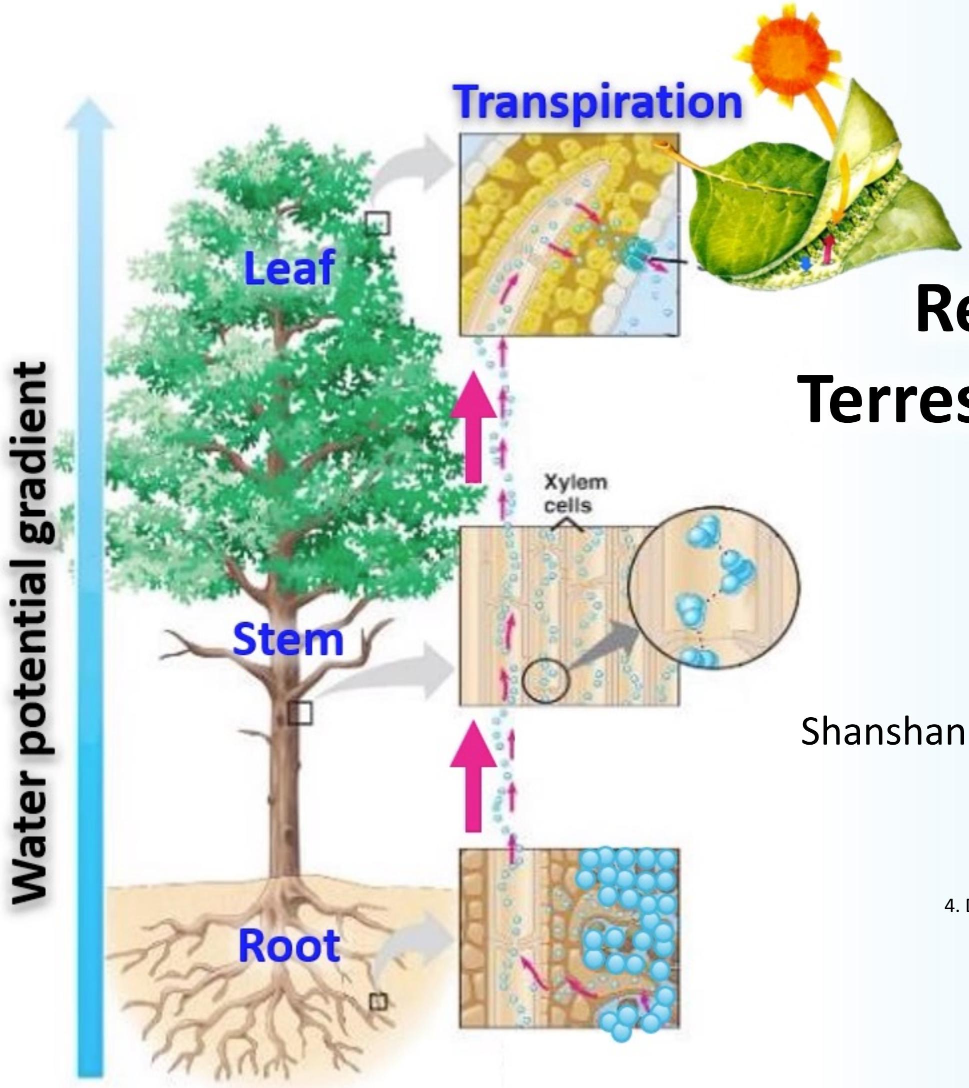

Refining Water and Carbon Fluxes Modeling in Terrestrial Ecosystems via Plant Hydraulics Integration

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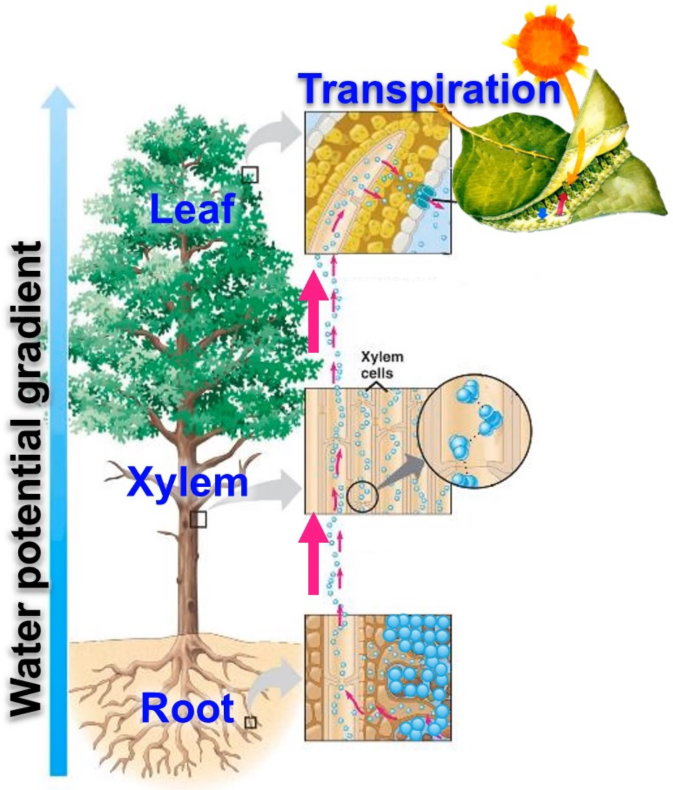
Noah-MP Workshop, Boulder, CO

