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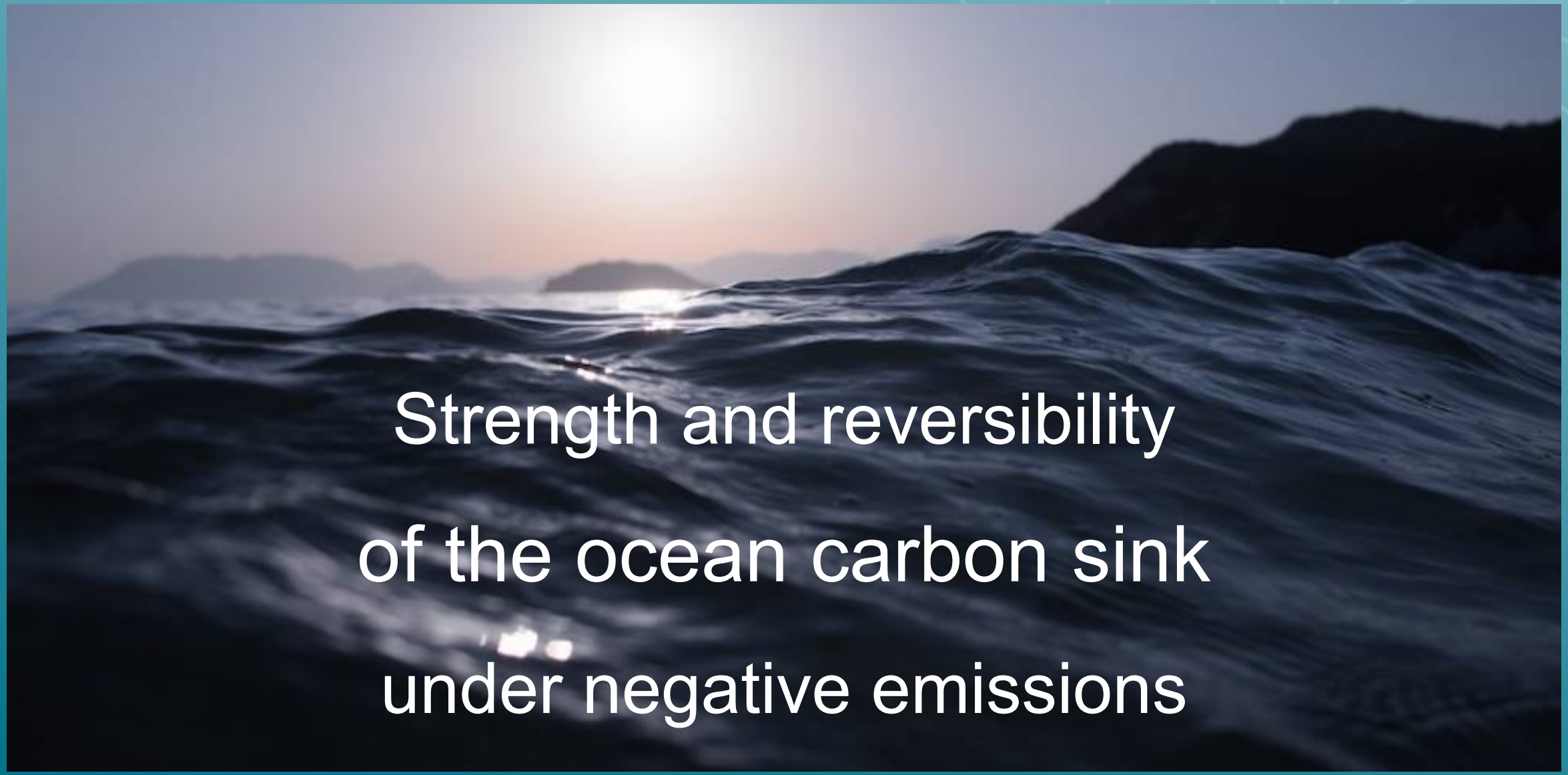
