THE GLOBAL OCEAN SHIP-BASED HYDROGRAPHIC INVESTIGATIONS PROGRAM

www.go-ship.org
usgoship.ucsd.edu
cchdo.ucsd.edu
www.jcommops.org

GO-SHIP: into the second decade (2012-2023) of global repeat hydrography

Lynne Talley, Scripps Institution of Oceanography
Co-chair, U.S. GO-SHIP; Member GO-SHIP Exec.

IIOE-2 workshop, Sept. 11, 2017
Scripps Forum

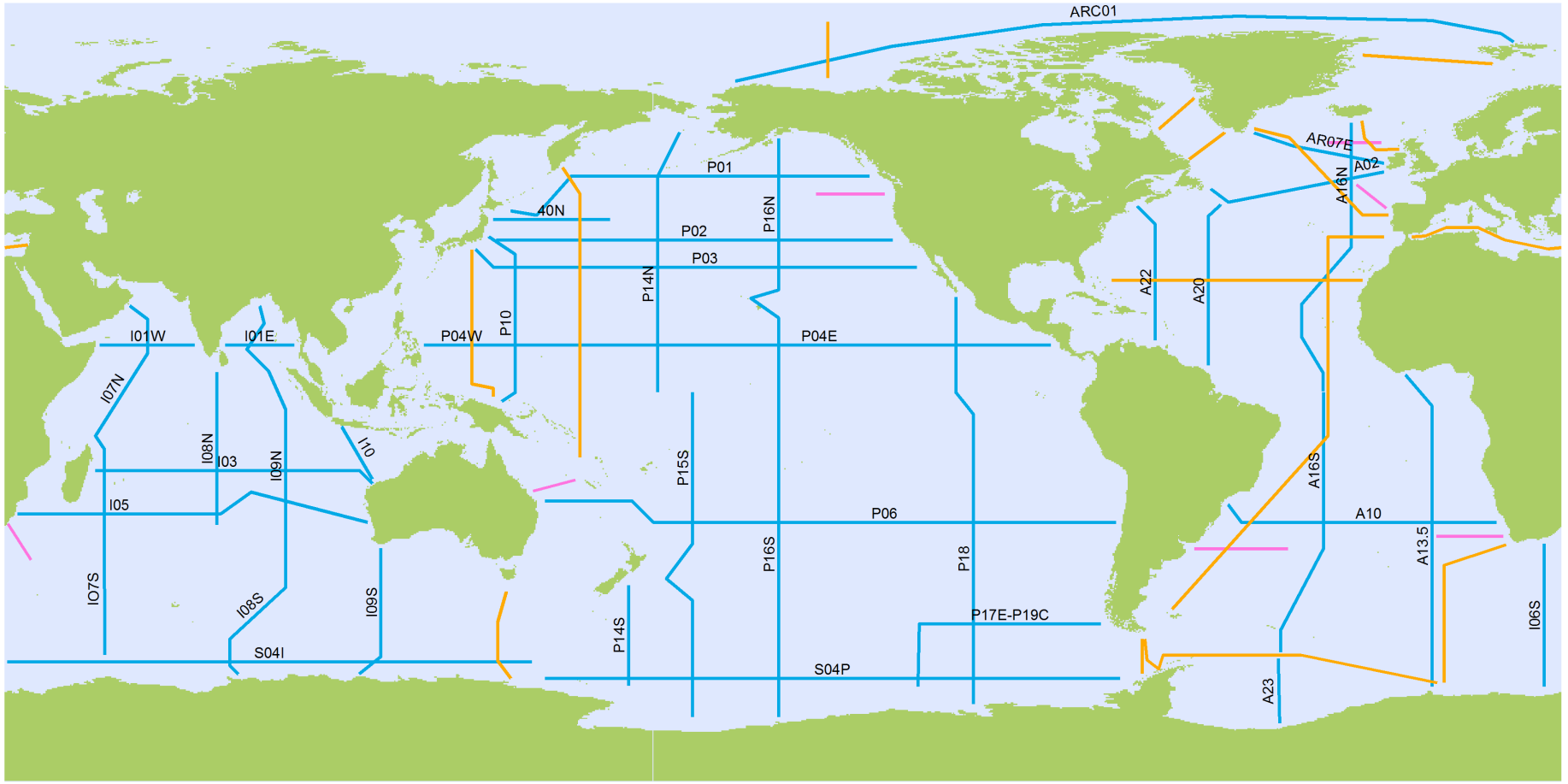
GO-SHIP program

- 'Reference standard': Accurate, full ocean depth measurements of full physical and biogeochemical (carbon and some NCP) system
- Adequate to discern interdecadal (5-10 years) evolution of carbon, heat, freshwater, oxygen, nutrients, tracers
- Calibration standards for all other water column projects, including Argo, BGC-Argo, Deep Argo, OOI, GO-SHIP associated hydrography

S. Howell (U. Hawaii)

GO-SHIP is part of the Global Climate Observing System/ Global Ocean Observing System GCOS/ GOOS

Reference Sections



GO-SHIP 2012-2023 Survey (61 Lines)

Design Map - February 2016

- High frequency GO-SHIP (reduced requirements with decadal full GO-SHIP occupation)
- Decadal full GO-SHIP occupation (all requirements)
- GO-SHIP associated line (GO-SHIP similar requirements off regular lines)

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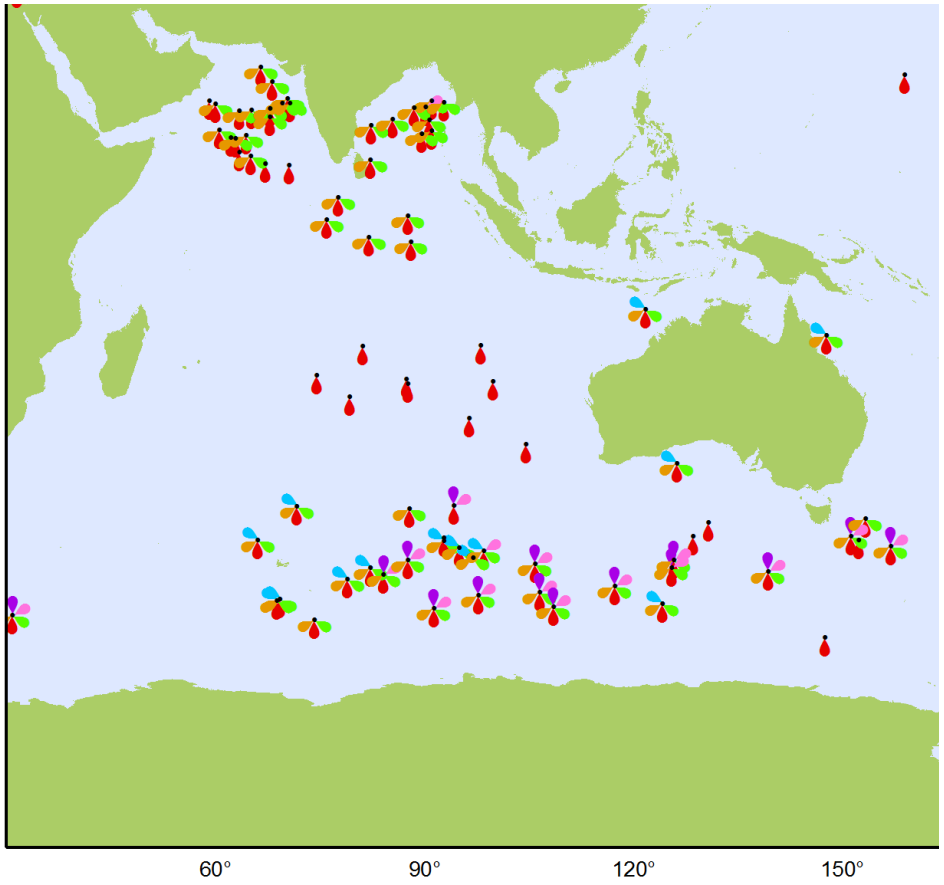
GO-SHIP utility



Biogeochemical Argo

Latest location of

Use GO-SHIP as a deployment platform for biogeochemical floats, So with shipboard verification of Calibrations

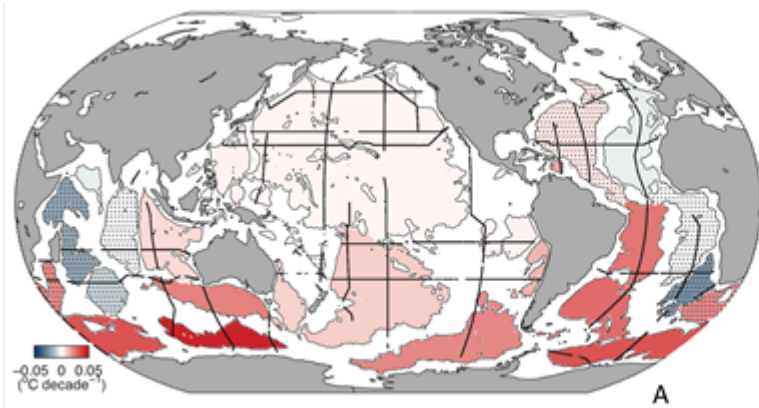
Map from
www.jcommops.org
(August, 2017)

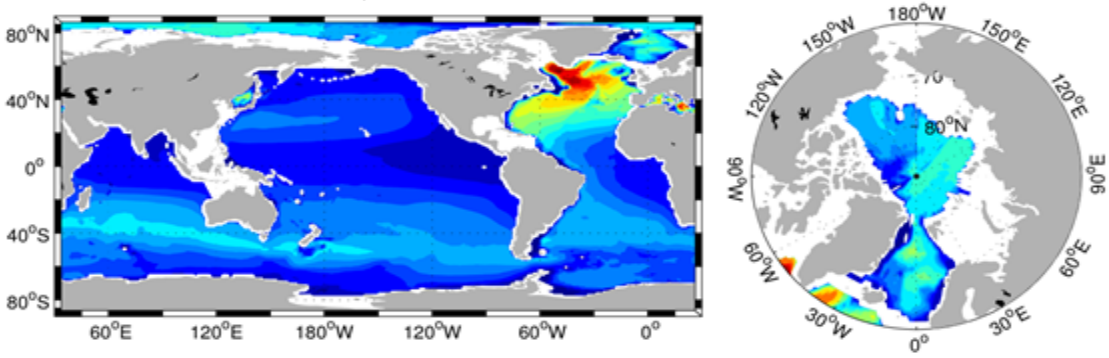
Annual Review of Marine Science

Annual Review of Marine Science, 8, 19.1-19.31, 10.1146/annurev-marine-052915-100829, 2016.

