KOPRI's Observing Plan for Arctic Ocean (2014~)

# Comprehensive Observational Study in the Seasonal Ice Zone:

## Role of Air-sea Interaction in the Arctic Amplification


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# Comprehensive Observational Study in the Seasonal Ice Zone: Role of Air-sea Interaction for Arctic Amplification

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***Executive Summary:*** With recent rapid decline of summer Arctic sea-ice, the air-sea interaction over the seasonal ice zone (SIZ) is expected to be much more vigorous, significantly contributing to Arctic Amplification (AA). AA in turns modifies mid-latitude jet streams toward a much wavier pattern, causing extreme weather events over many mid-latitude regions. Our preliminary assessment in this paper demonstrates that high heat flux event (HHFE), much intense heat exchange events during a cold air outbreak in the SIZ, is in particular a key interest, because of its connection to AA and in turn extreme weather in the mid-latitude, especially if we are to improve our seasonal and decadal predictability of the impacts of future Arctic climate changes. Here we propose a comprehensive observational study centered at Korea Polar Research Institute (KOPRI)'s major infrastructures, aiming at accurate evaluation of HHEFs and potentially unveiling their linkages to AA and large-scale circulation. Our proposal includes land-based camp at the northern Barents/Kara Seas and Korean ice-breaker ARAON's excursion in the Chukchi shelf and northern East Siberian Sea. The paper also contains the description of observation techniques for both physical and bio-geochemical parameters within the atmosphere-ocean-sea-ice system. Accurate measurements of such parameters would reveal the entity of air-sea interaction and the way in which air-sea interaction contributes to AA. In the long run the proposed observations can lead to the improvement of numerical models' capability of the Arctic simulation.

# Motivation

- With recent rapid decline of summer Arctic sea-ice, the air-sea interaction over the seasonal ice zone (SIZ) becomes much more vigorous, significantly contributing to pronounced Arctic warming, which is often called as Arctic amplification (AA).

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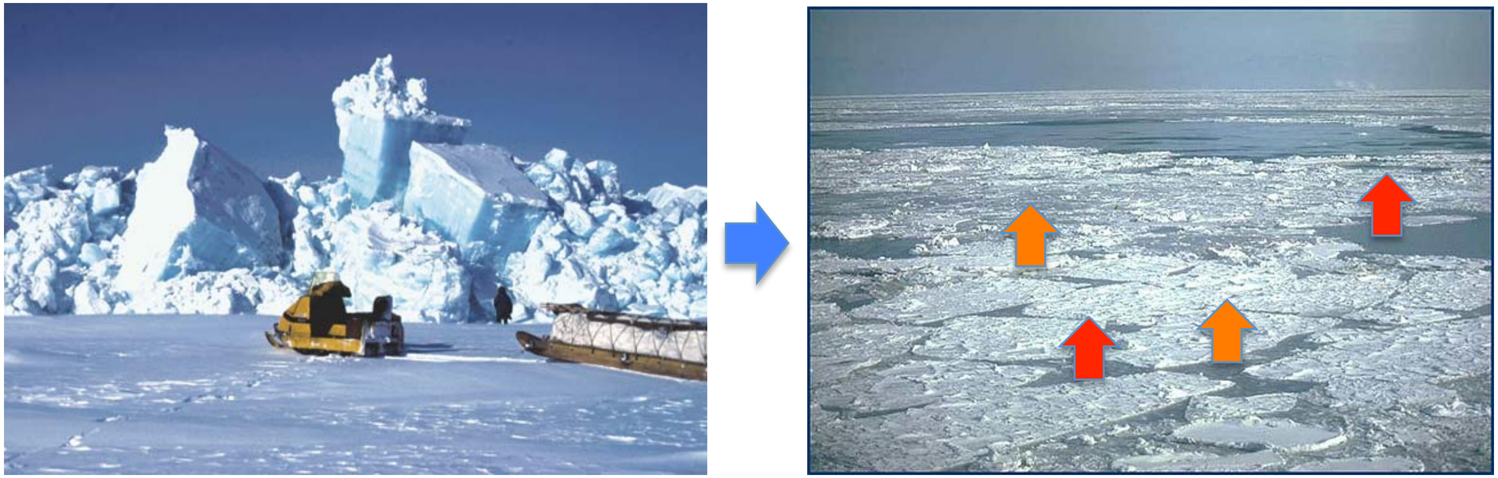