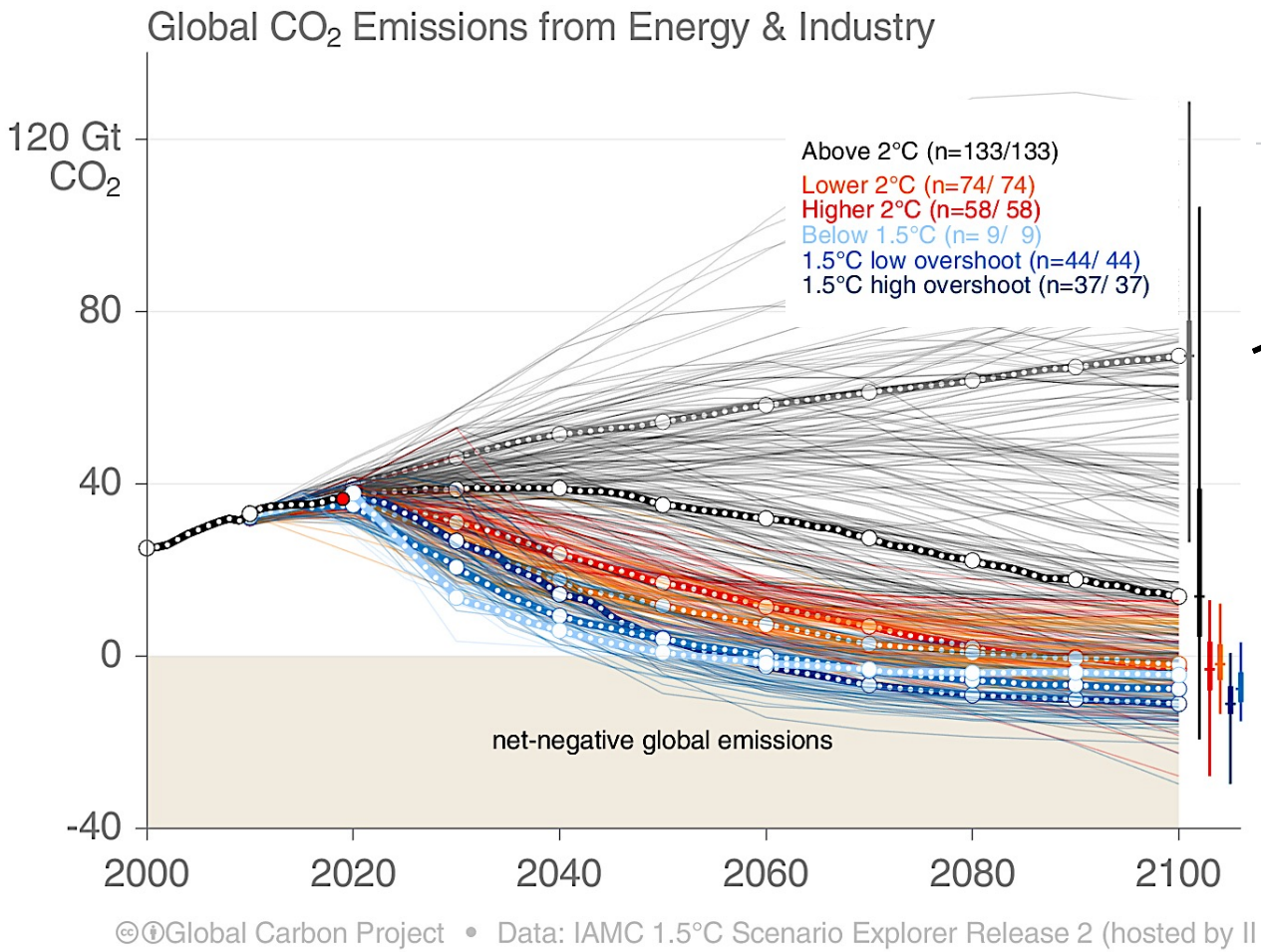
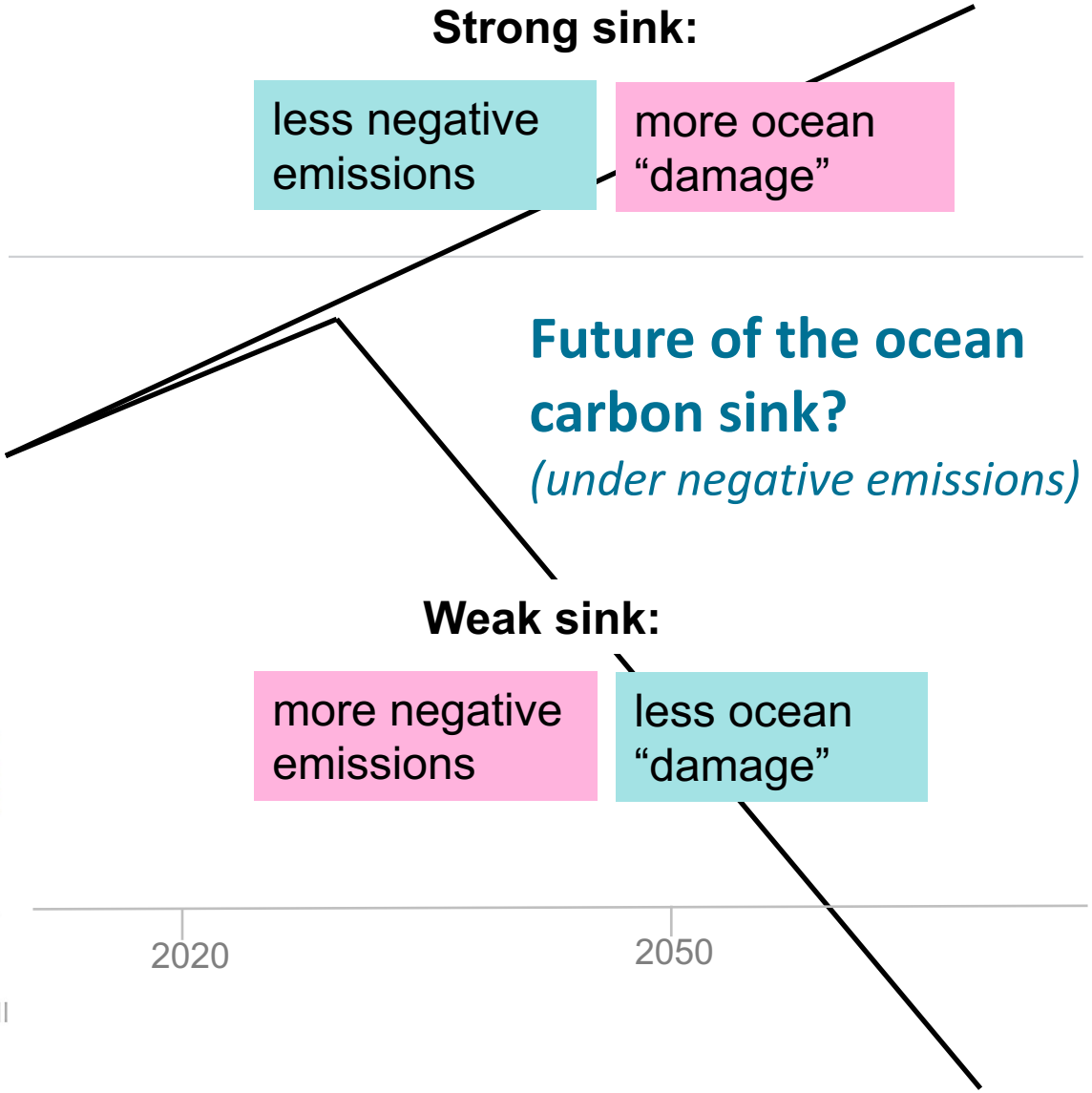


