Structure and transport of the North Atlantic Current in the eastern subpolar gyre from sustained glider observations

Loïc Houpert

Mark Inall, Marie Porter, Estelle Dumont,
Stefan Gary, Bill Johns & Stuart Cunningham

8th EGO Meeting and International Glider Workshop
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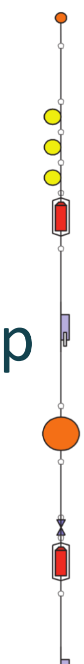
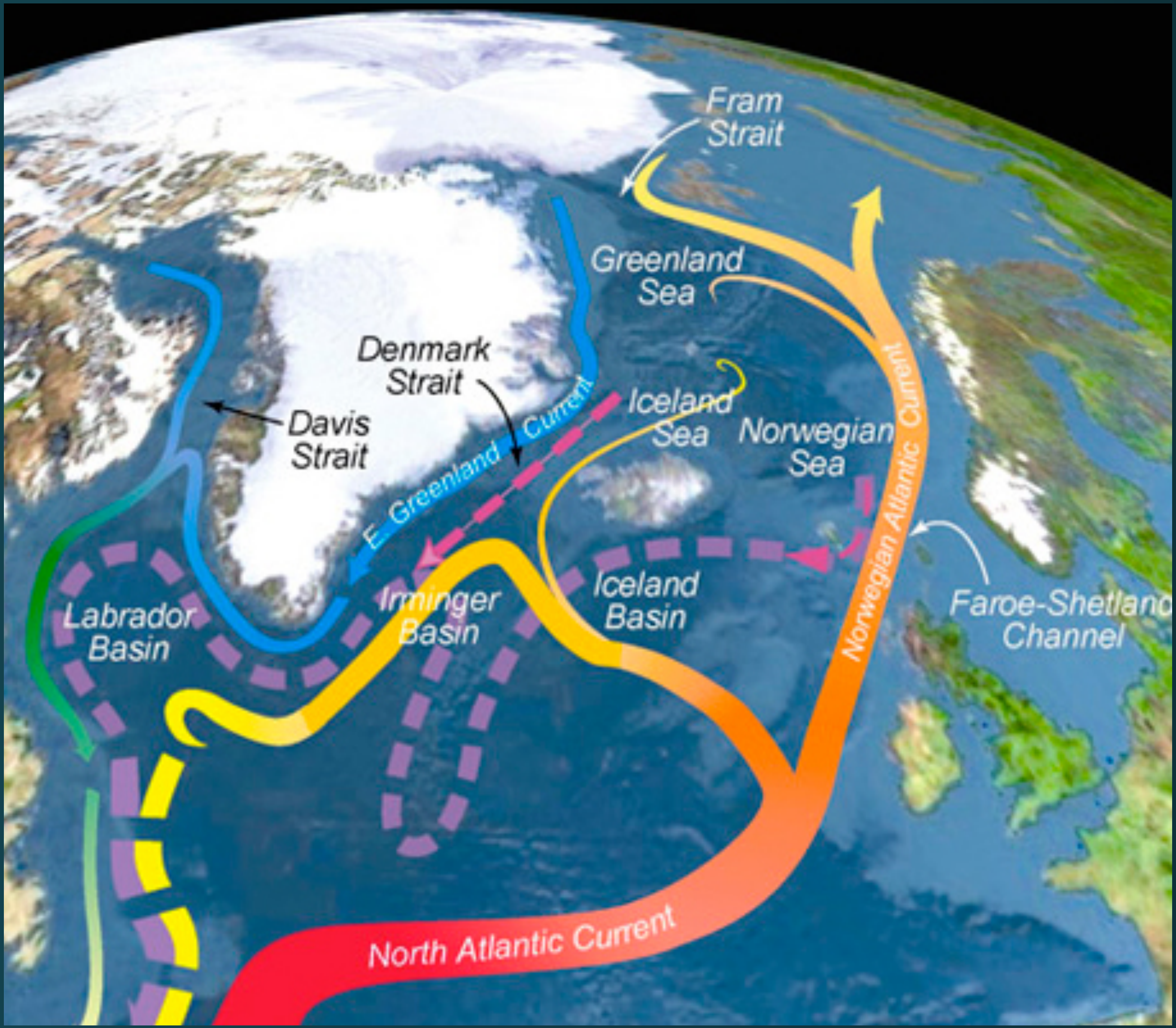


National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

OSNAP
OVERTURNING IN THE SUBPOLAR NORTH ATLANTIC PROGRAM

NERC
SCIENCE OF THE ENVIRONMENT

Importance of the North Atlantic for global climate

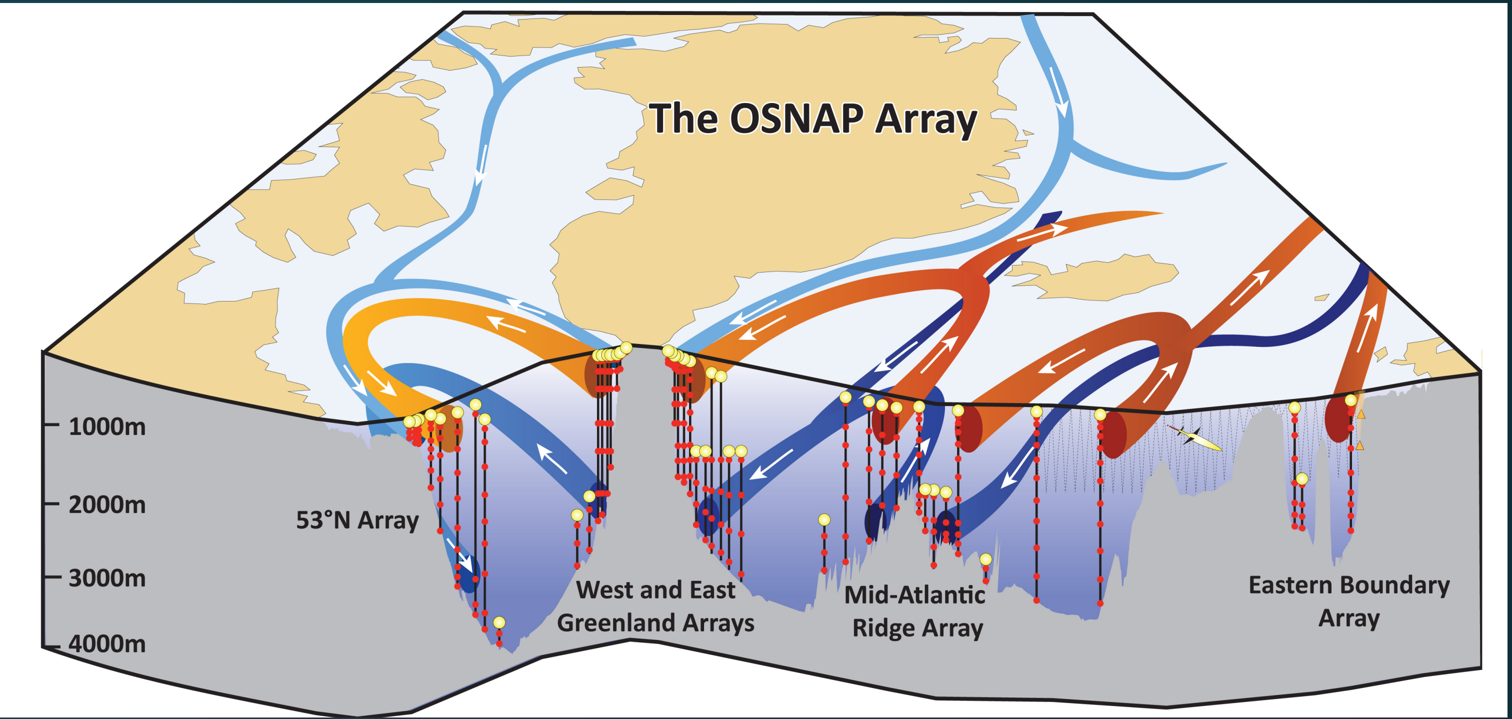


[Credits: Ruth Curry (WHOI) and Cecilie Mauritzen (NMI)]

- critical importance for European weather & climate (temperature, wind, precipitation)
- strong atmosphere-ocean-ice interactions
- global impacts (marine ecosystems)

Until recently no continuous measurements were available in the subpolar gyre boundary currents, and no ocean general circulation model represents it accurately.

Overtuning in the Subpolar North Atlantic Programme



"… continuous record of the full-water column, trans-basin fluxes of heat, mass and freshwater in the subpolar North Atlantic…"

Observations 2014-2018 *(2020)*
Moorings, gliders, floats (Argo and RAFOS)

Deployed in 2014, turnaround in 2016/2018
First results published in 2019 (Lozier et al.)

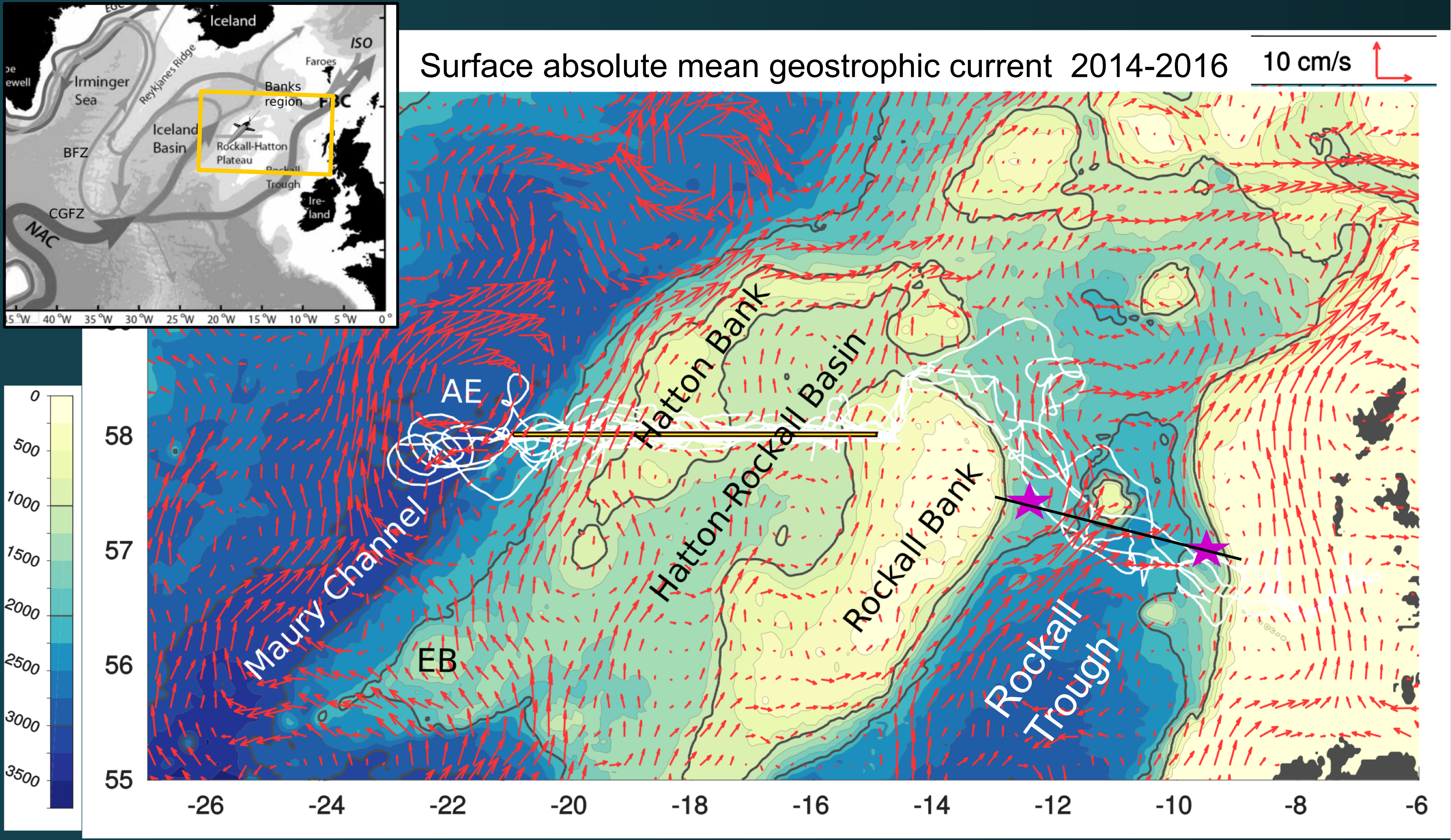
7 countries involved, 14 institutions
UK: Eastern Boundary, DWBC (until 2018)
and East-Iceland (from 2018)

