Glider Observations of the Properties, Circulation and Formation of Water Masses on the Rockall Plateau in the North Atlantic.

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Glider Observations of the Properties, Circulation and Formation of Water Masses on the Rockall Plateau in the North Atlantic.

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1) OSNAP, new observing system of the North Atlantic Subpolar Gyre

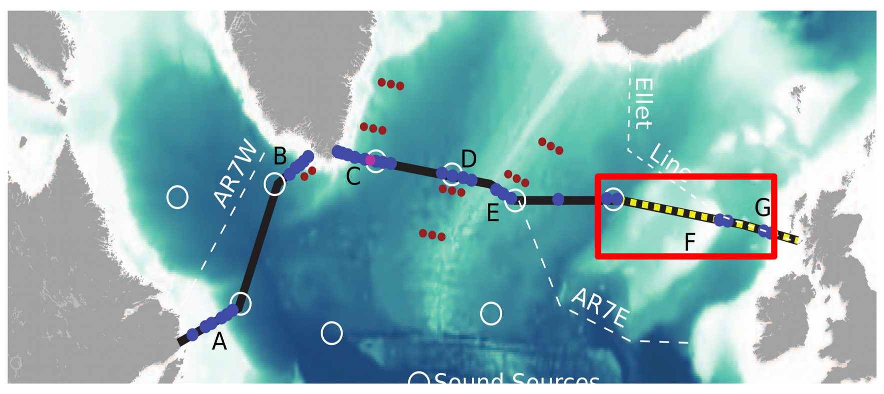

Fig. 1: The OSNAP line, comprising: 1) German (A), US (B,E), US/UK (C), Netherlands (D), UK-SAMS (G) mooring arrays; 2) UK-SAMS glider survey (F); 3) US floats (red dots) and sound sources (white circles)

UK-OSNAP is a partnership between SAMS, NOC, and the Universities of Oxford and Liverpool. The UK-OSNAP team is developing a **new observing system** and **innovative modelling techniques** to characterise the **ocean circulation** and **fluxes** of the **North Atlantic Subpolar Gyre**. The first aim of the programme is to provide a **continuous record for four years** (2014–18) of full-depth, **trans-basin mass**, **heat**, and **freshwater fluxes** in the Subpolar Gyre.

UK-OSNAP is part of an international collaboration to establish **a transoceanic observing system** (Fig. 1) in the **subpolar North Atlantic** (the **OSNAP** array). International OSNAP is led by USA and includes 10 further partner groups in Canada, France, Germany, the Netherlands and China. The OSNAP array is designed to complement the **RAPID** array and **NACLIM** observations, thereby providing measurements to evaluate inter-gyre connectivity within the North Atlantic.

2) Gliders to quantify circulation, fluxes and water mass modification on Rockall Plateau

Since July 2014, 5 gliders were deployed in the framework of the UK-OSNAP glider program (Fig. 2). 12 sections (~1 section every 1-2 months) were achieved in Rockall Plateau. In total 1900 temperature and salinity profiles were acquired between July 16[th] 2014 and September 25[th] 2015, between 23W and 15W.

