Fifteen years of observations from a very tall tower on the responses of landscape-scale productivity to climate anomalies and extremes

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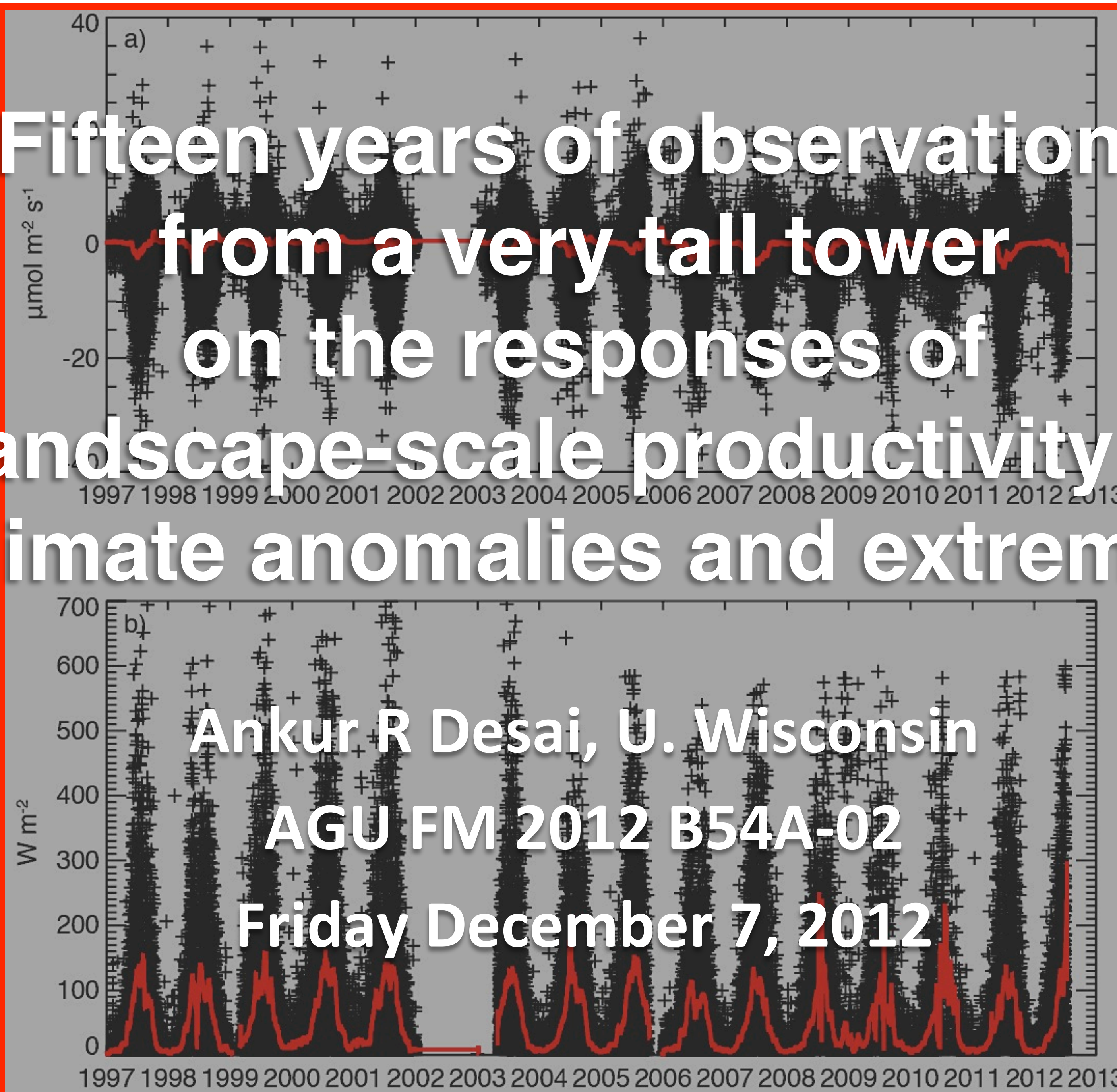
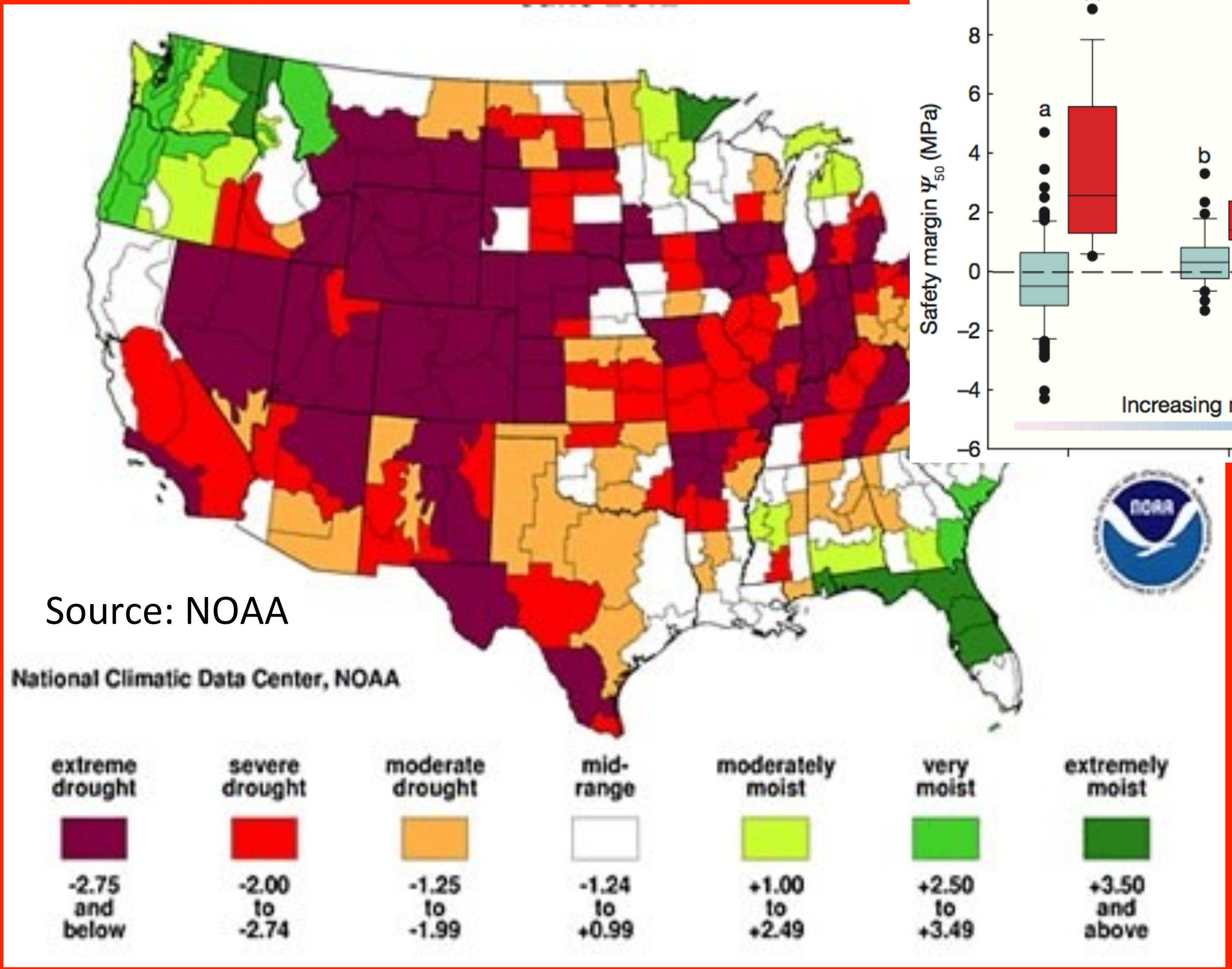
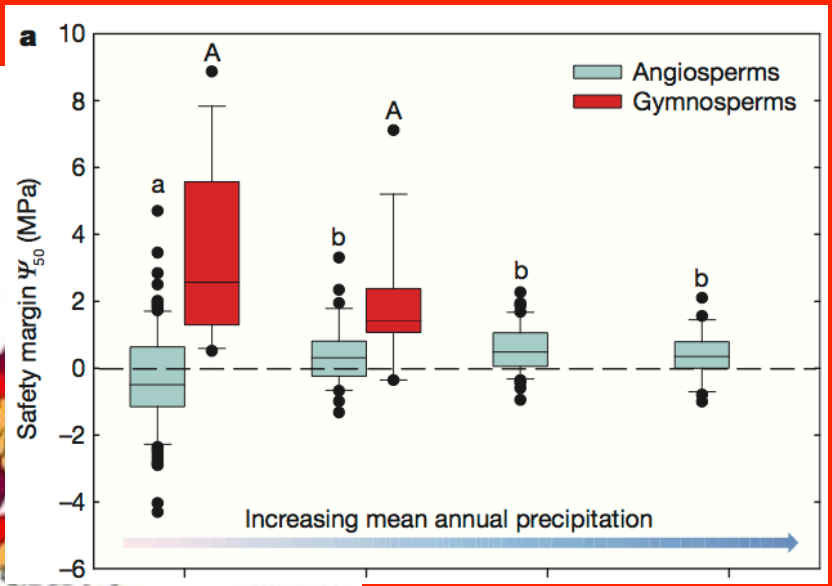


