Scales and dynamics of submesoscale eddies in the North Atlantic Subpolar Gyre

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Location : IUEM and National Oceanographic Center (Southampton, UK)

Current IPCC projections of an AMOC slowdown in the 21st century based on climate models are attributed to the inhibition of deep convection in the North Atlantic. However, there has been no clear observational evidence of AMOC variability in response to changes in deep water formation. Motivated by the need for a mechanistic understanding of the AMOC, an international community has assembled an observing system, Overturning in the Subpolar North Atlantic (OSNAP), to provide a continuous record of the trans-basin fluxes of heat, mass and freshwater and to link that record to convective activity and water mass transformation at high latitudes (Figure 1; [Lozier et al.,

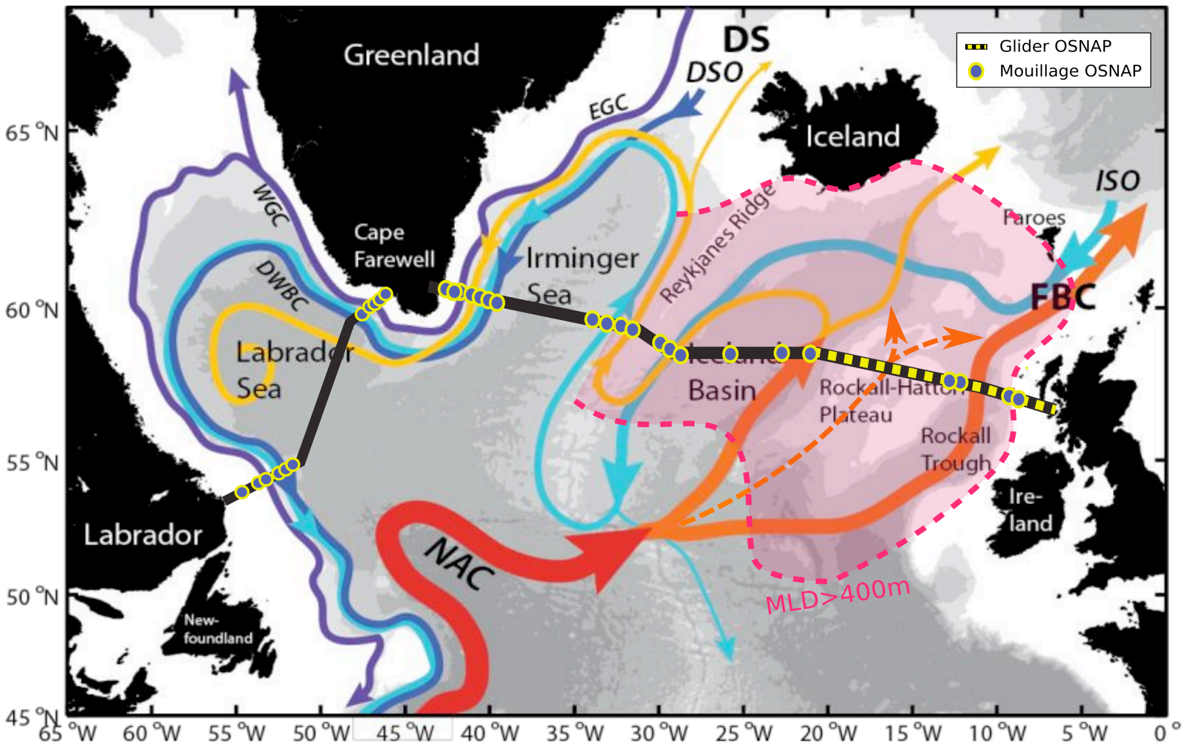


Figure 1: Main pathways of the warm (red to yellow) and cold (blue to purple) water masses in the North Atlantic subpolar gyre. The area of subpolar mode water (SPMW) formation is higlighted according to [Brambilla and Talley, 2008]. Locations of the OSNAP mooring and glider line are also shown. Acronyms: Denmark Strait (DS); Faroe Bank Channel (FBC); East and West Greenland Currents (EGC, WGC); North Atlantic Current (NAC); DSO (Denmark Straits Overflow); ISO (Iceland-Scotland Overflow)

2016]).

