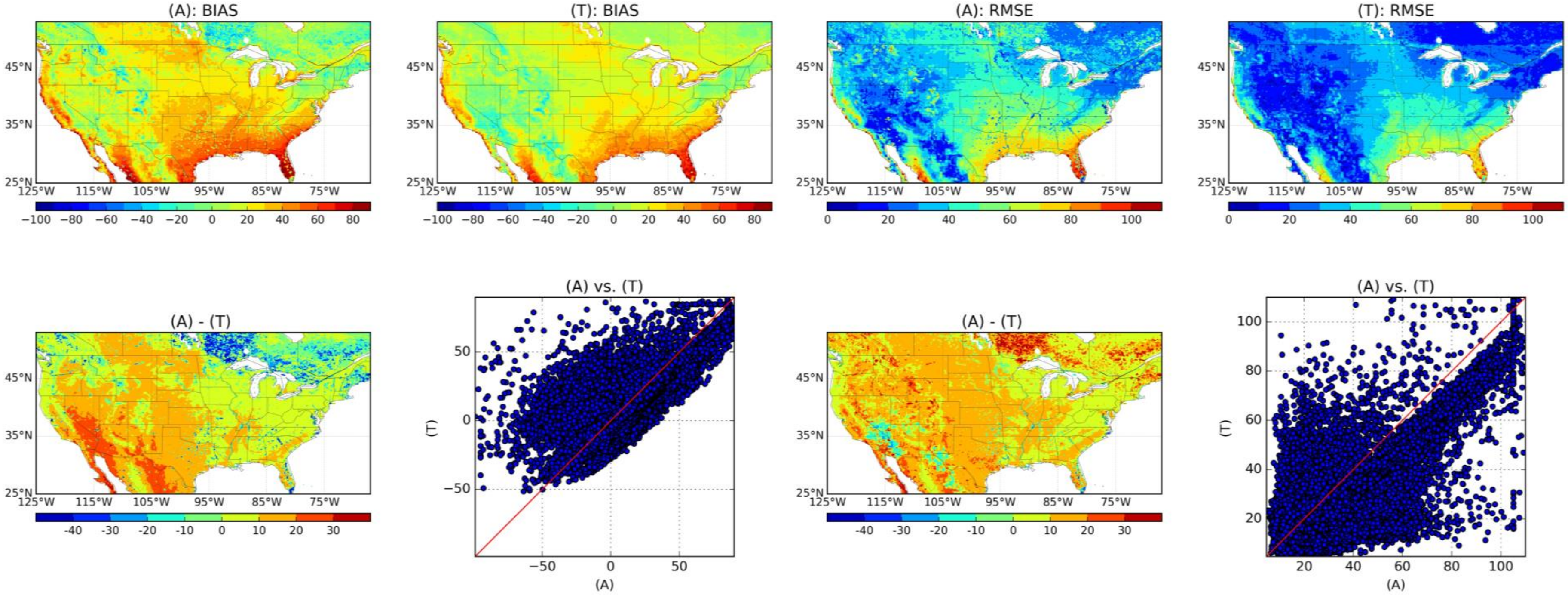


Summary 3 – Latent Heat Flux

- **JULES (A) and JULES (T) have significant differences, especially in parts of Ontario and Quebec neat the Great Lakes, as well as the Rocky Mountain areas.**
- **Both JULES (A) and JULES (T) have less consistency than VIC, Noah-MP, Noah and Catchment to the FLUXNET MTE latent heat flux.**

