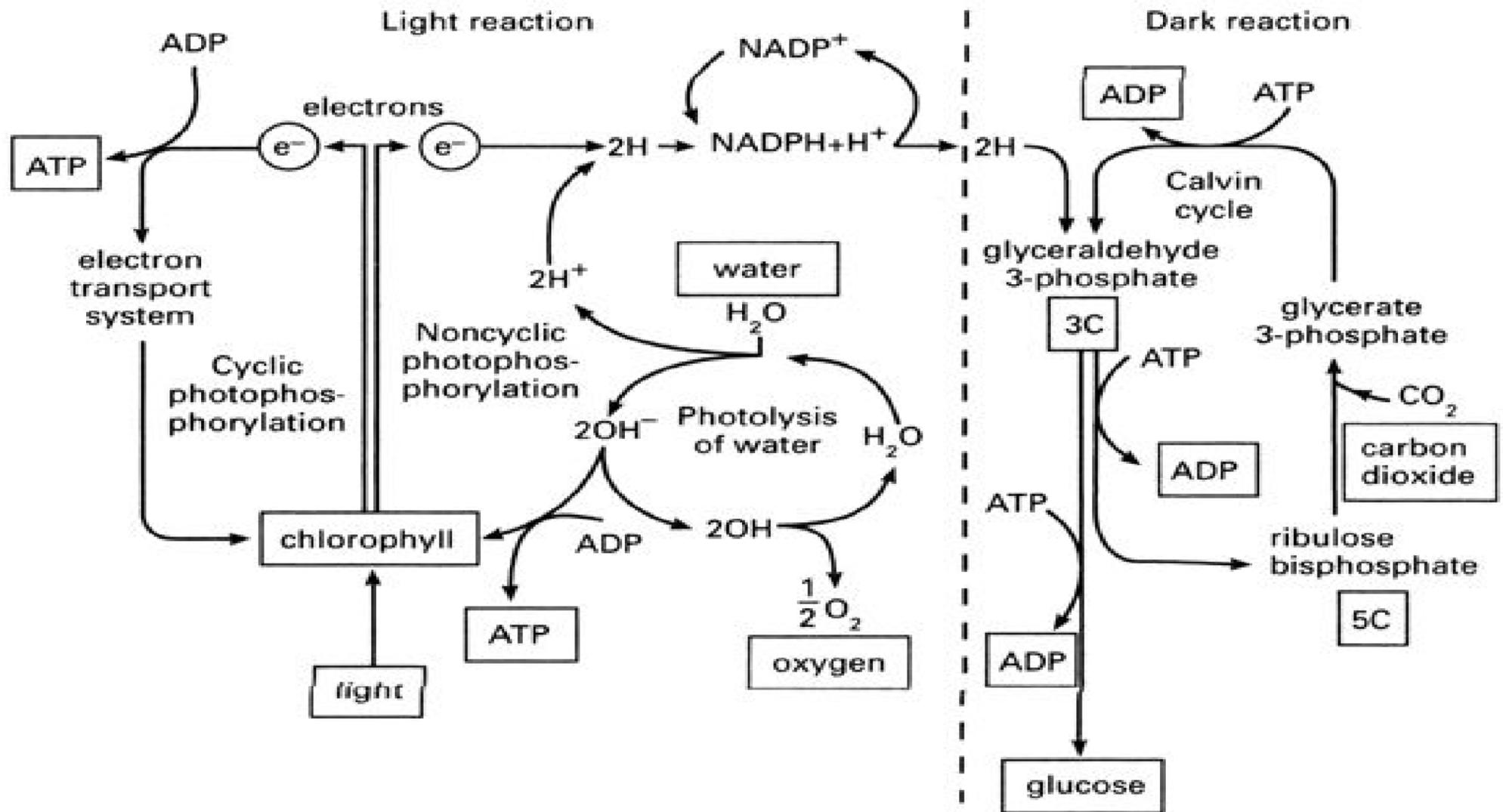
An aerial photograph taken from the perspective of someone on a research aircraft. The dark, metallic wing of the aircraft is visible in the lower foreground, extending towards the right. Below the wing, a dense, green forest stretches across the landscape. In the distance, a tall, thin, silver tower rises vertically against the blue sky. The sky is filled with scattered white clouds. The overall scene suggests a remote research site in a natural environment.

The “last” breath of the biosphere?

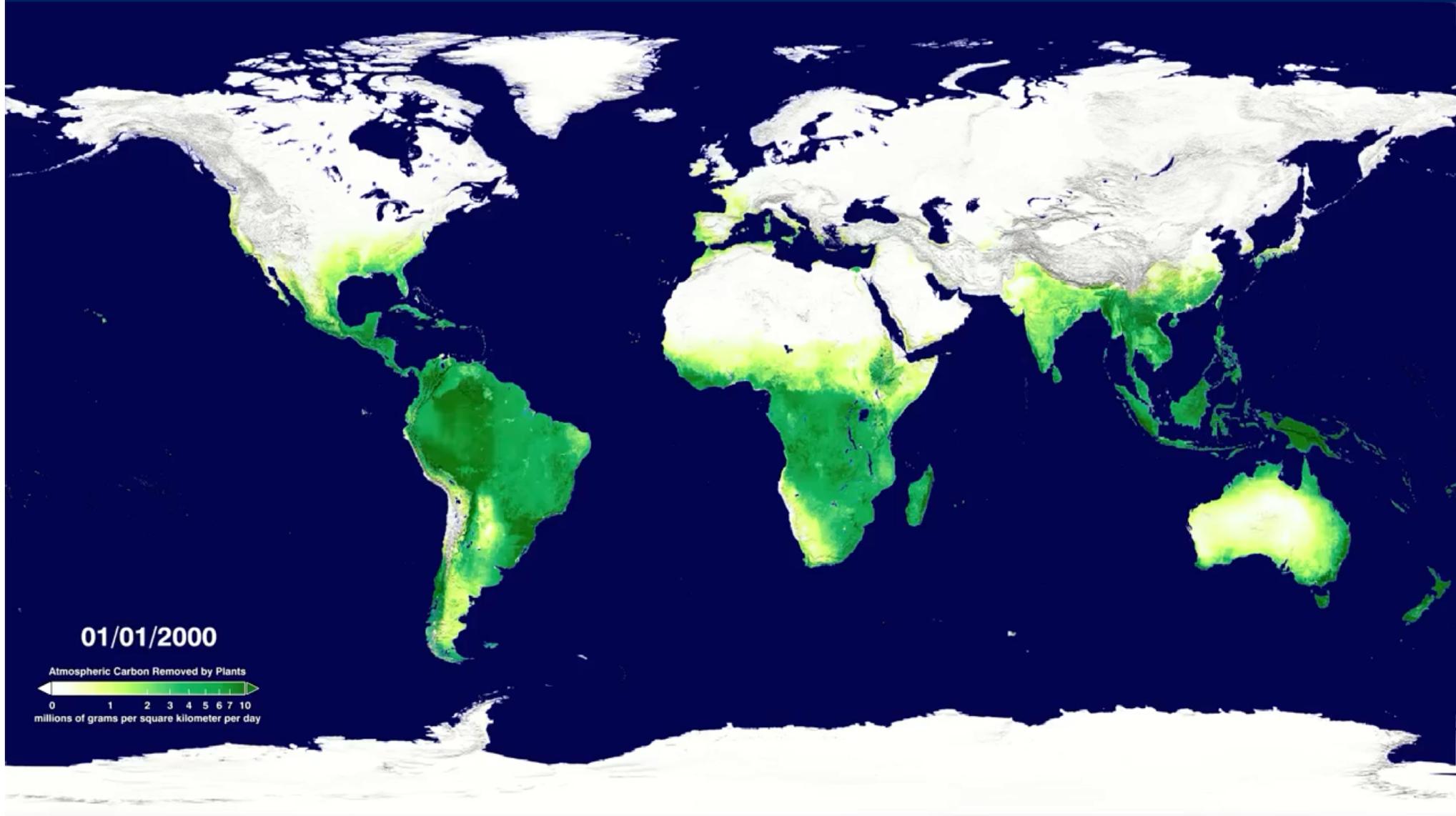
**Ankur Desai, UW-Madison
CCR Climate Change Symposium
Feb 13, 2020**

Photo: B. Butterworth

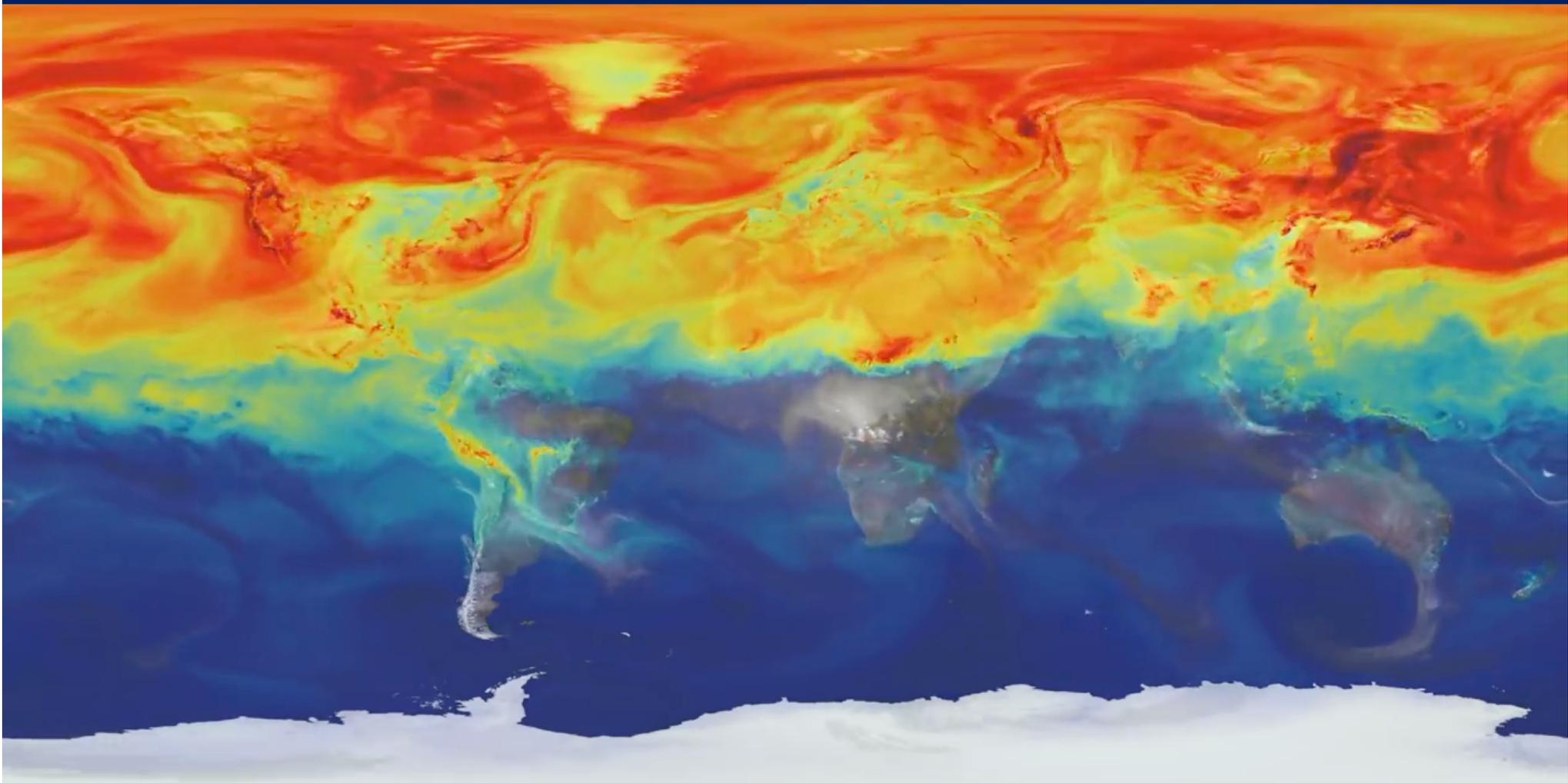




GPP = Gross Primary Productivity = photosynthesis



MODIS GPP (NASA)



2006 / 05 / 23

Global Modeling and Assimilation Office

Carbon Monoxide Column Abundance [1.0×10^{18} molec cm^{-2}]



Carbon Dioxide Column Concentration [ppmv]





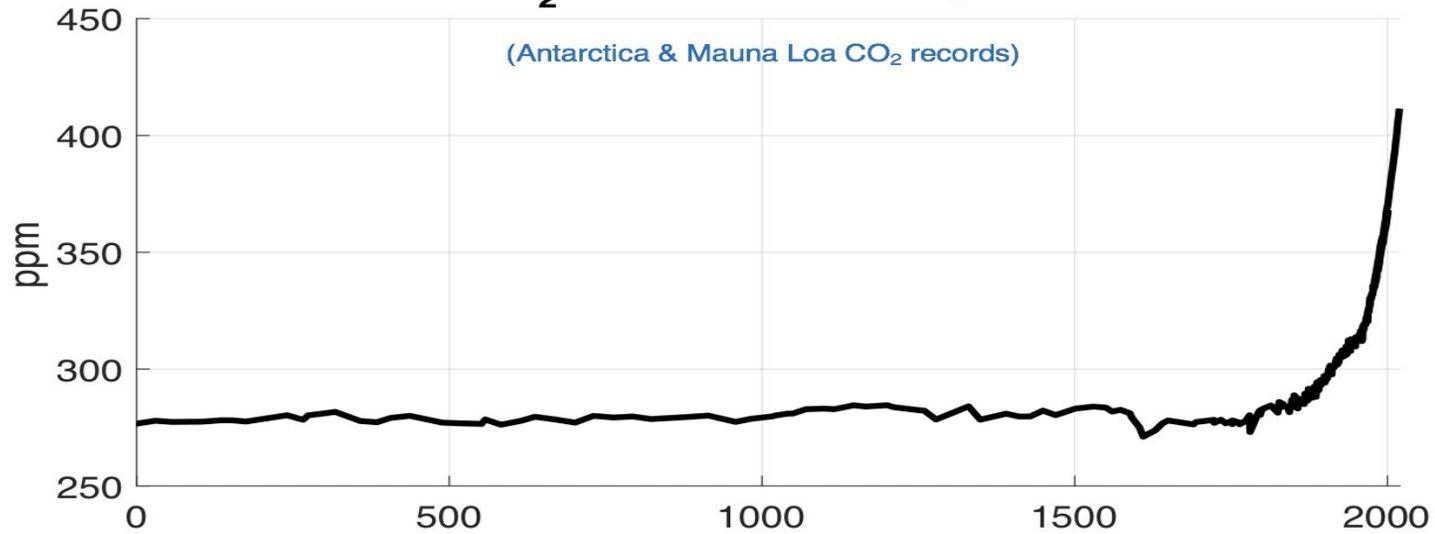
<https://www.nytimes.com/2020/01/10/world/australia/australia-wildfires-photos.html>



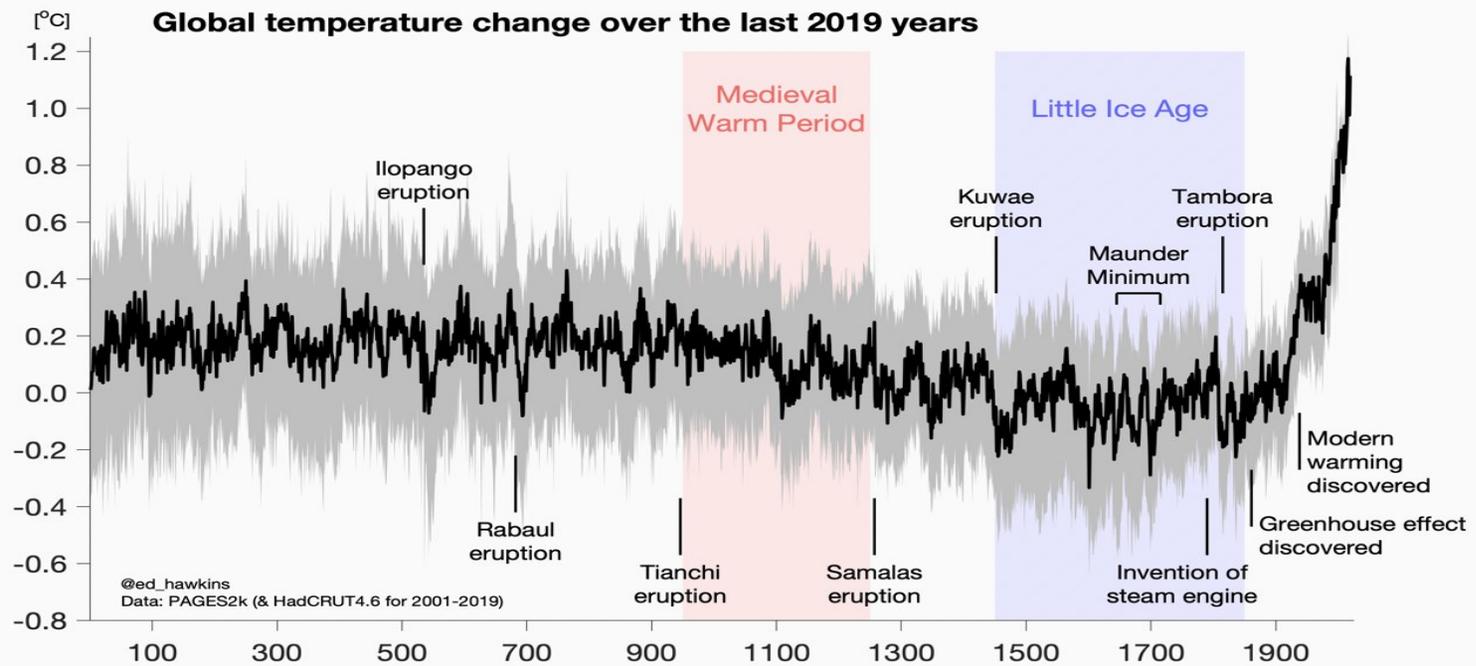
Is the “breath of the biosphere” changing
as a result of climate change?

What does it mean for the future?

CO₂ over the last 2019 years



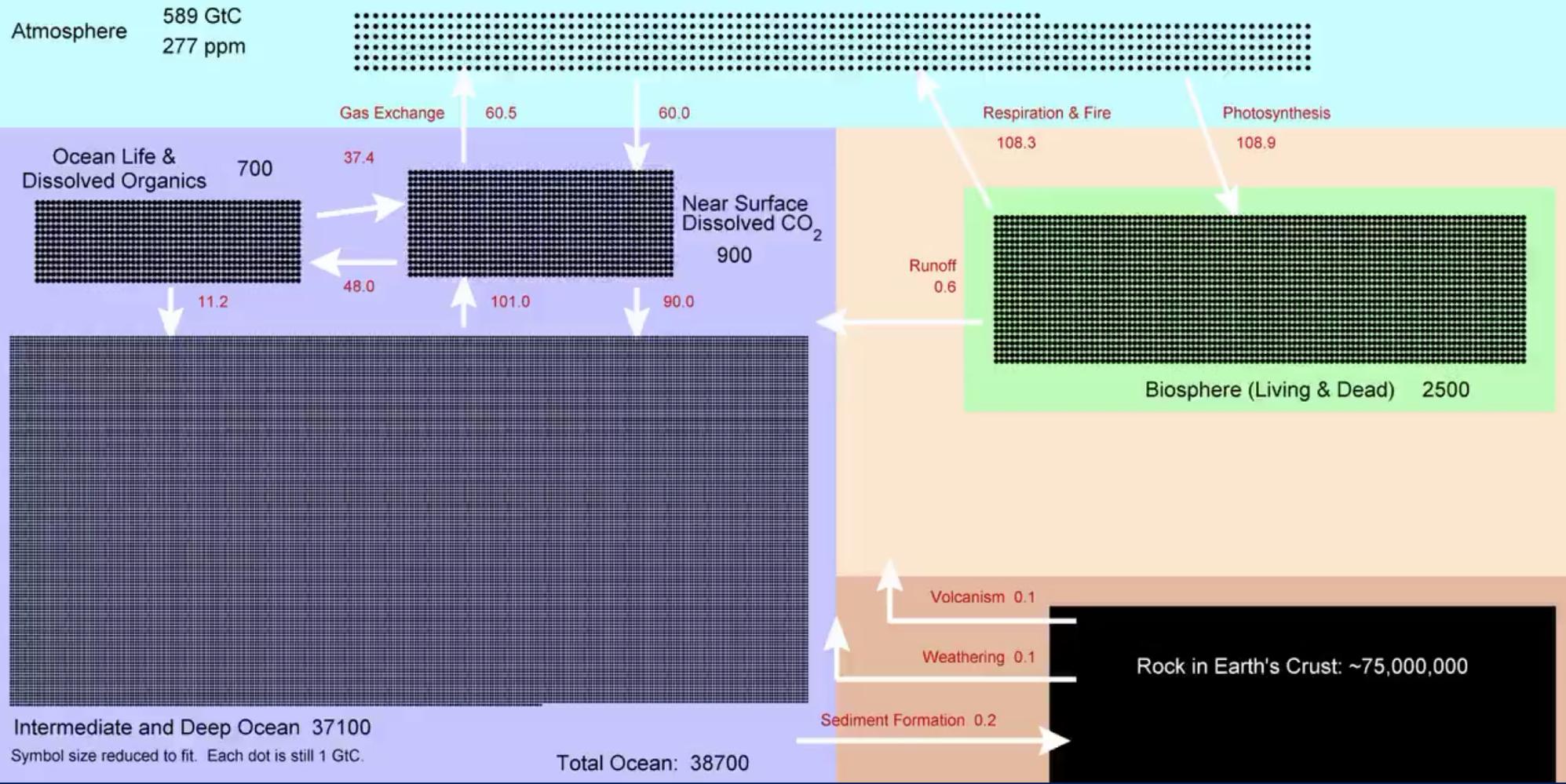
Global temperature change over the last 2019 years

