From historical climatology to near-real time data

Mapping ocean physics using scattered observations and robotic gliders

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1. Comparing historical data climatologies to glider observations

e.g. Potential Energy Anomaly (strength of stratification, Simpson et al., 1990)

$$\phi = \frac{g}{h} \int_{z=bottom}^{z=surface} (\rho_{depth\ mean} - \rho)\, z\, \partial z$$

Depth of maximum buoyancy frequency (primary stratification depth, e.g. Carvalho et al., 2017)

$$N^2 = -\frac{g}{\rho_{ref}} \frac{\delta\sigma\theta}{\delta z}$$

Seasonal climatology

September average from climatology

Robotic glider mission (sept 2016)
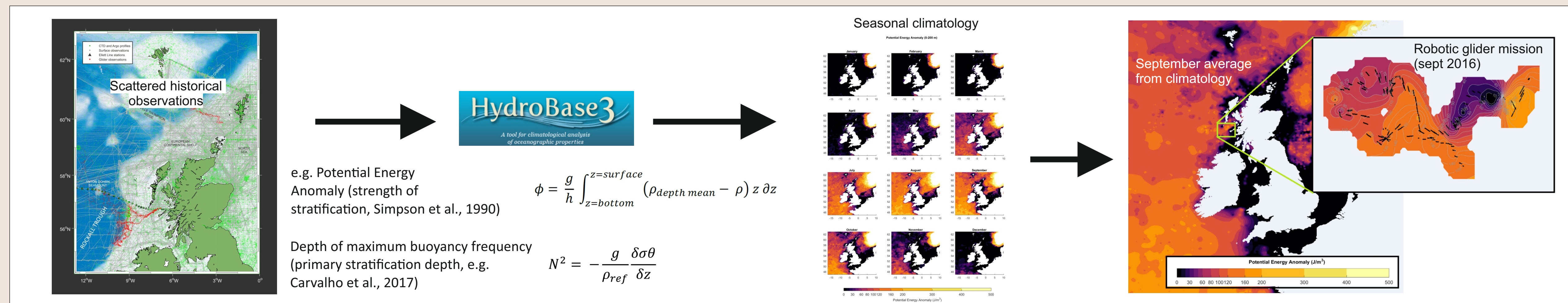
MASSMO (Marine Autonomous Systems in Support of Marine Operations) is a pioneering multi-partner series of trials and demonstrator missions that aim to explore the UK seas using a fleet of innovative marine robots. For these large-scale exercises, in collaboration with DSTL and BODC we are developing the capability to ingest near-real time glider data in the industry standard EGO file format, compute water column diagnostics and output as GIS layers. To contextualise the glider data, climatologies were generated from historical observational data using Hydrobase3 (e.g. Lozier et al., 1995). These layers can be displayed in a mission portal in combination with other data streams to aid situational awareness and decision-making.

## 2. Near-real time diagnosis of water column properties from robotic glider fleets
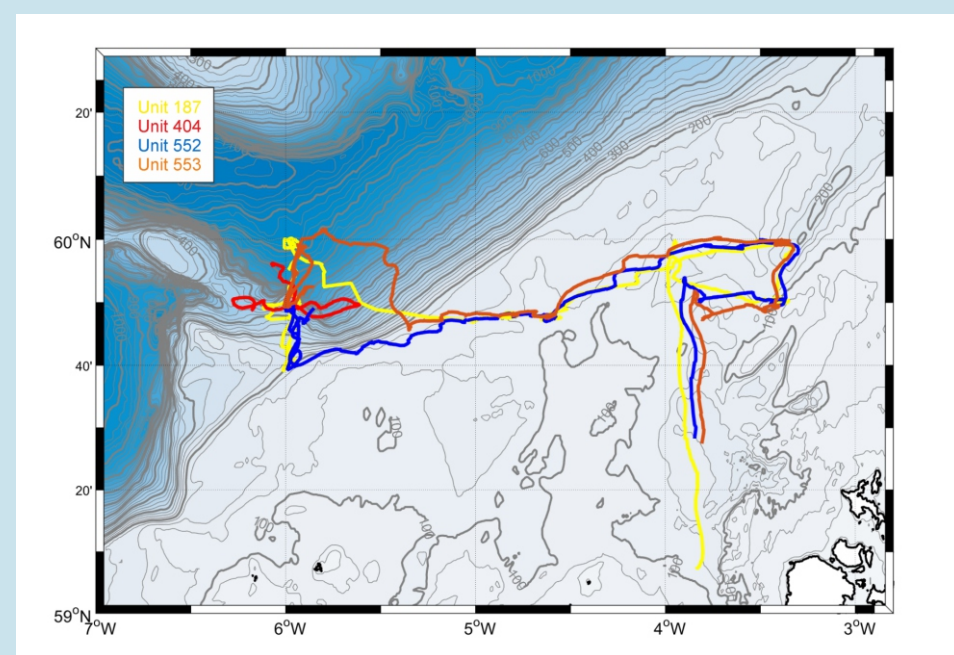
MASSMO 4 operations area in Faroe-Shetland Channel

