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Special guests

- ✧ *Circulation*:
  - Arctic – N. Atl.
- ✧ *Sea ice*:
  - ocean impacts
- ✧ *Stratification*:
  - a lot vs. a little
  - heat, momentum, etc

Today's sponsors

NSF, NASA, ONR

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Seattle, WA, USA

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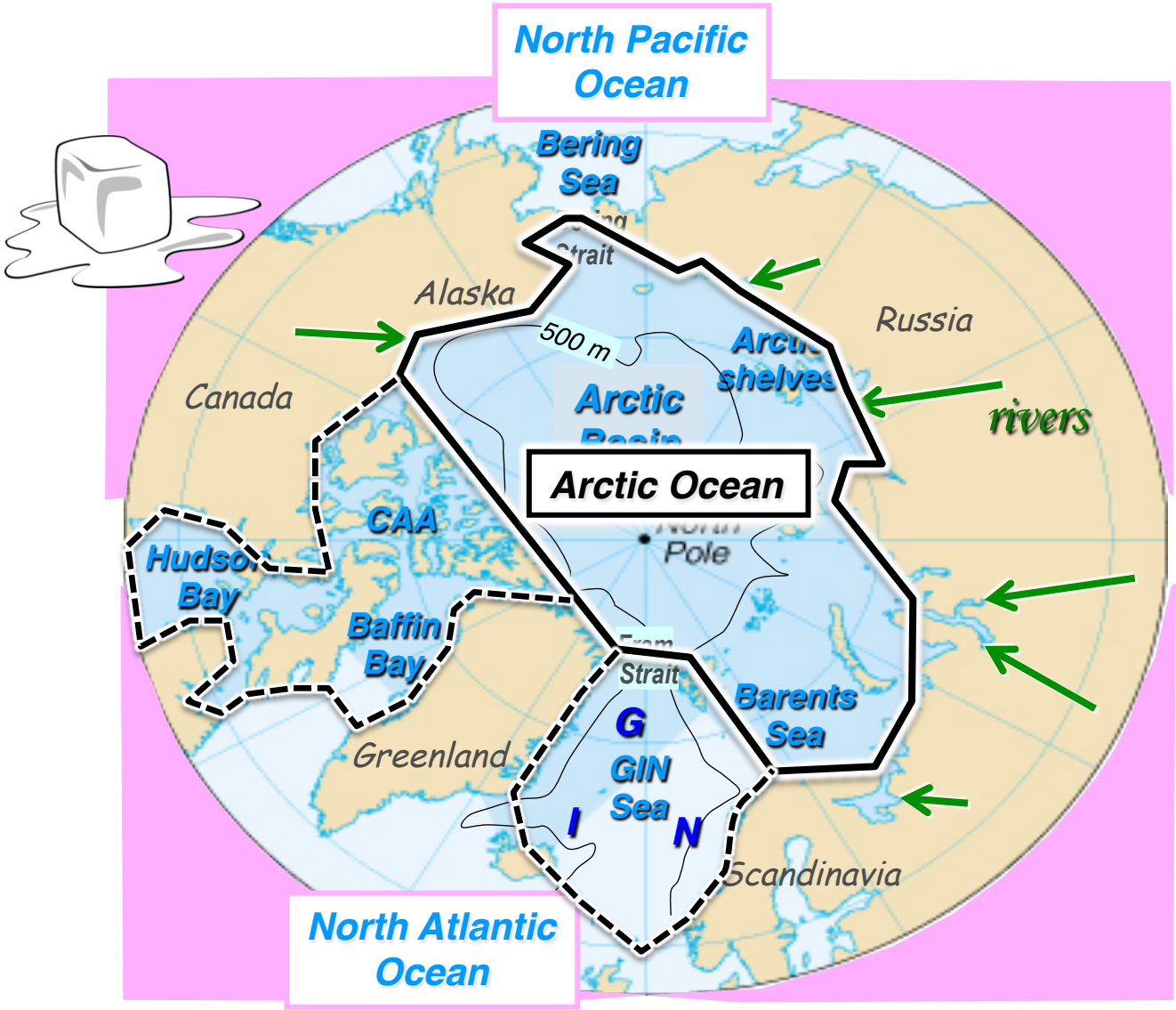
The Arctic Seas



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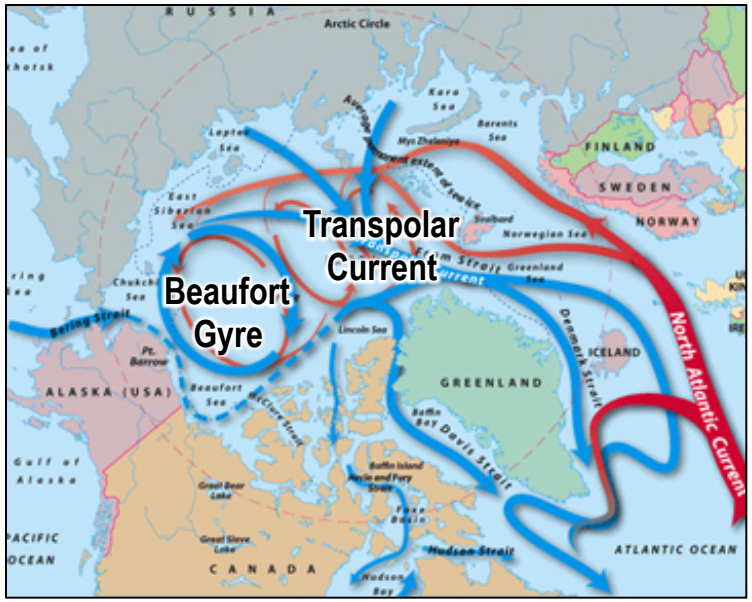
Arctic – N. Atlantic Circulation

Standard, arm-wavy view:



Warm in, cool out

More accurate:

1) Most heat loss near Atlantic inflow

2) It's **NOT** a dead-end! ("*backdoor*")

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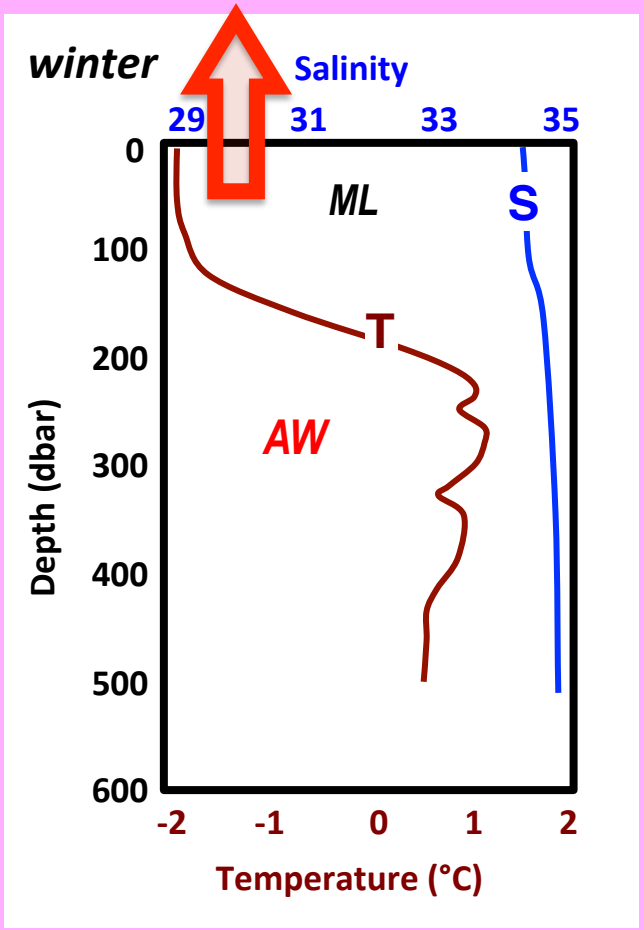
AIR · SEA · ICE