Strength and reversibility of the ocean carbon sink under negative emissions

NADINE GORIS (NADINE.GORIS@NORCERESEARCH.NO), J. TJIPUTRA, J. SCHWINGER, I. PILSKOG

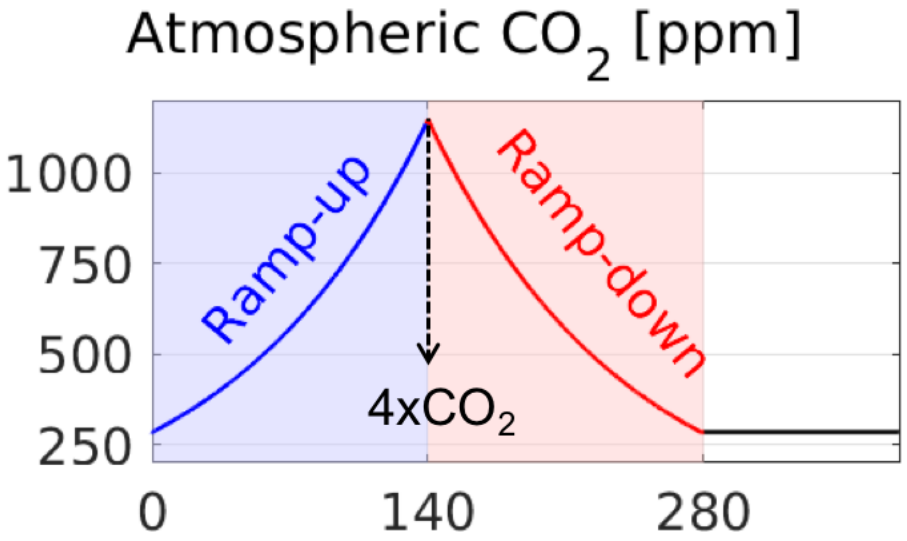
IPCC Special Report on “Global Warming of 1.5°C”





Net emissions include those from bioenergy with carbon capture and storage (BECCS).
Source: Huppmann et al 2018; IAMC 1.5C Scenario Database; IPCC SR15; Global Carbon Budget 2019

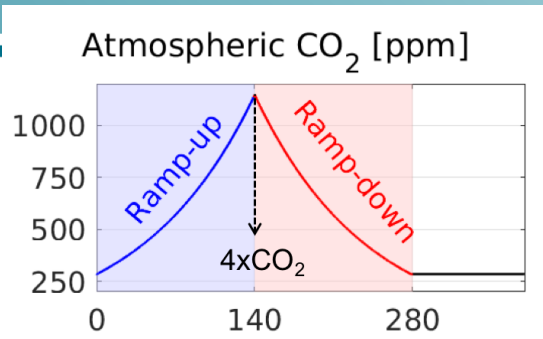
Experimental set-up

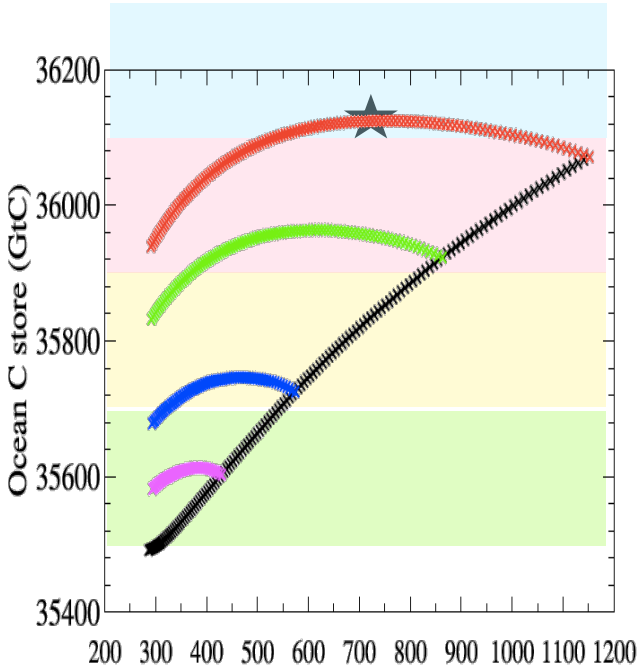


- Idealized experiment: 'Climate and carbon reversibility experiment' (part of CDRMIP/ CMIP6)
- Our Model: Norwegian Earth System Model, NorESM1-ME

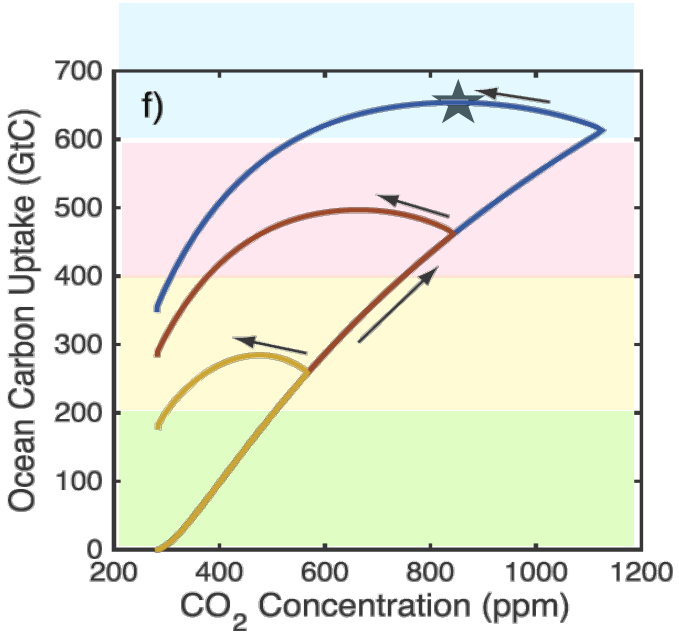
Global results: large degree of uncertainty

both in the amount of carbon taken up by the oceans during Ramp-up
and in the amount of carbon released by the oceans during Ramp-down

