A profile approach for the recovery of the mean dynamic topography

Wolfgang Bosch and Roman Savcenko
Deutsches Geodätisches Forschungsinstitut (DGFI), München
bosch@dgfi.badw.de

DGFI FGS Forschungsgruppe Satellitengeodäsie

DFG SPP1257
Projekt GEO-TOP

Rationale of the Profile Approach

1 GRACE gravity field models realize essential improvements over previous estimates of the Earth gravity field and justify to recover the mean dynamic topography (*MDT*) by subtracting geoid heights *N* from sea surface heights *SSH* (the "*geometric*" method)

$$MDT = SSH - N \quad (1)$$

2 The geometric method allows to assess the *absolute MDT*, ensures the same reference level in different ocean basins and is independent of the level-of-no-motion assumption.

3 The geometric method requires consistency with respect to the tide system and the spectral content of the quantities to be subtracted.

4 Altimetry leaves the permanent tidal deformation of the Earth surface due to the gravitation of Sun and Moon uncorrected. Thus geoid heights are to be computed in the *zero tide system*. (in agreement with IAG resolution 1983)

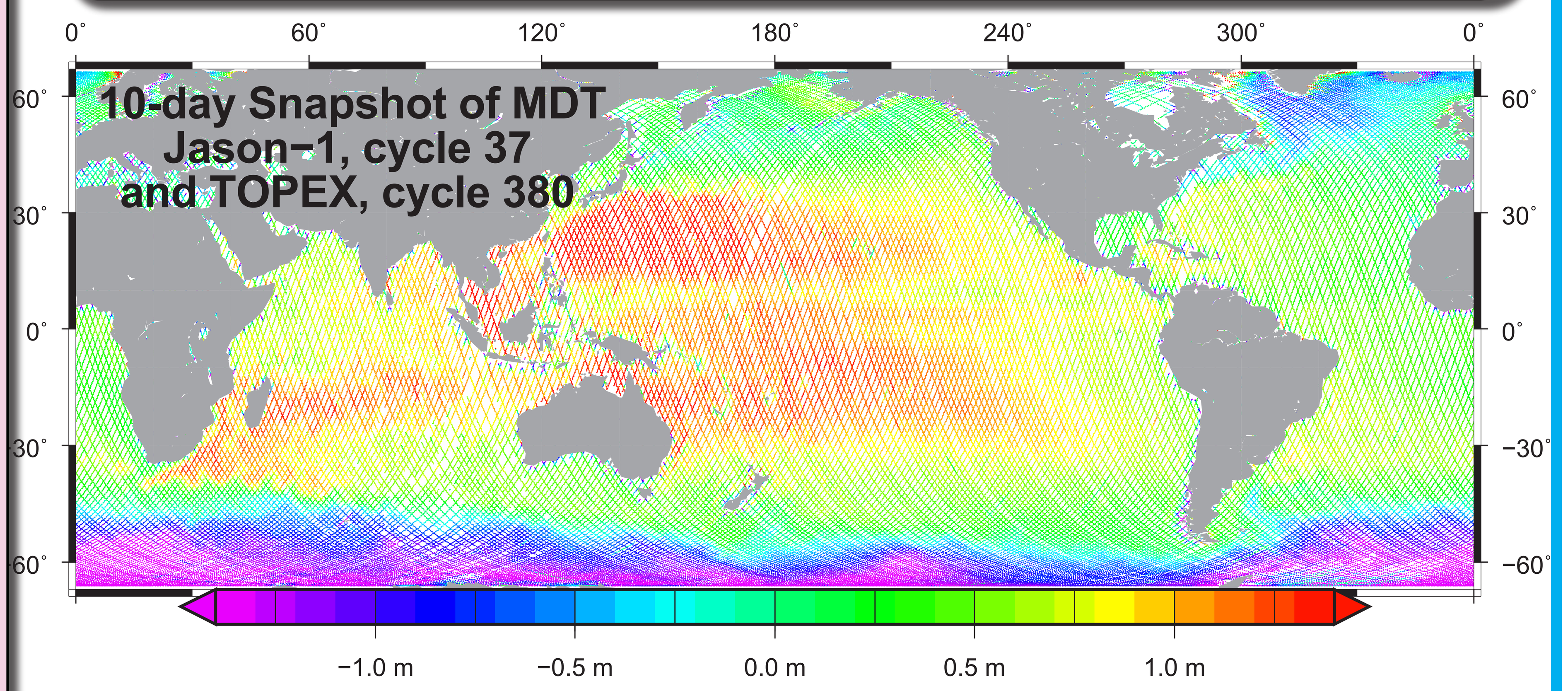
5 The spectral content of geoid and sea surface is diverse (small scale sea surface structures are not resolved by the geoid - due to the band limited gravity field models). Thus one and the *same filter* has to be applied to both, geoid heights and sea surface heights.

