Ocean Warming and Greenland's Ice Loss:

The case for sustained ocean observations on Greenland's continental shelf

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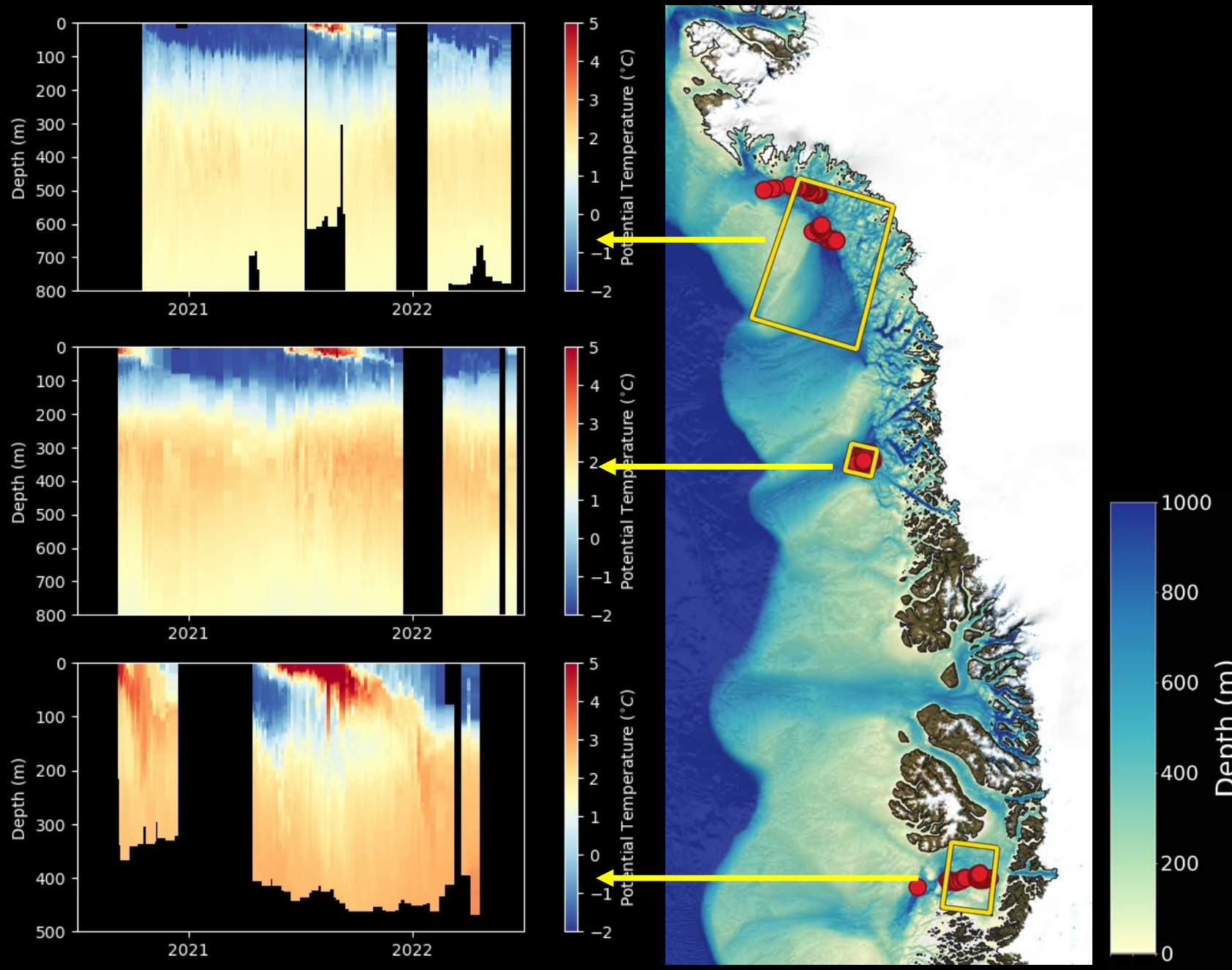
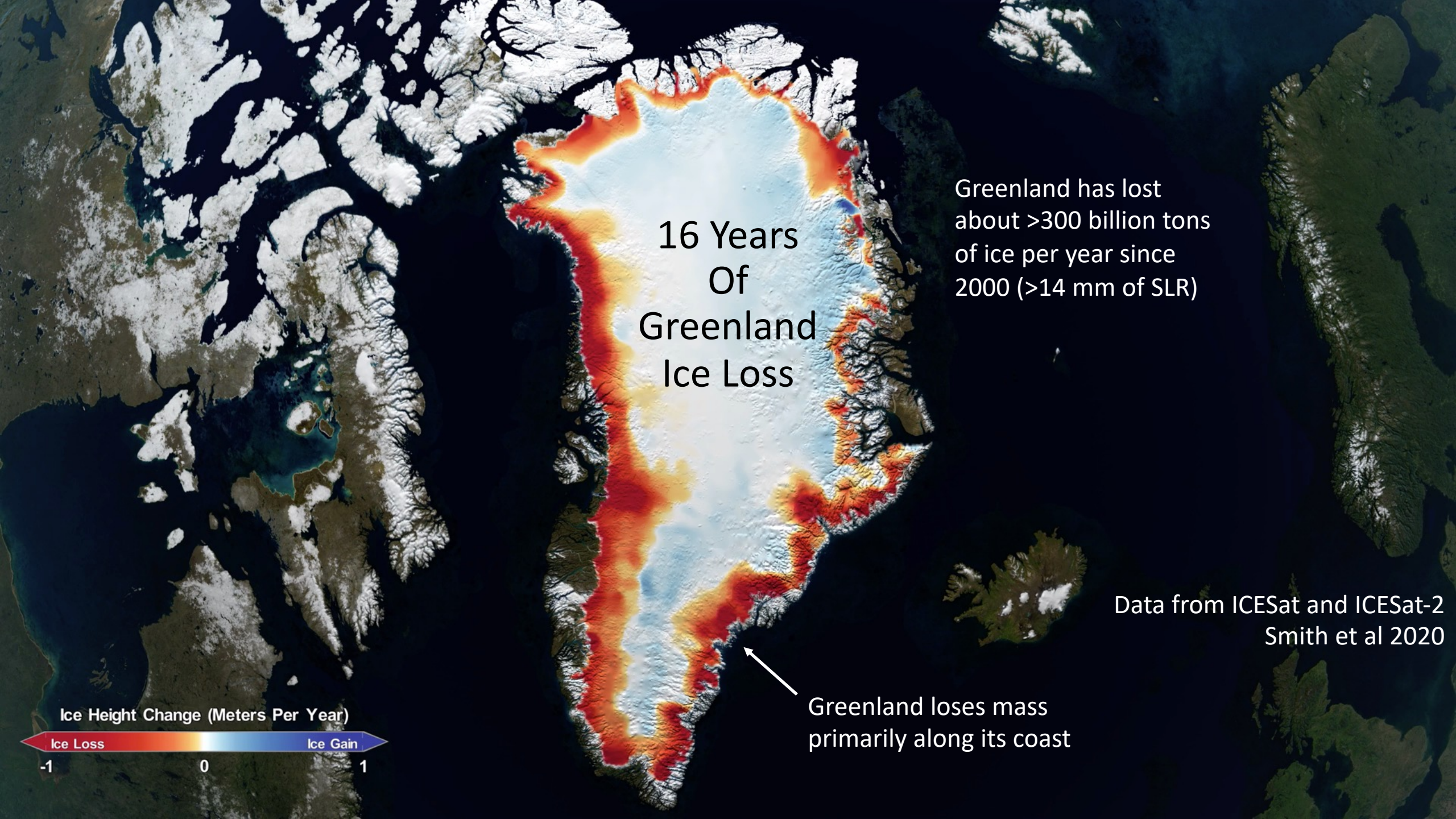
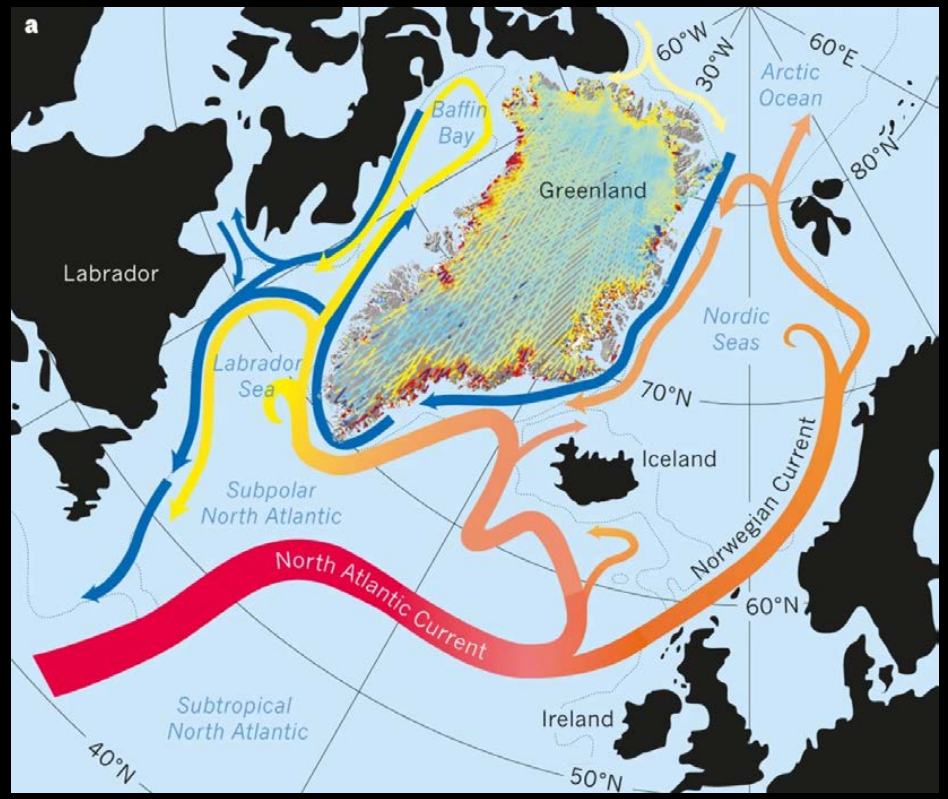
Autonomous Profiling Floats on Greenland's Shelf