The motivation for this work was to increase the value and utilisation of Marine Autonomous Systems (MAS) through data synthesis. Several metrics for characterising the internal structure of the water column were developed, focusing on properties such as the depth of primary stratification and the strength of stratification. Once these metrics were calculated for individual glider profiles, they were spatially mapped using the GMT mapping package (Smith & Wessel 1990). The approach is adaptive to data density, so the addition of glider observations can dramatically increase the resolution of the mapped surfaces.
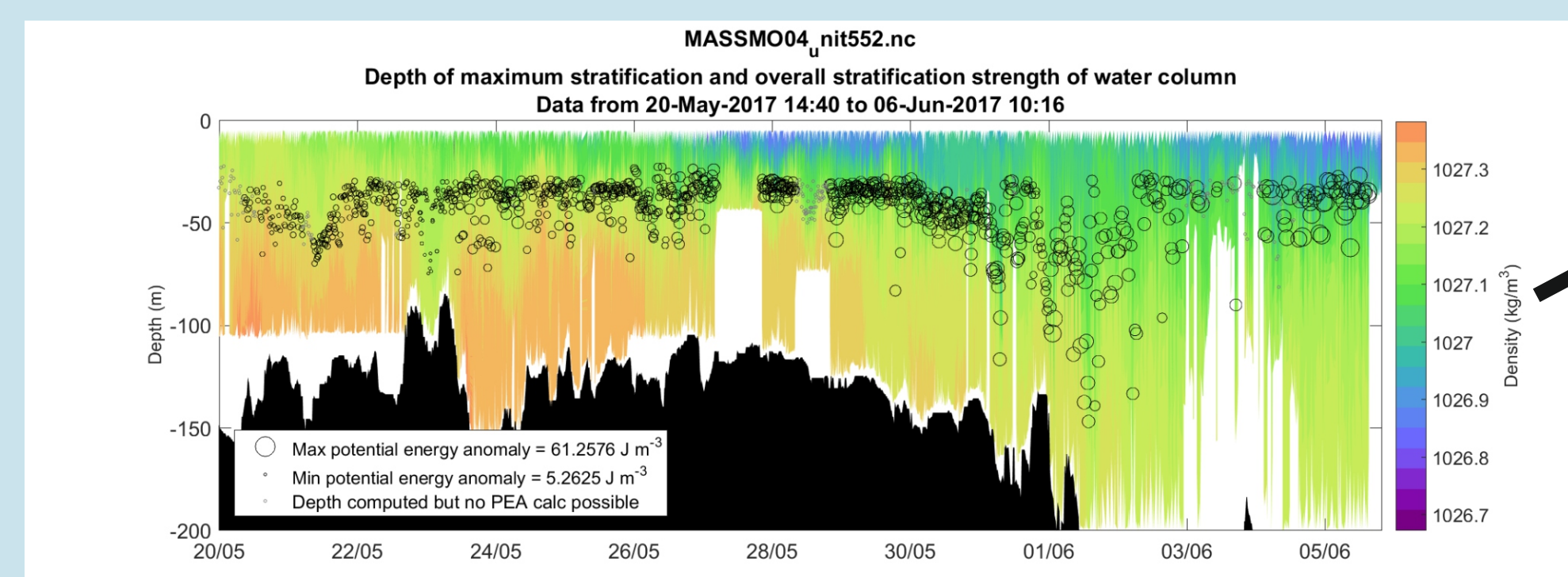

A glider density section with the depth of maximum stratification (N²) highlighted. Circle size shows strength of water column stratification for each profile.

