Continental-Scale Calibration of Surface Energy and Heat Flux in CSU Unified Land Surface Model Using MODIS and FLUXNET observations

Toshihisa Matsui[1], Adriana Beltrán-Przekurat[2], Roger A. Pielke Sr.[2], Dev Niyogi[3], and Jih-Wang (Aaron) Wang[2]

1. **Colorado State University, Department of Atmospheric Science**
2. **University of Colorado at Boulder, Cooperative Institute for Research in the Environmental Sciences**
3. **Purdue University, Department of Agronomy and Department of Earth and Atmospheric Sciences**

LCLUC PI Meeting

University of Maryland, College Park, MD

April, 2007

Motivation

1. Land Surface Models (LSMs) compute surface energy flux using the tunable parameters for the each land-use and land-cover (LULC) type and the parameters related to the geographical feature (e.g., topography, soil type, and leaf area index).
2. LSMs create the spatialization of surface energy flux by specifying the tunable parameters for the each land-use and land-cover (LULC) type and the parameters related to the geographical feature (e.g., topography, soil type, and leaf area index).
3. Limited-site calibration or assimilation does not support the accuracy in the spatialization of surface heat flux predicted by LSMs.
4. Therefore, we must establish the large-scale grid-by-grid calibration and assessment of the LSM for improving the coupled atmospheric modeling.

Model

- This study uses the Colorado State University (CSU) Unified Land Model (ULM), which are extracted from the CLM 2.0 (Oleson et al. 2004), GEMTM (Chen and Coughenour 1994), and the LEAF2 model (Walko et al. 2000).
- ULM is a **tuning-oriented** LSM.
- ULM currently uses UMD-type 13-class LULC type.
- ULM is coupled with the Parameter Estimation (PEST) model [*Watermark Numerical Computing* 2004] for calibration purpose.

Input Data and Flux Comparison

1. CSU ULM has been developed within the NASA GSFC's Land Information System (LIS) that contains several different LSMs and a wide variety of surface boundary conditions and meteorological forcings. Thus, off-line simulations of LSM can be tested anywhere on globe down to the urban-resolving scale (Peters-Lidard et al. 2004).
2. Subgrid #: 1~13 (+1) based on the MODIS LULC class. (+1) indicates the patch allocated for Fluxnet sites if available. The Mhe minimum tile fraction is 0.0013 that fully utilize 1km MODIS information.
3. LAI: The 1km LAI data are aggregated for each UMD LULC classes on the 0.25°grid map. Fluxnet patch uses the nearest 1km MODIS LAI.
4. Initial Soil Moisture: 1-year spun up of control simulation
5. CSU LSM is run off-line (uncoupled mode), and is driven by the North American Land Data Assimilation System (NLDAS) and/or ground-truth meteorological field on a one-hour time step.
6. NLDAS meteorological forcing consists of following data:

Radar-gauge assimilated precipitation: Hourly National Weather Service Doppler radar-based (WSR-88D0) precipitation analyses were used to disaggregate the daily NCEP CPC gauge-based precipitation to produce an hourly observation-based precipitation data set.

GOES-based surface radiation: Surface downwelling solar and thermal radiation is derived from GOES radiation data.

