

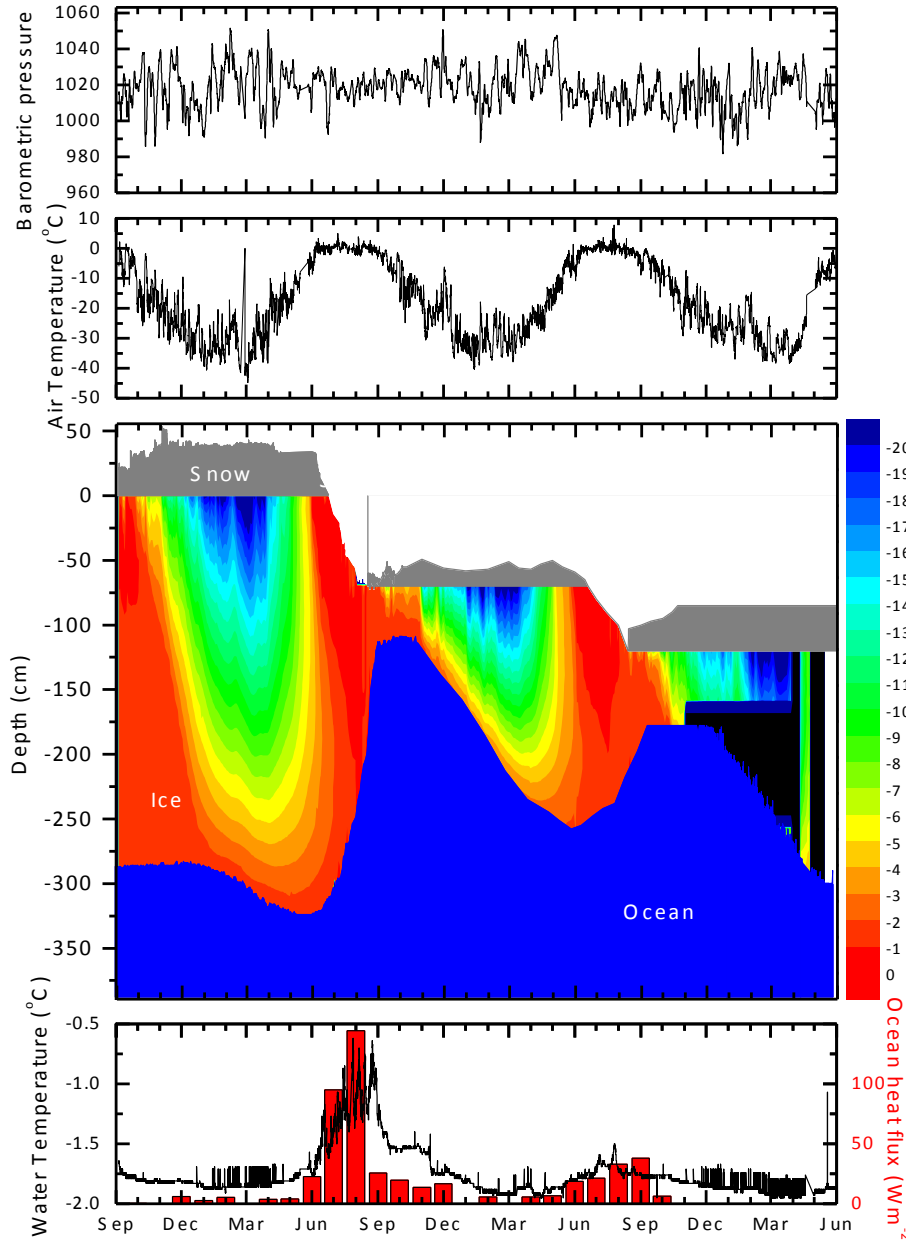
Autonomous observations of the heat and mass balance of Arctic sea ice



Don Perovich, Jackie Richter-Menge, Bruce Elder, Chris Polashenski, Chris Williams, Alexandra Arntsen, and Bonnie Light

