Land carbon sinks under zero emissions and decarbonization

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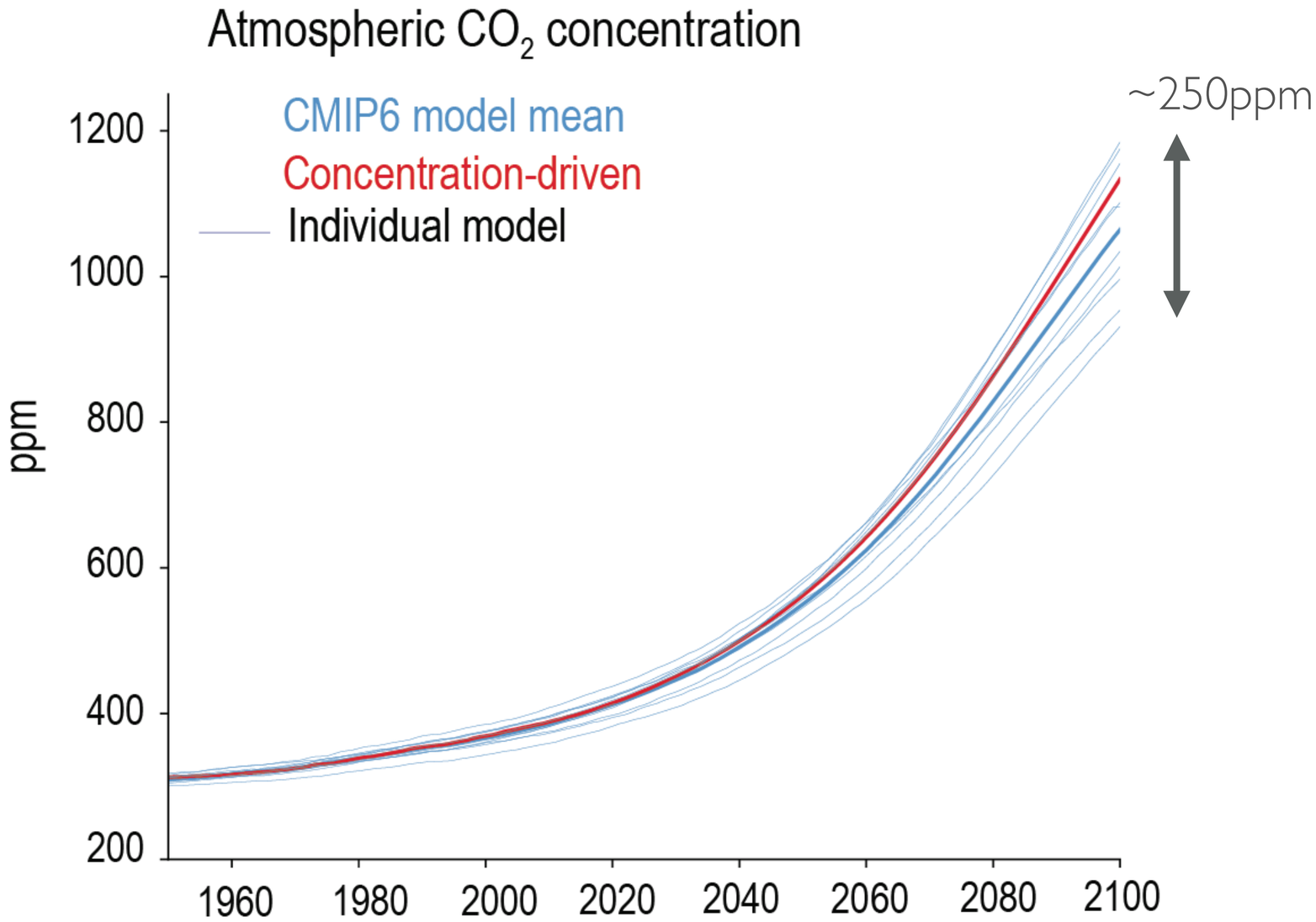
Work with: Charlie Koven, Ben Sanderson, Flat10MIP contributors

Funding from NSF

Emissions-driven simulations show big spread in atm CO_2

CMIP6 had a limited number of runs as part of C4MIP (~12 models)

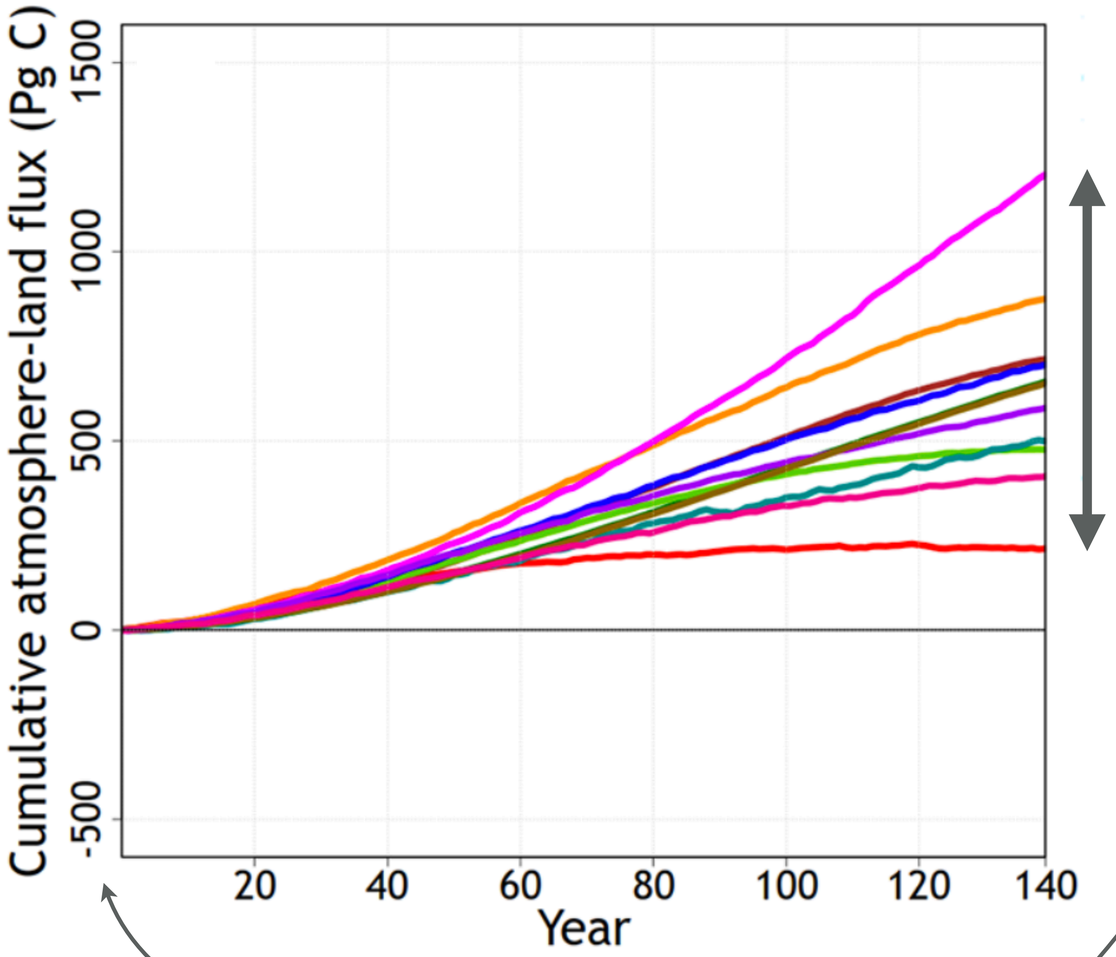
CMIP7 will have more emissions-driven simulations



IPCC AR6 WGI, Fig. 4.3

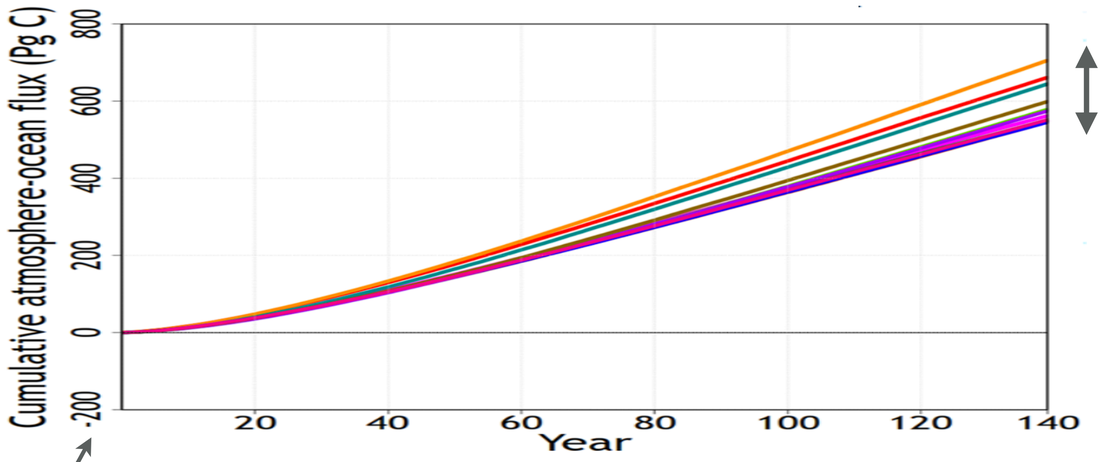
Across model spread in CO_2 is due (largely) to differences in land fluxes of C

