On the spectral properties of eddy covariance time series

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Co-authorship strategy
Any members of FLUXNET or the broader scientific community who are interested in spectral analysis and willing to provide substantial academic input to the proposed project are welcome as coauthors. If any site PI would rather their data not be used in the proposed synthesis activity, data from their site will not be analyzed.

Background: Over the past 5 years, a number of studies (e.g. [*Baldocchi, et al.*, 2001a; *Falge, et al.*, 2001; *Law, et al.*, 2002]) have explored the spectral properties of long-term eddy covariance (EC)- measured CO_2 and H_2O fluxes. It is clear from these studies that several 'energetic' or 'active' frequencies (i.e. modes, time scales) are predictable. For example, models well-reproduce flux variability at diurnal and seasonal frequencies given their tight coupling to environmental driving variables such as radiation or temperature [*Stoy, et al.*, 2005]. When these well-characterized frequencies are removed from EC time series, the relationship between environmental drivers and ecosystem fluxes becomes more ambiguous and less localized in both time and frequency. In other words, variability in drivers at these frequencies may not translate into EC flux variability at concomitant time scales. These features pose unique challenges to existing ecological models [*Siqueira, et al.*, 2006], and stem in part from the fact that flux varability at a given frequency may have long memory due to both variability in forcing variables and possibly even the initial state of the ecosystem when flux measurements commenced.

To date, few studies have investigated the properties of eddy covariance time series in the frequency domain and the interaction between flux and environmental drivers at multiple frequencies. We intend to explore the frequency characteristics of EC-measured time series on a global spatial scale using a number of modern approaches in time series analysis; namely orthonormal wavelet transformation [*Braswell, et al.*, 2005; *Katul, et al.*, 2001; *Stoy, et al.*, 2005], Fourier decomposition [*Baldocchi, et al.*, 2001a; *Baldocchi, et al.*, 2001b; *Siqueira, et al.*, 2006], singular systems analysis [*Mahecha, et al.*, in open access review], and the Lomb-Scargle periodogram & multiple segmentation to calculate the 'color' of flux time series via the $1/f^{\alpha}$ scaling exponent [*Richardson, et al.*, in review]. By employing multiple time series techniques, we intend to fully characterize the salient features of the flux time series despite some overlap in the methodologies. These features include the possibility of long memory in the flux record, missing data ('gaps'), cospectral relationships between flux and environmental drivers [*Stoy, et al.*, 2005] and flux response at to both climatic events that are localized in time as well as trends at multiple frequencies (e.g. interannual).

The goals of the proposed analysis are to:

1) Identify similarities and differences in the spectra, co-spectra and color of flux time series from similar ecosystems in different climatic zones (and *vice versa*), ideally to characterize 'canonical' relationships between driver and flux for different ecosystems. From this analysis we can also identify the transfer of spectral energy between environmental or hydrologic drivers to ecosystem fluxes [*Katul, et al.*, in press].

2) Investigate the spectral properties of the residuals of a simple ecosystem model with time-varying inputs of environmental drivers, ecosystem characteristics and model transfer parameters [*Stoy, et al.*, 2005]. This analysis is meant to identify the frequencies at which models fail and to identify improvements for process-based ecosystem models.

We anticipate that we will uncover both obvious relationships between environmental driver and flux (e.g. seasonality in deciduous ecosystems), as well as unintuitive responses that will require more detailed investigation, particularly at the longer time scales. An eventual goal of this project is to bridge the gap between intensive EC-based measurements (currently reaching one decade or longer) and studies of the global C cycle which span seasonal to geologic time scales).

We intend that this analysis will be distinct from yet build upon the studies cited above due to its global scope, goal to characterize global ecosystems based on their properties in the frequency domain, and potential to identify the time scales which ecosystem models require improvement. We note that the above analysis is also distinct from FLUXNET proposals regarding short-term disturbance (Luyssaert and others) and ecosystem responses to weather/climate anomalies (C. Williams and others) due to its more general focus and goals to identify model improvements. However, we acknowledge that careful coordination will be required such that research interests are complimentary rather than overlapping.

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