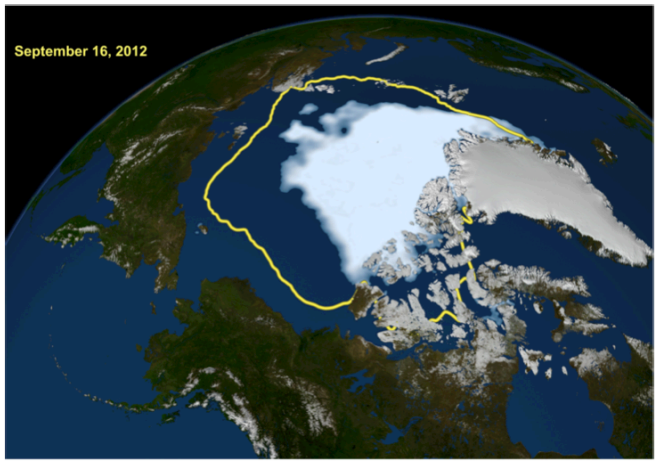
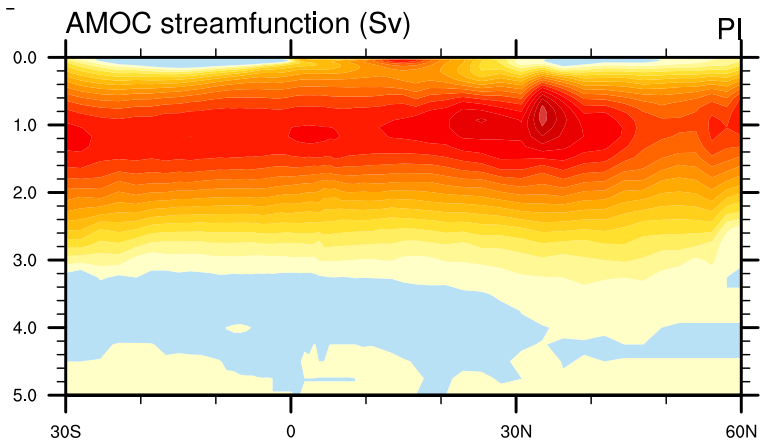
Arctic ocean freshening, the slow-down of the Atlantic Meridional Overturning Circulation (AMOC) and global impacts of Arctic sea ice decline

Alexey Fedorov

Yale University and LOCEAN

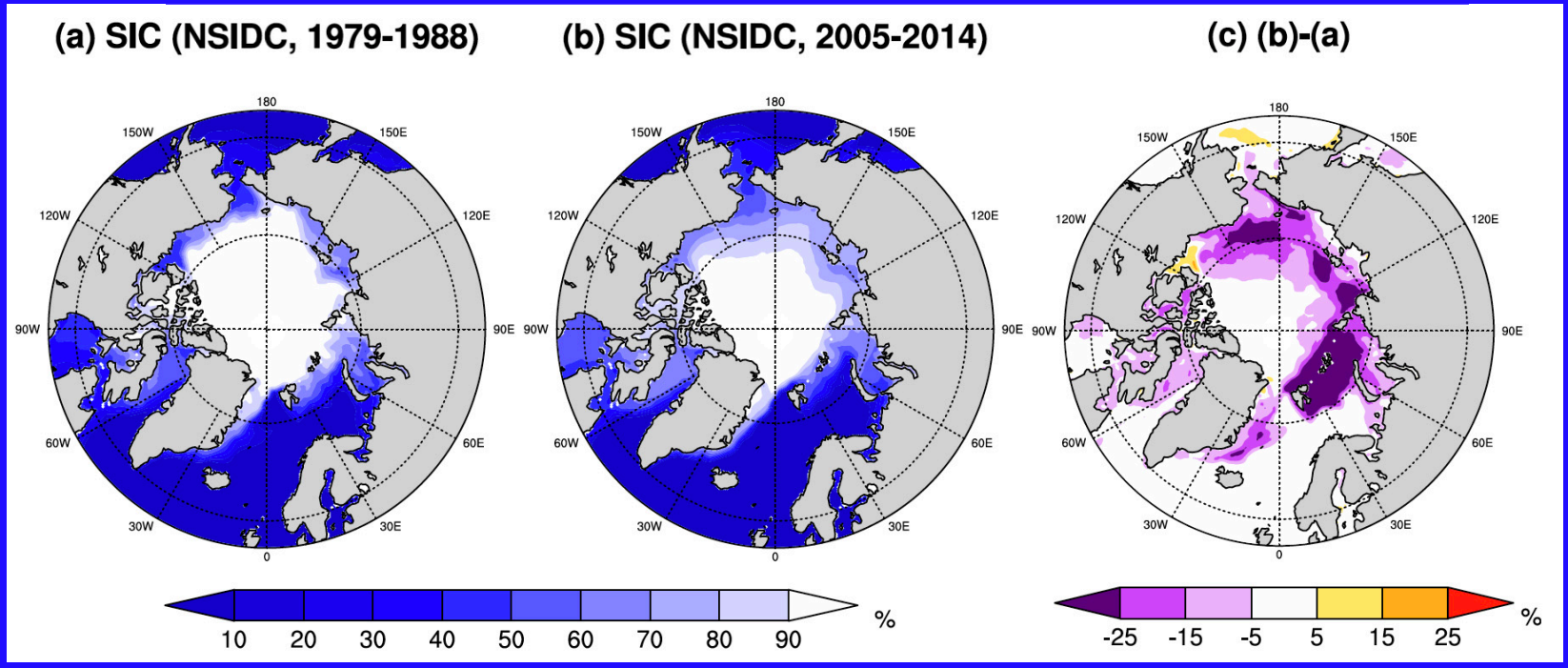


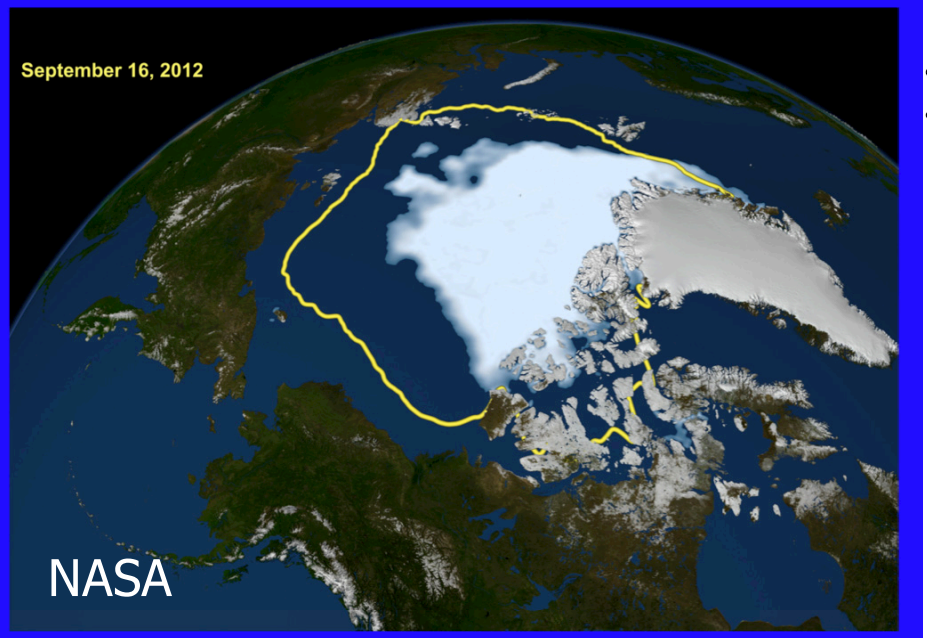


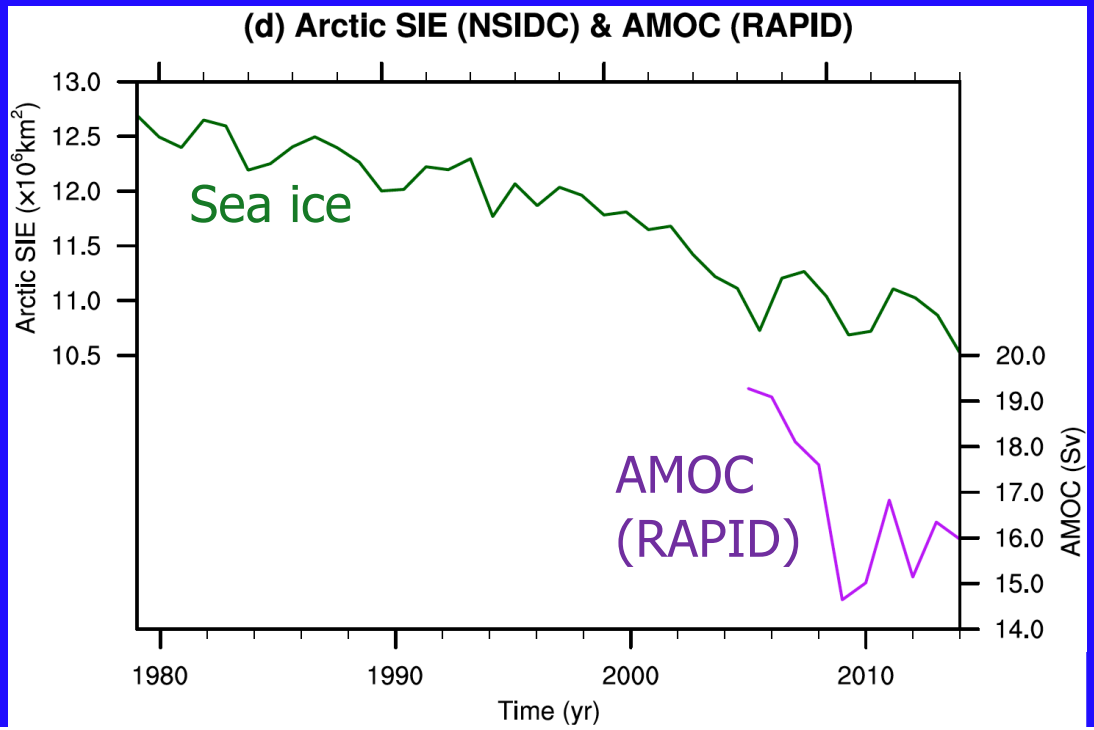
Co-authors: Florian Sévellec, Brest; Wei Liu, UC Riverside; Hui Li, Yale

Funding: NSF and ARCHANGE (MOPGA)

Arctic sea ice decline since 1979







Outline:

