Linking scales of motion in the atmosphere to variation in the surface below

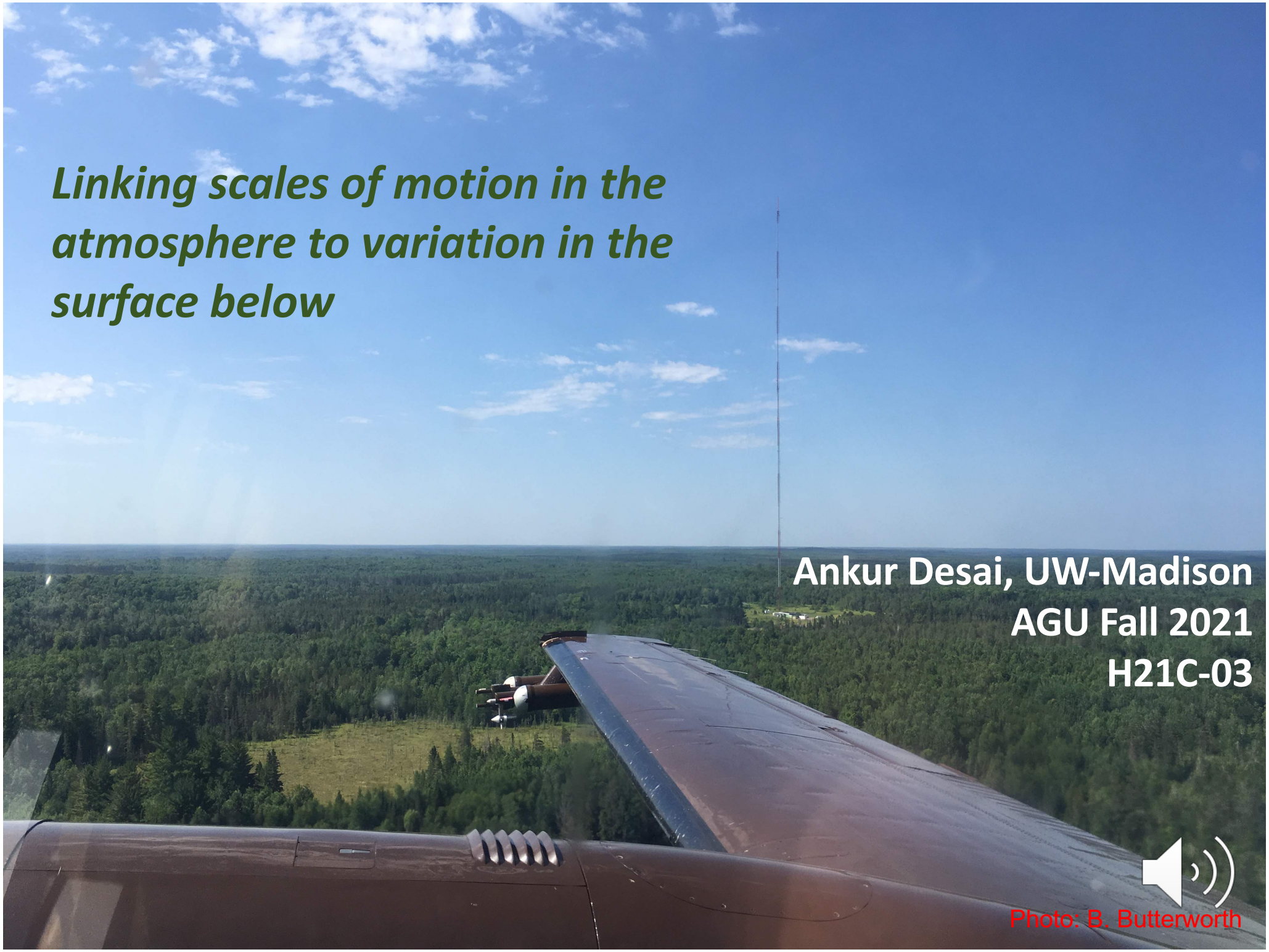
Ankur Desai[1]

[1]University of Wisconsin Madison

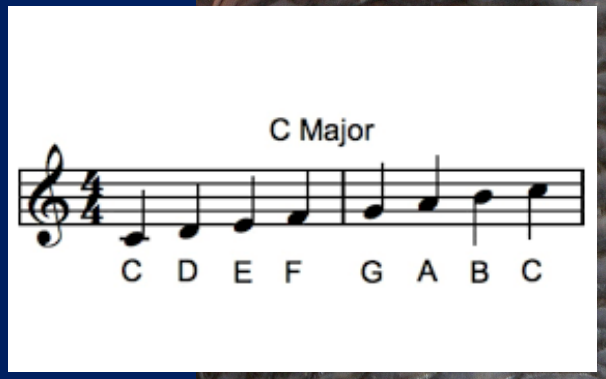
November 24, 2022

Abstract

The surface is the interface through which the bedrock interacts with the boundary-layer. Here, living organisms of various shapes, sizes, and function intermingle with the mineral soil, organic residue, and canopy air space that reside there. Together, they breath, absorb momentum, exchange water and gases, and bask in the heat from the sun and clouds above and thermal reservoirs below. While many of these functions are well understood, we knew less about how those functions operate and behave at different spatial and time scales. More intriguing, surface variance with scale influences scales of motion in the atmosphere. Here, I present a generalized look at how land and atmosphere scales interact, focusing on the lens of the surface energy budget. These processes are investigated through intensive measurements and high-resolution models conducted at the CHEESEHEAD19 field experiment in Wisconsin. A combination of airborne and tower eddy covariance networks, drone and airborne canopy imaging, and turbulence resolving simulations reveal persistent mesoscale contributions in the atmosphere enabled by surface heterogeneity.


Linking scales of motion in the atmosphere to variation in the surface below
Ankur Desai, UW-Madison
AGU Fall 2021
H21C-03
Photo: B. Butterworth

What is scale?



https://www.adeedo.com/how-to-prevent-scale-buildup-in-household-pipes/

HYDROLOGICAL PROCESSES, VOL. 9, 251–290 (1995)

SCALE ISSUES IN HYDROLOGICAL MODELLING: A REVIEW

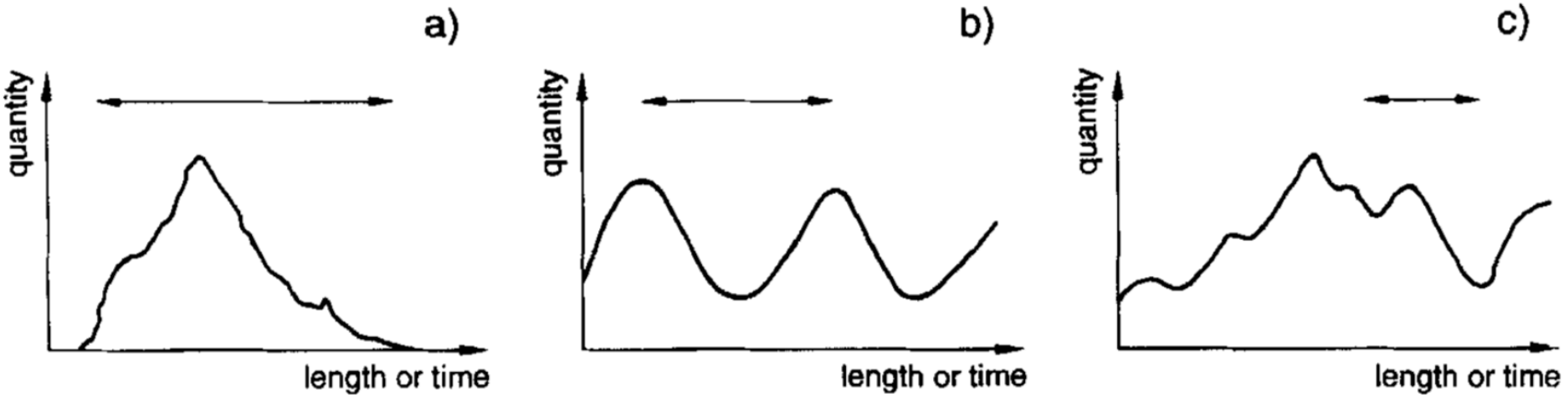
G. BLÖSCHL*

Centre for Resource and Environmental Studies, The Australian National University, Canberra City, ACT 2601, Australia

AND

M. SIVAPALAN

Centre for Water Research, Department of Environmental Engineering, University of Western Australia, Nedlands, 6009, Australia



Contents lists available at ScienceDirect

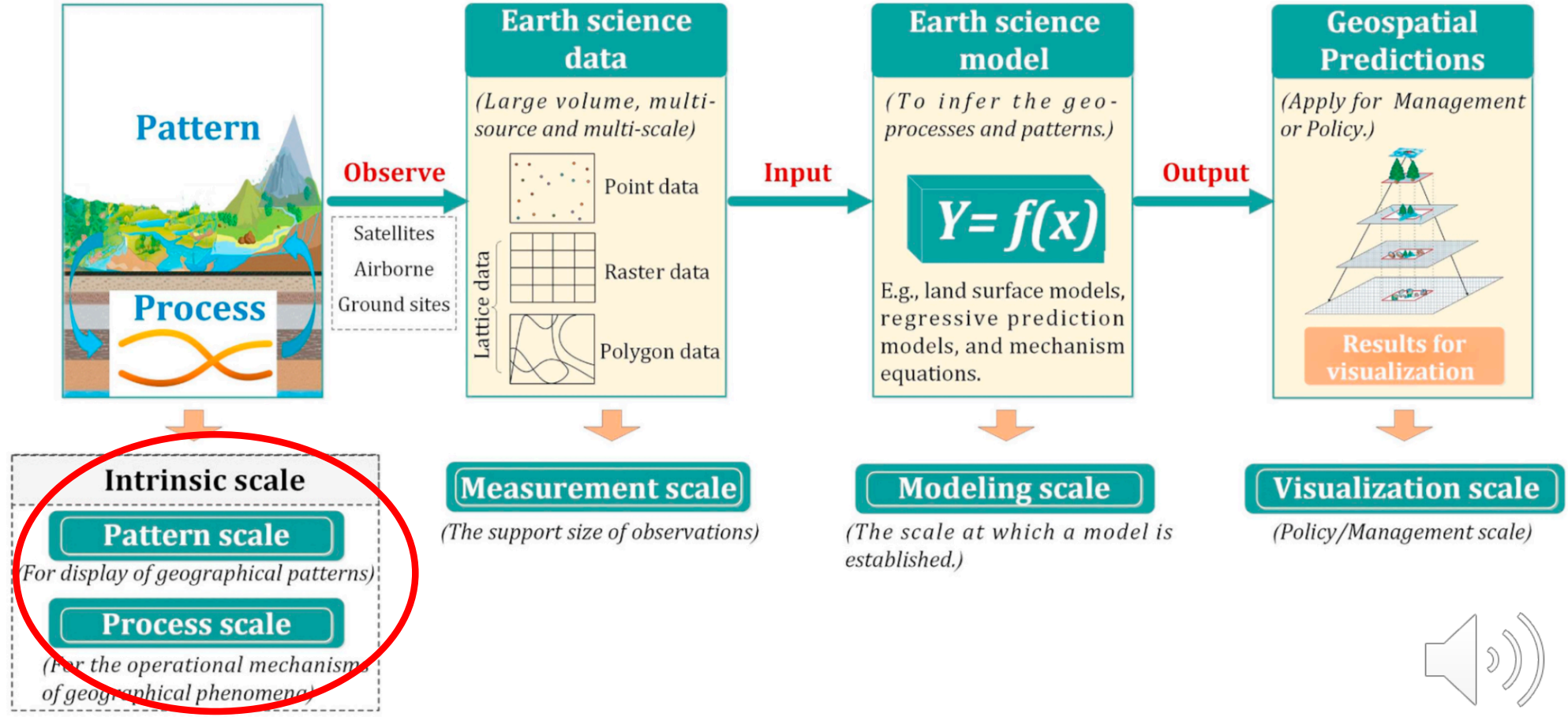
Earth-Science Reviews

journal homepage: www.elsevier.com/locate/earscirev

Principles and methods of scaling geospatial Earth science data

Yong Ge[a,b,*], Yan Jin[c,d], Alfred Stein[e], Yuehong Chen[f], Jianghao Wang[a], Jinfeng Wang[a], Qiuming Cheng[g], Hexiang Bai[h], Mengxiao Liu[a,b], Peter M. Atkinson[i]