Some of OSNAP objectives :

- MOC variability vs variability of deep water formation and wind-driven circulation
- MOC forcing over range of lats
- Deep layer pathways/mixing

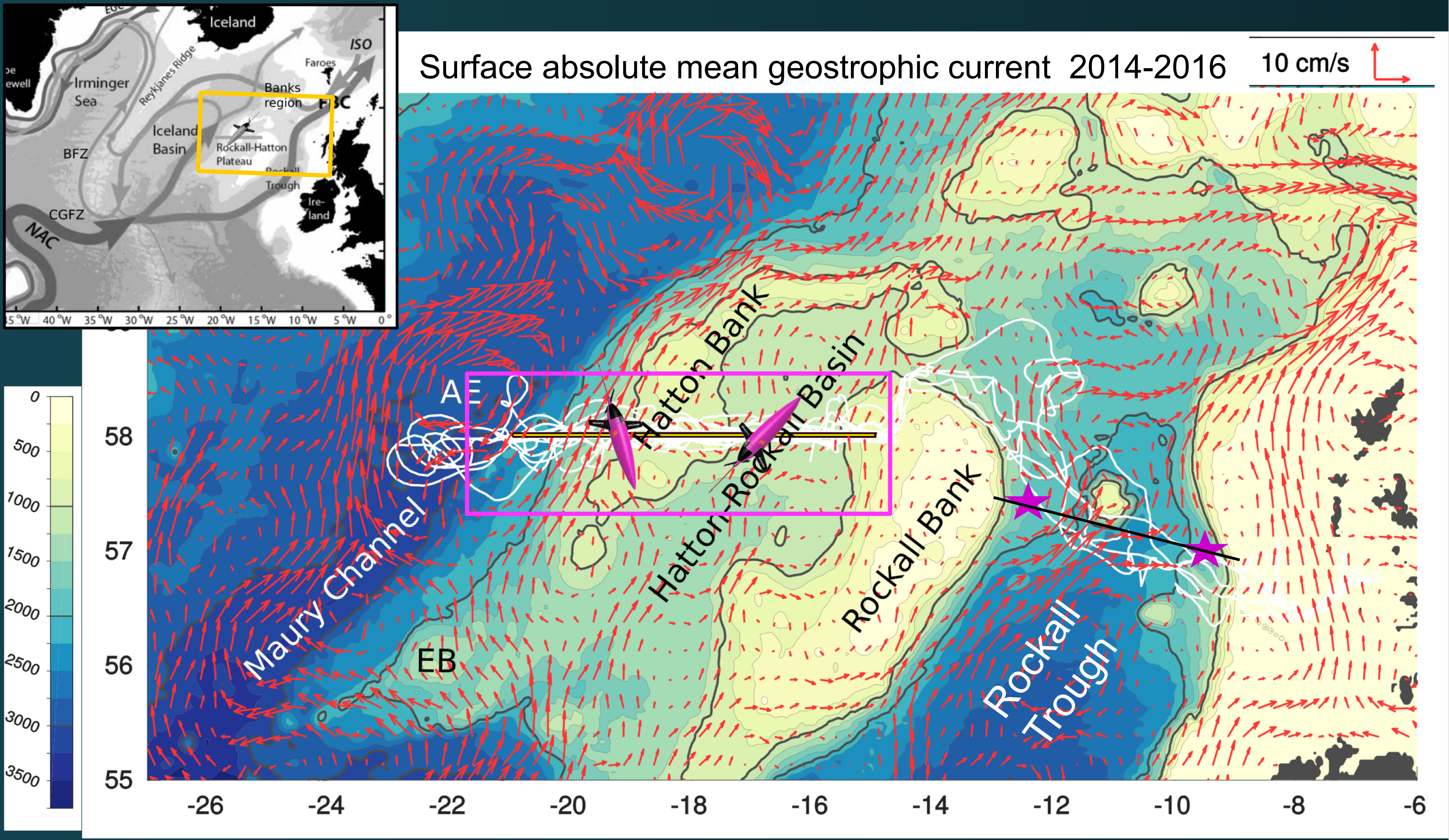
(models, reanalyses, obs.)

Surface geostrophic currents in the Eastern SPG



Complex circulation pathways over Rockall Plateau and Rockall Trough, splitting and merging of NAC branches, energetic eddy field

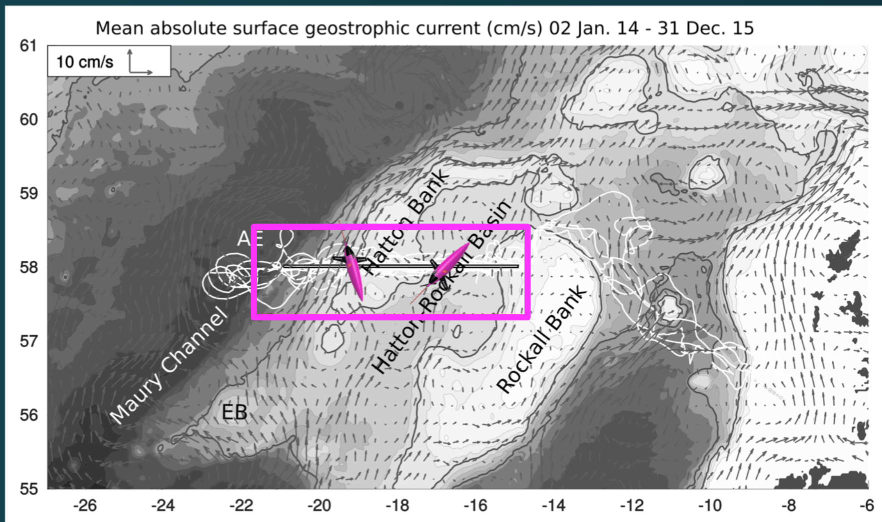
Surface geostrophic currents in the Eastern SPG

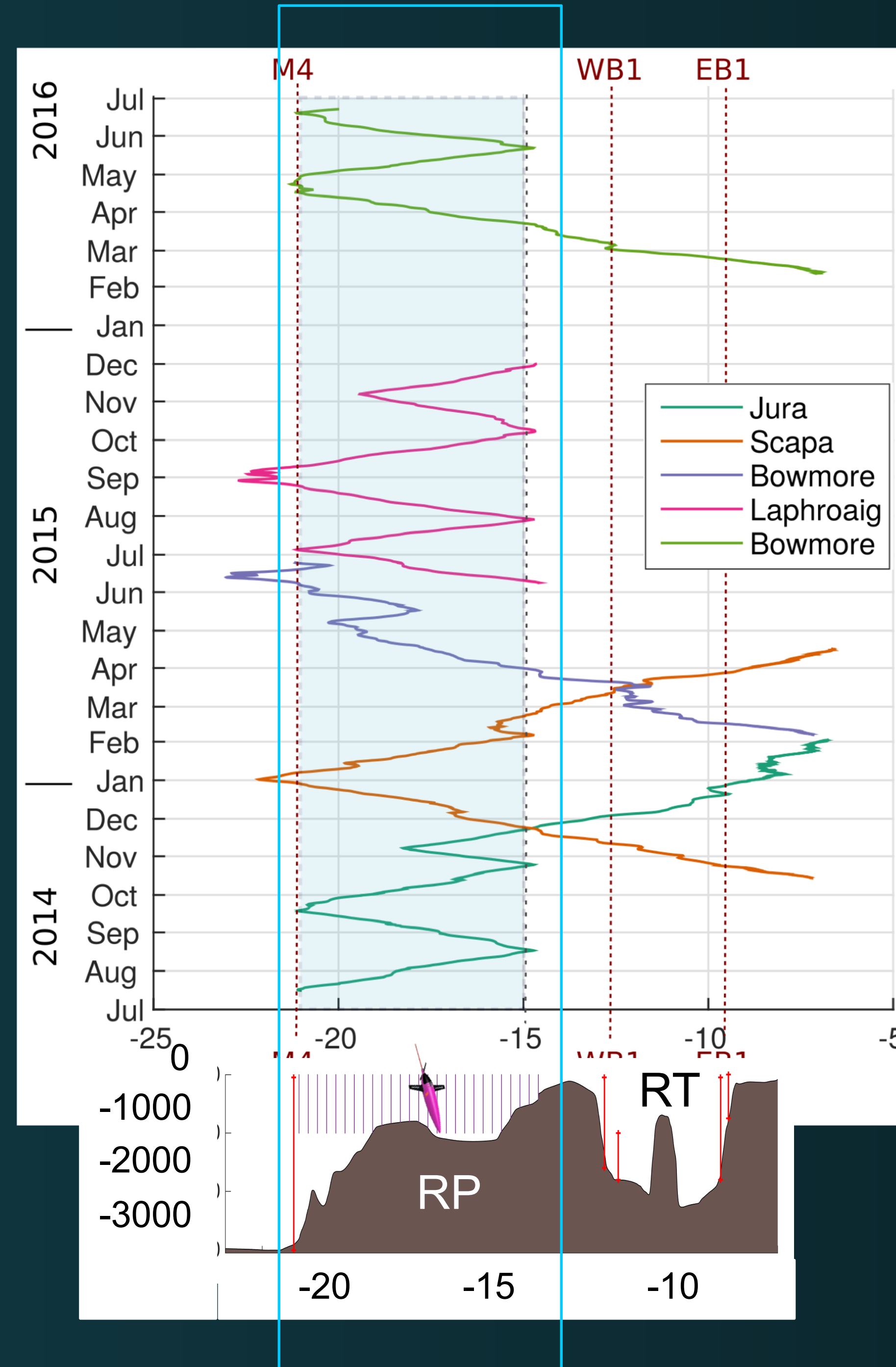


Complex circulation pathways over Rockall Plateau and Rockall Trough, splitting and merging of NAC branches, energetic eddy field

