

Evolution of variability in atmospheric CO₂ in a coupled carbon-climate model

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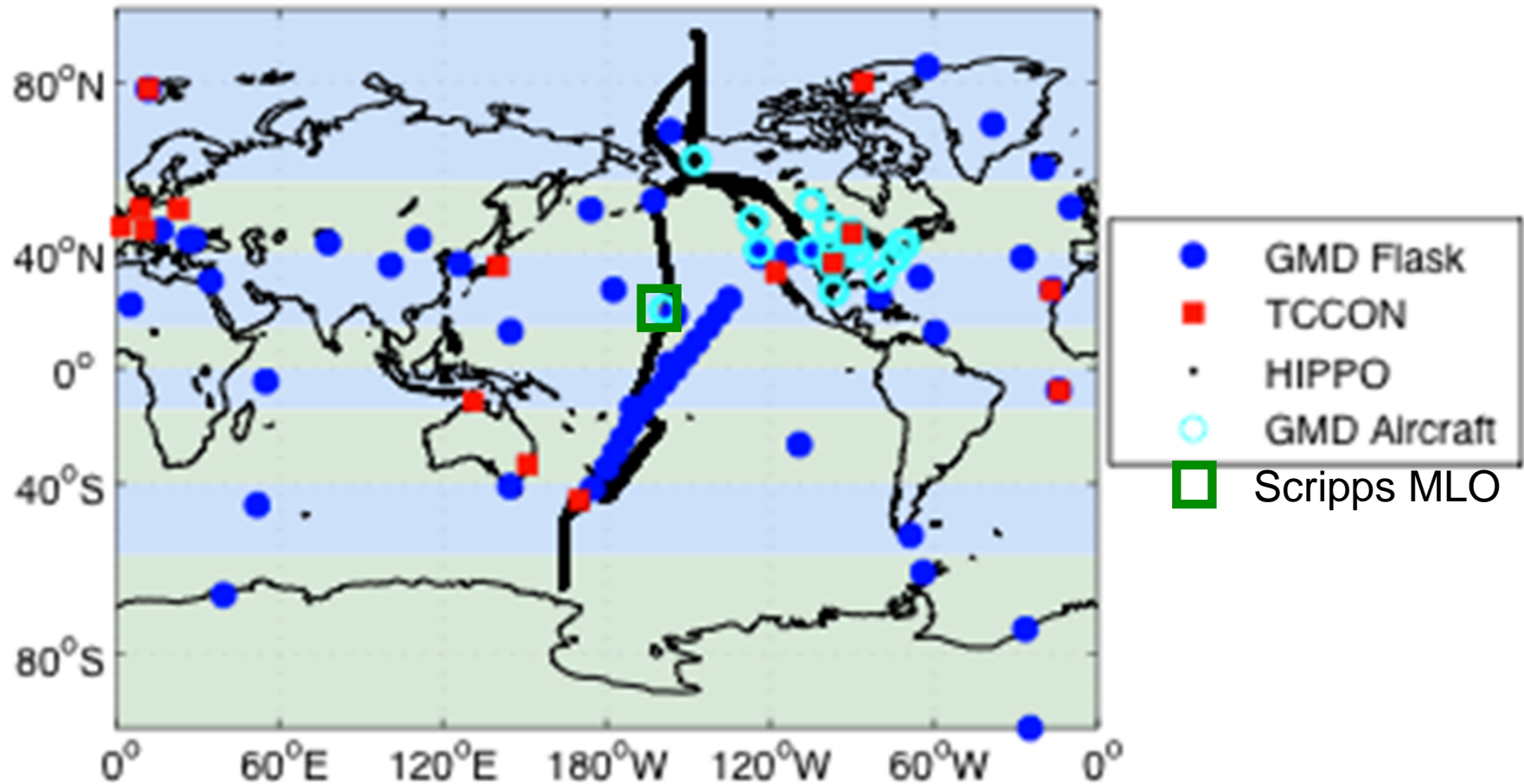
Project Goals

Evaluate CO₂ fields in CESM against observations to determine how accurately CESM captures seasonal, interannual, and decadal variations in CO₂

Link changes in 21st century CO₂ to fluxes and climate drivers

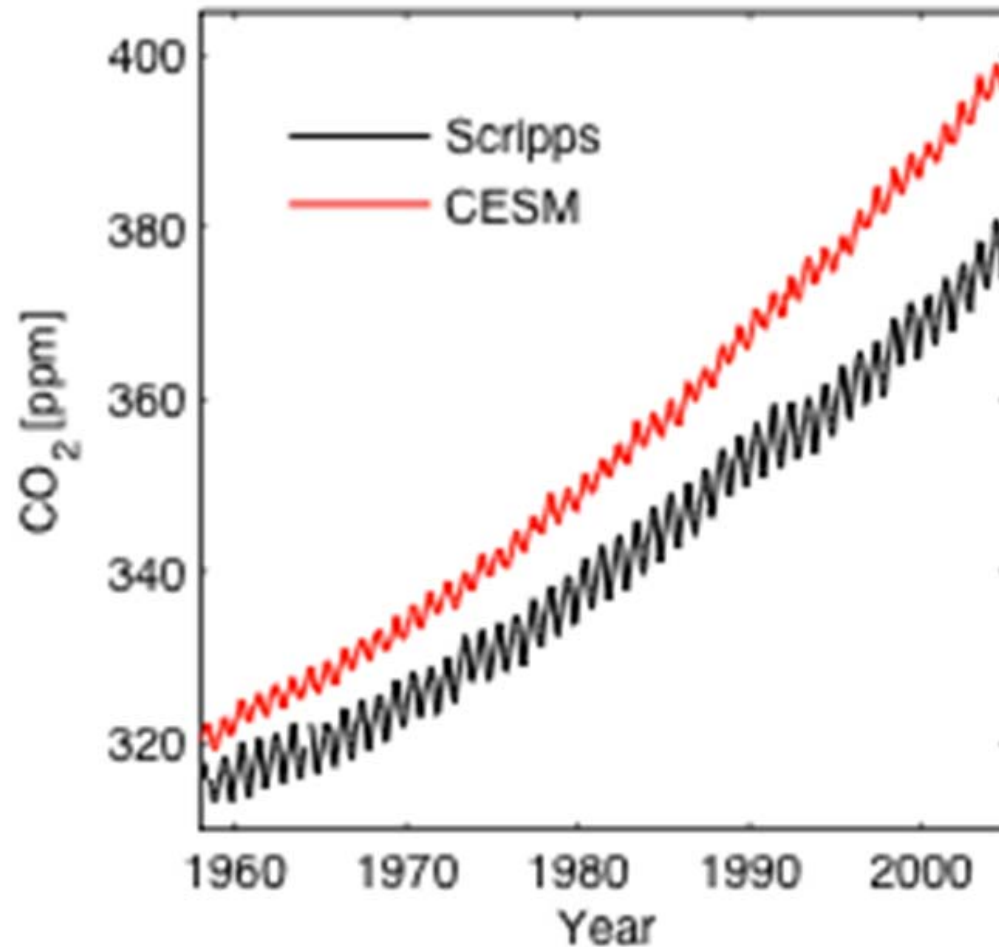
Determine how the changes in atmospheric CO₂ might impact our ability to use monitoring networks for flux attribution

