Role of AMOC in ZEC and Reversibility

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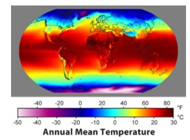
The Flat10 experiment group:

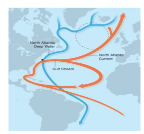
Andrew MacDougall, Jorg Schwinger, Ben Sanderson, Victor Brovkin, Tatiana Ilyina, Hongmei Li, Roland Seferian, Lori Sentman, Jerry Tjiputra and others

Research Questions

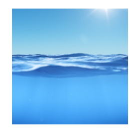
Where does the heat and carbon enter/exit/stored in the ocean?



What is the relative role ocean heat & carbon uptake in GMST change?



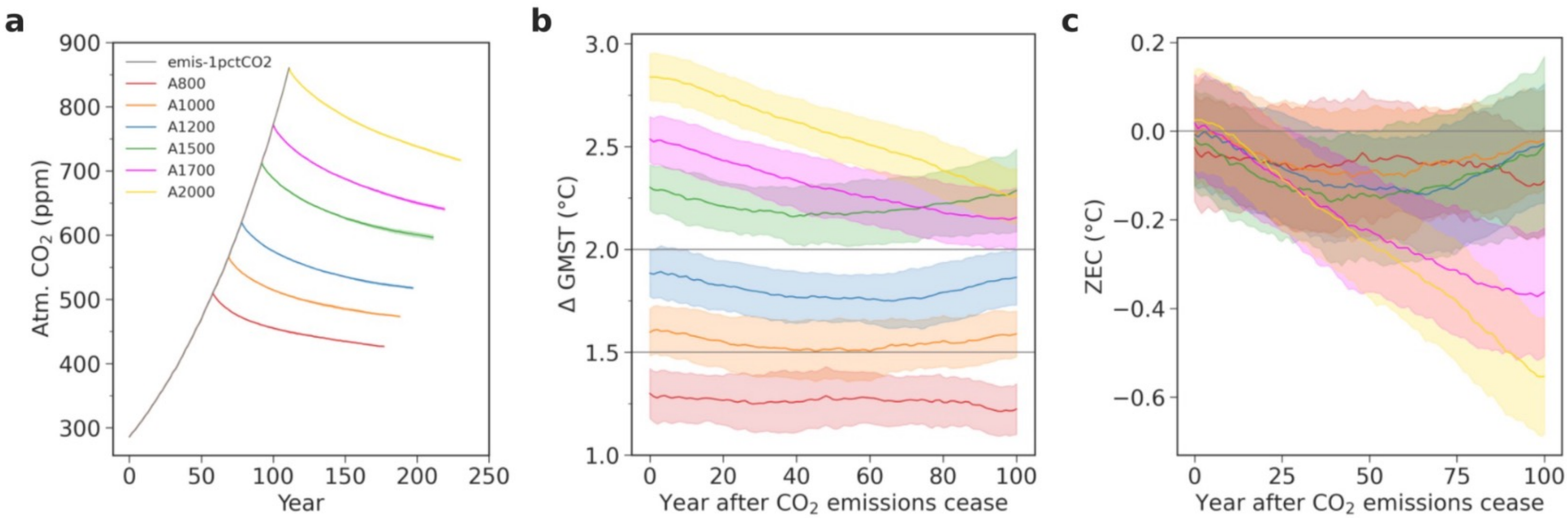
How does ocean heat & carbon uptake vary with AMOC in different models?



What is the ocean's role in climate reversibility?

