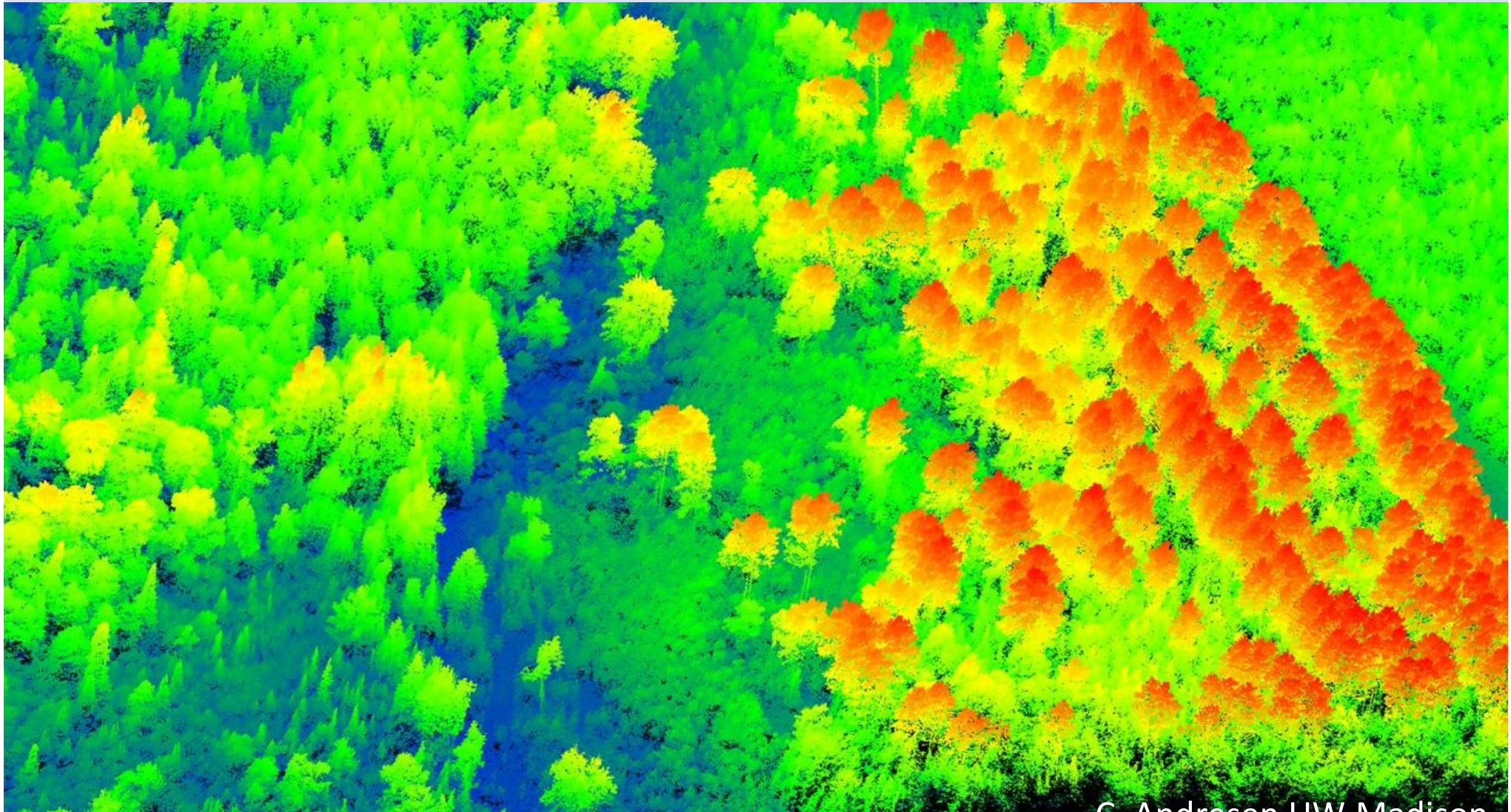# Resolving fine-scale variation in drivers of surface-atmosphere fluxes: A case study for land surface temperature in CHEESEHEAD19

Ankur R Desai, University of Wisconsin-Madison

34th AMS AgForMet, Presentation 7.6, 22 June 2021

C. Andresen UW-Madison

Cast and crew

- Ankur R Desai, UW-Madison, CHEESEHEAD lead PI
- Anam M Khan, UW-Madison
- Ting Zheng, UW-Madison
- Sreenath Plaeri, UW-Madison
- Brian Butterworth, UW-Madison (* presenting at live session)
- Temple Lee, NOAA ATDD
- Joshua Fisher, NASA JPL
- Glynn Hulley, NASA JPL
- Tania Kleynhans, Rochester Institute of Technology
- Aaron Gerace, Rochester Institute of Technology
- Phil Townsend, UW-Madison
- Paul Stoy, UW-Madison
- Stefan Metzger, Battelle, NEON
- Many CHEESEHEAD collaborators, co-PIs, data providers, technicians including NCAR EOL and U Wyoming King Air
- Chequamegon-Nicolet National Forest, the community of Park Falls, and the Ojibwe people
- National Science Foundation (1822420), German DFG, NOAA, NASA, DOE Ameriflux

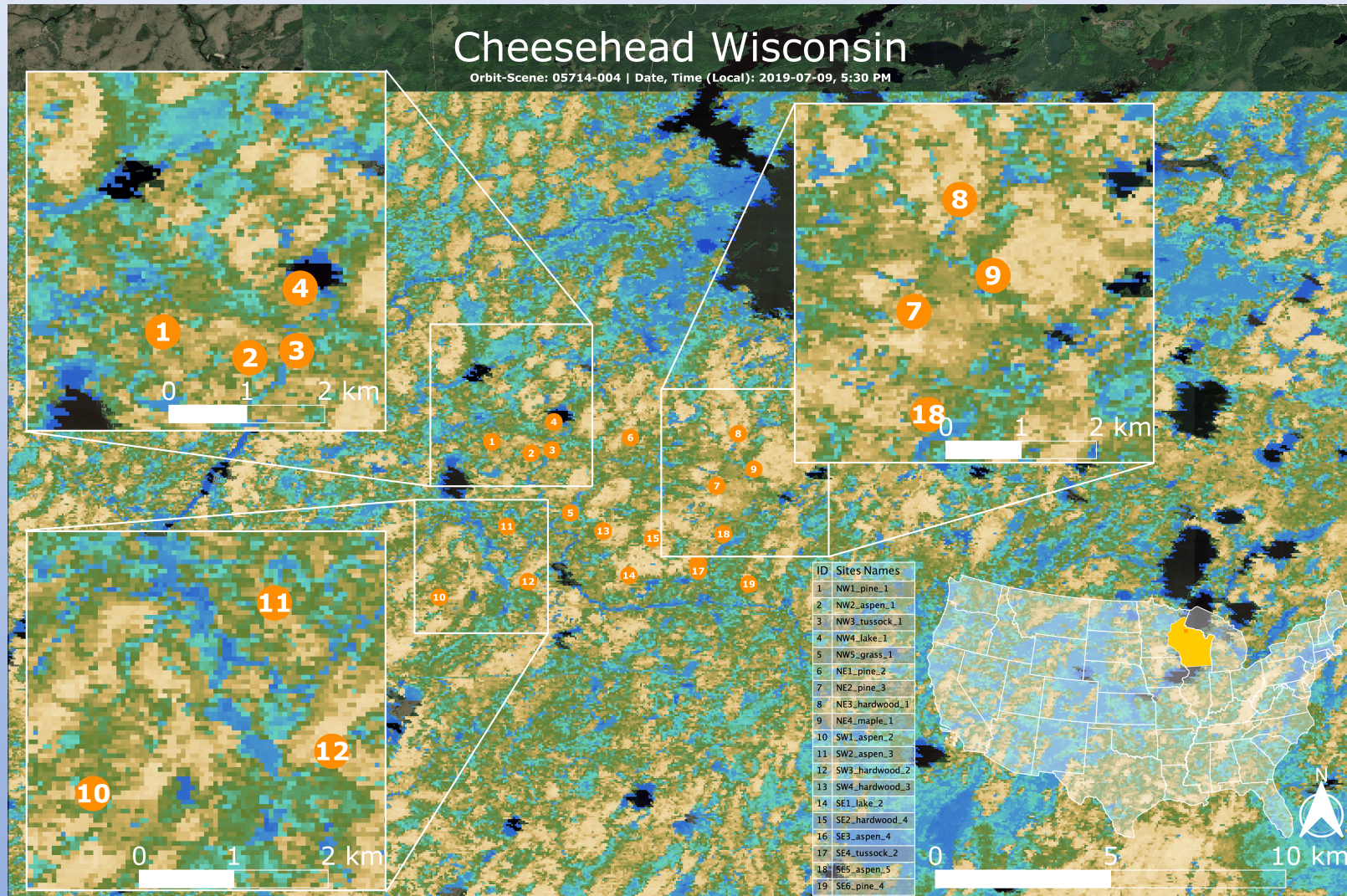Hourly, High-Resolution merged Satellite Land Surface Temperature for CHEESEHEAD Domain

Data: https://bit.ly/2Rmb4fG   Pre-print: https://bit.ly/3yZCaKv

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

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.

