Behaviors of Water Masses around the Chukchi Borderland, western Arctic Ocean

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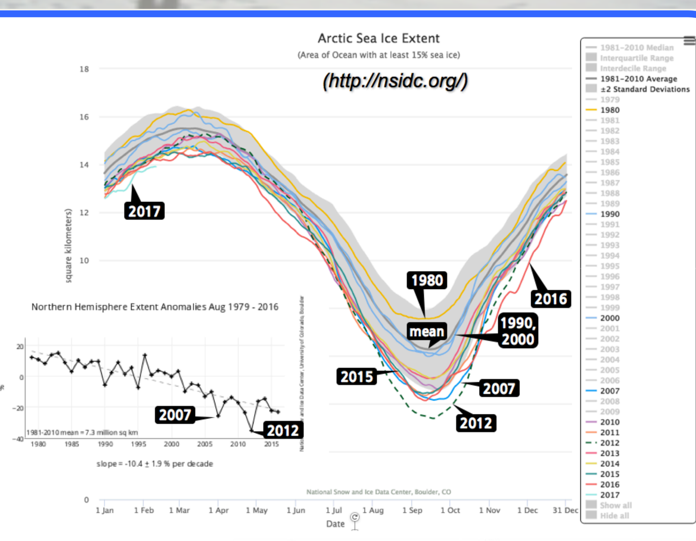
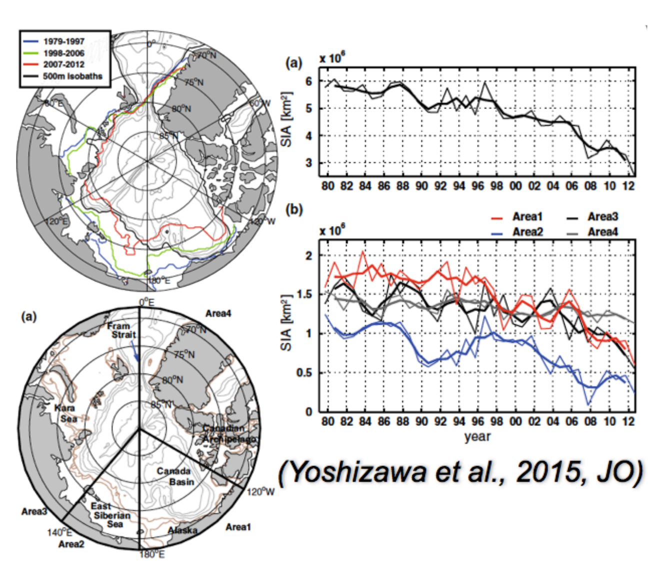
ABSTRACT: We investigated the behavior of water masses around the Chukchi Borderland (CB) in the western Arctic Ocean using historical hydrographic survey data and yearlong ocean mooring data. The water masses were mainly analyzed with salinity, temperature, and ocean current. Anomaly of sea ice extent (SIE) is negatively correlated with temperature anomaly of the Pacific summer water (PSW) whereas it is positively correlated with salinity anomaly of surface melt water (MW). It implies that oceanic heat content from the Pacific plays a significant role on melting sea ice and increasing freshwater content in the western Arctic Ocean. Yearlong temperature and water velocity data showed spatial and temporal variations of water masses over the Chukchi Plateau (CP). The westward current was dominant in the southern CP while the southward current was significant in the northern CP from summer 2014 to summer 2015. From autumn to mid-winter of 2014, PSW in the southern CP appears to be suppressed by a mixed layer beneath sea ice and sustained for nearly 4 months, indicating that substantial heat storage within the PSW layer is associated with wind pattern (northeasterly) and sea ice covering. In addition, we will discuss on the relationship between water mass and biochemical properties (e.g., dissolved oxygen, nutrients, and chlorophyll-a) to understand the ecosystem response to the variation of water masses.

