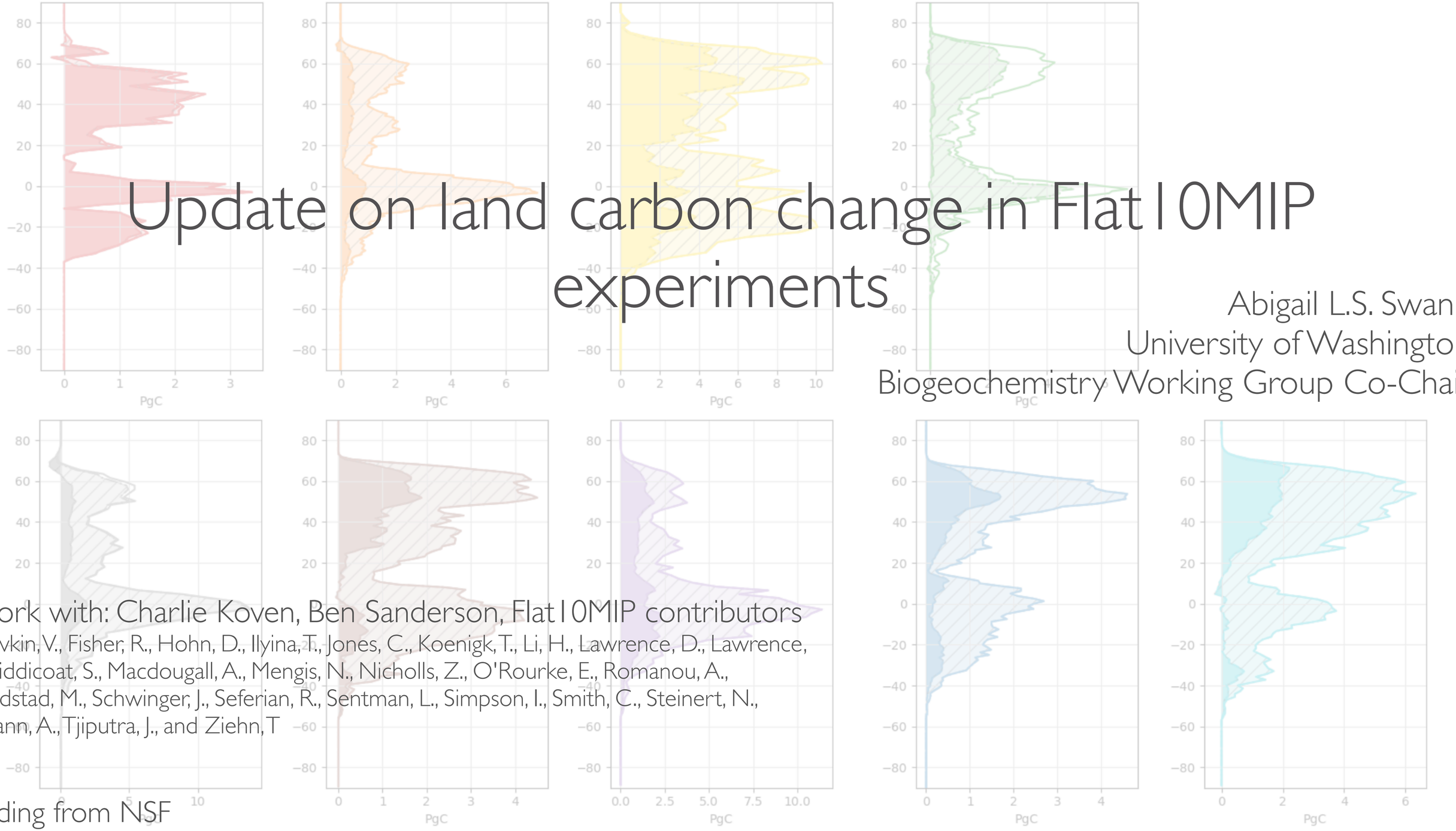


Update on land carbon change in Flat10MIP experiments

Abigail L.S. Swann
University of Washington
Biogeochemistry Working Group Co-Chair

Work with: Charlie Koven, Ben Sanderson, Flat10MIP contributors

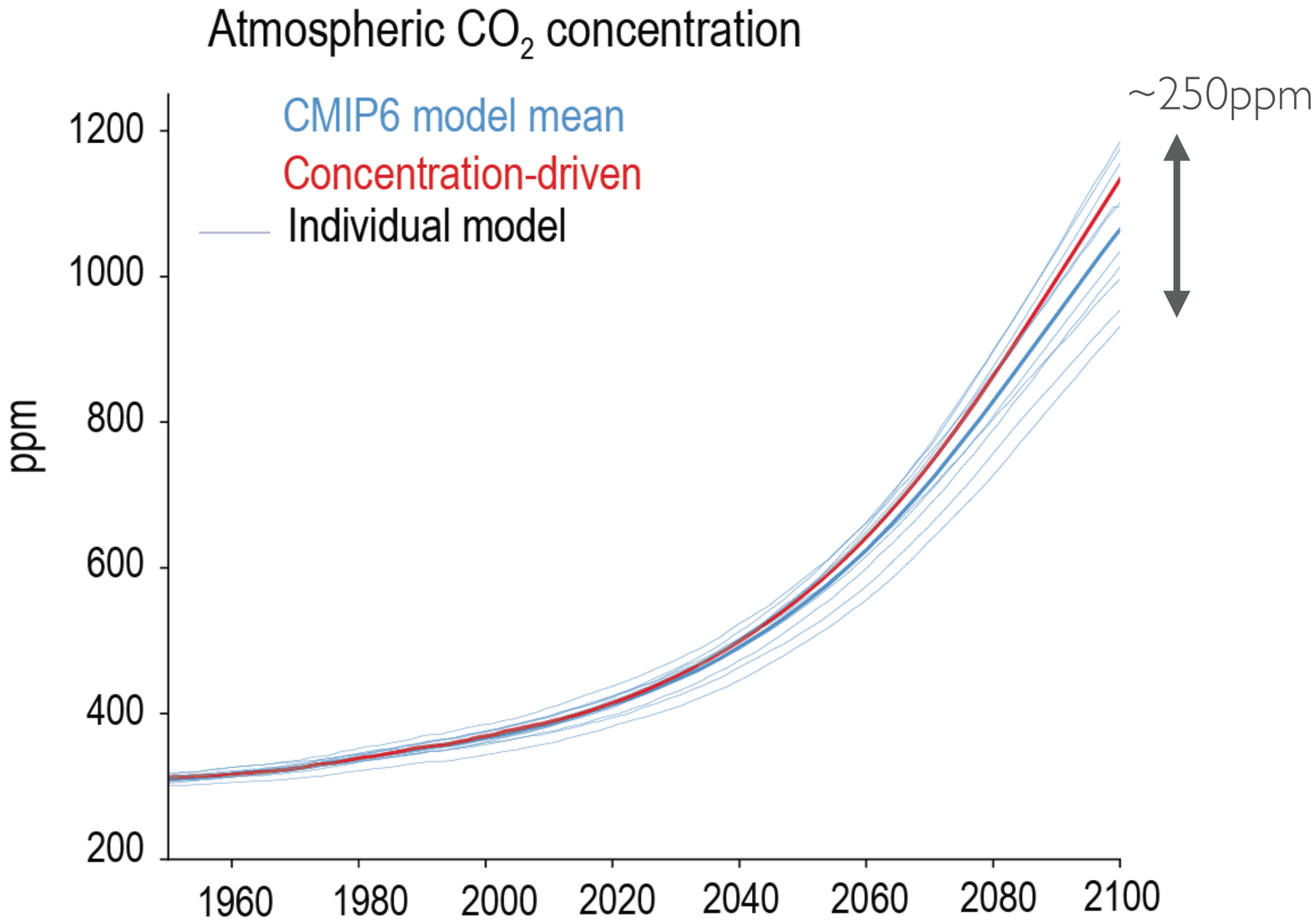
Brovkin, V., Fisher, R., Hohn, D., Ilyina, T., Jones, C., Koenigk, T., Li, H., Lawrence, D., Lawrence, P., Liddicoat, S., Macdougall, A., Mengis, N., Nicholls, Z., O'Rourke, E., Romanou, A., Sandstad, M., Schwinger, J., Seferian, R., Sentman, L., Simpson, I., Smith, C., Steinert, N., Swann, A., Tjiputra, J., and Ziehn, T

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)

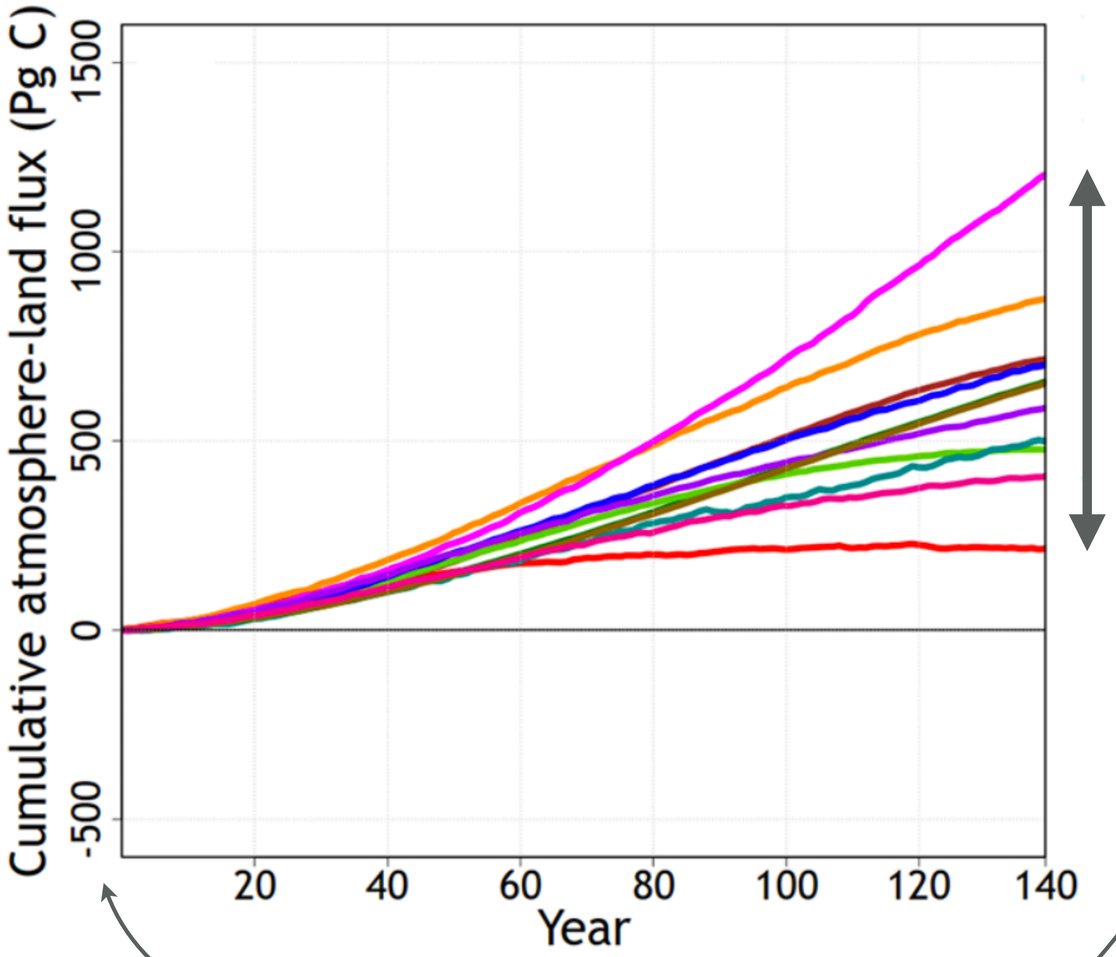
CMIP7 will have more emissions-driven simulations



IPCC AR6 WGI, Fig. 4.3

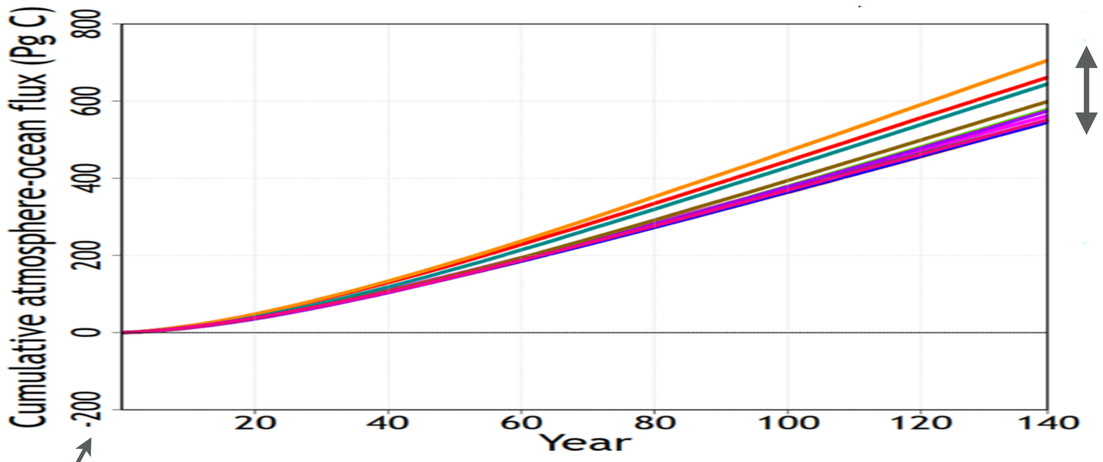
Across model spread in CO_2 is due (largely) to differences in land fluxes of C

