US GO-SHIP TRANS-ARCTIC CRUISE ARC-01

An Update on Planning

Presentation for the UNOLS Arctic Icebreaker Coordinating Committee

20 July 2023

Alison M. Macdonald, James Swift, and Lynne D. Talley

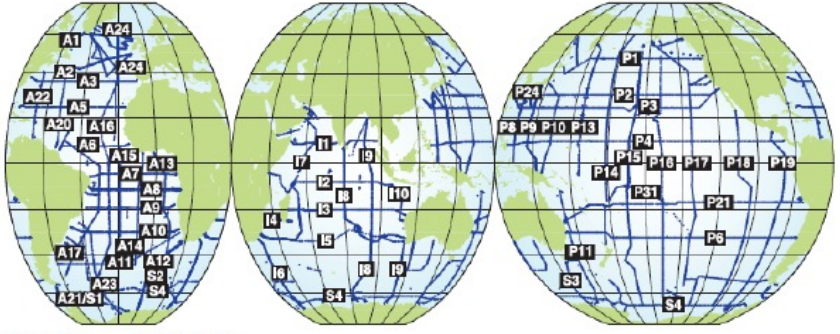
Representing the US GO-SHIP Executive Council

(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.)

A little history on global scale hydrography

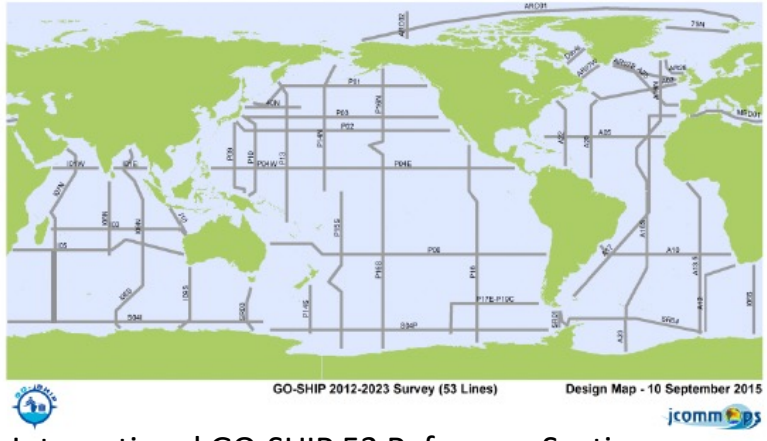
IGY → GEOSECS → WOCE → CLIVAR → GO-SHIP

1950s 1970s 1990s 2003-2014 2015→



WOCE 1990

One-time Global Ocean Survey



International GO-SHIP 53 Reference Sections

Global **O**cean **S**hip-based **H**ydrographic **I**nvestigations **P**rogram

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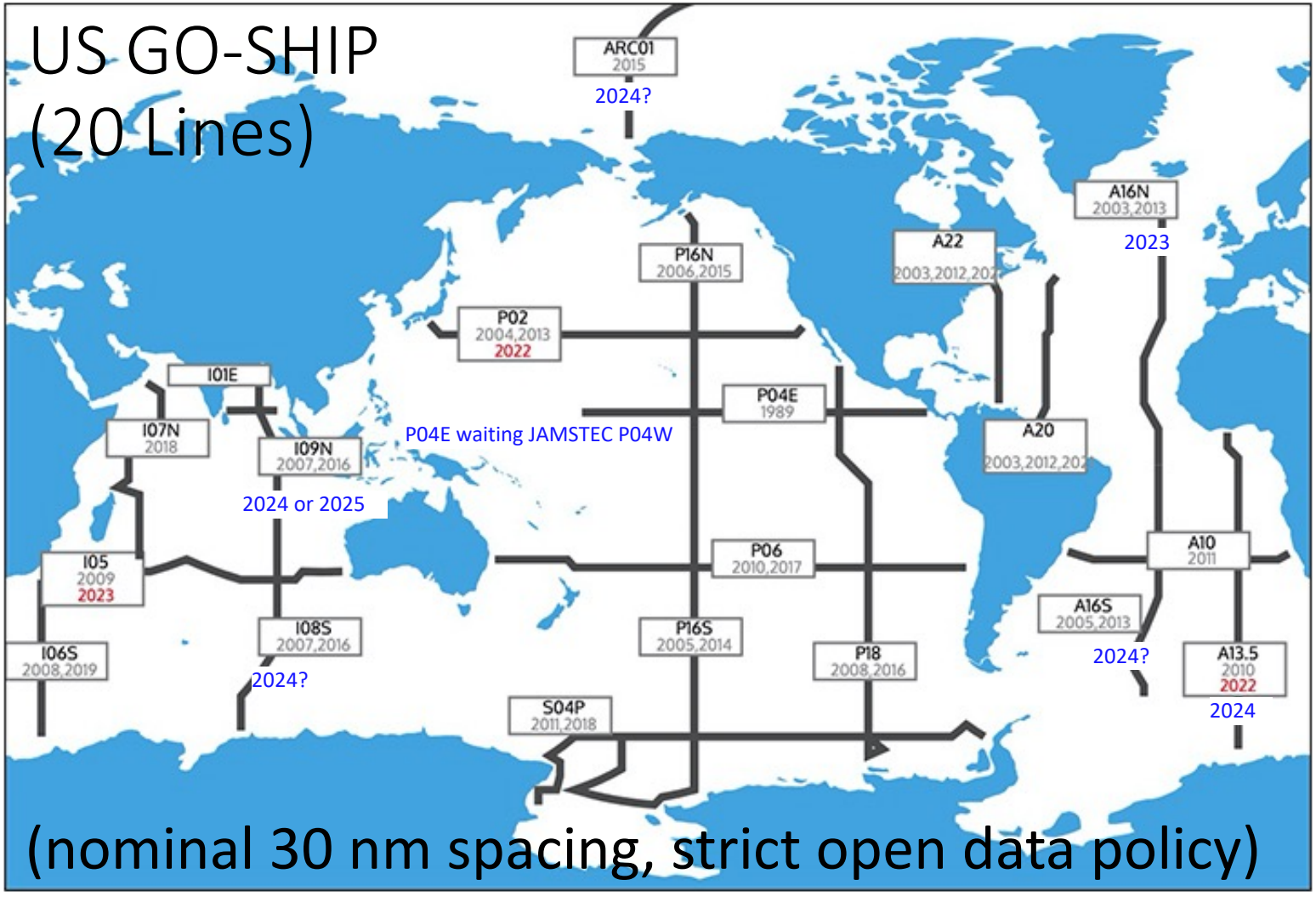

