**Steve Burges Retirement Symposium**

Hydrology in the 21st Century: Links to the past, and a vision for the future

Steve Burges Retirement Symposium, March 24 - 26, 2010

# Satellite-based estimation of land surface evapotranspiration for the conterminous U.S.


*Qiuhong Tang[1]* and Dennis P. Lettenmaier[1]*

[1]Department of Civil and Environmental Engineering, University of Washington, Seattle WA

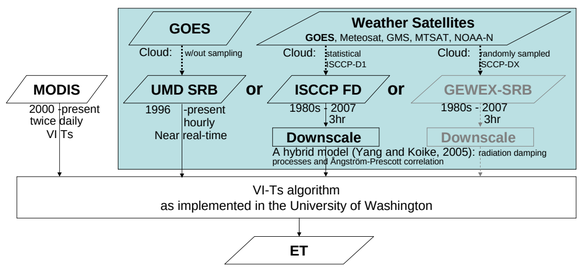
*Email: qiuhong@hydro.washington.edu


## Abstract

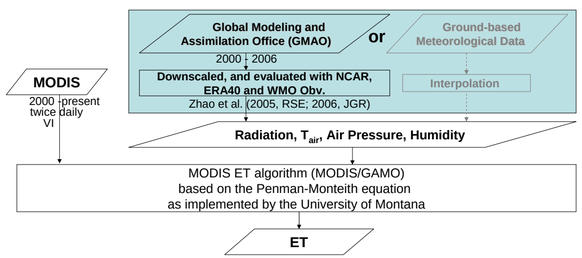

We describe an evapotranspiration (ET) product based solely on satellite remote sensing data. The product is based on a variation of the Moderate Resolution Imaging Spectroradiometer (MODIS) evapotranspiration algorithm. The satellite data sources are MODIS land surface products and the International Satellite Cloud Climatology Project (ISCCP) surface radiative fluxes (FD-SRF) data which are derived based on ISCCP cloud climatology. ET is estimated using the VI-Ts method, in which the primary parameters, vegetation index (VI) and surface temperature (Ts) are from twice daily EOS Terra overpasses at around 11:00 and 21:30 local time. The downward shortwave radiation is taken from the ISCCP FD-SRF data which are available globally. We compare the resulting MODIS/ISCCP ET estimates, MODIS/SRB ET estimates using the same algorithm but with NOAA/NESDIS surface radiation budget (SRB) products derived from the Geostationary Operational Environmental Satellites (GOES), MODIS/Global Modeling and Assimilation Office (GMAO) ET estimates using the Penman-Monteith equation based method with MODIS and GMAO meteorology data, and AVHRR/GEWEX ET estimates using Penman-Monteith equation based method over the conterminous United States for the period 2001 to 2006. We also compare the satellite-based ET estimates with AmeriFlux tower measurements for the satellite grid cell within which the towers lie. Monthly mean ET is estimated using the water budget method with PRISM precipitation, USGS streamflow gauges, and water storage change from Gravity Recovery and Climate Experiment (GRACE) for 14 river basins in the conterminous United States. The satellite-based ET products are further evaluated with the basin averaged ET estimates using the water budget method. The results show that MODIS/ISCCP, MODIS/SRB and AVHRR/GEWEX ET estimates show considerable consistency with the ET estimates using the water budget method while MODIS/GMAO ET appears to underestimate ET.


## Satellite-Based ET Approaches

*MODIS/ISCCP and MODIS/SRB algorithm*

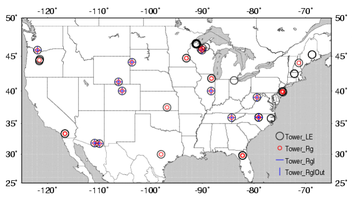



*MODIS/GAMO algorithm*




## Flux Tower Measurements and Water Budget ET Estimates

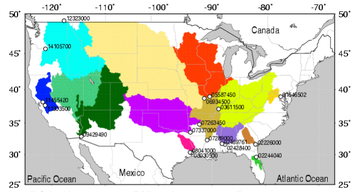
*AmeriFlux tower sites*




*Locations of the AmeriFlux sites*

Number of the sites with valid data: 66
Temporal resolution: half hours
Measured periods vary for different sites.
The measurements in 2001-2006 are used in this study.
Measured variables vary for different sites:
*Rd: incoming global radiation [W m$^{-2}$]*
*LE: latent heat flux [W m$^{-2}$]*
*Ld: incoming longwave radiation [W m$^{-2}$]*
*Lu: outgoing longwave radiation [W m$^{-2}$]*

