GOCESeaComb

External calibration/validation of ESA's GOCE mission and contribution to DOT and SLA determination through stochastic combination with heterogeneous data

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GOCESeaComb

The **GOCESeaComb** project is funded by the European Space Agency (ESA) within its Scientific Experiment Development Program (PRODEX) following a successful application to the General Secretariat for Research & Technology (GSRT) after an invitation to the Greek scientific community in response to the 1st PRODEX Programme Call for Greece.

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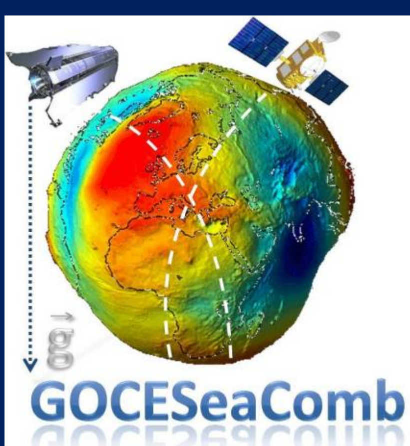


The GOCESeaComb Project Logo

MDOT and TDOT Covarinace Function Determination

During the period of this newsletter and since the last newsletter in August 2013, all project activities are going according to schedule. Having completed the detailed validation of the GOCE/GRACE GGMs, and before the data combination for DOT and SLA determination, the analysis of existing DOT models has been carried out. This refers to the determination of empirical and analytical covariance functions so that both the MDOT and TDOT information will be incorporated within an LSC adjustment scheme.

MDOT Analytical Covarinace Function Models

In order to determine some analytical model for the DOT covariance function, various options are tested. The first class of analytical models, refers to exponential ones and the second refers to 2nd and 3rd order Gauss-Markov. For the exponential ones six choices are examined, with varying number of parameters to be determined as follows:

$$C_{\zeta\zeta}(\psi)=\alpha e^{b\psi},$$

$$C_{\zeta\zeta}(\psi)=\alpha e^{b\psi}+ce^{d\psi},$$

$$C_{\zeta\zeta}(\psi)=\alpha e^{-\left(\frac{\psi-b}{c}\right)^2},$$

$$C_{\zeta\zeta}(\psi)=\alpha e^{-b\psi^2},$$

$$C_{\zeta\zeta}(\psi)=\alpha e^{-b\psi}\cos(\omega\psi),$$

$$C_{\zeta\zeta}(\psi)=\alpha(1+b\psi)e^{-b\psi}.$$

In the above equations, a, b, c *and* d denote parameters to be determined so that the analytical covariance model will fit the empirical one. Note that all above models are a function of the spherical distance between the points where DOT values observations exist. The 2nd and 3rd order Gauss-Markov models are outlined in the following equations, where D is the characteristic distance, r is the planar distance and σ_ζ^2 the MDOT variance:

$$C_{\zeta\zeta}(r)=\sigma_\zeta^2\left(1+\frac{r}{D}\right)e^{\left(-r/D\right)},$$

$$C_{\zeta\zeta}(r)=\sigma_\zeta^2\left(1+\frac{r}{D}+\frac{r^2}{3D^2}\right)e^{\left(-r/D\right)}.$$

Moreover, a model similar to that of Tcherning and Rapp for the gravity field disturbing potential will is tested, where the analytical model is described as:

$$C_{\zeta^c\zeta^c} = \sum_{n=0}^{\infty} \sigma_n(\zeta^c) \left(\frac{R_B}{R}\right)^{2(n+1)} P_n(\cos\psi),$$

where $\sigma_n(\zeta^c)$ are the degree variances of ζ^c. For the description of the behaviour of the degree variances given in the analytical model

$$C_{TT}(P,Q) = \left(\frac{GM}{R}\right)^2 \sum_{n=0}^{n_{max}} c_n(T) \left(\frac{R^2}{r_Q r_P}\right)^{n+1} P_n(\cos\psi_{PQ}) + \left(\frac{GM}{R}\right)^2 \sum_{n=n_{max}+1}^{\infty} \sigma_n(T) \left(\frac{R_B{}^2}{r_Q r_P}\right)^{n+1} P_n(\cos\psi_{PQ})$$

we employ a 3rd degree Butterworth filter, so that the degree variances of the MDT are given as:

$$(\sigma_n(\zeta^c))^2 = b\left(\frac{k_2^3}{k_2^3+n^3} - \frac{k_1^3}{k_1^3+n^3}\right).$$

