

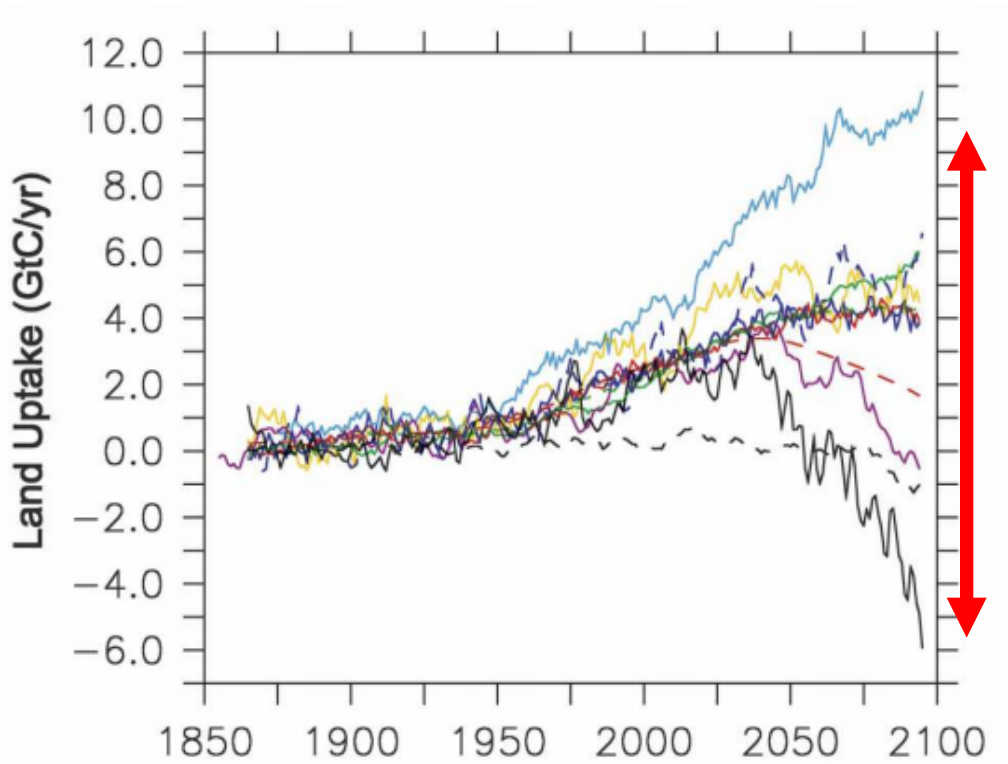
Increasing tropical water control on interannual CO₂ growth rate over the past decades

Laibao Liu, Philippe Ciais, Mengxi Wu & Sonia Seneviratne

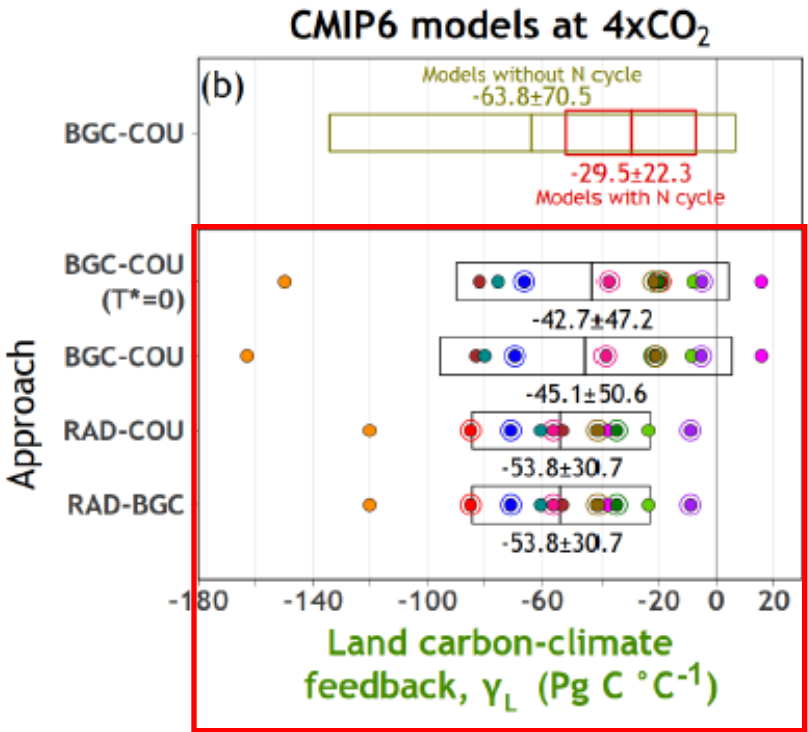
30. 04 2021, Zurich

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Uncertainties in future land carbon uptake



