# Investigating patterns in bottom water stagnation in a fjord-like strait in the Faroe Islands

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## Abstract

The northern part of the narrow fjord-like strait Sundalagið experiences bottom water stagnation with reduced oxygen concentrations almost every year. The onset is in spring as intruding oceanic water becomes less dense than the residing bottom water, and can no longer ventilate the bottom layer. It ends in late summer when the temperature falls, and precipitation and wind speed increase. In this study we use a decade of ocean temperature and salinity data as well as model data to investigate if there are patterns in e.g. temperature, salinity, tides, precipitation and wind that can explain the inter-annual variation in the degree and duration of stagnation and time of onset.

## Introduction

*Sundalagið norður – SUN* is the northern part of a narrow strait in the Faroe Islands. It has shallow sills in both ends (4 and 9 m deep) and one 60 m deep basin. It has strong tidal forcing as well as estuarine (freshwater) forcing. In addition, the winds can be strong and persistent and might also affect the flow considerably.

SUN is said to be fjord-like. This is firstly because of the constricting nature of the shallow and narrow southern sill, leading most of the tidal flow to be in and out over the northern sill as is typical in a tidally driven fjord. Secondly, the high mountains induce high precipitation rates and high runoff into the strait. It is therefore stratified, often with a pronounced brackish top layer, and less saline than the oceanic water. These features indicate that this body of water might behave more like an estuary than a strait.

Research has shown that SUN has two modes, a strait-like mode and a fjord-like mode. They are due to long-period tides and typically last a week each. Model data from February–March 2013 shows, that the strait-like mode mostly has flow southwards at all depths and that the fjord-like mode has flow of an estuarine character with northward flow in the surface and a counter-flow in the deep layer. The effect of these two modes on the summer circulation is not yet known.

It has been observed that the bottom waters of SUN will often become stagnant during summer with reduced oxygen concentrations in the deepest 20 m as is common for Faroese sill fjords (Figure 4). The bottom water stagnation begins in spring when the water outside the northern sill, on the well mixed Faroe shelf, becomes less dense than the water inside the fjord, and oceanic water entering SUN can no longer renew the bottom water. The stagnation ends abruptly in late summer when the temperature falls, and precipitation and wind speed increase.

10 years of temperature and salinity data show that there is an inter-annual variation in the degree and duration of stagnation and time of onset (Figure 2). In this study we will investigate if there are patterns in e.g. temperature, salinity, tides, precipitation and wind that can explain these variations.

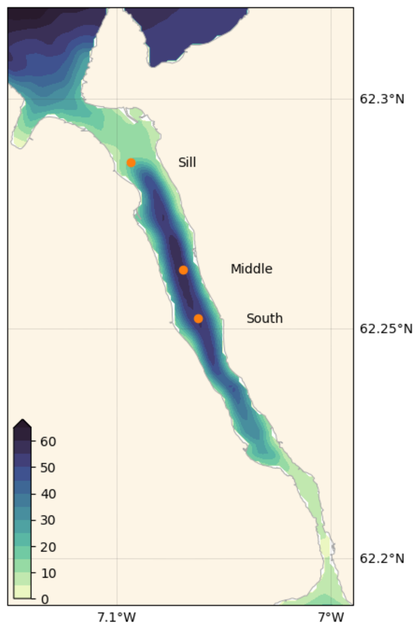


Figure 1: *Sundalagið norður* **SUN** is the northern part of a narrow strait in the Faroe Islands. It is around 10 km long, 700 m wide and the central basin is 60 m deep. The northern sill is 4 m deep and 1 km wide and the southern sill is 9 m deep and 160 m wide.