Changes in Ocean Heat, Carbon Content, and Ventilation: Review of the First Decade of Global Repeat Hydrography (GO-SHIP)

L.D. Talley,[1] R.A. Feely,[2] B.M. Sloyan[3], R. Wanninkhof,[4] M.O. Baringer,[4] J.L. Bullister,[2] C.A. Carlson,[5] S.C. Doney,[6] R.A. Fine,[7] E. Firing,[8] N. Gruber,[9] D.A. Hansell,[7] M. Ishii,[10] G.C. Johnson,[2] K. Katsumata,[11] R.M. Key,[12] M. Kramp,[13] C. Langdon,[7] A.M. Macdonald,[6] J.T. Mathis,[2] E.L. McDonagh,[14] S. Mecking,[15] F.J. Millero,[7] C.W. Mordy,[2,16] T. Nakano,[17] C.L. Sabine,[2] W.M. Smethie,[18] J.H. Swift,[1] T. Tanhua,[19] A.M. Thurnherr,[18] M.J. Warner,[20] and J.-Z. Zhang[4]

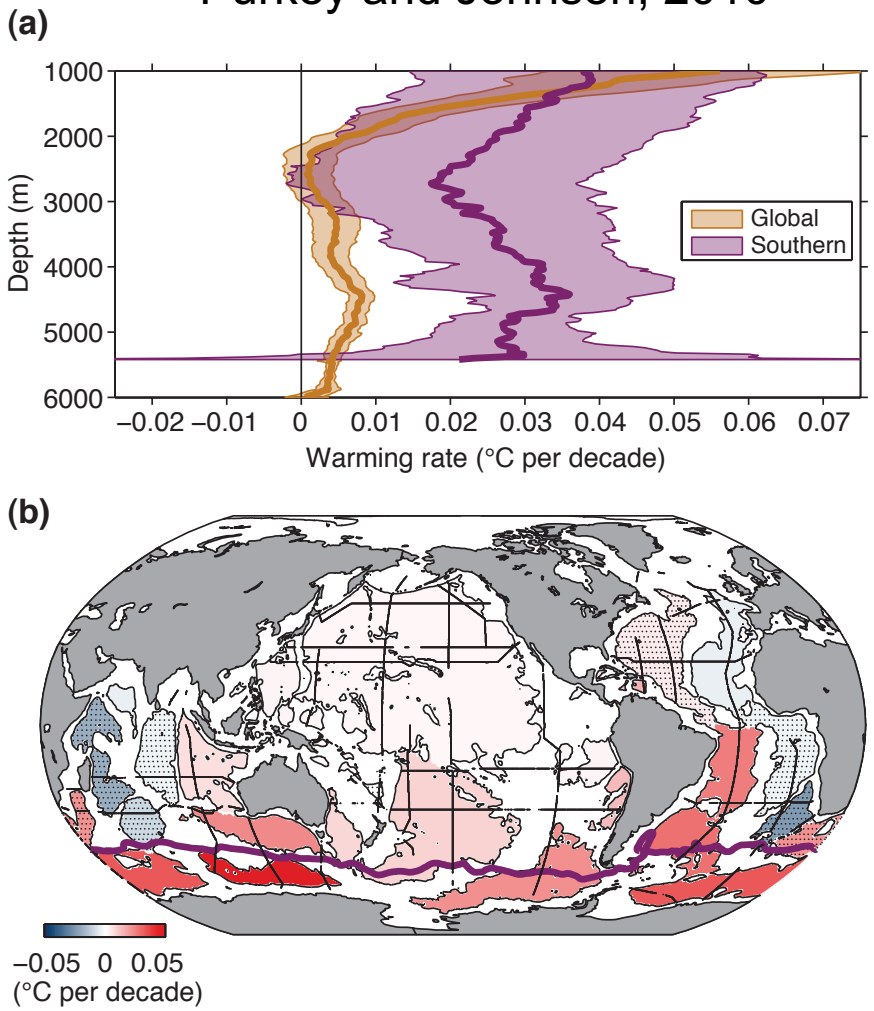




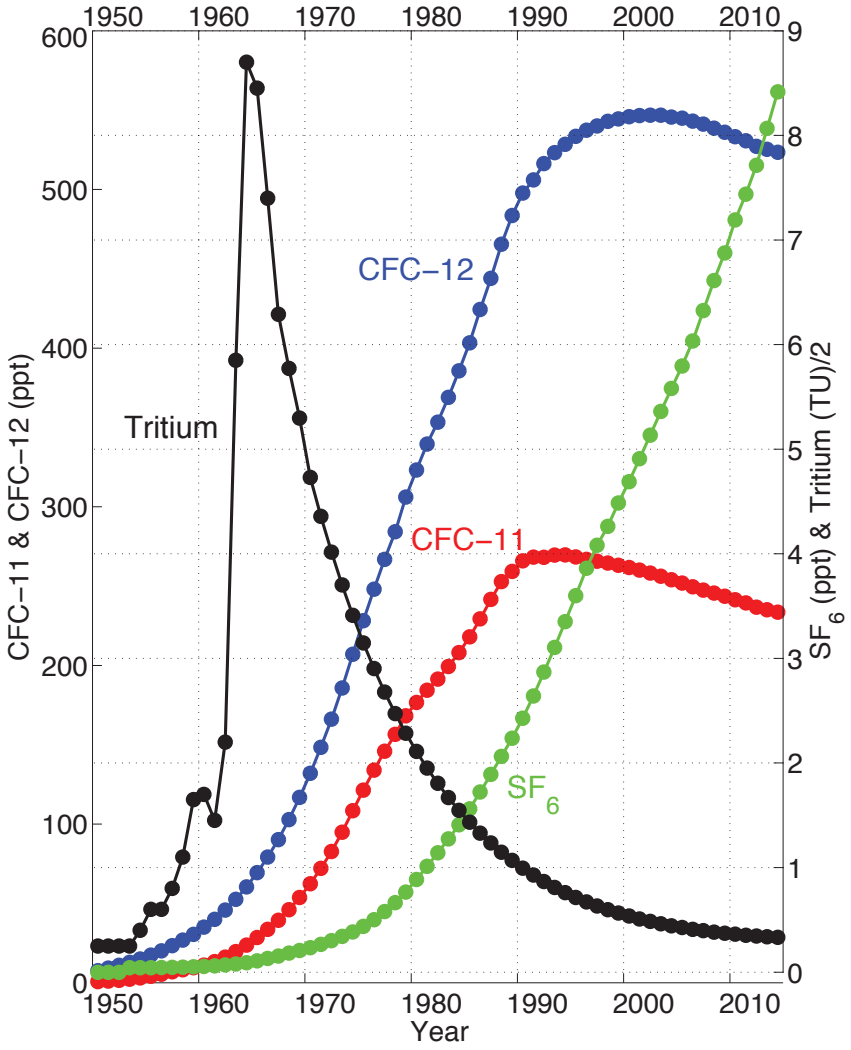
GO-SHIP science highlights

Rate of temperature change below 4000 m from repeat hydrography. Stippled areas are where change is not significant.

Purkey and Johnson, 2010

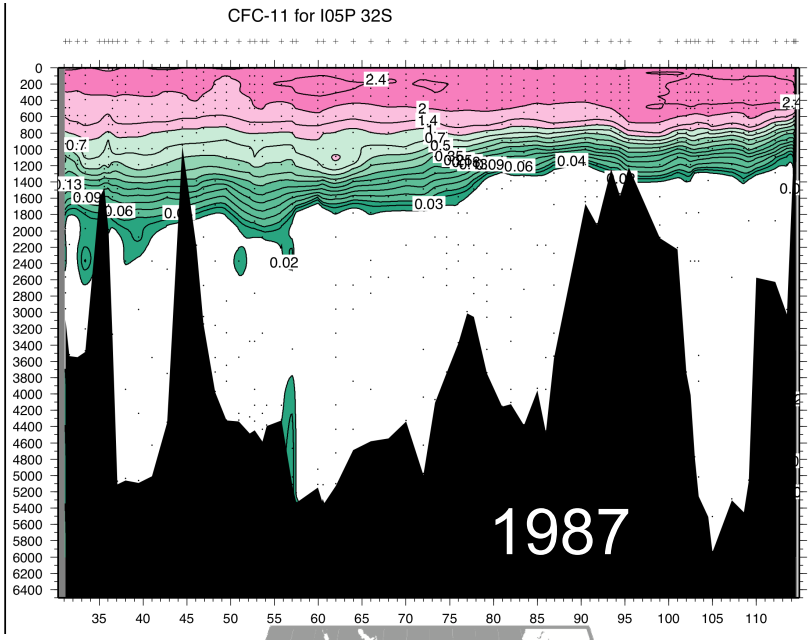


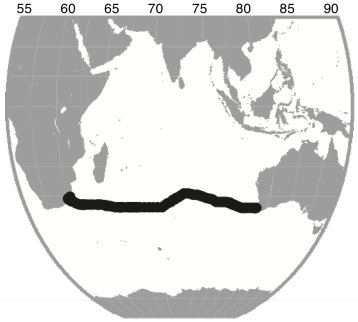
Results: Ventilation signals (CFC tracers)

