Denmark Strait Circulation Scheme In An Eddy-resolving Model

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1. INTRODUCTION

Denmark Strait Overflow Water, one of the main components of the thermohaline circulation in the North Atlantic, is a complex mixture of water masses. There has been no consensus yet on where it is formed and by which way it is brought to the strait. Here we analyze water properties, pathways and transports of dense overflow with particular attention to the North Icelandic Jet, recently observed to have a key role in the formation of the overflow.

MODEL: Eddy-resolving (1/16°) configuration of the Nordic Seas embedded in an eddy-permitting (1/4°) regional sea ice/ocean model of the Arctic-North Atlantic Ocean. Horizontal resolution: ~4 km. Grid: 664x704x46. Results: 1994-2011 mean fields are shown here.

NEMO framework: OPA ocean, LIM2 sea ice, AGRIF adaptive mesh refinement (two-way nesting, sea ice refinement included).
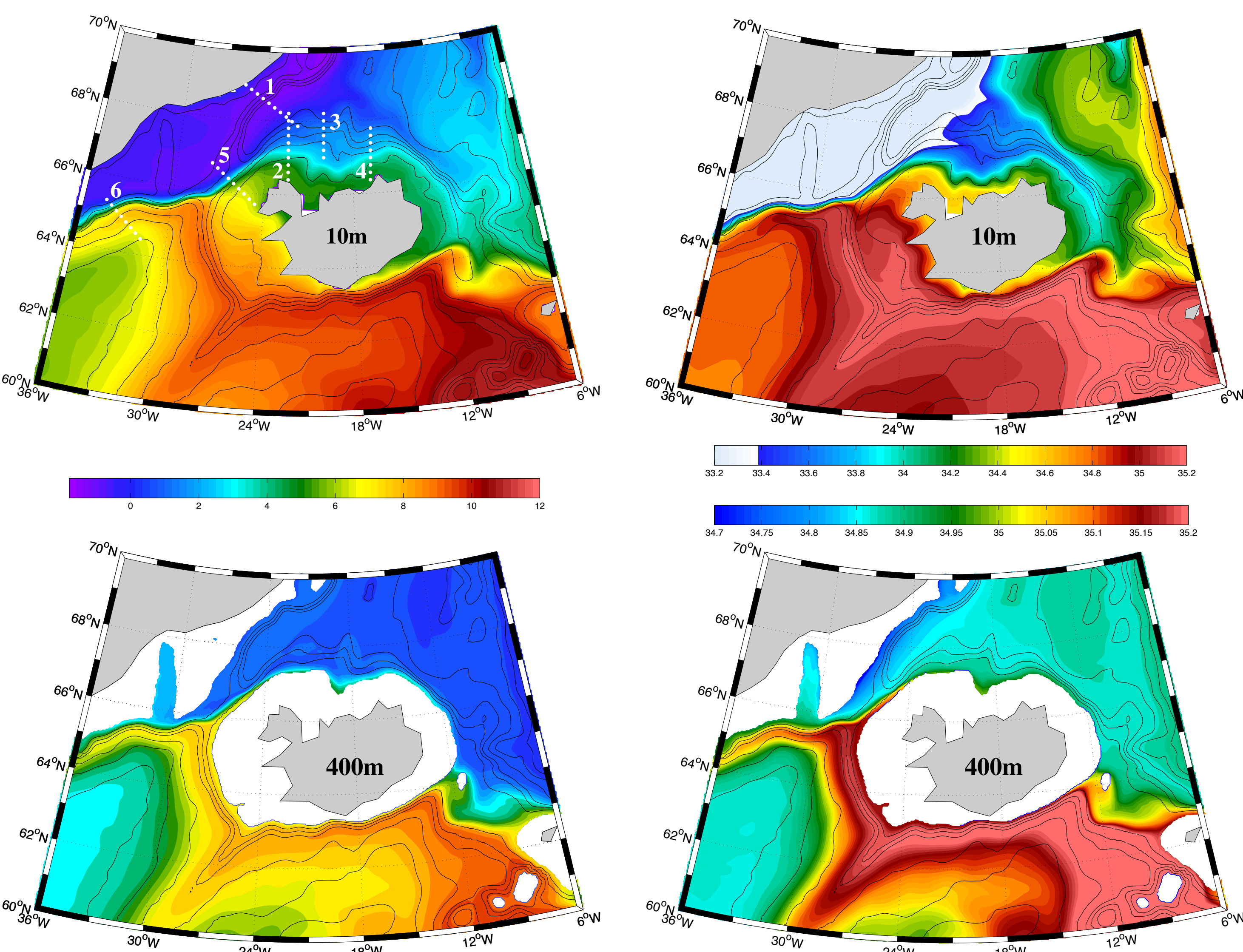
Surface Forcing: ERA-Interim atmospheric reanalysis from 1989 to 2011.
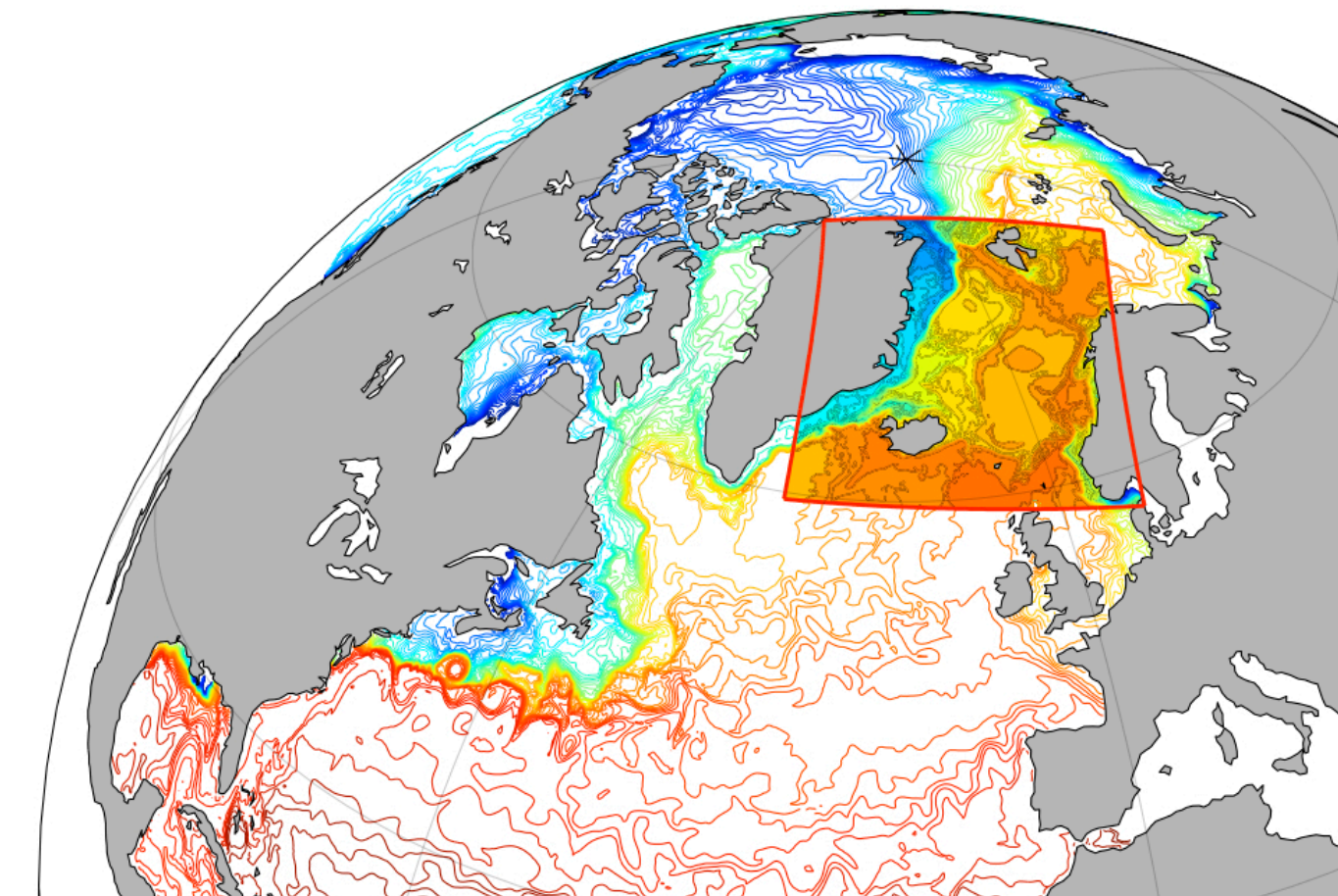
Sea Surface salinity as simulated in the 1/4° and 1/16° models. The red rectangle indicates the nested domain.

