Proceedings of
The 32nd International Symposium on Okhotsk Sea and Polar Oceans 2017

Mombetsu, Hokkaido, Japan

19-22 February 2017

Organized and Sponsored by:

OSPORA
National Institute of Polar Research (NIPR)
Kitami Institute of Technology (KIT)
Tokai University, Sapporo Campus
Tokyo University of Agriculture, Okhotsk Campus
Tokyo University of Marine Science and Technology
Institute of Low Temperature Science, Hokkaido University (ILTS)
Hokkaido National Fisheries Research Institute, Fisheries Research Agency
Japan Consortium for Arctic Environmental Research (JCAR)
City of Mombetsu

Proceedings published by
Okhotsk Sea and Polar Oceans Research Association
(OSPORA)

February 2017

C-2

Variability of water mass distribution on the northern Chukchi regions in the Arctic

Kyoung-Ho CHO[1], Koji SHIMADA[2], Young-Seok CHOI[1], Eri YOSHIZAWA[2], Jinyoung JUNG[1], Jisoo PARK[1] and Sung-Ho KANG[1]

[1]*Division of Polar Ocean Sciences, Korea Polar Research Institute, Incheon, Republic of Korea*
[2]*Tokyo University of Marine Science and Technology, Tokyo, Japan*

Abstract

To reveal the relationship between sea ice loss and Pacific-origin waters in the Pacific Arctic Sector, we utilized historical data from hydrographic surveys conducted by the Korea Polar Research Institute (KOPRI) and yearlong mooring data provided by the Tokyo University of Marine Science and Technology (TUMSAT). From 2010 to 2016, the anomaly of Pacific Summer Water (PSW) temperature is negatively correlated with the anomaly of sea ice extent. Consequently, the anomaly of surface melt water (MW) salinity is positively correlated with the anomaly of sea ice extent. Yearlong temperature and water velocity data show spatial and temporal variations of PSW over the northern Chukchi region. We will also discuss these temporal and spatial variations of PSW and water mass distribution in terms of physical-chemical view point.

Key words: Pacific waters,

1. INTRODUCTION

The Arctic Ocean has warmed over the past few decades and its peripheral seas may be vulnerable to overall warming trends in global climate changes (Polyakov et al., 2007; Steele et al., 2008; Polyakov et al., 2012; Solomon et al., 2007). Especially, change in extent and thickness of Arctic sea ice is recognized as a key indicator of Arctic climate change (Shimada et al., 2006). In oceanographic point of view, increase in temperature of warm waters entrained from the Atlantic and Pacific Oceans may be contributing to sea ice melt (Polyakov et al., 2010; Shimada et al., 2006). One of the reasons for rapid reduction of Arctic sea ice is associated with increase in heat transport of summer waters and vertical fluxes of heat and momentum on atmosphere-ice-ocean interfaces (Carmack and Melling, 2011). In the Pacific sector of the Arctic, most of heating during summer comes from ocean surface heat flux and lateral flux convergence (Steele et al., 2010) and relatively warm Pacific-origin summer halocline waters which passes through the Bering Strait and reaches the vicinity of the Chukchi Sea (Shimada et al., 2001; Steele et al., 2004). These relatively warm waters tend to be redistributed to the Beaufort Sea along the Alaskan coast and to the vicinity of northern Chukchi regions (i.e., Chukchi Borderland and Mendeleev Ridge).

Horizontal heat transport and heat release of the summer halocline water and its pathway variation may play a significant role in understanding not only temporal and spatial changes of the halocline structure in northern Chukchi Sea but rapid sea ice reduction in the Pacific sector. In this study, to understand these variations, we have conducted 2~3-week Arctic Ocean expedition every summer since 2010 using an ice breaker research vessel. We, especially, aim to investigate the variability of water mass structure and distribution in norther Chukchi regions and to understand the relationship between water mass properties and sea ice extent.

