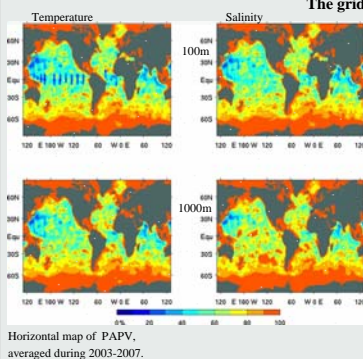


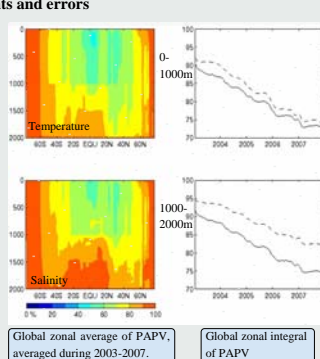
# Global hydrographic variability patterns during 2003-2007

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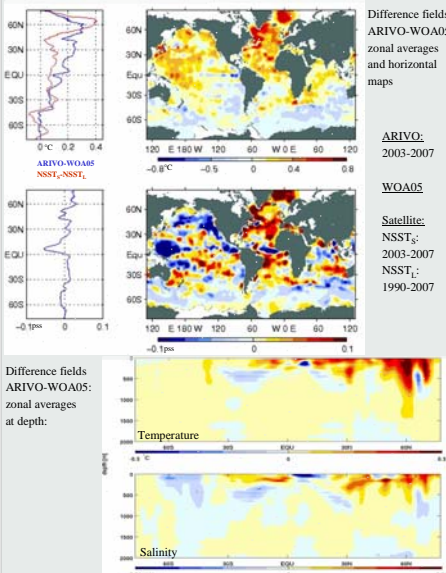
Monthly global temperature and salinity fields at 10-2000m depth based on ARGO measurements are used to analyze large-scale variability patterns on annual to interannual timescales during 2003-2007. Previous estimates of global hydrographic fluctuations have been derived using different data sets, partly based on scarce sampling. The substantial advantage of this study includes a detailed summary of global variability based on a single and more uniform database. The dominant signal of upper ocean variability is the annual cycle and the seasonal salinity field plays an important role in the upper layer of tropical and subtropical basin. The dominant harmonic of temperature increases at mid-latitudes at 10-300m depth and amplitudes are subsurface intensified in the tropical basin. Seasonal and interannual variability as well as long term changes are more pronounced in the northern hemisphere compared to the Southern Ocean. Moreover, features in the northern hemisphere are associated by strong interannual fluctuations and a warming signature at 10-1000m depth. In the Southern Ocean interannual changes are dominant and decadal fluctuations appear to be low in the area south of 40°S. Distinct freshening occurs between 40-60°S from the surface down to 1000m depth and in the upper 200m of the tropical basin. Saltening patterns are confined to the upper 500m depth of the southern subtropics and northern mid-latitudes. However, the dominant signatures of global interannual variability occur in the equatorial band and between 5-10°N during 2003-2007. Heat content and steric height changes are clearly associated with a positive trend during the 5 years of measurements. Changes of freshwater content are dominated by interannual variability. Steric height deduced from in-situ measurements are in reasonable agreement with satellite derived quantities than it was reported in previous results.



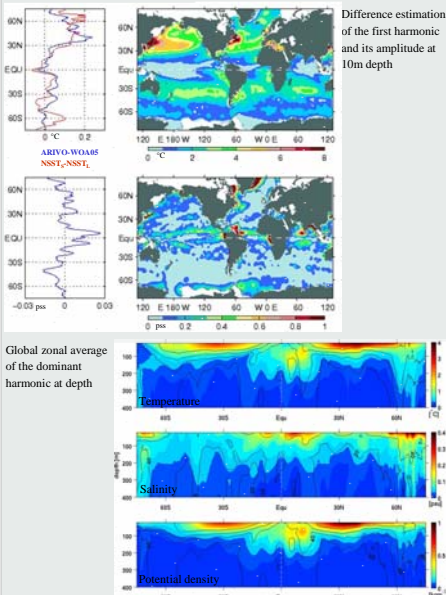
The monthly gridded fields of temperature and salinity are obtained by optimal analysis of quality controlled ARGO data from the CORIO LIS data centre produced by the French project ARIVO (www.ifremer.fr/po/arivo). XBTs as well as floats of type SOLO are excluded from ARIVO. The analyzed field is defined on a horizontal 1/2° Mercator grid with 152 vertical levels down to 2000m depth. The reference field is the World Ocean Atlas 2005 (WOA05). The mapping error is closely related to the data density. Where it equals 100% no information has been gained on the field, and remains identical to the reference field WOA05. PAPV shows that the data coverage between 45°S-60°N is high. The measurement density in the southern ocean could be improved in the last years of Argo.



