# Meeting Minutes

Korea Polar Research Insitute

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KOPRI

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**Introduction and Welcome: Sung-Ho Kang**

(PPT 0) The PAG Chair opened the meeting and welcomed the participants to the fall meeting in Incheon, Korea. He also provided a brief history of the PAG, how it began under the International Arctic Science Committee (IASC) although it is now an independent affiliate of the IASC. The Pacific Arctic Group's mission is to serve as a Pacific Arctic regional partnership to plan, coordinate and collaborate on science activities of mutual interest. The Fall PAG meeting is hosted at various locations in alternating PAG countries after the field season and is focused on review of accomplishments during the previous summer and outlooks for the future. The annual fall meeting will provide country updates on 2015 field activities and results, status reports on the developing Pacific Arctic Climate Ecosystem Observatory (PACEO) and shelf-basin exchange lines, sea ice studies, the Distributed Biological Observatory (DBO), and ongoing synthesis activities. These discussions are useful in developing scientific exchanges and other types of collaborations during and after field operations. The Spring PAG meetings are held during Arctic Science Summit Week and are focused on "business" issues and an update on research plans for the coming field season.

**Welcoming Remarks: Hyoung-Chul Shin (Yeadong Kim)**

On behalf of Yeadong Kim, the President of Korea Research Polar Institute (KOPRI), Hyoung-Chul Shin warmly welcomed all participants to the meeting. He noted the importance of furthering the advancement of scientific research in the yet poorly understood Pacific Arctic region, outlining the need for systematic integrated scheme of observation and a knowledge base that is truly collective.

**1.1 Canada: Jackie Grebmeier (Bill Williams)**

**(PPT 1)** On behalf of Bill Williams, **Jackie Grebmeier (University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory)** presented on Canadian field activities from 2015 cruises and preliminary plans for 2016. Every year, the CCGS Sir Wilfred Laurier conducts an annual program to the Canadian Arctic Archipelago, starting in Victoria, BC, transiting through the northern Bering and Chukchi Sea in order to occupy DBO lines 1,2,3,4 and 5 into the Arctic (from 62°N up to Barrow at 72°N)., then traveling eastward into the Canadian Arctic. Department of Fisheries Oceans (DFO) Canada, the main affiliation for Drs. Humfrey Melling and Bill Williams, is developing a sustained observatory in the marine environment in the Beaufort Sea. For more than a decade, Melling and Williams have been leading continuous observations in the Beaufort Sea and will continue to combine and maintain those observations on an annual basis.

This year they sampled on a new DBO line in the Beaufort Sea that was identified during the 2nd DBO data workshop last year, specifically a biological hotspot near Cambridge Bay. It is planned

that new time-series points will be initiated. In addition, Dr. Mellings occupied DBO 4 in fall 2015 for CTD measurements and these data will be shared at the next DBO data workshop in 2016.

DFO's monitoring of the Beaufort Sea is conducted year-round via moorings to determine the natural range of conditions (natural variability,) normal & extreme, and uses time series data to evaluate changes over time. Some of the parameters that are measured include sea ice, sea surface, ocean currents from surface to sea bed, key parameters to determine water masses, biological hotspots, sedimentation rates, and ambient sound.

This year, from August 7th to September 17th, there was a joint expedition between *CCGS Louis S. St-Laurent* UNCLOS with the *CCGS Terry Fox,* to undertake physical oceanography. In collaboration with JAMSTEC, trans-arctic XCTD sections were deployed from Tromsø, Norway to M'Clure Strait, Canada via the North Pole. Temperature and salinity profiles on the transects were shown as well as TNS tracking of different water masses..

From September 20th to October 17th this year, the 13th expedition of Joint Arctic Observing Network for Ice Studies (JOIS), Beaufort Gyre Observing System (BGOS) which was an international collaboration between WHOI from the US, the National Institute for Polar Institute (NIPR) and JAMSTEC from Japan. In this year's cruise, CTD/Rosette, geochemistry studies, 16 bongo tows for zooplankton, 53 XCTDs, 3 BGOS moorings were recovered and deployed, 2 IBO were deployed, 2 GAM moorings and 3 buoys were recovered. From 13 years of oceanographic expeditions to monitor the Beaufort Gyre, accumulation of freshwater in the gyre, due to Arctic river inflow and ice melt, could be observed.

The CCGS Amundsen had a cruise from August 20th to October 1st, as a part of ESRF integrated Beaufort Observatory (iBO) and ArcticNet. 7 moorings were recovered, 5 were deployed, and Arctic Net shelf to slop transects were done.

### 1.2 China: Jinping Zhao

**(PPT2) Jinping Zhao (Ocean University of China)** presented on the anticipated Xuelong Arctic cruise next year in 2016, as there is an Arctic research cruise every 2 years for China. While the cruise is not yet confirmed for next year, if possible, the expedition would head to the Canadian Basin and depending on Russian government approval, there could also be a collaboration with Russia for working in Russian waters. As for the new Chinese icebreaker, Jinping noted that it will hopefully be ready in 2018.

This year, 2 members of KOPRI went to the Arctic Ocean to support Jinping's team in testing a new buoy instrument, ITP for Upper Ocean. Contrary to last year's deployments, they were deployed successfully this year. It is planned that next year that another set of them will be deployed. It is also hoped that in using the Chinese icebreaker and from support from other projects, they can be deployed in other parts of the Arctic Ocean.

Another project that Jinping discussed was the Belmont Forum project that observes Arctic fog variability in a warming Arctic and its impact on maritime human Activities. The project was initiated from 2012 as fog was a serious issue with Arctic Ocean cargo ship acoustics, a matter

that interested private companies/industry and government particularly with regard to the Northeast and Northwest Passage. In 2014, observations of fog through optical instrument profiling were conducted. After encountering issues with the wind (causing the balloon to be unstable), a smaller balloon is being made to better conduct vertical profiling of Arctic fog.

### 1.3 Japan: Shigeto Nishino and Takashi Kikuchi

**(PPT 3) 1.3.1 Shigeto Nishino (JAMSTEC)** presented on the research vessel Mirai's 2015 Arctic Ocean Cruise that took place from 5th of September to 5th of October from the Bering Strait into the Arctic Ocean and back.

One of the objectives for this year's cruise was the intense observation of eddy using ADCP, Turbo MAP, and CTD water samples, as it was found that eddies play an important role in transporting key nutrients and sediments from the Chukchi shelf area to the Canada Basin. Another objective of the cruise was to understand the Siberian shelf basin interactions. Unfortunately, because the sea ice conditions inhibited Mirai's cruise activities, the research area was limited to the south of the ice-band. Two areas that were a focus of the cruise were around Barrow Canyon and Hanna Canyon. In these regions, we recovered and deployed moorings, deployed a new type of sediment traps, and conducted hydrographic surveys, including the DBO 5 line.

The eddy study was performed arounda warm water plume off Barrow. At first, XCTDwere used to obtain a rough sketch of eddy. A cyclonic warm eddy with a diameter of 25 kilometers was found. In addition, the eddy motion was traced usingGPS drifting buoys. Finally, a detailed eddy survey with CTDand water sampling was conducted. Here, vertical sections across theeddywere shown, for example, temperature, nitrate, ammonium, chlorophyll a, the ratio of large sized plankton chlorophyll *a* (> 20μm) to total chlorophyll *a*, and the ratio of small sized plankton chlorophyll *a* (< 2μm) to total chlorophyll *a* were shown.

Fixed point observations were done to capture the eddy transit and the eddy's fine structure. Furthermore, sediment traps were deployed to examine the difference of particles between the upstream and downstream of the eddy passage Unfortunately, the SCH-14 mooring in the southern Chukchi Sea had been maintained since 2012 was lost this year, so extra time is needed to search for it. Thus the DBO3 section and other hotspot observations had to be cancelled.

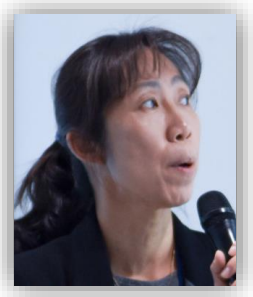
**(PPT 4) 1.3.2 Takashi Kikuchi (JAMSTEC)** introduced other Japanese activities undertaken in 2015 and preliminary plans for 2016. In 2015, aside from the Mirai Arctic Cruise, JAMSTEC participated in the ARAON Arctic cruise and CCGS Louis S. St. Laurent cruise for sea ice observation, hydrography and water sampling. Japanese mooring operations were undertaken by JAMSTEC, ILTS/Hokkaido University, and Grene/TUMSAt in the Pacific Arctic region and included a sediment trap mooring in the western Canada Basin, ice-thickness monitoring off Barrow, and long-term monitoring at the mouth of the Barrow Canyon. From 2000 to present, long-term moorings have monitored volume, heat and freshwater fluxes through the Barrow Canyon. In August 2015, mooring M2 was replaced and mooring M1 was recovered. For the

first time, mooring M3 was deployed further offshore to capture less sea ice influenced waters influenced by coastal and polynya processes to compare with airborne EM data.

After Japan was granted observer status in the Arctic Council (AC) in 2013, Japan has enhanced its contribution to the Arctic international community with science and technology, specifically with submission of science reports to the AC by experts and participation of AC working groups (WG) groups as observers, such as AMAP, CAFF, PAME, and other expert groups (e.g., EBM expert). Takashi also introduced a new Japanese Arctic research project, the Arctic Challenge for Sustainability (ArCS) that was started this September. This project aims to deliver robust scientific information to stakeholders (policy makers, AC WGs & Task Forces, industries, users, people, etc.) for decision making and problem solving.

