Alkalinity-driven changes of Ocean Acidification in the coastal zone

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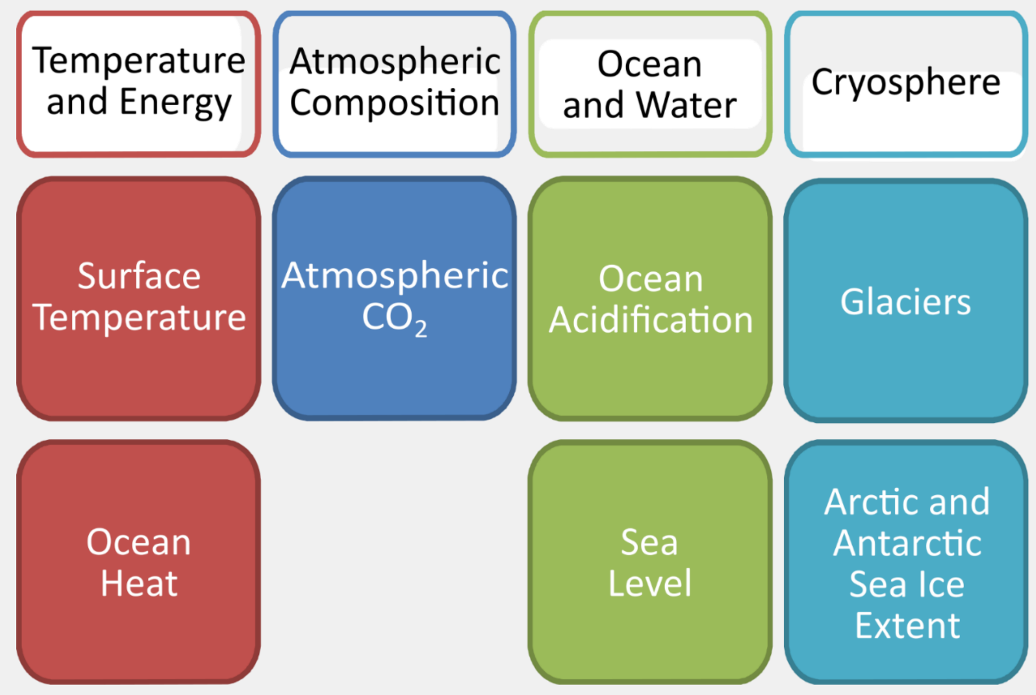
Rationale

Increasing atmospheric CO_2 concentrations lead to an overall increase of CO_2 concentrations in surface seawater and, consequently, a pH decrease – a mechanism called Ocean Acidification (OA). OA has been placed by GCOS and WMO as one of the seven Global Climate Indicators and the only biogeochemical one. This initiative triggered numerous of studies and actions towards understanding the consequences for marine ecosystems OA may have in the future CO_2-rich world. So far, OA is well understood and traceable in the open ocean, where large-scale projects and actions supply an enormous amount of observations and experimental data and where the magnitude of OA is to a large extent thermodynamically consistent with the increase in atmospheric pCO_2. In the coastal and shelf seas, OA is still a significantly understudied phenomenon despite their high socio-economic importance and potentially great vulnerability to acidification due to often lower salinity and corresponding lower buffer capacity of waters as compared to the open ocean. In the present study, we underline the importance of total alkalinity (A_T) changes as the key factor shaping the OA dynamics, pH fields, and the variability in the aragonite saturation state in the coastal seas.

