Be a CHEESEHEAD

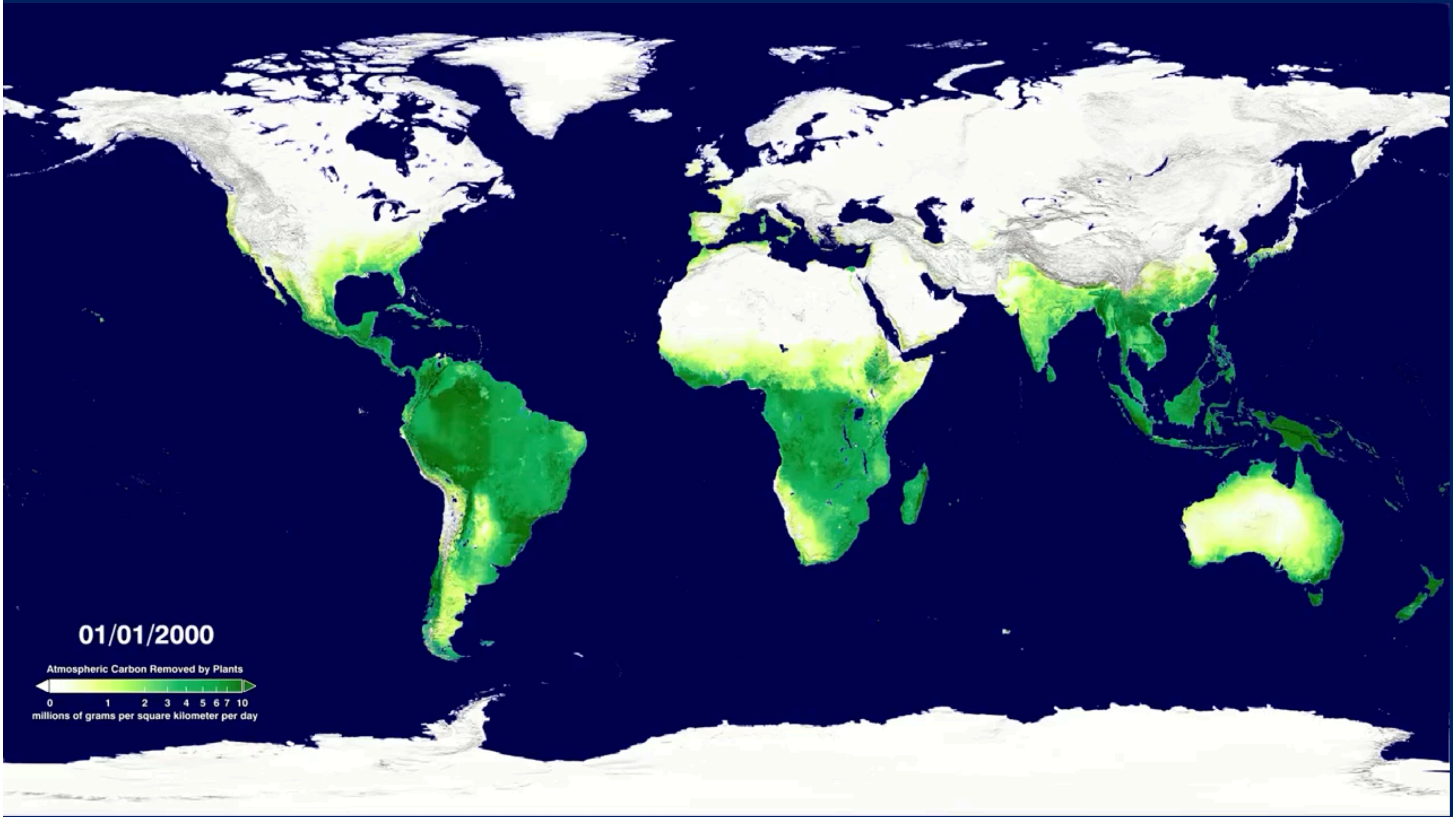
Introducing the

Chequamegon
Heterogenous
Ecosystem
Energy-balance
Study
Enabled by a
High-density
Extensive
Array of
Detectors
19