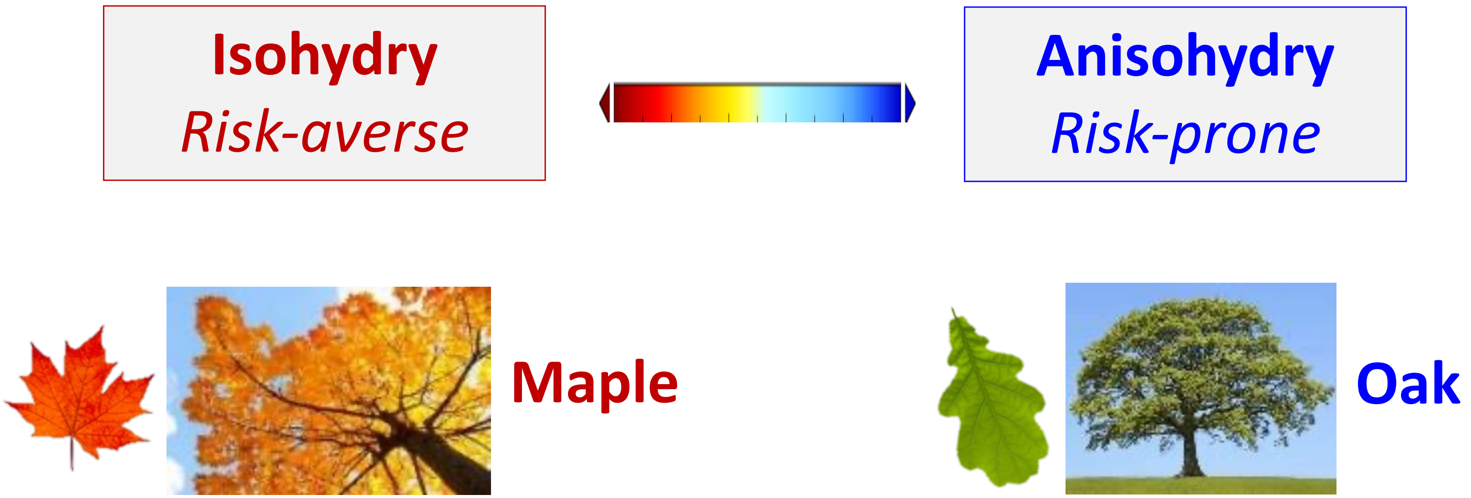
June 2024

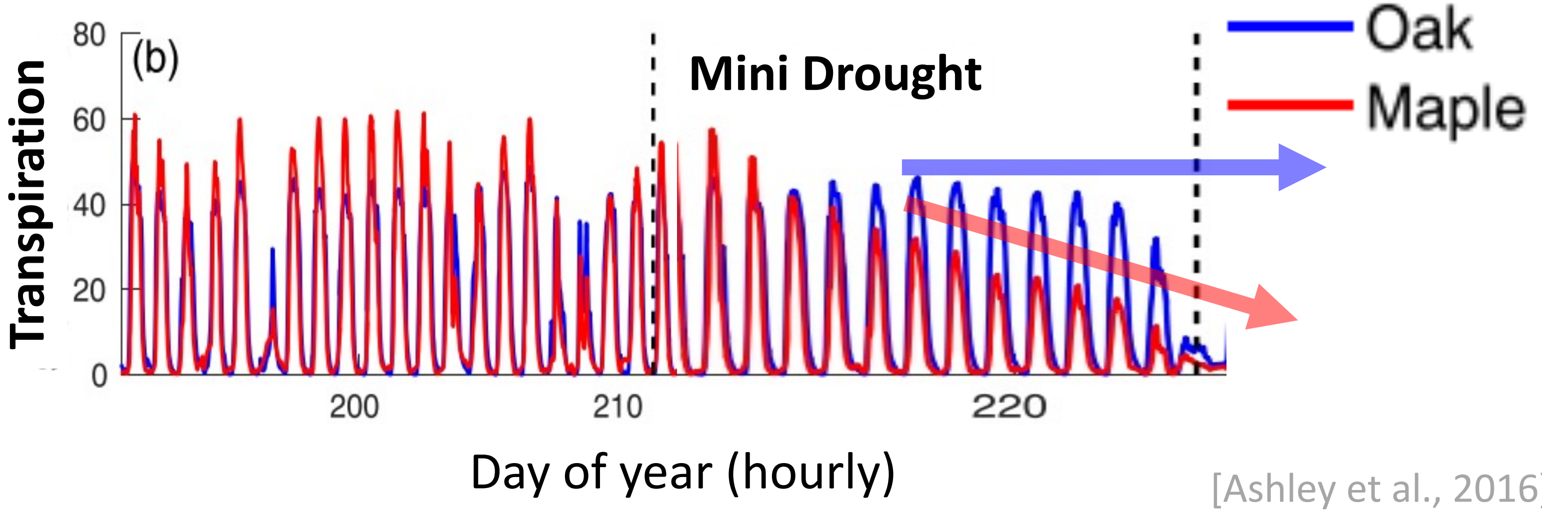
Plants have different water regulation strategies

- Plants have **different** hydraulic strategies



Plant Hydraulics

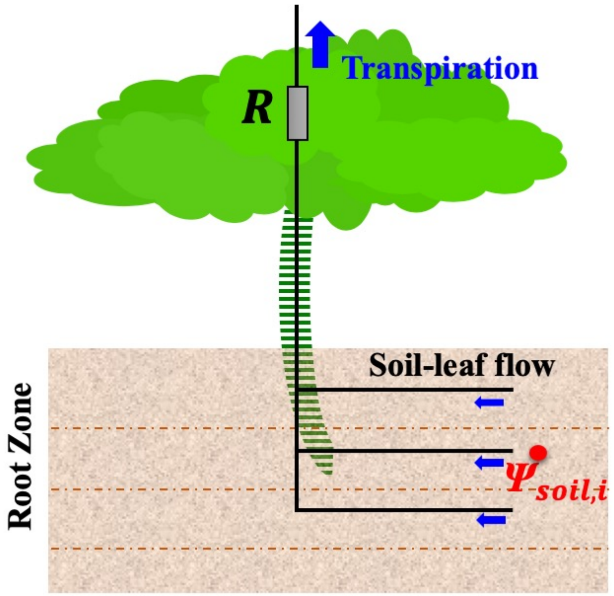




[Ashley et al., 2016]

Limitations in soil hydraulics schemes

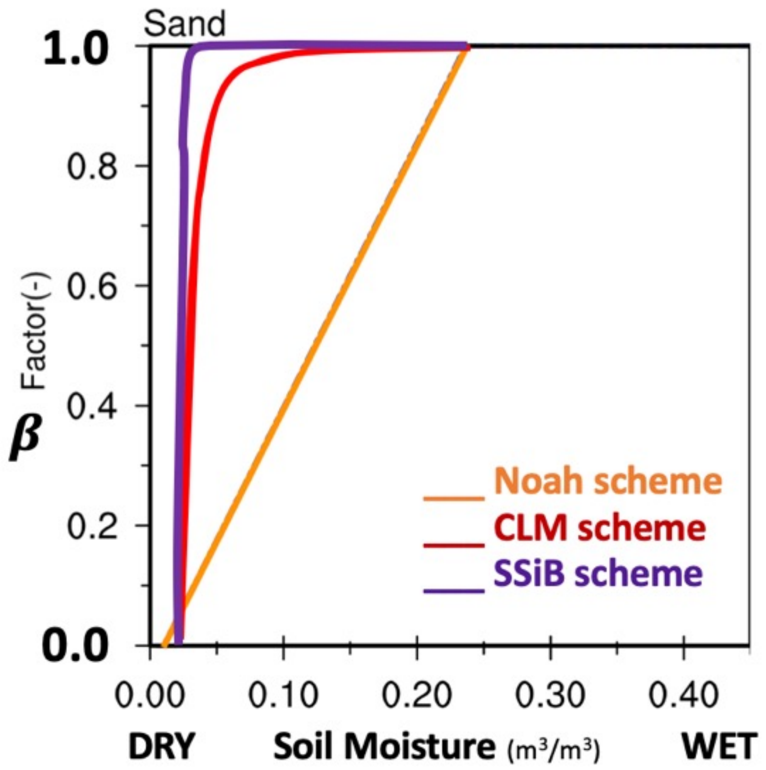
Big leaf model



- **No** water transport through plant
- **No** plant water storage
- Soil water → **Plant Water stress** β

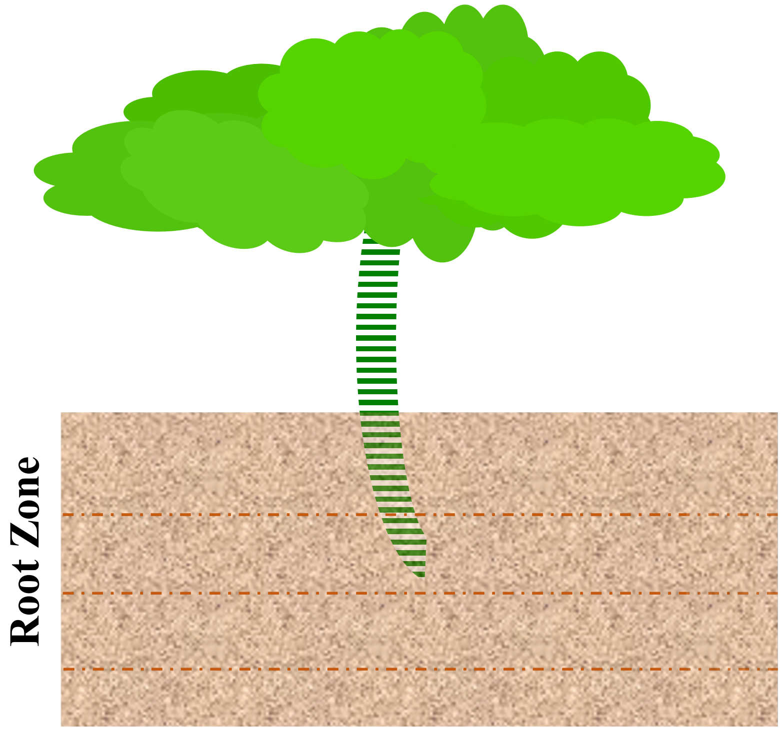
β → Stomatal conductance → TR

Three β schemes in Noah-MP



[Niu et al,. 2011; Yang et al., 2011; He et al., 2023]

“Big Leaf” → “Big Tree (Plant)”



“Big Leaf”

