Multi-physics Options; model sensitivity and parameters interaction

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Development of a LSM with multi-physics options

Background:

1) Soil moisture and ET and their relationship are critical for land-atmosphere interactions at seasonal and inter-annual scales,

2) No single LSM can adequately simulate the soil moisture–ET relationship, but the multi-model average performs better.

Objectives:

1) To facilitate physically-based ensemble climate predictions,

2) To identify optimal combinations of parameterization schemes, and

3) To identify critical processes controlling the coupling strength between the land surface and the atmosphere

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New Features Added to the Noah LSM:

1. Major components: 1-layer canopy; 3-layer snow; 4-layer soil

2. Subgrid scheme: semi-tiled vegetation and bare soil (Niu et al., 2009)

3. Modified two-stream radiation transfer scheme to consider the 3-D structure of the canopy (Niu and Yang, 2004).

4. More realistic snow physics (Yang and Niu, 2003) and a snow interception model (Niu and Yang, 2004).

5. A TOPMODEL-based runoff scheme (Niu et al., 2005).

6. An unconfined aquifer interacting with soil (Niu et al., 2007).

7. More permeable frozen soil (Niu and Yang, 2006).

8. Ball-Berry stomatal resistance related to photosynthesis (Bonan, 1996)

9. A short-term leaf phonology model (Dickinson et al., 1998).

Optional Schemes

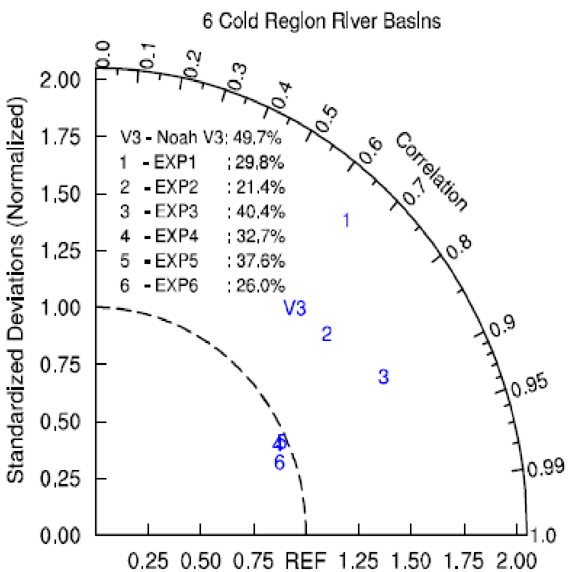
1. Leaf dynamics (prescribed or predicted)
2. Turbulent transfer (Chen et al., 1997; general M-O)
3. Soil moisture factor for stomatal resistance (Noah; CLM; SSiB)
4. Canopy stomatal resistance (Jarvis; Ball-Berry).
5. Snow surface albedo (BATS; CLASS).
6. Frozen soil permeability (Koren et al., 1999; Niu et al., 2006).
7. Supercooled liquid water content (Koren et al., 1999; Niu et al., 2006).
8. Radiation transfer:
   - Modified two-stream: Gap = F (3D structure; solar angle ...)
   - Two-stream applied to the entire grid cell: Gap = 0.
   - Two-stream applied to fractional vegetated area: Gap = 1-GVF (like CLM).
9. Partitioning of precipitation to snowfall and rainfall (CLM; Noah).
10. Runoff and groundwater:
    - TOPMODEL with groundwater
    - TOPMODEL with an equilibrium water table (Chen and Kumar, 2001)
    - Original Noah scheme (Schaake et al., 1996)
    - BATS surface runoff and free drainage