2. DATA

2.1 Hydrographic Survey Data

Intensive oceanographic surveys were conducted in the summertime from 2010 to 2016 around the Chukchi Borderlands using the ice breaking research vessel, Araon. At all stations shown in Fig. 1, vertical profiles of temperature, conductivity, dissolved oxygen and water samples were obtained from the hydro-casts of a SBE32 carousel water sampler equipped with a SBE9plus Conductivity-Temperature-Depth (CTD) profiler, a SBE43 dissolved oxygen sensor, and so on. For the precise reading, the salinity of collected water samples were further analyzed by a Guildline's Autosal 8400B Laboratory Salinometer. To increase the spatial resolution for measurement of temperature and salinity, the expendable CTD (XCTD) probes were released at locations between hydrographic stations in consideration of local bathymetry and distance (XCTD stations are not shown in Fig. 1).

2.2 Ocean Mooring Data

Two ocean mooring systems, CP13 and CP14, were deployed in 2013 and 2014, respectively, over the Chukchi Plateau (CP) to examine water mass modifications and local heat release, and were recovered in 2015. each mooring system was equipped with one or two WorkHorse Sentinel Acoustic Doppler Current Profilers (ADCP) several temperature sensors (SBE56) and CTD sensors (SBE37).

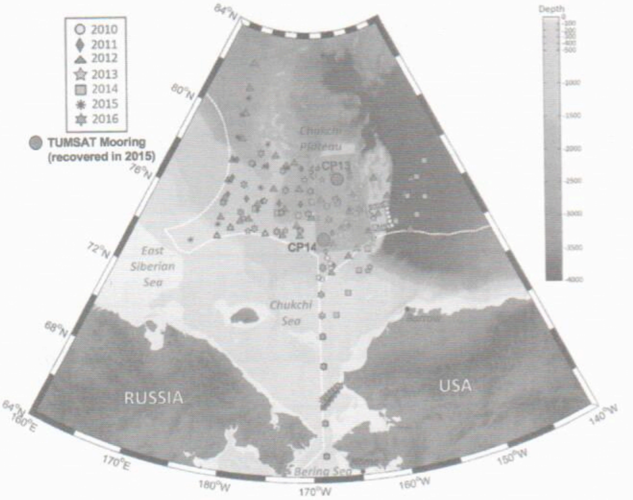

Fig. 1 A map of hydrographic survey stations during Araon Arctic expeditions from 2010 to 2016.

Table 1 Information on Araon Arctic expeditions conducted from 2010 to 2016 (numbers of stations and periods).

	2010	2011	2012	2013	2014	2015	2016
Shipboard CTD	38	18	44	16	32	42	34
XCTD		33	48	36	51	61	38
Period	Jul. 20 ~Aug. 10	Aug. 2~16	Aug. 4 ~Sep. 6	Aug. 24 ~Sep. 1	Aug. 1~23	Aug. 1~21	Aug. 5~20

3. RESULTS

3.1 Water mass characteristics from hydrographic survey data

We used the potential temperature and salinity (T-S) data obtained from deep downcasting at totally 491 CTD+XCTD stations (Table 1) to plot a T-S diagram (Fig. 2). The typical summer conditions (August) in the northern Chukchi Sea region are characterized by different water masses: Pacific Summer Water (PSW), Remnant Pacific Winter Water (RWW), newly ventilated Winter Water (WW), Atlantic Water (AW), and Melt Water (MW). We adopted the various water mass classifications defined by previous studies (Gong and Pickart, 2015; Itoh et al., 2015; Pisareva et al., 2015). We classified the Bering Summer Water (BSW) into PSW. The Alaskan Coastal Water (ACW) was present but not shown in Fig. 2 due to 2℃ upper limit in potential temperature.

