Observed Changes in Surface Conditions of the Arctic Ocean

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US Interagency Arctic Buoy Program (USIABP)

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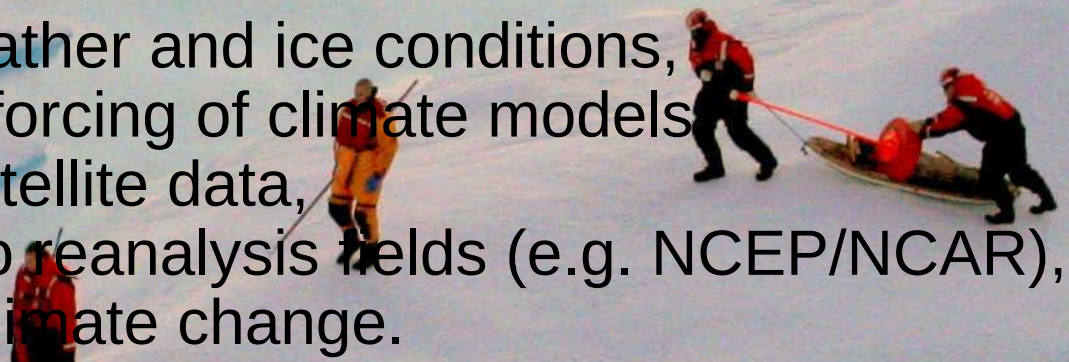
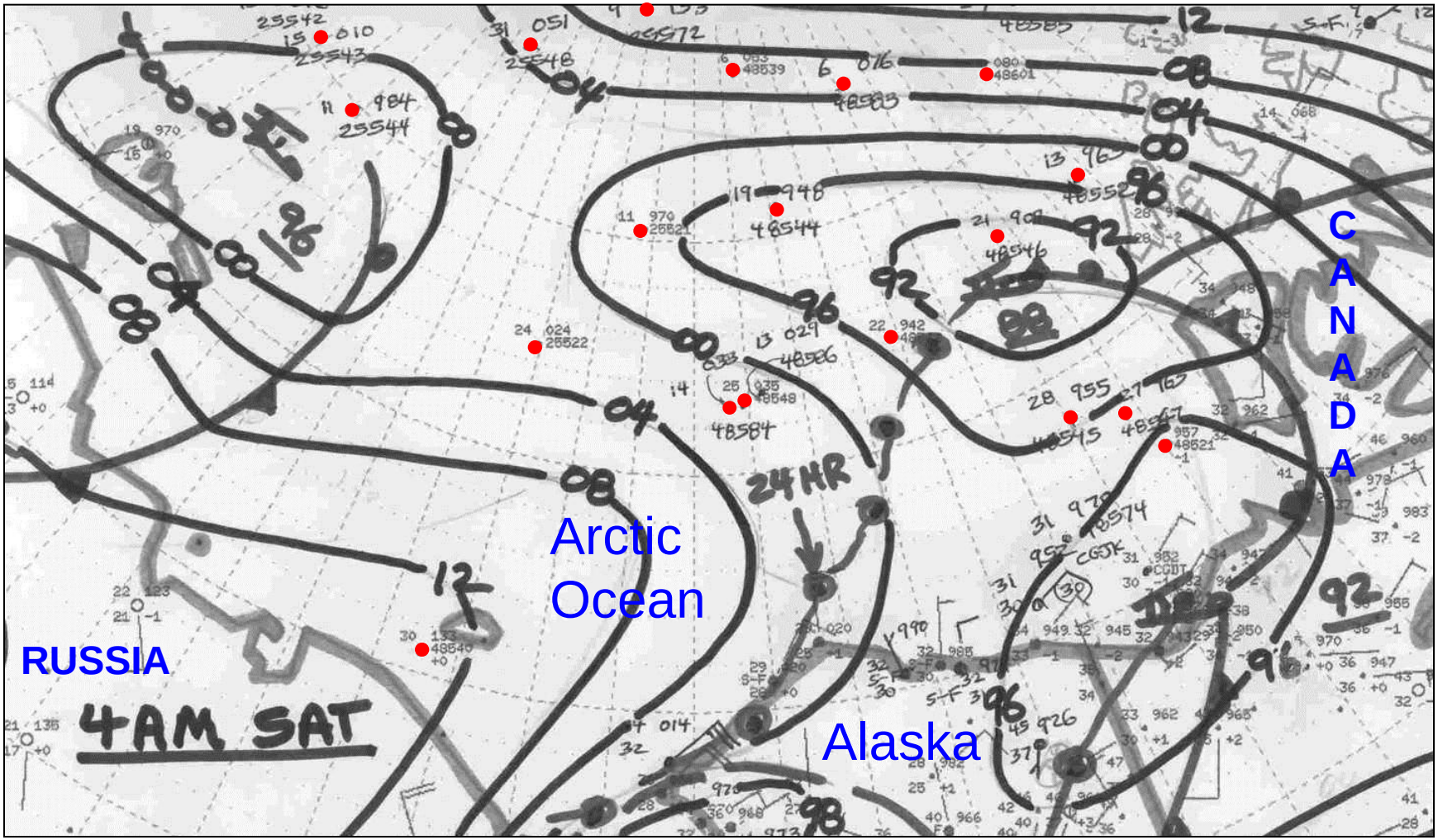
Ignatius Rigor & Mark Ortmeyer (PSC/APL/UW),

- **Goal:** Observe air, sea and ice using drifting buoys.
- **USIABP coordinates US contributions to the International Arctic Buoy Programme (IABP),** which has 34 Participants from 10 different countries, including the WCRP and EUMETNET.
- **Observations are used for both operations (WMO GTS) and research.**
  - forecasting weather and ice conditions,
  - validation and forcing of climate models,
  - validation of satellite data,
  - assimilated into reanalysis fields (e.g. NCEP/NCAR), and
  - for studies of climate change.
- **Data are archived** at MEDS, WDC-A (NSIDC), CADIS, etc.
- **Contributors to USIABP:** IARC, NASA, NIC, NOAA (ARO, NESDIS, OCO), NSF, Navy (NAVO, NRL, ONR), USCG.



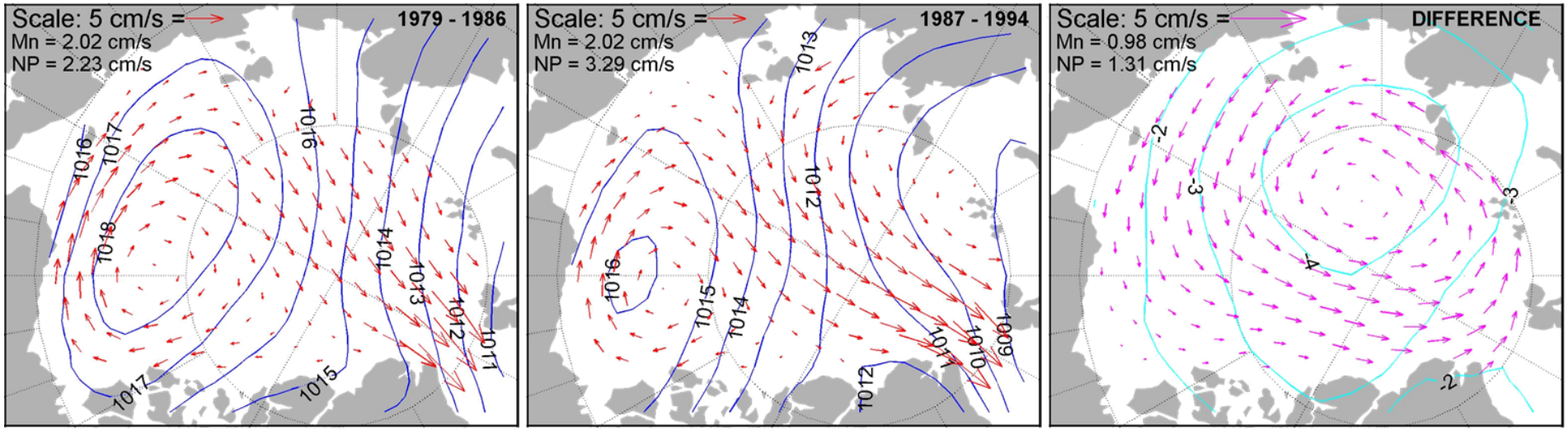
Forecasting Weather



The observations (red dots) from the IABP are essential for analyzing and forecasting weather features in the Arctic. In this example, we show storm approaching Alaska from the Arctic Ocean. The IABP observations are essential in detecting and determining the strength and intensity of storms from the Arctic Ocean.

