

Climate Change of upper-ocean stratification as inferred from the IPCC-AR4 models: A GLOBEC study

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In collaboration with:

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Why do we care about upper-ocean stratification?

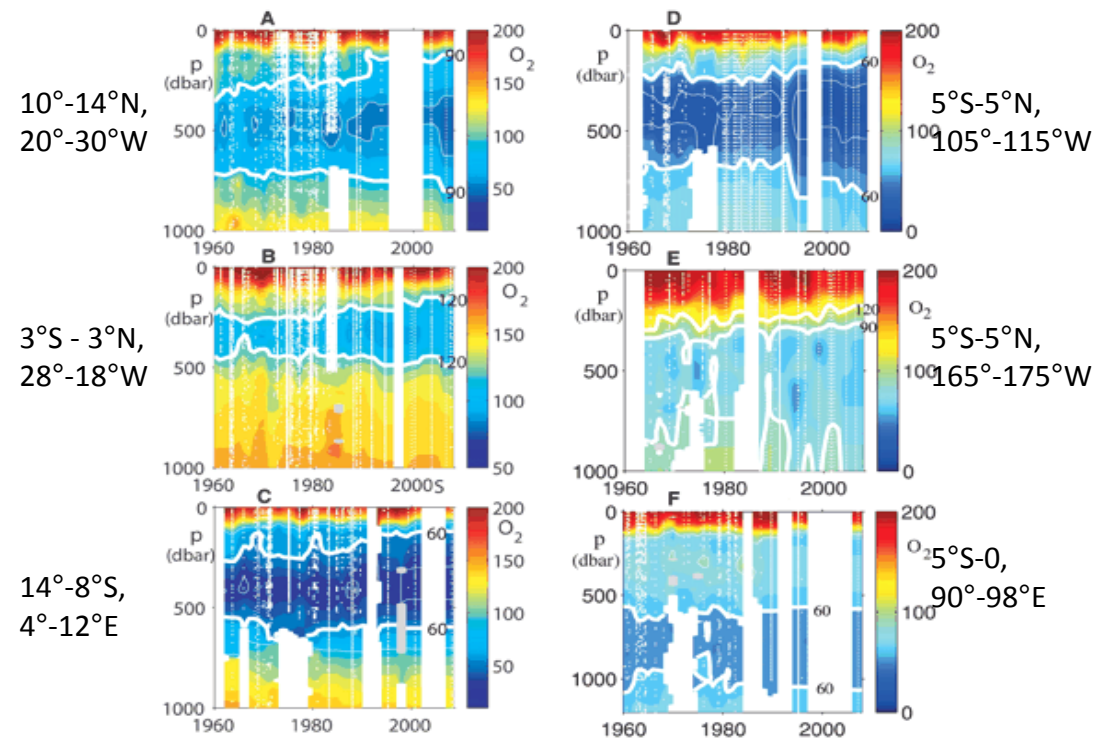
Biological processes



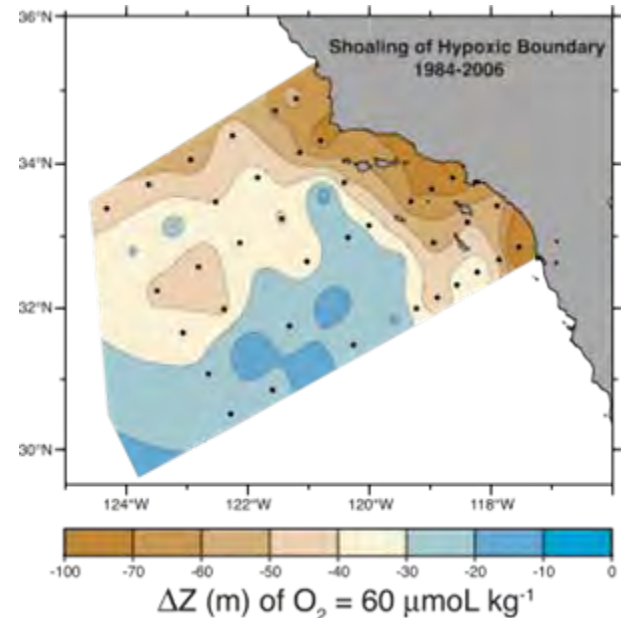
Dissolved oxygen

Dissolved oxygen concentration
In tropical oceans

CALCOFI data, Shoaling of
Hypoxic boundary



Stramma et al. 2008



Bograd et al. 2008

Whitney et al. 2007 found
oxygen decline and shoaling
at Papa in 1956-2006

Outline

- Changes in SST, wind stress, and sea surface salinity (SSS)
- Trends over the 21st century, and difference in mean conditions between the second half of the 21st century and the second half of the 20th century based on both the A1B and A2 scenarios.
- Influence of the changes in the surface fields upon the upper-ocean stratification over the Global Ocean.

Models :

NCAR_CCSM3

GFDL_CM2.1

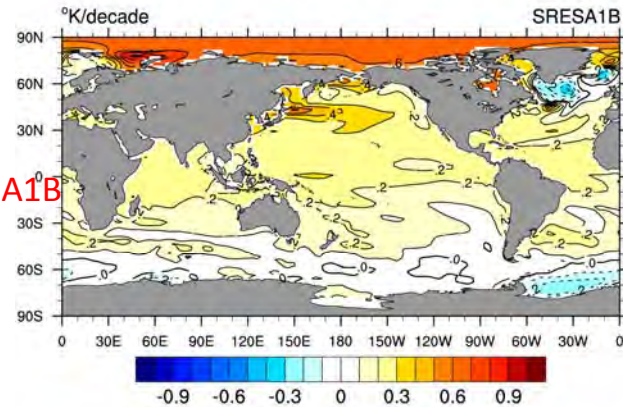
UKMO_HadCM3

CCCMA

SST Trend over 21st century

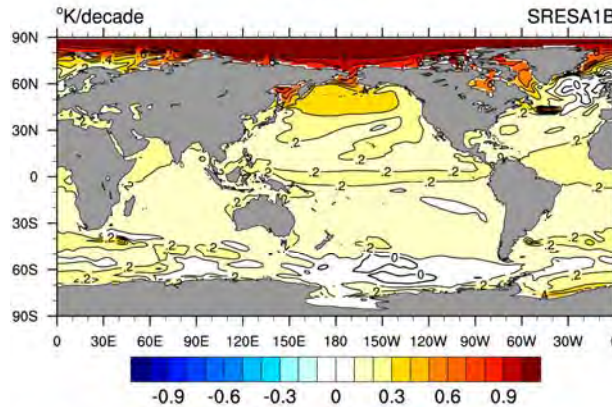
GFDL_CM21

GFDL_CM2_1



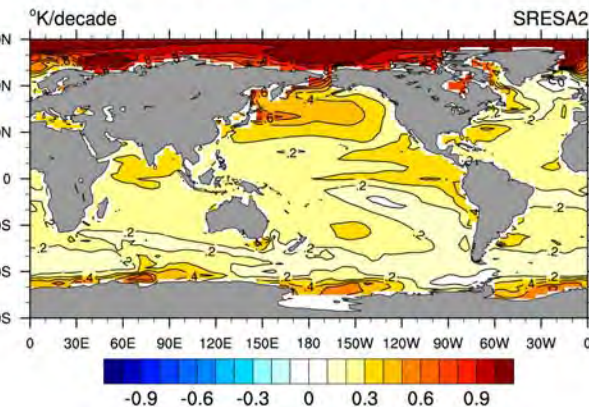
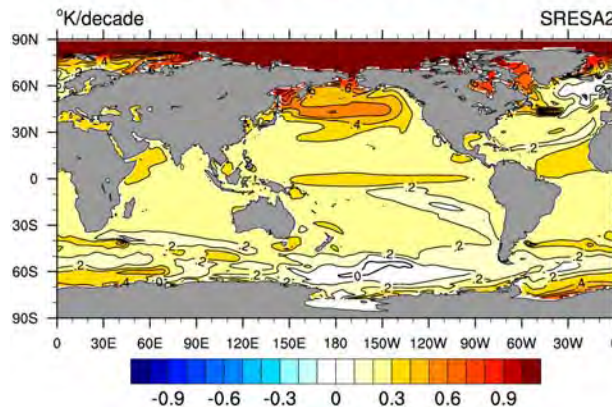
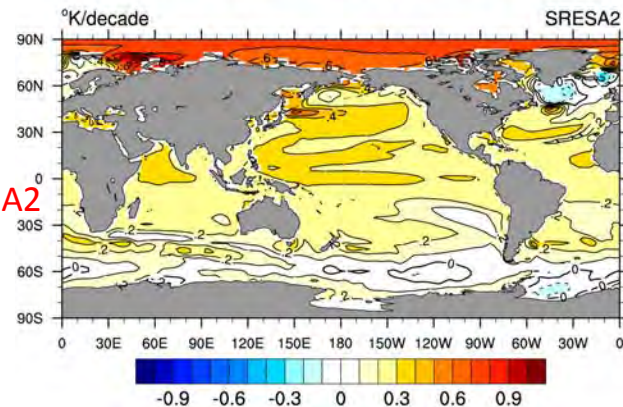
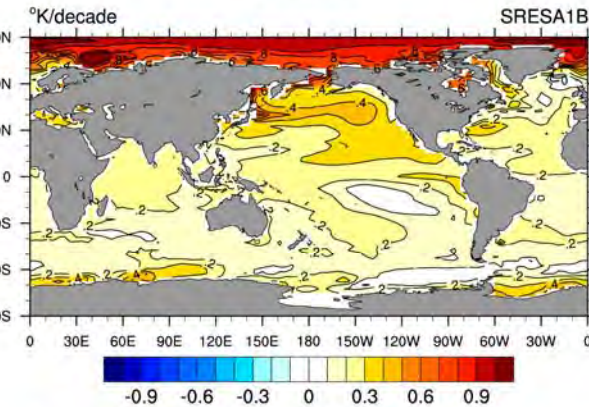
CCSM3