2019

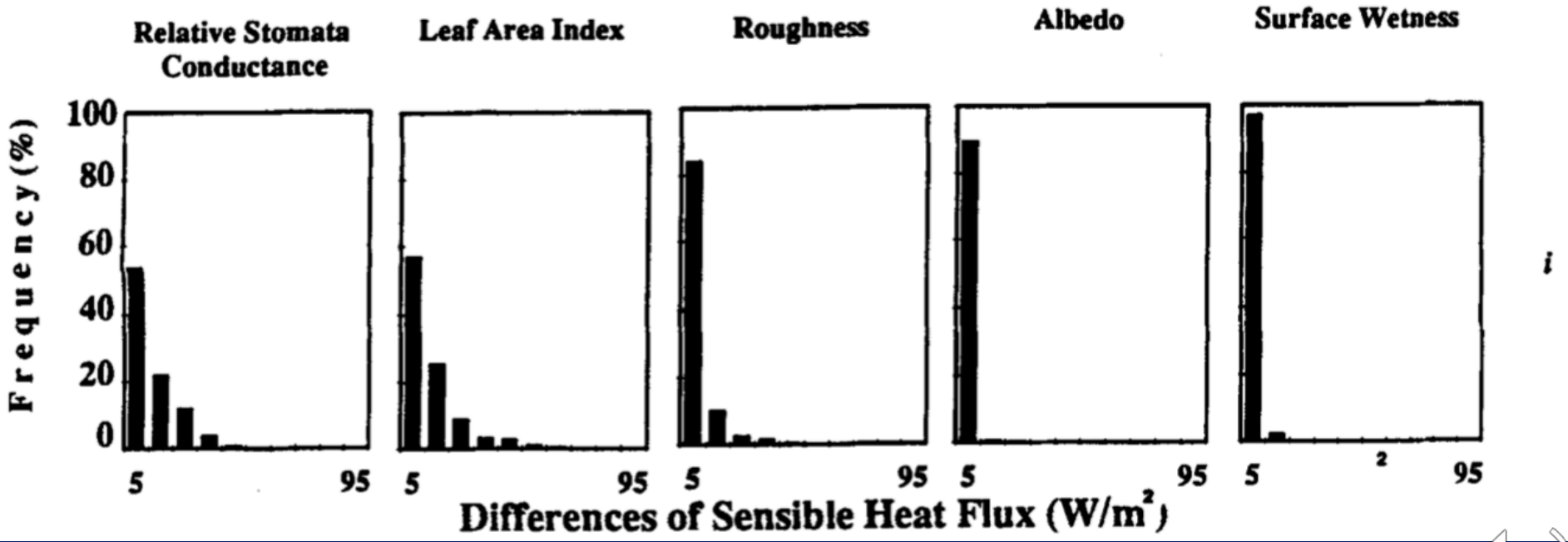


HYDROLOGICAL PROCESSES, VOL. 9, 679–695 (1995)

SCALING OF LAND–ATMOSPHERE INTERACTIONS: AN ATMOSPHERIC MODELLING PERSPECTIVE

RONI AVISSAR

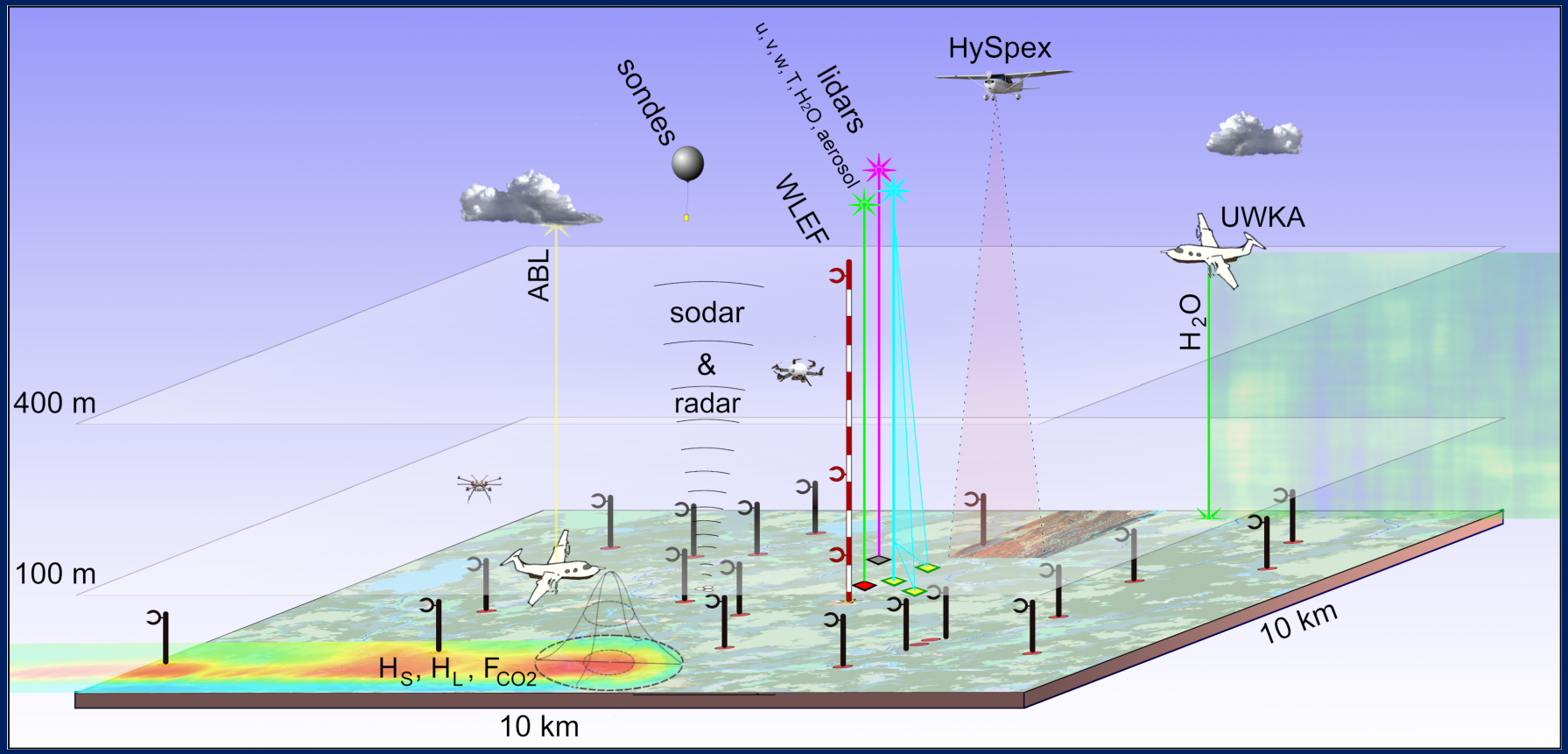
Department of Meterorology and Physical Oceanography, Cook College, Rutgers University, New Brunswick, NJ 08903, USA



When does scale matter?

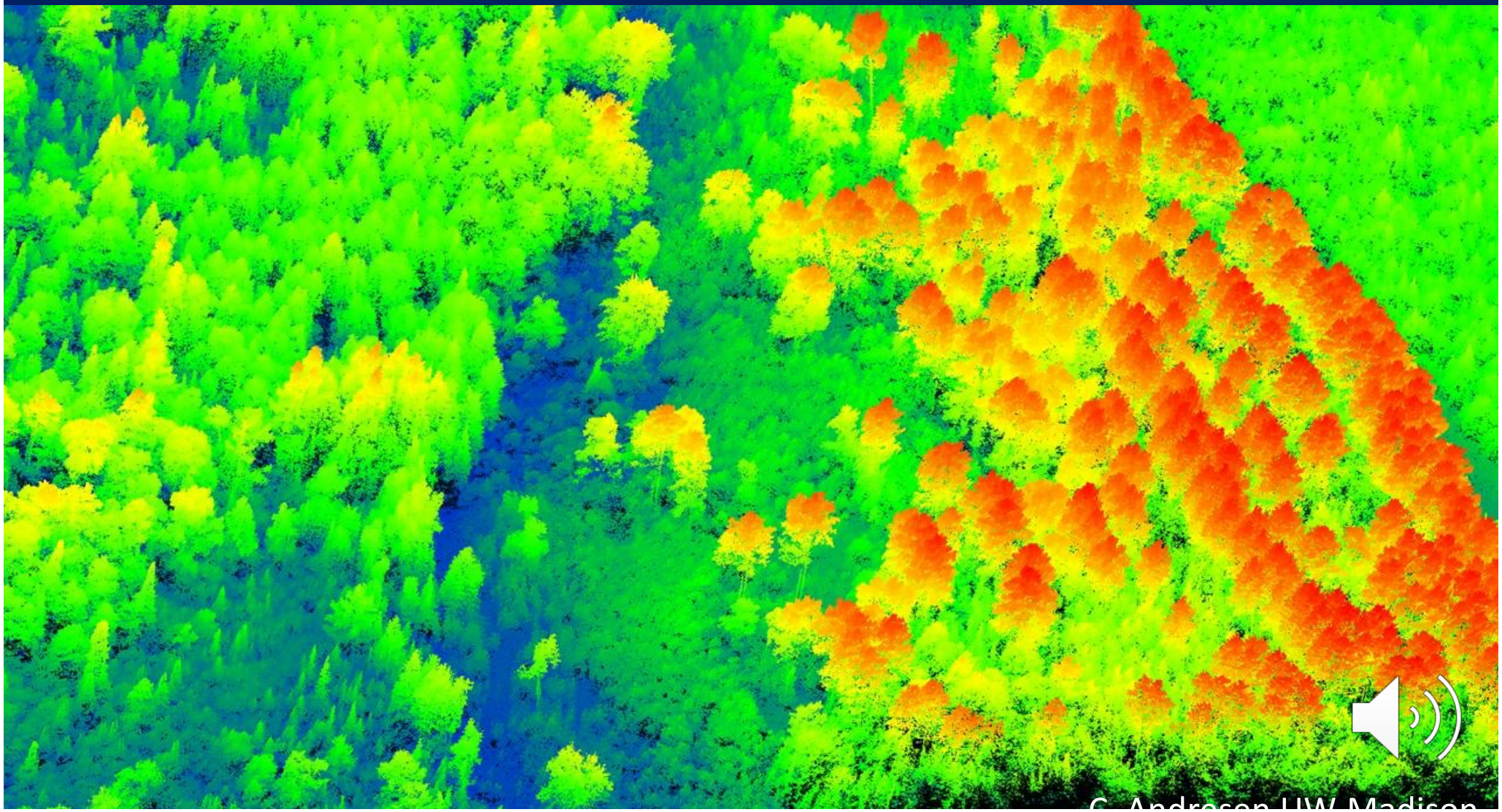
A good place as any to test

Chequamegon Heterogenous Ecosystem Energy-balance Study Enabled by a High Density Extensive Array of Detectors 2019 (CHEESEHEAD19) (NSF 1822420)