3.2 Relationship between sea ice extent and water mass properties

We examined a relationship between sea ice extent (SIE) and water mass properties. Figure 3 shows distributions of heat content and sea ice concentration in August 2015. Relatively high heat content area (>350 J m^{-2}) is analogous to melt area. Thus, we selected the area of 170~160°W and 74~78°N which is appropriately covered by the years from 2010 to 2016 (shaded area in Fig. 1). We defined the water masses in selected region in the same manner and calculated the mean and anomaly values of potential temperature and salinity for each water mass. In Figure 4, SIE anomaly is negatively correlated with PSW temperature anomaly and positively correlated with MW salinity anomaly. SIE anomaly is, however, not correlated with surface MW temperature (not shown). This implies that PSW has an influence on ice melting in the northern Chukchi region and meltwater tends to decrease surface salinity. Relatively strong PSW was presented in summers of 2011, 2012, and 2013. However, PSW in summers of 2010, 2014, and 2016 appears to be weakened.

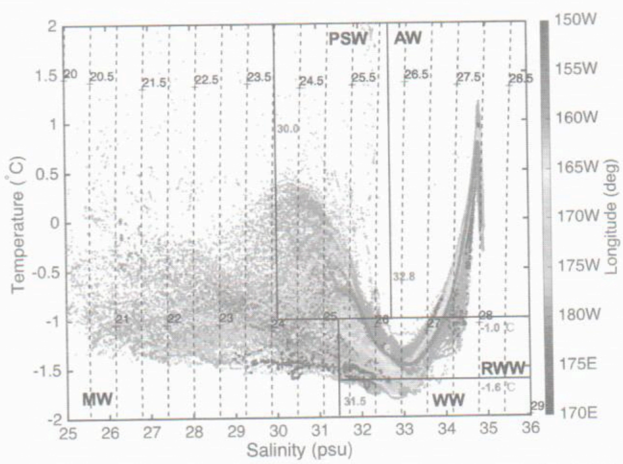

Fig. 2 A diagram of potential temperature and salinity at the CTD stations from 2010 to 2016. Data obtained from 2010 to 2016 are gray-colored and data in 2016 are color-coded according to the longitude.

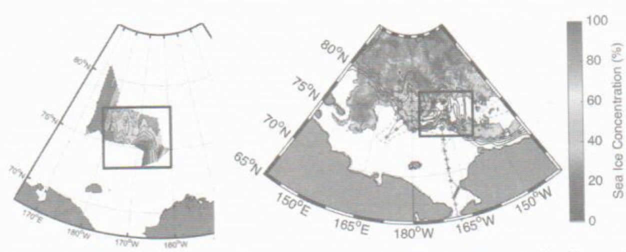

Fig. 3 Horizontal distribution of heat content (left) and sea ice concentration (right) in August 2015. Heat content is contoured in 50 J m^{-2} interval. The area of high heat content (> 350 J m^{-2}) is analogous to zero concentration area in a rectangular region.

3.3 Water mass variations from mooring data

Yearlong data obtained from two mooring stations, CP13 (northern CP) and CP14 (southern CP), show temporal and spatial variations of water masses. PSW at

CP13 sustained over winter 2013 (not shown) and was maintained in depths of 30 ~ 80 m until October 2014 (Fig. 5). At the moment, northeasterly winds started to blow and lasted for nearly 20 days. During the perturbation period, southeastward currents dominated at CP13. However, at CP14, northwestward currents were dominant and changed to northeastward currents when northeasterly winds halted (Fig. 6).

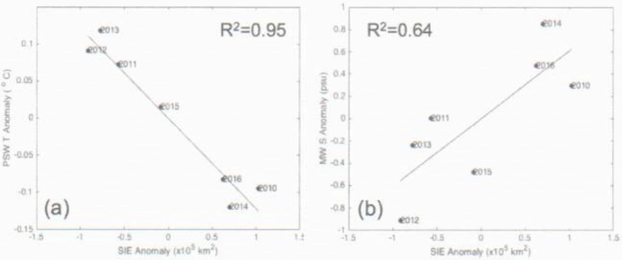

Fig. 4 Relationships between sea ice extent (SIE) anomaly and Pacific Summer Water (PSW) temperature anomaly (a), and between SIE anomaly and Melt Water (MW) salinity anomaly (b) in shaded region shown in Fig. 1.