Atmospheric CO₂ Observations



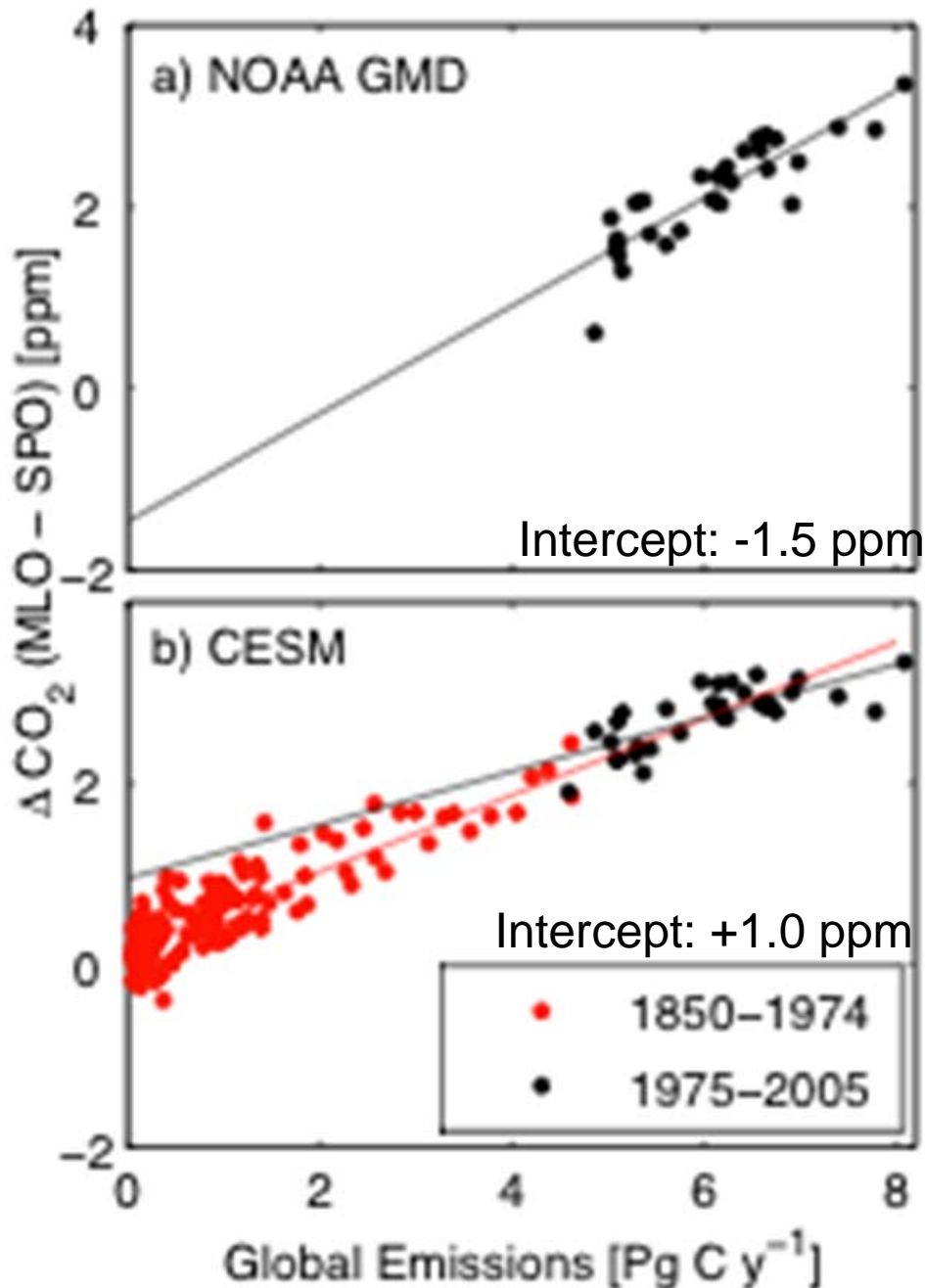
We use multiple observational platforms to evaluate 3-D CO₂ fields in CESM.

