PAG 2015 (Toyama, Japan)

Updates – atmosphere and sea ice researches

Joo-Hong Kim

Division of Climate Change, Korea Polar Research Institute

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KOPRI

Korea Polar Research Institute

Summary (2014 fall meeting, Seattle)

- For the topic of sea ice and atmosphere,
  - KOPRI will enhance meteorological observations and **cloud** observing instruments.
  - As a legacy of the MIZ program, KOPRI will continue to observe **floe-scale dynamic** sea ice deformation with an autonomous platform next year.
  - KOPRI atmospheric scientists will participate in **N-ICE2015** to study cloud, turbulence, sea ice energy balance, and atmospheric boundary layer.
  - KOPRI atmospheric scientists will aim to have an integrated platform to study **thermodynamic** sea ice – atmosphere interaction (& sea ice energy balance). (2016??~)

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On-board atmospheric observation

- **Basic meteorological variables**
  - pressure, temperature, wind speed & direction, and humidity

Radarmast (38m)
Short-wave radiometer (PSP)
Long-wave radiometer (PIR)
Temperature & RH (HMP45D)
Pressure sensor (PTB100)
Quantum sensor (LI-200)
Data logger (CR3000)
2D sonic anemometer

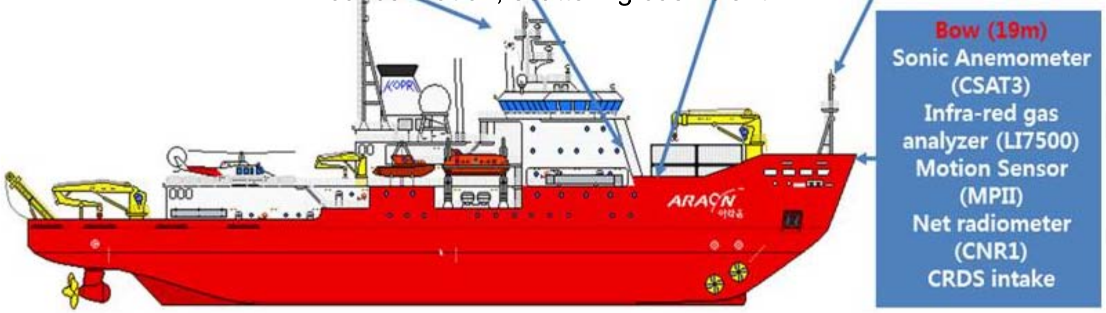
Atmospheric Sciences Lab. (03Deck)
CPC
Aethalometer
Nephelometer

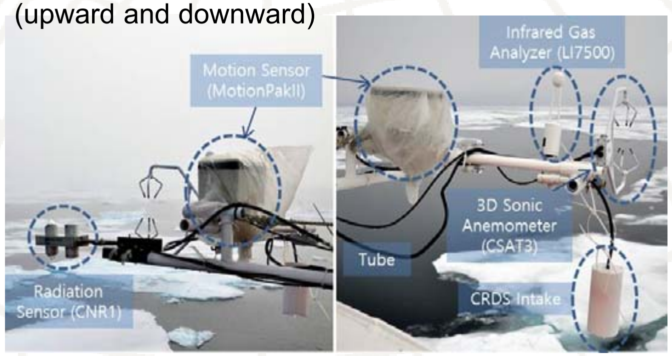
CRDS Shelter 02Deck (15m, Port)
CRDS (G2301-f)
Data logger (CR3000)
Motion Sensor (MPII)

Foremast (29.8m)
Windmill Anemometer (031050-L)

- **Aerosols properties**
  - condensation particle count, black carbon mass concentration, scattering coefficient

- **4-component radiations**
  - shortwave and longwave radiations (upward and downward)





* Heights in parenthesis are the distance of instruments from design load waterline (DLWL)

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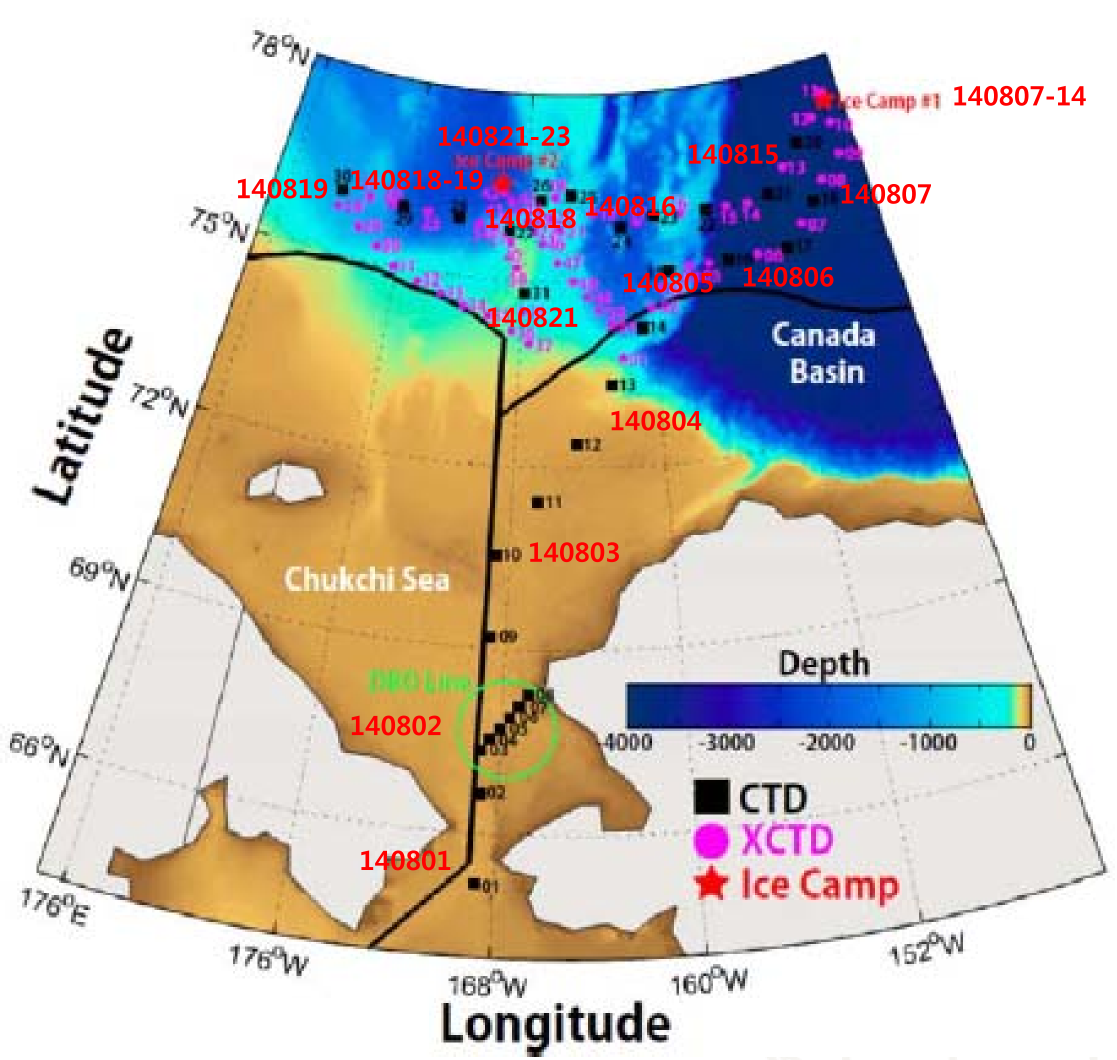
- **Eddy covariance system**
  - momentum, sensible heat, latent heat, and gas fluxes