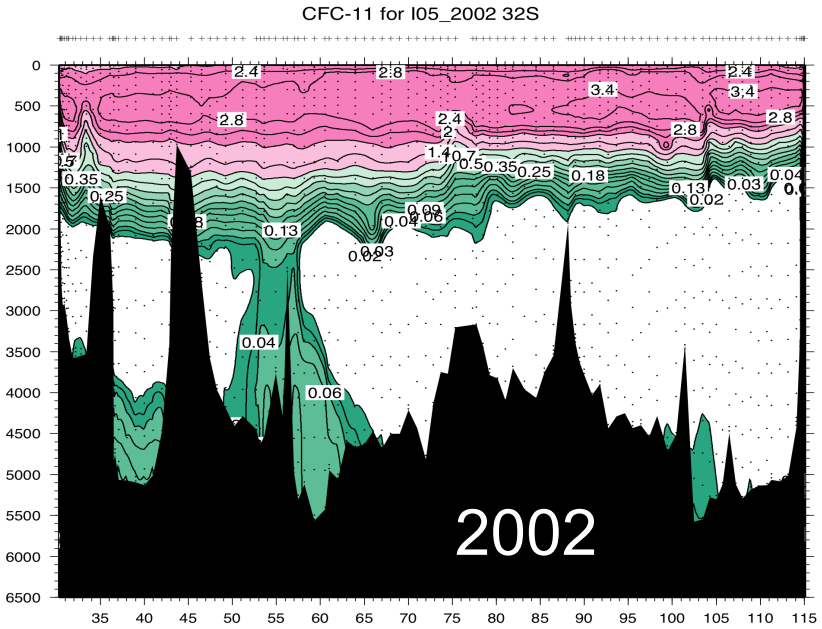


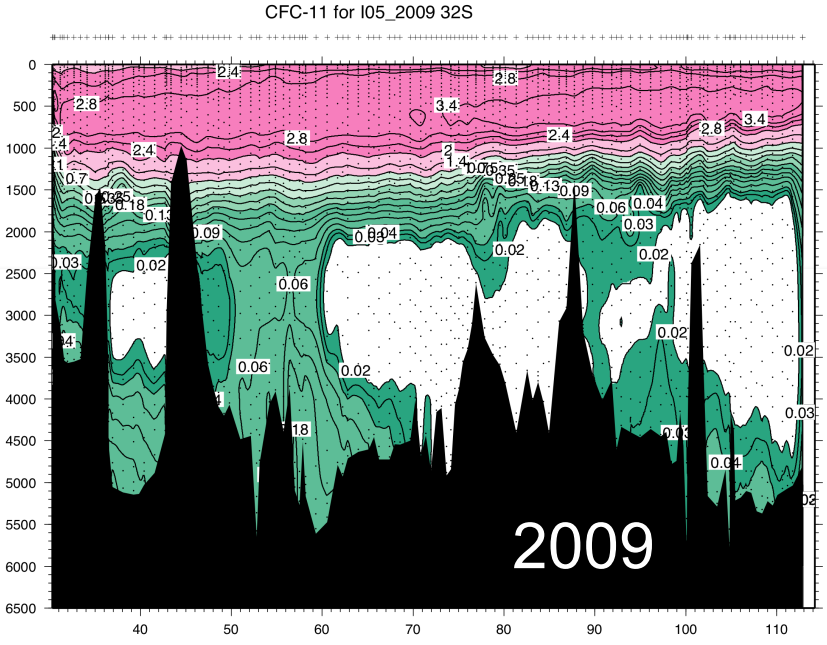
- Time history of anthropogenic transient tracers in the atmosphere: chlorofluorocarbons, SF_6 and tritium

Visualization of the Indian overturn: CFC-11 changes









Invasion of CFC-11 marks deep ventilation pathways.

Lack of invasion may mark southward IDW pathways

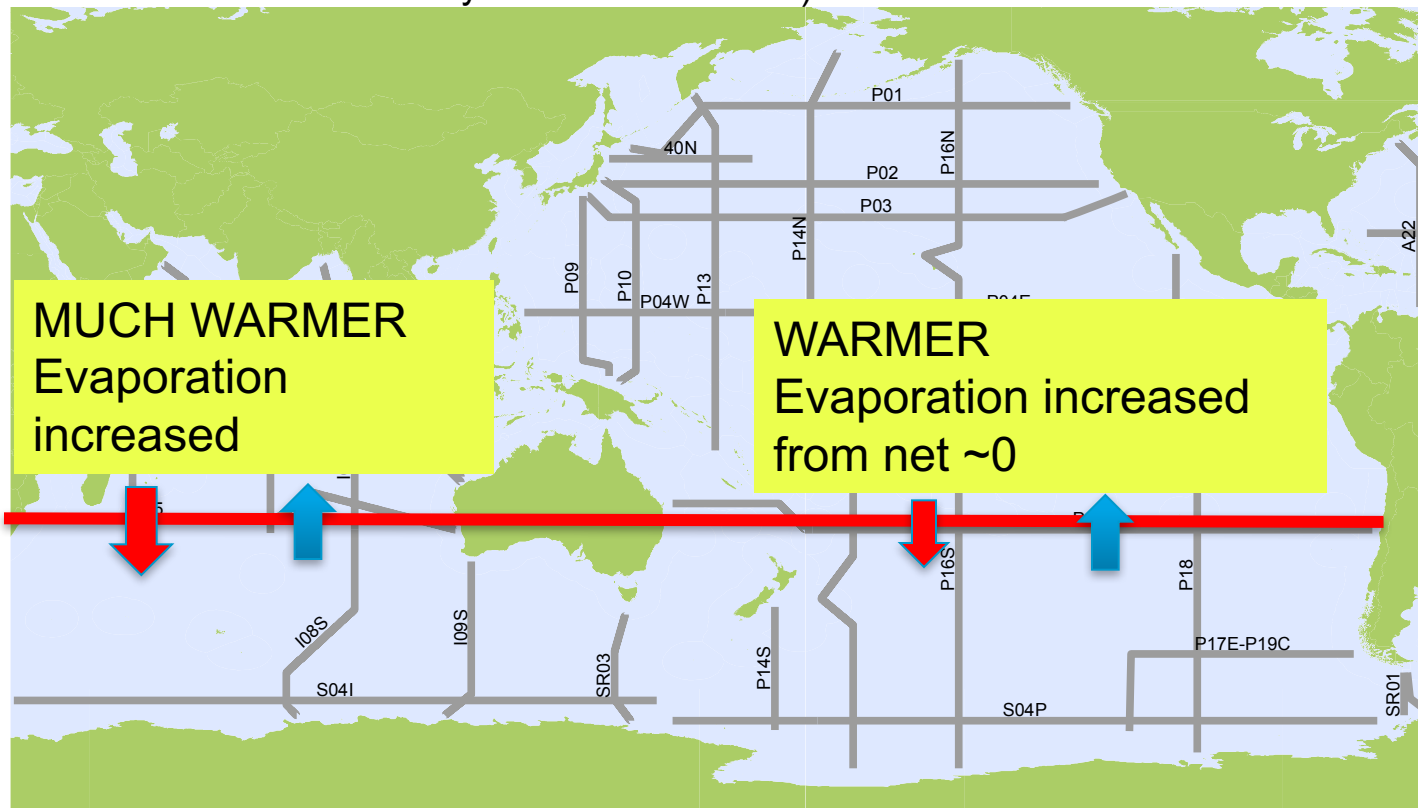
Enhancement of upper ocean CFC-11 marks subtropical circulation.

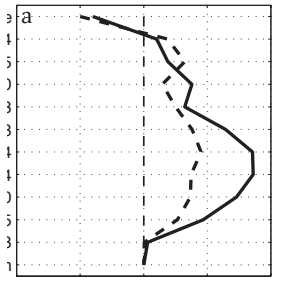
Indian vs. Pacific changes 2002/03 to 2009 in heat and FW transport: GO-SHIP

Indian: shift to warmer, lower density, probable reduction in deep overturn
Southward heat transport in Indian/Pacific doubled, associated with ocean warming

Heat transport change
Indian HT increased by 0.6 PW
Pacific HT increased by 0.2 PW

Freshwater transport change
Indian FWT increased from 0.2 Sv by 0.3 Sv
Pacific FWT increased from ~0 in 2002 (historical value) to 0.2 to 0.3





Changes in
Heat transport
Freshwater
transport

Hernandez-Guerra and Talley (PiO,2016)

GO-SHIP Chemistry/Biology Objectives in the Indian Ocean (Richard Feely)

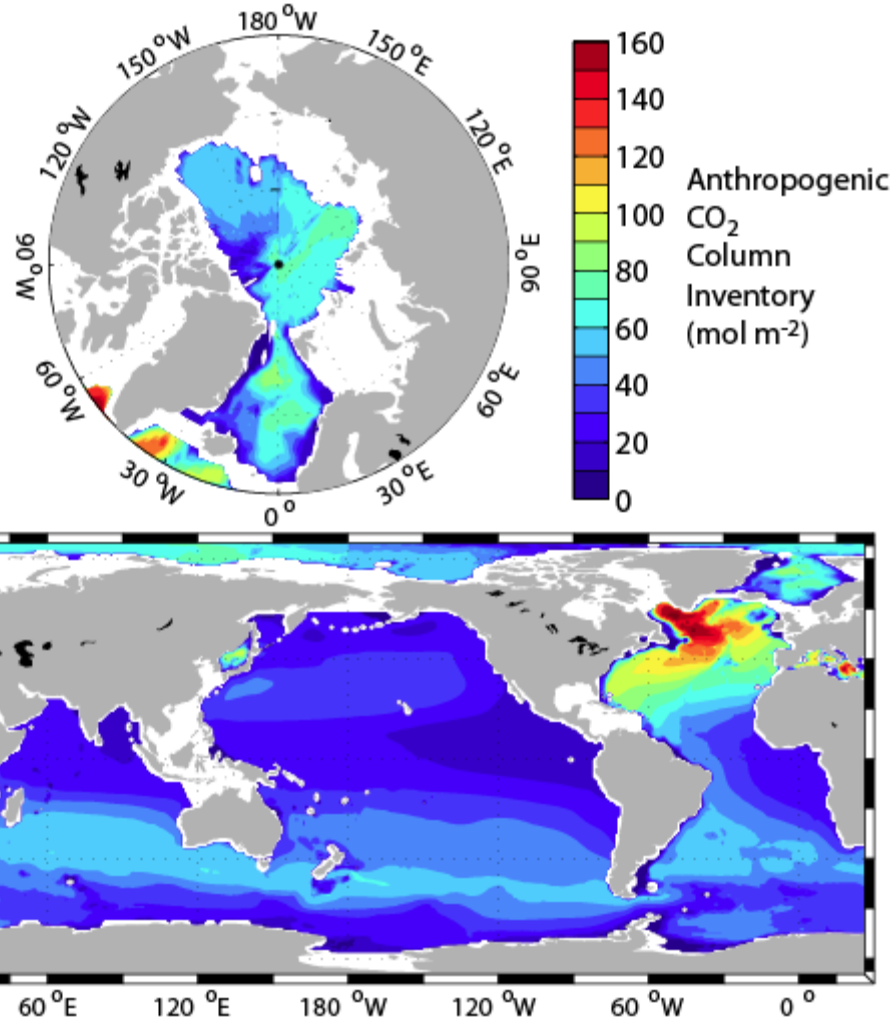
- Determine Decadal Changes in Anthropogenic CO_2 Uptake
- Determine Decadal Changes in Nutrient and Oxygen Distributions
- Determine Decadal Changes in pH and Aragonite Saturation State
- Determine Decadal Changes in Biogeochemistry and Biology