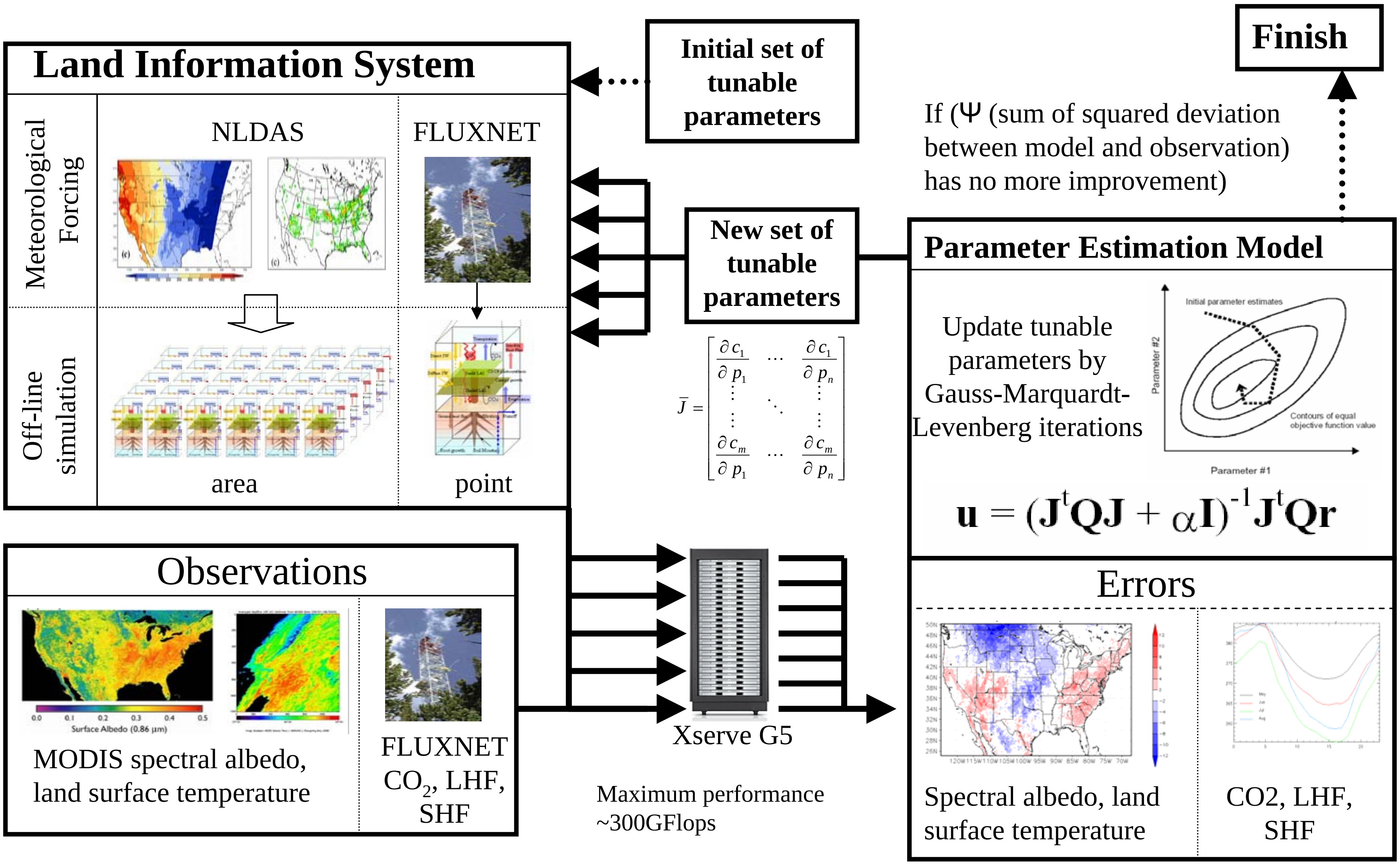
ETA field: Surface air temperatures, water vapor mixing ratios, horizontal winds, and surface pressures are derived from NCEP EDAS output fields.

7. This study also uses CO2 flux, latent/sensible heat flux measurements from the network of surface eddy covariance measurements Fluxnet [*Baldocchi et al.* 2001].
8. In addition to these fluxes, light use efficiency (*LUE*) for the cosine of solar zenith angle greater than 0.5 is also computed and compared with the model output, since *LUE* is critical for examining the ADE [*Niyogi et al.* 2004; *Chang* 2004]

ID	Site	Species	UMD LULC class	Lat Lon (°)
Niwt	Niwot Ridge Forest, Colorado	subalpine fir, engelmann spruce, and lodgepole pine	evergreen needleleaf forests	40.033, -105.546
Meto	Metolius, Oregon	ponderosa pine, antelope bitterbrush, and greenleaf manzanita	evergreen needleleaf forests	44.437, -121.567
Wind	Wind River Crane Site, Washington	douglas –fir, western hemlock, and etc.	evergreen needleleaf forests	45.821, -121.952
Morg	Morgan Monroe State Forest, Indiana	sugar maple, tulip popla, sassafras, white oak, black oak and etc.	deciduous broadleaf forests	39.321, -86.413
Umic	U. of Michigan Biological Station, Michigan	bigtooth aspen, quaking aspen, eastern white pine, and northern red oak	deciduous broadleaf forests	45.560, -84.714
Gret	Great Mountain Forest, Norfolk, Connecticut	red maple, eastern white pine, and hemlock	mixed forests	41.967, -73.233
Harv	Harvard Forest, Massachusetts, USA	oak, red maple, black birch, white pine, hemlock, white oak, black oak, and hickory	mixed forests	42.536, -72.172
Duke	Duke Forest, Pine, North Carolina	loblolly pine with red maple, sweetgum, and white oak in the understory.	mixed forests	35.978, -79.094
Will	Willow Creek, Wisconsin	white ash, sugar maple, basswood, green ash, and red oak with sugar maple and ironwood saplings, leatherwood, maidenhair, bracken ferns, and blue cohosh in the understory.	mixed forests	45.906, -90.080
Bond	Bondville, Illinois	annual rotation between Corn (C4) - 2001, Soybeans (C3) - 2000	croplands	40.006, -88.292
Fort	Fort Peck, Montana	C3 grass	grasslands	48.308, -105.101

