Proposal for Fluxnet Synthesis Paper

Title: "A Comparative Study of Optimized Process Parameters and their Response to Current and Future Climate in Evergreen Needleleaf Ecosystems "

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Use of the SIPNET Model

For the past five years, we have been working on methods of model-data assimilation as a means to use high-density flux data sets to constrain an ecosystem process model (SIPNET) and generate optimized posterior parameter sets for the 35 fundamental parameters of the model. The Photosynthesis and Evapotranspiration (PnET) model was originally developed for use with deciduous forests (Aber and Federer 1992, Aber et al. 1996), although recently it was simplified (principally by modification to the carbon allocation and plant phenology algorithms) so that it could also be used for both deciduous and coniferous forests (Braswell et al. 2005, Sacks et al. 2006a, 2006b). The simplified version (SIPNET) contains two vegetation carbon pools (leaves and wood), a soil carbon pool and a soil water pool. The model is deployed such that the pools evolve over time on the basis of carbon and water fluxes that are driven by 54 fundamental parameters. Our approach is to use SIPNET as an extension of ordinary maximum likelihood optimization to minimize the variance between assimilated and modeled eddy flux data and generate posterior estimates of a subset of the model's 54 driving parameters. The use of SIPNET to simultaneously estimate parameters is an improvement over traditional approaches in which parameters are estimated independently and covariances are ignored. By simultaneous parameter estimation we have the opportunity to resolve covariances and assign standard errors. Once optimized, the model can be used in forward mode to partition observed net fluxes into estimates of gross component fluxes (e.g., GPP, R_E) and assign confidence intervals to retrieved values. Thus, SIPNET allows for the resolution of NEE in a manner that is highly constrained by observations, dependent on seasonal and interannual climate variation, and defined with accompanying error estimates.

Flux data is assimilated into SIPNET as half-daily means obtained from the 30-min averaged data after appropriate filtering for gap-filled periods (see Sacks et al. 2006a). It would be possible to assimilate observations at a finer temporal scale, but our experience has informed us that most of the process-level contrasts (e.g., between photosynthesis and respiration) occur between day and night. Following data assimilation and initial parameterization (see Braswell et al. 2005), the model is allowed to explore predefined 'parameter space' for some or all of the parameters, providing an estimated NEE for each half-daily time period. The estimated NEE is compared to the observed NEE for all time periods and if the match is improved over the previous estimate (evaluated by maximum likelihood), the new parameter set is retained; if the match is not improved, the old parameter set is retained and a new random set of values is chosen to start the process again. The model typically runs through hundreds of thousands of possible parameter sets before settling on a subset of most likely values. The optimized set reflects a highly-constrained description of ecosystem processes and can be used to parameterize the model and run it forward to predict ecosystem responses to future climate scenarios.

How We Would Deploy SIPNET in the Fluxnet Synthesis

We will focus on the use of SIPNET to optimize estimates of GPP, R_e, E and T and their response to temperature and precipitation for a subset of twenty-five coniferous forest sites represented within Fluxnet with at least five years of continuous flux data. We have limited the analysis to coniferous forests as this is the ecosystem best represented by our current version of SIPNET, which was originally developed for the deciduous Harvard Forest Ameriflux site and has been used extensively at the coniferous forest at the Niwot Ridge AmeriFlux site. We have made a tentative list of the sites to use (see Appendix). However, this list may be modified once we get into the data sets; the ultimate list will depend on completeness of the flux database, availability of ancillary studies with which to generate initial parameter estimates, and distribution of sites in order to provide an optimal sample of climate regions. The final list of sites will be made by September 1, 2007.