Results: Anthropogenic carbon

- Estimate of current Anthropogenic CO_2 Distributions

- Total 2008 Inventory: 140 ± 25 Pg C

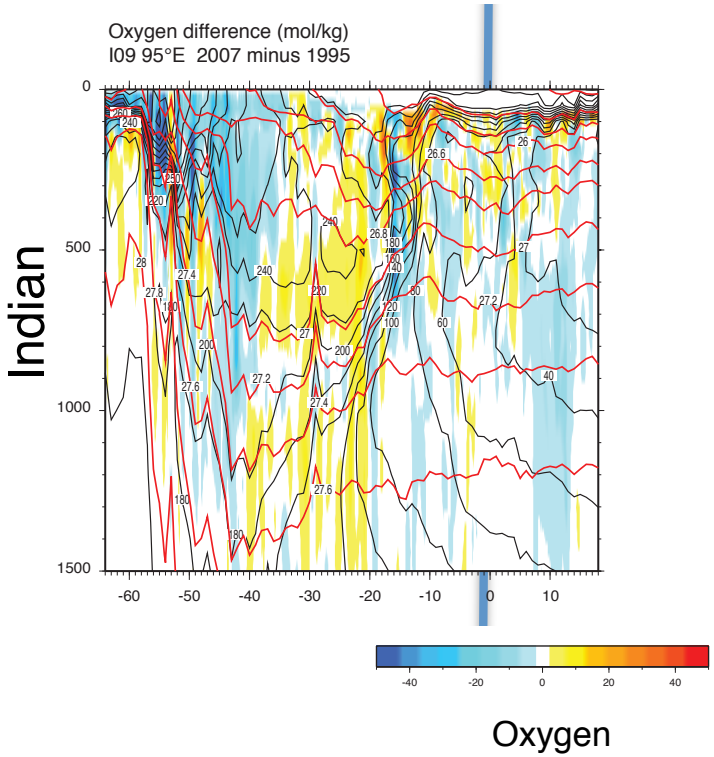
- ~ 6% (8.2 Pg C) stored in Marginal Seas (including the Arctic)



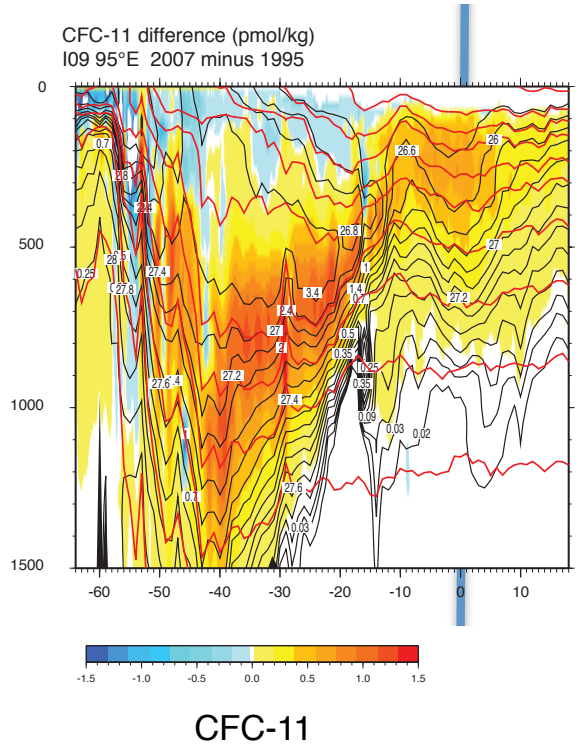
Khatiwala et al. (2013

Results: Ventilation signals (Oxygen, CFCs)
GO-SHIP minus WOCE (2007 minus 1995)

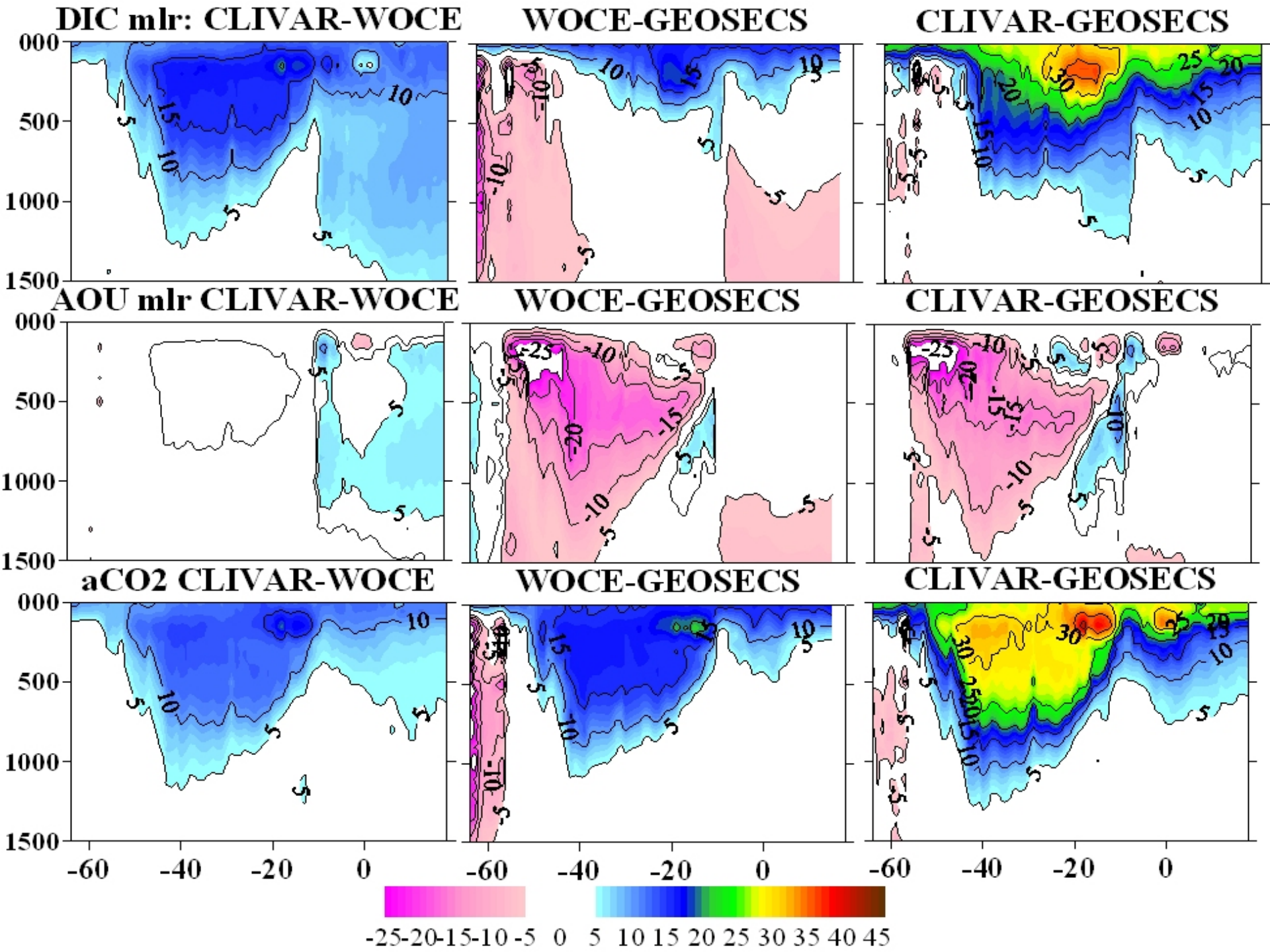
Southern Hemisphere subtropical gyres were more strongly ventilated in 2000s than in 1990s, opposite to Northern Hemisphere and tropical oxygen minimum zones