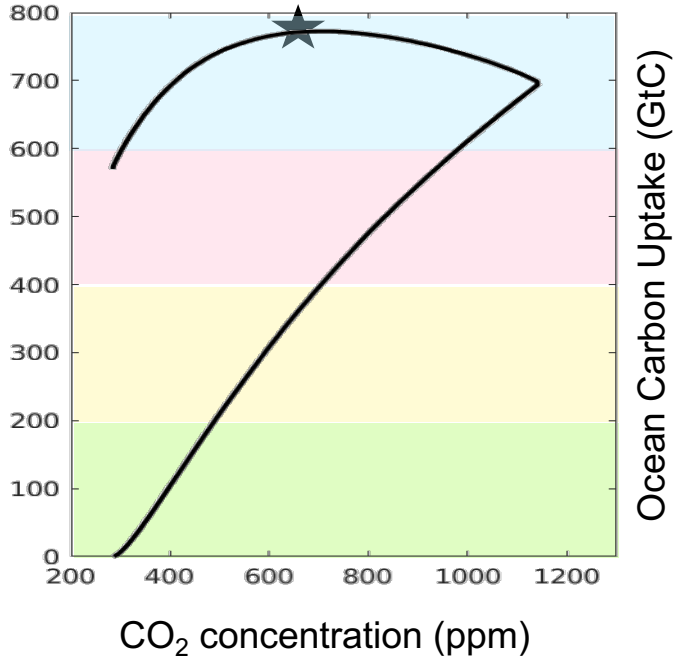




Boucher et al., 2012
(upper curve = 4xCO_2)



Zickfeld et al., 2016
(upper curve = 4xCO_2)



This study
(4xCO_2)

The large uncertainty points toward the need for better understanding of the processes involved

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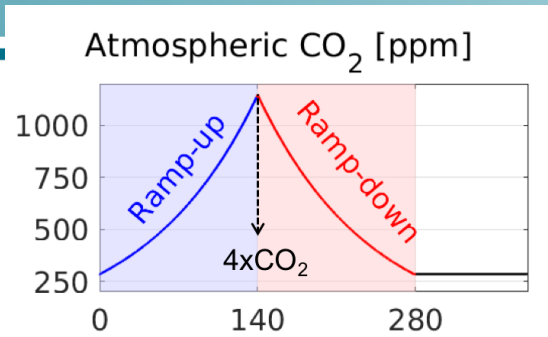
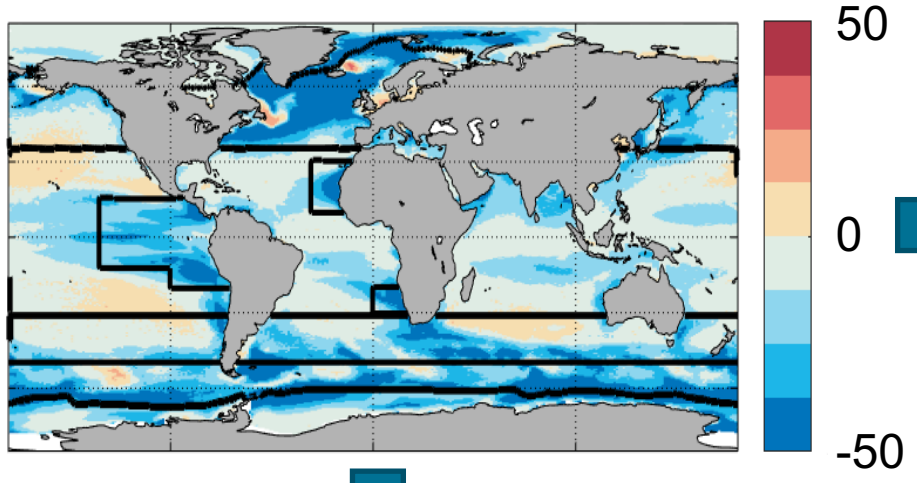
Analysis of our model-simulation

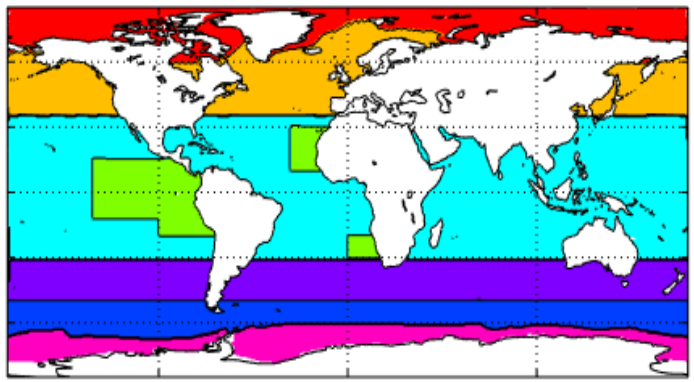


Δ Sea-Air CO_2-flux [mol C/m^2/yr], Ramp-up

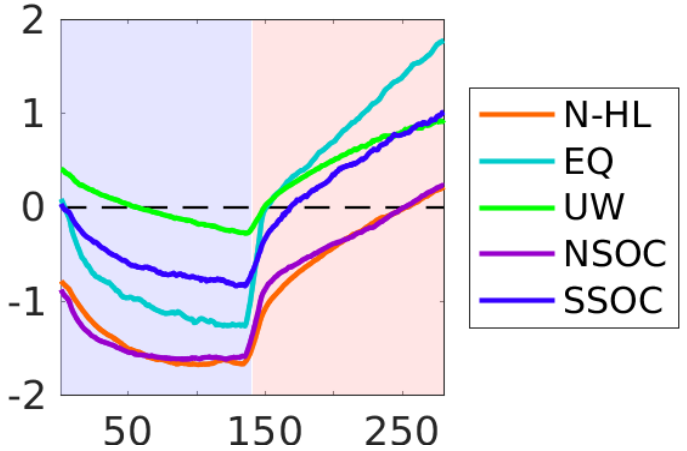


During Ramp-up/ Ramp-down, our model shows the most increase/decrease in carbon uptake in **high latitudes and upwelling regions** (per m^2).

