Using phenological indicators derived from FLUXNET data to improve predictive models of vegetation phenology

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Motivation:

Phenological events, such as budburst and leaf abscission, regulate many ecosystem processes and significantly influence biosphere-atmosphere feedbacks in the climate system. Phenology is also a sensitive and robust indicator of biological responses to climate change, particularly warming trends and altered precipitation regimes. However, phenological theory is incomplete and phenology sub-models implemented in state-of-the-art earth system models are overly simplistic, resulting in biased predictions (Fig. 1).

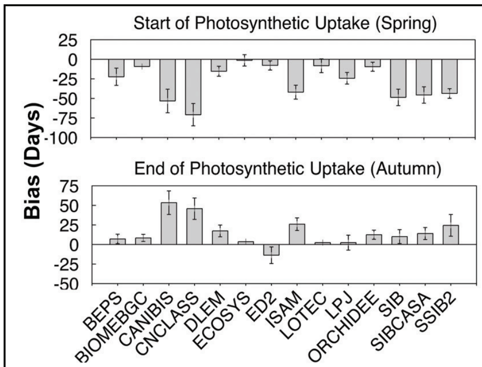

Fig. 1. Analysis of model runs (2000-2006) from the NACP Interim Synthesis indicates that models consistently predict spring onset too early, and autumn senescence too late, at the Harvard Forest. Errors of up to 25 d are common, and errors of more than 50 d are observed in some cases (Richardson, unpublished)

Although the phenology of temperate, deciduous forests is well studied, there is remarkably little agreement regarding the degree to which photoperiod, cold temperatures, and warm temperatures combine to regulate spring budburst in these ecosystems. Consequently, numerous models to predict budburst have been described in the literature, but there is no consensus model that works well across species, or across geographically distinct populations of a given species. Especially in the context of long-term predictions of ecosystem responses to climate change, improving phenological models is critical.

Therefore, there is an urgent need to develop better theory and models of vegetation phenology. More than a decade ago, Baldocchi (1996) recognized the value of eddy covariance time series of CO_2 and H_2O exchanges for evaluating and improving model representation of seasonal vegetation dynamics — i.e., phenology, and its role in regulating ecosystem processes related to carbon and water cycling. We propose to use both flux and radiometric data from the FLUXNET “LaThuile” database to test and improve existing theories and models of the environmental controls on vegetation phenology.

Methods:

We will use methods similar to those implemented by Richardson et al. (2010) to extract phenological transition dates from eddy covariance NEE time series, including start and end of the photosynthetically active period, and source/sink transition dates.

A variety of approaches have been proposed to model spring onset in temperate and boreal ecosystems. These including the “spring warming” (no chilling) model, as well as alternating, sequential, and parallel chilling, the growing season index model, and the promoter-inhibitor model, as well as the method of Baldocchi et al (2005) based on soil temperature thresholds. Models for autumn are much less well developed, but will be a focus of our analyses.

We will use data-model fusion approaches to parameterize and evaluate different phenological models, constrained with FLUXNET data, and will use Akaike’s Information Criterion for formal model selection. Our objective will be to develop general model parameterizations that function well across sites, and at the same time also adequately capture the interannual variation in the timing of phenological events.

Data:

Because of our interest in the interannual as well as spatial patterns, we emphasize those sites for which 3 or more years of data are available. We will focus primarily on data from forested (both conifer and deciduous) and grassland sites in temperate and boreal regions (i.e., sites with a pronounced "summer active" and "winter dormant" period). Data from other ecosystems with strong seasonal cycles may also be analyzed, provided that enough site-years of high-quality data are available.

Authorship policy:

All data contributors making an intellectual contribution will be included as named coauthors. Data contributors not making an intellectual contribution will be included as group coauthors in the author list, if possible with the journal (i.e., "and the FLUXNET Synthesis Group"). Group coauthors will be identified by name in the acknowledgements. We will circulate a summary of initial findings to all data providers, and solicit feedback; this will be followed by a draft manuscript, which we will also circulate for feedback. Data providers who have contributed intellectually and will be included as coauthors will be sent the final version of the manuscript prior to journal submission.

Potential Conflicts with Other Synthesis Projects:

We understand that another group has recently proposed a similar synthesis project. Our desire to conduct this analysis is motivated by Richardson's recent NACP analysis, presented at the AGU 2010 meeting (see abstract below). We see this as a sufficiently important topic, with a diversity of potential approaches, so that there should be room for more than one group to pursue work in this direction. If the SMC deems it necessary, we would be happy to discuss our planned approach in more detail with the other group to minimize potential overlap and facilitate scholarly collaboration.

AGU 2010 Fall Meeting Abstract:
Evaluation of land surface model representation of phenology: an analysis of model runs submitted to the NACP Interim Site Synthesis

Andrew D. Richardson, Harvard University, and NACP Interim Site Synthesis Participants

Phenology represents a critical intersection point between organisms and their growth environment. It is for this reason that phenology is a sensitive and robust integrator of the biological impacts of year-to-year climate variability and longer-term climate change on natural systems. However, it is perhaps equally important that phenology, by controlling the seasonal activity of vegetation on the land surface, plays a fundamental role in regulating ecosystem processes, competitive interactions, and feedbacks to the climate system.

Unfortunately, the phenological sub-models implemented in most state-of-the-art ecosystem models and land surface schemes are overly simplified. We quantified model errors in the representation of the seasonal cycles of leaf area index (LAI), gross ecosystem photosynthesis (GEP), and net ecosystem exchange of CO2. Our analysis was based on site-level model runs (14 different models) submitted to the North American Carbon Program (NACP) Interim Synthesis, and long-term measurements from 10 forested (5 evergreen conifer, 5 deciduous broadleaf) sites within the AmeriFlux and Fluxnet-Canada networks.

Model predictions of the seasonality of LAI and GEP were unacceptable, particularly in spring, and especially for deciduous forests. This is despite an historical emphasis on deciduous forest phenology, and the perception that controls on spring phenology are better understood than autumn phenology. Errors of up to 25 days in predicting “spring onset” transition dates were common, and errors of up to 50 days were observed. For deciduous sites, virtually every model was biased towards spring onset being too early, and autumn senescence being too late. Thus, models predicted growing seasons that were far too long for deciduous forests. For most models, errors in the seasonal representation of deciduous forest LAI were highly correlated with errors in the seasonality of both GPP and NEE, indicating the importance of getting the underlying canopy dynamics correct.

Most of the models in this comparison were unable to successfully predict the observed interannual variability in either spring or autumn transition dates. And, perhaps surprisingly, the seasonal cycles of models using phenology prescribed by remote sensing observations was, in general, no better than that that predicted by models with prognostic phenology. Reasons for the poor performance of both approaches will be discussed.

These results highlight the need for improved understanding of the environmental controls on vegetation phenology. Existing models are unlikely to accurately predict future responses of phenology to climate change, and therefore will misrepresent the seasonality of key biosphere-atmosphere feedbacks and interactions in coupled model runs. New data sets, as for example from webcam-based monitoring networks (e.g. PhenoCam) or citizen science efforts (USA National Phenology Network) should prove valuable in this regard.