I: The mechanisms of the AMOC slow-down induced by Arctic sea ice decline

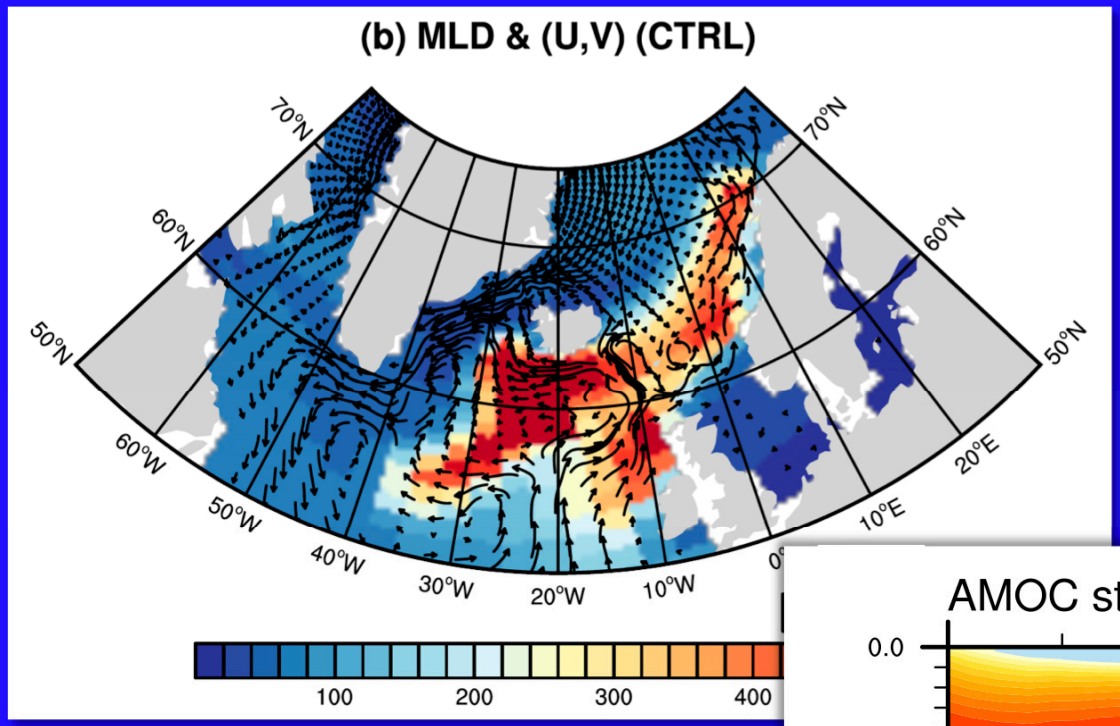
II: Arctic ocean freshening induced by the sea ice decline

III: Global climate impacts of Arctic sea ice decline modulated by the AMOC slow-down

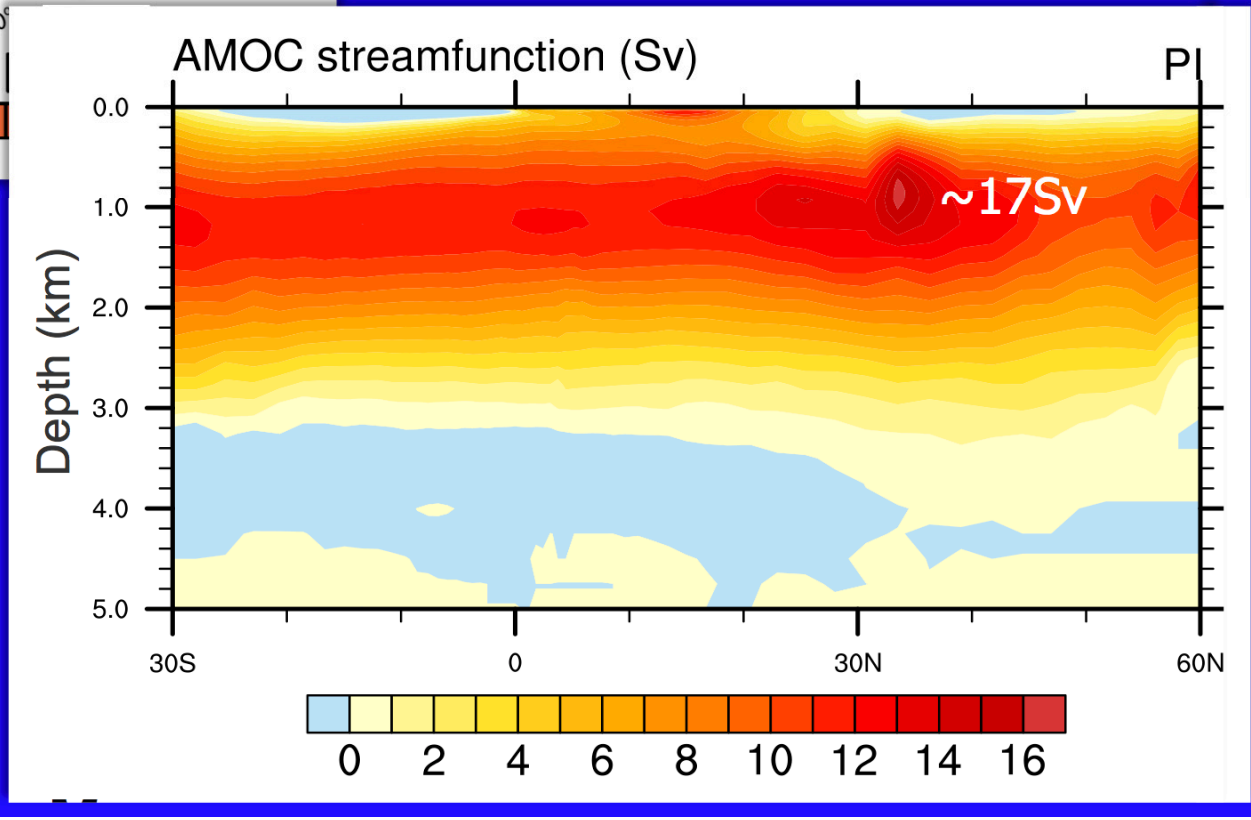
Numerical experiments to isolate the impacts of Arctic sea ice decline

- Climate model: CESM_T31
- Experiments – creating positive radiative imbalance for Arctic sea ice:
  (1,2) reducing albedo of sea ice (SW and strong SW experiments)
  (3,4) reducing emissivity of sea ice (LW and weak LW experiments)
- 200-year perturbed simulations
- SW and LW experiments are repeated in a 10-member ensemble

Model and observed March mixed layer depth

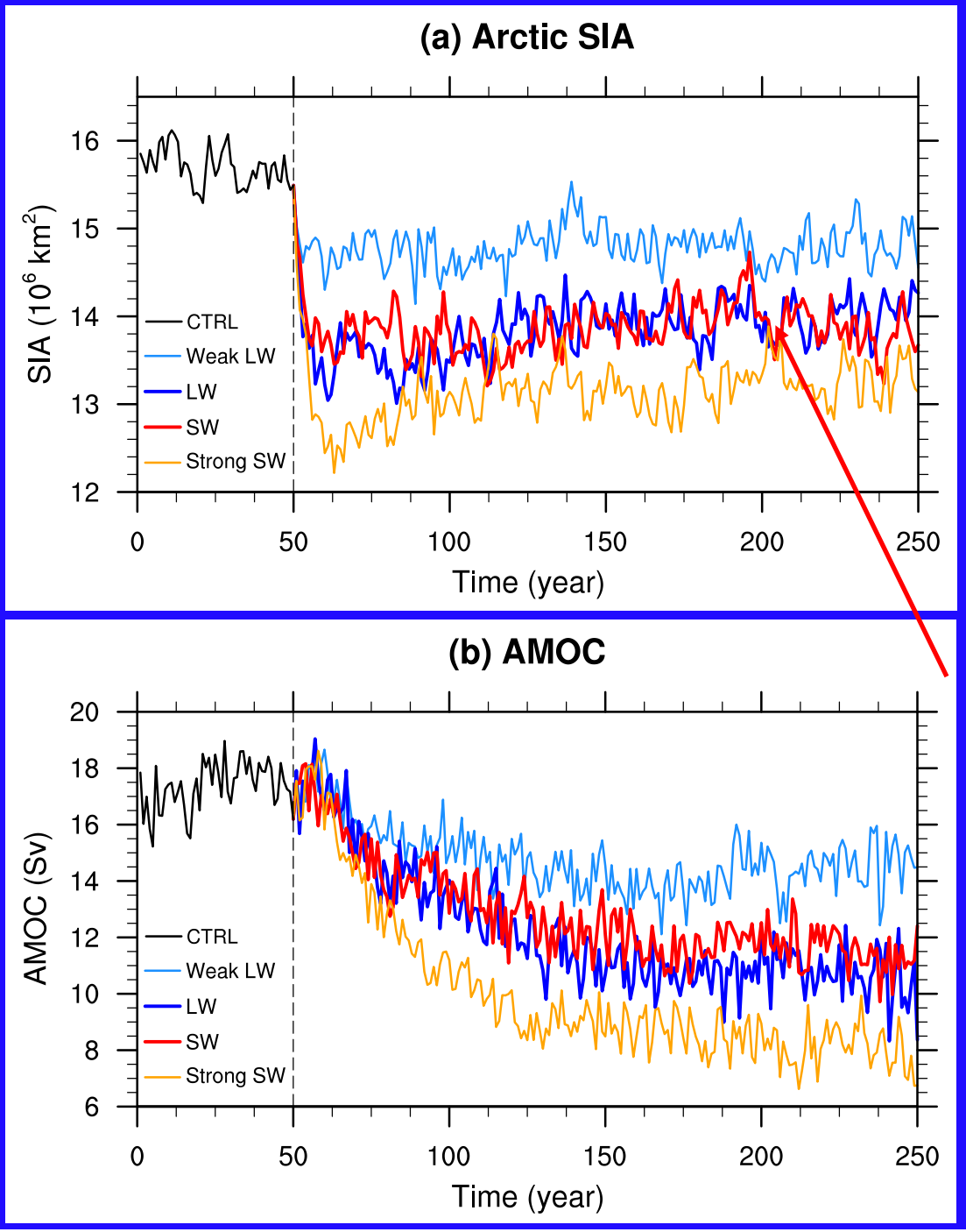


AMOC



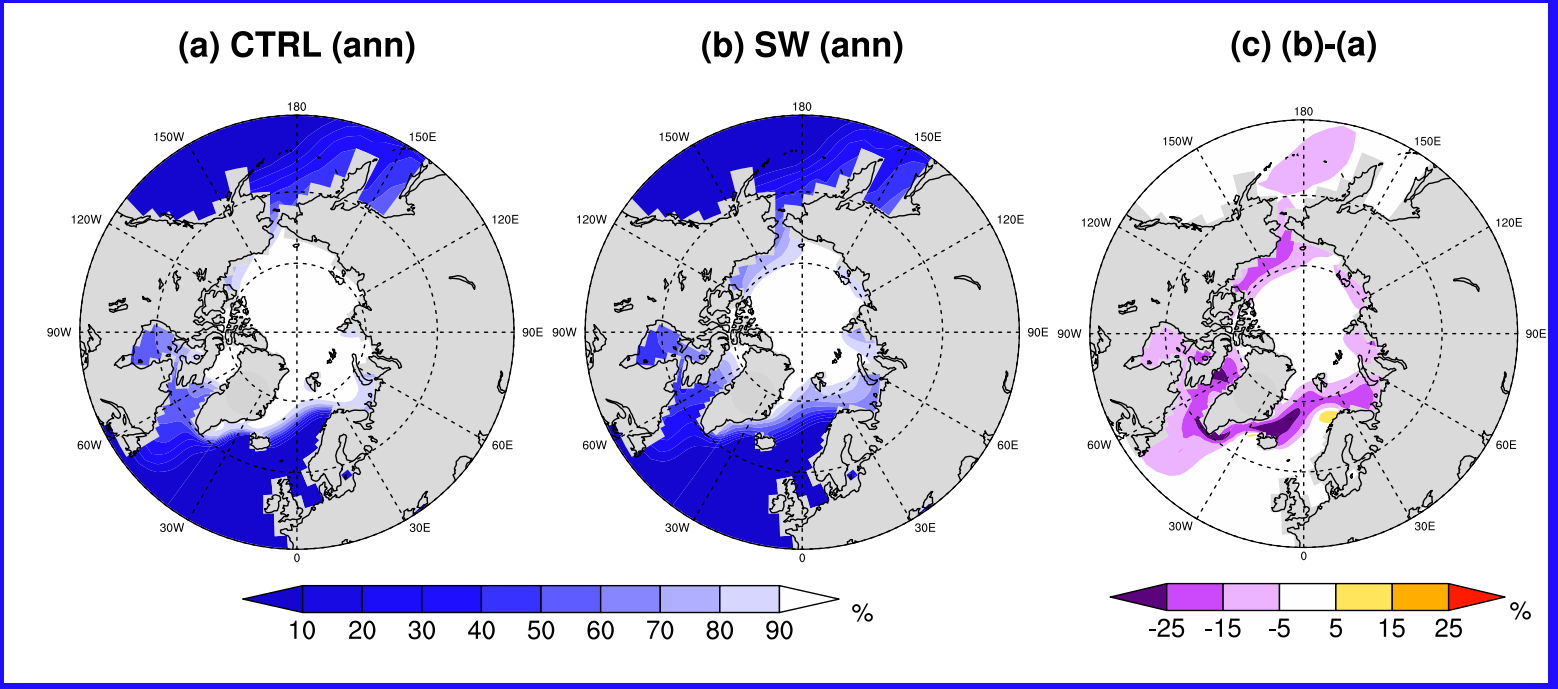
Part I: The mechanisms of the AMOC slow-down induced by Arctic sea ice decline