### 1.4 Korea: Eun Jin Yang

**(PPT 5) Eun Jin Yang (KOPRI)** presented on KOPRI's 2015 Arctic field activities and on preliminary plans for 2016. This year, the ARAON arctic cruise expedition took place from August 1 to September 10. This cruise had a total of 83 participants from 8 countries—United States, China, Japan, UK, France, Spain, India and Korea. The target study area was North Bering Sea, Chukchi Sea (including DBO line 3), East Siberian Sea and Mendeleev Ridge. During this cruise, they visited 41 CTD stations and set up sea ice camp stations for 3 days at 81 north degrees. KOPRI deployed mooring systems at two sites and recovered Japanese mooring systems at three sites. The first leg of the cruise (August 1-22) focused on an ocean geophysics study, investigating the structure and processes in the water column and sub-bottom layers around the North Bering Sea, Chukchi Sea, and the North site of the East Siberian Sea within a rapid transition of ocean properties as well as to understand sea ice dynamics and sea ice ecosystem. The 2015 Arctic survey consisted of: 1) Atmospheric observational studies, where they measured the Air-Sea Greenhouse Fluxes using open-path eddy covariance, 2) Chemistry of water column, monitoring of spatial and temporal variation of $CO^2$, 3) Satellite Remote Sensing study to improve ocean color where they measured ocean parameters using Hyper-spectroradiometer, 4) Hydrographic survey to understand water column distribution and characteristics using CTD and LADCP, XCTD, and ocean mooring systems, 5) Microbes and plankton ecology by focusing on tropic relationship of lower level organisms including bacteria, virus, phytoplankton, heterotrophic protists, and mesozoplankton, 6) Phytoplankton physiology to understand the photosynthetic characteristics of phytoplankton, 7) Bioacoustic surveys to know the spatial variation of dominant Arctic copepods, 8) Marine geophysics, 9) Sea ice biogeochemical to study the effect of changing sea ice on Arctic marine ecosystem, and 10) Melt pond studies to identify their characteristics on sea ice floes. The 2nd Leg of the 2015 Arctic cruise focused on paleoceanography of the ESS and the Chukchi Sea from 35 August to 9 September. Future ARAON's Arctic cruise will cover the Chukchi Borderland to the ESS and Mendeleev Ridge.



### 1.5 Russia: Vladimir Ivanov

**(PPT 6) Vladimir Ivanov (Arctic and Antarctic Research Institute)** presented on preliminary results from 2015 NABOS-II Arctic Cruise. The 2015 NABOS-II Arctic Cruise expedition on R/V "Akademik Tryoshnikov" was carried out from August 18th to September

30th, going from Kara Sea to the East Siberian Sea. Normally, the Akademik Tryoshnikov goes as far east as the Lomonosov Ridge, but this year the cruise track extended to 176 °E.

Originally the program was called NABOS (Nansen and Amundsen Basins Observational System ) and it was a joint US-Russian project first initiated in 2002 and carried out until 2009. In 2012, the program was re-launched and was then called NABOS-II. The overarching goal of this 5 year study (from 2012 to 2017), as an element of the Arctic Observing Network, is to compile a cohesive picture of climatic change impacts over continental slope and deep basins of the Arctic Ocean, with particular focus on understanding three major observational targets: 1) along-slope Atlantic Water (AW) transport by boundary currents, 2) Interaction of AW branches with shelf waters, the deep basin interior, and Upper Ocean, and 3) indications of changes in upper-ocean circulation and thermohaline structure.

The specific objective is to develop a comprehensive, quantitative understanding of the role of the upper ocean and halocline in regulating heat and freshwater transports, and projecting their effects upon ecological components of the shelf and deep areas toward improved predictions of the role of the ocean in a new, seasonally ice-free Arctic. A combination of multidisciplinary observations using repeated sections, moorings and Lagrangian drifters is used.

During the 2015 NABOS cruise, 8 moorings were recovered and 13 moorings, 3 ITP buoys, 2 O-buoys, 1 IMB-buoy and 1 K-buoy were deployed while 94 CTD casts, 24 biology casts and more than 2000 chemical samples were taken. The scientific results obtained from a combination of autonomous anchored moorings and adjoining CTD transects proved the efficiency of chosen observational strategy. In line with the tradition of the NABOS project, the cruise combined scientists from various countries (UK, New Zealand, Poland, Russia, Germany, and Korea) and institutes, making the research program truly international and multidisciplinary. The data collected during the cruise, and in particular the two year-long records recovered from 8 moorings in the Nansen Basin and in the Laptev Sea, provide solid foundation for fundamental scientific research.

### 1.6 United States: Jackie Grebmeier and Robert Pickart

**(PPT 7) 1.6.1 Jackie Grebmeier** gave an overview of the 2015 PAG and DBO Field Season table and presented on some of the activities and results of the Arctic Marine Biodiversity Observing Network (AMBON) project in 2015. AMBON is a 5-year project with field work in years 2015-2017 in the Chukchi Sea. The first year of field work was successfully completed during August-September 2015. In terms of biology, observations of microbes, phytoplankton, zooplankton, benthos, fish, seabirds and marine mammals were made.

Preliminary results show that areas in the northern study region with high chlorophyll deposition to the seafloor coincide with regions of high benthic biomass and abundance of benthic feeding marine mammals, predominantly walrus. The AMBON field region is located on the Chukchi Sea continental shelf in the US Arctic as a region exposed to climatic changes and anthropogenic influences.

**(PPT 8) 1.6.2 Robert Pickart (Woods Hole Oceanographic Institution)** presented on the Marine Arctic Ecosystem Study (MARES) program, a program that monitors and studies the

ecosystem of the Beaufort Sea with an integrated-science approach. With different experts for different components of the ecosystem, the full ecosystem of the Beaufort Sea, as well as a little bit of Barrow Canyon, is studied. Bob showed the mooring arrays across the Beaufort shelf/slope, which included a shelf to basin interaction mooring array deployed back in 2002 and 2004, another one in 2008-9 and a new one to be deployed next summer in 2016. While this mooring was originally planned to be deployed this summer, Bob and his team were prohibited from entering the study area due to whaling activity. Being denied access to the proper channels that were normally used, moorings could also not be recovered. Bob explained as a form of caution to PAG members that whalers are becoming more strict about interference with their activities and hence efforts to communicate and make negotiations need to be strengthened and intensified. Bob showed a cross section of the tentative shelf-slope mooring array. Another effort for the rest of the team is to be on the icebreaker USCGC Healy early next summer (possibly mid-June to mid-July) in 2016. A tentative scheme is to run shelf slope transects across the Beaufort Sea, starting from the Barrow Canyon DBO5 line.

On the subject of communicating with local whaling communities, Jackie urged PAG members to begin negotiations during the fall season, as communities want to know sooner cruise dates. She reiterated the importance of pre-discussing with the US Arctic Icebreaker Coordinating Committee (AICC) when planning cruises that would impact whaling activities in coastal regions. Jackie noted that for any cruises planning to go near St. Laurence Island (they whale in spring) all then up to Point Hope and Barrow and eastward in the Beaufort Sea the default date after which access would be prohibited is September 15$^{th}$. Bob added that the Alaskan Eskimo Whaling Commission will be holding its winter meeting in February in Barrow and that this would be the time during which the first disclaimer notifying summer cruise plans should be made. Both Jeremy Mathis and Bob suggested having a template for cruise dates and a coordinated one-pager(s) of planned activities for each project and when communicating with whaling communities. Jackie reminded participants to take advantage of the AICC that will be having a meeting in November to review issues and difficulties that were encountered this year, Bob's team being prohibited access for example. John Bengston noted that there is a workshop being planned for January (now December 2015) with the new Coastal Waterways Group, the Native group, Alaska Native Hunting and Species Commissions as an effort to come up with a better, more deliberate process, which should provide PAG and others a better framework for planning.

## 2. Updates and Planning of PAG Joint Field and Modeling Activities

### 2.1 C/B Basin and Shelf-Basin Exchange Lines: Koji Shimada

**(PPT 9) Koji Shimada (TUMSAT)** presented on the background on how the idea of Pacific Climate Line section came about. With regard to the picture of the climate section (that was many times introduced during this meeting), Pacific summer water can be seen at the ocean dynamic depth at 50 decibar.

For the past 20 years, the center of the oceanic gyre has not changed much. The oceanic gyre was established near the Chukchi Borderland by sea ice motion. This area is key area to understand the interaction

between the Pacific and the Arctic. This area is important as east of the center of the Gyre, ocean circulation flows south, while west of the Gyre, sea water is entering the deep Arctic Basin. This area is key to understanding shelf and climate dynamics.

This summer, 4 moorings that were deployed to understand the areas seasonal variation, property of ice bonds, and to further understand the Arctic region and biological activity were recovered. To observe shelf to basin interaction and the influences of sea ice cover, observations of oceanographic sections across the Beaufort Gyre from east to west have been sustained since 2003 and should continue to be sustained. Koji's personal recommendation is for the monitoring section and moorings at key locations to be sustained. Koji showed the moorings deployed by KOPRI and JAMSTEC along 150 degrees west and recommended that moorings along the shelf slope and along the Arctic basin monitoring section should be sustained.

Between 2013 and 2014, there was a big difference in the temperature at the bottom of surface layer. In the winter of 2013-2014, temperature was close to almost freezing temperature with almost no time scale variation. In 2014, however, there was a high increase in temperature at the surface mixed layer. During this past winter (2014 to 2015), inflexion of Pacific summer water on sea ice cover was large. Indeed, in 2013, there was not much heat flux. But in 2014, with the upper heat flux of Pacific summer water, Pacific summer water temperature was higher than that of the surface mixed layer. Sea ice motion seems to play an important role.

Another mooring near the Chukchi Plateau is located at a critical latitude. At this critical latitude, there was dissonance focus, dissonance meaning strong vertical mixing. From the mooring data for one year, Pacific summer water and a large oceanic heat flux to the surface mixed layer were observed. With a large retreat of sea ice around the Chukchi Borderland, this area is a kind of hotspot for Arctic climate system.

Another key set of data was obtained from lMP moorings. Since 2000, upper bound CTD moorings have been serviced. Seasonal variation with interannual variation from the water pond structure was checked. From mooring data at 40dbar negative to 300 dbar, there was barely no seasonal variation, only plus minus 1 centimeter. Thus, it was found that interannual variation is much larger than seasonal variation. Koji thus recommended that one section in this area is enough to understand long-term climate variation in the Pacific sector of the Arctic Ocean.

Takashi asked if there was any eddy information with regard to interannual variation. Koji replied that for such kind of information, drifting buoy measurements would be needed. Based on observations of eddy activity from drifting buoy installations about 20 years ago, it was found that eddy activity is significantly lower on the west side of the Northwind Ridge, while there was strong wind activity on the east side of the Ridge. Koji suggested that while eddy activity is sometimes very important, the main current is much more important in controlling the climate system.

Sea topography is important to understand water mass transportation into the basin. With almost no seasonal variation, interannual variation is much more important and to understand the interannual variation of ocean circulation, a simple model was made to measure the spin down time of the upper ocean circulation. It was found that the current status of ocean circulation in the Arctic Ocean reflected the last 3 years of surface forcing. Indeed, using

surface forcing the upper ocean circulation could be completely reconstructed.

