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Recent Observations of Water Columns and Sea Ice over the Chukchi Borderland

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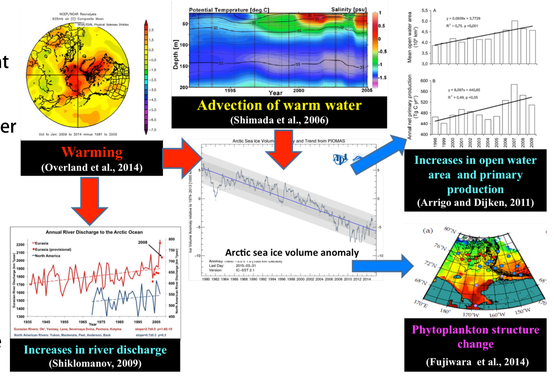
Abstract: *Summertime Arctic Ocean expeditions have been intensively carried out since 2010 to examine how rapidly marine environment changes over the Pacific Arctic region. We present recent findings from water columns and sea ice over the Chukchi Borderland, with a focus on the variability of physical and biochemical properties. Yearlong mooring data show temporal variation of the Pacific summer water (PSW) over the Chukchi Plateau (CP). The PSW layer on the northern portion of CP remained over the winter of 2013. On the southern portion of CP, however, substantial heat within the PSW layer was released from October and mid-winter of 2014. It implies that the PSW heat influences on sea ice formation/melting along the PSW pathways. In two ice camp stations, physical and biochemical properties of melt ponds and under-sea ice water were investigated. In closed ponds, relatively high concentrations of nitrogen species were found whereas no SiO_2 was detected. In comparison, in opened ponds, PO_4 and SiO_2 concentrations were similar to those in surface seawater and nitrogen species were depleted. These results suggest that nutrient can be used as an indicator to characterize the types of melt ponds. Under Arctic sea ice, we investigated vertical variability of Arctic copepod using an acoustic Doppler current profiler and its relations with water column structure (potential temperature, fluorescence, and dissolved oxygen). This study indicates that the vertical distribution of Arctic copepod under sea ice with 1–2 m thickness is effectively regulated by light intensity associated with the halocline depth at high dissolved oxygen. Furthermore, satellite observations indicate that surface chlorophyll concentration has a relatively significant positive relationship with open water period over the Chukchi Borderland, implying that chlorophyll-a concentration tends to increase as sea ice period becomes shorter.*

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
- Increase of annual river discharge to the Arctic Ocean
- Consequent Arctic sea ice volume diminution

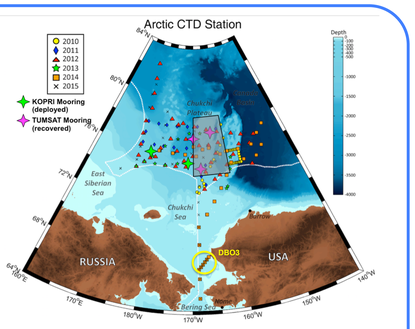
◆ Increase of net primary production corresponds to increase of open water area -> will change phytoplankton structure and ecosystem in the Arctic Ocean



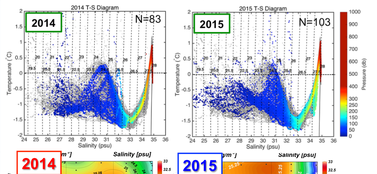
◆ Research Objective
This study aims to investigate recent ocean environmental changes using hydrographic and biochemical data obtained by the Araon Arctic summer surveys from 2010 to 2015.

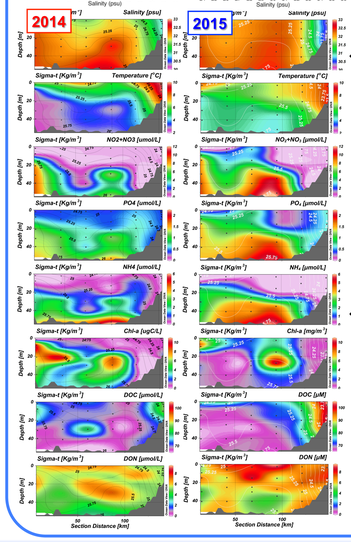
2 DATA

◆ Hydrographic Surveys from 2010 to 2015
1) Equipment used on the ice breaker R/V ARAON
- CTD, lowered ADCP, XCTD
- Bio/Geo/Chemical equipment
2) Yearlong ocean mooring systems
- MicroCAT CTD, temperature logger, ADCPs
3) Sea Ice Camps
- Melt pond studies - Under ice mooring



	2010	2011	2012	2013	2014	2015
CTD	38	18	44	16	32	42
XCTD	*	33	48	36	51	61
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