How do terrestrial plants respond to extremes?

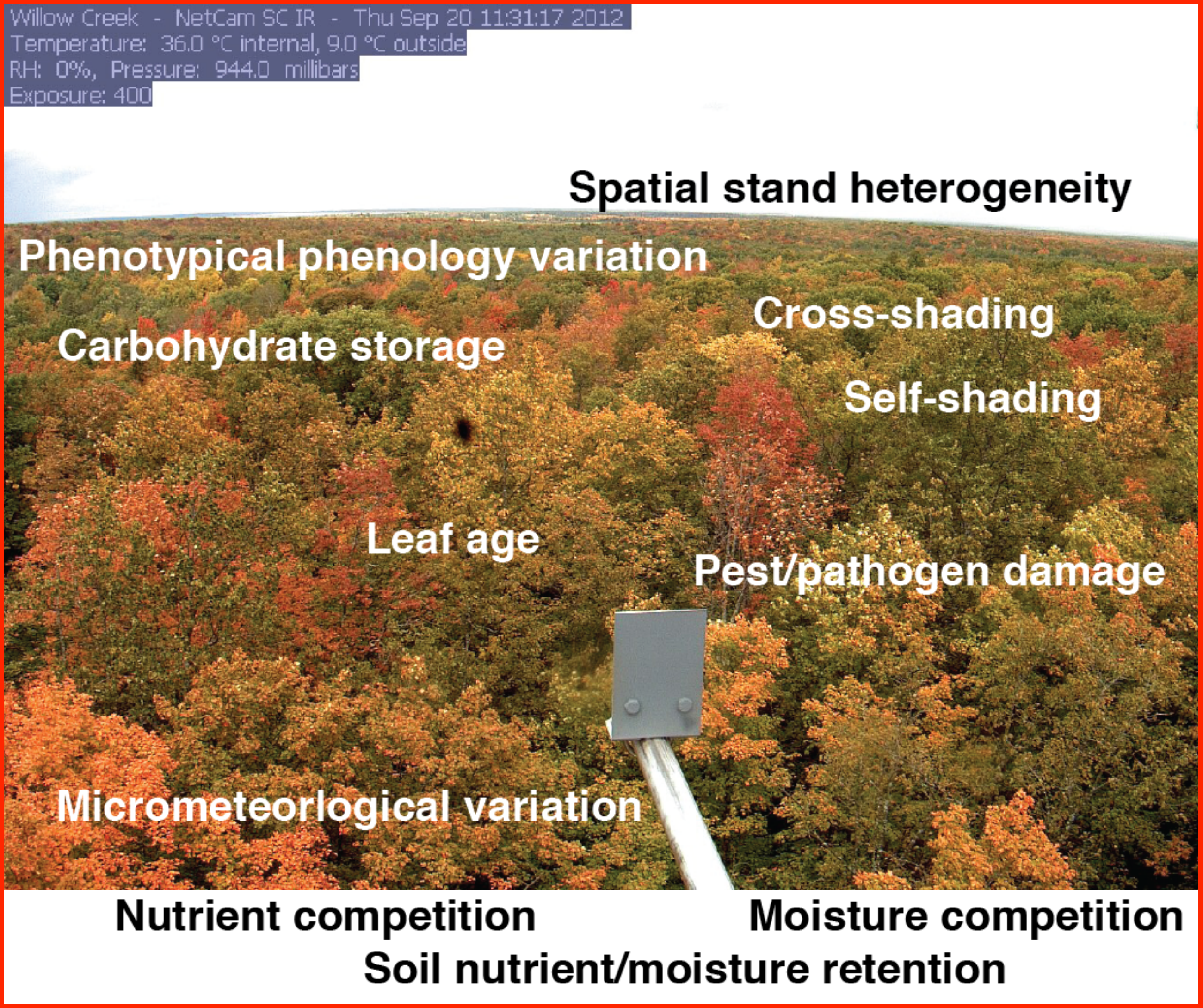


Source: NOAA

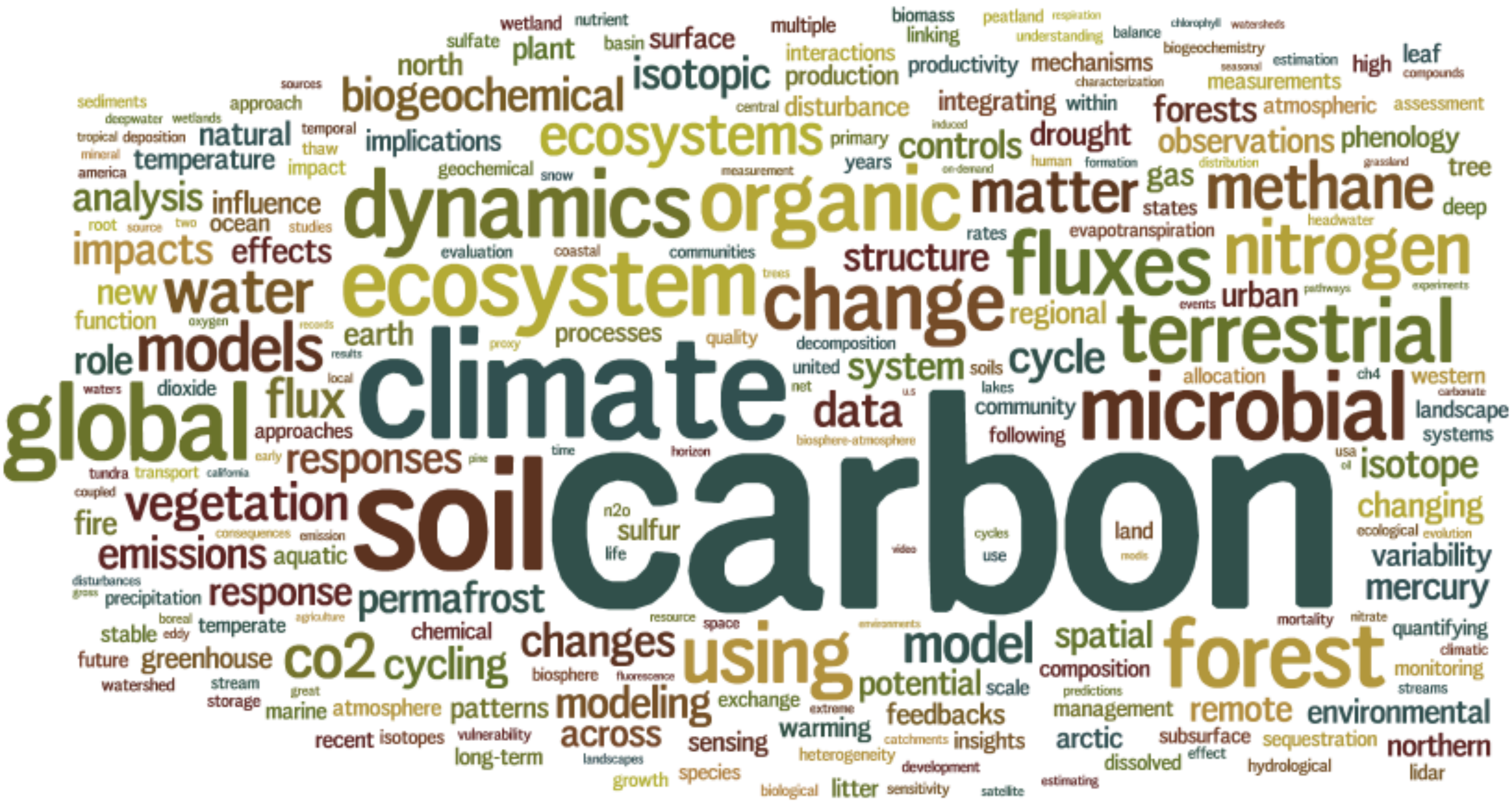


Choat et al., 2012, PNAS

How do ecosystem-scale responses vary from leaf-scale?