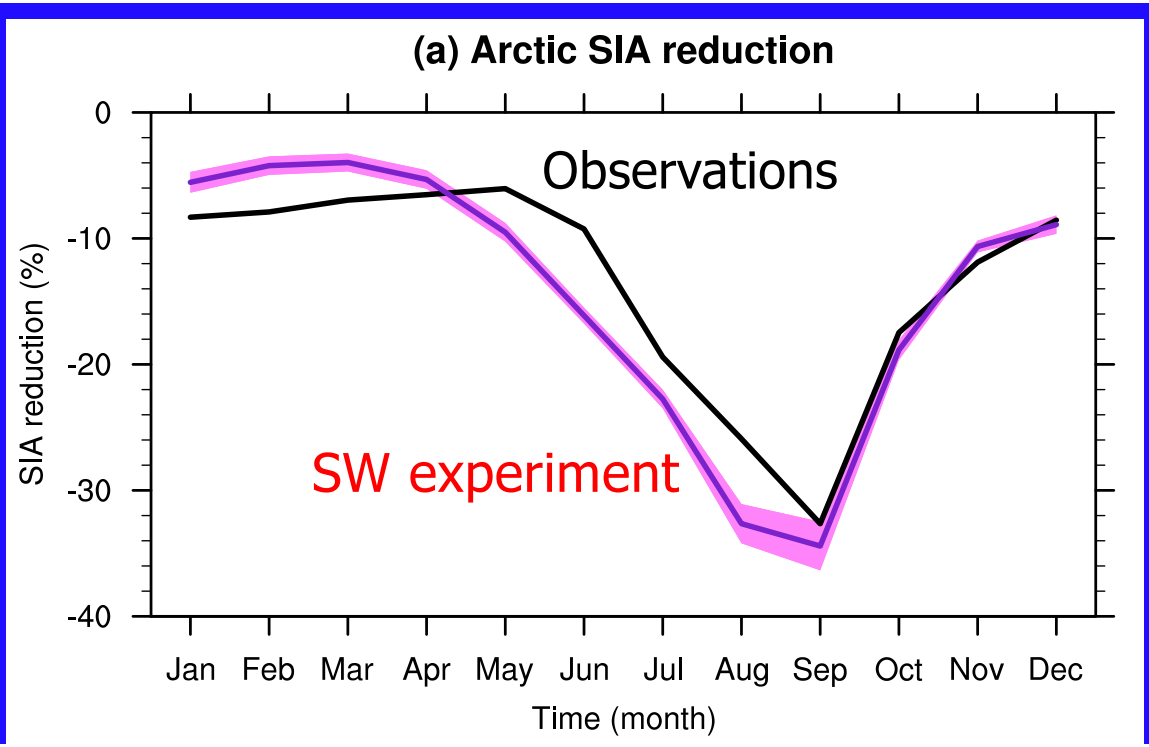
Model changes in sea ice area (SIA) and AMOC response



Liu, Fedorov, Sevellec 2018

Modeled sea ice decline in the SW experiment

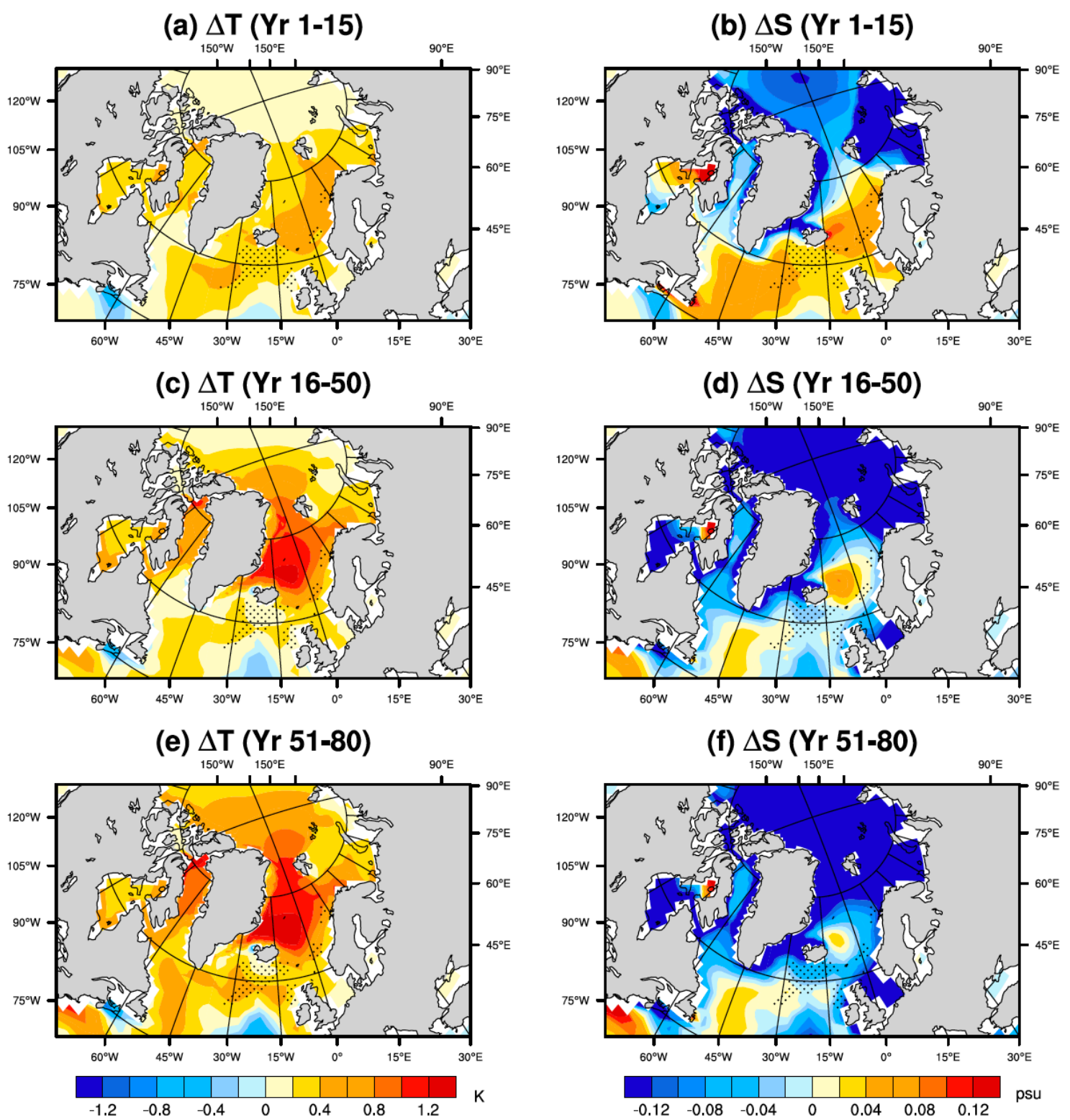




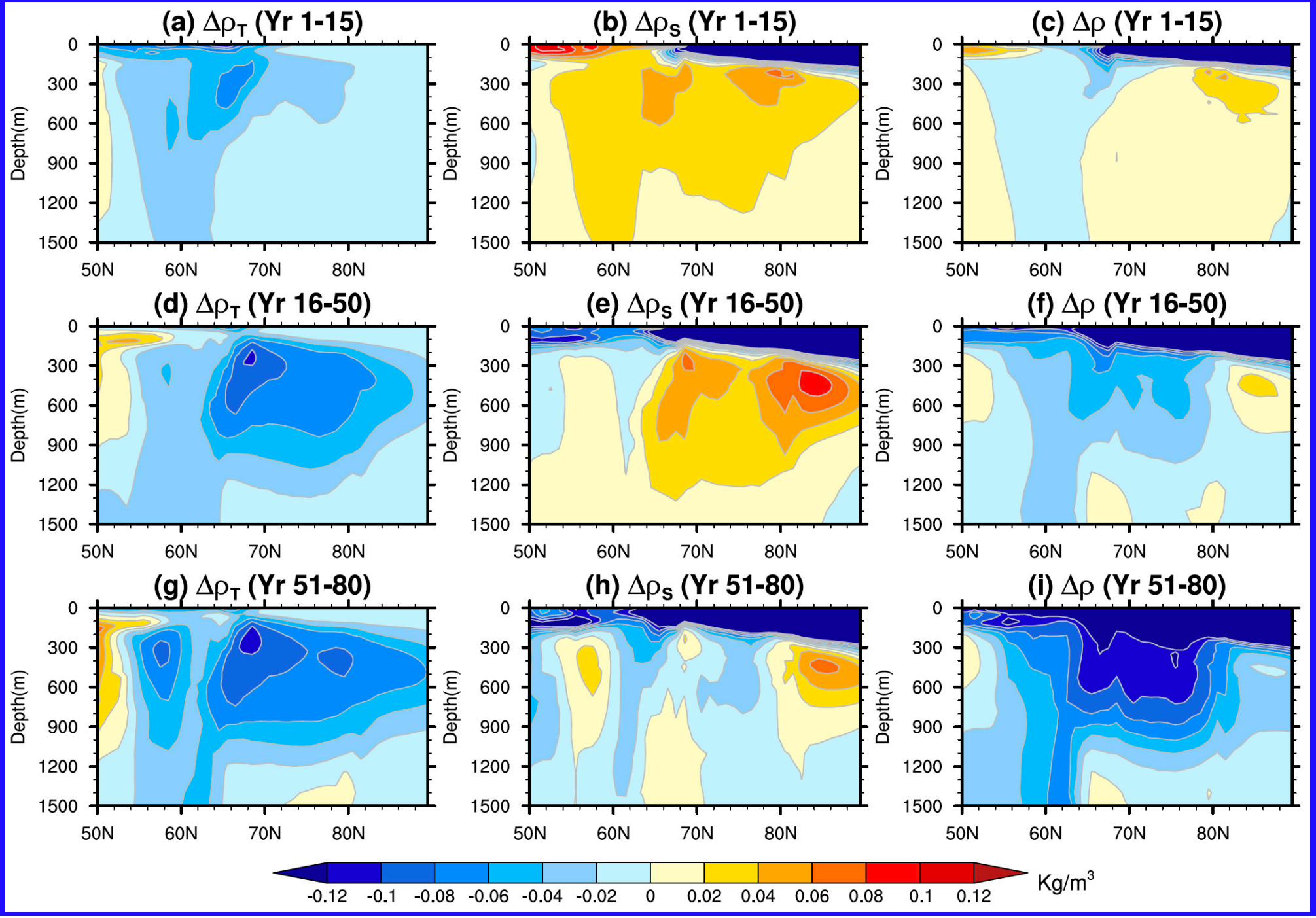
Why is the AMOC weakening?

