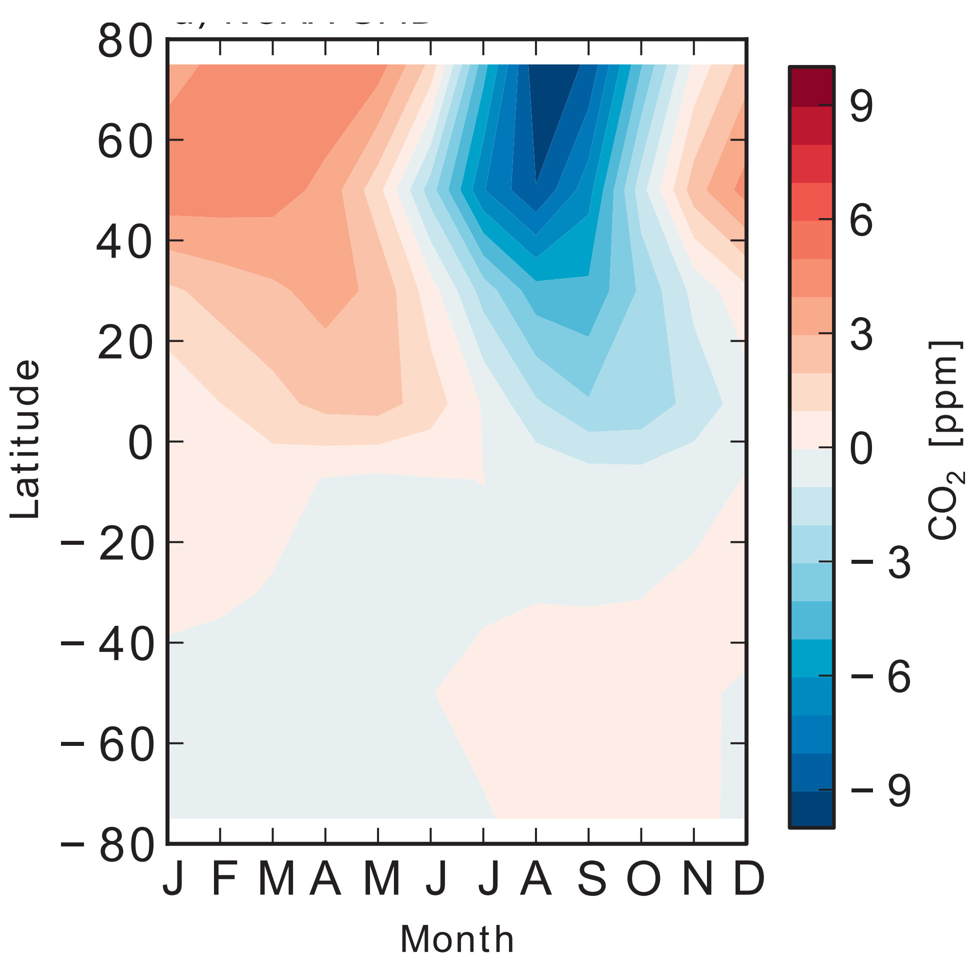
Regional influences on Northern Hemisphere atmospheric CO_2 seasonal amplification

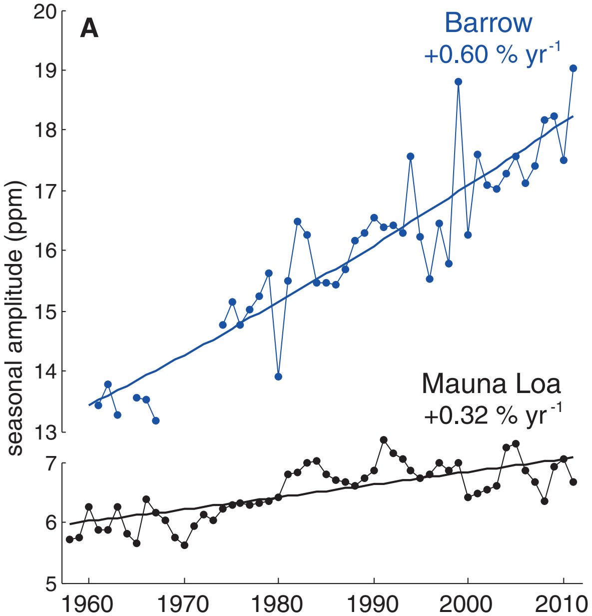


Gretchen Keppel-Aleks

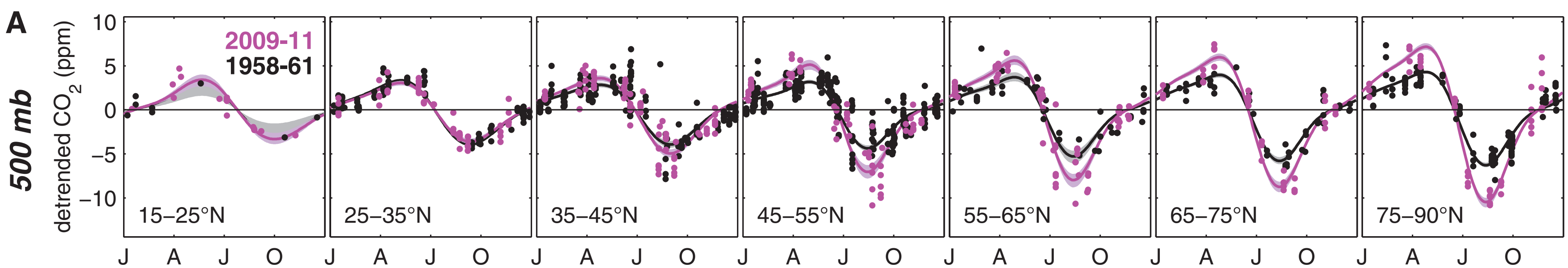
gkeppela@umich.edu

RUBISCO Science Friday

October 2021

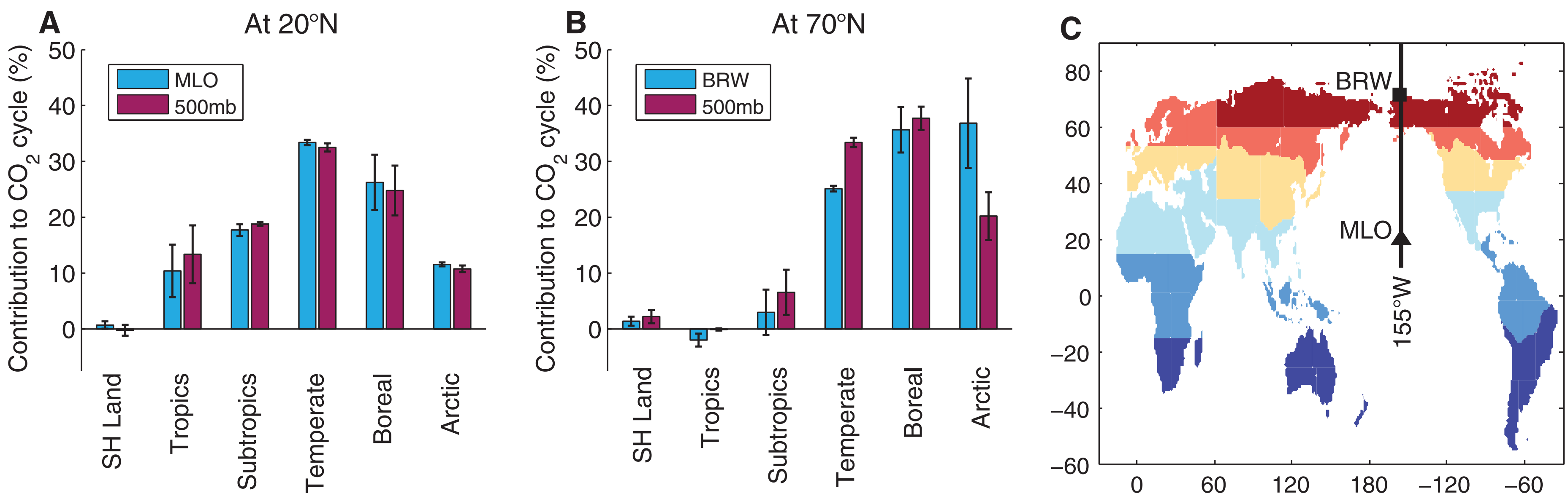


The Northern Hemisphere atmospheric CO_2 seasonal cycle amplitude (SCA) has been increasing since observations began in the late 1950s

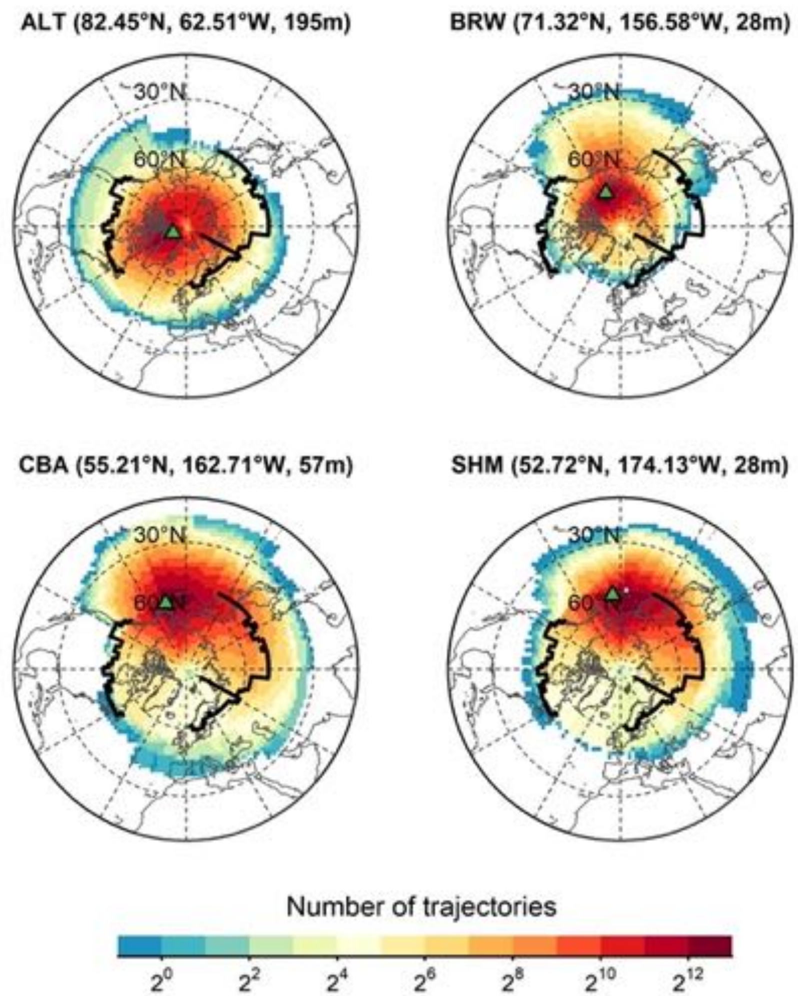


Graven et al., 2013

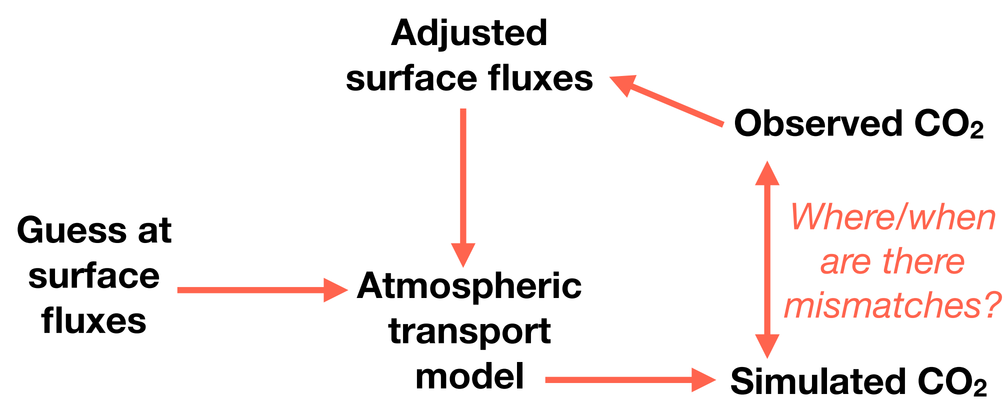
Observations at different latitudes and different altitudes have shown differential increases, which can be used for flux inference



Graven et al., 2013



Atmospheric inversions provide optimal estimates of surface net ecosystem exchange, consistent with spatiotemporal variations in observed CO_2



Lin et al., 2020

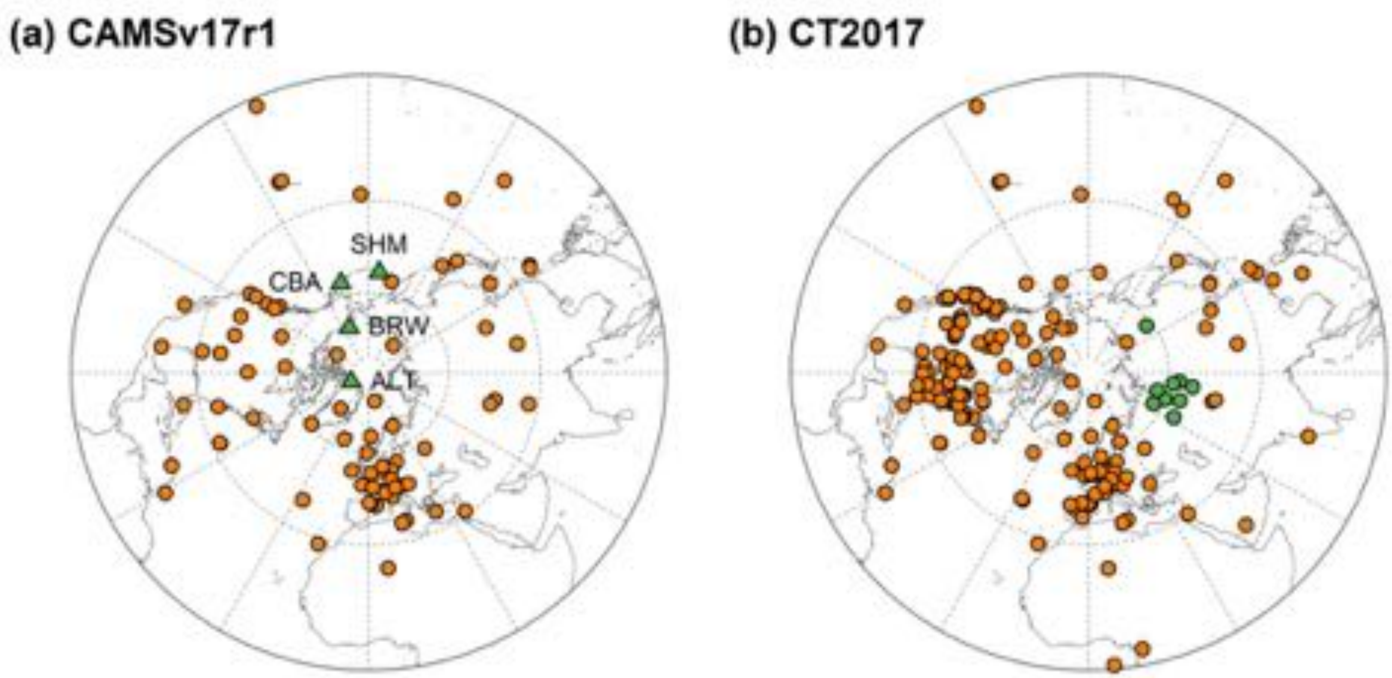
Approach: Simulate regional contributions to atmospheric CO_2 distribution using optimized fluxes from inverse models

