

How well do flux towers observe the landscape? Depicting a northern Wisconsin forest by integrated ecology, dendrochronology and remote sensing

Matt Bizjack¹, Bjorn Brooks^{2*}

1. University of Chicago, Department of Geophysical Sciences

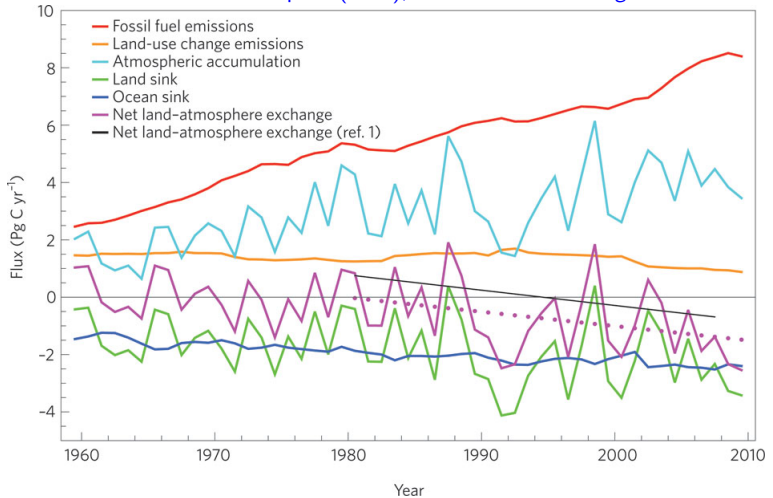
2. University of Illinois, Urbana-Champaign, Dept. of Atmospheric Sciences

* Presenting author

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Problem Statement: Where's the missing sink?

Taken from Raupach (2011), *Nature Climate Change*



Measuring atmospheric CO₂ fluxes from the bottom up

Tower Representativeness

Bizjack & Brooks

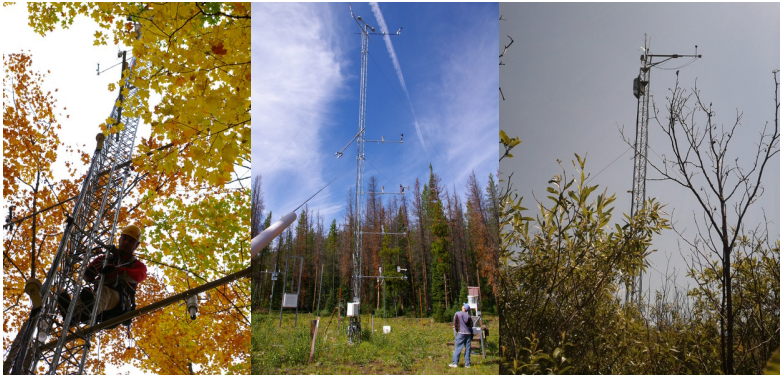
- Eddy covariance towers observe instantaneous exchanges of carbon, water, and energy.

BACKGRND

PLAN

RESULTS

ANALYSIS



Measuring atmospheric CO₂ fluxes from the bottom up

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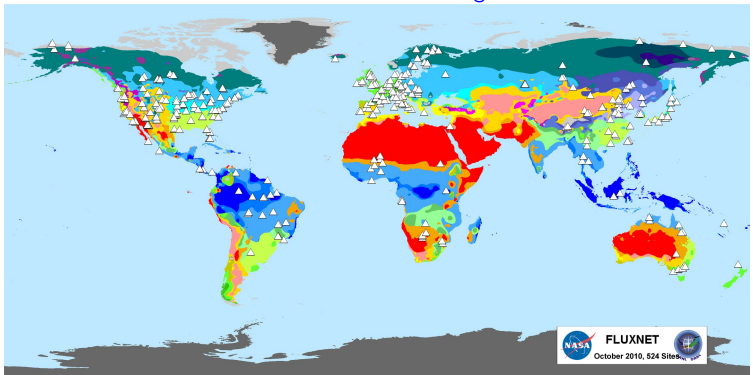
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- FluxNet is a global cooperative of 500+ continuously running towers, about one-fifth of which are in North Am.