Positive buoyancy anomalies (warm and fresh) grow, accumulate and spread from the Arctic to the North Atlantic

Temperature and salinity anomalies (SW experiment; upper 1000m)

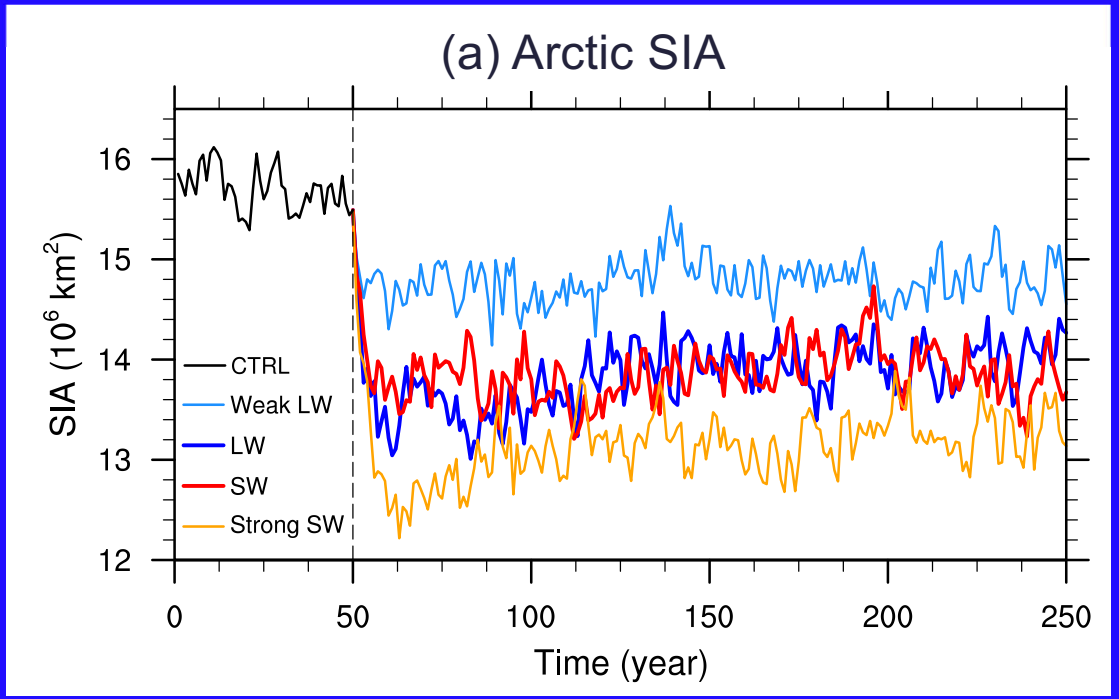


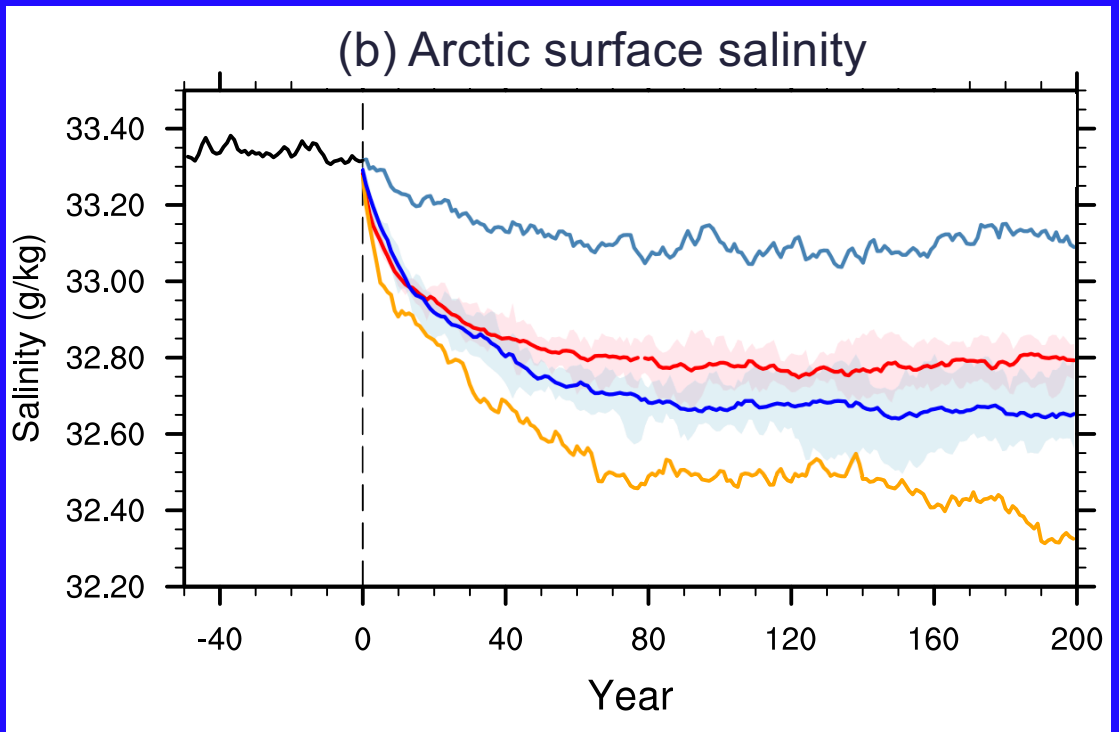
Density anomalies due to temperature and salinity, and totals



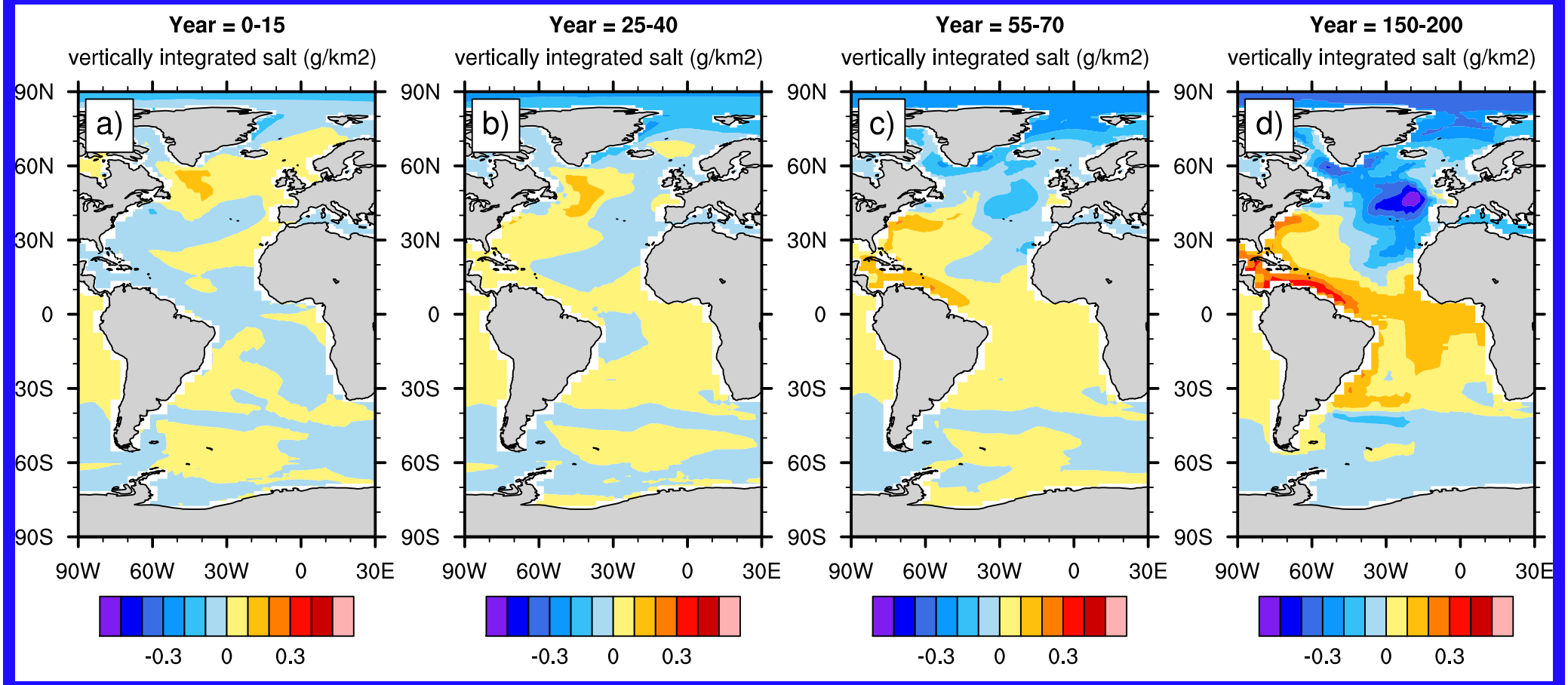
Part II: The freshening of the Arctic caused by Arctic sea ice decline

