Assessment of Water and Energy Budgets in Major Basins for Land Surface Model Component Evaluation

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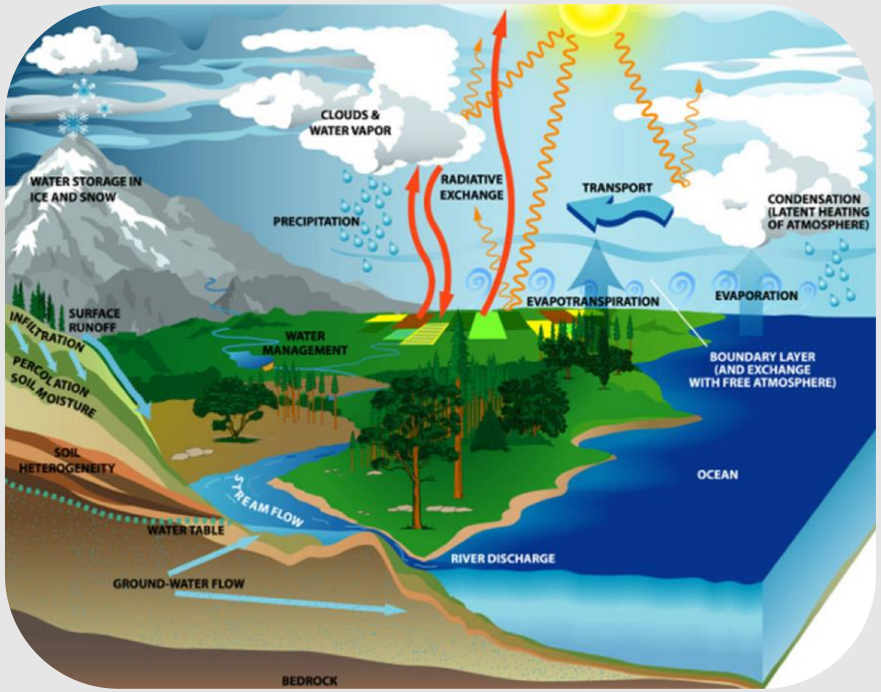
Table of Contents

Predictive Modeling for the Interactions in Terrestrial Ecosystems

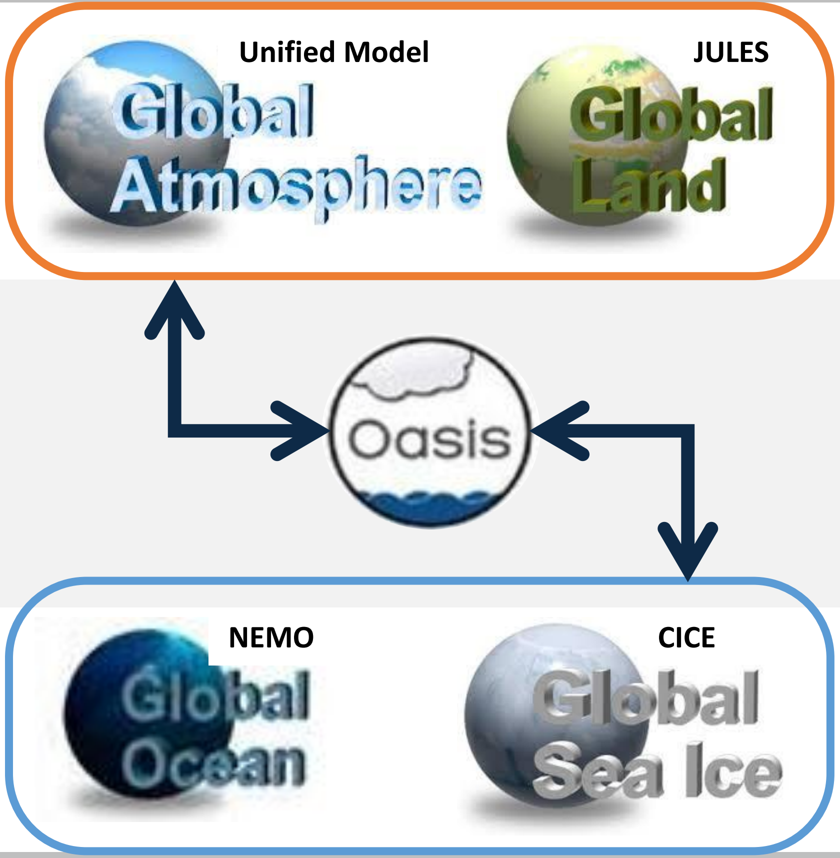
Applications of Land Information System (LIS)

