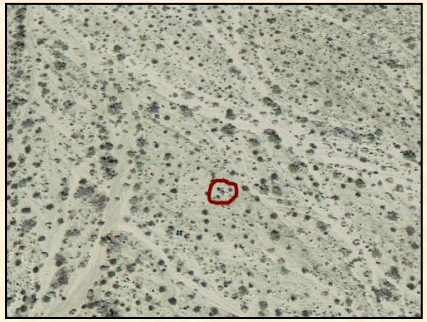
Terrestrial ecosystem carbon exchange across semiarid southwestern North America

Joel Biederman, R. Scott, G. Ponce-Campos, M. Litvak, W. Oechel, M. Goulden, T. Kolb, E. Yepez,J. Garatuza, D. Bowling G. Maurer, D. Krofcheck, et al.

MAP = 800 mm

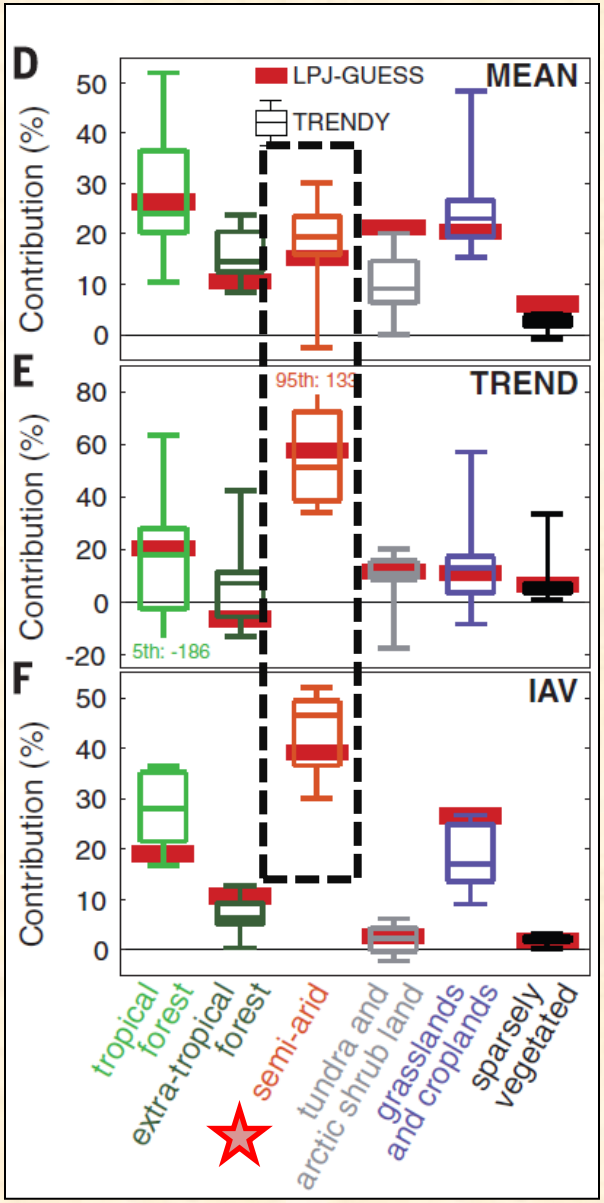
MAP = 500 mm



MAP = 120 mm

MAP = 350 mm

Semiarid lands in the global C cycle



- Global-scale studies → semiarid lands → increasing trend and interannual variability **(IAV)** of land C sink

- Terrestrial biosphere models, remote sensing models poorly constrained by semiarid measurements

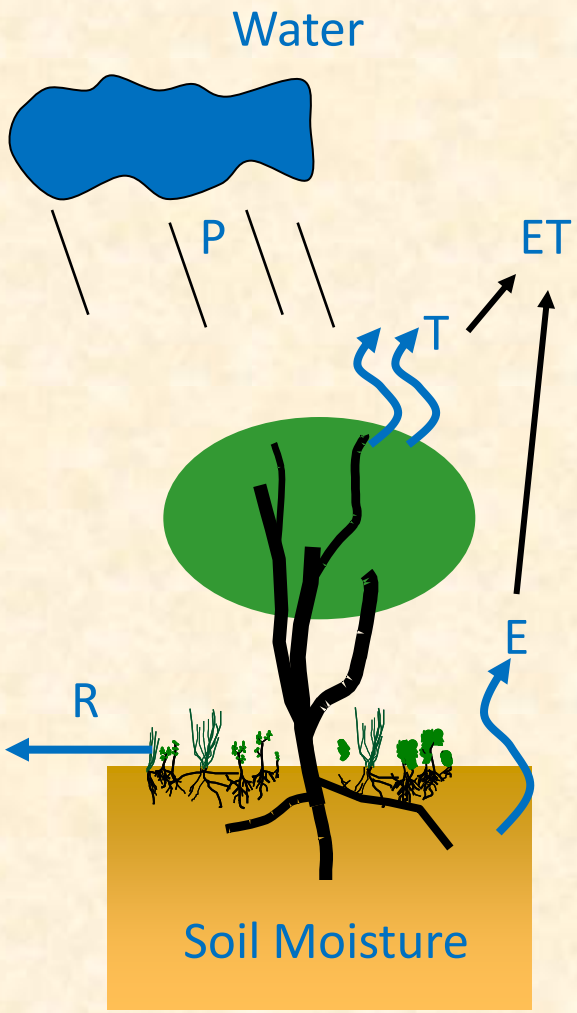
The Land CO_2 Sink: *Ahlström et al.* 2015 (Science)

Research Questions:
In semiarid SW North America. . .

1. What are the magnitudes of spatial and interannual variability in measured CO_2 exchange?

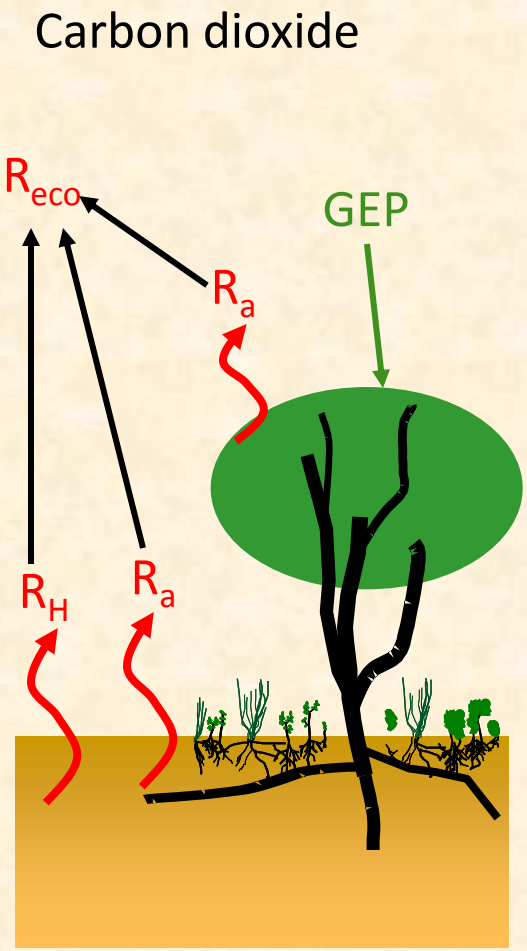
2. How well is the measured variability captured by models?
   - terrestrial biosphere models
   - remote sensing models

