Evaluating CMEMS products in the western Mediterranean using an eddy tracker and multiplatform in situ data

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Introduction

The MedSub project aims to improve understanding of ocean circulation associated with meso- and submesoscale features (e.g., eddies, fronts, and filaments). Focus region is the western Mediterranean (WMED). Numerical and observational data (in situ and satellite) from the Copernicus Marine Envrionmental Monitoring Service (CMEMS). Desired MedSub outcome is improvement of CMEMS products based on new understanding of fine-scale ocean processes.

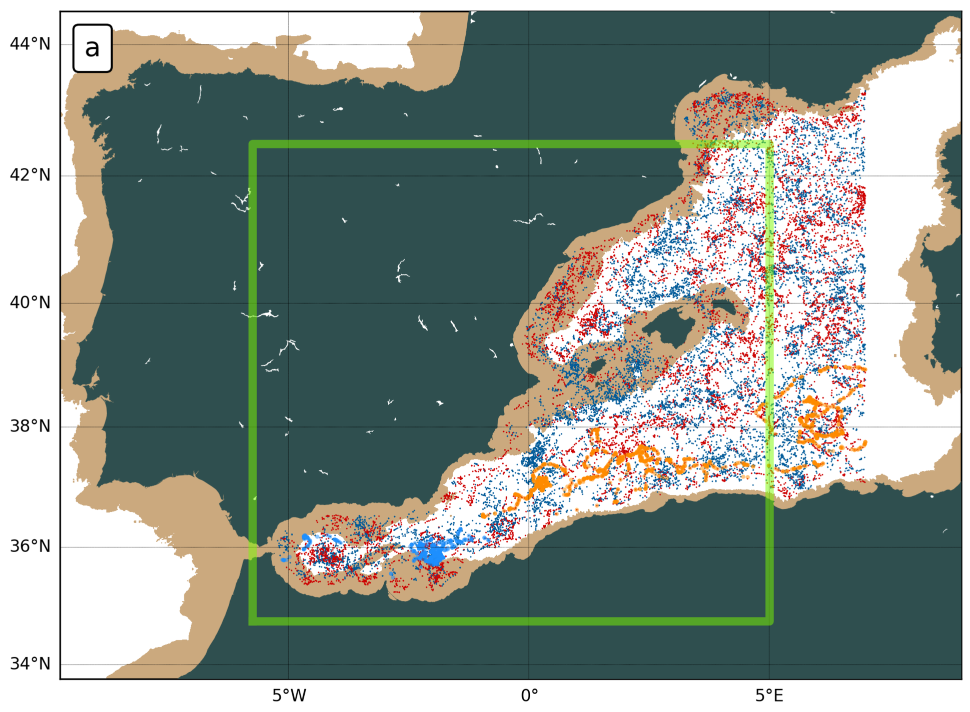

Figure 1: Eddy tracks from altimetry in the WMED study region between 2013-2016. Cyclones (anticyclones) in blue (red); long-lived examples (>1 year) in light blue (orange). Beige shading for bathymetry above 1000 m.

MedSub methodology

Numerical data from three CMEMS operational models:

- **IBI** Atlantic-Iberian Biscay Irish- Ocean Physics Analysis and Forecast (`IBI_ANALYSIS_FORECAST_PHYS_005_001_B`)
- **MFS** Mediterranean Sea Physics Analysis and Forecast (`MEDSEA_ANALYSIS_FORECAST_PHYS_006_001`)
- **GLO** Global Mercator 1/12° Physics Analysis and Forecast (`GLOBAL_ANALYSIS_FORECAST_PHY_001_024`)

***In situ* data** from glider+satellite experiments between Mallorca and the Algerian shelf during project *ABACUS* in the WMED between 2014-2015 (e.g., Cotroneo et al., 2016).

