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# Seawater properties and Ocean Heat Content in in Kongsfjorden, Svalbard

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**Abstract**

The Arctic Ocean is the Northern hemisphere heat sink for our planet and is experiencing drastic and fast climatic changes. A major connection between the Arctic Ocean and global climate that has come to the foreground during the past decades is the oceanic component of the global water cycle. Two aspects of the interaction between the Arctic Ocean and global climate appear particularly important. The first involves sea ice and the second involves heat and ocean mass budgets. Considerable effort has been invested in understanding sea ice and the dynamics and thermodynamics of sea ice are probably as well understood as any part of the polar climate system. For example, we know that every year about 3,000 $km^3$ less sea ice was frozen within the Arctic Ocean then is melted, and recently ice melting has increased (Murray et al, 2015). Data about freshwater balance of the Arctic Ocean had been mainly calculated from sea-ice melting and through the contribution of fresh water from land-based glacier runoff after increased atmospheric temperature.

The contribution of heat from the ocean and from the oceanographic processes at the interface between the sea and tidewater glaciers has been suggested as a possible trigger destabilizing glaciers' front. Freshwater input into the ocean and the estimate of seawater properties and movements able to affect submarine melting of tidewater glaciers has been studied theoretically and in situ in several locations (Straneo et al, 2012) and are one of the objectives of ARCA Project. Ocean Heat Content (OHC) is a powerful indicator of climate changes (Levitus et al, 2005), but plain temperature data are more widely used because they are easy to collect and manage and, as a matter of fact, a good indicator. OHC derived from the record of hydrographic profiles and seabed morphology is usually poorly addressed in most of papers on ocean tidewater glacier interaction, including from Kongsfjorden, except one general reference to surface OHC in Cottier et al (2005) and a recent paper by Aliani et al (2016).

OHC is defined as the depth-averaged temperature over a given volume of seawater times its density, times the specific heat capacity (eq.1):

$$H = \rho \, c_p \, V \, T$$

where $\rho = 1027$ kg/m$^3$ is water density, $c_p = 4000$ J/kg $^\circ$C is sea water specific heat capacity, V is the volume and $\bar{T}$ is the depth averaged temperature. The concept of OHC from oceanographic data includes many variables that may locally affect the heat content of a water mass of the ocean and the properties of ocean glacier interaction. It is a global index (Levitus et al, 2005), but at the same time it is very site specific. A snapshot of the spatial differences in OHC between the inner fiord and the ocean at close proximity of glacier interface has been described by Aliani et al (2016) using CTD data collected in September 2014.

In this paper, we estimated OHC, calculated as described in equation 1, based on volumes as inferred from bathymetric survey (Aliani et al, 2016) and on temperature time series from Mooring Dirigibile Italia. We used temperature time series over the year 2014-2015 at about 25 m depth, that is the depth where the warm core of Atlantic water has been historically found (Aliani et al, 2004) to infer OHC in the water column. The aim is to explore the seasonal changes of OHC in the

innermost part of Kongsfjorden.

The Kongsfjord is a glacial fjord of the Arctic in North-West Svalbard located at 79 °N, 12 ° E where 5 major glaciers interact with warm water of Atlantic origin. See Svendsen et al (2002) and Aliani et al. (2016) for a description of study site and mooring Dirigibile Italia, respectively. For the purposes of this paper, we report the relevant volumes of the basin where MDI was located, and where OHC is calculated.
The volume of inner basin (Area A in figure 2) was 1.73 $km^3$ over a total volume of Kongsfjorden of 29.4 $km^3$. The volume of warm Atlantic water at mooring location was 1.61 $km^3$ and 0.12 $km^3$ was the volume of cold water. Although we are aware that temperature from the mooring is not fully representative of the water column, for example seasonal changes in thermocline depth may affect estimates, we calculated OHC temporal variability assuming that there were no changes in the structure of the water column over time.
The time series of OHC within Kongsfjorden from September 2014 to March 2015 is reported in Fig. 2. The series ranges from $15 \bullet 10^{15}$ to $-5 \bullet 10^{15}$ Joules. Maximum was in September 2014. This value refers to OHC at the mooring site at 27 m depth, i.e. to the warm core of entering Atlantic water. This is higher than the value calculated by Aliani et al (2016) using temperature from CTD casts from Area A ($4.5 \bullet 10^{15}$ Joules) although the temperature from time series recorder at 27 m depth was about 6 °C and on the day of CTD cast (10 September 2014) at the same spot was about the same.
The OHC value from CTD casts was an integration over the water column for a single day from the lower depth of surface fresh water exiting the fjord (-7.5m) to the depth of the Lovenyane ridge. The objective of that paper was to assess the inflow of OHC into the area of the glaciers termini and to adjust for outflow, entrainment and mixing processes taking place at the sill, temperature below 30 m were considered not relevant to regularly interact with glaciers. The time series recorded the core of water, i.e. the OHC entering the fjord without vertical dilution/depth integration. As a result we can argue that about $10 \bullet 10^{15}$ Joules are lost in ocean mixing processes and morphological

