The Community Noah LSM with Multi-physics Options

Guo-Yue Niu

Collaborators:

ZL Yang, KE Mitchell, F Chen, MB Ek, M. Barlage, L. Longuevergne, A Kumar, K Manning, D Niyogi, E Rosero, M Tewari, and Y. Xia

UT Austin, NCEP, NCAR, NASA, and Purdue Univ.

Prepared for CCSM workshop, June 16, 2009

Backgrounds:

1. Soil moisture and ET and their relationship are critical for land-air interactions at seasonal and inter-annual time scales.

2. No single LSM can adequately simulate soil moisture–ET relationship, but multi-model average performs better (Dirmeyer et al. 2007).

3. Ensemble simulations using multiple cumulus convection schemes provide better climate predictions (Liang et al., 2007)

4. Hydrologists have pursued multi-model ensemble streamflow predictions (Geogakakos et al., 2004; Duan et al., 2007; Clark et al., 2008)

Objectives:

1. Improve short-term climate predictions by coupling with NCEP Global Forecasting System (GFS) and Climate Forecasting System (CFS)

2. Improve weather predictions by coupling with Weather Research and Forecasting (WRF) modeling system.

An LSM with multi-physics options may

1. facilitate physically-based ensemble climate predictions,

2. identify optimal combinations of parameterization schemes,

3. identify critical processes controlling the coupling strength.

THE UNIVERSITY OF TEXAS AT AUSTIN
JACKSON
SCHOOL OF GEOSCIENCES

Flaws in Noah:

1. A combined surface layer of vegetation canopy and ground. Such a layer structure impedes further developments on dynamic vegetation model (PAR and canopy T).

2. A bulk layer of snow and soil. The ground heat flux can not be accurately resolved for a thick snowpack.

3. Too shallow soil column (2-meter deep) and free drainage at the soil bottom. Groundwater effects are neglected.

4. Too impervious frozen soil; too strong runoff peaks in cold regions.

5. Neglect of the effects of zero-displacement height (d_0) on CH; thus a smaller CH over forest regions.

New features:

1. Major components: 1-layer canopy; 3-layer snow; 4-layer soil
2. Subgrid scheme: semi-tile vegetation and bare soil
3. Iterative energy balance method to predict skin temperatures of the canopy and snow/soil surface.
4. Modified two-stream radiation transfer scheme to consider the 3-D structure of the canopy
5. More realistic snow physics: a thin surface layer, liquid water retention and refreezing, and snowpack densification.
6. A TOPMODEL-based runoff scheme.
7. An unconfined aquifer interacting with soil.
8. More permeable frozen soil.
9. Ball-Berry stomatal resistance related to photosynthesis.
10. A short-term leaf dynamic model.

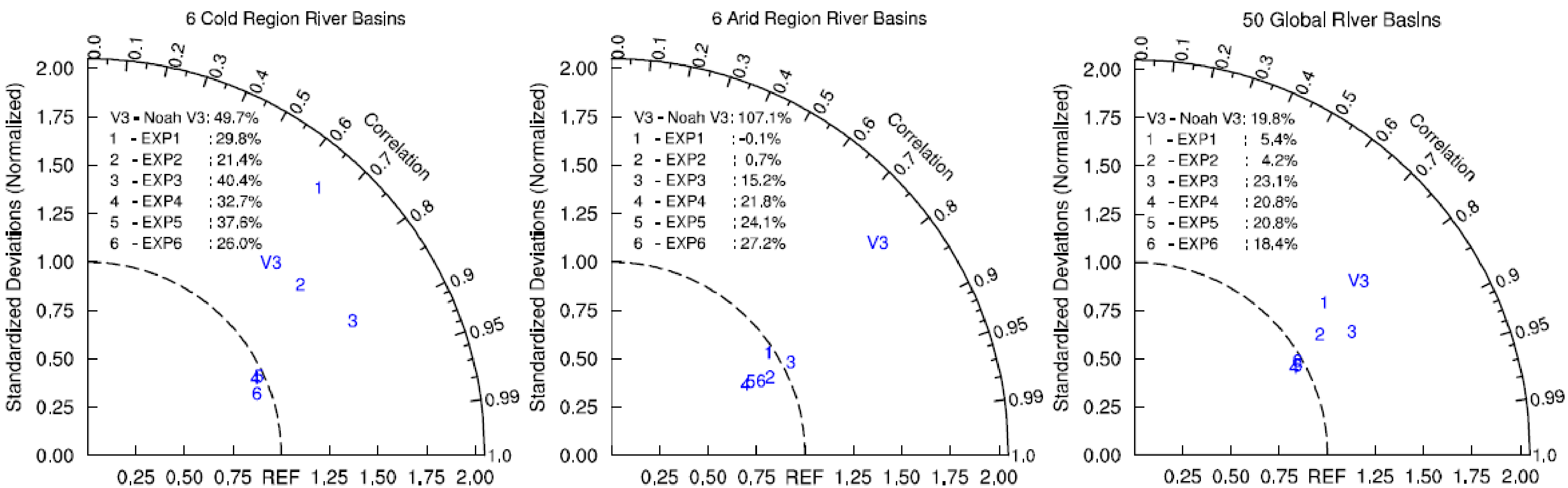
Multi-physics options:

1. Leaf dynamics (prescribed or predicted)
2. Turbulent transfer (Chen97; 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 (Koren99; NY06).
7. Supercooled liquid water (Koren99; NY06).
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.
9. Partitioning of precipitation to snowfall and rainfall (CLM; Noah).
10. Runoff and groundwater:
    - TOPMODEL with groundwater (SIMGM)
    - TOPMODEL with an equilibrium water table (SIMTOP)
    - Original Noah scheme (Schaake96)
    - BATS surface runoff and free drainage (BATS)

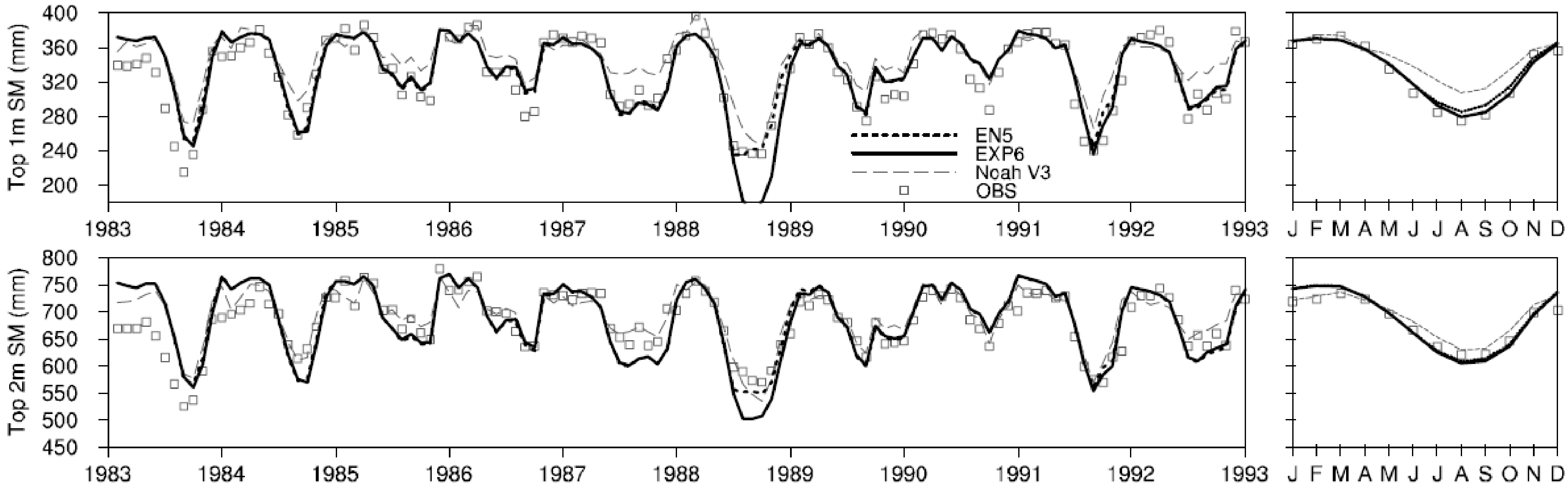
Modeled Runoff vs. GRDC estimates

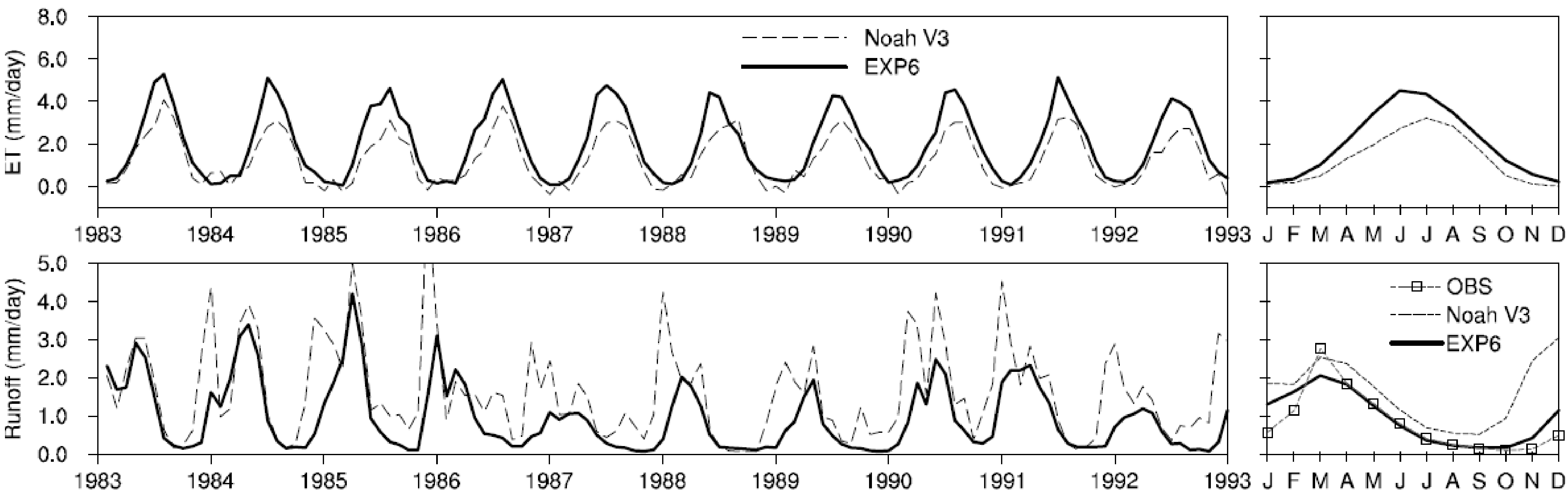
Table 1. Experiments with different combinations of schemes

