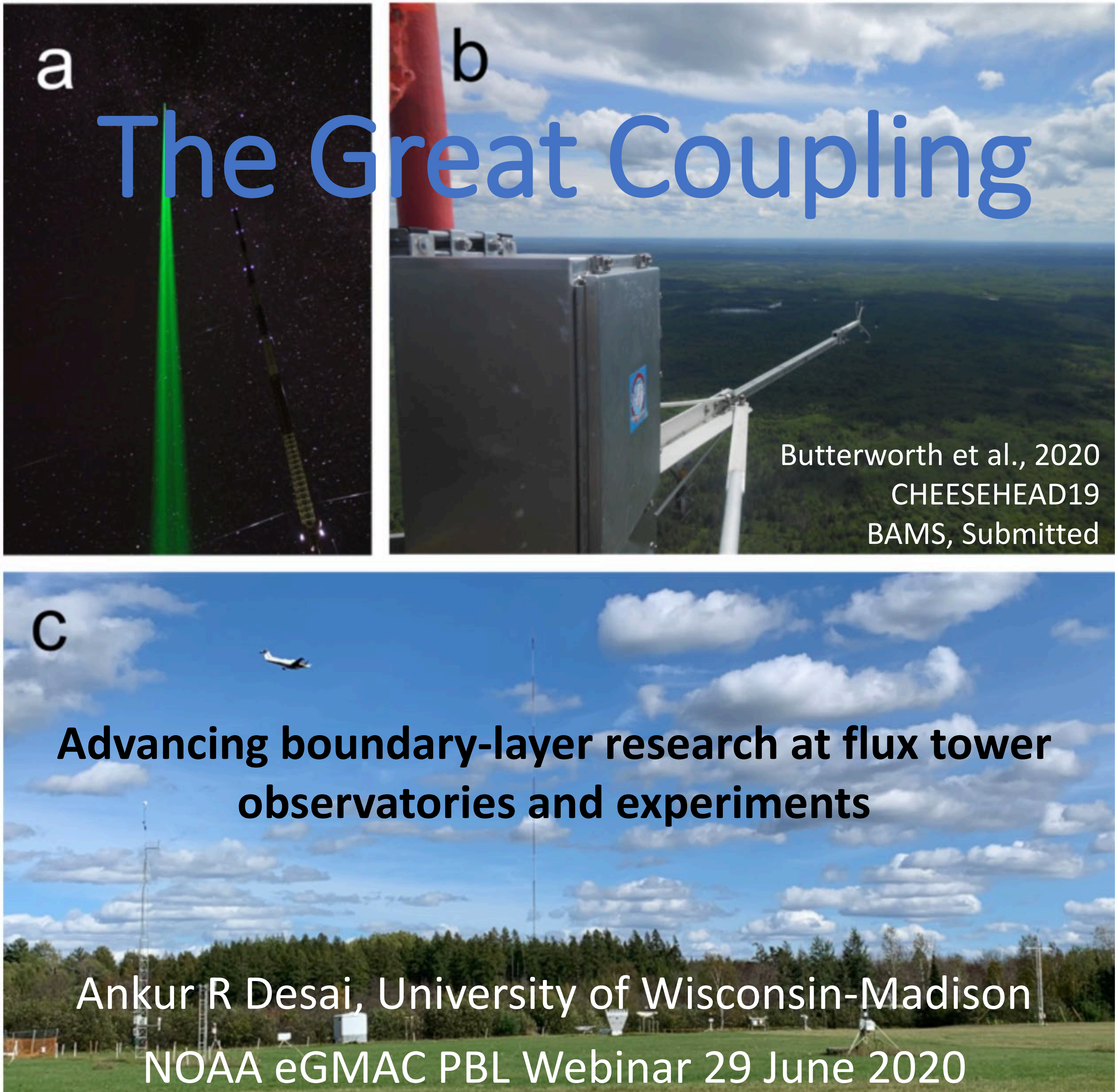
The Great Coupling



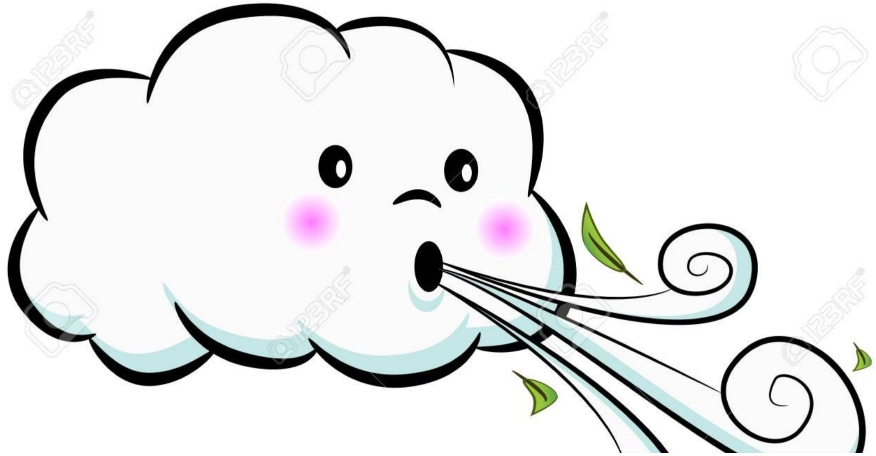
Butterworth et al., 2020
CHEESEHEAD19
BAMS, Submitted

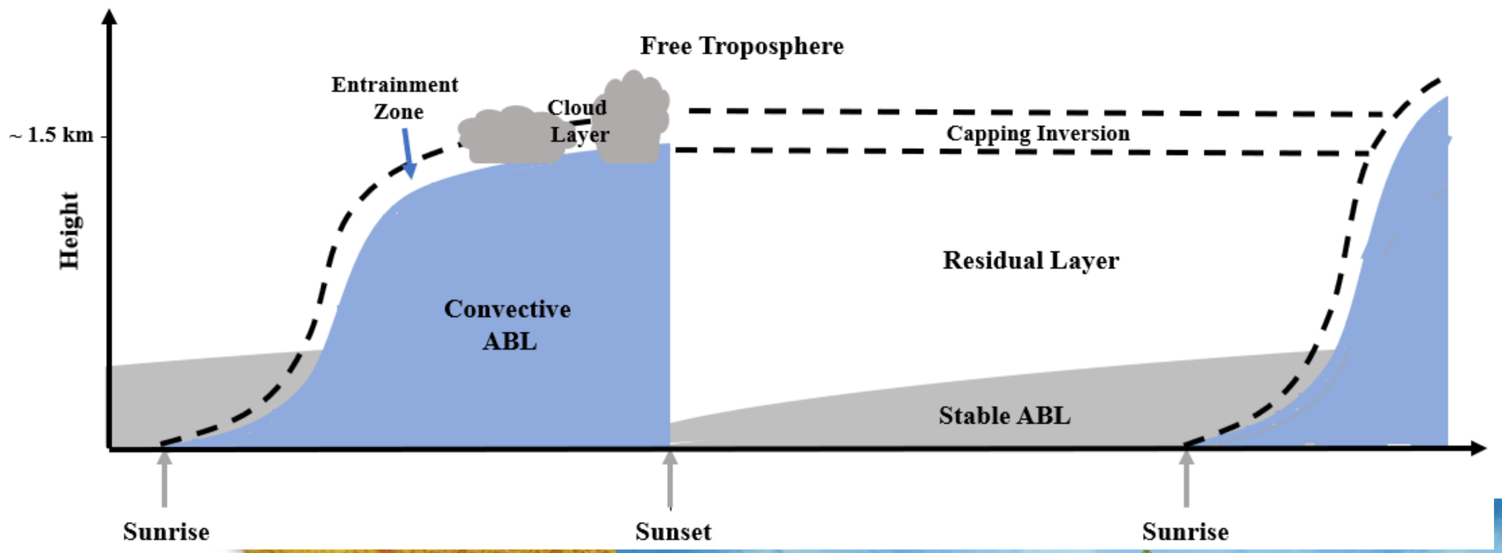
Advancing boundary-layer research at flux tower observatories and experiments

