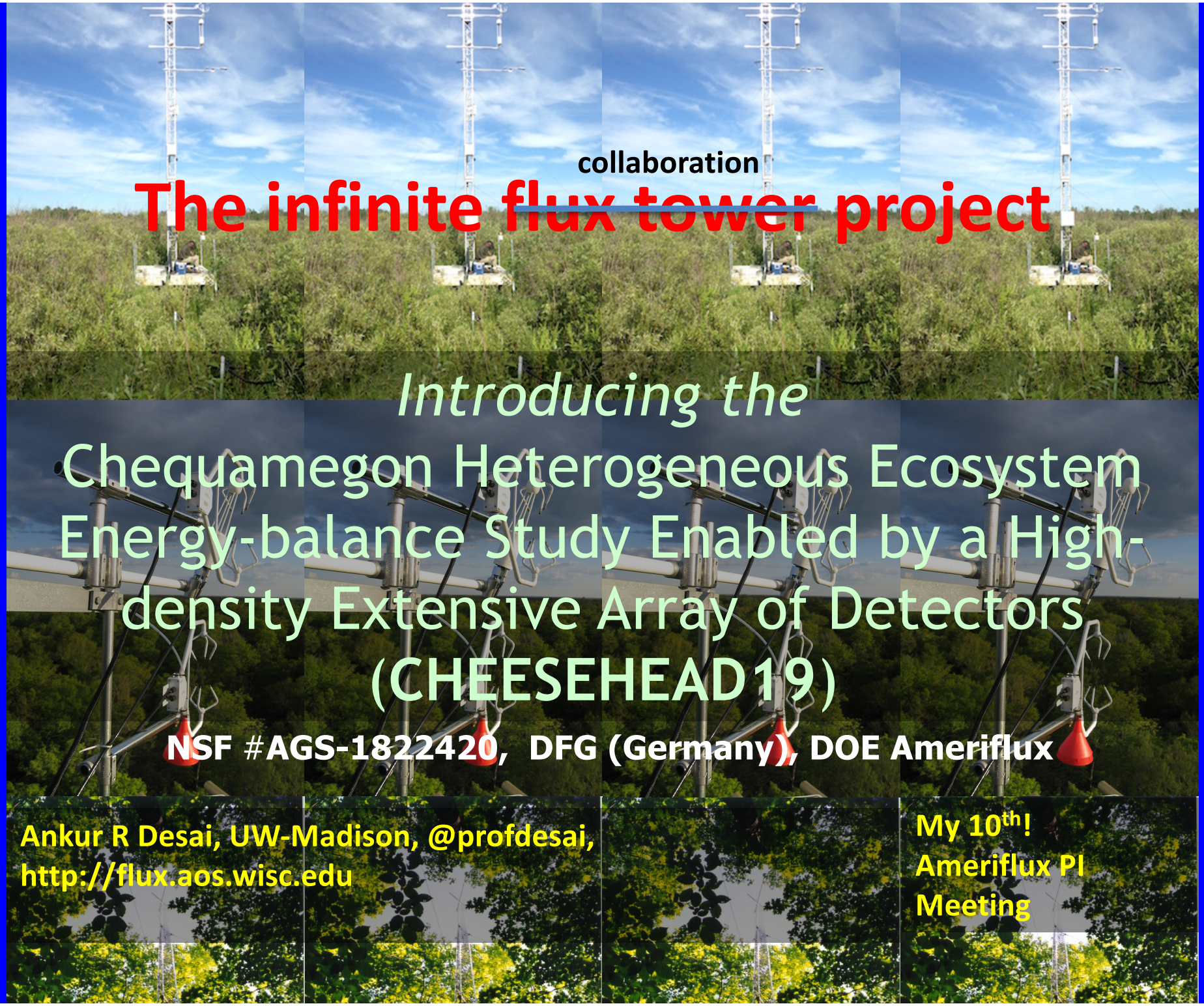


collaboration

The infinite ~~flux tower~~ project

Introducing the

Chequamegon Heterogeneous Ecosystem Energy-balance Study Enabled by a High-density Extensive Array of Detectors (CHEESEHEAD19)

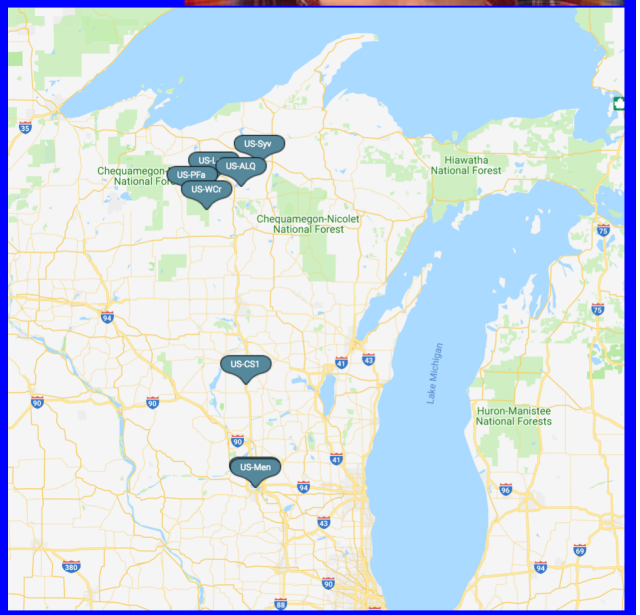
NSF #AGS-1822420, DFG (Germany), DOE Ameriflux

Ankur R Desai, UW-Madison, @profdesai, http://flux.aos.wisc.edu

My 10th! Ameriflux PI Meeting

First, an advertisement, meet and use our t

- Our Upper Midwest sites:
  - US-PFa (1997-), very tall tower (fluxes at 30, 122, 396 m)
  - US-WCr (1999-), mature northern hardwood
  - US-Los (2000-), fen shrub wetland
  - US-Syv (2001-), old-growth mixed forest
  - US-Men (2012-2018), Lake Mendota shoreline (LTER)
  - US-PnP (2016-), Lake Mendota peninsula (LTER)
- New sites:
  - US-CS1 (2018), center pivot irrigated potato
  - US-ALQ (2018), grass fen, stream (USGS)
- Upcoming:
  - US-CS2 (2018), central sands pine plantation
  - US-DFC (2018), USDA dairy farm restoration
  - US-DF? (2019), Kernza perennial wheat
- All online, in near real-time, thanks to hard work of Jonathan Thom and others: http://flux.aos.wisc.edu/twiki/bin/view/Main/ChEASData



Yes, I am shameless

Another advertisement

- Submit your Ameriflux papers to JGR-G (Biogeosciences)
  - Model/flux editors: Ankur Desai, Debbie Huntzinger
  - Flux-y associate editors: Elise Pendall, Gil Bohrer, Ian Baker, Claire Phillips, Rodrigo Vargas, Patrick Crill, Dave Moore, Shuli Niu, George Vourlitis, Diego Riveros-Iregui, Jing Chen
  - < 45 (+/- 30) day average time to first decision
  - Special issues:
    - "MexFlux: advances in ecosystem carbon and water fluxes across Mexico"
    - "Carbon and Weather: Results from the Atmospheric Carbon and Transport – America mission"
    - "Extreme Climate Event Impacts on Aquatic Biogeochemical Cycles and Fluxes"
  - Strictly enforced publication data policy

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JOURNAL OF GEOPHYSICAL RESEARCH
Biogeosciences
AN AGU JOURNAL

Research Article

Fluxes all of the time? A primer on the temp… representativeness of FLUXNET

JOURNAL OF GEOPHYSICAL RESEARCH
Biogeosciences
AN AGU JOURNAL

Research Article

A Unique Combination of Aerodynamic and Surface Properties Contribute to Surface Cooling in Restored Wetlands of the Sacramento-San Joaquin Delta, California

Kyle S. Hemes, Elke Eichelmann, Samuel D. Chamberlain, Sara H. Knox, Patricia Y. Oikawa, Cove Sturtevant, Joseph Verfaillie, Daphne Szutu, Dennis D. Baldocchi

JOURNAL OF GEOPHYSICAL RESEARCH
Biogeosciences
AN AGU JOURNAL

Commentary | Free Access

Data Sharing and Scientific Impact in Eddy Covariance Research

B. Bond-Lamberty

First published: 26 March 2018 | https://doi.org/10.1002/2018JG004502

Gerard Kiely, Gitta Lasslop, Miguel D. Mahecha, Hank Margolis, L…

First published: 14 September 2015 | https://doi.org/10.1002/201…

and Fluxes"
– Strictly enforced pub…

Impact of hydrological variations on modeling of peatland CO_2 fluxes: Results from the North American Carbon Program site synthesis

Benjamin N. Sulman, Ankur R. Desai, Nicole M. Schroeder, Dan Ricciuto, Alan Barr, Andrew D. Richardson, Lawrence B. Flanagan, Peter M. Lafleur, Hanqin Tian, ... See all authors

First published: 10 March 2012 | https://doi.org/10.1029/2011JG001862 | Cited by: 19

In the beginning…

- Wanted to measure fluxes “everywhere and all of the time” [Chu et al., 2018]
- But we can’t just keep building more flux towers, could we?