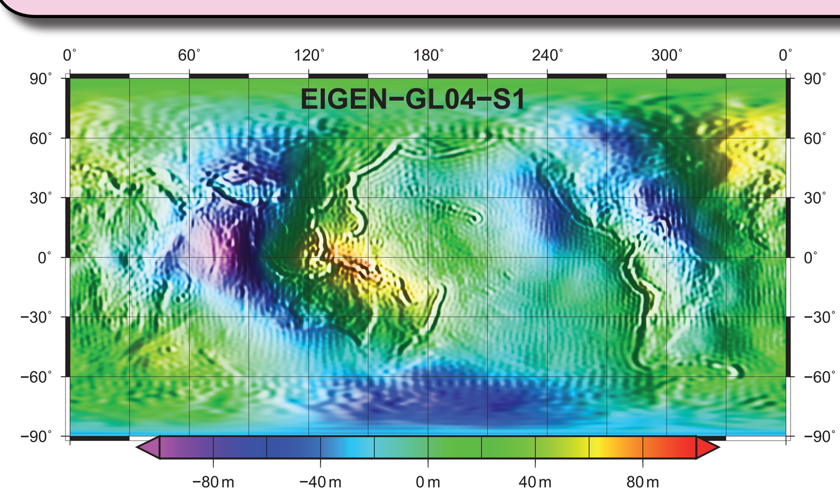
6 The along-track resolution of altimetry is much higher than the resolution of gridded sea surface heights. To avoid a significant loss of signals through gridding and to keep as much informations as possible the geometric method should be applied along the profiles directly observed by altimetry.

7 With a high resolution geoid (EIGEN-GL04C) the profile approach provides reasonable results even if applied to the data of a ten day period only (see right). The difference (1) should be based on satellite-only gravity fields which do not already include altimetry data.

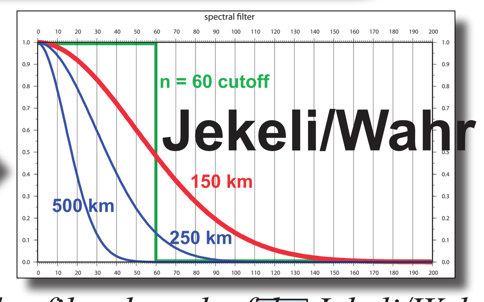
Objectives

The GEO-TOP project aims to assimilate the mean dynamic topography (MDT) into dynamic models of the ocean in order to derive the three dimensional ocean circulation and to derive absolute mass and heat flux. The accuracy level of GRACE geoids allows for the first time to determine the MDT with a signal-to-noise ratio small enough to infer ocean circulation. The present paper conducts a profile approach by (i) smoothing a GRACE gravity field, (ii) merging zero-tide geoid profiles with the along-track sea level measurements of satellite altimetry and (iii) applying a common low pass filter to both, geoid and sea surface height profiles. The approach produces the expected topographic features which are compared with independent estimates of the MDT.

