US GO-SHIP TRANS-ARCTIC CRUISE ARC-01

Presentation for the UNOLS Arctic Icebreaker Coordinating Committee

12 January 2023

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Representing the US GO-SHIP Executive Council

(The US National Science Foundation and the National Oceanographic and Atmospheric Administration are primary support agencies for US GO-SHIP. The materials and views contained in this presentation are, however, those of the authors, and are not specifically approved or endorsed by either agency.)

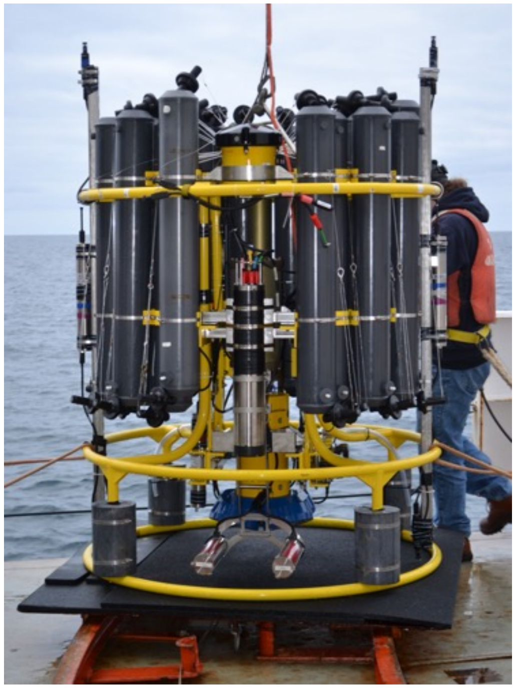
What is GO-SHIP?

GO-SHIP is a sustained program which provides

the highest required accuracy **global ≈decadal scale, basin-wide, full water column,**
observations of multiple properties
(recently including biology)

To resolve changes in

heat, freshwater, and carbon, oxygen,
nutrient & transient tracer inventories



[GO-SHIP is ranked as critical (63% of respondents) or very important (28%) in supporting the science goals of US CLIVAR and the Ocean Carbon and Biochemistry Program.]

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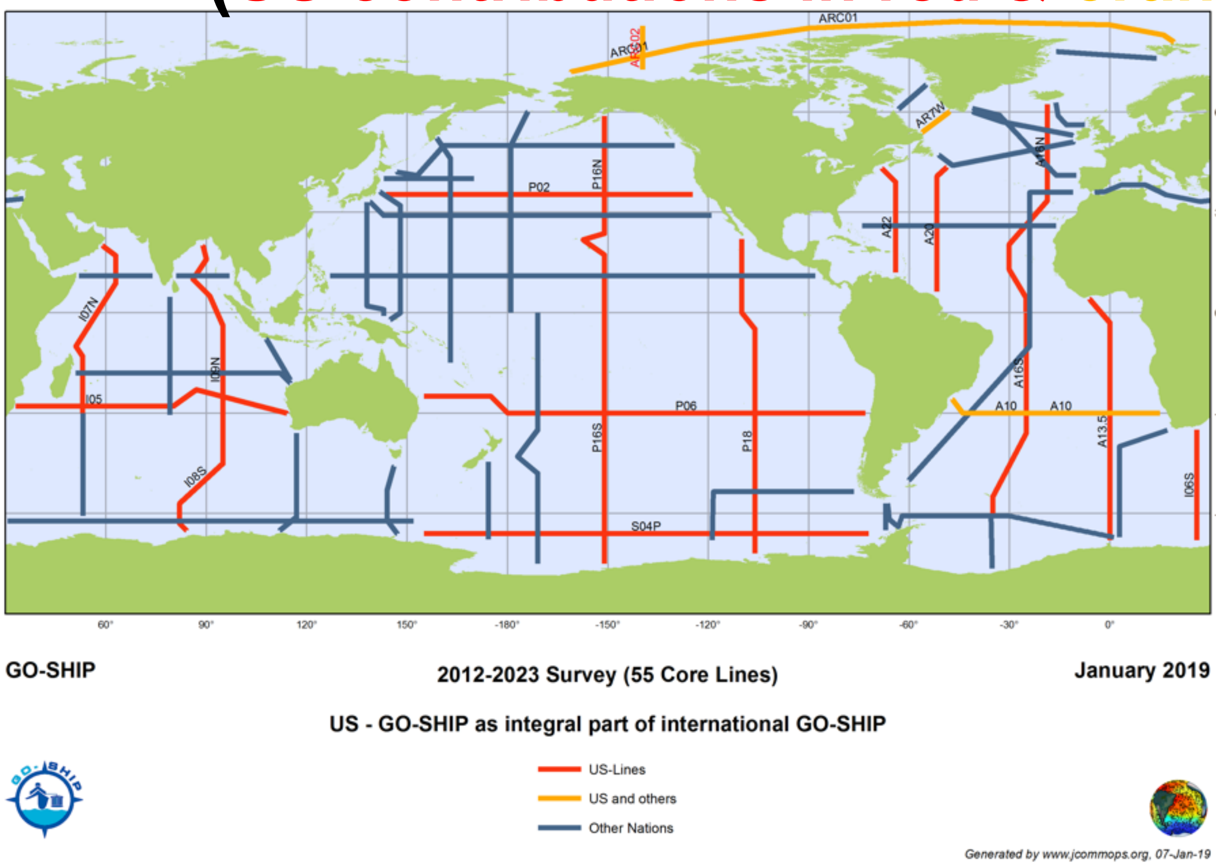
International GO-SHIP