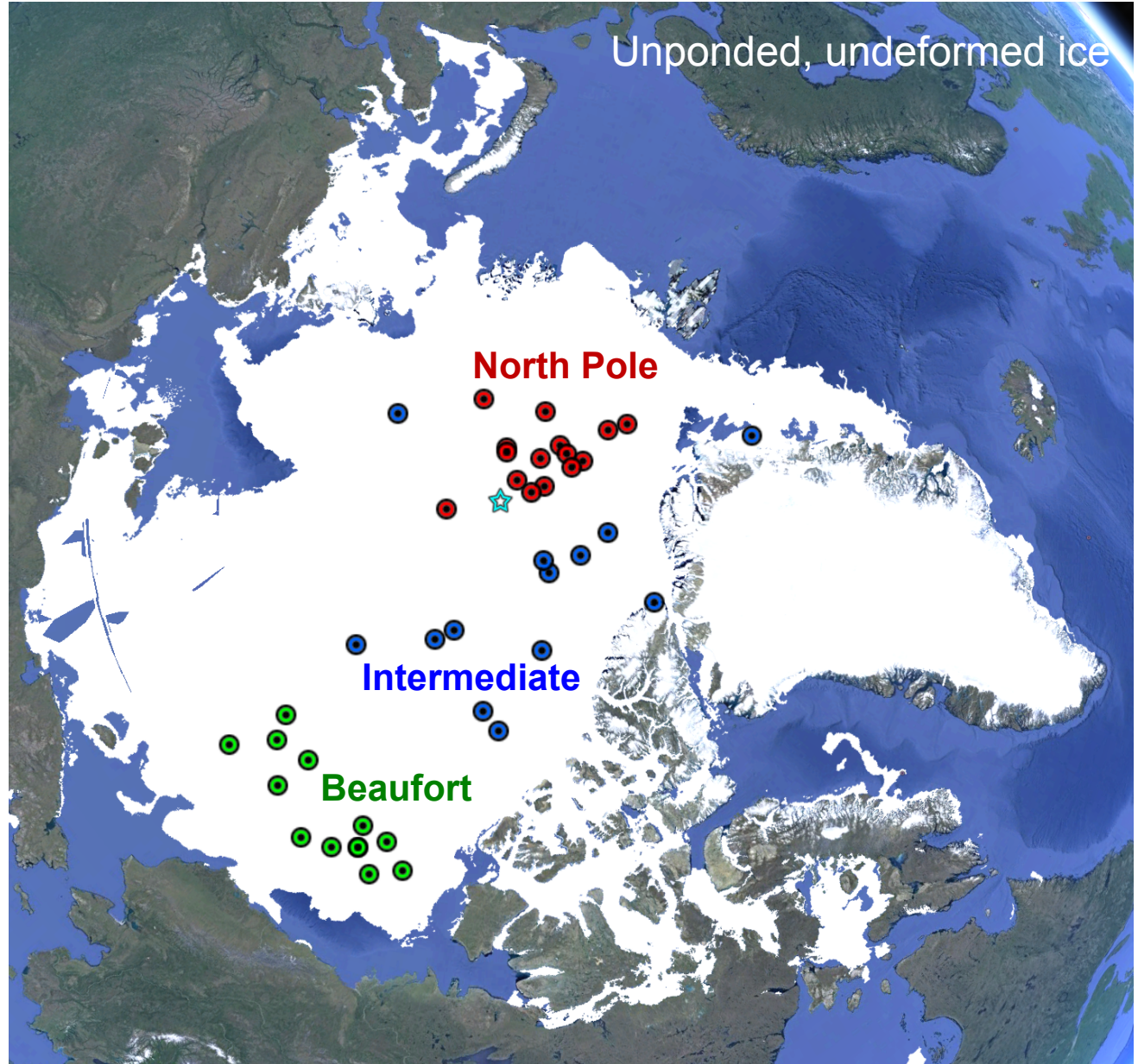
Sea ice mass balance

- Snow accumulation
- Snow melt
- Ice growth
- Surface ice melt
- Bottom ice melt
- Position
- Ice motion
- Air temperature
- Barometric pressure
- Ice temperatures
- Upper ocean temperatures
- Ocean heat flux



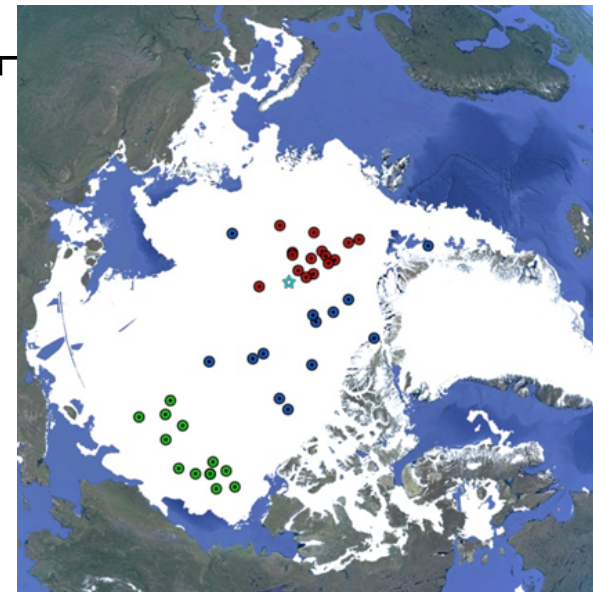
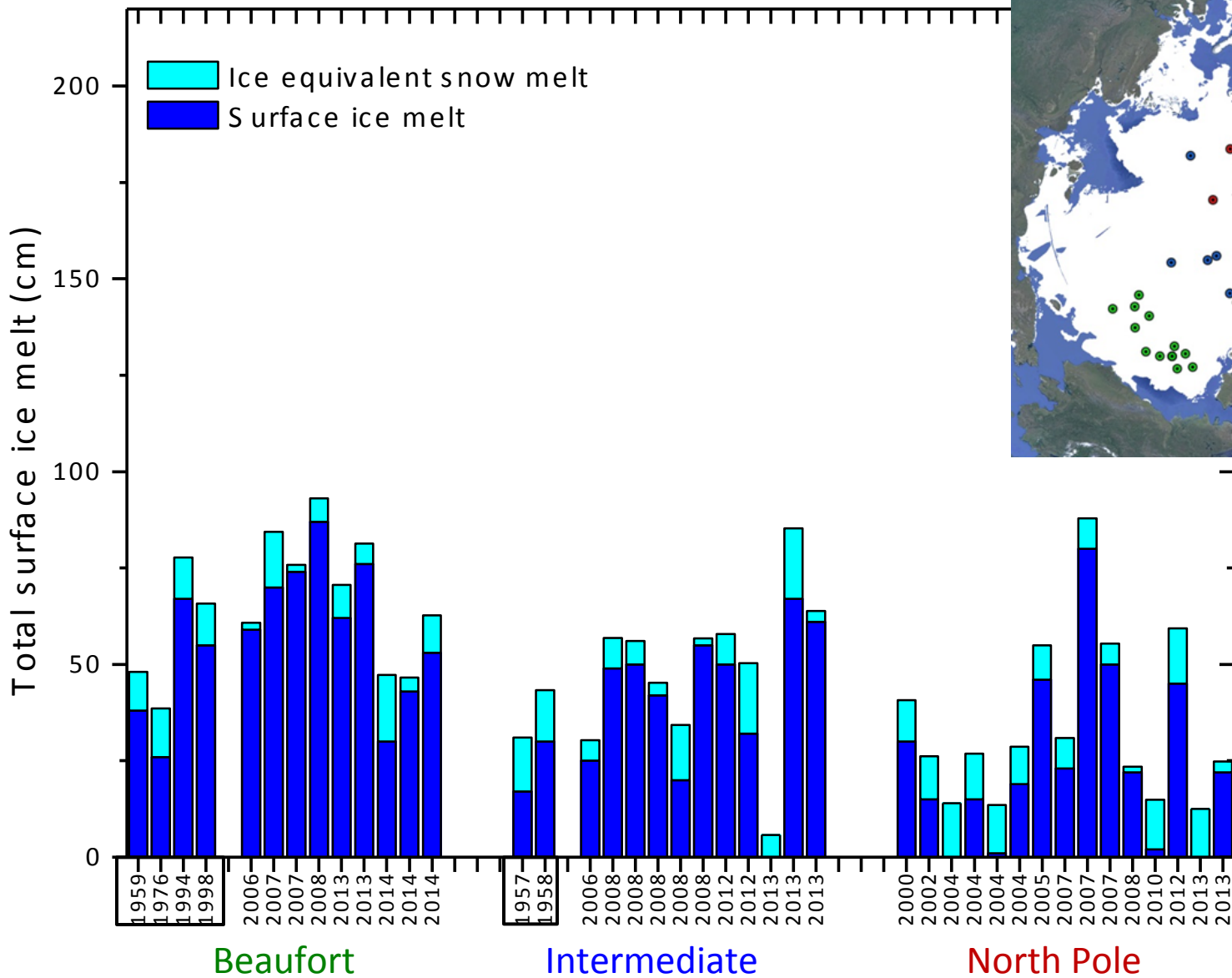
Simple, but powerful observation – attributes change

