Sub seasonal to seasonal land influence on the atmopshere

Pierre Gentine – Columbia University
Julia Green, Ben Lintner, Adam Sobel,
Jung-Eun Lee, Joe Berry, Usama Anber...

How can we assess the role of the surface?

- **Climate models:**

  define an experiment to isolate feedback
  (e.g. GLACE: impose soil moisture)

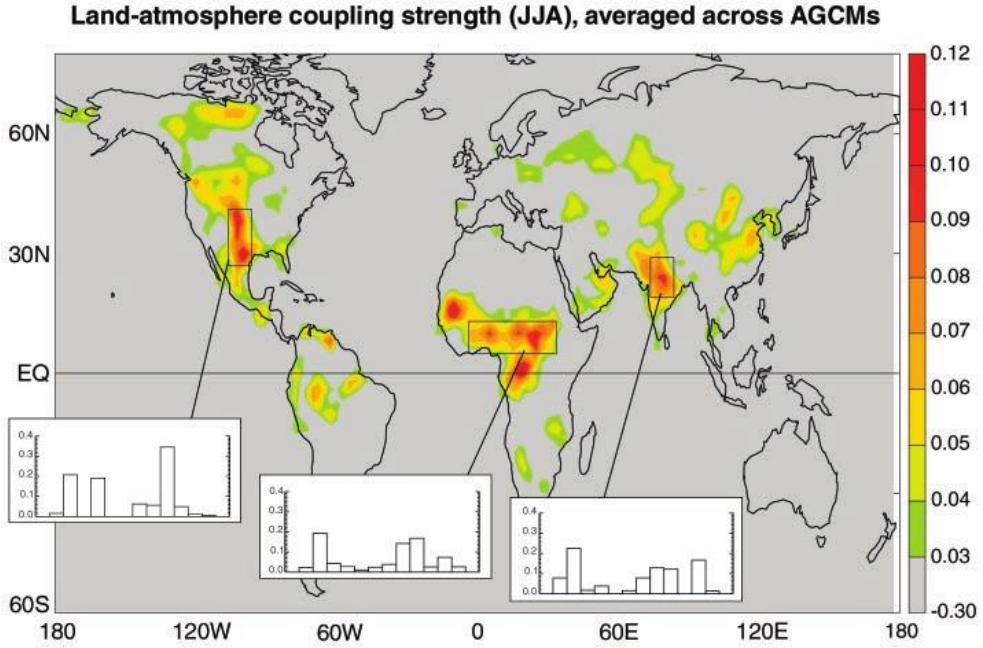


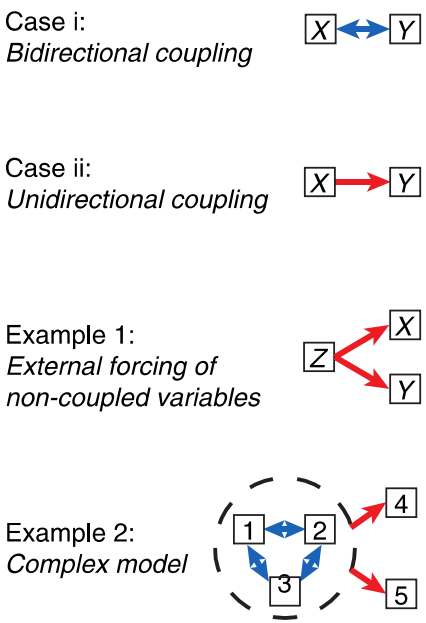
Fig. 1. The land-atmosphere coupling strength diagnostic for boreal summer (the Ω difference, dimensionless, describing the impact of soil moisture on precipitation), averaged across the 12 models participating in GLACE. (**Insets**) Areally averaged coupling strengths for the 12 individual models over the outlined, representative hotspot regions. No signal appears in southern South America or at the southern tip of Africa.

Koster, R. D. et al. (2004), Regions of strong coupling between soil moisture and precipitation, *Science*, *305*(5687), 1138–1140.

How can we assess the role of the surface?

- **Observations: limitations:**

- Many variables are **not observed** (e.g. soil moisture, evapotranspiration…)
- Only statistical link: **no causality**



Sugihara et al. 2012 *Science*

How can we assess the role of the surface?

- **Observations**:

We need:

- **Surface fluxes observations** (or estimates)

Solution: Use novel Solar-Induced Fluorescence (SIF)

- **Statistical method highlighting causality** and not correlations

Solution: multivariate Granger causality

Solar Induced Fluorescence (SIF)