(Courtesy of Rick Stevens, NWS, AK)

Changes in Atmospheric Circulation 1979 - 1994

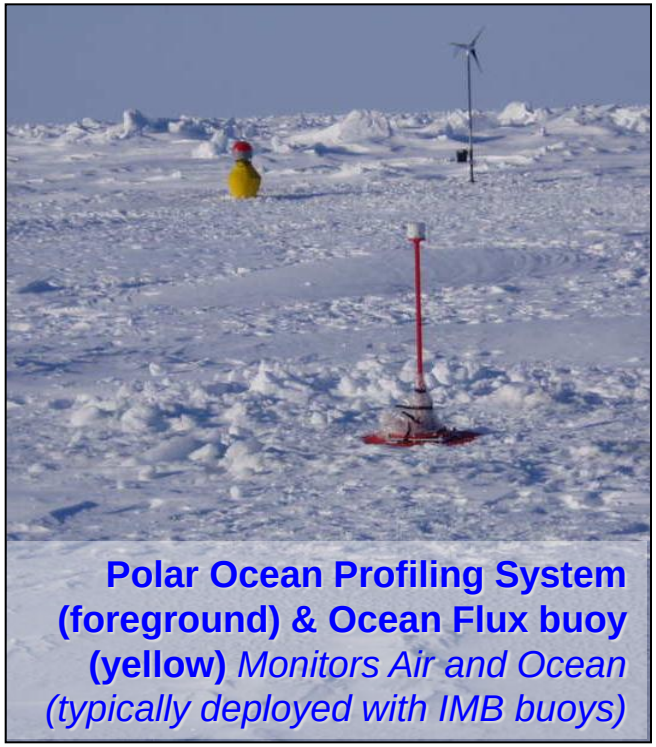


Using the IABP Sea Level Pressure (SLP) fields, Walsh et al. (1996) showed that SLP dropped by as much as 4 mb over the Arctic Ocean, which drives a counter-clockwise anomaly in ice motion (right). These figures show the mean field of SLP and ice motion for 1979 – 1986 (left), 1987-1994 (middle), and the the difference between these two 8 year periods (right). This is one of the first studies to report Arctic Climate Change!

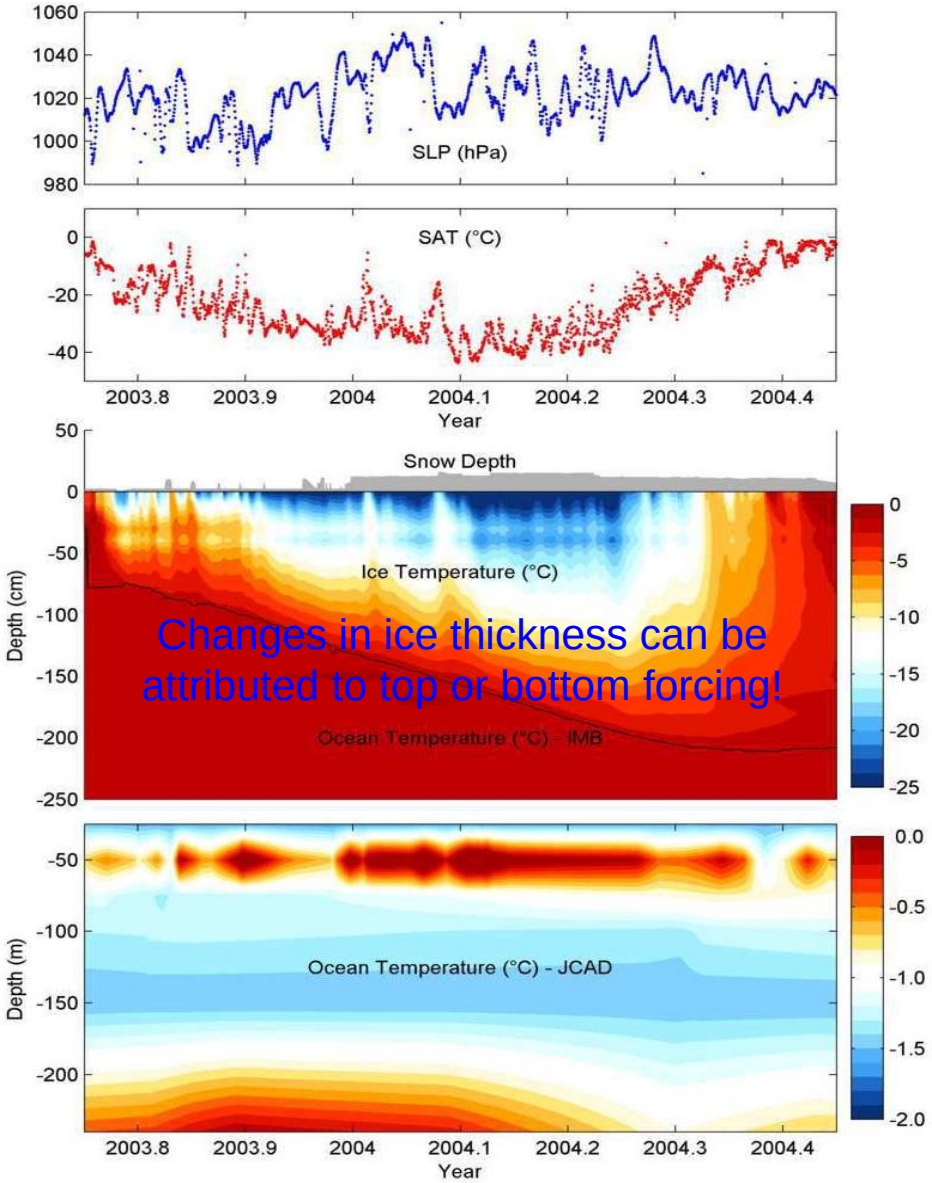
(Adapted from Walsh et al. 1996)

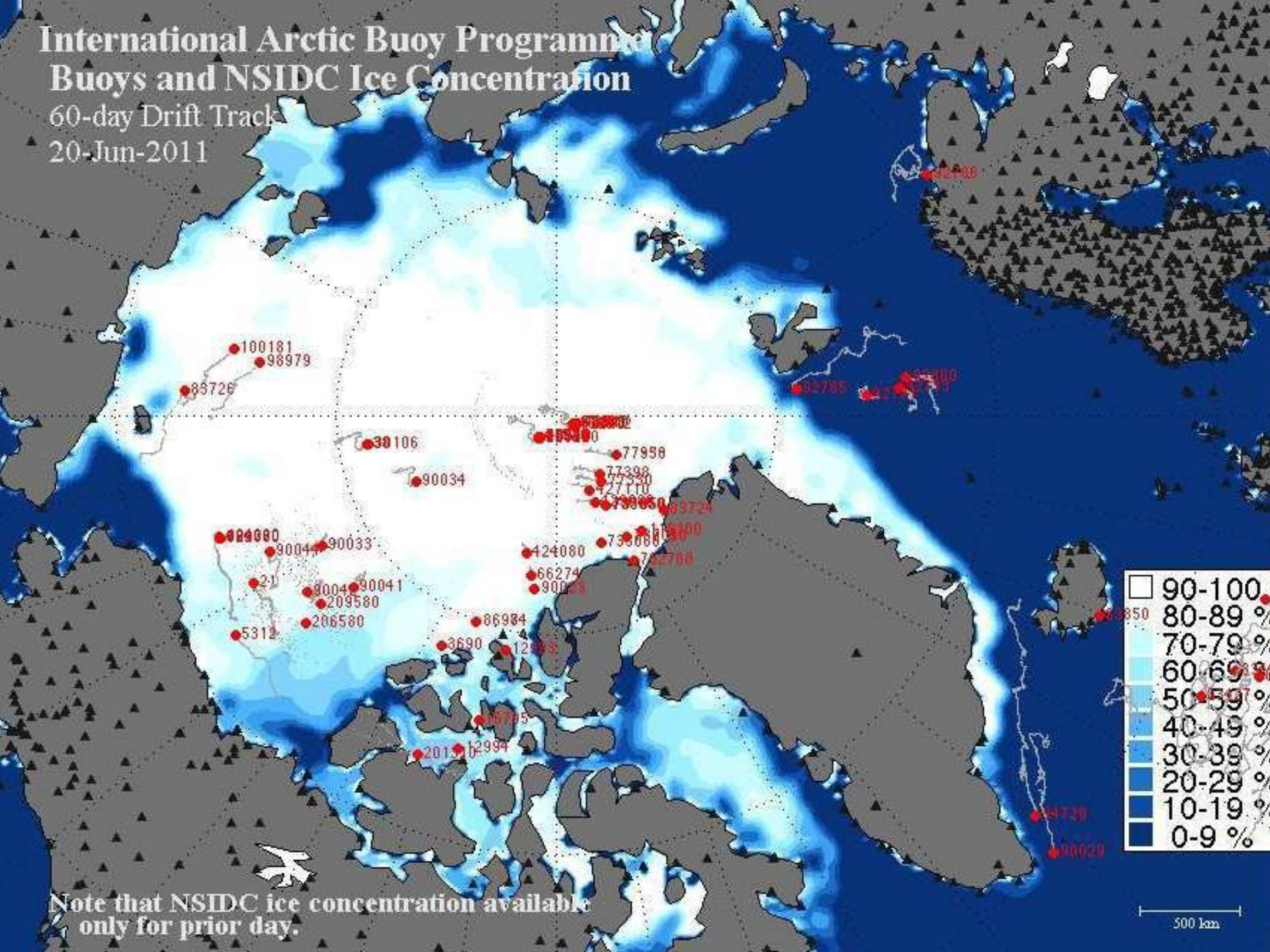
International Arctic Buoy Programme (IABP)

