A first overview of the 53 year past hydrodynamical variability in the Bay of Biscay from a regional simulation

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Objectives

In the frame of the ENIGME project, we aim to describe and to analyze the past interannual variability over decadal to multi-decadal periods in the Bay of Biscay and the English Channel (41°N – 52.5°N / -15°W – 4°E). These investigations will allow identifying the capabilities and the limitation of our numerical approaches for an application in future *scenarii*.

Three main groups of processes are considered

- Interannual evolutions (haline and thermal budgets and currents),
- Shelf and slope current system and (sub)mesoscale dynamics,
- Sea level in regional models.

In the present study, first results from a long-term simulation are presented. The hydrological content and the circulation are described regards with *in situ* and remotely sensed data. The interannual evolution of the temperature and the salinity are also described.

Model experiment

Numerical simulation are performed using the Primitive Equation Ocean Model, MARS3D (Duhaut et al., 2008; Lazure and Dumas, 2008) in the BACH4000 configuration (without tide dynamics, Theetten *et al.*, 2014). The modelled spatial resolution is 4Km for 40 sigma vertical levels. The atmospheric forcings are based on the ECMWF reanalysis (ERA40 for the 1958-1978 period; ERAINTERIM for the 1979-2010 period). The open boundary conditions are based on the ORCA024-GRD100 DRAKKAR simulation (global, ¼° spatial resolution).

The simulation in the Bay of Biscay/English Channel (Figure 1) extends from 1rst January 1958 to the 31rst December 2010 with daily outputs (Theetten *et al.*, 2014 – poster n°B975).

