Temporal variability of particle fluxes and bottom density-driven currents on the Storfjorden continental slope (Svalbard)

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Introduction

The offshore SW Svalbard Archipelago (Fig. 1) is a region where Atlantic waters, considerably warmer than the locally-formed dense waters, flow northwards embedded in the so-called West Spitsbergen Current (WSC) through the eastern side of the Fram Strait. They keep this region nearly ice-free even during winter season. Additionally, dense waters formed during winter through freezing and brine rejection fill the bottom of the Storfjorden polynya. After their generation, they flow down to the continental slope, and then, geostrophically adjusted move northwards along the isobaths. The cascading of the brine-enriched shelf water can reshape the sea bottom and transport large quantities of water, sediment and associated organic matter, and gases (mainly CO_2 and dissolved O_2) toward the deep-sea environment. In particular, two contourite depositional systems were discovered in the area: the Isfjorden and Bellsund contourite drifts (Rebesco et al., 2013). Sanchez-Vidal et al. (2015) have investigated from July 2010 to July 2011 the environmental processes driving the sinking of particles and organic matter along the Storfjorden slope, by using 4 moorings equipped with automatic sediment traps, current meters and temperature and salinity recorders. Higher lithogenic fluxes and coarsening of settling particles in late winter–early spring have been forced by a seasonal WSC intensification. An increased arrival of ice rafted detritus by sea ice transport from the southern Spitsbergen coast along with terrestrial organic matter was also observed during winter. In spring–summer, phytoplankton blooms have augmented the biogenic compounds (opal, organic carbon and calcium carbonate) of the downward particle fluxes (Sanchez-Vidal et al., 2015). Several studies suggest that reduced sea ice extent and thickness caused by global warming are likely to increase the export of marine organic matter as a result of a longer phytoplankton growing season and enhanced under-ice productivity (Arrigo et al., 2008). To acquire a better understanding of these processes and assess the impact of climate change on the cycling of organic carbon (OC), including shifting the relative magnitude of the main OC sources, further long-term observations in polar continental margins are considered necessary.
In the framework of different projects (Eurofleets2-PREPARED and BURSTER, Premiale-ARCA and PNRA-DEFROST) and in a common effort between CNR-ISMAR, OGS and University of Gothenburg, the mooring S1 has been re-deployed in June 2014 and serviced annually by using the *RVs* G.O. Sars, Helmer Hansen and Polarstern. Although the experiment is still in progress, first results are presented in the following section.

Results

The mooring S1 is specifically devoted to investigate near-bottom processes. For this reason, instruments are placed close to the seabed (Fig.1). From the bottom, an Aanderaa RCM8 current-meter at ~20 m is tethered to the mooring line, just 5 m below the automatic McLane sediment trap. At the same depth, a SBE16plus recorder of temperature, conductivity and turbidity is mounted. At the mooring top, a downward looking RDI 150 kHz ADCP is placed.