10 m temperature

10 m salinity

0-200 m Potential energy anomaly

Depth of maximum N²
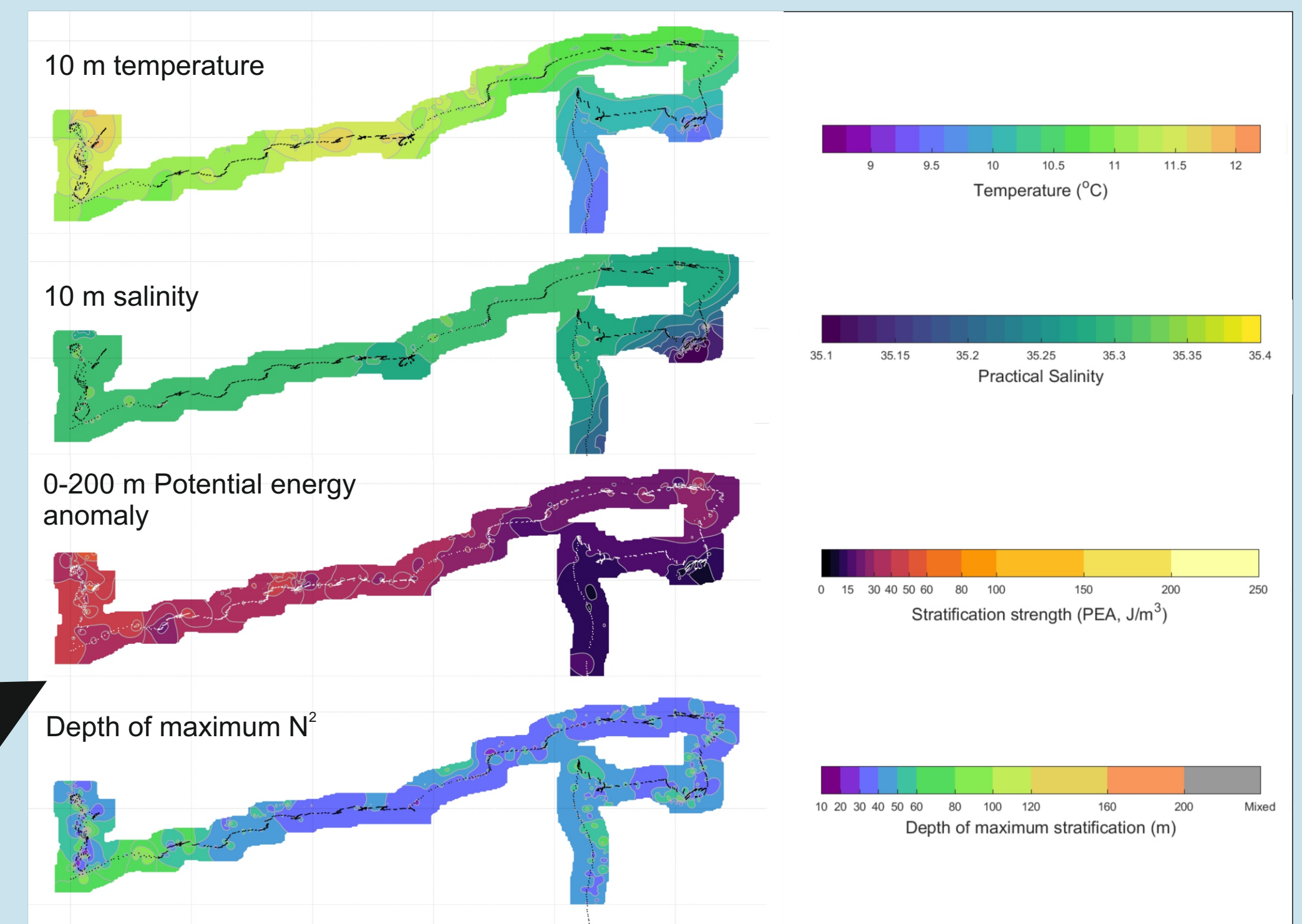
Examples of high resolution mapped surfaces fitted to glider data in