The salinity signature of Agulhas mesoscale eddies

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Mesoscale eddies can transport salinity and temperature. They are in this way an important feature of the general circulation. The Agulhas rings are eddies allowing the transport of these properties from the Indian ocean to the Atlantic ocean. Here we use SMOS/SMAP Sea Surface Salinity data to try to characterise the salinity structures of those eddies, in order to understand the transport modality of salinity and its importance in the general oceanic circulation.

The oceanic circulation is composed of the surface circulation, forced by the winds, and the thermohaline circulation, forced by density gradients [Geistdoerfer 2002]. The thermohaline circulation allows to link the superficial circulation and the deep layers of the ocean [Rintoul 2018]. It is therefore important for the ventilation and for the climate.

The Agulhas current and the sub-tropical front are two key areas of this thermohaline circulation. They connect the Indian ocean and the Atlantic ocean. The Agulhas current is an intense and instable current forced by the winds. It closes the sub-tropical gyre of the South Indian ocean. It transports water masses from the Indian ocean to the South of Africa and then retroflexes along the tip of Africa. During this retroflexion, it sheds large eddies, the Agulhas rings, that are released into the Atlantic ocean. They transport warm and saline waters from the Indian ocean, ensuring the inter-basin transport towards the Atlantic ocean [Beal et al. 2011].

Eddies plays an important role in the general oceanic circulation. Indeed they have an impact on Sea Surface Temperature (SST), Sea Surface Salinity (SSS), and Sea Surface Height (SSH) [Melnichenko et al. 2016]. While they are moving, eddies can transport physical properties of sea water, such as temperature and salinity. There are two processes of transport : by trapping a water mass in the core of the eddy. The eddy will show a coherent monopolar structure, i.e it will show a unique SST/SSS anomaly. The other modality of transort is by stirring. The velocity field of the eddy will advect the surrounding gradients of SST/SSS, creating two anomalies of opposite signs. These anomalies are situated at the eddy's edges. This structure is called a dipolar structure (see figure 1).

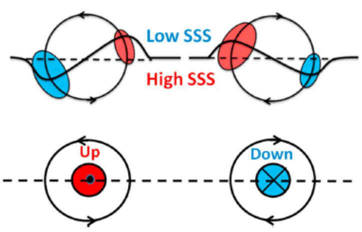


Figure 1 – horizontal and vertical advection of salinity gradients, by anticyclonic (left) and cyclonic (right) eddies.(from Delcroix et al. 2018)

In this study we use the SMOS/SMAP SSS data to characterize the salinity structure of the mesoscale circulation. We focused on mesoscale eddies, i.e eddy with synoptic scales (50-200 km).

The first objective was to colocalize the eddies detected via the "Mesoscale eddies trajectory Atlas", provided by SSALTO/DUACS, with the SSS and SSH data sets, from SMOS/SMAP and Aviso respectively. From the longitude, latitude and radius of the eddy given by the atlas, we computed an ellipse to indicate the eddy on the SSS and SSH fields (see figure 2). Once the three data sets coordinated, we were able to track an eddy from its detection until its disparition, with a time step of one week. We focused on the eddies from 2016, the first year with data from SMOS available for the whole year.

We then wanted to calculate SSS anomalies, to be able to characterise the salinity structure of eddies. The SMOS data are composed of several fields. The ISAS field is a field of in-situ data for the correction of large scale bias. We also used the OI2 field, a field interpolated two times with the method of Optimal Interpolation. The anomalies were computed by substracting the ISAS field to the OI2 field. We also computed mensual standard deviation maps to observe the inter-annual variability of SSS.

In the purpose of creating composites, an average of the salinity on the lifespan of the eddy, we needed the maximums of salinty at each time step to be superposed. After normalizing the salinity by the standard deviation, we performed a rotation followed by an interpolation (Optimal Interpolation), to be able to average the salinity. Before realizing the composites, we selected the eddies according to the following criteria : the eddies are not too deformed, they don't split or merge during their lifetime and they are coherent enough. We also classified them into different categories : anticyclonic or cyclonic, monopolar or dipolar structure in salinity, positive or negative anomaly for the monopolar eddies. We finally computed the composites for each eddy and also for each category of eddies.