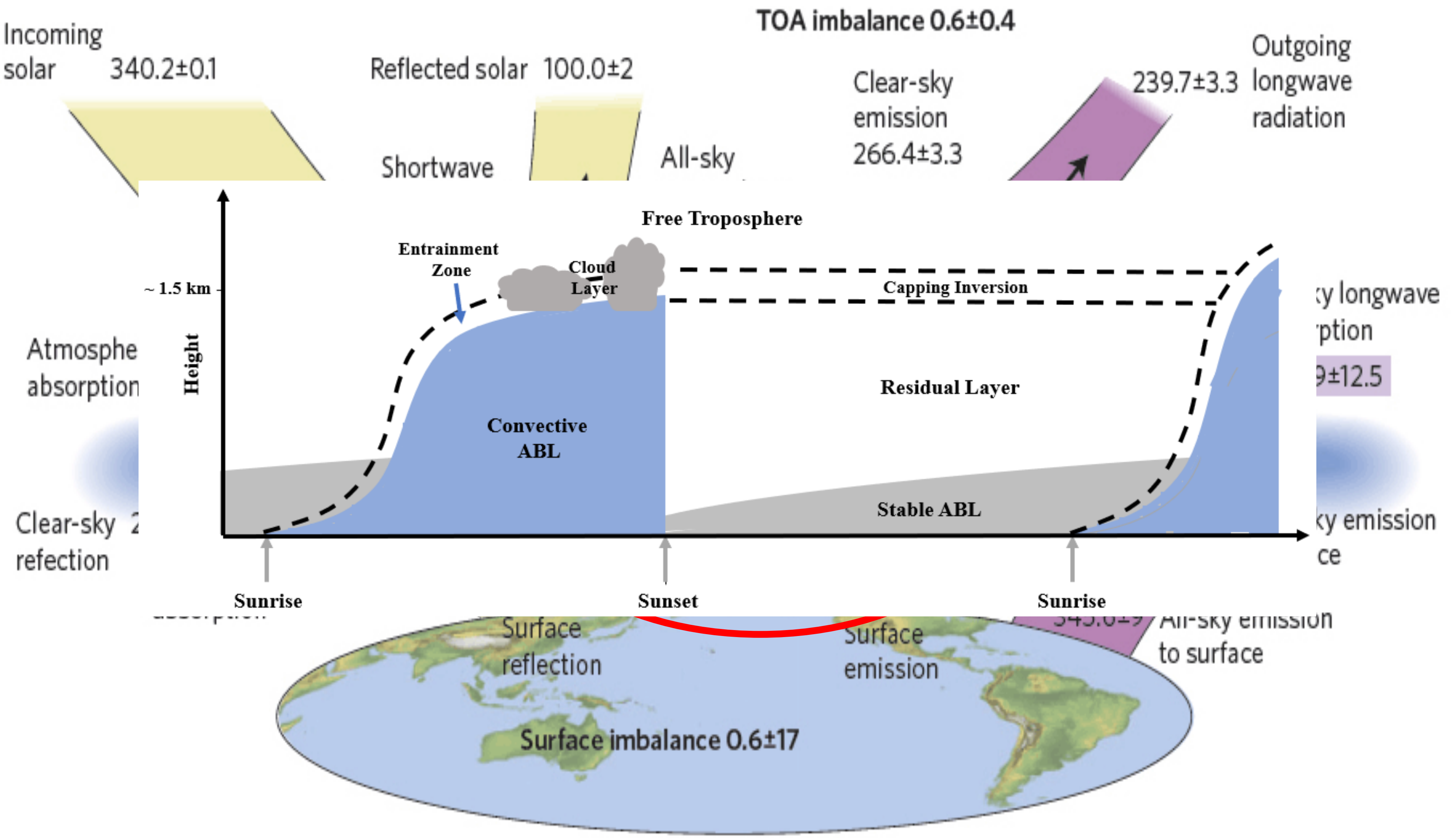
Ankur Desai,
Brian Butterworth
UW-Madison
NCAR EOL seminar
Dec 1, 2020

Photo: B. Butterworth

GPP = Gross Primary Productivity = photosynthesis



MODIS GPP (NASA)

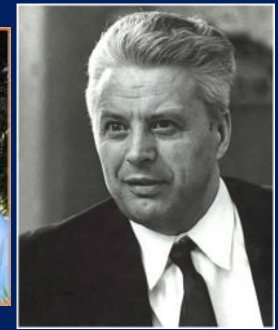
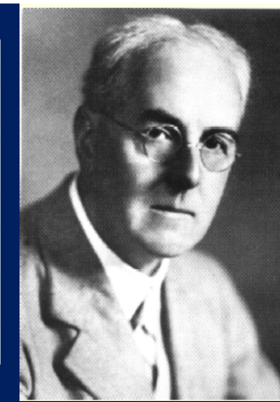


Stephens et al., 2012, Nature Geosci


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





- 1880-1920s Turublence 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 CO_2 fluxes (Desjardins, Leuning)
- 1980s Infrared gas analyzers (Verma, Anderson, Valentini)
- 1990s First long-term regional CO_2 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?)





