GEOTRACES: Inspired by GEOSECS to investigate trace elements and their isotopes in the ocean

Goldschmidt 2019 – Session 08m

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Catherine Jeandel, LEGOS, Toulouse
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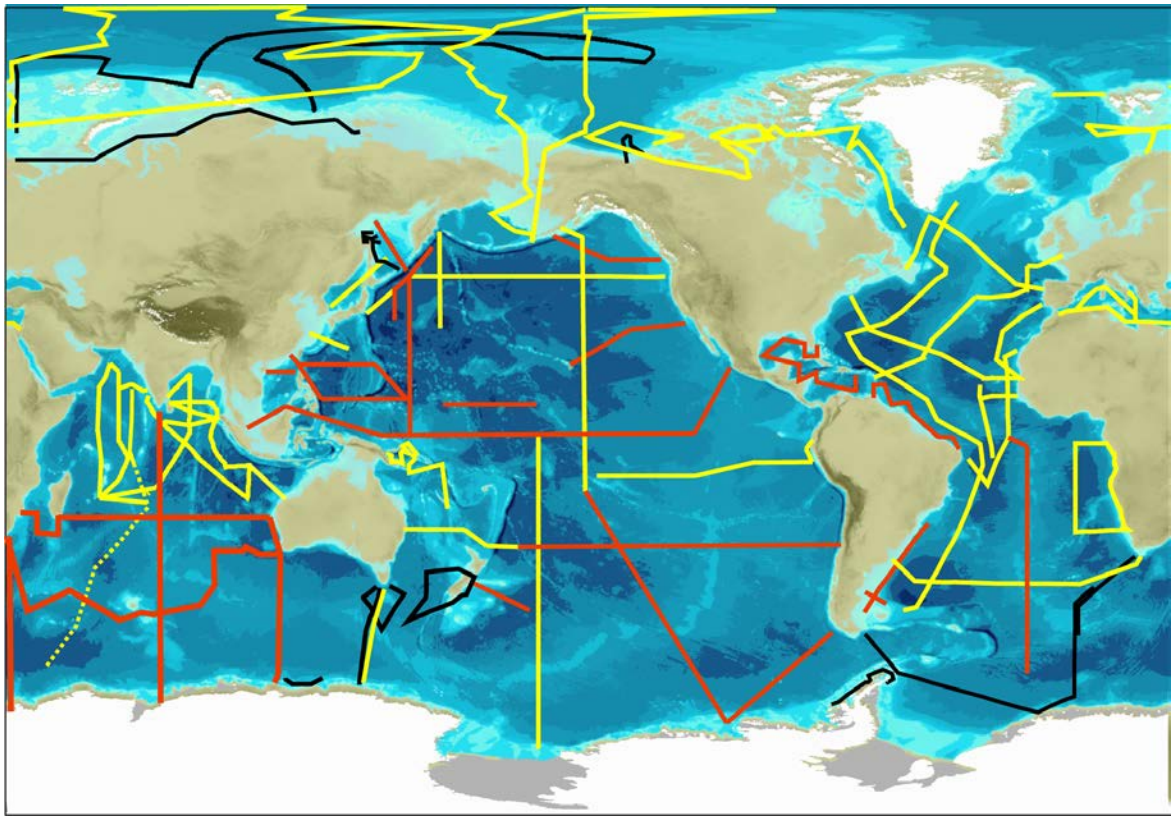
http://www.geotraces.org/

GEOTRACES: An international study of the marine biogeochemical cycles of trace elements and their isotopes



August 2019:

- Cruises completed: 113
- Nations supporting cruises: 17
- Publications: > 1200
- Data shared publicly: http://www.geotraces.org/dp/idp2017

GEOTRACES: An international study of the marine biogeochemical cycles of trace elements and their isotopes

Inspired by GEOSECS . . .

. . . what do they have in common?

GEOTRACES: An international study of the marine biogeochemical cycles of trace elements and their isotopes

Inspired by GEOSECS . . .