PSC/APL/UW North Pole Environmental Observatory

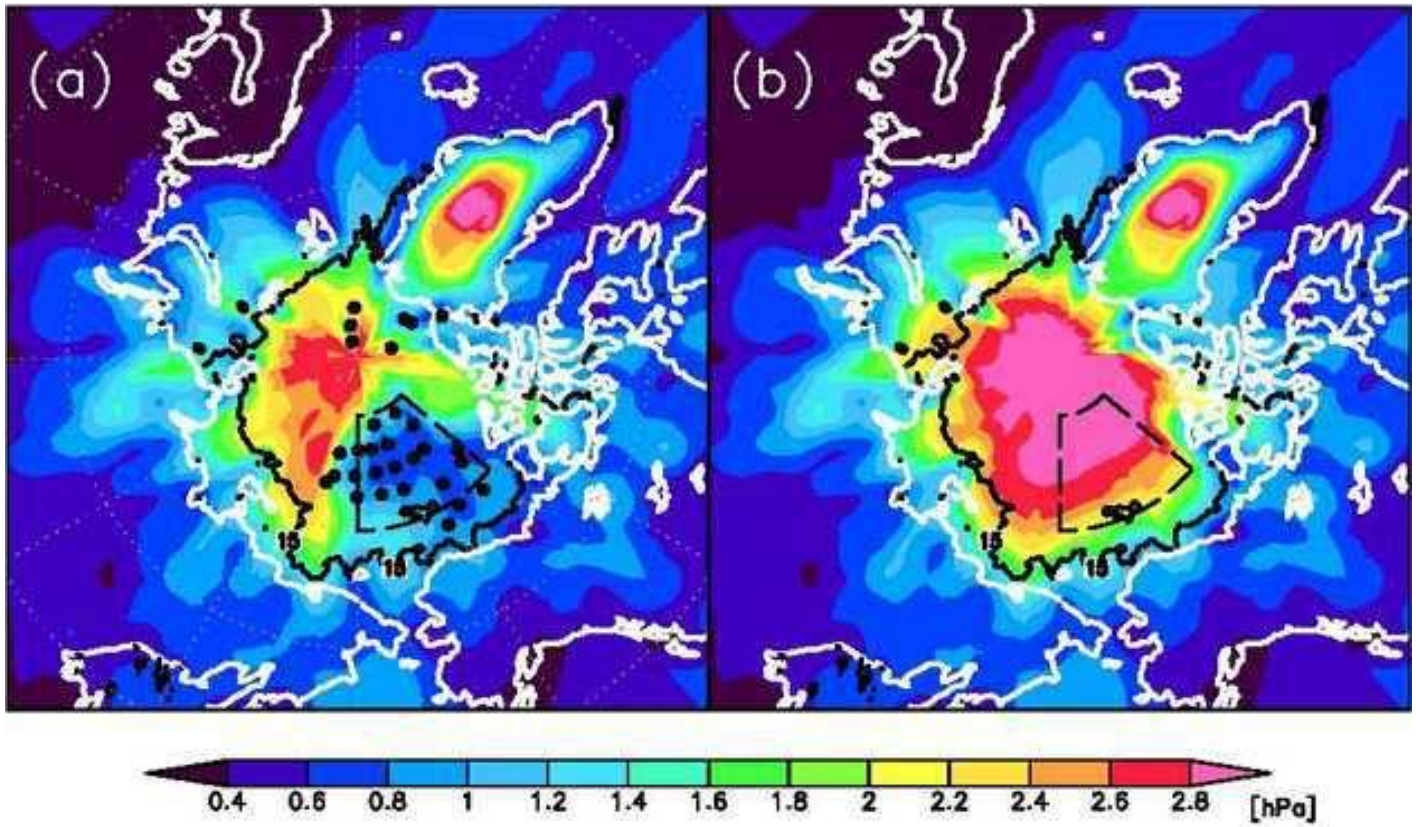


IMB and Ocean Observations




International Arctic Buoy Programme
Buoys and NSIDC Ice Concentration
60-day Drift Track
20-Jun-2011
100181
98979
85726
38106
90034
77958
90044
90033
424080
66274
90041
209580
206580
5312
86984
3690
12994
90-100
80-89 %
70-79 %
60-69 %
50-59 %
40-49 %
30-39 %
20-29 %
10-19 %
0-9 %
500 km
Note that NSIDC ice concentration available only for prior day.

Spread of
Sea Level Pressure (SLP) Reanalyses

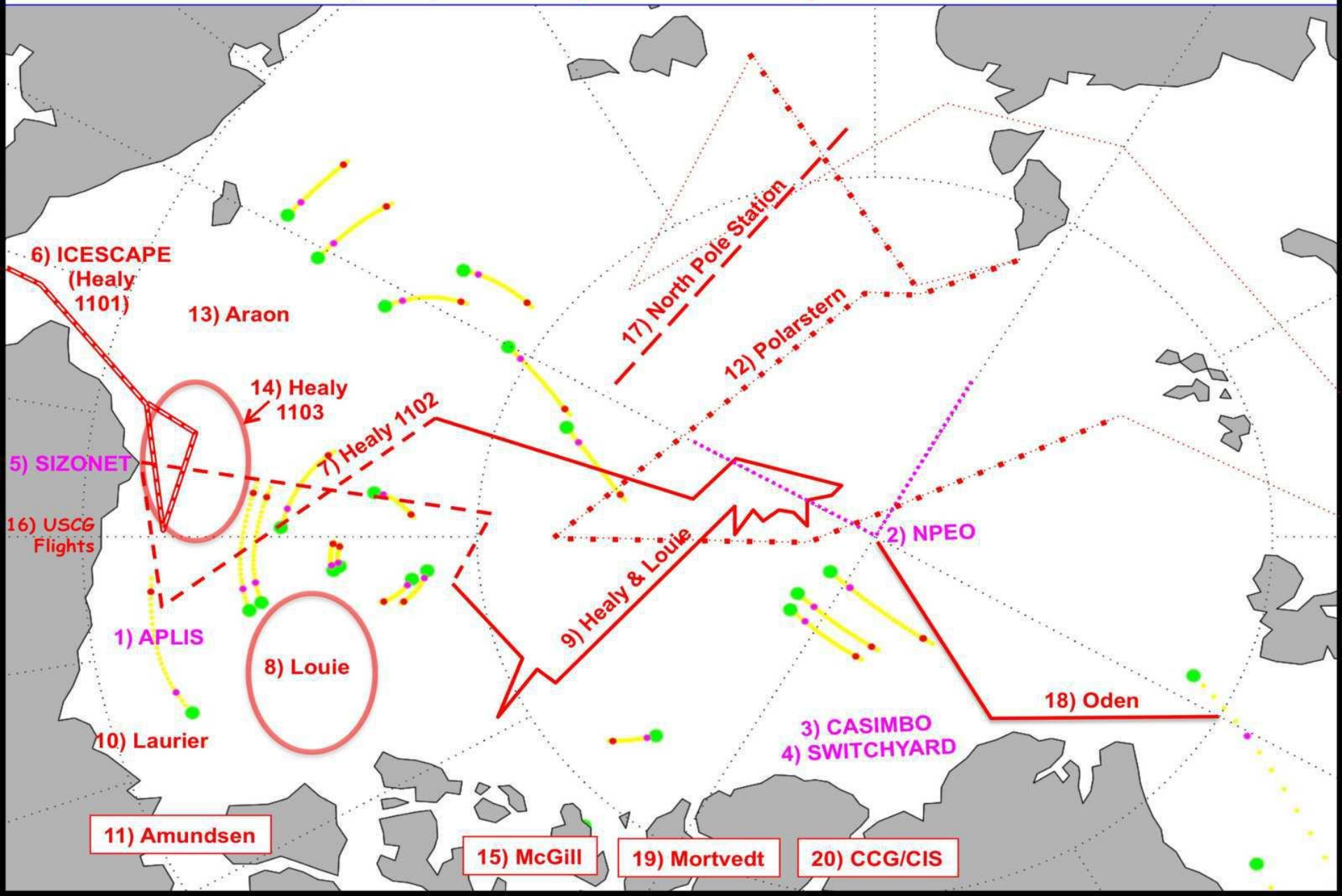


The spread between SLP Reanalyses is low in areas where there are buoy observations (left). The spread increases to cover the whole Arctic when the buoys are removed from the reanalyses (right). The buoy obs. also help constrain of estimates of wind and heat.