Land



Same y-axis scale

Ocean

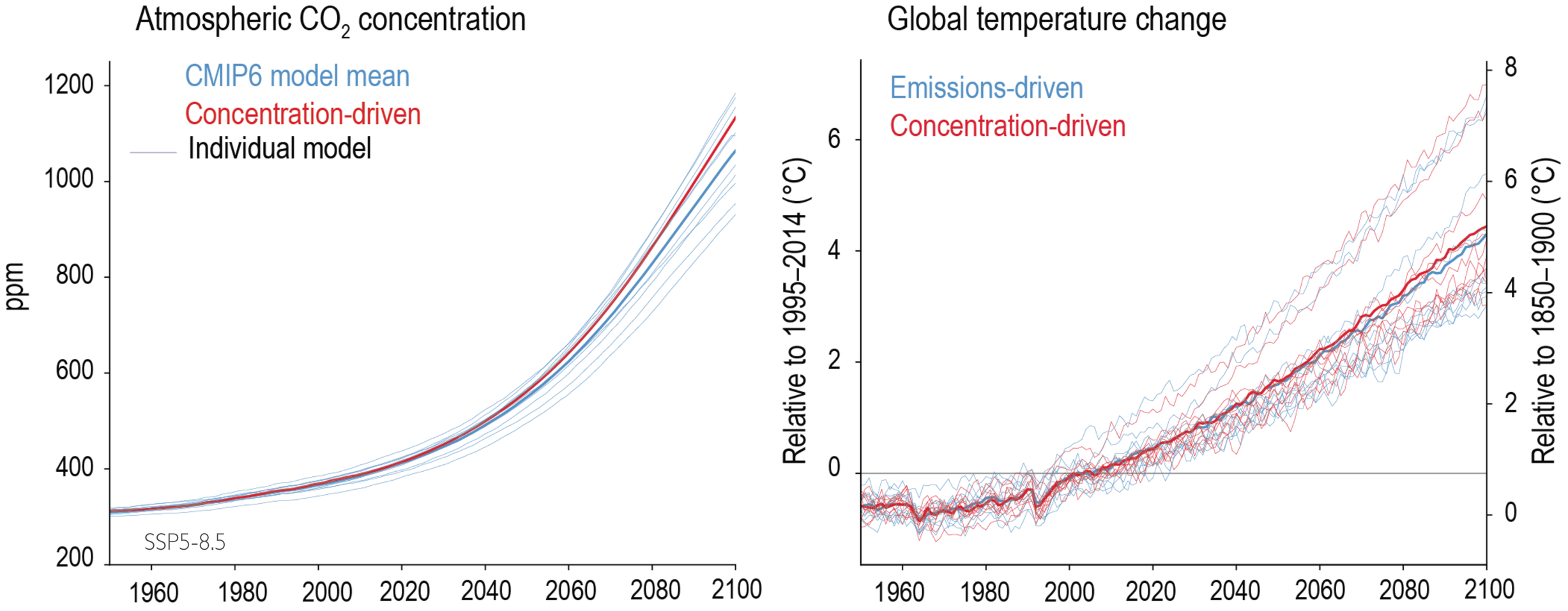


Land uptake of C depends entirely on Biological processes

Ocean uptake of C controlled mostly by physics and chemistry

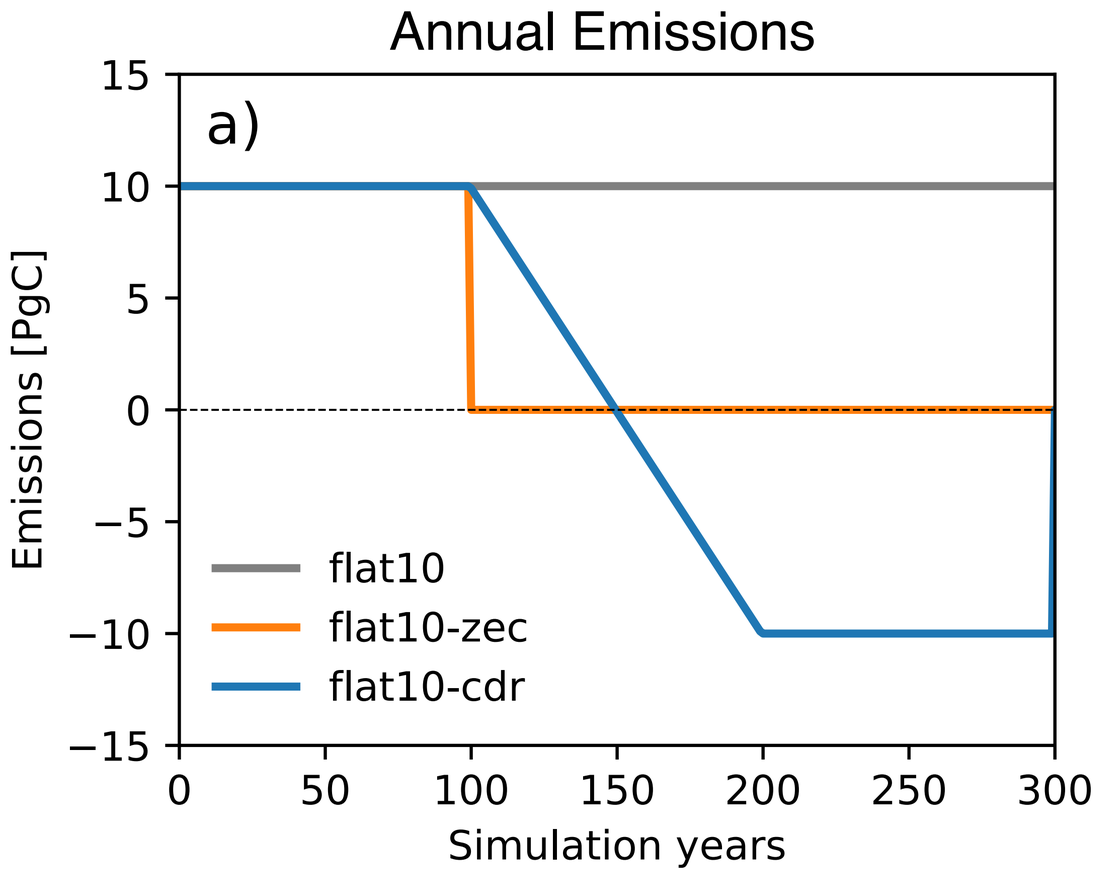
Arora et al. 2020, Biogeosci.

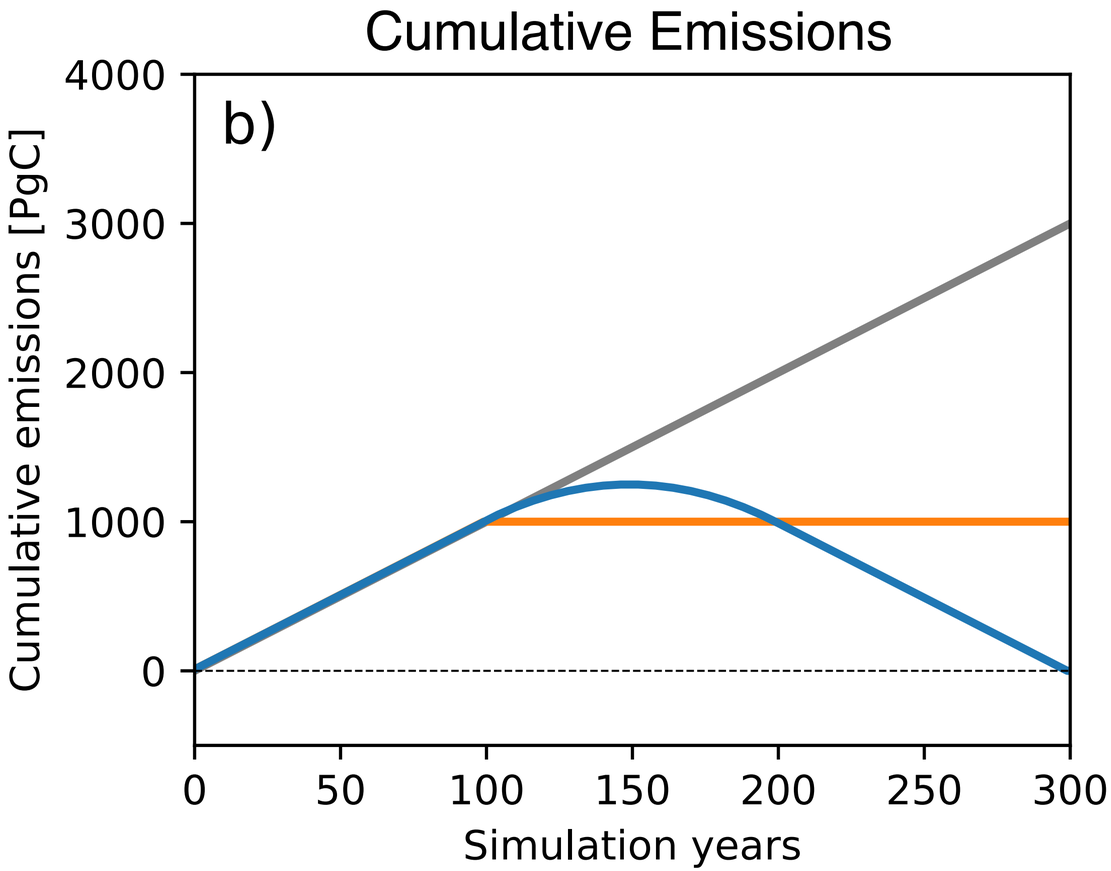
Spread in atm CO_2 ⇒spread in global temperature



IPCC AR6 WGI, Fig. 4.3

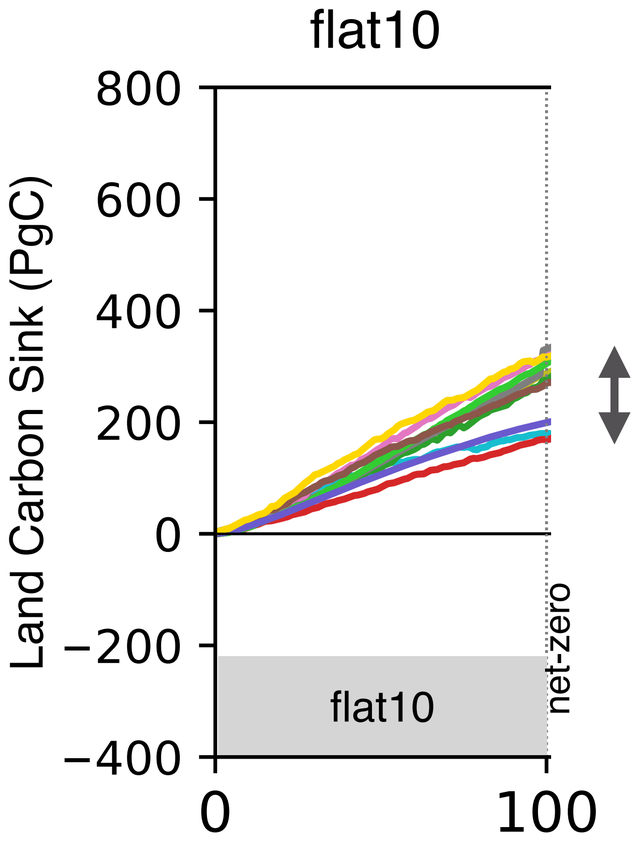
Flat10 set of experiments ⇐ part of Fast Track for CMIP7





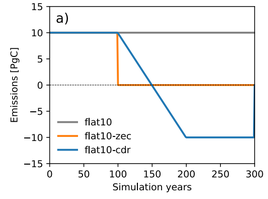
Sanderson et al. 2025, GMD

Land carbon sink increases while emissions increase



Large spread in land carbon sink across models

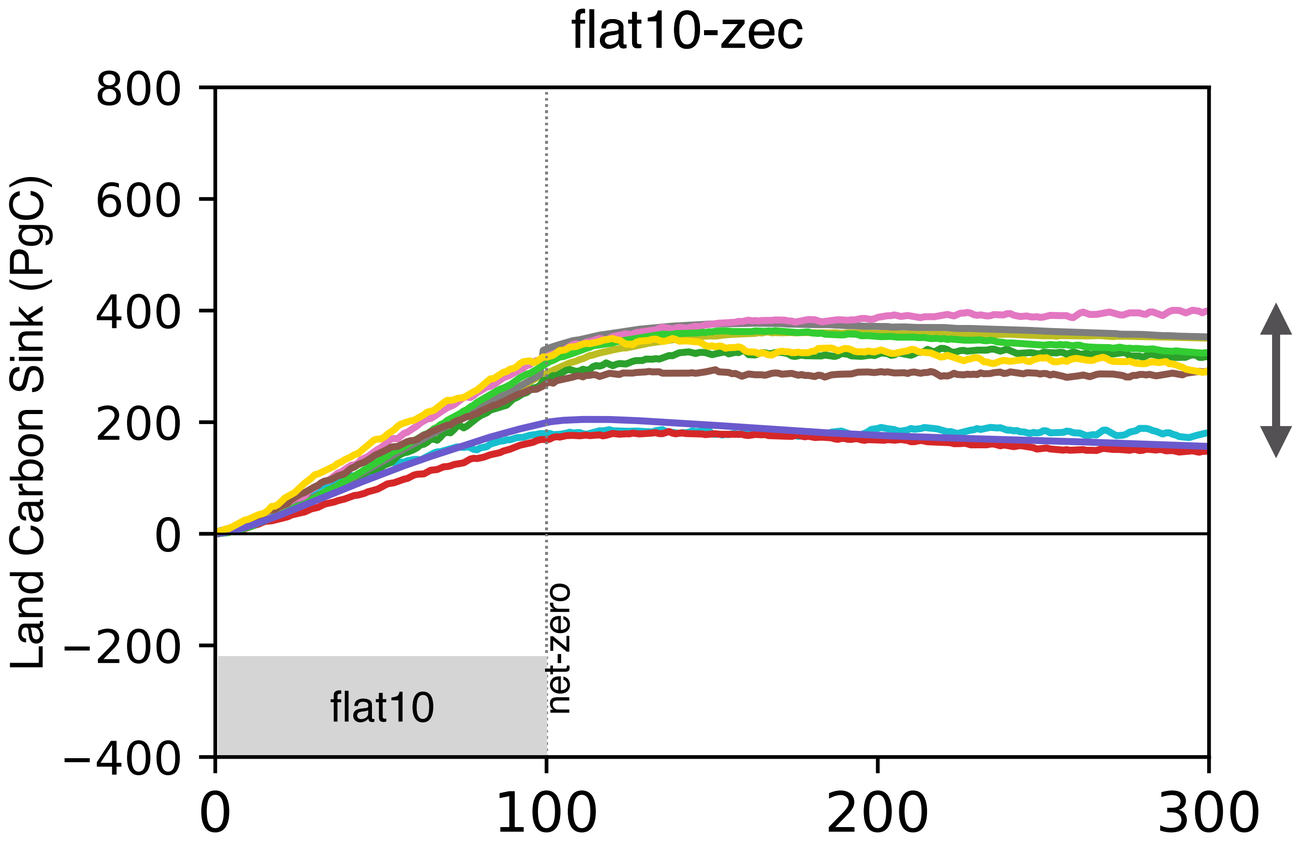
CO_2 fertilization
Higher productivity with warming
etc.