2014 Araon Arctic cruise (Leg 1)

- 2014.07.30 ~ 2014.08.25



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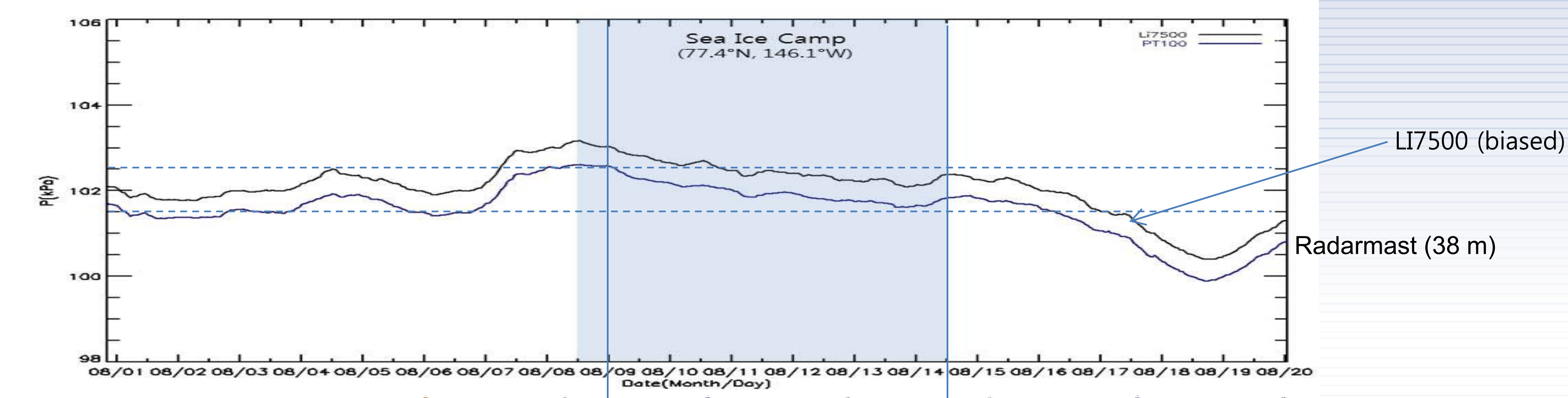
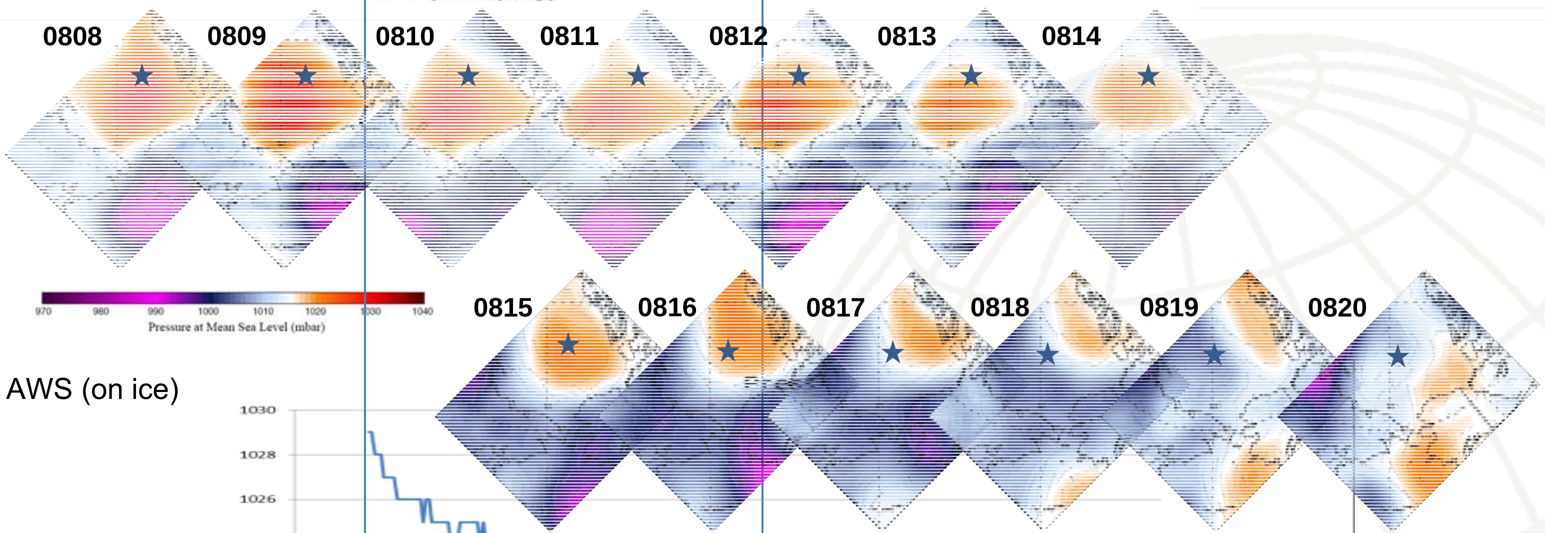
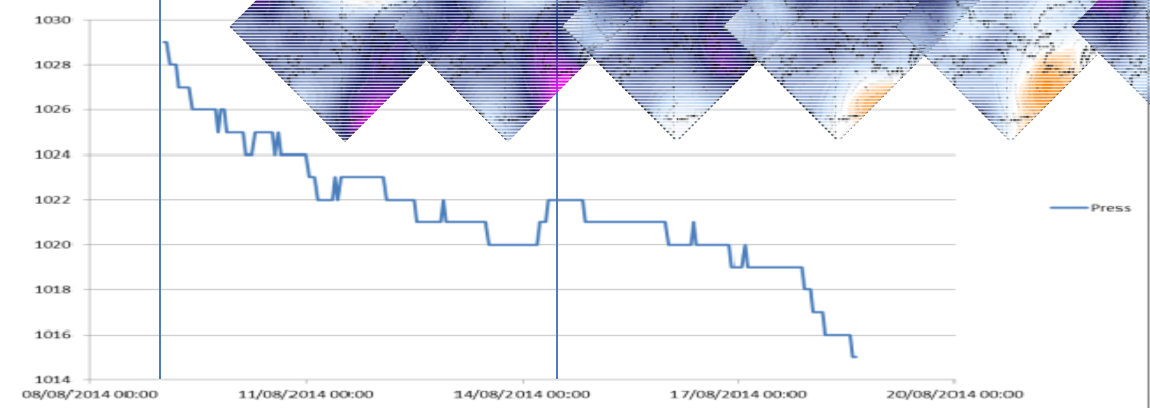
Meteorological Data (Air Pressure)



Reanalysis



AWS (on ice)



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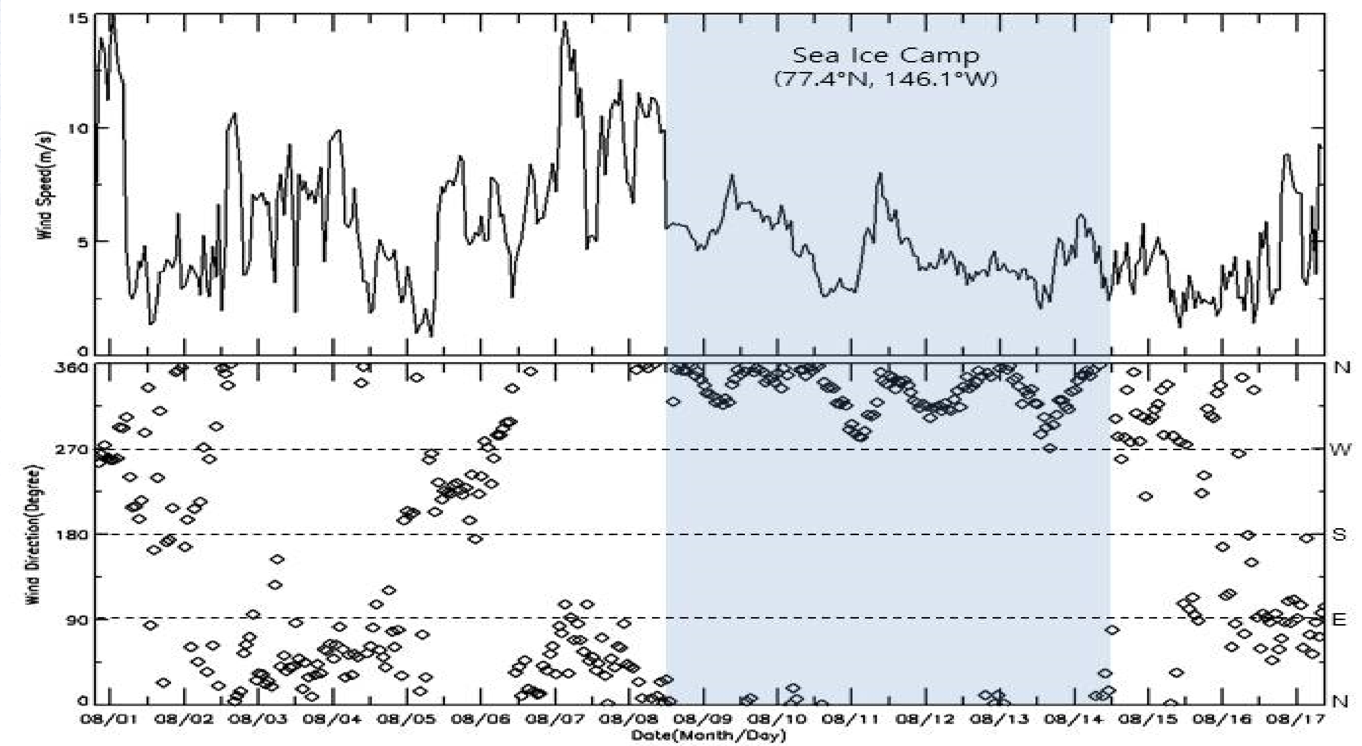
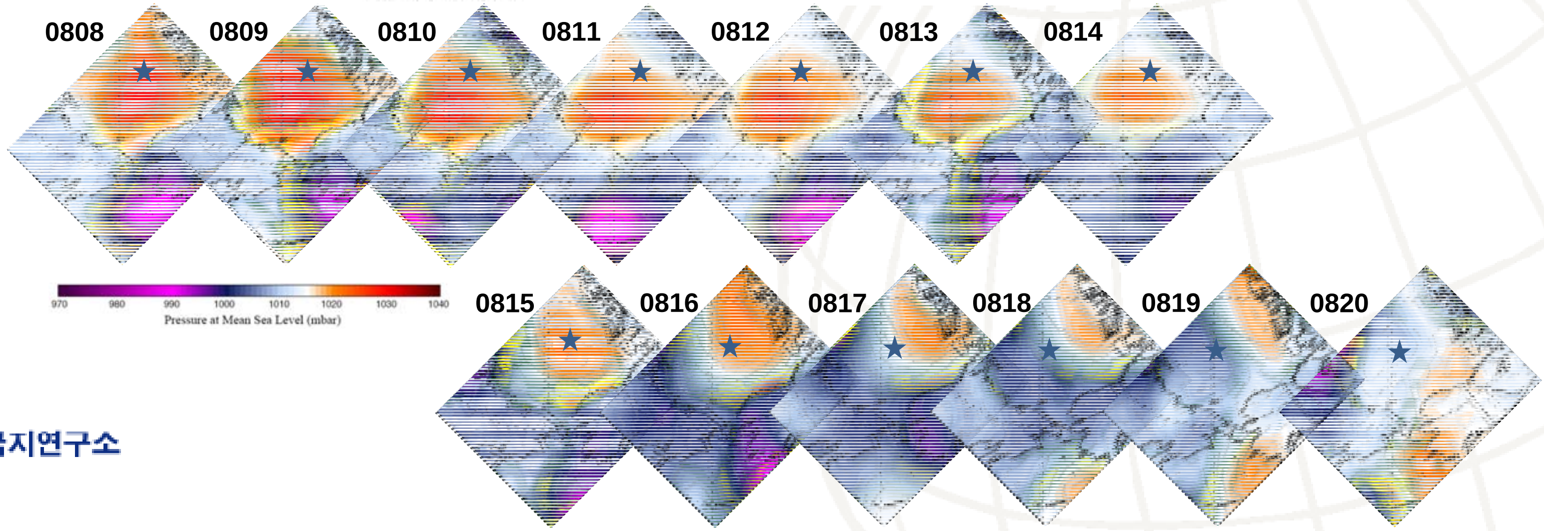
Meteorological Data (Wind)



Foremast (29.8 m)