For the next 10 years, Koji suggested that international studies should focus on the western part of the Beaufort Sea, including the Chukchi Shelf, the East Siberian Shelf and the Makarov Basin.

**(PPT 10) Aleksey Ostrovskiy (Group Alliance, Russia)** presented on preliminary plans for RUSALCA cruise next summer in 2016. For almost a decade, RUSALCA, a joint research effort between the Russian Academy of Sciences and NOAA, has undertaken expeditions to the Pacific Sector, specifically near Bering Strait and the Chukchi Sea. Due to ship failure and bureaucratic issues, however, the cruise for RUSALCA this year originally scheduled for October was delayed from June and July and is now scheduled for late August/September 2016. Next summer, moorings will be serviced to download the data, batteries will be replaced and moorings redeployed. Despite difficulties with government regulations, for the past few years, RUSALCA could access the Russian EEZ and territorial waters for water sampling. The general trend that RUSALCA is pursuing is to sam;le more northwards and to the west, while maintaining the monitoring effort of the Bering Strai and southern Chukchi Sea, as a hydrophysical understanding of this gateway into the Arctic from the Pacific Ocean is crucial. This year, there was a successful collaboration with NABOS expedition. Through the new Pacific Arctic Climate Ecosystem Observatory (PACEO) in the Pacific Arctic Region, gaps between the areas covered by NABOS and RUSALCA could be filled.

Aleksey showed climate system observations made from 2004 to 2014, during a decade of extreme environmental change. Based on RUSALCA scientific data, results are being prepared to be published in Oceanography magazine. Relaying Kathy Crane's suggestion, Aleksey reminded all RUSALCA participants to continue working on the publications as the date for publication is near. In conclusion, Aleksey outlined the vision of RUSALCA, which is for Pacific Arctic Data to bring about the expansion of results as part of the Arctic Council Sustaining Arctic Observing Network (SAON) that may monitor and cover the whole area.

### 2.3 Satellite Observations

#### 2.3.1 Satellite Observations of the Arctic: Josefino Comiso

**(PPT 11) Josefino Comiso (NASA, Goddard Space Flight Center)** presented on satellite observations of the Arctic. A list of NASA/GSFC Polar Data sets was shown, as was a link to the DBO website, on which there are animated maps for currents, sea ice and winds, surface temperature, and chlorophyll concentrations, with weekly averages for the most recent week of sea ice, SST, Chlorophyll, cloud fraction, winds and sea level pressure and plots of the various parameters.

Establishing a long satellite data record is difficult because satellite sensors do not normally last that long. Passive Microwave sensors to measure historical Satellite Ice Extent and Ice Area in the Arctic include SMMR, SSM/I, AMSR-E and AMSR2. The best systems to use currently are AMSR-E and AMSR-2.

The Arctic sea ice cover has been observed for a long time, at least in the last 1,435 years. It appears that we might see a blue ocean in the Arctic within this century. Indeed, the Arctic is warming at least 3 times faster than the rest of the globe. Decline of winter ice volume is about 4170 km3 per decade using 1 rho technique or 3635 km3 per decade using 2 rho technique.

From comparing salinity data with chlorophyll and SST data, it confirms the strong connection between salinity, sea ice and chlorophyll. That is, when ice retreats and freshwater is introduced in the surface, due to the lower density of freshwater there is enhanced stratification, the new layer is exposed to abundant sunlight, which enhances productivity (increase in chlorophyll).

In sum, satellite observational data provides the temporal and spatial coverage needed for a complete understanding of processes in the Arctic. GSFC has had a long history of research and quality assessment of satellite data. Continuation of such activities is needed. As new or improved sensors are launched by many countries there should be a sharing of data sets for optimum utilization of capabilities.

### 2.3.2 Remote Sensing Activities of KOPRI: Hyun-Cheol Kim

**(PPT 12) Hyun-Cheol Kim (KOPRI)** gave an introduction of remote sensing activities in KOPRI. Satellite data have uncertainties in accuracy and precision, and so his aim is to improve ocean color data quality in the Arctic regions. To achieve this goal, measurements of Inherent Optical Properties (IOP) and Apparent Optical Properties (AOP) are important to obtain. In the 2015 ARAON Arctic cruise, he measured IOP every 2 hours and obtained bio-optical samplings to improve algorithms for ocean color products in high latitudes. Two different types of hyper-spectroradiometers were deployed to measure vertical profile (HPRO-II) and horizontal profile (HSAS). KOPRI is in collaboration with Korea Aerospace Research Institute (KARI) and can use images from KOMPSAT (Korea Multi-purpose Satellite). The KOMPSAT-5, which uses microwave band - useful for retrieving sea ice structure and characteristics, was used for the Arctic expedition. Images were requested to be taken in time with the ARAON cruise allowing near real time image acquisition, this however, was a challenge as the satellite needs time before capturing the image. KOMPSAT-3 high resolution images were able to capture ARAON as it was departing Nome for the Arctic. With such high resolution satellite images, they could also trace sea ice variations, movements and dynamics. Cloud cover, however, was a big obstruction to getting the images. 2014 KOMPSAT-3 images were used to trace sea ice cover and its movement. Several satellite data, with visual and IR (thermal) bands, were used to characterize the kinds of melting ponds (open/closed) and evolution stage by temperature difference. Future plans are to provide sea ice information to 1) develop sea ice classification techniques, high resolution KOMPSAT SAR images are needed to analyze sea ice characteristics and develop a method for identifying different sea ice structures and their stage of development, 2) obtain accurate and high resolution Sea Ice Concentration (SIC) products by evaluation and improvement of operation SIC algorithms, 3) develop techniques for identifying and detecting melt pond and retrieval of accurate statistics (for example, pond fraction, pond area and density, and 4) improve the estimation of ice thickness with the assimilation of multi-sensor datasets and in situ observations.

**2.4 Long-term planning for Joint Program Scientific Research and Monitoring in the central Arctic Ocean and adjacent shelf areas: Phil Mundy**

**(PPT 13) Phil Mundy (NOAA)** presented on the work of Joint Program Scientific Research and Monitoring (JPSRM). At the third meeting of Scientific Experts on Fish Stocks in the Central Arctic Ocean (April, 2015) in Seattle, scientists from Canada, China, Iceland, Japan, Korea, Norway, Russia and the United States gathered and identified the need for Joint Program of Scientific Research and Monitoring (JPSRM) in the Central Arctic Ocean and Adjacent Seas. The series of meetings on arctic fish stocks would support international discussions on controlling fishing in the extraterritorial waters of the high arctic, also known as the Central Arctic Ocean. Under JPSRM, nations and institutions working in the arctic would have the opportunity to collaborate on assembling the coherent body of physical, chemical and biological observations and analyses that is essential to support the diplomatic process that is exploring the potential for controlling fishing in the extraterritorial waters of the central arctic.

Significant gaps in knowledge were identified to be lack of quantitative estimates of abundance and distribution of fishes in the extraterritorial waters of the central Arctic Ocean and the adjacent territorial waters that are ecologically linked. In addition to observations on individual fish species that may be subject to harvest (species of interest), ecosystem-based fisheries management, EBFM, requires information to inform understanding of trophodynamics and biophysics.

The arctic coastal states concluded an agreement on control of fishing in the central Arctic Ocean in July 2015. At the GLACIER arctic summit in Anchorage, Alaska (August 2015), US Ambassador David Balton announced on behalf of the United States the intention to expand the reach of the present Agreement by entering into negotiations with all interested nations later in the year. Amb. Balton further announced that the US plans to support the negotiations with a program of scientific research, including making estimates of fish biomass. The National Oceanic and Atmospheric Administration (NOAA) would be responsible for making biomass estimates and the National Aeronautics and Space Administration (NASA) would administer the research program.

Within the Arctic Council, the joint ecosystem approach expert group, EA-EG, of the working groups PAME, CAFF and AMAP have fostered an interdisciplinary and international dialog on information requirements for implementing the ecosystem approach to management, including EBFM. The dialogue culminated in a workshop on Integrated Ecosystem Assessment, IEA, for the central Arctic Ocean (WKICA) organized by the International Council for the Exploration of the Sea, ICES, and sponsored jointly by PAME, CAFF and AMAP. Based on the findings of WKICA, ICES has initiated a working group (WGICA) to develop the IEA further.

The formation of WGICA creates an international forum on integrated ecosystem in the central arctic that can unite and focus the efforts of Pacific and Atlantic nations. Opportunities for participation in research and monitoring are expected to be available to scientists of all the nations that participate in PAG and ICES. The first meeting of the WGICA is scheduled for May 2016.

## 2.5 Updates of 2015 Activities and 2016 Data Workshop: Jackie Grebmeier

**(PPT 14) Jackie Grebmeier** started her presentation by showing the table of mooring arrays near and within the DBO region that Phyllis Stebano put together. She reminded PAG members to send Phylllis mooring locations so that the table can be filled and uploaded on the DBO website.

For the 2016 PAG Arctic cruise map, Jackie said that she will be sending out emails so that this map can be filled out and uploaded by spring next year. On the DBO website, Jackie noted that a report of the successful 2nd DBO Data Workshop is available. Having been an action item at that very workshop, a data submission metafile was completed; a web-based, standard, simplified metafile was developed. By such metafile, a point of contact is available for anyone doing work on the DBO to know where and how to obtain data, as well as a matrix that helps with categorization of data.

The five DBO lines in the Chukchi Sea and 3 Beaufort Sea lines are on the DBO website; since thw 2014 data meeting there had been interfacing discussions with Canadian colleagues and active scientists up at the Beaufort on where to place DBO lines 6,7, and 8. Jackie showed the finalized locations that the three new DBO lines are located and explained that the reason for the locations is based on data on the increase in the mass of organisms, zooplankton, dissolved organic carbon in the sediment that was found not near shore but in the outer shelf and upper slope.

Jackie gave a reminder of the weekly satellite data sets on temperature, salinity, sea ice is available on the NASA website, which Joey Comsio had talked about in his presentation. Currently, there is a climatology for the five DBO sites that show sea surface temperature, sea ice concentration, sea ice breakup/formation timing, chlorophyll-a biomass, surface nitrate and solar insolation. As was done for the DBO lines, Jackie highlighted the need to develop a matrix with the locations, dates and information on parameters being measured for the Pacific Climate Line.