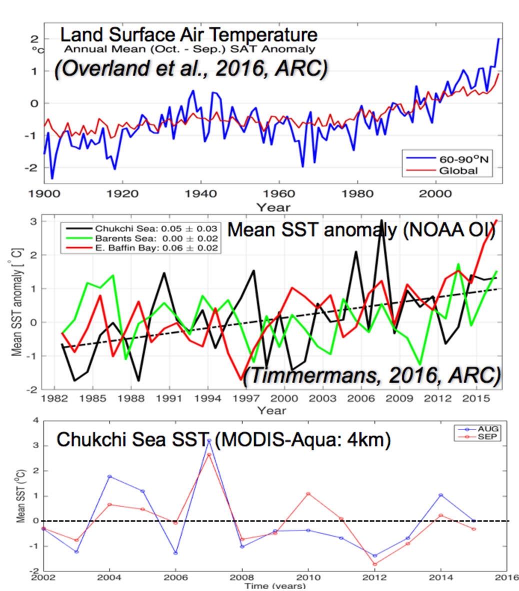
1 INTRODUCTION

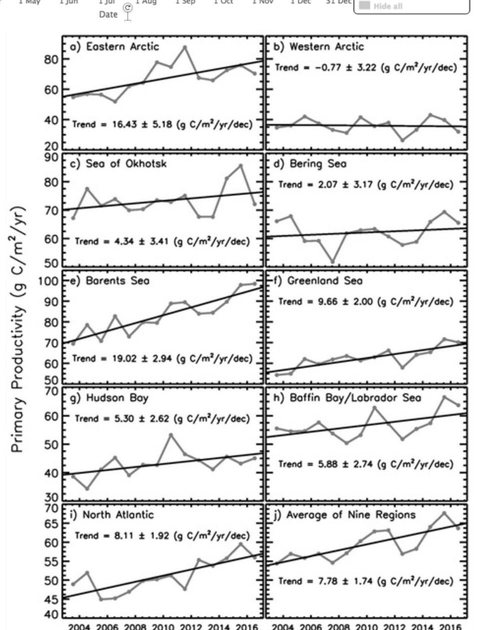
◆ Environmental Change in the Arctic Ocean

- Mean air temperature in recent 5 years warmer than that in 1981~2000
- Extension of warm Pacific Water to the Arctic Ocean
- Sea ice extent drastically diminished
- Increase of annual river discharge to the Arctic Ocean
- Consequent Arctic sea ice volume diminution but PP increases









◆ Research Objective

This study aims to understand water mass distribution and its its variability in recent years around the Chukchi Borderland, western Arctic Ocean using ship-based hydrographic data obtained from 2010 to 2016 and yearlong data from several ocean mooring stations.

2 Methods & Data

◆ Hydrographic Surveys from 2010 to 2016 (Fig.1)

1) Equipment used on the ice breaker R/V ARAON
   - CTD, lowered ADCP, XCTD (Table 1)
   - Bio/Geo/Chemical equipment
2) Items observed from the Araon
   - Temperature, salinity, water velocity,
   - DO, fluorescence, PAR, transmission, backscatter,
   - Atmospheric components,
   - Primary production and new production,
   - Chlorophyll-a and HPLC,
   - Phytoplankton, Zooplankton compositions,
   - Nutrients, POC, PON, DOC, DON, DOP,
   - N_2O gas, pCO_2, DIC, pH, SS, TA,
   - etc.