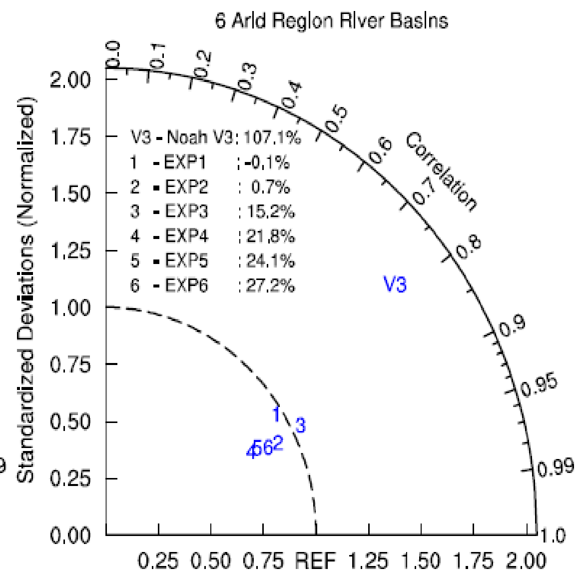
Total # of combinations: 5184 models

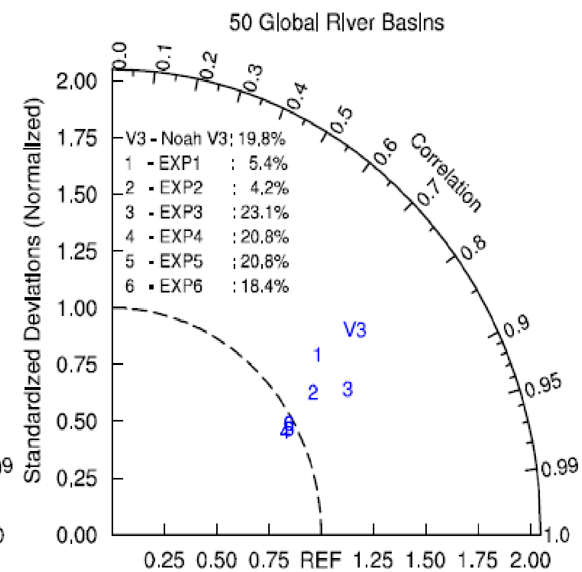
Transitional Experiments

Table 1. Experiments with different combinations of schemes

	$\theta_{liq\,\max,i}$	Frozen soil permeability	C_H	Runoff	r_s	Leaf Dynamics
Noah V3	Koren99	Koren99	Chen97	Schaake96	Jarvis	Off
EXP 1	Koren99	Koren99	Chen97	Schaake96	Jarvis	Off
EXP 2	NY06	NY06	Chen97	Schaake96	Jarvis	Off
EXP 3	NY06	NY06	M-O	Schaake96	Jarvis	Off
EXP 4	NY06	NY06	M-O	SIMGM	Jarvis	Off
EXP 5	NY06	NY06	M-O	SIMGM	Ball-Berry	Off
EXP 6	NY06	NY06	M-O	SIMGM	Ball-Berry	On





