MULTI-SATELLITE ALTIMETER PROCESSING FOR SEA LEVEL AND OCEAN CIRCULATION MONITORING

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Our TOPEX/POSEIDON - Jason-1 investigation includes:

1. **the inter-calibration of altimeter missions and the improvement of data merging techniques,**
2. **near real time processing of altimeter data,**
3. **use of combined altimeter data sets with model results to analyse the large scale and mesoscale ocean circulation,**
4. **inverse modeling combining in-situ data with altimeter data to estimate the mean and the seasonal/interannual variations of the 3D ocean circulation.**

Inter-calibration and improvement of altimeter data merging techniques

The first part of the investigation deals with the precise inter-calibration of past, present and future altimeter missions and the improvement of altimeter data merging techniques for ocean circulation estimation. Merging multiple altimeter data sets is not easy. It requires homogenous, inter-calibrated data sets; correcting of orbit error for the less precise altimeter missions; extracting the Sea Level Anomaly using a common reference surface; and combining the data through a mapping (or assimilation) method. This work was done for T/P and ERS-1/2. In particular, we showed that ERS-1/2 orbit error can now be estimated with a precision of almost 2 cm rms using T/P as a reference [Le Traon and Ogor, 1997]. We also developed an improved space-time objective analysis technique which takes account of residual long wavelength errors (e.g. due to tides, inverse barometer, residual orbit errors). It provides a much better mapping of sea level variations [Le Traon et al., 1997]. As a result, homogeneous, precise, consistent data sets are obtained for the different missions. This is illustrated in Figure 1, which shows the rms differences between T/P and ERS-1 sea level anomaly maps: the rms difference is only 3 cm rms in low eddy energy regions. The difference can be larger than 10 cm rms in high eddy energy regions (e.g. Gulf Stream). These are the regions where merging will have the biggest impact. The rms differences are completely explained by the T/P and ERS-1 mapping errors.. All these processing techniques will be enhanced and applied to Jason-1, EnviSat and GFO.

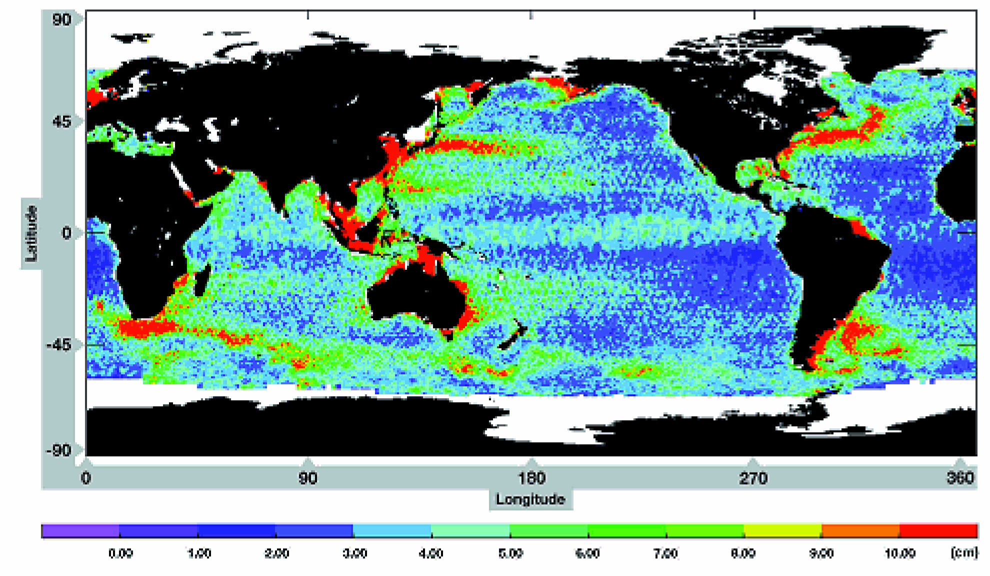

Figure 1
Rms differences, in cm, between T/P and ERS-1 Sea Level Anomalies maps, October 1992 to October 1993.

Near real time processing

Real time processing is crucial for the development of operational oceanography. As part of the European project DUACS, we are now processing T/P and ERS-2 data in near real time. Thanks to dedicated processing, the accuracy of near real time data is similar to the delayed time data (GDR) accuracy (Figure 2). In the near future, real time processing will become fully operational and will include GFO, EnviSat and Jason-1. This will be done mainly as part of the MERCATOR project.

