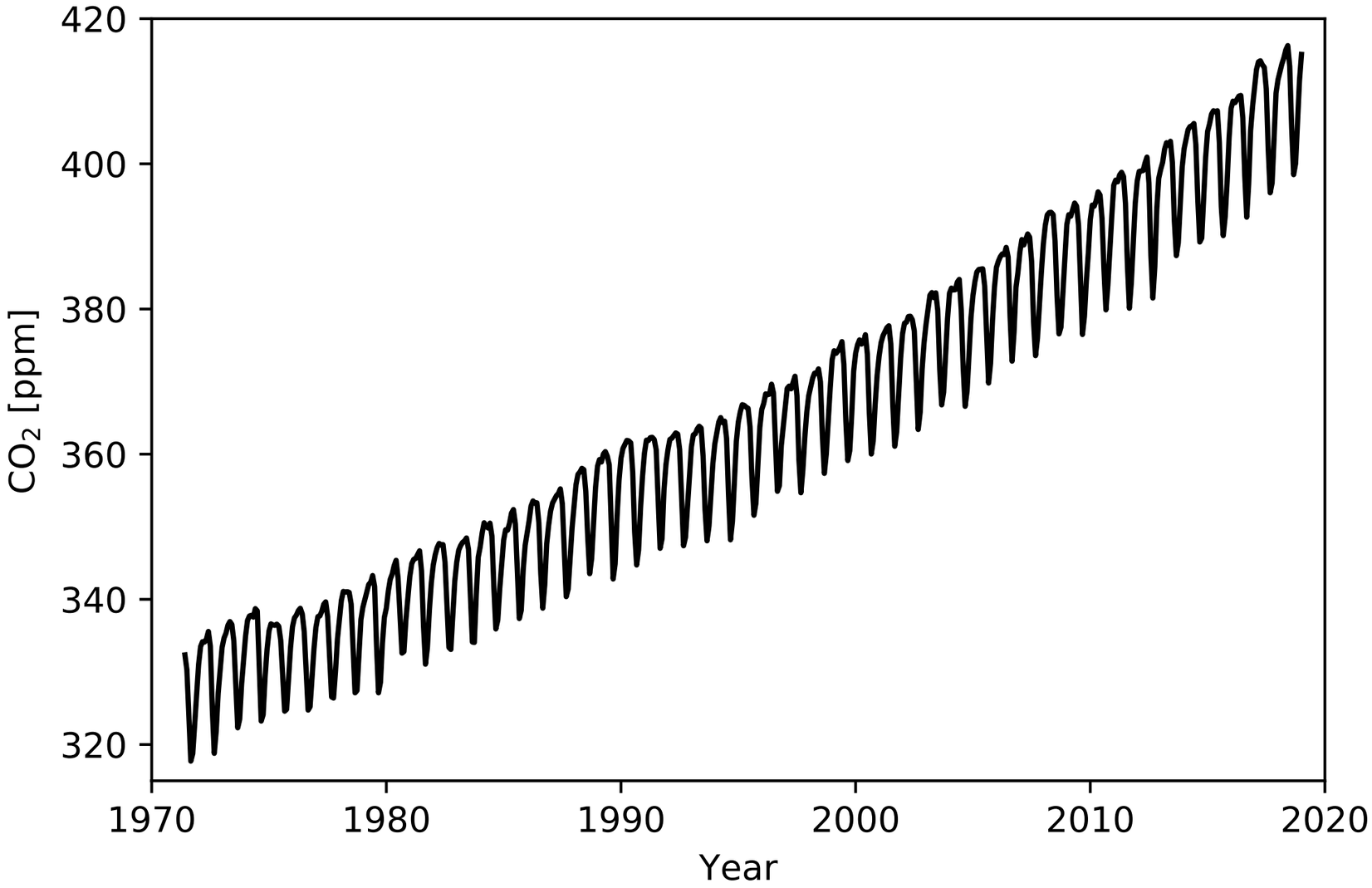
Diagnosing Regional Drivers of Carbon Cycle Variability from Atmospheric CO_2



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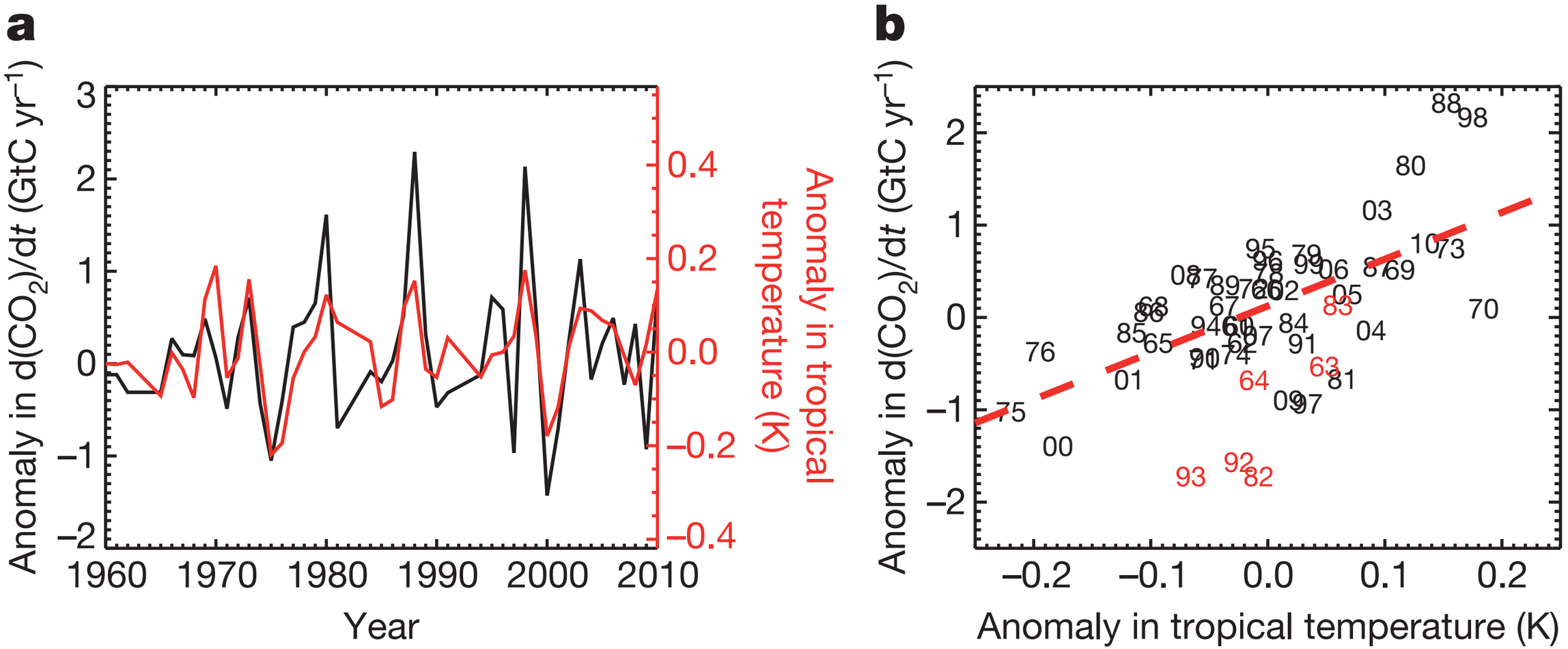
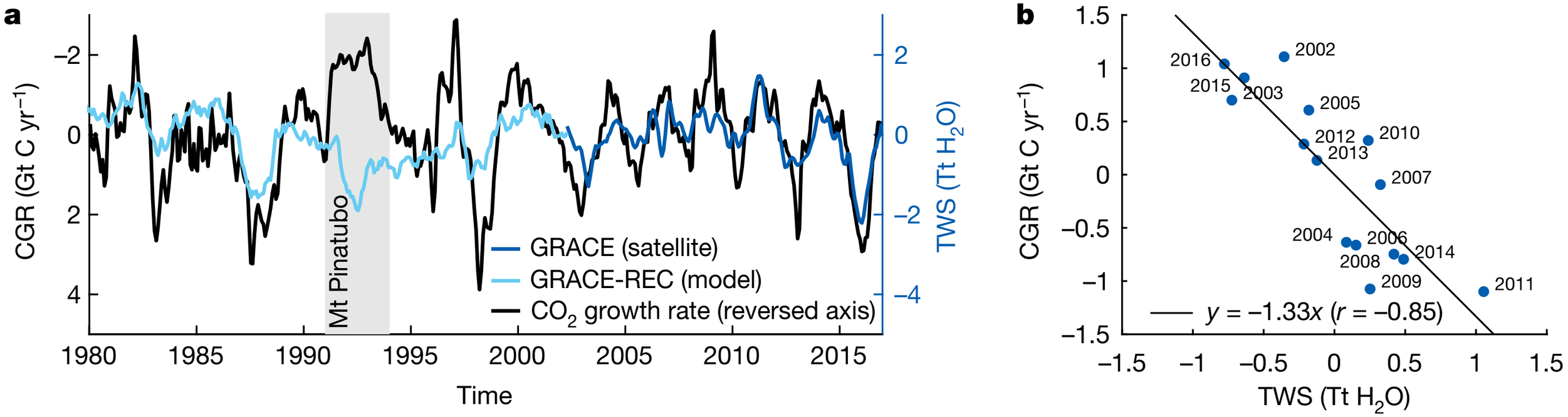
Simple Linear Regression has been used to suggest that tropical temperature variations control the atmospheric CO_2 growth rate



