Interannual variability of the upper ocean water masses as inferred by Argo

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Abstract

Interannual variability of Ocean Heat Content (OHC) is intimately linked to ocean water mass changes. Water mass characteristics are imprinted at the ocean surface and are modulated by climate variability on interannual to decadal time scales. In this study, we investigate the water mass change and their variability using an isopycnal decomposition of the OHC. For that purpose, we address the thickness and temperature changes of these water masses using both individual temperature/salinity profiles and optimal interpolated products from Argo data. Isopycnal decomposition allows us to characterize the water mass interannual variability and decadal trends of volume and OHC. During the last decade (2006–2015), much of interannual and decadal warming is associated with Southern Hemisphere Subtropical Mode Water and Subantarctic Mode Water, particularly in the South Pacific Eastern Subtropical Mode Water, the Southeastern Indian Subantarctic Mode Water, and the Southern Pacific Subantarctic Mode Water. In contrast, Antarctic Intermediate Water in the Southern Hemisphere and North Atlantic Subtropical Mode Water in the Northern Hemisphere have cooled. This OHC interannual variability is mainly explained by volume (or mass) changes of water masses related to the isopycnal heaving. The forcing mechanisms and interior dynamics of water masses are discussed in the context of the wind stress change and ocean adjustment occurring at interannual time scale.

Method

For the purpose of this study, OHC, thickness and mean temperature are computed for each isopycnal layer from ISAS15 (*Kolodziejczyk et al.*, 2017) monthly fields in z-coordinates (*Δz=5-10 m*) using :

OHC :

$$OHC_{12}=\int_{z_1}^{z_2}\rho C_p T(T)\,dz$$

Thickness :

$$h_{12}=\int_{z_1}^{z_2} dz$$

Mean temperature

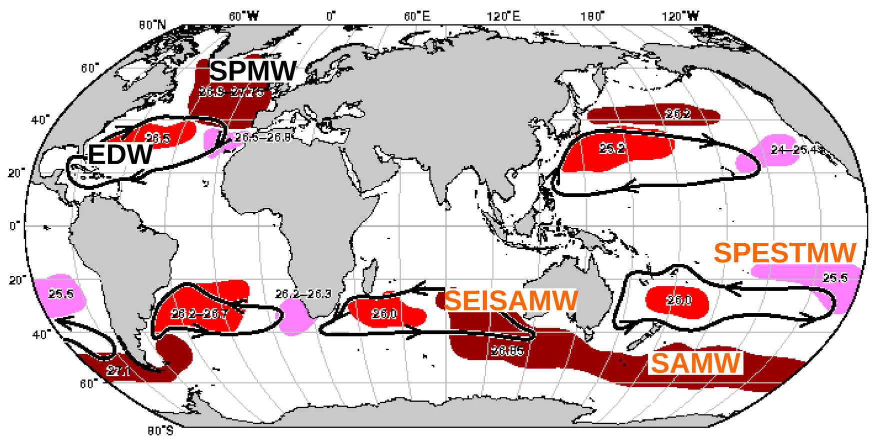
$$T_{12}=\frac{1}{h_{12}}\int_{z_1}^{z_2} T(z)\,dz$$

Where ρ is the density of sea water; C_p is the isobaric thermal capacity of sea water, and T the potential temperature anomaly with respect to 0°C; z_1 and z_2 are the depth of the lower and upper potential density surface limiting a chosen isopycnal layer ($\Delta\sigma$=0.1 kg.m^{-3}).

Results

Isopycnal decomposition (Figure 1) reveals the largest interannual and decadal OHC variability is mainly associated with Southern Hemisphere Subtropical Mode Water (STMW) and Subantarctic Mode Water (SAMW), in particular, in the South Pacific Eastern Subtropical Mode Water (SPESTMW), Southeastern Indian Subantarctic Mode Water (SEISAMW) and in the Southern Pacific SAMW. In the meanwhile, Antarctic Intermediate Water retracts and loses heat.