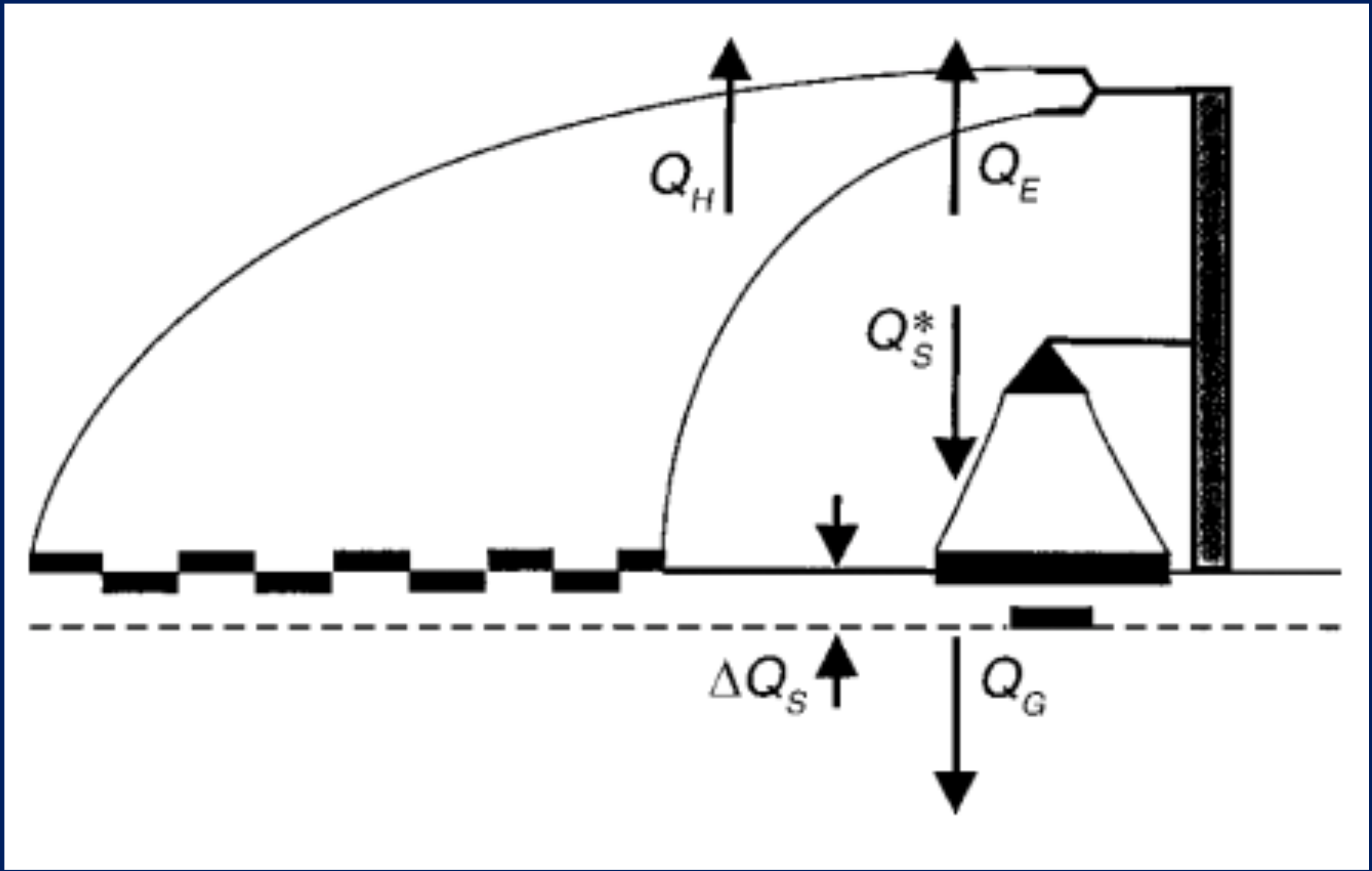


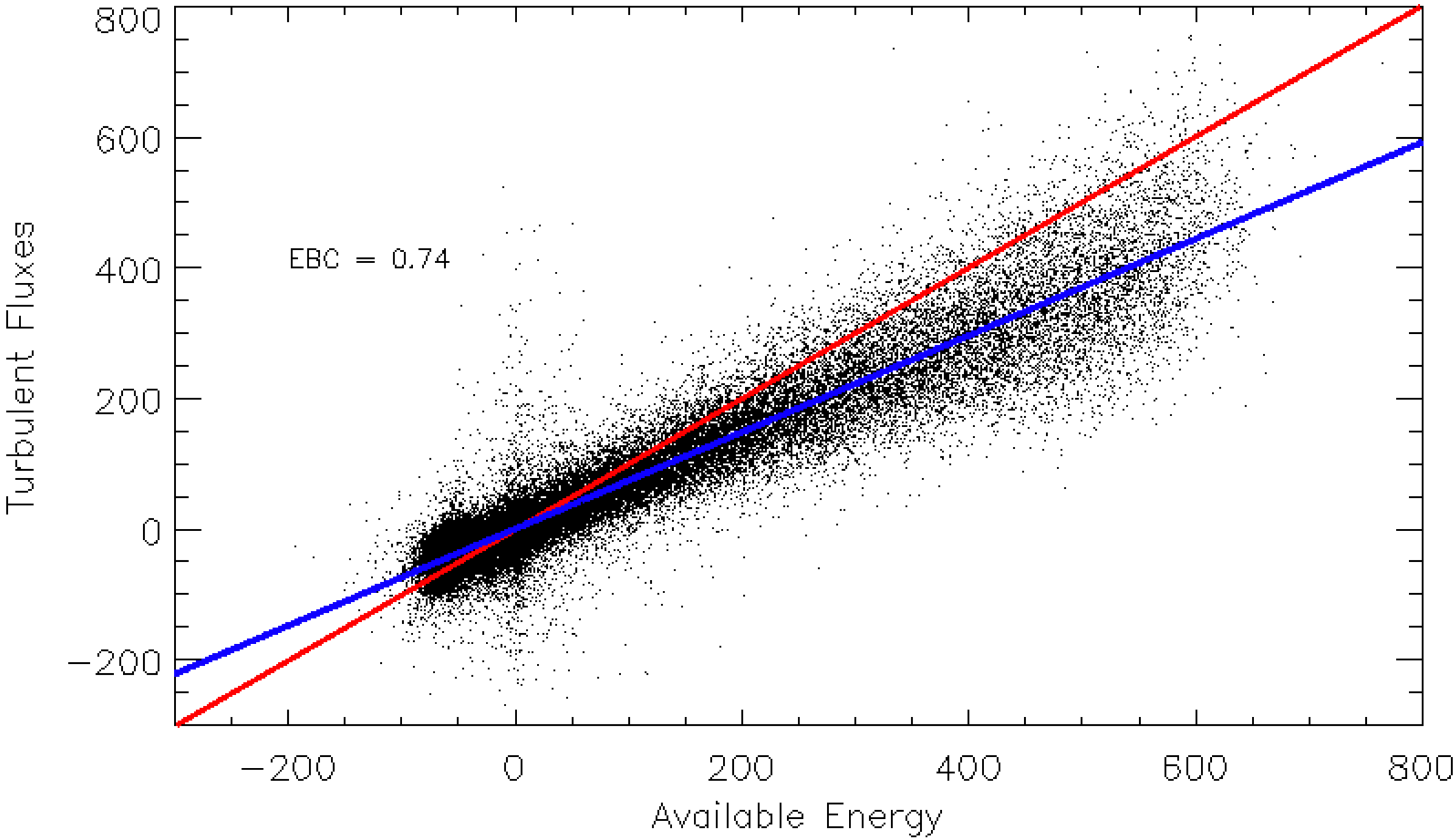

Huge Ecology!

Ecological Applications, 18(6), 2008, pp. 1351–1367

THE ENERGY BALANCE CLOSURE PROBLEM: AN OVERVIEW

THOMAS FOKEN[1]