(Inoue et al, 2009)

IABP Deployment Plans - Logistics

The dots show the location of drifting buoys reporting March, 2011, and expected positions on April 15, 2011 and September 15, 2011.



IABP Deployment Plans – Logistics & EEZ

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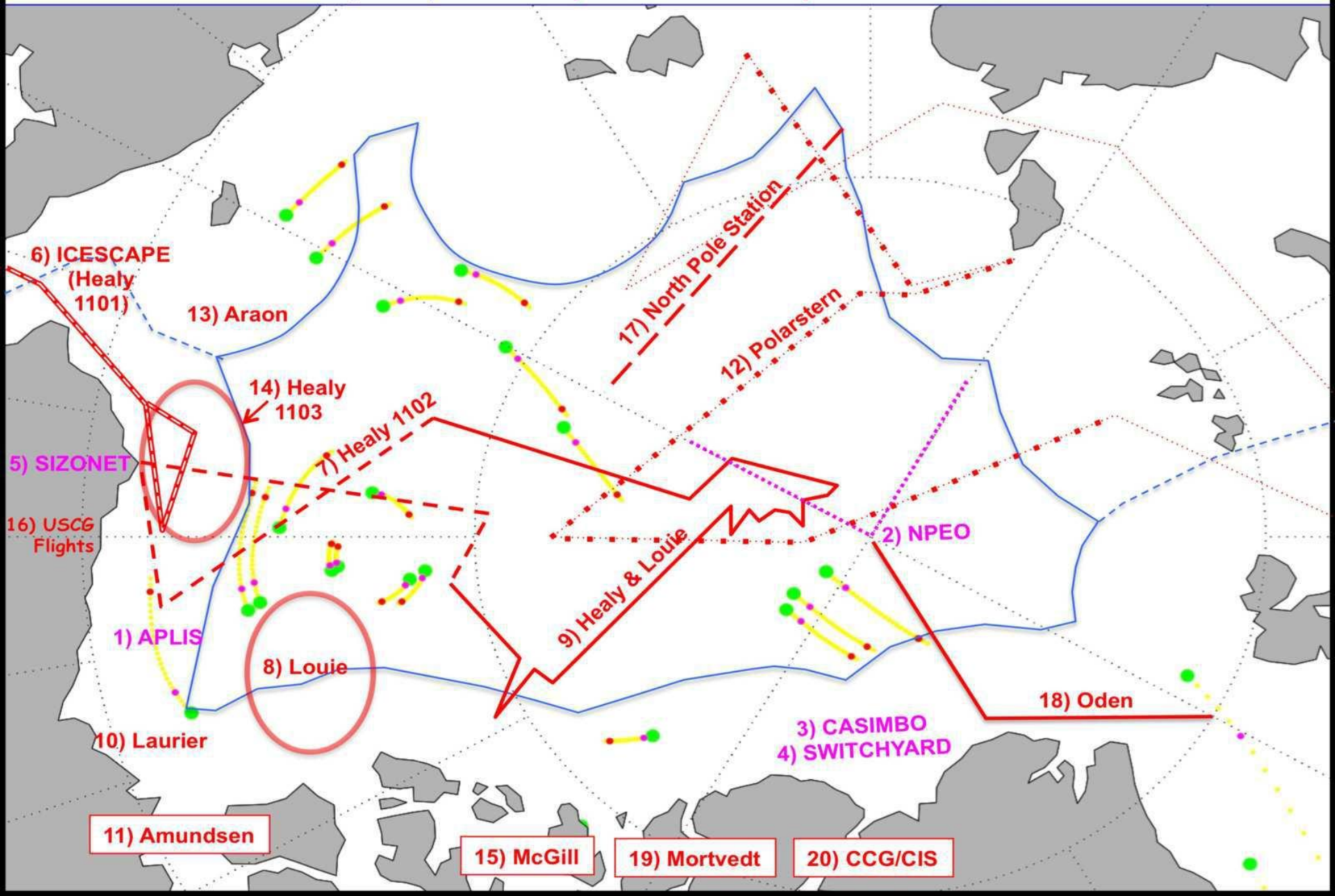
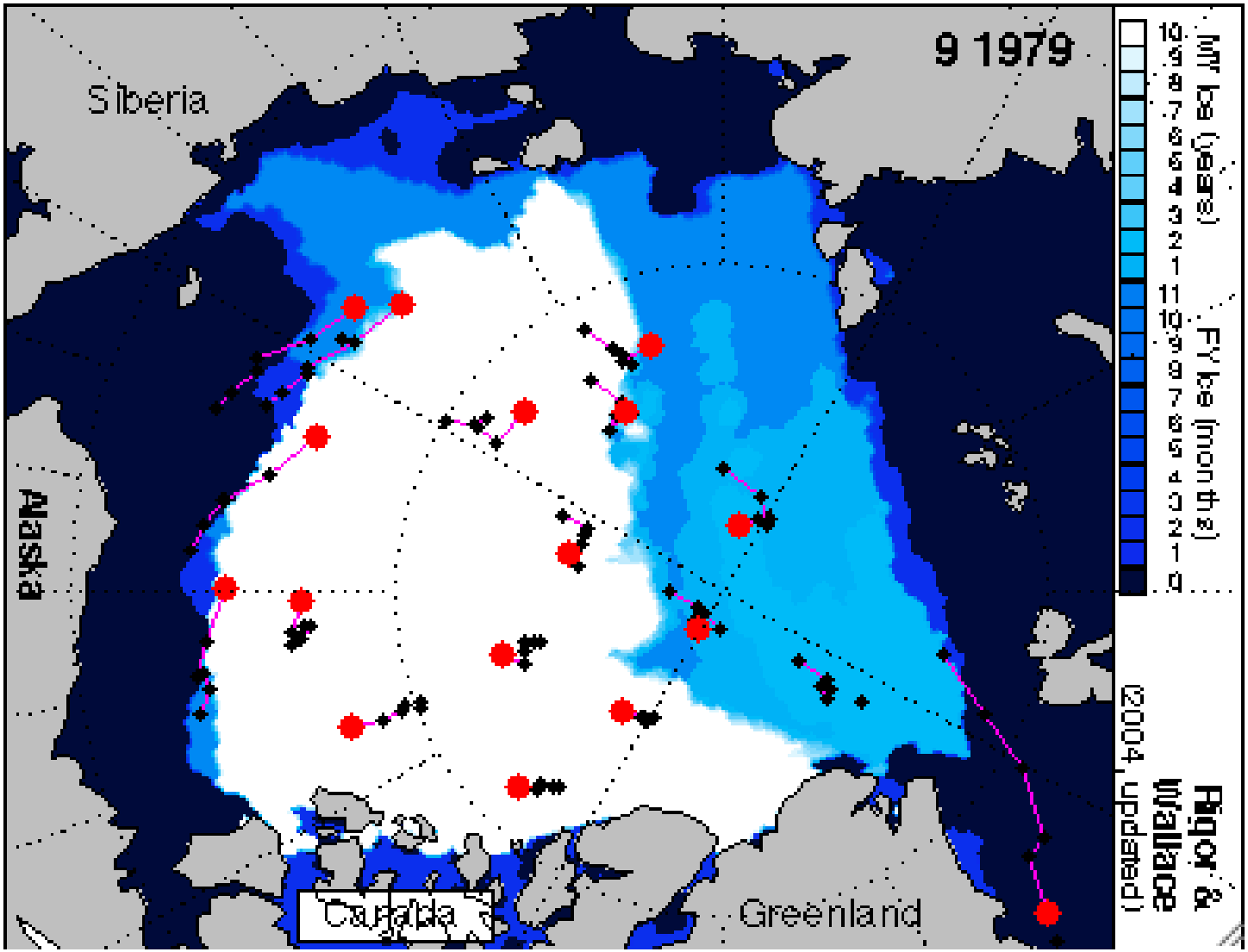


