Brief Introduction to MODIS Evapotranspiration Data Set (MOD16)

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The MOD16 global evapotranspiration (ET)/latent heat flux (LE)/potential ET (PET)/potential LE (PLE) datasets are regular 1-km^2 land surface ET datasets for the 109.03 Million km^2 global vegetated land areas at 8-day, monthly and annual intervals. The dataset covers the time period 2000 – 2010. Future years will be produced and posted periodically, but not in near-real time.

The MOD16 ET datasets are estimated using Mu et al.'s improved ET algorithm (2011) over previous Mu et al.'s paper (2007a). The ET algorithm is based on the Penman-Monteith equation (Monteith, 1965). Surface resistance is an effective resistance to evaporation from land surface and transpiration from the plant canopy.

Terrestrial ET includes evaporation from wet and moist soil, from rain water intercepted by the canopy before it reaches the ground, and the transpiration through stomata on plant leaves and stems. Evaporation of water intercepted by the canopy is a very important water flux for ecosystems with a high LAI. Canopy conductance for plant transpiration is calculated by using LAI to scale stomatal conductance up to canopy level. For many plant species during growing seasons, stomatal conductance is controlled by vapor pressure deficit (VPD) (Oren et al., 1999; Mu et al., 2007b; Running & Kimball, 2005) and daily minimum air temperature (T_{min}). T_{min} is used to control dormant and active growing seasons for evergreen biomes. High temperatures are often accompanied by high VPDs, leading to partial or complete closure of stomata. For a given biome type, two threshold values for Tmin and VPD are listed in the Biome-Property-Look-Up-Table (BPLUT) to control stomatal conductance (Mu et al., 2007a; 2009; 2011).

The required MODIS data inputs to the Collection 5 1-km^2 MOD16 ET algorithm include 1) global Collection 4 land cover type 2 (MOD12Q1) (Friedl et al., 2002); 2) Collection 5 FPAR/LAI (MOD15A2) (Myneni et al., 2002); and 3) Collection 5 MCD43B2 and MCD43B3 albedo (Lucht et al., 2000; Jin et al., 2003). The use of Collection 4 land cover is because Collection 5 FPAR/LAI is generated based on the Colleciton 4 land cover. For MODIS albedo, we use the 10th band of the White-Sky-Albedo from the 8-day MCD43B2/B3 products. The input non-satellite data are NASA's MERRA GMAO (GEOS-5) daily meteorological reanalysis data from 2000 to 2010. The output variables include, 8-day, monthly and annual ET, LE, PET, PLE and 8-day, annual quality control (ET_QC). The 8-day MOD16A2 QC field is inherited from MOD15A2 in the same period. However, the cloud-contaminated FPAR/LAI has been temporally filled with those having good QC. For annual QC of MOD16A3 products, we used the method proposed by Zhao et al. (2005) to define a more meaningful annual ET QC as

$$QC = 100.0 \times NU_g / Total_g$$

where *NUg* is the number of days during growing season with unreliable or missing MODIS LAI inputs, and*TOTALg* is total number of days in the growing season. The growing season is defined as all days with Tmin above the value where stomata close as in the BPLUT. The MOD16 ET algorithm has a good performance in generating global ET data products, providing

critical information on global terrestrial water and energy cycles and environmental changes (Mu et al., 2007a, 2009, 2011).

Note: For some pixels in African rainforests, the MODIS albedo data from MCD43B2/MCD43B3 have no cloud free data throughout an entire year. As a result, corresponding fill values of ET/LE/PET/PLE are assigned for these pixels in that year.

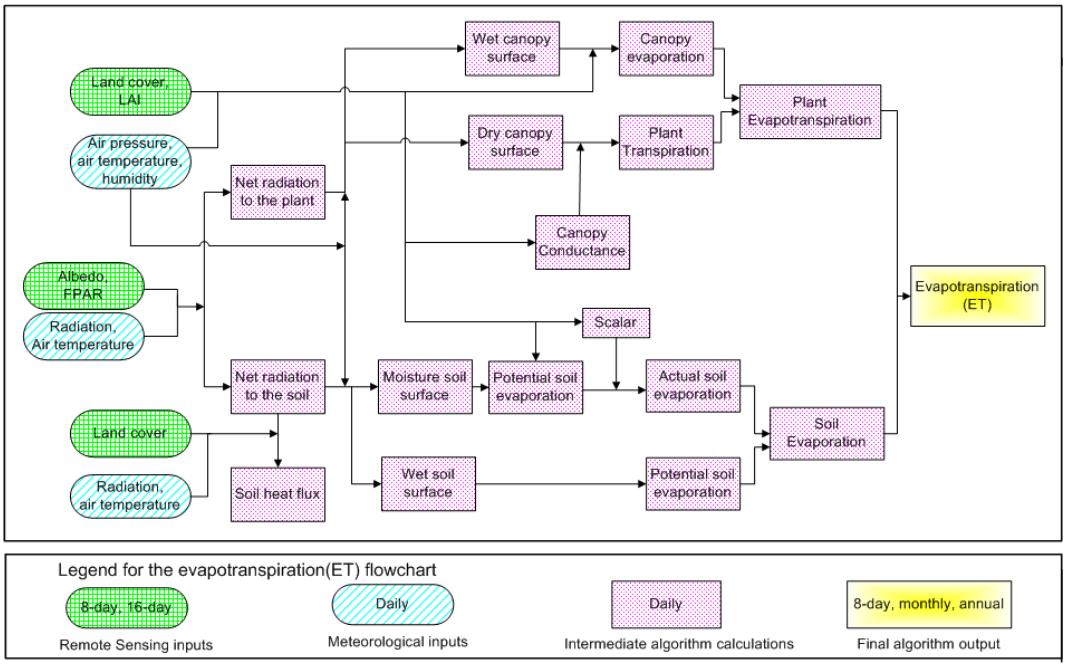

Figure 1. *Flowchart showing the logic of the MODIS ET algorithm for calculating daily ET (Mu et al., 2011).*