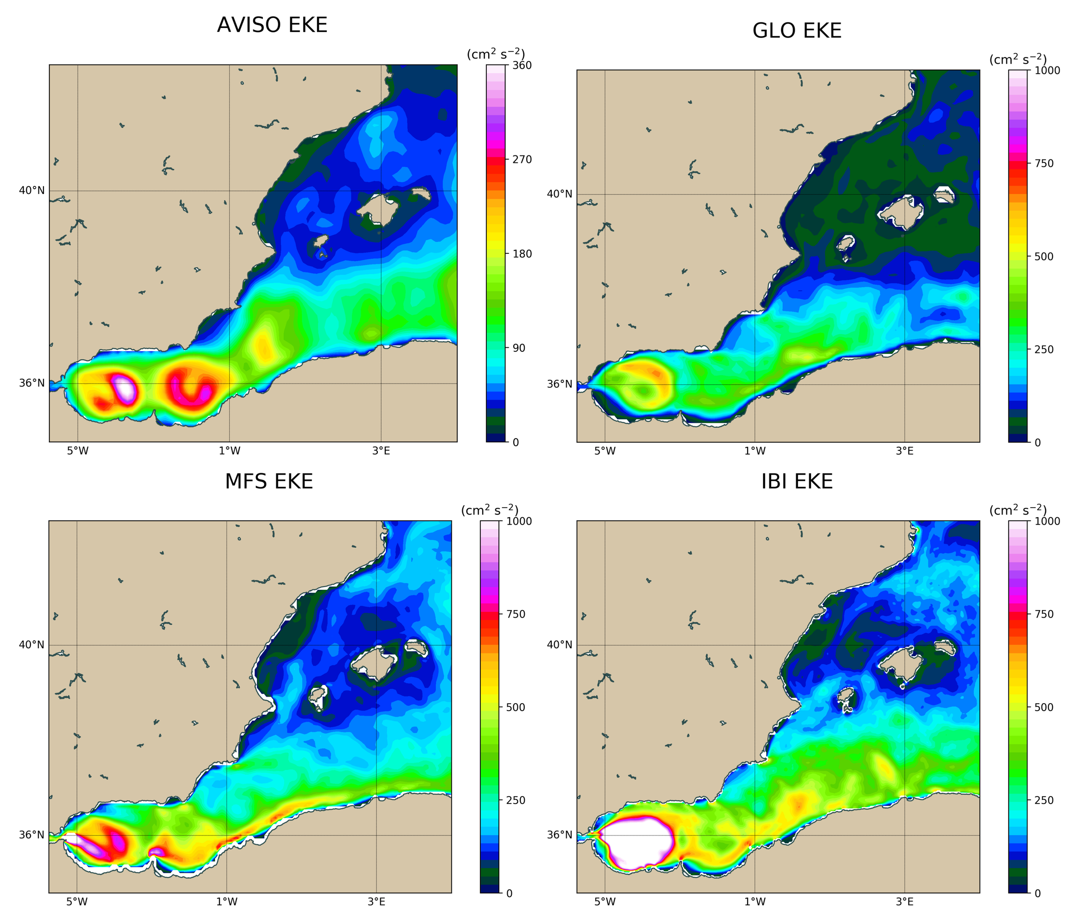

Figure 2: Maps of mean (2013-2016) WMED eddy kinetic energy from CMEMS altimetry and the three forecast models GLO, MFS and IBI. (The IBI domain ends at 5°E.)

Maps of eddy kinetic energy in figure 2 reveal the large and variable eddy energy distributions, especially in the southern WMED regions - motivation for a **subregional mesoscale eddy composite analysis intercomparison** (e.g., Mason et al., 2017).

Eddy identification and tracking: The *py-eddy-tracker* eddy tracking code provides four years of eddy tracks and properties using sea surface height (SSH) from daily Mediterranean CMEMS-AVISO altimetry (ALT), GLO, MFS and IBI (Mason et al., 2014).

MedSub results for the western Mediterranean

Eddy tracks: Regions of eddy dominance of both signs visible in cyclone and anticyclone eddy tracks from altimetry and the three models are evident across the WMED in figure 3.