## Mean field and annual cycle

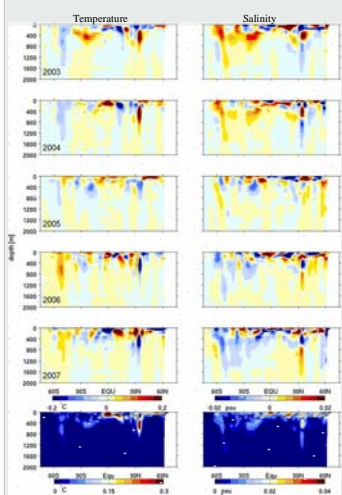


A clear hemispheric asymmetry of the temperature difference can be observed as amplitudes are considerably higher in the northern hemisphere. The same can be seen in the satellite derived estimates thus indicating that interannual variability and most notably long term changes are most pronounced in the northern hemisphere leading to comparable lower differences in the southern basin. A distinct surface freshening signature occurs in the entire Southern Ocean between 40-60°S and reaches down to 1000m depth. Moreover, a warming/salting pattern at 50-60°N exists probably associated with long-term changes in the North Atlantic as reported by Häkkinen and Rhines, 2004. In the northern tropics, a warming/freshening signature can be observed and its southern counterpart is characterized by a warming/salting.

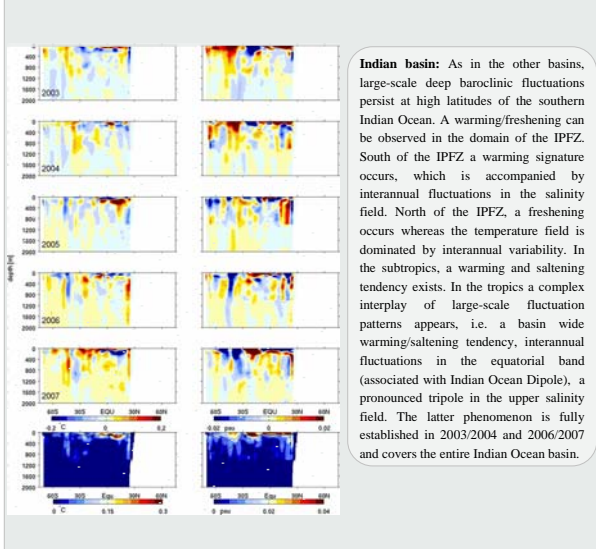
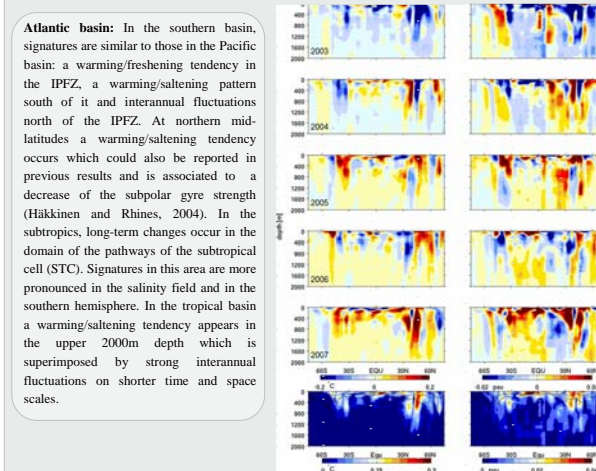


A hemispheric asymmetry of seasonal SST changes occurs at mid-latitudes as observed in previous results (e.g. Antonov et al., 2004) and amplitudes are high down to more than 200m depth. In the tropics, the annual amplitude of temperature is subsurface intensified at the depth of the equatorial thermocline. Seasonal changes of salinity are dominant in the upper layer of the tropics and at high latitudes. The annual cycle of the potential density field is predominantly influenced by the temperature changes except in the areas where seasonal changes of salinity are dominant.