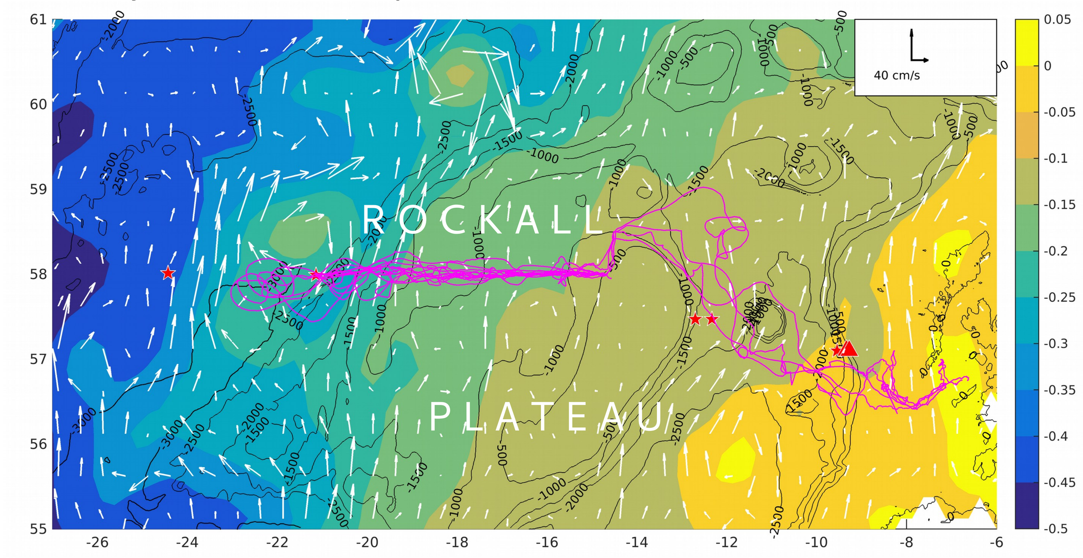

Fig. 2: UK-OSNAP gliders tracks (purple lines) between July 2014 and September 2015; US (west of 20W) and SAMS (east of 14W) mooring locations (red stars and triangles); gridded mean Absolute Dynamic Topography (in meters) between January 2014 and April 2015 from AVISO delayed-time data (blue-yellow colormap) with the associated absolute surface geostrophic current (white arrows); the bathymetry is in black

3) Processing of the Glider Data

Data quality control

First quality control protocols are applied on the raw temperature/salinity data. Spikes are removed, thermistor lag and thermal-inertia of the conductivity sensors are corrected by the Seaglider basestation v2.08. A comparison to climatological data is made, and the remaining bad data are removed through manual QC.

Data Filtering

Due to the relatively low speed of the glider relative to the water (~0.25m.s^{-1}), high frequency internal wave motion appears (Fig. 3a). The sections were objectively mapped using a Gaussian autocovariance (Fig. 3b). An appropriate decorrelation length scale of 20km is chosen, of the same order than the 1[st] baroclinic Rossby radius of deformation that can be estimated from glider data (between 10 km and 20km in summer, and down to 1km in winter when Subpolar Mode Water formation occurs)

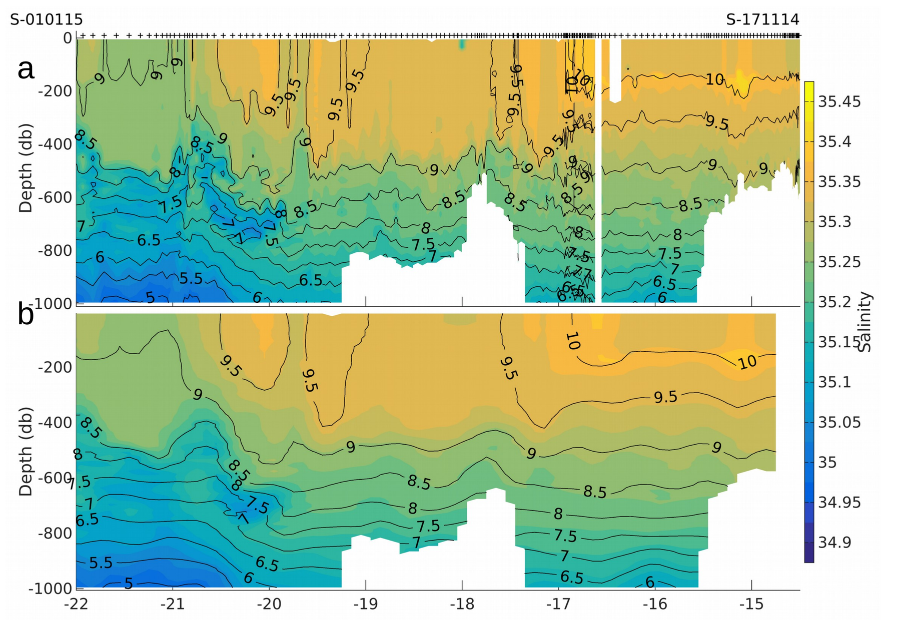

Fig. 3: A longitudinal glider section observed from Nov. 2014 to Dec. 2014, showing salinity with potential temperature contour (a) binned in 2m vertical bins, (b) objectively mapped with a 20 km Gaussian length scale. Tick marks at the top indicate the mean location of the gliders profiles.

