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The South Icelandic Current

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Summary

The circulation of Icelandic waters is simulated by the three-dimensional ocean model CODE. The high resolution simulation reveals several new insights into the regional oceanography. Thus, the northward transport of Atlantic Water over the Icelandic shelf, from the Irminger Sea and the Iceland Basin into the Nordic Seas, is simulated as a symmetrical system of two currents, with the established North Icelandic Irminger Current (NIIC) over the north-western and northern shelf, and a hitherto unnamed current over the southern and south-eastern shelf, denoted here as South Icelandic Current (SIC). Both currents are driven by barotropic pressure gradients induced by a sea level slope across the Greenland-Scotland Ridge. Being an upstream precursor of the Faroe Current (FC) the SIC is simulated to be an energetic flow with a mean volume flux of around 2 Sv south-east of Iceland which clearly differs from the wider, sluggish flow of the North Atlantic Drift east of it. With an additional numerical experiment the NIIC/SIC structure is reproduced by an idealised model setup which illuminates its basic dynamics.

Introduction

Iceland is located at the intersection of the Mid-Atlantic Ridge and the Greenland-Scotland Ridge. This topography, together with the basin-scale wind field and the meridional gradient of the air-sea heat flux, is responsible for the complex hydrography of Icelandic waters whose predominant characteristic is a zonal thermal front, the Arctic Front, separating cold Arctic waters north of the Greenland-Scotland Ridge from the warmer Atlantic Water to the south. Southwest of Iceland the Irminger Current (IC) carries Atlantic Water towards Denmark Strait. Here, a small part of the current ($\approx$ 1.5 Sv) branches off, passes the strait and forms the NIIC which flows eastwards over the North Icelandic shelf. Northeast of Iceland the near-surface circulation is dominated by the East Icelandic Current (EIC) which carries around 2 Sv of Arctic and Polar waters south-eastwards. Below the EIC and NIIC a deep counter current, the North Icelandic Jet (NIJ), exists which carries deep Arctic Waters onto the Denmark Strait sill, this way providing the densest part of the Denmark Strait Overflow. However, the knowledge about the circulation southeast of Iceland is still very limited and numerous, partly conflicting, schemes are still in use.

Materials and Methods

The ocean model CODE (Logemann and Harms 2006; Logemann et al. 2012) was used to simulate the North Atlantic flow, temperature and salinity fields covering the time period 1992 to 2006. The model's computational mesh was adaptively refined in Icelandic waters reaching here a maximum resolution of 1 km horizontal and 2.5 m vertical. The atmospheric forcing was provided by the NCEP/NCAR re-analysis fields. Icelandic river runoff data was taken from the output of the hydrological model WaSiM operated by the Icelandic Meteorological Office. 16,802 conductivity-temperature-depth profiles recorded in Icelandic and Faroese waters during the simulated time period were extracted from the NISE data set and assimilated into the simulation by using the technique of incremental analysis updating. A series of sensitivity experiments was carried out in order to determine the role of the different physical processes in forcing the currents. Furthermore, addressing the Rossby adjustment problem (Rossby 1937; 1938; Hsieh and Gill 1984), the idealised case of a circular island (radius: 210 km) in the centre of a rectangular ocean basin (side length: 1600 km, depth: 3000 m) surrounded by a shelf and placed on a stationary zonal density front (density contrast: 0.5 kg m^{-3} over 30 km) is solved numerically and analysed.

Results and Discussion

The simulated 1992–2006 mean flow field shows a general dominance of an eastward flow around Iceland caused by the different sea level height between the Atlantic Water to the south and the Arctic waters to the north. With the exception of the south-western shelf, where, east of the IC, a sluggish north-westward current of Atlantic Water and a coastal current exist, we find the north-western and northern shelf dominated by the eastward NIIC and the southern and south-eastern shelf dominated by the north-eastward SIC, a current which opens out into the FC (Figure 1). Like the NIIC the SIC transports Atlantic Water from the south over the Greenland-Scotland Ridge into the Nordic Seas and therefore forms a part of the Atlantic meridional overturning circulation.

The SIC has highest current speeds over the narrow shelf at the southernmost tip of Iceland at around 19°W: more than 20 cm s^{-1} averaged over the 1992–2006 period (Figure 1). The SIC volume flux increases towards the east: 0.3 Sv at 18°W, 0.7 Sv at 16°W, 1.7 SV at 14°W. Taking into account the simulated volume flux of the FC: 2.1 Sv at 6°W, we conclude that 33% of its water stems from the SIC at 16°W, 81% from the SIC at 14°W.

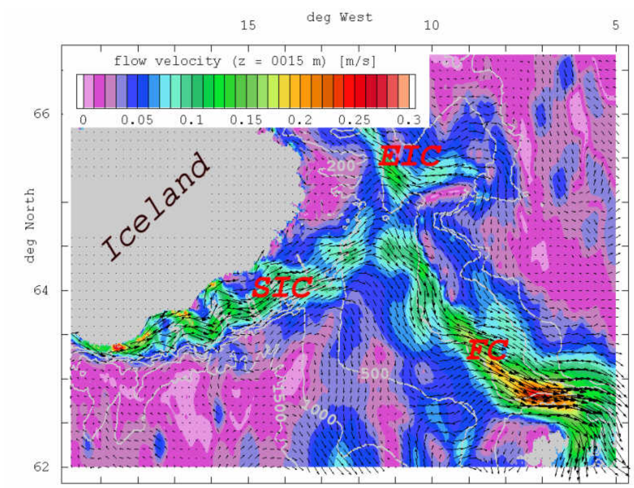

Figure. 1 Simulated 1992-2006 mean current at the depth of 15 m south-east of Iceland and bottom topography (200, 500, 1000 and 1500 m isobaths).

Our numerical experiments reveal that neither the NIIC nor the SIC are primarily forced by the local wind field or by the local density field. Instead, both currents result from topography-induced distortions of Arctic Front barotropic pressure field. I.e. referring to the geostrophic, near-surface, eastward flow along the Artic Front, the upwind (downwind) piling up (down) of water at the west (east) coast leads to a signal of high (low) sea surface height which spreads over the northern (southern) shelf and thereby leading to the NIIC (SIC).

Our results confirm the circulation scheme proposed by Orvik and Niiler (2002) and raise the question whether the simulated SIC could be observed by future current measurements.

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