Land



Same y-axis scale

Ocean

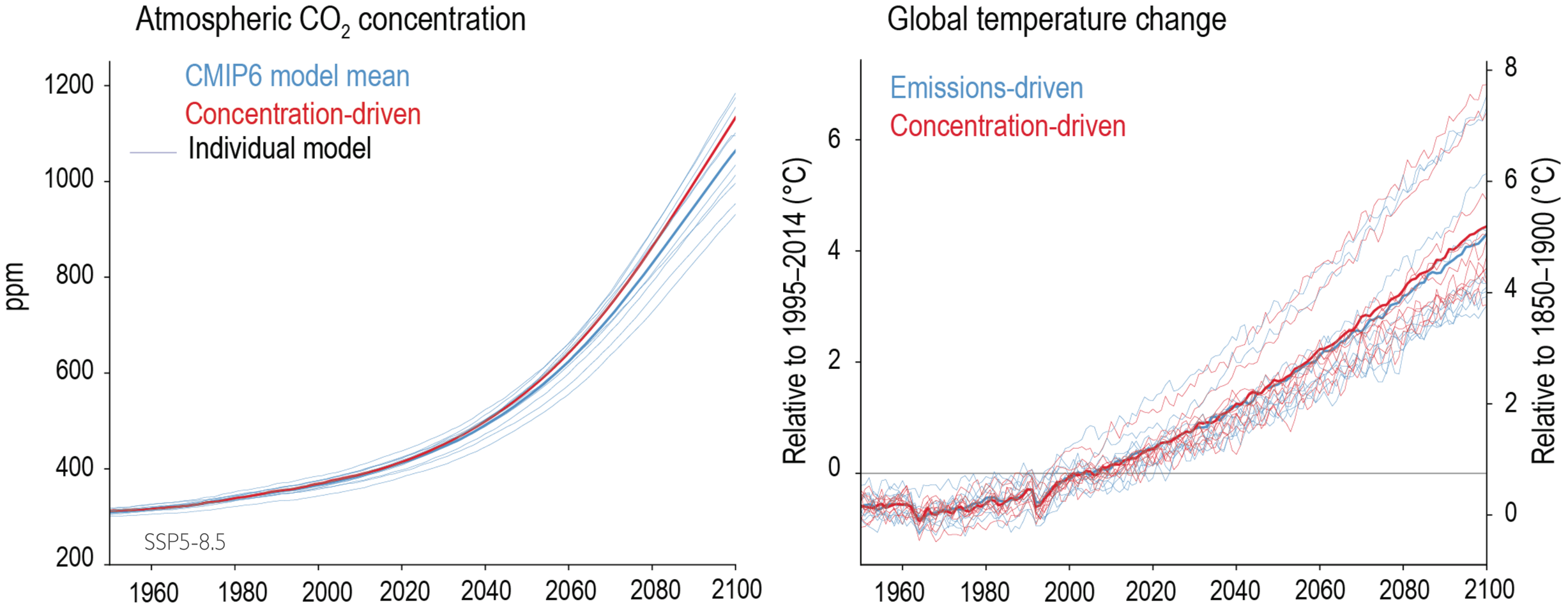


Land uptake of C depends entirely on Biological processes

Ocean uptake of C controlled mostly by physics and chemistry

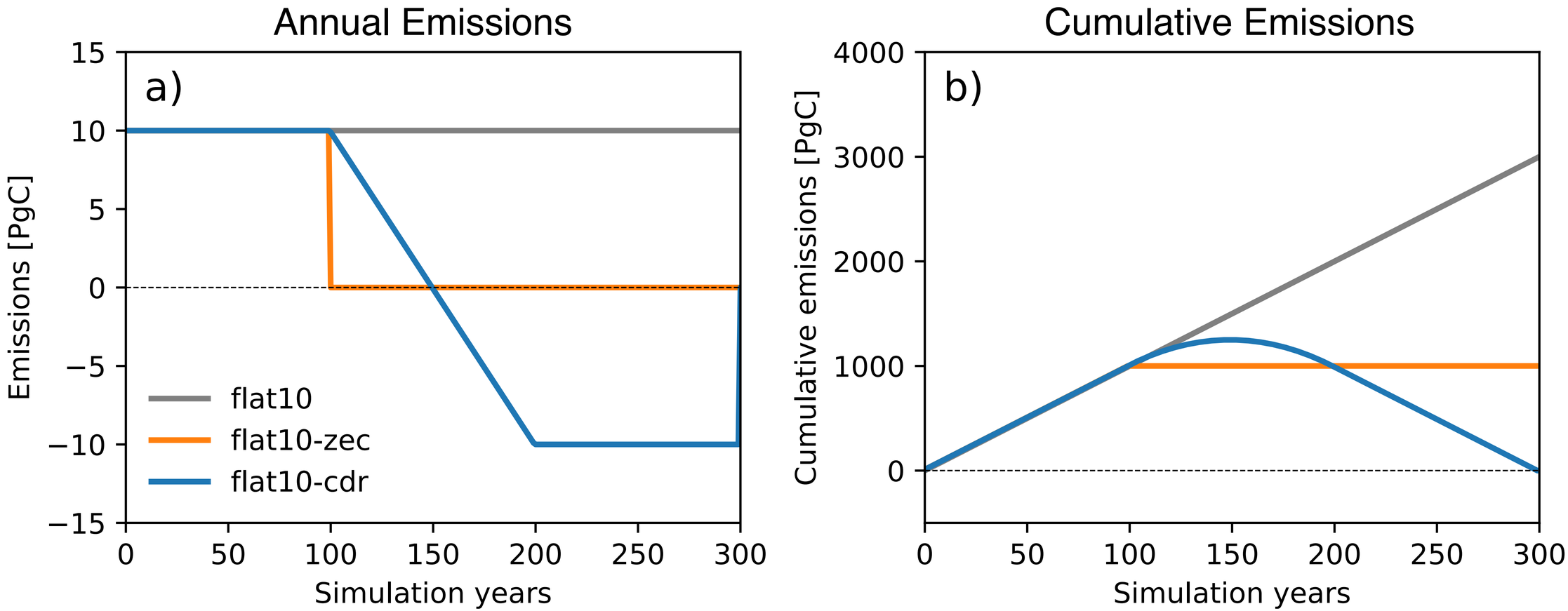
Arora et al. 2020, Biogeosci.

Spread in atm CO_2 ⇒spread in global temperature



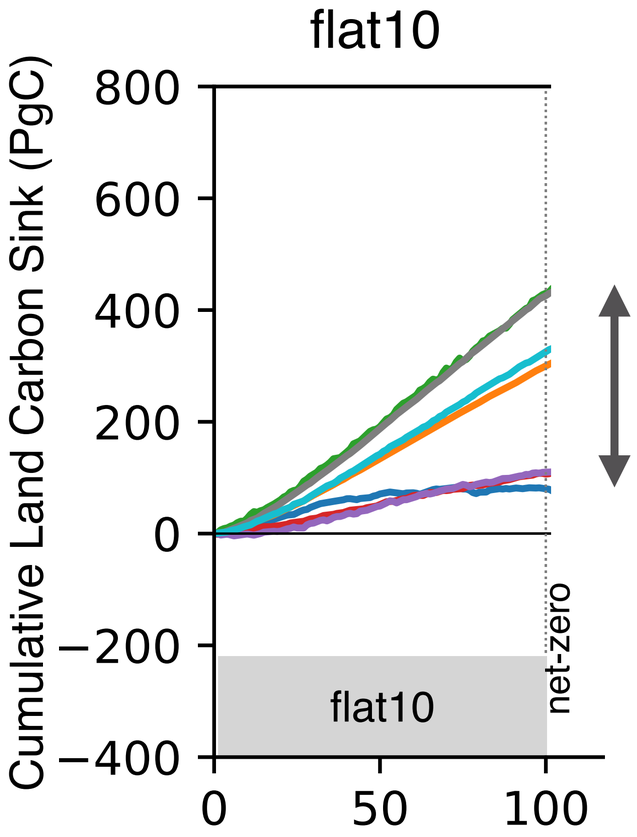
IPCC AR6 WGI, Fig. 4.3

Flat10 set of experiments ⇐ part of Fast Track for CMIP7



Sanderson et al. in review

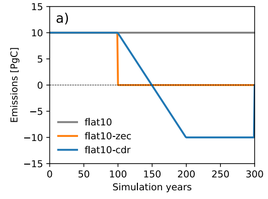
Land carbon sink increases while emissions increase



Large spread in land carbon sink across models

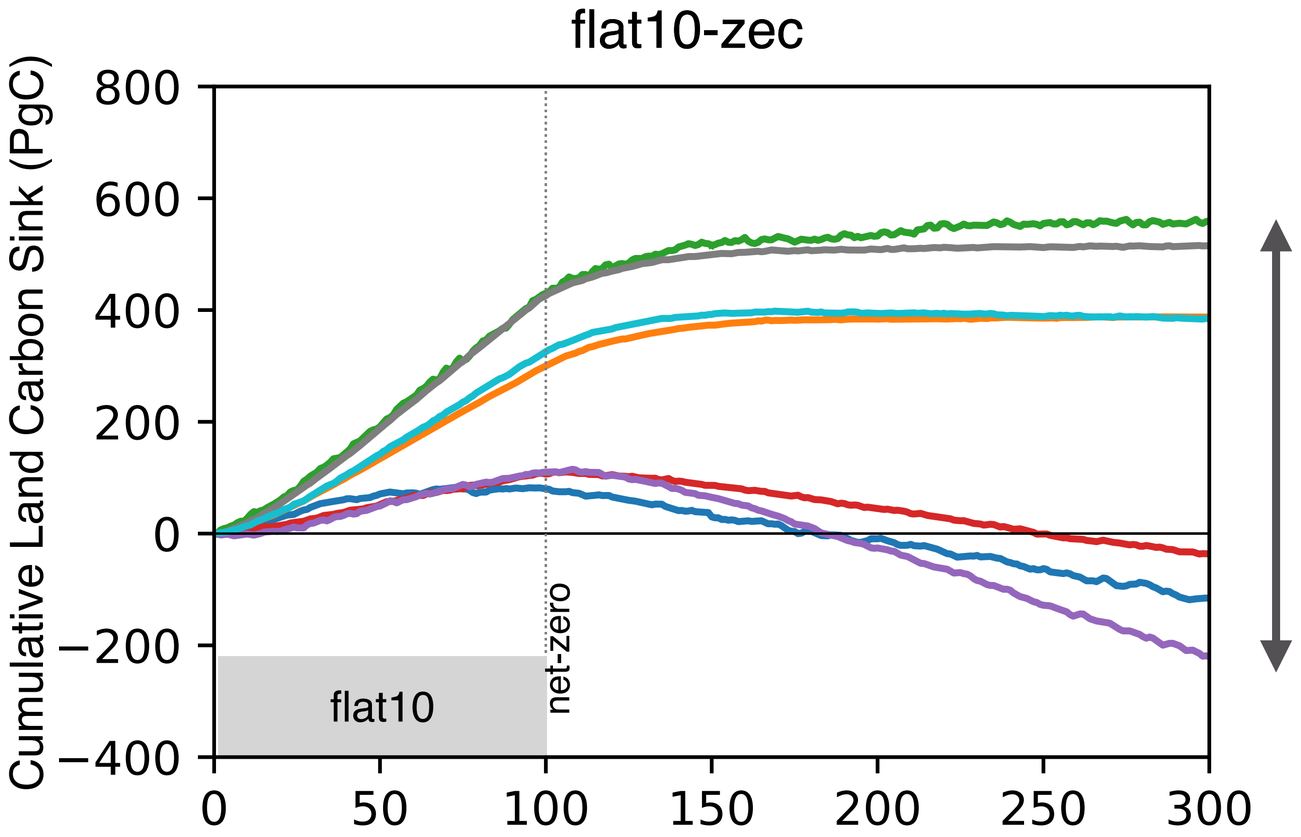
CO_2 fertilization
Higher productivity with warming
etc.