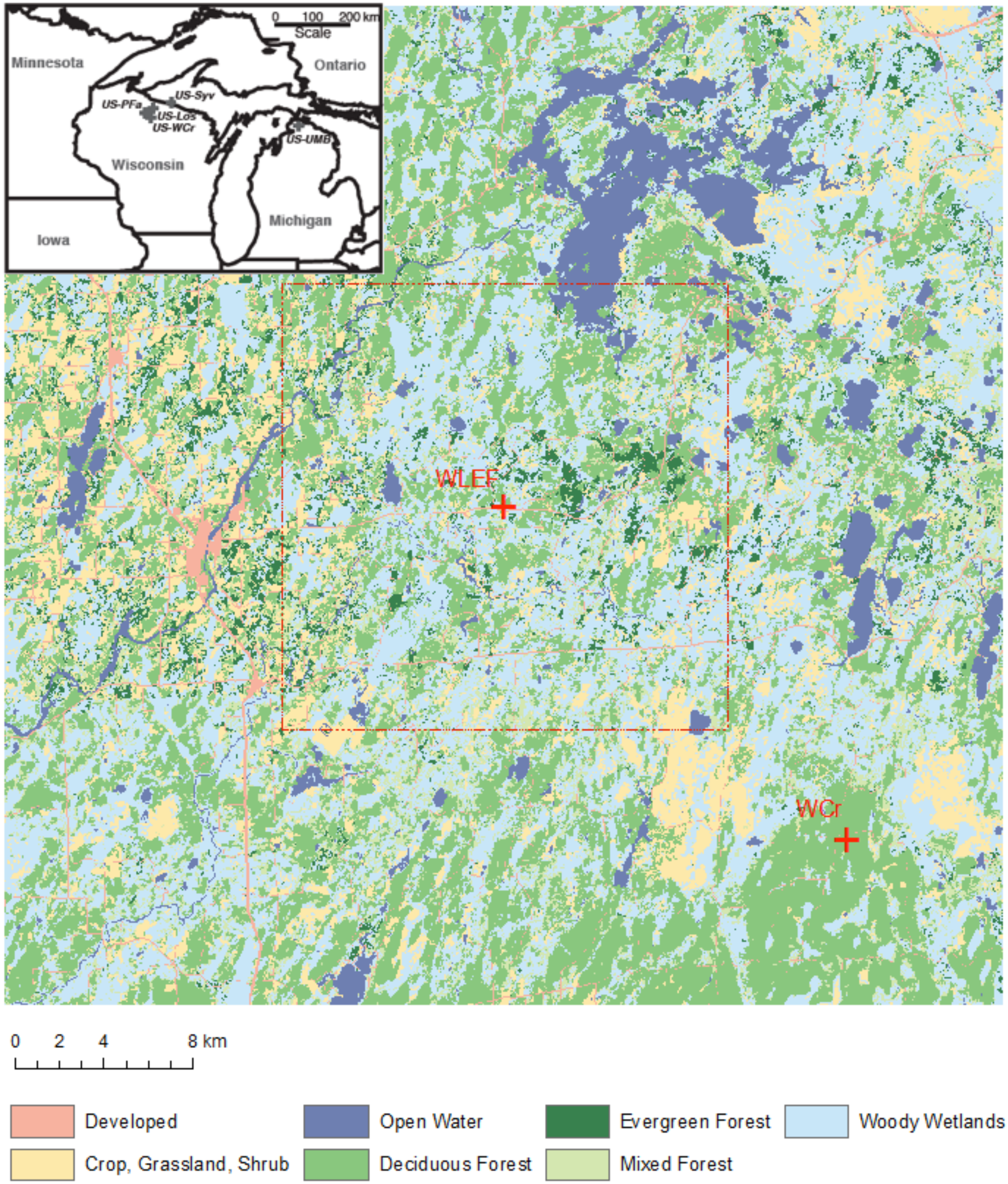
EBC = 0.74
Turbulent Fluxes
Available Energy
800
600
400
200
0
−200
800

So how does that lead to this?

CHEESEHEAD 2019

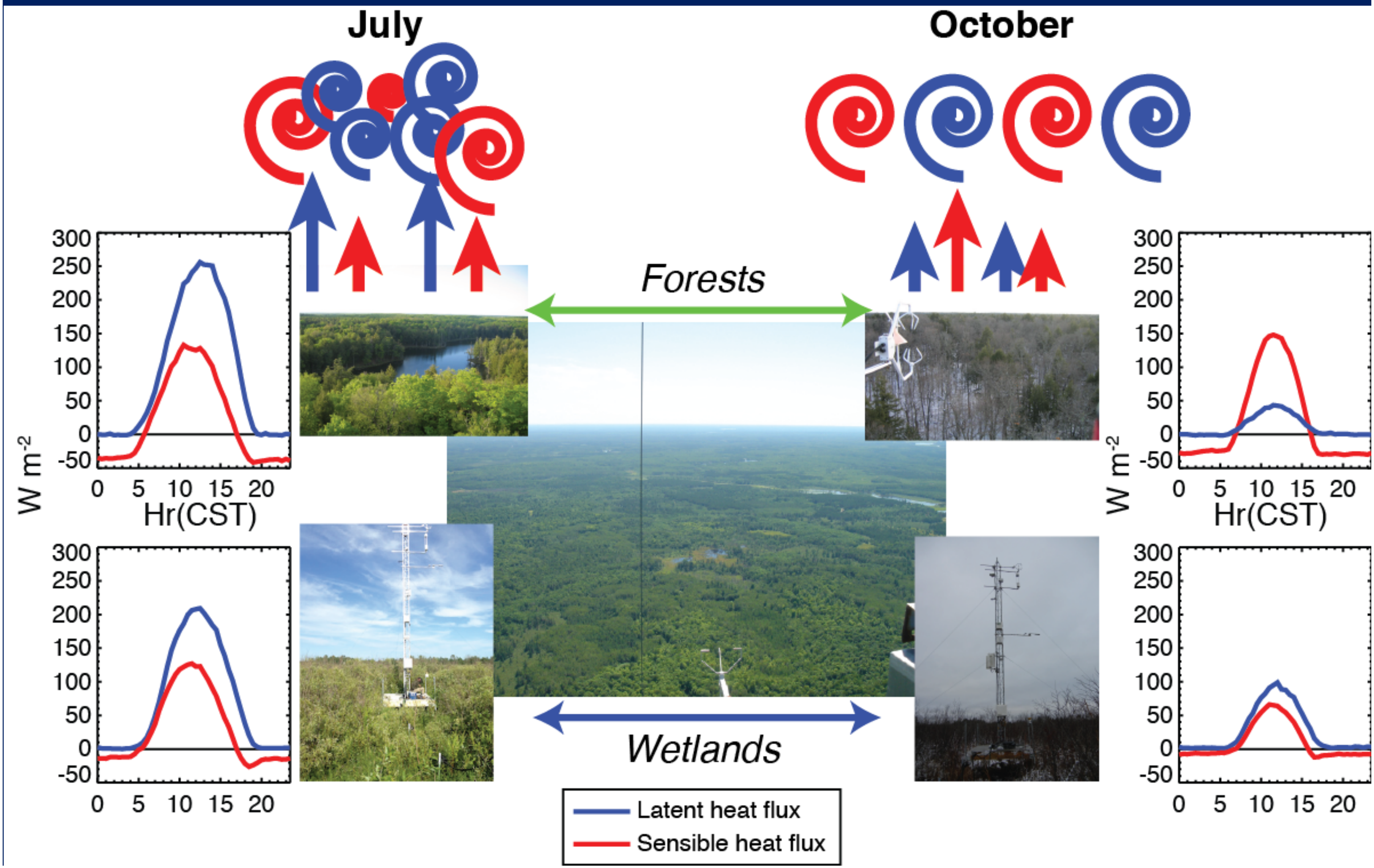
Chequamegon Heterogeneous Ecosystem Energy-balance Study Enabled by a High-density Extensive Array of Detectors