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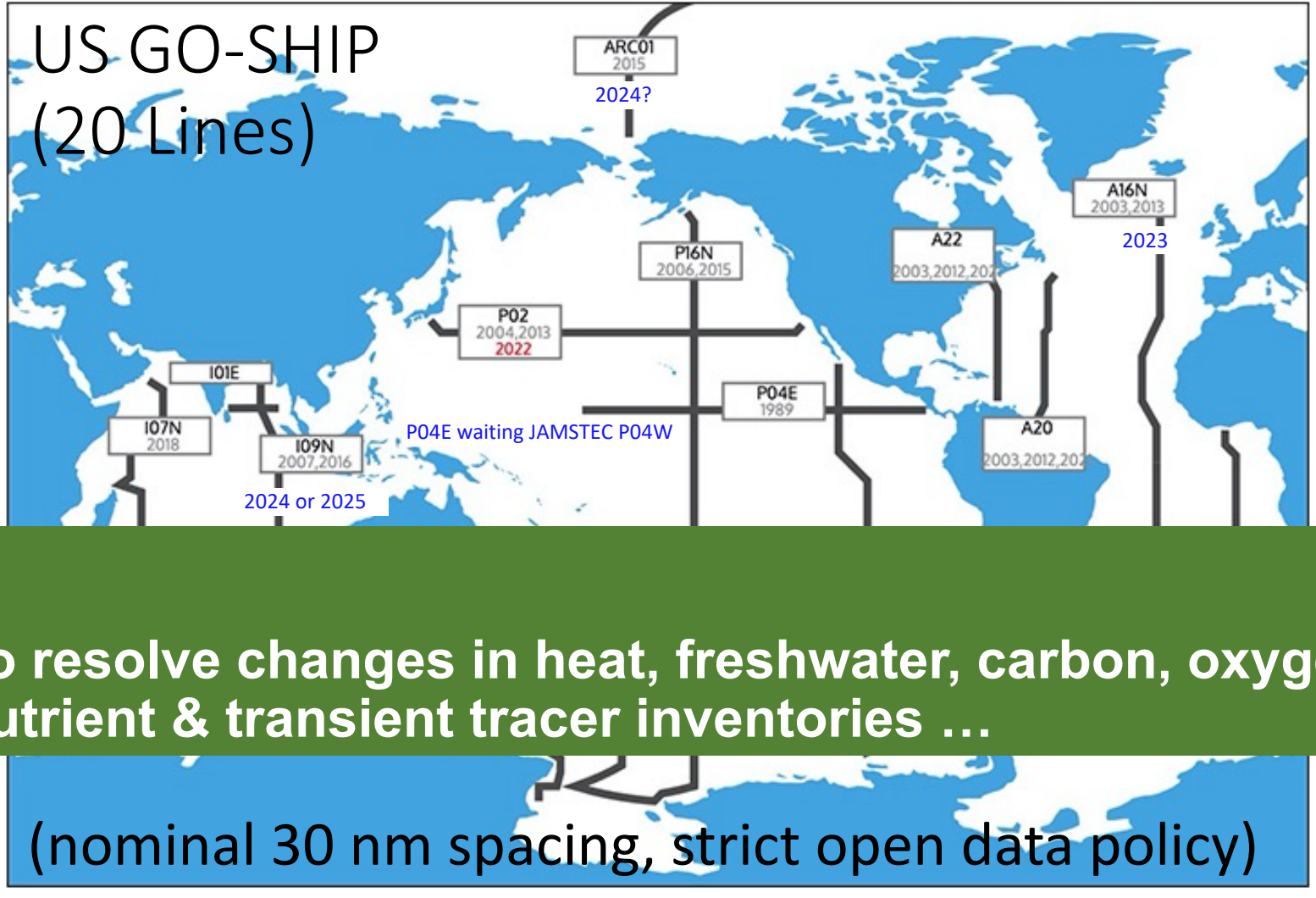
US GO-SHIP (20 Lines)



To resolve changes in heat, freshwater, carbon, oxygen, nutrient & transient tracer inventories …

(nominal 30 nm spacing, strict open data policy)

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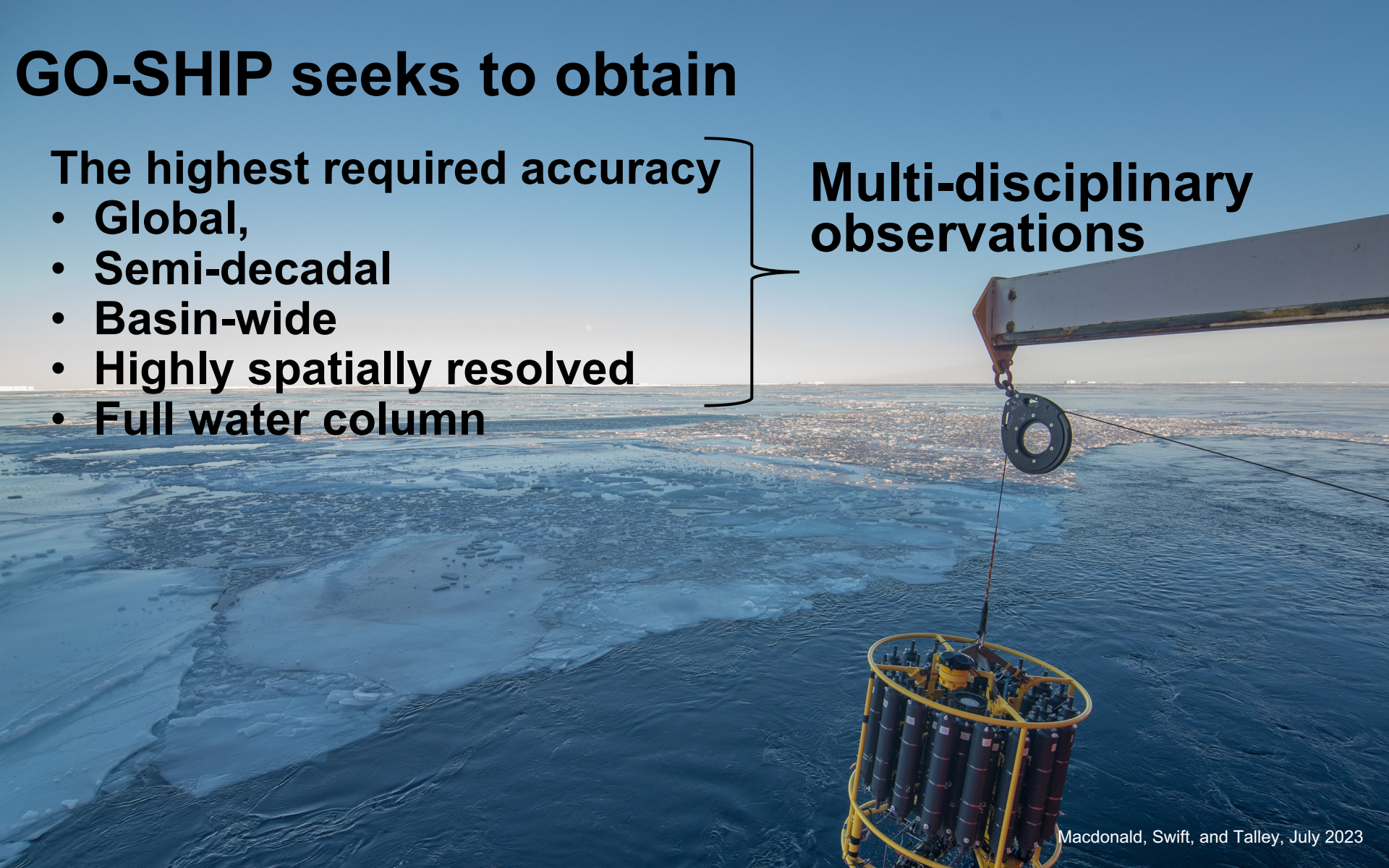
GO-SHIP seeks to obtain

The highest required accuracy

- **Global,**
- **Semi-decadal**
- **Basin-wide**
- **Highly spatially resolved**
- **Full water column**