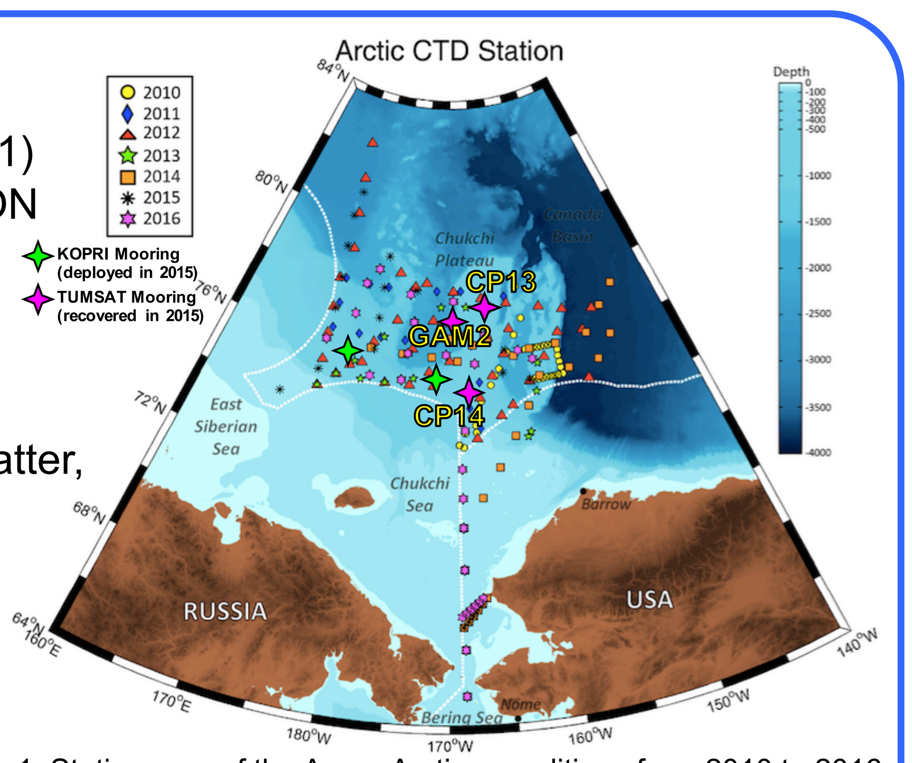


Figure 1. Station map of the Araon Arctic expeditions from 2010 to 2016.

Table 1. Information on CTD/XCTD from 2010 to 2016.

	2010	2011	2012	2013	2014	2015	2016
CTD	38	18	44	16	32	42	34
XCTD	*	33	48	36	51	61	38
Period	07/20~08/10	08/02~08/16	08/04~09/06	08/24~09/01	08/01~08/23	08/01-08/21	08/05-08/20

◆ Ocean Mooring Systems

1) Three mooring systems were recovered from the ice breaker R/V ARAON (Figs. 1)
   - CP13, CP14, GAM2 (ADCPs, microCATs, temperature loggers, MMP-type CTD, etc.)
2) Items measured from the mooring systems
   - Temperature, salinity, water velocity, ice speed, pressure, etc.

◆ Collection of other datasets

1) Sea ice concentration and sea ice extent: AMSR2 (http://www.iup.uni-bremen.de:8084/)
2) SST & sea surface chlorophyll-a: MODIS-Aqua (http://oceandata.sci.gsfc.nasa.gov/)
3) Atmospheric variables: ECMWF ERA Interim – monthly (http://apps.ecmwf.int/datasets/data/)
4) Sea ice motion vectors: EORC JAXA (http://www.eorc.jaxa.jp)

3-1 RESULTS

◆ Horizontal distribution of water masses: PSW (BSW,CSW) vs. PWW (RWW,WW) (Fig. 2)