Under positive, zero or negative emissions

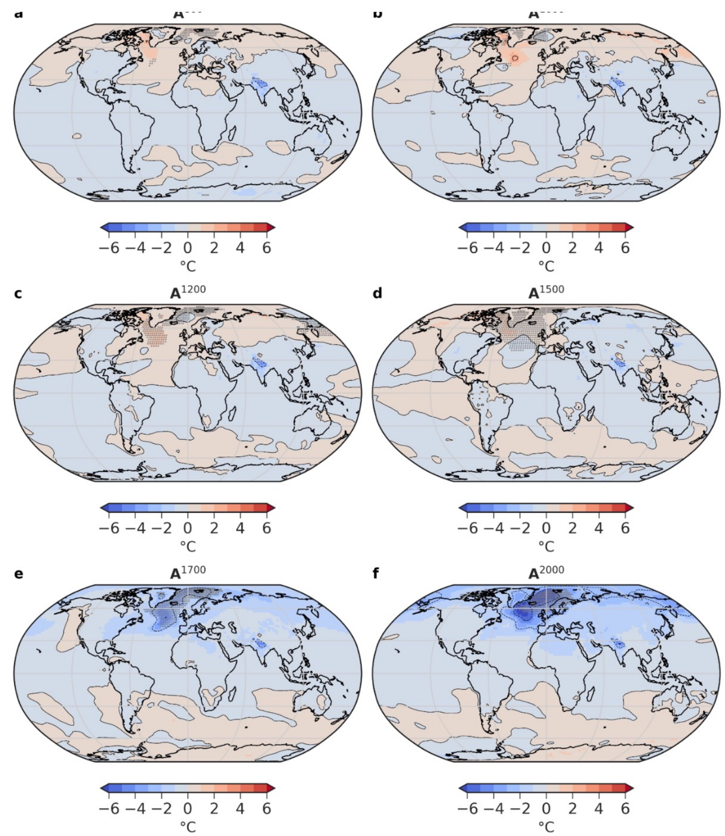
Zero Emissions at different emission levels



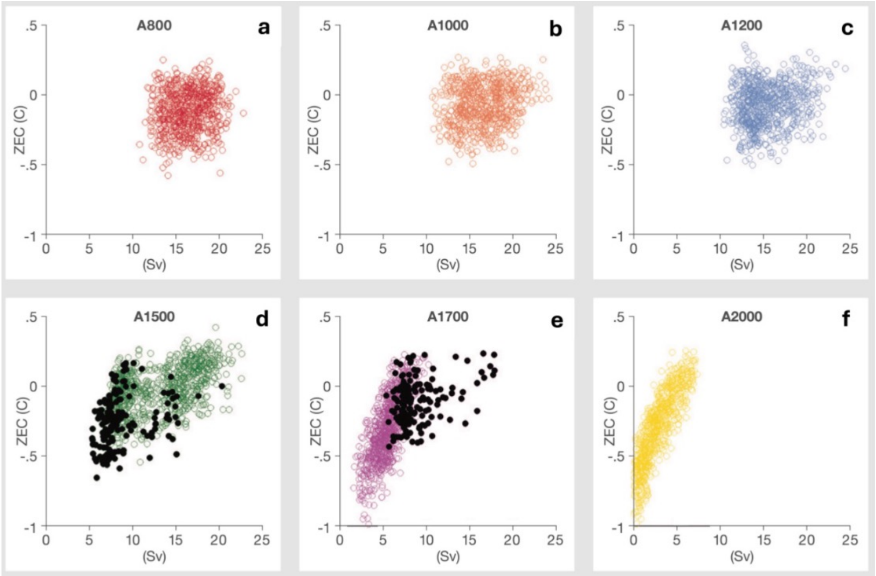
Romanou, Liddy, Lerner, MacDougal, Schwinger, Schmidt, Nature Geosci., in review

Spatial patterns of ZEC100

- Lower scenarios warming in the North Atlantic "**warming dome**"
- Higher scenarios cooling in the North Atlantic and warming in the Southern Ocean "warming hole"

