Estimating mean dynamic topography in the tropical Pacific ocean from altimetry and gravity satellites

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1.Introduction

Because of geoid uncertainties, altimetric applications have concentrated on ocean variability, using sea level anomalies. Several satellite gravity missions such as CHAMP, GRACE and GOCE have been devised to provide high resolution, highly accurate geoids, in order to improve our knowledge of the absolute circulation of the ocean. Motivated by improvements in the geoid due to the CHAMP mission, a mean dynamic topography for the 1993-1999 period was computed from satellite altimetric and geodetic data, providing an estimate of the absolute sea level over that period.

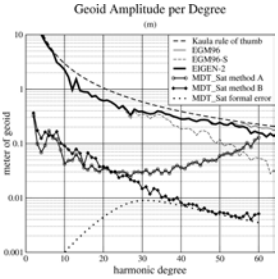
We focused on the tropical Pacific Ocean which has been intensively surveyed since the Tropical Ocean Global Atmosphere (TOGA) programme began in an attempt to understand and predict the climatic ENSO (El Niño-Southern Oscillation) phenomenon. The satellite solution was compared with a new synthetic solutions [Rio, 2003] in terms of dynamic topography and geostrophic circulation. Its contribution to absolute sea level is quantified with independent *in-situ* data, such as those from the Tropical Atmosphere Ocean TAO/TRITON mooring arrays.

2. Mean Dynamic Topography from a geoid

The geoid used in this study was computed from the EIGEN-2 Earth gravity field model, based on 6 months of data from the CHAMP satellite gravity mission in 2000 and 2001 [Reigber *et al*., 2003]. The improvement in spectral content made possible by the very low flight altitude of CHAMP is clearly visible in the Figure: EIGEN-2 has a spectral power comparable to that of the 'combined' field EGM96 up to about degree 53, while the spectral power of the 'satellite-only' part of EGM96 (EGM96-S) already starts to decrease around degree 25.

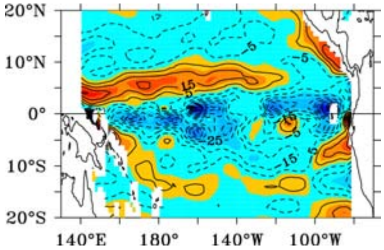
The mean sea surface used here corresponds to a 7-year mean (1993-1999) based on the most recently processed TOPEX/POSEIDON, ERS1-2 and GEOSAT altimetric satellite data (SMO CLS01, Hernandez *et al*. [2001]).

The mean dynamic topography was then computed by subtracting the satellite-only, derived geoid from the mean sea surface. A crude solution (Figure, method A) – simply differentiating the two surfaces and solving for the mean sea surface spherical harmonic coefficients without constraints, – was not satisfactory. We thus chose a more refined solution (Figure, method B) in which a constraint is added in the inversion process to ensure that the solution spectrum follows an *a-priori*, geophysically consistent, law. This led to a significant improvement of both the spectra of the mean dynamic topography and of its associated error (see Figure). It is possible to use the method B solution up to degree 60. The formal cumulated error of the mean dynamic topography reaches 4 cm at degree 36 and 5 cm at degree 60.



3. Satellite Mean Surface Geostrophic Currents

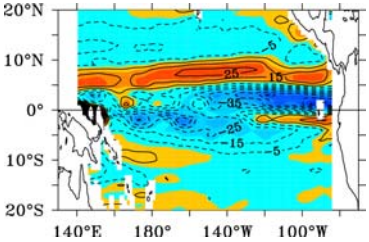
Satellite solution



Tropical oceans exhibit mainly zonal circulation. Computation of zonal geostrophic currents is very sensitive to the latitudinal gradient of the dynamic topography, particularly towards the equator, where the Coriolis force vanishes. Therefore, estimating the equatorial currents is a stringent test for validating the satellite dynamic topography. The satellite solution (left) is compared to a new synthetic solution from Rio [2003] (right) which integrates all the information available from in-situ, altimetric, and gravimetric data.

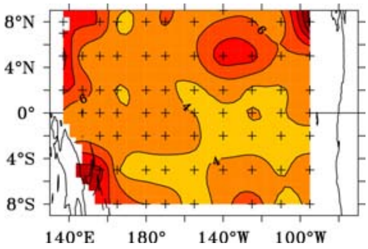
The classical surface geostrophic currents are clearly visible both in the satellite and synthetic solutions: the North Equatorial Current (NEC, [10°N-17°N]), the North Equatorial Counter Current (NECC, [5°N-10°N]), the northern and southern branches of the South Equatorial Current (SEC, [7°S-4°N]), and also the South Equatorial Counter Current (SECC) at 10°S in the western Pacific.

