Evaluating models of heterotrophic respiration with atmospheric CO_2

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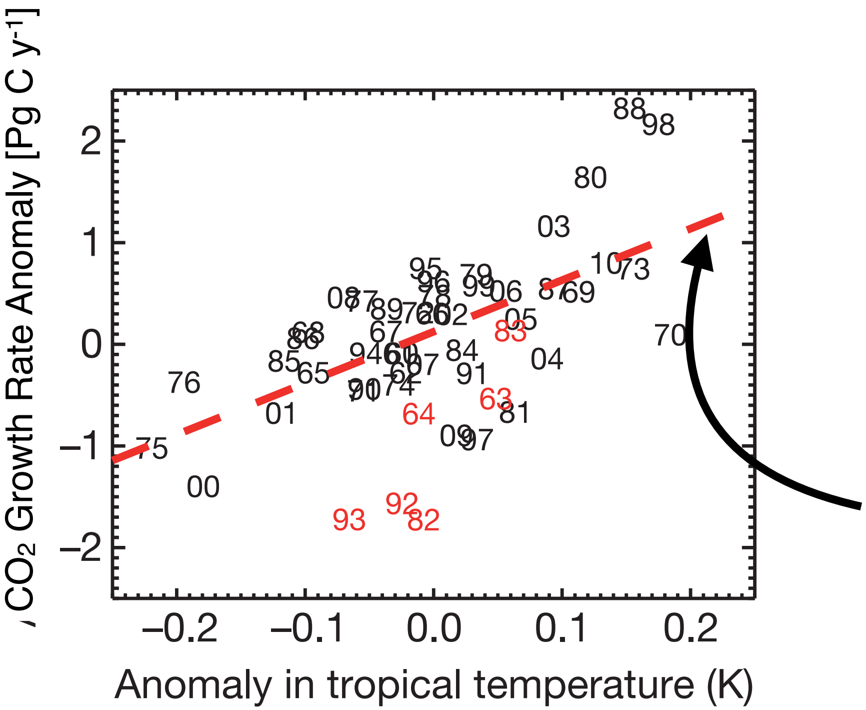
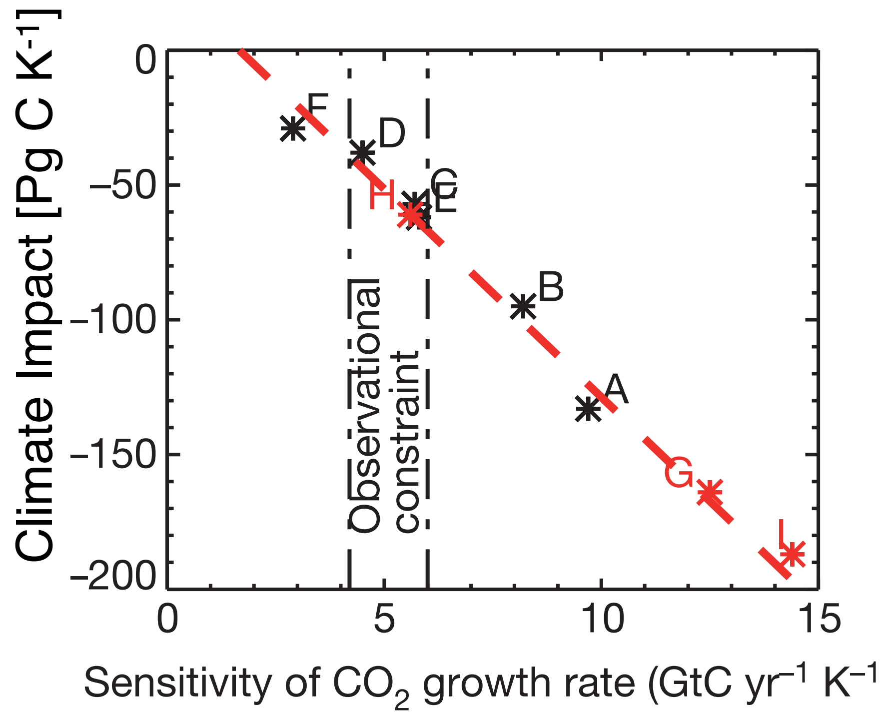
Terrestrial ecosystem fluxes are sensitive to climate variations and are expected to have large feedbacks to climate change

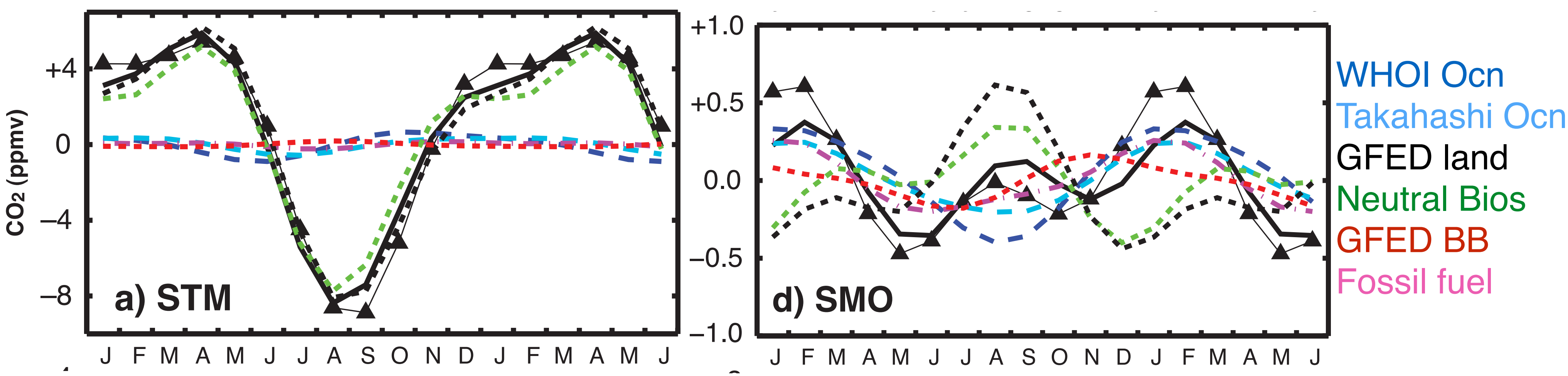


Slope represents interannual sensitivity of sink to temperature



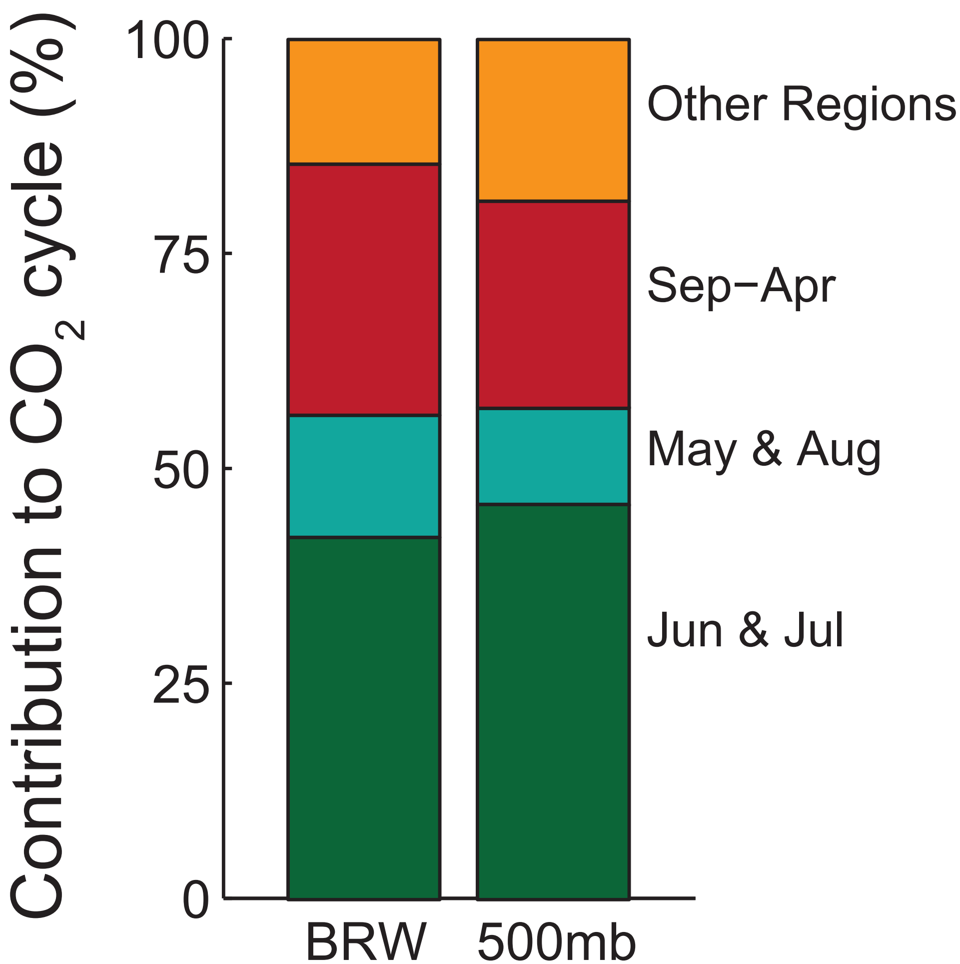
Cox et al., 2013

Atmospheric CO2 contains the imprint of many different fluxes, but terrestrial processes dominate seasonal and interannual variability



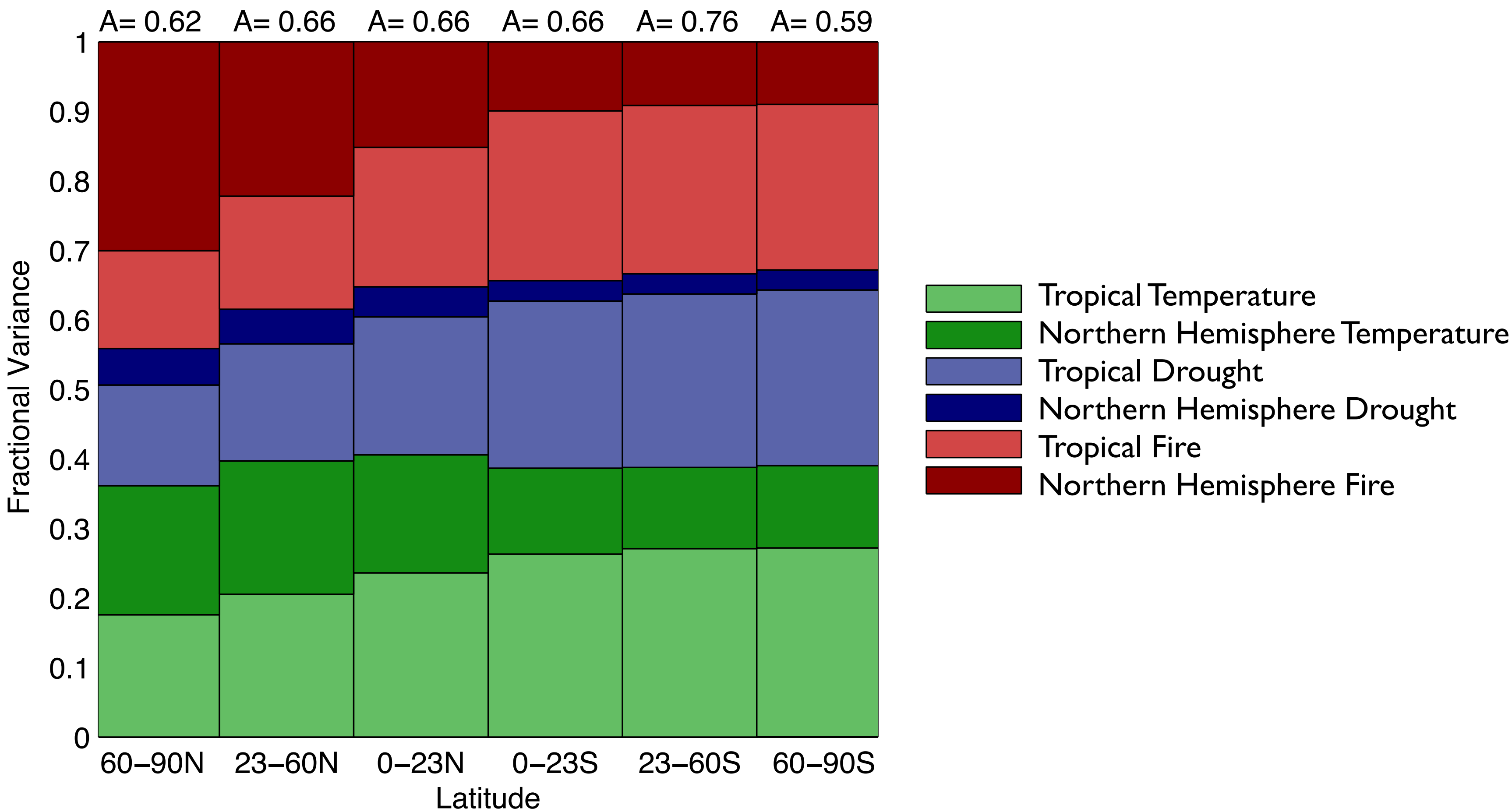
Nevison et al., 2008

Atmospheric CO_2 annual cycle reflects both growing season uptake and net release of CO2



