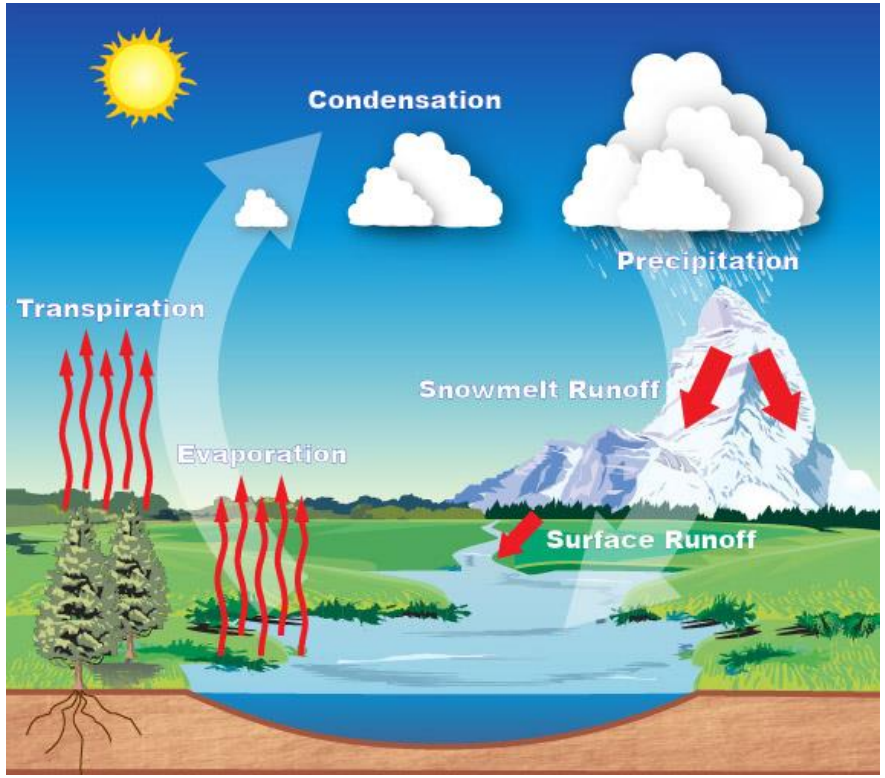
The Competition Between Plant Water Stress and Stomatal Conductance Configurations: Which is More Important for transpiration?