- Floats deployed on the shelf and parked on the bottom remain on the shelf throughout the winter
- In these key regions, floats sample temperature year-round

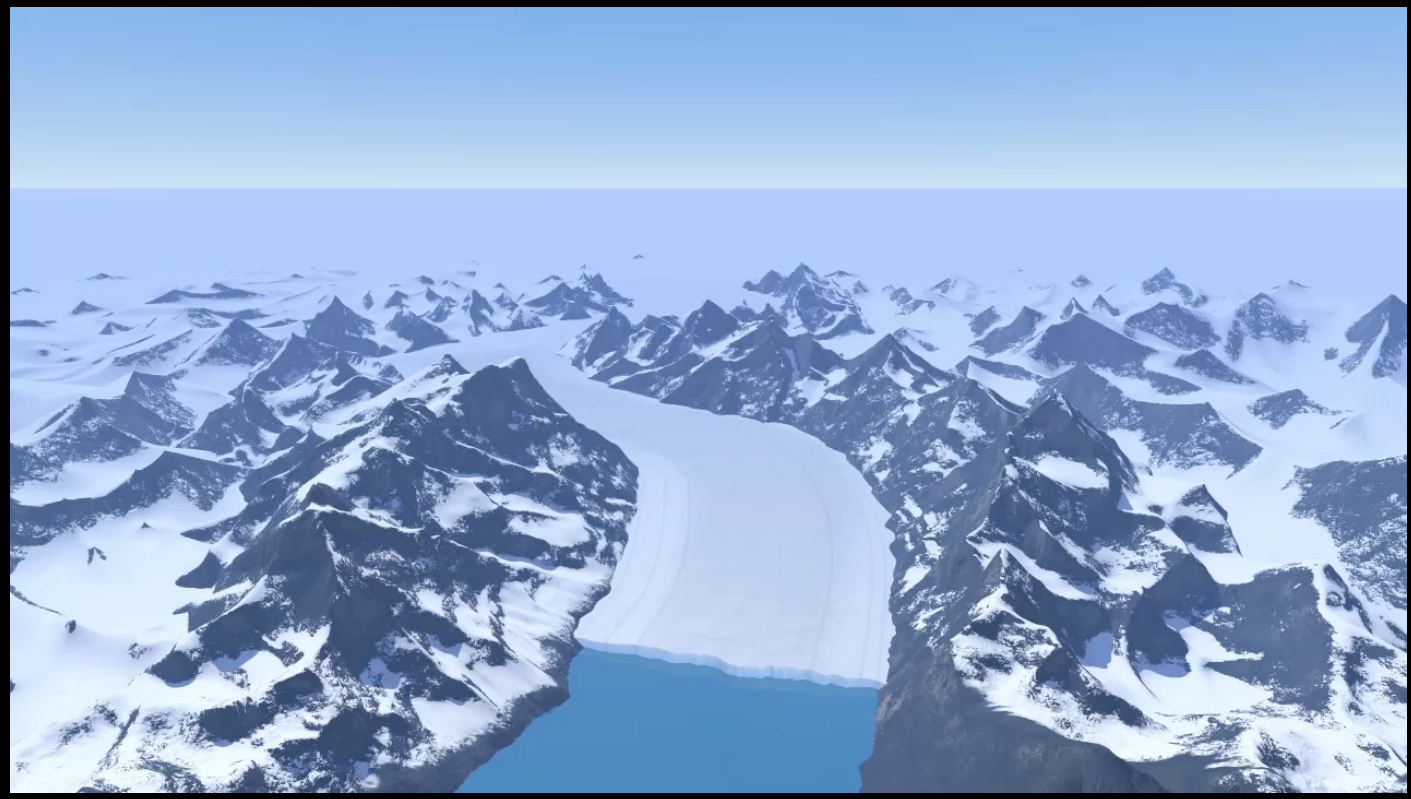



16 Years
Of
Greenland
Ice Loss
Greenland has lost about >300 billion tons of ice per year since 2000 (>14 mm of SLR)
Data from ICESat and ICESat-2
Smith et al 2020
Greenland loses mass primarily along its coast
Ice Height Change (Meters Per Year)
Ice Loss
Ice Gain
-1
0
1