The biosphere is heterogenous at all scales

Cheesehead Wisconsin

Orbit-Scene: 05714-004 | Date, Time (Local): 2019-07-09, 5:30 PM

ID	Sites Names
1	NW1_pine_1
2	NW2_aspen_1
3	NW3_tussock_1
4	NW4_lake_1
5	NW5_grass_1
6	NE1_pine_2
7	NE2_pine_3
8	NE3_hardwood_1
9	NE4_maple_1
10	SW1_aspen_2
11	SW2_aspen_3
12	SW3_hardwood_2
13	SW4_hardwood_3
14	SE1_lake_2
15	SE2_hardwood_4
16	SE3_aspen_4
17	SE4_tussock_2
18	SE5_aspen_5
19	SE6_pine_4

J. Fisher / F. Galvan (JPL)

Land surface temperature (LST) is an essential climate variable

- Trade-offs in how finely one can observe this across space versus how frequently one can observe across time
  - Both are needed for studying land-atmosphere feedbacks, resolving microclimate impacts to ecology, and benchmarking Earth system models
  - Also, pesky clouds get in the way for satellites
  - Growth of LST satellite observations at either fine (ECOSTRESS, 70m, 1-2 day) or frequent (GOES-16/17 ABI, 2 km, hourly) scales
    - Coupled with increasing deployment of UAS drone and airborne thermal infrared sensors and hyperspectral imaging

It complicates interpreting eddy flux measurements
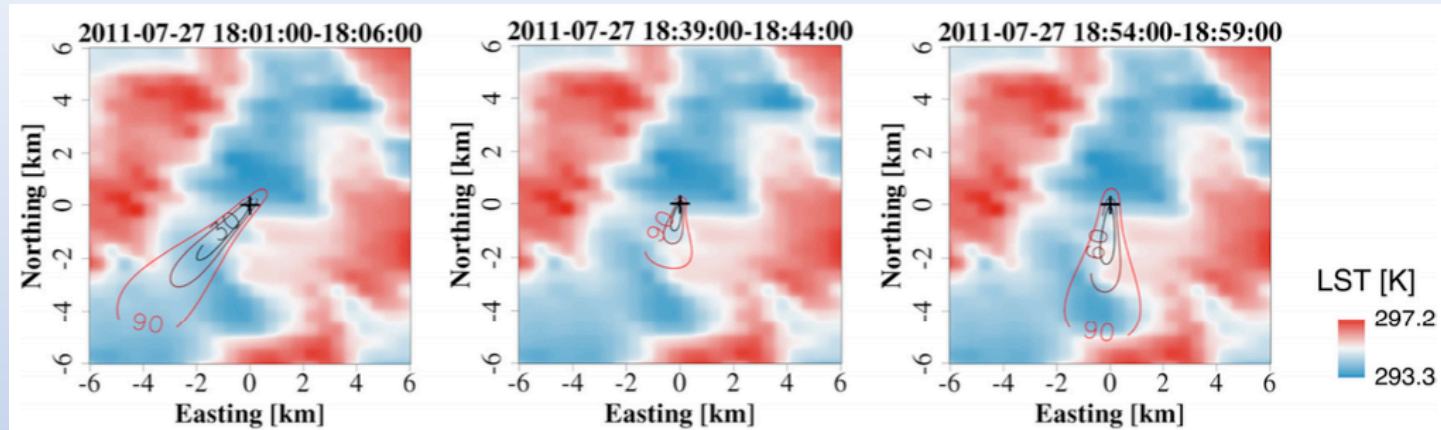
Xu et al., 2017, *Ag. Forest Meteorol*.
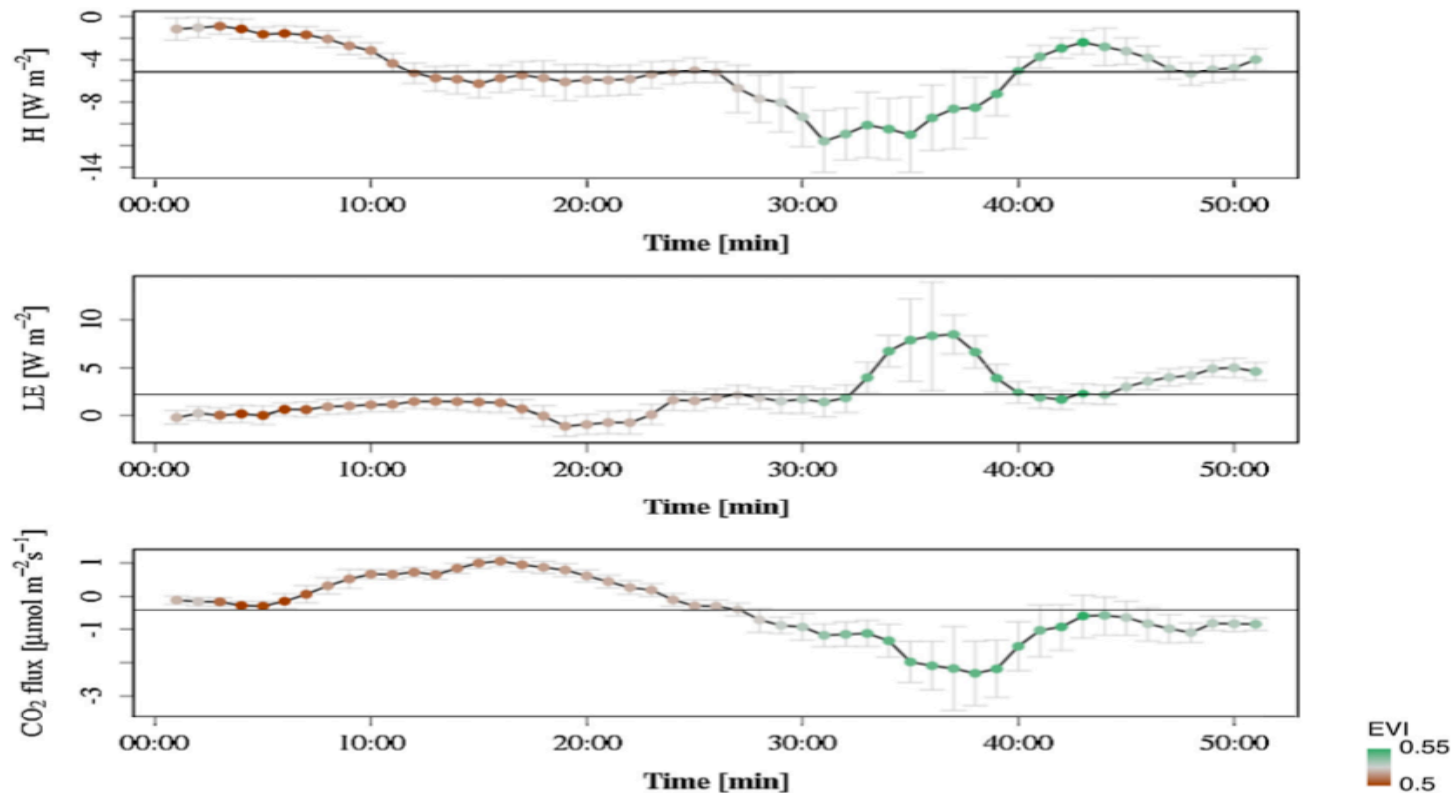
A good place as any to test

Chequamegon Heterogenous Ecosystem Energy-balance Study Enabled by a High Density Extensive Array of Detectors 2019 (CHEESEHEAD19) (NSF 1822420)
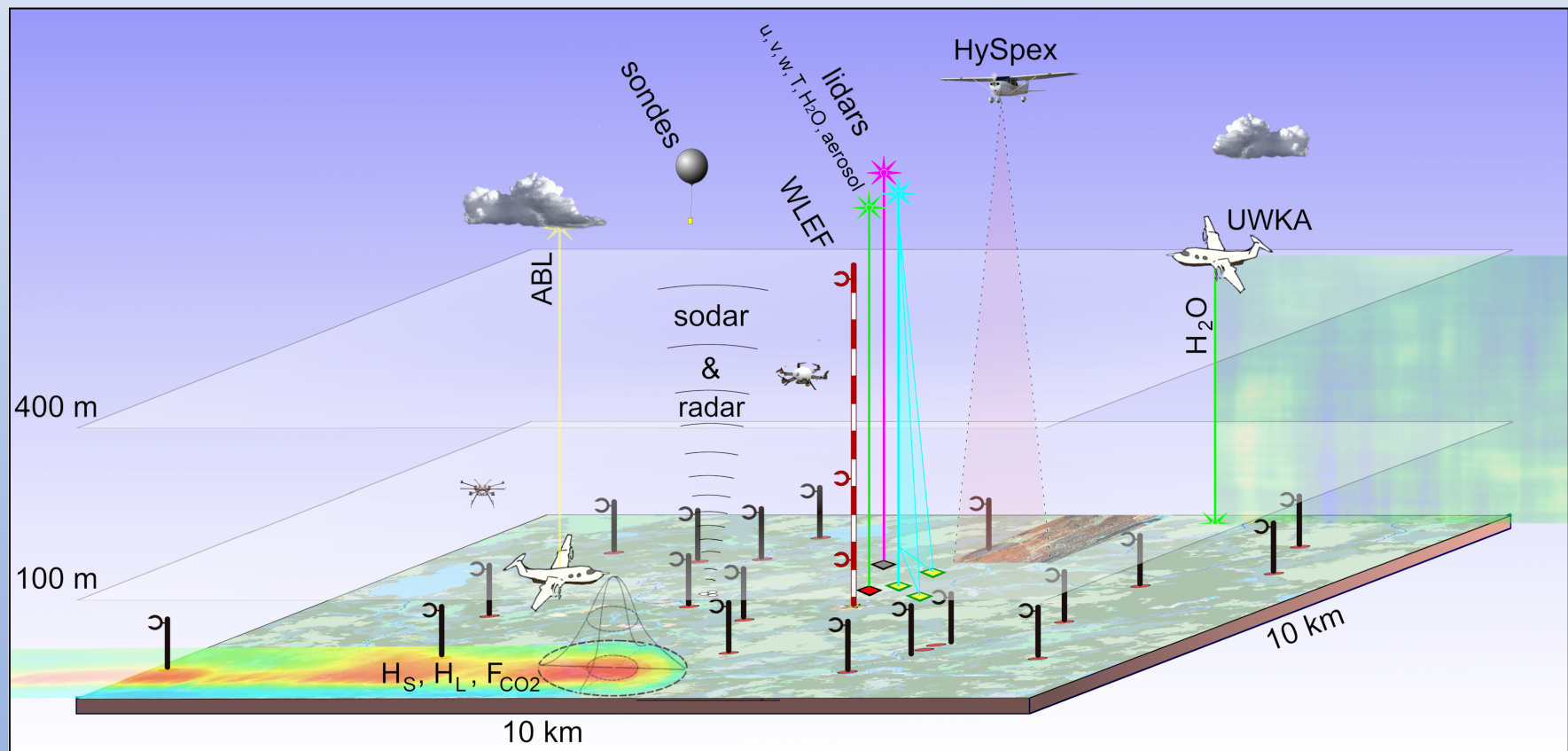
Butterworth et al., 2021, *Bulletin of the American Meteorological Society*