- **Solar-Induced Fluorescence (SIF)**

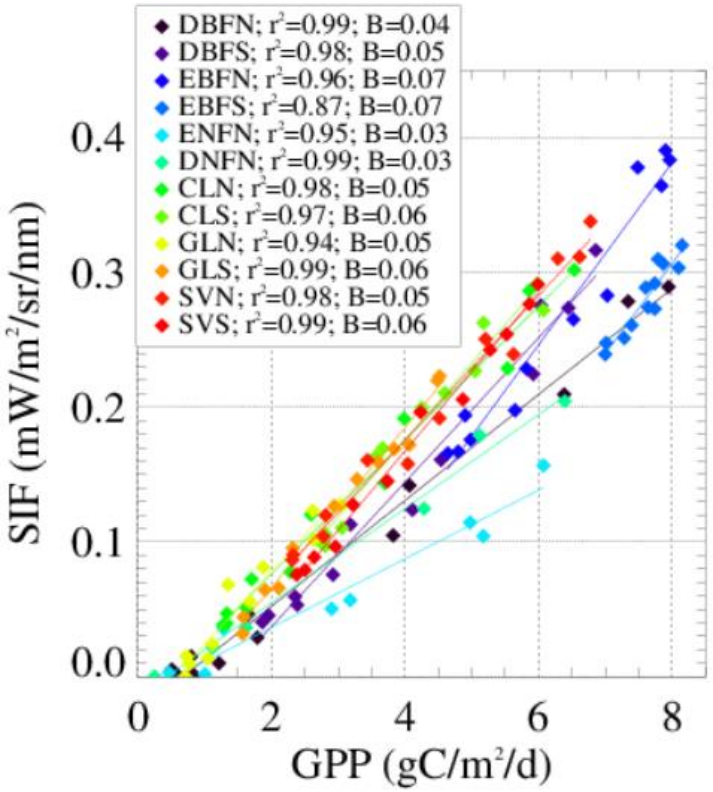
During photosynthesis a plant absorbs energy through its chlorophyll

- % used for ecosystem gross primary production (GPP)
- % lost as heat
- % re-emitted (SIF: **byproduct**)

Relationship between GPP and SIF is ~ linear

Responds to stressors (water, light, T)

We can then relate surface flux to water stress



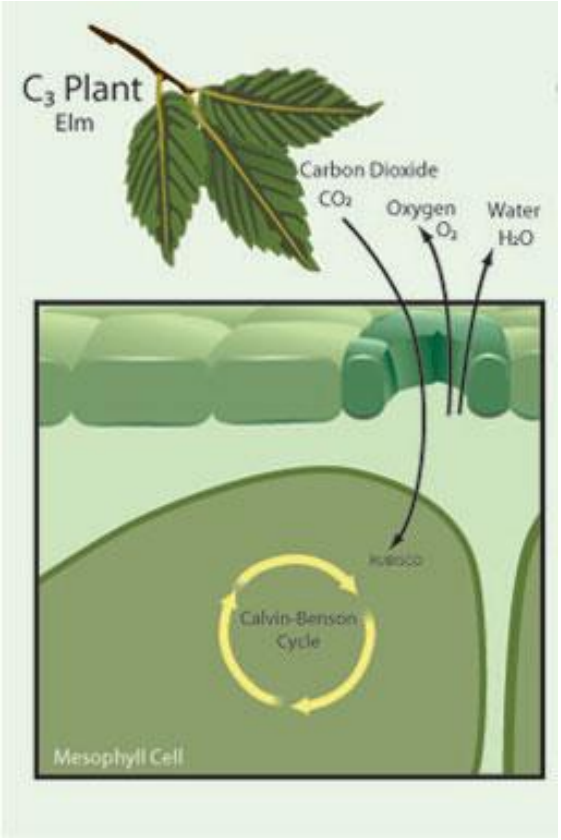
Guanter, L., et al. 2013

Solar Induced Fluorescence (SIF)

How can we constrain ET magnitude?