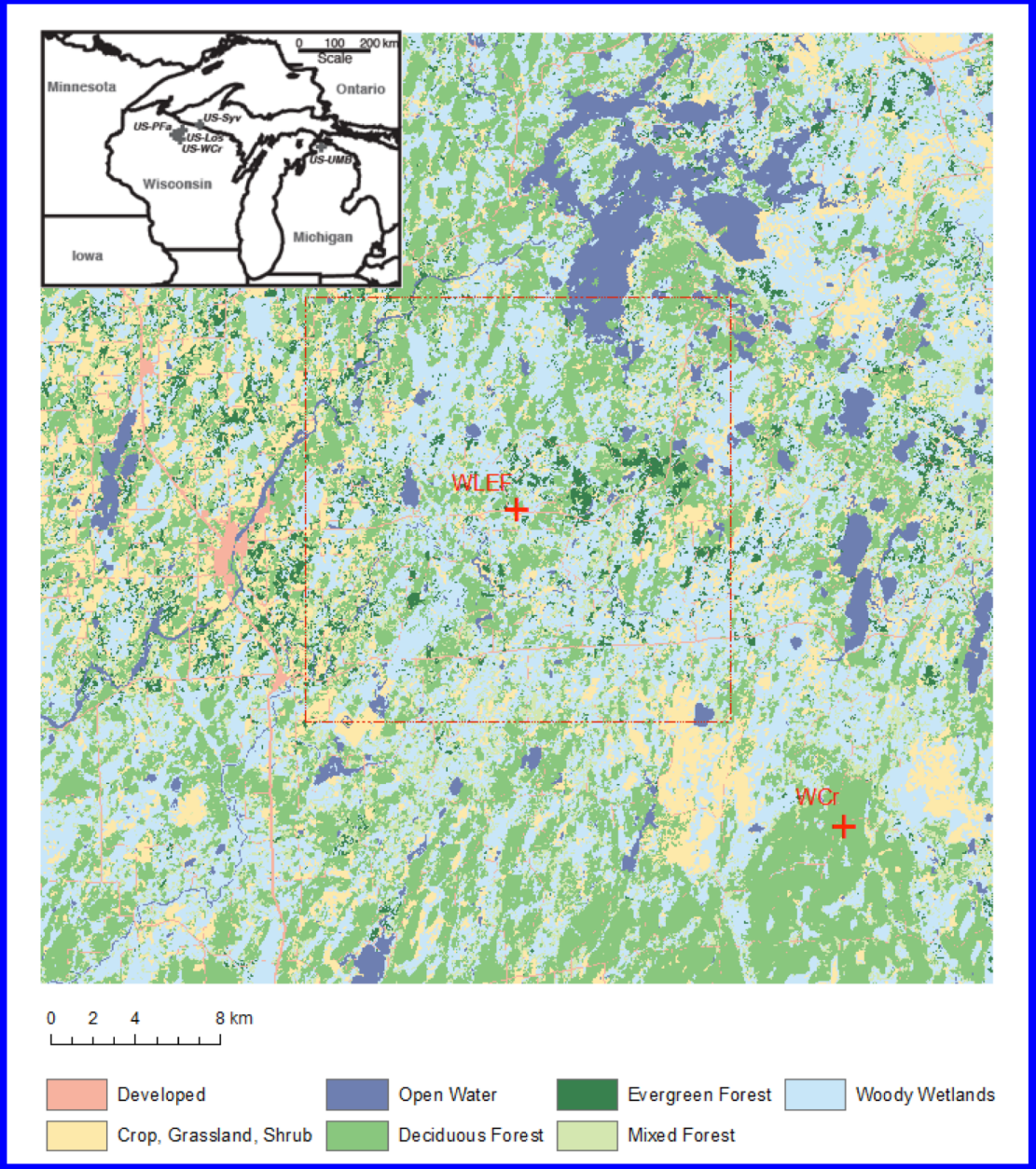
בְּרֵאשִׁית

So how does that lead to this?

Park Falls/Chequamegon-Nicolet National Forest region, Wisconsin

Park Falls WLEF tower (US-PFa)
EC fluxes at 30, 122, 396 m
NOAA tall tower greenhouse gas site
COSMOS soil moisture
TCCON column GHG

Credit: Matt Rydzik (U Wisconsin)



Desai et al., 2015, AFM

Park Falls/Chequamegon-Nicolet National Forest region, Wisconsin

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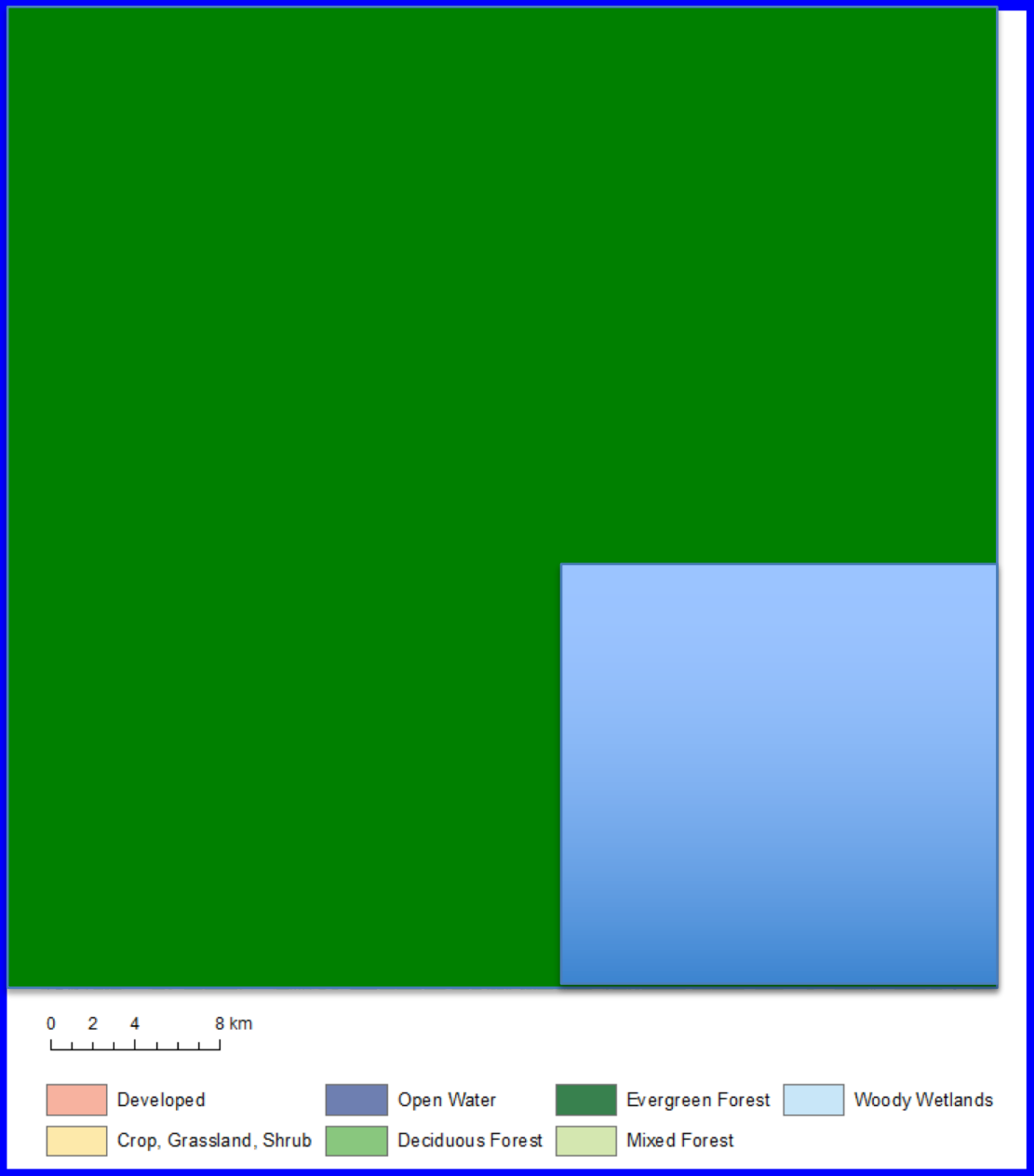


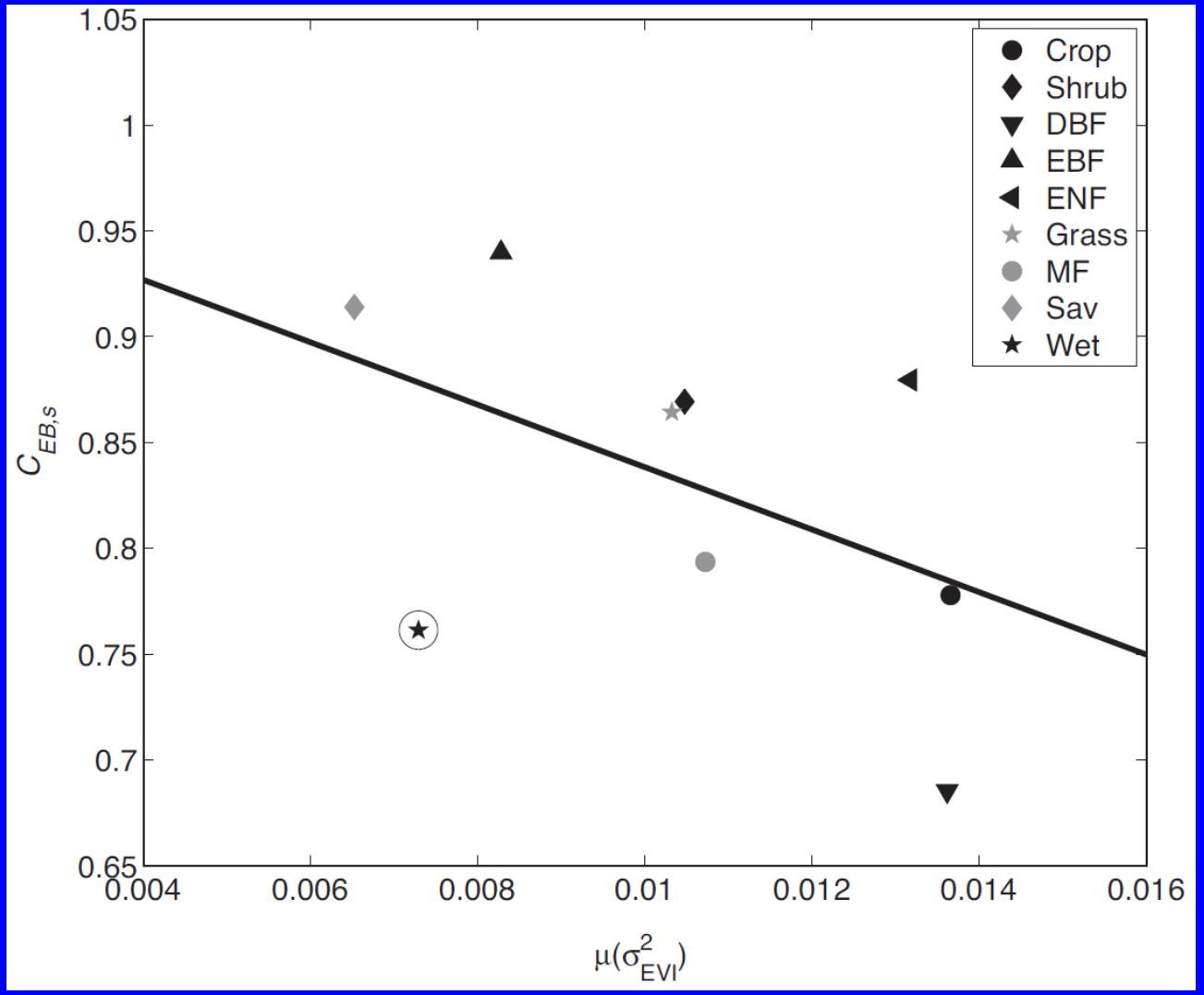
Credit: Matt Rydzik (U Wisconsin)