Water and CO_2 Exchanges



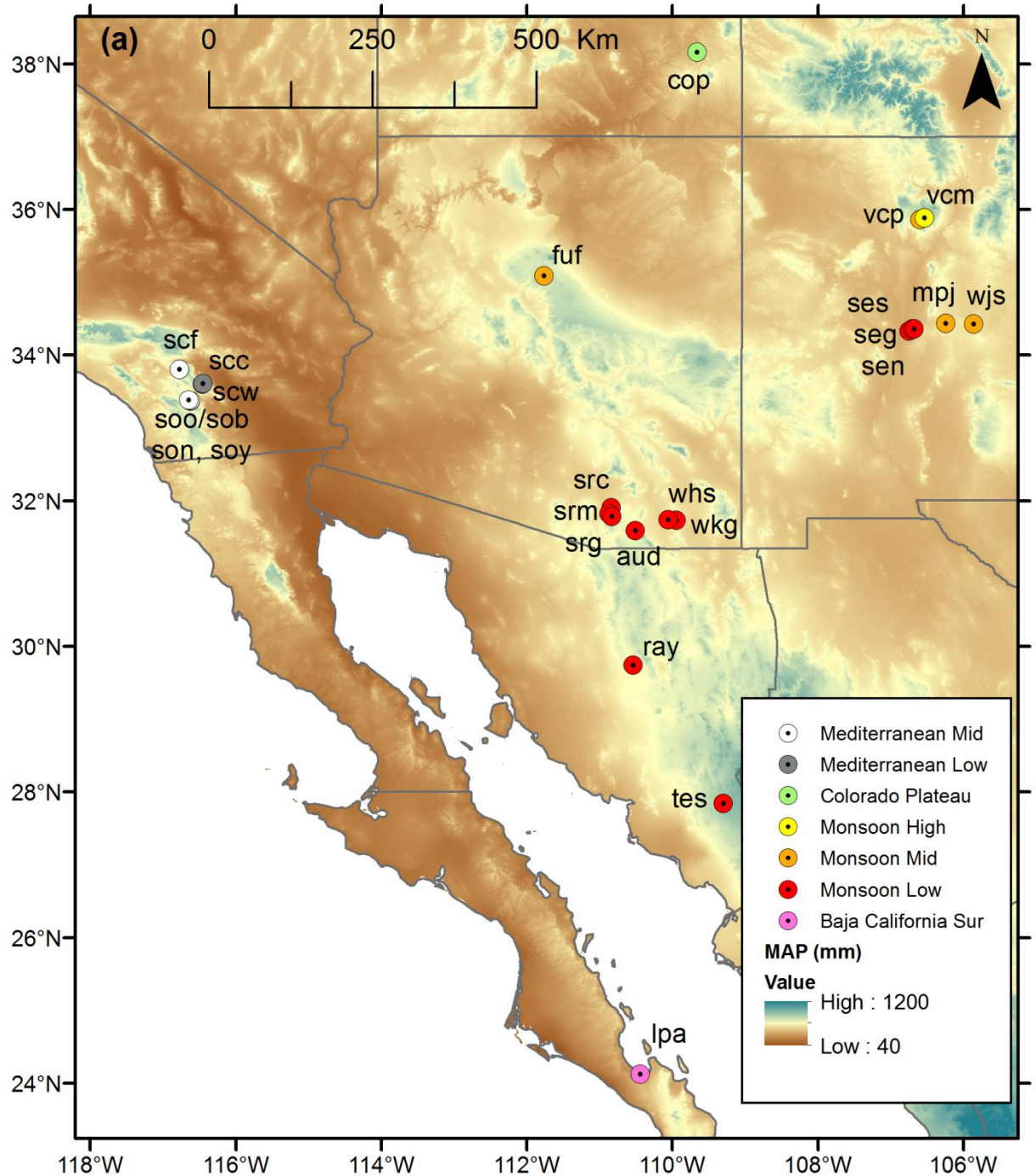
Net Ecosystem Production

NEP = GEP - R_{eco}

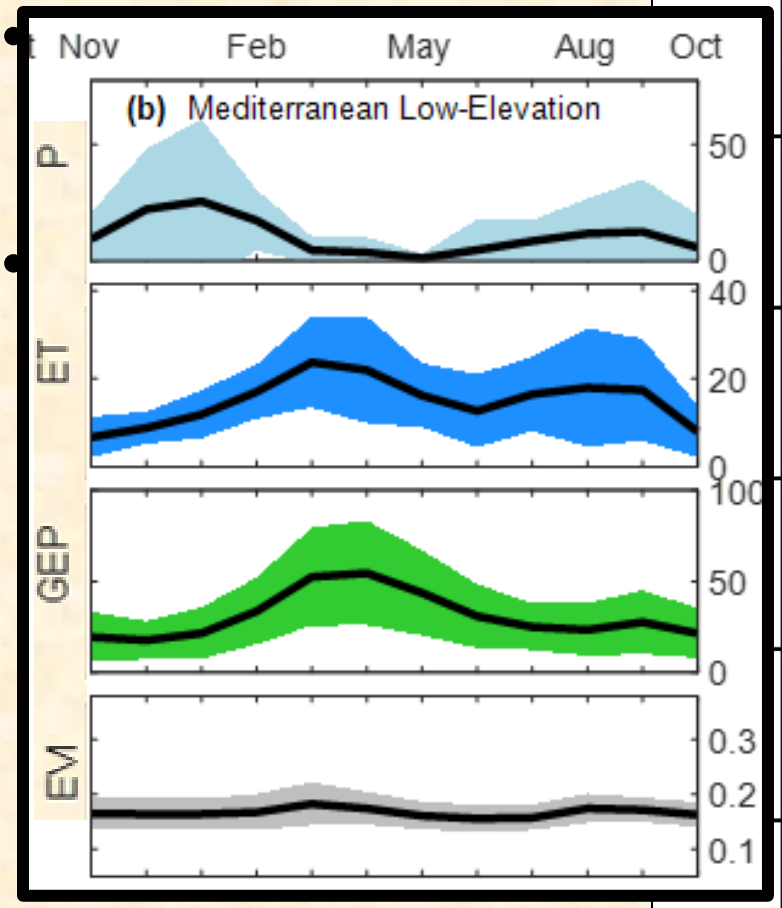


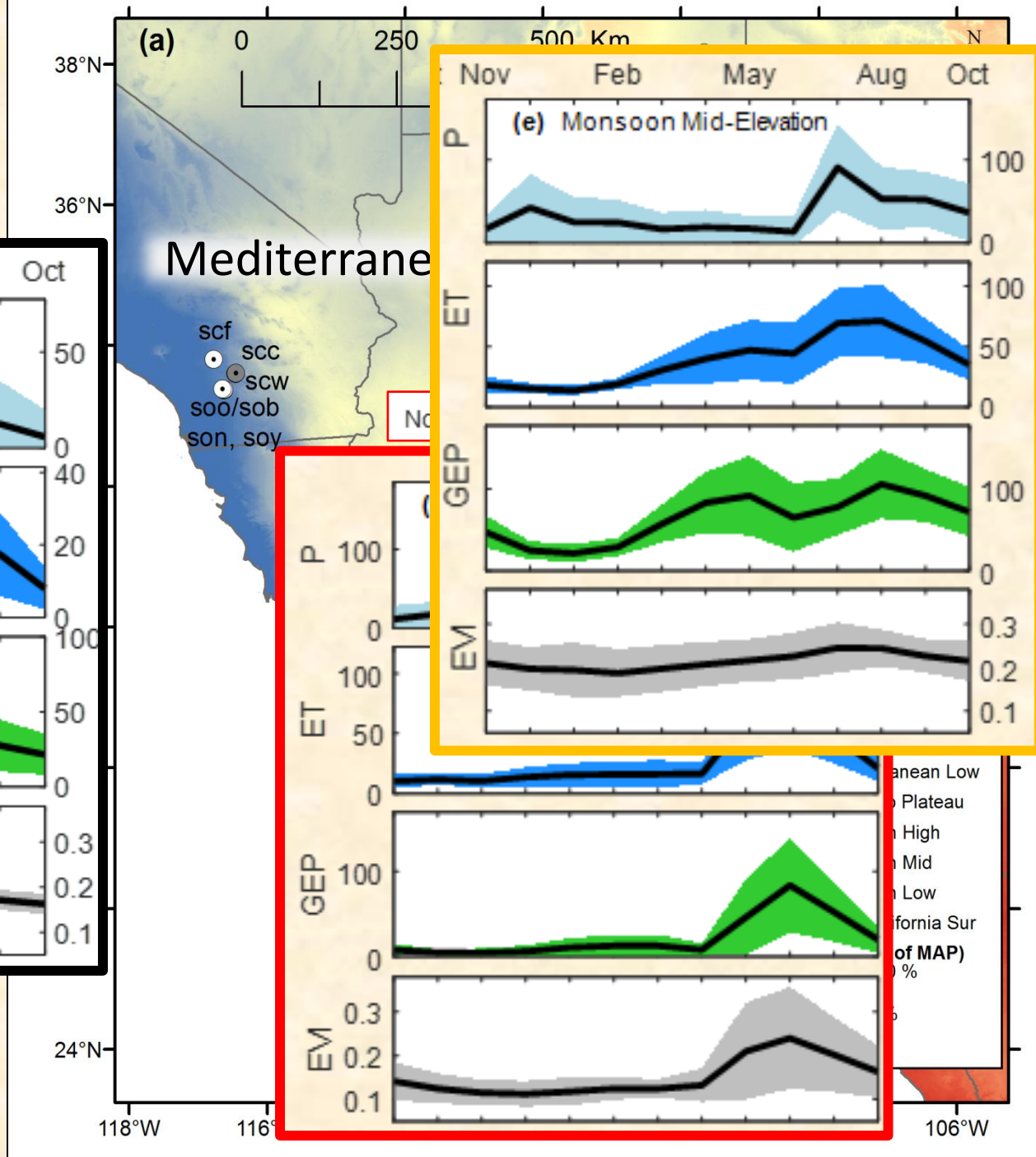
Eddy Covariance Measurements

- 25 sites, 150 site-years
- SW biomes: desert, grass, shrub, savanna, woodland, forest