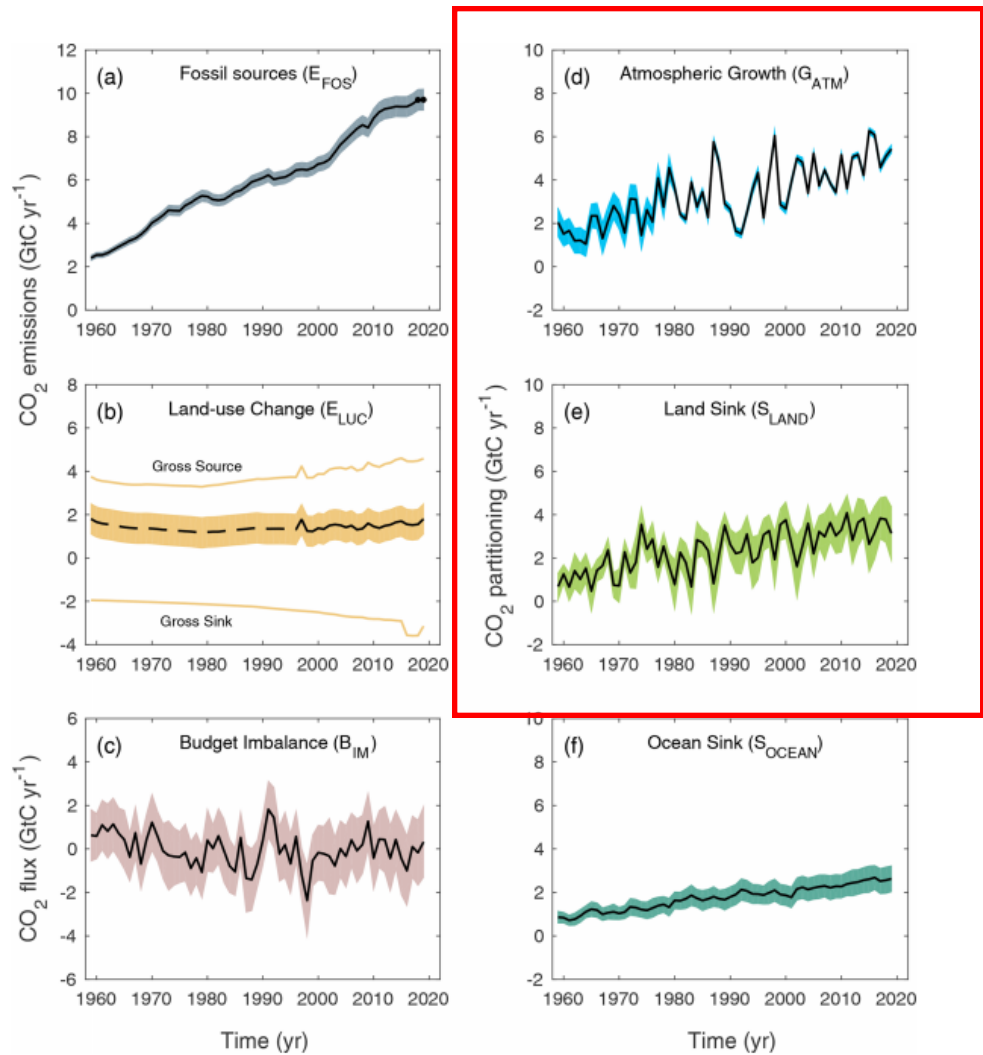
Friedlingstein et al., 2006 Journal of Climate



Arora et al., 2020 Biogeosciences

We need better understanding on terrestrial carbon-climate feedbacks!

Natural experiment: Interannual variations (IAV) of CO₂ growth rate (CGR)



IAV of CGR main reflect the IAV of terrestrial carbon uptake.

Global Carbon Budget 2020

Tropics dominate IAV of terrestrial carbon uptake

Land carbon
cycle model

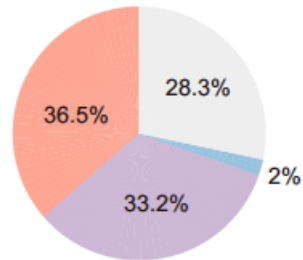
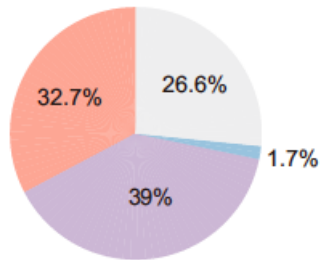
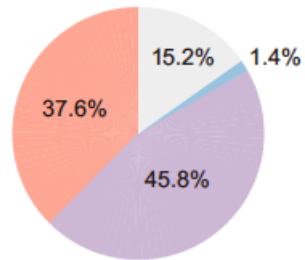
Atmospheric
inversion model

Machine
learning model

(b) Regional contribution (LM)

Regional contribution (INV)

Regional contribution (FLUXCOM)



Legend: Tropical non-semi-arid (orange), Tropical semi-arid (purple), Extra-tropical semi-arid (blue), Others (grey)

Tropics:
83.4%

Tropics:
71.7%

Tropics:
69.7%

IAV of CGR is driven by terrestrial carbon uptake, dominated by tropics.

Now, we can link CGR to tropical climate...