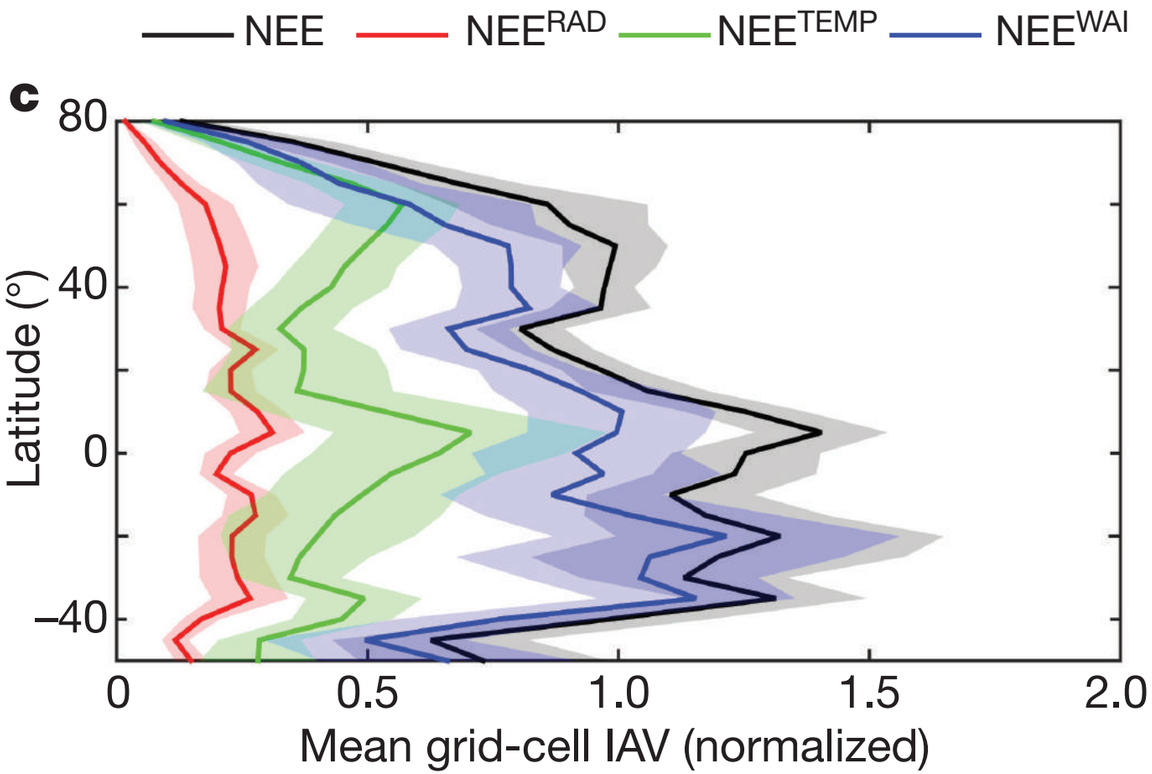
Cox et al., 2013

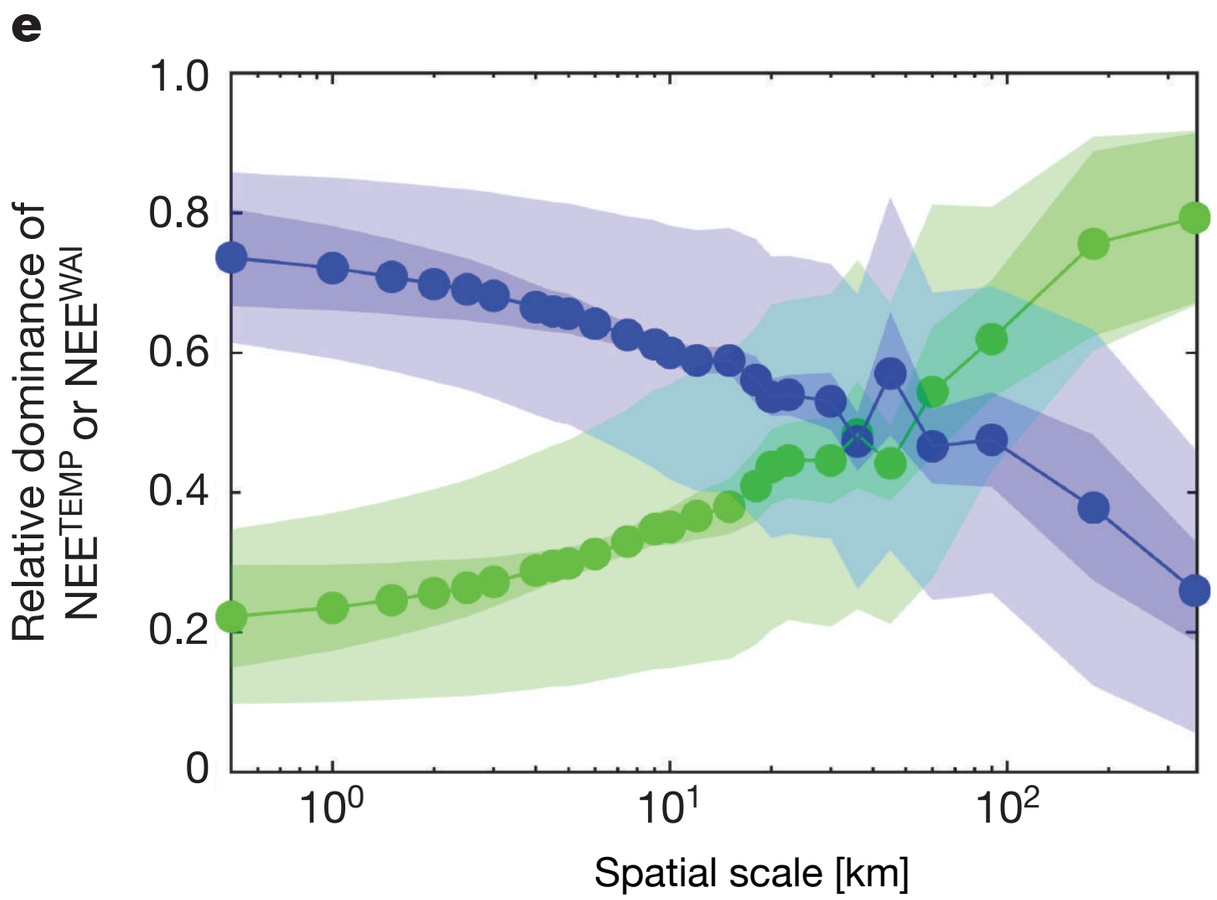
Alternatively, the global CO_2 growth rate has shown an even higher correlation with GRACE terrestrial water storage



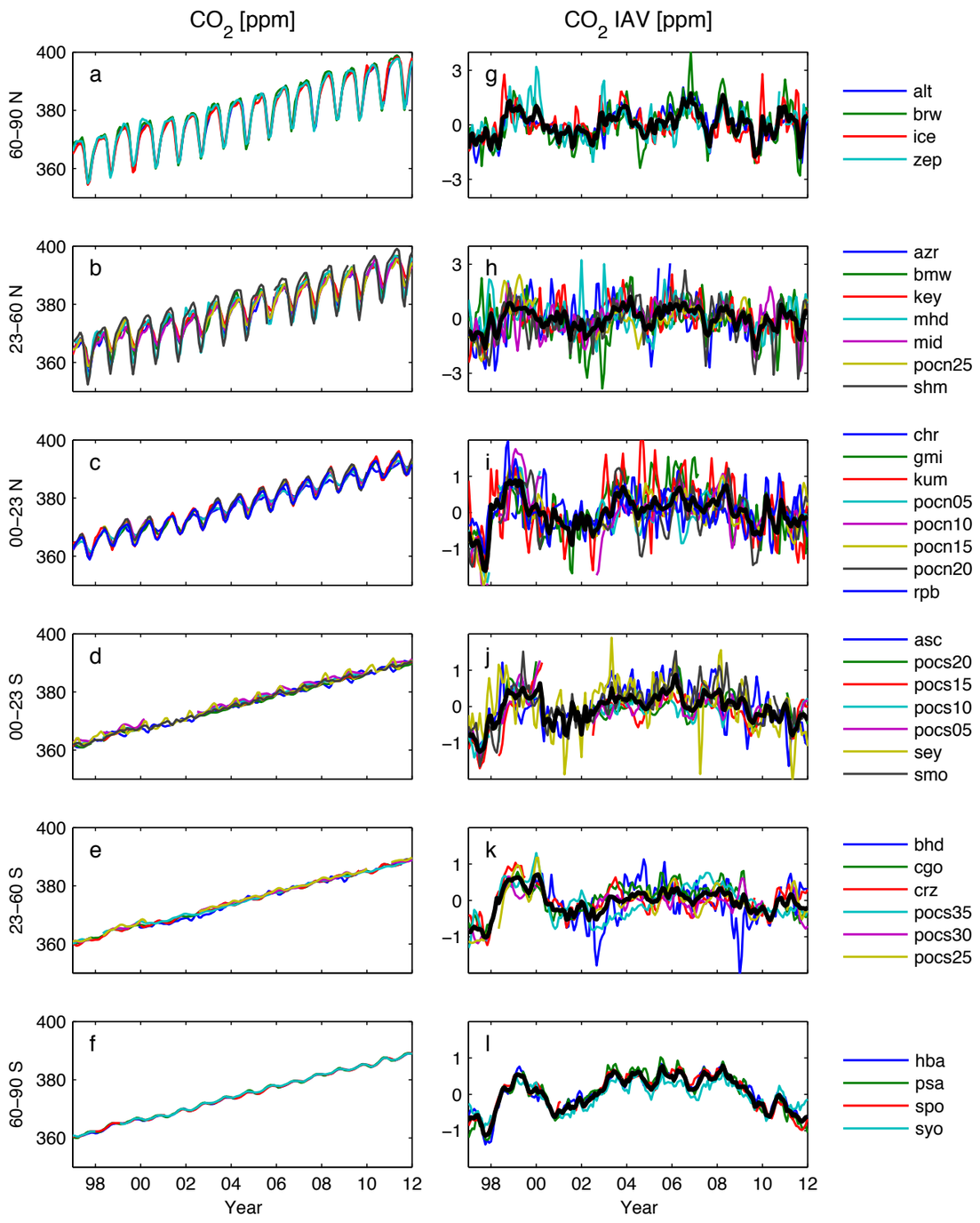
Humphrey et al., 2018

Global patterns may obscure the drivers that account for variability at the ecosystem to regional scale





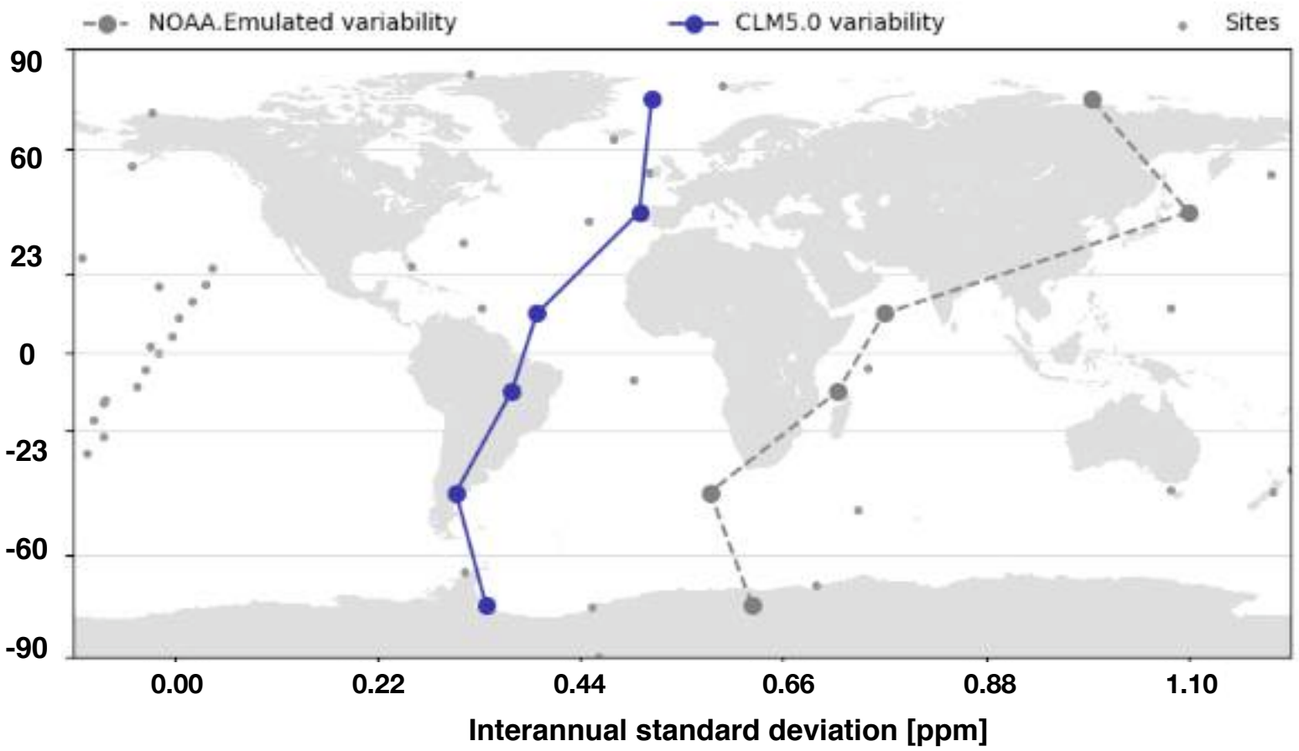
Jung et al., 2017



Ultimately, metrics to account for interannual variability must both account for regional mechanisms and top-down emergent behavior of atmospheric CO_2