From the 2007 meeting in Canada, DBO standardized sampling protocols were started. This metafile not only helps in communicating different sets of data and status of work on different data, it further brings to light what is needed in research collaborations.

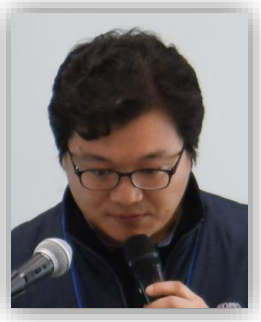
Indeed, the DBO can serve as a framework for international research coordination, specifically as being part of the Arctic Council Circumpolar Biodiversity Monitoring Program (CBMP) and is a recognized task of the pan-Arctic Sustaining Arctic Observing Networks (SAON) program, facilitated by the Arctic Council.

Jackie urged everyone to fill out the metafile for national and international DBO sampling before the spring meeting during ASSW next year. The third DBO workshop will be held March 9-10 next year in Seattle, at PMEL/NOAA, right before the 2016 ASSW meeting in Fairbanks (March 12-18).

Koji mentioned that there are no WHP hydrographic stations in the Arctic Ocean and suggested that a discussion on which station is important to sustain monitoring measurements is needed. Koji suggested that this discussion can take place with the IASC Marine working group. Also, Jackie agreed with a point that Koji made about the need for a synoptic survey of the Arctic at the same time by different countries.

## 2.6 Sea Ice and Atmosphere: Joo Hong Kim

**(PPT 15) 2.6.1 Joo Hong Kim (KOPRI)** presented on KOPRI's PACEO pilot activities and plans in terms of atmospheric and sea ice observations made during the August 2015 ARAON cruise. While atmospheric observations had not been a main focus for DBO thus far, Joo Hong suggested that PAG can try to extend its focus to climate and environmental observations, and he proceeded to show the importance of atmospheric temperature on sea ice seasonal cycle. Compared to 2014, arctic temperatures were warmer in June and July of 2015. During the same period, there was relatively lower level of sea ice concentration. Joo Hong suggested that the accelerated decreasing of sea ice extent in late summer of 2015 may be related to the warmest atmosphere temperature in July 2015.



This year, atmospheric off-air observations and cloud properties that were not observed previously during ARAON cruises were initiated. Radiosonde sounding was performed every 12 hours, regular based sky image was taken to measure cloud amount, which is important to control atmospheric temperature and surface radiative properties in the Arctic Ocean.

Joo Hong introduced the three major atmospheric measurements and purpose of each measurement briefly: 1) Surface basic meteorological variables, which are important for physical understanding of weather events, numerical weather prediction, assessment of reanalysis data; 2) radiosonde launch for physical understanding of weather events, numerical weather prediction, assessment of reanalysis data, cloud and radiation and 3) Cloud and radiative fluxes for cloud radiative effect on surface, assessment of reanalysis data, and physical understanding of weather events.

From 2017, there will be an effort to strengthen radiosonde, all sky camera and cloud LIDAR observations and make them more sustainable on ARAON arctic cruises as these upper-atmosphere observations can be used to monitor atmospheric climate change.

The reduction of sea ice by increase in Arctic temperatures may be due to many factors. From atmosphere point of view, cloud, atmosphere bound layer and sea ice interactions are crucial measurements. Joo Hong cited Wang's "Planning for Future PAG climate observation" from last year's PAG spring meeting that the Pacific sea ice component is influenced by a feedback between atmospheric ocean circulation and role of cloud and vapor in the atmosphere. Enhanced cloud observations will be very fitting for PACEO activities in the coming years.

Joo Hong noted that an application to the Year of Polar Prediction (YOPP) endorsement will be submitted within November. During the Arctic cruise, sea ice buoys for physical observation were deployed. Ice mass balance GPS drifts bought from SAMS, in collaboration with Jeremy Wilkinson from BAS in arctic sea ice camps, which initiated many international collaborations. We deployed GPS drifters, designed by Dr. Phil Hwang who's interested in small-scale ice deformation. The guiding key question for this project was: how is atmospheric forcing related to sea ice deformation at different scales?

Two new-type buoys with radiation sensors were experimentally deployed in different melt ponds, with one deployed in a saline pond and another in a freshwater pond. The objectives were to capture thermal and thickness variation of the pond water and ice all together

throughout the annual cycle and to understand the effect of pond salinity on evolution characteristic during transition (melting/freezing) season. A point of interest for further research is how to apply this kind of buoy for retrieval of ocean heat flux. The level of precision the sensors remains a key issue as ocean heat flux is a very difficult property to observe. A small change in ocean heat flux leads to long-term change of arctic sea ice; continuous monitoring using the "residual method" is needed. Temperature profile and thickness variation of ice measurements can retrieve ocean to ice heat flux. Joo-Hong noted, however, that this kind of method, while it can be applied in winter season when sea ice temperature is very stable, it cannot be applied during the summer season when sea ice variation is very dramatic due to solar heat input in short time scale. Buoy deployments should be continued through international collaborations.

Takashi recommended that buoy data should be sent to the Global Telecommunications System (GTS) website. Joo-Hong agreed that it would be a good idea to upload buoy data online.

### 2.7 Modeling Activities

#### 2.7.1 KOPRI's Modeling Activities & Future Contribution to PAG: Baek-Min Kim

**(PPT 16) Baek-Min Kim (KOPRI)** presented on KOPRI's atmospheric and ocean sea ice modeling activities and plans, as well as on the assimilation of data. For atmospheric modeling activities, KOPRI focuses on Arctic mid-latitude link. Baek-Min mentioned the hypothesis of Jennifer Francis, who insisted that extreme weather in mid-latitude states was linked to Arctic ice melting. A study that Baek-Min led entitled "Weakening of Stratospheric Polar Vortex by Arctic Sea-Ice Loss" supports Francis' hypothesis, but Baek-Min added more evidence is needed to show the link between the jet stream and the warming Arctic. Baek-Min explained that the intensification of cold winter is linked to the weakening of polar vortex, which propagates down to the troposphere. During the study, arctic clouds are key to understanding the Arctic mid-latitude teleconnection. In the modelling study, when sea ice is reduced, warm arctic, cold continent appears; cloud friction was changed slightly with all other conditions kept the same, but the impact/response was very large. Also, surprisingly, the impacts were not confined to the arctic but also to other mid-latitude regions. That is why we need to study cloud dynamics in the Arctic. KOPRI will make an effort to make precise measurements of cloud fraction. Land-based observation systems will be reinforced in Dasan Station in Svalbard as well as ship based observation instruments like Radiosonde, all-sky camera, and LIDAR on ARAON cruises will be reinforced to measure Ocean Arctic cloud. There will be an effort to develop physical packages for Arctic cloud, as well as to devise a true formula for Arctic cloud and boundary processes. Based on these types of observations, focus will be put on micro physics and process modeling on hydrocarbon layer. PAG satellite and observation data will try to be used, and participation in MOSAiC is possible (not yet confirmed). There will be an effort to construct regional and global modeling system equipped with newly developed physics.

Baek-Min continued with a discussion of the preliminary plans for ocean sea ice modeling activities. The Community Earth System Model (CESM) will be used. The Community Ice CodE (CICE) 5 model is a significant upgrade from CICE 4 as it prognoses sea ice salinity, capturing variability of sea ice salinity inside ice column as well as sophisticated melt pond

parameterization, both important for the PAG observing activity. Baek-Min suggested that this kind of physics will link the observing activity with the modeling activity.

Final topic that Baek-Min discussed was Ocean Reanalysis Inter-comparison Project (ORA-IP). With large discrepancies among re-analyses, research and development of assimilation methods for sea ice is necessary. KOPRI will try to assimilate sea ice products and other observations in PACEO and compare with reanalysis data. Baek-Min shared the preliminary plans by giving an overview of the roadmap for the development of Sea Ice Initialization. Next year, KOPRI will try to do offline sea ice initialization, which will essentially collect existing sea ice data and keep atmosphere and ocean data fixed for global model long-term simulation.

### 2.7.2 Modeling Ice-Ocean-Ecosystem in the Bering-Chukchi-Beaufort Sea: Jia Wang

**(PPT 17) Jia Wang (NOAA Great Lakes Environmental Research Laboratory)** presented on modelling ice-ocean-ecosystem dynamics in the Bering-Chukchi-Beaufort Seas. One of the main models that Jia Wang and his team have been focusing on is CIOM - fully capturing dynamics and thermodynamics and multiple category ice thickness in the Arctic and, in the near future, the Antarctic. He submitted a paper in modeling coastal circulation and Temperature Salinity properties in the Chukchi Sea using CIOM. A map showed ice cover and ice velocity, SST and ocean velocity. In the 2004 RUSALCA data, they observed the cold bottom water from the southern Chukchi, which was located on the western region but moved towards the eastern side. There is a similar pattern in the model for salinity occurences as well. The 2009 RUSALCA data captured basic features of the temperature – salinity, but the model fit was not as good. He investigated volume transport through five straits (Bering Strait, Barrow Canyon, Herald Valley, Central Channel, Long Island Strait), which showed transport reversals that are caused by the Pacific Arctic pressure head and wind forcing. Statistics of the whole year for the transport shows that the ratio of Mean: STD for Barrow Canyon and Central Channel and Herald Canyon was always smaller than the standard deviation. The ratio of Max: Min for Barrow Canyon, Herald Canyon and Long Strait are below 1, but for Central Channel and Bering Strait, have a larger value that 1, which can be explained by the Pacific Arctic pressure head and wind forcing which then results in transport reversal. The same model, CIOM, was also used to model ice-ocean system response to storm passage in the Beaufort Sea. The heat flux is very small, one day before the storm, while in the peak of the storm, the ice heat flux increases significantly being released into the atmosphere and then normalizes. This was also simulated to model coastal circulation and land fast ice in the Beaufort Sea. A small simulation of currents and eddies was done, with most of them with an anti-cyclic forcing. He used the Ikeda 1983–theory and a Wang and Ikeda 1997 3D model to support the theory. CIOM captured landfast ice features, but there was insufficient anchoring. Jia has proposed the R & D: Arctic Dipole Anomaly (DA) as the major force accelerating Arctic summer sea ice decline, which will gradually open up the Arctic for economic opportunity. A study has examined the changes in sea ice along the Arctic Northeast Passage from 1979 with remote sensing data, which showed ice is becoming thinner. The correlation between AO (Arctic Oscillation) and DA showed that DA had more correlations to the opening of the Arctic Northeast Passage compared to AO. The future plans from 2016-2020 consists of enhancing the Arctic-CIOM and Arctic-FVCOMice.

