Regional carbon fluxes by simultaneous assimilation of multiple flux towers in a simple ecosystem model

Ankur R Desai, David S Schimel, National Center for Atmospheric Research (NCAR); Kenneth J Davis, Pennsylvania State University; William J Sacks, University of Wisconsin
Corresponding author : Ankur Desai, The Institute for Integrative and Multidisciplinary Studies (TIIMES), NCAR, P.O. Box 3000, Boulder, CO 80307, adesai@ucar.edu

The Dilemma: Reconciling stand-scale and regional flux

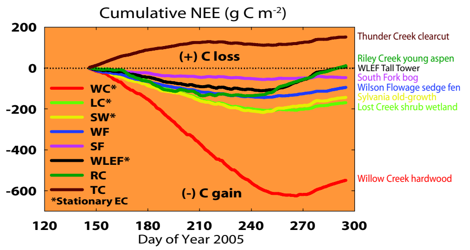

Fig 1. NEE in the growing season of 2005 from a number of upland and wetland sites in the northern Wisconsin and upper Michigan region. Figure courtesy of N. Saliendra, USFS.

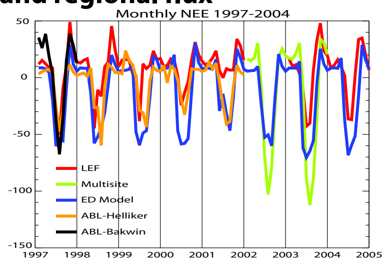

Fig 2. Estimates of regional flux from a variety of methods - tall tower eddy covariance (LEF), multiple site landcover upscaling (Multisite), biometric constrained ecosystem model (ED), and two single tower ABL budgets (Helliker and Bakwin)

- Extensive sampling of net ecosystem exchange (NEE) of CO_2 by a dense mesonet of eddy covariance flux towers in northern Wisconsin and Michigan shows that no single stand-scale tower (Fig. 1) can represent a regional flux as estimated by a very tall tower, ABL budgets or high resolution observationally-constrained models (Fig. 2) (Desai et al., in press)
- This is true despite climate forcing being roughly the same across the mesonet
- Large scale landcover and models typically classify entire area as "mixed forest" and compute the same flux for all portions of the region. This flux is unlikely to be the true regional mean flux

The Tool: Sipnet and Markov Chain Monte Carlo

	Prior	Posterior
Growth parameters		
photosynthetic capacity (amax)	112	58.6 +/- 2.2
VPD modifier (dVPD_slope)	0.05	0.066 +/- 0.009
Half saturation PAR	17	9.0 +/- 0.76
Light attenuation	0.5	0.67 +/- 0.02
WUE factor	10.9	13.4 +/- 0.46*
Decomposition parameters		
Lloyd-Taylor E0	309	448 +/- 121
Lloyd-Taylor T0	-46	-59.5 +/- 10.6
Growth respiration fraction	0.33	0.34 +/- 0.06
Plant woody turnover rate	0.03	0.19 +/- 0.02

Table 1. Prior parameter values and MCMC estimated posterio mean and standard deviation of >114,000 accepted parameter sets. * implies parameter approached constraint range. Some parameters (E0,T0) were strongly correlated.

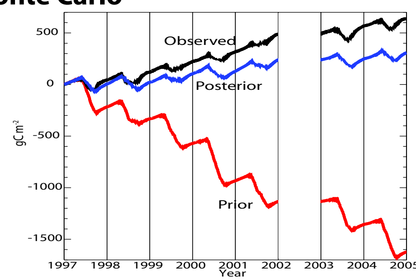

Fig. 3 Cumulative NEE from 1997-2005 from observed (black) and modeled prior (red) and posterio (blue) parameter sets. 2002 missing in data due to instrument failure and removed from modeled.