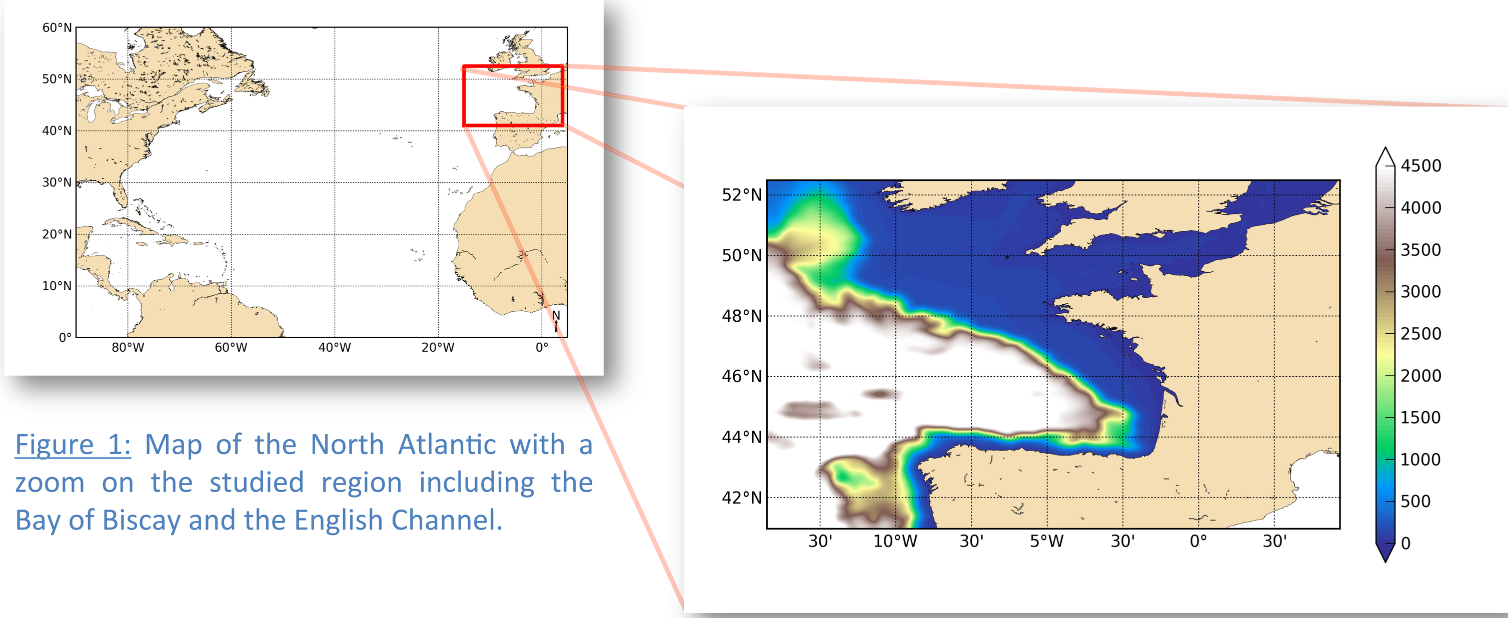

Figure 1: Map of the North Atlantic with a zoom on the studied region including the Bay of Biscay and the English Channel.

CORA-IBI – an *in situ* database in the Ireland-Biscay-Iberia region

A dataset has been aggregated over the Ireland-Biscay-Iberia (IBI) region (20°N – 60°N / 35°W – 12°W) for the period 1958-2012 (Szekely, 2014, pers. communication). This dataset is an extraction from CORA4.0 (Cabanes *et al.*, 2013) global dataset combined with the BOBYCLIM dataset (Vandermeirsch *et al.*, 2010).

The Figure 2 displays the number of vertical profiles during the whole period with the opening of the international databases (SeaDataNet, since 1990), the advent of the ARGO profilers in 2000's. We can also notice the impact of measurements of opportunity with the RECOPESCA project since 2007.

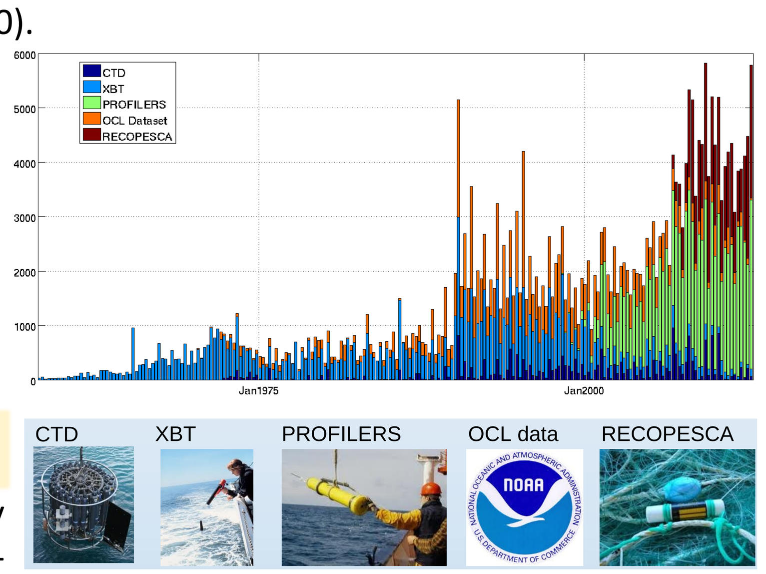

Figure 2: Number of vertical profiles by sources in the CORA-IBI database.

BOBYCLIM – a regional climatology

The BOBYCLIM interannual climatology (http://www.ifremer.fr/climatologie-gascogne/) and the associated dataset (Michel *et al.*, 2009a; Vandermeirsch *et al.*, 2010) are used as a reference to evaluate our simulations.

Remotely sensed Sea Surface Temperature

Sea Surface Temperature – SST: from SEVIRI (Spinning Enhanced Visible and InfraRed Imager) sensor, carried on the Meteosat Second Generation (MSG) platform, provided by OSI-SAF (Ocean and Sea Ice Satellite Application Facility) belong to EUMETSAT.

Available products extend from 60°S to 60°N and 60°W to 60°E and are produced hourly with a 0.05° spatial resolution from 2006.

