Tracking the imprint and impact of spatiotemporal variability of CO_2 emissions

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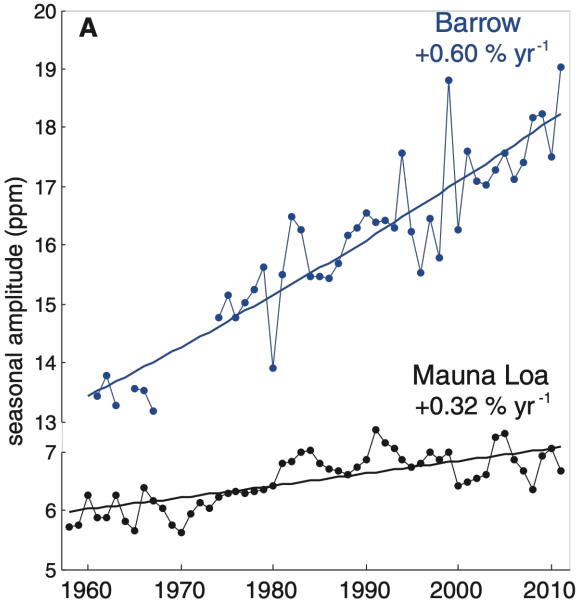
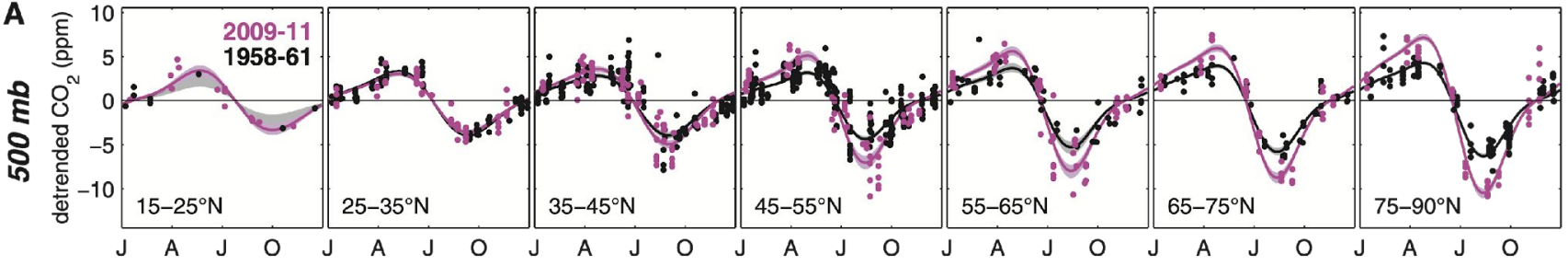
Why should we track atmospheric CO_2 in emissions driven CESM simulations?