Zhiyi Zhou, Danica Lombardozzi, Dave Barnard

ECOSYSTEM SCIENCE AND SUSTAINABILITY
COLORADO STATE UNIVERSITY

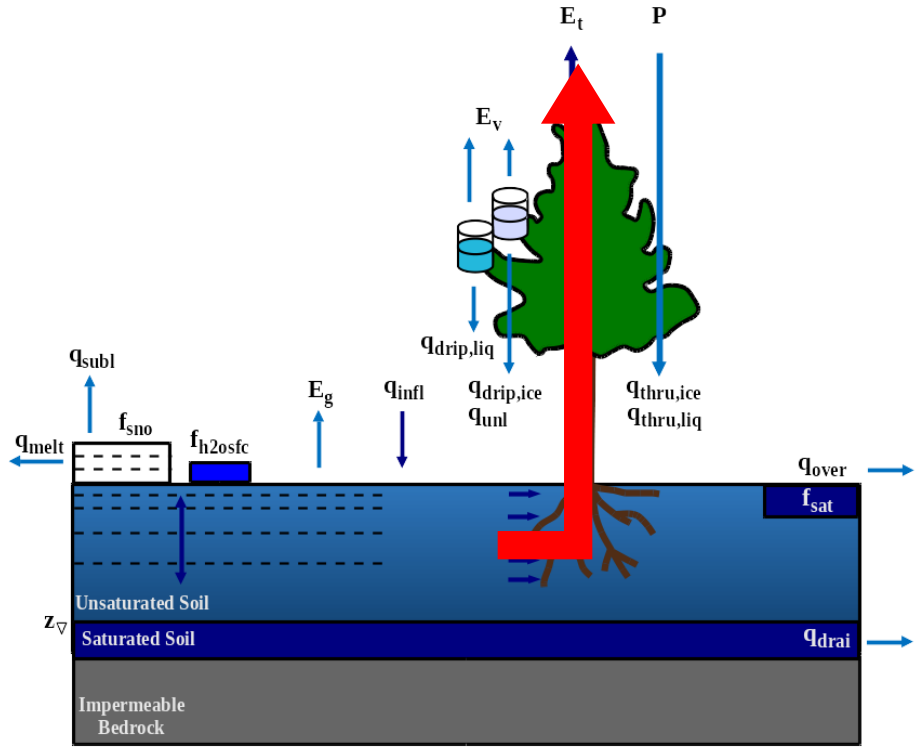
Plant Transpiration in Water Cycle

Water Cycle



NOAA

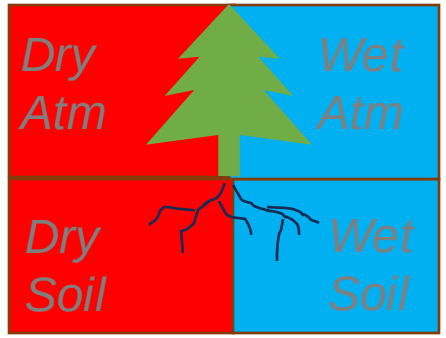
Hydrologic Process in CLM5



CLM5.0 Technical Note

Stomatal Conductance

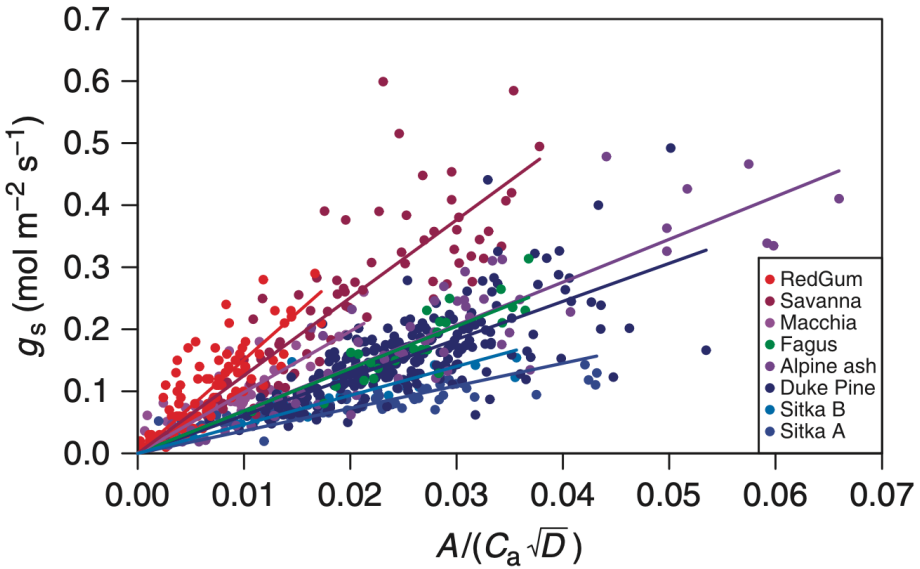
Plant Water Stress



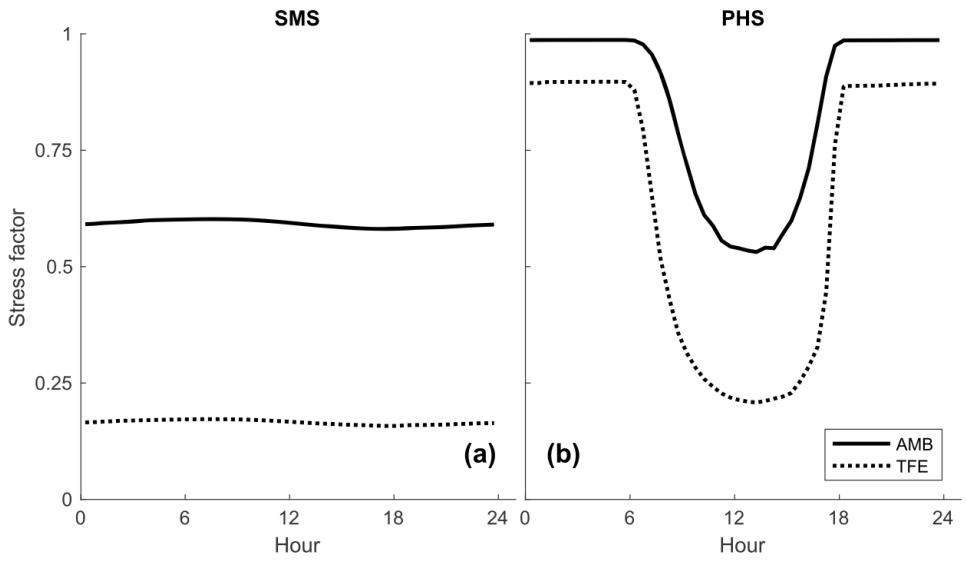
Transpiration represents 80-90% of terrestrial evapotranspiration (Jasechko et al. 2013 Nature)

Plant Transpiration Configurations in CLM

	Stomatal Conductance	Plant Water Stress
CLM 4.5	**Ball et al. 1987:** $g_s = g_0 + g_1 A_n \frac{h_s}{c_s}$	**Soil Moisture Stress (SMS):** $f_{w,SMS} = \sum_{i=1}^{n} r_i w_i \quad w_i = \frac{\varphi_{soil} - \varphi_c}{\varphi_o - \varphi_c}$
CLM5	**Medlyn et al. 2011:** $g_s = g_0 + 1.6\left(1 + \frac{g_1}{\sqrt{D}}\right)\frac{A_n}{C_a}$	**Plant Hydraulics Stress (PHS):** $f_{w,PHS} = 2^{-\left(\frac{\varphi_{leaf}}{P_{50}}\right)^{c_k}} \quad \varphi_{leaf} = \varphi_{soil} + \Delta\varphi$