CAMS
1979-2017

Atm: LMDZ
Land: Orchidee
Ocean: Landschutzer

CT2017
2000-2016

Atm: TM5
Land: CASA
Ocean: Takahashi



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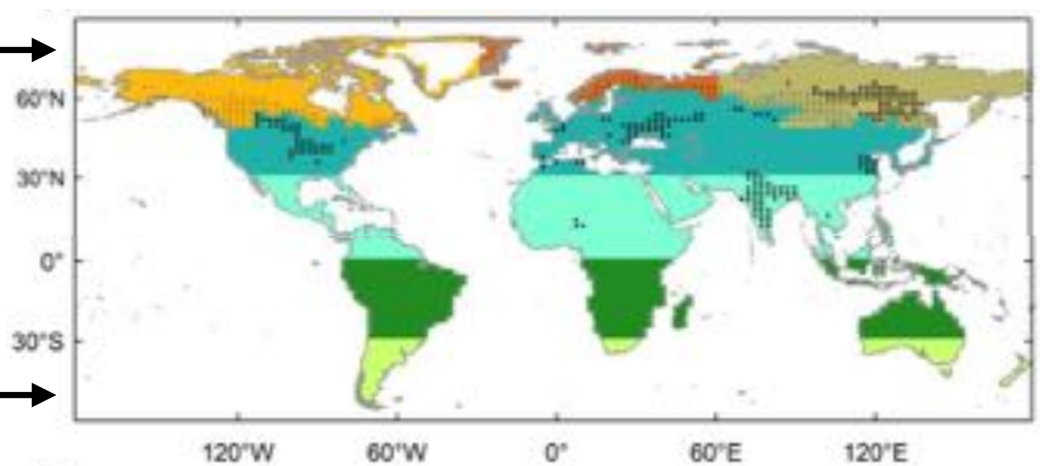
GEOS-Chem Atmospheric Transport Model



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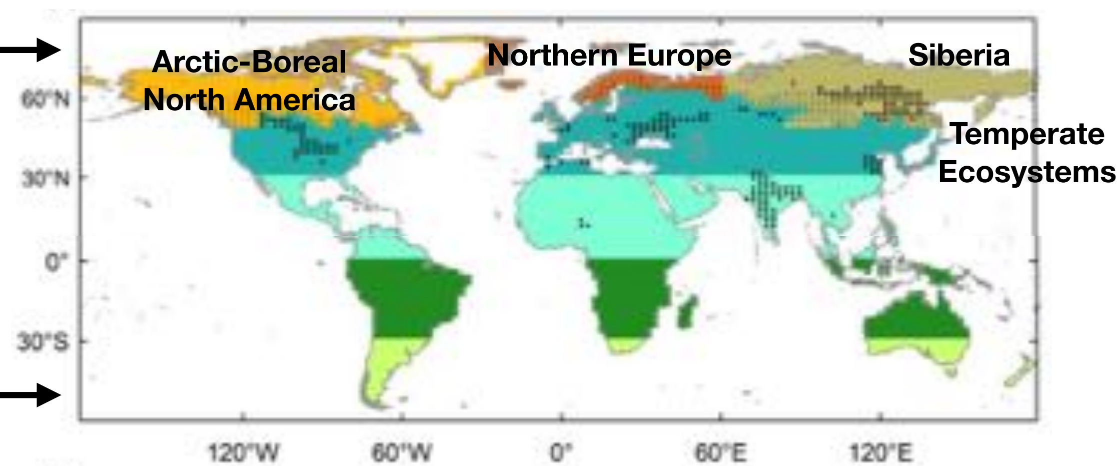
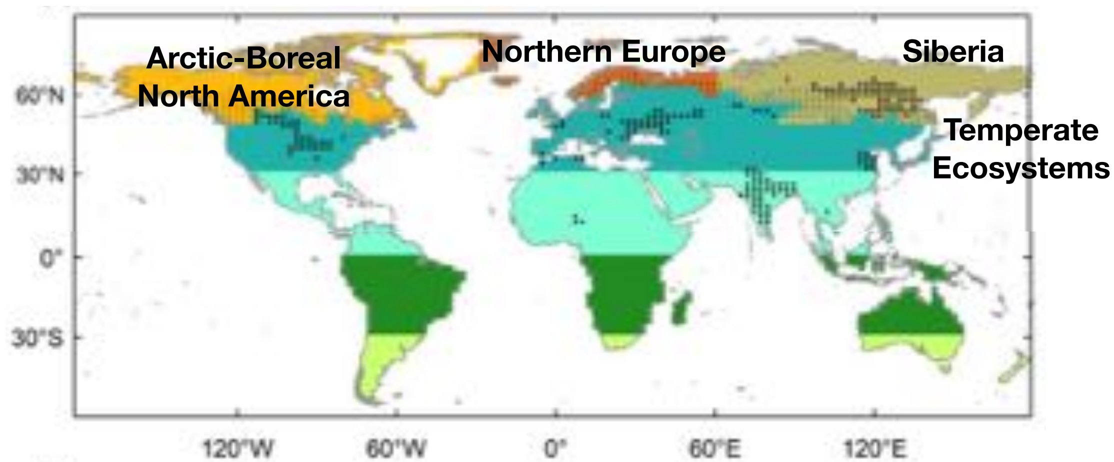
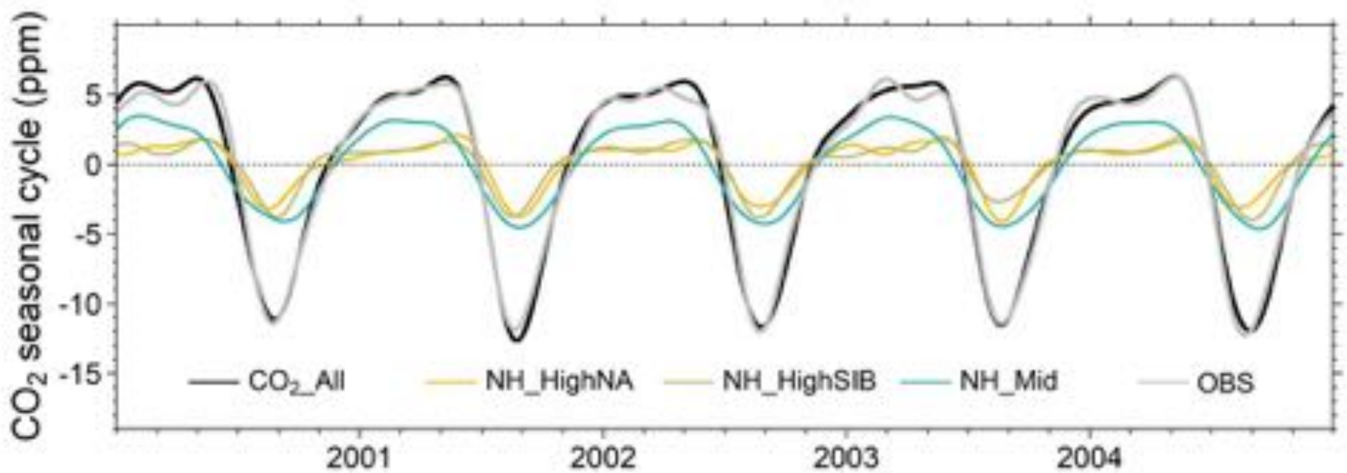


Lin et al., 2020

CO_2 species from individual regions sum to provide an estimate comparable to observations





Lin et al., 2020

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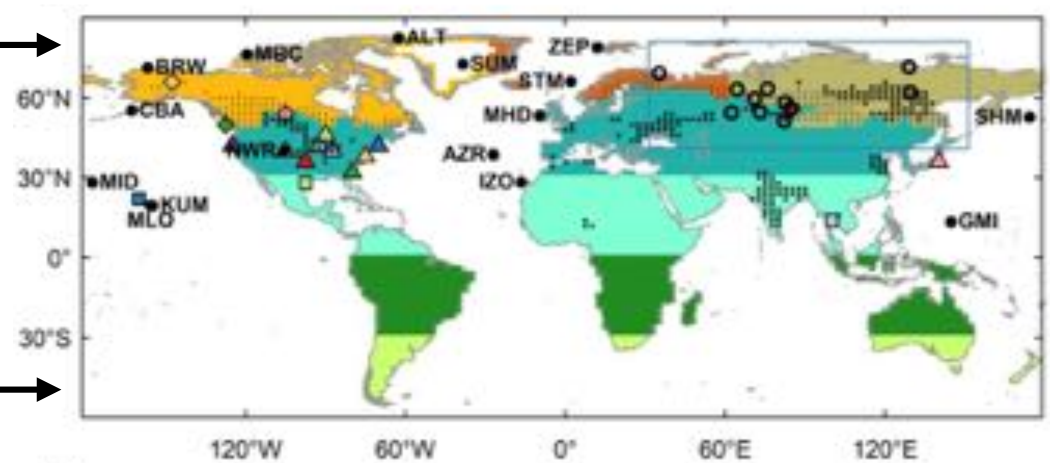

Lin et al., in review

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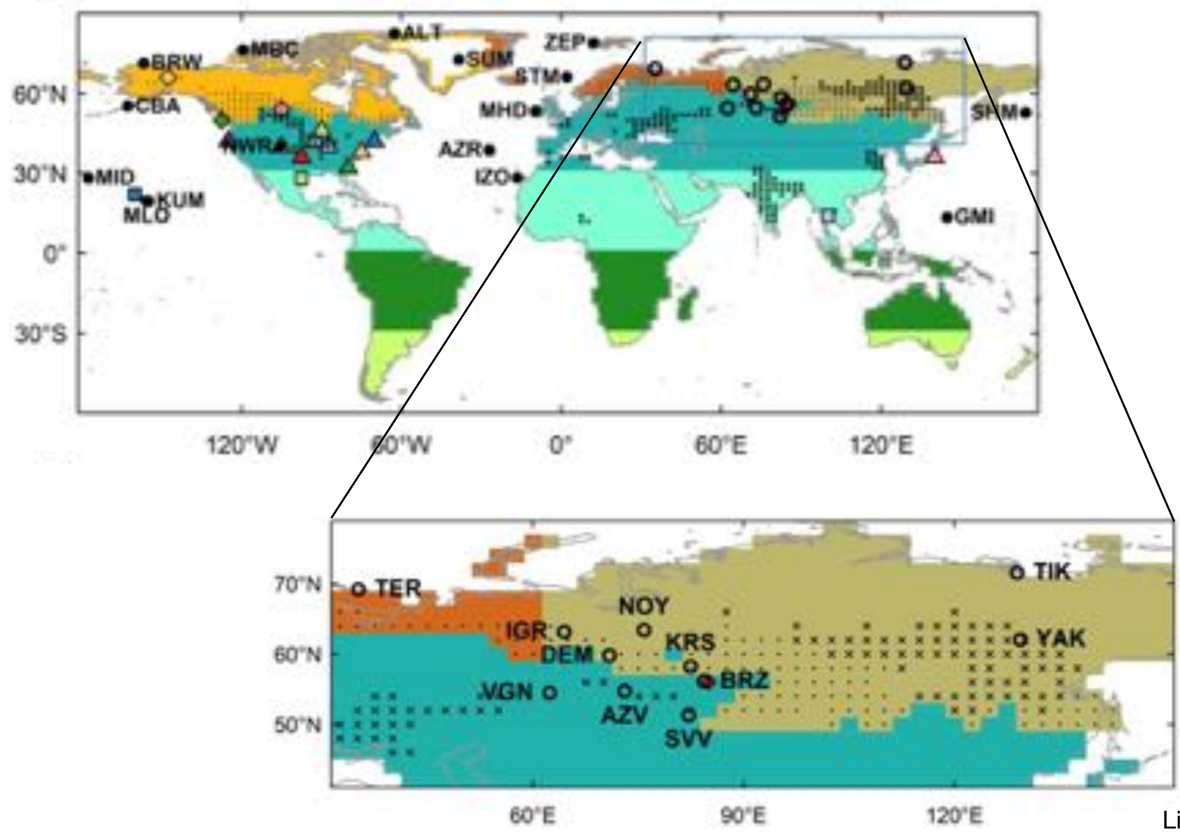
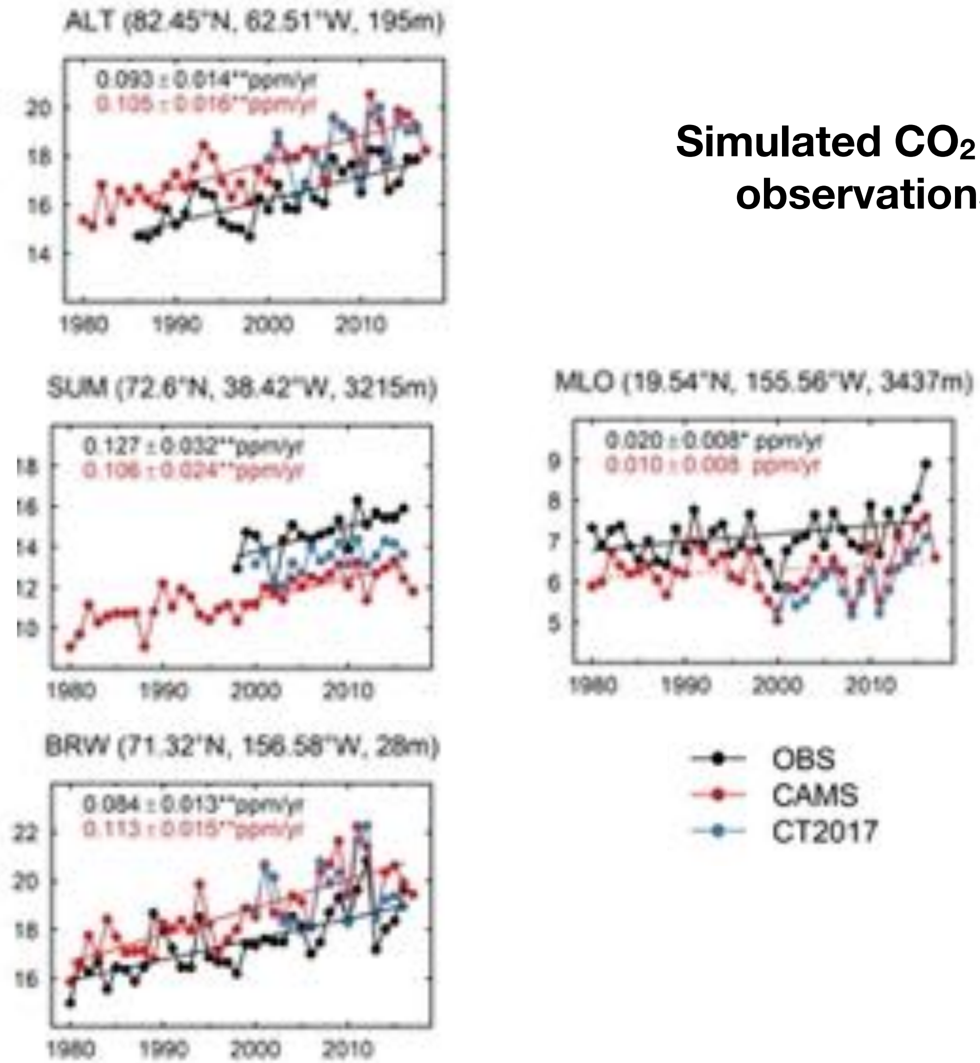