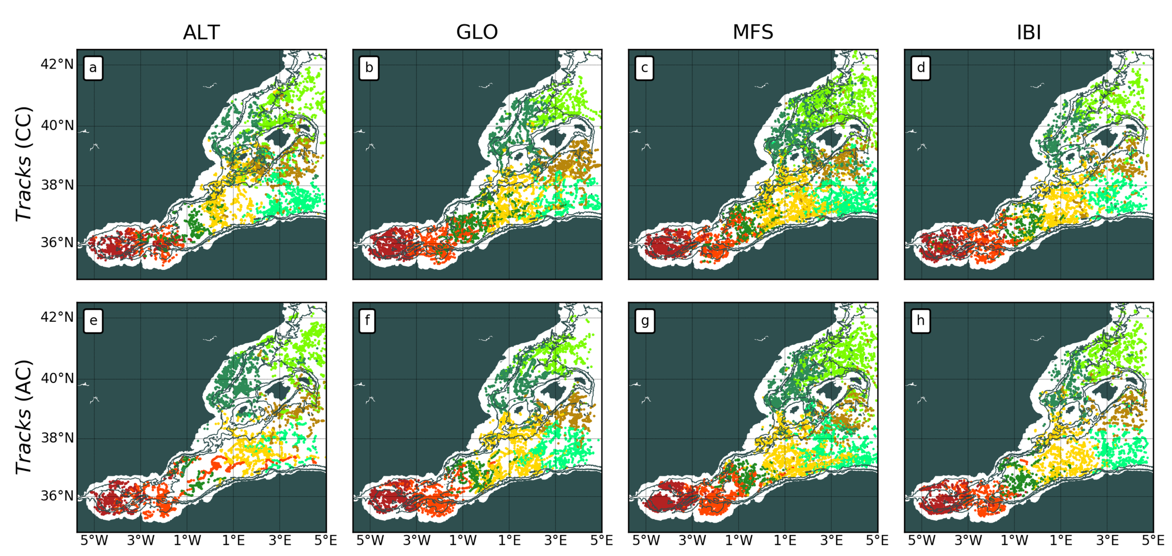

Figure 3: Eddy tracks for cyclones (top row) and anticyclones (bottom row) between 2013 and 2016 from (a) CMEMS-SLA, (b) GLO, (c) MFS, and (d) IBI. Colours are used to differentiate between several regions of eddy origin.

- Cyclone anticyclone asymmetry explained by preferential formation of eddies of both signs, dominance in eddy longevity, and/or conditions favoring preferred propagation pathways
- Note the long-lived tracks in ALT

MedSub results for the western Mediterranean

Eddy properties amplitude and radius: Hotspots in eddy amplitudes and radii in figure 4 for cyclones and anticyclones found in the Alboran gyres and along the Algerian coast. General dominance of anticyclones, although GLO shows equal weight between cyclones and anticyclones.