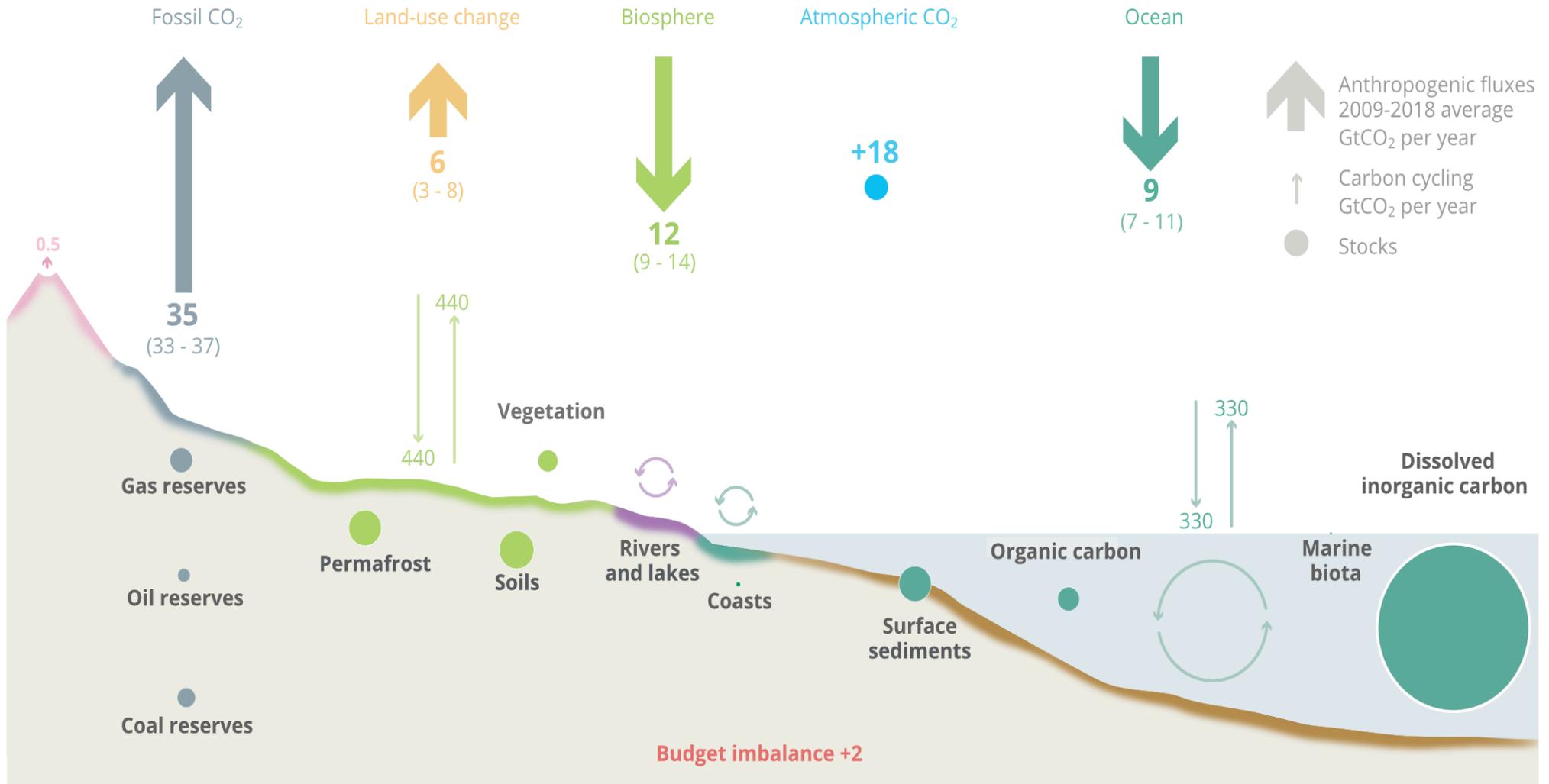


Earth's Carbon Cycle

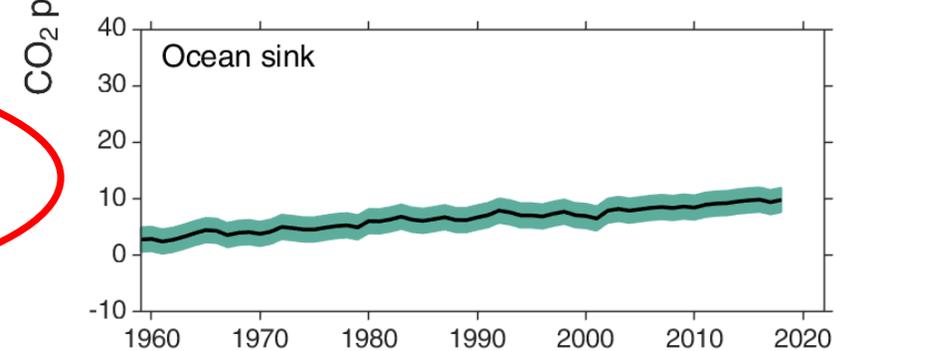
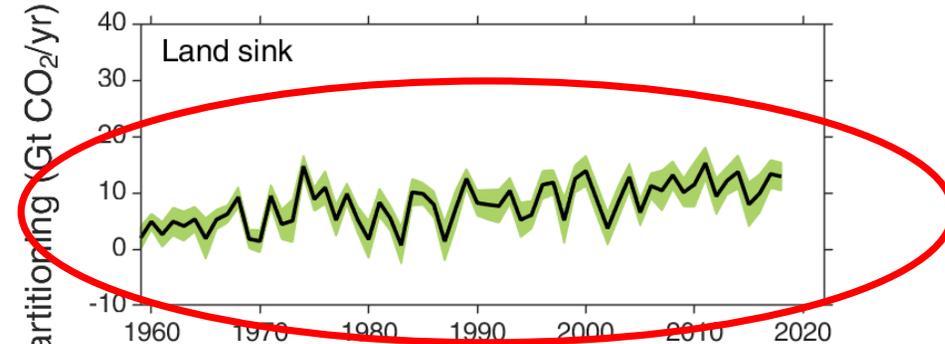
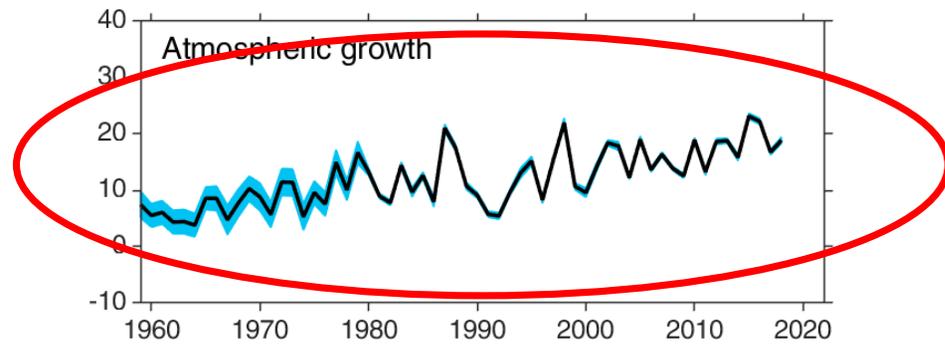
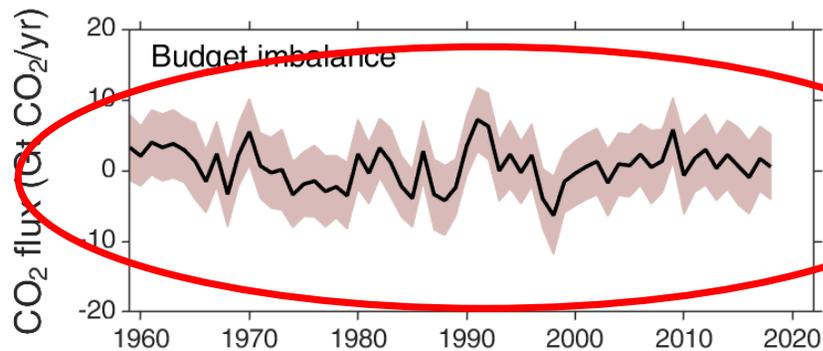
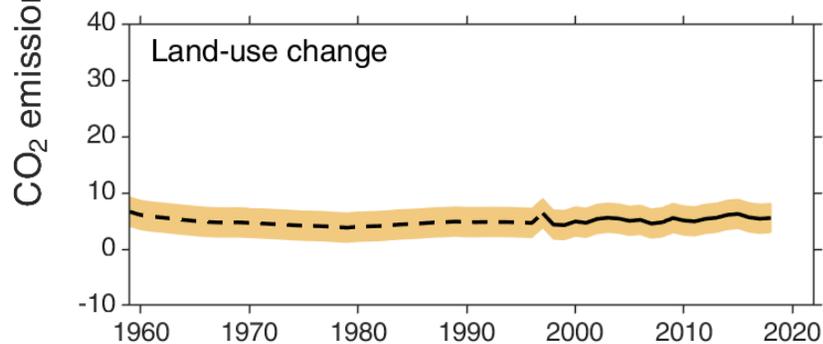
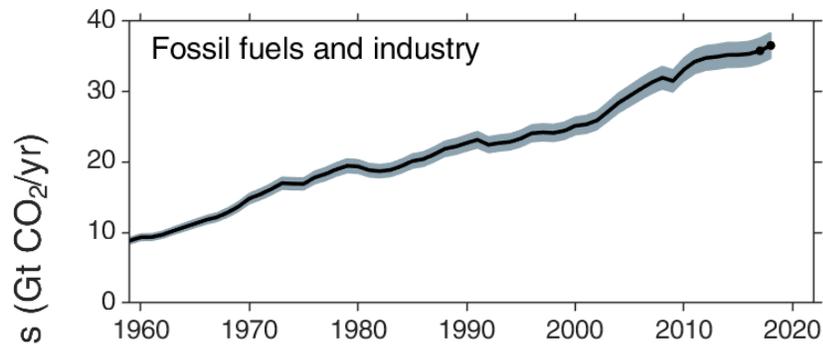
Pre-Industrial

• = 1 GtC = 10^{12} kg of Carbon
 Stocks in GtC Flows in GtC / year





Source: [CDIAC](#); [NOAA-ESRL](#); [Houghton and Nassikas 2017](#); [Hansis et al 2015](#); [Friedlingstein et al 2019](#); [Global Carbon Budget 2019](#)



© Global Carbon Project • Data: GCP

Source: [CDIAC](#); [NOAA-ESRL](#); [Houghton and Nassikas 2017](#); [Hansis et al 2015](#); [Friedlingstein et al 2019](#); [Global Carbon Budget 2019](#)

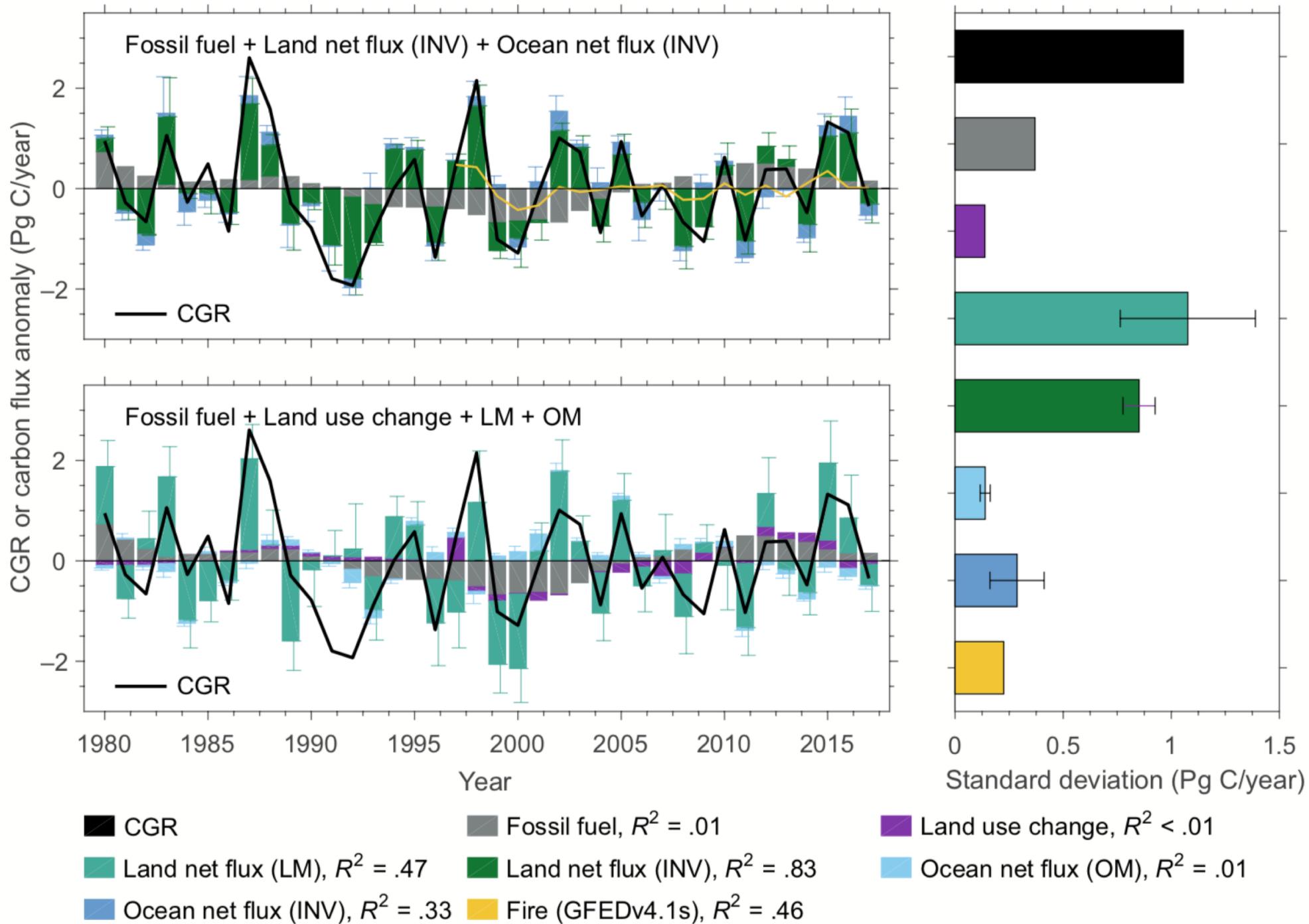
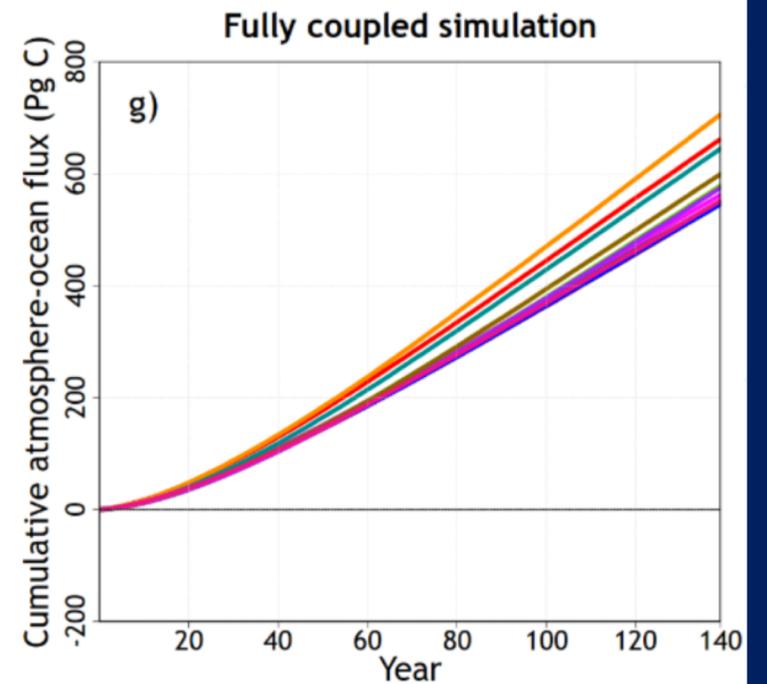
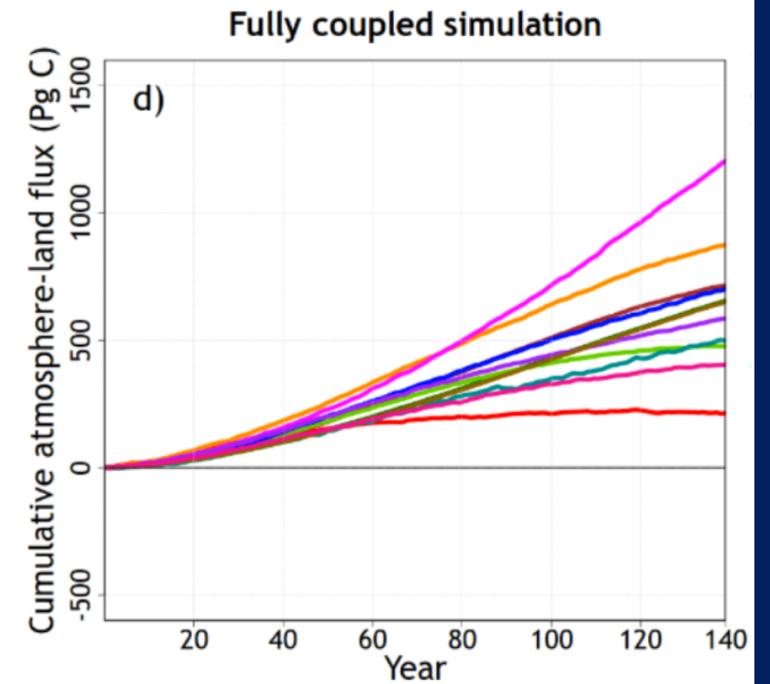
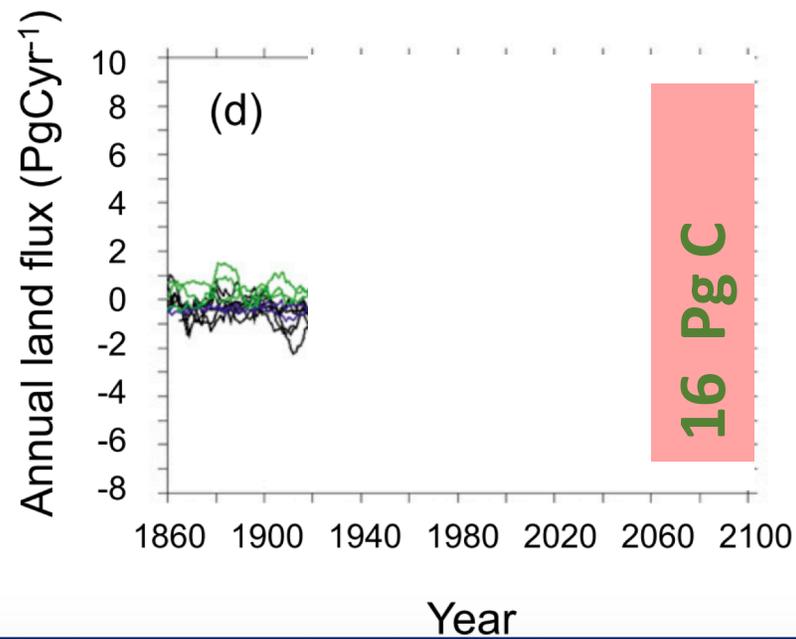
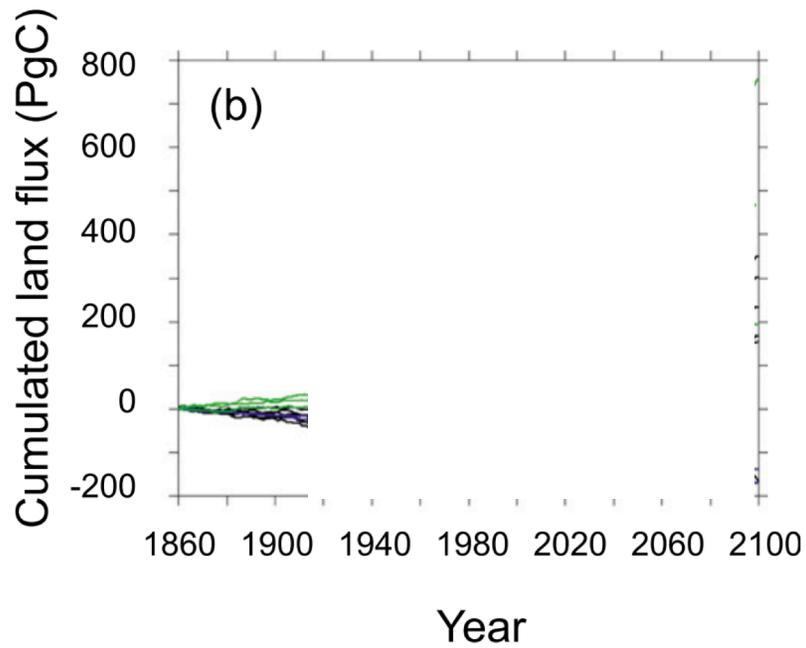
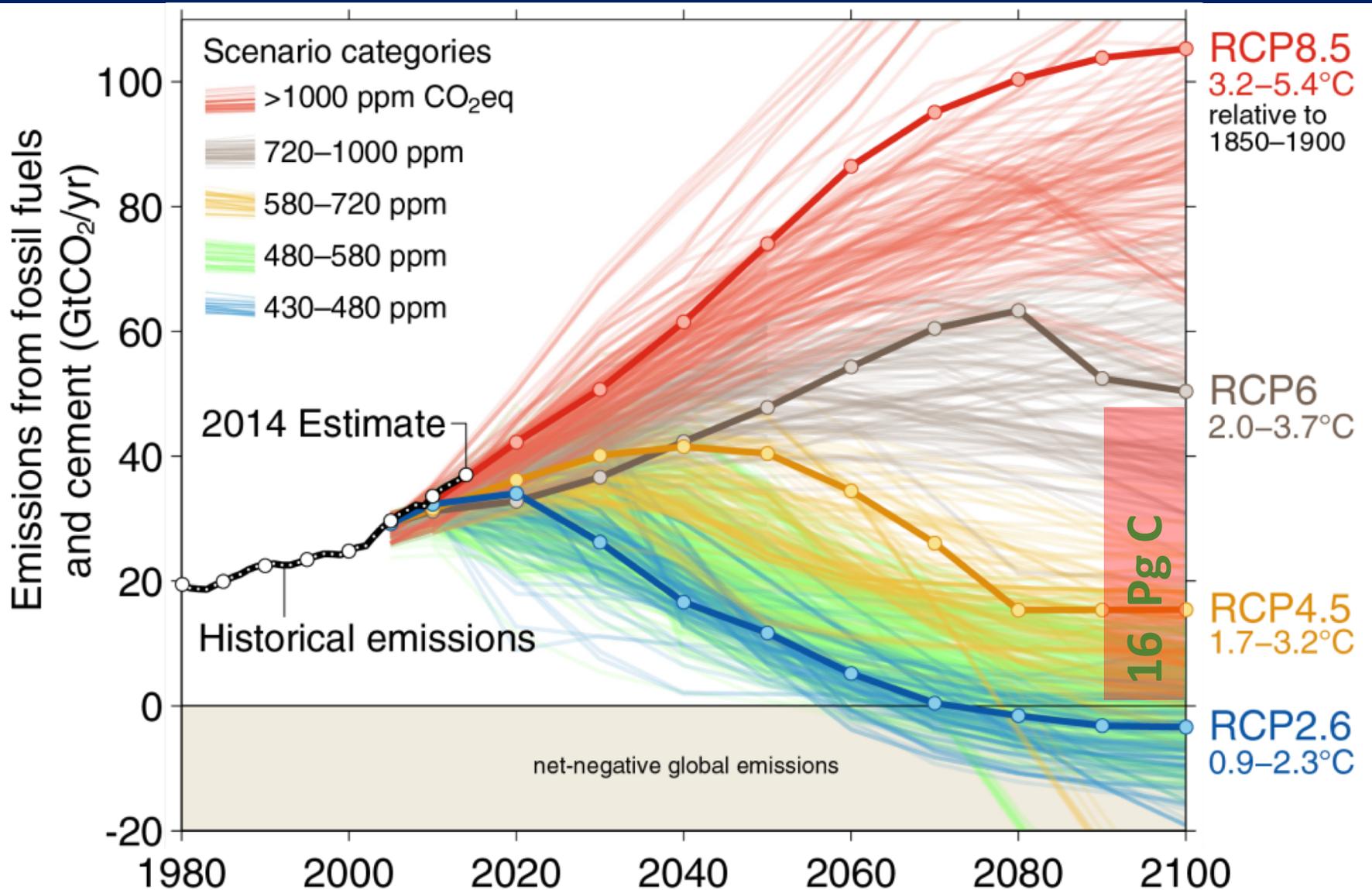


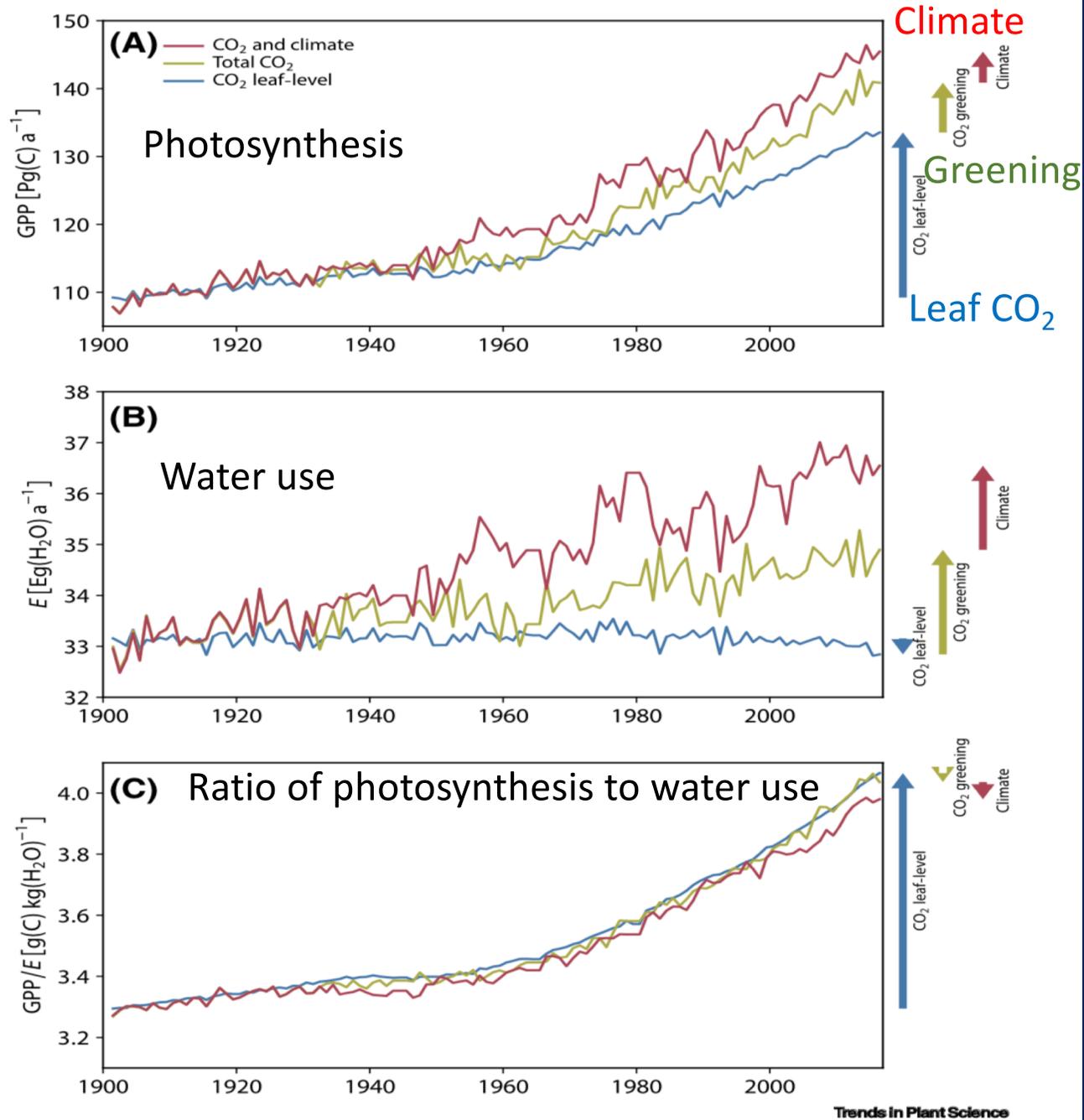
FIGURE 2. Interannual variability (INV) in natural components of the global CO₂ budget (top) and their standard deviations (bottom) from 1980 to 2015. The standard deviation of the total CO₂ budget is shown in black. The standard deviation of the natural components is shown in grey, purple, teal, and blue. The standard deviation of the anthropogenic components is shown in yellow.