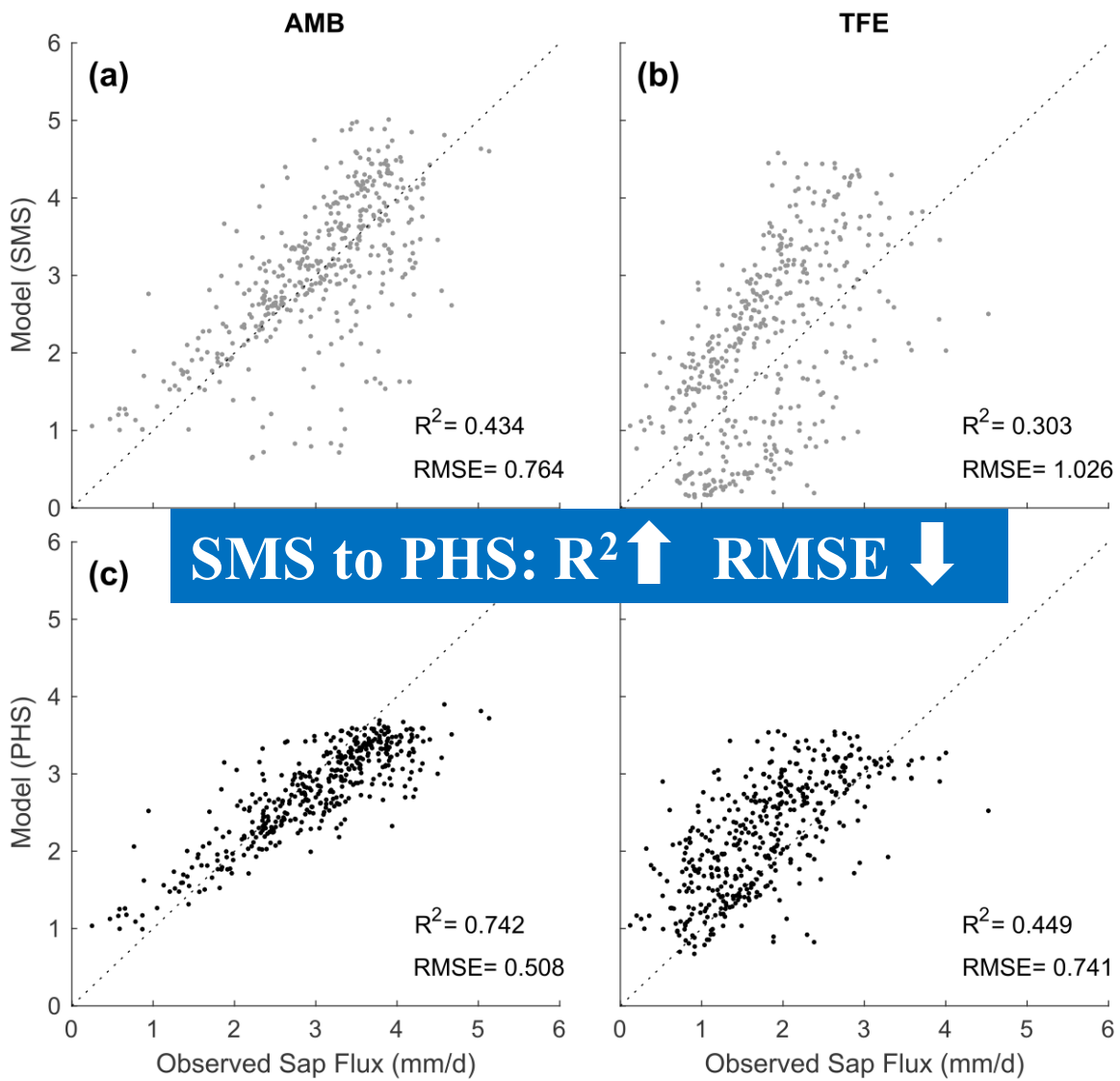


Medlyn et al. 2011 Global Change Biology

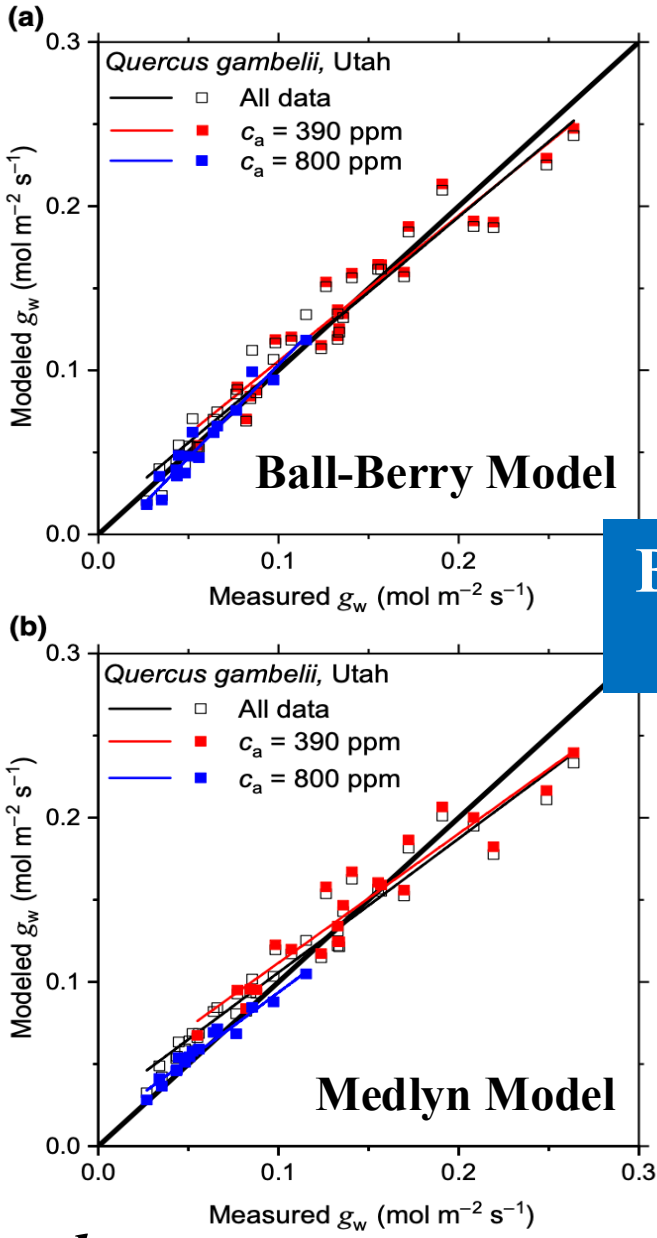


Kennedy et al. 2018 JAMES

From SMS and BB to PHS and MED: Model Performance



SMS to PHS: R^2 ⬆ RMSE ⬇



BB and MED: R^2 = 0.91