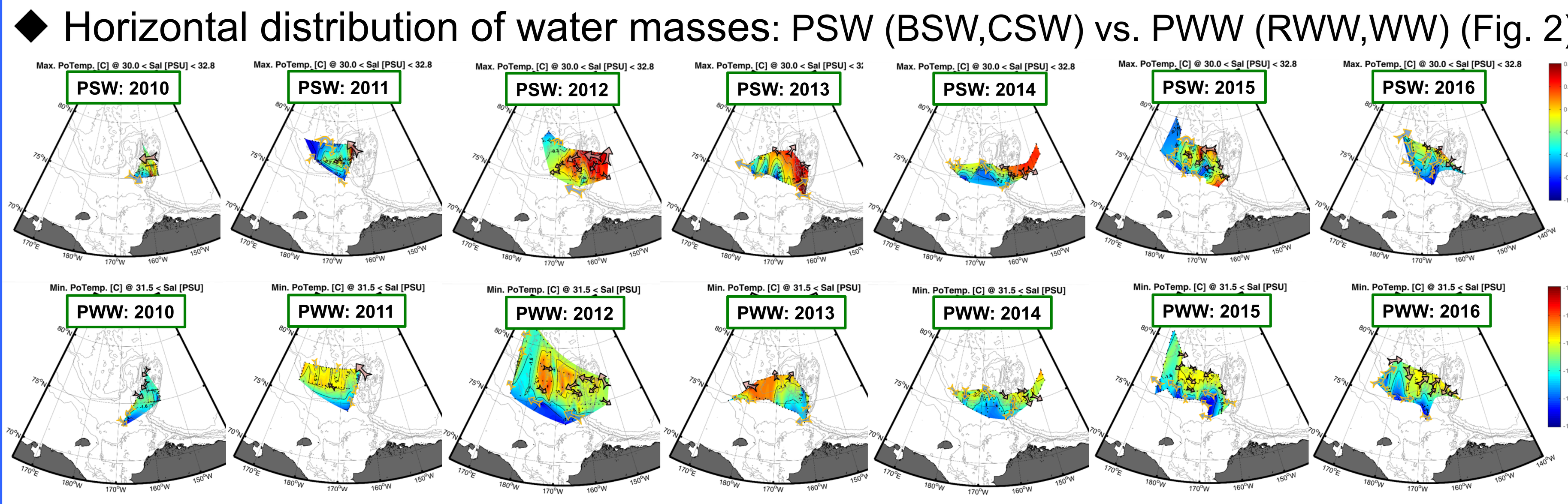


Figure 2. Horizontal distributions of maximum potential temperature in PSW (upper) and minimum potential temperature in PWW (lower) with the layer-integrated lowered ADCP current vectors in August from 2010 to 2016 (left to right).

◆ Anomaly correlation between variables in August

- Water: 170W~160W, 74~78N; - Atmosphere: 150E~150W, 72~82N; - Sea ice: 180~165W, 70~85N

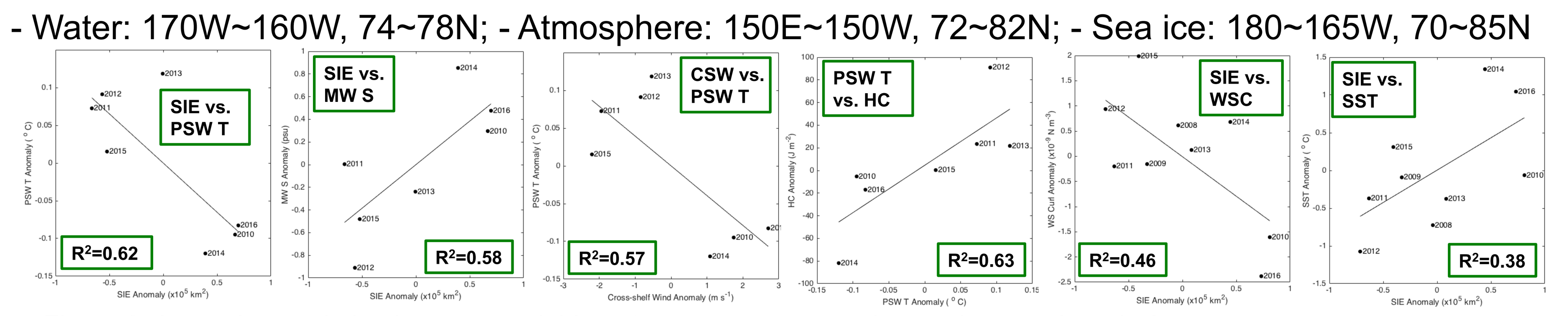


Figure 3. Anomaly correlation between variables of water masses, sea-ice, and atmosphere in August.

