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Lateral supply and downward export of particulate matter from upper waters to the seafloor in the deep eastern Fram Strait

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ABSTRACT

Time-series sediment traps were deployed at 4 depths in the eastern Fram Strait from July 2007 to June 2008 to investigate variations in the magnitude and composition of the sinking particulate matter from upper waters to the seafloor. Sediment traps were deployed at 196 m in the Atlantic Water layer, at 1296 and 2364 m in the intermediate and deep waters, and at 2430 m on a benthic lander in the near-bottom layer. Fluxes of total particulate matter, particulate organic carbon, particulate organic nitrogen, biogenic matter, lithogenic matter, biogenic particulate silica, calcium carbonate, dominant phytoplankton cells, and zooplankton fecal pellets increased with depth, indicating the importance of lateral advection on fluxes in the deep Fram Strait. The lateral supply of particulate matter was further supported by the constant fluxes of biomarkers such as brassicasterol, alkenones, campesterol, β-sitosterol, and IP_{25} at all depths sampled. However, enhanced fluxes of diatoms and appendicularian fecal pellets from the upper waters to the seafloor in the presence of ice during spring indicated the rapid export (15–35 days) of locally-produced large particles that likely contributed most of the food supply to the benthic communities. These results show that lateral supply and downward fluxes are both important processes influencing the transport of particulate matter to the seafloor in the deep eastern Fram Strait, and that particulate matter size dictates the prevailing sinking process.

1. Introduction

The Fram Strait is a deep gateway between the northern North Atlantic and the Arctic Ocean. Warm Atlantic Water (3–4 °C) carried by the northward West Spitsbergen Current enters the Arctic Ocean boundary current on its eastern side (Beszczynska-Möller et al., 2012) and sea ice exits the Arctic Ocean by the southward East Greenland Current on its western side (Smedsrud et al., 2011). The Long-Term-Ecological Research (LTER) observatory HAUSGARTEN has been maintained for more than a decade in the eastern Fram Strait by the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research to monitor the impact of large-scale environmental changes on downward fluxes and benthic communities in this transition zone, approximately 120 km west of Spitsbergen (Fig. 1; Soltwedel et al., 2005, 2016). Long-term measurements of downward fluxes at the HAUSGARTEN central station showed that the annual export of particulate organic carbon (POC) at ~300 m is relatively constant in the eastern Fram Strait, ranging from 1.6 to 2.6 g m^{-2} yr^{-1} from 2000 to 2008 (Bauerfeind et al., 2009; Lalande et al., 2013). These long-term measurements also showed that the composition of the biogenic matter exported out of the upper ocean varies temporally depending on the temperature of the Atlantic Water inflow and on the presence of ice cover in the eastern Fram Strait, with enhanced fluxes of larger phytoplankton cells generally observed when sea ice is concurrently present with sunlight in the area (Bauerfeind et al., 2009; Hardge, 2012; Lalande et al., 2013). However, little is known on the magnitude and composition of particulate matter fluxes that actually reach the deep seafloor in the region.

Results from recent benthic studies conducted at HAUSGARTEN pointed toward the importance of organic matter supply for the deep-sea benthic community in eastern Fram Strait. Soltwedel et al. (2009, 2016) reported that large-scale distribution patterns of deep-sea megafauna at the long-term observatory were mainly controlled by food availability while water depth and seabed properties played a secondary role. The importance of food availability was further reflected in meiofauna distribution, with higher nematode and harpacticoid copepod densities observed with

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increased organic content in sediments (Hoste et al., 2007). Moreover, a decrease in megafaunal densities observed from 2002 to 2007 at the central HAUSGARTEN station was partly attributed to a decrease in total organic carbon content in the sediments (Bergmann et al., 2011). These results identify supply of organic matter as a major factor shaping benthic distribution and density in the region and underscore the necessity of assessing how the magnitude and composition of fluxes are modified as particulate matter sinks toward the seafloor in the eastern Fram Strait.

In this study, sediment traps were deployed at 4 depths from July 2007 to June 2008 at the HAUSGARTEN central station to investigate spatial and temporal variations in the magnitude and composition of particulate matter fluxes from upper waters to the seafloor in the eastern Fram Strait. More precisely, fluxes of total particulate matter (TPM), particulate organic carbon (POC), particulate organic nitrogen (PON), biogenic particulate silica (bPSi), calcium carbonate ($CaCO_3$), diatoms, coccolithophores, zooplankton fecal pellet carbon (FPC), and biomarkers were measured at 196 m, 1296 m, 2364 m, and 2430 m (3 m above seafloor). The biomarkers sampled included brassicasterol (diatom biomarker), alkenones (coccolithophore biomarker), campesterol and β-sitosterol (terrestrial biomarkers), and IP_{25} (sea ice diatom biomarker).

2. Material and Methods

2.1. Remote sensing

Daily averaged sea ice concentration for the area above the central station (78°30′ – 79°30′ N; 2°30′ – 6°30′ E) was obtained by analysis of Advanced Microwave Scanning Radiometer-EOS (AMSR-E) data provided by the National Snow and Ice Data Centre. The 89 GHz AMSR-E sensor and the ARTIST Sea Ice (ASI) algorithm were used, yielding a spatial resolution of 6.25 × 6.25 km (Spreen et al., 2008).