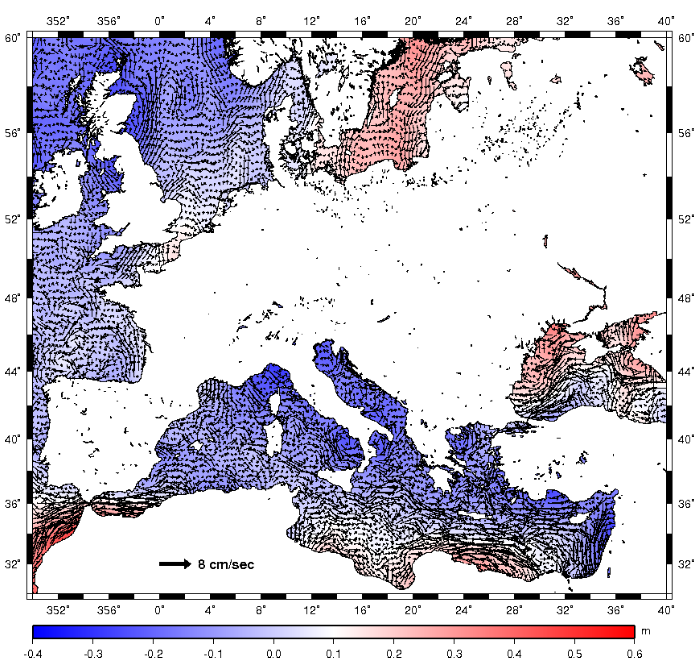
The factors b, k_1, k_2 *and* R^B are determined so that the analytic model fits the empirical values describing the statistical characteristics of the MDOT in the area under study and more precisely the variance and the correlation length

TDOT Analytical Covarinace Function Models

For the determination of analytical covariance function for the time varying DOT a model similar to the one of Knudsen (1991) will be used. In this model, the signal degree variances of the $\delta\zeta$ have been introduced, so that $\delta\zeta$ varies with time. Time-dependency should enter in the computation of $C_{\delta\zeta\delta\zeta}$ in a way that temporal correlations are given in the same way as spatial ones. Therefore, for some time-separated points $\Delta t = |t - t'|$ the covariance function of $\delta\zeta$ can be expressed as:

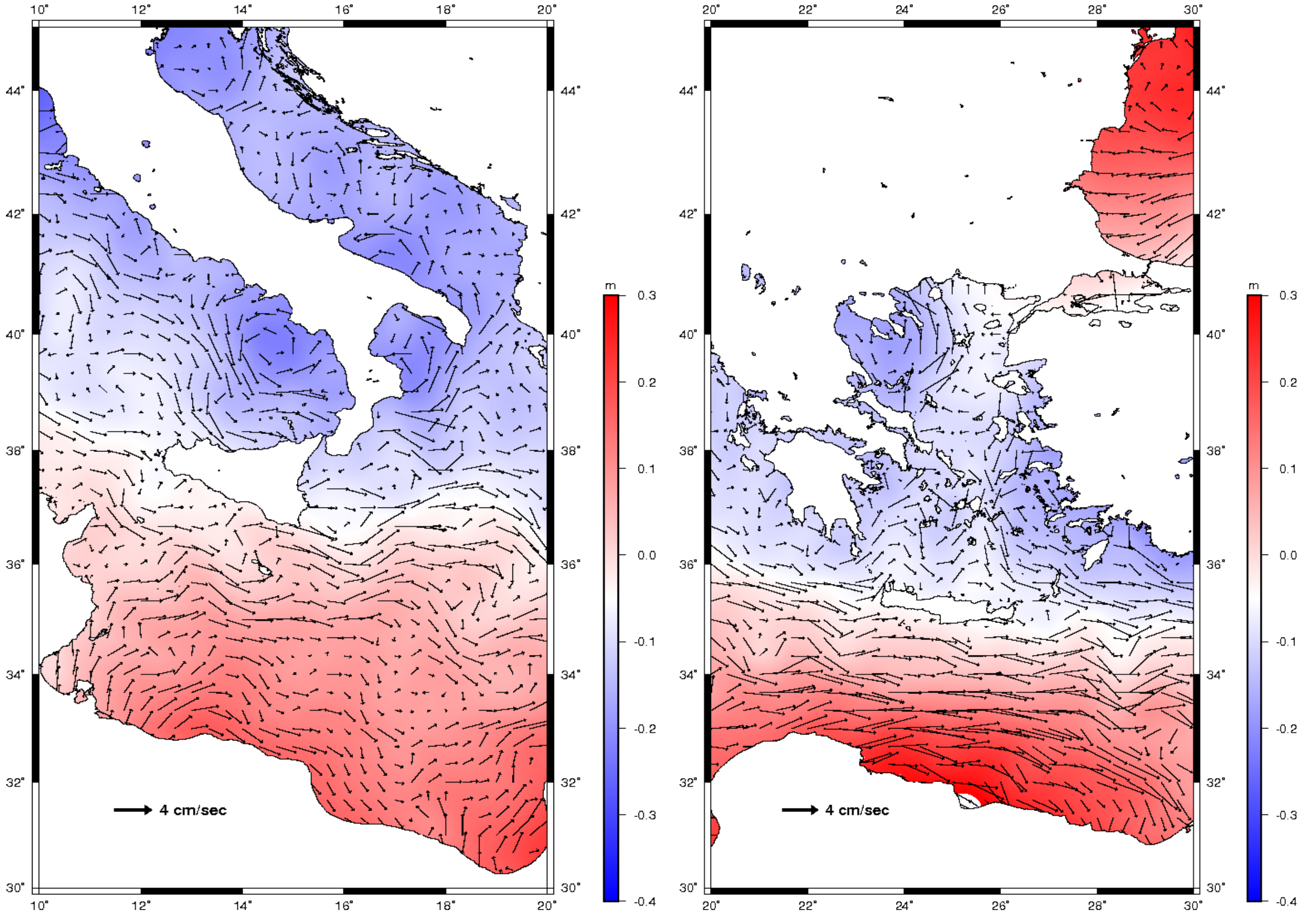
$$C_{\delta\zeta\delta\zeta}(\psi,\Delta t) = \begin{cases} \sum_{n=0}^{\infty} \sigma_n^2(\delta\zeta) P_n[\cos(\psi+\kappa\delta\zeta\Delta t)] & \text{for} \quad (\psi+\kappa\delta\zeta\Delta t) \le \pi \\ 0 & \text{for} \quad (\psi+\kappa\delta\zeta\Delta t) > \pi \end{cases},$$