Joo-Hong Kim questioned on the physical origin of the arctic dipole anomaly. Jia answered

that when there is an accumulation of warm water from the Atlantic side to the Barents Sea, there is an imbalance, and the sea level pressure increases.

## 3. Status report on PAG-endorsed DBO and PACEO ongoing and planned future activities

### 3.1 Results from pilot PACEO in 2015: Kyoung Ho Cho

**(PPT 18) Kyoung-Ho Cho (KOPRI)** shared preliminary results from the 2015 ARAON summer cruise that covered the Chukchi Borderland to the Mendeleev Ridge. The hydrographic station map of the summer cruise showed where the CTD and XCTD stations were deployed this year. 2014 results observed in DBO 3 with CTD shows there is relatively cool saline water near the bottom from Station 3 to 6. Nearshore freshwater was relatively warmer at Station 8. 2015 results, however, showed warmer and less saline water at Stations 3 to 6, relatively warmer and less saline freshwater at station 8, and surface fresh water extended out to Station 7. Stations 9 to 12 are found in the Chukchi Sea. Station 10 had a low temperature gradient but strong salinity gradient in 2014, but this year warmer water occupied the upper layer, more than 7℃, with a strong temperature gradient but weak salinity gradient. The velocity vector from LADCP showed an eastward direction at stations 3 and 4 but this year, they were different. There were 7 transects outside of the EEZ line, focusing on the Chukchi Borderland measuring potential temperature that showed the movements of PSW, which extended to 77°N, and PWW. To compare temperature-salinity of the Chukchi Plateau, Kyoung-Ho calculated the anomaly for the mean temperature and salinity profiles for each year from 2010 – 2015 with PSW (red), PWW (blue) and surface mixed layer (green).

Compared with a temperature anomaly in the PSW to sea ice extension index, they had a negative relationship, but with the salinity anomaly in the surface mix layer and sea ice extension the anomaly had a positive correlation. A horizontal distribution of the PSW in the Chukchi Plateau seems to be meandering which is similar to the 2012 expedition results while the PWW flows into the southern region of the Chukchi Plateau. Heat and freshwater content had a similar pattern to PSW. PSW and Heat content was compared with Sea Ice Concentration (SIC), which showed a similar trend to PSW and heat content spatial distribution.

Future work includes analyses of observation data with lowered ADCP and long-term mooring data, understanding the relationships among atmospheric forcing, sea ice motion and upper ocean circulation and surveys to monitor the variation of Pacific-origin waters around the Chukchi Borderland and ESS. The 2016 ARAON Cruise plan consists of maintaining the mooring system for one more year and deploying 3 - 4 more ocean moorings in the PACEO line.

Bob asked for the depth of mooring to be deployed. Kyoung-Ho replied that the target depth is 500m, but they will also focus on the upper layer water mass distribution with an upward looking ACDP at 300m in the western side and 140m in the eastern side. Sediment traps for ecological studies at 320m will hopefully be deployed. Jia questioned about the bottom water on the Chukchi plateau as being Atlantic water. Atlantic water is below the 300 m with high temperature. Atlantic Water usually exists below 400m. Takashi and Koji commented that

seasonal variation should be taken into account when doing annual comparisons as this affects the results. Also, there is a need to separate the mixed interior layer to see the seasonal variation, which needs a separate discussion.

### 3.2 Physical Oceanography and Sea Ice Dynamics

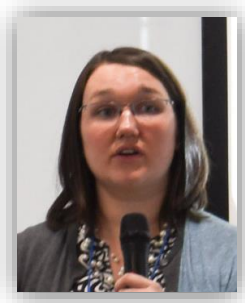
**(PPT 19) Jinping Zhao** informed the PAG members on the collaboration between OUC and KOPRI on the existence of the Mendeleev Gyre. The stations across the ESS were classified into 3 types depending on the water. They analyzed the salinity – temperature sea ice graph. The salinity at station 14 was used to observe the vertical profile of salinity difference (PSU), which clearly shows that the water mass at the base of the Chukchi is different from the Pacific and Shelf water. Numeric modeling on the gyre was done, but sea ice under the gyre for 2013 and 2014 were not clear due to heavy sea ice. But, if there is low sea ice concentration, the model could capture the movement of water from the Atlantic to the slope area. The existence of the Mendeleev Gyre had shelf water transported to the east. If the Pacific water is transported laterally by momentum to the gyre, the gyre also reaches the Atlantic water, which adds momentum to the gyre. The gyre can exist if there is low sea ice and also maybe seasonal or temporal variability of water mass types.

Bob questioned the nature of the three arrows in the schematic that was coming to the south of the Chukchi, the arrow that is coming from the west to east along the shelf. Jinping's reply was that the arrow from west to east is shelf water that is transported. Koji commented that the water is ESS, which is cold water with relatively high salinity but low temperature, thus, it is not PW along the slope. Bob asked what the nature of the flow is and where is the water mass was coming from? Koji replied that the moorings show the origin of the ESS to be coming from the East Siberian Shelf winter water. But the salinity is much lower than the winter water and the density is almost the same as the PSW.

### 3.3. Chemical Oceanography:

#### 3.3.1 Carbon Cycling and Ocean Acidification: Jessica Cross

**(PPT 20) Jessica Cross (UAF and NOAA/PMEL)** presented on carbon cycling, ocean acidification and the development of autonomous technology for Arctic research, specifically on one of NOAA's new pilot programs called, Innovative Technology for Arctic Exploration Program. She presented its proof of concept and how it can be used for future activities related to PAG. In this year's project mission, a carbon wave glider was used to run the DBO-4 line several times taking temperature, salinity measurements, with also the $CO_2$ system mapping to obtain carbon data. One of the important findings was on the evolution of two different types of ice melt. Among the two different types of ice melt, it was found that old ice melt sitting at the surface for a while, warms up, carbon and oxygen has equilibrated, higher salinity values, and productivity levels not lasting very long. When the wave glider was driven autonomously to brand new ice melts near Hanna Shoal, on the other hand, low salinity, high levels of oxygen, strong productivity with a big drop in $pCO_2$ were found. In sum, she showed that autonomous tools like wave gliders can be useful to track the ecosystem, particularly the evolution of ice melt and its impact on carbon cycling. She noted the only disadvantage of wave gliders is its



slowness and small payload, so that in order to track additional paramters to carbon parameters, such as temperature, oxygen, phytoplankton and nitrate, a whole separate package is needed. On this note, she introduced Saildrone Inc., a company based out of San Francisco, and discussed the performance of one platform that was used on the proof of concept mission this year in the Bering Sea. Despite the region being very cloudy and the platform being primarily reliant on solar power, Jessica shared that the mission was very successful with the platform being incredibly efficient, with minimal bio fouling. As such, Jessica underscored the usefulness of such tools by Saildrone Inc. for covering the expansive territory of PACEO lines.

Another effort of chemical oceanography is synthesis. Over the years, sporadic measurements of carbon were made through RUSALCA cruises. Regarding ocean acidification, by synthesizing all of these measurements, it was found that under saturations in Bering Strait, in the western part of Herald Valley, and through the Central Channel in the Chukchi Seat, with big impacts on biology. Our preliminary estimates indicate that at least 40% of the Chukchi Sea benthos is exposed to corrosive bottom waters during the summer. Going forward, one of the questions that will be investigated is where this undersaturated summer water would go.

Jessica also discussed the combination of ship-based measurements with mooring efforts. She explained that $pCO_2$ measurements were taken and related to aragonite saturation states and, ocean acidification states. From making use of this relationship, the area covered by undersaturated water in the summer time can be known, as well as the amount of time that undersaturated water is around. Slight undersaturation or slight corrosivity can be seen around 80% of the year, while severe corrosivity can be seen 30% of the year. Jessica underlined that as ocean acidification progresses, these time periods will get longer and will have serious impacts on the ecosystem.

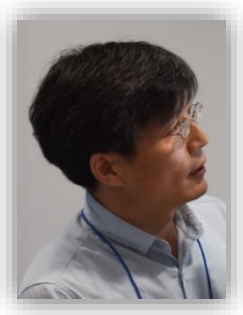
The data from aforementioned ship-based measurements, autonomous measurements, and mooring measurements can be used and combined to synthesis to ground truth some of the models. Minimal problems were encountered in predicting saturation states for a biogeochemical model for CESM in 2012. Prediction for saturation states in 2015 and 2100 could also be made. Jessica underscored that departure from natural variability will be the major impact that ocean acidification will have on biology. As found in the study near the Beaufort Sea, natural variability is to be overwhelmed by 2050. It is expected that surface waters from this Alaskan shelf will be covered by oversaturated water by 2100.

That being said, Jessica concluded that with the relatively mature status of this synthesis effort, it makes a strong case that carbon measurements should be done more often in chemical oceanography in PAG and PACEO efforts. Accordingly, she noted that carbon measurements could very much become a standard part of future RUSALCA cruises.

Takashi asked about the life time of the wave gliders and whether it has to be recovered. Jessica replied that they were out for a little over the month and must be picked up and deployed by a ship.

### 3.3. 2 Greenhouse Gas Observations: Tae Siek Rhee

**Tae Siek Rhee (KOPRI)** presented on greenhouse gas observations by KOPRI and KIOST in the western Arctic Ocean. $CO_2$ and methane are the two main greenhouse gases that have major impact in the Arctic area. Based on rough estimations, emission of methane in the atmosphere is more important than the absorption of $CO_2$ in permafrost or the Arctic Ocean. In just the



ocean, about 74 Tg of Carbon is emitted to the atmosphere every year.

Since 2012, 1400 to 3000 measurements were typically made in August or September of the saturation anomaly. Most of the time, there is large under saturation in the Chukchi Sea. But in 2012, when sea ice extent (SIE) was smallest, the saturation anomaly, which is deviation from saturation between air and water, was highest in the Arctic Basin. Compared to other years, chlorophyll-a concentration and wind speed, were high. In other years, there were lower or similar wind speeds in the Arctic Basin, as were atmospheric CO2 levels.

