WATER MASS CHARACTERISTICS AND THEIR TEMPORAL CHANGES IN A BIOLOGICAL HOTSPOT IN THE SOUTHERN CHUKCHI SEA

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<Abstract> We analysed mooring and ship-based hydrographic and biogeochemical data obtained from a Hope Valley biological hotspot in the southern Chukchi Sea. The moorings were deployed from 16 July 2012 to 19 July 2014, and data were captured during spring and autumn blooms with high chlorophyll *a* concentrations. Turbidity increased and dissolved oxygen decreased in the bottom water at the mooring site before the autumn bloom, suggesting an accumulation of particulate organic matter and its decomposition (nutrient regeneration) at the bottom. This event may have been a trigger for the autumn bloom at this site. The bloom was maintained for 1 month in 2012 and for 2 months in 2013. The maintenance mechanism for the autumn bloom was also studied by hydrographic and biogeochemical surveys in late summer to autumn 2012 and 2013. Nutrient-rich water from the Bering Sea supplied nutrients to Hope Valley, although a reduction in nutrients occurred in 2012 by the influence of lower-nutrient water that would have remained on the Chukchi Sea shelf. In addition, nutrient regeneration at the bottom of Hope Valley could have increased nutrient concentrations and explained 60% of its nutrient content in the bottom water in the autumn of 2012. The high nutrient content with the dome-like structure of the bottom water may have maintained the high primary productivity via the vertical nutrient supply from the bottom water, which was likely caused by wind-induced mixing during the autumn bloom. Primary productivity was 0.3 g C m^{-2} d^{-1} in September 2012 and 1.6 g C m^{-2} d^{-1} in September 2013. The lower productivity in 2012 was related to strong stratification caused by the high fraction of surface sea ice meltwater.

R/V Mirai cruises

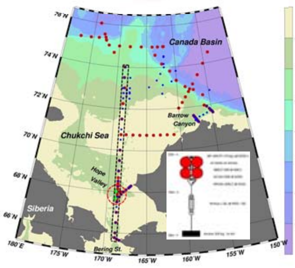

Figure 1. Map showing the bathymetric features of the study area and the hydrographic stations for the R/V *Mirai* cruises in 2012 (red dots) and 2013 (blue dots). Green diamonds represent the SCH-12 (southern site) and SCH-12-2/SCH-13 (northern site) mooring sites. Data from the stations enclosed by black dotted lines were used for the illustrations of vertical sections shown in Figs. 4–5. The area enclosed by the red dotted circle is the southern Chukchi Sea biological hotspot, where the moorings were installed and detailed hydrographic surveys were conducted.

Time series data from the moorings

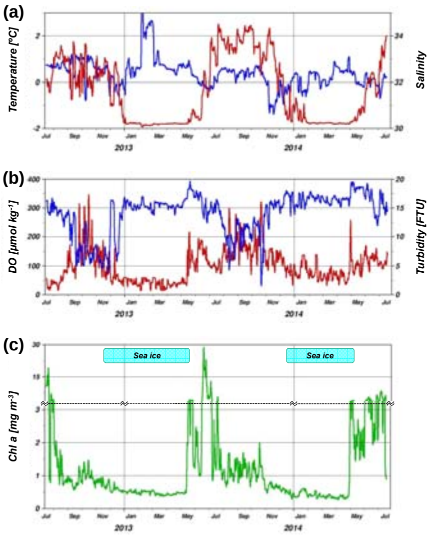

Figure 2. Time series of (a) temperature (° C; red) and salinity (blue), (b) dissolved oxygen, DO, (μmol kg^{-1}; blue) and turbidity (in formazin turbidity units, FTUs; red), and (c) chlorophyll *a*, Chl *a*, (mg m^{-3}; green). The data were obtained from the SCH-12, SCH-12-2, and SCH-13 moorings during 16 July 2012–19 July 2014. The vertical axis scale in (c) below the dotted line is exaggerated where the concentration is <3 mg m^{-3}. Periods when sea ice concentration was >50% at the mooring site are indicated by blue bars.

Chl a and primary productivity

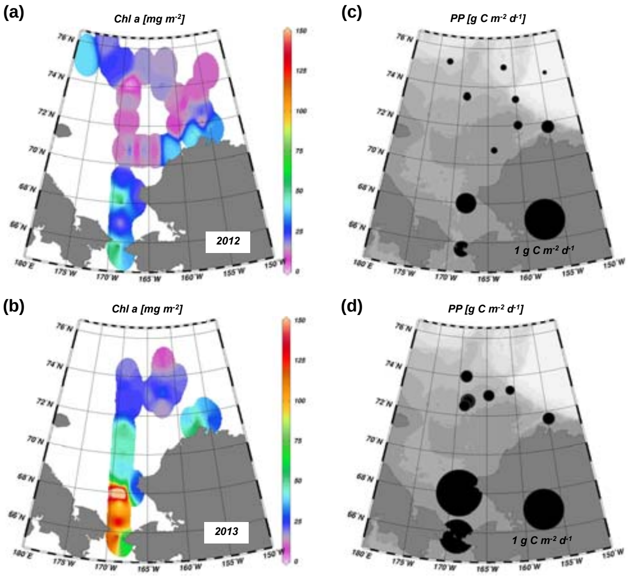

Figure 3. (a, b) Chlorophyll *a* integrated over the water column (mg m^{-2}) and (c, d) daily primary productivity in the water column (g C m^{-2} d^{-1}) obtained from the R/V *Mirai* cruises in 2012 and 2013, respectively.