Water mass structure of the western *Eurasian Basin*



~ northern GIN Sea

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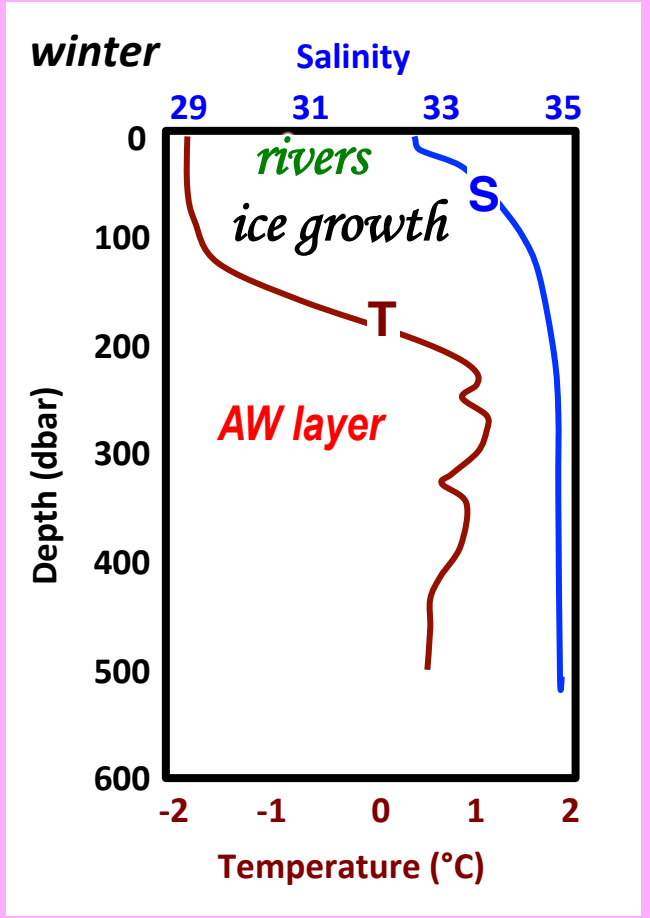
Water mass structure of the eastern *Eurasian Basin*



real Arctic structure

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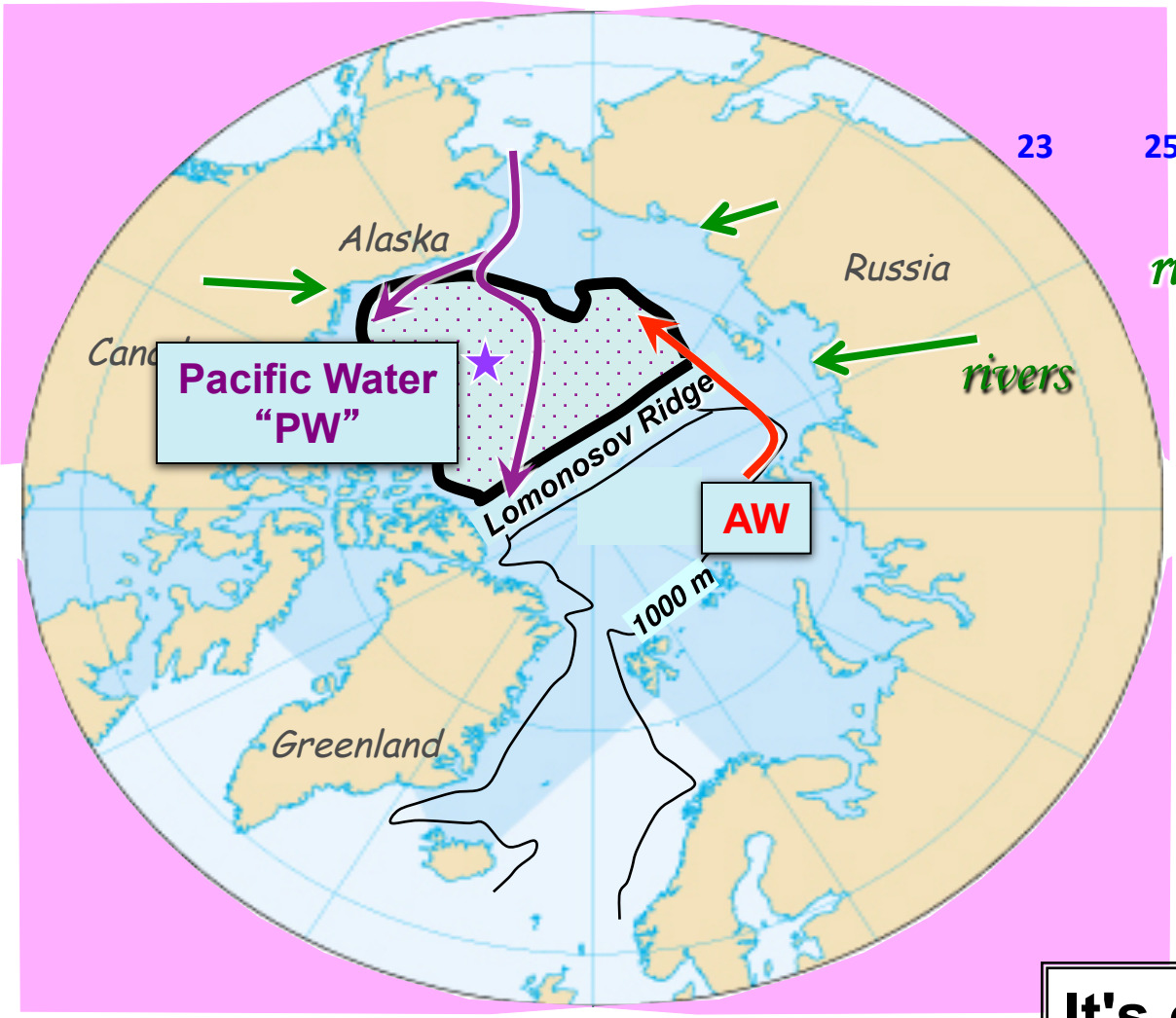
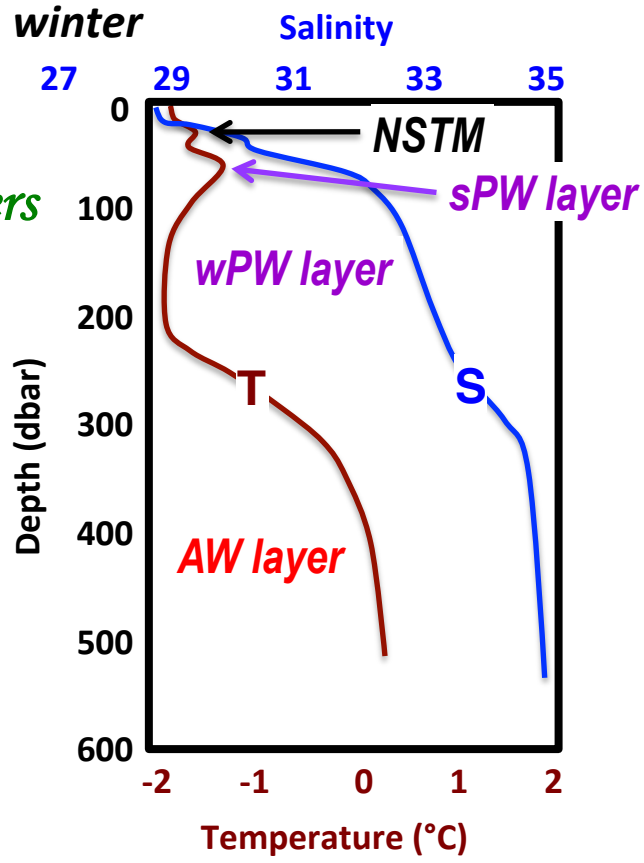
Water mass structure of the *Canadian Basin*





It's complicated...

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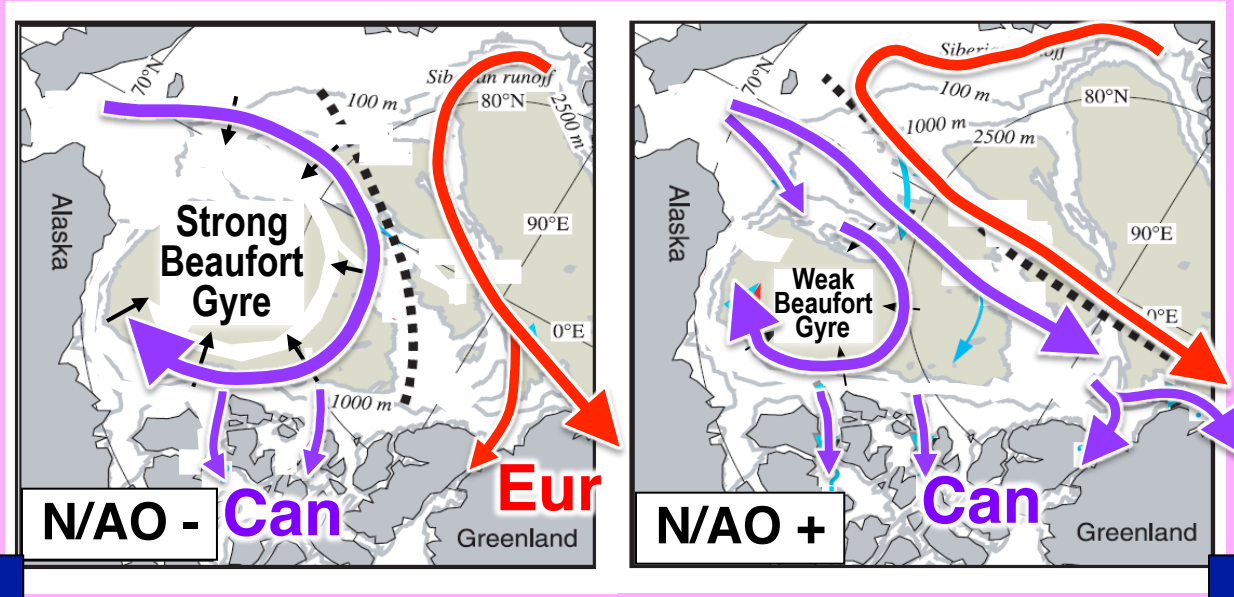
Arctic Ocean Outflows

Steele et al., 2004



2000s

1990s

Interannually variable

...espec. E & W of Greenland...