. . . what do they have in common?

Both were created to address problems to large to be achieved without a large coordinated effort.

Large programs are required to address certain complex topics in oceanography

Selected historical examples

- Overturning circulation of the ocean
- Ocean-atmosphere partitioning of carbon
  (both natural and anthropogenic)
- Global biogeochemical cycles

Birth of GEOSECS –
To quantify the rate of ocean overturning circulation

Henry Stommel

Motivated GEOSECS by identifying a problem too large to solve without a large program

Photo from chapter by Walter Munk in 50 years of Ocean Discovery

Atlantic early ^{14}C data helped constrain rate of overturning circulation (Broecker et al., JGR 1960)

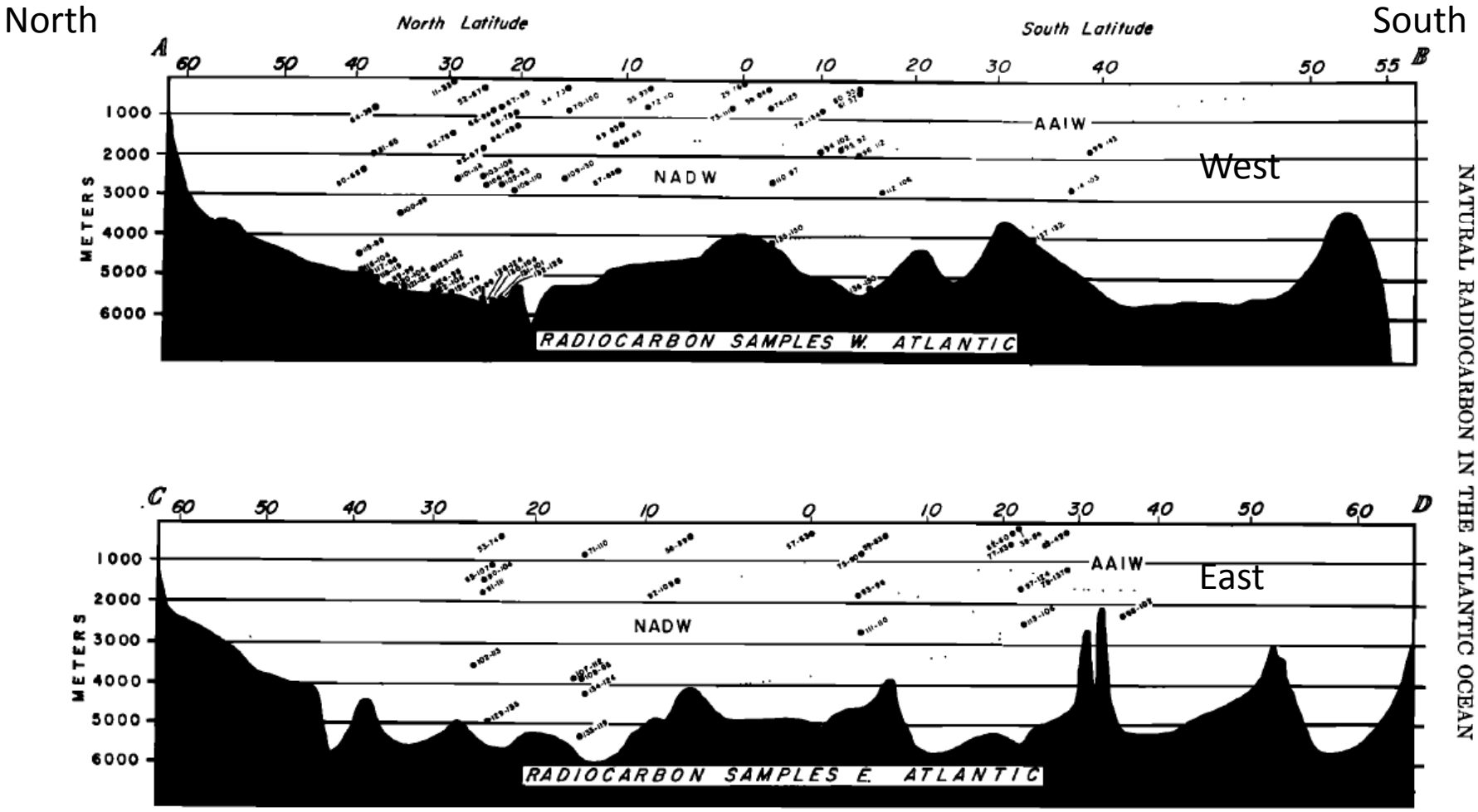


Fig. 4. Locations of subsurface ocean water samples projected onto north-south profiles through the western basin (upper) and eastern basin (lower) of the Atlantic Ocean. The first number beside each dot is the sample index number and the second the ΔC^{14} value. The location of the profiles is given in Figure 3.

Birth of GEOSECS

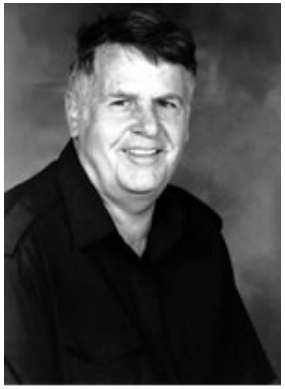
"Ed Goldberg (Scripps Institution of Oceanography) and I were attending some sort of meeting at WHOI during the late 1960s. Hank came to us and said that radiocarbon measurements in the sea were of great importance. He went on to gently chastise us (the geochem community) for doing only scattered stations.

What is needed, he said, is a line of stations extending the length of the Atlantic.

Gee, we said, that would cost a million dollars, a sum greater than the entire NSF annual budget for ocean chemistry.

Hank replied, "Well it would be worth more than a million."

Quote from Wally Broecker repeated in John Farrington's chapter in 50 Years of Ocean Discovery - Confirmed by personal communication with Wally

