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Near-surface circulation in Icelandic waters derived from satellite tracked drifters

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ABSTRACT

A co-operative drifter program between the Marine Research Institute and Scripps Institute of Oceanography started in spring 1995. Ten Surface Velocity Profilers (SVP's) were deployed in Icelandic Waters four times a year for three years at fixed locations south and west of Iceland. This paper deals with a study on data from the first six deployments of the project. Results of the drift reveal seasonal as well as inter-annual variability of the surface currents and the strong influence of the bottom topography. Further, the observations confirm cyclonic circulation in the Iceland Basin. Binned mean velocities show spatial differences in the drift from low mean velocities in the Iceland Basin to high current speeds along the Reykjanes Ridge and the oceanic fronts between Greenland and Iceland and Iceland and the Faroe Islands respectively.

Keywords: Satellite tracked drifters, Icelandic waters, near surface circulation.

INTRODUCTION

Iceland is located at the intersection between large submarine ridges. On the one hand are the Reykjanes Ridge and Kolbeinsey Ridge, which run in a SW-NE direction to the south and north of Iceland respectively, and on the other the Greenland-Iceland Ridge and the Iceland-Faroe Ridge, which lie in a NW-SE direction to the northwest and southeast of Iceland, at an approximately right angle to the other two (cf. Figure 2). These features of the bottom topography around Iceland play a major role in determining the flow of ocean currents in Icelandic waters.

To the south and west of Iceland are the warm waters of the north flowing Irminger Current, which is a branch of the North-Atlantic Current (6-8°C). On meeting the cold East Greenland Current in the area of the Greenland-Iceland Ridge, the Irminger Current splits in two. The larger western branch forms a cyclonic eddy in the Irminger Sea. The other branch rounds the northwest peninsula of Iceland and continues eastwards off the north coast. Its influence can reach the shelf area east of Iceland in warm years. Farther offshore, to the northwest, north and east of Iceland, are the cold East Greenland and East Icelandic Currents (<0° to 2°C). Finally, a coastal current runs in a clockwise direction around Iceland. The traditional picture of the flow of surface ocean currents around Iceland and in neighbouring areas is shown in Figure 1.

In consequence, Icelandic waters are *i.a.* characterized by strong horizontal and vertical temperature gradients or fronts, arising where the cold waters of the East Greenland Current and the East Icelandic Current meet the warm Atlantic water flowing into the area from the south and west. These warm/cold water fronts are most pronounced in the areas to the northwest and southeast of Iceland, where the Atlantic water proper

Dedicated to Professor Unnsteinn Stefánsson in honour of his contributions to oceanography and education.

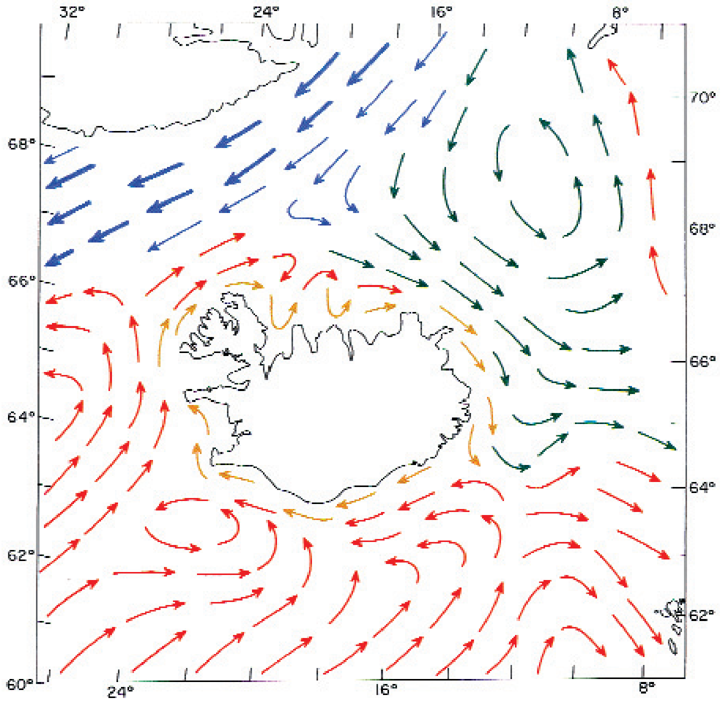


Figure 1. Ocean currents around Iceland. Red: Relatively warm and saline Atlantic water. Blue: Cold and low-salinity water. Green: Artic water. Yellow: Icelandic coastal water (From Stefánsson and Ólafsson 1991).

meets the cold East-Greenland and East Icelandic Currents, respectively. The flow of the various water masses and the location of these fronts may be variable from one year to another as well as over longer periods, at times resulting in large variations in hydrographic conditions of Icelandic waters (Malmberg *et al*. 1996). These changes are furthermore reflected in atmospheric or climatic conditions in and over the country and the surrounding seas (the Iceland Basin, Irminger, Iceland and Norwegian Seas), mainly through variations in intensity and location of the Iceland Low and the Greenland High. The variability of climatic and oceanographic conditions has an impact on biological processes in Icelandic waters, expressed *i.a*. through the food chain and affecting recruitment and catch of commercial fish species.

Naturally, the first attempts to describe ocean currents in Icelandic waters concentrated on near-surface currents. After World War II and until the 1960s, Danish and Icelandic investigations were based on drift-bottle experiments (*e.g*. Hermann and Thomsen 1946, Einarsson and Stefánsson 1954) as well as water mass distribution and geostrophic calculations (*e.g*. Dietrich 1957, Krauss 1958, Stefánsson 1962, Malmberg 1962, Malmberg *et al*. 1972). Since then, direct current measurements were occasionally made, often as part of international hydrographic investigations focused mainly on deep water circulation. Furthermore, Valdimarsson (1982) reported on results of experiments with sea-bed drifters in the Icelandic shelf area. New techniques, based on altimetry of the sea-surface, obtained from satellites and combined with numerical circulation models, have recently also been used for estimating circulation in Icelandic waters and adjacent seas (Samuel 1993, Mortensen 1997).

Despite all these investigations, the character of the flow of warm water from the south into the Icelandic area is still disputed. While the main features of water circulation may be known, there are uncertainties with regard to exactly how and where the warm Atlantic water reaches the Icelandic area as can be gleaned from the many different publications. Furthermore, details are also lacking with regard to the continuity or otherwise of the flow of the coastal current from one location to another around the Icelandic coastline. Recently developed and novel techniques, using near-surface drifters, located continuously by satellites, have added new information on ocean currents in the North-Atlantic and the Nordic Seas (Krauss 1995, Poulain *et al*. 1996, Otto and van Aken 1996). However, as shown in Figure 3, very few such observations have until recently been made in the area immediately south, west and north of Iceland.

The main objectives of the investigations described here was to fill in this gap in information on the flow of the Irminger Current into Icelandic waters and to collect more detailed data on the flow of the coastal current from the main spawning areas south of Iceland to the feeding areas off the north coast. After an initial test period, using a few drifters deployed in Icelandic waters (Malmberg and Briem 1993), the present project was carried out jointly by the Scripps Institute of Oceanography, La Jolla, California (SIO), and the Marine Research Institute, Reykjavík (MRI). The project is part of the World Ocean Circulations Experiment, Surface Velocity Programme (WOCE-SVP; Anon. 1990).

MATERIAL AND METHODS

Implementation of the programme

The MRI has amassed a long series of data for monitoring environmental conditions of Icelandic waters. These data derive from general quarterly hydro-biological surveys, including investigations of recruitment to major local fish stocks in spring and summer. The joint MRI/SIO drifters programme was coupled to these surveys and started in spring 1995. A total of 10 drifters were deployed four times a year at selected locations as shown in Figure 2. The deployments were carried out in May/June, August and November 1995, in February, May/June, August and November 1996 and 1997, and in February and May 1998. Thus, a total of 120 drifters were deployed during the whole project.

The instruments used were Clearwater (SIO) and Technocean (MRI) WOCE-SVP drifters with a drogue at 15 m depth. An Argos 1/3 duty cycle was used throughout the programme, *i.e.* there were 8 or 24 hours of transmitting alternating with 16 or 48 hours of silence.