ACCESS-ESM1-5
CESM2
GFDL-ESM4
GISS
NorESM2-LM
MPI-ESM1-2-LR
CNRM-ESM2-1



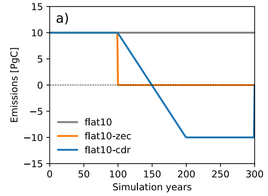
Sanderson et al. in review

Land carbon sink starts to decline after net-zero emissions



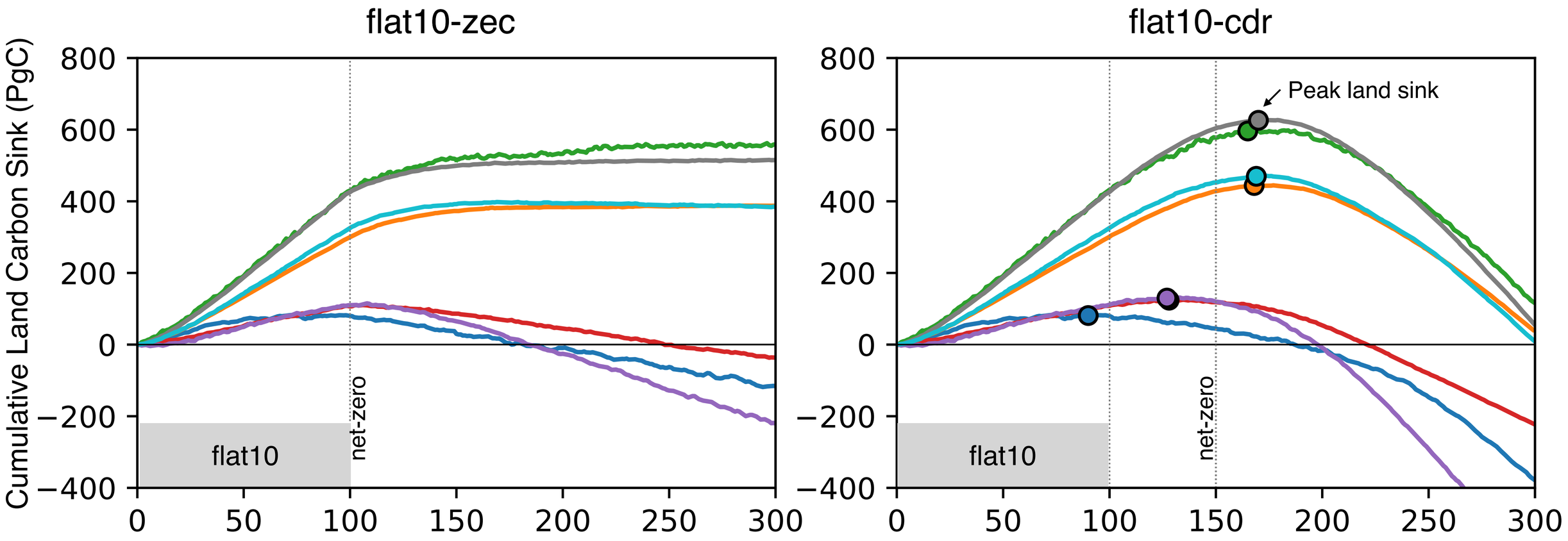
Spread remains large
Land becomes source in some models

ACCESS-ESM1-5
CESM2
GFDL-ESM4
GISS
NorESM2-LM
MPI-ESM1-2-LR
CNRM-ESM2-1



Sanderson et al. in review

Timing of peak land sink varies under more gradualy declining emissions



ACCESS-ESM1-5
CESM2
GFDL-ESM4
GISS
NorESM2-LM
MPI-ESM1-2-LR
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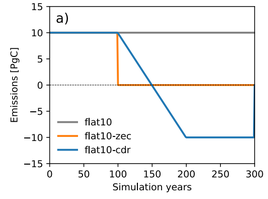
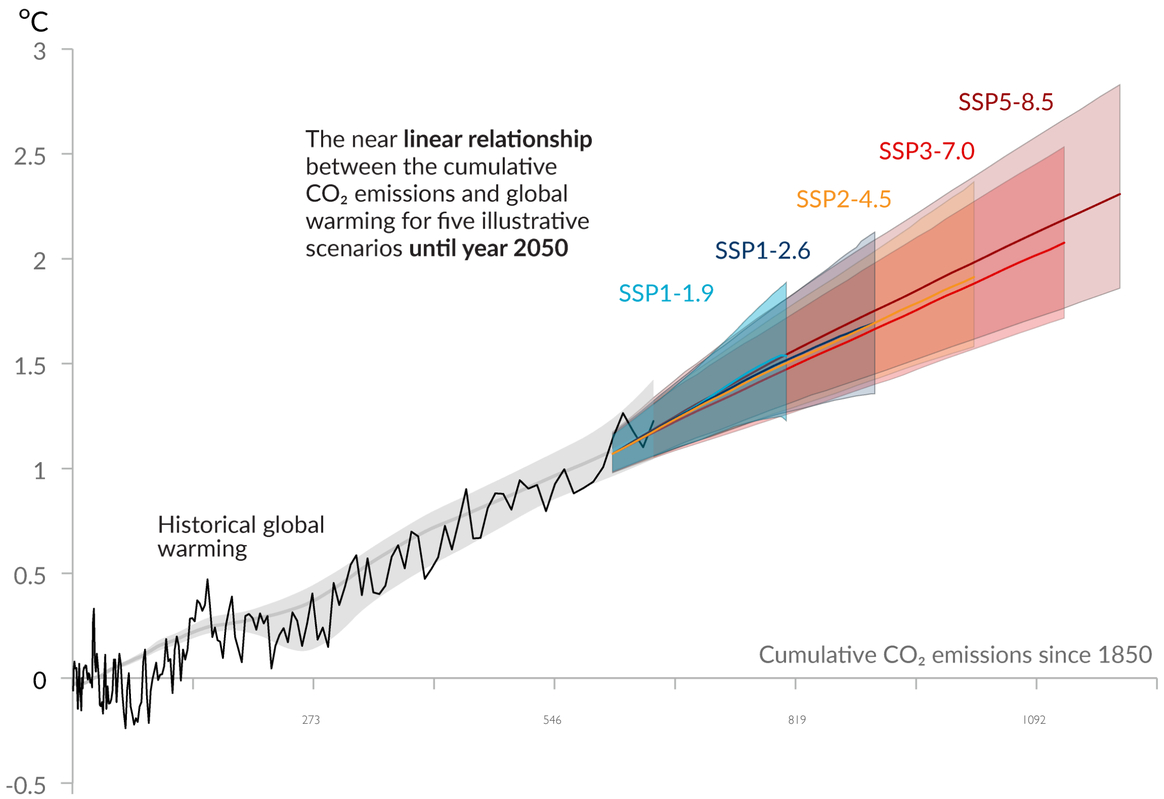