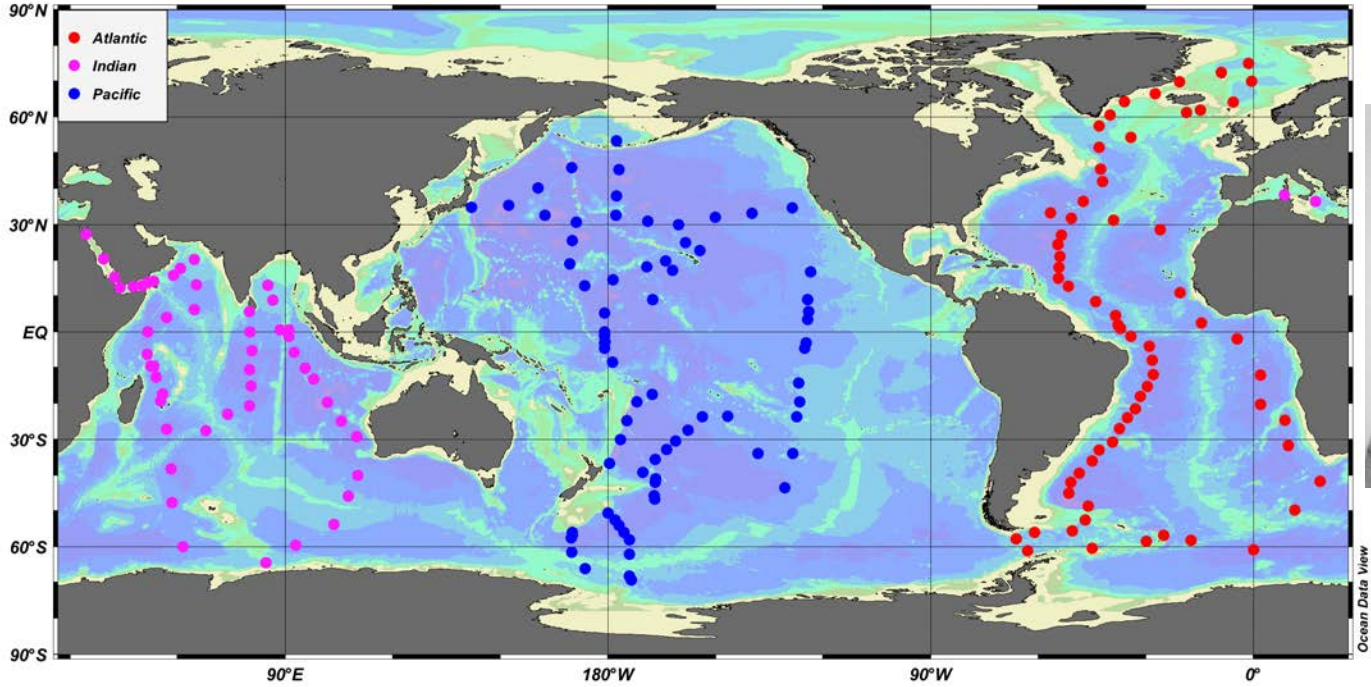


Harmon Craig

Wally Broecker

Karl Turekian

Arnold Bainbridge



Joe Reed

Derek Spencer