The main aims of the programme were:

a) to obtain detailed information on the flow of North-Atlantic water into Icelandic waters and
b) to track the flow of the coastal current from the spawning grounds of cod south of Iceland, as well as the drift of cod eggs and larvae, northwards off the west coast and then east into the main feeding and nursing areas in North Icelandic waters.

The present paper deals only with results from 1995 and 1996. However, at the time of writing the programme was still running and the latest deployments were made in February and May 1998. The present analysis of the 1995-1996 data is a continuation of work carried out at the MRI and the University of Copenhagen, Denmark by Valdimarsson (Valdimarsson 1998; Malmberg and Valdimarsson 1999). Preliminary results have also been reported to the Data Buoy Co-Operation Panel (DBCP) of the IOC and WMO (Valdimarsson *et al.* 1998).

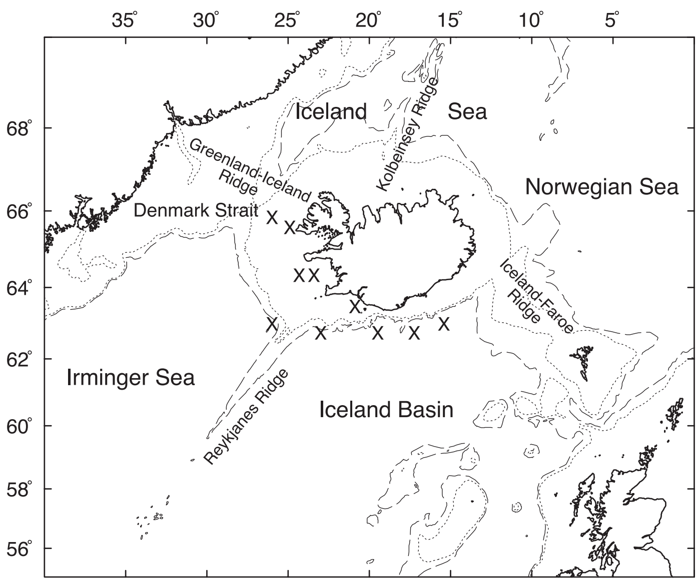


Figure 2. Bottom topography of Icelandic and adjacent waters and location of deployments of SVP drifters dealt with in the paper. Depth contours are 500 amd 1000 m.

Instrumentation

The satellite tracked drifters, used in this study, consist of a surface float and a drogue connected to it with a tether (Fig. 4; Poulain *et al.* 1996). This type is commonly referred to as a WOCE-SVP drifter. The surface float is equipped with a transmitter, batteries, submergence censor and a thermistor for SST

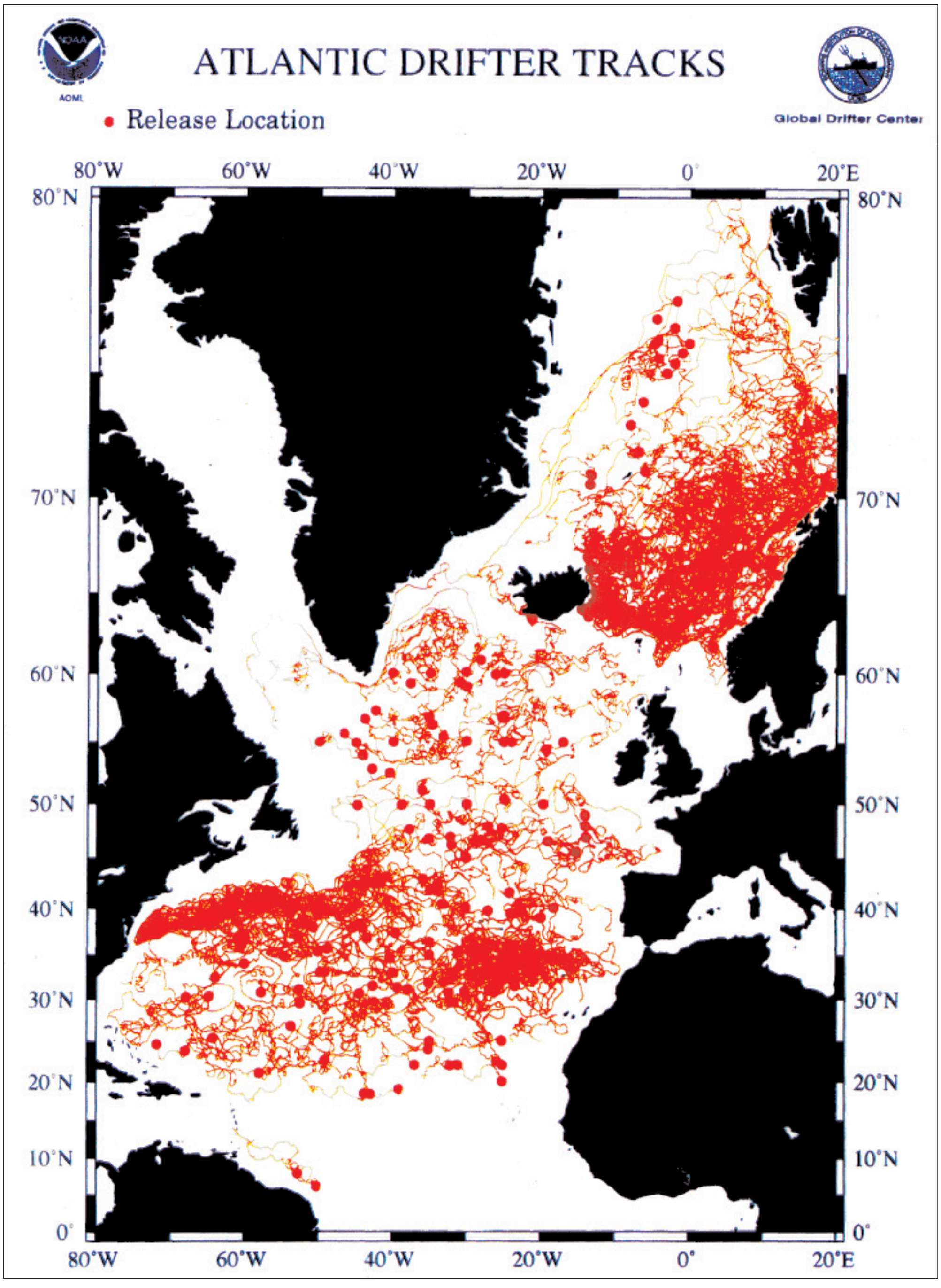


Figure 3. Atlantic drifter tracks in 1992-1994, drogued at 15 m. Red dots indicate release locations (Global Drifter Center).

measurements. A thin polyurethane coated wire tether connects the float to the Holey sock drogue, which is centred at 15 m depth. On the tether between the surface float and the drogue, at approximately 3 meters depth, is a smaller float to damp the jerk of waves on the drogue assembly. The drifters are assumed to follow the mixed layer velocity consistently as long as the drogue is attached. The slippage of the drogue through the water has been estimated to be <1 cm/sec (Otto and van Aken 1996, Valdimarsson 1998). To extend battery life-time and reduce the transmitting cost, transmitting time was limited to one third of the drifting time.

In the area studied, the number of positions recorded was on the average 5-7 during an 8 hours transmission period (Poulain et al. 1996, Valdimarsson 1998). Gaps in the drifter tracks are then filled by interpolated values using a kriging method (Hansen and Poulain 1996).

The Argos system (Anon. 1996), used to position the drifters, makes use of a receiver aboard the NOAA satellites series and the transmitter in the surface float. Positions are calculated by measuring the Doppler effect on the transmission frequencies. The Argos processing centre at CLS (Collect, Localization, Satellites) in Toulouse, France, computes the locus of possible positions for the transmitter. In general, location accuracy in the study area is better than 350 m.

Data processing

After Argos has processed the location data, the Drifter Buoy Data Assembly Centre (DBDAC) at NOAA's Atlantic Oceanography and Meteorological Laboratory (AOML) in Miami, Florida, processes the data further (Hansen and Poulain 1996).

