Heat and Salinity Variability over the Upper Ocean in two global re-analyses

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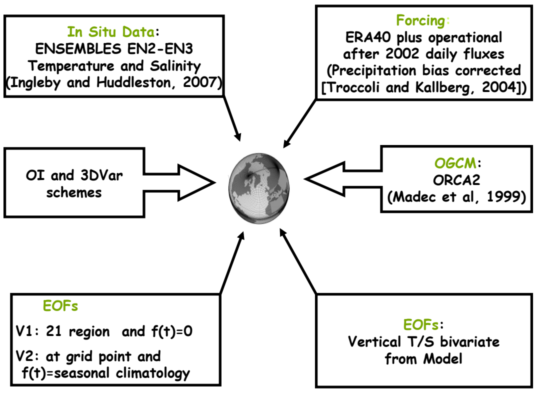
ABSTRACT

Despite recent advances in the state of the global ocean observing system and numerical modeling, the estimate of oceanic variability over the last several decades remains difficult. In particular, subsurface ocean data scarcity and uneven distribution over large ocean extents have limited the understanding of interannual-to-decadal variability in the ocean. Only recently data assimilation has been recognized as a possible tool needed to synthesize basin and global climate data sets. Ocean analyses providing dynamically consistent three-dimensional time series of ocean properties can indeed be used as the basis for climate dynamics studies. The analyses produced by ocean data assimilation systems can also be used to evaluate time and space variability of the heat and salinity content for the global ocean and separate basins. The ocean heat and salinity content trends and changes over the 1960-2008 period have been analyzed for separate regions and for different depths. In order to give an estimate of the uncertainties associated with ocean trends and variability, we have used two independently developed global data assimilation systems. The two systems use exactly the same ocean model and the same atmospheric fluxes but different assimilation systems. The first approach is based on a reduced order multivariate optimal interpolator that make use of vertical bivariate EOFs. The second is a 3D-VAR scheme recently implemented and that also models the background error covariances by the use of vertical EOFs, but find the global solution for the analysis.

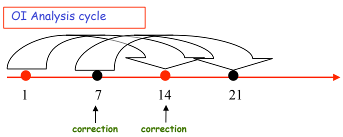
Ocean Data Assimilation at CMCC-INGV



OI analysis

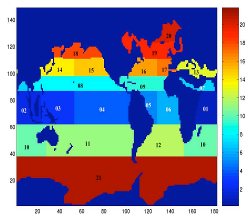
The 49-year run (1958-2006) was produced using a reduced order OI scheme (Bellucci et al., 2007) which represents a global implementation based on the SOFA (De Mey and Benkiran, 2002). Order reduction is achieved by projecting the state vector onto a set of precalculated bivariate T/S vertical empirical orthogonal functions obtained from the model.

The analysis was produced correcting the model fields every 7 days. Temperature/Salinity misfits are collected in a 14 day time window centered in the correction time.



EOFs V1
Domain Splitting and Time Independent Approach

EOFs are calculated for different subregions, representing different dynamical regimes (e.g, WBC vs Open Ocean dynamics), using the model output from a control run. Only the dominant modes are retained (order reduction)



EOF mask

EOFs V2
Grid Point Approach and Climatological Seasonal Dependence

EOFs are calculated at each grid point, and are seasonally dependent (Bellucci et al, 2007)

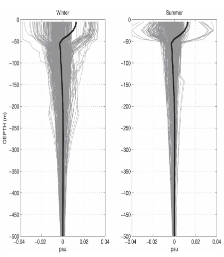
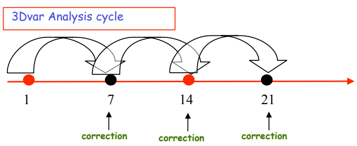


Fig. 1 First vertical EOF of salinity in the NE extra-tropical Pacific; (left) winter, (right) summer. In thick, first EOF of V1, in gray, related first EOFs of V2

3DVAR analysis

The 49-year run (1958-2006) was produced using the global implementation of a new multivariate 3dvar scheme based on the technique developed by Dobricic and Pinardi (2008) for the assimilation of several types of observations in the Mediterranean Sea. Order reduction using vertical EOFs is used also in this case (only EOFs V2 type).