2. MEAN HORIZONTAL CIRCULATION

Schematic of the ocean circulation: **Atlantic inflow**, **Polar water**, **overflows** and **coastal current**.

IC – Irminger Current   EIC – East Icelandic Current
NIIC – North Icelandic Irminger Current   DSOW – Denmark Strait Overflow Water
EGC – East Greenland Current   NIJ – North Icelandic Jet

General notion: the Nordic Seas cyclonic boundary current system has a main role in the transformation of the inflowing warm Atlantic water into the dense overflow and the EGC is the main pathway supplying the DSOW.
Recent concept (ref. 1): the NIJ, a barotropic current flowing westward along the continental slope north of Iceland, accounts for roughly half of the total DSOW. The formation of the NIJ is strongly connected to lateral exchanges between the NIIC and the interior Iceland Sea.
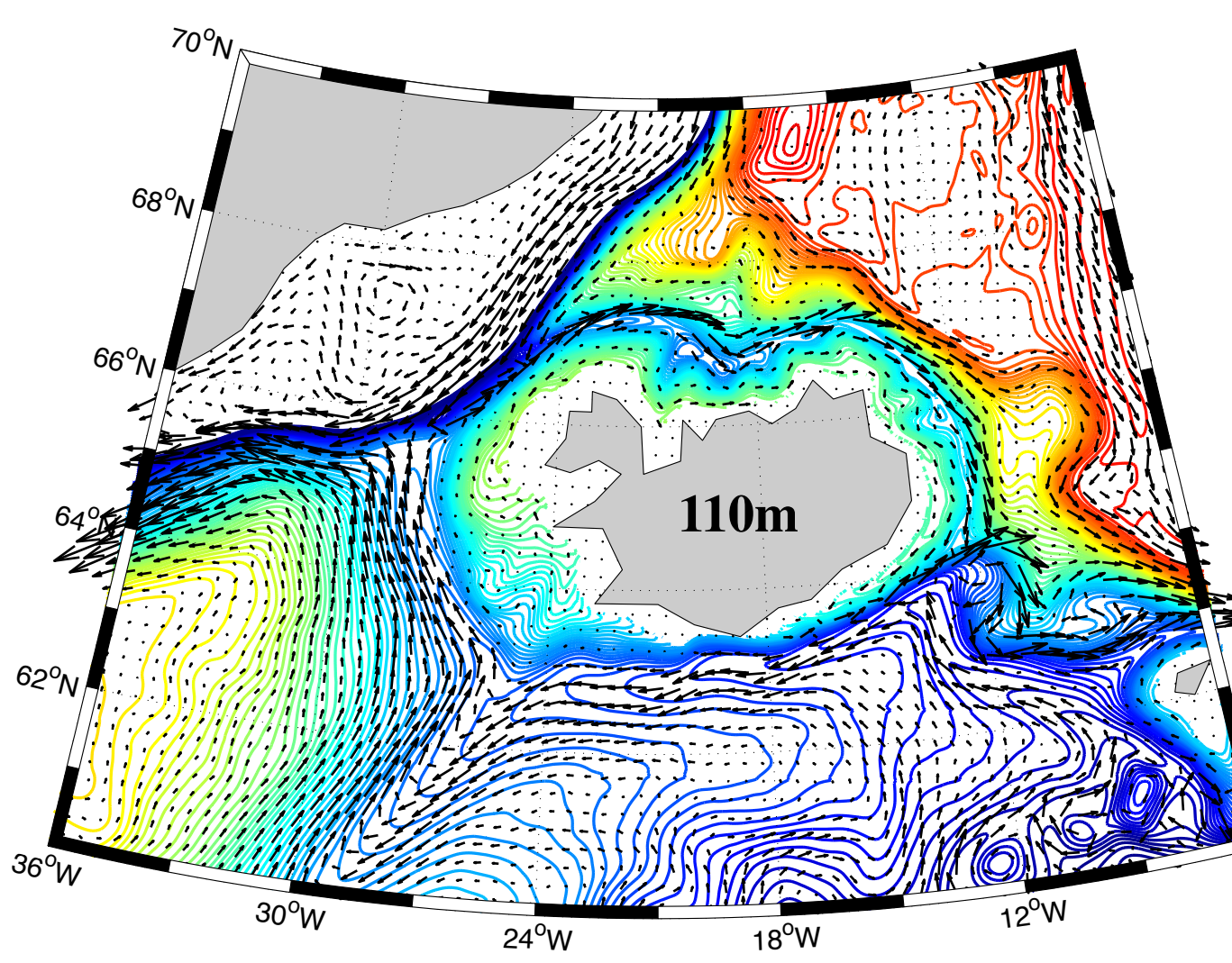
Simulated time-mean currents around Iceland at two different depths, 110 and 400 m. Colored contours represent the density field.