Desai et al., 2015, AFM

Paul Stoy is almost always right

EBC=
H+Le

Rnet-G



Greenness spatial variance

Stoy et al., 2013, AFM

Landscape variance potentially drives stationary eddies

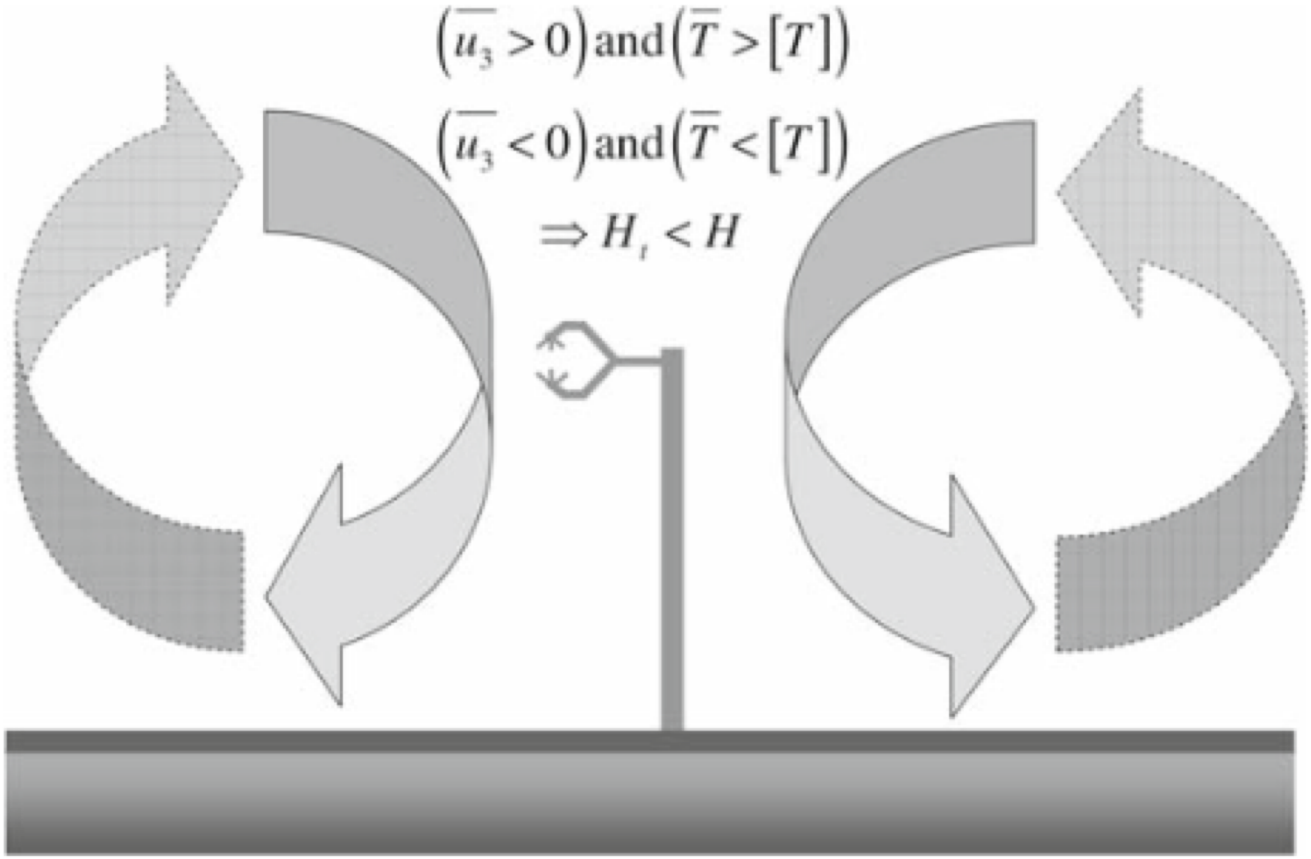


Fig. 1 Schematic showing how quasi-stationary eddies cause an underestimation of the total sensible heat flux H when using the temporal EC method to calculate H_t. The single-point sonic measurement in the centre is not able to resolve quasi-stationary eddies

Mauder et al., 2008, BLM

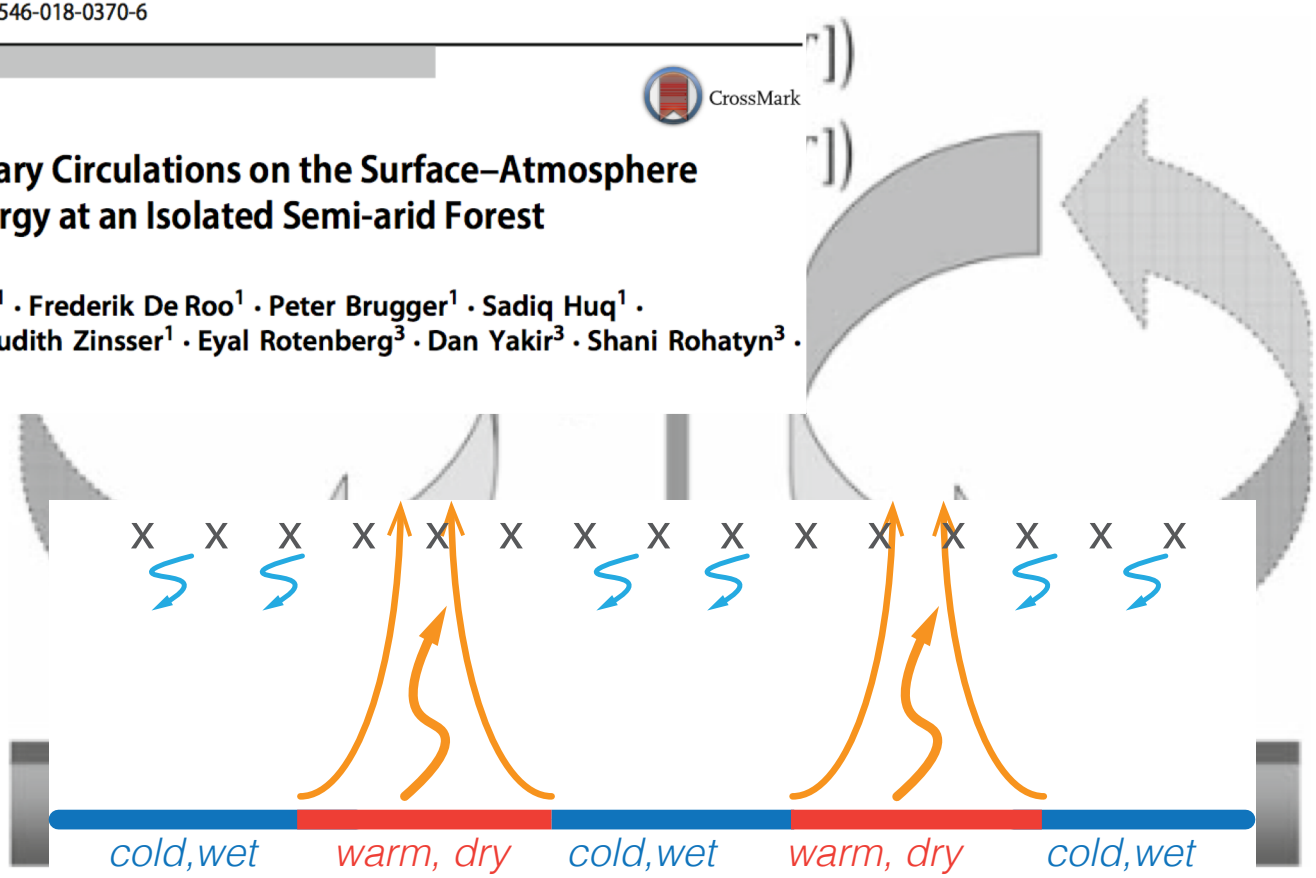
Landscape variance potentially drives stationary eddies

Boundary-Layer Meteorology (2018) 169:209–232
https://doi.org/10.1007/s10546-018-0370-6

RESEARCH ARTICLE

Effect of Secondary Circulations on the Surface–Atmosphere Exchange of Energy at an Isolated Semi-arid Forest

Konstantin Kröniger[1] · Frederik De Roo[1] · Peter Brugger[1] · Sadiq Huq[1] · Tirtha Banerjee[1,2] · Judith Zinsser[1] · Eyal Rotenberg[3] · Dan Yakir[3] · Shani Rohatyn[3] · Matthias Mauder[1]