NCAR_CCSM3_0



HadCM3

UKMO_HADCM3



Surface Wind Stress Trend over 21st century

GFDL_CM21

TAU GFDL_CM2_1

CCSM3

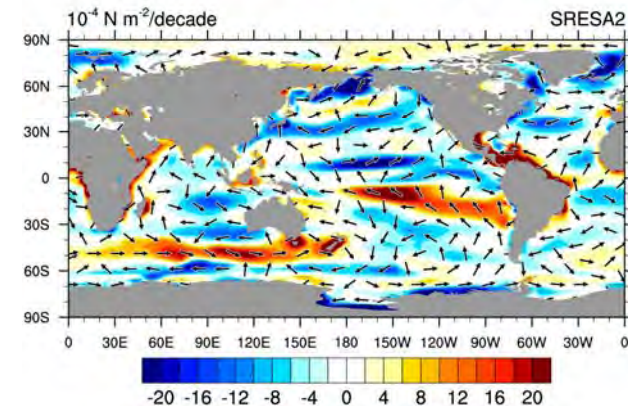
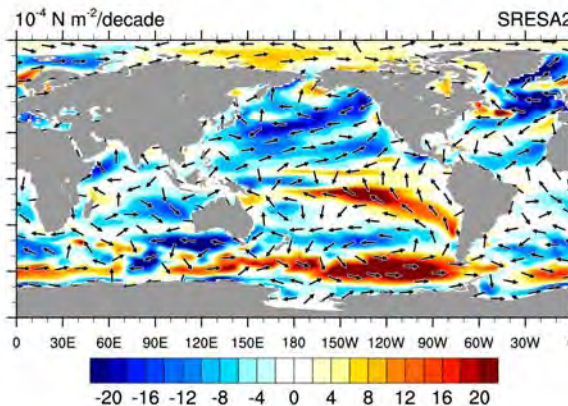
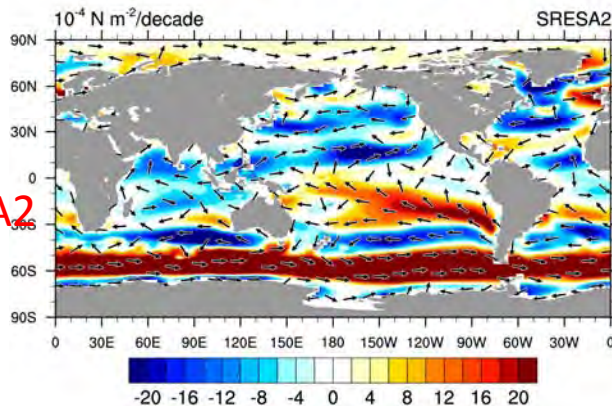
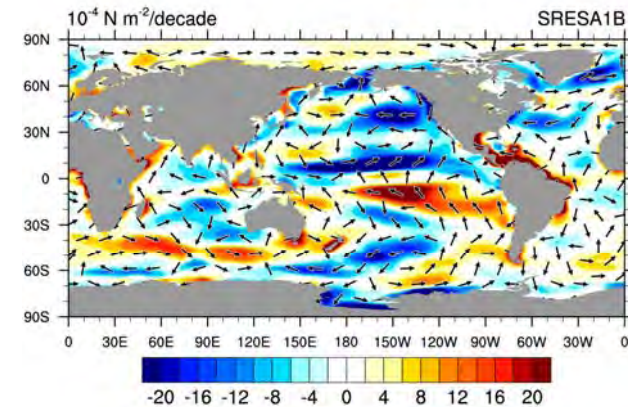
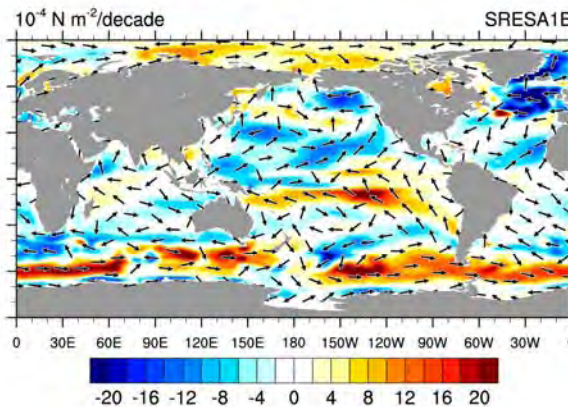
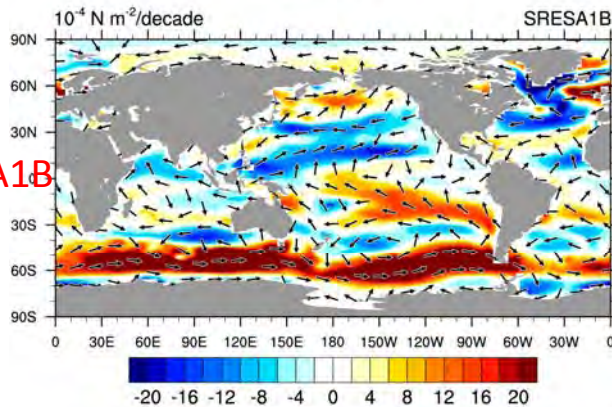
TAU NCAR_CCSM3_0

HadCM3

TAU UKMO_HADCM3

A1B

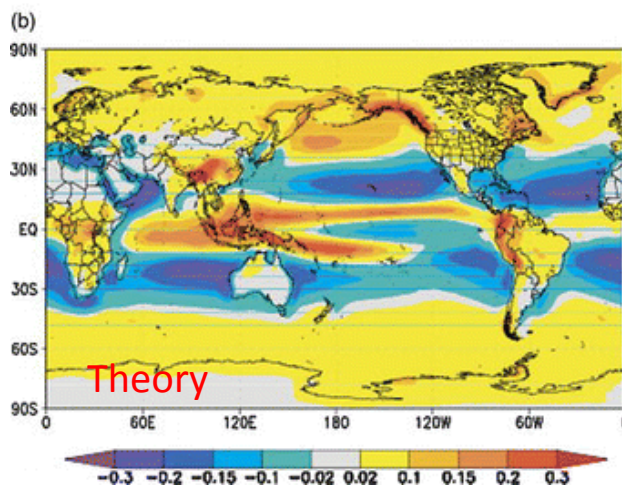
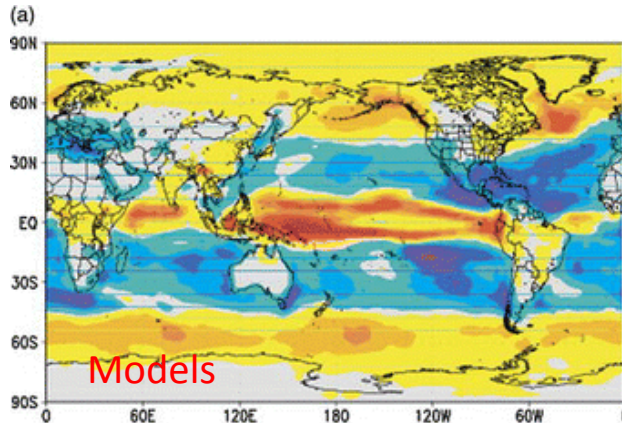
A2