*River basins for water budget estimates*




*River basins*

Number of the basins: 14

Areas of the basins vary from 1.3 million km$^2$ to 17,000 km$^2$. Total area of the 14 basins is 4.75 million km$^2$.

## Water Budget ET Estimates

The terrestrial water balance can be written as: DS = P – ET – R, where DS is the terrestrial water storage change over time, P is precipitation, E is evapotranspiration, and R is runoff. ET can be estimated using the water budget method:

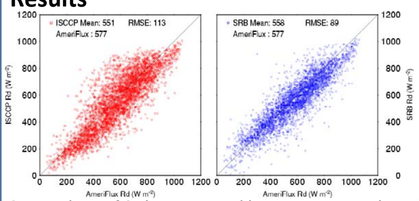
$$ET = P - R - DS$$

The P is taken from PRISM (Parameter-Elevation Regressions on Independent Slopes Model) Data. PRISM is a knowledge-based system that uses point measurements of precipitation, temperature, and other climatic factors to produce continuous, digital grid estimates of monthly, yearly, and event-based climatic parameters. The monthly PRISM precipitation data were used.

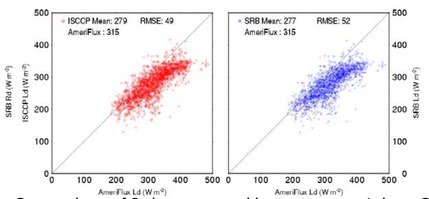
R is calculated from US Geological Survey (USGS) streamflow observations (http://waterdata.usgs.gov/nwis/sw).

DS is obtained from monthly GRACE (Gravity Recovery and Climate Experiment) mass grids dataset. The GRACE data were processed by D. P. Chambers, supported by the NASA MEASURES Program, and are available at http://grace.jpl.nasa.gov