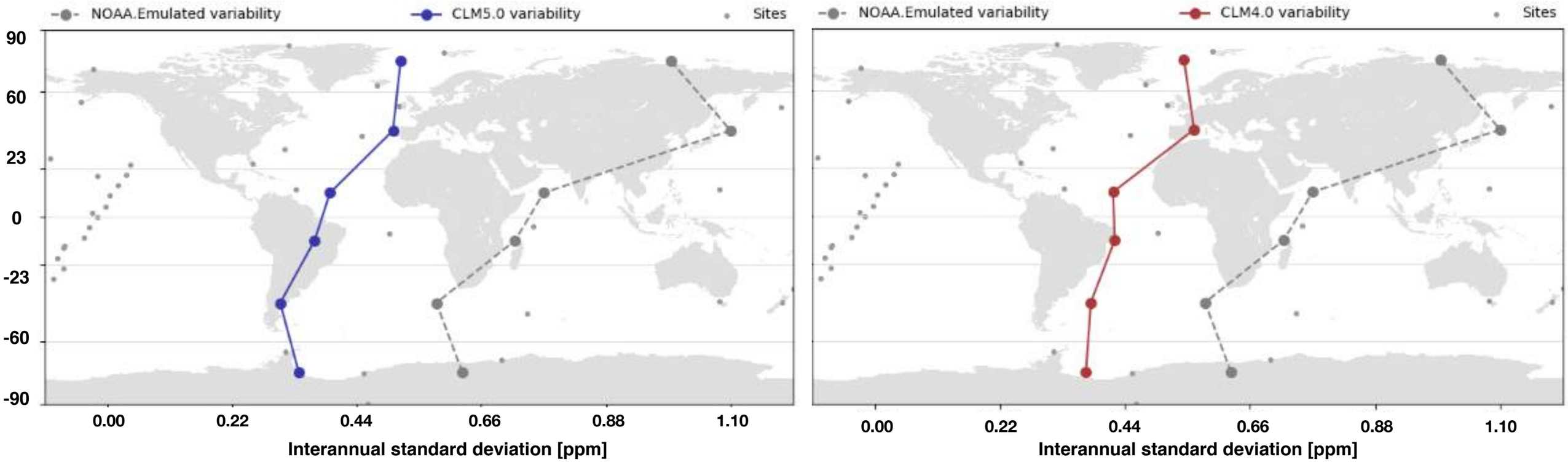
Keppel-Aleks et al., 2014

A quantitative description of the mechanisms and relationships that drive these patterns is crucial to have confidence in prognostic model



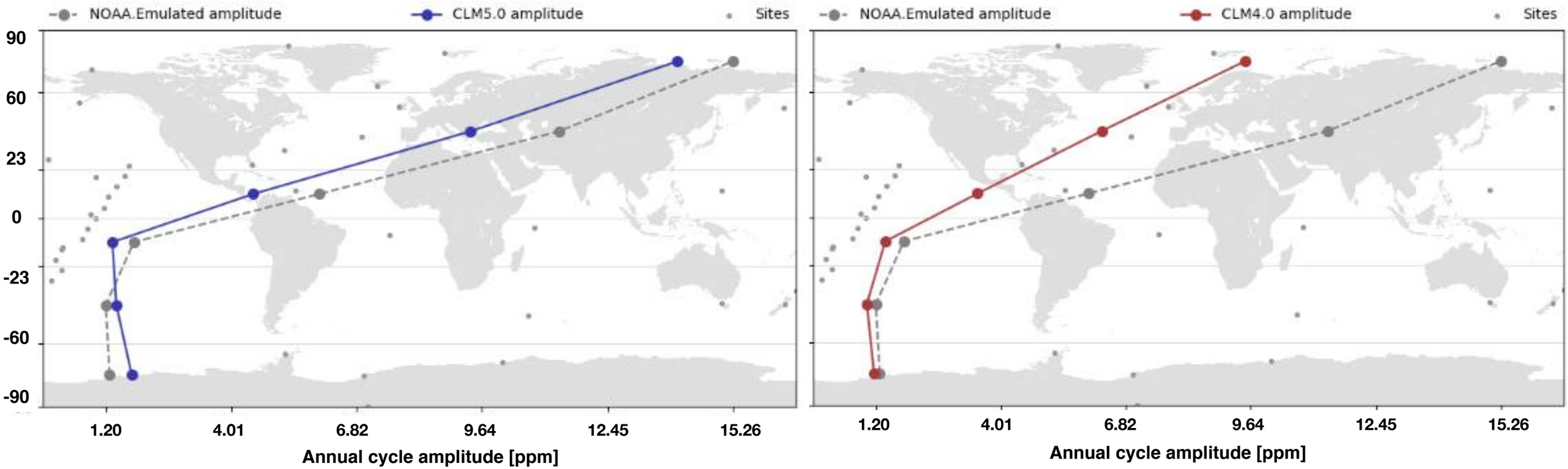
ILAMB; Collier et al., 2018

In the Community Land Model (CLM) simulation of atmospheric CO2 IAV has degraded as the model developed from CLM4 through CLM5

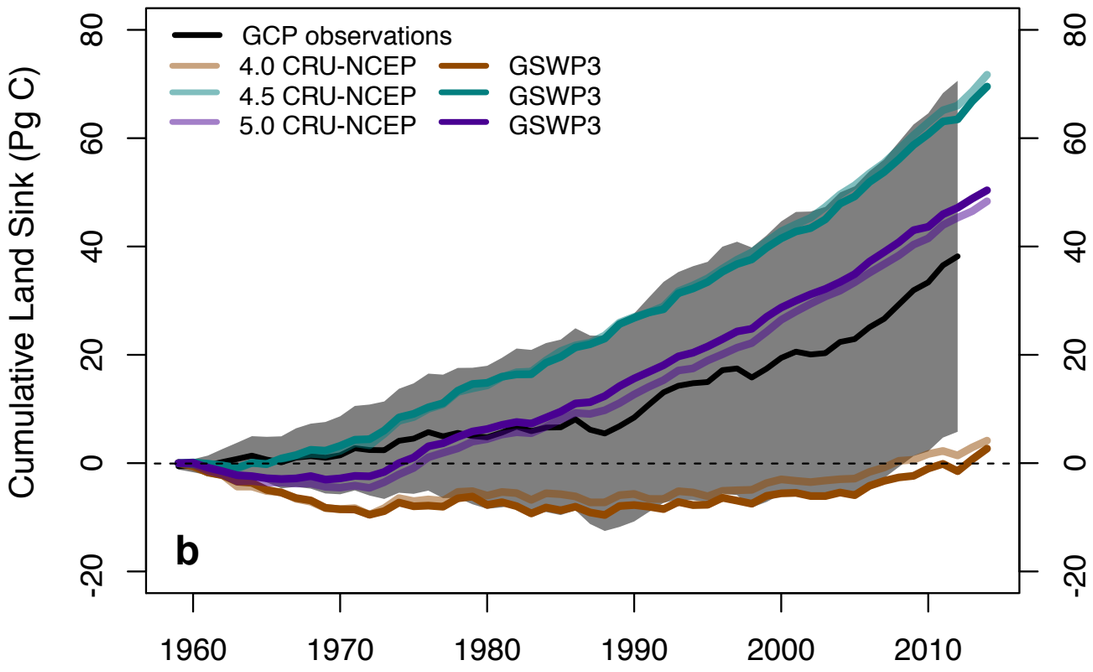


ILAMB; Collier et al., 2018

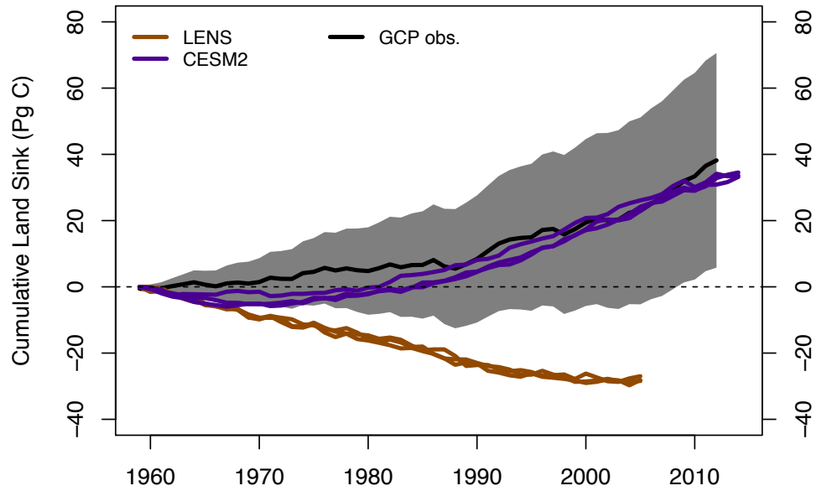
At the same time, simulation of other timescales has improved