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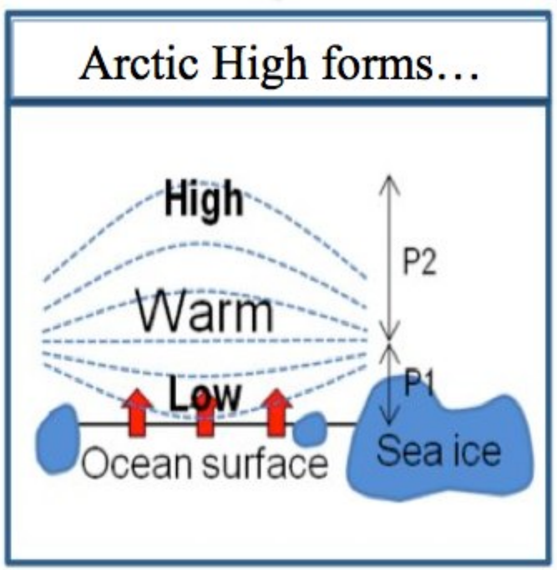
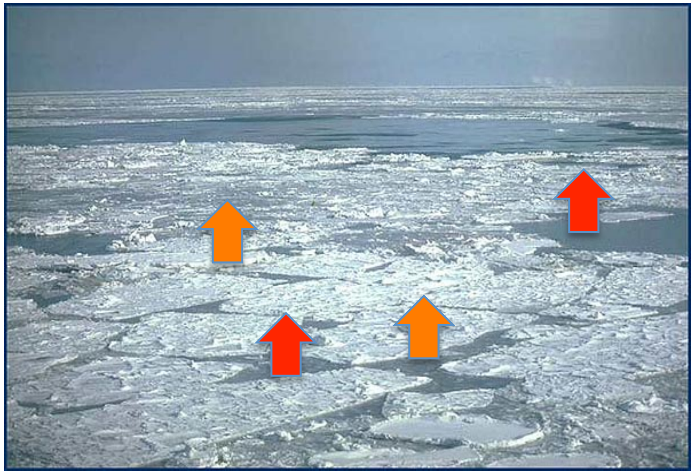
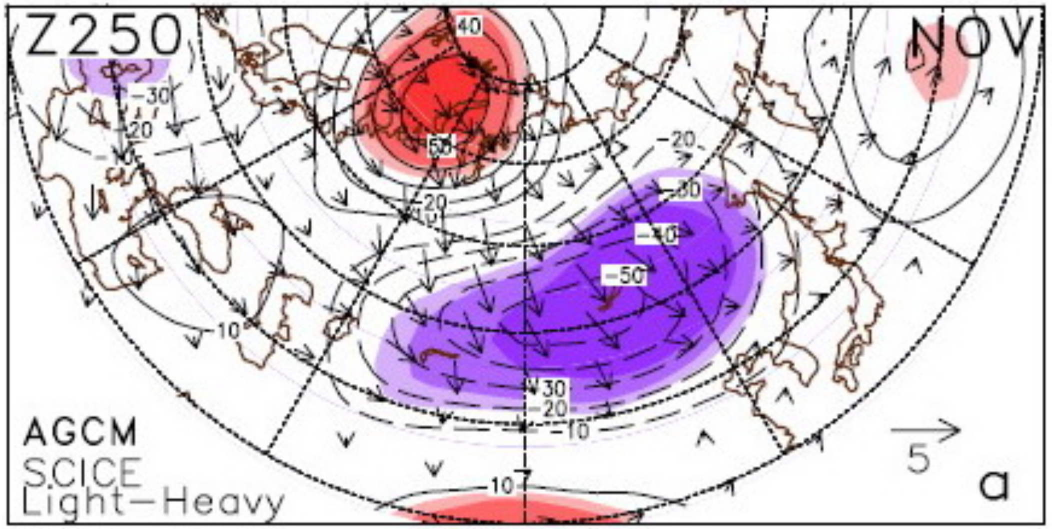


# Motivation

- There exist growing evidences that the impact of AA is not just confined within the Arctic Ocean, but also leads to global atmospheric circulation change.

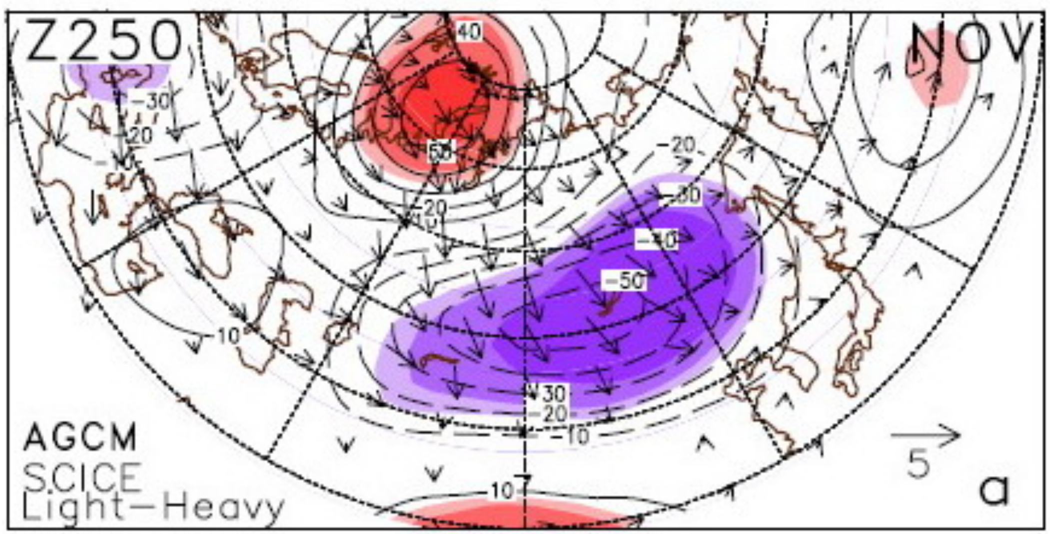



<Influence of low Arctic sea ice minima on anomalously cold Eurasian winters>

Honda et al. (2009)

# Motivation

- Especially, the Korean Peninsula situates over the East Asian coastal region where the meandering of the jet is usually amplified.

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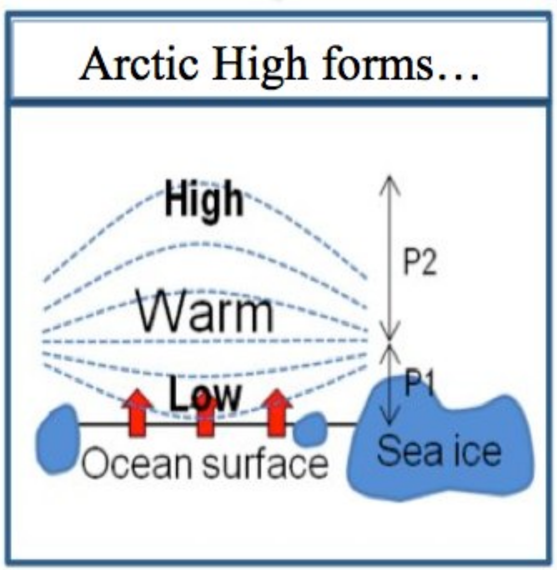
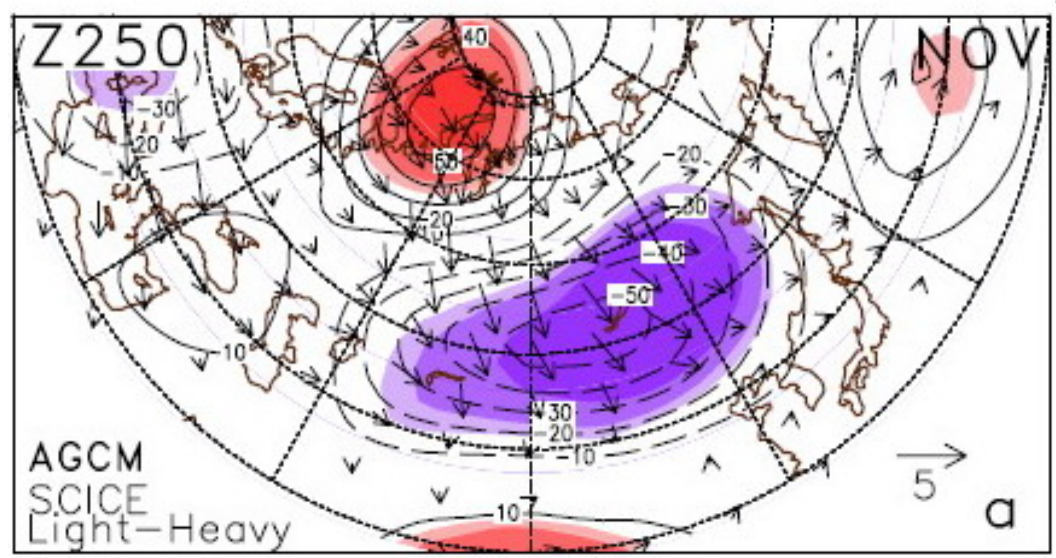
# Motivation