4) Absolute Geostrophic Velocity from Gliders

The cross-section component of the thermal wind equation is given by:

$$\rho_0 f \frac{\partial v_n}{\partial z} = -g\frac{\partial \rho}{\partial s} \quad \text{(E.1)}$$

where *s* is the along-section coordinate, z is the vertical coordinate, $v_n(z)$ is the velocity normal to the section, f the Coriolis parameter, g is the acceleration of gravity, rho is the density and rho0 a reference density. By integrating (E. 1) from the maximum depth H to the depth z we obtain:

$$v_n(z) = v_n(-H) - \frac{g}{\rho_0 f}\int_{-H}^{z}\frac{\partial \rho}{\partial s}dz \quad \text{(E.2)}$$

By assuming that the contribution of the Ekman current to the depth-averaged current V derived from the glider is relatively small (the depth of the dive ~1000m is larger than the Ekman layer depth by one order of magnitude), and that most of the tide contribution is removed by detiding V using a 1/12° regional tide prediction model, the vertical integral of $v_n(z)$ over the depth of the dive can be considered as equals to the depth averaged current V :

$$V = \frac{1}{H}\int_{-H}^{0} v_n(z)\,dz \quad \text{(E.3)}$$

By integrating E.2 over the water column, and utilizing E.3, we obtain the velocity at maximum diving depth $v_n(-H)$:

$$v_n(-H) = V + \frac{g}{\rho_0 f H}\int_{-H}^{0}\int_{-H}^{\hat{z}}\frac{\partial \rho}{\partial s}d\hat{z}dz \quad \text{(E.4)}$$

$v_n(z)$ can then be estimated for each depth z by using E.4 in E.3

5) Subpolar Mode Water formation

The Mixed Layer deepened in Autumn and Winter due to strong surface buoyancy losses. Fig. 3 shows a temporal and spatial evolution of the MLD from November to January on Rockall Plateau. The mixed layer deepened down to 600m in Rockall Plateau in Feb./Mar. 2015 (Fig. 4b, 5b.) associated with the formation of the 27.3σ_θ and 27.4σ_θ Subpolar Mode Waters. In Summer 2015 (Fig. 5b), the 27.4σ_θ isopycnal is 200m thicker than in Summer 2014 (Fig. 4b)