Oxygen



CFC-11


DIC mlr: CLIVAR-WOCE
WOCE-GEOSECS
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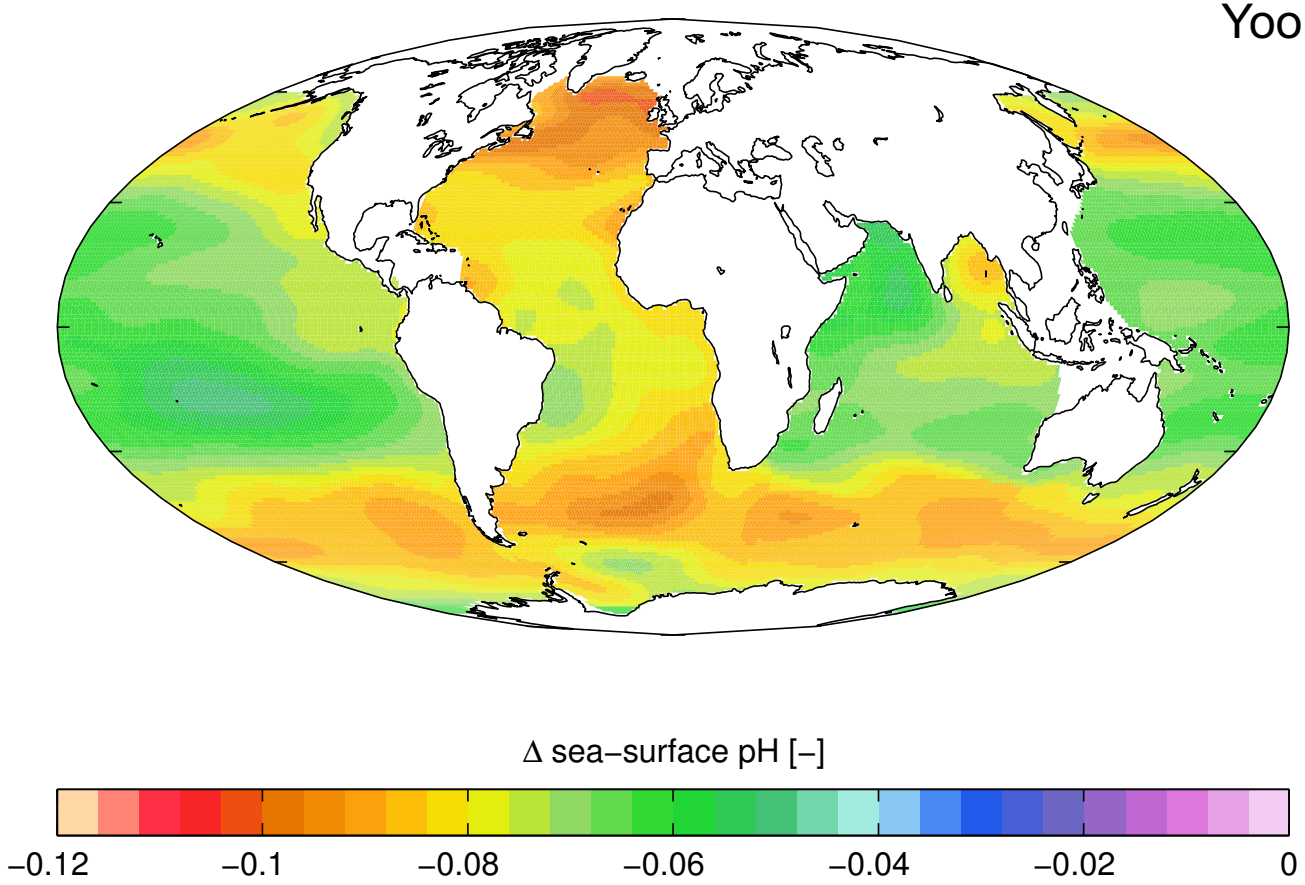
CLIVAR-GEOSECS
000
500
1000
1500
-60
-40
-20
0
-25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45

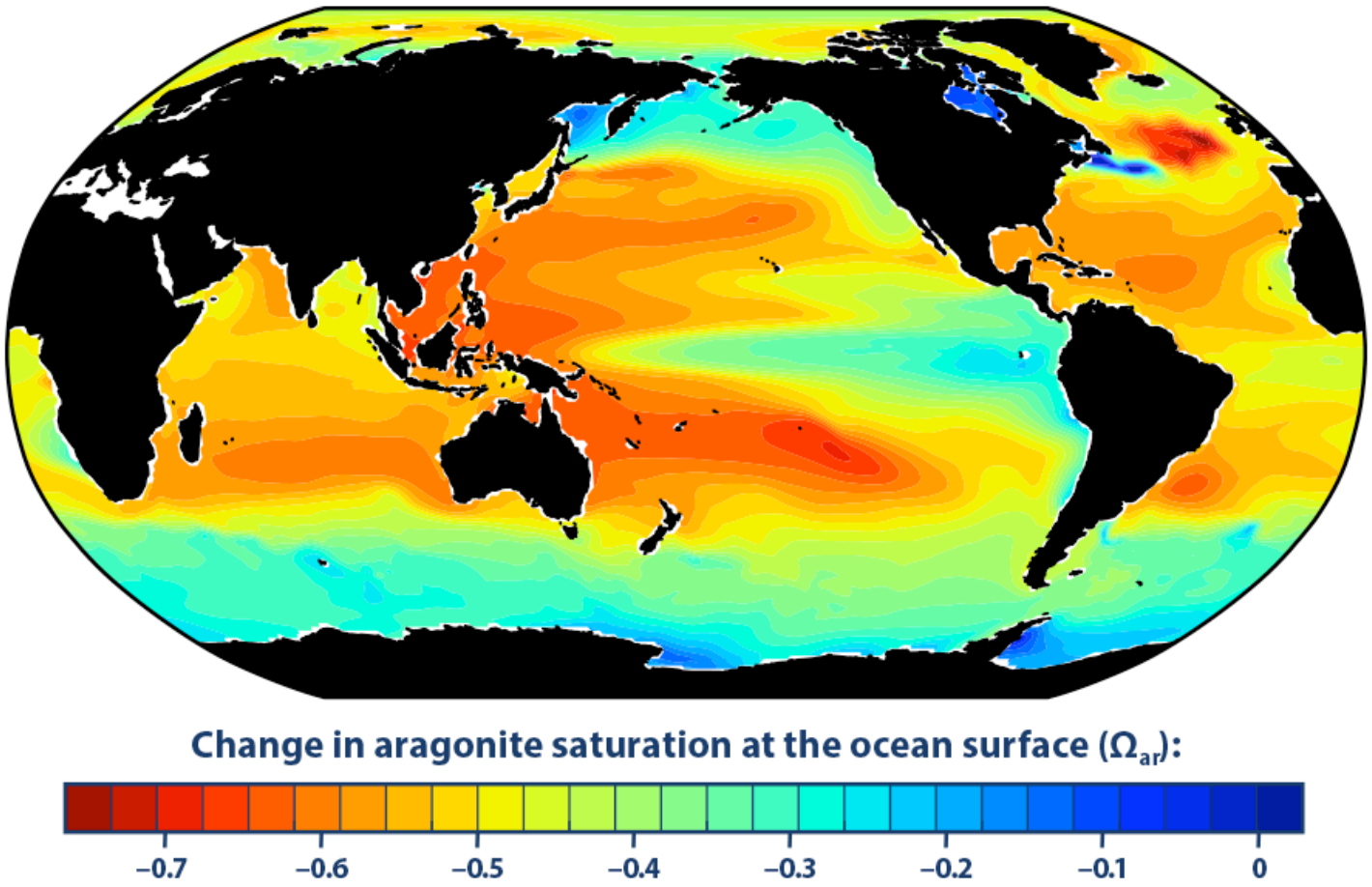
Surface pH change

Yool et al. 2013



Estimated pH change from pre-industrial to present, using GLODAP and WOA05

Surface ocean acidification



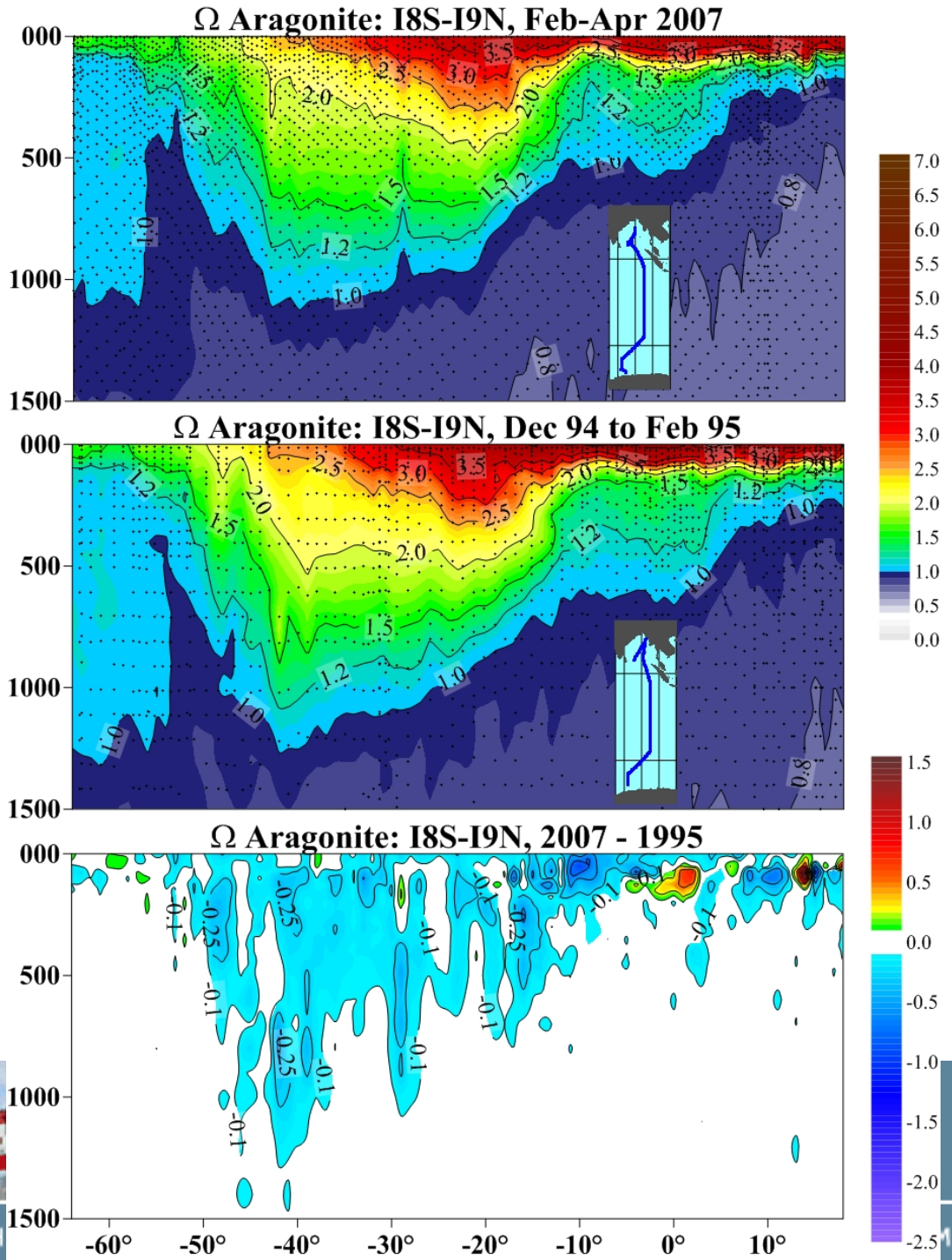
Feely et al. (2009) updated in 2016

Data source: Woods Hole Oceanographic Institution. 2016 update to data originally published in: Feely, R.A., S.C. Doney, and S.R. Cooley. 2009. Ocean acidification: Present conditions and future changes in a high-CO_2 world. Oceanography 22(4):36–47.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

