The linkages between the hydrological cycle, ocean salinity and transient climate change

Maofeng Liu[1#], Gabriel Vecchi[2,3], Brian Soden[1], Wenchang Yang[2], Bosong Zhang[1]

1, Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL 33149 (# mxl1744@rsmas.miami.edu).

2, Department of Geosciences, Princeton University, Princeton, NJ 08544. 3. High Meadows Environmental Institute, Princeton University, Princeton, NJ 08544

1 Introduction

Background

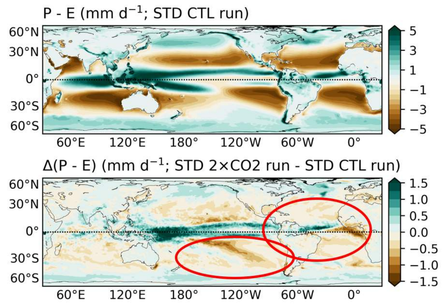
- Both observations and climate model simulations suggest a growing trend of ocean warming over the past few decades.
- The ocean is warmed from surface downward, leading to enhanced upper-ocean warming and therefore thermal stratification that reduces the rate of ocean warming.
- We propose that the ocean salinification due to enhanced global water cycle provides an important mechanism for reducing ocean-warming-induced stratification and enhancing ocean heat uptake.

Main work

- We conducted a series of coupled climate model experiments with both 1) control run in which the radiative forcing is maintained at yr-1990 level and 2) CO2 run in which CO2 concentration is increased 1% per year until it reaches double. Besides the standard (STD) runs, we designed a perturbation experiment (fixed-SSS-GL) in which the surface salinity is nudged with seasonally varying climatology simulated from the STD control run.

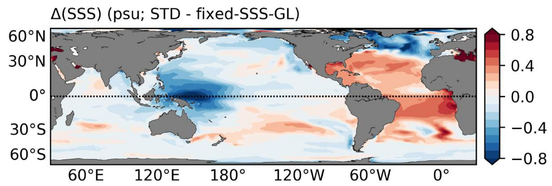
2 Impact of enhanced global hydrological cycle on ocean salinity

Enhancement of water cycle under warming



P: Precipitation
E: Evaporation
STD: Standard
CTL: control

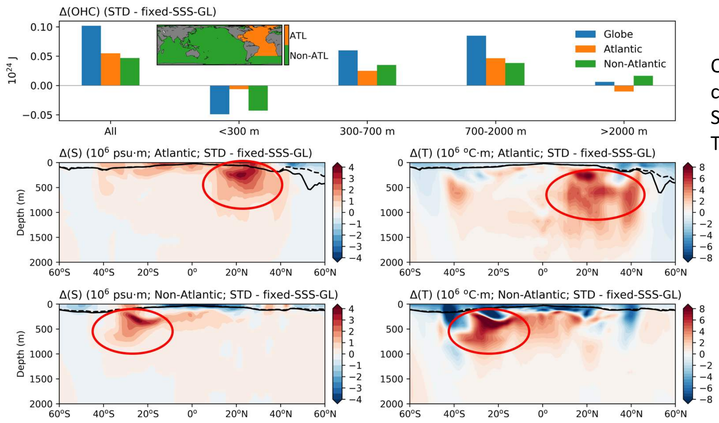
Water cycle impact on sea surface salinity (SSS)



- Under global warming, there is an enhancement in global hydrological cycle: wet gets wetter while dry gets drier.
- An consequence of this enhancement is amplified pattern of salinity: fresh gets fresher while salty gets saltier.
- We propose that subtropical salinification in both South Pacific and Atlantic are important in reducing the ocean stratification and therefore increasing heat uptake.

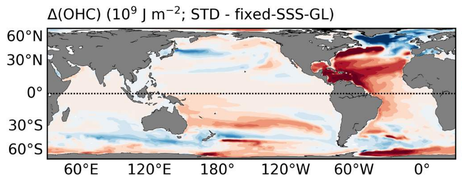
3 Salinity impact on ocean heat uptake and surface warming