Proshutinsky et al., 2009
Rabe et al., 2011
Morison et al., 2012

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The *GIN Sea (in 1 minute)*

ASOF

Arctic-Subarctic
Ocean Fluxes

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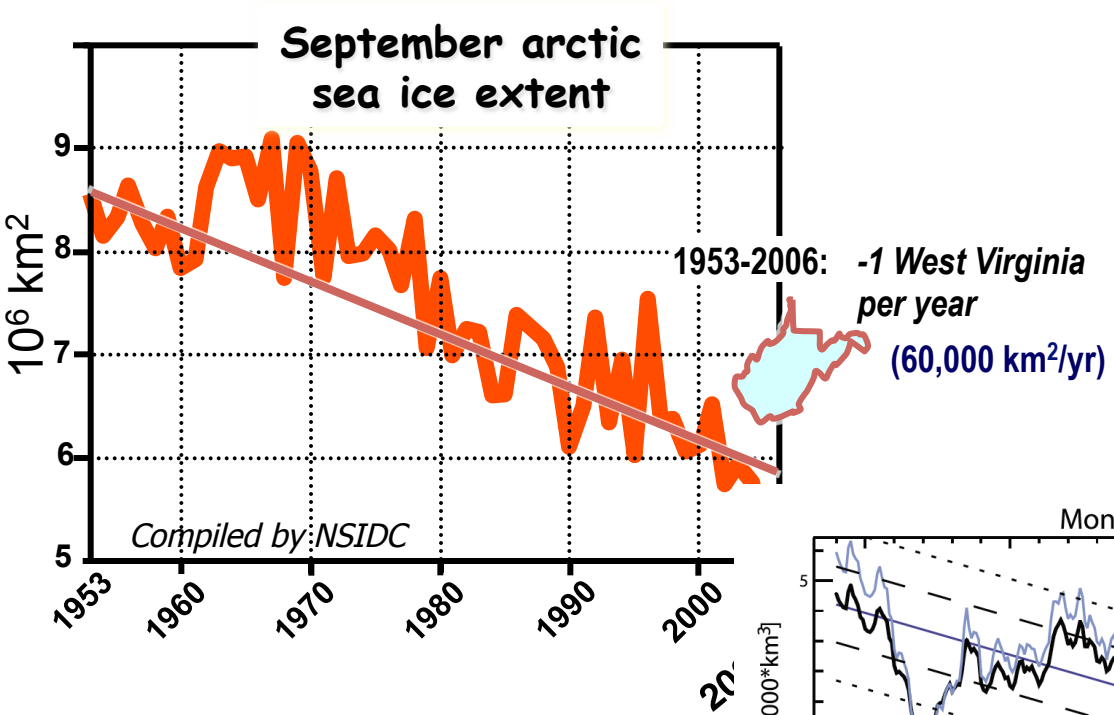
Sea Ice Decline

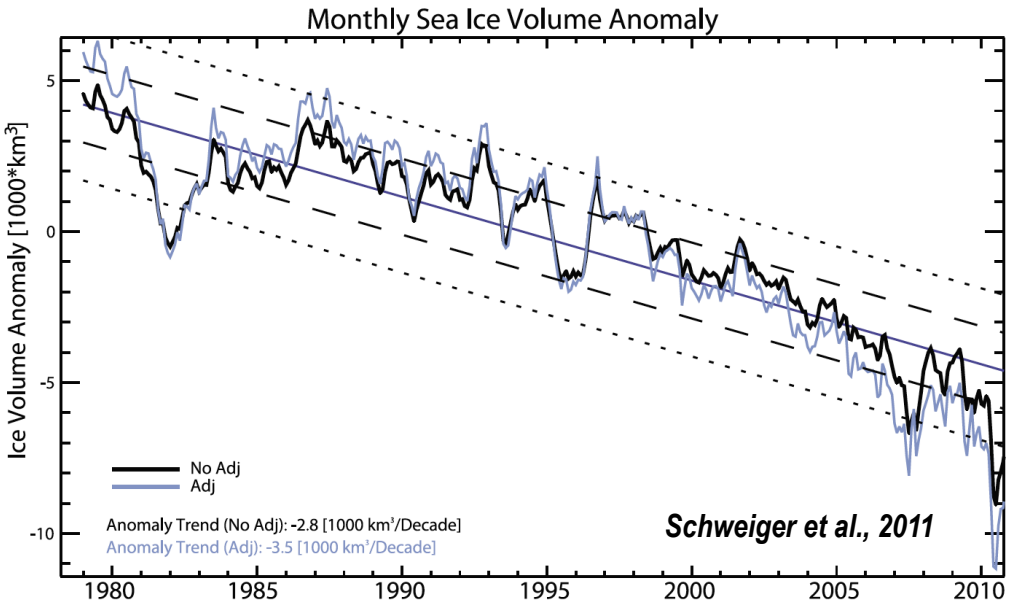


1953-2006: *-1 West Virginia per year*

(60,000 km^2/yr)

2006 → 2007:

(1.6 million kr



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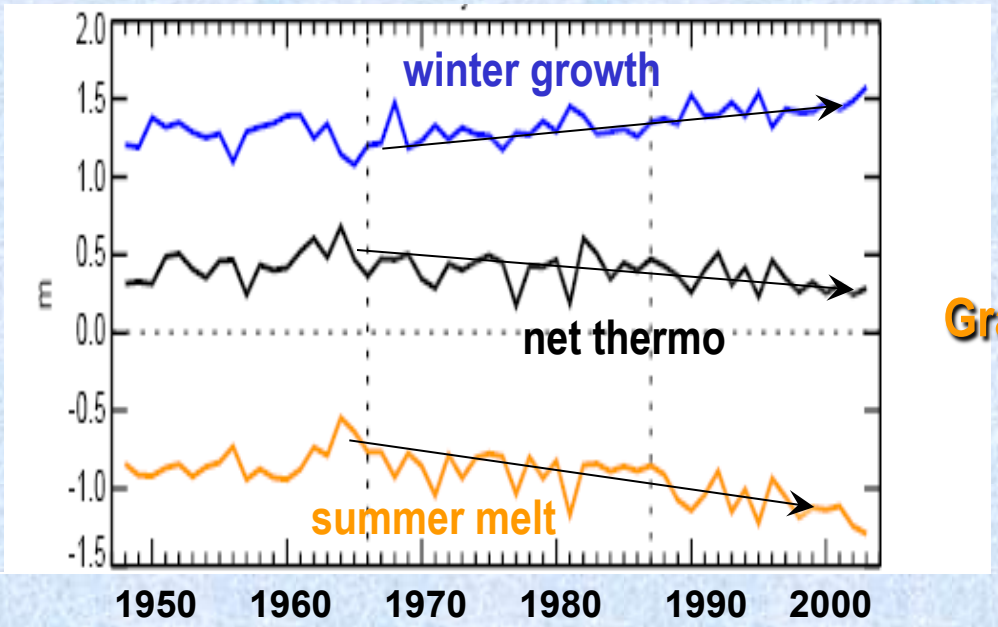
Why is sea ice declining?