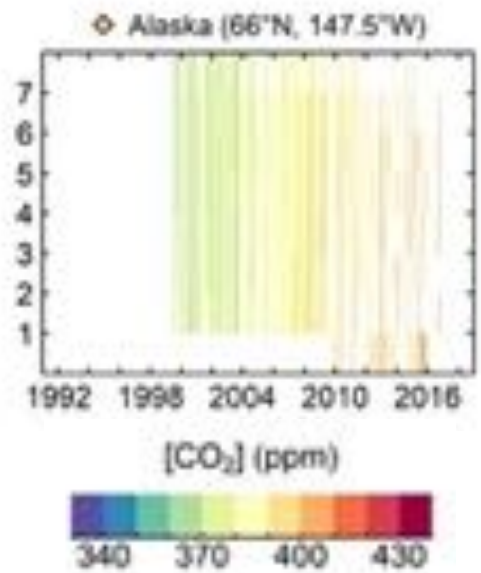
Lin et al., in review

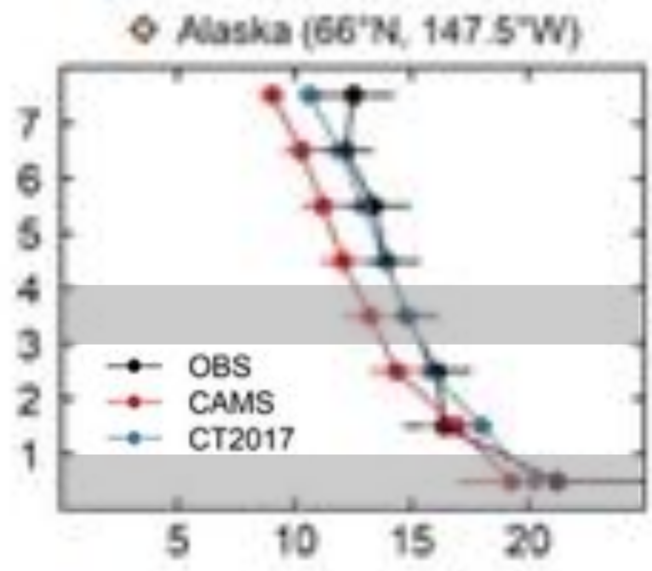


Simulated CO_2 is carefully evaluated against surface observations for both mean values and trends.

Lin et al., 2020

CO2 observed from aircraft provides independent evaluation of inversion results and ensures that results are not due to bias in vertical transport within atmospheric model.

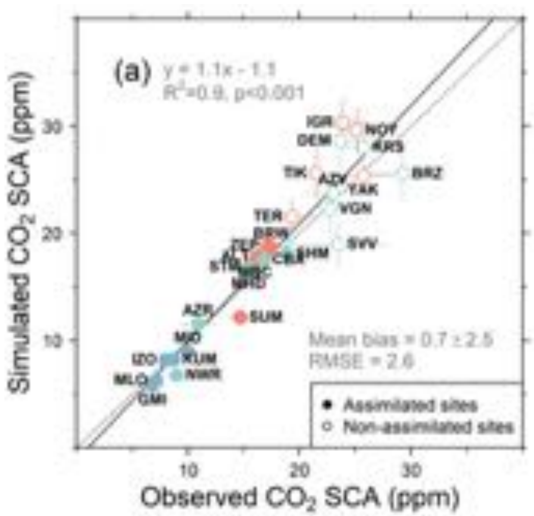




Data sources: **NOAA GGGRN**
CONTRAIL
NIES/CGER

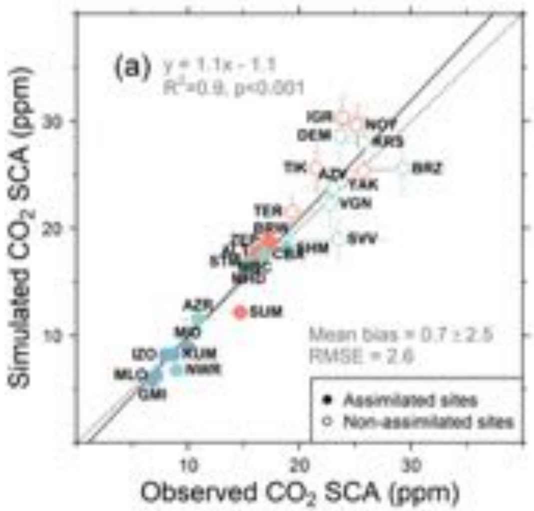
Lin et al., 2020

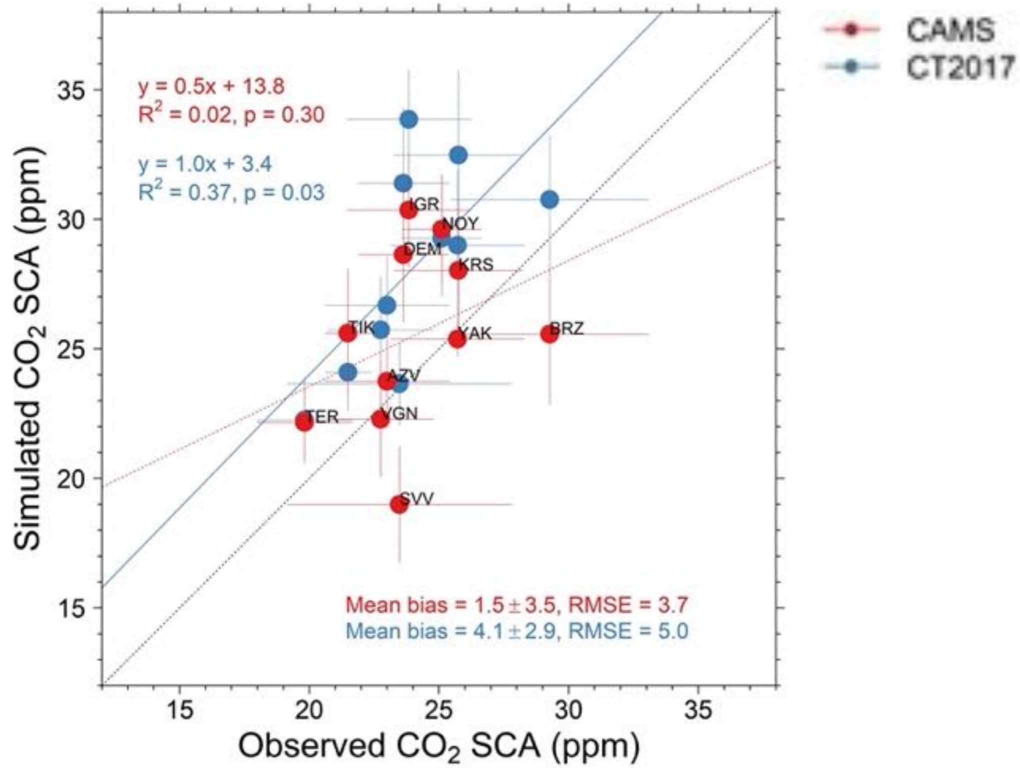
Simulations capture seasonal dynamics and trend, albeit some bias in vertical mixing in GEOS-Chem



Lin et al., 2020

Particular focus on Siberian sites reveals modest mean bias in CAMS despite lack of assimilated observations there





Lin et al., 2020

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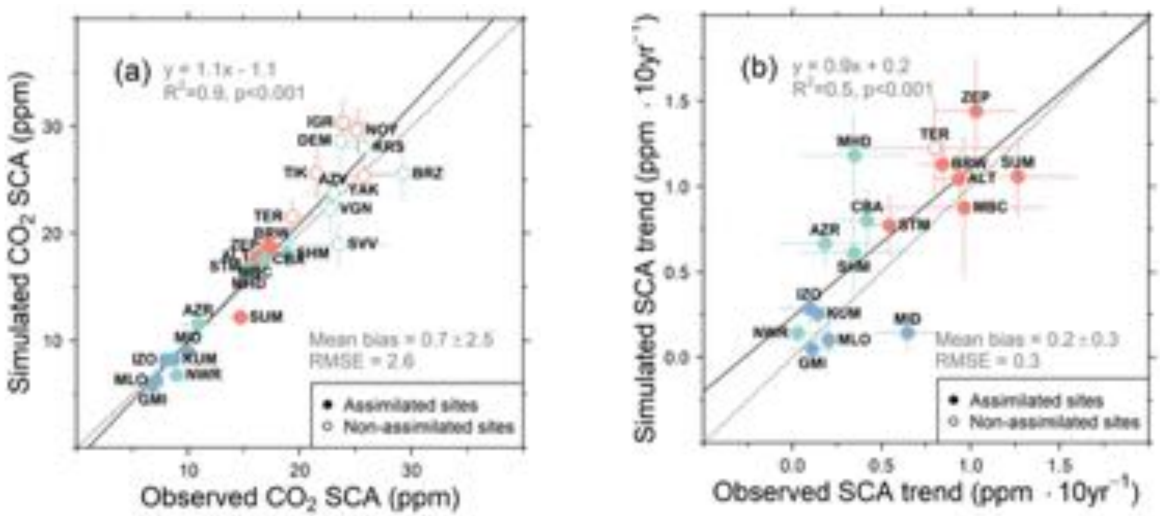

Lin et al., 2020

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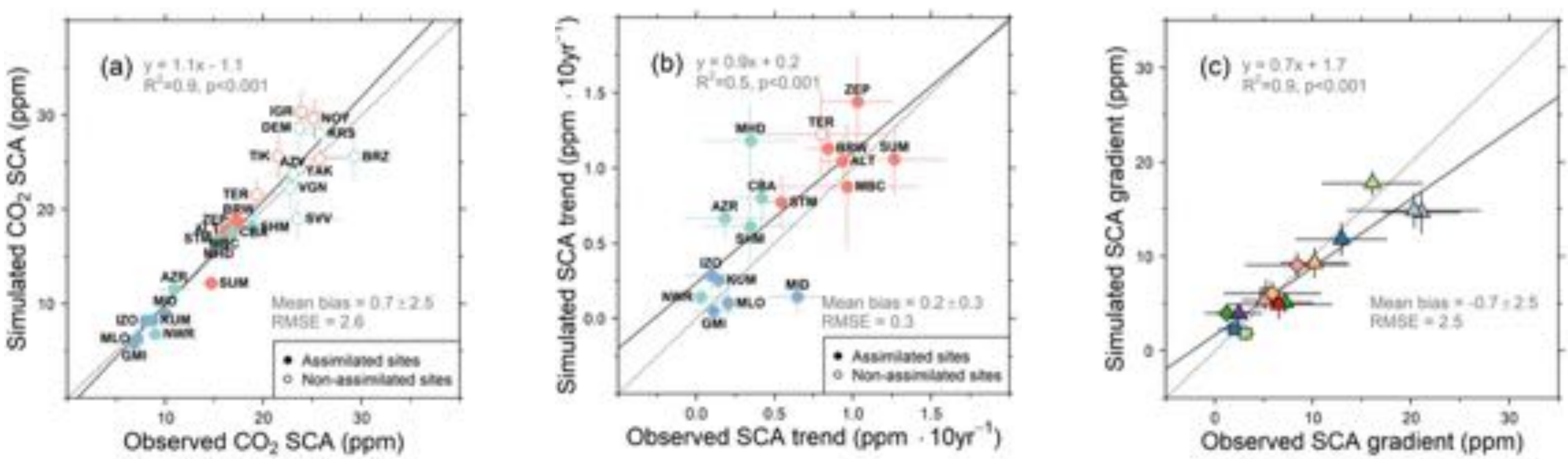
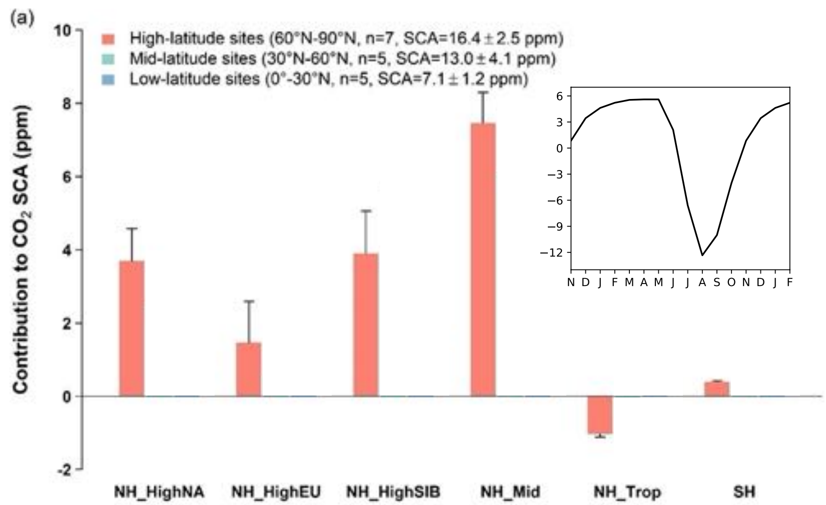


