Understanding the representativeness of FLUXNET for upscaling carbon flux from eddy covariance measurements

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Introduction

FLUXNET links regional networks of eddy covariance sites across the globe to quantify the spatial and temporal variability of fluxes at regional to global scales and to detect emergent ecosystem properties. The locations of the sites in the network were not formally designed to uniformly and consistently observe global biomes and thus represent a sparse and spatially biased sampling of the global terrestrial ecosystem. Careful synthesis of spatio-temporally sparse flux observations is required to understand the regional to global scale carbon cycle. Upscaling of fluxes to regional to global scales requires understanding and quantification of the spatial representativeness of the global network of flux sites.
In this study, we conduct a systematic quantitative assessment of representativeness of observations collected at global FLUXNET network sites and develop a a scheme for statistical upscaling of eddy covariance fluxes at high spatio-temporal resolution.

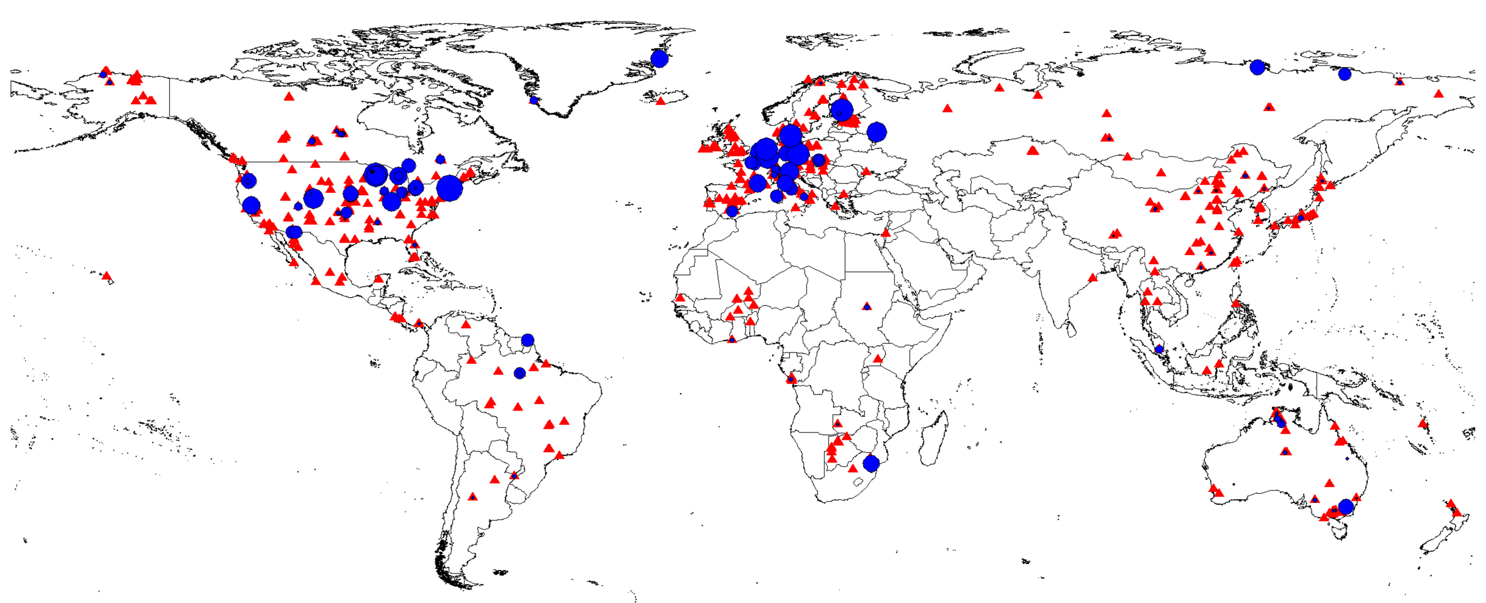


Figure 1: *Global network of FLUXNET sites (Red triangle: registered FLUXNET sites (∼770); Blue circle: FLUXNET2015 site (165))*