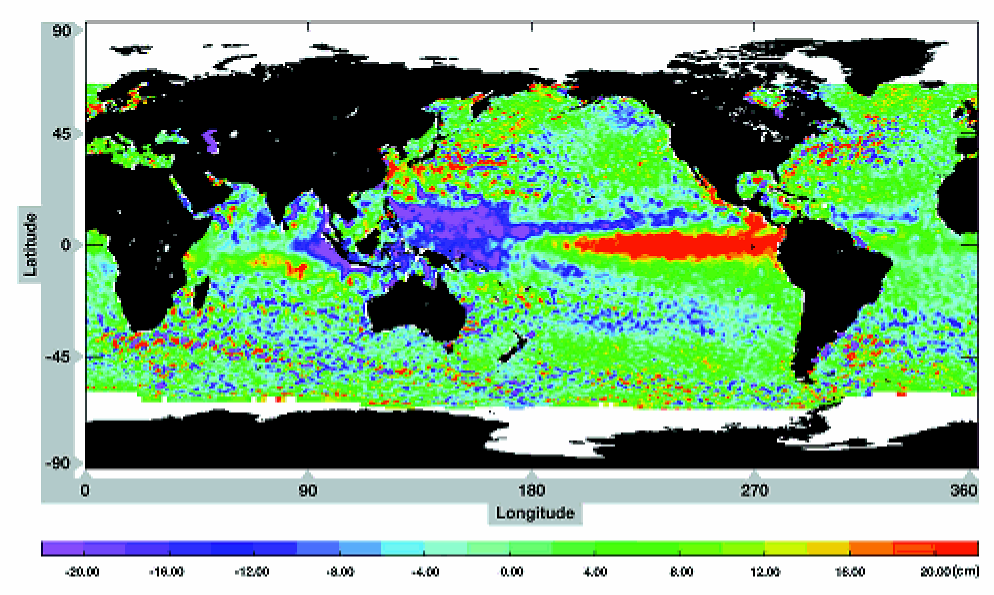

Figure 2

Sea Level Anomaly for POSEIDON cycle 186 (October 10, 1997). Range: -20 cm to +20 cm. The map was obtained within just three days, using the fast POSEIDON IGDRs which include a precise near real time DORIS orbit (accuracy of 3-4 cm rms). Note the strong signature of the El Niño event in the Equatorial Pacific.

Using the combined altimeter data sets

We will use the combined altimeter data sets to analyse the large scale and mesoscale sea level variations at both regional and global scales. Regional analyses in the Mediterranean sea [Larnicol et al., 1995; Ayoub et al., 1997] and in the Azores/Canary regions [Hernandez et al., 1995] will be conducted, mainly as part of European research programmes. With T/P, ERS-1 and ERS-2, it was thus possible to characterise the seasonal and interannual changes in the Mediterranean (Figure 3) for the first time. Comparison with a high resolution primitive equation model will be the next step towards quantifying the main circulation forcing mechanisms. Analysis of mean sea level variations from intra-seasonal to interannual time scales was also performed [Larnicol et al., 1995; Le Traon and Gauzelin, 1997]. Further work will aim at understanding the physics of mean sea level variations (relationship with atmospheric pressure, wind, evaporation, precipitation and the role of Gibraltar Straits dynamics).

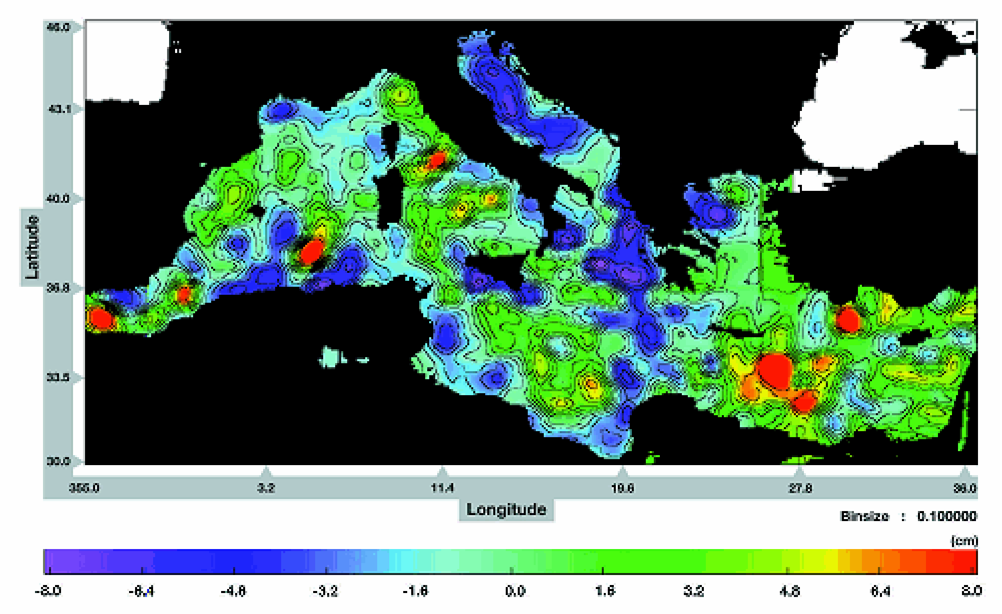

Figure 3

Seasonal variation in Sea Level Anomaly observed by combining TOPEX/POSEIDON and ERS-2 in summer 1996 in the Mediterranean Sea. The map is an average over a three-month period. The scale is from -8 cm to +8 cm, and the contour interval is 1 cm. This figure and the figures for the other 3-month periods (not shown) show the main characteristics of the Mediterranean circulation (Alboran gyres; Algerian eddies; Ionian, Ierepetra, Mersa-Matruh and Shikmona gyres, etc.) and the seasonal/interannual variations in these features.

Global analyses will focus on the comparison of altimeter data with high resolution primitive equation models (Clipper and MERCATOR projects). The objective will be to validate models but also to better understand the content of altimetric signals. Global ocean models are more and more realistic, and can now be used to better understand the signals seen in altimetric data. But they still have deficiencies which can now be quantified using satellite altimetric data. The comparison of eddy kinetic energy, frequency/wavenumber spectra, seasonal/interannual signals should thus be very useful.

Inverse modeling

The objective here will be to combine WOCE and TOGA in-situ data (hydrography, drifters/floats, currentmeters) with altimeter data to estimate the mean and the seasonal/interannual variations of the large scale 3D oceanic circulation and its heat transport. The work started in the Atlantic and the ultimate goal will be to develop a global inverse model. The model used is the non-linear inverse model described in Mercier et al. [1993]. It provides a good representation of 3D general circulation and of heat transport [Larnicol, 1997]. The model also shows realistic seasonal variations in meridional heat transport, and can combine the information given by altimetry (variations in the surface circulation, and constraints on net heat fluxes) with in-situ measurements. The model will also be used to quantify the impact of the new geoid models derived from the CHAMP , GRACE and GOCE missions on the estimation of the oceanic circulation and heat transport.

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