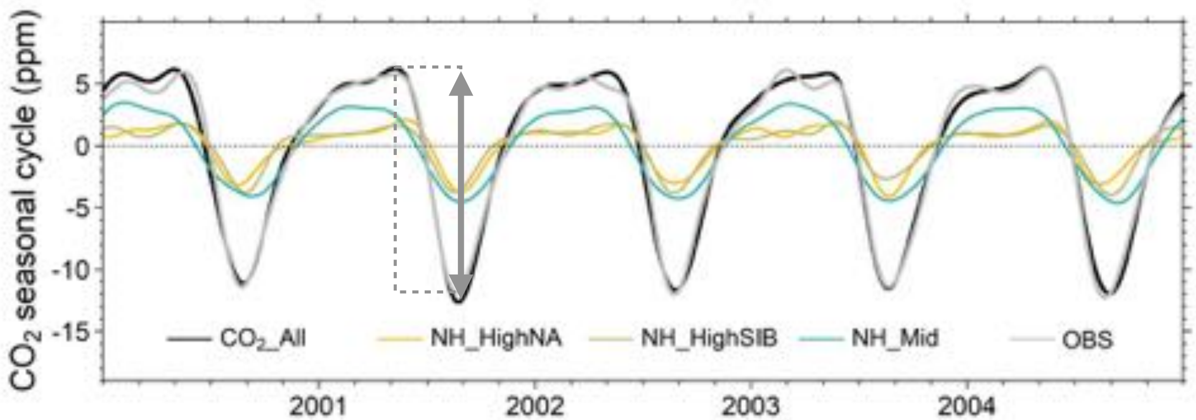
Lin et al., 2020



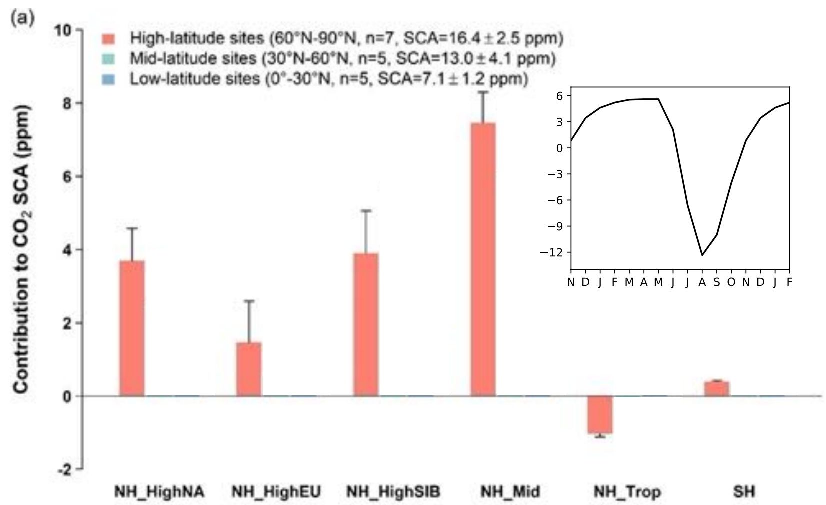
At high latitude sites, equable contributions to mean annual cycle from:

— North America and Siberia

— High latitude and temperate ecosystems



Lin et al., 2020



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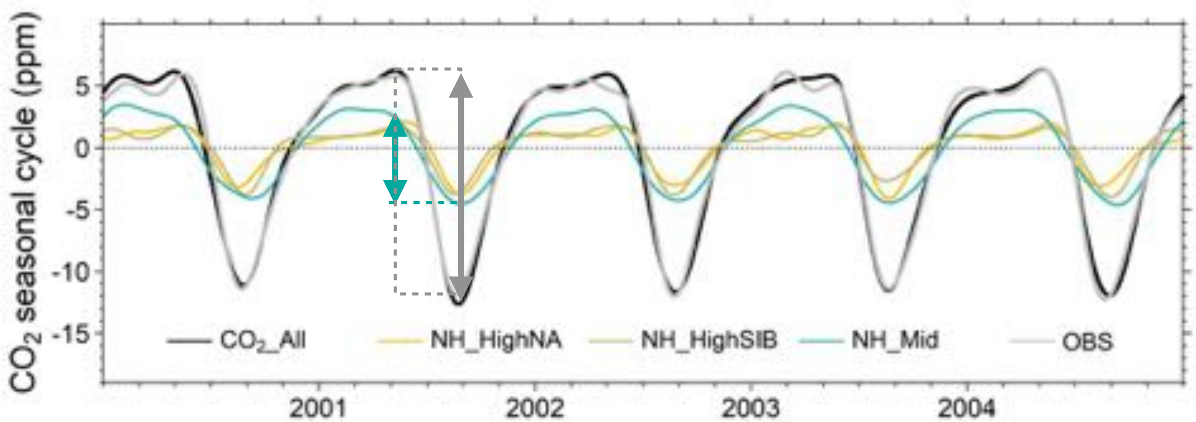
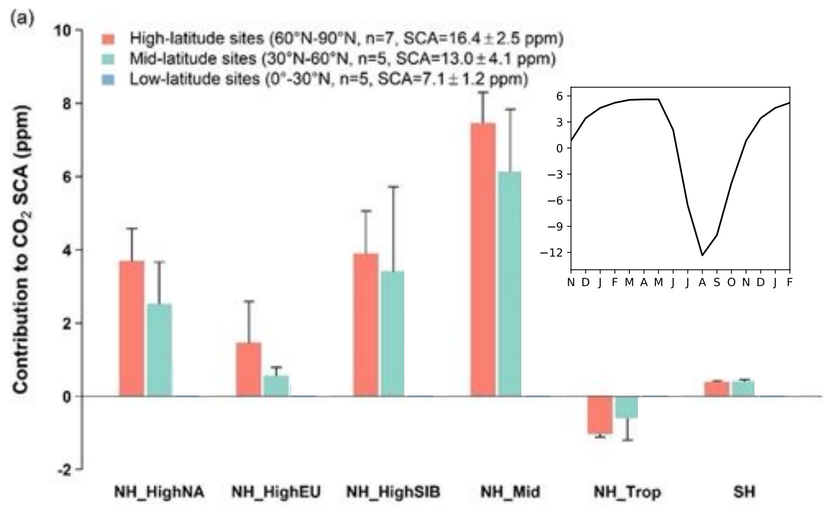


Lin et al., 2020



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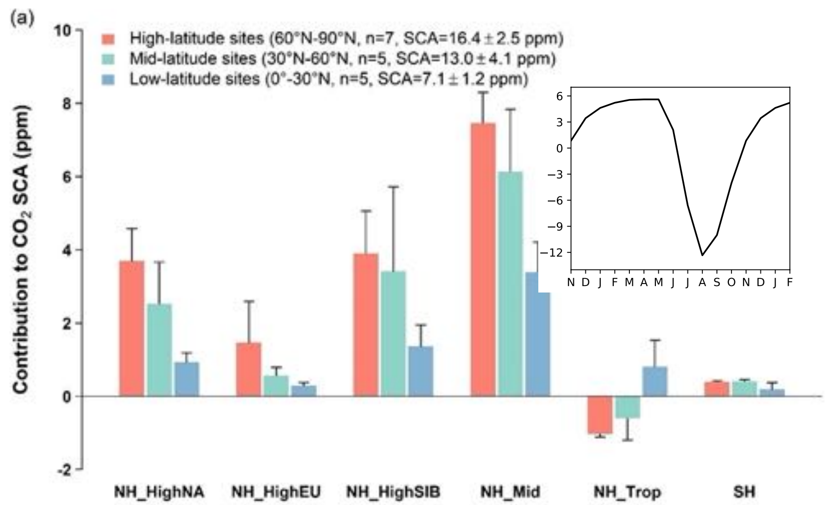

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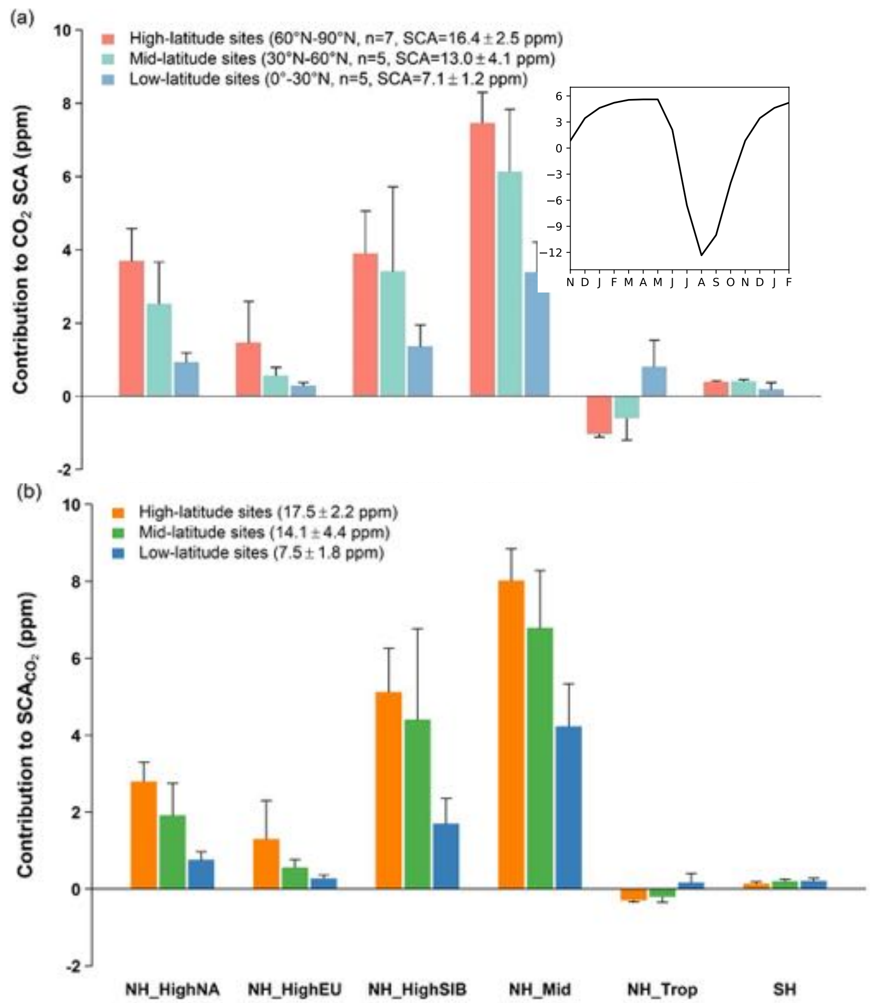

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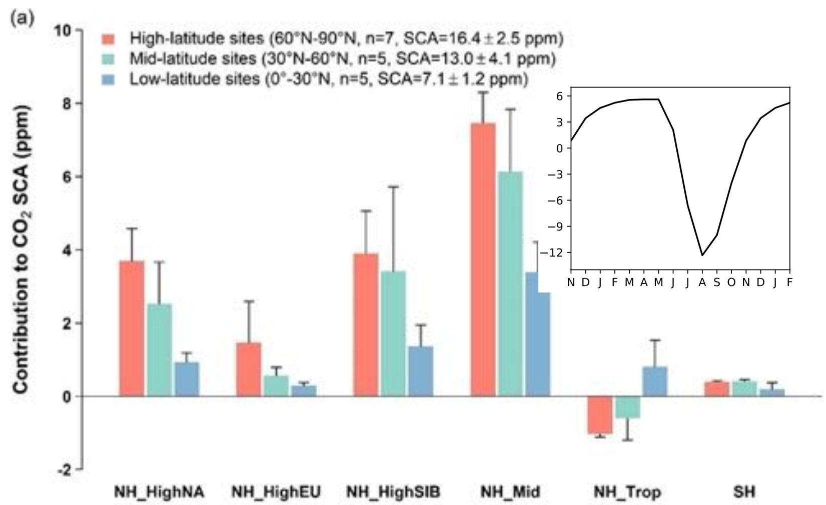
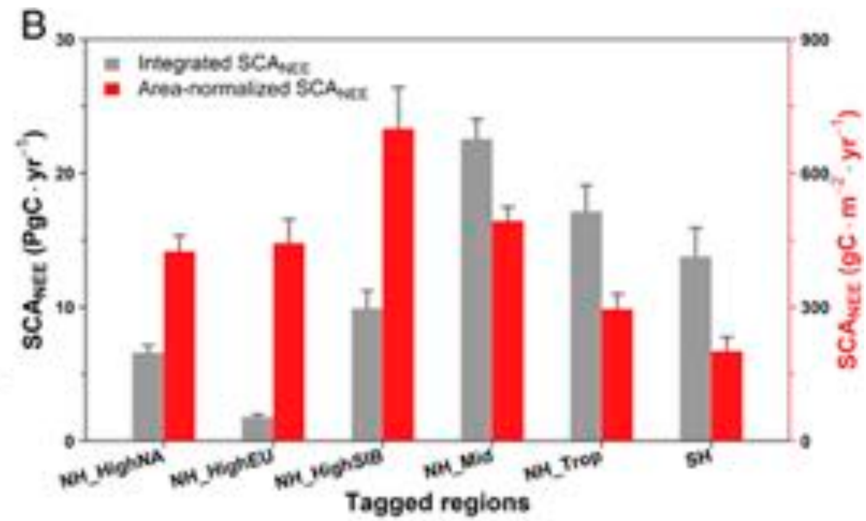
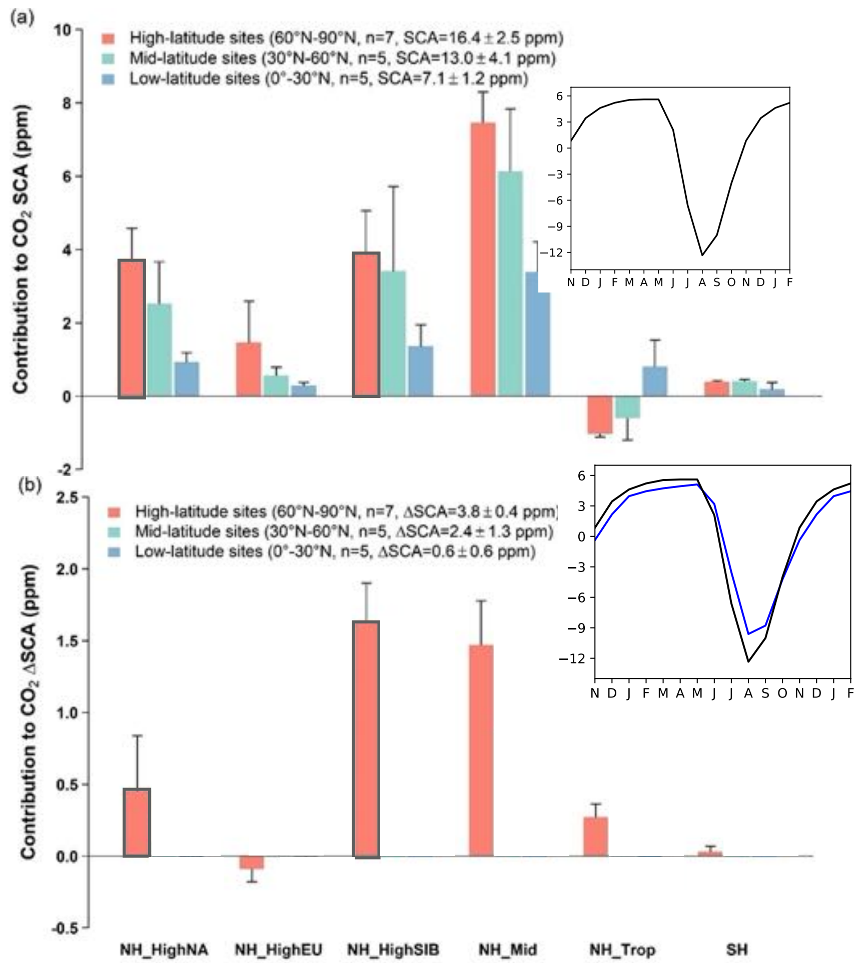