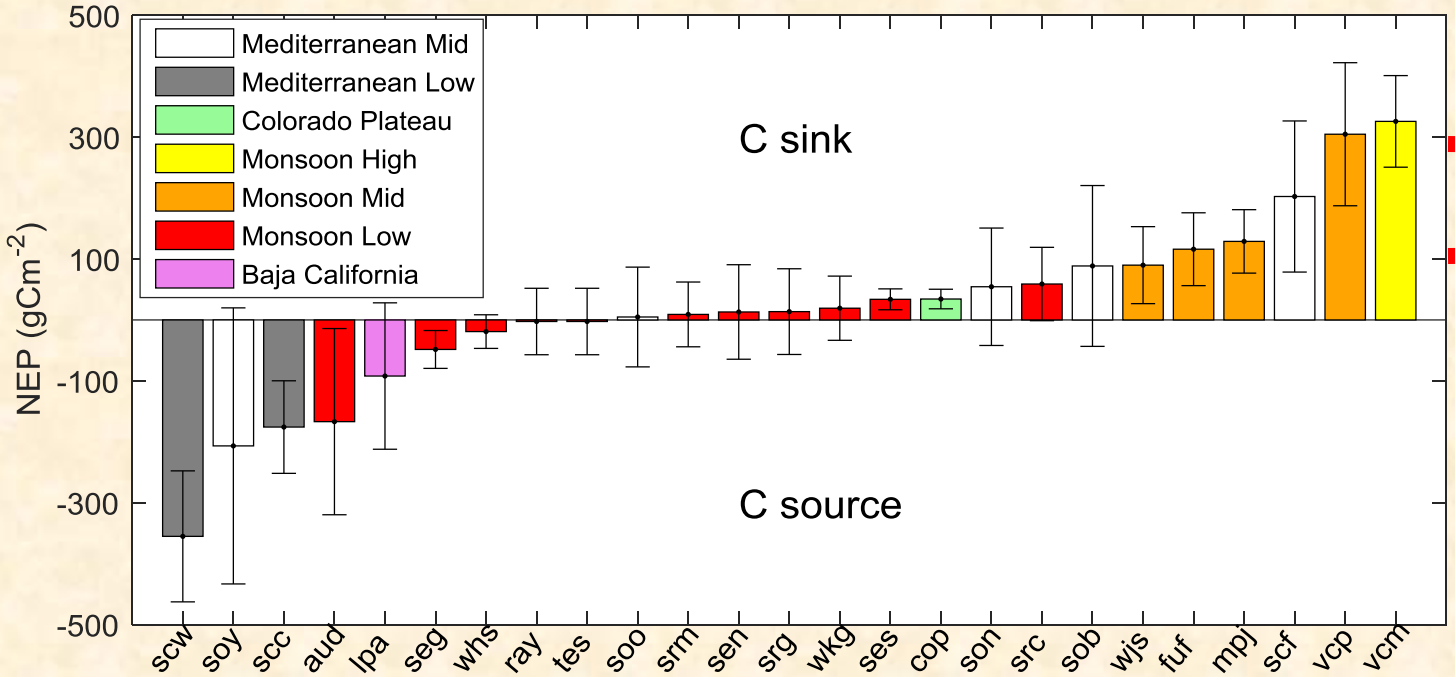


Complexities of the Southwest





Annual NEP: Sinks, Sources, Pivots

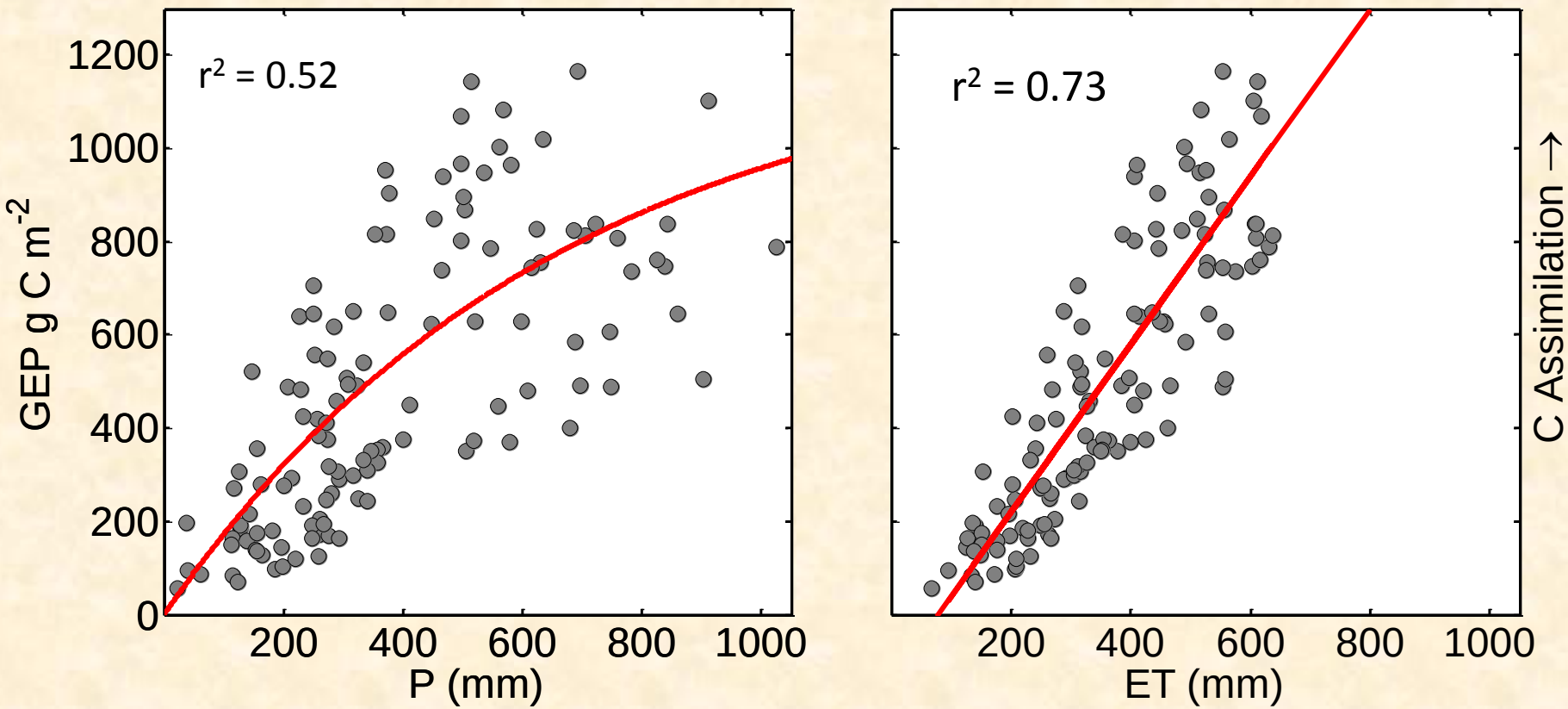


typical mesic forest range

Biederman et al., in review

- Wide range of persistent sinks, sources.
- ~Half of sites fluctuate between sink/source in wet/dry years – **pivot point precipitation** (*Scott et al.* 2015)