	$\theta_{liq\,\max,i}$	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

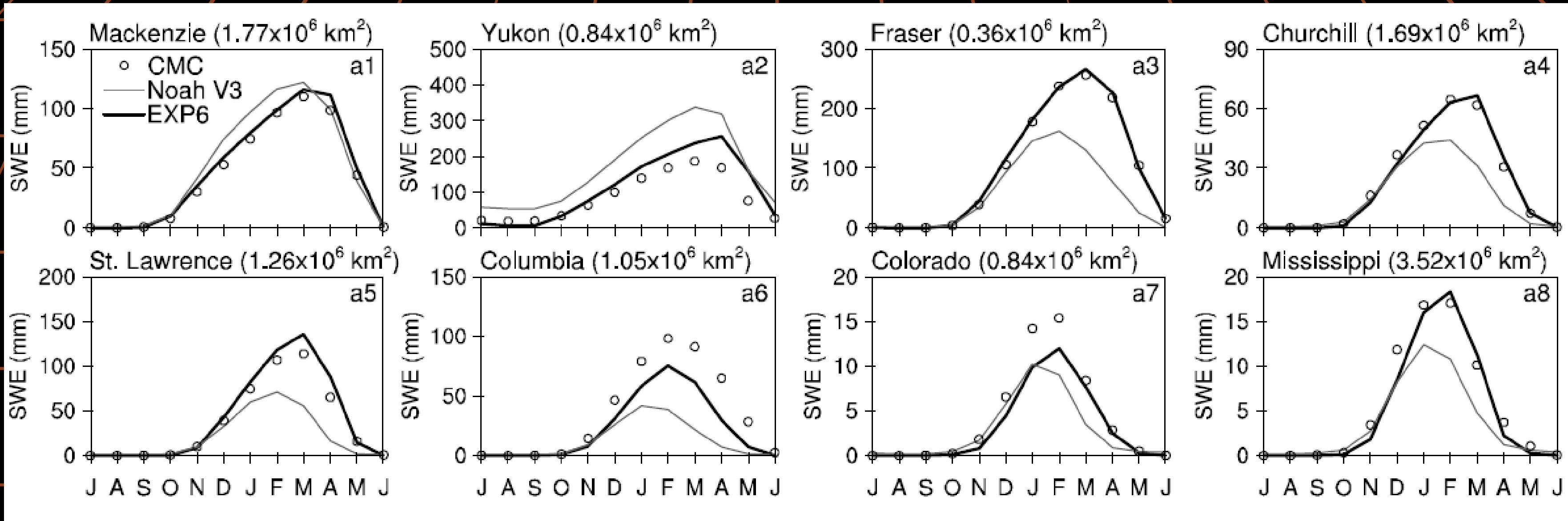


Soil Moisture over Illinois:

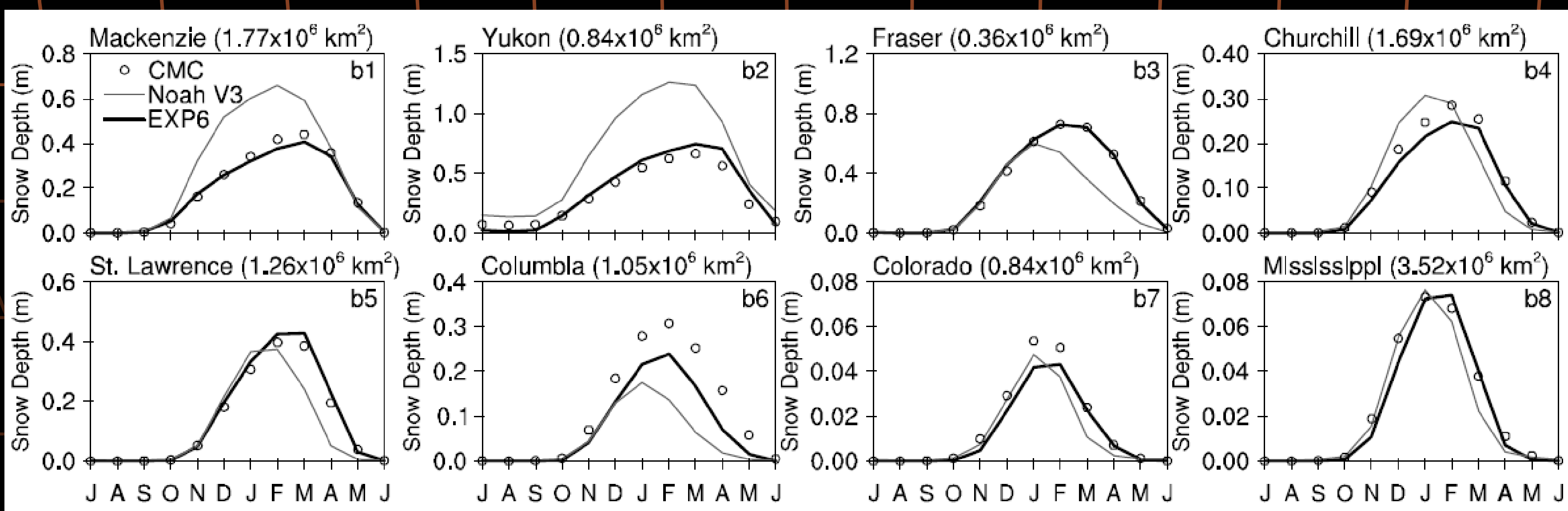




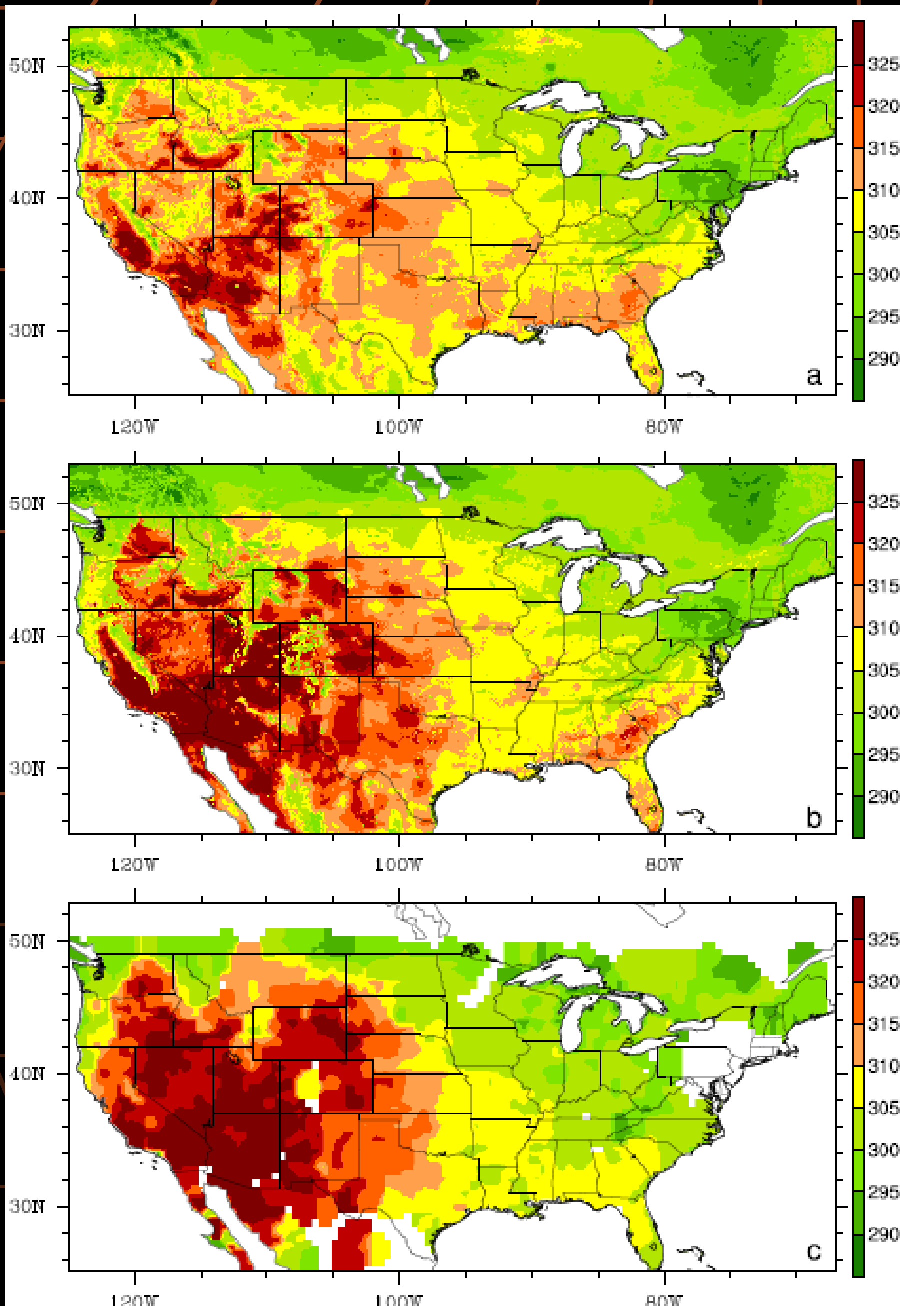
Snow Water Equivalent (in mm)



Snow Depth (in m)



Modeled Tskin (July 12th, 21:00 UTC, 2004)