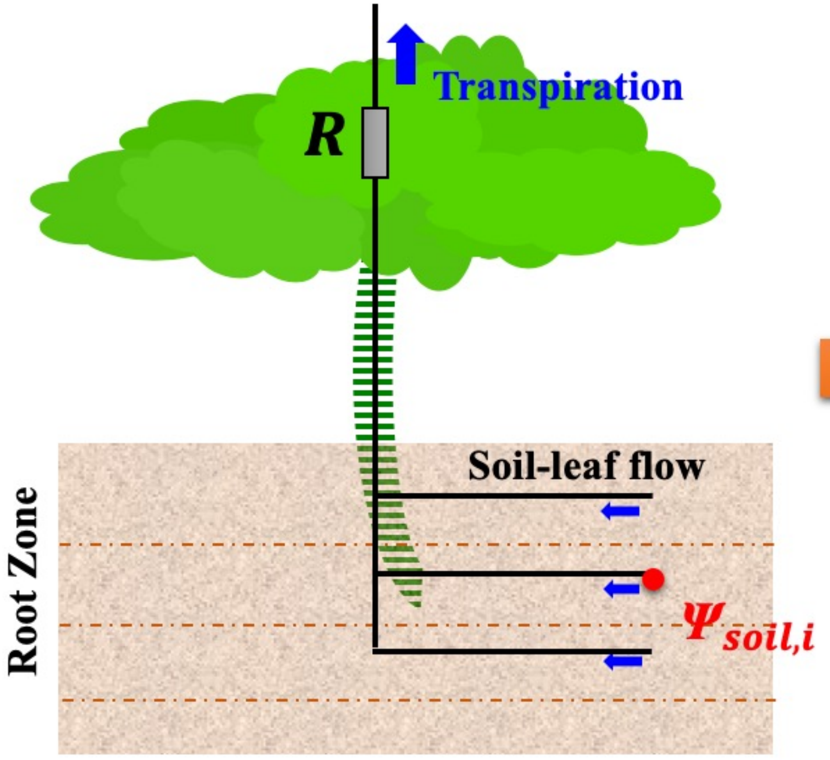
W_{leaf}

R_{stem} W_{stem}

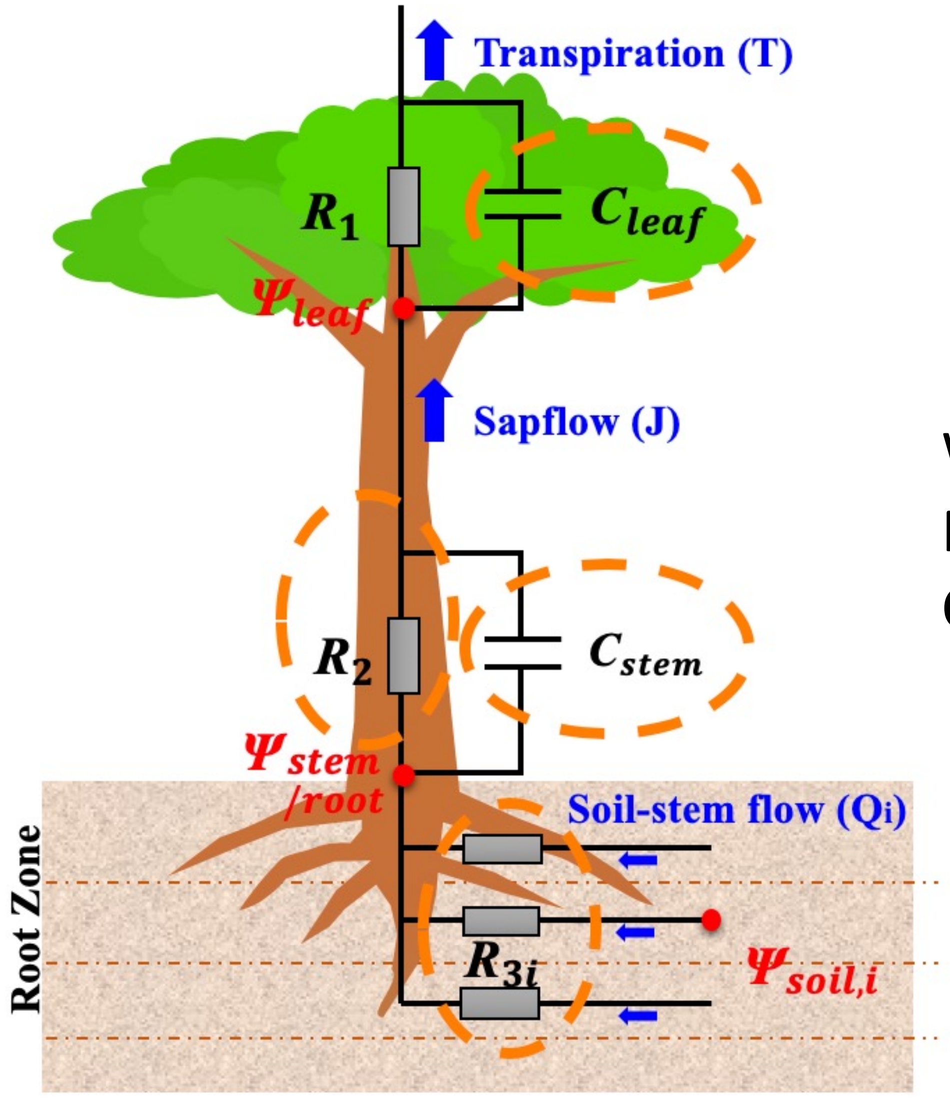
R_{roots}

“Big Plant”

"Big Leaf" → "Big Plant"



"Big Leaf"



"Big Plant"

Water Potential Continuum

Noah-MP-PHS performs well at a single site and tree levels

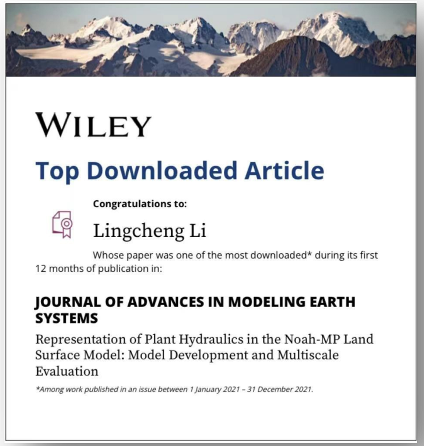
JAMES | Journal of Advances in Modeling Earth Systems

RESEARCH ARTICLE
10.1029/2020MS002214

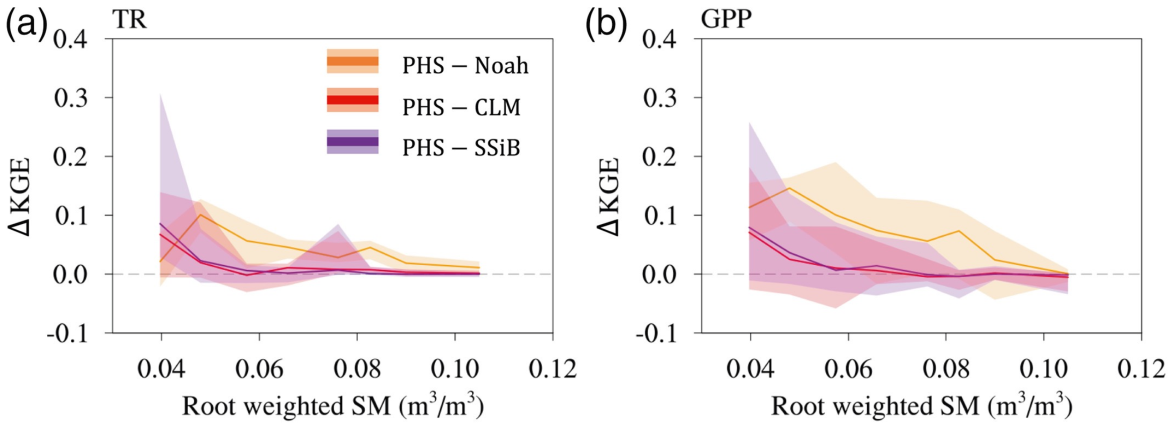
Key Points:
- Noah-MP-PHS improves the water and carbon simulations over the default soil hydraulics schemes, especially under dry soil conditions
- Noah-MP-PHS captures different

Representation of Plant Hydraulics in the Noah-MP Land Surface Model: Model Development and Multiscale Evaluation