Multi-disciplinary observations



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- **Global,**
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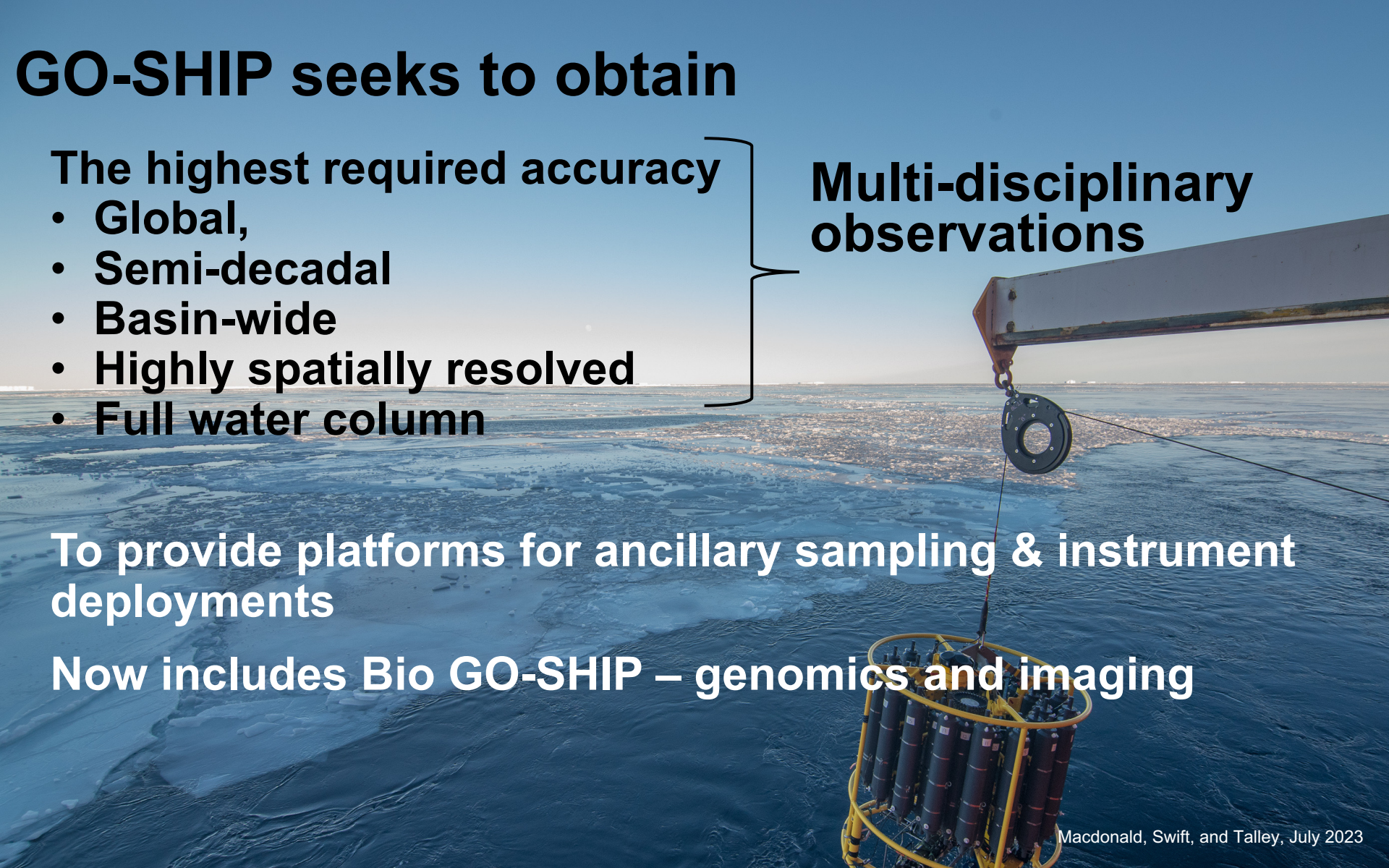
Multi-disciplinary observations

To provide platforms for ancillary sampling & instrument deployments

Now includes Bio GO-SHIP – genomics and imaging



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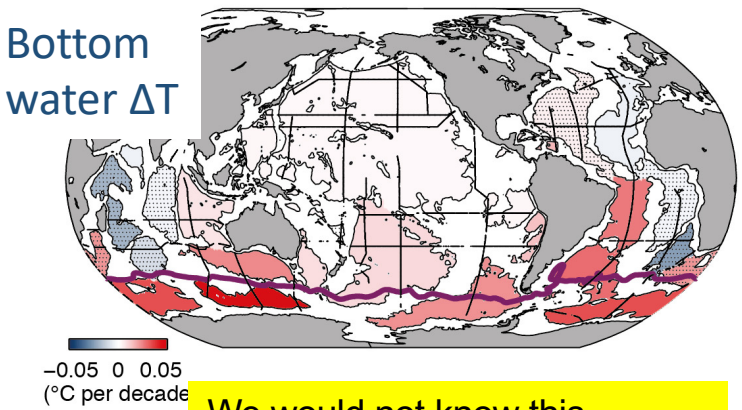
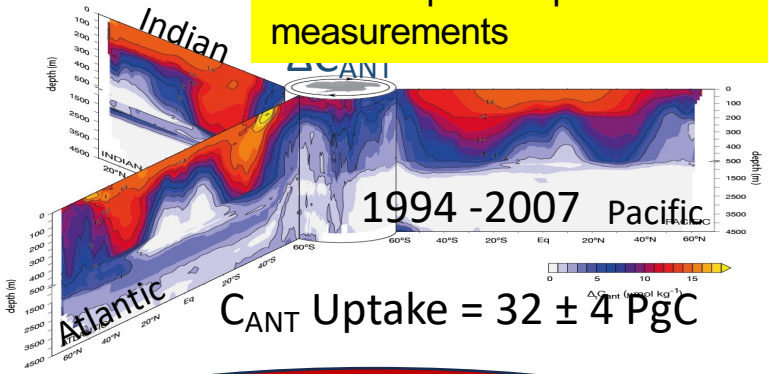
Multi-disciplinary =

US GO-SHIP Level 1 measurements: required with strict data policy

From http://usgoship.ucsd.edu/about



We would not know this without repeat ship-borne measurements



From 1995-2005 to 2005-2015 Pacific C_{ANT} storage increased by 1/3 in upper 1500 m

- Dissolved inorganic carbon (DIC)
- Total Alkalinity (TAlk)
- pH
- CTD pressure, temperature, salinity (calculated)
- CTD oxygen (sensor)
- Bottle salinity
- Nutrients by standard auto analyzer (NO3/NO2, PO4, SiO3)
- Dissolved oxygen
- Chlorofluorocarbons (CFC-11, -12) and SF6
- Dissolved organic carbon (DOC)
- Dissolved organic nitrogen (TDN)
- Surface underway system (T, S, pCO2)
- ADCP shipboard
- ADCP lowered
- Underway navigation and bathymetry
- Meteorological

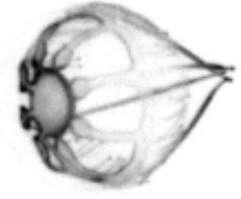
Level 2: Highly desirable (with strict data policy)

- CTD Transmissometer
- N_2O
- Tritium-^{3}He
- Discrete pCO2
- 14C by AMS
- CCl4
- CFC-113
- ∂13C of DIC
- Fe/trace metals – now often GEOTRACES
- Surface underway system: nutrients, O2, Chl, skin temperature