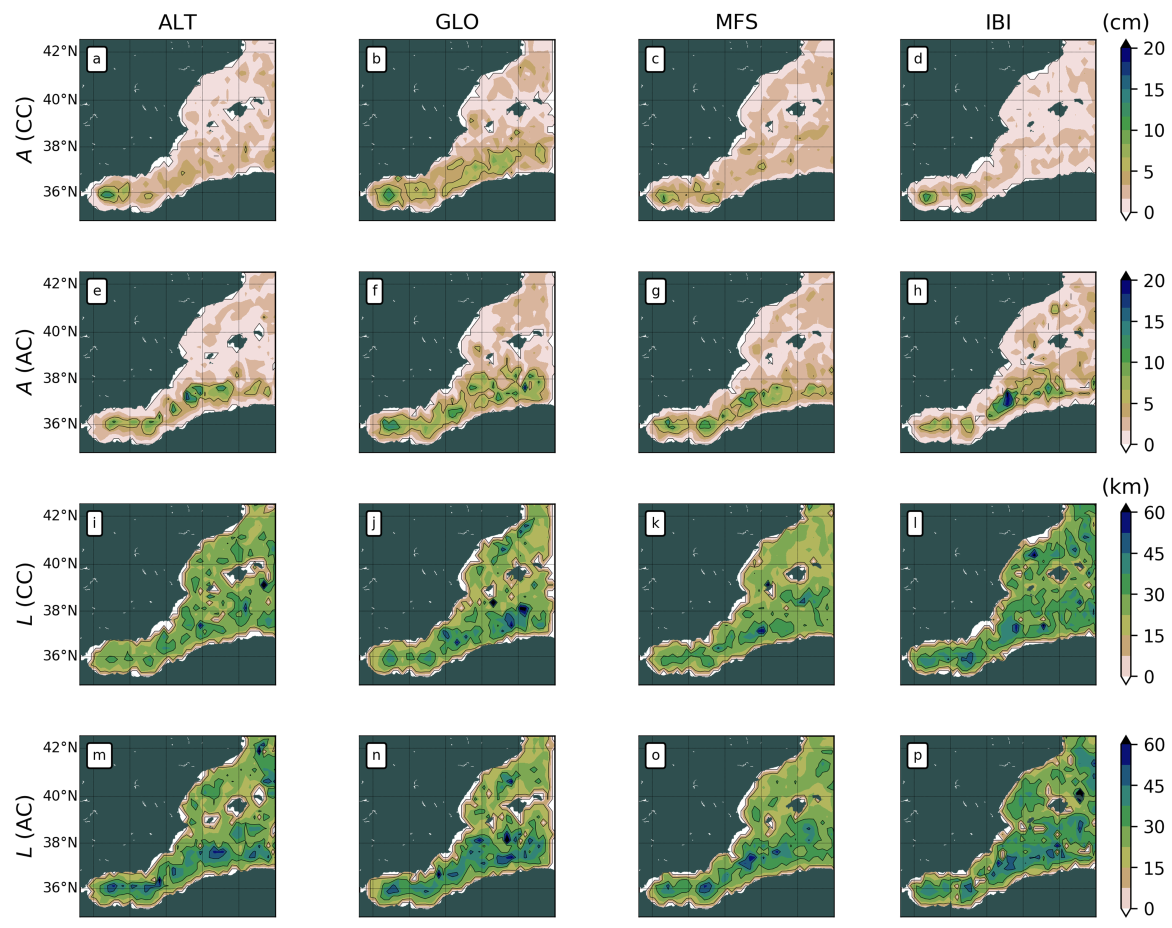

Figure 4: Maps of WMED mean eddy amplitudes for (left to right) CMEMS-SLA, GLO, MFS and IBI from the eddy tracker on a 0.5°×0.5° grid for anticyclones (first row) and cyclones (second row). Corresponding maps of eddy radii for anticyclones (third row) and cyclones (last row).

- Strong localised amplitude anomalies in IBI anticyclones southeast of Cartagena

Eddy properties nonlinearity and intensity: Eddy nonlinearity defined as ratio between eddy swirl speed and advection ($\frac{u}{c}$); eddy intensity is ratio between amplitude and radius.