Growth rate in atmospheric CO₂



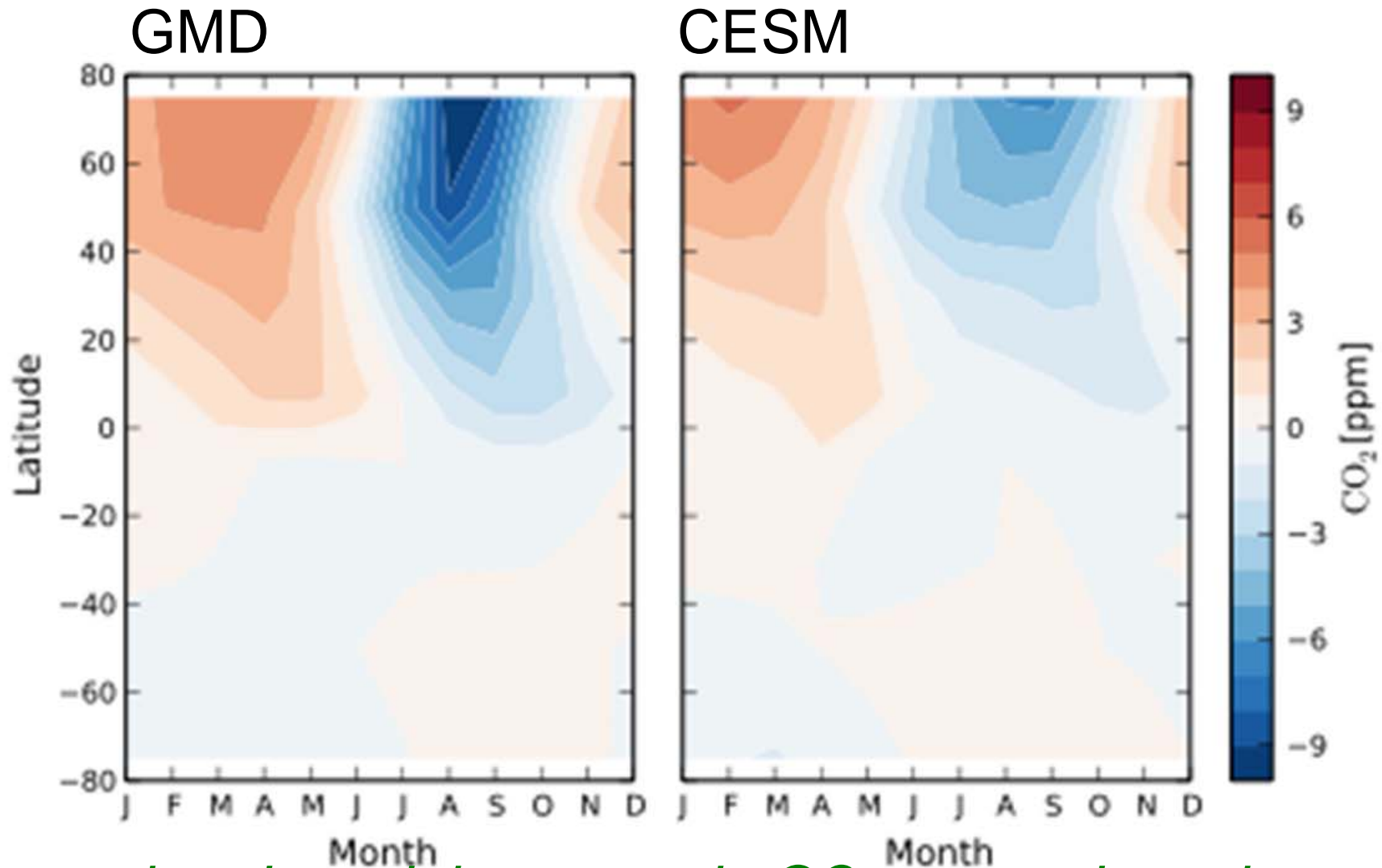
CESM airborne fraction of anthropogenic CO₂ is 25% higher than observations.

Interhemispheric CO₂ difference



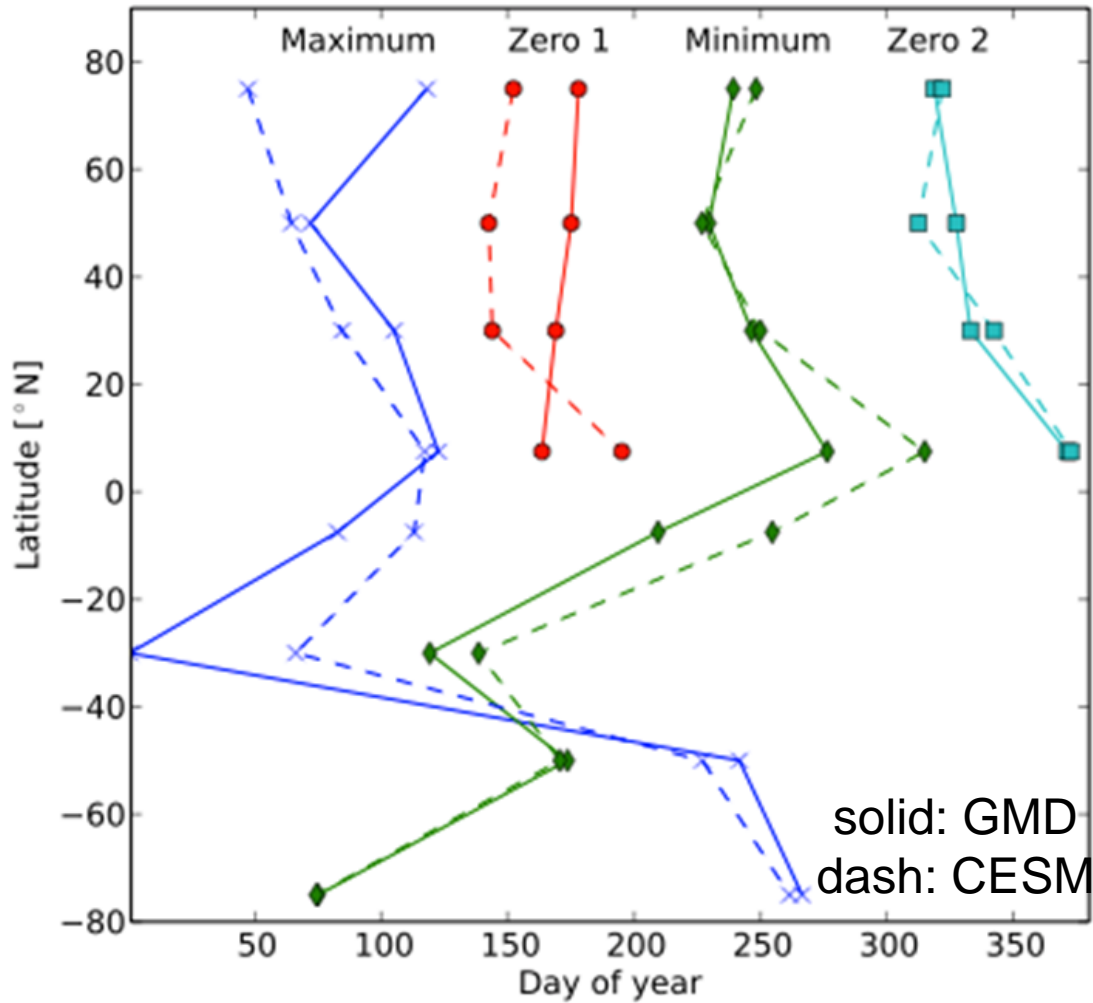
CESM has higher northern hemisphere background CO₂, opposite what is inferred from the observations, likely due to weak exchange in Southern Ocean.