Some Mode and Intermediate waters :
EDW : Eighteen Degree Water
SPMW : SubPolar Mode Water
SAMW : Subantarctic Mode Water
SEISAMW : South Eastern Indian SAMW
SPESTMW : South Pacific Eastern STMW
AAIW : Antarctic Intermediat Water
(From Hanawa and Talley, 2001)



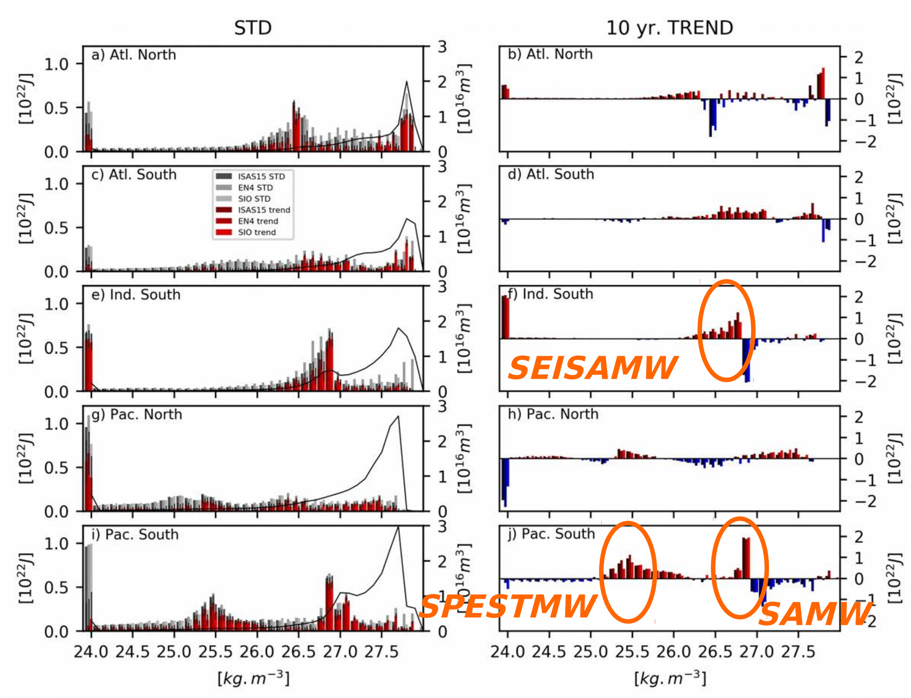
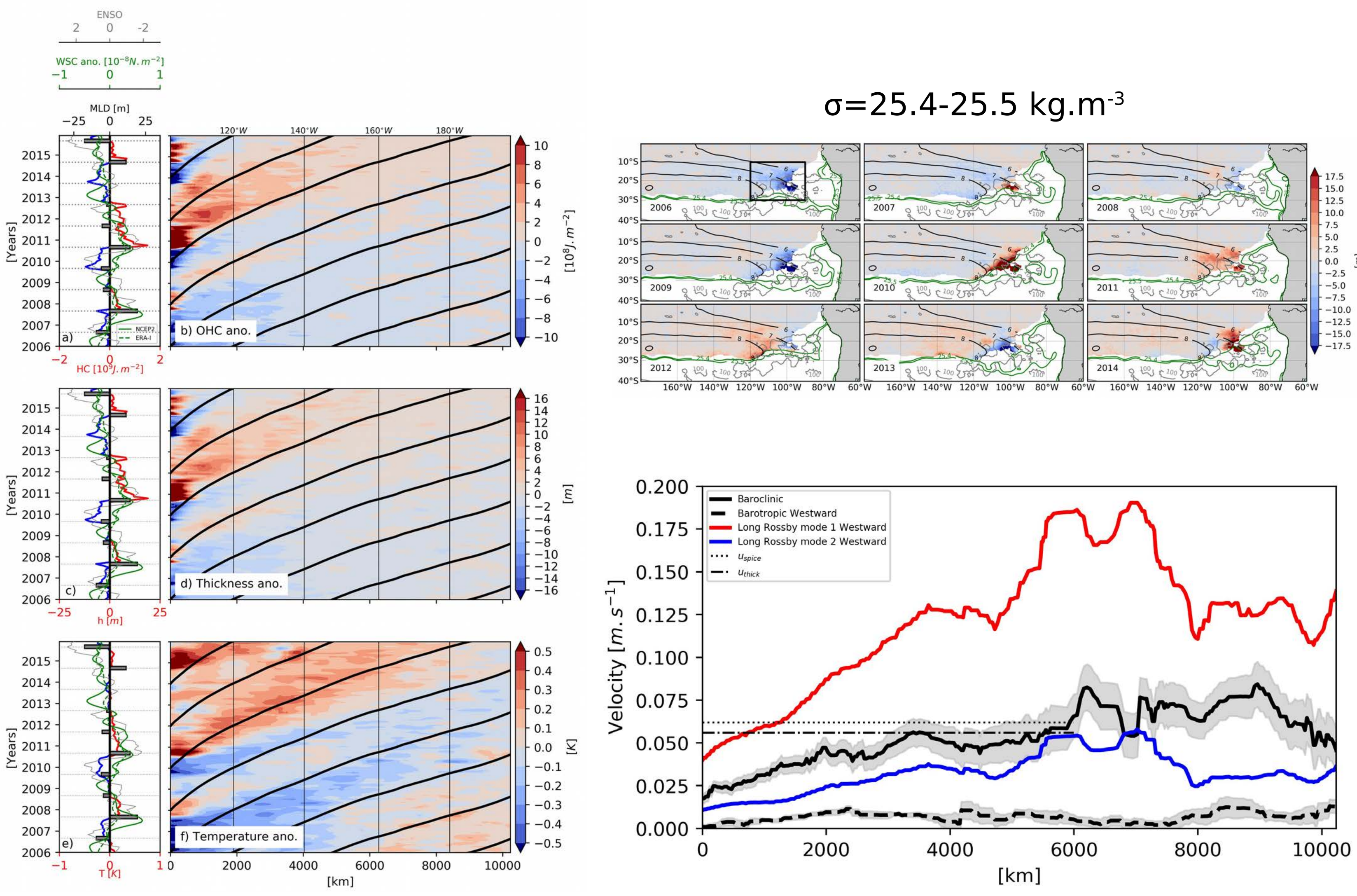


