AUV based study on physical and ecological processes at fronts

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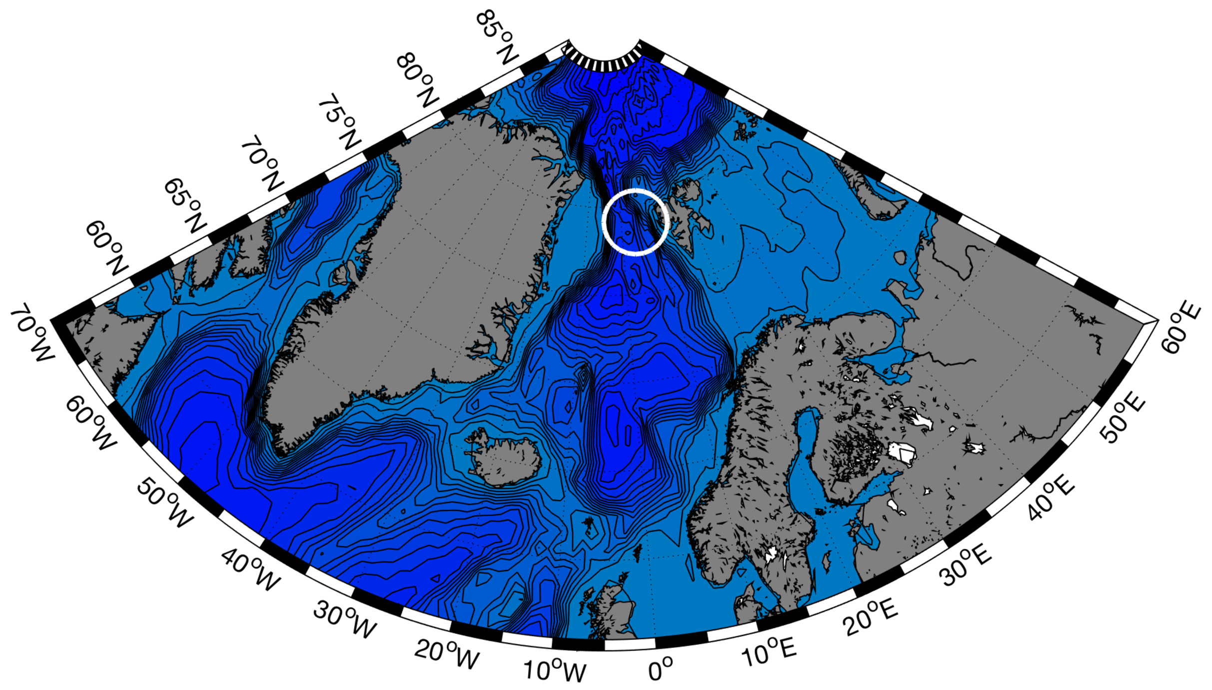
Introduction

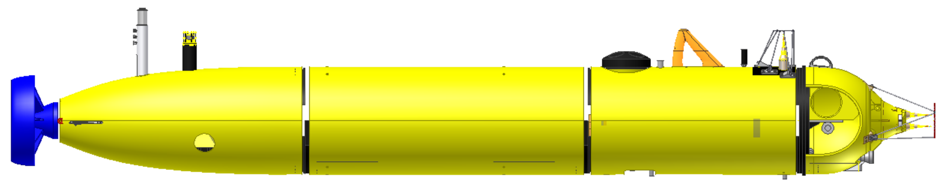
In the Fram Strait the northward flowing atlantic water and the southward flowing polar water intersect and form meanders, eddies and small scale filaments. Strong physical gradients on sometimes very small spatial scales dominate the area and control the ecological environment. The physical dynamics as well as the finescale biological response is what we aim to investigate.