(US contributions in red & orange)



Global
Ocean
Ship-based
Hydrographic
Investigations
Program

The US contribution to GO-SHIP approximately
- One UNOLS cruise per year
- One NOAA cruise per year
- “cruise” = 1 long or 2 short legs

- 30 nmile nominal station spacing
- Specified standards for accuracy & precision
- Support of ancillary projects
- Immediate open data policy (for all)

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US GO-SHIP Components

- **Planning and implementation -** Data collection, QC, prompt data reporting and unfettered public access (via CCHDO)
- **Data synthesis** to understand heat/freshwater fluxes, carbon system and biogeochemistry, and water mass ventilation; and support model validation, state estimation, and autonomous sensor calibration
- **Leveraging** – support new technology development/deployment and other complementary observations
- **Work force** – build and maintain scientific and technical staff capacity
- **Leadership** – attention to continuity and succession
- **Training and mentoring** – a key aspect across the science teams
- **Ships and instrumentation** – endurance and deck/lab/berth space to support data collection
- **Coordination and communication** - with international GO-SHIP, complementary observing programs (GDP, Argo, BGC-Argo, SOCCOM, etc.), and US-based science programs (US CLIVAR and OCB)

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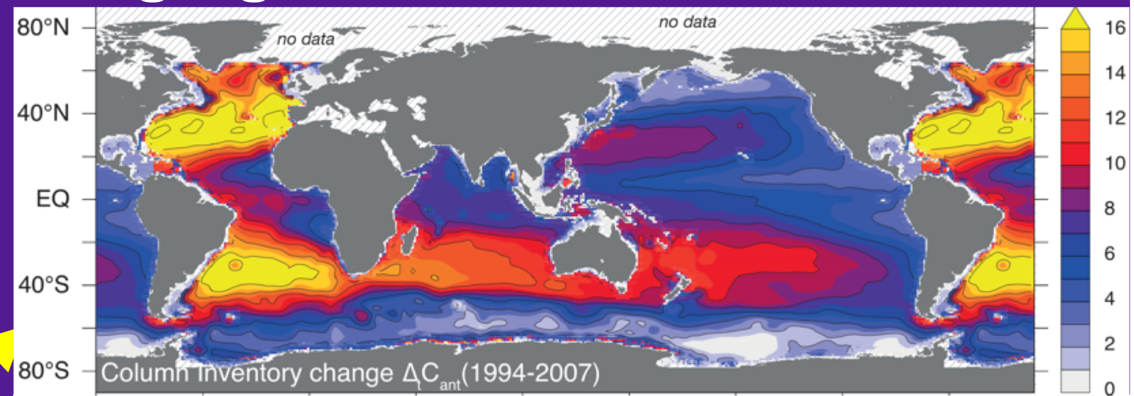
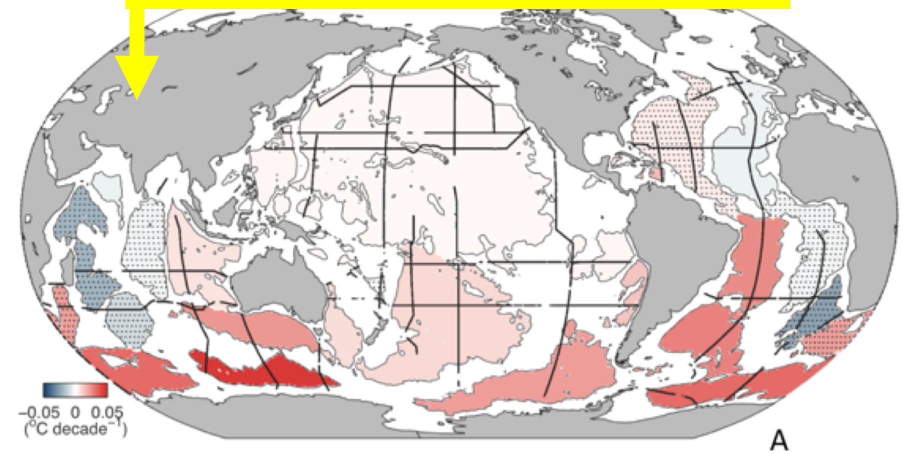
In an ocean that is clearly changing, GO-SHIP:

- **observes** and accurately documents **global decadal climate change**
- **provides the reference** standard observations for calibration of autonomous data (floats, drifters, buoys, moorings)

We would not know this without repeated ship-borne measurements



1994-2007 carbon inventory change (mol m^{-2}), based on repeat hydrographic observations. Note: Insufficient Arctic data for calculation. (Gruber *et al.* 2019)



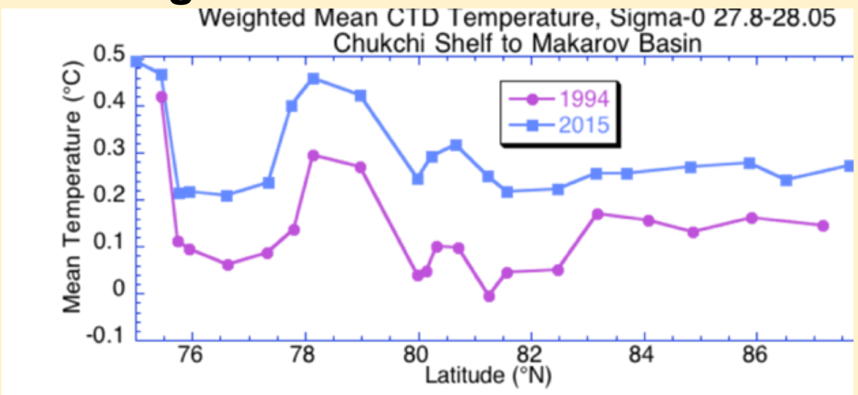
Mean 1992-2005 **warming rates** (°C/decade) below 4000m based on overlaid repeat hydrographic lines. (Purkey & Johnson 2010.)

Another powerful use of repeat ship-based hydrography is **comparison of observed changes to those predicted from oceanographic theory or models**. This has already found extensive areas of the oceans where there is less and greater gas exchange than expected.