- Therefore, accurate evaluation of the energy fluxes over source regions is crucial for better predicting the extreme weathers in highly populated regions.

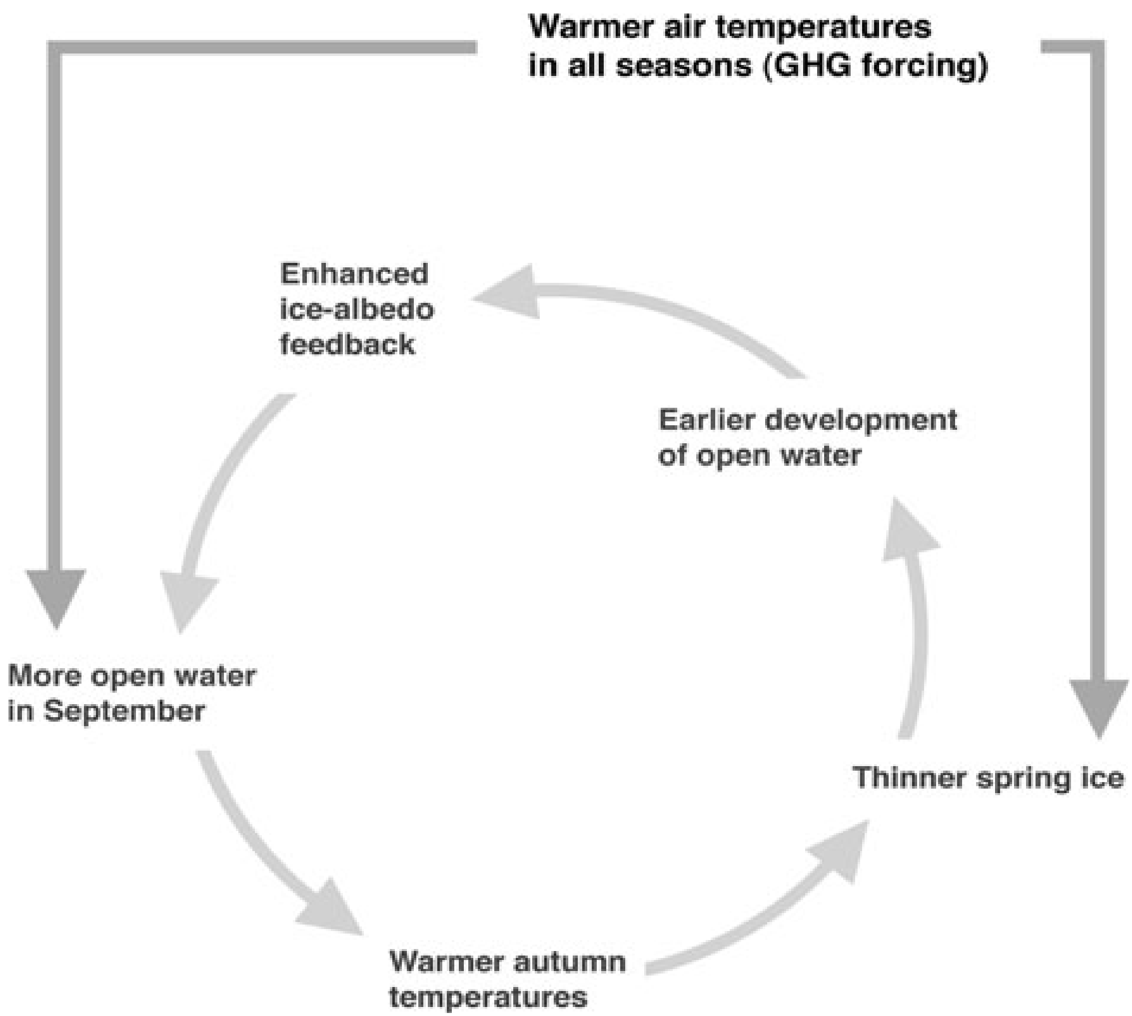


# Motivation

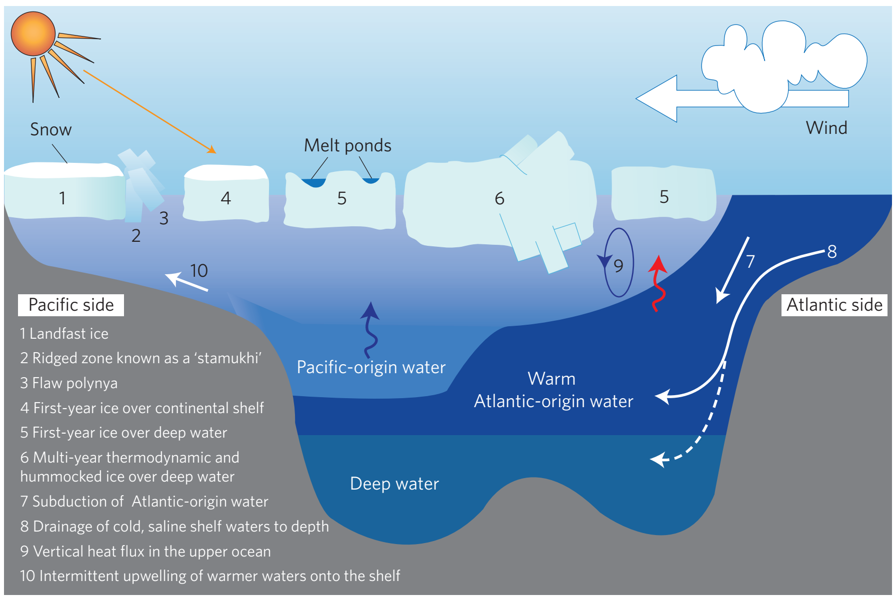
- Why recent Arctic warming is occurring in such an amplified manner?
- All the involved physical processes are complexly interweaved and the decline of Arctic sea-ice itself is not merely a consequence but a major component in various feedbacks that can significantly accelerate overall changes in Arctic climate.