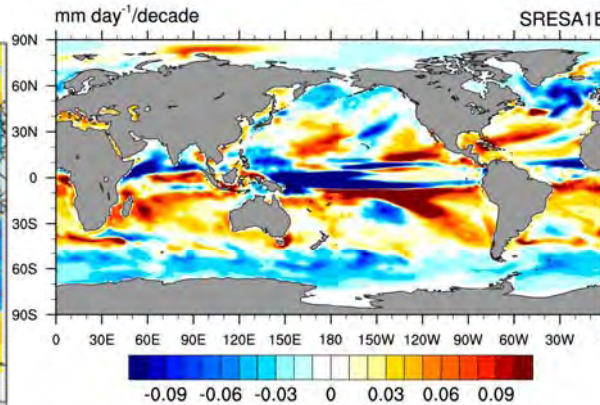
Changes in the hydrological cycle

A1B scenario P-E
2080-2100 minus 2020-2000

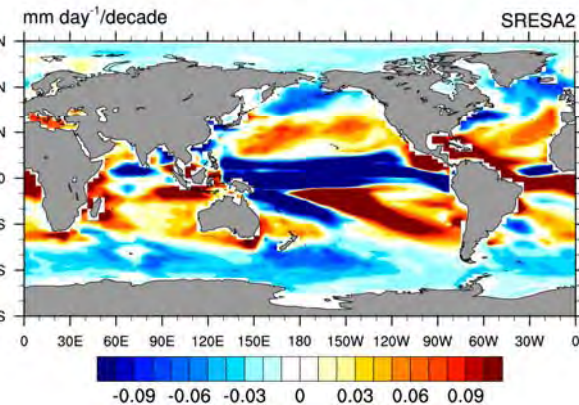
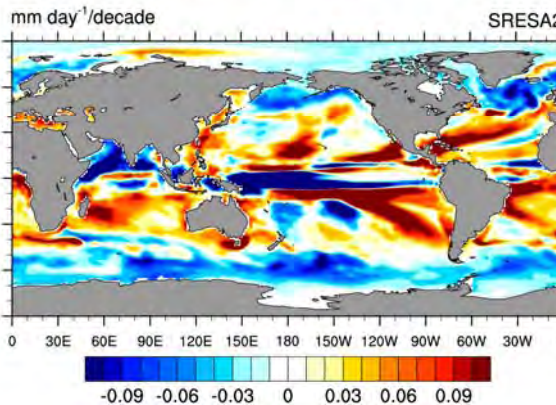
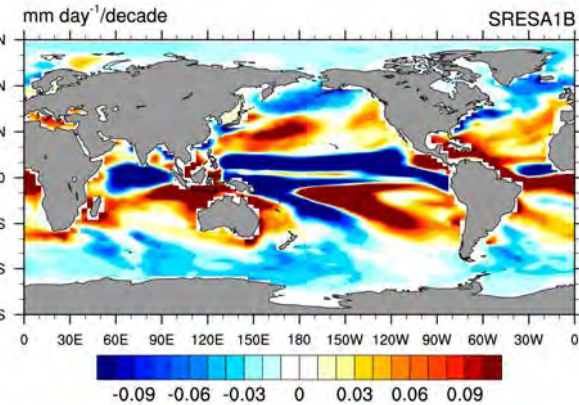
E-P



E-P NCAR_CCSM3_0

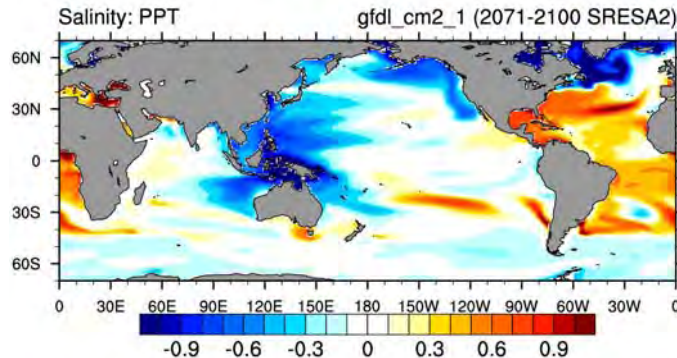


E-P UKMO_HADCM3

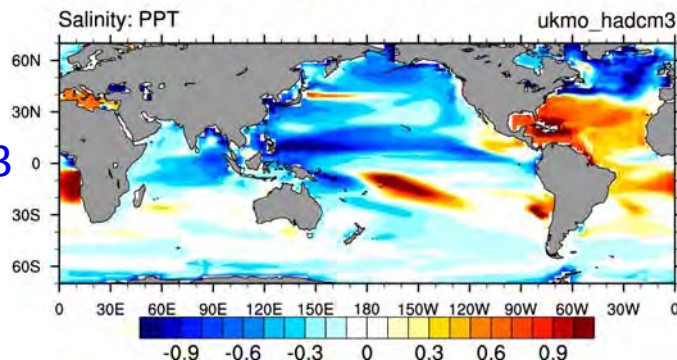
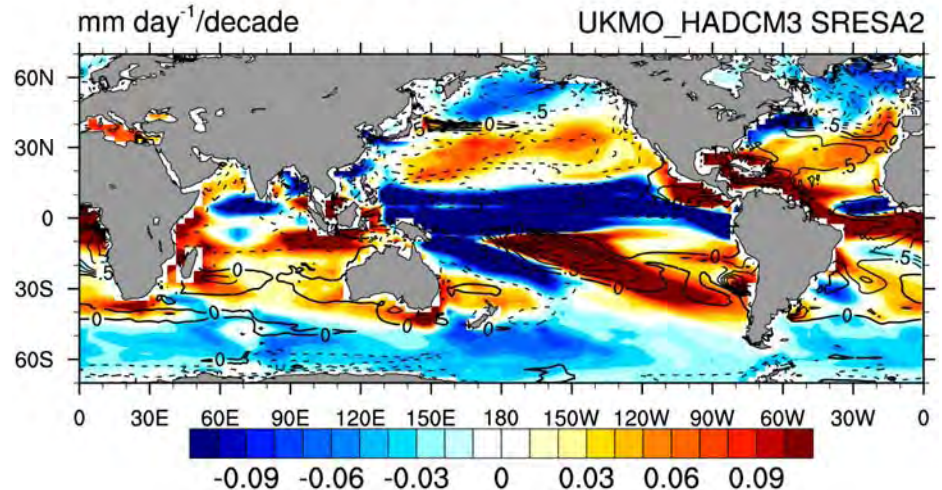
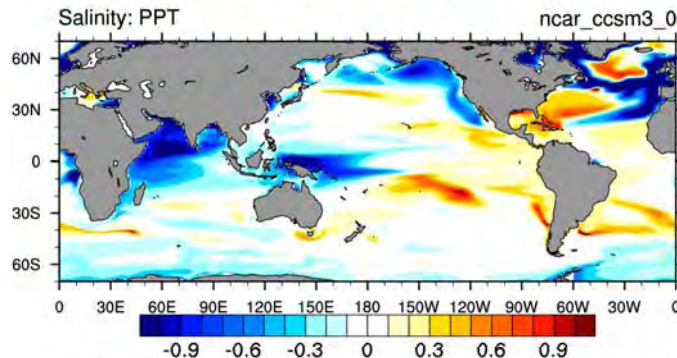
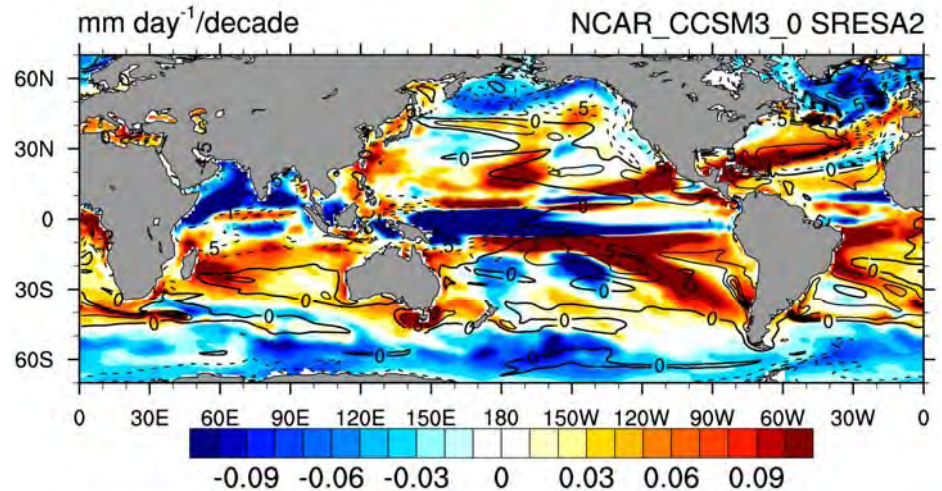