Ocean-Forced Ice Loss



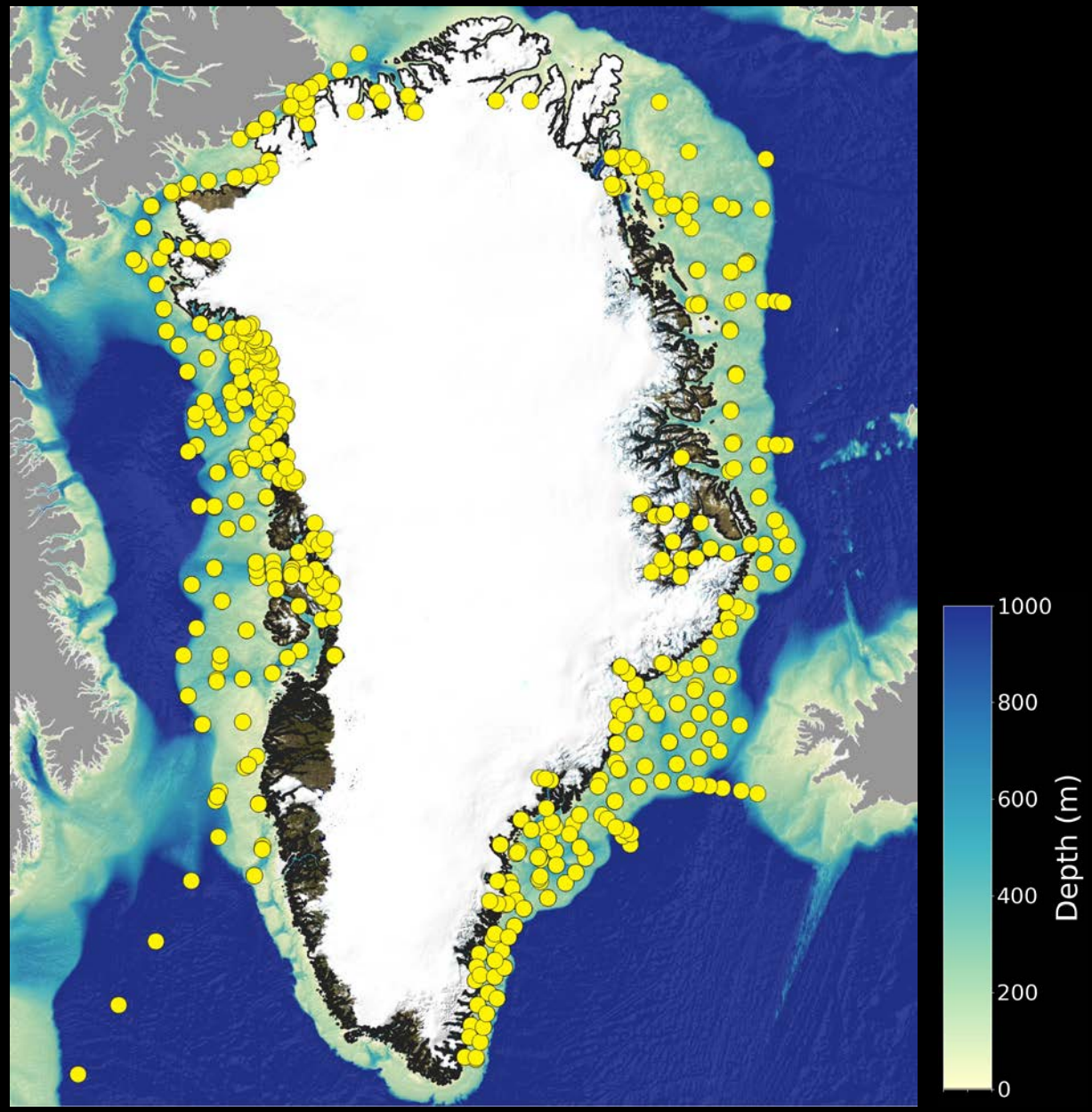
Warm, Salty water is advected around Greenland form the North Atlantic



Depth and temperature measurements are key for to quantifying melt!

Ocean Observations during NASA's OMG

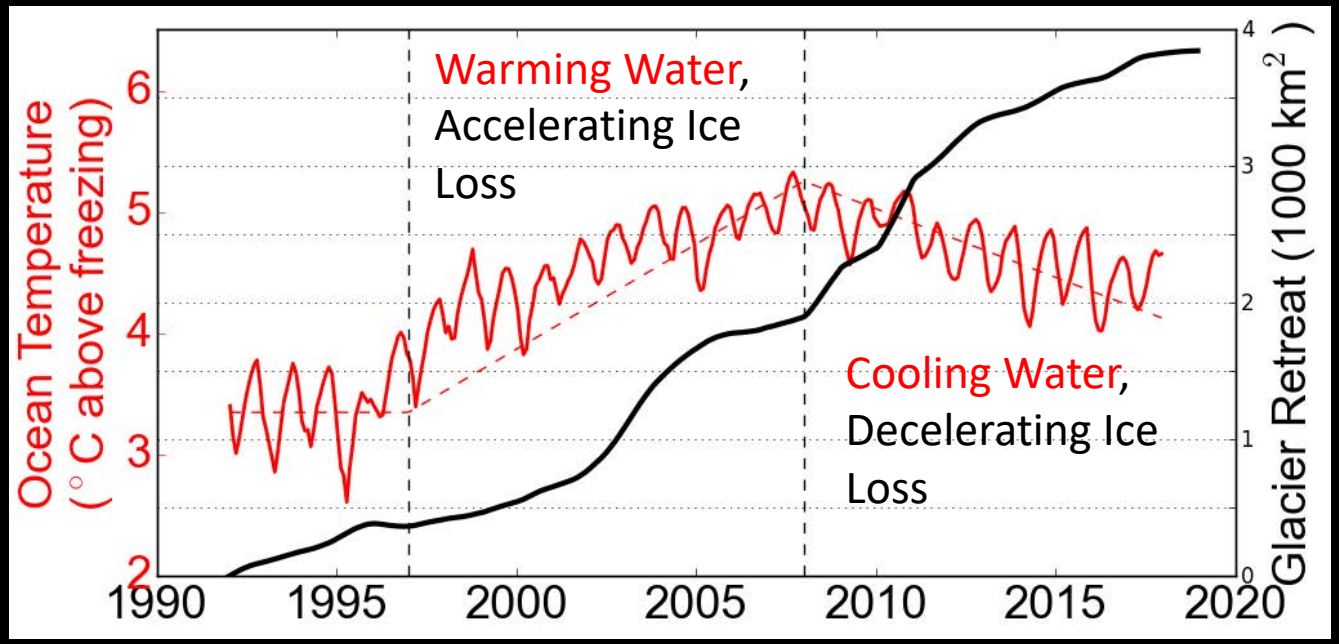
- OMG was an airborne mission aimed at understanding how the Oceans Melting Greenland
- Surveyed summertime (Aug-Oct) temperature between surface and 1000m on the shelf and inside the fjords
- Deployed >= 250 expendable CTDs by aircraft each year 2016-2021
- Supplemented by ship-based CTDs mostly in 2015, 2016



Shelf AXCTD Measurement Locations 2016-2021

OMG Results: Ocean Forcing Drives Glacier Retreat in Greenland

- Glaciers started to retreat when water warmed around Greenland
  - Warming linked with anomalies in the N.Atlantic and to a shift in the phase of the NAO
- Retreat relaxed when in tandem with ocean temperature
- Ocean temperature is key for understanding glacier mass loss