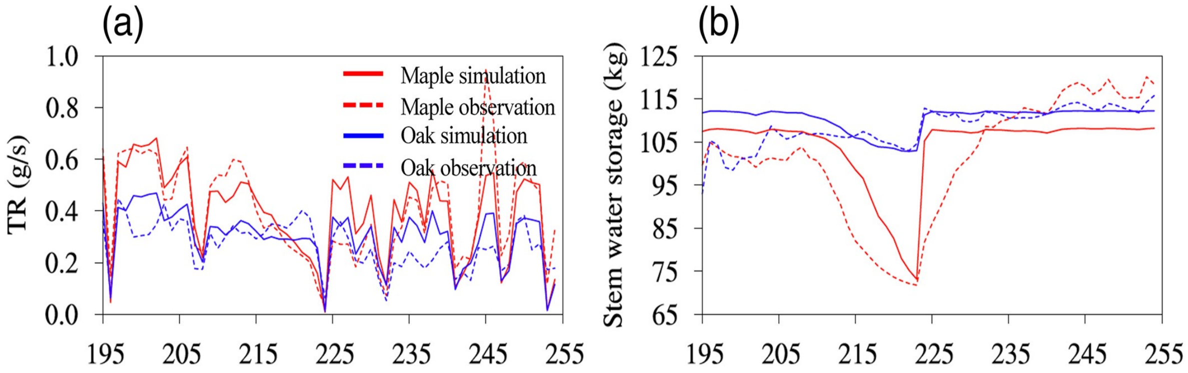
Lingcheng Li[1], Zong-Liang Yang[1], Ashley M. Matheny[1], Hui Zheng[2], Sean C. Swenson[3], David M. Lawrence[3], Michael Barlage[4], Binyan Yan[1], Nate G. McDowell[5], and L. Ruby Leung[5]



- Improve TR and GPP simulations at UMBS

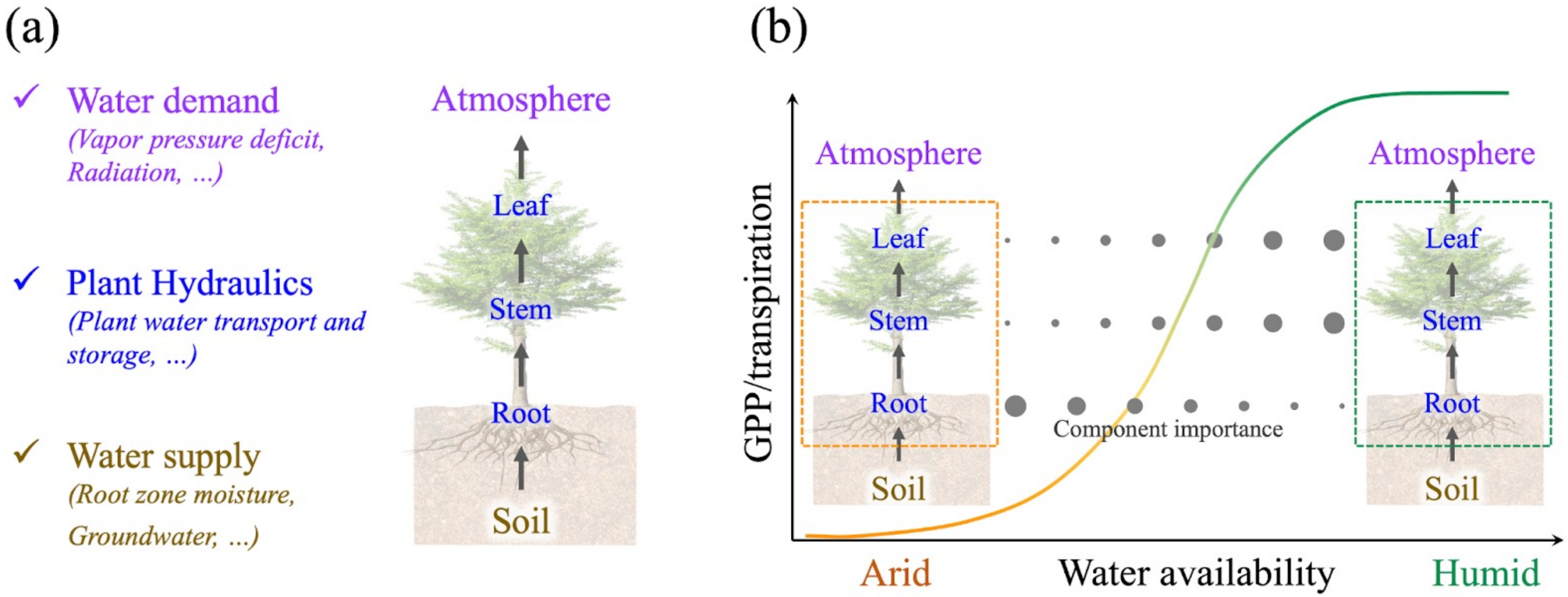


- Good TR and water storage simulations for Oak and Maple trees



Noah-MP-PHS @ global ecosystems

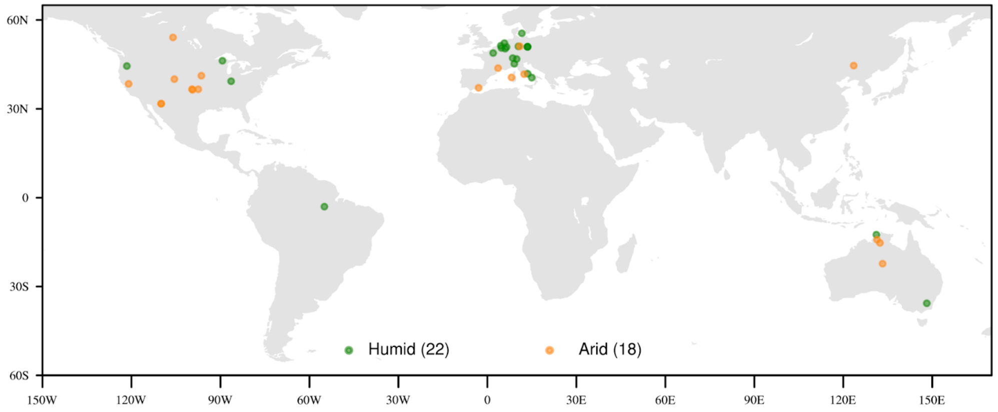
➢ Whether Noah-MP-PHS can refine water and carbon modeling across ecosystems?



[Sun et al., under revision]

Data and method

- ✓ Global FLUXNET sites: 8 ecosystems, 40 sites, from humid to arid
- ✓ Target variables: GPP and ET



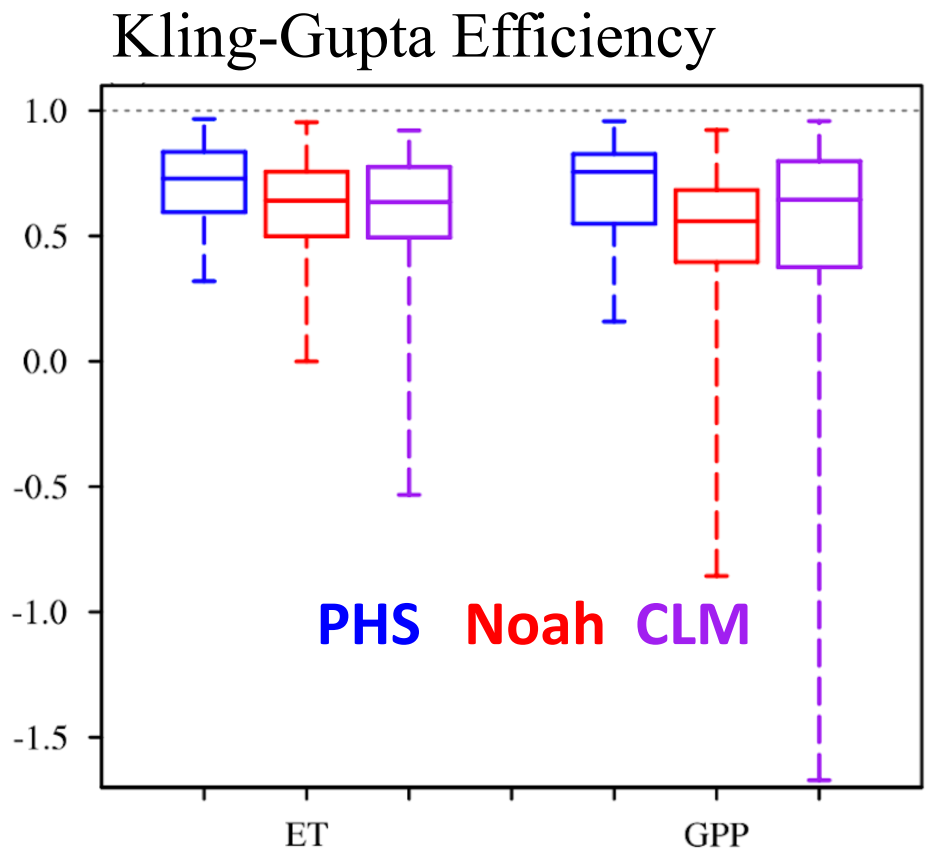
- ✓ Calibration: SCE-UA (Duan et al., 2004)
- ✓ PHS parameters:
  - ✓ Leaf: TLP,
  - ✓ Xylem: Ksat, P50,
  - ✓ Root: depth, ratio, distribution