Ankur R Desai, University of Wisconsin-Madison

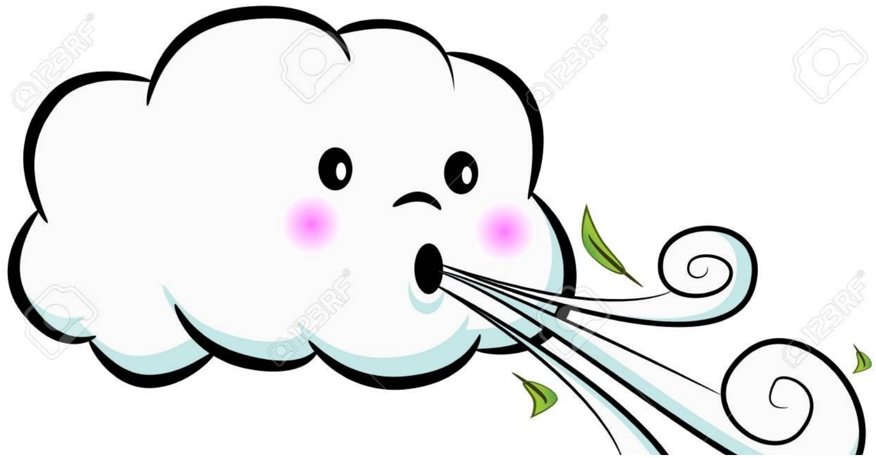
NOAA eGMAC PBL Webinar 29 June 2020

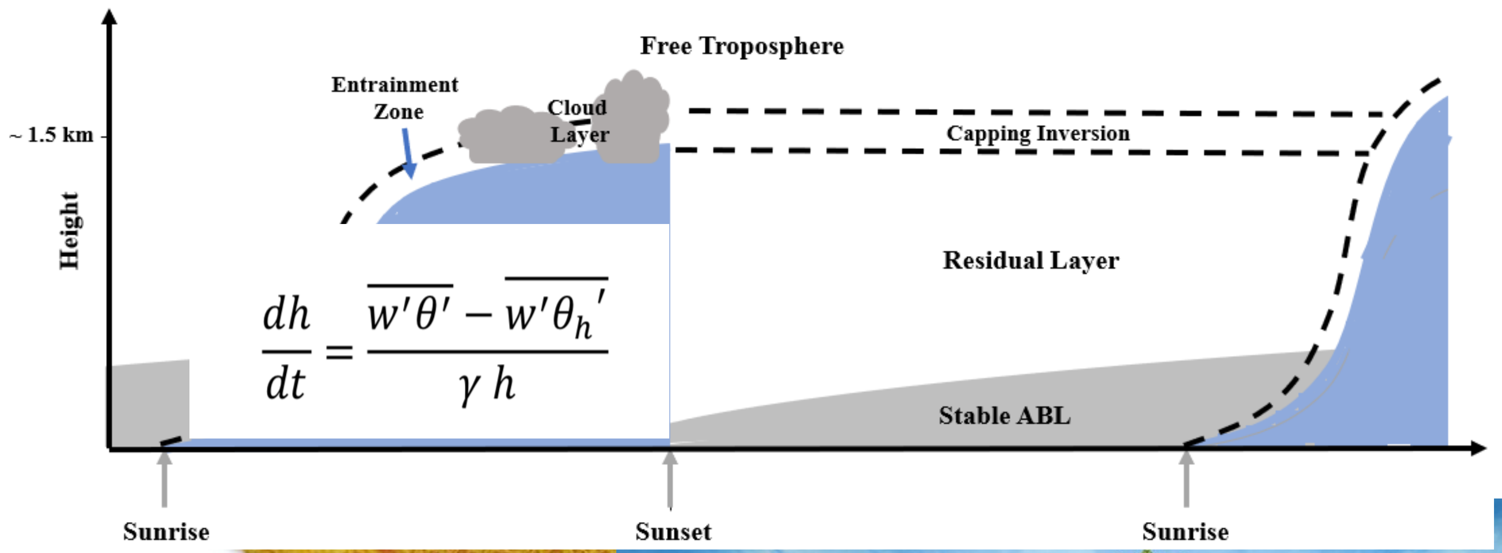
https://edensstructural.com
https://www.homedepot.com/
https://www.pinterest.com



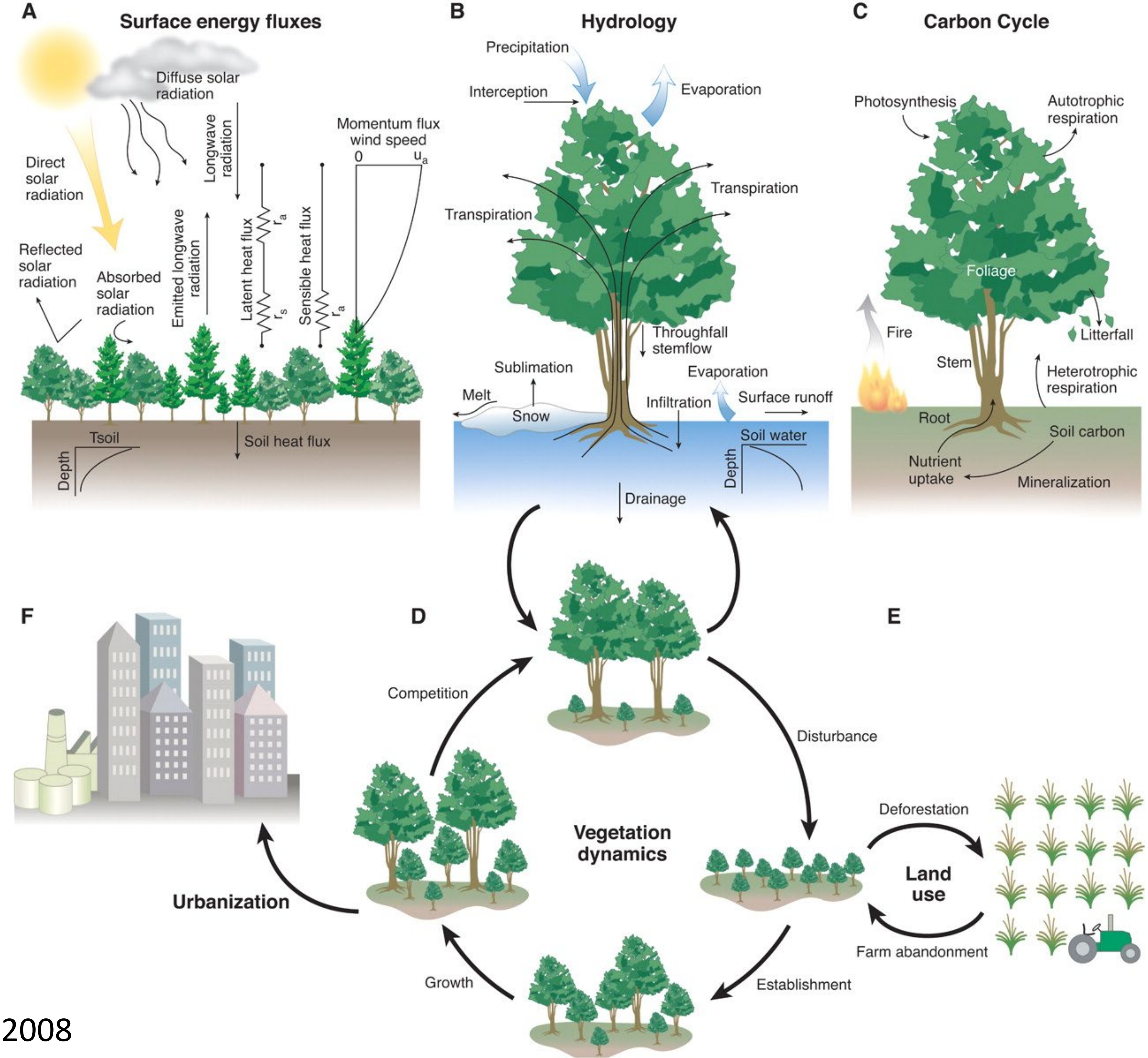


https://edensstructural.com
https://www.homedepot.com/
https://www.pinterest.com





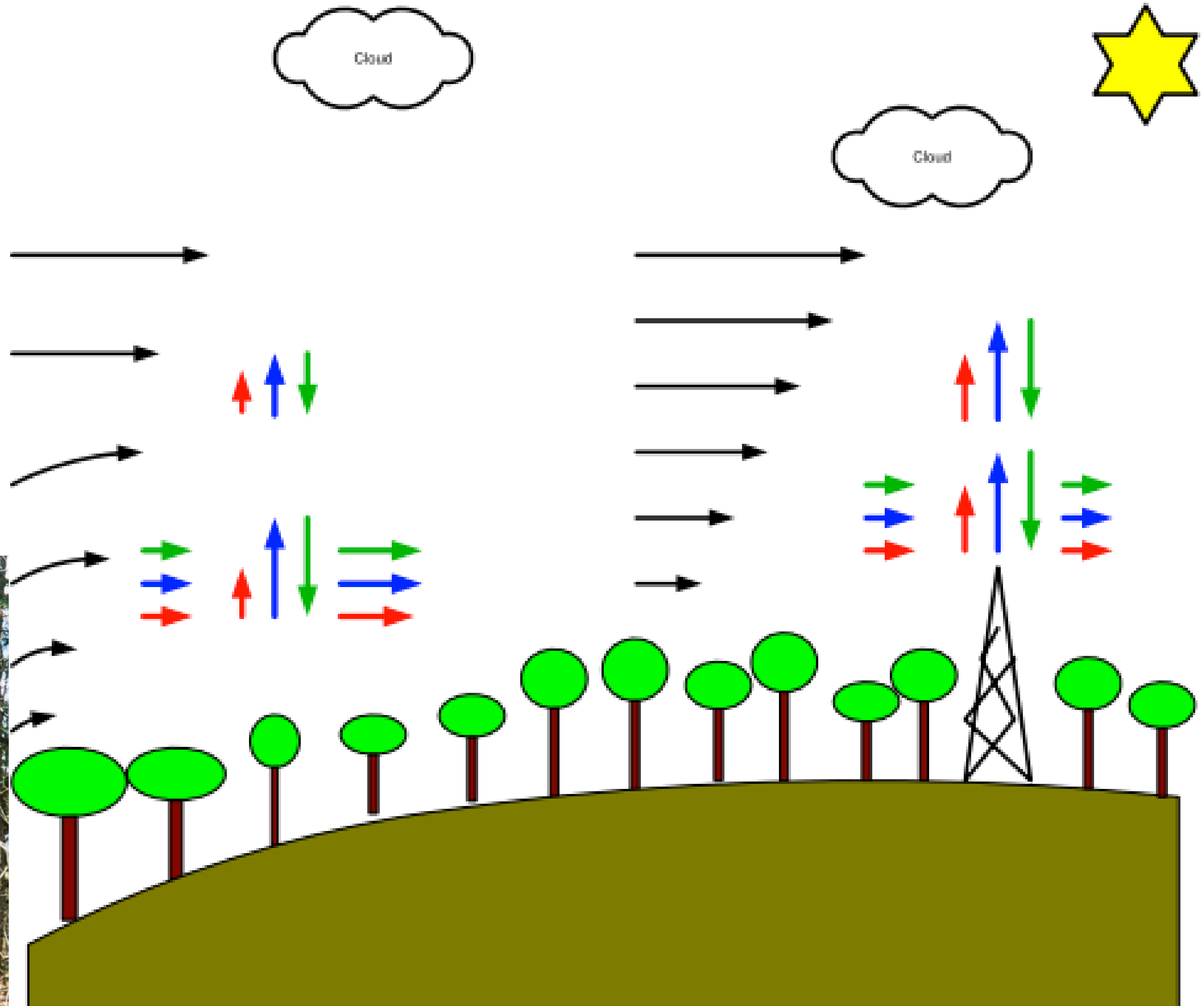
https://edensstructural.com
https://www.homedepot.com/
https://www.pinterest.com