Earth Systems: Fully Coupled Modeling Approach

Land-Atmosphere-Ocean



GloSea6
Global coupled modeling configuration

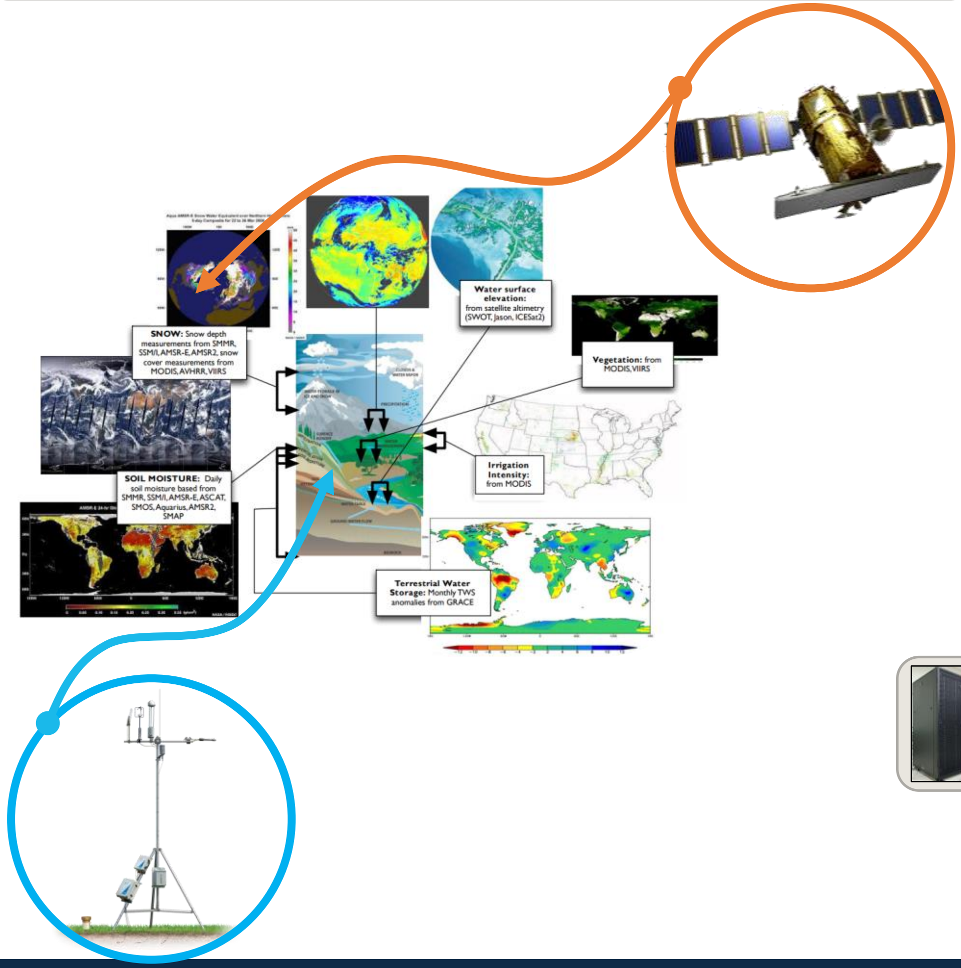


Supercomputer simulations

Maru/Guru, ThinkSystem SD650 V2,
612,864 cores, 51PFlops
GloSea6 experiments

Land Information System (LIS) for the Interactions' Predictioins

Data collections for land-atmosphere interactions → LIS

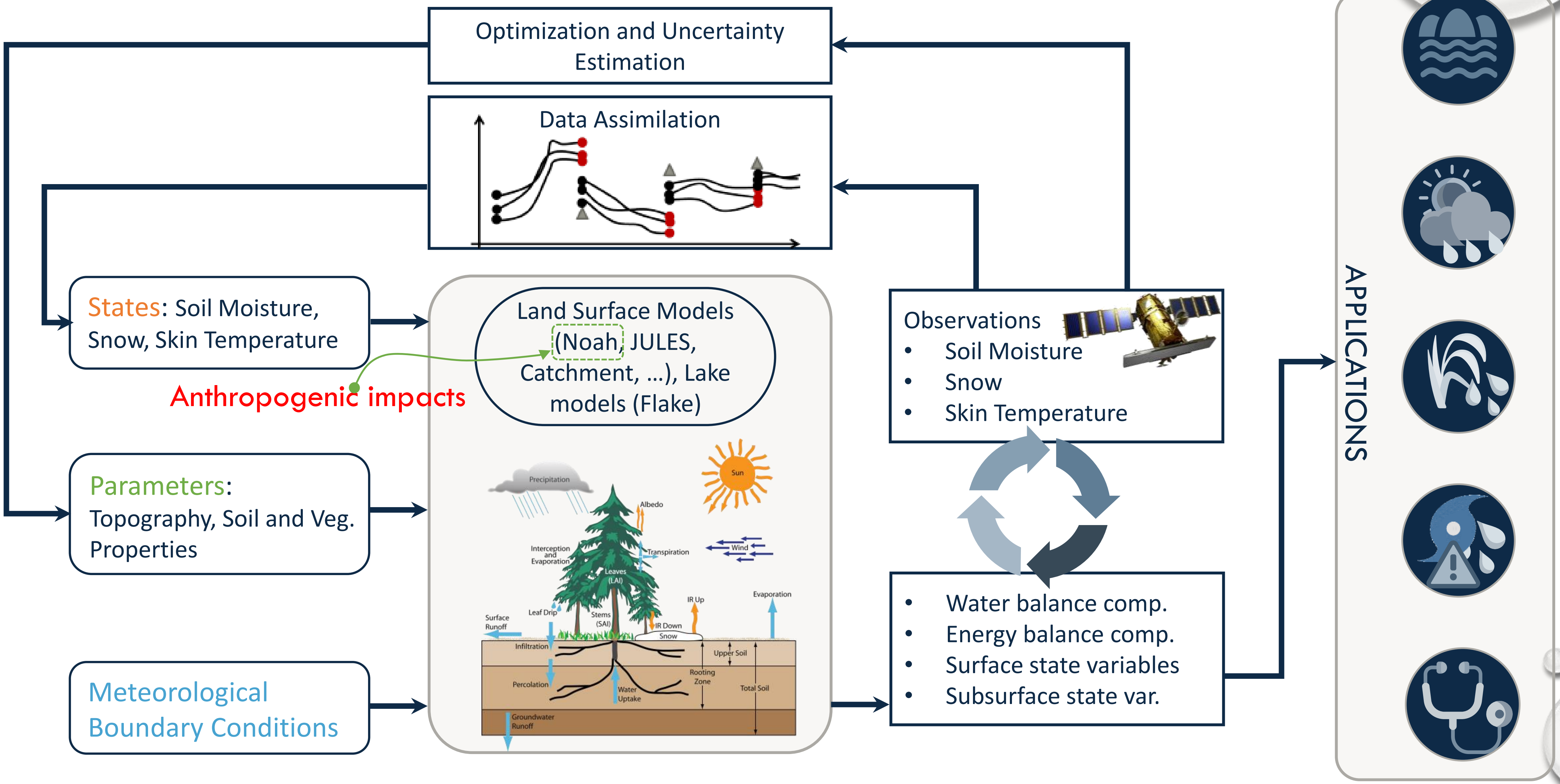


NASA Land Information System LIS

Duru, ThinkSystem SD530, 20,448 cores, 1,897TFlops

- Led by the Hydrological Sciences Laboratory at **NASA**'s Goddard Space Flight Center
- A software framework for high performance terrestrial water, energy, and carbon modeling and data assimilation
- To produce optimal fields of **land surface sates and fluxes**
  - By integrating **satellite** and **ground-based** observational data products and advanced **modeling techniques**
- To enable the use of an **ensemble of land surface models**

Land Information System (LIS)



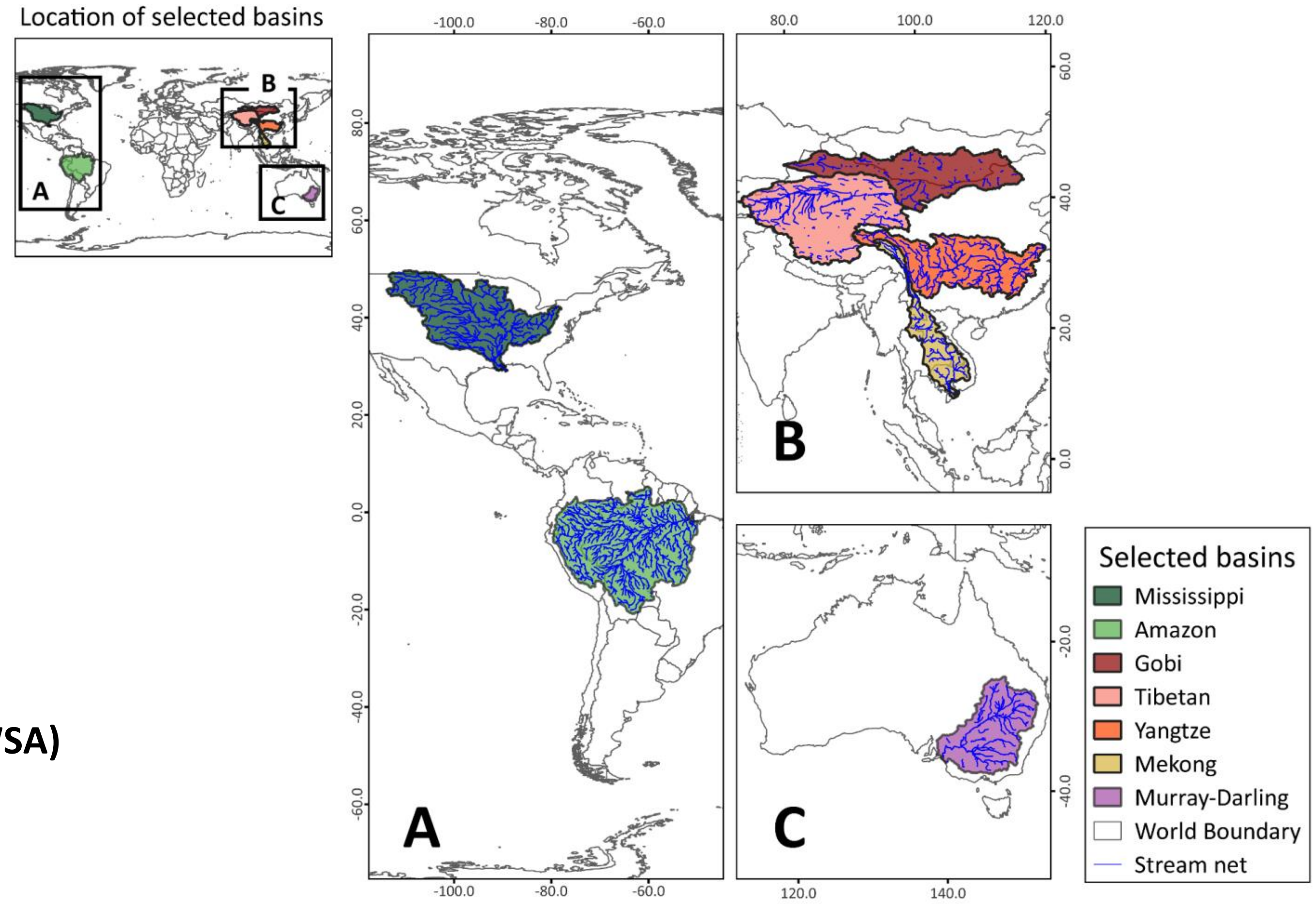
Comparative Assessment of Energy and Water Budgets