3-2 RESULTS

◆ T-S diagram and contrasting years

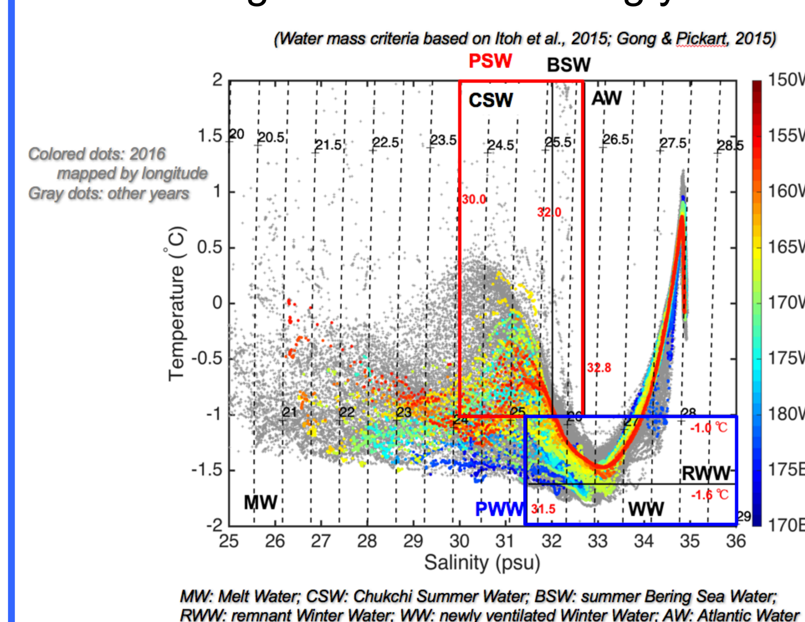


Figure 4. T-S diagram using CTD/XCTD from 2010 to 2016(colored).

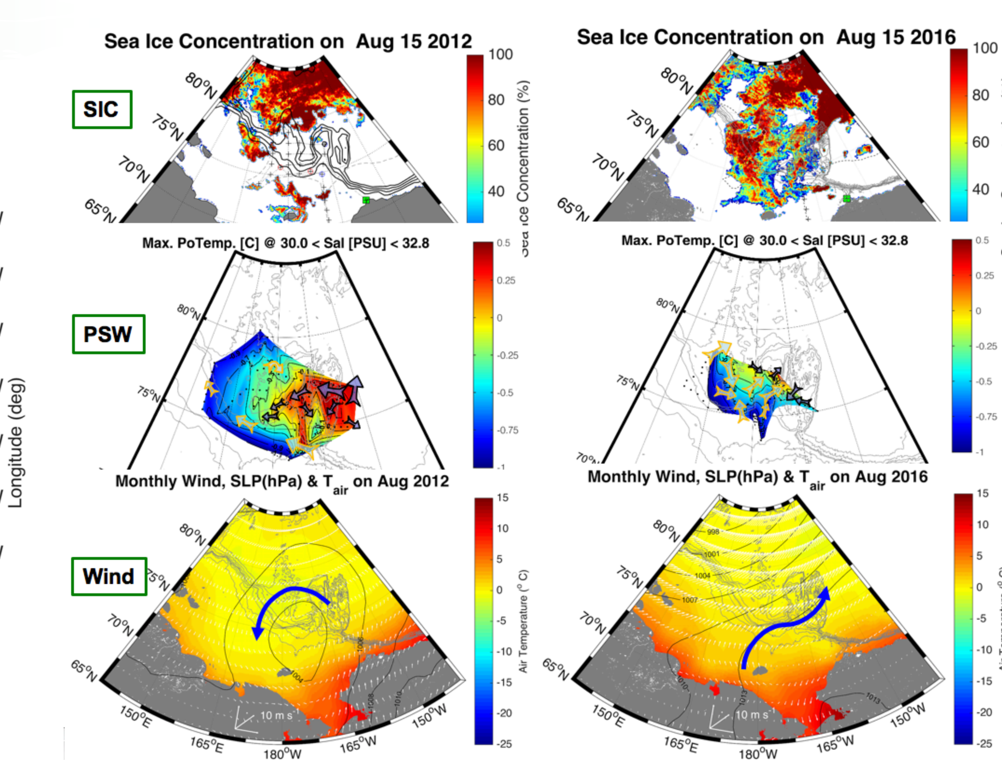


Figure 5. Horizontal distribution of SIC, PSW max T, atmospheric parameters in August 2012 (left) and 2016 (right).