Summer mass balance observations



From camps, ships, and autonomous buoys

Surface melt



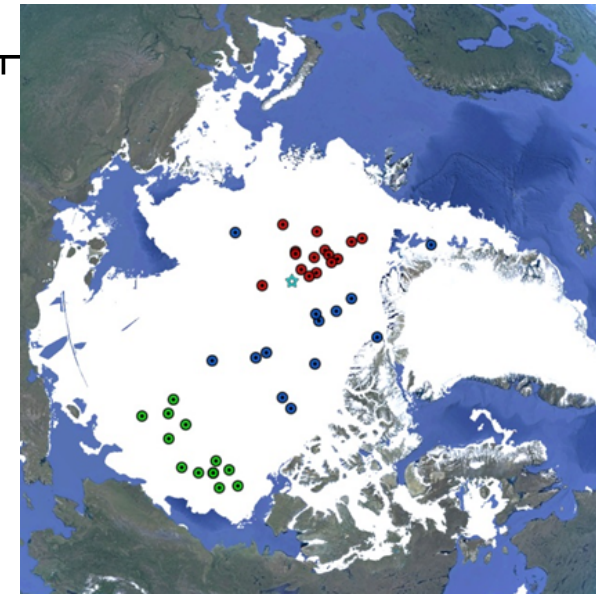
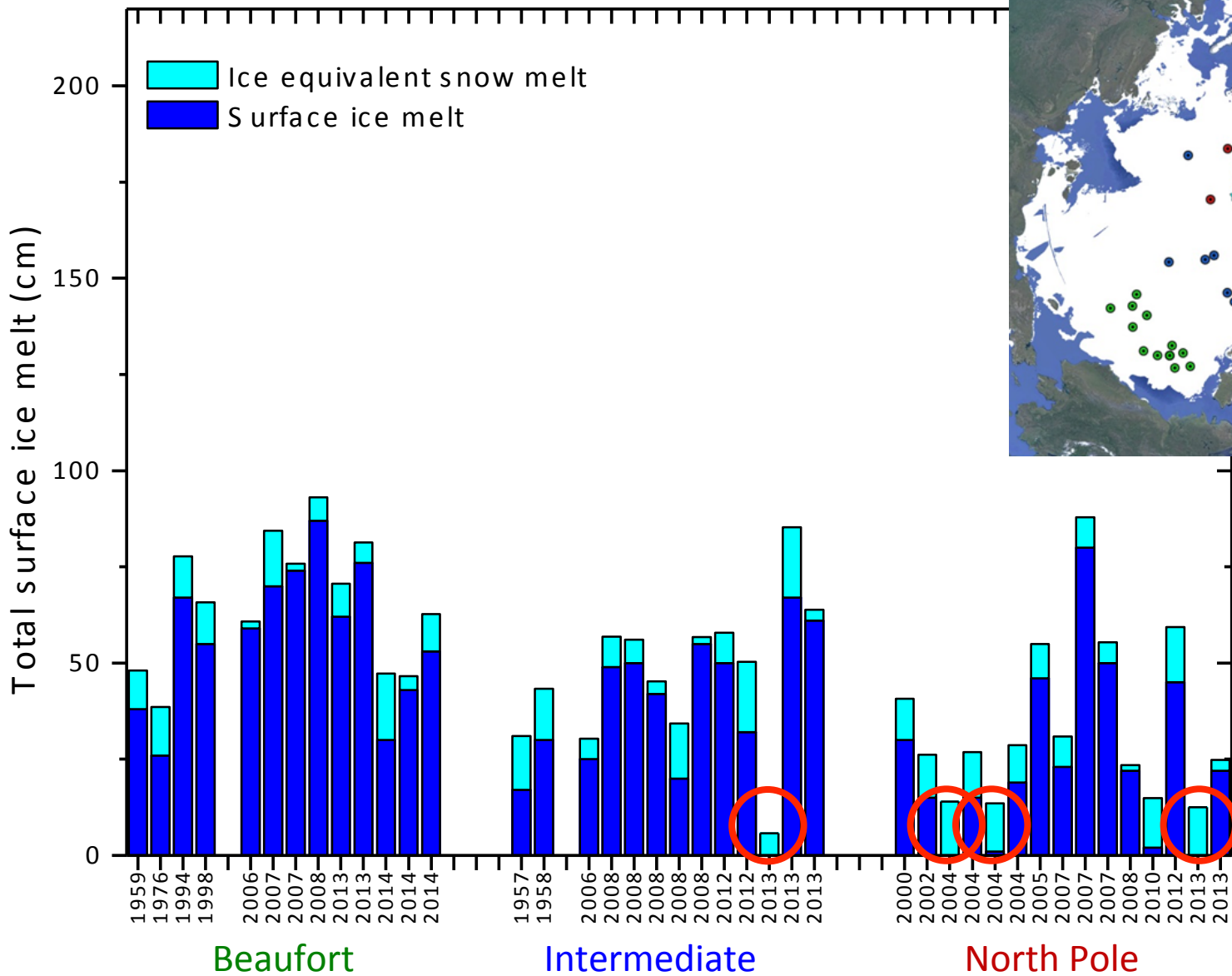
Beaufort