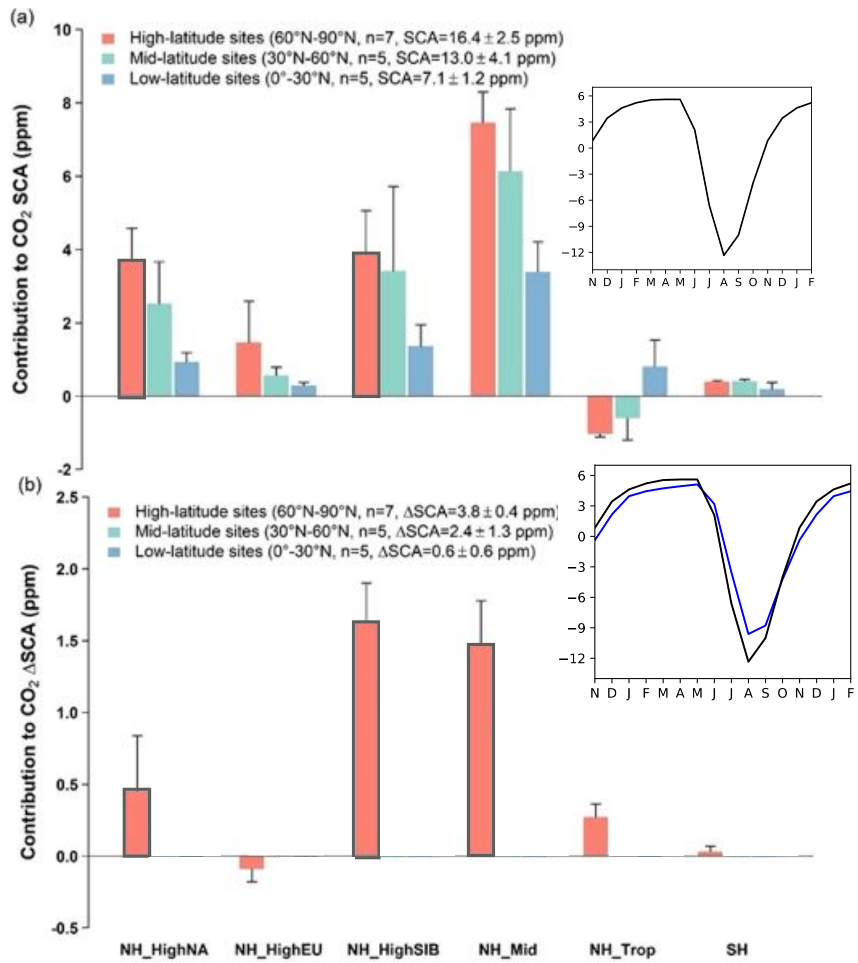
Equable contribution to mean SCA from high latitude North America and Siberia consistent with similar integrated flux amplitudes

Lin et al., 2020



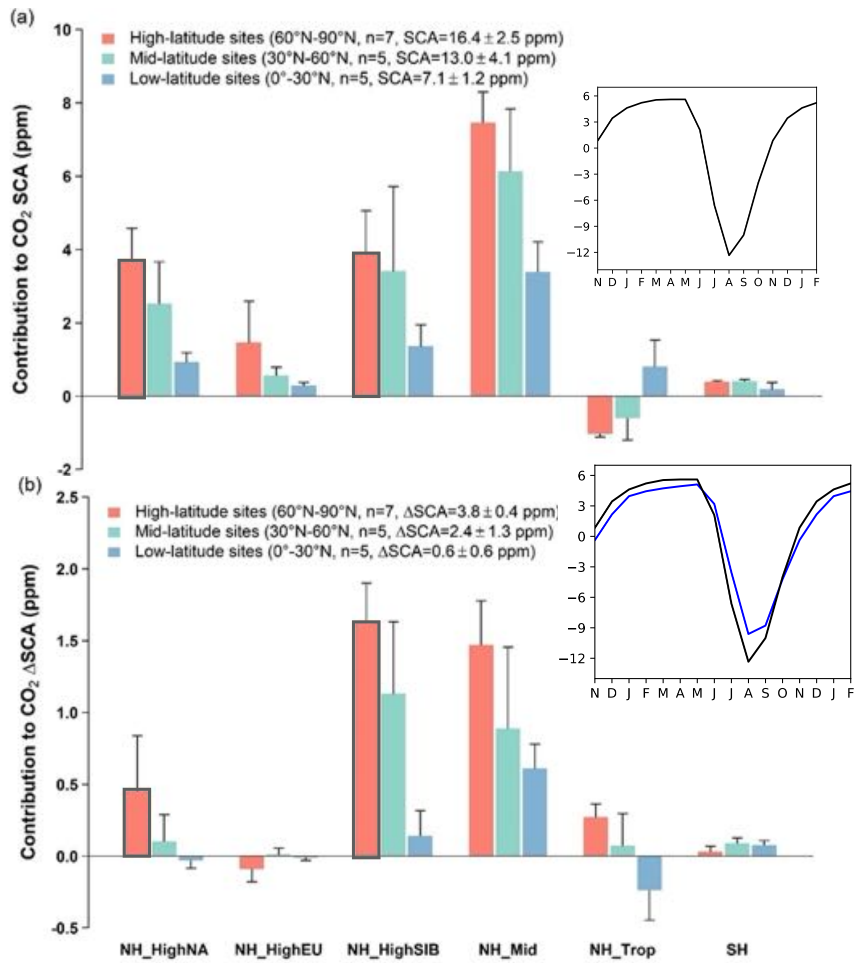
Although North America and Siberia contribute equally to mean annual cycle, Siberia dominates the trend

Lin et al., 2020



Temperate ecosystems contribute almost as much as Siberia to high latitude amplification

Lin et al., 2020



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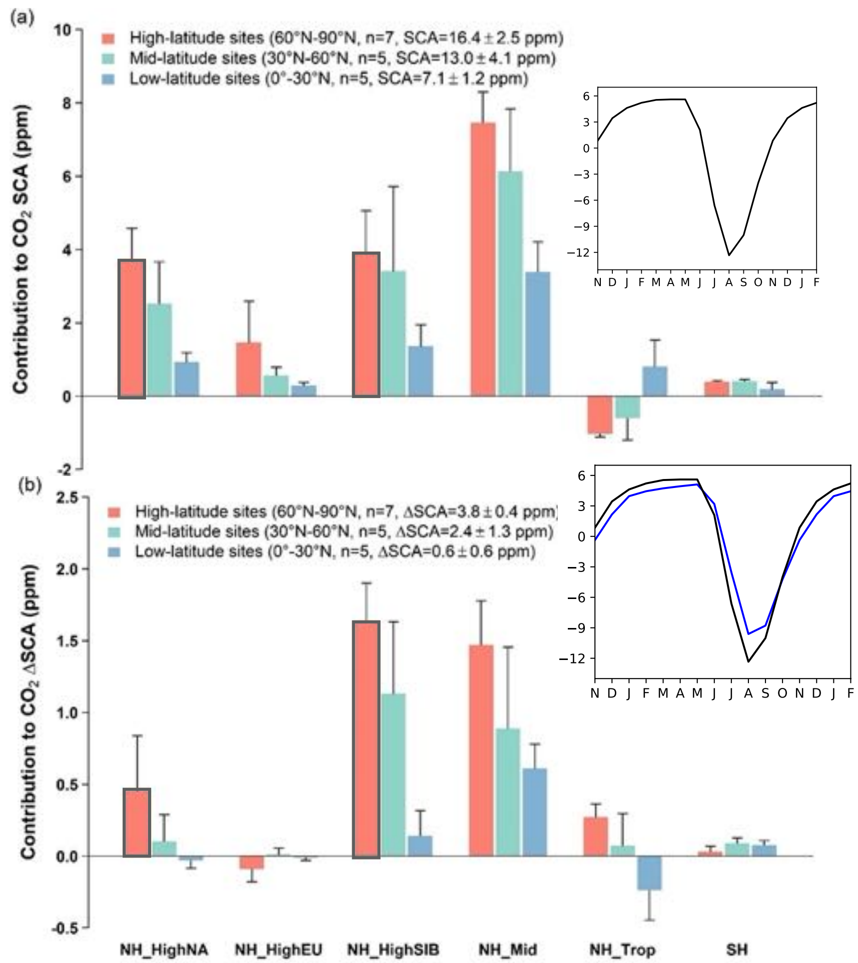
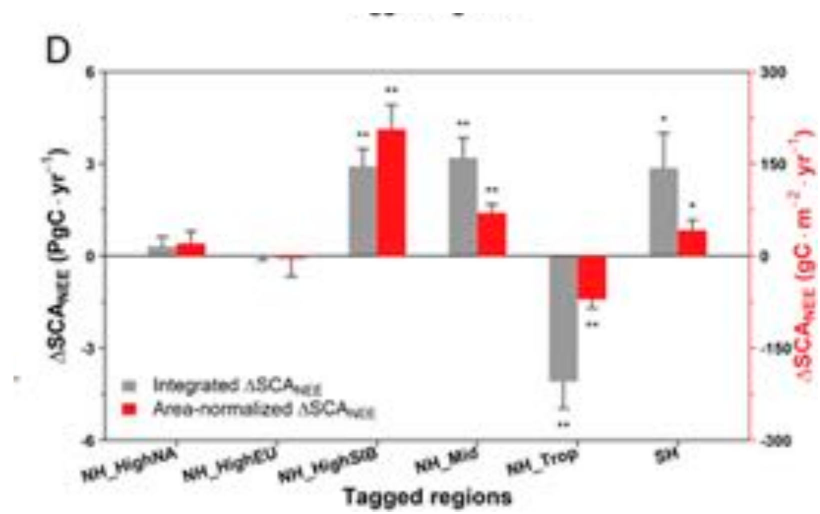
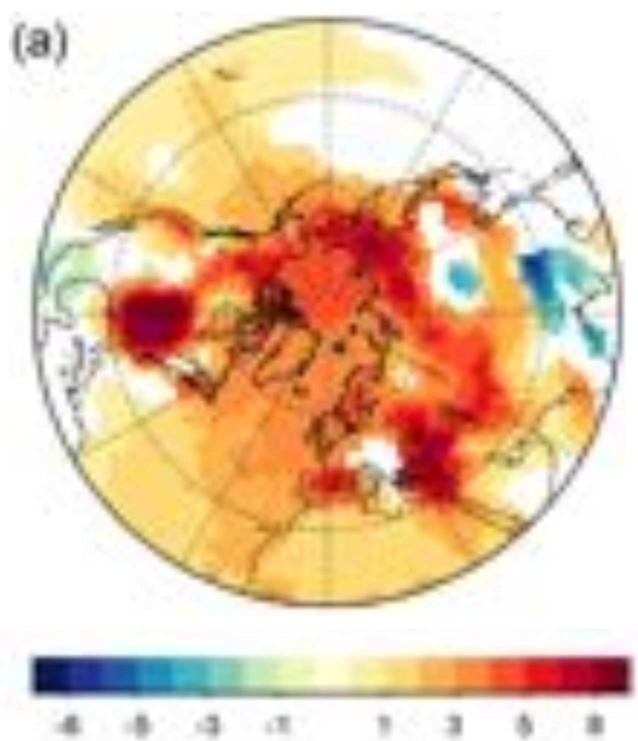




Lin et al., 2020

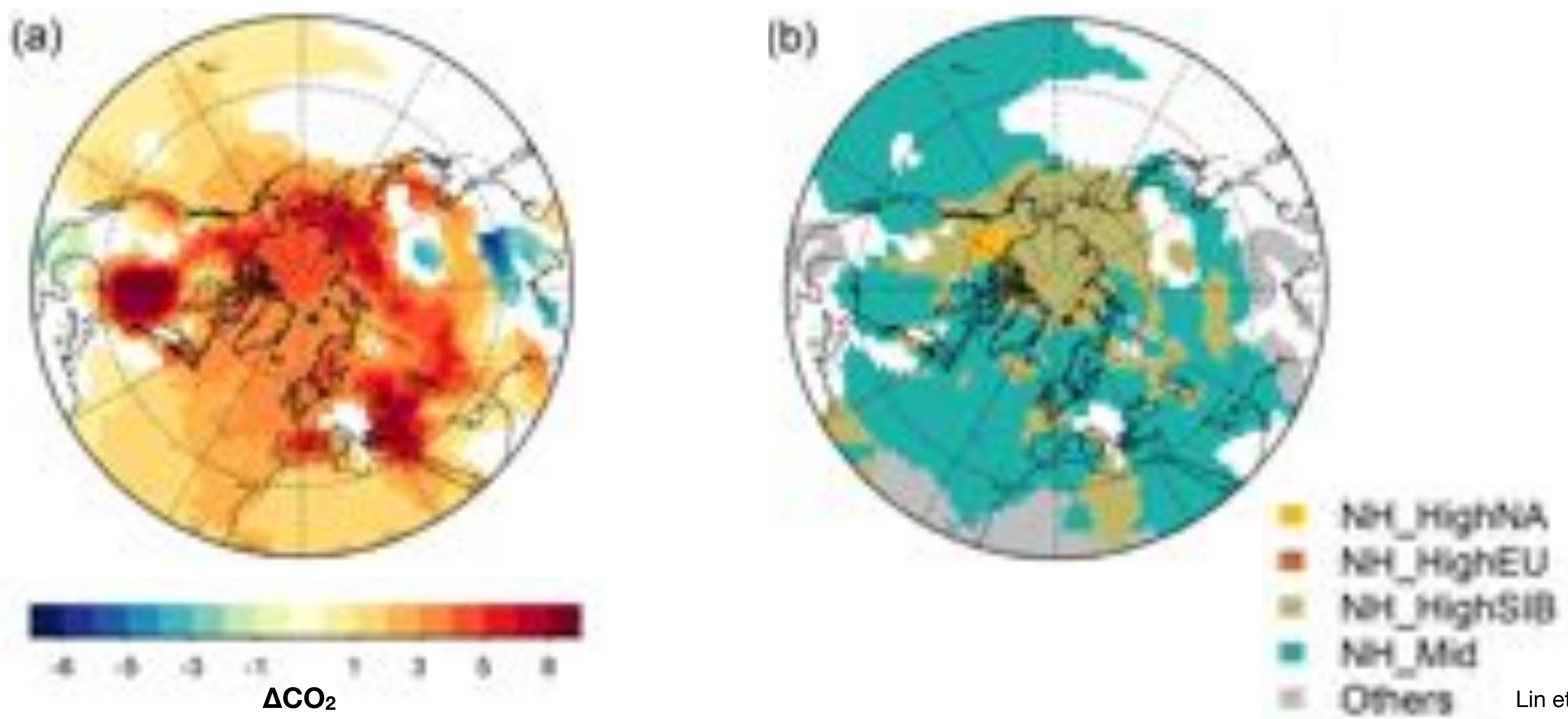
Northern Hemisphere surface shows regionally heterogeneous trends in seasonal amplitude