Butterworth et al., 2021, *Bulletin of the American Meteorological Society*

Scales of land surface temperature

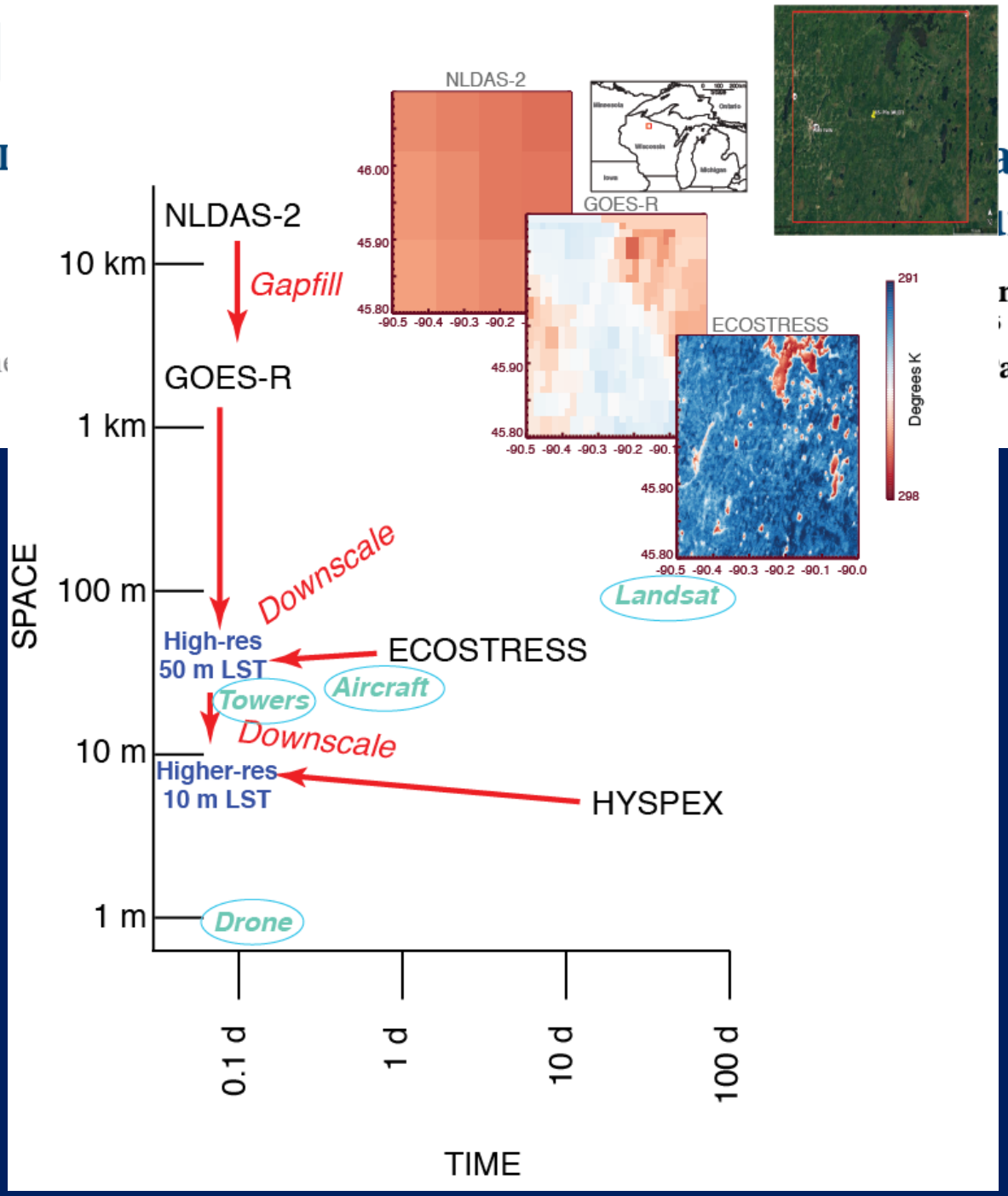


Earth and

RESEARCH ARTICI

10.1029/2021EA001842

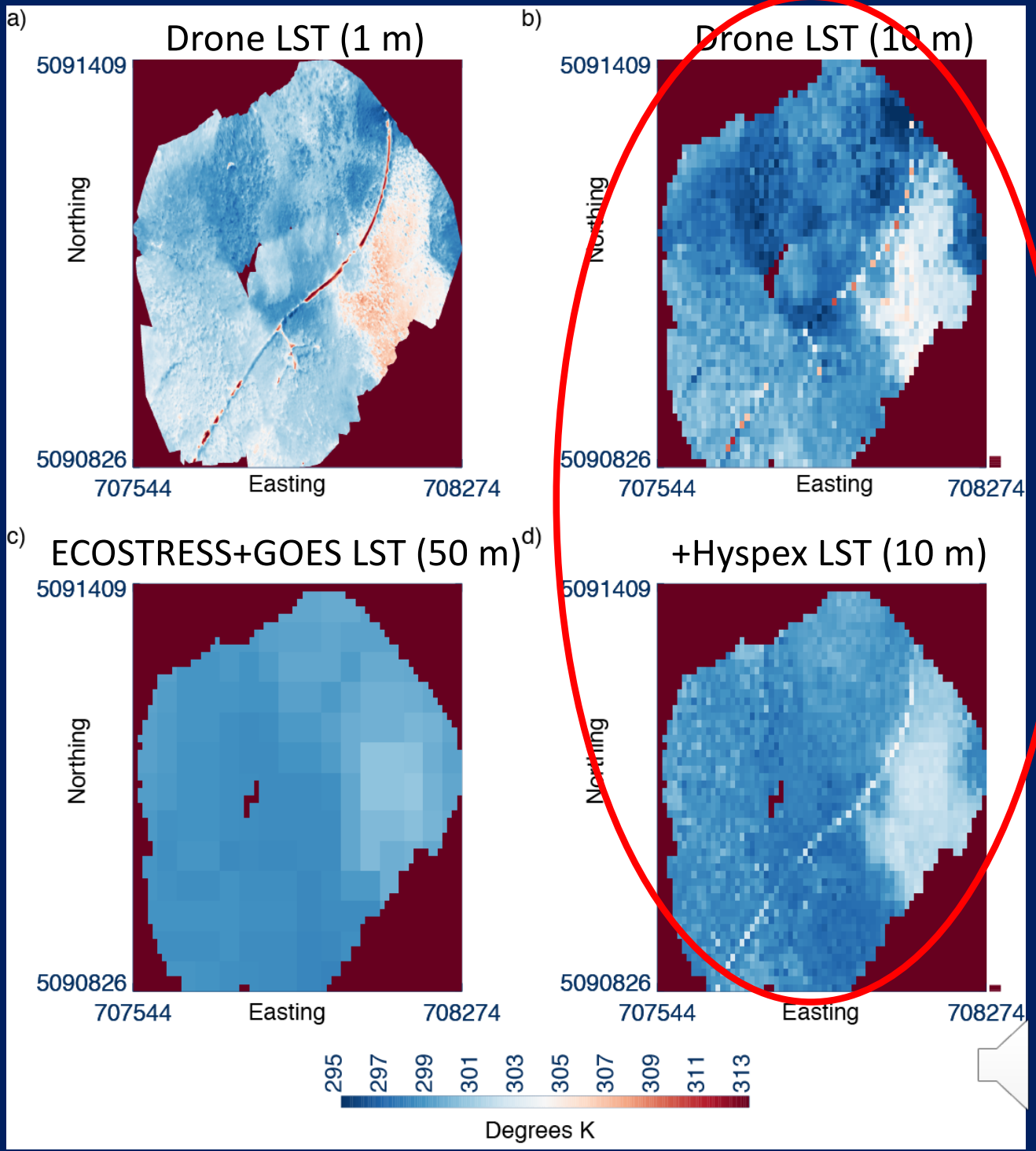
Special Section:
Advances in scaling and modeling of land-atmosphe interactions