Configurations

	NOAH	NOAH-MP	JULES
Environment	LIS (DURU system)		Rose/Cylc (NARU system)
Met forcing	GDAS		
Period	2007–2011		
Resolution	1° × 1°		0.56° × 0.83°
Timestep	15 min		30 min
Spinup	88 years		30 years

- **LSM-simulated TWSA**
  - TWSA: Total column soil moisture, snow water equivalent, and canopy water storage
- **GRACE-observed Total Water Storage Anomaly (TWSA)**
- **Satellite-based soil moisture and ET (GLEAM)**
- **FluxCom (Qle, Qh)**

Selected basins



Data Collections: Water Balance Components

- **GRACE**-observed **Total Water Storage Anomaly** (TWSA)
  - TWSA: Simple mean of the CSR, JPL, and GFZ products
    - Center for Space Research (CSR), Jet Propulsion Laboratory (JPL), and GeoForschungsZentrum (GFZ)
  - TWSC (TWS change): *[TWSA(t+1)-TWSA(t-1)]/2*
- LSM-simulated TWS
  - TWSA: Total column soil moisture, snow water equivalent, and canopy water storage
  - TWSC: *dS/dt = P-Q-ET*
- **Global Land Evaporation Amsterdam Model (GLEAM)**
  - 0.25° × 0.25° daily resolution

Forcing Variable	GLEAM v3.2a
Radiation	ERA5[8]
Air Temperature	ERA5[8]
Precipitation	MSWEP v2.2[9]
Snow Water Equivalent	GLOBSNOW L3Av2[10] & NSIDC v01[11]
Vegetation Optical Depth	LPRM[12,13,14*]
Surface Soil Moisture**	ESA-CCIv4.5[15,16,17]
Vegetation fractions	MEaSUREs VCF5KYR_001[20]

1. *E* – Actual evaporation [mm/day]
2. *Ep* – Potential evaporation [mm/day]
3. *Ei* – Interception loss [mm/day]
4. *Eb* – Bare-soil evaporation [mm/day]
5. *Es* – Snow sublimation [mm/day]
6. *Et* – Transpiration [mm/day]
7. *Ew* – Open-water evaporation [mm/day]
8. *S* – Evaporative stress factor [–]
9. *SMroot* – Root-zone soil moisture [m^3/m^3]
10. *SMsurf* – Surface soil moisture; 0–10 cm [m^3/m^3]

Data Collections: Energy Balance Components

FluxCom

- Max Planck Institute for Biogeochemistry

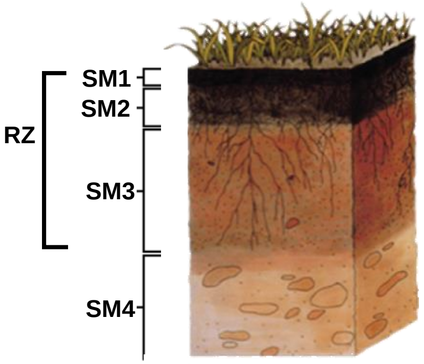
Specifications	FluxCom
Spatial resolution	0.5°
Temporal resolution	daily
Time period	2001-2013
Machine learning method	3: RF, ANN, MARS
Climate input	CRUNCEPv8, WFDEI, GSWP3, CERES-GPCP
Number of flux observations for training	~200,000
Spatial features	PFT, Max of MSC(WAI_U), Mean of MSC(BAND 6), Max of MSC(fAPAR*Rg)
Spatial, seasonal features	Rpot, MSC(NDWI), MSC(LST_{Night}), MSC(EVI*Rg)
Spatial, seasonal, interannual features	Rg, Rain, Rh, Rg*IWA*MSC(NDVI)

Random forest (RF),
Artificial Neural Network (ANN),
Multivariate Adaptive Regression Splines (MARS),

Primary Attributes of Land Surface Models

Physics	Noah	NoahMP	JULES
Soil hydrology	4 soil moisture layers (0–10, 10–40, 40–100, 100–200 cm)	4 soil moisture layers (0–10, 10–40, 40–100, 100–200 cm)	4 soil moisture layers (0–10, 10–35, 35–100, 100–300 cm)
Canopy interception (capacity; mm)	0.5	0.5	Minimum canopy capacity: 0.5, a function of LAI; fixed canopy capacity: 0.5 for Urban, 0 for water, soil, & ice
Vegetation transpiration	Sellers et al. (1986)	Ball-Berry (Ball et al., 1987)	Sellers et al. (1986)
Soil thermodynamics	4 soil temperature layers (same as soil moisture); heat conduction equation	4 soil temperature layers (same as soil moisture); heat conduction equation	4 soil temperature layers (same as soil moisture); heat convective-diffusive equation
Snowpack physics	1 snow model layer	3 snow model layers	User-specified N_{max} & d_k
Runoff generation	Surface and free drainage	Surface and baseflow including interaction with groundwater (TOPMODEL)	surface runoff: Dolman and Gregory(1992), soil mositure and baseflow: TOPMODEL
Snow-free albedo	Monthly input background field	Monthly input background field	Bulk albedos; Spectral albedos and snow ageing

