OCEAN CIRCULATION, HEIGHT SYSTEMS, AND GRAVITY FIELD STUDIES BASED ON TOPEX/POSEIDON ALTIMETRY

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This papers covers the highlights of the DEOS research plan for the TOPEX/POSEIDON Extended Mission (TPEM). It partly elaborates on themes of the original T/P science investigation plan, and partly deals with new challenges or ocean circulation, height systems, and gravity field studies. In addition, some recent results and publications are summarized.

Introduction

In 1996 the Announcement of Opportunity (AO) for the TOPEX/POSEIDON Extended Mission (TPEM) was issued as a follow-on to the TOPEX/POSEIDON (T/P) Science Investigation plan. It embroidered on the successes of the exploitation of altimeter data from the T/P mission for studying ocean circulation and ocean tides. DEOS, the Delft Institute for Earth-Oriented Space Research, a joint venture between the faculties of Aerospace and Geodetic Engineering of the Delft University of Technology, has a long record in altimetry related studies. It took advantage of the AO by updating its research plan. This plan partly elaborates on themes of the original T/P science investigation plan, and partly deals with new challenges.

In principal, the plan is based on three lines of interest: the stationary behavior of the global mean sea surface, temporal variations of the sea surface at various scales, and calibration and validation of altimeter data. DEOS is most interested in continuing to use altimetry in its long term research activities. The justification is a continuation of an important measurement series of the global oceans. DEOS strives to use this series for continuing to understand the long periodic behavior of sea level anomalies which are vital for observing and predicting ENSO events and inferred Rossby waves, annual and semi-annual cycles in the oceans and global ocean tides. Obviously, continuation of the T/P time series implies improved results for ocean tide models, mean sea surface, ocean circulation, and sea level change. The activities in the field of orbit determination are drastically reduced due to the present accuracy of T/P orbits. The main focus is on exploring new possibilities of altimeter and TDRSS case studies for orbit and gravity field improvement, and on orbit improvement of Low Earth Orbit satellites from T/P ocean tide models.

Other regions of interest are the European continental shelf, the Indonesian Archipelago, and the Chinese Sea. Here T/P results are used for regional ocean tide and circulation models, connection and unification of height datums, regional sea level change and land subsidence studies.

The TPEM project at issue unites three Dutch institutes and one German institute, namely the Delft University of Technology (PI: K.F. Wakker, Co-Is: M.C. Naeije, R. Scharroo, R.H.N. Haagmans, and E.J.O. Schrama), Utrecht University (Co-Is: W.P.M. de Ruijter, and P-J. van Leeuwen), Survey department Rijkswaterstaat (Co-I: R.C.V. Feron), and the Technical University of Munich (Co-I: R. Rummel).

Ocean circulation

The extension of the high precision altimetric database has been used to obtain better ocean tide, and ocean circulation results, both global and regional. In particular T/P altimetry is well suited to regional tide model improvement and storm surge predictions for the North Sea and the Chinese Sea. Intra- and inter annual variations, and the eddy shedding mechanisms of the western boundary currents have been studied in detail. A long term objective is to determine the decadal variability in the climate system. A key element in this system is the global thermohaline circulation, in which the Agulhas region is thought to be a major link. For a better understanding of the Agulhas system the precise mechanism of shedding of rings from the Agulhas Current is studied by means of assimilation of altimetry data in a regional ocean model. Also the decay and the interaction of Agulhas rings with the bottom topography are studied using a combination of altimeter data, infrared data, and optical data together with numerical models. To illustrate the complexity of the dynamics in this area, the 2nd and 3rd EOF of T/P data (1994-1997) for the oceans around South Africa are plotted in Figure 1, which reveals a mix of short (3 months) to long periodic (3 years) patterns.