A
Surface energy fluxes
Diffuse solar radiation
Longwave radiation
Momentum flux wind speed
0
u_a
Direct solar radiation
Reflected solar radiation
Absorbed solar radiation
Emitted longwave radiation
Latent heat flux
r_a
r_s
Sensible heat flux
r_a
Tsoil
Depth
Soil heat flux
B
Hydrology
Precipitation
Interception
Evaporation
Transpiration
Transpiration
Throughfall stemflow
Sublimation
Evaporation
Melt
Snow
Infiltration
Surface runoff
Soil water
Depth
Drainage
C
Carbon Cycle
Photosynthesis
Autotrophic respiration
Foliage
Fire
Litterfall
Stem
Heterotrophic respiration
Root
Soil carbon
Nutrient uptake
Mineralization
F
D
E
Competition
Disturbance
Vegetation dynamics
Deforestation
Land use
Farm abandonment
Urbanization
Growth
Establishment

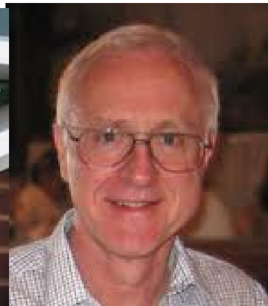
Bonan, 2008

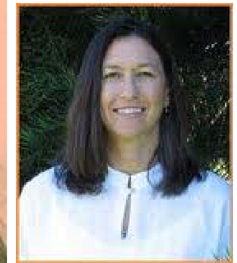
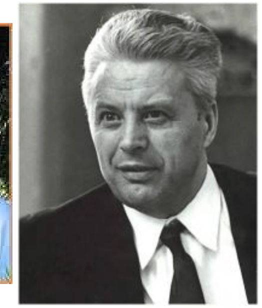
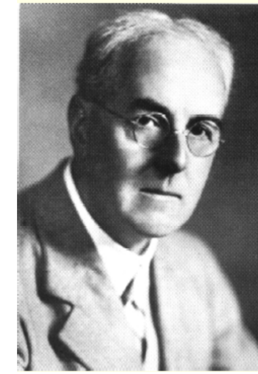
Main thoughts

- Flux tower networks and surface-atmosphere experiments are great testbeds for improving PBL processes in models, understanding role of ecosystems on weather and climate, and advancing approaches to integrate observations
  - Don’t reinvent the wheel!
- Networks and experiments have differing goals that influence their suitability for types of PBL research
- Growing community interested in advancing PBL studies at flux tower sites



D. Baldocchi

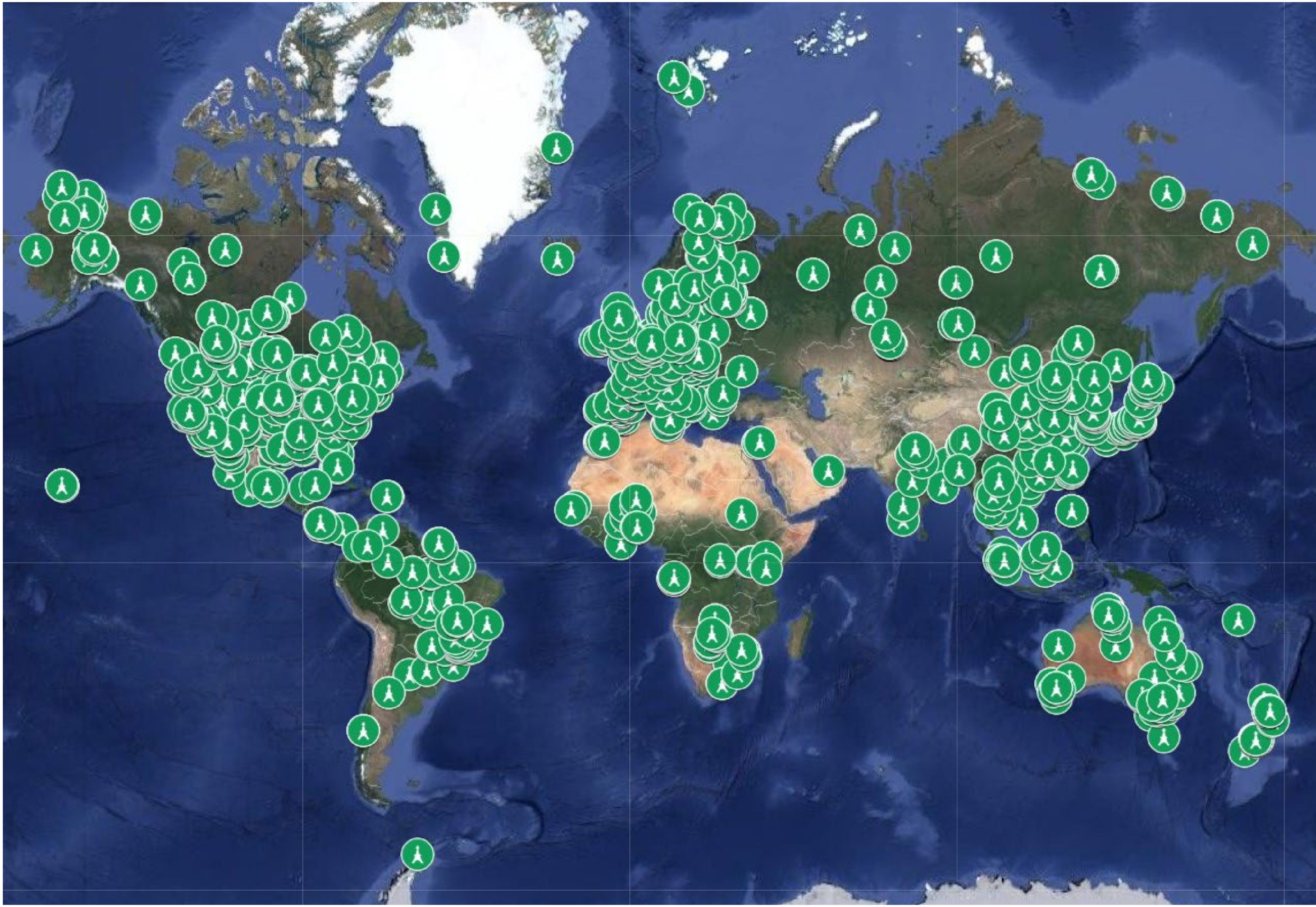





- 1880-1920s Turublence theory (Reynolds, Prandtl, Richardson, Taylor)
- 1940s-1950s Surface-layer theory (Monin-Obhukov, Kolmogorov), development of fast sensors for anemometry
- 1960s early measurements (Inoue, Wyngaard, Kaimal)
- 1970s forest fluxes (Raupach, Lenschow, Denmead)
- 1970s CO_2 fluxes (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?)