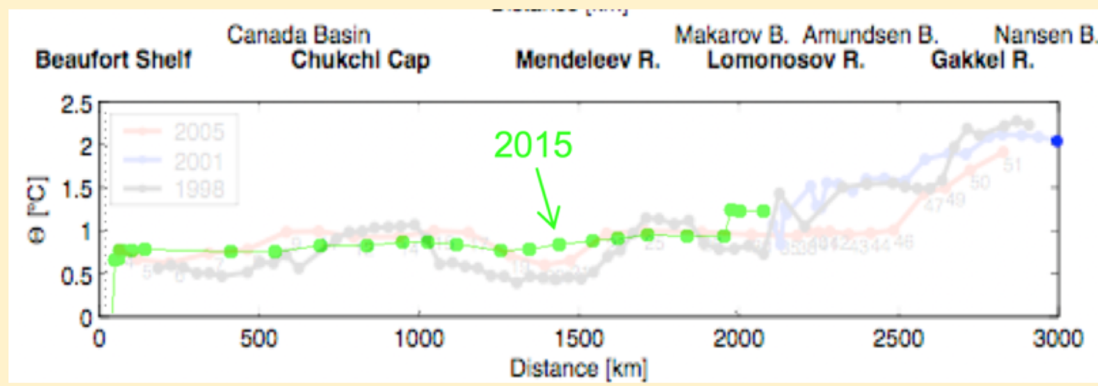
Arctic Ocean climate change from hydrographic observations

Cross-Arctic cruises since 1994 show significant changes in ocean carbon, tracers, & nutrients are also taking place.

Warming

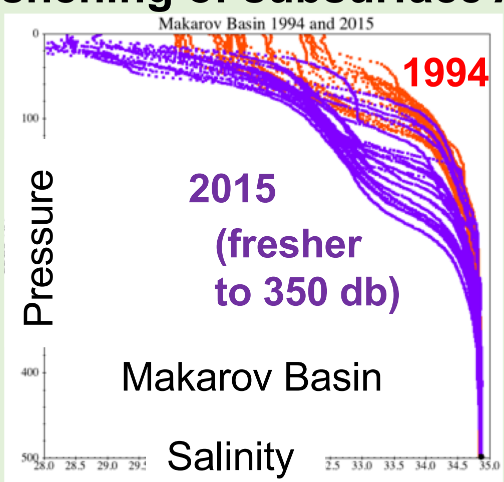


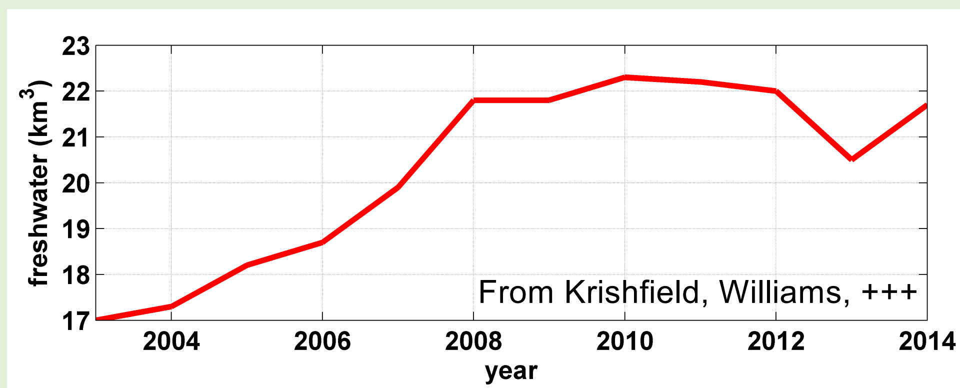
The layer which eventually feeds the dense Denmark Strait Overflow to the North Atlantic Ocean significantly warmed from the Chukchi shelf through the Makarov Basin, 1994 to 2015.



A 1990's "warm event" in mid-depth Atlantic layer water arrived via boundary currents: 1998 submarine data (dim grey) showed warm cores aligned with bathymetry, but by 2015 (green dots), warm water had spread through the Canadian sector.