Uncertainties on the net poleward transport → need of high frequency obs

The UK-OSNAP glider programme





Station-spacing (30-50km) from past ship occupations is too large correctly resolve the mesoscale field over Rockall Plateau

→ **uncertainties on the net circulation**

Main objectives of the glider programme:

- Permanent monthly occupation of RP for the duration of OSNAP (2014-18)
July 2014/16: 15 sections (5000 profiles)

- Quantify northward-flowing flux in Rockall Hatton Plateau (RP)

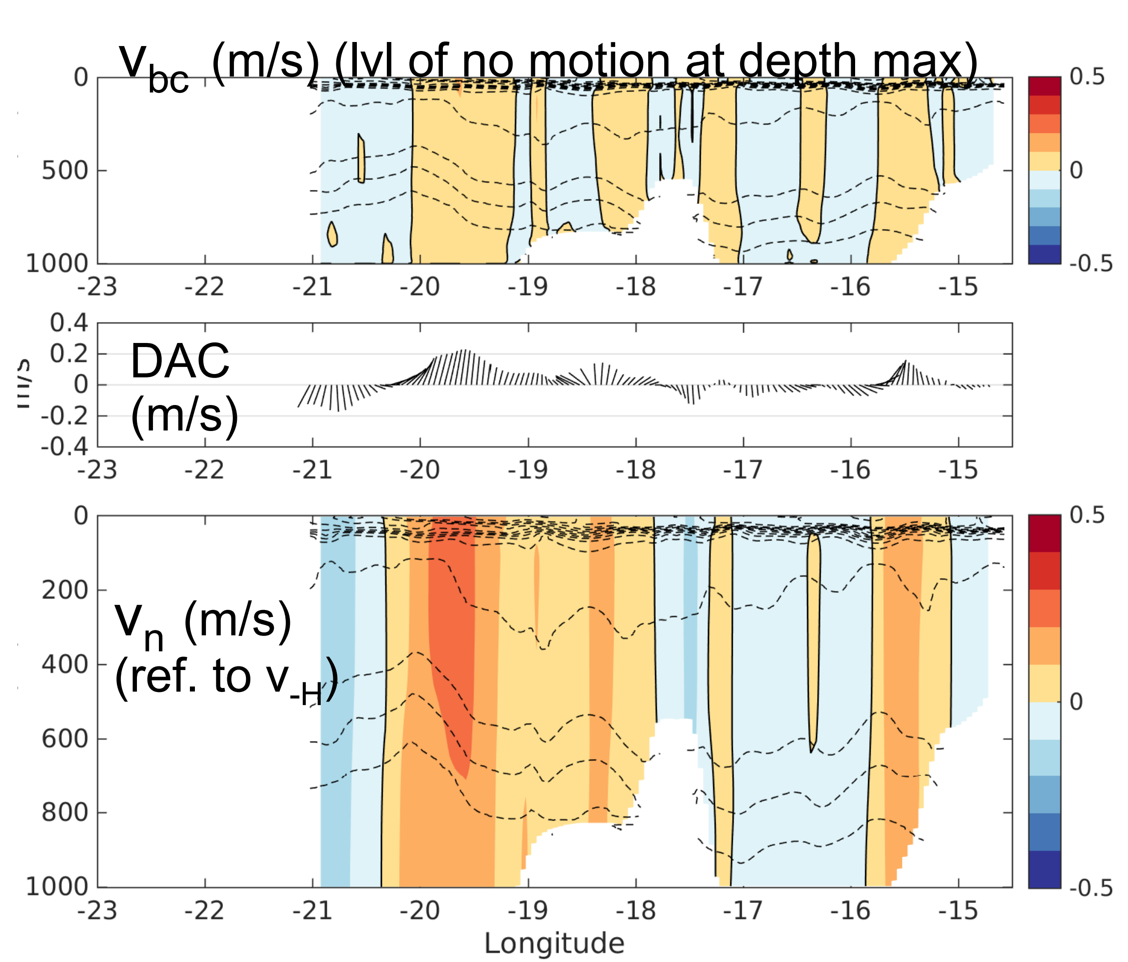
Absolute geostrophic velocity from glider

$$\rho_0 f \frac{\partial v_n}{\partial z} = -g \frac{\partial \rho}{\partial s}$$

↓ vertical integration

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

barotropic compo. (v_{-H}) — baroclinic compo. (v_{BC})

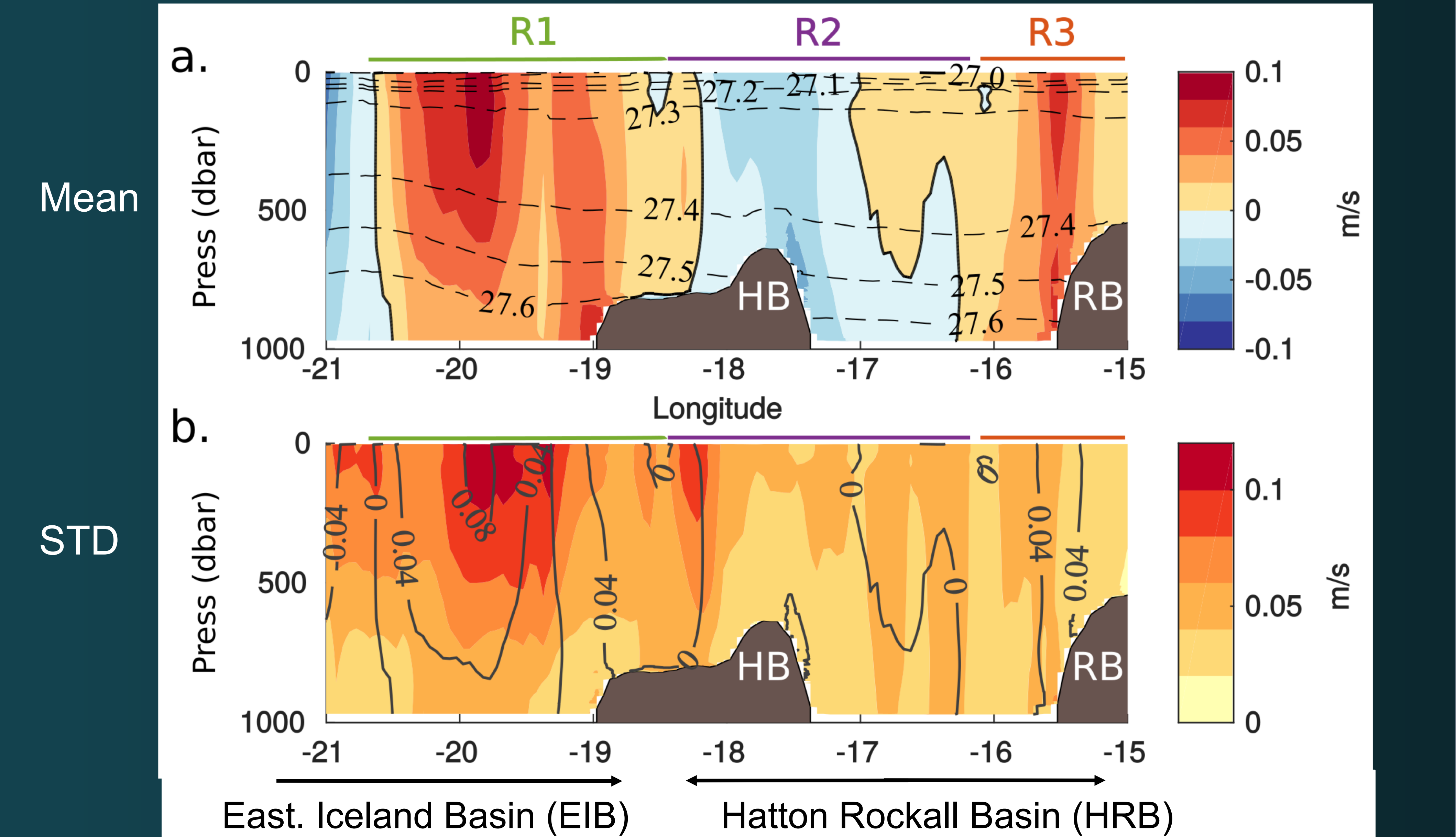


$v_n(z) = v_{-H} + v_{BC}(z) \longrightarrow$ **v_{-H} ?**

Depth Average Current (DAC) is estimated from the end-dive dead reckon position (from the flight model) and the end-dive GPS positioning.

$DAC = \overline{v_n}(z) = v_{-H} + \overline{v_{BC}}(z) \longrightarrow$ **$v_{-H} = DAC - \overline{v_{BC}}(z)$**

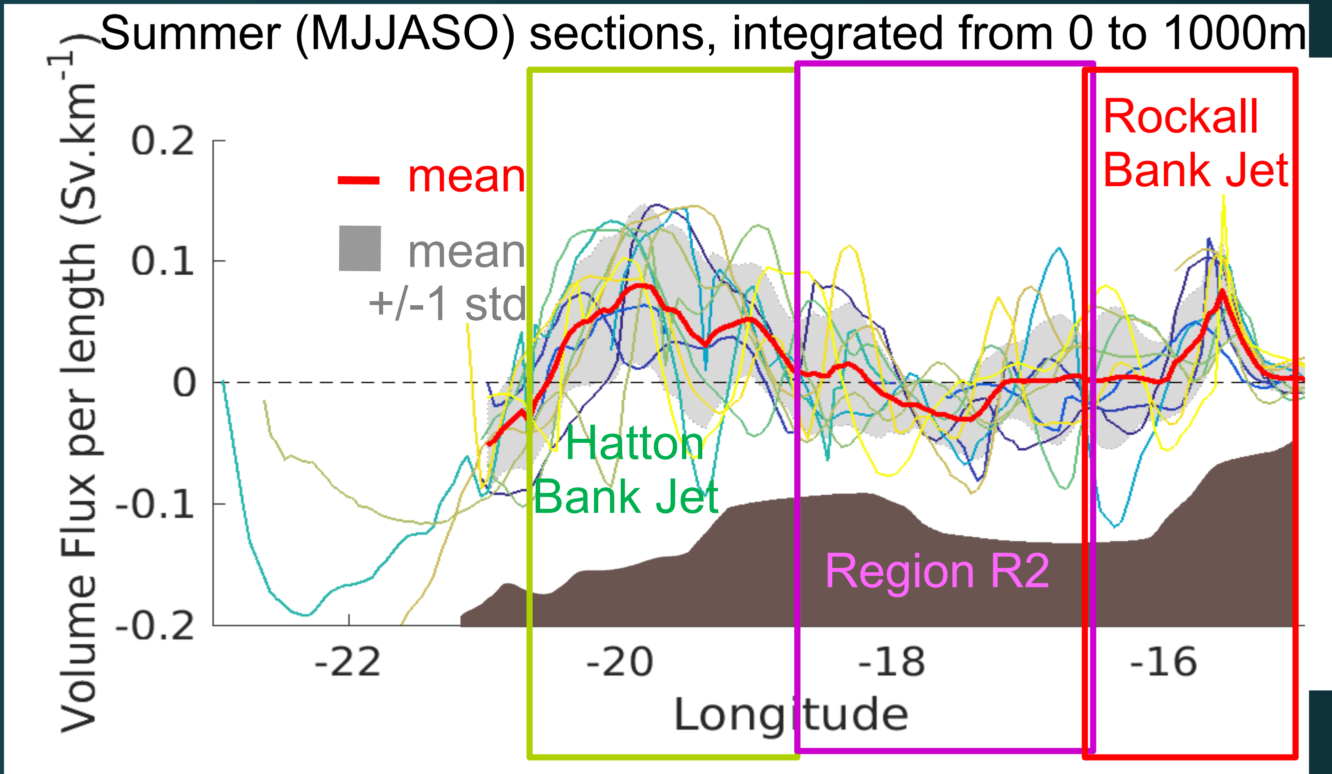
Vertical structure of the mean flow



→ 2 semi-permanent northward flows: the Hatton Bank Jet (in R1) and the Rockall Bank Jet (in R3)