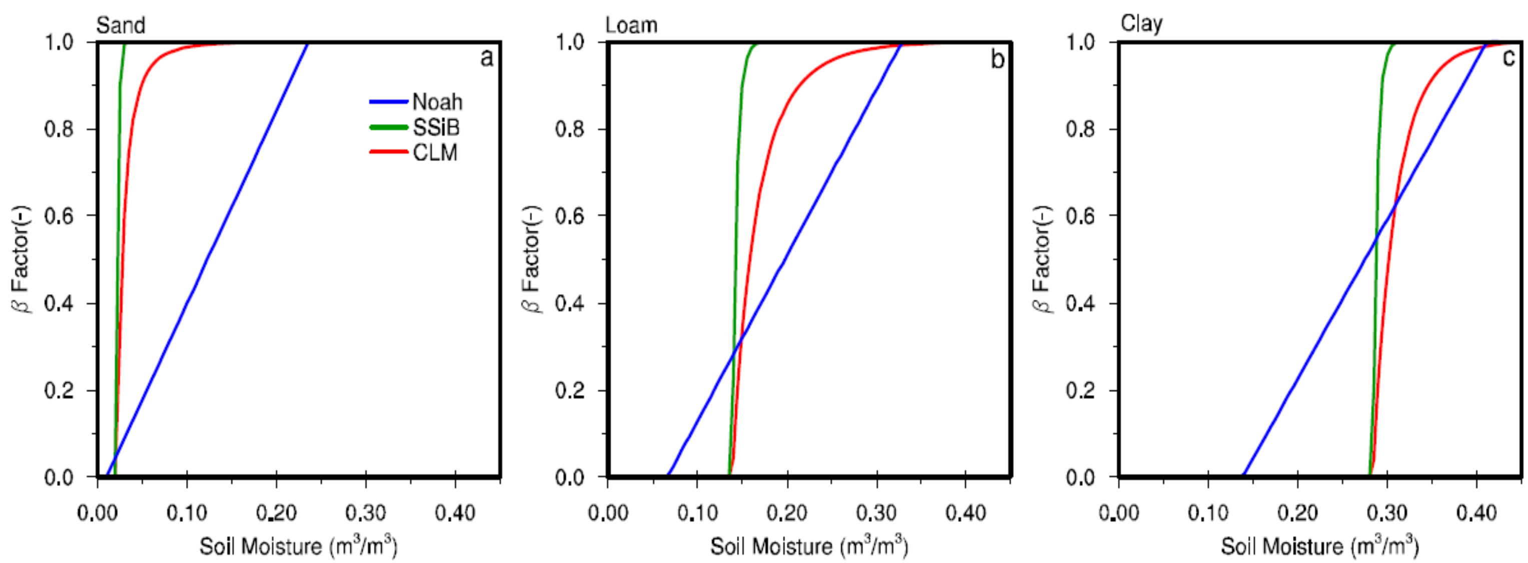


36 Ensemble Experiments

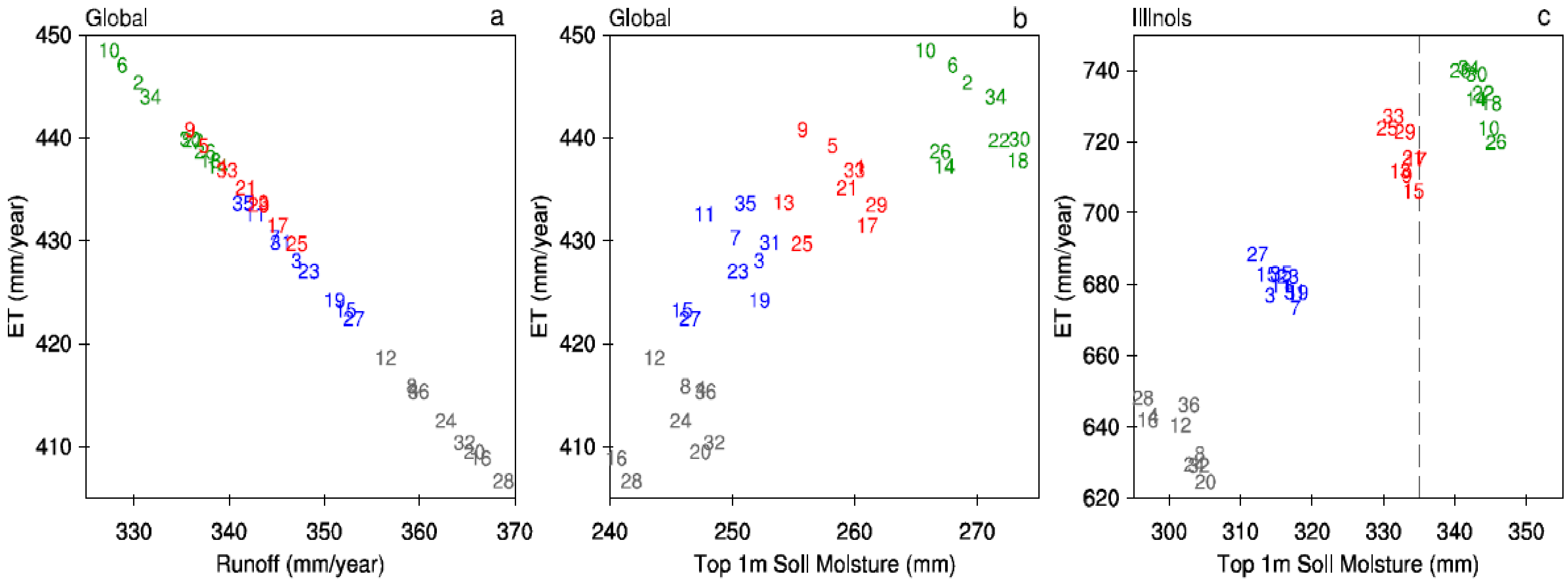
Table 3. The first group of 12 experiments and their corresponding options of schemes.

Exp.	Dynamic vegetation	r_s	β	Runoff schemes
EN1				SIMGM
EN2			Noah	SIMTOP
EN3				Schaake96
EN4				BATS
EN5				SIMGM
EN6	On	Ball-Berry	CLM	SIMTOP
EN7				Schaake96
EN8	**Off**	**Ball-Berry**		BATS
EN9	**Off**	**Jarvis**		SIMGM
EN10			SSiB	SIMTOP
EN11				Schaake96
EN12				BATS