near-real time using the Hydrobase and GMT packages.
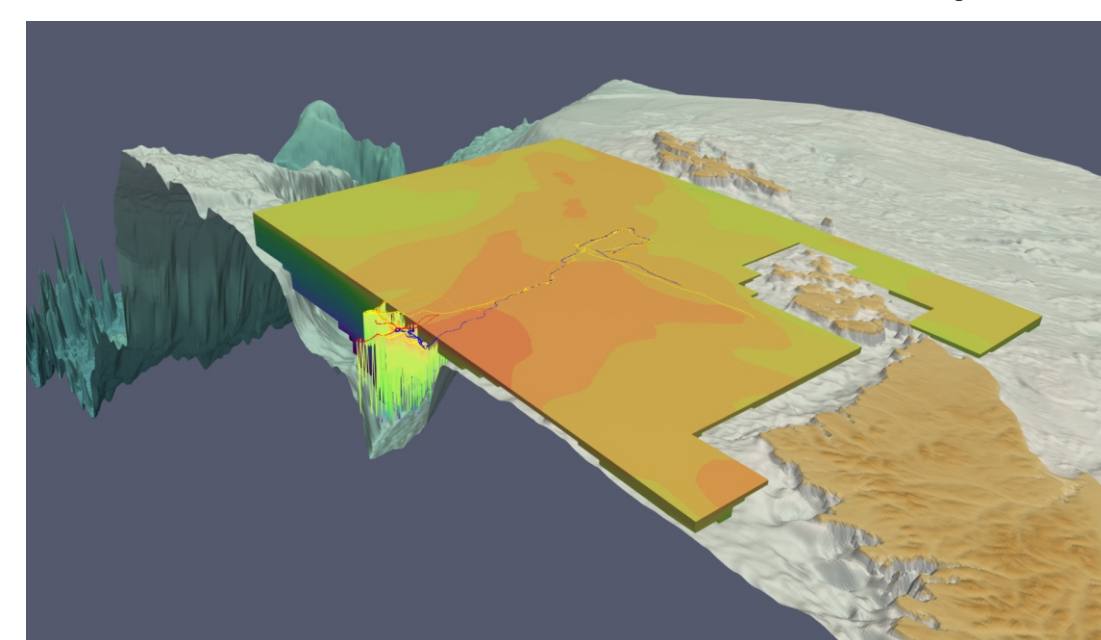
3. Further work
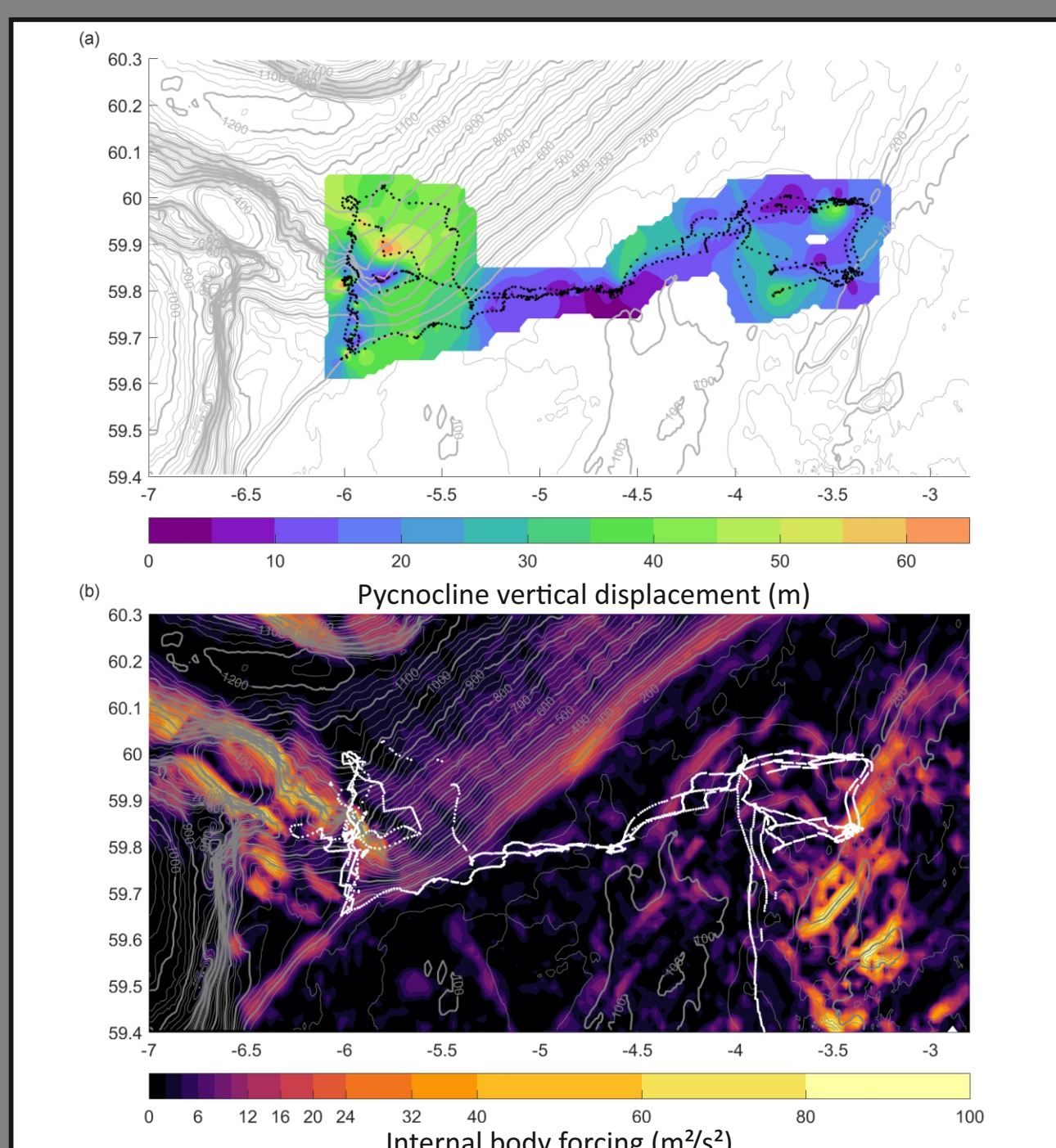
a) Observed pycnocline vertical displacement from 4 simultaneous glider occupations compared to b) predicted regions for internal wave generation in the Faroe-Shetland Channel. Modelled parameters derived from AMM60 (Guihou et al., 2018).