## Interannual fluctuations

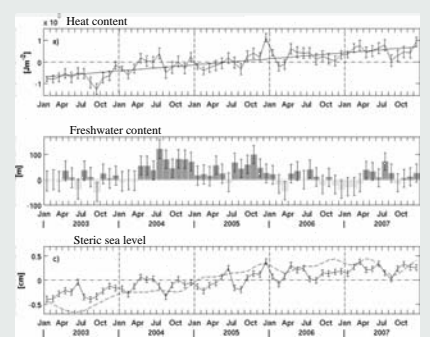


**Pacific basin:** Large scale patterns in the South Pacific are characterized by deep baroclinic temperature and salinity changes. A warming/freshening tendency can be observed in the Inter Polar Frontal Zone (IPFZ, 50-55°S). Recent studies have shown that deep warming and freshening tendencies are associated with an increase in the southern annular mode (Roemmich et al., 2007; Morrow et al., 2008). North of the IPFZ shorter periods prevail, i.e. at interannual scales. South of the IPFZ, a warming/salting tendency exists. At northern mid-latitudes, anomalies increase in the energetic boundary current and in region associated with the atmospheric Pacific Decadal Oscillation (PDO, Carton et al., 2008). Complex baroclinic structures occur in the subtropics and tropics. The dominant pattern exist in the equatorial band due to the ENSO phenomenon - with an interesting pattern in salinity.

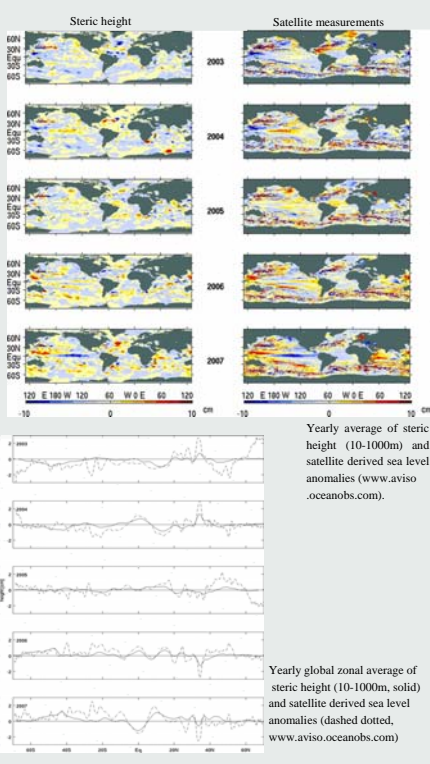


**Indian basin:** As in the other basins, large-scale deep baroclinic fluctuations persist at high latitudes of the southern Indian Ocean. A warming/freshening can be observed in the domain of the IPFZ. South of the IPFZ a warming signature occurs, which is accompanied by interannual fluctuations in the salinity field. North of the IPFZ, a freshening occurs whereas the temperature field is dominated by interannual variability. In the subtropics, a warming and salting tendency exists. In the tropics a complex interplay of large-scale fluctuation patterns appears, i.e. a basin wide warming/salting tendency, interannual fluctuations in the equatorial band (associated with Indian Ocean Dipole), a pronounced tripole in the upper salinity field. The latter phenomenon is fully established in 2003/2004 and 2006/2007 and covers the entire Indian Ocean basin.

## Global changes with time



Global heat content variability is characterized by an increase of ocean heat content with a changing rate of  $0.84 \pm 0.02 \text{ Wm}^2$  from the beginning of 2003 to the end of 2007. This value is comparable to the results from Willis et al., 2004. The time series of freshwater content is dominated by interannual variability, but a weak positive trend can be observed during the 5 years of measurements. The time series of global steric sea level is associated with a clear positive trend and are in reasonable agreement with satellite derived quantities.



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