Sanderson et al. in review

Key metrics - TCRE and ZEC

Transient Climate Response to Emissions TCRE



AR6 WGI, Fig. SPM 10

Key metrics - TCRE and ZEC

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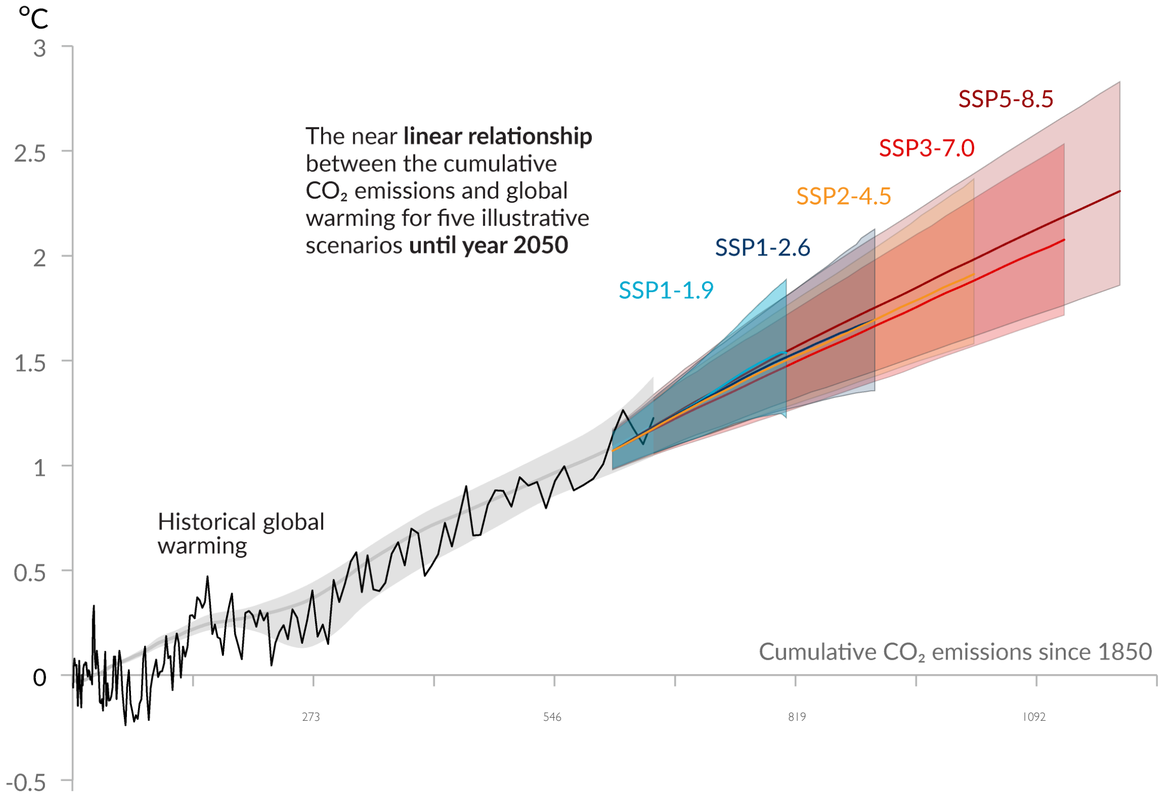
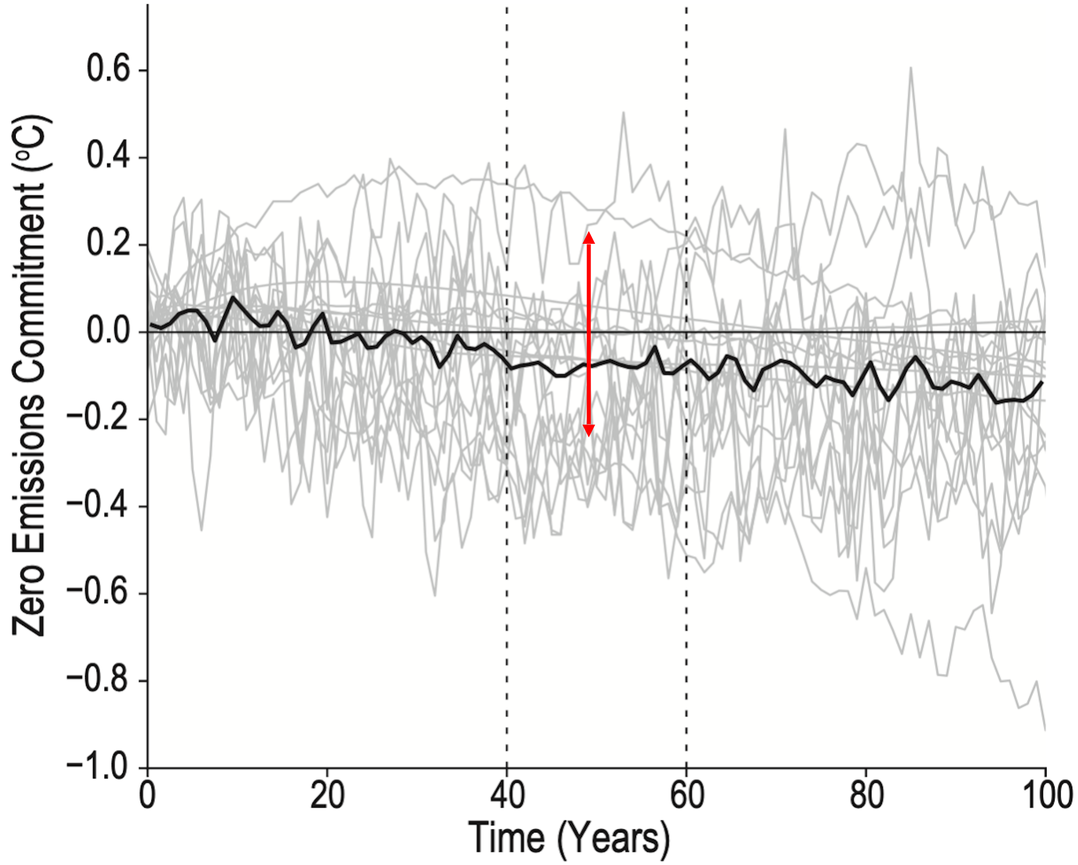