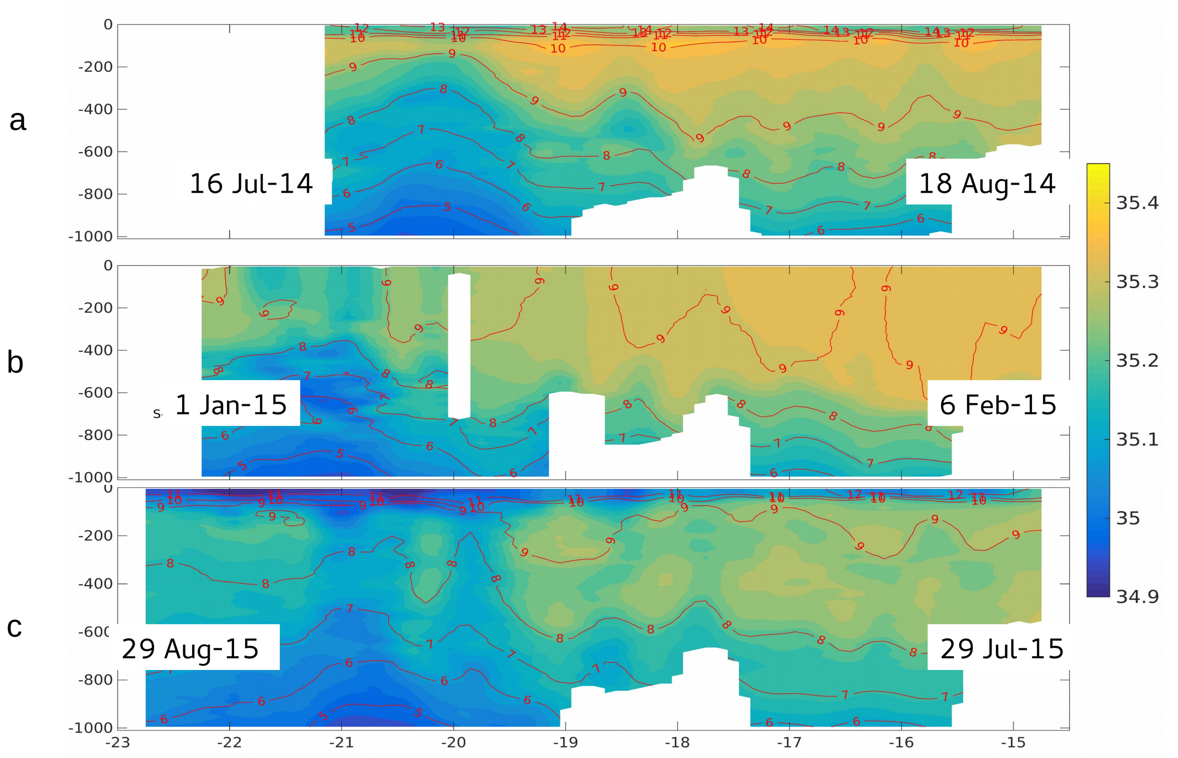

Fig. 4: Objectively mapped salinity with potential temperature contour (red) as a function of depth and longitude, for summer 2014 (a), winter 2014-15 (b) and summer 2015 (c)

6) Absolute geostrophic velocity and transport estimated from gliders

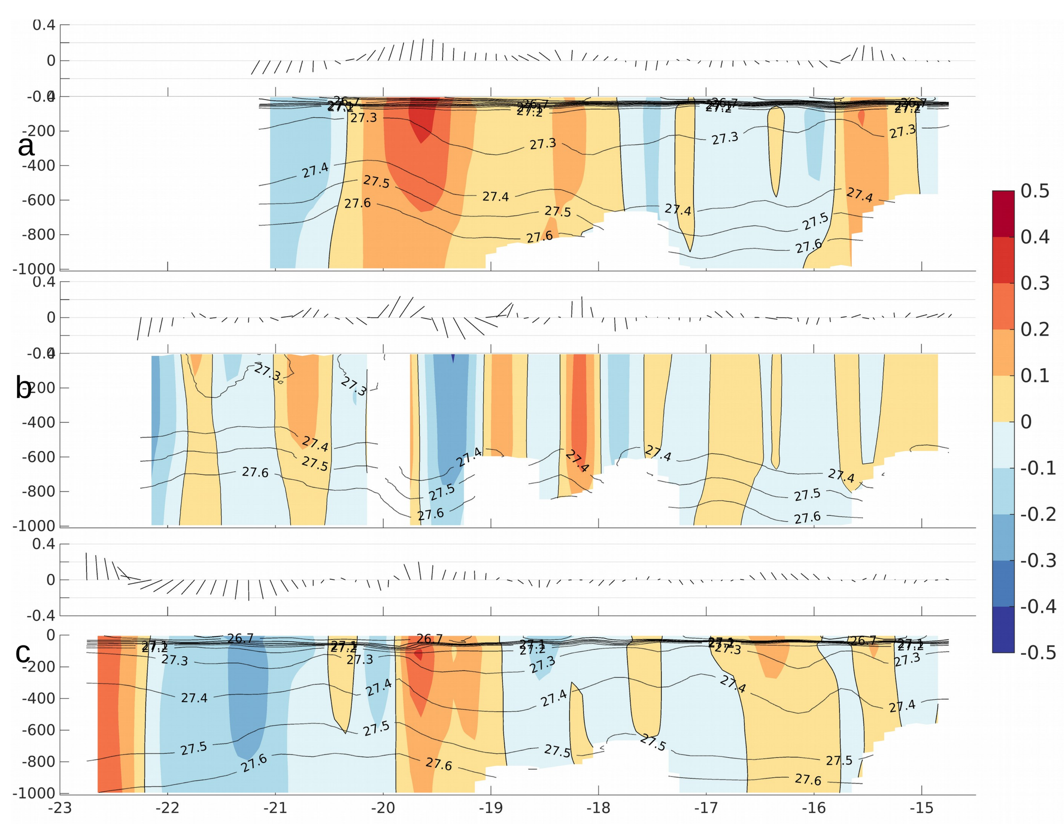

Fig. 5: Color contour plot of the absolute meridional geostrophic velocity (in m.s^{-1}) with potential density contours and stick vector diagrams of the Depth Average Current (in m.s^{-1}) used to reference the geostrophic current

Absolute geostrophic velocities are obtained by vertically integrating the thermal wind balance (see section 4) on the smoothed density section (see section3) and by taking as a reference for the 0-1000m mean velocities the cross-section component of the depth-averaged currents derived from the glider movement.