Freshening of subsurface Arctic





Freshwater increase in the upper Beaufort Gyre in the 2000s: (relative to salinity 34.8)

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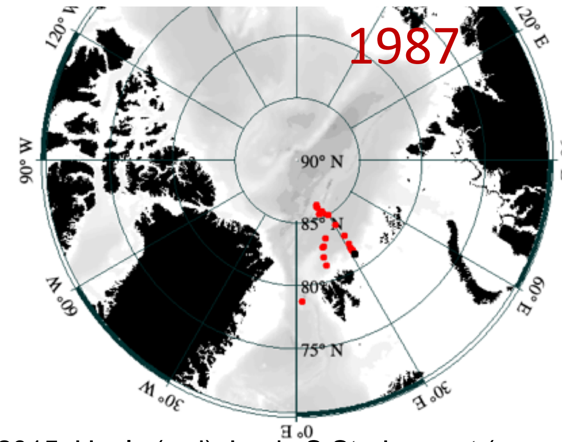
A single-ship trans-Arctic GO-SHIP quality section has yet to be completed!

A complete one-ship trans-Arctic section to GO-SHIP standards has never yet been completed, despite good intentions and efforts.

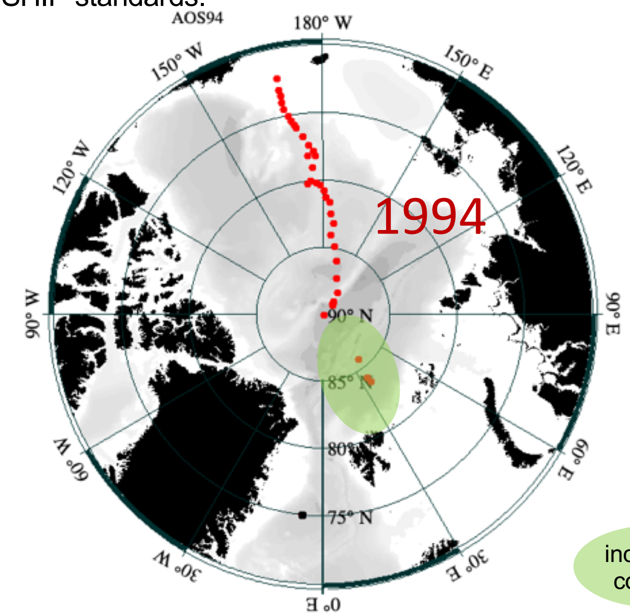
- Uniform analysis standards to provide highest precision and accuracy
- Single cruise to provide single season (45 days) continuity

The 2015 Arctic Geotraces cruises did provide data from which GO-SHIP trans-Arctic sections can be assembled.

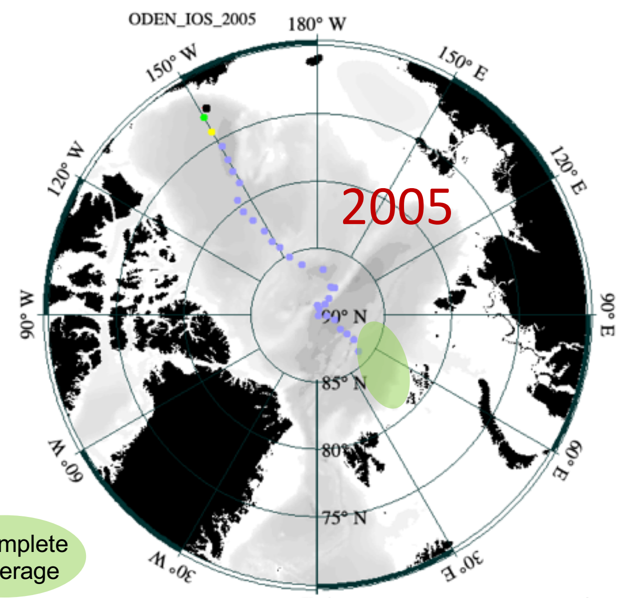
1987: Polarstern completed the first crossing of the Nansen Basin (to GO-SHIP quality).



