Continental-Scale Calibration of Surface Albedo in CSU Unified Land Surface Model Using Remote Sensing Data and Parameter Estimation Model

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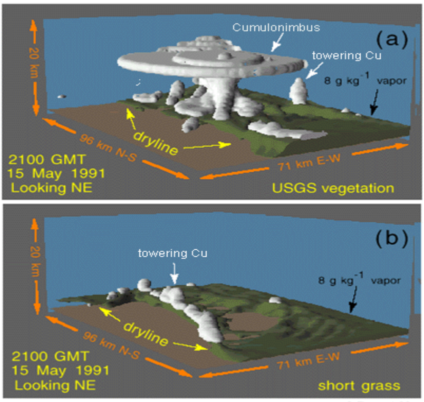
Motivation

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 spatilization 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 spatilization created 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.

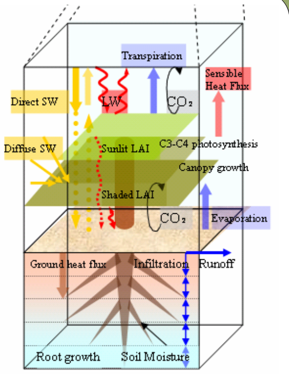
Example of the impact of LULC on the regional weather



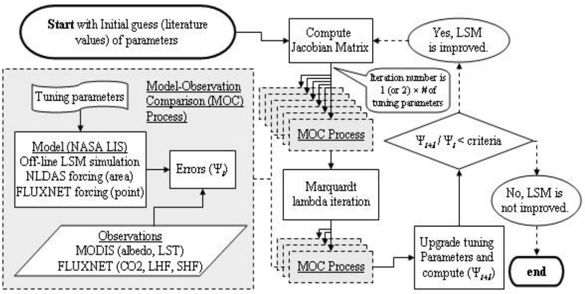
(C. Ziegler, NSSL)

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.



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



Input Data and Albedo Comparison

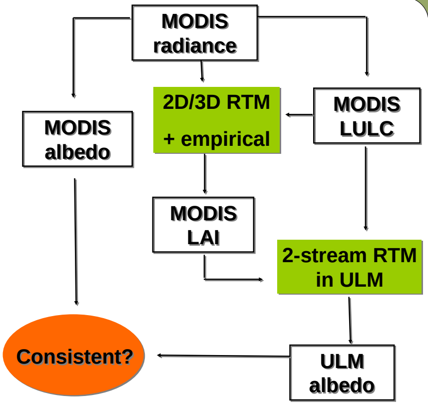
CSU ULM has been developed within the NASA GSFC's Land Information System (LIS) that contains several different LSMs and a wide variety of surface boundary conditions and meteorological forcings. Thus, off-line simulations of LSM can be tested anywhere on globe down to the urban-resolving scale (Peters-Lidard et al. 2004).

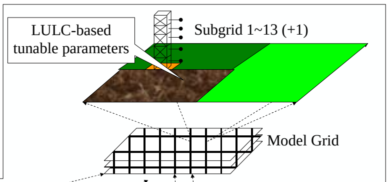
- **Subgrid #:** 1~13 (+1) based on the MODIS LULC class. (+1) indicates the patch allocated for Fluxnet sites if available. Mhe minimum tile fraction is 0.0013 that fully utilize 1km MODIS information.
- **LAI:** The 1km LAI data are aggregated for each UMD LULC classes on the 0.25°grid map. Fluxnet patch uses the nearest 1km MODIS LAI.
- **Initial Soil Moisture**: 1-year spun up of control simulation
- 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.
- 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.

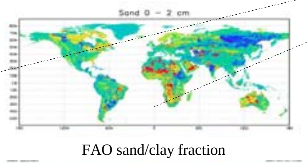
ETA field: Surface air temperatures, water vapor mixing ratios, horizontal winds, and surface pressures are derived from NCEP EDAS output fields.



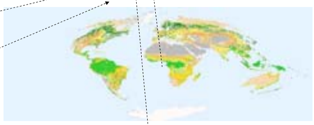


NASA GSFC Land Information System

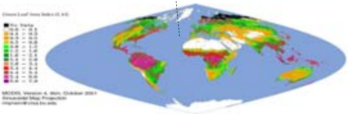
Fluxnet location



FAO sand/clay fraction



1km MODIS UMD LULC



1km MODIS LAI

Reference

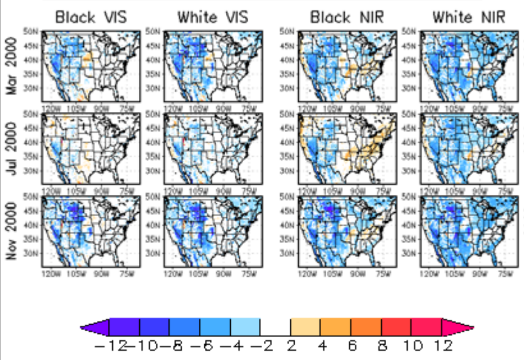
Peters-Lidard, C. D., S. Kumar, Y. Tian, J. L. Eastman, and P. Houser, 2004. Global Urban-Scale Land-Atmosphere Modeling with the Land Information System, Symposium on Planning, Nowcasting, and Forecasting in the Urban Zone, 84th AMS Annual Meeting 11-15 January 2004 Seattle, WA, U.S.A.