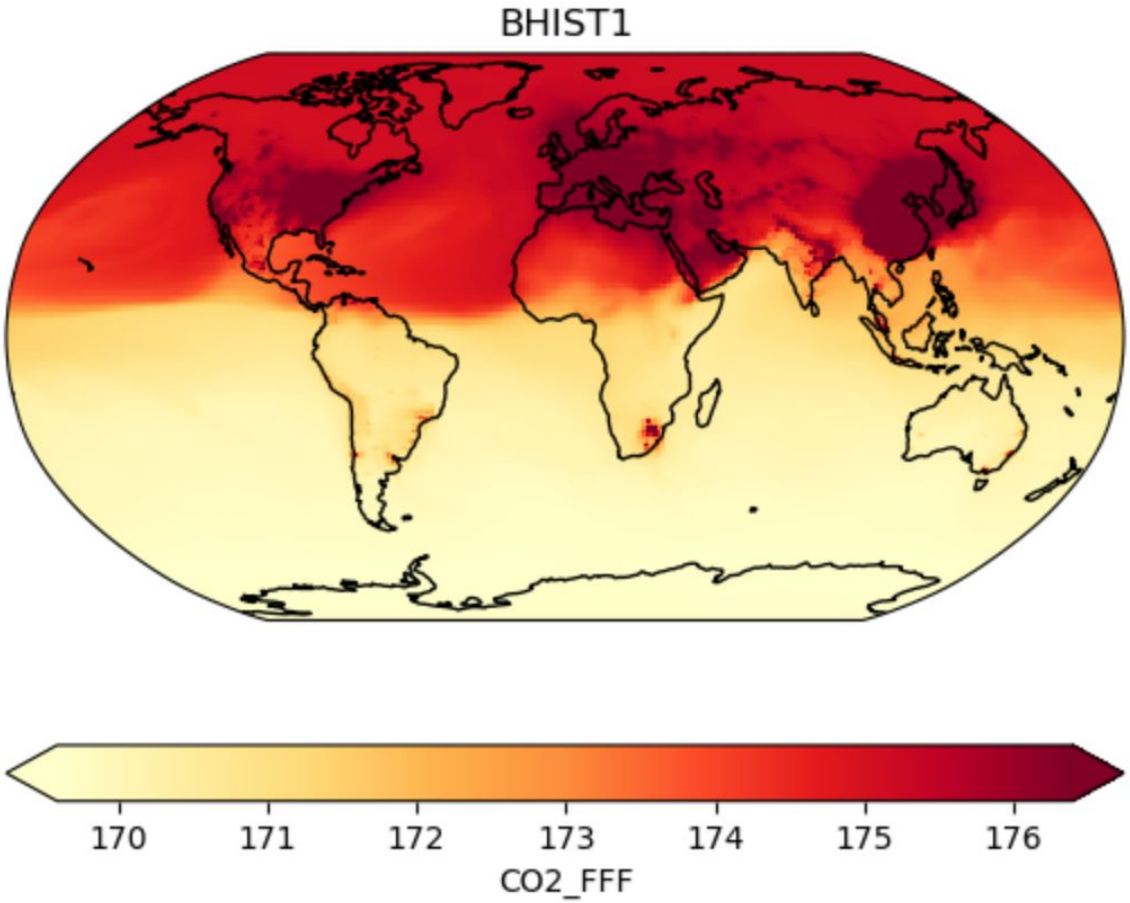


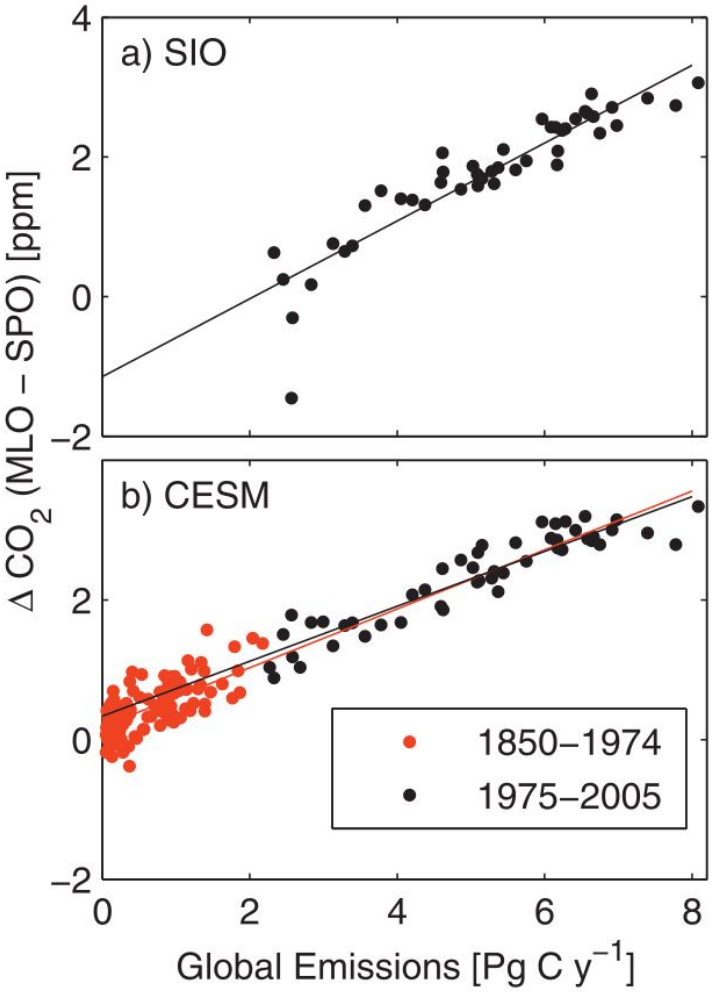
Atmospheric CO_2 provides unique constraints on Earth system processes

Graven et al., 2013



Fossil fuel CO_2 is emitted to the atmosphere according to a spatial and seasonal pattern

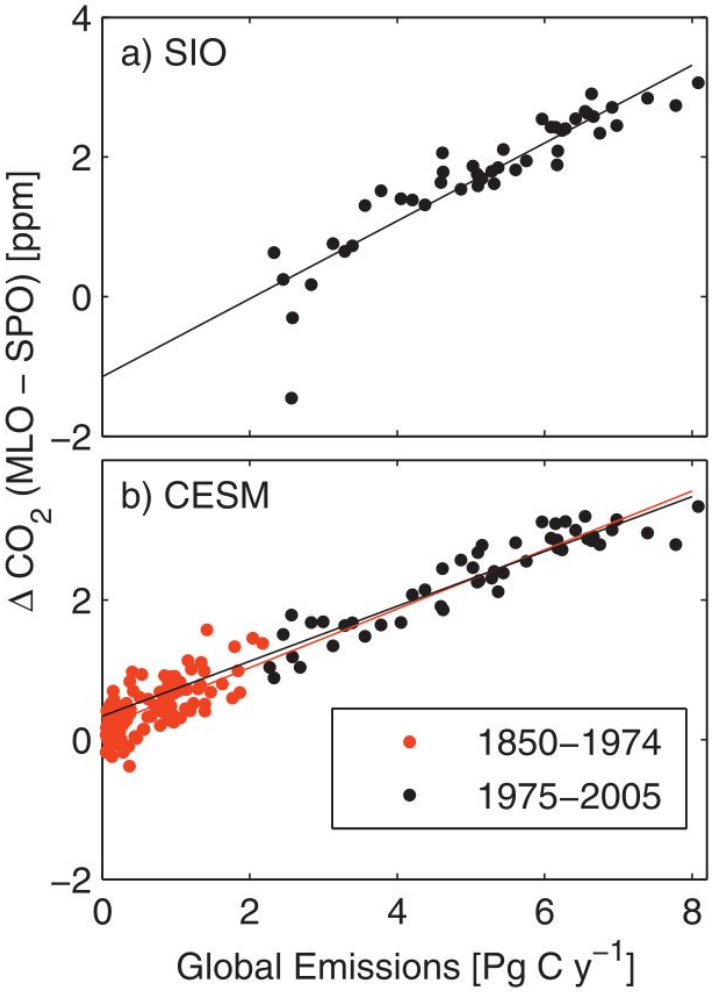


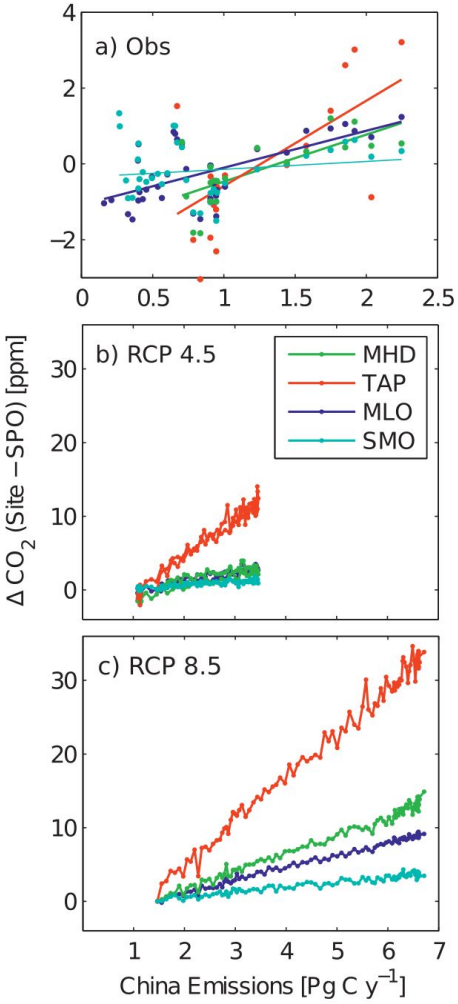


The interhemispheric contrast in CO_2 reflects the fact that most fossil emissions are in the Northern Hemisphere

