Faroe Current and Faroe Bank Channel overflow 2018-2019

Tórshavn · December 2019

Bogi Hansen

Karin Margretha Húsgarð Larsen

Hjálmar Hátún

Svein Østerhus

HAVSTOVAN NR.: 19-05

TECHNICAL REPORT

The present project has been supported by the Danish Ministry of Climate, Energy and Utilities as part of the Arctic Climate Support Programme. The authors are solely responsible for the results and conclusions presented in the report. They do not necessarily reflect the position of the Danish Ministry of Climate, Energy and Utilities.

Faroe Current and Faroe Bank Channel overflow 2018-2019

Bogi Hansen, Karin Margretha Húsgarð Larsen, Hjálmar Hátún, Svein Østerhus

Abstract

This report is intended to give a brief update on monitoring of the Faroe Current and the Faroe Bank Channel overflow. Both flows were successfully monitored from summer 2018 to summer 2019 and updated time series of transport and properties for the complete monitoring periods are presented.

For the Faroe Current, an optimized monitoring system has been designed, which should ensure high quality future monitoring if the necessary funding for implementation is acquired. Experiments have also been carried out to reduce the uncertainties in previously calculated transports, but the new algorithms await updated satellite altimetry data for the complete in situ observational period and will be produced in early 2020. Preliminary time series of volume, relative heat, and salt transports for the Atlantic water in the Faroe Current continue to show a high degree of stability. All of the transport series had positive trends, but only heat transport (relative to 0°C) had a trend that was significantly higher than zero.

The volume transport of Faroe Bank Channel overflow also remained highly stable from summer 2018 to summer 2019, whereas the bottom temperature close to the deepest part of the sill continued to increase. Since high-accuracy monitoring of this temperature was initiated in summer 2001, the bottom water of the channel has warmed by ≈ 0.2°C. A new initiative in 2018 was the deployment of equipment for bottom temperature logging on the Faroese slope of the channel at a depth where the interface hits the bottom. The temperature at this site was found to vary with the magnitude of the overflow, as expected.

Monitoring in the 2018-2019 period has been supported by the FARMON II project, which has been funded by the Danish Ministry of Climate, Energy and Utilities as part of the Arctic Climate Support Programme. Support for processing and analysis has also been gained from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 727852 (Blue-Action).

The Faroe Current

The monitoring system for the Faroe Current is designed to record time series of volume, heat, and salt transport of the Atlantic water that has crossed the Iceland-Faroe Ridge and continued eastward to pass through the monitoring section (Figure 1). Originally, the system was based purely on in situ observations, but it has been demonstrated that the velocity field may be monitored by satellite altimetry, once the altimetry data have been calibrated by the long series of ADCP measurements on the section (Hansen et al., 2019a).