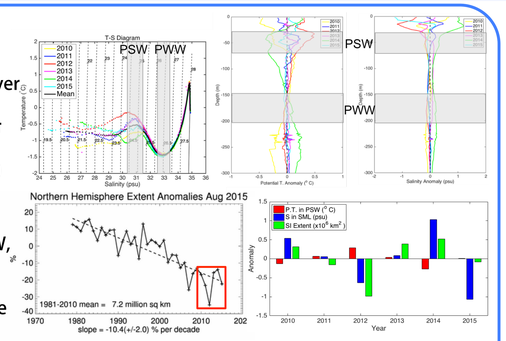


◆ Observed items
- Temperature, salinity, water velocity,
- DO, fluorescence, PAR, transmission, backscatter,
- Atmospheric components,
- Primary production and new production,
- Chlorophyll-a and HPLC,
- Phytoplankton, Zooplankton compositions,
- Nutrients, POC, PON, DOC, DON, DOP,
- N_2O gas, pCO_2, DIC, pH, SS, TA,
- Micro-zooplankton biomass, composition, grazing, &
- Bacterial and virus biomass

◆ Distributions of water properties
1) T-S Diagrams using all CTD/XCTD data (2010~2015)
- Distribution of distinct water masses
2) T, S, nutrients and organic matters in the DBO-3 transect
- DBO-3 survey in the same period (Aug. 01-04)
- Warmer, less saline water on the bottom in 2015
- Higher nitrogen species & PO_4 on the bottom in 2015
- Higher dissolved organic matters on the surface in 2015

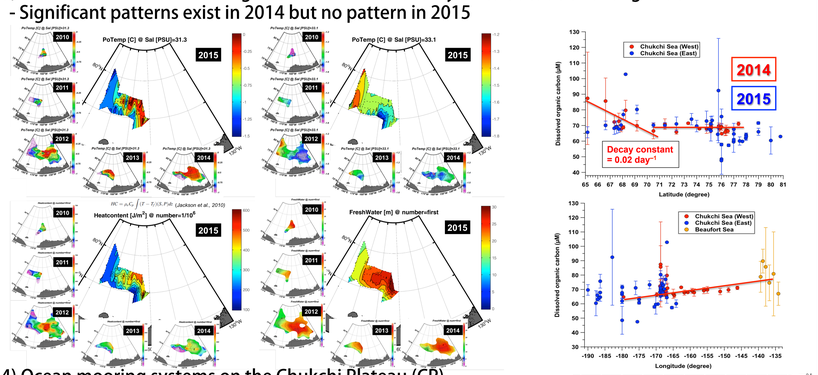
3-1 RESULTS: Hydrographic

◆ Variability of the Pacific waters
1) Vertical structures of T, S averaged over the selected region
- Anomaly of T, S in the Pacific summer water (PSW) layer, Pacific winter water (PWW) layer, surface mixed layer (SML)
- T in PSW vs. sea ice extent: negative
- S in SML vs. sea ice extent: positive

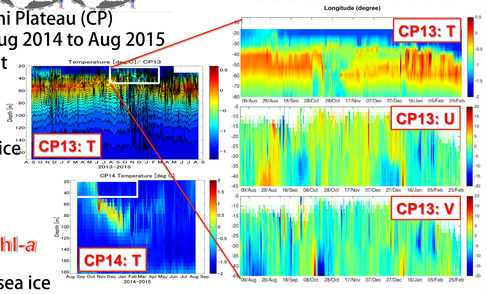


2) Horizontal distributions of PSW, PWW, heat content (HC), and freshwater content (FWC)
- PSW and HC patterns are similar to ice melt region

3) Distribution of dissolved organic carbon in surface layer vs. latitude and longitude
- Significant patterns exist in 2014 but no pattern in 2015

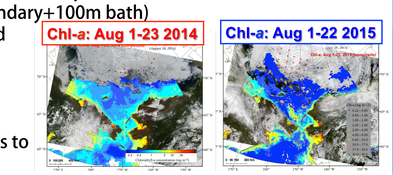


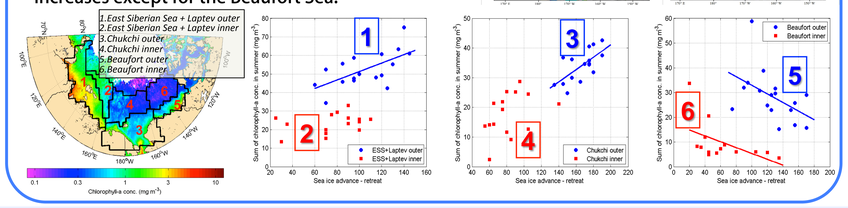
4) Ocean mooring systems on the Chukchi Plateau (CP)
- CP13: Aug 2013 to Aug 2015, CP14: Aug 2014 to Aug 2015
- PSW remains over the winter of 2013 at CP13 (northern CP).
- PSW heat was released to CP14 (southern CP) from Oct to mid-winter of 2014, implying that it may influence on ice formation/melting along the PSW pathways.



