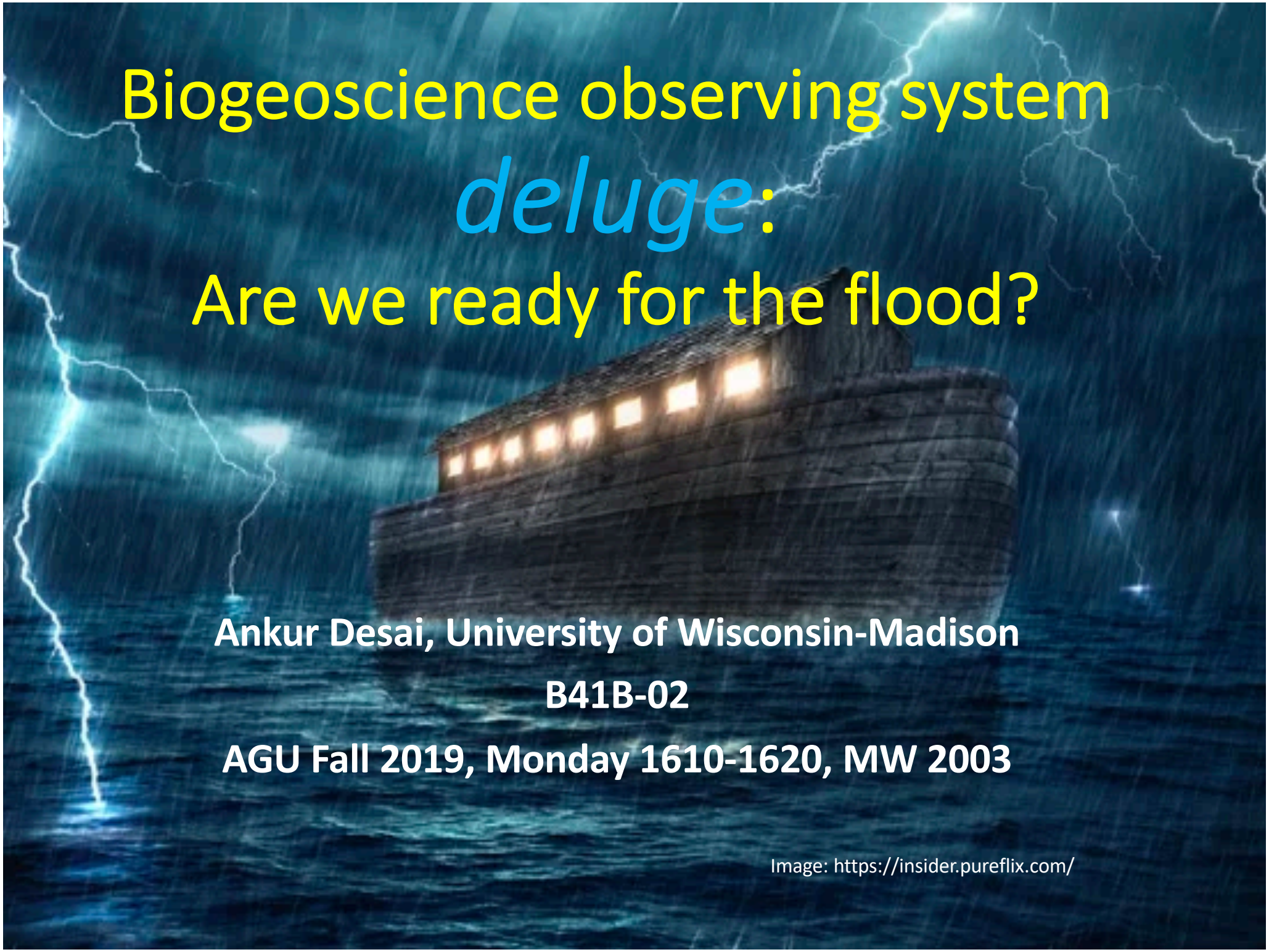
Biogeoscience observing system *deluge*: Are we ready for the flood?