Why was pCO2 content so high in the Arctic Basin in 2012 compared to other years? This past summer, KOPRI visited a melt pond near the Arctic Basin and measured $CO_2$ and compared it with other parameters like oxygen and chlorophyll. Melt pond $CO_2$ concentrations were below $CO_2$ concentration in the surrounding seawater. This indicated that sea ice is not source of p $CO_2$ that, sea ice melting won't be a source of larger $pCO_2$ with the decrease of SIE. Tae Siek said that this is comparable to what Jessica shared in her presentation, that is to say, when sea ice melting areas were monitored, salinity was found to be lower together with p $CO_2$, which may be related to productivity. Tae Siek suggested that this finding may be due to the release of sea ice melt.

A paper by Shakhova et al. in 2010 estimated that about 11 Tg of methane is emitted every year from sea to atmosphere. Global ocean flux for this methane is about only 1 Tg per year. We went to Beaufort Sea because it is an area of gas hydrate in the sediment. Increasing temperature in the water column destabilizes the gas hydrate in the sediment. Unstable $CH_4$ hydrate in the sediment is released due to warming seawater. In 2013 during our cruise in the Beaufort Sea, we also saw a gas layer in the bottom layers. From 2014, saturation anomaly for methane is over 0; super saturated, whereas $CO_2$ was under saturated. For methane, average saturation anomaly is about 0.07, which is lower than global coastal emissions. In 2014, it was the same, only 0.1, which is lower than global coastal emission. This means that the Beaufort Sea is not a hotspot for methane emission compared to the Laptev Sea and East Siberian Sea, where concentration reached 200 up to 500.

Tae Siek summarized his presentation with the following points: 1) $CO_2$ uptake seems to be enhanced with sea-ice retreat in the Arctic Basin; 2) dissolved $CO_2$ observations in the melt pond suggests sea-ice melting should enhance atmospheric $CO_2$ uptake and 3) the Beaufort Sea is not a hot spot for atmospheric $CH_4$ yet.

### 3.3.3 Research on dissolved organic carbon: Jinyoung Jung

**(PPT 21) Jinyoung Jung (KOPRI)** presented on preliminary results of the distribution of dissolved organic carbon from 2013-2015 field observations in Chukchi and Beaufort Sea. As the Arctic Ocean is experiencing rapid environmental change, one of the most remarkable changes is sea ice loss. As sea ice concentration continues to decrease due to warming and advection of warm water, primary production in the Arctic Ocean continues to increase. Also, there is an increase in river discharge, leading to a large influx of terrigenous organic matter into the Arctic Ocean.

Delivered to the Arctic Ocean from the discharge of major rivers, terrigenous dissolved organic carbon is most important factor to understand the carbon cycle in the Arctic Ocean, especially from the Mackenzie River and Yukon River, which are major sources of terrigenous dissolved carbon. To investigate the behavior of dissolved carbon, KOPRI occupied many research stations, including DBO line 3 in the Chukchi Sea and stations in the Beaufort Sea.

There are two water masses entering the Arctic Ocean through the Bering Strait during summer. One is Anadyr Water which is colder, saltier, and more nutrient-rich water. The second one is Alaska Coastal Water, which is warmer, fresher, and nutrient-limited water.

From observations of DBO line 3; the fresher, warmer and nutrient-limited Alaska coastal water is distributed in the eastern side of Alaskan coast and upper surface water. Anadyr water is dominant in the bottom waters and on the west side. This year, however, temperature, salinity, phosphate concentration and amount of nitrate on the surface all increased compared to last year. Other data also showed similar patterns. High concentrations of DOC can be seen on Alaska Coast side, but this year, even higher DOC concentrations were found in the same site, while DON remained the same. Thus, it can be said that Alaskan coastal water influence is more on the eastern side of the Alaska Coast, which explains why DOC is more distributed on the eastern side.

In 2014, the station focused on the right side of the 170 degrees west longitude, and when the DOC concentration was plotted against latitude, there was a gradual decrease in DOC concentration from station 1 to 9. The flow-weighted DOC concentration in the Yukon River in August was 382 μM. This suggests this DOC concentration is derived from the Yukon River. In station 10 of Chukchi Sea, however, DOC concentration wass distributed homogenously. By using the distance and northward velocity at Bering Strait, the decay constant could be calculated. It was found that about 21 μM (24%) of DOC was removed. When DOC concentration was plotted against longitude, a gradient of DOC concentration could be found, which is probably due to the influence of Beaufort gyre. This year, KOPRI's research station focused on the right side of the 170 degrees west and contrary to last year, where there was no clear pattern of DOC when plotted against latitude. High concentration of DOC was found at DBO line 3. In the East Siberian Sea, the distribution was lower and more scattered. When plotted against longitude, the data was more scattered. It appears that the mechanisms for the removal of DOC for the eastern and western part of the Pacific Arctic is different, hence KOPRI is trying to interpret this topic more.

Melt ponds are the most distinctive summertime feature of Arctic sea ice, which are formed by melting snow and surface sea ice due to surface melt driven by increased short-wave radiation absorption in summer. Although considerable effort has been devoted to investigate physical processes and feedbacks of melt ponds, relatively little is known about biogeochemical properties of melt ponds.

Jinyoung first classified two types of melt ponds which are 1) open pond, where the bottom of the ice is open with similar salinity to sea water, and 2) closed pond, where the bottom of the ice is closed with salinity almost 0.

KOPRI carried out two ice camps last year: one in the Canada Basin and other one in East Siberian Sea. Last year, in 2014, salinity of the closed pond was below 5. High ammonium concentration was found. In the open pond, however, ammonium was not detected. In

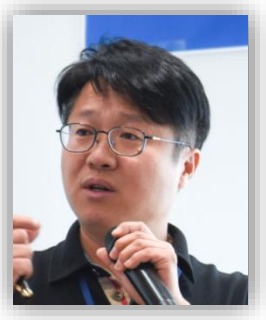
comparison, in the closed pond, there was no silicate, but in the open pond, silicate concentration was similar to that of sea water. Similar results occurred for phosphate: high concentration was found in the open pond. In the open pond, DOC concentration was similar to that of sea water, being about 60. This year, similar results were found.

As chlorophyll-a concentration in the closed pond was found to be high, the nutrient was probably used by phytoplankton. Also, in MP4, the DOC concentration was extremely high, as well as DON. Jin Young said that there is an effort to interpret this data with other biological data such as bacterial activity.

Jinyoung shared two goals for future studies. The first goal asks, if warming continues, with continued sea ice loss and increased open water, will the production of DOC be influenced by the increase in primary production or will the photo-oxidation or removal of DOC by exposure of open water to UV have more influence on carbon cycle? The second goal addresses the high DOC concentration in melt ponds. With Arctic warming and sea ice loss continuation, there is an increase of first year ice, melt ponds and exposure to UV. Jin Young hopes to design an experiment that can find out the mechanism for DOC removal.

**Importance of monitoring small phytoplankton: Sang Heon Lee**

**(PPT 22) Sang Heon Lee (Pusan National University)** presented on the importance of monitoring small phytoplankton and sea ice ecosystem in a changing Arctic Ocean. In warmer conditions, small phytoplankton is expected to increase. Indeed, Li et al found that small phytoplankton thrives in changing Arctic Ocean. Even though the phytoplankton community is different, the total chlorophyll concentration is basically the same. That is to say, a higher abundance of small phytoplankton was found with no chl-a change in the Arctic Ocean. Based on different size-fractionated, chlorophyll-a concentration, small contribution of small phytoplankton near the Chukchi sea area can be found, but in the higher Arctic Ocean, there is a bigger contribution of small phytoplankton. It was also found that there was a higher contribution (60-80%) of POC than primary production of small phytoplankton (20-40%) in the Chukchi Sea.



Primary productivity of small phytoplankton is significantly lower (t-test, $p < 0.01$) than that of large phytoplankton. The low primary production may be due to high contribution of small cells. The measurements of primary production that Sang Heon made for the past decade was 3 times lower than the previous results (before the 2000s) in the same Chukchi sea area. Thus it can be said that the higher contribution of small phytoplankton was caused by the low primary production level.

Furthermore, even though chlorophyll level may stay the same, small phytoplankton increases. With the kind of composition that makes lower primary production, small phytoplankton is found in lower tropic levels. Also, as small phytoplankton prefers ammonia over nitrate, strong recycled ammonia is found in the pelagic system, thereby providing lower sinking particles in the deep ocean.

Sang Heon also discussed the different biochemical composition of small phytoplankton. In the Arctic Ocean, small phytoplankton has more lipids, whereas in the Antarctic, they have more proteins. In the northern Chukchi Sea area, small phytoplankton produces more

carbohydrates. Thus, as small phytoplankton produces more carbohydrates, they affect more sinking particles to the deep ocean. That is, the different biochemical composition affects higher tropic levels and sinking particles.

The last topic Sang Heon discussed was a sea ice ecosystem study. With reduction of sea ice extent, there is an increasing amount of melt ponds on top of sea ice. Sang Hun measured the primary production of melting ponds to find out what kind of contribution melt ponds have in the Arctic Ocean. The contribution was found to be less than 1%. POC of entire sea ice floes was 2.8 % to 5.3 % of the POC in the euphotic water column in the Arctic Ocean Last year, Primary production of entire sea ice floes contributed 6.0 to 10.7% to that in the euphotic water column in the Arctic Ocean.

In conclusion, Sang Heon presented suggestions and plans for PACEO in 2016, which include 1) the monitoring of small phytoplankton contribution to total chlorophyll-a concentration, POC concentration, and primary production (no changes in total chlorophyll but POC and total primary production), 2) to determine the biochemical compositions of small phytoplankton versus large phytoplankton and consequently effects on higher trophic levels e.g., herbivorous zooplankton, 3) to clarify the effects of small phytoplankton on sinking particles in terms of quantity and quality aspects and 4) to determine the current roles of sea ice (e.g., melting ponds) to arctic marine ecosystems.

### 3.5 Ecosystem

**Assessment of the Zooplankton Ecosystem using Acoustic system in the Arctic Ocean: Hyoung Sul La**

**(PPT 23) Hyung Sul La (KOPRI)** presented on the impacts of environmental change on the abundance and habitat of zooplankton in the Arctic Ocean, as well as on the effective value of acoustic system as sustainable long-term observation for zooplankton's key ecosystem functions in the changing environment.

