Cryosat2 insights in the Mediterranean Circulation through wavelet multi-resolution analysis and selective filtering

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Rationale and goals

Modeling the Dynamic Ocean Topography (DOT) and determining the circulation pattern of the ocean currents has always been a challenging task in the Mediterranean Sea, mainly due to:

a) the limited number of satellite altimetry data in the area, given land intrusion by the isles and islands,

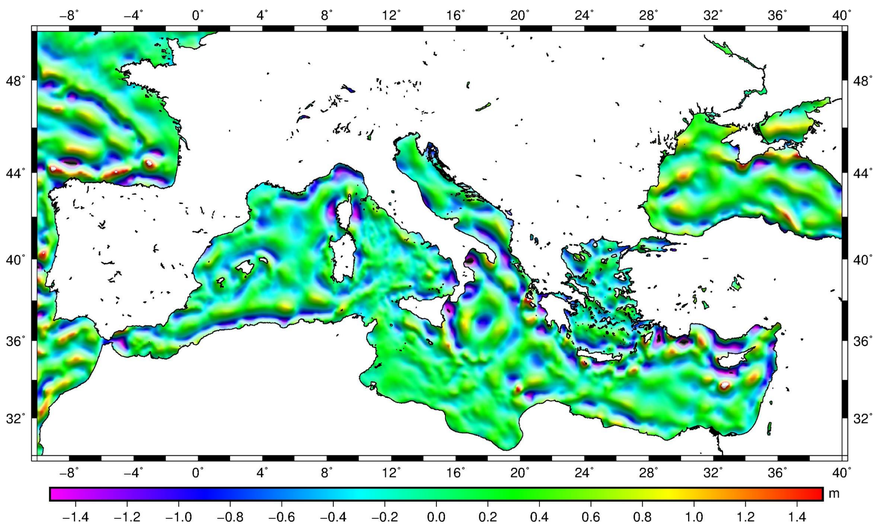
b) the limited number of gravity-related data, so that the geodetic determination of the DOT was deemed as low-accuracy and

c) the nature of the Mediterranean circulation itself, being mainly the result of small-scale gyres and eddies as well as cyclones and anti-cyclones.

To tackle the aforementioned limiting factors, two pillars need to be addressed, i.e., improved representations of the long and medium wavelength geoid information and higher accuracy and resolution satellite altimetry data.

The main scope of the present study is to utilize the satellite altimetry data of Cryosat2, from mission start in July 2010 up to the end of 2015 (Cycles 4 to 73) and the latest DIR-R5 and EIGEN6c GOCE-derived global geopotential models in order to determine the DOT and circulation for the Mediterranean Sea.

For the DOT determination, filtering is first investigated to model and remove/reduce the effects of the geoid omission and commission errors.



Geodetic MDOT determination

Spatial filtering is based on Gaussian, Wiener, cosine arch and boxcar filters, while the spectral filtering was carried out with wavelet (WL) Multi-resolution analysis (MRA).

The DOT can then be estimated as:

$$\zeta = \tilde{h} - N$$

where, ζ is the DOT, N denotes the GOCO02s derived geoid height and $\tilde{h}$ the MSS. If in the above equation we consider:

a. the geoid omission error (δN_L), arising from the fact that the used GGM to derive the geoid represents the geoid spectrum only up to some maximum degree and order $L=n_{max}$ and not to ∞, and

b. the geoid commission error (δ_L), arising from the propagation of the spherical harmonics errors to the geoid defined,

we can re-write it as (N_L denoting the truncated contribution of the GGM):

$$\tilde{\zeta} = \tilde{h} - N_L = \zeta + N - N_L + \delta_L = \zeta + \delta N_L + \delta_L$$

Therefore, the estimation of the DOT needs to account for the unmodeled parts of the geoid still remaining in the DOT due to the limited representation offered by the GGM.

Having estimated this initial DOT, and in order to remove, or at least reduce, the influence of the δN_L and δ_L terms, some spatial/spectral filtering is needed.

The filtered DOT ($\hat{\zeta}$) is then estimated by filtering the residuals, or initial DOT estimates, as:

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

where, h(x,y) denotes the filter function with $H(u,v)$ being its frequency impulse response. The filter functions tested 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.