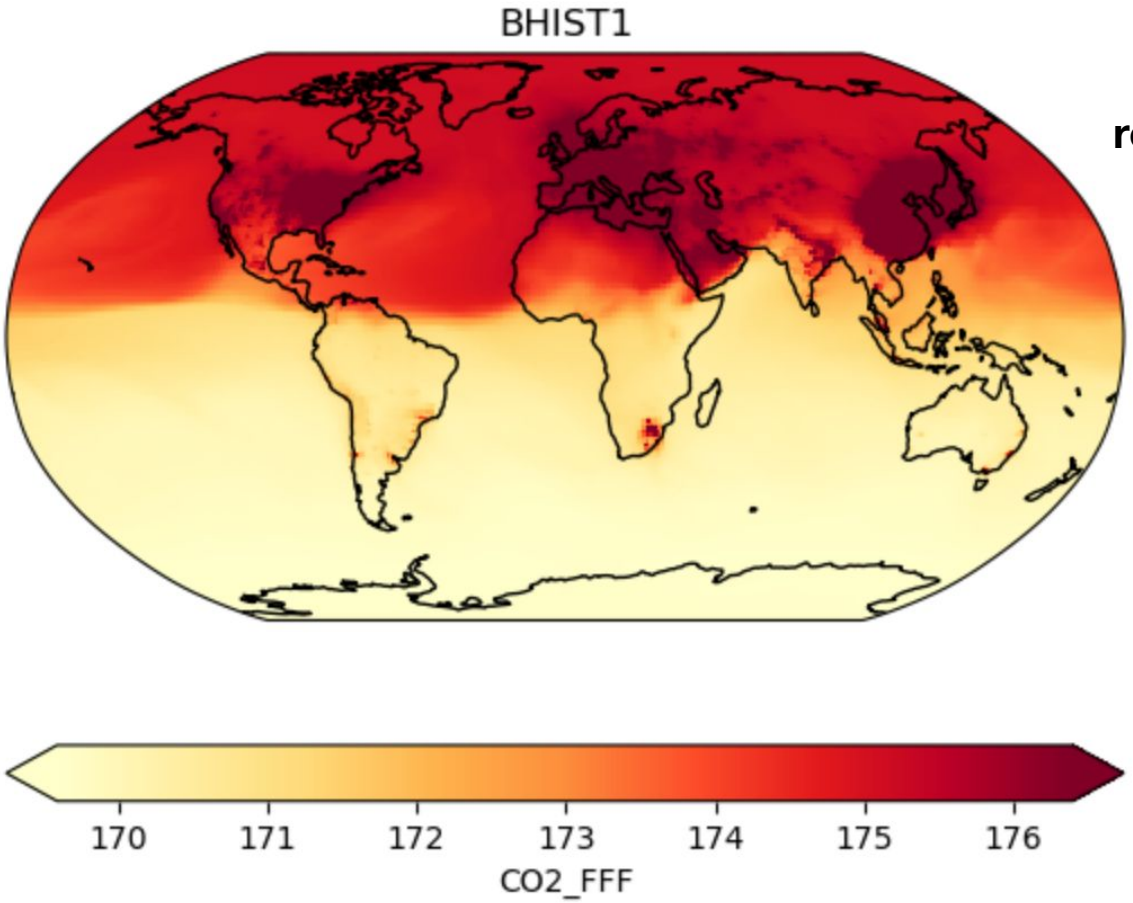
Keppel-Aleks et al., 2013

Tracking 4-D CO_2 fields in CESM enables us to project how observations will change with changing emissions and associated feedbacks in land and ocean carbon uptake

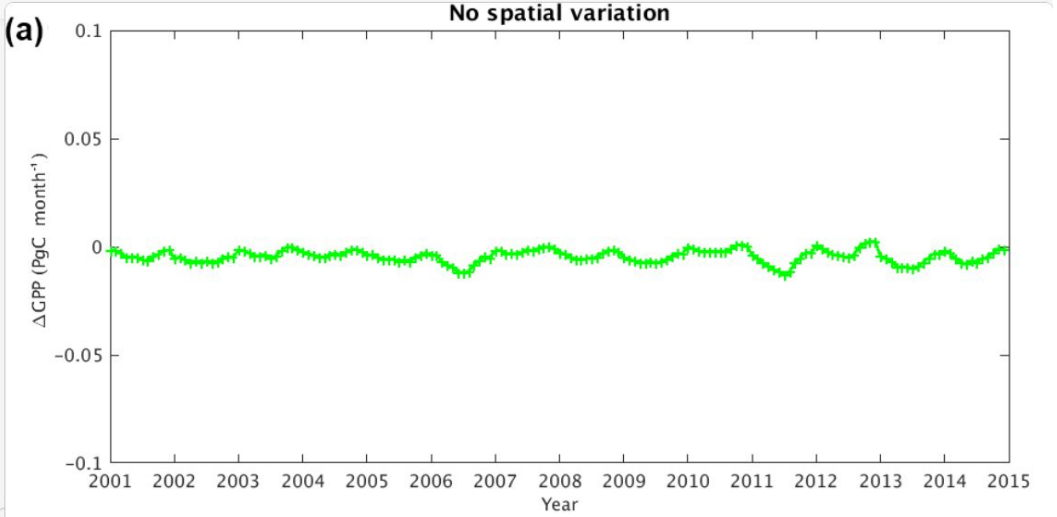


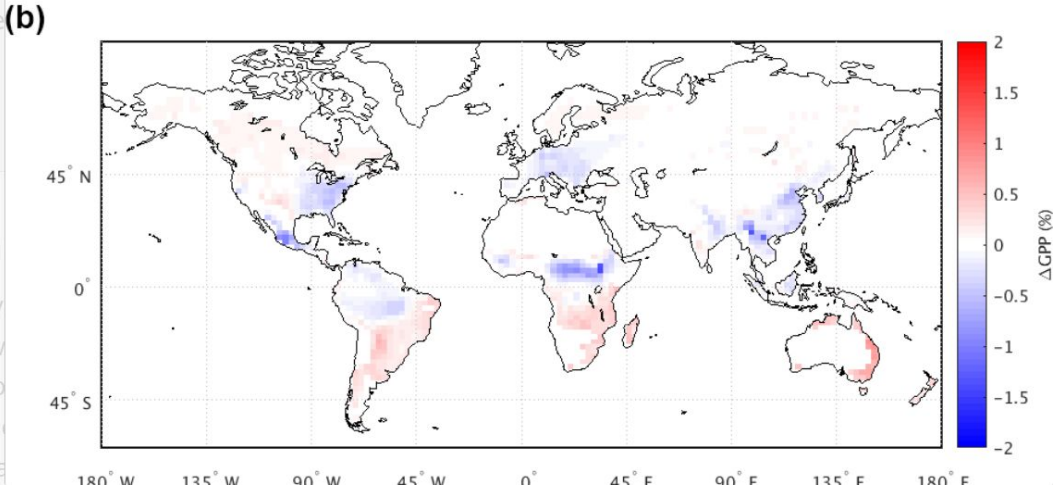


Keppel-Aleks et al., 2013



Fossil fuel CO_2 is emitted to the atmosphere according to a spatial and seasonal pattern, resulting in distinct atmospheric patterns of variability