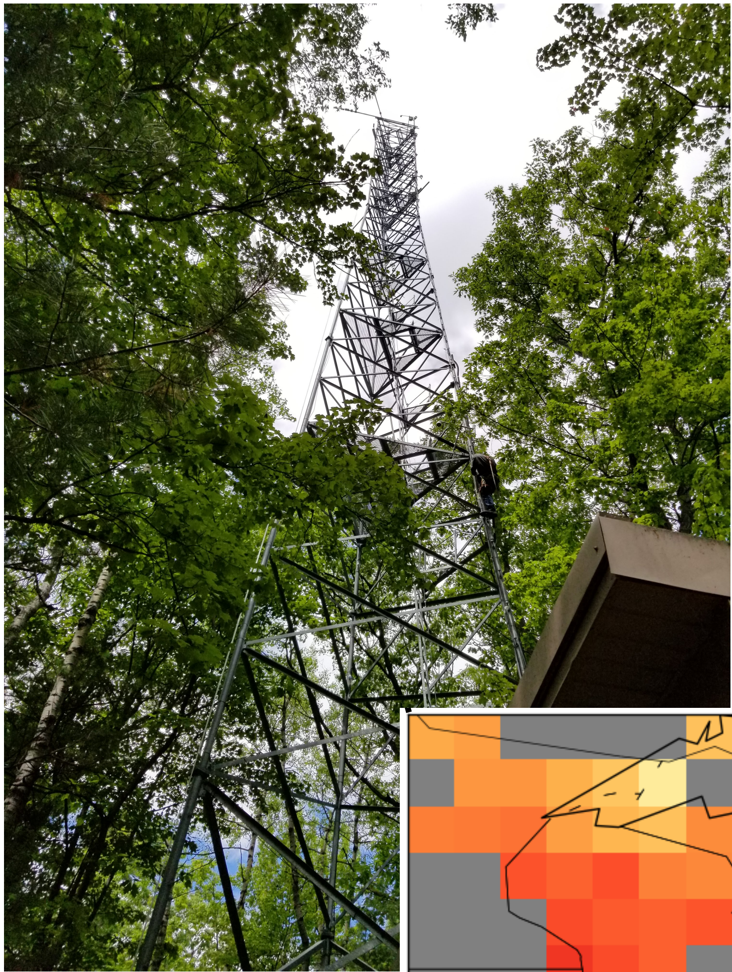
Graven et al., 2013

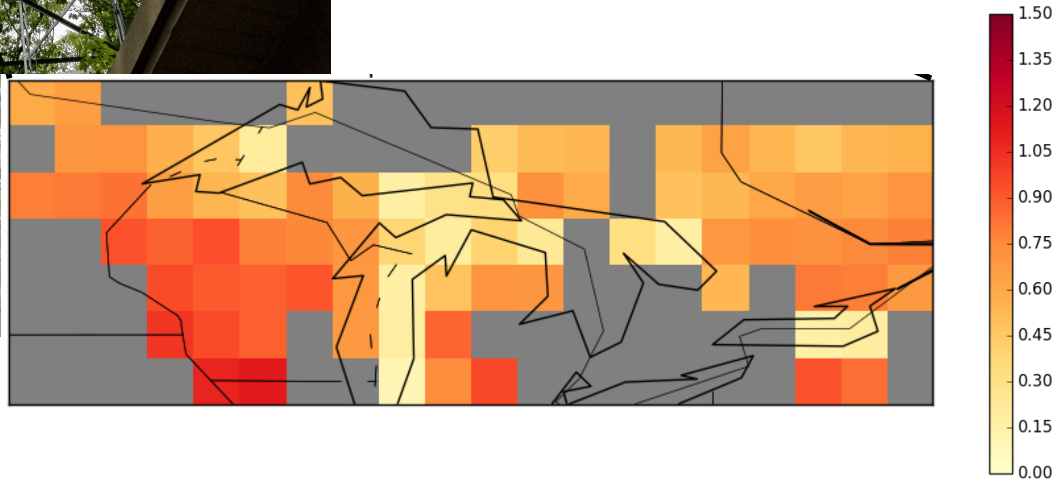
Carbon cycle responds to multiple climate drivers across diverse regions