Greenhouse forcing & Arctic response

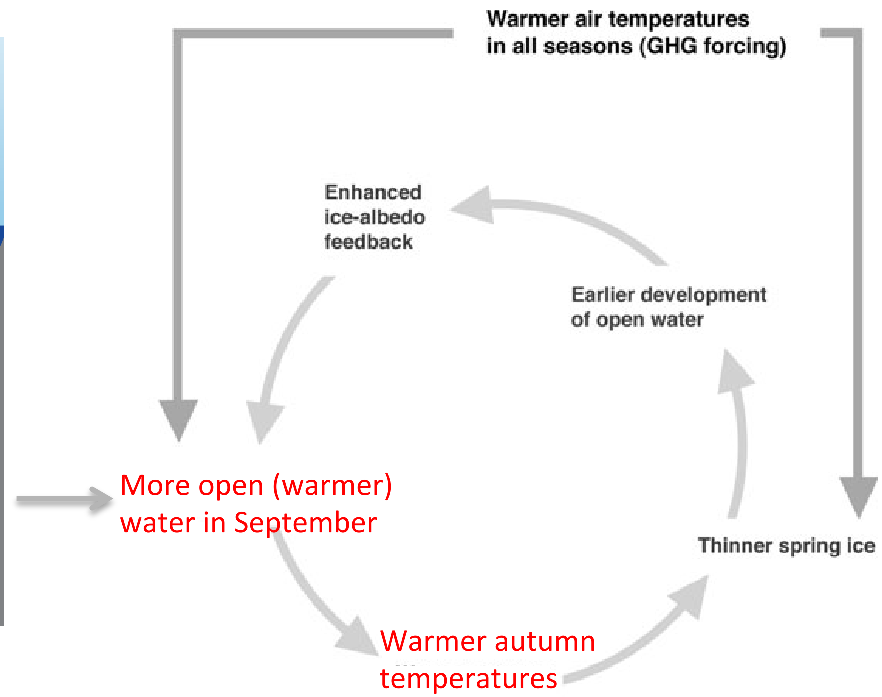



Stroeve et al. (2012)

# Our Observing Focus




Carmack & Melling (2012)

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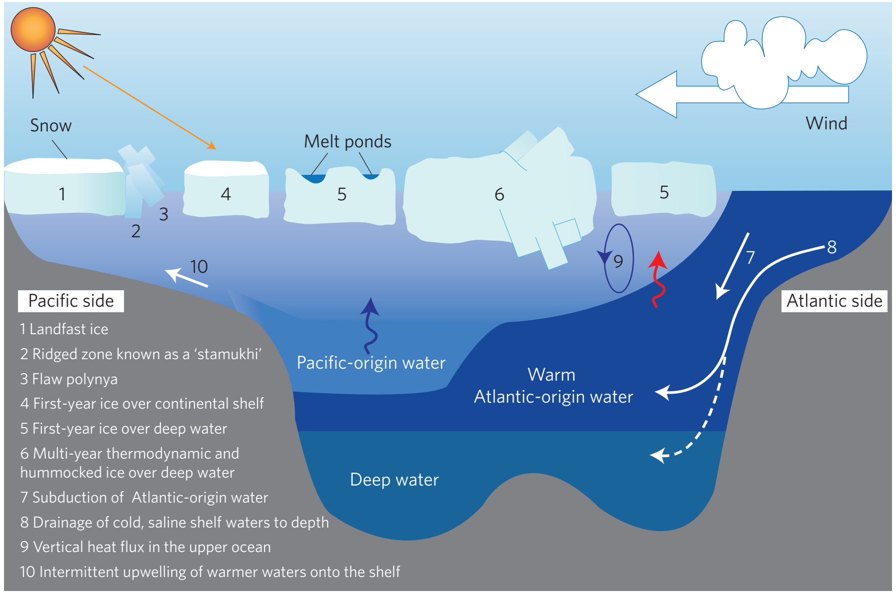


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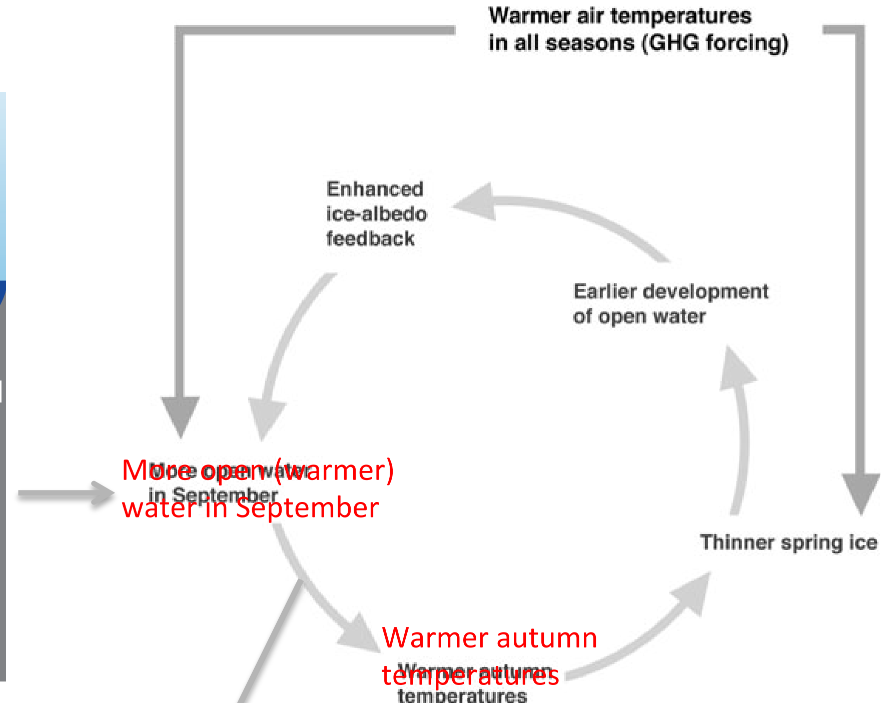



Stroeve et al. (2012)

HHFEs

- One of key component of ASIA is energy exchange between air and Ocean surface in the Arctic.
- Intensive, abrupt heat exchange in the SIZ, referred as high heat flux event (HHFE), can occur during short period of time. This localized and short-lived event is thought to play a key role in maintaining AA.