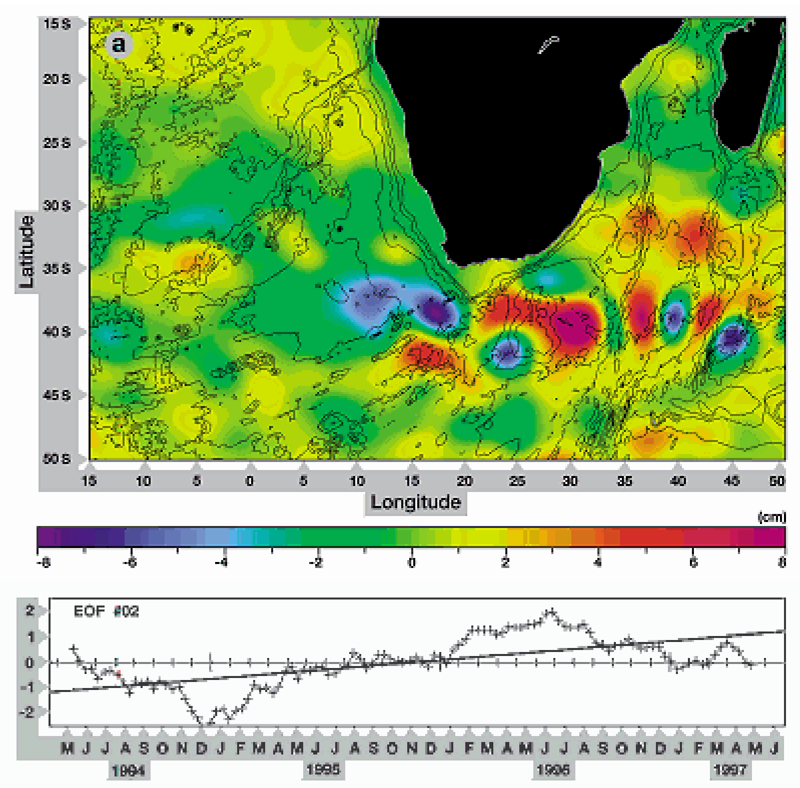
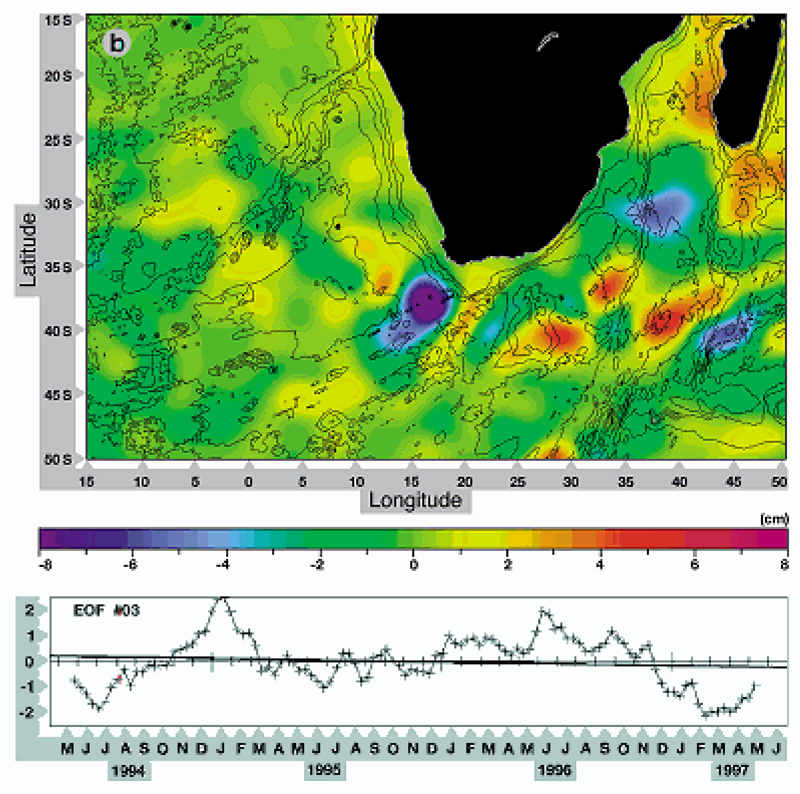


Figure 1

(a) 2nd EOF of T/P altimeter data (1994-1997) for the oceans around South Africa. Units in cm



(b) 3rd (b) EOF of T/P altimeter data (1994-1997) for the oceans around South Africa. Units in cm

In addition, assimilation studies are also applied to the equatorial Pacific region to obtain a better insight into the El Niño/Southern Oscillation, and ocean-atmosphere interaction. Special attention is given to the impact of the upper ocean salinity structure on the western Pacific dynamics. For this purpose the ability of the altimeter to serve as a salinometer is studied. This research is carried out in cooperation with the Royal Dutch Meteorological Institute (KNMI), NOAA, and NCEP.