Ankur Desai, University of Wisconsin-Madison

B41B-02

AGU Fall 2019, Monday 1610-1620, MW 2003

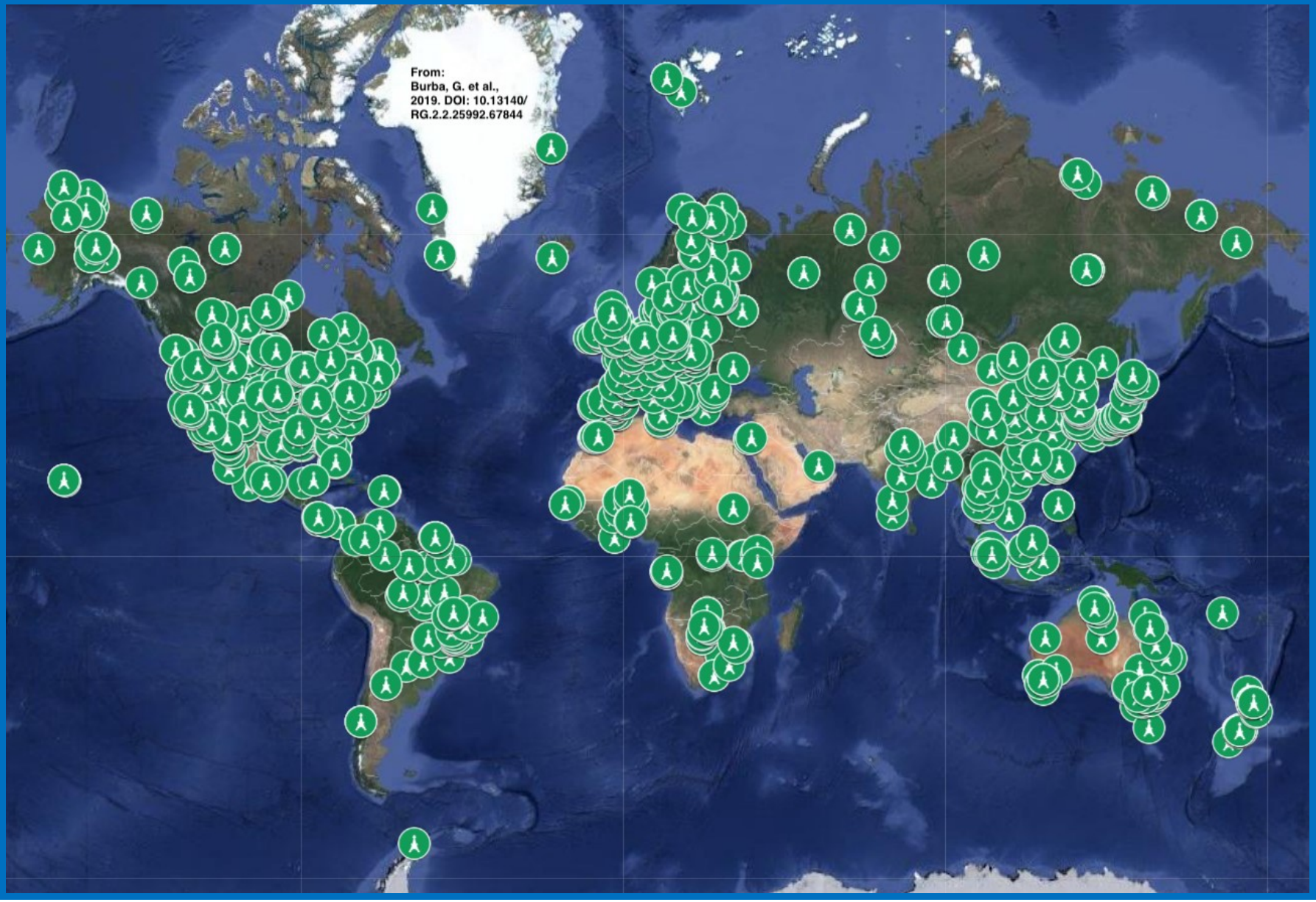
Image: https://insider.pureflix.com/

Acknowledge

- PEcAn project (NSF DBI-1457897)
  - Mike Dietze, Istem Fer, Bailey Murphy, Katie Zarada
- CHEESEHEAD (NSF AGS-1822420)
  - Stefan Metzger, Sreenath Paleri, Dave Durden, Ke Xu
  - Cyverse: Tyler Swetnam
- DOE Ameriflux
  - Kim Novick, George Burba
- Ben Bond-Lamberty, Jack Williams, many conversations from many of you, especially students...

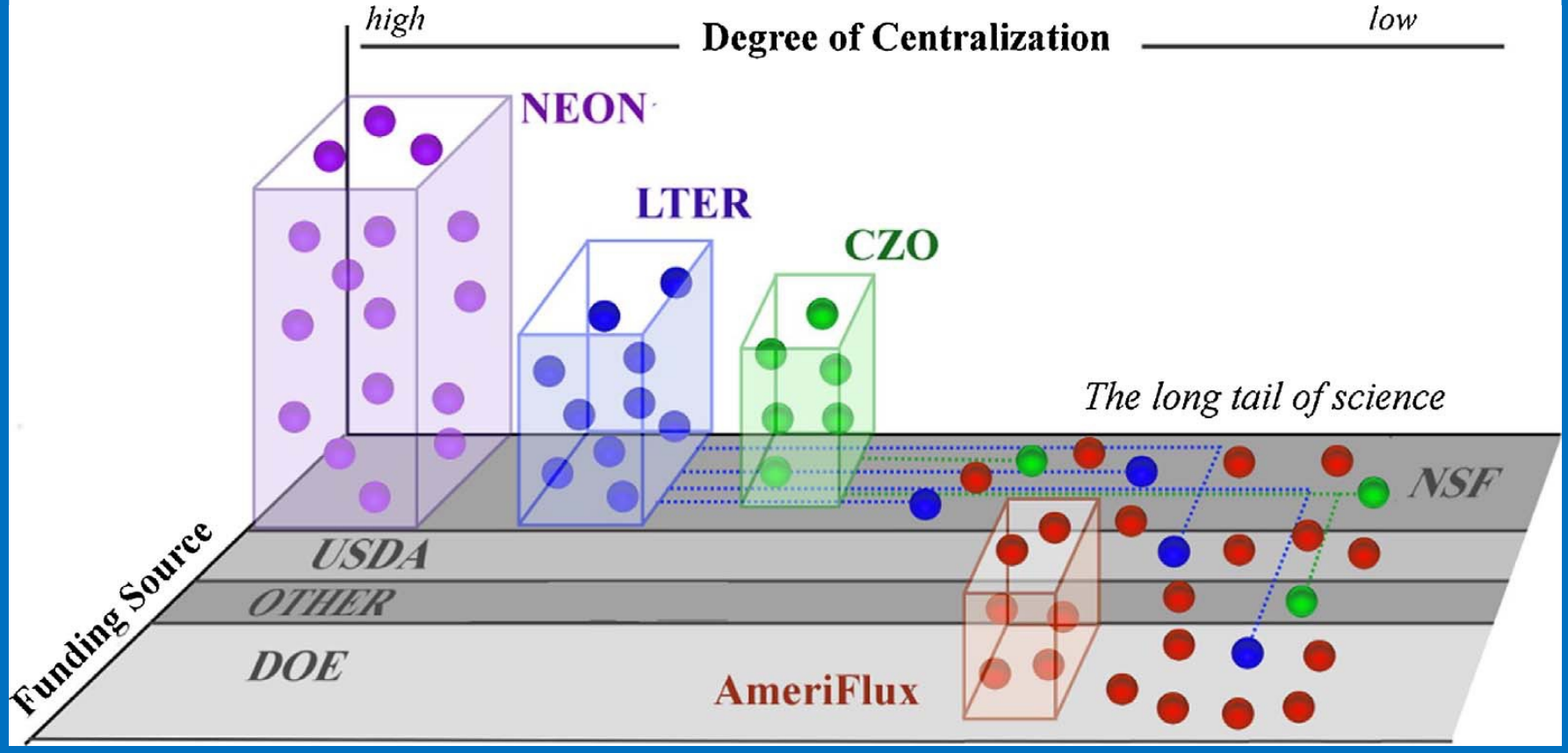

Photo: A Desai

Huge Ecology?