The vertical displacement of isopycnals can indicate internal wave activity, an important mechanism for energy transfer and mixing on continental shelf slopes (Nash et al., 2004). Using observations of pycnocline depth, we are developing an algorithm to identify patterns consistent with internal waves in glider profiles. The scattered estimates of wave amplitude are spatially mapped using GMT.

Paraview / Python framework for ocean data

Paraview is an open-source data analysis and visualisation application with a Python backend. It enables the display and exploration of complex 3D / 4D datasets. This makes it a potentially powerful tool for synthesising the datastreams from multiple robotic vehicles in a dynamic ocean environment. We aim to automate the import of BODC NetCDF files into Paraview to enable a real-time 3D interface to be hosted on a remote server.

No ipad?
For more information on Paraview for ocean data, see samcjones.com/data-visualisation/
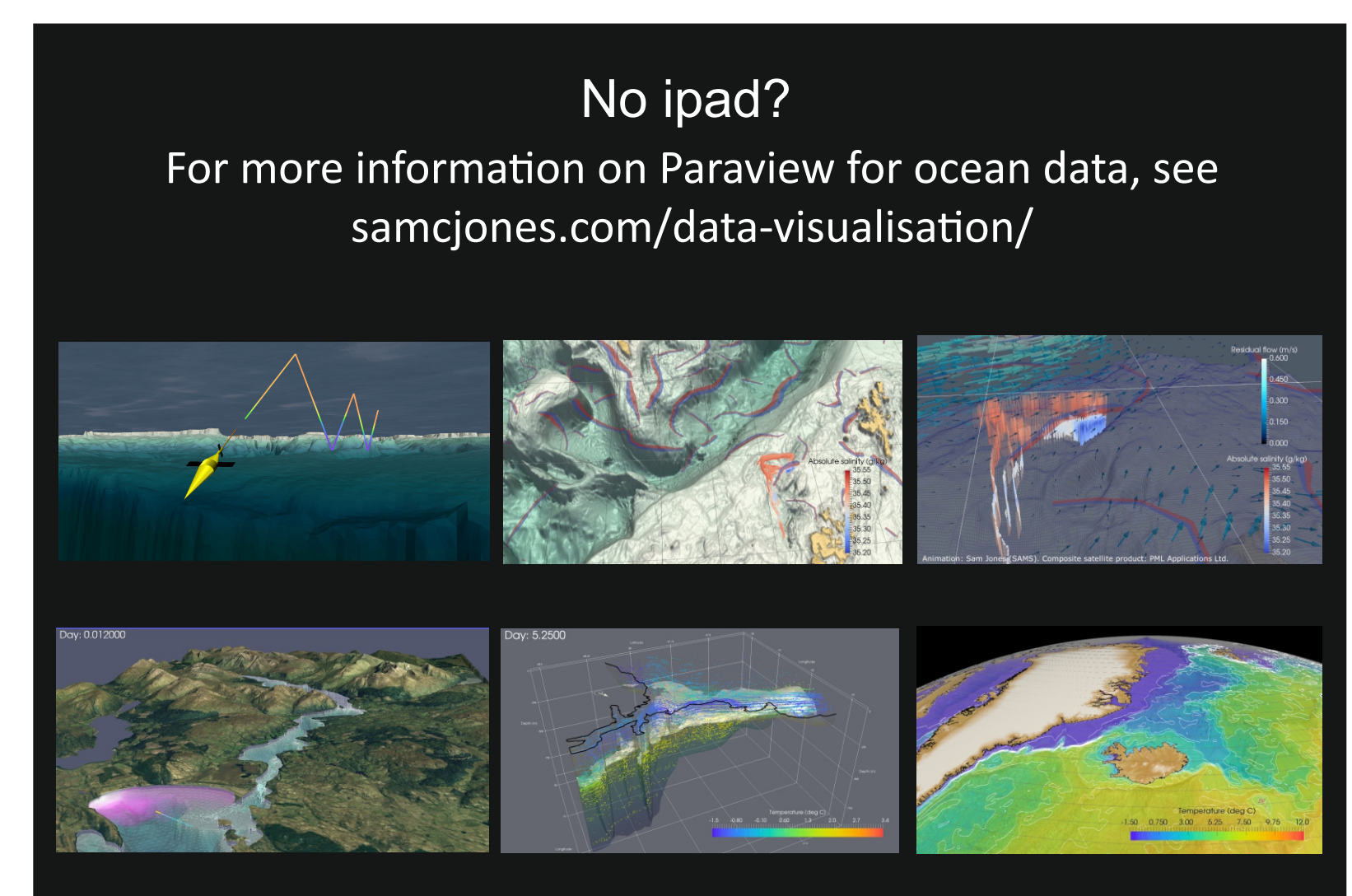
References

Carvalho, Filipa, et al. 2017. "Defining the ecologically relevant mixed layer depth for Antarctica's Coastal Seas." Geophysical Research Letters.

Guihou, K., Polton, J., Harle, J., Wakelin, S., O'Dea, E. and Holt, J., 2018. Kilometric scale modeling of the North West European shelf seas: exploring the spatial and temporal variability of internal tides. Journal of Geophysical Research: Oceans, 123(1), pp.688-707.

Nash, J. D., E. Kunze, J. M. Toole, and R. W. Schmitt (2004), Internal tide reflection and turbulent mixing on the continental slope, J. Phys. Oceanogr., 34, 1117–1134

Lozier, M. Susan, W. Brechner Owens, and Ruth G. Curry, 1995. The climatology of the North Atlantic. Progress in Oceanography 36.1: 1-44.

Simpson, Brown, Matthews and Allen, 1990. Tidal straining, density currents and stirring in the control of estuarine stratification, Estuaries, 13(2), 125-132

Smith, W. H. F., and P. Wessel. Gridding with continuous curvature splines in tension, 1990. Geophysics 55.3: 293-305.

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