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SHORT COMMUNICATION

Oceanographic observations in the Nordic Sea and Fram Strait in 2016 under the IO PAN long-term monitoring program AREX

Waldemar Walczowski*, Agnieszka Beszczynska-Möller, Piotr Wieczorek, Malgorzata Merchel, Agata Grynczel

Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland

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Summary Since 1987 annual summer cruises to the Nordic Seas and Fram Strait have been conducted by the IO PAN research vessel *Oceania* under the long-term monitoring program AREX. Here we present a short description of measurements and preliminary results obtained during the open ocean part of the AREX 2016 cruise. Spatial distributions of Atlantic water temperature and salinity in 2016 are similar to their long-term mean fields except for warmer recirculation of Atlantic water in the northern Fram Strait. The longest observation record from the section N along 76°30′N reveals a steady increase of Atlantic water salinity, while temperature trend depends strongly on parametrization used to define the Atlantic water layer. However spatially averaged temperature at different depths indicate an increase of Atlantic water temperature in the whole layer from the surface down to 1000 m.

1. The IO PAN long-term monitoring program AREX

The northernmost polar region is most sensitive to global climate change and its effects are most exaggerated and have the biggest impact in the Arctic. Climate change is faster and more severe in the Arctic, which is warming at a rate of almost twice the global average (Cohen et al., 2014; Serreze et al., 2009). A steady temperature increase, observed both in the atmosphere and in the ocean, has a profound impact on the sea ice cover in the sub-Arctic seas

* Corresponding author at: Institute of Oceanology, Polish Academy of Sciences, 81-712 Sopot, Poland. Tel.: +48 58 73 11 904; fax: +48 58 551 21 30.
E-mail address: walczows@iopan.gda.pl (W. Walczowski).
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and Arctic Ocean (e.g. Polyakov et al., 2012; Stroeve et al., 2012). In the last two decades, the summer sea ice extent has shrunk dramatically together with a strong decline of its thickness and volume (Serreze and Stroeve, 2015). While many complex feedback processes contribute to the enhanced warming of the Arctic region called Arctic amplification, it is largely driven by the loss of the sea ice cover, allowing for strong heat transfers from the ocean to the atmosphere. By exposing larger dark open areas, where the ocean can absorb more of the sun's energy and in consequence warm further, the loss of sea ice in the Arctic Ocean also has the potential to accelerate global warming trends and to change climate patterns (Overland, 2016).

Large oceanic exchanges between the North Atlantic and the Arctic Ocean result in the strong conversion of water masses when warm and salty Atlantic water (AW), transported through the Nordic Seas into the Arctic Ocean, undergo cooling, freezing and melting. As a result, it is transformed into freshened shelf waters over the shallow shelves, sea ice and dense (and highly saline) deep waters (e.g. Dickson et al., 2008). Southward transport of the Arctic origin and dense overflow waters is one of the main mechanisms of the global thermohaline circulation (THC, e.g. Mauritzen, 1996). A better understanding of the variability of volume and heat transports between the North Atlantic and Arctic Ocean as well as processes of water mass conversion is necessary for improved qualitative and quantitative estimation of the large-scale meridional overturning circulation and its role in shaping the climate change in the northern hemisphere on inter-annual to decadal time scales.

Fram Strait is the only deep passage linking the Nordic Seas and the Arctic Ocean. The northward transport of warm and salty Atlantic water, carried by the Norwegian-Atlantic Current and farther by the West Spitsbergen Current, has a significant impact on conversion and circulation of water masses in the Arctic Ocean (e.g. Rudels et al., 2015) as well as on sea ice and atmospheric fluxes in the Arctic. The complex bottom topography of the northern Greenland Sea and Fram Strait results in the splitting of both currents into several branches, located along the underwater ridges and the continental slope (e.g. Bourke et al., 1988; Quadfasel et al., 1987; Walczowski, 2014). The spatial extent and relative intensity of these branches to a great degree determine oceanic heat flux into the Arctic Ocean (e.g. Beszczynska-Möller et al., 2012; Schauer et al., 2008).