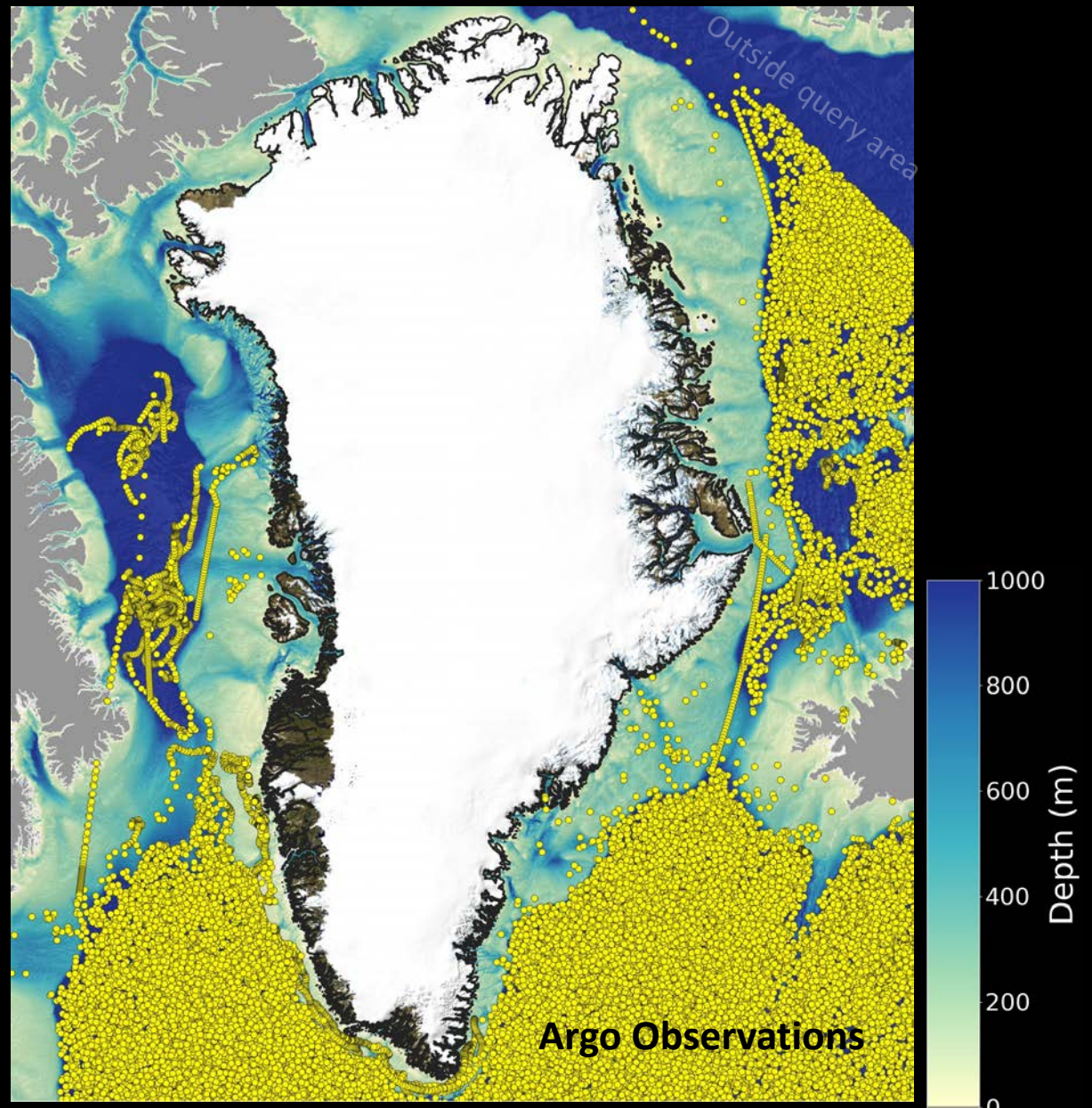
Mean AW shelf temperature is is linked with glacier retreat (N=226)

Wood et al 2021, Science Advances

What observations are available on the shelf?

- On Greenland's shelf, sampling is sparse and sporadic
- The shelf is 500-1000 m deep

  ⟹ Argo floats do not measure temperature on the shelf
- Measurements in Greenland are confined to irregular PI-led cruises
- For sea level rise, its critical to have continued observations on the shelf



Argo largely does NOT sample the shelf

Autonomous Profiling Floats on Greenland's Shelf

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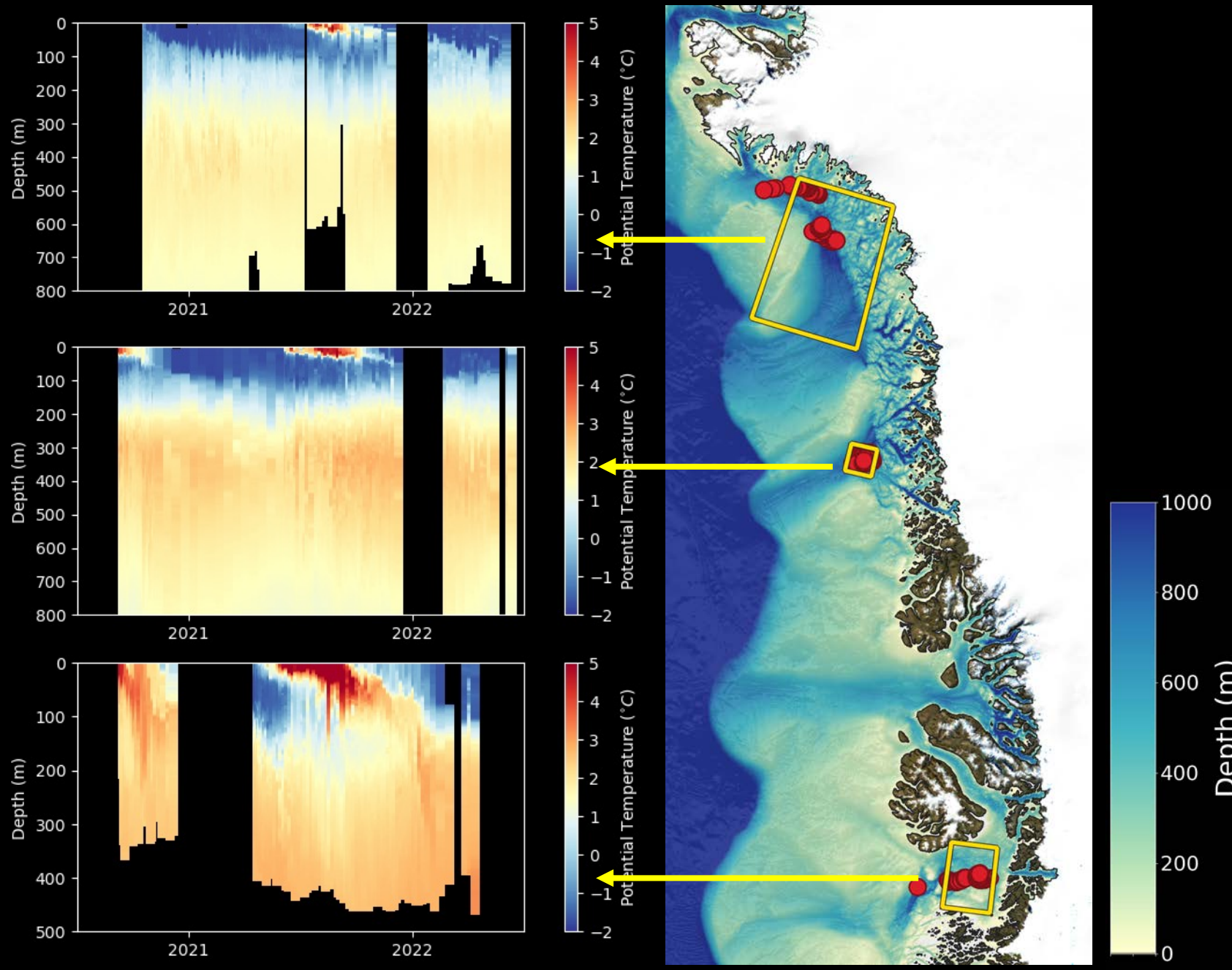


Autonomous Profiling Floats during OMG

During OMG, we experimented with two types of autonomous floats designed to withstand seasonal surface ice (icebergs and/or sea ice)