◆ Time series of water temperature from ocean mooring systems on the Chukchi Plateau (CP) (Fig.6)

- CP13: deployed from Aug 2013 to Aug 2015 at northern CP
- CP14: deployed from Aug 2014 to Aug 2015 at southern CP
- GAM2: deployed from Oct 2014 to Aug 2015 at the western CP

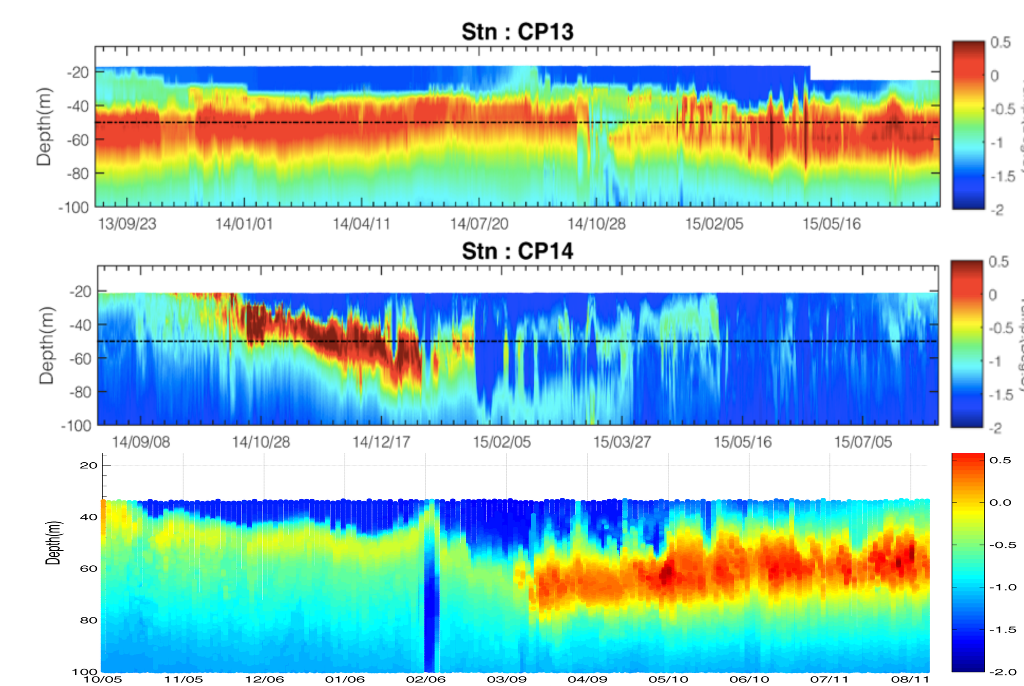


Figure 6. Time series of observed water temperature at CP13 (top), CP14 (middle), and GAM2 (bottom).

◆ Current pattern and water mass distribution from ocean mooring systems (Figs.7&8)

- Current at 49.5 m, CP13: dominant southwestward flow but southward in summer
- PSW at 47 m CP13 was stable during 2013-2014 but disturbed by an event during fall 2014
- Current at 43.9 m, CP14: dominant westward flow but southward in summer
- CP14-50 m, initially occupied by WW, PSW existed until early winter 2014, and back to WW
- CP14-148m, RWW, WW newly ventilated in spring/summer 2015