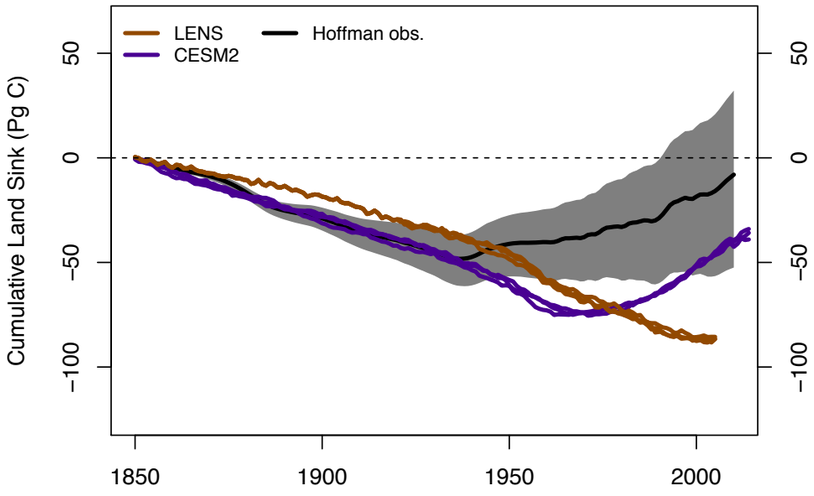


ILAMB; Collier et al., 2018



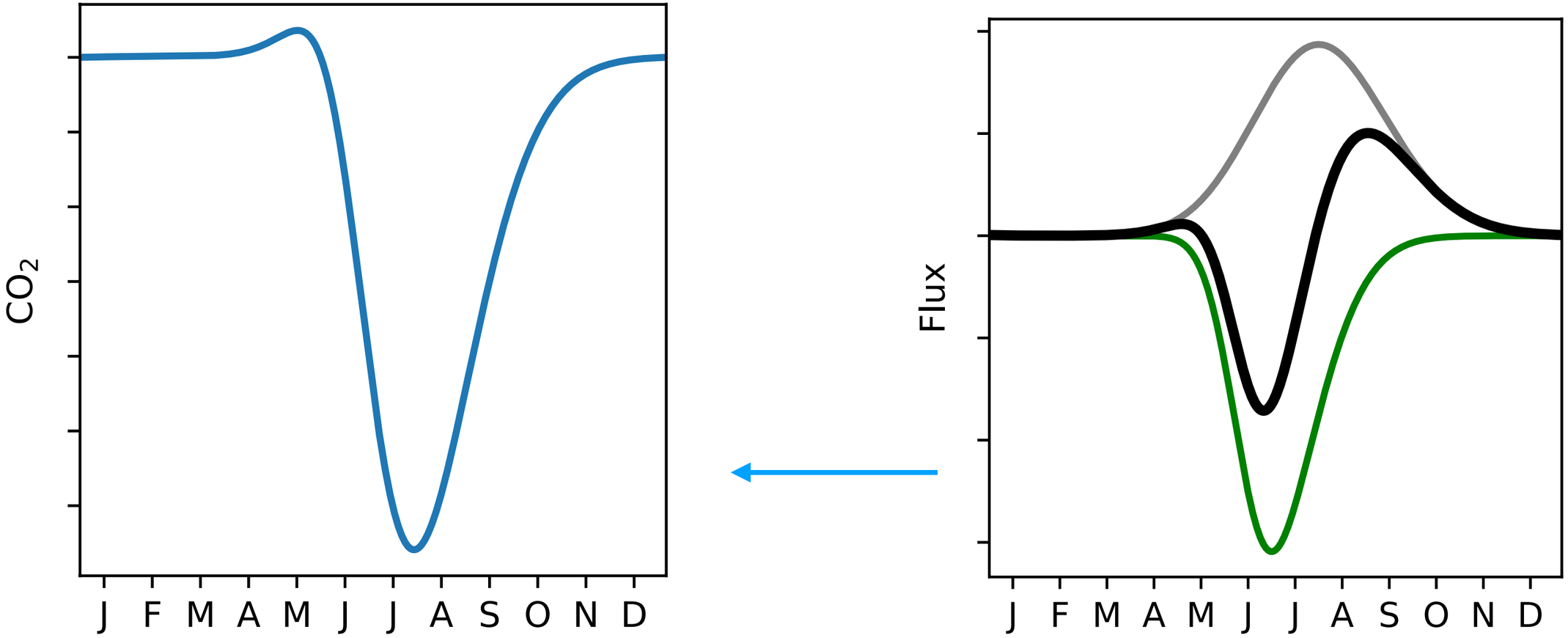
Can we trust long-term emergent timescales if we can't trust other emergent timescales?



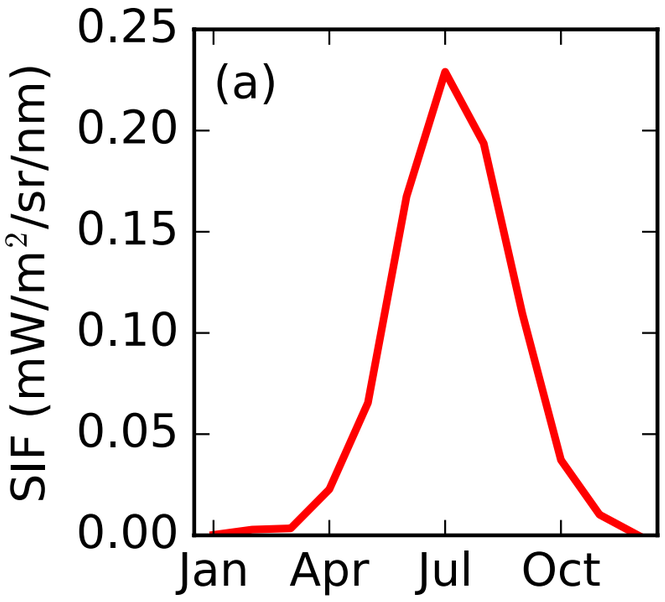


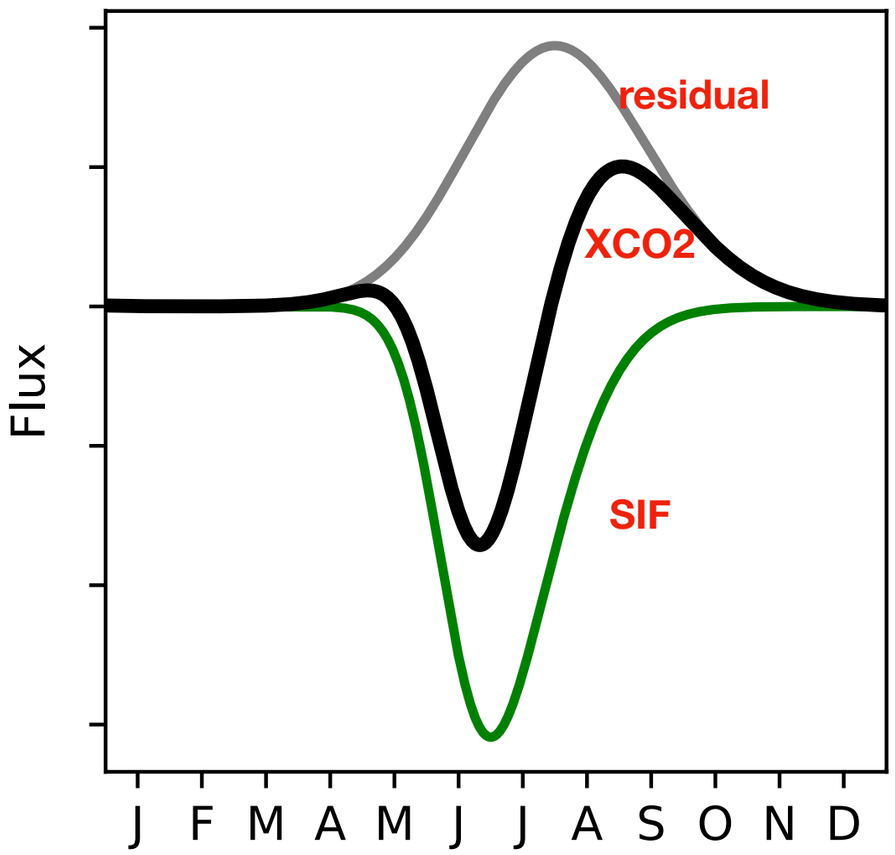
Figures: Will Wieder

Correctly attributing IAV in CO_2 requires more process level insight about component fluxes



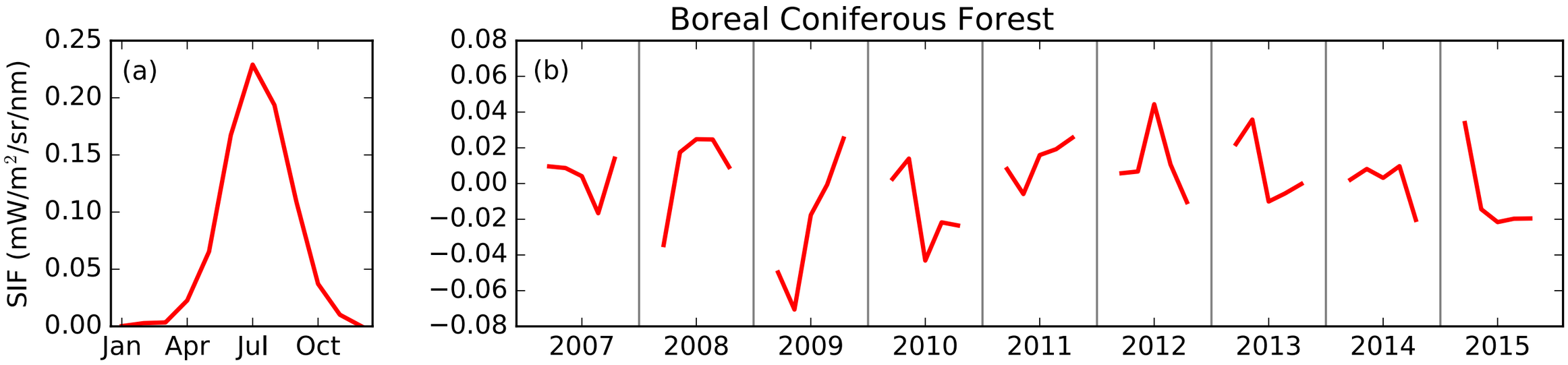
Large seasonal cycle in boreal forest SIF from GOME-2





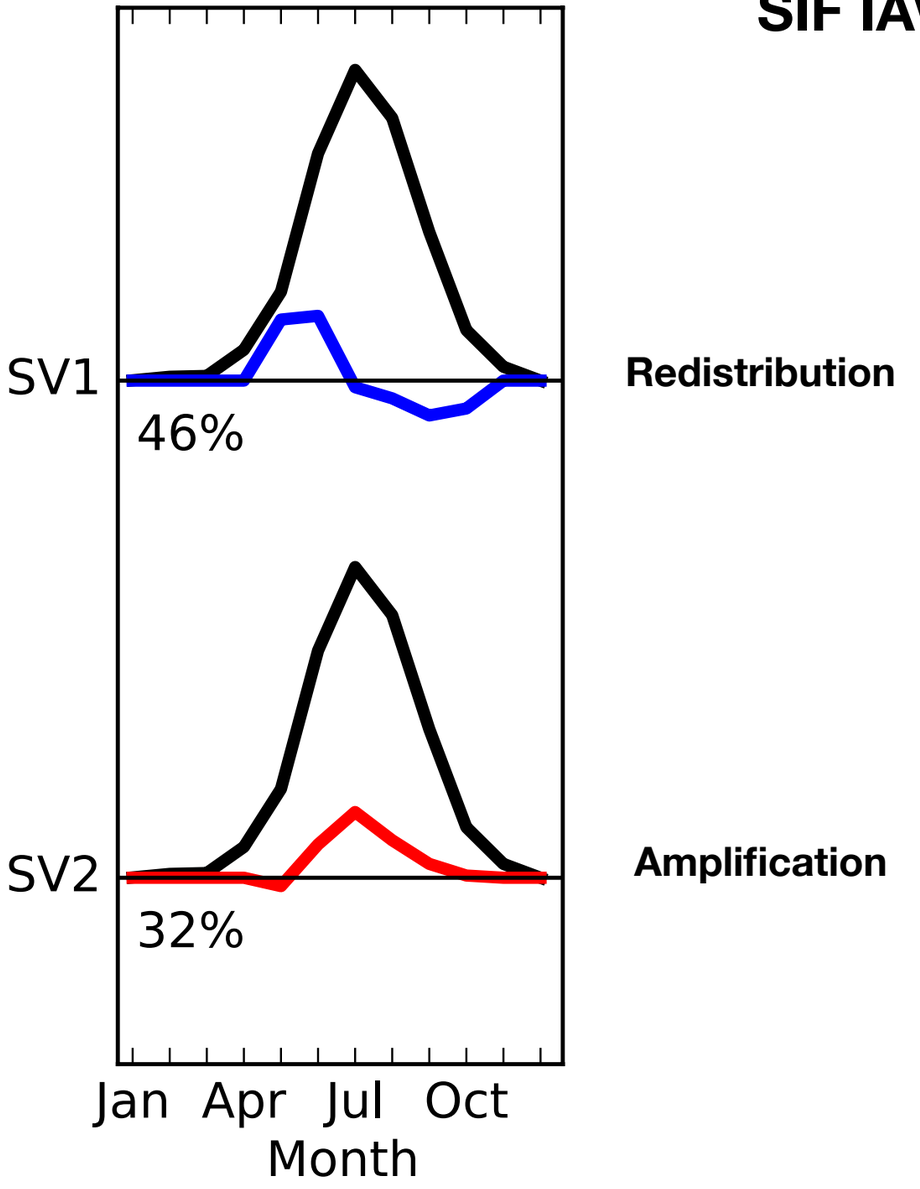
Butterfield et al., in review

Interannual or climate-driven variations are at most a few percent of peak SIF signal