# Observing Goal

- Through field campaigns, we will synthesize various aspects of multiple meso-scale or synoptic-scale HHFEs in the SIZ and reveal the causes of the HHFEs and their linkage to large-scale circulation from both Ocean and Atmosphere aspects.
- We aim at obtaining the comprehensive field observation data that enhance the understanding of the various aspects of Air-sea Interaction in the changing Arctic Ocean (ASIA) from the viewpoint of both of oceanic and atmospheric scientists.

# Observing Strategy: Where?

Land-based Research Camp

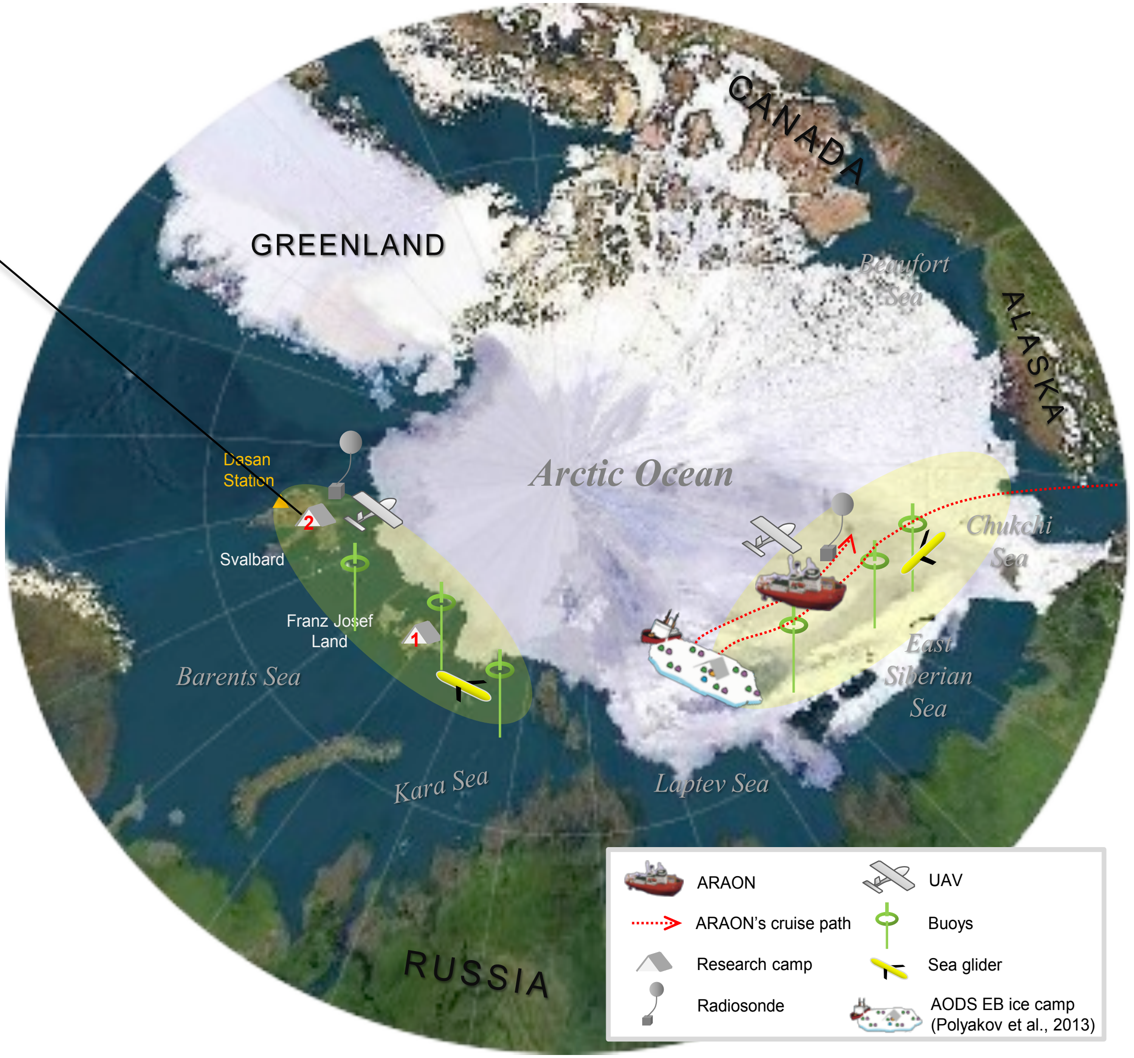
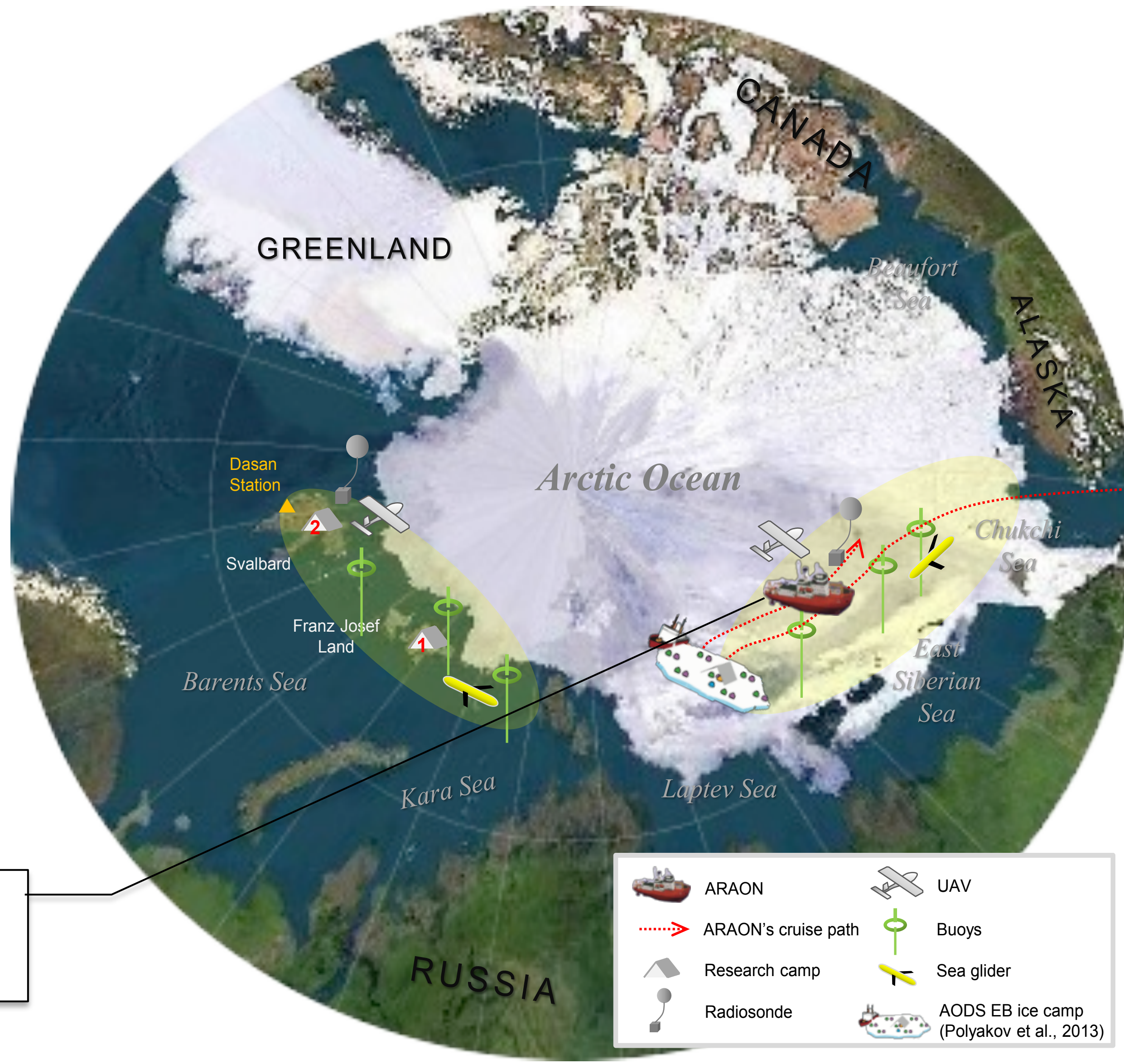