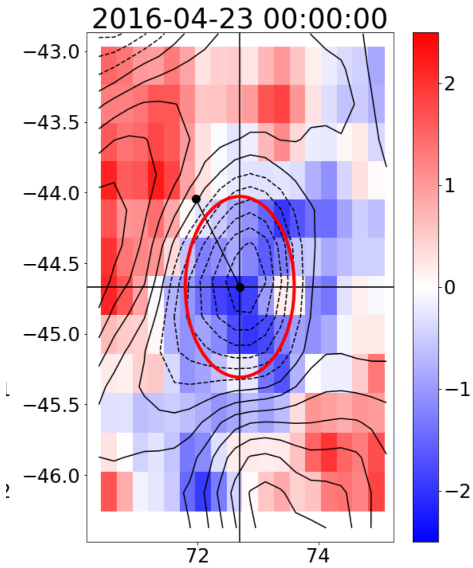
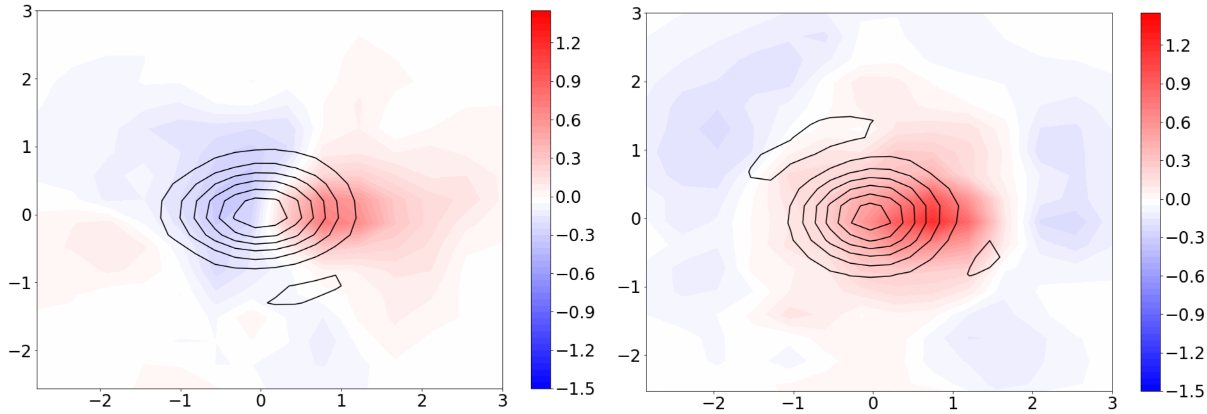


FIGURE 2 – Example of an eddy colocalization. The ellipse is defined from the Atlas and the SSH contours and the salinity fields are from altimetry and SMOS data.

We focused on two areas : the sub-tropical front, around 45°S, and the Agulhas current, south from the coast of Africa. We first traced the eddies trajectories for the two areas, separating the cyclonic eddies from the anticyclonic eddies. We found about the same proportions of cyclonic eddies than antiyclonic eddies for the two areas.

We found that the salinity structure of the eddies can either be monopolar or dipolar. A monopolar eddy in salinity will prensent only one anomaly of salinity (positive or negative) , usually centered on its core. A dipolar eddy in salinity will show two anomalies of salinity, one positive and one negative. Those anomalies will rotate around the eddy's core (see figure 3).



(a) dipolar composite

(b) monopolar composite

FIGURE 3 – Anticyclonic composites of the Agulhas current

We computed the general composites for each categories of eddies. We found that the anticyclonic eddies in the Agulhas current show almost the same proportions of monopolar and dipolar structures in salinity, while in the subtropical front they have exactly the same proportions. For both areas, the cyclonic eddies on the other hand, show always more dipolar sturctures than monopolar ones. We also see that for the monopolar structures in salinity, the anomaly is more often negative than positive (see table 1).

We see that sometimes the anomalies are not centered on the eddy's core. It's due to the fact that the eddies detected by the atlas are not always perfectly round and/or that their SSH signature is not coherent enough during all their lifespan. The algorithm sometimes also detects eddies that merge or split. We can improve this aspect by performing a better selection on the time frame in which we compute the composites. We can also use an algorithm detecting the splitting/merging of the eddies, like the one in LAXENAIRE et AL. 2018, to resolve these problems.

With this study, we have been able to characterise the salinity structure of mesoscale eddies from SMOS/SMAP data. We found that these structures can either be monopolar, with one anomalie in the eddy's core, or dipolar, with two rotating anomalies on the eddy's edge. These structures reflects the modality of transport of SSS by eddies.

Knowing the structure of eddies is important because they play a role in the transport of salinity anomalies. This transport is associated with heat and fresh water fluxes, and is hence important to understand the general circulation and its impact on the climate.

We could go further by performing the same analysis on the temperature structures of eddies, to observe potential similarities with the salinity structures.

	Agulhas current					Front				
total nb of eddies	464					761				
nb of resolved eddies	295					555				
	ac		c			ac		c		
nb of eddies	145		150			277		278		
nb of coherent eddies	41		42			48		55		
	m	d	m+	m-	d	m	d	m+	m-	d
nb of eddies (%)	46.7	53.3	10.0	20.0	70.0	50.0	50.0	10.9	30.9	58.2

Table 1 – Overview table of the numbers of anticyclonic (ac) and cyclonic (c) eddies and of the numbers of monopolar (m) and dipolar (d) structures in salinity for the two areas .

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