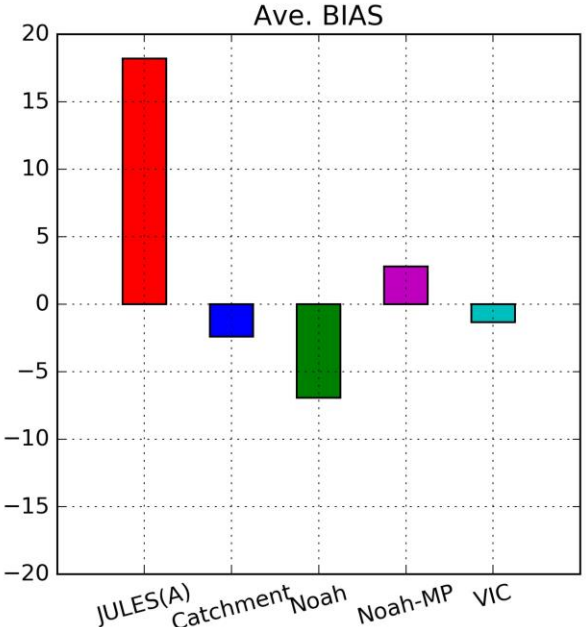
FLUXNET MTE Sensible Heat Flux JULES (A) vs. JULES (T)

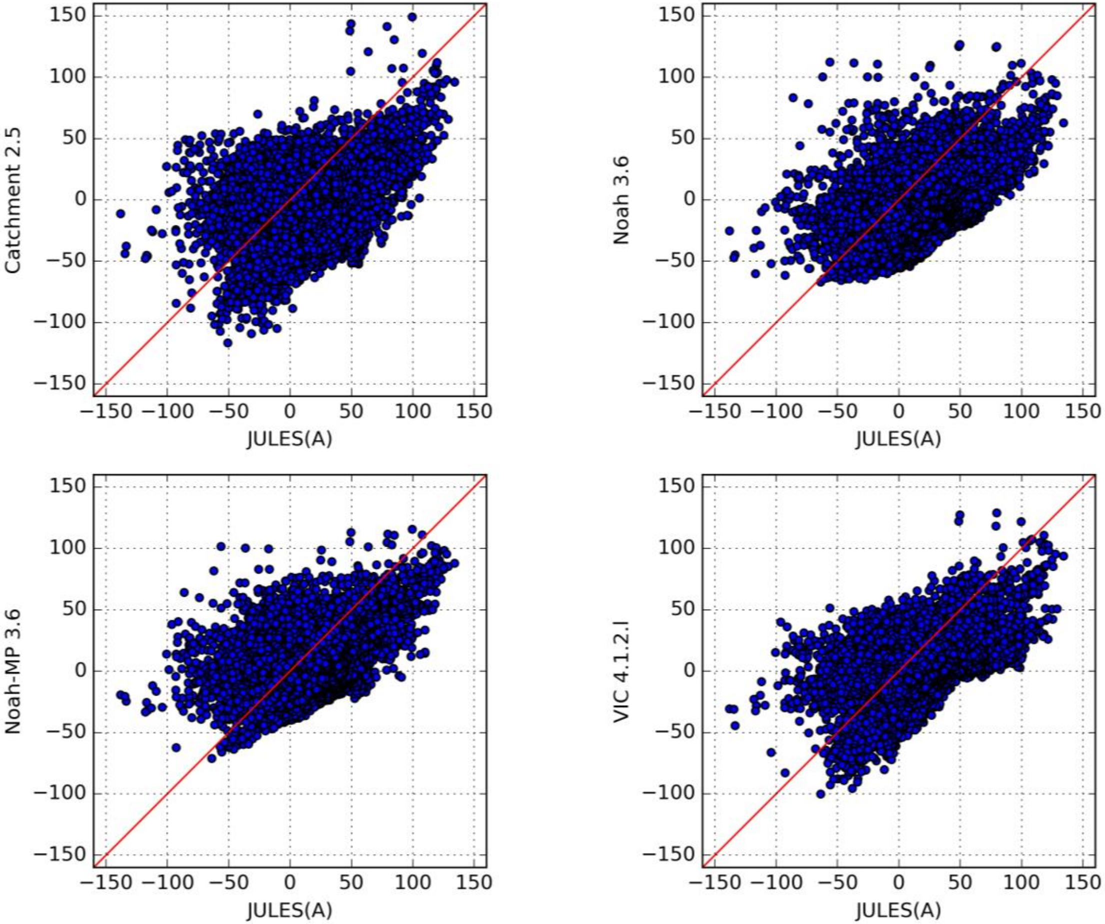
- **Data period: 1982 – 2008**
- **JULES (T) has narrower distribution of biases than JULES (A)**
- **JULES (A) has larger RMSE than JULES (T) for more grid boxes.**