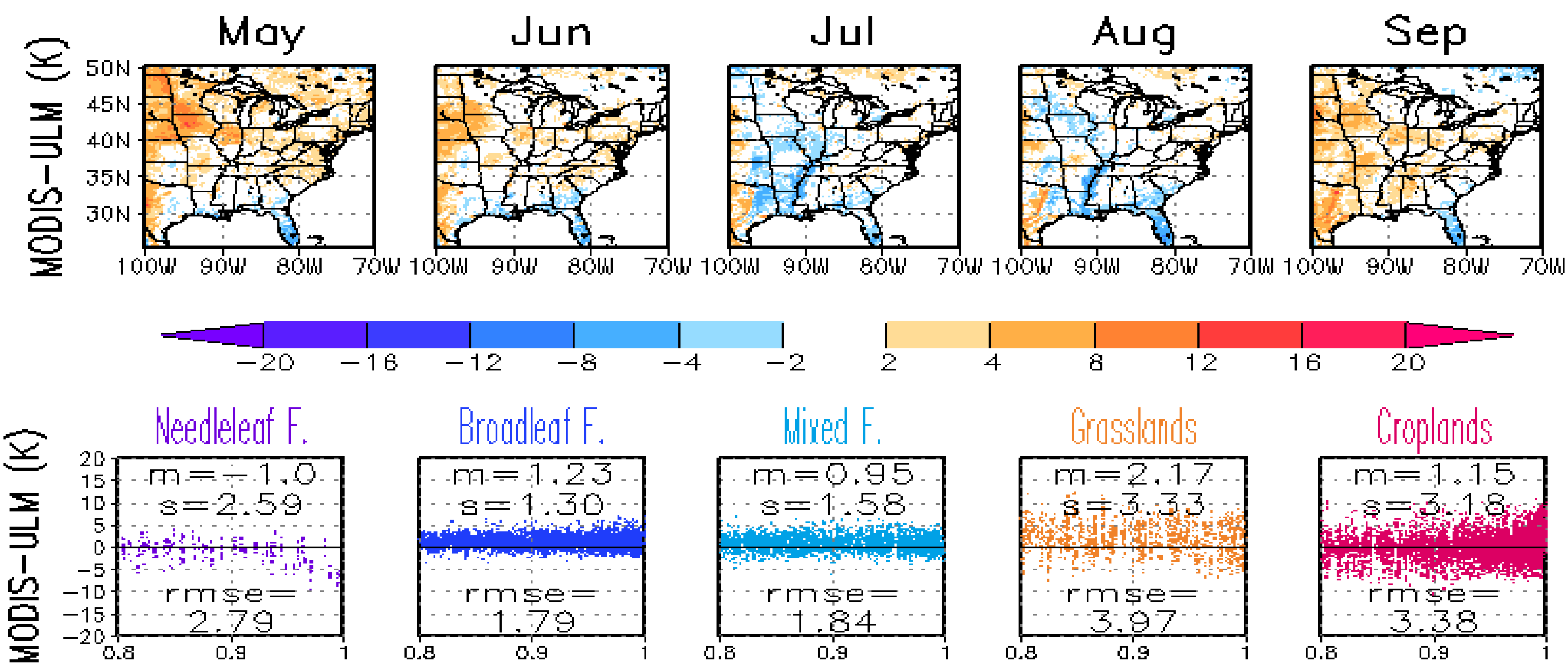
Table 7.3. A list of the FLUXNET observation sites

Flow chart of the calibration system. The Part II study uses MODIS and FLUXNET simultaneously. Model-Observation Comparison (MOC) processes are distributed in the parallel computing environment.