Butterfield et al., in review

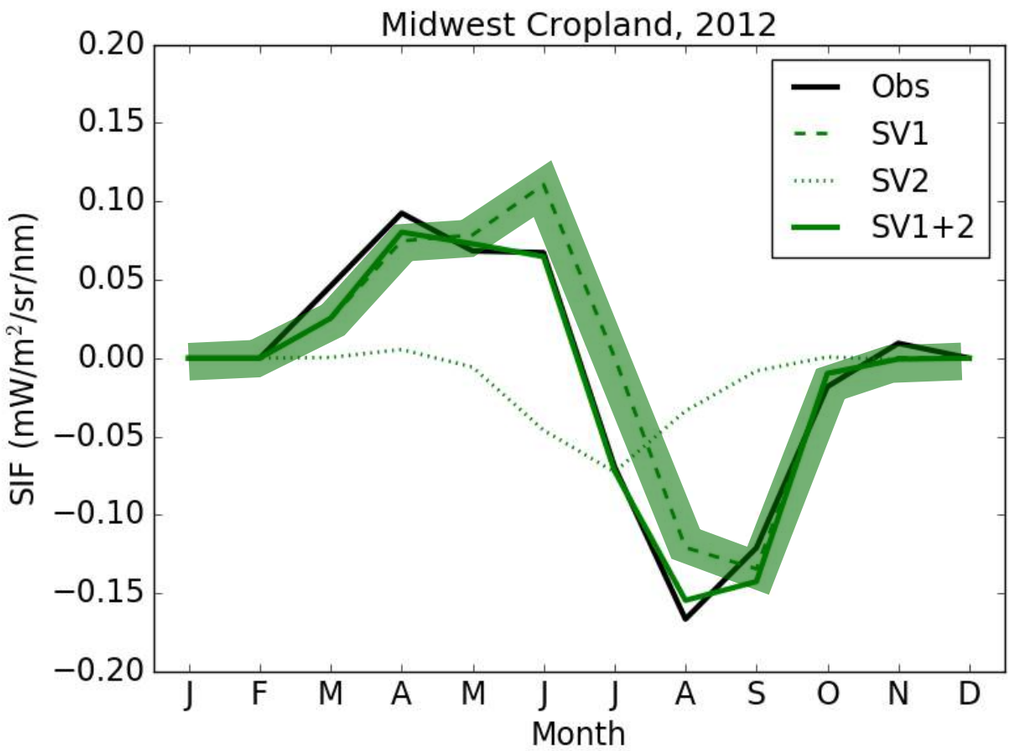
Although noisy, we can decompose SIF IAV into dominant modes

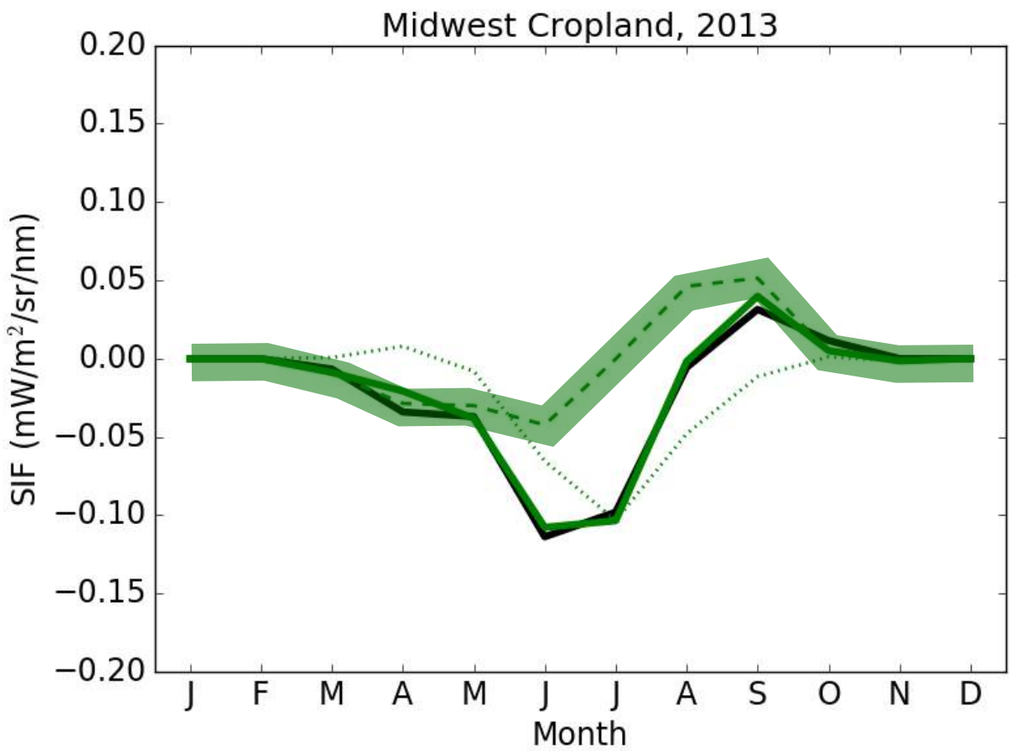


Butterfield et al., in review

SIF IAV in any given year reflects weighted sum of redistribution and amplification vectors

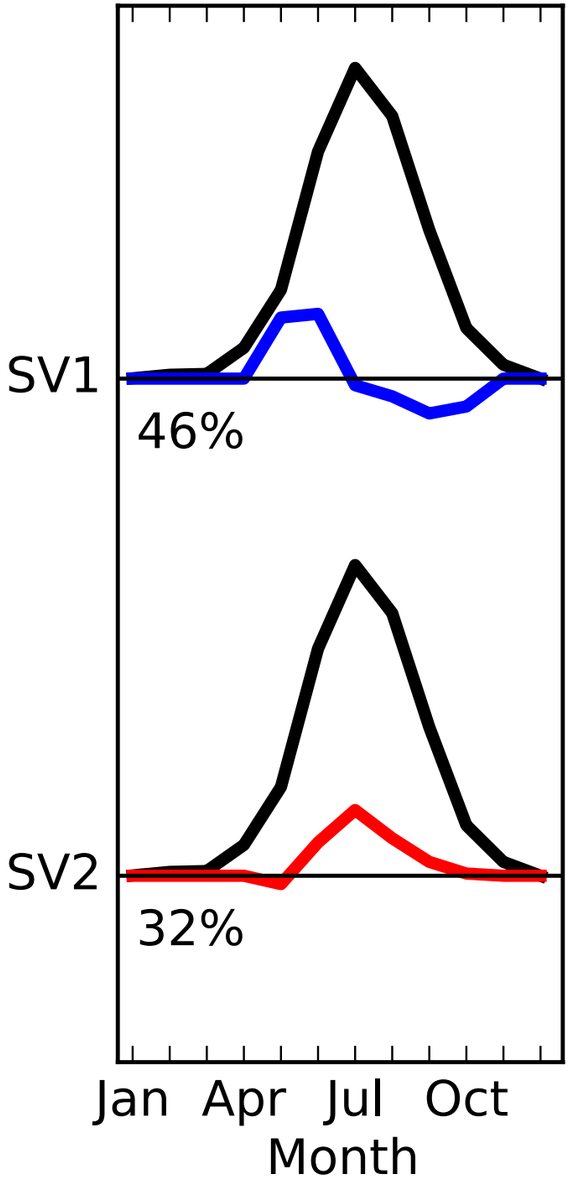
$$\text{SIF IAV} = w_r\,\text{SV1} + w_a\,\text{SV2}$$





Butterfield et al., in review

Climate drivers of IAV modes are different across Northern Hemisphere

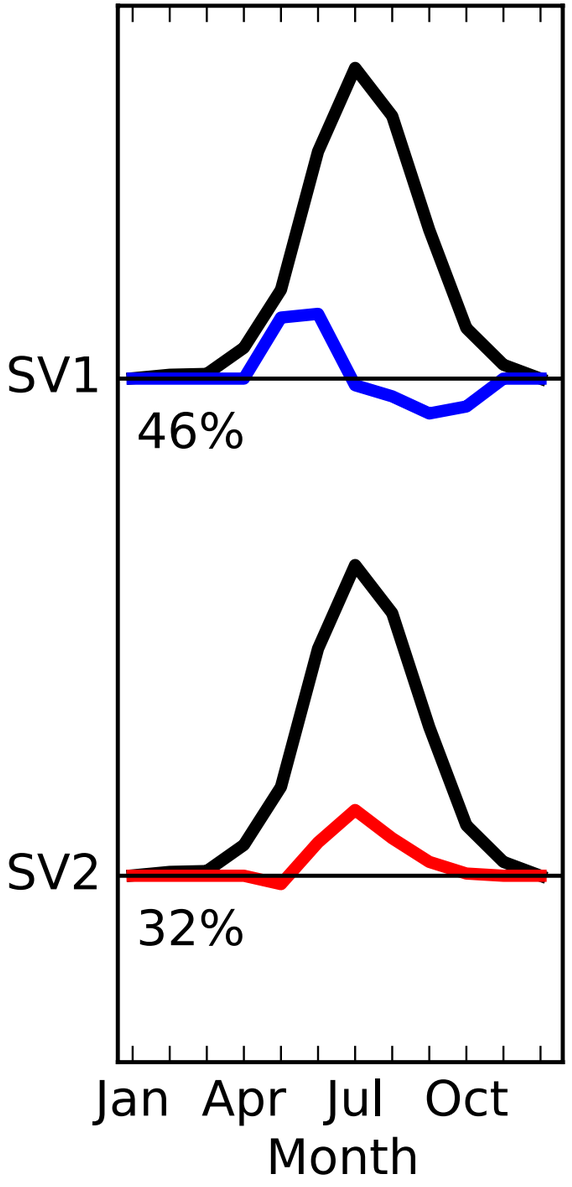


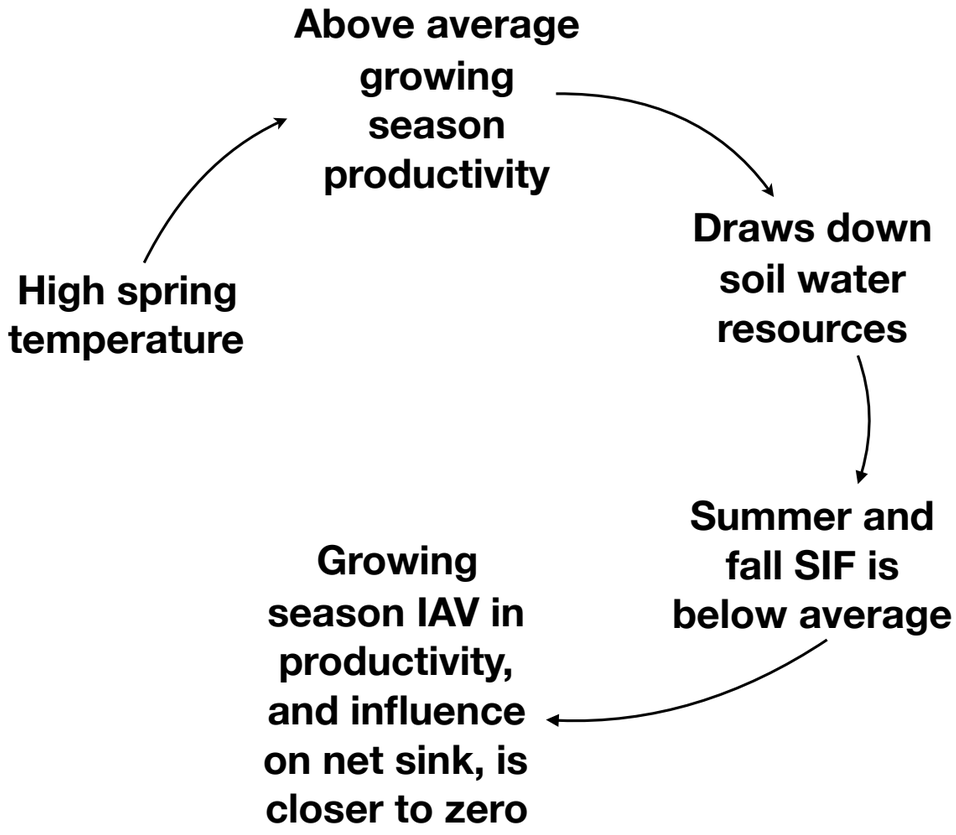
Most strongly correlated with spring temperatures