Reanalysis



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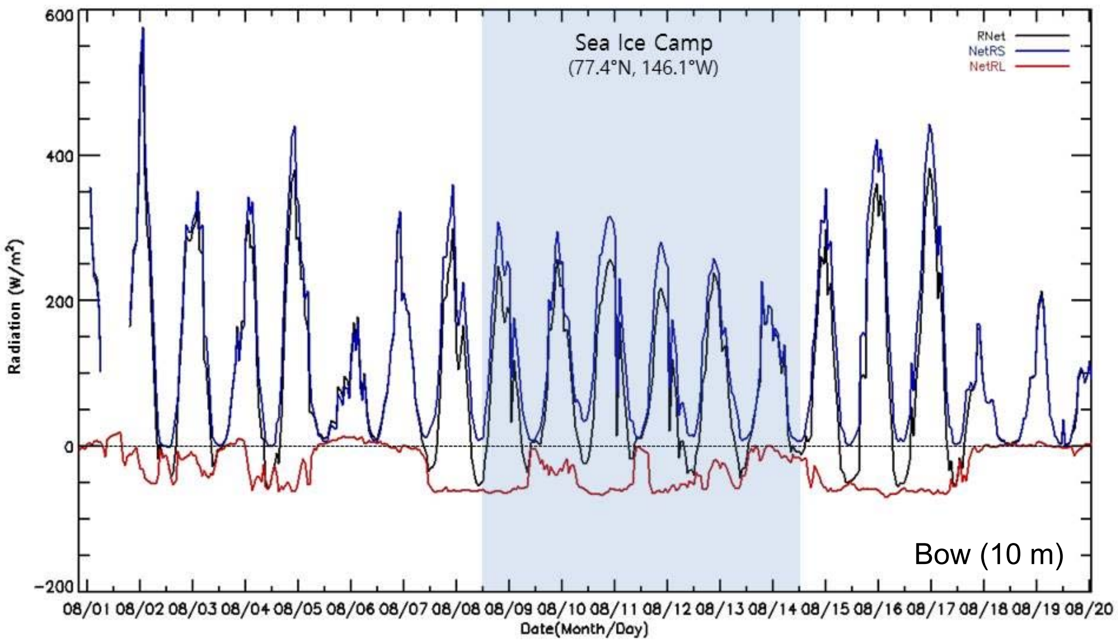
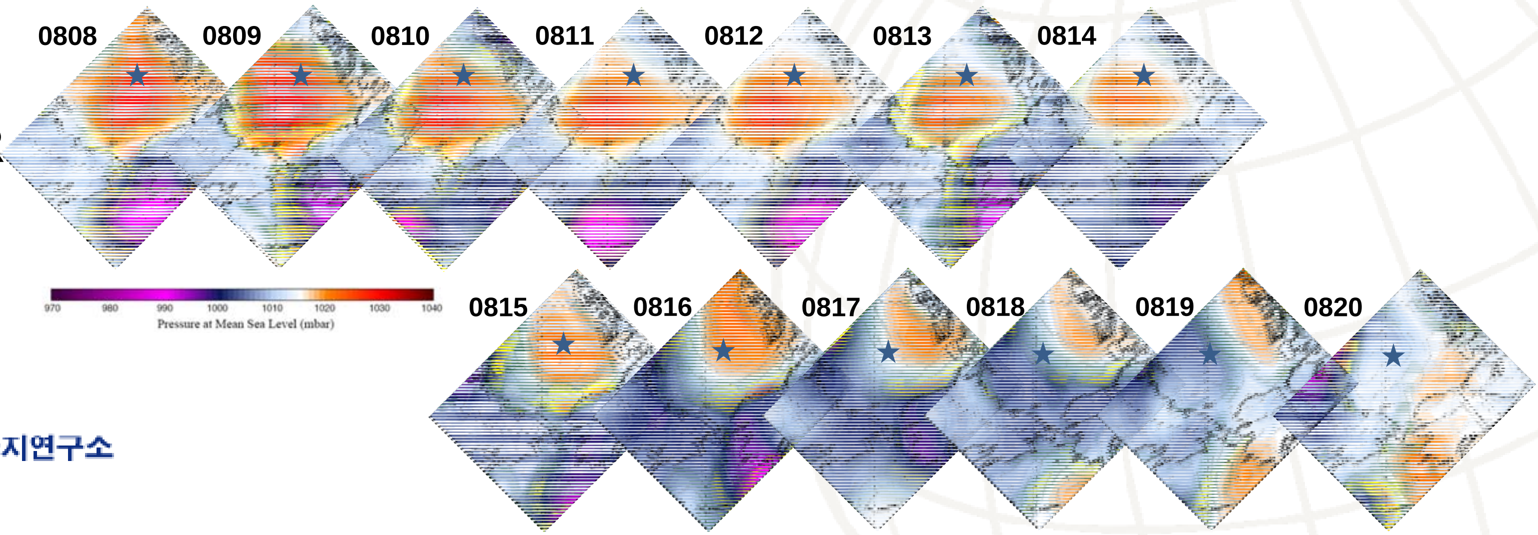
Meteorological Data (Net Radiation)



NCEP CFSR



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Enhanced atmospheric observations (vertical profiles & clouds)

- Basic meteorological variables
  - pressure, temperature, wind speed & direction, and humidity

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Short-wave radiometer (PSP)
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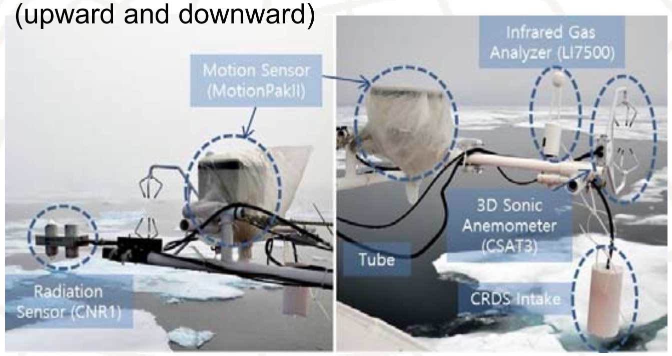

* Heights in parenthesis are the distance of instruments from design load waterline (DLWL)

- Eddy covariance system
  - momentum, sensible heat, latent heat, and gas fluxes

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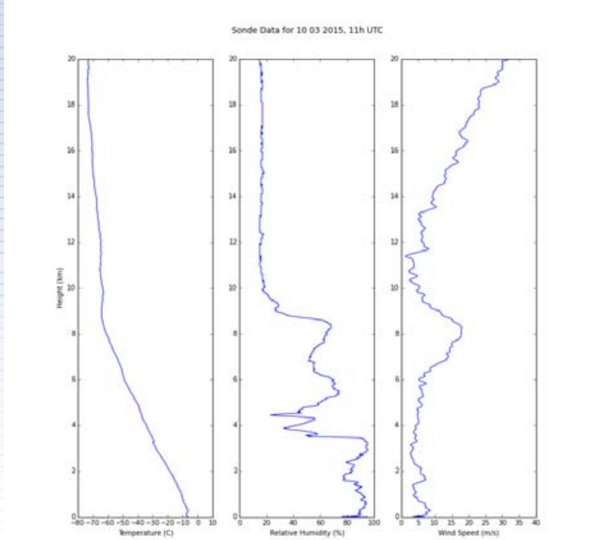
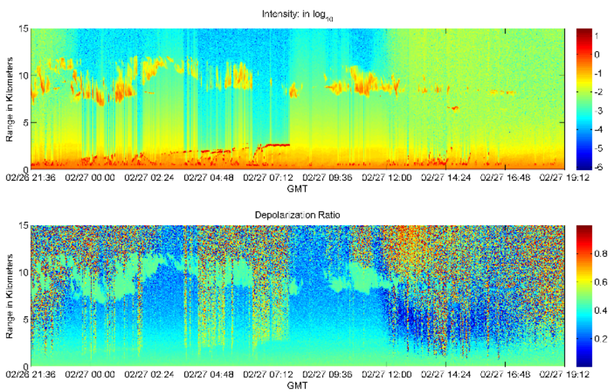
Added observations

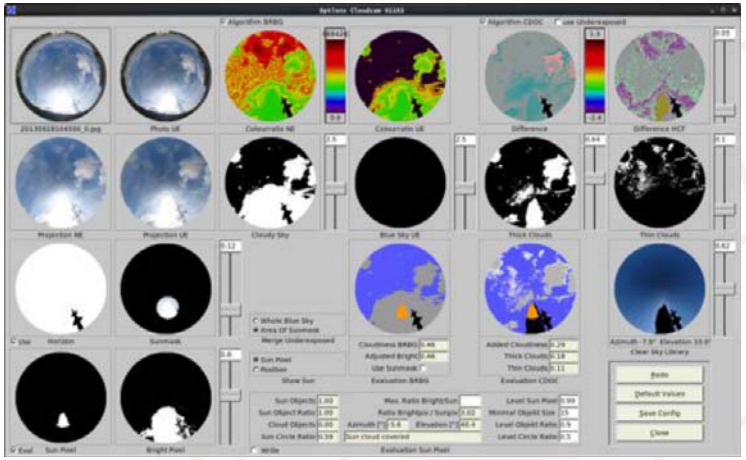
- Radiosonde



- Lidar (Laser Radar)



- All-sky camera



Why necessary?

- Thus far…
  - Only routine on-board surface observations along the ship track
  - No atmospheric field scientists mainly involved in the Pacific Arctic met observation

- In the coming years, under the auspices of PAG climate line…
  - Enhance on-board measurements of upper atmosphere & clouds
  - Participate in the internationally coordinated observation supportive of the YOPP initiative
  - Try a sea ice-based observing platform for the ice-atm-ocn interaction with scientific motivations and organized international collaboration (e.g., MOSAiC)

- Added observing components
  - **Atmospheric vertical profiles** to study characteristics of atmospheric stability, cloud, and moisture distribution under different synoptic backgrounds and to be used to evaluate numerical model predictability
  - **Clouds** (cover, height, optical thickness, etc.) as a key factor to control the surface radiative fluxes
    - Clouds can respond to the change in Arctic surface type (open ocean, marginal ice zone, ice surface, etc.)
    - Clouds can influence on the change in Arctic surface properties through radiative fluxes

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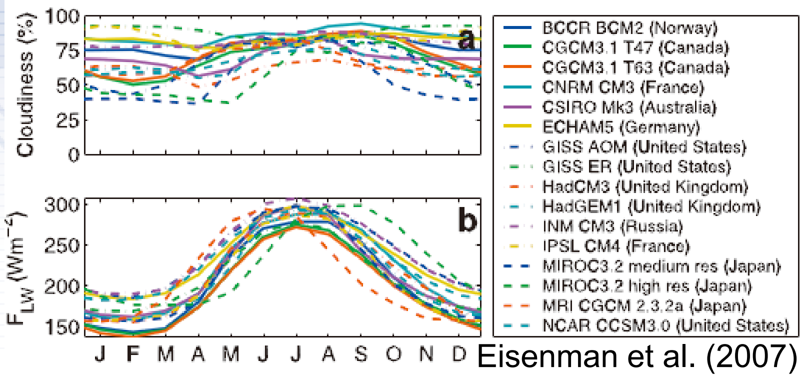
Clouds – Largest Atmospheric Source of Model Uncertainty