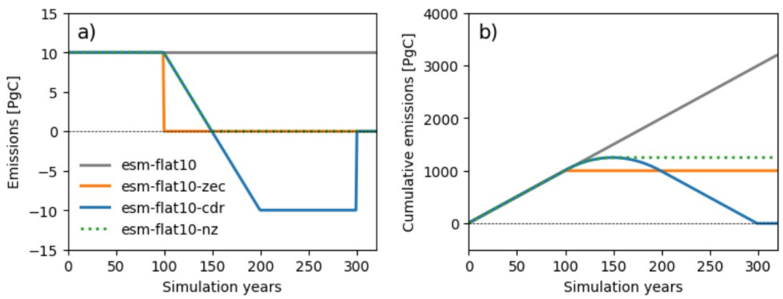


AMOC control at high emission levels



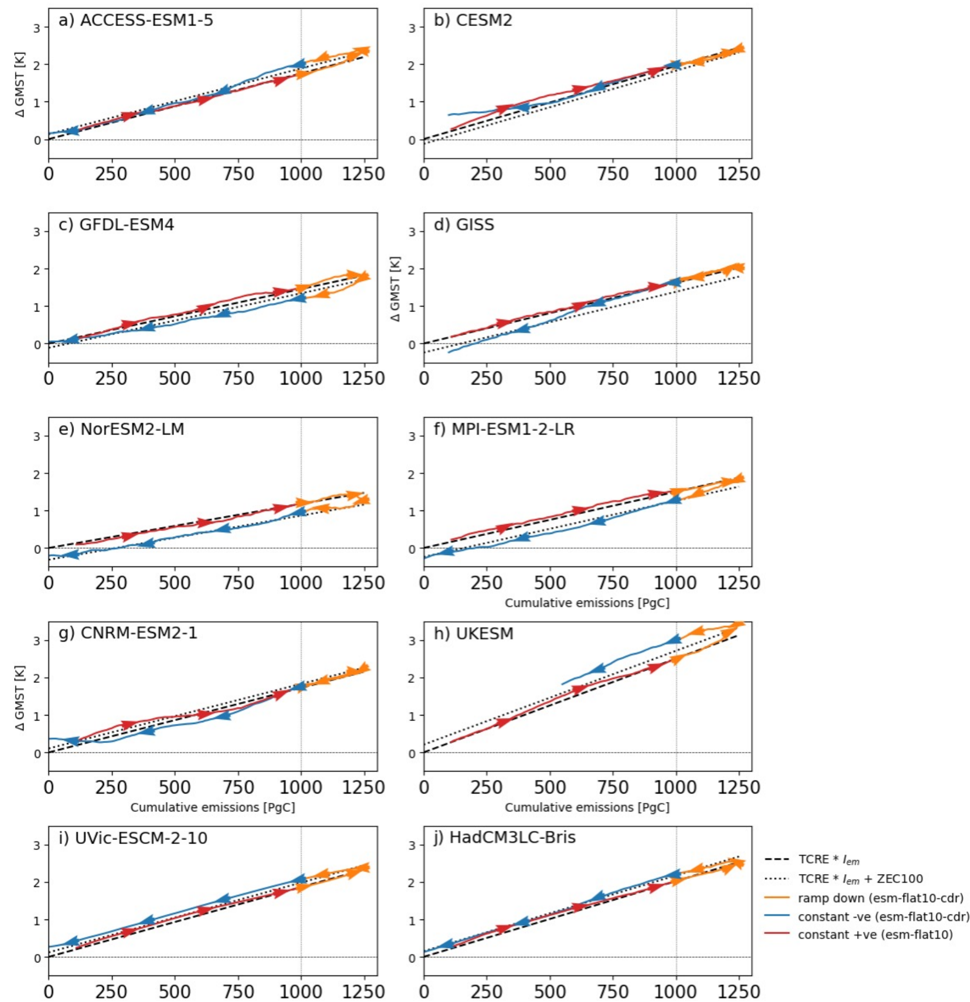
Romanou et al., Nature Geosci., in review