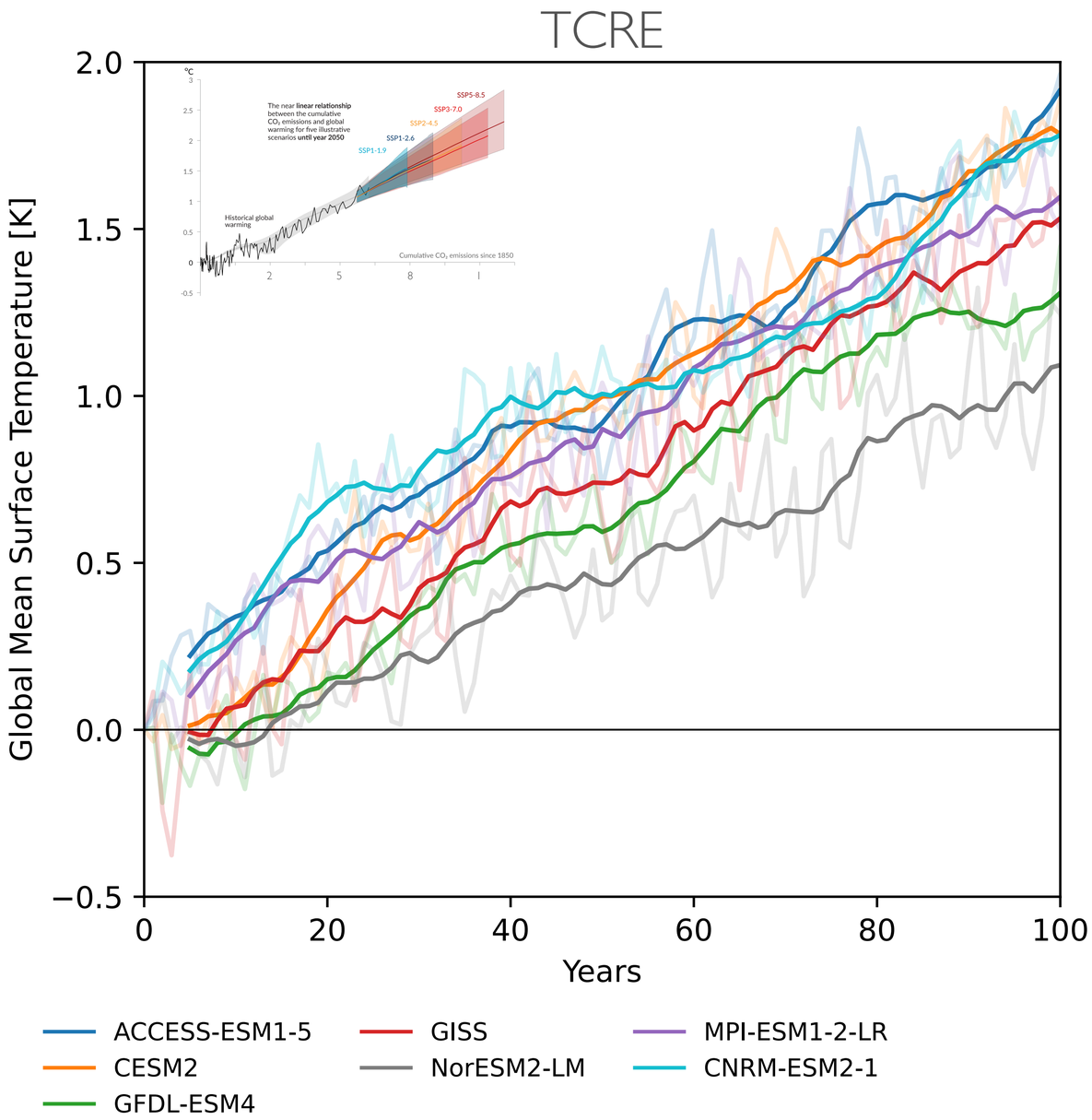
AR6 WGI, Fig. SPM 10

Zero Emissions Committment ZEC



IPCC AR6 WGI Fig. 4.39

Spread in carbon sink + physical climate impacts temperature



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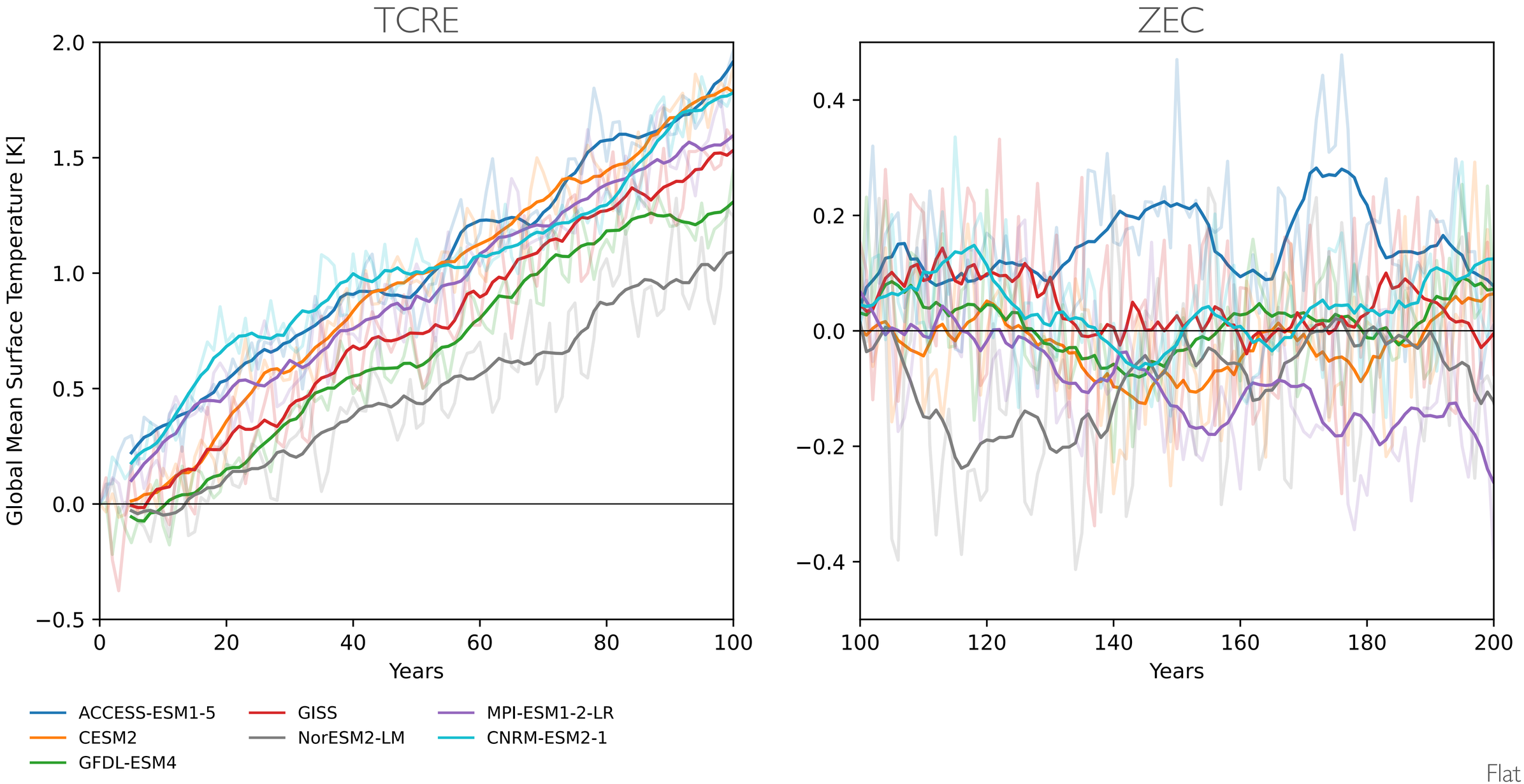
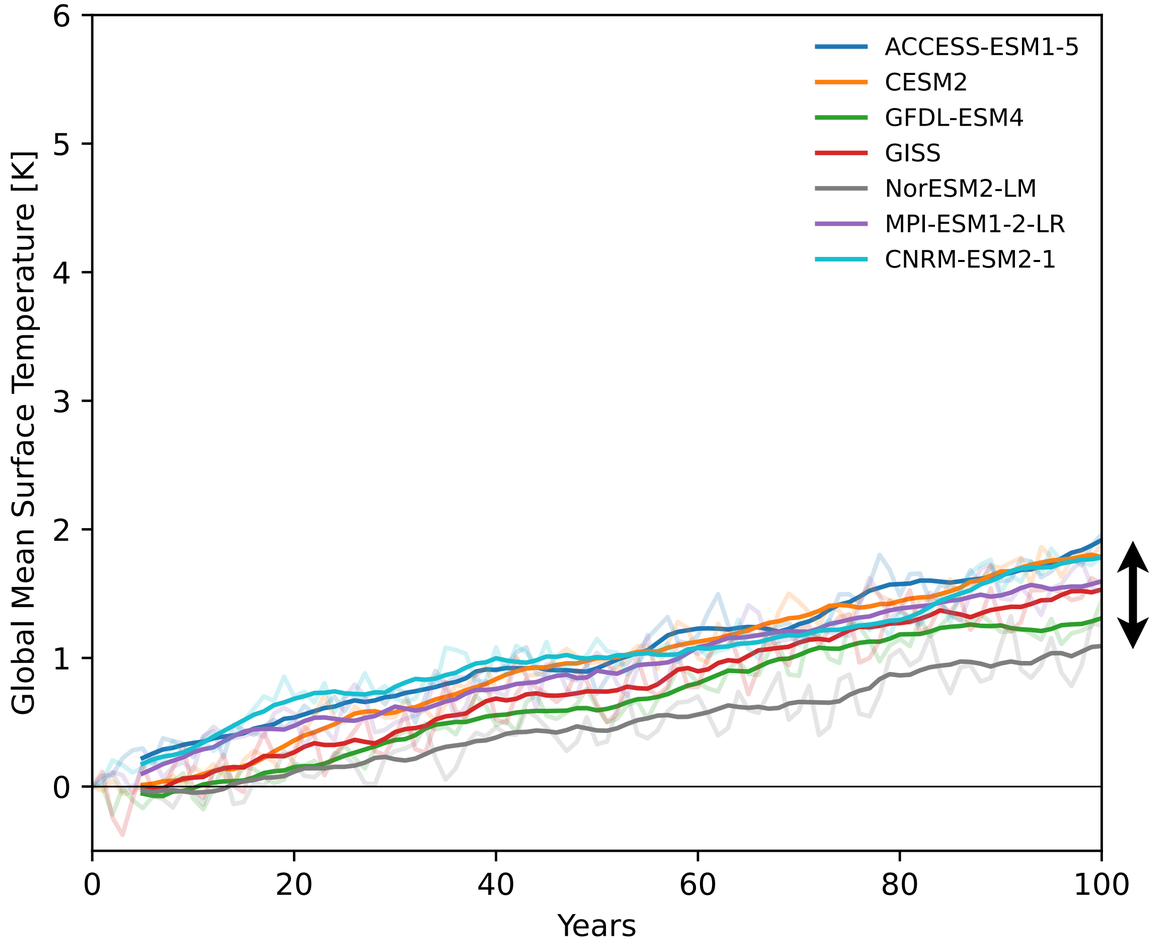
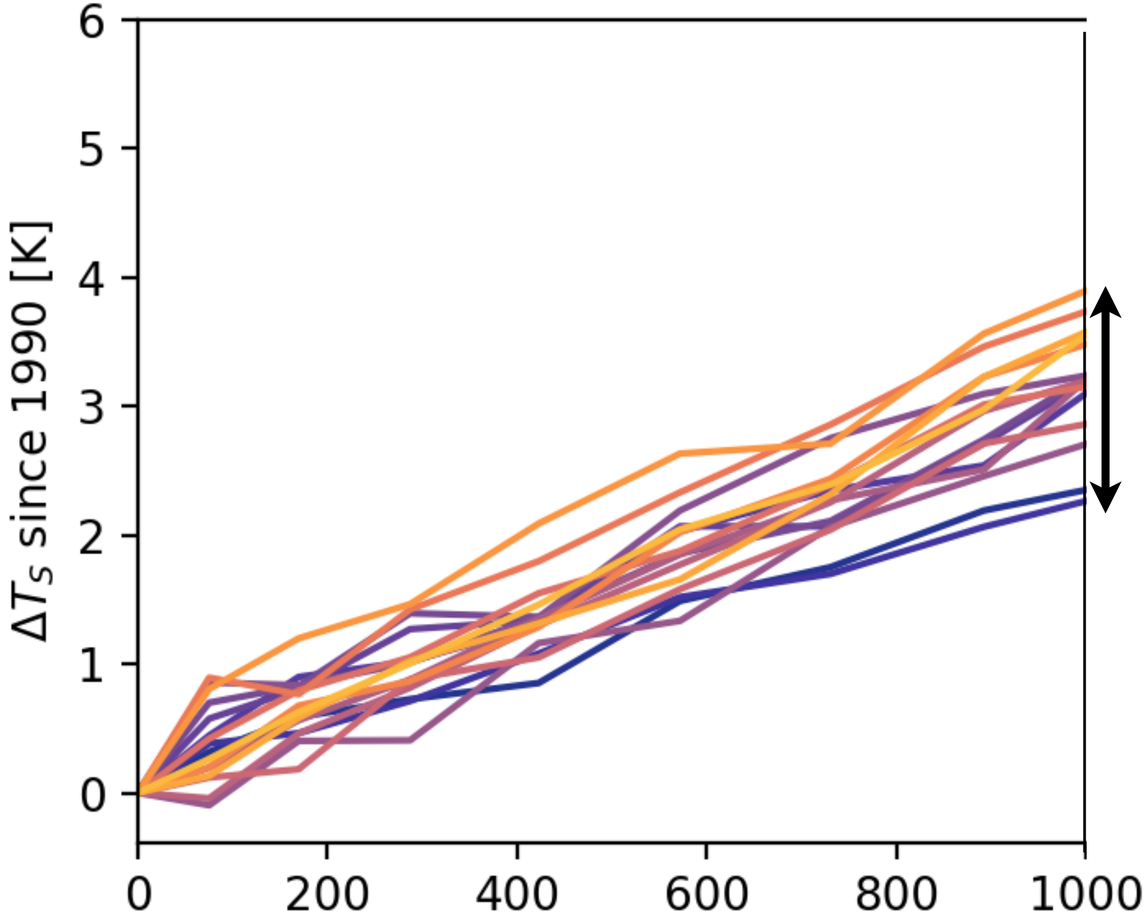