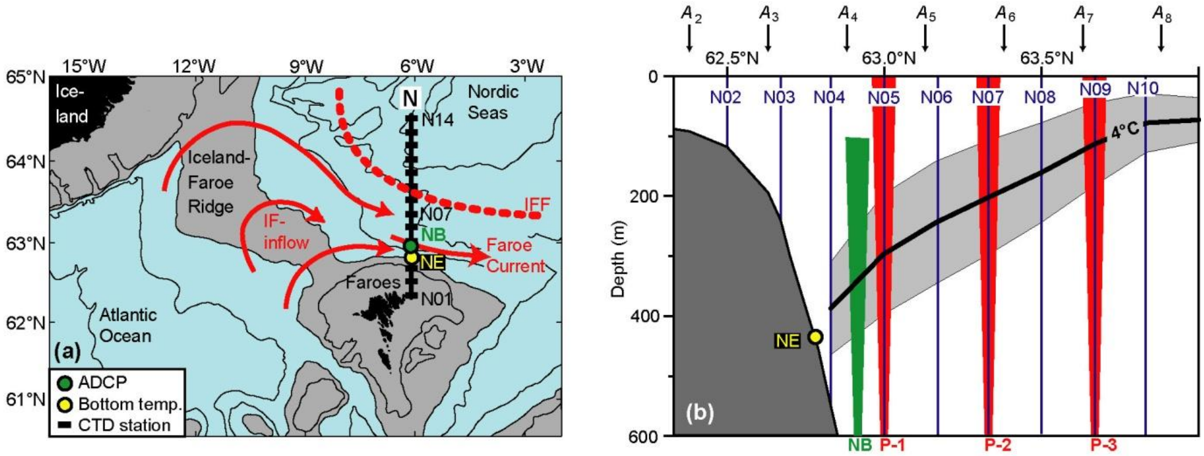

Figure 1. **(a)** The Iceland-Faroe region with red arrows indicating the Atlantic water inflow to the Nordic Seas between Iceland and the Faroes (IF-inflow) and its continuation in the Faroe Current. The thick black line shows the monitoring section, the N-section, with CTD standard stations indicated by black rectangles labeled N01 to N14. **(b)** The central part of the monitoring section with the CTD standard stations from N02 to N10 indicated by vertical blue lines and altimetry grid points A_2 to A_8 indicated by arrows. The thick black line shows the average depth of the 4°C isotherm and the grey area indicates its standard deviation. Red cones indicate the three moored PIES planned to be included in the future system. Green cone indicates a long-term ADCP mooring at site NB. In both panels, "NE" indicates bottom temperature monitoring.

In addition to the velocity field, monitoring of the hydrographic (temperature and salinity) fields is also required for distinguishing the Atlantic water on the section from other water masses, as well as for calculation of heat and salt transport. A central problem is monitoring the depth of the 4°C isotherm, which is used to define the depth of the Atlantic layer, along the section. In the future monitoring system (Figure 1b), PIES (Pressure Inverted Echo Sounders) are planned to perform this task (Hansen et al., 2019b).

For the historic data set, dating back to 1993, the high-resolution data from three PIES are not available and other observations are required to determine short-term (days to months) variations of the 4°C isotherm. Fortunately, the hydrographic fields respond rapidly to sea level variations (Hansen et al., 2019b), which implies that satellite altimetry may also help monitoring the depth of the 4°C isotherm once the altimetry data have been calibrated with in situ observations. This was employed by Hansen et al. (2015) to develop algorithms for transport calculation.

Since the development of these algorithms, new in situ observations have been acquired, which allow revision of the algorithms for the velocity field as well as for the hydrographic fields. For the velocity field, only slight revisions were required as documented in Hansen et al. (2019a). For the hydrographic fields, fundamentally new information was obtained from an experiment with two PIES moored on the section from autumn 2017 to summer 2019. This information is expected to allow more accurate algorithms to be developed for the whole monitoring period, back to 1993. The analysis has to await, however, release of satellite altimetry data for the complete PIES deployment period, and has therefore been delayed to early 2020.

The transport time series for the Faroe Current, presented here, are therefore based on the algorithms documented in Hansen et al. (2015) with the modifications for the velocity field documented in Hansen et al. (2019a). When the algorithms for the hydrographic fields have been modified, the preliminary time series published here will be revised, but major changes are not expected, especially on long time scales.