Fig. 5 and 6 show the important and complex **mesoscale variability. By** looking at altimetry data (Fig. 2) part of these mesoscale structures could be associated with a **permanent eddy** in the East of the Iceland Basin (centered around 22W) and the presence of one of the **branches of the North Atlantic Current** (~20W-19W). The **formation of the Subpolar Mode Water** in Winter (Fig 5b) certainly also plays a role in generating high energy mesoscale/submesoscale eddy.
Absolute meridional geostrophic velocity did not show any seasonal variability on the Rockall Plateau (Fig 6.) and is generally lower than west of the edge of the Plateau (<18E).

By depth integrating the absolute meridional geostrophic velocity in each bin, we obtain the volume flux per length as a function of longitude for all the section, highlighting the repartition of **the transport per length** along the UK-OSNAP glider section. The higher values are found west of the Rockall Plateau (<18E), where the altimetry also indicate significant surface geostrophic current.

Finally the transport for the top 600m of each section is calculated by integrating the transport per length (Fig. 7) by longitude. Each section is splited in two (East of 18W and West of 18E) and transport values are indicated on Fig. 8. There is not apparent seasonal pattern in the transport on Rockall Plateau.

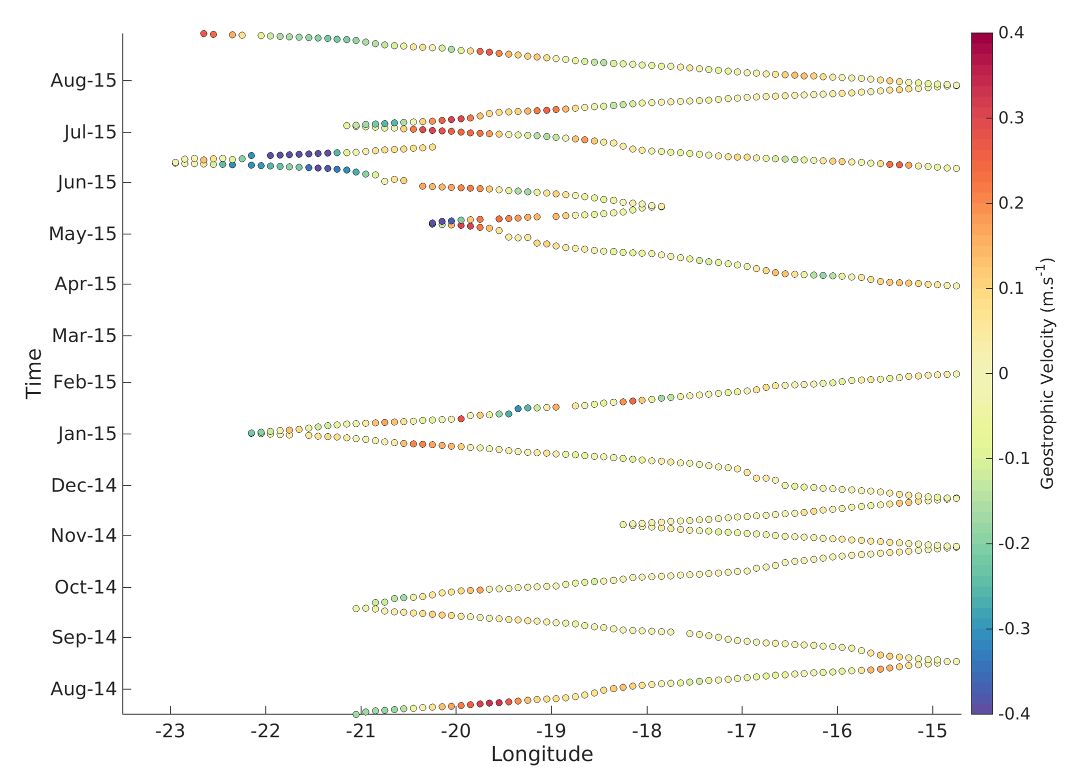

Fig. 6: Time series of absolute meridional geostrophic velocity averaged between the surface and 100m