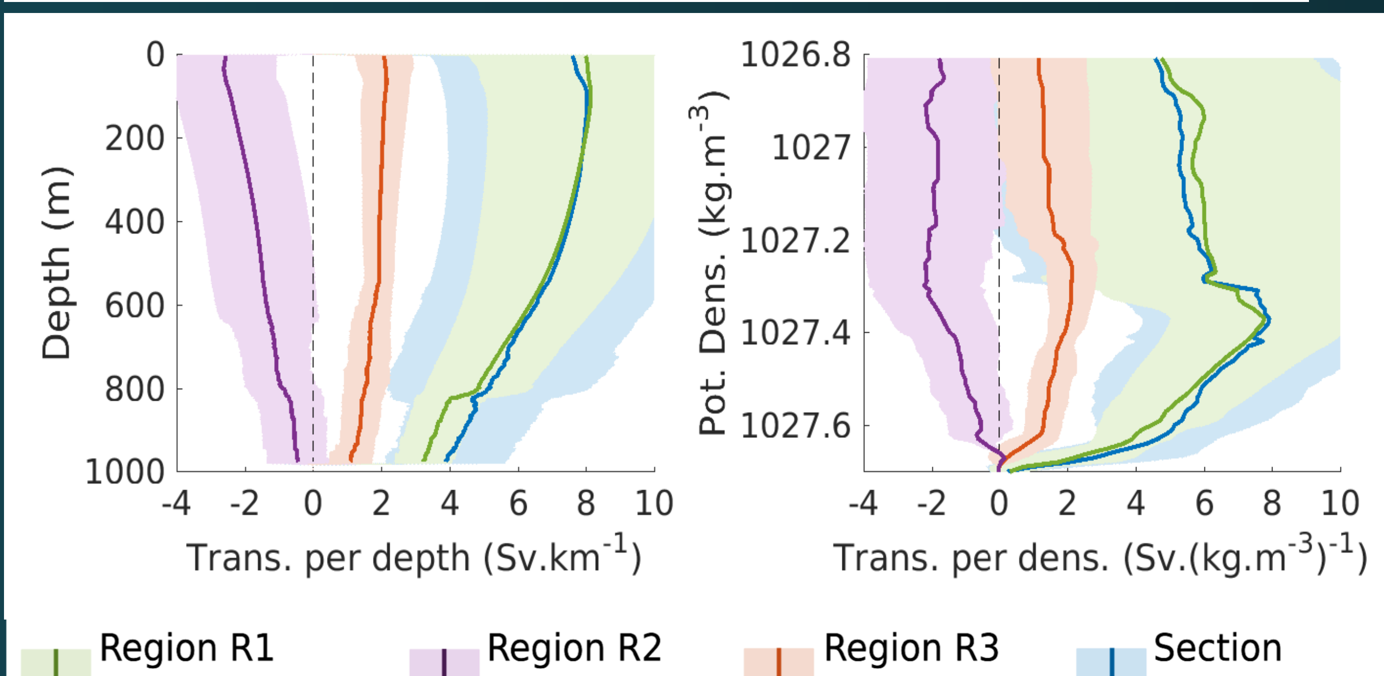
→ 1 southward flow in R2

Horizontal and vertical structure



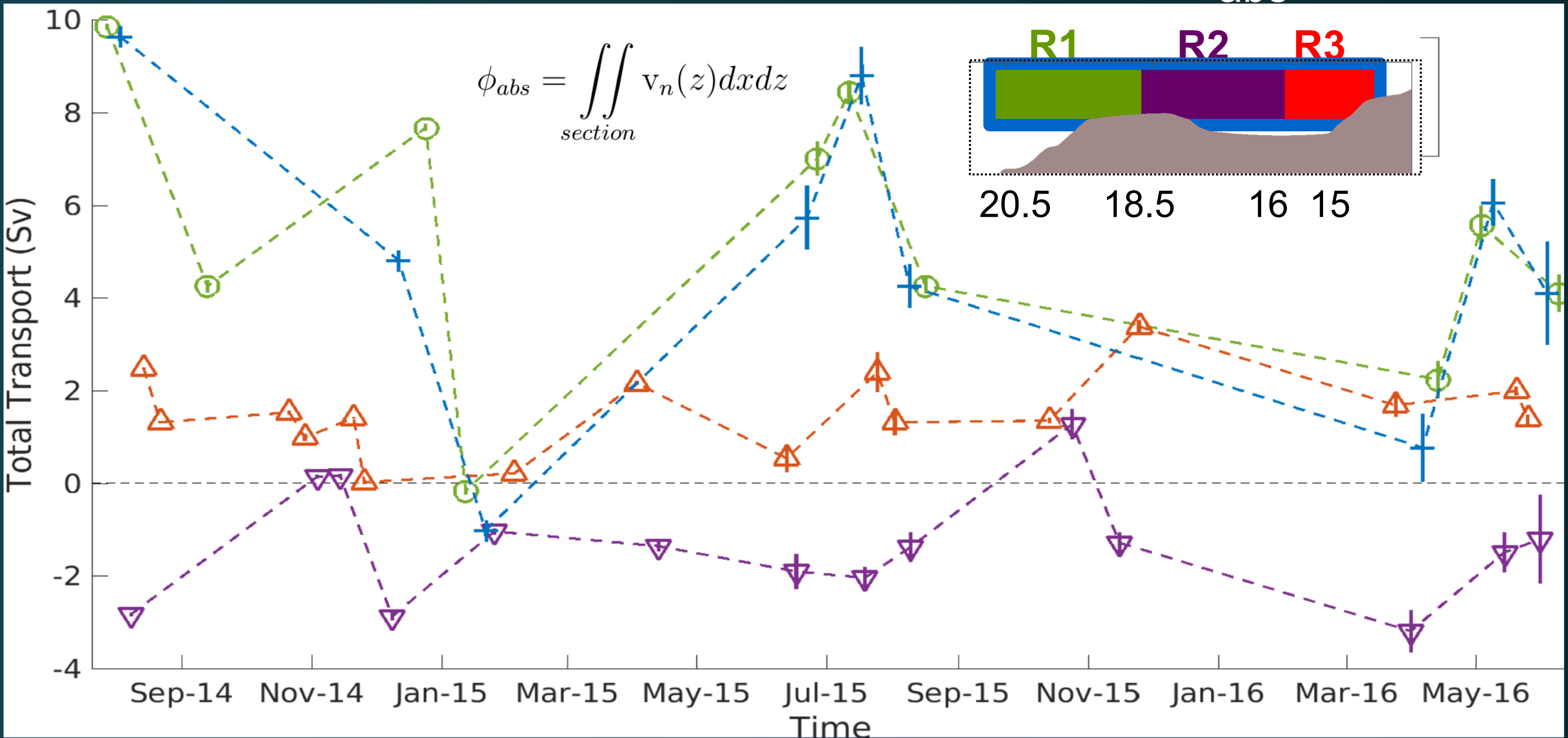
- Two semi-permanent northward branches of the NAC: the Hatton Bank Jet and the Rockall Bank Jet

- Not enough sections in NDJFMA (4) to distinguish a clear longitudinal structure



- 1/3 of Hatton Bank Jet transport is baroclinic (=due to geostophic shear)
- Rockall Jet and R2 mostly barotropic
- Max mean trans. for 27.3-27.4 $kg.m^{-3}$
-> mode water (SPMW)

Time variability of the absolute transport Φ_{abs} (0-1000m)



MJJASO statistics :

	Mean	Std
R1 (HBJ)	6.3	2.1
R2	-1.1	1.4
R3 (RBJ)	1.5	0.7

Uncertainties about 10-15 % of transport estimates → using Monte Carlo approach: creating 100 sections with random perturbations on the DAC and density field associated with the GPS accuracy, compass calibration and CT sensors drift, following Beaird et al. (2013)

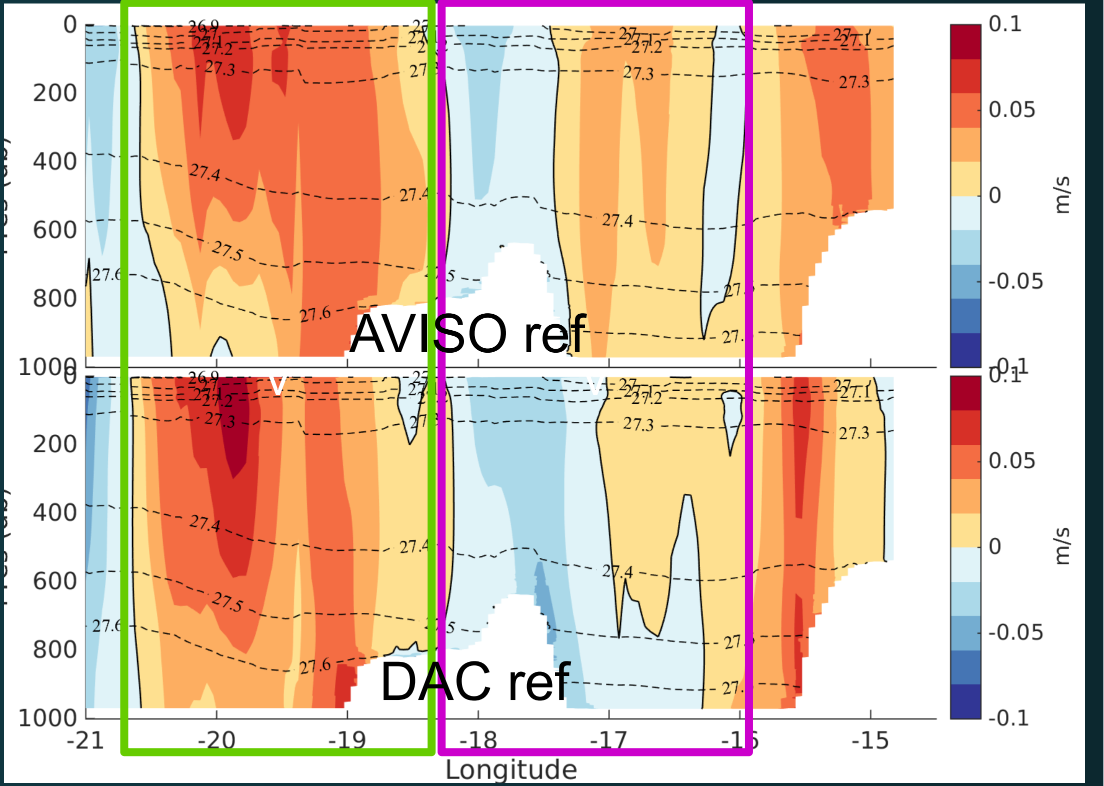
Comparison with referencing to surface altimetry