Flat10 Experiments



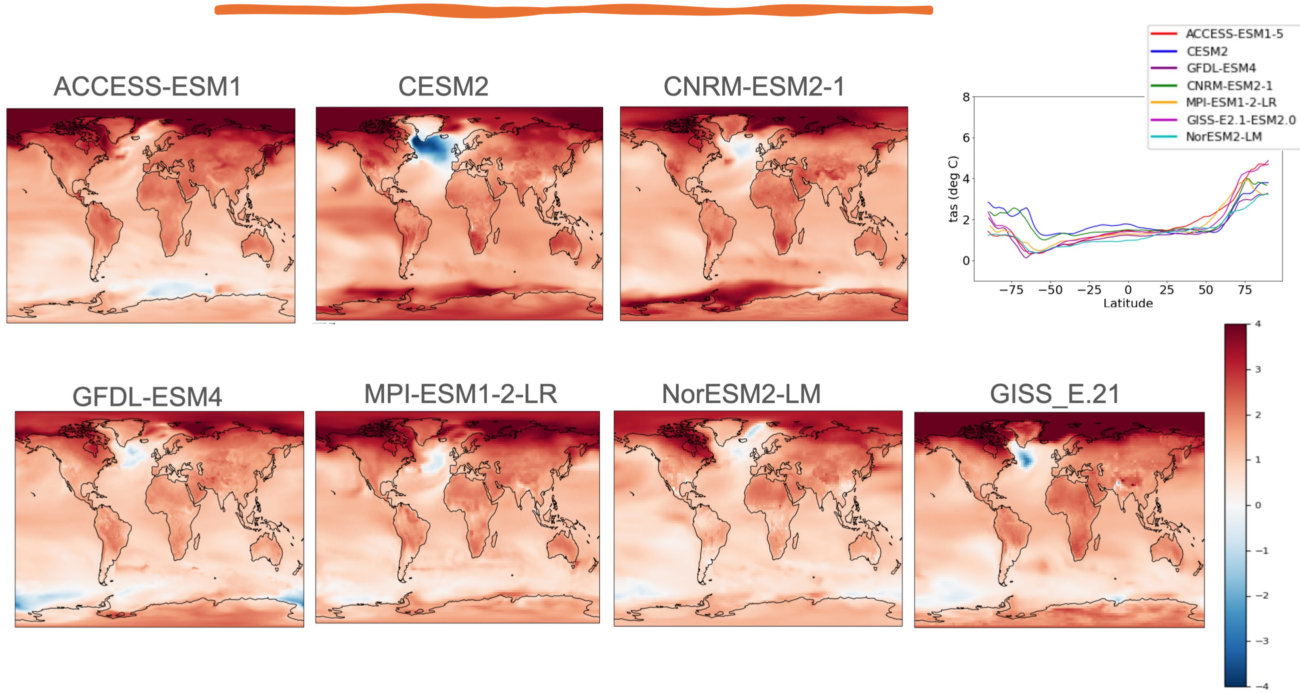
Sanderson et al., Geosci. Model Dev., in press.

Benjamin M. Sanderson[1], Victor Brovkin[2], Rosie A. Fisher[1], David Hohn[3], Tatiana Ilyina[4,5,2], Chris D. Jones[6,7], Torben Koenigk[8], Charles Koven[9], Hongmei Li[5,2], David M. Lawrence[10], Peter Lawrence[10], Spencer Liddicoat[6], Andrew H. MacDougall[11], Nadine Mengis[3], Zebedee Nicholls[12,13,14], Eleanor O'Rourke[15], Anastasia Romanou[16,17], Marit Sandstad[1], Jörg Schwinger[18], Roland Séférian[19], Lori Sentman[20], Isla R. Simpson[10], Chris Smith[13,21], Norman J. Steinert[1], Abigail L. S. Swann[22], Jerry Tjiputra[18], Tilo Ziehn[23]