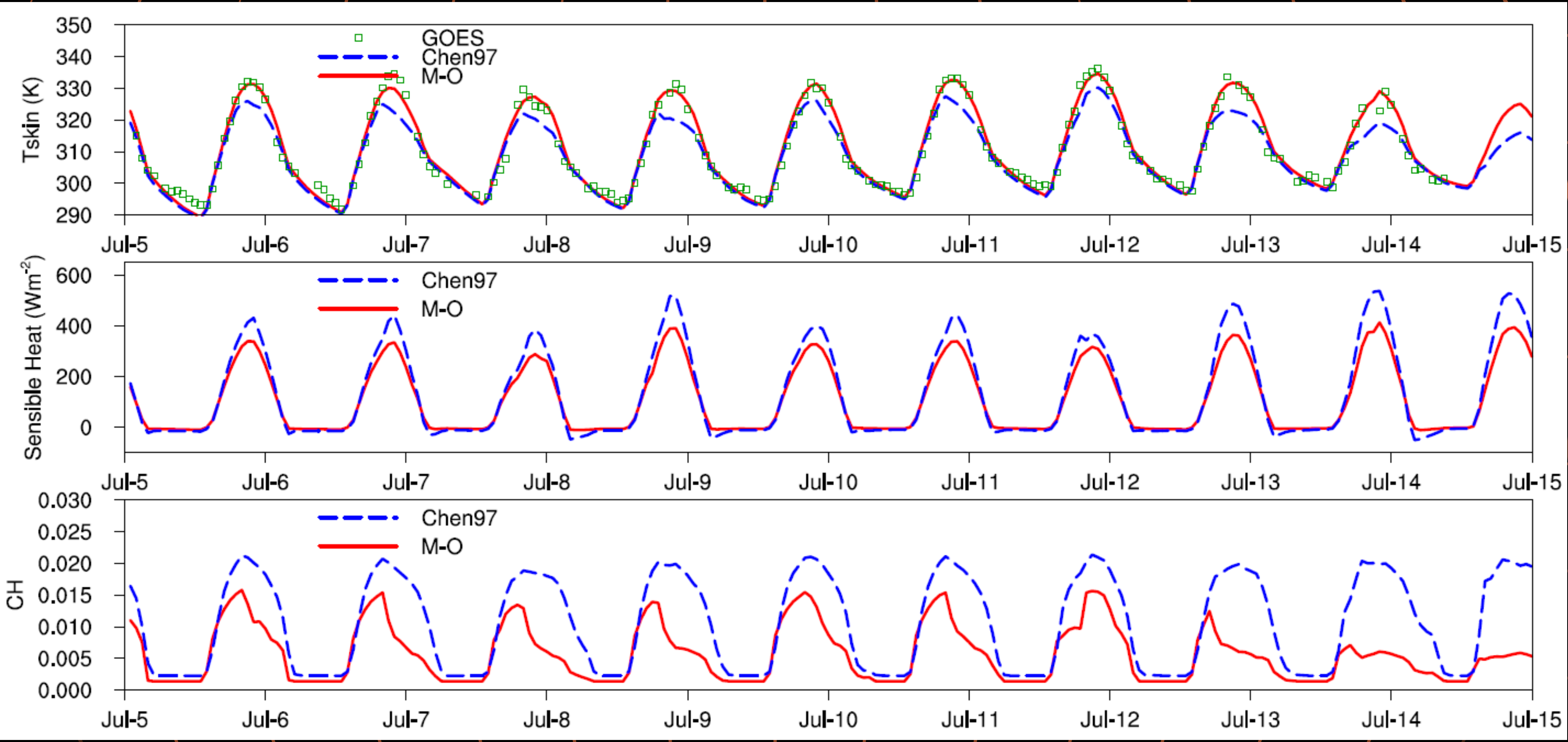
Noah_MP with Chen97

Noah_MP with M-O

GOES

Modeled Tskin (July, 2004)

Western US (33N, 114W)