Huge uncertainty in representing processes



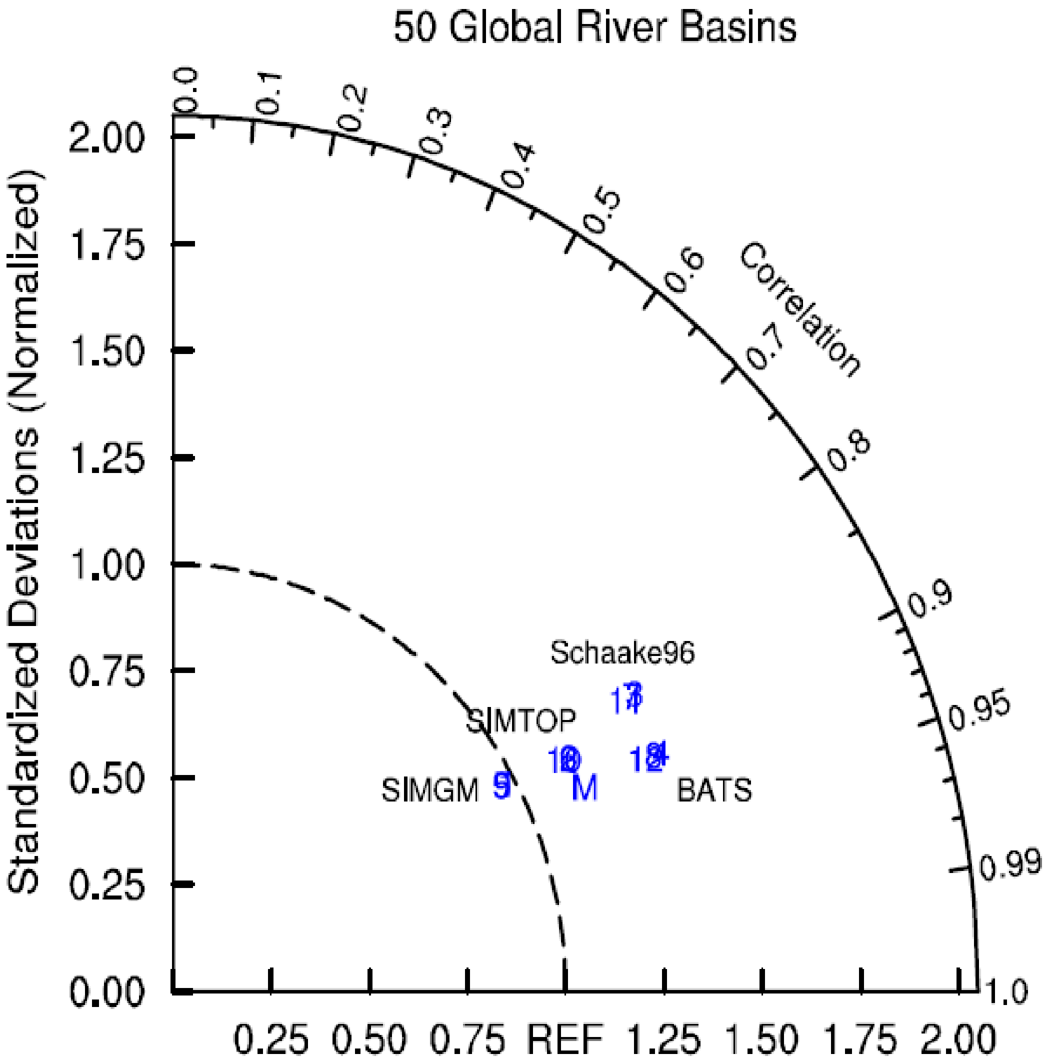
36 Ensemble Experiments



1. Runoff scheme is shown as the dominant player in the SM-ET relationship: SIMTOP (bottom sealed; green) produces the wettest soil and greatest ET; BATS (greatest surface runoff: grey) produces the driest soil and smallest ET.

2. Runoff scheme plays as a provider of soil water (besides precipitation) while surface schemes plays as a "consumer" of soil water.

36 Ensemble Experiments

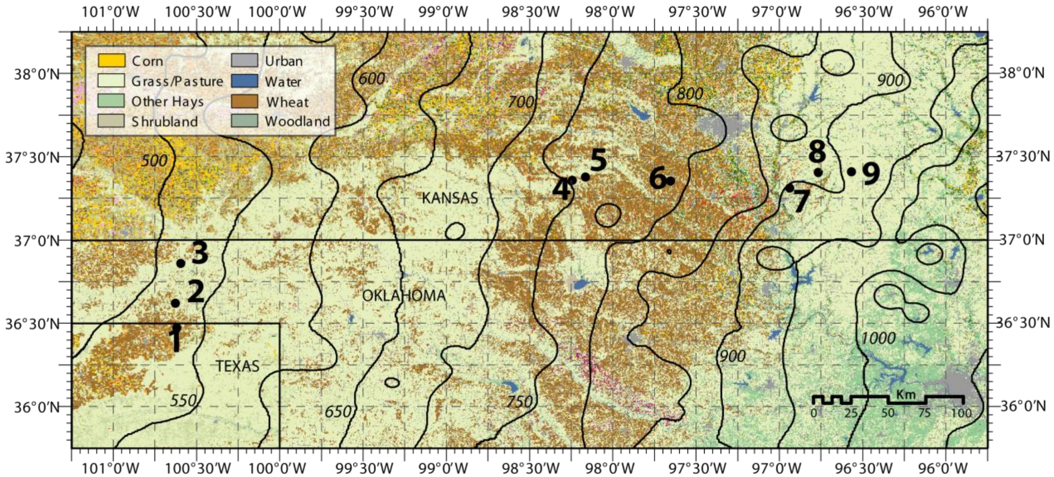


The mean (M) of the 36-member ensemble simulations out performs the simulation from any single combination of parameterization schemes.

Quantifying Parameter Sensitivity, Interactions and Transferability in Hydrologically Enhanced Versions of Noah-LSM over Transition Zones

We perform two Monte Carlo – based sensitivity analyses to answer:

- What are the most important model parameters (for STD, GW and DV) across the region?
- What are the dominant interactions between model parameters, and how do these change between models?
- How do behavioral parameters change with dominant physical characteristics of the land?