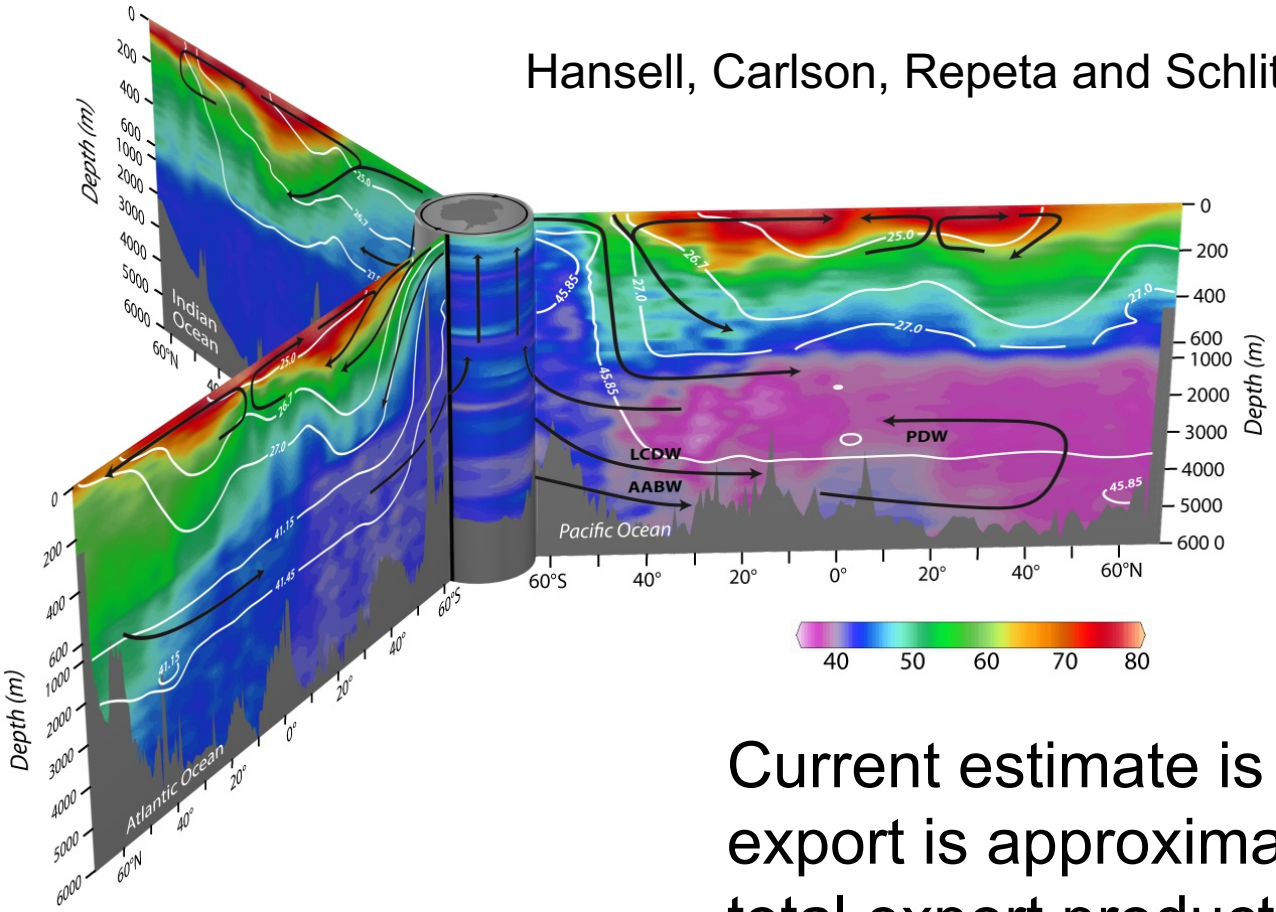
Change in aragonite saturation along 95°E (I8S/I9N) 1995 to 2007

(ocean acidification)



Results: Dissolved Organic Carbon

Hansell, Carlson, Repeta and Schlitzer (Oceanography,2009)



Current estimate is that DOC export is approximately 20% of total export production

Measurement requirements of GO-SHIP: Level 1 variables [Required] *profiles to ocean bottom*

(*All data are to be released in final form 6 months after the cruise*)

- Dissolved inorganic carbon (DIC)
- Total Alkalinity (TAlk)
- pH
- CTD pressure, temperature, salinity (calculated)
- CTD oxygen (sensor)
- Bottle salinity
- Nutrients by standard auto analyzer (NO_3/NO_2, PO_4, SiO_3)
- Dissolved oxygen (Winkler)
- Chlorofluorocarbons (CFC-11, -12, -113) and SF_6
- Surface underway system (T, S, pCO_2)
- ADCP shipboard
- ADCP lowered
- Underway navigation and bathymetry
- Meteorological.

Measurement requirements of GO-SHIP: Level 2 variables [Highly Desired]

(*All data are to be released in final form 6 months after the cruise*)

- Discrete pCO_2
- ^{14}C by AMS
- CCl_4
- $\partial^{13}C$ of DIC
- N_2O
- $^{3}H/^{3}He$
- Fe/trace metals
- CTD Transmissometer
- Surface underway system (nutrients, O_2, Chl, skin temperature, pH, DIC, TAlk).
- Dissolved organic carbon (DOC)
- Dissolved organic nitrogen (DON)

Measurement requirements of GO-SHIP: Level 3 variables [All additional programs]

(*All data are to be released in final form within 2 years of analysis*)

- Examples include, but are not limited to, microstructure/turbulence; chlorophyll; Primary production; HPLC pigments; Experimental continuous analyzers; $\partial_{15}N$; NO_3; $_{32}Si$; $\partial_{18}O$ of H_2O; NH_4; Low level nutrients; Total organic phosphorus; Upper ocean optical; isotopes of O_2; N_2, Ar, O_2; Methyl halides; DMS.

GO-SHIP Associated

As of September 2015:

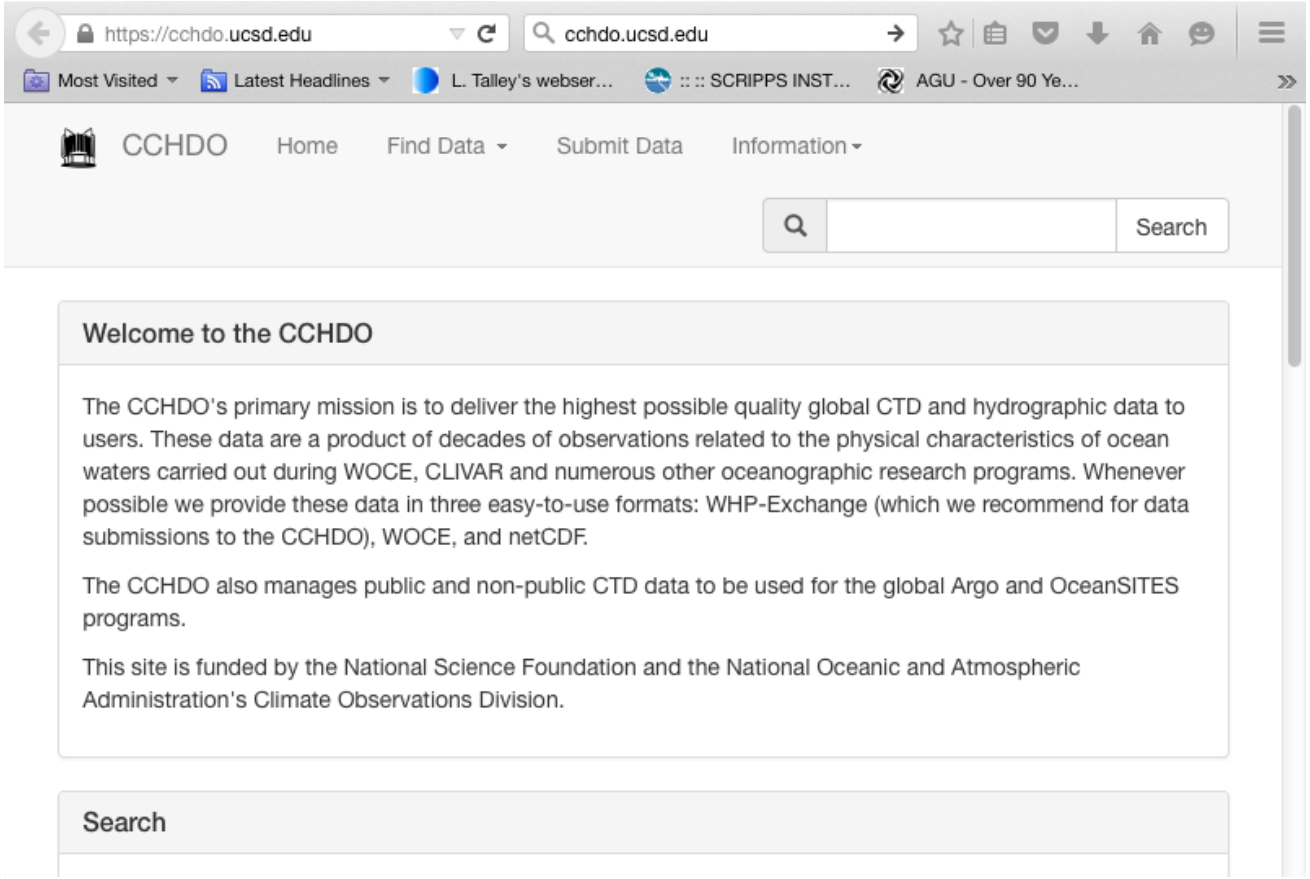
Repeat hydrographic sections along regular GO-SHIP lines and not necessarily coast-to-coast or coast-to-ice, that:

- deliver high quality data,
- establish full depth stations below 2000m at least every 240nm,
- are repeated on decadal frequency or more, with at least once per decade sufficient level 1 parameters to determine decadal changes in inorganic carbon and heat,
- at a minimum resolution of 60nm, and
- comply with the data policy.