	Parameter	Description
	TLP	Turgor loss point (LWP when photosynthetic capacity rate halves)
Leaf	C_{leaf}	Leaf water capacitance
	a_3	Empirical parameter controlling plant water stress
	$K_{s,\text{sat}}$	Sapwood-area-specific saturated xylem hydraulic conductivity
	P_{50}	Stem water potential at 50% loss of conductivity
	C_{stem}	Stem water capacitance
Stem (xylem)	S_{sap}	Specific sapwood area index
	V_{sap}	Specific sapwood volume index
	h_c	Canopy height
	a_1	Empirical parameter controlling length of water flow route
	a_2	Empirical parameter controlling xylem hydraulic conductance
	$f_{\text{root-shoot}}$	Fine root area to shoot (i.e., leaf area + stem area) ratio
Root	Root depth	Fine rooting depth (also used in SHSs)
	Root ratio	Fine root distribution in root zone each layer (also used in SHSs)

[Sun et al., under revision]

Noah-MP-PHS performs well in ET and GPP simulations

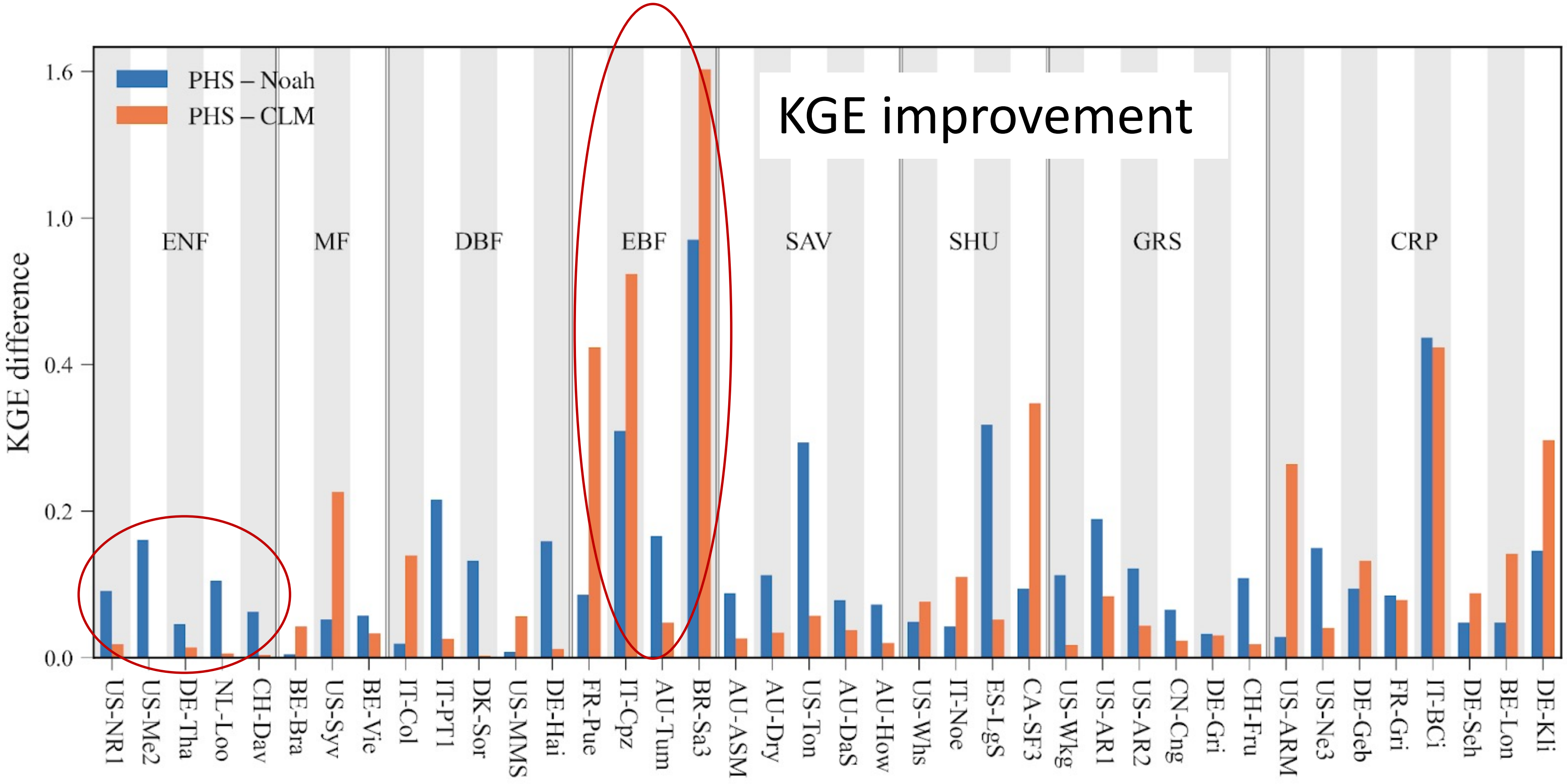
- ✓ Most KGE > 0.5
- ✓ PHS performs better than Noah and CLM



[Sun et al., under revision]