Intermediate

North Pole

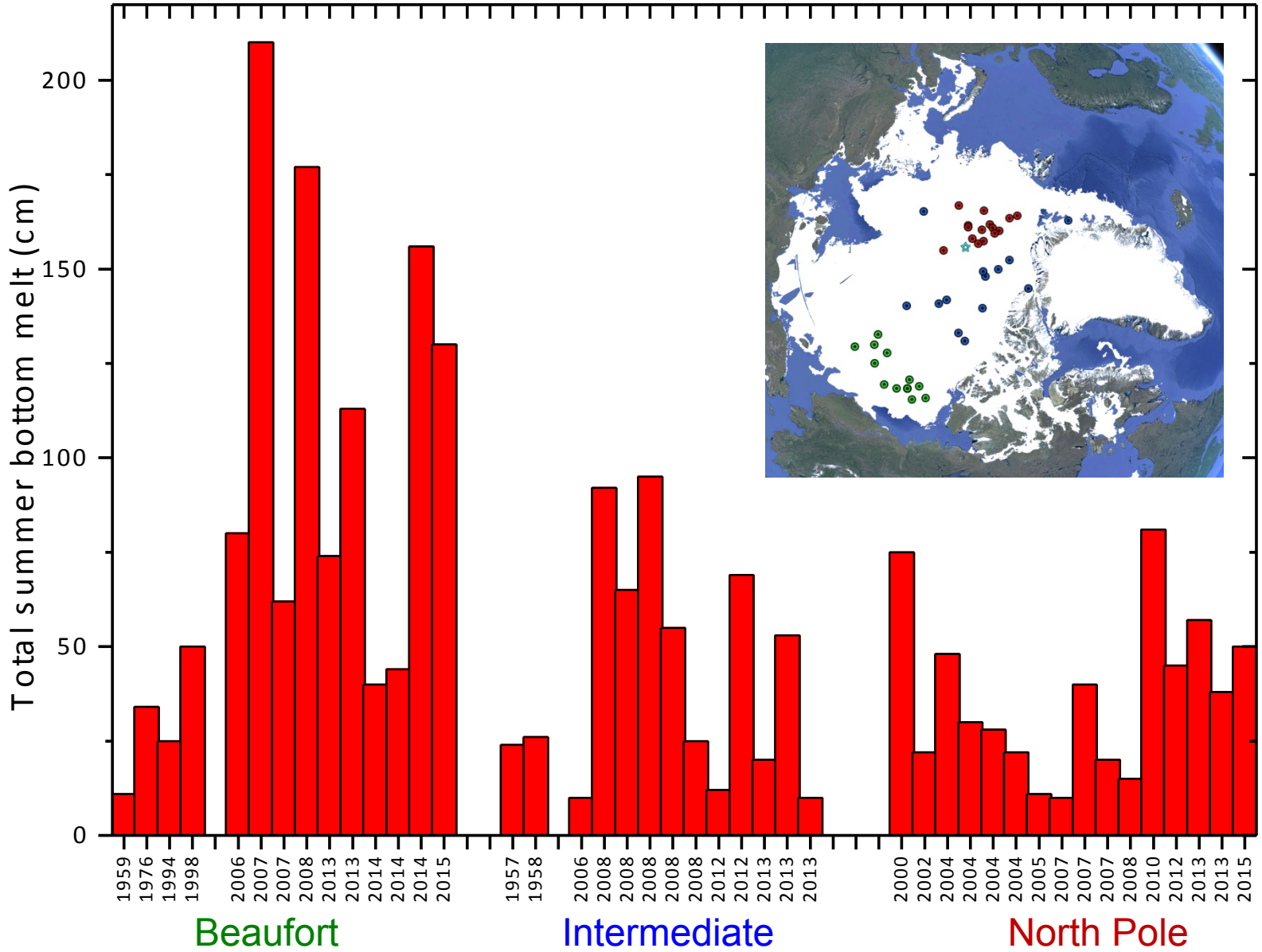
Large spatial and temporal variability

Surface melt



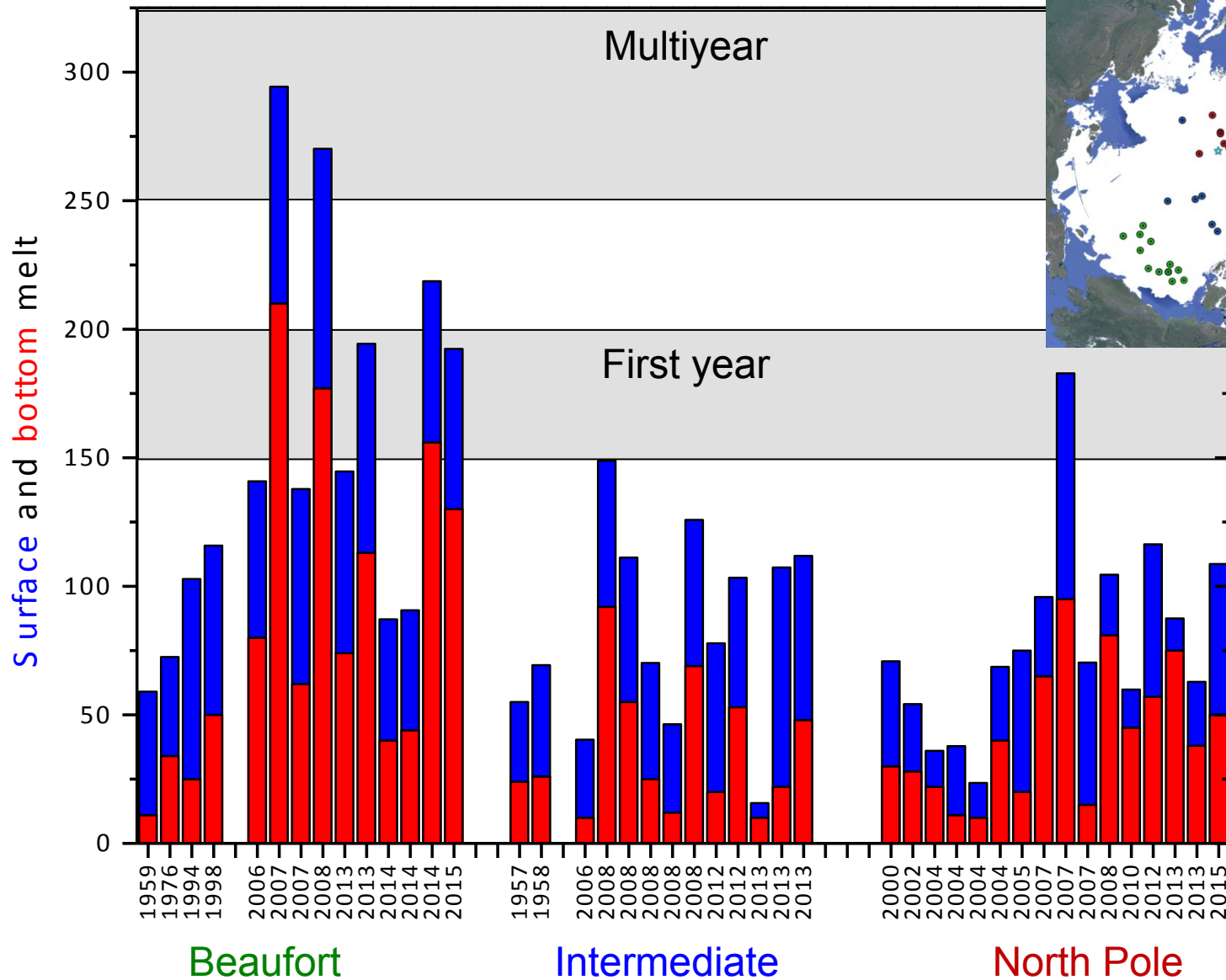
A few summers with little surface ice melt