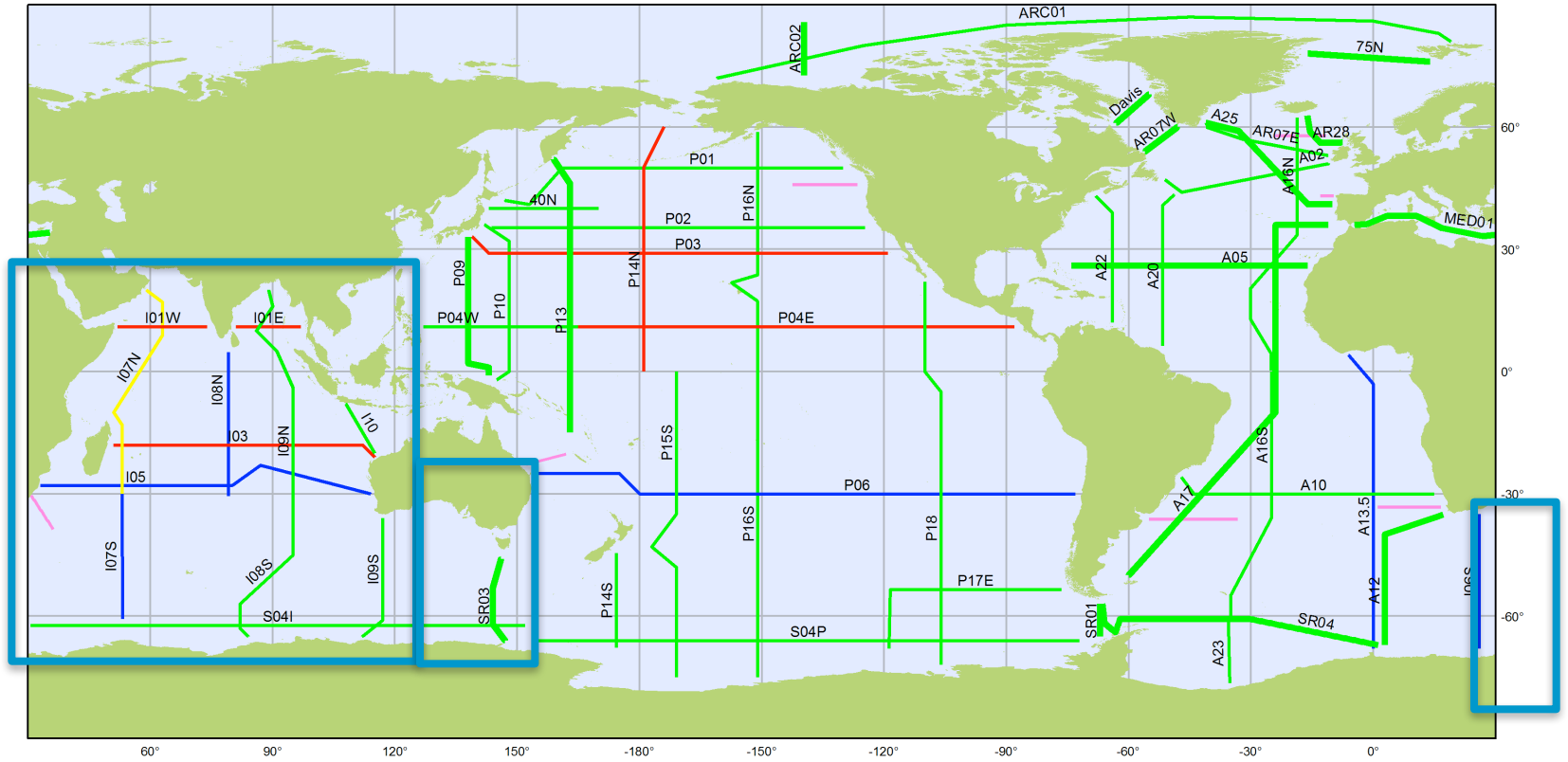
GO-SHIP data management

https://cchdo.ucsd.edu

Online data sets satisfying the data delivery requirement



Current Status of Decadal Survey



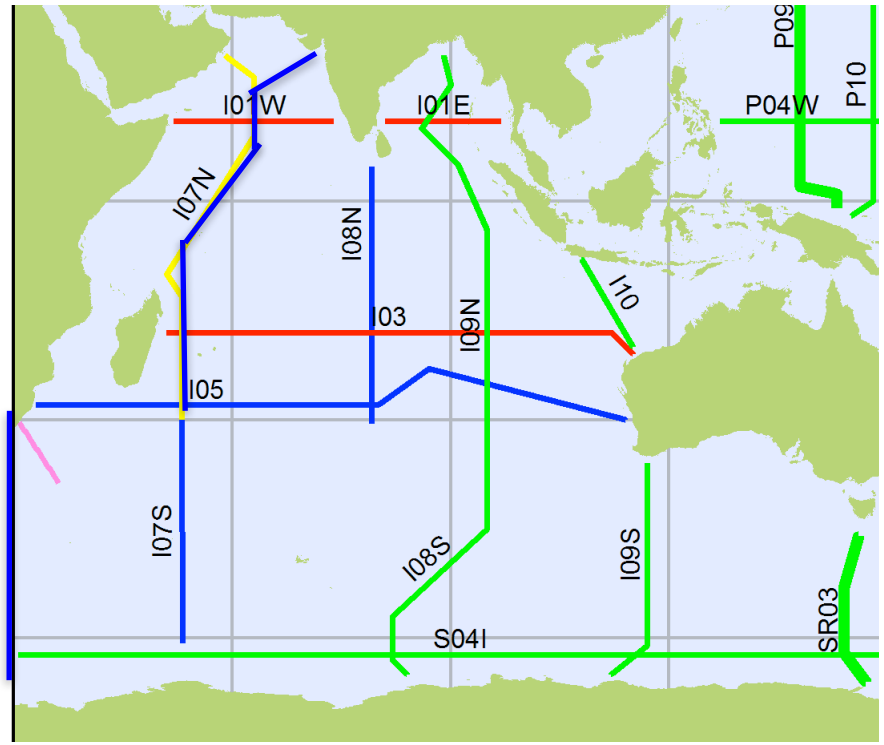
GO-SHIP **Status of 2012-2023 Survey (61 Lines)** **May 2017**

Bold lines: High Frequency (reduced requirements) Thin lines: Decadal GO-SHIP (full requirements)

completed | at sea | funded | planned | not planned yet | associated & completed

THE GLOBAL OCEAN SHIP-BASED HYDROGRAPHIC INVESTIGATIONS PROGRAM

Current Status of Decadal Survey: Indian Ocean



Upcoming & Funded

Section	Location	Country	Year
SR3	150E	Australia	2018
I7N	60E	US	2018
I5	32S	US	2019
I7S	55E	Japan	2019
I8N	80E	Japan	2019
I9S	110E	Australia	2020
I6S	40E	US	2020

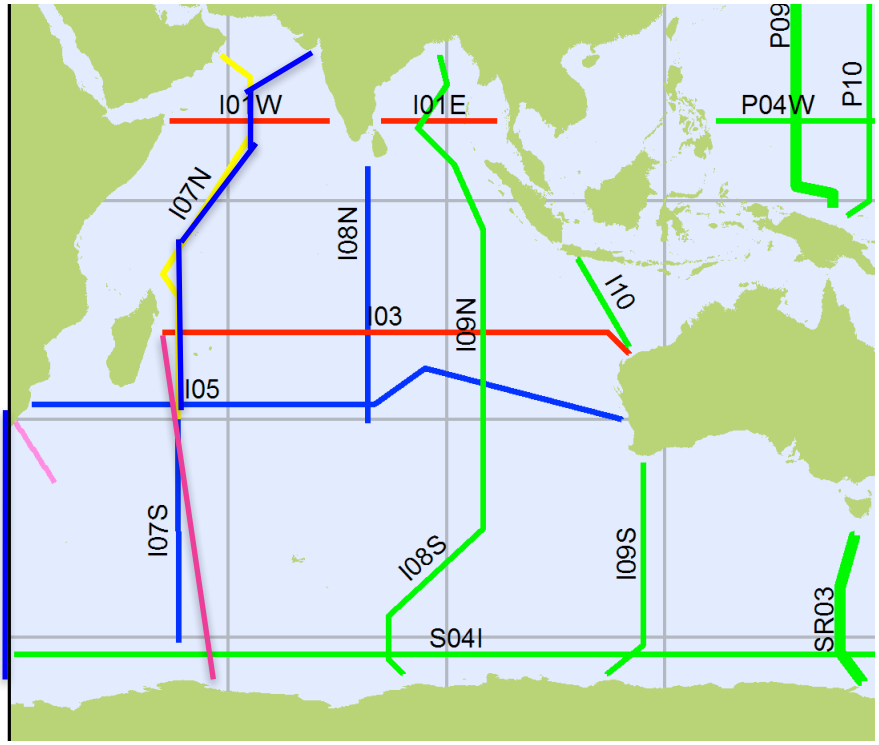
Recently completed

Section	Location	Country	Year
S4I	60S	Japan	2012-2013
I10	110E	Japan	2015
I8S	95E	US	2016
I9N	95E	US	2016

Unplanned

Section	Location	Country	Year
I01W	8N	?	?
I01E	8N	?	?