Seasonal patterns in surface CO₂

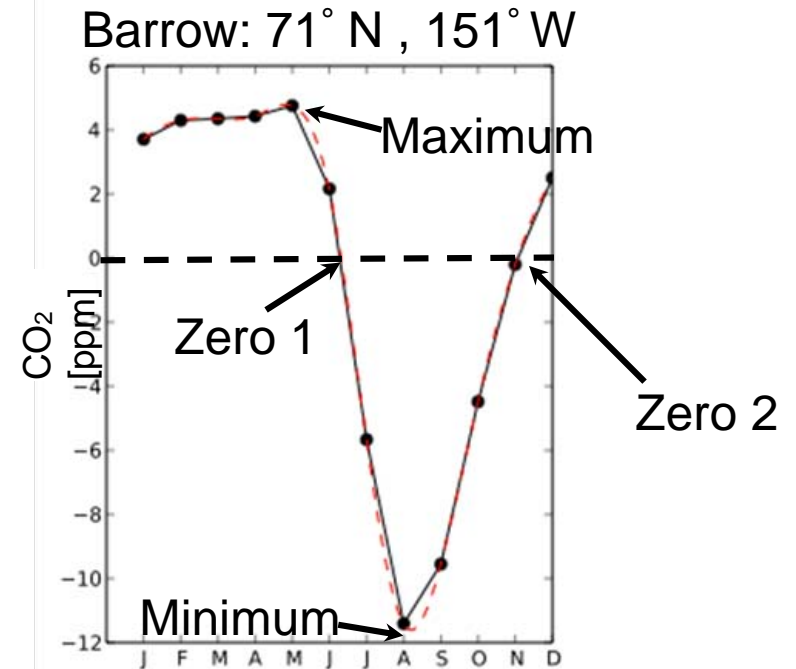


Seasonal and spatial patterns in CO₂ are underestimated in CESM.

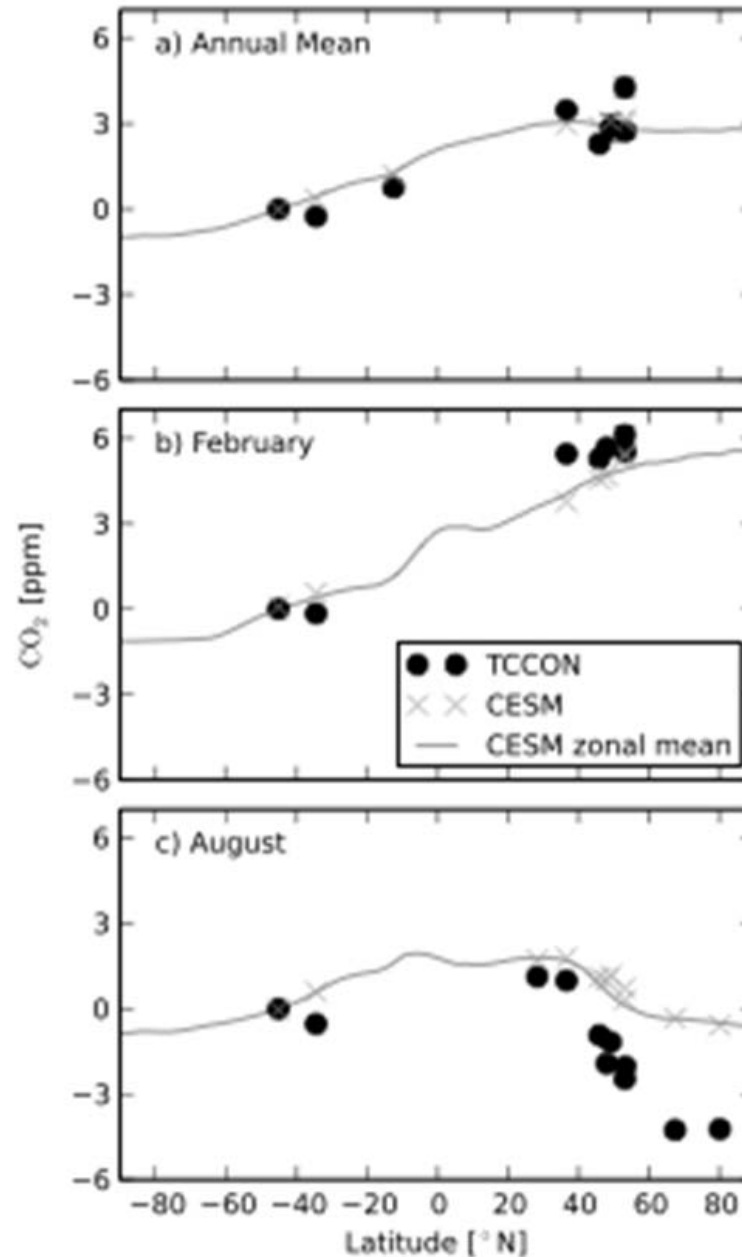
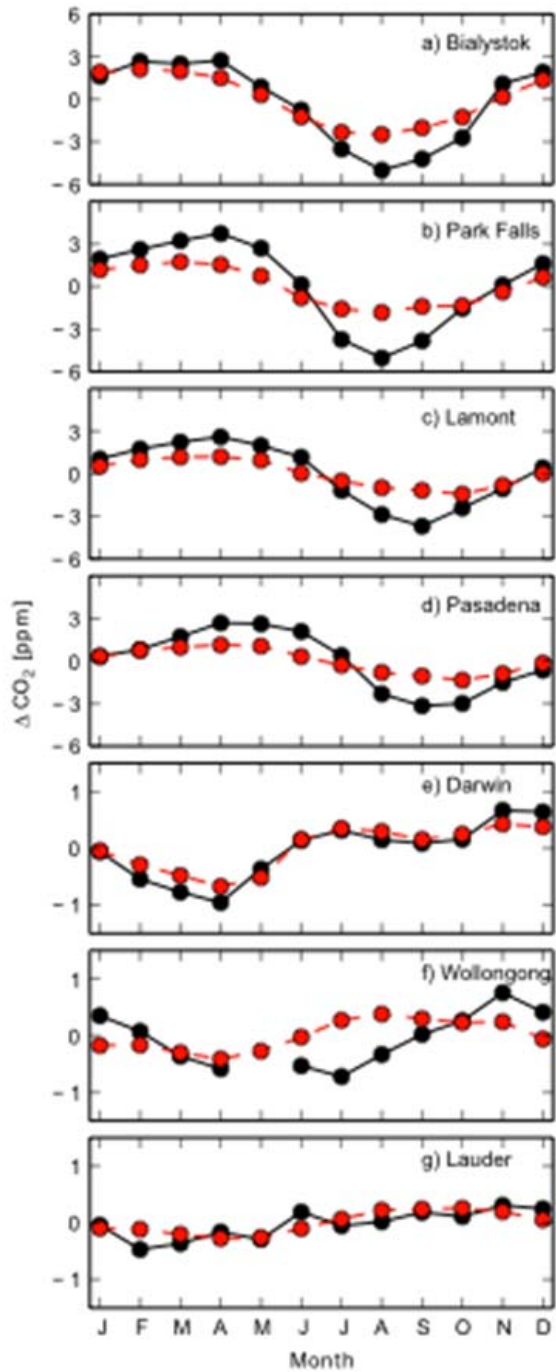
Phasing of the seasonal cycle in surface CO_2



