Interannual and Decadal scale salinity variability in oceanic subtropical gyres

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Abstract

The Simple Ocean Data Assimilation (SODA) reanalysis global data set provides an assimilated view of interannual and decadal salinity variability in the subtropical gyres. This is useful for resolving long term variability and underlying processes, where historically, direct observations have been sparse in such regions. Our results indicate an salinity increase within the mixed layer, and a salinity decrease at depths greater than 200m for the subtropical gyres over six decades. Freshwater fluxes have been established as one of the primary drivers of the local sea surface salinity signature over open ocean regions. The observed increase of sea surface salinity in high salinity gyres supports the growing evidence of an evaporation-precipitation (E-P) pattern amplification on the global scale. These decadal changes in salinity are most pronounced in the three southern hemisphere gyres. Inter-basin contrasts are also evident, as the intense salinification of the subtropical Atlantic relative to the Pacific implies a net transport of freshwater from the Atlantic to the Pacific through atmospheric pathways. This examination of subsurface salinity in the subtropical gyres over the past 6 decades through reanalysis data aids in understanding the role of surface and sub-surface salinity as it relates to freshwater and heat fluxes on the regional and global scale.

Introduction

The global water cycle is expected to have accelerated as a response to anthropogenic global warming

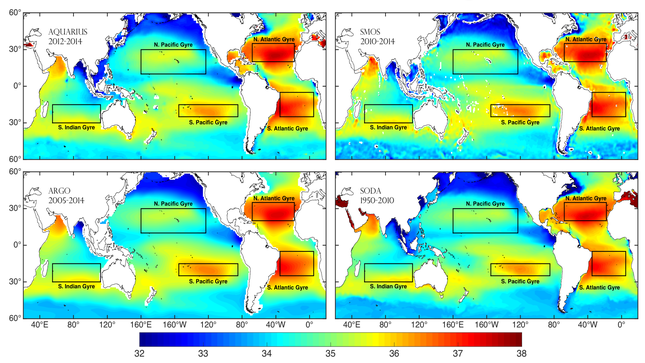
Global water cycle is largely dictated by freshwater fluxes over the oceans, which account for 86% of global evaporation and 78% of global precipitation [*Ren et al.*, 2014]

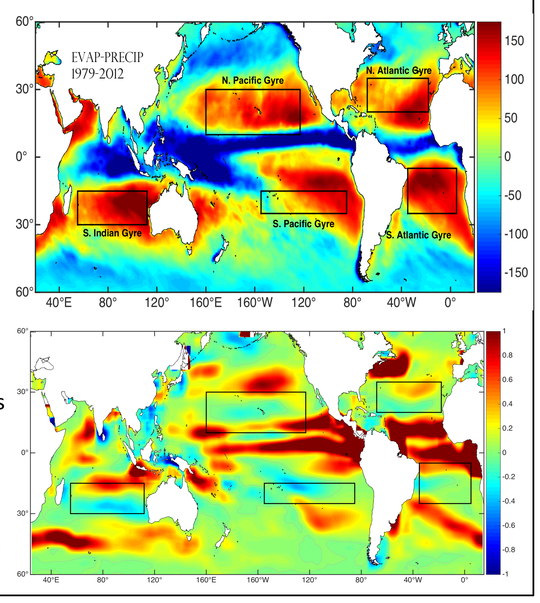
Sea surface salinity can be used as a proxy for evaporation and precipitation estimates over the ocean:
Evaporation → loss of freshwater → increase in salinity
Precipitation → gain of freshwater → decrease in salinity

Subtropical gyres are evaporation-dominated regions with a corresponding high salt content in the mixed layer; previous studies [*Durack et al.*, 2012] have indicated these gyres are increasing in sea surface salinity on climatological time scales

This study is conducted primarily with Simple Ocean Data Assimilation (SODA) reanalysis monthly gridded product