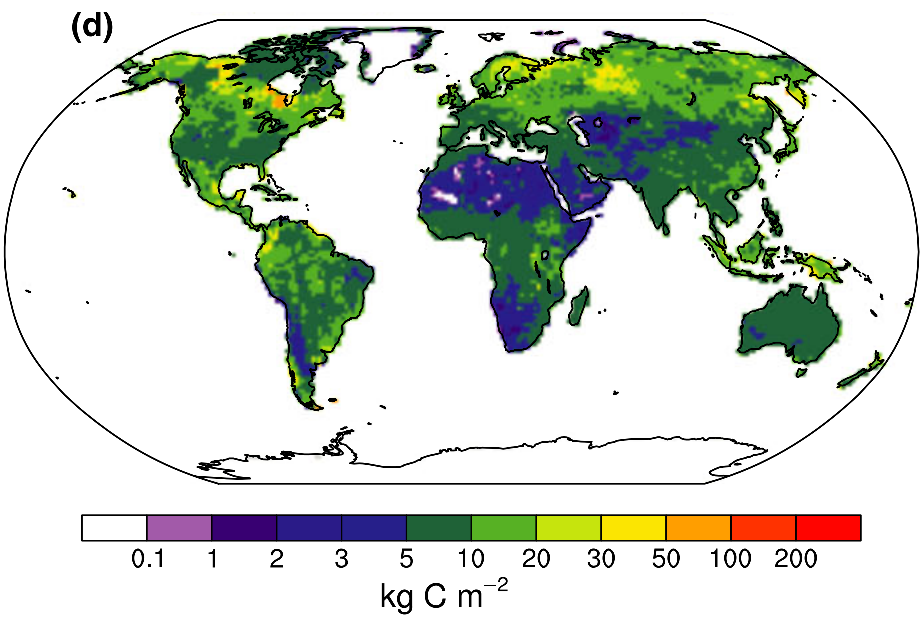
Keppel-Aleks et al., 2014

We have constraints on ecosystem productivity over a range of spatial scales

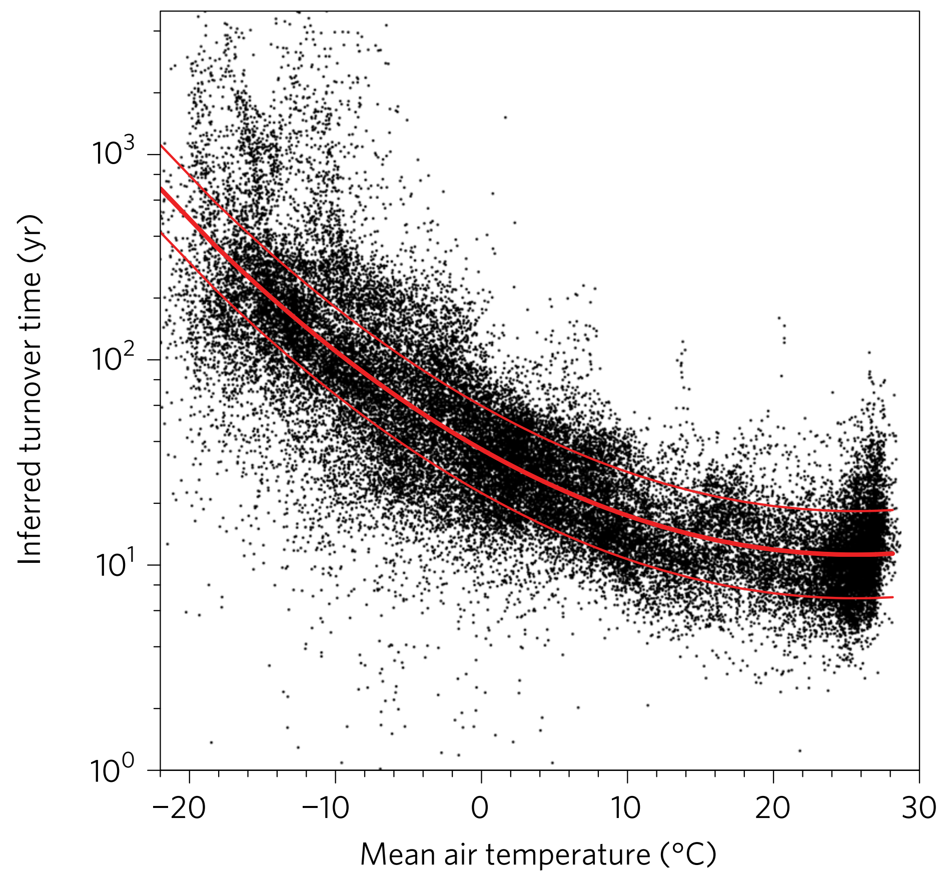




We have approaches to benchmark soil stocks at regional scales…



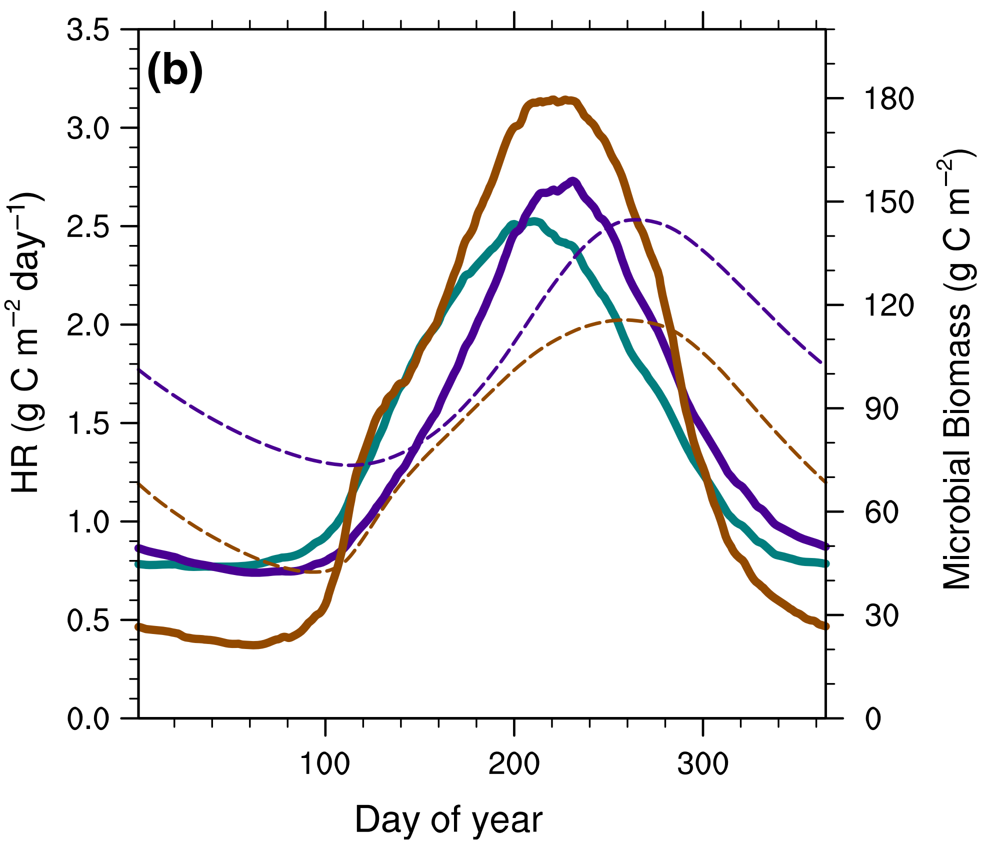
Wieder et al., 2018

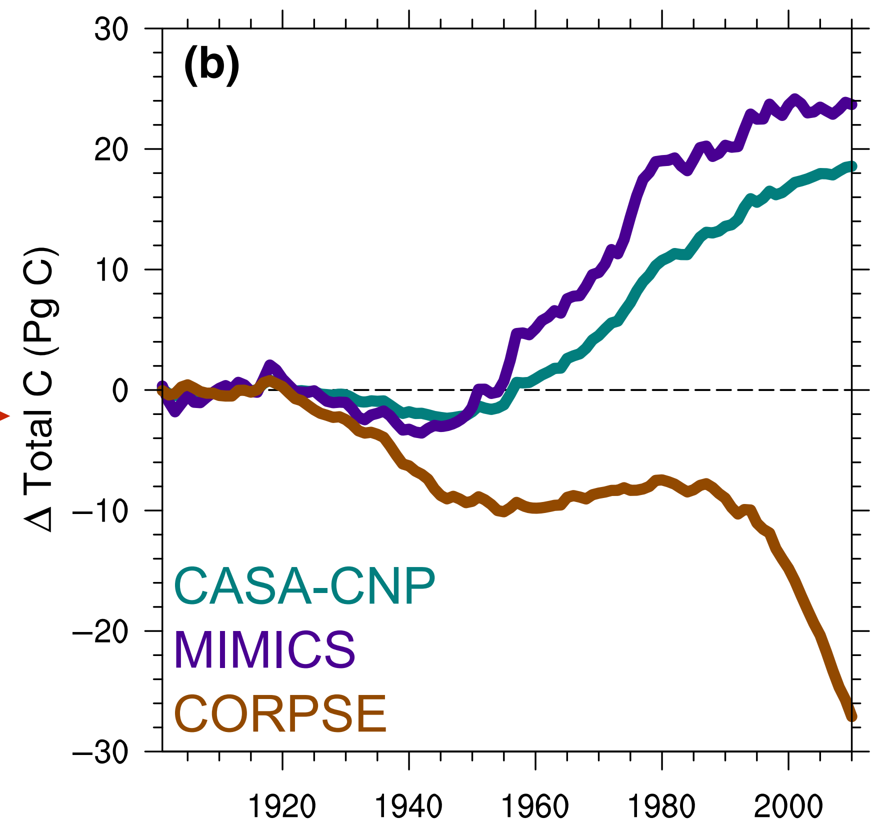


Koven et al., 2017

… but observations of soil fluxes are limited to local scales

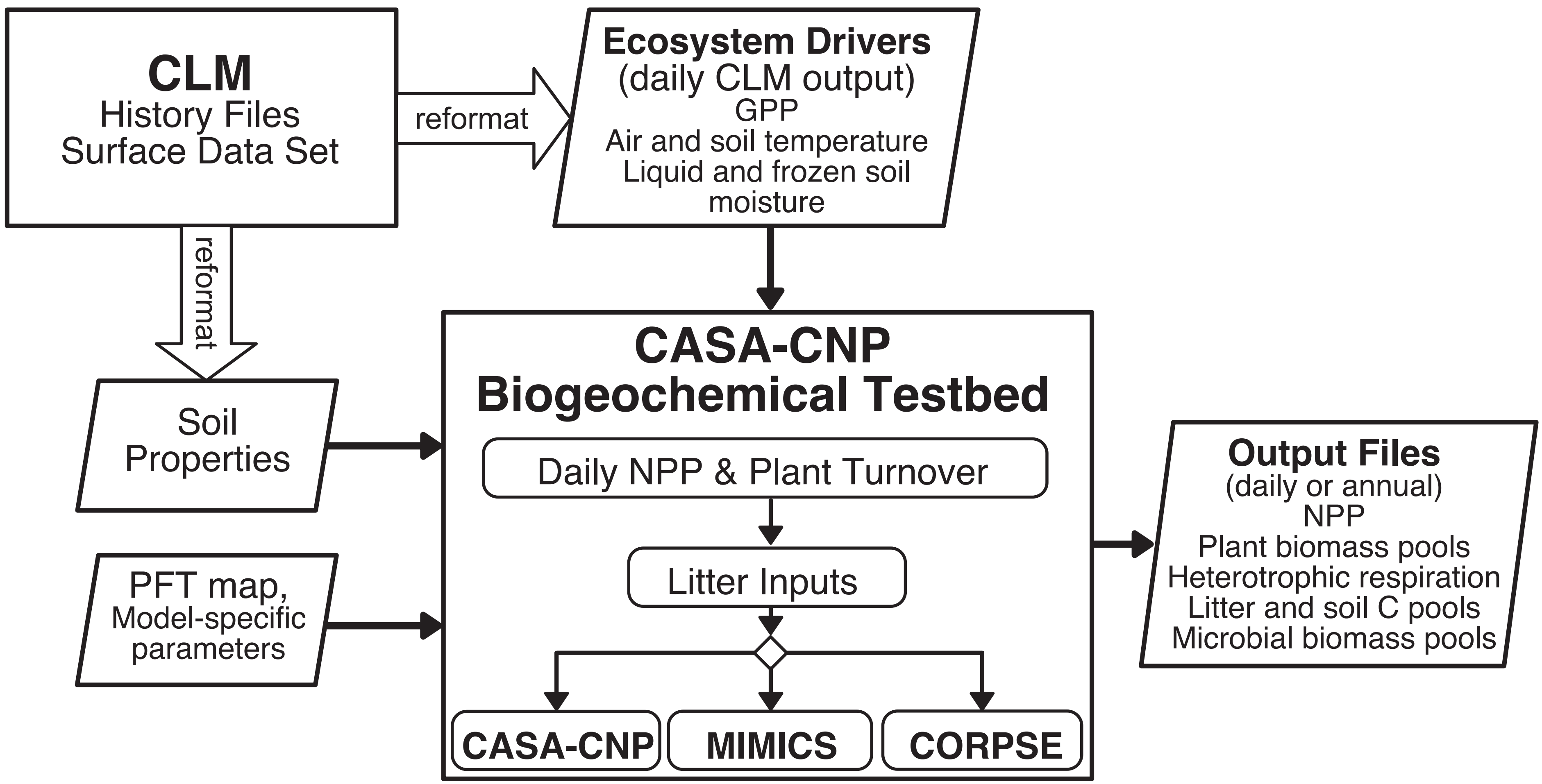
Flux patterns will affect accumulation of soil carbon over 21st century





Wieder et al., 2018

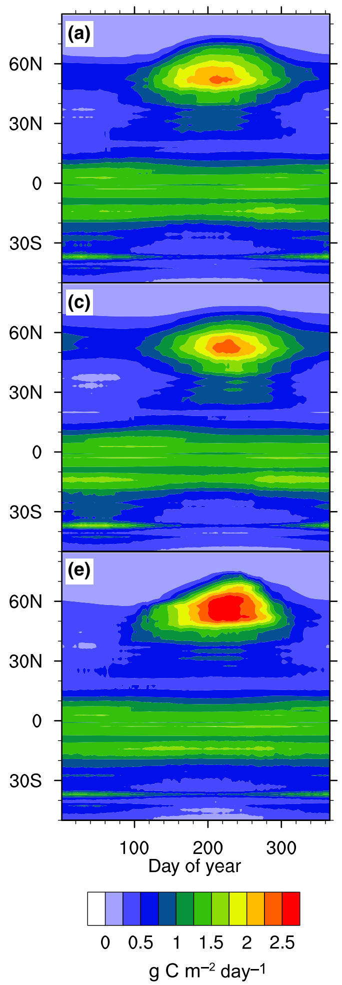
Can we evaluate model predictions of heterotrophic respiration using atmospheric CO2?



Wieder et al., 2018

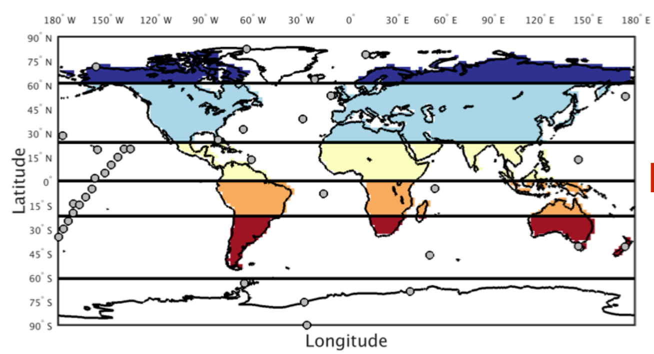
Use testbed models to develop three plausible representations of atmospheric CO2

CASA NPP + Testbed HR Fluxes as boundary conditions



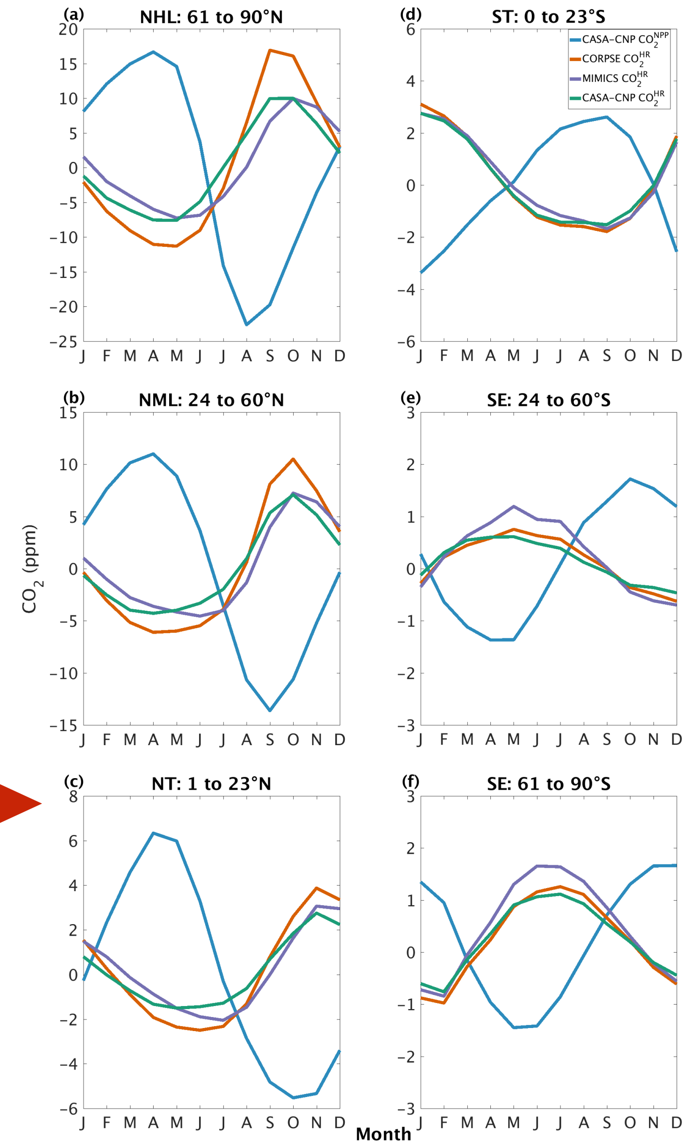
GEOS-Chem
Atmospheric transport model

2x2.5 deg



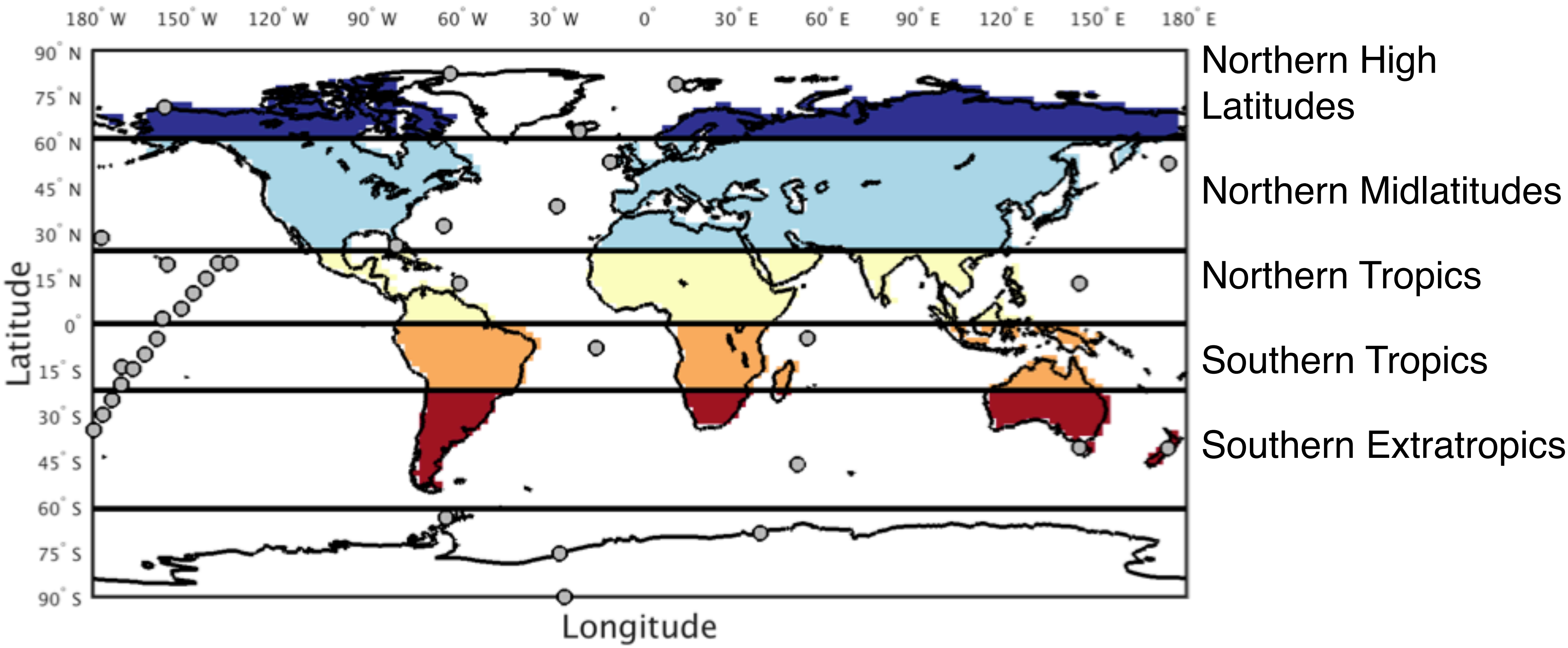
Sample at NOAA observatories

Zonal CO_2 patterns



Basile et al., in prep.