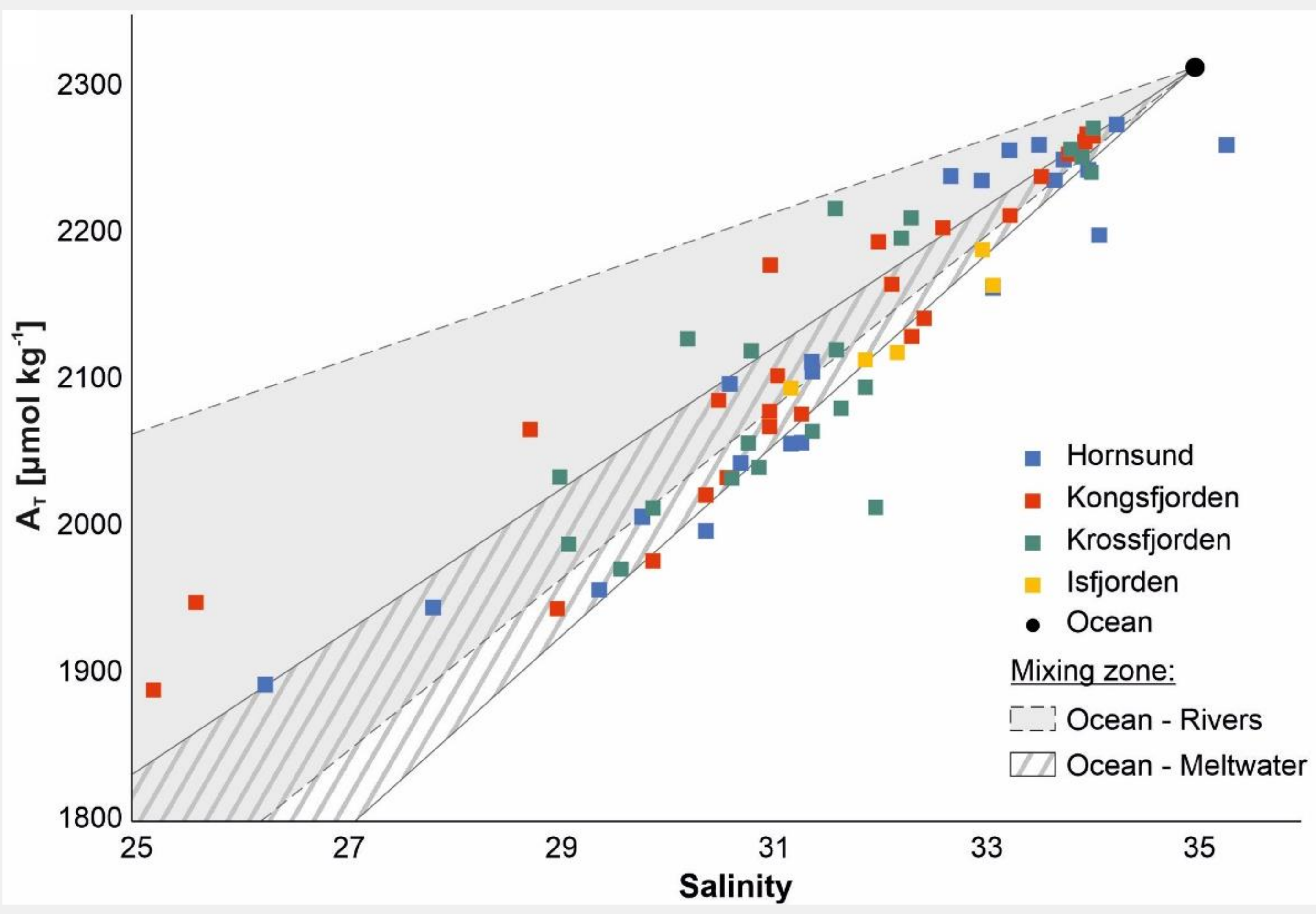
$$A_T = [HCO_3^-] + 2[CO_3^{2-}] + [B(OH)_4^-] + [OH^-] + [HPO_4^{2-}] + 2[PO_4^{3-}] + [SiO(OH)_3^-] + [NH_3] + [HS^-] + \ldots + \text{minor bases} - [H^+]_{free} - [HSO_4^-] - [HF] - [H_3PO_4] - \ldots - \text{minor acids}$$