Hotspot sections in 2012

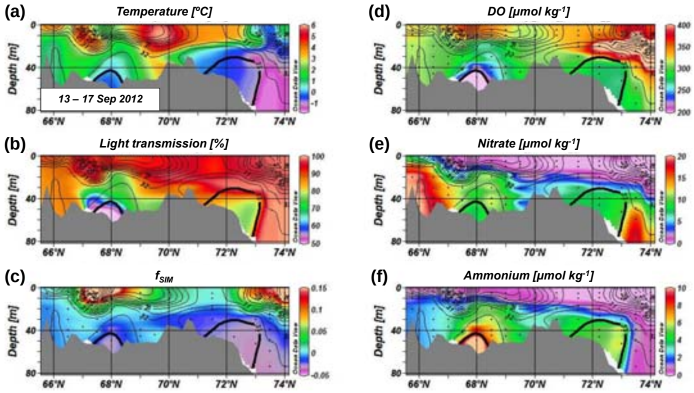

Figure 4. Vertical sections of (a) temperature (° C), (b) light transmission (%), (c) fraction of sea ice meltwater, (d) dissolved oxygen (μmol kg^{-1}), (e) nitrate (μmol kg^{-1}), and (f) ammonium (μmol kg^{-1}) along the 168° 45′W meridian near the U.S.–Russia border obtained during the 13–17 September 2012 R/V *Mirai* cruise. The water sampling level at each station is indicated by a black dot. Salinity contours are superimposed on each section with a 0.5 contour interval. The thick contour in each section indicates a salinity of 33.

Hotspot sections in 2013

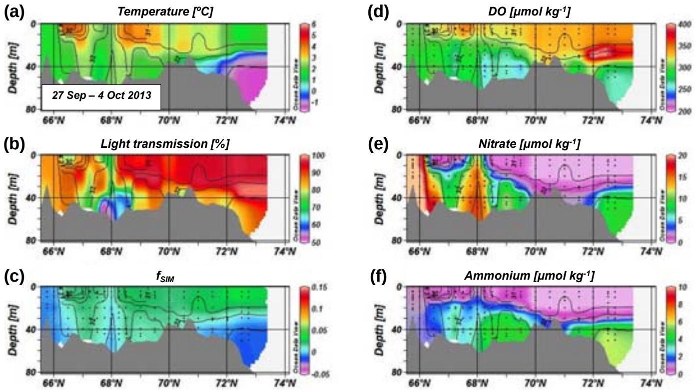

Figure 5. Vertical sections of (a) temperature (° C), (b) light transmission (%), (c) fraction of sea ice meltwater, (d) dissolved oxygen (μmol kg^{-1}), (e) nitrate (μmol kg^{-1}), and (f) ammonium (μmol kg^{-1}) along the 168° 45′W meridian near the U.S.–Russia border obtained during the 27 September–4 October 2013 R/V *Mirai* cruise. The water sampling level at each station is indicated by a black dot. Salinity contours are superimposed on each section with a 0.5 contour interval.

The mooring data indicated a seasonal change in water masses, i.e. the Bering Shelf-Anadyr Water (BSAW) in summer/autumn and Bering Winter Water (BWW) in winter/spring. The ship-based hydrographic and biogeochemical data suggested that the BSAW was largely modified by the BWW in autumn 2012 but not during a typical autumn (2004, 2008, 2010, and 2013). As a result, a prominent core of bottom water, which was characterised by lower temperature and higher salinity (density) than the surrounding water, was detected in 2012.

The large influence of the BWW in 2012 would have reduced nutrient concentrations because nutrients in the BWW that had remained in the Chukchi Sea until summer/autumn were probably used for the spring and autumn blooms, and/or were diluted by mixing with nutrient-poor water. In contrast, nutrient regeneration at the bottom increased nutrient concentrations and explained 60% of the nutrient levels evident in mid-September 2012. This high nutrient content, which was supplied by the BSAW and nutrient regeneration in the dome-like structure of the Hope Valley bottom water, maintained high primary productivity during the autumn bloom. However, primary productivity was largely controlled by water column stratification characterised by the distribution of freshwater from sea ice meltwater and river water.

Although the mooring in this study was deployed only at the biological hotspot site in the southern Chukchi Sea, the data show a temporal change in phytoplankton biomass and related parameters for the first time. We observed spring and autumn blooms associated with high Chl *a* concentrations. At the onset of the spring bloom, both DO and turbidity increased sharply, which is consistent with the oxygen production accompanying phytoplankton photosynthetic activity and the resultant increase in phytoplankton particles. On the other hand, before the autumn bloom, turbidity increased but DO decreased, suggesting accumulation and decomposition of POM (nutrient regeneration) on the bottom. This may have been a trigger for the autumn bloom at this site. The mooring data further suggest that the autumn bloom had a time scale of months with fluctuations that might have been related to autumn events, such as storms, surface cooling, and the formation of sea ice.