Arctic copepods are predominant species comprising of 80 or 90% of zooplankton. With their special ability to transport and convert low level carbohydrate in algae to high level lipid, their lipid concentration is extremely high and comprises up to 60% of their weight. Thus, they are valuable food item for larger crustacean, fish and whales, some that can also be detected by acoustic system.

The rapid decline of sea ice extent due to climate change in the Arctic directly impacts the Polar pelagic marine ecosystem, from lower tropic to higher tropic levels. Hyoung Sul's research focus is on the mid tropic level, particularly on mesoplankton and microzooplankton, as they can be easily detected by acoustic system.

To observe and understand how the abundance and habit of zooplankton is being affected by environmental change, as well as the likely causes and consequences of a changing environment on the key ecosystem functions of zooplankton, sustainable long-term observations, including both spatial and temporal measurements, are needed. For this purpose, acoustic method is very fitting.

Hyoung Sul compared the pros and cons of the three representative types of acoustic methods

to measure zooplankton, which are vessel-based, UMV-based, and mooring-based. The first two methods are very useful to measure spatial variability, but not good for temporal variability. For temporal variability, the mooring-based system is ideal. If these three systems are used properly, understanding and predicting what will happen in the Arctic marine ecosystem will be easier.

Hyoung Sul is focused within PACEO on the East Siberian Sea, northern Chukchi Sea and northern Bering Sea up to 80 degrees north latitude. If data of chemical, biological and physical conditions is collected on a long-term basis from the DBO and PACEO regions, predicting the future of Arctic Ocean will be easier.

The first Arctic cruise of ARAON was carried out to Northwind Ridge, where the existence of warm eddy in Pacific Summer water from 150 depth could be found. Using the EK60, vertical distribution of sound scattering layer was observed, that is the layer in the Ocean that consists of a diversity of marine organisms. From mass sampling, it was found that arctic copepods were the predominant species, mainly distributed from 20 to 100 m depth, where there was a distribution of warm eddy and Pacific summer water. Thus, the abundance was closely related with water column structure, Pacific summer water, high level of chlorophyll and nutrients. In 2014, there was a big ice camp station 200 meters off of ARAON to observe what is going on under the sea ice. Ice holes were made for deployments of ADCP and sediment traps. ADCP data could retrieve vertical distribution of sound-scattering layer.

What is interesting is that contrary to previous years, in 2010, Arctic copepods were distributed above the Pacific summer water (as opposed to *within* Pacific summer water). Hyoung Sul postulated that the possible reason for this may be closely related with water column structure, as they could have been caught by large density gradients.

This year in 2015, to observe seasonal variation and inter-annual variation of zooplankton, Acoustic Zooplankton Fish Profiler was purchased and attached on the mooring line near the East Siberian Sea. It is planned that this mooring will be recovered next year.

Hyoung Sul concluded with a discussion of future plans which includes a continuation of mooring work to compare zooplankton ecosystem with climate change, to observe the vertical distribution of zooplankton below the euphotic zone, the typical variation of migration and the abundance of zooplankton which can be seen in direct proportion to the level of acoustic intensity.

### 3.6 Sediment Trap

#### 3.6.1 Particle fluxes in the Arctic Ocean: Dongseon Kim

**(PPT 24) Dongseon Kim (KIOST)** presented on the details of a research proposal started this year. The area of study: 2 sediment traps are deployed at two sites, station 15 and 18. Sediment trap moorings were deployed at 500 meter at both stations with ADCP deployed at 300 meters, with RCM deployed at station 18. Vertical profiles of nitrate and chlorophyll concentration at sediment trap mooring stations were shown. Nitrate concentration completely depletes at the surface to about 30 meter and then increases at both stations. Chlorophyll-a concentration at both stations is very low: only 0.3 (units?) at station 18 and 0.2 (units?) at

station 15. Dongseon thus suggested that the sediment trap mooring area is very oligotrophic. From August 10th this year to August 31st next year, samples are being collected from the sediment trap every 15 days, except for winter season (Jan, Feb, March), during which samples are collected every 30 days.

He outlined the components of his research purpose which are: 1) to determine the annual variations of biogenic fluxes in Arctic Ocean; 2) to find out the lateral transport of biogenic materials from the shelf to the deep basin and 3) to find out the effects of sea ice on the biogenic fluxes.

Dongseon discussed in detail about the first component of his research aims, which is the annual variation of biogenic fluxes in the Arctic Ocean. As primary production increased 30% over the Arctic Ocean from 1998 to 2012, biogenic flux will also increase with time with primary production in Arctic area. Surface pH has decreased from 8.2 during 1880 to 1889 to 8.0 between 2003 and 2012, and it will drop to 7.6 in 2095. Surface water in the Arctic area will be undersaturated in the near future, which means calcium carbonate flux will decrease over time due to ocean acidification.

The second research aim is to find out the lateral transport of biogenic materials from the shelf to the deep basin. In the Chukchi Sea, some of biogenic materials will be produced in the shelf area and transported to basin. Transport of biogenic materials from shelf to basin can be evaluated from data that will be collected from a sediment trap that was deployed at 300 meter depth.

The third aim is to find out the effects of sea ice on the biogenic fluxes. A study by Kevin Arrigo showed that phytoplankton blooms occur under the sea ice in the Chukchi Sea. Biogenic flux can be obtained when sea ice exists and disappears; sediment trap data can be used to find out the effects of sea ice on biogenic flux.

### 3.6.2 JAMSTEC Sediment trap moorings: Jonaotaro Onodera

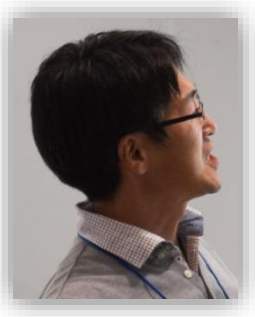
**(PPT 25) Jonaotaro Onodera (JAMSTEC)** presented on JAMSTEC sediment trap moorings. JAMSTEC studies the lower tropic marine ecosystem and biogeochemical cycle in the western Arctic Ocean. Since October 2010, sediment trap moorings have been deployed. The main station is NAP10t in the southern part of the Northwind Abyssal Plain.

For the past three years, no physical oceanography sensors were attached on the sediment trap moorings. From 2013, however, many kinds of physical and biogeochemical sensors ($pCO_2$, pH, DO, CT sensors) were deployed on the moorings. From October 2010 to September this year, seasonal increase of particle flux in early winter and summer can be observed. Low particle flux can be observed in 2012. This event was probably due to the interannual variation of Beaufort Gyre. From this year, sediment traps were deployed in upper stream region near the Barrow Canyon to monitor the condition of ocean circulation.

The objectives that were outlined are: 1) to understand the relationship between settling particle fluxes and hydrographic condition (e.g., oceanic eddy advection) and 2) through the deployment of pH and dissolved oxygen sensors, to conduct sampling of calcareous plankton shells using sediment trap and evaluation on the influence of acidification

to calcareous shells.

### 3.6.3 SGLI/GCOM-C: Toru Hirawake



**(PPT 26) Toru Hirawake (Hokkaido University)** presented on Global Change Observation Mission– Climate (GCOM-C), which will be launched in 2017 by Japan Aerospace Exploration Agency (JAXA). As the focus of GCOM-C will be put on carbon cycle, Toru shared details about the preparation activity, which include the preparation of algorithms, the construction of models for many ocean color products, with 250 meter resolution in shelf region. He gave a detailed explanation for a list of ocean products that will be put out by GCOM-C, which included both standard and new research products. Some examples include: CDOM, SST, Water leaving radiance, Atmospheric correction parameters; Euphotic zone depth, IOPs (absorption, scattering), Net primary production and Phytoplankton functional type and size class.

## 4. Data Sharing and Issues

### 4.1 DBO Data Policy: Jackie Grebmeier

**(PPT 27) Jackie** gave a brief overview of the DBO distributed data archive, how DBO metafiles should be uploaded on the website and the function the metafile serves for PAG. Invented by members of the DBO workshop, the executive committee of PAG and others of interest, the data policy for DBO is generic: anyone part of the DBO effort is required to fill out a DBO metafile that is available on the DBO EOL data archive website, (http://dbo.eol.ucar.edu) so that which cruises, which parameters and locations of data sets can be shared. The template for generic DBO metafile can be linked from other sites that are supporting the DBO effort (e.g., the Alaska Ocean Observing System (AOOS) DBO workspace; NODC; KOPRI, JAMSTEC, etc.). Jackie explained that that there are four different types of forms for the four different areas of data: transects, upper tropic data, satellite and mooring. The instructions for how to upload the data are available on the website.

The metafile not only allows different agencies to have access to data sets and where the data is being put, but every time a data set is used by someone, the person responsible for the data collected would receive credit. Jackie highlighted how the metafile helps with coordinating communication and data sharing between agencies from different nations: with one metafile, the point of contact for further information on data is made available. This point is particularly important as international collaboration is a key component of PAG.

After showing a suite of DBO data types and parameters, Jackie encouraged participants interested in submitting potential papers for the DBO special issue to send her an email with a note and a title. She mentioned that the special issue would be published by the end of 2016 and noted there are 14 potential papers thus far.

Jackie also informed participants about the biannual Gordon Research Conference, a forum during which there are speakers, discussion sessions to be held in Ventura, California. In 2017, the focus will be on time series observations in the Polar Regions. There is also Gordon Research Seminar the weekend before for early career scientists. She noted that by its international component, PAG will play a likely prominent role. Jackie said that a meeting

listing will be available after January.

### 4.2 K-Port (Korean-Polar Ocean in Rapid Transition) Web GIS: Junhwa Chi

**(PPT 28) Junhwa Chi (KOPRI)** presented on Korean-Polar Ocean in Rapid Transition (K-PORT) web GIS system, which can be a baseline for data sharing for PAG members. The Korean Polar Ocean in Rapid Transition (K-PORT) web GIS was launched 2 years ago with the motivation to further understanding on the environmental changes in the Arctic and Antarctic oceans, as they are difficult to observe compared to other regions. In 2009, when the first Korean icebreaker ARAON was built, research activities could be performed independently. Indeed, massive in-situ data could be produced, but it was still difficult to obtain high quality data. Thus, an effort was made to find a way to share data among multiple research teams and global research groups in the world. By utilizing field data associated with spatial data such as GIS and remote sensing data, a better understanding of environmental changes will be furthered.