Outliers are removed by a despiking program and the despiked data interpolated over 2-hour intervals by a kriging method. The resulting data are then subsampled every 6 hours and velocity then calculated from the 6-hourly positions. The combination of the 1/3 duty cycle and kriging interpolation procedures are assumed to partially suppress tidal and inertial signals (Otto and van Aken 1996). After this processing, the data record consists of time, position and the velocity components U (E-W) and V (N-S). Finally DBDAC flaggs the drifter data as drifters with drogue on or off, using the submergence indicator.

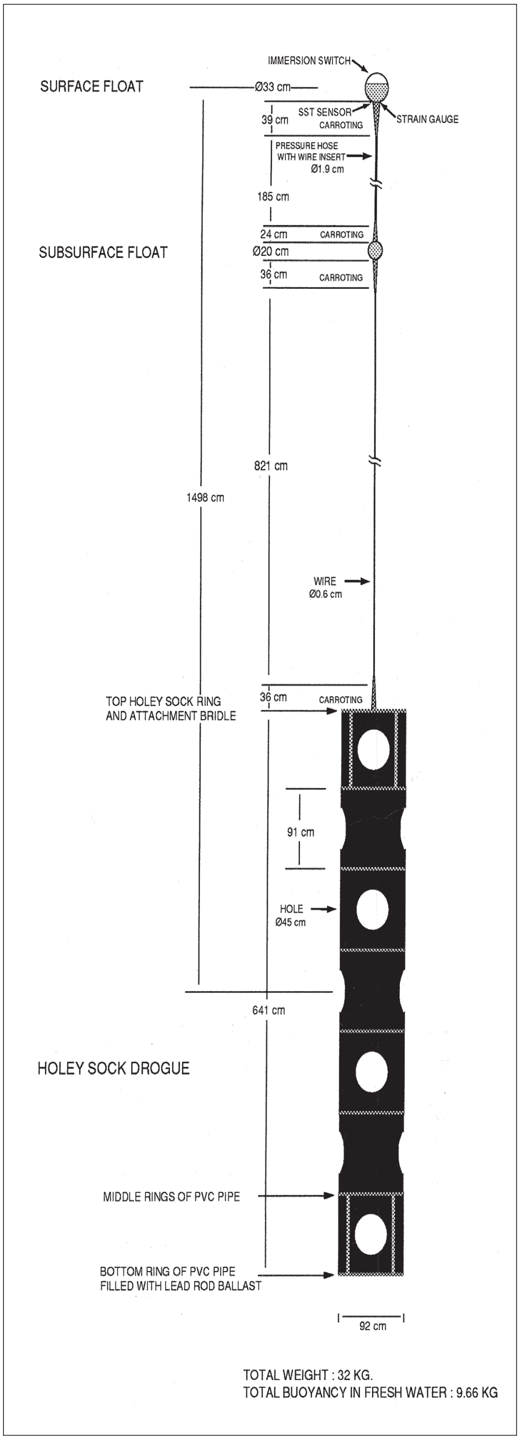


Figure 4. WOCE-SVP type drifter (Poulain et al. *1996).*

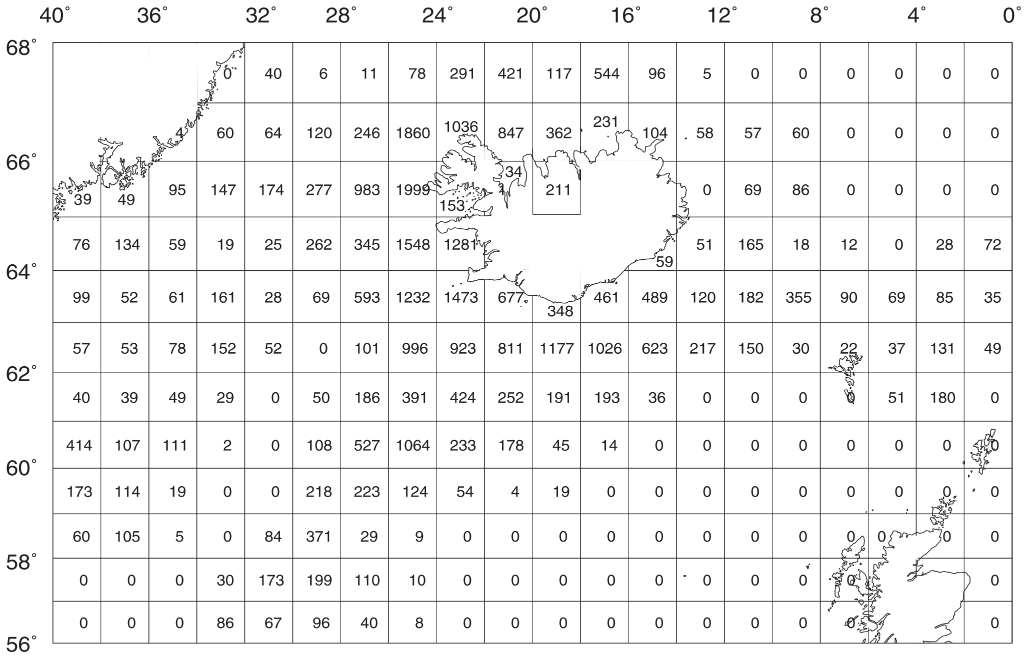


Figure 5. Number of observations per bin during the period May 1995 to November 1996.

In the present study, only drifters with the drogue attached are considered. Further analyses included computation of Eulerian mean velocities in squares or bins, corresponding to 1° of latitude by 2° of longitude. These are shown in Figures 11 and 12 as current vectors. The number of observations in each bin is shown in Figure 5.

Lifetime of drifters

The lifetime of the drifters was highly variable. A few failed from the beginning, some lasted for a few days, weeks or months, while others remained operational for up to two years (Fig. 6). In addition to general information on lifetime, Figure 6 shows the number of days since deployment for all drifters in the data set until 31 August 1996.

In Icelandic waters, the drifters last for a shorter time than in many other areas. The main reason for this seems to be drift-ice in the Denmark Strait area. The same is true for areas off the coast of Greenland bordering on the Irminger and Labrador Seas. In addition, a few drifters were stranded at Iceland. On the other hand, drifters not captured by drift-ice or stranded, may travel over long periods

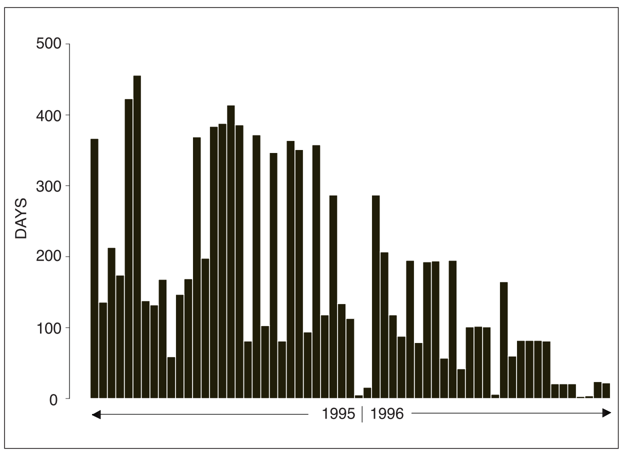


Figure 6. Number of days since deployment for the drifters in the studied data set until 31 August 1996.

(years) and distances (Malmberg and Valdimarsson 1999). Some drifted eastwards into Faroese and Norwegian waters, others to the west into Greenland waters and even into the Labrador Sea and Newfoundland waters (Fig. 7). Of the 30 drifters deployed in 1995, nine were still operational at the end of 1996, while 25 of the 40 drifters, deployed in 1996, were operational at the end of that year.

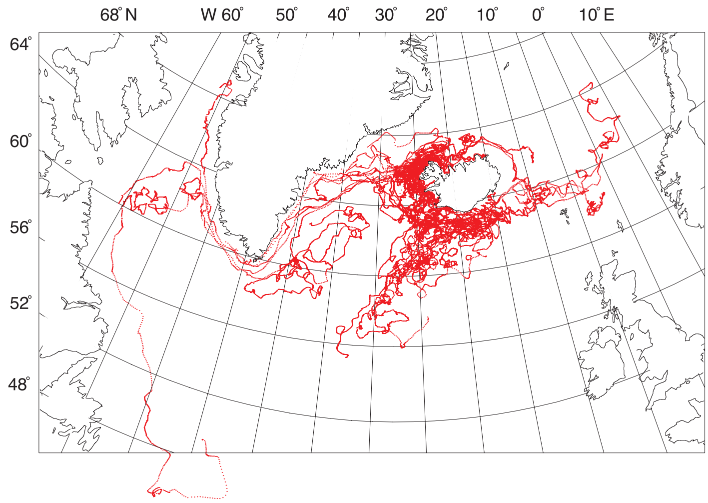


Figure 7. Observed drift of SVP drifters from Icelandic Waters into adjacent seas during 1995 and 1996.