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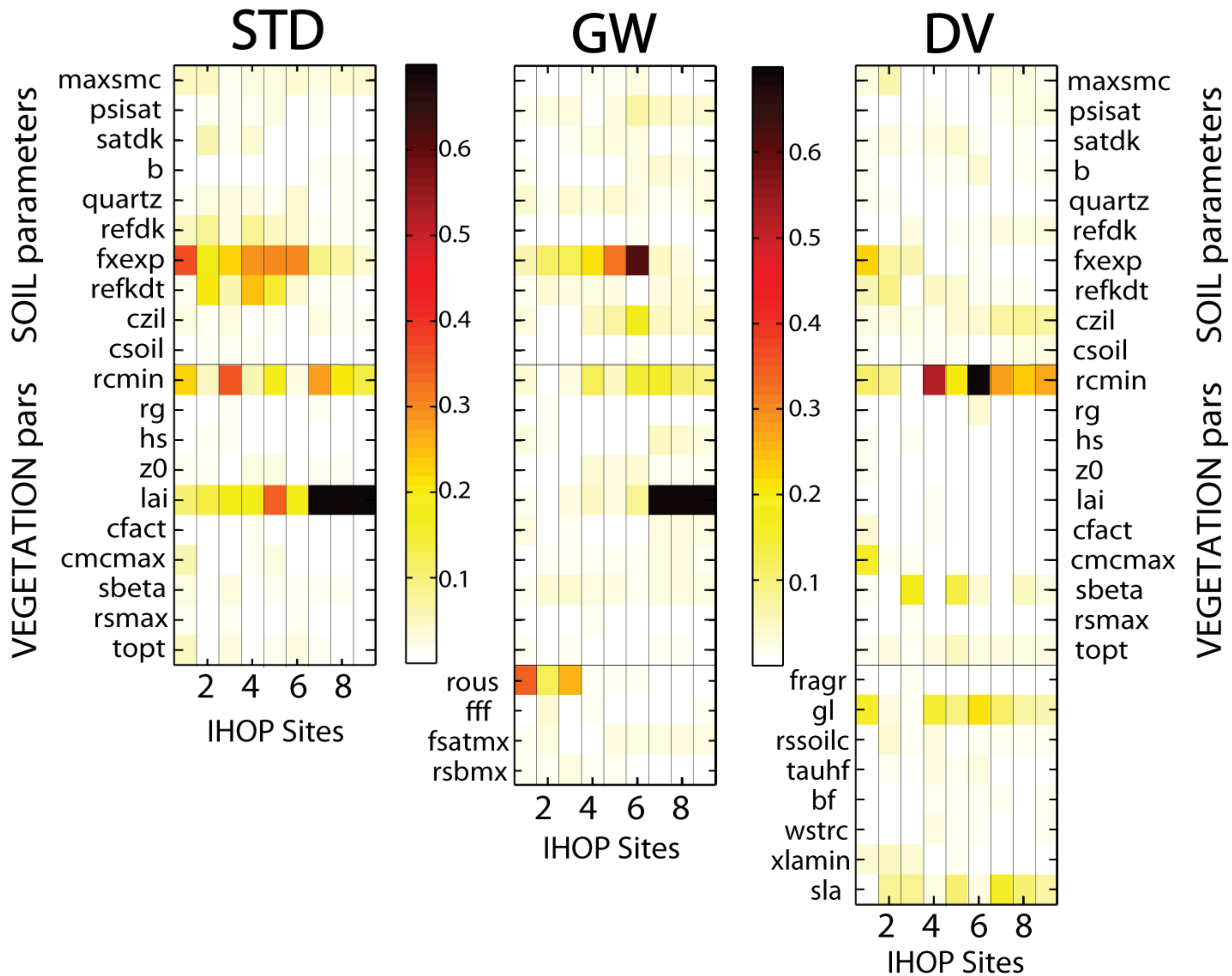
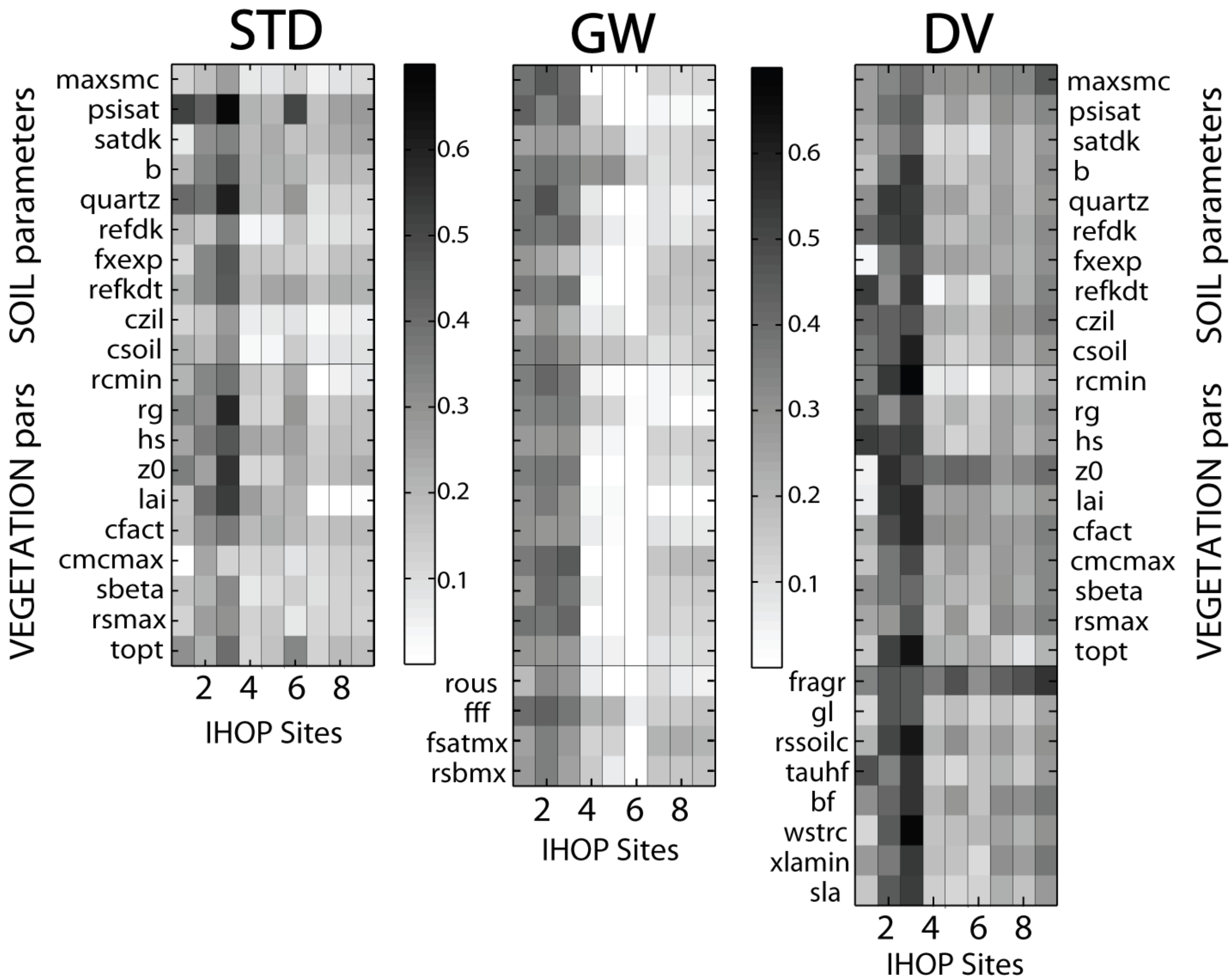
Sobol first-order sensitivity of LE