Area-Mask used in this study



Sea-Air CO_2-flux [Pg/yr]

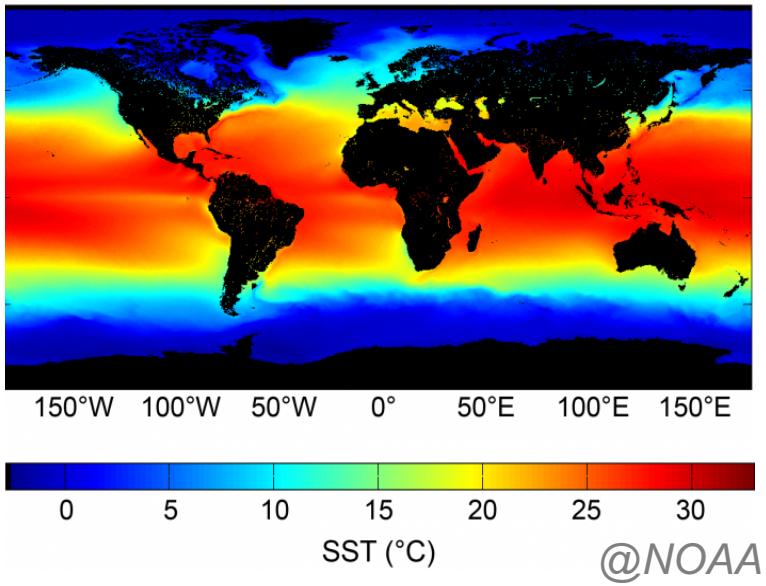


Analysis of our model-simulation:

Ocean carbon uptake is to first instance dependent on:

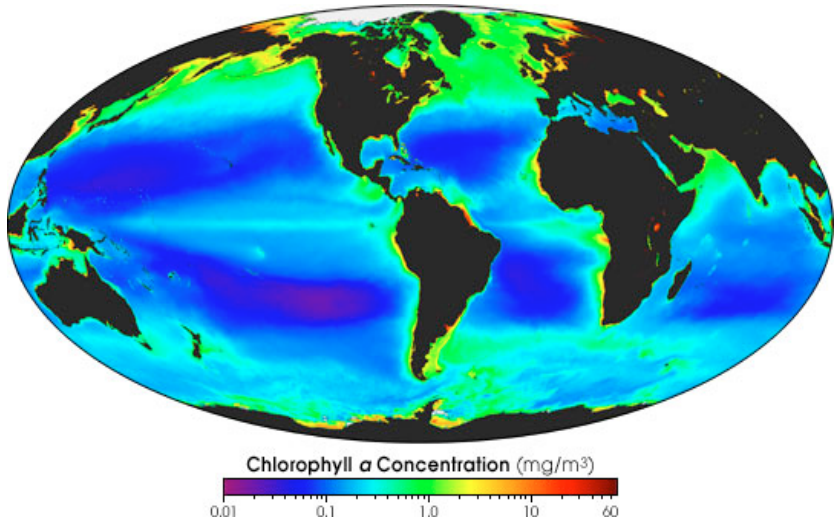
- sea surface temperature (more uptake in colder waters)
- surface concentration of dissolved inorganic carbon (more uptake when there is less DIC)