RESULTS

Long distance drifts

The observed long-distance drifts are in accordance with the general knowledge of the ocean current system in these areas of the northern North Atlantic. Some of the drifters travelled from Icelandic waters to the east into Faroese and Norwegian waters (Fig. 7). These drifters followed two main routes:

1. directly from the waters south of Iceland eastwards into the area north of the Faroes and
2. a northward course from south and west of Iceland into North Icelandic waters (North Icelandic Irminger Current). From there, the drifters continued east and south towards the Faroes (East Icelandic Current and Faroe Current) and joined the drifters described in paragraph 1.

From north of the Faroes all of the drifters, which had followed the routes described above, continued east into the waters west of Norway (Norwegian Atlantic Current with its different branches). By 1997, some of them had reached as far north as west of Spitzbergen (not shown in Fig. 7) and into the Barents Sea (August 1995-December 1997).

None of the drifters, deployed in the waters south of Iceland, drifted into the area south of 62°N in the eastern part of the Iceland Basin. Further information on the number of observations in the different areas is shown in Figure 5. There were no observations from three different areas, *i.e.* the eastern part of the Iceland Basin, the deep waters east and northeast of Iceland and the central Irminger Sea.

Some of the drifters deployed in Icelandic waters turned west towards Greenland (Irminger Current). They then followed the East- and even the West-Greenland Current all the way into the Labrador Sea, where contact with most of them was lost, probably due to damage by drift-ice. However, one drifter deployed on the shelf west of Iceland in August 1995, took a southward course and followed the Labrador Current to 46°N, *i.e.* southeast of Newfoundland, where it turned eastwards and crossed the Mid-Atlantic Ridge just south of the Charlie-Gibbs Fracture Zone at about 52°N. From there, this drifter moved northwards along the Iceland Basin to 58°N, 28°W, *i.e.* to the east of the Reykjanes Ridge. Then its course shifted to the west and, crossing the Reykjanes Ridge at 59°N, continued northwards west of the ridge to 65°N (June 1998). This drifter thus completed the circuit in the so called Sub-polar Gyre of the northern North Atlantic in about two and a half years (Fig. 8). The drifter than made a second run more or less along the same paths as before, at least until October 1999 (Malmberg and Valdimarsson 1999a), when it had reached 52˚N and 28˚W.

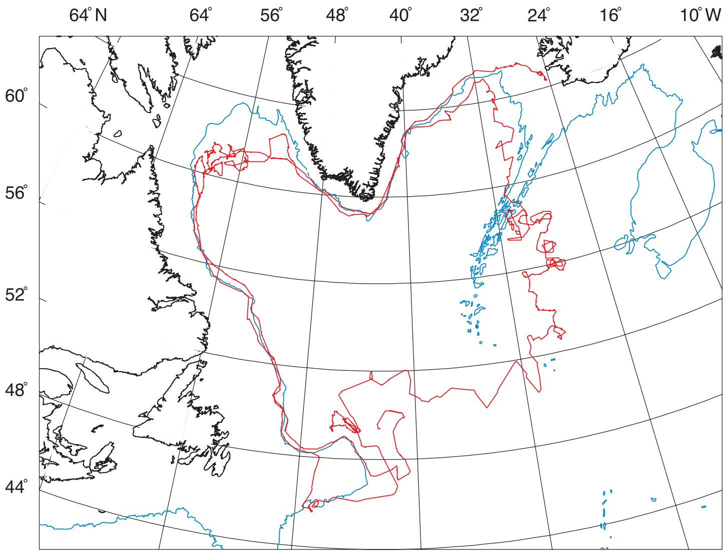


Figure 8. Observed drift of one SVP drifter around the Sub-polar Gyre from August 1995 to June 1998. The blue line represents the 1500 m isobath.

Variability in annual and seasonal drift

There appear to be both annual and seasonal differences in drift patterns and velocities.

Drifters deployed in spring 1995 (Fig. 9a) drifted southwards along the Reykjanes Ridge, but also west and north along the Icelandic shelf and then either eastwards into the western part of North Icelandic waters or westwards into Greenland Waters. No drifters from this deployment moved into Faroese waters.

Drifters deployed in summer 1995 (Fig. 9b) did neither drift southwards along the Reykjanes Ridge nor did they move east into Faroese waters. Instead, drifters from the summer 1995 deployment moved west and northwards. Some of them continued into North Icelandic waters and eastwards into the waters north of the Faroes as described earlier. A number of drifters from this deployment also drifted westwards into the Irminger Sea and Greenland waters.

However, drifters deployed in fall 1995 (Fig. 9c) drifted southwards along the Reykjanes Ridge as well as west- and northwards to the west of Iceland and even into the western part of North Icelandic waters. No drifters from this deployment reached Greenland nor Faroese waters.

Drifters deployed in winter 1996 (Fig. 9d) moved to the southwest along the Reykjanes Ridge and westwards off the south coast of Iceland, but none of them reached Faroese or Greenland waters.

Drifters deployed in spring 1996 (Fig. 9e) drifted from South Icelandic waters eastwards into Faroese waters and also northwards to the west of Iceland. From off the NW-peninsula, some took an easterly course into North Icelandic waters while others moved west into Greenland waters. No drifter from these deployments moved southwards along the Reykjanes Ridge.

Drifters deployed in summer 1996 (Fig. 9f) moved from south Icelandic waters directly towards Faroese waters and from West Icelandic waters northwards along the Icelandic coast and then westwards into Greenland waters. No drifter from this deployment reached the North Icelandic area and none of them moved south along the Reykjanes Ridge.

Looking further into the drifter tracks in 1995 (Fig. 10a), no drift was observed towards Faroese waters. Furthermore, only a slight indication of a southward drift along the Reykjanes Ridge was observed in 1995. Thus, the 1995 drift is concentrated in the area south and west of Iceland with some drift into North Icelandic waters as well as into Greenland waters. In 1996 (Fig. 10b), a few drifters, which had been deployed in 1995 and moved into North Icelandic waters, continued eastwards into the Norwegian Sea north of the Faroes. Noteworthy is the flow in the latter half of 1996 from South Icelandic waters directly eastwards into Faroes waters as well as southwards along the Reykjanes Ridge (winter 1995/96 deployments).

The general conclusion is that in 1995 (May to December) the observed drift was towards South and West Icelandic waters and even to the waters north of Iceland. In 1996 (January to November), however, the drifters also took more southerly routes, *e.g.* along the Reykjanes Ridge in winter,