Current Status of Decadal Survey: Indian Ocean



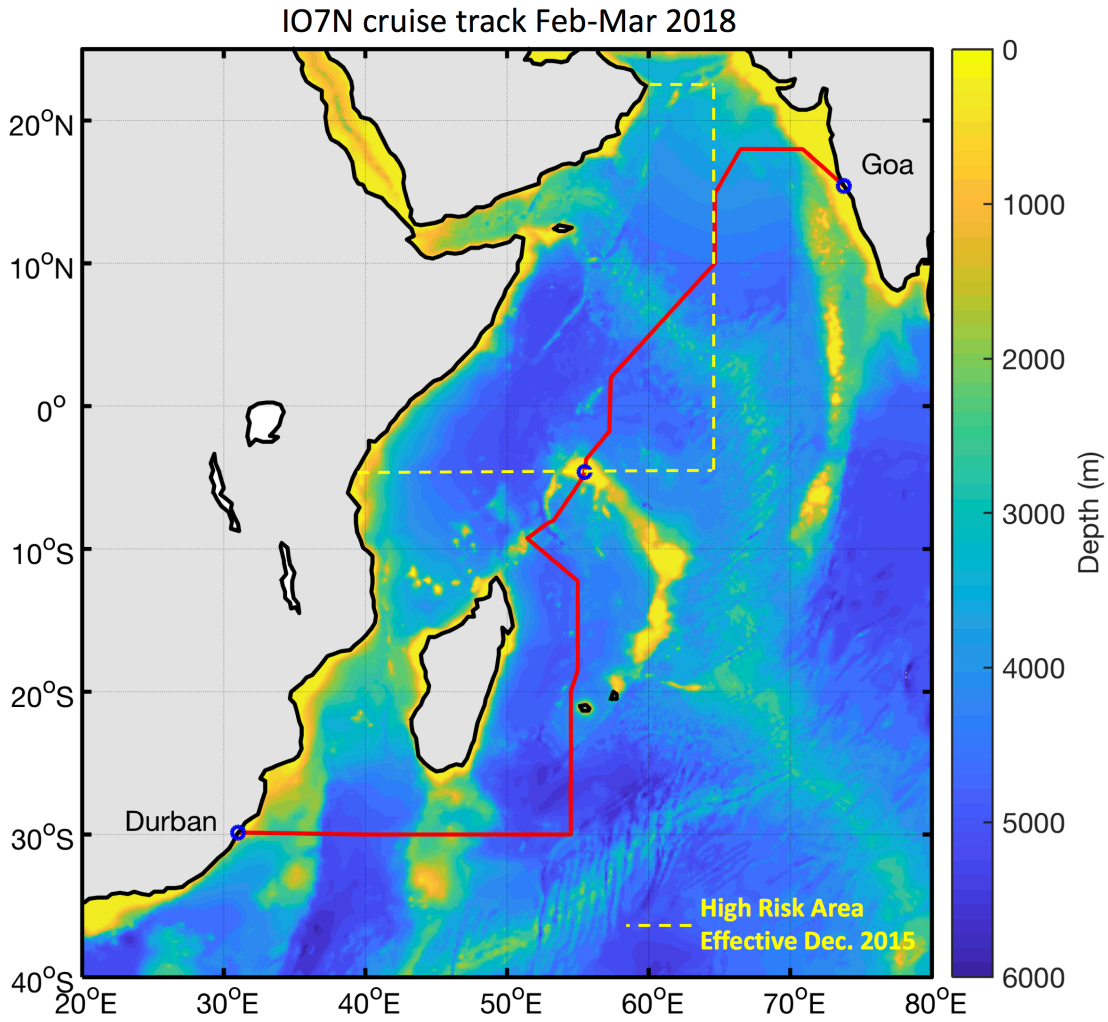
Associated

Section	Location	Country	Year
Marion	Agulhas	South Africa	annual
I7S	*55E*	*India*	*annual*

Potential associated?

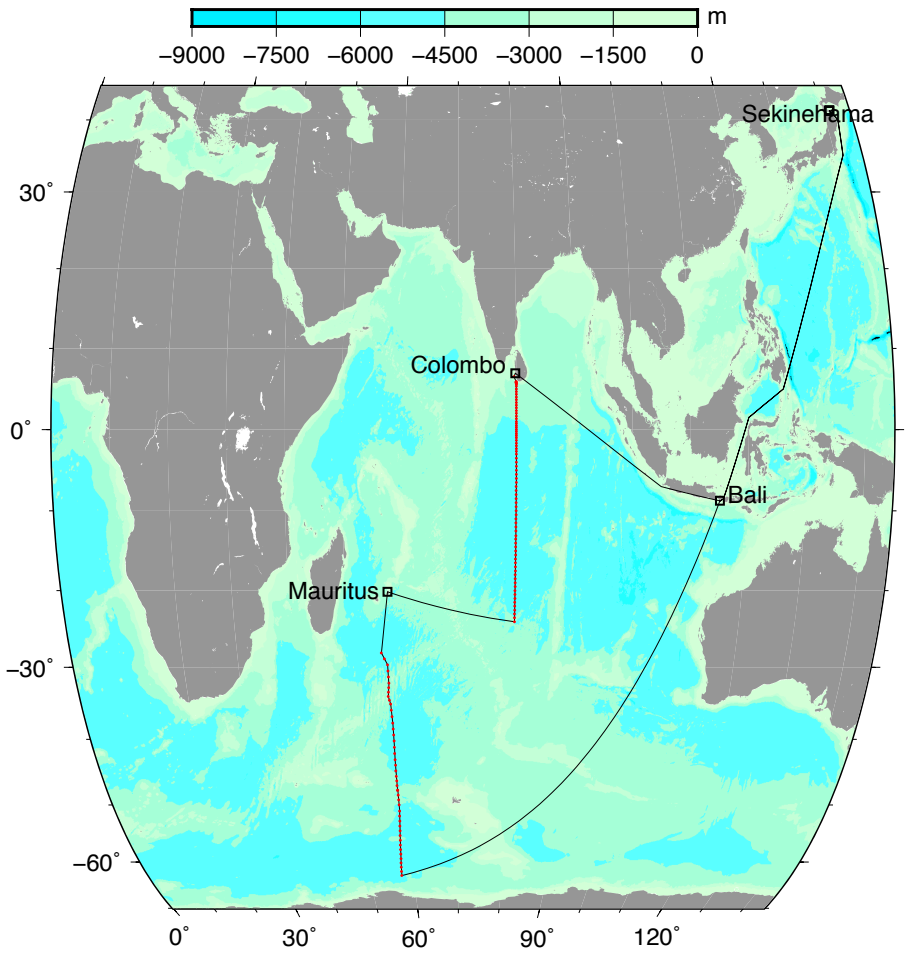
Region	Location	Country	Year
ISS1, S4I	SW Indian/Kerguelen	France Australia	Annual
Prydz Bay	Prydz Bay	China	Annual
Others?		?	?

I7N plans (funded, U.S., Feb-March 2018)



RV Ron Brown
NOAA funding
Denis Volkov, Chief Sci
Vivianne Menezes, Co-Chief Sci.

I7S, I8N plans (funded, Japan, 2019)

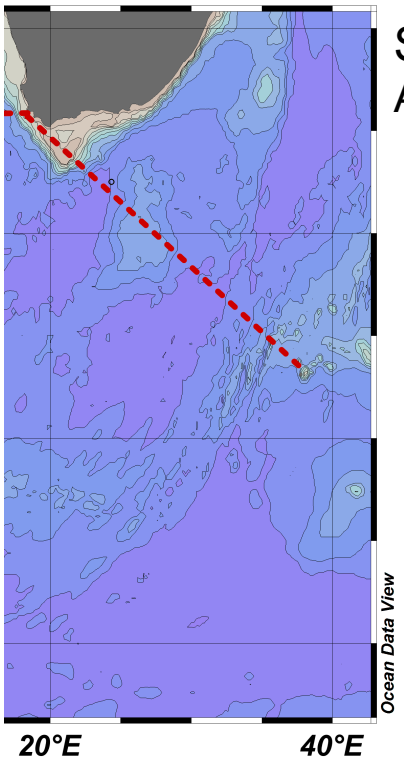


Mirai (Japan)
JAMSTEC funding.

Associated GO-SHIP: Marion Isl. (S. Africa) and I7S (India)

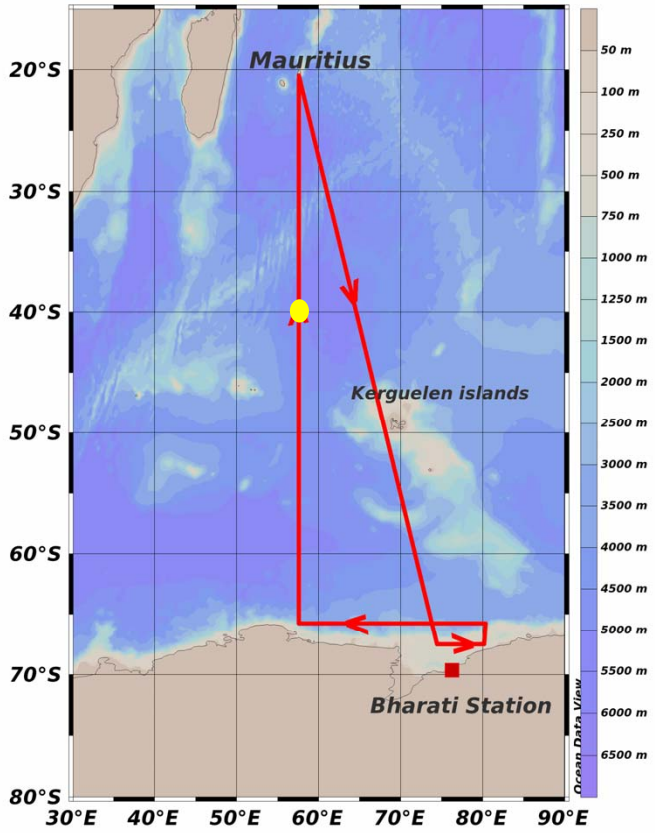
Follow GO-SHIP data management.

Other candidates? Might be an excellent outcome of IIOE-2.



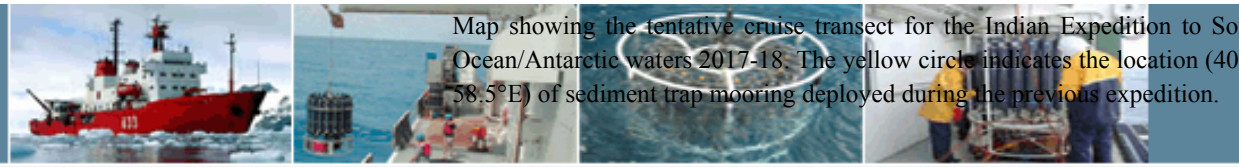
South Africa
Agulhas II every year

India
NCAOR funding.
Agulhas I this year
and last



Cruise track for SOE 2017-18

Map showing the tentative cruise transect for the Indian Expedition to So Ocean/Antarctic waters 2017-18. The yellow circle indicates the location (40 58.5°E) of sediment trap mooring deployed during the previous expedition.



IIOE-2 discussions?

- Some way to implement I01E? I01W off table due to security?
- Other associate sections, or even just using the cchdo.ucsd.edu data management system for cruise data, declaring a data set that is “IIOE-2”
- Piggyback projects that require no additional wire time (Argo, BGC-Argo, Deep-Argo, drifters, etc. being deployed; underway observations, additional chemistry/biology from water samples, microstructure proxy measurements, etc)