MRV Alamo

Cost: $25K
Air deployment:
- Interior Chute

During OMG:
- Purchased: 17
- Deployed: 15
- Returned Data: 9

Teledyne APEX

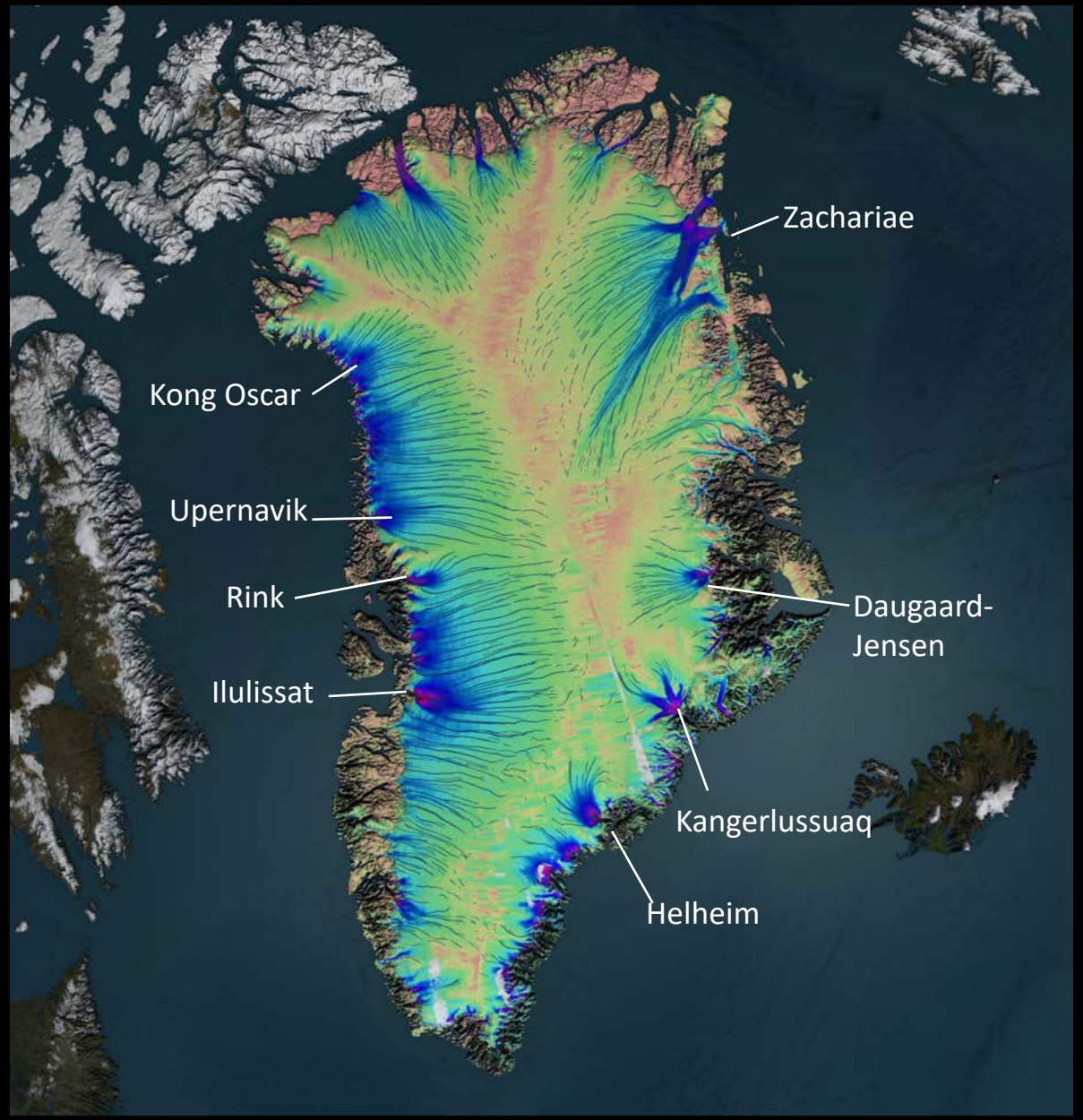
Cost: $25K
Air Deployment:
- Aircraft door

During OMG:
- Purchased: 6
- Deployed: 6
- Returned Data: 5

Where should we deploy the floats?

<u>Location selection criteria</u>

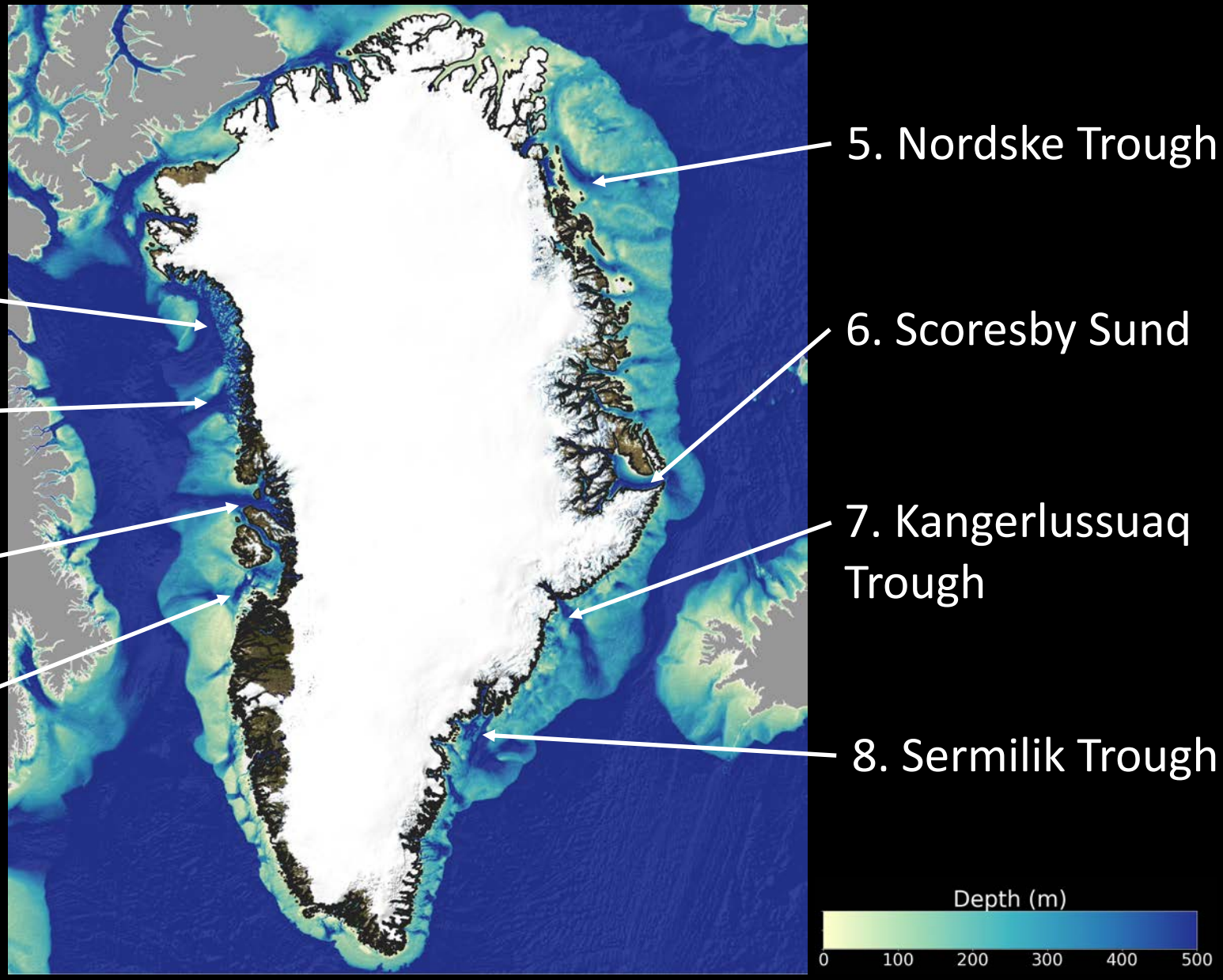
1. Local glaciers contribute substantially to flux and mass loss, and are deep (>= 250m)
2. Ability for float to reliably maintain position (e.g. no strong currents)
3. Location is deep and hydrographically unique from other deployment sites