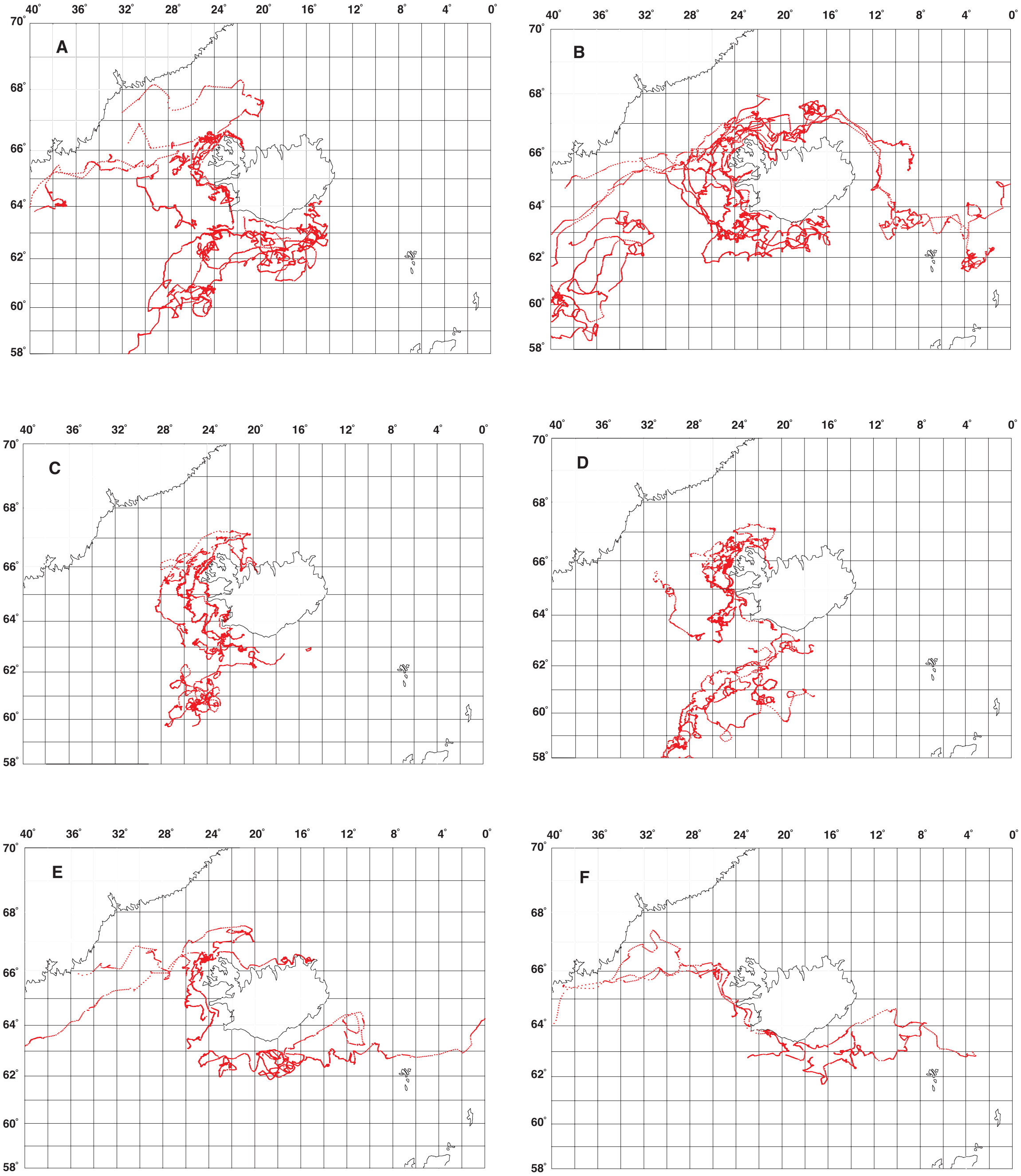


Figure 9. Observed drift of SVP drifters deployed in May-June 1995 ***A****; August 1995* ***B****; November 1995* ***C****; February-March 1996* ***D****; May-June 1996* ***E*** *and August 1996* ***F****.*

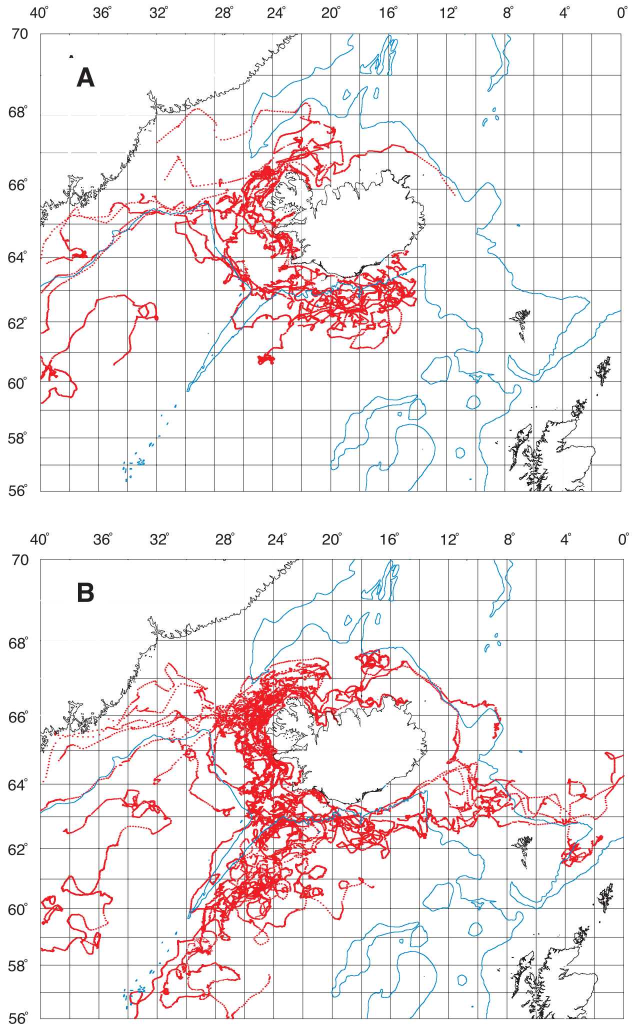


Figure 10. Observed drift of SVP drifters during 1995 ***A*** *and 1996* ***B****. The blue line represents the 1000 m isobath.*

May 1995 to November 1996 (Fig. 12a and b) indicate generally stronger means in winter than in summer. The overall mean velocities are relatively low in Icelandic waters as well as in the Iceland Basin proper (<20 cm/sec), but much higher (>40 cm/sec) along topographic features like the Reykjanes Ridge and fronts in the Denmark Strait and off East Greenland as well as in the East Icelandic Current between Northeast Iceland and the Faroes.

DISCUSSION AND CONCLUSIONS

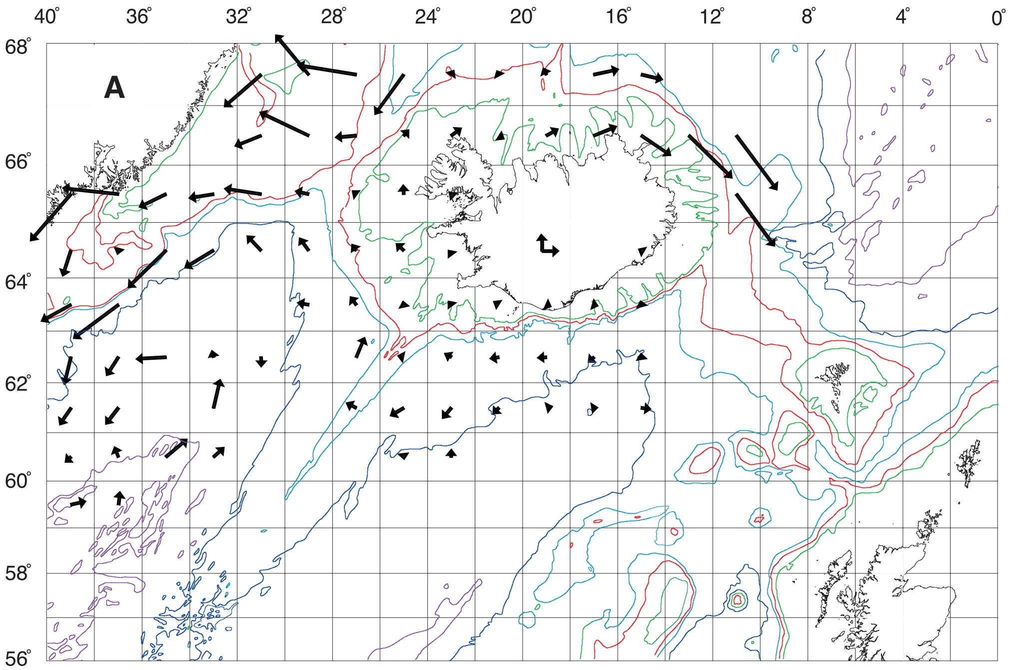
The long distance drift described above is in general accordance with present knowledge of the ocean current system in these areas (Fig. 7). The same is not quite true for Icelandic waters as regards that part of the drifters which moved southwestwards along the Reykjanes Ridge (Figs. 7 and 9d).