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

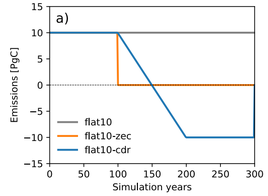
Sanderson et al. 2025, GMD

Land carbon sink largely flat, some decline after net-zero emissions



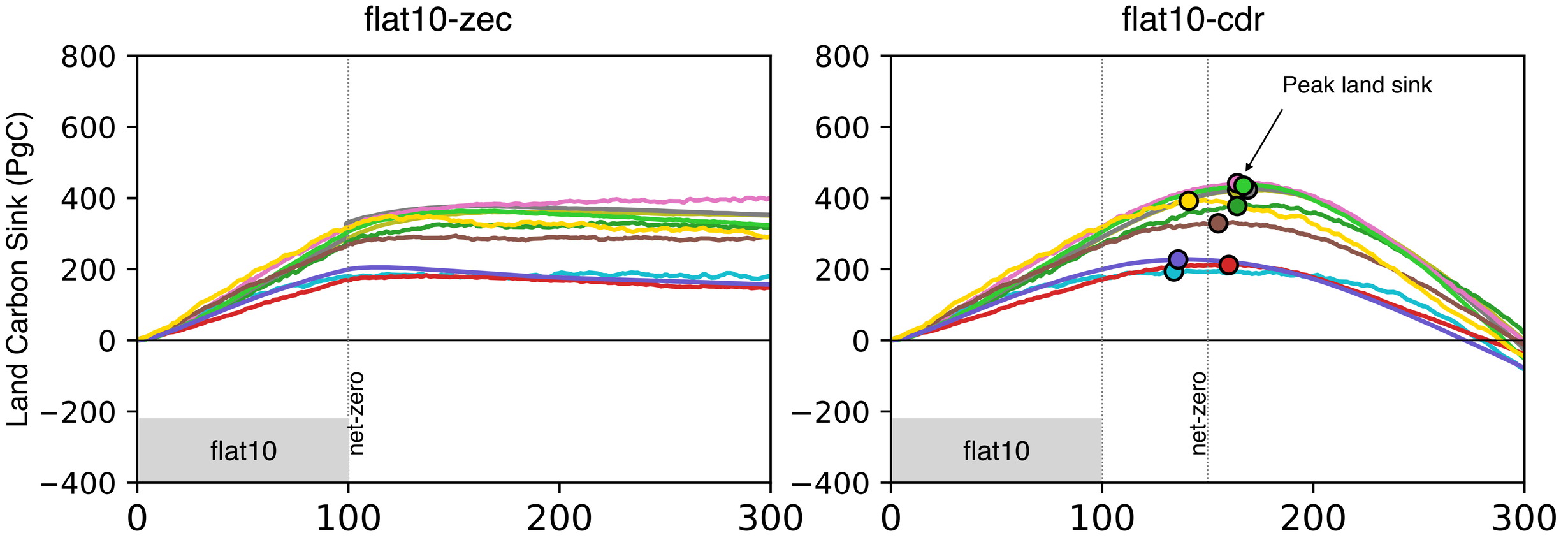
Spread remains large

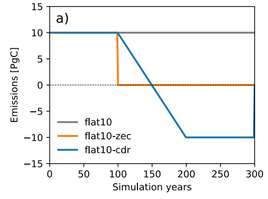
ACCESS-ESM1-5
CESM2
GFDL-ESM4
GISS
NorESM2-LM
MPI-ESM1-2-LR
CNRM-ESM2-1



Sanderson et al. 2025, GMD

Timing of peak land sink varies under more gradually declining emissions

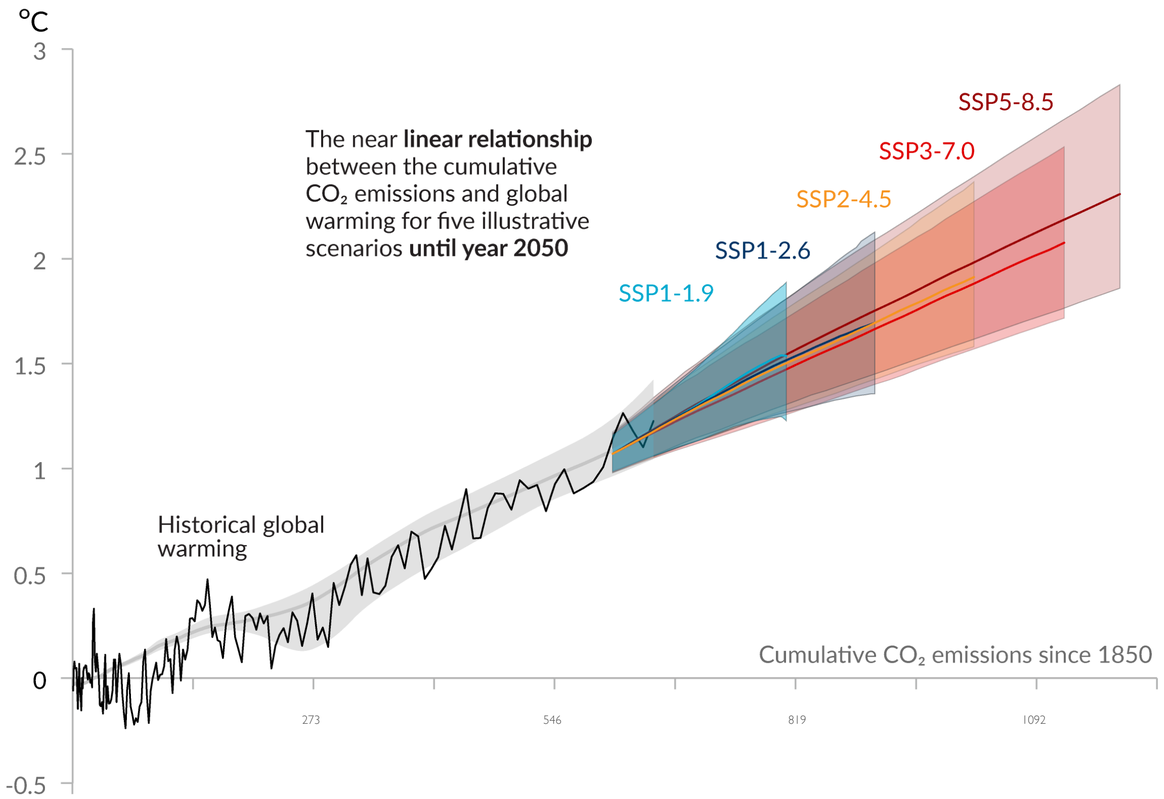




Sanderson et al. 2025, GMD

Key metrics - TCRE and ZEC

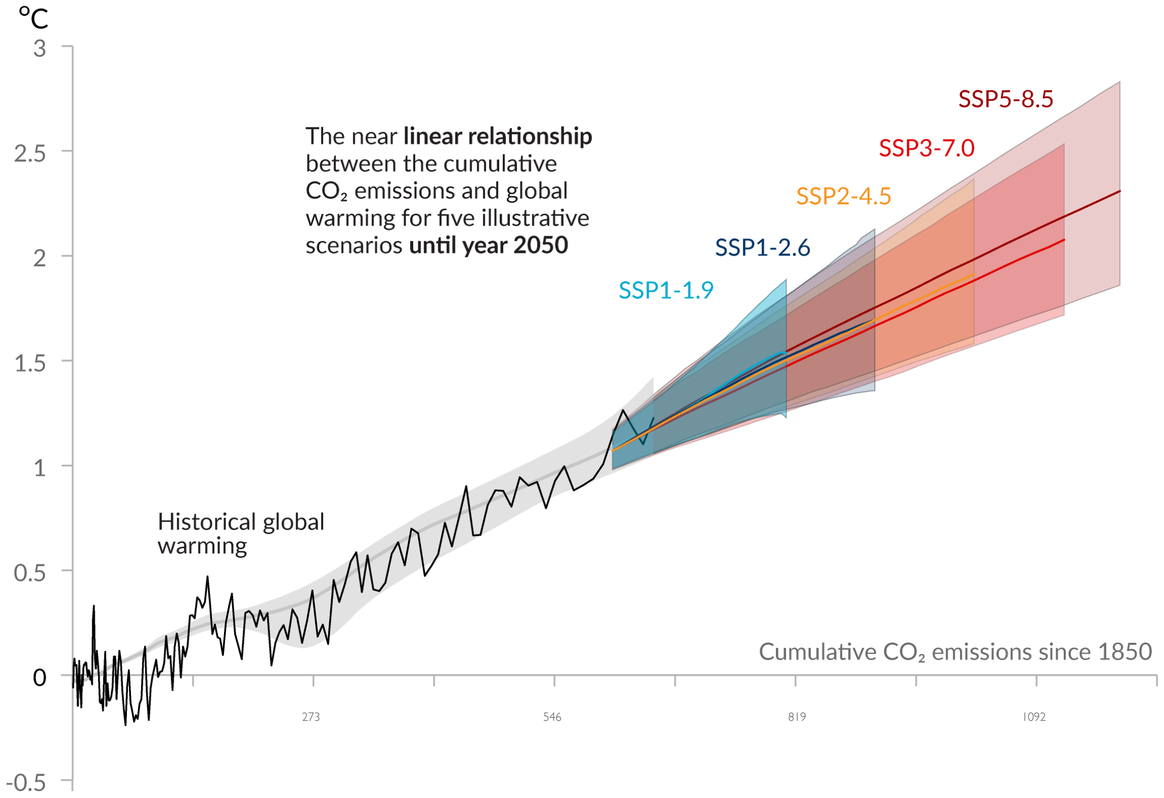
Transient Climate Response to Emissions TCRE