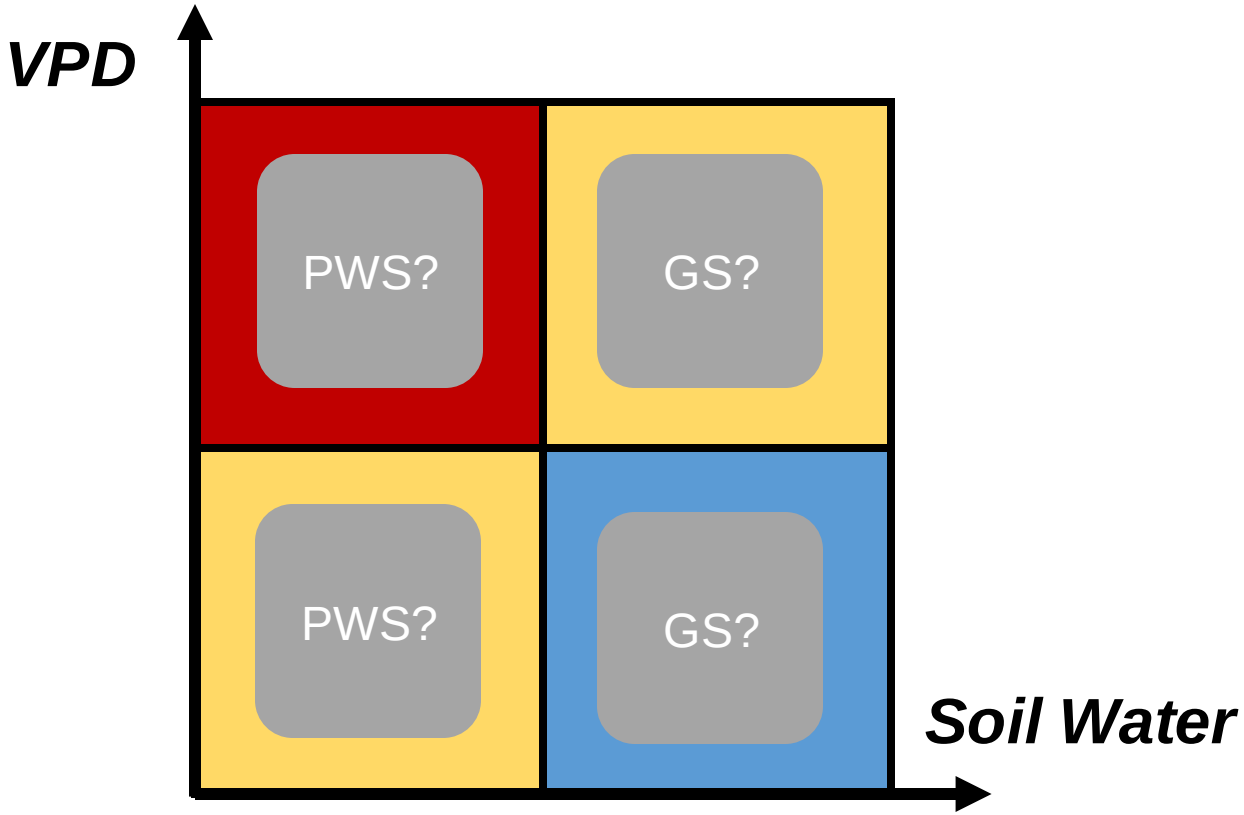
Kennedy et al. 2018 JAMES

Franks et al. 2018 Global Change Biology

Questions and Hypothesis

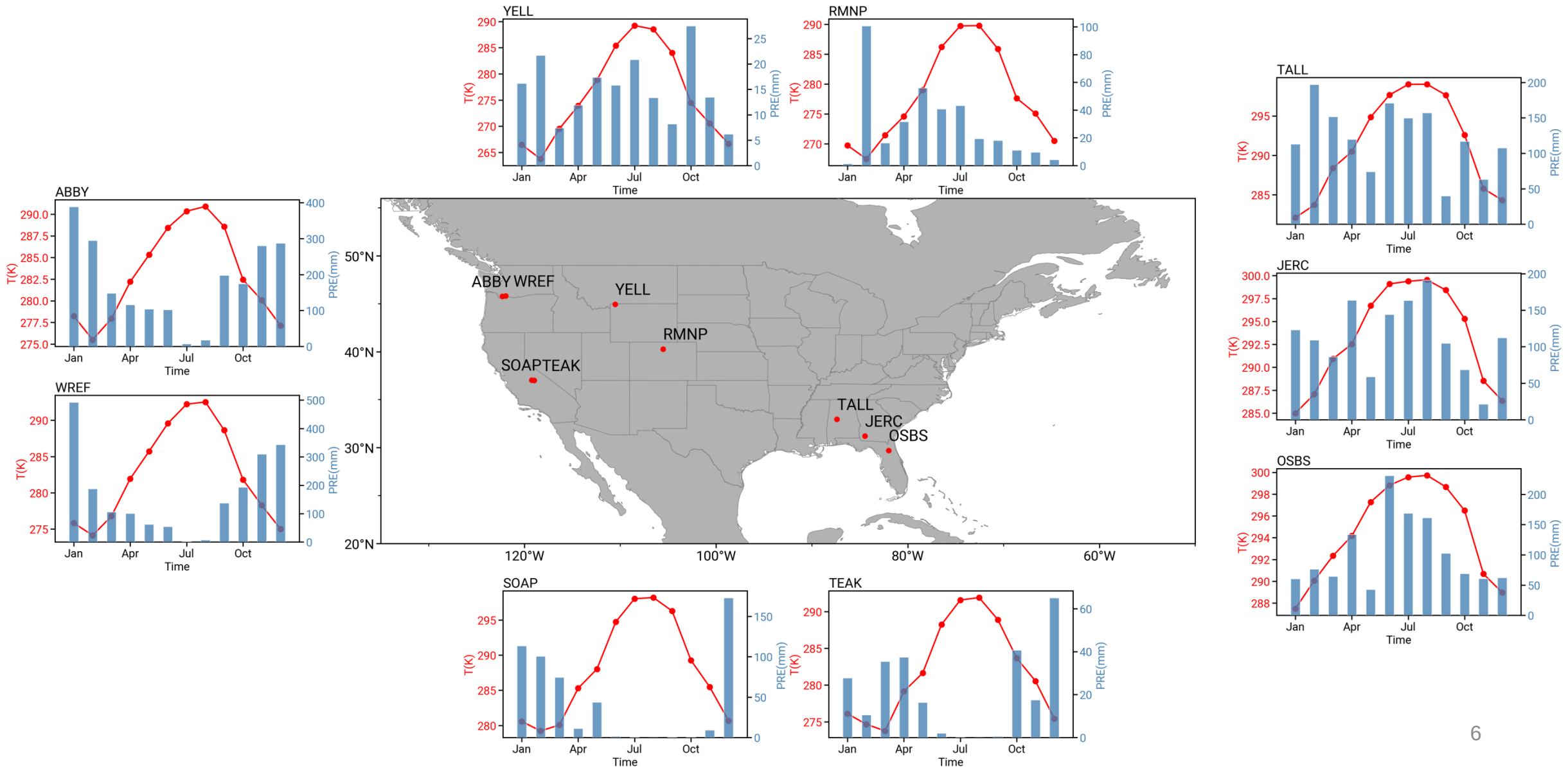
- **Which configuration, stomatal conductance (GS) or plant water stress (PWS), has a greater impact on transpiration?**