Here, we will present a 2-yr long time-series of current, temperature and salinity from the near-bottom instruments together with downward particle fluxes of the first year of deployment.
For most of the year, potential temperature and salinity remained almost constantly around -0.9 °C and 34.90 (Fig. 2), respectively, confirming that the Norwegian Sea Deep Water occupied site S1 near the bottom (Sanchez-Vidal et al., 2015). However, from October to April several short-lived increases in potential temperature (up to +2.0°C) and salinity (up to 35.02) were observed suggesting the remote influence of the shallower, warmer, and saltier Atlantic Water. These injections of water masses at lower density (Fig. 2) were accompanied by a significant intensification of near-bottom currents (peak values up to 73 cm/s and 58 cm/s in winters 2015 and 2016, respectively), although in some cases (e.g., in early Jan. 2015), the speed peak anticipated of some days the temperature and salinity increase. The current direction at site S1 was highly variable, but the mean flow was roughly oriented along-slope with minor fluctuations from year to year (9°N in June 2014-June 2015; 358°N in June 2015-June 2016). The current variations were dominated by low frequency fluctuations of 2–8 day periodicity, and to a lesser extent by semi-diurnal tidal oscillations, with median values of about 12-13 cm/s. Unfortunately, the sediment trap rotation failed after the fifth sample. Thus, from mid-August 2015 until June 2016, we have only an integrated sample. Nevertheless, some significant considerations can again be done. Total mass fluxes (TMF) varied between 88 and 326 mg m^{-2} d^{-1}. They were lower in summer (Fig. 3), while in winter they increased during the episodes of current strengthening, confirming the contribution of bottom currents in transferring particles from the shelf toward the deep basin. The winter sample was characterized by low contents of OC and total nitrogen, and more negative $\delta^{13}C$ values (higher terrestrial OC fraction). The high contents of $CaCO_3$ (17-27%), also in winter, suggest an important contribution of detrital carbonates. In summer, fresh organic matter (OC > 4%) composed by phytoplanktonic detritus was characterized by less negative $\delta^{13}C$ values (higher marine OC fraction) and lower values of $\delta^{15}N$ due to the influence of relatively nutrient-enriched surface waters (Fig. 3).
In conclusion, the time series of particle flux and composition, as well as water mass characteristics and dynamics, gathered in 2014-2016 seem to confirm the results published by Sanchez-Vidal et al. (2015). The seasonal variability appears characterized by higher marine OC contents in summer and larger contribution of particles coming from the continent in winter due to intensification of the WSC that, impinging on the continental margin, resuspends sediment at the shelf edge, transfers it down to the slope and reshapes the seafloor. Nevertheless, some questions remain unsolved, such as what process triggers the pulses of warm, less dense and energetic Atlantic waters or why cascading events of brine-enriched shelf waters were not registered in the three years of observations? For its fluctuating nature, dense shelf cascading is known to be a highly episodic process, with strong interannual variability. All these considerations lead to the suggestion to keep the observation site S1 permanently.

References

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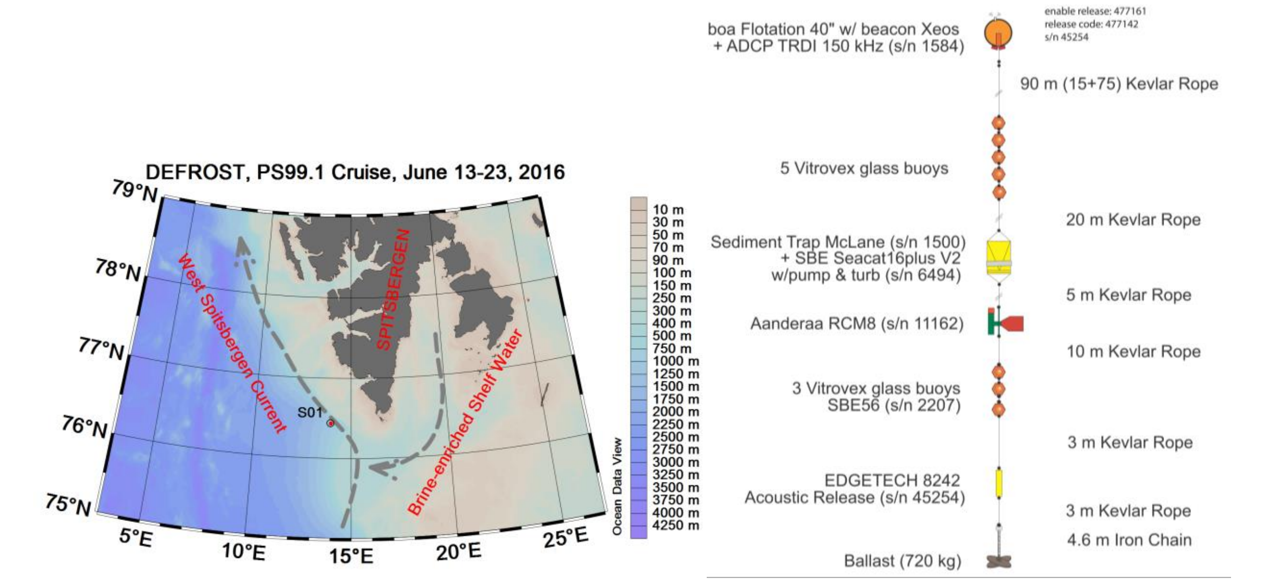