Figure 4. Illustration of areas of KOPRI's field experiments. Transparent yellow ovals are our major target SIZs. While the eastern area over the northern East Siberian and Chukchi Seas will be cover by the research vessel ARAON, the western area over the northern Barents/Kara Seas will be studied with the land-based research camp. One of the proposed locations (1: Franz Josef Land, 2: Svalbard) will be selected for the land-based research camp.

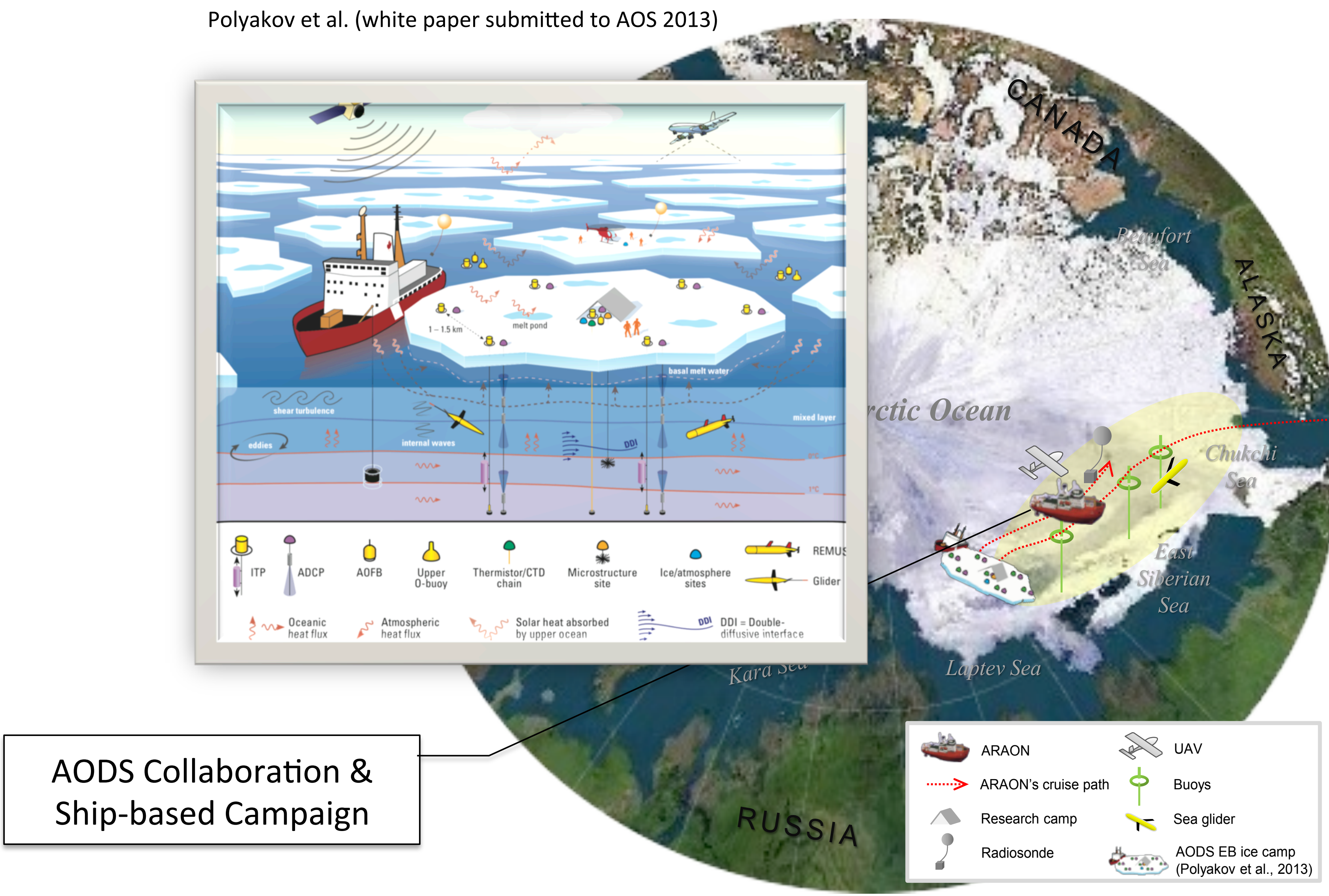
# Observing Strategy: Land-based

- Since our main focus on air-sea interaction in early freezing season (Sep.-Nov.), the Franz Josef Land (Zemlya Frantsa-Iosifa) in the northern Barents/Kara Seas is located at the center where trends in sea-ice concentration show a large declination, and thus provides an ideal place to study whole processes (from the ocean to the atmosphere) of air-sea interaction in the SIZ.
- The Svalbard archipelago is also an alternative. The KOPRI's Arctic research station, named "Dasan station", is located at Ny- Alesund, on the high Arctic island of Spitsbergen. Experiments in the offshore north and east of Svalbard can be conducted if the establishment plan of the research camp can be realized.

# Observing Strategy: Where?




AODS Collaboration & Ship-based Campaign

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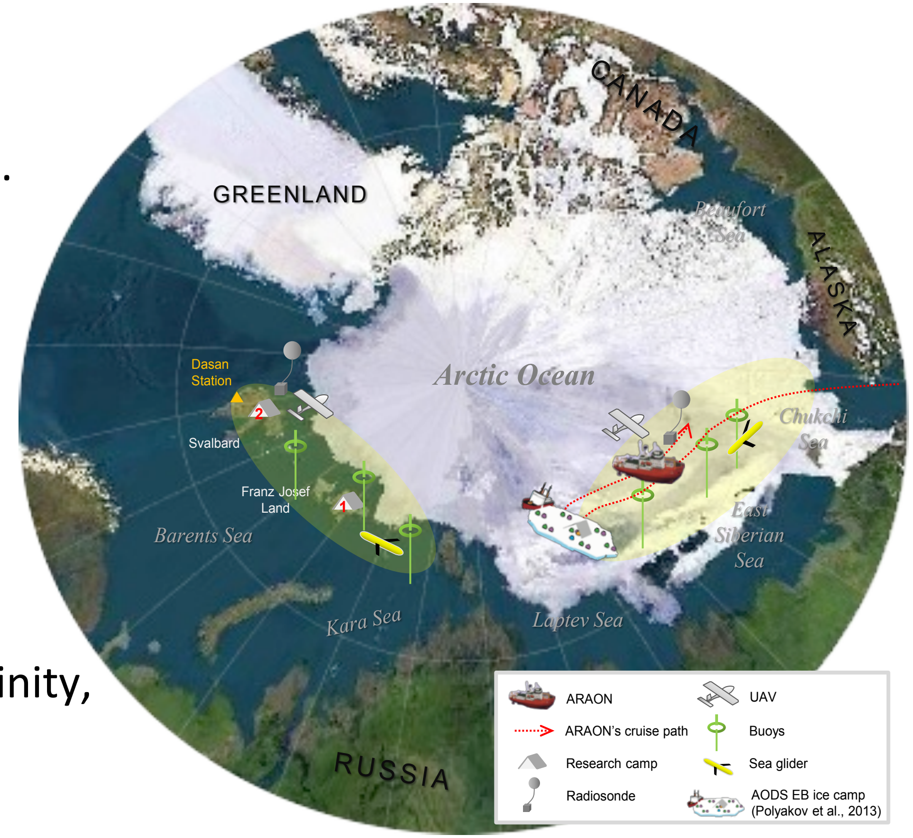
# Observing Strategy: Where?

As a part of international collaboration with Dr. Craig Lee at Applied Physics Lab/ University of Washington (APL/UW), the cutting-edge platforms (e.g., sea gliders) are potentially deployed to measure the processes under the ice-covered and inaccessible SIZs.
The sea gliders will visualize the structures of many oceanographic cross-sections by measuring the distribution of temperature, salinity, dissolved oxygen (DO) and turbulence.

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# Observing Strategy: Ship-based