ΔCO_2

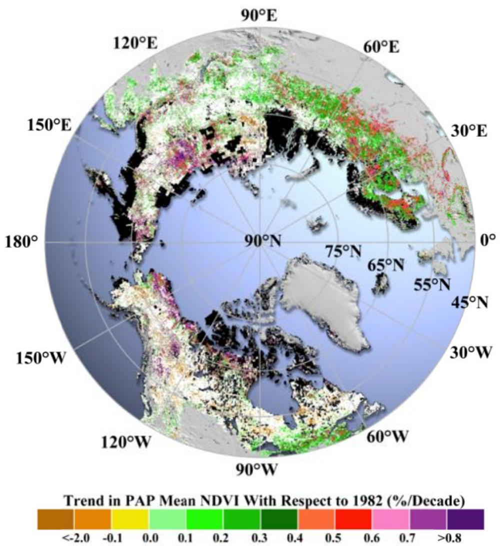
Lin et al., 2020

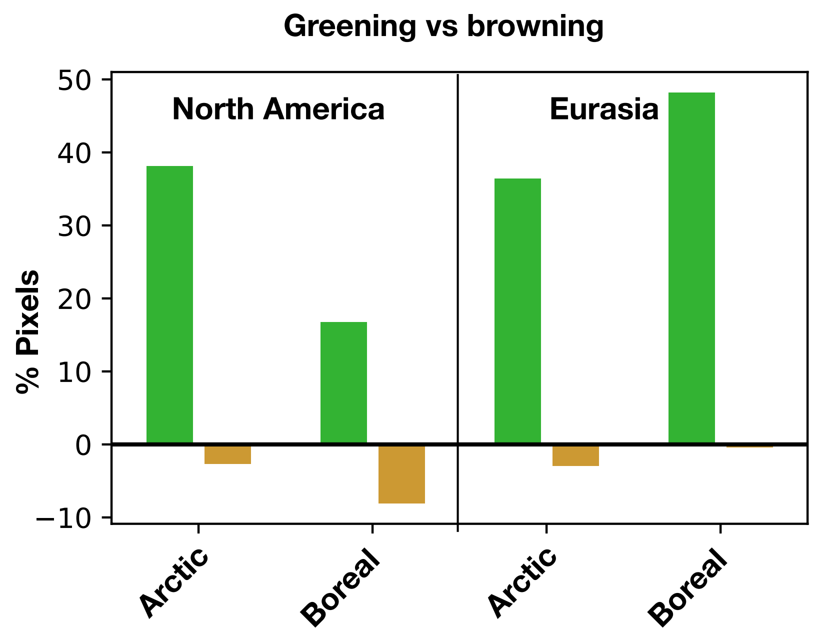
At high latitudes, the imprint from North America is localized, whereas the influence of Siberia is wide-spread



Lin et al., 2020

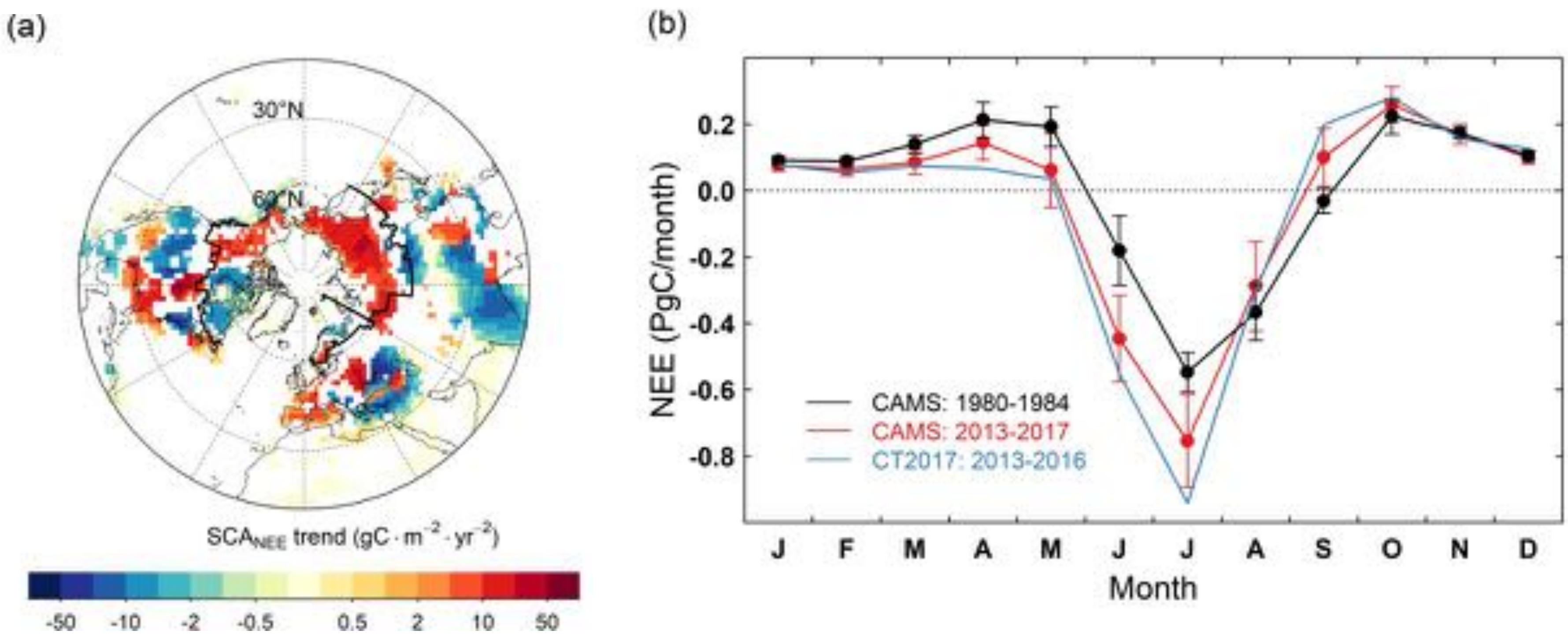
Top-down constraints from atmospheric CO_2 corroborate bottom-up ecosystem observations and satellite trends





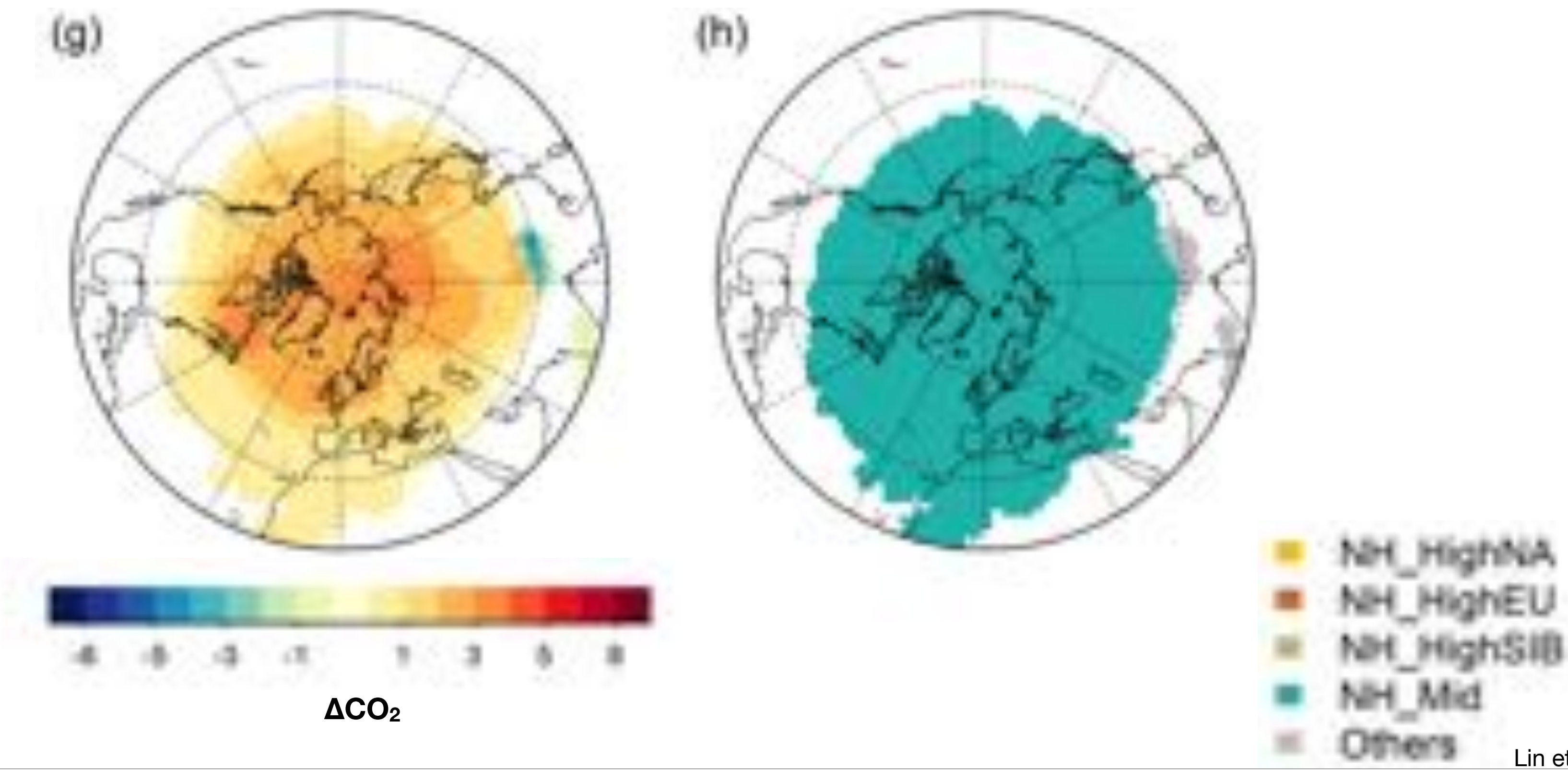
Bi et al., 2013

CAMS NEE shows strong increases in Siberia, western boreal North America, and temperate croplands



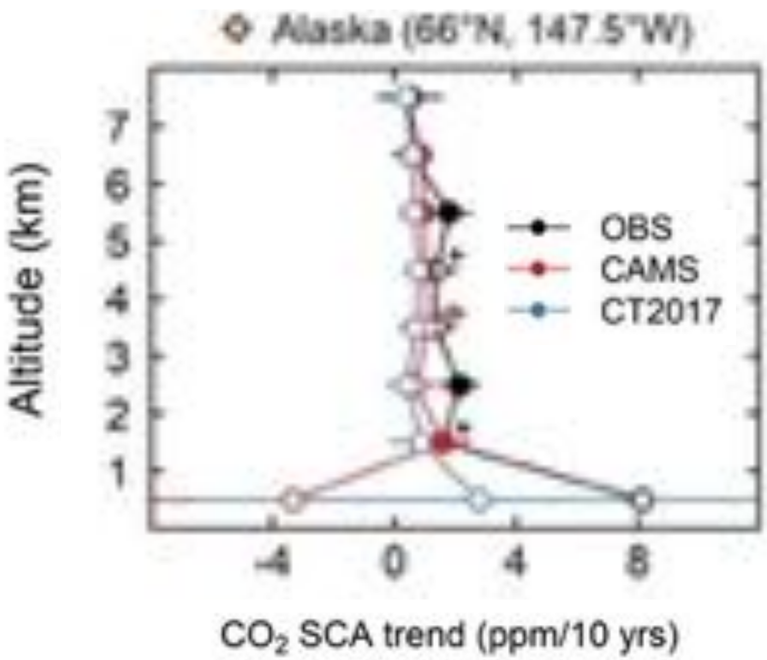
Lin et al., 2020

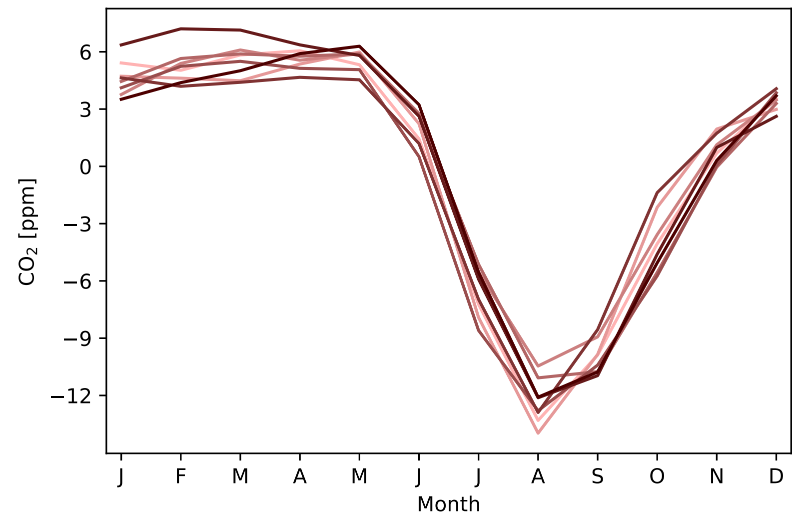
Simulated CO_2 at 500 mb is much more strongly influenced by mid-latitude fluxes



Lin et al., 2020

Neither modeled nor observed trends are robust throughout free troposphere, likely due to large interannual variability