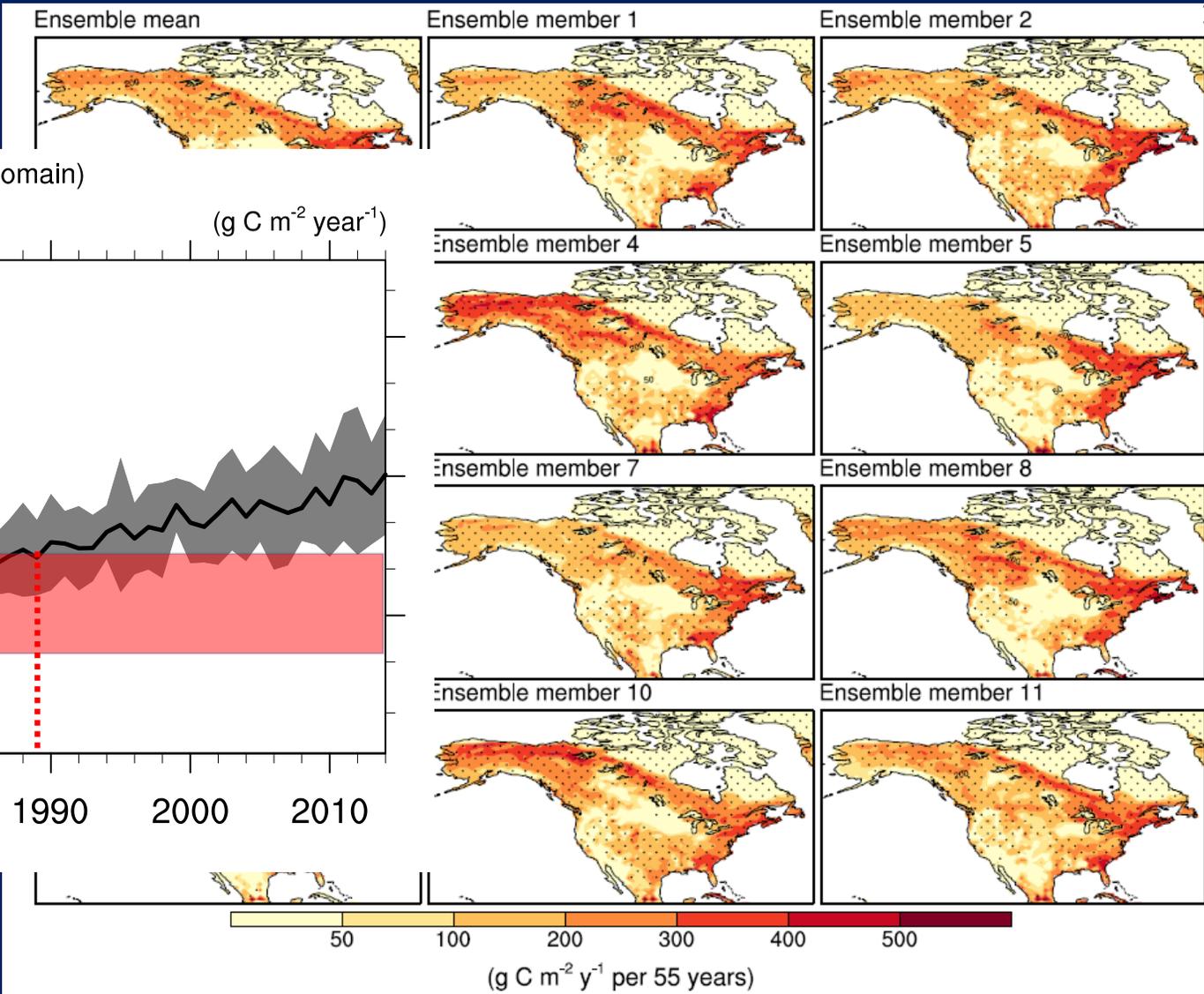
Freidlingstein et al., 2014; Arora et al., 2019



Global Carbon Project 2019: Over 1000 scenarios from the IPCC Fifth Assessment Report are shown
 Source: [Fuss et al 2014](#); [CDIAC](#); [Global Carbon Budget 2014](#)



GPP trends (1960-2014) from CESM large ensemble





Peter Bakwin
NOAA (Colorado)



Ken Davis
Penn State



Arlyn Andrews
NOAA (Colorado)



Jon Kofler
NOAA (Colorado)



Bruce Cook
NASA Goddard



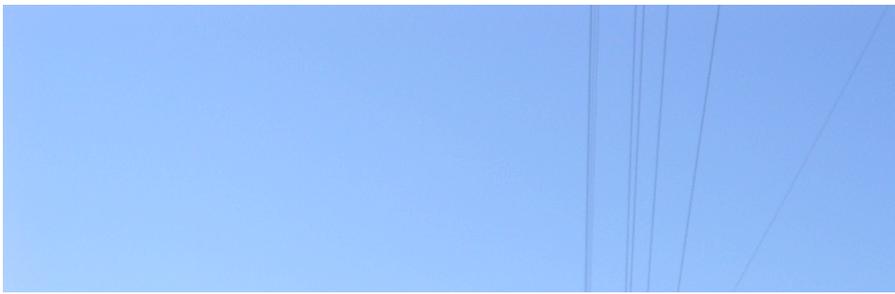
Ankur Desai
UW-Madison
AOS



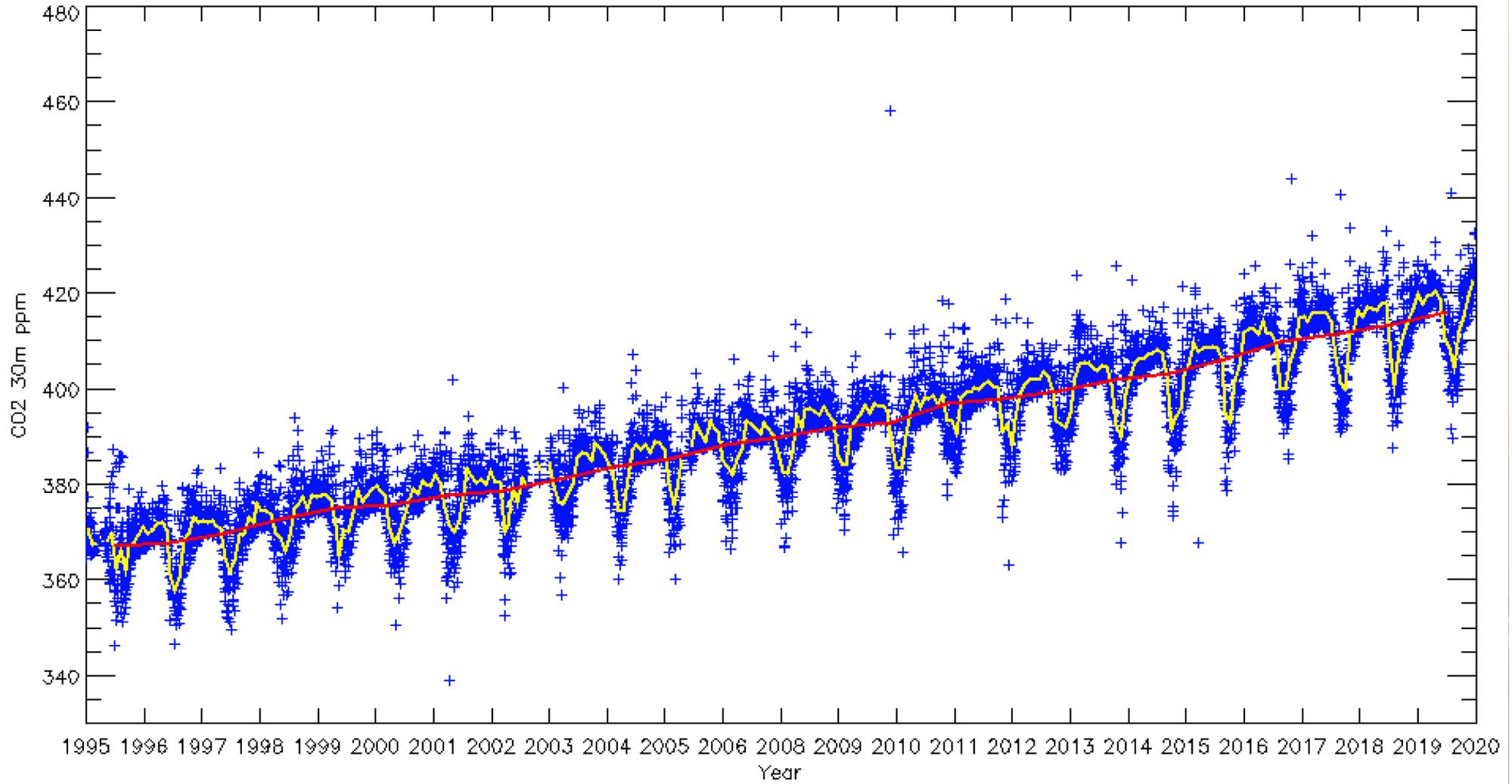
Jonathan Thom
UW-Madison
SSEC

The true journey of discovery is not in seeing
new landscapes but in developing new eyes
-Marcel Proust

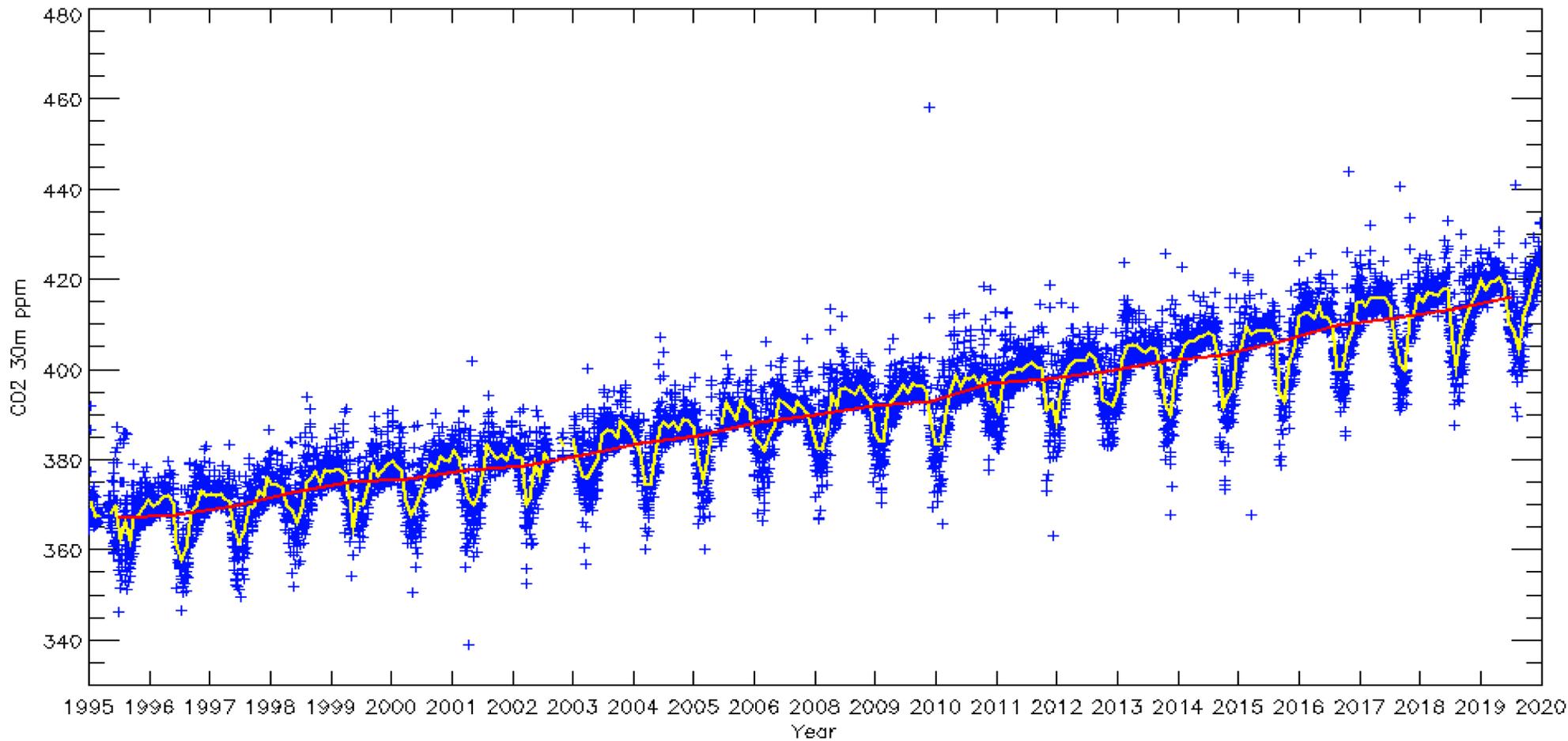




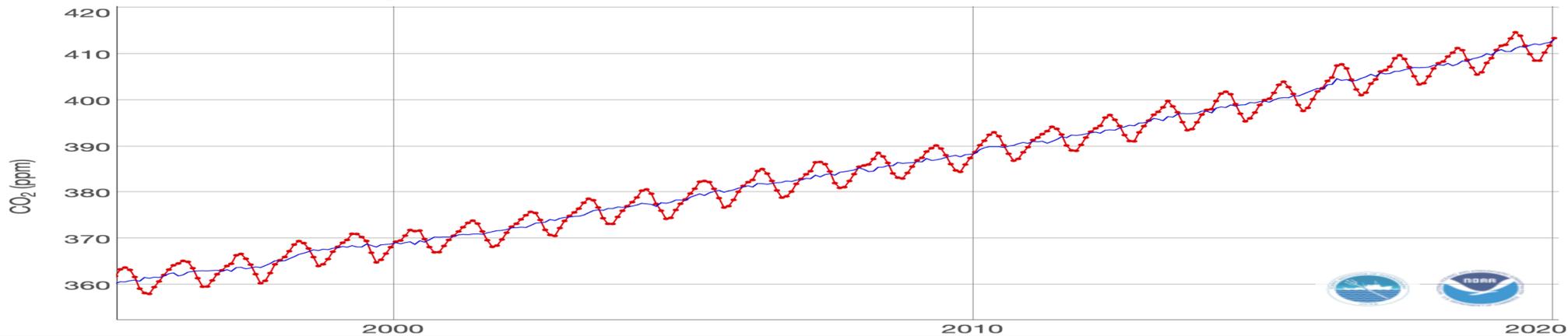
Park Falls



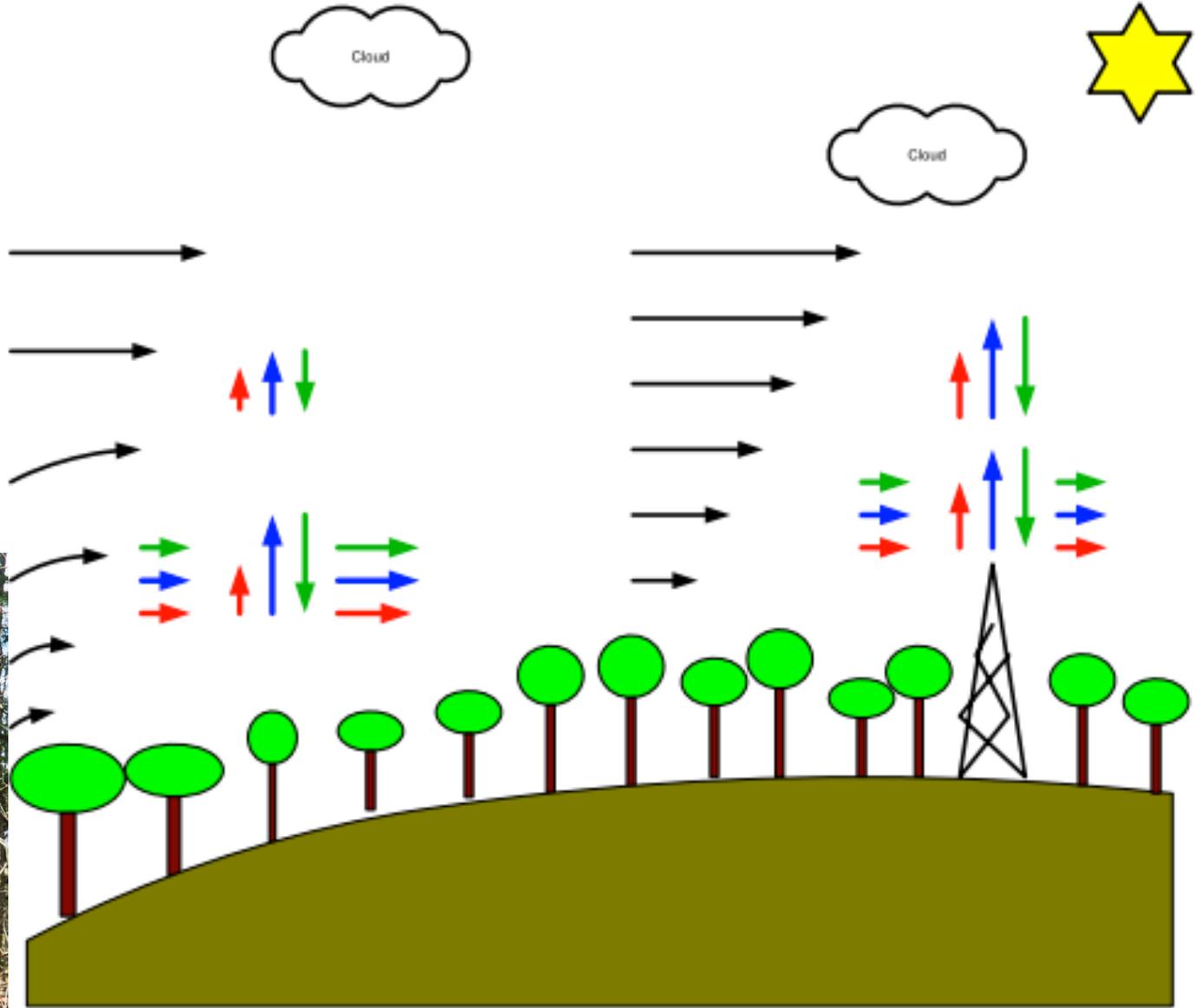
Park Falls

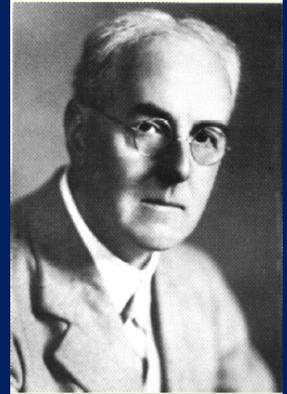
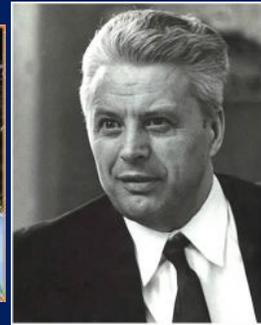


Mauna Loa Monthly Averages





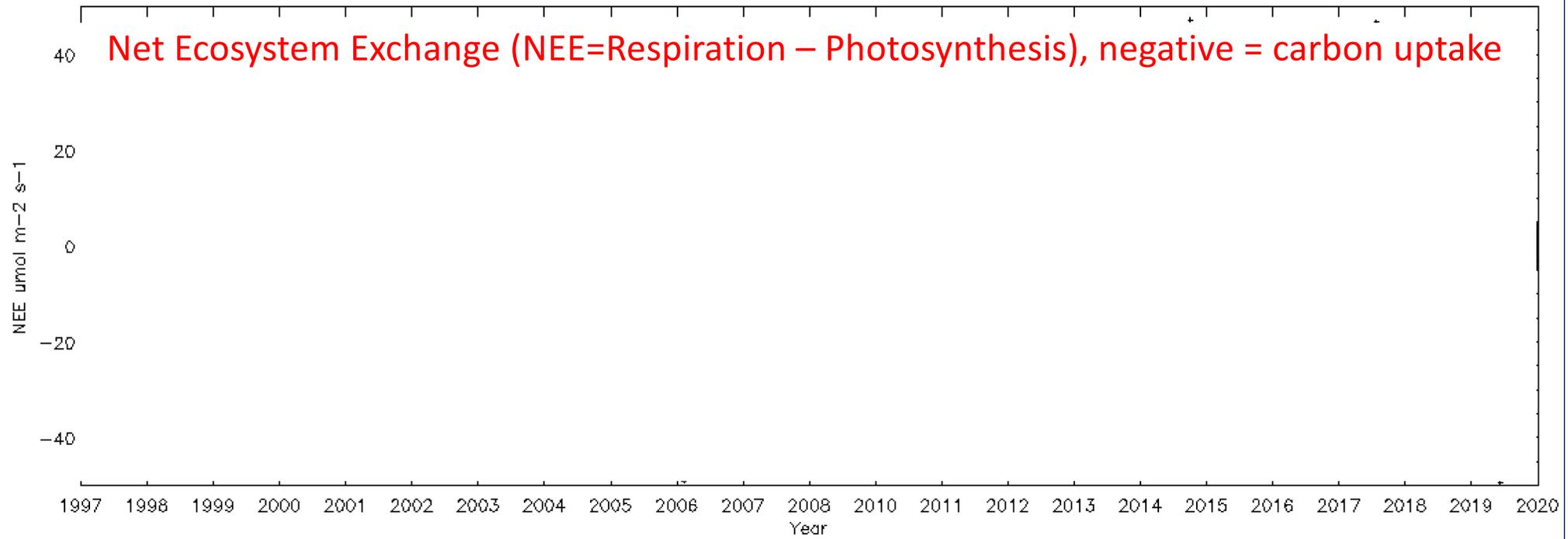




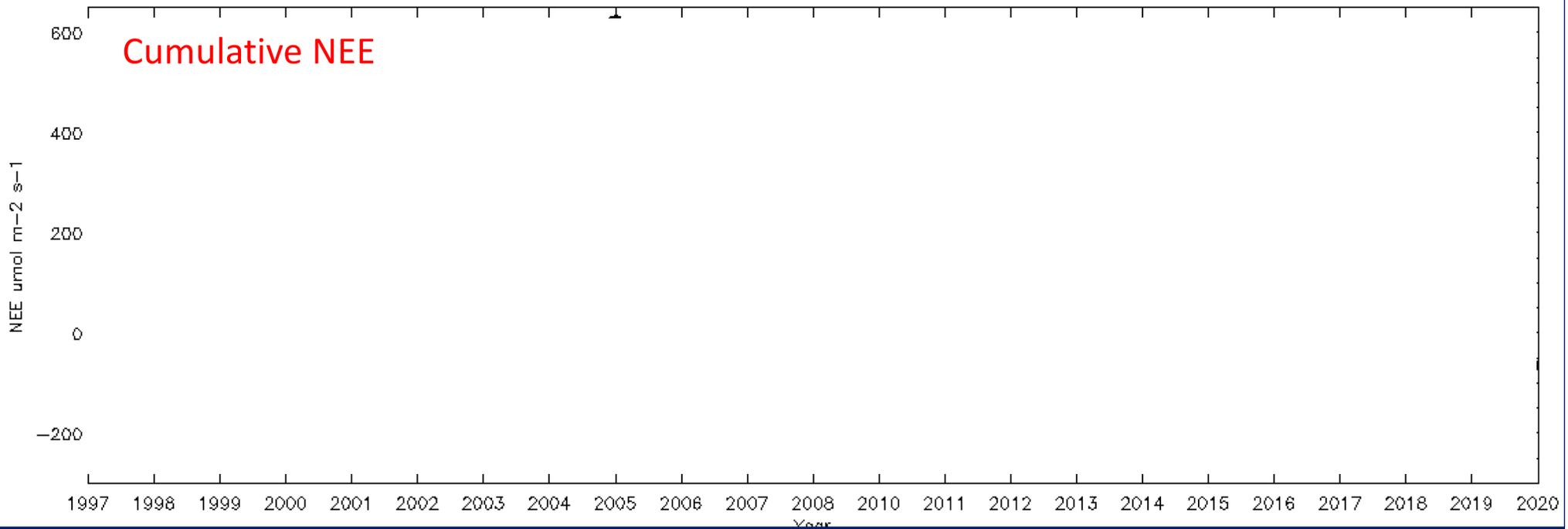
- 1880-1920s Turbulence theory (Reynolds, Prandtl, Richardson, Taylor)
- 1940s-1950s Surface-layer theory (Monin-Obhukov, Kolmogorov), development of fast sensors for anemometry
- 1960s early measurements (Inoue, Wyngaard, Kaimal)
- 1970s forest fluxes (Raupach, Lenschow, Denmead)
- 1970s CO₂ fluxes (Desjardins, Leuning)
- 1980s Infrared gas analyzers (Verma, Anderson, Valentini)
- 1990s First long-term regional CO₂ flux networks (Wofsy, Baldocchi, Goulden, Law, Aubinet, Torn)
- 2000s Global syntheses (FLUXNET, Falge, Papale, Reichstein, Moffat, Novick)
- 2010s Model-data integration, development of operational measurements (NEON, ICOS, you?)

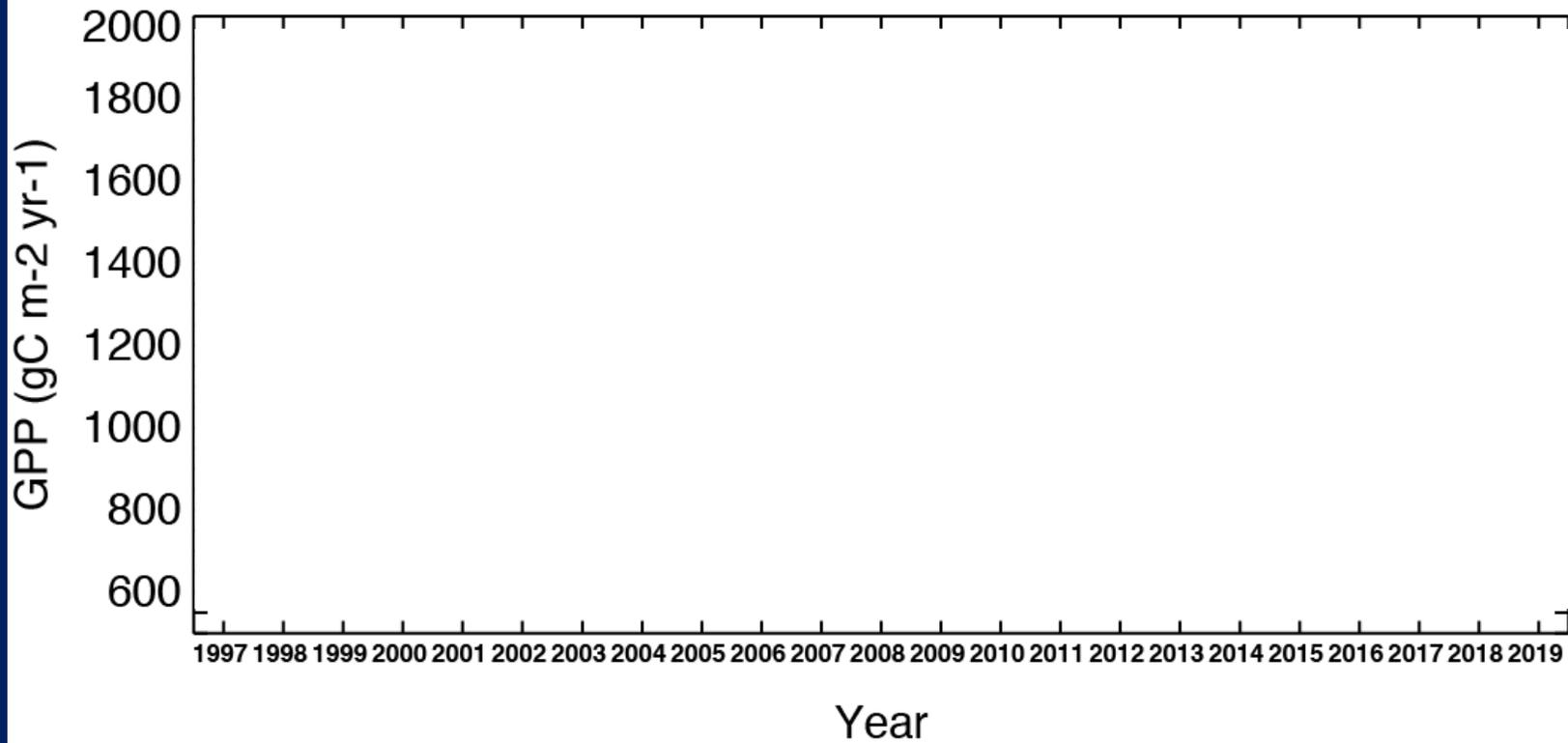
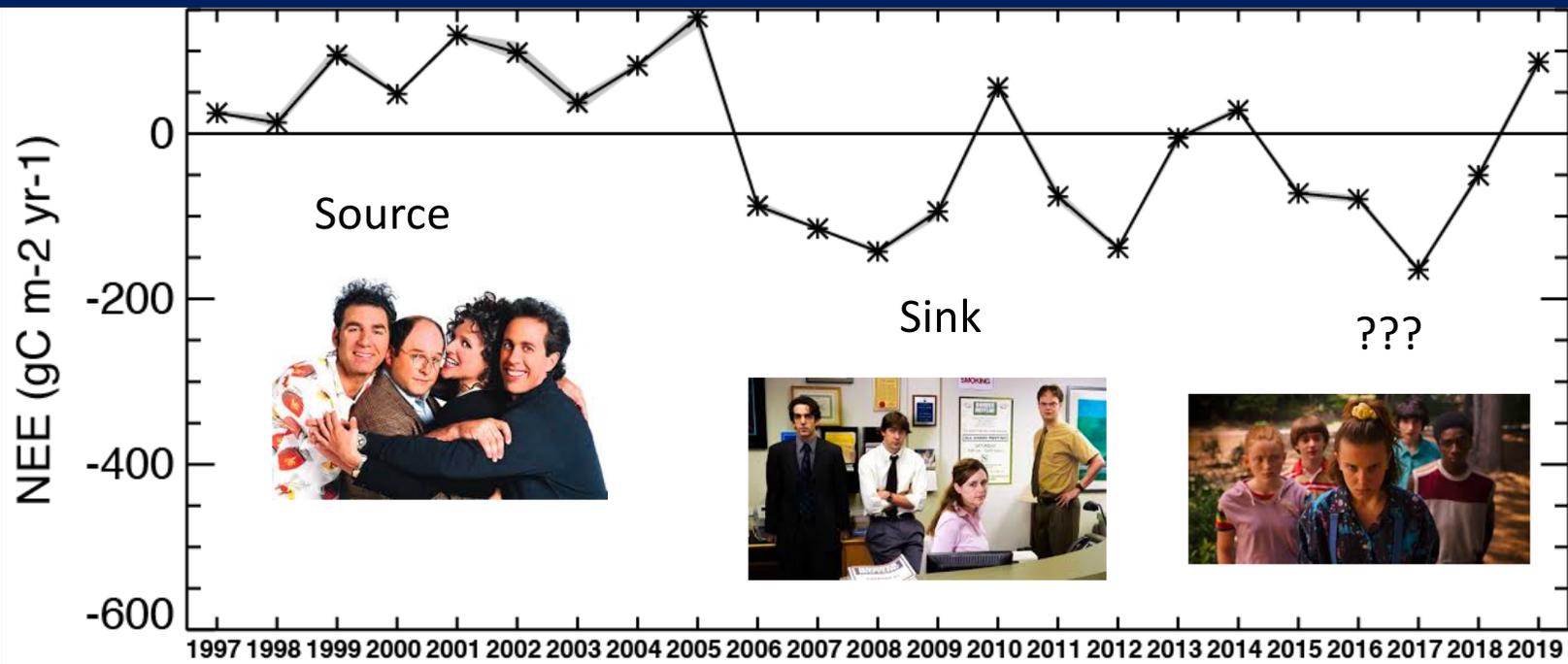