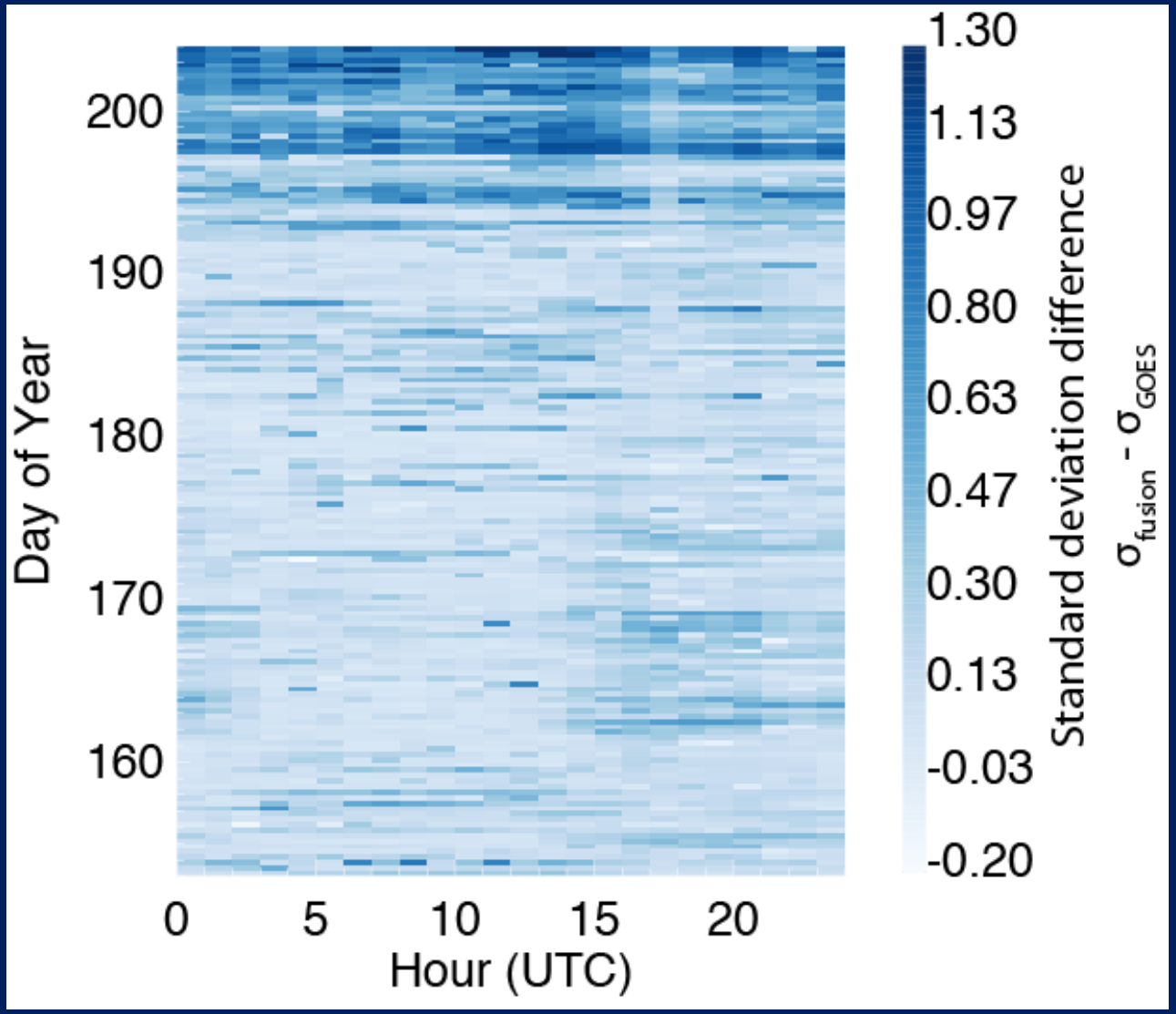
ace and Time
ire

nath Paleri[1], , Glynn Hulley[7], aul Stoy[9], and

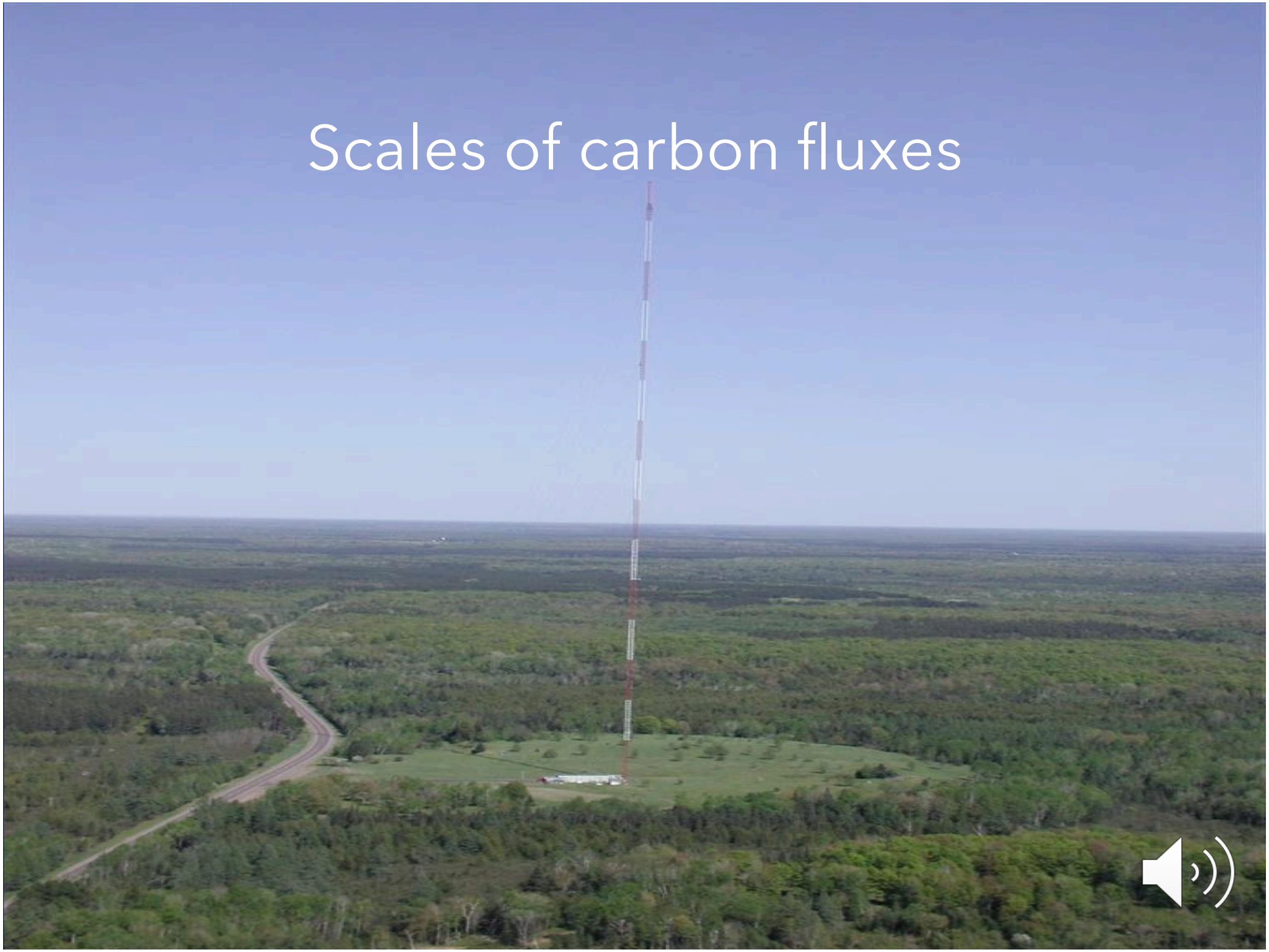
- Drone reveals fine structure of LST over one tower footprint
- A linear model captures basically all the main features with scale



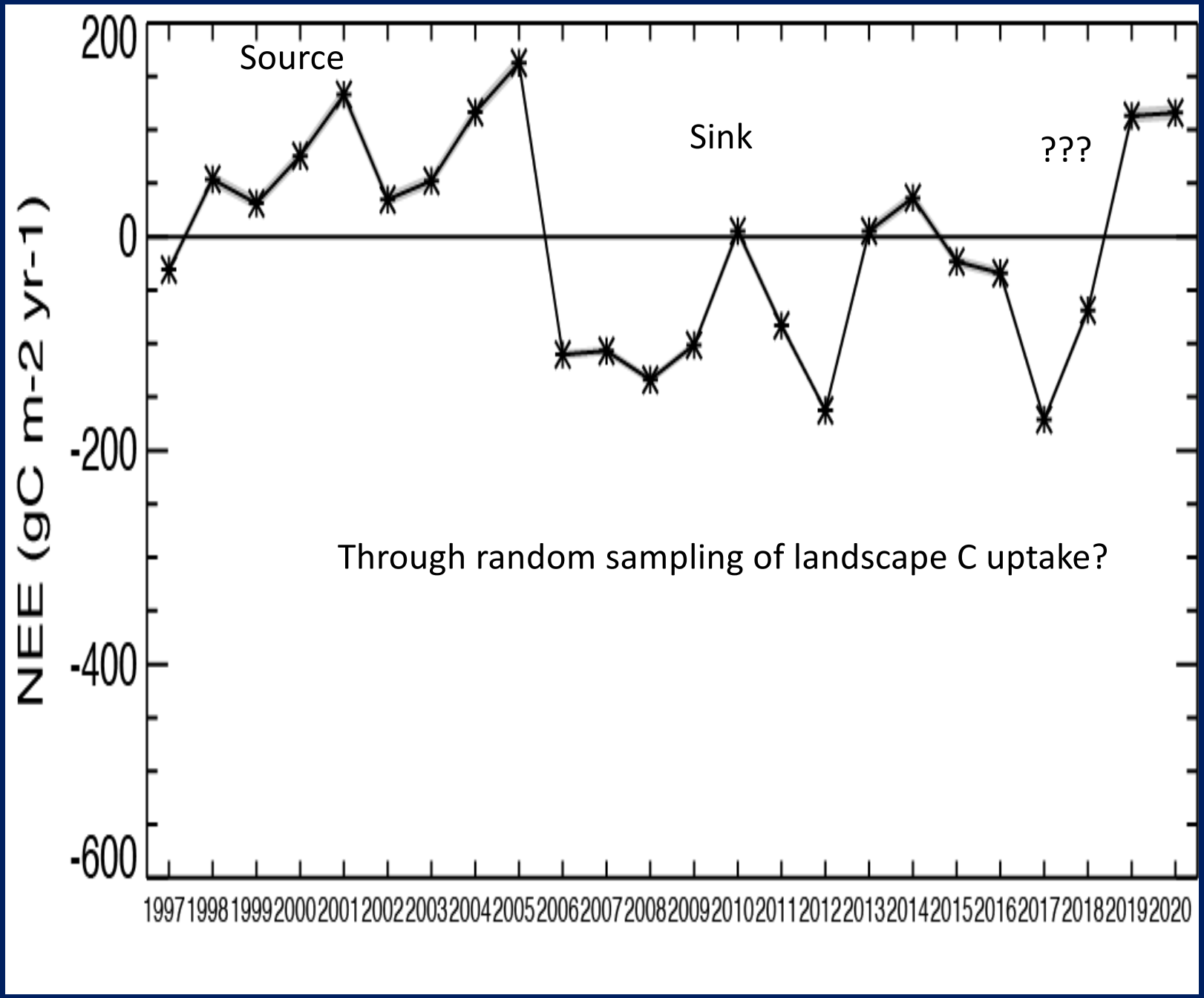
But we can still reveal features of spatial variance relevant for land-atmosphere interactions