PHS performs better than default schemes

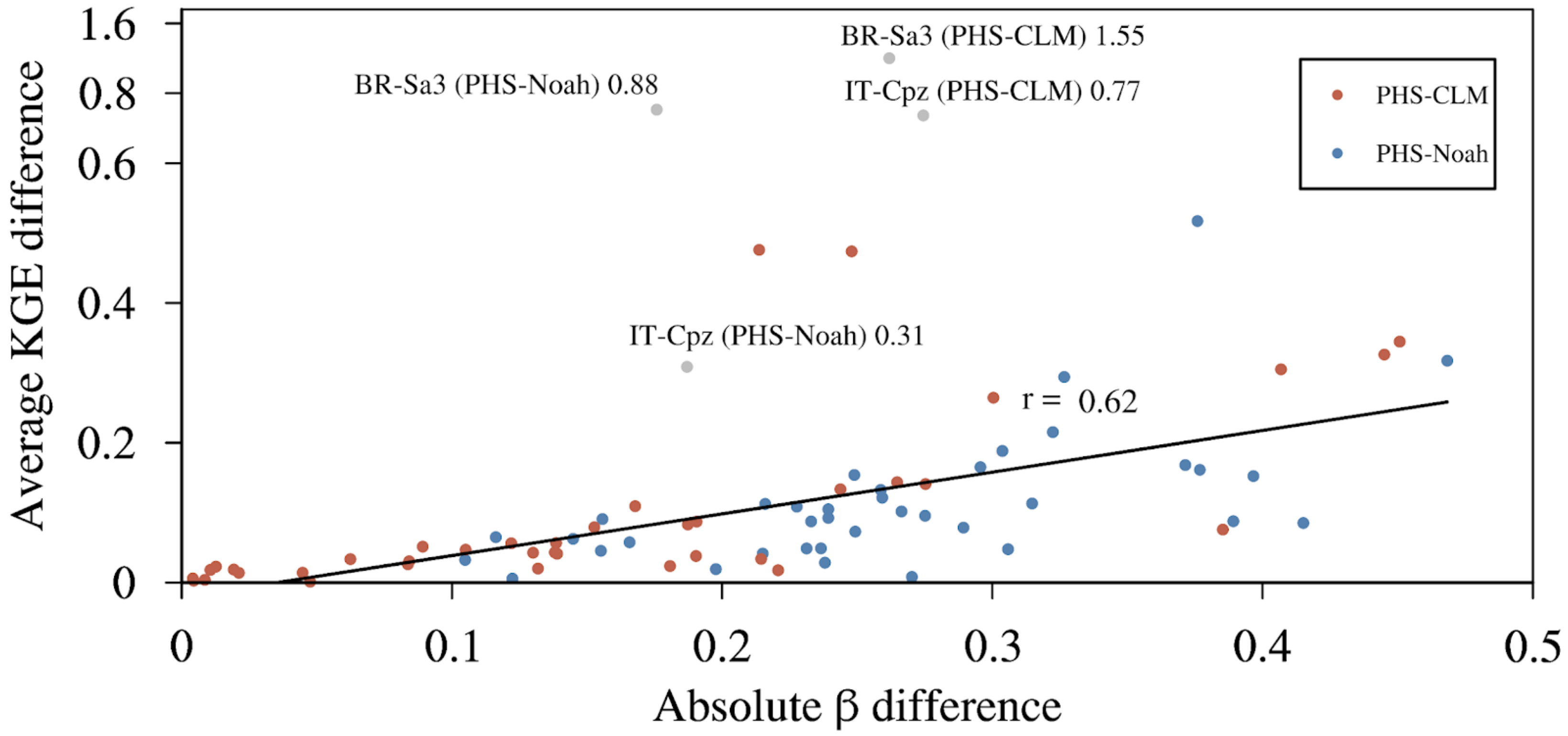
✓ PHS show variable improvements across different ecosystems



[Sun et al., under revision]

PHS better represent plant water stress

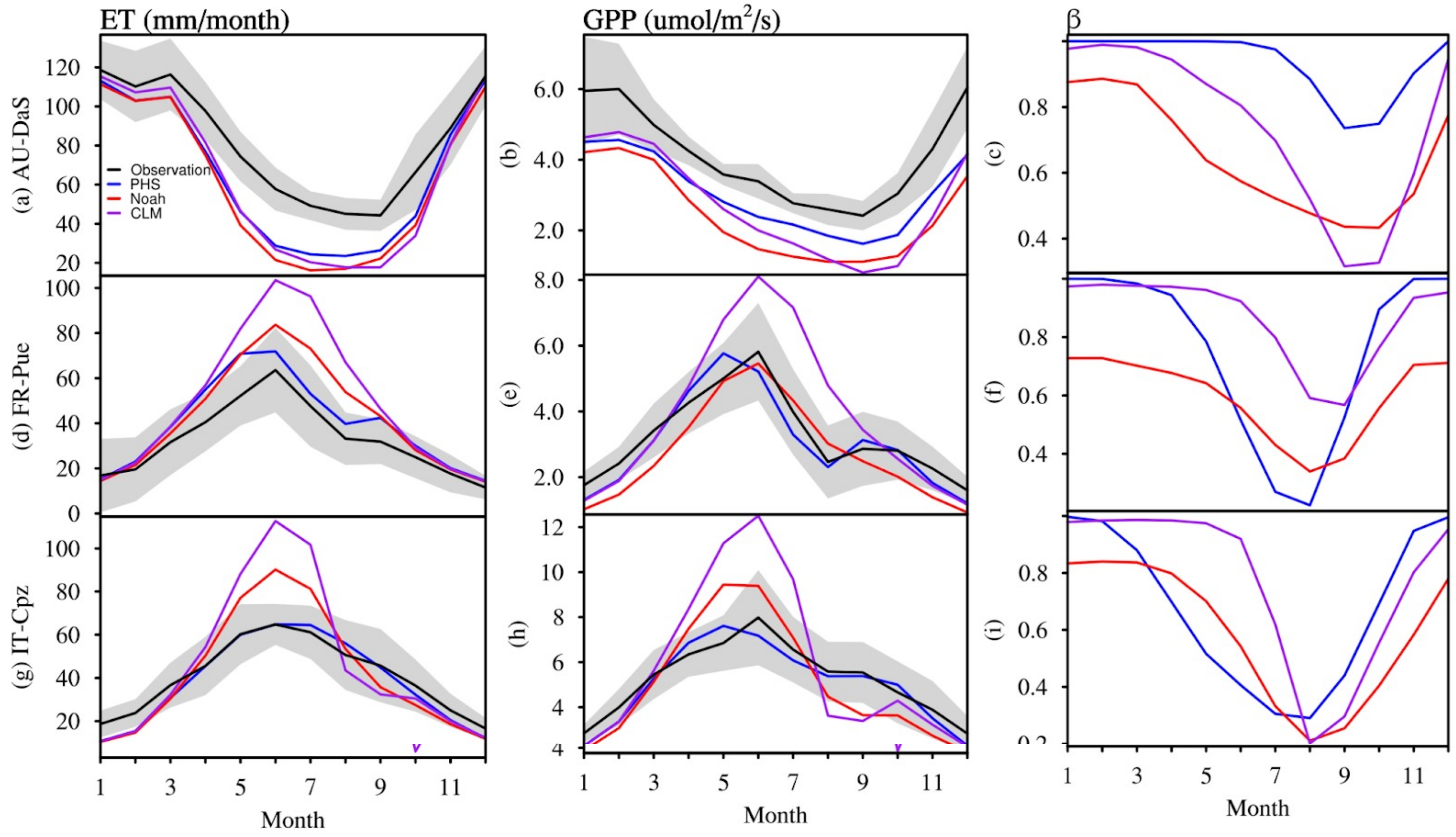
✓ Large Beta difference → higher KGE



[Sun et al., under revision]

Illustration of various improvement types

- ✓ Underestimation
- ✓ Overestimation
- ✓ Seasonality



PHS Noah CLM

[Sun et al., under revision]