Temperature and Salinity over 53 years

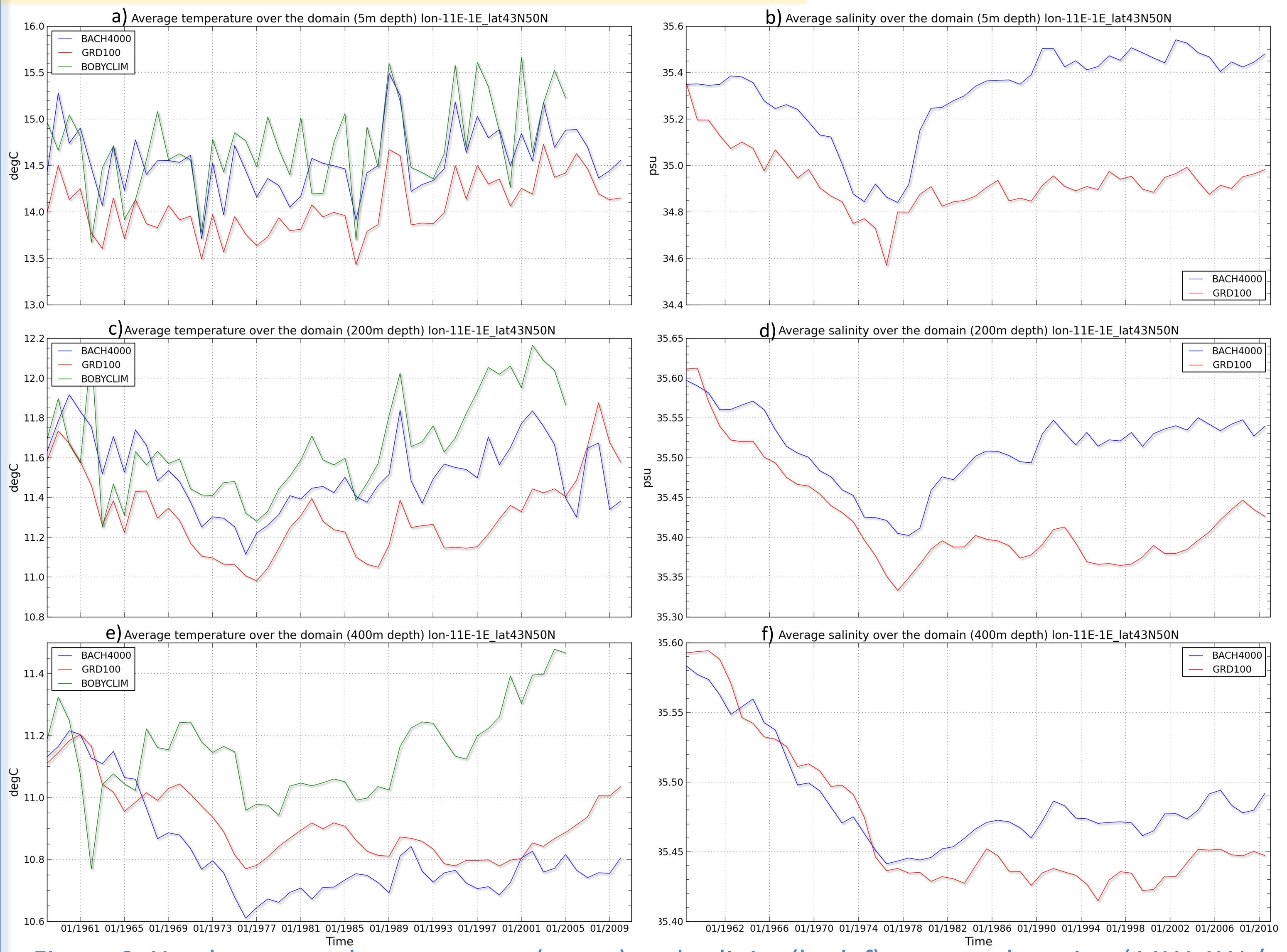

Figure 3: Yearly averaged temperature (a, c, e) and salinity (b, d, f) over a sub-region (11W-1W / 43N-50N) at 5m depth (a, b), 200m depth (c, d), and 400m depth (e, f) for the regional model (BACH4000), the global simulation (GRD100) and the regional interannual climatology (BOBYCLIM) for the temperature only.