Level 3: Ancillary (Data policy set outside GO-SHIP - encourage submission & link to other archives) Leverage: new technology, biology, etc

- Chlorophyll
- Primary production
- HPLC pigments
- POC*
- UVP*
- Optical instruments*
- CDOM*
- Fluorometry and backscatter*
- Rare earth elements (REE)
- Experimental continuous analyzers
- ∂15N
- Isotopes of NO3
- 32Si
- ∂18O of H2O
- NH4
- Low level nutrients
- Total organic phosphorus
- Radionuclides
- Underway EK-80
- Isotopes of O2
- N2, Ar, O2
- Methyl halides
- DMS
- Bacterial Abundance
- Bacterial Production
- Dissolved combined neutral sugars
- DNA
- Cytometry
- Floats
- Gliders
- Drifters
- Chipods/turbulence

* EOVs



GO-SHIP Observations

Are used to advance our understanding of

- Heat and freshwater storage and transport
- Carbon & biogeochemical cycling
- Ocean acidification,
- Ventilation (i.e., air-sea exchange)

+ Decadal-scale changes in the same

Alone & with Argo/BGC-Argo/SOCCOM/Deep Argo float data that provide seasonal to annual timescales

With Bio GO-SHIP to understand global ocean plankton diversity & abundance – their relationships with biogeochemical cycling within the changing ocean.

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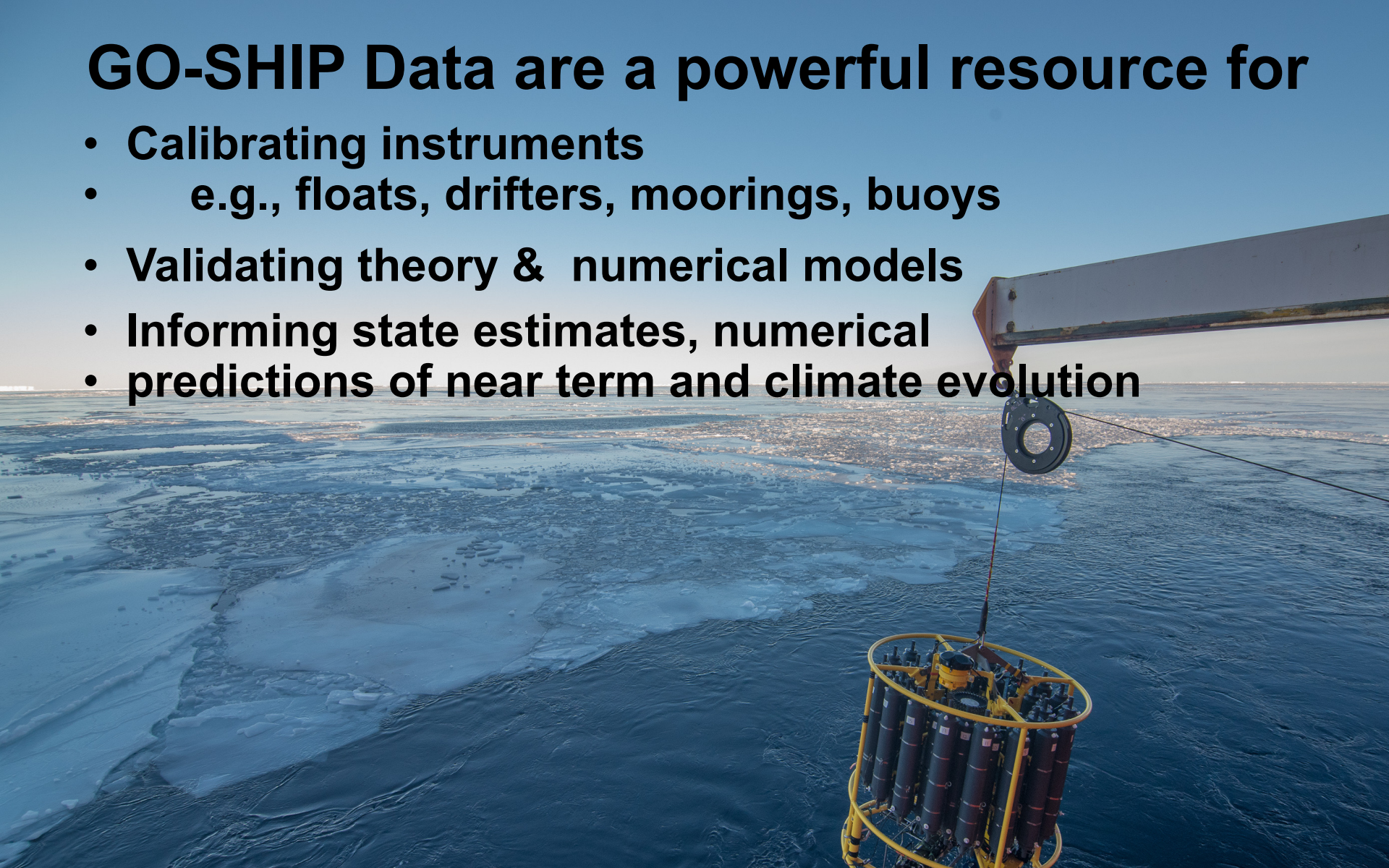
A few recent publications:

	TOPIC
Bourbonnais, A., et al. (2023) Marine N2O cycling from high spatial resolution concentration, stable isotopic and isotopomer measure-ments along a meridional transect in the eastern Pacific Ocean.	N2O
Tan, S., & Thurnherr, A. M. (2023). On the global decrease in the deep and abyssal density stratification along the spreading pathways of Antarctic Bottom Water since the 1990s.	ΔAABW stratification
Bif, M. (2022) Controls on surface distributions of dissolved organic carbon and nitrogen in the southeast Pacific Ocean	DOC/TDN
Cainzoz v. et al., (2022) Thirty Years of GOSHIP and WOCE Data: Atlantic Overturning of Mass, Heat, and Freshwater Transport	AMOC Heat, FW
Cainzoz et al. (2022) Anthropogenic Carbon Transport Variability in the Atlantic Ocean Over Three Decades	$\Delta\Psi_{CANT}$
Johnson, G. C. (2022) Antarctic Bottom Water Warming and Circulation Slowdown in the Argentine Basin from Analyses of Deep Argo and Historical Shipboard Temperature Data	ΔT /w Deep Argo
Larkin et al. (2021) High spatial resolution global ocean metagenomes from Bio-GO-SHIP repeat hydrography transects	Microbial Commun-ities
Talley, L.D., 2021. Global ocean climate change: observing from ships.	For young readers