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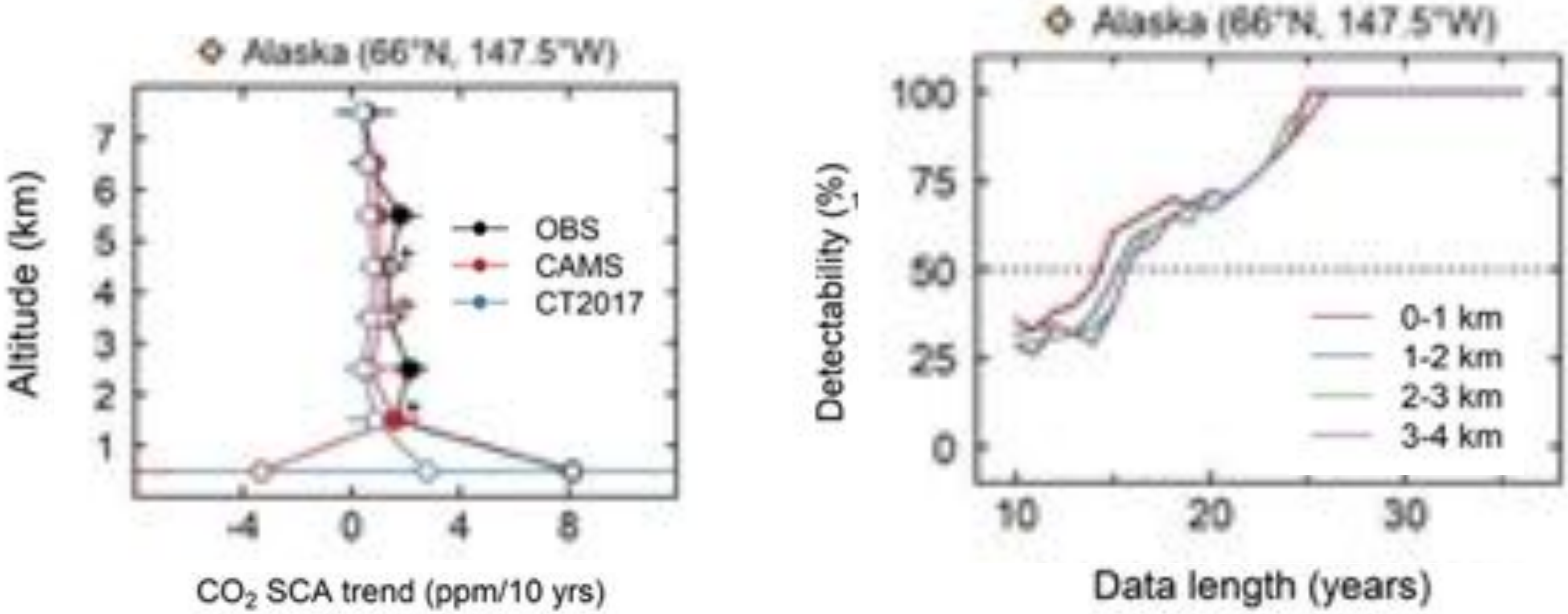
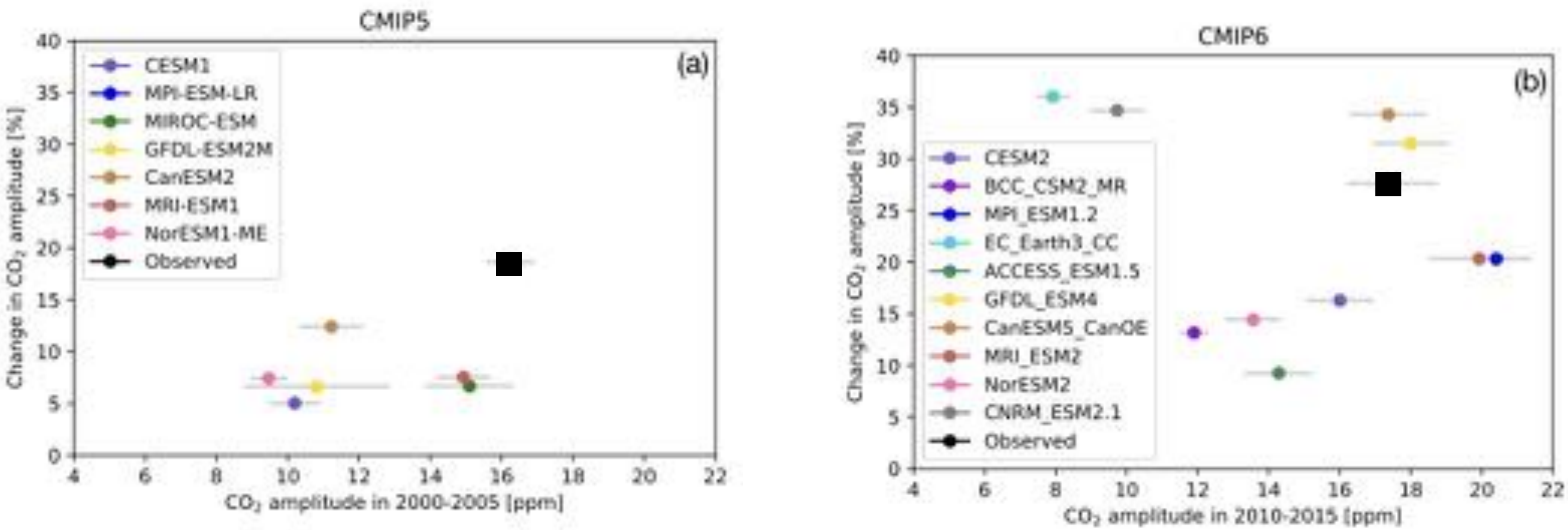


Lin et al., 2020

Improvements in modeling both amplitude and trend are seen in CMIP6 ensemble



Lombardozzi et al., in review

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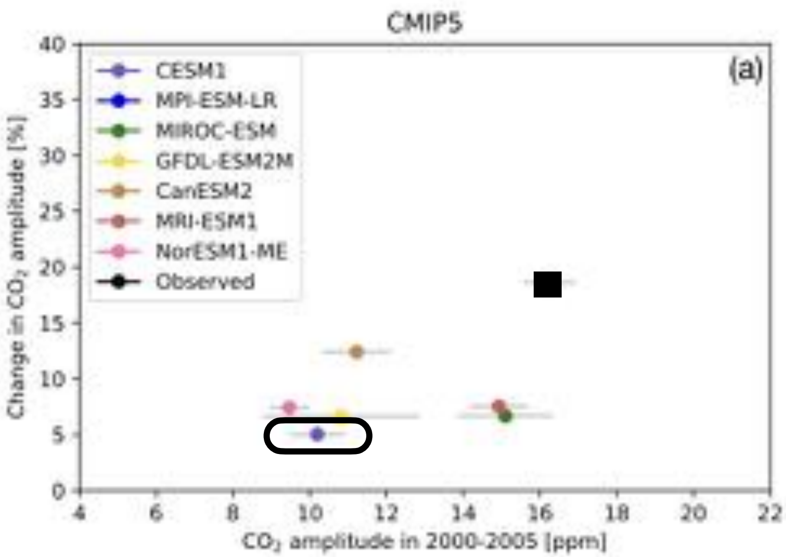
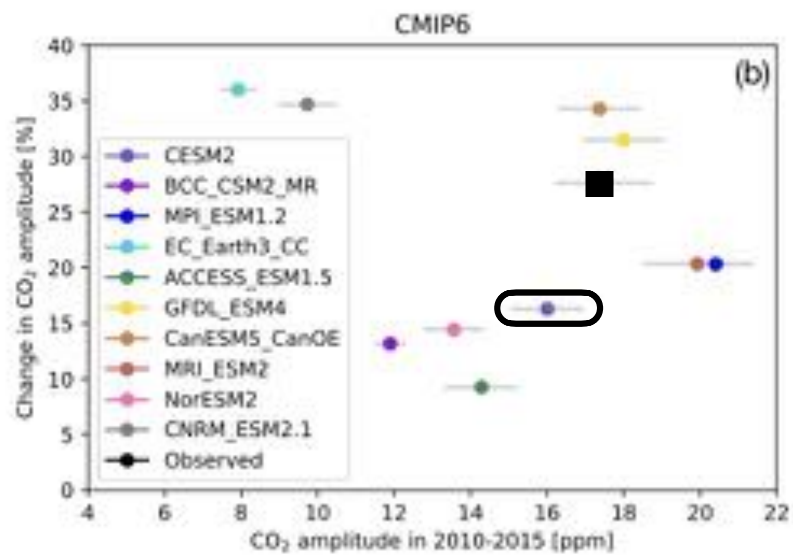
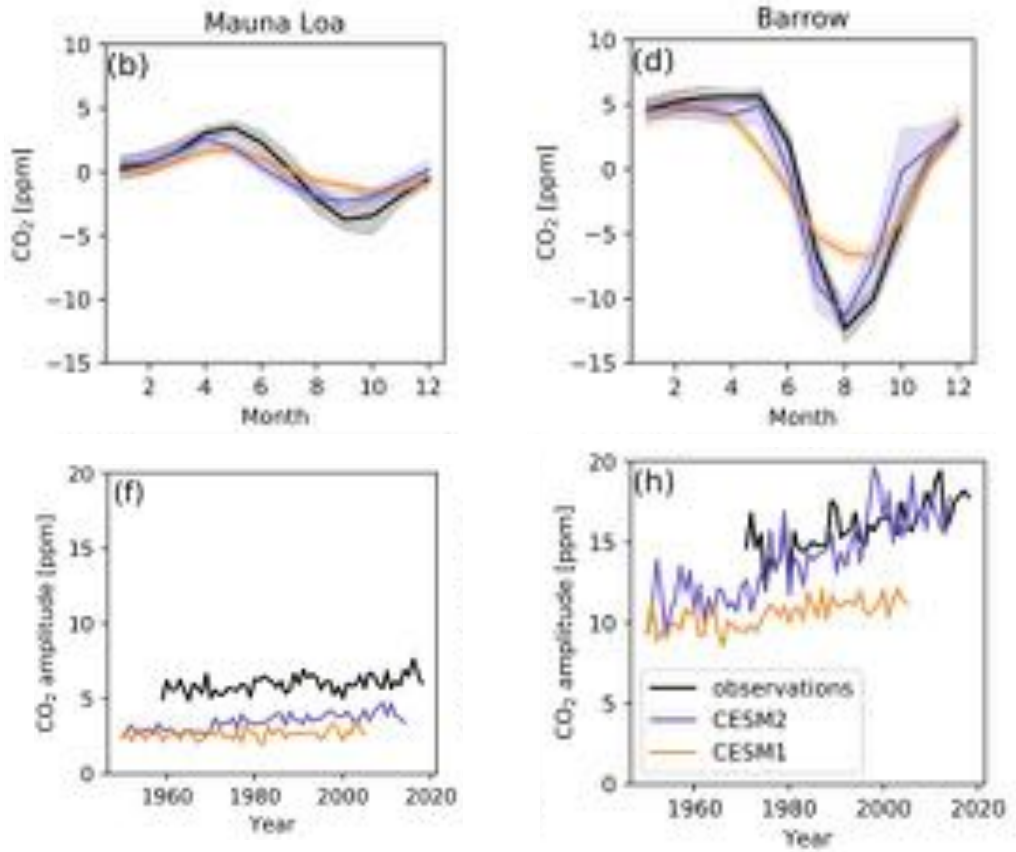




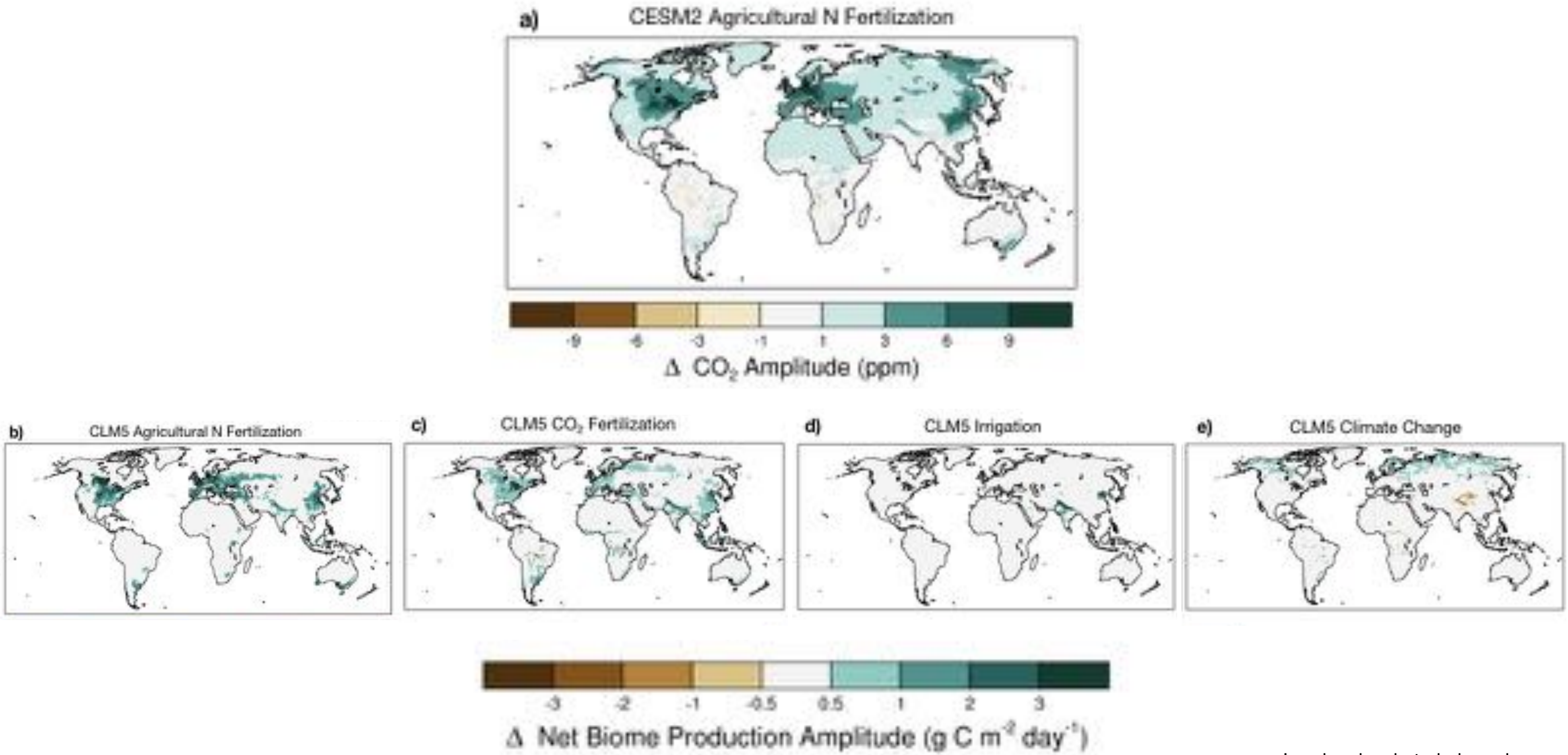
Lombardozzi et al., in review

CESM2 better captures amplitude and trend over a range of latitudes and altitudes



Lombardozzi et al., in review

Nitrogen fertilization in managed croplands drives most of the change in amplitude