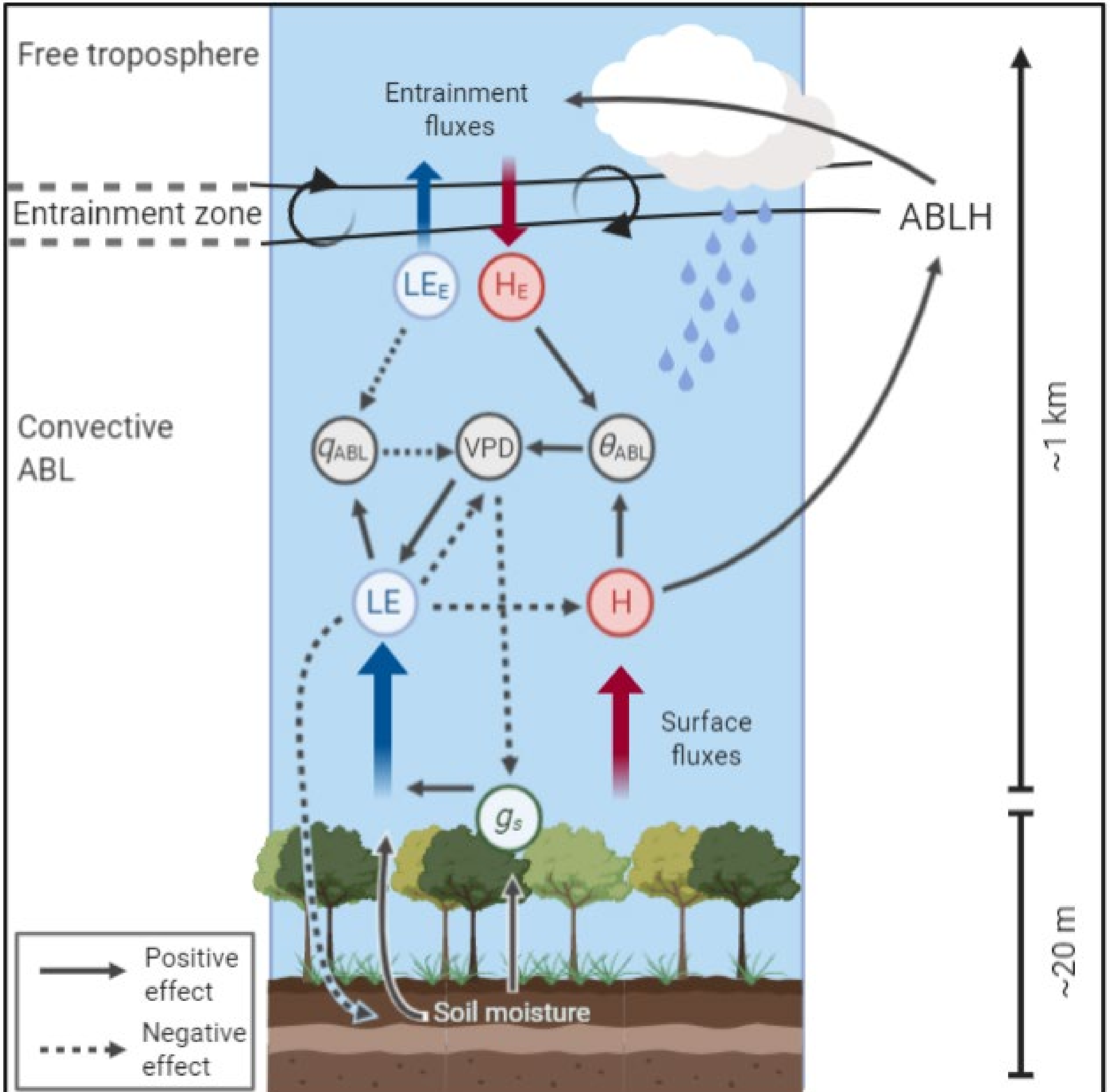


Burba, G., 2019. Illustrative Maps of Past and Present Eddy Covariance Measurement Locations. Research Gate, doi:10.13140/RG.2.2.25992.67844/1

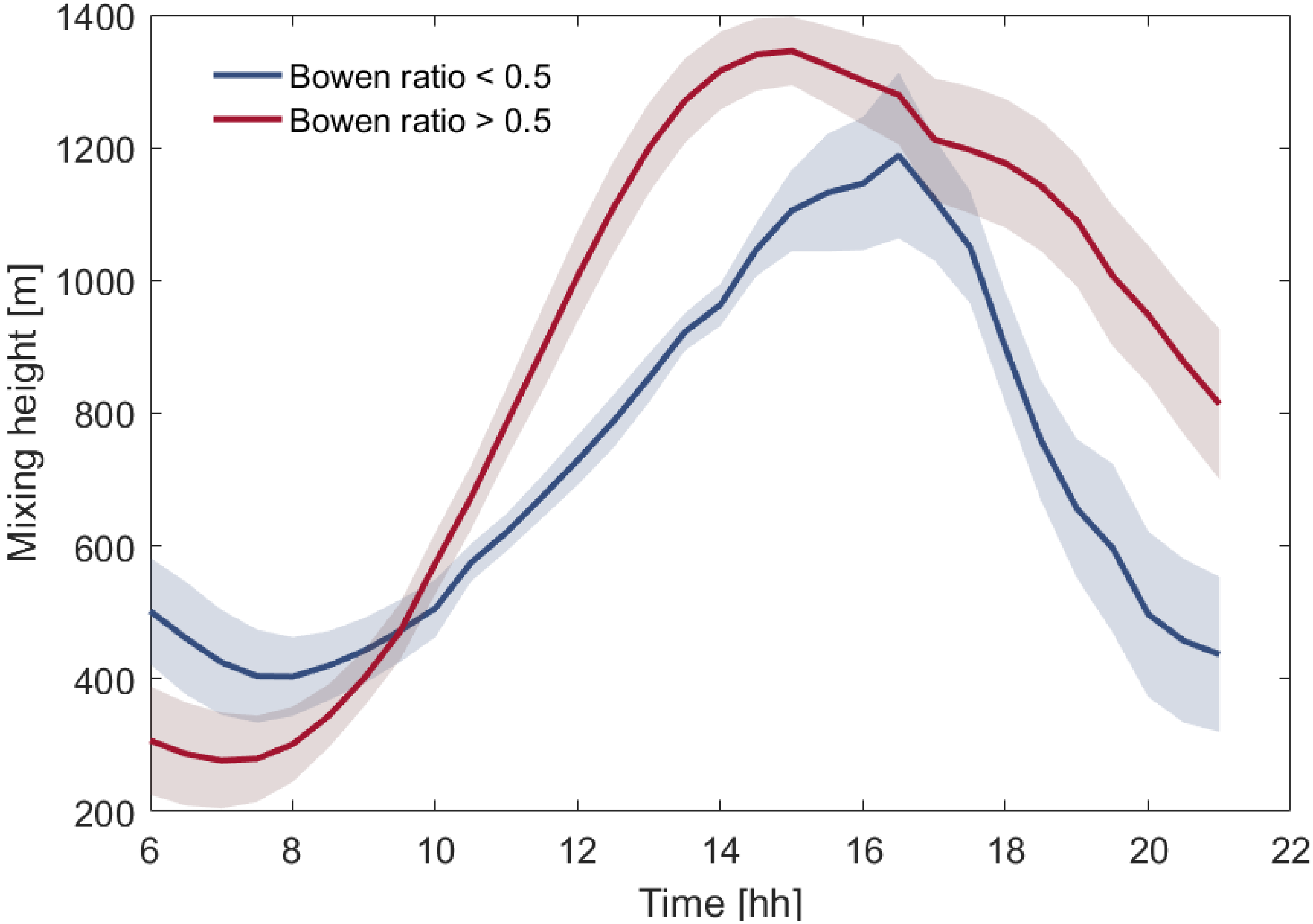
Flux towers abound, but very few have contiguous PBL profile or depth observations

- Helbig, M., Gerken, T., Beamesderfer, E., Baldocchi, D. D., Banerjee, T., Biraud, S. C., Brunsell, N. A., Burns, S. P., Butterworth, B., Chan, W. S., Desai, A. R., Fuentes, J. D., Hollinger, D. Y., Kljun, N., Mauder, M., Novick, K. A., Perkins, J. M., Rey-Sanchez, C., Scott, R. L., Seyednasrollah, B., Stoy, P. C., Sullivan, R. C., Vilà-Guerau de Arellano, J., Wharton, S., Yi, C., and Richardson, A. D.: White Paper: Understanding land-atmosphere interactions through tower-based flux and continuous atmospheric boundary layer measurements, AmeriFlux Management Project, Berkeley, CA, U.S.A., 47 pp., 2020.
  - https://ameriflux.lbl.gov/community/highlight/whitepaper-understanding-land-atmosphere-interactions-through-tower-based-flux-and-continuous-atmospheric-boundary-layer-measurements/



Helbig et al., 2020

Kansas (US-KFS)