where $\kappa\delta\zeta$ is a conversion factor representing in the case of the time-varying SST the correlation time of the signal. This should be studied and determined in each region under study, since the characteristics of $\delta\zeta$ vary significantly for each area and in open or closed sea regions (Knudsen and Tscherning 2006). The degree variances $\sigma_n^2(\delta\zeta^t)$ are determined as in the case of the MDOT, i.e., through a 3rd order Butterworth filter. Salinity and temperature, in-situ oceanographic data, climatology and geostrophic surface current models can be used in order to fit analytical values to empirical ones.



GOCE-based MDOT

Given the availability of the recent GGMs from the satellite gradiometry mission of GOCE and their validation within GOCESeaComb, the latest GGMs based on GOCE and GRACE can be used to determine a DOT model for the wider area under study. As far as the mean dynamic ocean topography model is concerned, this can be derived from a combination of a GGM and some mean sea surface (MSS) model, which for the GOCEseaComb project will be the one from the Danish Space Agency group (DTU2010). The concept of DOT (ζ) estimation is quite simple and relies on the fact that it can be computed as the difference between the MSS and the geoid, taking into account that both are available for the area under study. Two points that need attention are that both the MSS and geoid fields should refer to



the same reference ellipsoid and the same tidal system. Within GOCESeaComb, and in order to be compatible with all other processing methodologies followed, the tide-free system have been used. The filtered DOT ($\hat{\zeta}$) is then estimated by filtering the residuals, or initial DOT estimates, as:

$$\hat{\zeta} = h(x,y) \circ \left\{\tilde{\zeta}\right\} = h(x,y) \circ \left\{\zeta + \delta N_L + \delta_L\right\},$$

where *h(x,y)* is the filtering function with *H(u,v)* being its frequency impulse response. The ones to be used refer to boxcar, cosine arch, Gaussian and wiener-type of filters, for all of which the smoothness of the estimated DOT is related to the filter width chosen. Examples from such GOCE and altimetry based estimations of the MDOT and the ocean circulation are presented in the Figures below.

Acronyms

LSC Least Squares Collocation

MDOT Mean Dynamic Ocean Topography

TDOT Time-varying Dynamic Ocean Topography

SLA Sea Level Anomalies

Contact Us

GeoGrav - AUTh
Department of Geodesy and Surveying, Aristotle University of Thessaloniki
University Campus, University Box 440, GR-54124
Thessaloniki, Greece
T: ++302310996125 | **F**: ++302310995948
tziavos@topo.auth.gr vergos@topo.auth.gr
http://olimpia.topo.auth.gr/GOCESeaComb/