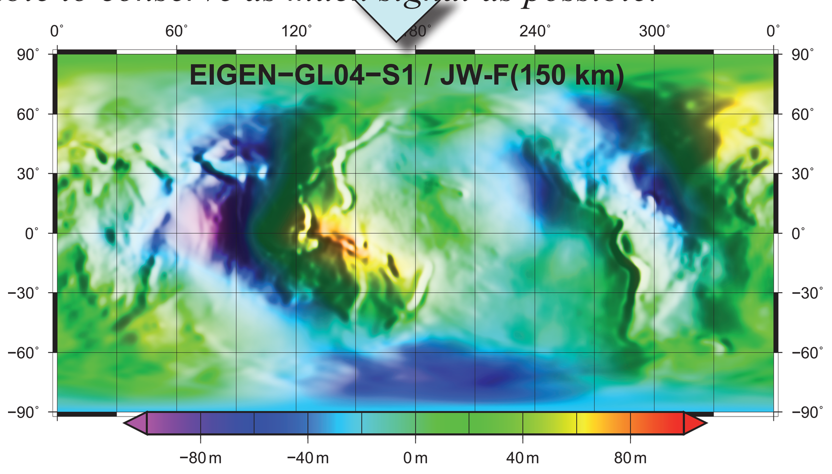


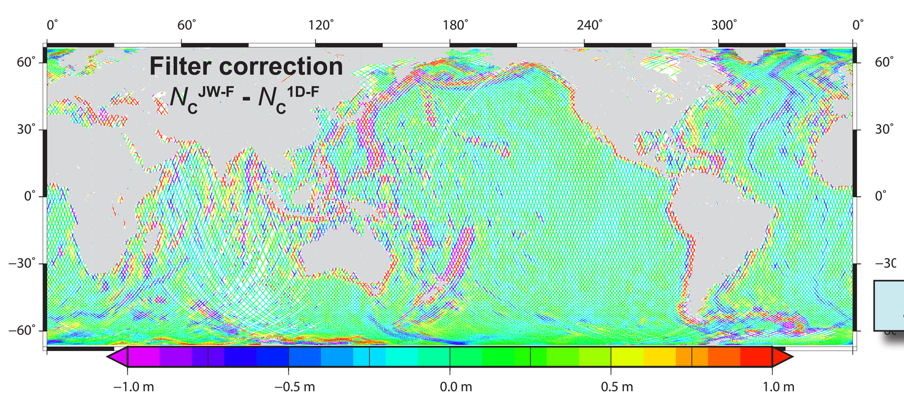


point 1, blue box



The 150 km filter length of the Jekeli/Wahr-filter was chosen long enough to remove the striping and as short as possible to conserve as much signal as possible.

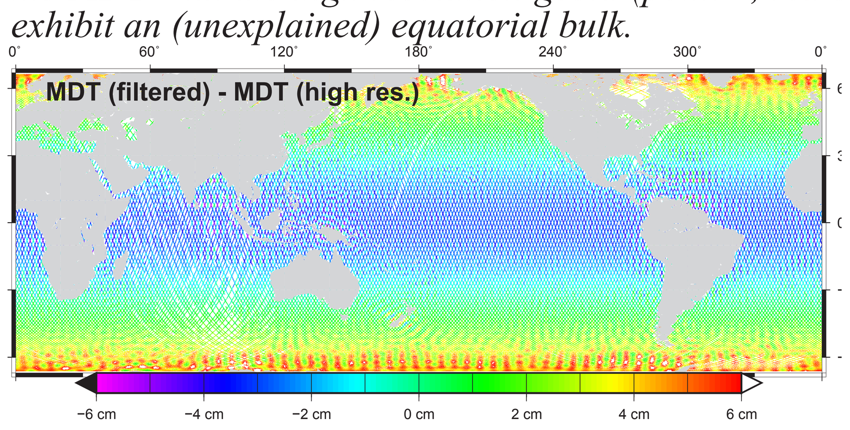


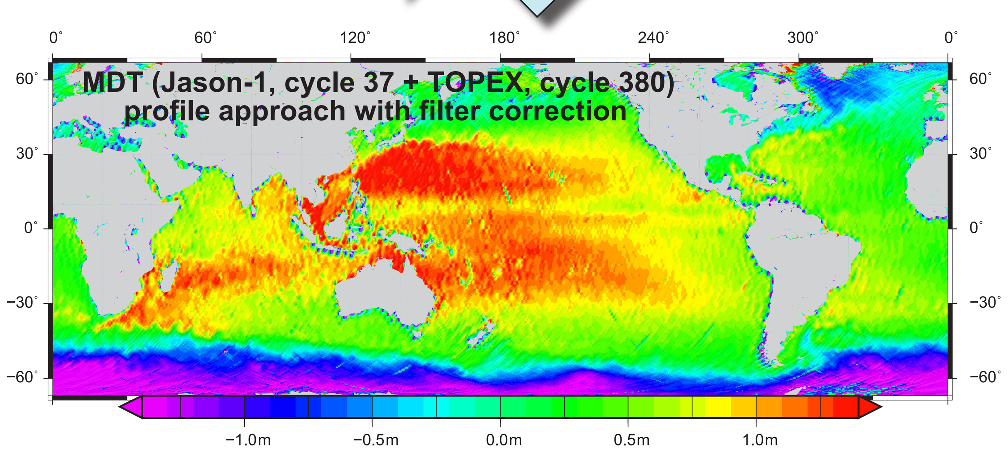


see point 5, blue box

Eq. 2, blue box

The differences between the filtered MDT (blue box) and the MDT with the high resolution geoid (point 7, red box) exhibit an (unexplained) equatorial bulk.