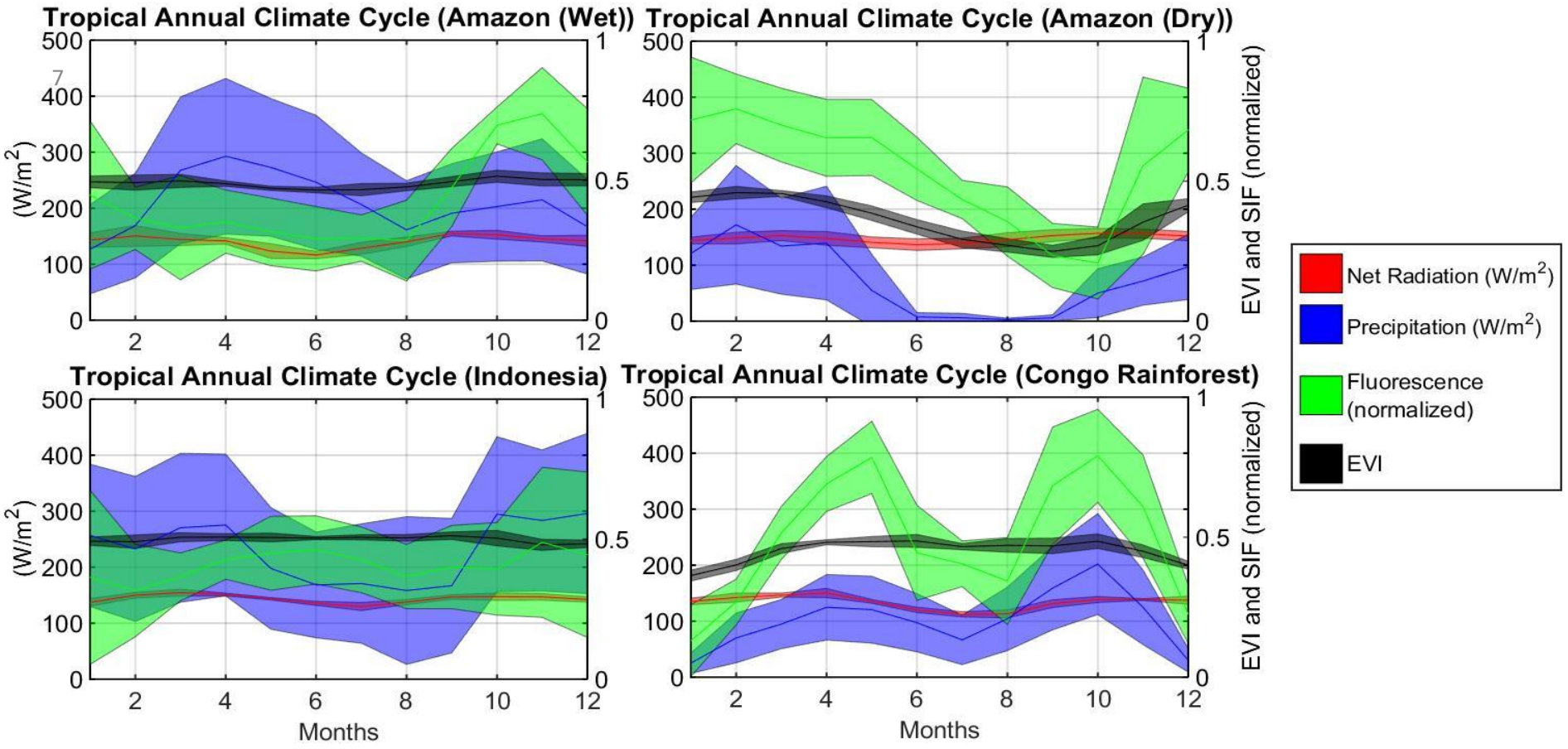
GPP (**CO_2 uptake**) is directly related to transpiration *T* (**H_2O release**)

$$GPP = wue\ T$$



SIF is thus a good **proxy for *T*** (main flux)

Example: Tropical Climate



Except for Indonesia all tropical regions exhibit some seasonal cycle due to light/water limitations

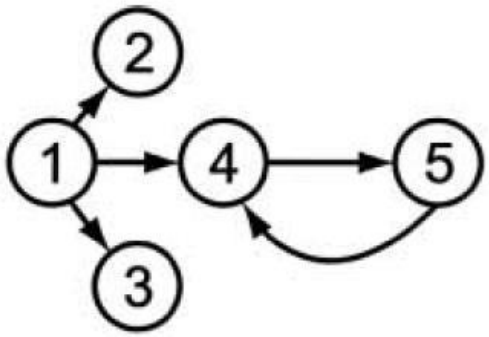
Can we observe land-atmosphere interactions?

Statistical tool: Conditional Multivariate Granger **Causality**

Based on Vector Autoregressive (VAR)

$$\boldsymbol{U}_t = \sum_{k=1}^{p} A_k \cdot \boldsymbol{U}_{t-k} + \boldsymbol{\varepsilon}_t$$

Computes added variance with each variable to define **causality direction and strength**