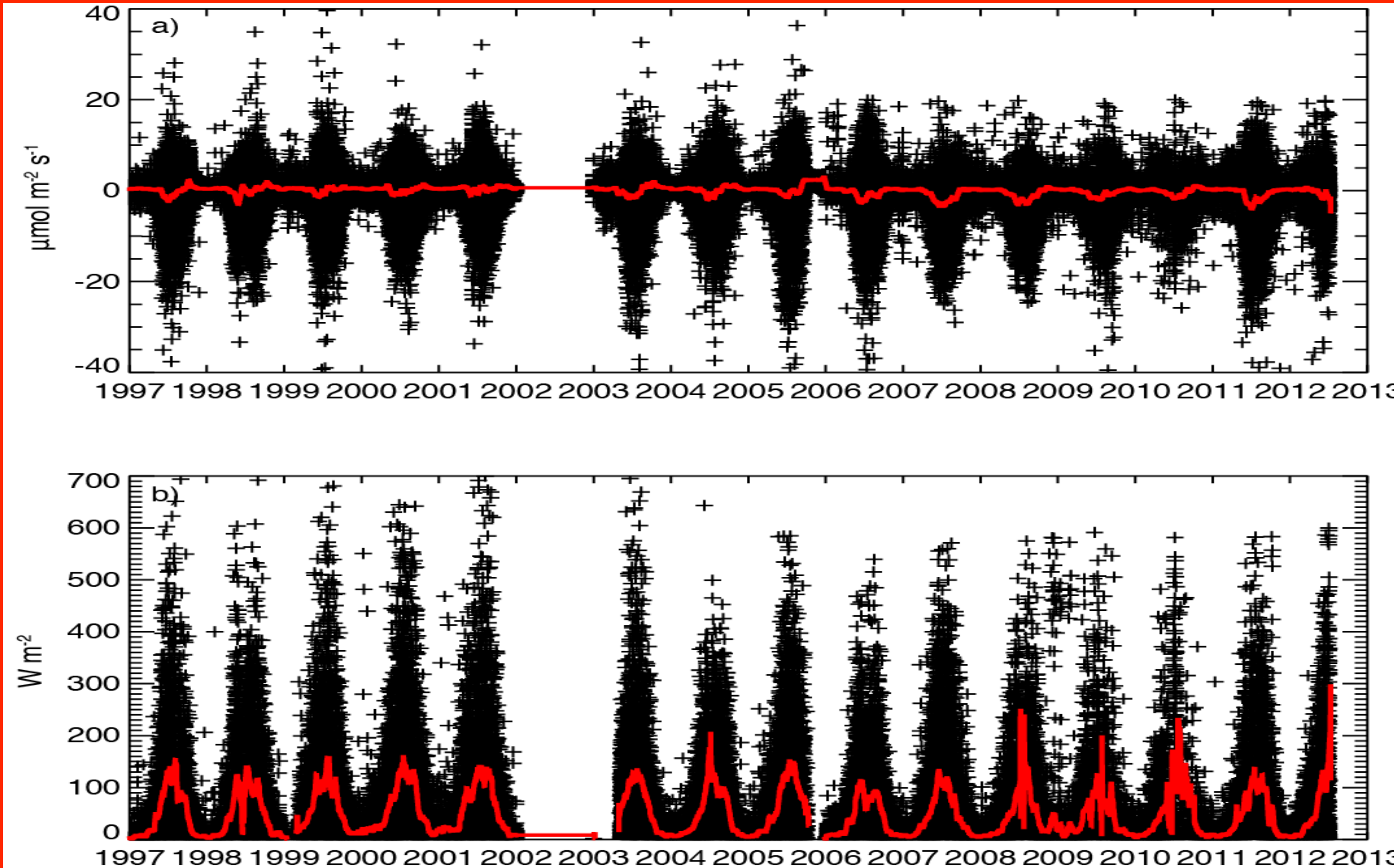


Where are we looking?



We have a very tall tower that might help!

Long-term NEE and ET has weak trends



What could we do with these data?

- Extract measure of productivity
- Identify modes of variability
- Derive standardized anomalies across modes of variability
- Assess autocorrelation of anomalies to recognize statistical significance
- Test for anomaly correlation and lagged anomaly correlation across all modes
- Build predictive anomaly models to identify causality

Why?

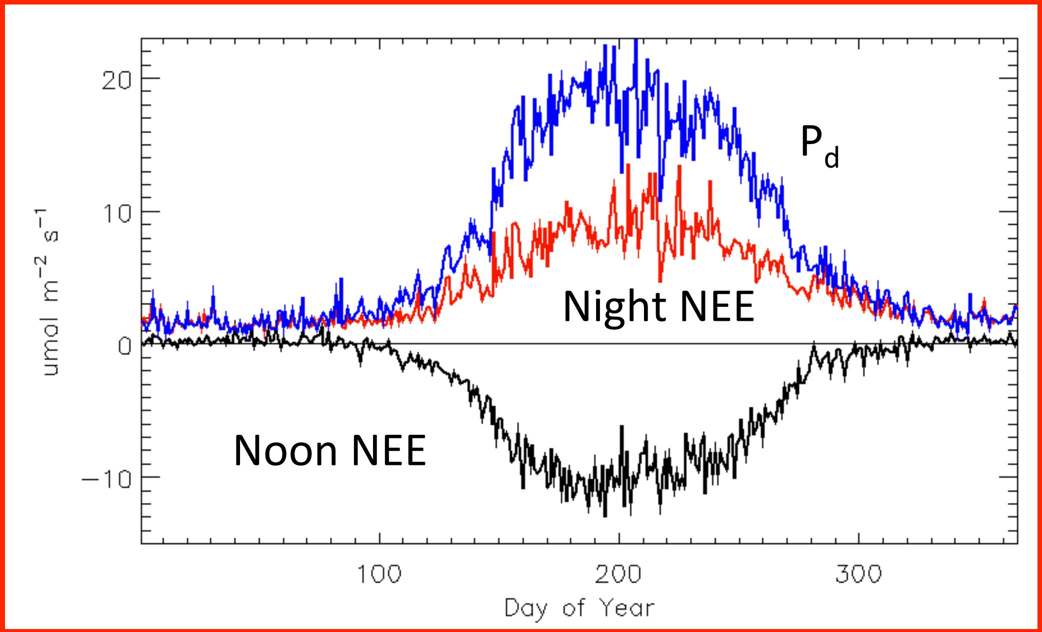
- Test 1. Positive lagged autocorrelation of productivity anomalies implies a strong internal feedback in response to extremes (e.g., non-structural carbohydrate allocation)

- Test 2. At some timescales, moisture stress can overwhelm internal feedbacks and lead to decreased productivity

- Essential observational tests for scaling from leaf to ecosystem and evaluating/developing models

From NEE to Productivity

- Flux tower derived GPP is sensitive to model selection and gaps (Desai *et al.*, 2008)
- INSTEAD: Use a data-based approach
  - P_d = Max nighttime observed NEE – Mean noon (10-14) NEE
    - Reject noon NEE is > 50% gap-filled