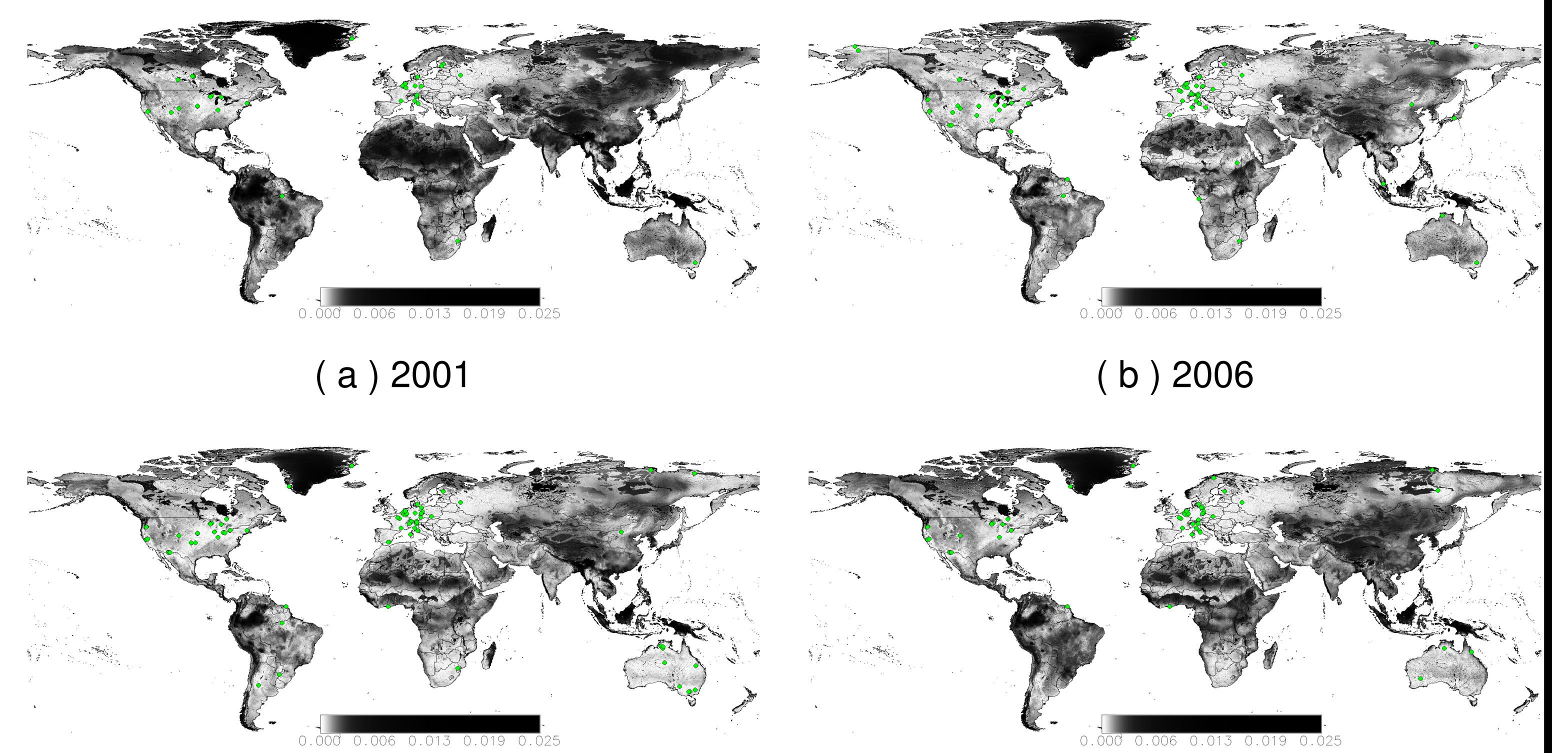
While over ∼770 sites are registered within FLUXNET network, data is available from only a limited number of sites (165 in FLUXNET2015 release). In addition, the sites often come and go out of operation and thus an assessment of available data was conducted.