Why here?

- Four months (Jun-Oct 2019) of intensive land-atmosphere sampling
- Including 20 flux towers, many with longwave radiation
- Airborne EC with upwelling IR
- UAS with thermal IR
- Repeat airborne hyperspectral imaging
- Lots of other measurements
- Good people
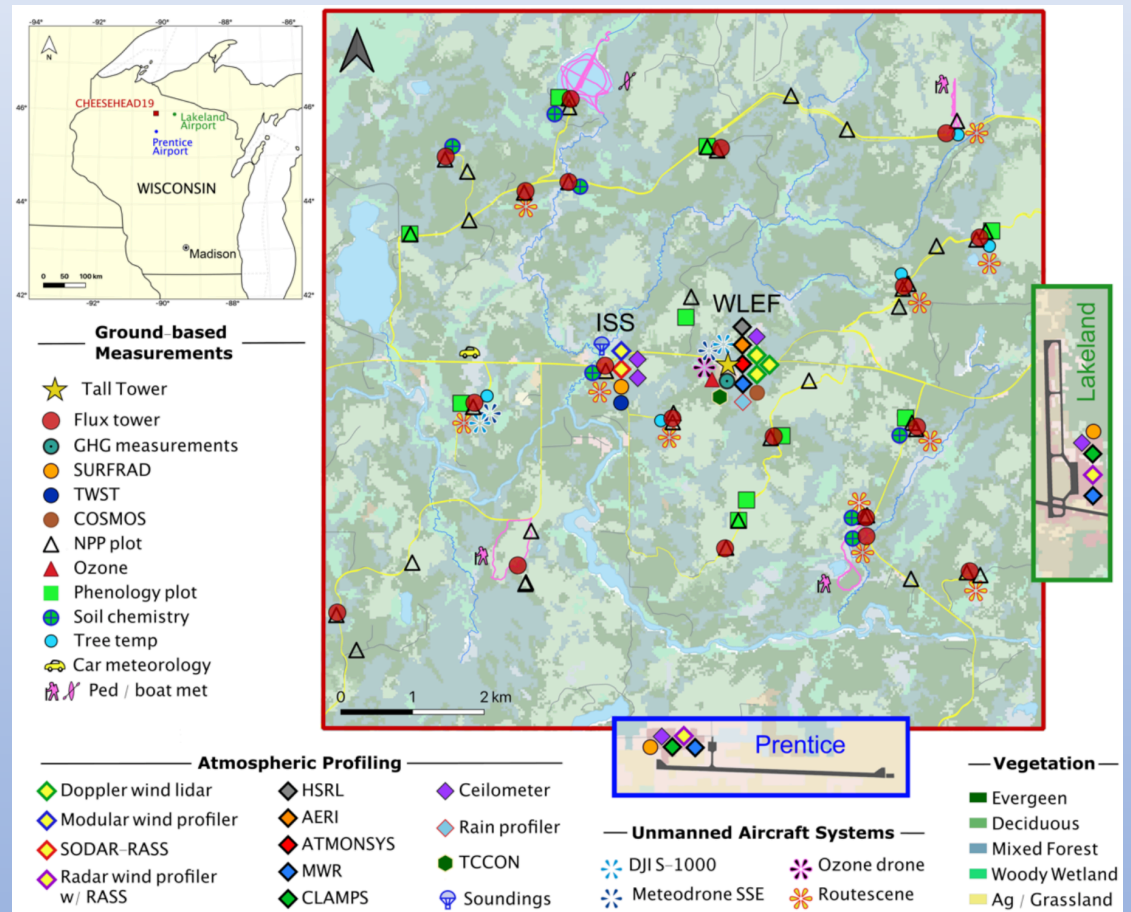
Research goals

- How reliably can we fuse high space and high temporal resolution satellites to generate continuous, cloud-free gridded LST?
    - Hourly, 50 m resolution

- Can we further downscale to higher resolution by connecting hyperspectral indices combined with the LST fusion
    - 10 m resolution?