The onset of the growing season occurs too early in CESM.

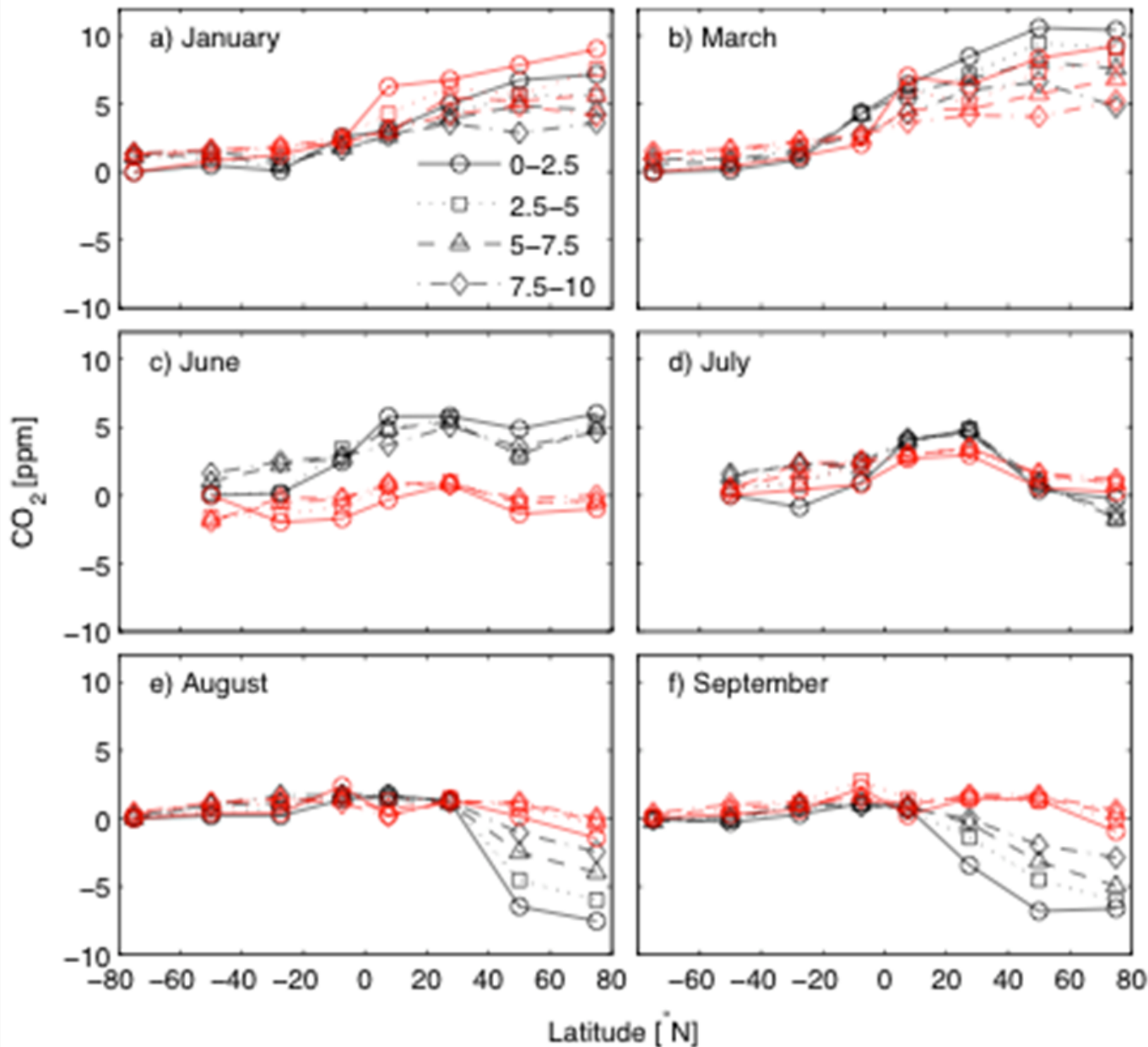


Seasonal variations in column CO₂



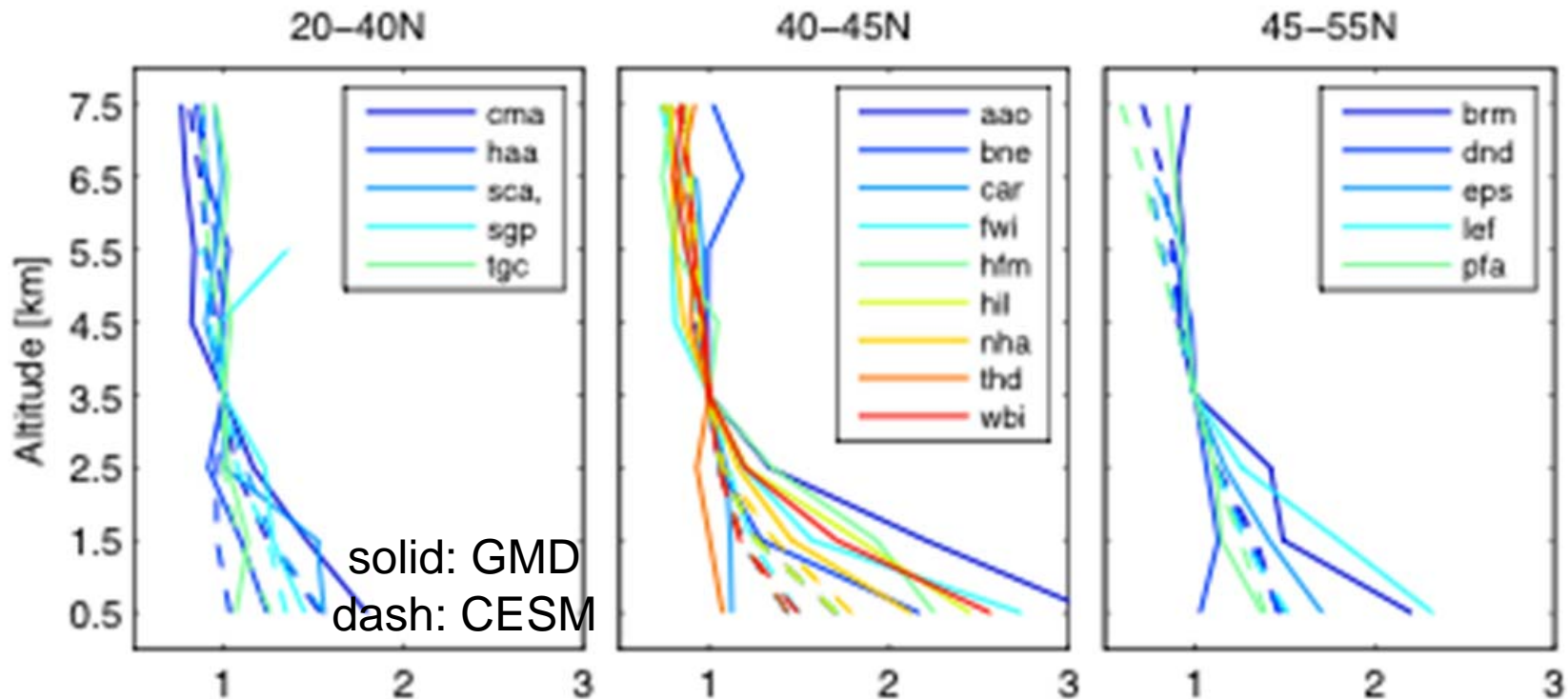
Total column CO₂ suggests that CESM northern hemisphere NEP is small during the growing season by 50%.