Coldest in high latitudes/ Winter



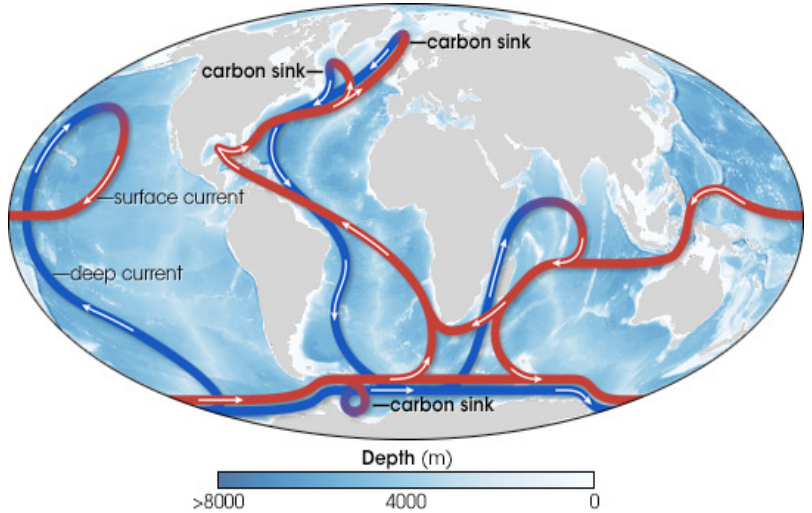
@NOAA

DIC-drawdown via biological production:
in high latitudes/ Spring-Summer



@SeaWiFS project

DIC-drawdown via downwelling:
in high latitudes/ Winter



@ Robert Simmon, Nasa

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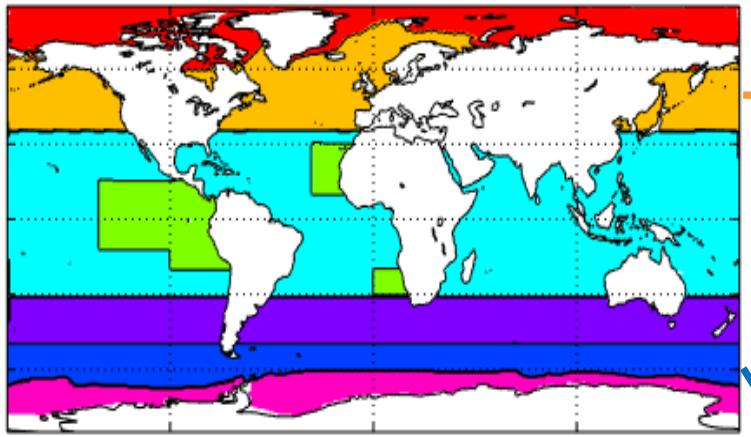
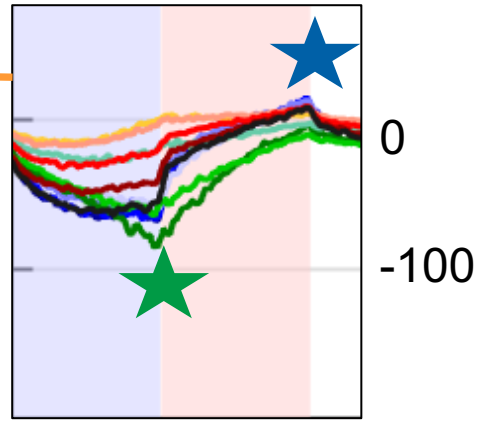
Seasonality gives indication of governing processes of ocean carbon uptake!

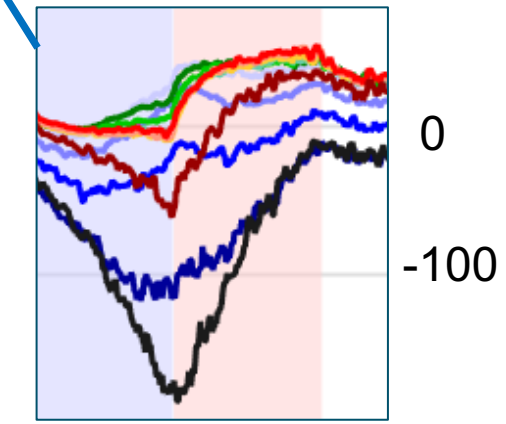
Analysis of our model-simulation

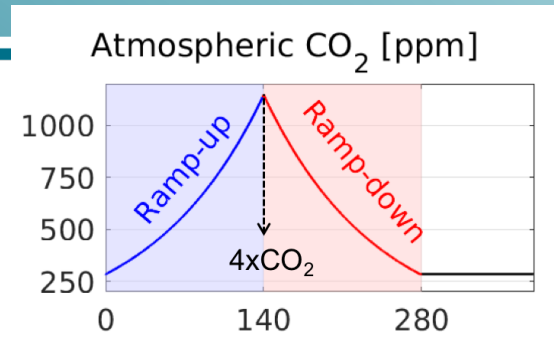


CO_2-flux [kg C/m^2]



CO_2-flux [kg C/m^2]





★ **high latitude Spring/ Summer:** pronounced and continued oceanic uptake

★ **high latitude Winter**: sudden CO_2-uptake decrease during the onset of negative emissions

All months show a slow-down in carbon uptake under negative emissions!

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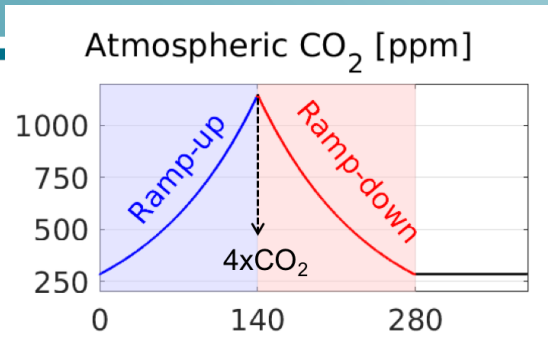
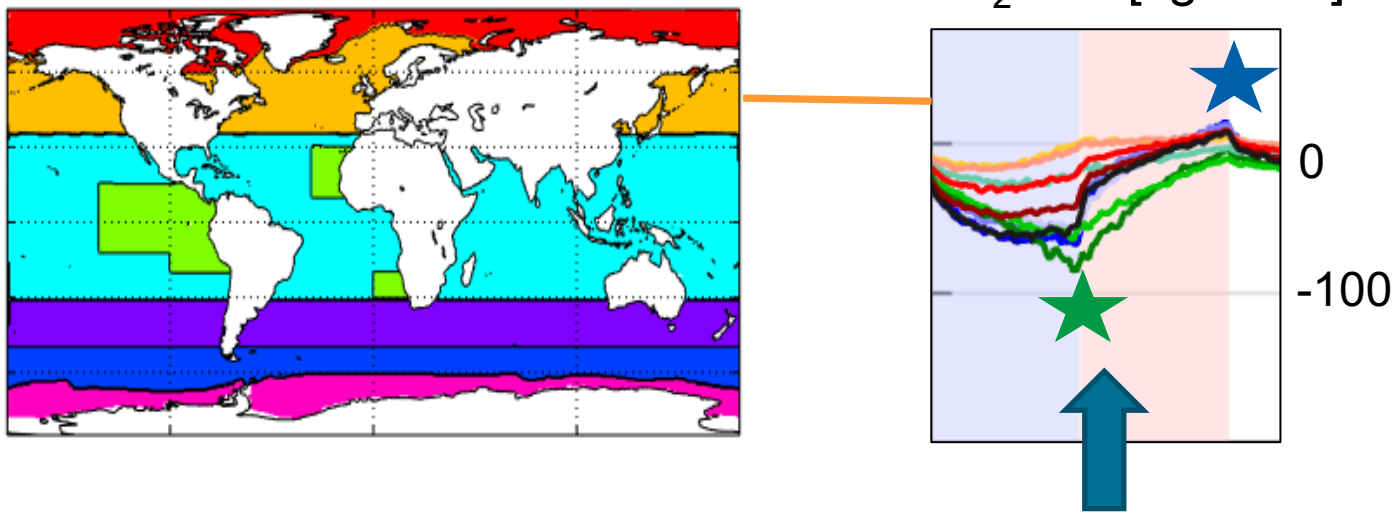
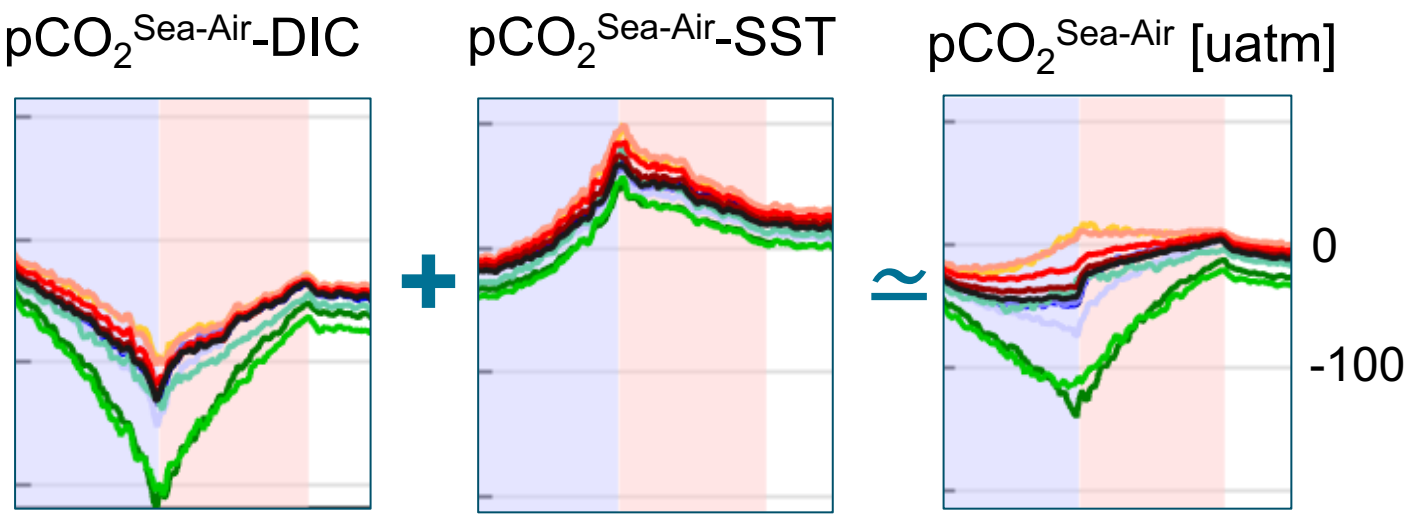
Analysis of our model-simulation