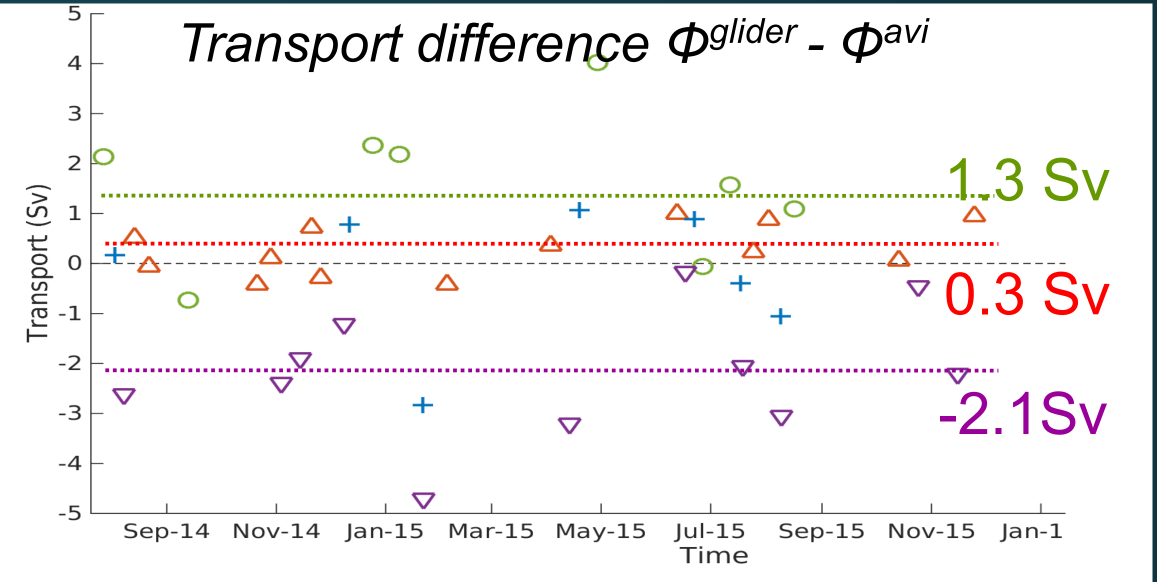
$$v_n(z) = \boxed{v_{surf}} + \frac{g}{\rho_0 f}\int_z^0 \frac{\partial \rho}{\partial s} dz$$

from AVISO interp on gl. track

$$v_n(z) = \boxed{v_n(-H)} - \frac{g}{\rho_0 f}\int_{-H}^{z} \frac{\partial \rho}{\partial s} dz$$

from glider DAC



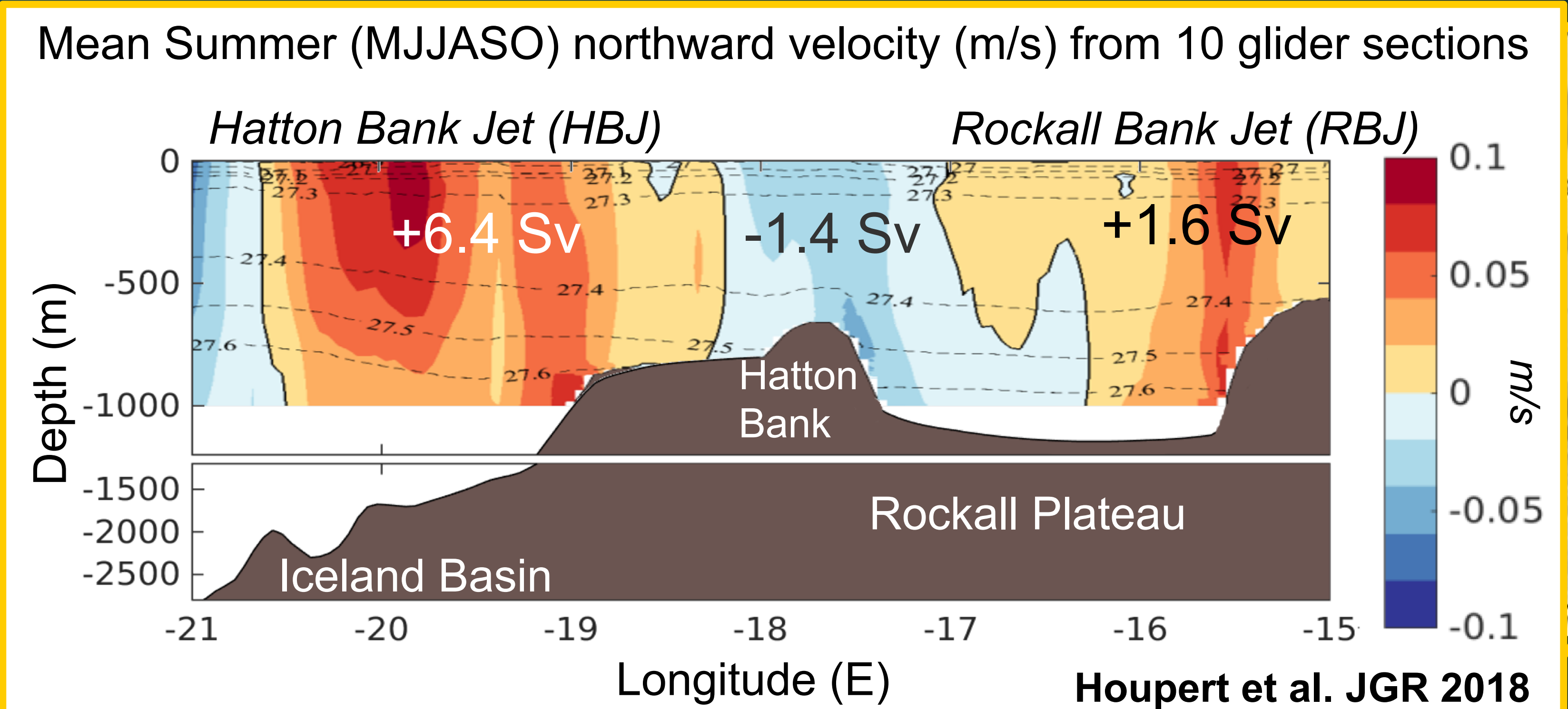


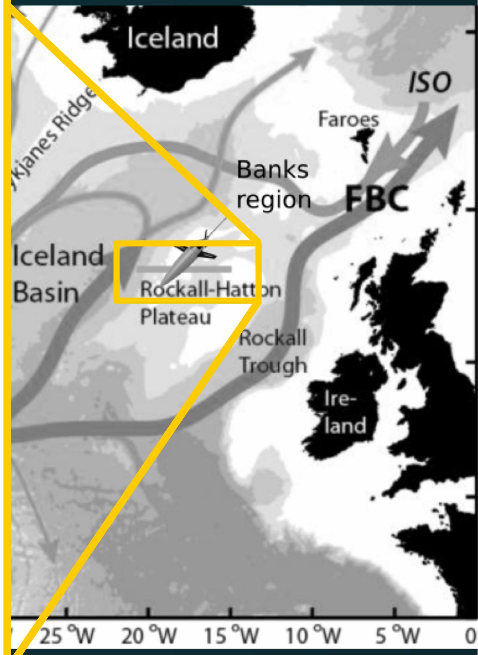
Altimetry differences with glider :

- southward flow too weak in R2
- northward flow too weak in R1

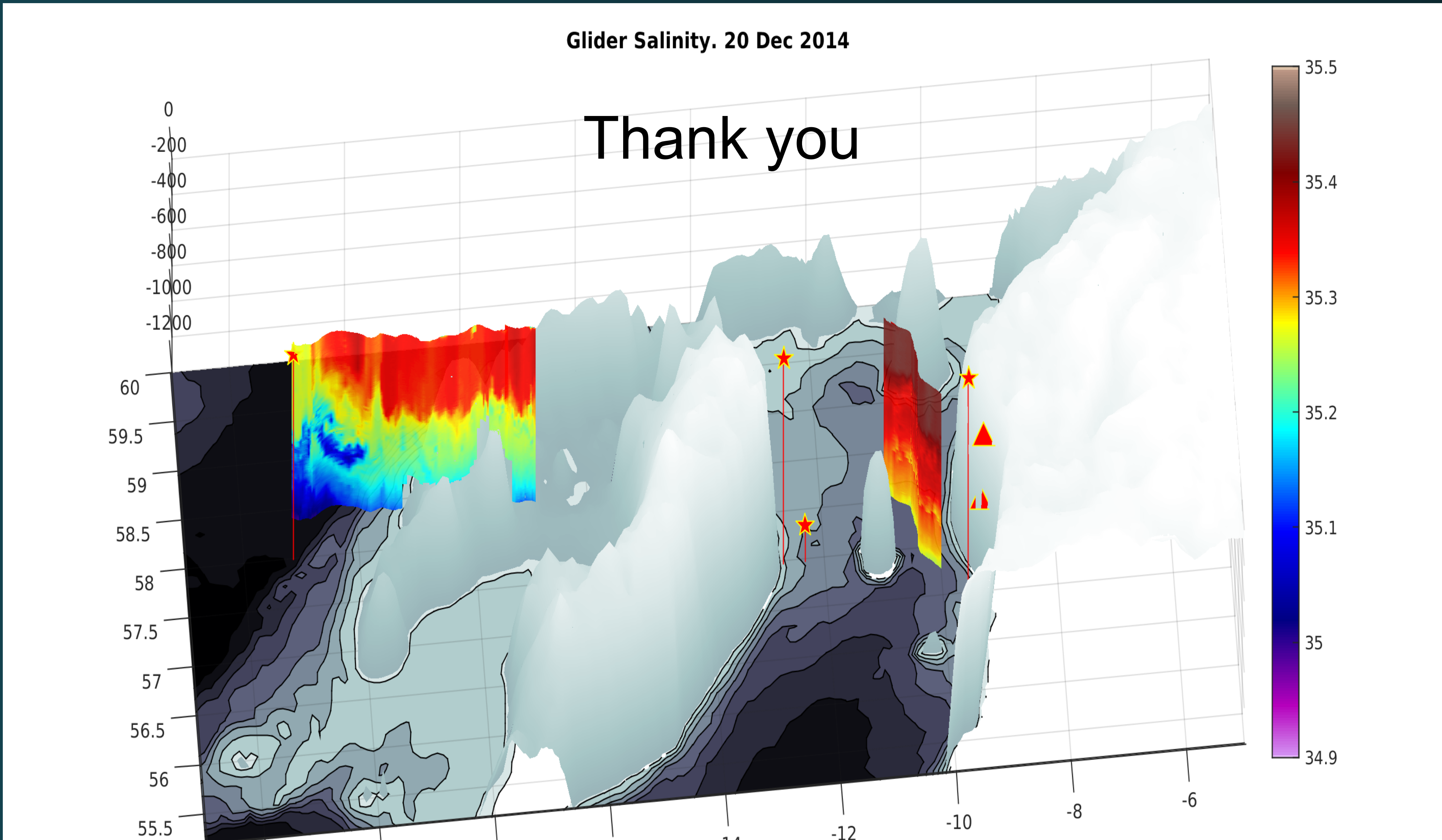
→ due to accuracy of MDT + mapping methodology + altimeter constellation sampling capability ?