Piao et al., 2020 GCB

Climate drivers: Temperature and Water

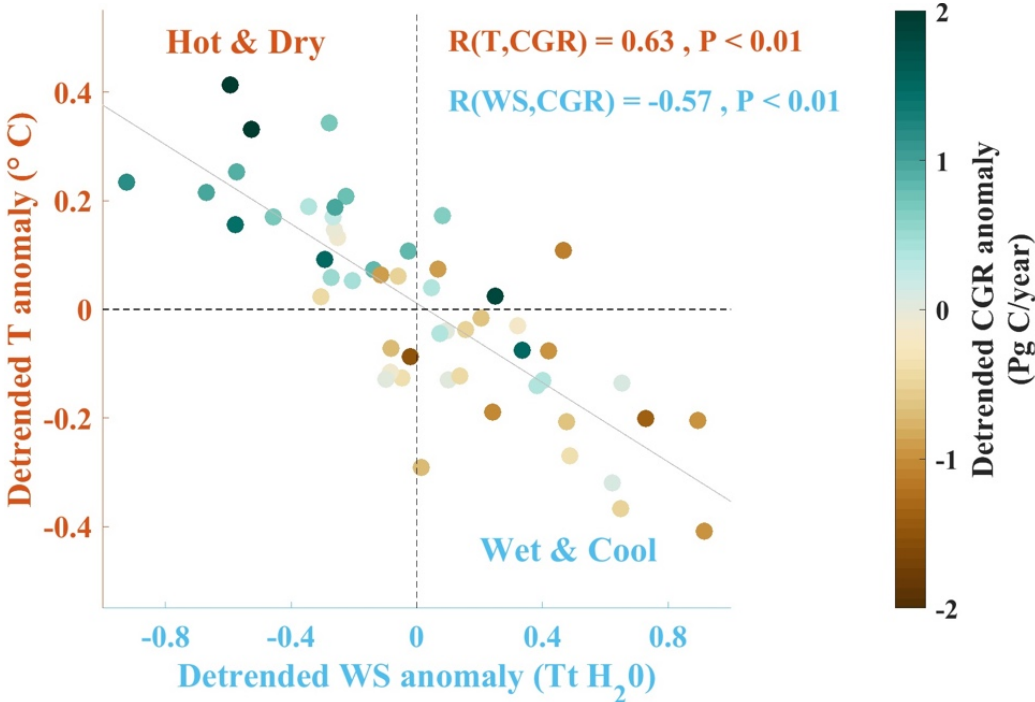
CGR

Tropical Temperature

Wang et al., 2013 PNAS;
Cox et al., 2013 Nature;
Wang et al., 2014 Nature;
Anderegg et al., 2015 PNAS;
Jung et al., 2017 Nature

Tropical/Global Water

Wang et al., 2016 BG;
Humphrey et al., 2018 Nature
Humphrey et al., 2021 Nature



Hotter, Higher CGR

Drier, Higher CGR

We wonder

In the context of **climate change, **do** the identified terrestrial climate-carbon coupling **hold** over the past decades (1960-2018)?**

- **Carbon**

- a. CO₂ growth rate (CGR) from NOAA/ESRL **(1960-2018)**

- b. Aboveground carbon (AGC) retrieved from VODCA long-term vegetation optical depth **(1988-2016)**

- **Climate**

- Water: a. GRACE TWS + REC-TWS v3 **(1960-2018)**

- b. Lagged Precipitation from CRU TS 4.03 **(1960-2018)**

- Temperature: a. CRU TS 4.03 ; b. Berkeley T **(1960-2018)**

- Remove Volcano years (1963,1964,1982,1991,1992,1993)

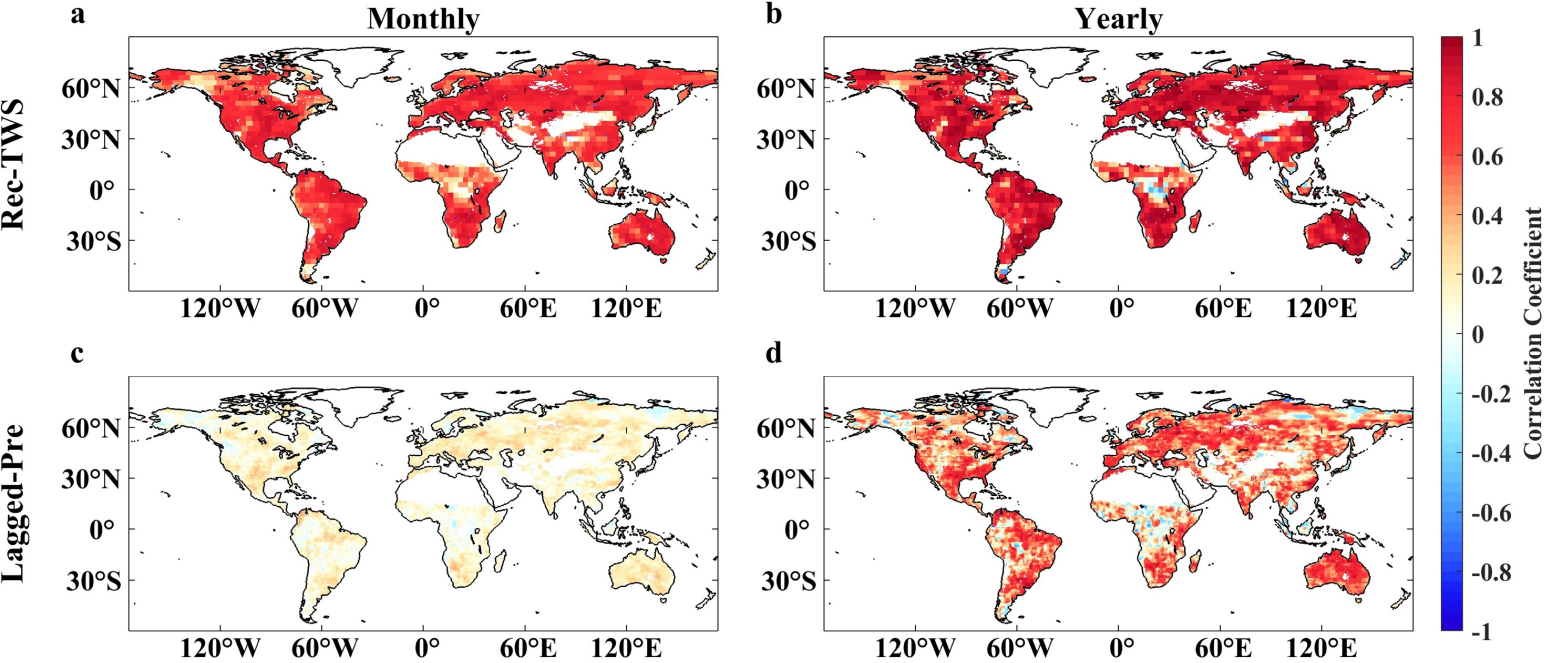
Reliability of water storage proxies: Rec-TWS and Lagged-Pre