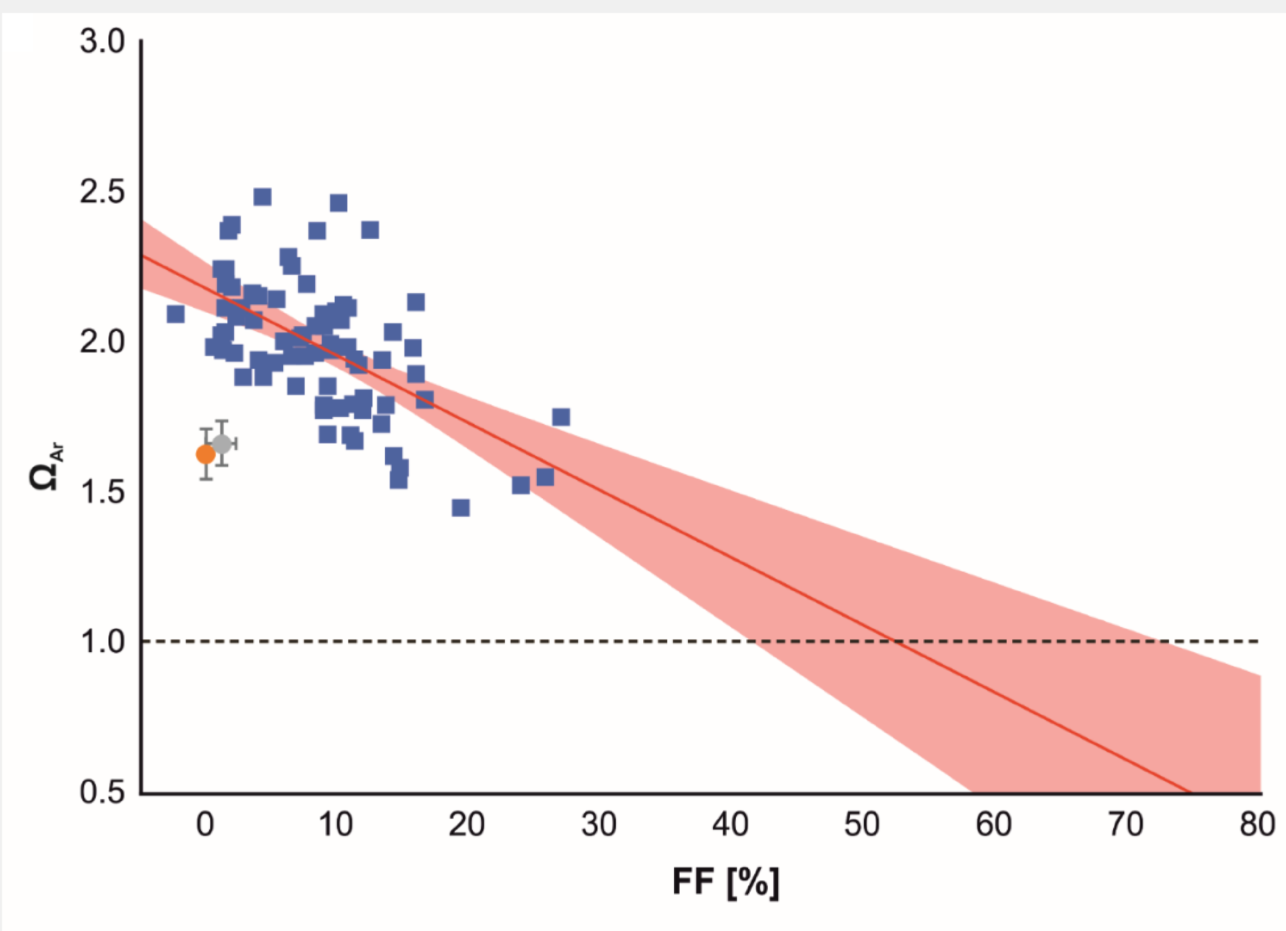
Goal

The study aims at identifying the role that freshwater input may have on shaping the structure and variability of the CO_2 system and thus also on OA in the coastal zone through changing alkalinity distribution. This has been done by performing intensive observations in two regions where the freshwater supply is an important driver for the coastal ecosystems, namely Spitsbergen fjords (Svalbard European Arctic) and the southern Baltic Sea (northern Europe). The former is highly influenced by meltwater, while the latter being one of the largest brackish ecosystems in the world is under high pressure of riverine runoff. By investigating these two contrasting regions we would like to demonstrate two different effects the freshwater input may have on the acid-base balance in the coastal zone.