NAC transport over Rockall Plateau observed from UK-OSNAP glider





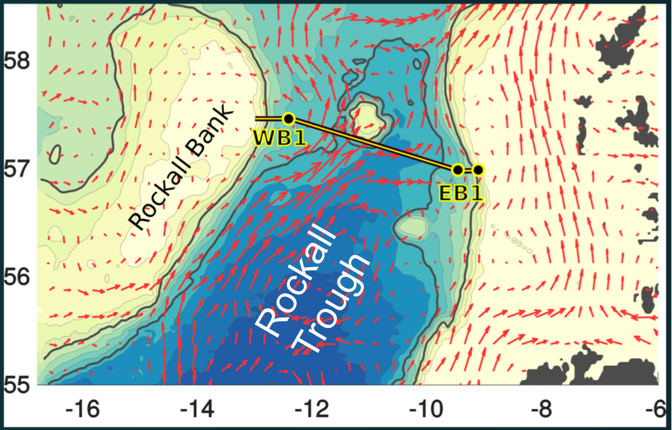
- Two quasi-permanent branches of the North Atlantic Current
- HBJ transport >6Sv consistent with SADCP and hydrographic estimates
- 1/3 of HBJ transport appears to be baroclinic
- RBJ (1.5Sv) & southward flow east of HB not documented before and not completely resolved by altimetry
- 2 glider missions per year funded until at least 2023 as part of the new £22m UK CLASS (Climate Linked Atlantic Sector Science) project

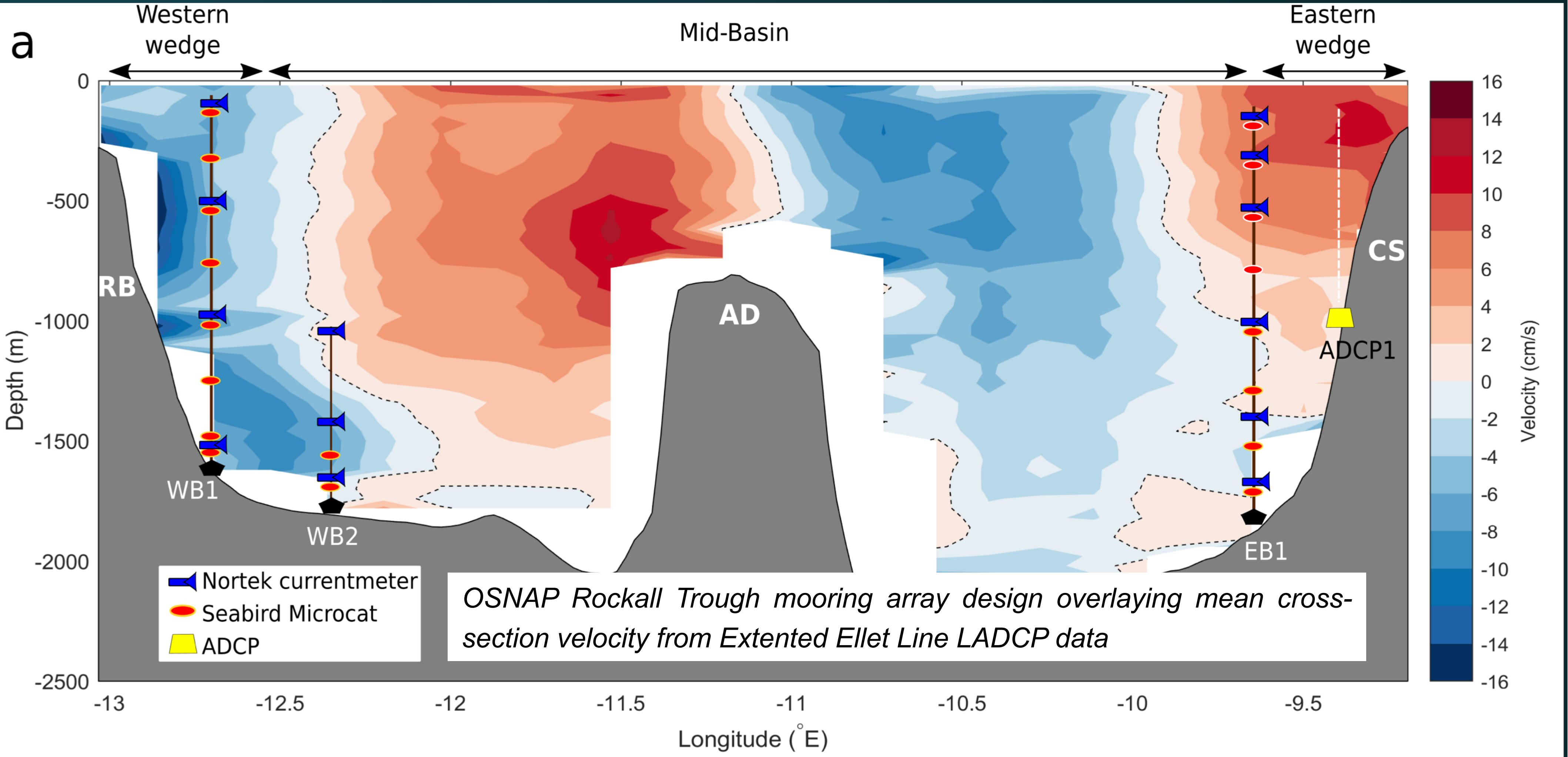

Glider Salinity. 20 Dec 2014
Thank you
0
-200
-400
-600
-800
-1000
-1200
60
59.5
59
58.5
58
57.5
57
56.5
56
55.5
-14
-12
-10
-8
-6
35.5
35.4
35.3
35.2
35.1
35
34.9

The Rockall Trough mooring array

Deployed since July 2014, the main goals are:

- to measure the transport of warm Atlantic Water to the Nordic Seas
- determine the magnitude/variability of the Wyville-Thomson Ridge overflow waters



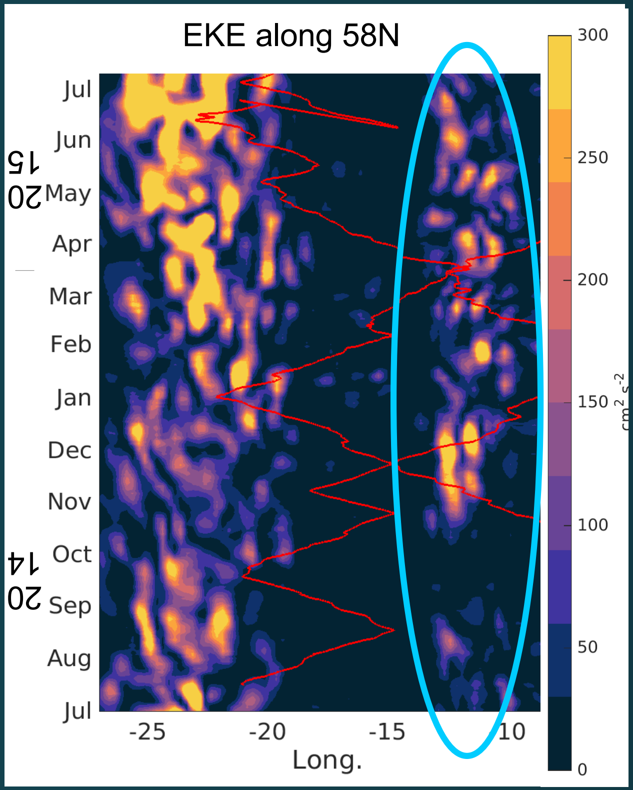


OSNAP Rockall Trough mooring array design overlaying mean cross-section velocity from Extented Ellet Line LADCP data

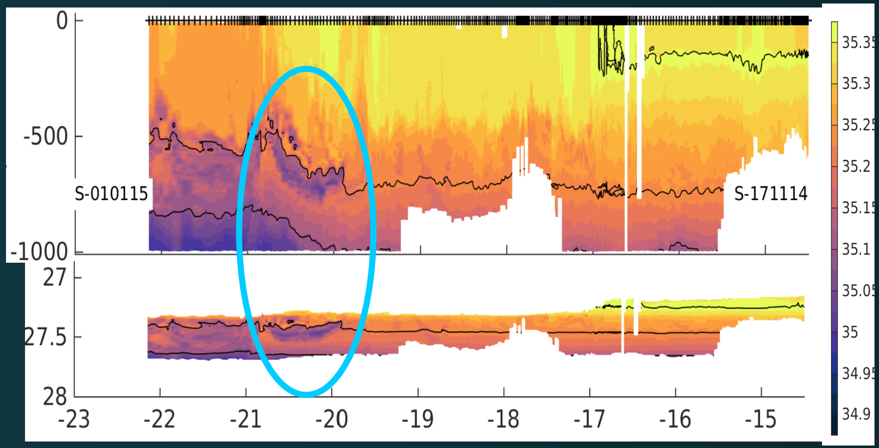
Perspectives meso- / submeso-scale variability

Collaboration with J. Gula (to combine ROMS outputs with high frequency obs)

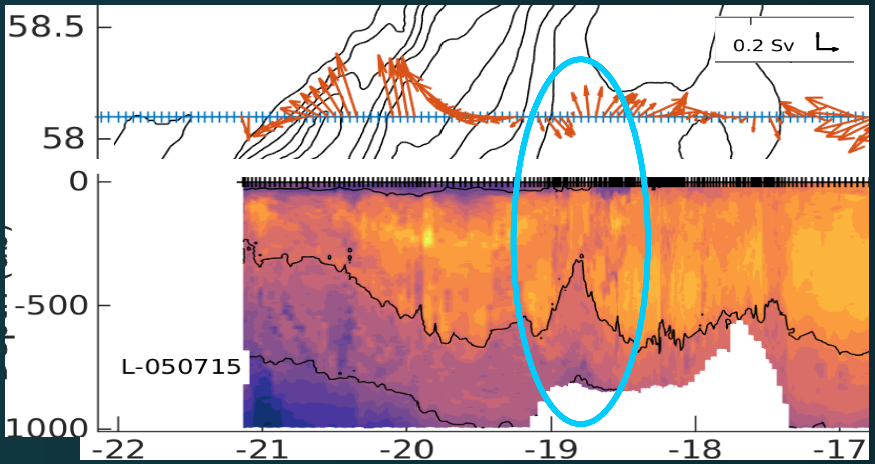
- understand the origin of the mesoscale variability observed in Rockall Trough



- what process drive the small scale variability in T-S below the deep mixed layer in winter?