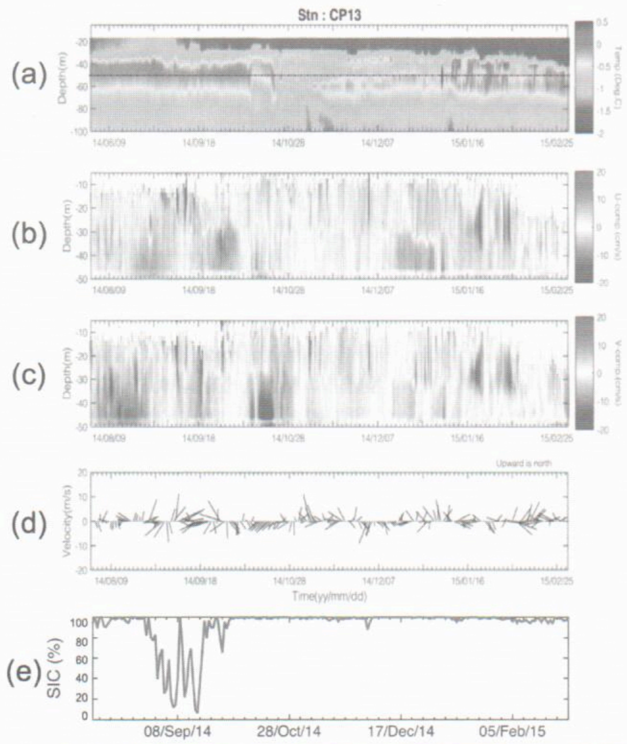

Fig. 5 Time-series of potential temperature (a), water velocity u-component (b) and v-component (c), wind vector from NCEP (d), and sea ice concentration from AMRS2 (e) at the CP13 mooring station. All data are daily mean values.

At CP14, after sea ice closed, warm water layer became trapped by fresher/colder (lower density) surface water and lasted for nearly 20 days in 30 to 50 m. In this period, northeastward currents dominated. After that, PSW depth gradually thickened and deepened until the end of December 2014.

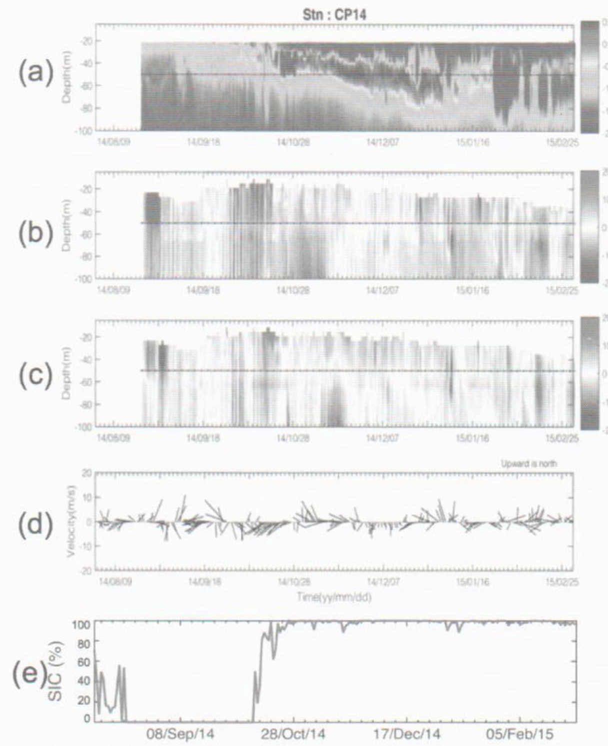

Fig. 6 As in Fig. 5 but for at the CP14 mooring station.