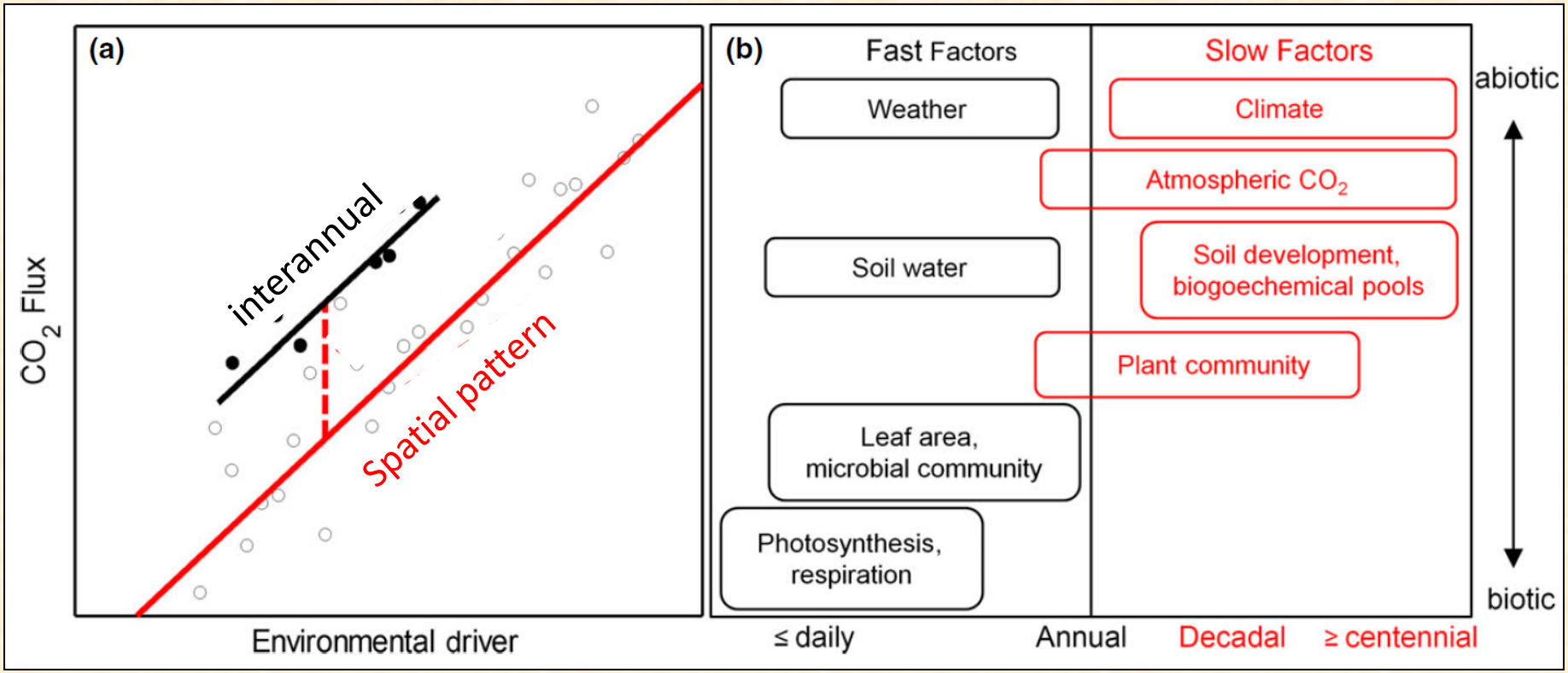
Annual Photosynthesis vs. Water



ET ≈ water available after runoff & drainage

Biederman et al., GCB 2016

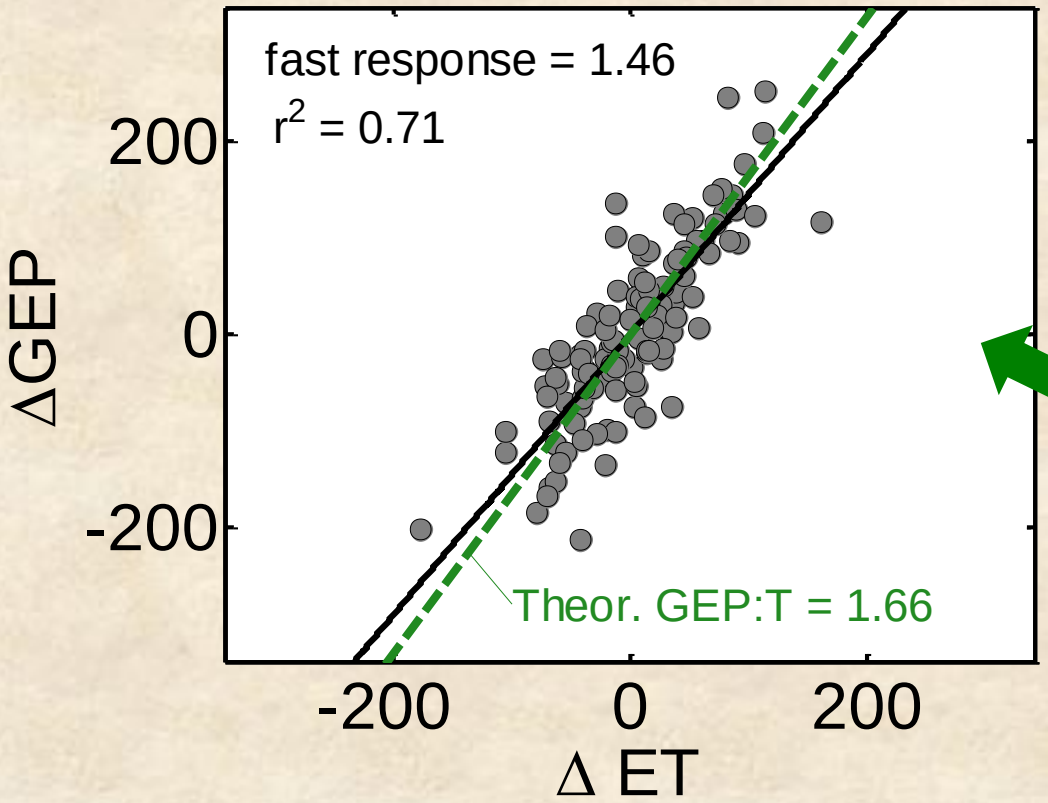
Analysis Framework

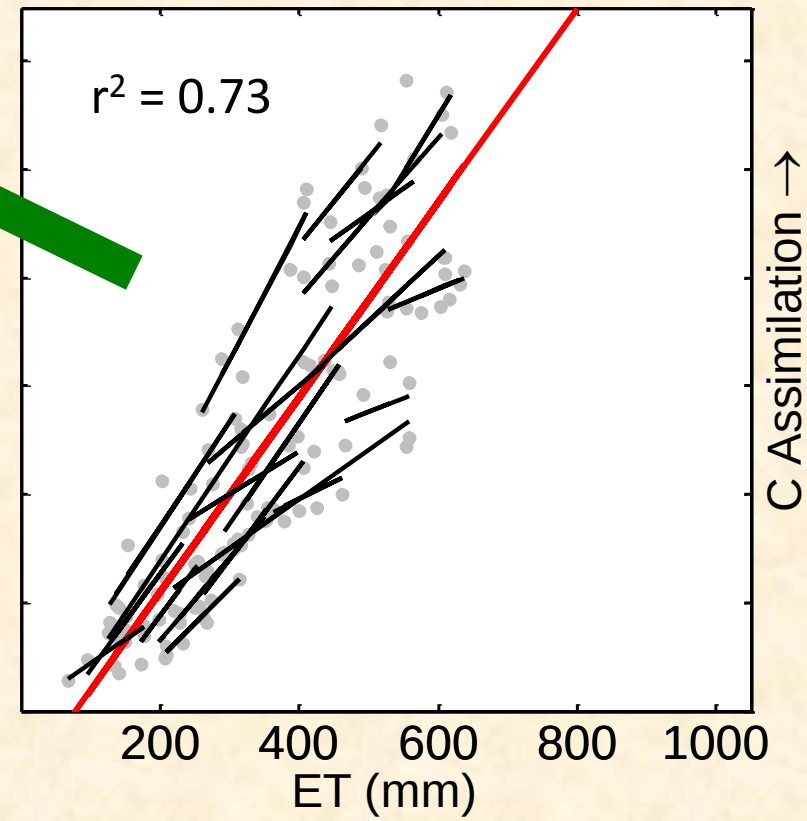


- Slow Factors ~ **spatial** pattern across mean values
- Fast Factors ~ **interannual** response at a site