Model changes in sea ice area (SIA) and Arctic salinity

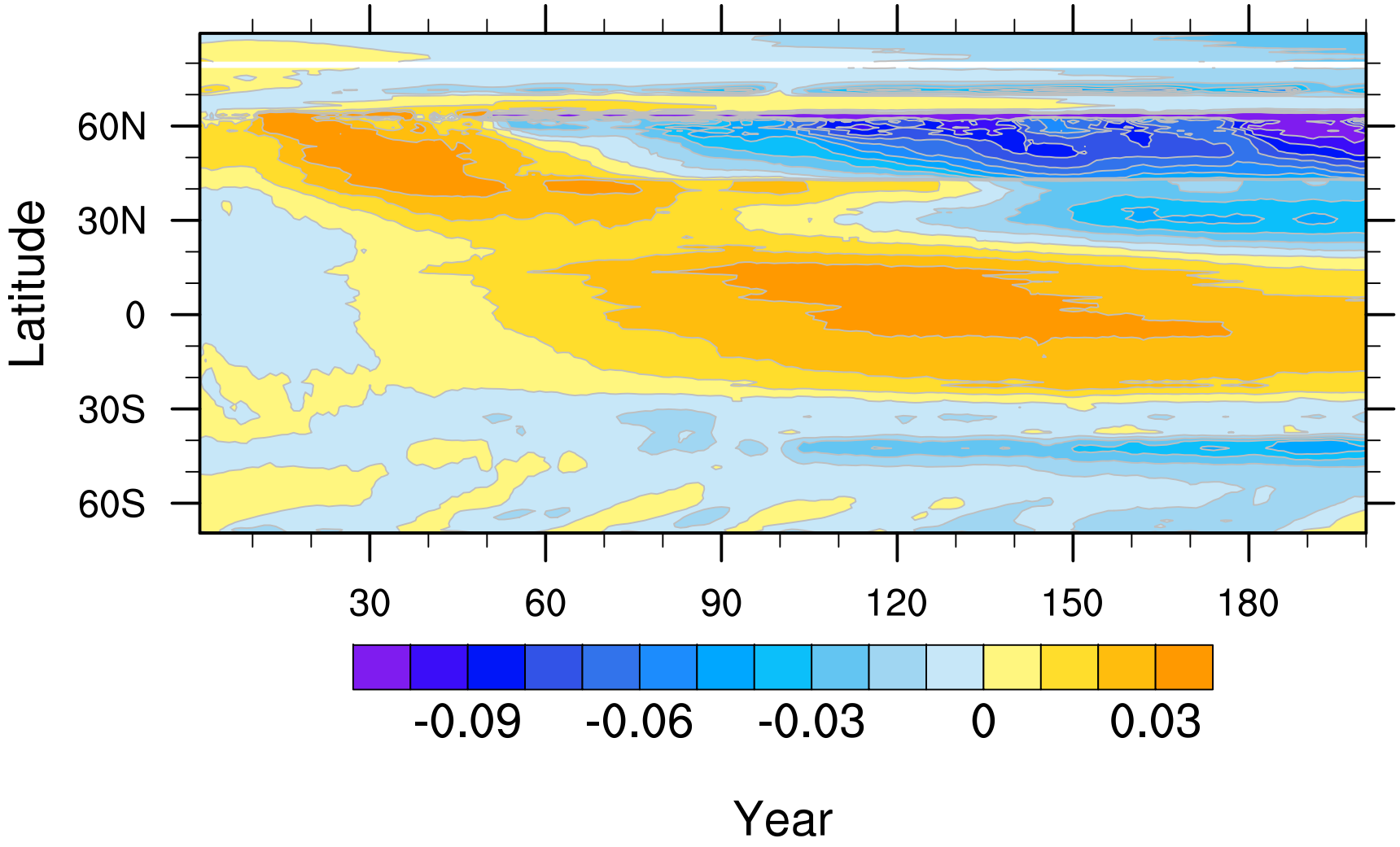




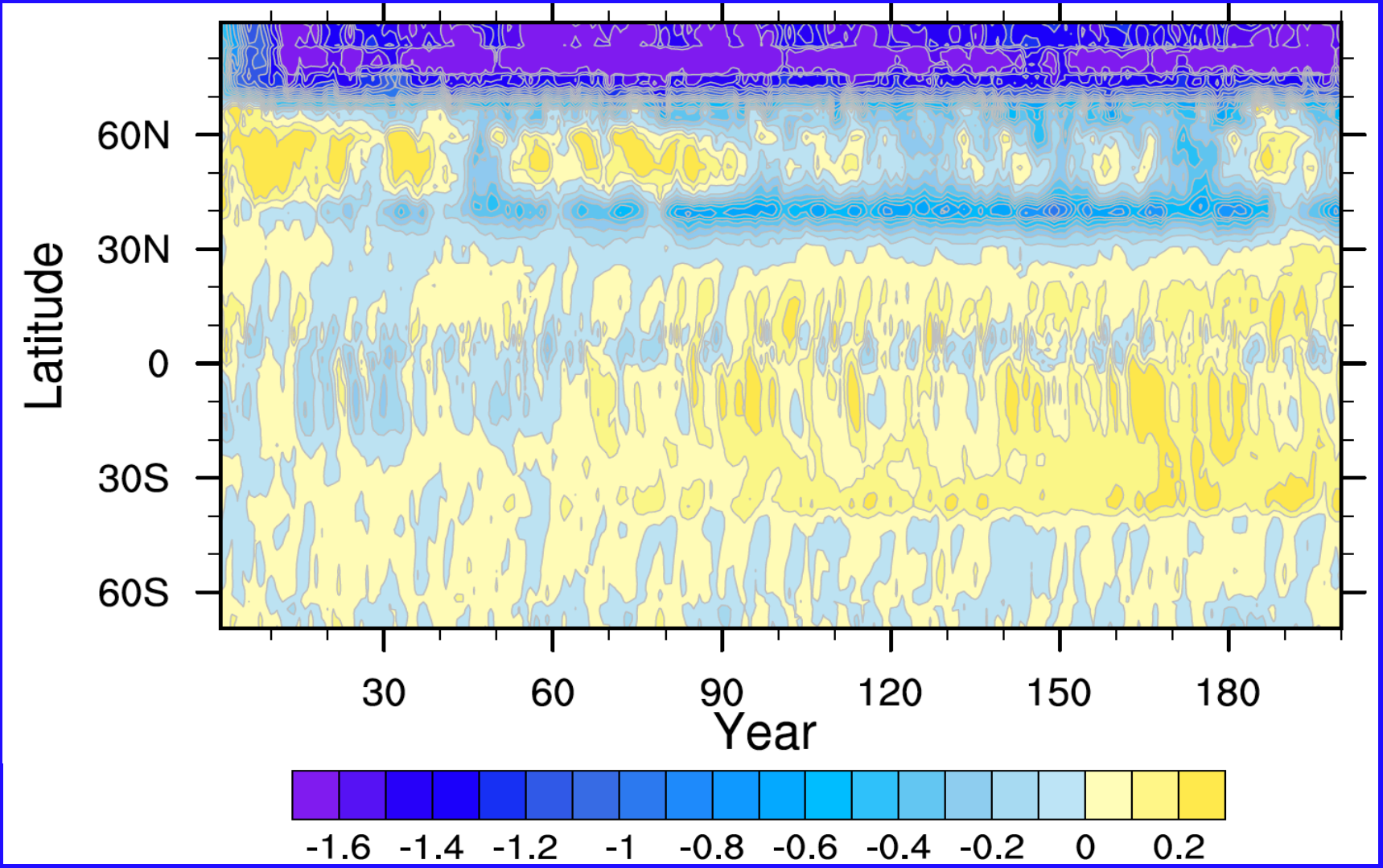
Arctic freshening: Column-integrated salt anomalies ($10^6 g/m^2$)



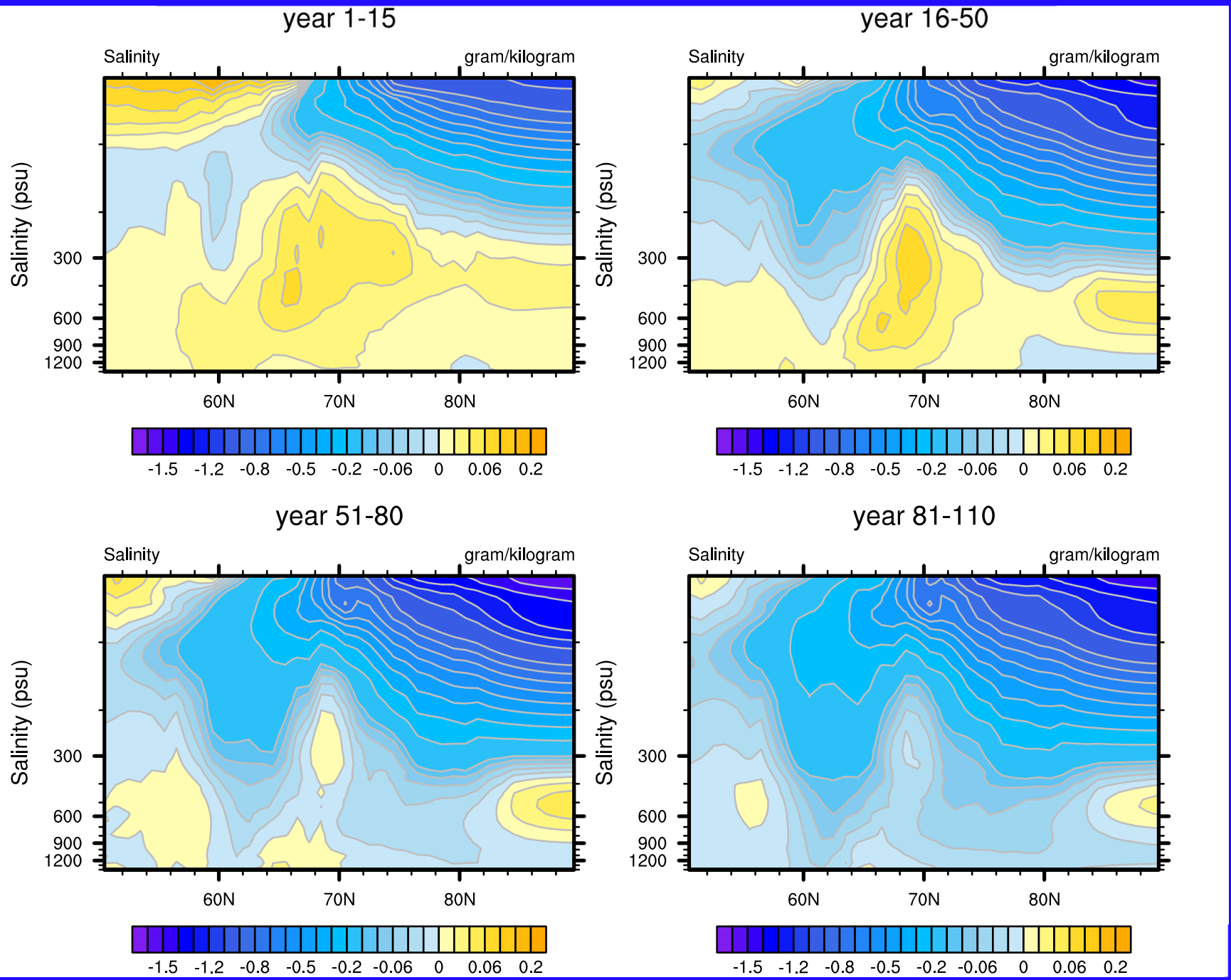
Salinity anomalies (psu) between 1700-2000m at the depth of the Deep Western Boundary Current



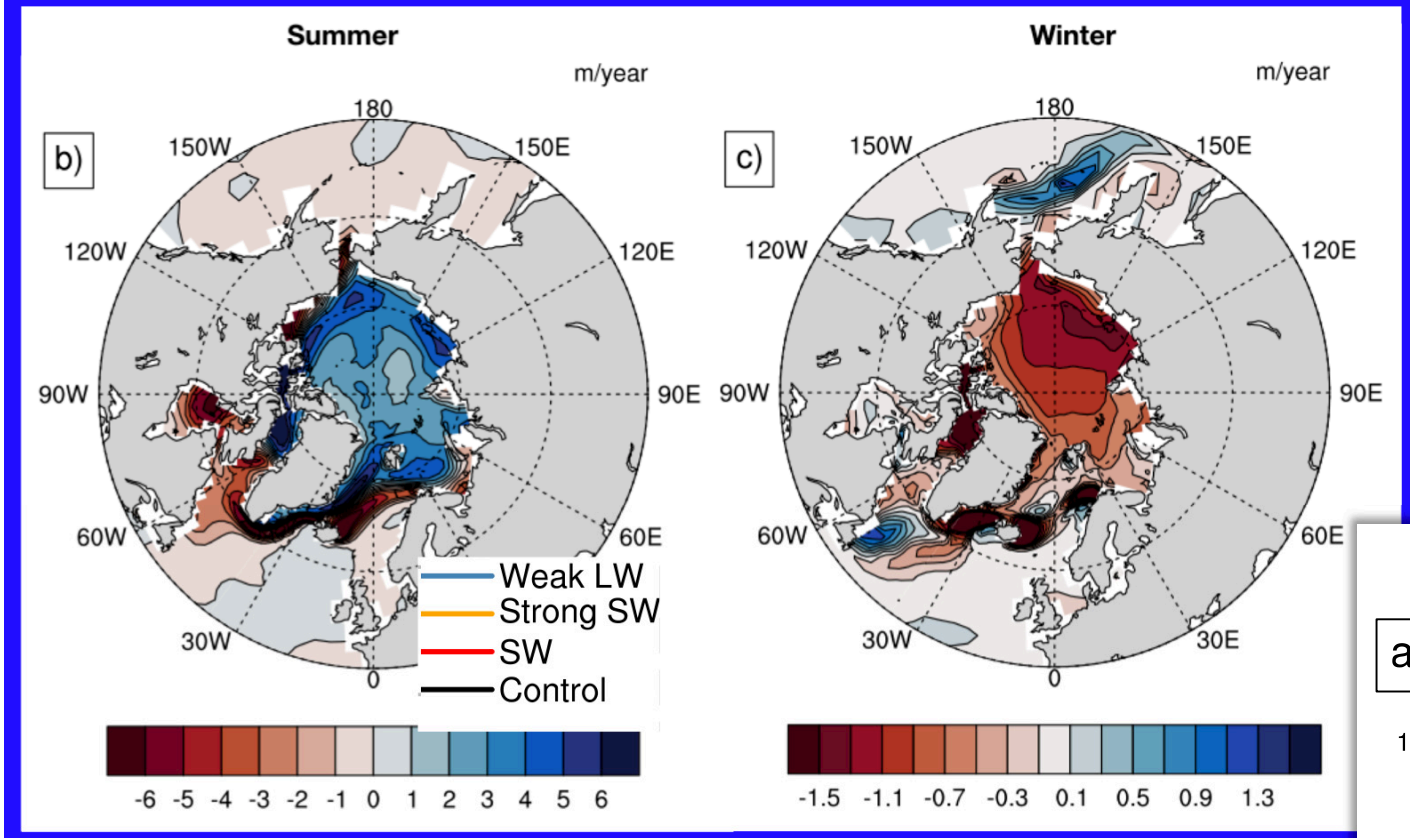
Arctic freshening:
Surface salinity anomalies (psu)

