GOCINA

FINAL RESULTS

Geoid and Ocean Circulation in the North Atlantic

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Background and Motivation

The North-Eastern branch of the Gulf Stream carries a tremendous amount of heat from the central Atlantic Ocean to Northern Europe. This causes the water to be around 3 to 6 degrees warmer than the global average at these latitudes.

Changes in the strength and position of the Gulf Stream may have a significant impact on the climate in Northern Europe which could become cooler. The exchange of water masses across the Scotland-Greenland ridge has a profound influence on the thermohaline circulation. Changes in the deep water circulation may change larvae transports relevant for fish populations.

The GOCINA Project

GOCINA was a multi-disciplinary project consisting of six partners and lasted for a 3-year period. It has developed generic tools for ocean analysis from a simultaneous analysis of sea surface height and geoid related observations. The analysis was based on the three quantities:

- Geoid
- Mean sea surface (MSS)
- Mean Dynamic Topography (MSS)

(see also box 1) with primarily focus on the region around the Greenland-Scotland Ridge. Existing data associated to these quantities has been collected and compiled and new gravity data were measured on an airborne gravity survey figure 1).

The models were regularly validated and assessed in order to improve an optimal estimation of the geoid and MDT by integration the three quantities. This resulted in an improved MDT that allows estimating the ocean circulation in the region and to give specific recommendations for quality assessment of the GOCE satellite and for geoid and MDT computations.

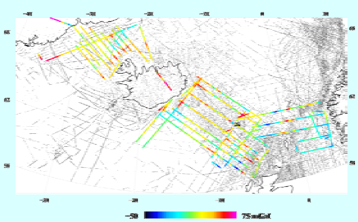


Figure 1. The new airborne gravity data used for the calculation of the GOCINA geoid. Existing gravity data are shown as grey dots.

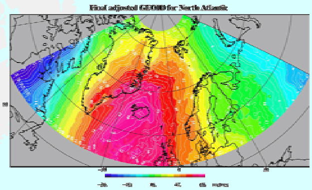


Figure 2. The final FFT-GRACE geoid of the North Atlantic region. The geoid accuracy should be better than 10 cm.

The Optimal Mean Dynamic Topography

The influence of the thermohaline circulation is leading to a horizontal and vertical density structure of the ocean waters. The question is then how the mean dynamic topography reveal this characteristics structure. To examine this three surface fields: the geoid, the MSS, and the MDT, for the ocean area has been investigated.

Ideally the relationship between the geoid, MSS, and MDT are

MDT = MSS – geoid.

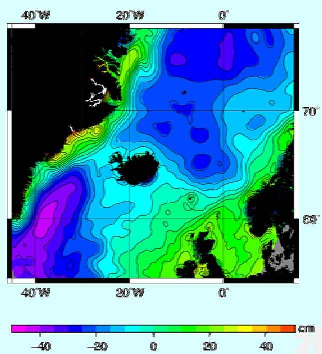


Figure 3. The GOCINA Iterative Combination Method MDT. A key outcome of the project.

Geoid

A highly accurate geoid has been estimated using the collected gravity, extended with altimetric gravity in area with large data gaps, and supplied by the airborne gravity survey. The GRACE geopotential model was used for longer wavelengths up to degree and order 120. The residual geoid was then determined with spherical FFT and the errors with least squares collocation. The model shows an excellent agreement to estimates of the geoid from MSS - MDT, showing that the geoid accuracy should be better than 10 cm.

MSS

Based on recompiled altimetry from ERS and TOPEX/POSEIDON for the period 1993-2001 a new highly accurate high-resolution mean sea surface (MSS) was computed. The model showed very high quality evaluated against altimeter data and existing high-resolution global mean sea surfaces. An updated MSS was computed using data from ENVISAT and JASON-1 covering the period 1993-2003.

MDT

Different existing MDT products based on ocean hydrographic data were studied, several of them were identified as suitable for continued study and comparisons. Having adjusted each MDT to the reference time period of 1993-2001, a composite MDT (CMDT) was formed by taking the mean of seven filtered MDTs. For each of the filtered MDTs the implied geostrophic surface currents, were also calculated. These currents agree well with mean geostrophic velocities for 1992-1996 calculated using drifter data (figure 4).

After the regularly assessment of the three models by looking at the residuals, r = MSS – geoid – MDT, integrated techniques took the respectively error characteristics into account and gave an optimal estimation of the MDT.