Most strongly correlated with spring water availability from GRACE

Butterfield et al., in review

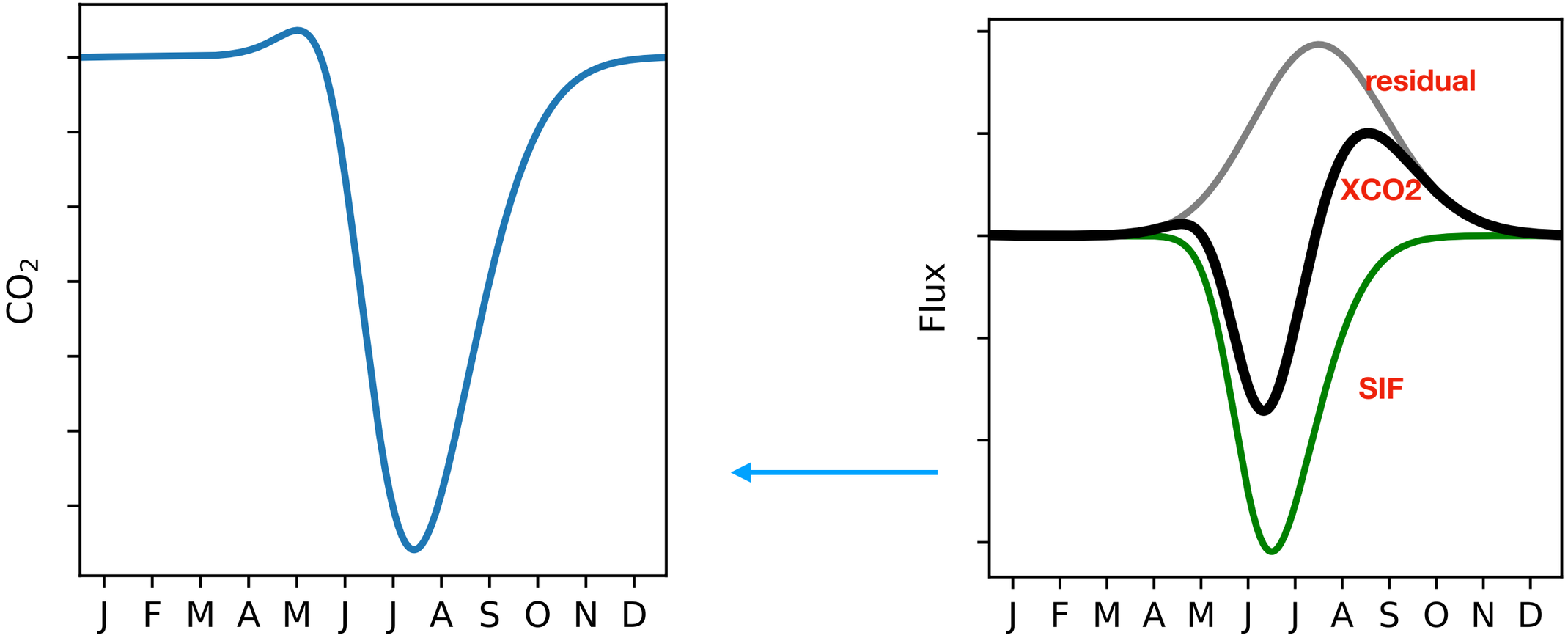
Contribution of productivity variabilities to net CO_2 signal is self-limiting



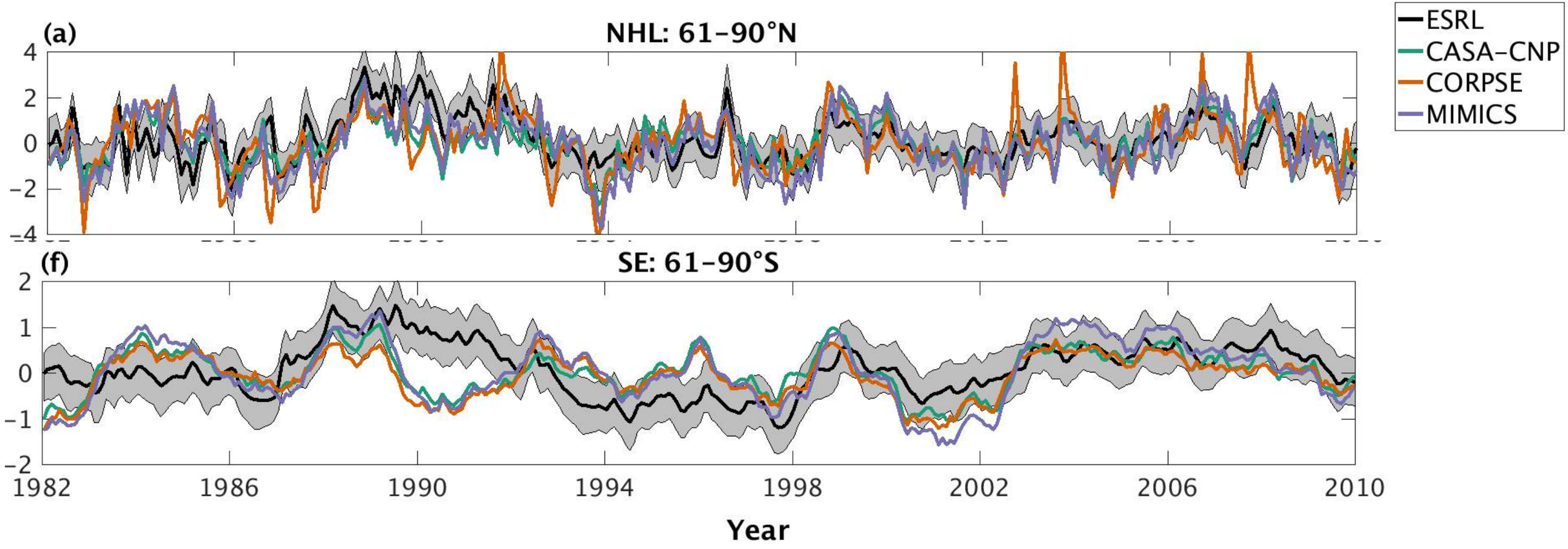


Butterfield et al., in review

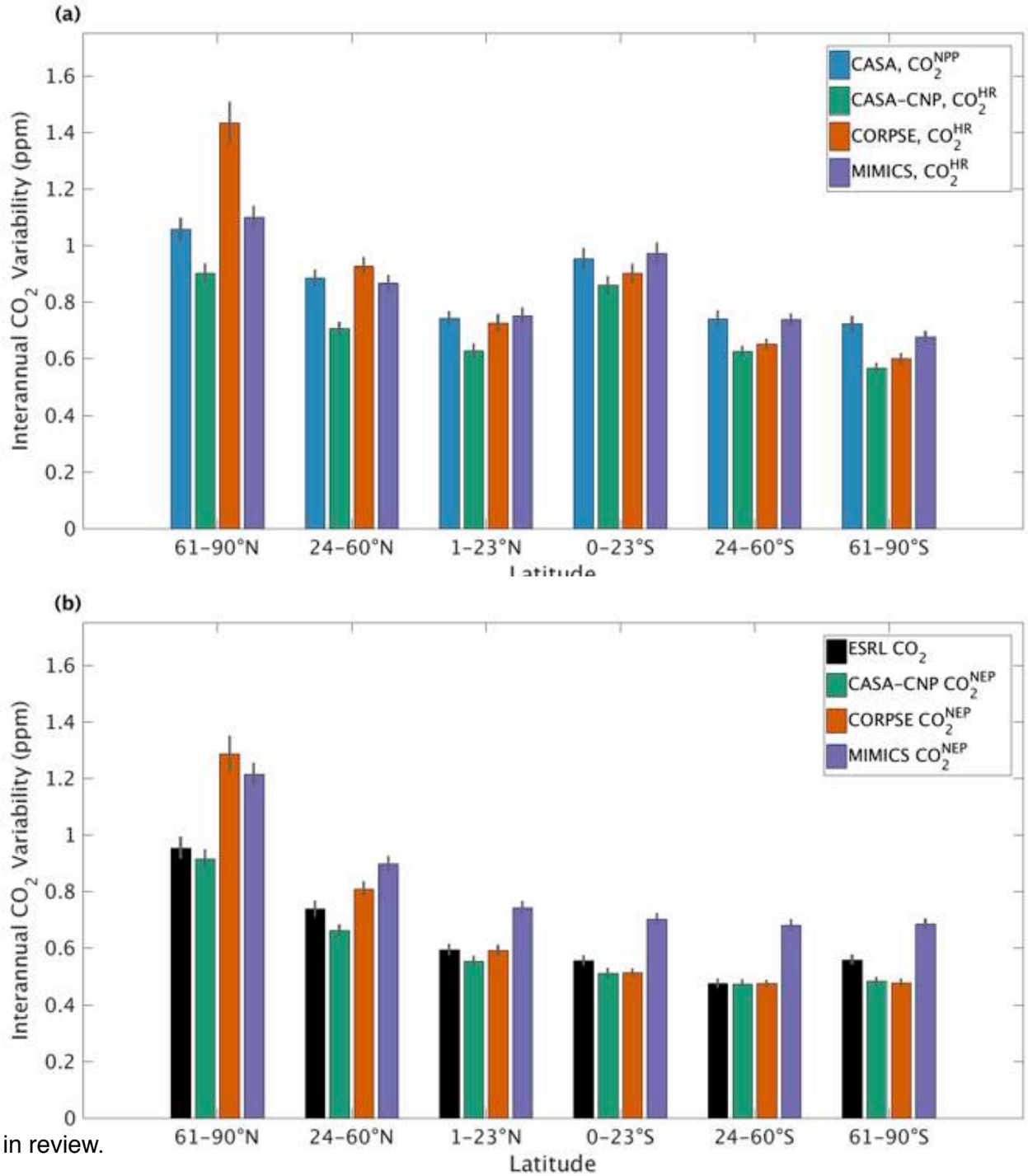
Correctly attributing IAV in CO_2 requires more process level insight about component fluxes



We simulate patterns of CO_2 variability owing to three different models for heterotrophic respiration affected by identical climate and NPP fluxes



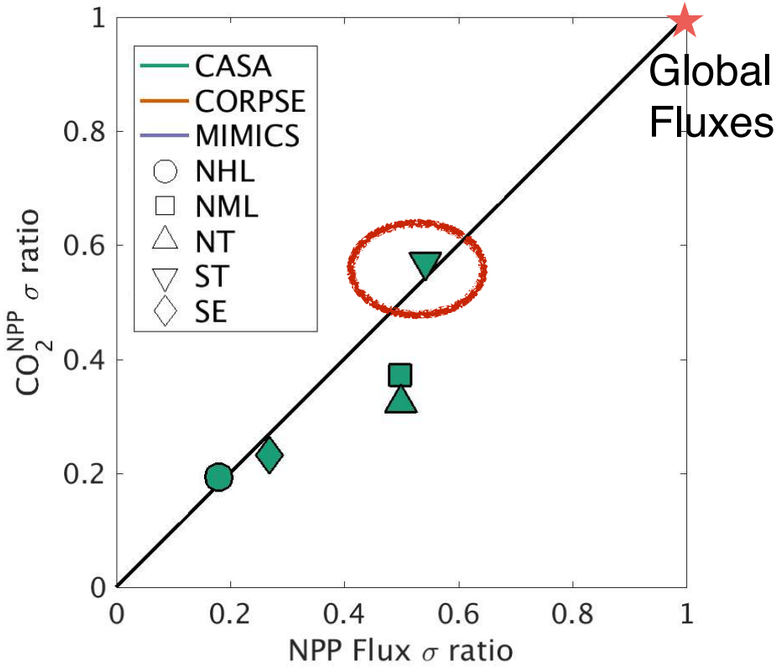
Basile et al., in review.