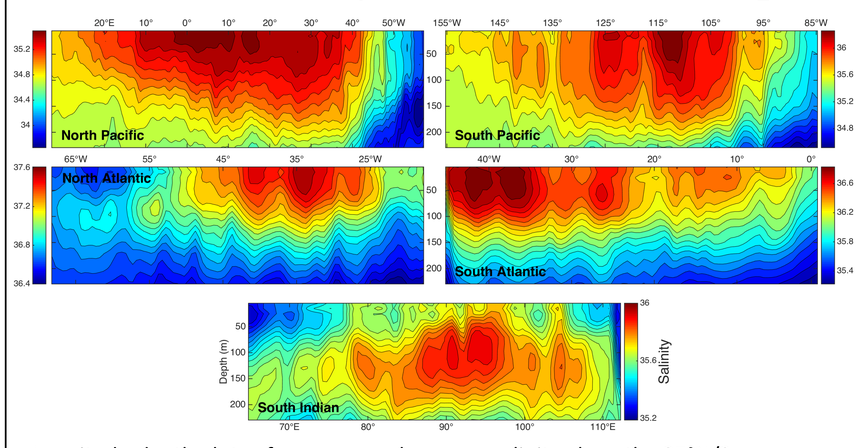
Regions of interest





Top left: Global mean sea surface salinity from satellites (Aqaurius and SMOS), Ago floats data, and SODA reanalysis. The five subtropical gyre regions are denoted by boxes.
Top right: Climatological evaporation-precipitation (E-P) over the global ocean (cm/yr)
Bottom right: Normalized spatial covariance between E-P and sea surface salinity over the global ocean, with contour lines at zero.

Salinity Structure of Subtropical Gyres



- Atlantic saltiest ocean in subtropics, Pacific freshest
- Salinity maximum generally occurs at the surface
- Vertical salinity gradient inversion in center of South Indian gyre
- Strong horizontal gradient on the eastern boundary of Pacific gyres

Longitude-depth plots of mean annual average salinity along the 25°N/S transect from SODA reanalysis of subtropical gyres a) north Pacific, b) south Pacific, c) north Atlantic, d) south Atlantic, and e) south Indian oceans.

Acknowledgements

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References

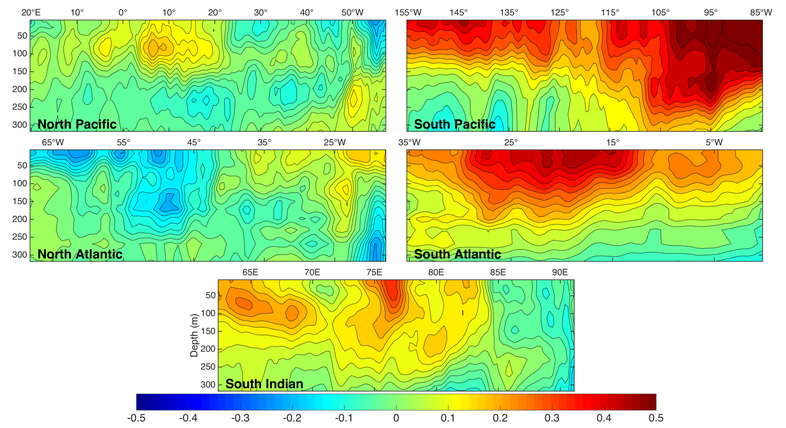
Durack, P. J., S. E. Wijffels, and R. J. Matear (2012), Ocean salinities reveal strong global water cycle intensification during 1950 to 2000. *Science*, *336*(6080), 455-458.

Ren, L., E. Hackert, P. Arkin, and A. J. Busalacchi (2014), Estimating the global oceanic net freshwater flux from Argo and comparing it with satellite-based freshwater flux products, J. Geophys. Res. Oceans, 119, 7869–7881.