- **Does this impact vary with climate conditions?**

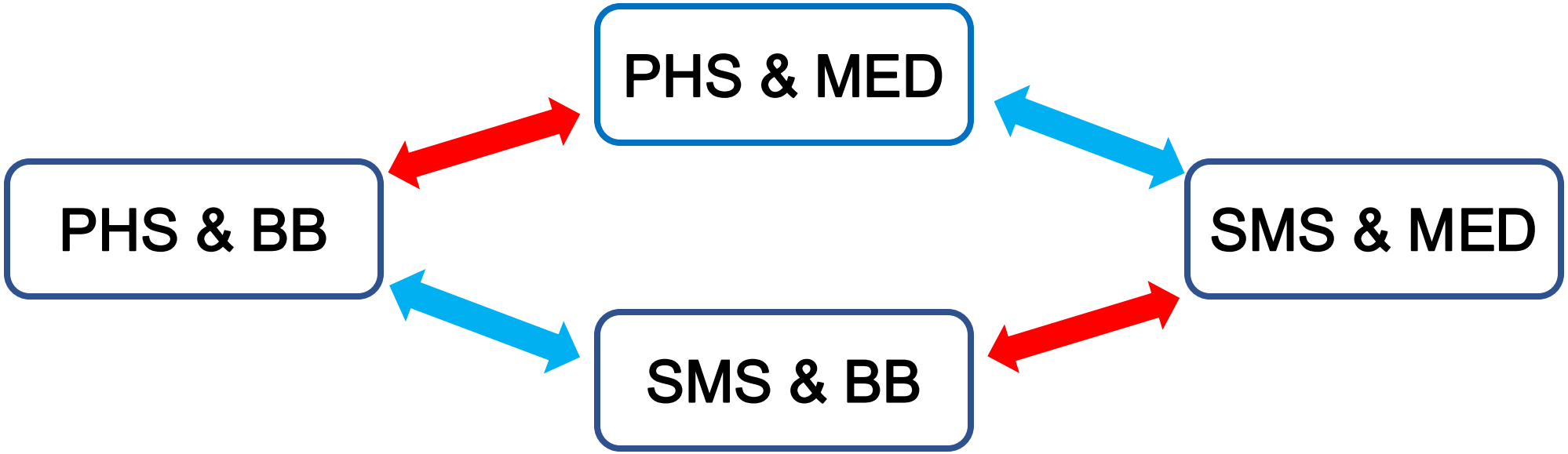


Climate Variability Across 9 NEON Sites with Same PFT

PFT 1: needleleaf evergreen tree-temperate



Experiments



Ball-Berry (BB): $g_s = f_w g_0 + g_1 A_n \frac{h_s}{c_s}$

g_0= 1000 for C3, 4000 for C4 Plant

g_1 varies by PFT (PFT=1, g_1= 8.31)

Medlyn (MED): $g_s = f_w g_0 + 1.6\left(1 + \frac{g_1}{\sqrt{D}}\right)\frac{A_n}{C_a}$

g_0= 100

$g_1$varies by PFT (PFT=1, g_1= 3.096)