Lauenroth & Sala, 1992; Huxman et al., 2004; Biederman et al. GCB 2016

Annual Photosynthesis vs. Water

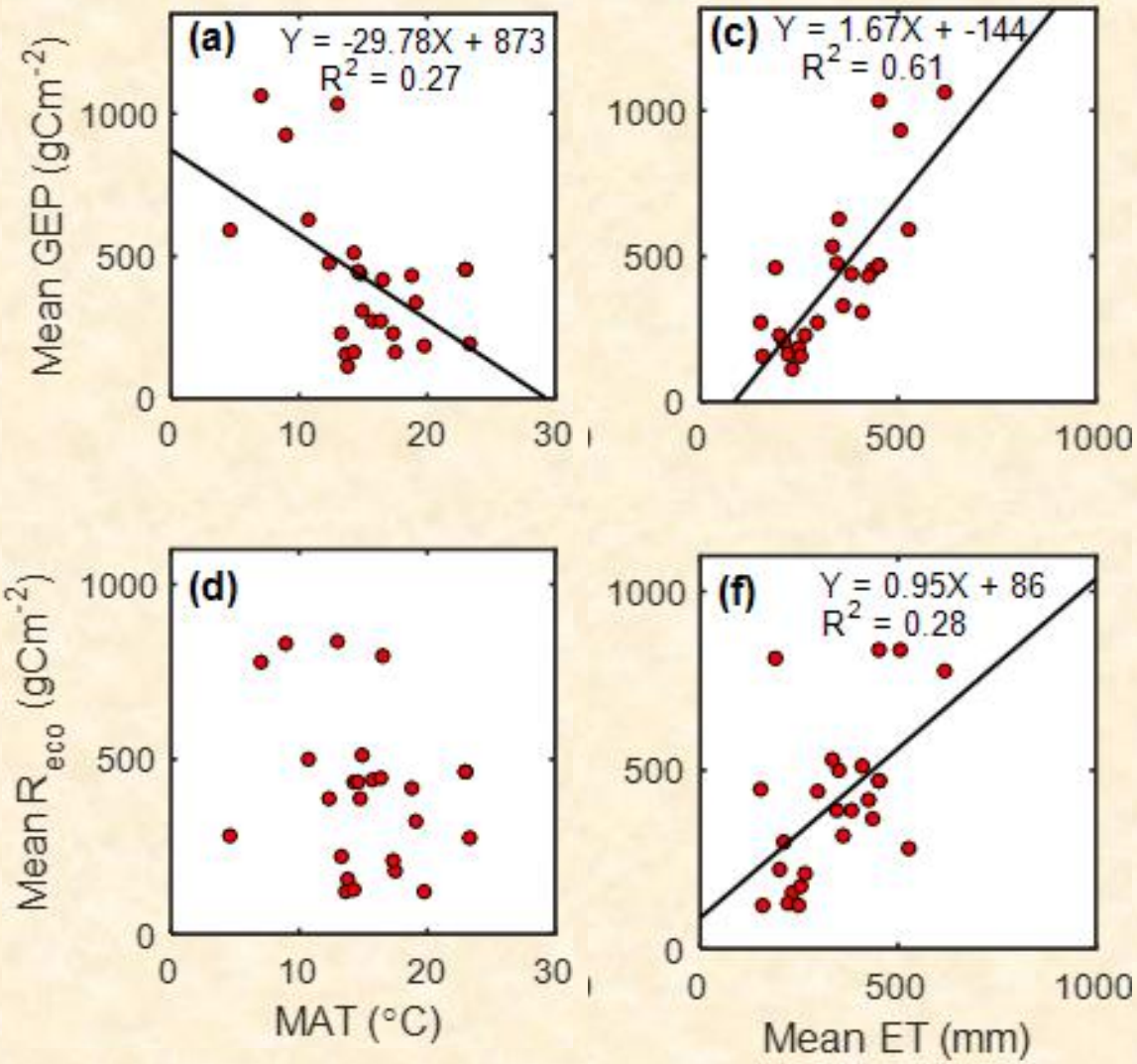


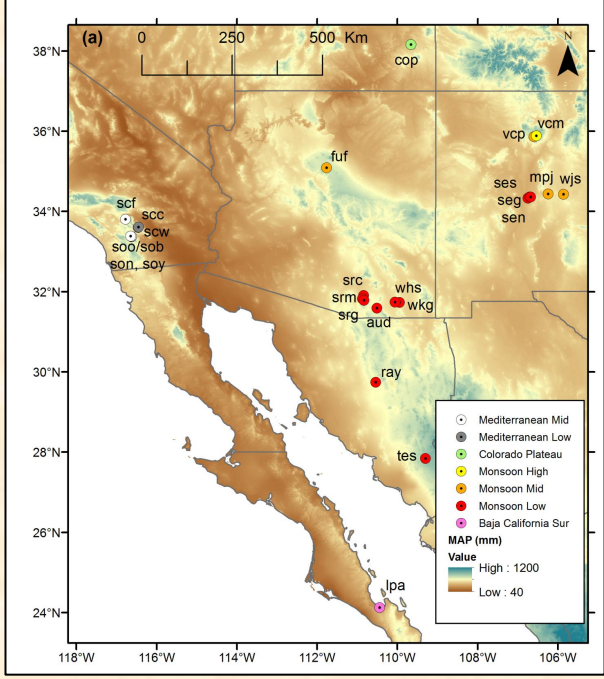


Similar interannual responses to water availability across diverse ecosystems

Biederman et al., GCB 2016

Spatial patterns - climatic temperature and water avail.