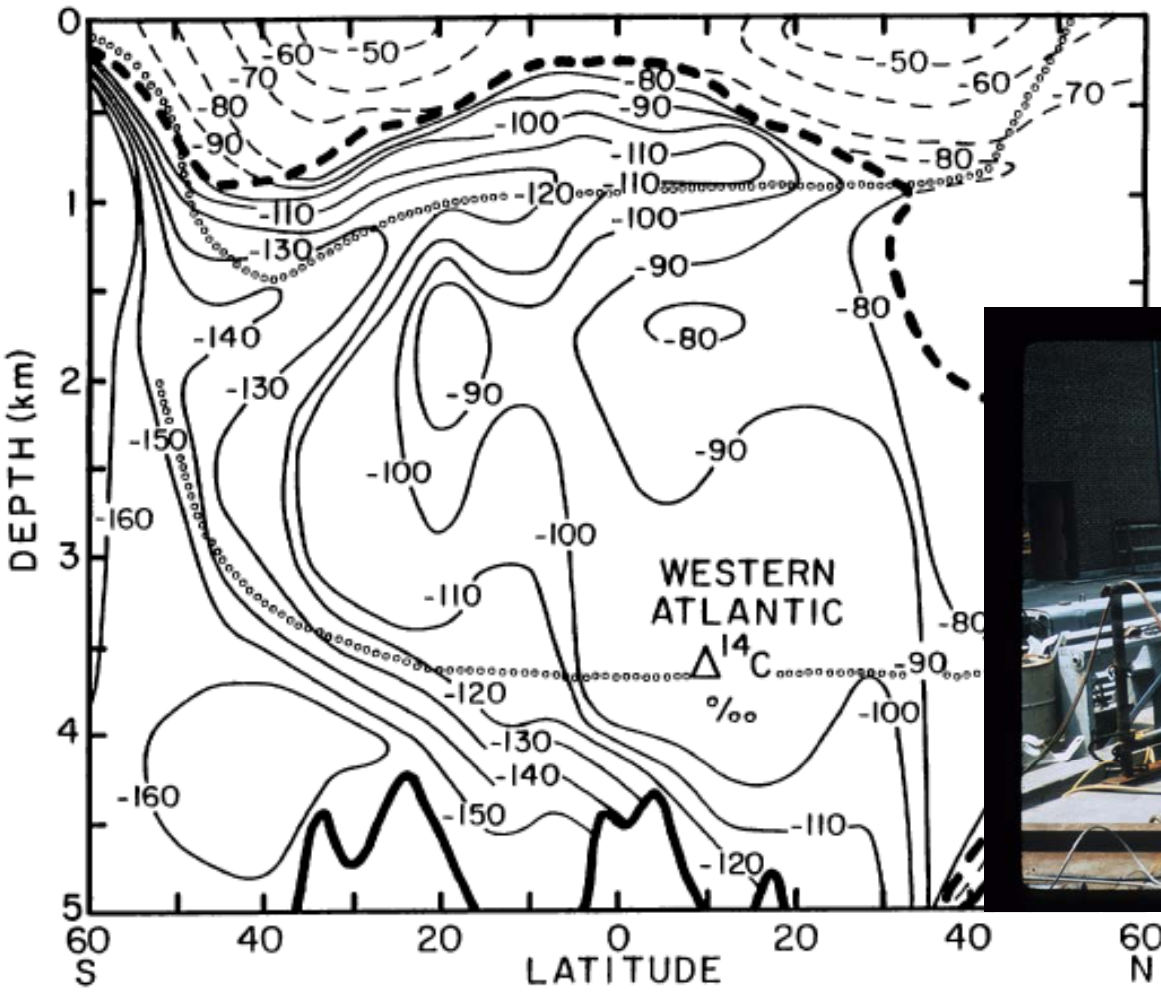
GEOSECS 1972-1978
First global survey of ocean chemistry
28 Investigators, 14 institutions, $24M