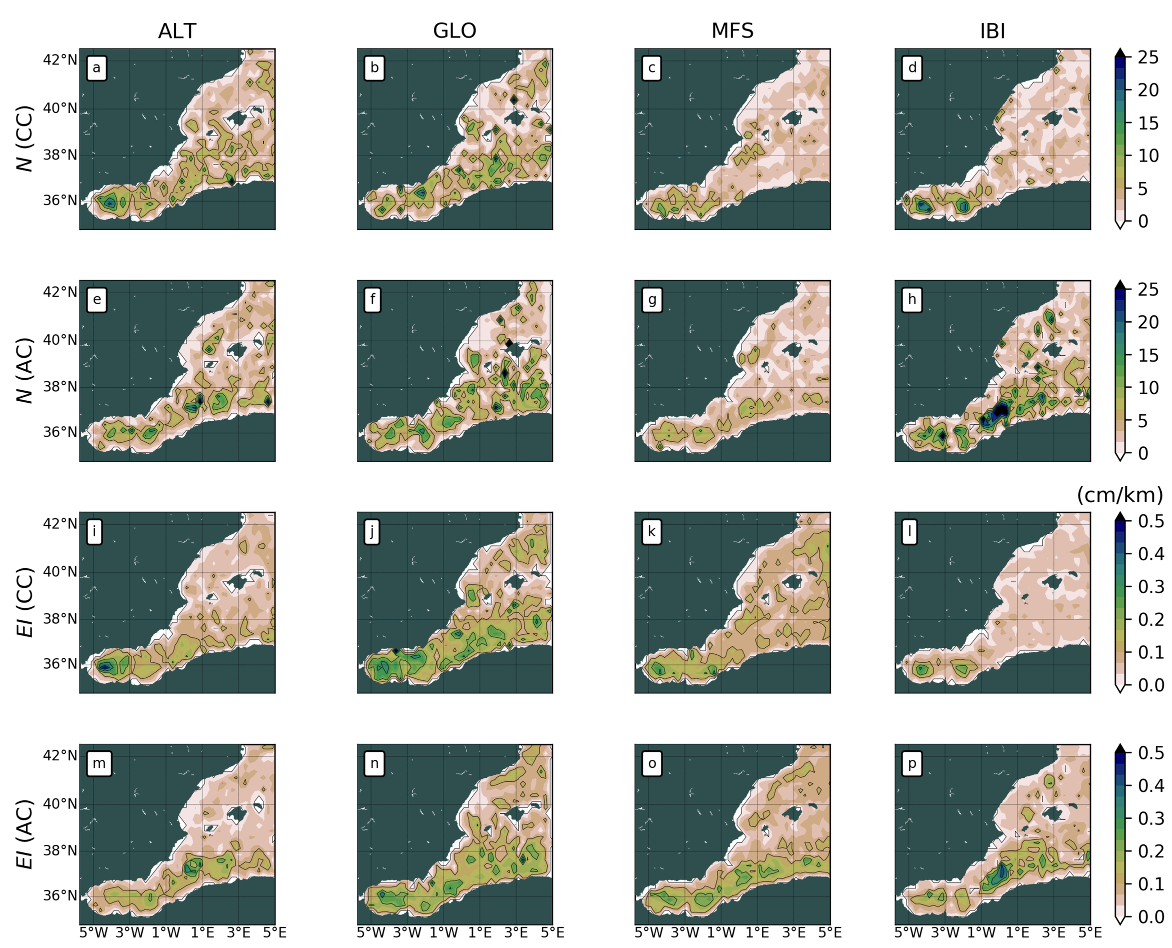

Figure 5: Maps of WMED mean eddy nonlinearity for (left to right) CMEMS-SLA, GLO, MFS and IBI from the eddy tracker on a 0.5°×0.5° grid for anticyclones (top row) and cyclones (bottom row). Corresponding maps of eddy intensity for anticyclones (third row) and cyclones (last row).

- GLO has generally larger values for both ratios

Eddy compositing: For a variable ϕ, composites are made by matching with eddy observations in time and space. Radial dimensions of each eddy instance are normalized by the eddy radius, allowing interpolation to a Cartesian grid (limits ± 4 at intervals $\Delta x = 0.2$). The collocated observations are temporally averaged to produce composites of ϕ for specified subregions and periods.

Eddy composites of ζ/f, S' and T' in the western Alboran gyre: Vertical sections in figures 6 and 7 distinguish between zonal and meridional views.

