

Why are there more submesoscale anticyclones than cyclones in the interior ocean?

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Location : IUEM and/or UCLA (Los Angeles, California)

Introduction: Submesoscale oceanic currents arise in the worldwide ocean in the form of density fronts and filaments, coherent vortices, and topographic waves (McWilliams, 2016). They are found at spatial scales below the first Rossby deformation radius, 0.1-10 km, and they last from hours to days. A particular type of submesoscale structures are submesoscale coherent vortices (SCVs). They are long-lived energetic eddies with a radius smaller than the Rossby deformation radius and a structure localized in the vertical (McWilliams, 1985). Their velocity field usually has a subsurface maximum and the azimuthal circulation is in geostrophic or gradient-wind balance with a monopolar geopotential field. SCVs can form from convection, wind blowing over over fronts or boundary currents undergoing flow separation that adjust into submesoscale or mesoscale balanced flows (McWilliams, 1985; D’Asaro, 1988; Molemaker et al., 2015; Gula et al., 2016; Bosse et al., 2016).

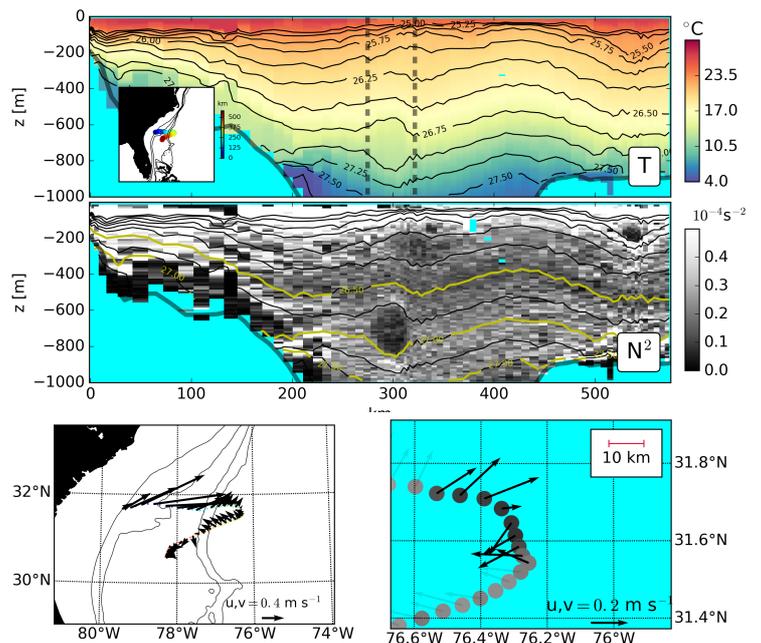


Figure 1: Generation of an anticyclonic SCV in the lee of the Charleston Bump observed in a glider section. The SCV is visible as a lens of well-mixed water. [from Gula et al. 18]

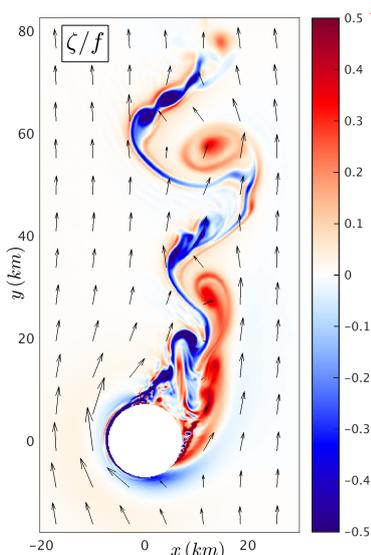


Figure 2: Generation of vorticity in the lee of a seamount [from Srinivasan et al., 18].

SCVs can be very long-lived (> 1 year) and travel far away from their origin, being primarily advected by mesoscale and mean currents. As SCVs retain much of their core water mass during their life, they can generate long-range anomalous transport of water properties. The cumulative effect of SCVs can potentially affect the large scale transport and distribution of heat, nutrients and other materials.

Historical observations of SCVs provide glimpses of the ocean interior richness, and suggest that it is populated by a large number of deep submesoscale structures, but the ocean is still largely undersampled and observational data remains limited. Furthermore, global or basin-scale models do not usually have a resolution sufficient to resolve submesoscale processes. Thus, we still do not have a quantitative assessment of the numbers and impact of SCVs for the ocean circulation.

However all the observations show a larger number of anticyclonic SCVs than cyclonic SCVs, but the reason why anticyclones dominate over cyclones is still an unresolved issue (McWilliams,

16). We do not know if it is related to an asymmetry of the generation processes or to different stability properties of the SCVs after their formation. Quasi-geostrophic theory does not predict any asymmetry between cyclones and anticyclones related to the generation process, nor their stability. The main generation process for SCVs in the interior seems to be boundary-slope vorticity generation, separation, and wake instability. An example showing generation of vorticity and vortices formation in a lee of a seamount is shown Fig.2. The generation of vorticity is symmetric in this case and does not explain the dominance of anticyclones.