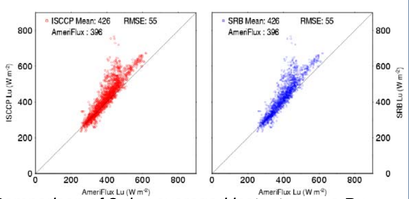
## Results



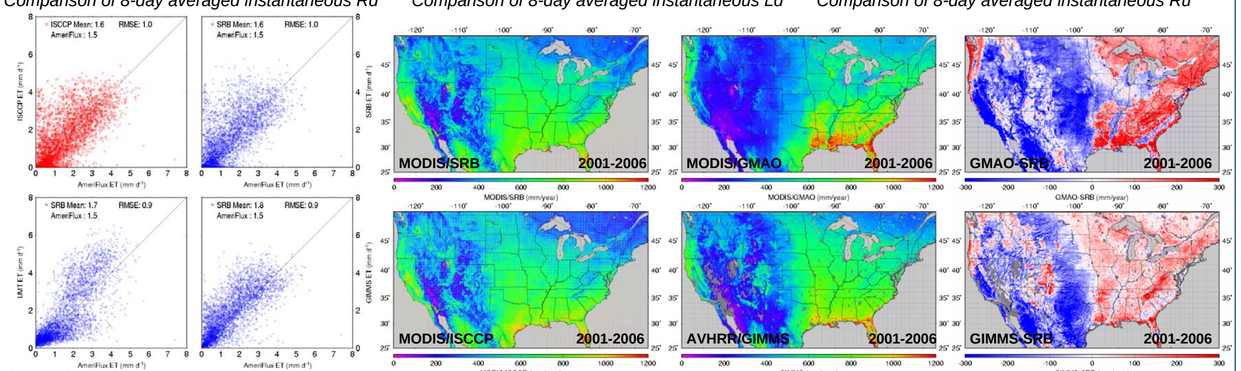

*Comparison of 8-day averaged instantaneous Rd*




*Comparison of 8-day averaged instantaneous Ld*

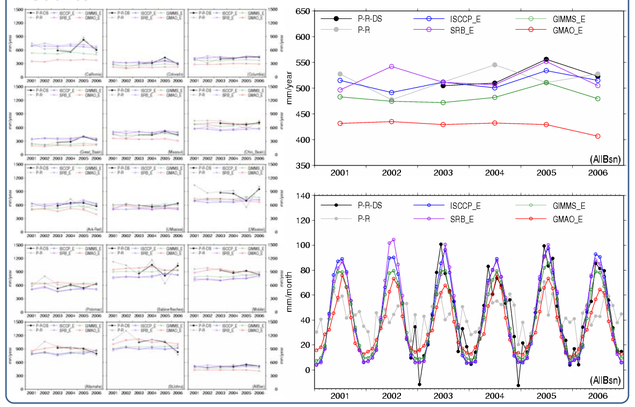



*Comparison of 8-day averaged instantaneous Ru*




*Comparison of 8-day averaged daily ET*

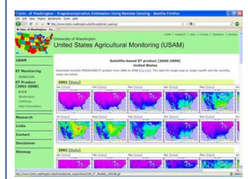
## Results



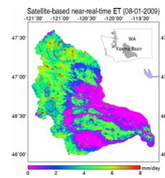

## Conclusion Remarks

We have developed a satellite-based ET approach, and evaluated it over the continental U.S. MODIS/ISCCP, MODIS/SRB and AVHRR/GEWEX ET estimates show considerable consistency with the ET estimates based on the water budget method while MODIS/GMAO ET appears to underestimate ET in summer and overestimate ET in winter. MODIS/ISSCCP can provide high resolution, free of charge ET estimates with global coverage.

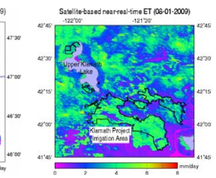
## ET Products and Website




*ET Product over U.S.*




*Yakima Basin*




*Klamath Irrigation Area*

The satellite-based ET product from 2001 to 2008 over the continental United States is available at the website: http://www.hydro.washington.edu/forecast/rset_usa/ Near-real-time MODIS/SRB ET monitoring (0.05 degree; daily updating; 3 days to 1 week latency) is available for the continental U.S. at the same site. High spatial resolution ET monitoring (~250 m; daily updating) are available in Washington State, northern California, and southern Oregon.

## References


- Mu, Q., F.A. Heinsch, M. Zhao, S.W. Running (2007). Development of a global evapotranspiration algorithm based on MODIS and global meteorology data. *Remote Sensing of Environment*, 111, 519-536.
- Tang, Q., S. Peterson, R. H. Cuenca, Y. Hagimoto, and D. P. Lettenmaier (2009). Satellite-based near-real-time estimation of irrigated crop water consumption, J. Geophys. Res., 114, D05114, doi:10.1029/2008JD010854.
- Tang, Q., H. Gao, P. Yeh, T. Oki, F. Su, and D.P. Lettenmaier (2010). Dynamics of Terrestrial Water Storage Change from Satellite and Surface Observations and Modeling. *J. Hydrometeor.*, 11, 156–170.
- Yang, K., and T. Koike (2005). A general model to estimate hourly and daily solar radiation for hydrological studies, *Water Resour. Res.*, 41, W10403, doi:10.1029/2005WR003976.
- Zhang, K., J. S. Kimball, Q. Mu, L. A. Jones, S. Goetz and S. W. Running (2009) Satellite based analysis of northern ET trends and associated changes in the regional water balance from 1983 to 2005. *Journal of Hydrology*, 379, 92-110.