★ **high latitude Spring/ Summer:** pronounced and continued oceanic uptake (DIC-driven biological pump)

★ **high latitude Winter**: sudden CO_2-uptake decrease during the onset of negative emissions (SST- and DIC-driven)

All months show a slow-down in carbon uptake under negative emissions!

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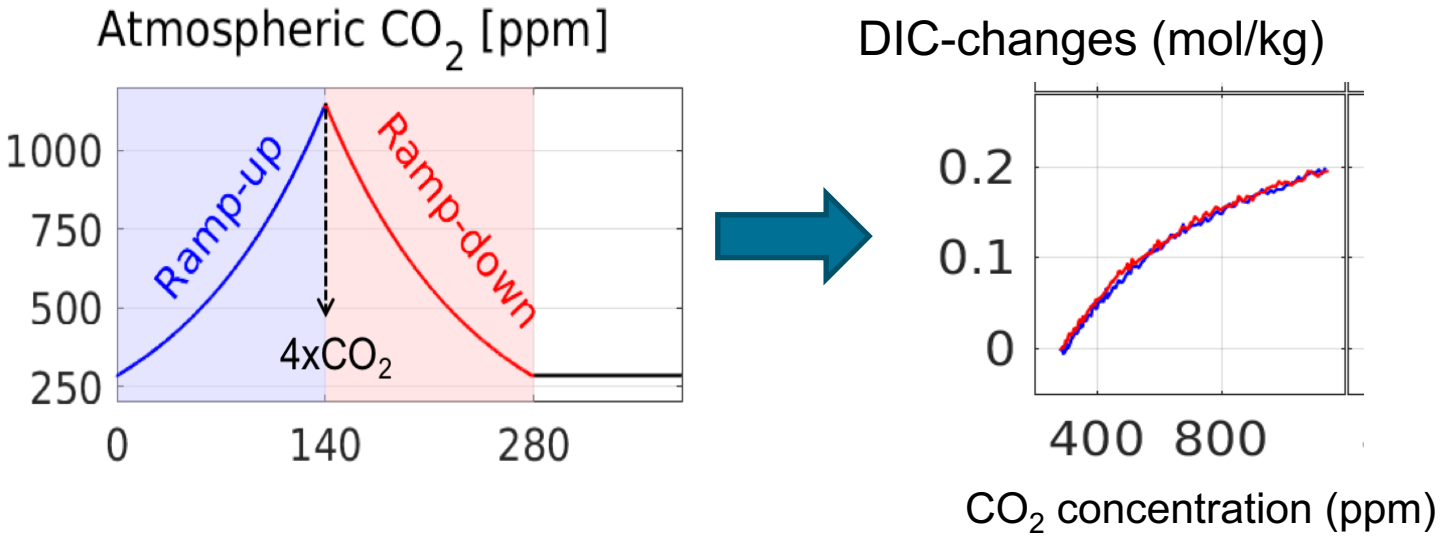
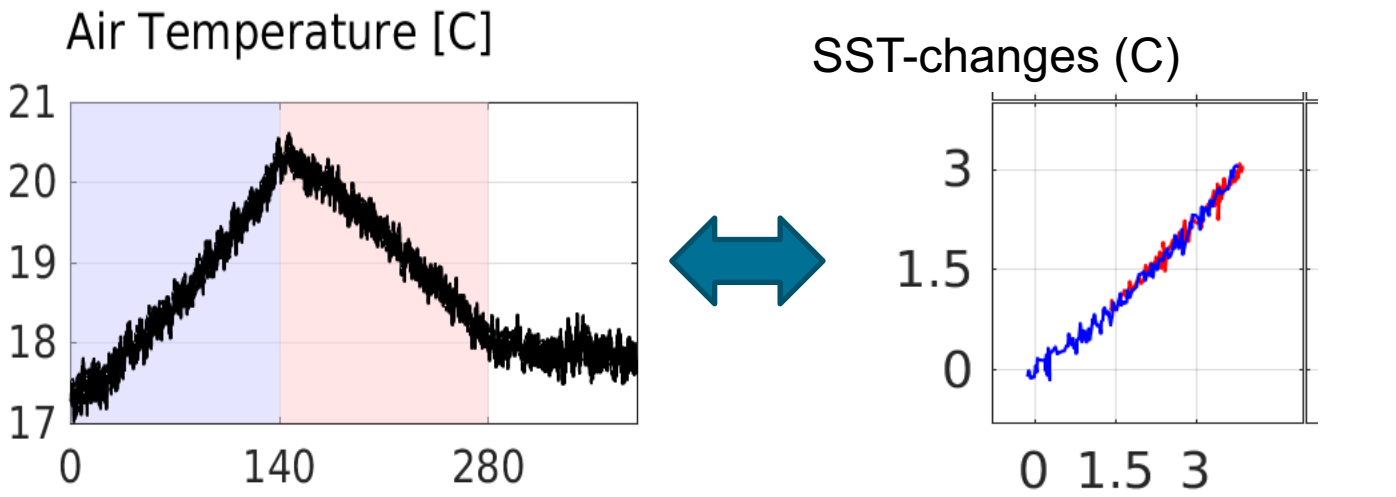
Speed of reversibility: Carbon versus Temperature