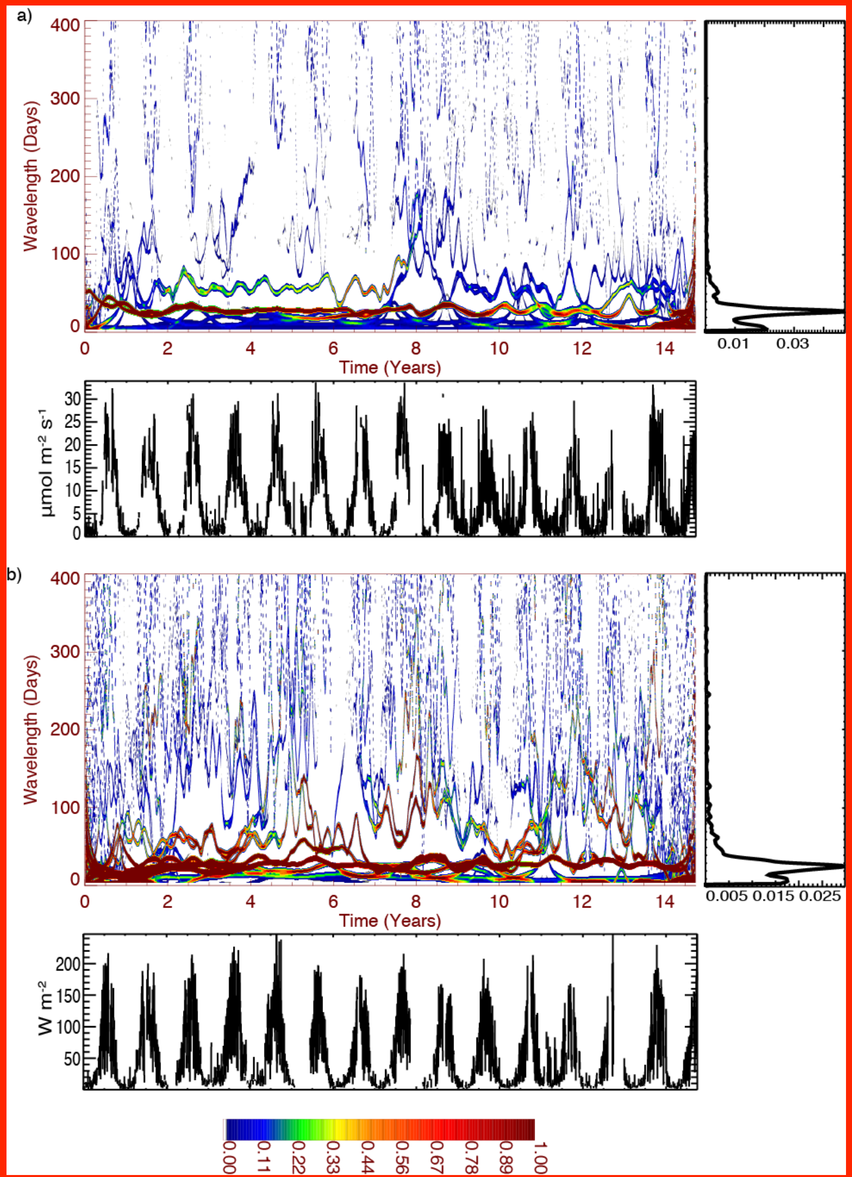
What to test?

- Productivity, moisture, and temperature

Abbreviation	Description	Source
P_d	Photosynthetic drawdown	Flux tower
EVI	Enhanced Vegetation Index, 8-day average	MODIS TERRA/AQUA
ET	Evapotranspiration	Flux tower
WUE	Water Use Efficiency (P_d/ET)	Flux tower
P_{recip}	Daily precpitation	NCDC + NARR Reanalysis
Q_{soil}	10 cm soil moisture	NARR Reanalysis
T_{mean}	Daily temperature	Flux tower + NCDC
T_{min}	Minimum daily temperature	Flux tower + NCDC
T_{max}	Maximum daily temperature	Flux tower + NCDC
T_{range}	Daily temperature range (max - min)	Flux tower + NCDC
LST	Land Surface Temperature, 8-day day/night average	MODIS TERRA/AQUA