Spin-up Behavior Characteristics



$$Percent\ in\ change(\%) = \frac{M_1 - M_2}{M_2} \times 100$$

M_1 : Monthly mean of soil moisture fromt the previous year

M_2 : Monthly mean of soil moisture fromt the current year

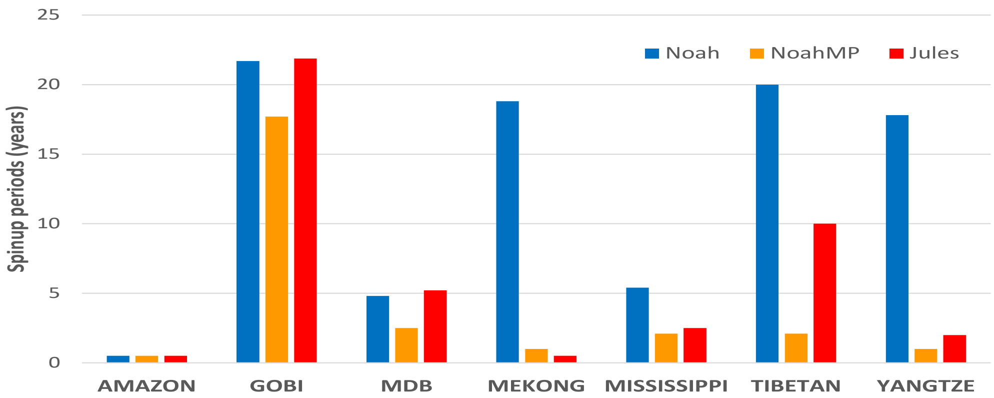
$$RZ = \frac{\sum_{i=1}^{3}(d_i \times sm_i)}{\sum_{i=1}^{3} d_i}$$

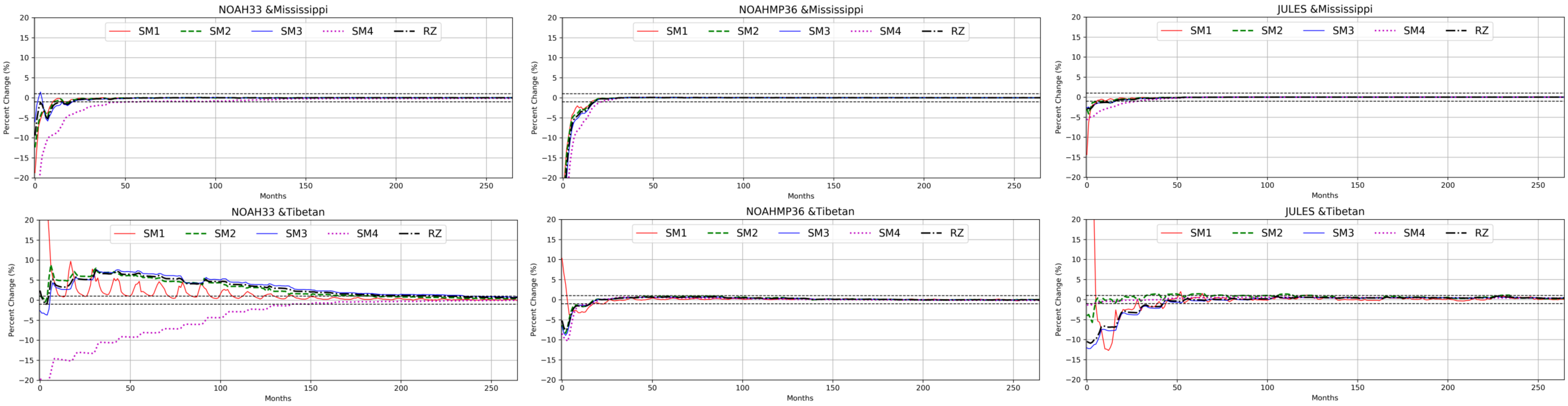
d_i : Deth at i^th soil layer

sm_i : Soil moisture at the i^th soil layer

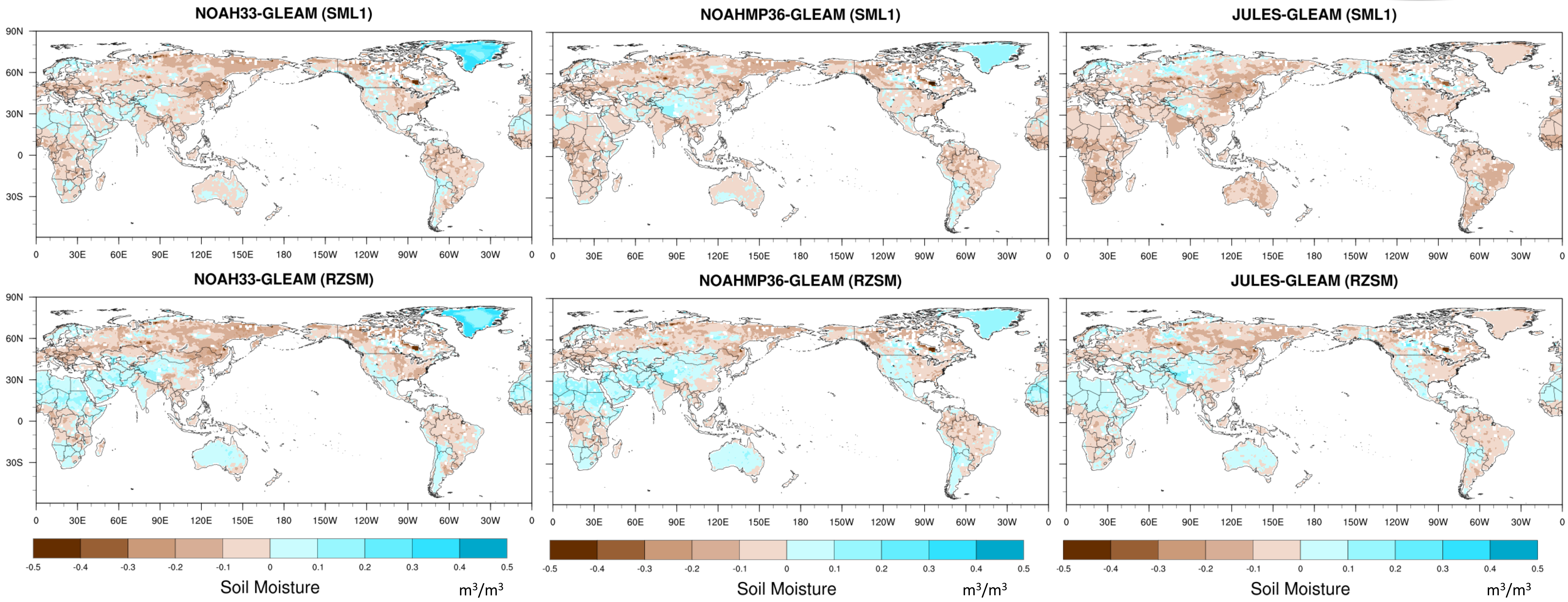
Noah and Noah-MP (m): d_1=0.1, d_2=0.3, d_3=0.6, d_4=1.0

