Anticyclonic eddy energy and pathways in the Algerian Basin (1993-2014)

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1- Motivations and objectives

The Algero-Provençal basin plays a key role in the circulation of the entire Mediterranean Sea and in the past its hydrodynamics has been intensively studied with infrared, altimetry and colour satellite imagery, moorings, surface drifters and in situ data. The basin is divided into two sub-basins by the North Balearic front, a thermal front characterized by high seasonal variability: the Provençal sub-basin in the north and the Algerian sub-basin in the south.

The Algerian basin is one of the most energetic areas of the Mediterranean Sea and is dominated by mesoscale phenomena, especially anti-cyclonic eddies. The Algerian Current, mainly constituted by Atlantic water flowing on the surface in the Mediterranean Sea, becomes unstable and meanders, often giving rise to mesoscale eddies of both signs[1]. Anti-cyclonic eddies can grow rapidly in horizontal and vertical extension. They can also separate from the Algerian slope and circulate for several months within the basin, while cyclonic ones tend to disappear quickly[2]. In spite of the current body of research, a study on the tracking, energy and interaction of these eddies in time and space is still lacking. In order to better explain their behaviour, we apply an automated eddy detection and tracking method, which reveals the complex movements and the dynamics of eddies and allows dividing the basin in formation, detaching and transition zones.

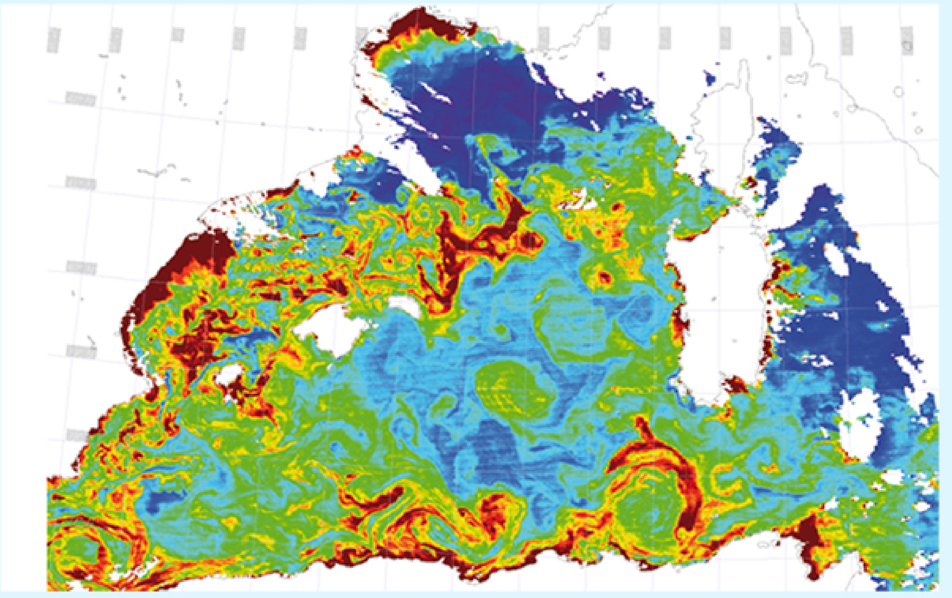


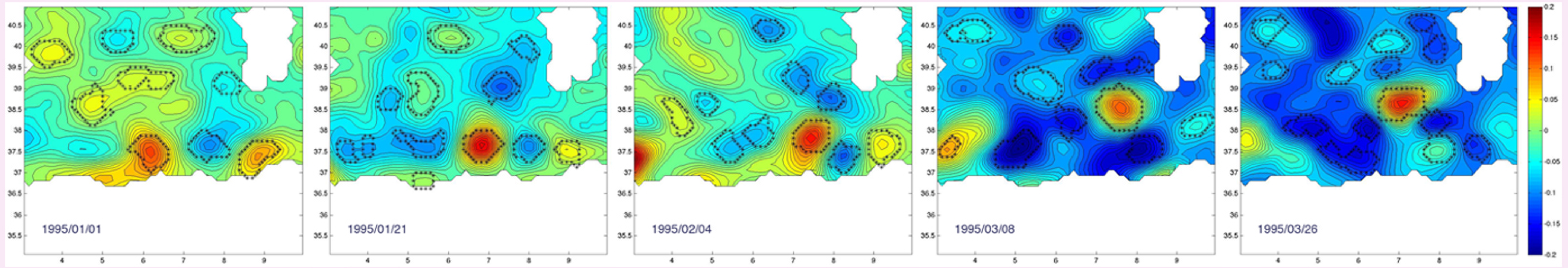
Image is Ocean Color (Chl-a product) level 2 single swath from AQUA MODIS for March 8th, 2013.