Greenland's Ice Velocity and Fastest Glaciers

8 Recommended Deployment Sites

1. Melville Bay
2. Upernavik Trough
3. Ummannaq Trough
4. Disko Bay
5. Nordske Trough
6. Scoresby Sund
7. Kangerlussuaq Trough
8. Sermilik Trough



Greenland Bathymetry, Saturated below 500m

Who, When, and How?

- Who: An international collaboration of scientific institutions, similar to the support of the global Argo program
- When: Scheduled deployments in the summer time to replace lost instruments, as needed
- How: Deployments can be conducted by boat or plane

Take-aways

- Ocean observations on Greenland's shelf are important for understanding, quantifying, and projecting sea level rise
- Currently, observations on the shelf are sparse and typically conducted in summer only
- Autonomous Profiling Floats (APFs) are a viable way to provide continuous observations

Gerald Cirtwell, Ken Borek Air Flight Engineer
Ready for APF deployment

Questions?

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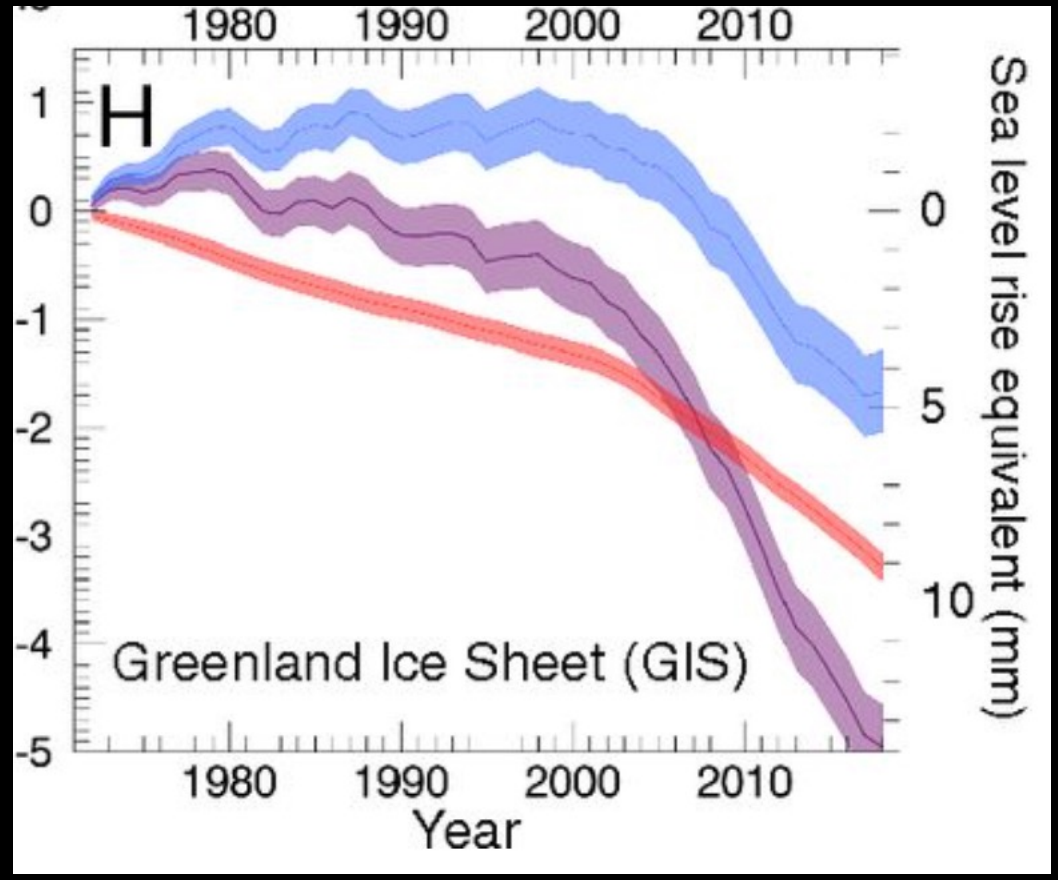
Extra Slides

Partitioning Greenland's Mass Loss

- Greenland is responsible for 14 mm of ice-driven sea level rise since 1972
- Glaciers lose ice in two ways:
  1. Anomalous melt on the surface (surface mass balance)
  2. Faster ice flow toward the ocean (glacier dynamics)