Table 1: *Environmental variables used for ecoregion delineation, representativeness analysis and upscaling. These data are in the form of ∼4 km raster grids.*

Variable Description	Units	Source
Bioclimatic Variables		
Annual mean temperature	°C	Hijmans et al. (2005)
Mean diurnal range	°C	Hijmans et al. (2005)
Isothermality	–	Hijmans et al. (2005)
Temperature seasonality	°C	Hijmans et al. (2005)
Temperature annual range	°C	Hijmans et al. (2005)
Mean temperature of wettest quarter	°C	Hijmans et al. (2005)
Mean temperature of driest quarter	°C	Hijmans et al. (2005)
Mean temperature of warmest quarter	°C	Hijmans et al. (2005)
Mean temperature of coldest quarter	°C	Hijmans et al. (2005)
Annual precipitation	mm	Hijmans et al. (2005)
Precipitation during the wettest quarter	mm	Hijmans et al. (2005)
Precipitation during the driest quarter	mm	Hijmans et al. (2005)
Precipitation during the warmest quarter	mm	Hijmans et al. (2005)
Precipitation during the coldest quarter	mm	Hijmans et al. (2005)
Edaphic Variables		
Available water holding capacity of soil	mm	Global Soil Data Task Group (2000); Saxon et al. (2005)
Bulk density of soil	g/cm^3	Global Soil Data Task Group (2000); Saxon et al. (2005)
Soil carbon density	g/m^2	Global Soil Data Task Group (2000); Saxon et al. (2005)
Total nitrogen density	g/m^2	Global Soil Data Task Group (2000); Saxon et al. (2005)
Topographic Variables		
Compound topographic index (relative wetness)	–	Saxon et al. (2005)

Representativeness of FLUXNET2015

Representativeness of a measurement site is the extent to which the measurements collected at any given location and time rep- resent the conditions at any other location and time. Eddy covariance flux towers measure a range of meteorological and flux variables. While the measurements captured by the sensors are direct measures of a small region in the footprint of the tower, understanding the representativeness of the measurements for a broader landscape is critical for upscaling of point measurements to the larger area. Representativeness was calculated as Euclidean distance of each map pixel containing a site from every other pixel on the map was calculated in the standardized n-dimensional data space (Table 1). When a network of sites is present, the Euclidean distance for the site closest to the pixel in data space was selected as the representativeness of that pixel.