AR6 WGI, Fig. SPM 10

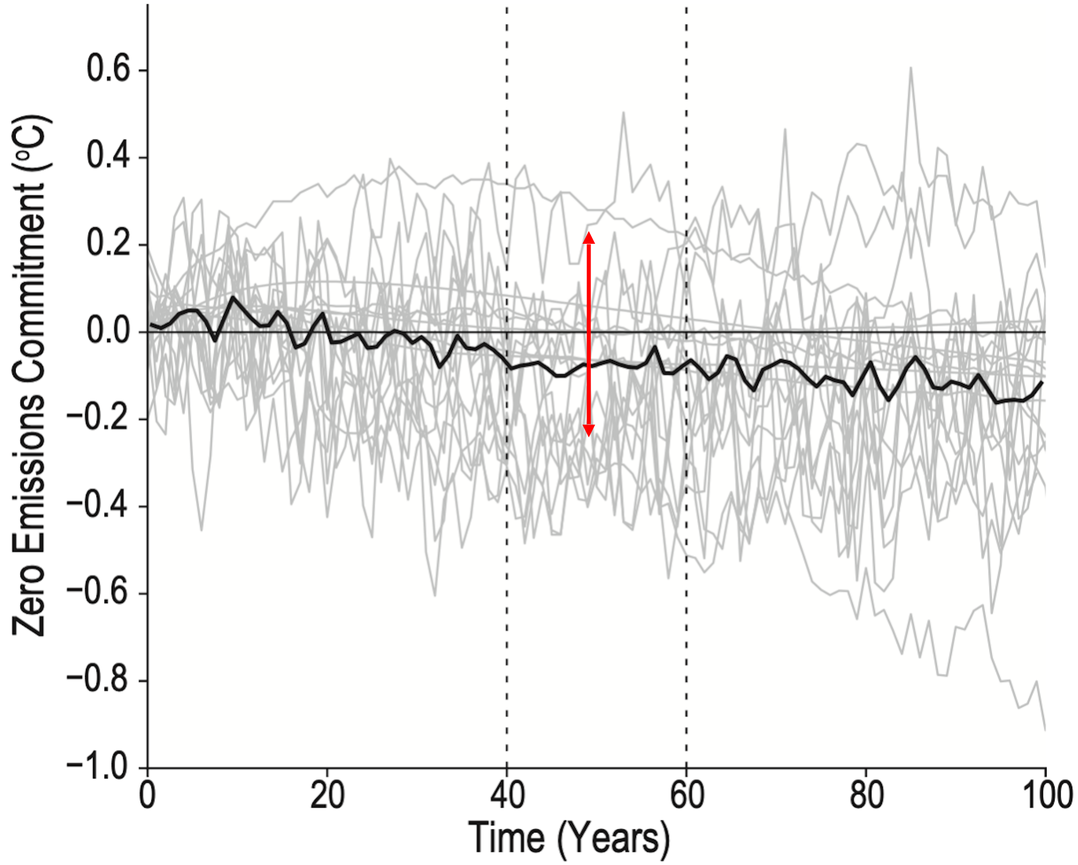
Key metrics - TCRE and ZEC

Transient Climate Response to Emissions TCRE



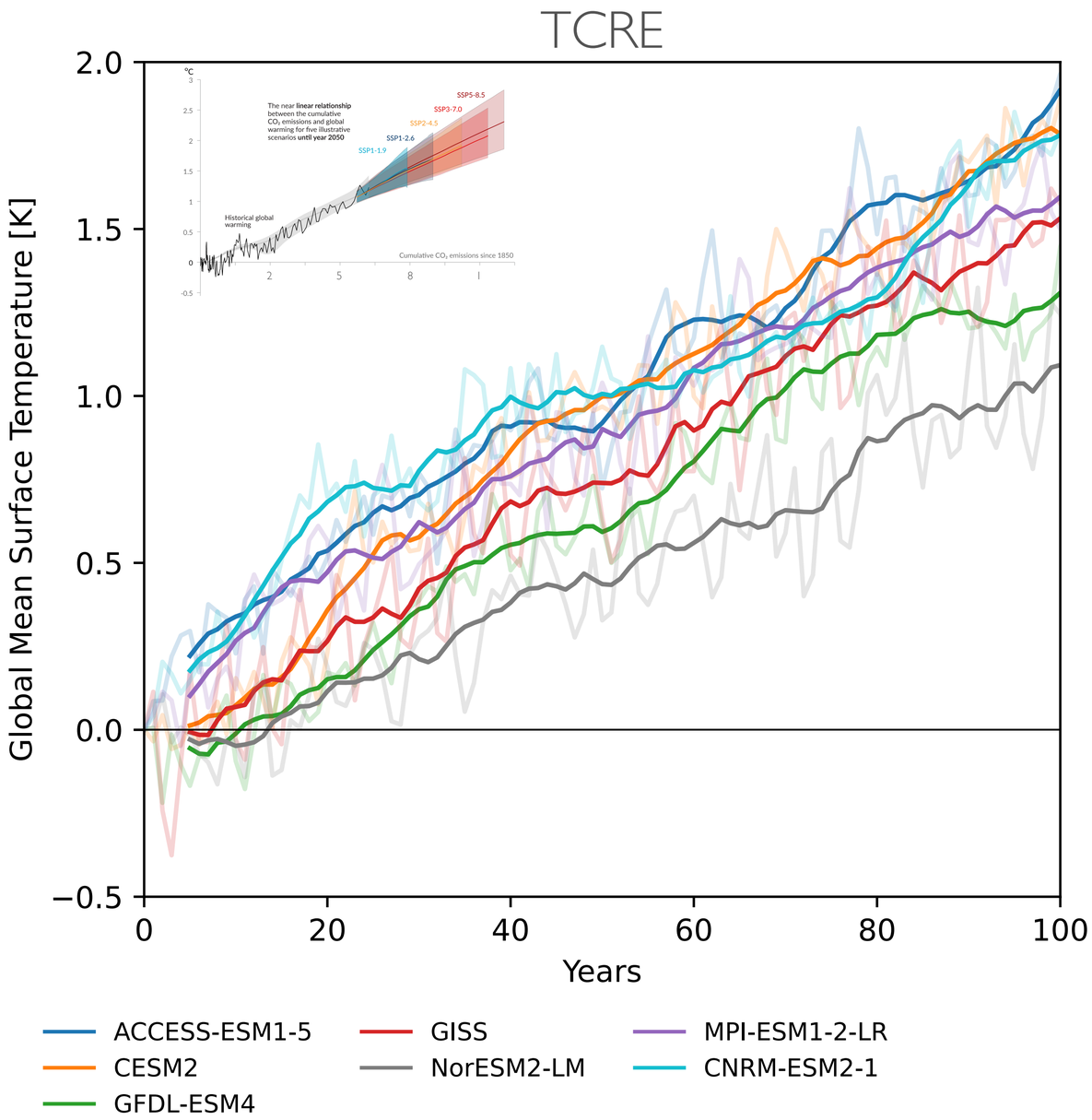
AR6 WGI, Fig. SPM 10

Zero Emissions Committment ZEC

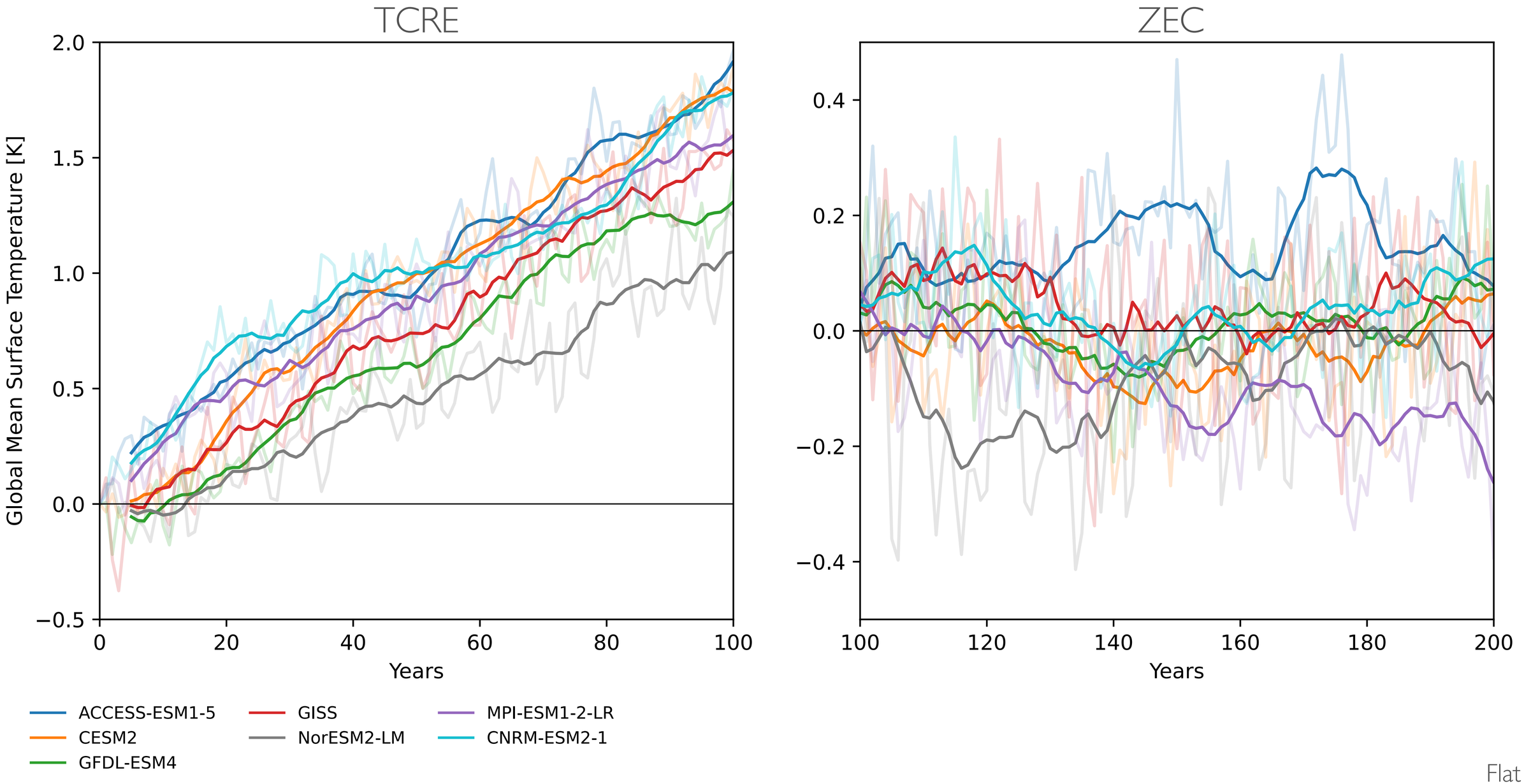


IPCC AR6 WGI Fig. 4.39

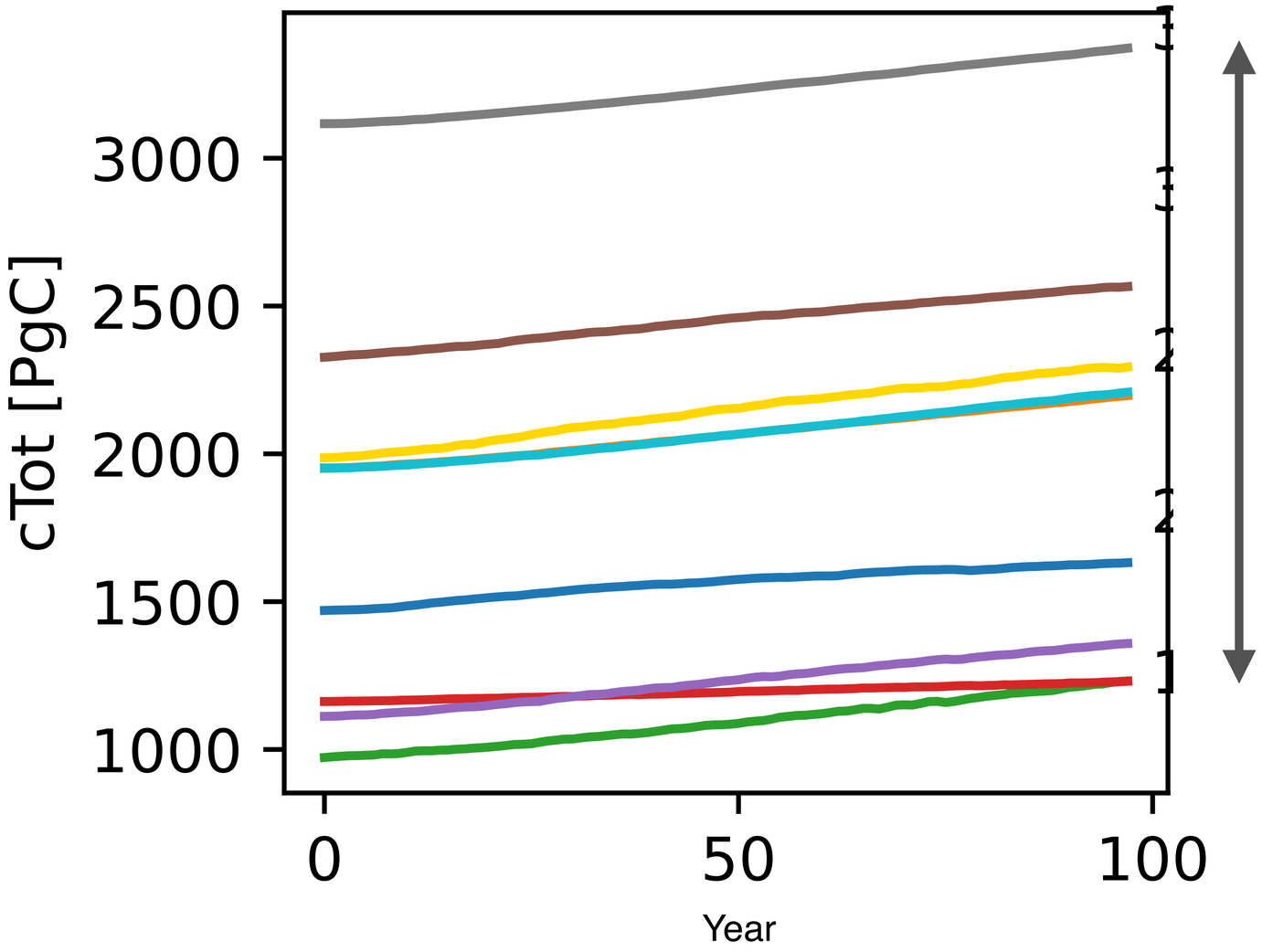
Spread in carbon sink + physical climate impacts temperature



Spread in carbon sink + physical climate impacts temperature



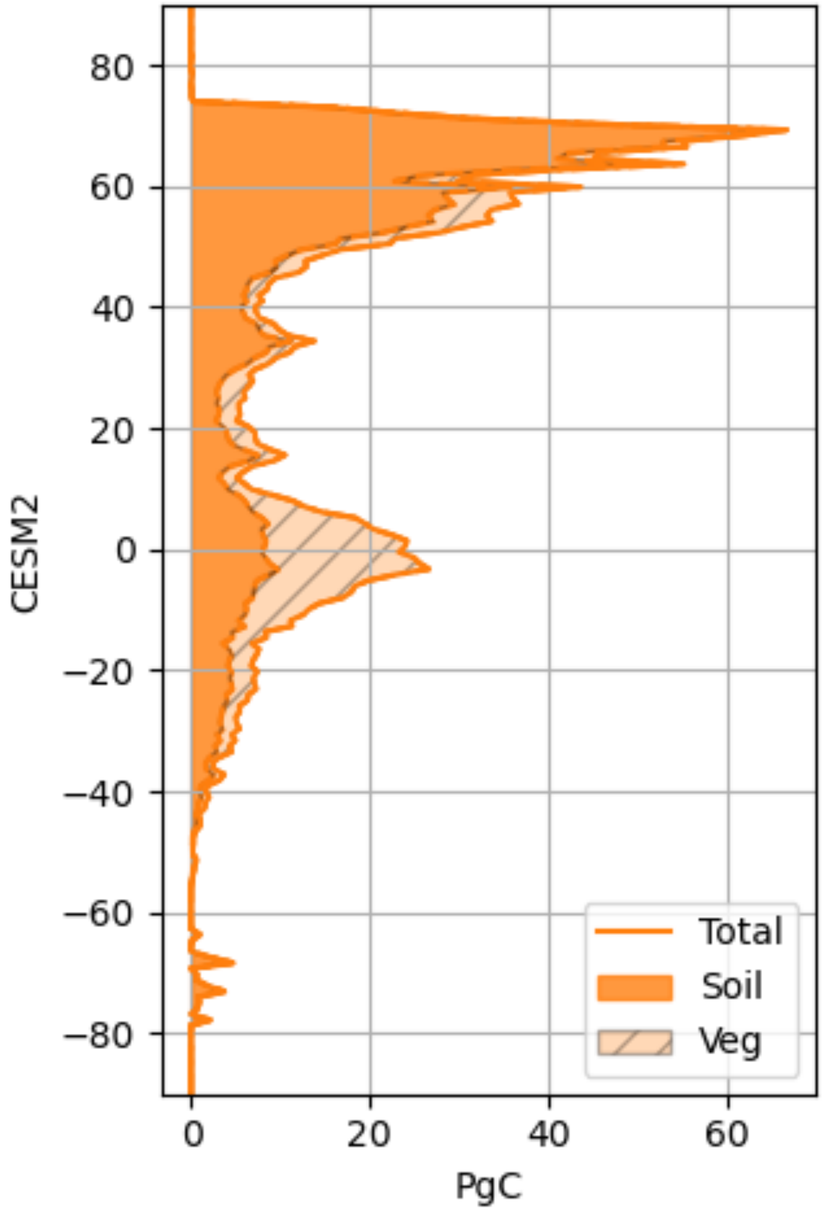
Big difference in initial carbon stocks across models



2000 PgC spread

ACCESS-ESM1-5
CESM2
GFDL-ESM4
GISS_E2.1
NorESM2-LM
MPI-ESM1-2-LR
CNRM-ESM2-1
HadCM3LC-Bris
UKESM1.2

Initial Carbon stocks [PgC]



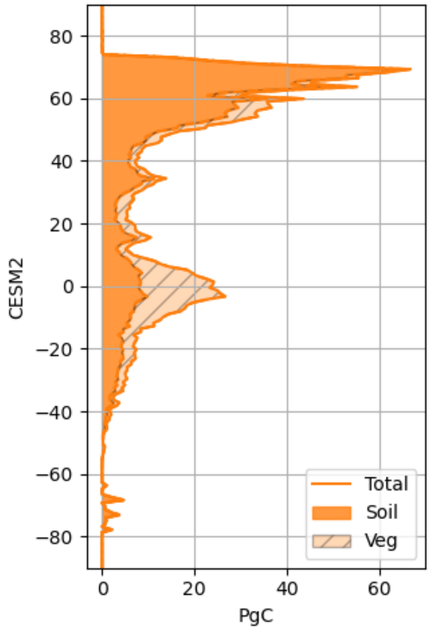
Initial Carbon stocks

Total carbon

Soil

Vegetation

Initial Carbon stocks [PgC]



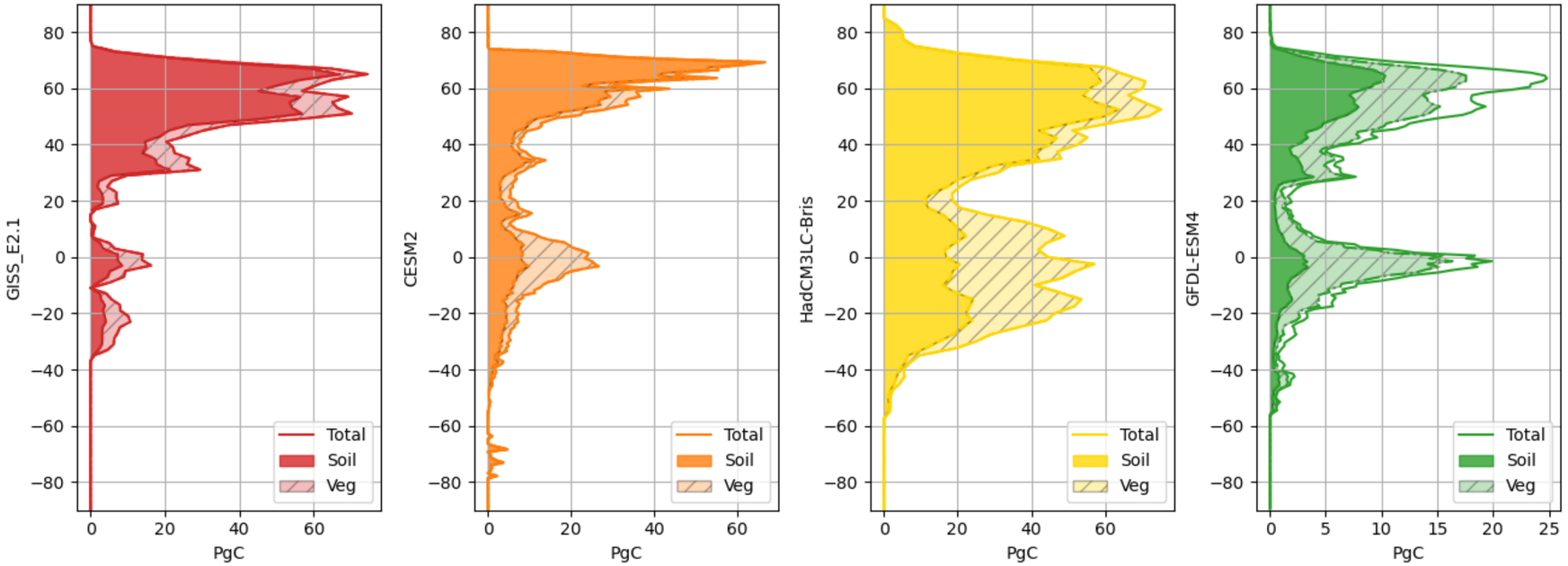
Initial Carbon stocks

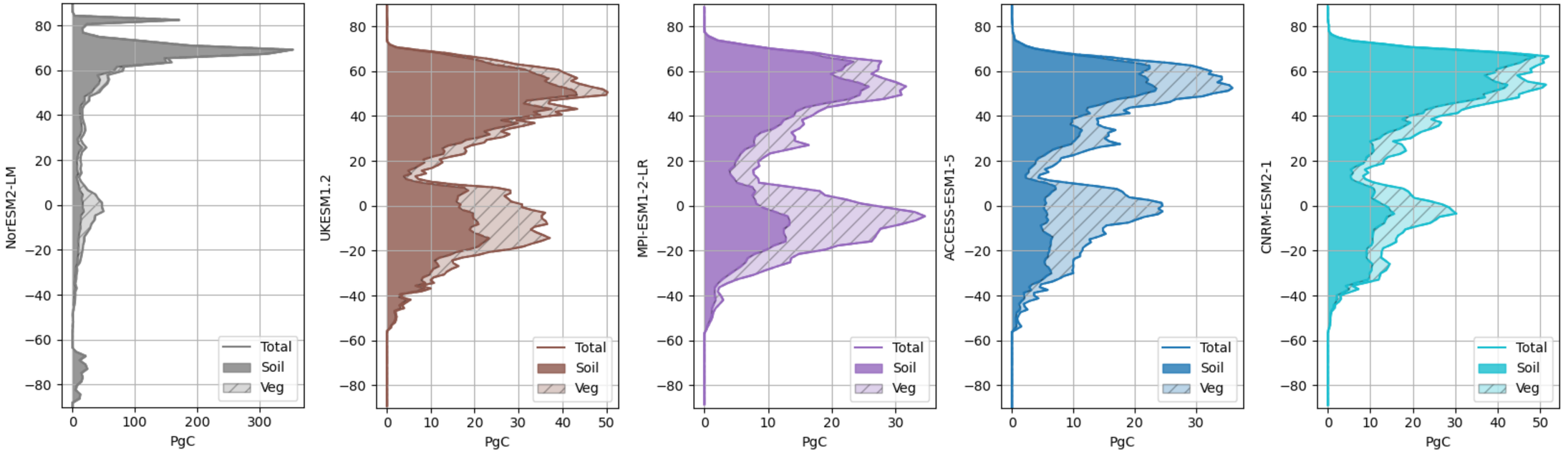
Total carbon

Soil

Vegetation

Initial Carbon stocks [PgC]