Figure 1: Interannual STD of Heat Content change for 0.1 kg.m^{-3} isopycnal layers between 24.0-27.5 kg.m^{-3} (gray); (left column) STD of trend (red) and uncertainty on trend (error bar), and (right column) heat trend gain (red) and loss (blue) over the 2006-2015 computed from ISAS15, SIO and EN4 product for the period 2006-2015 in (a,b) North Atlantic; (c,d) South Atlantic; (e,f) Indian ; (g,h) North Pacific and (i,j) South Pacific basin.

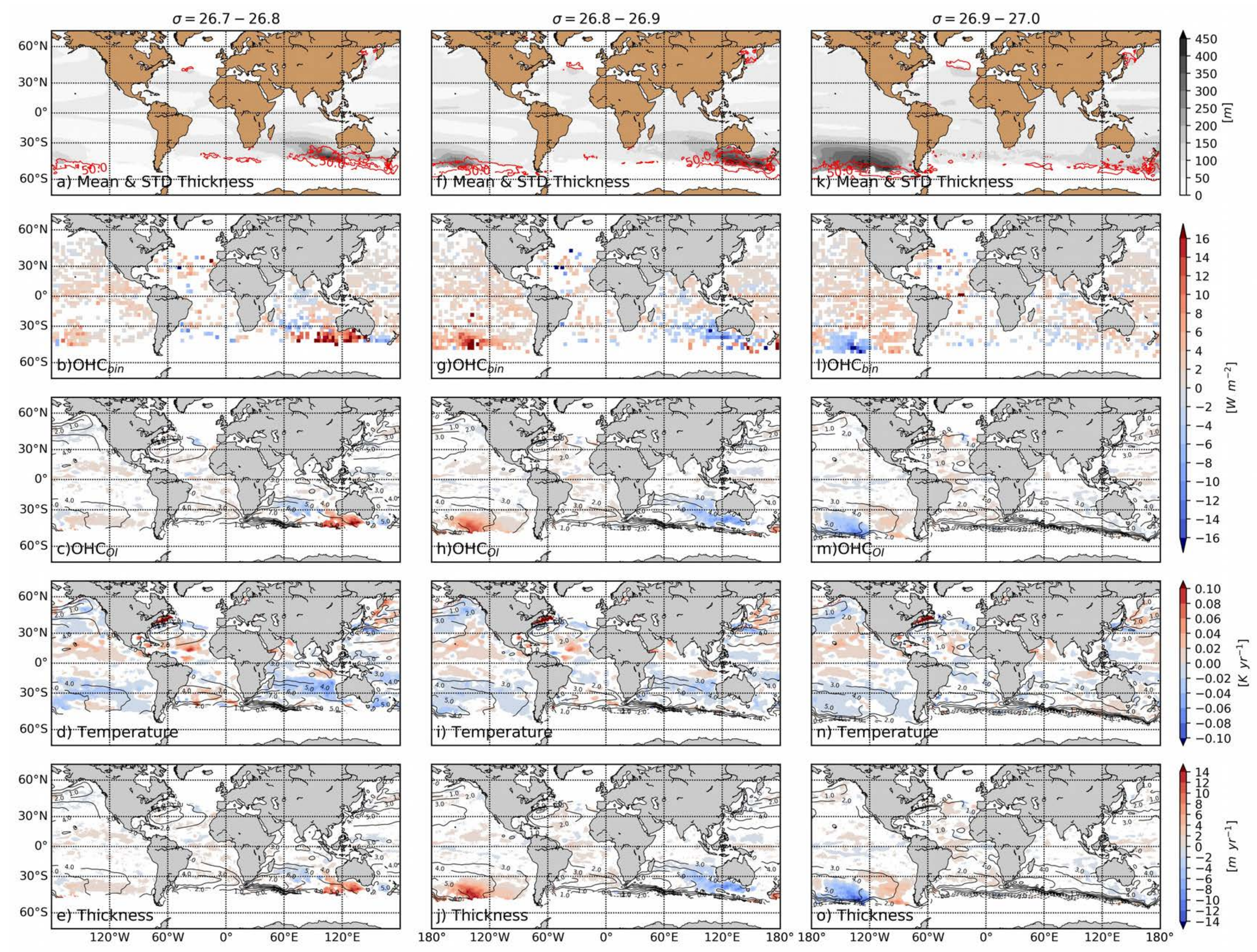
SPESTMW

Figure 3 : In the South Pacific subtropics, the interannual OHC change associated with mode water volume change appears to be propagated in the interior ocean along stream function (black curves, right and left upper panels below). The velocity of thikcness anomalies is close to the speed of mean baroclinic current along stream functions (lower right panel). Second baroclinic long Rossby wave speed (blue) advected (sum) by barotropic current (dashed black) exhibits speeds compatible with volume and temperature propagation (*Liu and Shin*, 1999). Isopycnal and diapycnal mixing may quickly reduce the propagating signal.



SAMW

Figure 2 : SAMW 2006-2015 decadal trend for SAMW isopycnal layers. First row : mean thikness and STD of the thikness. Second and third row : OHC computed from ISAS15 and individual profiles, respectively. Fourth row : mean layer temperature 10-years trend. Fifth row : thickness 10-years trend.



Conclusion

→ SPESTMW and SAMW volume increase explain of large part of global OHC storage (while underlying Intermediate Water retracts)

→ Mode Water OHC and volume interannual change leads to oceanic adjustment

→ The so called active (long Rossby waves) and passive (spiciness) tracer modes (*Liu and Shin*, 1999) are suspected to play a role in OHC interannual variability and oceanic adjustment

References

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