Improving the spatial representativeness and temporal consistency of tower-based eddy-covariance flux measurements using environmental response functions

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Ke Xu[1](kxu35@wisc.edu), Stefan Metzger[2], Natascha Kljun[3], Jeffrey R. Taylor[2], Ankur R. Desai[1]

[1]{University of Wisconsin Madison, Department of Atmospheric and Oceanic Sciences, Madison, Wisconsin, United States of America} [2]{National Ecological Observatory Network, Fundamental Instrument Unit, Boulder, Colorado, United States of America} [3]{Swansea University, Department of Geography, Swansea, Wales, United Kingdom}

THE UNIVERSITY of WISCONSIN MADISON

Abstract

Tower-based eddy-covariance (EC) flux measurements represent a temporally varying surface influence in the immediate vicinity (100-2000 m) of a measurement location. For remote sensing and numerical models, it is desirable to improve spatial representativeness.

Environmental response functions (ERFs) are capable of explicitly relating flux observations (responses) to meteorological forcing and biophysical surface properties (drivers) as they vary across the flux source contribution footprint (Metzger et al., 2013). However, thus far ERF have been developed with and utilized for aircraft-based measurements in the spatial domain. Here, we want to explore the potential of applying ERFs to 'rectify' the spatial representativeness of tower-based EC measurements.

Objectives

- **Apply ERFs to a very tall EC tower to extract relationships between turbulent exchange and biophysical surface properties.**
- **Project EC flux measurements to regional grids (Fig. 7) to explore to whether the ERF method can improve spatial representativeness.**

Method

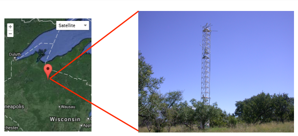


Fig. 1. Overview map and picture of Park Fall tower

- Pilot study with one month of EC observations from the US-PF Park Falls, Wisconsin WLEF tall tower at 122 m in August 2011(Fig. 1)
- MODIS LST, EVI interpolated and downscaled both in time and spatial scale
- Biophysical environmental variables and fluxes by processing fast eddy covariance data with 122m flux data of missing value less than 10%
- Fluxes computed at 1-min time intervals using frequency-domain wavelet processing
- Source area contribution in footprint calculated using footprint parameterization of Kljun et al, (2004).
- ERFs derived based on biophysical surface grids.

Result (1-hour)

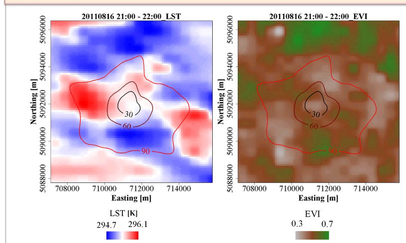


Fig. 2. 1 hour composite flux footprint superimposed over maps of LST and EVI

Result (zoom in 1-minute)

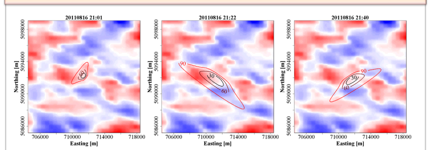


Fig. 3. Composite footprint maps when zooming into 1-min timescales

- Zooming in to smaller flux timescales shows large footprint shifts
- Necessary to process turbulence data at comparatively short time intervals

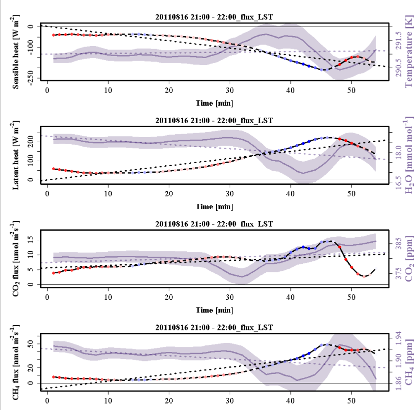


Fig. 4. Change of LST in the footprint of 1 minute observation superimposed on the variation in flux and concentration.

- In this case, during 30 and 50 min should be the Oasis effect of a wet patch
- Sensible heat, latent heat, CO_2 and CH_4 here significantly change due to this wet patch.

Result (Environmental response functions)

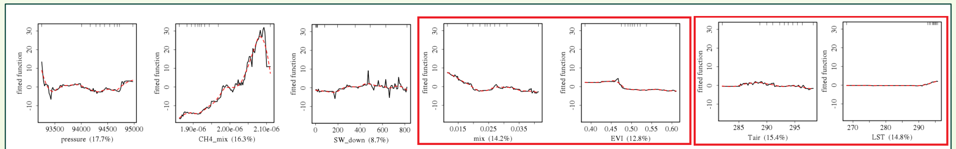


Fig. 5. Partial dependence plots show the effect of each individual variable on the methane response (nmol m-2 s-1) based on ERF method.

- Most important responses of CH_4 flux (nmol m^{-2} s^{-1}) is CH_4 mixing ratio.
- When pressure decreases, CH_4 flux increases possibly from soil suction effects.
- CH_4 exchange also shows positive relationship with short wave radiation.
- Flux response function achieved by calibrating flux gradient relationship. Here we set two pairs of variables (Tair, LST) (H_2O_mixing, EVI) representing temperature and wetness/greeness of the atmosphere and the surface separately.
- Surprisingly, CH_4 response decreases with higher water vapor mixing ratio.

CH_4 flux prediction grids

Fig. 6.

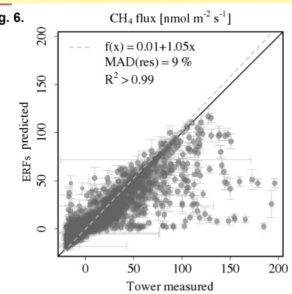
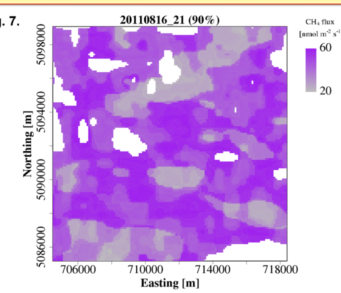


Fig. 7.



- Observation (N= 22840) and tower ERF prediction match well for CH_4 flux.
- Resulting flux grids for CH_4 flux cover 90% of 14x14 km spatial domain.
- More CH_4 emission released from warm and dry regions around the tower

Conclusion

1. ERFs allow one to decompose and extrapolate surface-atmosphere exchange of different land covers from a single tower
2. Spatio-temporally continuous predicted flux grids obtained within 14 km * 14 km around 122m level tower measurement. For this area, the tower measurements provide a good coverage of the environmental state-space.
3. When extending the prediction area, e.g., 100 km * 100 km, the representative coverage of prediction is around 60%.
4. The meteorological and biophysical drivers actually influence the combination of flux and storage term, so storage term will be considered in ERFs in further study.

Reference

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Companion Talk: Mon. Dec 9th 5 pm B11G-0437 by Stefan Metzger

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