Lindsay & Zhang (2005):
The Sea Ice "Tipping Point"

"Slow thermodynamics"

Gradual melt *increase* > growth *increase*

→ *ice thickness decrease*

→ stronger seasonal cycle

of
ice

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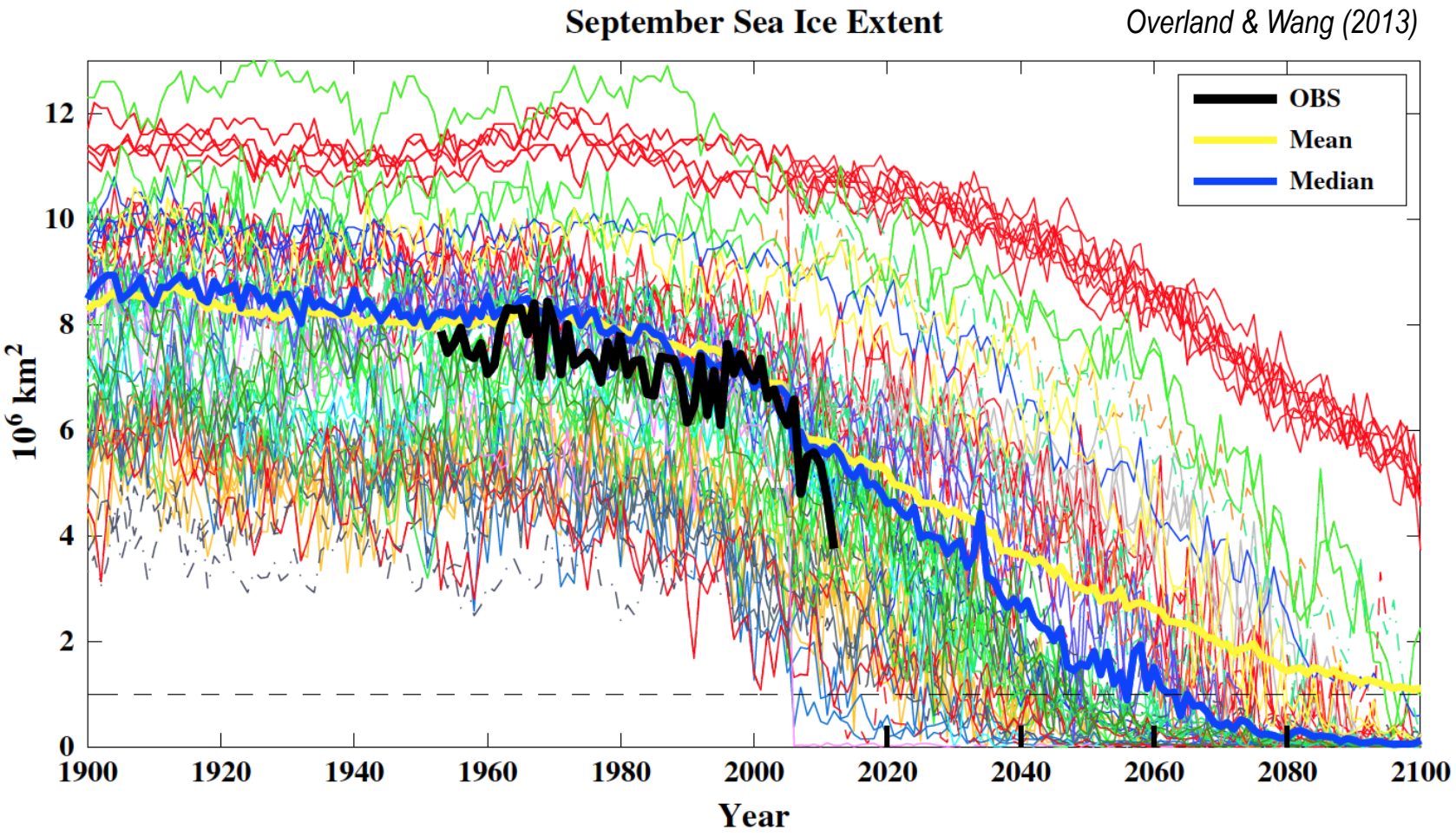
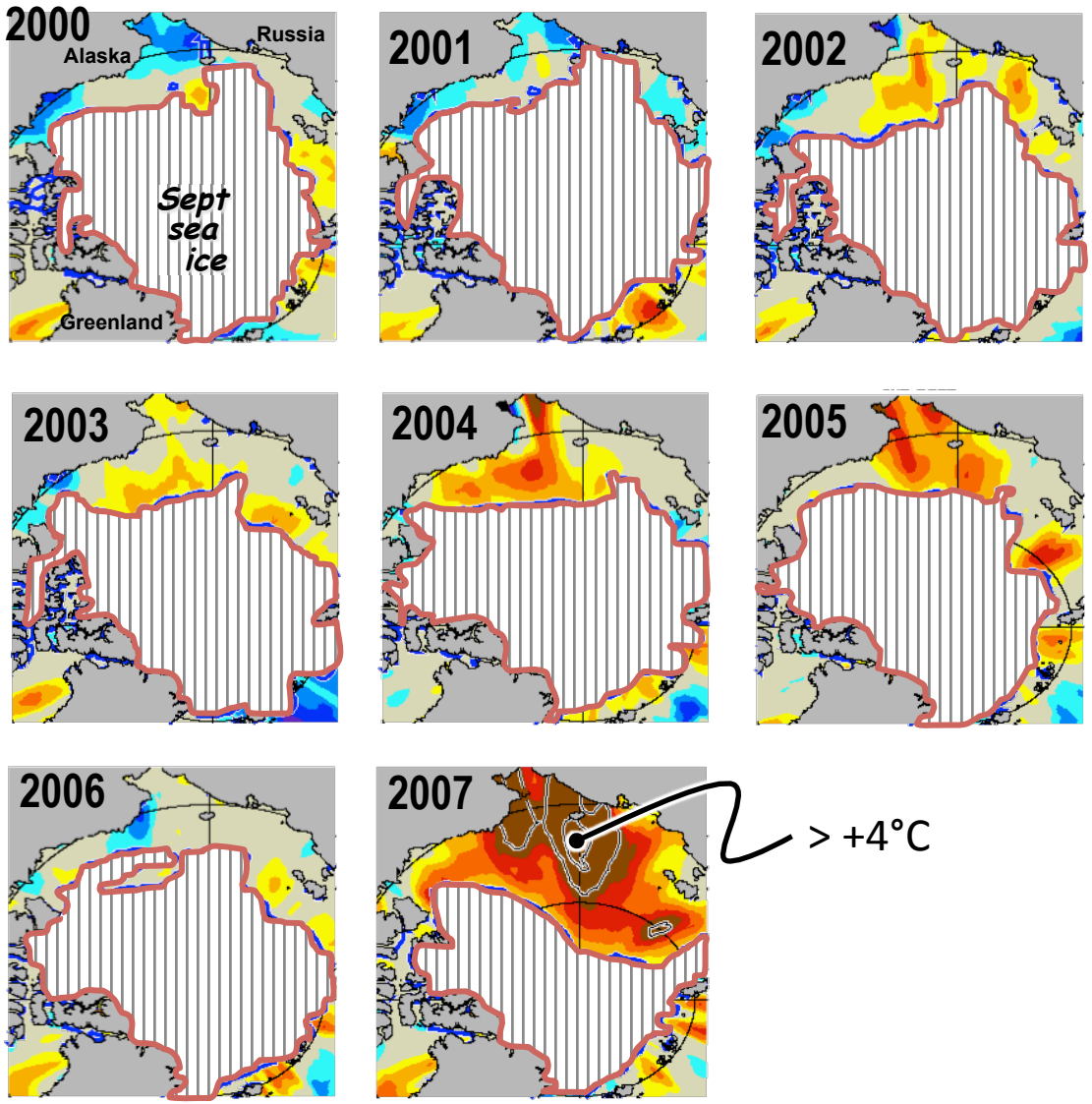
Future sea ice distribution



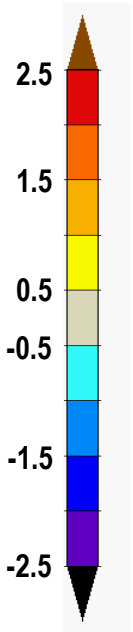
89 ensemble members from 36 CMIP5 models run under RCP8.5 (high) emissions scenario.

The ice is going away... 2060 ± ~30 years

Ice Retreat & Upper Ocean Warming



from Steele et al., GRL 2008



Anomaly of Summer ≡ JAS
Sea Surface Temperature (°C)

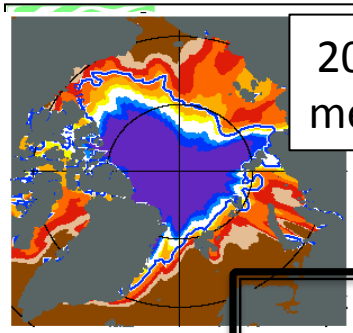
(relative to 1982-2007 mean)