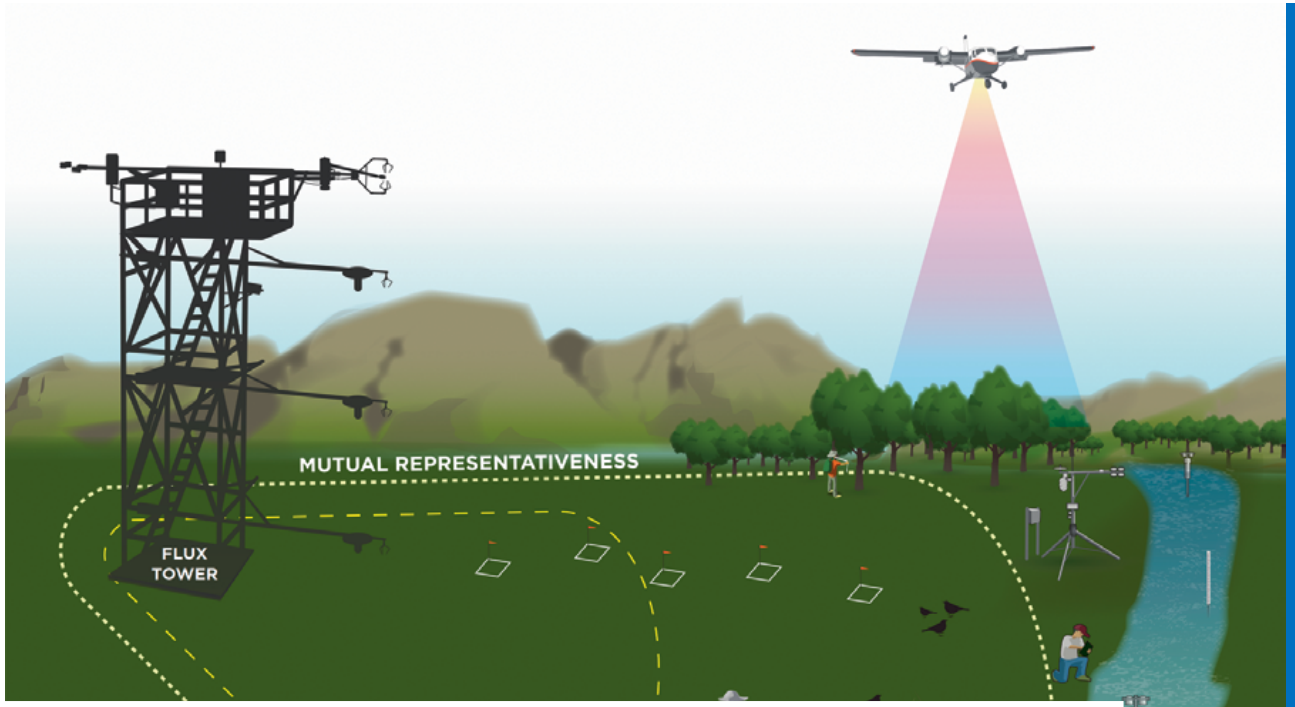


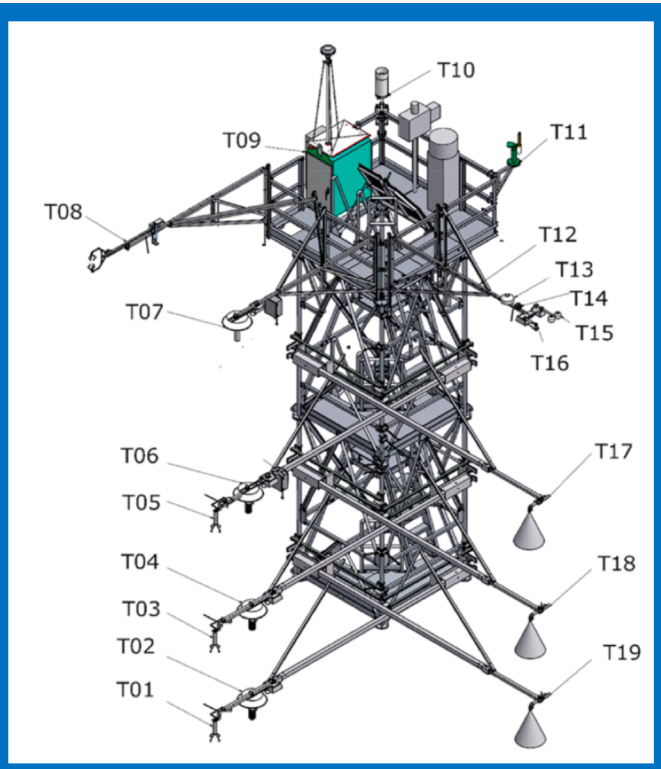
The AmeriFlux network: A coalition of the willing

K.A. Novick[a,*], J.A. Biederman[b], A.R. Desai[c], M.E. Litvak[d], D.J.P. Moore[e], R.L. Scott[b], M.S. Torn[f]

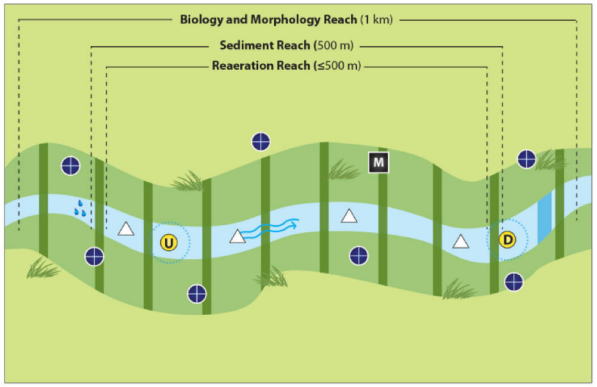


Novick et al., 2018, Agricultural and Forest Meteorology





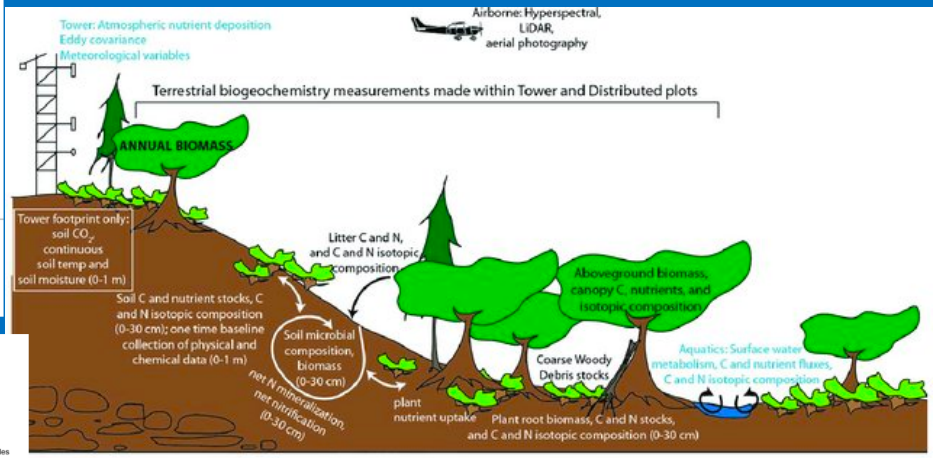
Wadeable Stream



Legend

- Sensor Station
- Water Chemistry Sampling
- Groundwater Well
- M Meteorological Station
- Riparian Assessment
- Reaeration Drip
- Rearation 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.

Metzger et al., 2019, Bulletin AMS; Hinckley et al., 2016, Ecosphere; neonscience.org

Huge Ecology!

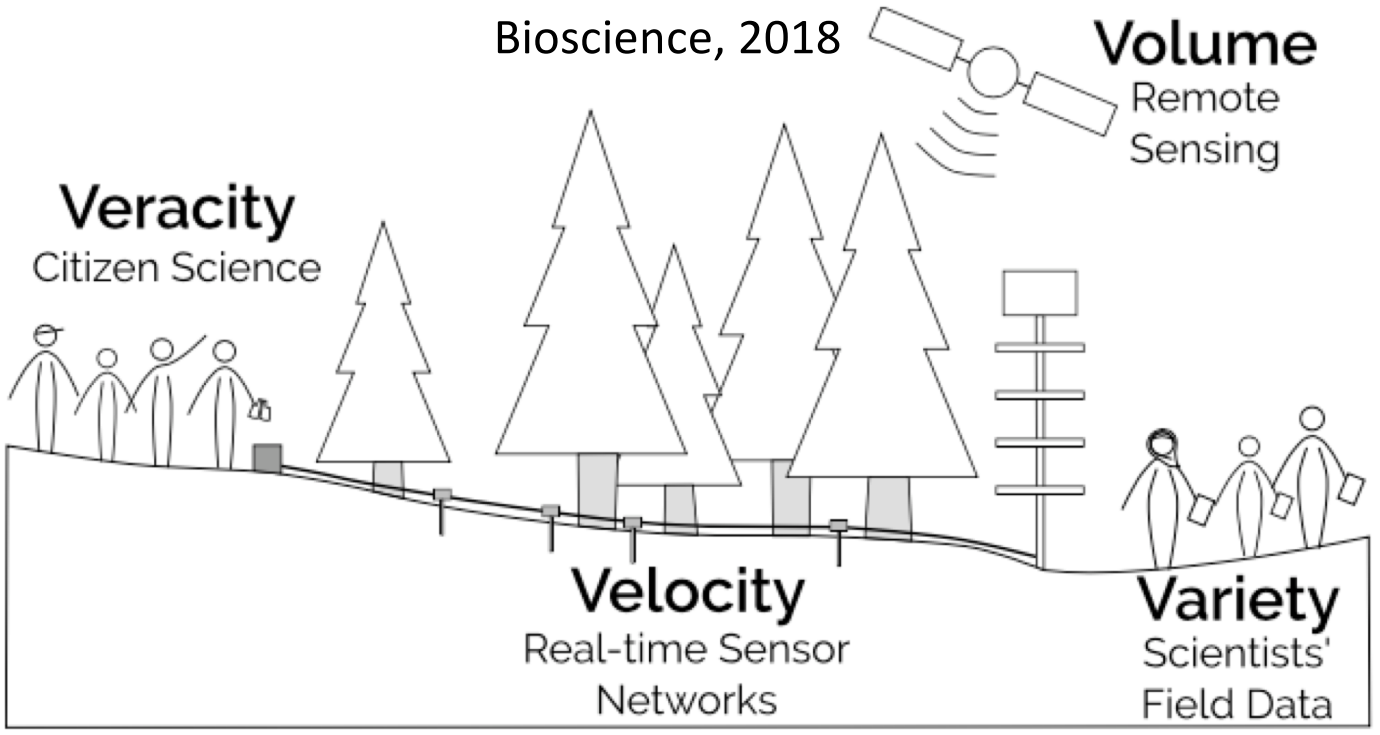
- The past 100 years of ecology went from its birth as a discipline, with theory tested primarily from small experiments in one's "backyard", to a modern science that sits at the center of key biogeoscience challenges on land, freshwater, and ocean management, global climate change, biodiversity and habitat loss, restoration, …