Park Falls



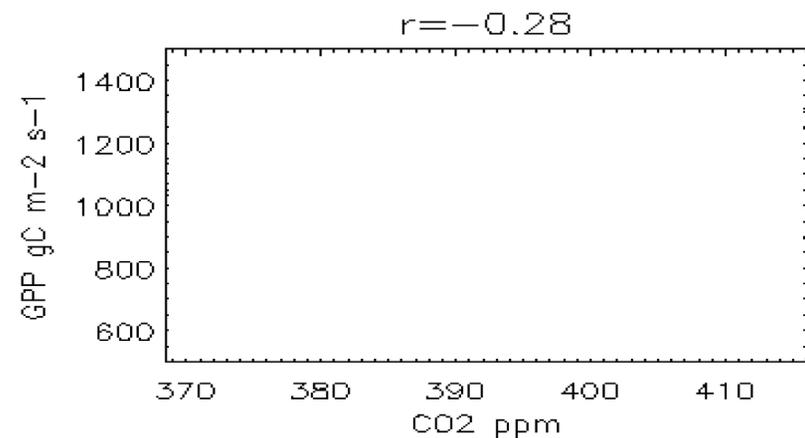
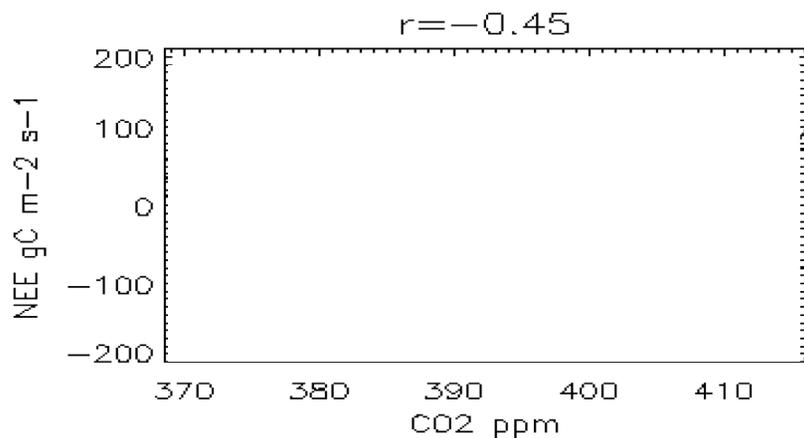
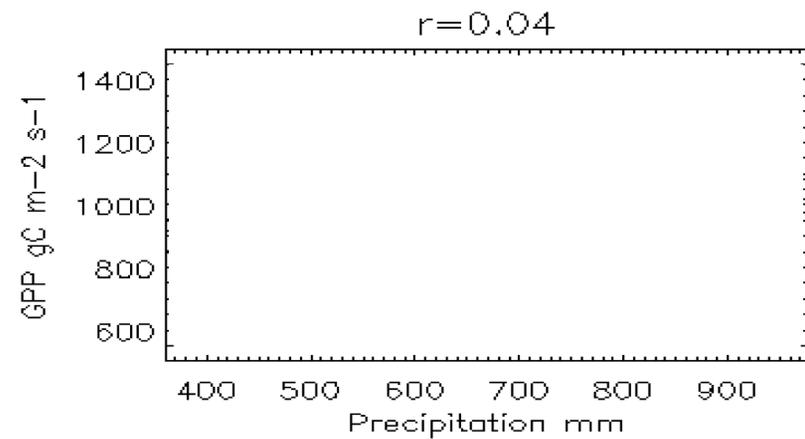
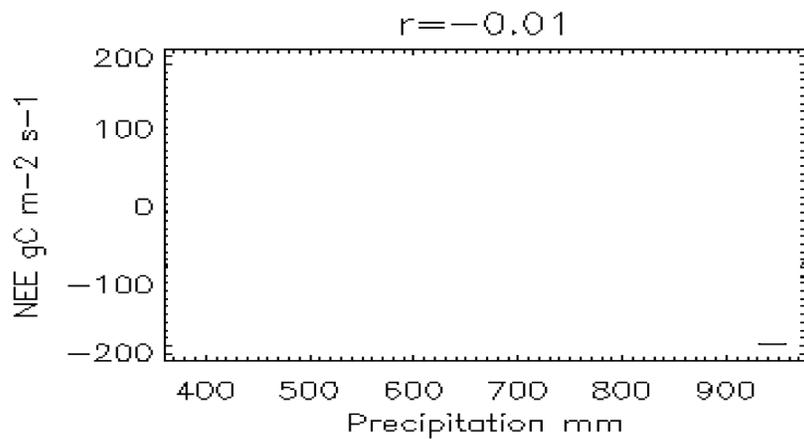
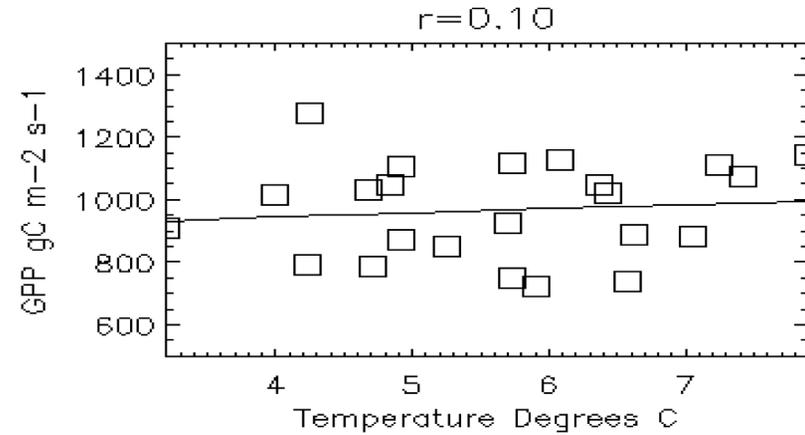
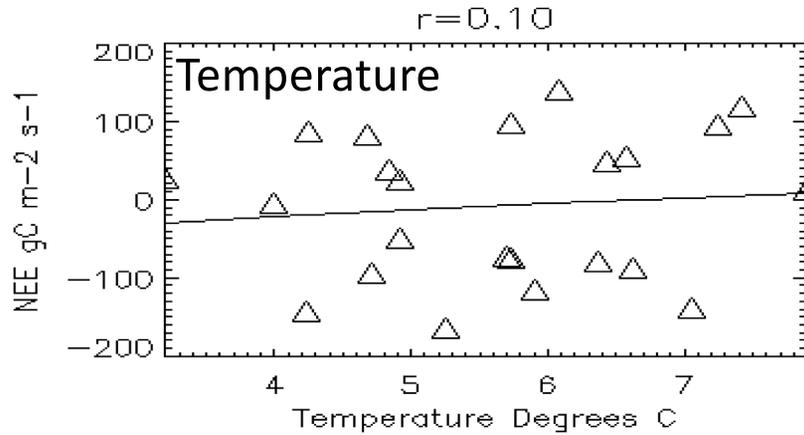
Park Falls

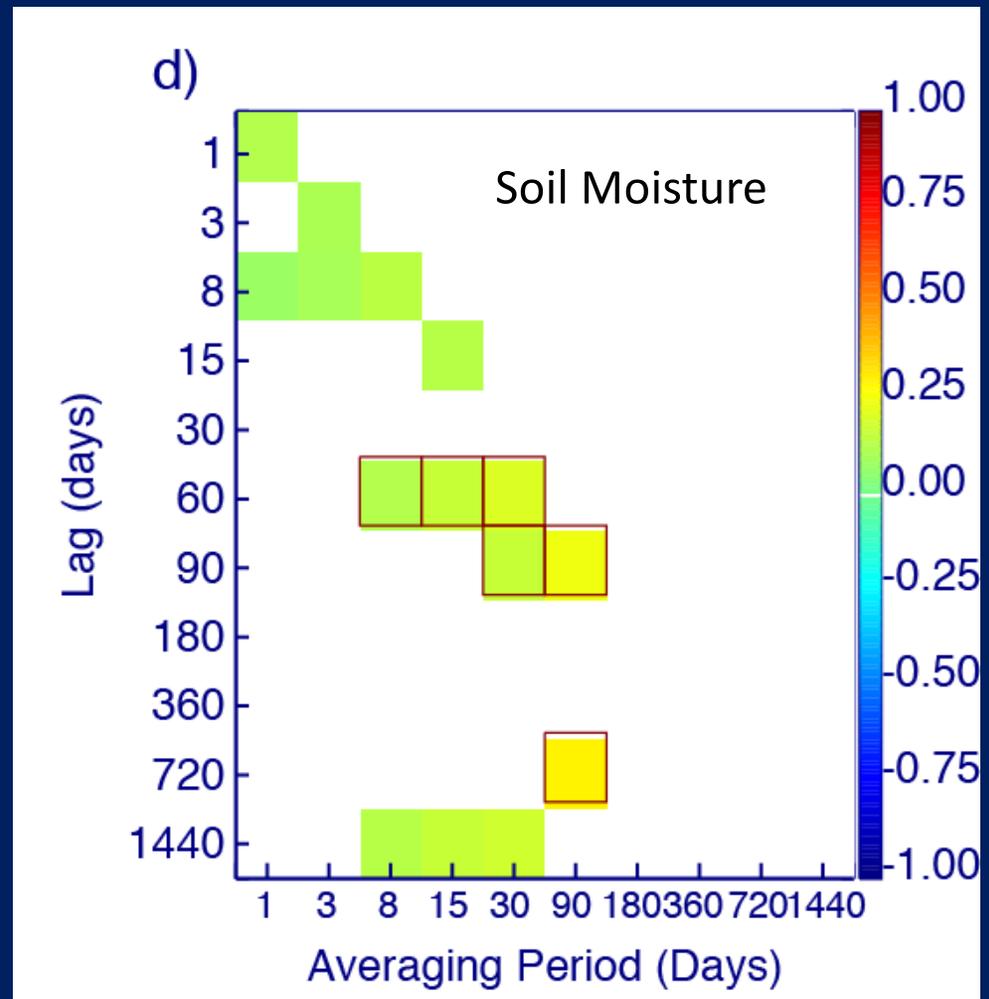
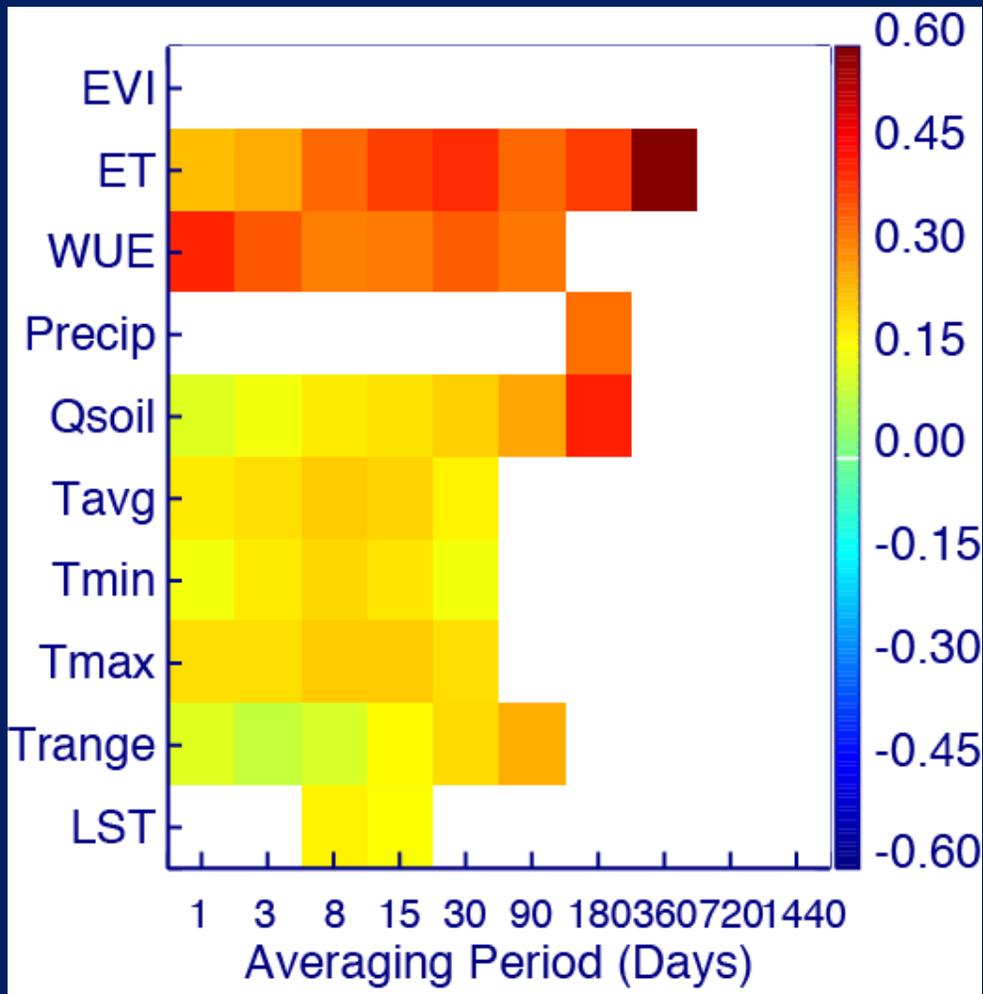




NEE

GPP





ChEAS core site cluster

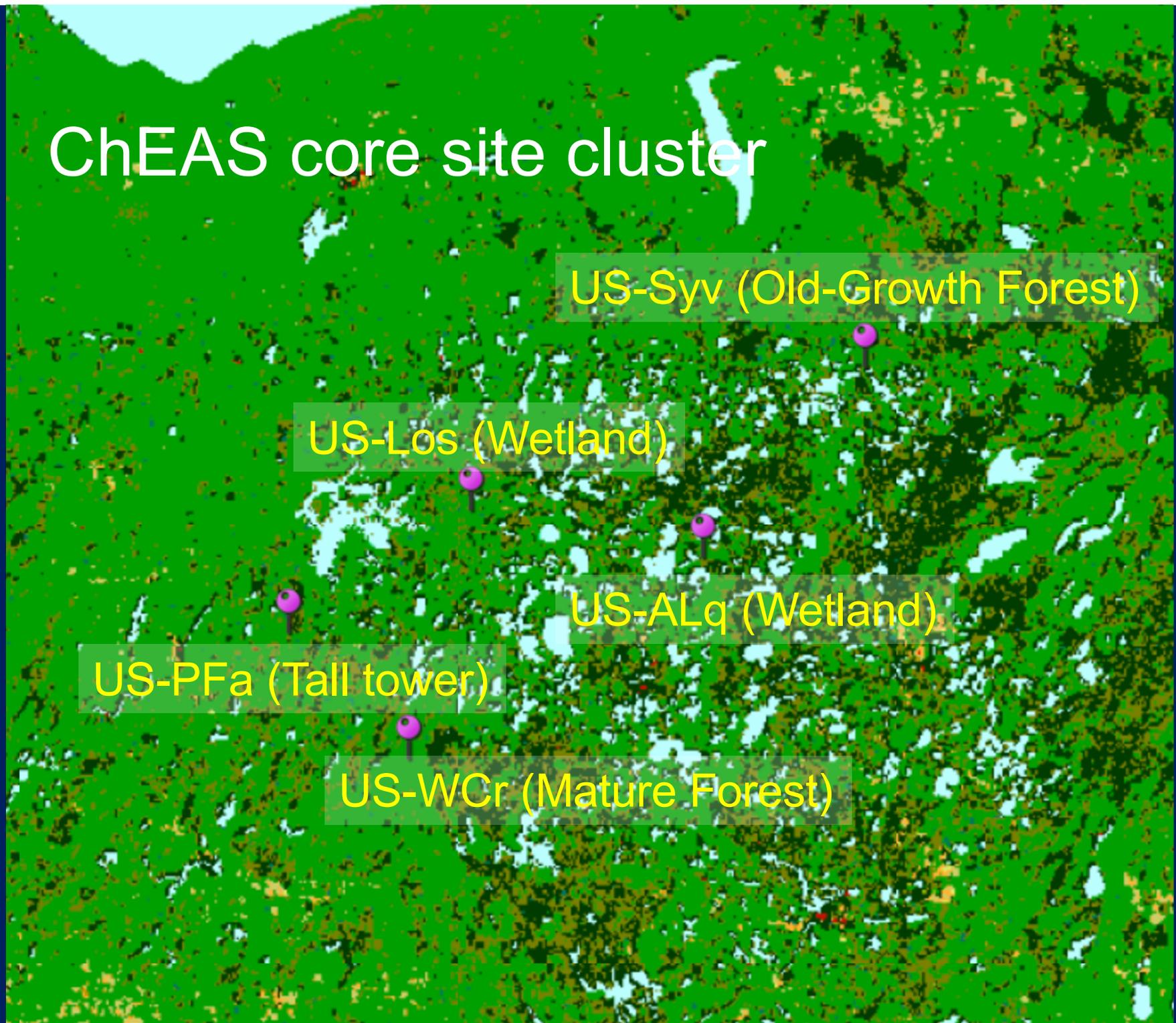
US-Syv (Old-Growth Forest)

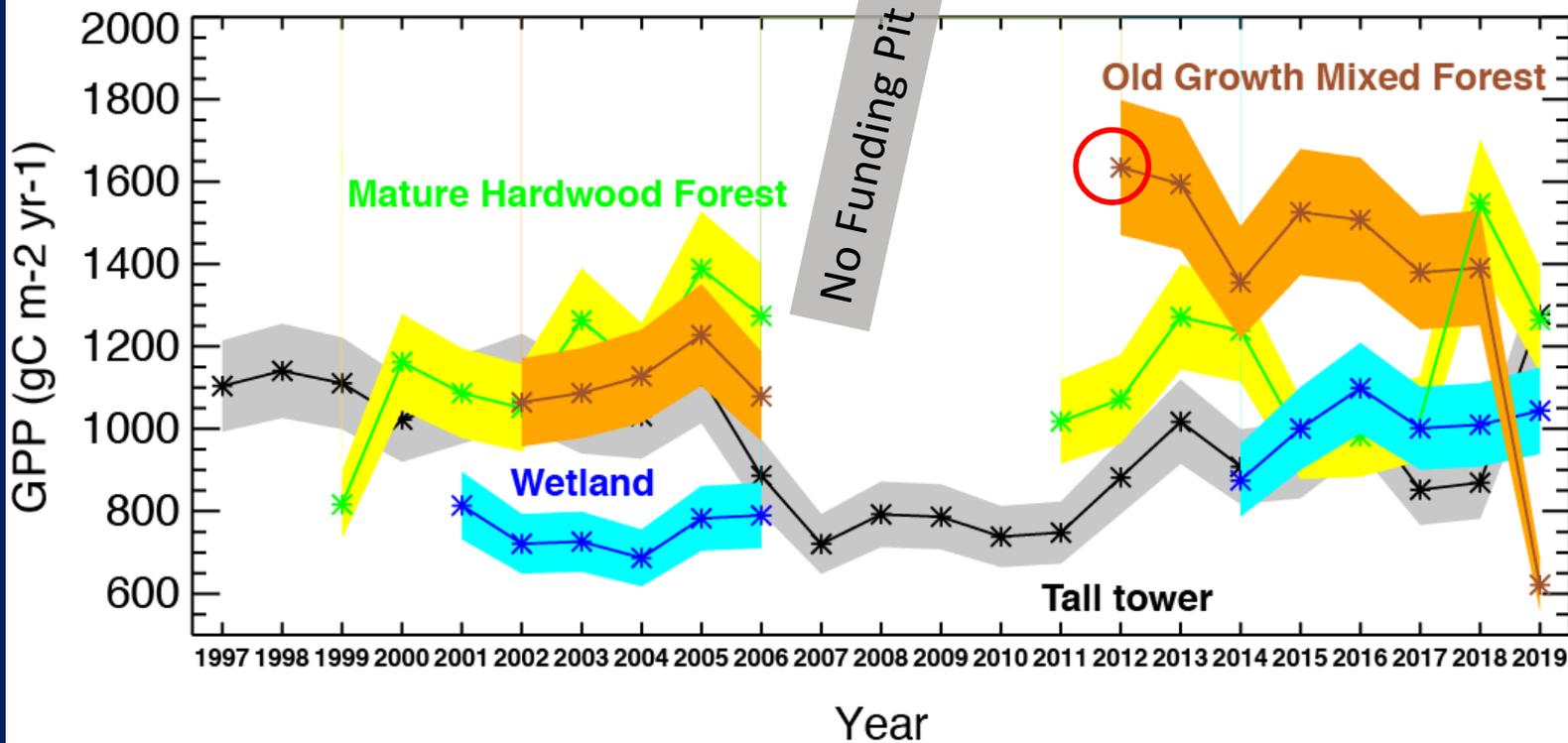
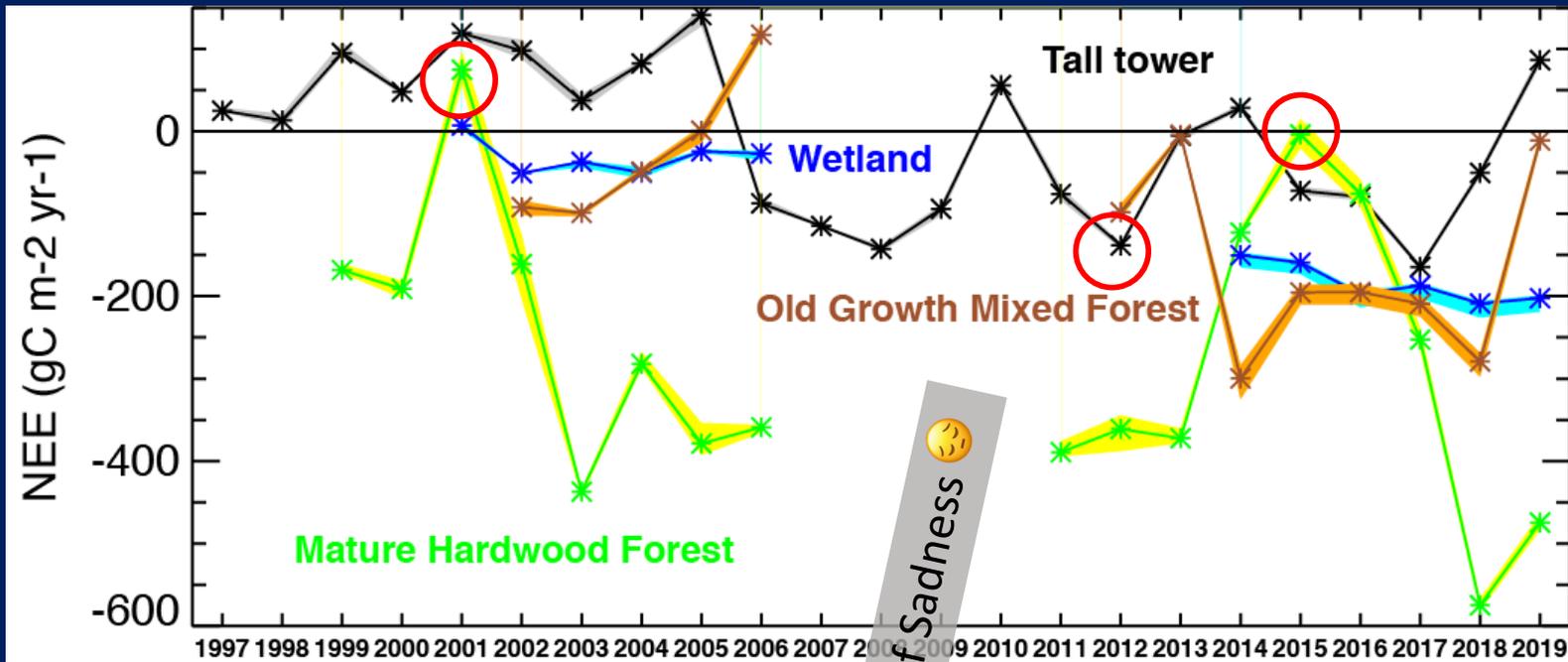
US-Los (Wetland)

US-ALq (Wetland)

US-PFa (Tall tower)

US-WCr (Mature Forest)





