A Framework for Multi-Physics Representation of the Coupled Land-Atmosphere System for Predicting Extreme Weather Events

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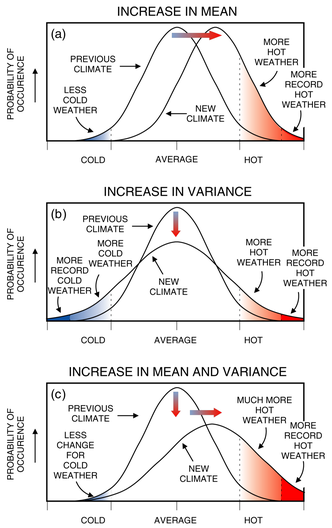
CLIMATE PREDICTION PROGRAM FOR THE AMERICAS CPPA

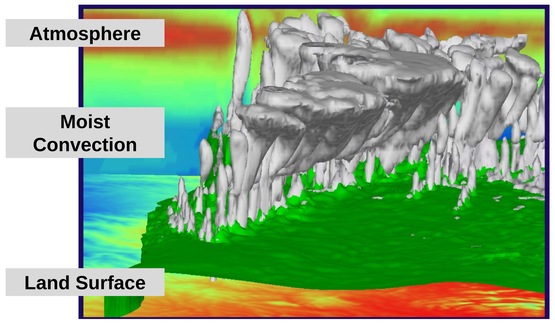
NASA



Climate change and its manifestation in terms of weather (climate extremes).

Global warming increases the frequency and intensity of extreme weather events!!!

IPCC, 2007



How is the land surface and the atmosphere coupled?

Probabilistic forecasts:
Initial condition ensemble
Multi-model ensemble
Parameter ensemble

One model but with multiple physics parameterizations!
Both in the Atmosphere and at the Land Surface.

Weather Research and Forecasting (WRF) Model
with multi-physics options

Coupling

Noah Land Surface Model
with multi-physics options

Offline LSM Simulation

Noah Land Surface Model (LSM)
with multi-physics options
(Niu et al., 2009)

1. Leaf area index
2. Turbulent transfer
3. Soil moisture stress factor for transpiration
4. Canopy stomatal resistance
5. Snow surface albedo
6. Frozen soil permeability
7. Supercooled liquid water
8. Radiation transfer
9. Partitioning of precipitation to snow- and rainfall
10. Runoff and groundwater

2x2x3x2x2x2x2x3x2x4 = 4584 combinations

1. a. Prescribed LAI, and b. Predicted LAI
2. a. Noah Scheme, and b. NCAR LSM Scheme
3. a. Noah, b. BATS, and c. CLM Scheme
4. a. Jarvis, and b. Ball-Berry Scheme
5. a. BATS, and b. CLASS
6. a. Noah, and b. Niu and Yang, 2006
7. a. Noah, and b. Niu and Yang, 2006
8. a. Modified two-stream: Gap = F (3D structure; solar zenith angle; …) ≤ 1-GVF
   b. Two-stream applied to the entire grid cell: Gap = 0
   c. Two-stream applied to fractional vegetated area: Gap = 1-GVF
9. a. CLM, and b. Noah
10. a. TOPMODEL with groundwater
    b. TOPMODEL with an equilibrium water table
    c. Original Noah scheme
    d. BATS surface runoff and free drainage

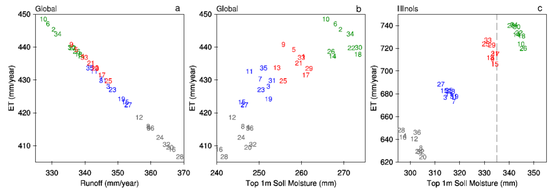
36 Offline Ensemble Simulations

First 12-experiment group

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

Second 12-experiment group – DV Off
Third 12-experiment group – DV off and Javis scheme for r_s

Result from the offline runs

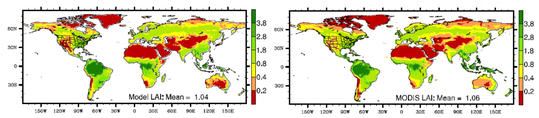


Experiments with different combination of schemes

	Maximum θ_{liq}	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

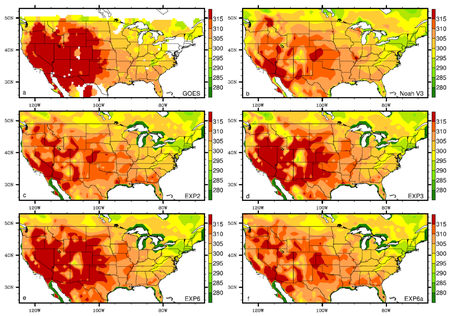
Comparison between modeled LAI and MODIS LAI

(averaged from 1983 ~ 2006)

