Evaluation of a Diagnostic Carbon Flux Model with Observations at Eddy Covariance Flux Towers

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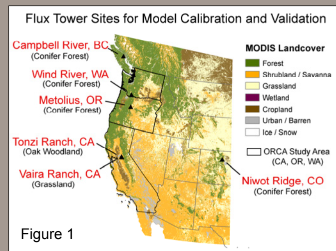
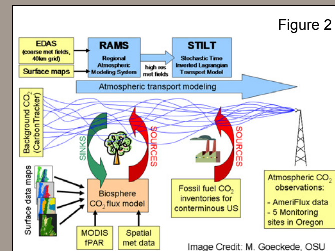
Introduction

Observations of carbon dioxide fluxes at eddy covariance flux towers offer the opportunity for calibration and validation of carbon flux models used for making regional estimates of the terrestrial carbon balance. For this study we assembled 3 years of daily flux data from 6 tower sites (Figure 1) varying widely in their climate and vegetation physiognomy. The data were used to evaluate the CFLUX model (Turner et al. 2006) which is the biosphere flux model component of a model-data fusion approach (Figure 2) to regional scaling of Net Ecosystem Production (NEP).





Approach

CFLUX employs a light use efficiency algorithm for gross primary production (GPP) and base rate functions for autotrophic respiration and heterotrophic respiration (Box 1).

Input requirements for diagnostic carbon flux models include daily meteorological data and estimates of FPAR (the fraction of incident photosynthetically active radiation that is absorbed by the canopy) from satellite imagery. Here, we evaluated 3 variations of the MODIS FPAR product.

Tower estimates of GPP, ecosystem respiration (Re), and NEP were used in parameter optimizations and in direct comparisons to model simulations.

Box 1: CFLUX algorithms for Gross Production, Autotrophic Respiration, and Heterotrophic Respiration

GPP = ↓PAR * FPAR * Єg

Where:
GPP = gross primary production (gC m^{-2} d^{-1})
↓PAR = incoming photosynthetically active radiation (MJ d^{-1})
FPAR = fraction of ↓PAR absorbed by the canopy (0-1)
Єg = light use efficiency (gC MJ^{-1})

Ra = Rm + Rg

Where:
Ra = autotrophic respiration
Rm = Rm-base * Q10^((Tair – 20)/10) * (1/-k) (log (1-FPAR))

Rm-base = base rate of autotrophic respiration (gC m^{-2} d^{-1})
Q10 = change in rate for a 10oC increase in temperature (here we use 2.0)
Tair = daily (24 hr) mean air temperature
k = radiation extinction coefficient (here we use 0.5)
FPAR = fraction of ↓PAR absorbed by the canopy.
Rg = (GPP – Rm) * Rg-frac

Rg-frac is the fraction of carbon available for growth that is used for growth respiration

Rh = f (Rh-base, FPAR, Tsoil, SW, SA)

Where:
Rh = heterotrophic respiration (gC m^{-2} d^{-1})
Rh-base = base rate of Rh (gC m^{-2} d^{-1})
FPAR = fraction of ↓PAR absorbed by canopy (0-1)
Tsoil = daily soil temperature (deg C)
SW = soil water content (%)
SA = stand age (years)

Results

1. Significant artifacts in the standard NASA FPAR product (Figure 3) were removed by the OSU gap filling procedure and the TIMESAT smoothing algorithm. The TIMESAT smoothed FPAR product gave improved fits of simulated to measured carbon fluxes relative to the other FPAR product.

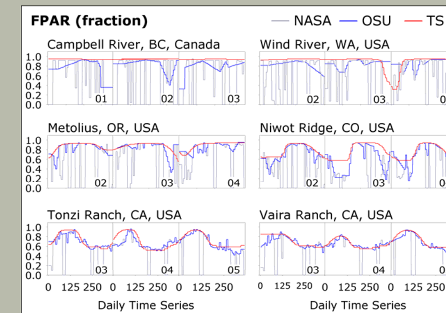


Figure 3: Comparison of alternative forms of FPAR (the fraction of photosynthetically active radiation that is absorbed by the vegetation canopy). NASA is the standard product from NASA, OSU is the NASA product with gap filling using the algorithm of Zhao et al. (2005), and TS is the NASA product smoothed using the TIMESAT algorithm (Jonsson and Eklundh 2004).