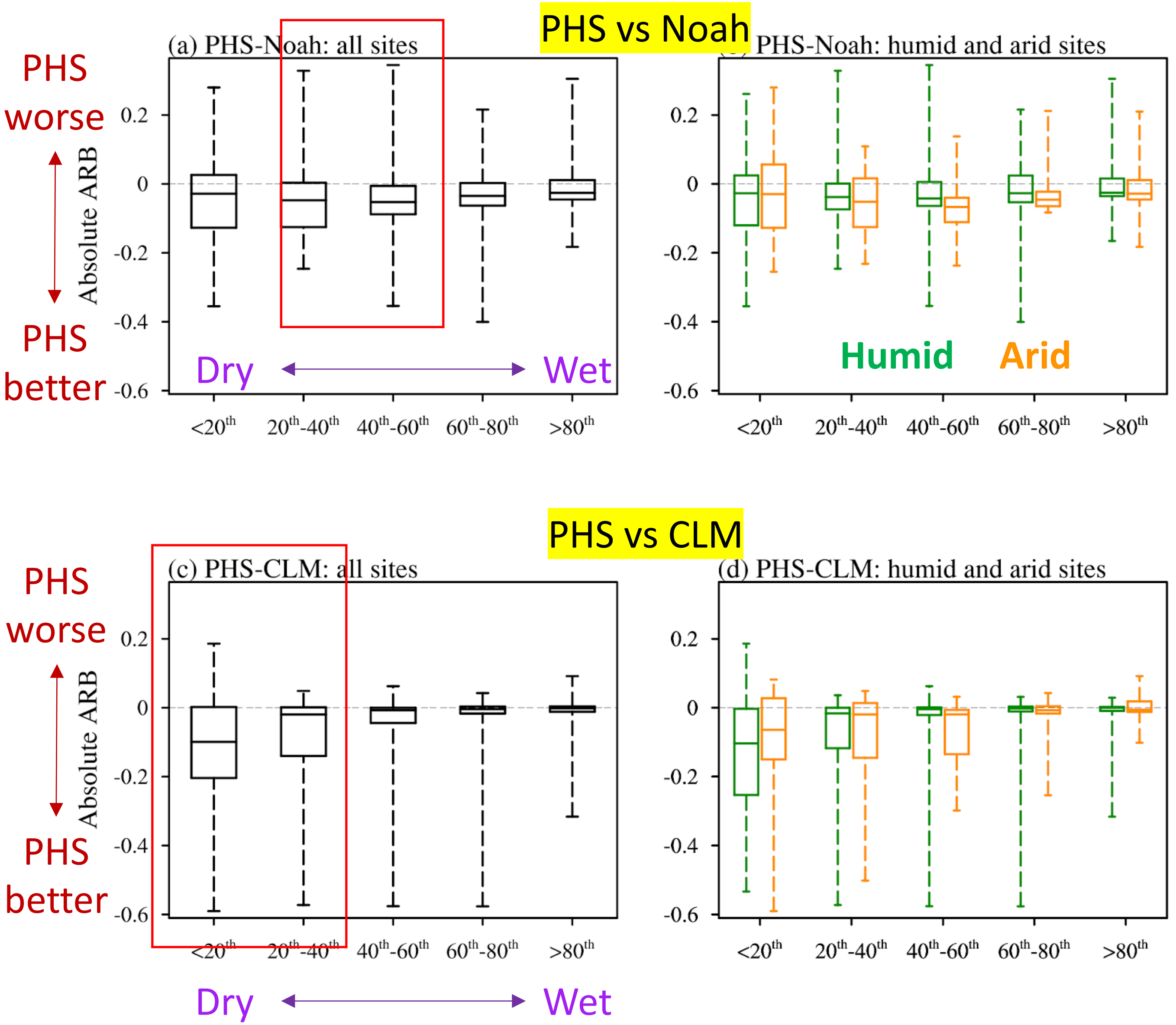
PHS improvements under varied water stress

✓ Larger improvement at dry conditions

- PHS vs Noah: Intermediate dry
- PHS vs CLM: Dry

✓ Improvements across aridity

- PHS vs Noah: Arid > Humid sites
- PHS vs CLM: Humid > Arid under dry conditions

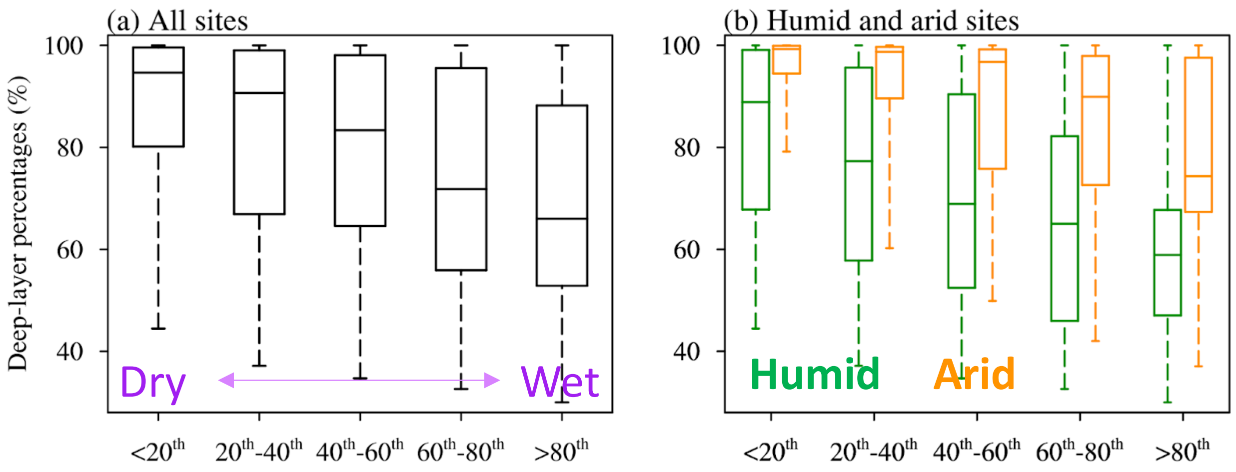


[Sun et al., under revision]

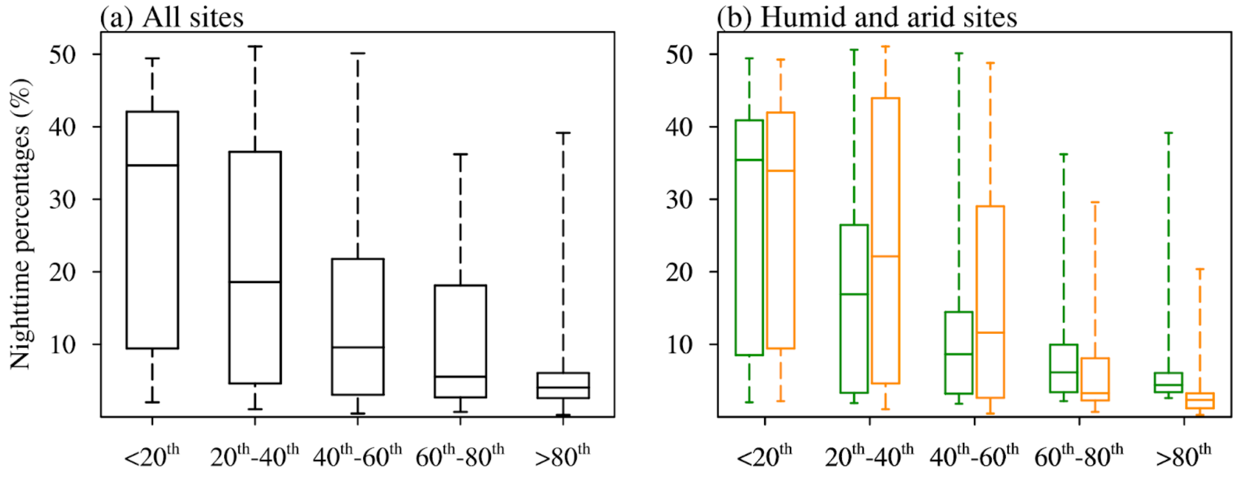
Reasonable PHS root water update under varied water stress

- ✓ Deep-layer root water update contribution
  - Dry > Wet conditions
  - Arid > Humid ecosystems
- ✓ Nighttime contribution
  - Dry > Wet conditions
  - Arid > Humid ecosystems under intermediate dry