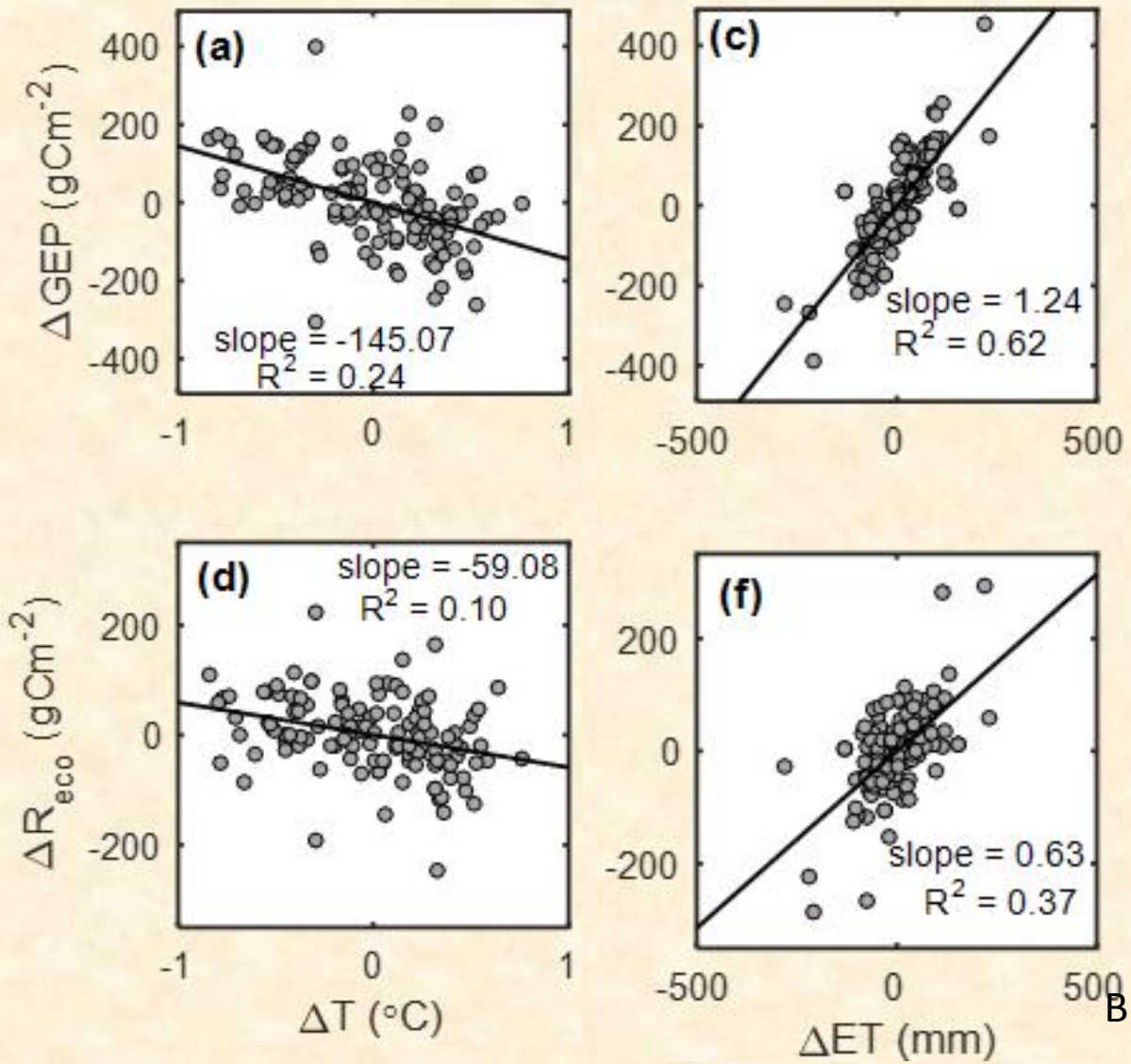


GEP ↑with water
↓with MAT

Respiration ↑
with water

Biederman et al., in review

Responses to temperature and water IAV
Δ from multi-year mean

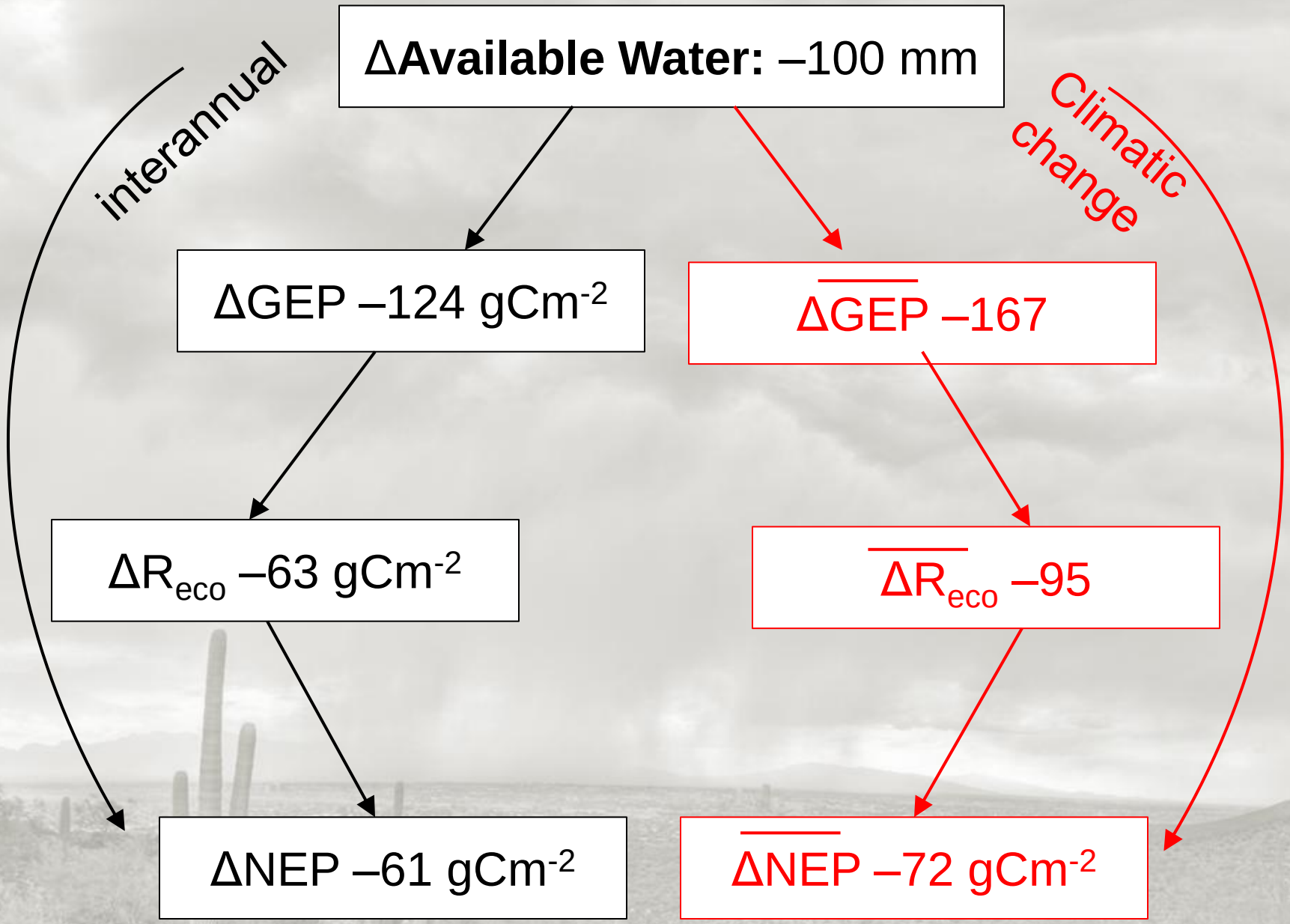


<u>Negative T response</u>

- Interannual 5 X spatial for GEP
- Persists when controlling for Water-Temp. Correlation