Salinity changes

SRESA2(2050-2099) - 20C3M(1950-1999)



E-P (SSS contour)



CM2.1

CCSM3

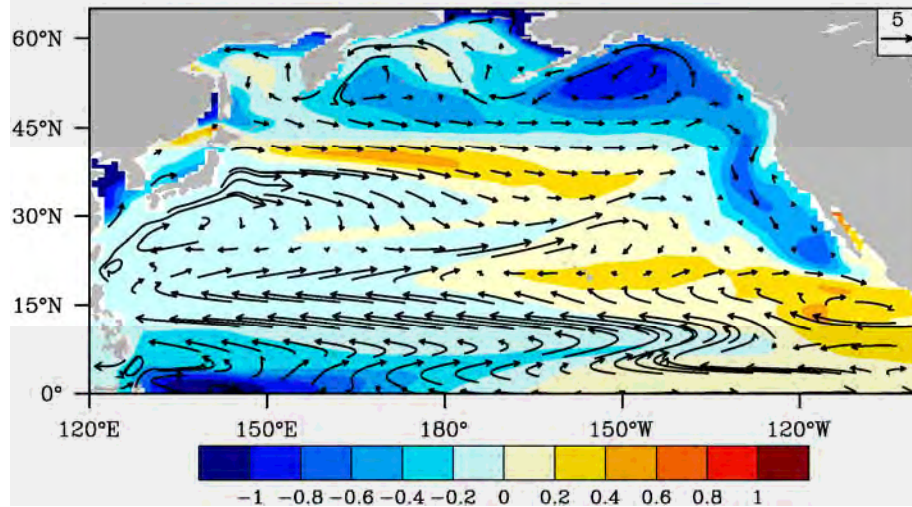
HadCM3

North Pacific

Salinity difference, upper ocean velocities

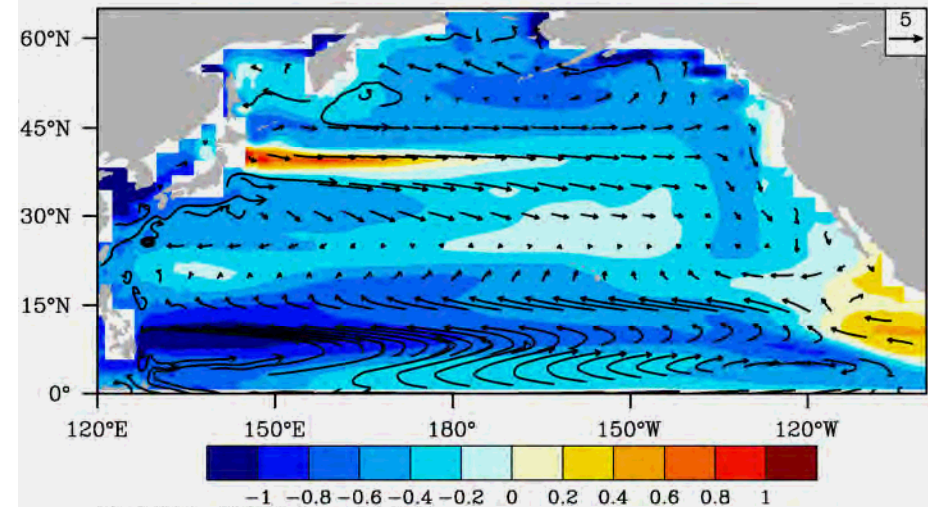
CCSM3 mean velocities

CCSM3, SRESA2 - 20C3M, Mean 20C velocities



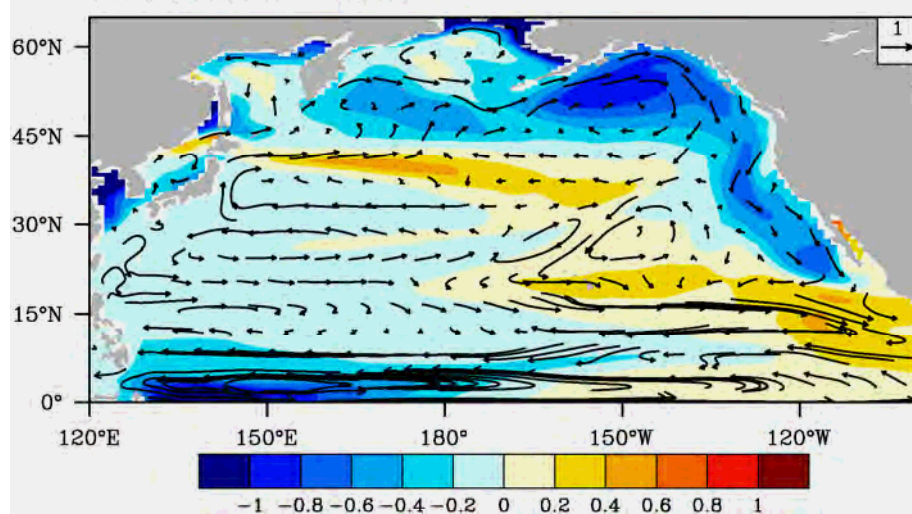
HadCM3

HadCM3, SRESA2 - 20C3M, Mean 20C velocities