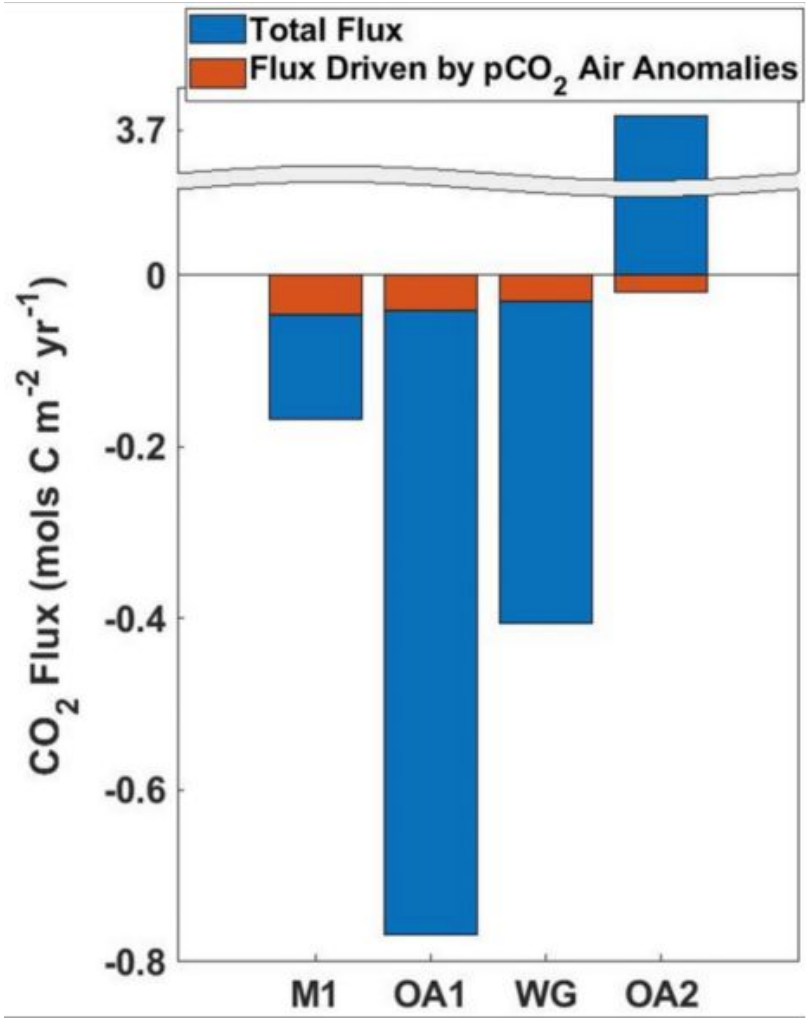




Why should a bunch of terrestrial ecologists care?

Spatial variations in CO_2 can change GPP through local fertilization effects

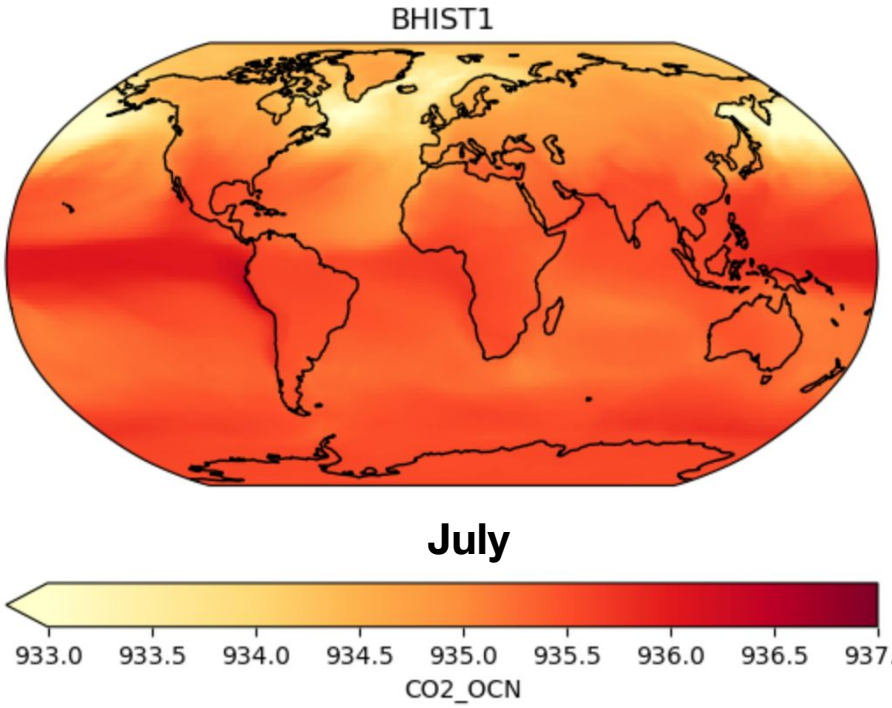
Lee et al., 2018

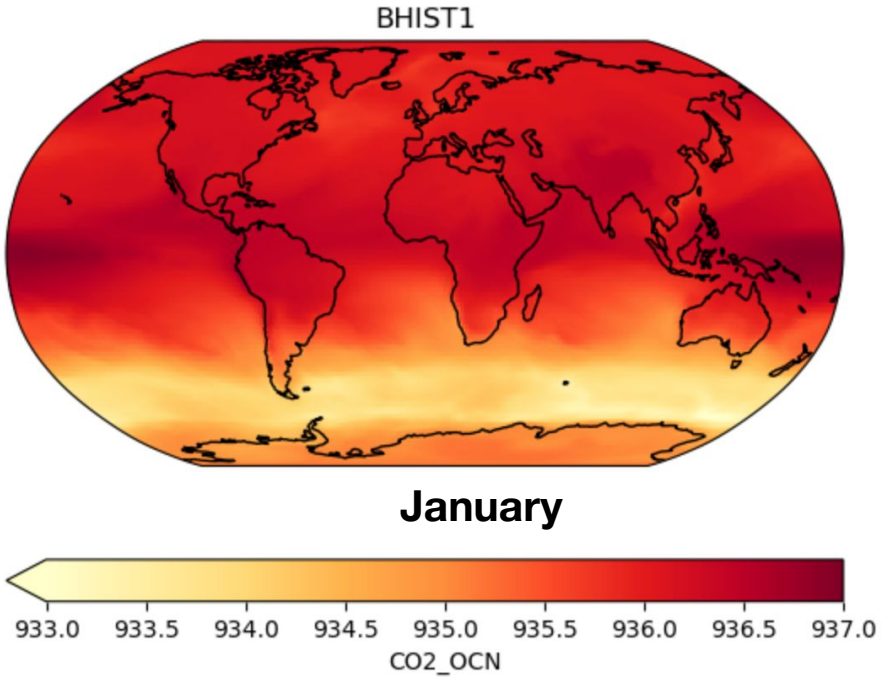


Why should a bunch of ocean biogeochemists care?

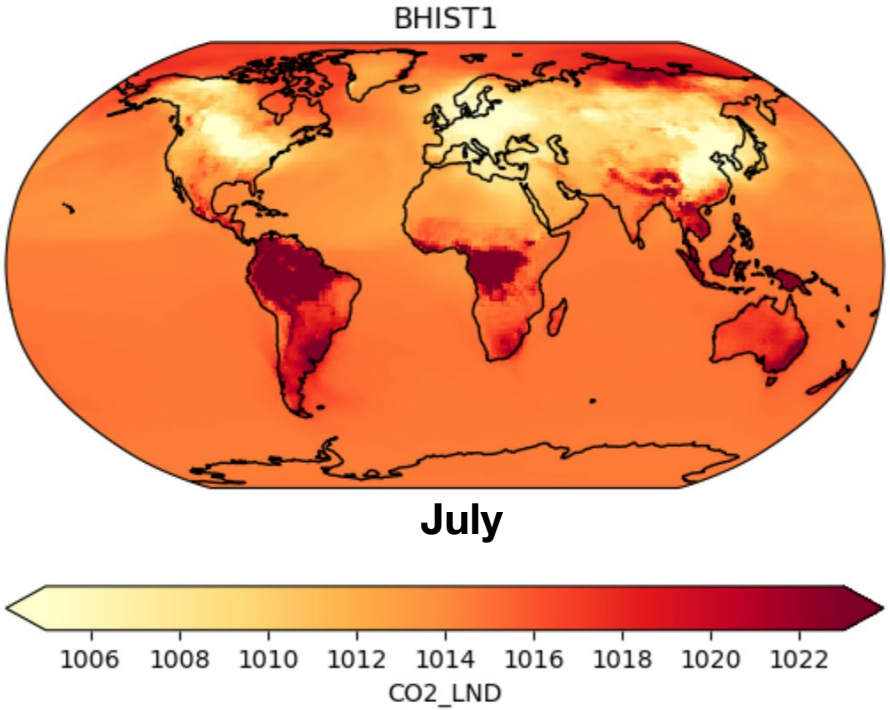
Spatial variations in CO_2 can change ocean uptake due to local differences in the air-sea pCO_2 contrast