  Faster ice flow is linked with ocean temperature variability



Red = Glacier Discharge

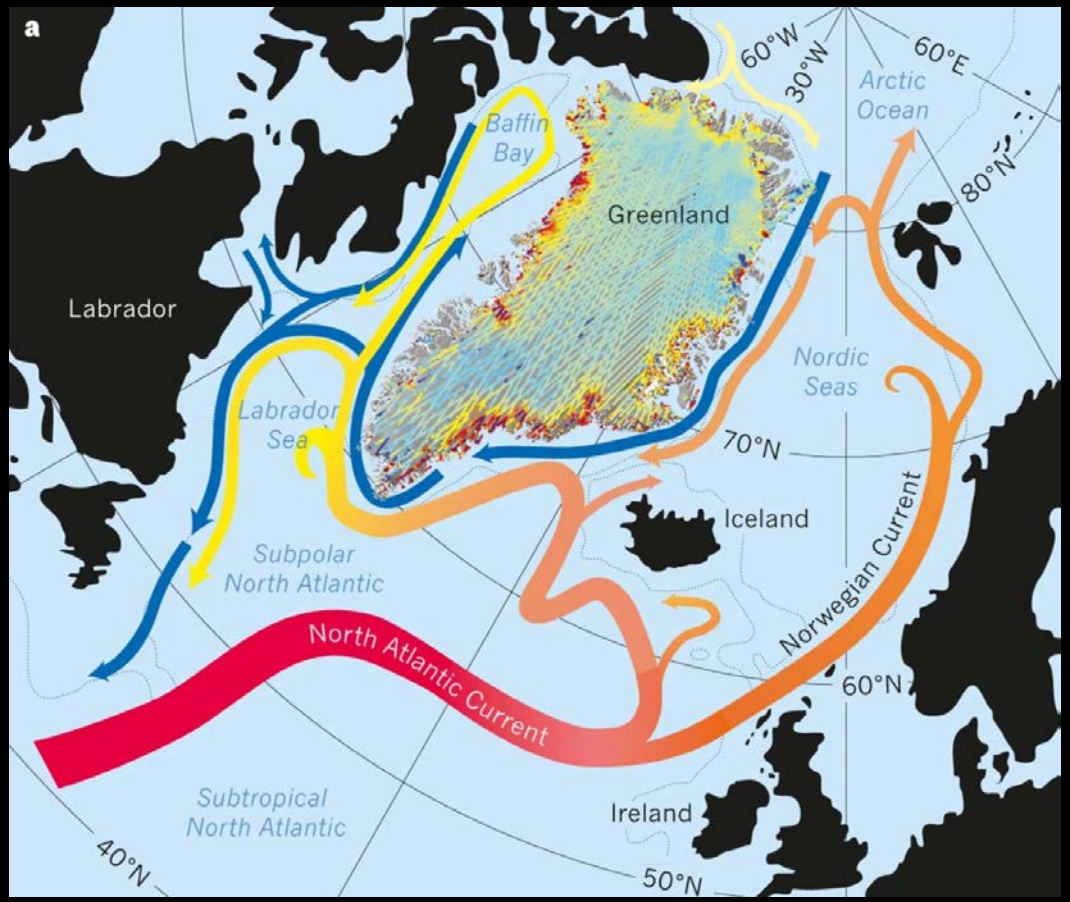
Blue = Surface Melt

Purple = Total

Mouginot et al 2019, PNAS

Ocean-Forced Ice Loss

Figures adapted from
Straneo and Heimbach 2013



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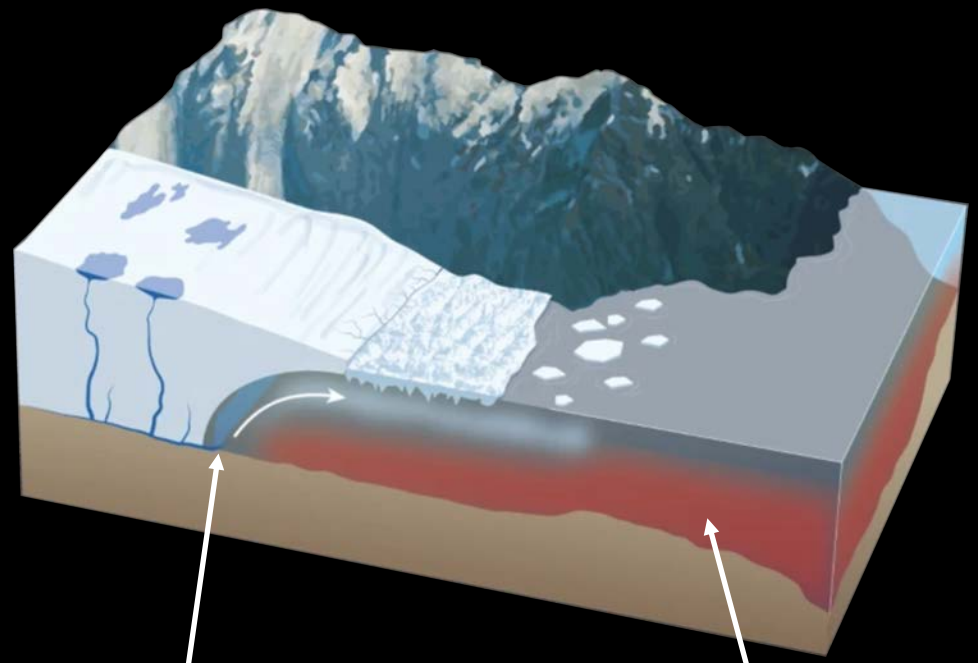


fresh, subglacial discharge plume

\+ warm water at depth

= vigorous melt that undercuts the glaciers

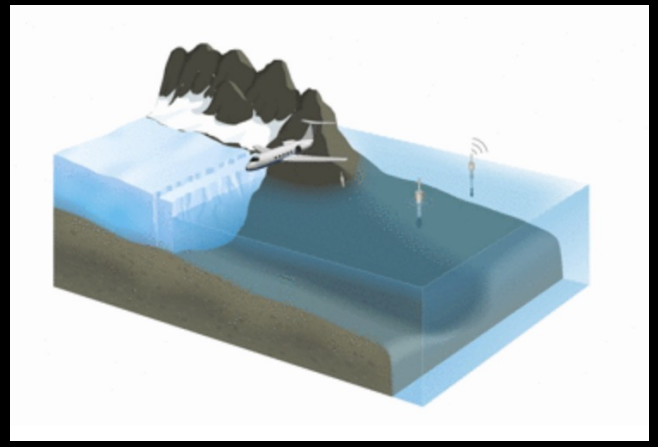
Need depth and temperature measurements in fjords to quantify melt!

Oceans Melting Greenland

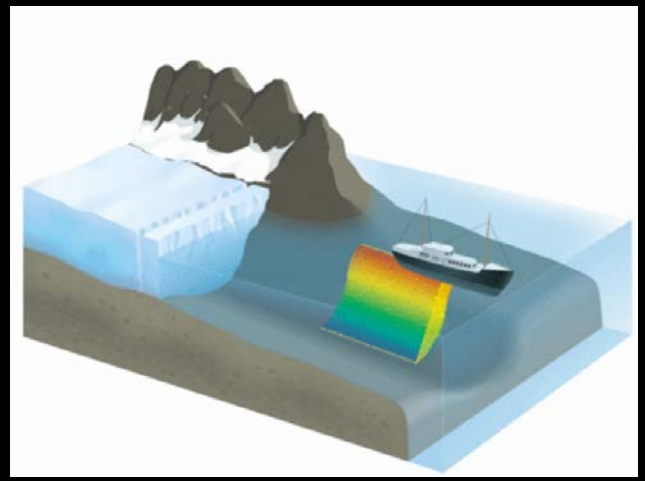
- 6-year NASA suborbital mission to investigate:

  To what extent does the ocean melt Greenland's ice from below?

- 4 main observational components
  1. Annual CTD survey (>250 per year, 2016-2021)
  2. Annual Ice Elevation survey (2016-2019)
  3. Airborne gravity survey for bathymetry (2016)
  4. Ship-based multibeam survey (2015, 2016)