- Its complexity and data volume will only accelerate in next 100…

Situating Ecology as a Big-Data Science: Current Advances, Challenges, and Solutions

SCOTT S. FARLEY, ANDRIA DAWSON, SIMON J. GORING AND JOHN W. WILLIAMS

Bioscience, 2018



Huge Ecology!

- What elements of Biogeosciences must be nurtured to make sure we are capable?

- I will talk about 3 (in 5 minutes!):
  - Promoting an open science culture
  - Enabling scalable and reproducible analysis
  - Removing the wall between models and observations

Promoting an Open Science Culture

CHEESEHEAD photos: https://groups.google.com/forum/#!forum/cheesehead

What is open science?

- Open, FAIR data (and models!)
- Citable code
- Transparency in methods (“pre-registration”)

https://www.agu.org/Publish-with-AGU/Publish/Author-Resources/Data-for-Authors

Citable code

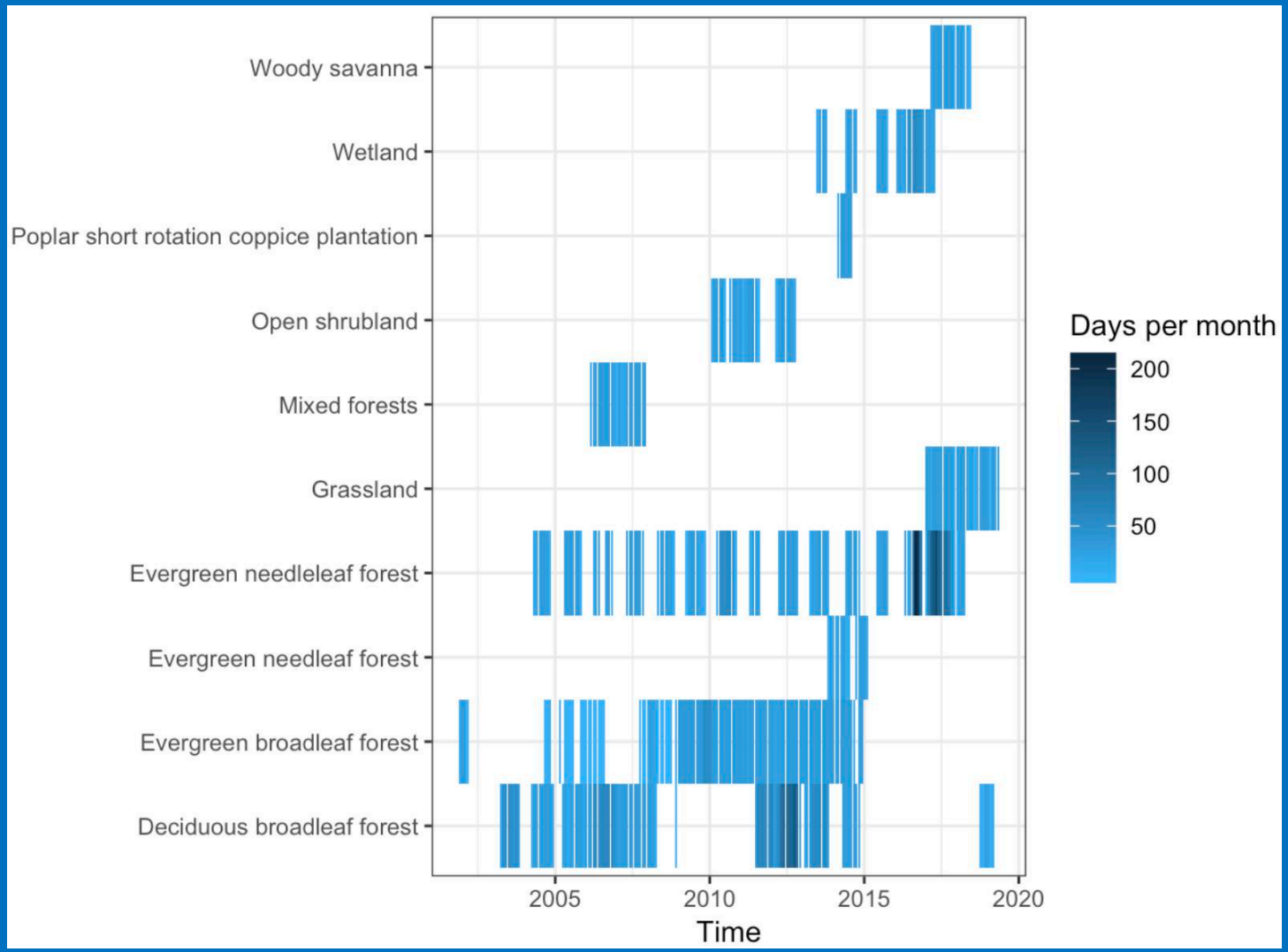
- https://guides.github.com/activities/citable-code/