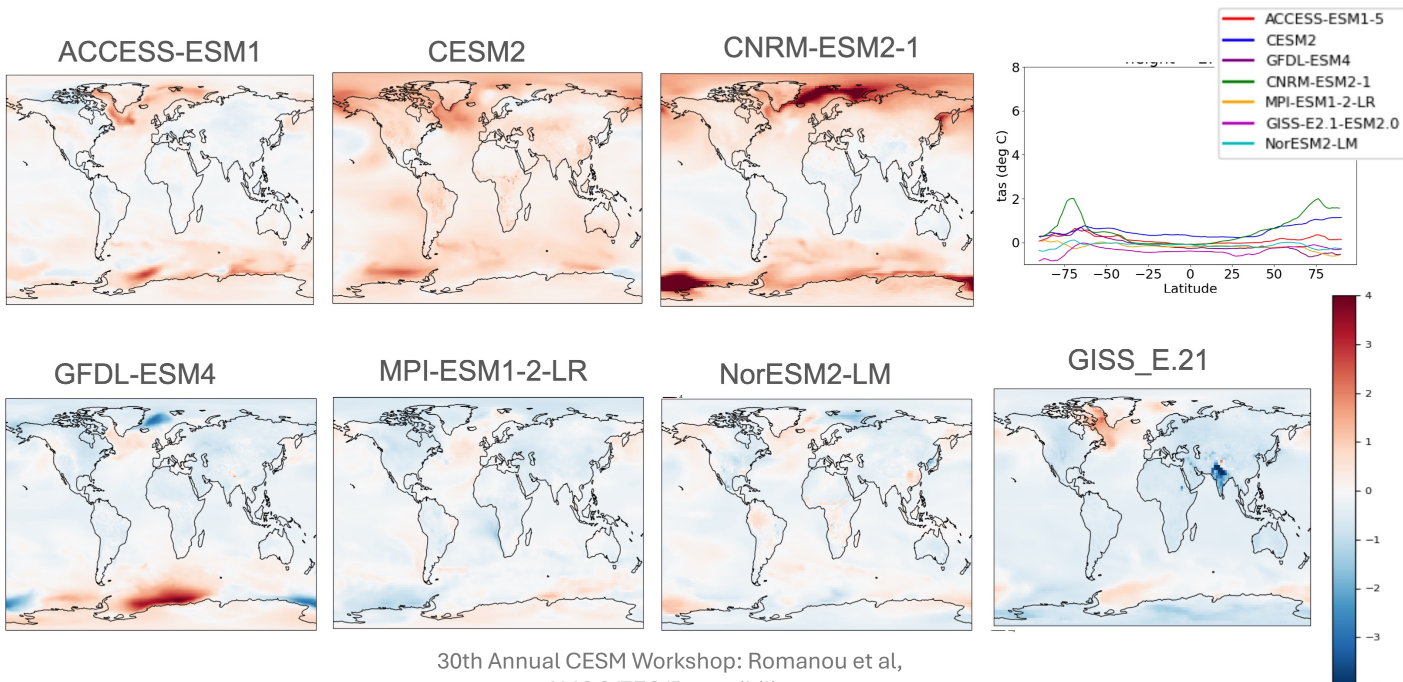
Surface Air Temperature change from PI (year 100 of Flat10)

“warming hole”