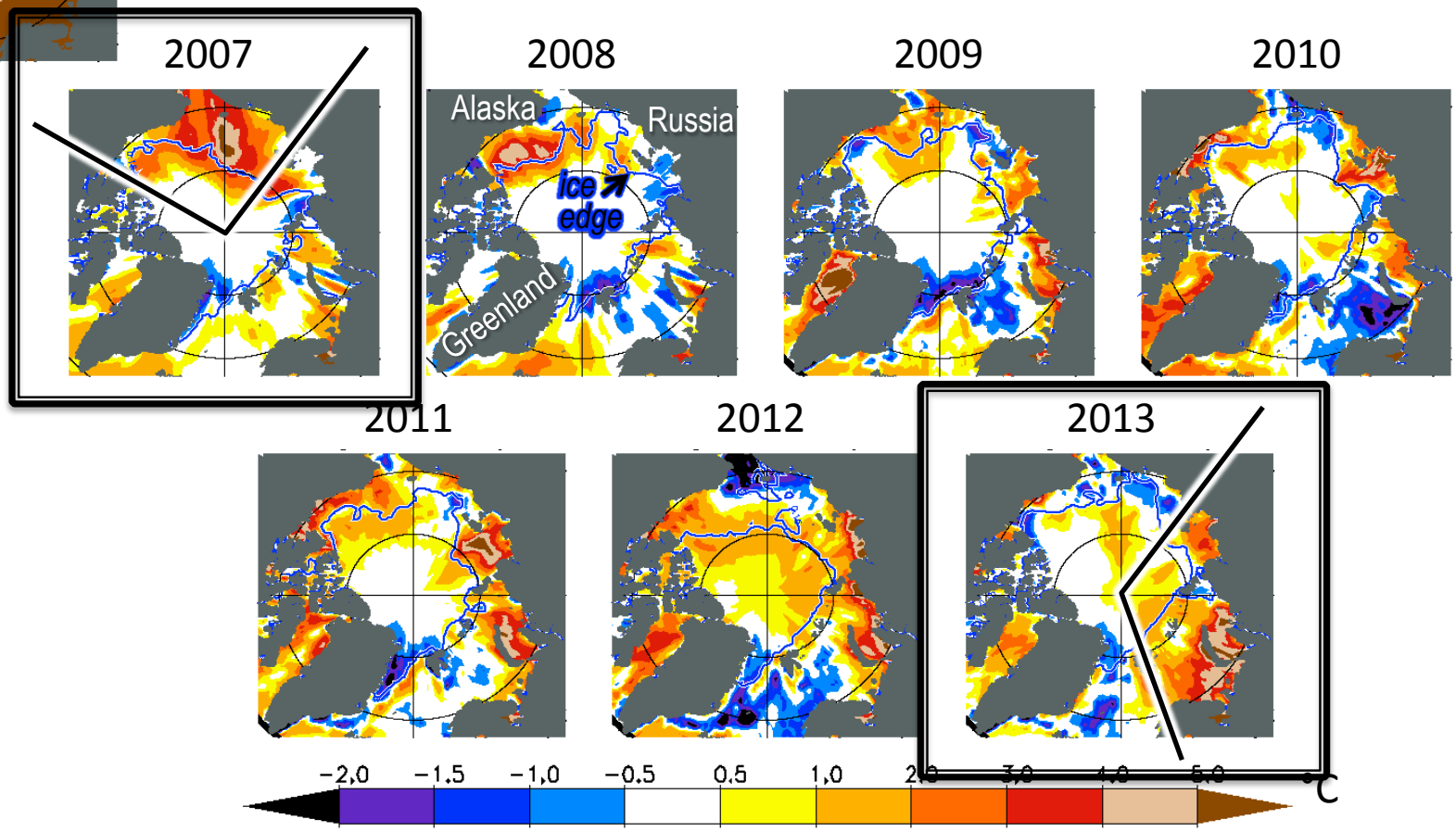
SSTs from monthly mean AVHRR (Reynolds et al)

National Weather Service
Environmental Modeling Center

Update since 2007

August Anomaly
(rel. to 1982-2006)





Canadian Arctic ➔ Eurasian Arctic

…paper in the works

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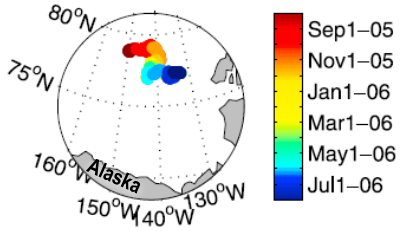
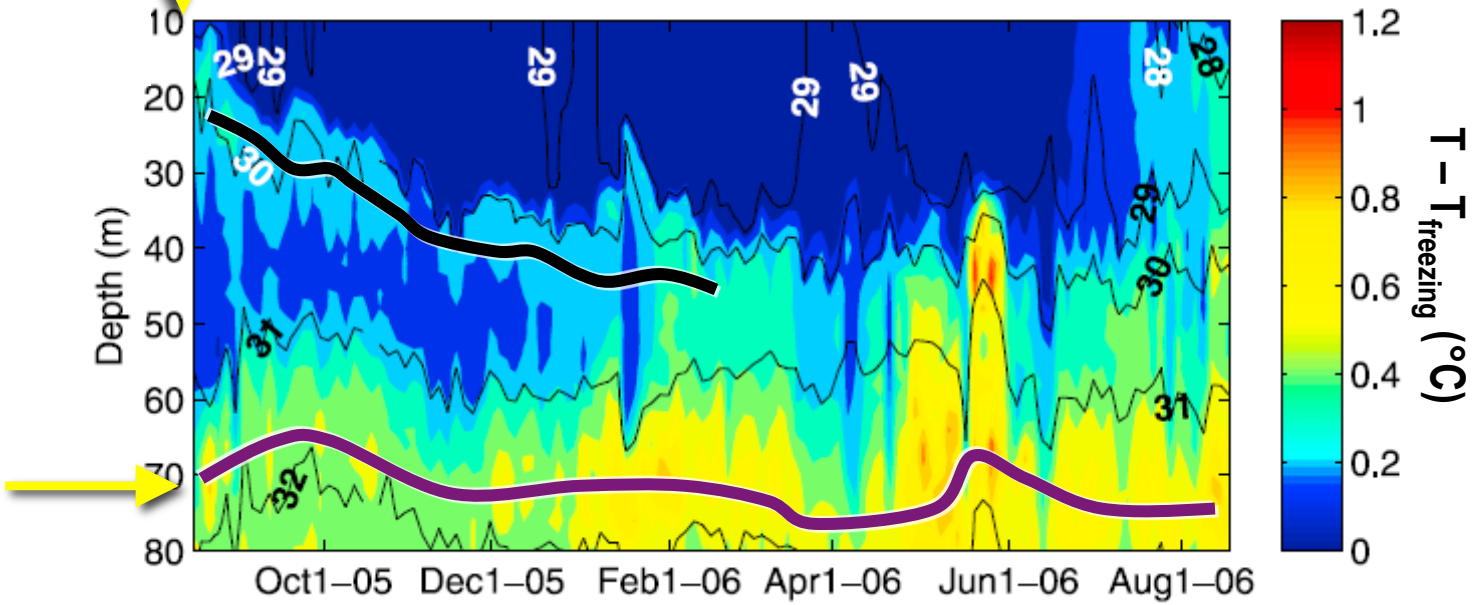
The "NSTM:" *Winter survival of summer heating*

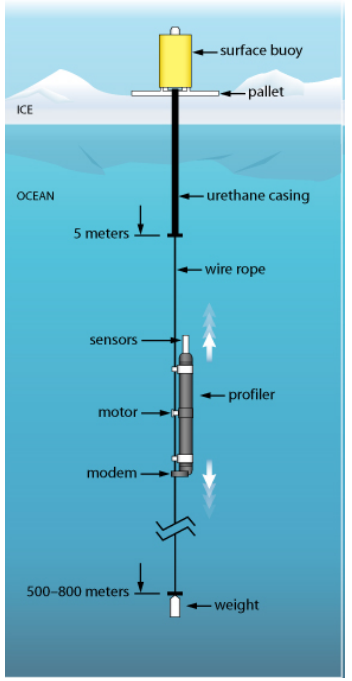


Jackson et al. JGR 2010



contours: Salinity

Data: Ice-Tethered Profiler



Krishfield et al. J. Tech. 2008

The "Near-Surface Temperature Maximum"
…a LOCAL Tmax layer, as opposed to…
"summer Pacific Water" (sPW)

ITP data 2007-2008: NSTM survives through the winter! Why? See: Steele et al. JGR 2011

