# Mixing and Stratification altered by a Sill in a Norwegian Fjord

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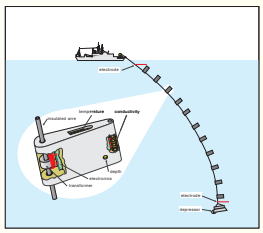
## Objectives and Area

To study mixing processes and hydrographic changes in the vicinity of underwater sills two cruises were carried out in the Norwegian Sogne Fjord. The Fjord at 61°N is more than 200 km long, 4 to 6 km wide and about 1300 m deep. Sills and narrows at the mouth of the fjord separate the inner fjord from the open ocean. The shallowest sill at 61°5'N, 5°3'E is only 170 m deep and about 4.5 km wide. High resolution measurements were carried out at the sill and adjacent regions by means of a 260 m long towed CTD-chain, a profiling Seabird CTD, a vessel-mounted 150 kHz acoustic Doppler current profiler and a free falling microstructure-turbulence-profiler. Results of the first cruise in February 2001 showing increased mixing and changes in stratification close to the sill, stimulated an intensive observational program during the second cruise in September /October 2002. The analysis of this data set has just started.


## Instruments

### CTD-Chain



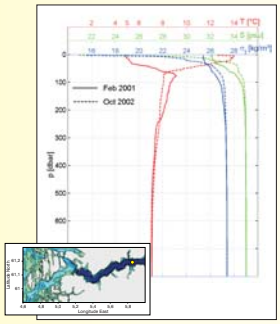
The towed CTD-chain enables high resolution measurements of the upper ocean underway. Fins equipped with temperature, conductivity and pressure sensors are inductively coupled to a simple coated steel wire. During both cruises 86 sensor fins were attached 3 m apart to a 260 m long wire. The chain was towed with about 6 knots.

### Microstructure-Turbulence -Profiler

The profiler is equipped with high resolution sensors for current shear (airfoil shear probe) and temperature (microthermistor) as well as standard CTD sensors for temperature (Pt100), conductivity (7-pole-cell) and pressure (piezoresistive) and an acceleration sensor (inertial mass). Weights are attached to the neutral buoyancy profiler to achieve a mean sinking rate of 0.7 m/s obtained from pressure and time measurements. This sinking speed and a sampling rate of 1 kHz allows a vertical resolution <1 mm but the size of the airfoil probe limits the resolution of the shear to approximately 5 mm. The almost neutral buoyancy cable attached to the profiler is lowered fast enough to allow a free sinking of the profiler and no disturbances of the meanwhile drifting ship are transmitted. The profiler can be used up to 100 m depth.

## Hydrographic Changes Winter 2001 / Fall 2002

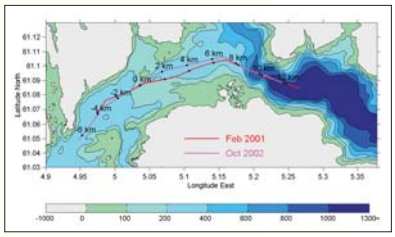
### CTD-profiles

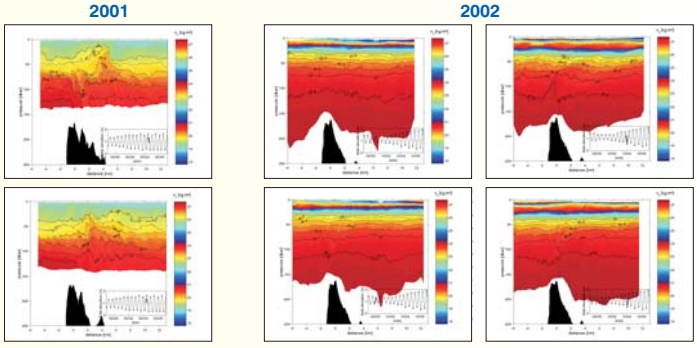



- In winter 2001 the surface layer was about 15 m thick, an intermediate temperature maximum (9°C) occurred at 80 m and a strong density gradient was observed in 30-120 m (0.015 kg/m³/m).
- In fall 2002 the cooling of the surface water (14°C) had just started and there was no mixed layer. The surface water was less saline (<21 psu) than in winter 2001 (>32 psu), but the water between 25 and 300 m was more saline. A very strong density gradient occurred in the upper 50 m (0.22 kg/m³/m).
- During both cruises the water column below 600 m was homogeneous down to the bottom of 1280 m.