Jules (m): d_1=0.1, d_2=0.25, d_3=0.65, d_4=2.0

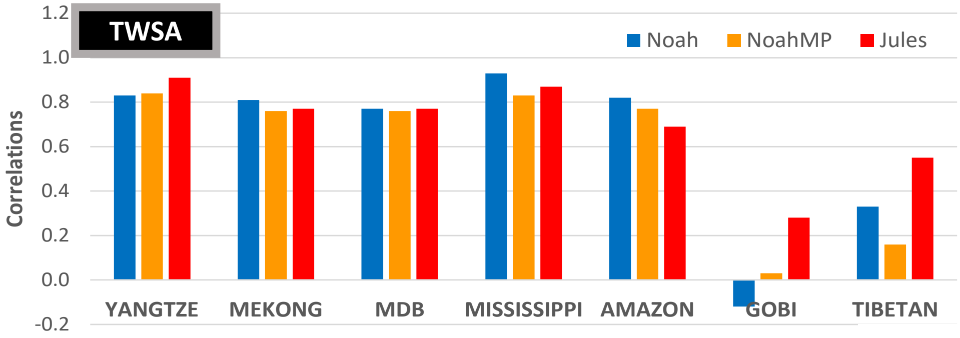


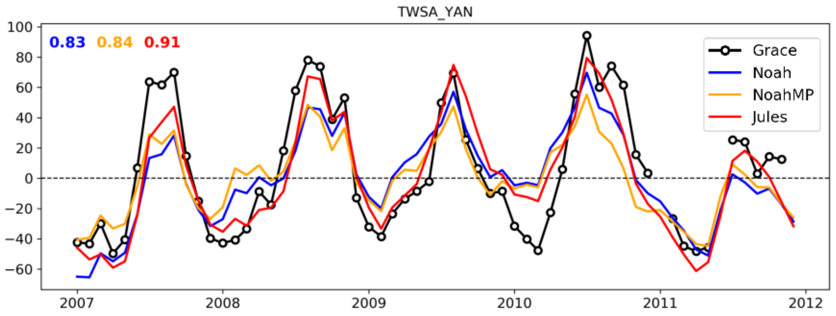


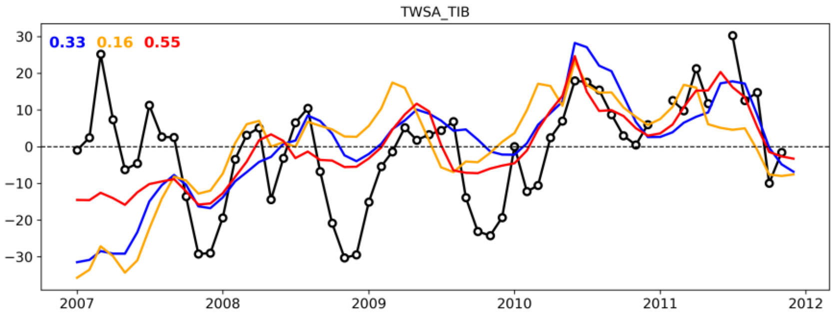
Comparisons of Soil Moisture (LSMs – GLEAM)

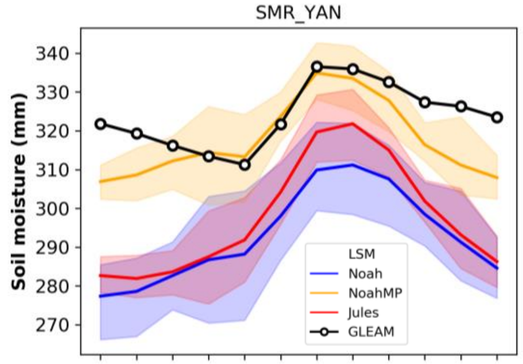


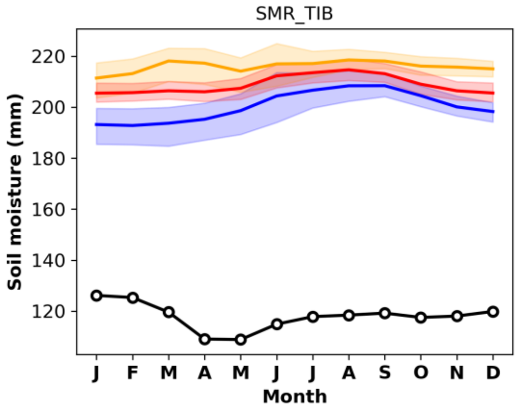
Water and Energy Budgets in the Selected Basins