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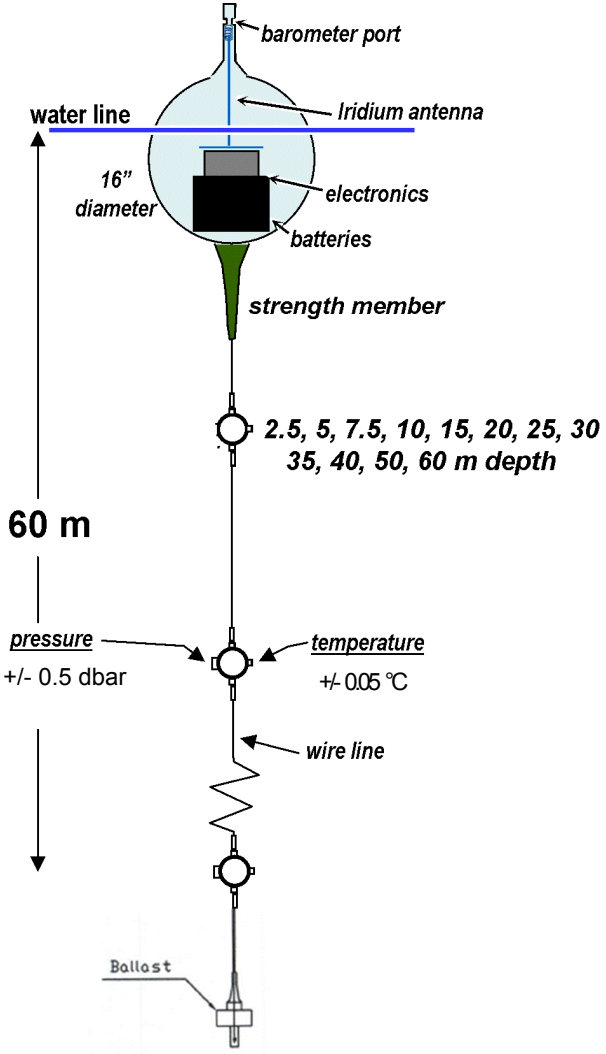
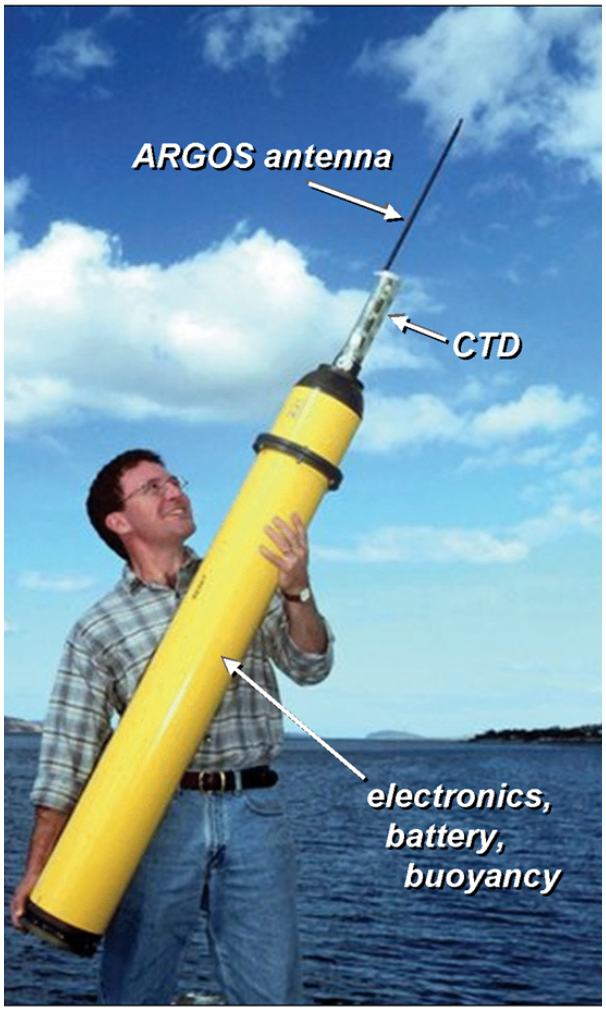
Measuring Upper Ocean Warming

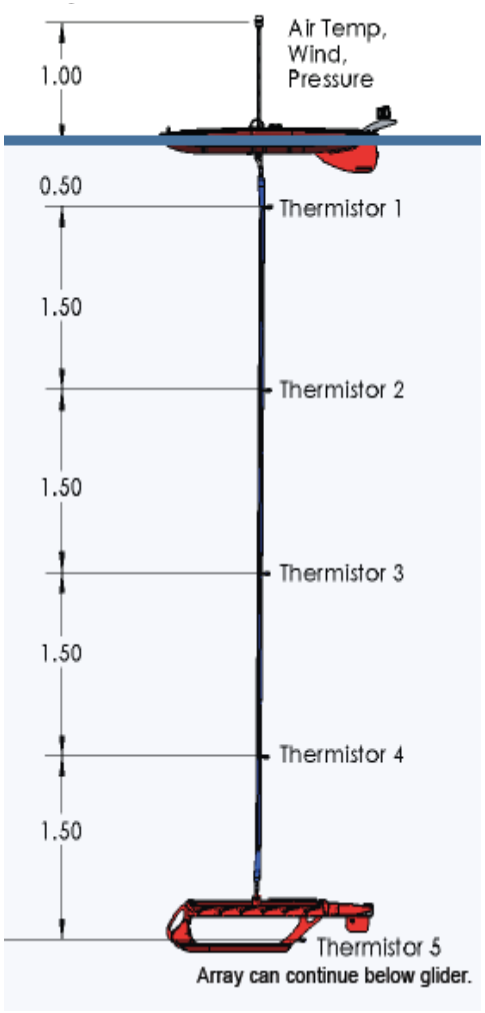
UpTempO buoys



profiling floats



wave glider



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Arctic Ocean: The Future

- Beaufort Gyre discharge: *soon?*
- ↑ precip/rivers, ↑ mixing: *stratification ↑ or ↓ ?*
  - *Δ upward flux of subsurface heat*
  - *Δ mixed layers*
  - *Δ liquid outflows to NE & NW Atlantic*
- *Sea ice: 'way thinner; no more summer export*

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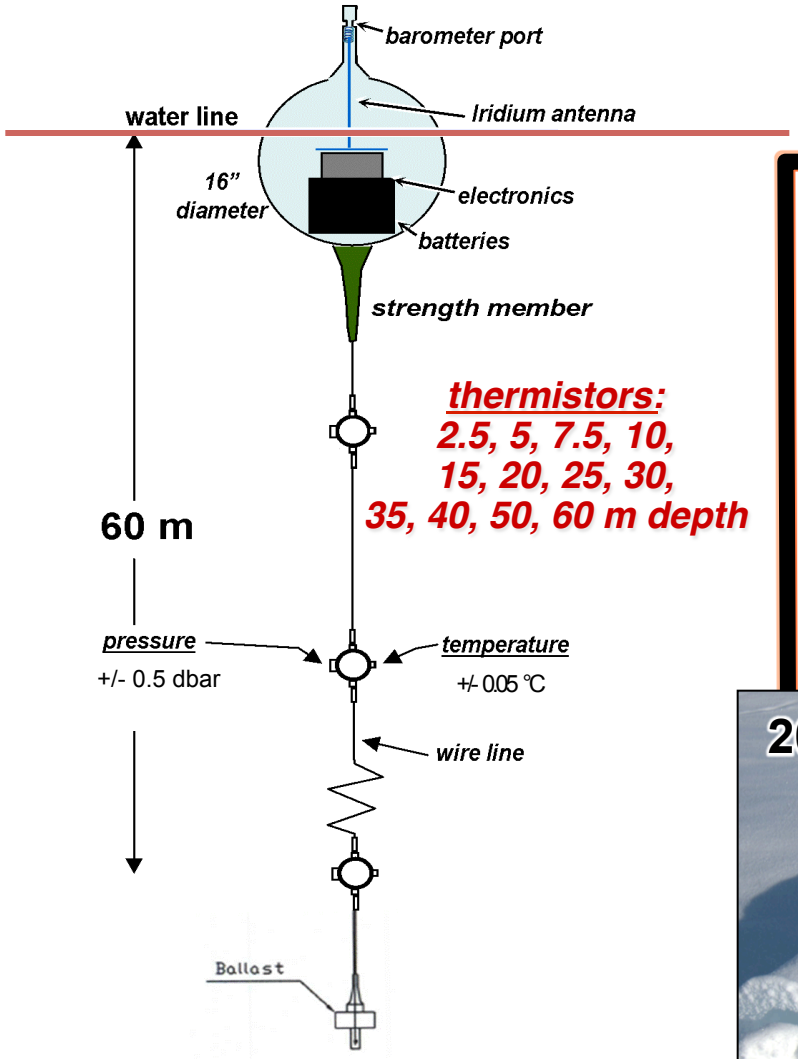
Thank You

The UpTempO buoy

M. ***Steele*** *+ I.* ***Rigor***

Upper Temperature of the polar Oceans



- SLP, GPS, Iridium antenna
- Deployable in *ice* or *water* by ship, ice camp, air
- 12-16 thermistors:
  - 0.05°C accuracy