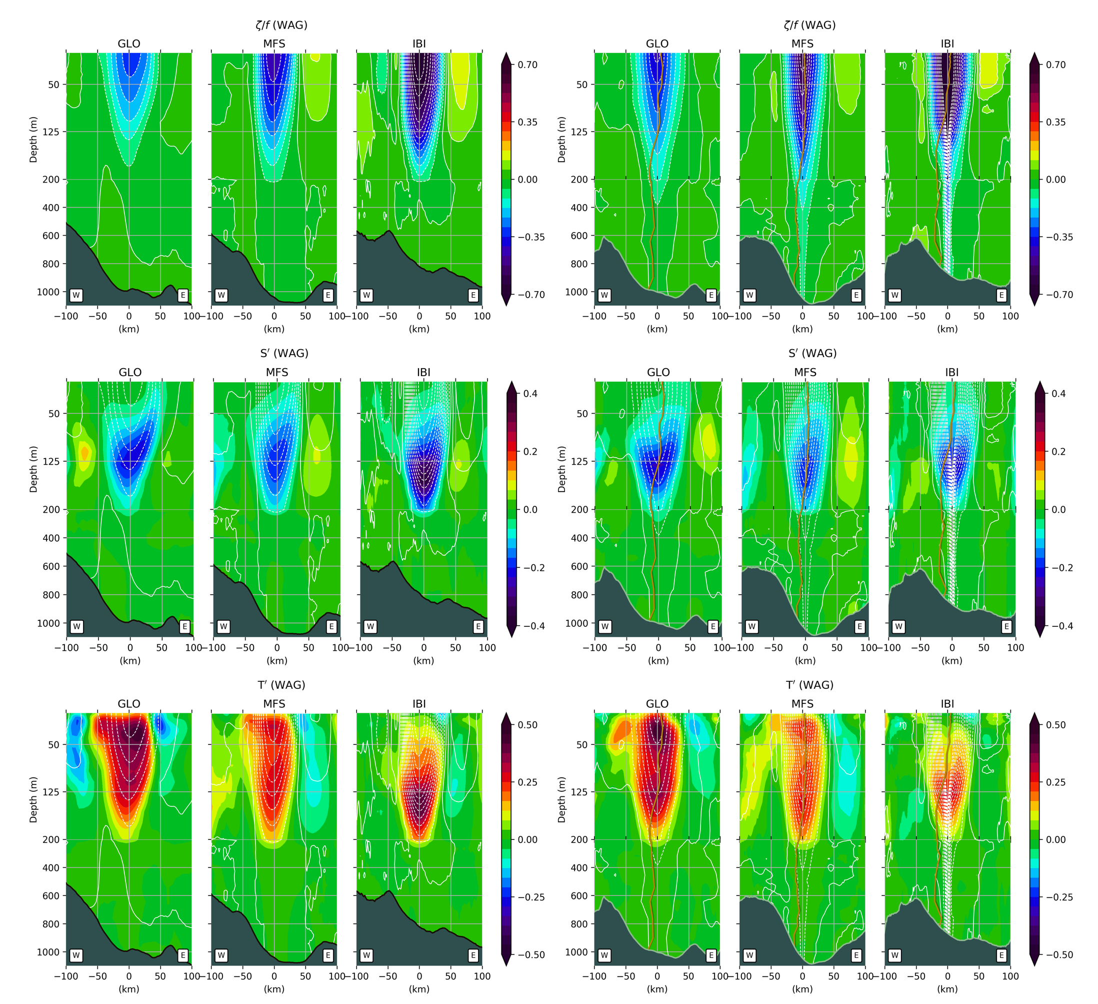

Figure 6: Zonal mean eddy-centric composite sections of ζ/f (top row), S' (middle row) and T' (bottom) for AC eddies in the western Alboran gyre from GLO, MFS and IBI. Left hand column sections without tilt correction; right hand columns corrected for tilt by aligning with the maximum of ζ/f at each level. Brown line indicates the magnitude of the eddy tilt correction. Horizontal axis scale in km.

- Close agreement in ζ/f and S' anomalies in figure 6. For T', GLO and MFS share a double warm core structure; IBI has only the lower core
- Tilt correction leads to stronger ζ/f, while S' and T' are slightly weakened