- submesoscale eddies observed on glider and mooring data (origin, transport of mode/deep water ?)

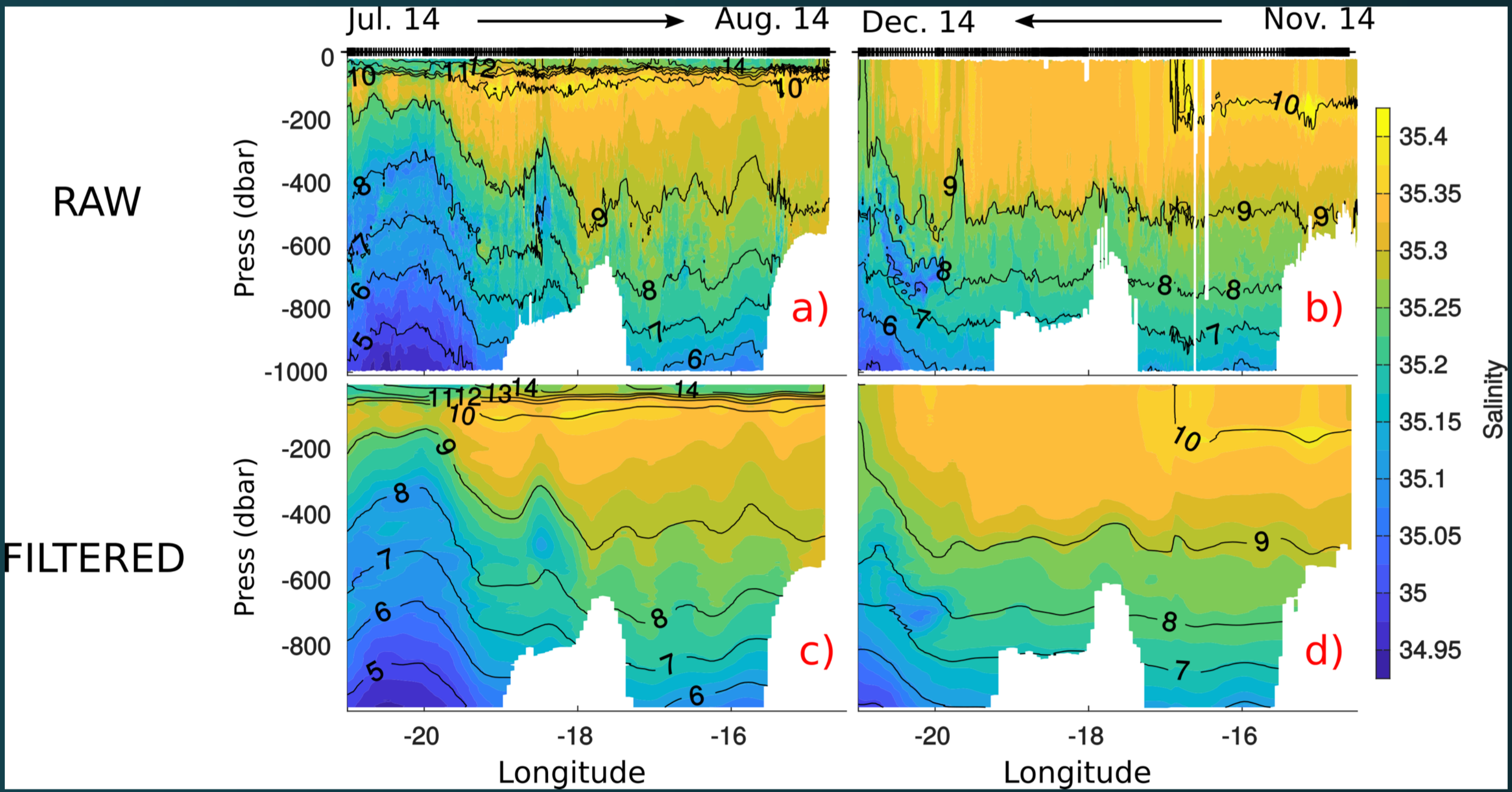


Data processing, filtering

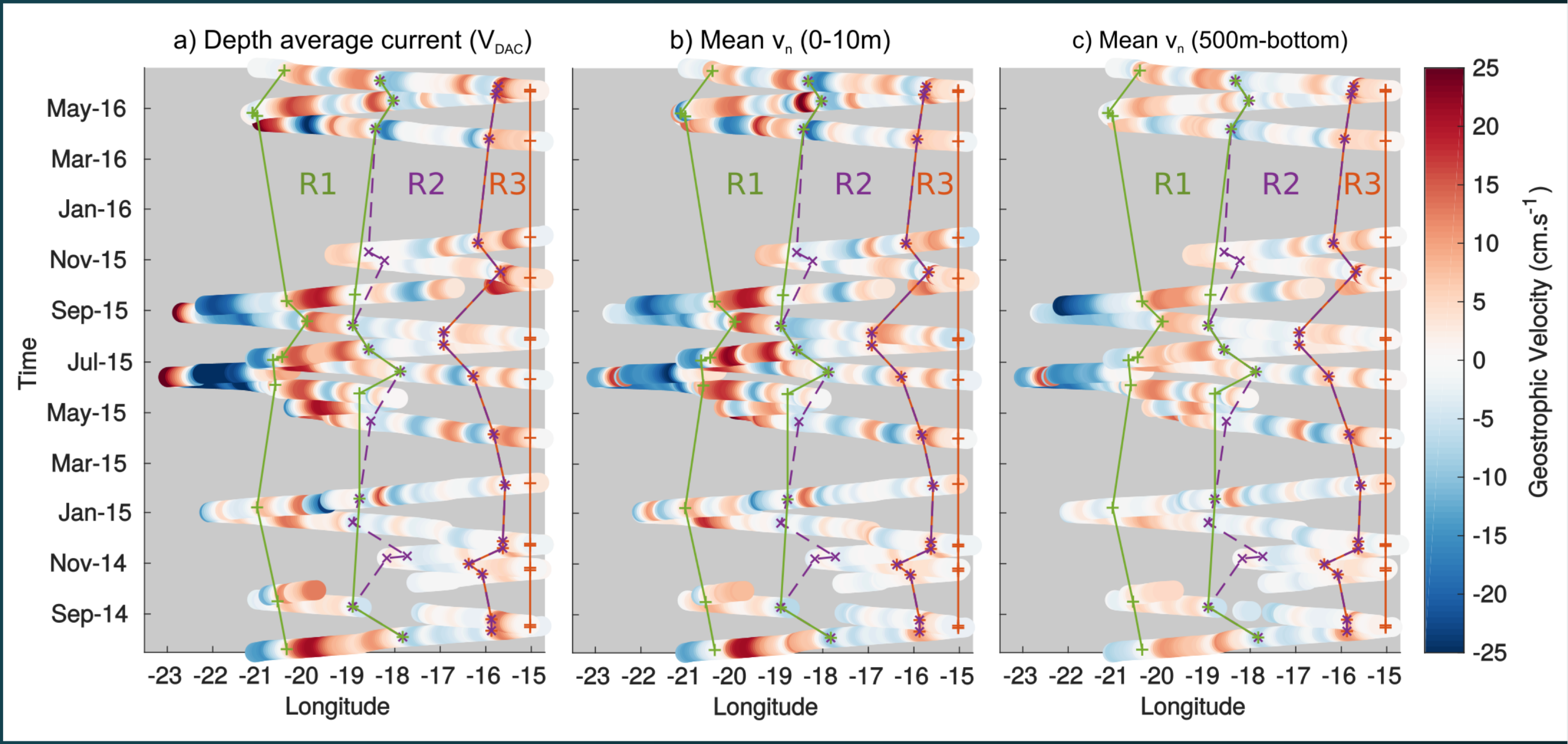
- Data quality control: spikes removed, thermistor lag and thermal-inertia of the conductivity sensor corrections (Seaglider basestation v2.09) ; comparison to climatological data ; manual QC

-Data filtering : gaussian moving average (FWHM : 18km) → filtering out of small-scale isopycnal oscillations (aliased sampling of high frequency internal waves)

DAC mostly geostrophic
- Ekman contribution to the DAC (depth of the dive ~1000m is larger than the Ekman layer depth by 1 order of magnitude),
- Low tides (5cm/s max at 14.5W from 1/12 tide perdition model); HF variability filtered



Absolute geostrophic velocity from glider



Transport uncertainties

3 sources used in a Monte Carlo approach: 100 sections created for each individual section with DAC and pden field randomly perturbed

Glider GPS positioning :
We add to the original GPS positions an error taken from a random exponential distribution, where 95% of the distribution is in 100 meters (exponential rate of 0.0461) [Bennet and Stahr, pers. comm., 2014].