CO₂ gradients in the free troposphere



HIPPO data show larger north-south gradients during the growing season and more vertical stratification than CESM.

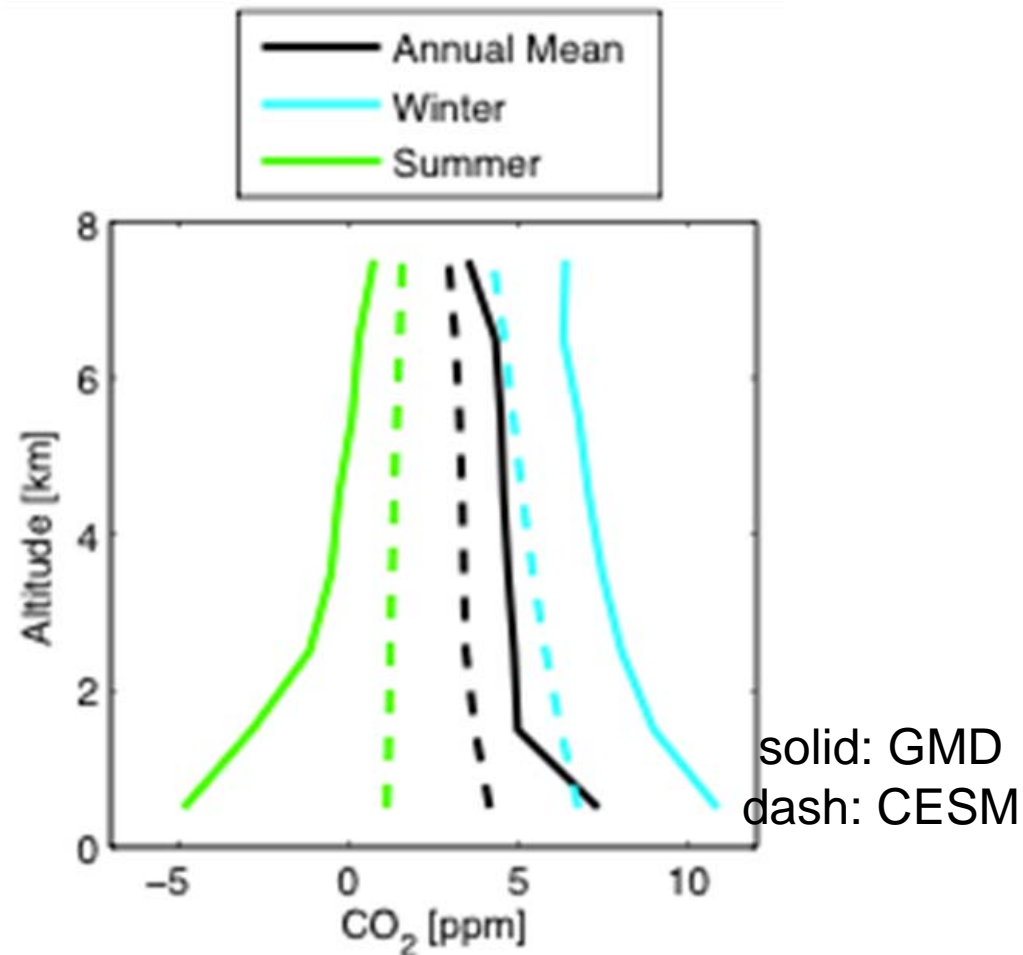
Vertical propagation of the seasonal cycle