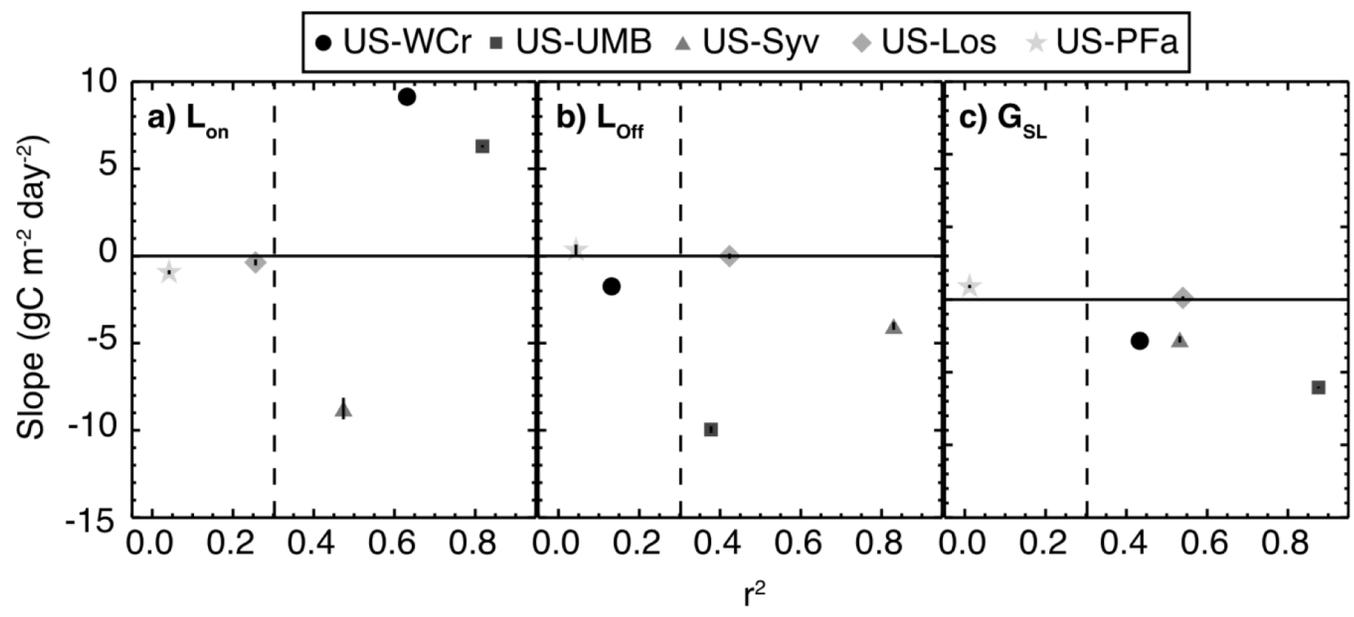
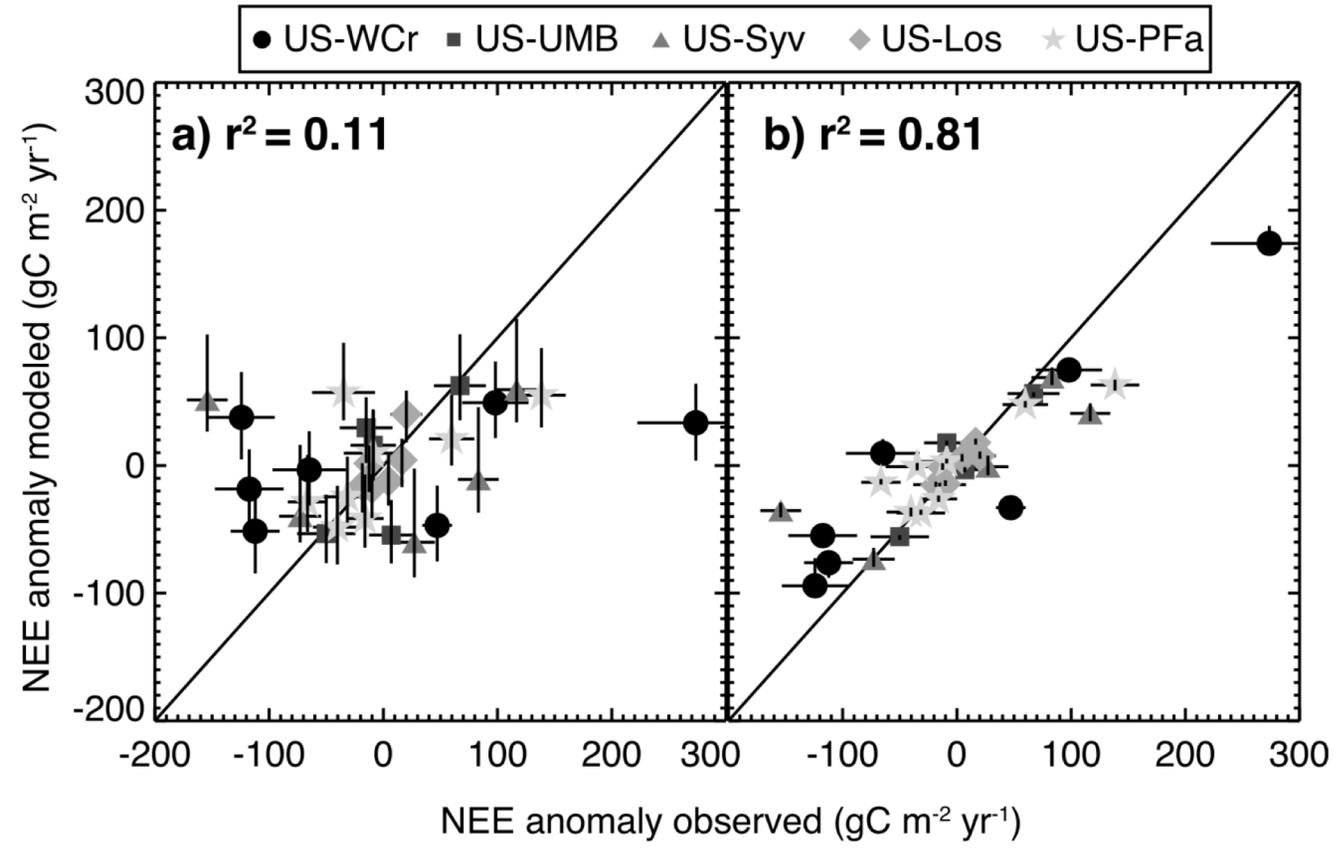
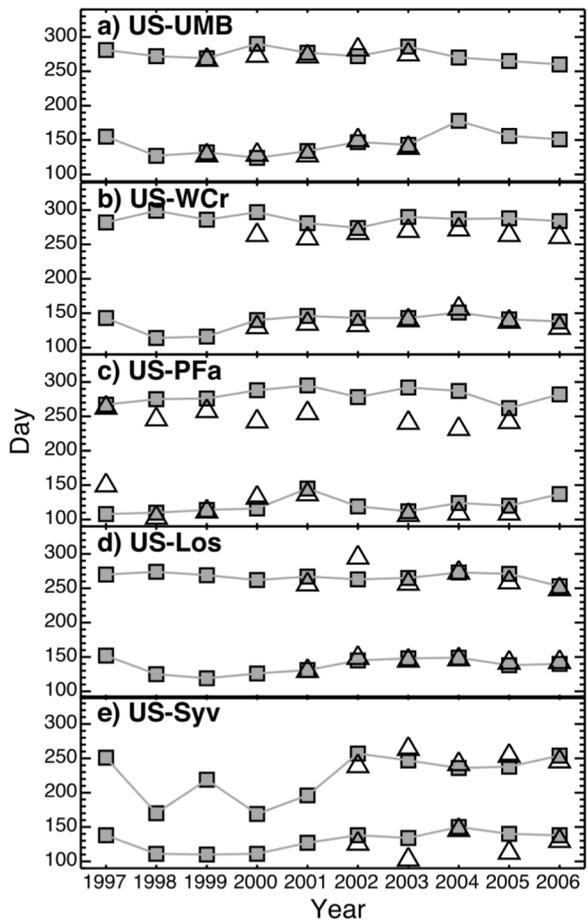
Willow Creek - NetCam SC IR - Thu Sep 20 11:31:17 2012

Temperature: 36.0 °C internal, 9.0 °C outside

RH: 0%, Pressure: 944.0 millibars

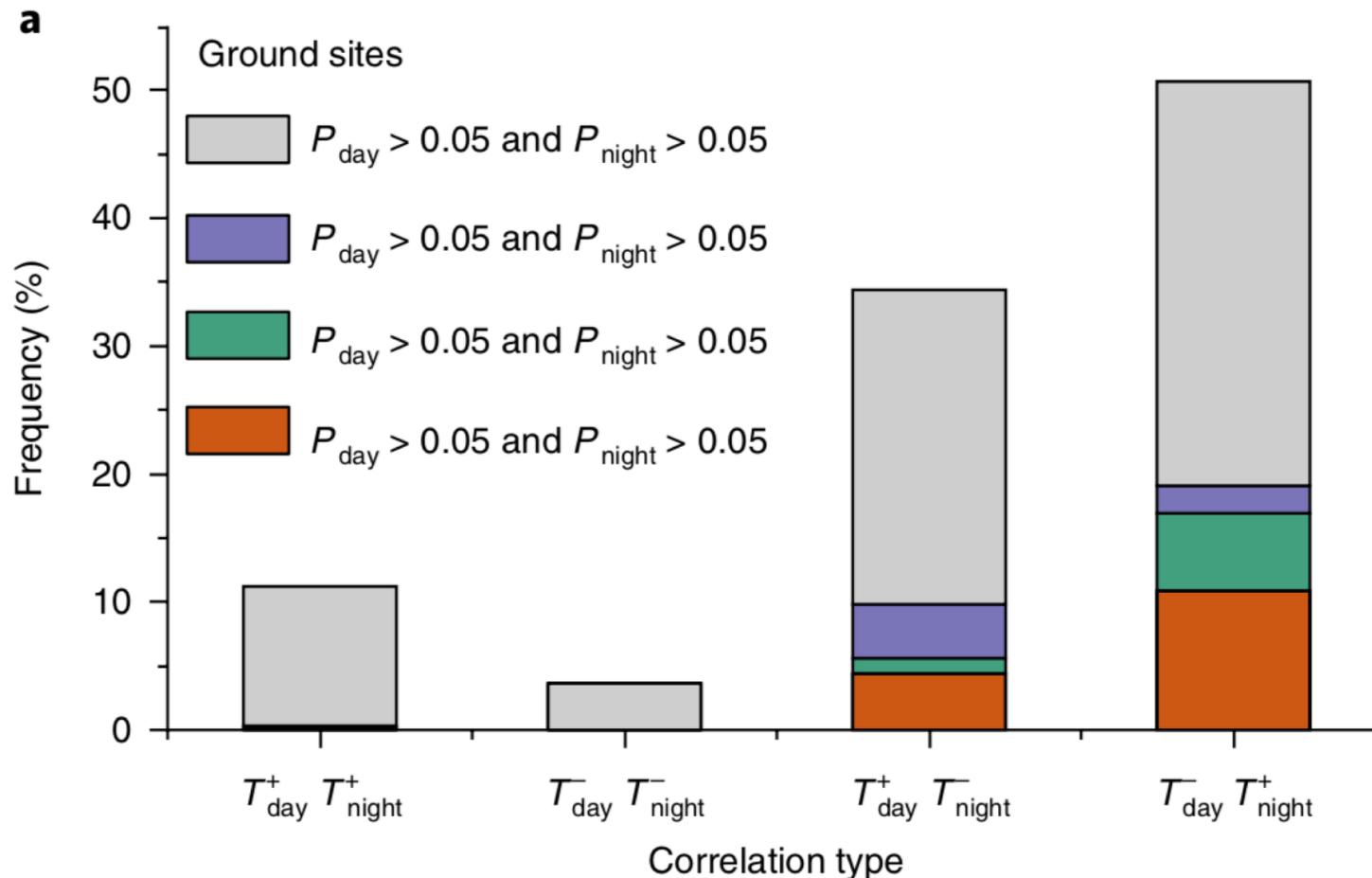
Exposure: 400



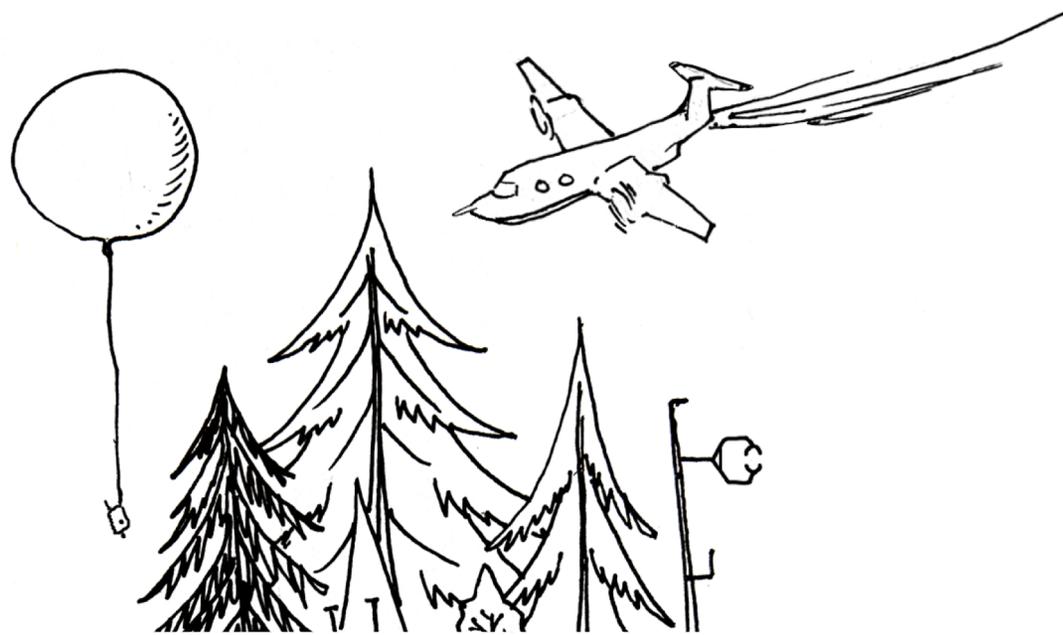


Contrasting responses of autumn-leaf senescence to daytime and night-time warming

Chaoyang Wu ^{1,2*}, Xiaoyue Wang^{1,2}, Huanjong Wang ^{1,2*}, Philippe Ciais ³, Josep Peñuelas ^{4,5}, Ranga B. Myneni⁶, Ankur R. Desai ⁷, Christopher M. Gough⁸, Alemu Gonsamo ⁹, Andrew T. Black¹, Rachhpal S. Jassal¹⁰, Weimin Ju¹¹, Wenping Yuan¹², Yongshuo Fu¹³, Miaogen Shen¹⁴, Shihua Li¹⁵, Ronggao Liu¹⁶, Jing M. Chen⁹ and Quansheng Ge ^{1,2*}

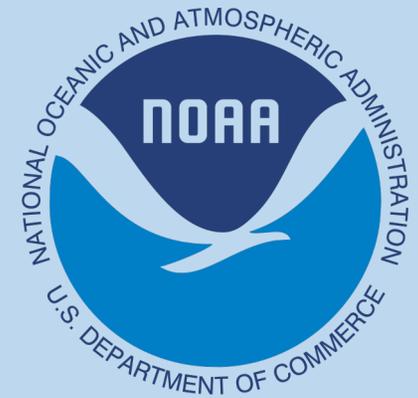


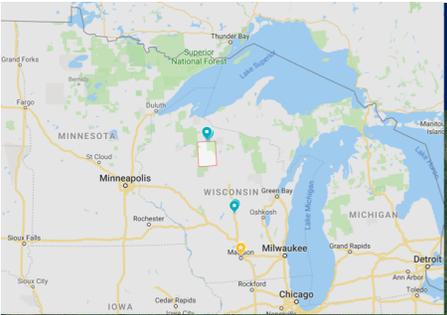
b



CHEESEHEAD 2019

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





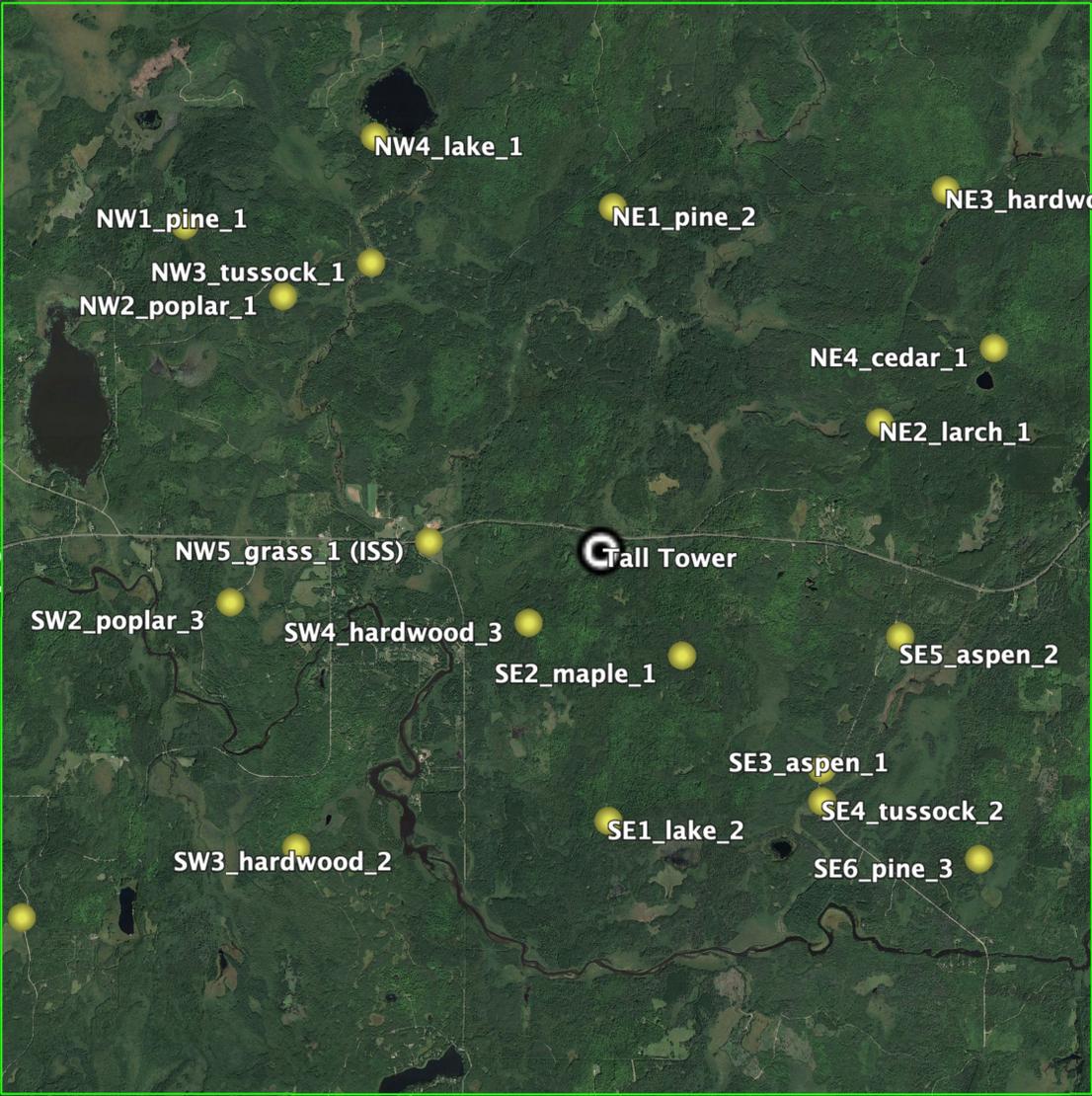
Legend

- EC towers
- 🌿 Study Area
- ⊙ Tall Tower

Park Falls

182

Google Earth



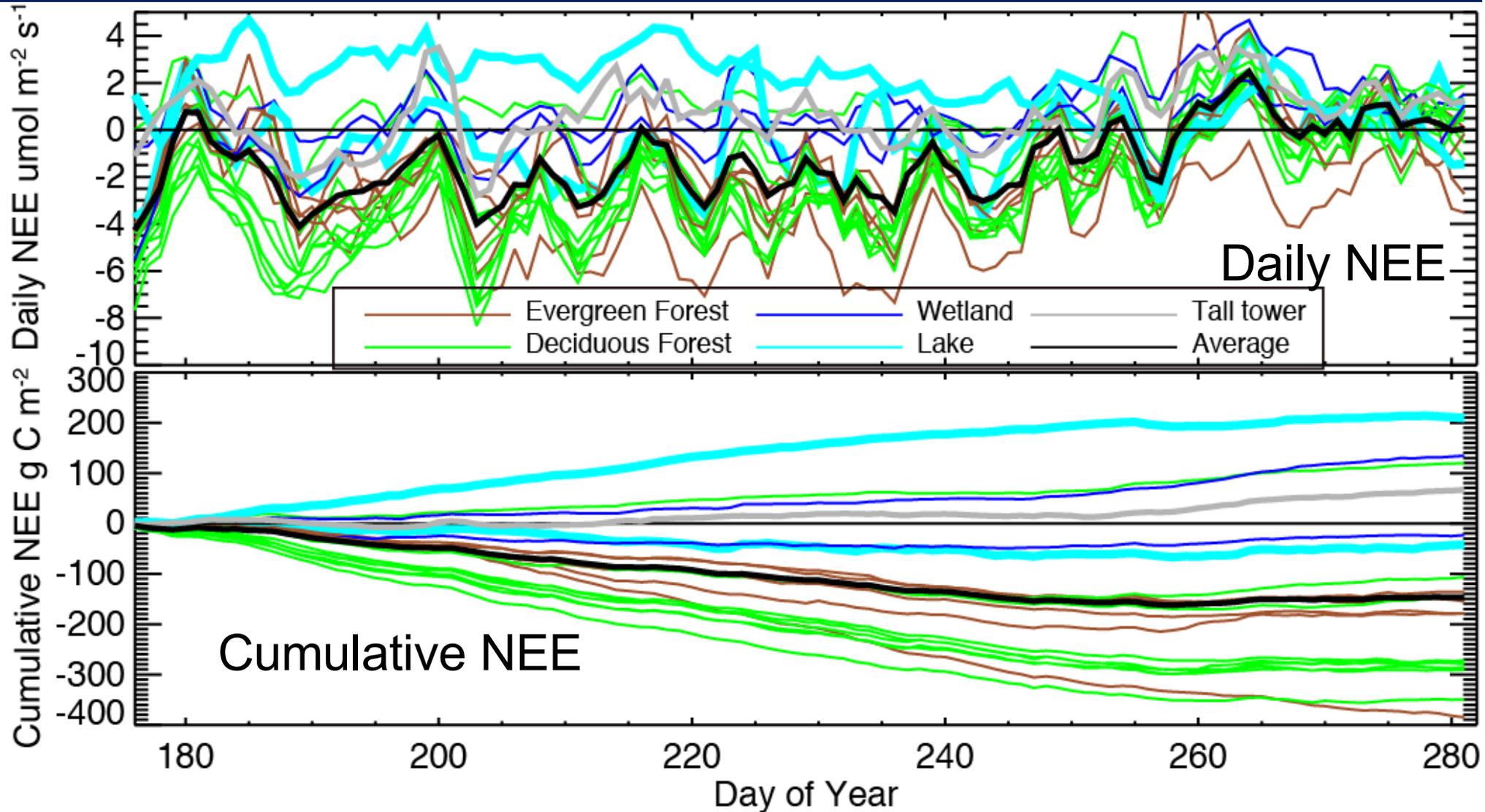




Tower: P. Stoy, B. Butterworth, J. Thom, N. Lottig, P. Schramm

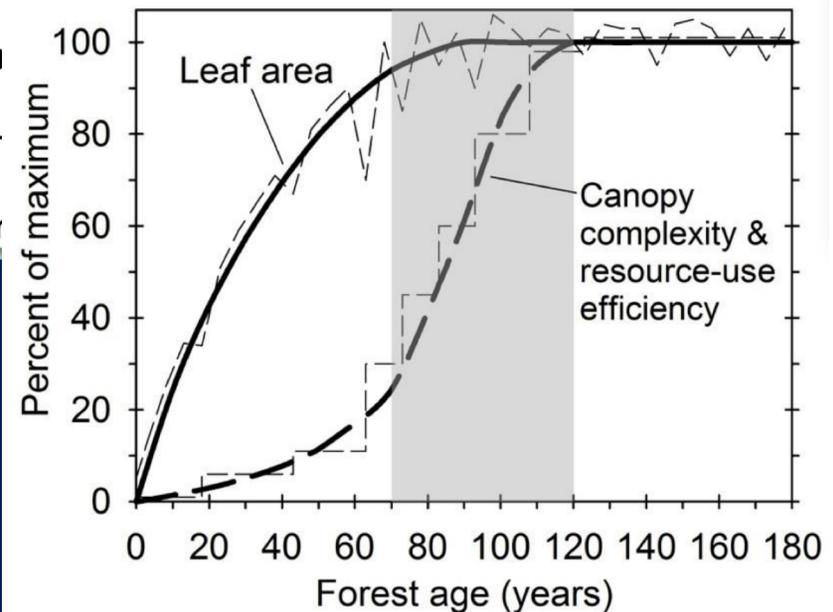
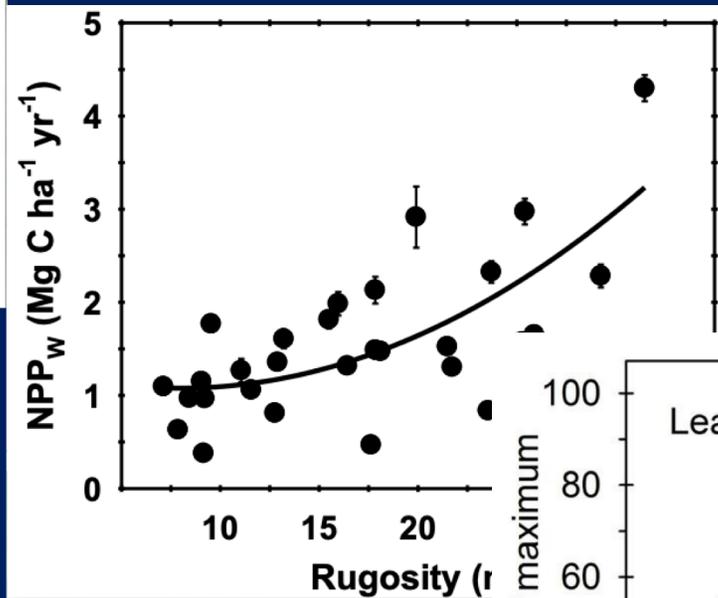
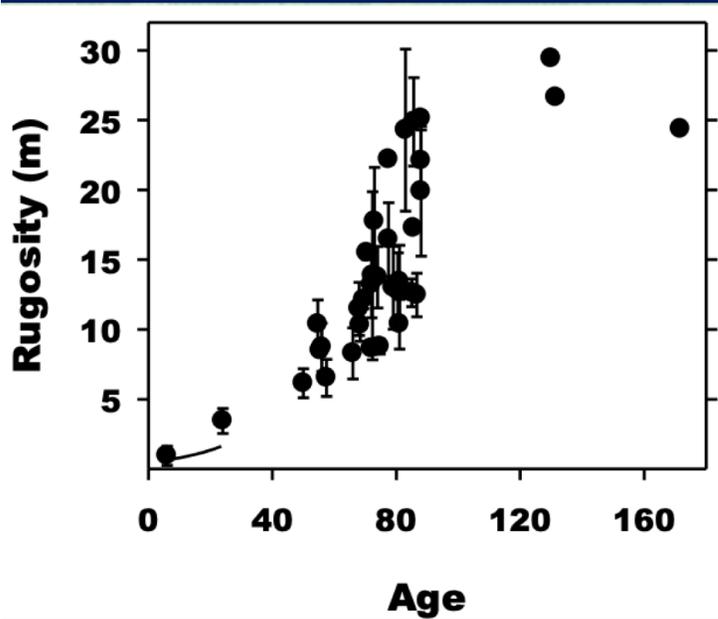
Photo: A. Desai

So, what have we learned so far about spatial variability?