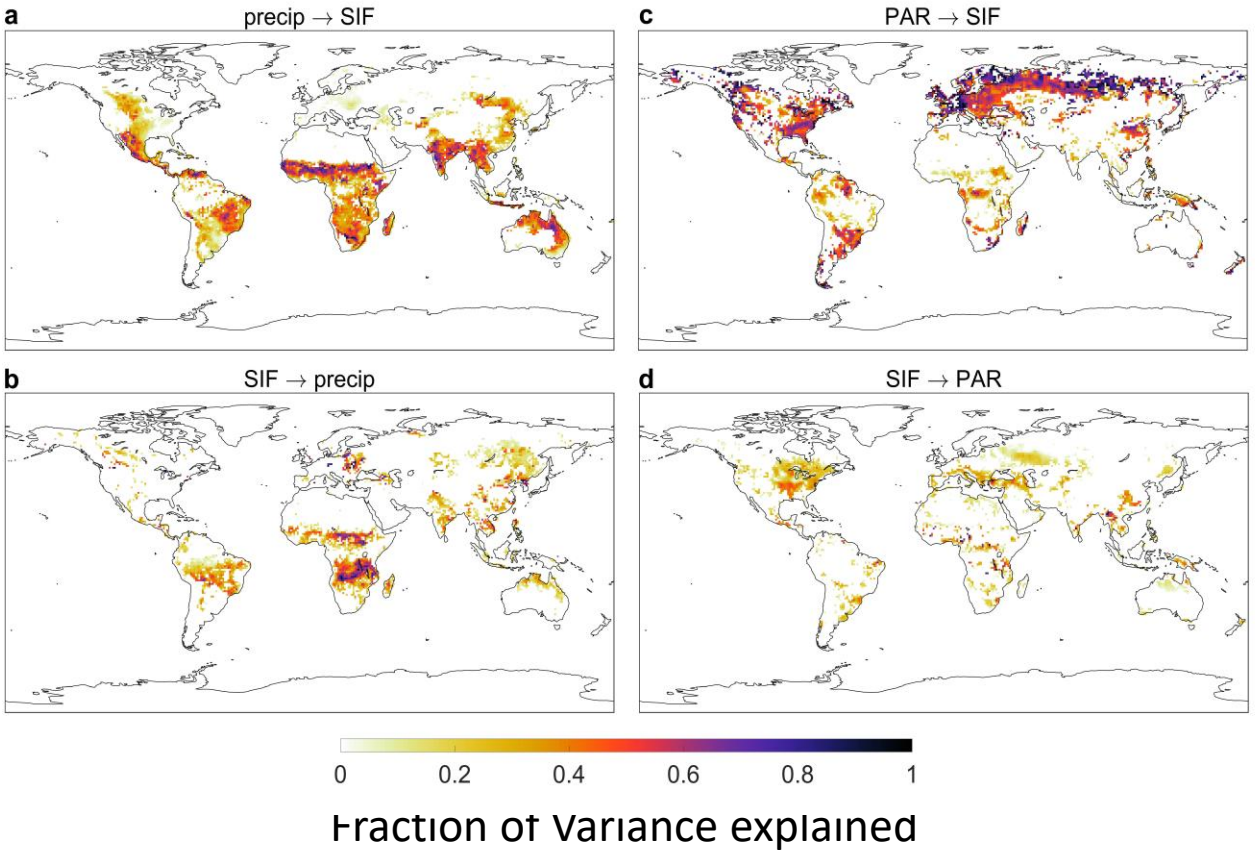
Seth et al. 2011

Causal biosphere-atmosphere feedbacks

- Consider Photosynthetically Active Radiation (PAR) (CERES), Precipitation (GPCP), Temperature (AIRS) and SIF (surface status)
- Monthly time scale – remote sensing only