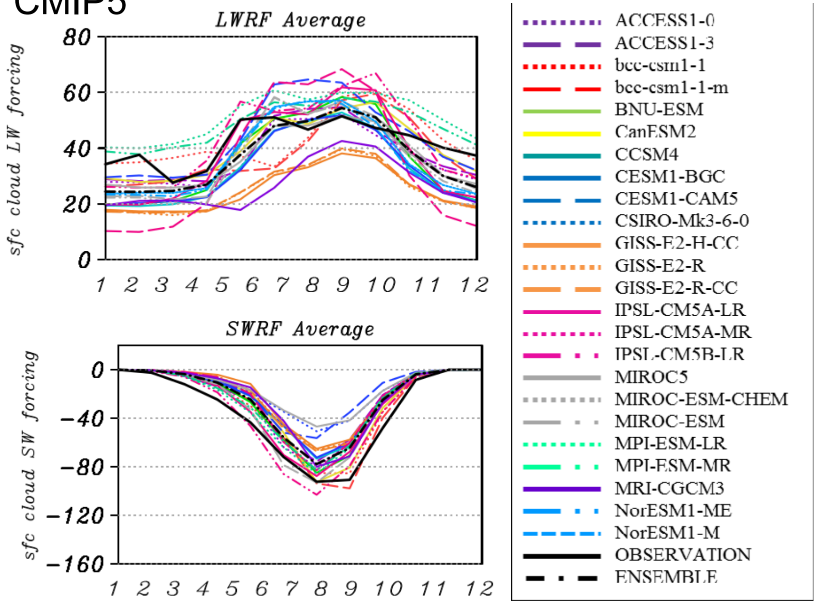
- Significantly influence the Arctic surface energy budget, thereby affecting sea ice

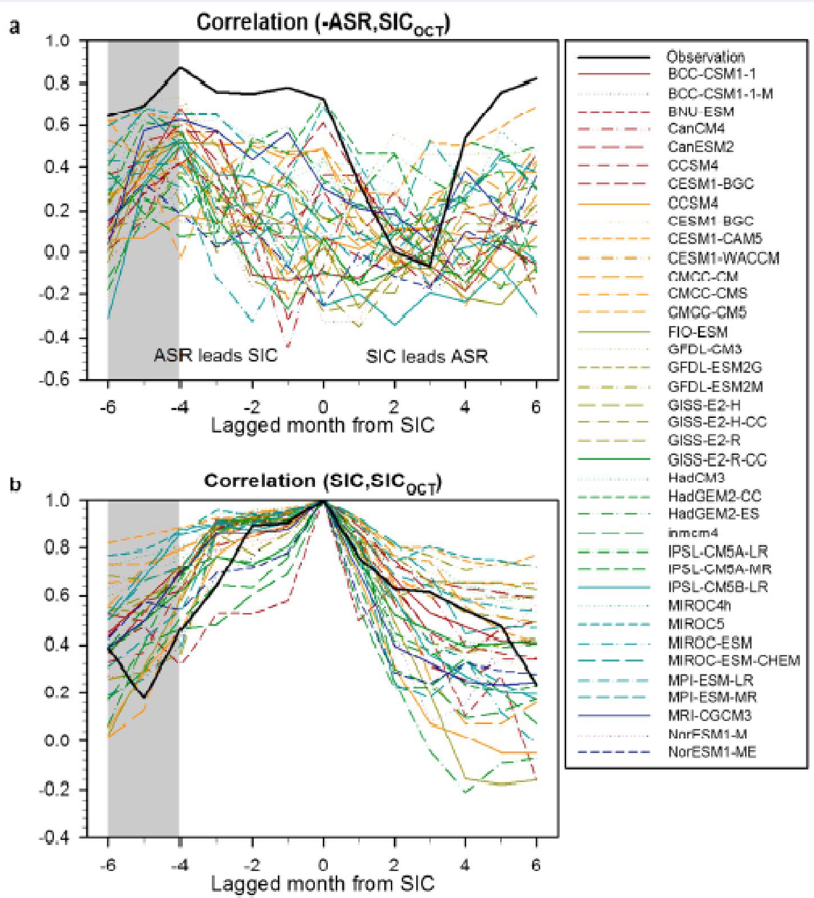
CMIP3



Eisenman et al. (2007)

CMIP5





Choi et al. (2014)

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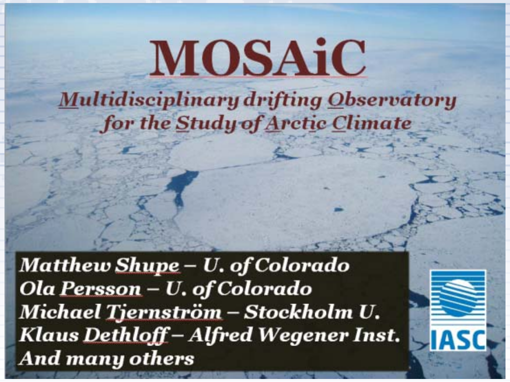
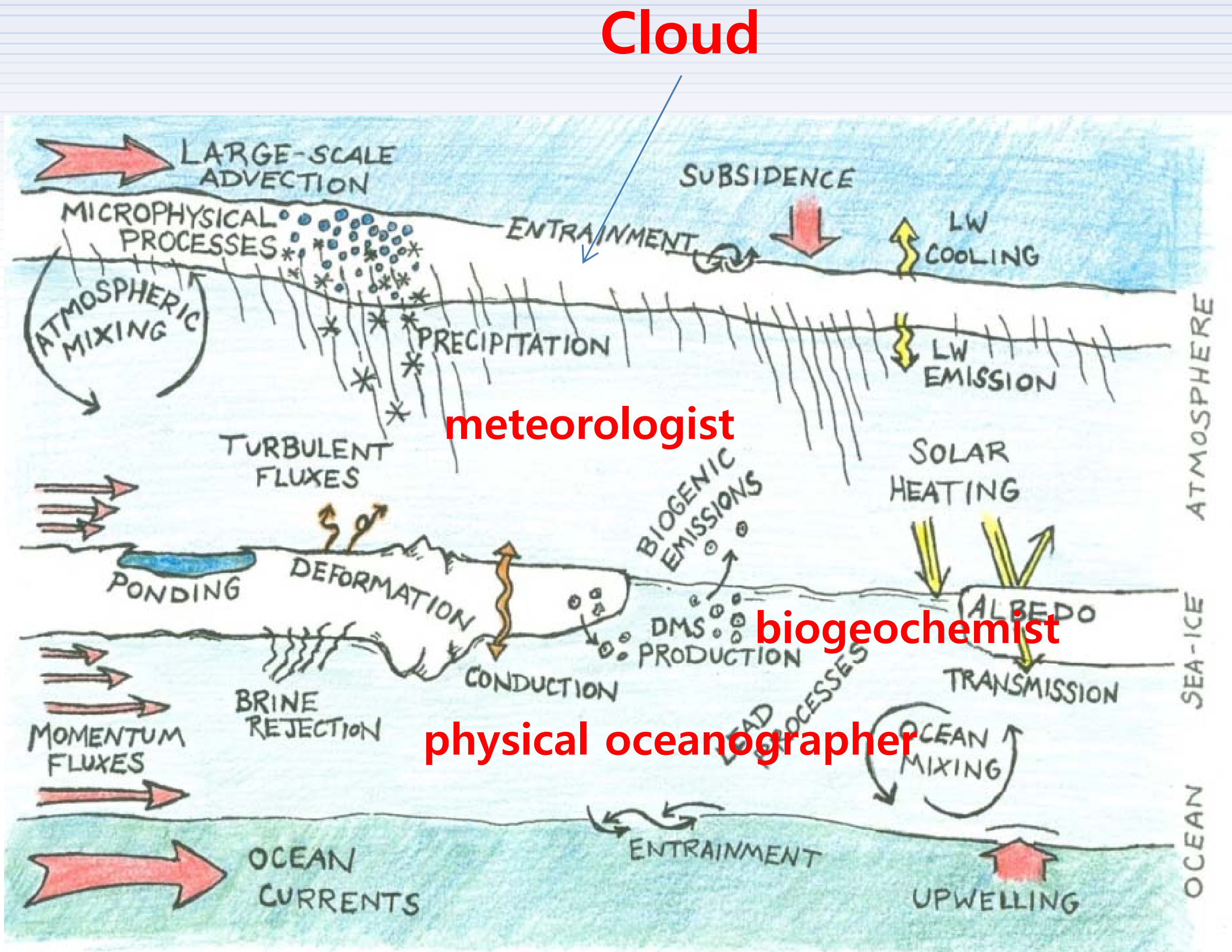
A cartoon from MOSAiC Introduction





Courtesy of Matt Shupe

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Results from satellite data provide us a nice motivation…

- Anomalies and trends in the downwelling **longwave radiation flux** have been implicated as important drivers of perennial sea ice loss [Francis and Hunter, 2006]
- …**Absorbed solar radiation** in early summer plays a precursory role in determining the Artic sea ice concentration in late summer [Choi et al., 2014]
- …Small changes in the cloud-radiative forcing fields can play a significant role as a climate feedback mechanism [Ramanathan et al., 1989]

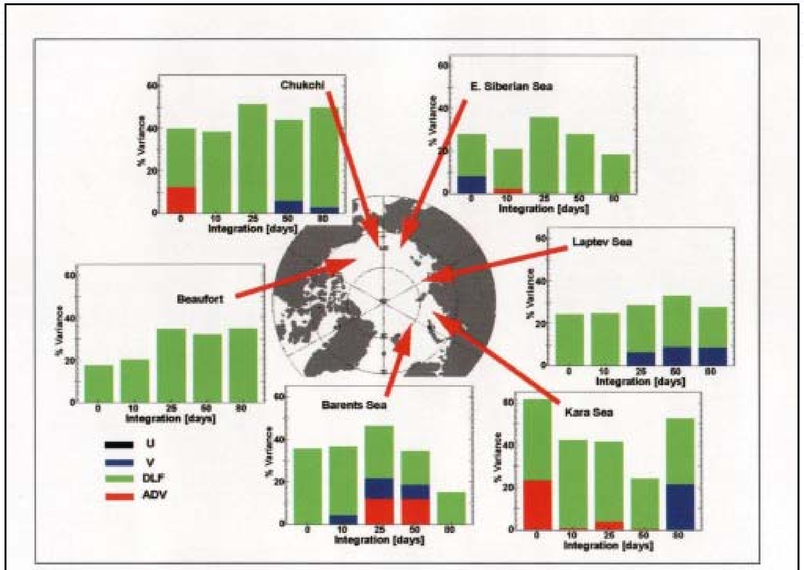

Fig. 2. Histograms exhibiting the total variance in the perennial ice edge attributable to anomalies in forcing parameters, integrated backward in time from the date of maximum ice retreat. Colors denote the portion contributed by each forcing parameter.