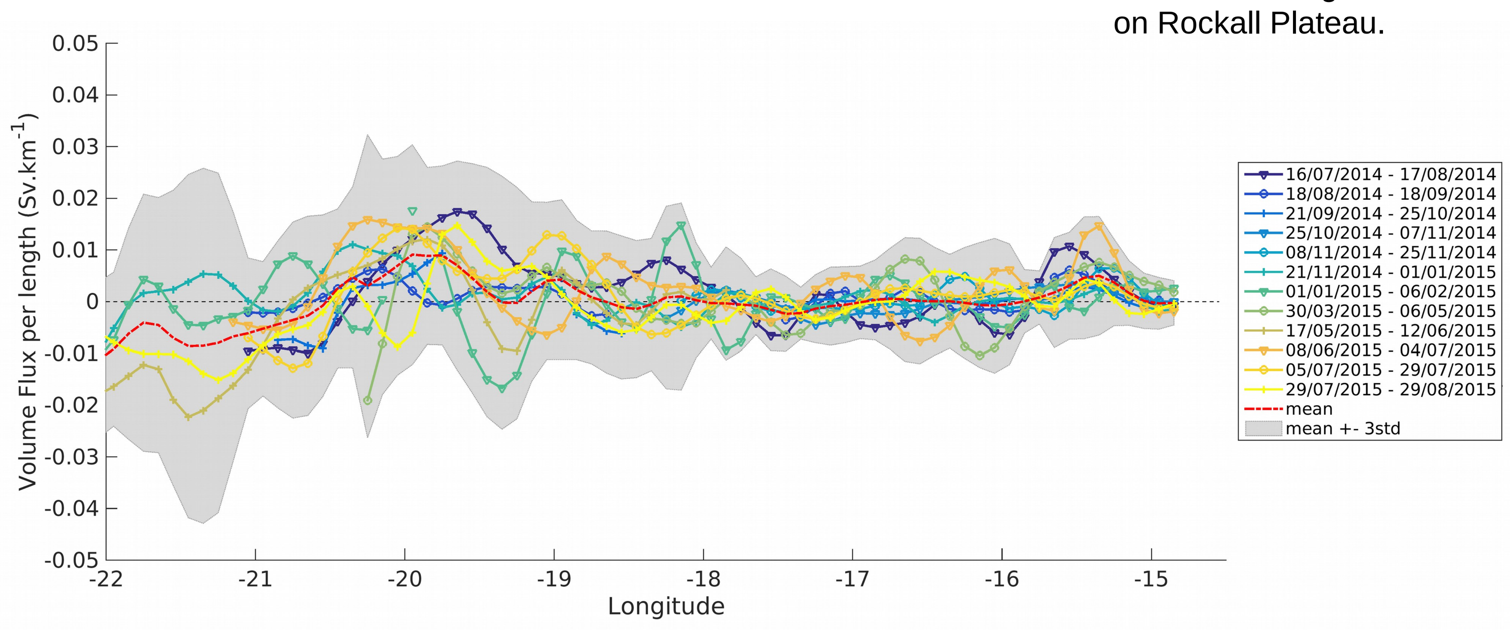

Fig. 7: Volume flux per length between 22W and 15W of the absolute geostrophic velocity integrated by depth from 0 to 600m, as a function of longitude. Color plots correspond to individual sections, the red line (and the grey area) to the mean per longitude bin and (and to the mean -+3 std envelope).