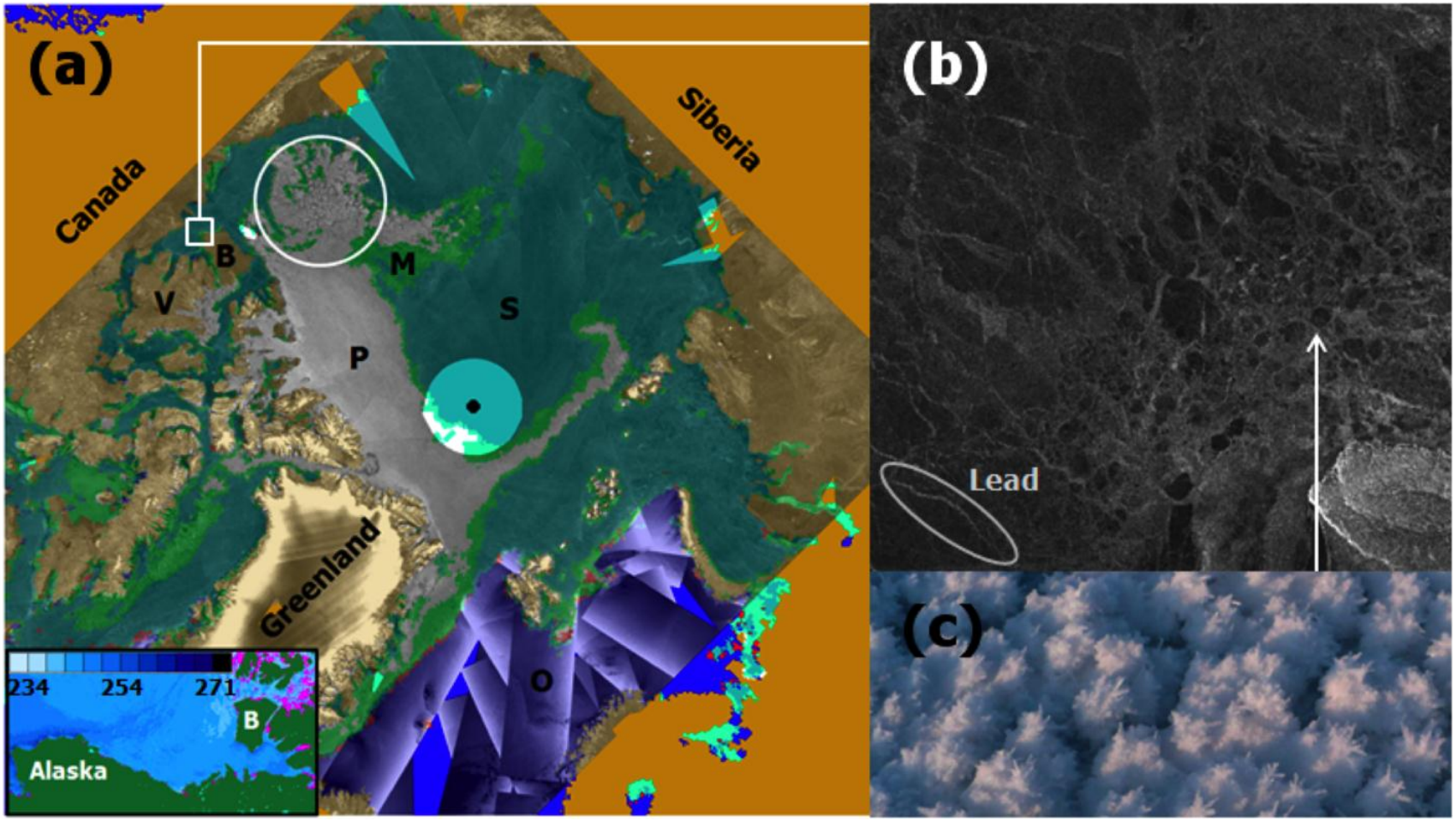
Changes in Wind, Ice Drift, Age and Thickness



- Sea ice grows thicker with age.
- Prior to 1989, ice over 80% of the Arctic Ocean is at least 10 years old.
- High AO conditions flushed most of the older thicker sea ice out of the Arctic.
- Younger (thinner) Ice persist through today despite "normal" AO conditions.

Tropospheric Ozone Depletion

Tropospheric Ozone reacts chemically with
plants, rubber, and the tissues of living creatures.



Satellite composites produced by NASA and NIC, field observations collected by International Arctic Buoy Programme and at Canadian Flaw Lead Study Camp.

Arctic Air Chemistry
A Synthesis of Observations

Tropospheric Ozone reacts chemically with plants, rubber, and the tissues of living creatures.

Ozone Depletion by Bromine:

- Increased first-year ice results in more leads.
- Frost Flowers form in leads during cold season.
- Bromine (Br_2) is wicked up by rising air over frost flowers.
- Sunlight (*hv*) forces Bromine to disassociate.
- Ozone is destroyed by Br
- Bromine reforms to repeat the cycle.

Ozone Depletion by Bromine Chemistry:

$Br_2 + hv \rightarrow Br + Br$ (1)

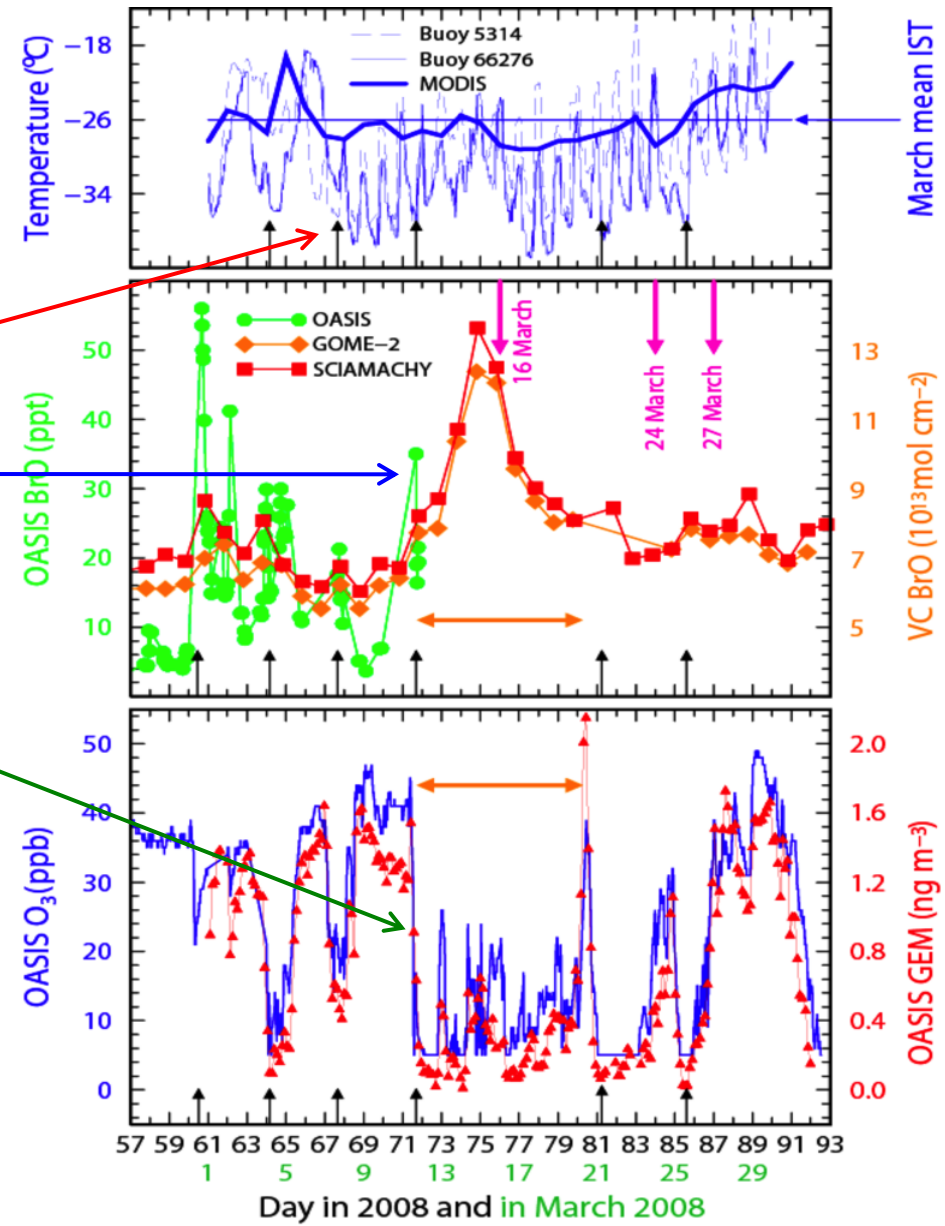
$2(Br + O_3 \rightarrow BrO + O_2)$ (2)