Spread across PPE is large relative to spread across models

TCRE from flat10MIP



TCRE from HadCM3 PPE



ACCESS-ESM1-5
CESM2
GFDL-ESM4
GISS
NorESM2-LM
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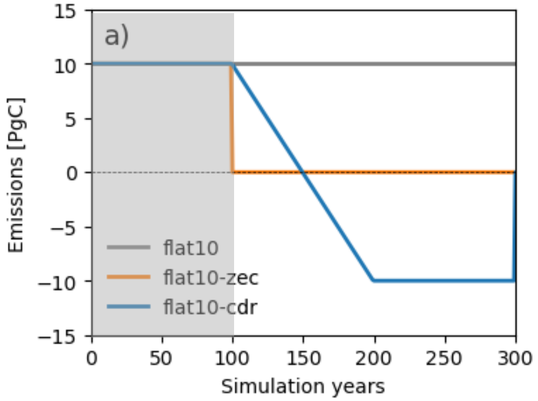
CNRM-ESM2-1

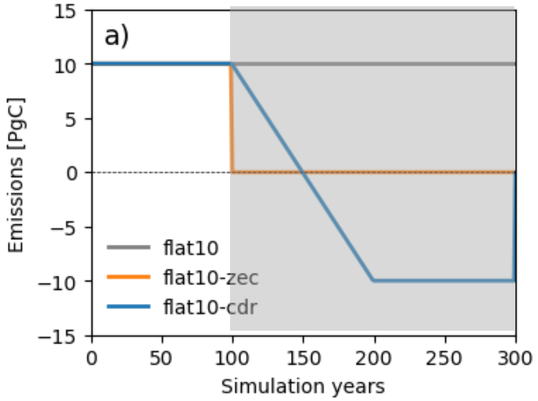
Flat10MIP

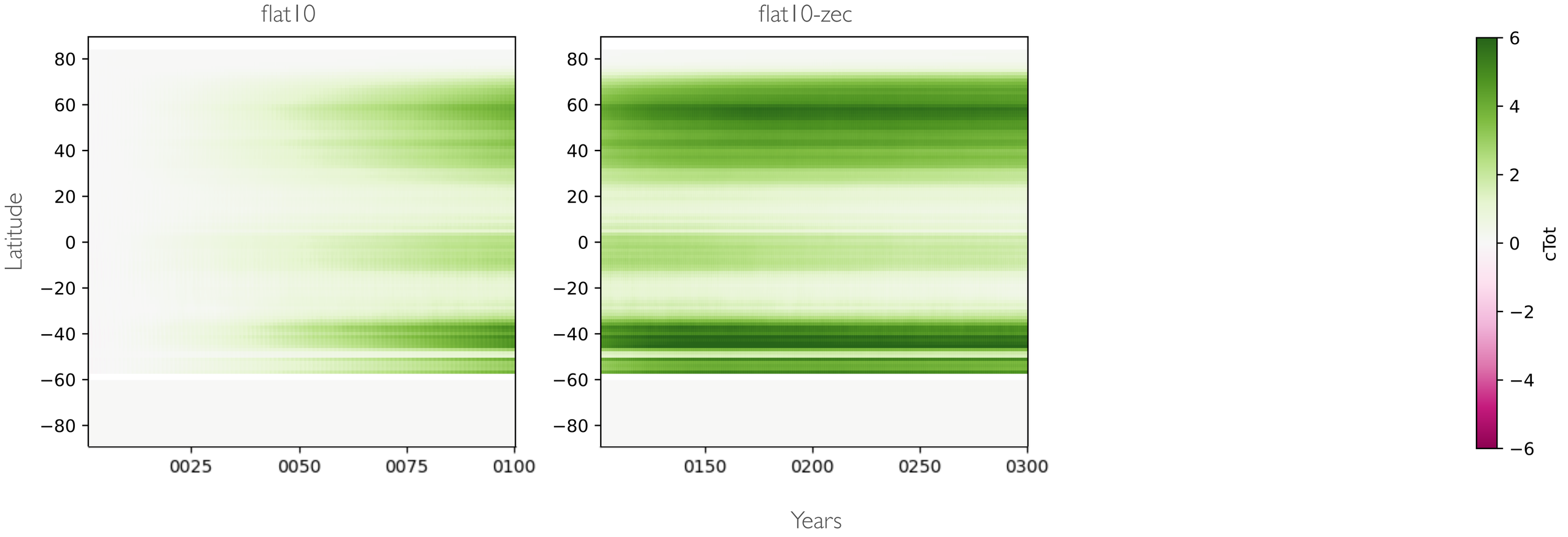
B. Buchovecky, B.Booth



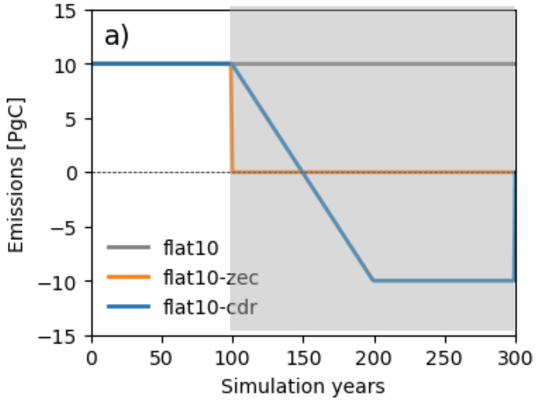
Vegetation carbon accumulates during emissions

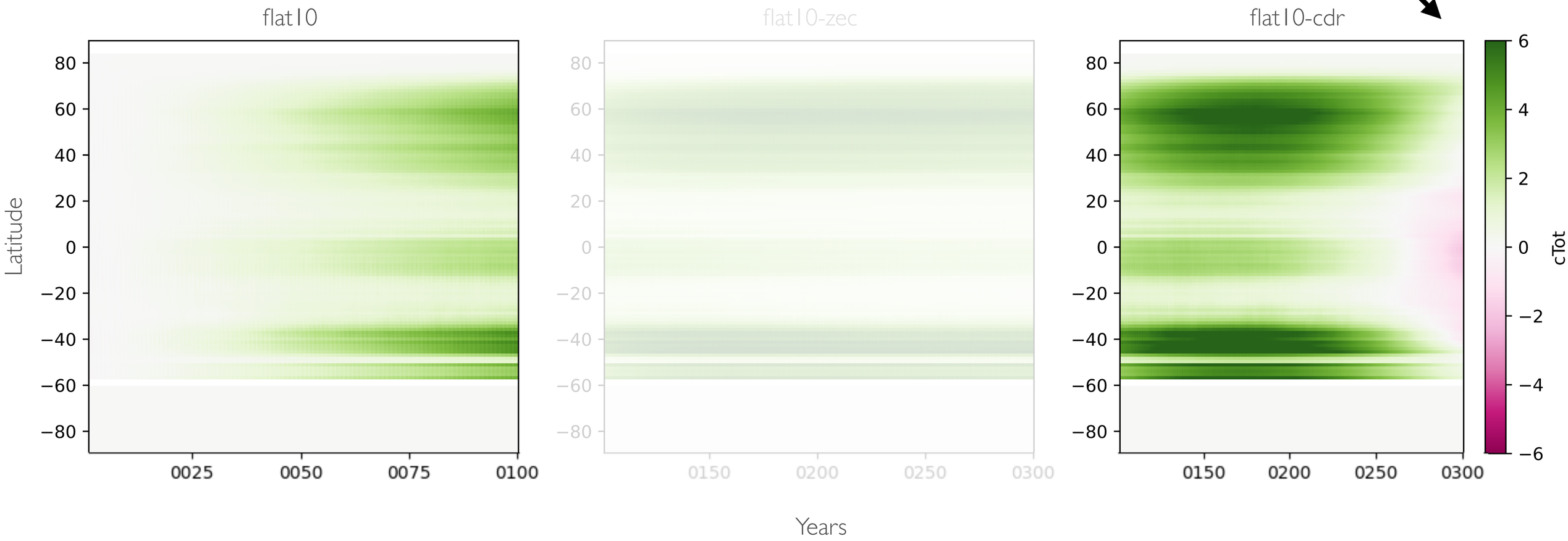
Vegetation carbon starts to decline under zero emissions