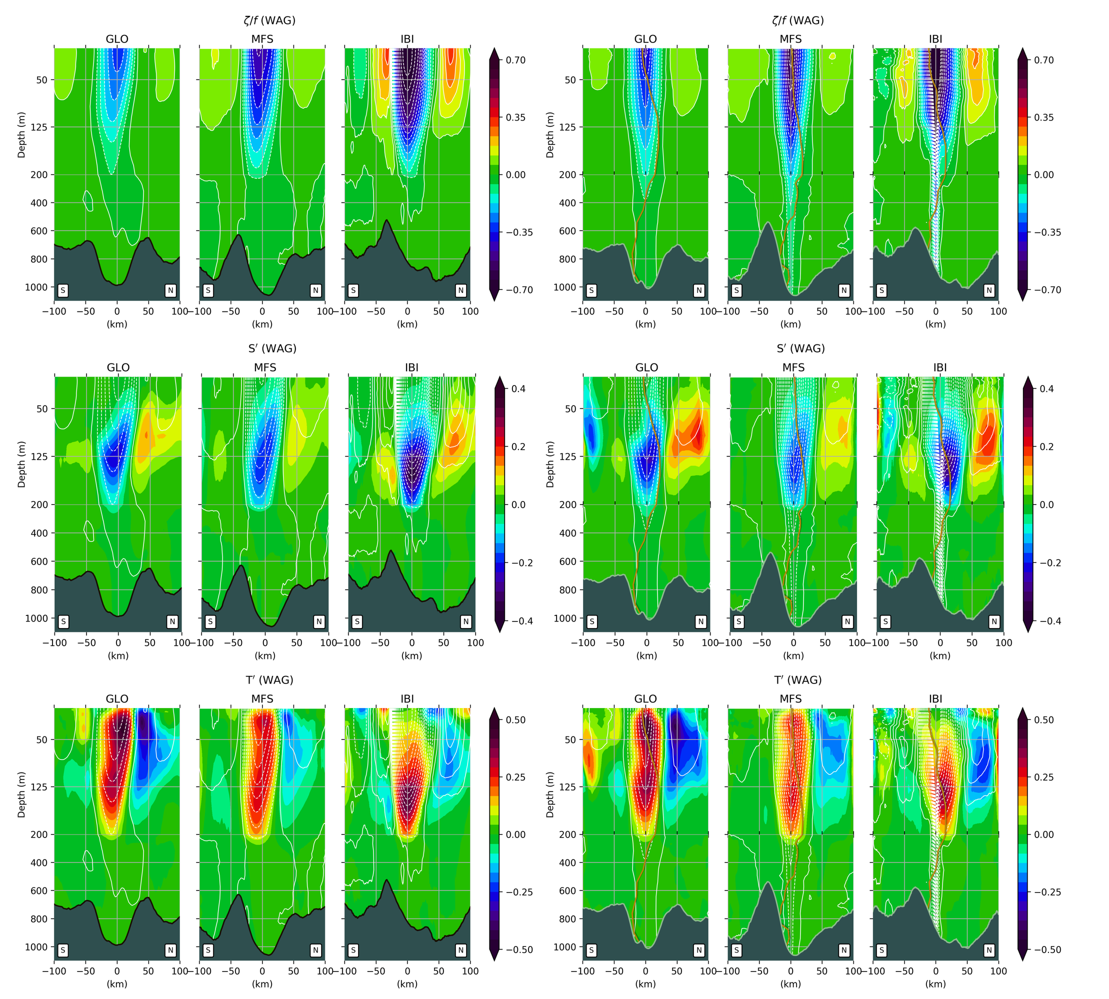

Figure 7: Same as figure 6 but in the meridional direction.

- Meridional views in figure 7 clearly reveal the competition between the Atlantic and Mediterranean water masses
- Clear correlations in vertical eddy structure between models revealed by eddy tilt correction

ABACUS multiplatform experiment

Model assessment based on particular events: As part of ABACUS, *in situ* data were collected during four glider missions carried out in 2014 and 2015 in the Algerian Basin along altimetry tracks (from Aulicino et al., 2017 under revision).

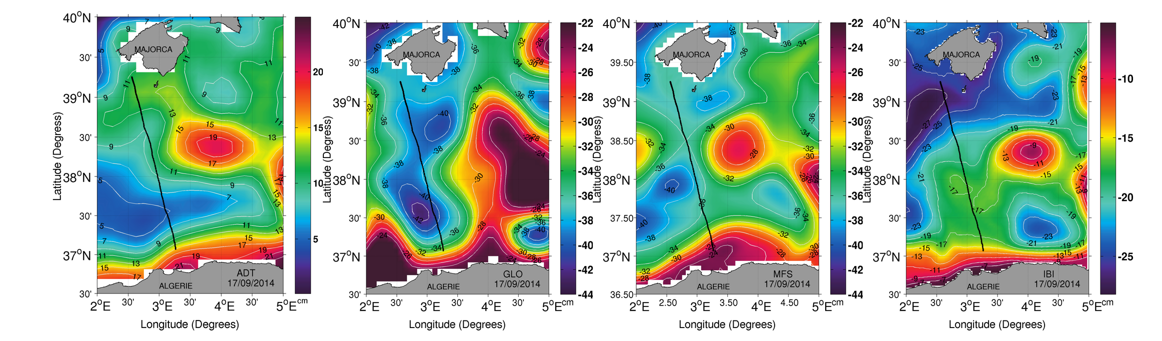

Figure 8: Maps of ADT on 17/09/2014 from (a) CMEMS-AVISO (altimetry), (b) GLO, (c) MFS and (d) IBI. Black lines shows a contemporaneous glider track.

- MFS gives generally best fitting results compared to altimetry
- Anticyclonic eddy at 38.5°N identified by MFS and IBI
- MFS RMS averaged over the four missions in figure 4 are smallest (table 1)
- For individual missions however MFS RMS smallest only in Nov and Dec 2014
- During Sep 2014 and Oct 2015 both GLO (1.06 and 2.61 cm) and IBI (1.97 and 3.15 cm) better fit the glider derived information than MFS (2.95 and 4.33 cm)

Table 1: CMEMS model products used in the ABACUS experiment. RMS of the differences between SSH from CMEMS models and dynamic height (reference level 900 m) computed from independent (not assimilated) CTD glider data from figure 8.

Model	Spatial resolution [deg]	Assimilation	RMS of SSH (model-glider) [cm]			
			Sep 2014	Nov 2014	Dec 2014	Oct 2015
MFS	1/16	Yes	2.95	2.52	2.19	4.33
IBI	1/36	No	1.97	3.02	4.11	3.15
GLO	1/12	Yes	106	2.56	3.34	2.61

Conclusions

- Through MedSub we are exploring new approaches to assessment of the mesoscale content of CMEMS operational models
- The automated eddy tracker is one example of a promising analysis tool
- Eddy tracking and compositing will benefit CMEMS operational services by enriching the CMEMS product menu with additional properties associated with the 2D circulation
- Multiplatform experiments also provide complementary approaches to model assessment

References

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Acknowledgments

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