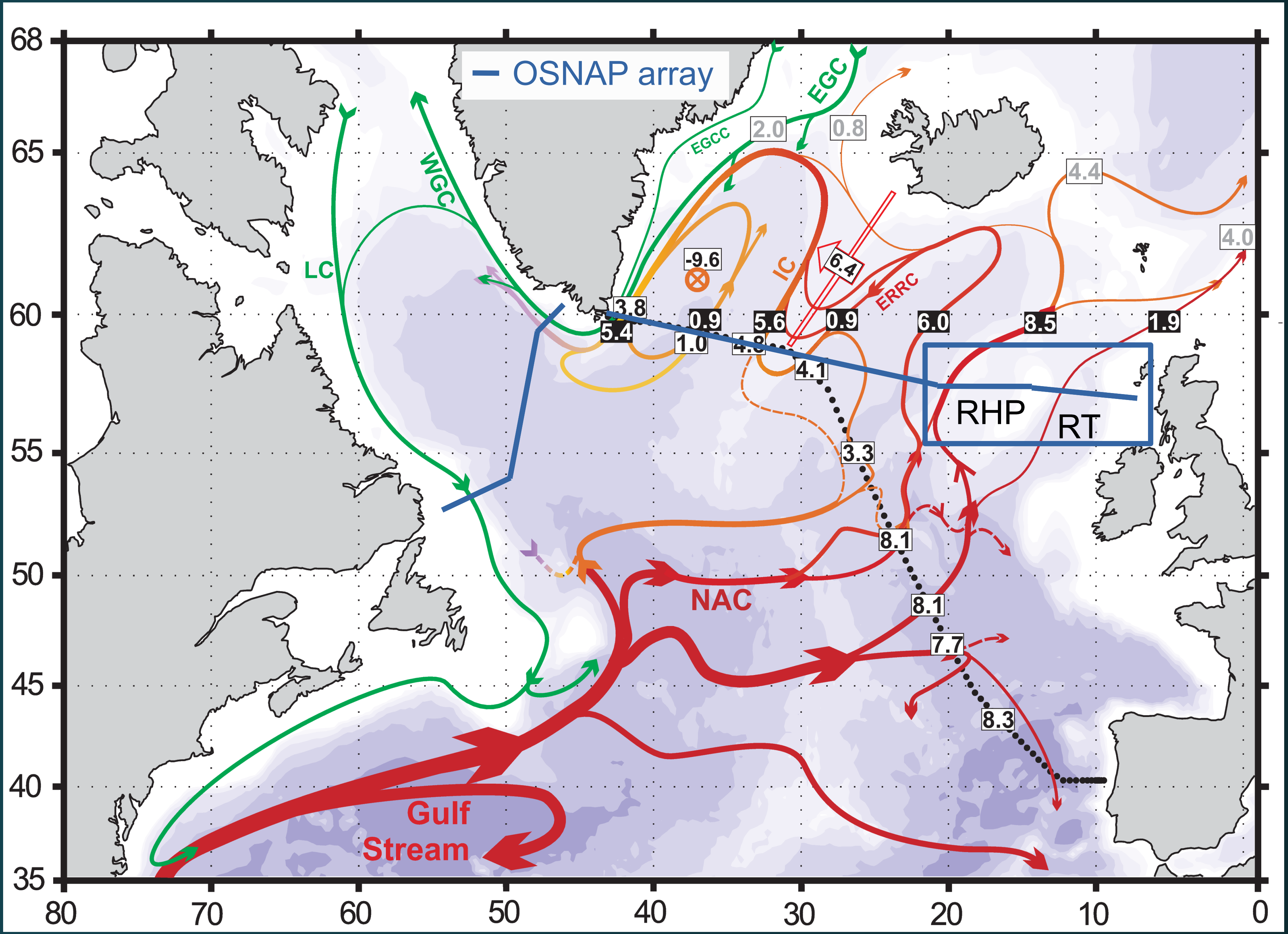
Compass
For each glider section an ensemble of heading errors, taken from a random uniform distribution where the boundaries are determined by the in-land compass checks carried out pre- or post- deployment (table)

CT sensors
Add to the original density field a density drift taken from a random uniform distribution for which the boundaries (± 0.0025 $kg.m^{-3}$ /month) are determined from the typical stability of the CT sensors (<0.001^{O} C/month in temp. and is 0.003/month in salinity, according to Sea-Bird).

Glider compass calibration checks

	OSNAP1		OSNAP2		OSNAP3		OSNAP4		OSNAP5	
Abs. Bearing	Err_{port}	Err_{stbd}	Err_{stbd}	Err_{port}	Err_{min}	Err_{max}	Err_{min}	Err_{max}	Err_{port}	Err_{stbd}
30	-0.5	4.0	-14.0	-13.5	-5.0	3.0	-10.0	10.0	-1.5	5.7
60	1.5	4.0	-9.0	-10.0	0	8.0	-10.0	10.0	4.0	7.0
90	3.5	4.0	-2.0	-3.5	-2.0	6.0	-10.0	10.0	7.5	6.0
120	-1.5	-2.0	2.0	0.5	-5.5	2.5	-10.0	10.0	7.5	2.5
150	2.5	0	14.0	12.0	-3.5	4.5	-10.0	10.0	7.0	0
180	-3.0	-6.0	11.5	10.5	-7.0	1.0	-10.0	10.0	4.0	-3.0
210	-1.5	-5.4	4.5	4.5	-11.5	-3.5	-10.0	10.0	2.0	-5.0
240	-1.5	-2.0	1.0	2.5	-11.5	-3.5	-10.0	10.0	-2.0	-5.0
270	-3.5	-4.0	-1.0	0.5	-13.0	-5.0	-10.0	10.0	-4.0	-4.0
300	-2.0	1.0	-4.5	-2.5	-7.0	1.0	-10.0	10.0	-7.0	-3.0
330	-2.0	2.0	-6.5	-5.0	-6.5	1.5	-10.0	10.0	-7.0	0.5
360	-0.5	4.0	-7.5	-7.0	-1.5	6.5	-10.0	10.0	-5.0	4.0

Upper Ocean circulation from altimetry and cruise



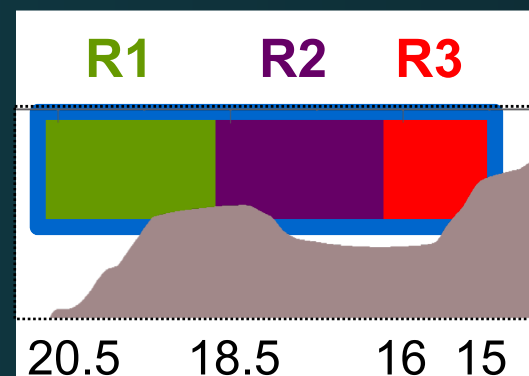
From Daniault et al., 2016

Importance of the barotropic component

$$\iint_{ection} \mathrm{v}_n(z)\,dx\,dz = \iint_{section} \mathrm{v}_n(-H)\,dx\,dy - \iint_{section} \left(\frac{g}{\rho_0 f} \int_{-H}^{z} \frac{\partial \rho}{\partial s} dz \right) dx\,dz$$

Φ_{abs} = Φ_{BT} (barotropic) + Φ_{BC} (baroclinic)

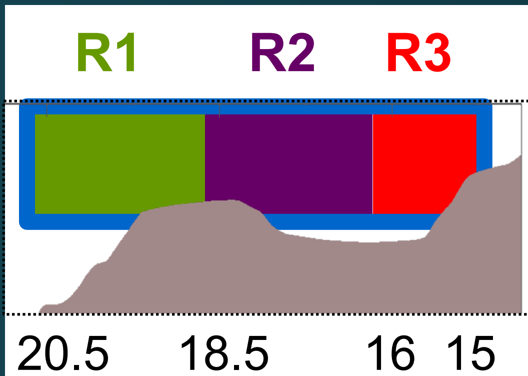
Mean ratio Φ_{BC}/Φ_{abs} from 10 *summer (MJJASO)* sections :



- R1 : Φ_{BC}/Φ_{abs} = 0.3 (std : 0.2) → $\Phi_{BC} \sim 1/3\ \Phi_{abs}$
- R2 : Φ_{BC}/Φ_{abs} = 0.0 (std : 0.3)
- R3 : Φ_{BC}/Φ_{abs} = 0.0 (std : 0.2)

(R2, R3) → $\Phi_{abs} \sim \Phi_{BT}$

Transport as a function of depth and density



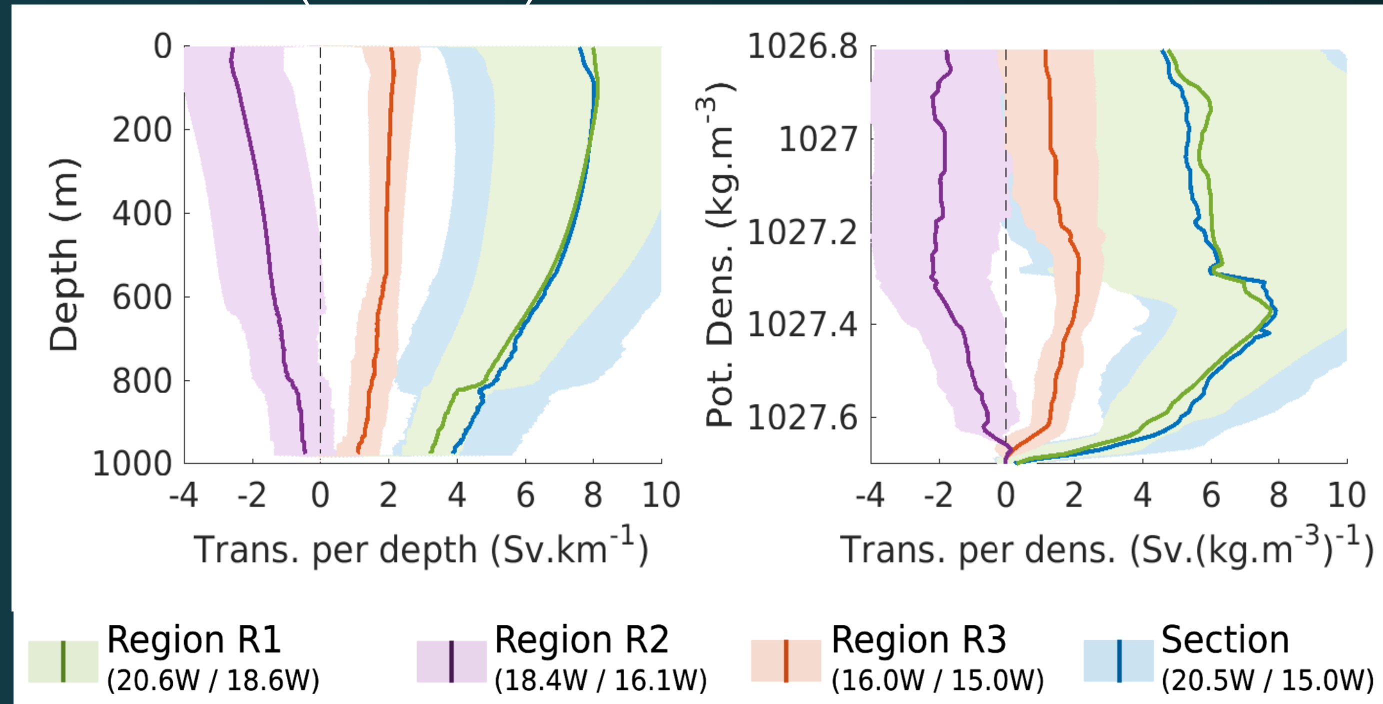
- Max mean trans. for 27.3-27.4 $kg.m^{-3}$
-> mode water (SPMW)

- 2.5Sv transport decrease in R1 in winter

- In Winter, low transport of North Atlantic Water (ρ<27.3 kg/m^3) due to SPMW formation

The heterogeneity in regional transports due to the low number of winter sections (4), not surveyed exactly at the same time

« Summer » (MJJASO) sections



« Winter » (NDJFMA) sections