- Goal: Optimize a regional ecosystem model against flux tower mesonet
- Markov Chain Monte Carlo (MCMC) is a statistical approach to estimate model parameters that minimizes model-data error by performing a quasi-random walk through constrained parameter space (Braswell et al., 2005)
- Typically done at one site. Model and parameter selection are critical to success of this method
- Here we use SipNet simple ecosystem model (Sacks et al., 2006) and MCMC to constrain 6 photosynthesis and 3 respiration parameters against 7 years of NEE at the WLEF very tall regional flux tower
- Prior parameters (Table 1) reflect typical mid-latitude forest values, which show a large uptake of carbon unlike that observed (Fig. 3)
- Posterior parameter values (Table 1) are better able to capture long-term trend, seasonal magnitude and some, but not all, interannual trends (Fig. 3)

The Plan: Multiple Flux Tower Assimilation

- MCMC approach was modified to allow simultaneous assimilation from multiple sites across space
- Goal is to find a regional parameter set that when applied to large scale models with regional climate forcing and landcover maps is able to reproduce estimated regional flux
- Some parameters are allowed to vary spatially while others are fixed for all sites
- Cost function (minimization/objective function) is modified to sum RMS model-data error at all sites and new parameter matrix is all accepted or rejected as a group for all sites
- For spatially varying parameters, quasi-random walk is independent at each site. For spatially invariant parameters, parameters are changed in same direction at each location

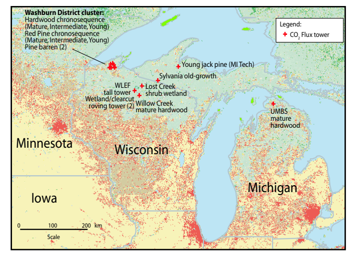

Fig. 4 Map showing location of flux tower mesonet and nearby sites against MODIS landcover background

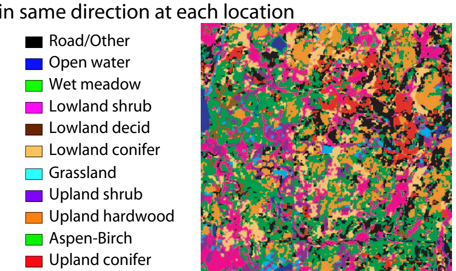

Fig. 5 IKONOS 4 m sample unsupervised land classifcation of 10x10 km around WLEF tall flux tower

The Future: Next steps

- Develop regional prior parameter set from ecological and biometric data observed in region
- Assimilate mesonet of flux towers (Fig. 4) in an upland-set, wetland-set and other combinations to create robust MCMC constrained regional ecosystem parameters
- Test scaling approaches with different land cover sets (e.g., Fig. 5)
- Evaluate multiple site assimilated model against regional flux estimates
- Use regional parameter set to make predictions, test climate change scenarios and evaluate against future observations

References

Braswell, B.H., W.J. Sacks, E. Linder, and D.S. Schimel (2005), Estimating diurnal to annual ecosystem parameters by synthesis of a carbon flux model with eddy covariance net ecosystem exchange observations, *Global Change Biology*, 11(2), 335, doi:10.1111/j.1365-2486.2005.00897.x.

Desai, A.R., et al. (in press), Influence of vegetation and seasonal forcing on carbon dioxide fluxes across the Upper Midwest, USA: Implications for regional scaling, in *Agricultural and Forest Meteorology*.

Sacks, W.J., D.S. Schimel, R.K. Monson, and B.H. Braswell (2006), Model-data synthesis of diurnal and seasonal CO2 fluxes at Niwot Ridge, Colorado, *Global Change Biology*, 12(2), 240-259.

Acknowledgements

This work is supported by a NCAR Advanced Study Program (ASP) postdoctoral fellowship. NCAR is sponsored by the National Science Foundation (NSF). Flux towers are supported with grants from the Department of Energy (DOE), National Aeronautics and Space Administration (NASA), NSF and U.S. Department of Agriculture (USDA). We also acknowledge the work of many technicians, students and researchers involved in the Chequamegon Ecosystem-Atmosphere Study (ChEAS).