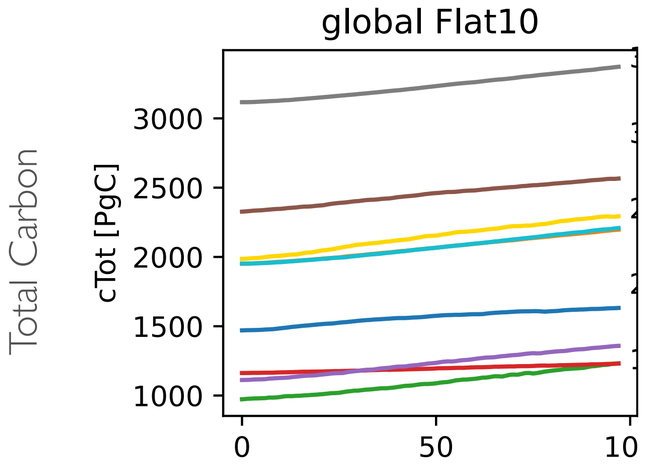


Initial Carbon stocks
(different x-scales)

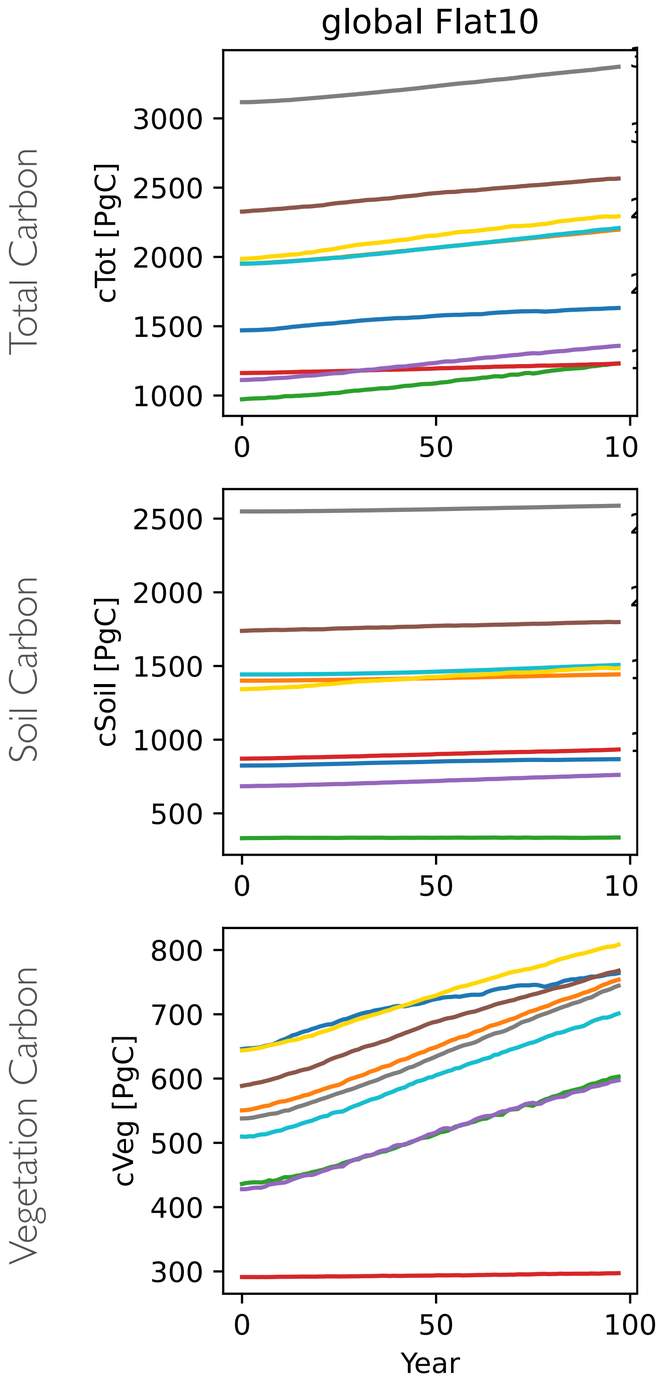
Total carbon

Soil

Vegetation

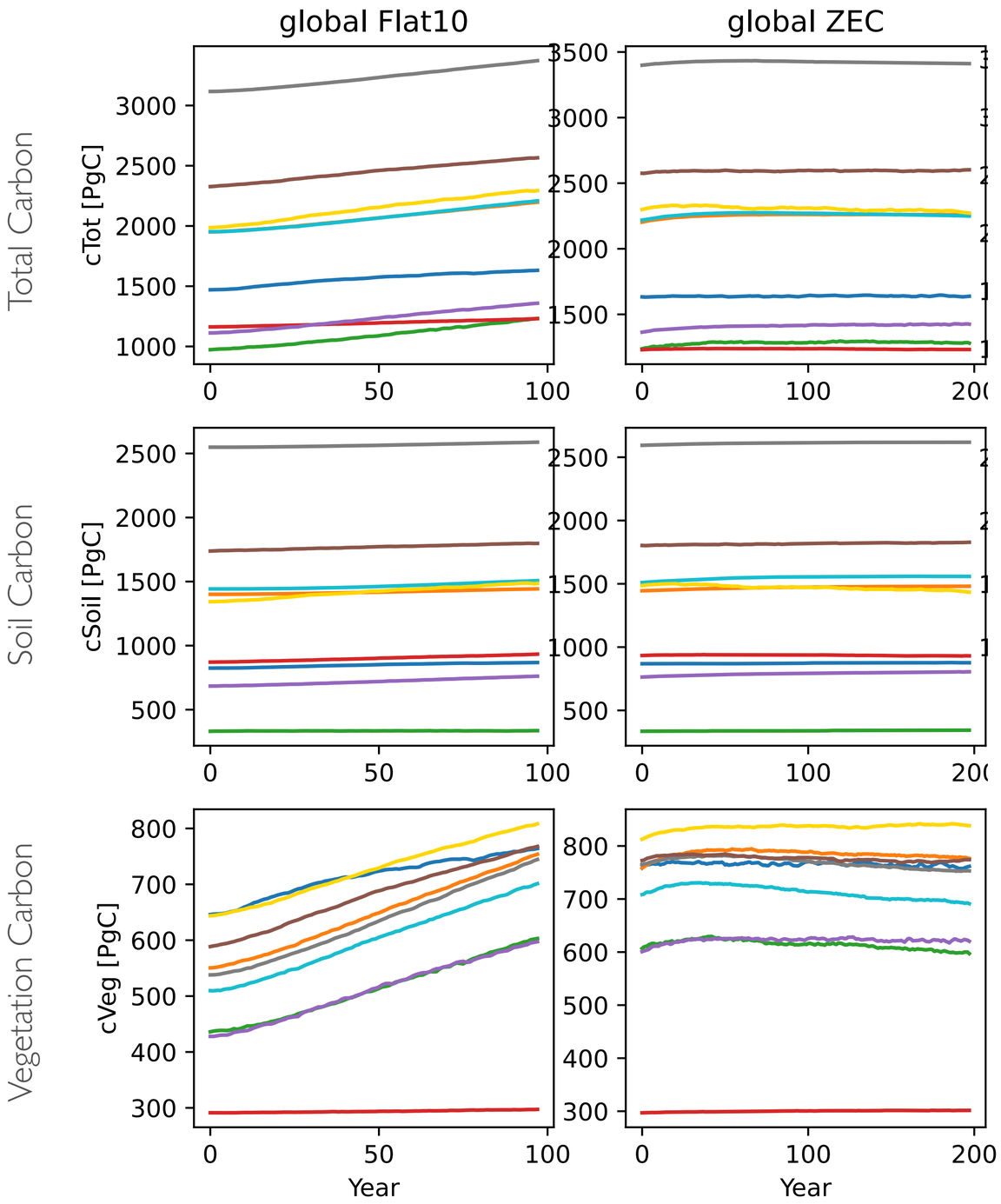


Big difference in initial carbon stocks across models

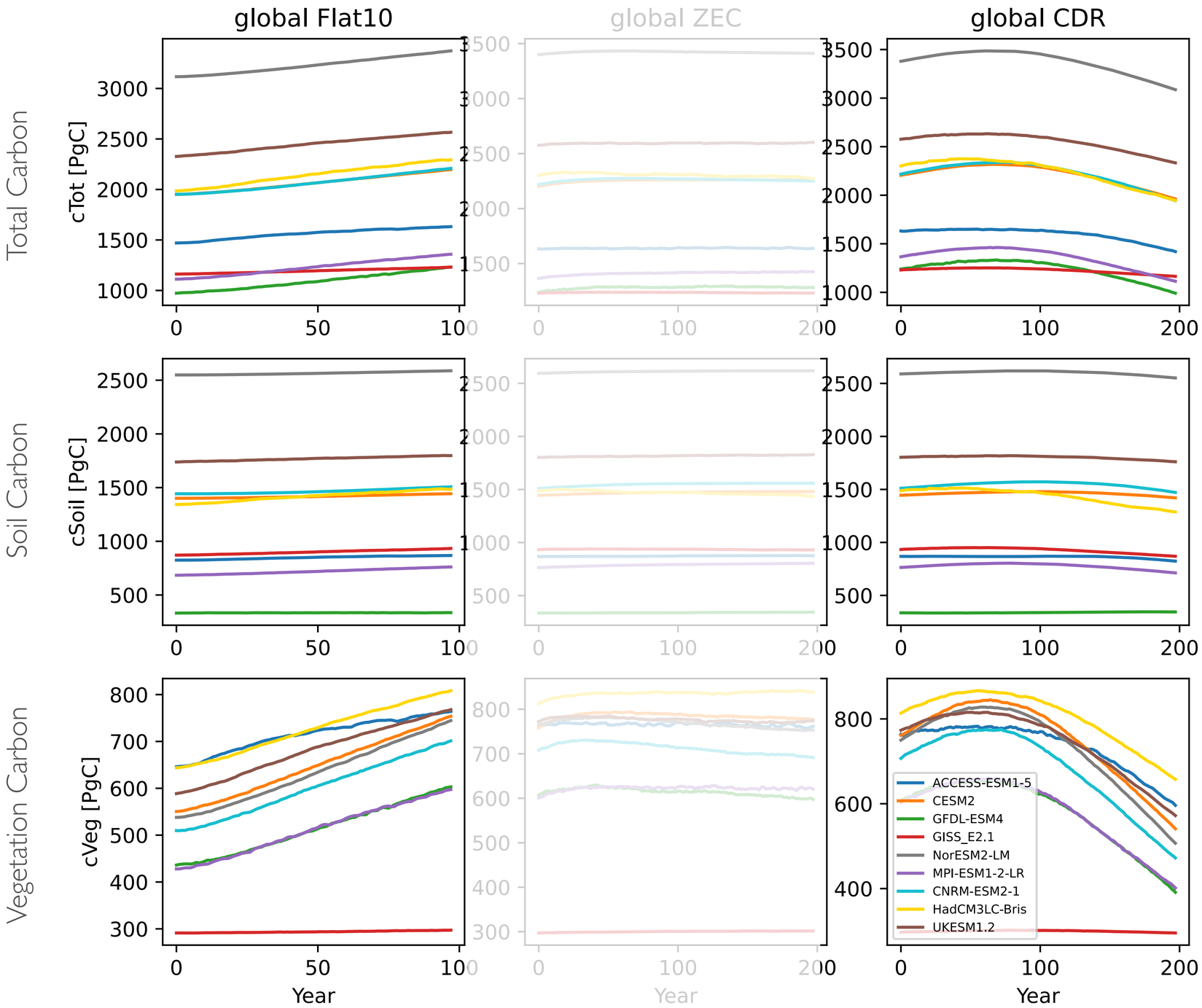


Big difference in initial carbon stocks across models

Carbon *gain* during emissions phase is mostly in vegetation



Carbon stocks are fairly stable after zero emissions, some models show vegetation decline

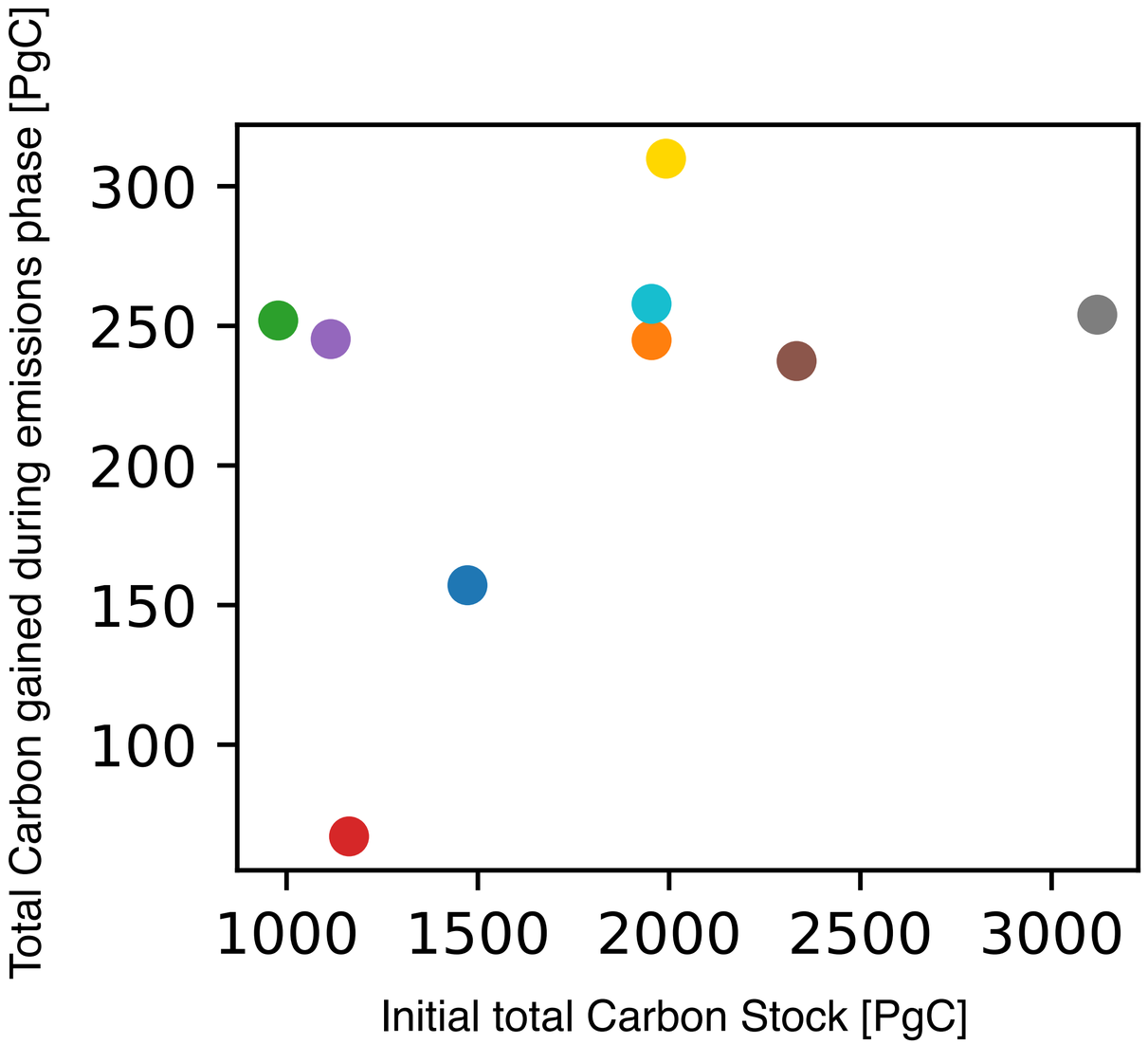


Carbon stocks decline under negative emissions, mostly vegetation

Models are different ⇒ Why models are different

- What determines land sink size?
- What causes variations in the location of the land sink?
- How does location of land sink or source impact TCRE, ZEC?