Regional scale

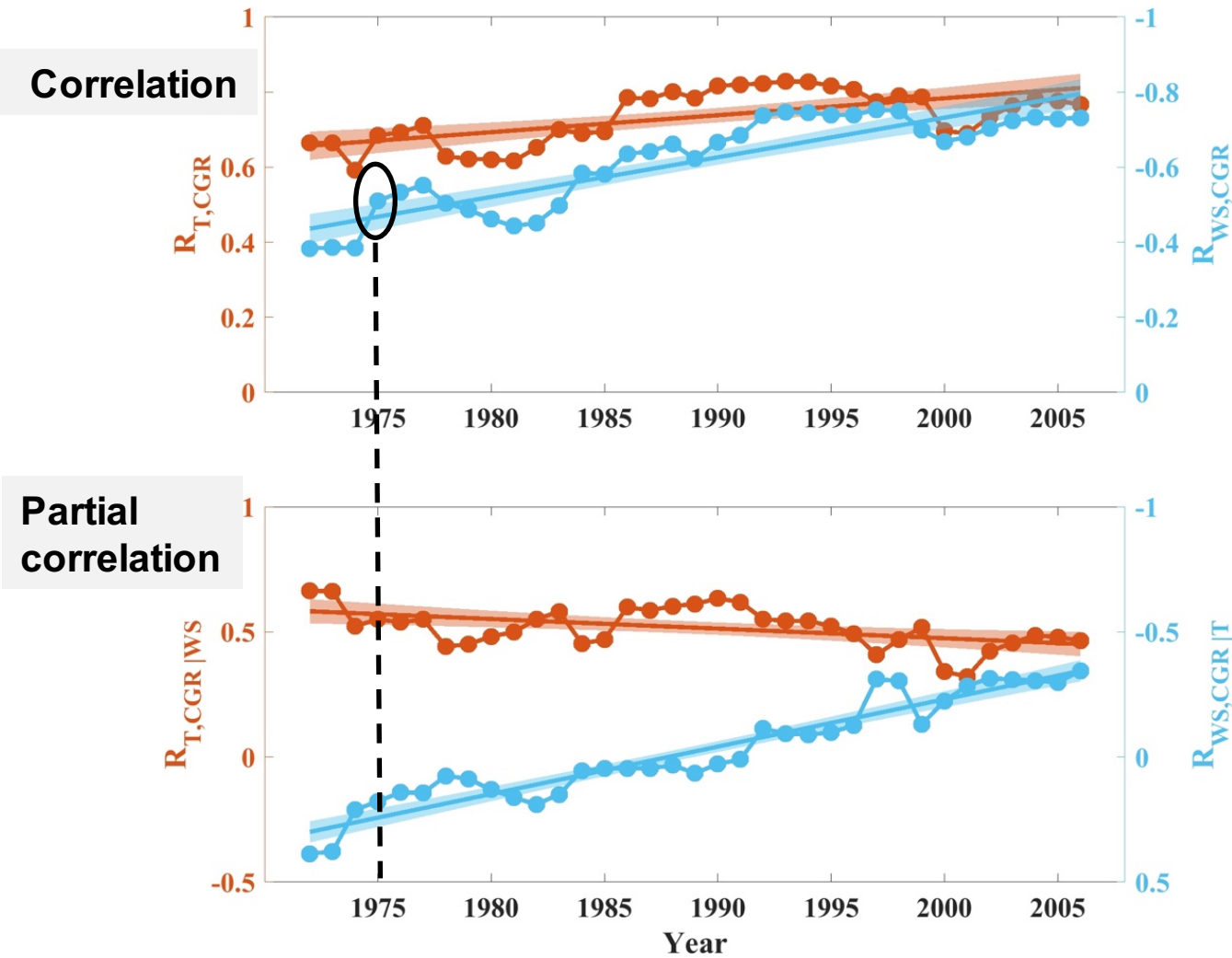
IAV correlation to original TWS during 2002-2016	Rec-TWS		6-month Lagged-Pre	
	monthly	yearly	monthly	yearly
Tropical	0.86*	0.93*	0.51*	0.88*
Tropical forest	0.84*	0.89*	0.37*	0.76*
Tropical semiarid	0.90*	0.98*	0.37*	0.91*

* indicates $P < 0.01$

Grid scale



1960-2018, Temporal dynamics of CGR-Climate IAV correlations

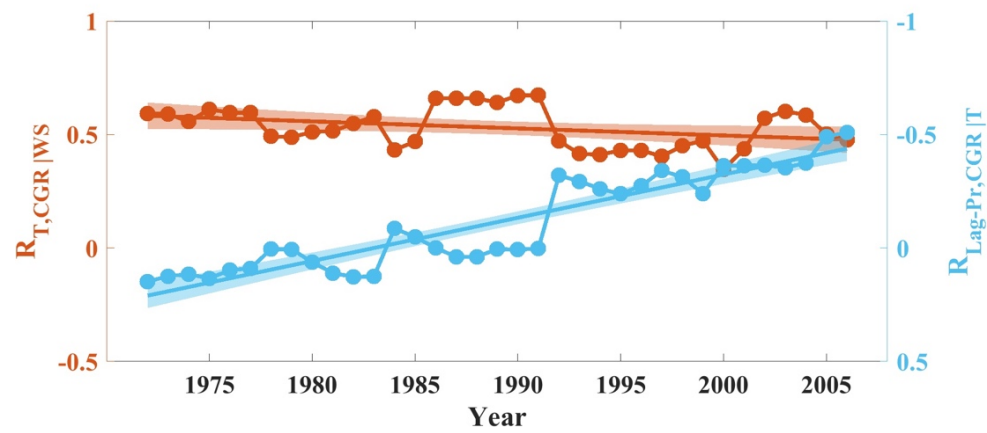


Time period: 1963-1987, central year: 1975 (25-yr window)