At 110m: Polar water in the EGC flowing south-westward on the East Greenland shelf. Atlantic inflow northward through Denmark Strait and then NIIC eastward north of Iceland (a great part of the flow is topographically steered).
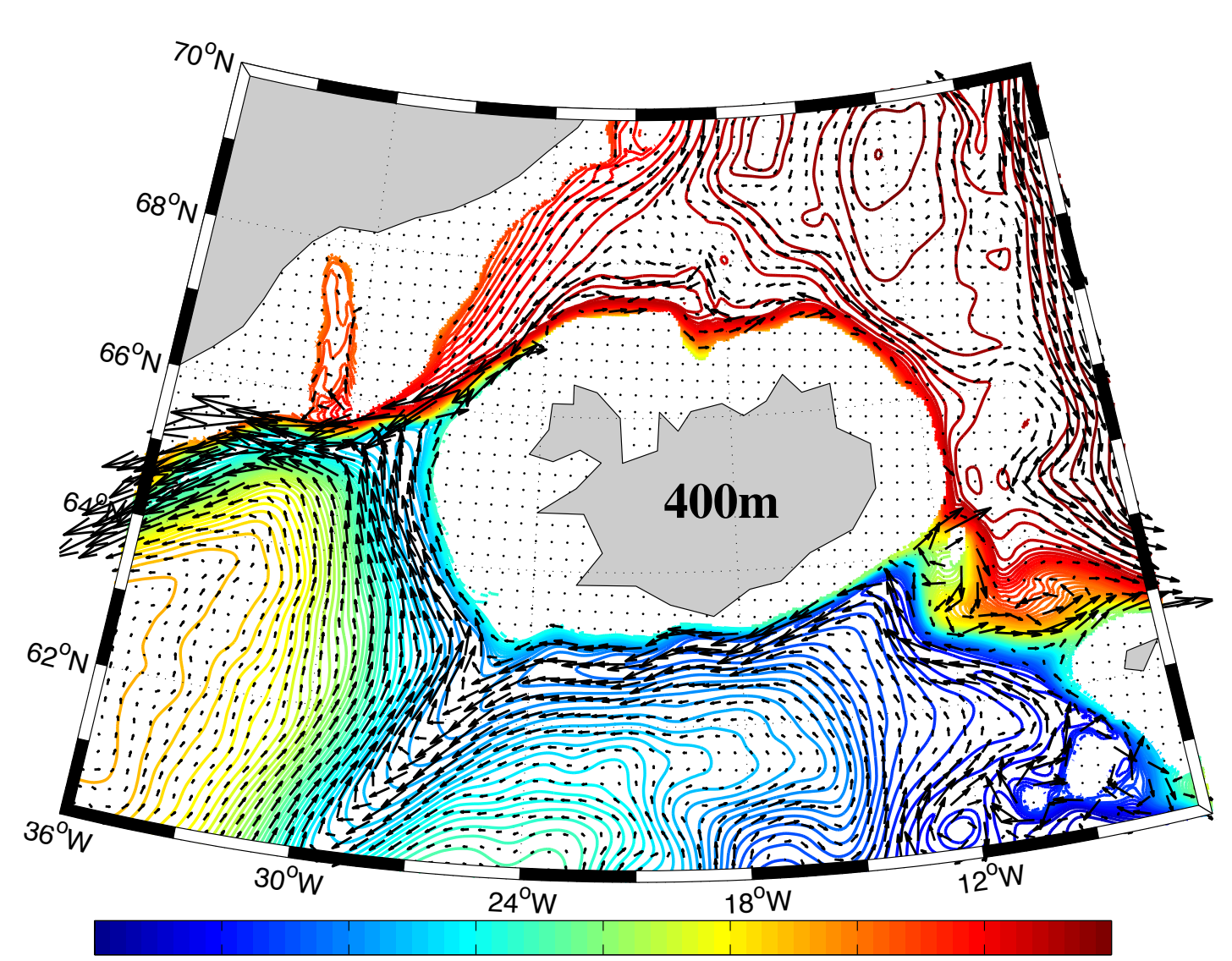
At 400m: EGC contribution to the overflow flowing along the Greenland shelf. NIJ tightly on the northern Icelandic slope flowing towards the strait (topographic steering evident at ~19°W), characterized by a small range of density (27.8 – 28 kg m^{-3}). Intense dense overflow southward across the strait.