1994: Louis S. St-Laurent with Polar Sea, completed the first section of the Makarov Basin and both sides of the Lomonosov Ridge to GO-SHIP standards.

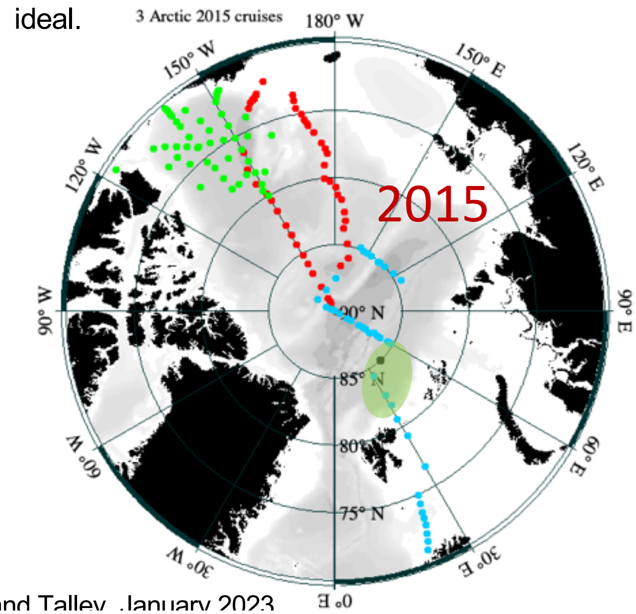


2005: Oden, with Healy completed first meridional section of the Canada Basin to GO-SHIP standards, along with the northern Makarov Basin, Lomonosov Ridge, and Amundsen Basin.



incomplete coverage

2015: Healy (red), Louis S St-. Laurent (green), and Polarstern (blue) provided trans-Arctic data to GO-SHIP standards, though track and station spacing in the Nansen Basin and Barents shelf slope were not ideal.