Ratio of seasonal cycle amplitude at altitude to seasonal cycle amplitude at 3.5 km

Seasonal cycle amplitudes are similar at the surface and aloft in CESM, whereas observations show a larger decrease in amplitude with altitude.

Mean vertical profiles in midlatitudes (40-60N)

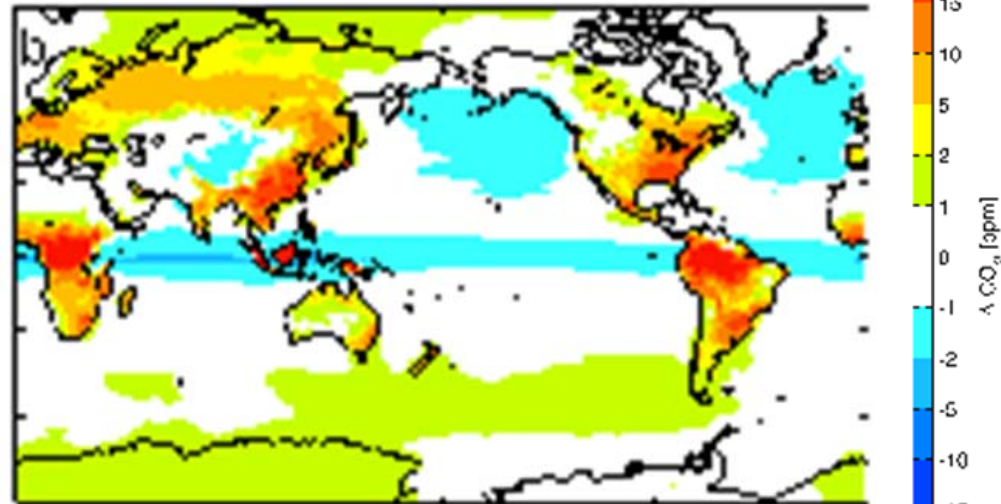


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CESM: trends in East-West surface gradient

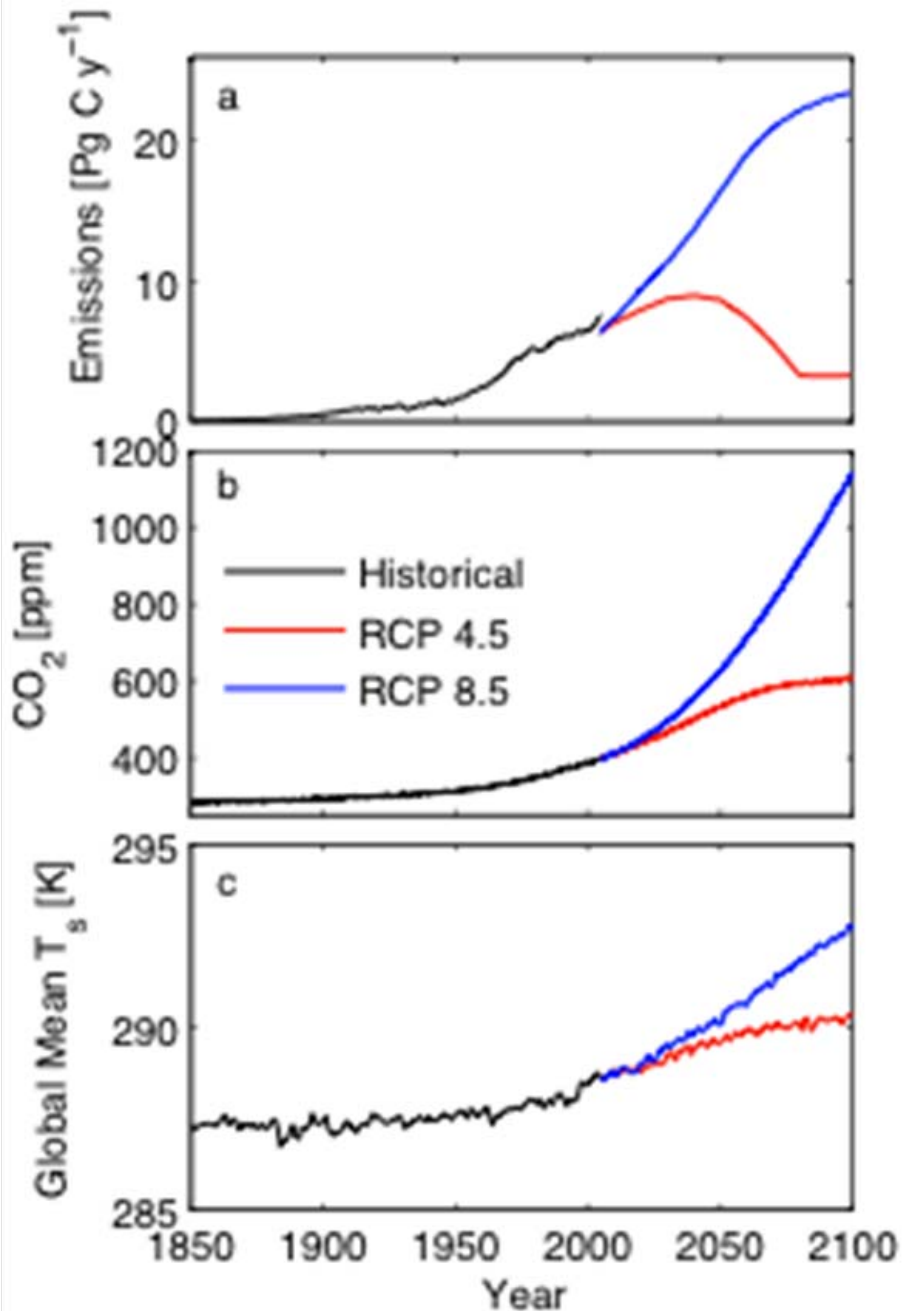
Trends in CO₂ relative to SPO [ppm yr⁻¹]