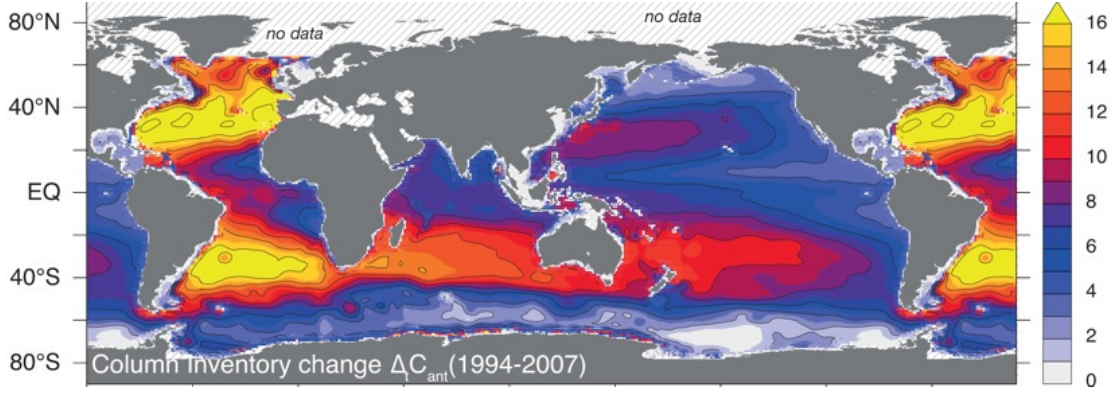
GO-SHIP Data are a powerful resource for

- Calibrating instruments
- e.g., floats, drifters, moorings, buoys
- Validating theory & numerical models
- Informing state estimates, numerical
- predictions of near term and climate evolution



The ocean, a central component of Earth's climate system, is changing

- Ocean is taking up most of the Earth's excess heat
- 1/4th of the excess goes into the Abyssal ocean below 2 km
- Warming & freshening -> Increased stratification -> decrease oxygen and increase nutrients in N. Hemisphere thermocline and expansion of oxygen minimum zones
- ~27% of Cant has gone into the ocean -> ocean acidification



1994-2007 carbon inventory change (mol m^{-2}), based on repeat hydrographic observations.. (Gruber *et al.* 2019)

Note: Insufficient Arctic data for calculation

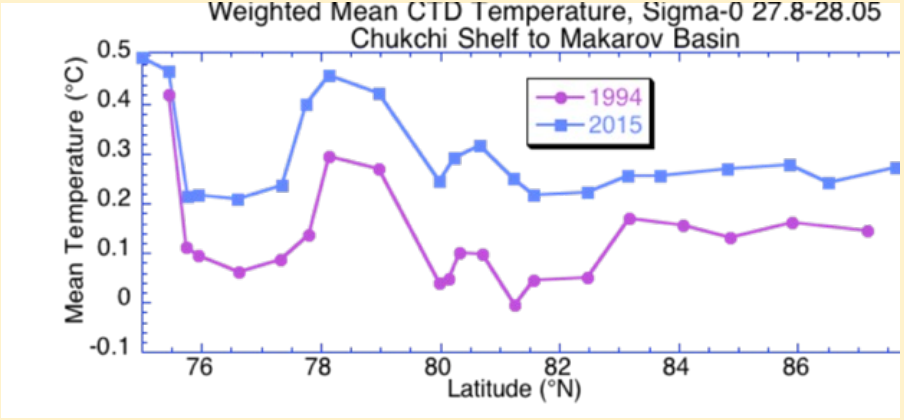
Arctic Change

Image From Wheeling, 2020 EOS story on GEOTRACES article https://doi.org/10.1029/2019JC015920
Image credit: Cory Mendenhall, U.S. Coast Guard

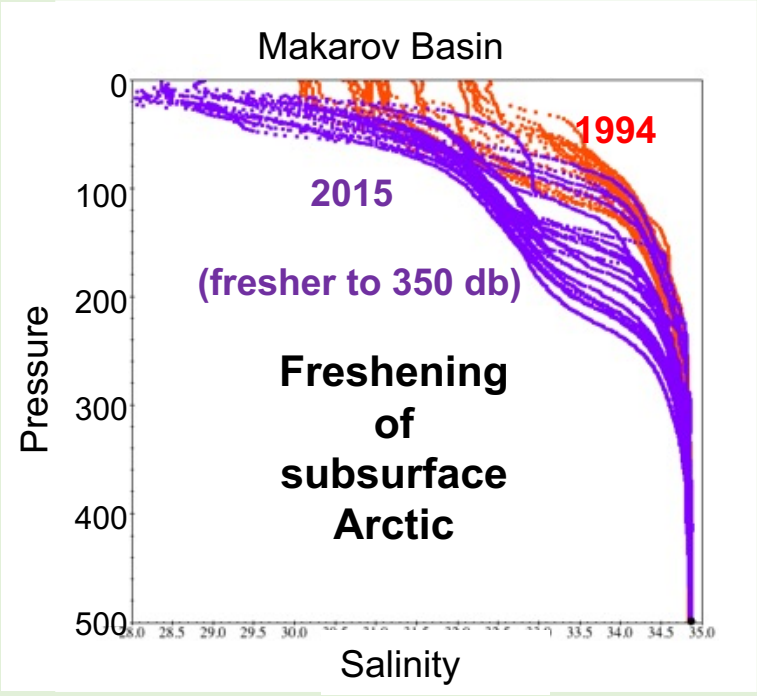
Arctic Ocean climate change from hydrographic observations

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

Warming

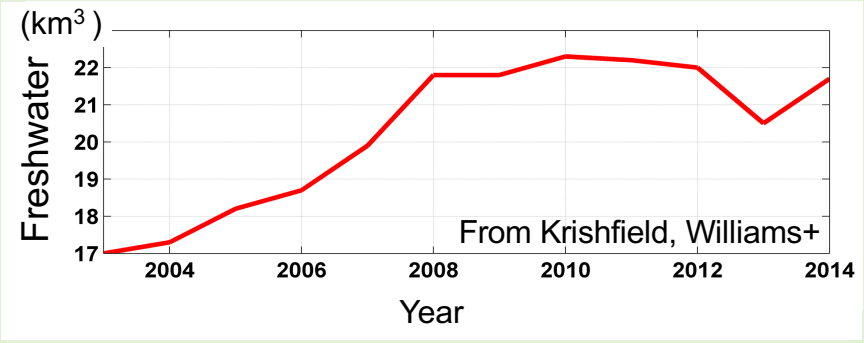


The layer which eventually feeds the dense Denmark Strait Overflow to the North Atlantic Ocean significantly warmed from the Chukchi shelf through the Makarov Basin, 1994 to 2015.



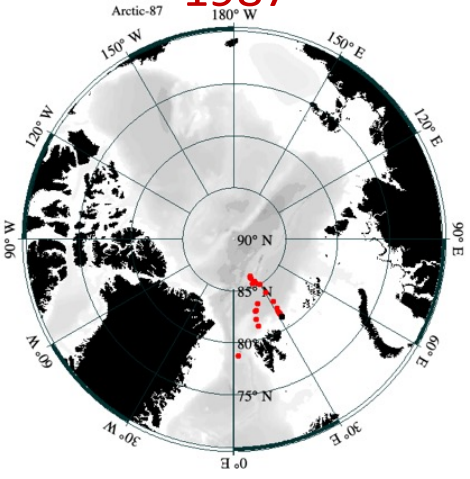
Freshwater increase in the upper Beaufort Gyre in the 2000s:

(relative to salinity 34.8)



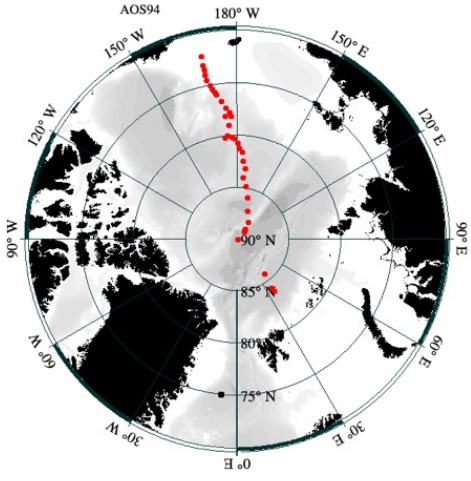
Previous cruises with GO-SHIP quality observations