Taken from fluxnet.ornl.gov



Network coverage in climate space

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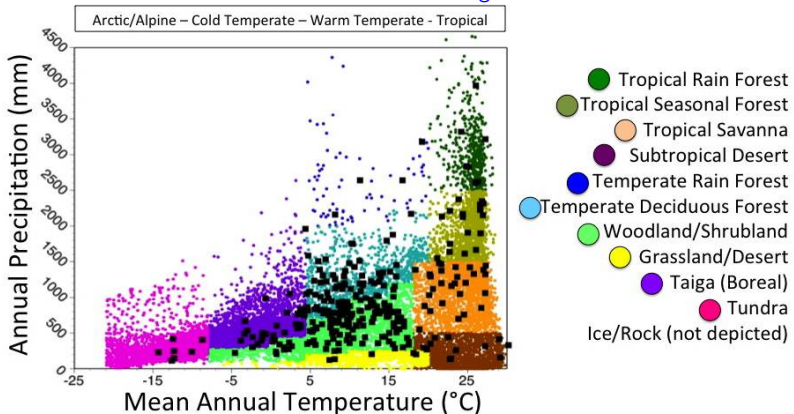
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- Sampling of FluxNet towers across temp.-precip. regimes

Taken from fluxnet.ornl.gov



'Scale me up Scotty'

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RESULTS

ANALYSIS

- Flux towers are indispensable for site level (1 km^2) whole ecosystem monitoring & verification
- What about using them on regional scales?
- Tall towers; Upscaling [Xiao 2008](#); [Jung 2009](#); [Sulkava 2011](#)



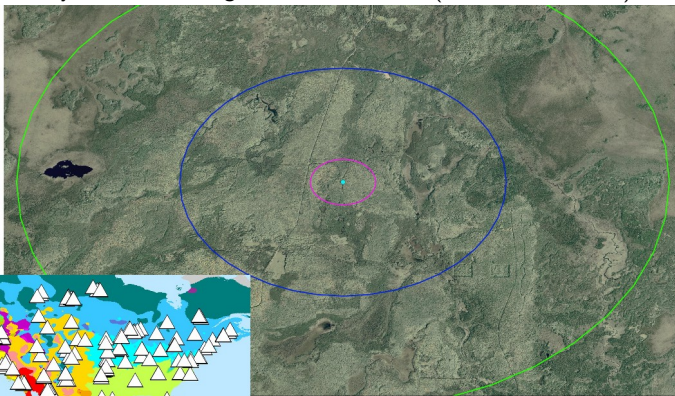
Obstacles to upscaling

- 1 Limited global sampling network
- 2 Landscape heterogeneity
(but see representativeness study by [Hargrove, Hoffman & Law 2003](#))
- 3 Interannual variability



Study site: Northern Wisconsin

Study area surrounding Willow Creek tower (northern Wisconsin)



Area around Willow Creek Atmosphere Study Tower with circles at 0.5km, 2.5km, and 5km radii outlining the extremes of 1km², 5km², and 10km² square plots around the tower.

Here's what we did

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RESULTS

ANALYSIS

- Forest Inventory Analysis data
- Multi-band surface reflectance 2006-2009 from Landsat
- New data from one Wisconsin **ChEAS** tower



Forest Inventory Analysis

Tower Representativeness

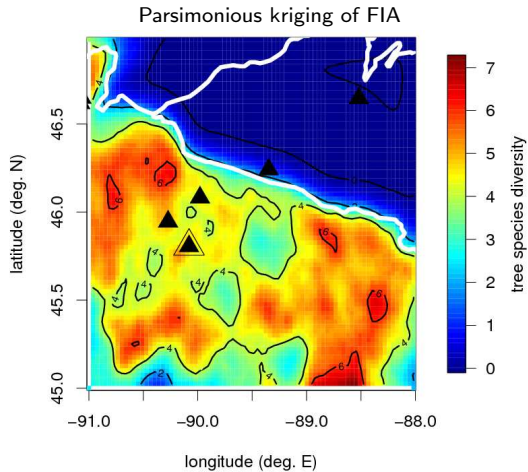
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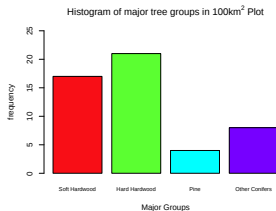
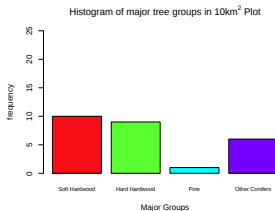
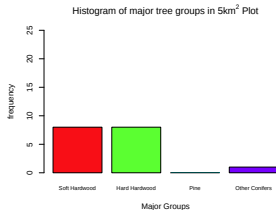
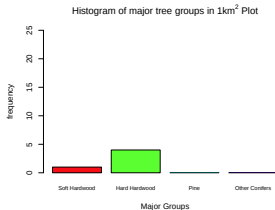
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ANALYSIS