Height systems

On a global scale the accuracy of sea level change estimates is improved. On regional scales the combination of T/P with ERS data and/or in situ data may improve the separability between the T/P instrument drift and sea level change. The current accuracy of T/P data enables incorporation of altimetry in the NOrth Sea Sea level monitoring system (NOSS) for sea level rise and land subsidence studies.

The precise determination of the sea surface in the region of the Indonesian Archipelago enables the connection and unification of height datums of the Indonesian islands, and analysis of the steady-state ocean topography. This is an important step towards an ultra precise regional sea-land monitoring system based upon various terrestrial and satellite observation techniques comparable to NOSS. Figure 2 illustrates a successful attempt to connect a land-based gravimetric geoid (The Netherlands) with the geoid or mean sea level at sea (North Sea) by fitting a correction model through T/P data and GPS and leveling data.

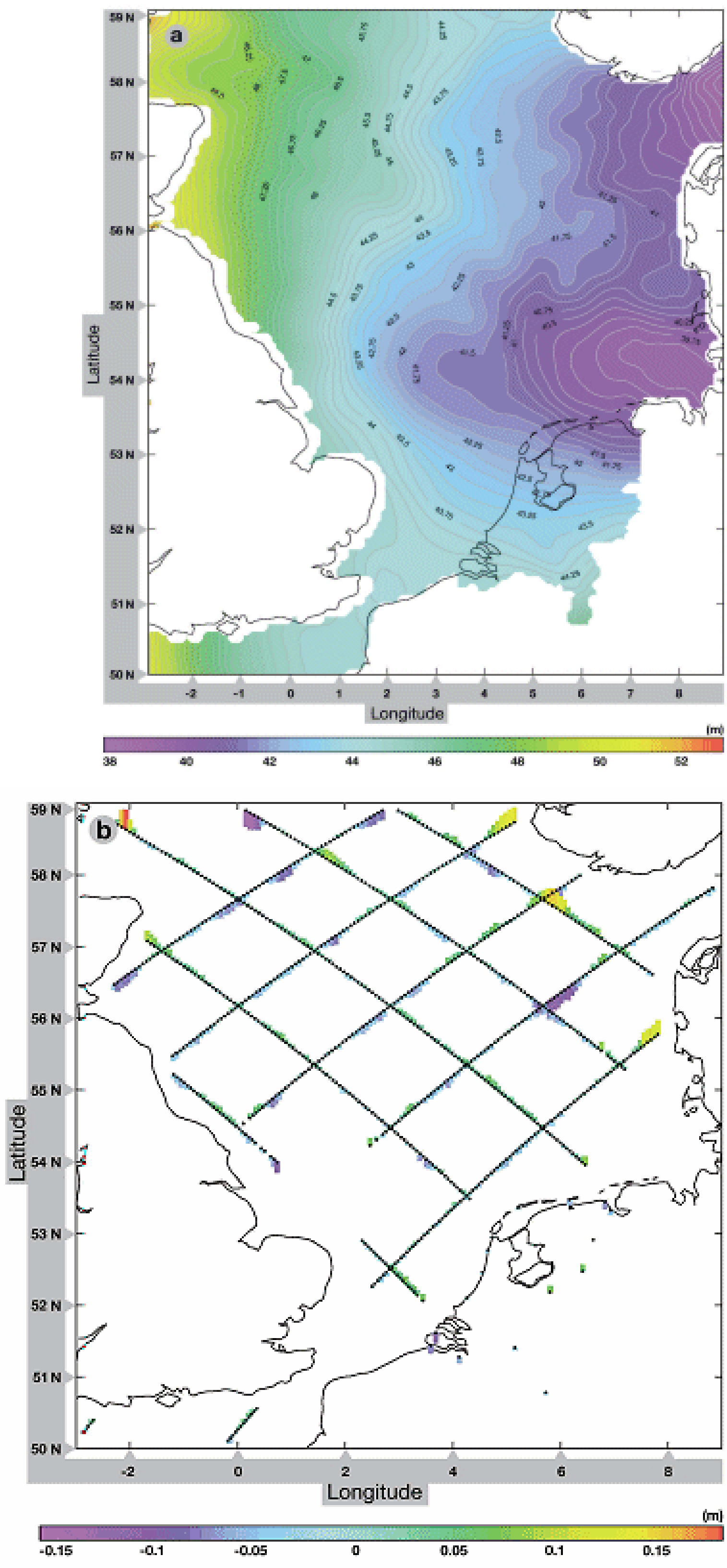


Figure 2

(a) North Sea geoid with respect to GRS80 in meters (contour interval 0.25 cm).

(b) Differences of T/P and NEREF (GPS/leveling) data points with North Sea geoid (in meters); mu=-0.1 cm, sigma=4.2 cm.

Gravity field