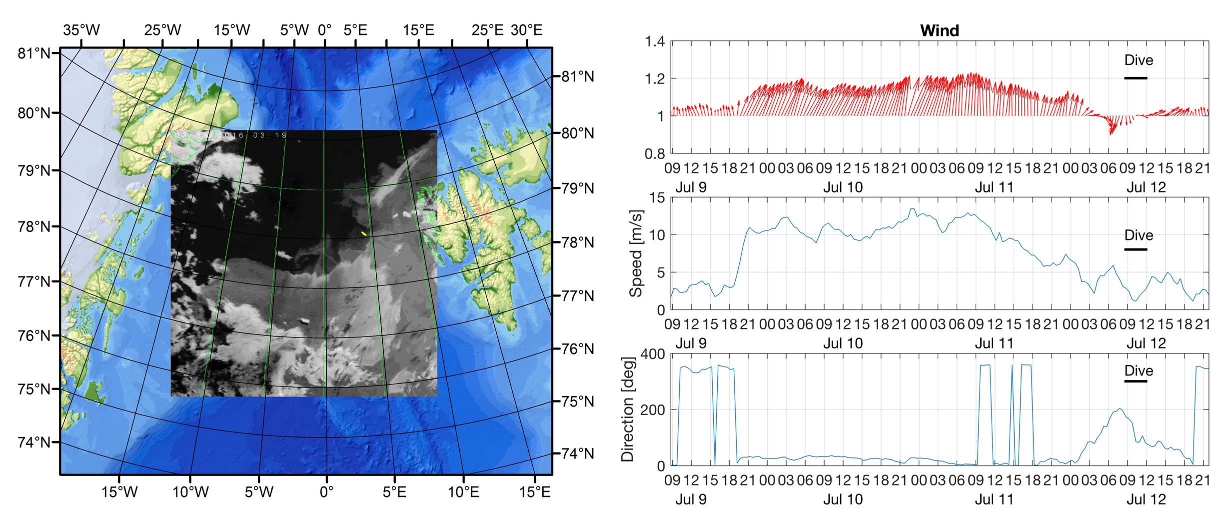
Study area in Fram Strait, entrance to the Arctic Ocean (white circle).

Instruments and Methods

To identify a front and to determine its orientation we steam back and forth over the expected front position analyzing the underway data from the research vessel. When a front is identified we program and deploy the AUV to record high-resolution vertical profiles of the upper water column perpendicular to the front. The dive consists of descending, ascending and floating parts as well as of segments along constant pressure for optimal data collection with the different sensors. The AUV is equipped with a conductivity, temperature and depth cell (CTD), an acoustic doppler current profiler (ADCP), a photosynthetically active radiation sensor (PAR), a chlorophyll *a* fluorometer, a nitrate sensor, an oxygen sensor, a colored dissolved organic matter (CDOM) sensor, a microstructure probe for velocity shear and temperature (MSP) and a water sample collector. To be able to analyze the along front structure we additionally deploy a small CTD from a zodiac operating parallel to the AUV track in a distance of 200 to 400 m. We use chlorophyll *a* concentrations as a proxy for phytoplankton.