- Code licenses matter!
  - https://choosealicense.com/licenses/

#COSORE (Bond-Lamberty)

https://github.com/bpbond/cosore

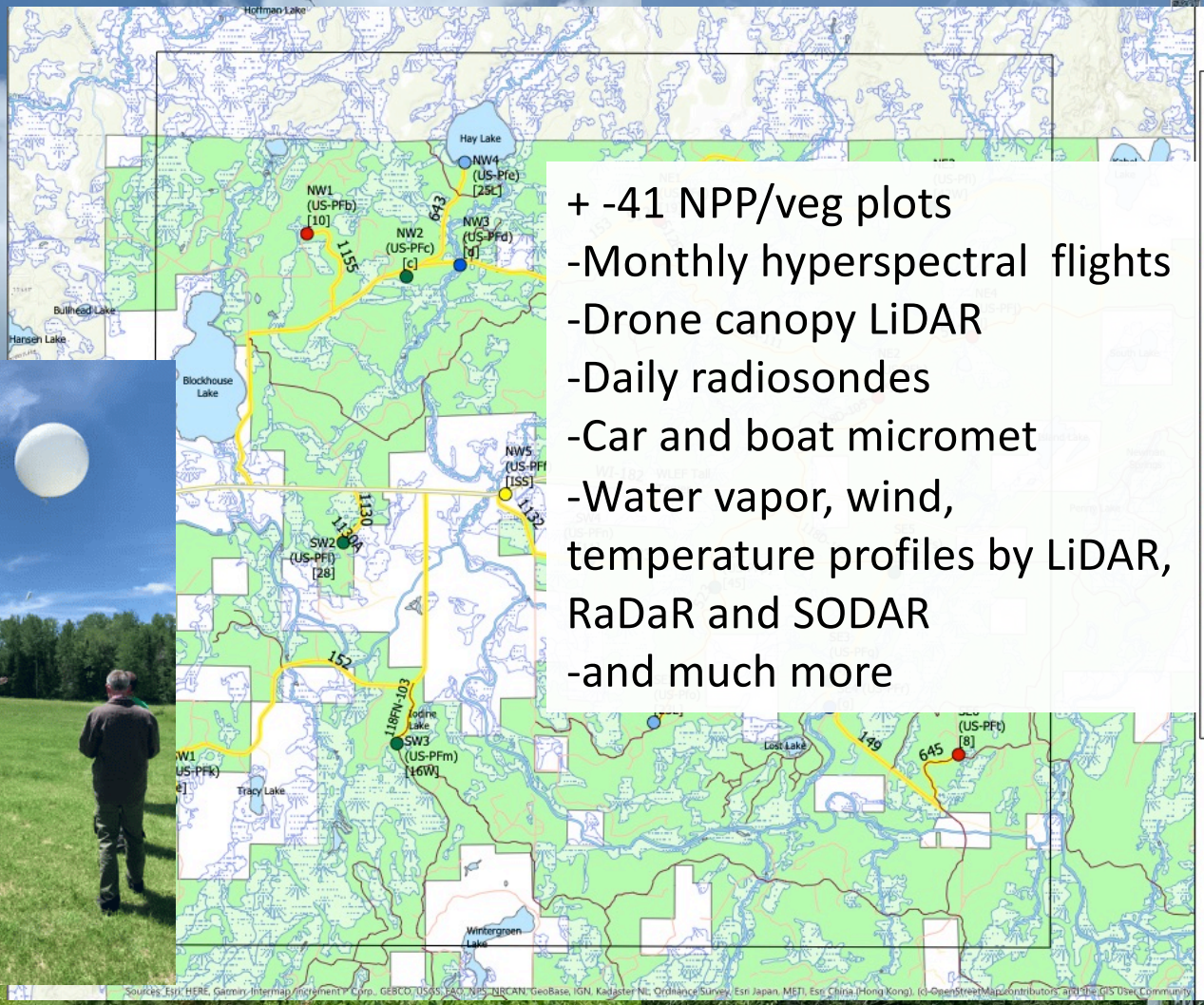
Open Science: Lamberty et al., 2016



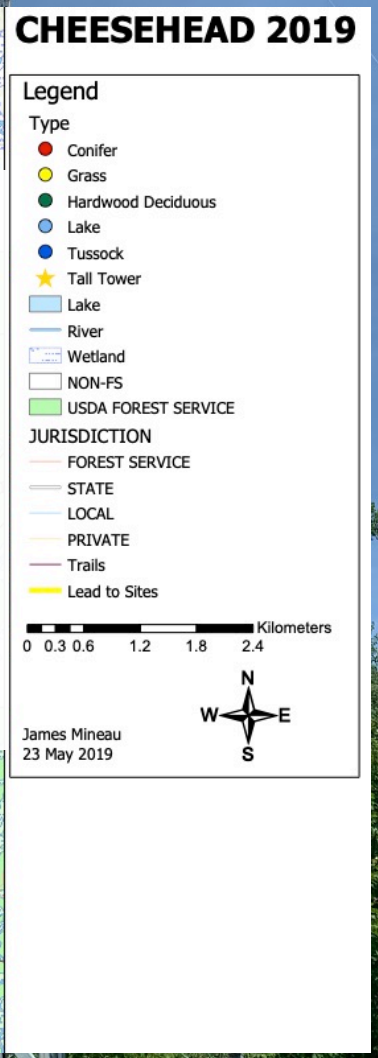
Enabling scalable and reproducible analysis

Metzer et al., 2019, BAMS

“Small” field projects…



+ -41 NPP/veg plots
-Monthly hyperspectral flights
-Drone canopy LiDAR
-Daily radiosondes
-Car and boat micromet
-Water vapor, wind, temperature profiles by LiDAR, RaDaR and SODAR
-and much more



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

Your eyes should now glaze over..