Basile et al., in review.

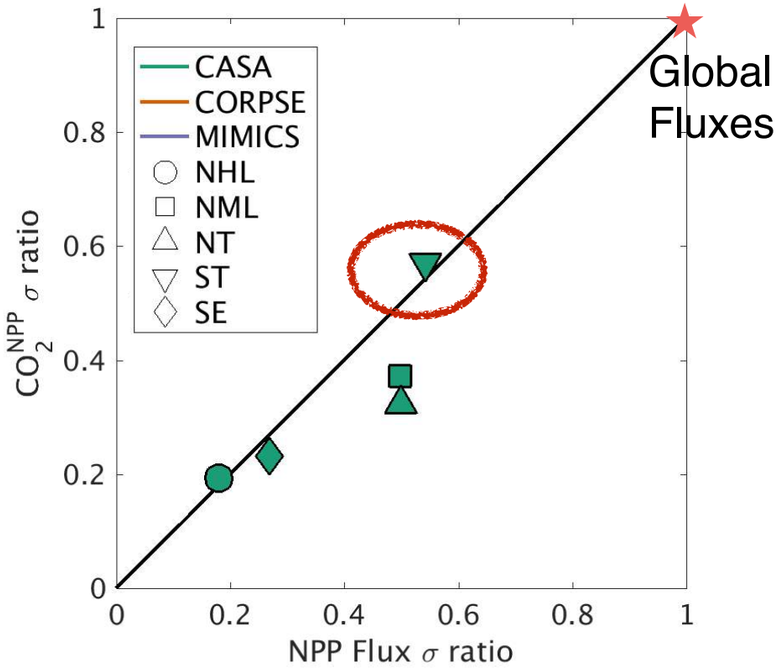
Phasing is important at interannual timescales:

MIMICS and CORPSE have similar IAV for HR, but different phase, so net CO_2 has large difference



Variability in Southern Hemisphere tropical NPP flux is about 60% of variability in global NPP flux

Basile et al., in review.



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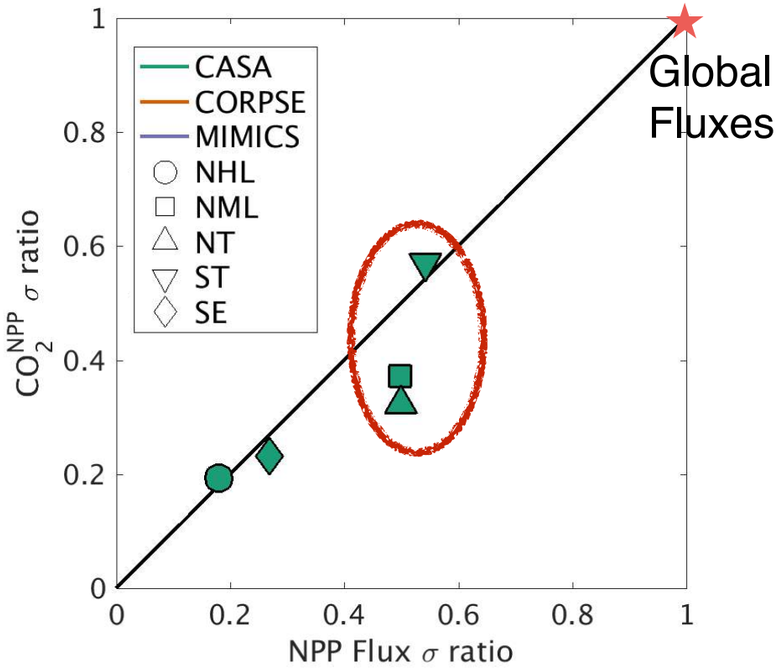
Basile et al., in review.



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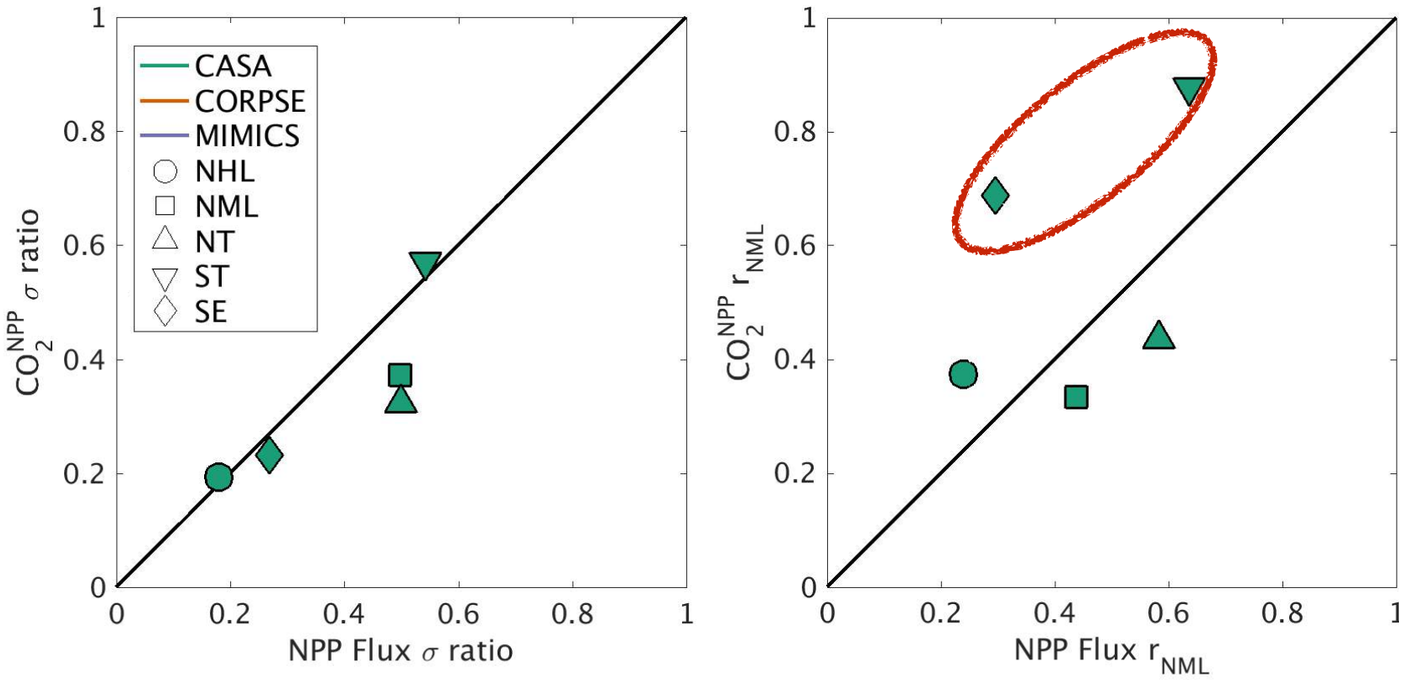
SH tropical fluxes are only slightly more variable than NH tropical and midlatitude fluxes…

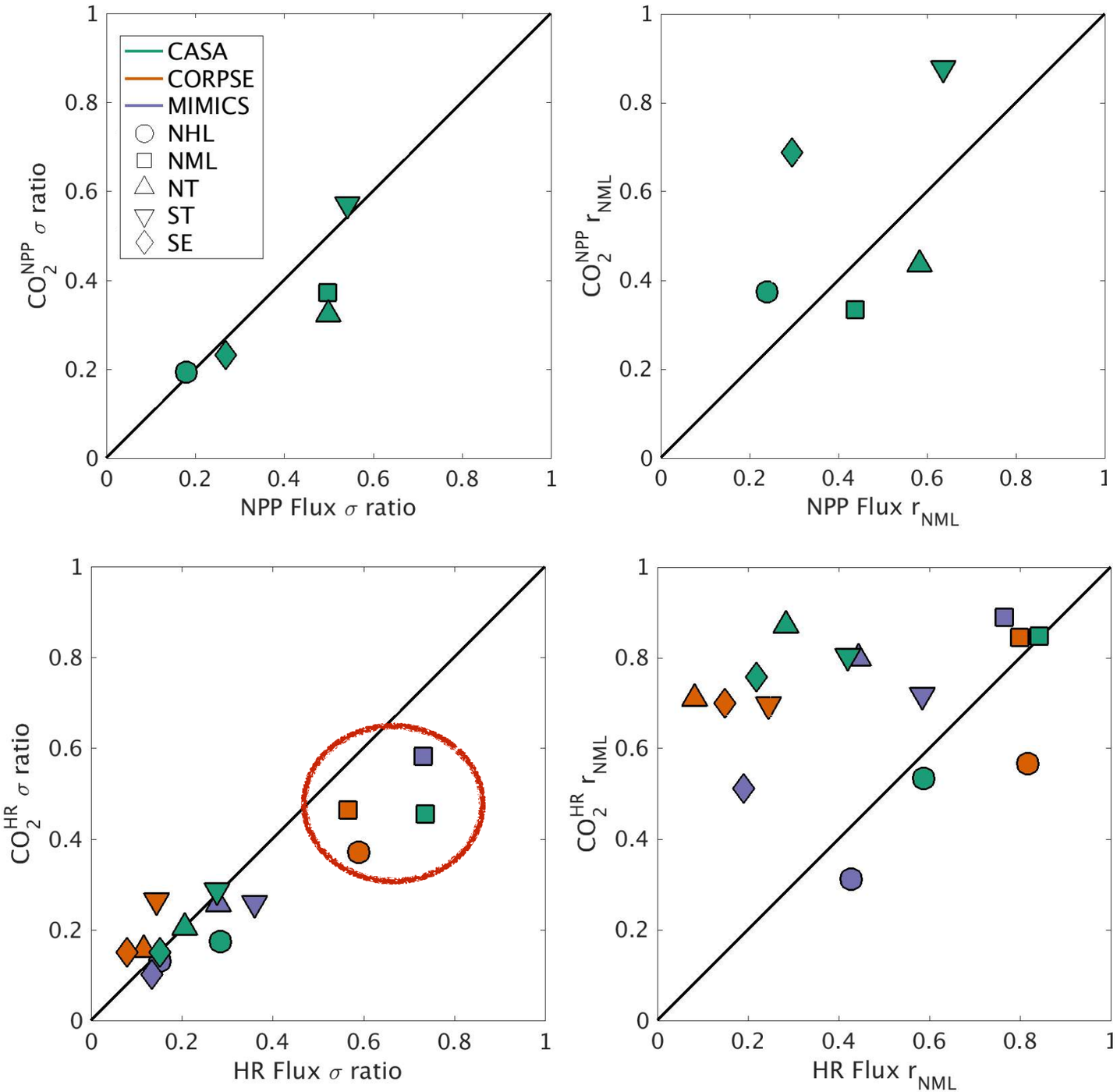
… but atmospheric circulation damps the apparent variability in these other latitude bands

Basile et al., in review.