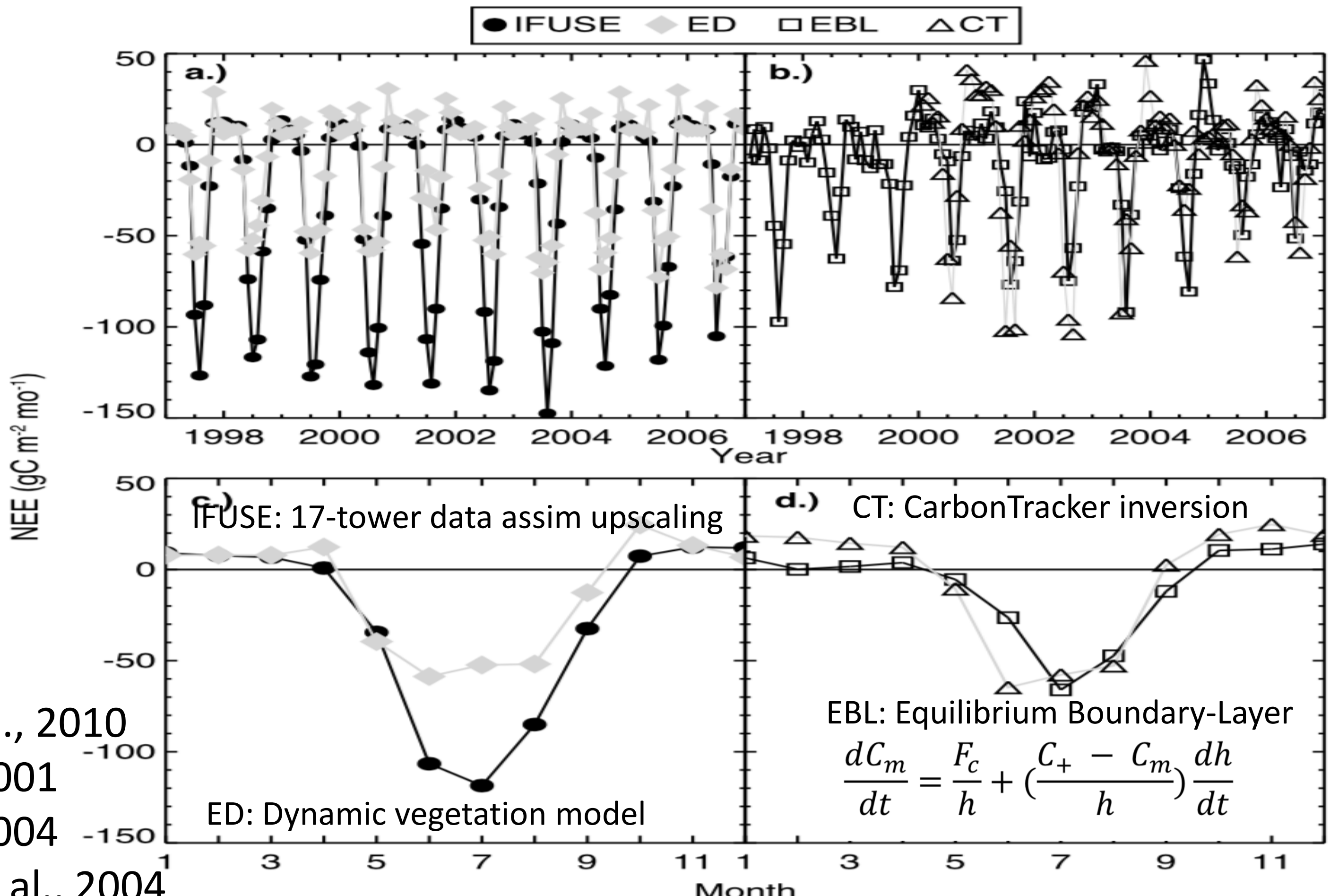
Helbig et al., 2020

Wisconsin (US-PFa + ChEAS network)

Climatic controls of interannual variability in regional carbon fluxes from top-down and bottom-up perspectives

Ankur R. Desai,[1] Brent R. Helliker,[2] Paul R. Moorcroft,[3] Arlyn E. Andrews,[4] and Joseph A. Berry[5]

DESAI ET AL.: TOP-DOWN AND BOTTOM-UP CARBON FLUX



$$\frac{dC_m}{dt} = \frac{F_c}{h} + \left(\frac{C_+ - C_m}{h}\right)\frac{dh}{dt}$$

Desai et al., 2010
Yi et al., 2001
Yi et al., 2004
Helliker et al., 2004

Ameriflux has been home to several PBL studies and instrument testbeds

Location	Site Code	Contact	Ecosystem	Measurements	Period	Instrument(s)
Walker Branch, TN[1]	US-WBW	K. Davis & D. Baldocchi	DBF	boundary layer height, wind profiles, radar reflectivity	1999	NCAR Integrated Sounding System
Park Falls, WI[1]	US-PFa	K. Davis	MF	boundary layer height, wind profiles, radar reflectivity	1998, 1999	NCAR Integrated Sounding System
Old Jack Pine, SK (BOREAS)[2]	CA-Ojp	J. Wilczak	ENF	boundary layer height	1994	NOAA/ETL 915 MHz radar wind/RASS profiler
Morgan Monroe State Forest, IN[3]	US-MMS	K. Novick	DBF	boundary layer height, cloud base and amount; backscatter profile	2006-2009, 2011-2013	Vaisala CL31 lidar ceilometer
Southern Great Plains ARM, OK[4]	US-ARM	DOE ARM	CRO	boundary layer height, cloud base and amount; backscatter profile; wind profiles;	2011-	CEIL lidar ceilometer; radar wind profiler; micropulse lidar
Utqiaġvik, AK[5]	US-A10	R. Sullivan	BSV	boundary layer height, cloud base and amount, water vapor, temperature, and turbulence profiles	2011-	Ceilometer, micropulse lidar, balloon sonde, G-band radiometer profiler, microwave radiometer
Tonzi, CA[6]	US-Ton	S. Wharton & D. Baldocchi	WSA	wind profile from ground to 150m, thermodynamic and wind profiles from ground to top of troposphere, PBL height	2012, 2013	WindCube v2, ZephIR 300, radiosondes
Howland Forest, ME	US-Ho1	D. Hollinger	ENF	boundary layer height, cloud base and amount; backscatter profile	2013-	Vaisala CL31 lidar ceilometer
INFLUX (Indianapolis Flux Experiment)[7]	-	K. Davis	URB	boundary layer height, wind profiles	2013-2015	Scanning doppler lidar
Oliktok Point, AK[5]	US-A03	R. Sullivan	BSV	boundary layer height, cloud base and amount, water vapor, temperature, and turbulence profiles	2014-	Ceilometer, micropulse lidar, balloon sonde, radar wind profiler, Doppler lidar
Walnut Gulch, AZ	US-Wkg/Whs	J. Perkins & P. Hazenberg	GRA/OSH	boundary layer height, cloud base and amount; backscatter profile	2017-	Lufft CHM15k lidar ceilometer
Walnut Gulch, AZ	US-Wkg/Whs	A. Richardson	GRA/OSH	boundary layer height, cloud base and amount; backscatter profile	2019-	Campbell CS135 lidar ceilometer

Helbig et al., 2020

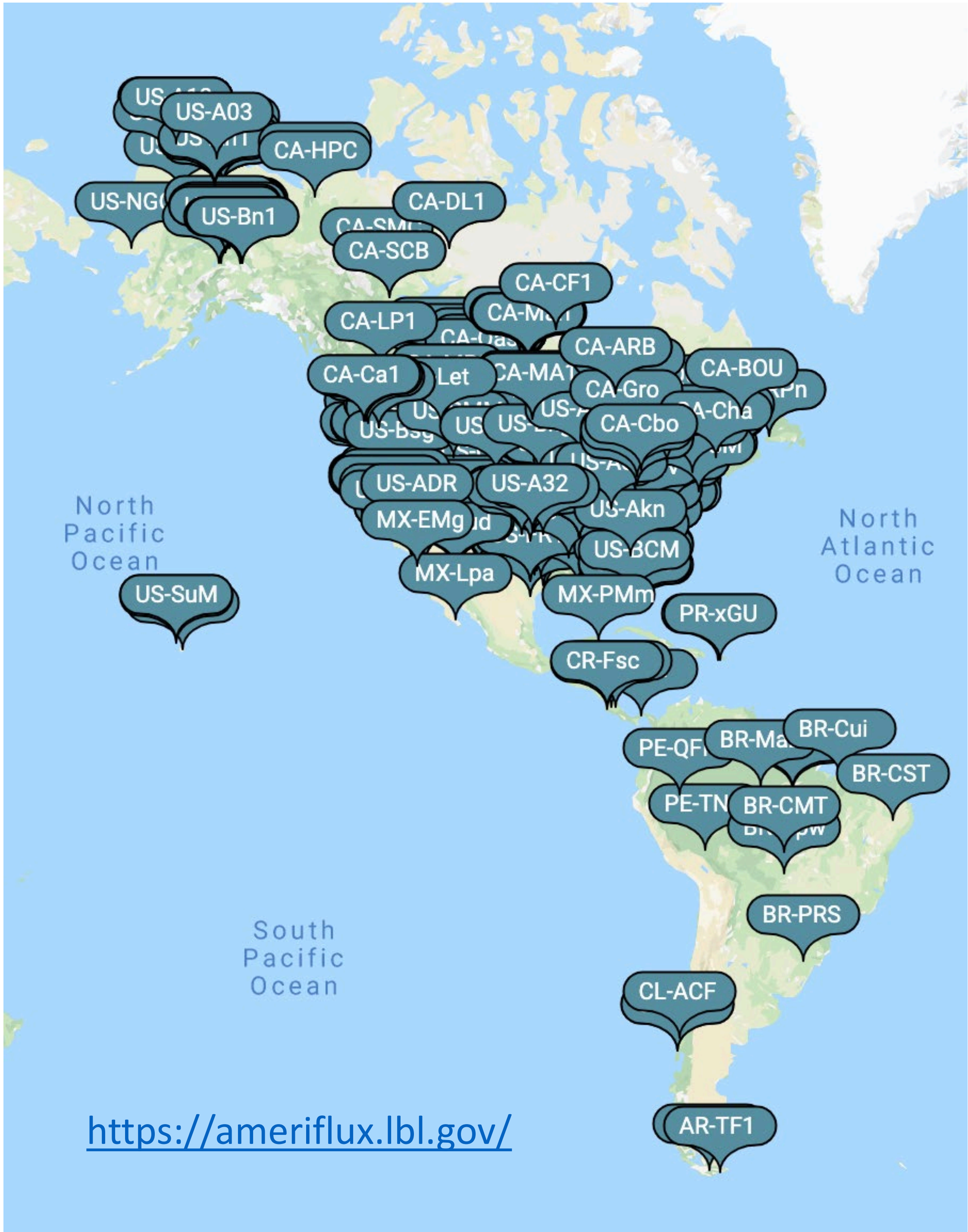
Networks with some aspects of surface flux are many and could serve as home for PBL studies and weather/climate model evaluation

- Ameriflux: https://ameriflux.lbl.gov/ (DOE)
- Fluxnet: https://fluxnet.fluxdata.org/ (many)
- NEON: National Ecological Observatory Network (NSF)
- ICOS: Integrated Carbon Observing System (ICOS)
- LTER: Long Term Ecological Research (NSF)
- LTAR: Long Term Agricultural Research (USDA)
- TCCON: Total Column Carbon Observing Network
- CZO: Critical Zone Observatories (NSF)
- ARM: Atmospheric Radiation Measurement (ARM)
- …