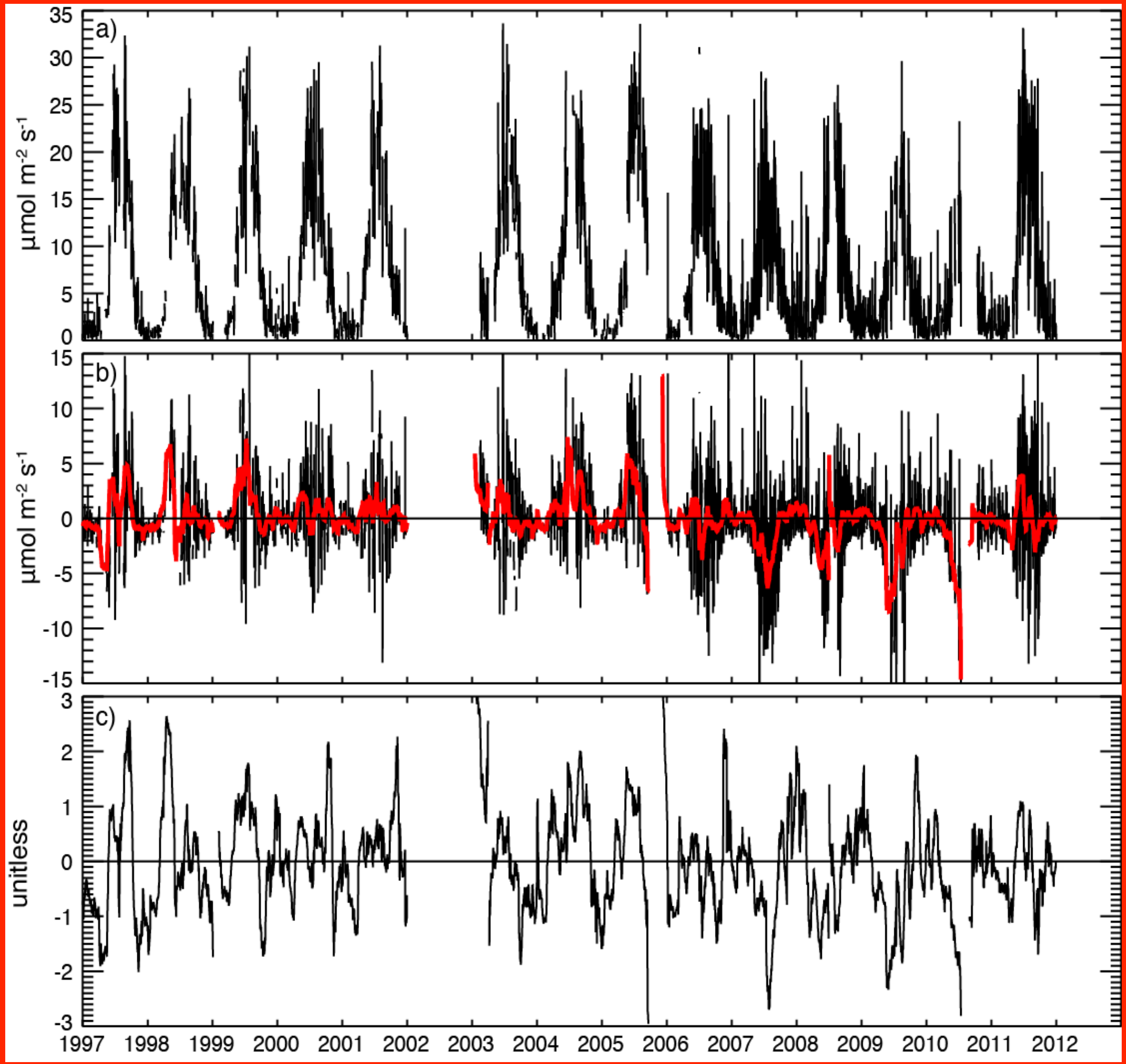
Identifying modes of variability

- Hilbert-Huang Transform (HHT) well suited to gappy non-stationary data
- Discontinuous empirical mode decomposition (DEMD) based approach
- P_d and ET spectra show characteristic modes of variability at daily, weekly, monthly, seasonal scales

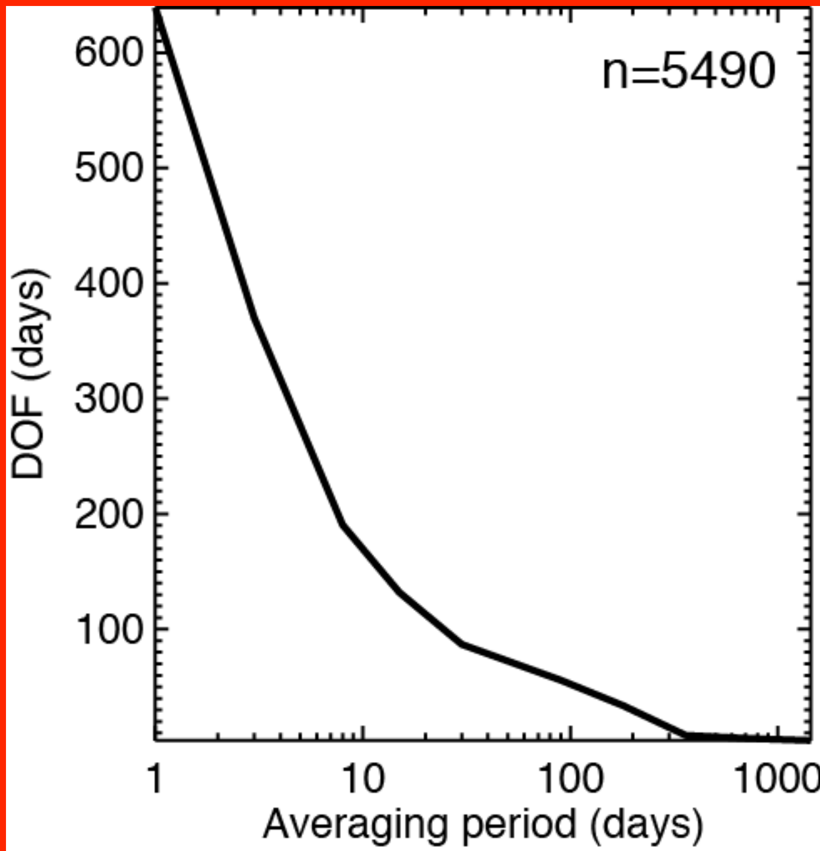


Pet peeve 1: Standardizing anomalies

- Without anomalies, spurious correlation from orbital forcing are likely!
- Focus on standardized anomalies to normalize units