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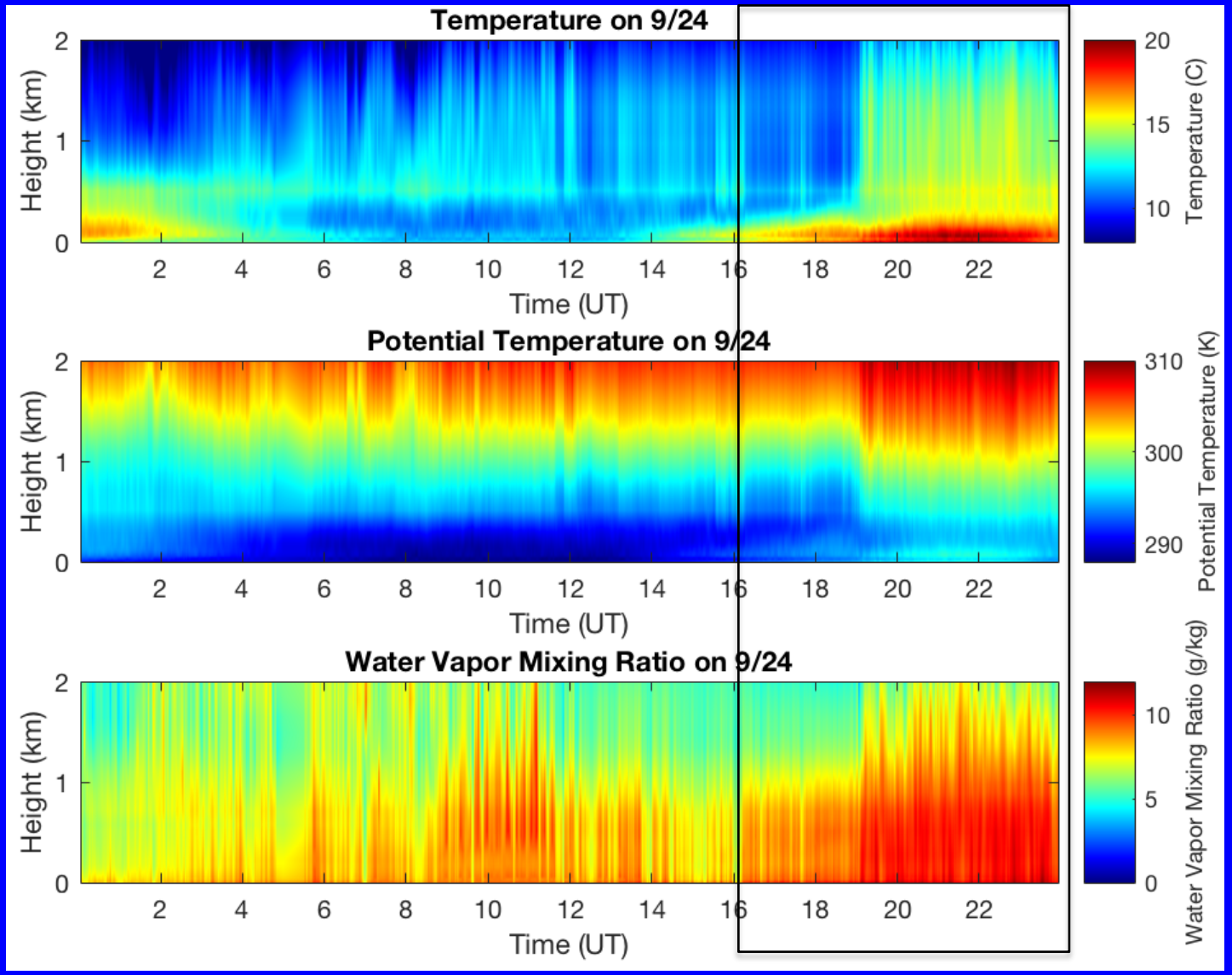
Mauder et al., 2008, BLM

Atmospheric Emitted Radiance Inferometer (AERI) at tall tower in fall demonstrates existence of large roll eddies > flux averaging time even near surface



QUESTIONS?????

- How homogenous is homogenous enough?
  - How well does a single eddy flux tower represent a typical earth system model domain (10x10 km) mean surface energy fluxes and how does mean flux and energy balance closure vary with surface flux heterogeneity?
- How many flux towers are towers enough?
  - If you had multiple towers, how many would you need before sufficiently sampling domain mean flux? Are there smarter ways to compute the mean flux when you have multiple towers?
- When and where does local surface heterogeneity drive local atmosphere circulations?
  - How does the presence or absence of these circulations influence the reliability and representativeness and energy balance closure of single-point eddy covariance flux tower measurements?

Chequamegon Heterogeneous Ecosystem Energy-balance Study Enabled by a High-density Extensive Array of Detectors (CHEESEHEAD19)

http://flux.aos.wisc.edu/twiki/bin/view/Main/CHEESEHEAD19

Ankur R Desai, U. Wisconsin-Madison (PI)
Grant Petty, U. Wisconsin-Madison (co-PI, UW Ultralight)
Phil Townsend, U. Wisconsin-Madison (co-PI, UW SpecEx)
Mark D Schwartz, U. Wisconsin-Milwaukee (co-PI, Phenology)
Stefan Metzger, NEON/Battelle (co-PI, ERF, NEON Assets)
Matthias Mauder, Karlsruhe Institute of Technology (co-I, LiDAR/LES)
Rose Pertzborn, U. Wisconsin-Madison (co-I, K-12 outreach)
Paul Stoy, Montana State University (co-I, towers + being rarely wrong)

+Instrument PIs: Al Rodi (U Wyoming King Air), Steve Oncley (NCAR ISFS), Bill Brown (NCAR ISS), Tim Wagner (SSEC SPARC), Eric Kruger (UW, Biometry), Ryan Pavlick (NASA JPL, CFIS), Randy Kawa (NASA GSFC, CARAFE), Joel McCorkel (NASA GSFC, CAMSIS)

NSF, Physical and Dynamic Meteorology, #**AGS-1822420**

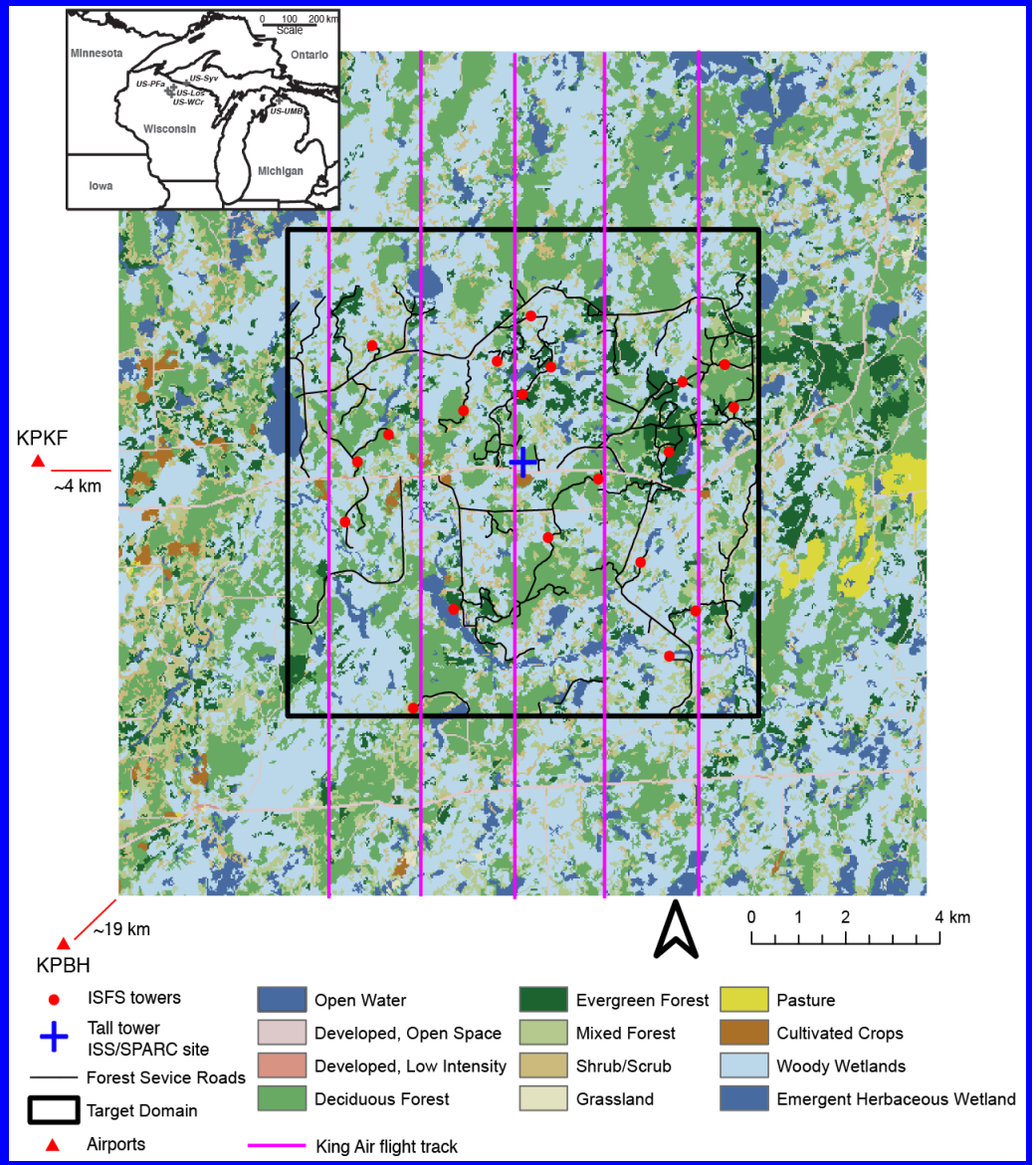
Experimental Design (Not BOREAS-II)

- Distribute 17 rapid-deployment eddy covariance flux towers (red dots) within 10x10 km box (black box, right) around US-PFa WLEF tall tower (blue cross).
- Run July-Oct 2019
- Ecophys, NPP, and phenology bi-weekly sampling