Workflow:
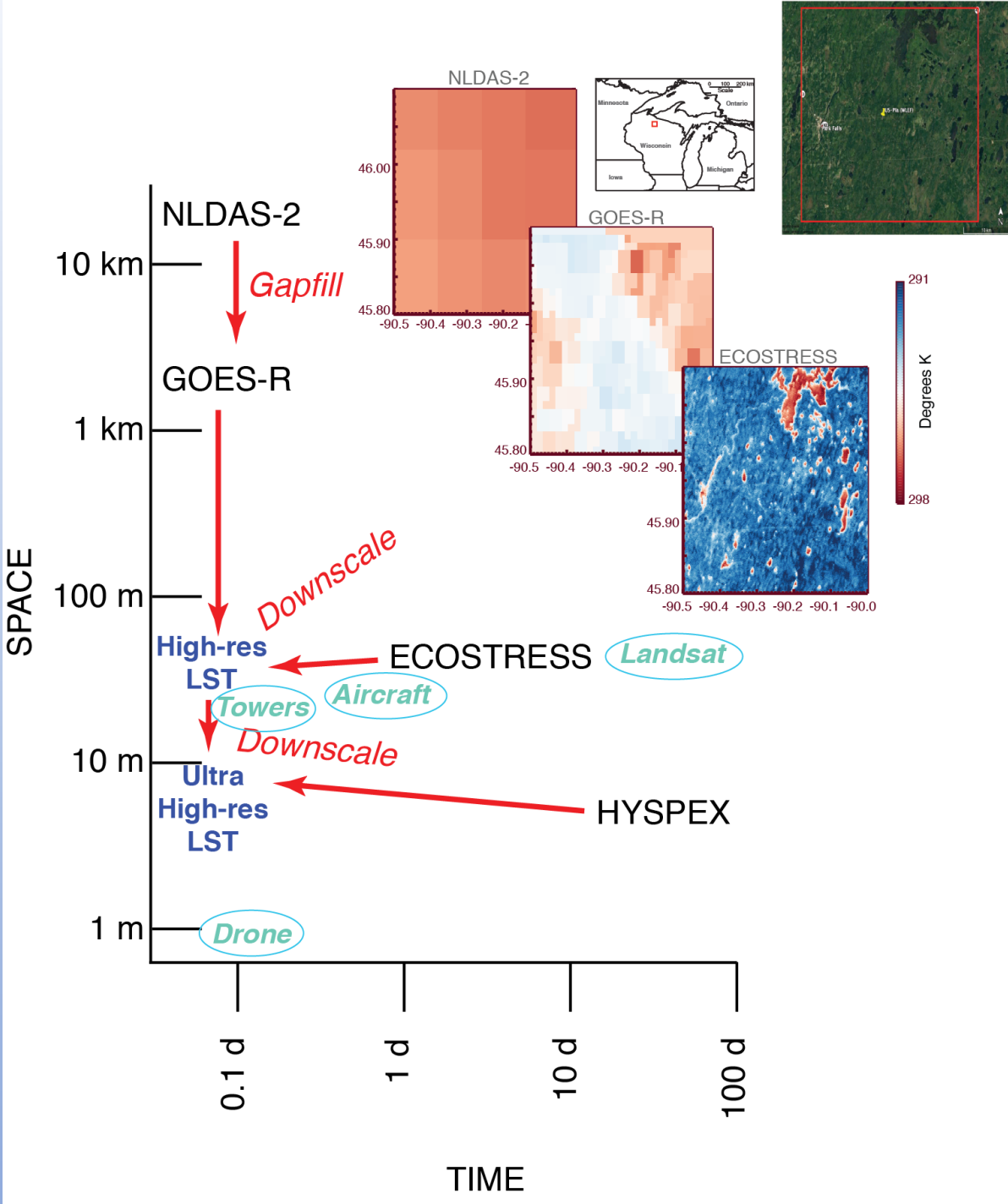
Step 1. Clear the clouds

- NLDAS-2 suite of data assimilation land surface models (12.5 km resolution) regressed to geostationary GOES-16 hourly 2 km satellite LST to gap fill clouds
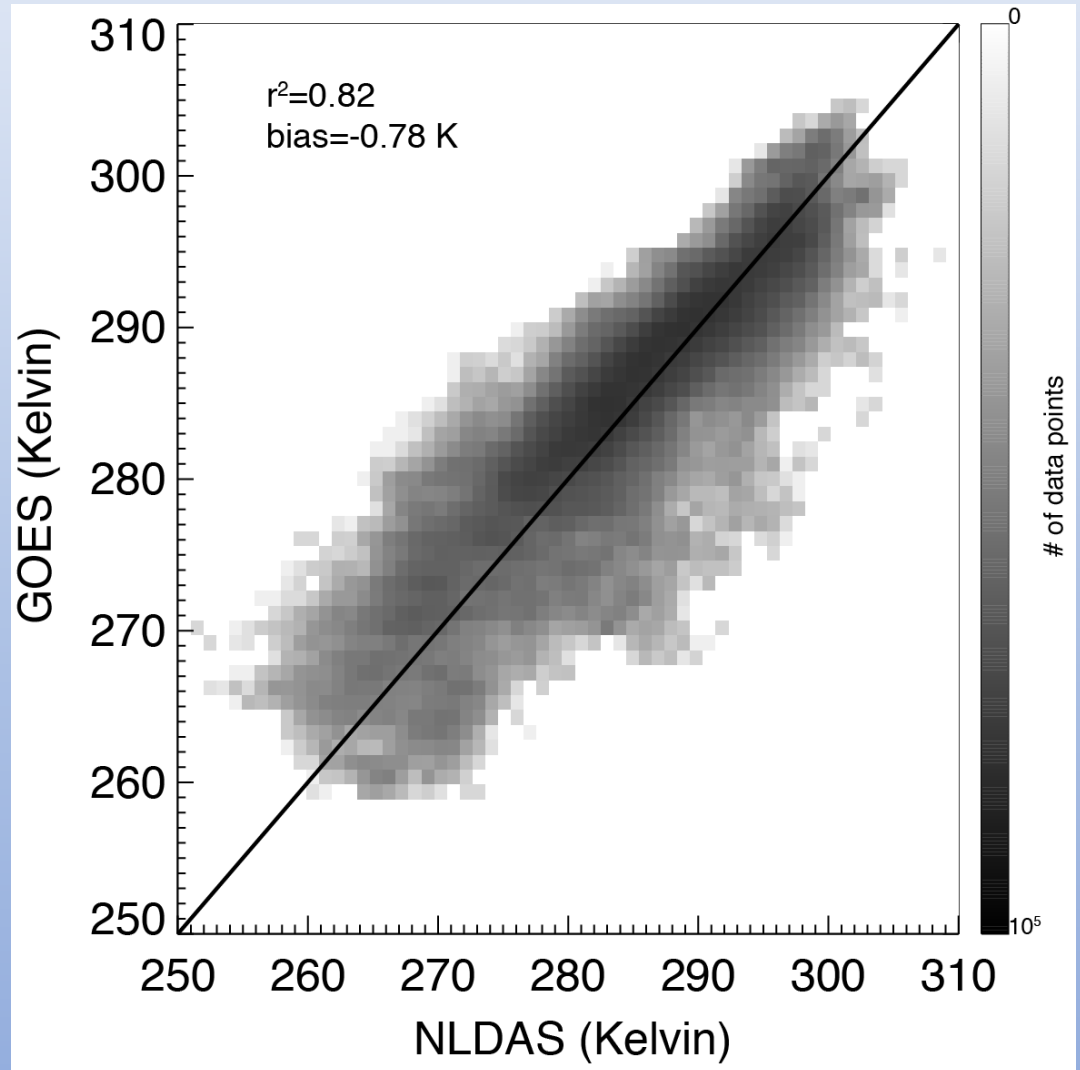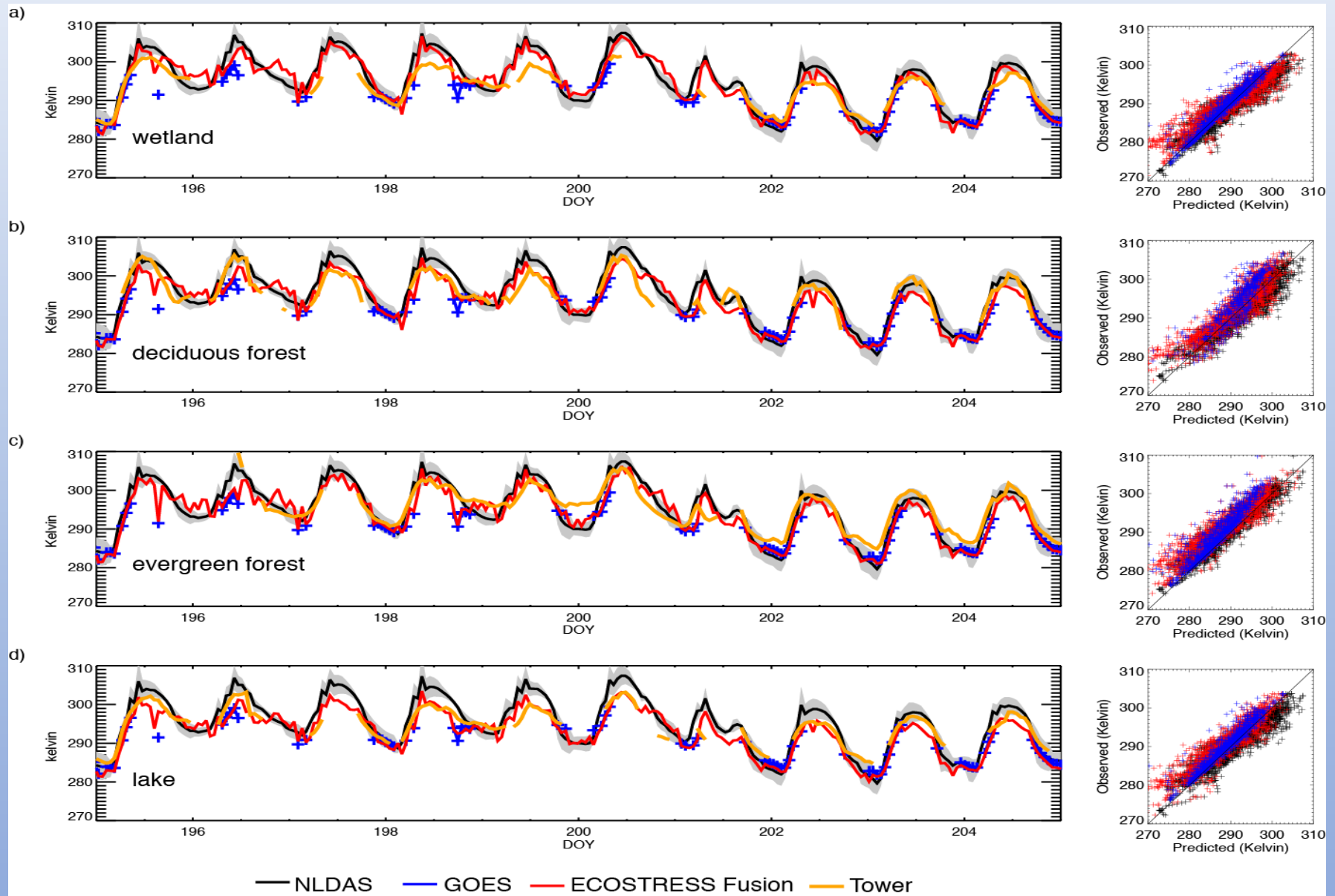
Step 2. Downscale with ECOSTRESS