Spitsbergen fjords

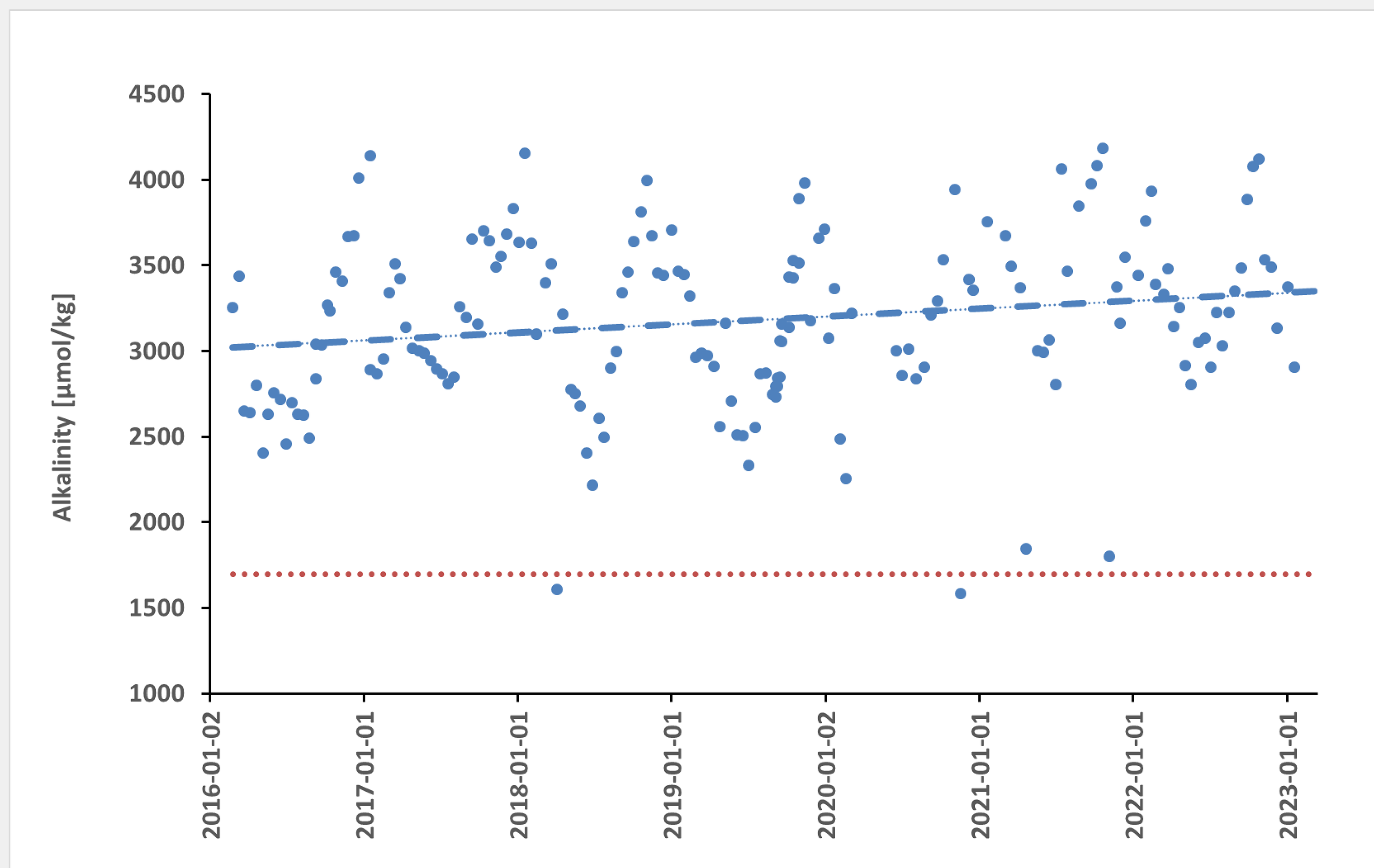


Although very high variability, the meltwater entering Spitsbergen fjords have significantly lower alkalinity concentrations than seawater and its inlow leads to A_T decrease (Koziorowska-Makuch et al., 2023)