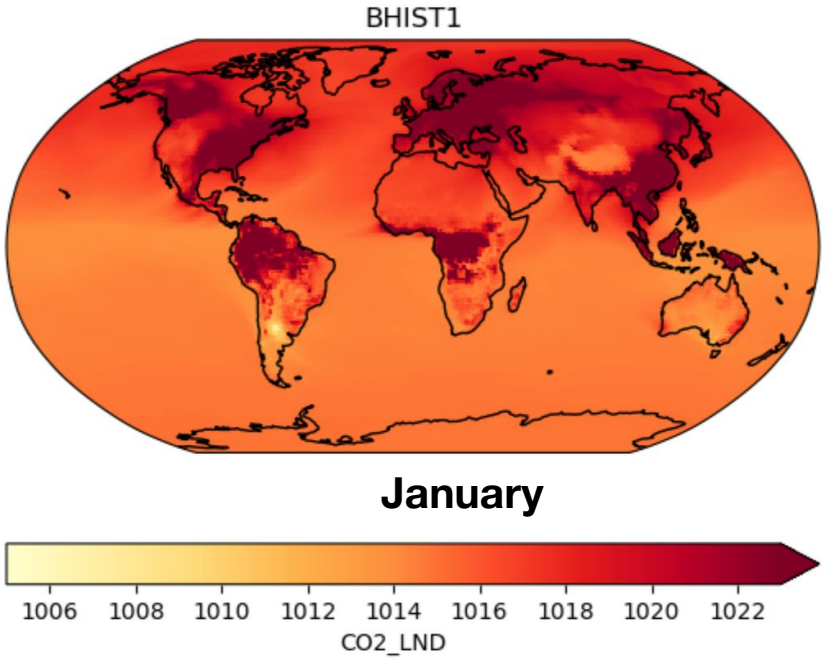
Northcott et al., 2019



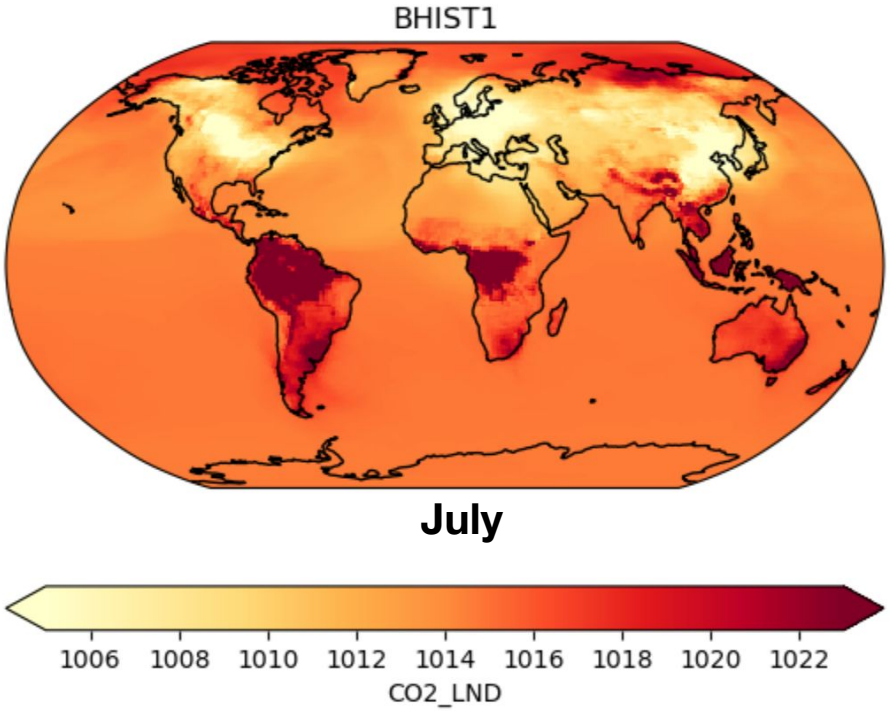


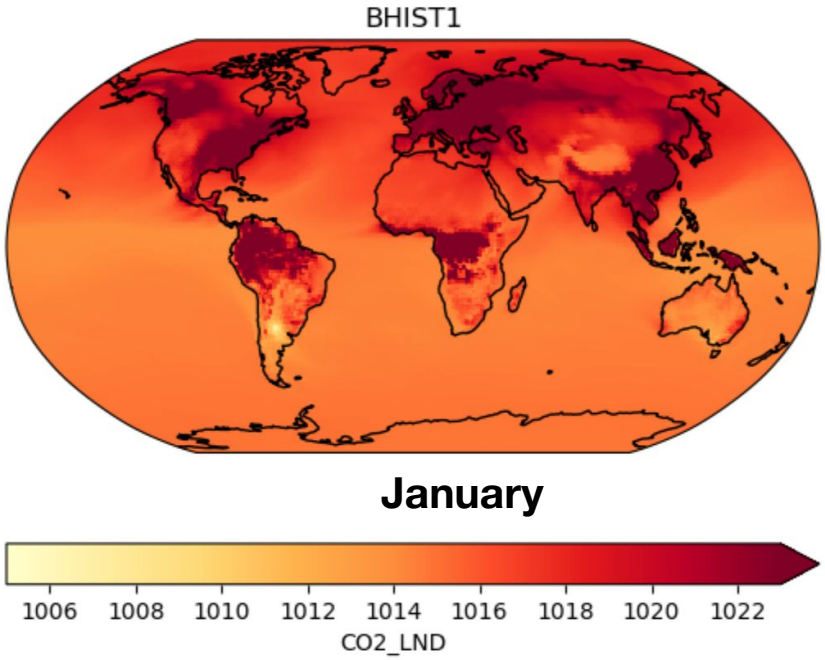
Of course, spatiotemporal variations in air-sea CO_2 fluxes are also tracked within CESM, resulting in modest spatial gradients in CO_2