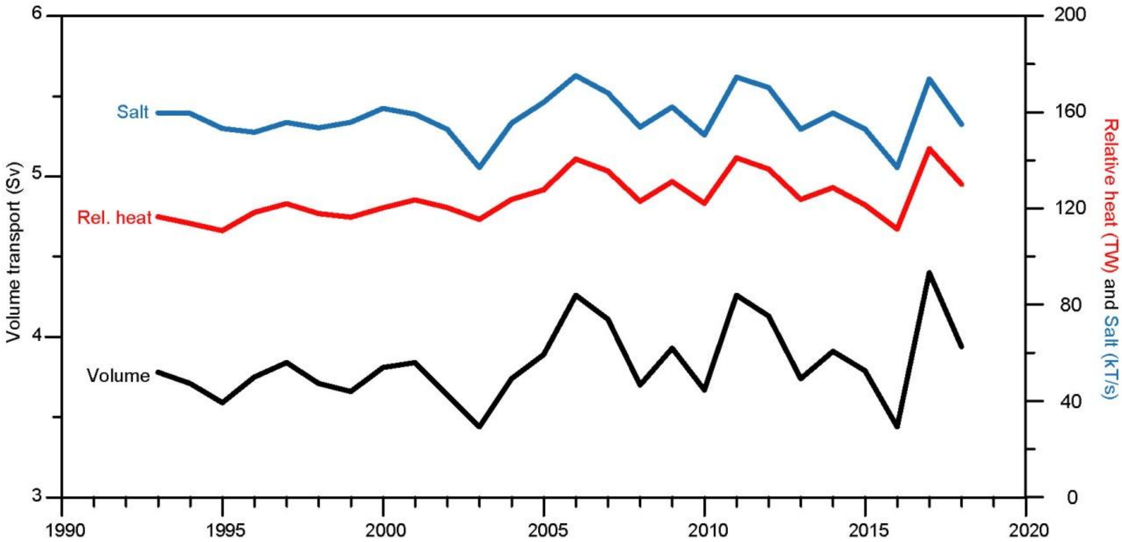

Figure 2. Annually averaged transport of volume (black, left scale), heat relative to 0°C (red, right scale), and salt (blue, right scale) of Atlantic water in the Faroe Current 1993 – 2018.

Annually averaged transport time series for the Faroe Current based on the latest in situ observations and updated altimetry are presented in Figure 2. Since most of the Atlantic water entering the Arctic Mediterranean returns to the Atlantic with temperatures close to °C, this reference temperature is used to calculate relative heat transport.

The volume transport was slightly lower in 2018 than in 2017, but for the whole 25-year period, there is an increasing – although not significant – trend (Table 1). Inter-annual variations of relative heat and salt transport are to a large extent dominated by the variations in volume transport, but over the whole period, variations in temperature are important, as well, so that relative heat transport appears to have increased significantly.

Table 1. Average values and trends for Faroe Current transports based on annual values. Uncertainties indicate 95% confidence intervals. The last column lists percentage changes over the whole 25 year period based on the linear trend analyses.

Parameter	Average	Linear trend	Percentage change
Volume transport	3.8 Sv	(0.011±0.012) Sv/yr	(7±8) %
Relative heat transport	125 TW	(0.67±0.42) TW/yr	(13±9) %
Salt transport	158 kT/s	(0.1±0.5) kT/s/yr	(2±8) %

Faroe Bank Channel overflow

In the field period from summer 2018 to summer 2019, ADCPs have been moored at standard locations FB and FC although the mooring at FC was not deployed until September 2018 (Mortensen et al., 2019). Figure 3 shows annually averaged “kinematic overflow”, which is calculated from the ADCP data at FB as documented in Hansen et al. (2016). This overflow transport continues to exhibit a high degree of stability. Over the complete monitoring period a linear trend analysis yielded an increase of (5±9) %, i.e. not significantly different from zero.