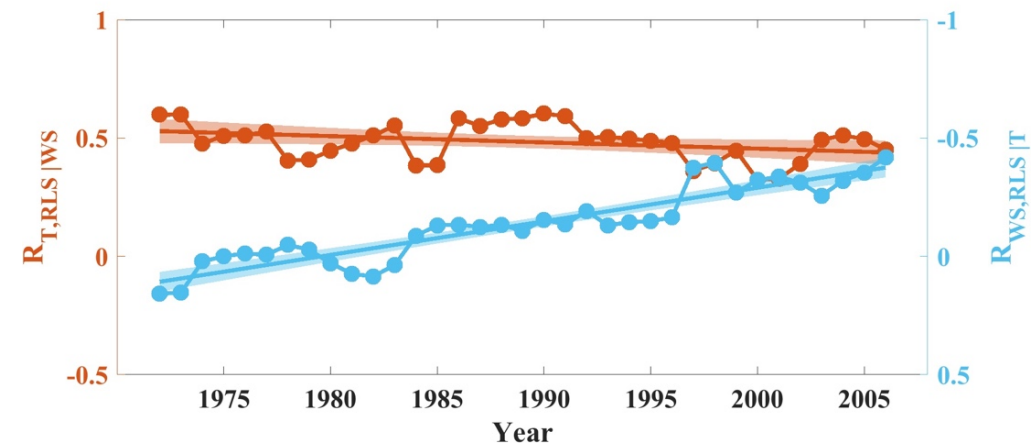
- Long-term: Tropical temperature is more important than tropical water.
- Trend: Tropical water's control on CGR IAV increased over time and could be as important as tropical temperature recently.

Sensitivity test

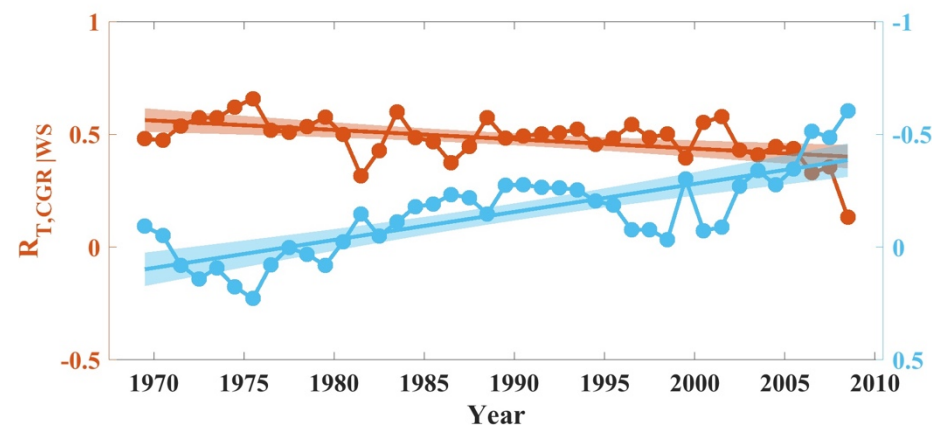
a. Climate data:
Lagged-Pr + Berkeley T



b. Residual Land Sink
(Global Carbon Budget 2020)

