Use of Argo data for global mean sea level trends monitoring

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Objectives

Tide gauges and satellite altimeter measurements indicate that the global mean sea level is currently rising and that very likely this rise is related to global warming (IPCC, 2007). Because of expected negative impacts that will affect human societies living in vulnerable coastal regions worldwide, sea level rise has important societal implications. It is thus of crucial importance to precisely measure rates of sea level rise globally and regionally and understand the various factors causing sea level rise.

The global mean sea level change as measured from satellite altimeter results in total from steric (effect of temperature and salinity) plus eustatic (ocean mass) changes. In order to separate these two physical processes, temperature and salinity profiles measurements from the global Argo array of profiling floats are used to quantify the steric contribution to sea level change.

Data and method are first presented. The impact of the sampling of the Argo observations is then discussed. Finally, mean sea level trends from total and steric parts are described.

Data and method

The full Argo dataset has been uploaded from the Coriolis Global Data Acquisition Center as of February 2008 (http://www.coriolis.eu.org). For this study, when available, delayed-mode data are preferred to real-time ones (i.e. for half of the floats) and only measurements considered "good" (i.e., with Argo quality control flags at '1') are used. As real-time quality controlled checks applied on the Argo data set are very simple and automated, additional quality controls were first performed following the method described in Guinehut et al., (2008). It compares collocated sea level anomalies from altimeter measurements and steric height anomalies calculated from the Argo temperature and salinity profiles. By exploiting the correlation that exists between the two data sets (Guinehut et al., 2006) along with mean representative statistical differences between the two, the altimeter measurements are used to extract random or systematic errors in the Argo float time series (drift, bias, spikes,etc). About 4% of the floats have been separated by this method.

Steric height at the surface are then computed relative to 900-m from each Argo temperature and salinity profiles. The 900-m depth was chosen as a compromise between the number of data selected and the maximum sampled depth of these data to provide optimum spatial and temporal coverage. Steric changes below 900-m do contribute to the sea level budget on multi-decadal time scales but observations and models suggest that major contributions come from the upper ocean (Antonov et al., 2005; Wunsch, 2007).

Argo floats profiles being discrete measurements in time and in space, steric sea level maps are constructed at a monthly period and on a 1/3° resolution grid prior to analysis. The mapping is based on an optimal interpolation method (Bretherton et al., 1976) and is very similar to the one used to compute the SSALTO/DUACS multi-mission combined products (AVISO, 2008; Ducet et al., 2000) but with specific parameters. Temporal correlation scale has been fixed to 45 days. The spatial correlation scales vary as a function of latitude (from 1500 km at the equator to 700 m at 50°N) with larger values in the zonal direction than in the meridional one. In order to take into account error associated with the aliasing of the mesoscale variability, noise-to-signal ratio is fixed to 2.0 for each in-situ measurement. Besides, a contemporaneous Argo climatology representing the time-mean is removed from the individual steric height prior to mapping. Finally, the monthly maps of steric height anomalies are globally averaged to produce the time series of steric sea level.

Impact of the sampling of the Argo observations

In order to precisely quantify the impact of the sampling of the Argo observations together with the impact of the method used to calculate the globally averaged values on the estimation of the steric sea level, the SSALTO/DUACS multi-mission combined products are used. They have first been interpolated at the time and location of each Argo floats profiles. Sea level maps have then been reconstructed using the same mapping technique as for the steric sea level maps. By comparing the area of the ocean reconstructed by the mapping method to the area of the ocean of the full SSALTO/DUACS products allowed us to quantify the area of reconstructed ocean for each month (Figure 1). At the beginning of the year 2002, the sampling of the Argo profiles allow to reconstruct about 40 % of the ocean, this number reaching values around 70 % in 2003, then 80 % at the beginning of the year 2004 to values greater than 90 % after mid 2006. The temporal window for the use of Argo data has thus been reduced to the 2004-2007 periods.

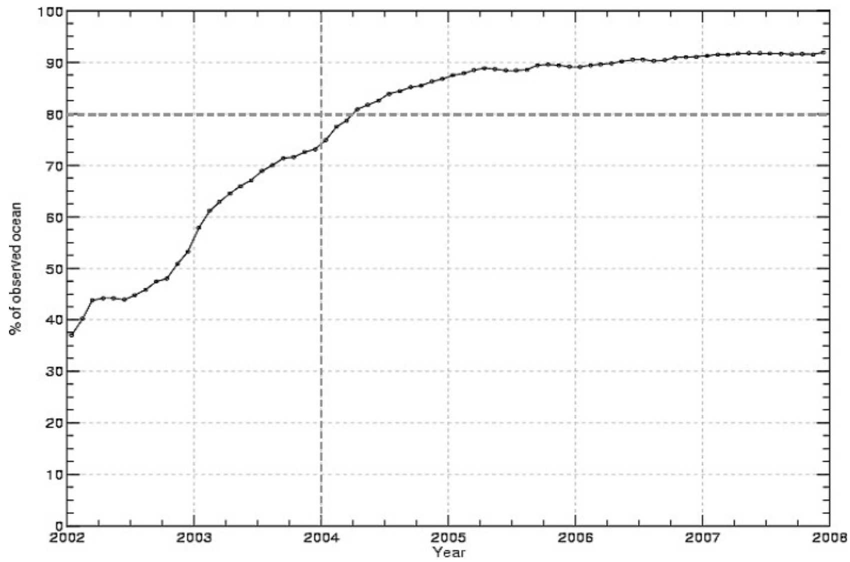

Figure 1 : Percentage of observed ocean as a function of time.