3. WATER MASSES

Time-mean temperature (°C, left) and salinity (right) at 10 and 400 m depth. Bottom topography in black (contour intervals 200 m (500 m) above (below) to 1 km. White numbers and lines indicate the analysis sections.

Mean properties of the overflow waters across analysis sections. NIIC and EIC water masses are indicated.

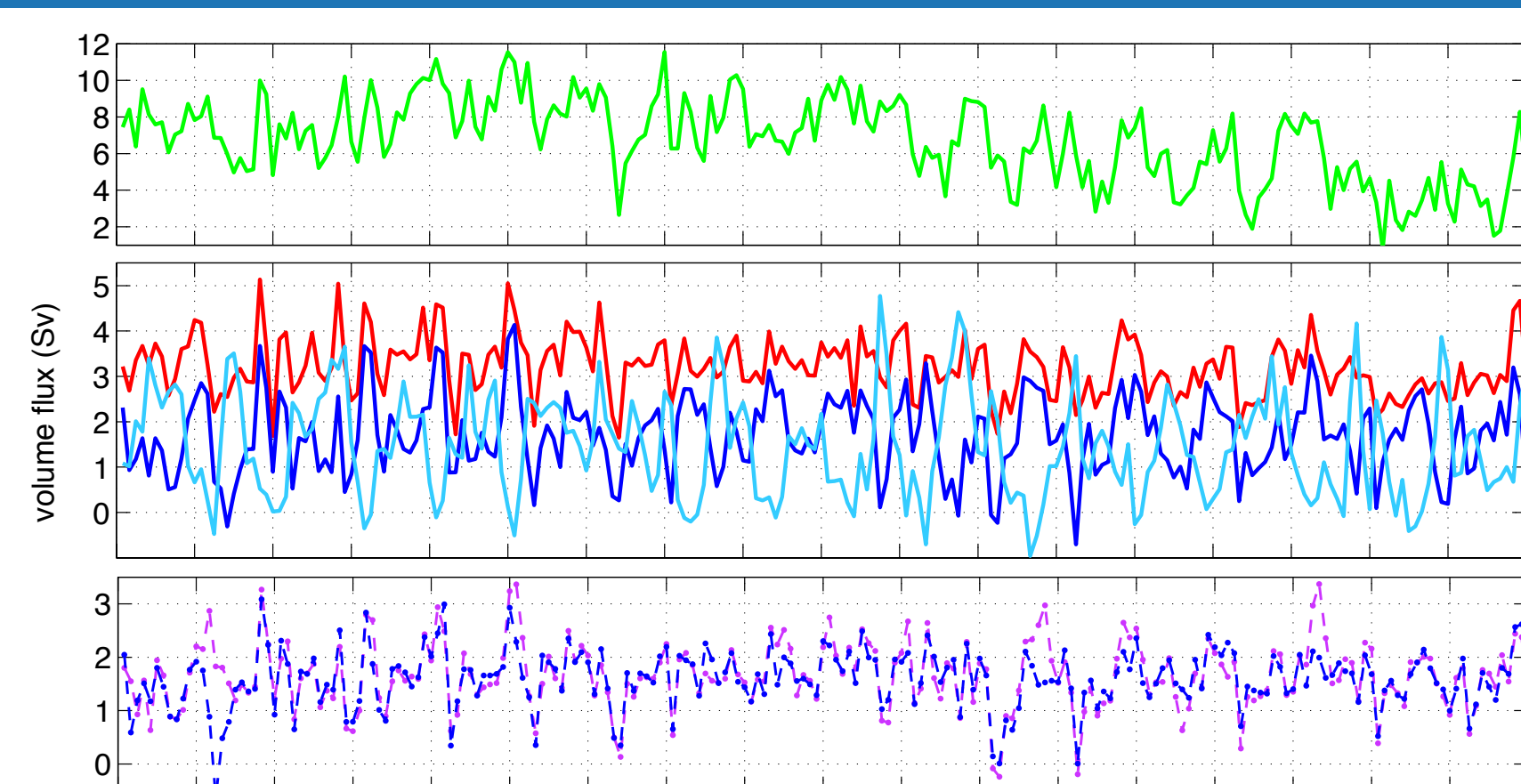| Current and locations	NIJ sec 2	NIJ sec 3	NIJ sec 4	DSOW sec 5	DSOW sec 6	NIIC sec 2	EIC sec 4
Temperature (°C)	0.38	0.21	0.32	1.18	2.21	6.1	2.74
Salinity	34.88	34.87	34.87	34.89	34.91	34.86	33.90

No seasonal variability is present in the water mass properties of the DSOW.