Site	Data	CESM	CESM(FFF)
Tae-Ahn	0.17	0.19	0.19
Mace Head	0.06	0.02	0.07
Mauna Loa	0.06	0.02	0.06
Samoa	0.03	-0.04	0.01



Tae-Ahn site on Korean peninsula shows larger growth rate than do sites in remote locations.

CMIP5 Representative Concentration Pathways



Divergent fossil fuel emissions trajectories in RCP 4.5 and RCP 8.5 scenarios leads to large differences in atmospheric CO₂ and surface temperature in the Community Earth System Model (CESM).

Conclusions and future work

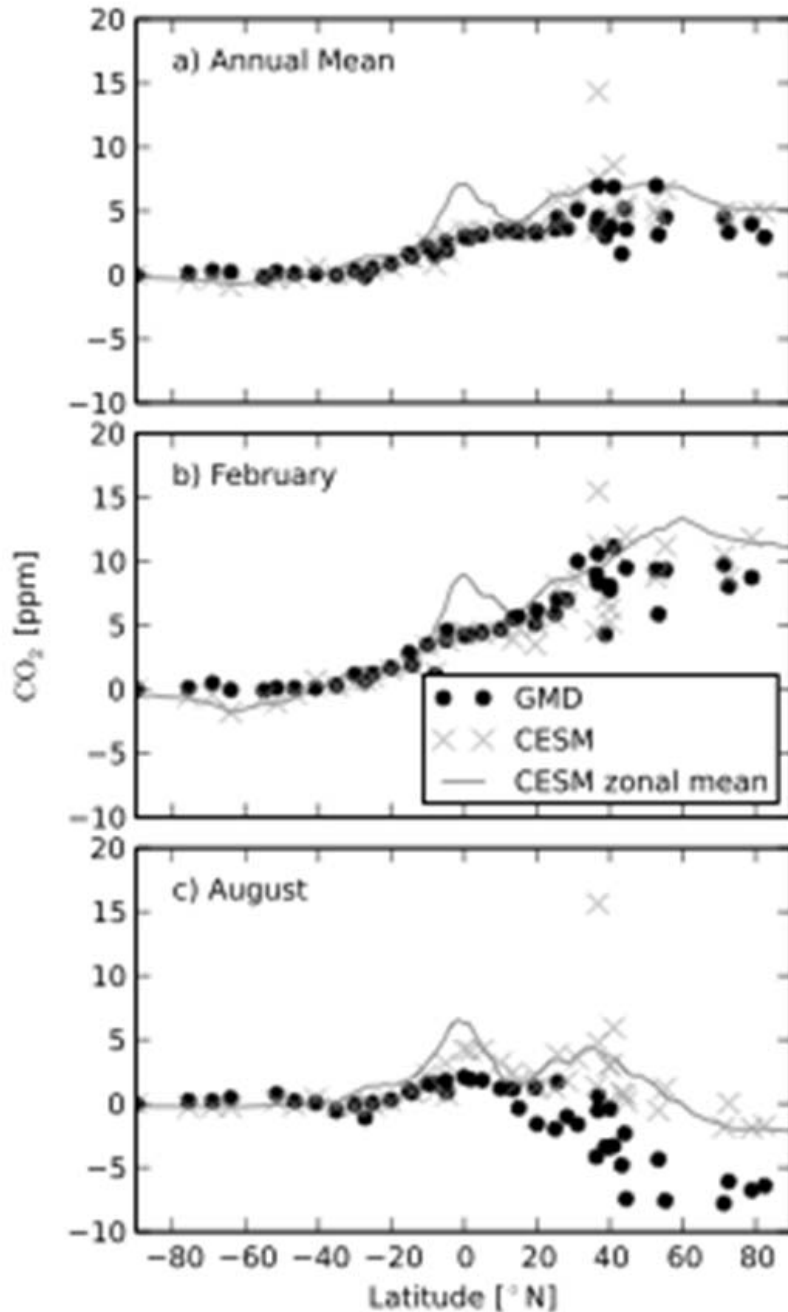
Northern hemisphere growing season net flux underestimated in CESM

Weak Southern Ocean storage of CO₂ affects growth rate and gradients

Atmospheric vertical mixing too diffusive during the summer leading to weak vertical stratification.

Large differences emerge in the 21st century as fossil fuel emissions follow different trajectories -- offline discussion

North-south gradient in surface CO₂



The northern hemisphere growing season north-south gradient is underestimated in CESM.