Another option is Wavelet (WT) Mutli-Resolution Analysis (MRA). WT is based on wavelets $\psi_\kappa(x)$ as basis function in order to represent other functions. The wavelet function (ψ) carries valuable information about the signal, while the scaling function (φ), reveals the functional approximation. Since wavelets are base functions with localization properties in both space (time) and frequency (scale) domains, there can be a multiresolution analysis (MRA) at various levels of decomposition.

$$\varphi_{(j,m,n)}(x) = 2^{(j/2)}\varphi\left(2^j x - m, 2^j x - n\right) \qquad \psi^i_{(j,m,n)}(x) = 2^{(j/2)}\psi\left(2^j x - m, 2^j x - n\right), i = H,V,D$$

Each Level of decomposition corresponds to a spatial resolution. To determine the number of levels the initial grid step of the data was used (5′ or ~9 km). The first level extends from 9 km to 18 km, the second from 18 km to 36 km etc., until the last levels' spatial analysis reaches the earth's perimeter. As a result when the grid step is 5′, there are 12 Levels of decomposition.

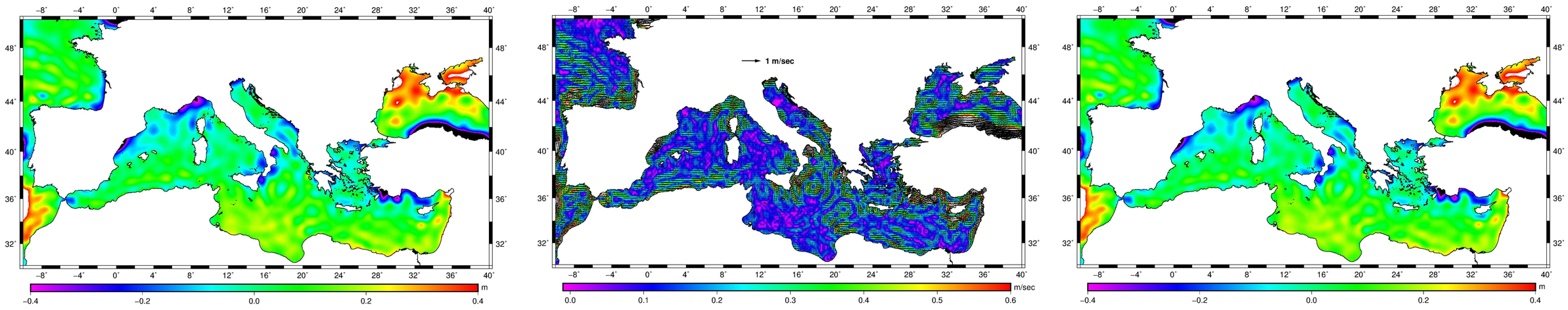


Figure 1: The initial MDOT (top), the boxcar filtered (200 km) MDOT (left), the resulting circulation (middle) and the boxcar filtered (600 km) MDOT (right)