The present data also reflect annual and seasonal differences in water circulation. Thus, the drifters deployed south of Iceland had a tendency to drift southwestwards along the Reykjanes Ridge during winter, indicating an influence of the bottom topography, whereas in summer the drifters cross the ridge and move into the waters west of Iceland according to the generally accepted picture. Decreased wind stress in summer compared with winter, and higher stability of the surface layers in summer and consequently an increased gestrophic anticyclonic flow around Iceland, may be the reason for these seasonal variations. Noteworthy is also that in 1995 no drift was observed from the waters south of Iceland directly eastwards to Faroese waters, while several drifters followed this route in 1996.

or moved directly eastwards into Faroese waters in summer. This difference between the years 1995 and 1996 is clearly shown by the binned mean velocities (Fig. 11a and b). Care should be taken in interpreting single vectors based on few observations, *e.g.* the northward flow west of the Reykjanes Ridge after crossing it at about 60°N, which is based on data from only one drifter. (Fig. 8a)

As expected, mean velocities in summer (April-September; 12 month means) and in winter (October-March; 9 month means) during the period

In general, the observed drift in the Iceland Basin is different from that described in many previous publications on this region (*e.g.* Hermann and Thomsen 1946, Dietrich 1957, Stefánsson and Ólafsson 1991, Fig. 1). However, a few



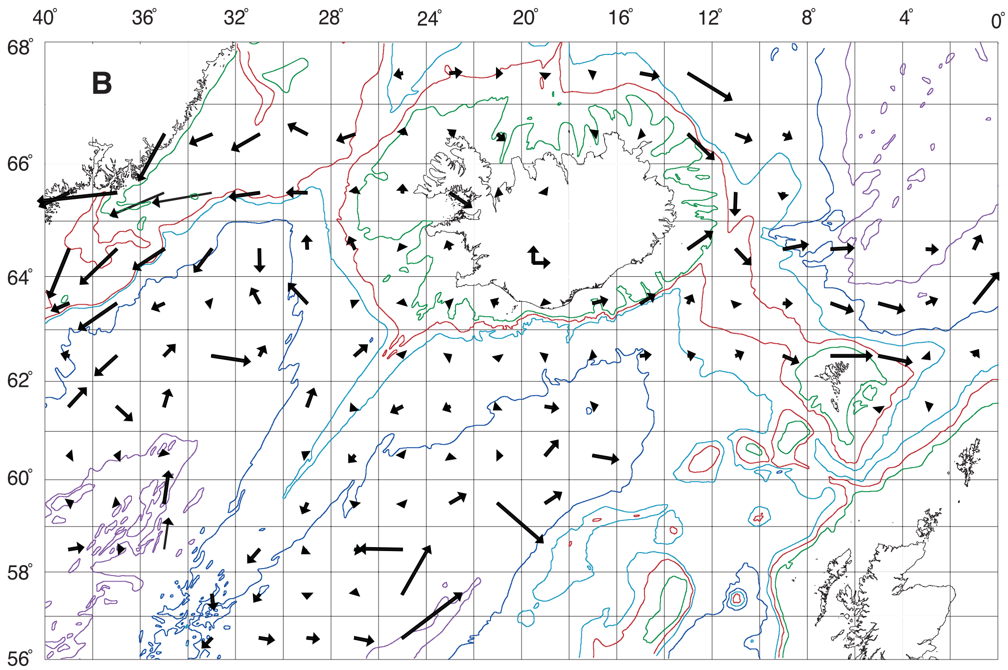
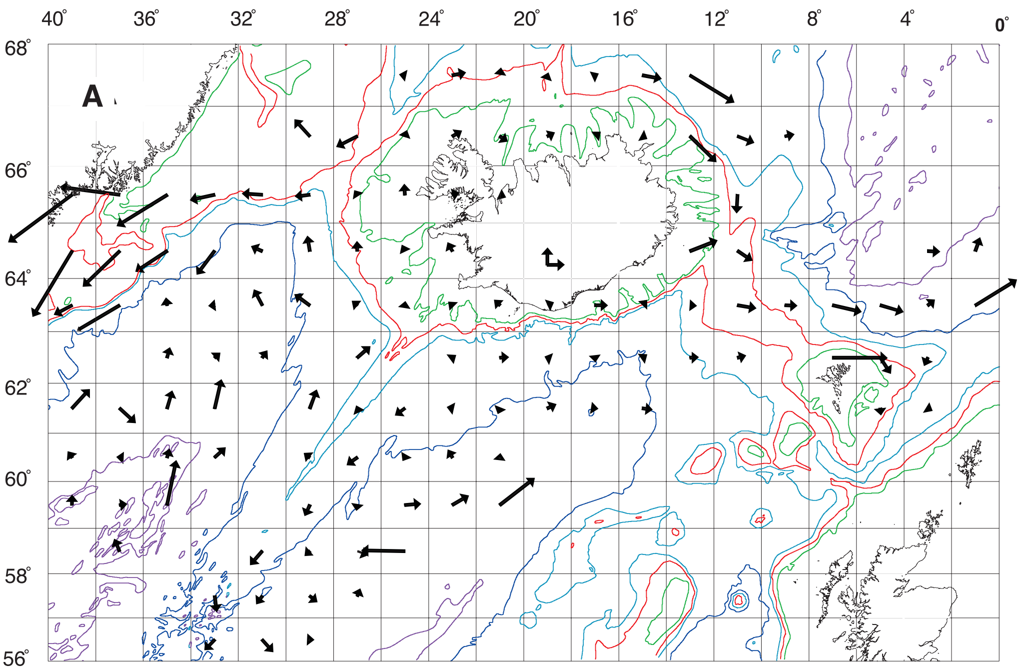


*Figure11. Binned mean velocities (cm/sec) in 1995 **A** and 1996 **B**. Depth contours are drawn for 200, 500 1000, 2000 and 3000 m. The length of the arrows on the map of Iceland represents a speed of 10 cm/sec.*



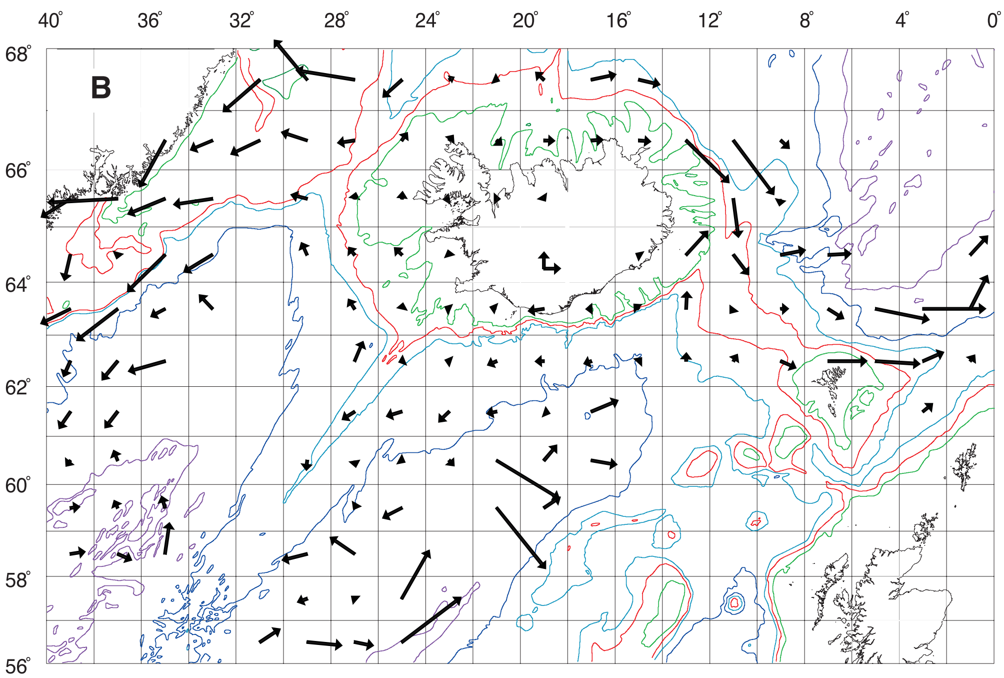


Figure 12. Binned mean velocities in summer 1995 and 1996 ***A*** *and in winter1995 and 1996* ***B****. Depth contours and current velocity scale as in Figure 11.*

old (Nansen 1912, Wüst 1928) and new (Otto and van Aken 1996) papers suggest or reveal similar features to the present drift pattern or cyclonic circulation in the Iceland Basin. Certainly, the warm North Atlantic water from the south reaches Icelandic waters (Irminger Current) apparently not as a continuos strong flow, but rather relatively slowly through eddies that are variable in size (Valdimarsson 1998).