Atmosphere ↓ Biosphere

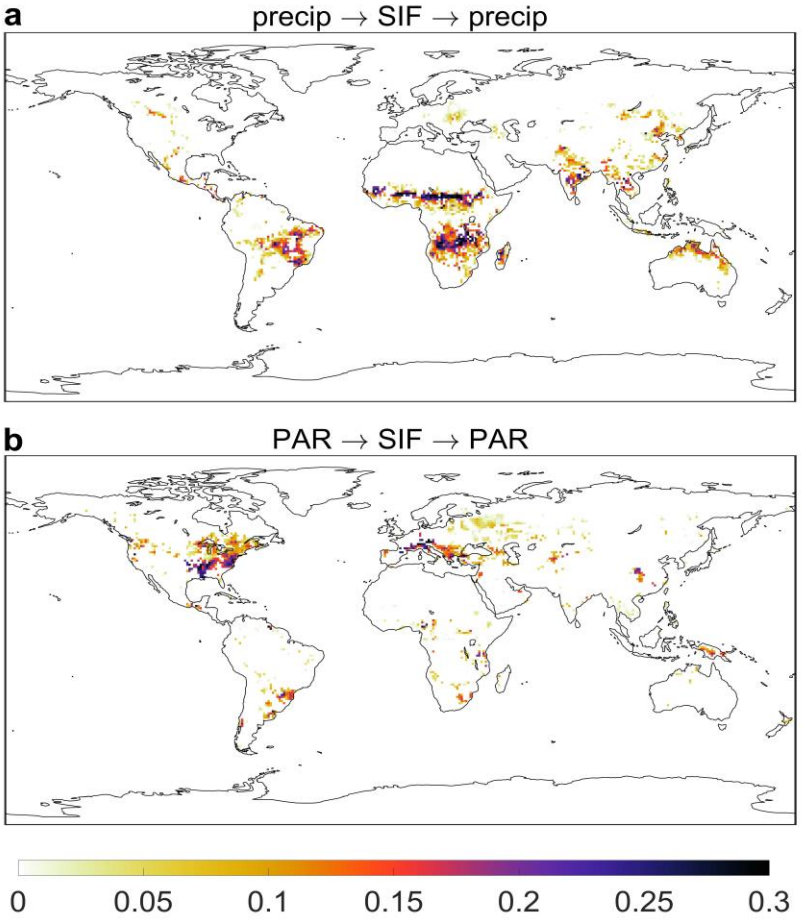
Atmosphere ↑ Biosphere



Green, Gentine et al. in revision

Causal biosphere-atmosphere feedbacks

- Feedback strength

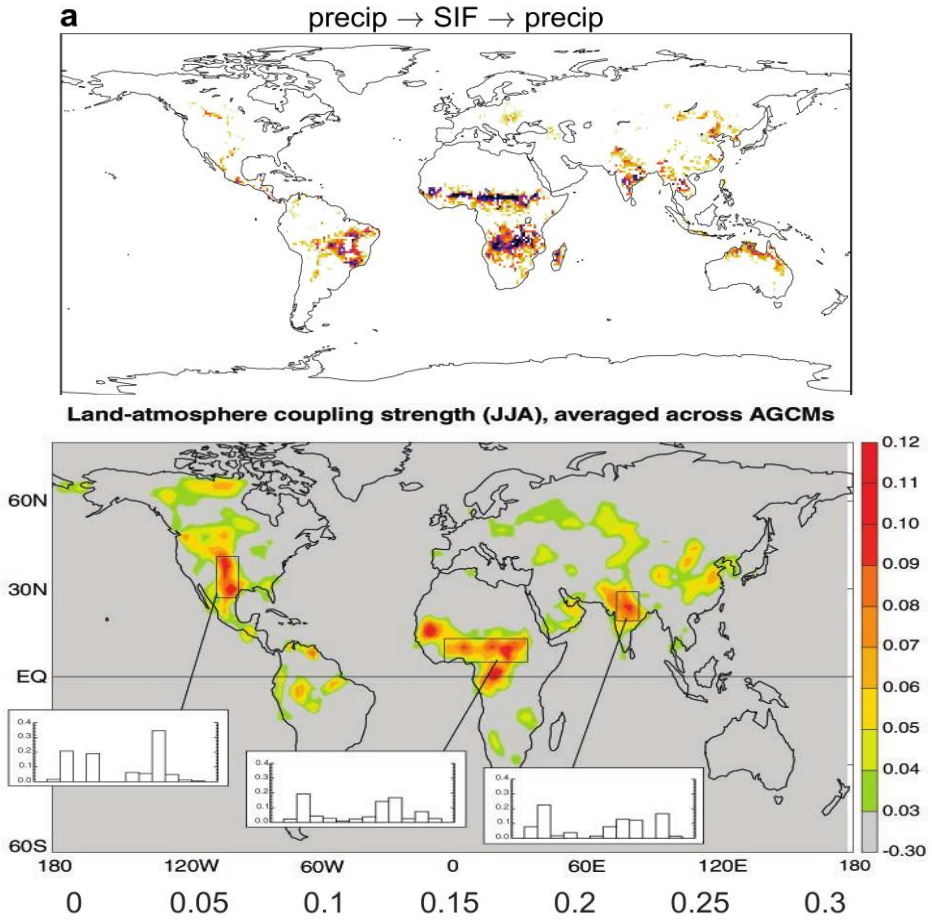


Fraction of Variance explained

Green, Gentine et al. in revision

Causal biosphere-atmosphere feedbacks

- Feedback strength: comparison with models