Bottom melt



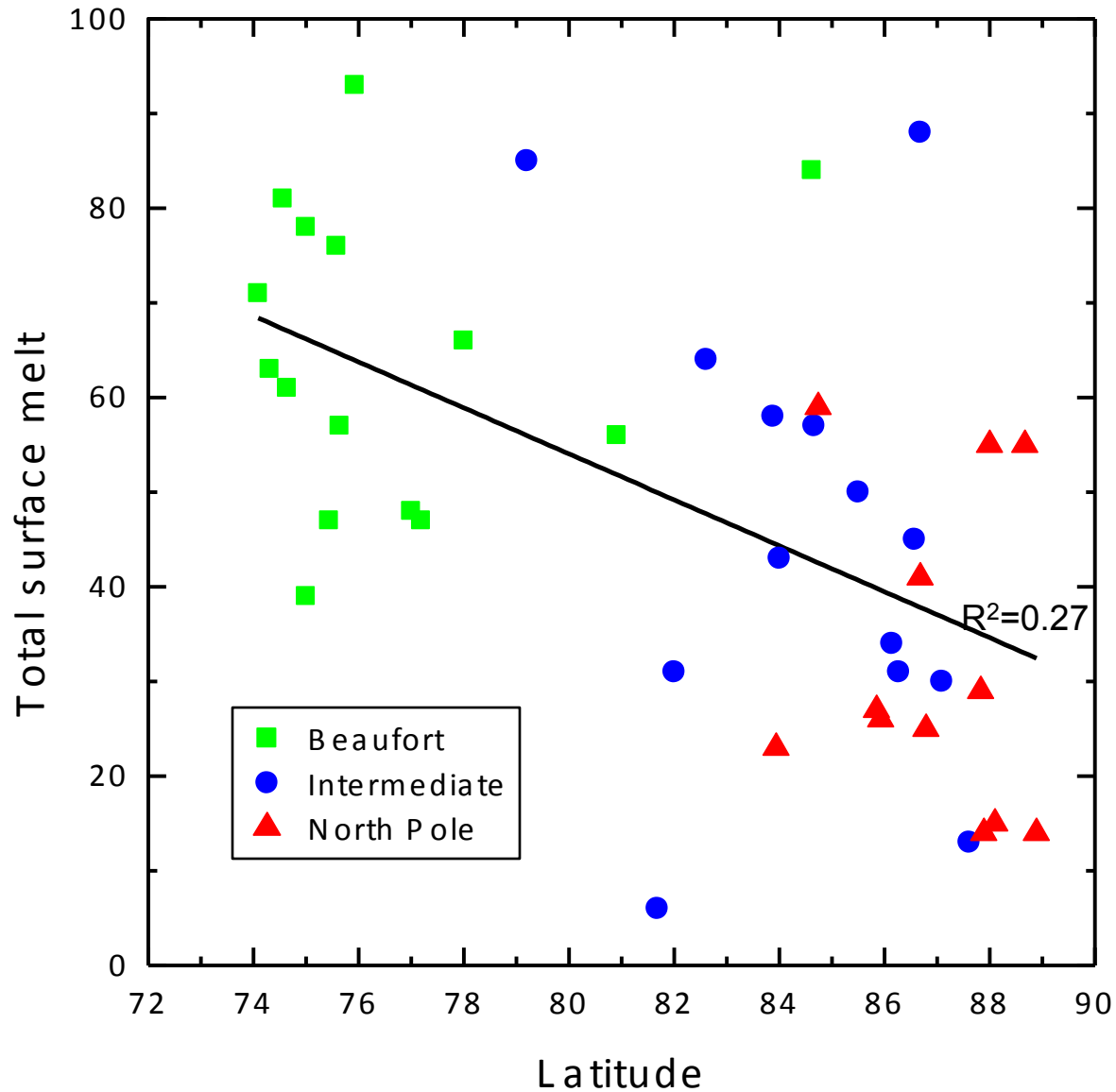
Large spatial and interannual variability

Summer melt in the age of first year



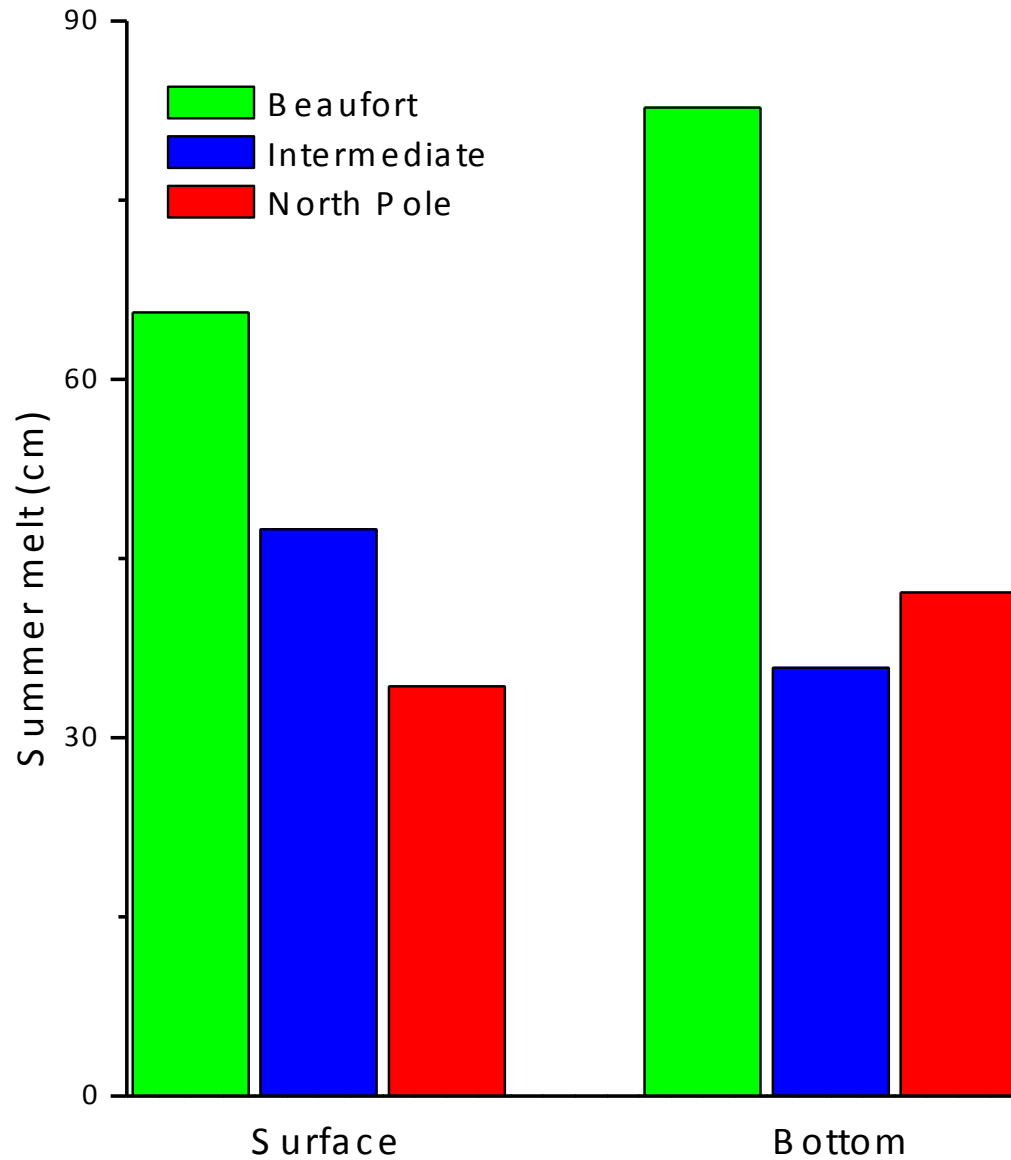
Don't be young in the Beaufort

Simple relationships for surface melt?