Filter Design and Correction for 1-DF

1 Even the latest GRACE satellite-only gravity fields (e.g. EIGEN-GL04S) exhibit a meridional striping, an artifact of GRACE processing which does not represent geophysical signal (see left plot with illumination from West).

2 The striping has to be removed by an adequate filter. The Jekeli/Wahr-Filter (JW-F) with radius 150 km applied to the spectrum of GL04S apparently removes the meridional striping. The JW-F has an equivalent 2-dimensional filter (2D-F) in the space domain.

3 The smoothed geoid heights $N_S^{JW\text{-}F}$ were evaluated at the altimeter profiles. In order to perform the subtraction

$$MDT = SSH^{JW\text{-}F} - N_S^{JW\text{-}F} \neq SSH^{1D\text{-}F} - N_S^{JW\text{-}F} \quad (2)$$

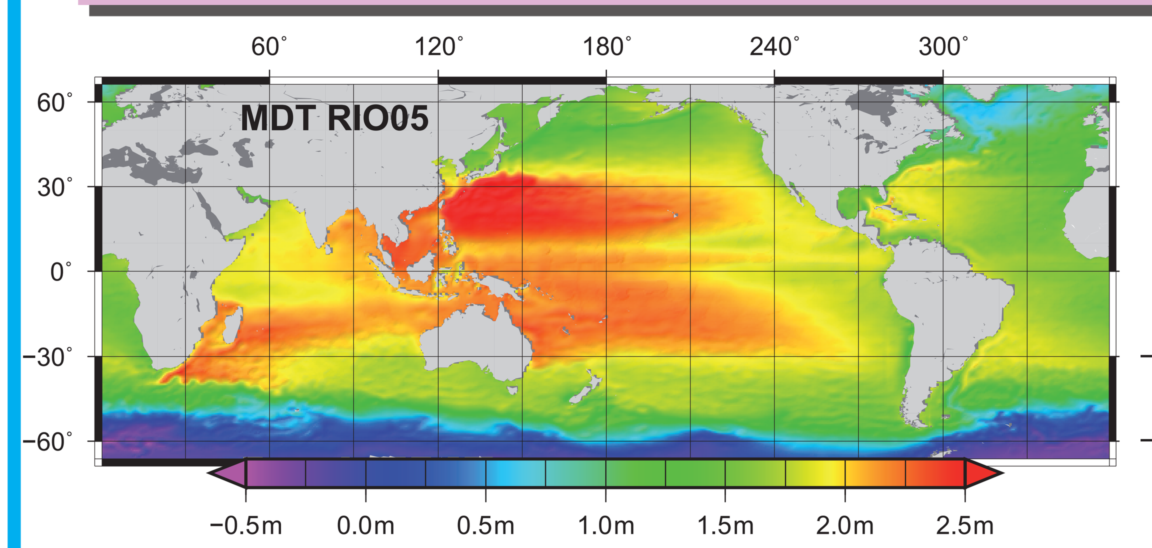
the sea surface heights *SSH* are to be smoothed in the same way but the filter can only be applied in the 1-dimensional space domain.