4. TRANSPORTS

Total mean transport of dense overflow across the Greenland Scotland Ridge is 5.7 Sv [~6 Sv observed, 1 Sv = 10^6 m^3 s^{-1}]. 3.33 Sv passes through Denmark Strait [3.1-3.7 Sv observed for the period 1999-2003, 2.9 ± 0.5 Sv for 2008-2009].

Mean NIJ transport increases as the current flows westward toward Denmark Strait. Dependence of the zonal transports of the NIJ, due to downwelling or mixing of the NIIC into it. The simulated NIJ flux is 1.68 Sv at ~20°W (section 3) [1.5 ± 0.2 Sv observed].

Mean NIIC transport is 1.42 Sv at sec 2 (~1Sv observed).

Time series of volume fluxes of dense water (σ >27.8 kg m^{-3}) at different sections. Total DSOW at section 5. Contributors: light blue = EGC at section 1, blue = NIJ at section 2. Violet (blue) dotted line = NIJ at section 3 (4). Green = dense water at section 6. Mean values are below in the table with NIIC inflow and EIC fluxes.
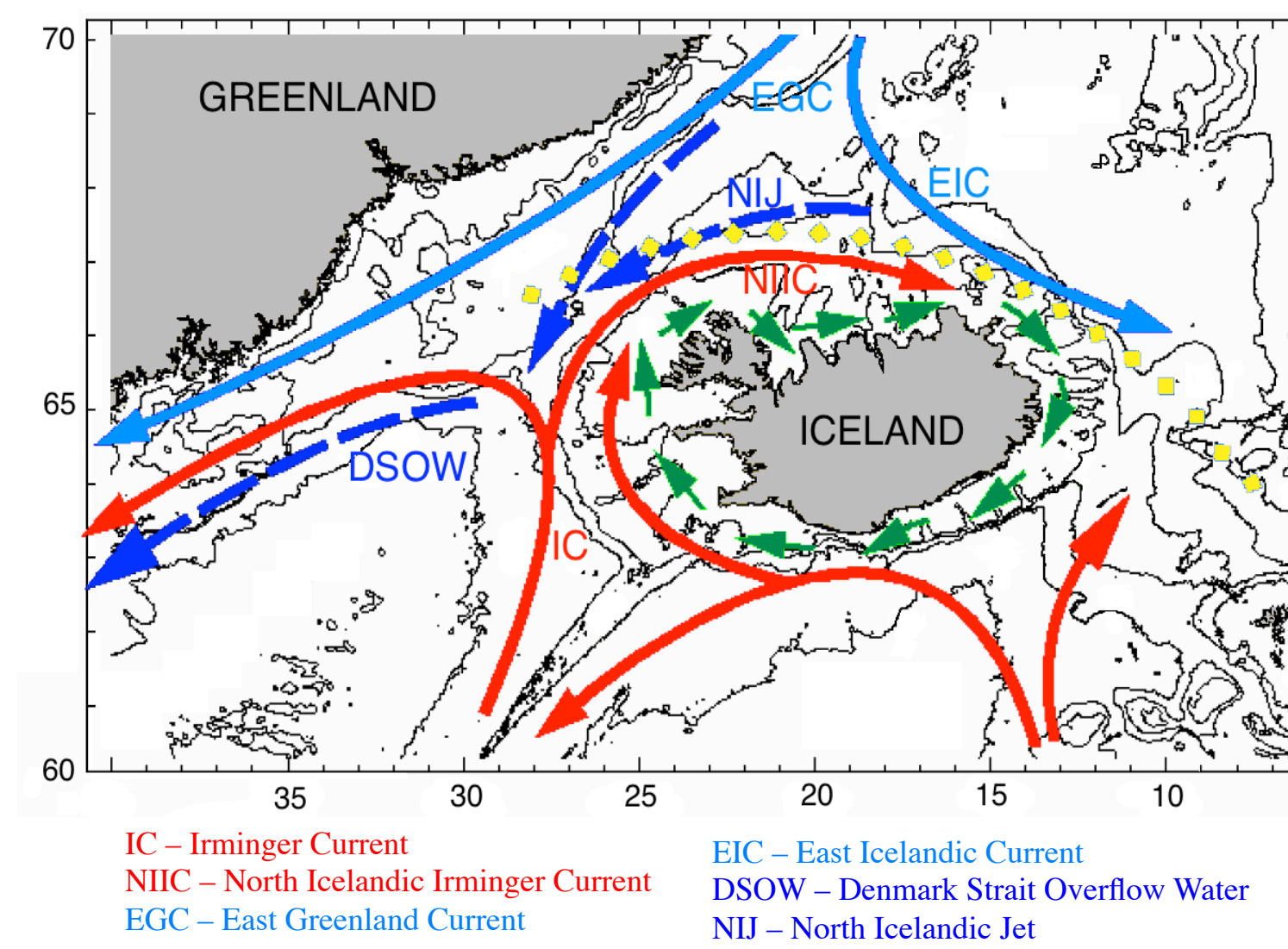
| NIJ sec 2	NIJ sec 3	NIJ sec 4	DSOW sec 5	EGC sec 1	DSOW sec 6	NIIC sec 2	EIC sec 4
1.71	1.68	1.59	3.3	1.51	7.22	1.42	1.36