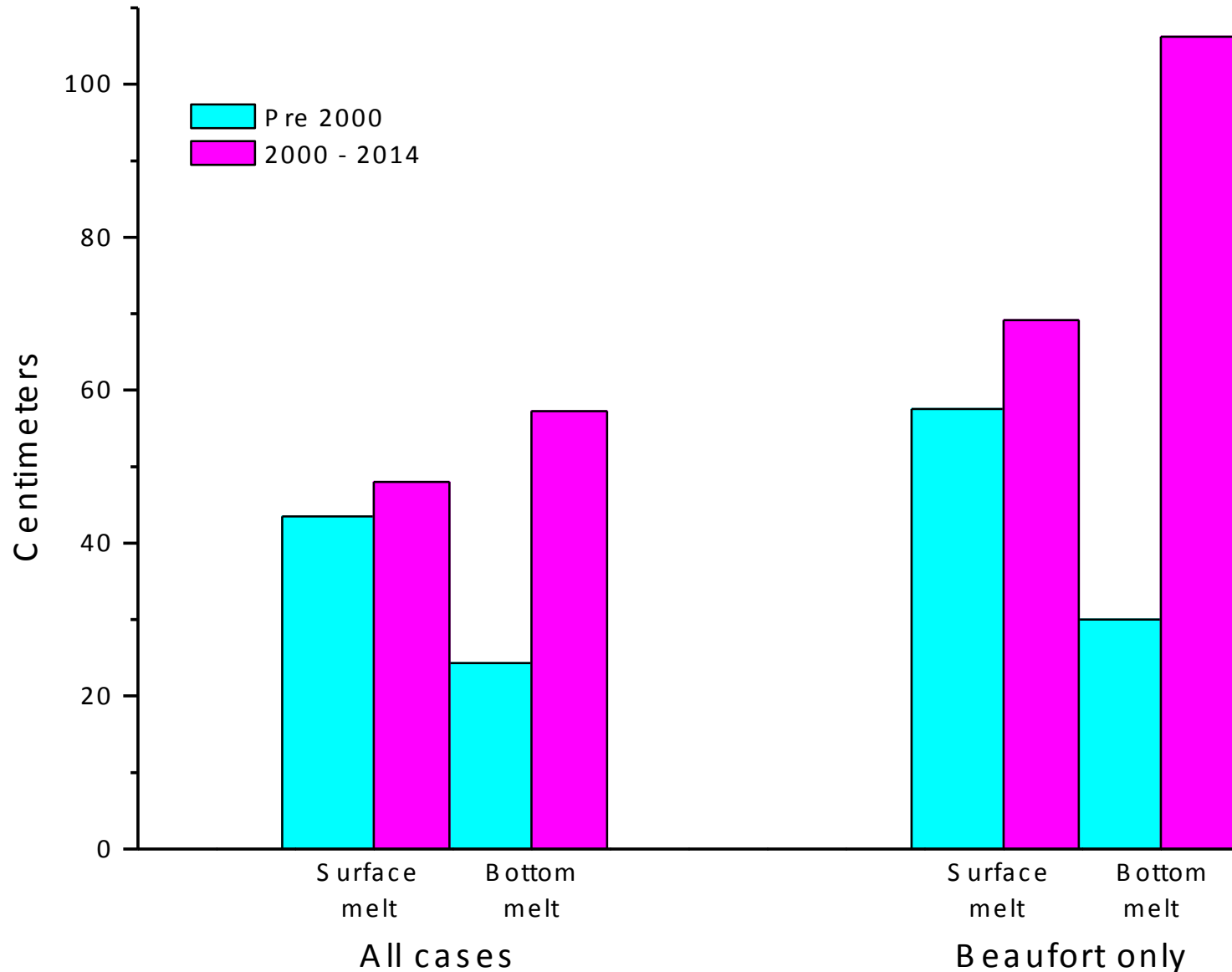
No, not really

Average conditions



Most melt in Beaufort

Pre 2000 versus 2000 – 2014



Big change in Beaufort bottom melt

Bottom melt: Solar heating of the ocean

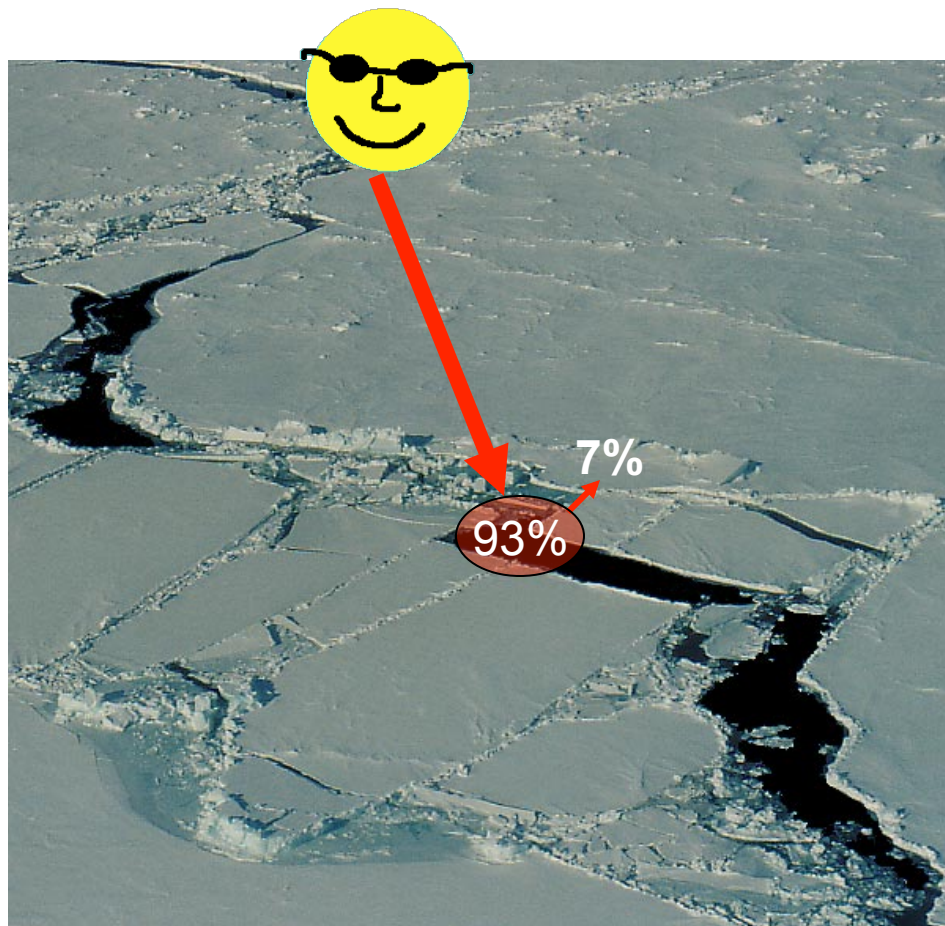
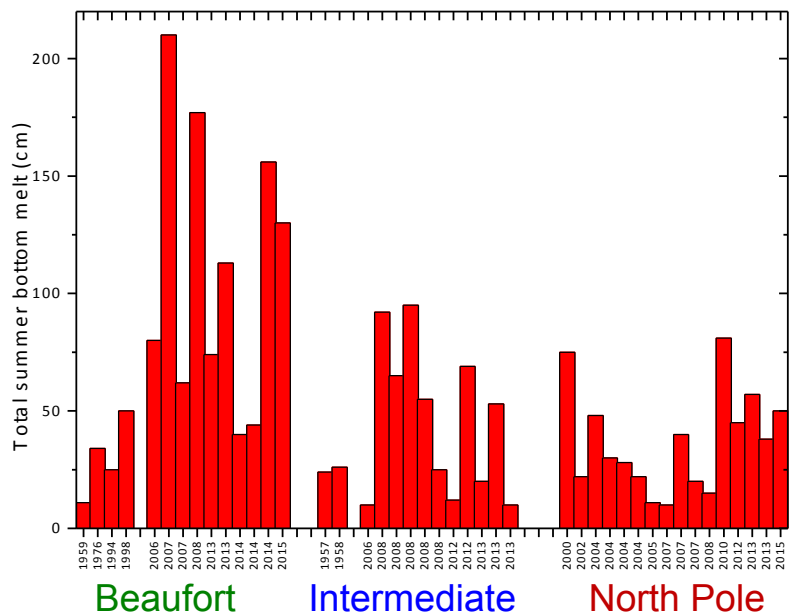
Heat to ocean = incident x (1 – concentration) x (1 – water albedo)

Input:

- Incident sunlight – reanalysis
- Concentration – satellite
- Ocean albedo = 0.07

Output:

- Solar input to ocean
- Day by day



How much sunlight is absorbed in leads?