  → 60 m depth spans euphotic zone
- Hourly sampling

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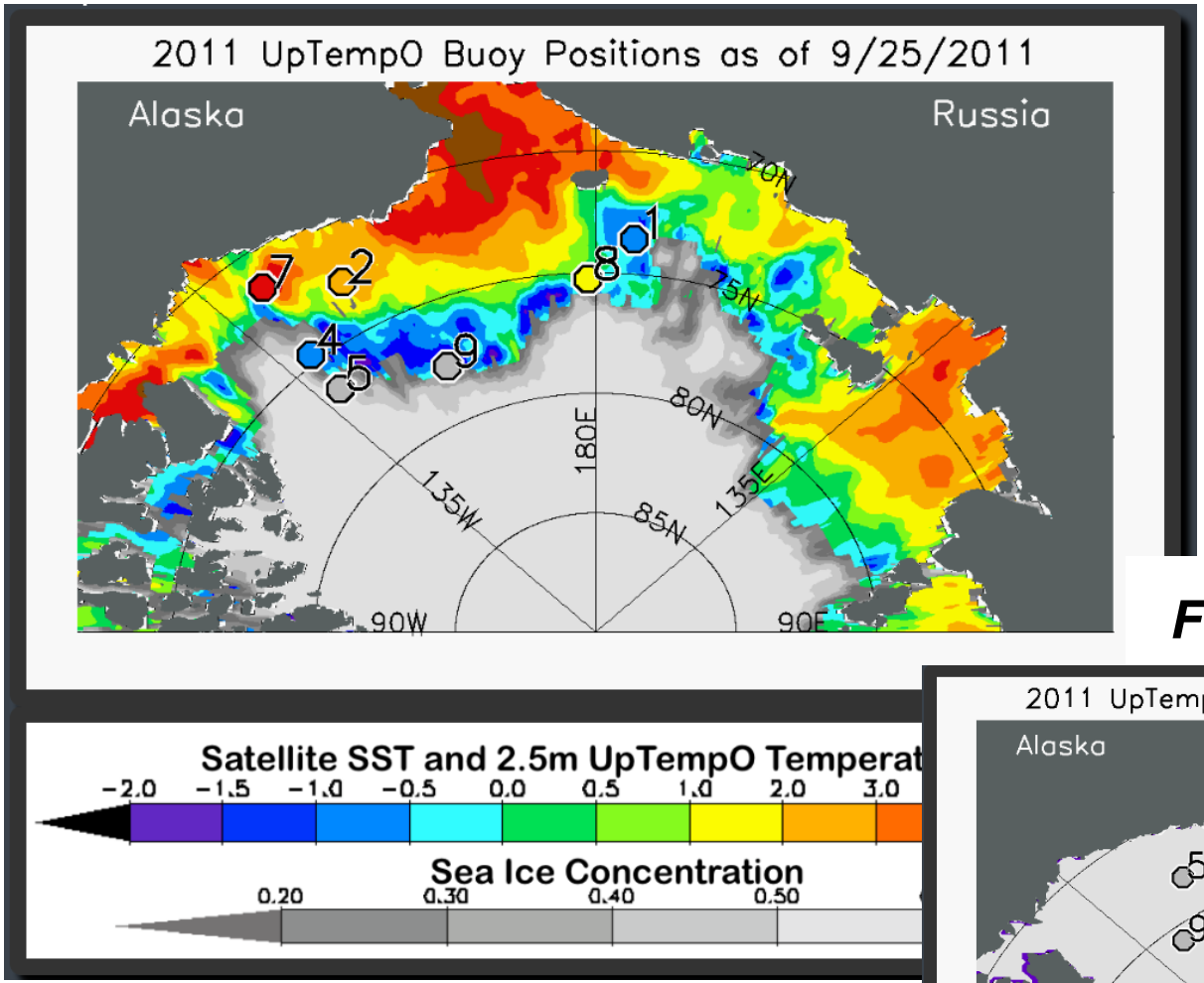
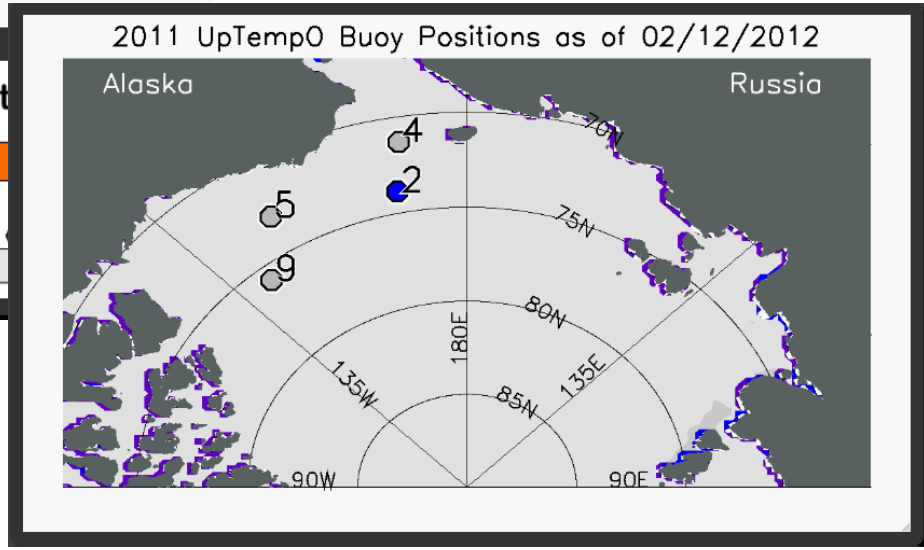
Satellite vs. Buoy SST: *September 25, 2011*



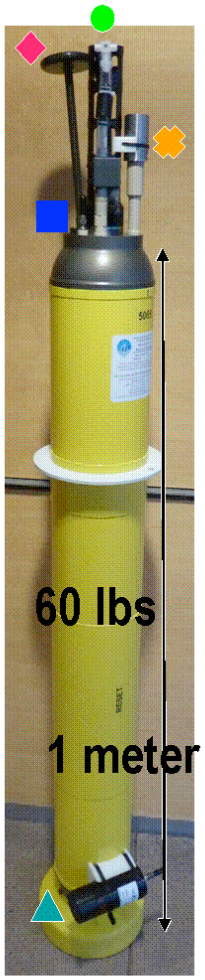
The “seasonal ice zone” is tough on buoys!

…not sure what to do…

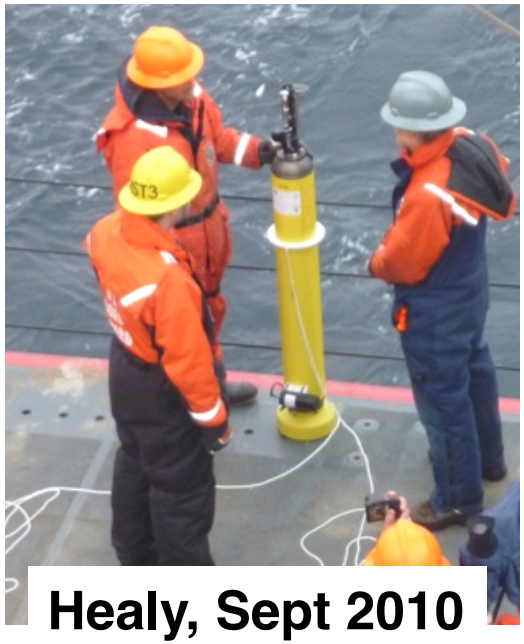
February 12, 2012



Profiling floats for Arctic Biogeochemistry



- Angled Iridium antenna
- Wetlabs FLBB fluorometer/ backscatter sensors *(700 nm; 470/695 nm)*
- ISUS nitrate sensor
- Seabird CTD
- Aanderaa optode O_2 sensor



Healy, Sept 2010

NASA Biogeochemistry Program:

M. ***Steele*** *+ P.* ***Matrai*** *+ S.* ***Riser***

challenges: *solutions*

- **ice cover**:
  "ice avoidance"
  (or repeat surfacing)
- **extreme stratification**:
  surface ballasting
  (or more buoyancy)