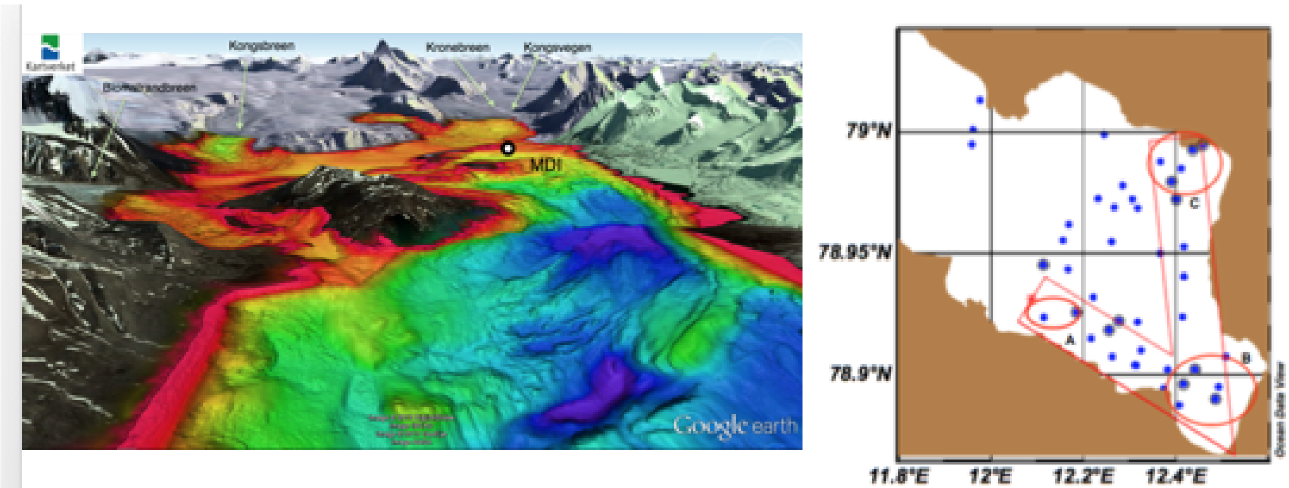


***Figure 1:*** *3D reconstruction of seabed used to assess water depth (left); Map of CTD casts used to assess hydrological properties.*

constraints in Area A before the water enters in the area of direct ocean-glacier interaction. A warm water vein was found in Kongsfiorden at MDI site for most of the year, suggesting that warm water intrusion was a quasi regular input in the innermost part of the fiord with a linear decrease in temperature found during the year. In wintertime temperature below 0 °C was recorded from end of December to mid March. OHC reached negative values (about -5 • $10^{15}$) and during this period we can assume that new ice can be formed, or at least conditions for ice melting did not take place.

In conclusion, melting at grounding lines has been suggested as a possible mechanism by which the marine-based glacier could be destabilized but external local forcing, as mixing and morphological constraints, may considerably affect the amount of heat reaching the ocean glacier interface. In Kongsfiorden, during winter 2014 no warm input was found at intermediate depth and ocean conditions were favourable for new ice production.

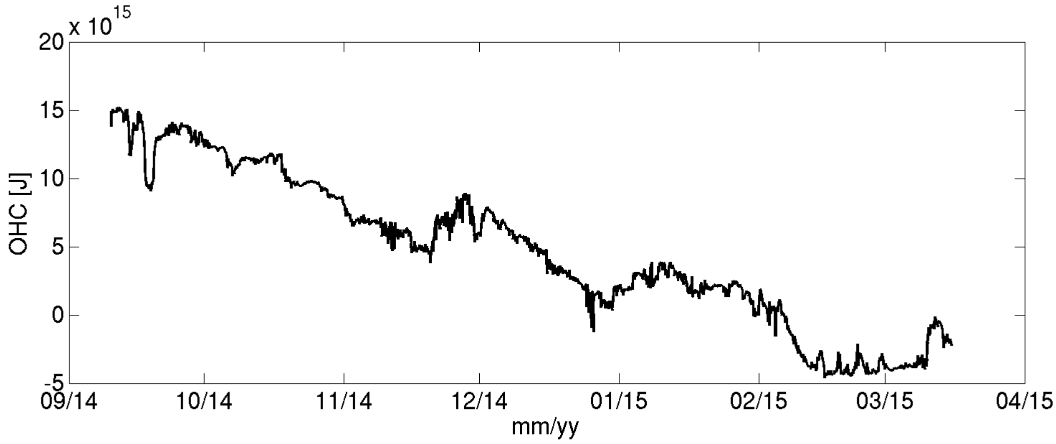


***Figure 2:*** *OHC timeseries from September 2014 to March 2015*

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