Pet peeve 2: Autocorrelation is a bugger

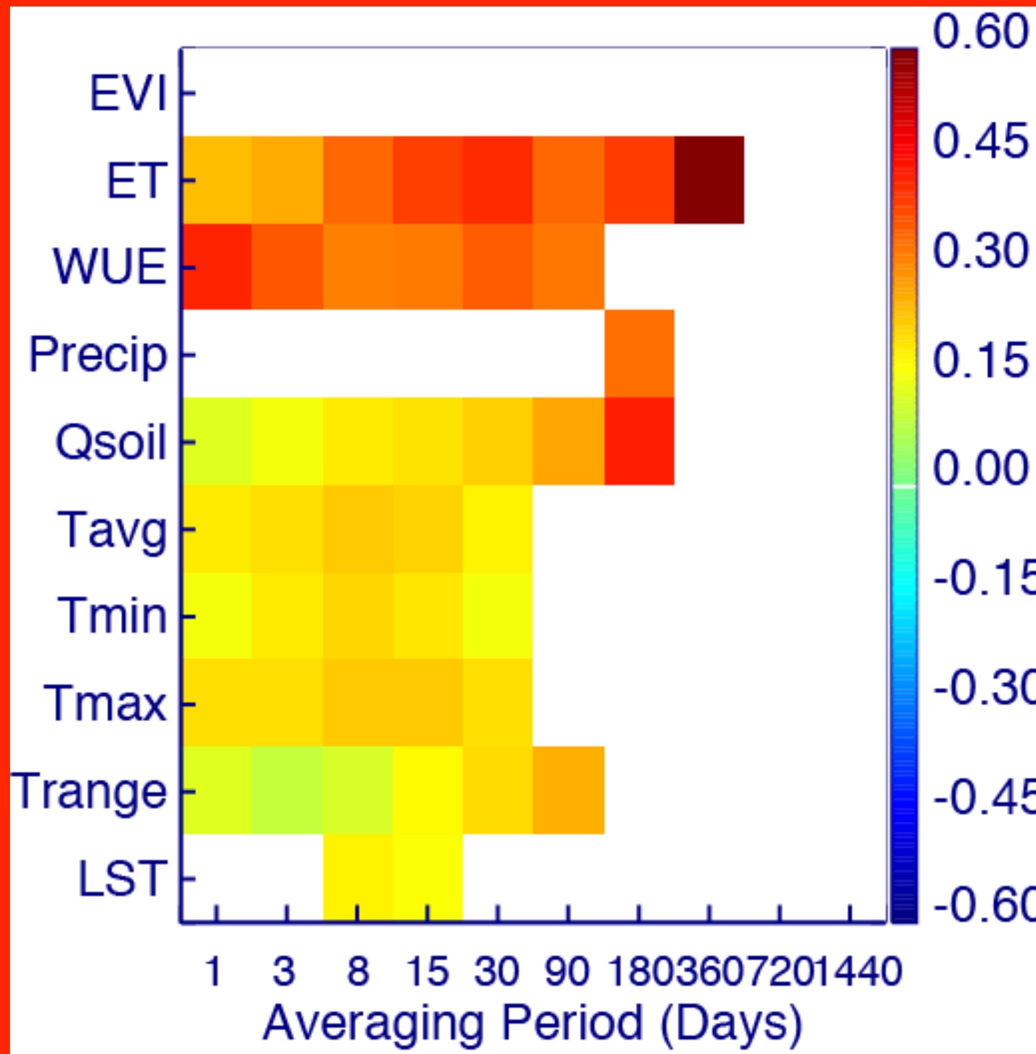


$$N_* = \frac{N}{\sum_{t=N/2}^{N}\left[\left(1-\frac{t}{N}\right)\rho_t^X \rho_t^Y\right]}$$

- Autocorrelated data overstates N for significance tests
- Used approach of Bretherton et al (1999) to estimate true degrees of freedom (DOF) of correlating time series as a function of autocorrelation

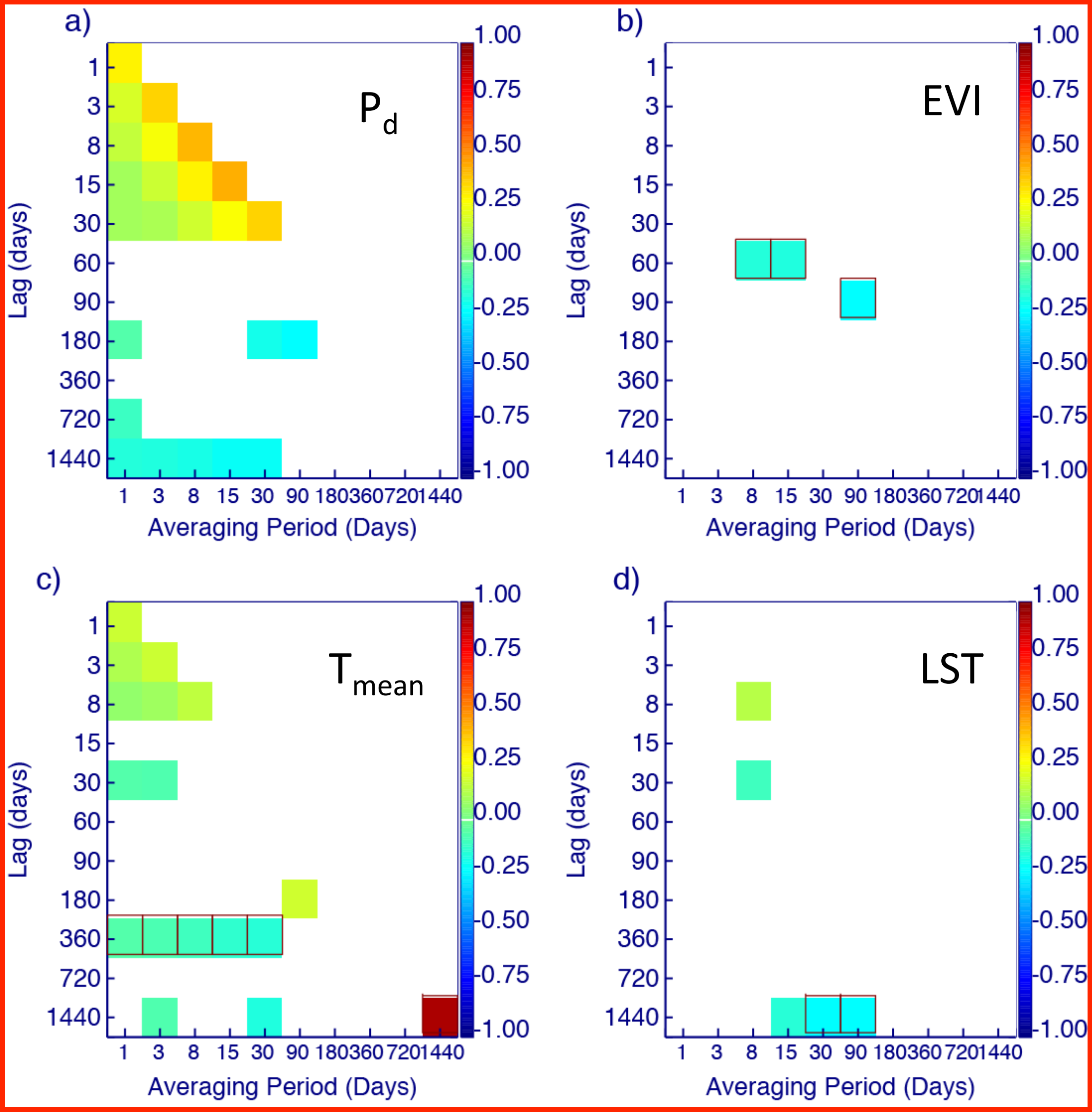
What do you get?