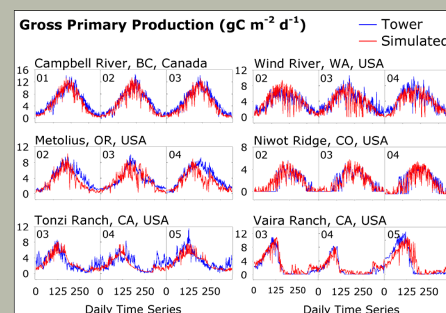


Figure 4: Comparison of measured (flux tower) and simulated (CFLUX model) gross primary production(GPP) at six sites.

2. Seasonal patterns in GPP were generally well replicated by the model at all sites. At the grassland and savannah sites, it was important that the model properly simulates the soil water balance to capture the sharp mid-summer decline in GPP (Figure 4).

3. Simulations of Re at the Metolius and Wind River conifer site were significant underestimates in particularly warm years, possibly associated with the unusually large proportion of Re that was from respiration of aboveground biomass at those sites. Measured Re at the savannah site (Tonzi) showed greater sensitivity to the soil water status than did the model (Figure 5).

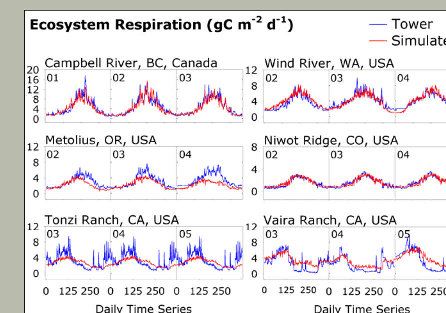


Figure 5: Comparison of measured (flux tower) and simulated (CFLUX model) ecosystem respiration (Re) at six sites.

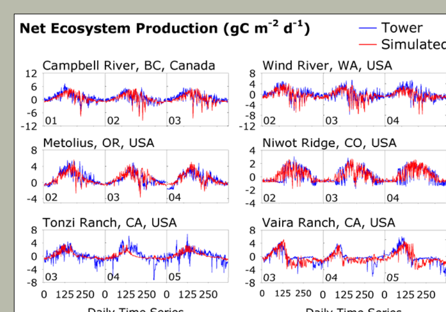


Figure 6: Comparison of measured (flux tower) and simulated (CFLUX model) net ecosystem production (NEP) at six sites.

4. Measured and simulated NEP generally followed the pattern of high positive (sink) NEPs in the spring and declines in the summer as air temperature rose and soil moisture fell. The biggest discrepancies in day to day differences between simulated and measured NEP were at the savannah site (Tonzi) (Figure 6).

5. The sign and magnitude of the interannual variation in the carbon fluxes were generally well captured by the simulations. The model sensitivity to interannual variation relied primarily on climate data rather than FPAR (Figure 7).

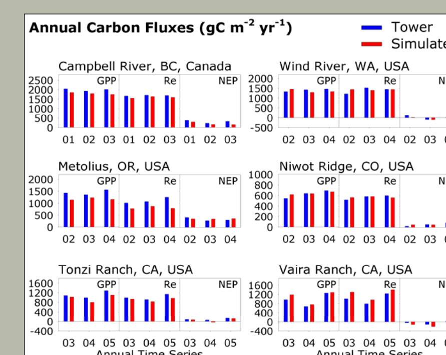


Figure 7: Comparison of interannual variation in carbon fluxes at six sites.

Conclusion

Diagnostic carbon flux models (such as CFLUX) with daily inputs of local meteorology and FPAR from satellite imagery are able to capture seasonal and interannual variation in GPP, Re, and NEP reasonable well across a broad range of climate and vegetation type. We are currently assembling the inputs to run CLFUX at the 1 km spatial resolution and daily time step over California, Oregon and Washington. Results will be evaluated in relation to spatial and temporal patterns in observations of atmospheric CO^2 concentration.

References and Acknowledgements

Jonsson, P., and L. Eklundh. 2004. TIMESAT - a program for analyzing time-series of satellite sensor data. Computers and Geosciences 30: 833-845.

Turner, D.P., W.D. Ritts, J.M. Styles, Z. Yang, W.B. Cohen, B.E. Law, and P. Thornton. 2006. A diagnostic carbon flux model to monitor the effects of disturbance and interannual variation in climate on regional NEP. Tellus 58B:476-490.

Zhao, M. S., F. A. Heinsch, R. R. Nemani, and S. W. Running. 2005. Improvements of the MODIS terrestrial gross and net primary production global data set. Remote Sensing of Environment 95: 164-176.

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