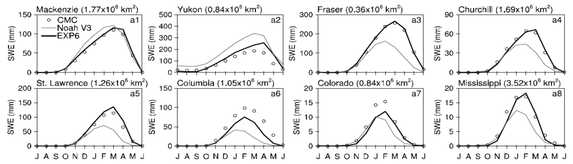


Comparison between modeled Tskin and GOES Tskin

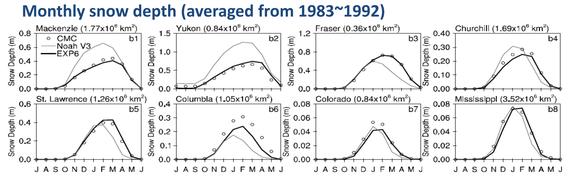
(July 12th , 21:00 UTC, 2004)



Monthly snow water equivalent (averaged from 1983~1992)



Monthly snow depth (averaged from 1983~1992)



Study Case: An Extreme Precipitation Event in Texas July 2002

Lowrey and Yang, 2008

- San Antonio River Basin, Central Texas
- June 30 – July 10
- Stationary upper-level trough and strong **southeasterly surface winds** cause continuous low-level **moisture flow** across the Gulf of Mexico into Central Texas
- Heavy rainfall (>100mm/day) persists over the San Antonio area for 6 days

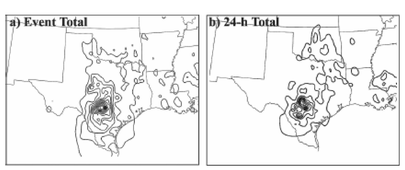


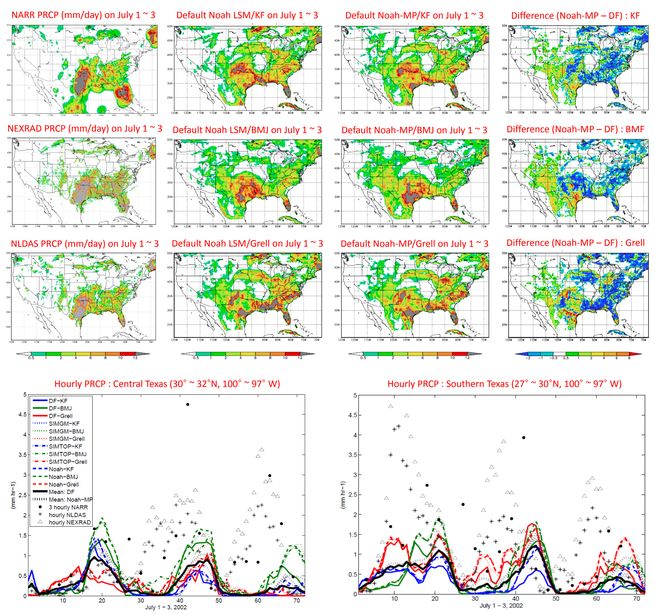
FIG. 1. The observational analysis of accumulated precipitation from gridded data acquired through NCDC. (a) The 8-day event total precipitation (every 50 mm) from 1200 UTC 23 Jun 2002 to 1200 UTC 7 Jul 2002. (b) The 24-h accumulated precipitation (every 20 mm) valid at 1200 UTC 2 Jul 2002. The location of SAT is marked with dots.

Zhang et al., 2006

Model and Experiments

- WRF 3.0.1
- Initial/Boundary Conditions: NARR Reanalysis
- 30-km grid spacing
- July 1-3, 2002
- Experiments :
  - WRF/Noah with three convection schemes (KF, BMJ, Grell)
  - WRF/Noah-MP (three runoff schemes: SIMGM, SIMTOP, Noah) and three convection schemes (KF, BMJ, Grell)

Comparison of July 1-3 Precipitation from observations and various runs



Summary

- We have developed a MP framework for the land surface. Together with the MP framework for the atmosphere, this MP framework is useful for probabilistic forecasts of the mesoscale extreme events. More research and experiments are warranted.
- Noah-MP improves over the default Noah LSM, both in offline and coupled simulations. In the coupled runs, runoff schemes have considerable effects on rainfall after day 1.
- Convection schemes dominate the simulations of extreme rainfall in the warm season!
- Special attention is required in initializing soil moisture and leaf biomass. A high-resolution land data assimilation system needs to be configured to provide required land data for initialization.

References

1) IPCC, 2007: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, edited by S. Solomon et al., 996 pp., Cambridge Univ. Press, Cambridge, U.K.
2) Lowrey, M. R. K. and Z.-L. Yang, 2008: Assessing the capability of a regional-scale weather model to simulate extreme precipitation patterns and flooding in Central Texas, *Weather and Forecasting*, 23, 1102–1126.
3) Niu, G.-Y., Z.-L. Yang, K. E. Mitchell, F. Chen, M. B. Ek, M. Barlage, L. Longuevergne, A. Kumar, K. Manning, D. Niyogi, E. Rosero, M. Tewari, and Y.-L. Xia, 2009: The community Noah land surface model with multi-physics options, *J. Geophys. Res.*, (in revision).
4) Zhang, F., A. Odins, and J. W. Nielsen-Gammon, 2006: Mesoscale predictablility of an extreme warm-season rainfall event. *Weather and Forecasting*, 21, 149-166.