- ECOSTRESS (70 m) mostly clear-sky imagery on ISS (available ~weekly during CHEESEHEAD distributed across all hours of day) regressed against GOES LST in both slope and intercept
  - Works well except across larger lake
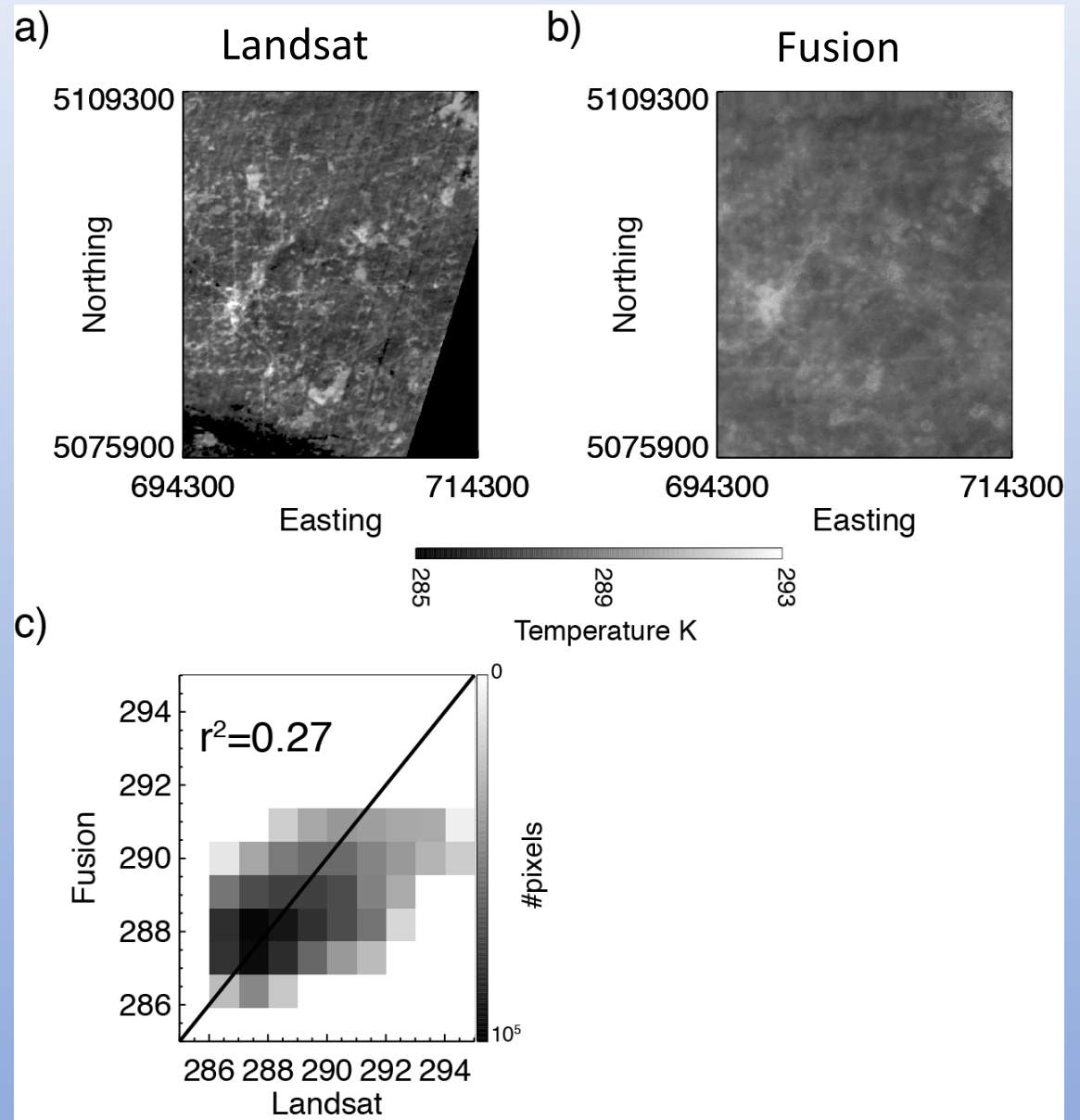 - Resampled to 50 m
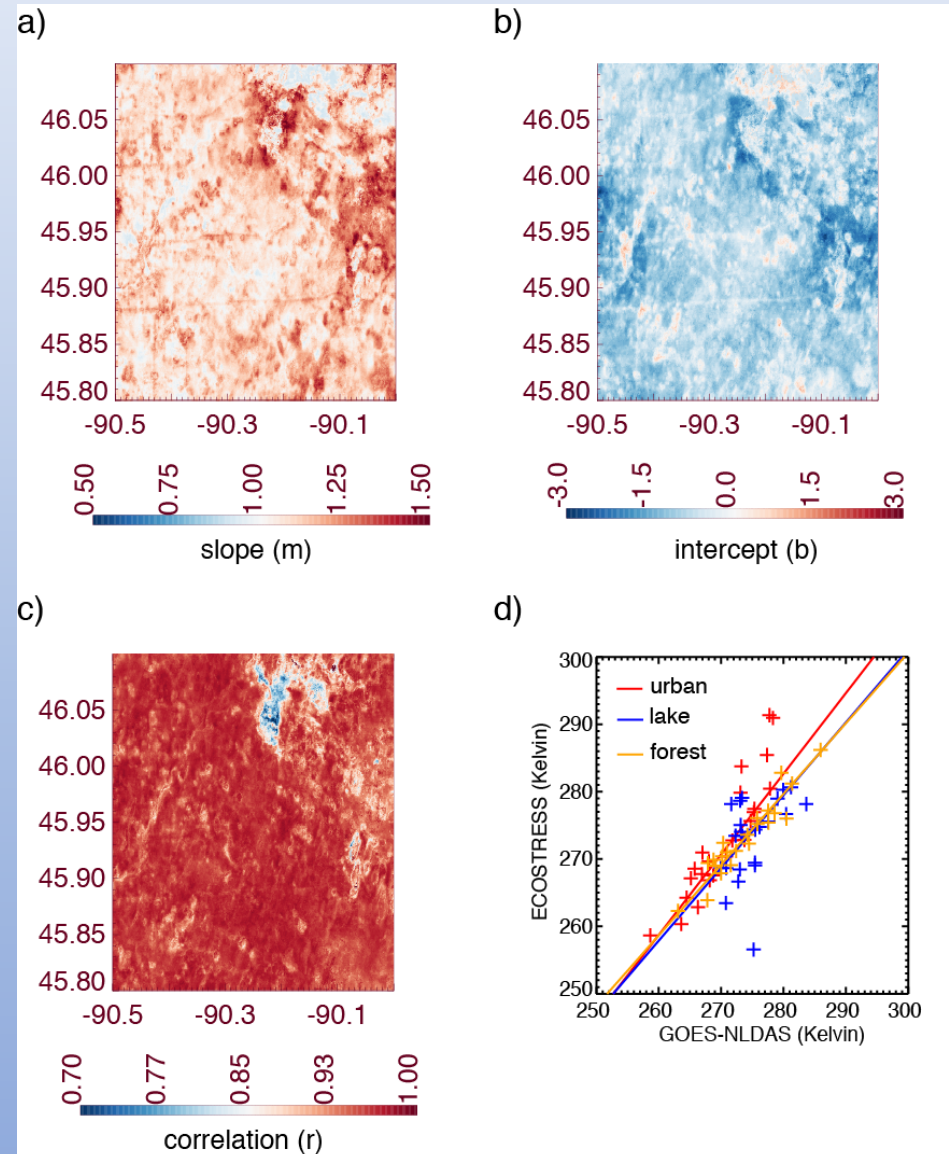
How well did it work?