1987



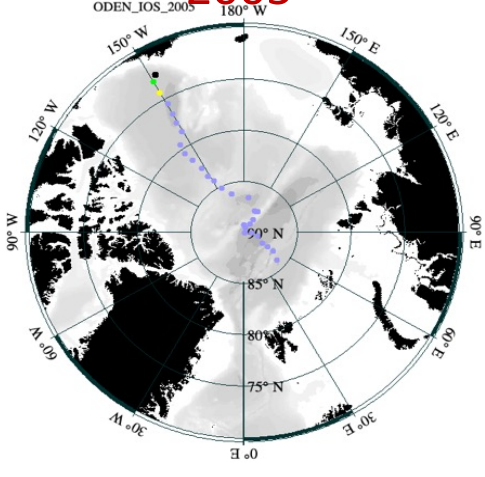
Polarstern **Nansen Basin**

1994



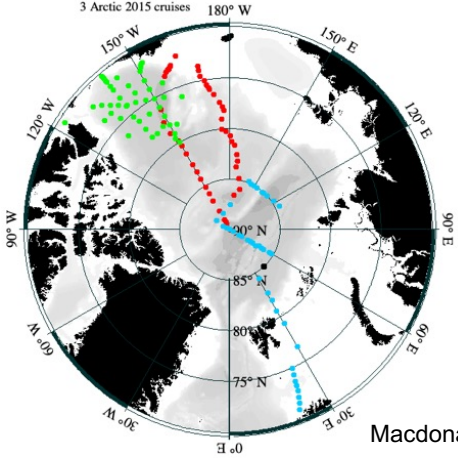
Louis S. St-Laurent + Polar Sea, **Makarov Basin** and **both sides of Lomonosov**

2005



Oden + Healy **Canada Basin, northern Makarov Basin, Lomonosov Ridge**, and **Amundsen Basin.**

2015



Healy (red), Louis St. Laurent (green), and Polarstern (blue) **combined form trans-Arctic data set.**

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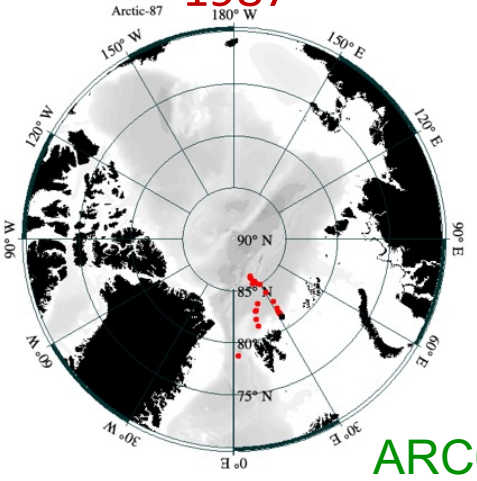
1987



Polarstern
Nansen Basin

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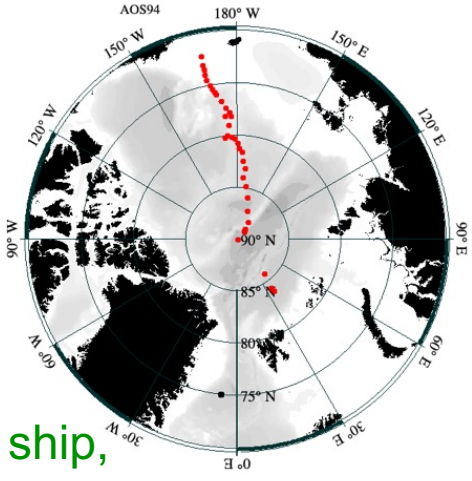
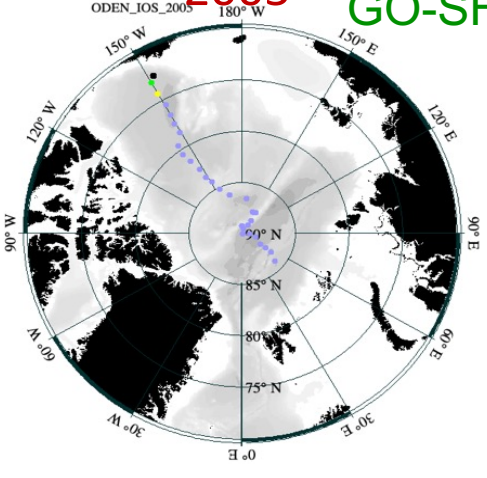


Louis S. St-Laurent + Polar Sea, **Makarov Basin** and **both sides of Lomonosov**

ARC01 – will be the *first* single ship, single season, trans-Arctic GO-SHIP quality & resolution transect

2005



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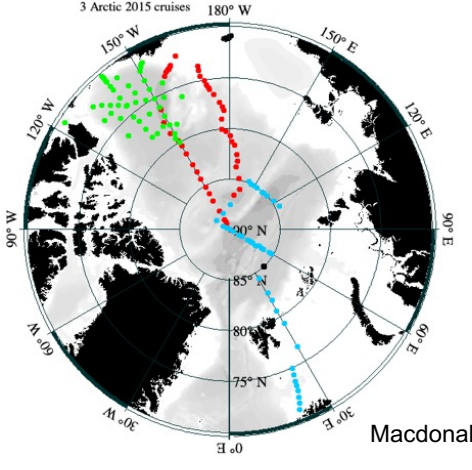

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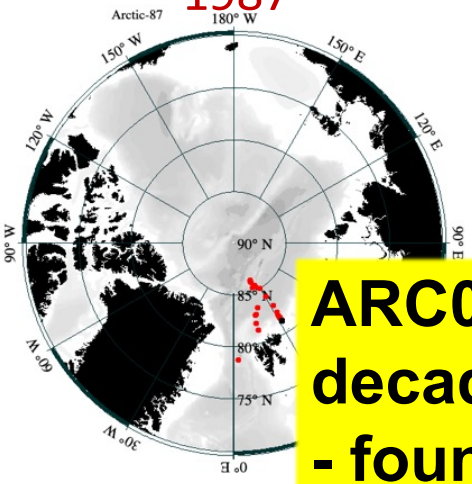
1987



Polarstern
Nansen Basin

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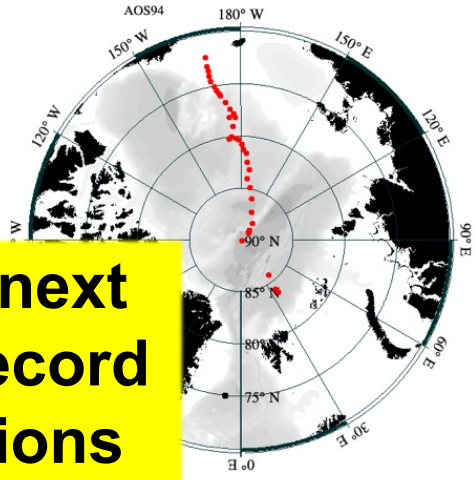
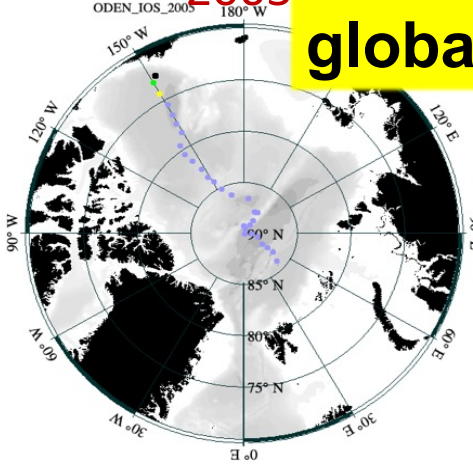


Louis S. St-Laurent + Polar Sea, **Makarov Basin** and **both sides of Lomonosov**

ARC01 will provide the next decade in the climate record - foundational observations as Arctic change outpaces global change.