NSF 1822420
DFG 406980118
NOAA ESRL, ATDD



0 100 200 km
Scale
Minnesota
Ontario
US-Syv
US-PFa
US-Los
US-WCr
US-UMB
Wisconsin
Michigan
Iowa
WLEF
WCr
0 2 4 8 km
Developed
Open Water
Evergreen Forest
Woody Wetlands
Crop, Grassland, Shrub
Deciduous Forest
Mixed Forest

Experiment ran from July to October 2019, to take advantage of the natural changes in vegetation that occur over the season



NSF

DFG

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

NCAR UCAR EOL Earth Observing Laboratory

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

neon
National Ecological Observatory Network

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WISCONSIN DEPT. OF NATURAL RESOURCES

BUTTERNUT SCHOOL DISTRICT

Chequamegon High School

SSEC

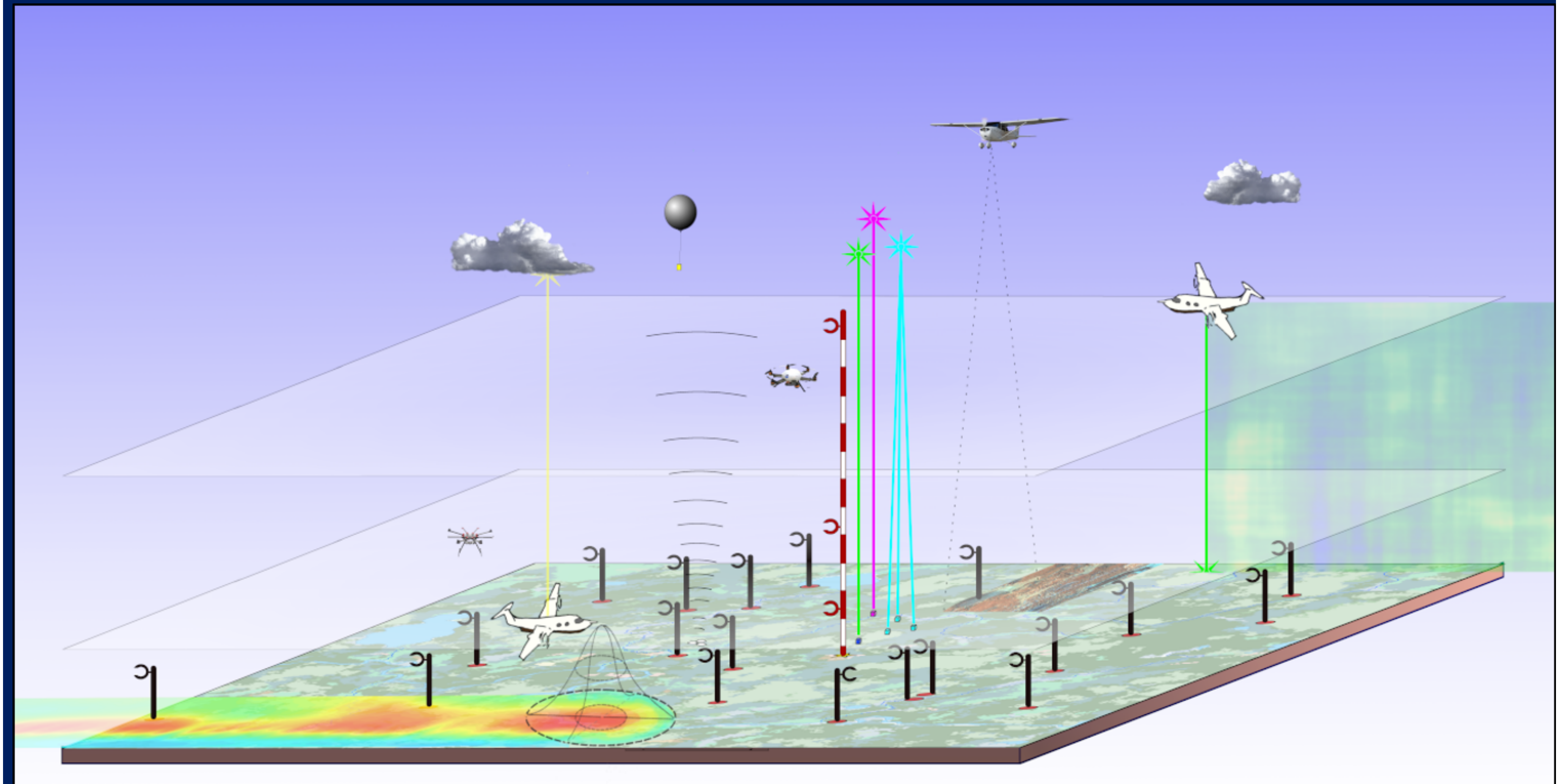
NASA

UNIVERSITY OF South Carolina
College of Education

U.S. DEPARTMENT OF ENERGY
Office of Science