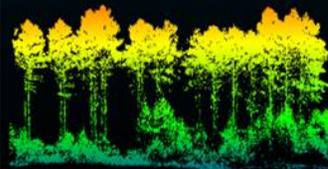


High rates of primary production in structurally complex forests

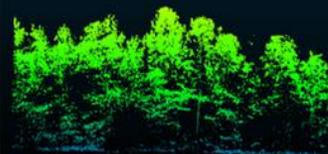
CHRISTOPHER M. GOUGH,^{1,4} JEFF W. ATKINS,¹ ROBERT T. FAHEY,² AND BRADY S. HARDIMAN³



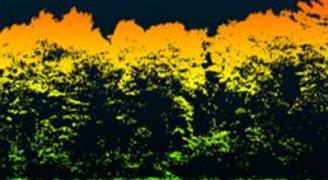
SE6



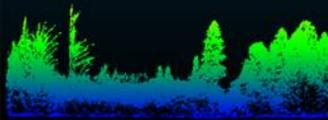
NE2



NE3



NE4



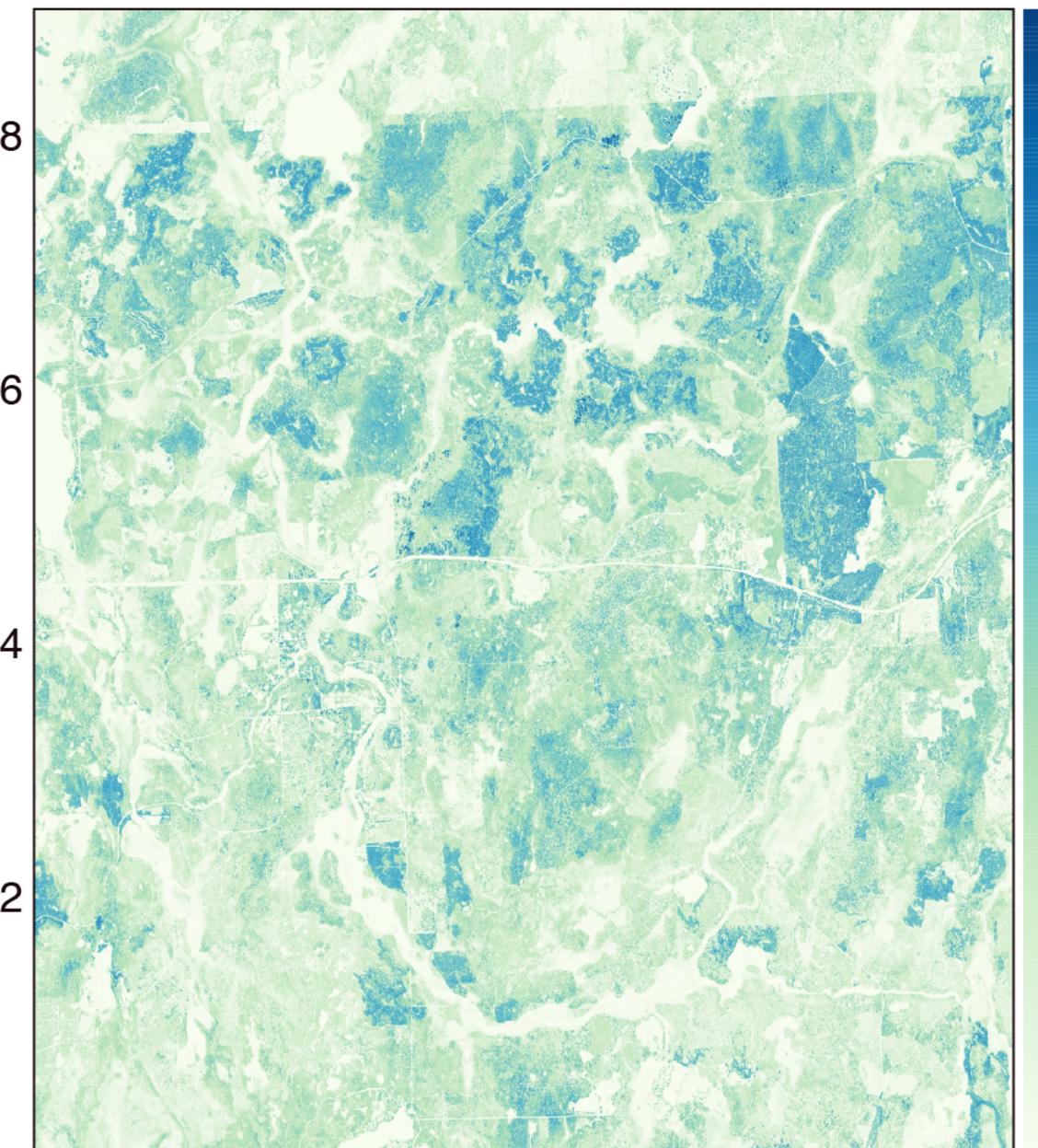
Lat

45.98

45.96

45.94

45.92



-90.34 -90.32 -90.30 -90.28 -90.26 -90.24 -90.22

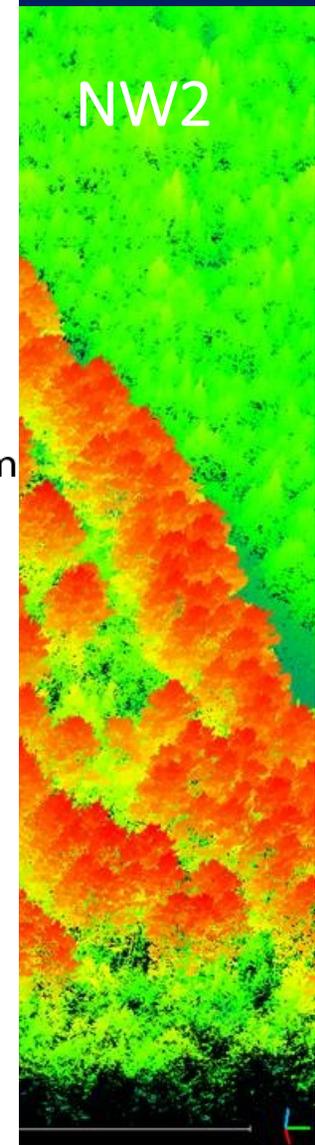
Lon

0 km 5

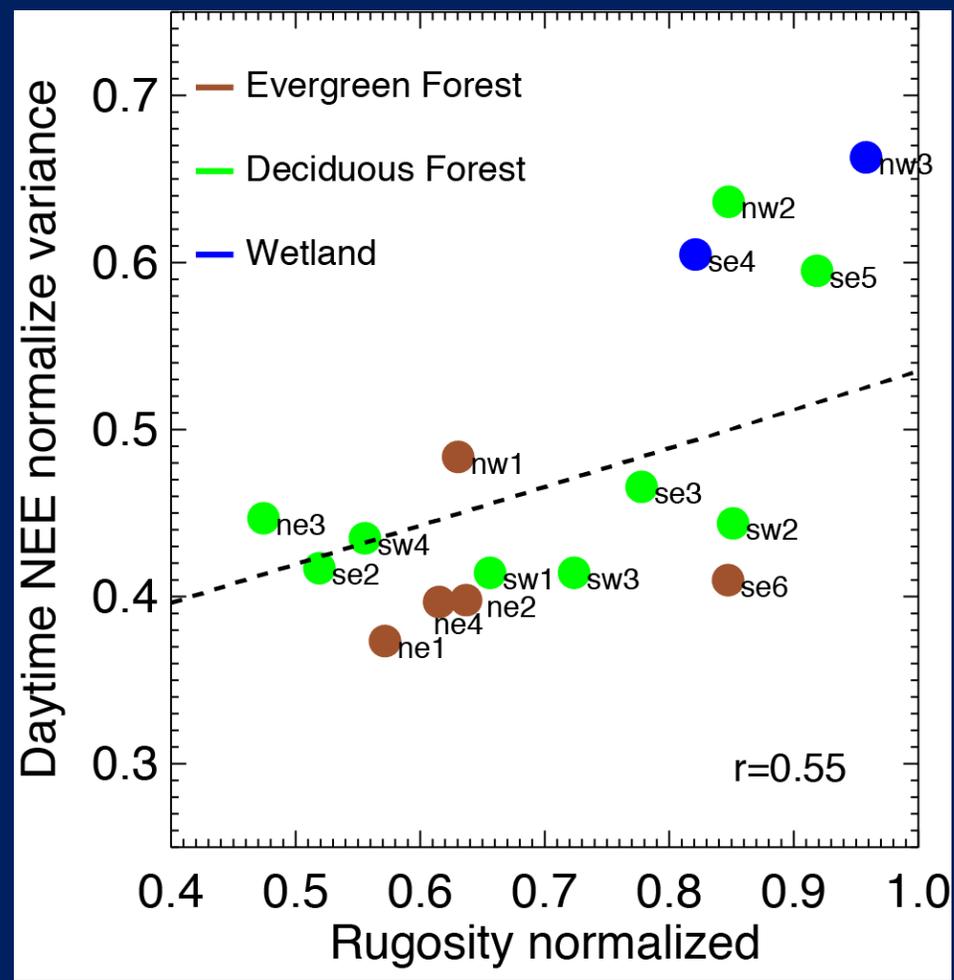
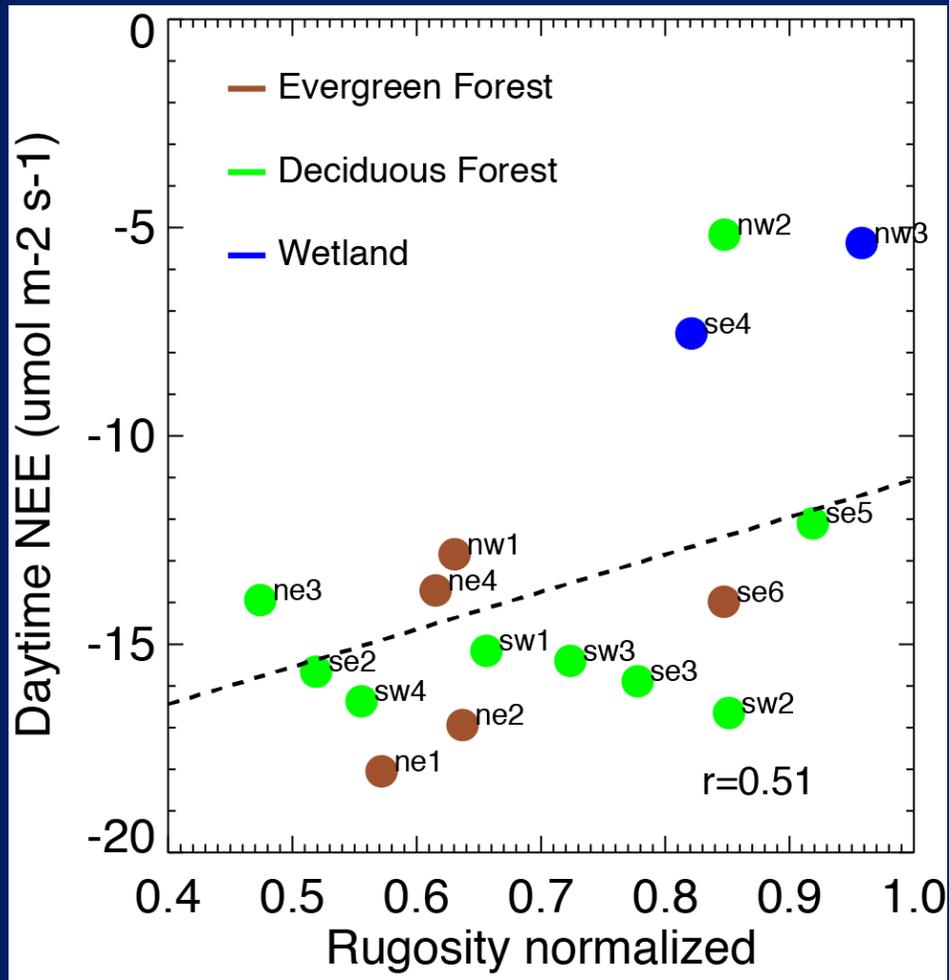
35
31
27
23
19
15
11
7
3
0

m

NW2



T. Zheng





CHEESEHEAD 2019

Legend

Research Sites

- Conifer
- Grass
- Hardwood Deciduous
- Lake
- Tussock
- ★ Tall Tower

- Research Boundary

Water Features

- Lake
- River
- Wetland

Land Ownership

- Private
- USDA FOREST SERVICE

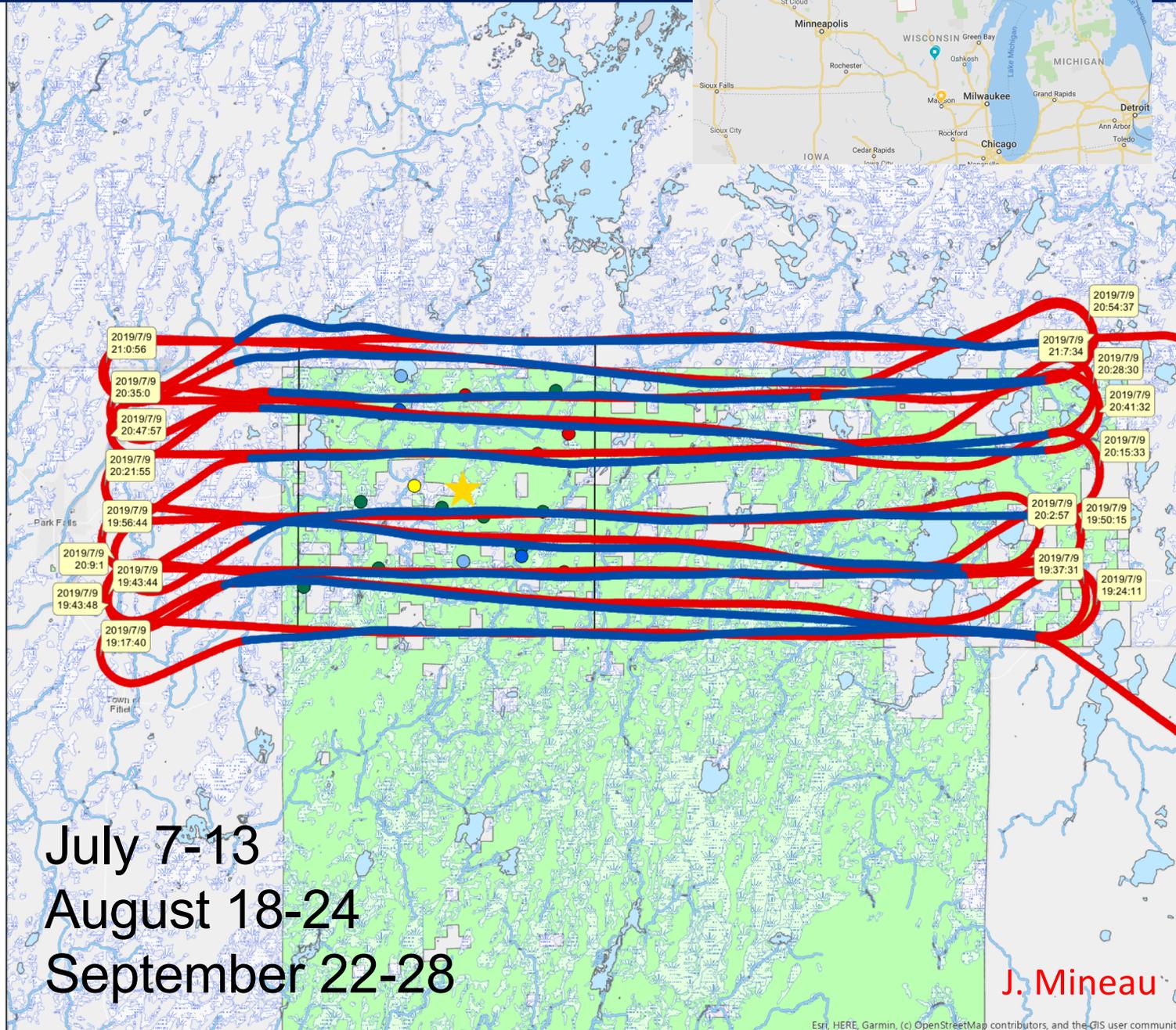
King Air Flight

Alt

- ≤600 MSL
- ≤1300 MSL
- ≤3000 MSL



James Mineau
12 Sep 2019



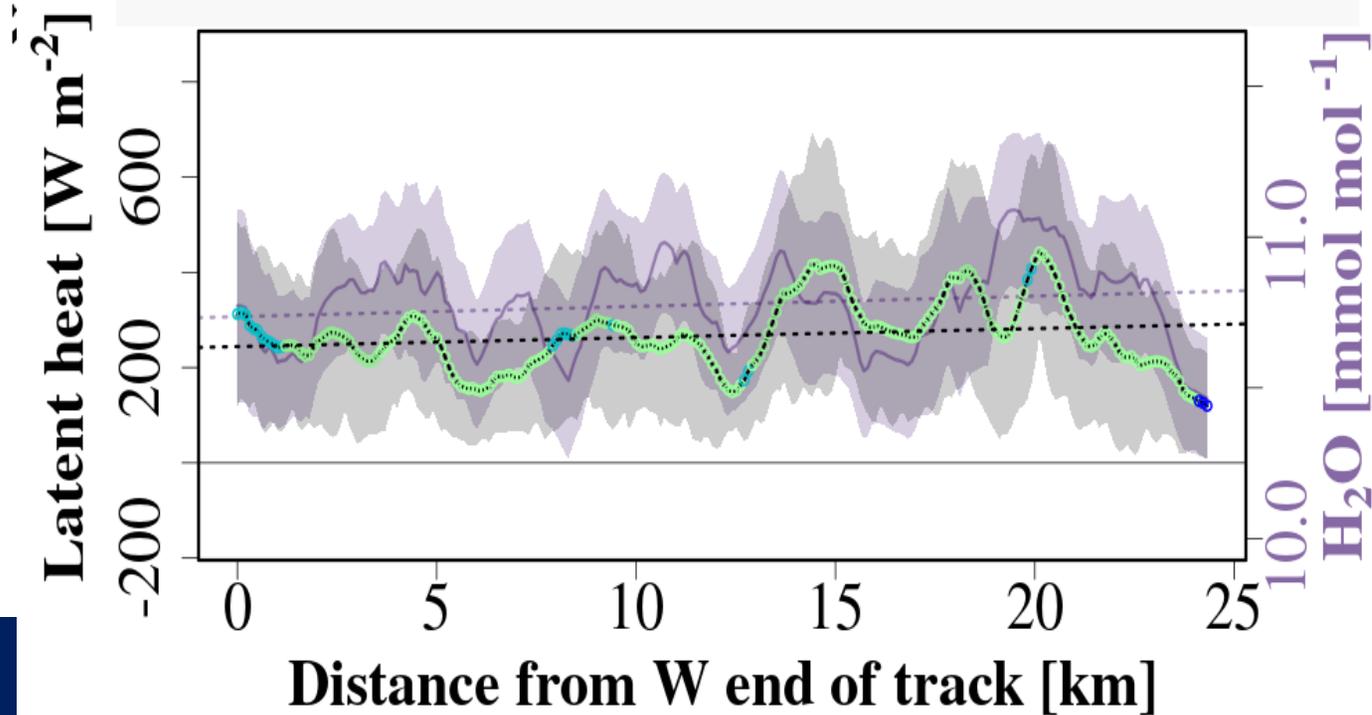
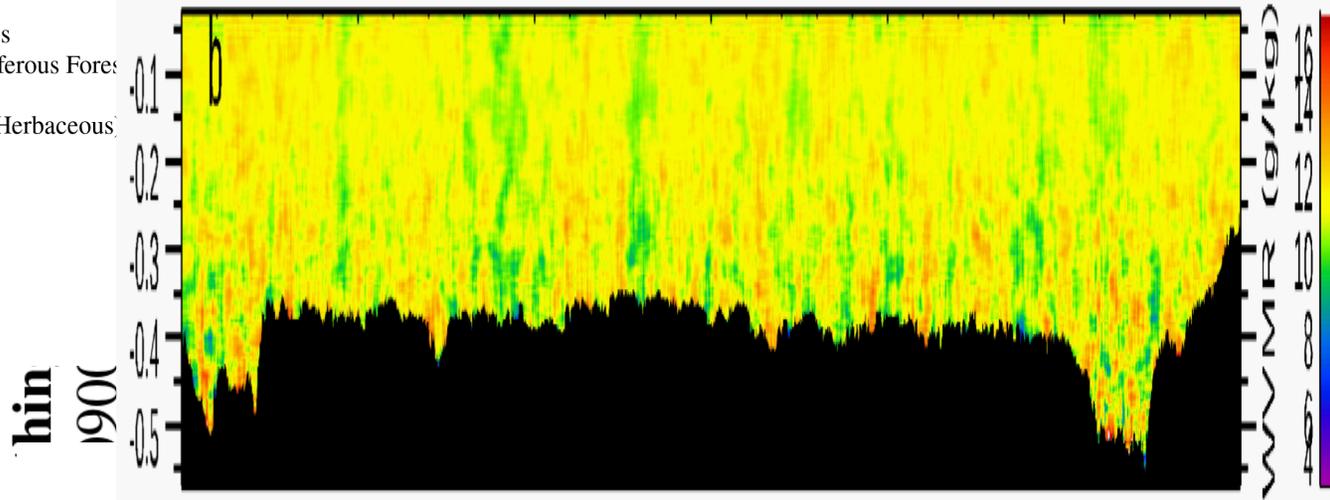
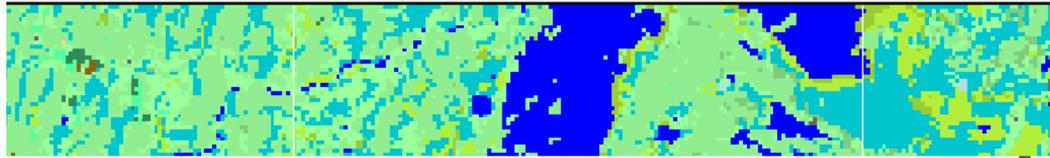
July 7-13
August 18-24
September 22-28

J. Mineau

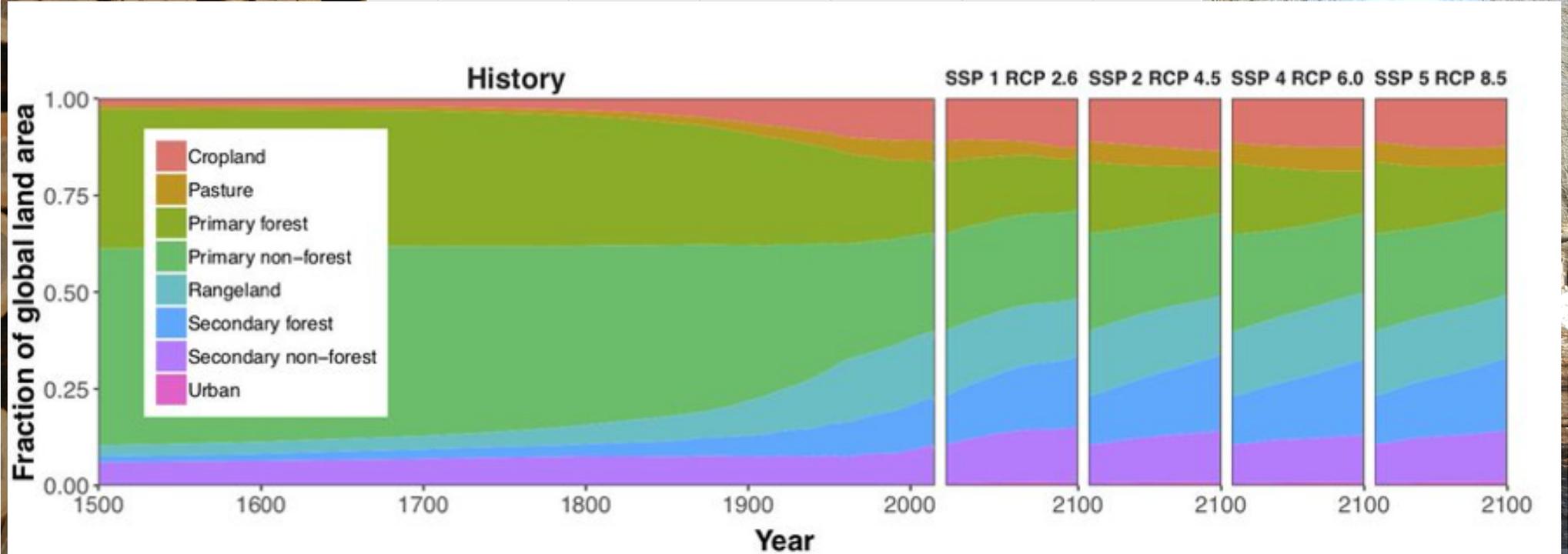
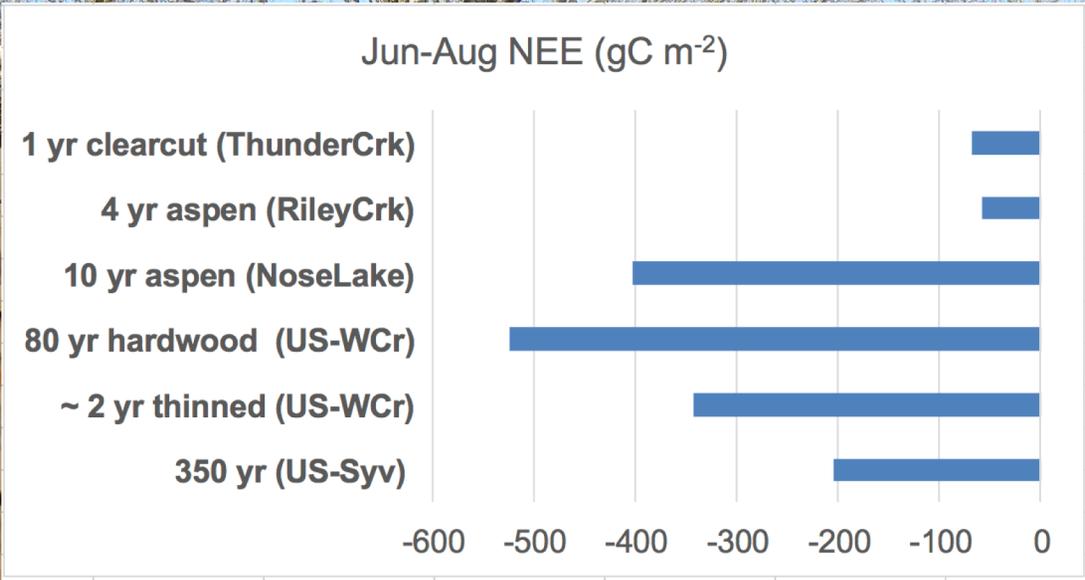
landcover_wisland