Another aim is the determination of a highly detailed precise mean sea surface using T/P data as a reference for ERS, and Geosat ERM and GM data. Then from this mean sea surface an improved geoid can be obtained whenever detailed models or data of the mean ocean dynamic topography become available. Furthermore, gravity anomalies, and gravity gradients are determined for regional geophysical interpretation, and improvement of statistical models of the global gravity field.

Outreach

On behalf of national and international projects DEOS is working on a consistent altimeter data base from all past and present altimeter missions, taking into account all different references and corrections. Validation of these corrections is a key issue. Figure 3 illustrates that the regression between pressure field and T/P height anomaly is geographically dependent and generally deviates from -1 cm/mbar. At least, one has to take the variations in wind speed and stress into account.

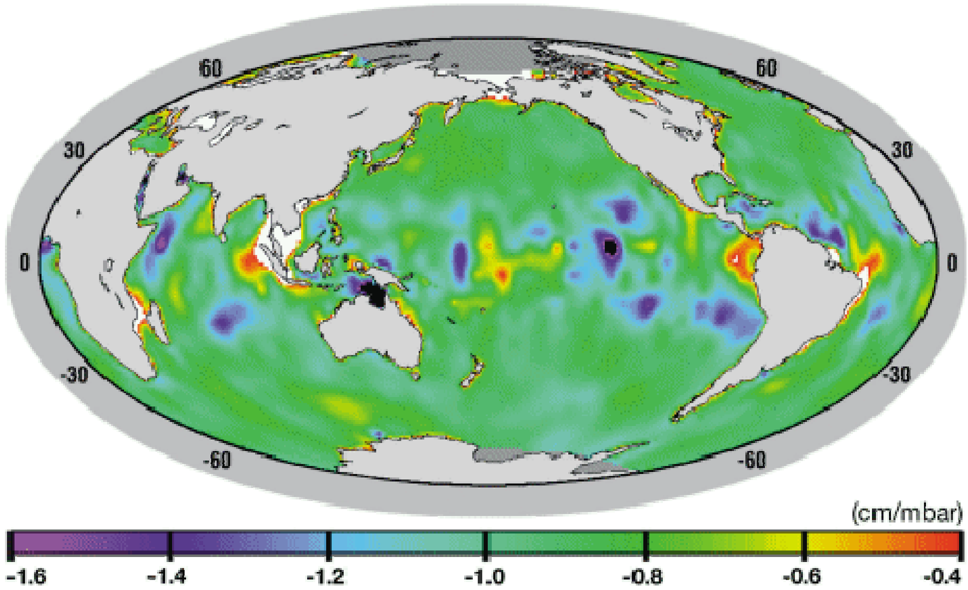


Figure 3

Inverse Barometer regression coefficient in cm/mbar derived from T/P collinear differences (cycles 2-84).

As pointed out earlier DEOS is interested in continuing its altimetry related research. This means that preparations are already being made for incorporating the data from the forthcoming Jason mission. A proper phasing of the orbit of Jason with respect to T/P can lead to an enhanced sampling strategy for mapping meso-scale variability phenomena and ocean tides. Intersatellite calibration with respect to T/P and ERS-2 or other orbiting altimeters will play a significant role in these studies.

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