The analysis was produced correcting the model fields every 7 days. Temperature/Salinity misfits are collected in the 7 days preceding the correction time.



OI2 minus 3Dvar climatologies (1958-2006).

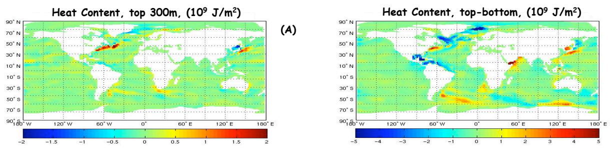


Fig.2: Integrated Heat Content differences, top 300m (A) and top-bottom (B)

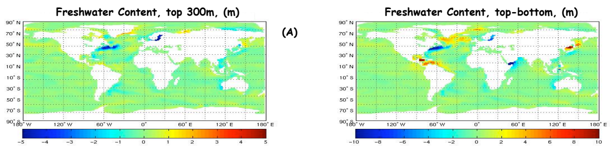


Fig. 3: Integrated Freshwater Content differences, top 300m (A) and top-bottom (B)

OI1 (green): analysis produced with OI, EOFs V1 and EN2-ENSEMBLES observations
OI2 (blue): analysis produced with OI, EOFs V2 and EN3-ENSEMBLES observations
3Dvar (red): analysis produced with the 3Dvar scheme, EOFs V2 and EN3 observations
OA Enact (Cyan): monthly set of objectively analyzed Temperature/Salinity fields derived from EN2

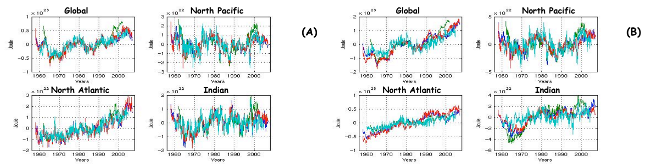


Fig 4: Integrated Heat Content Anomaly time series, top 300m (A) and top-bottom (B)

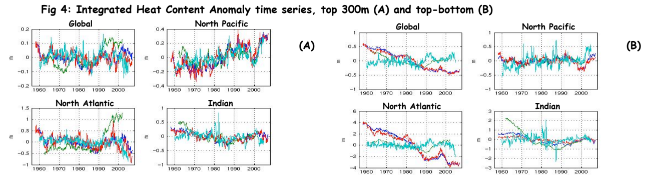


Fig 5 Integrated Freshwater Content Anomaly time series, top 300m (A) and top-bottom (B)

The comparison between OI2 and 3Dvar upper ocean heat content climatologies (1958-2006) shows that the two analyses have a very similar spatial distribution.

Differences are localized in areas characterized by large gradients such as the Gulf Stream and the Kuroshio regions.

In the deeper ocean heat content some differences are noticeable also in the Gulf of Mexico, North Atlantic, Arabian Sea and in the ACC.

Similar conclusions apply to the comparison between the two freshwater climatologies.

In summary, the analyses which assimilate the EN3-ENSEMBLES data sets and use the EOFs V2 (EOFs at each model grid point and with seasonal dependence) show a better representation of the time variability of heat content and freshwater content anomalies in the upper 300m.This applies for both the OI and 3Dvar analyses at the global and regional scales, and is particularly evident in the freshwater content anomaly averaged over the North Atlantic.

On the other way, the freshwater content anomalies in the deeper layers show a marked downward trend, which is mainly driven by tendencies localized in a small region in the Gulf of Mexico. This trend might be due to anomalously induced corrections in the salinity field, which appear by computing grid point seasonal EOFs instead of regional time independent EOFs (see Fig. 1).

References:

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