Difference in CO2 response between STD and fixed-SSS-GL run

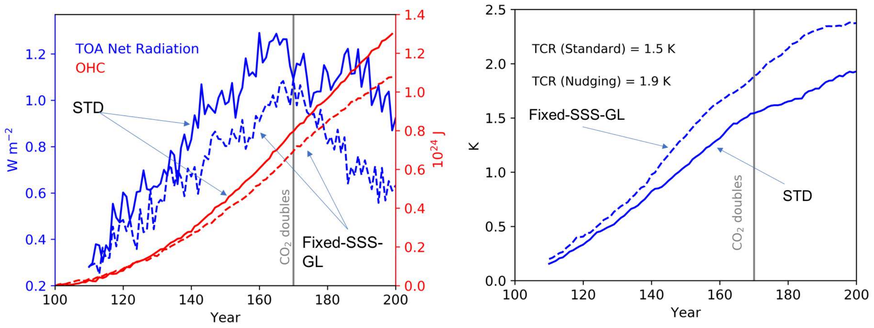


OHC: Ocean heat content
S: Salinity
T: Temperature

- Relative to fixed-SSS-GL, the STD run produces greater ocean heat uptake.
- The increased heat content in STD run is sequestrated in deeper oceans: less warming in the upper level while more warming in the relatively deep oceans.
- The regions with local heat anomaly well corresponds with local salinity anomaly, highlighting the impact of salinification on ocean warming.

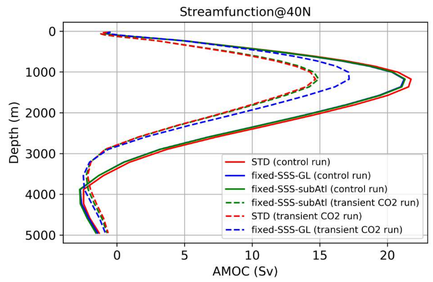


- The spatial pattern of greater ocean warming in the STD run relative to fixed-SSS-GL well corresponds with the pattern of surface salinity response.

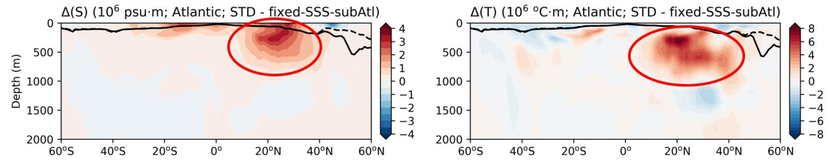


- Compared to fixed-SSS-GL run, the STD run produced greater ocean warming on the global scale over time (red), corresponding to a lower top-of-atmosphere net radiation (blue).
- Due to the deeper ocean warming pattern, the STD run produces a lower rate of surface warming over time.
- For transient climate response (TCR) defined as the global-mean surface warming at the time of CO2 doubling in a 1% CO2 experiment, the salinity impact is about 0.4 K, which is also the standard deviation of TCR from the CMIP6 model ensemble.

4 The impact of AMOC

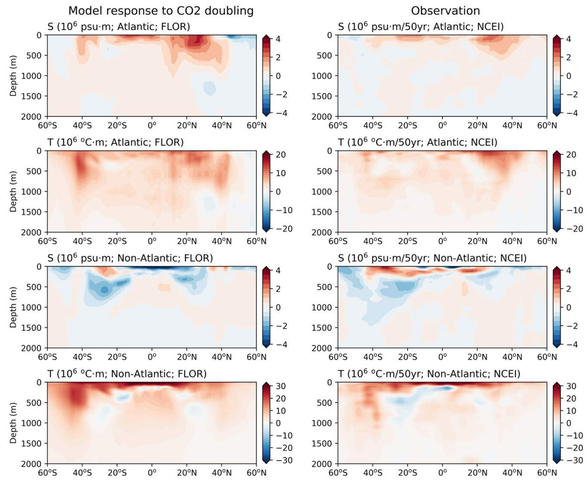


- To relieve the impact of Atlantic Meridional Overturning Circulation (AMOC) weakening on OHU, we conducted another salinity experiment (fixed-SSS-subAtl) in which we nudged salinity over 45S-45N in Atlantic and got similar AMOC weakening with the STD experiment.



- The salinity anomaly in the STD run relative to fixed-SSS-subAtl also seems to drive the heat anomaly in the similar regions, similar to what we see in the comparison between STD and fixed-SSS-GL, suggesting that the impact of AMOC may play a secondary role.

5 Resemblance between model and observations



- The resemblance in trend over the past 50 years between observed and modelled salinity & temperature implies the emergence of salinity impact on ocean warming.

6 Summary

- With a series of climate model simulations, we demonstrate the salinity response to enhanced water cycle due to global warming provides an important mechanism that reduces the ocean stratification, enhances ocean warming in the deeper oceans, and therefore reduces surface warming rate.
- The salinity impact on TCR is about 0.4 K, close to the standard deviation of the CMIP6 model ensemble.

References

Liu, M., Vecchi, G., Soden, B. et al. Enhanced hydrological cycle increases ocean heat uptake and moderates transient climate change. *Nat. Clim. Chang.* 11, 848–853 (2021). https://doi.org/10.1038/s41558-021-01152-0