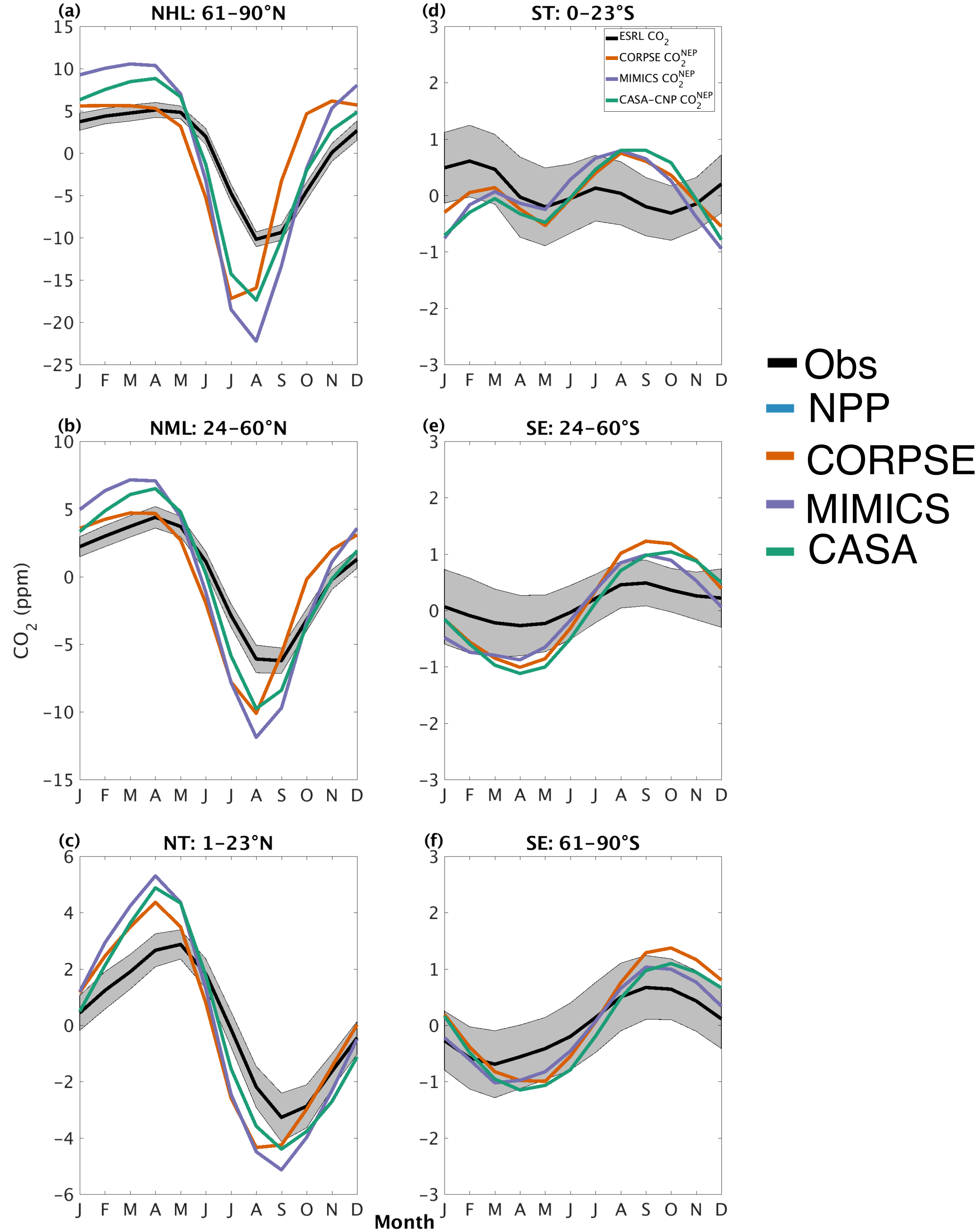
Fluxes are tagged separately by region



Sampling locations are marine boundary layer sites

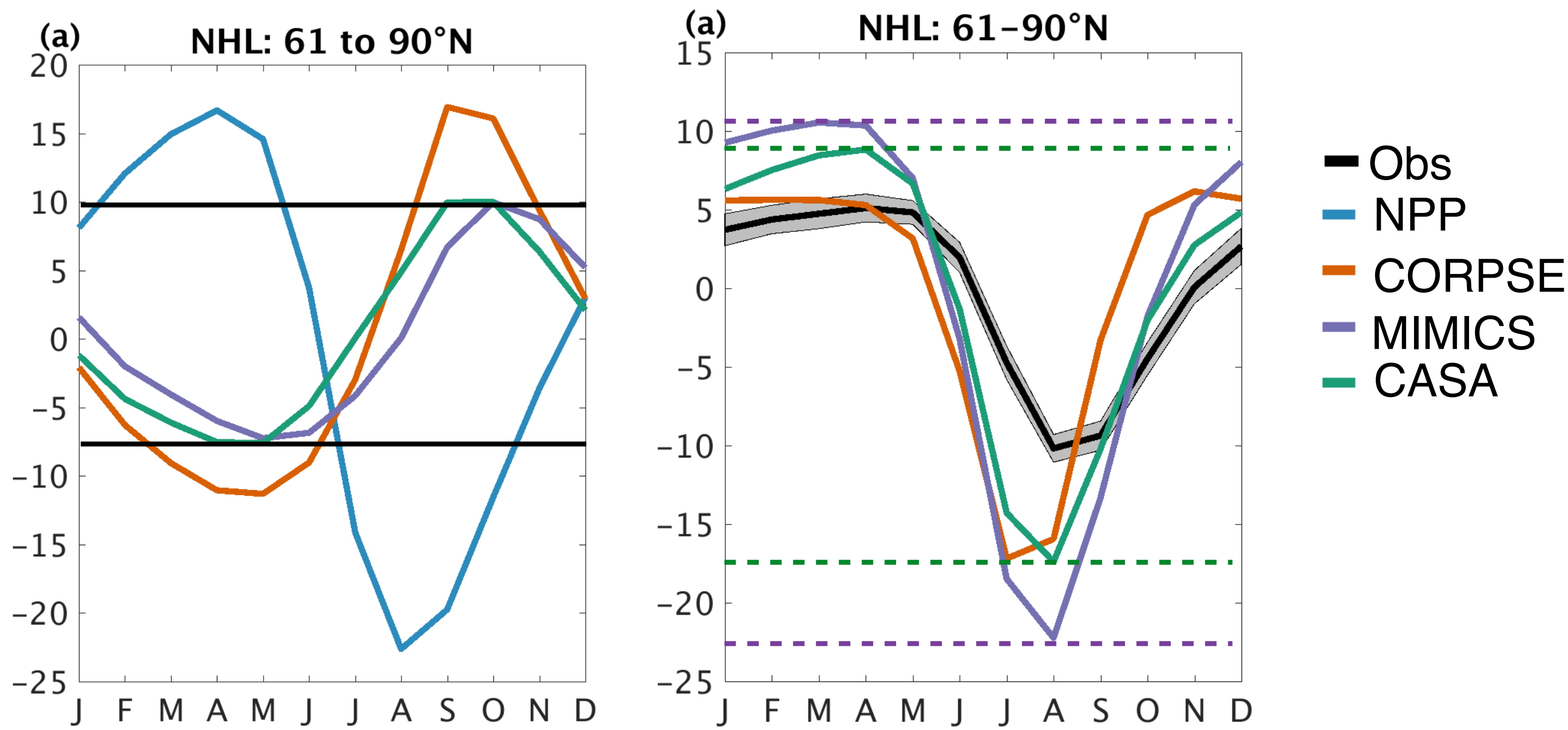
Basile et al., in prep.

Seasonal cycle overestimated by all testbed models

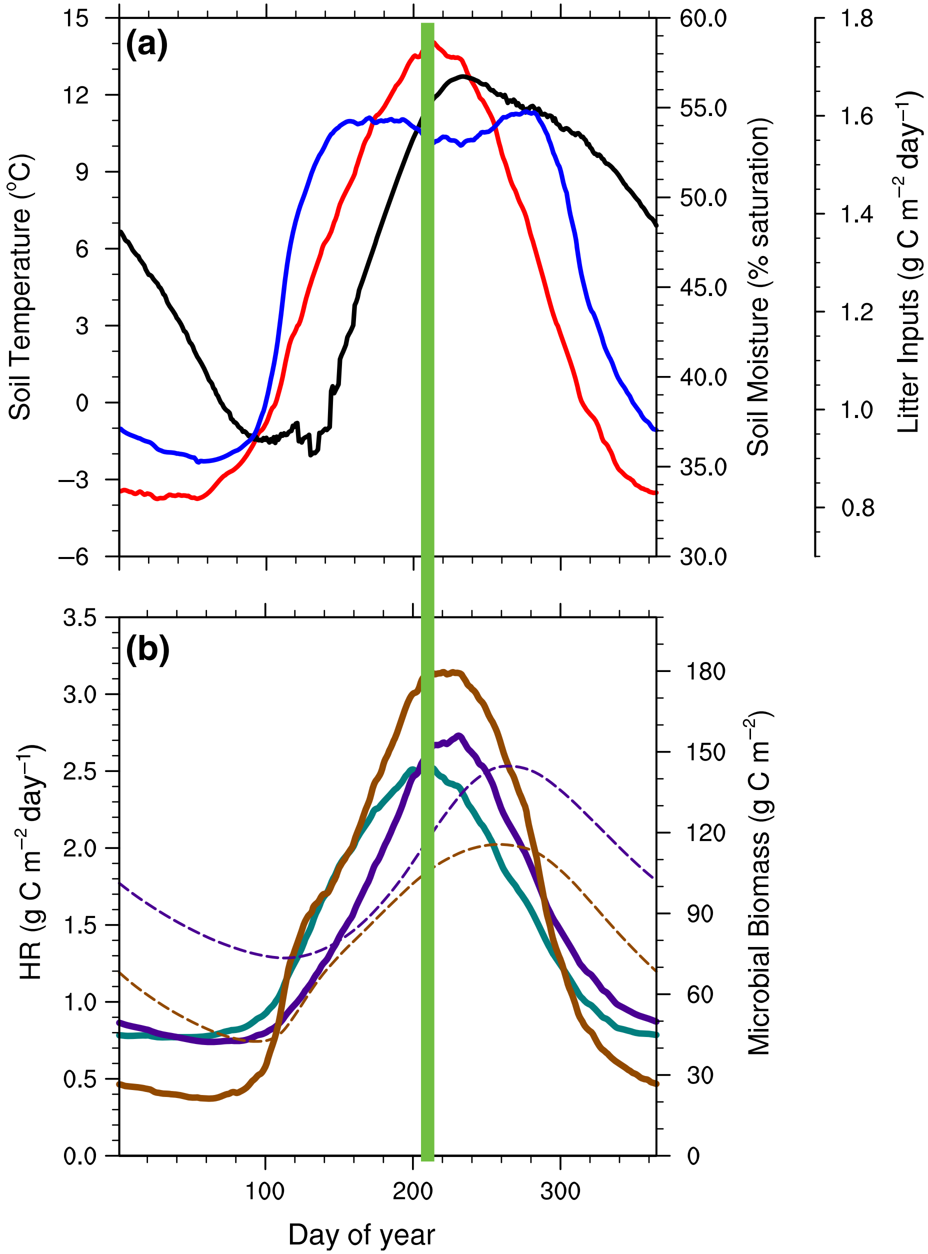


Basile et al., in prep.