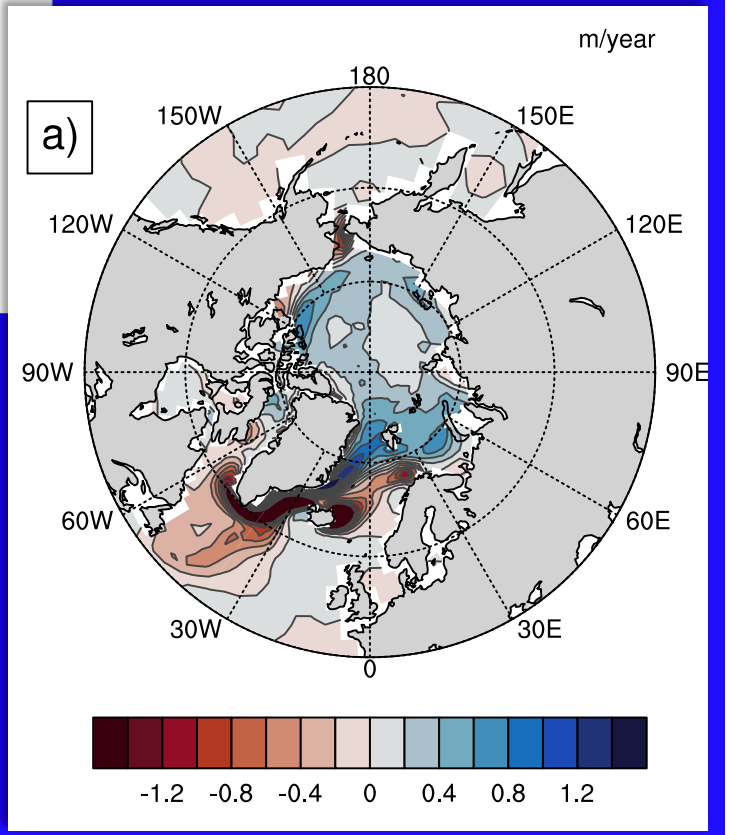


Salinity anomalies transects

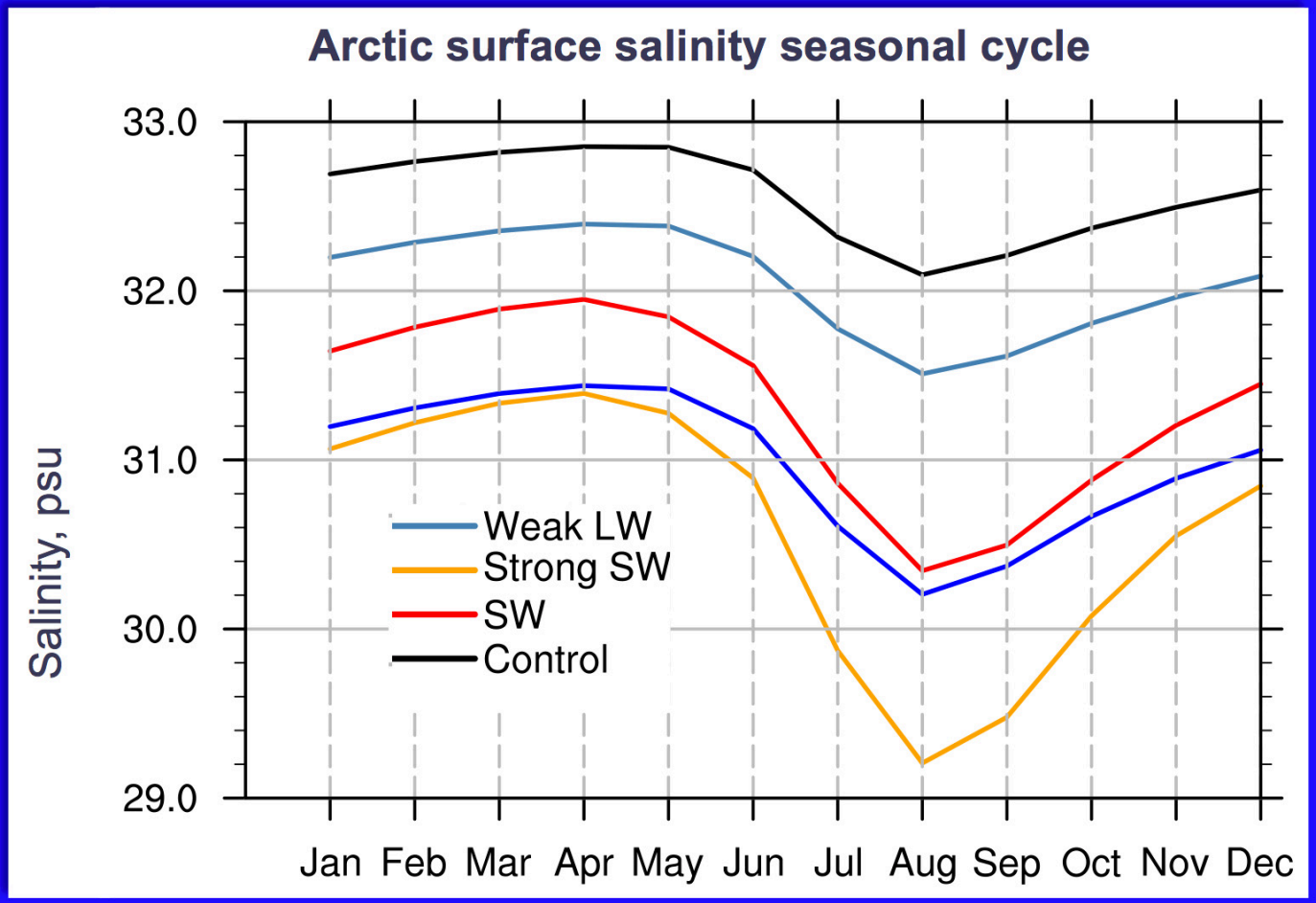


Anomalous virtual freshwater fluxes (SW experiment)





The strengthening of the seasonal cycle of Arctic salinity

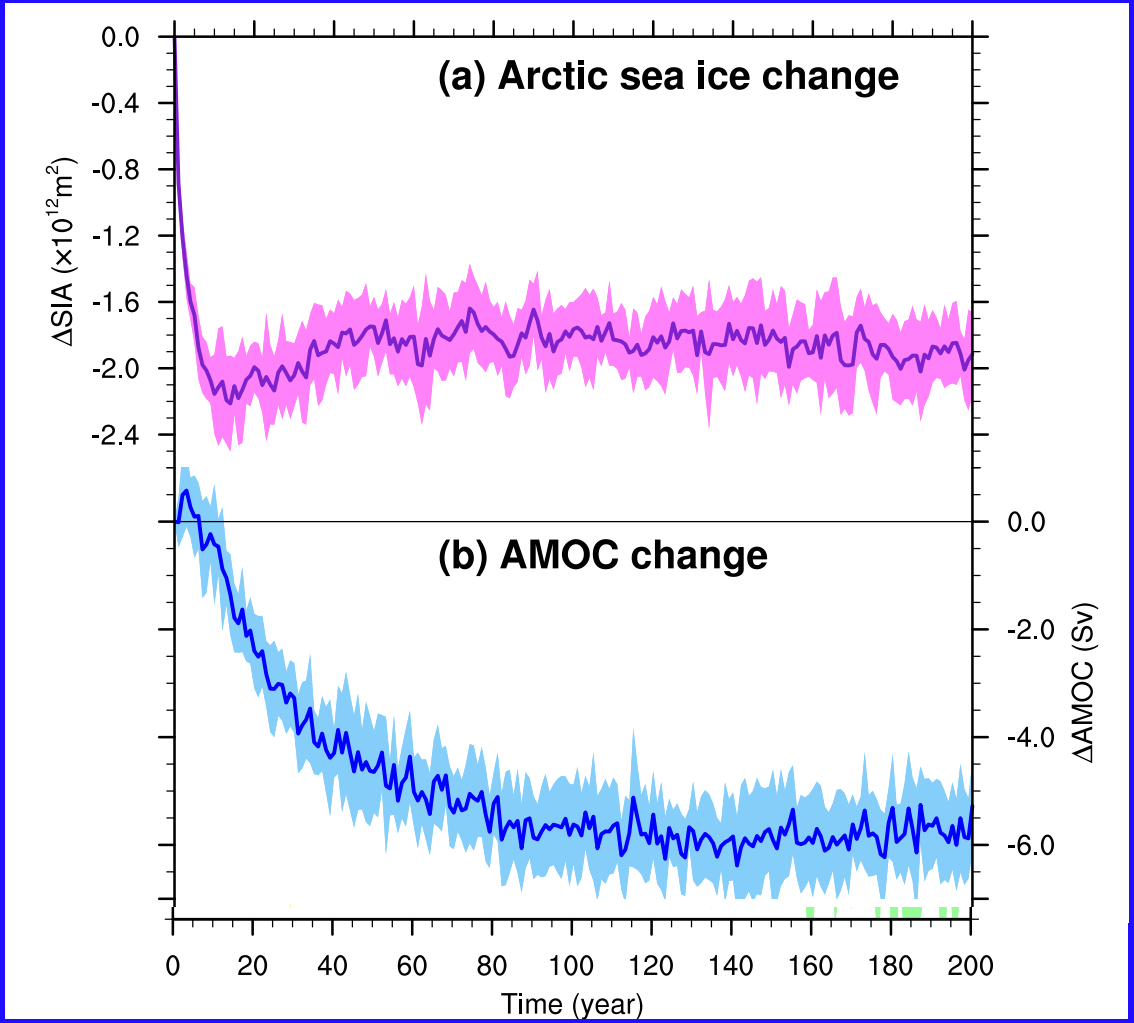


Part III: Global climate impacts of sea ice decline modulated by the AMOC slow-down

Changes in Arctic sea ice area and the AMOC response (SW experiment)