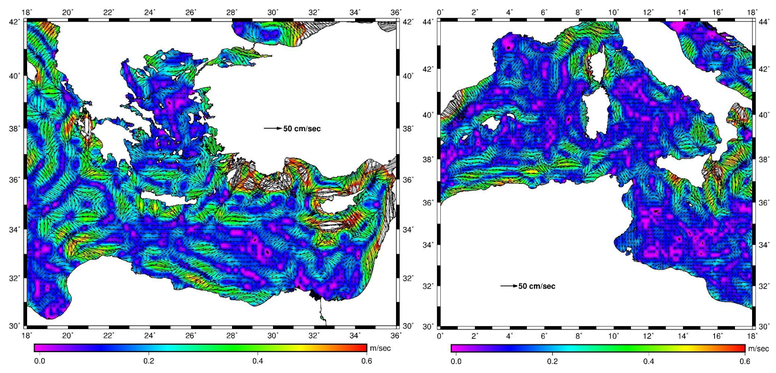


Figure 2: The boxcar filtered (200 km) circulation

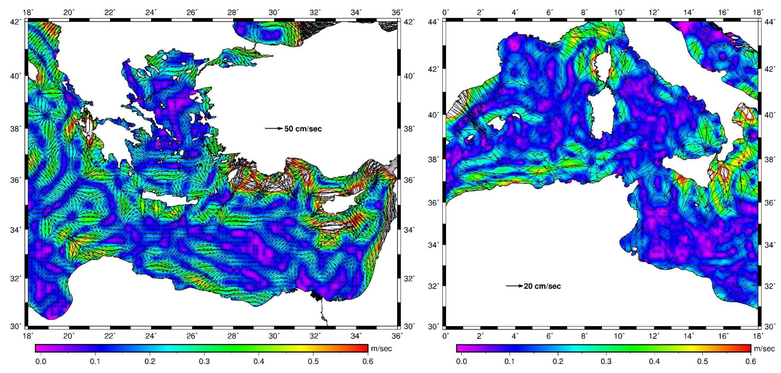


Figure 3: The boxcar filtered (400 km) circulation

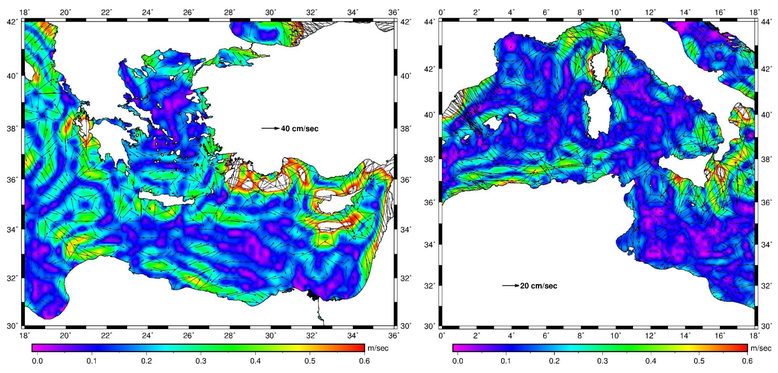


Figure 4: The boxcar filtered (600 km) circulation

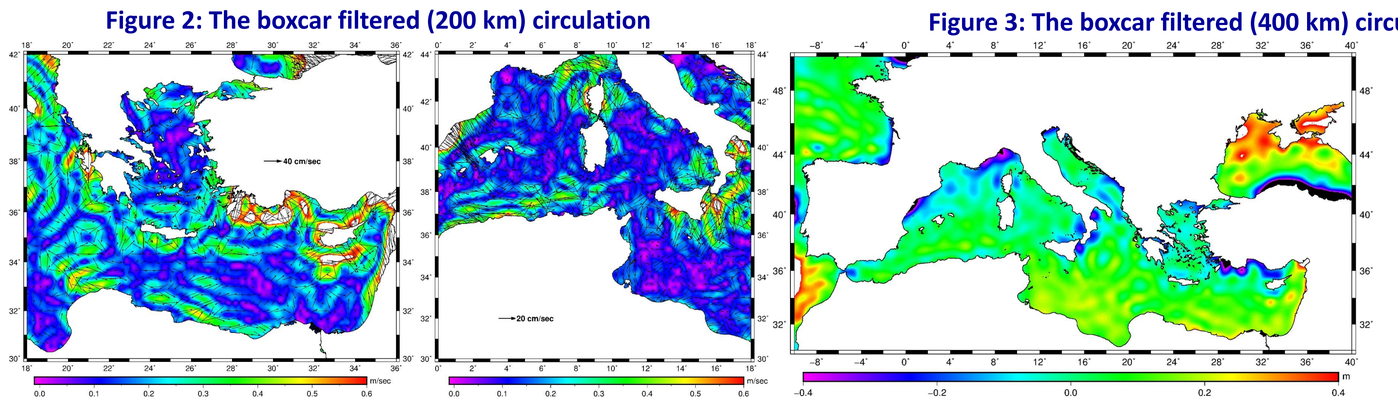


Figure 5: The Gaussian filtered (600 km) circulation and MDOT

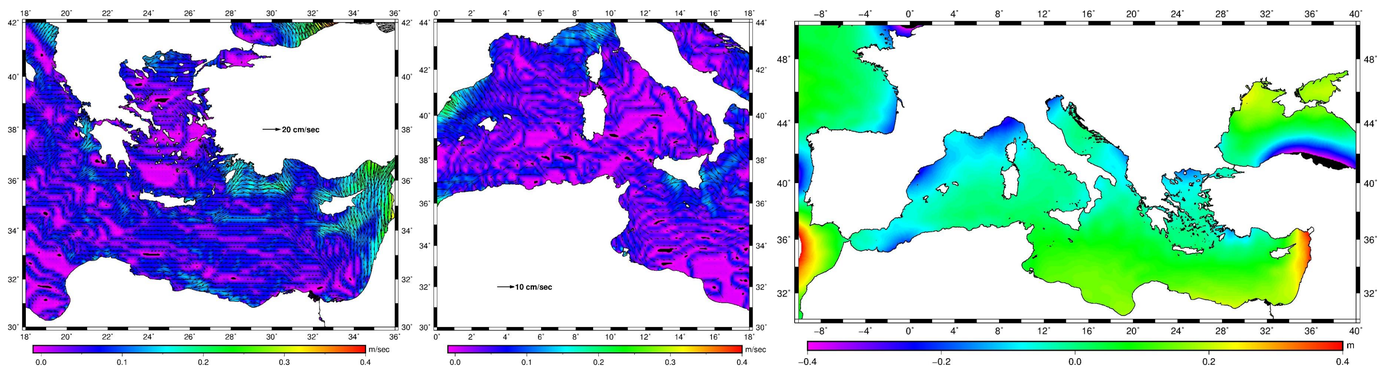


Figure 6: The Gaussian filtered (600 km) circulation and MDOT