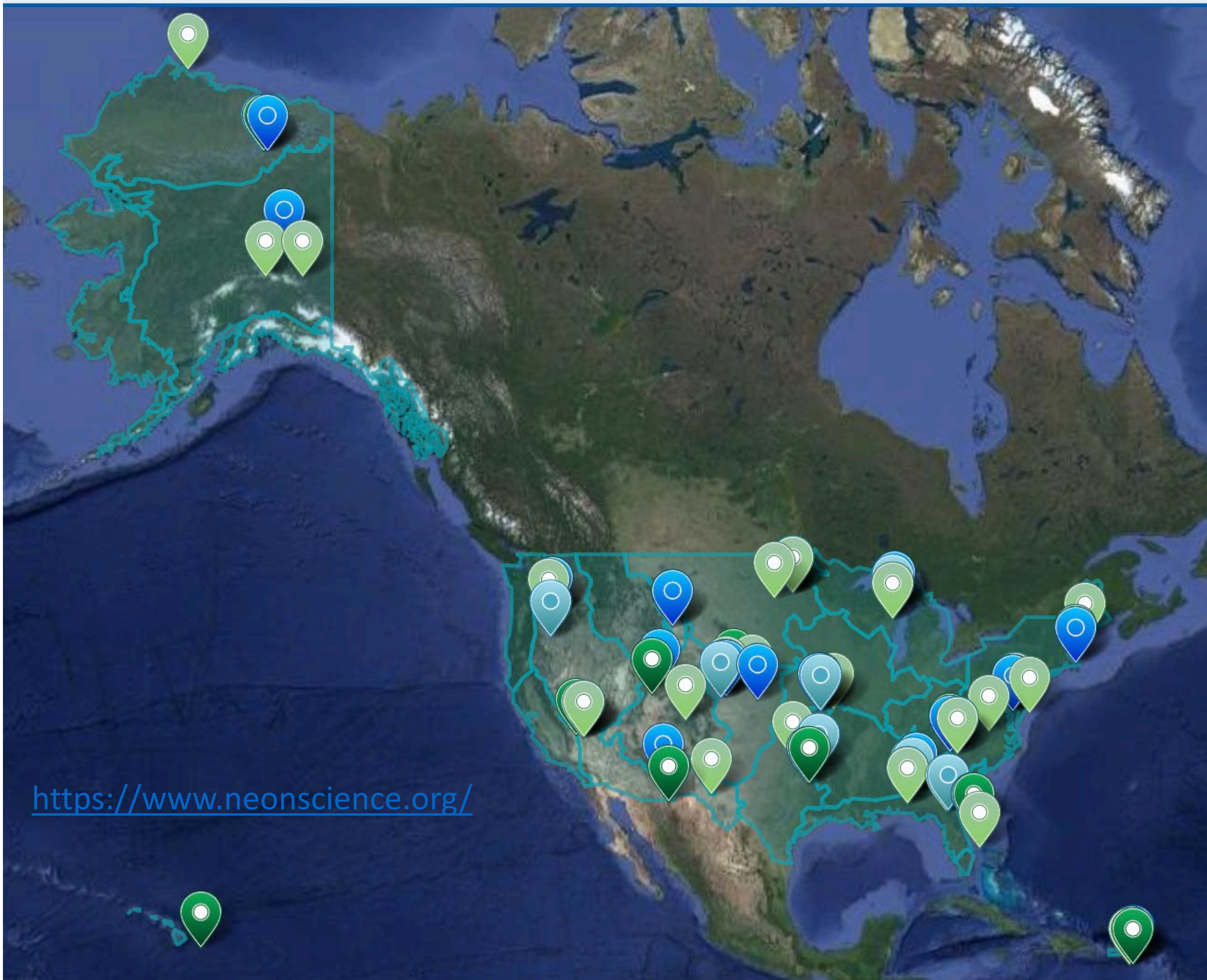
Networks have different goals, even if doing the same thing

Ameriflux

NEON



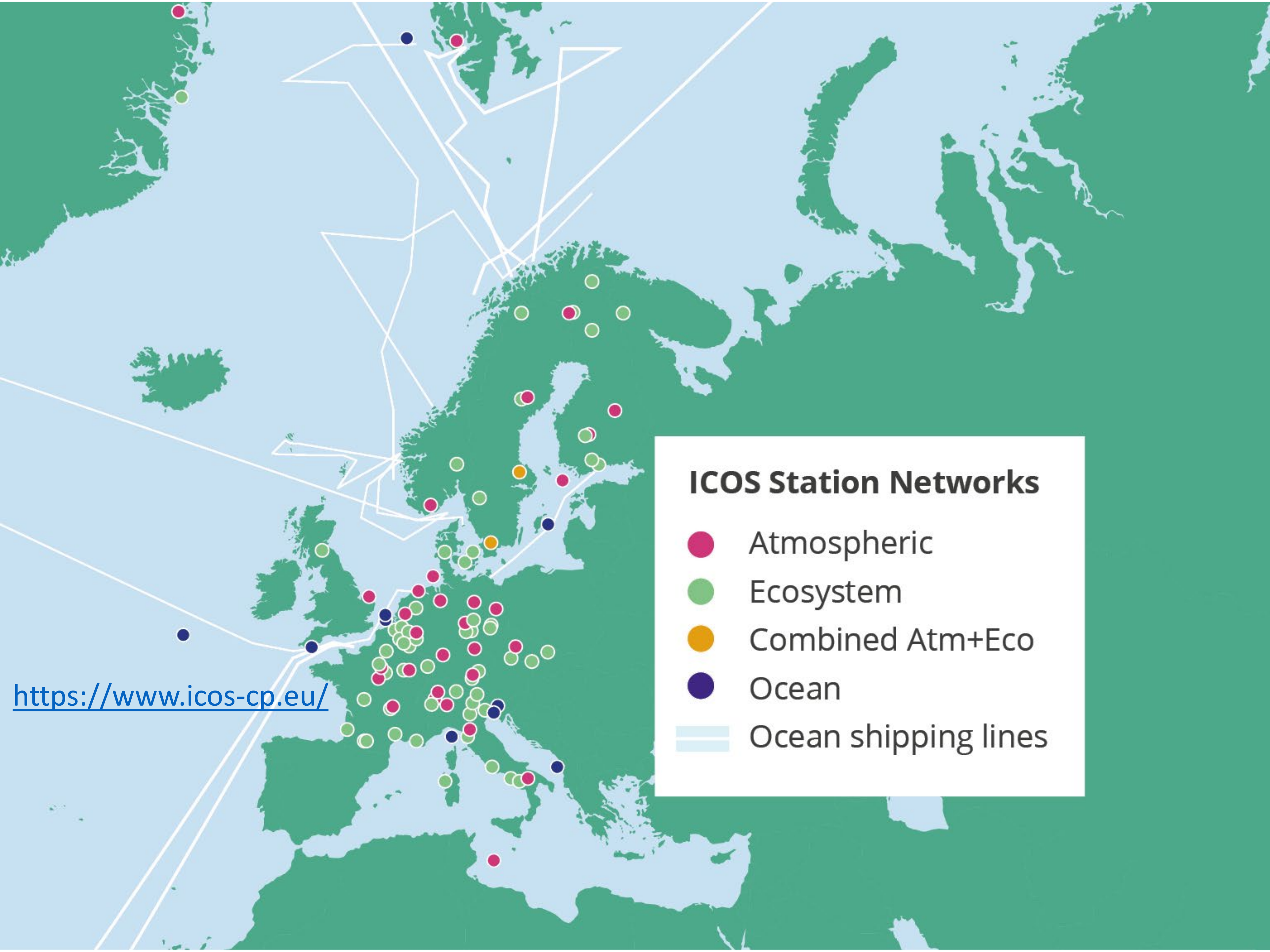
https://ameriflux.lbl.gov/


https://www.neonscience.org/

NCAR-NEON Supersite Concept

- NCAR observing capabilities can augment NEON observations, and there is strong interest in the ‘supersite’ concept with an expansive field campaign around a NEON core terrestrial site.
- Community-driven proposals would augment NEON observations with NSF Lower Atmosphere Observing Facility (LAOF) resources.
- Additionally, there is the potential to involve data and infrastructure from the Long-term Ecological Research Network (LTER) due to the high number of NEON-LTER collocated sites
- There is much potential, but the details need to be further developed by a working group.