Lines: Ensemble means

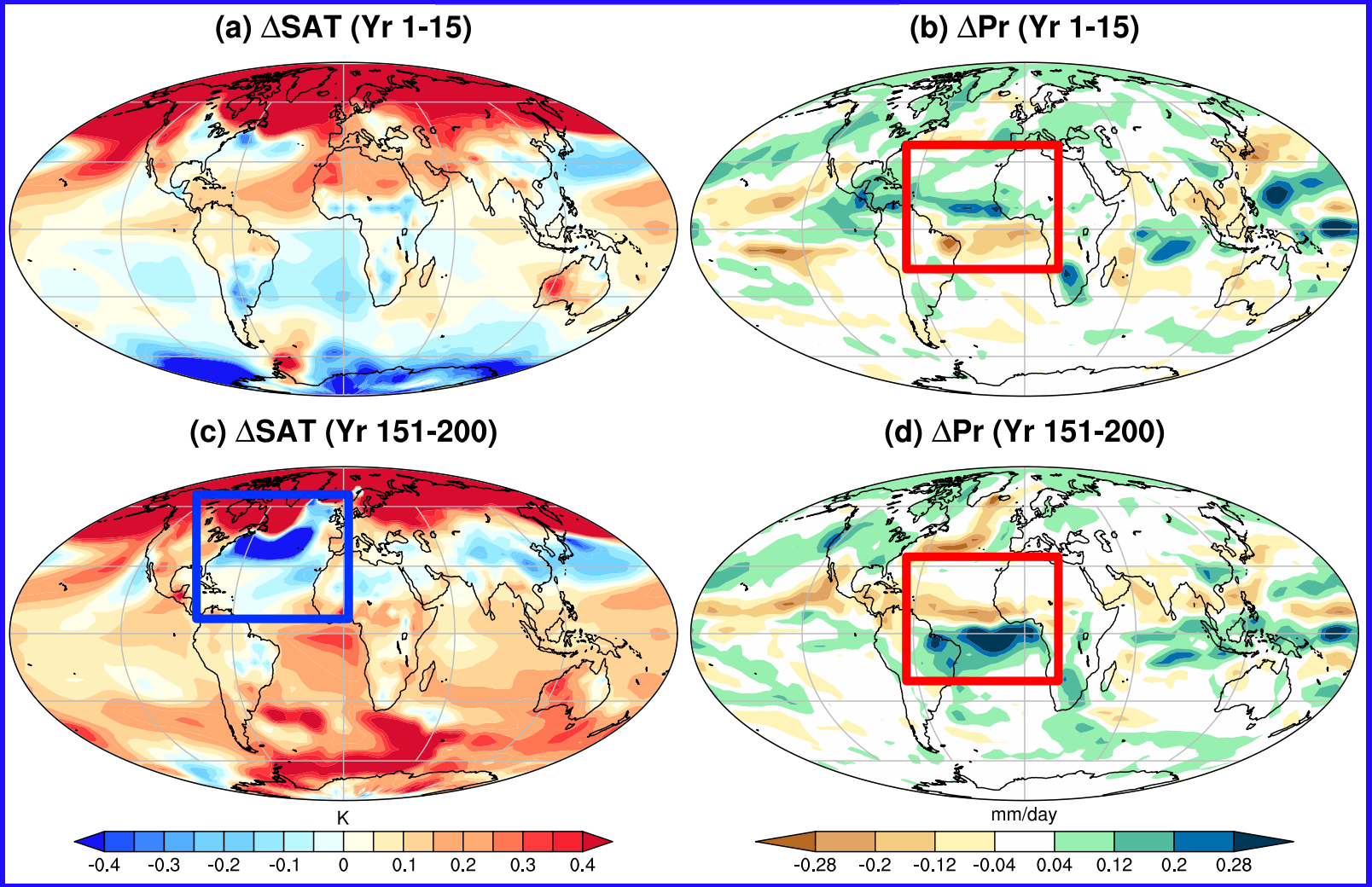
Shading: ensemble spread



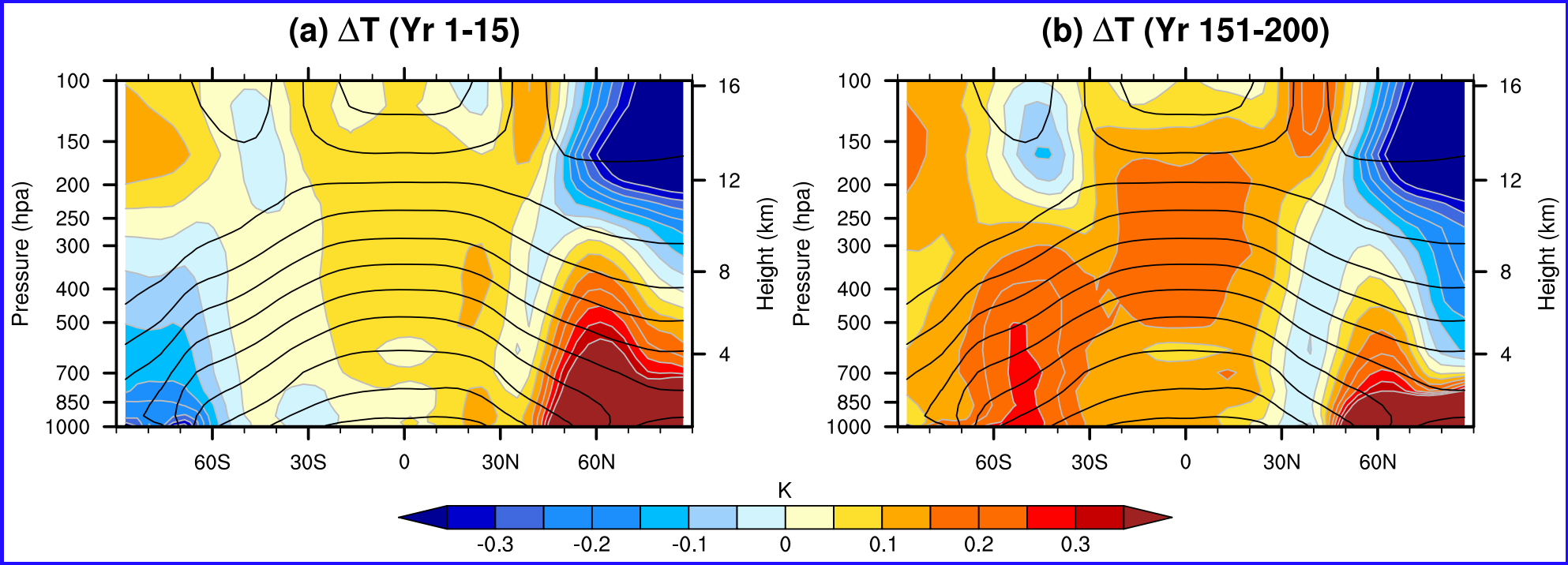
Impacts of Arctic sea ice loss: surface air temperature and precipitation anomalies