Francis and Hunter (2006)

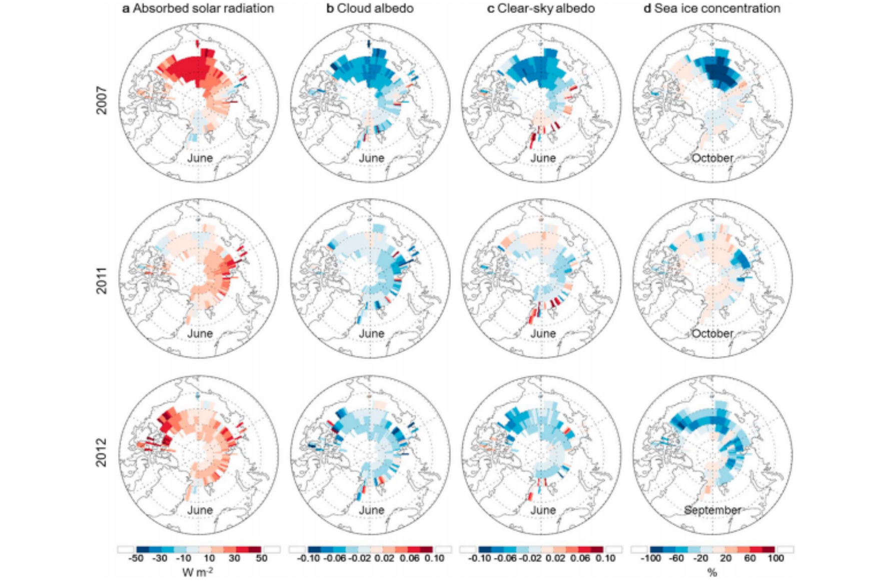

Figure 1. Regional distribution of the anomalies of (a) absorbed solar radiation (ASR), (b) the cloud albedo, and (c) the clear-sky albedo, all for June 2007, 2011, and 2012, and (d) sea ice concentration (SIC) for October 2007 and 2011 and September 2012. In these years, record-breaking minimal SIC was observed. Note that these figures do not include the regions where total SIC for August, September, and October were less than 15% or the regions with permanent SIC throughout the year.

Choi et al. (2014)

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Change in cloud - sea ice relationship?

Surface Cloud Radiative Forcing (SCRF)

$$SCRF = NetSW\_CRF + NetLW\_CRF$$
$$= (NetSW - NetSW_{cs}) + (NetLW - NetLW_{cs})$$

⇩ After some manipulation

$$= (SW\downarrow - SW_{cs}\downarrow)\cdot\cancel{(1-\alpha)} + (LW\downarrow - LW_{cs}\downarrow)$$

[Ramanathan et al., 1989]

Surface SW Cloud Rad. Forcing
= Cloud shield ~~& Surface albedo effects~~ (Cooling)
Always negative

Surface LW Cloud Rad. Forcing
= Greenhouse effect (Warming)
Always positive

- ❖ Surface SW CRF ↓ ➡ Cloud shield effect↑, ~~Surface albedo effect↓~~
- ❖ Surface LW CRF ↑ ➡ Cloud shield effect↑

Caution: For SW, ↓ indicates more negative (i.e., the increase of absolute value)

$SW\downarrow$: Surface downwelling shortwave radiation [W/m^2]
$SW_{cs}\downarrow$: Clear-sky surface downwelling shortwave radiation [W/m^2]
$LW\downarrow$: Surface downwelling longwave radiation [W/m^2]
$LW_{cs}\downarrow$: Clear-sky surface downwelling longwave radiation [W/m^2]
α : Surface albedo

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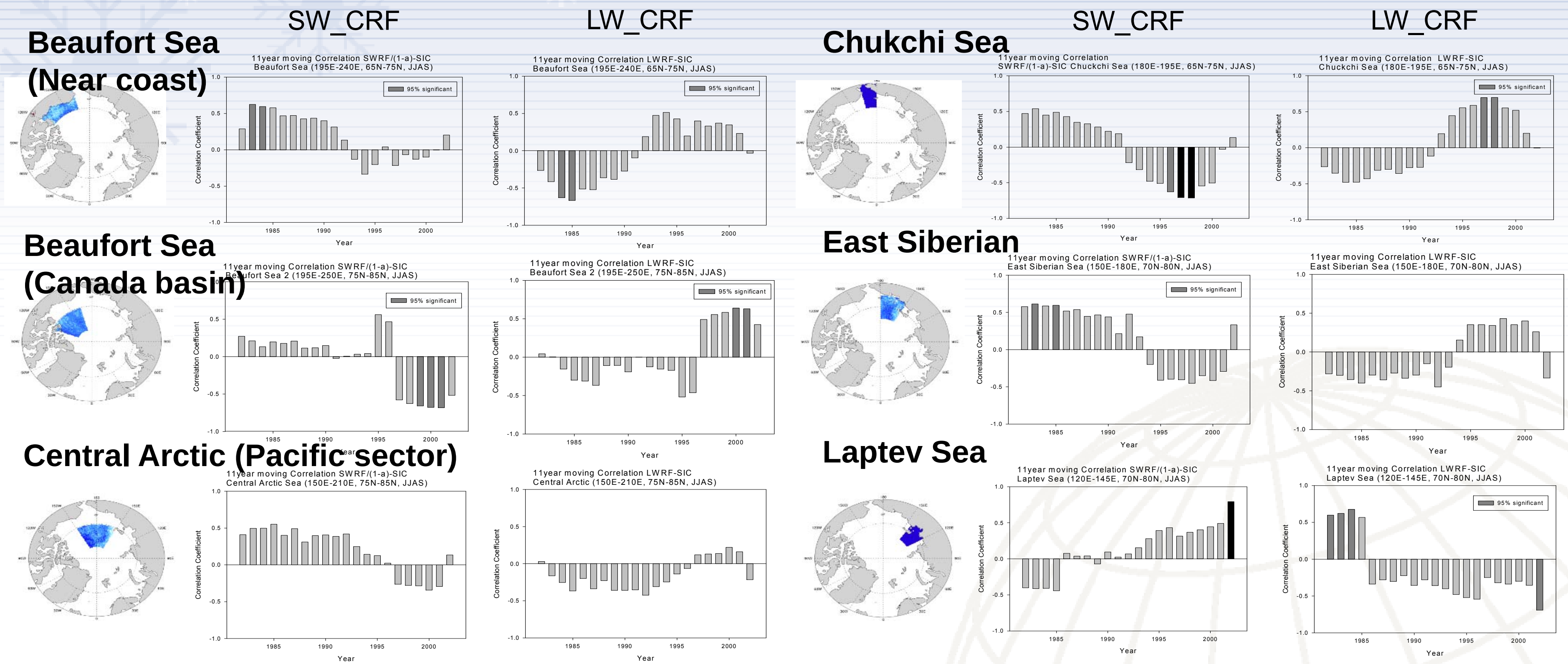
11-yr running cor. (CRF & SIC) 1982-2012 JJAS



- The relationship between sea ice concentration (SIC) and cloud radiative forcing (CRF) show large decadal changes
- Possible attributing factors: clouds response to the changing surface condition (from ice-covered to ocean), large-scale circulation and ice drift

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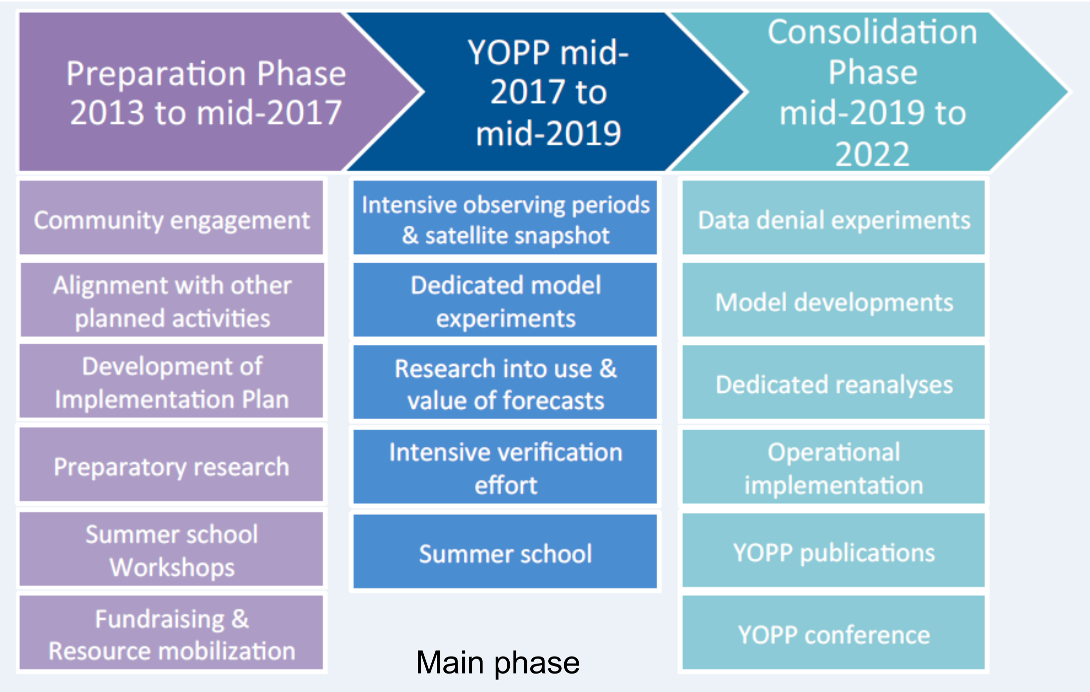
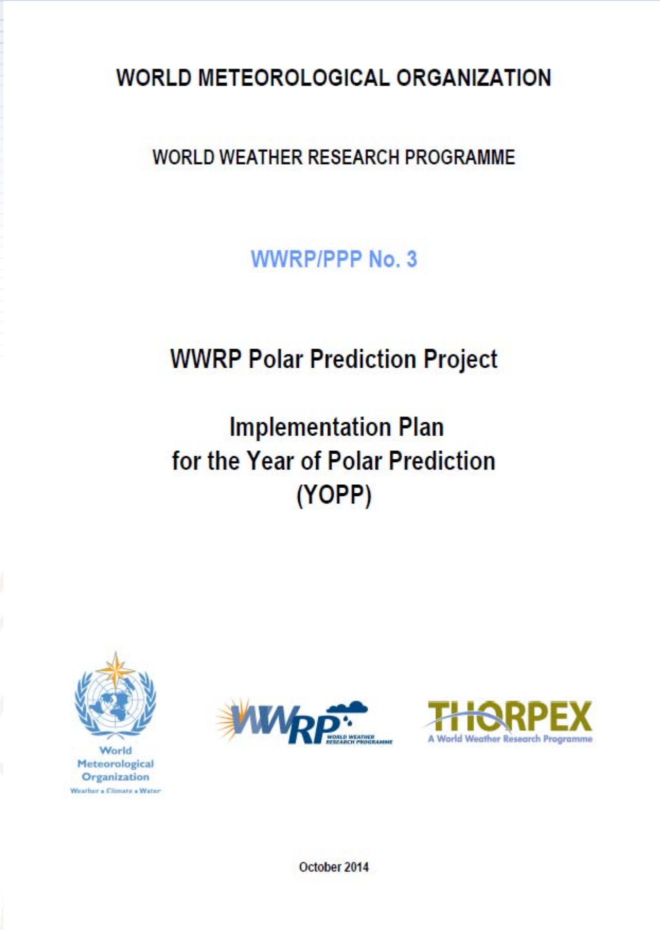
YOPP (Year of Polar Prediction)