a) Aircraft

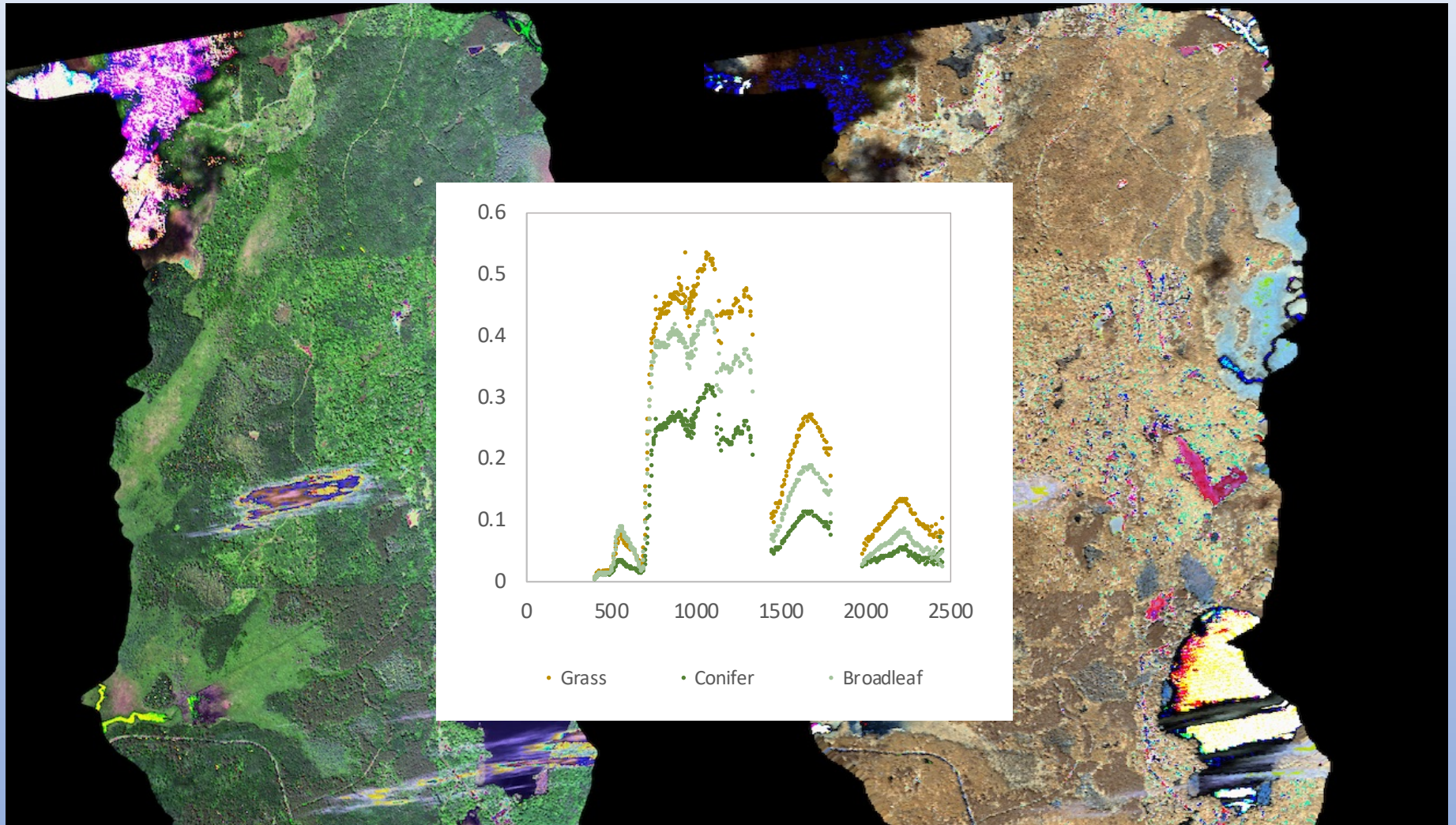b) Towers
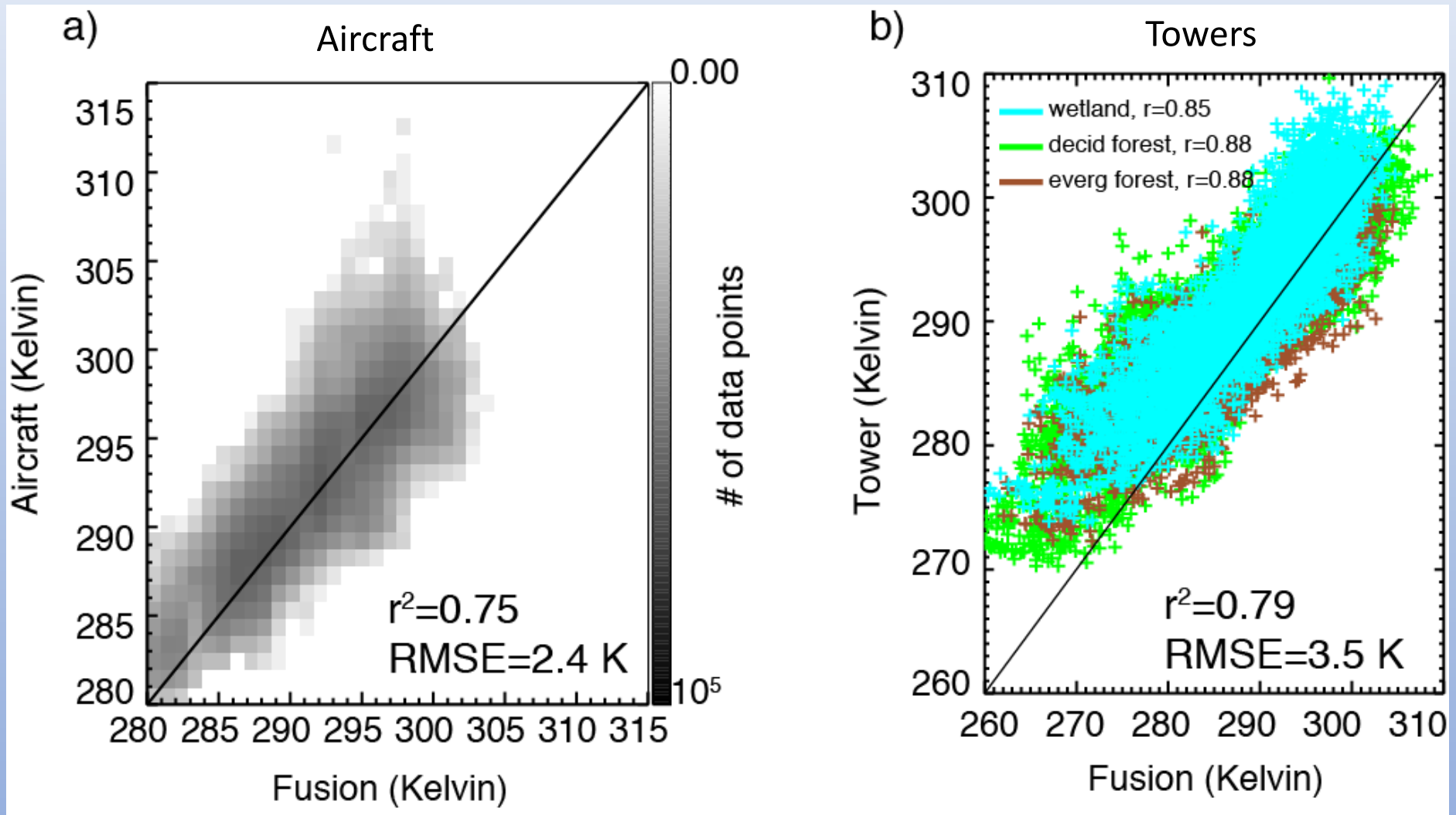
How does it behave through time?

How does it compare to Landsat?

- **Two-channel Landsat LST acquired**
  - One morning overpass was mostly clear
  - Generally good correspondence but "blurrier" aspects of fusion LST given linear model

Can we do better with additional non-thermal imaging?
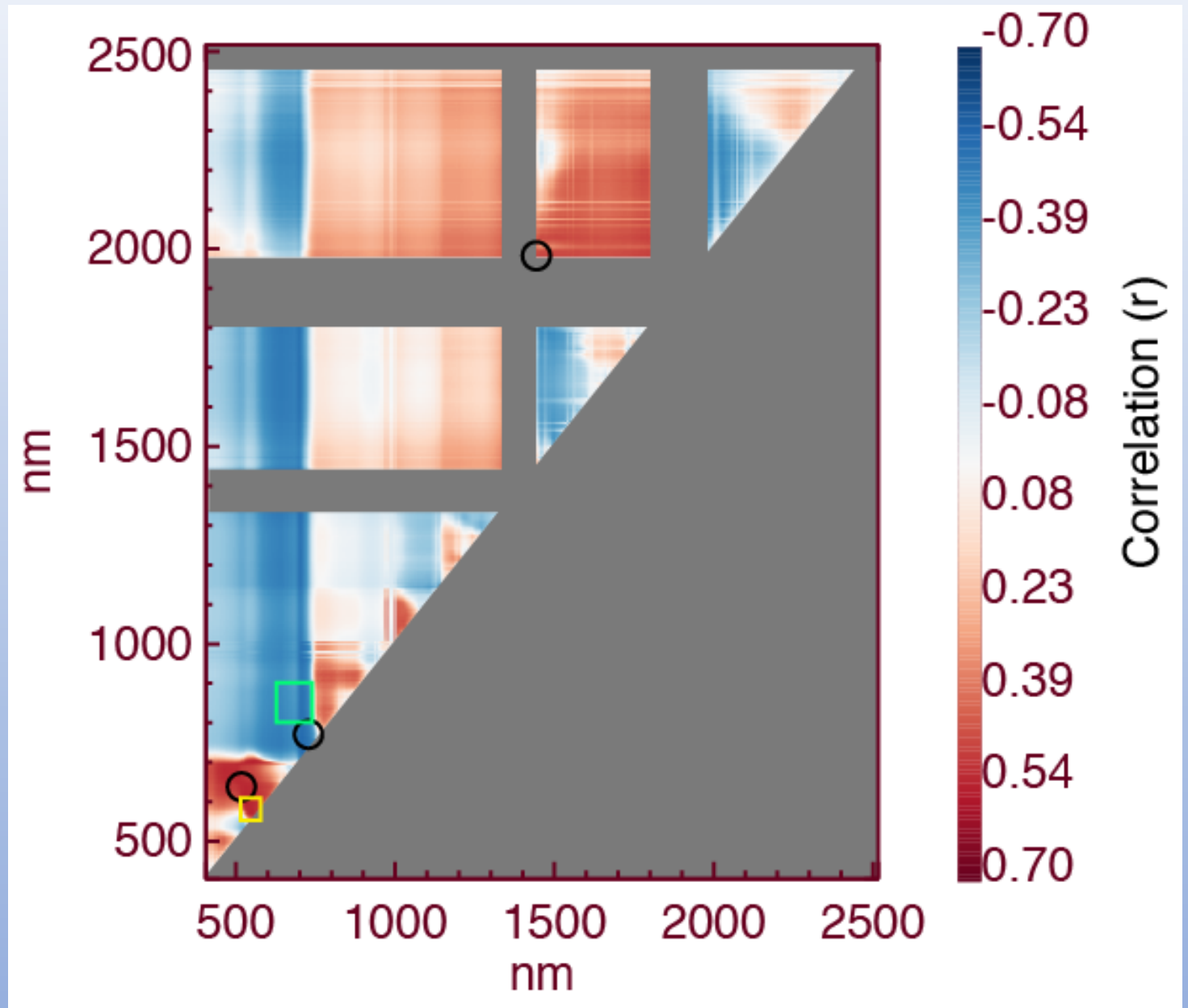

P. Townsend / T. Zheng / E. Wagner (UW)

NDSI =
Normalized
Difference
Spectral Index

Like NDVI on
steroids

Identified three
band ratios in
visible, near IR, and
shortwave IR that
correlated with
UAS 10 m LST
(black circles)

Two are close to
NDVI (green
square) and PRI
(yellow square)