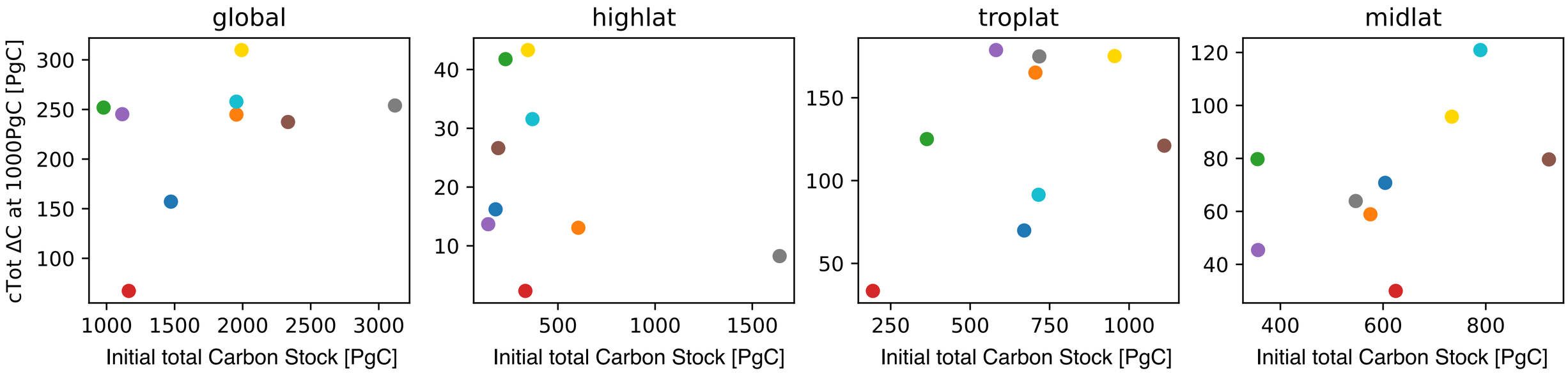
Do initial carbon stocks determine carbon sinks?



Maybe? for carbon gained during emissions phase

ACCESS-ESM1-5
CESM2
GFDL-ESM4
GISS_E2.1
NorESM2-LM
MPI-ESM1-2-LR
CNRM-ESM2-1
HadCM3LC-Bris
UKESM1.2

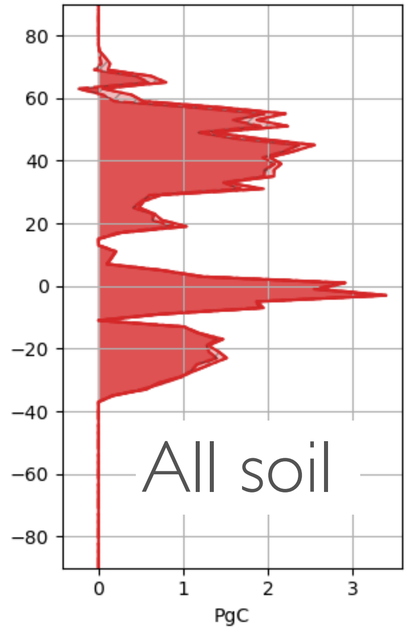
Do initial carbon stocks determine carbon sinks?

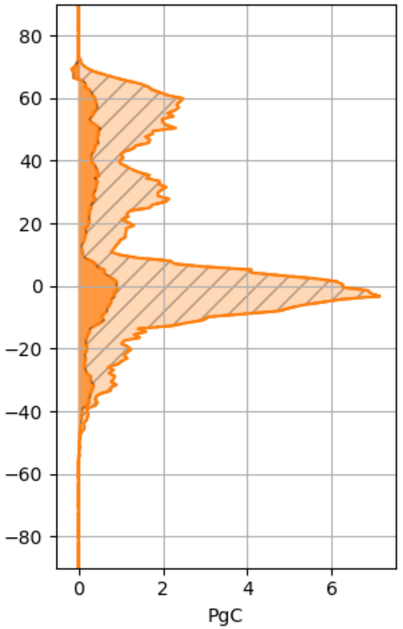


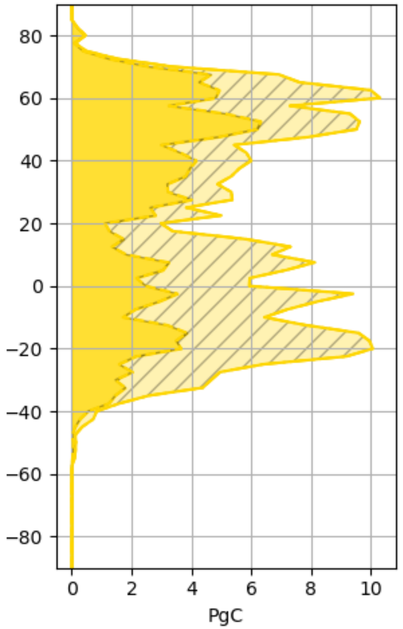
ACCESS-ESM1-5
CESM2
GFDL-ESM4
GISS_E2.1
NorESM2-LM
MPI-ESM1-2-LR
CNRM-ESM2-1
HadCM3LC-Bris
UKESM1.2

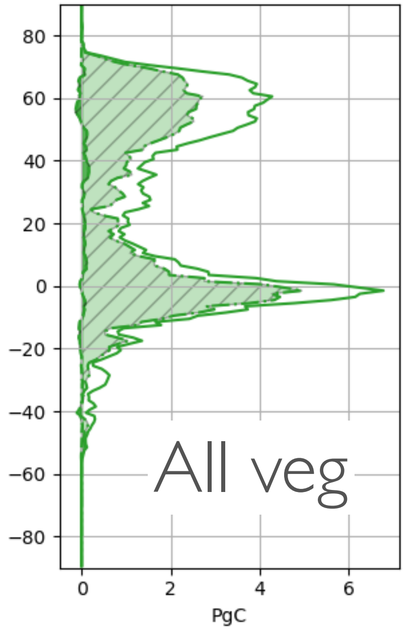
Carbon sink mostly correlates with tropical and midlatitude sinks

Carbon gain during emissions phase [PgC]

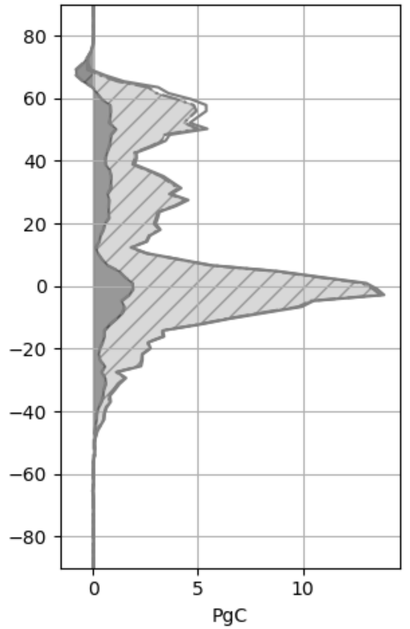


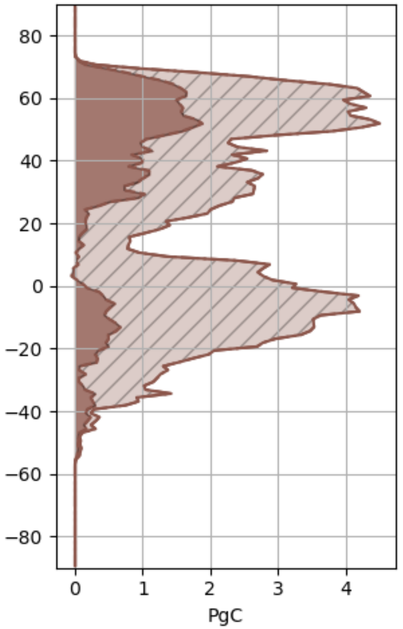


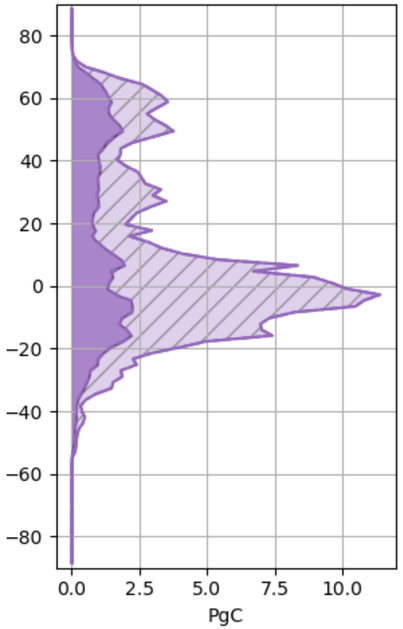


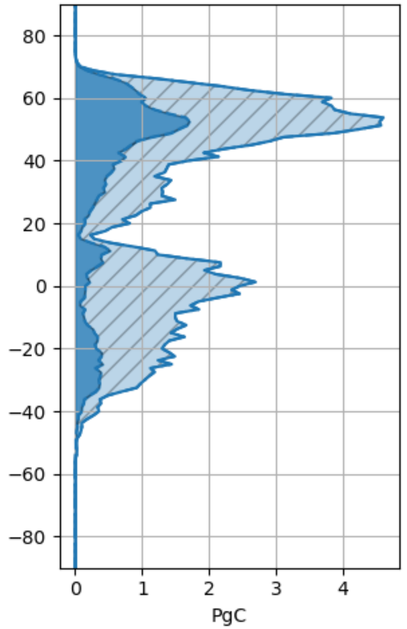


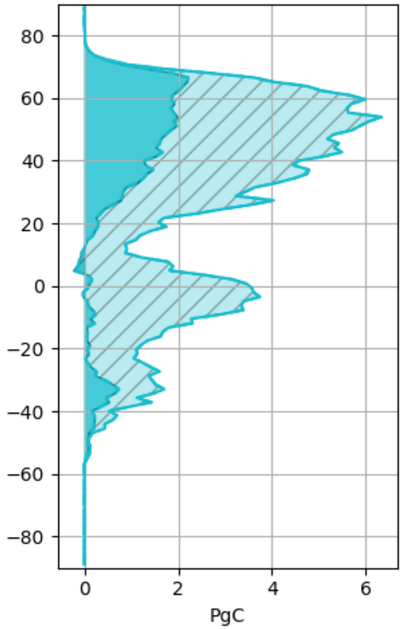
Carbon gain during emissions phase
Vegetation vs. soil varies across models

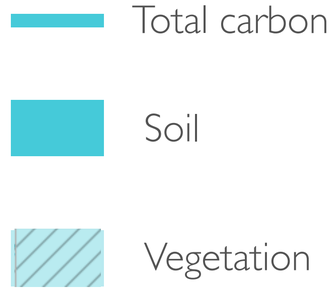




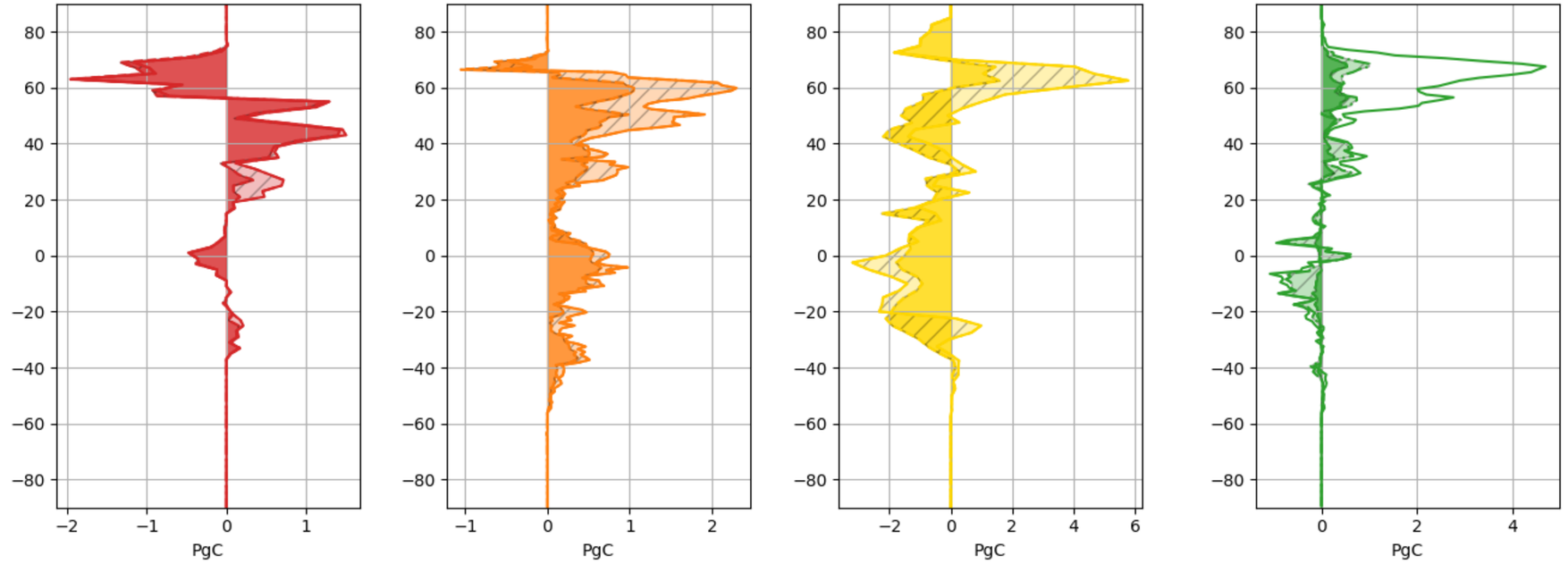




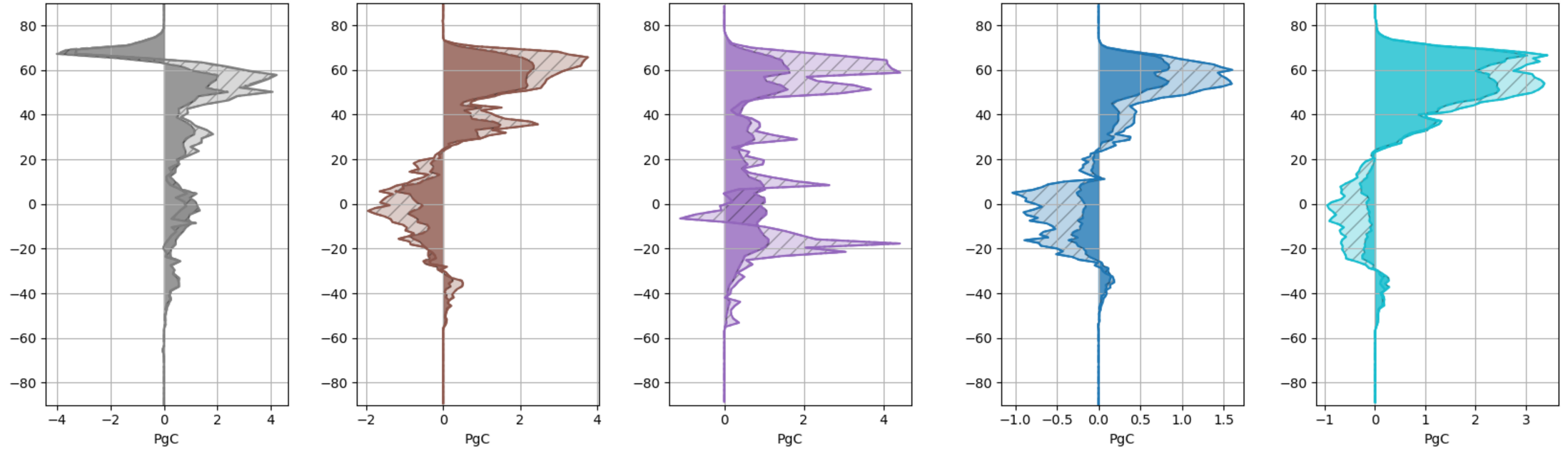




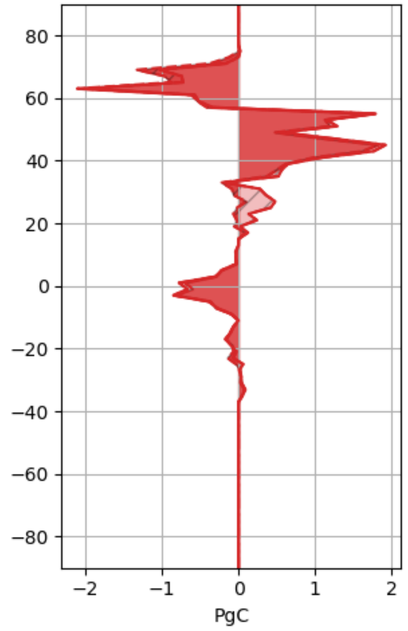
Carbon change during zero emissions [PgC]