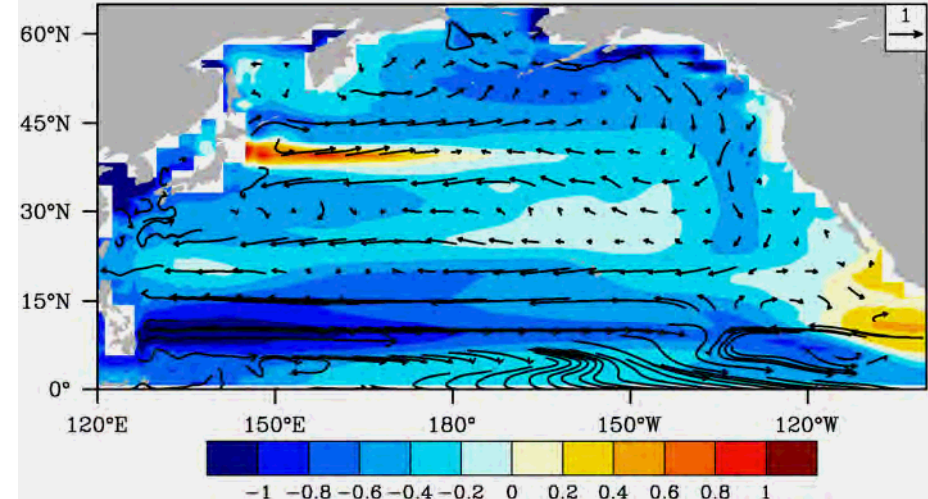


CCSM3, SRESA2 - 20C3M

Velocity difference

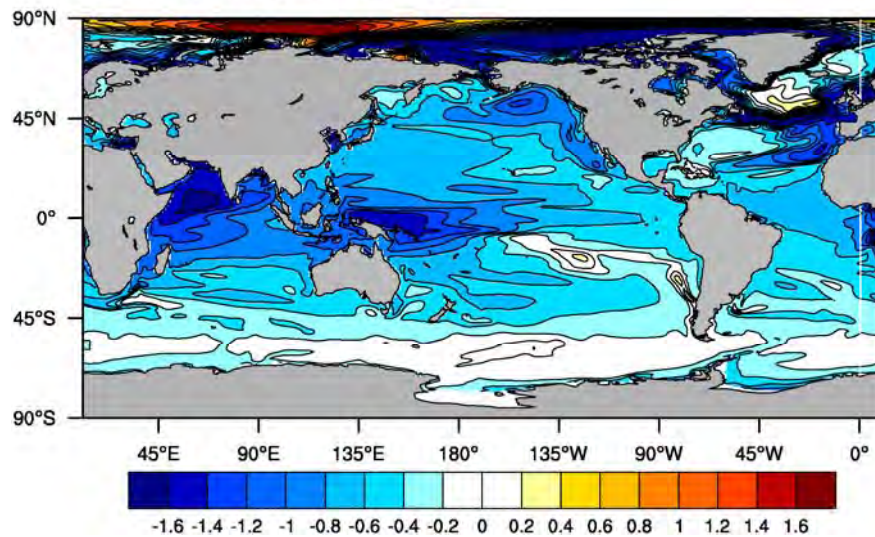


HadCM3, SRESA2 - 20C3M



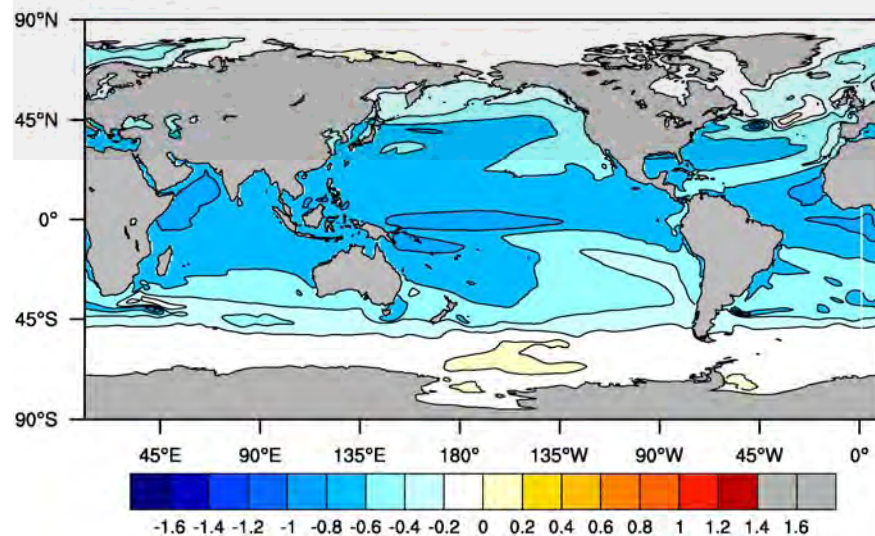
Surface Density Changes – CCSM3

CCSM3 - Surface Density Difference



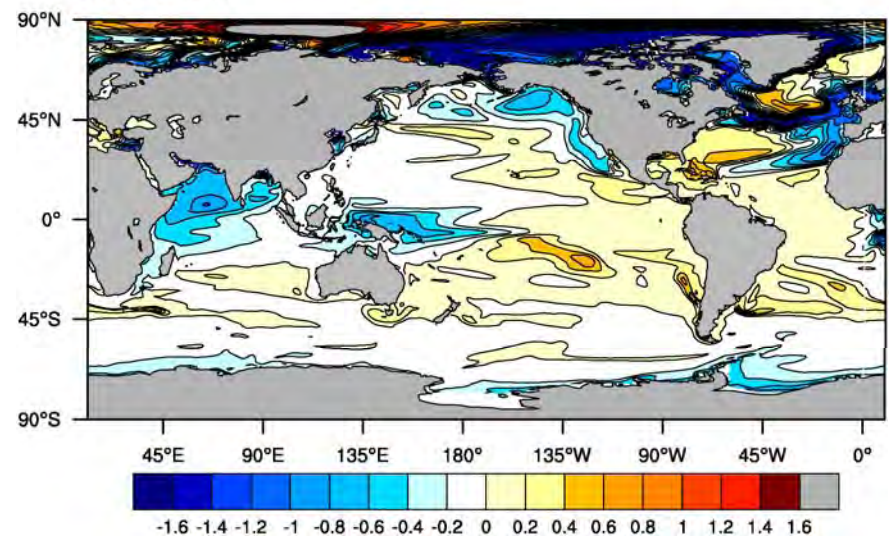
SST component

CCSM3 - ρ_{hot}



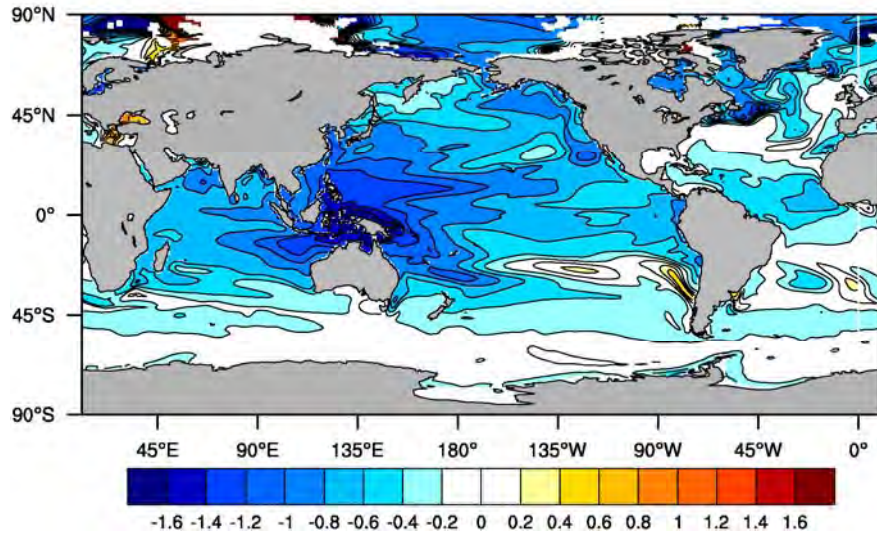