$2(BrO + HO_2 \rightarrow HOBr(g) + O_2)$ (3)

$2(HOBr(g) \rightarrow HOBr(l))$ (4)

$2(HOBr(l) + HBr(l) \rightarrow H_2O(l) + 2Br_2(g))$ (5)

Net: $2HO_2 + 2HBr + 2O_3 + hv \rightarrow 2H_2O + Br_2 + 4O_2$



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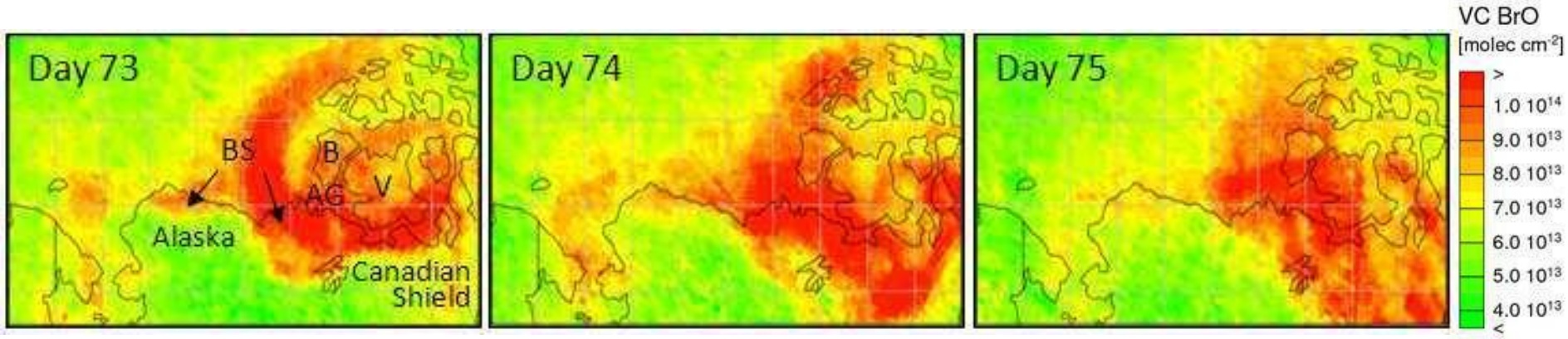
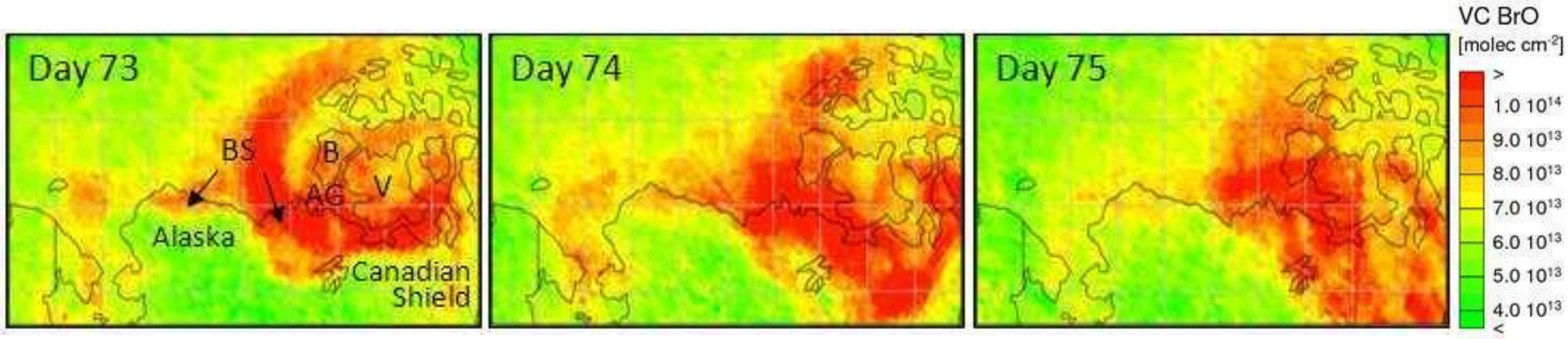
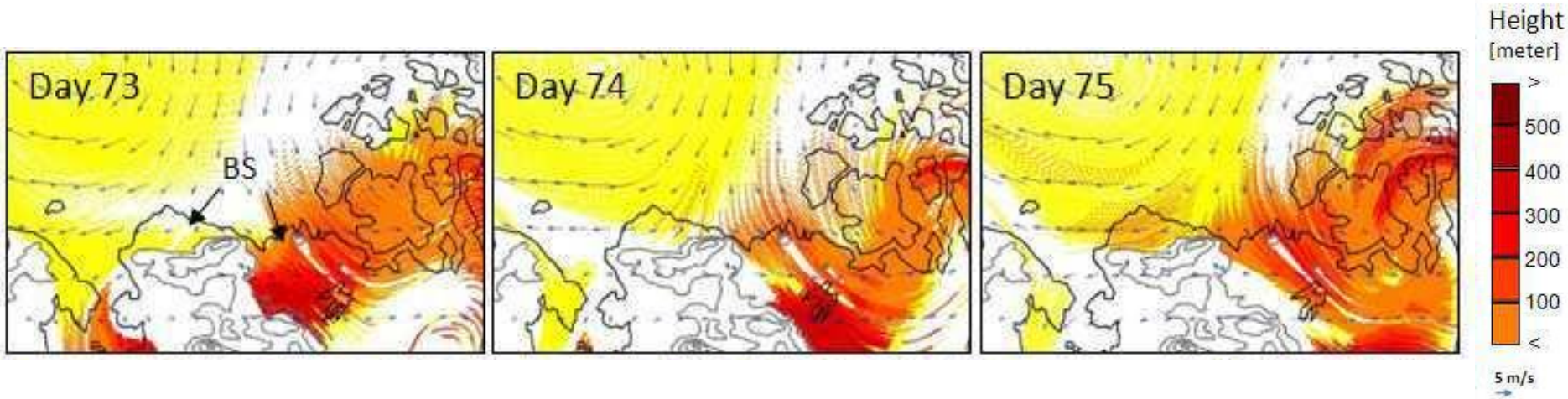


Global Ozone Monitoring Experiment-2 (GOME-2) satellite retrievals of Vertical Column (VC) Bromide shows extensive areas of bromide even over land?