FLUXNET MTE Sensible Heat Flux BIAS – JULES (A)

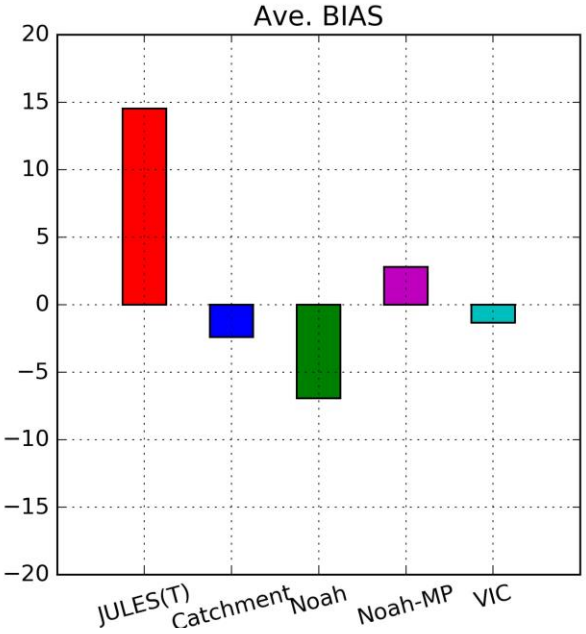
- JULES (A) has much more positive biases than the other 4 models
- For domain average, JULES (A) is positive and much higher than the other 4 models.