The first overview of the interannual variability reproduced by our regional simulation gives promising results. Indeed, in temperature, at 5m depth (Figure 3a) and 200m depth (Figure 3c), we observe a good agreement between the climatology and our simulation. Furthermore, the regional simulation is closer to the observations than the global results, suggesting a contribution of the regional dynamics resolved with higher spatial resolution. At the opposite, at 400m depth (Figure 3e), temperature are less coherent with observations due regional simulation too diffusive (solving of this issue in progress).

For the salinity (Figures 3b, d, f), despite the lack of observations, we observe a divergence of the solutions between the regional and the global simulations from 1979. This divergence can be due to the switch in atmospheric forcings (ERA40 to ERAINTERIM) and is under investigation.

Sea Surface Temperature – Model and Observations

After more than 50 years of integration, model results show a good agreement (Figures 4a) in Sea Surface Temperature (SST) over a sub-region focused on the Bay of Biscay and the English Channel excluding the open boundaries. The differences between observations and simulated fields does not exceed 2°C (Figure 4b) and are coherent with the dynamics reproduced by the model. Indeed, the simulation has been performed without the tide dynamics and major errors appears in regions of tidal fronts and shallower region with large tide amplitudes. The observation availability does not induce any artifacts in the statistics (not shown).

This comparison confirms that the numerical simulation does not drift. The atmospheric forcings are playing a major role on this circulation.

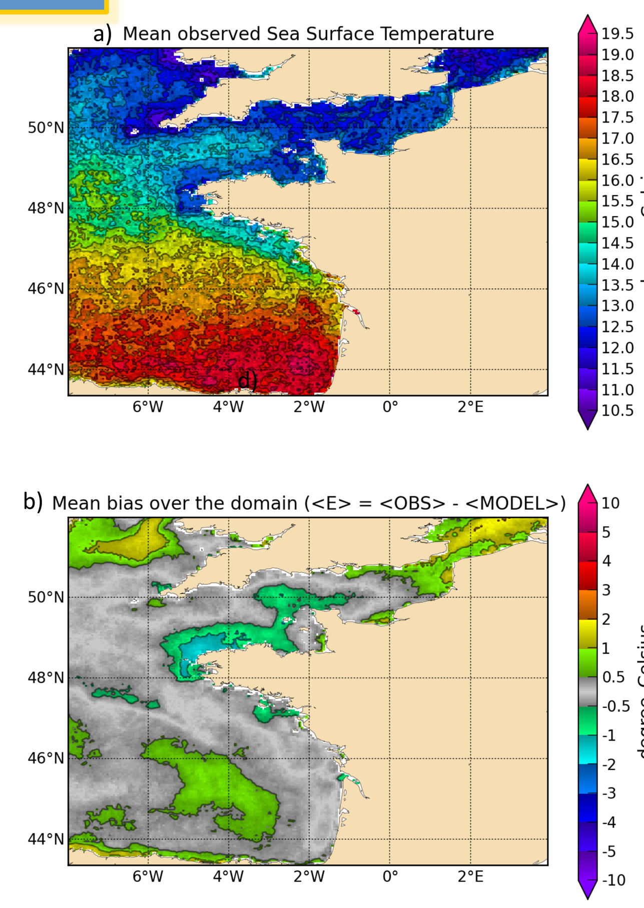

Figure 4: a) Observed remotely sensed Sea Surface Temperature during 2010, b) modelled SST during the same period, c) mean bias <Observations> - <Model>, and d) observation coverage in 2010.

Main findings

This first numerical experiment over the last 53 years highlights promising results about the multi-decadal hydrodynamical variability in the Bay of Biscay and the English Channel. Indeed, even if the system is driven by atmospheric conditions and the fluxes at the ocean open boundary conditions, our results show a signature of a regional dynamics, which can partly explain the differences in temperature between global simulation and observations. These results will lead improved estimation of the multi-decadal trends in the region including budget with new physical parameters (salinity and currents) not described in previous studies (Michel *et al.*, 2009b).

