Determining the Accuracy of Remotely-Sensed Evapotranspiration Estimates for Canadian Boreal Forest Ecosystems

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GEOL394

Introduction

-Boreal forests face changing evaporative demand as climate gets warmer. Understanding evaporative demand warrants an understanding of evapotranspiration (ET).
-ET is directly measured using eddy covariance flux towers, but many regions lack flux tower measurements.
-ET estimates are generated from the MOD16 algorithm developed by Mu et al. (2011), which uses data from NASA's MODIS sensor. MOD16 uses inputs that include albedo, leaf area index, land cover, meteorological data, and radiation
-MOD16 accuracy can be determined by comparing the product to flux tower measurements.
-For this project, I sought to determine if there were spatial variations in MOD16 accuracy. In figure 1 below, there is a notable, visible gradient in MOD16 ET going from east to west.
-However, precipitation in the east is higher, and since evapotranspiration is a function of precipitation, I would expect MOD16 ET to reflect that with higher ET values in the east.
-Figure 2 shows mean annual MOD16 ET at the flux tower sites. I expected to see a stronger relationship between the longitude of the tower and its ET value.
-**Hypothesis**: MOD16 is overestimating ET to a stronger degree in the dry, western Canadian boreal forest.

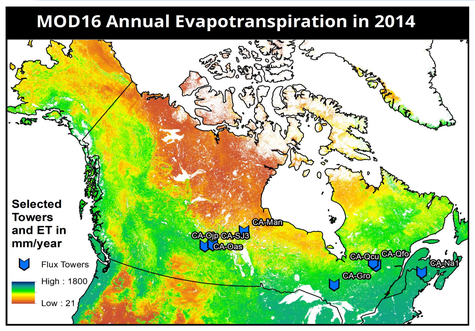

Fig 1: Flux tower sites chosen for analysis, spanning the Canadian boreal forest. Additionally, the MOD16 annual ET estimations are displayed.

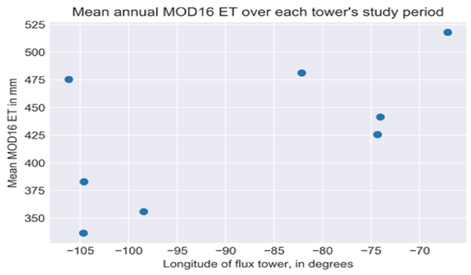

Fig 2: The mean annual MOD16 ET estimation at each tower over that tower's study period, i.e. when flux tower data is available

Methods

-To compare flux tower data to MOD16 data, gaps must be filled in the flux tower data. Gap filling methods followed those laid out by Hu et al. (2015), while determination of error resulting from gap filling followed Falge et al. (2001).
-Error on flux tower measurements is a function of gap filling error and random error from tower measurements. Gap filled data is show in figure 3.
-For MOD16 data, the extracted value is determined as the average of the pixels that lie within a 9 km^2 buffer of the tower, following the methods used by Tang et al. (2015).
-Values are then compared on the 8-day time scale, and accuracy is assessed using bias, percent bias, and root mean square error.

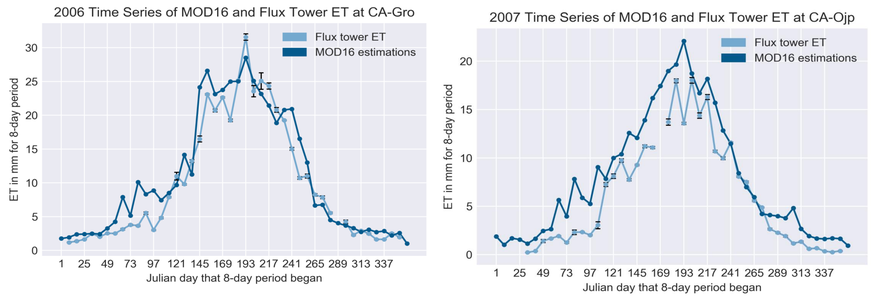

Fig 3: Example of annual times series comparing flux tower ET to MOD16 estimations at two different towers

Results

-When assessed on an annual scale, there is not a significant relationship between the measures of accuracy and the longitude of the flux tower.
-When assessed on a seasonal scale, there is a significant ($p < 0.05$) negative correlation between longitude and bias, percent bias in the fall (September, October, November), which is displayed in figure 4.
-Shown in figure 5, linear regression analysis suggests that there is a strong relation between flux tower ET and MOD16 ET, with R^2 values that often exceed those found in other biomes (Hu et al. 2015).