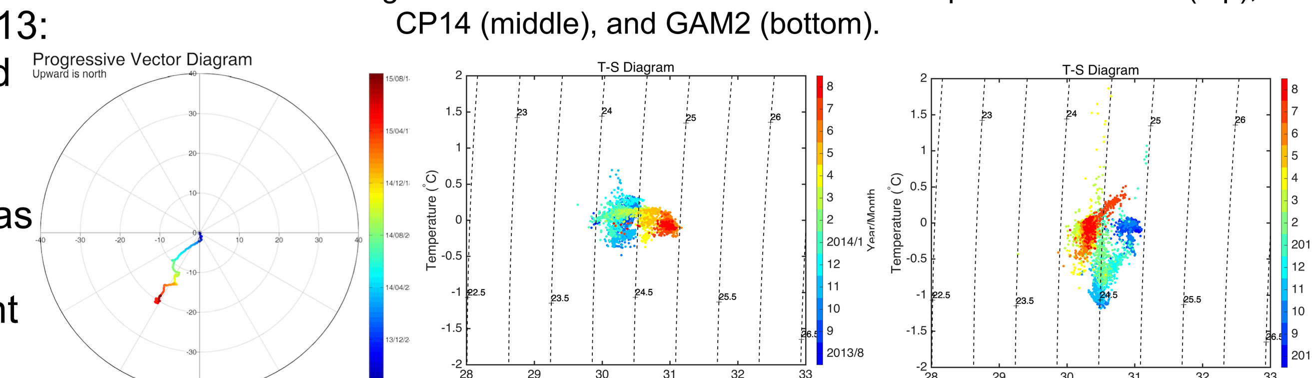


Figure 7. At CP13, progressive vector at 49.5 m (left), T-S diagrams at 47 m during Aug. 2013~Aug. 2014 (middle) and during Aug. 2014~Aug. 2015 (right).

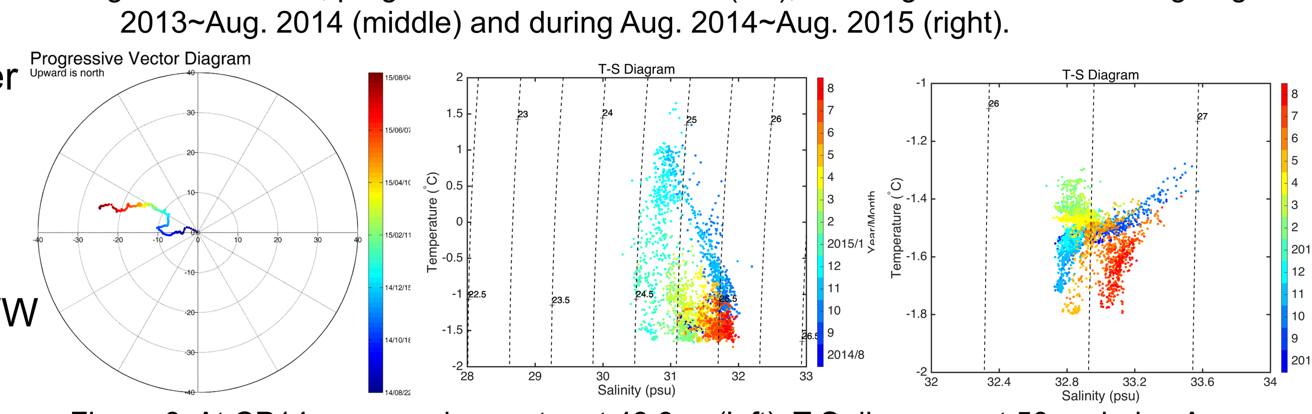


Figure 8. At CP14, progressive vector at 43.9 m (left), T-S diagrams at 50 m during Aug. 2014~Aug. 2015 (middle) and at 148 m during Aug. 2014~Aug. 2015 (right).