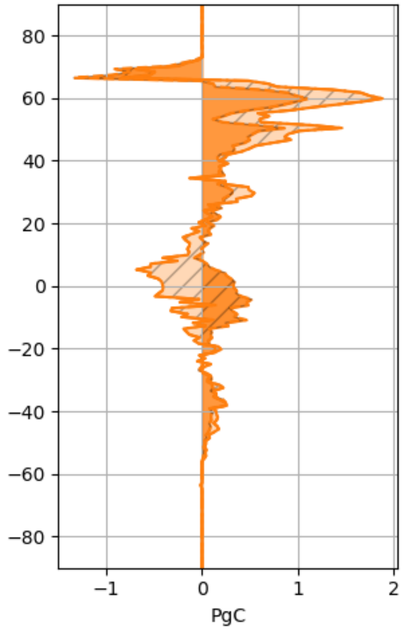


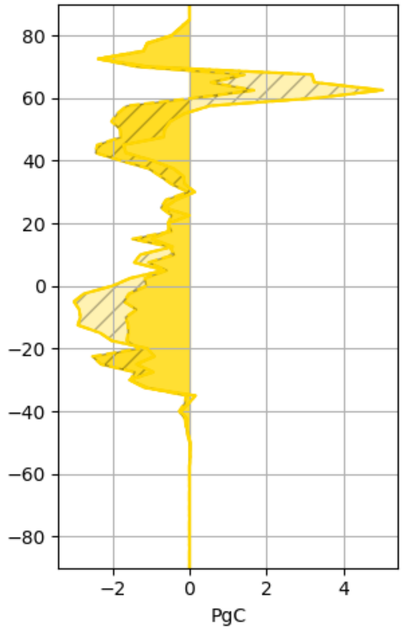
carbon gain in mid and high latitudes in most models

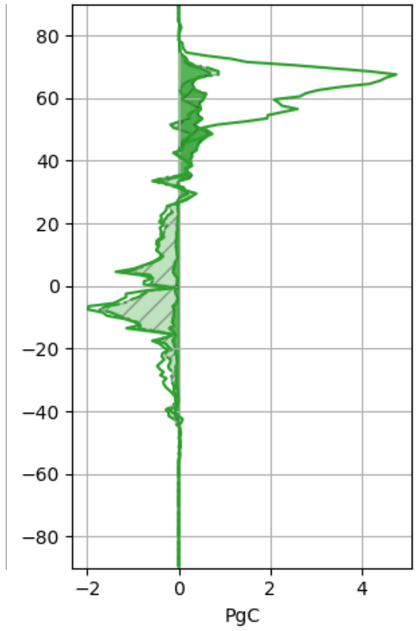


Carbon change after all anthropogenic CO_2 is removed [PgC]



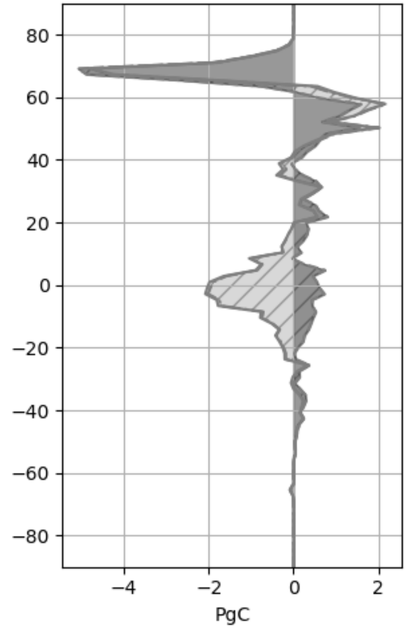


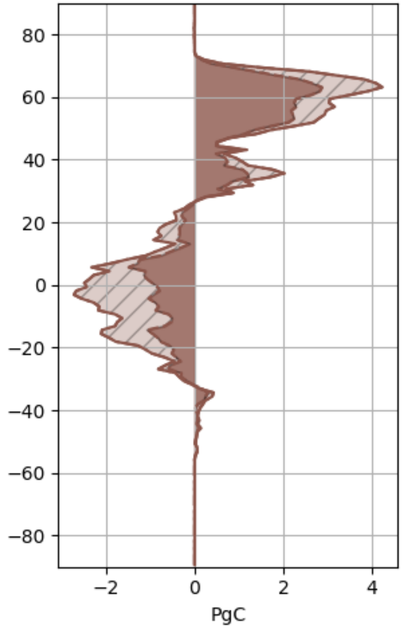


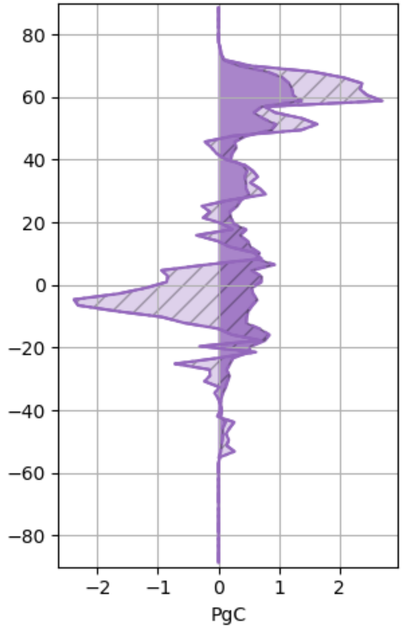


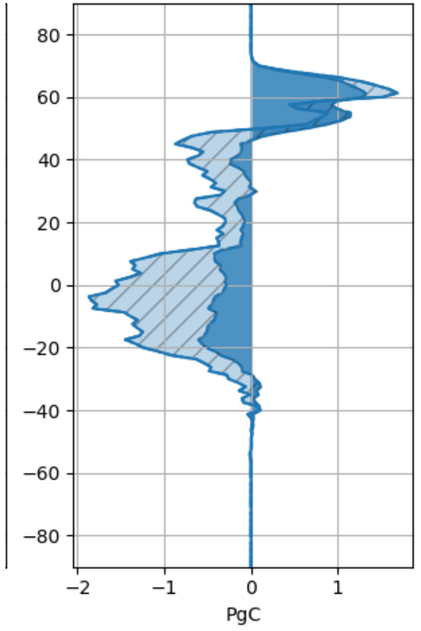
Carbon is generally lost in the tropics

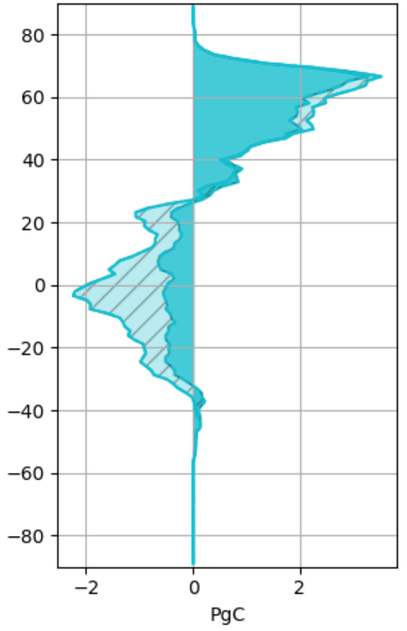
Some models gain carbon at mid and high latitudes









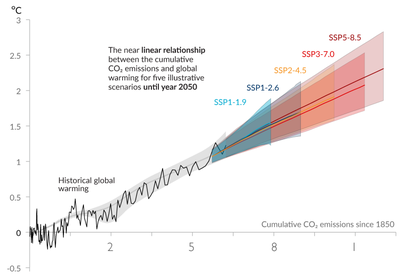


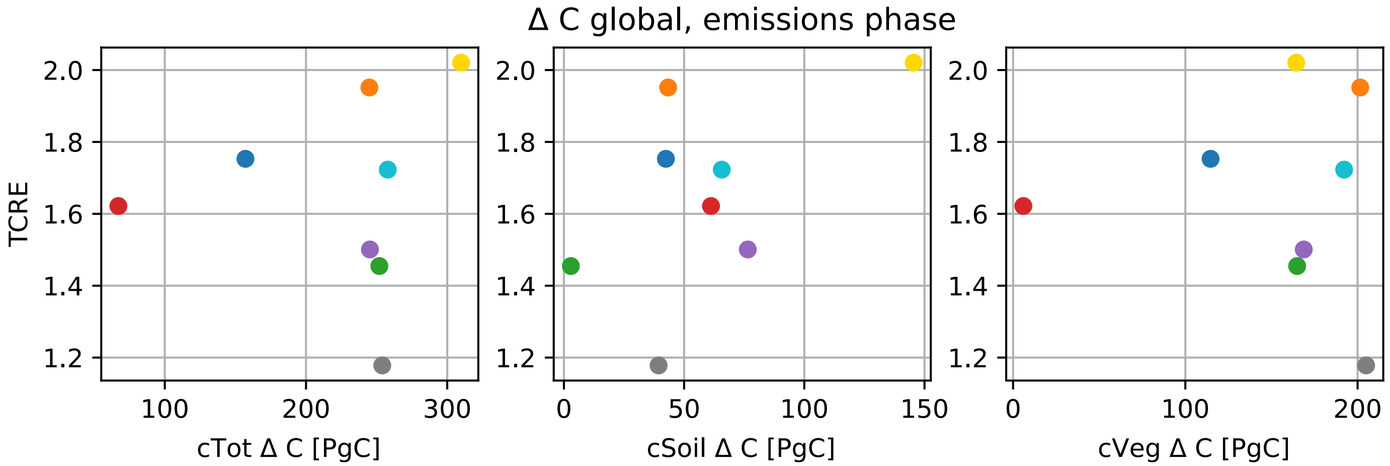
Total carbon

Soil

Vegetation

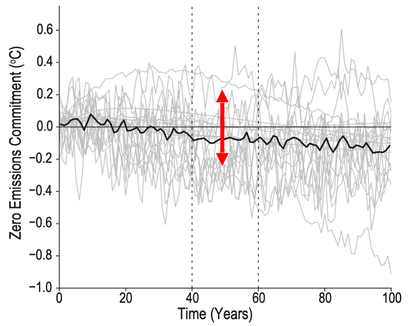
Does TCRE relate to carbon sink during emissions phase?

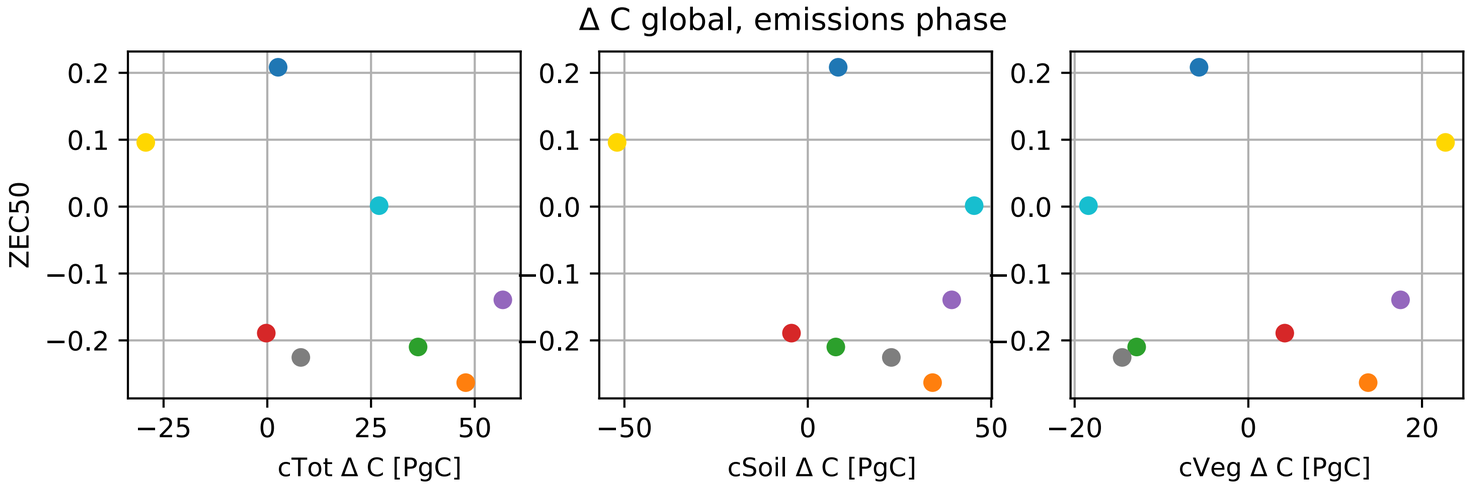




Not really?

Does ZEC relate to carbon sink during zero emissions?