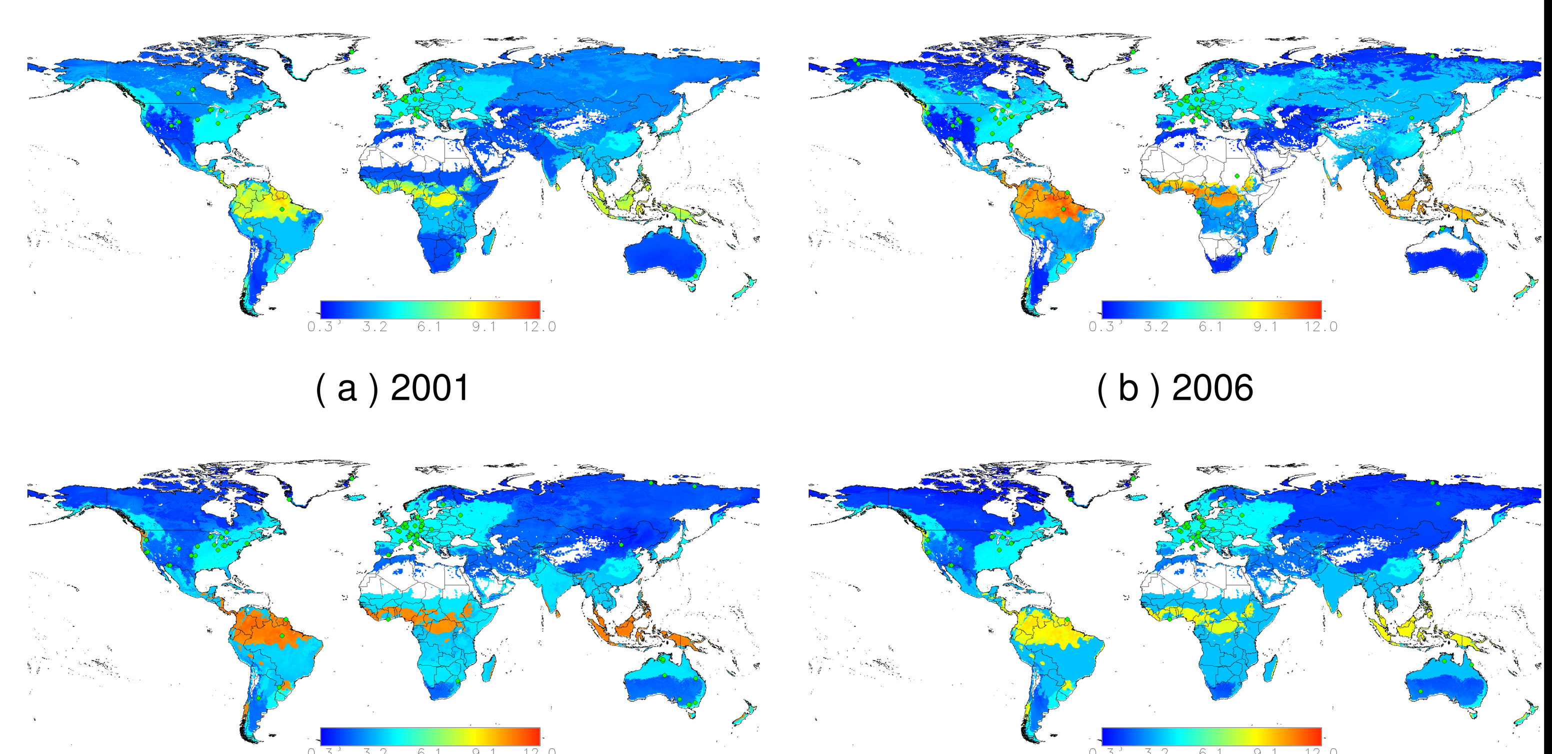
(a) 2001 (b) 2006 (c) 2011 (d) 2014

Figure 2: *Evolution of FLUXNET2015 representativeness during 1996-2014*

Figure 2 show the evolution and improvement in spatial representativeness of FLUXNET network over time as new sites were added globally. However, tropical and high latitude regions continue to be under-represented by the current network of sites.

Representativeness based upscaling of eddy covariance fluxes

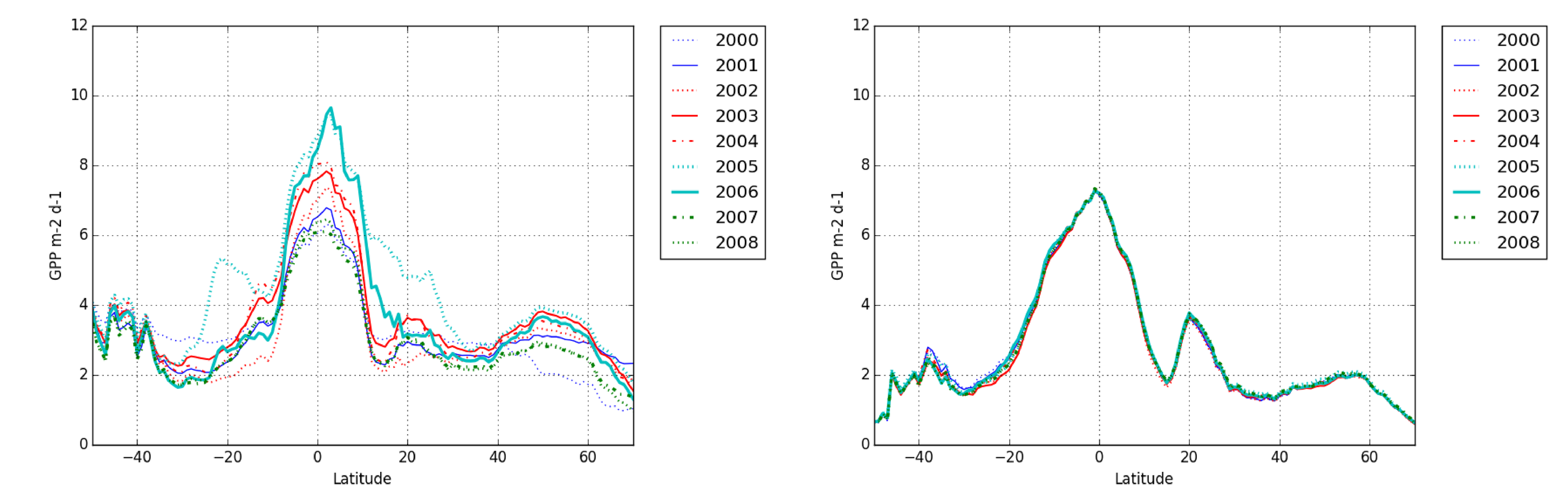
Quantitative representativeness of network sites can be utilized to upscale flux estimates to larger spatial and temporal scales for input to or evaluation of process modeling or for estimating landscape-scale characteristics.