Bottom melt: Solar heating of the ocean

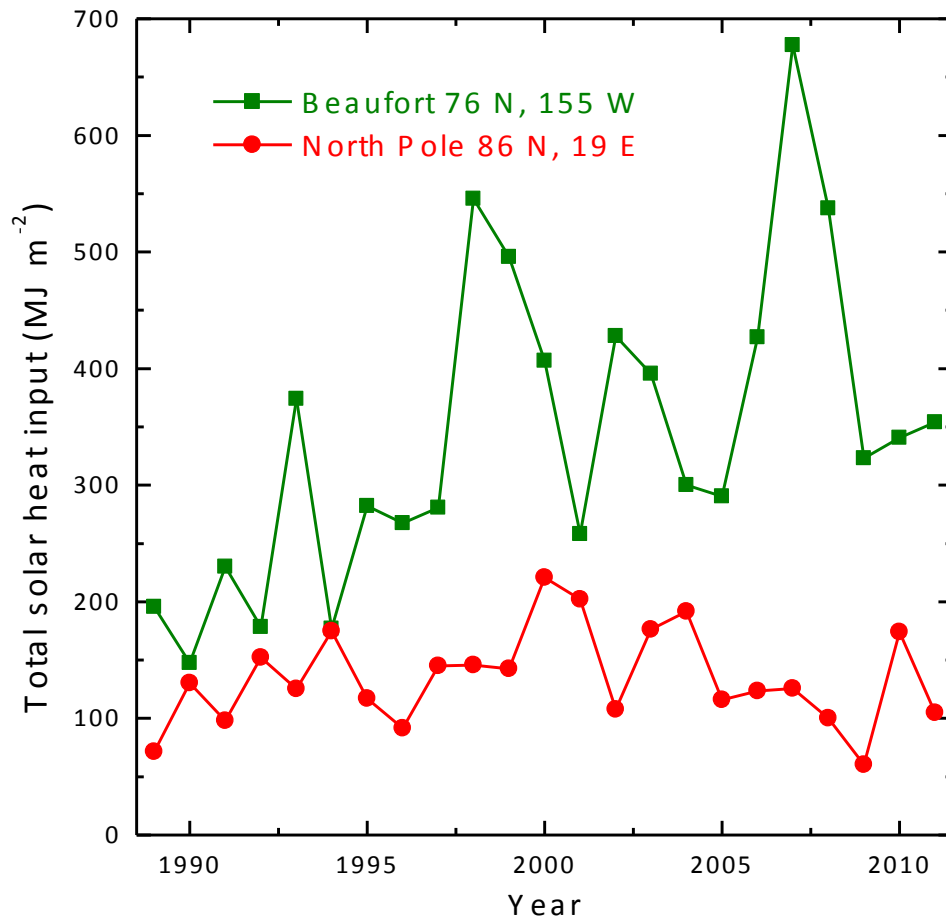
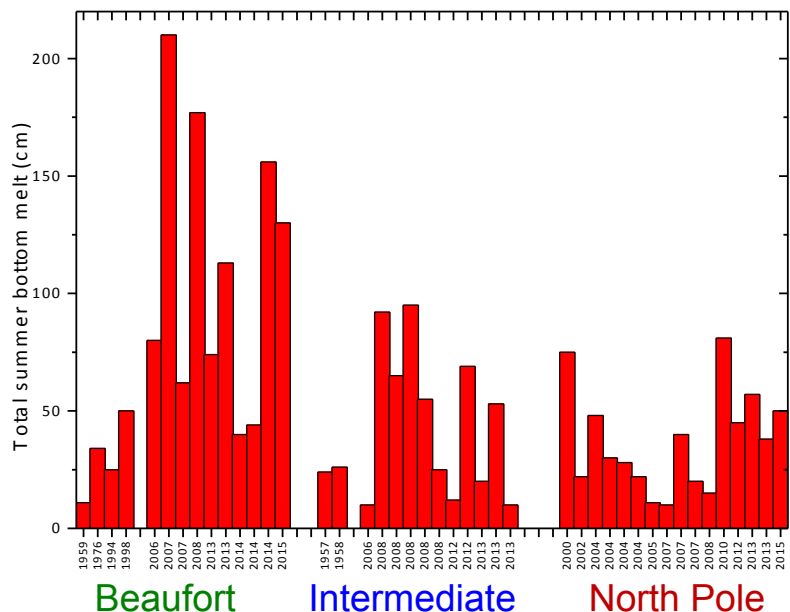
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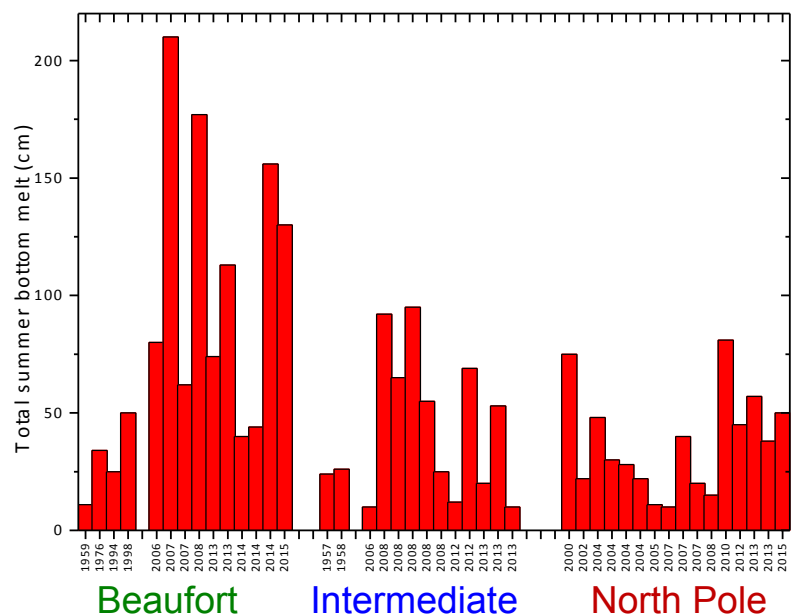


