# Validating Evapotranspiration Maps of the Conterminous USA Utilizing AmeriFlux Data

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## Abstract

Evapotranspiration (ET) plays a critical role in regulating the hydrological, climatic, and ecological dynamics at various scales. Accurately estimating ET over large areas is important but challenging due to its variability in space and time. Recently, Moderate Resolution Imaging Spectroradiometer (MODIS) land surface temperature (LST) data and NOAA atmospheric model fields have been used to estimate ET. The Simplified Surface Energy Balance (SSEB) model integrates weather fields such as the one derived from NOAA's Global Data Assimilation System (GDAS) and ET fraction generated from LST. We used point measurements of water vapor flux from the AmeriFlux network to validate estimated ET for 2000-2006 over the conterminous United States. A total of 23 validation sites across the conterminous USA resulted in coefficient of determination ($r^2$) ranging from 0.61 to 0.88. The validation results have shown that the proposed methodology can be used for generating ET maps of the conterminous USA and has potential to generate global ET maps on an operational level.

## I. Introduction

Changes in land use/land cover and climate will continue to affect the global water and energy balance. Accurately estimating ET, one of the major water balance components, is important in various modeling approaches related to the soil-vegetation-atmosphere continuum. Spatial and temporal information regarding ET has many applications in the fields of water management, hydrology, climatology, and ecology. Planners and decision makers can utilize ET information to improve decision making for water allocation, food security, drought mitigation, and carbon sequestration.

Availability of operational global data products related to vegetation and weather have helped modelers to use these products for various applications. We have used weather fields from NOAA GDAS for computing reference ET and LST from MODIS for computing ET fraction. Reference ET and ET fraction were used to compute actual ET for the conterminous United States using the SSEB model.

## II. Modeling Algorithm

Shortgrass-based reference ET ($ET_o$) was computed using the Penman-Monteith equation with 6-hourly GDAS datasets. The 1-degree GDAS datasets were downscaled to produce 10-km GDAS data based on the International Water Management Institute (IWMI) historical potential ET data. Average 8-day MODIS LST level 5 composite data at 1-km spatial resolution were used for computing ET fraction using "Hot" and "Cold" anchor pixels. In addition, ET fraction was also modified for Normalized Difference Vegetation Index (NDVI) correction (Senay et al. 2010). A schematic workflow of the modeling algorithm is shown in figure 1.

## II. Modeling Algorithms (cont.)

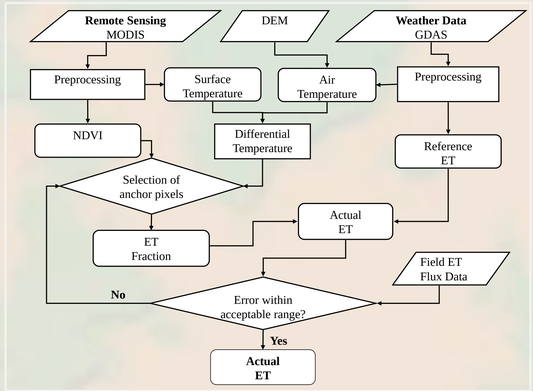


**Figure 1.** Model algorithm flowchart

## III Model Validation

The model-estimated monthly ET maps were validated using point measurements of water vapor flux from the eddy covariance towers of the AmeriFlux network (http://public.ornl.gov/ameriflux). A total of 23 flux towers (table 1) were used for this purpose.

**Table 1.** Details of eddy flux sites used in this study

| S No. | Site | Latitude | Longitude | IGBP Biome | Elevation (m) | Instrument Height (m) | Reference |
|---|---|---|---|---|---|---|---|
| 1 | OK-Lamont | 36.6058 | -97.4888 | CRO | 314 | 65 | Fischer et al. (2007) |
| 2 | IL - Fermi | 41.8593 | -88.2227 | CRO | 225 | 4 | Allison et al. (2005) |
| 3 | NE - Mead - Site 1 | 41.1651 | -96.4766 | CRO | 361 | 6 | Suyker and Verma (2008) |
| 4 | NE - Mead - Site 2 | 41.1649 | -96.4701 | CRO | 362 | 6 | Suyker and Verma (2008) |
| 5 | NE - Mead - Site 3 | 41.1797 | -96.4397 | CRO | 363 | 6 | Suyker and Verma (2008) |
| 6 | WI-Lost Creek | 46.0827 | -89.9792 | CSH | 480 | 10.2 | Yi et al. (2004) |
| 7 | IN - Morgan Monroe State Forest | 39.3231 | -86.4131 | DBF | 275 | 48 | Schmid et al. (2000) |
| 8 | MO - Missouri Ozark | 38.7441 | -92.2 | DBF | 219.4 | 30 | Gu et al. (2006) |
| 9 | MI - Univ. of Mich. Biological Station | 45.5598 | -84.7138 | DBF | 234 | 46 | Curtis et al. (2002) |
| 10 | WI - Willow Creek | 45.8059 | -90.0799 | DBF | 515 | 30 | Desai et al. (2005) |
| 11 | OR-Metolius pine | 44.4524 | -121.557 | ENF | 1253 | 32 | Law et al. (2004) |
| 12 | CO - Niwot Ridge Forest | 40.0329 | -105.5464 | ENF | 3050 | 26 | Monson et al. (2005) |
| 13 | IL - Fermi | 41.8406 | -88.241 | GRA | 226 | 3.76 | Matamala et al. (2008) |
| 14 | OK - Shidler-Oklahoma | 36.9333 | -96.6833 | GRA | 350 | 4.5 | Burba and Verma (2005) |
| 15 | CA - Vaira Ranch | 38.4067 | -120.95073 | GRA | 129 | 2 | Baldocchi et al. (2004) |
| 16 | NC-Duke hardwood | 35.9736 | -79.1004 | MF | 168 | 42 | Oishi et al. (2008) |
| 17 | MA - Harvard Forest EMS Tower | 42.5378 | -72.1715 | MF | 340 | 30 | Wofsy et al. (1993) |
| 18 | NC-Duke pine | 35.9782 | -79.0942 | MF | 163 | 21 | Oishi et al. (2008) |
| 19 | ME-Howland | 45.2041 | -68.7403 | MF | 60 | 29 | Hollinger et al. (1999) |
| 20 | WI - Park Falls | 45.9459 | -90.2723 | MF | 470 | 122 | Davis et al. (2003) |
| 21 | MI - Sylvania Wilderness Area | 46.242 | -89.3477 | MF | 540 | 37 | Desai et al. (2008) |
| 22 | CA - Sky Oaks- Old Stand | 33.3739 | -116.6229 | WSA | 1393.5 | 5 | Stylinski et al. (2002) |
| 23 | CA - Tonzi Ranch | 38.4316 | -120.966 | WSA | 177 | 23 | Xu and Baldocchi (2004) |