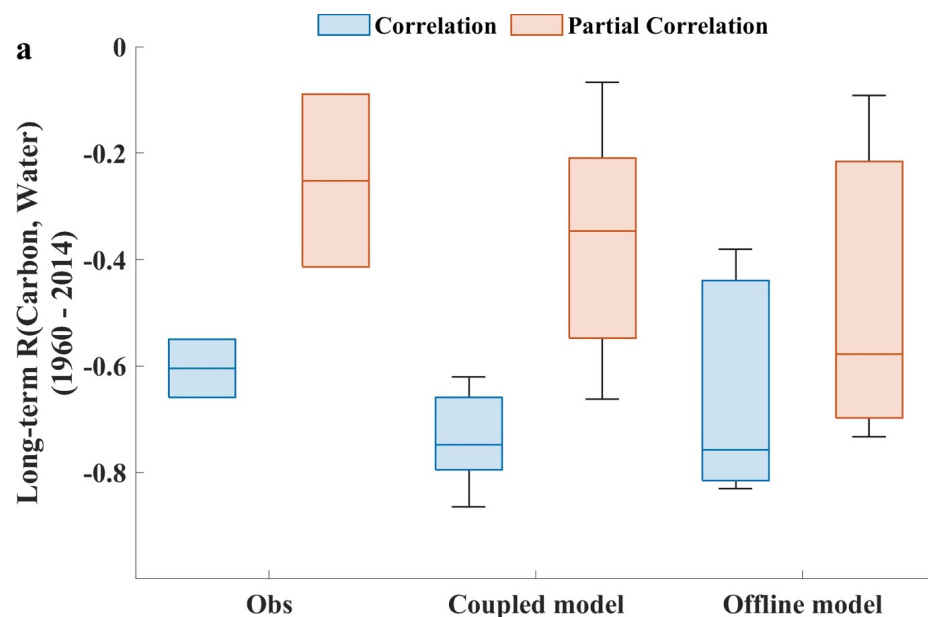


c. Time-window size of 20-yr

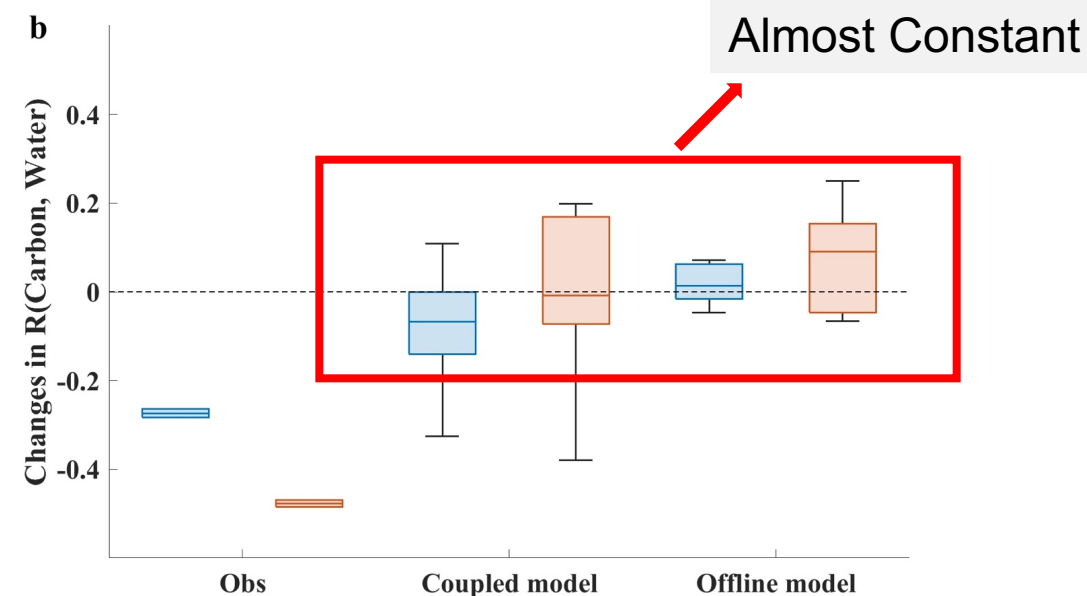


Do models capture this feature?

Long-term



Changes over time



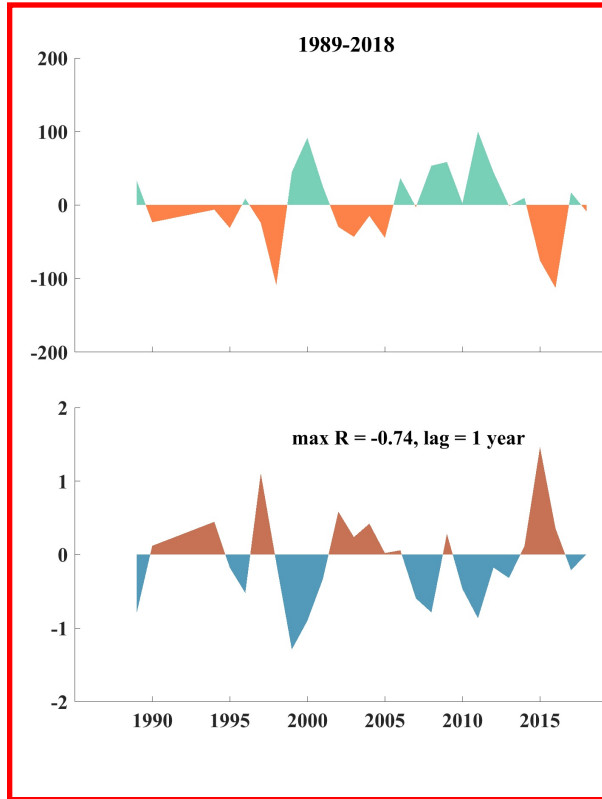
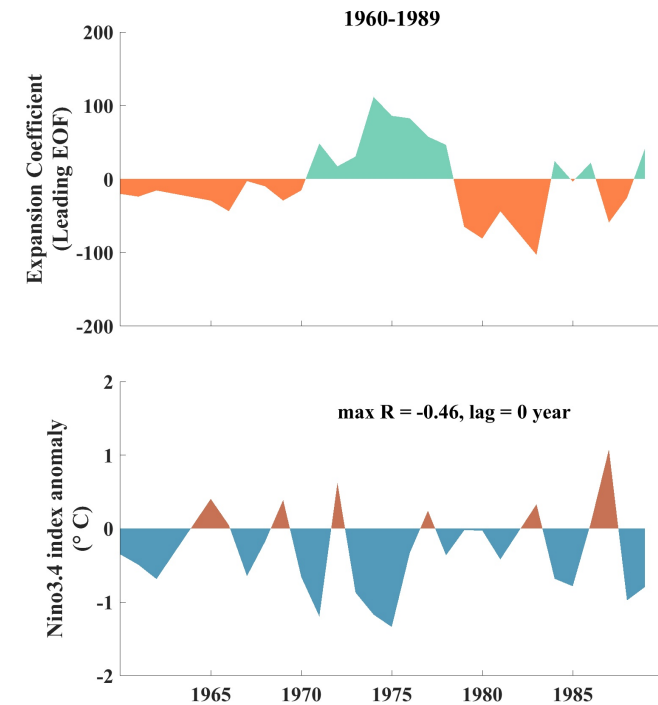
Obs : CGR, Tropical Rec-TWS and Lagged-Pr
Models : Global NEE (reversed), Tropical total soil moisture

Nope !

Why tropical water become more important?