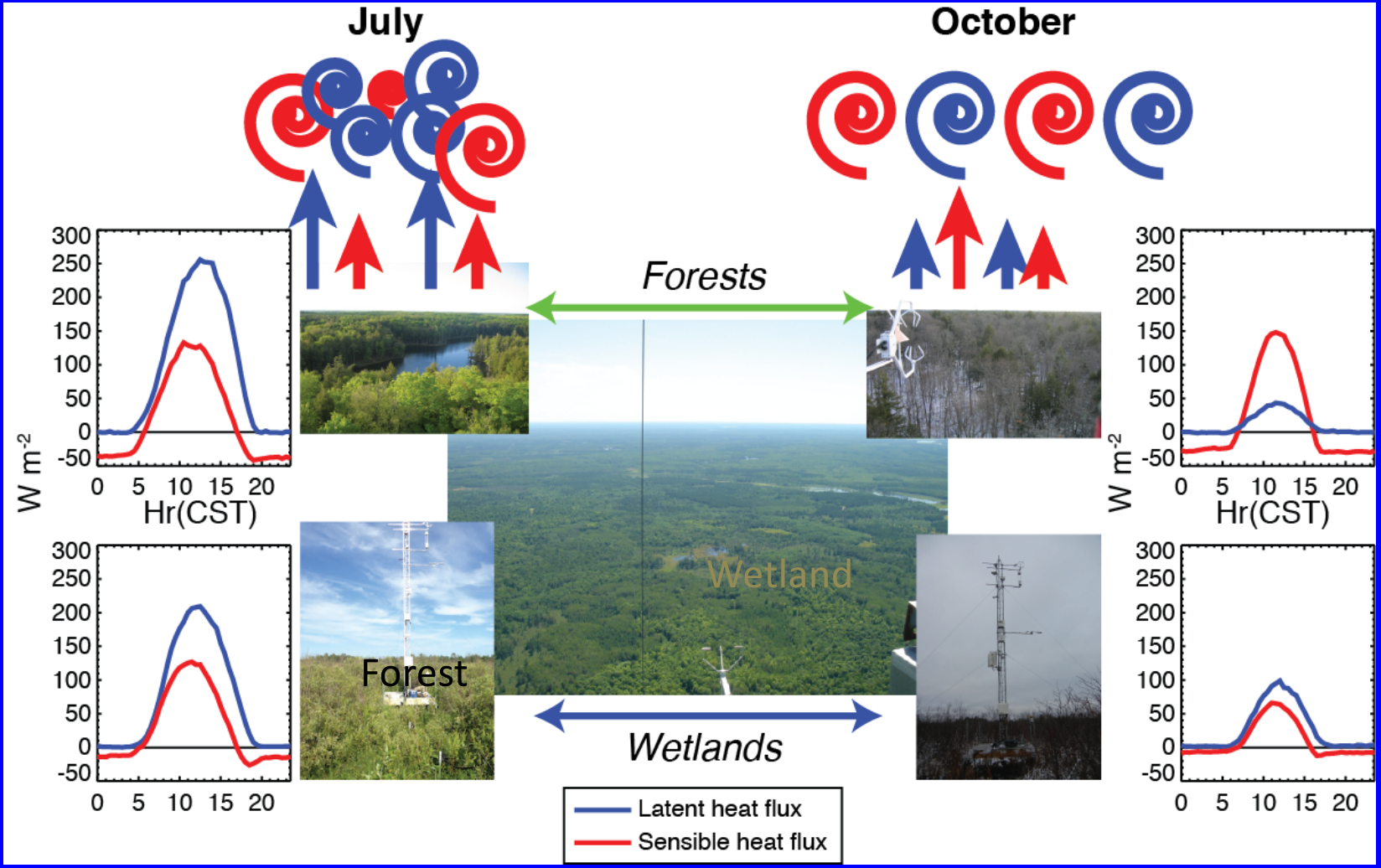
- Place in-situ and remote profiling instruments in 100 m clearing.

- 3 IOPs in late Jul, late Aug, late Sep with airborne legs in 2 km spacing at 500 and 1000 ft AGL (purple lines).
  - Upward pointing LiDAR to map PBL dept. Raman LiDAR for profiles of temperature and water vapor, if possible
  - Hyperspectral visible-IR and canopy LiDAR mapping mission from UW SpecEx

- LES simulations for each IOP and select cases across study period



July-October allows us to sample landscape as it evolves from homogenous LE (transpiration) driven, to patchier H and LE patterns depending on ecosystem



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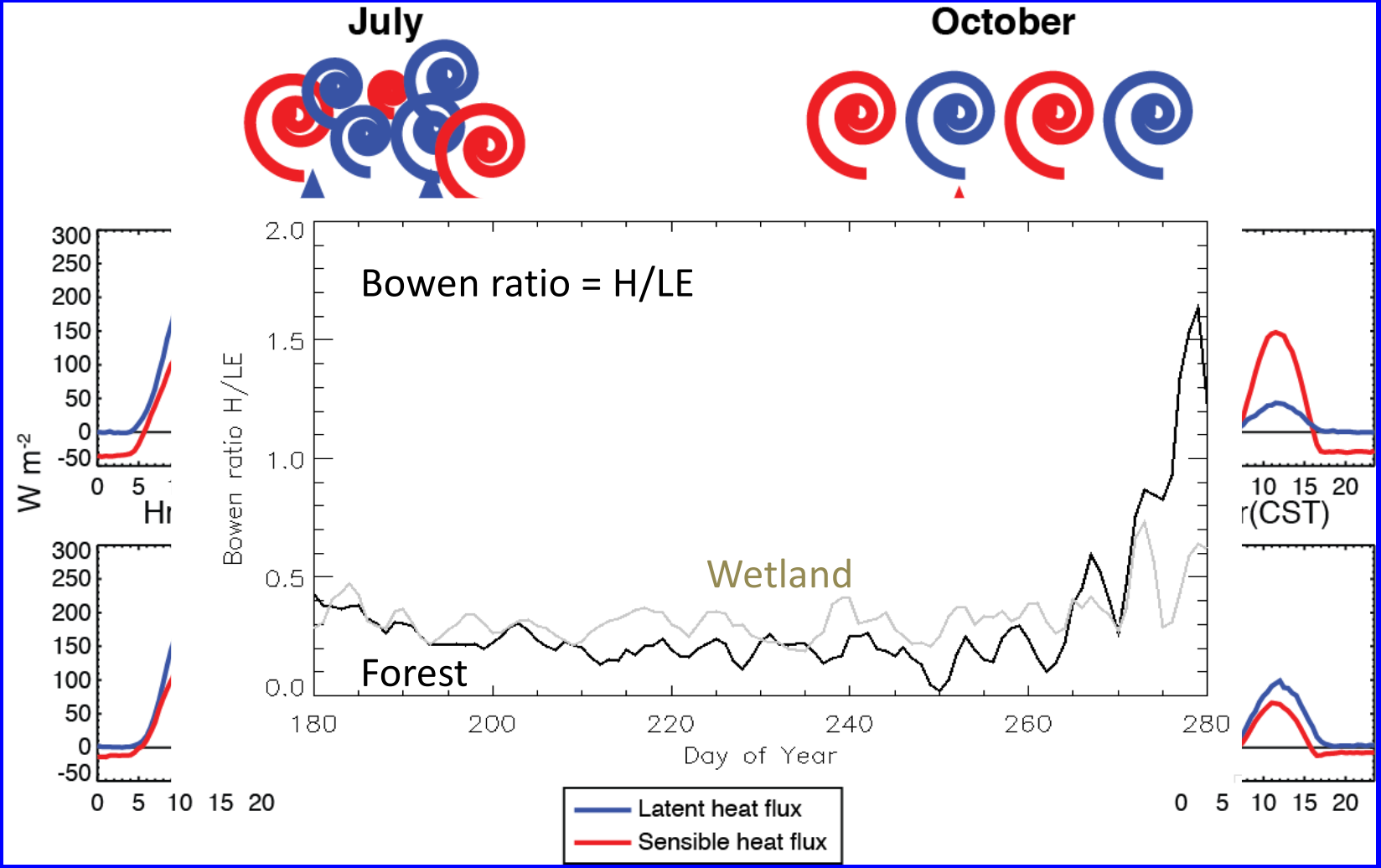

courtesy of Vanda Grubisic, Desert

Chlorophyll Fluorescence Imaging Spectrometer

CFIS

Surface (mostly distributed in 10x10 km area)

University of Wisconsin-Madison, Atmospheric and Oceanic Sciences (DESAI)

Ameriflux/NOAA very tall tower (US-PFa / WLEF)	Continuous, funded by DOE Ameriflux
ChEAS Ameriflux tower network (US-WCr/US-Los)	Continuous, funded by DOE Ameriflux

University of Wisconsin-Milwaukee, Geography (SCHWARTZ)

Ground-based vegetation/phenology sampling	July-Oct, weekly, campaign/student-based

NCAR EOL Integrated Surface Flux System (ISFS)

15-20 10-20 m EC flux towers	July-Oct, above canopy fluxes and met

In-Situ Profiling (mostly at US-PFa Very tall tower)

NCAR EOL Integrated Sounding System (ISS)

449 MHz modular wind profiler + RASS	July-Oct, Winds, T/RH profile
Radiosonde	Every morning (12 UTC) July-Oct

UW Space Science and Engineering Center Portable Atmospheric Research Center (SPARC)

Atmospheric Emitted Radiance Interferometer (AERI)	July-Oct, T and RH profile
HALO Photonics Streamline scanning Doppler LiDAR	July-Oct, Winds and turbulence
High-Spectral Resolution Lidar (HSRL)	July-Oct, aerosol backscatter
Vaisala Ceilometer	July-Oct, PBL depth

University of Wisconsin-Madison, Atmospheric and Oceanic Sciences (DESAI)

3-hourly high-resolution PBL sondes during IOPs	Daily during IOPs

Karlsruhe Institute for Technology (VOGELMANN)

DIAL/Raman Lidar	July-Oct, T and H2O profile
2x HALO Photonics Streamline scanning Doppler LiDAR	July-Oct, Winds and turbulence

Airborne

University of Wyoming King Air

Eddy covariance, Raman LiDAR, cloud LiDAR (70 hours)	2 IOPs w/ 8 hour ferry + 26 hours sampling

University of Wisconsin Spectral Explorer (UWSpex) (TOWNSEND)

Surface mapping of 400-2500 nm spectra	2 IOPs

University of Wisconsin Ultralight (PETTY)

Boundary-layer heat and water budget of domain; low level characterization of BL inhomogeneities	2 IOPs

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Atmosphe
HALO Pho
High-Spec
Vaisala C

But will it work?