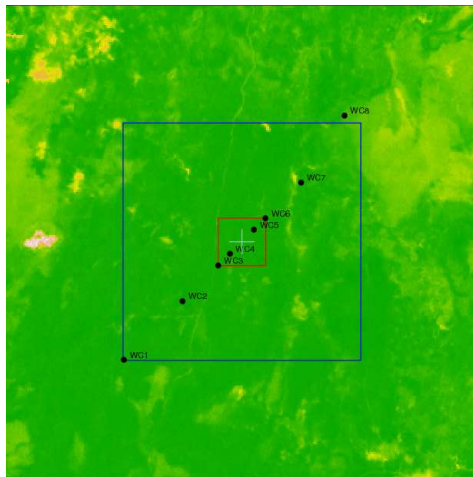
Forest Inventory Analysis

Histogram of FIA data on community composition across domain sizes



Landsat Normalized Difference Vegetation Index

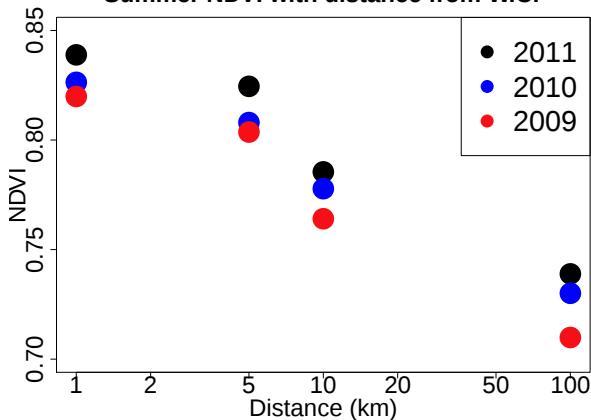
Domain-wide NDVI



Landsat Normalized Difference Vegetation Index

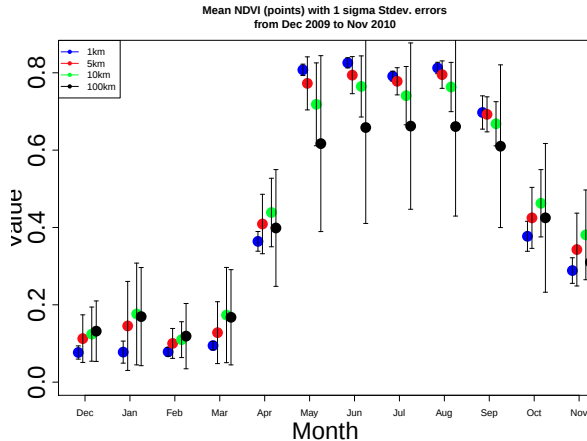
Growing season NDVI across domain sizes

Summer NDVI with distance from W.C.



Landsat

Monthly NDVI across domain sizes



Sample plots

Table: Plot descriptions

Plot	Lat,Lon	Canopy Cover	Notes
WC1	45.78,-90.11	65%	Elongate clearing trending East-West. Understory dominated by ash saplings
WC2	45.79,-90.09	95%	Slopes east. West half is 2m higher than east. Dense understory of ironwood/maple saplings
WC3	45.80,-90.08	85%	Relatively clear understory
WC4	45.80,-90.08	85%	Relatively clear understory with small area of hardwood saplings
WC5	45.80,-90.07	85%	Maple dom., rltv. open understory, few h'dwood sap. Grass, leaf litter. SW corner 2m ̳ NW
WC6	45.81,-90.07	85%	Rltv. open understory, some shrubs and hardwood saplings. Ferns, grasses
WC7	45.81,-90.06	60%	Aspen, even aged domin. Understory mix h'wood blkbry. Litter, downed trees. Moist soil. Frns,grs.
WC8	45.82,-90.05	80%	Not planned loc. Cedar dom. Moist fen. Moss, treefall. Supressed h'wood. Many dead trees.

Sample plots

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PLAN

RESULTS

ANALYSIS

Table: Plot biometrics

Plot	Tree Cnt.	Avg/Total DBH (cm)	Max/Min DBH (cm)	Total biom. (kg)	Biomass (Mt/ha)	Species
WC1	28	17.2/482.0	5.0/61.5	10615.9	212.3	BW HL ...
WC2	34	16.8/572.5	5.9/51.4	10799.0	216.0	BC IW ...
WC3	23	25.3/581.4	7.9/63.3	11590.5	231.8	BW GA ...
WC4	41	19.4/796.4	5.2/46.9	13570.4	271.4	BW GA ...
WC5	48	17.5/839.5	6.0/33.3	8866.0	177.3	BW IW ...
WC6	73	15.0/1093.4	5.0/56.2	8575.4	171.5	BO BW ...
WC7	55	11.5/629.9	5.0/21.9	1921.3	38.4	QA PB ...
WC8	86	14.6/1255.1	5.2/40.4	4361.1	87.2	HL WC ...