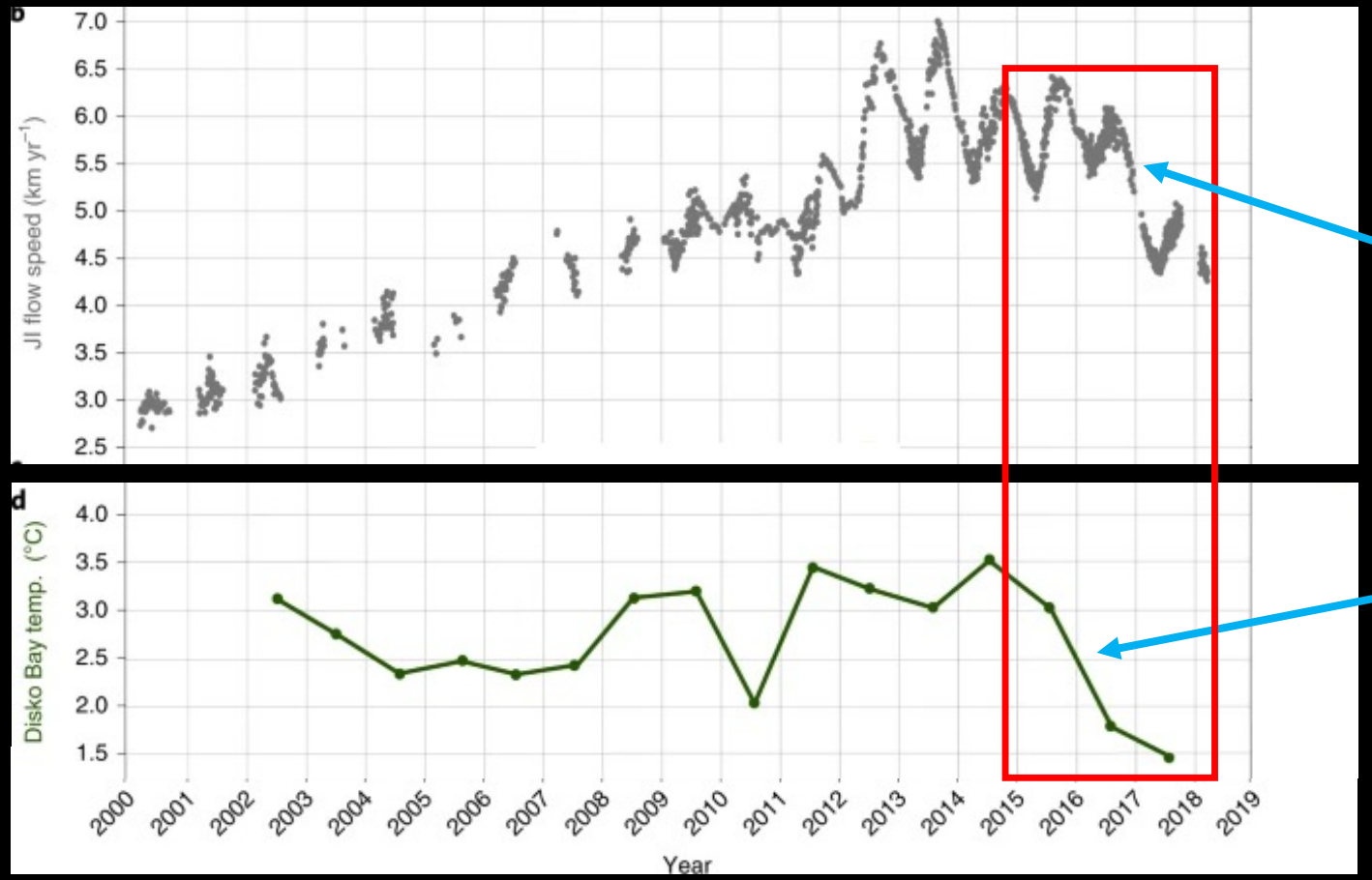
Airborne CTD Schematic



MBES Schematic

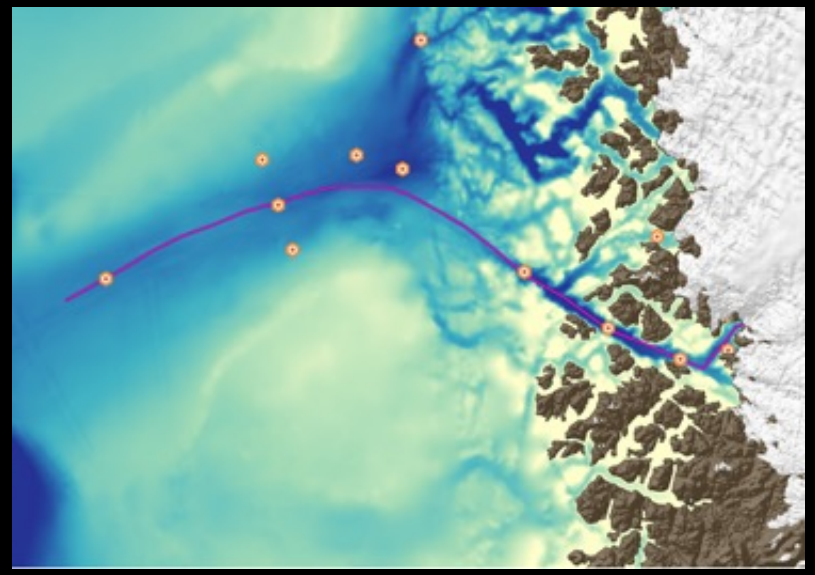
OMG Results: Ocean Cooling Slows Ilulissat Glacier

- Deeper glaciers are most sensitive to changes in ocean temperature
- Ilulissat glacier slowed down, thickened, and advanced when regional waters cooled
- Ocean temperature observations are key for monitoring glacier ice loss (SLR!)

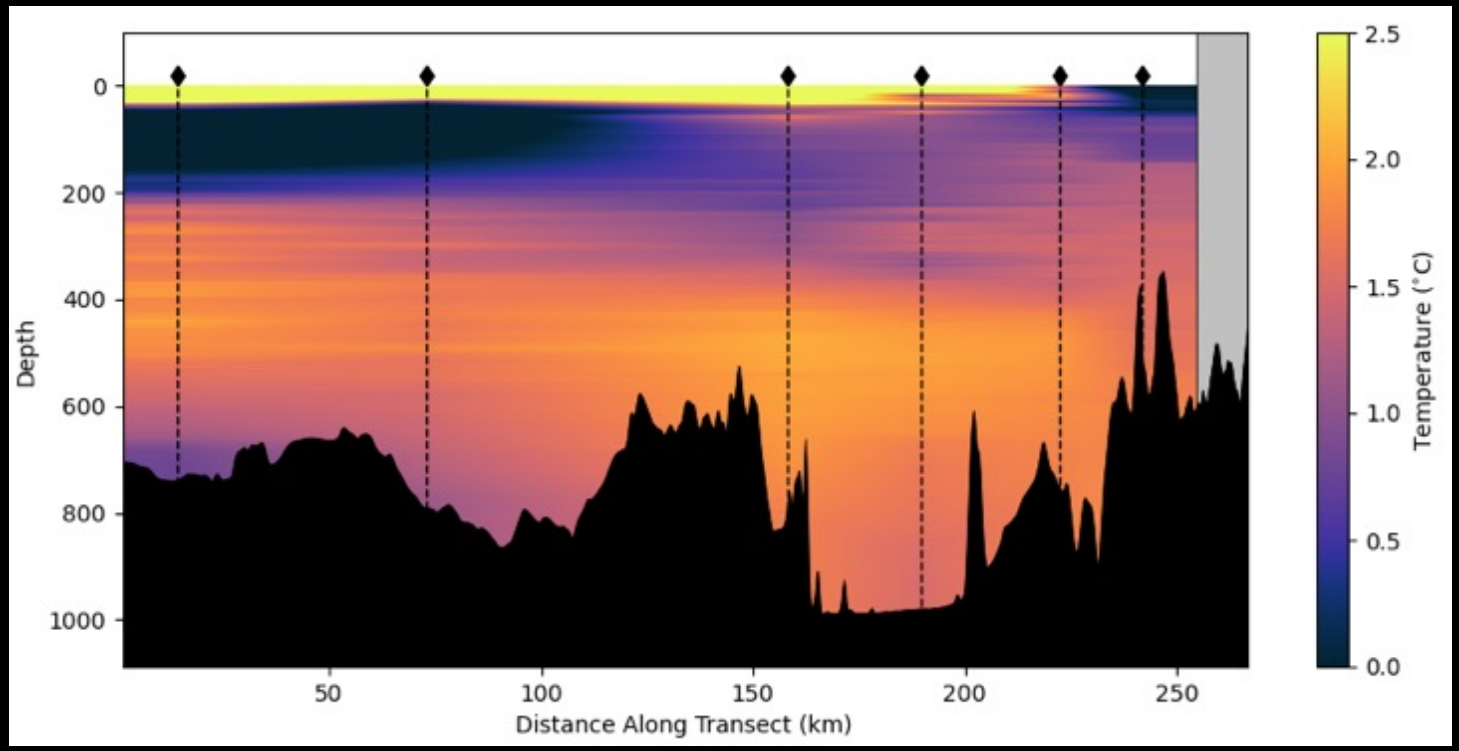


Khazendar et al 2019, Nature Geo. Sci.

Heat Transport Across Greenland's Shelf



Deep troughs and submarine channels connect the glaciers to the shelf break



Warm water flows into fjords through deep submarine channels