An accurate representation of the water masses resulting from overflows (ISOW, Iceland Scotland Overflow Water and DSOW, Denmark Straits Overflow Water) is particularly important to correctly represent the AMOC (vertical structure and distribution of heat transport), the deep convection zones, and provide reliable climate projections. This requires a good knowledge of the circulation associated with these water masses, especially coherent dense water eddies. These structures have a diameter of about ten kilometers [Krauss, 1996; Von Appen et al. 2014] and propagate with the basin-scale circulation. However, until very recently, few observational studies provide a fine description of the vertical structure and of the dynamic associated to these submesoscale eddies.

Submesoscale Coherent Vortices (SCVs) were initially described by McWilliams [1985]. SCVs are isolated and coherent circulation features characterized by small radius and extended lifetime (>1year). Their rotation sets transport barriers that drastically reduce the lateral exchanges between their core and the surrounding waters. They are therefore extremely efficient in transporting physical and biogeochemical tracers characteristics of their generation site over long distances, as observed in Lagrangian floats and mooring data [Lilly and Rhines, 2002]. In the recent years, glider studies provide for the first time very fine spatial and dynamic description of SCVs [Fan et al., 2013]. Due to their high number and their extended lifetime, SCVs can play an important part in the circulation and biogeochemical cycle of deep and intermediate water masses, as in the Northwestern Mediterranean Sea, where SCVs spread a significant amount (30%) of the newly-formed deep waters away from the winter mixing areas [Bosse et al., 2016].

The first part of this project will be dedicated to characterize the vertical structure and the dynamic of submesoscale eddies crossing the OSNAP and RREX mooring arrays located on the eastern flank of Cape Farewell, in the Icelandic Basin and over the Reykjanes Ridge (Figure 1). The OSNAP mooring array is originally designed to provide long-term time-series of large-scale transport in the subpolar gyre, and the aims of this project is to complement this approach by investigating the role of submesoscale eddies in the transport variability. Time-series will be analyzed to identify imprints of submesoscale eddies in the T-S field and in the currentmeter data following methods developed by Lilly and Rhines [2002], already used in the Northwestern Mediterranean Sea (Figure 2; [Bosse et al., 2016]). This analyze aims to document the vertical structure and characterize the dynamic parameters (radius, orbital speed, Rossby/Burger number) of the submesoscale eddies. The multi-year time series from the mooring arrays will be used to start establishing statistics on the presence of submesoscale eddies in different locations of the subpolar gyre. Given the limited number of moorings, careful consideration should be