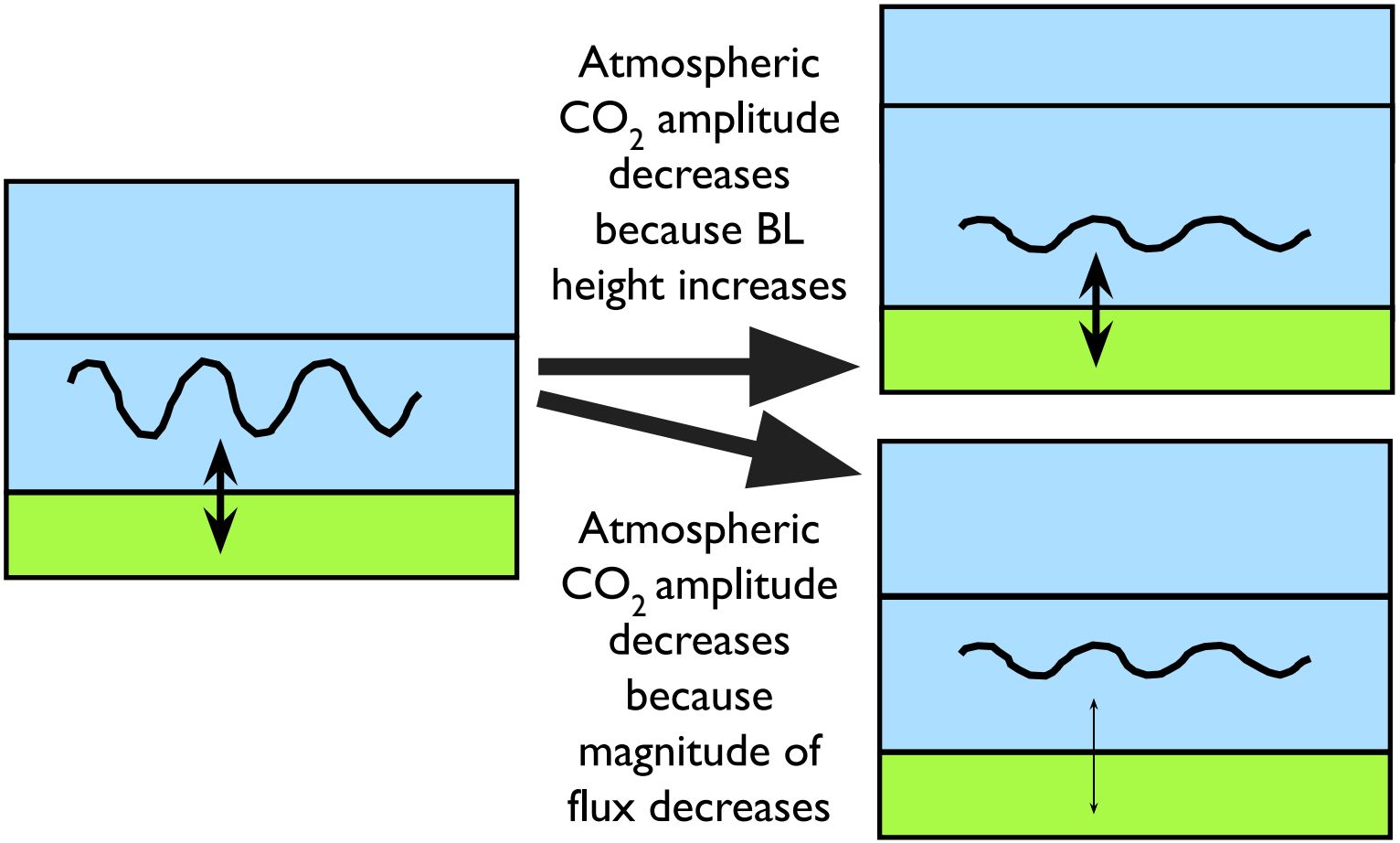
Land-atmosphere carbon exchange leaves a much larger imprint on atmospheric CO_2 than does ocean exchange