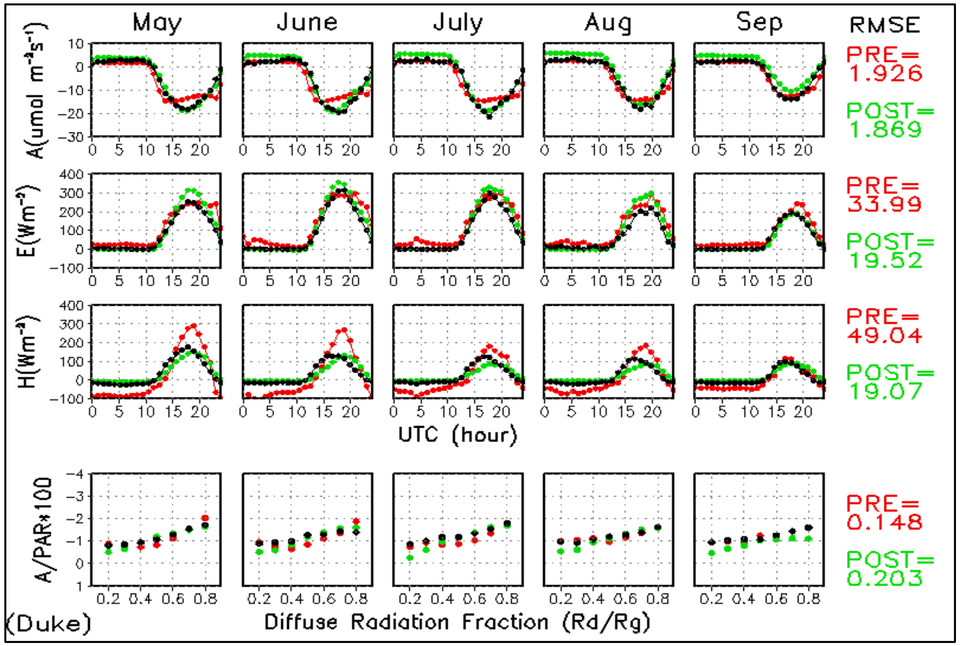


LULC-dependent parameter	z_{can}(m)	
	pre	*post*
evergreen needleleaf forests	.935	.028
deciduous broadleaf forests	1.925	.006
mixed forests	1.925	.019
grasslands	.06	.006
croplands	.06	.062