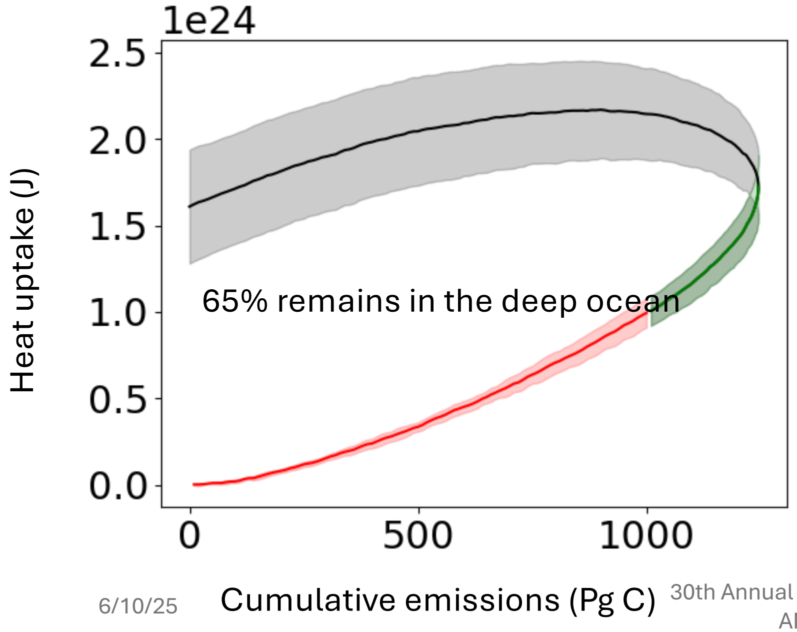


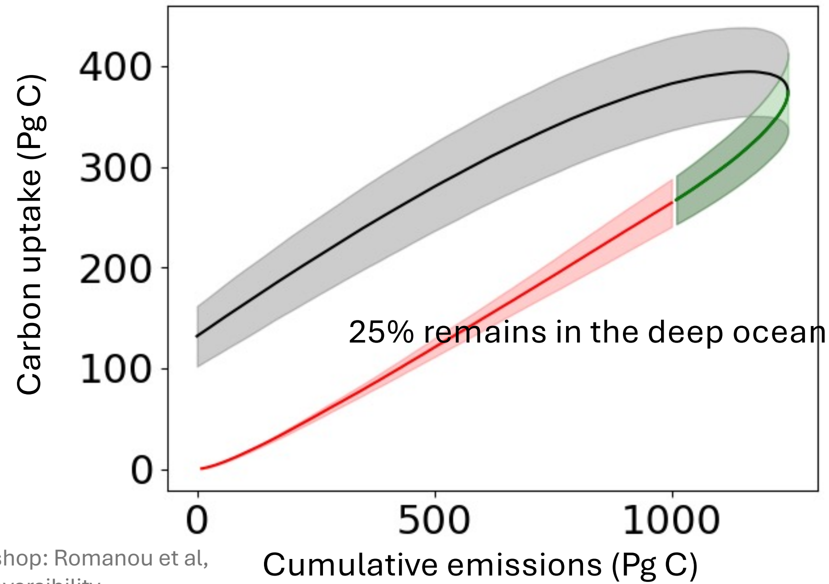
Surface Air Temperature change from PI (year 200 of Flat10cdr)

“warming dpme”

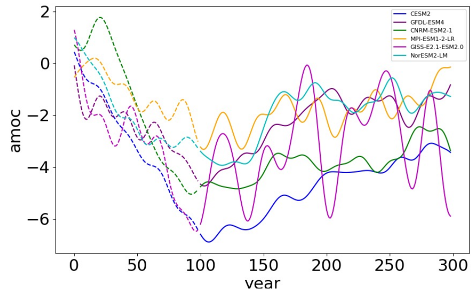


Heat and Carbon storage anomaly from PI

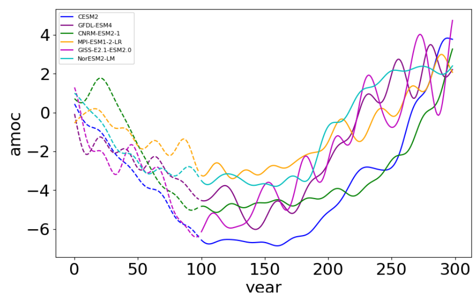




Role of AMOC



CESM2
GFDL-ESM4
CNRM-ESM2-1
MPI-ESM1-2-LR
GISS-E2.1-ESM2.0
NorESM2-LM
amoc
year



CESM2
GFDL-ESM4
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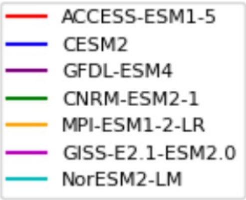
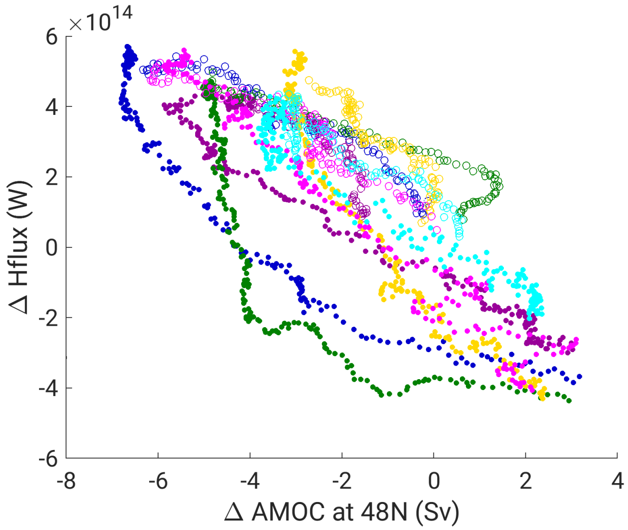
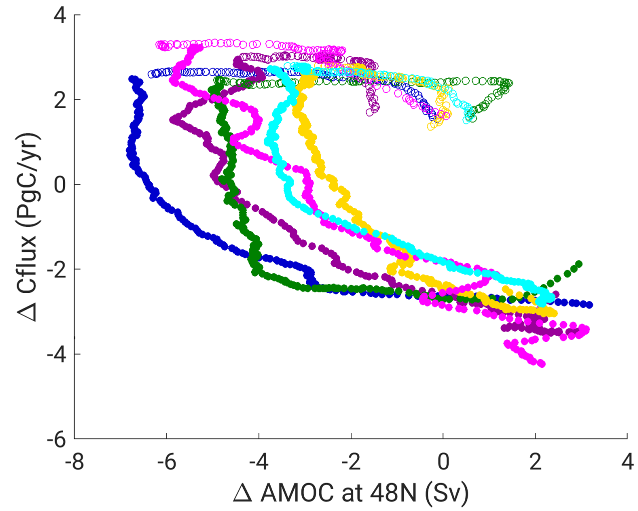