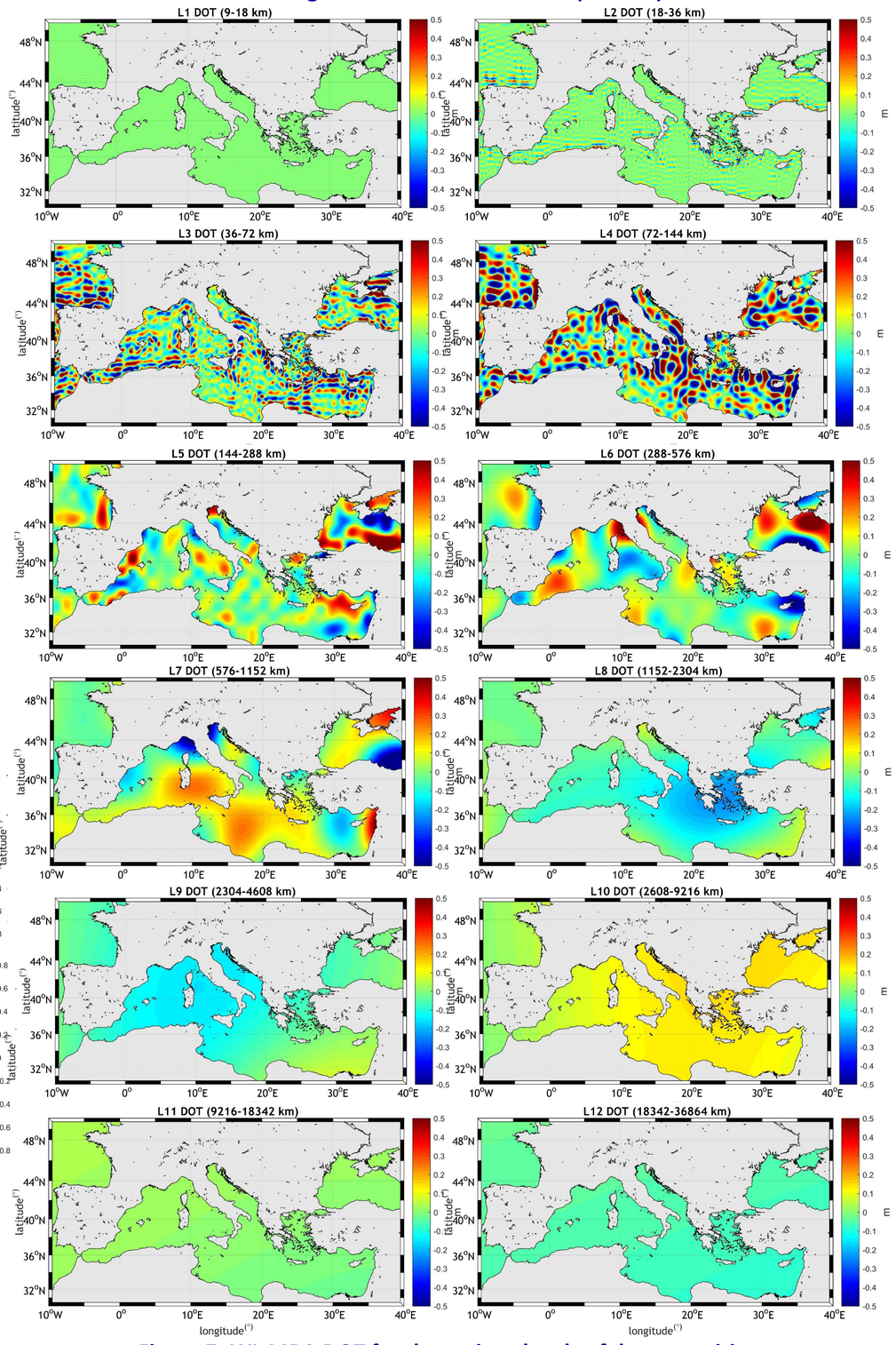


Figure 7: WL MRA DOT for the various levels of decomposition

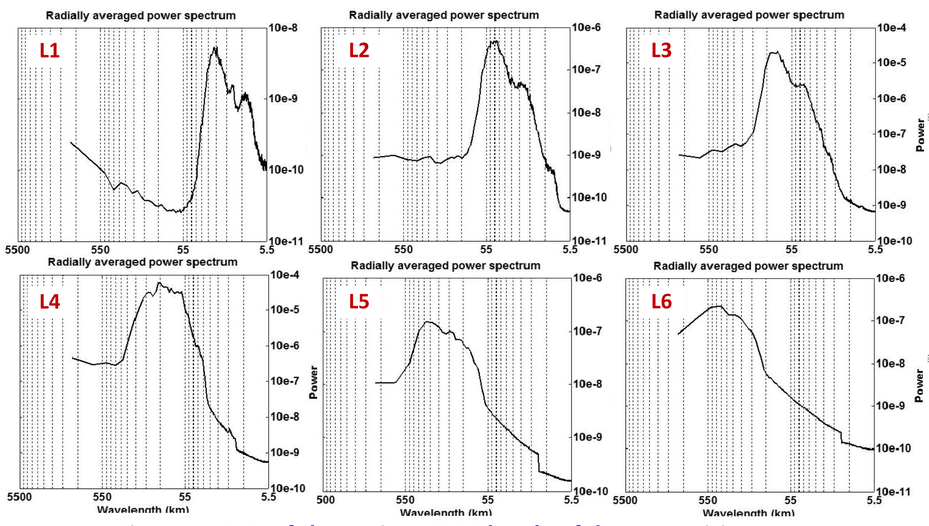


Figure 8: PSD of the various DOT levels of decomposition

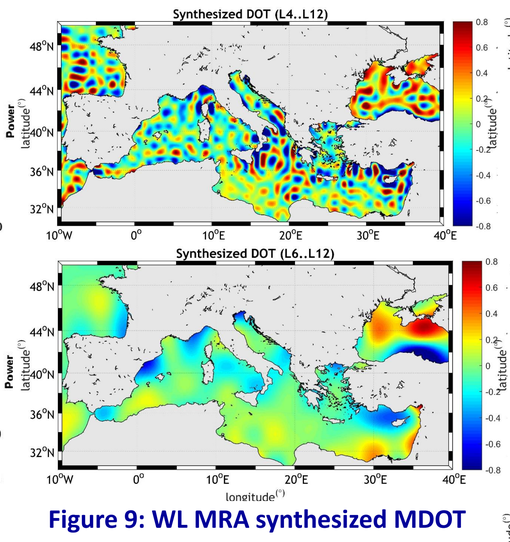


Figure 9: WL MRA synthesized MDOT

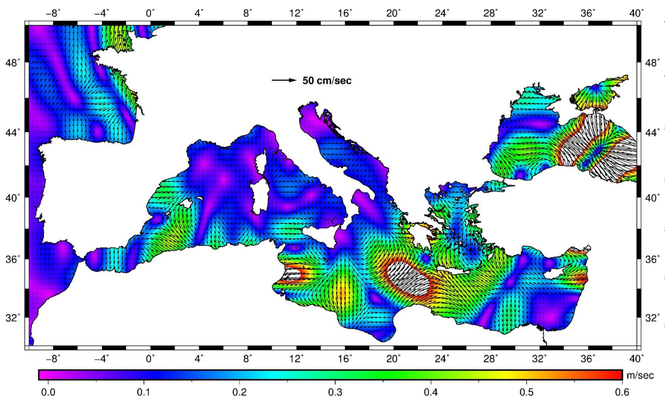


Figure 11: WL MRA synthesized circulation (L6-L12)

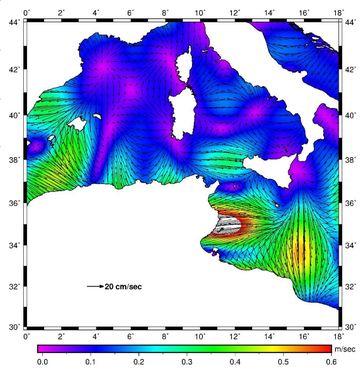


Figure 12: WL MRA synthesized circulation (L6-L12) in east and west Mediterranean

Conclusions

- MDOT can be resolved for following a geodetic approach from an MSS and a GOCE-based geoid model.
- Spatial filters seem to over smooth the MDOT thus removing useful information.
- WL MRA on the other hand allows for the decomposition of the signal and the application of selective filtering.
- Future work includes the application of edge enhancing diffusion methods on each level of decomposition.

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