Objective: The aim of this project is to provide the first census of anticyclonic and cyclonic SCVs in the North Atlantic Ocean. In particular, the objectives are to compute the ratio between cyclones and anticyclones in the different parts of the ocean, analyze its variations depending on the origin and formation mechanism of the SCVs, and see how it evolves depending on the age of the structures.

The main hypothesis, to be tested in this study, is that the asymmetry between cyclones and anticyclones is related to a bias toward prograde currents in the ocean interior, leading to a more likely generation of anticyclonic SCVs. Such process is supposedly symmetric for a seamount (Fig. 2), but it will generate preferentially cyclonic SCVs for a retrograde current (flowing with the coast on its left in the northern hemisphere, *Gula et al., 2015*) and anticyclonic SCVs for a prograde current (flowing with the coast on its right in the northern hemisphere, see Fig.3). As a result of the Neptune Effect (*Holloway, 87*), the vortex drag forcing is expected to force preferentially prograde currents on the slopes. So all this could explain the larger number of anticyclones in the ocean interior.

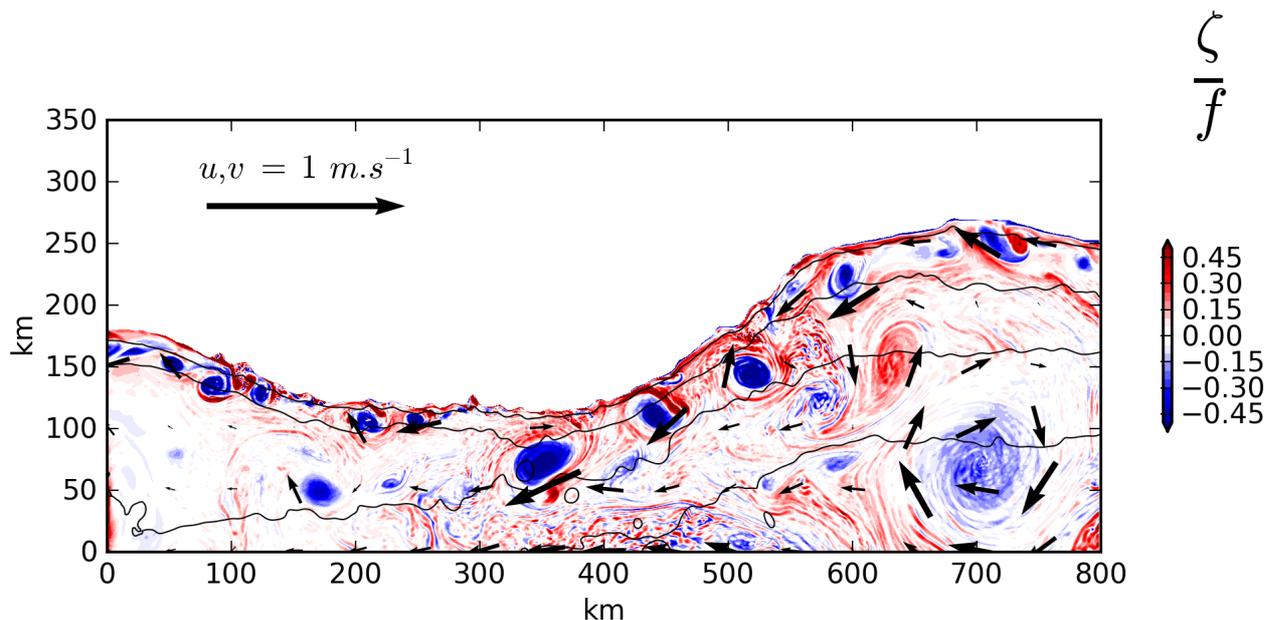


Figure 3: Generation of SCVs at 500 m depth along the Great Banks in the western North Atlantic subtropical gyre.

Methods: Realistic simulations of the North Atlantic ocean (other regions of the world will be available as well) at submesoscale permitting resolution ($dx = 1-2$ km) will be used. SCVs will be detected from model outputs using an adapted version of the eddy tracker code of Mason et al. (2014) following the methodology of Frenger et al. (2018). With this aim we will identify representative density surfaces embracing subsurface eddies, then we will identify anticyclonic (cyclonic) SCVs as positive (negative) anomalies of the density layer thickness. This method will be compared with the recently developed AMEDA eddy detection and tracking algorithm (Le Vu et al., 2018) applied to the detection of eddies in the Arabian Sea by Mathieu Morvan at LOPS.

Location: One part of the work will be done at LOPS, IUEM, Brest, France, under the supervision of Jonathan Gula and Xavier Carton and another part of the work will be done at the University of California, Los Angeles, USA, under the supervision of Jim McWilliams.

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