◆ Nutrient (nitrogen components)

- Denitrification is carried out by heterotrophic bacteria during which NO_3^-(or NO_2^-) serves as the terminal electron accepter for organic matter oxidation and the nitrogen oxides are reduced mainly to N^2 (*Devol, 2008*)
- N^{**}=0.87([TIN]-16[PO_4]+2.9) (µmol/kg) (*Codispoti et al., 2005*)
- Under a process of denitrification, NO_3^- is used for organic matter oxidation instead of oxygen, resulting in a decrease in N^{**} (*Nishino et al., 2013*)

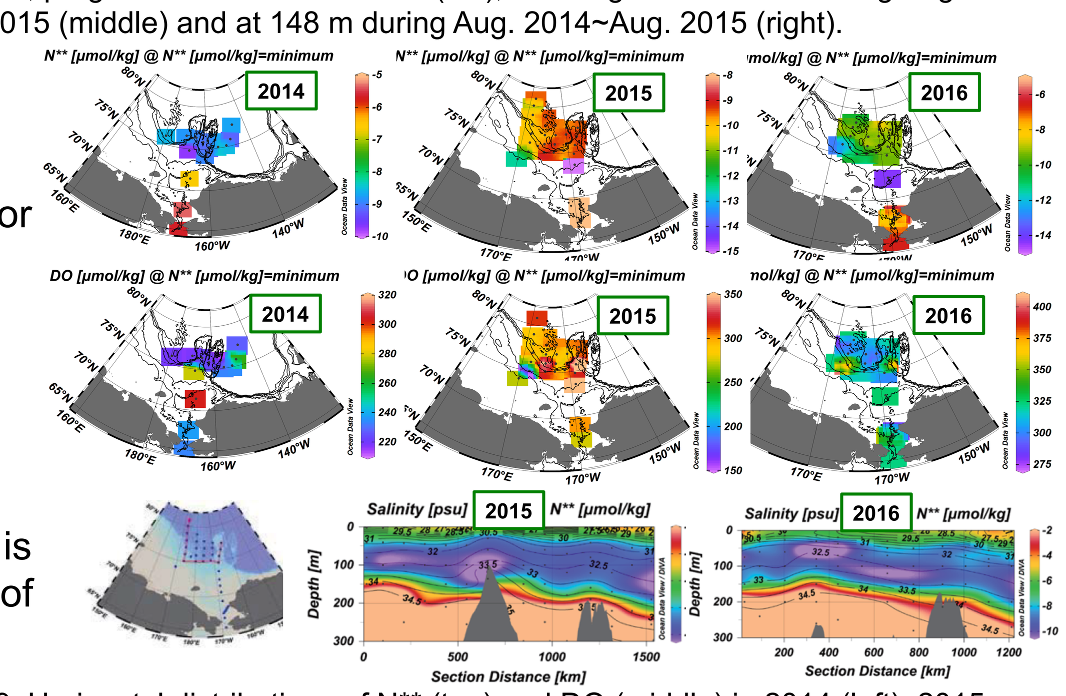


Figure 9. Horizontal distributions of N** (top) and DO (middle) in 2014 (left), 2015 (middle), and 2016 (right). Transect salinity profiles in 2015 and 2016 (bottom).

4 SUMMARY

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◆ The 7-year hydrographic survey data and yearlong mooring data were collected and analyzed to investigate recent behaviors of the Pacific-origin waters around the Chukchi Borderland (CBL). Ocean mooring data are available at three stations, CP13, CP14, and GAM2 where is southern, northern, and eastern parts of the Chukchi Plateau (CP), respectively.

◆ In August, anomaly of sea ice extent (SIE) has a negative correlation with that of PSW temperature whereas it has a positive correlation with that of MW salinity. This implies that inter-annual variation of PSW temperature plays an important role on the trend of sea ice melting and consequent ice melting has an influence on salinity reduction in the surface melt water layer. Anomaly of PSW T is correlated with anomaly of cross-shelf wind, that is, southerly/southwesterly winds tends to restrict westward flow which drives PSW extending to the west. Especially, variables in August 2012 and 2016 were contrasting.

◆ The mooring data showed that the PSW layer at CP13 remained over the 2013 winter but during 2014 fall some heat is possibly released to the surface or its pathway may change. During fall 2014 at CP13, PSW appeared to be ventilated from the south. At GAM2, the PSW layer appeared distinctly from the mid of March 2013 (not shown) and 2015 and its depth gradually became shallower during spring/summer.

Acknowledgement

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