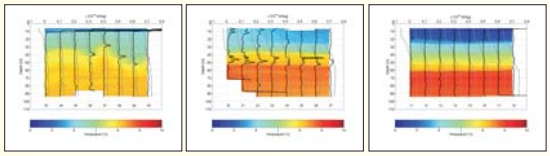
### CTD-chain density sections

- In winter 2001 5 CTD-chain sections were carried out over the sill during different tidal phases. Dense water ($\sigma_t$>27.2 kg/m³) above 140 m was only observed west of the sill's peak. During flood tide vertical mixing occurred on top of the two peaks of the sill and 4.6 km east of the sill the 26.4 kg/m³ isopycnal was lifted more than 40 m. During ebb tide this displacement moved westward and the amplitude decreased. Corresponding strong cross section currents in this area point to an anticyclonic eddy causing this displacement, which was not observed during fall 2002.
- In fall 2002 28 CTD-chain sections were carried out over the sill, but only occasionally significant isopycnal displacements were observed, especially during spring tides. Dense water ($\sigma_t$>27.2 kg/m³) above 140 m was recorded on both sides of the sill, but on the west side it was slightly warmer and more saline. The salinity of the surface water increased towards the west.




## Spatial Variations in Turbulence Winter 2001

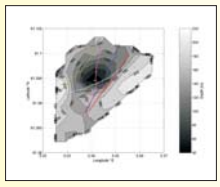



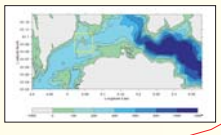

During winter 2001 microstructure-turbulence profiles were carried out inside the Sogne Fjord, just west of the sill and in the North Sea at the entrance of the fjord. Successive dissipation (black) and temperature (grey) profiles are shown for each area using an offset of $0.1*10^{-4}$ W/kg. Inside of the fjord dissipation rates were close to zero, but in the vicinity of the sill increased turbulent mixing was observed between 40 and 55 m, a layer of almost homogeneous temperature. In the North Sea high dissipation rates were recorded in the upper 10 m due to increased wind mixing. Occasionally increased dissipation rates occurred in an area of 7.5°C.

## Turbulence Observations at the Sill Fall 2002

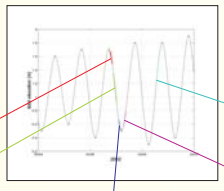
During two tidal cycles 174 microstructure-turbulence-profiles were collected around a top of the sill while WFS Planet was drifting from northeast to southwest. The bottom topography was surveyed by means of a shipborne ADCP operating in bottom-track mode. The positions of the profiler drops are marked with red dots. Representative profiles of dissipation (black) and temperature (grey) are shown for 5 selected sections during ebb and flood tide. The corresponding drift trajectories and tidal periods are marked with the same colours. The turbulent kinetic dissipation ($\epsilon$) rates were estimated for a pressure interval of 1 dbar assuming isotropic turbulence. The offset between the profiles varies with their distance. Turbulence with $\epsilon>5*10^{-6}$ W/kg was observed around the submarine hill above (o) and below (*) 50 m depth. Further analysis on the spatial distribution of turbulence will follow taking the tidal phases into account.

### Position of Sections

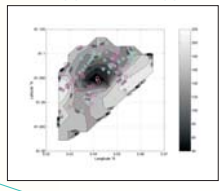




### Tidal Changes



### Turbulence Occurrence above (o) and below (*) 50m



### Dissipation and Temperature Profiles