Large increases in Beaufort

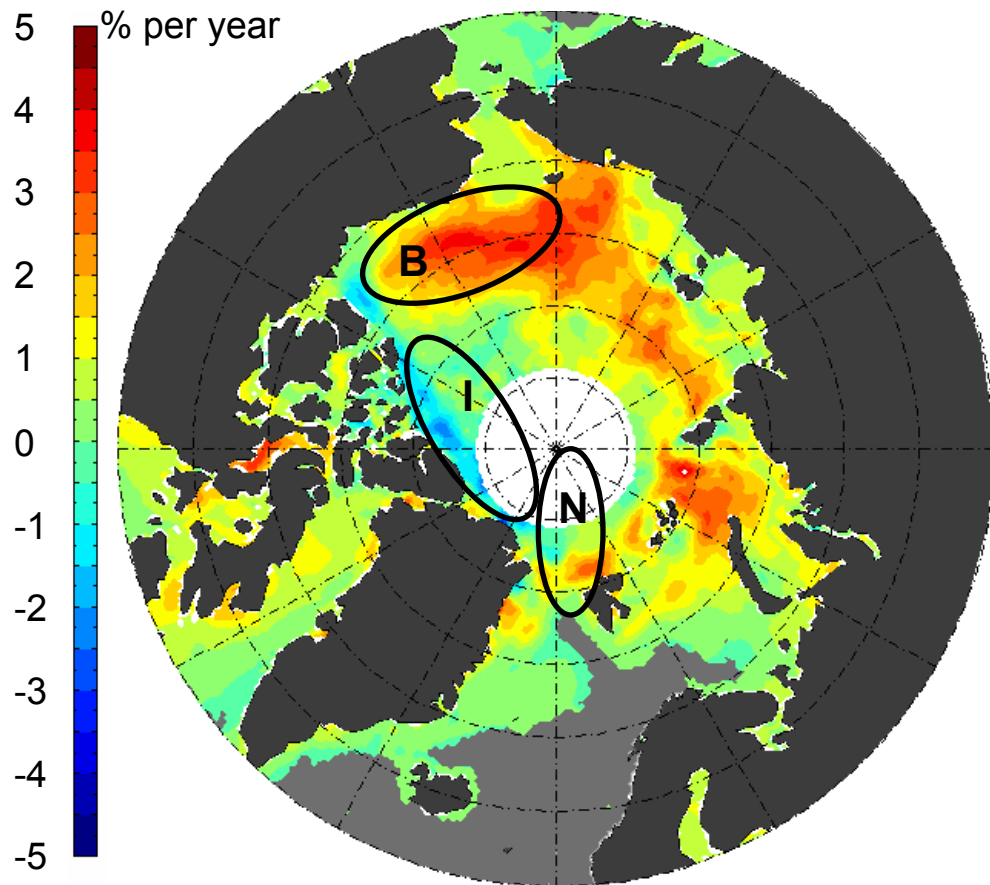
Bottom melt: Solar heating of the ocean

- Increased open water means more solar heat in ocean.
- More solar heat in ocean means more bottom melt.
- More bottom melt means more open water

- Much more bottom melt in Beaufort
- Evidence of ice albedo feedback



Trend of solar heat input to ocean



Increase in 90% of area, big increase in Beaufort

Summary

Trends and not

- Large spatial and interannual variability
- Less surface melt going north
- Modest temporal trends in surface melt
- No big trends: North Pole, Intermediate
- Much more bottom melt in Beaufort
- More bottom melting near the edges
- Ice albedo feedback is contributing

Key questions

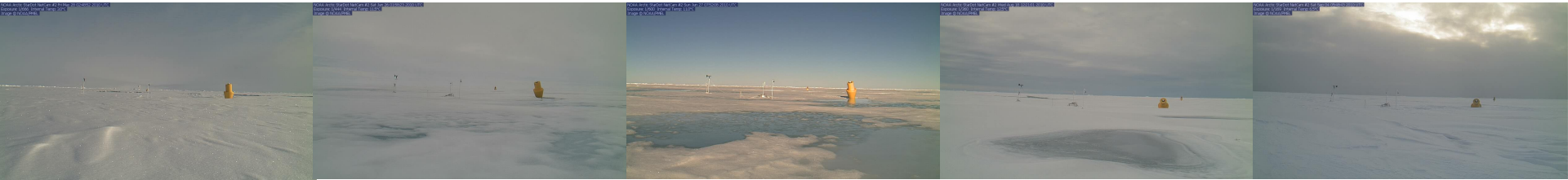
- What triggers the ice albedo feedback?
- What is the fate of ocean heat?
- How does ocean heat impact freezeup?
- Is the snow cover changing?
- Does more melt affect dynamics?



Thanks to NSF, NOAA, NPEO, BGEO, and many others

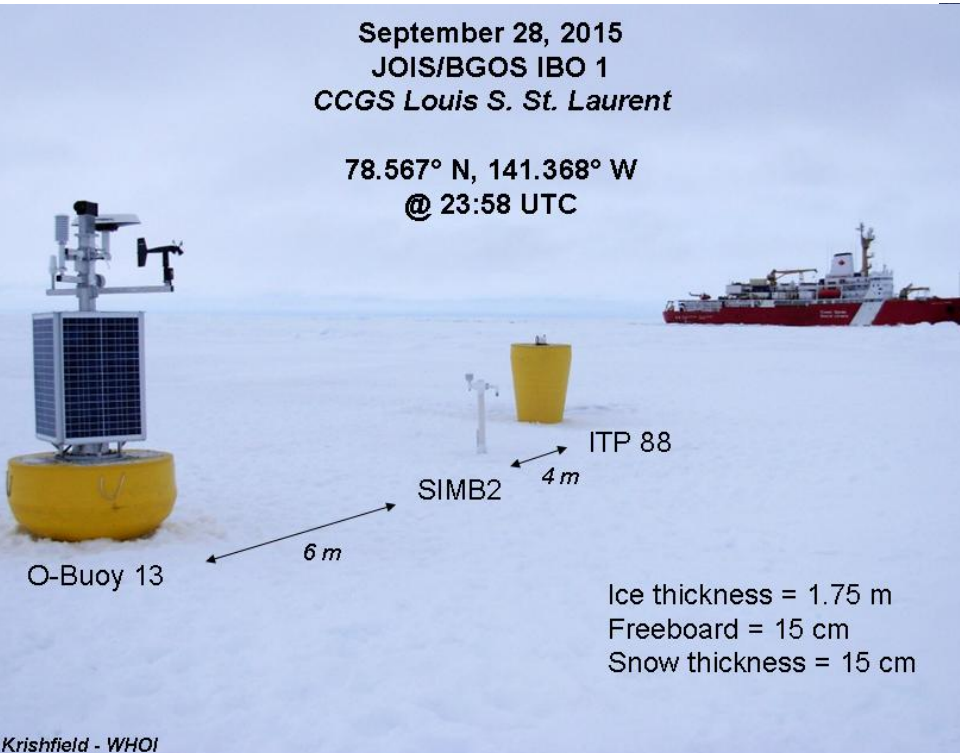
More ocean heat, more bottom melt, ice albedo feedback

Autonomous observing systems



Beaufort Gyre Environmental Observatory

North Pole Environmental Observatory



The key is atmosphere-ice-ocean-ecosystem observations