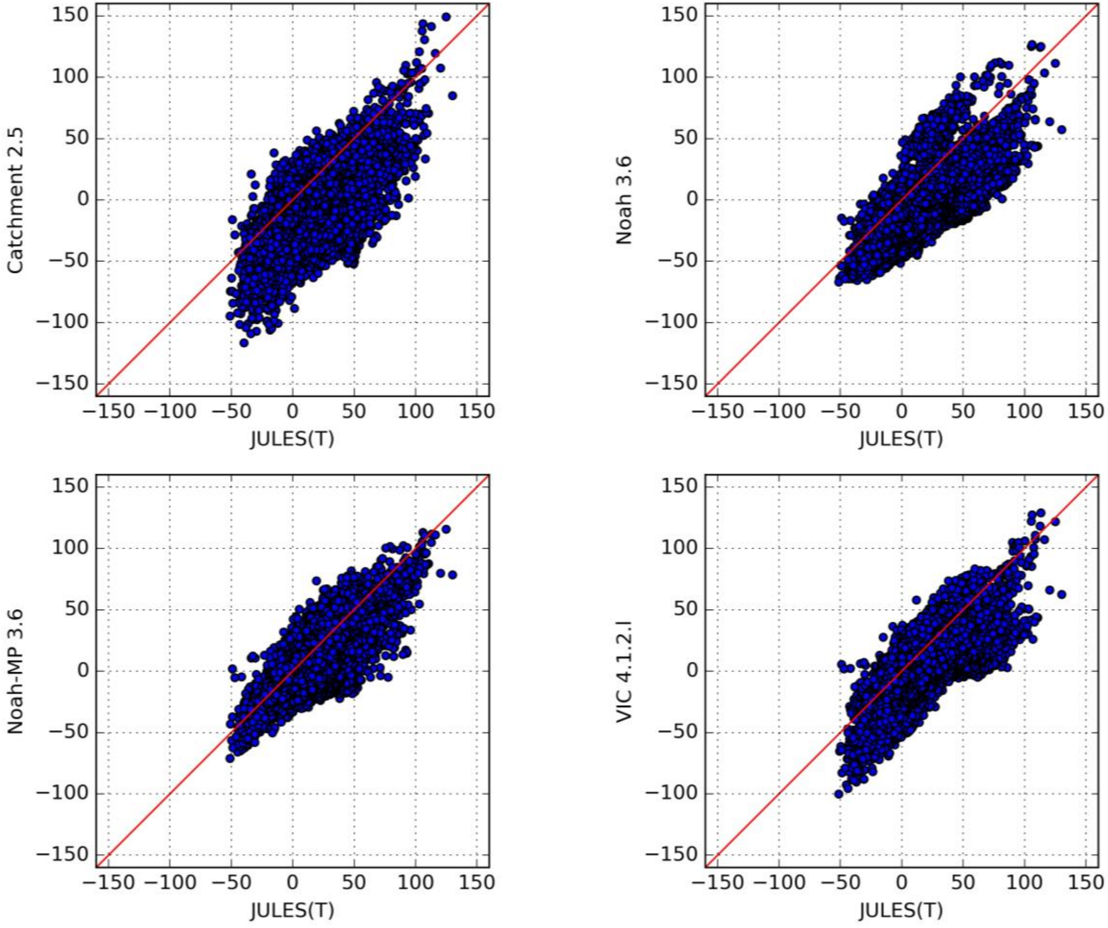




FLUXNET MTE Sensible Heat Flux BIAS – JULES (T)

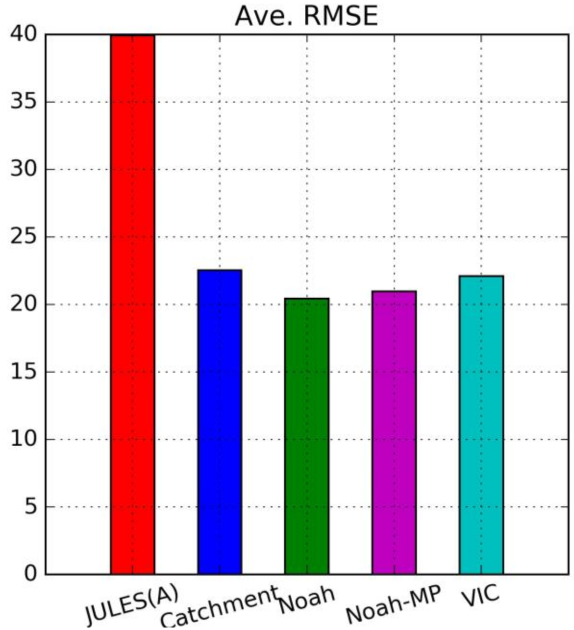
- JULES (T) is more correlated with the other 4 models than JULES (A).
- JULES (T) is also higher than other 4 models in much more grid boxes.