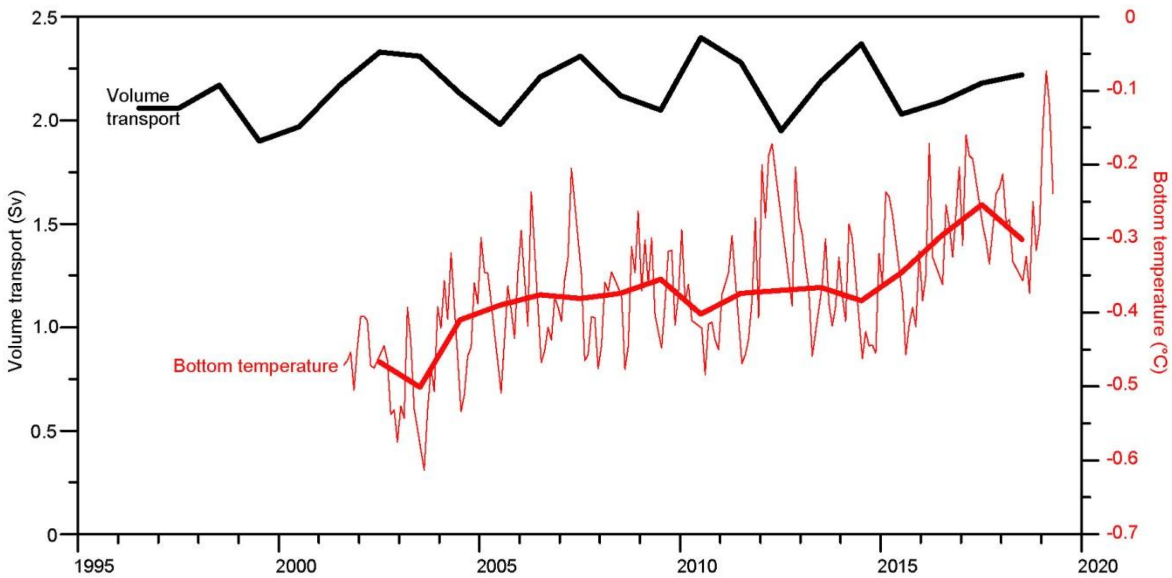

Figure 3. Annually averaged kinematic volume transport of Faroe Bank Channel overflow (thick black line) and monthly (thin red line) and annually (thick red line) bottom temperature in the Faroe Bank Channel (site FB). In the annual averaging, the period from day number 135 to day number 196 (instrument servicing) is excluded.

The red lines in Figure 3 show the bottom temperature at the sill of the Faroe Bank Channel as represented by measurements at site FB. On average, 2018 was colder than 2017, but the first four months of 2019 were among the warmest recorded. Thus, the warming of the bottom waters seems to continue.

Funding from the Danish Ministry of Climate, Energy and Utilities allowed acquisition of a trawl-proof frame with three LoTUS buoys inside (photo on the front page of this report), On June 17, 2018, the frame was deployed on the bottom at a site termed FG (61°28.404'N, 8°13.329'W, bottom depth: 569 m) on the Faroese slope of the channel where an ADCP has previously been deployed. Each LoTUS buoy records the temperature hourly and at a preprogrammed time it releases, surfaces, and transmits the data via satellite. The first buoy (id 49) surfaced on June 30, 2019 as planned and Figure 4 shows its temperature measurements.

As shown by the red curve in Figure 4a, the LoTUS buoy recorded temperatures intermediate between overflow water and the Atlantic water on top, as planned. There appears to be an inverse seasonal variation, which may be explained by the well-known seasonal variation of the overflow transport with maximum flow in summer.

On daily time scales (Figure 4b), the temperature at FG is better correlated with the interface height at FB ($R = -0,55$, $p<0.001$) than with the overflow volume transport ($R = -0.42$, $p<0.001$). When averaged over 28 days, almost identical correlations are found with interface height ($R = -0.72$, $p<0.05$) and volume transport ($R = -0.73$, $p<0.05$).