An Iterative Combination Method (ICM) algorithm was created to perform a MDT for assimilation studies of analyses of the ocean circulation (see figure 3). The method of solution involves a starting model for MDT, integrates a complete gravity field, and predicts a 'better' version of MDT. This is now used for the first MDT and the procedure iterated until the inserted MDT is consistent with the predicted MDT.

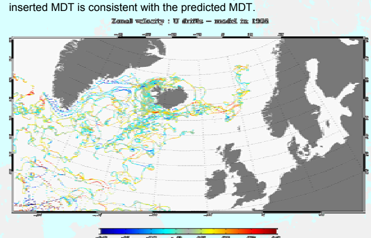


Figure 4. The annual zonal velocity from the GOCINA estimation compared with drifters.

Ocean Circulation

The impact of the new improved ICM MDT on the modelling of the ocean circulation in the sections between Greenland and Shetland has been tested using three Ocean General Circulation Models: FOAM, TOPAZ, and MERACTOR. A twin experiment has been performed: one using the GOCINA ICM MDT and one control run, using the operational systems own MDT.

As table 1 shows the use of the GOCINA ICM MDT improved the modelling of the volume transports thought the straits and increased the agreement with the observations.

In the FOAM system, the use of the new GOCINA MDT decreases the net northward heat transport (figure 5). The accuracy of the GOCINA MDT associated with an innovative altimetric data assimilation system leads to a better simulation of the Atlantic Thermohaline circulation.

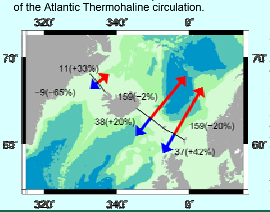


Figure 5. Total annual average heat transports in (10^{12} Watt). Percentages changes by introducing the GOCINA MDT are shown in brackets.

Recommendations for GOCE

The GOCE mission will be important for ocean circulation studies together with ENVISAT satellite altimetry and will provide in-valuable information for studies of the ocean's role in climate.

The GOCINA project has developed generic algorithms for using GOCE and ENVISAT data in ocean circulation modelling and, furthermore, supported GOCE by educating and preparing the oceanographic community in exploiting data from these missions.

Through the new and highly important findings and results achieved, the GOCINA project has contributed to valuable promotion of both the ENVISAT and the GOCE missions.

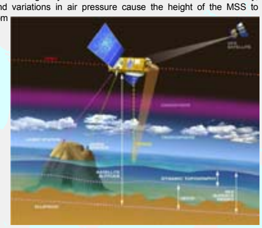
The highly accurate GOCINA gravity field is an important data set for regional validation of GOCE data.

TABLE 1. Observed and simulated north-(N) and southward (S) volume transport over the Green.-Scot. ridge in Sv (10^6 m^3/s). Yellow shaded boxes stand for sections where the GOCINA run leads to transport closer to observations than the control run.

Section		Obs	Simulated					
			FOAM	FOAM-C	TOPAZ	TOPAZ-C	MERCATOR	MERCATOR-C
Iceland-Greenland	N	0.8	1	0.7	2.5	2.2	4.23	4.45
	S	4.3	7.5	10.4	4.8	5.3	6.64	7.68
Faroe-Iceland	N	3.8	5	5.8	5.0	5.2	-	-
	S	1.0	1.3	1.2	2.3	2.2	-	-
Faroe-Shetland	N	3.8	4.3	5.9	3.2	3.5	-	-
	S	2.6	2.4	1.8	2.3	2.2	-	-
Iceland-Shetland	N	7.6	9.3	11.7	8.2	8.7	4.49	4.36
	S	3.6	3.7	3	4.6	4.4	3.02	3.24
All sections	N	8.4	10.3	12.4	10.7	10.9	8.72	8.81
	S	7.9	11.2	13.4	9.4	9.7	9.66	10.92
Net flow through the Green.-Scot. ridge		0.5N	0.9 S	1 S	1.3 N	1.2 N	0.94 S	2.09 S

BOX 1

Sea surface heights are measured by multiple altimetric satellites, such as ENVISAT and TOPEX/POSEIDON. These are used to determine a accurate high-resolution mean sea surface (MSS). If the oceans were motionless the MSS would correspond to the geoid, which reflects the variations in the gravity field. Differences in the ocean water density, winds, and variations in air pressure cause the height of the MSS to depart from the geoid creating the mean dynamic topography (MDT). This provides the absolute reference surface for ocean circulation and heat transport.



MORE INFO

On the internet: http://www.gocina.dk
http://geodesy.spacecenter.dk/~gocina/

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