Following this simulation, further experiments (at higher spatial resolution - 2.5Km and from other numerical models) will be performed in the frame of the ENIGME project, to deeply explore main physical processes in the Bay of Biscay and the English Channel.

Water masses in the Bay of Biscay

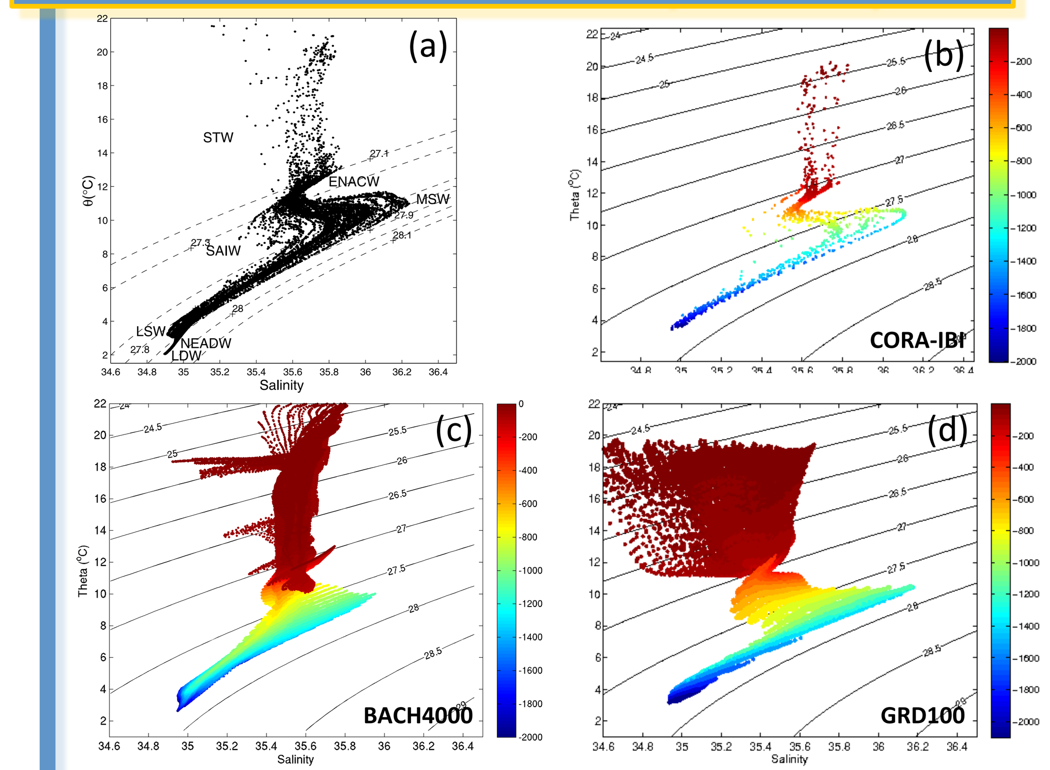

Figure 5: T/S diagrams (a) from Fraile-Nuez *et al.* (2008) during VACLAN cruises in August 2005, (b) from the CORA-IBI database, (c) from the regional simulation (BACH4000), and (d) from the global simulation (GRD100) during August 2005.

The main **water masses** in this region (Figure 5a) are represented in both global (Figure 5d) and regional simulations (Figures 5c) in agreement with vertical profiles, from ARGO floats, in CORA-IBI dataset (Figure 5b). At this stage, the comparison is qualitative and more quantitative scores are under production but we can already notice that the MSW (Mediterranean Sea Water) is eroded in the regional simulation (Figure 5c) with salinities lower than 36 for waters between 8°C and 10°C. This result confirms the improvements needed (*e.g.* open boundary conditions, position of vertical levels) in the resolution of deeper structures in the regional simulation.