- **An extended period of coordinated intensive observational and modelling activities**, in order to improve prediction capabilities for the polar regions and beyond, on a wide range of time scales from hours to seasons
- A key element of the WWRP-PPP





WORLD METEOROLOGICAL ORGANIZATION

WORLD WEATHER RESEARCH PROGRAMME

WWRP/PPP No. 3

WWRP Polar Prediction Project

Implementation Plan
for the Year of Polar Prediction
(YOPP)

October 2014

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Observational support

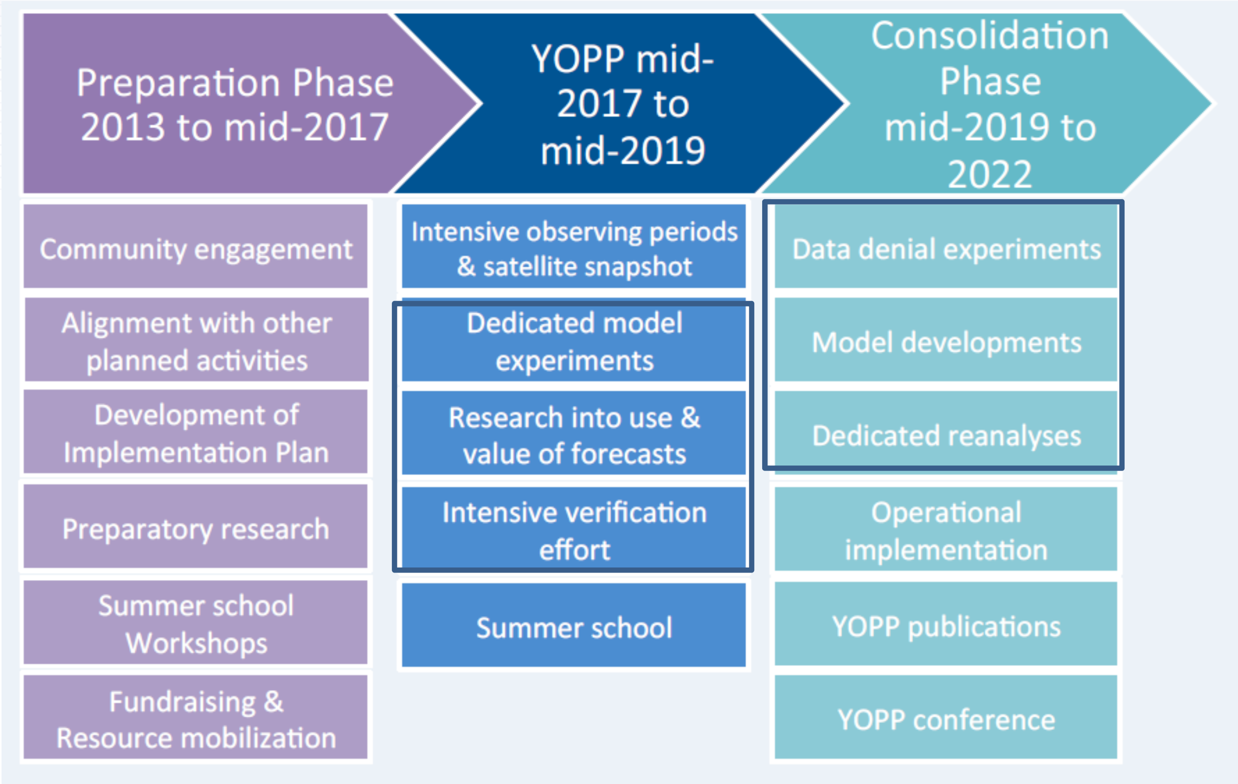
- ARAON-based
  - Met observation and radiosonde sounding for Arctic summer
  - Met observation and radiosonde sounding for Antarctic summer at Ross Sea and/or Amundsen Sea
  - Ice-tethered buoys in the Arctic

- Arctic land-based
  - Dasan station: N/A (Met data from Norway and German stations including T, q profile)
  - Svalbard (Hopen?) site: U,T,Q profile (wind lidar and MW radiometer) since 2017 summer? + additional sounding?
  - Russian (Baranova?) site: support AARI frequent sounding? (limited period 2017, 2018?)

- Antarctic land-based
  - Sejong station: radiosonde sounding (2018?)
  - Jangbogo station: frequent radiosonde sounding (2018?)

Modeling support

- Impact of the intense observation data on the predictability
- Analyses of model performance in various aspects (cloud, ABL, sea ice etc.)



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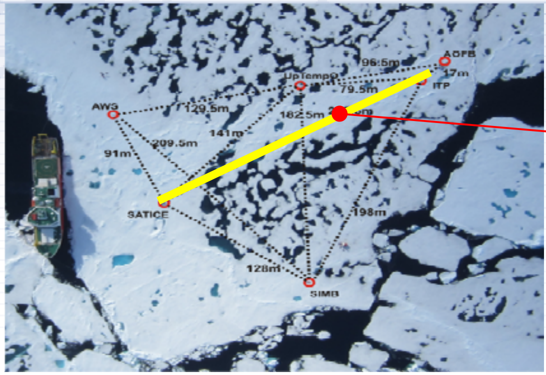
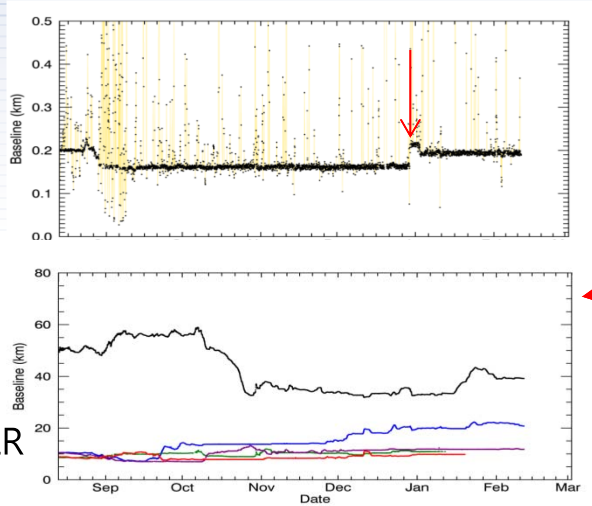
Sea ice dynamics – effects of scales on deformation

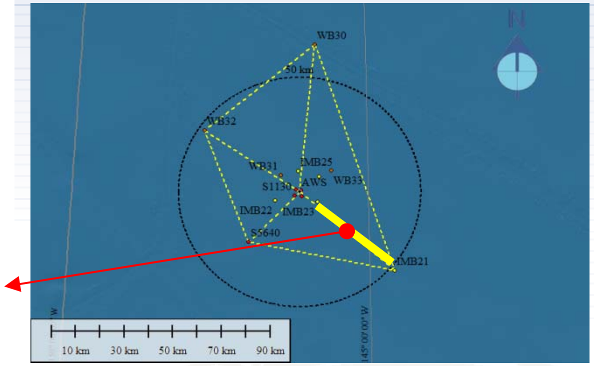
Phil Hwang, SAMS, Pedro Elosegui, ICM-CSIC/MIT, Jeremy Wilkinson, BAS

Small scale (< 1km) deformation

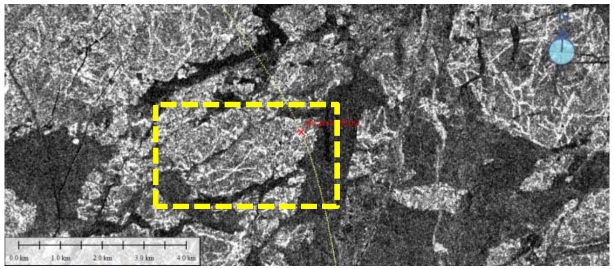
Large scale (> 1km) deformation



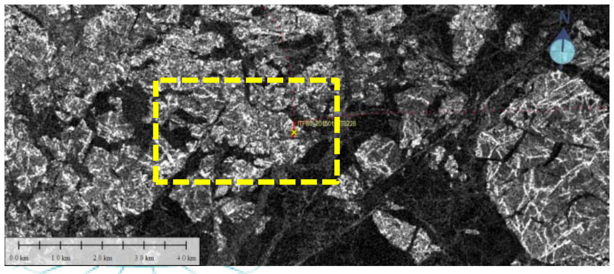




TerraSAR-X image 28/Nov/2014 ©DLR



TerraSAR-X image 20/Jan/2015 ©DLR



Early January the buoys deployed on the floe detected “displacement” (see red arrow above), indicating deformation of the floe. SAR images taken across this period show significant deformation of the floe (see yellow rectangles in the images on the right).

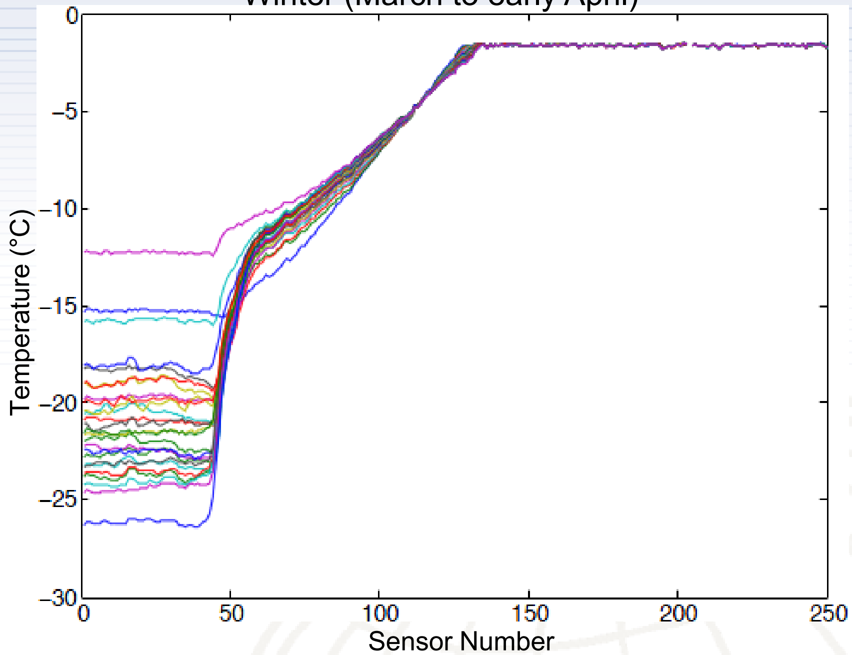
- ***How atmospheric forcing is related to sea ice deformation at different scales?***
- ***What is the spatial and temporal correlation across the scale?***
- ***Can we parameterize ice deformation across the scale?***