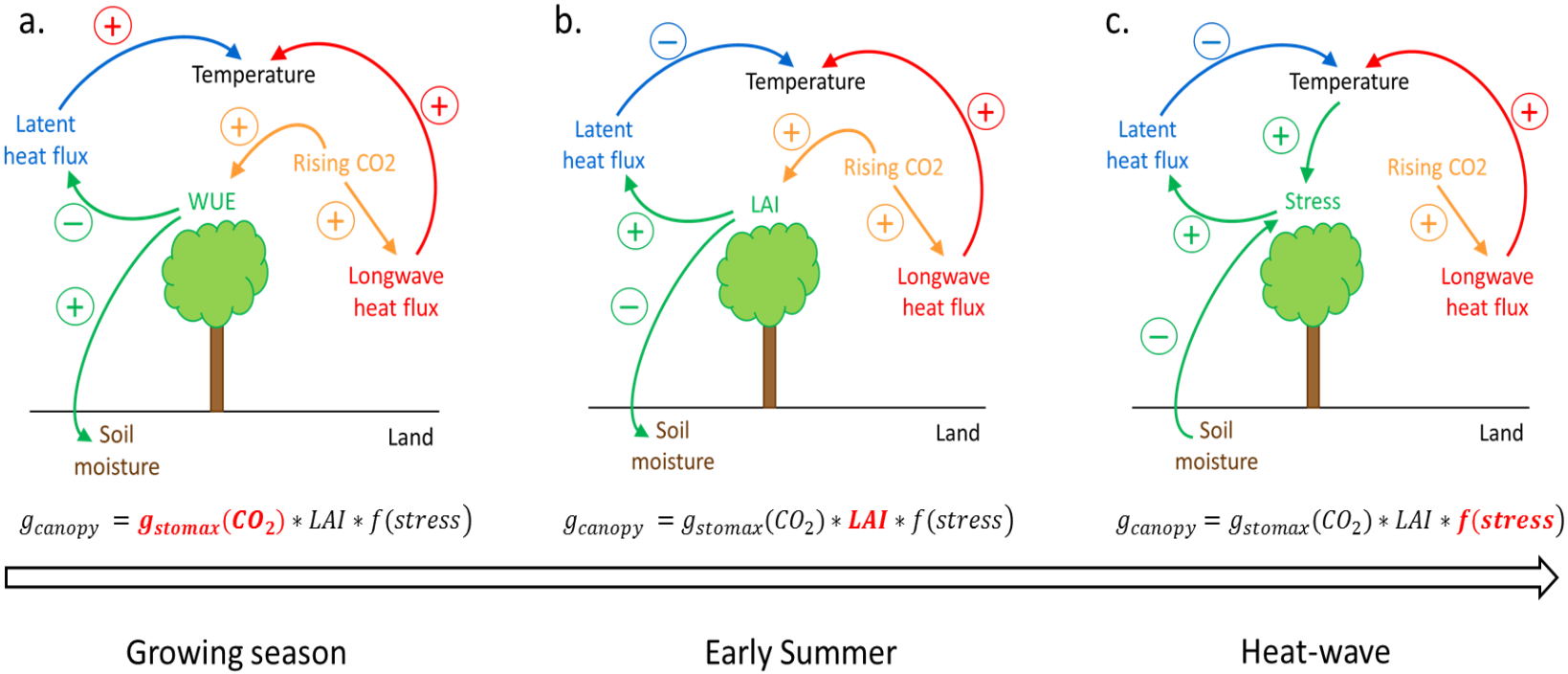


Fraction of Variance explained

Green, Gentine et al. in revision

CO_2 effect on land-atmosphere interactions

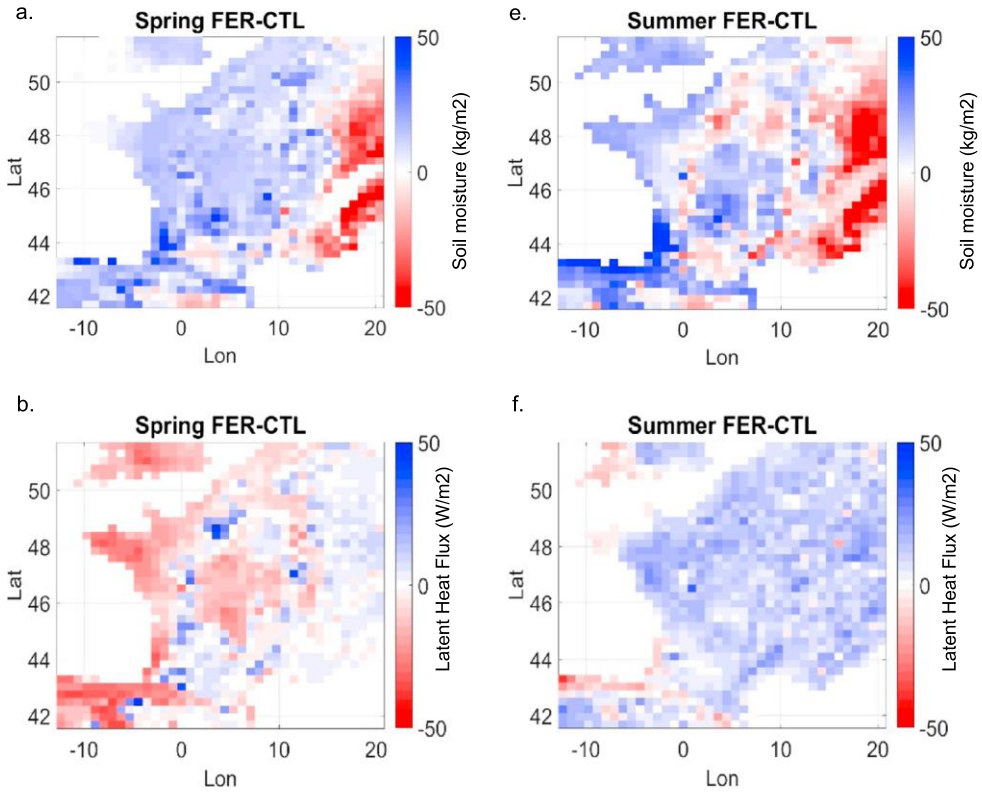
- So **H_2O and CO_2 are coupled**
- **What happens under rising [CO_2]?**
- In addition to radiative effect there is a surface carbon feedback