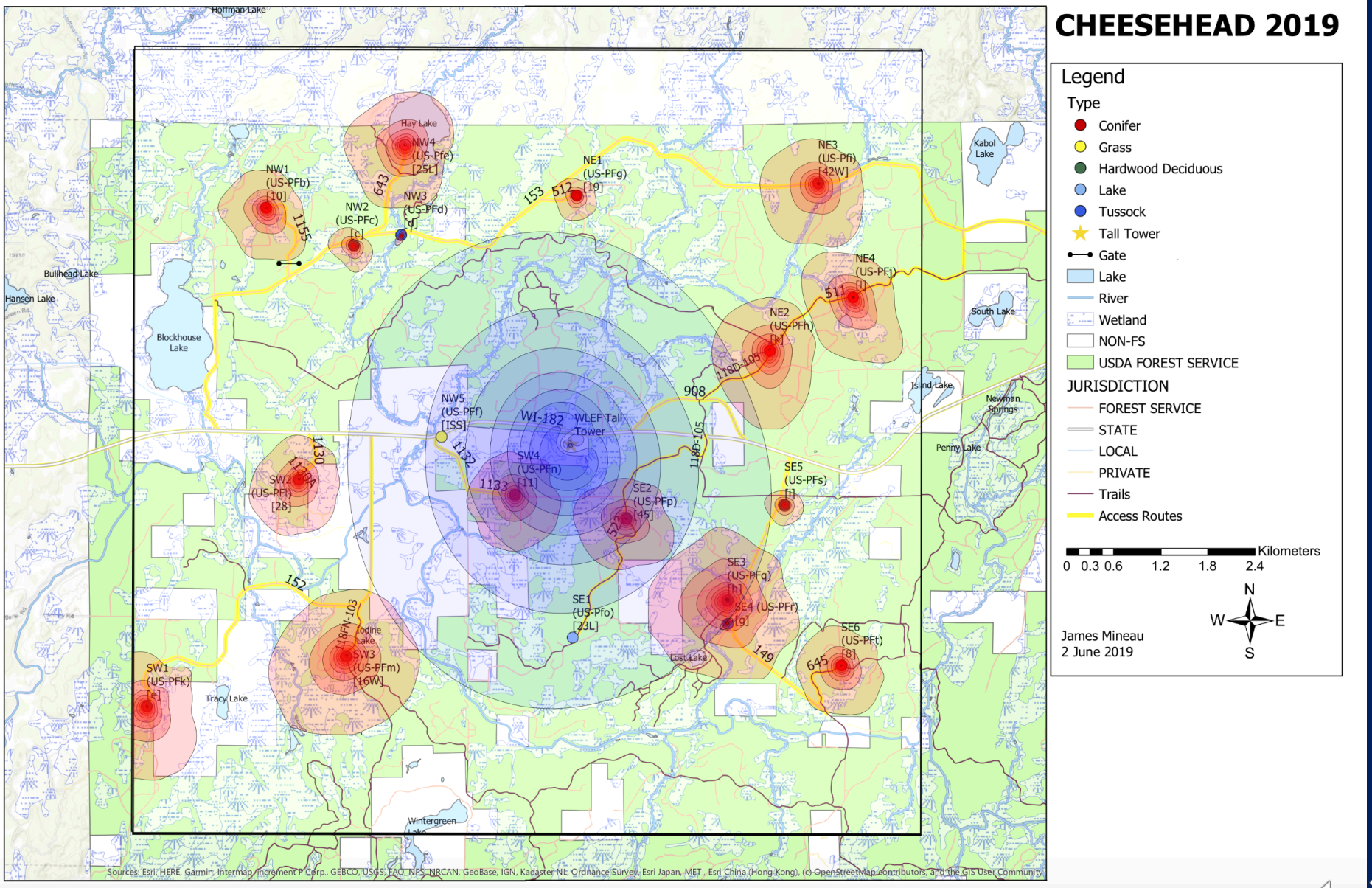


Scales of carbon fluxes

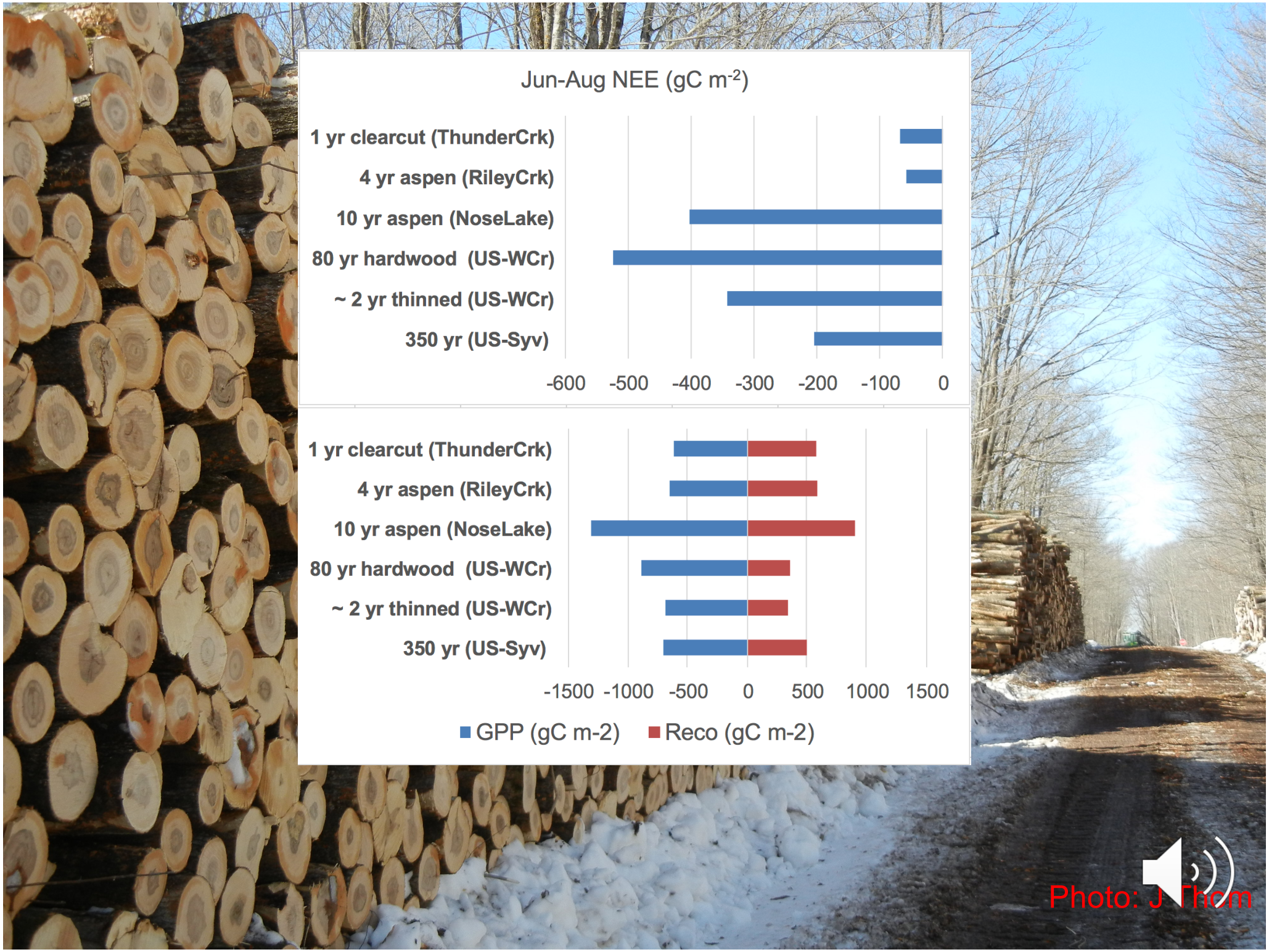


Can we explain regional annual carbon uptake?





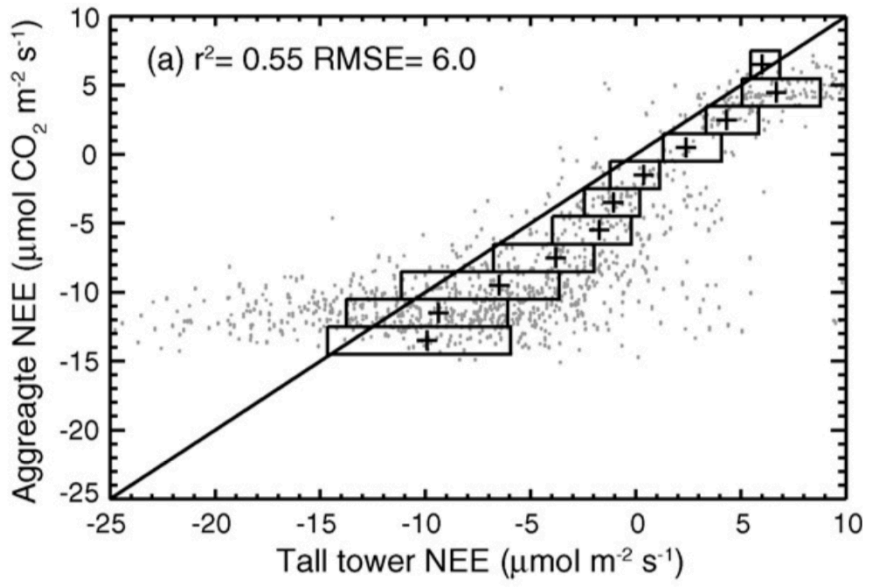
J. Mineau / B. Butterworth

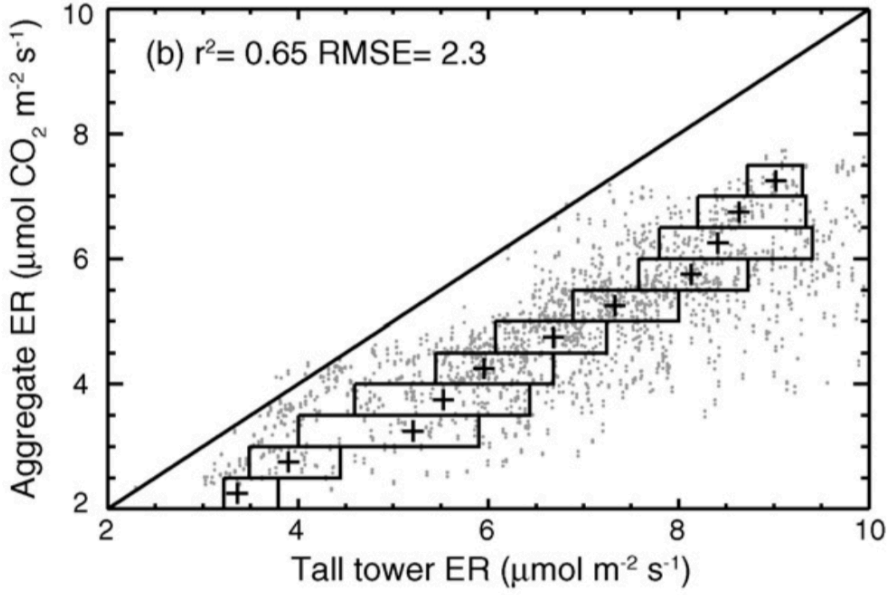

Jun-Aug NEE (gC m-2)
1 yr clearcut (ThunderCrk)
4 yr aspen (RileyCrk)
10 yr aspen (NoseLake)
80 yr hardwood (US-WCr)
~ 2 yr thinned (US-WCr)
350 yr (US-Syv)
-600 -500 -400 -300 -200 -100 0
1 yr clearcut (ThunderCrk)
4 yr aspen (RileyCrk)
10 yr aspen (NoseLake)
80 yr hardwood (US-WCr)
~ 2 yr thinned (US-WCr)
350 yr (US-Syv)
-1500 -1000 -500 0 500 1000 1500
GPP (gC m-2)
Reco (gC m-2)
Photo: J Thom

Influence of vegetation and seasonal forcing on carbon dioxide fluxes across the Upper Midwest, USA: Implications for regional scaling

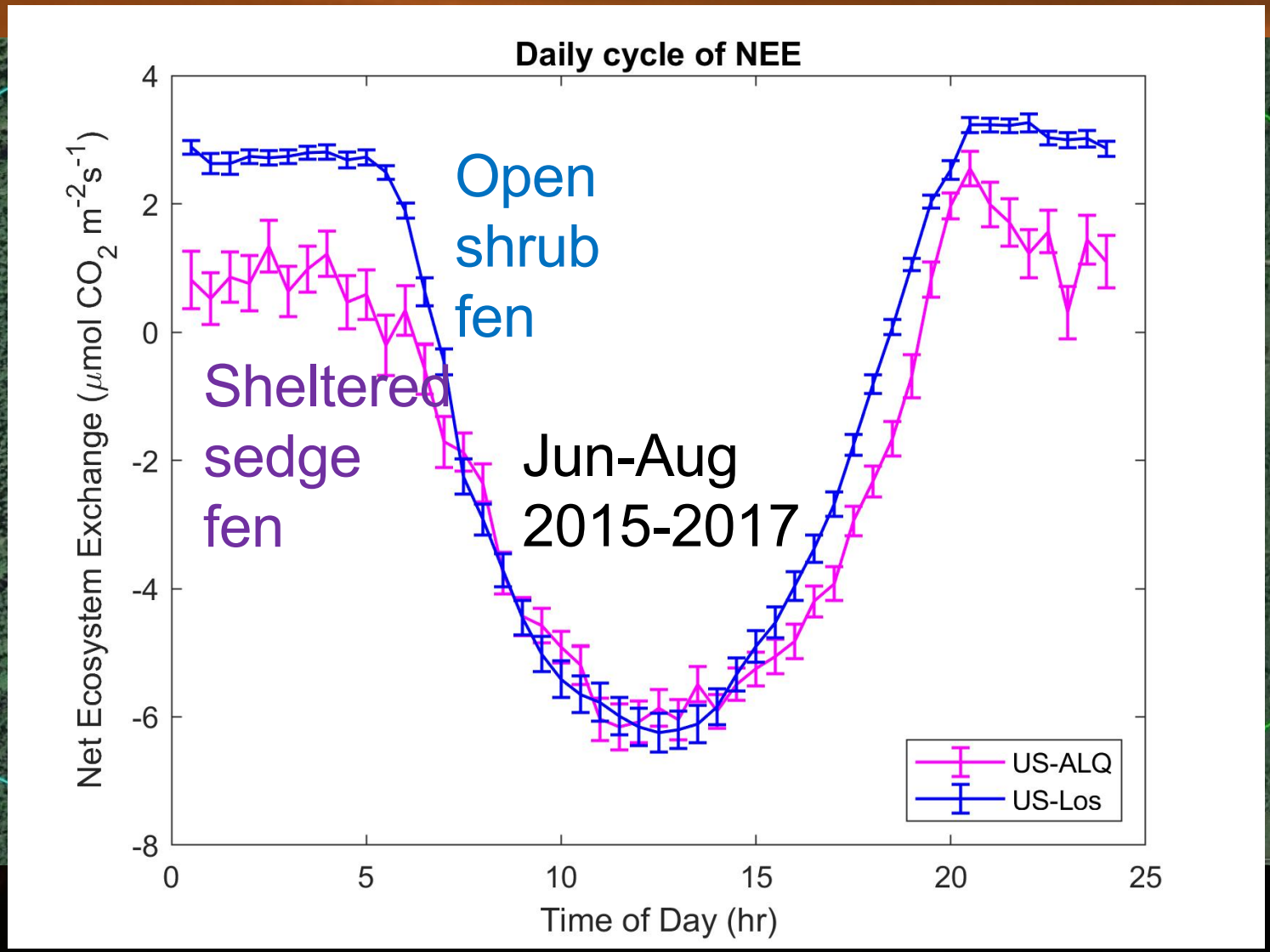
Ag For Met, 2008

Ankur R. Desai [a,*], *Asko Noormets* [b], *Paul V. Bolstad* [c], *Jiquan Chen* [d], *Bruce D. Cook* [c], *Kenneth J. Davis* [e], *Eugenie S. Euskirchen* [f], *Christopher Gough* [g], *Jonathan G. Martin* [h], *Daniel M. Ricciuto* [i], *Hans Peter Schmid* [j], *Jianwu Tang* [k], *Weiguo Wang* [l]