Landsat

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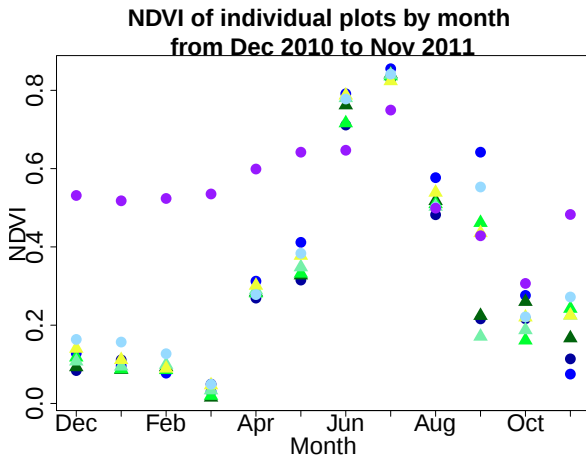
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RESULTS

ANALYSIS



NDVI as an indicator of plot characteristics

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PLAN

RESULTS

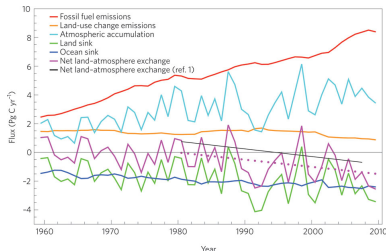
ANALYSIS

Table: Comparison of 30 m-NDVI to 22 m-sample-plot data. Data are mean centered & normalized. This shows skill of Landsat as proxy at plot scale. Correlations (r) to NDVI across 8 plots are also given

Plot	Ann.NDVI	No.Trees	Tot.DBH	Tot.Bmass
WC1	-0.80	-0.93	-1.10	+0.47
WC2	+0.08	-0.66	-0.76	+0.52
WC3	-0.55	-1.16	-0.73	+0.72
WC4	-0.43	-0.34	+0.06	+1.24
WC5	-0.55	-0.02	+0.21	+0.02
WC6	-0.17	+1.11	+1.14	-0.05
WC7	+0.08	+0.30	-0.55	-1.77
WC8	+2.35	+1.71	+1.74	-1.14
NDVI r	-	0.76	0.70	-0.58

Re-cap of motivations

- 1 Inv & Fwd model estimates still lack capability to verify the location & interannual variability of ecoregions needed to resolve the missing sink
- 2 Because of (1) we do not know how to properly parameterize carbon exchange processes as a function of scale (cf. [Desai 2011](#))
- 3 Consequently we also do not agree no how to evaluate models when confronted with observations of C exchange



Analysis of FIA and Landsat against the site level data

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PLAN

RESULTS

ANALYSIS

- 1 We sampled 0.2% of the total WC footprint (1 km^2) and 0.02% of the 5 km^2 area. We found twice the tree diversity of FIA for the WC footprint area, but about the same diversity for the 5 km^2 area suggesting that FIA similarly represents less than a 1% sampling of trees in the local area
- 2 Pixel vs. plot comparison shows that Landsat NDVI has a weak neg. relationship to AGB ($r \sim -0.6$), but may be suitable indicator for tree density and DBH ($r \sim 0.7$)
- 3 Poor NDVI/AGB relationship reflects lack of species specificity in surface reflectance information
- 4 Tree cores analysis (ongoing) will inform how significant missing species specificity is to carbon uptake rate

Upscaling caveats:

WC over-represents vegetation cover and AGB

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PLAN

RESULTS

ANALYSIS

- ① (To the level that NDVI reflects tree density & DBH) the footprint (1 km^2) of WC **over represents** the amount of vegetation cover of the larger 100 km domain by **$\sim 10\%$**
 - However lack of sp. specificity in Landsat data & weak correlations to plot data suggest inferences about biomass (or C-uptake) from NDVI alone would not be realistic
- ② Plot level estimates indicate that AGB is **20% greater within the WC footprint** than at the 5 km^2 scale
- ③ Although FIA and sample plots indicate that WC footprint lacks the heterogeneity of communities represented at 5 km scale and greater *tree cores will determine whether or not this translates into significant sampling limitation* of historical carbon uptake

Acknowledgements

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PLAN

RESULTS

ANALYSIS

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