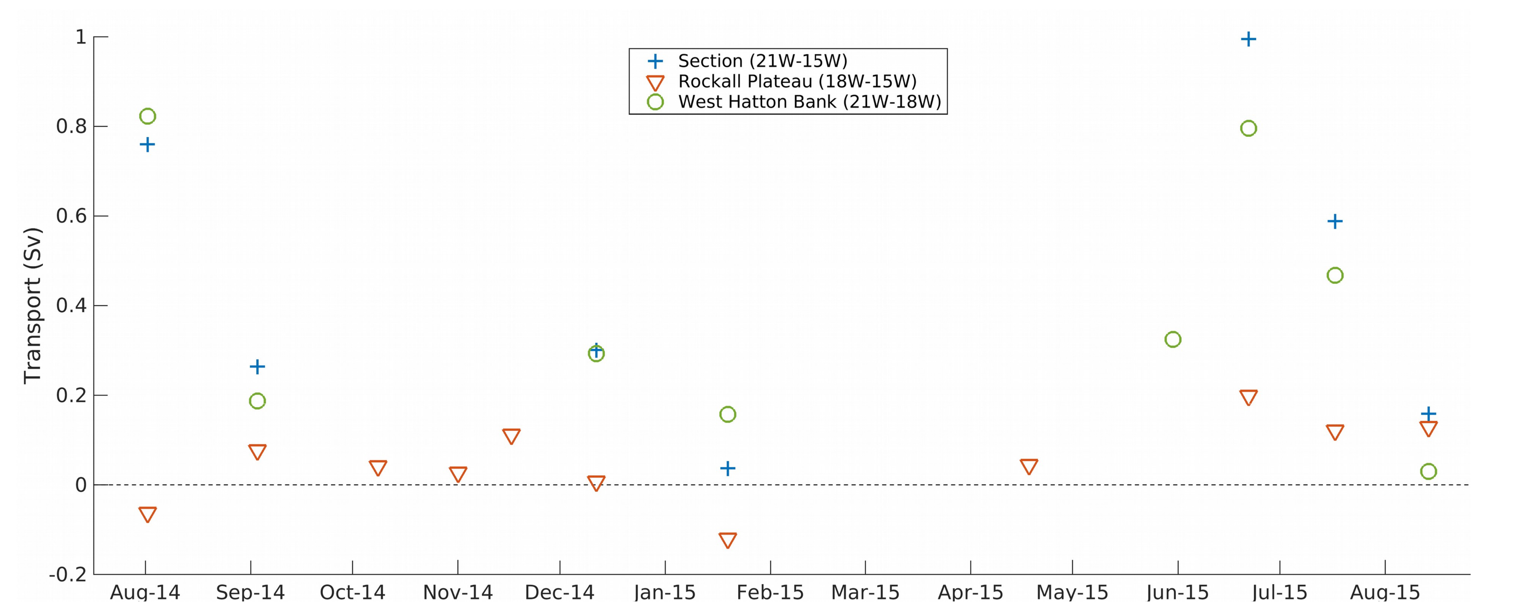

Fig. 8: Integrated absolute meridional geostrophic transport for the layer 0-600m, for each glider section covering the range from 21W to 15W, 21W to 18W and 18W to 15W. The mean of absolute meridional transport on Rockall Plateau (18W-15W) estimated from 11 sections is about 0.05Sv and the standard deviation is about 0.09Sv

Conclusion

- This is the first time that gliders are deployed in the Rockall Plateau producing a monthly monitoring of the absolute transport in the Rockall Plateau (18W-15W). The **mean of the absolute meridional transport** estimated from 11 sections is about **0.05Sv** and the standard deviation is about 0.09Sv, indicating a low transport.
- Highlight important mesoscale actvity associated with branches of the North Atlantic Current and permanent eddy on the Eastern part of the Iceland Basin,
- Invaluable dataset to monitor and study the Subpolar Mode Water Formation on Rockall Plateau

Future plans

- Use US M4 mooring and glider data to calculate 2[nd] transport estimate based on 2 simultaneous profiles.
- Assess the altimetry products in the area by comparing dynamic height and surface absolute geostrophic current from along track altimetry with glider data
- Add high resolution models in the area (1/36, 1/60°): 1) to quantify "representativity" erros associated with the 10 days transport sections estimated by the glider; 2) to estimate the part of the geostrophic flow along the glider section (and help to improve the design of the section to minimise the along-section geostrophic flow) ; 3) to better understand the branches regime of the North Atlantic Current.

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