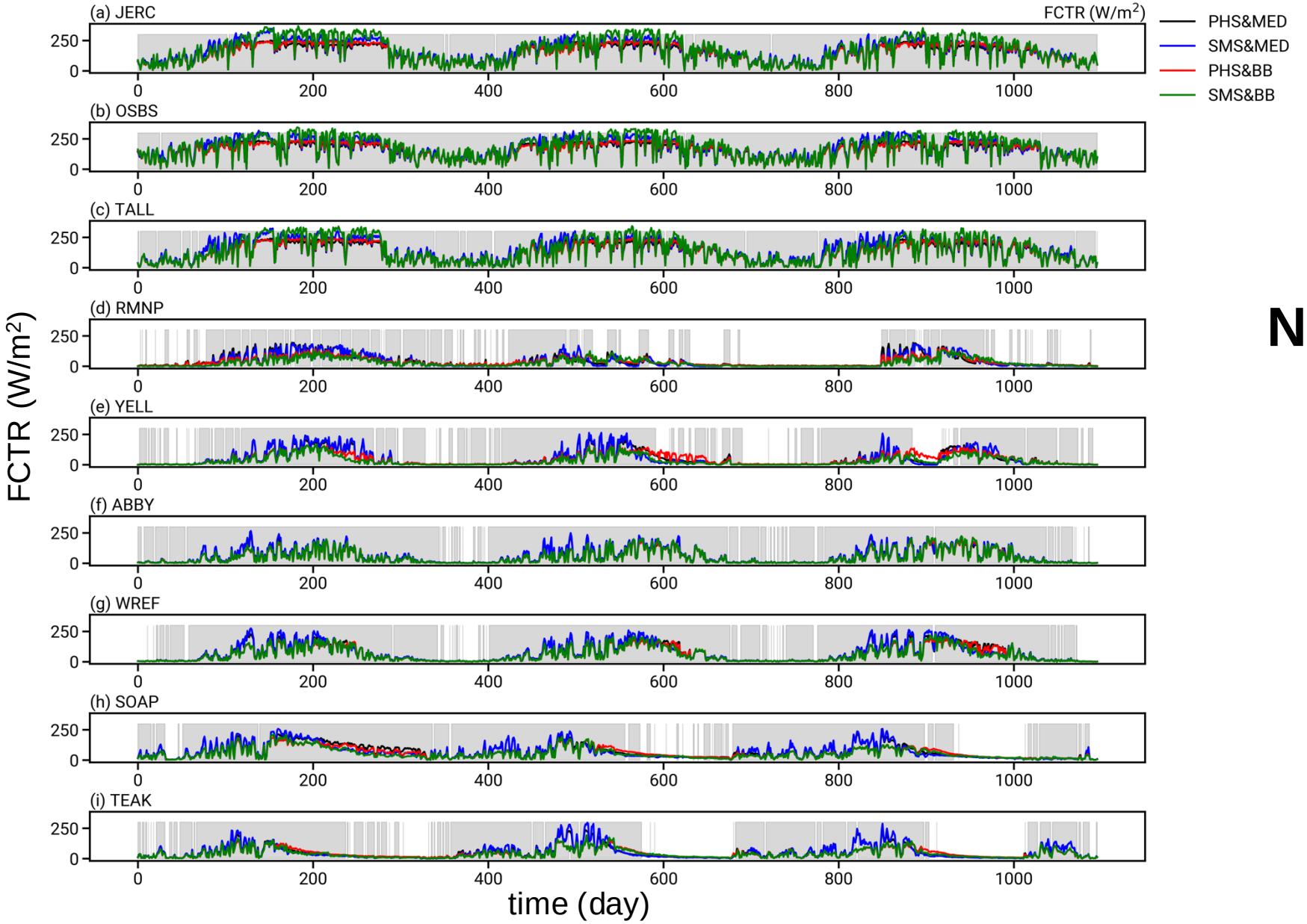
Soil Moisture Stress (SMS)

$f_{w,SMS} = \sum_{i=1}^{n} r_i w_i \quad w_i = \frac{\varphi_{soil} - \varphi_c}{\varphi_o - \varphi_c}$

Plant Hydraulics Stress (PHS)

$f_{w,PHS} = 2^{-\left(\frac{\varphi_{leaf}}{P_{50}}\right)^{c_k}} \quad \varphi_{leaf} = \varphi_{soil} + \Delta\varphi$