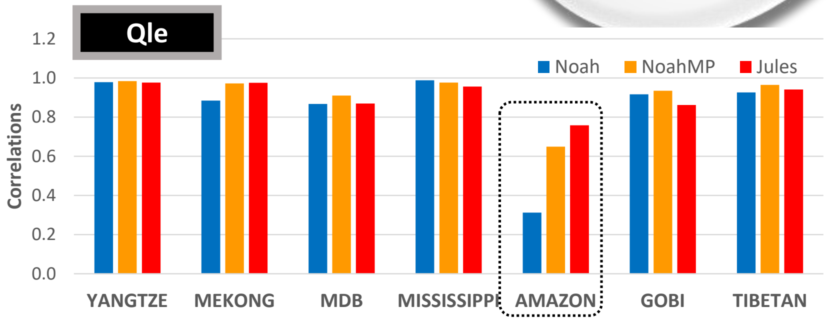


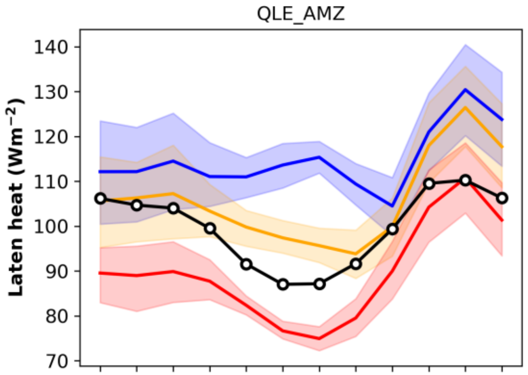


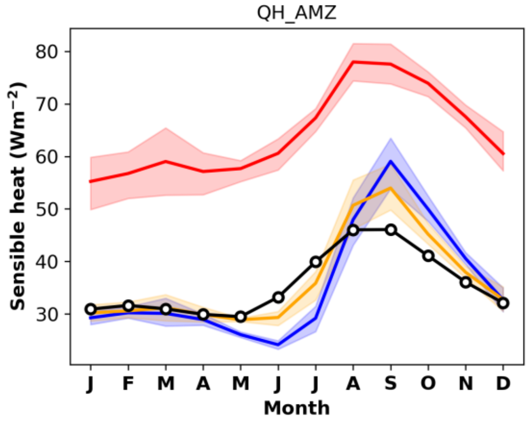






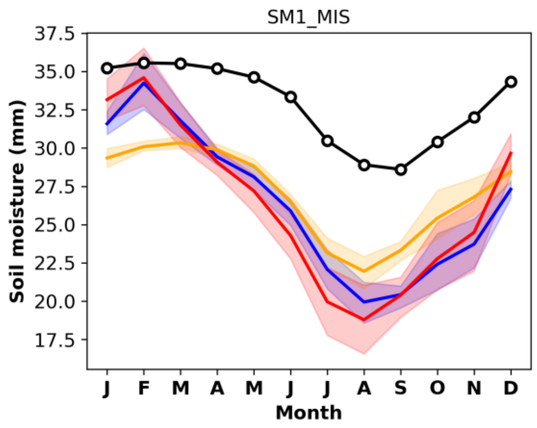


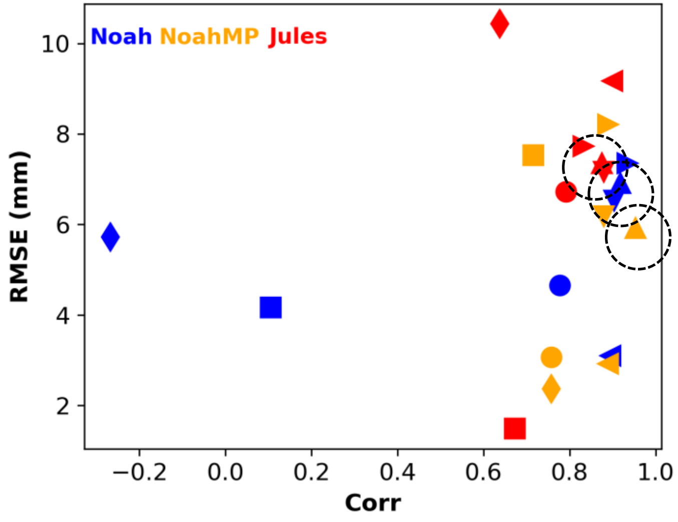




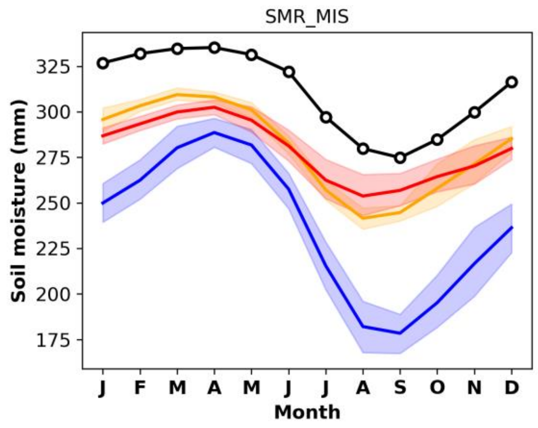
Water Balance Components: Soil Moistures and Evapotranspiration: Mississippi Basin

