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 spatiotemporal distribution 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 spatiotemporal distribution 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.

• This study uses the Colorado State University (CSU) Unified Land Model (ULM), which are extracted from the CLM 2.0 (Oleson et al. 2004), GEM-MHT (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.

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. The 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

• LSM ULM 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-88D) 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 temperature, water vapor mixing ratios, horizontal winds, and surface pressures are derived from NCEP EDAS output fields.

1km MODIS UMD LULC

NASA GSFC Land Information System

2km MODIS UMD LULC

LULC-based tunable parameters

Subgrid 1~13 (+1)

Model Grid

Consistent?

MODIS albedo

2D/3D RTM

MODIS LULC

MODIS LAI

Consistent?

ULM albedo

MODIS albedo

MODIS radiance

FAO sand/clay fraction

Fluxnet location

1km MODIS UMD LULC

1km MODIS LAI

Reference

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 and 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.

Results

<table>
<thead>
<tr>
<th>UMD</th>
<th>BU LAI</th>
<th>VIS - leaf</th>
<th>NIR - leaf</th>
<th>VIS - stem</th>
<th>NIR - stem</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. evergreen needleleaf forests</td>
<td>needleleaf forests</td>
<td>0.07 (0.047, 0.061)</td>
<td>0.35 (0.376, 0.418)</td>
<td>0.16 (0.094, 0.135)</td>
<td>0.38 (0.342, 0.357)</td>
</tr>
<tr>
<td>2. deciduous needleleaf forests</td>
<td>broadleaf forests</td>
<td>0.1 (0.15, 0.113)</td>
<td>0.45 (0.50, 0.51)</td>
<td>0.16 (0.096, 0.15)</td>
<td>0.38 (0.426, 0.457)</td>
</tr>
<tr>
<td>3. deciduous broadleaf forests</td>
<td>broadleaf forests</td>
<td>0.1 (0.054, 0.07)</td>
<td>0.45 (0.338, 0.388)</td>
<td>0.16 (0.88, 0.131)</td>
<td>0.38 (0.292, 0.386)</td>
</tr>
<tr>
<td>4. mixed forests</td>
<td>-</td>
<td>0.1 (0.054, 0.07)</td>
<td>0.45 (0.338, 0.388)</td>
<td>0.16 (0.88, 0.131)</td>
<td>0.38 (0.292, 0.386)</td>
</tr>
<tr>
<td>5. woodlands</td>
<td>savannas</td>
<td>0.07 (0.074, 0.088)</td>
<td>0.35 (0.420, 0.494)</td>
<td>0.16 (0.234, 0.217)</td>
<td>0.38 (0.551, 0.588)</td>
</tr>
<tr>
<td>6. grasslands</td>
<td>grasses / cereal crops</td>
<td>0.1 (0.081, 0.107)</td>
<td>0.45 (0.320, 0.355)</td>
<td>0.16 (0.527, 0.182)</td>
<td>0.38 (0.622, 0.667)</td>
</tr>
<tr>
<td>7. closed shrublands</td>
<td>shrubs</td>
<td>0.1 (0.132, 0.124)</td>
<td>0.58 (0.44, 0.539)</td>
<td>0.36 (0.158, 0.193)</td>
<td>0.58 (0.364, 0.38)</td>
</tr>
<tr>
<td>8. desert shrublands</td>
<td>open shrublands</td>
<td>0.1 (0.095, 0.116)</td>
<td>0.58 (0.477, 0.566)</td>
<td>0.16 (0.149, 0.156)</td>
<td>0.38 (0.321, 0.32)</td>
</tr>
</tbody>
</table>

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).

Spatial map of pre-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 AMJ (April-May-June), ASO (August-September-October), and DJF (December-January-February) in 2000. January and February correspond to 2001.

Multi-Year Validation

Multi-Season Validation

Conclusion

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.

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