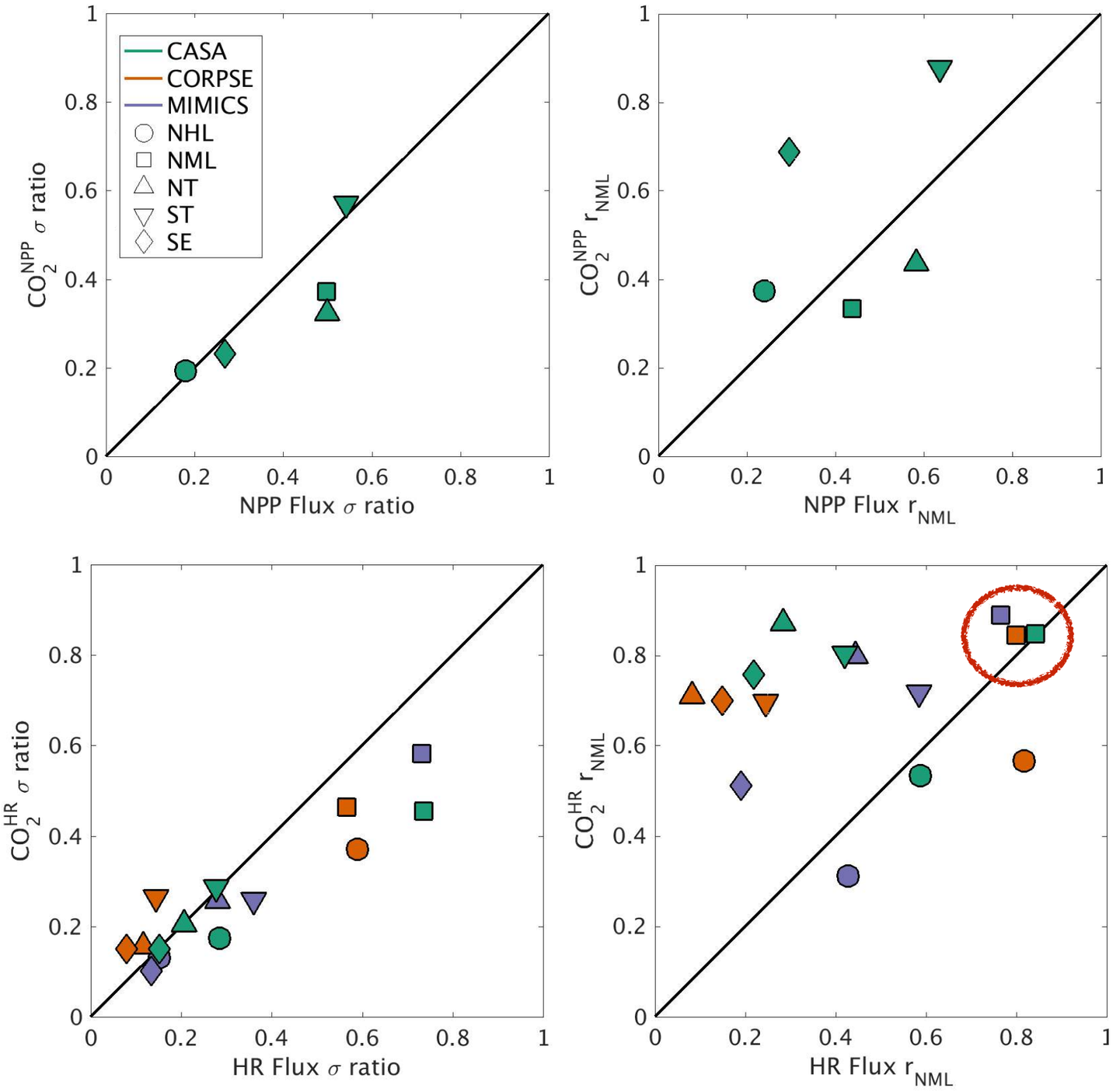
Atmospheric transport also magnifies the correlation of the Southern Hemisphere flux signal with the global flux signal

Basile et al., in review.



In contrast to NPP, the Northern Hemisphere midlatitudes have the largest variability in HR flux and imprint on atmospheric CO_2.

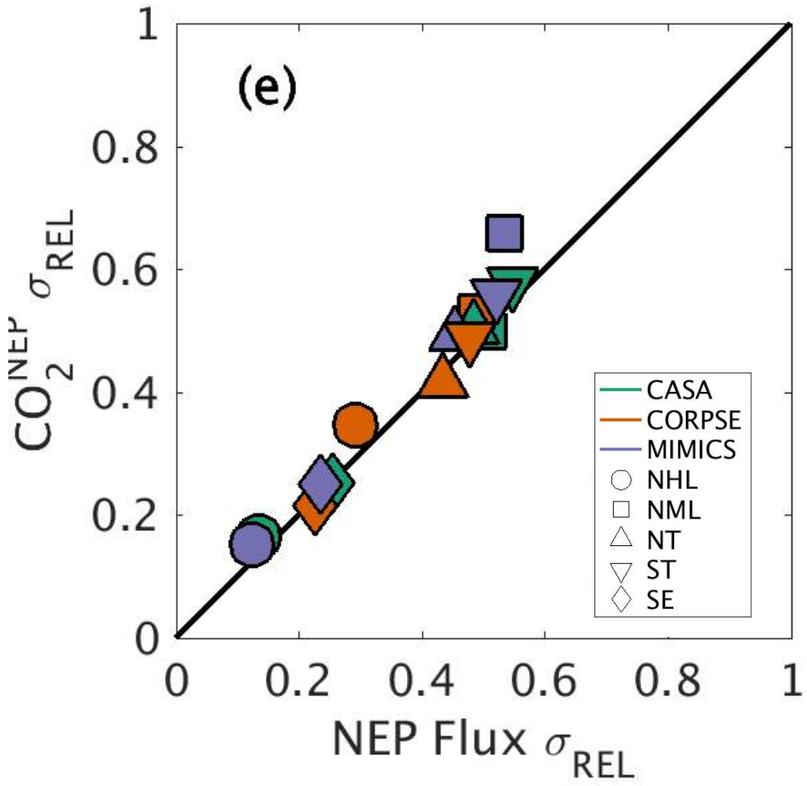
Basile et al., in review.



The influence of NH midlatitude fluxes is also most coherent with global signal

Basile et al., in review.

Variations in net fluxes partition evenly between Tropics and Northern midlatitudes



Basile et al., in review.

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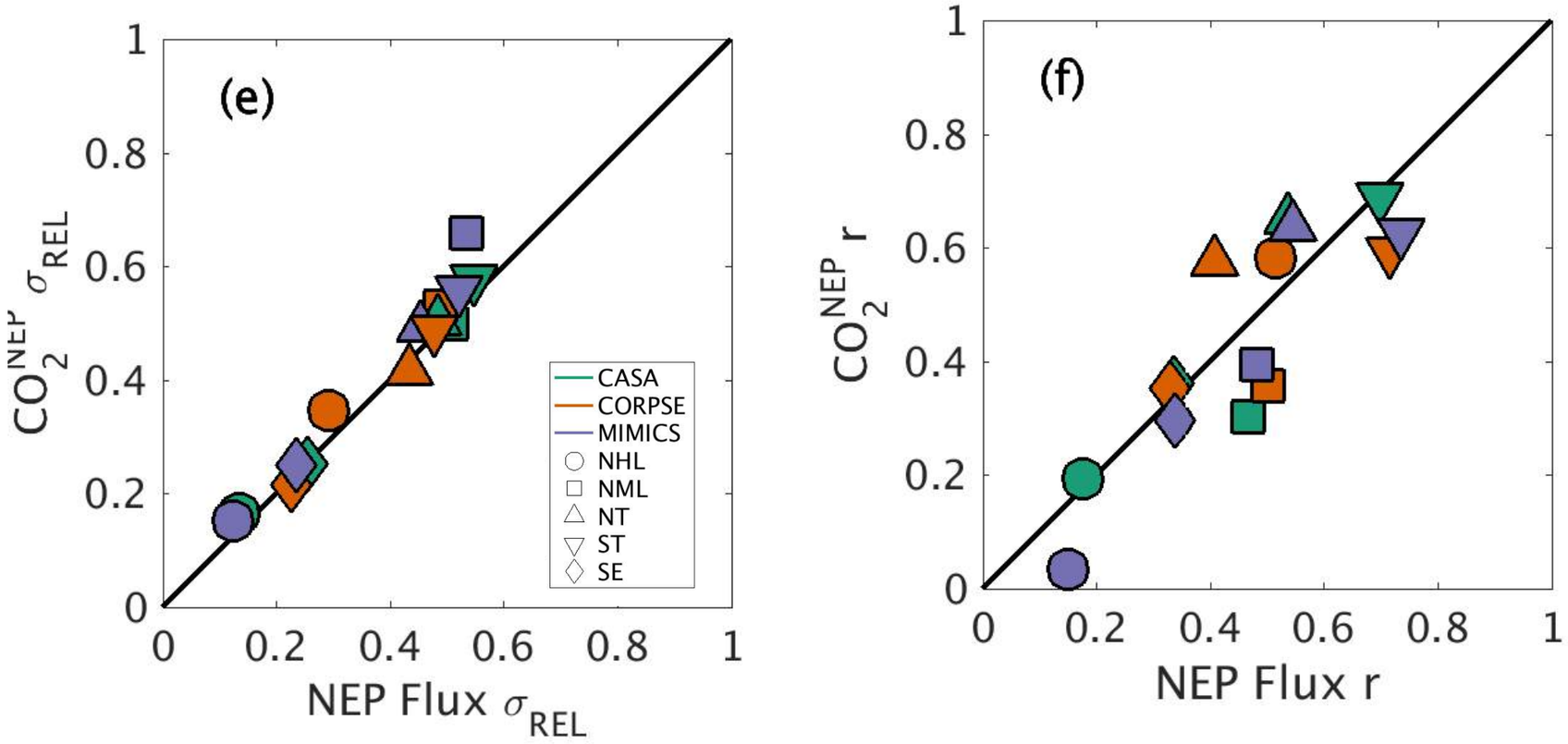

Although tropical influence is more temporally coherent with global signal

Basile et al., in review.

Ultimately atmospheric CO_2 determines the magnitude of radiative forcing, AND reflects the integral of global fluxes, so reconciling bottom-up and other satellite-based metrics for variability with atmospheric CO_2 from a mechanistic perspective is important

Interannual variability in longest-standing SIF observations from GOME-2 requires regional aggregation and reveals the importance of intraseasonal redistribution in productivity in response to climate variations

While much NPP variability arises in the tropics, modeling and CO_2 fingerprinting analysis suggests respiration is a dominant source of IAV in the extratropics

Diagnostic modeling is an essential tool to understand how to use datasets in synergy to develop a quantitative carbon-climate predictions