Wetlands: Scale matters

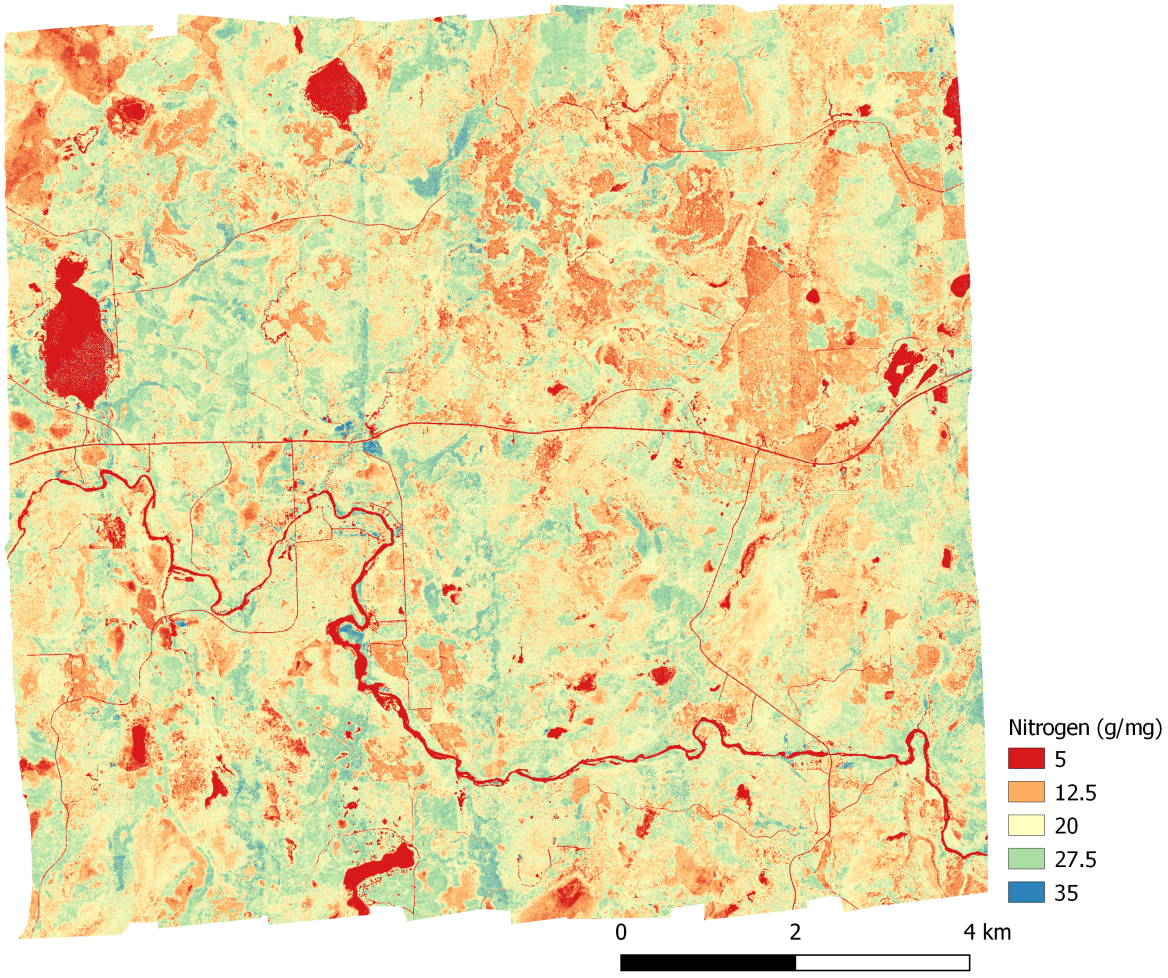


Turner et al., 2019, Frontiers in Envi Sci

Photo: J. Thom

Hyperspectral imaging of leaf traits also reveals spatial scale dependency

Leaf Nitrogen

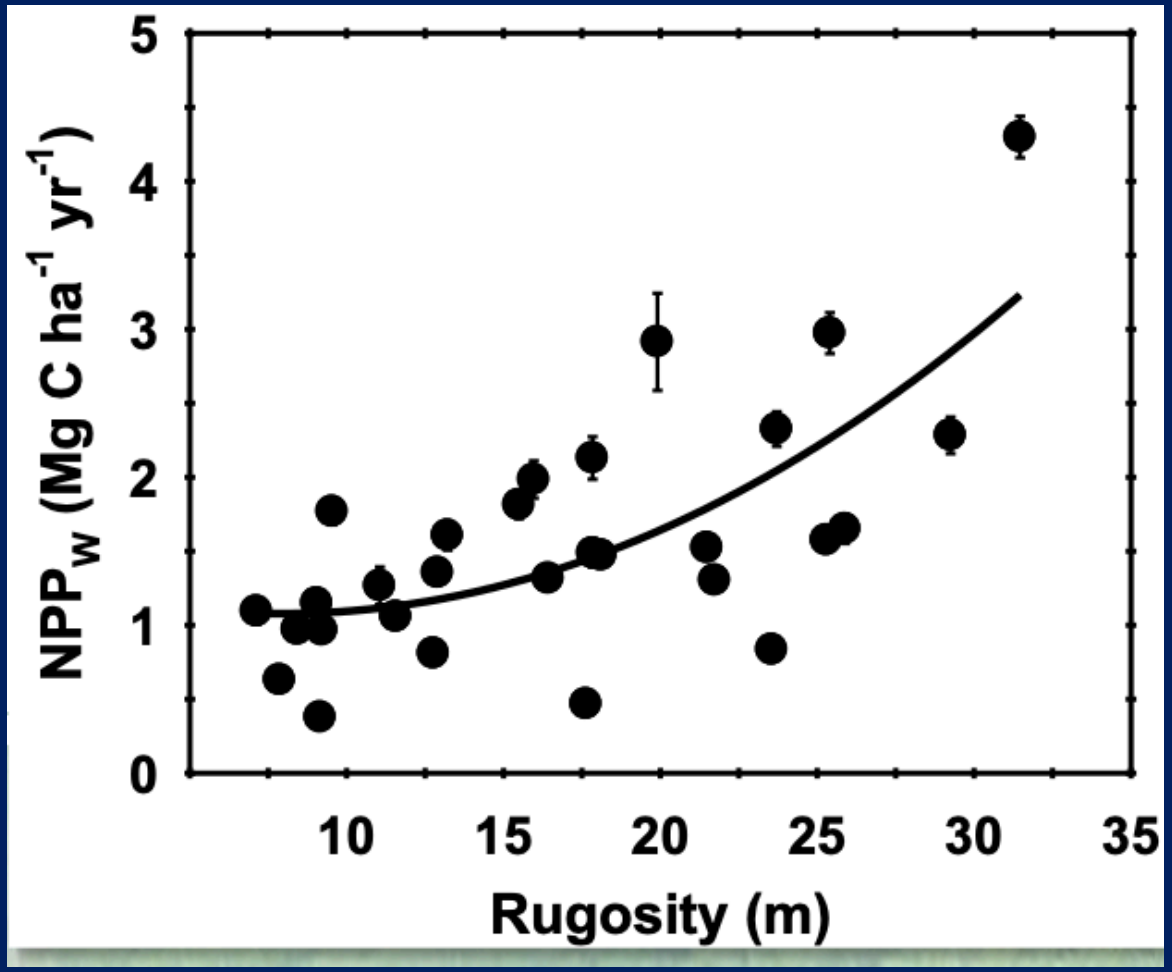


Phil Townsend and Ting Zheng, UW-Madison


Scales of land-atmosphere energy budget

High rates of primary production in structurally complex forests

CHRISTOPHER M. GOUGH,[1,4] JEFF W. ATKINS,[1] ROBERT T. FAHEY,[2] AND BRADY S. HARDIMAN[3]