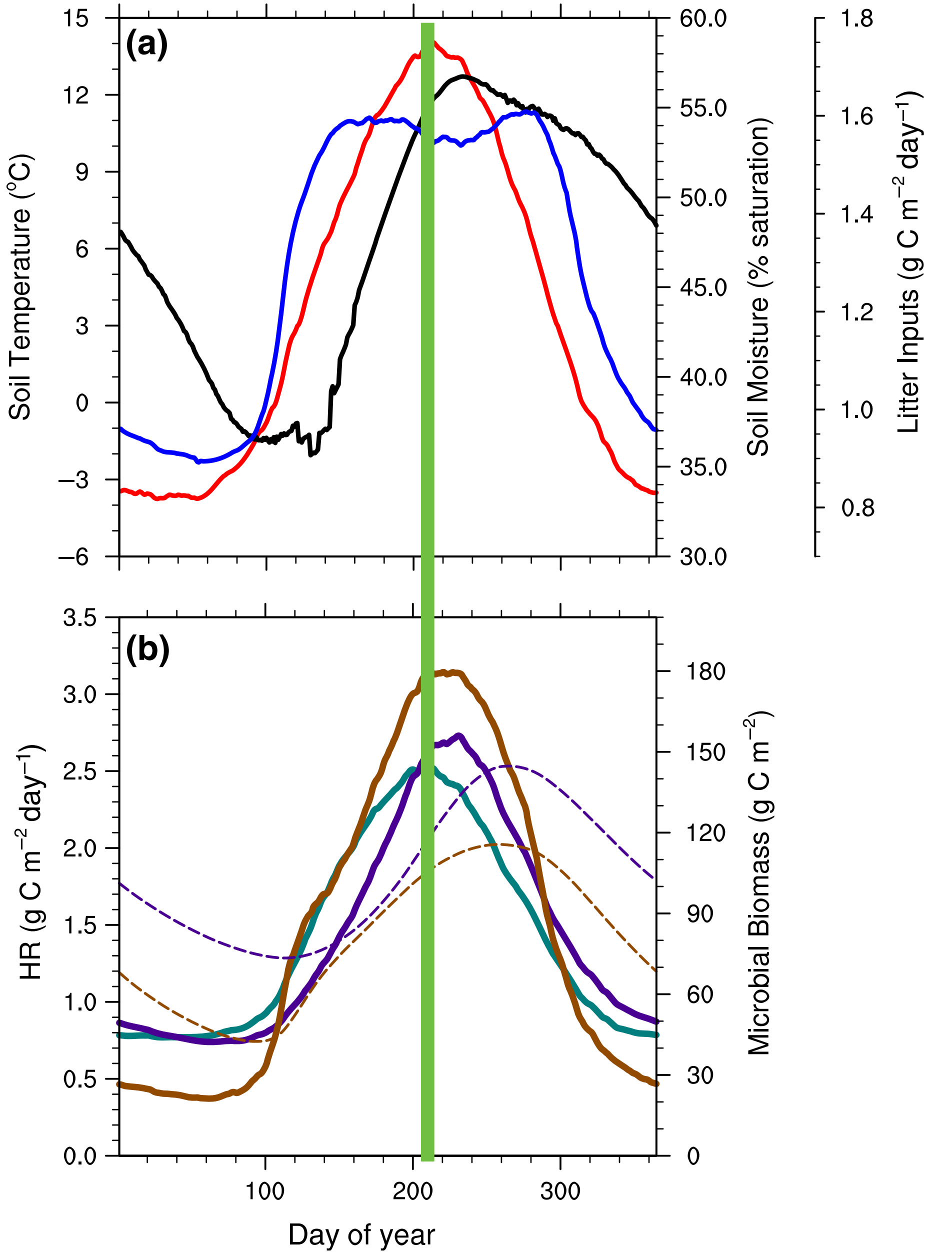
HR amplitude is essentially identical for CASA and MIMICS, but total amplitude is 6 ppm larger in MIMICS



Basile et al., in prep.



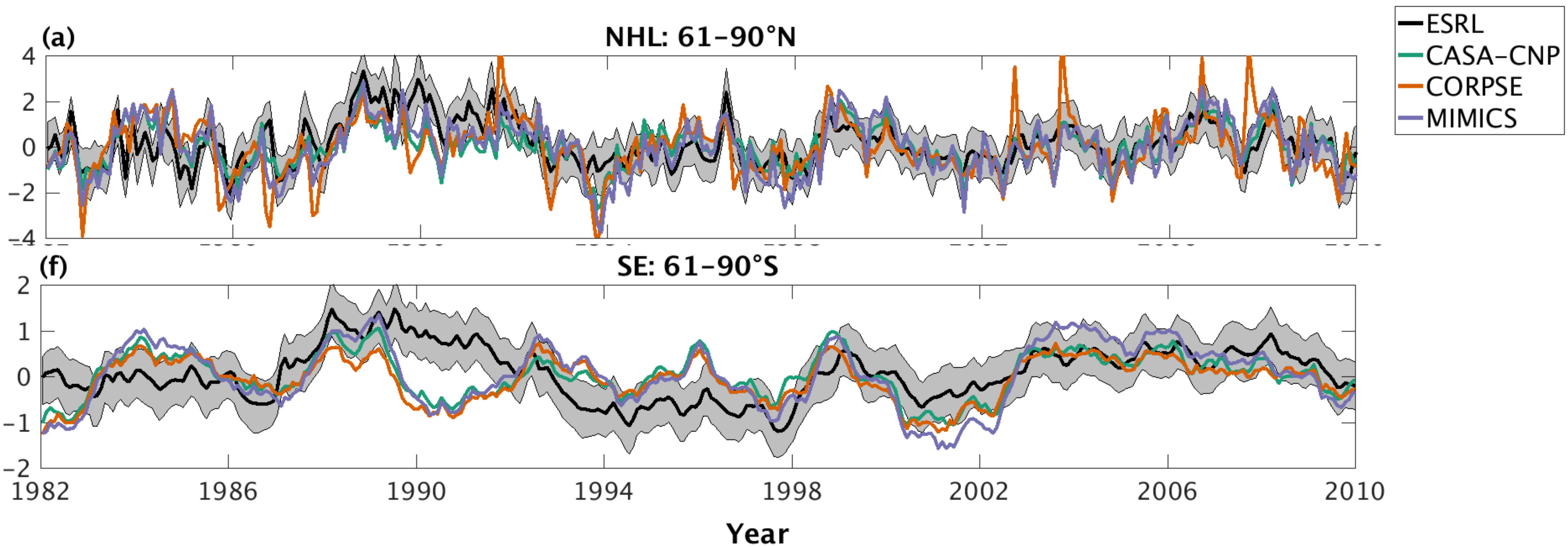
Seasonal cycle at 55 N depends on phasing of climate drivers, including temperature.



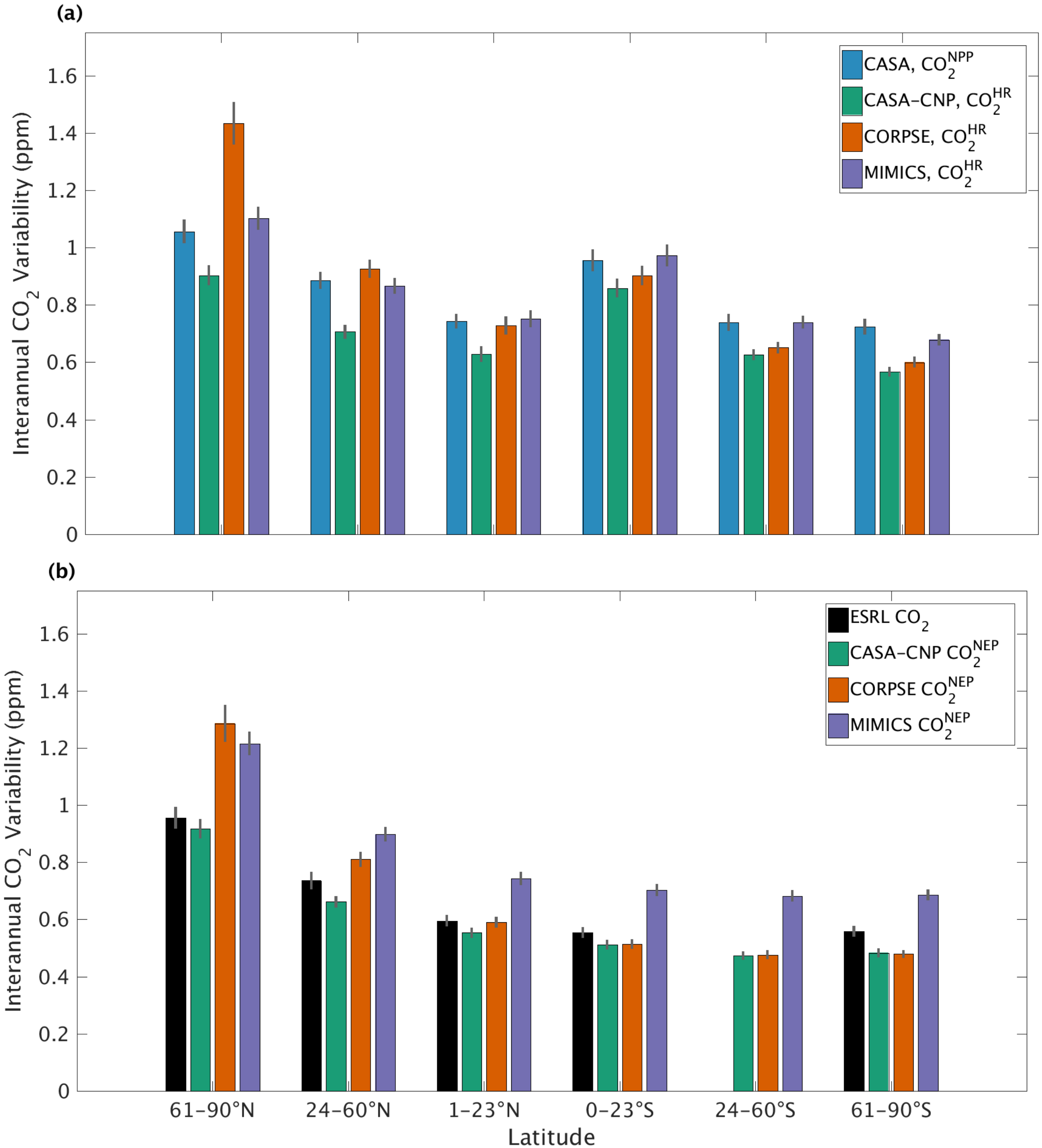
Seasonal cycle at 55 N depends on phasing of climate drivers, including temperature.

For CORPSE and MIMICS, seasonal maximum in HR is shifted later, possibly due to shift in peak microbial biomass