3-2 RESULTS: Trend of Surface Chl-*a*

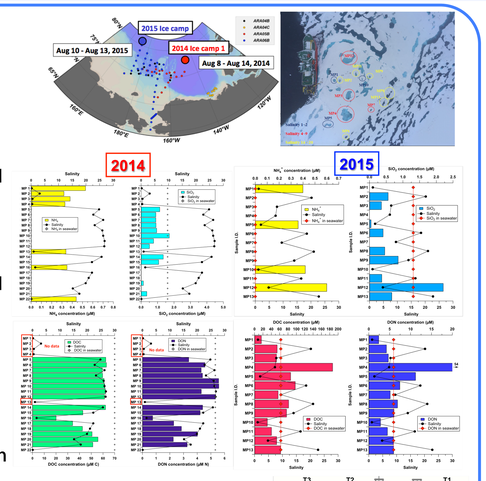
◆ Relationship between chlorophyll and sea ice
1) Data source
- Surface chl-a: SeaWiFS, MODIS, MERIS, VIIRS >> GlobColour (17 yrs)
- Sea ice concentration: SMMR, SSM/I, SSMIS (1998-2014, 17 yrs)
- Geographical classification: EASE grid (lat-lon boundary+100m bath)
2) Relationship between chl-*a* and open water period
- Regions 1, 3: significantly positive correlation
- Regions 5, 6: significantly negative correlation
- Regions 2, 4: weakly positive correlation
- As open water period gradually lengthens in most regions, summertime phytoplankton biomass tends to increases except for the Beaufort Sea.



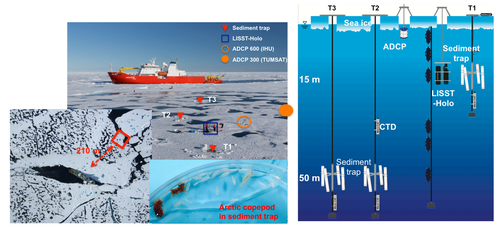


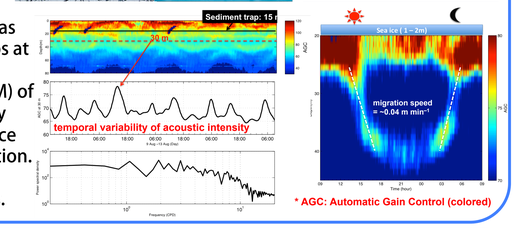
3-3 RESULTS: Sea Ice Camps

◆ Melt Pond Study
1) 2014 Ice Camp1
- Period: Aug 8~14, 2014
- Location: 77.6124ºN, 146.1012ºW
- 22 melt ponds (open-15; closed-7)
- Measurement: T, S, nutrients, DOC, DON
2) 2015 Ice Camp
- Period: Aug 10~13, 2015
- Location: 80.755ºN, 172.508ºE
- 13 melt ponds (open-7; closed-6)
- Measurement: T, S, nutrients, DOC, DON
3) Relationships with salinity
- NH_4 and SiO_2 showed high concentrations in the closed and opened ponds, respectively, suggesting that nutrients can be used as an indicator to distinguish the type of melt ponds.
- DOC and DON showed similar trend to that of SiO_2, with higher concentrations in the closed ponds.



◆ Under Ice Study
1) Deployment of mooring systems
- Period: Aug 9~13, 2014
- Location: 77.6124ºN, 146.1012ºW
2) Equipment
- ADCP (300 & 600 kHz), CTDs
- Sediment traps (15 & 50 m depths)
- LISST-HOLO (15 m depth)
- UV radiometer
3) Findings
- *Calanus hyperboreus* was collected as the copepod species in sediment traps at 15 m.
- Typical daily vertical migration (DVM) of *Calanus hyperboreus* was consistently present between 20-45 m under sea ice related to the diel cycle of solar radiation.
- The estimated migration speed was about 0.04 m min^{-1} at 20-45 m depths.





4 SUMMARY

◆ Anomaly of PSW temperature has a negative correlation with that of sea ice extent in August. The mooring data showed that the PSW layer at the northern CP remained over the 2013 winter but during 2014 winter some heat is possibly released to the southern CP or its pathway may change to the south.

◆ Surface chlorophyll concentration has a relatively significant positive relationship with open water period over the Chukchi Borderland implying that chlorophyll-*a* concentration increases as sea ice period shortens.

◆ NH_4 and SiO_2 concentrations in different types of melt ponds showed different trends, suggesting that nutrients as well as salinity can be an indicator to distinguish the type of melt ponds. In several opened ponds, DOC and DON concentrations were slightly lower than those in surface water, suggesting that those DOM were exposed to UV radiation and oxidized and/or degraded by microbial activities.

◆ The dominant copepod species, *Calanus hyperboreus* showed a clear diel vertical migration (DVM) from 20- to 45-m depth between two halocline layers under sea ice following a daily cycle of solar radiation. DVM was consistently generated above the subsurface chlorophyll maximum layer at 60 m and Pacific summer water from 40 to 70 m where dissolved oxygen showed high concentration.

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