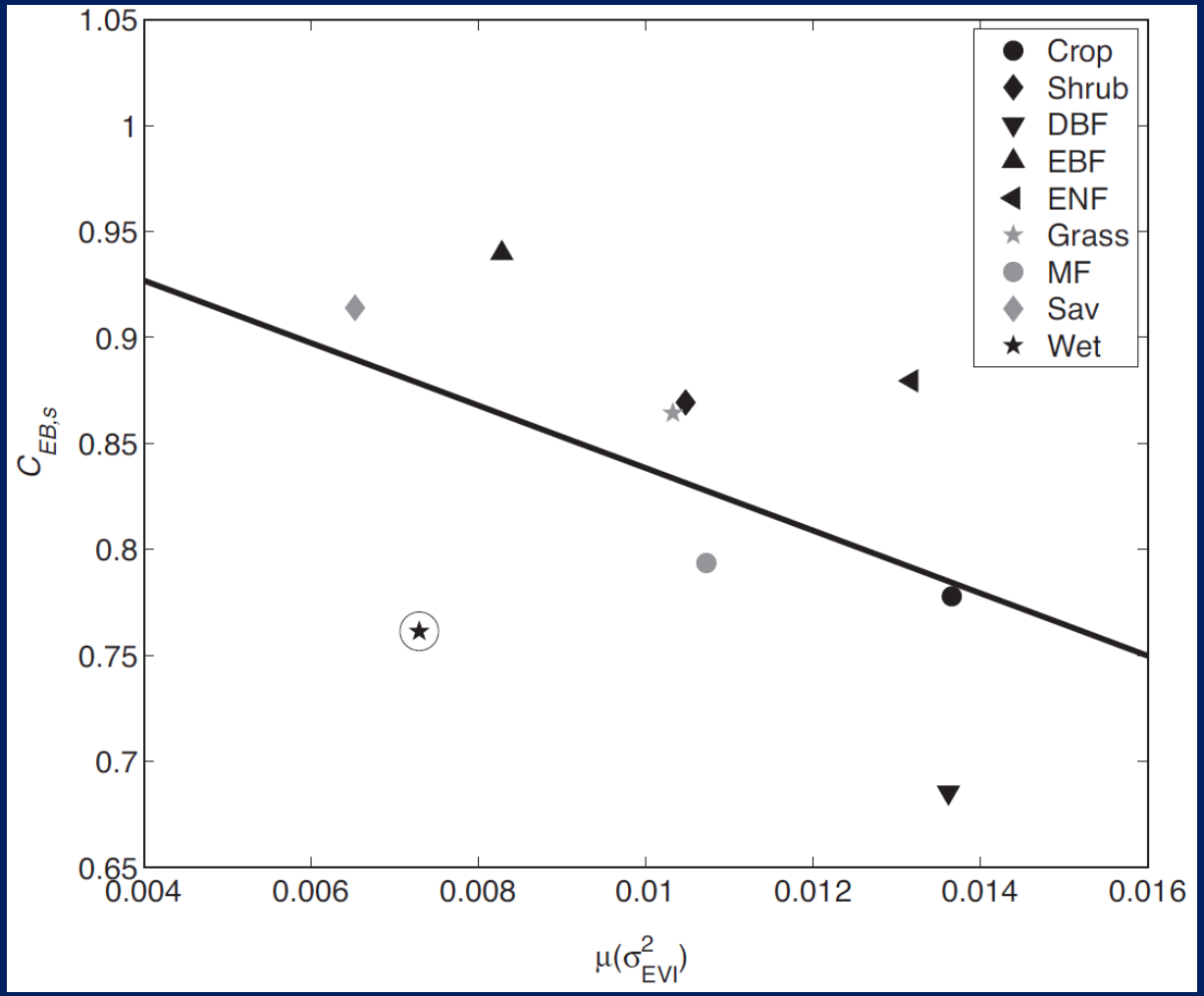


Chris Gough and Peter Curtis

Energy imbalance worsens with increased regional spatial heterogeneity

EBC=
H+Le

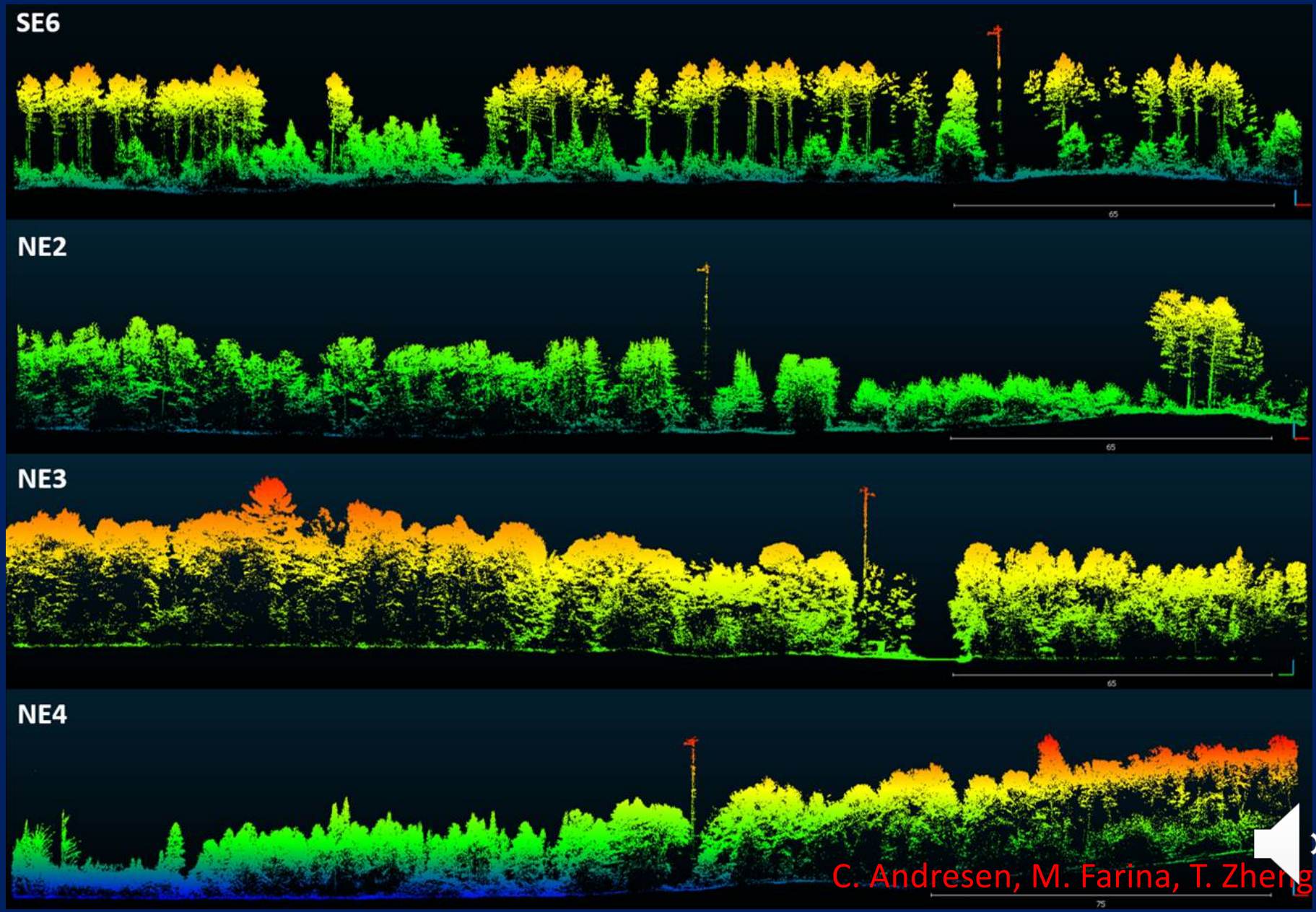
Rnet-G



Greenness spatial variance

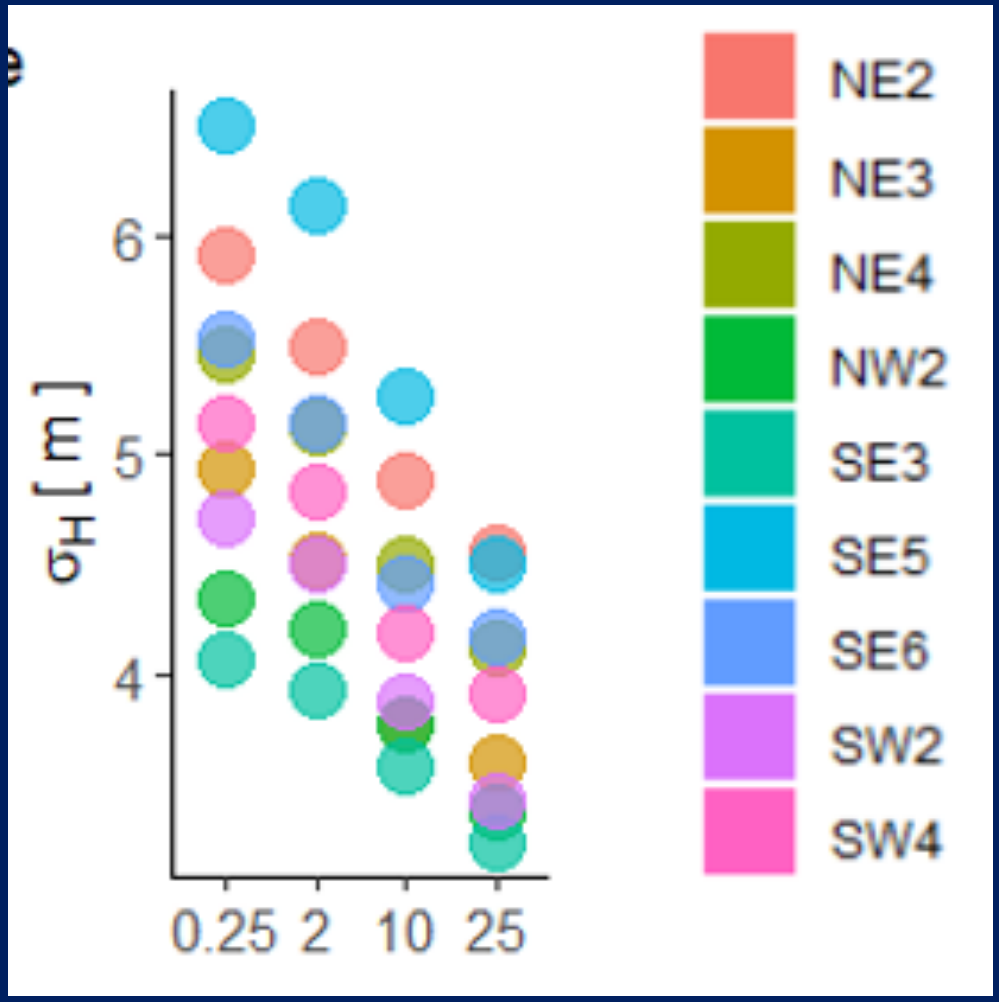
Stoy et al., 2013, AFM

Is it related to canopy structure?



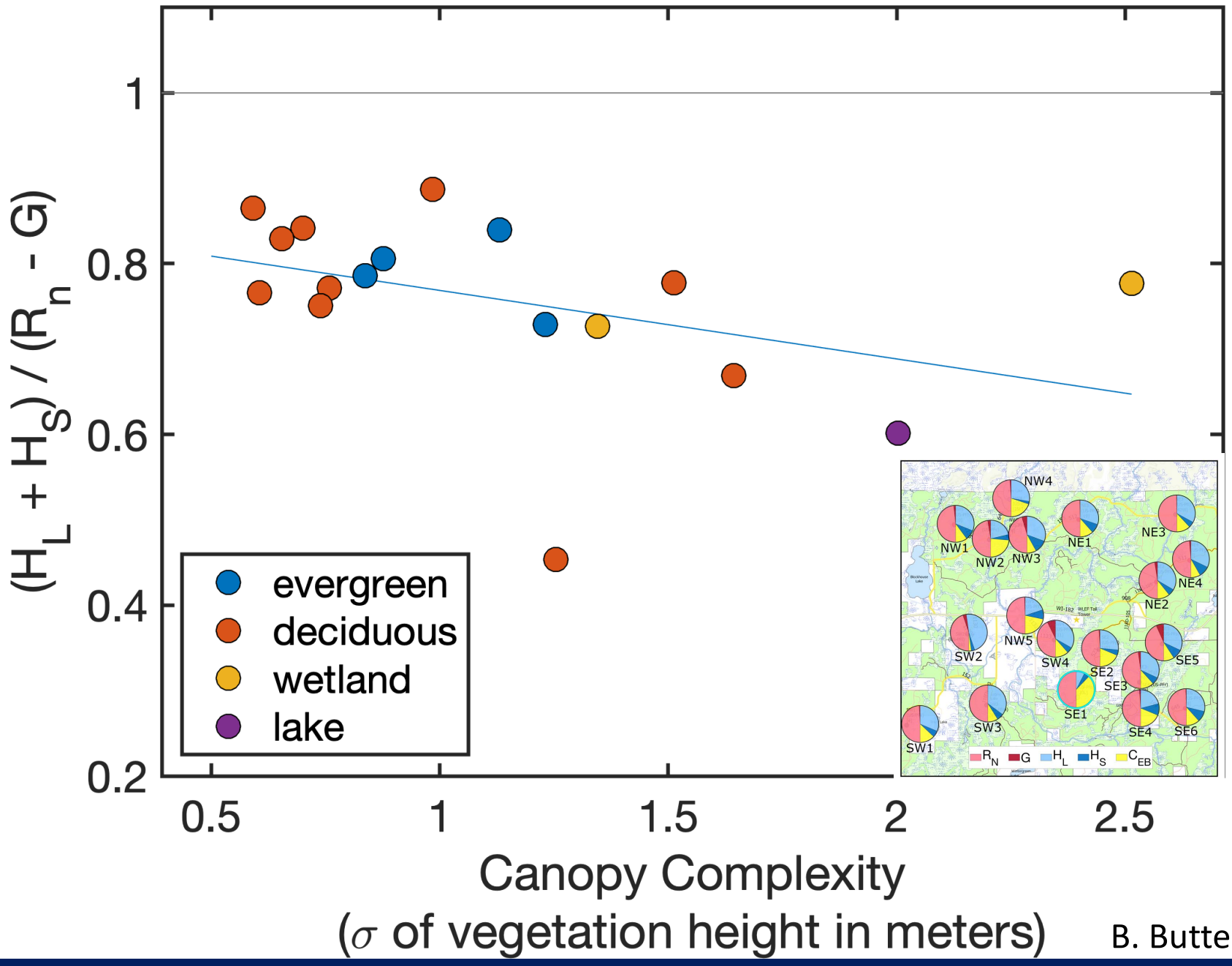
C. Andresen, M. Farina, T. Zheng

Canopy complexity varies with scale of sampling, but relative differences stay the same