Models generally capture patterns of interannual variability

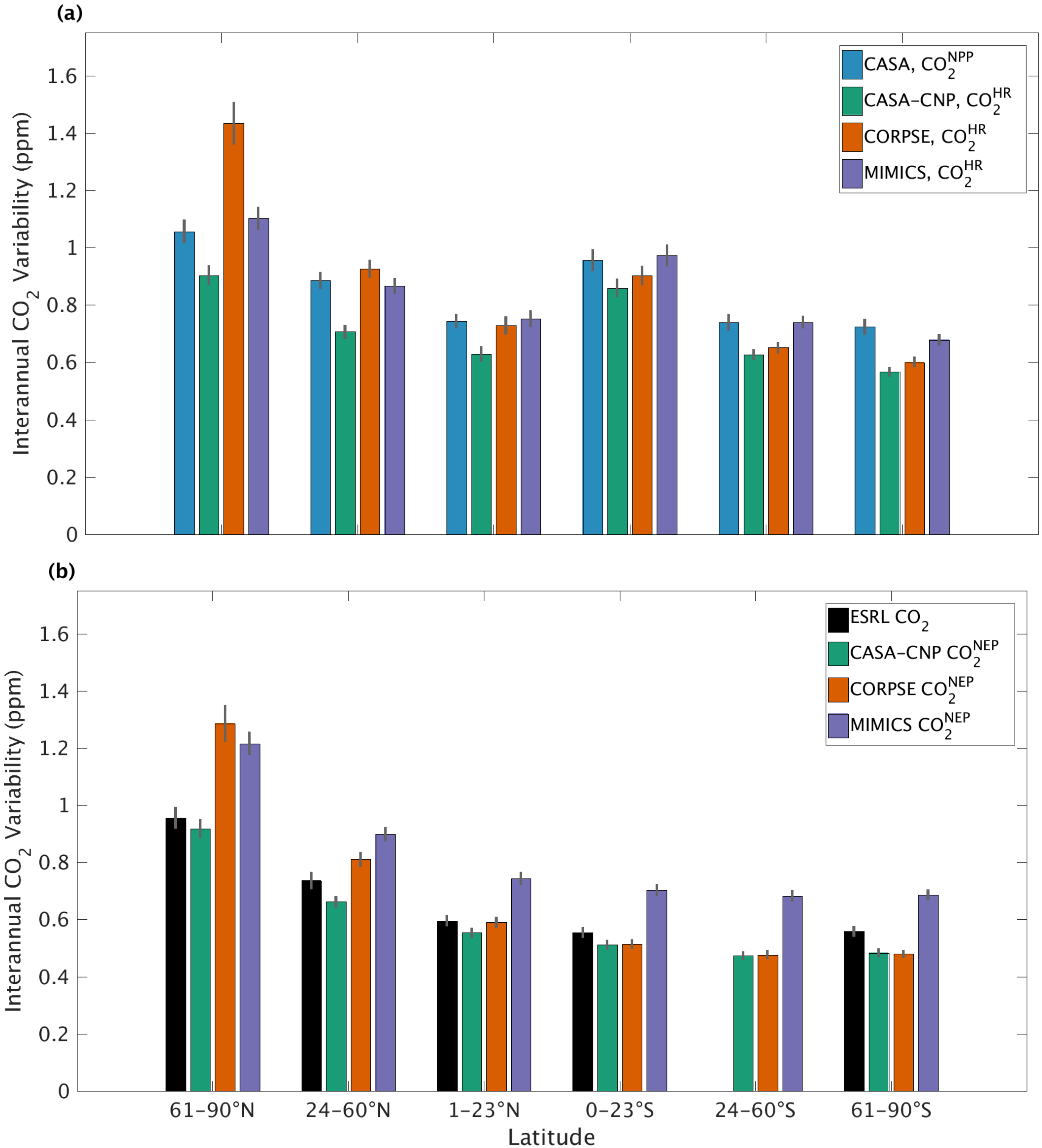


Basile et al., in prep.



Variability from HR is similar to that of NPP

Basile et al., in prep.



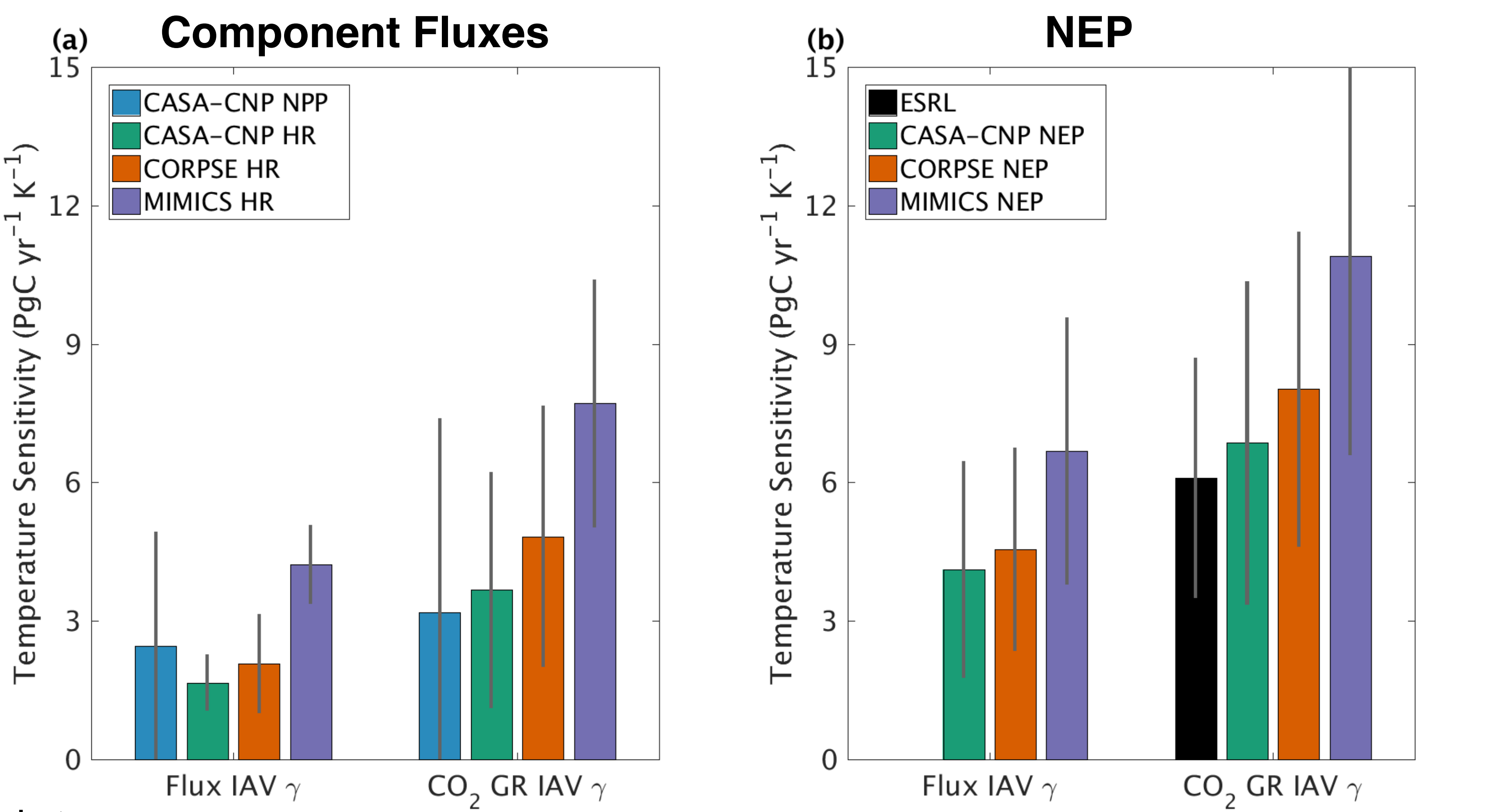
Variability from HR is similar to that of NPP

Phasing of NPP and HR is a significant determinant of overall IAV

Basile et al., in prep.

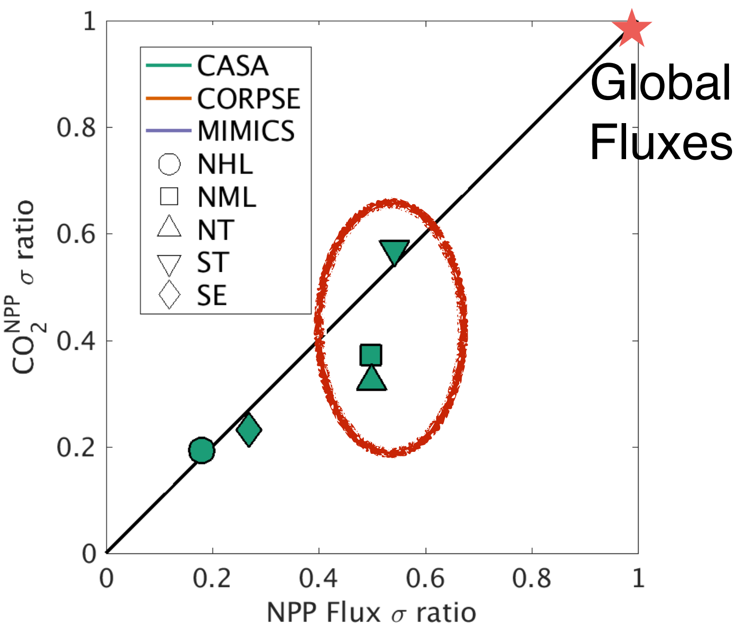
MIMICS' temperature sensitivity is too high

Distribution of observing sites leads to overestimate of flux temperature sensitivity (exacerbated for HR vs NPP)

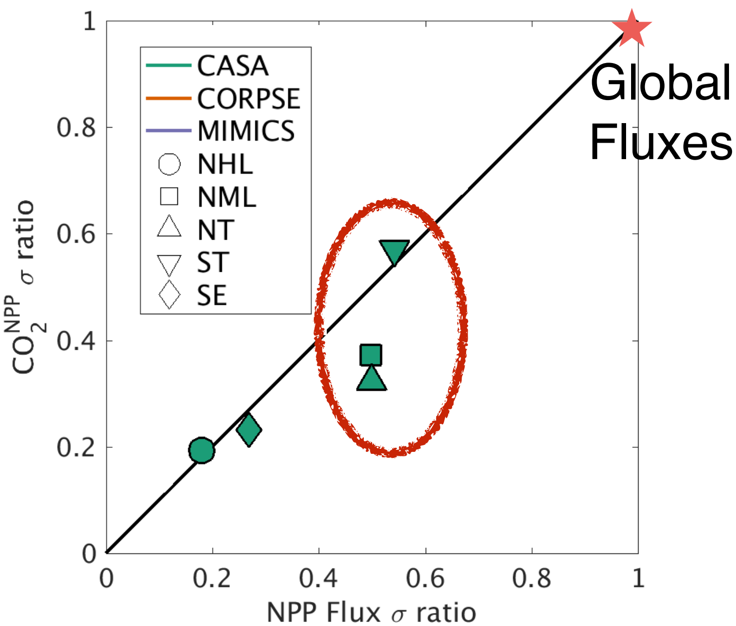


Basile et al., in prep.

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



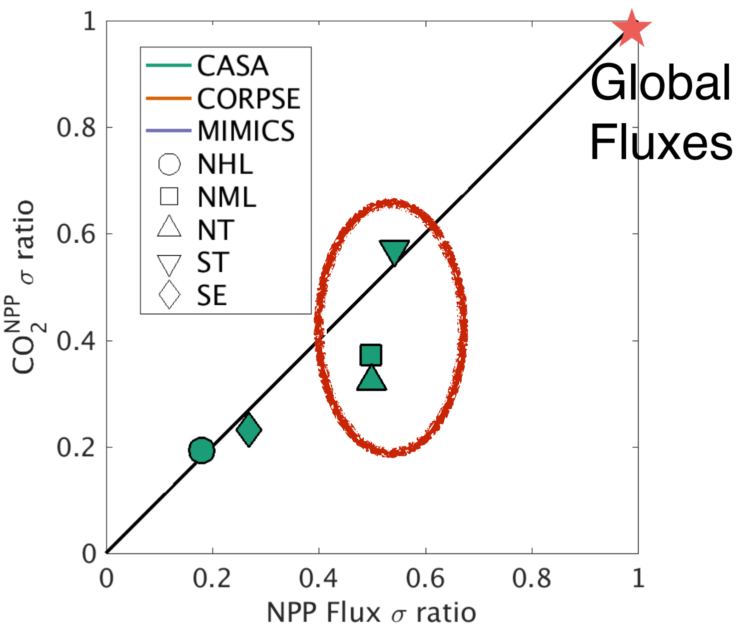
Basile et al., in prep.



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

Likewise, CO2 that contains only the imprint of SH tropical fluxes is about 60% as variable as CO2 that reflects global fluxes

Basile et al., in prep.