From 2013 to 2014, in the first year of K-PORT Web GIS system, a prototype was developed with only basic functions implemented. From 2014 to this year, the system could be more advanced, as more spatial analysis functions and practical functions were developed such as 3D viewer, as well as allowing users to upload in-situ data on the web server. Development plans from this year to next year will be focused on providing off line version for field researchers, more spatial analysis functions and making the system more stable.

The system supports both vector and raster layers. Display remote sensing data, SIC, DEM Bathymetry, EEZ can be displayed/overlaid. As mentioned earlier, the system supports field data, thus spatial distribution of field data can be analyzed. The current system supports more than 10 types of field measurements such as chlorophyll, temperature, salinity, geophysics, etc. Also, field measurements, image data, analysis results can be uploaded.

For future plans, Jun Hwa said that as there is a lot of room for improvement and development, focus will be put on Arctic Ocean, so that eventually all data produced from the Arctic Ocean can be shared, which Jun Hwa believes will lead to more potential research collaborations in the future. Lastly, as commercial GIS software is very expansive, KOPRI plans to convert GIS software to open GIS so that expensive commercial GIS software does not need to be purchased for analysis of spatial data.

## 5. Synthesis

### (PPT 29) Biogeosciences Special Issue: Takashi Kikuchi

**Takashi** noted that by papers were collected for the special issue of Biogeosciences. Eight papers can be found on Biogeosciences discussion. Takashi noted that later on, there may be 5 more papers. Takashi also informed participants about the 2017 ASSW meeting that will be held from March 31$^{st}$ to April 7$^{th}$ in Prague, Czech Republic. First half of the week would comprise of business meetings, during which the spring PAG meeting would take place, and the remaining 3.5 days will hold a science symposium on the theme, “A Dynamic Arctic in Global Change”. Takashi emphasized that the important point is that the program should be built based on session submissions which would help to engage the community. Therefore,

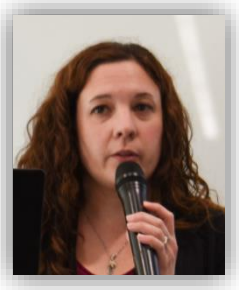
Takashi suggested that there should be a science session for the symposium that relates PAG. He plans to work with Sung-Ho and Jackie on a draft. The call for session proposals should be published right after the ASSW 2016, thus the list of sessions can be compiled during summer next year and the call for abstracts announced in September 2016.

**6. Updates on Interactions with other Organizations & Upcoming Meetings**

**6.1 Asian Forum for Polar Sciences: Relevance to PAG: Hyeon-Cheol Shin**

**(PPT 30) Hyeon-Cheol Shin (KOPRI)** introduced the Asian Forum for Polar Sciences (AFoPS), giving a brief overview of the organization's history, and relevant collaborative projects for PAG. Established 2004 with the aim to facilitate polar research and logistic cooperation, AFoPS is a regional alliance with a global perspective, an important medium for collective endeavors. There are usually 2 meetings each year, in the spring and summer, with 5 member nations, China Japan, India, Korea and Malaysia, there are also growing number of observers from nations such as Thailand, Sri Lanka, and Vietnam. Currently, from integration with existing national efforts, there are 5 endorsements for AFoPS collaborative projects, and two are relevant for PAG: Arctic Ocean observations, polar to mid latitude climate linkage. Converging points include ships going regularly to the Pacific Arctic, Atlantic and terrestrial observations, additional modeling efforts, as well as the development of AFoPS collaboration projects. Hyeon-Cheol concluded that as coordination between different organizations is not easy, it is for this very reason that AFoPS can play a coordination role in between different institutes and organizations from other countries.

**6.2 North Pacific Research Board's "Arctic Program": Danielle Dickson**



**(PPT 31) Danielle Dickson (North Pacific Research Board)** introduced a new research project, the Arctic program that will be funded by the North Pacific Research board, a funding agency for marine science in Alaskan waters. Every year, about 4 million US dollars are granted for individual research projects, but every 5 to 7 years, the NPRB also funds larger integrated ecosystem research projects. Building on the successful programs done in the Bering Sea and Gulf of Alaska, a new program is underway for the Arctic, the Arctic Program. These programs bring together about 50 to 100 scientists from different areas of expertise to work for 5 to 7 years and conduct research to reach ecosystem level of understanding. Researchers are funded to carry out usually 2 years of field research with substantial time left for synthesis, whether it be development of analytic techniques, advances in multidisciplinary analyses, the writing and publication of special issues. A minimum of 5 years of cooperative work is required, but additional funding may be granted for another 2 years. Together with U.S. Bureau of Ocean Energy Management, and Collaborative Alaskan Arctic Studies Program, the North Pacific Research Board has $8 million US dollar worth of funding for Arctic Program. As this funding amount is rather limited, NPRS is making an effort to play a coordinating role between existing programs, particularly focusing on regions in the Northern Bering Sea, Bering Strait and Chukchi Sea for this program. Currently, 22 existing projects funded by U.S. agencies will participate in this program. The

principal Investigators from these existing projects will attend annual meetings to share data and perform analysis and synthesis efforts. Additionally, a secure data portal is being developed for collaborating researchers. A Multidisciplinary program centered on the Chukchi is being developed. There will be potential opportunities to share vessel time, collect samples, deploy, recover equipment. It is planned that vessels will be put out in the field regions in 2017 and the 2nd field year will be in either 2018 or 2019. Currently, proposals are being accepted and reviewed and the NPRB will finalize decisions by next May which research projects will be funded from the $8 million. Thus, Danielle extended the invitation for all PAG researchers to participate in some of collaborative projects from the Arctic Program or have scientists from the Arctic program go onboard and collaborate on PAG Arctic cruises. Resources and data can be shared, whether on DBO lines, as can moorings be deployed or recovered.

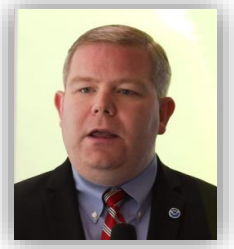
One specific research proposal Danielle was asked to share with PAG was Arctic Shelf Growth, Advection, Respiration and Deposition Rate Experiments (ASGARD), a project that is hoping to conduct field research in May and June next year and in 2018. If funded, a limited number of berths can be provided to national and international partners. For anyone interested, they can contact the principal scientist for this project, Seth Danielson at sldanielson@alaska.edu. Another project that Danielle was asked to share by Seth Danielson was the Chukchi ecosystem observatory. For anyone interested to cooperate in the deployment and recovery of 3 moorings at this observatory, they should contact Seth.

Hyeon-Cheol asked about how the $8 million dollar funding for the Arctic program is structured. Danielle replied that typically about 5 large projects would be funded.

**6.3 IAHR Symposium on Ice: Jia Wang**

**(PPT 32) Jia** invited all PAG participants to the 23rd IAHR Symposium on Ice that will be held from May 31st to June 4th, 2016 in Ann Arbor Michigan. The symposium title is "Research and Application of Ice Dynamics and Thermodynamics in Engineering and Climate Change". While ice dynamics and ice-related research including the ecosystem, biogeochemical properties of rivers, lakes and oceans will be discussed, the discussion can also extend to the Arctic and Antarctic sea ice and variability.

**6.4. Invitation to 2016, 2017 RUSALCA Arctic Cruise: Jeremy Mathis**



**Jeremy Mathis (NOAA)** extended an invitation to all PAG members to join the RUSALCA cruises in 2016 and 2017. As space is available on board, Jeremy encouraged PAG partners interested in carrying out measurements or conducting collaborative project with RUSALCA projects and the synthesis afterwards to get in touch with him.

**6.5 Invitation to 2017 NABOS Arctic Cruise: Vladimir Ivanov**

**Vladimir Ivanov** extended an invitation to all PAG members to join the 2017 NABOS-II cruise. As the general policy for NABOS-II is to attract participation from different nations and institutions and thereby make the program multi-disciplinary, Vladimir encouraged anyone interested in joining the NABOS cruise to contact him.

**PAG Secretary, Somang Jung**

### 7.1 List of Participants

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**7.2 Acronyms**

AARI (Arctic and Antarctic Research Institution of Russia)

ADCP (Acoustic Doppler Current Profiler)

AICC (Arctic Icebreaker Coordinating Committee)

AMBON (Arctic Marine Biodiversity Monitoring Network)

AON (Arctic Observing Network)

AOOS (Alaska Ocean Observing System)

ART (Arctic in Rapid Transition)

ASCOS (Arctic Summer Cloud Ocean Study)

ASR (Arctic Sea Route)

BGOS (Beaufort Gyre Observing System)

CAFF (Conservation of Arctic Flora and Fauna),

CBMP (Circumpolar Biodiversity Monitoring Program)

CS (Chukchi Sea)

DBO (Distributed Biological Observatory)

DFO (Department of Fisheries and Ocean Canada)

DSR II (Deep Sea Research II)

ECS (Early Career Scientists)

EEZ (Exclusive Economic Zone)

EPB (European Polar Board)

ESS (East Siberian Sea)

FARO (Forum of Arctic Research Operators)

IACE (Institute of Arctic Climate and Environment Research)

IARPC (Interagency Arctic Research and Policy Committee)

IASC (International Arctic Science Committee)

IASOA (International Arctic Systems for Observing the Atmosphere)

ICARP III (Third International Conference on Arctic Research Planning)

INSROP (International Northern Sea Route Programme)

ISTAS (Integrating Spatial and Temporal Scales in the changing Arctic System)

ITP (Ice Tethered Profiler)

JAMSTEC (Japan Marine Science and Technology Center)

JOIS (Joint Ocean Ice Studies)

KOPRI (Korea Polar Research Institute)

MIZ (Marginal Ice Zone)

MOSAiC (Multidisciplinary drifting Observatory for the Study of Arctic Climate)

NOAA (National Oceanic and Atmospheric Administration)

NSF (National Science Foundation)

OUC (Ocean University of China)

PACEO (Pacific Arctic Climate Ecosystem Observatory)

PPP (Polar Prediction Project)

PRIC (Polar Research Institute of China)

RUSALCA (Russian American Long-term Census of the Arctic)

SAON (Sustaining Arctic Observing

Network)

TRANSSIZ (Transitions in the Arctic Seasonal Sea Ice Zone)

TUMSAT (Tokyo University of Marine and Science Technology)

UMCES (University of Maryland Center for Environment Sciences)

USCG (US Coast Guard)

WHOI (Woods Hole Oceanography Institute)

YOPP (Year of Polar Prediction)