SSS component

CCSM3 - ρ_{hos}



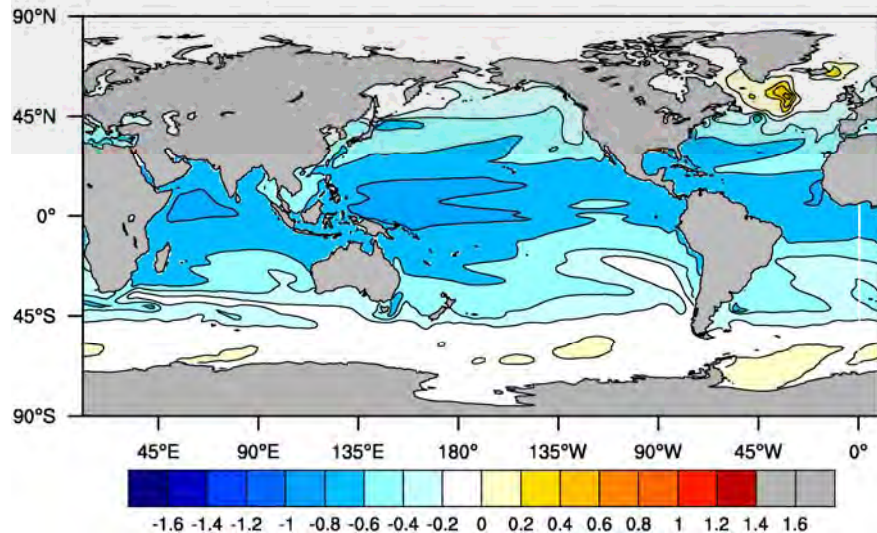
Surface Density Changes – CM2.1

GFDL_CM21 - Surface Density Difference

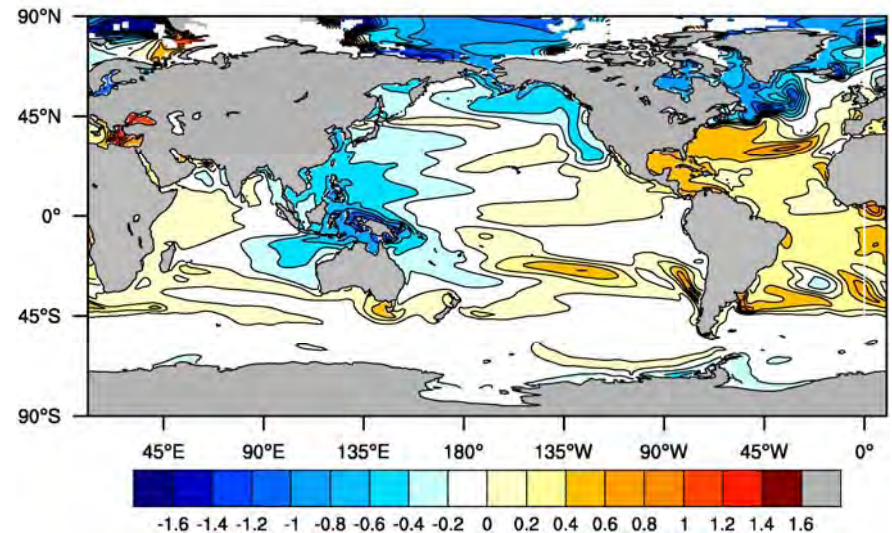


SSS contribution

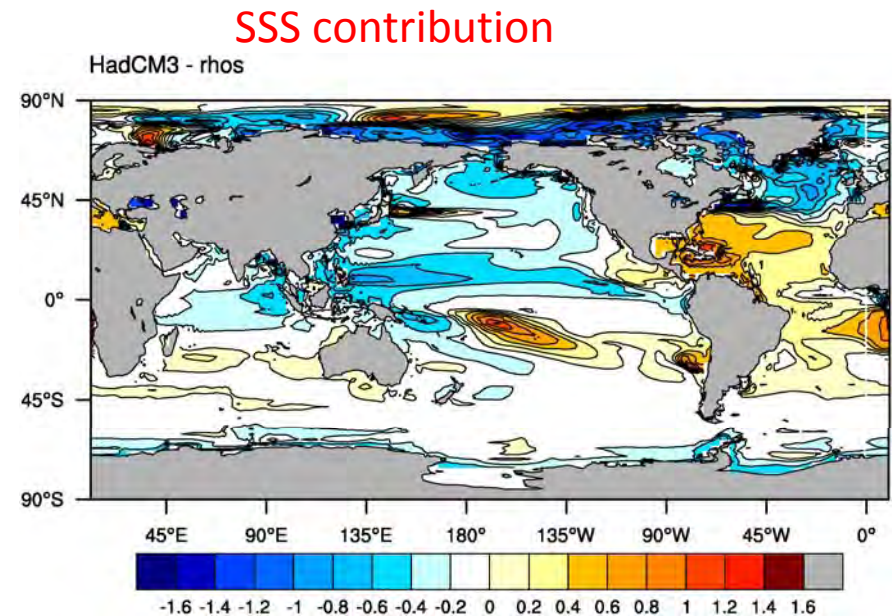
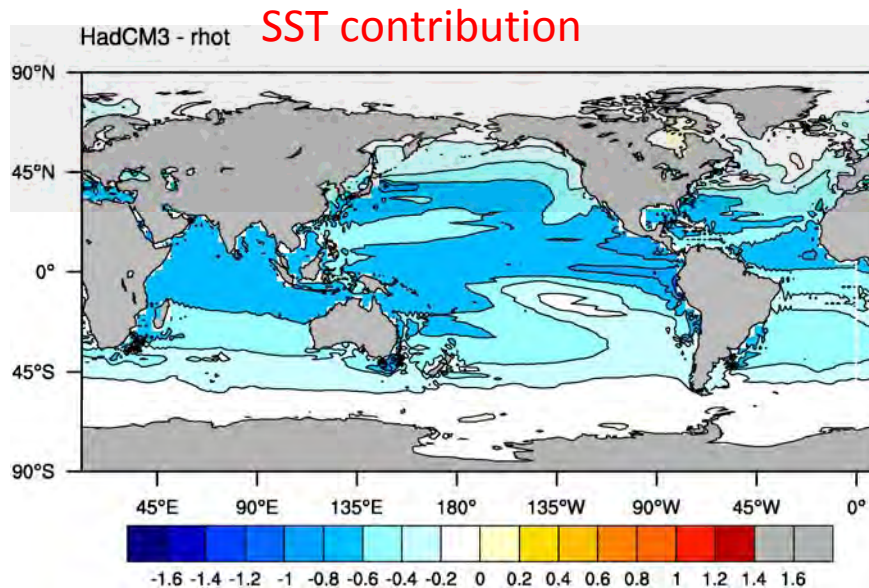
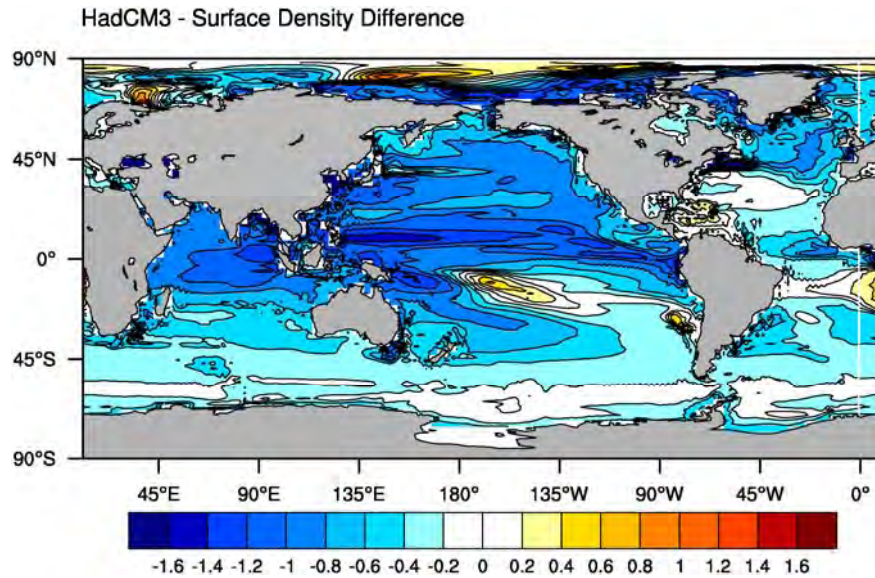
GFDL_CM21 - ρ_{hot} SST contribution