The modelled circulation

Main circulation patterns are reproduced by the regional simulation. In winter, the cyclonic circulation limited by the slope current (Figure 6b) appears with similar magnitude in modelled fields (Figure 6a) with a signature of coherent structures in the southern part of the domain. On the shelf, the poleward circulation is developed even if the lack of tidal dynamics is reducing the result quality. In summer, anticyclonic major patterns (Figure 6d) are simulated in the modelled currents (Figure 6c). Current intrusions around 45°N are also developed. On the shelf, weak equatorward currents are also reproduced.

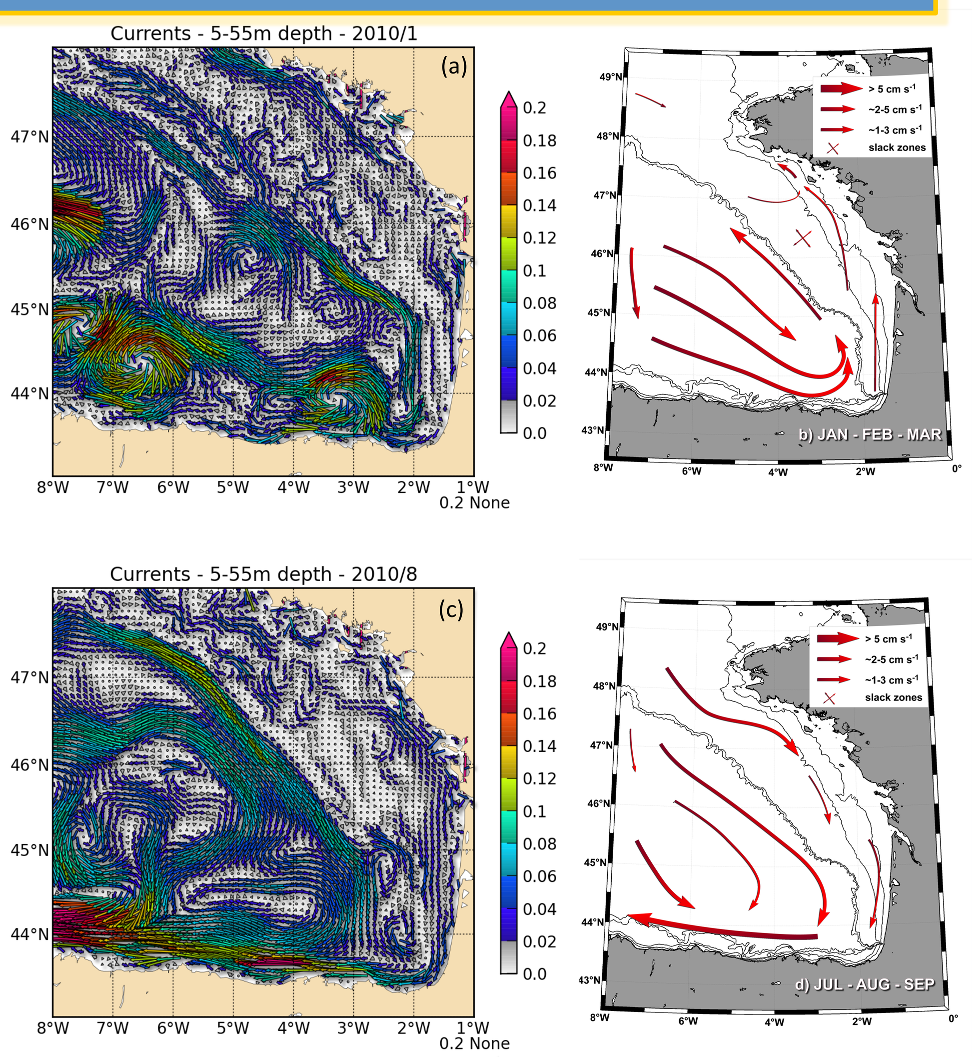

Figure 6: Averaged (between 5m and 55m depth) modelled circulation in January 2010 (a) and August 2010 (c). Drifter derived climatological seasonal circulation (Charria *et al.*, 2013) in winter (b) and summer (d).

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