2 - Materials and methods

The algorithm we used was created by Penven[3]. It combines the detection of the largest closed contours in Sea Level Anomaly (SLA) with a positive value of the relevant Okubo-Weiss parameter, which allows the separation of the flow in two regions, one vorticity-dominated and one deformation-dominated respectively. After detection, the algorithm uses a generalized distance between eddies belonging to consecutive time steps to track their pathways. This generalized distance takes into account the differences in latitude, longitude, radius, vorticity, mean height and amplitude.

Below is an example of five different temporal steps of eddy detection. Black closed contours in the figures refer to the Okubo-Weiss parameter. A comparison with satellite images of SST proves that this kind of method is accurate in detecting eddies in the basin.

The basin has been divided by a regular grid to better study the statistics of each area.



3 - Results and conclusions

After analysing 22 years of SLA data (1993-2014) with the Penven method, we found several kinds of eddies, with different properties and behaviours.

In general, in the southern part of the Algerian basin eddies have a greater Eddy Kinetic Energy (EKE) and usually a longer lifetime than in the northern part.

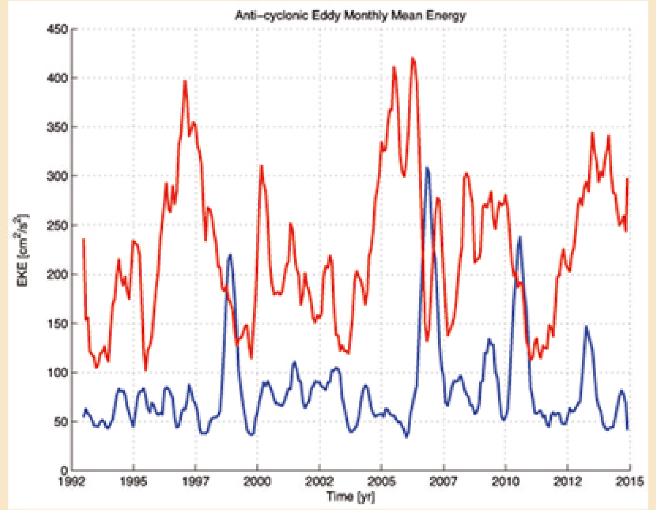
This method permits the identification of several different areas within the basin: formation, detachment and transition areas, where eddies respectively arise from baroclinic instabilities, detach from the coast to the open sea and move along particular pathways.

We found four different types of eddies, two with a long life span (lifetime greater than 100 days) and two with a short life (lifetime less than 100 days).

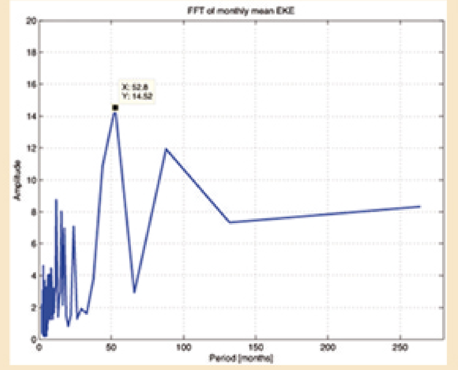
The long-life eddies arise in the southern part, mainly in sector D and M (blue bars), and we refer to them as Algerian Anti-cyclonic Eddies (AAEs) and Sardinian Anti-cyclonic Eddies (SAEs). None died in the same sector where they formed (dark red bar) and in general not many eddies (40% for M sector) die there (green bar). Rather, they tend to move cyclonically in the basin and to follow the same pathway.

The two short-life span eddies arise mainly in sectors E and P (blue bars). They usually end their life in the same sector where they have formed (dark red bar, 70% for E and 60% for P). This implies that these kinds of eddies don't move around the basin. We refer to them as Balearic Anti-cyclonic Eddies (BAEs) and Frontal Anti-cyclonic Eddies (FAEs) respectively.