2005



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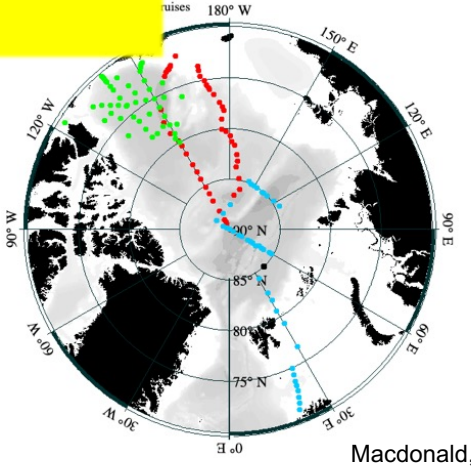

Healy (red), Louis S St-. Laurent (green), and Polarstern (blue) **combined form trans-Arctic data set.**

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Planned ARC01

Ports: Dutch Harbor & Trømsø
(either direction)

Requested:

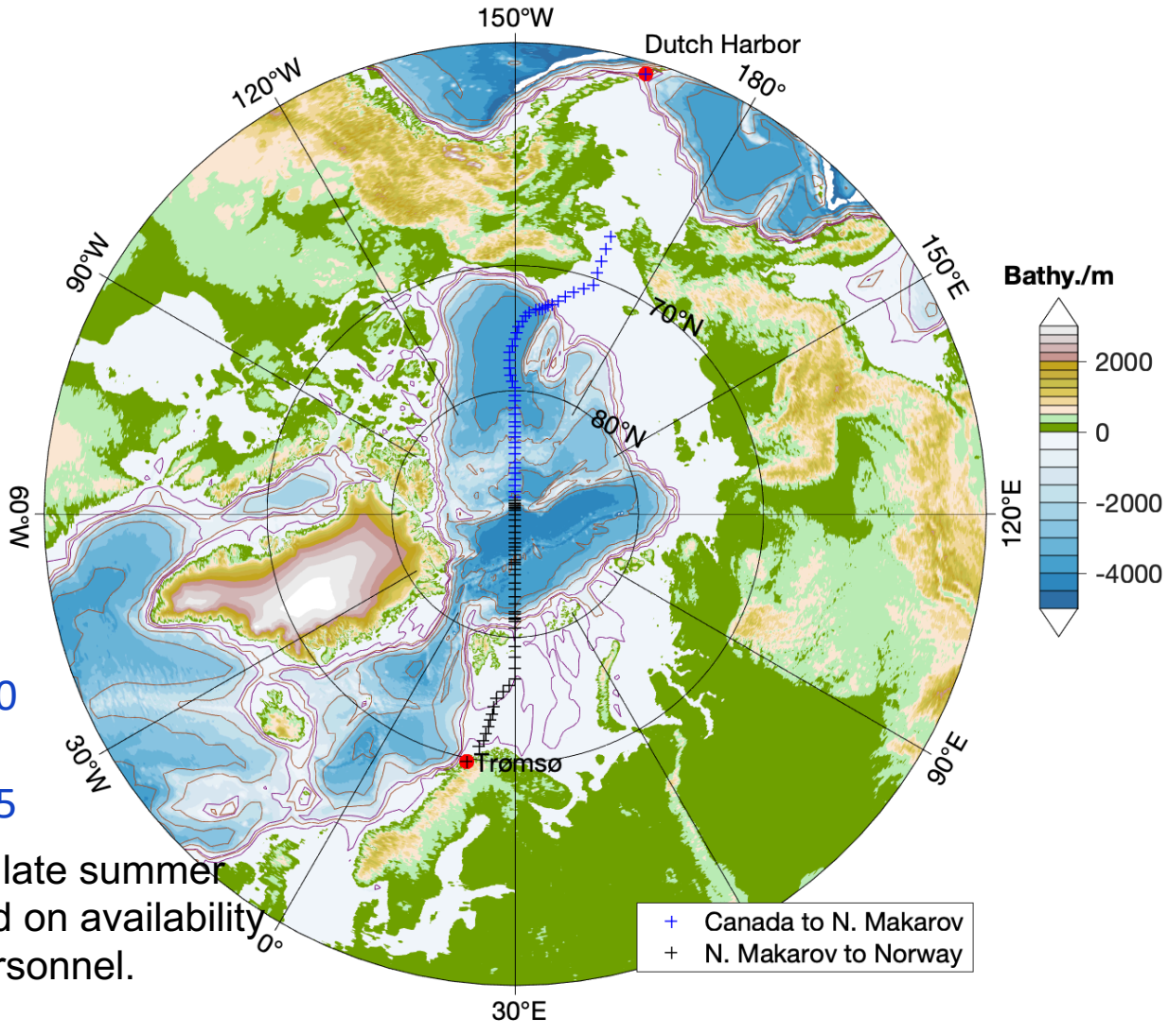
- 4 full days MOB
- 2 full days deMOB
- 43 GO-SHIP Science Days
- 2 Bio GO-SHIP Science Days
- = 45 Days at Sea

Total 51 days

Timeline:

Optimum Start	August 10
Earliest Start	July 25
Latest Start	August 25

Departure ~2-3 weeks ahead of late summer sea ice minimum, but also based on availability of equipment (shipping) and personnel.