Lemordant et al. 2016, GRL

CO_2-H_2O coupling in land-atmosphere interactions

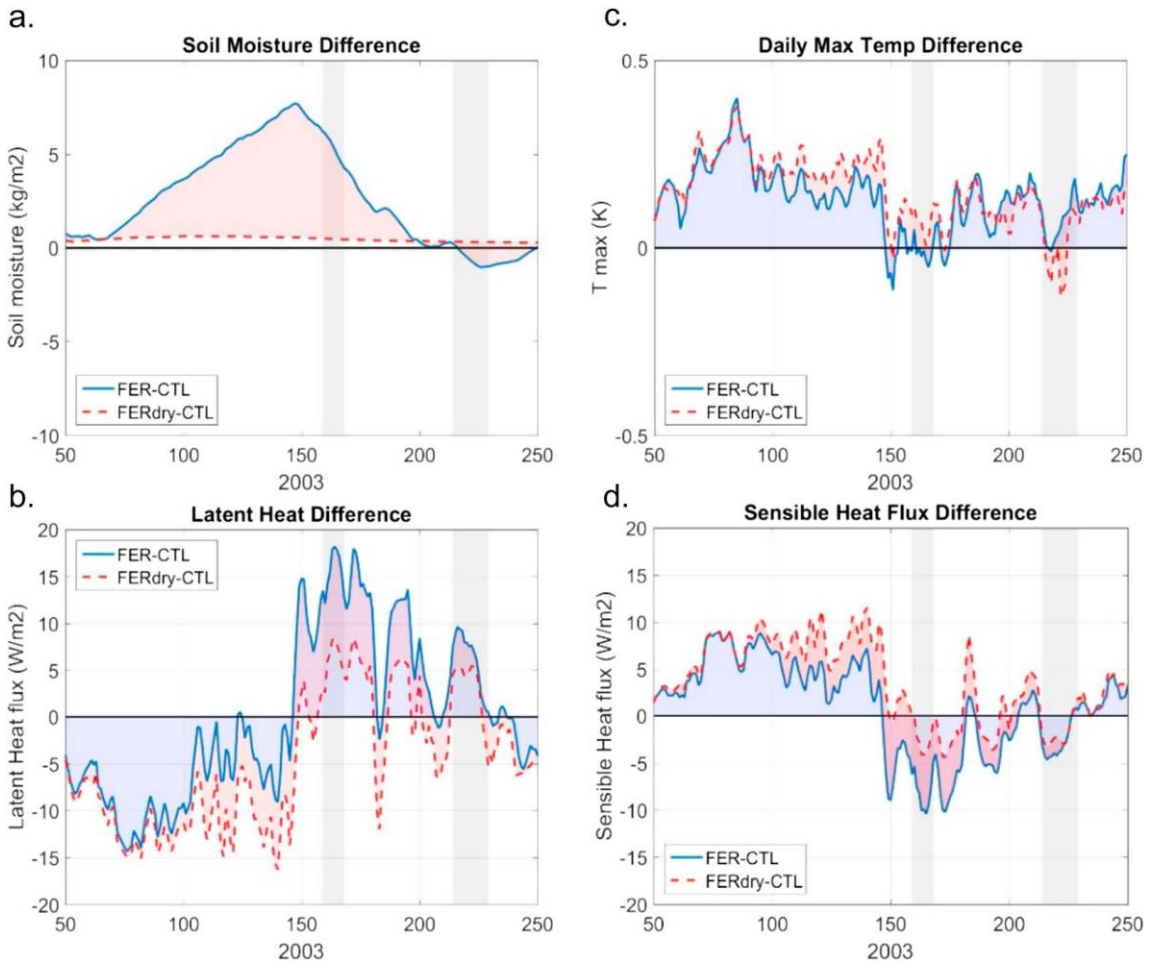
- Future [CO_2] will impact surface ET through changes in **WUE**
- Will feed back onto the atmosphere through LA coupling
- May reduce impact of heat wave through moisture buffer