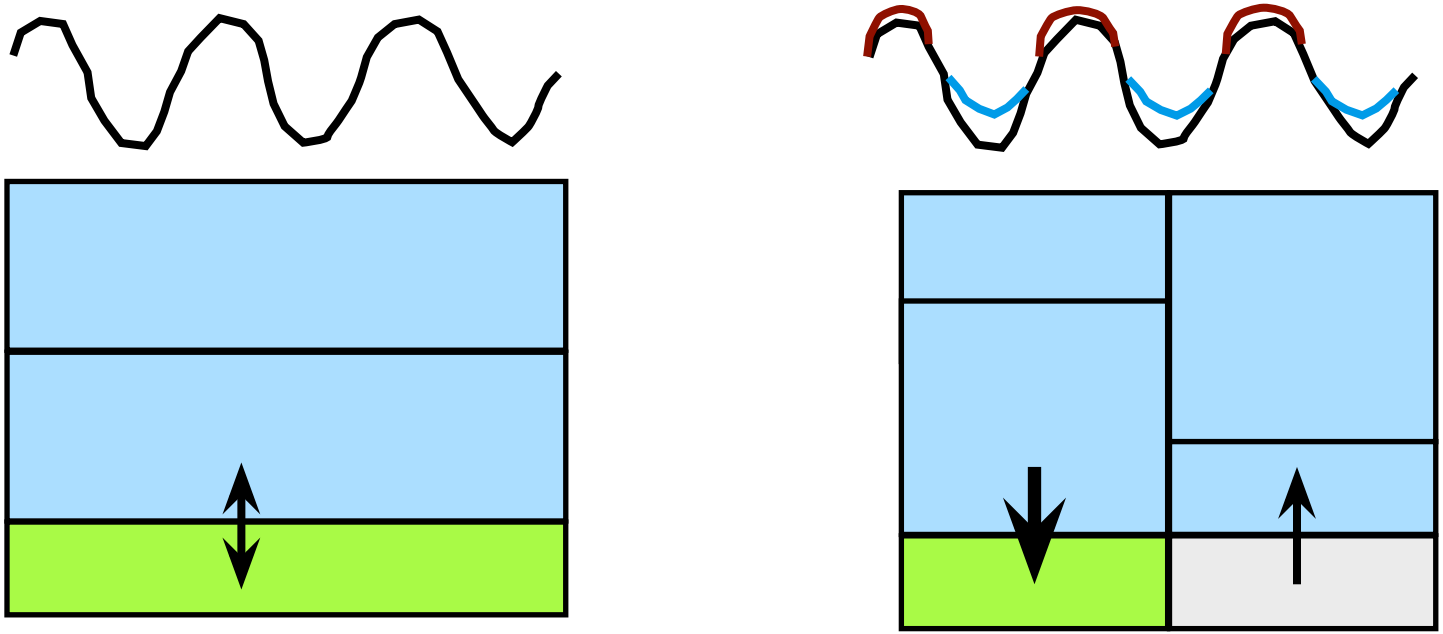


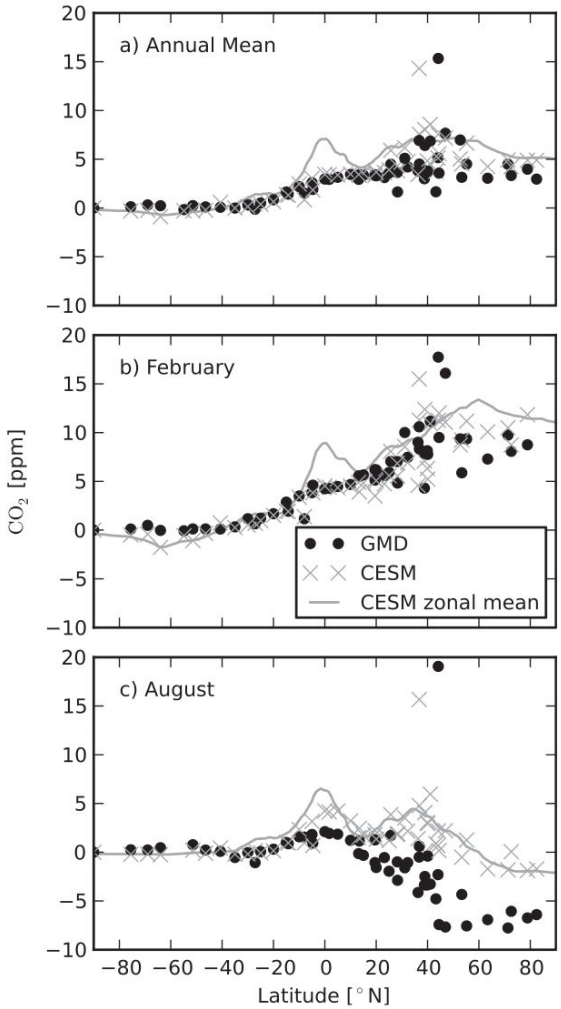
But why is CO_2 so high over tropical forests?!

Effect of boundary layer height on CO_2 signals

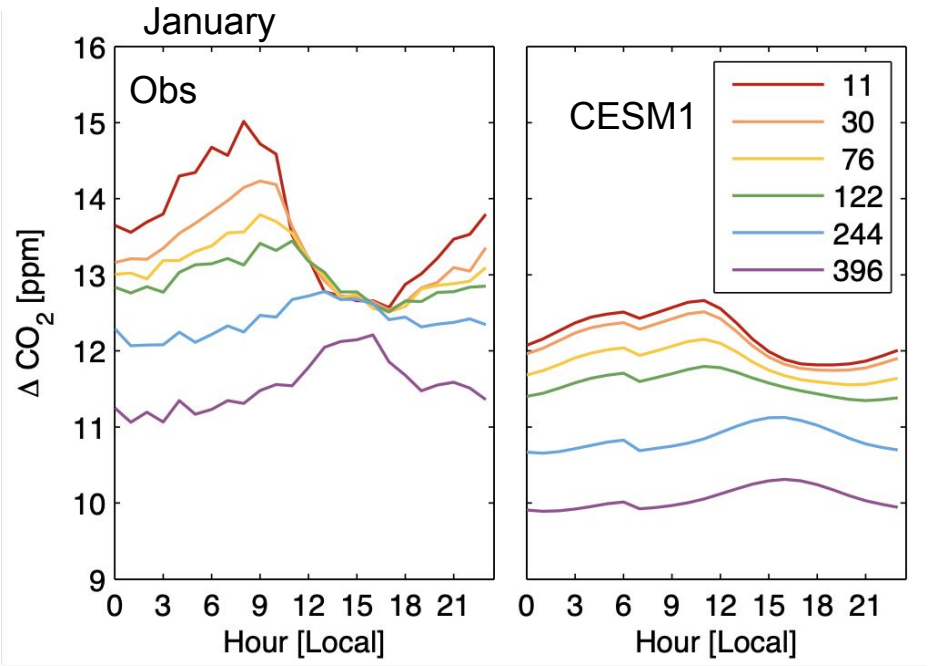


Effect of boundary layer height on CO_2 signals

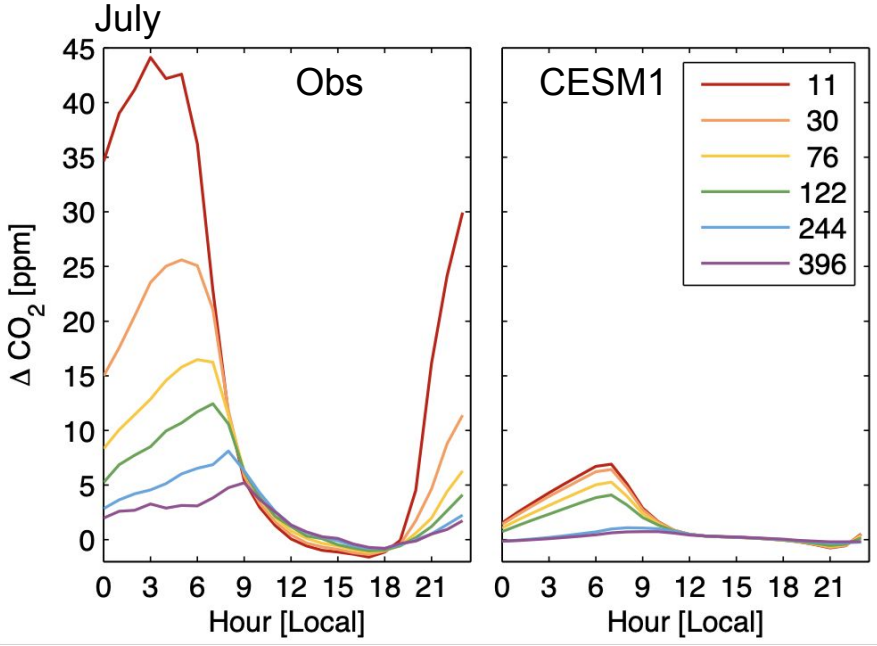




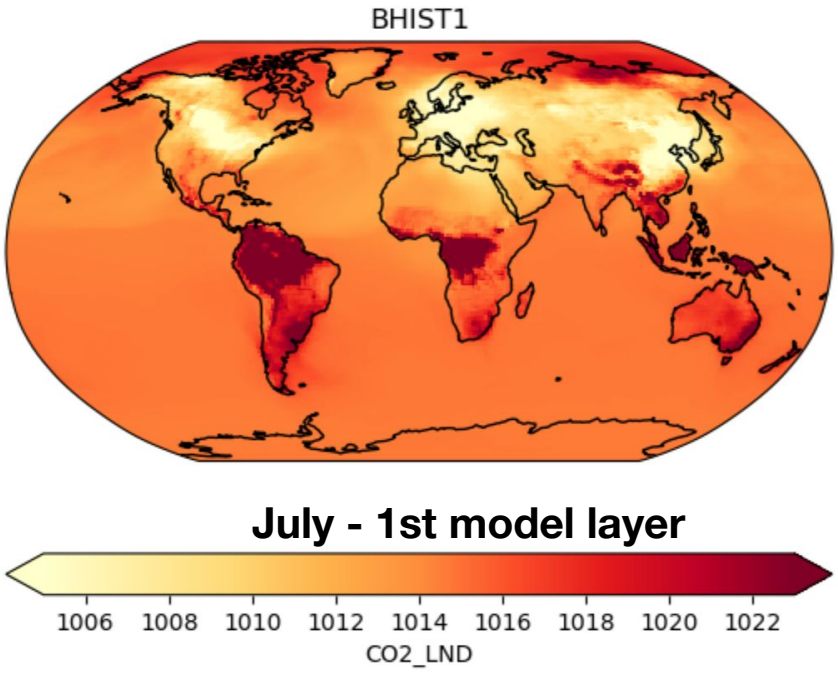
We see evidence of this rectifier effect in CESM1, where we also used atmospheric CO_2 comparisons with observations to reveal too-weak seasonal exchange