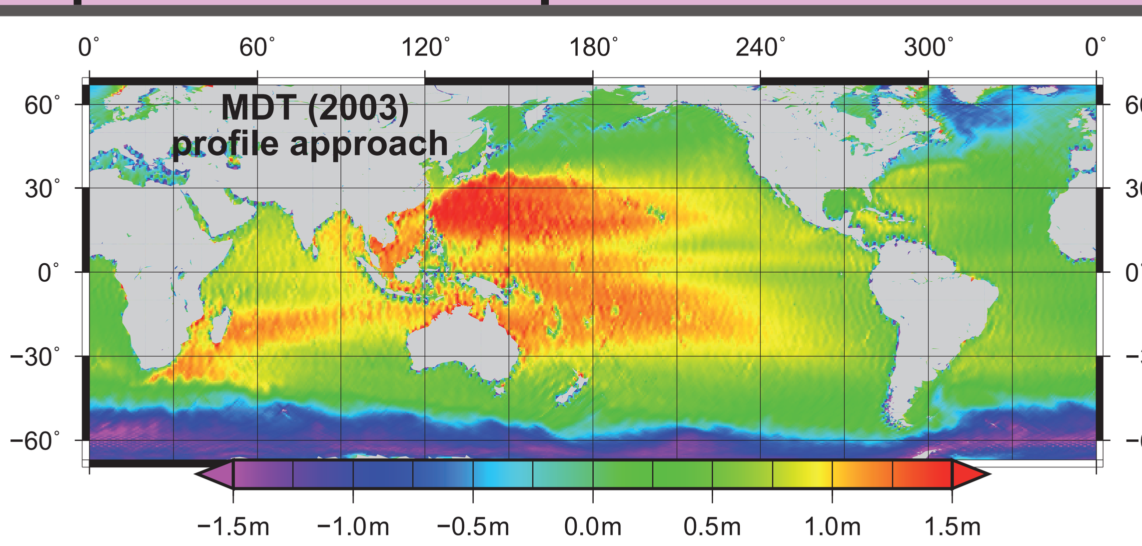
4 The 1-dimensional along track filter (1D-F) is not equivalent to the 2-dimensional filtering in the space domain (2D-F). (A profile following a long trench is lifted by 2-DF but remains low by 1D-F).

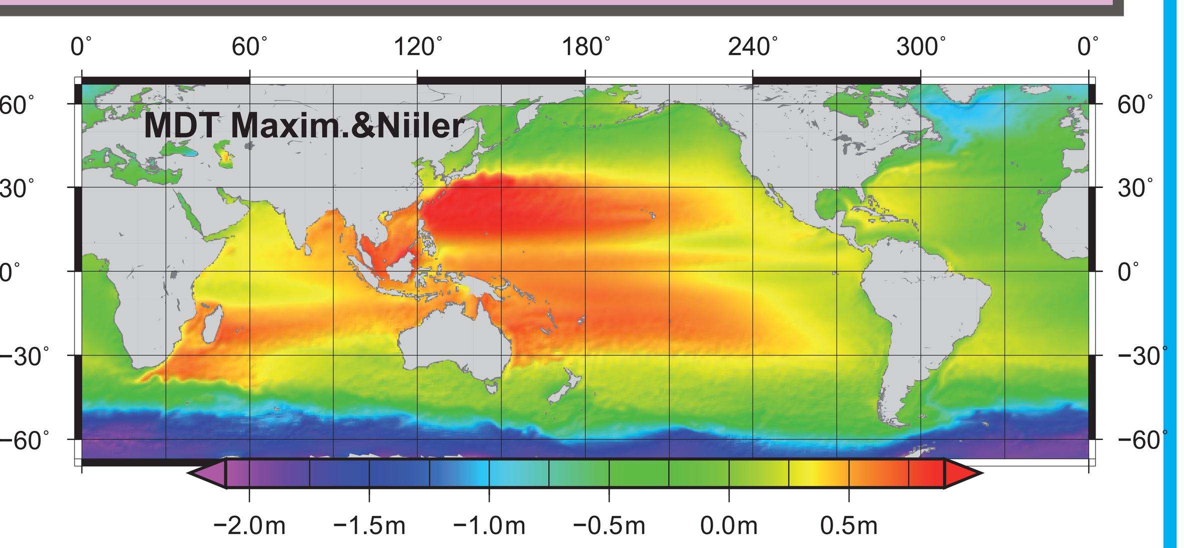
5 To correct for the differences of 1D-F and 2D-F (JW-F) two versions of a *high* resolution geoid (EIGEN-GL04C) were evaluated at the altimeter profiles, a spectrally smoothed $N_C^{JW\text{-}F}$ and an unsmoothed version N_C. The unsmoothed geoid heights were subject to the 1-dimensional filter ($N_C^{1D\text{-}F}$) and the difference $N_C^{JW\text{-}F} - N_C^{1D\text{-}F}$ is a correction for the different effects of 1-D and 2-D filtering.