S. Metzger (NEON), G. Bonan (NCAR), supersite working group



https://www.icos-cp.eu/

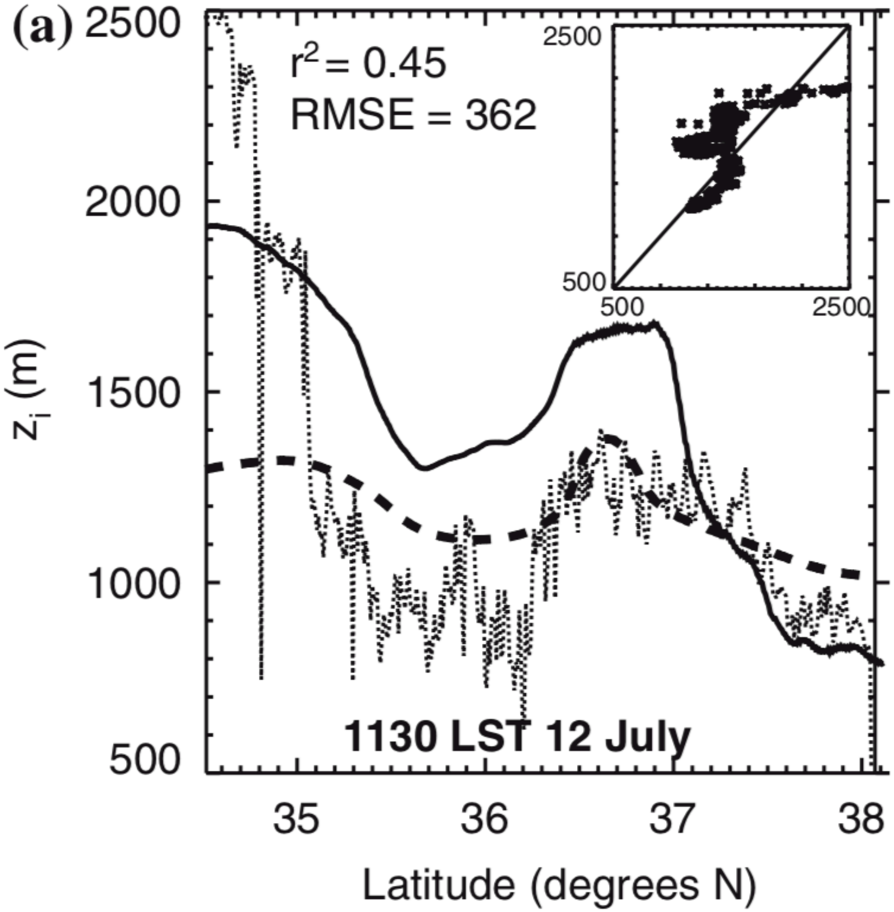
Intensive field campaigns provide another opportunity for model evaluation and parameterization

- FIFE, BOREAS, SGP97, CASES99
- IHOP, LITFASS-2003, EBEX, BEAREX
- HiWATER-MUSOEXE, SCALE-X, CHEESEHEAD19

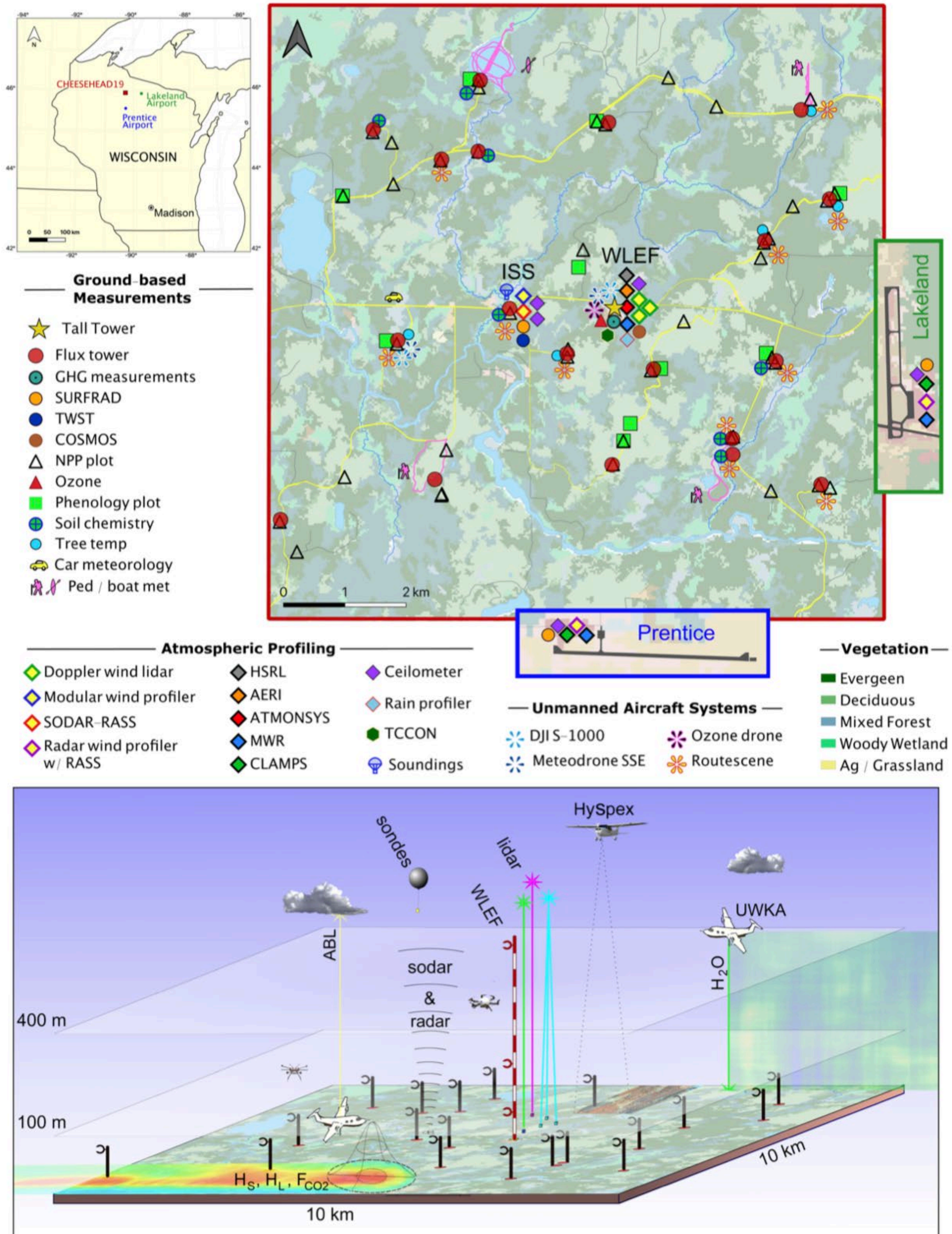
Boundary-Layer Meteorology (2006) 119: 195–238
DOI 10.1007/s10546-005-9024-6

A CASE STUDY ON THE EFFECTS OF HETEROGENEOUS SOIL MOISTURE ON MESOSCALE BOUNDARY-LAYER STRUCTURE IN THE SOUTHERN GREAT PLAINS, U.S.A. PART I: SIMPLE PROGNOSTIC MODEL

ANKUR R. DESAI[1,*], KENNETH J. DAVIS[1], CHRISTOPH J. SENFF[2], SYED ISMAIL[3], EDWARD V. BROWELL[3], DAVID R. STAUFFER[1] and BRIAN P. REEN[1]



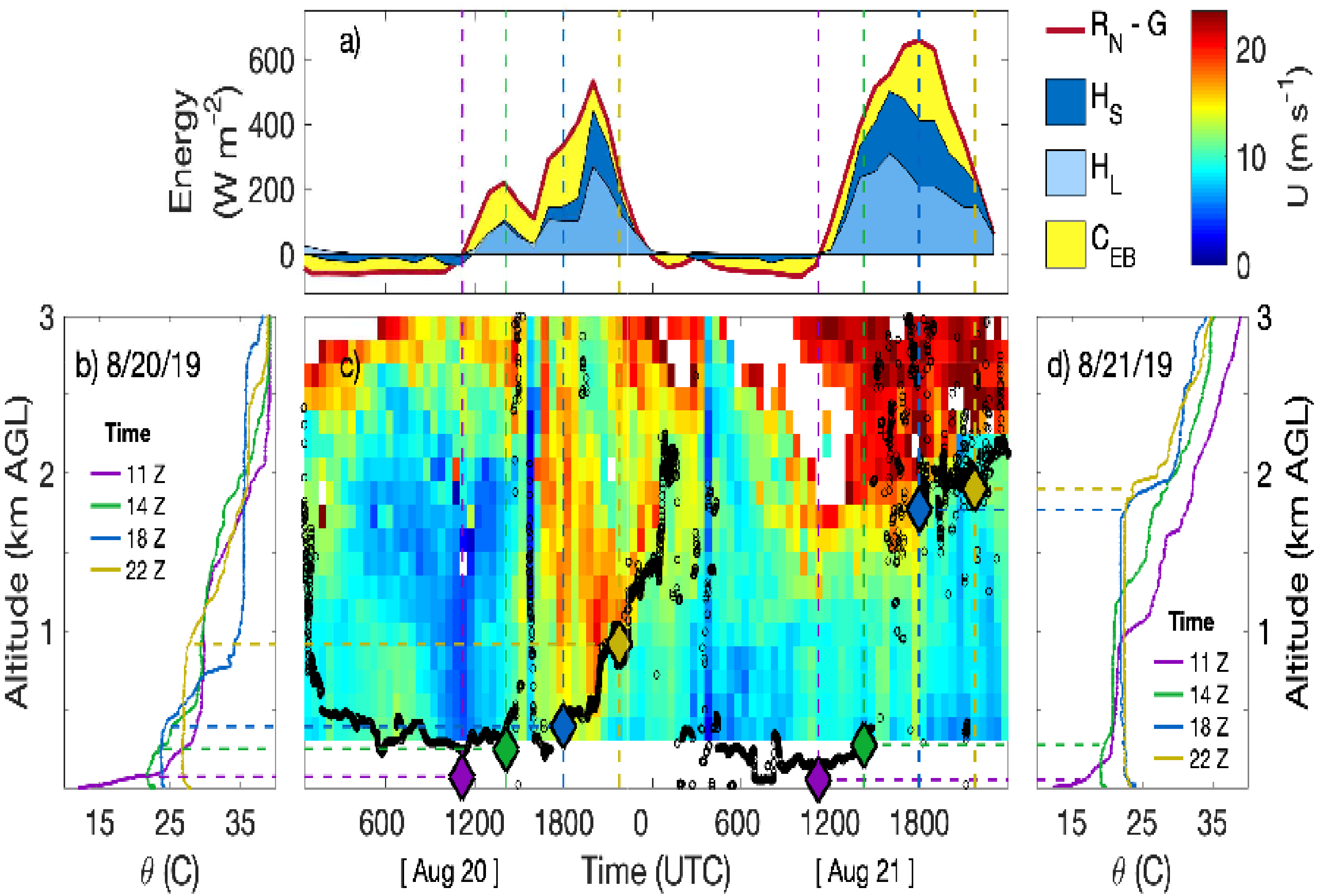
Chequamegon
Hetereogenous
Ecosystem
Energy-balance
Study
Enabled by a
High-density
Extensive
Array of
Detectors
20**19**