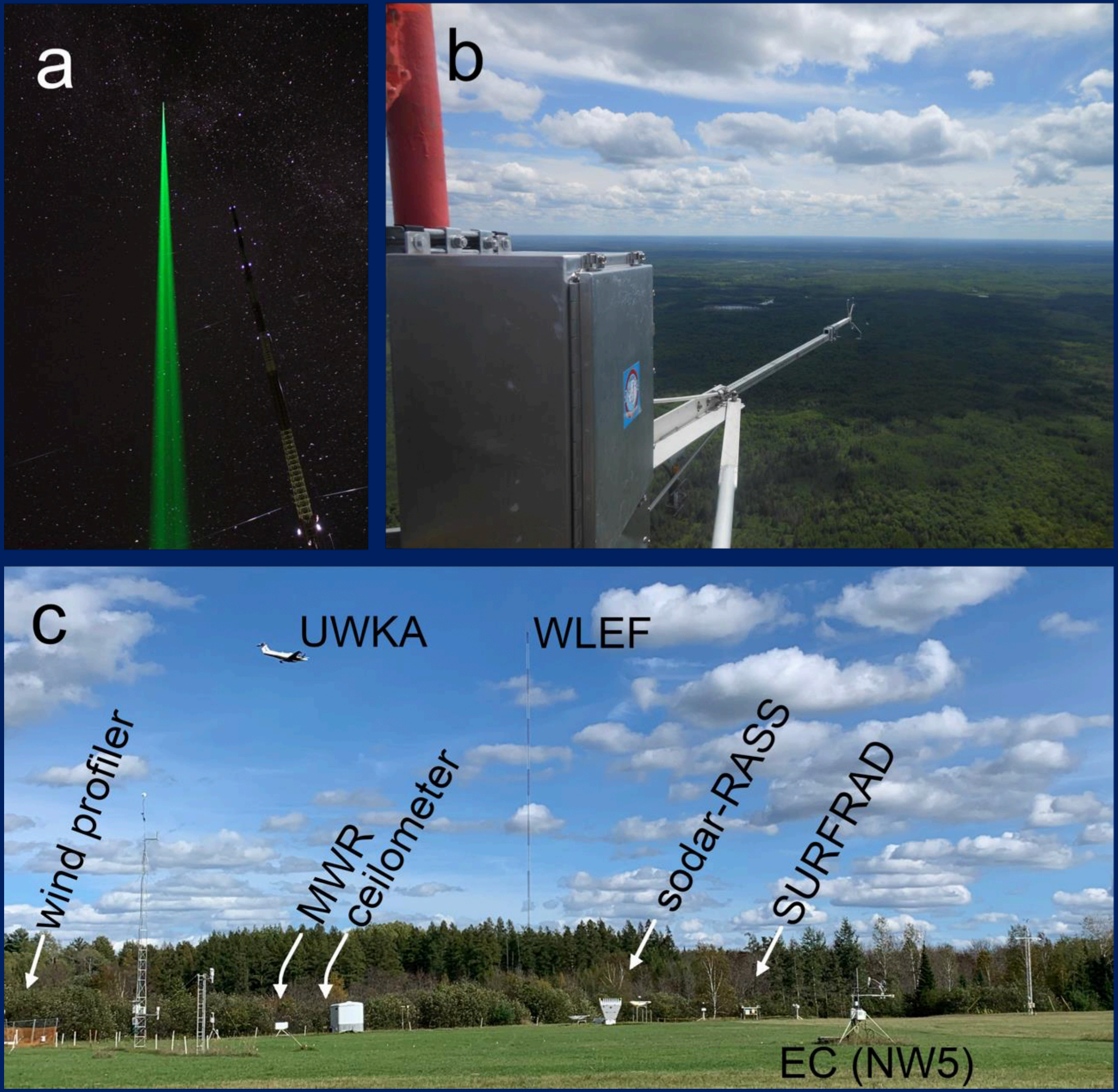
FOREST AND WILDLIFE ECOLOGY
COLLEGE OF AGRICULTURAL & LIFE SCIENCES

Intensively sample air and ground of 35 square miles of Northern Wisconsin

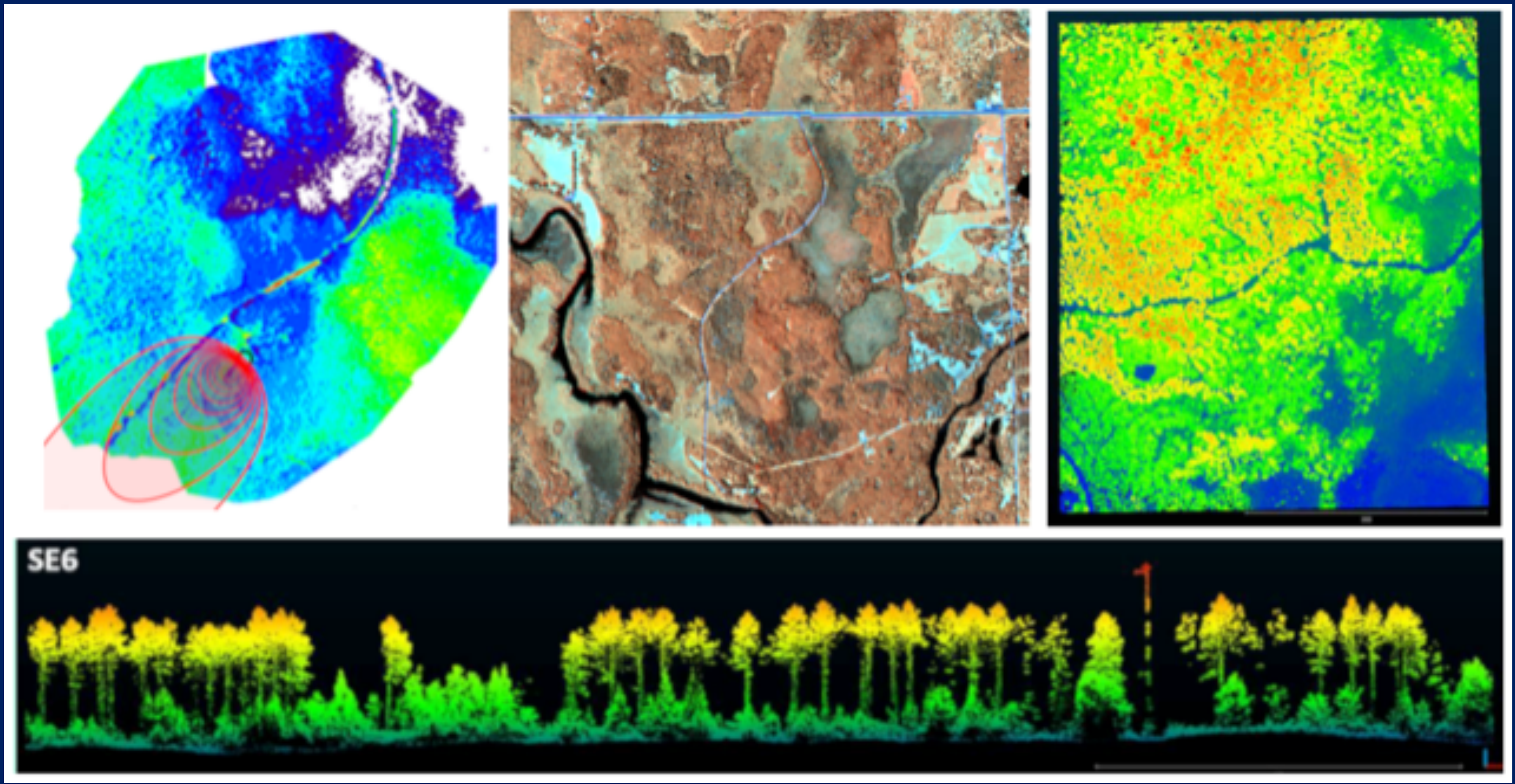


Butterworth *et al.*, 2020, BAMS

Comprehensive atmospheric sampling

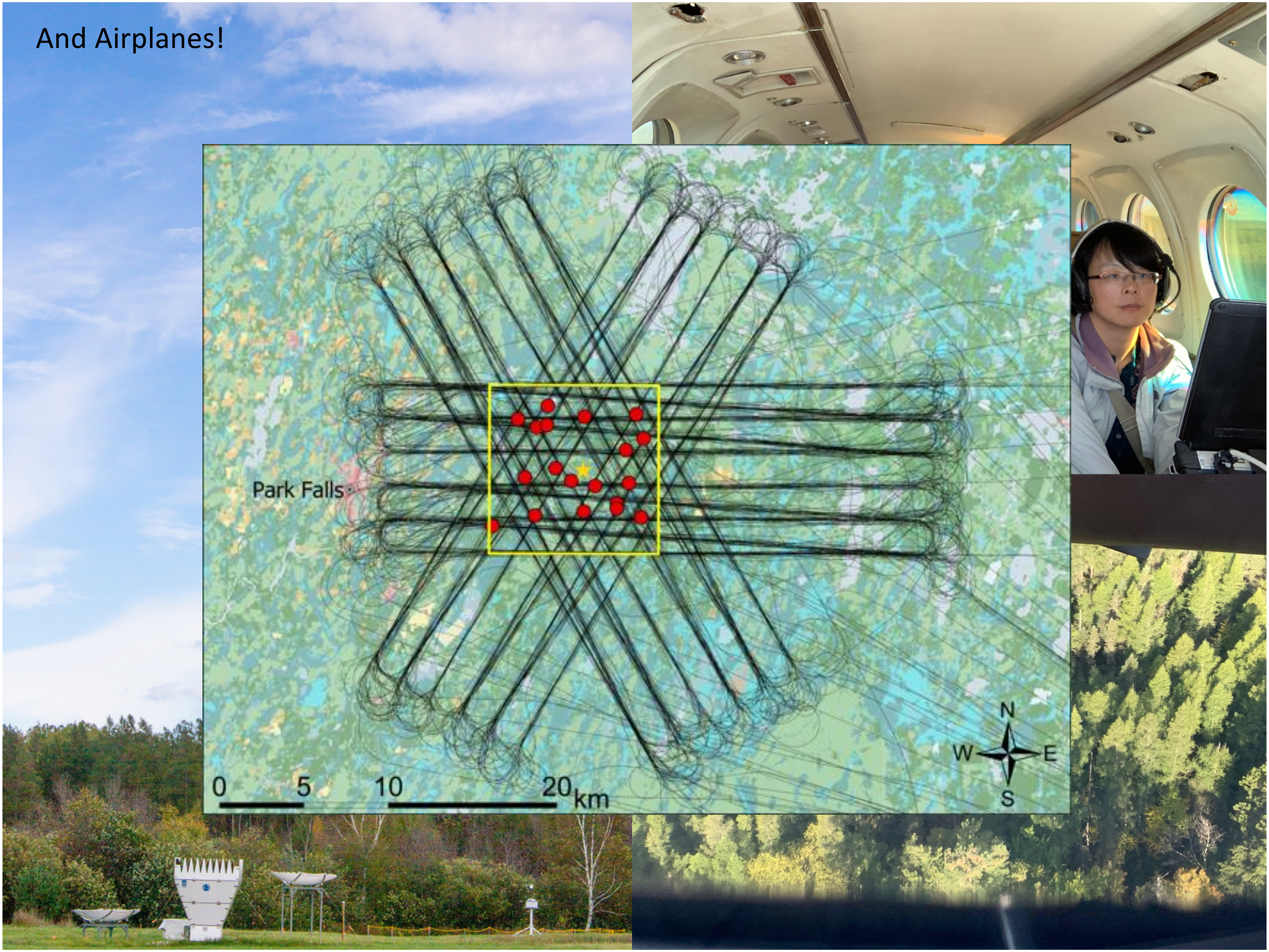


Comprehensive surface sampling



C. Andreson, M. Buban, T. Lee, E. Dumas

And Airplanes!