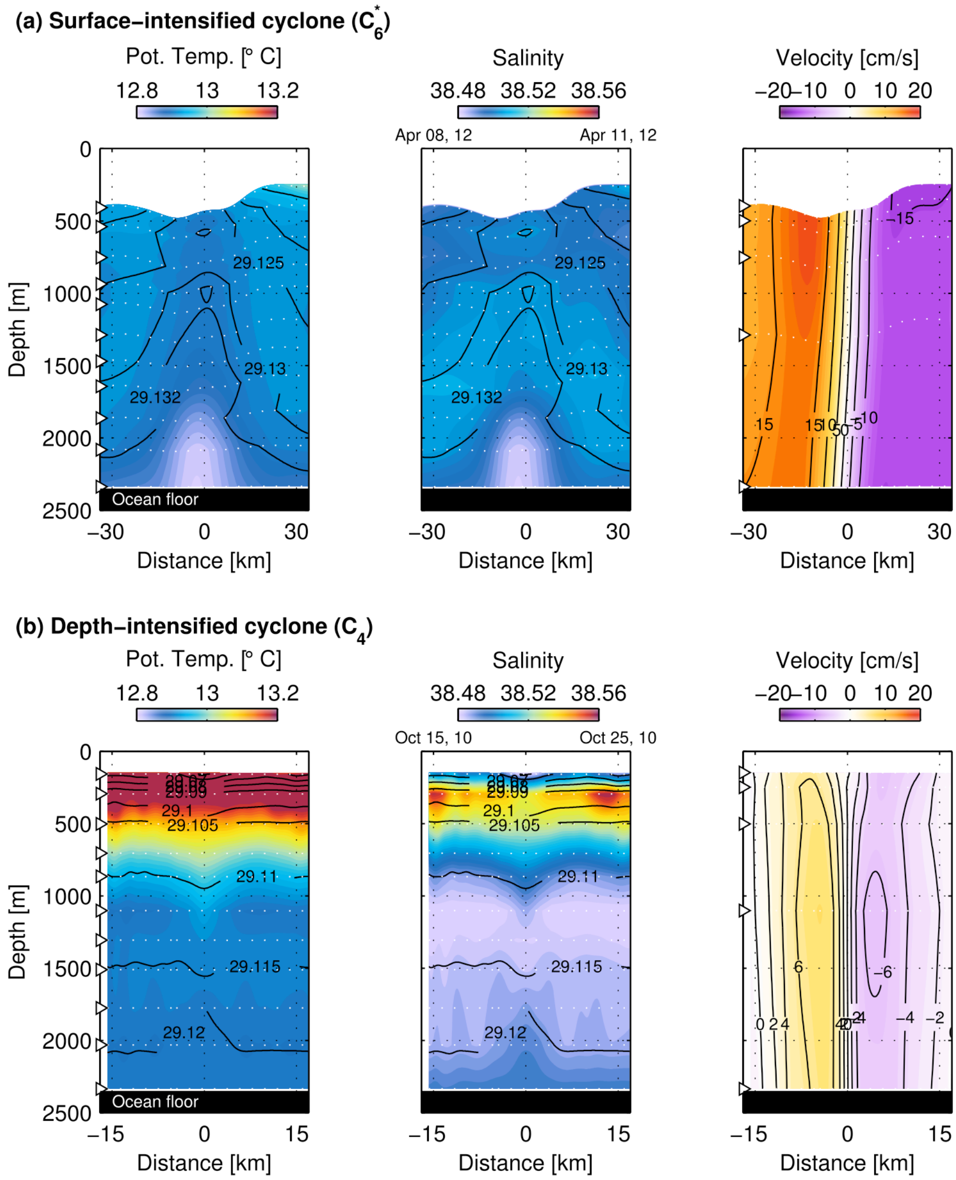


Figure 2: From figure 5 in [Bosse et al., 2016]: Two cyclonic eddies observed at the LION mooring line: (a) cyclone C6 observed in April 2012 exhibiting a core of Shelf Cascading Dense Waters located at the bottom; (b) depth-intensified cyclone C4 observed in October 2010 with a core located at great depth (>1000 m). For each eddy, the two left plots represent the potential temperature and salinity sections with isopycnals in black. The right plot shows the velocities perpendicular to the mean advection recorded by the current meters. The depth of the sensors is indicated by white triangles and dashed lines. The x axis represents the distance along the mean flow advection. Note that this advection is much