GFDL_CM21 - ρ_{hos}

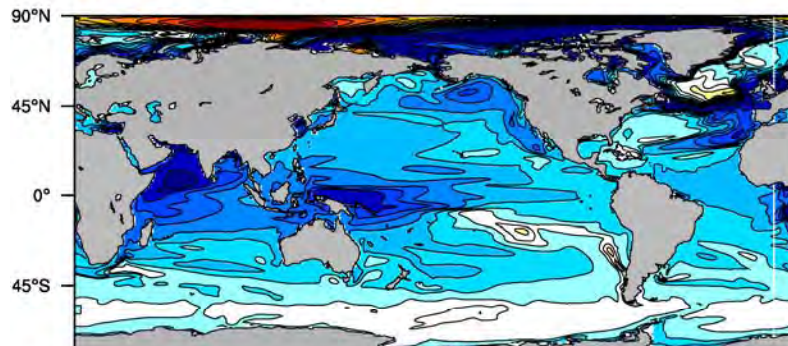


Surface density changes – HadCM3

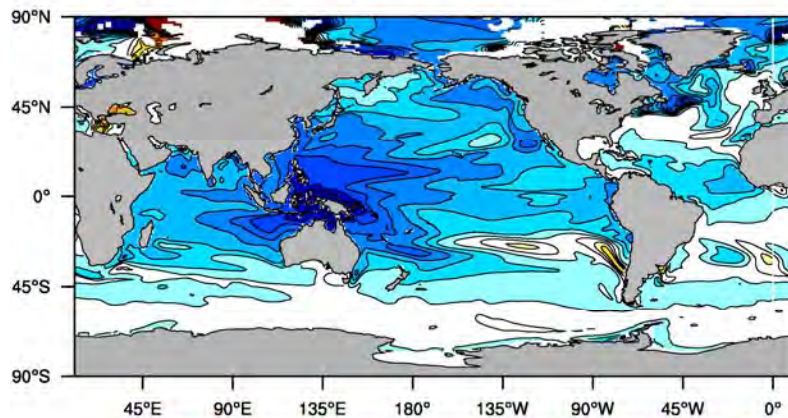


Surface density vs. deep density

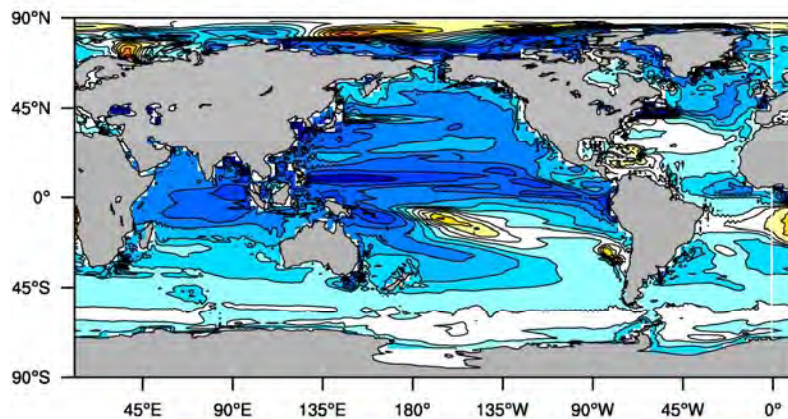
CCSM3 - Surface Density Difference



GFDL_CM21 - Surface Density Difference

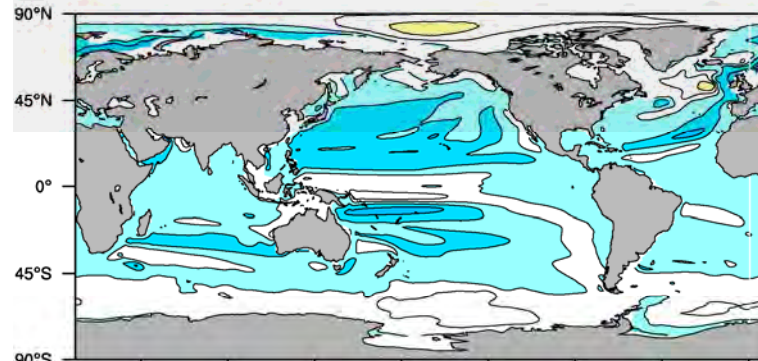


HadCM3 - Surface Density Difference

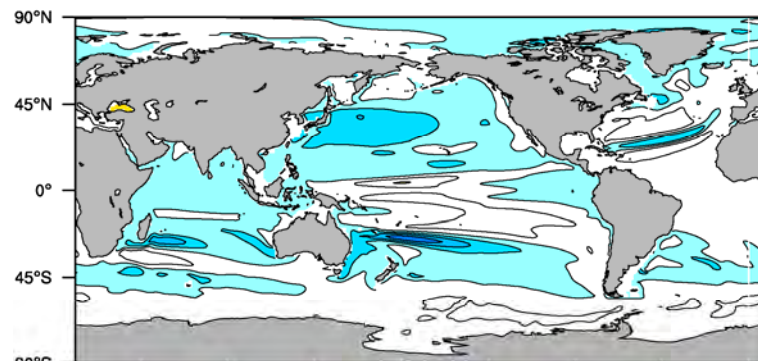


-1.6 -1.4 -1.2 -1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6

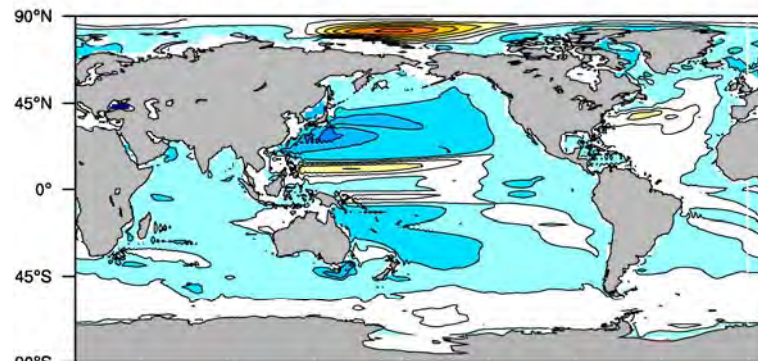
CCSM3 - 200m density difference



GFDL_CM21 - 200m density difference



HadCM3 - 200m density difference



-1.6 -1.4 -1.2 -1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6

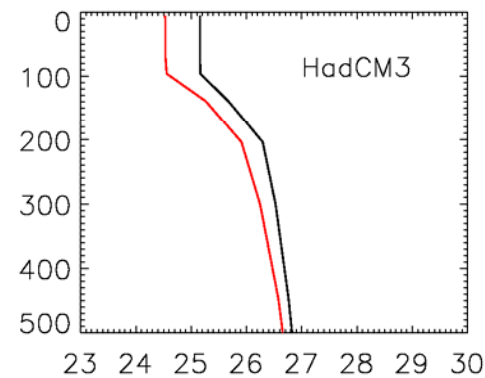
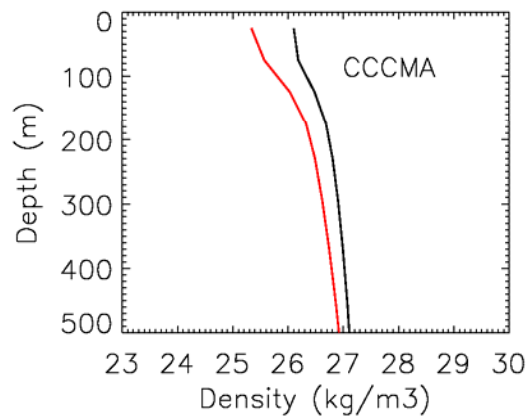
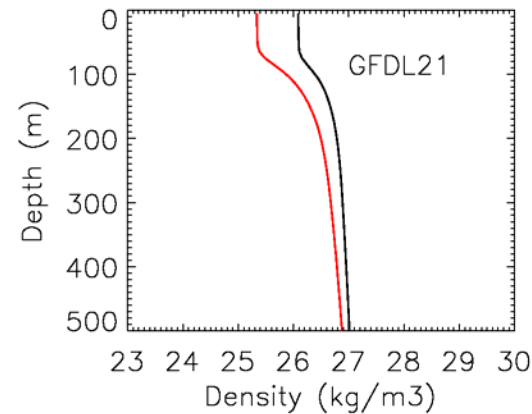
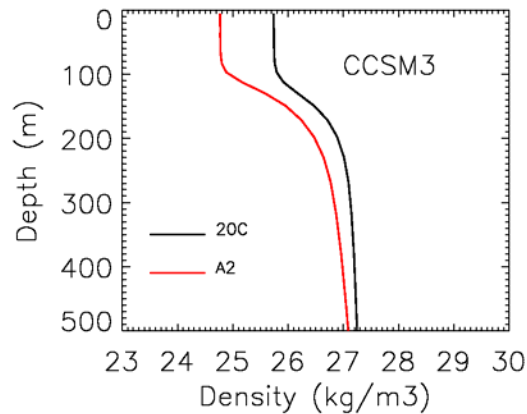
CCSM3

CM2.1

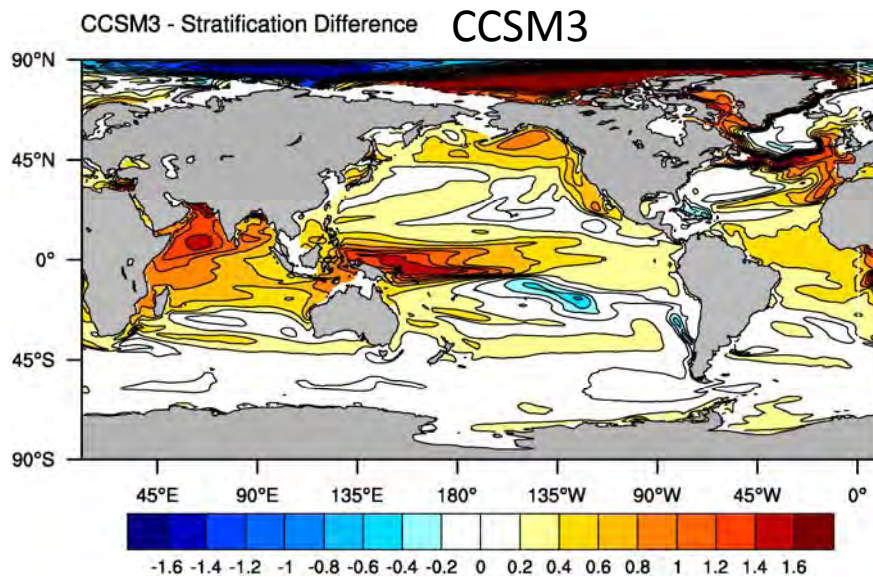
HadCM3

Vertical density profiles (JFM)