- Only significant correlations shown
- Moisture and temperature anomalies positively correlate with P_d at sub-annual scales

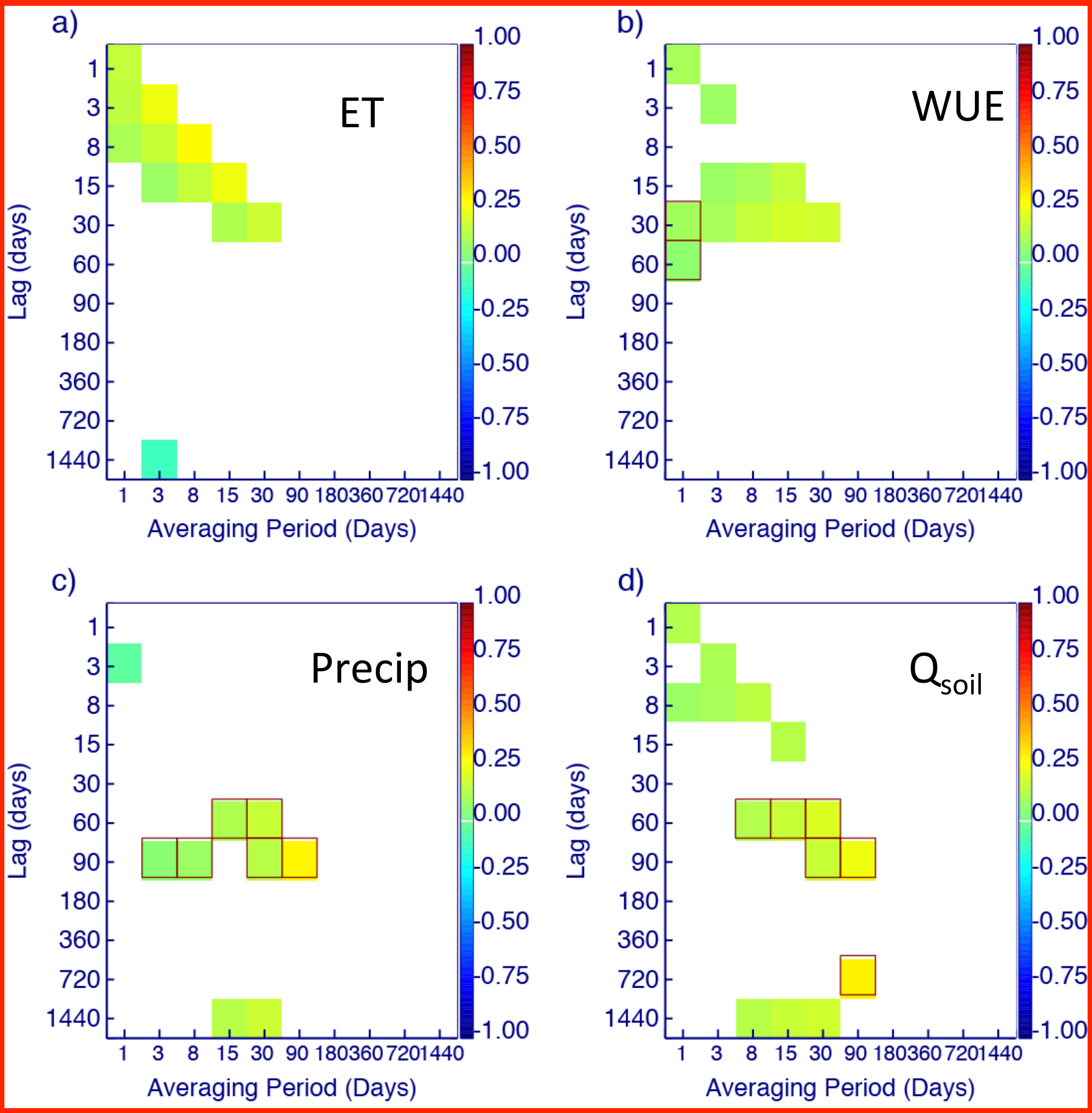


Lags are interesting

- Red squares = correlations > autocorrelation
- Remotely sensed variables (EVI,LST) have limited ability to predict P_d
- Previous year weekly-monthly temperature has a weak negative relationship to P_d



Moisture lags even more interesting



- Earlier season (2-3 month) weekly-seasonal precipitation/soil moisture has strongest predictive effect on P_d
- Beyond that, P_d autocorrelation dominates

Granger causality approach concurs

- Approach of Detto et al (2012) to build multiple-lag regression to P_d
- Limited predictive ability beyond monthly scale
- Moisture variables continue to be interesting

Variable/Averaging period (Days)	1	3	8	15	30	90
EVI						
T_{mean}	1	3	8			
LST						
ET	1-3	3	8-15	15		
WUE	1-3	3-30	8-30	15-30	30	
P_{recip}	3			60	60	
Q_{soil}			60	60	60	

Thoughts?

- Strong AR-1 autocorrelation for P_d supports a short term internal feedback at daily to seasonal scales
- Soil moisture is important, even in mesic forests, especially for early season moisture availability, which impacts late season photosynthetic stress
- 15-years of data may still be not long enough to credibly evaluate interannual to decadal scale modes of variability (see also recent Harvard Forest papers)
- Remotely sensed vegetation indices may not be so useful for detecting GPP anomalies
- Next steps: Model evaluation, multi-site evaluation

Thanks!

- More at:
  - Desai, A.R., submitted. Influence and predictive capacity of climate anomalies on daily to decadal extremes in canopy photosynthesis. Photosynthesis Research, #PRES-S-12-00139.
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