References:
Falge, E., D. Baldocchi, R. Olson, P. Anthoni, M. Aubinet, C. Bernhofer, G. Burba, et al. 2001. "Gap filling strategies for defensible annual sums of net ecosystem exchange." *Agricultural and Forest Meteorology* 107 (1): 43-69. doi: 10.1016/S0168-1923(00)00225-2.3
Hu, G., L. Jia, and M. Menenti. 2015. "Comparison of MOD16 and LSA-SAF MSG evapotranspiration products over Europe for 2011." *Remote Sensing of Environment* 156: 510-426. doi: 10.1016/j.rse.2014.10.017.
Mu, Q., M. Zhao, and S. Running. 2011. "Improvements to a MODIS global terrestrial evapotranspiration algorithm." *Remote Sensing of Environment*, 115 (8): 1781 – 1800. doi: 10.1016/j.rse.2011.02.019.
Ramoelo, A., N. Majozi, R. Mathieu, N. Jovanovic, A. Nickless, and S. Dzikiti. 2014. "Validation of Global Evapotranspiration Product (MOD16) using Flux Tower Data in the African Savanna, South Africa." *Remote Sensing* 6 (8): 7406-7423. doi: 10.3390/rs6087406.

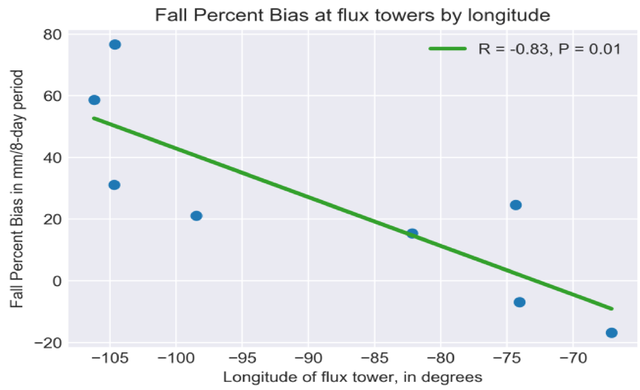

Fig 4: Significant negative correlation between flux tower longitude and percent bias of MOD16 for 8-day periods in the fall. MOD16 is more likely to overestimate in the west

Conclusions

-MOD16 ET estimations show better agreement with flux tower measurements in the Canadian boreal than for other biomes, including the African savanna (Ramoelo et al., 2014), and some deciduous and evergreen forests in Europe (Hu et al., 2015).
-In Canada's boreal forests, MOD16 appears to overestimate ET in the fall. Results for the remainder of the year are less conclusive
-MOD16 relationship to flux tower measurements could be used to correct MOD16 values in unmeasured areas.
-There is generally a negative correlation between bias/percent bias and tower longitude, RMSE did not show correlation with longitude.

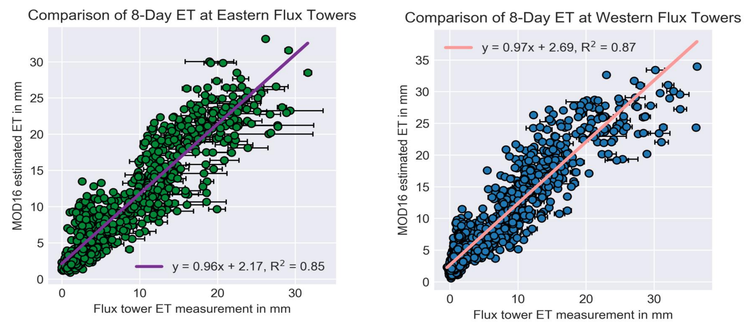

Fig 5: Linear regression between ET measurements and MOD16 estimations in the eastern sites and western sites. Each graph consists of data from four towers.