AMOC stays the same

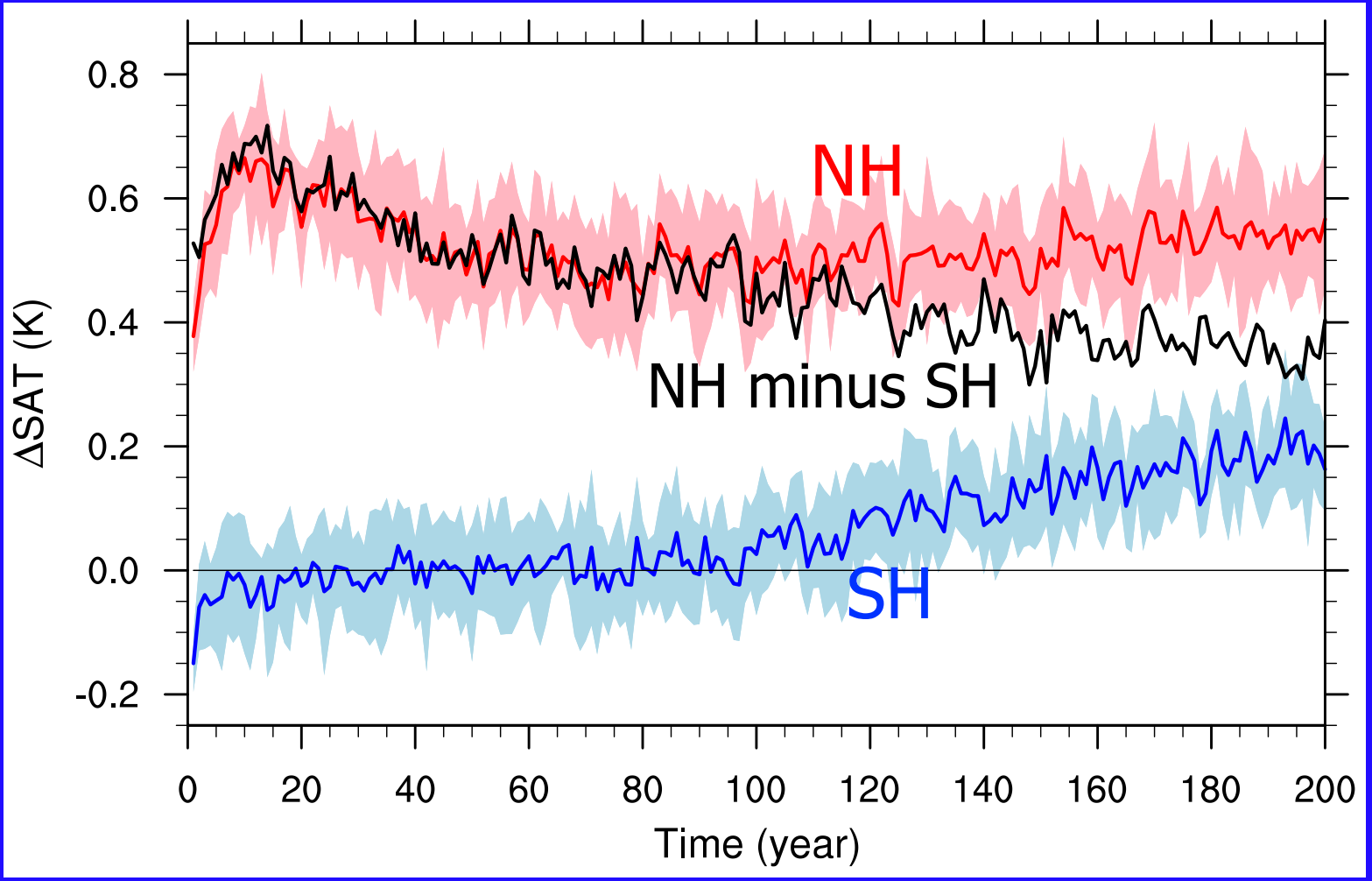
AMOC weakens



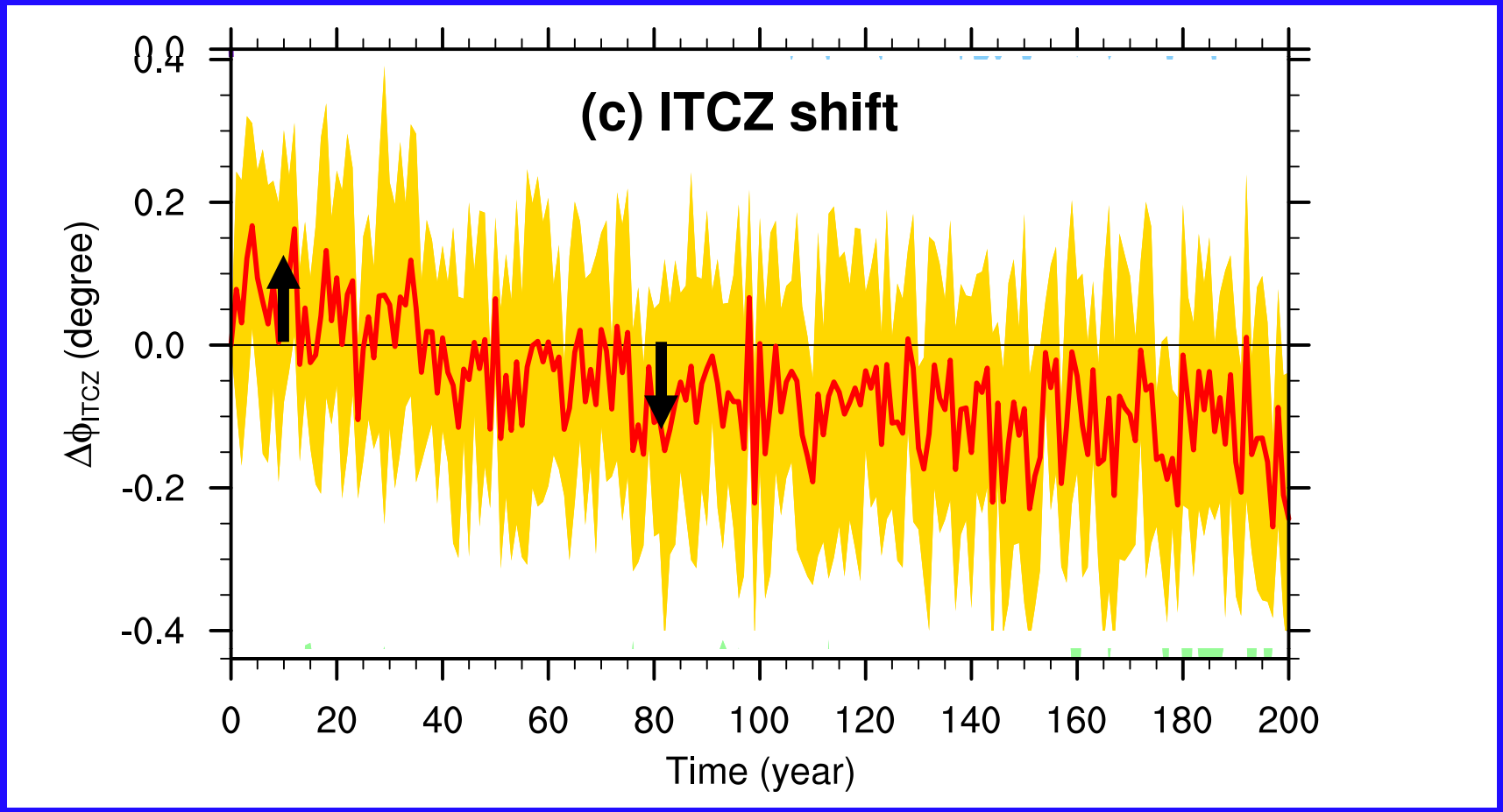
Atmospheric temperature anomalies



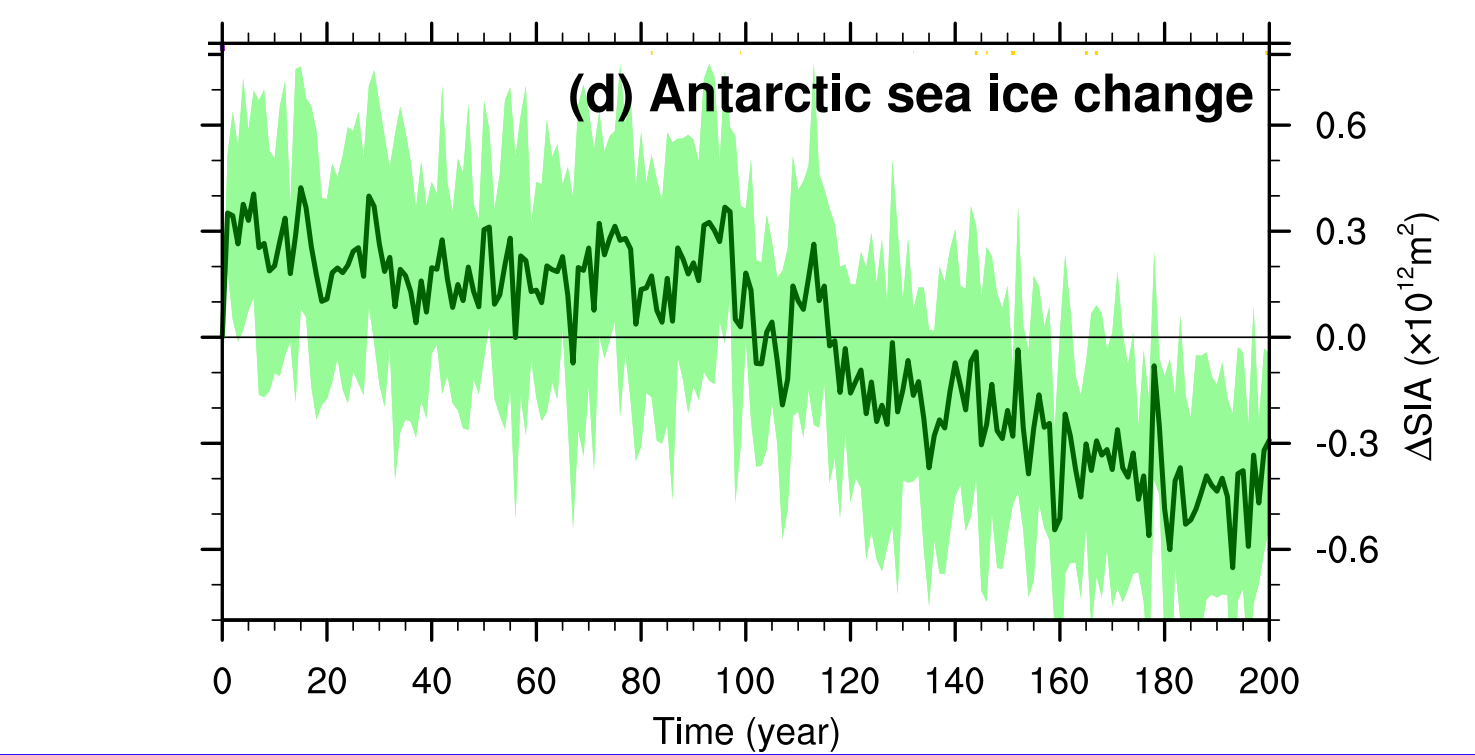
Temperature anomalies: NH, SH, NH minus SH



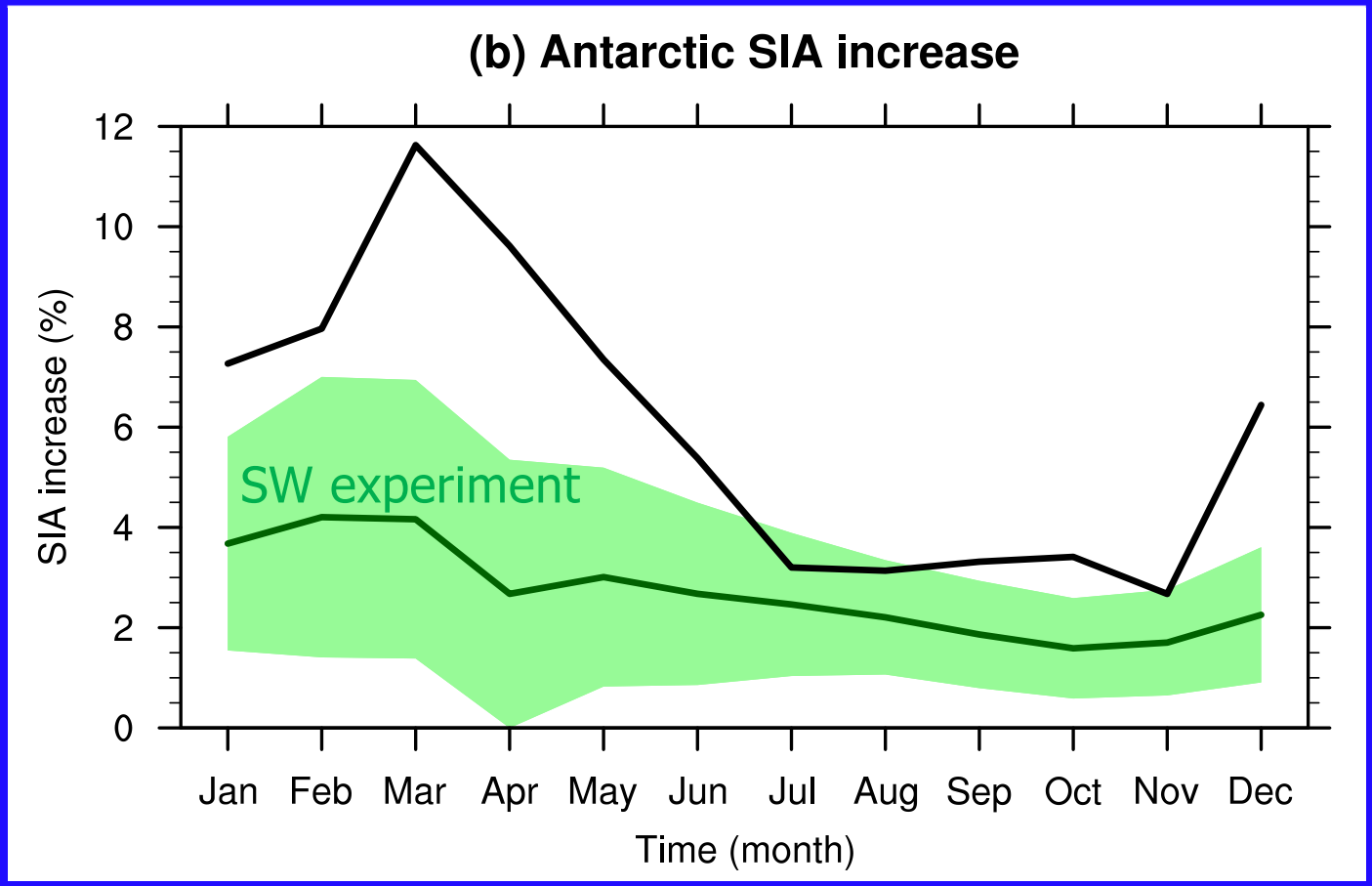
Changes in the ITCZ position



Changes in Antarctic sea ice area



Seasonal Antarctic sea ice increase: Observations (2010s minus 1980s) and SW experiment (first 30 years)



Summary

- Arctic sea ice decline generates positive (warm and fresh) buoyancy anomalies. On multi-decadal timescales these anomalies spread to the North Atlantic and weaken the AMOC. The effect is amplified by the salt-advection feedback. Global climate response to sea ice decline critically depends on AMOC changes.
- The freshening of the Arctic is a robust consequence of sea ice decline and the intensification of sea ice seasonal cycle. The freshening occurs as a distillation process – fresher waters remain in the Arctic, excessive salt is moved to the deep tropical Atlantic.

- Liu, W., Fedorov, A.V. and Sevellec, F. 2019: The mechanisms of the Atlantic meridional overturning circulation slowdown induced by Arctic sea ice decline. J. Climate
- Liu, W. and Fedorov, A.V. 2018: Global impacts of Arctic sea ice decline mediated by Atlantic meridional overturning circulation. GRL
- Sévellec, F. and Fedorov, A.V., and W. Liu, 2017: Arctic sea ice decline weakens the Atlantic meridional overturning circulation. Nature Climate Change
- Li, H., and Fedorov, A.V., 2019: Arctic freshening caused by sea ice decline. To be submitted.