100-day study
80+ hours airborne eddy flux
20 flux towers in 10x10 km
Lots of PBL profiling

NSF-1822420
Butterworth et al., submitted

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



Testing: HRRR PBL profiles, scaling point to grid (ERF), remote sensing of plant water stress

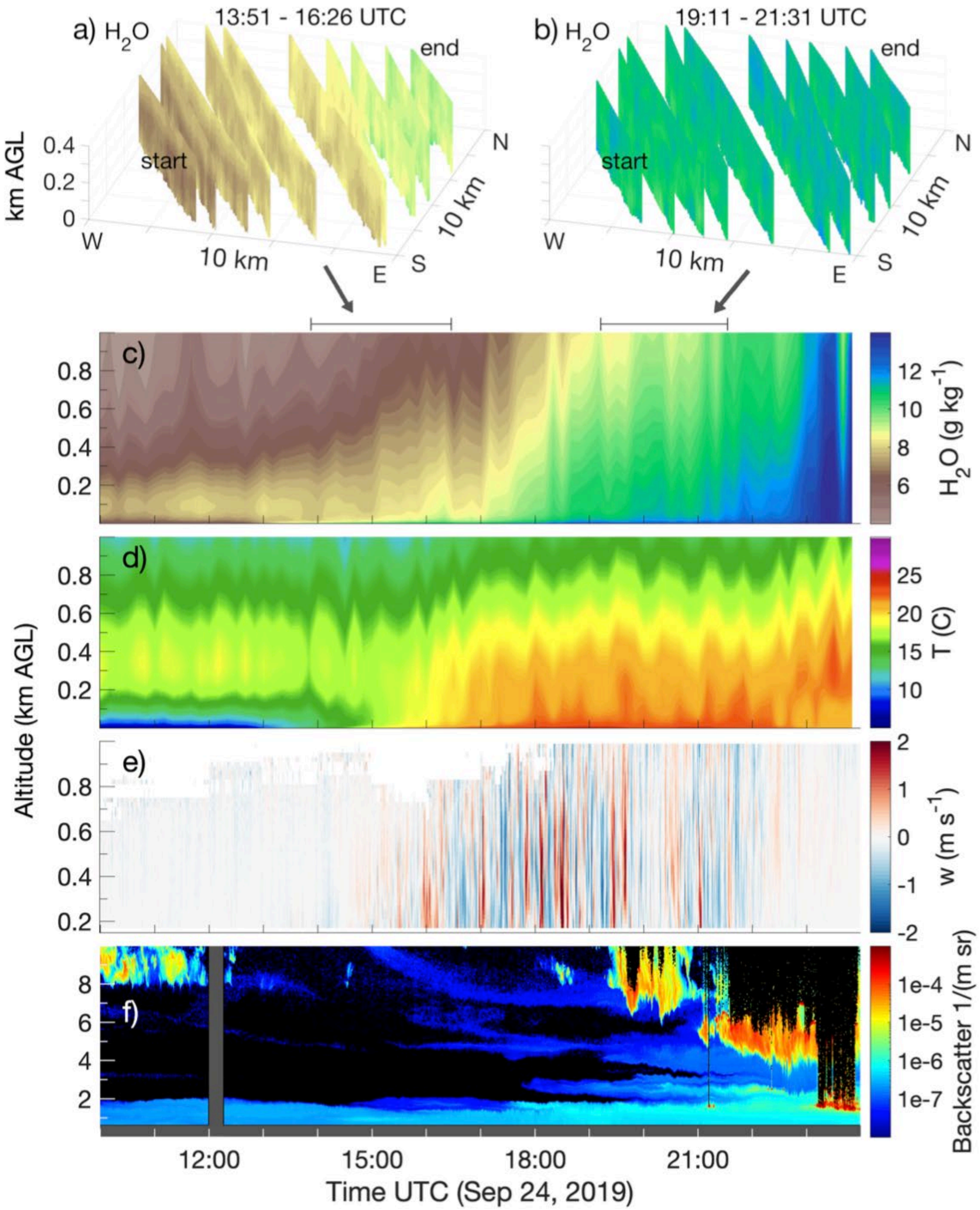
Helbig et al., 2020; Butterworth et al., submitted

Airborne
Compact Raman LiDAR
(water spatial variation)

Microwave interferometers
(water, temperature)

Doppler wind profilers
(vertical velocity)

High-spectral resolution LiDAR
(aerosol backscatter)



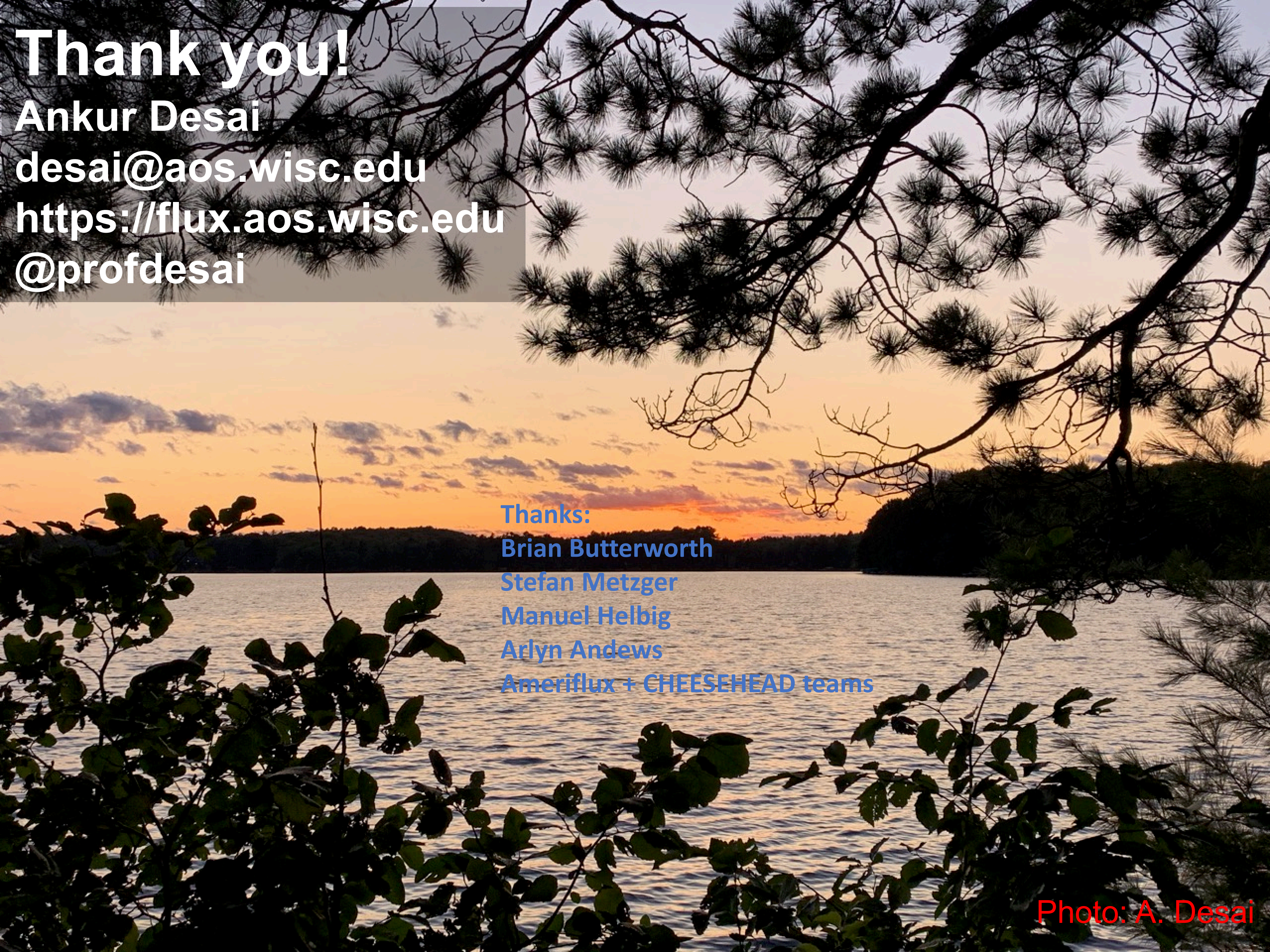
Butterworth et al., submitted

Take homes

- Carbon, water, heat, momentum fluxes and micrometeorology are being measured in lots of places for a variety of reasons
- Co-location of PBL observations at long-term tower sites and intensive experiments can make them significantly more useful for atmospheric and ecological science
- Use our data. Read the whitepaper (review paper in preparation)

Thank you!

Ankur Desai
desai@aos.wisc.edu
https://flux.aos.wisc.edu
@profdesai



Thanks:
Brian Butterworth
Stefan Metzger
Manuel Helbig
Arlyn Andews
Ameriflux + CHEESEHEAD teams

Photo: A. Desai