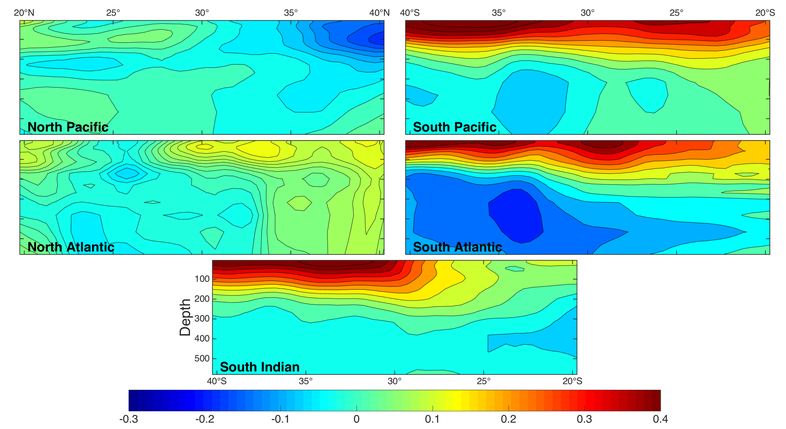
Subsurface Salinity trend in Subtropical Gyres

- Salinification trend evident in mixed layer
- Trend intensifies as you move poleward in the south Pacific and Atlantic
- Trends at all depths are stronger in southern hemisphere gyres
- Basin contrasts also present: Atlantic salinification is much higher than Pacific
- Although lateral distribution in each gyre is focused around a distinct maximum, the decadal salinity change is spatially fairly uniform

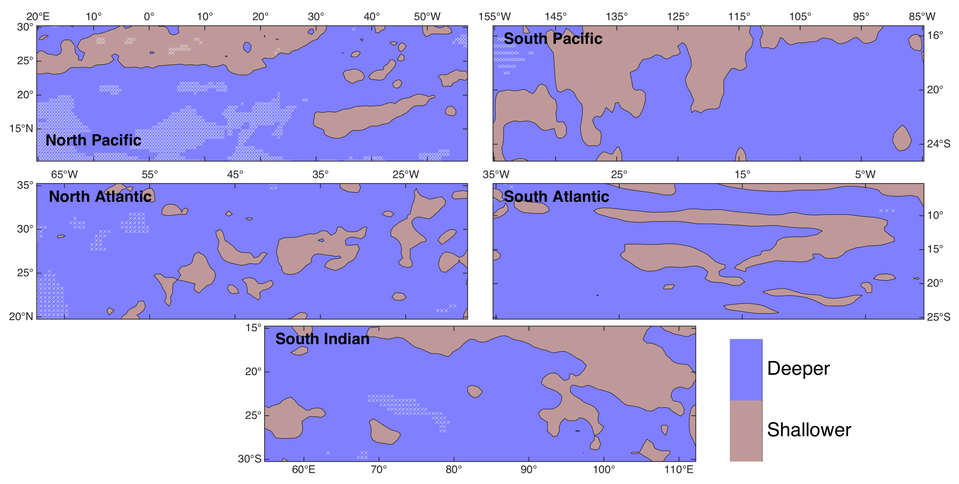
Evidence of increased local mixing:
1. Salt increase at the surface is compensated by freshening at greater depths
2. Overall expansion of mixed layer in subtropical gyres



Meridionally averaged *longitude*-depth plot of 1950-2010 linear salinity trend from SODA in each of the five Subtropical Gyres



Zonally averaged *latitude*-depth plot of 1950-2010 SODA salinity from linear trend in each of the five Subtropical Gyres



1950-2008 change in mixed layer depth inferred from linear trend of annual average. Regions marked by white crosses are those that have experienced a change in depth greater than 25% of the climatological average in that location. Mixed layer depth was determined using a potential density change threshold, where $\Delta\sigma = .125$ kg/m^3.

Conclusions/Relevance

This analysis provides further evidence of an accelerated global water cycle in regions not previously addressed due to limited amounts of historical in situ data by utilizing an assimilated reanalysis product

This apparent water cycle acceleration will change the global distribution of freshwater; can lead to increased severity of droughts and flooding

Salinity should be implemented into forecasting model simulations, as it has been shown to be a factor in ocean circulation and processes related to freshwater fluxes