At CP13, temporal variation of T-S at 47 m depth is shown in Figure 7. From August 2013 to August 2014, potential temperature changed within 0.5℃ and salinity in August 2013 is 0.5~1.0 psu larger than that in August 2014. From August 2014 to August 2015 (Fig. 7b), T decreased below -1℃ during the period of October to November 2014 corresponding to perturbation period shown in Fig. 6a. We plotted T-S diagram at CP14 (50 m depth) from August 2014 to August 2015 (Fig. 7c). Several water masses appeared at CP14. RWW presented in early summer 2014 and PSW sustained in late summer to early winter. After that, temperature gradually decreased below to -1.5℃ but salinity did not change as much as temperature. During late spring to early summer, CP14 became to be occupied by newly ventilated WW.

4. DISCUSSION AND CONCLUSION

This paper has focused on temporal and spatial variations of water masses in the northern Chukchi Sea region using 7-year summer hydrographic survey data and yearlong ocean mooring data. Increase of PSW temperature is highly correlated with decrease of sea ice extent in study area and the consequent melt water increase tends to decrease salinity in the surface mixed layer. Summers of 2011 to 2013 had relatively warm PSW whereas those of 2010, 2014, and 2016 had relatively cold PSW. In addition, water sampling data indicates that WW has higher concentration of nutrients (phosphate and silicate) than PSW. We will further study the relationship between water mass and nutrients.

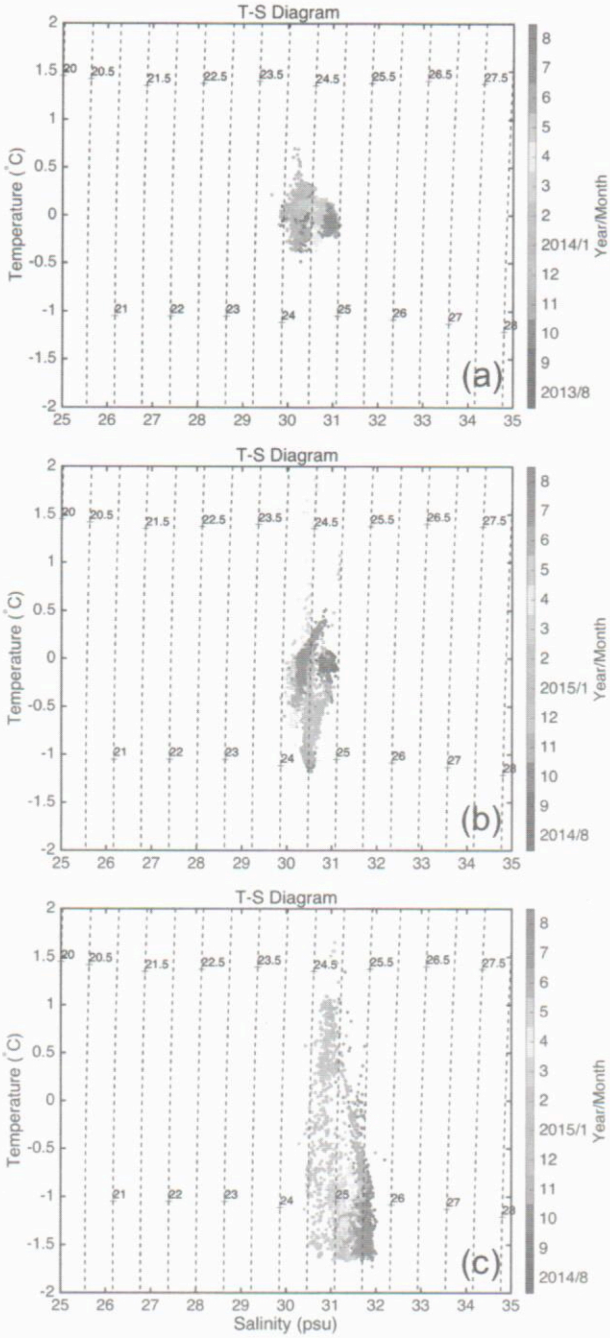

Fig. 7 Diagrams for potential temperature vs. salinity at the mooring stations: (a) Aug. 2013 to Aug. 2014 at CP13 (47 m), (b) Aug. 2014 to Aug. 2015 at CP13 (47 m), and (c) Aug. 2014 to Aug. 2015 at CP14 (50 m).