ACCESS-ESM1-5
CESM2
GFDL-ESM4
CNRM-ESM2-1
MPI-ESM1-2-LR
GISS-E2.1-ESM2.0
NorESM2-LM

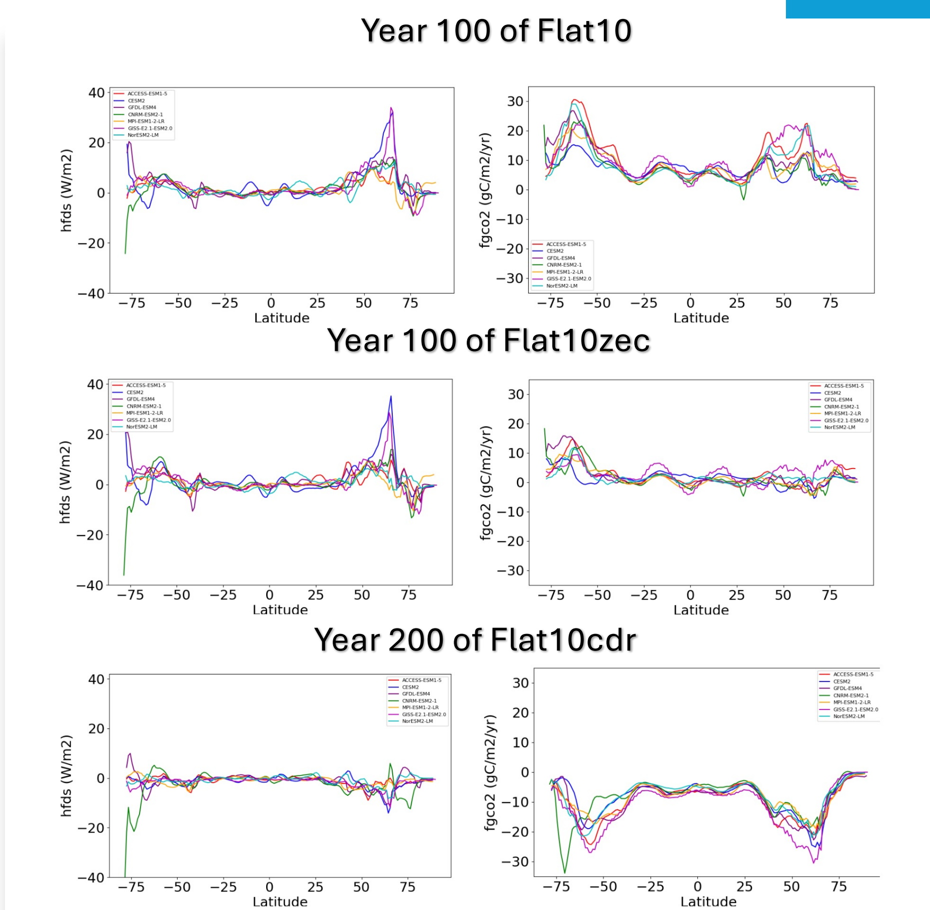


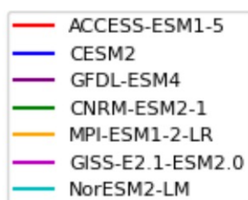
$\times 10^{14}$
Δ Hflux (W)
Δ AMOC at 48N (Sv)