2.2. Mooring line and benthic lander

2.2.1. Current meters

Aanderaa current meters were deployed from July 2007 to July 2008 at 281, 1355, and 2530 m on a mooring line at the central station of the HAUSGARTEN observatory (water depth: 2540 m), and at 2430 m on a benthic lander near the mooring line (water depth: 2433 m) to record current speed, current direction and water temperature (Fig. 1; Table 1). Mean current speed, mean current direction, temperature, and the geographical origin of the sinking material collected in the sediment traps were illustrated in progressive vector diagrams with temperature (PVD-T; Fig. 2). The Eulerian measurements of currents at the mooring and lander locations were displayed in a Lagrangian way following the movement of water parcels with winter-centred deployment period (Fig. 2).

2.2.2. Sediment traps

Three modified automatic Kiel sediment traps with sampling areas of 0.5 m^2 and 20 collection cups (Kremling et al., 1996) were installed at 196, 1296, and 2364 m (176 m above seafloor) on the same mooring deployed at the central station from July 2007 to July 2008 (Fig. 1; Table 1). Collection cups for each sediment trap rotated at intervals ranging from 10 to 31 days depending on the season. Because the mooring line was recovered before the completion of the last rotation, measurements from the last collection cup were dismissed from the study. An additional smaller sediment trap with a sampling area of 0.25 m^2 and 13 collection cups rotating at intervals ranging from 15 to 39 days was mounted on the benthic lander and deployed approximately 3 m above the seafloor at 2430 m from July 2007 to July 2008 (Fig. 1; Table 1). Collection cups from each sediment trap were filled with filtered seawater adjusted to a salinity of 40 with NaCl and poisoned with $HgCl_2$ (0.14% final solution) to preserve samples during deployment and after recovery. It is important to note that the trap

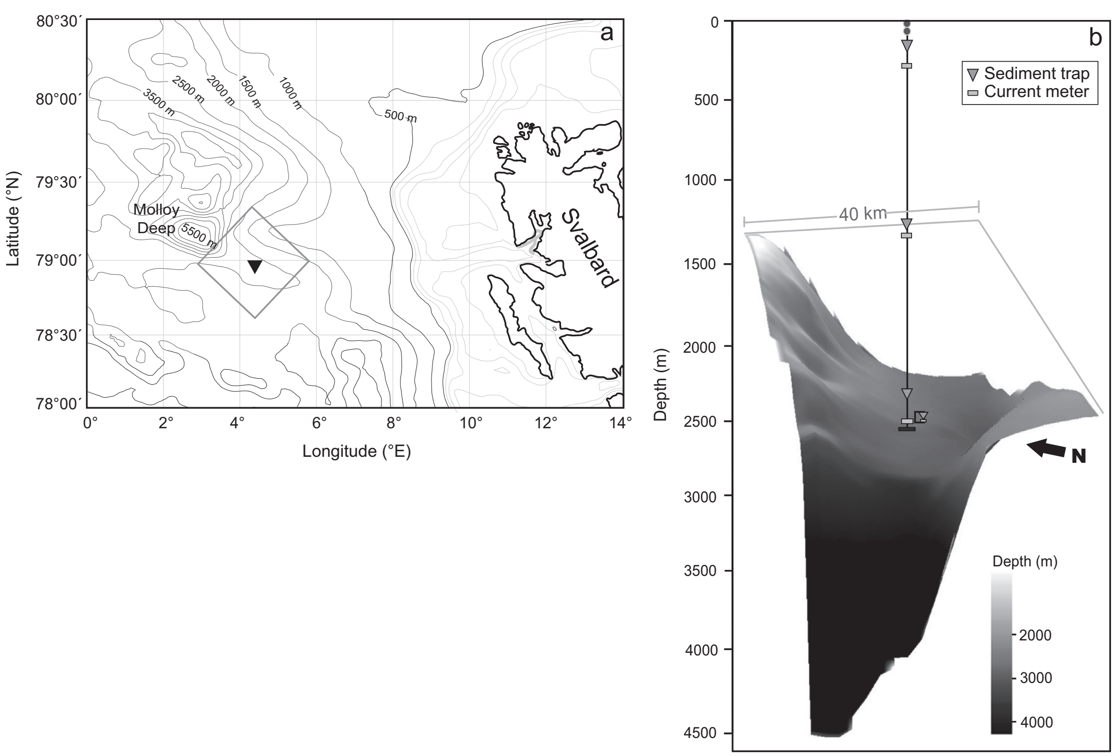

Fig. 1. (a) Map showing the location of the central station (triangle) at the HAUSGARTEN observatory west of Svalbard in the eastern Fram Strait (b) Diagram showing the depths of the sediment traps and current meters deployed on the mooring line at the central station and on the benthic lander near the central station in the context of the bottom topography at the observatory (not to scale; rectangle in panel *a*).