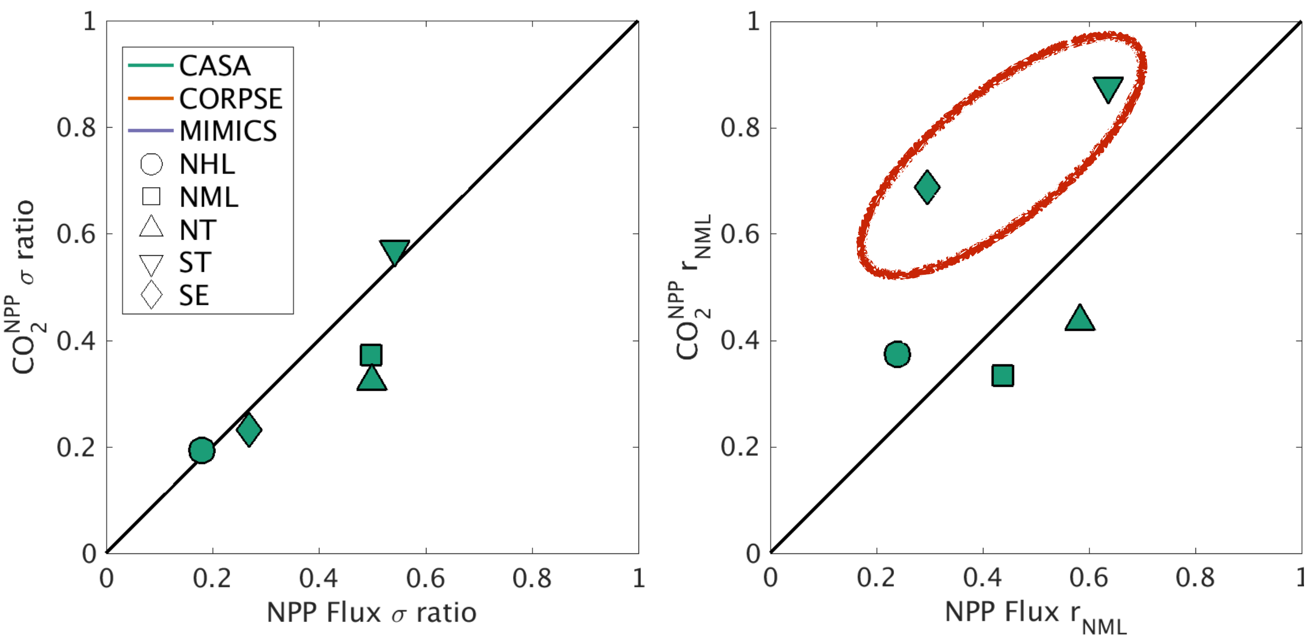
Variability in Southern Hemisphere tropical NPP flux is about 60% of variability in global NPP flux

Likewise, CO2 that contains only the imprint of SH tropical fluxes is about 60% as variable as CO2 that reflects global fluxes

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

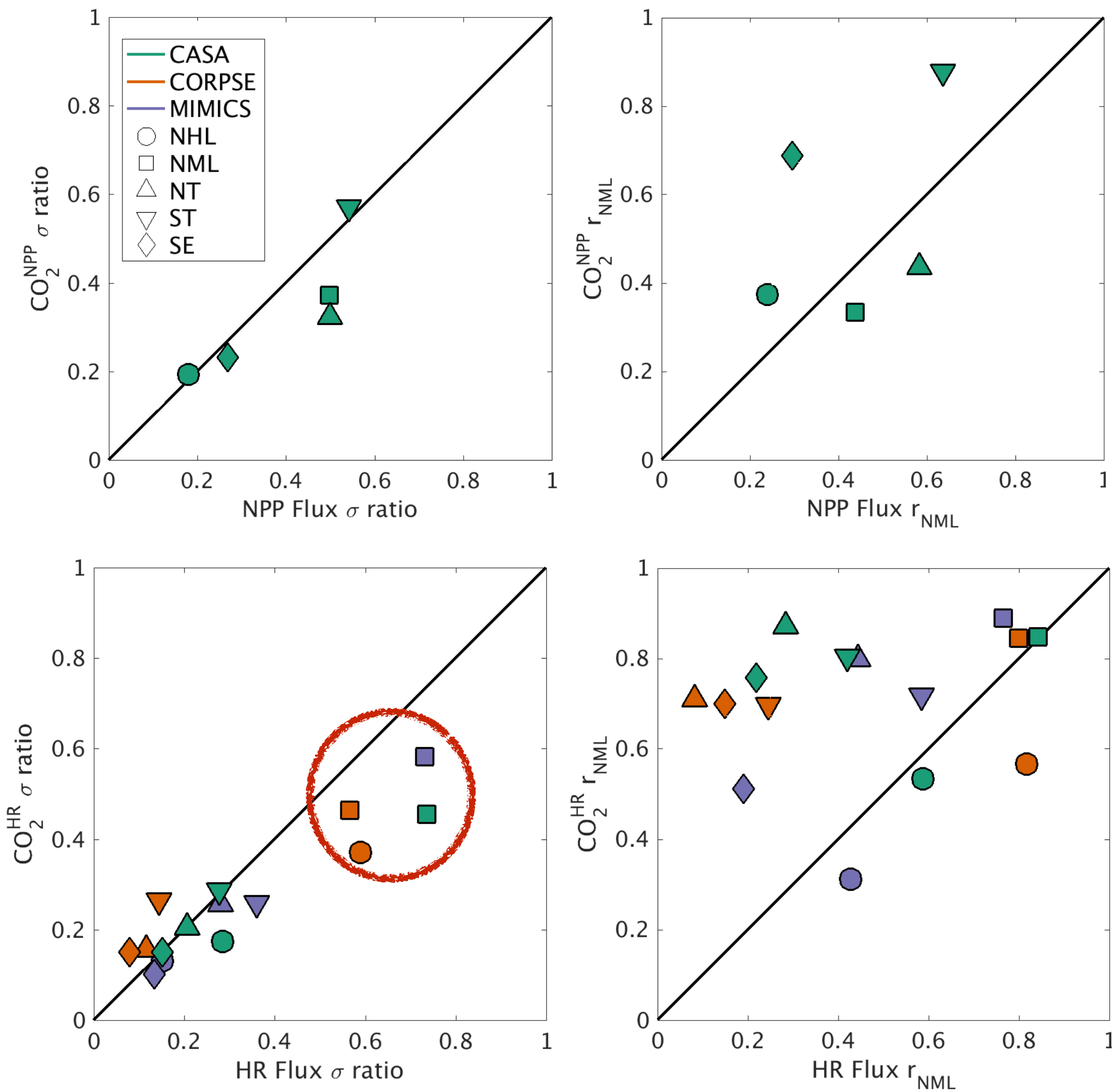
… but atmospheric circulation damps the apparent variability in these other latitude bands

Basile et al., in prep.



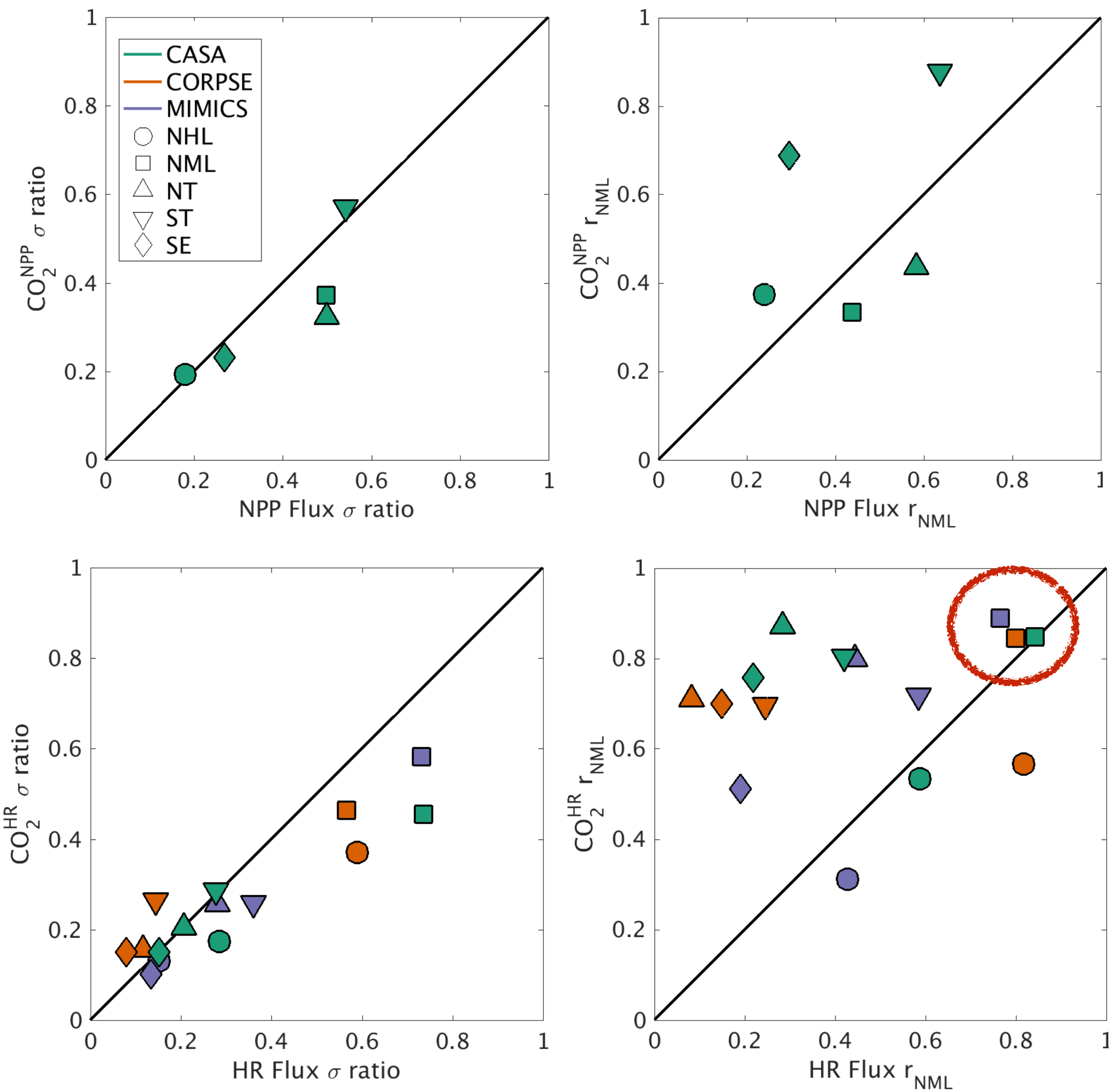
Atmospheric transport also magnifies the correlation of the Southern Hemisphere flux signal with the global flux signal

Basile et al., in prep.



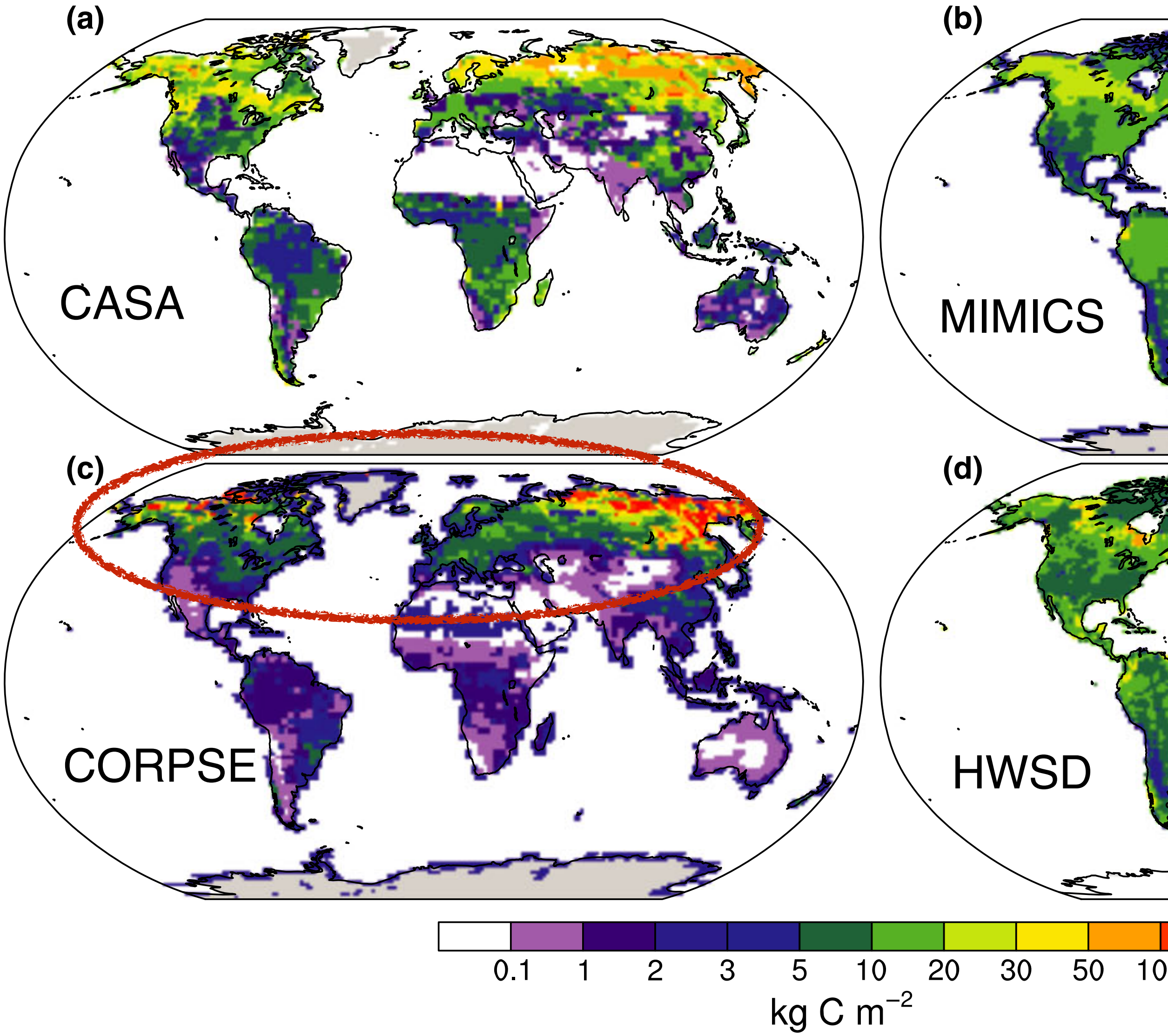
In contrast to NPP, the Northern Hemisphere midlatitudes have the largest variability in HR flux and imprint on atmospheric CO2.