Of further interest are the areas along the continental slope and over the outer shelf south and west of Iceland as well as off the northeast and east coasts, which were avoided by the drifters (Figs. 7 and 10). The outer limits of these areas show a characteristic feature of surface currents in the northern hemisphere, *i.e.* a current parallel to the coast, with land on the right hand and consisting of two discrete current bands, a shallow (baroclinic) coastal current and a stronger (barotropic) flow along the slope. In between these current bands, there are zones of divergence or upwelling from where deep nutrient rich water is distributed into the surrounding surface layers. The drifters which were deployed south of Iceland and crossed the Reykjanes Ridge, as well as those deployed west of Iceland, follow the coastal and slope currents around the country, even into the western part of the North Icelandic waters where they later join in the shelf area. Farther to the east, the bottom topography (Kolbeinsey Ridge) again influences the drift of the North Icelandic Irminger Current. Thus only a few drifters (3) moved east across the ridge, one near the coast but the other two along the continental slope, and from there eastwards into the Norwegian Sea. Only drifters deployed in 1995 moved in this fashion to Faroes waters, but those deployed in 1996 did not. Most of the drifters that reached into the western part of North Icelandic waters did not cross the Kolbeinsey Ridge, but drifted northwards along the ridge and then southwest again with the cold water from the north into the Denmark Strait area and Greenland waters.

The observed change in drift from 1995 to 1996 may still be an unexplained question. However, these differences may be linked to the variation of large-scale atmospheric conditions called the North-Atlantic Oscillation (NAO) (Fig. 13; Hurrell 1995). The NAO index is a measure of sea level pressure differences between the Azores High and the Iceland Low. During the period, dealt with in this paper (May 1995-November 1996), the NAO index was generally negative (high pressure in the conventional area of the Iceland Low), especially in winter from November 1995 to January 1996 (Fig.13) but also in March and May 1996. There was a change to positive values in mid-1996 as well as in winter 1996/97 continuing into winter 1997/98 (+0.43 and +0,5 respectively (Dickson and Meincke 1998). The year 1995 was also unusual with regard to climate in the Icelandic area, with extreme northerlies over the Nordic Seas at least during the first half of the year and a cold sea and air climate in the Icelandic area (Malmberg and Jónsson 1997).

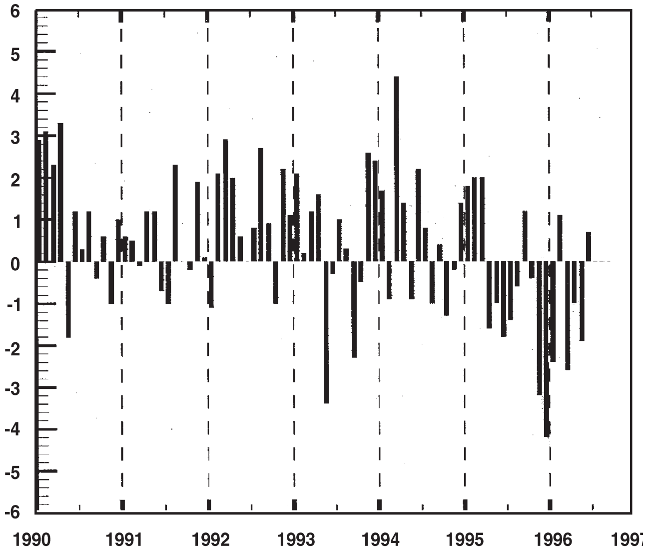
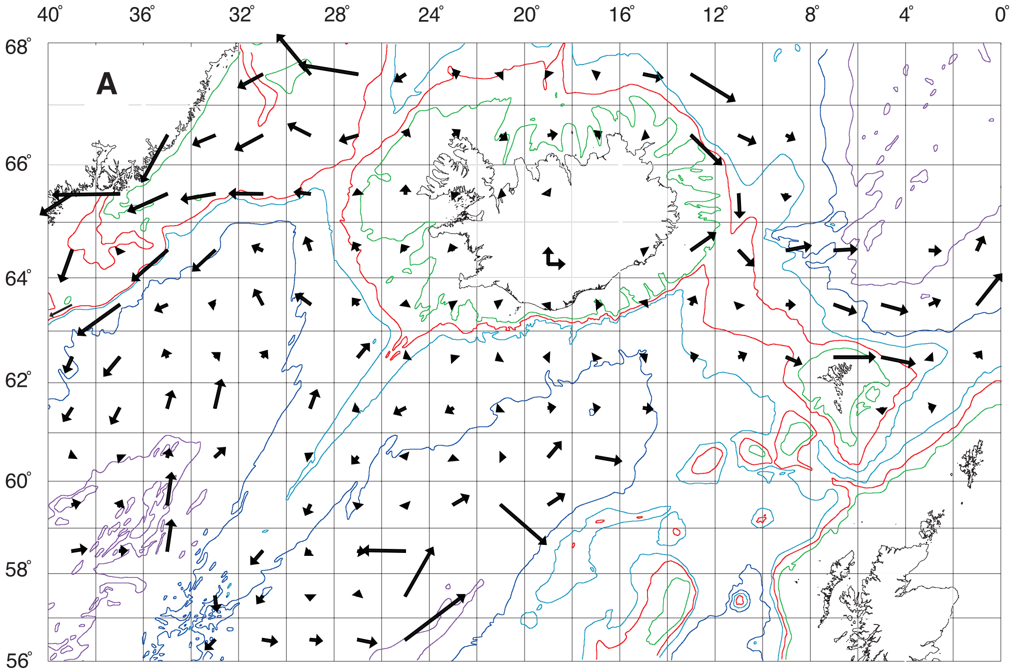


Figure 13. Index of the NAO based on differences of normalized sea level pressure betweeen Lisbon, Portugal (Azores High) and Stykkishólmur, Iceland (Iceland Low) for January to December 1990-1996 (data provided by J. W. Hurrel).

Thus, the drift along the Reykjanes Ridge in winter 1995/96 and no drift from South Icelandic waters directly eastwards to Faroese waters during 1995 and until mid-1996 may be related to a negative NAO index during the first year of



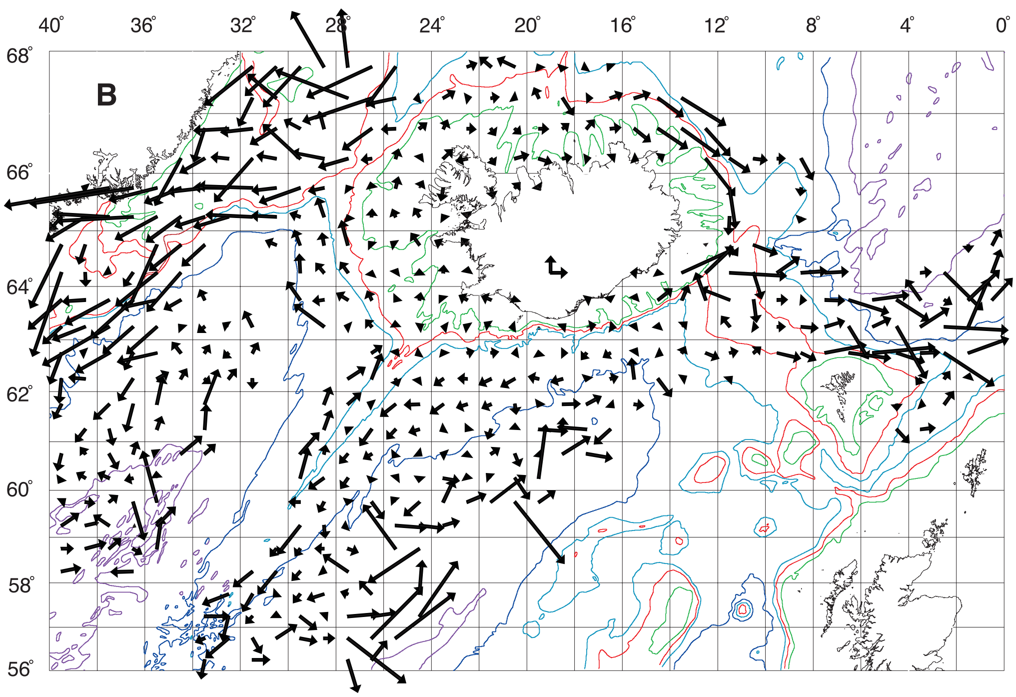


*Figure 14. Binned mean velocities for all data from 1995 and 1996. In squares of 1° of latitude by 2° of longitude **A** and in squares of 0.5° latitude by 1° longitude **B**. Depth contours and current velocity scale as in Figure 11.*