- Drone reveals fine structure of LST over one tower footprint
  - Fusion LST misses high temperatures on road and open field
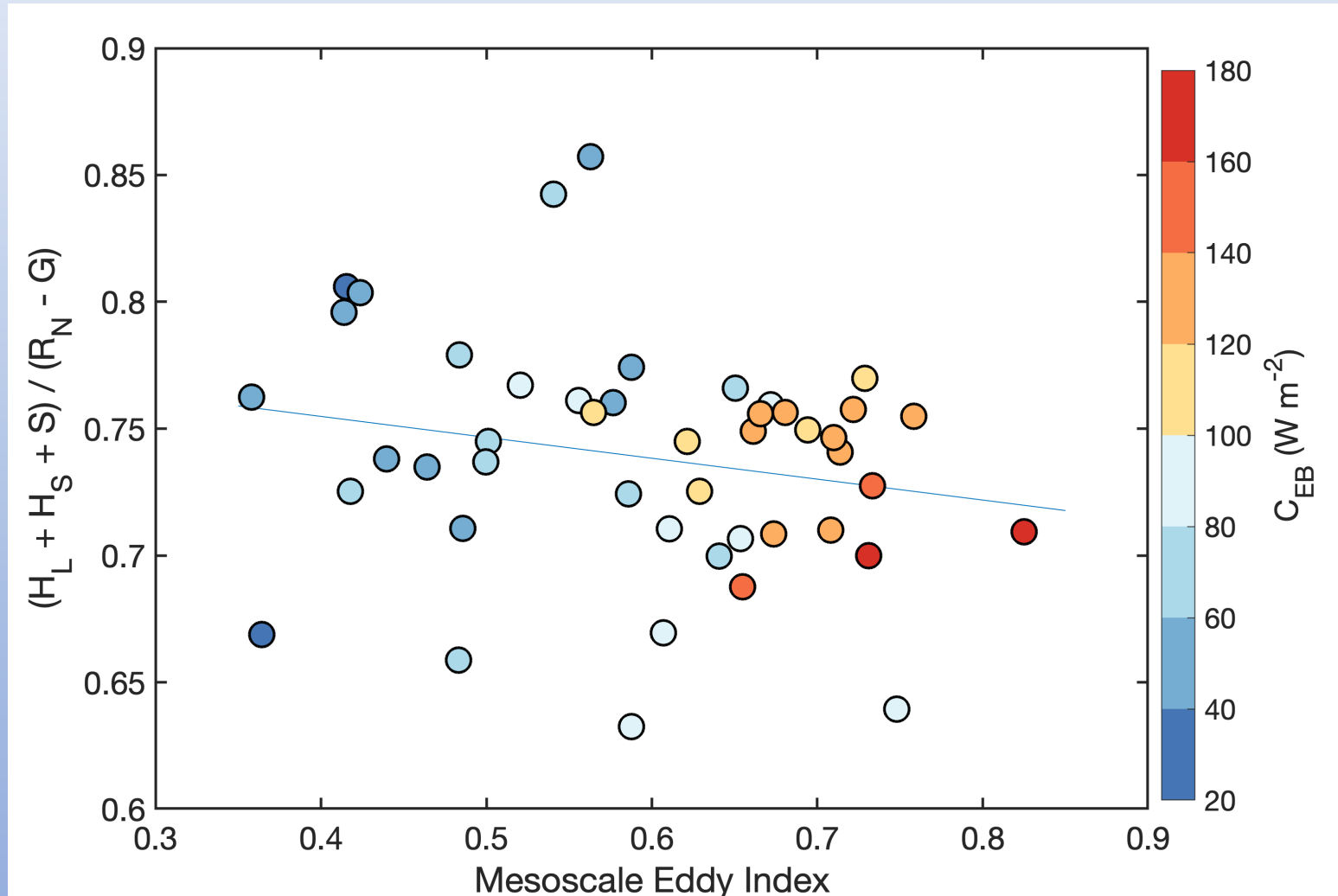 - Linear model with fusion + the three NDSI ratios fixes much of it
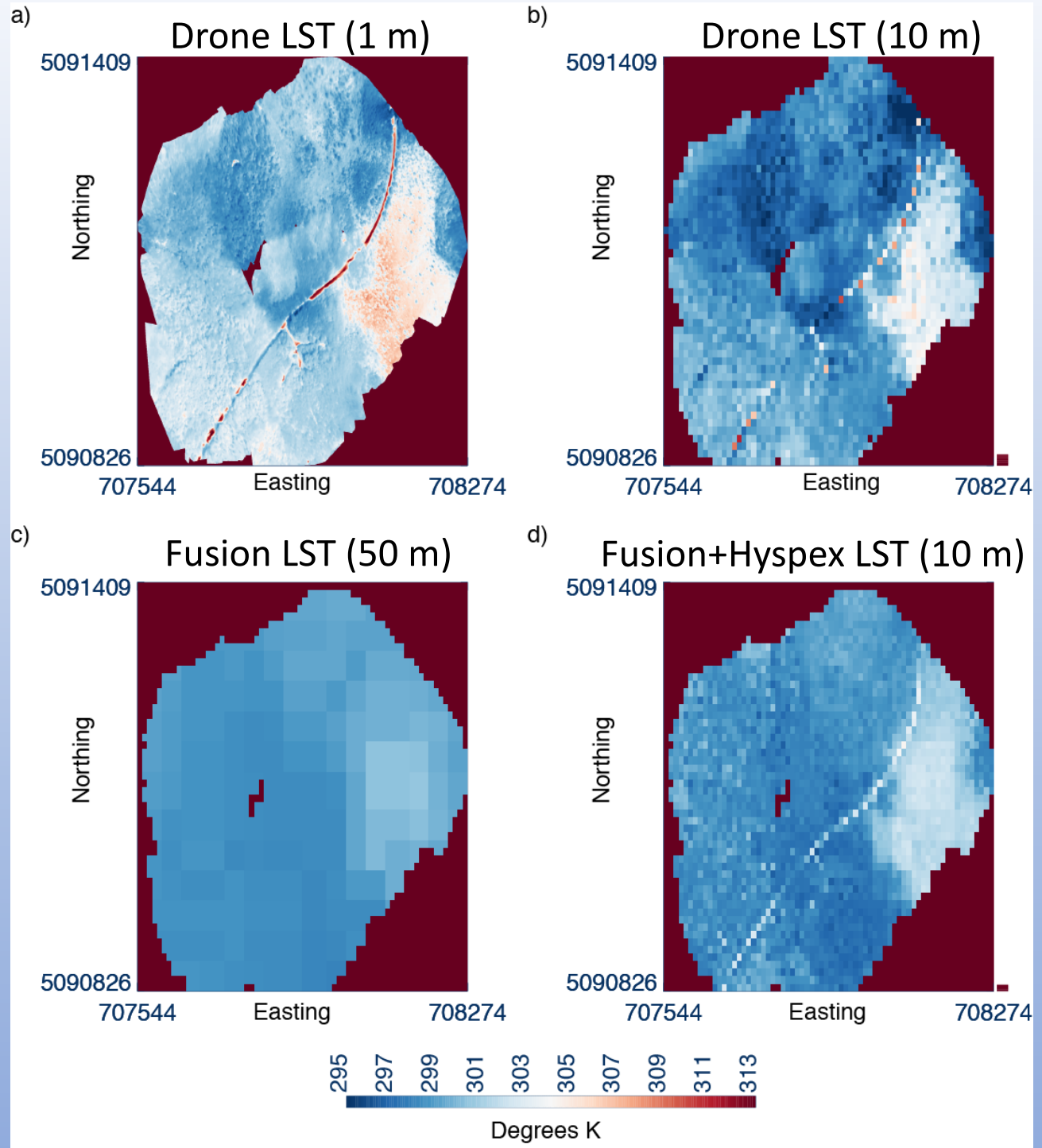
What does it mean?