5. VERTICAL STRUCTURE OF THE CURRENTS

The NIIC is positioned over the Icelandic continental shelf and reaches a maximum depth of ~300 m. Its core is located between 50 and 250 m depth. The NIJ is persistent over the northern Icelandic continental slope from 15°W toward the Denmark Strait. There is no signature of the NIJ on the northeast of Iceland. The jet has its maximum velocity (~10 cm s^{-1}) at ~20°W (section 3), with a time-mean velocities of ~6 cm s^{-1} as it approaches the sill.
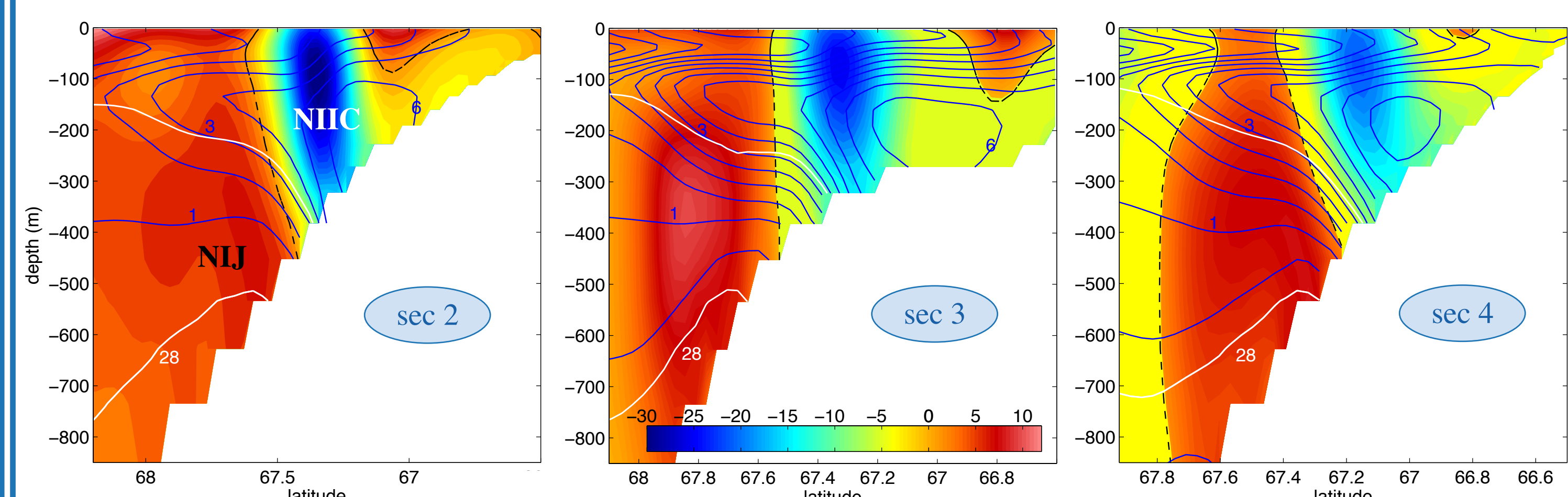
Mean zonal current (in cm s^{-1}) along the North Icelandic slope from section 2 to 4. Positive values denote westward flow. σ = 27.8 and 28 kg m^{-3} isopycnals are in white. Isotherms (°C) are in blue.