Deep-layer contribution



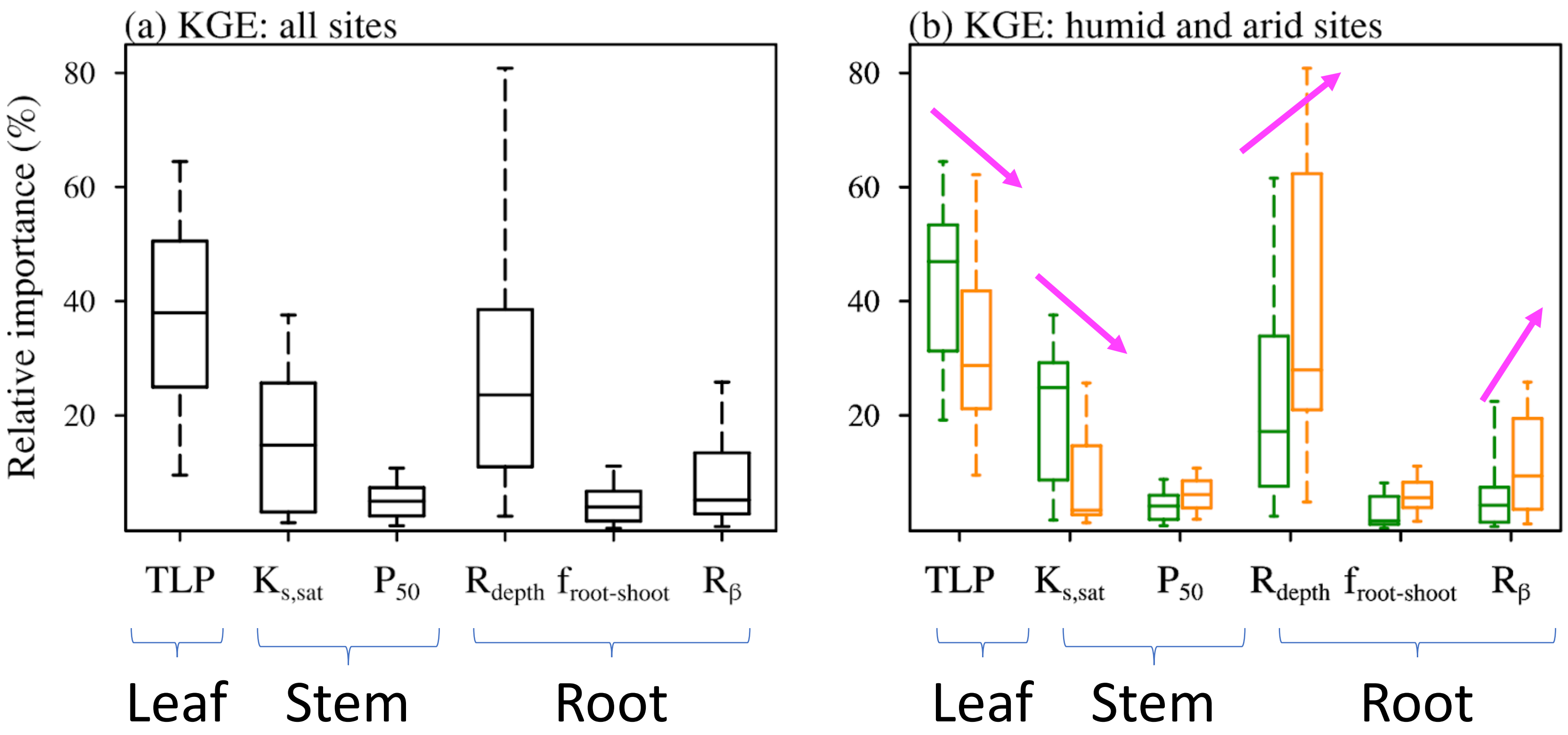
Nighttime contribution



[Sun et al., under revision]

PHS components importance analysis

- ✓ Parameters of leaf, stem and root are all important
- ✓ Importance changes Humid → Arid
  - Leaf and stem parameters become less important
  - Root parameters become more important.



[Sun et al., under revision]

Take-home messages

- ✓ Plant hydraulics improves GPP and ET simulation @ global various ecosystems.
- ✓ Larger improvements under dry or intermediate dry conditions.
- ✓ Plant hydraulics can better demonstrate the root water uptake process.
- ✓ All plant hydraulics components are essential and show varying importance across humid to arid ecosystems.

Refining Water and Carbon Fluxes Modeling in Terrestrial Ecosystems via Plant Hydraulics Integration

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Under revision, Preprint:
https://www.researchgate.net/publication/378333989_Refining_Water_and_Carbon_Fluxes_Modeling_in_Terrestrial_Ecosystems_via_Plant_2_Hydraulics_Integration

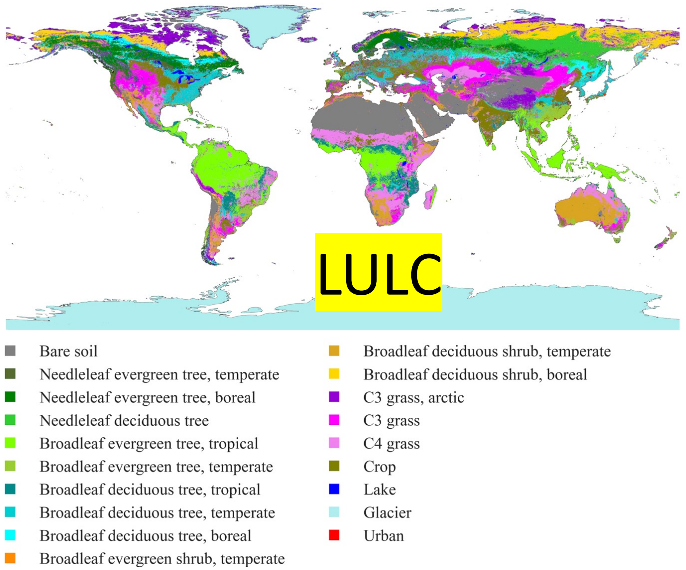
Email:
lingcheng.li@pnnl.gov

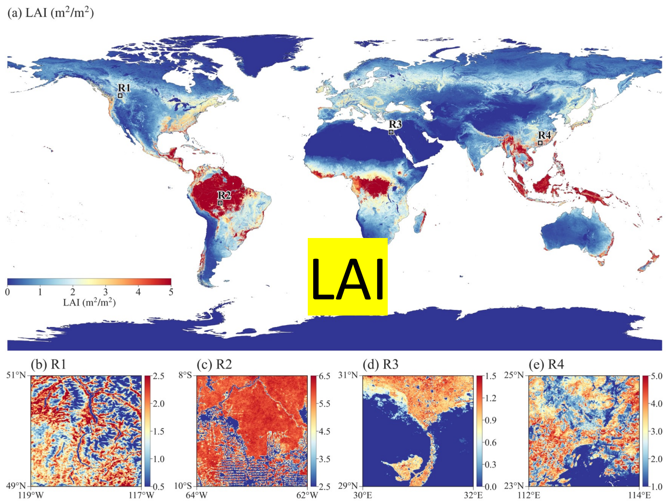
Global 1km surface datasets for the need of km-scale modeling

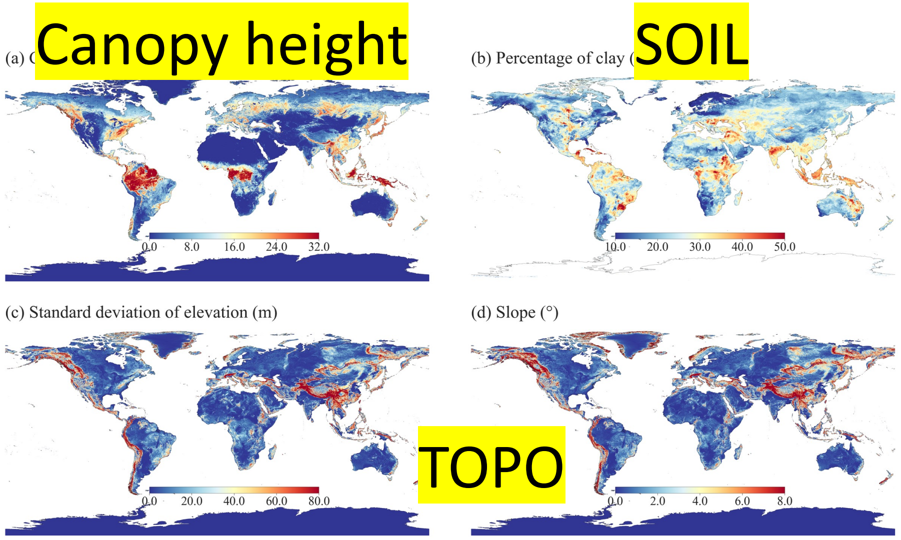
OLD
- low resolution
- limited years
- Outdated

NEW
- ✓ 1 km, global
- ✓ 20 years
- ✓ latest data

Category	Land surface parameters	Resolution
LULC	PFTs, Lake, Glacier, Urban	• 1 km, yearly, 2001-2020
Vegetation	LAI, SAI	• 1 km, monthly, 2001-2020
	Canopy height	• 1 km, temporally static
Soil	Percent sand, silt, and clay, soil organic matter	• 1 km, temporally static
Topography	Elevation, slope, standard deviation of elevation, aspect, sky view factor, terrain view factor	• 1 km, temporally static







Li, L., Bisht, G., Hao, D., and Leung, L. R.: Global 1 km land surface parameters for kilometer-scale Earth system modeling, Earth Syst. Sci. Data, 16, 2007–2032 (2024). [DOI: 10.5194/essd-16-2007-2024]