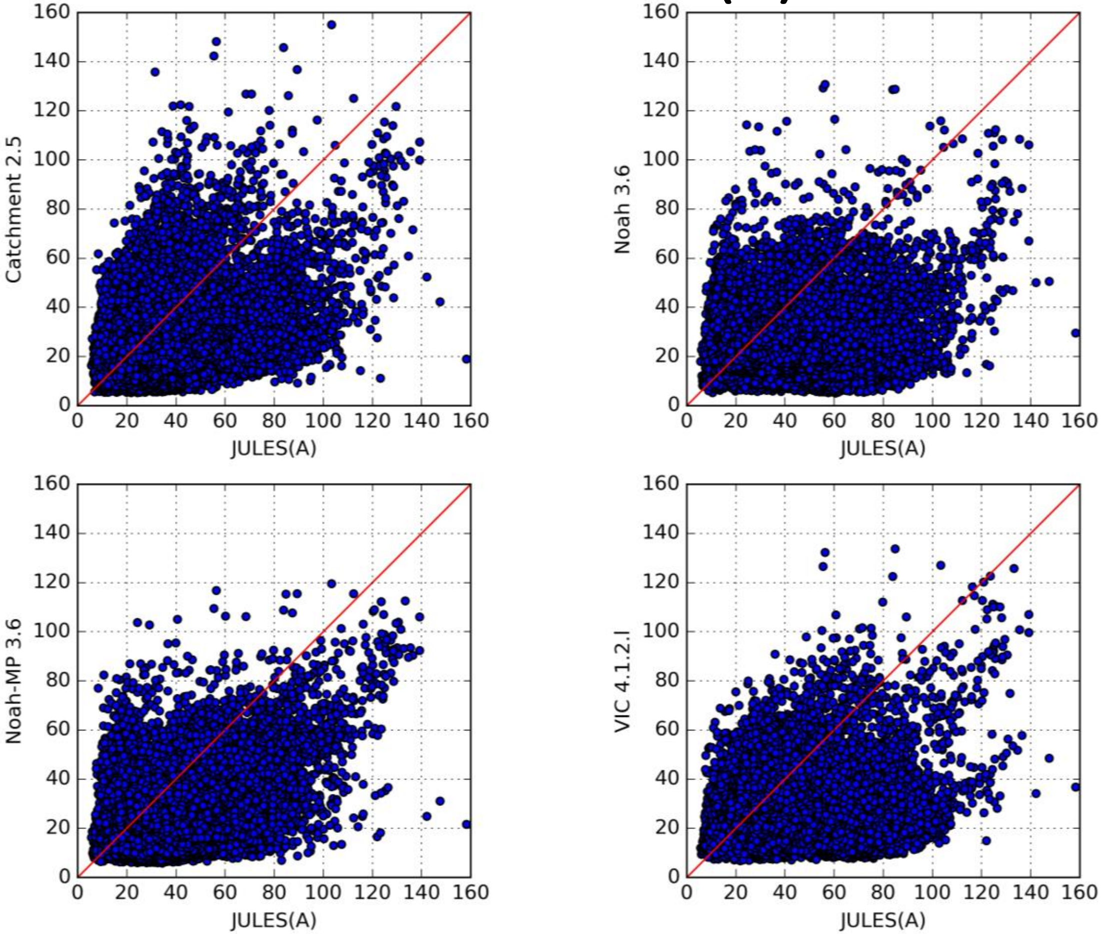




FLUXNET MTE Sensible Heat Flux RMSE – JULES (A)

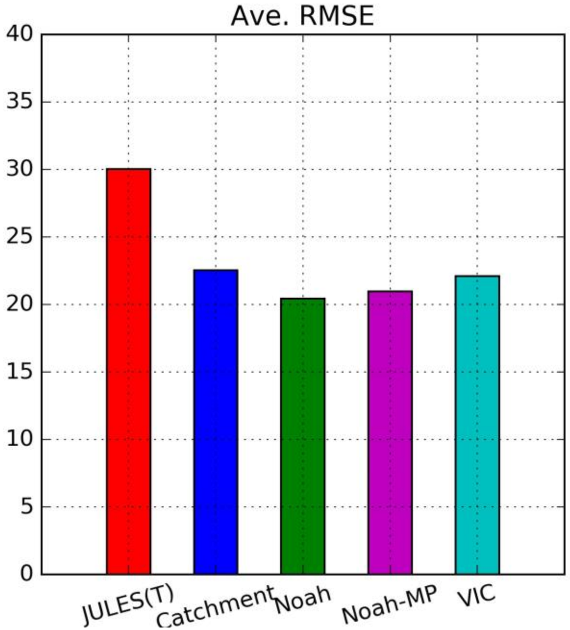
- JULES (A) is larger than the 4 models in much more grid boxes
- For domain average, JULES (A) is significantly larger than the other 4 models