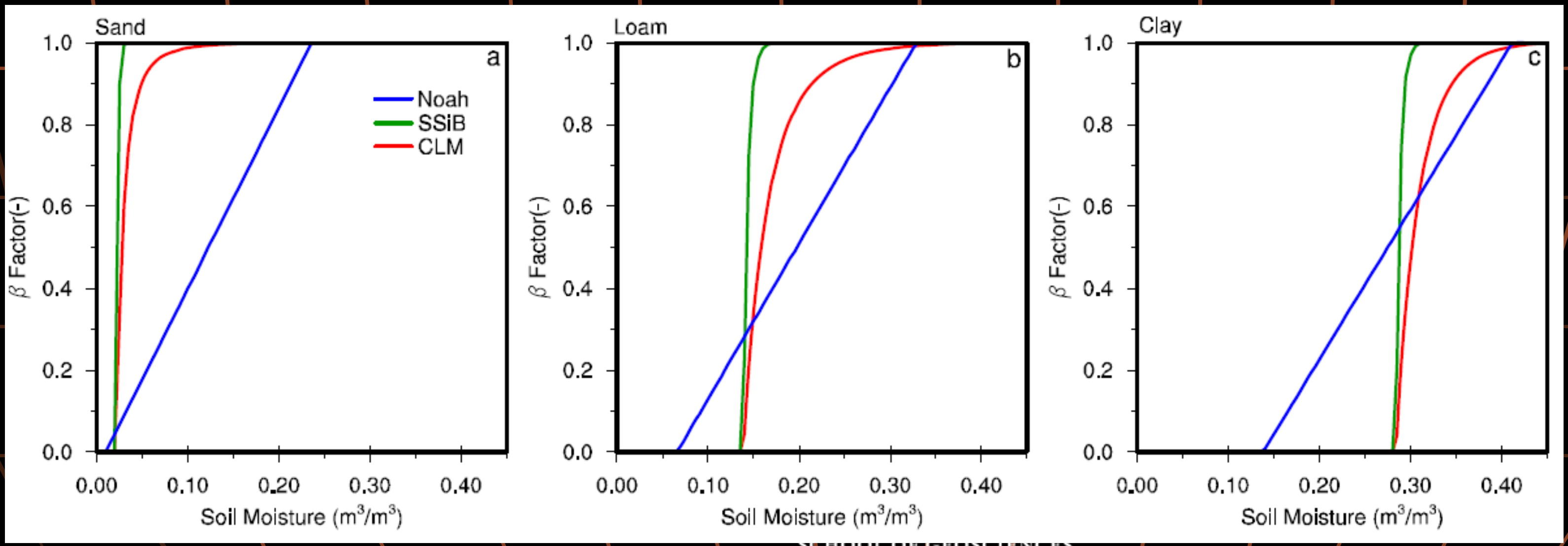
THE UNIVERSITY OF TEXAS AT AUSTIN
JACKSON
SCHOOL OF GEOSCIENCES

36 Ensemble Experiments:

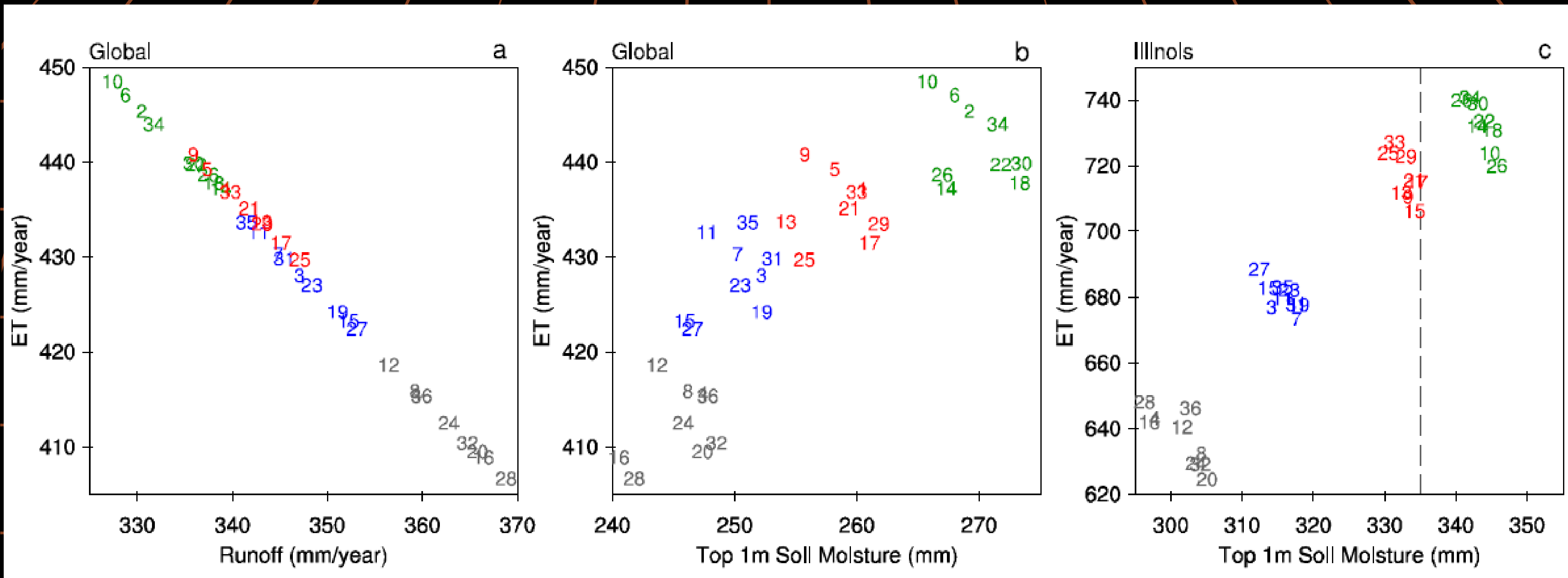
Table 3. The first group of 12 experiments and their corresponding options of schemes.