The regional pattern is consistent with physical expectations
Very few parameters directly control model output

Sensitivity of LE to interactions



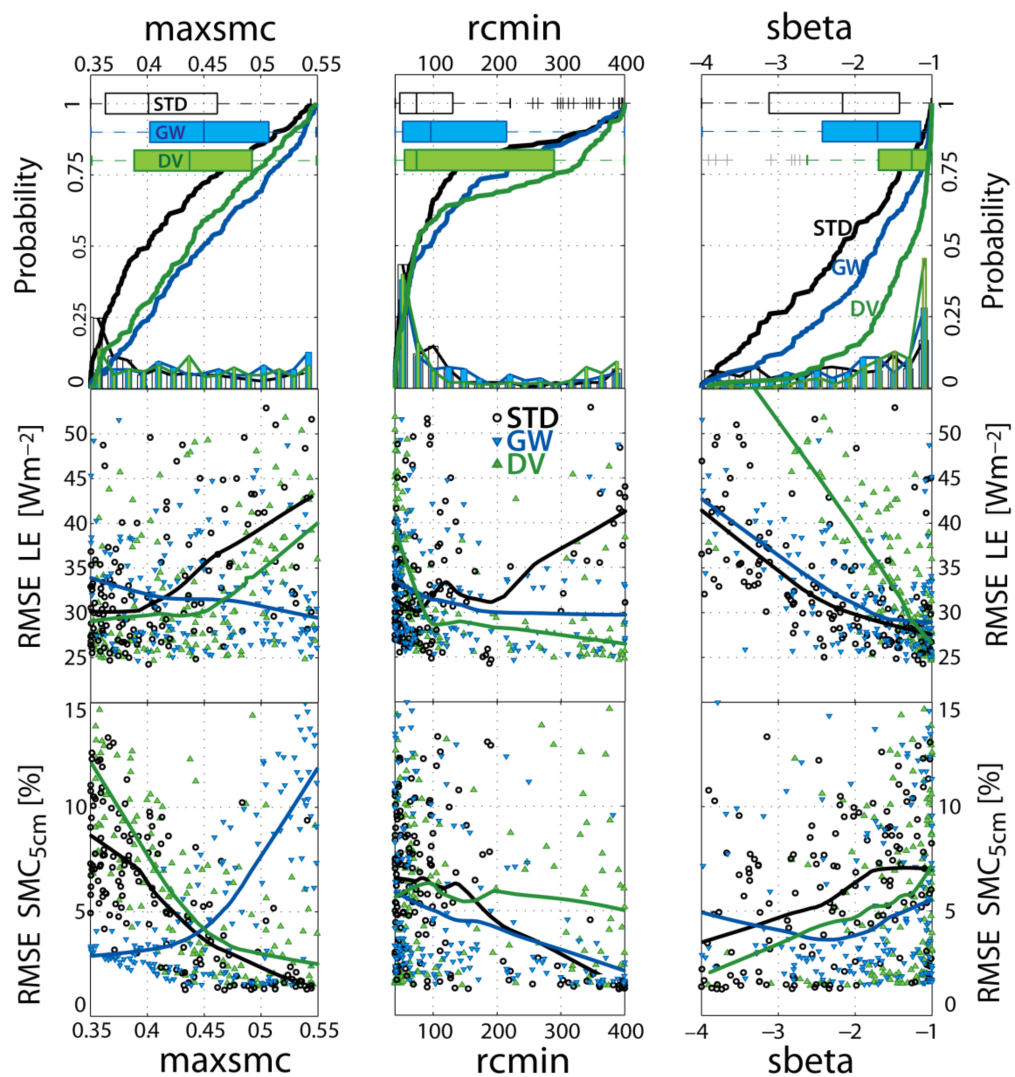
Interactions are the dominant mode of sensitivity.
GW shows less interaction than STD or DV