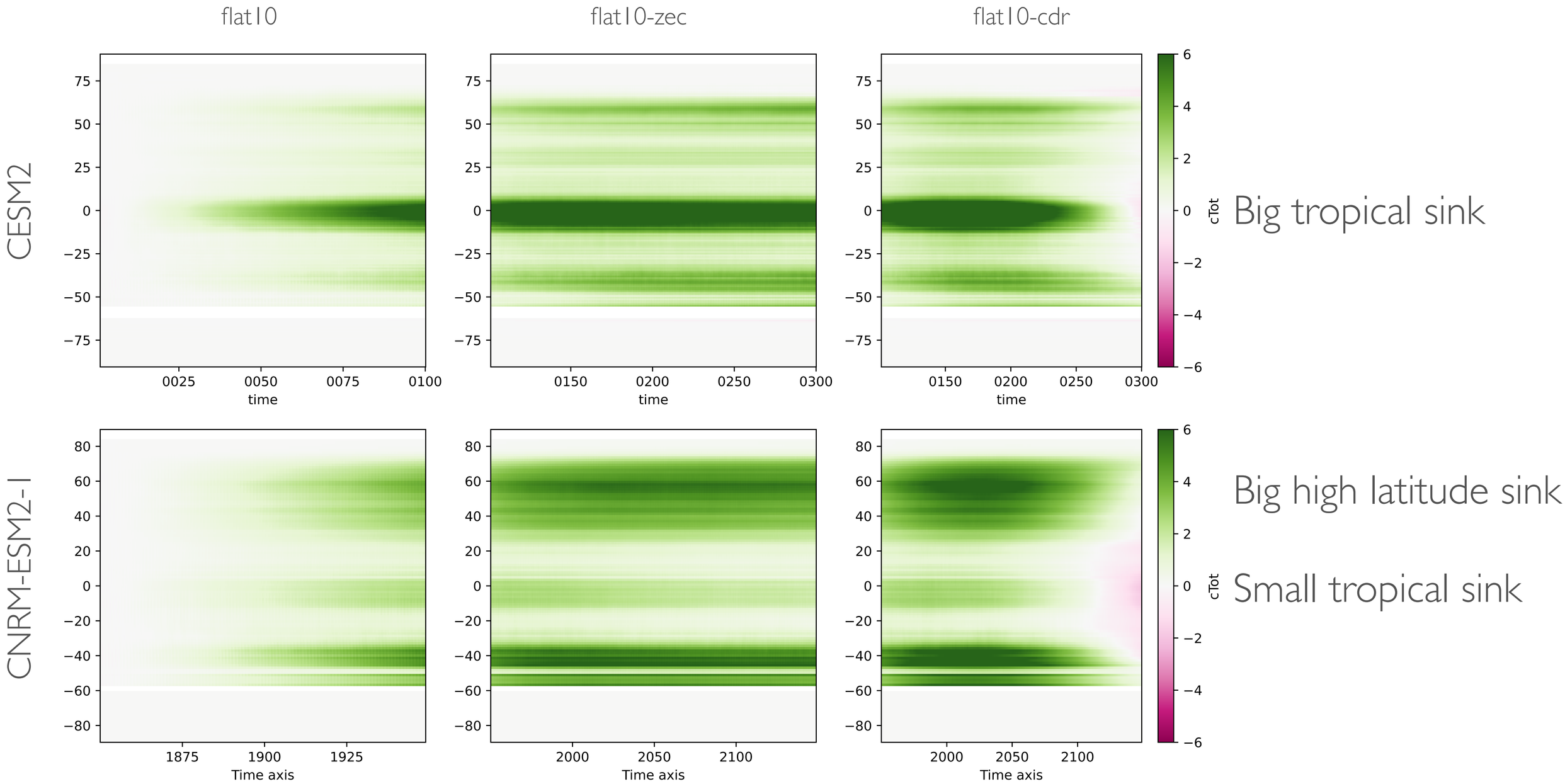


Total carbon ends up lower than preindustrial after CDR





Very different amount and location of land sink across models

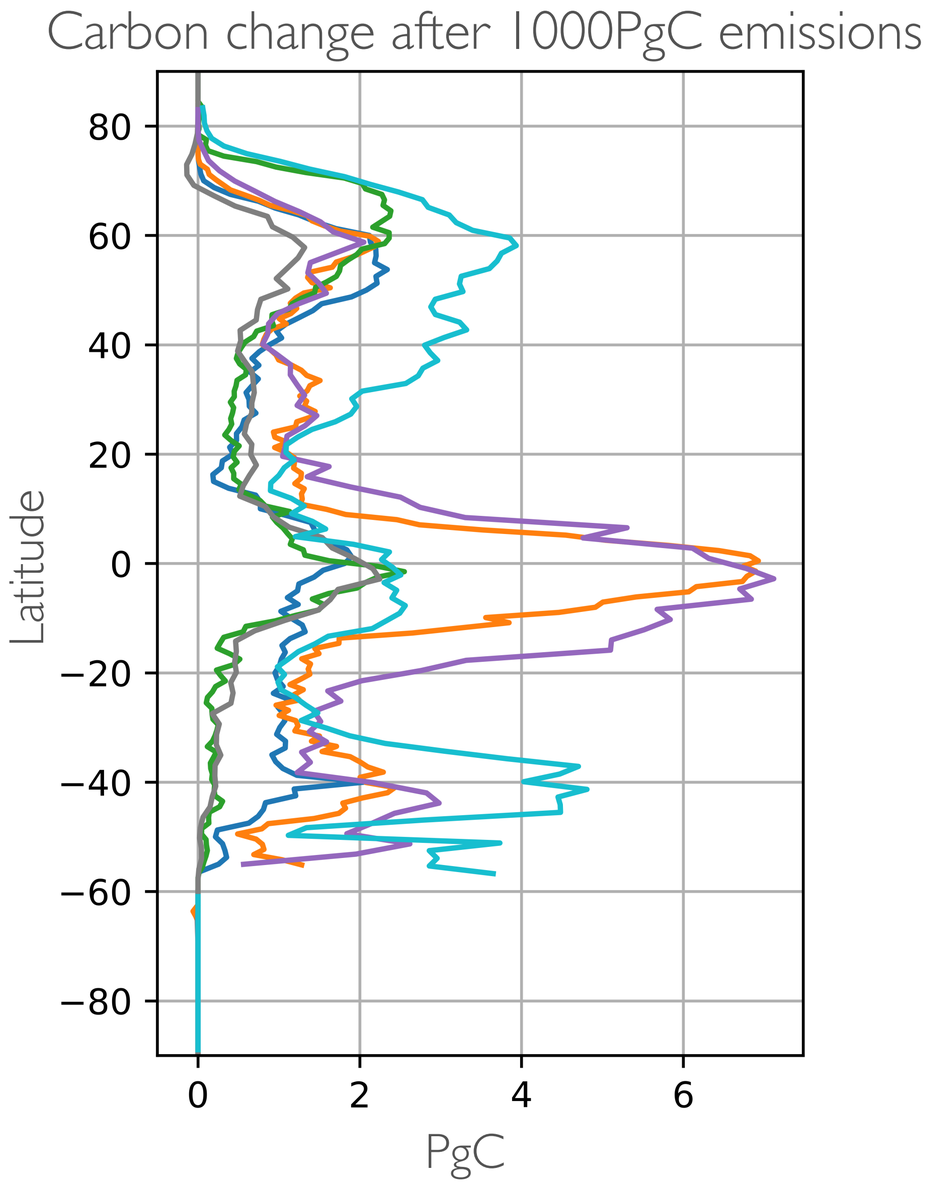


Big tropical sink

Big high latitude sink

Small tropical sink

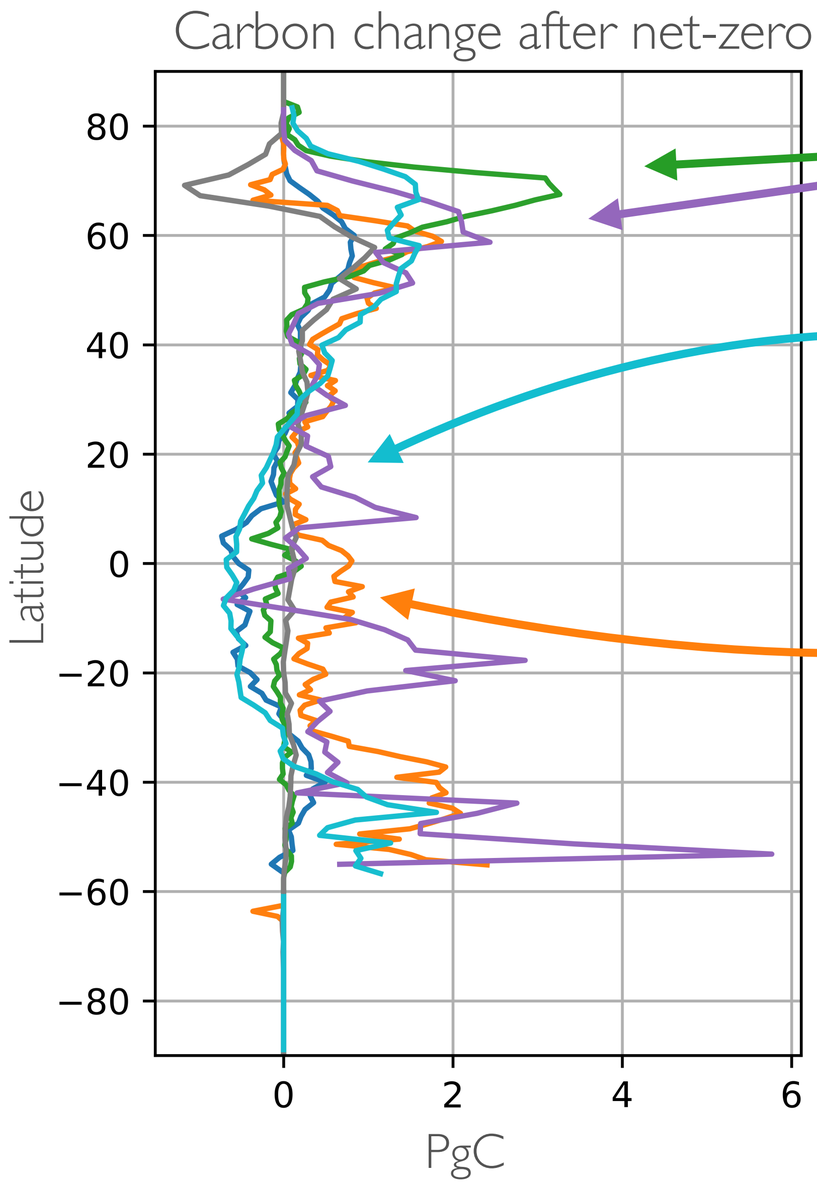
Very different amount and location of land sink across models



Big high latitude sink?

Big tropical sink?