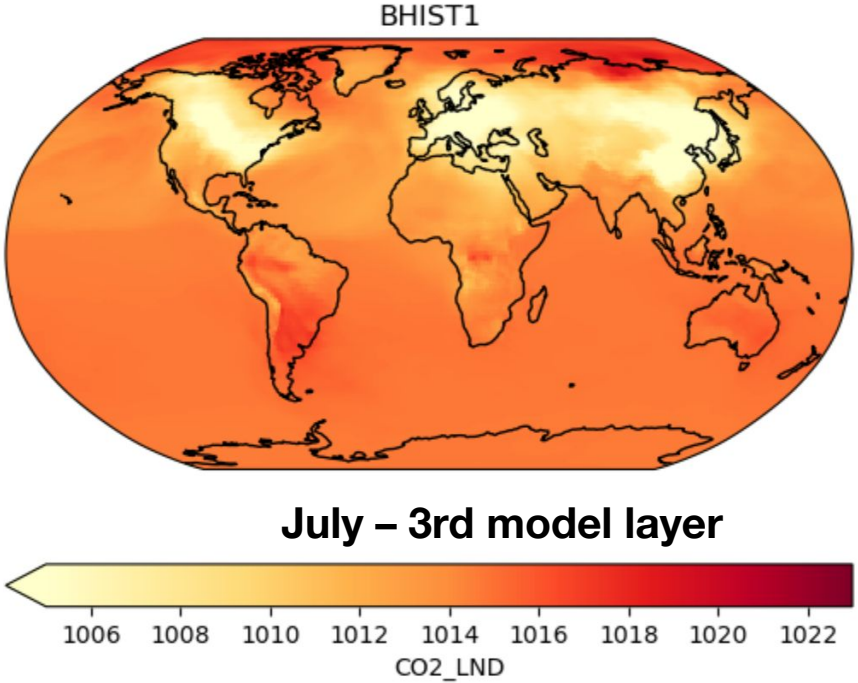
Observations of the diurnal cycle in CO_2 are hard to come by, or hard to interpret



(CO_2 reported relative to South Pole)

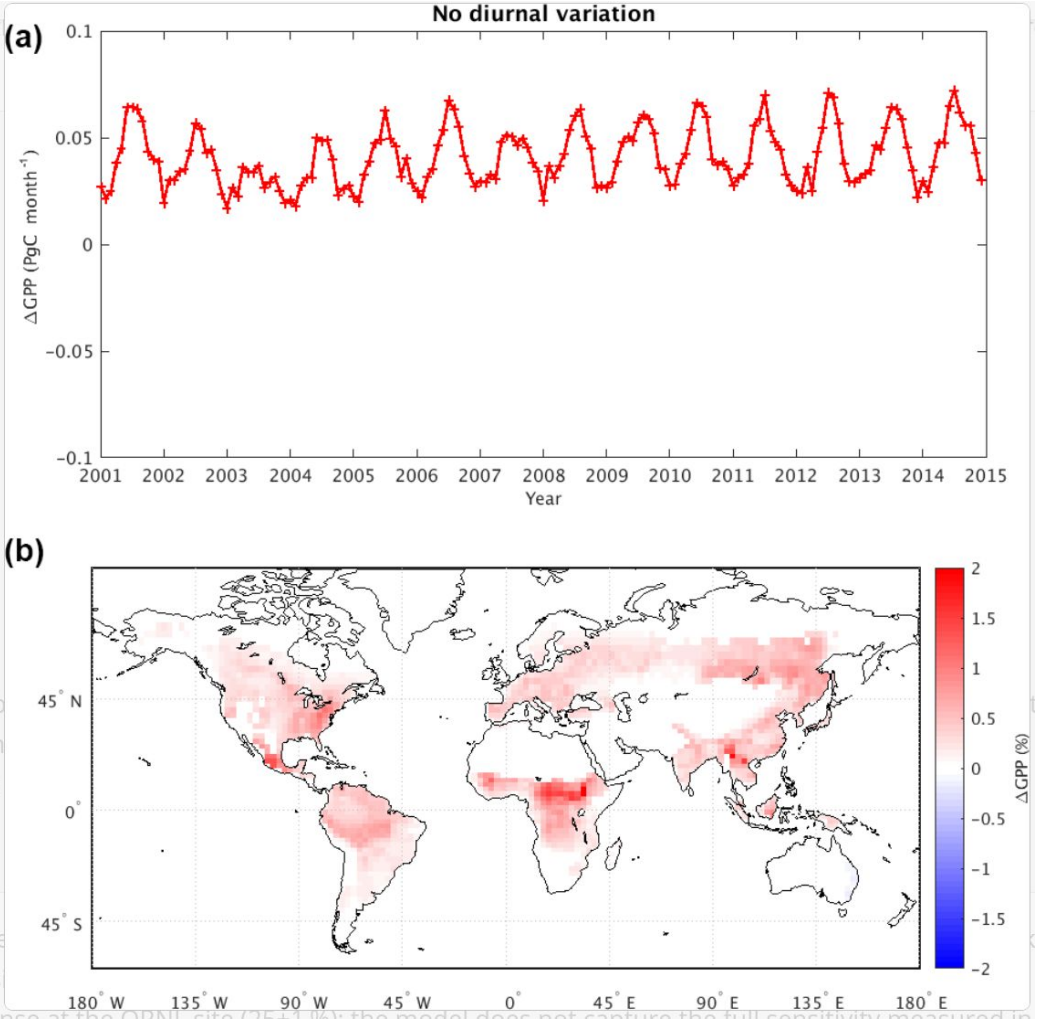


July - 1st model layer



July – 3rd model layer

If we look at CO_2 in the third model layer, the rectifier problem is essentially gone



But it's important to note that the diurnal cycle in boundary layer CO_2 also affects terrestrial fluxes

Lee et al., 2018

Tracking CO_2 provides a means to diagnose spatiotemporal variations in land, ocean, and fossil fluxes

Simulating 4-D variations in CO_2 enables concentration-driven feedbacks within CESM

This opens up lots of cool science in emissions driven simulations!

It is very hard to decouple the imprint of fluxes and transport on atmospheric CO_2, to proceed with caution