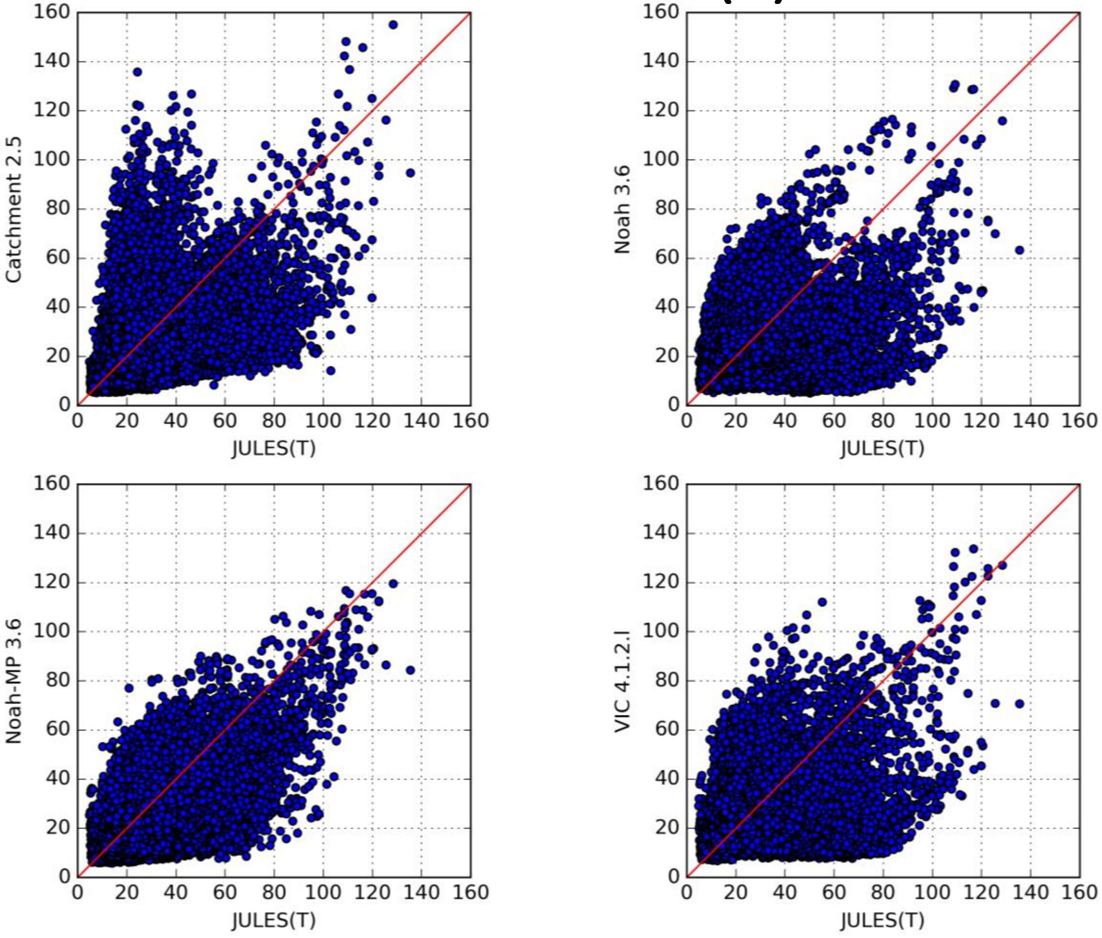




FLUXNET MTE Sensible Heat Flux RMSE – JULES (T)

- On average, JULES (T) is smaller than JULES (A). However, it is still larger than the 4 models in most grid boxes.
- For domain average, JULES (T) is also significantly larger than the 4 models.





Summary 4 – Sensible Heat Flux

- **JULES (A) and JULES (T) produce significantly different simulations of sensible heat flux.**
- **Both JULES (A) and JULES (T) have less constancy to the FLUXNET MET sensible heat flux data than Noah, Noah-MP, VIC and Catchment.**

Overall Summary

- **The JULES surface mode (A: l_aggregate=True, T: l_aggregate=False)**
  - **has no significant impacts on soil moisture simulation.**
  - **has significant impacts on snow depth and surface energy fluxes.**
- **JULES (A) and JULES (B) have significant differences with the 4 models.**
  - **For soil moisture, JULES is between (Noah, Noah-MP) and (Catchment, VIC).**
  - **For snow depth, JULES is between (Noah-MP, Noah, VIC) and Catchment.**
  - **For latent heat flux, JULES is between (VIC, Noah-MP, Noah) and Catchment**
  - **For sensible heat flux, JULES is next to Noah, Noah-MP, VIC and Catchment**
- **Why?**
  - **U.S. models have been well tuned in the NLDAS domain, but JULES may not.**