The globally averaged values computed from the reconstructed maps are finally compared to the ones obtained from the original SSALTO/DUACS multi-mission combined products. The two curves compare each other very well from the beginning of the year 2004 with rms differences between the two of 2.4 mm for the 2004-2007 periods. The trend in mean sea level time series is only slightly reduced by 0.02 mm/year. Having used fields completed by the time-mean in order to averaged global fields at each time step would have reduced further the trend by 0.32 mm/year. Furthermore, these results indicate that the mapping procedures used here are sufficient to map the mean sea level variability.

Mean sea level trends: steric versus total

The total and steric sea level time series are dominated by an annual cycle in response to the seasonal heating and cooling of the upper ocean and also in response to water mass exchange on the earth surface (Tableau 1). Over the 2004-2007 periods, the global mean sea level shows a trend of 2.4 mm/yr and the steric part a trend of 0.4 mm/yr. The contribution of the steric changes to the total variability is lower than what was computed for the previous years as thermal expansion has been estimated to contribute by ~50 % to the global mean sea level rise during the 1993-2003 decade(IPCC, 2007). The present study window of 4-years is indeed very short to calculate trends but also, the previous studies suffer from uncertainties on the XBT data sets.

The spatial distributions of the trends in total and steric sea level variability (Figure 2) show very good agreement in most part of the oceans. Large discrepancies are nevertheless visible in the South Indian Ocean, South of Australia and also in the South Atlantic Ocean. Further investigations will be carried on in order to understand these differences. Also, as our knowledge on Argo float measurements is improved, and particularly, our knowledge on common instrument errors and failure mode, improved estimate of global mean steric sea level trends will be completed. Particularly, it will be interesting to verify if the large discrepancies visible South and West of Australia corresponds to zones sampled by specific instruments.

	Amplitude	Phase	Slope
Total	4.5 mm	236 °	2.4 mm/yr
Steric	3.5 mm	95 °	0.4 mm/yr

Tableau 1 : Amplitude and phase of the seasonal cycle and slope of the interannual variability for the total and steric sea level and for the 2004-2007 periods.

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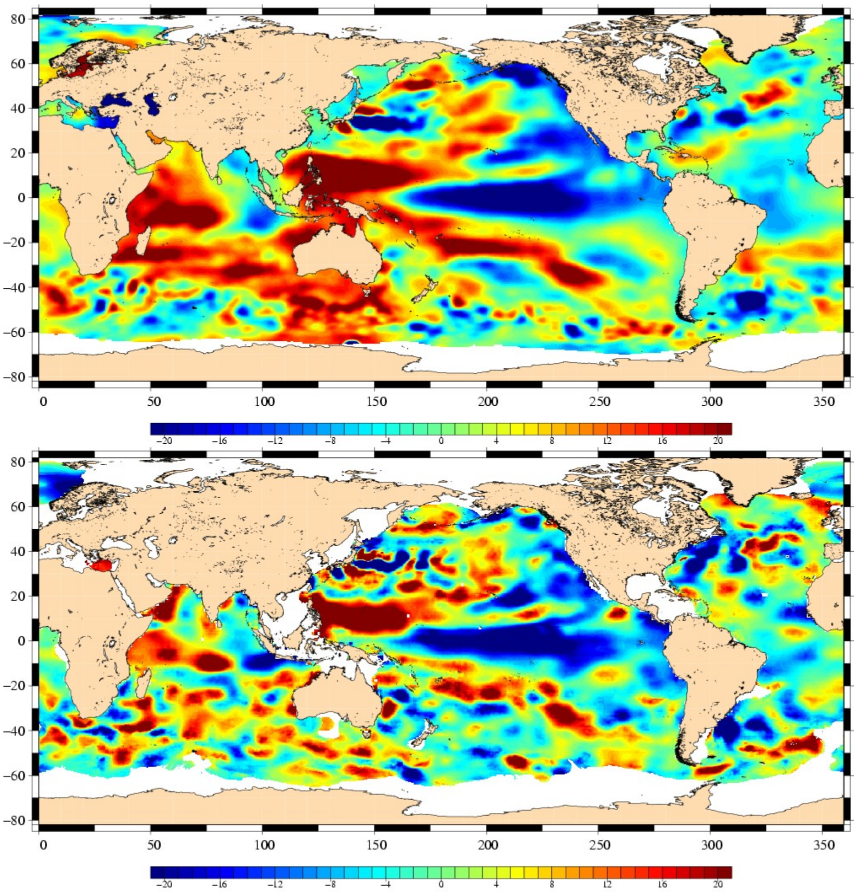

Figure 2 : Spatial distribution of the trend in total sea level from satellite altimeter (top) and steric sea level from Argo floats (bottom), for the 2004-2007 periods (in mm/year).