- High Intensity Urban/Developed
- Low Intensity Urban/Developed
- Crop Rotation
- Cranberries
- Foraged Grass
- Idle Grass
- Coniferous
- Broad-leaved Deciduous
- Mixed Deciduous/Coniferous Forest
- Open Water
- Aquatic Bed (Floating Herbaceous)
- Emergent/Wet Meadow
- Scrub/Shrub Wetland
- Forested Wetland
- Barren
- Shrubland

landcover_wisland

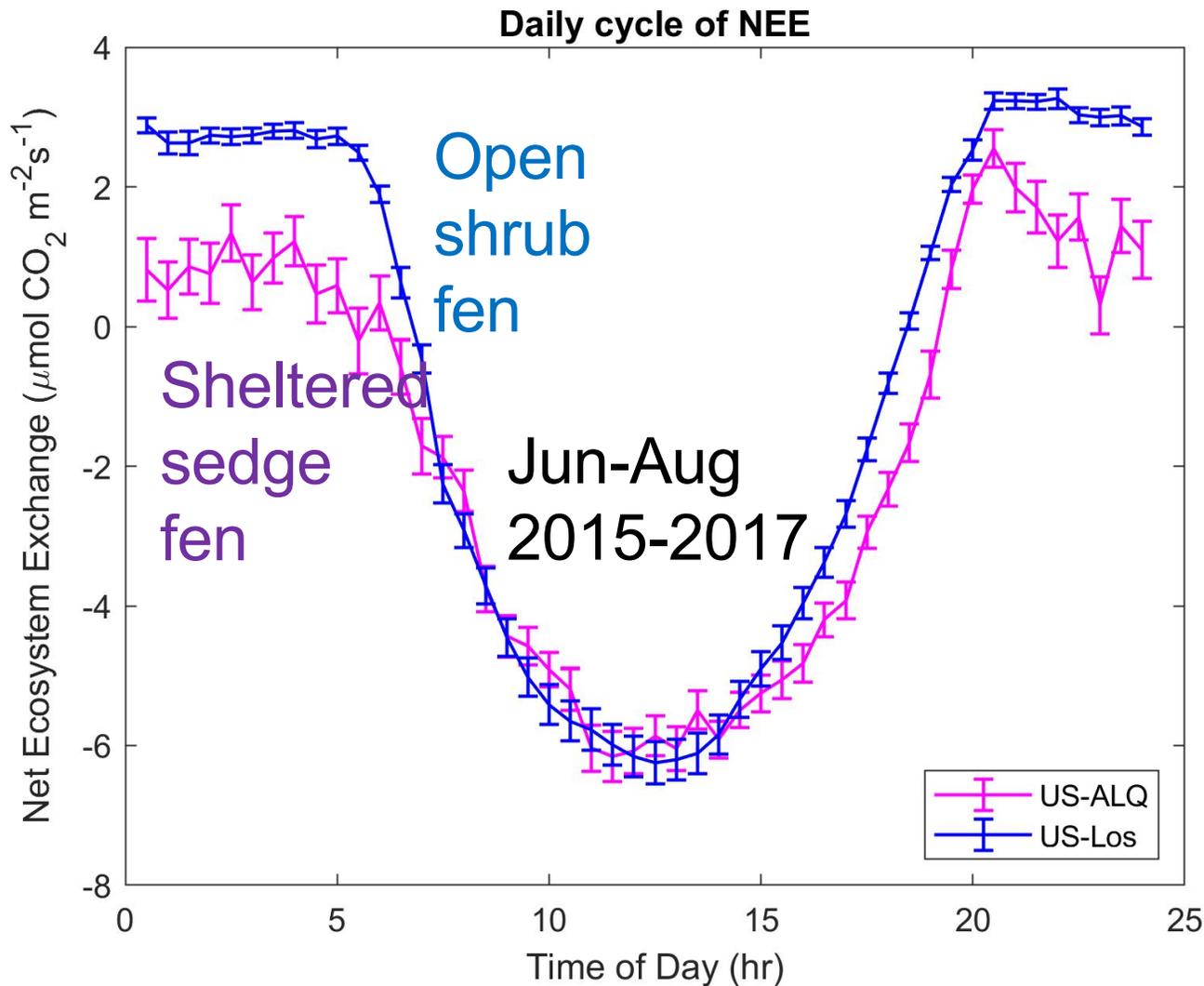


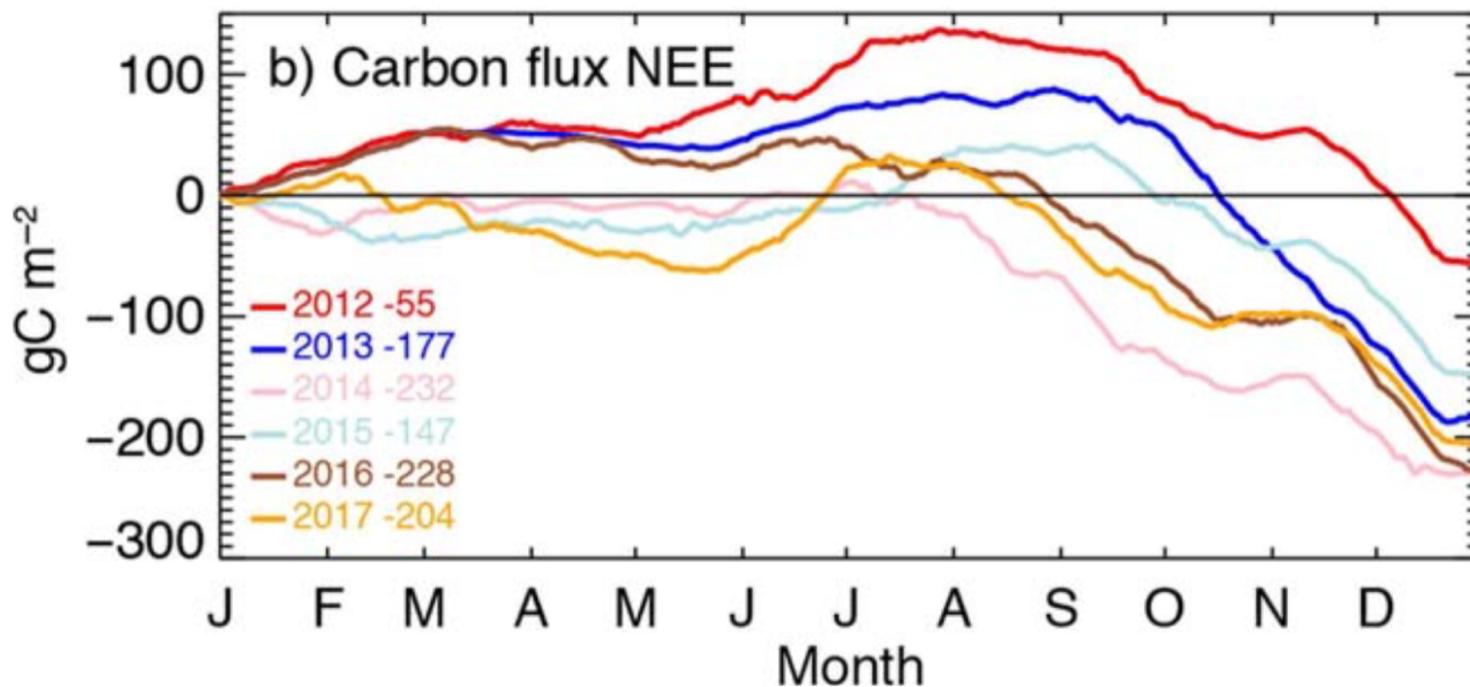
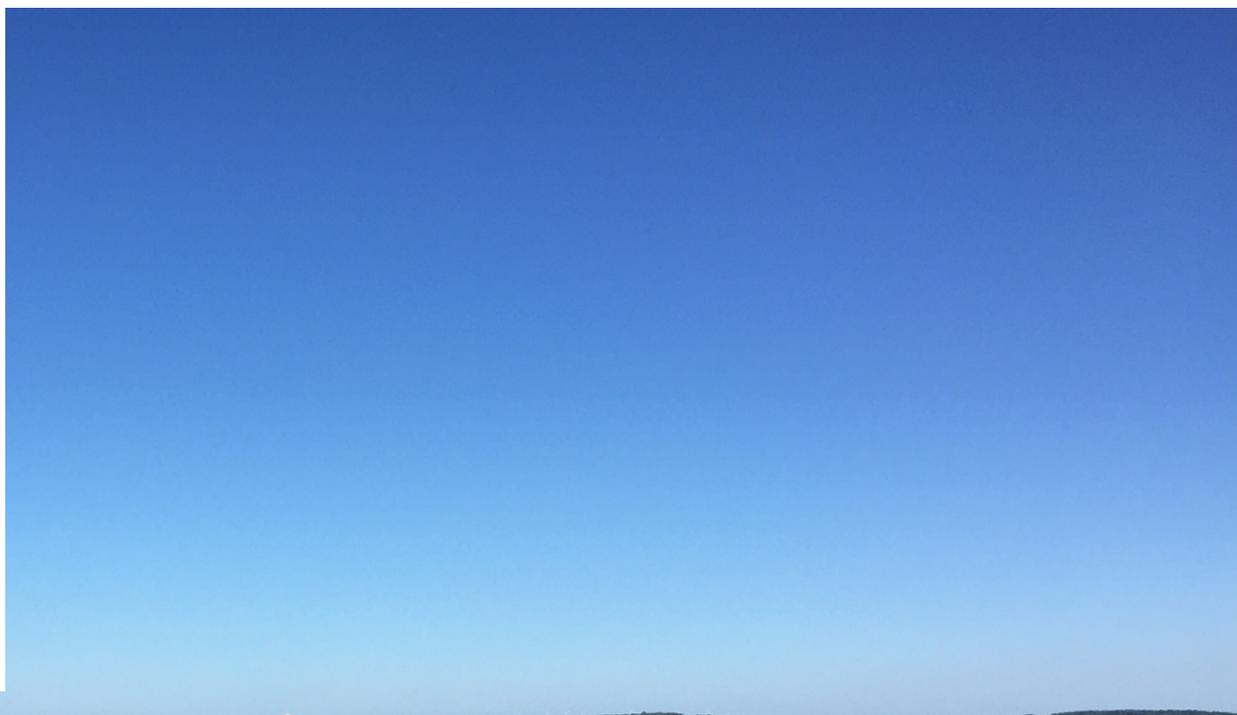
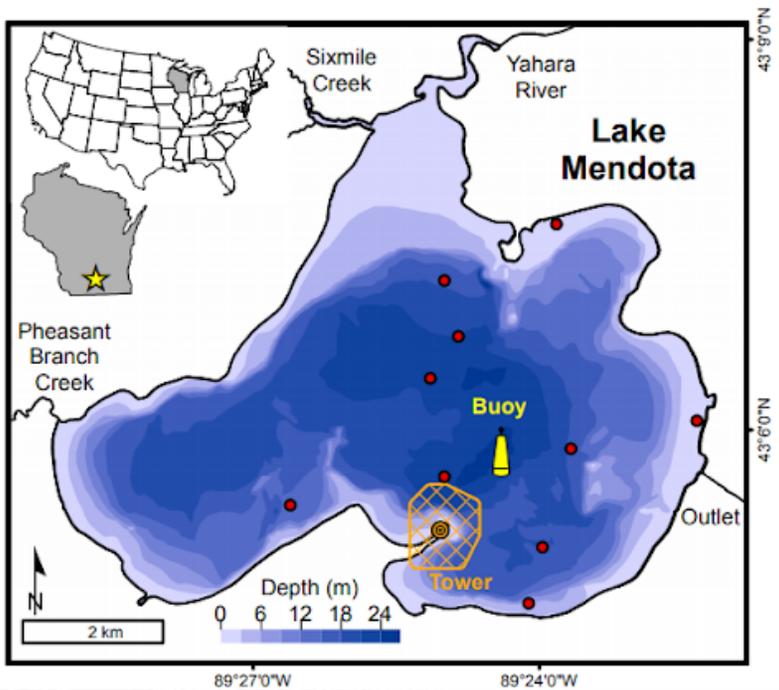
S. Paleri
S. Metzger
Z. Wang



B. Bond-Lamberty
Photo: J Thom

Wetlands: Scale matters

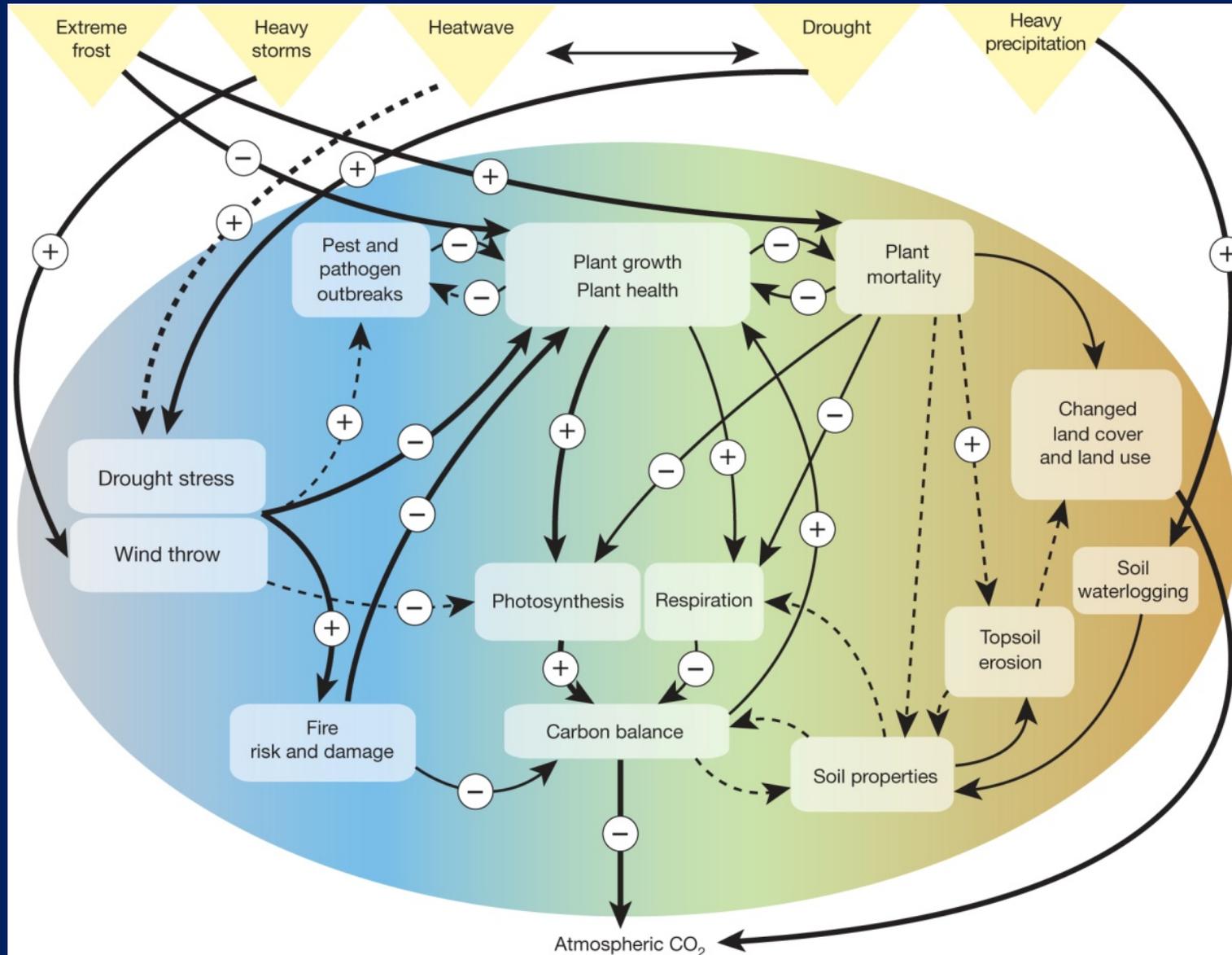




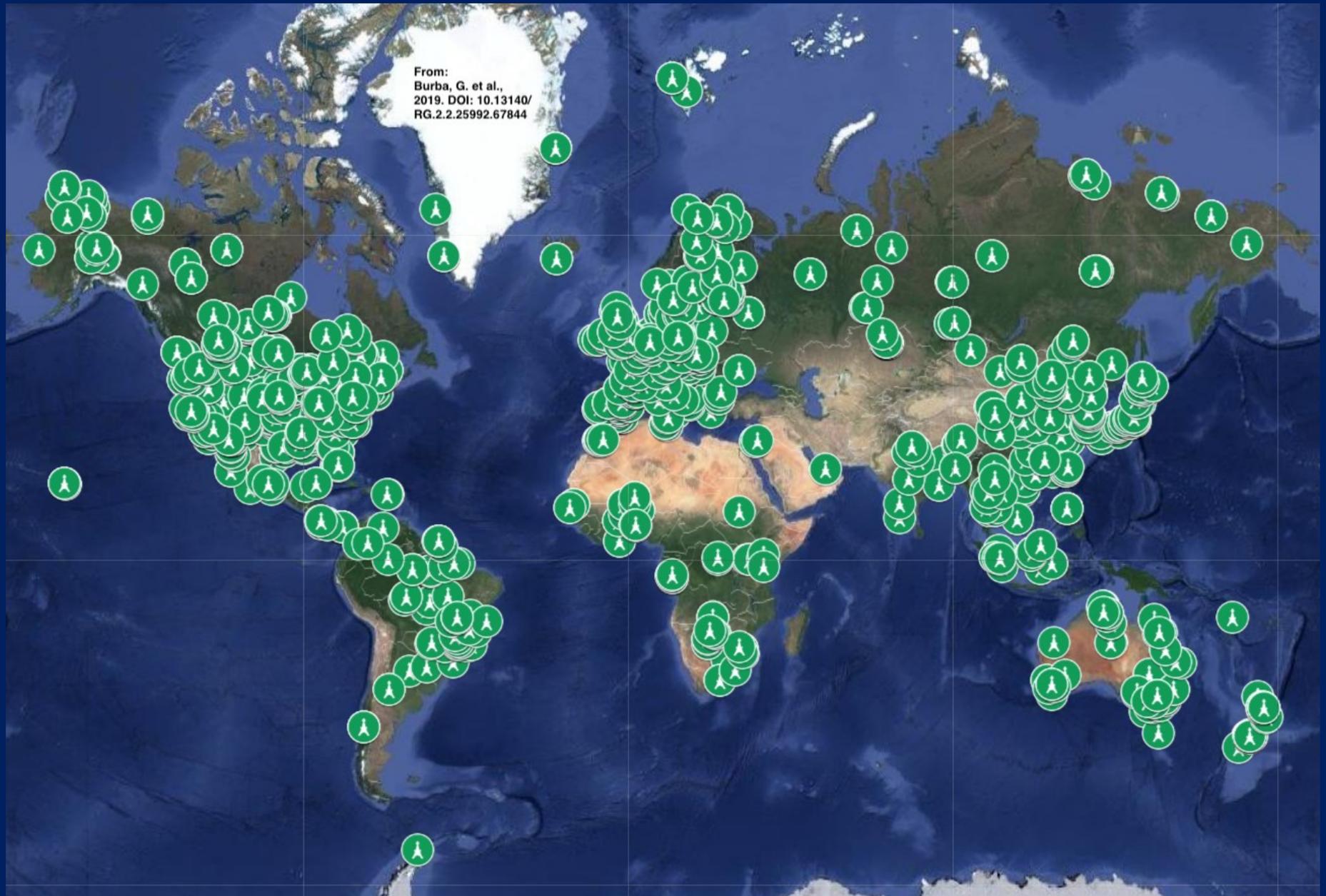
Reed et al., 2018; A. Baldocchi et al., in review

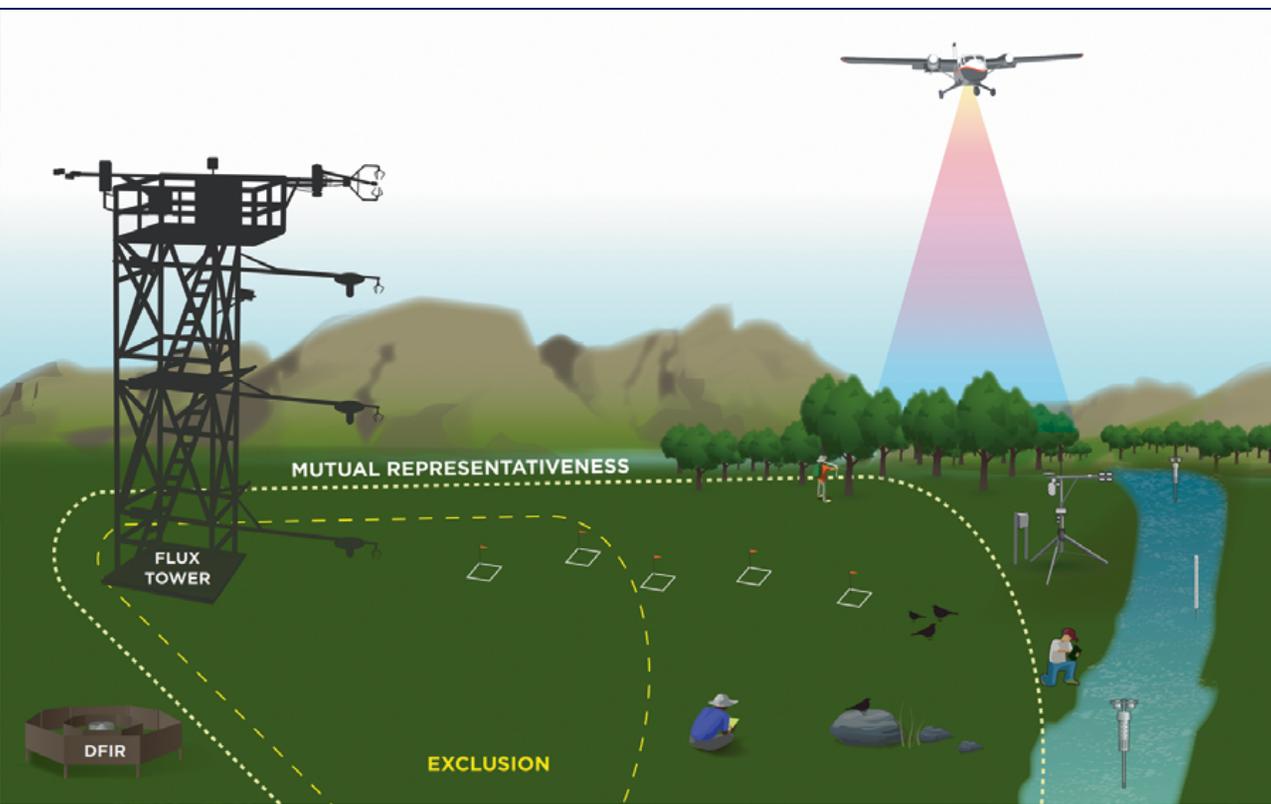
Catching the last breath
Rescuing the next breath

Processes and feedbacks triggered by extreme climate events?

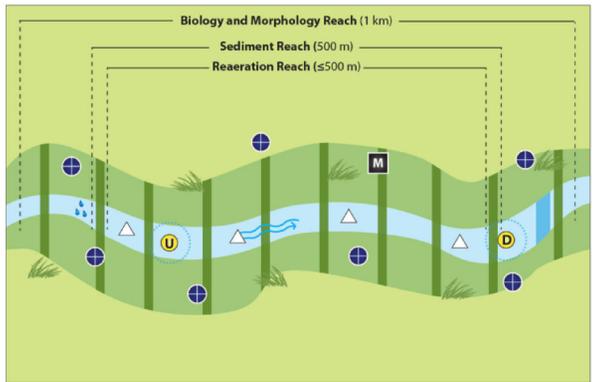


Huge Ecology?





Wadeable Stream



- Legend**
- Sensor Station
 - Water Chemistry Sampling
 - ⊕ Groundwater Well
 - M Meteorological Station
 - Riparian Assessment
 - 💧 Reaeration Drip
 - △ Reaeration Sampling

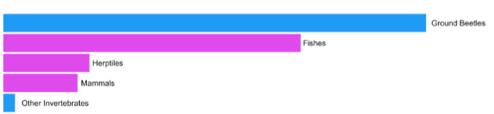
Note: Fish, sediments, macroinvertebrates, plants, and macroalgae are sampled based on site-specific habitats and are not identified in the figures.

> 62,000 samples

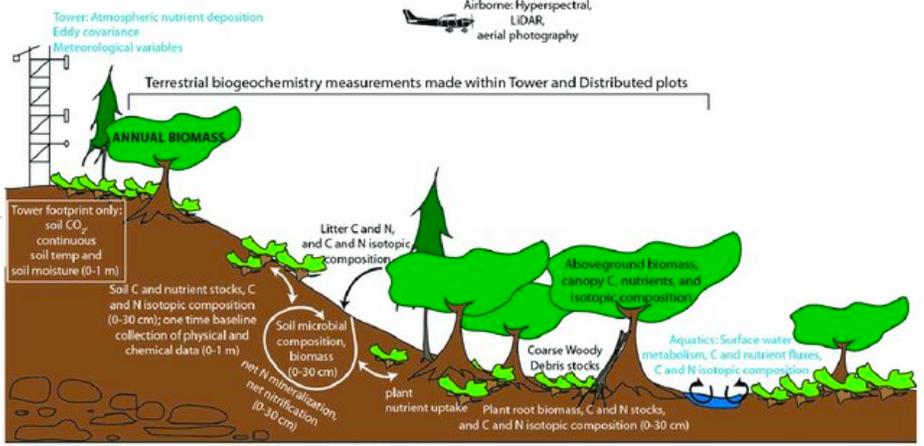


Distribution of samples by collection type.

> 400 taxa



Distribution of samples by top 5 determined taxa.