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Can data mining help eddy-covariance see the landscape? A large-eddy simulation study

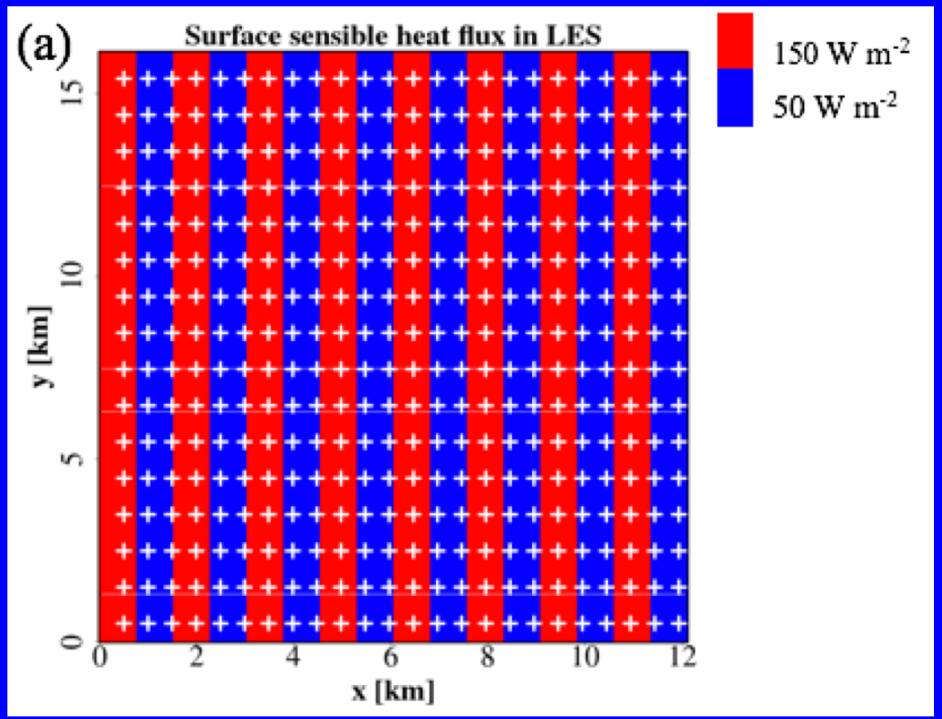
Authors: Ke Xu[1,2,*], Matthias Sühring[2], Stefan Metzger[3,1], David Durden[3], Ankur R Desai[1]

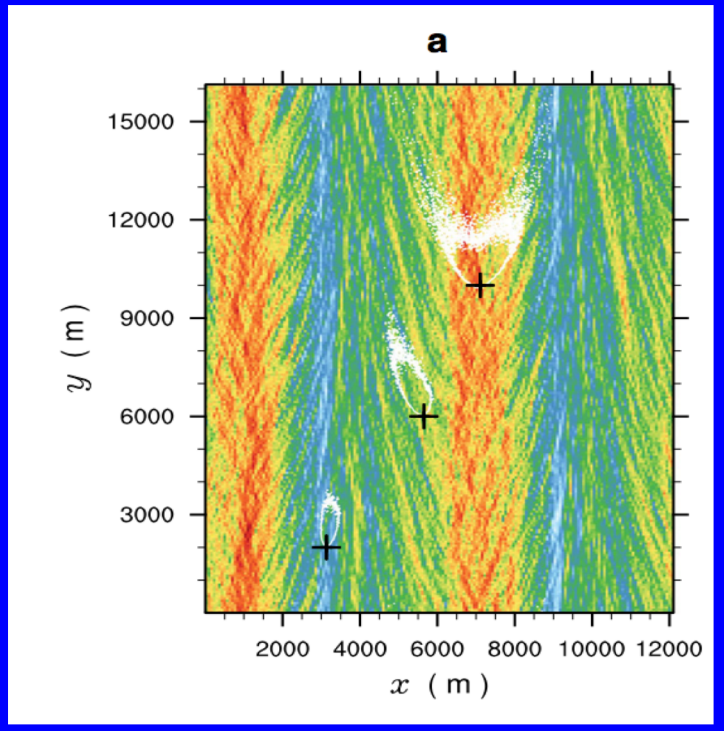
Boundary-Layer Meteorology
https://doi.org/10.1007/s10546-018-0387-x

RESEARCH ARTICLE

Trade-Offs in Flux Disaggregation: A Large-Eddy Simulation Study

Matthias Sühring[1] · Stefan Metzger[2,3] · Ke Xu[3] · Dave Durden[2] · Ankur Desai[3]





Boundary-Layer Meteorol (2007) 123:77–98
DOI 10.1007/s10546-006-9133-x

ORIGINAL PAPER

We can test 3 spatial eddy covariance methods that account for meso-scale eddies

Spatial representativeness of single tower measurements and the imbalance problem with eddy-covariance fluxes: results of a large-eddy simulation study

Gerald Steinfeld · Marcus Oliver Letzel · Siegfried Raasch · Manabu Kanda · Atsushi Inagaki

$$\left[\overline{F}\right] = \overline{\left[w\,\langle\Theta\rangle\right]} + \overline{\left[w\Theta'_{\text{filter}}\right]} + \left[\overline{w\Theta_b}\right]$$

Boundary-Layer Meteorol
DOI 10.1007/s10546-016-0161-x

RESEARCH ARTICLE

Exploring Eddy-Covariance Measurements Using a Spatial Approach: The Eddy Matrix

Christian Engelmann[1,2] · Christian Bernhofer[1]

$$B_{\text{comb}} = \overline{\langle w''\theta''\rangle} + \overline{\langle w\rangle'\langle\theta\rangle'} \tag{3a}$$

$$= \overline{B_a} + \left(\frac{1}{M-1}\right)\sum_{i=1}^{M}\left(\left(\langle w\rangle_i - \overline{\langle w\rangle}\right)\left(\langle\theta\rangle_i - \overline{\langle\theta\rangle}\right)\right), \tag{3b}$$

Boundary-Layer Meteorol (2008) 128:151–172
DOI 10.1007/s10546-008-9279-9

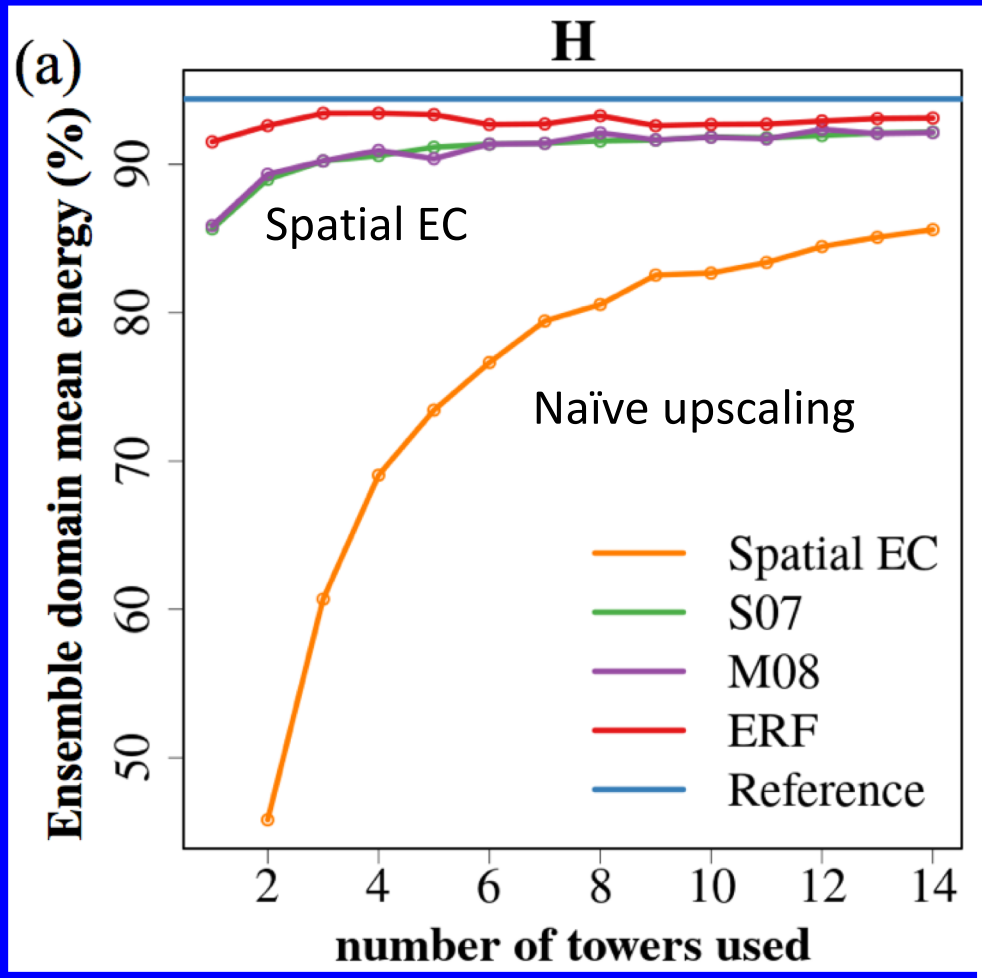
ORIGINAL PAPER

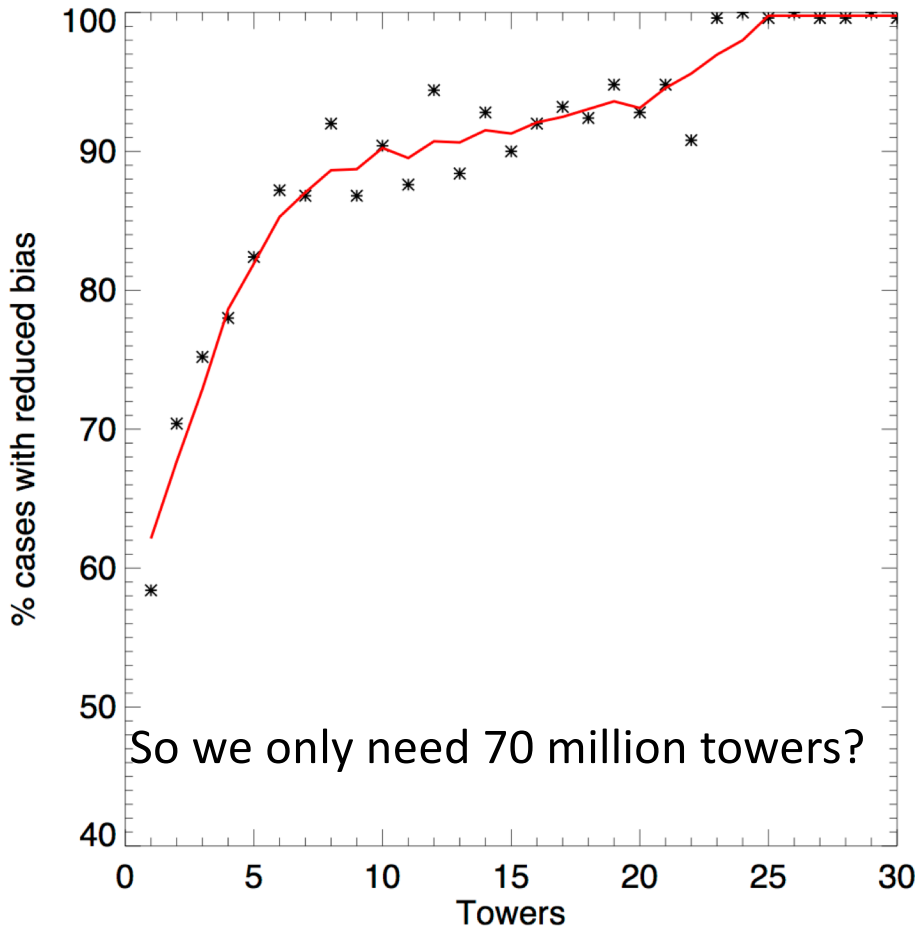
Measurement of the Sensible Eddy Heat Flux Based on Spatial Averaging of Continuous Ground-Based Observations