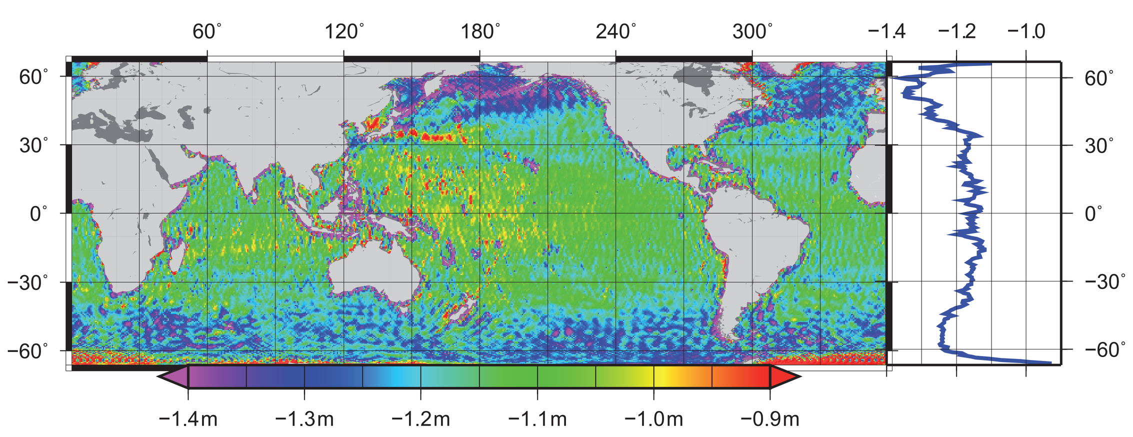
$$SSH^{JW\text{-}F} = SSH^{1D\text{-}F} + (SSH^{JW\text{-}F} - SSH^{1D\text{-}F})$$
$$\approx SSH^{1D\text{-}F} + (N_C^{JW\text{-}F} - N_C^{1D\text{-}F})$$

Comparison with independent estimates of MDT







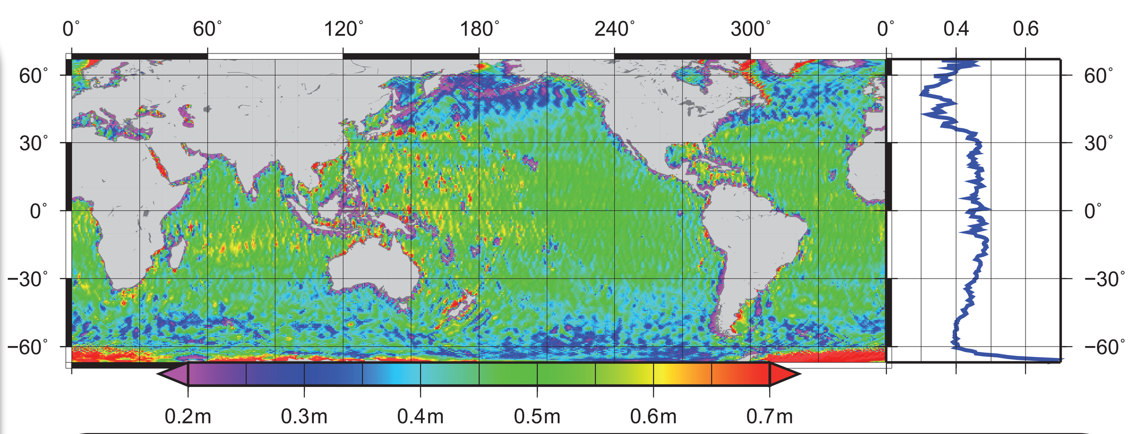


Discussion

1 The structure of the MDT, derived for 2003 by the profile approach (top) is very similar to MDT's of RIO05 (top left) and Maximenko&Niiler (top right) although these MDTs cover different time periods.

2 The differences to RIO05 (left) and Maximenko&Niiler (top right) exhibit considerable offsets of 1.2 m for RIO05 and 0.4 m for Maximenko&Niiler.

3 The zonal averages show also equatorial bulks of a few centimetres even though *N* was computed in the *zero-tide* system.



To Do

1 Error propagation for both, altimetry and geoid
2 Improved filtering at ocean land transition
3 Validation with in situ measurements (floater)

References:

Niiler, P.P., N.A. Maximenko, and J.C. McWilliams, 2003: Dynamically balanced absolute sea level of the global ocean derived from near-surface velocity observations. Geophys. Res. Lett., 30 (22), 2164, doi:10.1029/2003GL018628, 2003

Rio, M.H. and Hernandez, F, 2004. A Mean Dynamic Topography computed over the world ocean from altimetry, in-situ measurements and a geoid model. Journal of Geophysical Research, v. 109(12).

Joint International GSTM and SPP Symposium, Potsdam, 15.-17. October 2007