Exploiting Functional Convergence of Tundra Vegetation to Predict NEE Using Satellite Data

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Scaling a Simple Model of NEE

Background: The direction and magnitude of the net Arctic tundra CO_2 flux at annual timescales is highly uncertain. Given satellite observations that suggest vegetation productivity is increasing, and large soil C stocks vulnerable to mobilization with warming, the need to quantify tundra CO_2 flux has become increasingly important. This work exploits a simple model of tundra net ecosystem CO_2 exchange that is robust and generalizable.

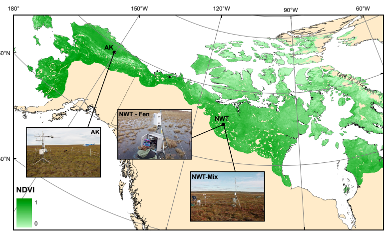

Figure 1. Map of tundra July NDVI. The three validation sites are labeled Anatuvuk River site is denoted (AK), and the Daring Lake sites denoted (NWT).

Methods & Results: A simple model of tundra NEE (Eq. 1), parameterized with chamber fluxes (Shaver et al, 2007), was successfully implemented with eddy covariance data (Figure 2). A synthetic dataset was used for the temporal scaling required to parameterize a daily model (Figure 3). Daily estimates of NEE predicted using tower meteorology and MODIS leaf area index (L) were comapared with tower observations of NEE (Figure 4).

$$NEE = \left(R_0 L e^{\beta T}\right) - L\left(\frac{P_M E_0 I_0}{P_M + E_0 I_0}\right) \qquad \text{Eq. 1}$$

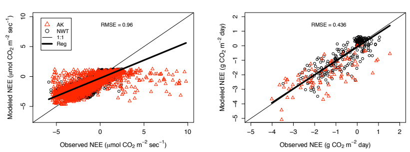

Figure 2. Comparison of half-hourly (left) and daily (right) predicted and observed NEE. Predictions are made with a model developed using chamber fluxes (Shaver et al, 2007)

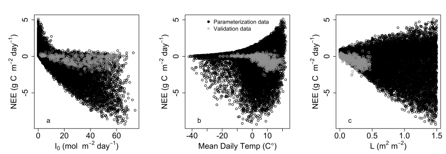

Figure 3. Response of daily NEE to I_0 (a), T (b), and L (c). Data shown in black are synthetic parameterization data, aggregated from half-hourly to daily temporal resolution. Half-hourly T and I_0 were a combination of synthetic and observed daily trajectories, and daily LAI values were generated randomly. Points show in gray are flux tower observations that were used for model validation. These plots illustrate that parameterization data encompassed a much larger domain than that of the validation data.

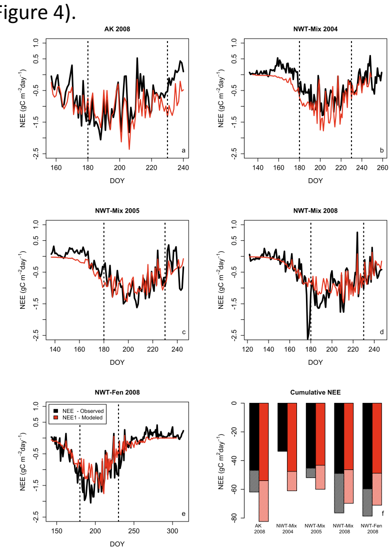

Figure 4. Annual trajectories of NEE for the AK-2008 (a), NWT -Mix in 2004-5, 2008 (b-d), and NWT-Fen 2008 (e). Modeled NEE was derived using MODIS L and tower met data. Bar plot (f) shows cumulative NEE where the solid and hashed portions of each bar represent NEE accumulated during the growing season, and outside of the growing season respectively.

MODIS Derived Estimates of Tundra NEE

MODIS Data: To derive estimates of tundra NEE for the Arctic landscape we relied on inputs from NASA's MODIS platform. Incident Photosynthetic Radiation (I_0) was produced daily at 4km resolution (Liang et al, 2006) and was obtained from the ORNL DAAC (Figure 5). The mean of day and night MODIS land surface temperature from the standard 8-day product was used as a daily temperature input (Figure 6). L was estimated from NDVI, calculated from the MCD43B4 NBAR reflectance product.

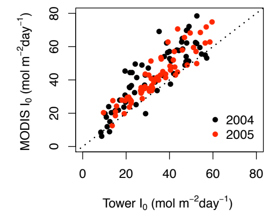

Figure 5. Comparison between MODIS and Tower I_0 for the Daring Lake site

Results:

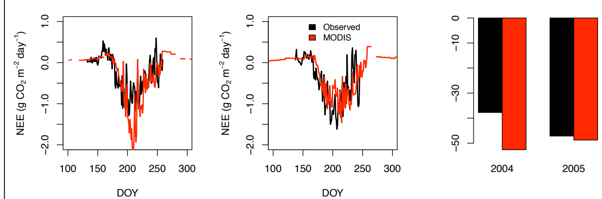

Figure7. Annual trajectories of observed (black) and modeled (red) NEE for the Daring Lake mixed tundra site for 2004 and 2005. The bar graph shows cumulative NEE over the growing season (July-August) for each year.

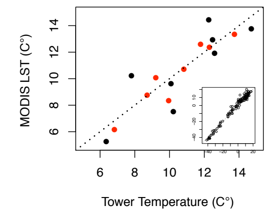

Figure 6. Comparison between MODIS LST and mean daily air temperature at Daring Lake (inset is daily).

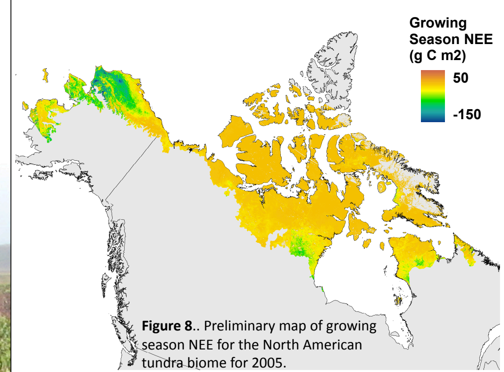

Figure 8.. Preliminary map of growing season NEE for the North American tundra biome for 2005.

Conclusions & Future Work:

- A simple model of tundra NEE scales relatively easily and well.
- Flux data from high-Arctic sites are needed to assess model utility for estimating biome wide CO_2 fluxes.
- MODIS I_0 works well given its resolution, an operational product would be useful.
- More & consistent estimates of L are needed in tundra ecosystems.

References:
Loranty, M.M., et al, 2011. Scaling an instantaneous model of tundra NEE to the Arctic landscape. Ecosystems. 14:74-93
Liang, S., et al, 2006. Estimation of incident photosynthetically active radiation from Moderate Resolution Imaging Spectrometer data. Journal of Geophysical Research. Vol 111 D15208
Shaver, G.S. et al. 2007. Functional convergence in regulation of net CO2 flux in heterogeneous tundra landscapes in Alaska and Sweden. Journal of Ecology. 95: 802-817.