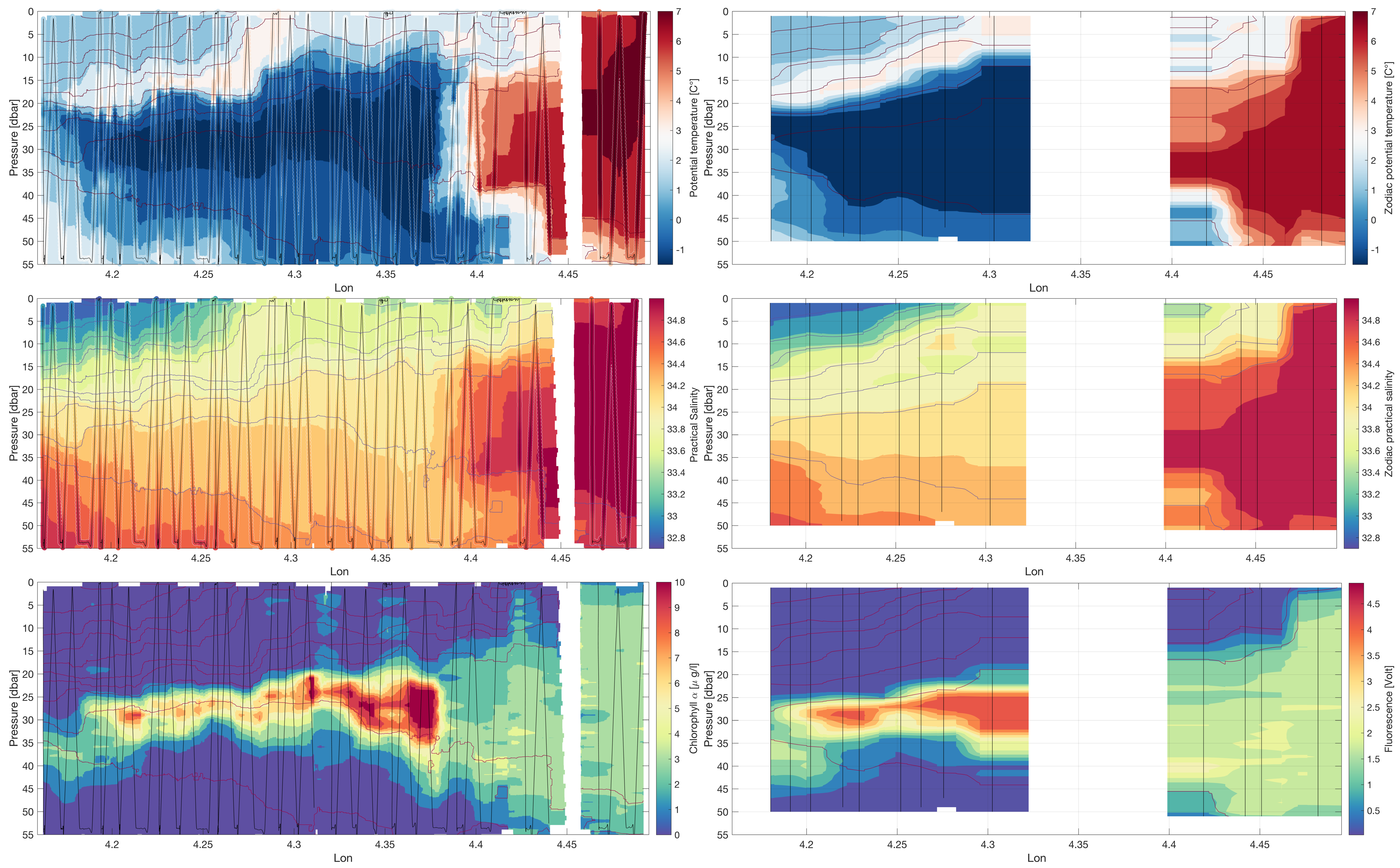
Satellite Background Information



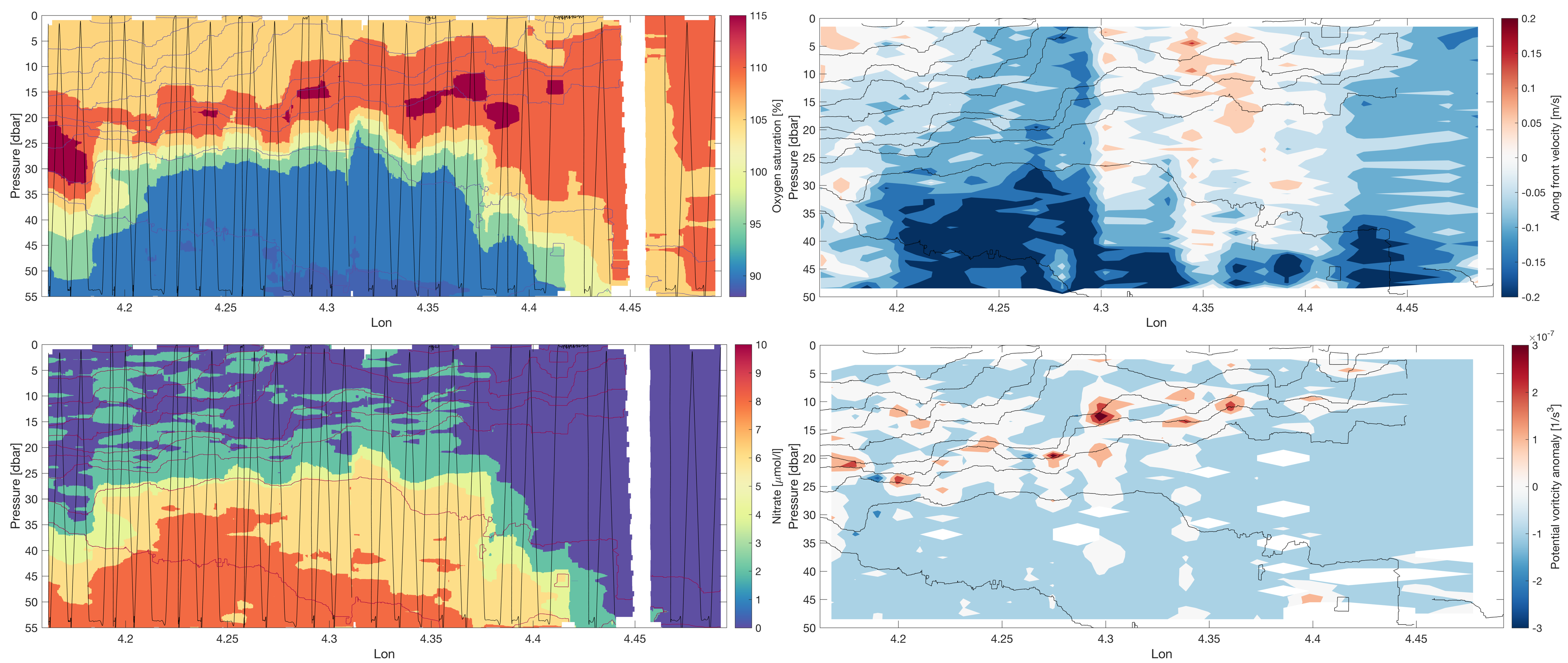
Infrared image and wind data three days prior to the dive.

The Infrared image nicely illustrates the meanders and filaments in the eastern Fram Strait.

Observations - 1



Temperature (upper), salinity (middle) and chlorophyll a (lower) observed with the AUV (left) and with the zodiac-CTD (right).