- Integrated 2-D power spectrum of our product generally more closely tracks high resolution LST than geostationary LST
  - Spectral loss explains some of the blur
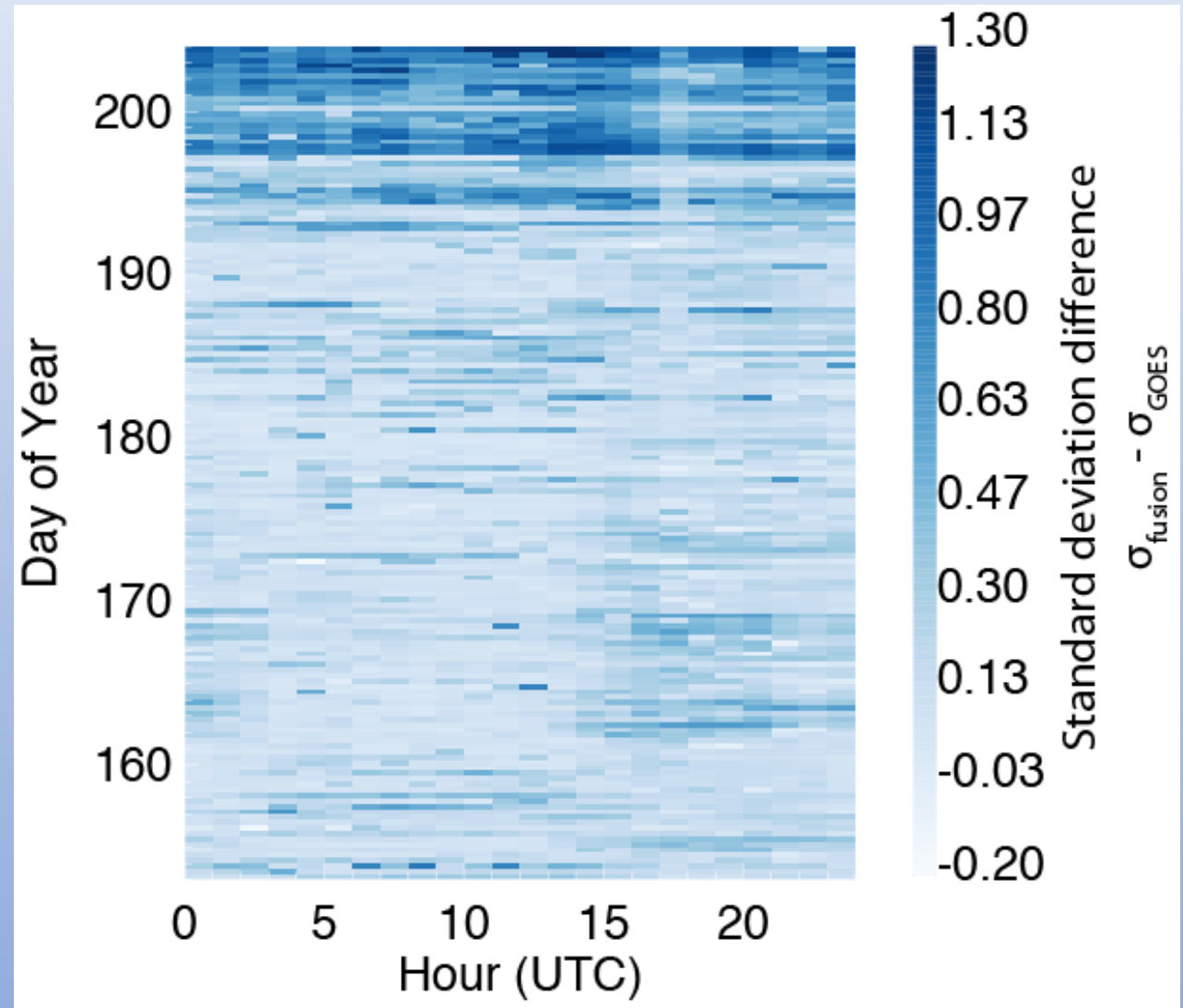 - Higher resolution proxies can fix some of that
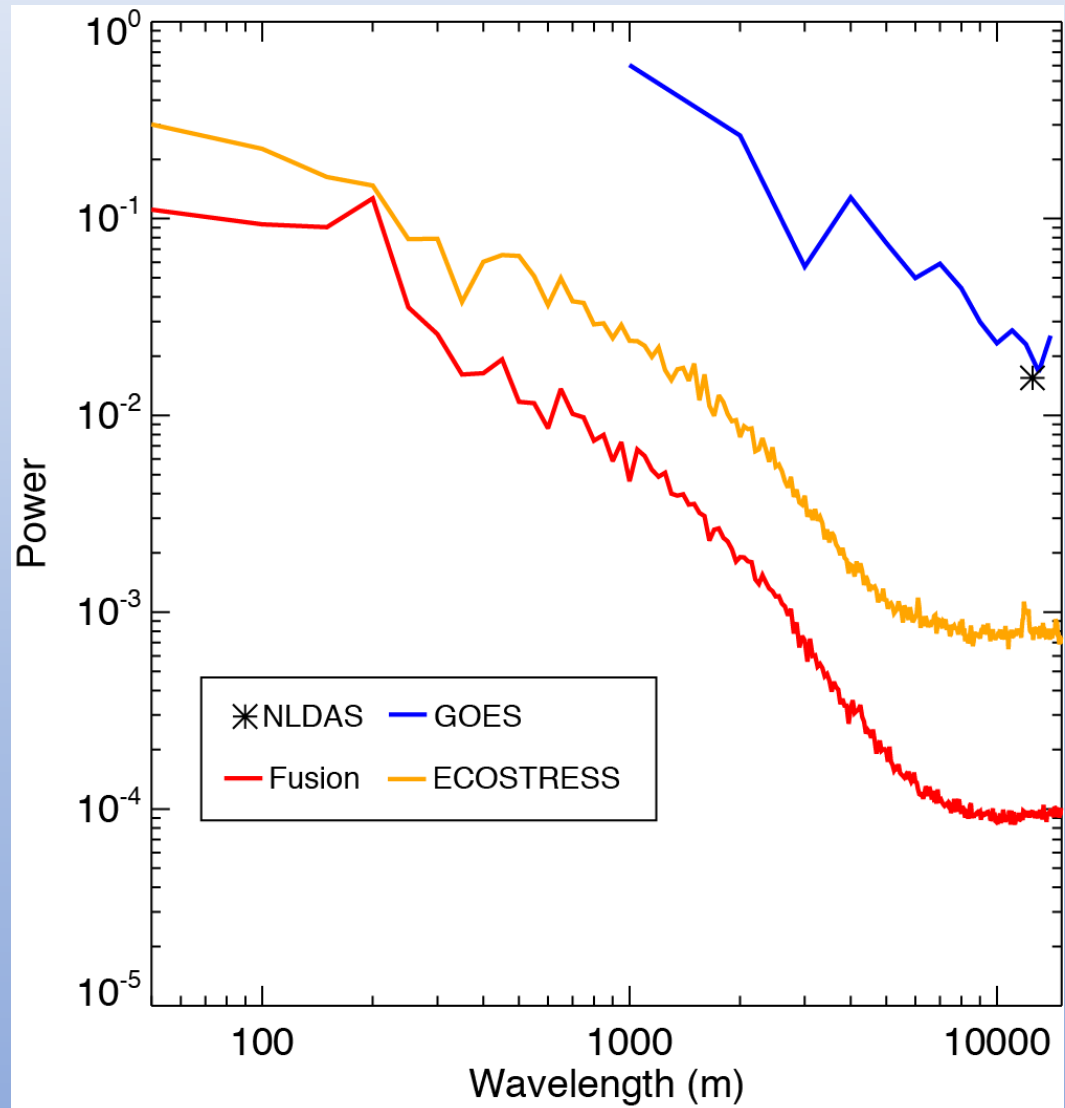
Potential applications: Understanding energy balance
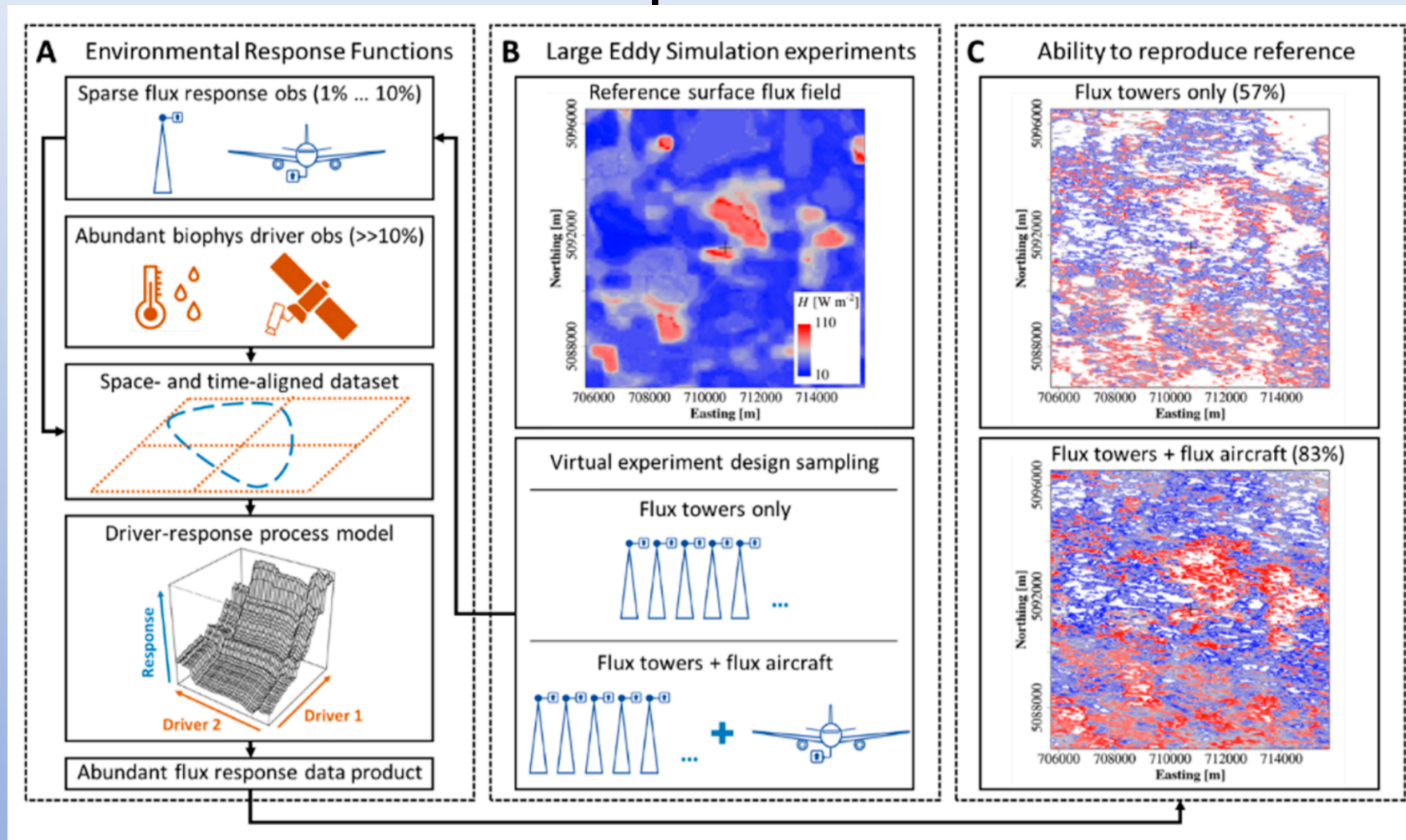

B. Butterworth

Potential applications: Understanding energy balance

- Can relationship between secondary circulations and energy imbalance be linked to diel or seasonal changes in heterogeneity of LST across space?

Potential application: Mapping fluxes across space

Metzger et al.: Observing system simulation experiments double scientific return of surface-atmosphere synthesis, Atmos. Meas. Tech. Discuss., 2021, 1-39, doi:10.5194/amt-2021-86, 2021.

Thanks!

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https://www.eol.ucar.edu/field_projects/cheesehead
https://data.eol.ucar.edu/dataset/592.147