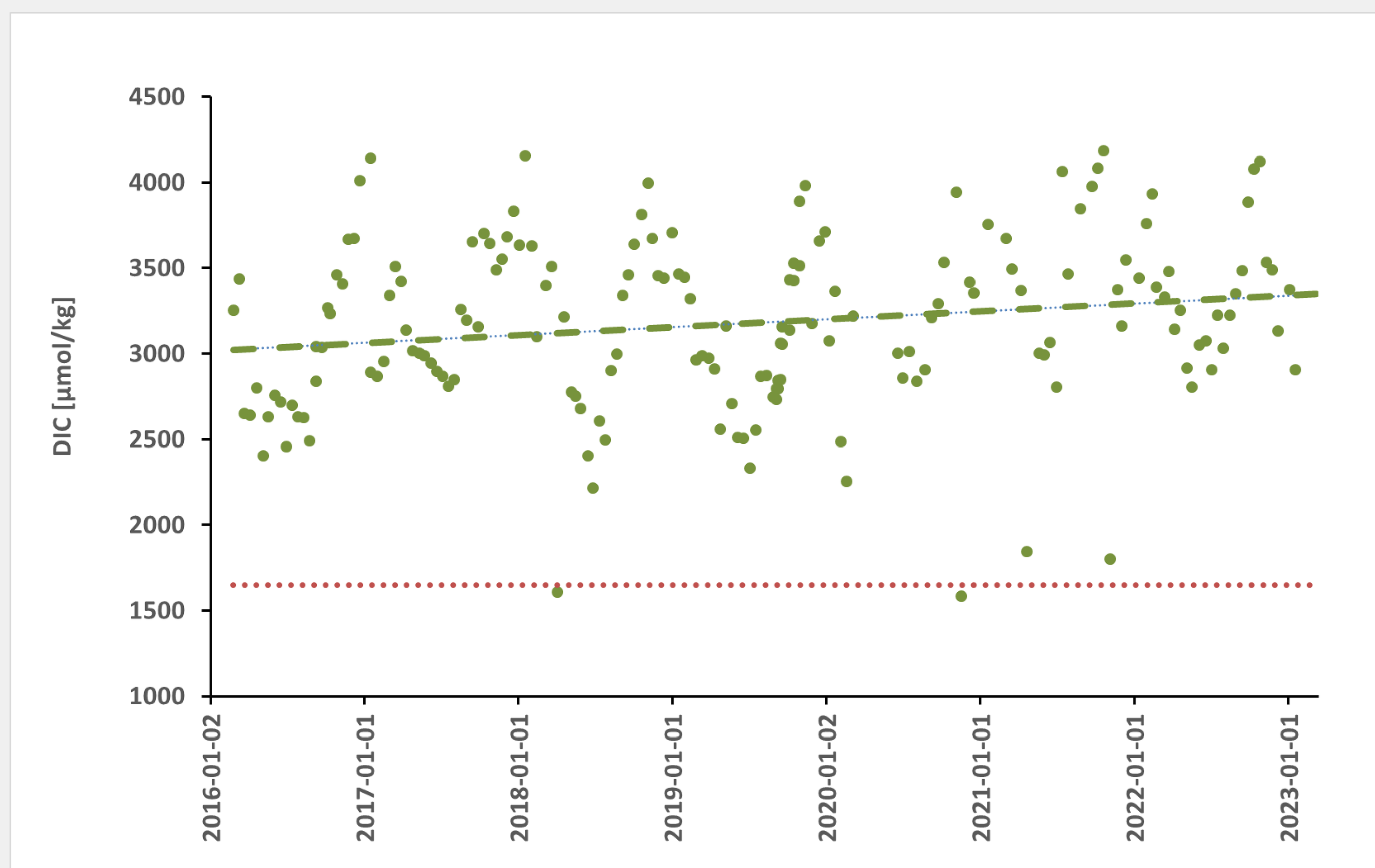


Seawater dilution with meltwater, expressed as an increase in freshwater fraction (FF) leads to a decrease in the saturation state of aragonite (Ω_{Ar})

Vistula River mouth (Baltic Sea)



VistuLa River is a net source of alkalinity to the Baltic Sea. A_T concentrations in the river (blue dots) are significantly higher than in the Baltic (red dotted line) and increase over time at a rate of approx. 46 µmol kg^{-1} yr^{-1}



DIC concetrations in the Vistula River are significantly higher than in the Baltic Sea (red dotted line) and increase over time at a rate of approx. 70 µmol kg^{-1} yr^{-1}

Conclusions

- Ocean Acidification in the open ocean can be understood from atmospheric CO_2 increase and the air/sea CO_2 exchange.
- In coastal waters number of other drivers play the role. Within them alkalinity balance is one of the most crucial.
- We should better understand the role of alkalinity transport from land as the climate change and related to that changes in freshwater supply and weathering processes in the catchment have the potential to change alkalinity fields in the coastal zone and either accelerate or mitigate the effect of OA.
- Ocean Acidification, by being made one of seven Global Climate Indicators (and the only biogeochemical one) by WMO and GCOS has gained a lot of attention in the scientific community but also in policy and society. This, however, requires an urgent revision.

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