M. Mauder · R. L. Desjardins · E. Pattey · Z. Gao · R. van Haarlem

$$H = \overline{u_3}\left(\overline{T} - T_0\right) + \overline{u_3'T'} \approx \overline{u_3}\left(\overline{T} - [T]\right) + \overline{u_3'T'} = \overline{u_3}\left(\overline{T} - [T]\right) + H_t$$

Spatial eddy covariance improves energy balance and more rapidly converges to domain mean flux than naïve upscaling





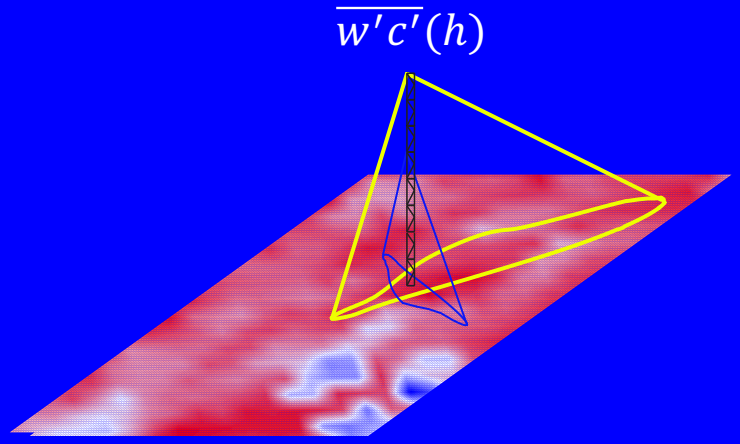
Xu et al, in review, BLM

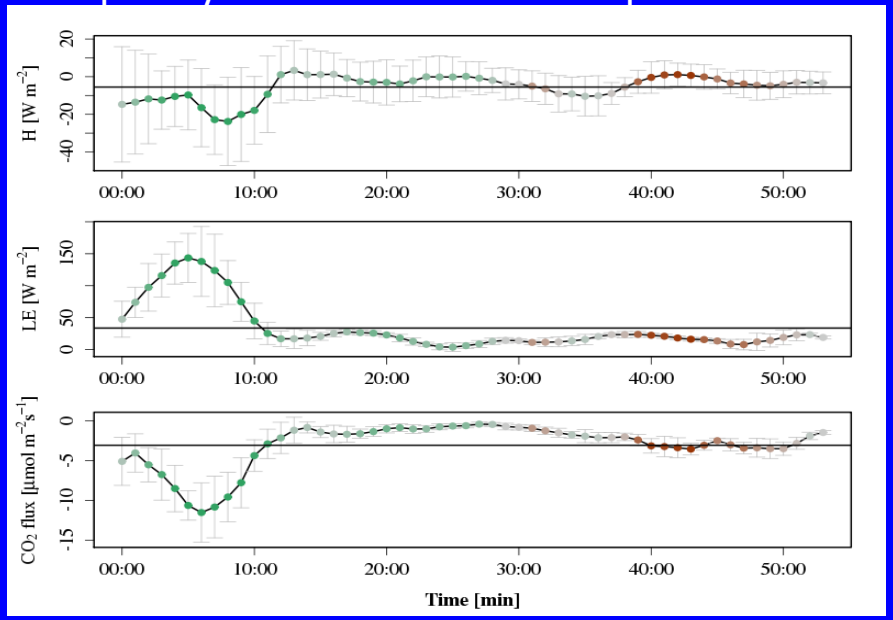
What's the ERF one?

Environmental Response Function (ERF) scaling method

Metzger et al., 2013, Biogeosci , Xu et al., 2017, AFM, Metzger, 2018, AFM, Xu et al., 2018, AFM

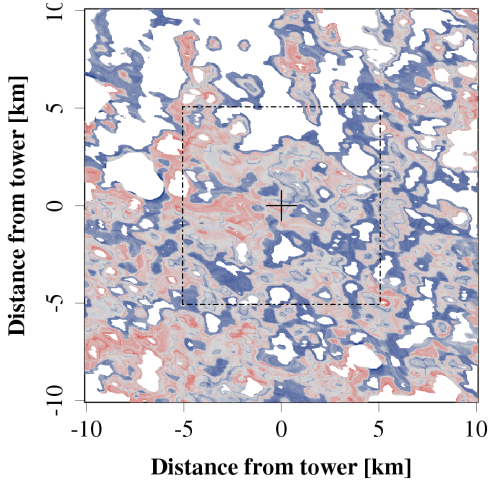
High frequency time series of flux response and drivers



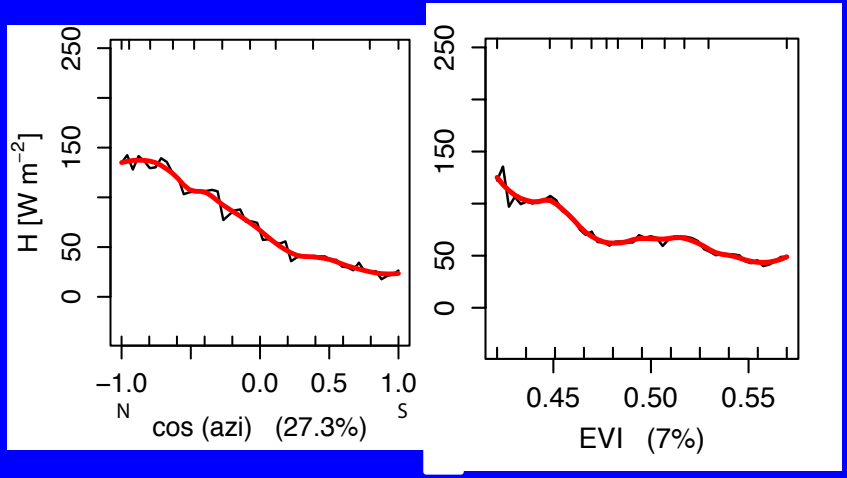


$$\frac{1}{4L^2}\int_{-L}^{+L}\int_{-L}^{+L}\overline{w'c'}(h)\ dx\ dy$$

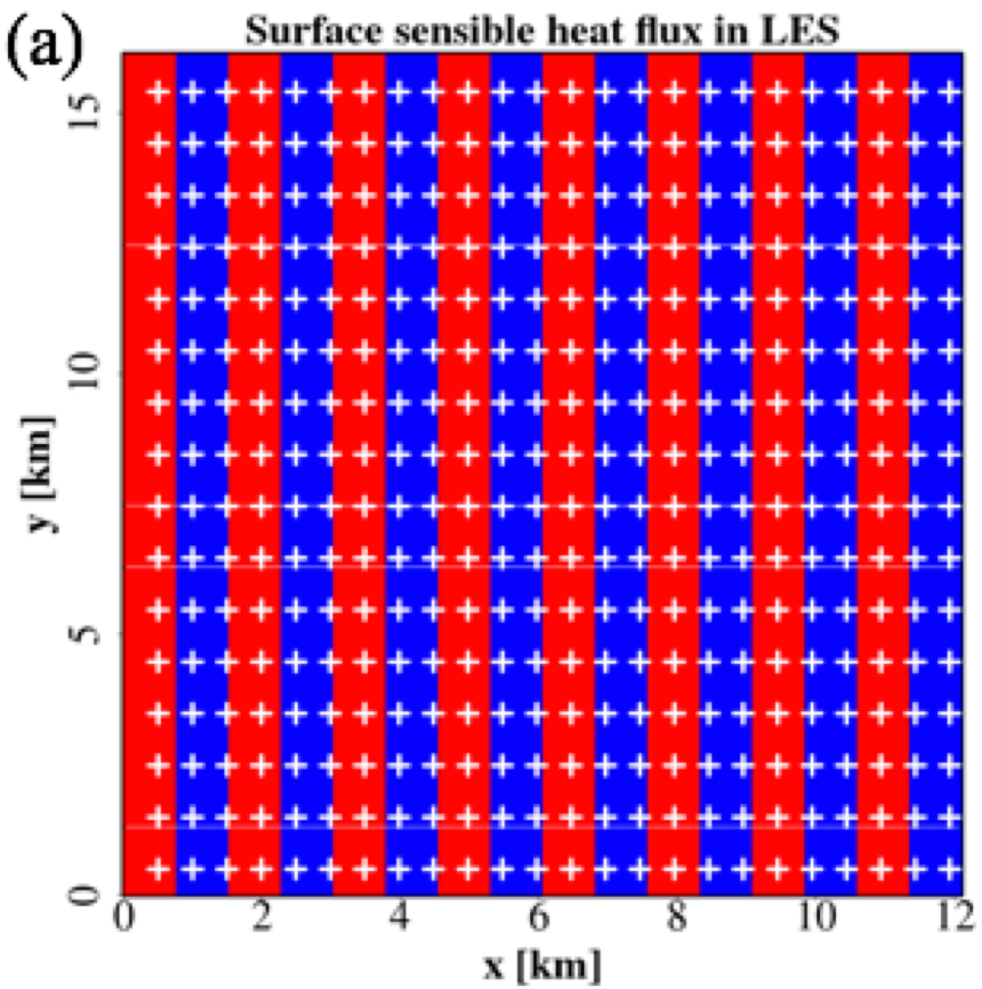
Domain-projected turbulent flux at measurement level