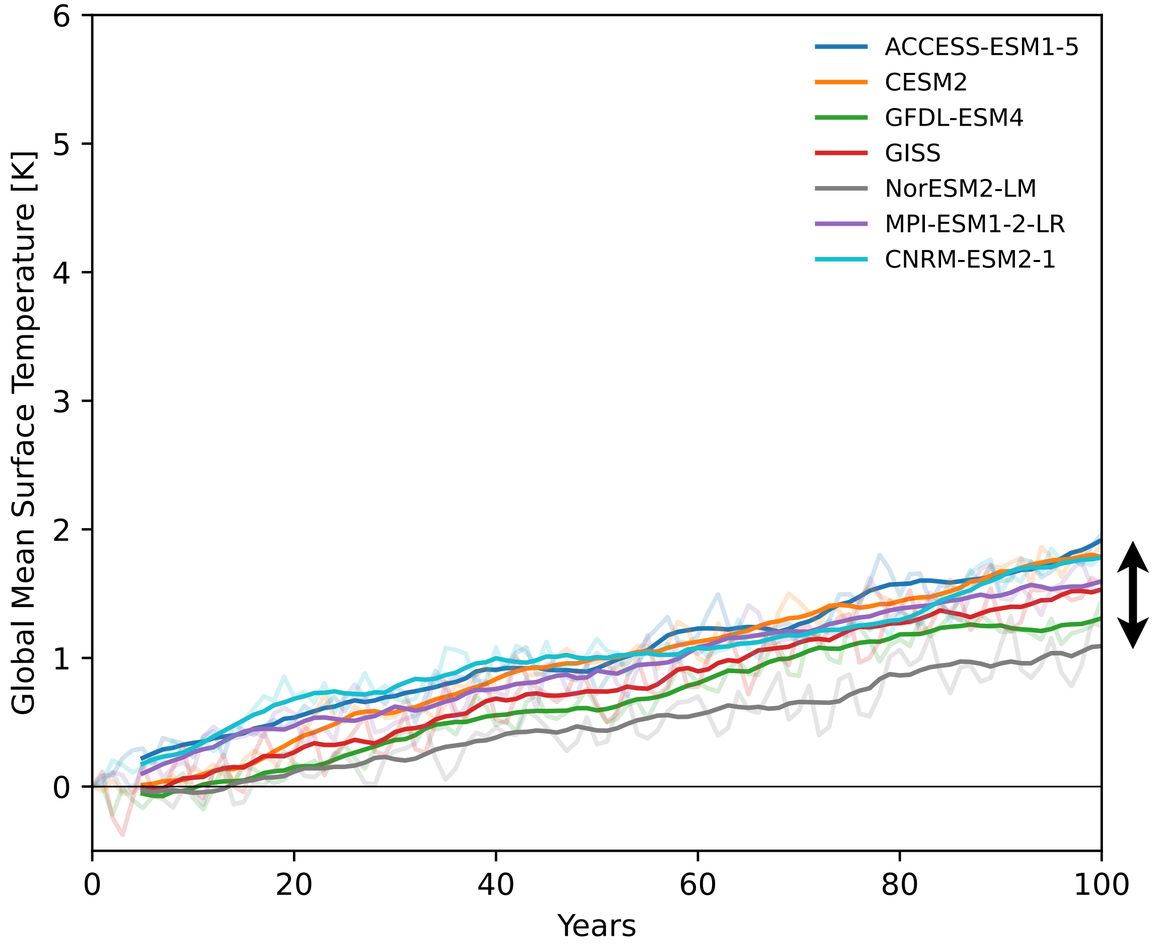




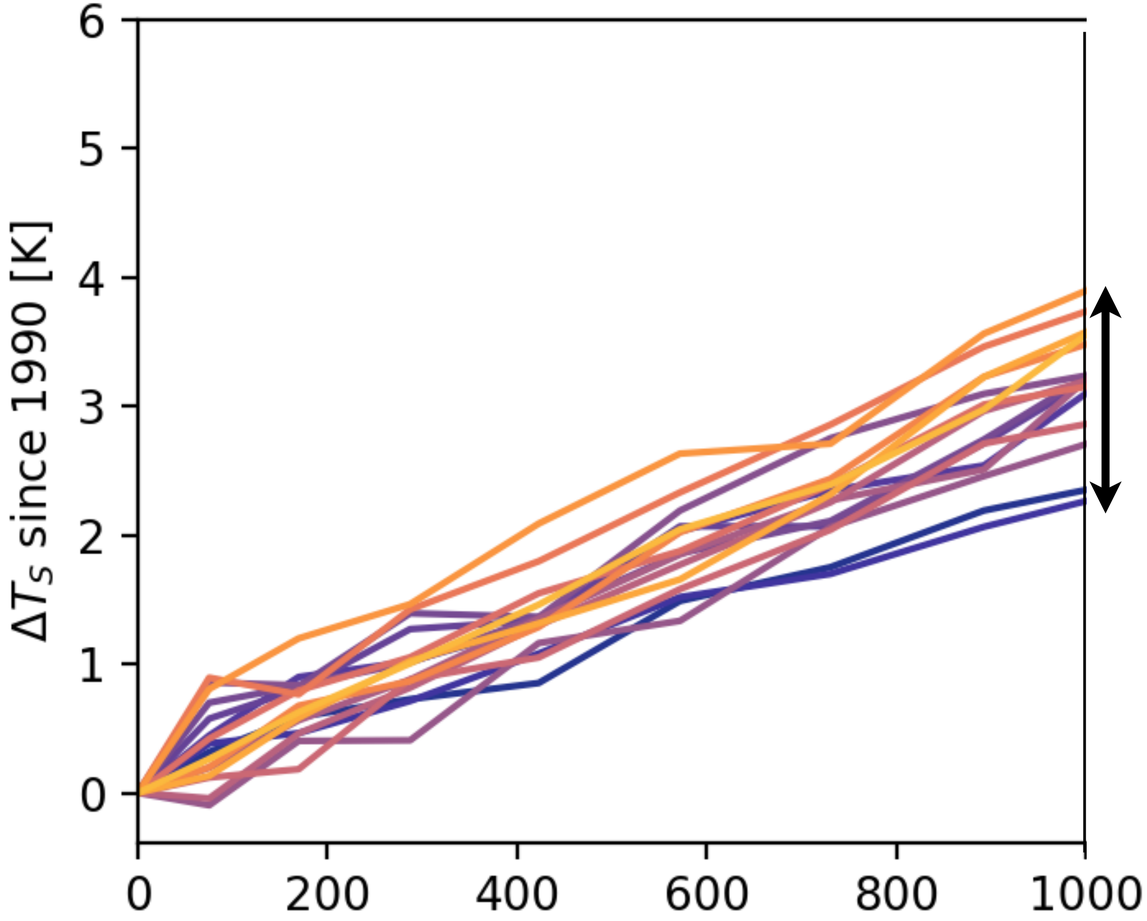
No…

Spread across a PPE is large relative to spread across models

TCRE from flat10MIP



TCRE from HadCM3 PPE



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

Flat10MIP

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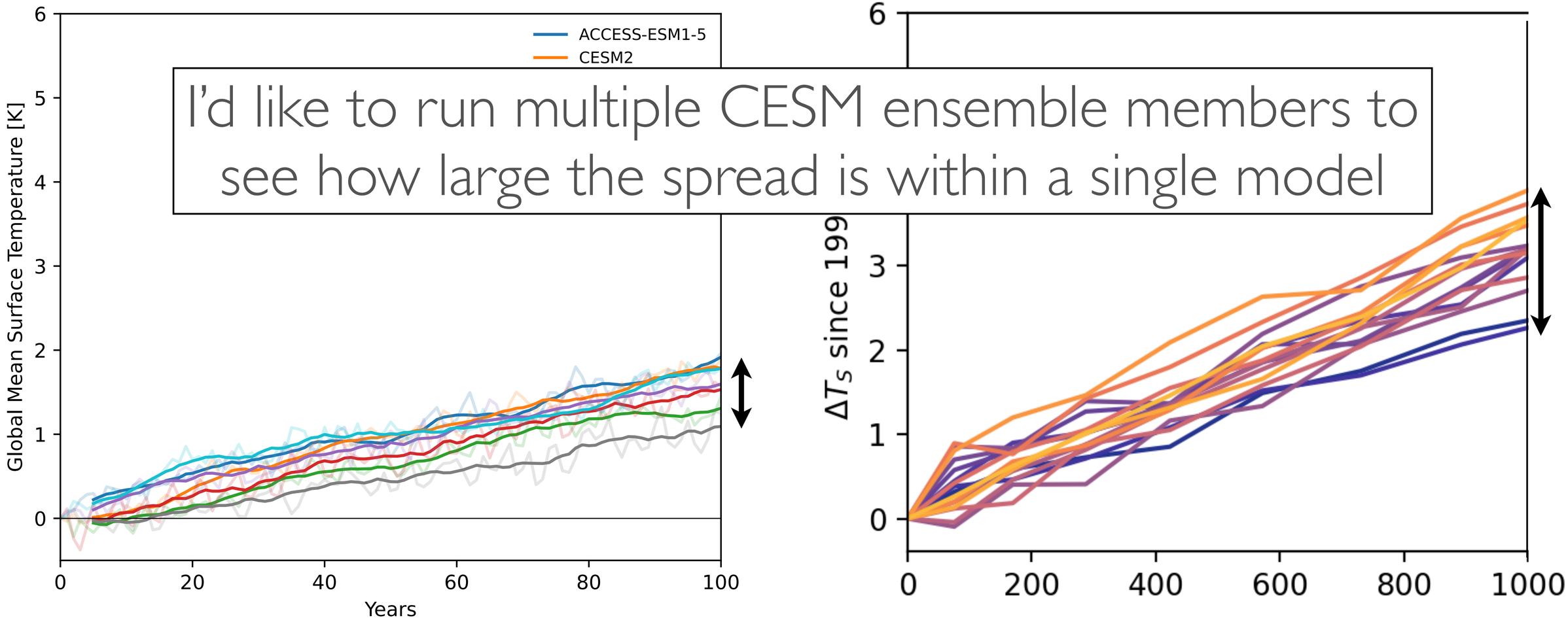
Spread across a PPE is large relative to spread across models

TCRE from flat10MIP

TCRE from HadCM3 PPE

I'd like to run multiple CESM ensemble members to see how large the spread is within a single model



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

Flat10MIP

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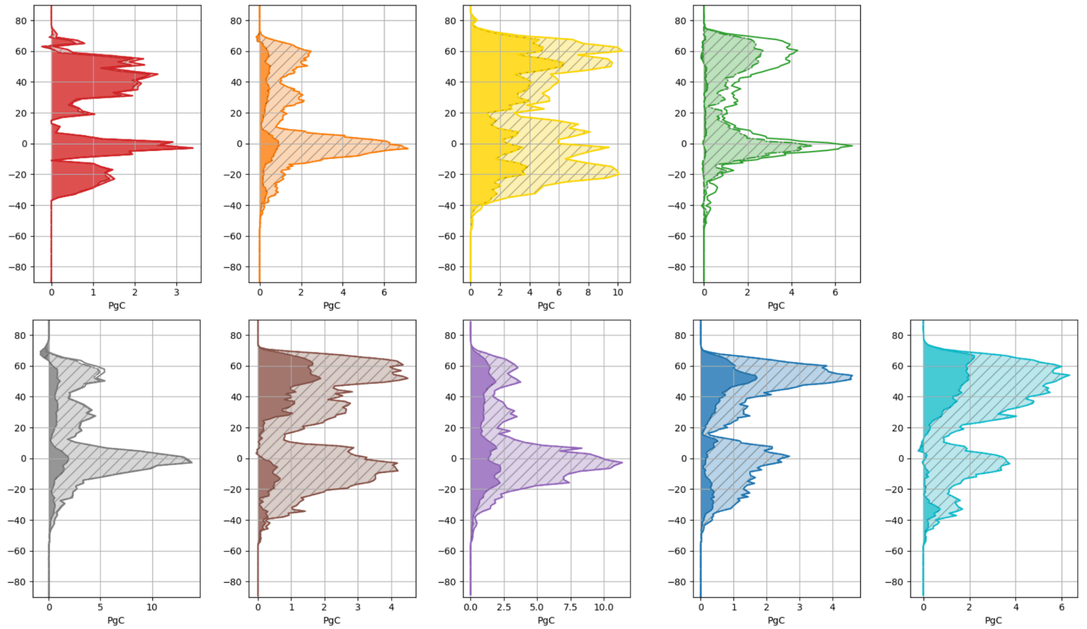
Models are different ⇒ Why models are different

- What determines land sink size?
- What causes variations in the location of the land sink?
- How does location of land sink or source impact TCRE, ZEC?



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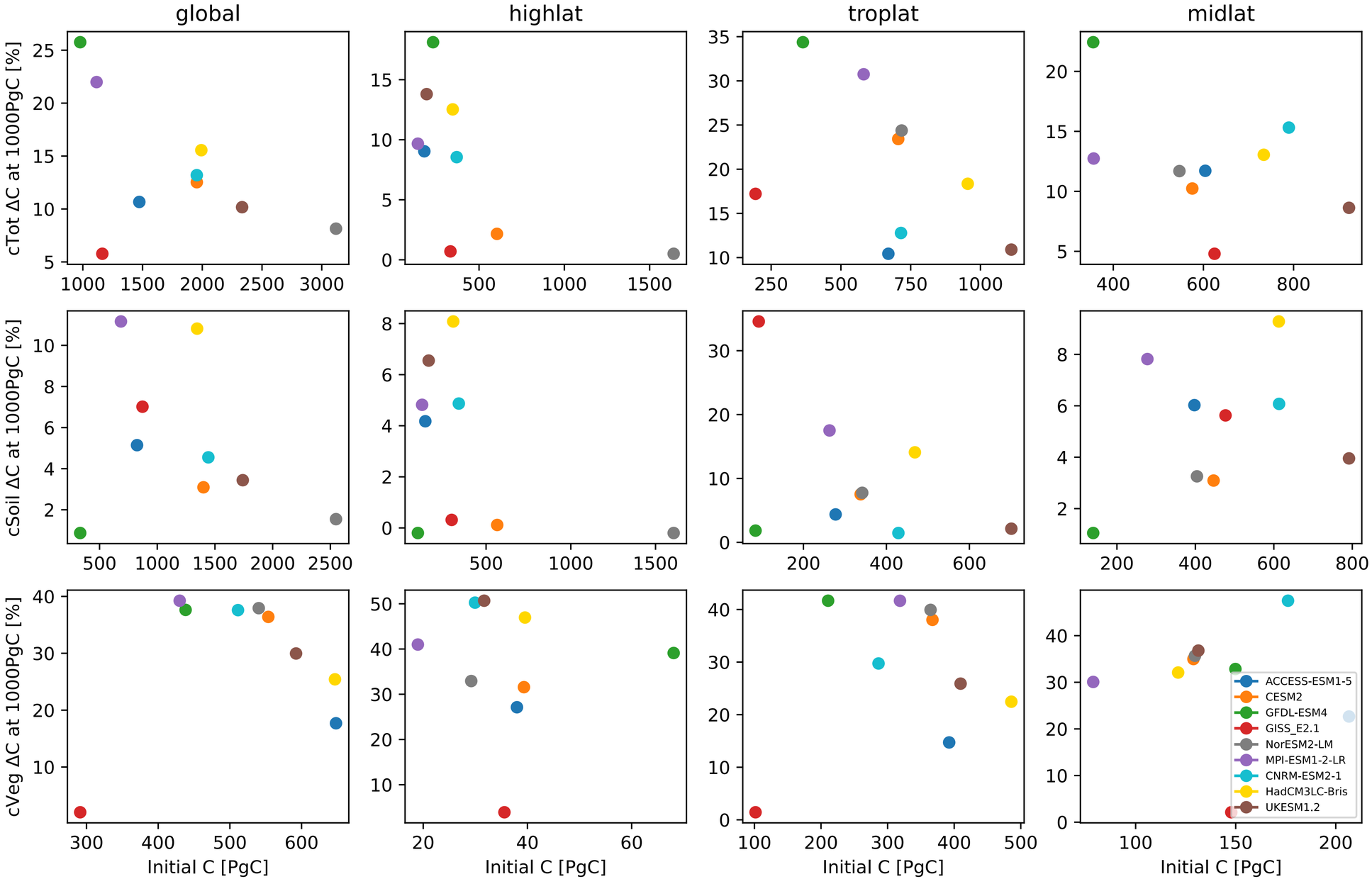
Carbon accumulation during emissions phase



Reversibility