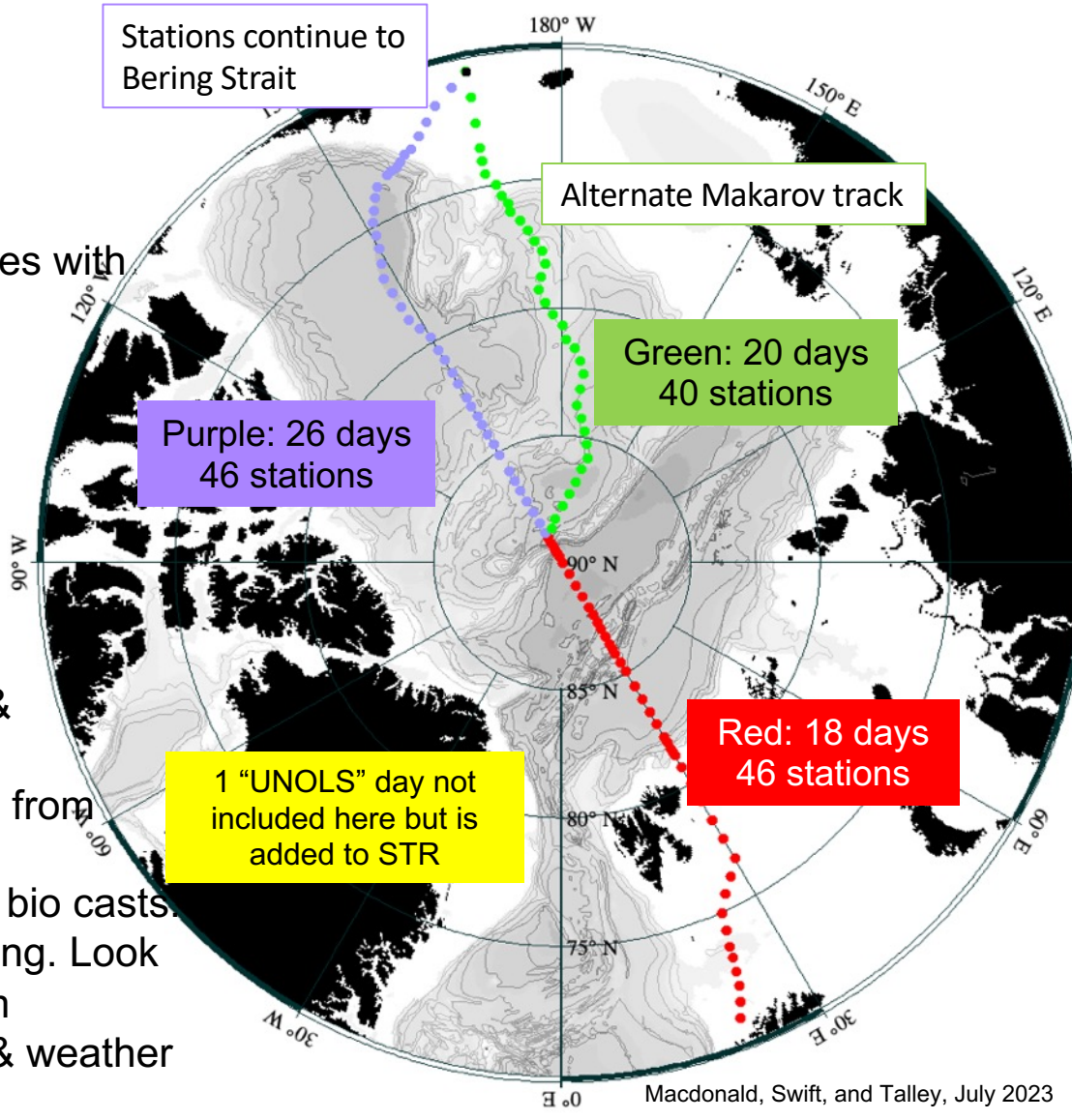
ARC01 (purple & red dots)
Alternate (green)

Proposed segments: repeat earlier cruises with GO-SHIP quality data

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

Cruise duration: 45 days + port days

- Transit times assume Dutch Harbor & Tromsø.
- Ship speed & ice condition estimated from experience.
- Includes ~1 hour every 3rd station for bio casts.
- This plan includes some 60 nm spacing. Look to reduce to nominal GO-SHIP 30 nm
- 92 to 108 stations depending on ice & weather



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US GO-SHIP ARC-01 Logistics

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

The total 45 DAS + 4 mob + 2 demob days with ~100 CTD casts & 33 bio casts, **does not include time for extra programs**

However: there has been a request for ITP deployment (J. Toole & S. Cole)

- They suggest it is feasible to deploy these instruments while the rosette is in the water.

ARC01 Logistics

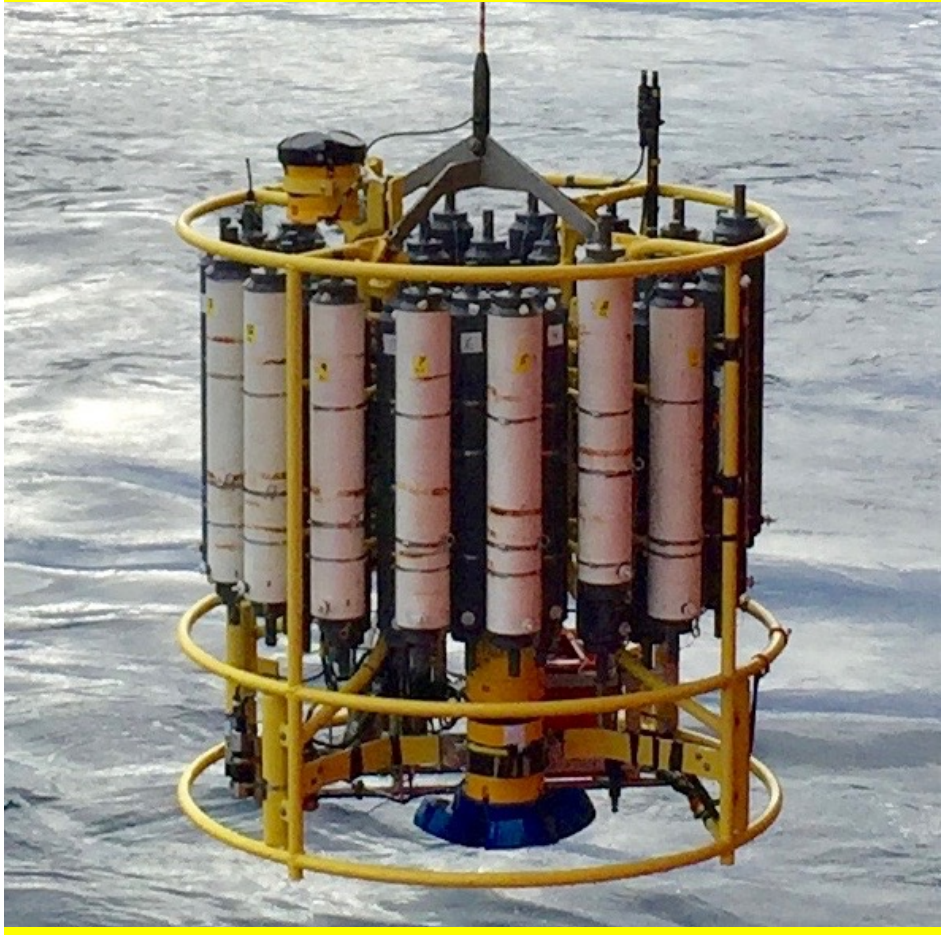
US GO-SHIP:

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
- one shallow (1000 m) bio-cast ~every 3rd station
- ~1 hour in-water per 1000m
- ~2 hours to 'turn-around' rosette

NEW-GENERATION 36 BOTTLE ROSETTE



LOWER DRAG, BETTER SENSOR EXPOSURE

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*

MSR required: Norway

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

We are expecting:
- Float deployments &
- Requests (other than ITP)

Other possibilities:
- EK-80 on transits
- Collaboration with JAMSTEC fall coastal cruise
- Indigenous participation (Equitable Arctic Research)

On US GO-SHIP cruises, we

- Mentor students in numerous at-sea activities as members of the science teams
- Mentor early-career scientists as co-chief scientists
- Hold student & first timer precruise meetings
- Begun holding Bystander Training for all participants
- Follow up with post-cruise surveys

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Points of Contact

- **Chief Scientist** - Lauren Juraneck (main POC)
  - Oregon State University
  - laurie.juranek@oregonstate.edu
- **GO-SHIP Project Manager** – Alison Macdonald (will assist)
  - Woods Hole Oceanographic Institution
  - amacdonald@whoi.edu

Questions?

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