Data source	Data provider	POC	Location(s)	Measurement domain	Funded by NSF?	Collection period	Archive location
Ameriflux/NOAA very tall tower (US-PFa/WLEF)	University of Wisconsin-Madison, Atmospheric and Oceanic Sciences	Ankur Desai <desai@aos.wisc.edu>	WLEF	Surface	Y	Continuous	http://ameriflux.lbl.gov and https://flux.aos.wisc.e
NOAA tall tower greenhouse gases	NOAA ESRL	Arlyn Andrews <Arlyn.Andrews@noaa.gov	WLEF	Surface		Continuous	https://www.esrl.noaa.gov/gmd/ccgg/obspack/ o
NOAA Airborne greenhouse gas profiles	NOAA ESRL	Colm Sweeney <colm.sweeney@noaa.gov	WLEF	Airborne Profiling		Biweekly	https://www.esrl.noaa.gov/gmd/ccgg/aircraft/dat
ChEAS Ameriflux tower network (US-WCr/US-Los/US-Sy	University of Wisconsin-Madison, Atmospheric and Oceanic Sciences	Ankur Desai <desai@aos.wisc.edu>	Ameriflux sites (4)	Surface		Continuous	http://ameriflux.lbl.gov and https://flux.aos.wisc.e
Total Column Carbon Observing Network (TCCON)	CalTech	Coleen Roehl <coleen@gps.caltech.edu>	WLEF	In-Situ Profiling		Continuous	https://tccondata.org/
Ground-based vegetation/phenology sampling	University of Wisconsin-Milwaukee, Geography	Mark Schwartz <mds@uwm.edu>	10x10 domain, 27 plots	Surface	Y	Sept-Oct 2019	NCAR EOL
Vegetation inventory, root growth, NPP, Biometry, leaf spe	University of Wisconisn-Madison, Forest and Wildlife Ecology	Eric Kruger <elkruger@wisc.edu>	10x10 domain, 41 plots	Surface		June-Oct, 2019	NCAR EOL
ISFS Eddy covariance towers: CO2/H2O/H flux, netrad, n	NCAR EOL Integrated Surface Flux System (ISFS)	Steve Oncley <oncley@ucar.edu>, Gary G	10x10 domain, 17 locations	Surface	Y	June-Oct, 2019	https://www.eol.ucar.edu/field_projects/cheesehead (a
MSU Eddy covariance towers	University of Wisconsin-Madison, Biological Systems Engineering	Paul Stoy <pcstoy@wisc.edu>	NW5 (ISS) and SE1	Surface		June-Oct, 2019	NCAR EOL
449 MHz modular wind profiler	NCAR EOL Integrated Sounding System (ISS)	Bill Brown <wbrown@ucar.edu>	ISS/Flambeau field	In-Situ Profiling	Y	July-Oct, 2019	https://www.eol.ucar.edu/field_projects/cheesehead (a
RASS/SODAR	NCAR EOL Integrated Sounding System (ISS)	Bill Brown <wbrown@ucar.edu>	ISS/Flambeau field	In-Situ Profiling	Y	July-Oct, 2019	https://www.eol.ucar.edu/field_projects/cheesehead (a
Ceilometer	NCAR EOL Integrated Sounding System (ISS)	Bill Brown <wbrown@ucar.edu>	ISS/Flambeau field	In-Situ Profiling	Y	July-Oct, 2019	https://www.eol.ucar.edu/field_projects/cheesehead (a
All sky camera and web camera	NCAR EOL Integrated Sounding System (ISS)	Bill Brown <wbrown@ucar.edu>	ISS/Flambeau field	Surface	Y	July-Oct, 2019	https://www.eol.ucar.edu/field_projects/cheesehead (a
Surface tower met (T,RH,P,winds,precip,winds)	NCAR EOL Integrated Sounding System (ISS)	Bill Brown <wbrown@ucar.edu>	ISS/Flambeau field	Surface	Y	July-Oct, 2019	https://www.eol.ucar.edu/field_projects/cheesehead (a
Daily radiosonde	NCAR EOL Integrated Sounding System (ISS)	Bill Brown <wbrown@ucar.edu>	ISS/Flambeau field	In-Situ Profiling	Y	July-Oct, 2019	https://www.eol.ucar.edu/field_projects/cheesehead (a
High-resolution PBL sondes during IOPs	University of Wisconsin-Madison, Atmospheric and Oceanic Sciences	Ankur Desai <desai@aos.wisc.edu>	10x10 domain, ISS field	In-Situ Profiling	Y	IOPs	https://www.eol.ucar.edu/field_projects/cheesehead (a
3-hrly daytime sondes (4-5 per day, 5 days per IOP)	NCAR EOL Integrated Sounding System (ISS)	Bill Brown <wbrown@ucar.edu>	ISS/Flambeau field	In-Situ Profiling	Y	IOPs	https://www.eol.ucar.edu/field_projects/cheesehead (a
Atmospheric Emitted Radiance Interferometer (AERI)	UW Space Science and Engineering Center Portable Atmospheric Research Center (SPARC)	Timothy J Wagner <tim.wagner@ssec.wis	WLEF	In-Situ Profiling	Y	July-Oct, 2019	http://webmads.ssec.wisc.edu/#SPARC/dash
HALO Photonics Streamline scanning wind LiDAR (1)	UW Space Science and Engineering Center Portable Atmospheric Research Center (SPARC)	Timothy J Wagner <tim.wagner@ssec.wis	WLEF	In-Situ Profiling	Y	July-Oct, 2019	
High-Spectral Resolution Lidar (HSRL)	UW Space Science and Engineering Center Portable Atmospheric Research Center (SPARC)	Ed Eloranta <eloranta@wisc.edu>, Timoth	WLEF	In-Situ Profiling	Y	July-Oct, 2019	http://hsrl.ssec.wisc.edu/
Microrain radar (MRR)	UW SSEC	Claire Pettersen <claire.pettersen@ssec.w	WLEF	In-Situ Profiling		July-Oct, 2019	
Precipitation Imaging Probe (PIP)	UW SSEC	Claire Pettersen <claire.pettersen@ssec.w	WLEF	In-Situ Profiling		July-Oct, 2019	
COSMOS Soil Moisture	University of Arizona	Marek Zreda <marek@hwr.arizona.edu>	WLEF	Surface		July-Oct, 2019	http://cosmos.hwr.arizona.edu/Probes/StationDat/042
DIAL/Raman Lidar	Karlsruhe Institute for Technology, IMK IFU	Hannes Vogelmann <vogelmann@kit.edu>	WLEF	In-Situ Profiling		July-Oct, 2019	
HALO Photonics Streamline scanning wind LiDAR (2,3)	Karlsruhe Institute for Technology, IMK IFU	Hannes Vogelmann <vogelmann@kit.edu>	WLEF	In-Situ Profiling		July-Oct, 2019	
CAMSIS GOES-simulator vegetation camera	NASA Goddard	Joel McCorkel <joel.mccorkel@nasa.gov>	WLEF	Surface		July-Oct, 2019	
Airborne eddy-covariance (25 Hz)	University of Wyoming King Air	David Plummer <dplumme1@uwyo.edu>	30x30 domain, 24 flights	Airborne	Y	IOPs	http://flights.uwyo.edu/projects/cheesehead19/
Airborne meteorology and radiation (1 Hz)	University of Wyoming King Air	David Plummer <dplumme1@uwyo.edu>	30x30 domain, 24 flights	Airborne	Y	IOPs	http://flights.uwyo.edu/projects/cheesehead19/
Compact Raman LiDAR (CRL)	University of Wyoming King Air	Zhien Wang <Zhien.Wang@colorado.edu>	30x30 domain, 24 flights	Airborne	Y	IOPs	http://flights.uwyo.edu/projects/cheesehead19/
Wyoming cloud LiDAR (WCL)	University of Wyoming King Air	David Plummer <dplumme1@uwyo.edu>	30x30 domain, 24 flights	Airborne	Y	IOPs	http://flights.uwyo.edu/projects/cheesehead19/
Hyperpsectral high-resolution maps (Hyspex)	University of Wisconsin Hyperspectral Imager	Erin Wagner <ephokanson@wisc.edu>, Ph	10x10 domain, 4 flights?	Airborne	Y	IOPs	http://flights.uwyo.edu/projects/cheesehead19/
~~Boundary-layer heat and water budget of domain~~	~~University of Wisconsin Ultralight~~	~~Grant Petty <gwpetty@wisc.edu>~~	~~10x10 domain~~	~~Airborne~~	~~Y~~	~~IOPs~~	
~~UAVs (fixed wing and quadcopter) - payloads TBD~~	~~University of Wisconsin-Madison, Atmospheric and Oceanic Sciences~~	~~Grant Petty <gwpetty@wisc.edu>~~	~~ISS~~	~~Airborne~~	~~Y~~	~~IOPs~~	
NOAA SURFRAD Station and TWST (downwelling and u	NOAA ESRL GMD	Kathy Lantz <kathy.o.lantz@noaa.gov>	ISS field	Surface		July-Oct, 2019	https://esrl.noaa.gov/gmd/grad/tools/cheesehead/ ftp:
NOAA RadSys Stations, Ceilometer (total/direct/diffuse S	NOAA ESRL GMD	Kathy Lantz <kathy.o.lantz@noaa.gov>	Prentice Airport, Arbor Vitae	Surface		July-Oct, 2019	https://esrl.noaa.gov/gmd/grad/tools/cheesehead/ ftp:
CLAMPS (Microwave radiometer, AERI, Doppler wind lida	NOAA NSSL	Dave Turner <dave.turner@noaa.gov>	Prentice Airport, Arbor Vitae	Surface		Sept-Oct 2019	https://www.nssl.noaa.gov/users/dturner/public_html/
Mobile vehicle transects	Jackson State University	Loren White <Loren.D.White@jsums.edu>	10x10 domain, trails	Surface	Y	IOPs	
Pedestrian/boat mobile transects	Jackson State University	Loren White <Loren.D.White@jsums.edu>	10x10 domain, trails and Ha	Surface	Y	IOPs	
NOAA ATDD Drones (2, Metex and IR temp)	NOAA ATDD	Temple Lee <temple.lee@noaa.gov>, Edw	WLEF and SW2	Airborne Profiling		IOPs	
UWEC Ozone Profile	UW-Eau Claire	Patricia Cleary <clearypa@uwec.edu>	WLEF	Airborne Profiling		IOP1	
Ozone flux profile	UW-Madison Chemistry	Michael Vermeuel <mvermeuel@wisc.edu	WLEF	Surface		IOP1	
Soil and water chemistry	Butternut Schools	Laurie Fox <ladfox85@gmail.com>, Rosal	5 sites	Surface	Y	July 2019	
Tree temperature	Class ACT Charter, Chequamegon High School	Travis Augustine <taugustine@csdk12.net	5 sites, 10 trees	Surface	Y	Oct 2019	
Soil carbon, nitrogen	University of Wisconsin-Madison AOS	Bailey Murphy <bamurphy5@wisc.edu>	16 tower sites	Surface		Oct 2019	
Soil bulk density and heat capacity	NCAR	Steve Oncley <oncley@ucar.edu>	17 tower sites	Surface	Y	July-Oct, 2019	
Drone canopy height LiDAR leaf-on	University of Wisconsin-Geography	Christian Andresen <candresen@wisc.edu	8 1x1 km plots	Surface	Y	June 2019	
QL2 leaf-off LiDAR	United States Forest Service	Mark Farina <mark.farina@usda.gov>	30x30 domain	Airborne		Fall 2018	https://www.sco.wisc.edu/data/elevationlidar/
NASA ECOSTRESS, GEDI, OCO3 overpasses	NASA JPL, target mode planned for October 8	Annmarie Eldering <annmarie.eldering@jp	30x30 domain	Satellite		July-Oct, 2019	
Earth observing landcover datasets, vegetation maps	Globalview, WISCLAND, Landsat, MODIS, Suomi, Sentinel, GOES, and other land cover overpas	Varies		Satellite and Maps		IOPs	
G-LiHT thermal and LiDAR 2012	NASA Goddard	Bruce Cook <bruce.cook@nasa.gov>		Airborne		June 2012	https://glihtdata.gsfc.nasa.gov/files/G-LiHT/
NWS model forecasts and soundings	NOAA NWS via NCAR (HRRR, NAM, GFS, Soundings, local weather stations)	Varies		Model + Other Obs	Y	N/A	
Large Eddy Simulation (LES)	University of Hanover	Matthias Sühring <suehring@muk.uni-hannover.de>		Model		N/A	
Large Eddy Simulation (LES)	University of Wisconsin	Sreenath Paleri <paleri@wisc.edu>		Model		N/A	
Large Eddy Simulation (LES)	KIT IMK IFU	Matthias Mauder <matthias.mauder@kit.edu>		Model		N/A	
Photos and videos	UW-Madison and partners, camera, drones	Brian Butterworth <bbutterworth@wisc.edu	30x30 domain	Photos	Y	July-Oct, 2019	https://photos.google.com/share/AF1QipN58-BZf77B
Field notes, logs, documents	All	Brian Butterworth <bbutterworth@wisc.edu>		Documents	Y	July-Oct, 2019	https://drive.google.com/drive/u/0/folders/1yMuVDBW
NEON TOS data (biomass, biodiversity, small mammals,	National Ecological Observatory Network (NEON)	Stefan Metzger <smetzger@battelleecolog	UNDE, TREE, STEI	Surface	Y	Continuous	Data Portal - NEON Data