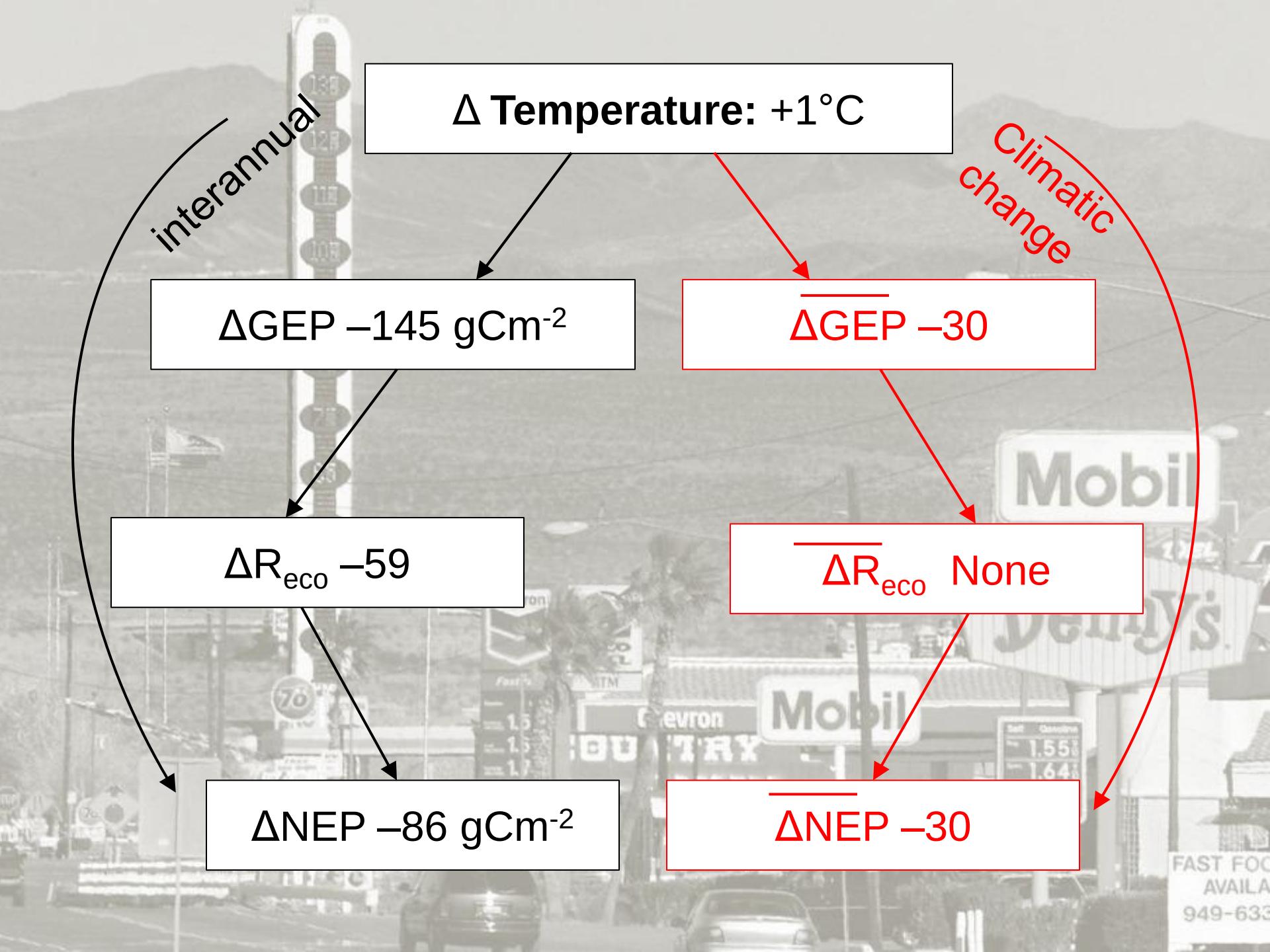
Biederman et al., in review

ΔAvailable Water: –100 mm

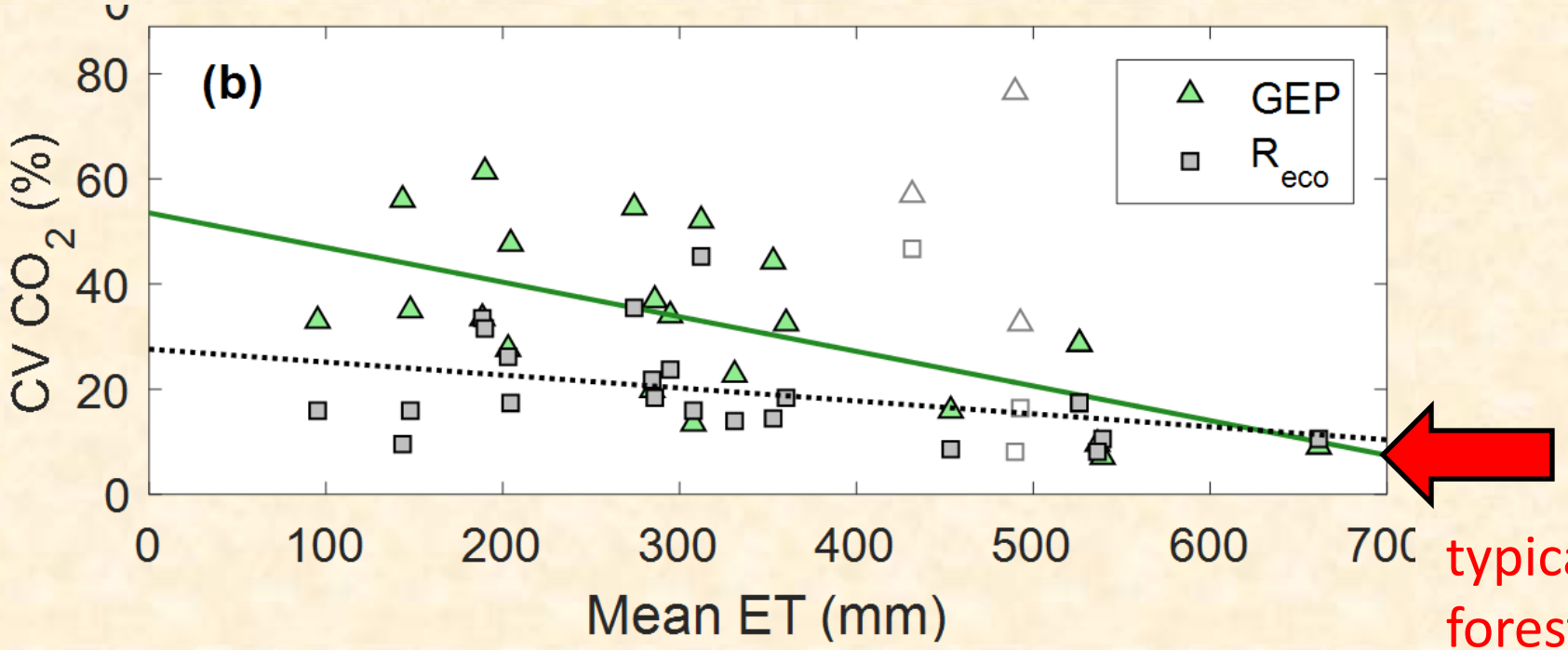


Biederman et al., GCB 2016

Δ Temperature: +1°C
Mobil
Denny's
Chevron
Mobil
Chevron
76
FAST FOO
AVAILA
949-633


Δ Temperature: +1°C
interannual
Climatic change
ΔGEP –145 gCm-2
ΔGEP –30
ΔReco –59
ΔReco None
ΔNEP –86 gCm-2
ΔNEP –30

High Internannual Variability (IAV)

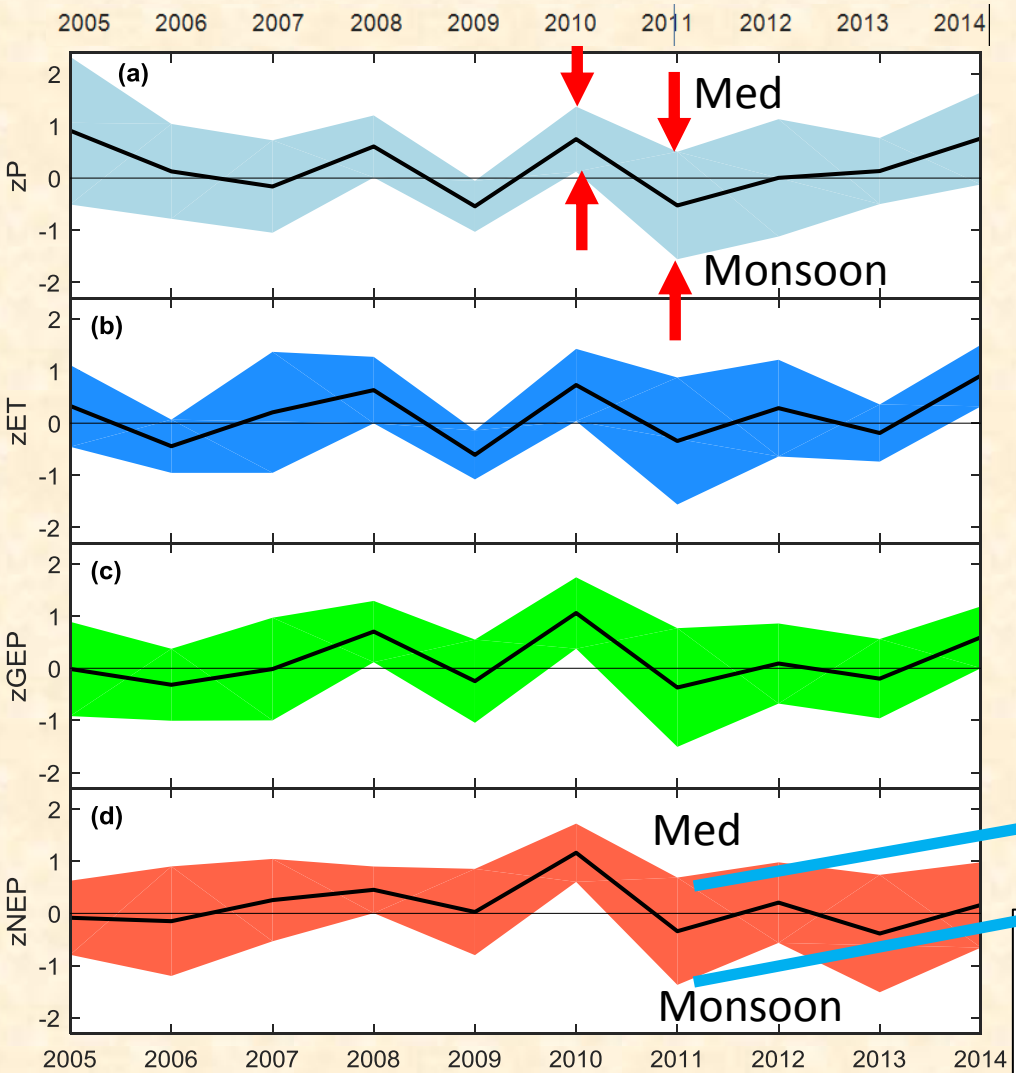


typical mesic forest CV <10%

- IAV is highest at the driest sites
- Water inherently more variable than light, nutrients.