Understanding of Arctic climate processes is the main aim of the current oceanographic and atmospheric studies carried on in the polar region. The Institute of Oceanology PAN (IO PAN) contributes to this challenge with the strategic research initiative addressing the role of the ocean in changing climate and its effects on the European seas. Its core activity, the long-term monitoring program AREX, is focused on multidisciplinary observations in areas such as physical oceanography, air—ocean interactions, ocean biogeochemistry and ecology to study the long-term changes of abiotic and biotic Arctic environment. Every summer since 1987 the large-scale field measurements have been carried out in the Nordic Seas and European Arctic from the board of the IO PAN research vessel *Oceania*. These data, collected under the observational program AREX every year in the same way, provide time series of key ocean variables which allow monitoring changes of the Arctic environment and improving numerical simulations of ocean, sea ice and climate in the Arctic region.

The main aim of the long-term AREX program and annual cruises, carried by r/v Oceania for the last 30 years in the Nordic Seas and Fram Strait, is to recognize and describe processes responsible for changing ocean climate and marine ecosystem in the sub-Arctic and Arctic region with a special focus on the European Arctic (Walczowski, 2014). To achieve this goal a large-scale study area, covering the poleward flow of Atlantic water in the eastern Nordic Seas and Fram Strait, has been selected for annually repeated ship-borne measurements on a regular grid. Most of the regularly repeated stations are distributed along several zonal sections, crossing the continental shelf break at the right angle and extending towards the deep basin. On the eastern side, the AREX oceanographic sections are limited by the Barents Sea shelf break and the shelf area west and north of Svalbard. To the west, the sections cross the Arctic Front, located above the system of underwater ridges (the Mohn and Knipovich ridges) and limiting the extent of Atlantic water in the Nordic Seas. The zonal sections following the Atlantic water inflow from the Norwegian Sea to the northern Fram Strait allow to assess transformation of water masses originating from the North Atlantic and advected northward. Two meridional sections, one from the northern Norway towards the Bear Island and one between the Bear Island and the southernmost tip of Svalbard (Sørkapp), cover the eastward flow of Atlantic water to the Barents Sea.

The AREX program and IO PAN field campaigns in the Arctic region are mainly based on statutory funding but since the early 90s they have also contributed significantly to several international projects, e.g. VEINS (Variability of Exchanges in the Nordic Seas, 1997—2000), ASOF-N (Arctic and subArctic Oceanic Fluxes — North, 2003—2005), and IP DAMOCLES (Developing Arctic Modelling and Observing Capabilities for Long-term Environment Studies, 2006—2009). The summer measurement campaigns of r/v Oceania and year-round observations with oceanographic moorings in the Nordic Seas, Fram Strait and, in recent years, in the southern Nansen Basin also provided crucial data for several projects under the Polish-Norwegian Research Program, including AWAKE-1 and -2, PAVE, CDOM-HEAT, POLNOR, and others. Last but not least, time series of ocean observations, collected in the last 30 years from r/v Oceania, have been employed by many IO PAN researchers and PhD students to carry on numerous studies of the Arctic climate and environment in the frame of IO PAN statutory research.

2. Oceanographic measurements during the AREX 2016 cruise

The AREX cruise of the IO PAN research vessel *Oceania*, repeated every summer over the same time period (June—August), in 2016 took place from June 14 to August 29. Two legs of the AREX 2016 cruise were devoted to the collection of oceanographic, meteorological, aerosol and ocean ecosystem observations in the open ocean regions, including the eastern Norwegian and Greenland seas, Fram Strait and the southern Nansen Basin of the Arctic Ocean.

The hydrographic survey carried out during the AREX 2016 cruise consisted of 11 sections extending from the outer