Tropospheric Ozone Depletion

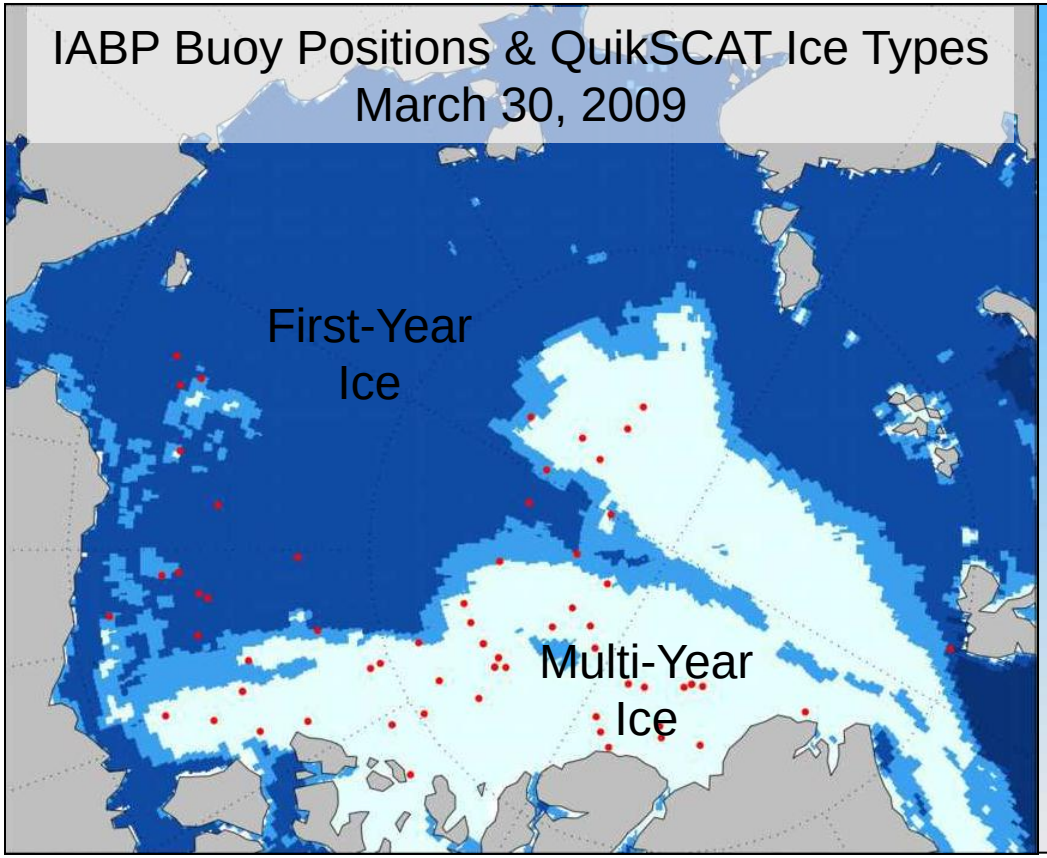


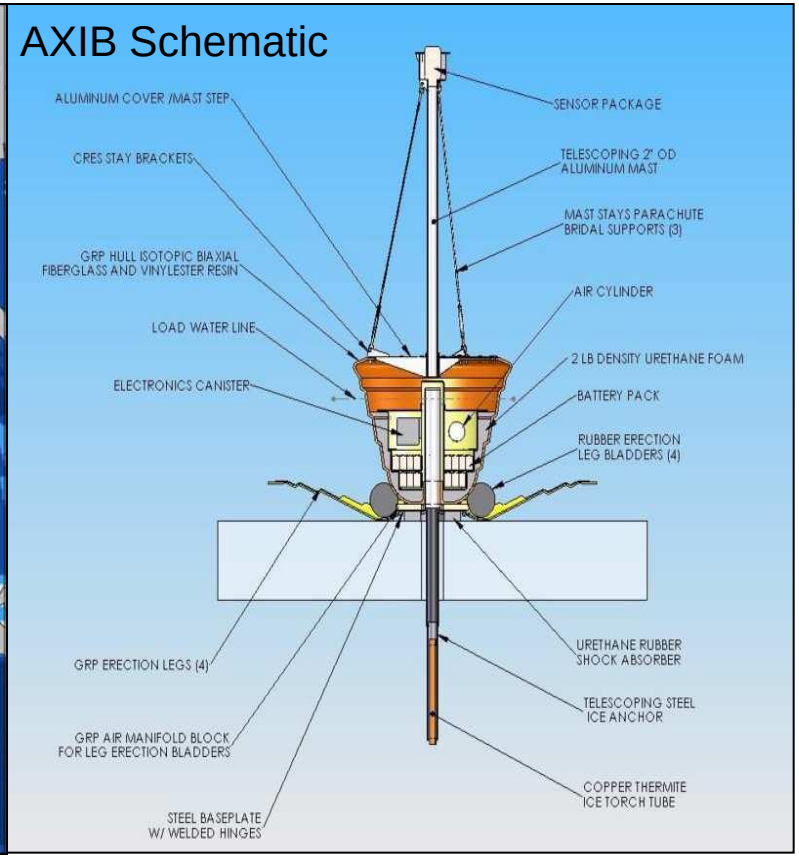
Global Ozone Monitoring Experiment-2 (GOME-2) satellite retrievals of Vertical Column (VC) Bromide shows extensive areas of bromide even over land?



To explain this we traced parcels of air rising from areas of first-year ice when temperatures were below 25C, and were able to reproduce the patterns seen by GOME-2, and show how topography limits the distribution of air borne Bromide rising from sea ice.

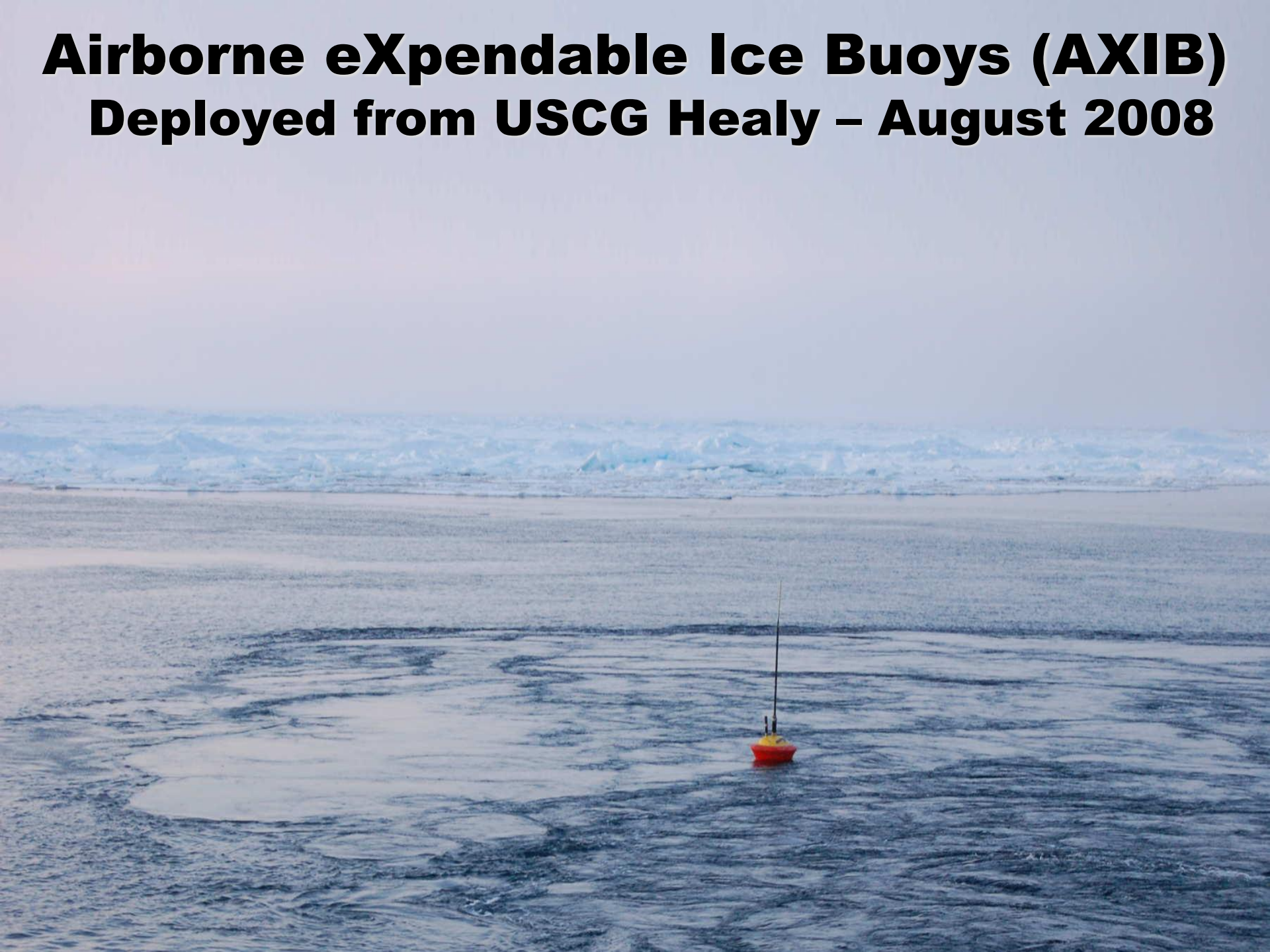
Airborne eXpendable Ice Buoys (AXIB)