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Global meta-analysis shows pervasive phosphorus limitation of aboveground plant production in natural terrestrial ecosystems

Enqing Hou ^{1,2,3*}, Yiqi Luo³, Yuanwen Kuang^{1,2}, Chengrong Chen ⁴, Xiankai Lu^{1,2}, Lifen Jiang³, Xianzhen Luo^{1,2} & Dazhi Wen^{1,2*}

The impact of rising CO₂ and acclimation on the response of US forests to global warming

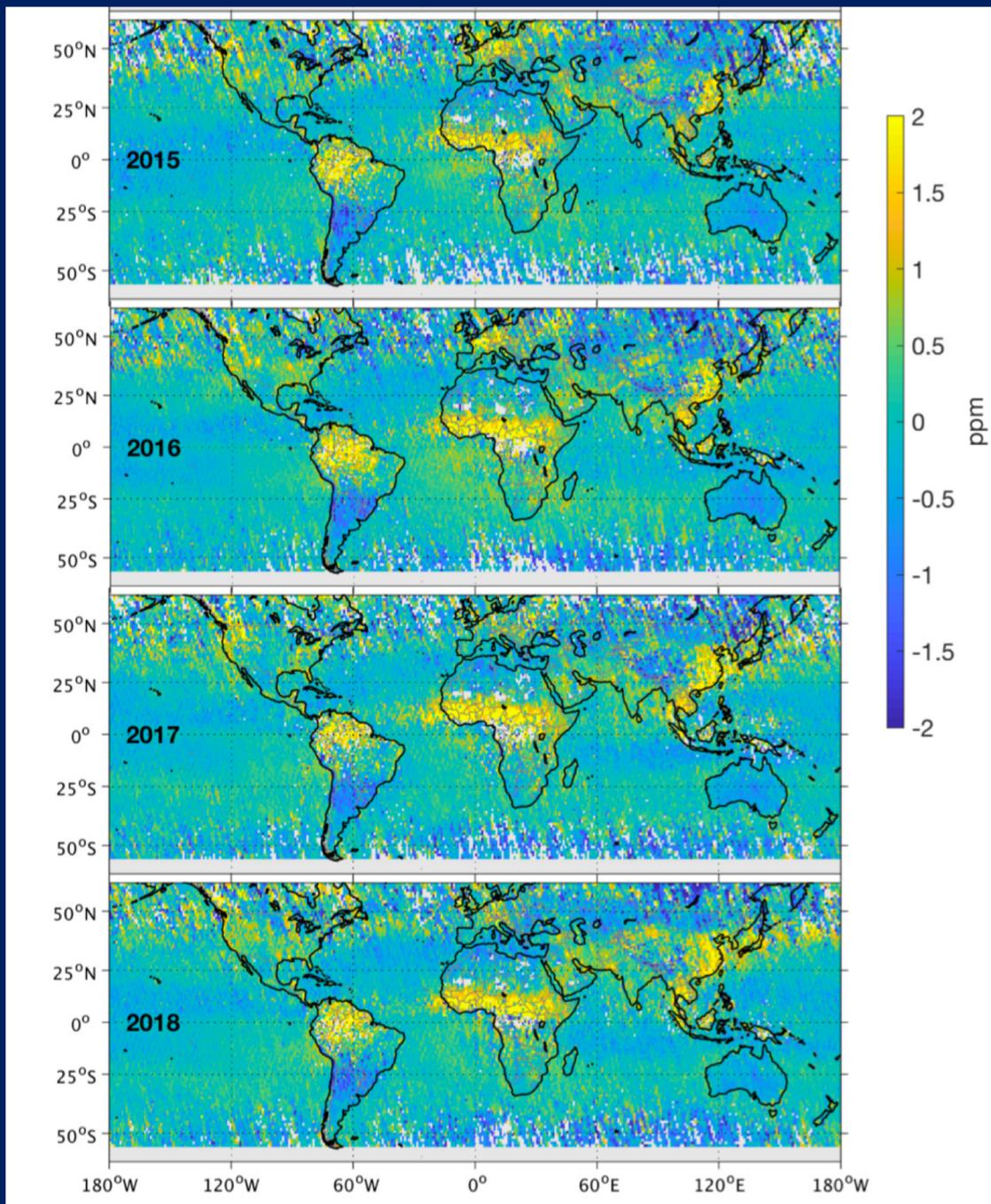
John S. Sperry^{a,1}, Martin D. Venturas^{a,1,2}, Henry N. Todd^a, Anna T. Trugman^{a,b}, William R. L. Anderegg^a, Yujie Wang^a, and Xiaonan Tai^c

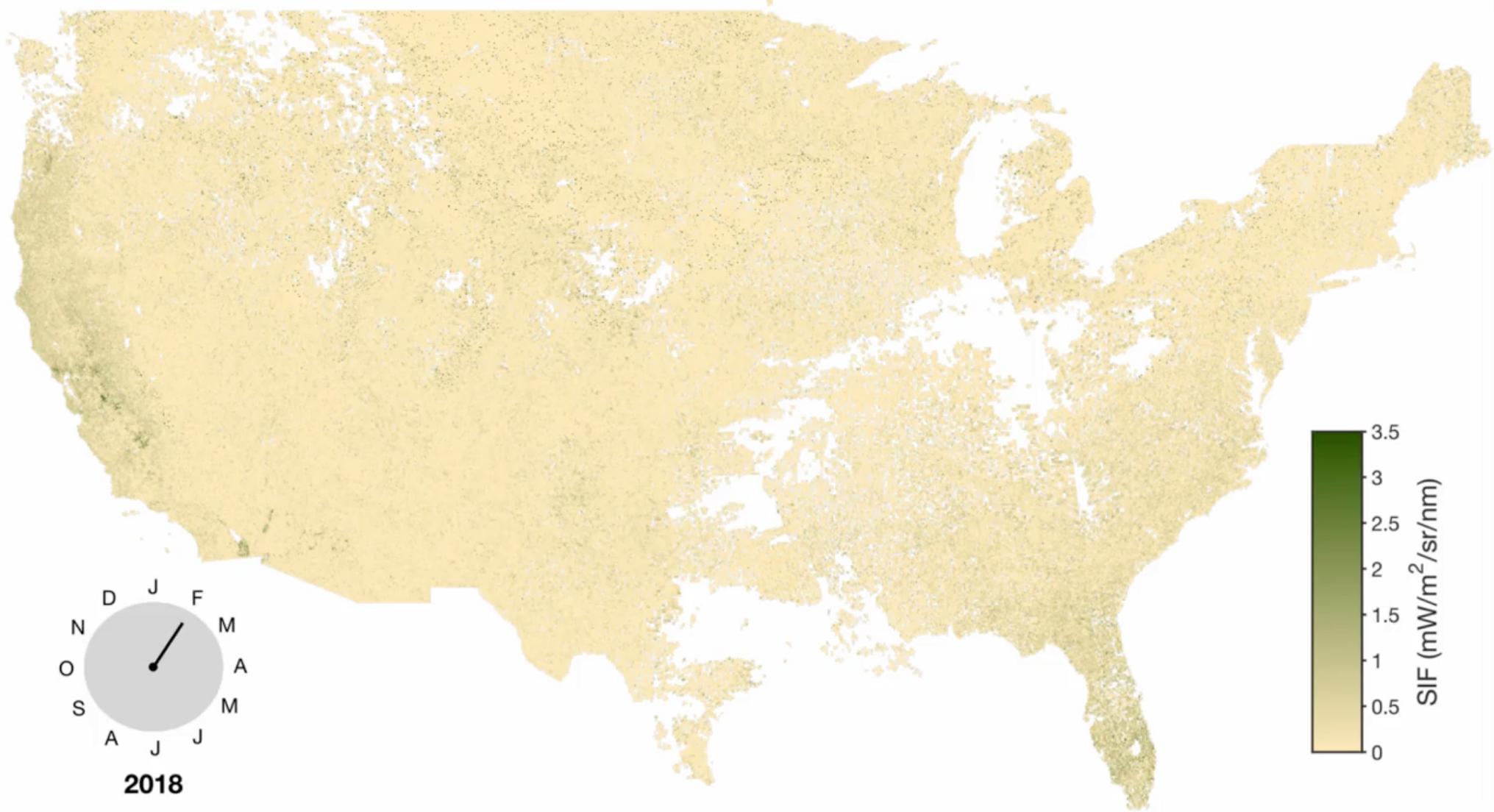
Global Carbon Sequestration Is Highly Sensitive to Model-Based Formulations of Nitrogen Fixation

Jing Peng¹, Ying-Ping Wang², Benjamin Z. Houlton³, Li Dan¹, Bernard Pak², and Xiba Tang⁴

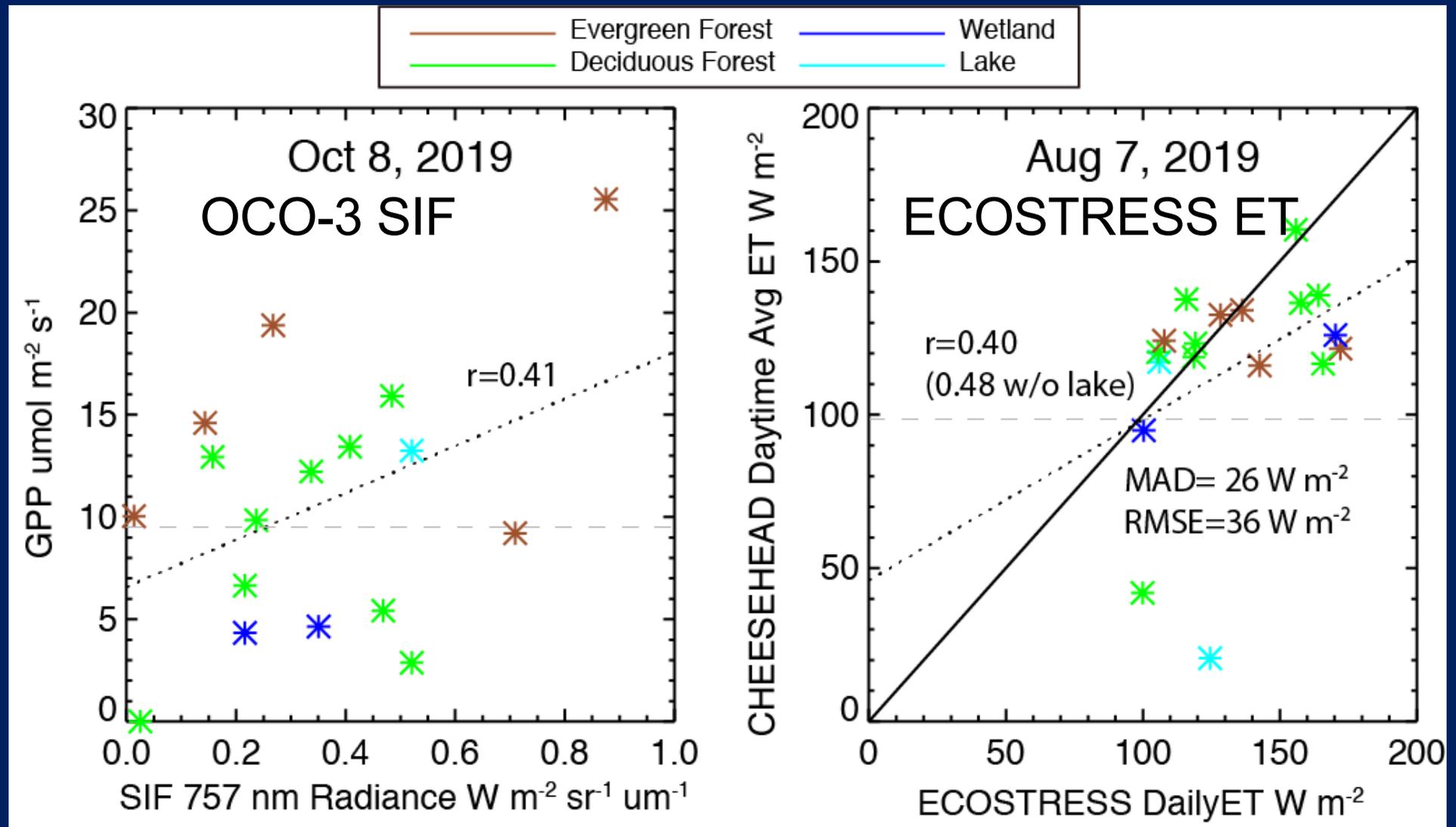
Microbial carbon limitation: The need for integrating microorganisms into our understanding of ecosystem carbon cycling

Jennifer L. Soong¹  | Lucia Fuchslueger^{2,3}  | Sara Marañon-Jimenez^{4,5}  | Margaret S. Torn¹  | Ivan A. Janssens²  | Josep Penuelas^{4,5}  | Andreas Richter^{3,6} 





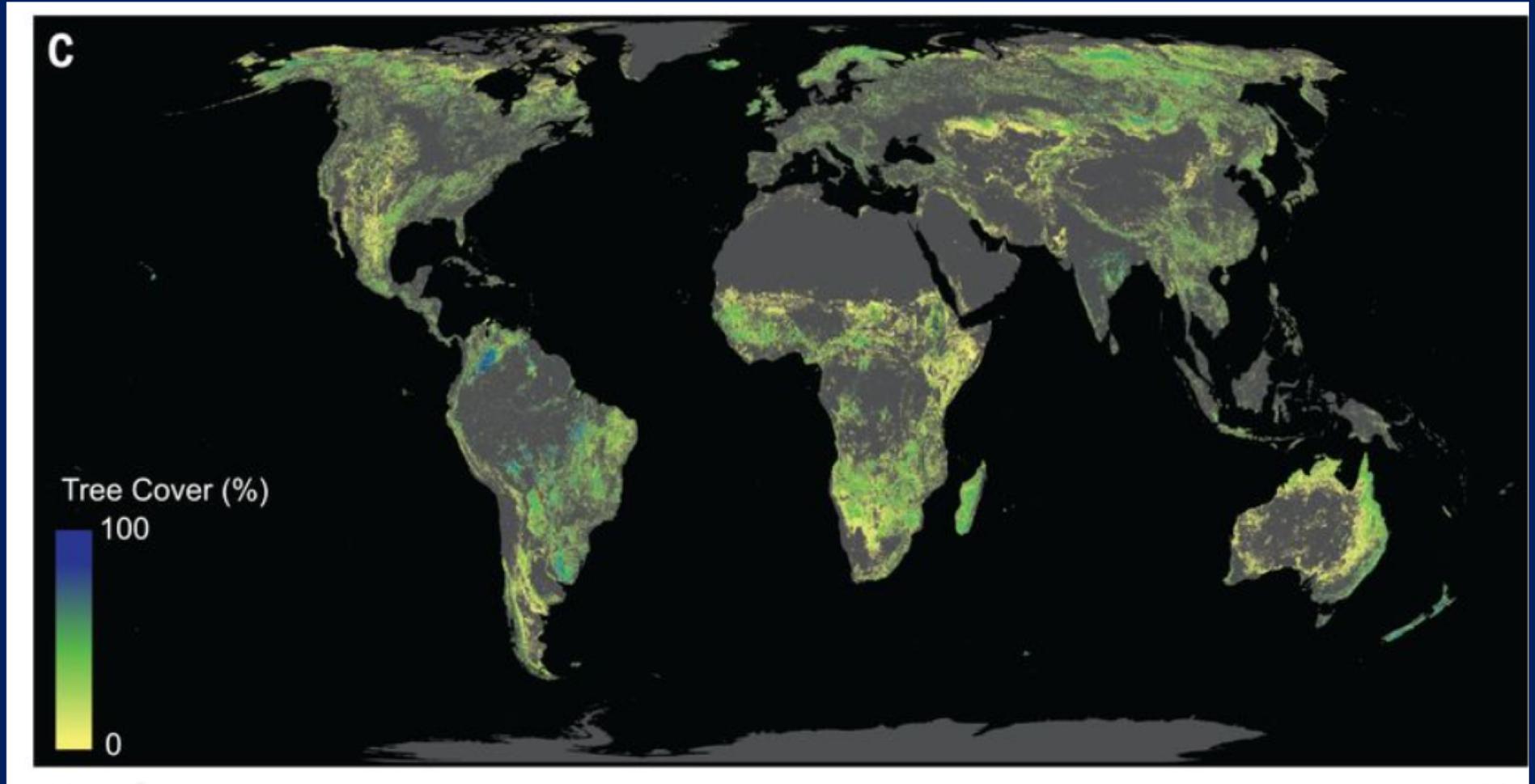
Next generation remote sensing has potential to continuously monitor the last breath...



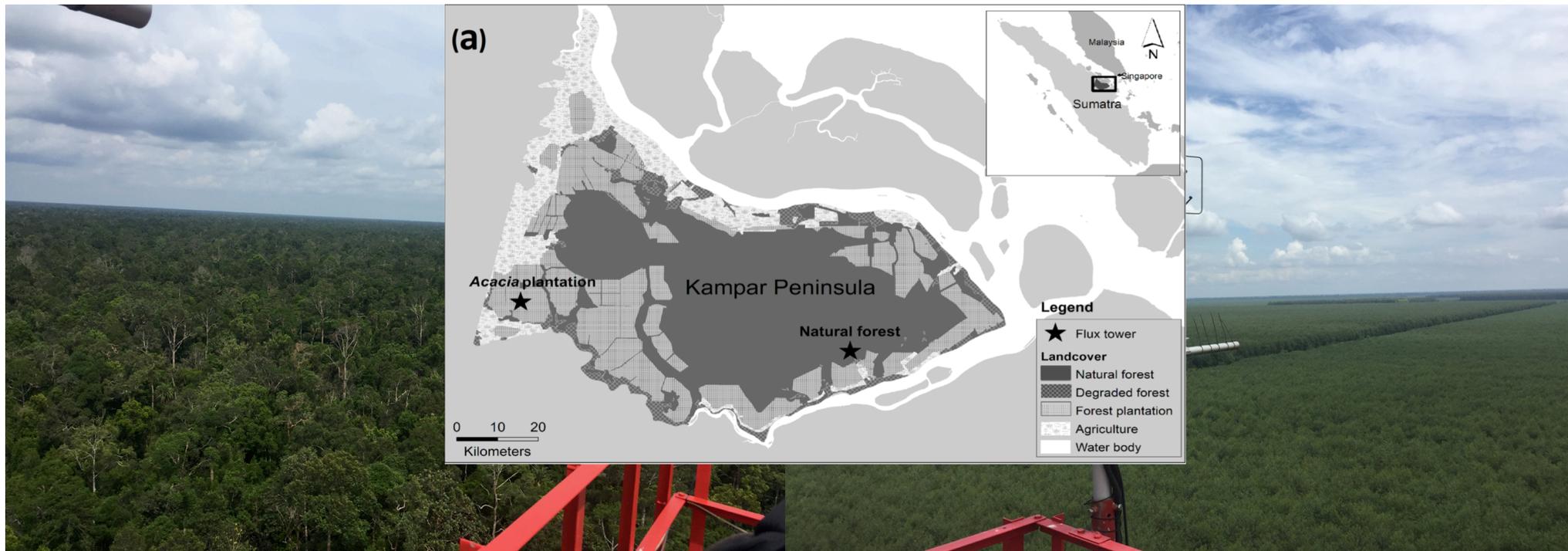
RESTORATION ECOLOGY

The global tree restoration potential

Jean-Francois Bastin^{1*}, Yelena Finegold², Claude Garcia^{3,4}, Danilo Mollicone²,
Marcelo Rezende², Devin Routh¹, Constantin M. Zohner¹, Thomas W. Crowther¹



Bastin et al., 2019



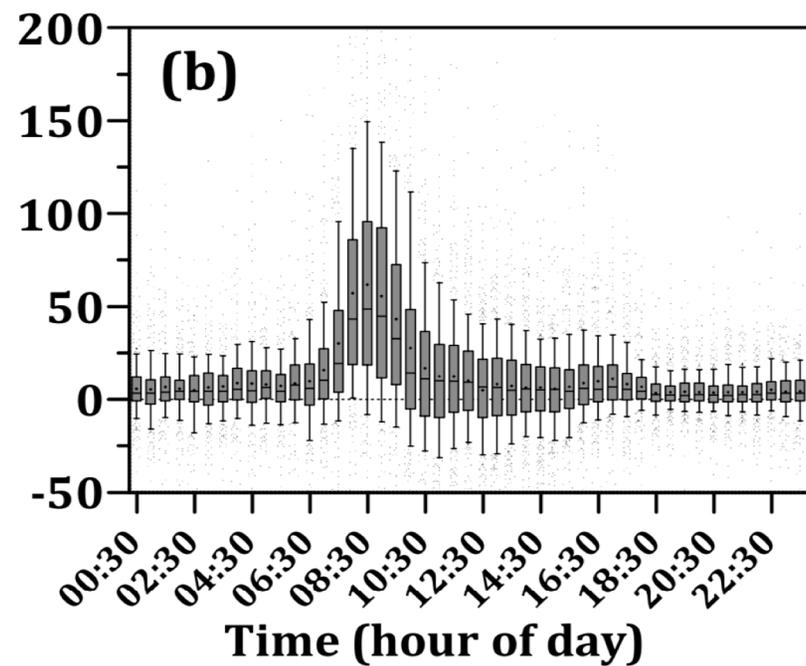
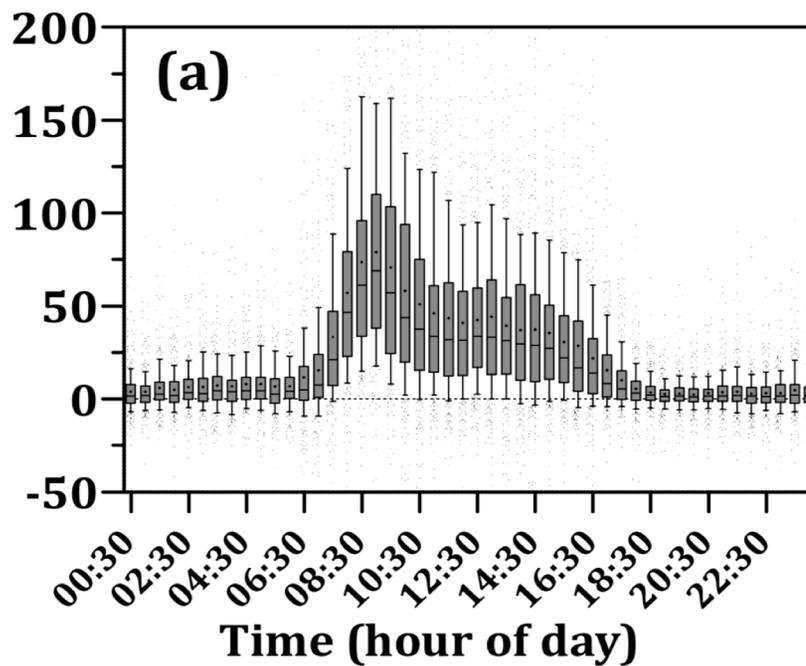
Natural forest

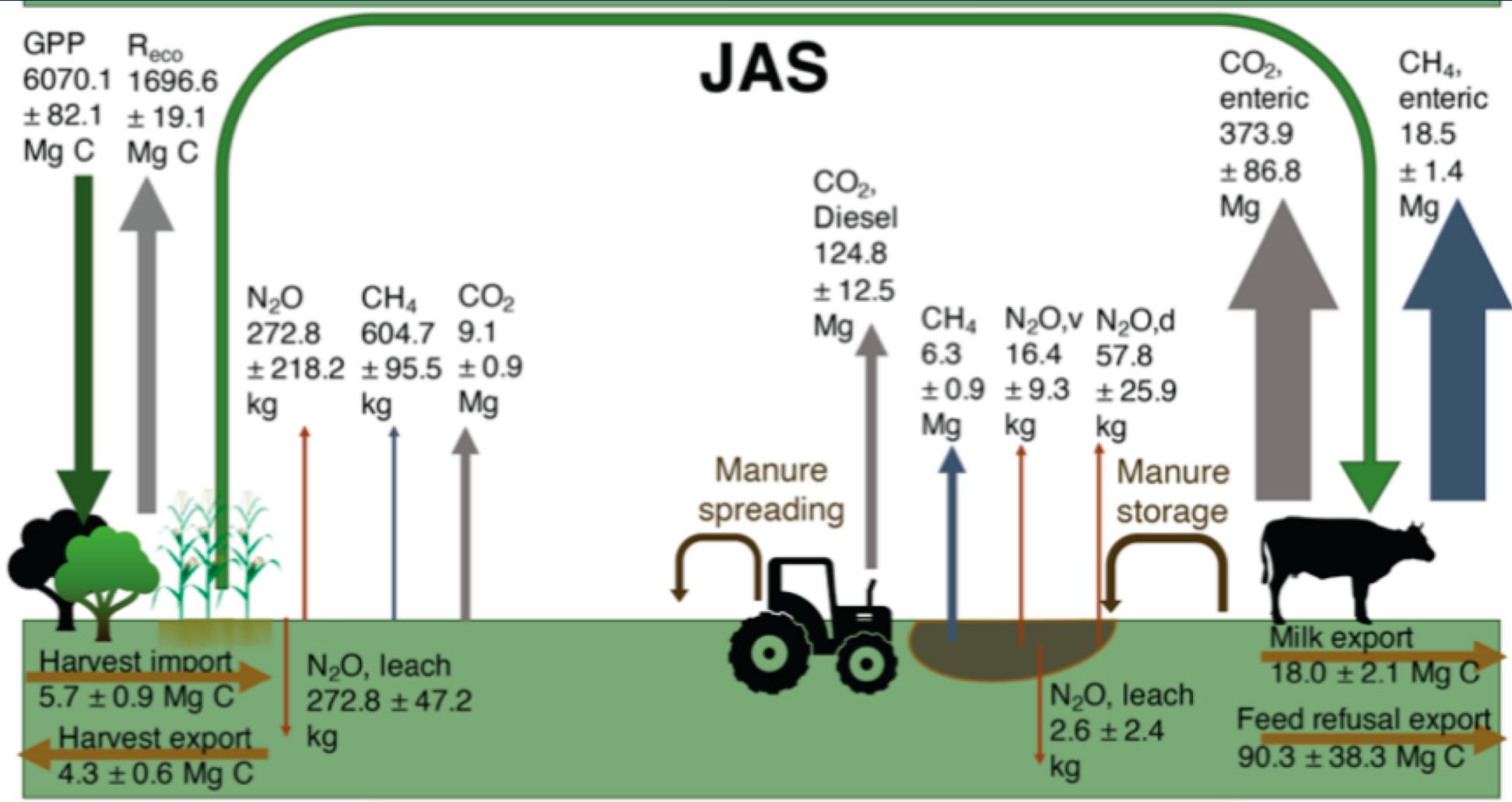
Acacia plantation

Deshmukh et al., 2020

Net ecosystem CH_4 exchange

$(\text{mg m}^{-2} \text{ day}^{-1})$

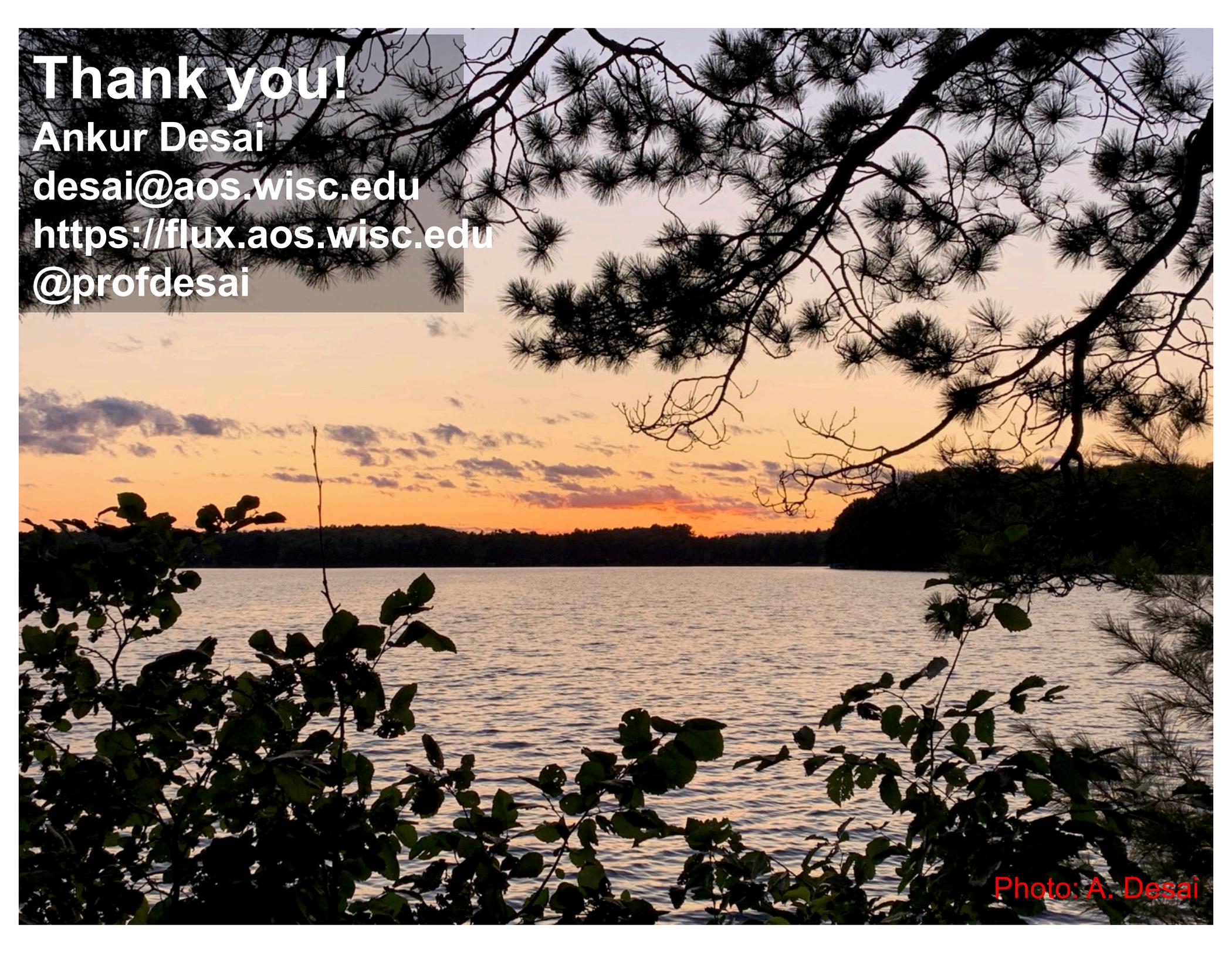






<https://gfycat.com/oddballuniteddeviltasmanian-nature>





Thank you!

Ankur Desai

desai@aos.wisc.edu

<https://flux.aos.wisc.edu>

[@profdesai](#)

Photo: A. Desai

Barrow Atmospheric Baseline Observatory, United States (BRW)