- Ship-based field campaigns from the Korean icebreaker ARAON can be only realized during short periods of late summer and early autumn because the ARAON must return to South Korea no later than early October to prepare her long journey to Antarctica.
- Thus ship-borne observations will focus on the longitudinal sector east of 125°E (e.g., Chukchi Sea, East Siberian Sea), but, if ship time is allowed, the cruise can be extended to the eastern Eurasian Basin (EB) where the EB ice camp of the AODS will be established in September 2015 (*Polyakov et al.,* 2013).
- Our provisional plan of the ARAON excursion is as follows. She will enter the Arctic Circle in August and navigate through the Chukchi Sea and its north, the northern fringe of the East Siberian Sea, and near the AODS EB ice camp during August and September. The cruise route will be carefully designed to increase the probability of encountering the Arctic storm initiating the HHFE in the SIZ.

# Observing Parameters

- ***A land-based camp*** will be established primarily for the purpose of meteorological observations at the sea front of the SIZ in the northern Barents/Kara Seas.
- For the vertical profile of those basic parameters, a radiosonde will be launched at 6-hourly intervals, and a tethersonde balloon will be used to simultaneously collect them at multiple levels in the atmospheric PBL.
- In addition, a Microwave Radiometer Profiler (MWRP) will also provide vertical profiles of temperature, humidity, and cloud liquid water content at much finer time intervals.
- An all-sky camera will help to quantify total cloud cover during the daytime.
- A LIDAR instrument will be operated to measure cloud properties including height, concentration and optical property.
- Additionally, an Unmanned Aerial Vehicle (UAV) will be operated to capture three-dimensional variation of the PBL in the SIZ.