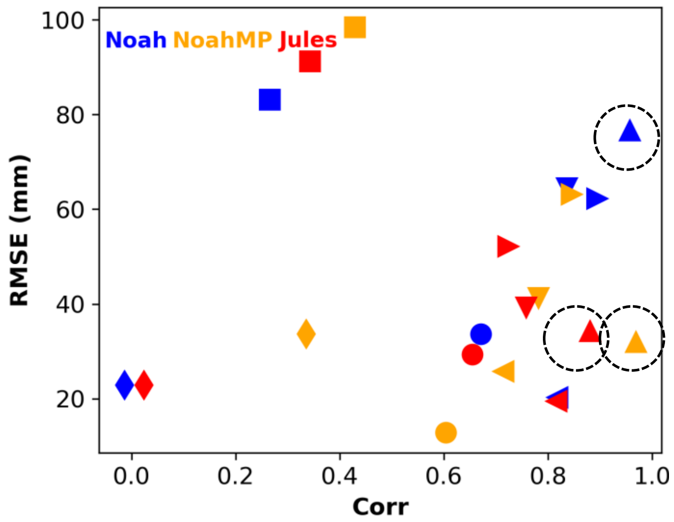
Surface soil moisture



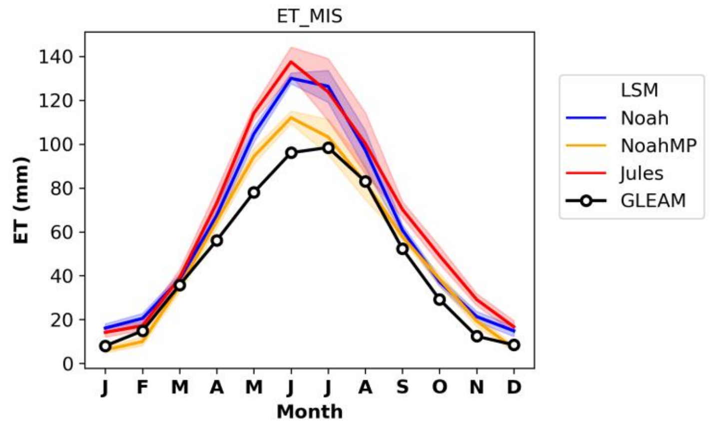


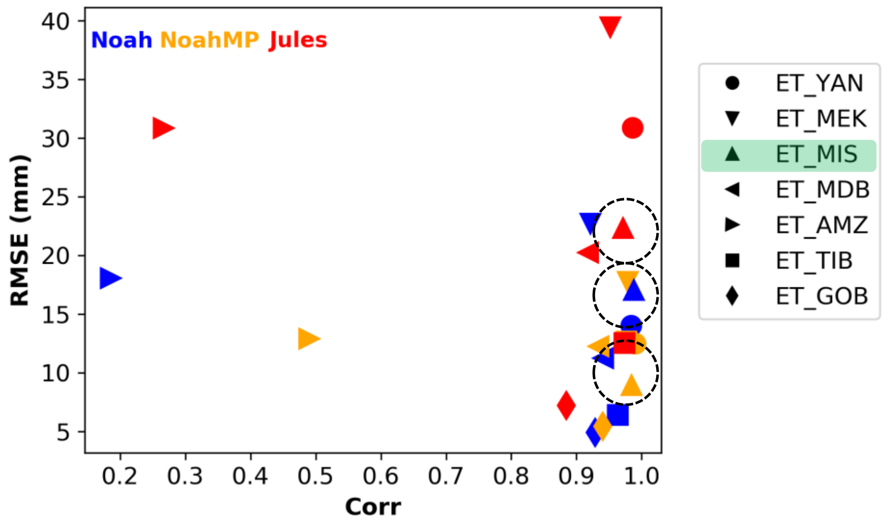
Rootzone soil moisture





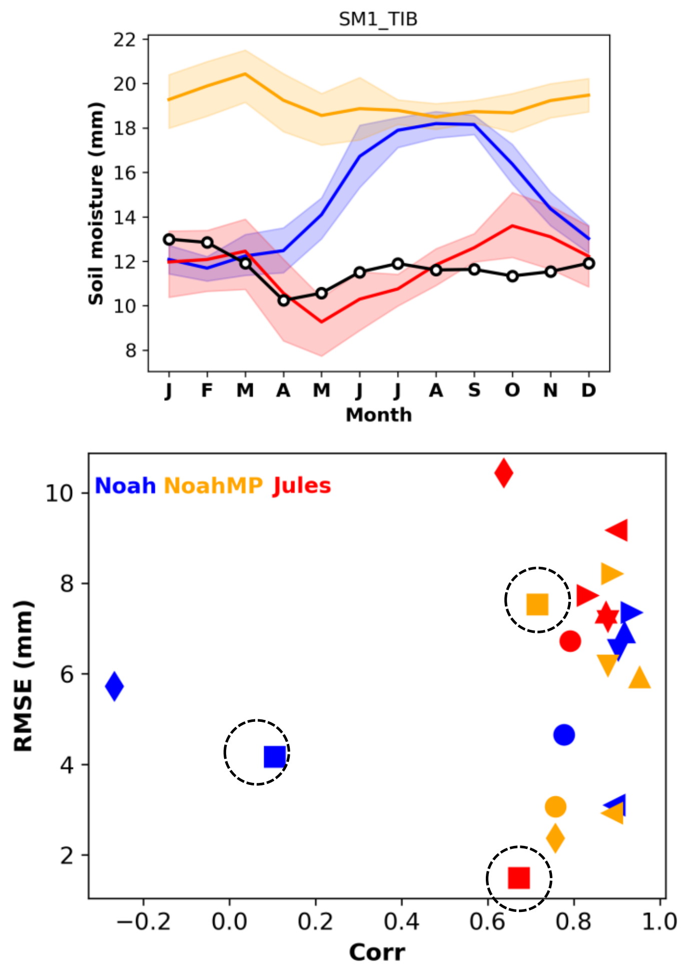
Evapotranspiration



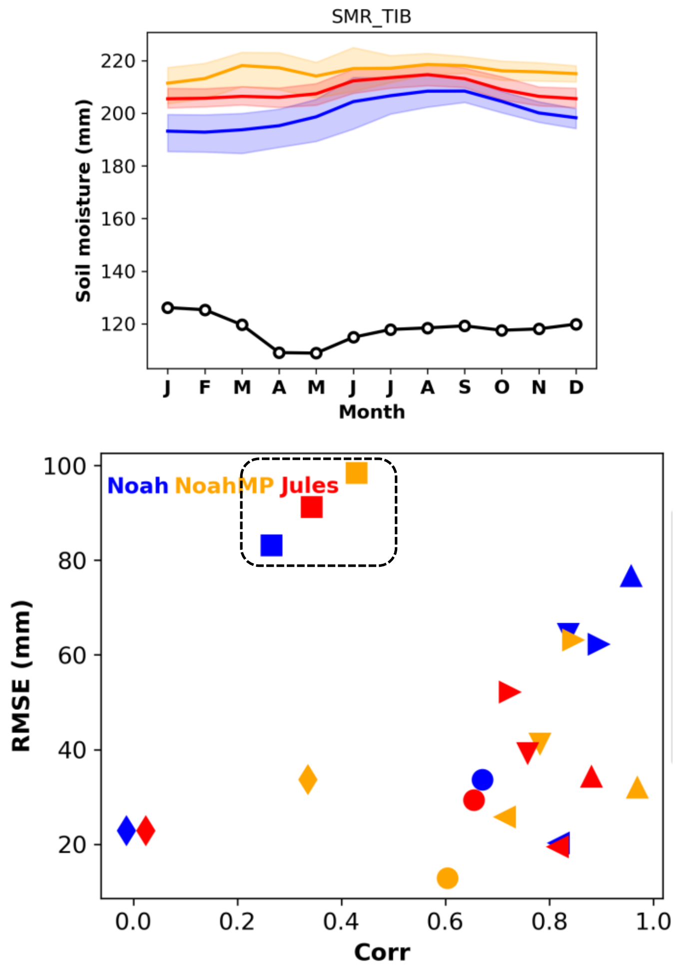


Water Balance Components: Soil Moistures and Evapotranspiration: Tibetan Basin

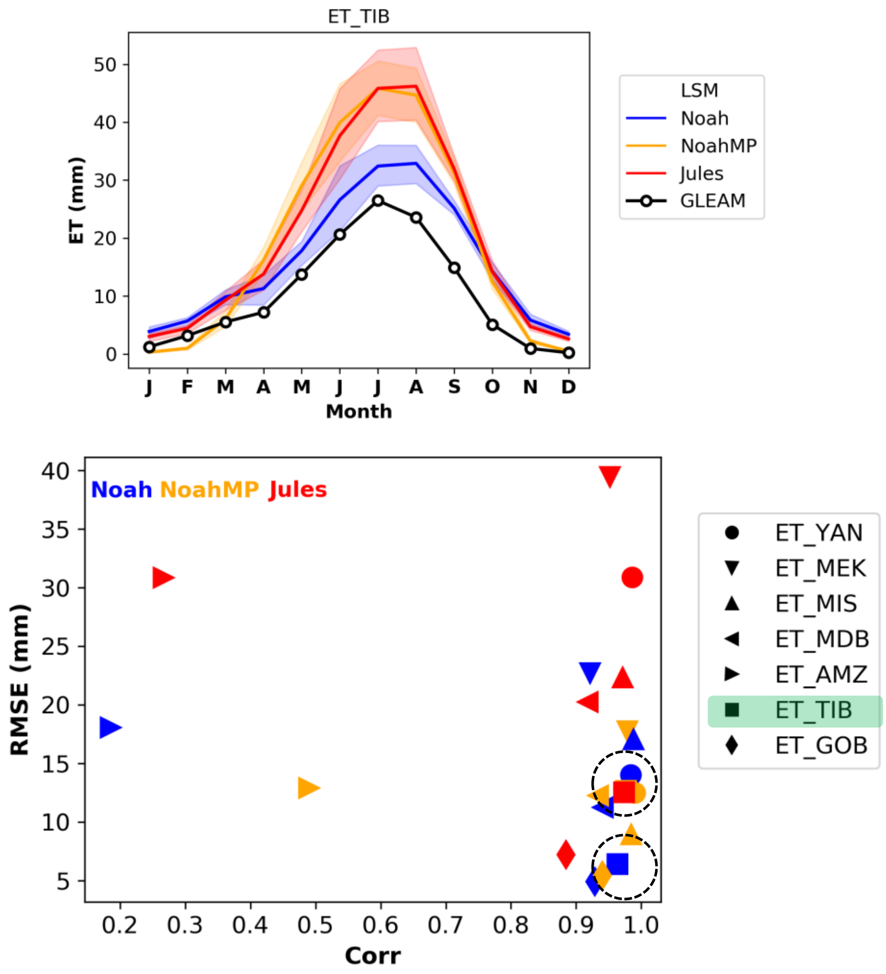
Surface soil moisture



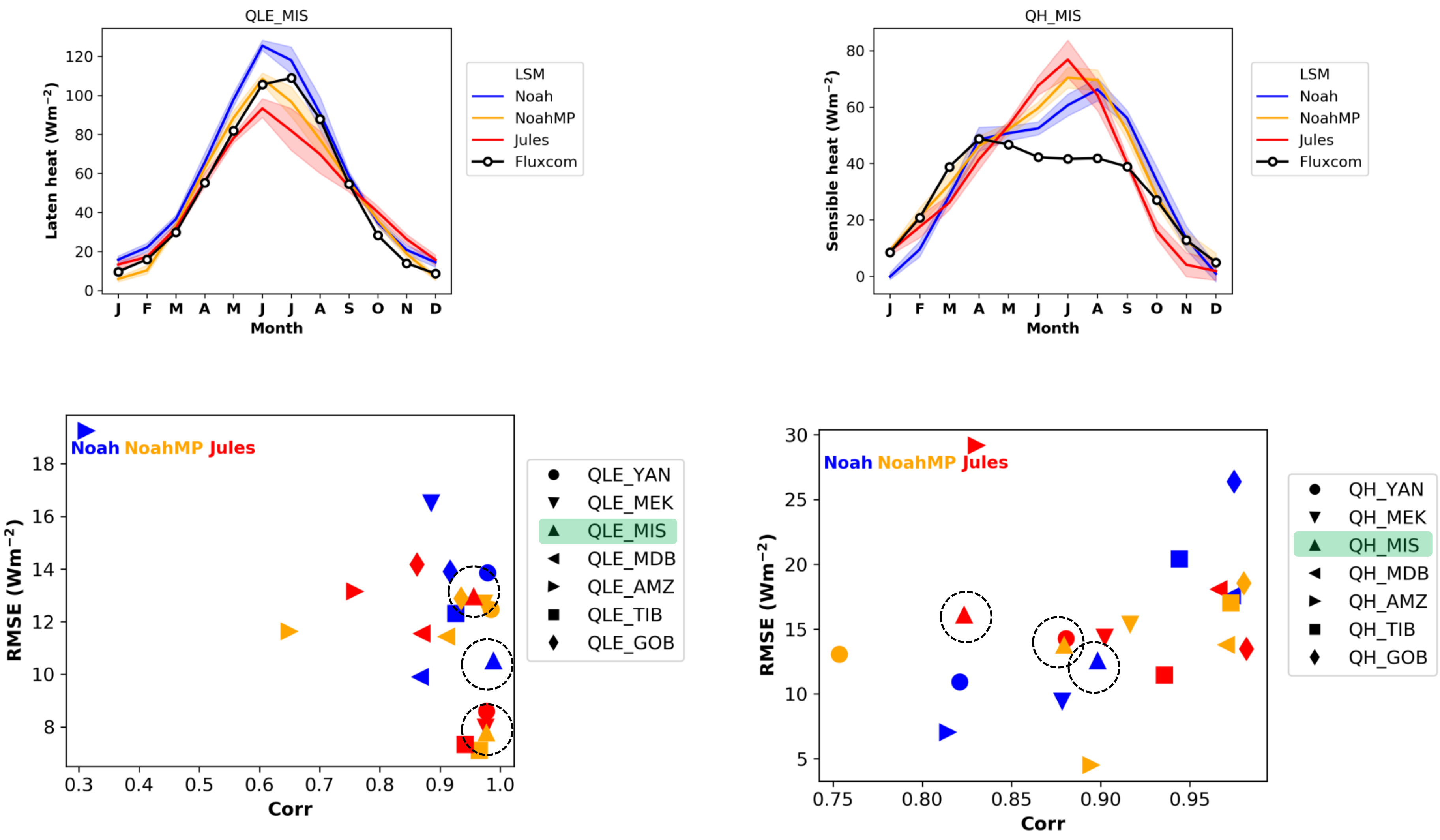
Rootzone soil moisture