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				SIMGM
EN10			SSiB	SIMTOP
EN11	**Off**	**Jarvis**		Schaake96
EN12				BATS

Huge uncertainty to represent processes



Modeled GVF Using NLDAS

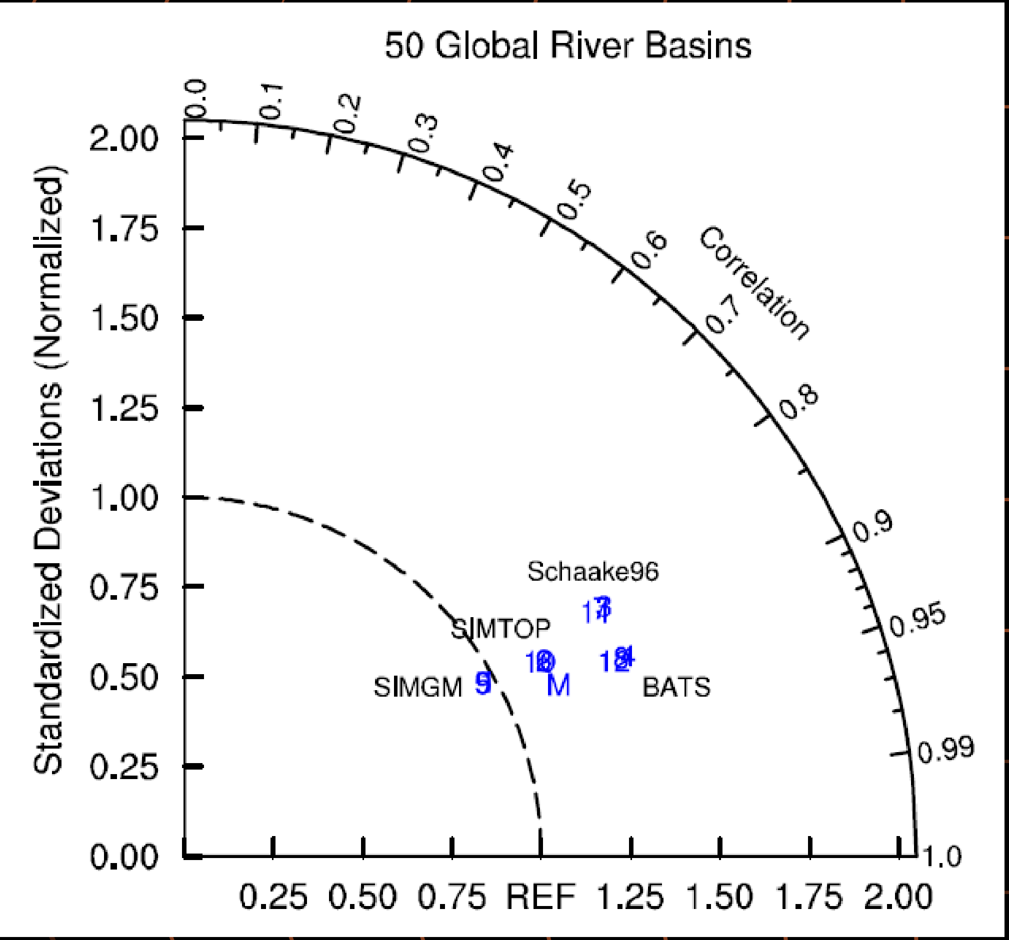


Runoff scheme is shown as the dominant player in the SM-ET relationship;

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

THE UNIVERSITY OF TEXAS AT AUSTIN
JACKSON
SCHOOL OF GEOSCIENCES

Modeled Runoff over 50 River Basins



The mean of 36-member simulations out performs the simulation from an single member.

Summary:

1. We added many new features and multi-parameterization options for an ensemble representation of processes to Noah.

2. Noah_MP shows improved simulations on runoff, soil moisture, snow, and skin temperature over Noah V3.

3. Runoff scheme play a dominant role in the SM-ET relationship, indicating a dominant role in controlling the coupling strength.

It plays as a provider of soil moisture. This may help explain soil moisture simulations.

4. The mean of 36-member ensemble simulations shows potential in hydrological modeling and climate predictions (when coupled with climate models).

THE UNIVERSITY OF TEXAS AT AUSTIN
JACKSON
SCHOOL OF GEOSCIENCES