The 8-day ET (0.1mm/8days or 0.1mm/5days) is the sum of ET during these 8-day time periods (5 days for 361 composite data in 2001, 2002, 2003, 2005, 2006, 2007, 2009, 2010, 6 days for 361 in 2000, 2004, 2008). The monthly ET (0.1mm/month) is the sum of monthly ET. For February, there are 29 days in a leap year and 28 days in normal years. The annual ET (0.1mm/yr) is the sum of the ET during each year. There are 366 days in 2000, 2004, 2008, and 365 days in 2001, 2002, 2003, 2005, 2006, 2007, 2009, 2010. The 8-day, monthly and annual LE/PLE (1.0e4 J/m2/day) is the average daily LE/PLE over the corresponding time period.

The users should multiply 0.1 to get the real ET/PET values in mm/8day or mm/month, or mm/yr, and 1.0e4 to get LE/PLE in J/m2/day.

For the 8-day and monthly ET/LE/PET/PLE, annual LE/PLE, the valid value range is -32767-32700.

Fill value, out of the earth 32767
Water body 32766
Barren or sparsely vegetated 32765

Permanent snow and ice 32764
Permanent wetland 32763
Urban or Built-up 32762
Unclassified 32761

For the annual ET/PET, the valid value range is 0- 65500.

Fill value, out of the earth 65535
Water body 65534
Barren or sparsely vegetated 65533
Permanent snow and ice 65532
Permanent wetland 65531
Urban or Built-up 65530
Unclassified 65529

References

Mu, Q., F.A. Heinsch, M. Zhao, and S. W. Running, (2007a), Development of a global evapotranspiration algorithm based on MODIS and global meteorology data, *Remote Sensing of Environment*, 111, 519-536, doi: 10.1016/j.rse.2007.04.015

Mu, Q., M. Zhao, F. A. Heinsch, M. Liu, H. Tian, S. W. Running. (2007b). Evaluating water stress controls on primary production in biogeochemical and remote sensing based models. *Journal of Geophysical Research*, 112: G01012, doi: 10.1029/2006JG000179.

Mu, Q., L. A. Jones, J. S. Kimball, K. C. McDonald and S. W. Running (2009) Satellite assessment of land surface evapotranspiration for the pan-Arctic domain. *Water Resources Research* 45, Number W09420 - 2009 (doi: 10.1029/2008WR007189).

Mu, Q., M. Zhao, S.W. Running (2011). Improvements to a MODIS Global Terrestrial Evapotranspiration Algorithm. *Remote Sensing of Environment*. (in press).

Cleugh, H.A., R. Leuning,, Q. Mu., and S. W. Running (2007), Regional evaporation from flux tower and MODIS satellite data, *Remote Sensing of Environment*, 106, 285-304, doi:10.1016/j.rse.2006.07.007

Friedl, M. A., McIver, D. K., Hodges, J. C. F., Zhang, X. Y., Muchoney, D., Strahler, A. H., et al. (2002), Global land cover mapping from MODIS: Algorithms and early results, *Remote Sensing of Environment*, 83(1–2), 287−302.

Jin,Y., Schaaf, C. B.,Woodcock, C. E.,Gao,F.,Li,X., Strahler,A.H., et al. (2003), Consistency of MODIS surface BRDF/Albedo retrievals: 2. Validation , *Journal of Geophysical Research*, 108(D5), 4159. doi:10.1029/2002JD002804

Lucht, W., Schaaf, C. B., and Strahler, A. H. (2000), An Algorithm for the retrieval of albedo from space using semiempirical BRDF models, *IEEE Transactions on Geoscience and Remote Sensing*, 38, 977−998.

Monteith, J. L. (1965), Evaporation and environment. In: B.D. Fogg, (Ed.), The State and Movement of Water in Living Organism, *Symposium of the society of experimental biology*, 19, Cambridge University Press, Cambridge (1965), 205–234.

Myneni, R. B., Hoffman, S., Knyazikhin, Y., Privette, J. L., Glassy, J., Tian, Y., et al. (2002), Global products of vegetation leaf area and fraction absorbed PAR from year one of MODIS data, *Remote Sensing of Environment*, 83(1–2), 214−231.

Oren, R., Sperry, J. S., Katul, G. G., Pataki, D. E., Ewers, B. F., Phillips, N., et al. (1999), Survey and synthesis of intra- and interspecific variation in stomatal sensitivity to vapour pressure deficit. *Plant, Cell and Environment*, 22, 1515−1526

Running, S. W. and J. S. Kimball (2005). Satellite-Based Analysis of Ecological Controls For Land-Surface Evaporation Resistance. *Encyclopedia of Hydrological Sciences*, M. Anderson (Ed.), *John Wiley & Sons*, Ltd. – 2005.