(a) 2001 (b) 2006 (c) 2011 (d) 2014

Figure 3: *Upscaled GPP: time integrated annual mean*

We developed and applied a Inverse Distance Weighted scheme to upscale GPP observation from global FLUXNET network to develop a global gridded 4 km resolution monthly GPP time series product.



(a) Upscaled GPP (b) FLUXNET-MTE

Figure 4: *Upscaled GPP: interannual variability during 2000-2008*

Comparison with FLUXNET-MTE GPP data set, upscaled GPP product show improved spatial distribution, and a more realistic interannual variability in GPP fluxes during 2000-2008.

Tropical Observation Networks

In various regions of globe, especially Tropics, a number of observation network exist that collect complementary observations. Quantitative representativeness analysis would allow optimal use of observations from existing networks, help identify gap in current sampling strategies and design new campaigns.

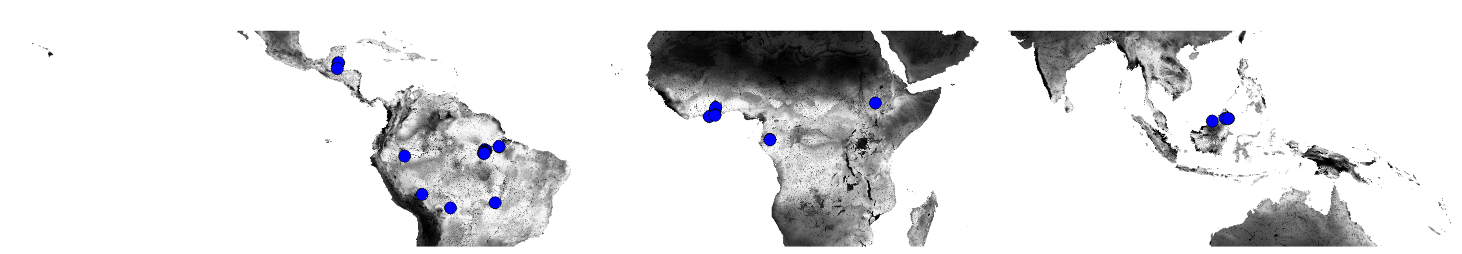


Figure 5: *Quantitative representativeness of GEM network of sites (blue circles show the locations of GEM sites)*

Figure 5 show the representativeness of the 67 sites in GEM (Global Ecosystem Monitoring) network. With a extensive network of sites, observations from GEM network can be great value and supplement observations from networks like FLUXNET. Figure 6 show the regions of Tropics where observations from GEM network help improve the flux observations from FLUXNET.

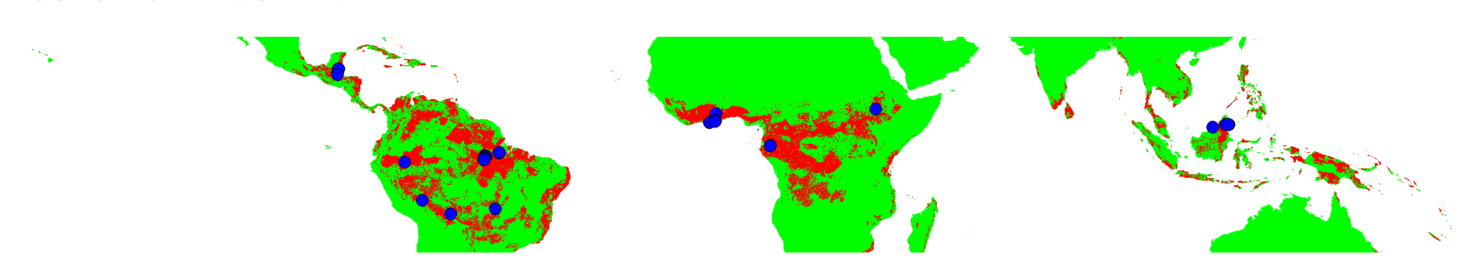


Figure 6: *Representation by multiple observation networks (in red are the regions where GEM network provide improved representation over FLUXNET network)*

Summary

Representativeness based method developed here presents a quantitative tool to design of optimal sampling strategies, quantitative assessment of existing observations and provides a systematic method for upscaling of point measurements.

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