Biederman et al., in review

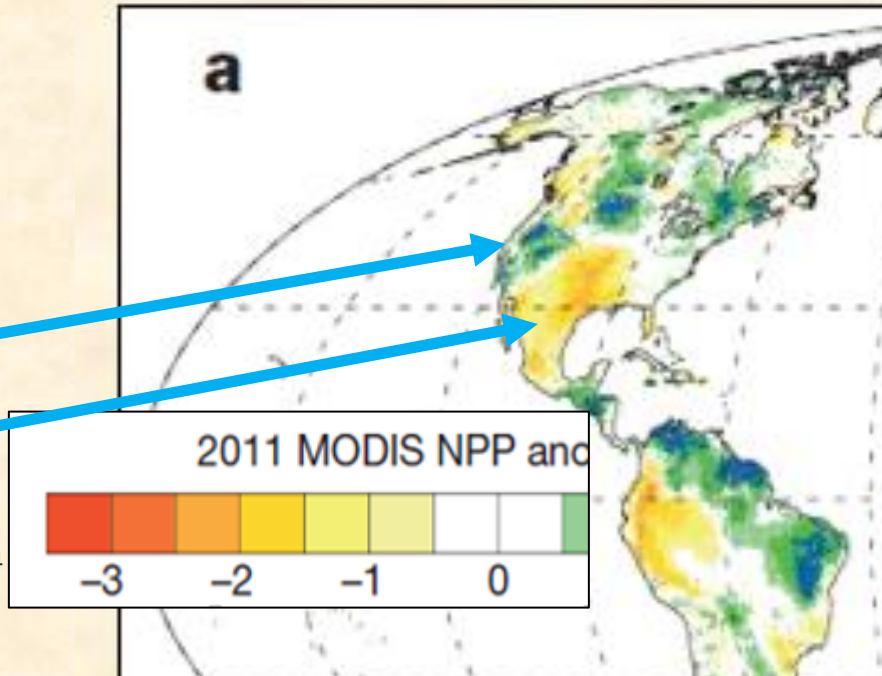
IAV at Southwest Regional Scale



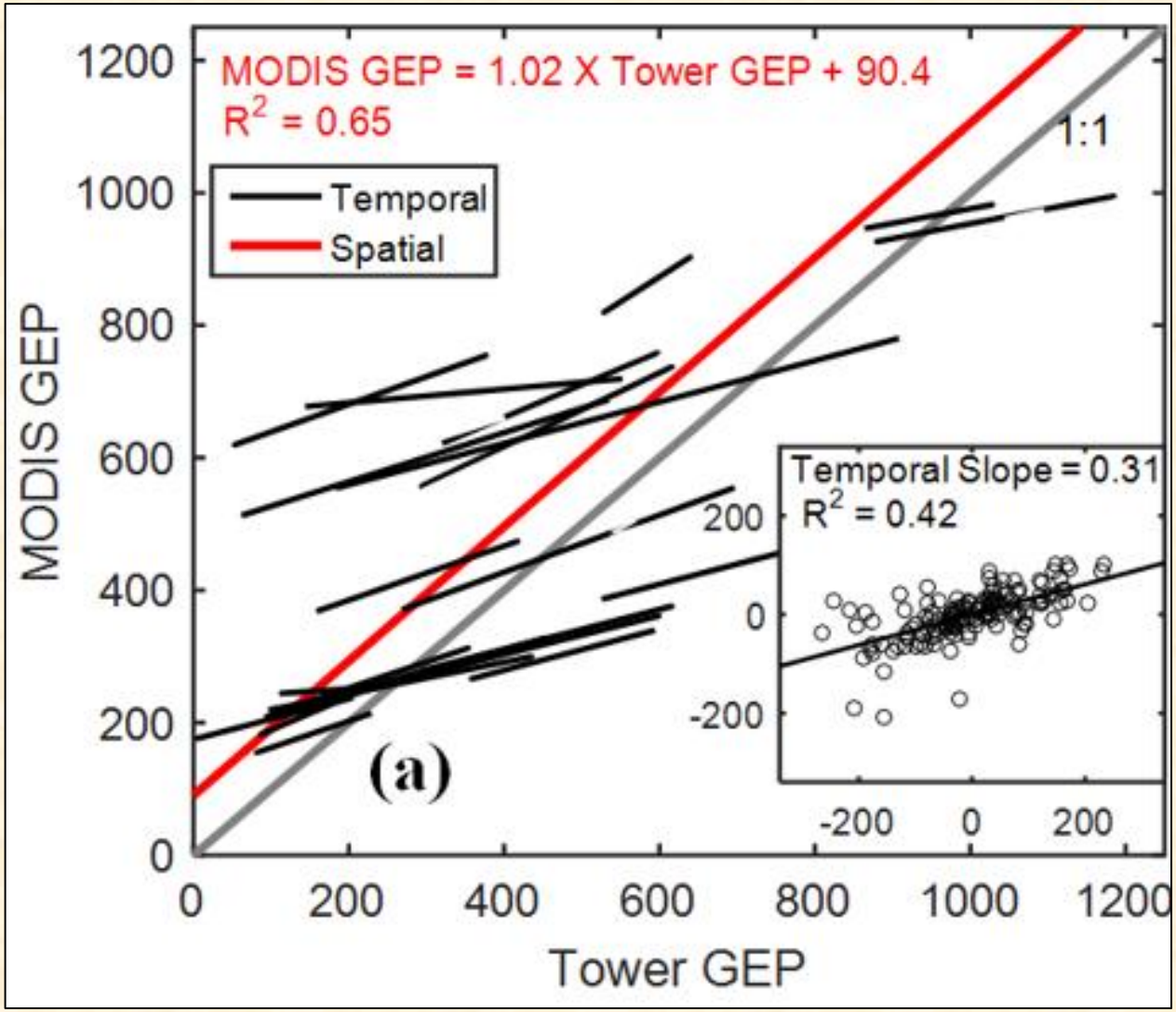
Biederman et al., in review

Coherence varies:

- 2010 wet everywhere, big sink
- 2011 wet Mediterranean sites, dry Monsoon sites.
- zNEP agrees with MOD17 NPP



MODIS Model vs. EC Tower

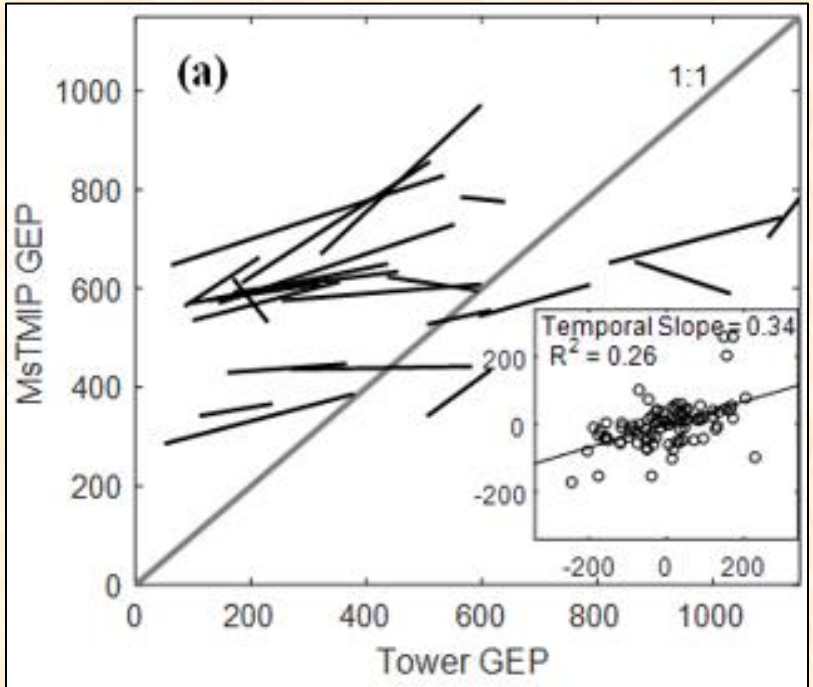


MOD17A2 GEP

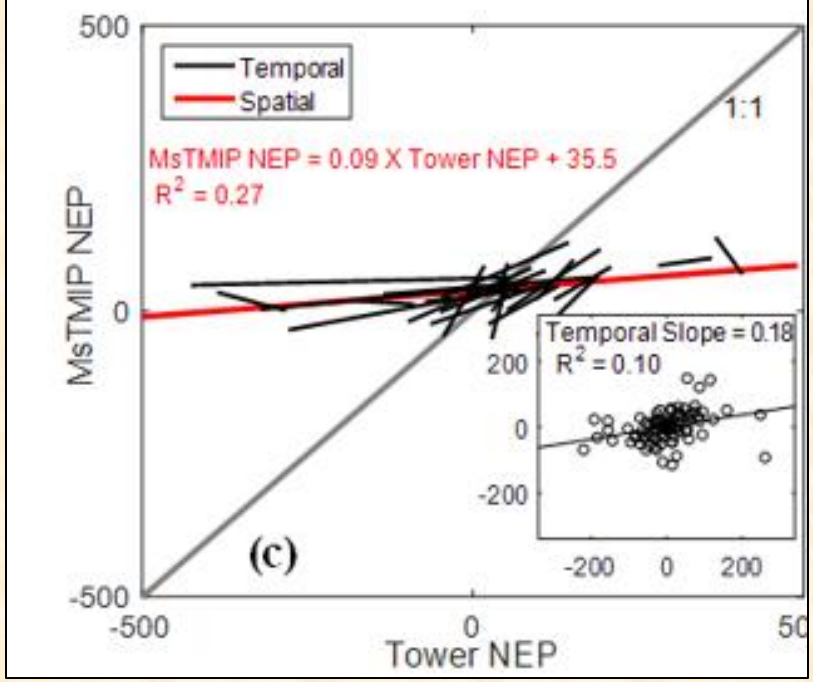
- captures spatial pattern
- 31% of IAV magnitude

Biederman et al., in review

MsTMIP vs. EC Tower



- No spatial pattern in GEP across Southwest
- 34% IAV magnitude, weak fit



- Little spatial NEP variation across Southwest
- ~20% IAV magnitude, weak fit

Biederman et al., in review

Conclusions

- C sinks, sources, and many sites that pivot
- Productivity and respiration both decline in warmer years
- MUCH higher IAV than mesic forests. IAV could be 3-5 times larger than current estimates
- Southwest ecosystems are complicated: seasonality, little change in greenness, interannual variability, water vs. temperature controls. . . .

Next Steps

- Run remote sensing models and terrestrial biosphere models with site-level weather data, ecosystem (cover) data
- Upscale EC tower data to gridded regional estimates using bio-geo-climatic empirical regressions
- Assess Southwest impacts on global C cycle using empirical product, remote sensing, biosphere models

Terrestrial ecosystem carbon exchange across semiarid southwestern North America

Joel.Biederman@ars.usda.gov

We are hiring

Ph.D. Assistantship in Semiarid Biosphere-Atmosphere Exchange at the University of Arizona with **Russ Scott and Dave Moore.** Advanced students with research experience (e.g., MS degree in an Earth science).

1) Field experiments at eddy covariance sites to elucidate carbon and water cycling processes.
2) Using simulation models or empirical techniques to upscale eddy covariance observations across the western U.S.

Contact: russ.scott@ars.usda.gov

Postdoc: Remote sensing of North American ecosystem dynamics, with **Bill Smith**

1. Evaluate novel remote sensing indicators against long term eddy flux tower observations distributed across North America.
2. Develop new remote sensing-based methods for upscaling eddy flux observations.

Contact Bill Smith (wksmith@email.arizona.edu).