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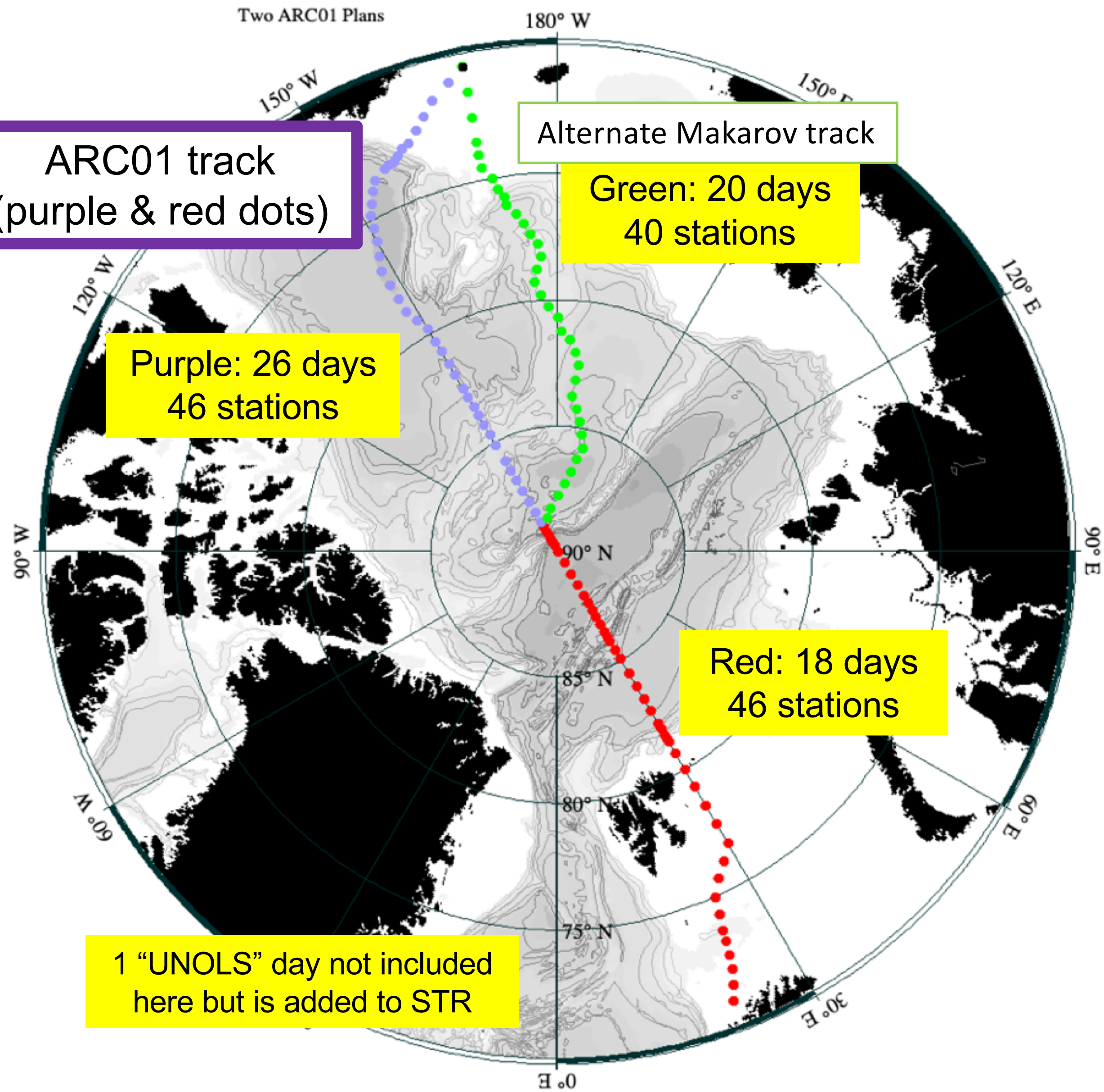
Planning for the NSF-funded US GO-SHIP ARC01

Proposed segments: repeat previous cruises that had GO-SHIP quality data. (Chukchi Sea stations continue to Bering Strait.)

Science priorities: Canada Basin track (purple) highly preferred over Makarov Basin (green) track.

Cruise duration: 45 days + port days

- Transits assume Dutch Harbor and Tromsø.
- Ship speed and ice condition estimated from experience.
- ~1 hour every 3rd station added for bio-eco casts.



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US GO-SHIP ARC-01 Logistics

US GO-SHIP Prefers:

2026 Occupation of ARC01[1]
2025 is okay, 2027 'distant' 3rd choice

Mob/demob Seattle/Trømso or reverse (4 mob days; 2 demob days)

Dutch Harbor[2] **to Tromso** (or reverse), proposed 45 days - does not include time for extra programs

Departure about 2-3 weeks ahead of late summer sea ice minimum

[1]science preference plus coordination with other US GO-SHIP cruises, availability of equipment and tech teams, and proposal timeframe
[2]if ship can fuel in Nome, then Nome would be preferred to Dutch Harbor

ARC01 will include:

29 to 35 persons in science party

Heavy lab use plus 1 to 2 lab vans; 1 to 2 storage vans

No GO-SHIP: on-the-ice science operations; small boat operations; diving; helo ops

No radioisotope use (natural level work only); ship swab-tested to assure freedom from 14C and tritium contamination

