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Long- and short-term glider observations of Atlantic inflow into the northwestern North Sea

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Quantifying the volume of water flowing into the North Sea and understanding the temporal variability of its physical and biogeochemical properties is essential for understanding, modelling and managing the ecosystems of the North Sea. The JONSIS section is a zonal hydrographic section in the northern North Sea that crosses the path of the main northwestern inflows of Atlantic water, the Fair Isle Current (FIC) and the East Shetland Atlantic Inflow (ESAI). An autonomous underwater glider was deployed along the section between 12th October and 2nd December 2013, during which time ten occupations (three to five days per occupation) were competed. Physical and biogeochemical observations are used to understand short-term variability of the FIC and ESAI. Four water masses, from coastal and oceanic regions, are identified from the physical and biogeochemical observations. We use the observations to determine the relative contributions of the observed water masses to the FIC and ESAI. At the beginning of the glider deployment, water masses are distinguished by both their temperatures and salinities. Towards the end of the deployment, once surface heat loss has reduced temperature differences between water masses, we find that they may still be distinguished by their salinities. Volume transport over the period of each occupation is derived from geostrophic shear referenced to the glider's dive-average currents. Transport is consistently southward (i.e. inflow to the North Sea) and varies from a minimum of 0.22 Sv (1 Sv = 10^6 m^3 s^{-1}) to a maximum of 0.85 Sv. Volume transport is dominated by wind-driven flow, with thermohaline flow (driven by horizontal density gradients) representing, on average, approximately 30% of the total. Spatially, the inflowing velocity is sometimes constant across the section; at other times, the inflows are present as two separate jets. We use these results to update previous knowledge of circulation in the region, based on observations of limited temporal and spatial resolution, and to demonstrate that the circulation that is more variable on weekly timescales than previously thought. Biogeochemistry is investigated using the glider's optical sensors. Chlorophyll concentration is higher over offshore, stratified waters than in well-mixed, near-shore waters. A turbidity maximum is consistently observed in sub-thermocline bottom waters, which we hypothesise is caused by tidal re-suspension of sediments.