Sea ice thermodynamics

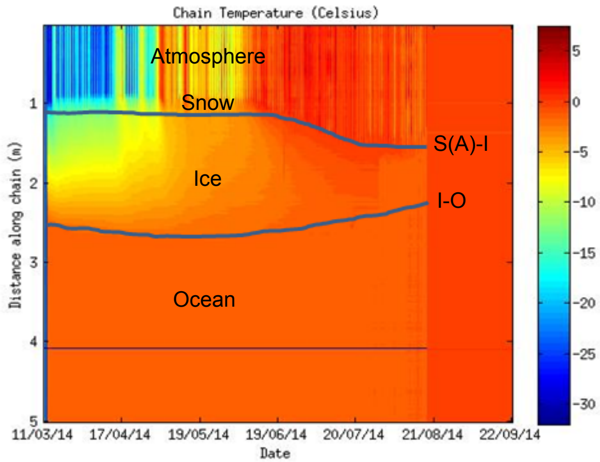
- Collected 24 IMB data (from Jeremy Wilkinson, BAS) during the MIZ campaign

Sea ice Mass Balance Buoy

Winter (March to early April)



Temperature profile (MIZ_IMB04)



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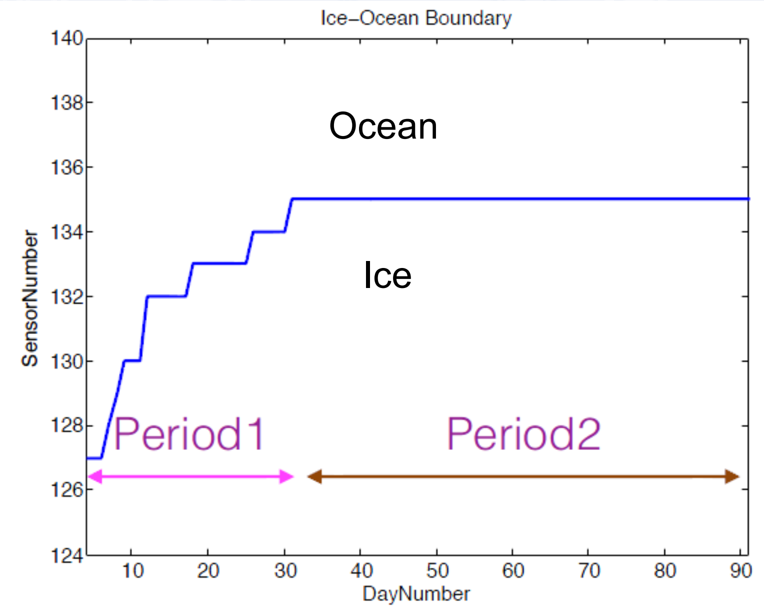
Scale of oceanic turbulent heat flux



Boundary condition at ice-ocean boundary

$$F_W - k(T,S)\frac{\partial T}{\partial z} = \rho_i L_i \frac{dh}{dt}$$

$$\left[\rho_i L_i \frac{dh}{dt}\right] \sim \left[k\frac{\partial T}{\partial z}\right]$$

Assume that the conductive heat flux is in same order with the phase change on the boundary

$$\Delta t \sim \frac{\rho_i L_i \Delta h \Delta z}{k \Delta T} = \frac{2.97 \times 10^5 \times 917 \times 0.1 \times 1.0}{2.04 \times 15} \simeq 10 days$$

Considering the resolution of the sensors (2cm), roughly I assume that we need to see the reasonable amount of change (0.1m) to deduce the boundary movement.

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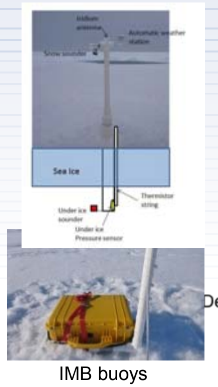
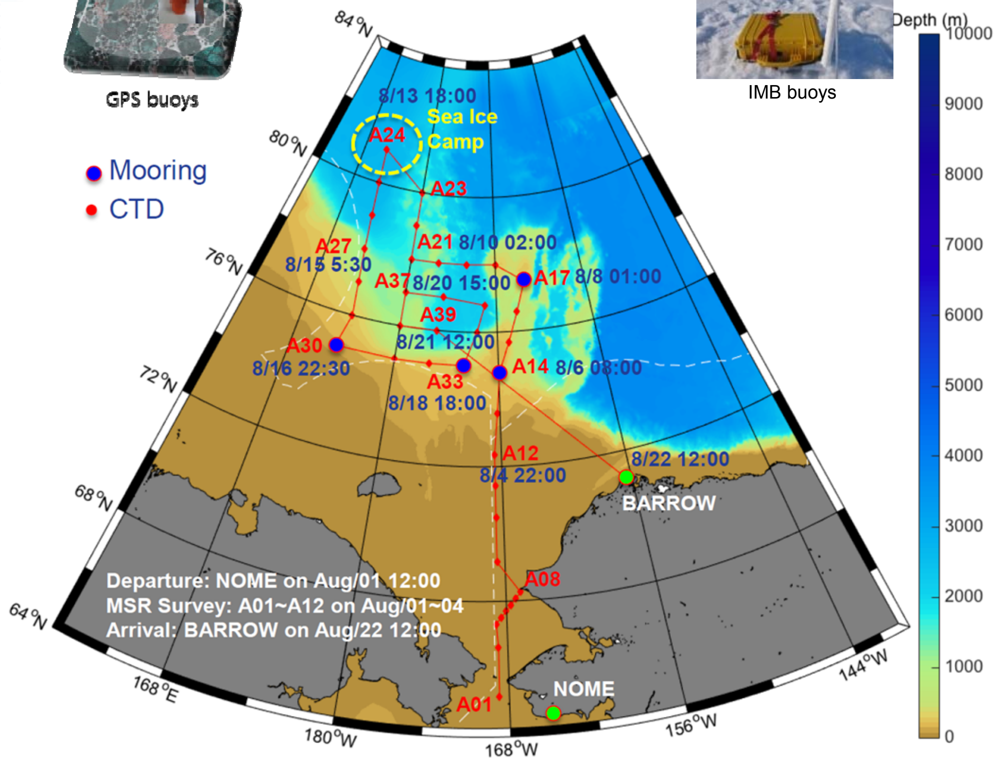
Upcoming 2015 summer cruise

- Q: How atmospheric forcing is related to sea ice deformation at different scales?



- 10 KOPRI GPS
- 1 KOPRI IMB



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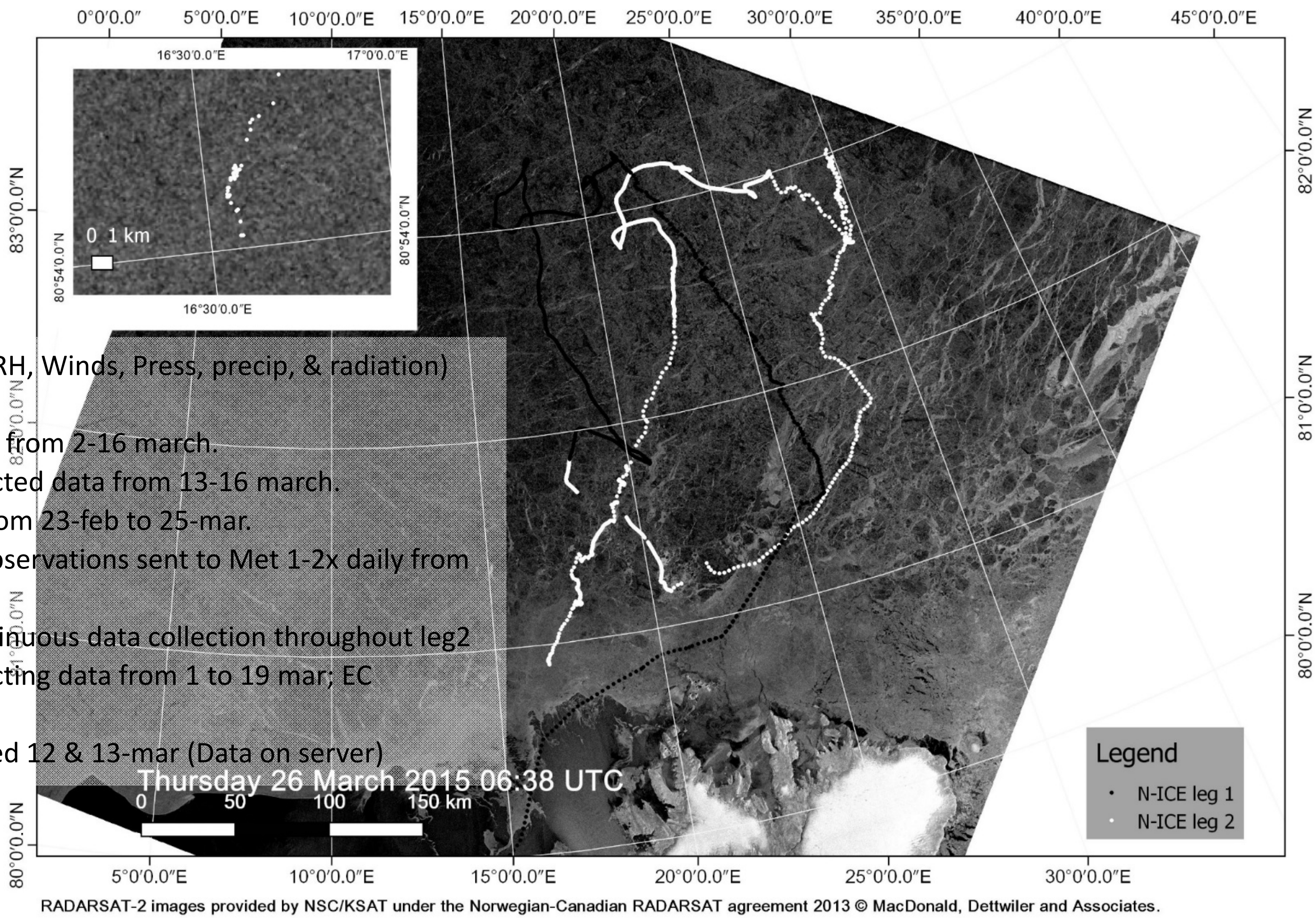
Norwegian young sea ice cruise 2015 (N-ICE2015)

- Period: January to June 2015
  - Norwegian RV Lance
  - leg 1 (early January to mid-February, 2) and 2 (mid-February to late March, 2)