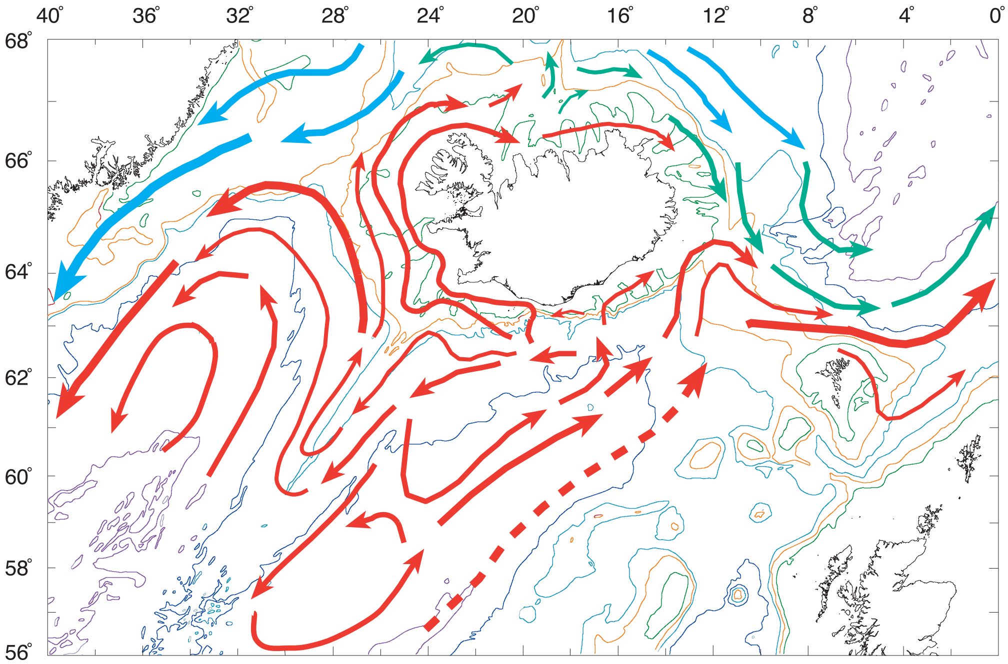


Figure 15. Schematic presentation of the surface circulation in Icelandic waters based on the drifter data set from May 1995 to November 1996. Red arrows: Atlantic water; Blue arrows: Polar water; Green arrows: mixed water. Depth contours as in Figure 11.

drift (May 1995 - May 1996), especially in winter 1995-1996, and a positive index from mid-1996. Since the drifter programme lasted until February-May 1998, data still to be collected may well throw further light on this relationship.

Figure 15 is a schematic presentation of the surface circulation in Icelandic waters, based on the binned means of data from drifters deployed in 1995-1996 (Fig. 14), where seasonal and annual variabilty is not taken into account. As mentioned above, some of the present results agree fairly well with the generally accepted picture of oceanic circulation in the study area with respect to:

a) the flow from North Icelandic waters into the waters north of the Faroes,

b) the eastwards flow from the Iceland Basin south of Iceland directly into Faroese waters and

c) the southward flow of the East Greenland Current on the East Greenland shelf.

(Hermann and Thomsen 1946, Dietrich 1957, Krauss 1958, Poulain *et al*. 1996). The cyclonic current system in the Irminger Sea is also a generally accepted feature (Hermann and Thomsen 1946, Dietrich 1957, Krauss 1995), as well as the northwards flow of the Irminger Current west of Iceland into the area of the Denmark Strait, where it divides into two branches. One branch flows eastwards into North Icelandic waters and one westwards in the Irminger Sea to join the East Greenland Current (*e.g*. Krauss 1958, Stefánsson 1962). It is, however, noteworhthy how the inflow into North Icelandic waters is influenced by the topography of the Kolbeinsey Ridge. Thus, most of the drifters reaching into the western part of North Icelandic waters did not cross the Kolbeinsey Ridge. The main flow in this area appears to be cyclonic, following topographic conditions and to join the westward flow of the cold water from tbe north into the Denmark Strait area and Greenland waters. This is at variance with many previous investigations (*e.g*. Stefánsson 1962) and may be related to the variable inflow of Atlantic water into this area, experienced in recent decades (Malmberg *et al*. 1996, Malmberg and Jónsson 1997).

In the Iceland Basin and along its boundaries, *i.e.* the Reykjanes Ridge and the Iceland-Faroe-Scotland Ridge, the present results are different from the picture given in many previous publications (*e.g*. Hermann and Thomsen 1946, Stefánsson and Ólafsson 1991 (Fig. 1)), at least in the western part of the area. There, the present results reveal cyclonic features not shown in most of the recent literature. The southwestward flow along the eastern slope of the Reykjanes Ridge is especially noteworthy. These flow patterns along the Reykjanes Ridge were suggested in older literature by Nansen (1912) and Wüst (1928). They based their interpretation on ship drifts, temperature and salinity measurements as well as on topographic features, but not on geostrophic calculations as done in later publications. The present results, of a southward flow along the eastern side of the Reykjanes Ridge and a northward flow on the western side of the ridge towards the Denmark Strait area, are also indicated in the extensive drifter programme (along 62°N at 100 m depth), carried out by Krauss (1995). In both the present and Krauss's studies, there is also some evidence of a turbulent flow from the Iceland Basin into the Irminger Sea, across the Reykjanes Ridge south of 60°N. In a schematic circulation map, which summarizes Krauss's presentation together with a few more drifters (19; Otto and van Aken 1996), similar large scale features occur in this area in the Iceland Basin and around the Reykjanes Ridge.

At the eastern boundary of the Iceland Basin and along the Iceland Faroe Ridge, the present circulation map (Fig. 15) shows a northerly flow of the warm water southeast of Iceland. The circulation then changes to a southeasterly direction, paralell to the cold water of the East Icelandic Current. Finally, the warm water flows into the Norwegian Sea as the Faroe Current. These results are comparable with those of Poulain *et al*. (1996) and, in part, to those of Krauss (1995). To some extent, the present results also agree with findings by Hansen *et al*. (1991), based on the tracks of two drifters in 1987 and one in 1988. Indeed, the change from a northerly to southeasterly flow along the Iceland-Faroe Ridge is only seperated by 10-15 nautical miles. This reveals a sharp front between different watermasses in this generally very complicated and variable area, where much more detailed studies are needed in order to clarify the picture. This is also the case in many other areas.

It should be borne in mind that Figure 15 is based on all drifter data from 1995 and 1996. As stated earlier, there are seasonal and annual variations to be accounted for when discussing a schematic circulation maps based on averages. As an example, the different areas in Figure 14 refer to conditions in 1995 or 1996, where the distribution of drifters was wider in the latter case.

The main objectives of the investigations dealt with in this paper were to obtain new information on:

1. the flow of the warm water from the south (Irminger Current) into Icelandic waters, and
2. the coastal current around Iceland in relation to the drift of larval fish.

The findings from the present experiment fill the gap in information on the area south of Iceland referred to in the introduction, and connect the sites of deployment south and west of Iceland with other areas within Icelandic waters and adjacent seas. Our investigations also throw some light on various details as well as the overall hydrographic conditions of Icelandic waters. At present, we are only able to deal with results from one and a half year of deployments during 1995-1996, *i.e.* those derived from 70 drifters out of a total of 120 drifters deployed during 1995-1998. Further studies may give additional answers, studies not only including drifters but also general hydrographic conditions and altimetric observations from satellites.

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