Yearlong mooring data provide us to understand the seasonal or inter-annual variability of water masses. In the northern Chukchi Plateau, PSW was more stable than that in the southern Chukchi Plateau. PSW in the northern CP appears to be influenced by Beaufort Gyre but that in the southern CP appears to be affected by more complicated local forcings (winds, WW and BSW pathways, and so on) in the northern Chukchi shelf. This issue will be focused on the further study.

Acknowledgement

This research was a part of the project titled 'Korea-Arctic Ocean Observing System (KOPRI, PM16040)', funded by the Ministry of Oceans and Fisheries, Korea.

REFERENCES

Carmack, E. and H. Melling (2011): Warmth from the deep. *Nature Geoscience*, **4**, 7-8

Polyakov I., L. Timokhov and 17 others (2007): Observational program tracks Arctic Ocean transition to a warmer state, *EOS Trans. AGU*, **88**, 398-399, doi:10.1029/2007EO400002.

Polyakov, I.V., L.A Timokhov and 16 others (2010): Arctic Ocean warming contributes to reduced polar ice cap. *J. Phys. Oceanogr.*, **40**, 2743-2756, doi:10.1175/2010JPO4339.

Polyakov, I., J.E. Walsh and R. Kwok (2012): Recent changes of Arctic multiyear sea ice coverage and the likely causes. *BAMS*, 145-151, doi:10.1175/BAMS-D-11-00070.

Shimada, K., E.C. Carmack and 2 others (2001): Varieties of shallow temperature maximum waters in the western Canadian Basin of the Arctic Ocean. *Geophys. Res. Letters*, **28**, 3441-3444.

Shimada, K., T. Kamoshida and 6 others (2006): Pacific Ocean flow: Influence on catastrophic reduction of sea ice cover in the Arctic Ocean. *Geophys. Res. Letters*, **33**, doi:1029/2005GL025624.

Solomon, S., D. Qin, M. Manning, R.B. Alley, T. Berntsen, et al., 2007. Technical Summary. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. (Eds.) S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, et al., Cambridge, UK/New York, Cambridge University Press.

Steele, M., J. Morison and 4 others (2004): Circulation of summer Pacific halocline water in the Arctic Ocean. *J. Geophys. Res.*, **109**, C02027, doi:10.1029/2003JC002009.

Steele, M., W. Ermold and J. Zhang (2008): Arctic Ocean surface warming trends over the past 100 years. *Geophys. Res. Letters*, **35**, L02614, doi:10.1029/2007GL031651.

Steele, M., J. Zhang, and W. Ermold, 2010. Mechanisms of summertime upper Arctic Ocean warming and the effect on sea ice melt. *J. Geophys. Res.*, **115**, C11004, doi:10.1029/2009JC005849.

Gong D. and R.S. Pickart (2015): Summertime circulation in the eastern Chukchi Sea. *Deep-Sea Res. II*, **118**, 18-31.

Itoh, M., R.S. Pickart and 11 others (2015): Water properties, heat and volume fluxes of Pacific water in Barrow Canyon during summer 2010. *Deep-Sea Res. I*, **102**, 43-54.

Pisareva, M.N., R.S. Pickart and 5 others (2015): Flow of pacific water in the western Chukchi Sea: Results from the 2009 RUSALCA expedition. *Deep-Sea Res. I*, **105**, 53-73.