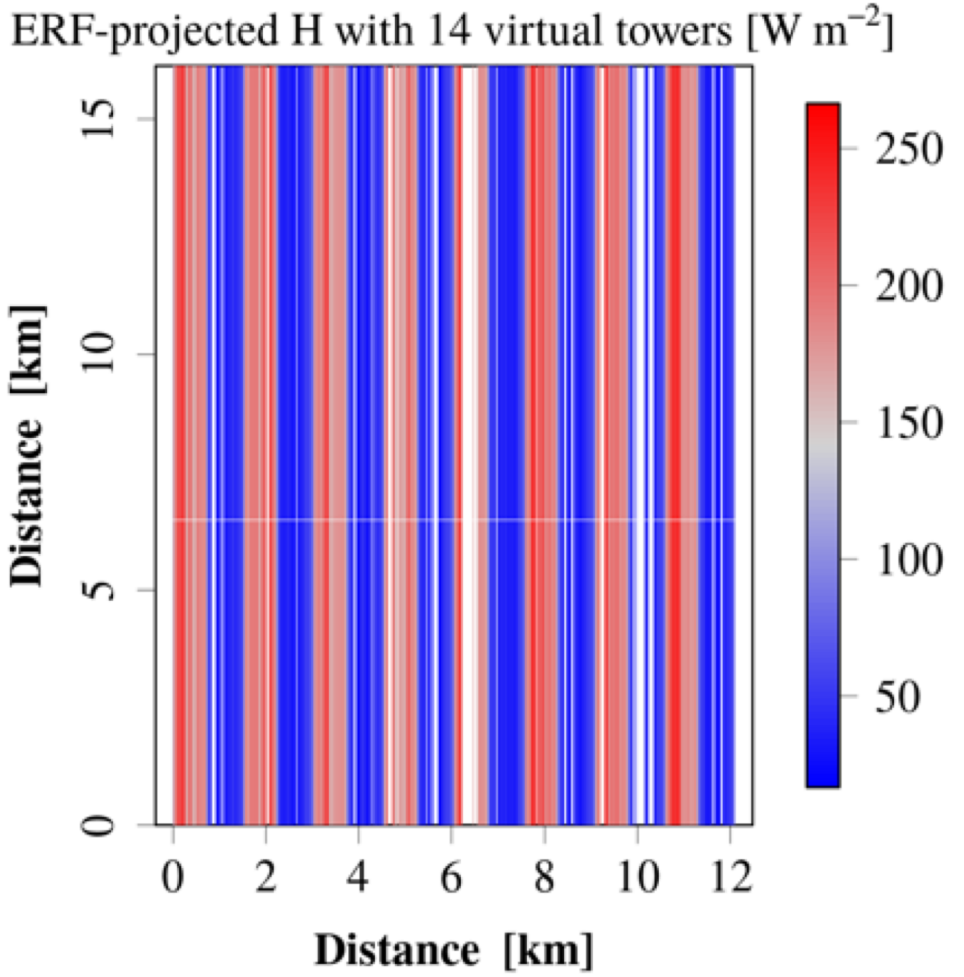


Extracted relationships



With 14 towers, we can recover highly heterogeneous fluxes in LES with ERF





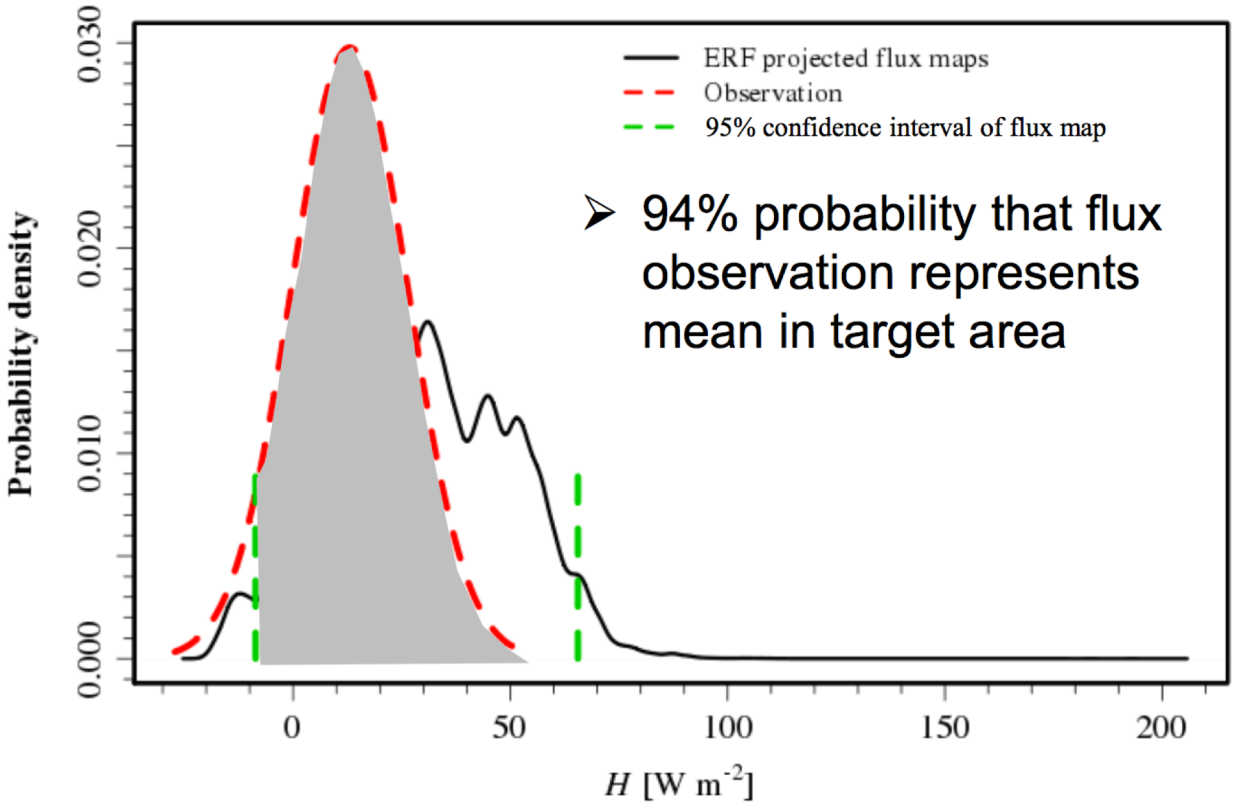
Original

Xu et al, in review, BLM

Retrieved

So how regional is our very tall tower?

- WLEF tall tower, Wisconsin, United States



➢ 94% probability that flux observation represents mean in target area

Metzger, S.: Surface-atmosphere exchange in a box: Making the control volume a suitable representation for in-situ observations, Agric. For. Meteorol., 255, 68-80, doi:10.1016/j.agrformet.2017.08.037, 2018.

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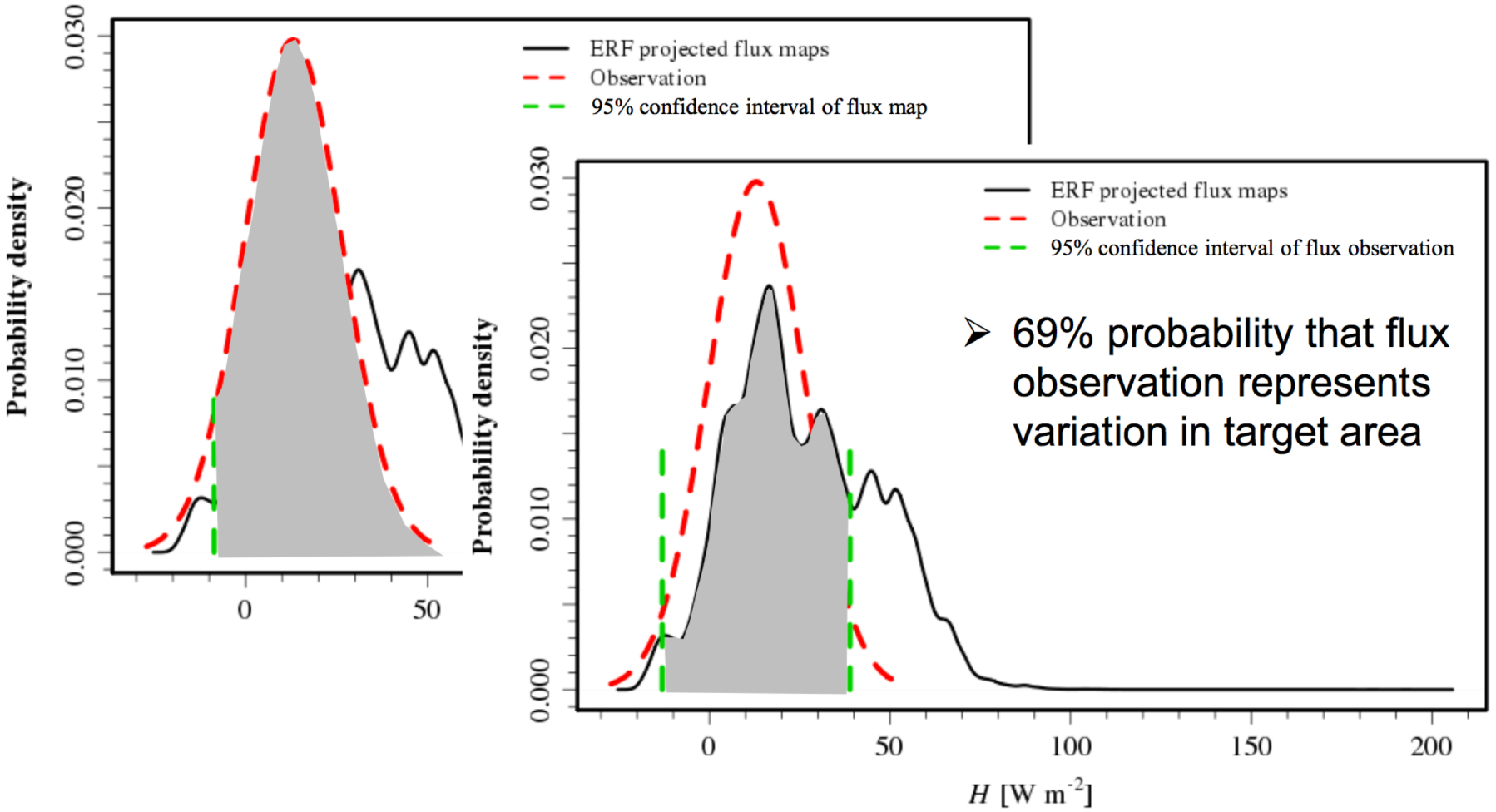

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We are looking for infinite collaborators!

- Working on permitting now for tall tower clearing, USFS tower sites, FAA waivers
- Towers to operate mid June 2019 to mid October 2019
- All data (including raw turbulence) open-access, online < 6 months, NCAR hosted repository
- One post-doc position may be available still…
- Contact: Ankur Desai, desai@aos.wisc.edu 608-218-4208, Twitter: @profdesai
- http://flux.aos.wisc.edu