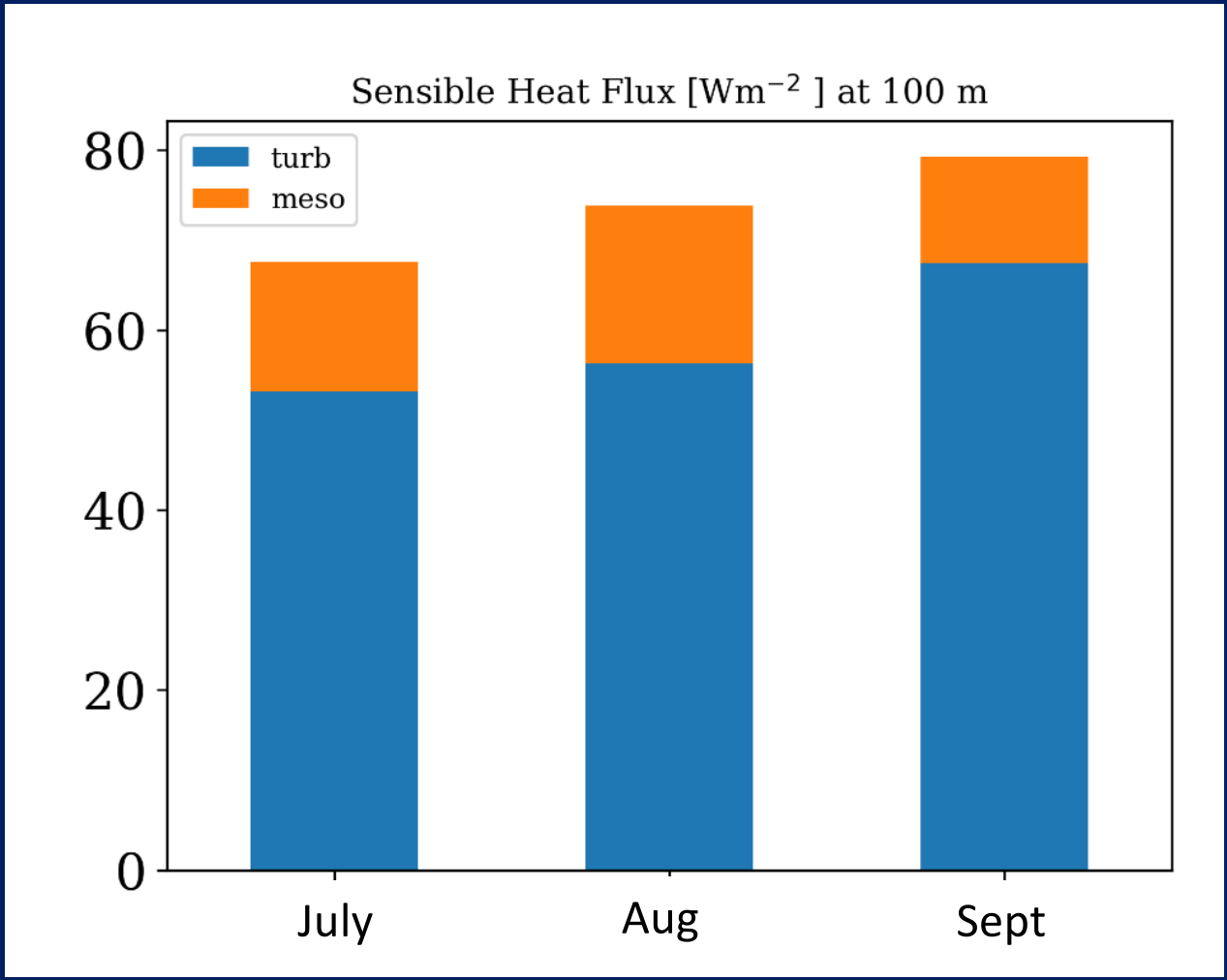
Spatial Scale (m)

B. Murphy et al., in prep



B. Butterworth

The missing energy is in the "mesoscale" according to flux aircraft

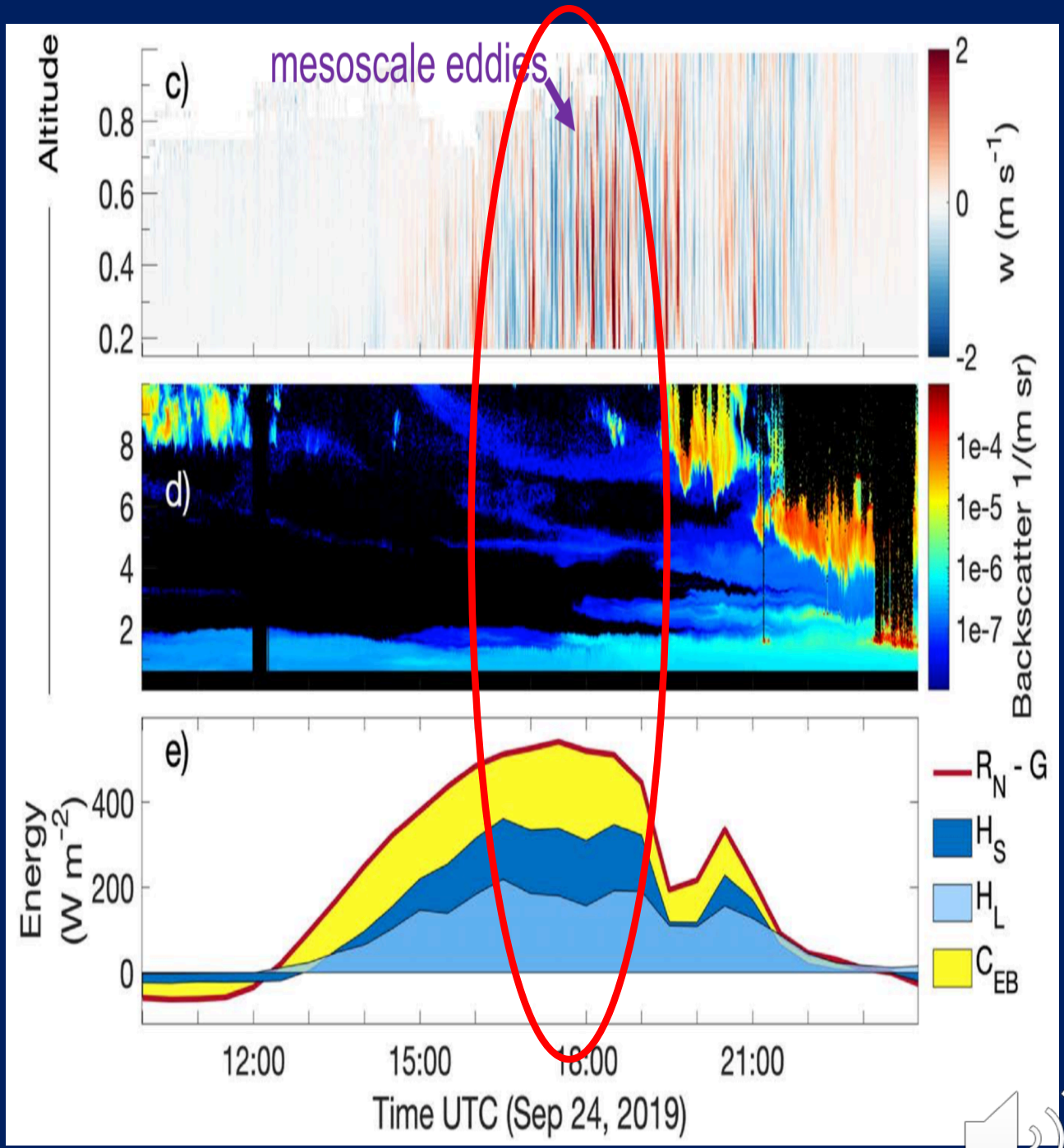


S. Paleri, in prep

Vertical wind

Aerosol backscatter

Energy balance



L. Wanner, H. Vogelmann,
E. Eloranta, T. Wagner, E. Olson, B. Butterworth

Process and pattern scale matters sometimes

- Sometimes it is just linear (land surface temperature) – can randomly sample and average
- Sometimes it is conditioned on a variable (stand age on carbon fluxes) – conditionally sample
- Sometimes it is highly non-linear (mesoscale eddies from canopy variation) – requires new ways to sample or conceptualize system

AGU cross-journal special collection https://bit.ly/2TIYtEh

Deadline Extended to end of May 2022!

Advances in Scaling and Modeling of Land–Atmosphere Interactions

Papers are invited for a new cross-journal special collection on insights in scaling land-atmosphere interactions from field experiments, data analyses, and modeling.

More at AGU:

- B11C-04 - Diagnosing the Effects of Surface Heterogeneity Induced Secondary Circulations from Large Eddy Simulations of Diurnal Cycles During the CHEESEHEAD19 Field Campaign (Paleri et al) MON 8:30 am
- B14D-08 - Exploring Natural Climate Solutions: Could flux towers be useful at industrial scales? (Metzger) MON 3:15 pm
- B15G-1515 - Modeling the Energy Balance Gap Based on Atmospheric Stability and Surface Heterogeneity (Wanner) MON posters
- H22B-01 - Partitioning evaporation and transpiration from 17 eddy covariance towers in a diverse forest landscape (Stoy) TUE 9:45 am
- B25I-1603 - Unravelling Forest Complexity: Resource Use Efficiency, Disturbance, and the Elusive Structure-Function Relationship (Murphy) TUE posters
- GC41D-10 - Merging eddy covariance and remote sensing models to facilitate high resolution spatiotemporal monitoring of agricultural greenhouse gas budgets (Wiesner) THU 8:45 am
- B55D-1234 - The Influence of Interannual Carbon Variability on Long-Term Carbon Sequestration in Proximate Northern Forests and Wetlands (Abyazani) FRI posters

Thank you!

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- Contributions from:
  - Stefan Metzger, Bailey Murphy, Sreenath Paleri, Luise Wanner, Jonathan Thom, Jess Turner, Ting Zheng, CHEESEHEAD19 participants, ChEAS Ameriflux and LTER participants
- Support:
  - DOE Ameriflux Network Management Project contract to ChEAS core site cluster, NSF AGS 1822420 (CHEESEHEAD), NSF DEB 1440297 (NTL LTER), NOAA ESRL + ATDD, USFS, USGS, WI Educational Comm Board, WI Dept of Natural Resources, DFG, NASA, NCAR

Photo: A. Desai