Time Selection for Each Site



Noon Time
&
NEE < 0

The Impact of PWS and GS Varies with VPD and Soil Water

$$Impact\ Index_{GS|PHS} = \frac{|TR(PHS,MED) - TR(PHS,BB)|}{MaxDiff}$$

$$Impact\ Index_{PWS|MED} = \frac{|TR(PHS,MED) - TR(SMS,MED)|}{MaxDiff}$$

PHS & MED

PHS & BB

SMS & MED

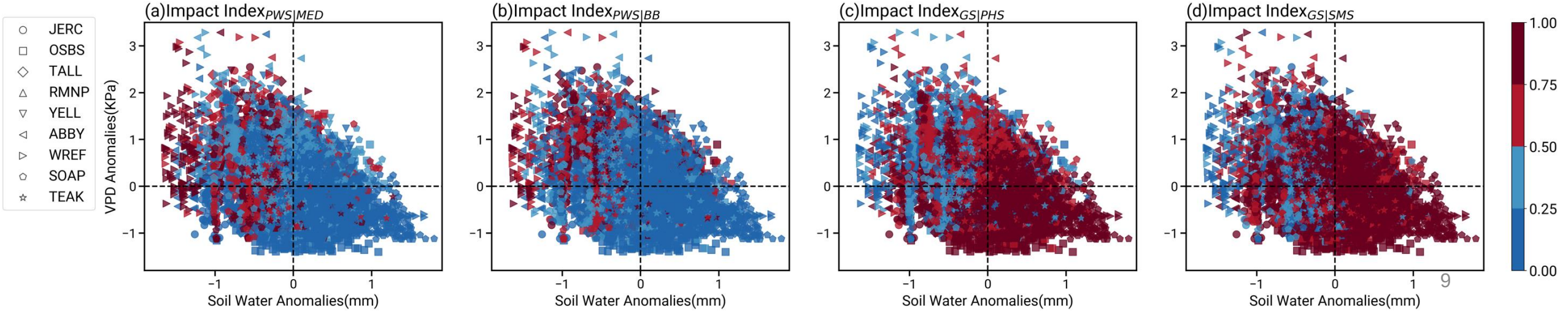
SMS & BB

$$Impact\ Index_{PWS|BB} = \frac{|TR(PHS,BB) - TR(SMS,BB)|}{MaxDiff}$$

$$Impact\ Index_{GS|SMS} = \frac{|TR(SMS,MED) - TR(SMS,BB)|}{MaxDiff}$$

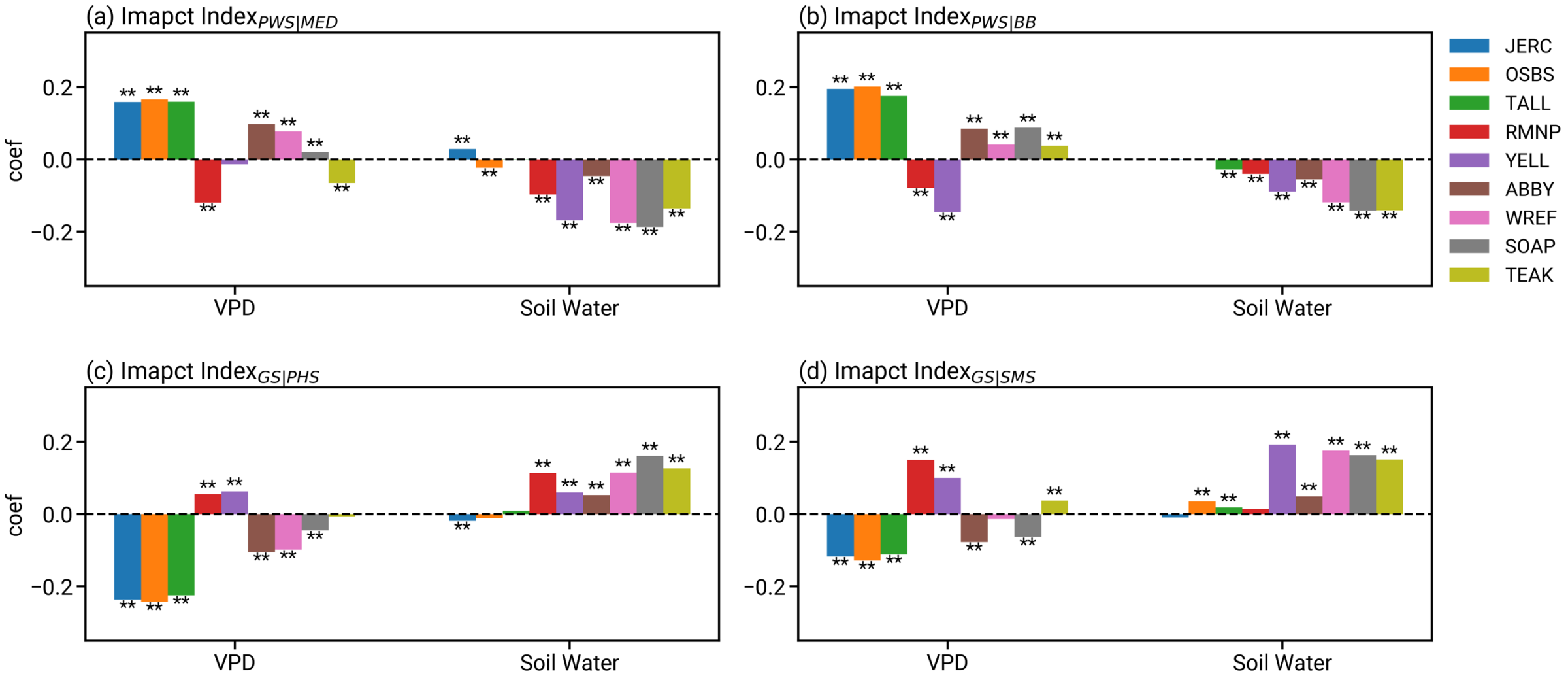
$$MaxDiff = \max(TR) - \min(TR)$$

Larger values of *Impact Index means* stronger Impact



Linear Regression Model on the Impact of GS and PWS

$$Impact\ Index \sim c_{vpd}\, VPD + c_{sw}\, SW + Intercept$$

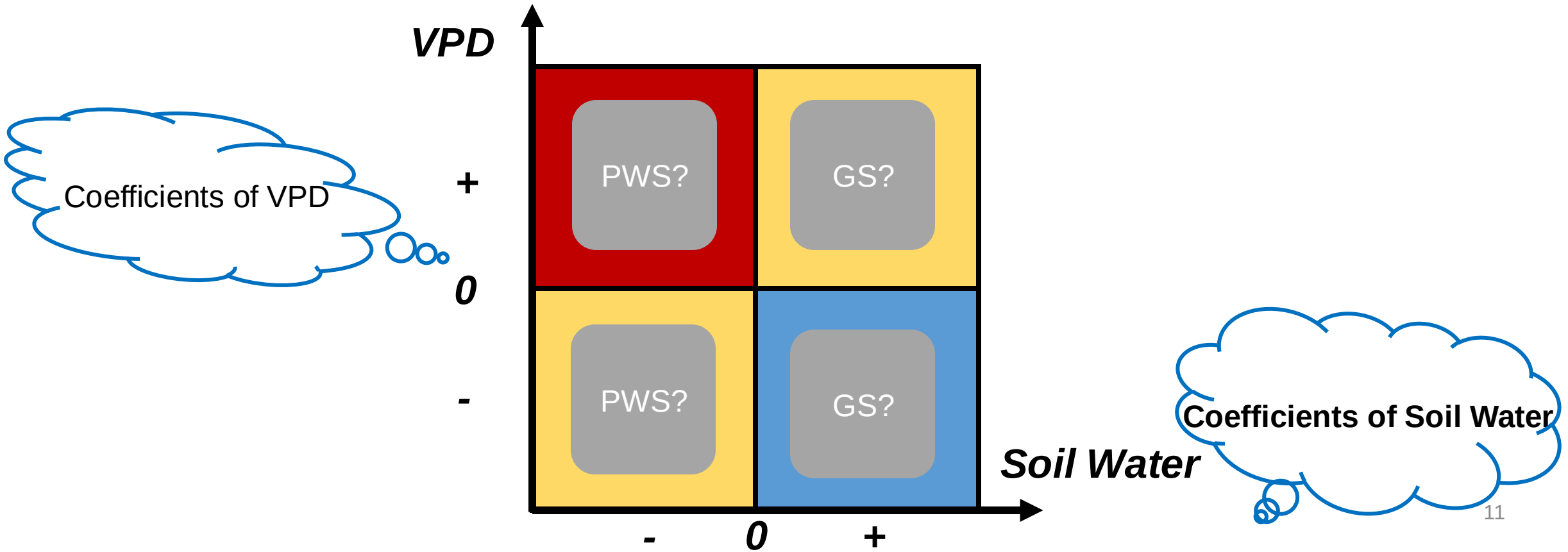


** p-values less than 0.05

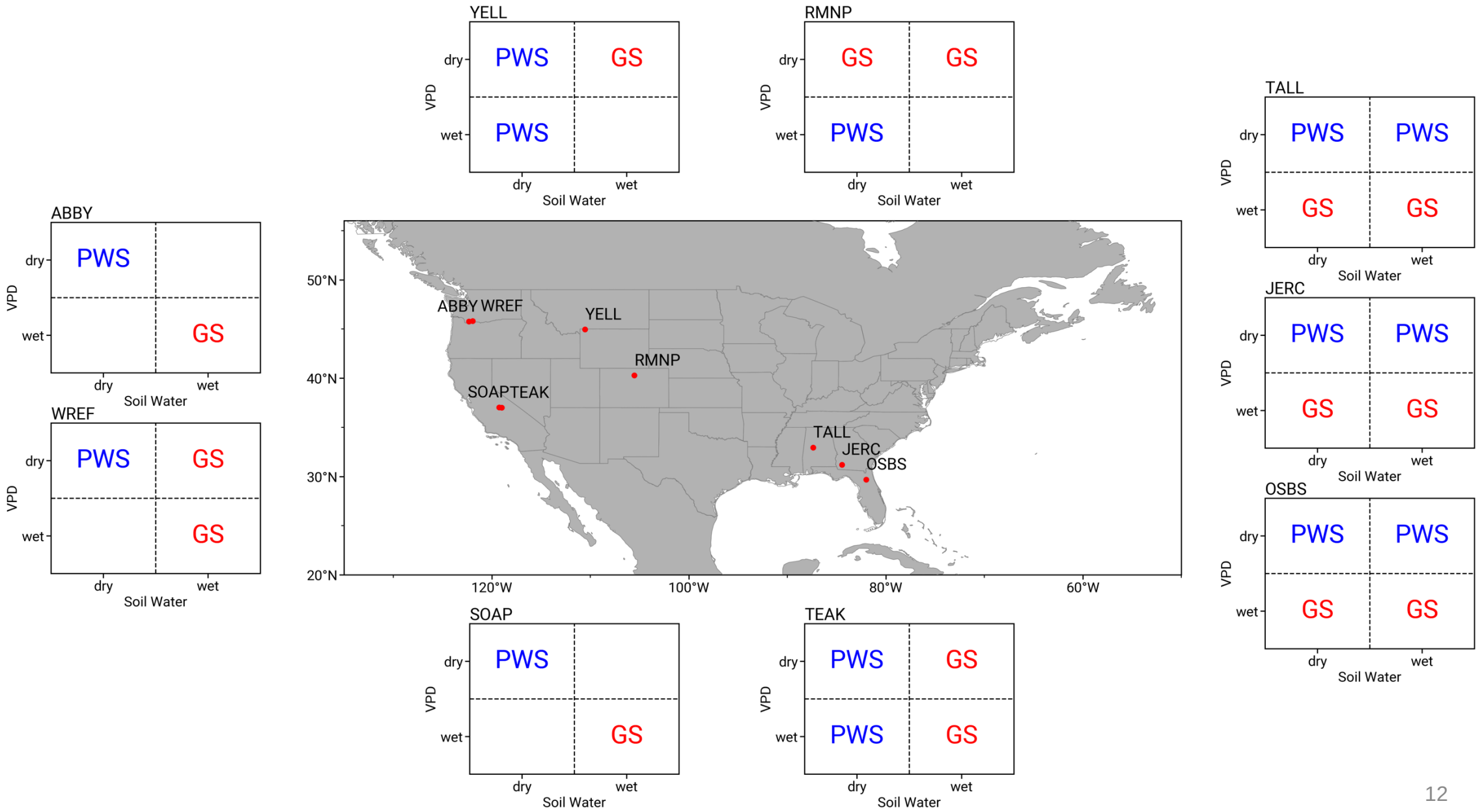
Review: Questions and Hypothesis

- **Which configuration, stomatal conductance (GS) or plant water stress (PWS), has a greater impact on transpiration?**

- **Does this impact vary with climate conditions?**



Distribution of the impact of PWS and GS



Conclusions and Implication

- The impact of stomatal conductance (GS) and plant water stress (PWS) on transpiration varies across different sites and climate conditions.

  In JERC, OSBS, TALL and RMNP, VPD primary alters the impacts.

  In YELL, WREF, and TEAK, soil water mainly modulates the impact.

  In ABBY and SOAP, both VPD and soil water contribute to the impact.

- The choice of the GS function is as important as the selection of the PWS function. Both GS and PWS functions should be carefully considered, as their selection can influence the transpiration to varying degrees.

Acknowledge

Danica Lombardozzi

Dave Barnard

Adrianna Foster

Will Wieder

Thank you!

Please feel free to reach out : zhiyi.zhou@colostate.edu