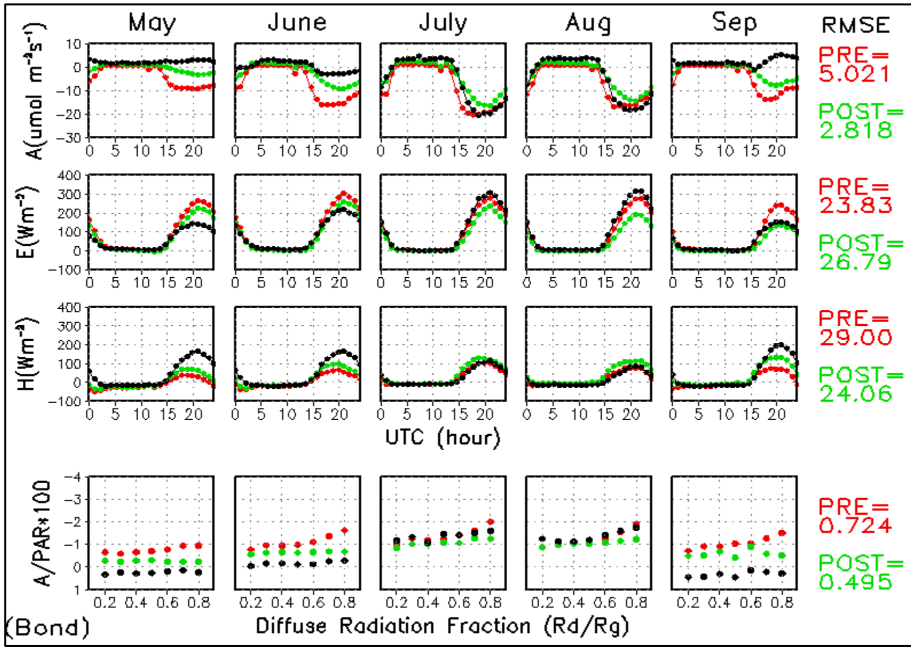
LST Post-Calibration Experiment



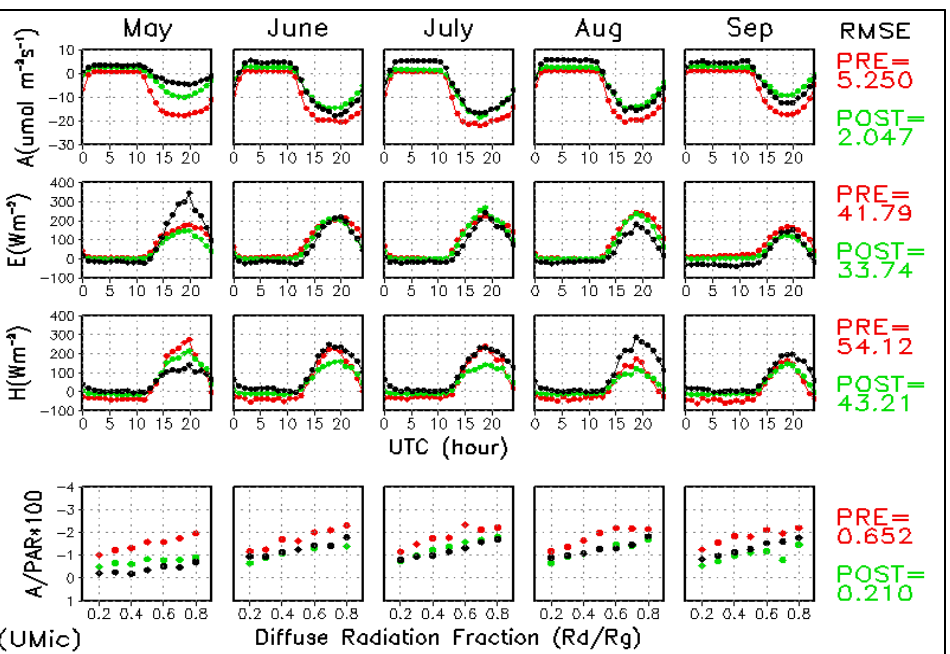
- Mixed forests



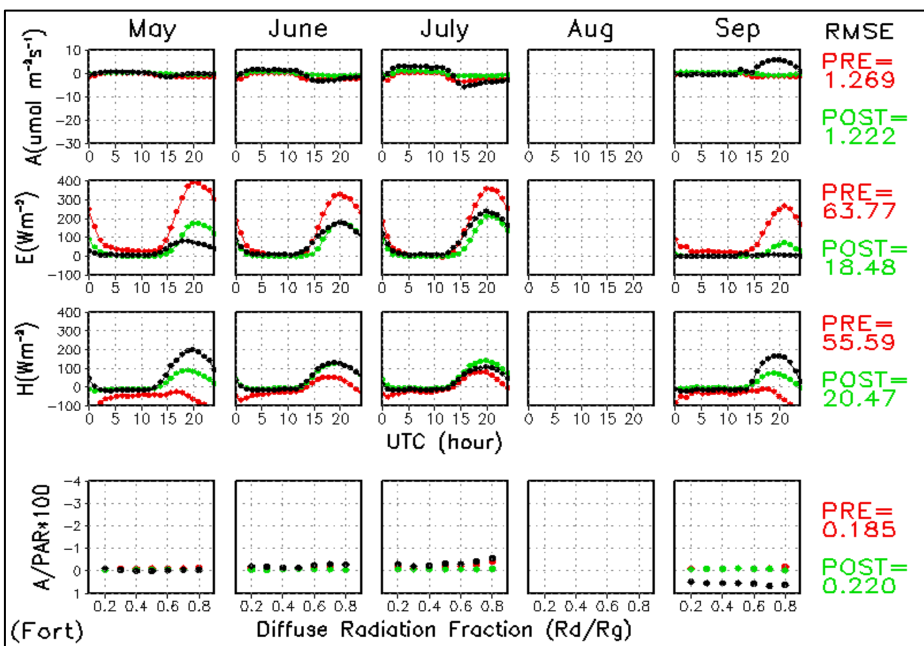
- Croplands



- Evergreen Broadleaf forests



- Grasslands



Conclusions

1. The performance of ULM is significantly improved after the calibration.
2. Calibration process is very effective for *A, E, H*, and *LUE* of broadleaf forests and mixed forests sites, which are the dominant LULC classes over eastern U.S.

Publications

Matsui, T., A. Beltrán-Przekurat, R. A. Pielke Sr., D. Niyogi, and M. B. Coughenour (2007), Continental-scale multi-observation calibration and assessment of Colorado State University Unified Land Mode: Part I. Surface albedo, *Journal of Geophysical Research - Biogeoscience*. (In press)

Matsui, T., A. Beltrán-Przekurat, R. A. Pielke Sr., D. Niyogi, S. A. Denning, M. Coughenour, and Z. Wan (2007), Mechanical response of surface carbon and turbulent heat flux to the aerosol direct effect, using well-calibrated sun-shade canopy model, *Journal of Geophysical Research - Biogeoscience*. (in press)

Acknowledgement

This work is funded by NASA CEAS fellowship (NAG512105), NASA Radiation (NNG04GB87G), NASA Terrestrial Hydrology (NNG05GQ47G), and NASA Interdisciplinary Sciences (NNG04GL61G). The authors thank to Eric Moody for providing the snow-free continuous MODIS surface product, Brian Cosgrove and Kristi Arsenault for providing the NLDAS dataset, Jim Geiger and Sujay Kumar for installing Land Information System, Tony Arcieri and Michael Aumock for assisting with parallel computational resources.