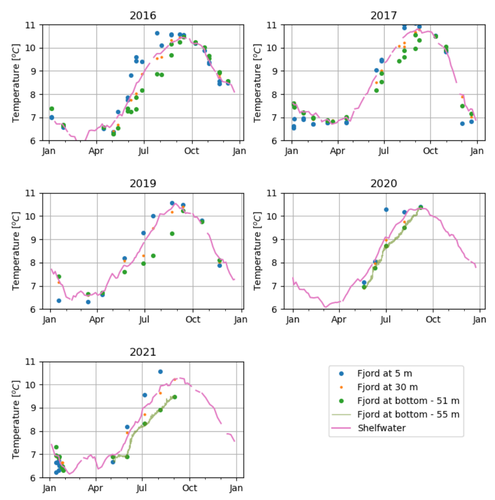


Figure 2: Temperature in SUN and on the Faroe shelf for 5 different years (2016, 2017, 2019, 2020 and 2021). The SUN station is 'South'.

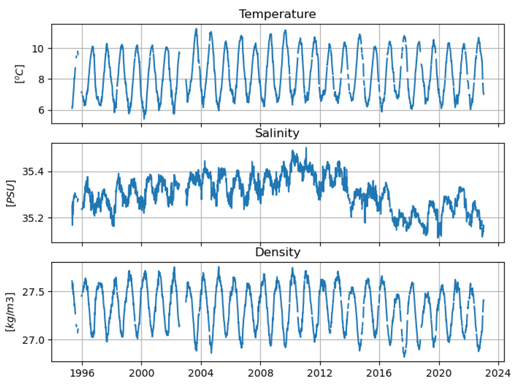


Figure 3: Temperature, salinity and density at the coastal station since 1995.

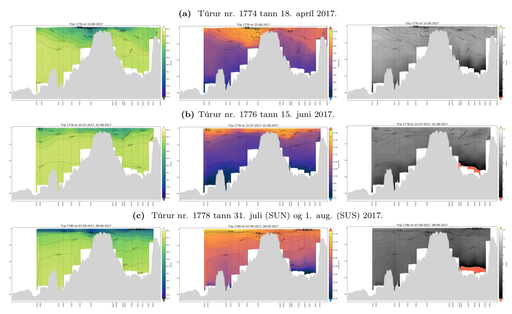


Figure 4: Salinity (col 1), temperature (col 2) and oxygen concentration (col 3) for the whole strait of Sundalagið. The 3 rows are for May, July and August in 2017. Sundalagið South is the deeper left basin and Sundalagið north (SUN) is the basin on the right.

## Data

In this study we utilize 10 years of temperature and salinity (CTD) data from SUN as well as occasional summer data from temperature loggers.

There is no data from right outside the sill, but there is 26 years of semiweekly temperature and salinity data from Skopun (*Coastal station*), representing the well mixed shelf water on the inner Faroe shelf.

There is model data from the high resolution ROMS setup FarCoast32 for january – july in 2013. Additionally FarCoast version2 is in the works and a 10 year ocean data library is part of that project.

Atmospheric data is available from the Danish Meteorological Institute. A hydrologic model, under development, will produce better fresh water runoff data.

## Method

Research addressing stagnated bottom water often focuses on the renewal event. In this case we are interested in the reasons for the formation, and its intensity and duration.

We will analyze the aforementioned data regarding factors that play a role in the formation of the bottom water. The salinity and temperature variations on the shelf and yearly freshwater variations due to rainfall are of special interest. Additionally the effect from the two fjord-like and strait-like modes on the bottom water begs for more investigation.

## Discussion

From the CTD data we know that the water column is mostly stratified with a fresh surface layer. Saline water enters SUN over the northern sill in the bottom 1-2 m and flows down the slope to the bottom of the basin. The intrusion at the sill continues throughout the year, but from late spring the intruding water no longer reaches the bottom and the stagnation begins.

Figure 3 shows that temperature, salinity and density values on the shelf have an inter-annual variation. In 2013 and 2016 there were freshening events where the salinity fell considerably. The reason for these is not yet fully understood. The effect can be seen in the low 2016-2017 winter density, but the effects on the bottom waer in SUN are not yet clear.

## Future work

When we have an understanding of the processes leading to bottom water stagnation in SUN, the next step is trying to predict the summer condition based on winter values.

An other subject of interest is whether the bottom water conditions in SUN are affected by the large scale oceanographic and atmospheric variations in the Northern Atlantic that affect salinity and temperature on the Faroe shelf.