Lombardozzi et al., in review

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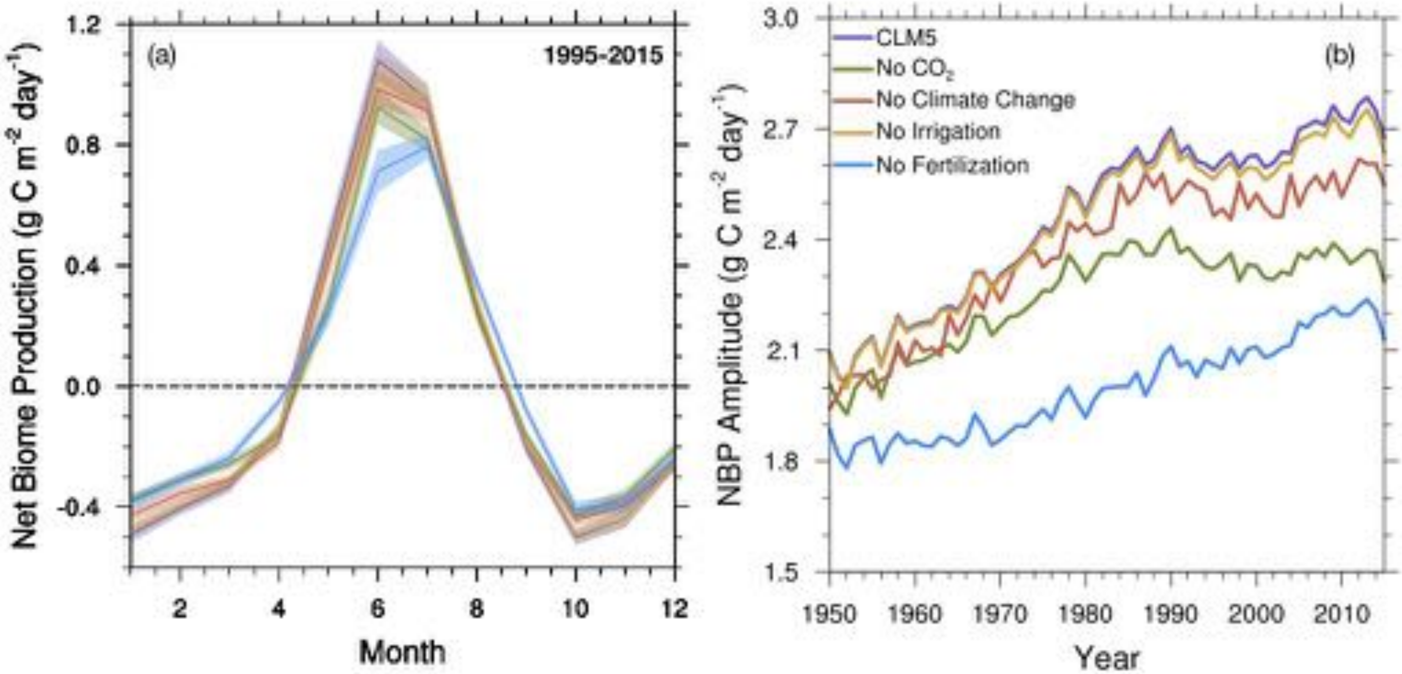
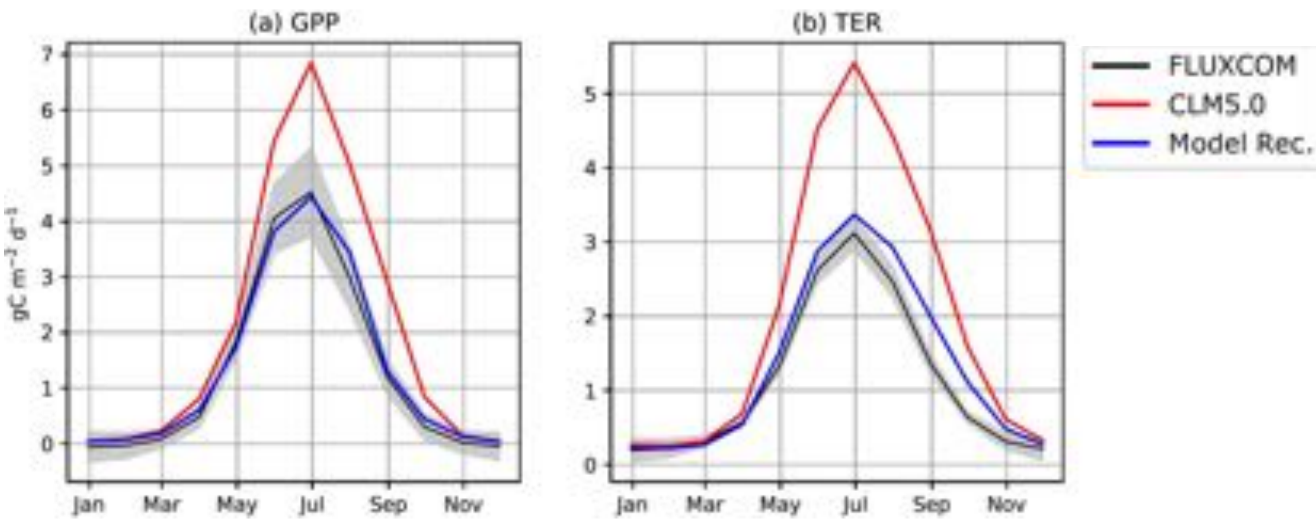


Lombardozzi et al., in review

Model development focused on phenology and PFT-level behavior at high latitudes has improved CLM5 performance



Birch et al., 2021

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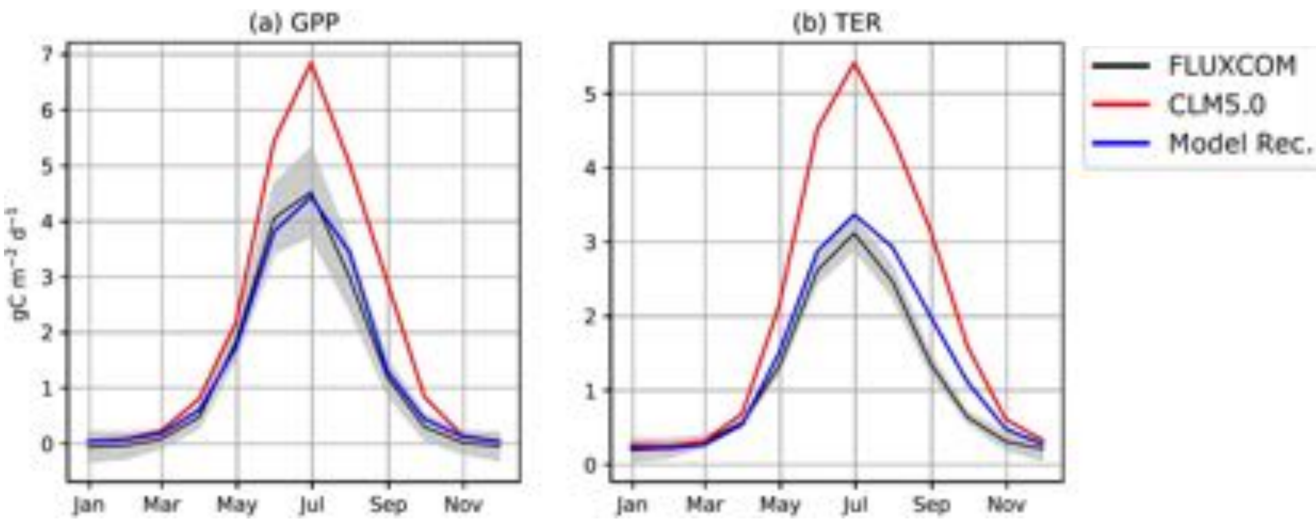
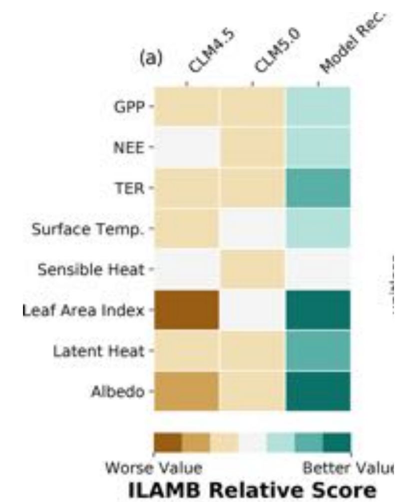
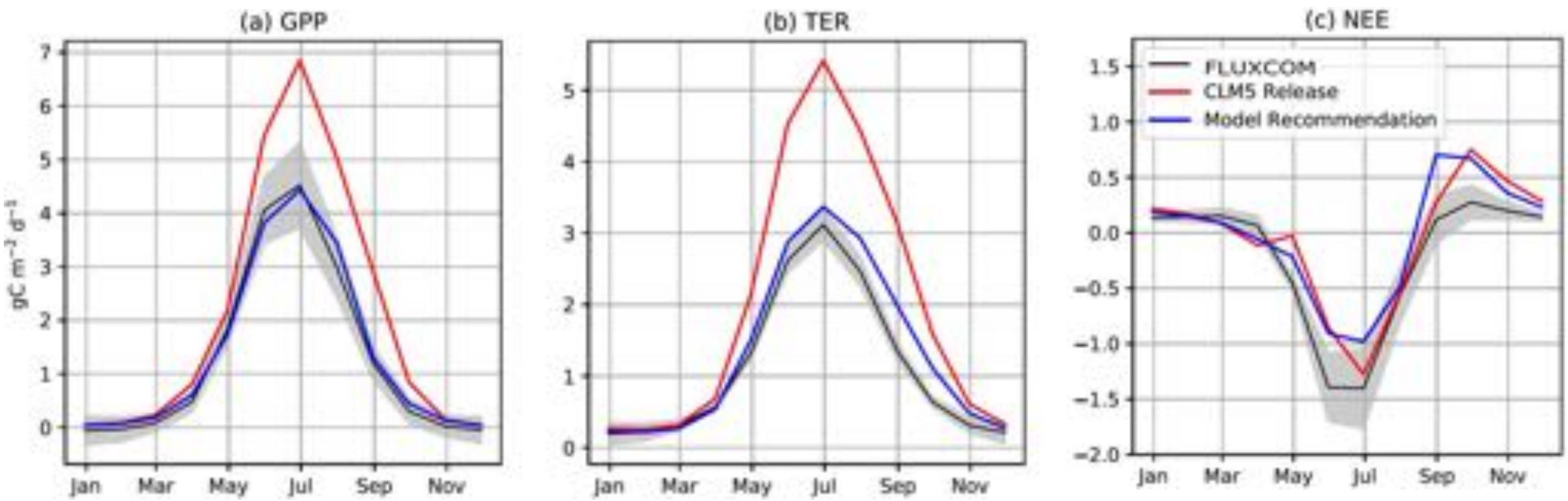


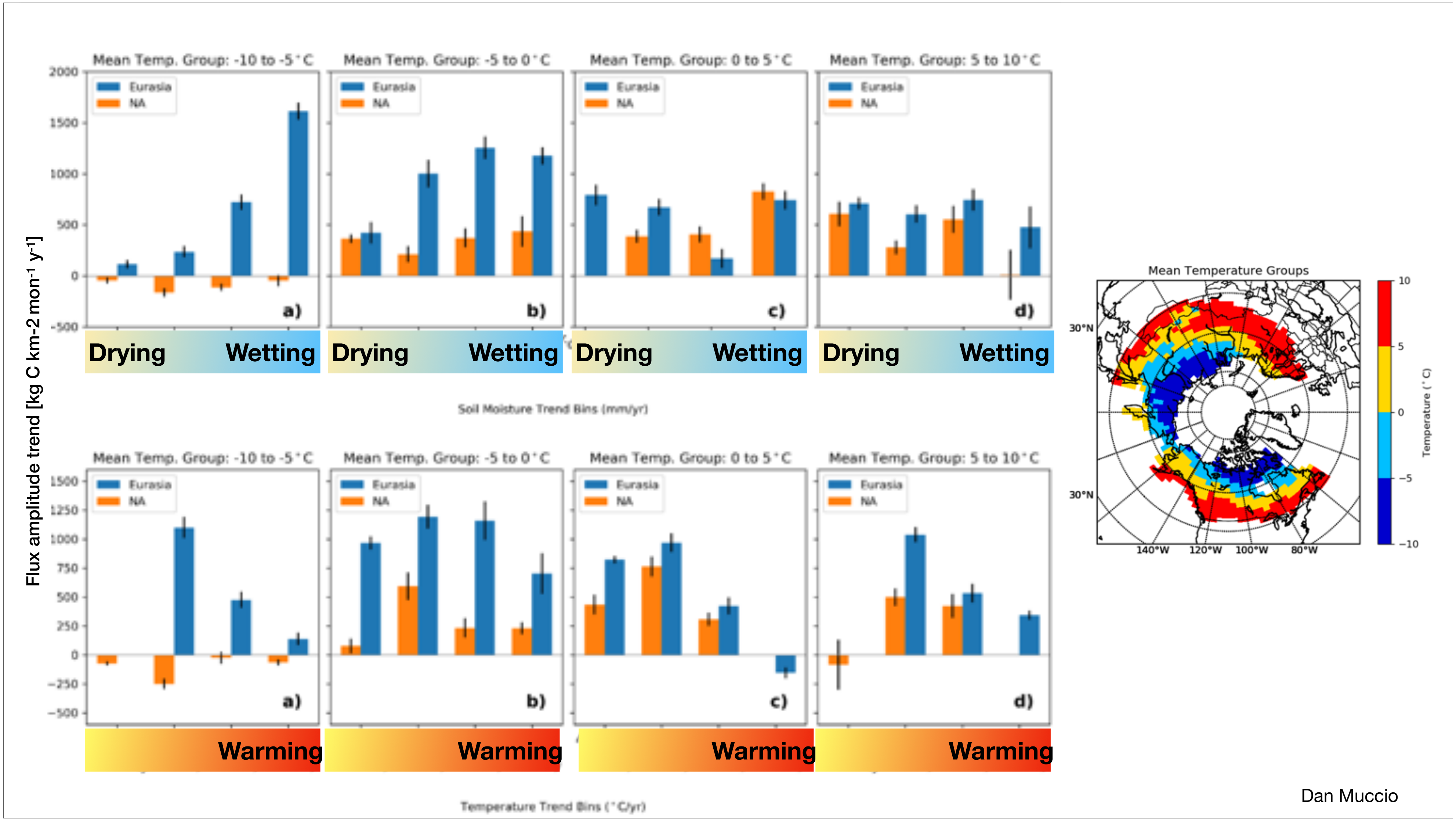


Birch et al., 2021

… but NEE amplitude remains weaker than inferred from FLUXCOM and doesn't capture amplification



Birch et al., 2021


Mean Temp. Group: -10 to -5 °C
Mean Temp. Group: -5 to 0 °C
Mean Temp. Group: 0 to 5 °C
Mean Temp. Group: 5 to 10 °C
Eurasia
NA
a)
b)
c)
d)
Drying
Wetting
Soil Moisture Trend Bins (mm/yr)
Flux amplitude trend [kg C km-2 mon-1 y-1]
Warming
Temperature Trend Bins (°C/yr)
Mean Temperature Groups
30°N
140°W
120°W
100°W
80°W
Temperature (°C)
Dan Muccio

Conclusions

Boreal and Arctic ecosystems in Siberia cause about half of high-latitude seasonal cycle amplification

North American Arctic-boreal ecosystems indicate, at regional scale, a smaller net amplification

This continental asymmetry is consistent with satellite metrics for ecosystem greening/browning

Temperate ecosystems play a large role in shaping the annual cycle amplitude at high latitudes

CESM2 shows that the bulk of the NEE amplitude change is due to agricultural nitrogen fertilization

Acknowledgements and Citations

Xin Lin
Danica Lombardozzi
Leah Birch
Brendan Rogers

NASA Carbon Cycle Science
NNX17AE13G

Lin, X., Rogers, B. M., Sweeney, C., Chevallier, F., Arshinov, M., Dlugokencky, E., Machida, T., Sasakawa, M., Tans, P., & Keppel-Aleks, G. (2020-09). Siberian and temperate ecosystems shape Northern Hemisphere atmospheric CO2 seasonal amplification. *Proc Natl Acad Sci USA*, *117*(35), 21079. https://doi.org/10.1073/pnas.1914135117

Lombardozzi, D., Wieder, W. R., Keppel-Aleks, G. , Lawrence, D. M., Lin, X., Bonan, G., Koven, C., Friedlingstein, P., and K. Lindsay (in review). Agricultural Fertilization Drives Increased Amplitude of Land-Atmosphere CO_2 Exchange

Birch, L., Schwalm, C. R., Natali, S., Lombardozzi, D., Keppel-Aleks, G., Watts, J., Lin, X., Zona, D., Oechel, W., Sachs, T., Black, T. A., & Rogers, B. M. (2021-06). Addressing biases in Arctic-boreal carbon cycling in the Community Land Model Version 5. *GMD*, *14*(6), 3361–3382. https://doi.org/10.5194/gmd-14-3361-2021