Seasonal dynamics of carbonate chemistry, nutrients and CO_2 uptake in a sub-Arctic fjord

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Framsenteret

Abstract

Biogeochemical cycling in a **sub-Arctic fjord** of northern Norway (Kaldfjorden) was investigated during a full seasonal cycle in 2017-2018.

Monthly changes in **total inorganic carbon** (C_T), **alkalinity** (A_T), major **nutrients** and **calcium carbonate saturation** (Ω) were driven by freshwater discharge, biological production and mixing with subsurface carbon-rich coastal water.

Key findings

- **Meteoric water** (snow melt, river runoff, precipitation) freshened and stratified surface waters (Fig. 3-4) and subsequent **dilution effects** accounted for 81% of the monthly C_T deficit.
- **Biological carbon uptake** strongly counteracted dilution and dominated Ω seasonality (Fig. 5). Intense C_T and nitrate drawdown occurred during the spring phytoplankton bloom, driving fCO_2 undersaturation (Fig. 6) and high Ω (> 2). **Net community production** (estimated from carbon uptake) during the productive season was modest at 14 ± 2 g C m^{-2} yr^{-1}.
- **Calcification** reduced A_T, relative to C_T, and accounted for 21% of the monthly change in Ω during a coccolithophore bloom (Fig. 7). Freshwater was a minor source of **terrestrially-derived** minerals.
- Lowest Ω (~1.6) was driven by **organic matter remineralisation**, seasonal **cooling** and vertical **mixing** into sub-surface water during winter and spring.
- Surface waters were **undersaturated in CO_2** with respect to the atmospheric (Fig. 4), resulting in modest uptake of –0.32 ± 0.03 mol C m^{-2} yr^{-1}. Like other high latitude coastal and fjord systems, **Kaldfjorden is a sink for atmospheric CO_2** of 3.9 ± 0.3 g C m^{-2} yr^{-1}.

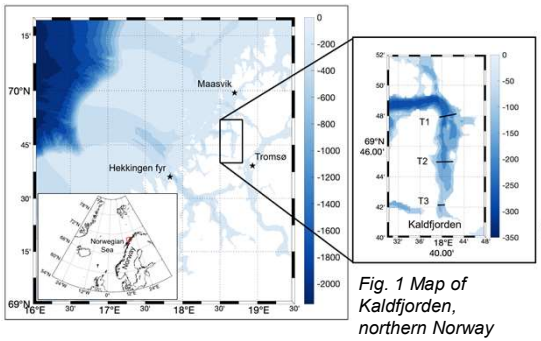


Fig. 1 Map of Kaldfjorden, northern Norway

Sub-Arctic fjord

- Kaldfjorden is an ice-free fjord in northern Norway (Fig. 1) important for pelagic and benthic calcifiers, herring migration and aquaculture.
- The Norwegian Coastal Current carries coastal water along the continental shelf.
- Small streams transport freshwater into the fjord.

Sampling

- CTD profiles (Fig. 2) were made on outer (T1), middle (T2), inner (T3) transects across the fjord.
- Carbonate chemistry, nitrate+nitrite (NO_3+NO_2), phosphate (PO_4), silicic acid ($Si(OH_4)$) and stable oxygen isotope ($\delta^{18}O$) were sampled on the central station on each transect from the surface to bottom.

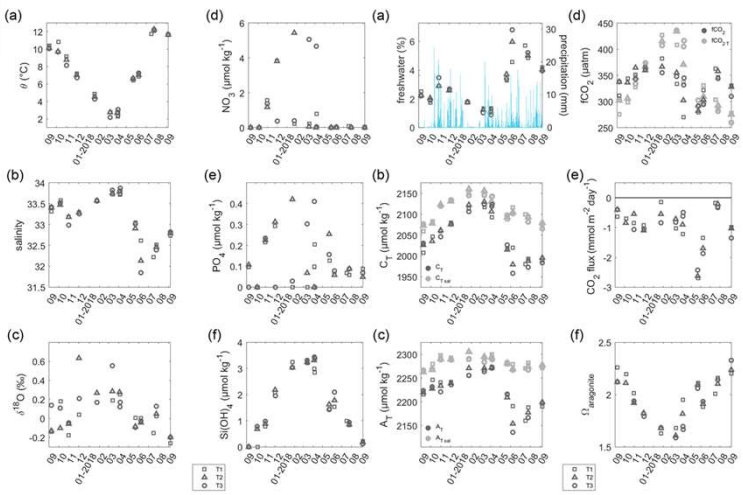


Fig. 3 Seasonality in surface water hydrography and biogeochemistry

Fig. 4 Seasonality in surface water carbonate chemistry

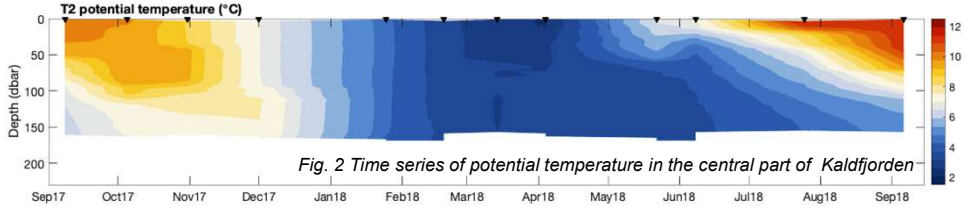


Fig. 2 Time series of potential temperature in the central part of Kaldfjorden

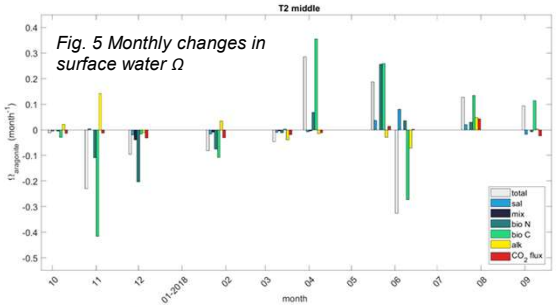


Fig. 5 Monthly changes in surface water Ω

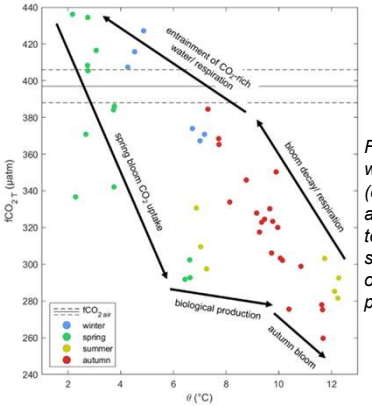
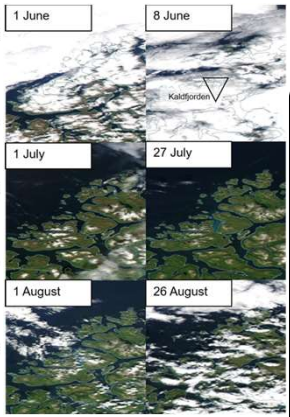


Fig. 6 Surface water fCO_2 (corrected to average temperature) showing impacts of biological processes

Fig. 7 Satellite surface water reflectance showing summer coccolithophore blooms



Fjords in the future

- **Seasonal time series** data are vital to understand biogeochemical cycling and CO_2 uptake in dynamic fjords and coastal systems.
- **Freshwater fluxes** impact stratification and mixing, phytoplankton species composition, bloom development, and biogeochemical cycling.
- In addition to **uptake of anthropogenic CO_2**, these processes increase the vulnerability of **surface waters to acidification**.

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