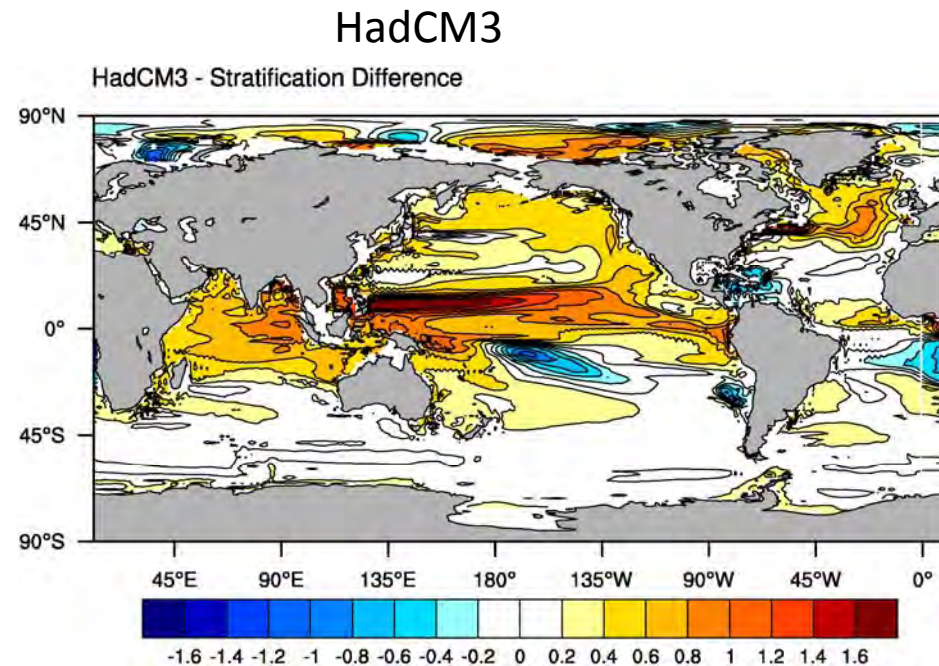
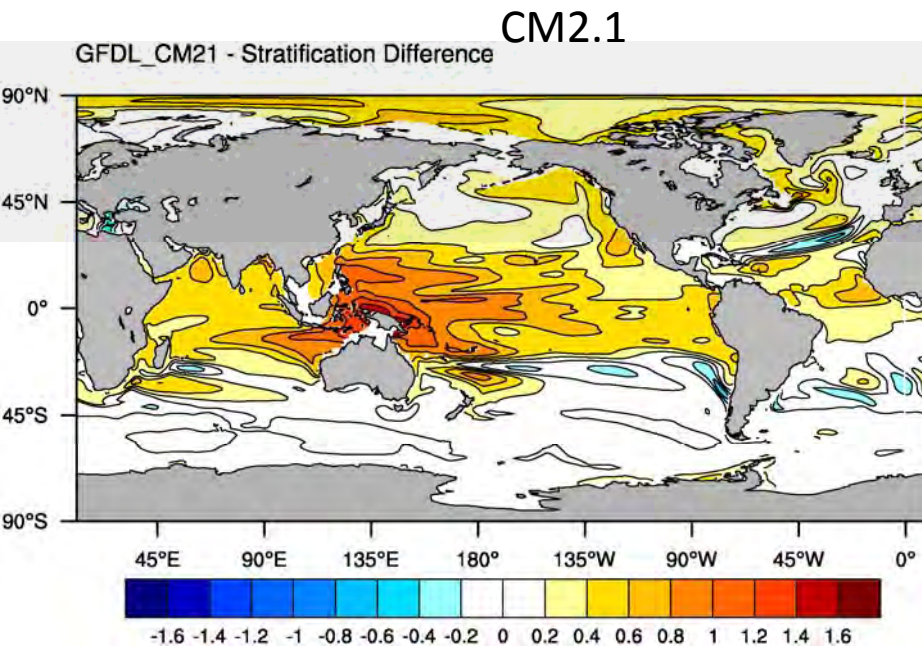
Ocean Weather Station Papa (145°W, 50°N)



Stratification difference



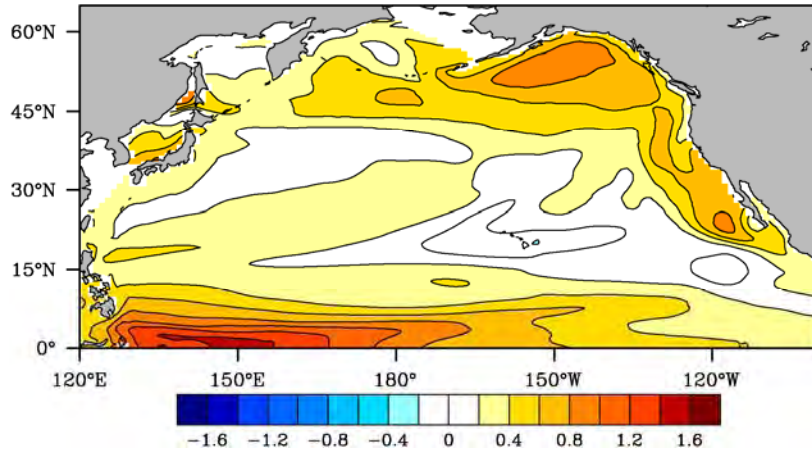
Stratification = $pd(200m) - pd(surface)$



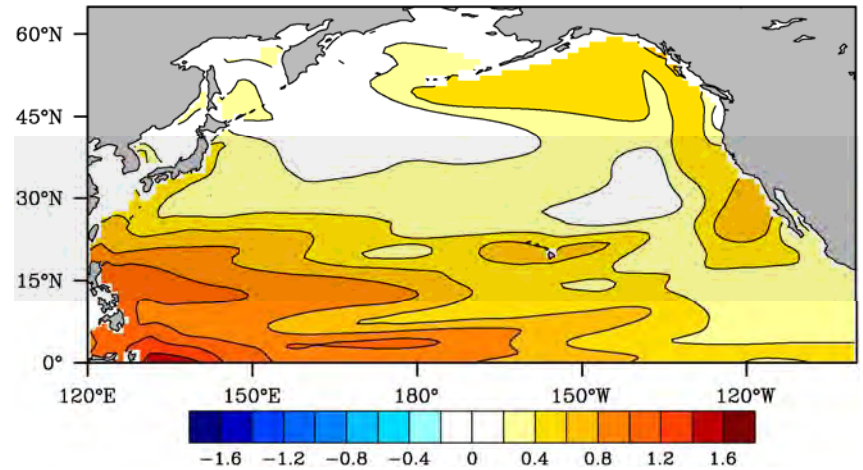
North Pacific

Vertical density gradient (200m – surface, SRESA2 -20C)

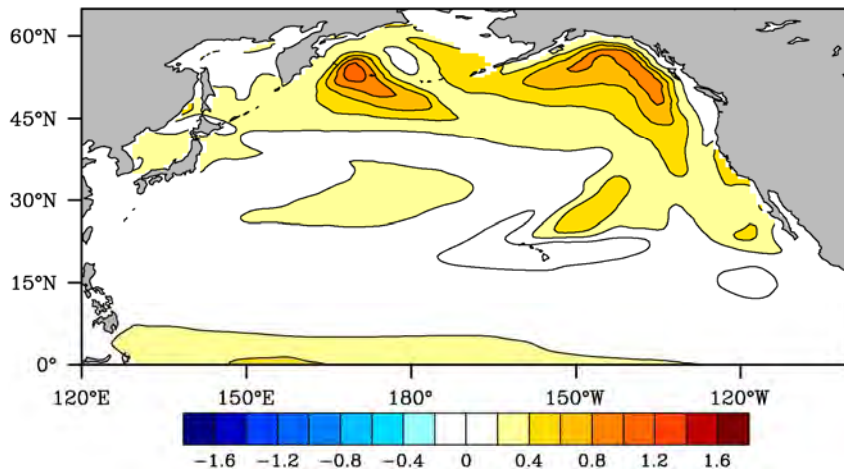
CCSM3 – Stratification Difference



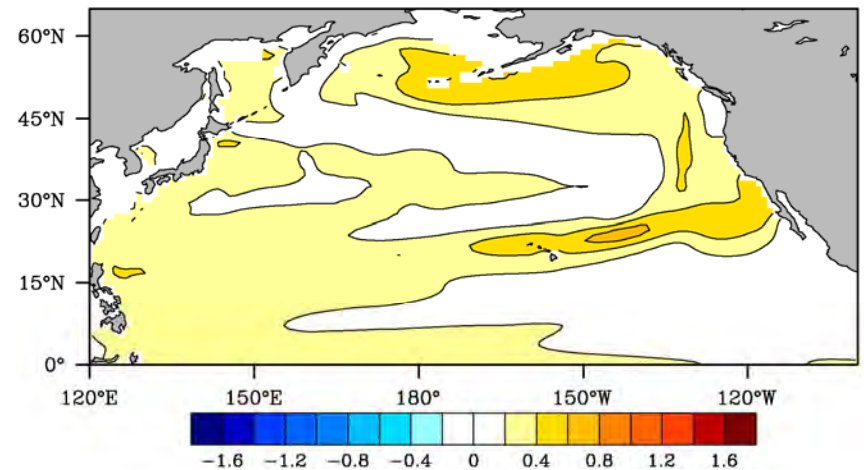
GFDL CM21 – Stratification Difference



CCSM3 – Normalized Stratification Difference



GFDL CM21 – Normalized Stratification Difference



Summary

Apart from SST increases over the World Ocean, climate change will affect also SSS through changes in the hydrological cycle and ocean advection.

SST and SSS both have a large influence on surface density. The influence of salinity being more localized in specific areas

Density changes at depth are much smaller, resulting in significant stratification increase over large areas of the World Ocean.