Analysis and coding are now central to ecology

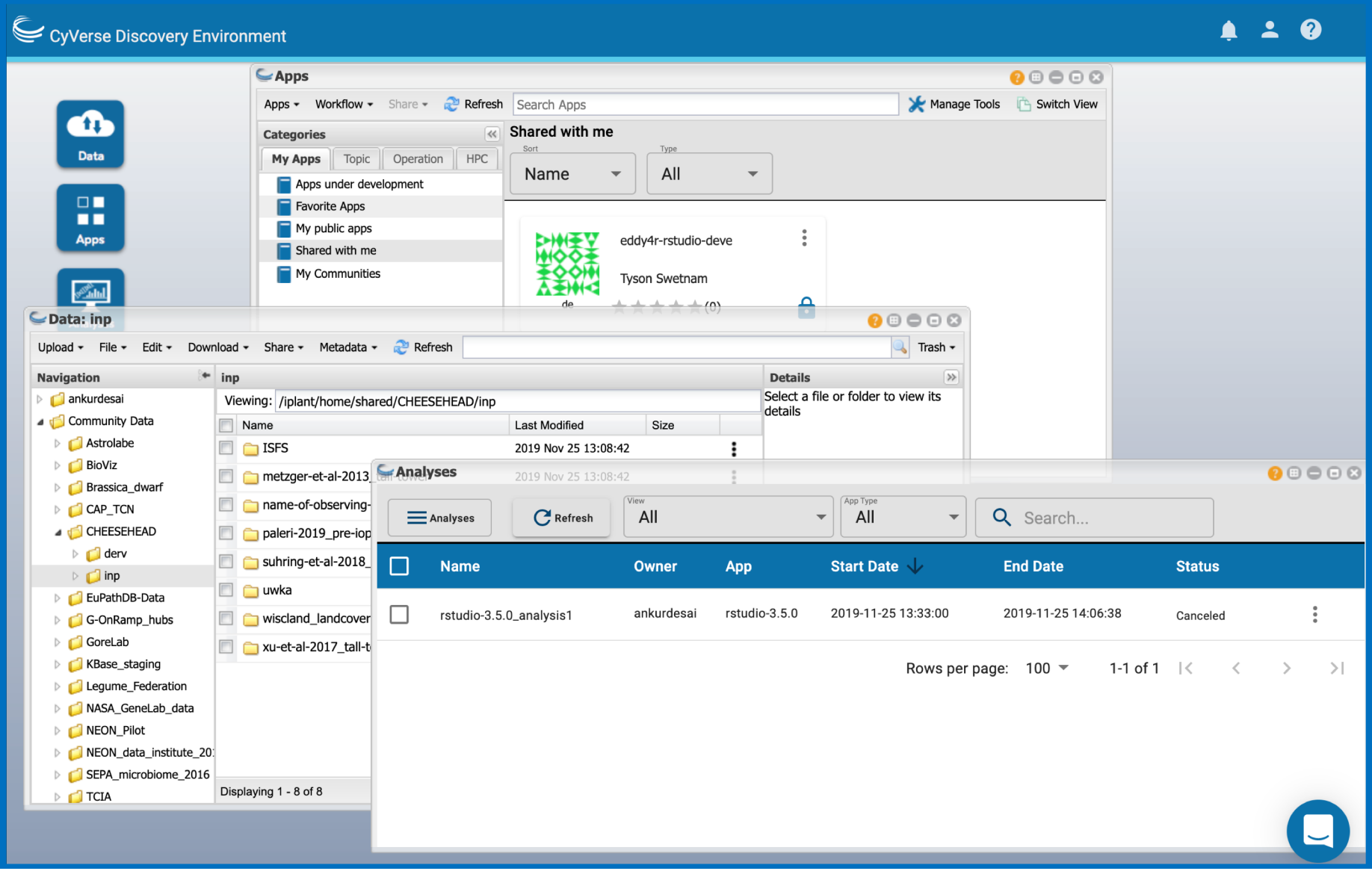
- When data volume is in terabytes, data types number in the dozens, and collaborator lists are in the tens to hundreds, traditional “cottage-industry” style analysis is impractical and inefficient