First 30-yr

Recent 30-yr

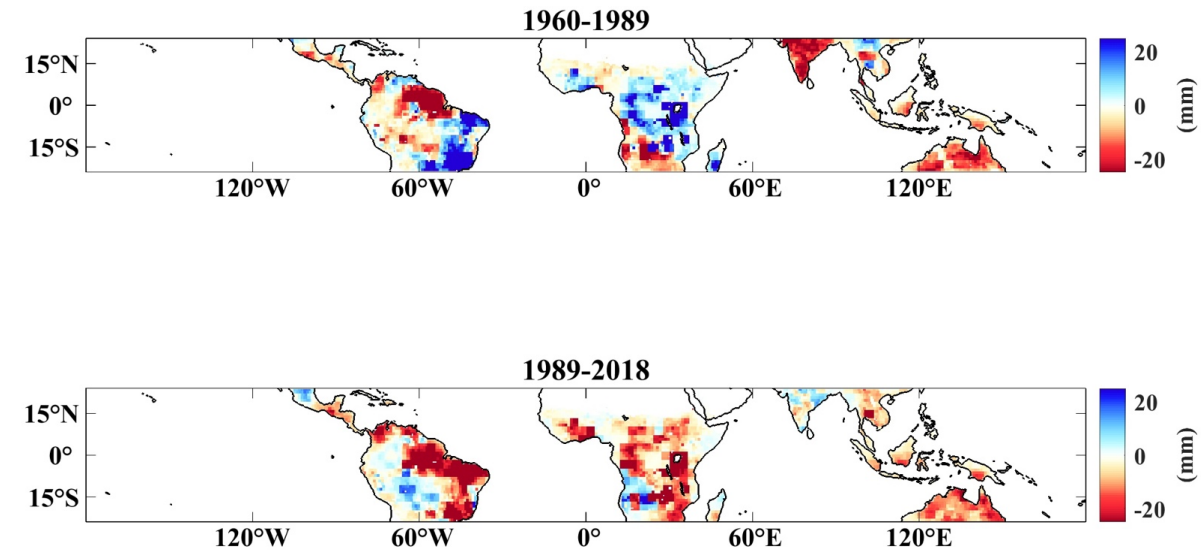


Leading EOF of tropical WS anomalies controlled by El Niño (Niño 3.4) recently

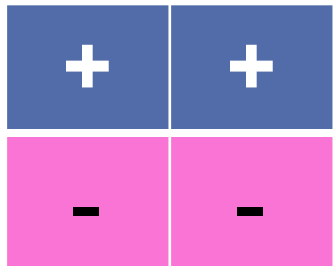


Broader-scale footprints of El Niño recently

WS anomaly during El Niño conditions

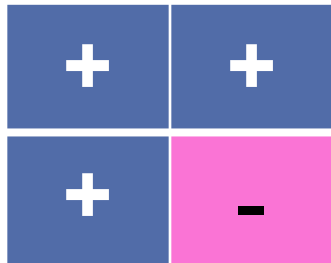


Why tropical water become more important?