Data source	Data provider	Location(s)	Measured Variables	Period
Ground-based Measurements				
AmeriFlux/NOAA tall tower (US-PFa/WLEF)	UW AOS	WLEF	H_S, H_L, F_{CO2}, τ, R_n, meteorology	Continuous
ChEAS AmeriFlux towers: US-WCr / US-Los / US-Syv / US-Alg	UW AOS	AmeriFlux sites (4)	H_S, H_L, F_{CO2}, τ, R_n, meteorology	Continuous
ISFS Eddy covariance towers	NCAR EOL ISFS	10x10 km (17 sites)	H_S, H_L, F_{CO2}, τ, R_n, meteorology, soil G, Q, Cv, T profile, precip (5 sites)	June-Oct
MSU Eddy covariance towers	Montana State U & UW BSE	NW5 (ISS) and SE1	H_S, H_L, F_{CO2}, τ, R_n, soil G, Cv, meteorology	June-Oct
Surface meteorology	NCAR EOL ISS	ISS field	T, RH, P, precip, wind, sky images	July-Oct
SURFRAD & TWST	NOAA GML	ISS field[1] Prentice Airport[2] Lakeland Airport[2]	Downwelling SW/LW[1,2], direct SW[1,2], diffuse SW[1,2], upwelling SW/LW[1], PAR[1], sky images[1], cloud optical depth[1], cloud fraction[1,2], cloud base height[2], mixed layer depth[2], meteorology[1]	July-Oct (TWST: Sep-Oct)
Precipitation Imaging Package	UW SSEC	WLEF	PSD, fall speed, rain rate	July-Oct
Vehicle/ Pedestrian/ Boat transects	Jackson State U	10x10 km – Roads/ Trails / Hay Lake	T, RH, P, total downwelling SW, IR brightness temperature, water T	IOP 1, 2, 3
Chemical ionization mass spec & ozone photometric analyzer	UW Chem	WLEF	Ozone concentration and flux	IOP 1
Tall tower greenhouse gases	NOAA GML	WLEF	CO2, CH4 concentration & CO2, CH4 profiles	Continuous & Biweekly
Tree temperature	Chequamegon HS	5 sites, 10 trees	T at breast height (1.37 m AGL)	Oct
Atmospheric Profiling				
449 MHz modular wind profiler	NCAR EOL ISS	ISS field	3D wind profiles	July-Oct
Sodar-RASS	NCAR EOL ISS	ISS field	3D wind, T_v and θ_v profiles	July-Oct
Ceilometer	NCAR EOL ISS	ISS field	Attenuated backscatter profiles, cloud base height, ABL height	July-Oct
Daily radiosonde	NCAR EOL ISS	ISS field	18Z (1pm local)	July-Oct
3-hourly daytime radiosondes	NCAR EOL ISS	ISS field	4-5 per day for 5 days per IOP	IOP 1, 2, 3
AERI	UW SSEC SPARC	WLEF	Downwelling IR radiance, profiles of T, H_2O, and cloud properties	July-Oct
HALO Lidar (1) – vertical stare	UW SSEC SPARC	WLEF	Profiles of 3D wind (virtual tower)	July-Oct
HSRL	UW SSEC SPARC	WLEF	Backscatter, depolarization	July-Oct
Micro Rain Radar (MRR)	UW SSEC	WLEF	Precipitation rate, reflectivity, particle size distribution (PSD)	July-Oct
ATMONSYS: Backscatter, Raman, and Differential Absorption Lidar	KIT IMK-IFU	WLEF	Vertical profiles of aerosol backscatter, T, H_2O	July-Sep
HALO lidars (2,3) – RHI scans	KIT IMK-IFU	WLEF	Profiles of 3D wind (virtual tower)	July-Sep
915 MHz radar wind profiler w/ radio acoustic sounding system	NOAA PSL	Prentice Airport, Lakeland Airport	Profiles of U, T_v, Convective ABL height	July-Oct
MWR	NOAA PSL	ISS field[1] Prentice Airport[2] Lakeland Airport[3]	Downwelling microwave radiance, profiles of T, H_2O, and liquid water path	July-Oct[3] July-Sep[2] Sep-Oct[1]
CLAMPS (MWR, AERI, Doppler wind lidar)	NOAA NSSL	Prentice Airport, Lakeland Airport	Profiles of U, T, H_2O	Sep-Oct
Airborne Measurements				
Airborne eddy covariance	UWKA	30x30km, 24 flights	3D wind, T, H_2O, CO2 (25 Hz; ~3 m)	IOP 1, 2, 3
Airborne met. and radiation	UWKA	30x30km, 24 flights	Meteorology (1 Hz; ~80 m)	IOP 1, 2, 3
Compact Raman Lidar (CRL)	UWKA	30x30km, 24 flights	H2O and T cross sections	IOP 1, 2, 3
Wyoming Cloud Lidar (WCL)	UWKA	30x30km, 24 flights	ABL height	IOP 1, 2, 3
Meteodrone SSE sUAS	NOAA ARL ATDD	WLEF and SW2	T, H_2O, U	IOP 1, 2, 3
Ozone sUAS	UWEC	WLEF	O_3, T, H_2O	IOP 1
Surface Environment				
HySpex	UW FWE	10x10 km, 4 flights	hyperspectral imagery (474 bands), foliar functional traits	June-Aug
DJI S-1000 (sUAS)	NOAA ARL ATDD	WLEF and SW2	LST, Hs	IOP 1, 2
Routescene lidar (sUAS)	UW-Mad Geog	11 tower sites	Ground and canopy height (leaf on)	June
QL2 lidar	USFS	30x30 km	Ground and canopy height (leaf off)	Fall 2018
Vegetation/phenology sampling	UW-Mil Geog	10x10 km (10 plots)	Leaf color / fall level	Sep-Oct
Vegetation Sampling	UW FWE	10x10 km (41 plots)	inventory, root growth, NPP, biometry, leaf spectra, foliar tissue chemistry, LMA	June-Oct
Soil samples	NCAR EOL	17 tower sites	heat capacity and soil bulk density	July-Oct
Soil samples	UW AOS	16 tower sites	Soil carbon, nitrogen	Oct
Soil samples	Butternut Schools	7 sites	Soil and water chemistry	July
ECOSTRESS, GEDI, OCO3	NASA JPL	30x30 km	LST, emissivity, evapotranspiration	periodic

https://www.eol.ucar.edu/field_projects/cheesehead

CHEESEHEAD Open House, August 2019

Up Next: Brian Butterworth

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Photo: A. Desai