Total carbon change after net-zero

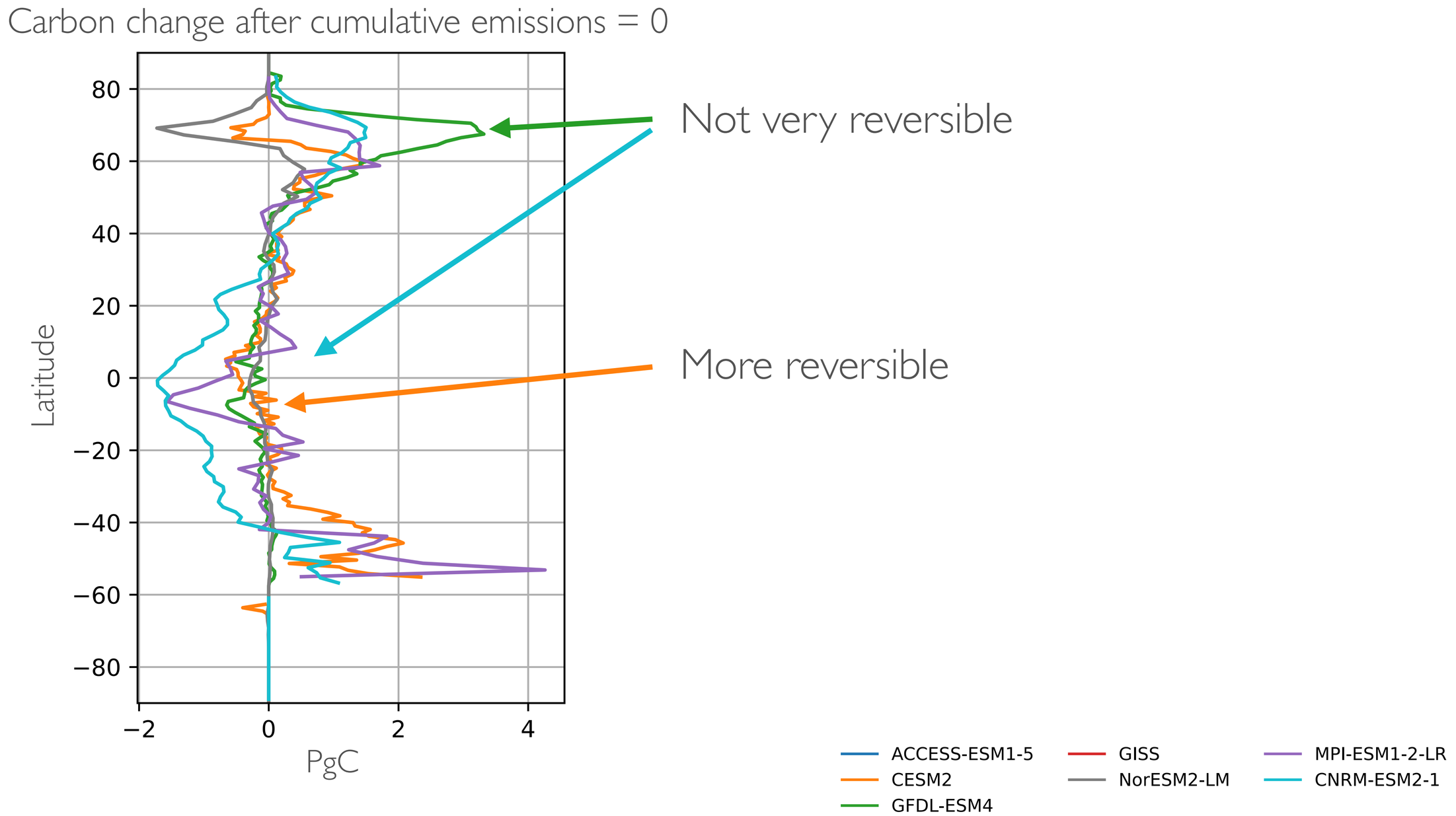


High latitude remains a sink in many models

Tropical sink is lost is some models, but not others

ACCESS-ESM1-5
CESM2
GFDL-ESM4
GISS
NorESM2-LM
MPI-ESM1-2-LR
CNRM-ESM2-1

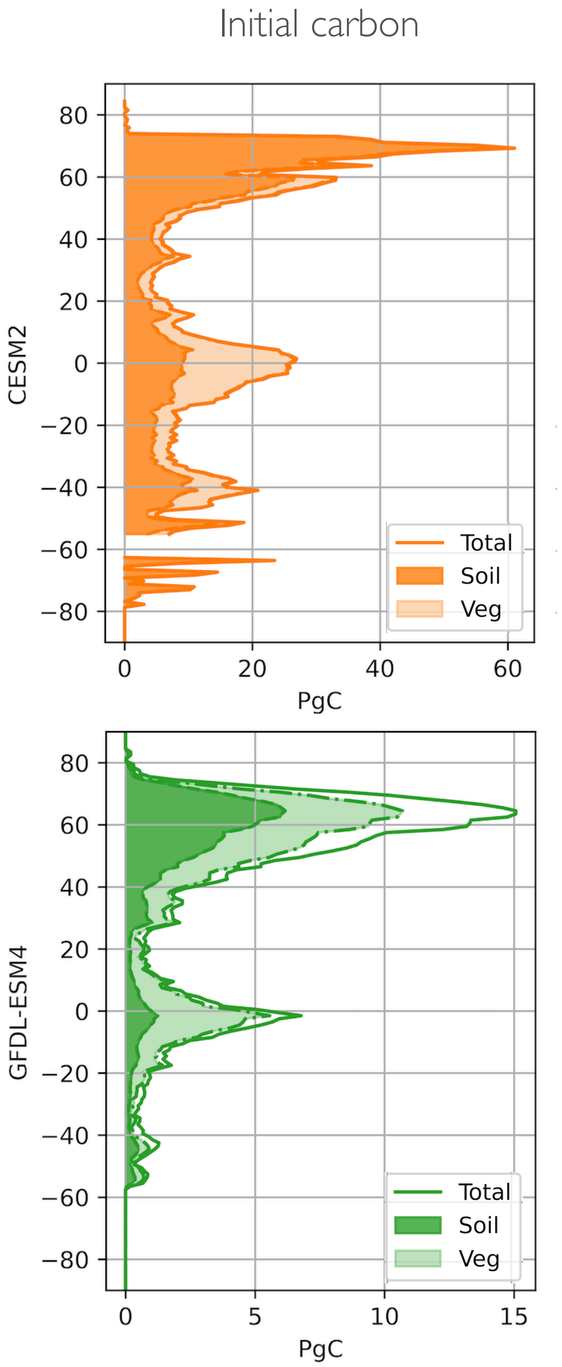
Some models show more reversibility than others



Big differences in carbon pools and responses across models

Fair amount of soil carbon to start

Way less soil carbon to start



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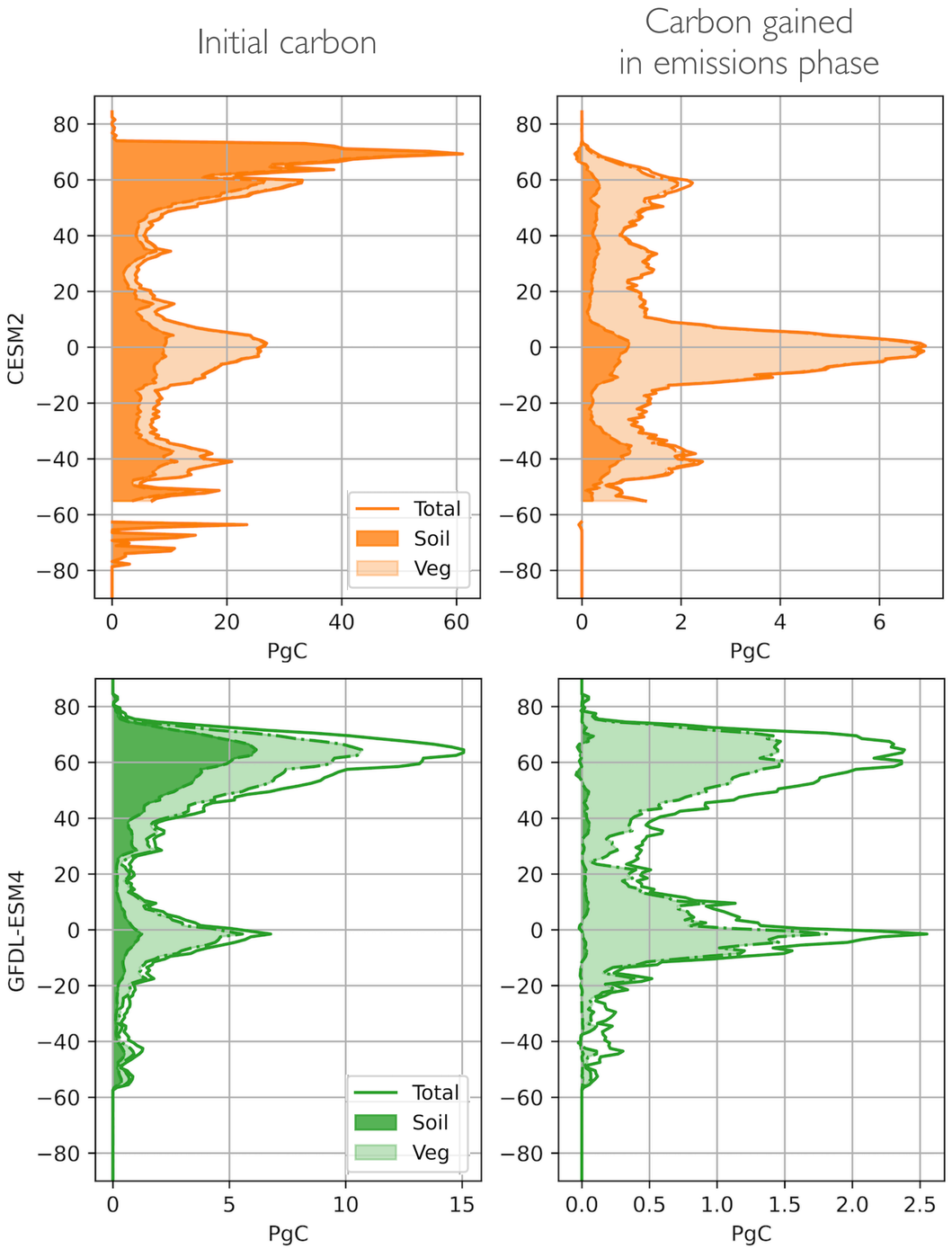

some change in soil carbon

almost no change in soil carbon

Many remaining questions!

- What controls difference in total land sink?
- What causes variations in the location of the land sink?
- How does location of land sink or source behavior impact TCRE, ZEC?

Models are different ⇒ Why models are different