…lots of room for improvement

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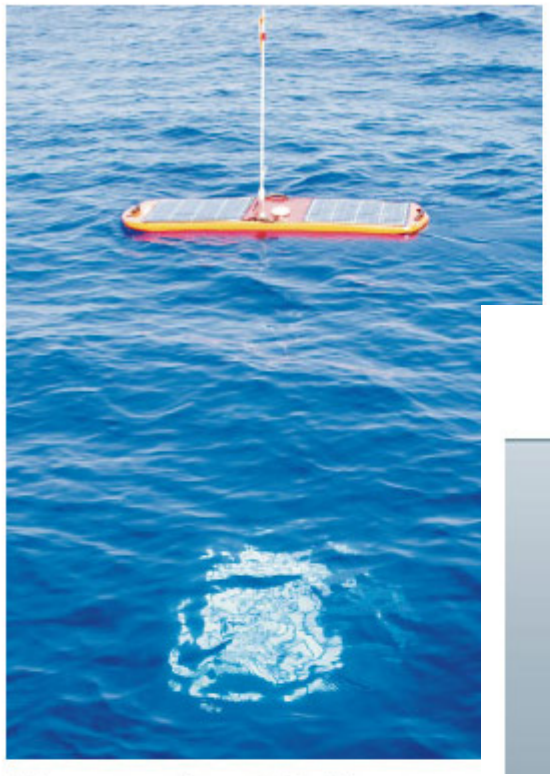
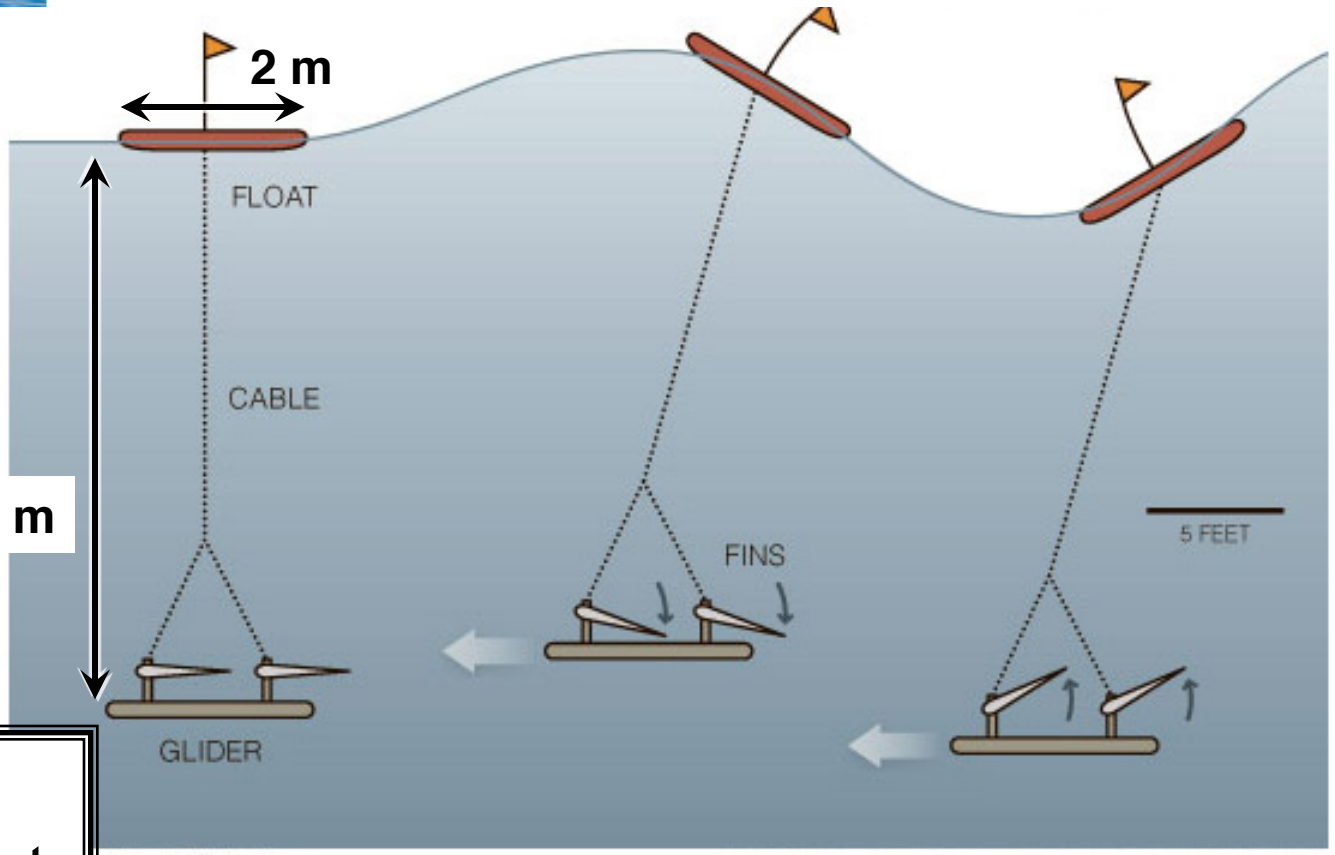
Wavegliders

…by Liquid Robotics Co., Sunnyvale, CA



Waves → motion

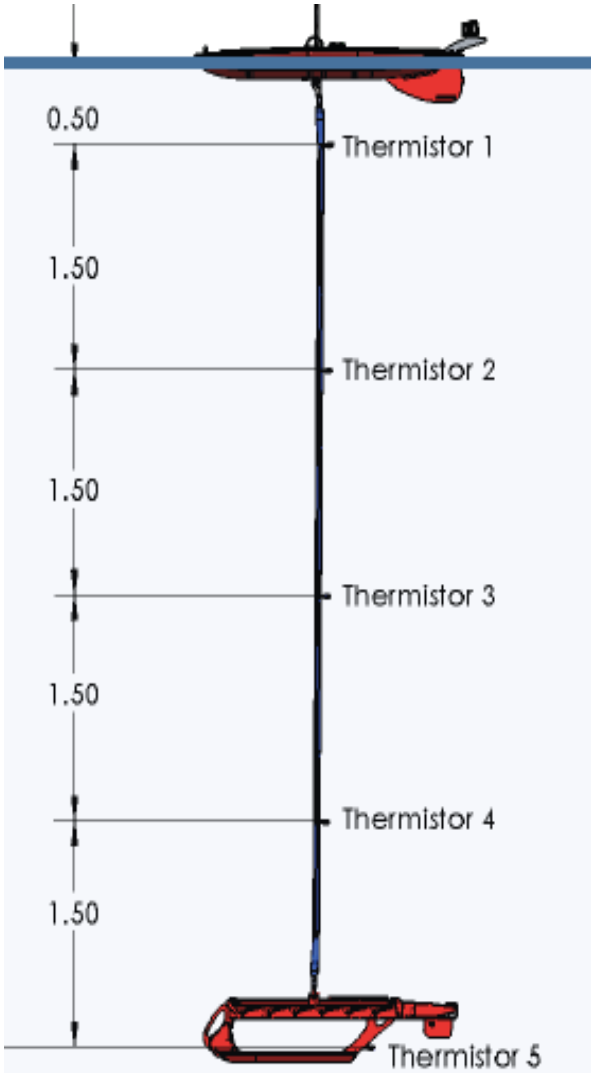


Min wave height: ~5 cm

“typical” speed: ~ 0.5-2 knots

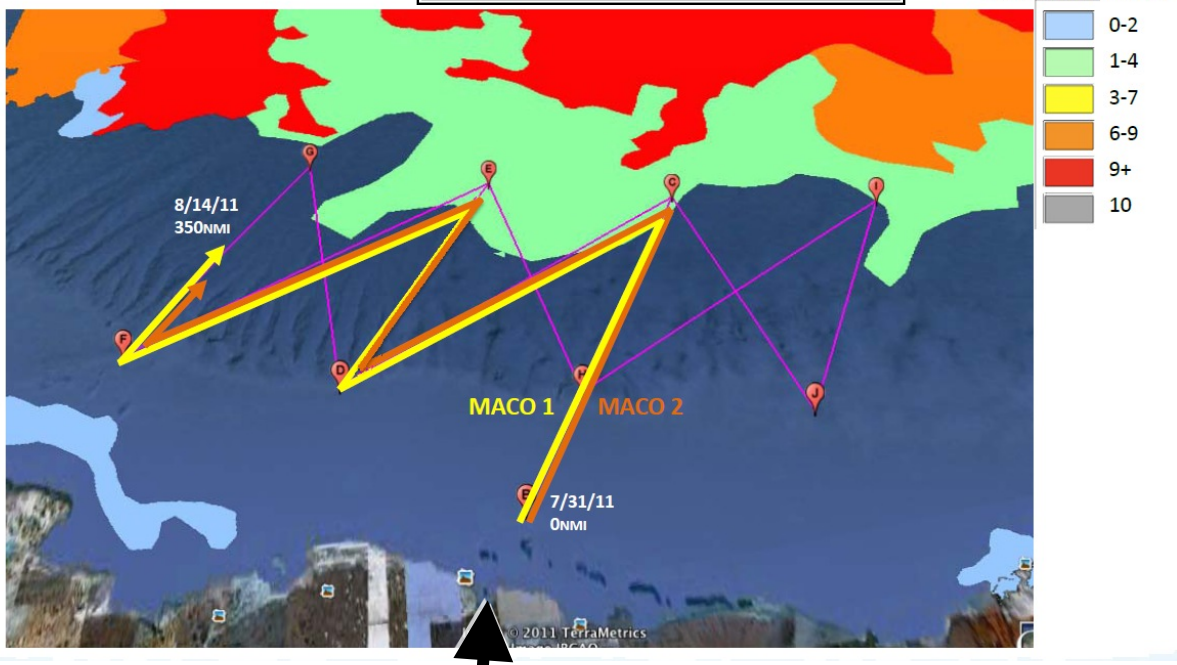
Waveglider for Arctic SST

- Idea: *N. Untersteiner*
- Science: *M. Steele*
- Logistics: *NOAA/PMEL + LRI*



Arctic Wave Glider Program

July 31 – Sept 14, 2011



Prudhoe Bay, Alaska

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The Arctic "Backdoor"

Steele & Ermold (2007)