## IV. Results and Discussions

There was good agreement between the model-estimated monthly ET and the flux tower measured monthly ET (fig.2). The coefficient of determination ranged from 0.61 to 0.88 during 2000-2006. In general, the model performed better in the Midwest than in the coastal areas because most of the anchor pixels were selected from the Midwest, which is dominated by agriculture.

## IV. Results and Discussions (cont.)

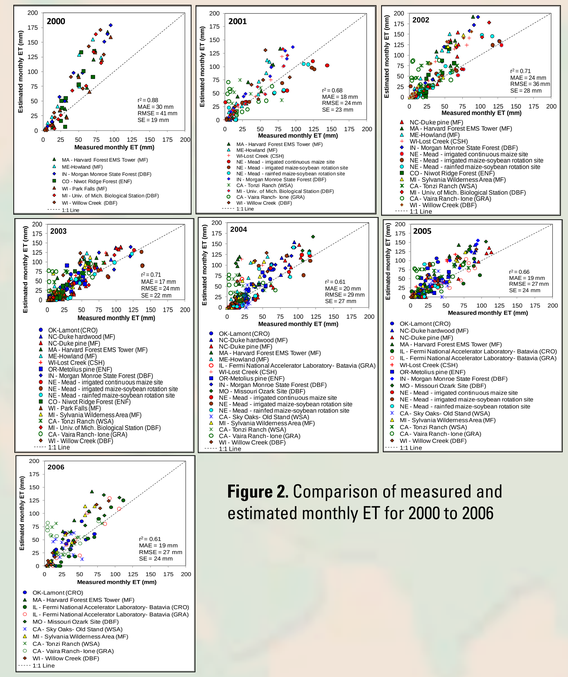


**Figure 2.** Comparison of measured and estimated monthly ET for 2000 to 2006

The SSEB model estimated annual ET for the conterminous USA showed temporal as well as spatial variation (fig. 3).

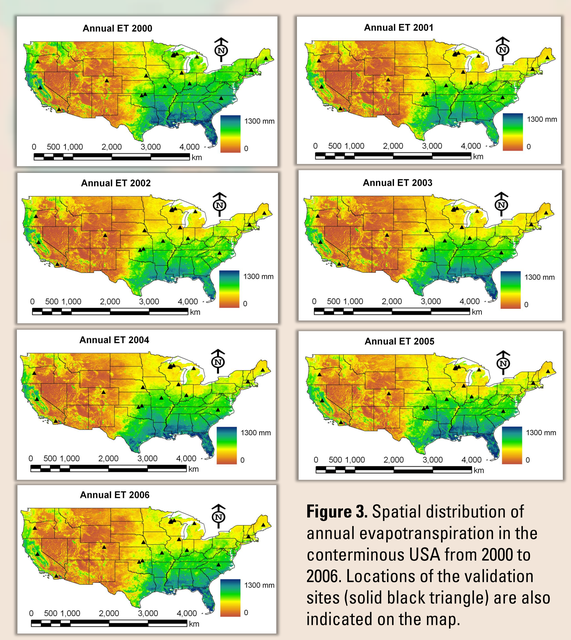


**Figure 3.** Spatial distribution of annual evapotranspiration in the conterminous USA from 2000 to 2006. Locations of the validation sites (solid black triangle) are also indicated on the map.

## IV. Results and Discussions (cont.)

The highest ET occurred in July for most of the states. Monthly ET of some of the states is shown in figure 4.

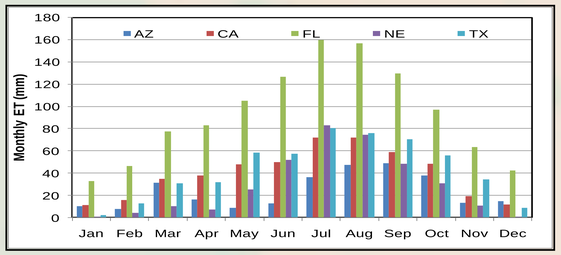


**Figure 4.** State averaged monthly ET of five sampled states during 2006

## V. Conclusions

- ✓ The model captured the spatial and temporal ET variation.
- ✓ In general, the model overestimated ET for the higher measured ET values.
- ✓ Due to ease of operationalization and reasonable estimate of ET, the model has the potential for mapping ET at regional, continental, and global scales.

## VI. Future Works

- ✓ Incorporate seasonality effect based on ecoregions.
- ✓ Include weather data at 1/8-degree resolution from North American Land Data Assimilation Systems.
- ✓ Quantify the SSEB model uncertainty in estimating ET.

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