Synthetic solution

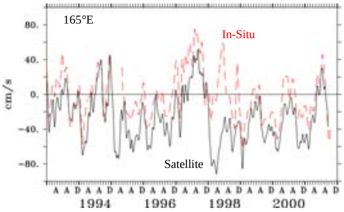


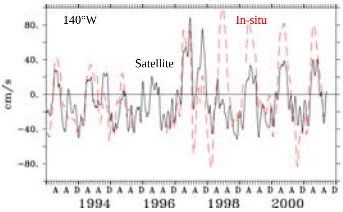
4. Altimetric Sea Level Data Versus Independent In-Situ Data

The ocean is constantly changing, so the absolute circulation is time dependant. To get absolute sea level, the satellite mean dynamic topography was added to the TOPEX/Poseidon sea level anomalies, referenced to the 1993-1999 period. Sea level and corresponding surface geostrophic currents were mapped onto a 1°*1° resolution grid, and sampled every 5 days over the 1993-2001 period. They were compared in time and space with *in-situ* data. The tropical Pacific is continuously observed through the 70 TAO/TRITON moorings located in the 8°N-8°S equatorial band where the ocean exhibits a dominant baroclinic signature.



Rms differences between the 0/500 dbar TAO dynamic height and sea level, which integrate the differences both in term of mean and variability, are in the 4-8 cm range. The rms of the average difference between the sea level and the TAO dynamic height is around 4 cm, similar to the rms of the variability difference.



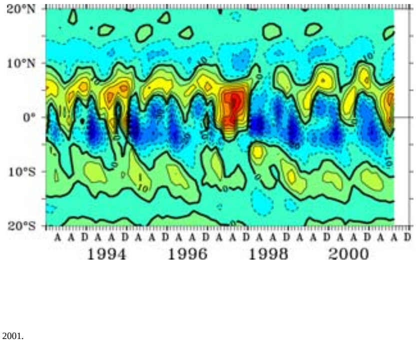


In-situ comparisons of sea level-derived zonal currents are performed from currents measured at the TAO equatorial moorings at 165°W, and 140°W. the time series were filtered with a 35-day Hanning filter. The rms differences between the time series of sea level-derived zonal current and *in-situ* measurements are 31, and 32, cm/s at 165°E, and 140°W respectively, compared with the 27, and 40 cm/s rms of the observed currents, with corresponding correlation coefficients of 0.77, and 0.63.

At 165°E, the rms difference was attributed to a mean difference around 25 cm/s. The westward shift of the satellite current may be attributed to some errors at the equator in the curvature of the mean dynamic topography. At 140°W the mean satellite current is close to the mean observed current, in a 5 cm/s range, and the rms difference has been attributed to a higher seasonal variation in the observed current than in the satellite current from 1998 to 2001.

4. Discussion and Conclusion

The time/latitudinal section of sea level-derived geostrophic current at 175°E clearly shows the strong seasonal variability of the SECC around 10°S, at a maximum in February-March with a 15 cm/s magnitude and minimum in October, in phase opposition with the NECC which reaches a 30 cm/s magnitude. When the SECC grows, it migrates to the north from 15°S to 5°S, similarly the NECC migrates to the south. The El Niño conditions are clearly visible in 1993, 1994, 1997 and 2001 with equatorial eastward currents centred in July-August. The NECC is intensified during El Niño (reaching 70 cm/s in 1997), whereas the SECC disappears during the extreme 1997 El Niño, and the SEC reverses. During La Niña conditions, as in 1998, the NECC disappears, and both the SEC and the SECC intensify.



Improved knowledge of the geoid due to the CHAMP mission, and the great accuracy of altimetric data are capable of providing mean dynamic topography up to degree 60 for the global ocean, independent from any *in-situ* data. This satellite solution seems to match the reality for the tropical Pacific. It has been used to reference altimetric sea level without introducing dramatic errors (errors are less than 5 cm rms). Part of this error, due to the altimetry, corresponds to white noise; another part, due to the geoid, is correlated in space and time. The resolution and accuracy of sea level and its associated geostrophic circulation are compatible with oceanographic studies in the tropics. This now offers a new perspective for using altimetry.

This satellite surface information, when assimilated in numerical models, may prove very useful for improving simulations of the tropical oceans. In the future, the GRACE and GOCE missions will provide new information in terms of geoid resolution and variations which will improve our knowledge of the absolute circulation. More details can be found in Gourdeau et al. [2003].

References:

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