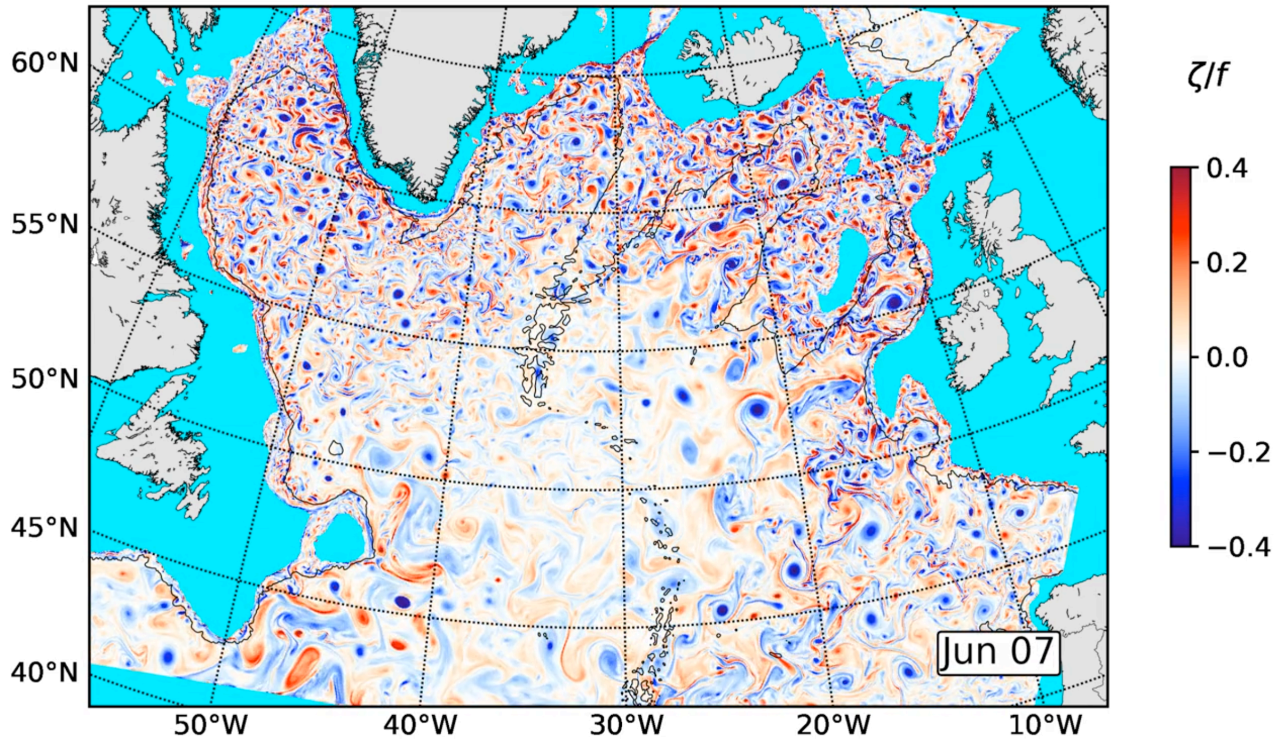
given to the estimation of error bars.

The second part of the project will compare the results obtained from in situ observations to high resolution simulations developed at LOPS.

A series of nested simulations with the model ROMS have been constructed in the subpolar gyre with successive horizontal grid nesting refinements from a parent grid resolution with resolution dx = 6 km including the full North Atlantic, to dx = 2 km for the subpolar gyre. Some animations of vorticity at different depths are visible here:

http://stockage.univ-brest.fr/~gula/Movies/polgyr_vrt_surface.mp4
http://stockage.univ-brest.fr/~gula/Movies/polgyr_vrt_500m.mp4
http://stockage.univ-brest.fr/~gula/Movies/polgyr_vrt_1000m.mp4

Statistics from in-situ observations will be used to validate results from the model. Model results will be used to characterize the significance of the data from in-situ observations and extrapolate results to the full domain. Model outputs will also allow to investigate the formation mechanisms and the fate of submesoscale eddies in the subpolar gyre. The joint analysis of in-situ observations and model outputs will allow to characterize the submesoscale eddies scales and dynamics in the subpolar gyre, and to assess their role in the transport of overflow waters. Finally this work will also help to design new observing experiments to better observe submesoscale variability.



One part of the work will be done at LOPS, IUEM, Brest, France, under the supervision Jonathan Gula and Xavier Carton and another part of the work will be done at the National Oceanogaphy Center, Southampton, UK, under the supervision of Loïc Houpert. The student might also interact with different members of the OSNAP and RREX community.

If interested or for more information, please contact jonathan.gula@univ-brest.fr

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