Lemordant et al. 2016, GRL

CO_2-H_2O coupling in land-atmosphere interactions

- **May reduce impact of heat wave through moisture buffer**



Lemordant et al. 2016, GRL

CO_2-H_2O coupling in land-atmosphere interactions

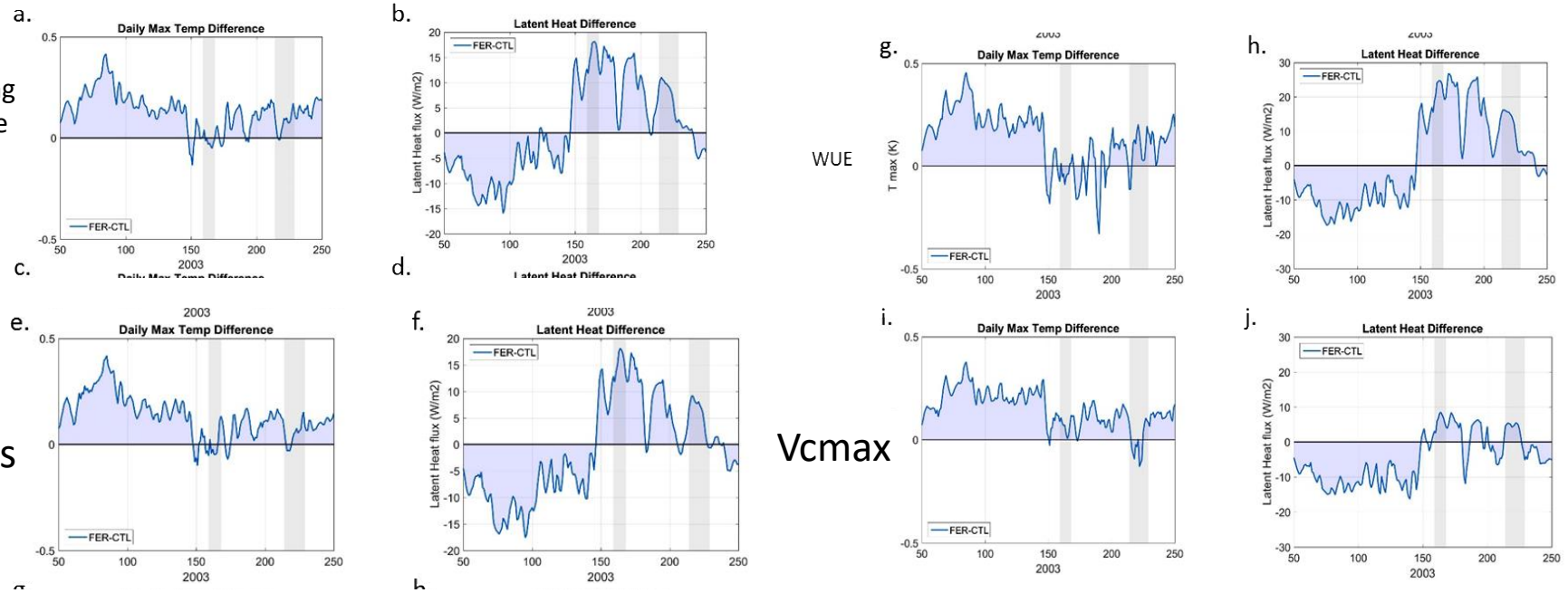
- **Main control of this feedback: WUE**
- **Main coupling parameter between CO_2 and H_2O cycles**

Growing Degree day

T stress

WUE

Vcmax



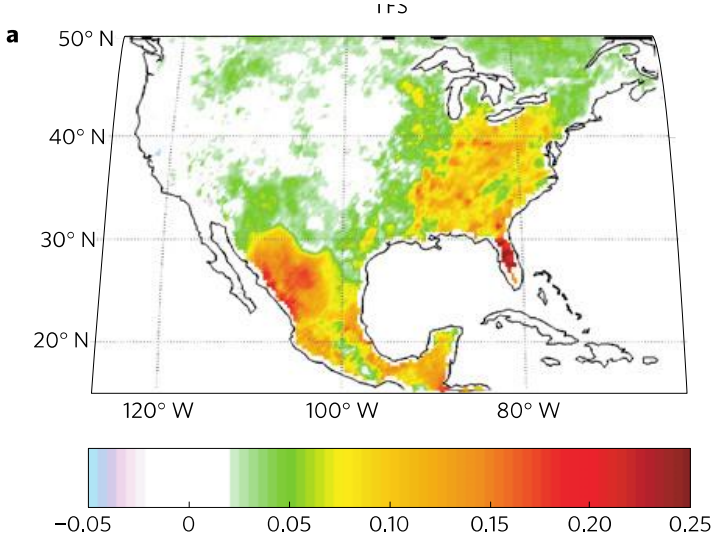
Lemordant et al. 2016, GRL


Thank you!

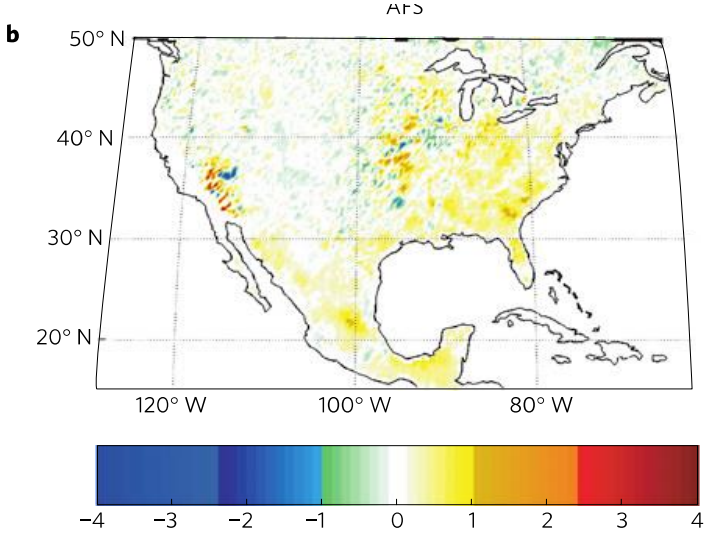
How can we assess role of the surface?

- **Observations:**

  define metrics to isolate feedback



$$TFS = s_{EF} \frac{\P\text{freq(Rain)}}{\P EF}$$



$$AFS = s_{EF} \frac{\P\text{Intensity(Rain)}}{\P EF}$$

Findell, K. L., P. Gentine, B. R. Lintner, and C. Kerr (2011), *Nat Geosci*