At the onset of negative emissions is a short time-window where

- SST is still increasing
- DIC is already decreasing
- both point in the direction of less carbon uptake

All months show a slow-down in carbon uptake under negative emissions due to the slow SST-reversal

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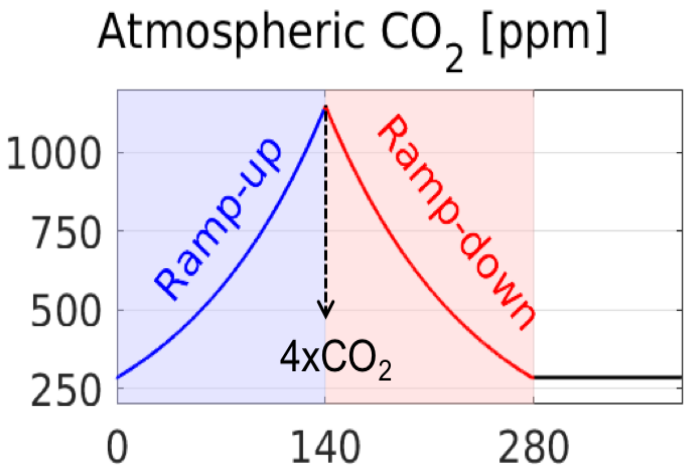
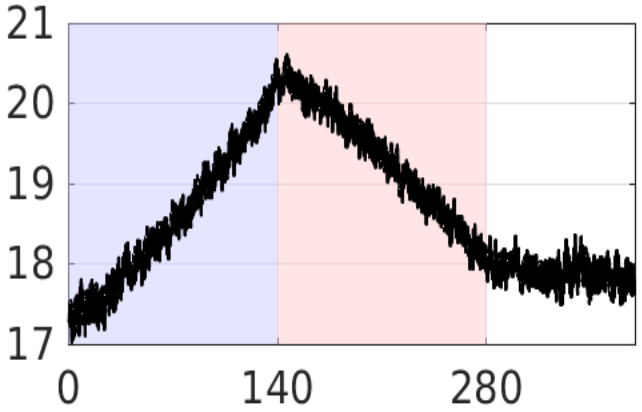
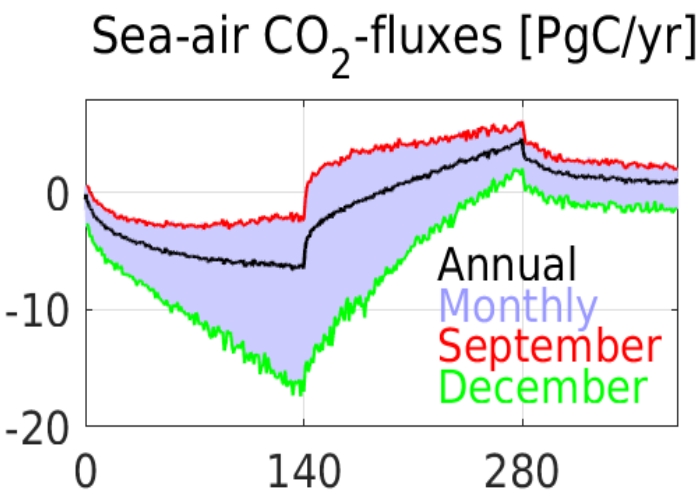
Speed of reversibility: Carbon versus Temperature







The feedback of the sea-air fluxes on atmospheric carbon is decompensated by the amount of negative emissions.

This is not the case for sea-air heat-fluxes.

Summary and Conclusion

There is a lot of uncertainty as to how the ocean carbon sink reacts to negative emissions

Though Earth System Models seem to agree on the sluggish cooling of SST and the sudden decrease of CO_2 uptake at the onset of negative emissions, there is no agreement on the amount of carbon taken up/ released under negative emissions by the oceans.

Our analysis points toward the fact that **correct seasonal characteristics** are important to determine the behaviour of the ocean carbon sink under negative emissions. Specifically,

- The biological pump has to be represented as accurate as possible
- Models have to be able to correctly simulate if and how much a month is SST- or DIC-driven

This is so far not given for state-of-the-art Earth System Models.