- Bringing code to the data is the new mantra
  - Example: Cyverse

CyVerse

(NSF, U Arizona)

- https://www.cyverse.org/atmosphere https://de.cyverse.org/de/

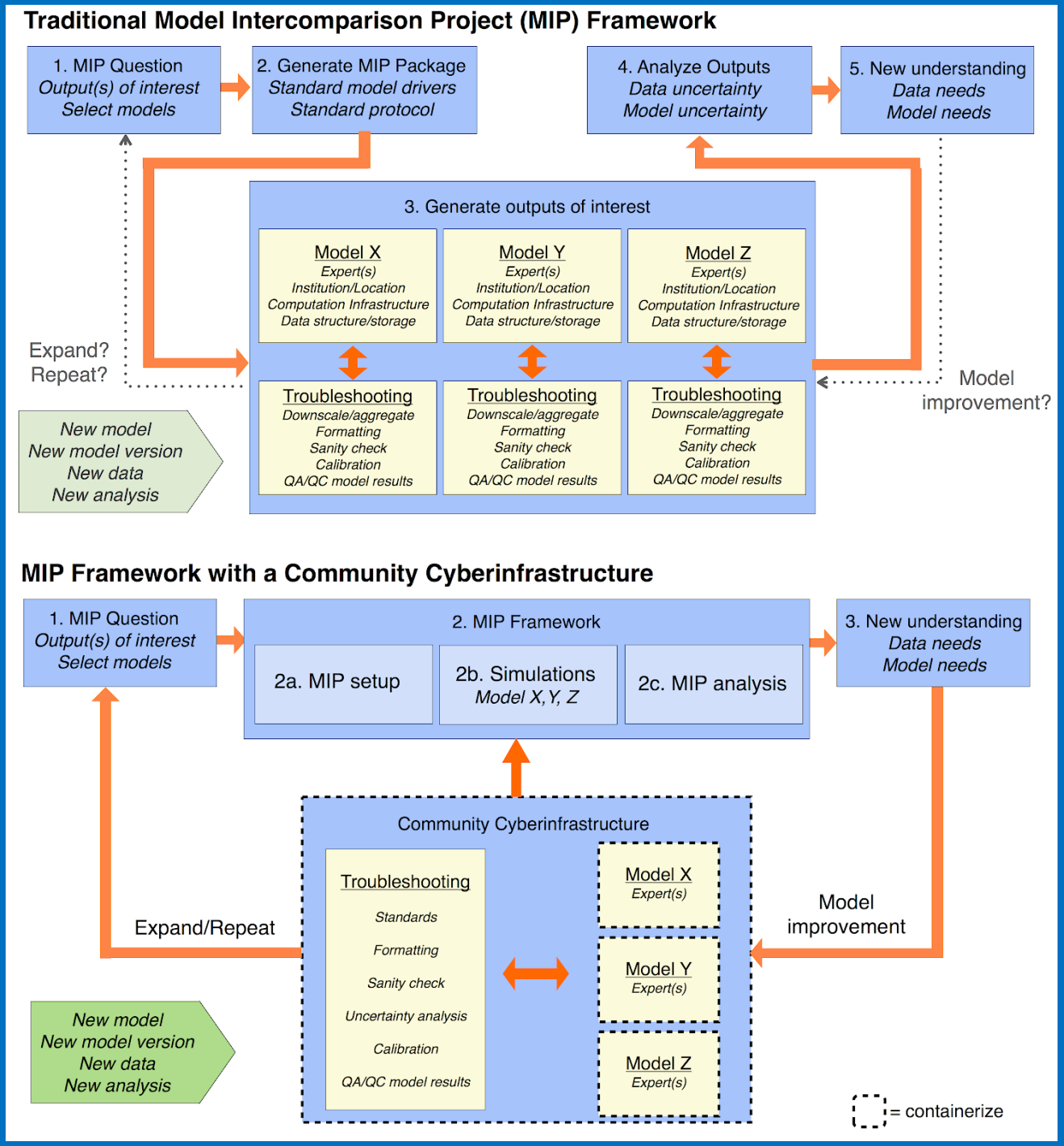


Removing the wall between models and observations

Katie Zarada, Mike Dietze, PEcAn project

No one should be called a “modeler” or an “experimentalist”

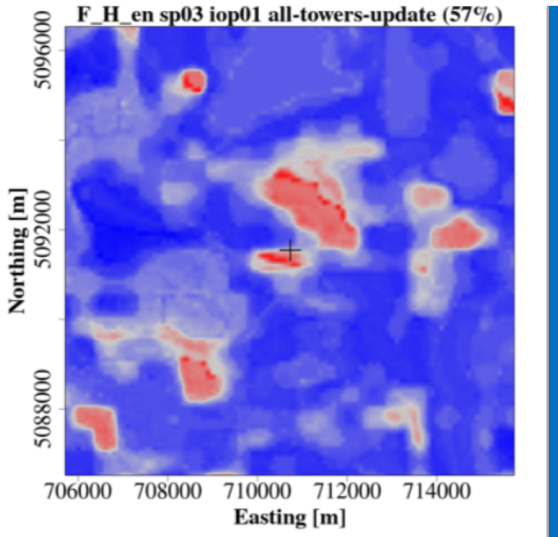
- Models are how we represent complex non-linear interactions among our theories
- No single type of observation is sufficient to evaluate the hypotheses embedded in models
- Model intercomparison and benchmarking projects can be made more routine



Gardella et al., in prep

Learn more at B22D-01 Metzger TU 1020 MW3007 and B21C-06 Paleri TU 915-930 MW3007

Observing System Simulation Experiments (OSSEs) flip the script on how models are used in experiments

tower projection	tower + aircraft projection	original LES "truth"
		

Metzger *et al*., 2013; Xu *et al*., 2017, 2018;

S. Metzger, S. Paleri, K. Xu

Huge Ecology is possible

- A diverse community makes global change ecology possible
- Diverse solutions are needed to confront the increasing volume in data and complexity in theory and models
- There are challenges that need to be solved mostly by students and early career scientists
  - But supported by community, funders, mentors
- The next few decades will be consequential for our discipline for a number of reasons


Thank you!
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@profdesai
Photo: A. Desai