Behavioral sensitive parameters at site 7

Optimal value of 'physically meaningful' parameter changes between models.

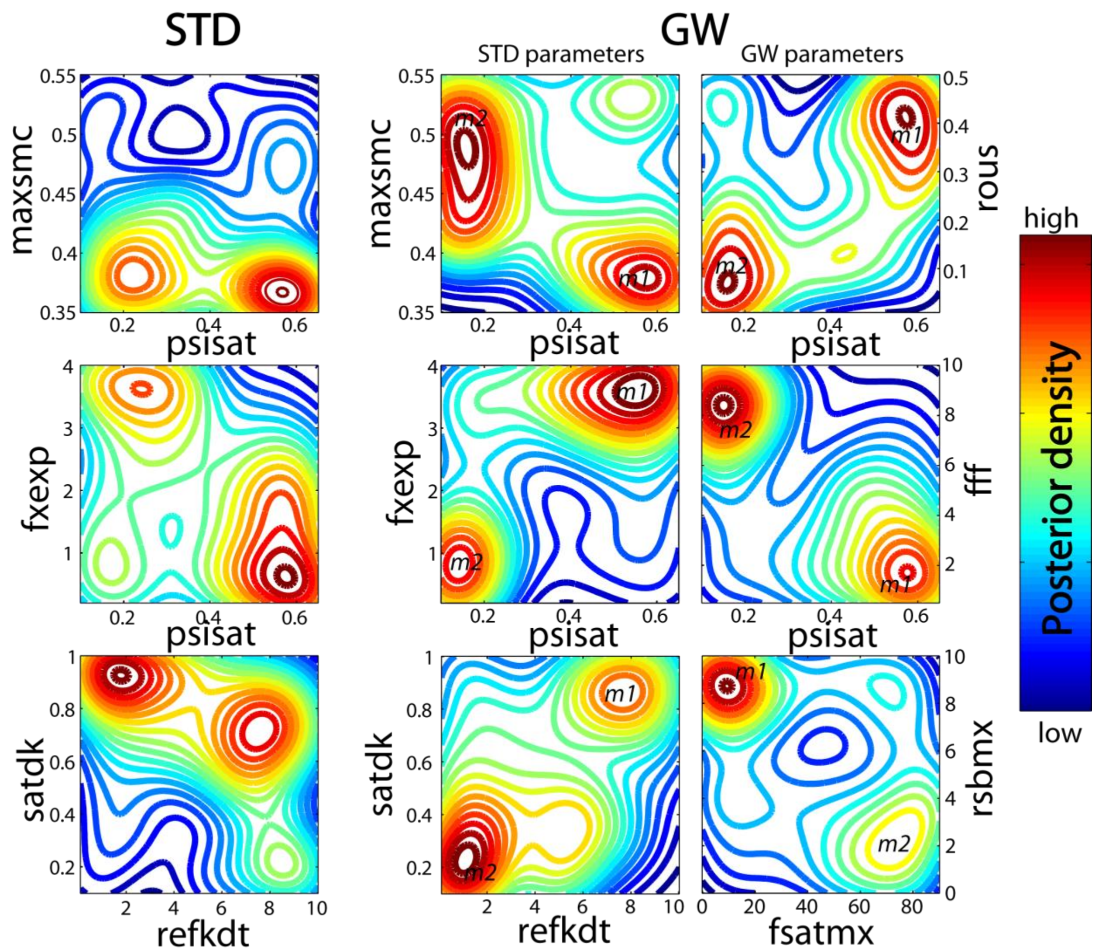
Local sensitivity (ΔRMSE/Δpar) changes too.