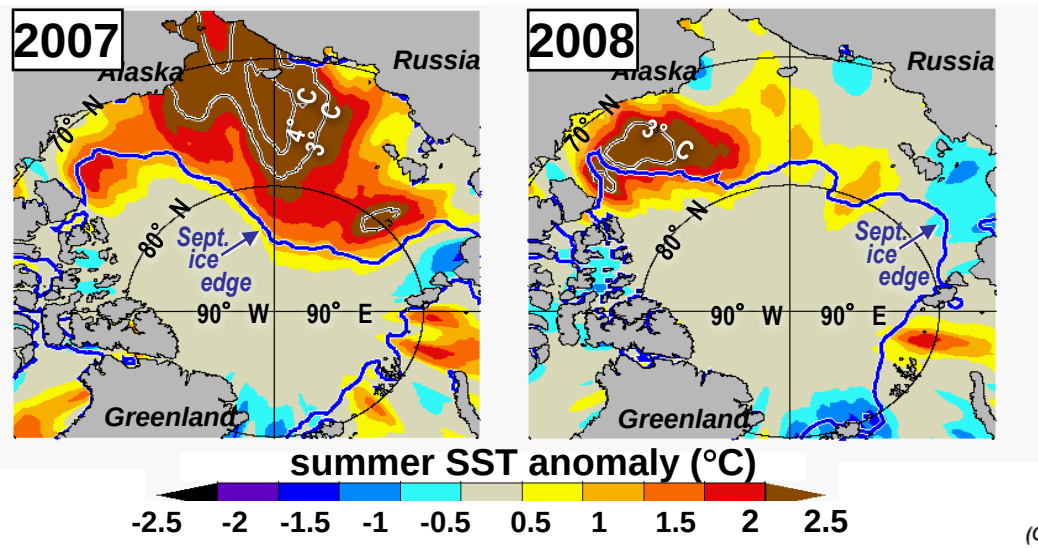
- Developed by USIABP through a NOAA SBIR.
- Capable of operation in ice, and open water through freeze/thaw cycles.
- Sensors include air and ocean temperature, surface pressure, GPS location, and Argos transmitter.
- Currently

Airborne eXpendable Ice Buoys (AXIB)
Deployed from USCG Healy – August 2008



Airborne eXpendable Ice Buoys (AXIB)
Deployed from USCG ADA – October 2010

Measuring the Upper Layer Temperature of the Arctic Ocean: UpTempO Buoys

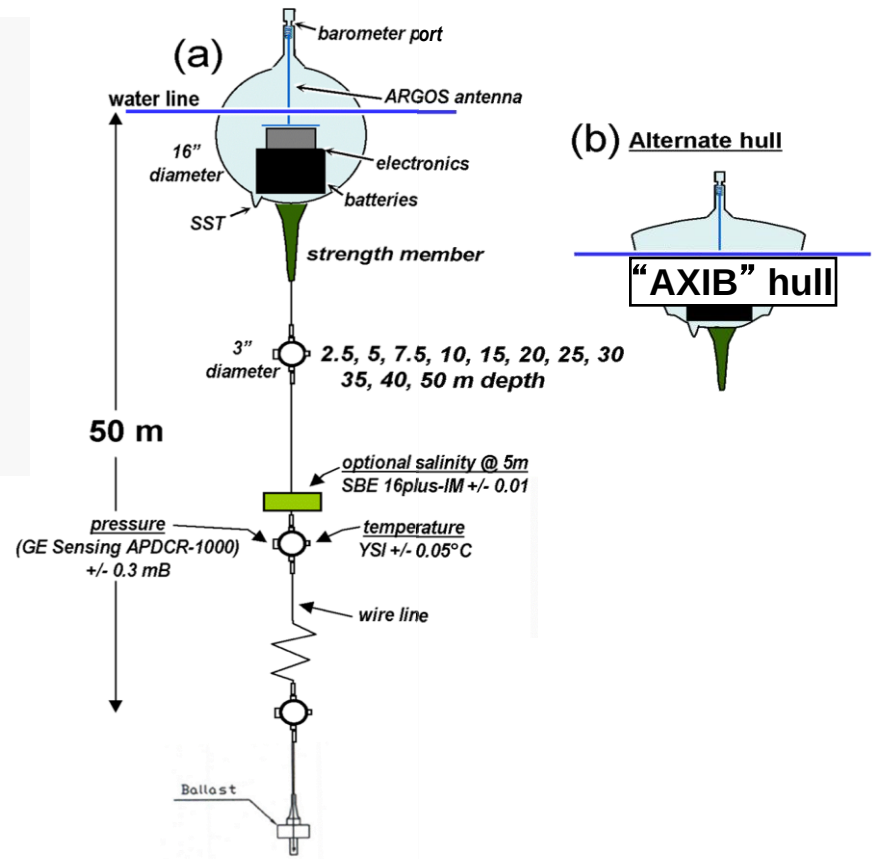


Satellite (AVHRR) SST anomalies (relative to 1982-2006 mean, from R. Reynolds data, NCDC)

This is historically unprecedented warming!

OK, but what is the evolution *below the surface* of:

- summer upper ocean heating?
- fall upper ocean cooling?



Eleven UpTempO buoys will be deployed this summer.

Impacts of Retreating of Arctic Sea Ice

Solar heating penetrates down into the Ocean

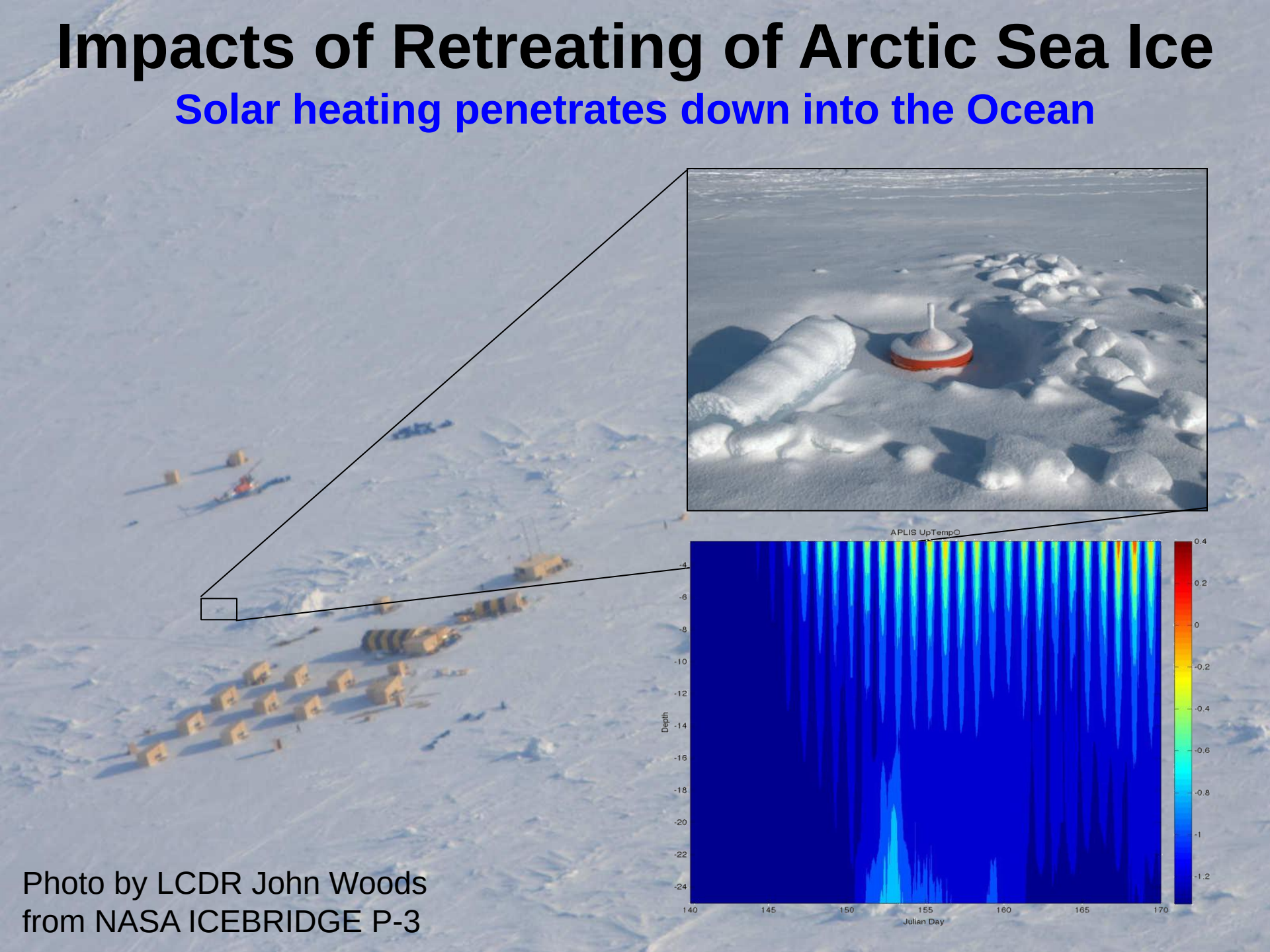


Photo by LCDR John Woods
from NASA ICEBRIDGE P-3

Summary

- Partnerships and collaboration have been one the keys to the success of the USIABP and IABP(operations and research; interagency; international).
- Maintaining the Arctic Observing Network (AON) is a challenge.
- In order to predict weather, sea ice, climate and climate change, we must overcome this challenge.