# Observing Parameters

- ***Ship-borne:*** The Conductivity-Temperature-Depth (CTD), Salinometer, and the Acoustic Doppler Current Meter (ADCP) will measure the basic oceanic physical parameters including temperature, salinity, and ocean currents at various depth levels.
- Direct observations of turbulent fluxes of heat, moisture, momentum, carbon dioxide, and methane will be obtained using the eddy covariance method.
- Cloud height and properties will be measured continuously using the onboard LIDAR.
- For detection of the bio-geochemical parameters (e.g., phytoplankton, sea-ice algae, etc.), either a Niskin sampler or electric submersible pump through the ice hole will be used to collect water sample under sea-ice.

# Observing Parameters

- ***Drifting buoys*** can offer continuous observation of location (GPS), sea-ice melt and growth rates, air, ice and upper ocean temperatures, and meteorological parameters (e.g., pressure, temperature, humidity, and wind at near-surface levels).
- GPS and meteorological data from drifting buoys can be used to locate the passage of cyclones and thus HHFEs.
- Divergence and convergence of sea-ice can be continuously monitored from DKPs (differential kinematic parameters), which is calculated from buoy GPS data.
- From sea-ice buoy, water temperature can be measured up to a depth of a few tens of meters within mixed layer, while dedicated ocean temperature buoys can measure temperature up to 60-m depth.
- Small portable CTD sensors can be attached at the bottom of the buoys that allow us to measure salinity as well.
- Direct measurements of sensible heat flux can also be realized if sonic anemometer be installed and corrected for the motion and icing.
- Buoy observation is critical if we are to observe the transitional processes occurring from melting summer through freezing autumn.
- In order to capture regional variability in large area, it is essential that large quantity of buoys are to be deployed on various surface types, e.g. open water, multi-year ice and first year ice.

# Observing Parameters

- ***Long-term mooring systems*** are essential to measure the change of sea-ice and associated heat and mass balance in the upper ocean. Because reduction of sea-ice is crucially related with warm water inflow from the Pacific and Atlantic Ocean, the heat exchange in the interfaces between air, sea-ice and sea surfaces, and thus the spatial and temporal variability of Pacific-origin Summer Water (PSW) and Atlantic Water (AW) will be investigated by a series of hydrographic observation using CTDs and ADCPs.
- Several long-term moorings including thermistors and current profiler will be deployed along the gateway of PSW and AW.
- The Chukchi shelf and Barents/Kara Seas are potential candidates for installing the mooring systems.

# Observing Parameters

- ***Satellite data*** can provide information on surface and atmospheric conditions, which help us to fill the gap between the limited ground-based observations and much larger scales.
- Large-scale surface turbulent heat fluxes can be derived from combined information of radiometers (both microwave and infrared) and scatterometer as first approximation.
- Identifying HFFE-induced cloud formation may be a key to bridge between AA and ASIA because clouds warm the atmosphere through increasing downward longwave radiation.
- For the detection of clouds, high-resolution vertical profiles from CALIPSO can be also utilized, provided that the satellite passes over the location of field observations.
- High-resolution Synthetic Aperture Radar (SAR) and visible images [Kwok *and Untersteiner,* 2011] can offer much better spatial resolution (up to 1-m resolution).
- High-resolution images can also be used to monitor sea-ice divergence and convergence caused by storm events at potentially sub-daily temporal resolution (e.g. COSMO- SkyMed, TerraSAR-X) and at spatial resolution of tens of meters.

# Observing Parameters

- ***Aircraft measurements*** (piloted either directly or remotely) can provide a "slap shot" of atmospheric status in a large area. Light Remotely Piloted Aircraft (LRPA) (under 150 kg, e.g., CryoWing and Sumo) can be used to measure small-scale variability (e.g. active leads) of turbulent heat fluxes in an area of about 50 km from a launching platform (ship, sea-ice or shore). Wide range of sensor capabilities are available, e.g. aerosol and cloud physics, turbulent fluxes, atmospheric profiling, and sea-ice and ocean mapping (e.g. camera, multispectral), but all the sensors cannot be deployed simultaneously on a LRPA due to limited payload capacity [AMAP, 2012]. Pilot (manned) aircrafts includes a variety of range from Twin Otters (CIRPAS in US, MASIN in UK) to C-130 'Hercules' (US Coast Guard) and BAe 146-301 (Facility for Airborne Atmospheric Measurements (FAAN), UK). They can accommodate the same or much wider range of sensors, and repeated long- range observations can be also realized. The operation of both LRPA and manned aircrafts requires careful flight planning and access permits from designated airspace regulators [AMAP, 2012].

# Expected Outcomes and Influences

- Straightforward outcome is the accurately measured data of physical and bio-geochemical parameters on various surface types in the Arctic Ocean:

  1) turbulent heat fluxes (both sensible and latent)
  2) basic met-parameters (temperature, humidity, pressure, and wind), radiative fluxes (both longwave and shortwave) and clouds (cover and height)
  3) ocean physical parameters (temperature, salinity, and currents) and their vertical profiles
  4) bio-geochemical parameters (e.g., phytoplankton, ice algae, fluxes of $CO_2$ and methane, etc.)
  5) sea-ice properties (melting and growing rates, ice temperature and thickness, motion, etc.). Those parameters will be collected under various surface conditions (open water, multi-year ice, and first-year ice).

# Expected Outcomes and Influences

- The modelers will benefit by the invaluable data and scientific perspective obtained from this project. The observed data will help to improve the physical parameterizations of the state-of-the-art earth system model. First, in the perspective of atmospheric modeling, more realistic simulation of cloud-PBL interactions in the Arctic Ocean will be expected if it should help to improve the model's atmospheric processes.

- Undoubtedly this may be one of the most significance influences of this field observation project for atmospheric modeling. Second, in the perspective of ocean (including sea-ice) modeling, the physical processes at the ocean-ice interface influencing growth/ablation of the bottom of sea-ice will be more reasonably modeled if both the ice melting and freezing rates at the sea-ice bottom and the heat gain of ice from the upper ocean should be accurately quantified.

- Furthermore, ocean modelers will be able to improve the feedback processes involving the bio-geochemical effects that effectively control the upper ocean heat content. All of these prospective improvements of the earth system model components would eventually reduce uncertainty in the future projection of Arctic climate.

# Expected Outcomes and Influences

- A desired primary scientific outcome through these integrated efforts is an identification of the linkage between ASIA and AA synthesizing the processes from the ocean to the atmosphere.

- Both the scientific and technological advancement through this effort will encourage Korean scientists to join the international collaboration network for the Arctic researches.