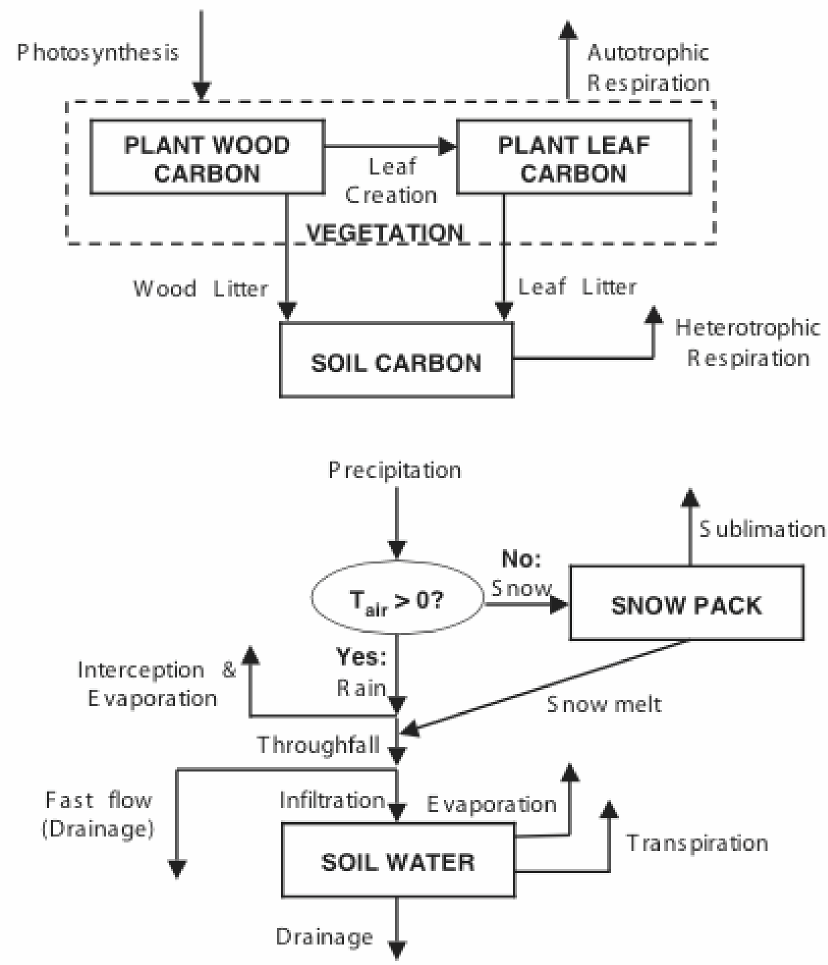

Figure 1: SIPNET pools and fluxes. The model has two vegetation carbon pools and one soil carbon pool. The soil moisture sub-model includes a single soil moisture pool and a snow pack. Soil moisture affects both photosynthesis and soil respiration. Not shown are the most recent additions including the Ball-Berry model for canopy stomatal conductance and a routine to link growing-season GPP to the subsequent spring control over rhizospheric respiration.

We have most recently modified SIPNET to include surface conductances and to assimilate both CO_2 (NEE) and H_2O (ET) fluxes as a means of partitioning E and T as well as GPP and R_e. Although we will initially focus on comparative aspects of partitioned GPP, Re, E and T, we will also have generated optimized parameter estimates for the remaining model parameters. We will use this optimized parameter set, along with climate drivers generated from the recent 20-model IPCC climate analysis and efforts at the National Center for Atmospheric Research to decompose monthly IPCC climate projections into half-daily climate projections, to run SIPNET forward for each site, evaluating response of GPP, Re, E and T to climate expected for 2050 and 2100. Through this overall analysis we will establish a comparative framework for evaluating differences among forest ecosystems with regard to their future responses to projected changes in climate. We will look for distinct geographic distributions and trends. For example, we might construct (1) a map of predicted changes in climate drivers between now and 2050 or 2100, (2) a map of flux sensitivity to each change estimated from the available Fluxnet data and (3) a map NEE, GPP, TER and water use estimated by SIPNET optimized for each site using current, 2050 and 2100 climate drivers.

To accomplish these goals we will need to:

(1) Settle on a final list of sites to be used in the analysis. We will select sites based on the vegetation type and data availability and through literature searches and communication with the site principle investigators to ensure that the processes represented in SIPNET are appropriate for each system. This stage will be accomplished by September 2007.

(2) Collate climate data to drive the model (air and soil temperature, photosynthetically active radiation, precipitation, wind speed, vapor pressure, and the vapor pressure deficit between the leaf and air, and between the soil and air) and measured fluxes to allow parameter estimation (NEE, ET, friction velocity) from each site. All data required to run SIPNET are standard measurements at Fluxnet sites or derivatives thereof. Dependent on data availability this stage will be completed by November 2007.

(3) Estimate starting ("first-guess") parameter values for each site so that the model has a starting point in parameter space. We will rely on values from the published literature and personal communication with the site principle investigators (e.g., studies of soil respiration, leaf gas exchange etc.). This stage including estimating the parameters using data assimilation will be completed by February 2008.

(4) Assemble the climate change data sets for each of the sites. This will be accomplished by correcting the half daily climate model predictions from the UCAR Community Climate System Model to conform to monthly predictions of climate variables from the most recent IPCC multi-model comparison. This stage will be completed by February 2008.

(5) Analyze the model output, conduct quality assurance and make the data available to the greater Fluxnet community. This stage will be completed by Summer 2008 and should be coincident with the submission of a manuscript for peer review.

Co-authorship Policy

The lead authors of the study will be David J.P. Moore, Russell K. Monson, David S. Schimel with co-authorship offered to one representative of each Fluxnet site used in the analysis (we can stretch this to more than one rep from each site if justified).

References

Aber JD, Federer CA (1992) A generalized, lumped-parameter model of photosynthesis, evapotranspiration and net primary production in temperate and boreal forest ecosystems. Oecologia 92:463–474

Aber JD, Reich PB, Goulden ML (1996) Extrapolating leaf CO_2 exchange to the canopy: a generalized model of forest photosynthesis compared with measurements by eddy correlation. Oecologia 106:257–265

Braswell BH, Sacks WJ, Linder E, Schimel DS (2005) Estimating diurnal to annual ecosystem parameters by synthesis of a carbon flux model with eddy covariance net ecosystem exchange observations. Global Change Biology 11:335–355.

Sacks WJ, Schimel DS, Monson RK, Braswell BH (2006a) Model data synthesis of diurnal and seasonal CO_2 fluxes at Niwot Ridge, Colorado. Global Change Biology 12:240–259.

Sacks WJ, Schimel DS, Monson RK (2006b) Coupling between carbon cycling and climate in a high-elevation, subalpine forest: a model-data fusion analysis. Oecologia 151: 54-68.

Appendix 1. Tentative List of Fluxnet Sites

Campbell River, Canada
BOREAS, Old Black Spruce, Canada
BOREAS, Old Jack Pine, Canada
Bily Kritz, Czech Republic
Hyytiala, Finland
Kenttarova (Matorova), Finland
Alkkia Scots Pine, Finland
Sodankyla, Finland
Wetzstein, Germany
Renon/Ritten (Bolzano), Italy
Sardina/Arca di Noe, Italy
Lavarone Forest, Italy
San Rossore, Italy
Polwet, Poland
Fedorovskoje (Drained Spruce), Russia
Zotino, Russia
El Saler, Spain
Flakaliden, Sweden
Blodgett Forest, USA
Niwot Ridge, USA
Kennedy Space, USA
Duke Forest, USA
Metolius (Int Aged), USA
Wind River, USA
Howland Forest, USA