- ✓ Weather station data (T, RH, Winds, Press, precip, & radiation) collected 2-15 march.
- ✓ EC system collecting data from 2-16 march.
- ✓ EC methane sensor collected data from 13-16 march.
- ✓ Radiosondes—2x daily from 23-feb to 25-mar.
- ✓ SYNOP meteorological observations sent to Met 1-2x daily from 25-feb to 24-mar.
- ✓ MPL and ceilometer continuous data collection throughout leg2
- ✓ KOPRI profiler & EC collecting data from 1 to 19 mar; EC relocated on 9-march
- ✓ Tethered sonde performed 12 & 13-mar (Data on server)

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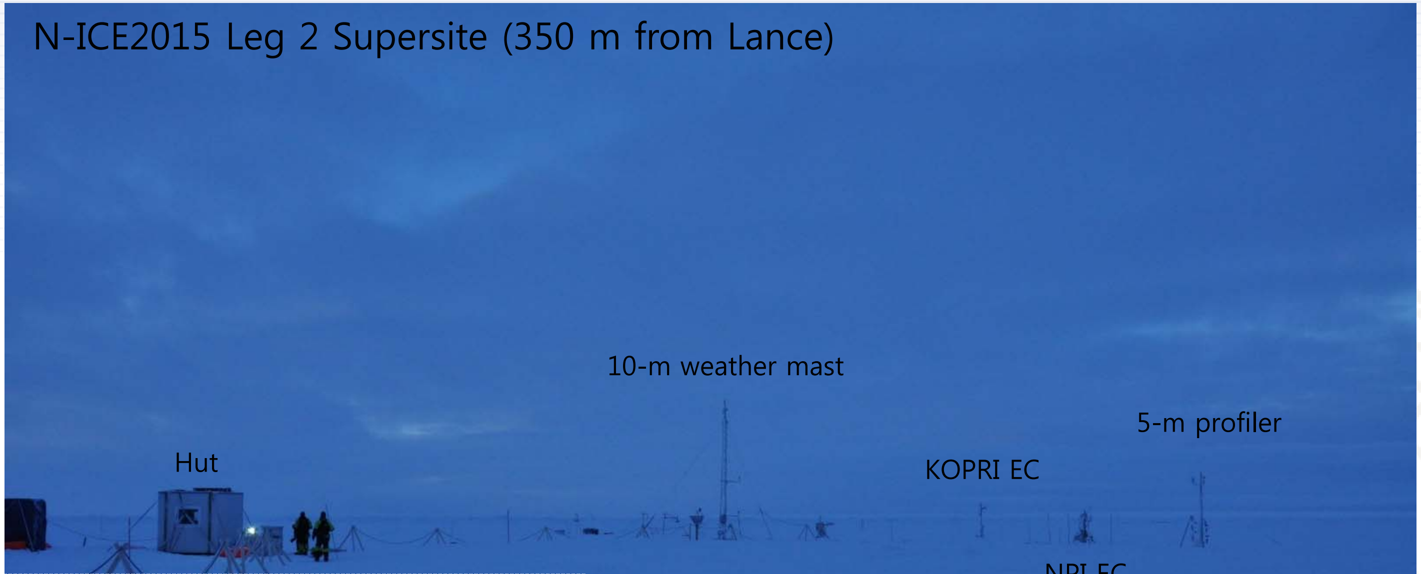

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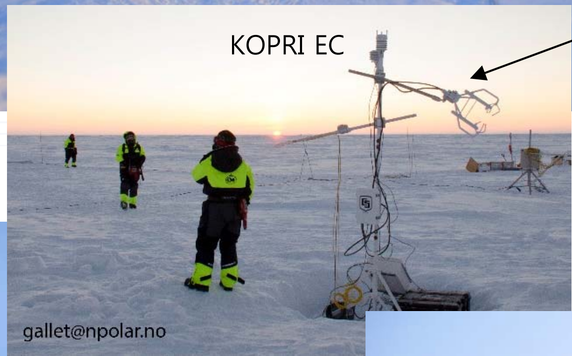
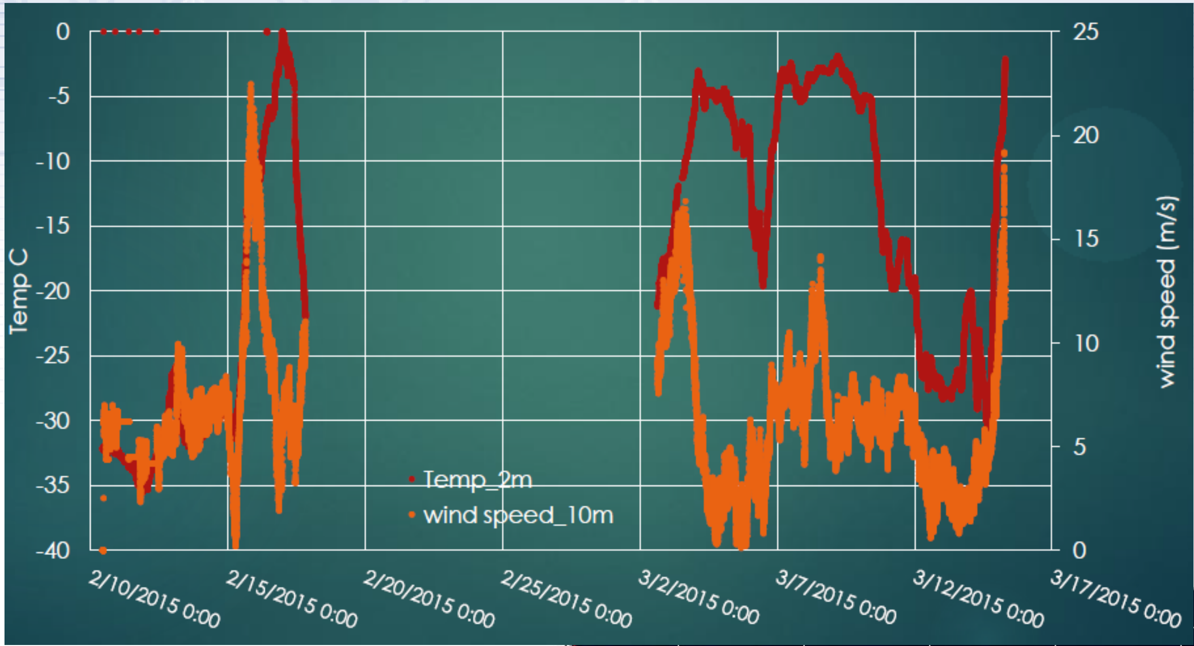
Painful outdoor labor, polar beak attack, but lots of fun

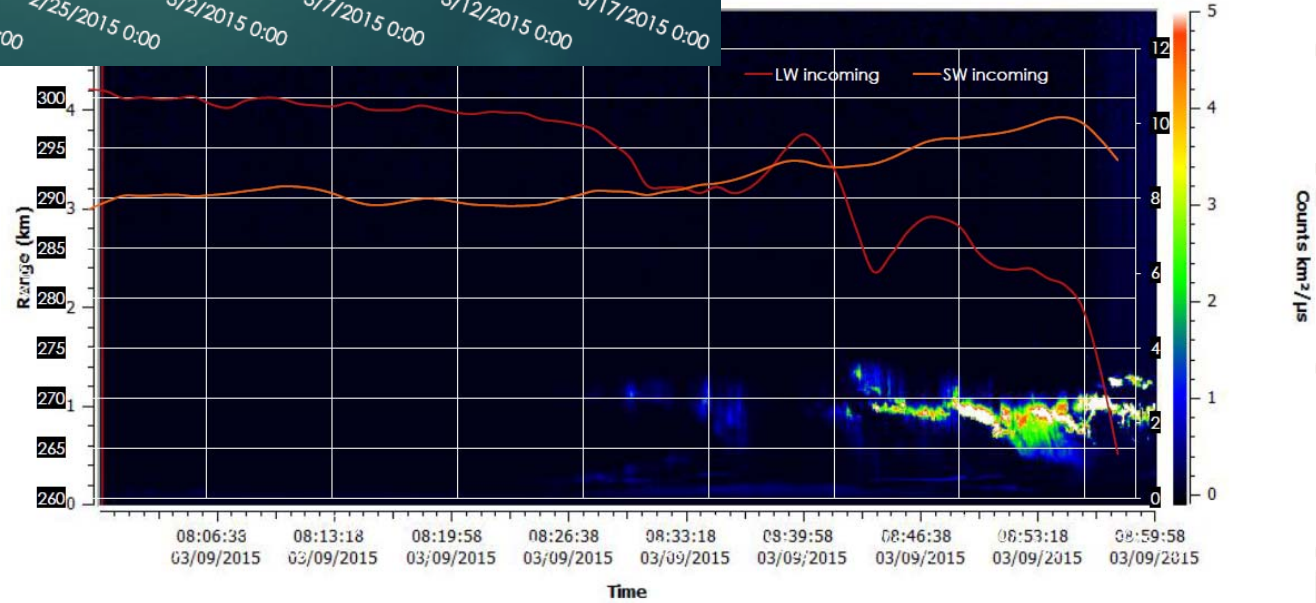


Some preliminary results

Temperature and Wind Speed



Radiation and Clouds



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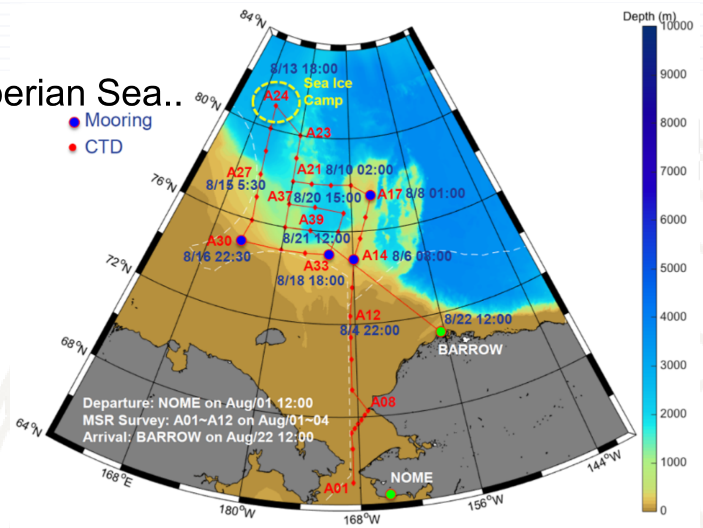
Summary

- For the topic of sea ice and atmosphere,
  - KOPRI will enhance meteorological observations and **cloud** observing instruments.
  - KOPRI will continue to observe **floe-scale dynamic** sea ice deformation with an autonomous platform next year.
    - GPS and IMB buoys will be deployed north of East Siberian Sea..



  - KOPRI ~~atmospheric~~ and oceanic physical scientists will aim to have an integrated platform to study **thermodynamic** sea ice – atmosphere – ocean interaction (& sea ice energy balance). (2016??~)

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