Figure 1: *left, Study area and position of mooring S1; right, Mooring design*

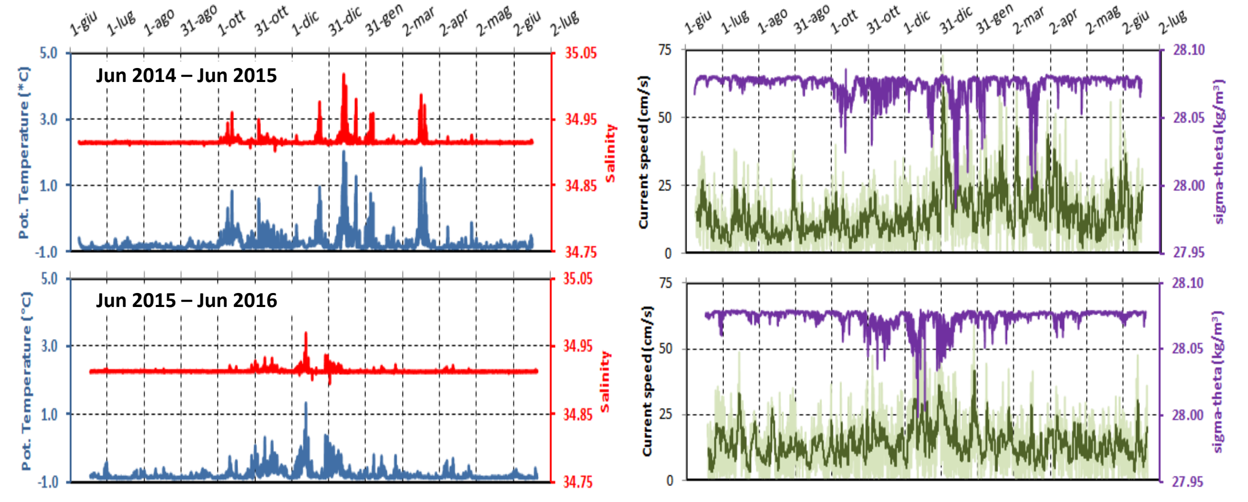

Figure 2: *Time series of temperature, salinity, density anomaly and current speed for periods June 2014-June 2015, and June 2015-June 2016 (CT and speed data acquired each 30 and 60 minutes, respectively) .*

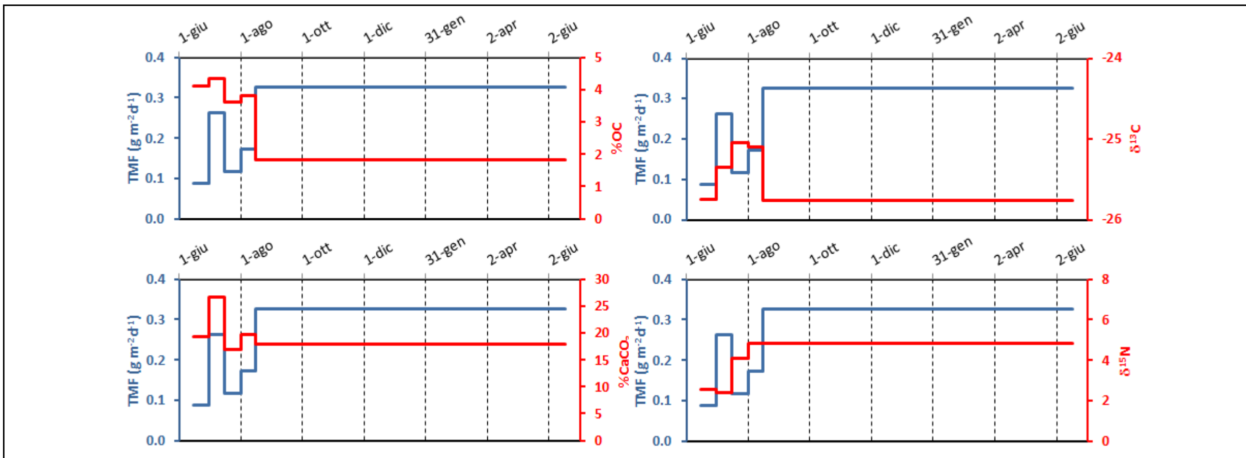

Figure 3: *Time series of total mass fluxes plotted against biogenic components and stable isotopes of organic matter from June 2014 to June 2015.*