Results

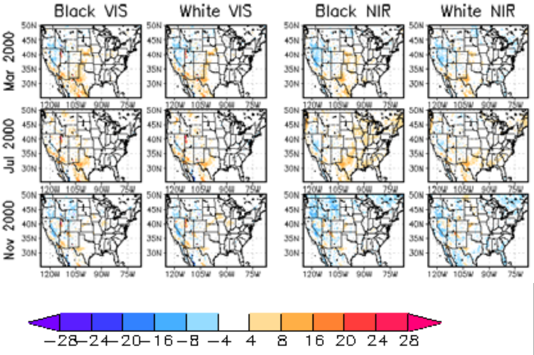
UMD	BU LAI	reflectance of pre- (post1-, post2-) calibration VIS - leaf	NIR - leaf	VIS - stem	NIR - stem	leaf angle departure
1. evergreen needleleaf forests 3. deciduous needleleaf forests	needleleaf forests	0.07 (0.047, 0.061)	0.35 (0.376, 0.418)	0.16 (0.094, 0.135)	0.38 (0.342, 0.357)	0 (-0.208)
2. evergreen broadleaf forests 4. deciduous broadleaf forests	broadleaf forests	0.1 (**0.15**, 0.113)	0.45 (0.516, 0.517)	0.16 (0.096, 0.15)	0.38 (0.426, 0.457)	0.25 (**-0.4**)
5. mixed forests	-	0.1 (0.054, 0.07)	0.45 (0.338, 0.388)	0.16 (**0.08**, 0.131)	0.38 (0.292, 0.386)	0.25 (**0.6**)
6. woodlands	savannas	0.07 (0.074, 0.088)	0.35 (0.420, 0.494)	0.16 (0.234, 0.217)	0.38 (0.551, 0.588)	0 (-0.017)
7. wooded grasslands						
8. closed shrublands	shrubs	0.1 (0.081, 0.107)	0.45 (0.329, 0.355)	0.16 (0.327, 0.182)	0.38 (0.622, 0.667)	0 (-0.24)
9. open shrublands						
10. grasslands	grasses / cereal crops	0.11 (0.132, 0.124)	0.58 (0.44, 0.539)	0.36 (0.158, 0.193)	0.58 (0.364, 0.38)	0 (**0.6**)
11. croplands	broadleaf crops	0.11 (0.095, 0.116)	0.58 (0.477, 0.566)	0.16 (0.149, 0.156)	0.38 (0.321, 0.32)	0 (**0.6**)
		a^{VIS}	b^{VIS}	a^{NIR}	b^{NIR}	
Soil Parameters		(0.0524, 0.0543)	(0.07, 0.0529)	(0.0285, 0.0279)	(0.0263, 0.0236)	

A second calibration was implemented from the lessons learned from the first calibration: i) fixed the functional error in diffuse-radiation upscattering fraction, and ii) manually fixed the surface albedo for the urban class (0.06 VIS and 0.20 NIR) based on the mean albedo of the urban pixels from the MODIS, and iii) is fixed as the initial value (not calibrated) to prevent the unrealistic diurnal cycle of within-canopy sunlight penetration.

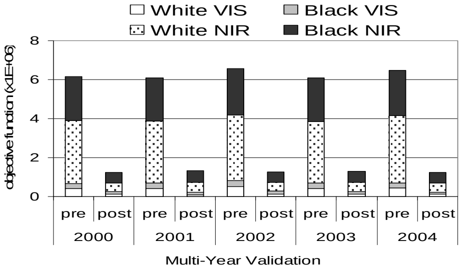
Spatial map of pre-calibration differences (MODIS – ULM) in spectral surface black and white albedos (×100)



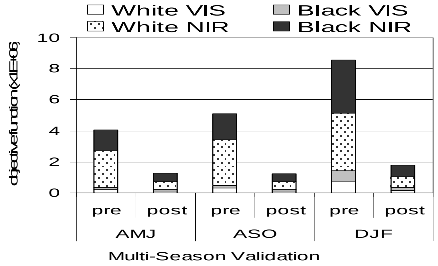
Spatial map of post-calibration differences (MODIS – ULM) in spectral surface black and white albedos (×100)



Objective Function of spectral surface albedo for pre- and post-calibration simulations for March, July, November in 2000 (calibrated year), and 2001 ~ 2004 (validation years).



Objective Function of spectral surface albedo for pre- and post-calibration simulations for AMJ (April-May-June), ASO (August-September-October), and DJF (December-January-February) in 2000. January and February correspond to 2001.



Conclusion

1. Continental-scale calibration improved the model representation of surface albedo over the entire domain in comparison with the operational MODIS snow-free albedo, although the set of the tuned parameters might not be the global optima.
2. Continental-scale calibration suggests the functional error in the model. We found the errors in the formulation of diffuse-radiation upscattering fraction in the original TCRT model. The model must be corrected to reduce the overestimation of white-sky albedo. Our suggested formula would be easy to incorporate into different models that use TCRT.
3. The leaf angle distribution function cannot be calibrated probably because of the fundamental difference between the formulations used in the TCRT model the MODIS operational albedo products.
4. The albedo in ULM was improved for not only the calibrated period but also non-calibrated years and seasons. The choice of calibration periods must be short for computational efficiency, but needs to have as large a variation in the calibrating parameters as possible for the representativeness of the tuning parameters. This enables an efficient, robust calibration process.
5. Errors in the surface albedo directly control the surface energy and mass flux in the land surface model (LSM). Because all LSMs use a different set of parameterizations and datasets, albedo calibration over the simulated domain must occur first.

Future Work

1. Tune the coefficients for land surface temperature and turbulent heat flux. For a given short- and long-wave radiation with tuned albedo, land surface temperature is a function of turbulent sensible and latent heat flux and ground conductance.
2. Calibrate ULM photosynthesis and respiration rate against Ameriflux observations.
3. Couple ULM with an atmospheric model and do sensitivity tests.

Acknowledgement

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