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ARC01 Logistics

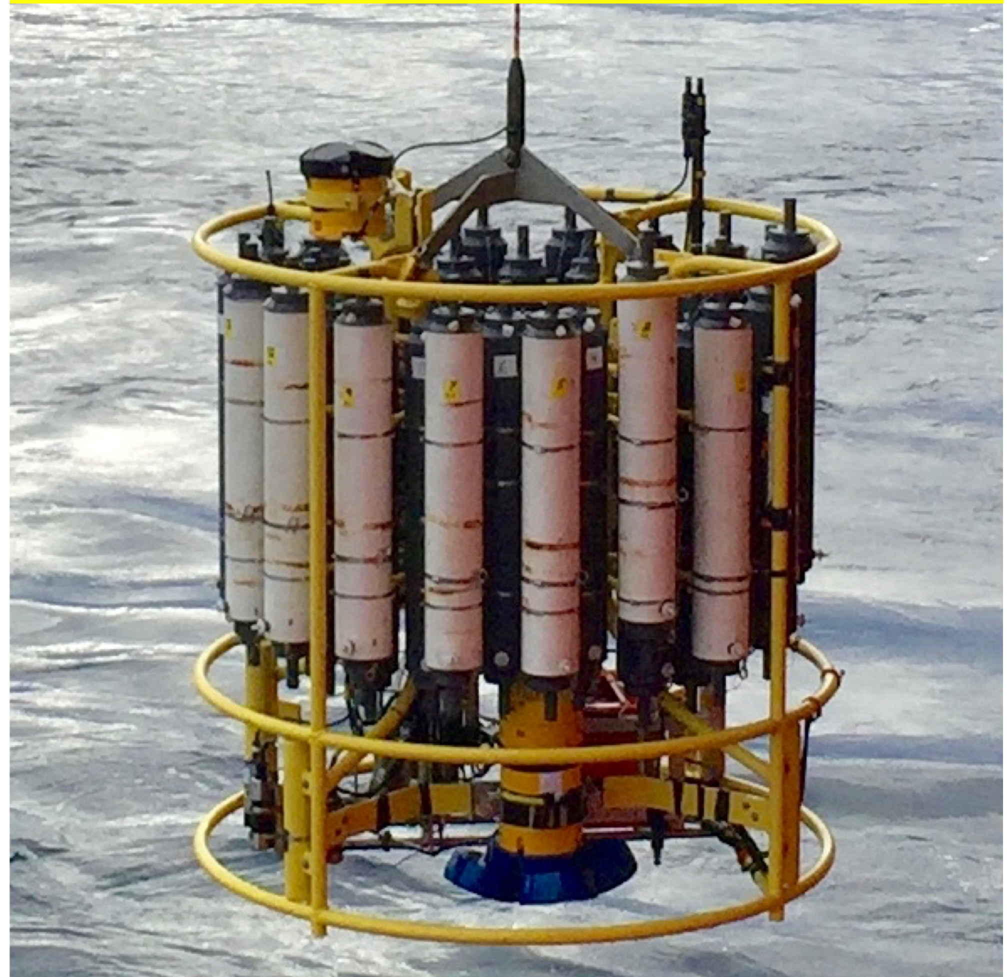
US GO-SHIP:

Provides large rosette with 36 10-liter bottles (demanding of cables, handling equipment, and deck ops personnel)

Requires 24/7 scientific operations

- one full-depth CTD cast per station
- ~4 hours in-water time for deep stations
- shallower stations run ~1 hour/1000m
- ~2 hours to 'turn-around' rosette
- Note, if Bio GO-SHIP participates there could be a 2nd shallow (1000 m) cast every 3rd station

NEW-GENERATION 36 BOTTLE ROSETTE



LOWER DRAG, BETTER SENSOR EXPOSURE

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US GO-SHIP ARC-01 Logistics

Will use ship's:

- Dynamic positioning
- ADCP
- met system
- science data network
- multi-beam sonar (for depth to bottom and knowledge of nearby bathymetry)

Requests:

- Main winch with at least 6000 m of wire
- May need portable winch with 2000m CTD cable for bio GO-SHIP program

Requires: water sampling in above-freezing, weather protected are with good lighting (e.g., Healy's starboard staging bay)

GO-SHIP will appoint a single-point-of-contact science logistics coordinator to work with the ship's team and would appreciate the same from the ship's team.

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