Mean flow (in cm s^{-1}) across sections 5 and 6. Positive values denote southward flow. σ = 27.8 kg m^{-3} isopycnal in white. Isotherms (°C) are in blue.
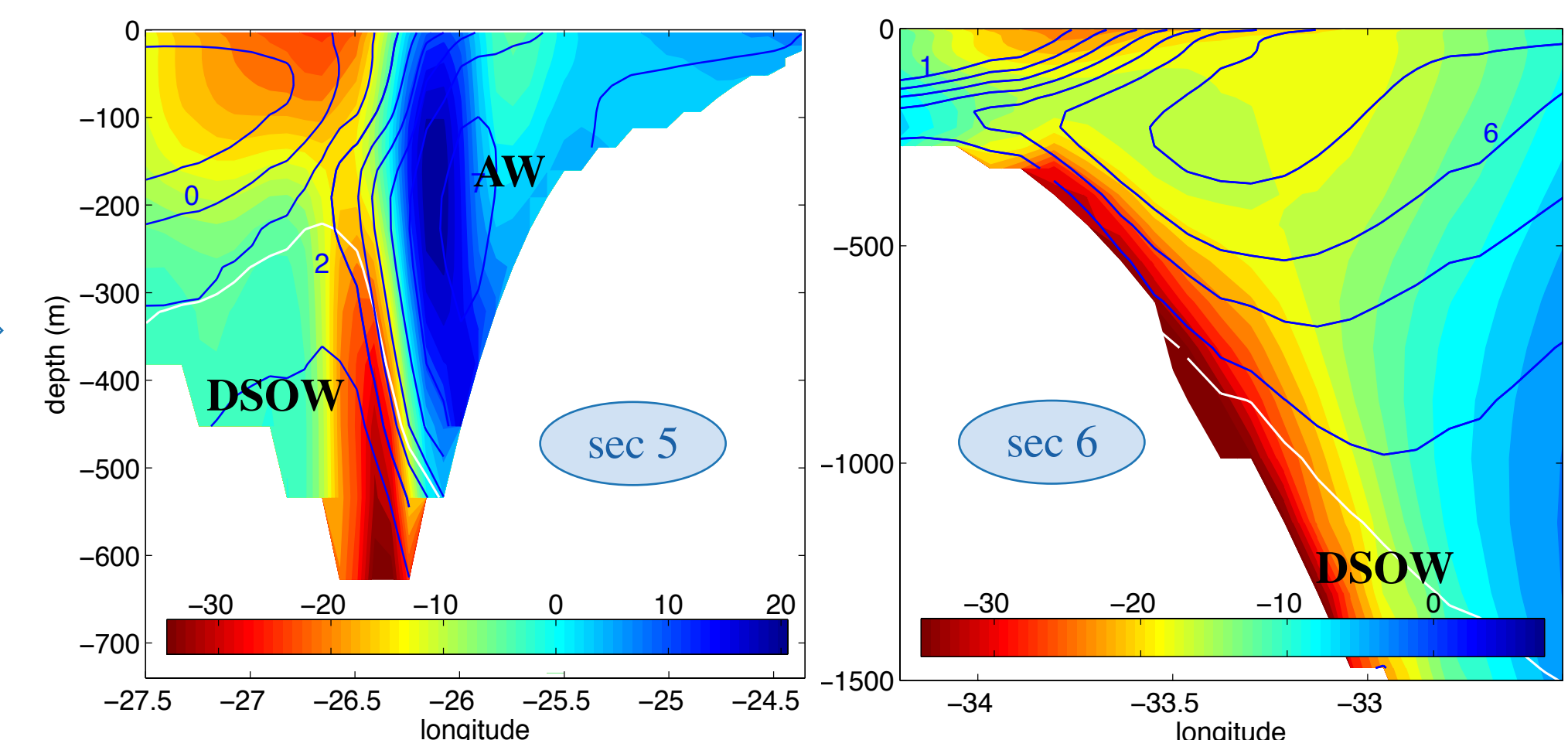
Velocity and potential density fields observed across section 2 in August 2011 (left, *ref. 4*), across Denmark Strait (middle) and section 6 (right) during October 2008 (*ref. 2*).