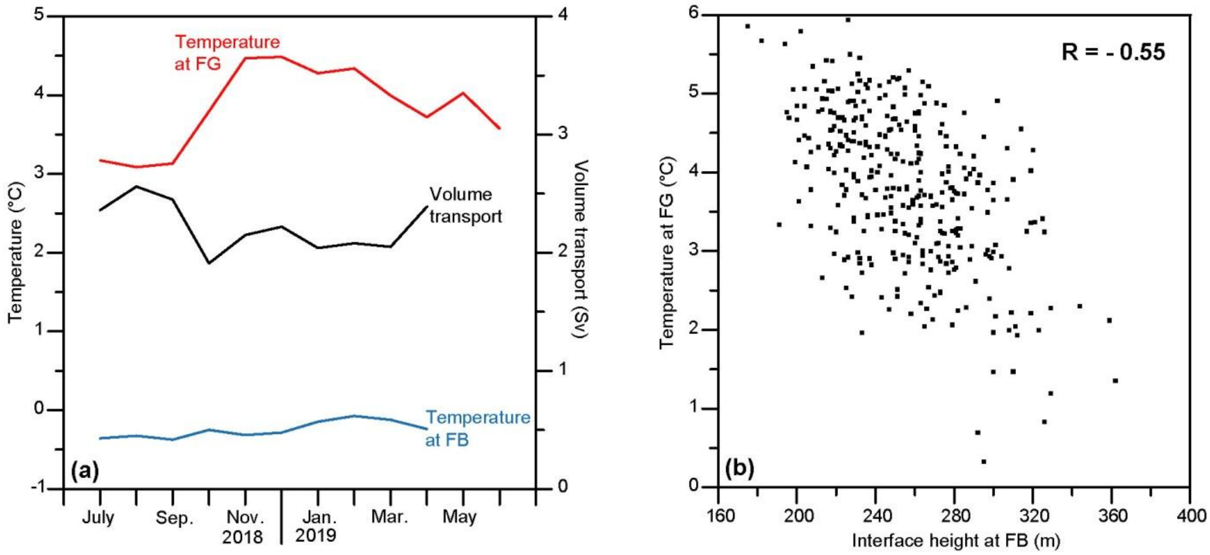

Figure 4. (a) Monthly averaged bottom temperature at site FB (blue, left scale) and at site FG (red, left scale) and kinematic overflow volume transport (black, right scale). **(b)** Daily averaged bottom temperature at site FG plotted against interface height (defined in Figure S1 in Hansen et al., 2016) with correlation coefficient indicated.

The two remaining LoTUS buoys in the frame are planned to release by the end of June in 2020 and 2021, respectively. Hopefully, funding can be secured to deploy new instruments before that so that monitoring of the interface over the Faroe slope can be continued.

References

Hansen, B., Larsen, K. M. H., Hátún, H., Kristiansen, R., Mortensen, E., Østerhus, S. (2015). Transport of volume, heat, and salt towards the Arctic in the Faroe Current 1993–2013. Ocean Sci., 11, 743-757, 2015. www.ocean-sci.net/11/743/2015/. doi:10.5194/os-11-743-2015.

Hansen, B., Larsen, K. M. H., Hátún, H., Østerhus, S. (2016). A stable Faroe Bank Channel overflow 1995–2015. Ocean Sci., 12, 1205–1220, 2016. doi:10.5194/os-12-1205-2016.

Hansen, B., Larsen, K. M. H., Hátún, H. (2019a). Monitoring the velocity structure of the Faroe Current. Havstovan Technical Report Nr.: 19-01. (http://www.hav.fo/PDF/Ritgerdir/2019/TechRep1901.pdf).

Hansen, B., Larsen, K. M. H., Hátún, H., Jochumsen, K., Østerhus, S. (2019b). Monitoring the hydrographic structure of the Faroe Current. Havstovan Technical Report Nr.: 19-02. (http://www.hav.fo/PDF/Ritgerdir/2019/TechRep1902.pdf).

Mortensen, E., Larsen, K. M. H., Hansen, B., Hátún, H., Kristiansen, R., Østerhus, S. (2019b). FARMON II Deployments in Faroese waters 2018 - 2019. Havstovan Technical Report Nr.: 19-04. (http://www.hav.fo/PDF/Ritgerdir/2019/TechRep1904.pdf).

P.O. Box 3051 · Nóatún 1
FO-110 Tórshavn
Faroe Islands

Tel +298 35 39 00
hav@hav.fo
www.hav.fo