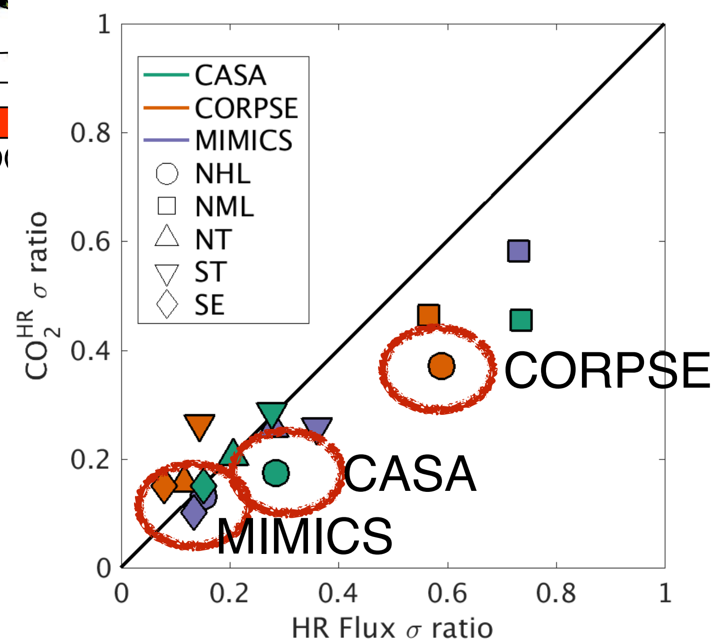
Basile et al., in prep.



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

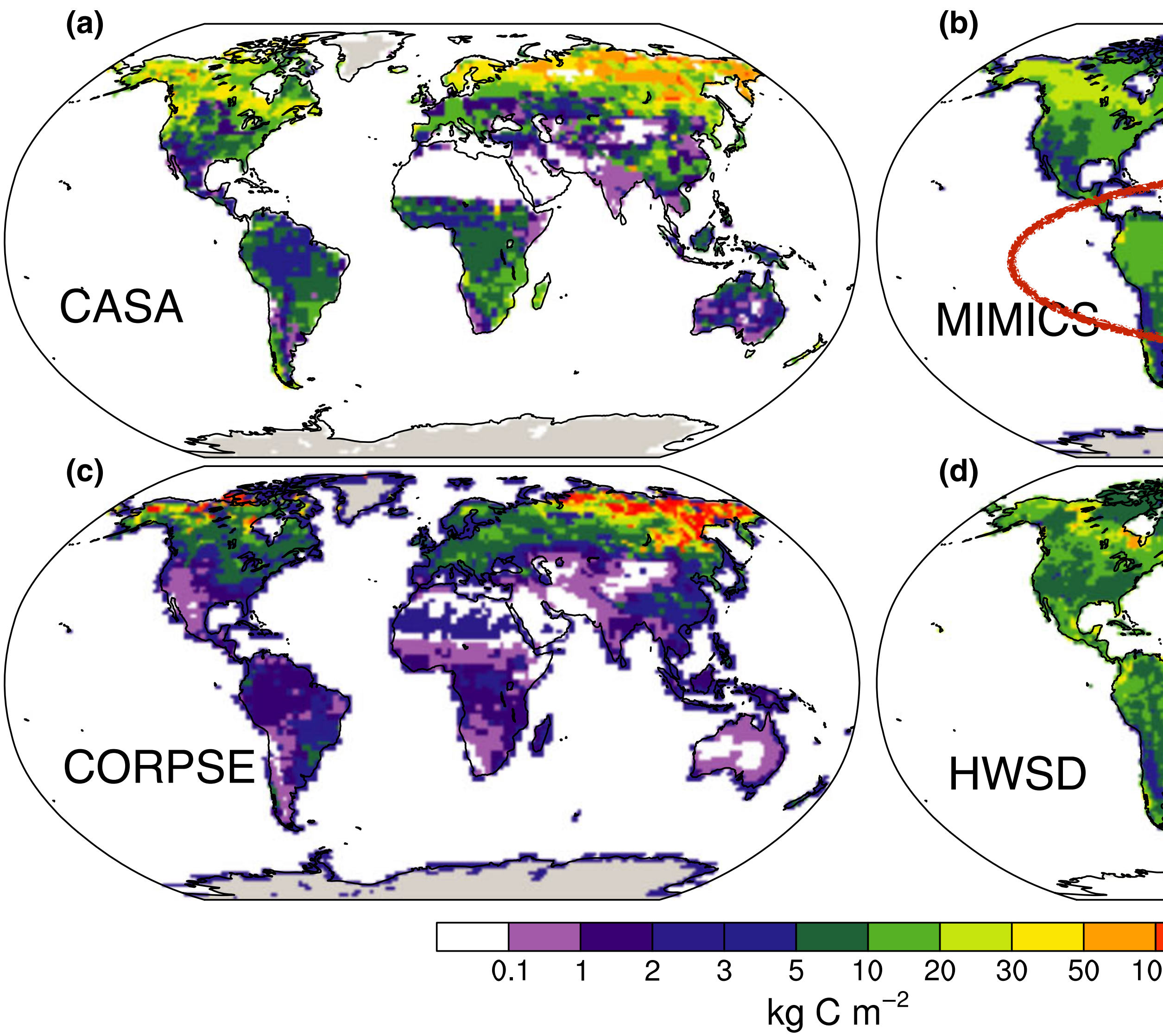
Basile et al., in prep.

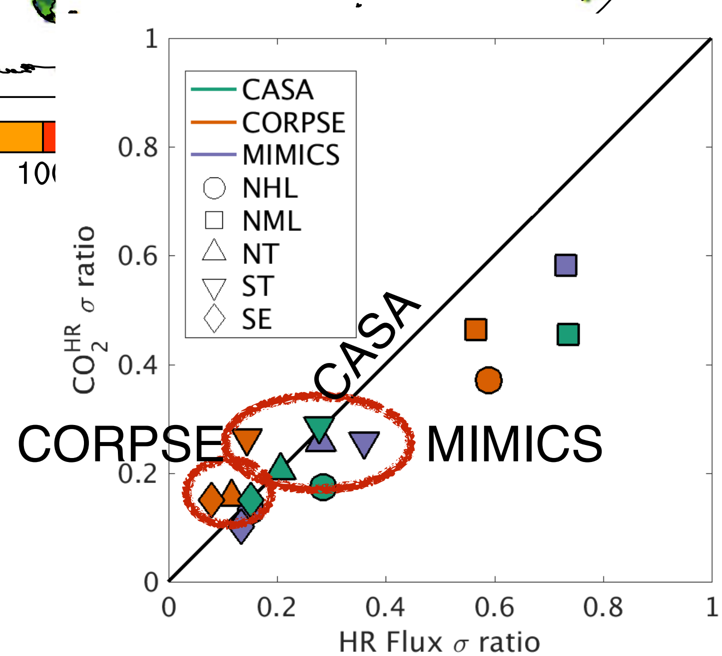




Across three models, magnitude of IAV scales with stocks at high latitudes

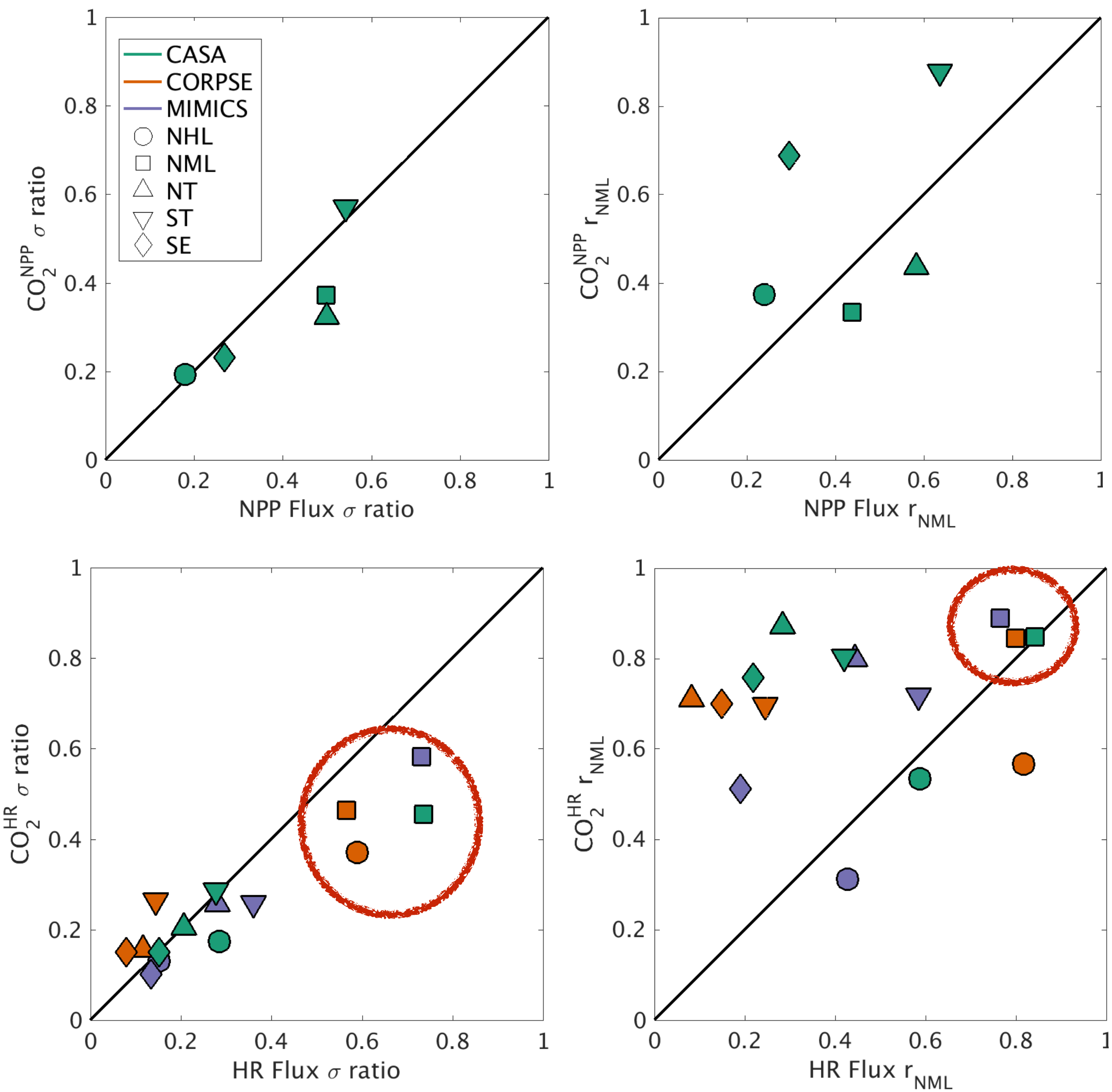
Wieder et al., 2018; Basile et al., in prep.





Tropical IAV also scales with soil carbon stocks across three models.

Wieder et al., 2018; Basile et al., in prep.



High variability at high latitudes likely originates from the fact that HR is positively correlated with NPP and T, but NPP is strongly negatively correlated with T in the tropics, so these factors compete

Basile et al., in prep.

What can we evaluate?

These models overestimate the seasonal cycle of CO_2 in NH. Possible that seasonality of NPP is too large, and/or that seasonality in HR is too small. The phasing of HR in MIMICS exacerbates this problem.

Magnitude of IAV is generally too large in NH, this issue is largest in the microbially explicit models. MIMICS has too high IAV overall despite having similar magnitudes as other models for HR, suggesting phasing of HR relative to NPP is amplifying variability.

Temperature sensitivity of MIMICS is too large.

Challenges for model evaluation:

HR is not independent of NPP, so using CO2 to evaluate HR requires additional constraints on NPP (from satellite?).

Atmospheric transport can distort flux patterns (e.g., atmosphere has higher temperature sensitivity, atmosphere is relatively more sensitive to tropical fluxes).

Diagnostics like the mean annual cycle amplitude are incredibly sensitive to phasing of model maximum and minimum

Implications for carbon cycle science

Model results show that we can’t assume that HR simply follows patterns of NPP at seasonal or interannual timescales

Northern hemisphere contributes significantly to seasonal and interannual variability in HR, whereas paradigm is that CO2 IAV originates in the tropics