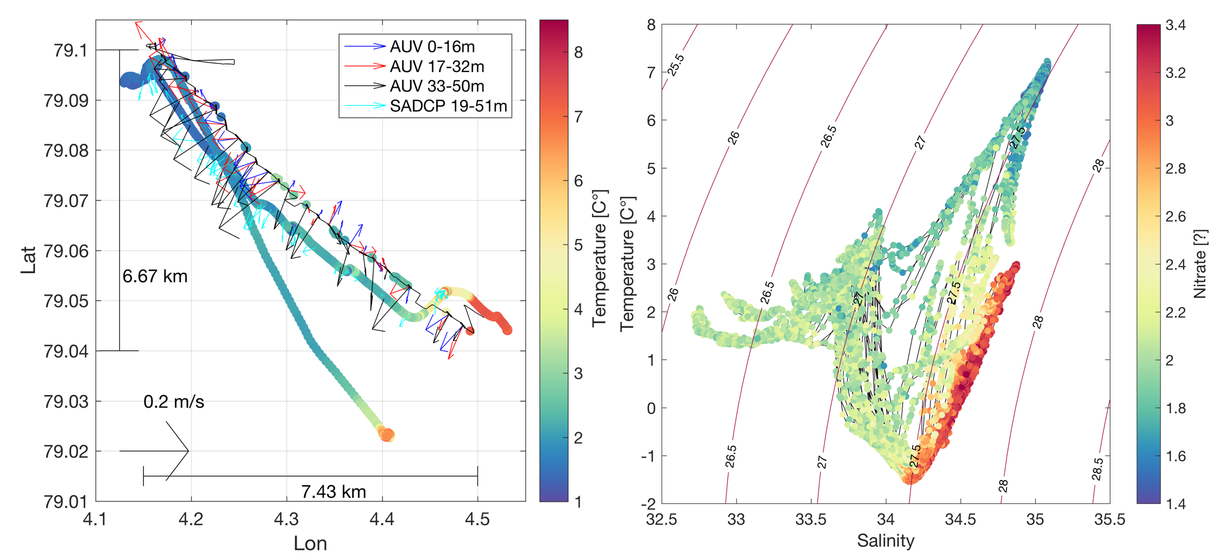


AUV based oxygen saturation (upper left), Nitrate (lower left), along-front velocity (upper right) and potential vorticity anomaly (lower right).

A strong but density compensated temperature and salinity front was observed between 15 and 40 m water depth. The warm saline water mass contained 3-4 $\mu g\ l^{-1}$ chlorophyll *a*. It was saturated with oxygen and nitrate concentrations were near the lower detection limit. The cold water mass contained more than 10 $\mu g\ l^{-1}$ chlorophyll *a* and was oversaturated with oxygen. Nitrate was almost depleted. The AUV based and the zodiac based sections were in good agreement.

Down-front velocities where present below 30 to 40 m depth. Above, a dipole structure with down-front velocities to the west and upfront velocities to the east where observed. The vorticity anomaly was elevated in a high stratification band in the layer above the cold water mass.

Observations - 2



Left: AUV and ship based ADCP together with surface temperature from the ships thermosalinograph.

Right: T-S diagram color-coded with nitrate concentrations.

The surface temperature indicated the front to be directed in a north-east to south-west direction. The AUV and the ships ADCP consistently revealed down front velocities below 30 m depth. From the T-S diagram polar surface water and atlantic water can be identified.

Interpretation

The AUV based and the zodiac based section obtained in about 200 to 400 m distance from the AUV track showed a very good agreement. This suggests the along-front scale of variability to be larger than the 400 m separation of the two section. This indicates the observed structure to belong to a frontal system and not to an Eddy like feature. The Rossby radius estimated from the stratification in the upper 50 m was approximately 5 km.

The warm and saline water mass was weakly stratified allowing phytoplankton to sink. Assuming phytoplankton to have the limited ability to regulate its buoyancy, the homogeneous chlorophyll *a* distribution might indicate a physically forced subduction process. This is supported by the low nitrate concentrations at depth as well as the presence of phytoplankton below the euphotic depth.

The 3°C layer in the western half of the section overlying the cold water mass, introduces a band of high stratification. In the same layer the vorticity anomaly is elevated. This might indicate the water mass to recently have been in contact with the atmosphere. The down-front wind a few hours prior to the observations might have contributed to the subduction, although the time scale of about 5 hours is rather short.

Outlook

To reinforce the above stated interpretations further analyses will be done. This will include surface satellite as well as high-resolution model data. Additionally, in an idealized model experiment the physical dynamics will be tested.

A more detailed analysis of the T-S properties will help to identify the different water masses. With a better understanding of the water masses influencing the observed phenomena, the physical mechanisms will become clearer and support the conclusions from the dynamical analyses.

It was planned to estimate fluxes using the dissipation rate of turbulent kinetic energy derived from velocity shear observation. Unfortunately the data appears unusable at the moment due to spikes which are likely linked to the very high chlorophyll *a* levels. In the future we will try to get some information about the dissipation rates, possibly also using the temperature microstructure observations.