Δ Cflux (PgC/yr)
Δ AMOC at 48N (Sv)

Heat and carbon flux anomaly from PI





The relative role of heat and carbon uptake in the radiative cooling of the planet

$$\lambda(T - T_0) = -R\int_{t=t_0}^{\infty}\frac{f_O}{C_A}\,dt - R\int_{t=t_0}^{\infty}\frac{f_L}{C_A}\,dt \;-\epsilon(N - N_0) + R\int_{t=t_0}^{\infty}\frac{F_{EMISSIONS}}{C_A}\,dt$$

carbon uptake contribution

heat uptake contribution

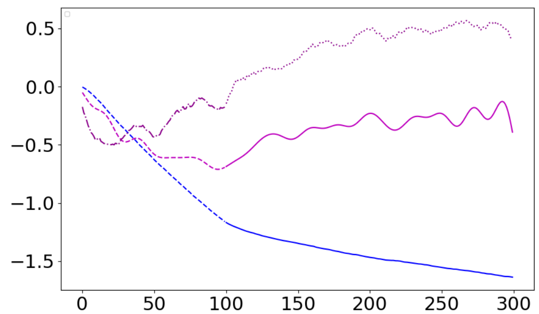
*ϵ obtained from MacDougal et al., 2020; Romanou et al., in review: non-constancy of ϵ

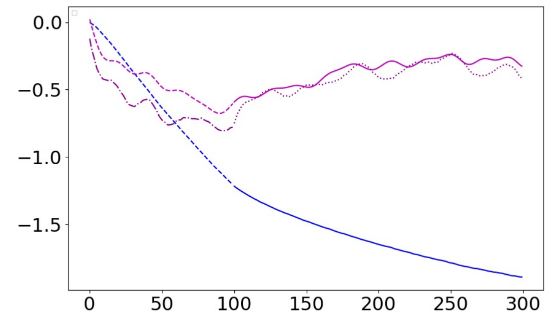
Contributions to ΔTsurf

Ocean carbon uptake
Ocean heat uptake
Ocean heat uptake: efficacy matching TAS

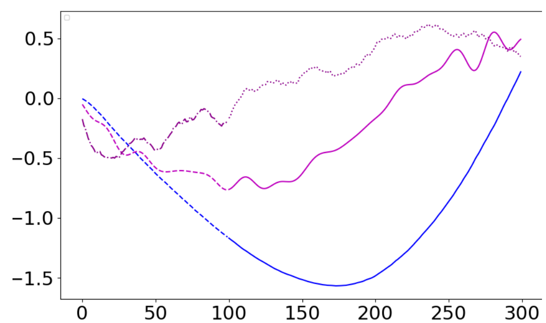
GFDL-ESM4 | GISS-E2.1-CC

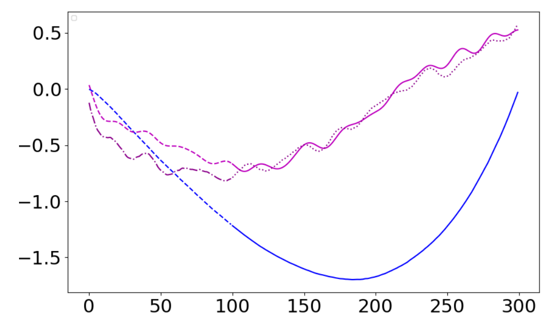
Flat10+Flat10zec





Flat10+Flat10cdr





Summary

During positive emissions, heat and carbon enter through the North Atlantic and the Southern Ocean sinks

During stabilization: heat is taken up in the North Atlantic, but carbon mainly in the Southern Ocean

During negative emissions: North Atlantic is a source of heat and carbon

Net storage of heat and carbon occurs below 1000m; 65% heat; 25% carbon

During positive emissions heat and carbon uptake contribute equally to the global mean temperature change

During stabilization, heat uptake is reduced but carbon uptake cools the planet

During negative emissions, heat uptake and carbon uptake contribute less to cooling of the planet