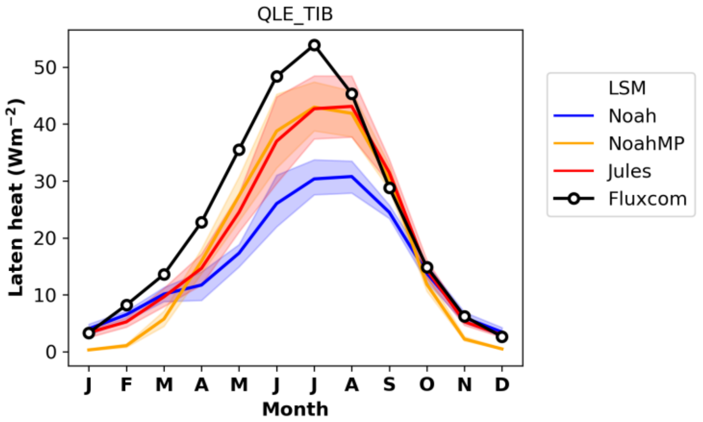
Evapotranspiration

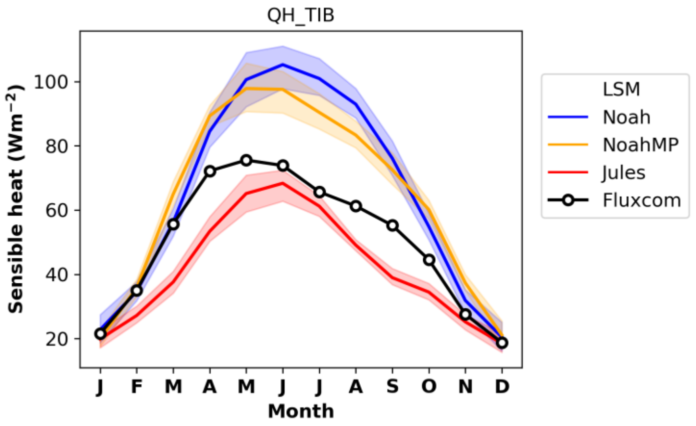


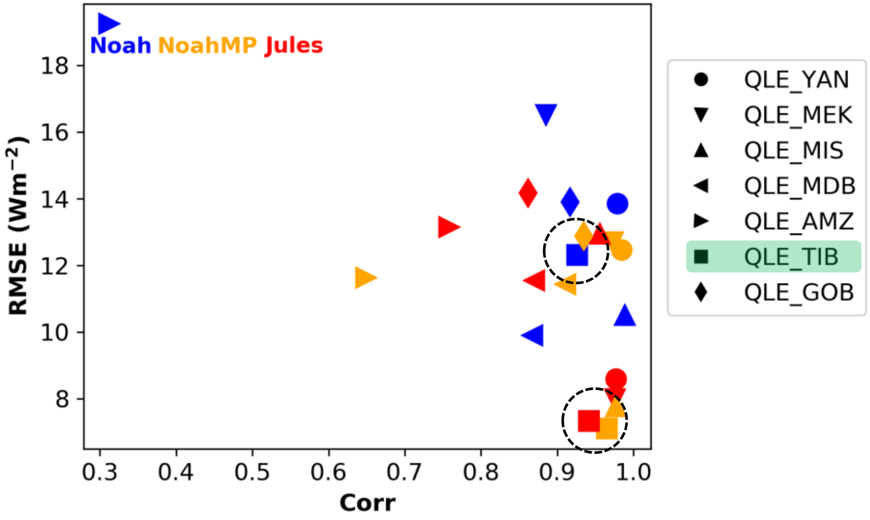
Energy Balnce Components: Mississippi Basin

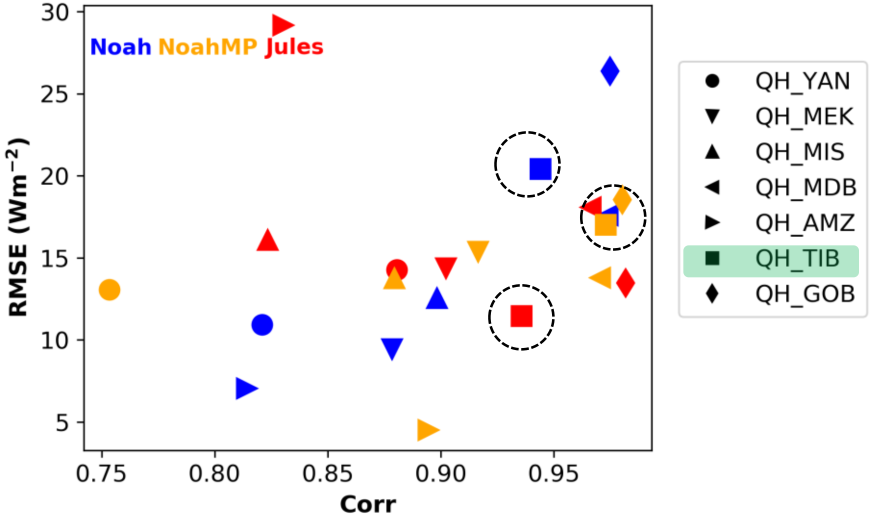


Energy Balnce Components: Tibetan Basin









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Mercé
Matondo
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Tenki
Grandmercé
Nirringrazzjak
Sagolun
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