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Partitioning and lateral transport of iron to the Canada Basin

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Abstract

The concentration of dissolved iron (DFe) and suspended leachable particulate iron (LPFe) in the water column of the western Beaufort Sea were investigated during the late summer of 2010. Elevated concentrations of surface DFe (0.49–1.42 nM) were similar to those reported in resent studies, likely reflecting input from melting sea ice and river discharge. The rapid decrease in DFe (5.20–0.48 nM) and LPFe (88.2–1.83 nM) values observed from inshore to offshore in Pacific influenced waters, suggest scavenging processes limit the input of DFe from the shelf to the deep basin. However, frequent eddies found in this region are likely important in promoting lateral advection, as suggested by higher surface DFe concentrations at an offshore station in the vicinity of a warm-core eddy. Within the Atlantic layer, relatively homogeneous DFe (0.69–0.80 nM) and LPFe (1.18–2.13 nM) concentrations were observed at all the stations, reflecting a balance in the interplay between input and removal processes within this watermass. An input of DFe east of the Lomonosov Ridge was inferred by comparing DFe values within the core of Atlantic water between the Eastern and Western Arctic.

Keywords: Trace metals; Dissolved iron; Arctic Ocean; Canada Basin; Shelf input

1. Introduction

Although abundant in the continental crust, iron (Fe) is sparingly soluble in oxygenated seawater resulting in extremely low oceanic dissolved iron (DFe) concentrations. Iron is an essential nutrient to phytoplankton, and inadequate external inputs along with low Fe solubility can result in limiting DFe concentrations over large regions of the surface ocean (Boyd et al., 2007; Hutchins et al., 1998; Martin et al., 1991). Characteristic open ocean DFe profiles exhibit surface depletion with a gradual increase to a mid-depth maximum due to the remineralization of organic matter. The flux of DFe from rivers is not considered a major source of DFe to the oceans (De Baar and De Jong, 2001), because this input is lost via flocculation mostly within estuarine waters (Boyle et al., 1977). However, rivers flowing onto broad shelves can provide substantial reactive iron to surface sediment (Chase et al., 2005), and large rivers can influence offshore surface DFe concentrations ([DFe]) (Klunder et al., 2012a; Tovar-Sanchez et al., 2006). According to recent studies, the input from continental margin sediments appears to be a major source DFe to the oceans (Elrod et al., 2004; Lam et al., 2006; Moore

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and Braucher, 2008) and this subsurface delivery can extend far offshore (Johnson et al., 1997). In polar regions, the release of DFe from melting sea ice has also been identified as an important source to surface waters (Aguilar-Islas et al., 2008; Lannuzel et al., 2008; Measures, 1999). In terms of sinks, biological uptake and particle scavenging are mechanisms important in the removal of DFe from the water column. The dynamic interplay of removal processes and the processes that maintain Fe in solution (complexation by dissolved organic Fe-binding ligands, association with colloids, and reductive dissolution) controls the distribution of DFe in the ocean. The relative importance of these processes varies along with temporal and spatial oceanographic conditions.

The Arctic Ocean is uniquely set to receive large continental inputs of DFe. Arctic continental shelves are extensive and occupy roughly one third of its surface area. Several major rivers flowing into the Arctic Ocean provide a disproportionately large riverine flux when compared to its surface area (~10% of the global river flux to ~1% of the global ocean area). Additionally, the Arctic Ocean is impacted by the sea ice transport of sediment (Eicken et al., 2005) through the cycles of sea ice formation and melting. In the Western Arctic Ocean (Pacific sector), water of Pacific origin modified by its transit through the broad and shallow Bering and Chukchi shelves contributes to the halocline (Aagaard et al., 1981). In addition to providing nutrients (Wang et al., 2006), this water is a likely source of iron. Until recently, the distribution of DFe in Arctic Basins was unknown, but new studies from the Western (Nakayama et al., 2011) and Eastern (Klunder et al., 2012a, 2012b; Thuroczy et al., 2011) Arctic have illuminated the range of DFe concentrations found in Arctic waters, and the processes controlling the observed distributions. Klunder et al. (2012a) proposed that the high DFe (>2 nM) surface waters of the Amundsen and Makarov basins were derived from the transport of Eurasian river water by the Transpolar Drift (TPD), while the lower surface DFe values (<0.5 nM) observed above the Mendeleev-Alpha Ride and in the Nansen Basin offshore of the Barents Sea reflected the influence of sea ice meltwater and Atlantic water respectively. In deep waters, losses of DFe due to scavenging appeared to dominate over remineralization inputs (Klunder et al., 2012b) and stabilization by organic complexation (Thuroczy et al., 2011). An enhancement in deep DFe values (>1.5 nM) above background levels (<0.5 nM) was attributed to input from a hydrothermal plume above the Gakkel Ridge (Klunder et al., 2012b). In the Western Arctic, Nakayama et al. (2011) observed DFe profiles with subsurface maxima (>1.0 nM) within the upper halocline layer, and attributed this input to remineralization of organic matter given the coincident maxima in other nutrients and apparent oxygen utilization values. Similar to the Eurasian Basins, surface DFe values in the Western Arctic were relatively high (0.61–1.30 nM) (Nakayama et al., 2011) reflecting input from rivers and melting sea ice.

Here we present DFe, and suspended leachable particulate Fe (LPFe) data from the late summer of 2010 at seven stations in the Western Arctic (Fig. 1). The region surveyed during this study overlaps the region occupied by Nakayama et al. (2011) during the summer of 2008, providing information on interannual variability on the offshore transport of Fe.

2. Background: hydrography and circulation

The flow of Atlantic water (AW) through the Arctic Ocean follows an eastward trajectory towards the Canada Basin. Atlantic water, characterized by high salinity and high potential temperature (θ), interacts with continental margins in its eastward trajectory, and is found at intermediate depths in the Eastern and Western Arctic (Aksenov et al., 2011). Above the Atlantic layer is the lower halocline water (LHW), which is formed on shelf regions of the Eastern (Atlantic Sector) Arctic Ocean (Aagaard et al., 1981) and winter convection in the Nansen Basin (Rudels et al., 2004). In the Western Arctic, LHW is also thought to be influenced by diapycnal mixing of less dense Pacific-origin water (Woodgate et al., 2005a). Pacific-origin water entering through Bering Strait and modified over the Chukchi Shelf influences the upper part of the water column in the Western Arctic, and has strong seasonal characteristics which classify it as either Pacific winter water (PWW with salinity of ~33 and near freezing temperature) or Pacific summer water (PSW with salinity of 31–32 and warm temperature) (Coachman and Barnes, 1961). The upper halocline water (UHW) of the Western Arctic, which lies above the LHW, is composed of PWW and is characterized by a nutrient maximum due to diminished nutrient uptake during winter over the Bering and Chukchi shelves (Codispoti et al., 2005; Hansell et al., 1993), and the entrainment of nutrients regenerated in the seafloor of these shallow seas (Jones and Anderson, 1986). North of the Bering Strait, the outflow of PSW is enhanced in the vicinity of the Herald and Barrow Canyons (Coachman et al., 1975) and consequently