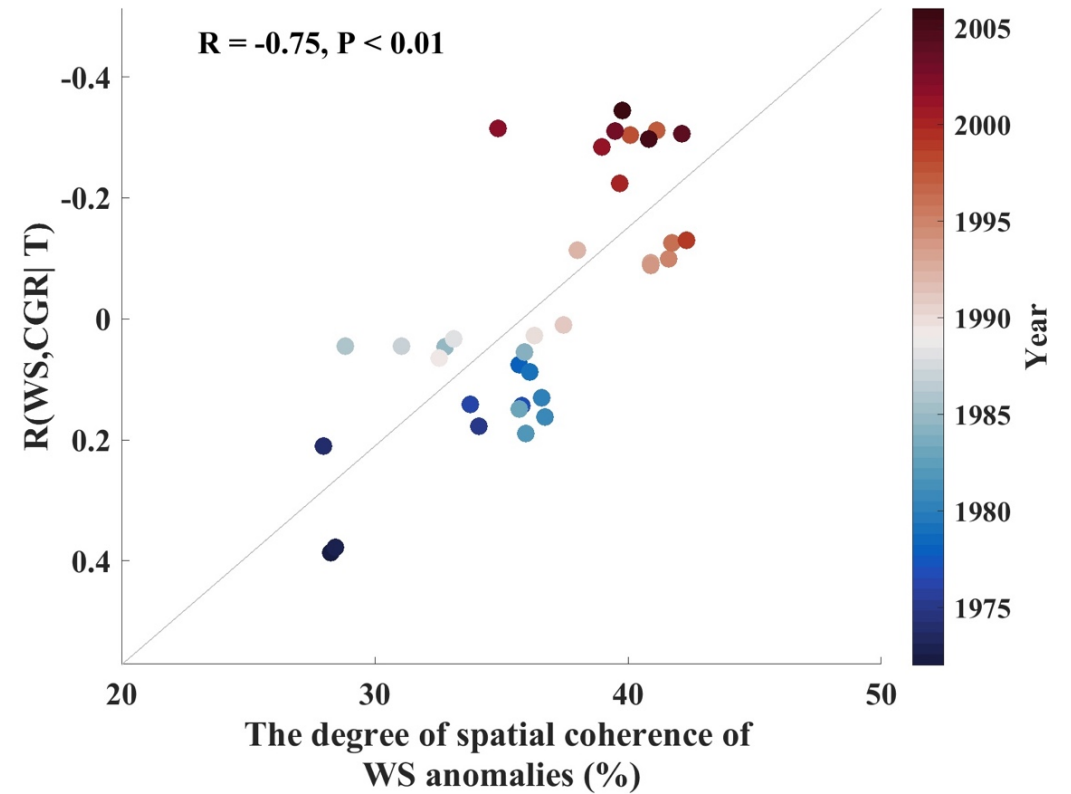
First 30-yr

**Low spatial coherence
(counterbalance each other)**



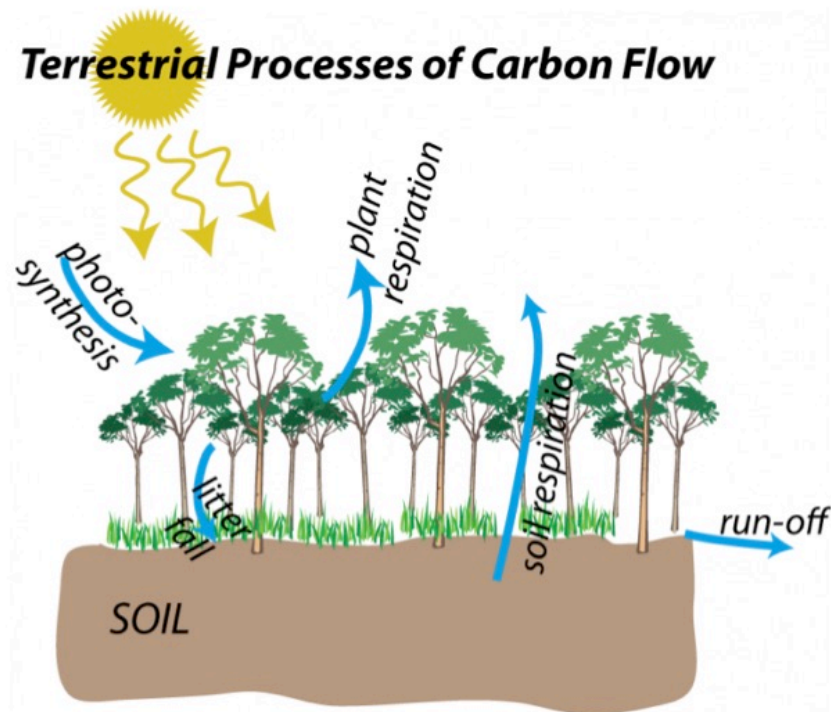
Recent 30-yr

**High spatial coherence
(low compensatory effects)**

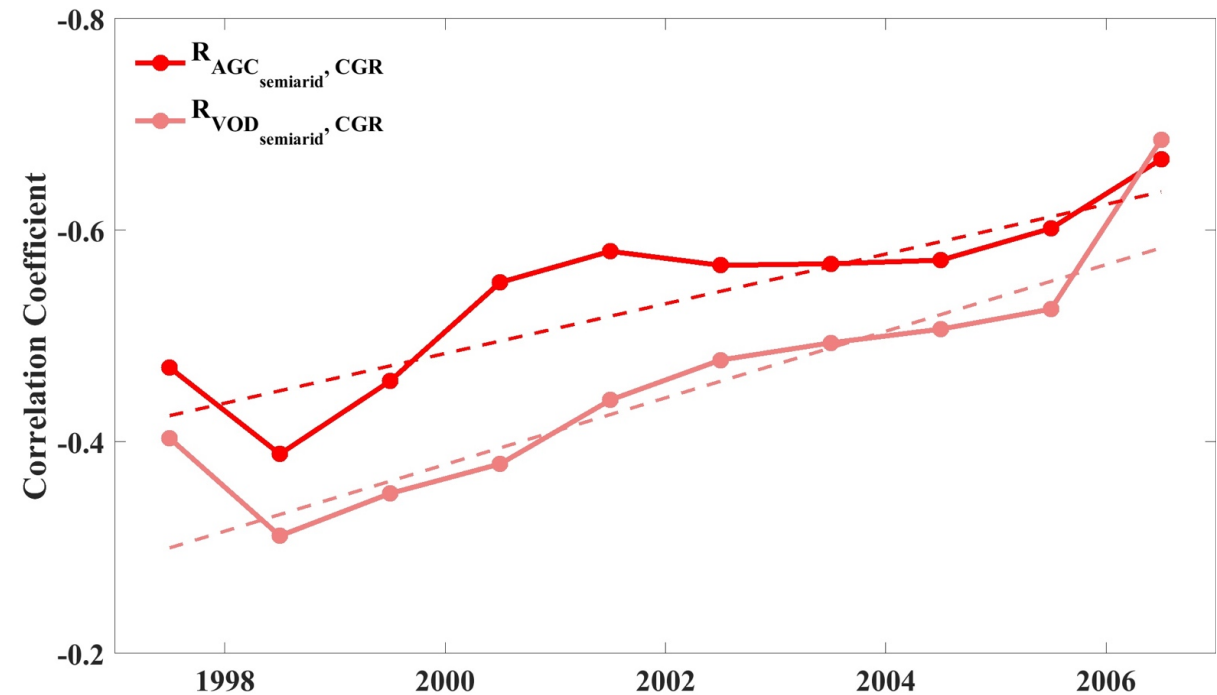


**Enhancing spatial coherence
lead stronger tropical water control !**

Which terrestrial mechanism matter?



Provenance: Dave Bice figure



Tropical **semiarid aboveground carbon (water-limited) increasingly correlated with CGR!**

Conclusions

- **Increasing tropical water control on interannual CO₂ growth rate over the past decades.**
- **Most state-of-the-art Earth System models and Offline land surface models do not capture this feature.**
- **This increment could be partly attributed to stronger ENSO effects on tropical water storage in a warming climate. Semiarid aboveground carbon uptake could be a vital underpinning terrestrial process.**

Thank You!

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