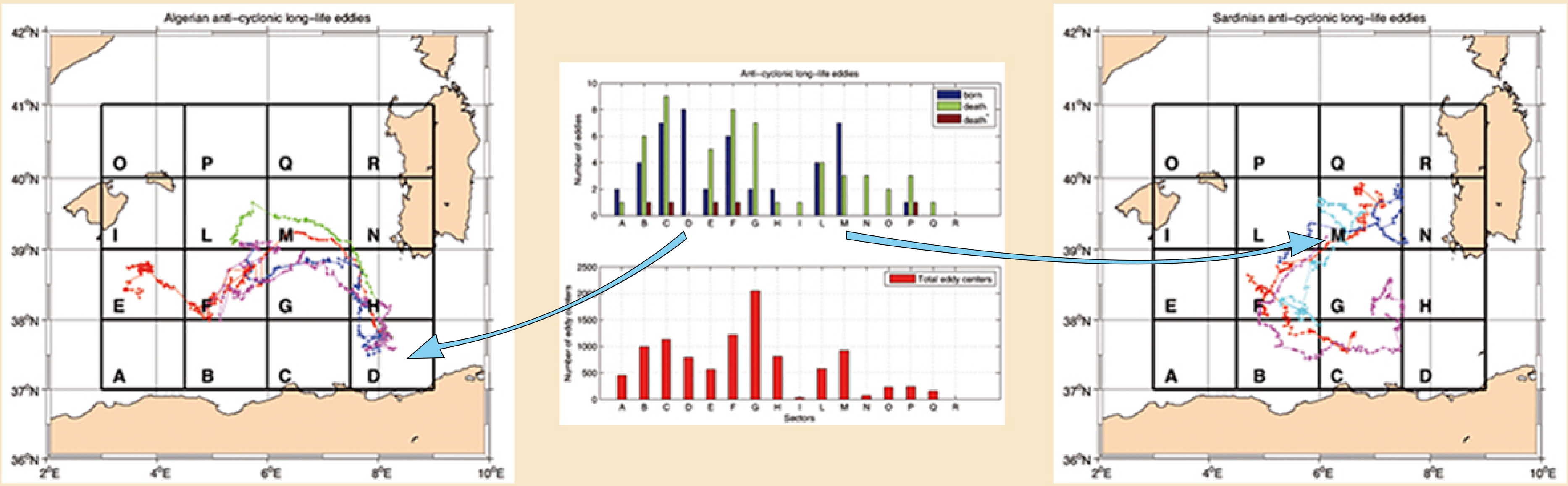
Despite the small size of the basin, these long-life and these short-life eddies don't interact with each other.

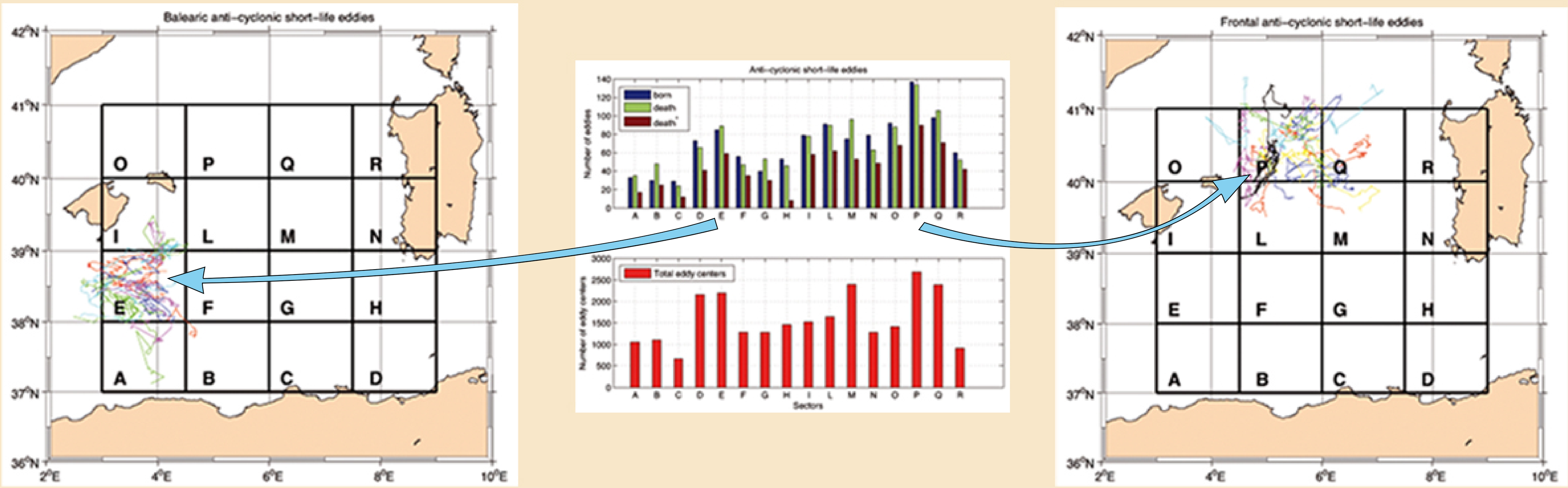


The figure shows the monthly mean EKE for the entire period. The southern part of the Algerian basin (37° - 39° N) is shown in red and the northern part (39° - 42° N) in blue. Eddies born south of the latitude of 39° N are more energetic then the others.



The Fourier Transform analysis shows a peak frequency of 52 months (about 4.4 years).





The upper panel shows long-life eddies awhile the lower panel shows short-life eddies.
Blue, green and dark red bars refer to formation and death.
Red histograms present the distribution of the total number of eddy centres in each sector.

References

1 Millot, C. (1999). Circulation in the western Mediterranean Sea. J Mar Syst.
2 Fuda, J. L., Millot, C., Taupier-Letage, I., and U. Send, J. M. B. (2000). Xbt monitoring of a meridian section across the western Mediterranean Sea. Deep-Sea Research I.
3 Penven, P. and Echevin, V. (2005). Average circulation, seasonal cycle, and mesoscale dynamics of the Peru Current system: A modeling approach. Journal of Geophysical Research.

Acknowledgements
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