Therefore, the relationships between parameters must change between models.

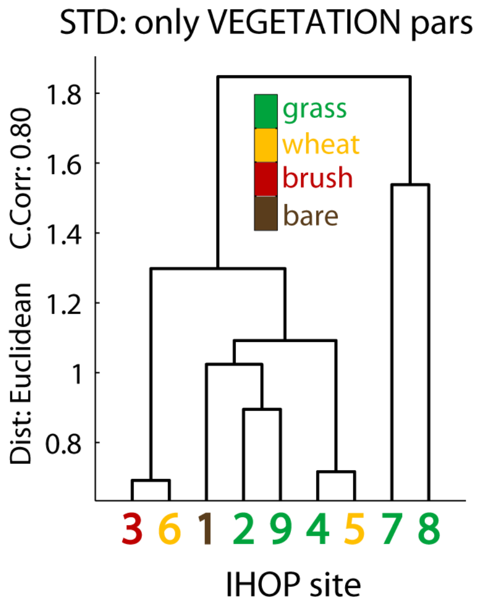


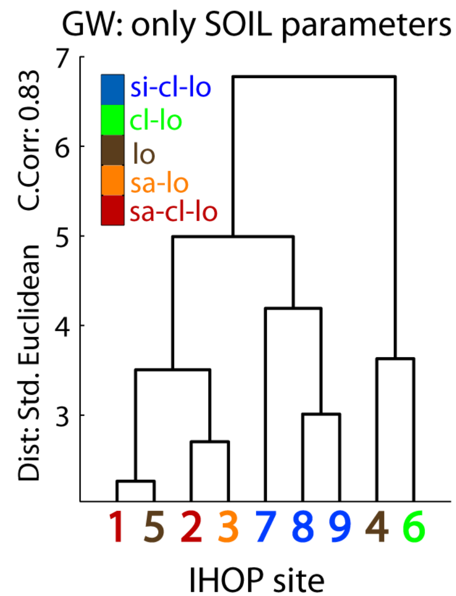
Multivariate posterior distribution of behavioral parameters at site 7

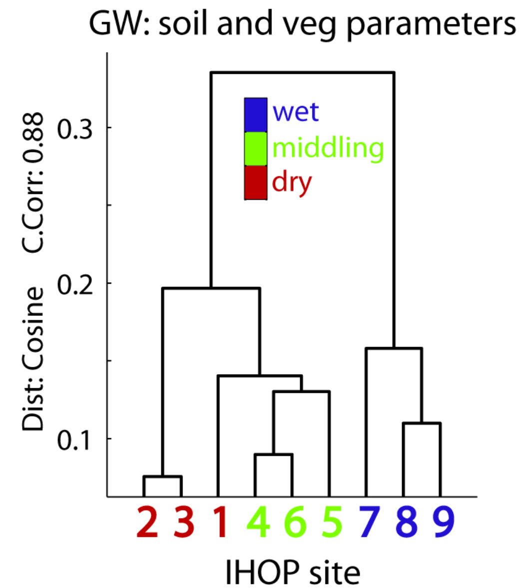
The relationships between the parameters change between models.
GW functions in two modes: GW-like (m1) and STD-like (m2)
Interactions make the relationships more important than optimal values

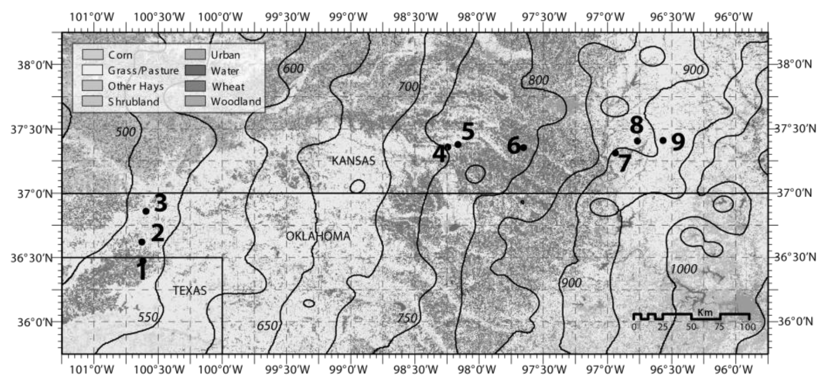


Classification of posterior distribution of behavioral parameters at all sites









Vegetation (soil) parameters are less similar between sites with the same vegetation (soil) type than they are between neighboring sites.

Clusters of soil and vegetation parameters resemble the climatic gradient

Summary and Conclusions:

- Only a few parameters directly control the variance of H, LE and SMC
- Most parameters exert most of their influence through interactions
- Interactions are model dependent. They shape the relationship between parameters to the point of altering optimal values of parameters between models
- Similar parameter distributions cannot be classified solely on the basis of soil or vegetation type. The similarity shows strong correlation with climate.