Slide Courtesy Chris Measures

John Edmond

Scanned at the American Institute of Physics

GEOSECS Success – Ocean Ventilation Time Scales



Broecker & Peng 1982

Derek Spencer
Wally Broecker
Arnold Bainbridge

GEOSECS Success: First assessment of the ocean's uptake of anthropogenic CO_2

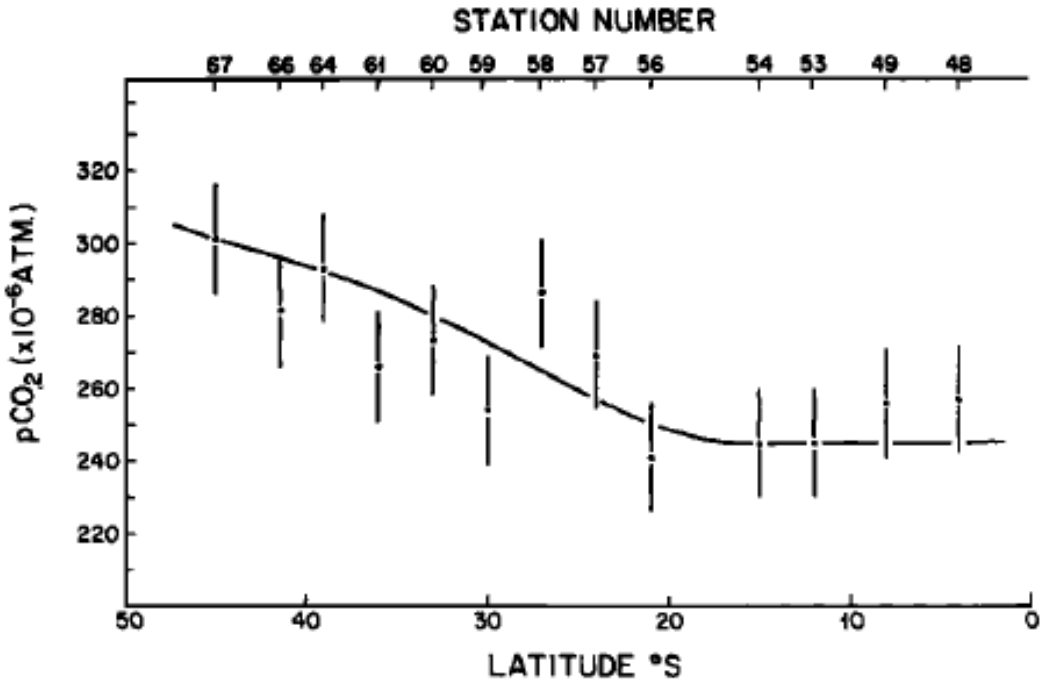
VOL. 5, NO. 12 GEOPHYSICAL RESEARCH LETTERS DECEMBER 1978

DIRECT OBSERVATION OF THE OCEANIC CO_2 INCREASE

Peter G. Brewer

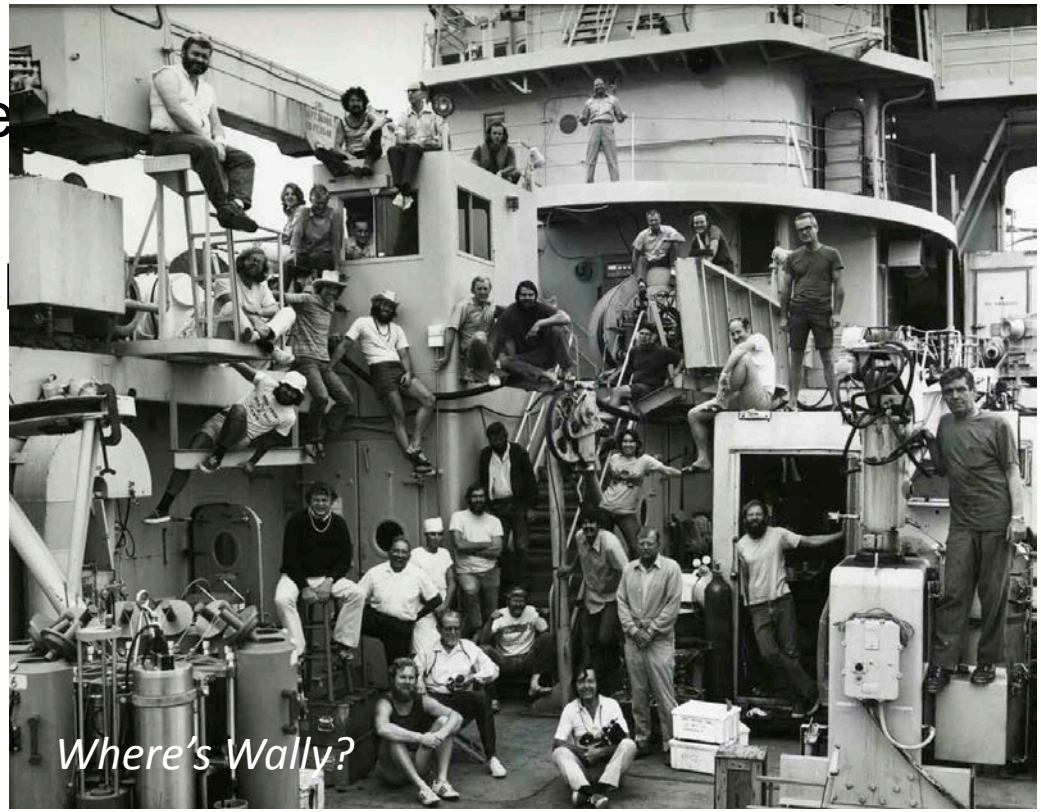
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

Abstract. The increase in atmospheric CO_2 of approximately 50 ppm from the mid-nineteenth century to 1972 has led to a corresponding increase in the pCO_2 of sea water. The record of this increase is present in the oceanic water masses, though the signal is obscured. By observing the alkalinity and total CO_2 concentration within a water mass, and stripping off the perturbations of the CO_2 system due to respiration, carbonate dissolution and nitrate addition, the original atmospheric equilibration signal may be recovered. The application of these calculations to GEOSECS (1972) data from the core of the Antarctic Intermediate water reveals propagation of the atmospheric CO_2 signal northwards.



GEOSECS Success – Foundation for Future Programs

- TTO - Transient Tracers in the Ocean
- WOCE - World Ocean Circulation Experiment
- JGOFS - Joint Global Oce
- CLIVAR Repeat Hydrogra
- GEOTRACES
- and more

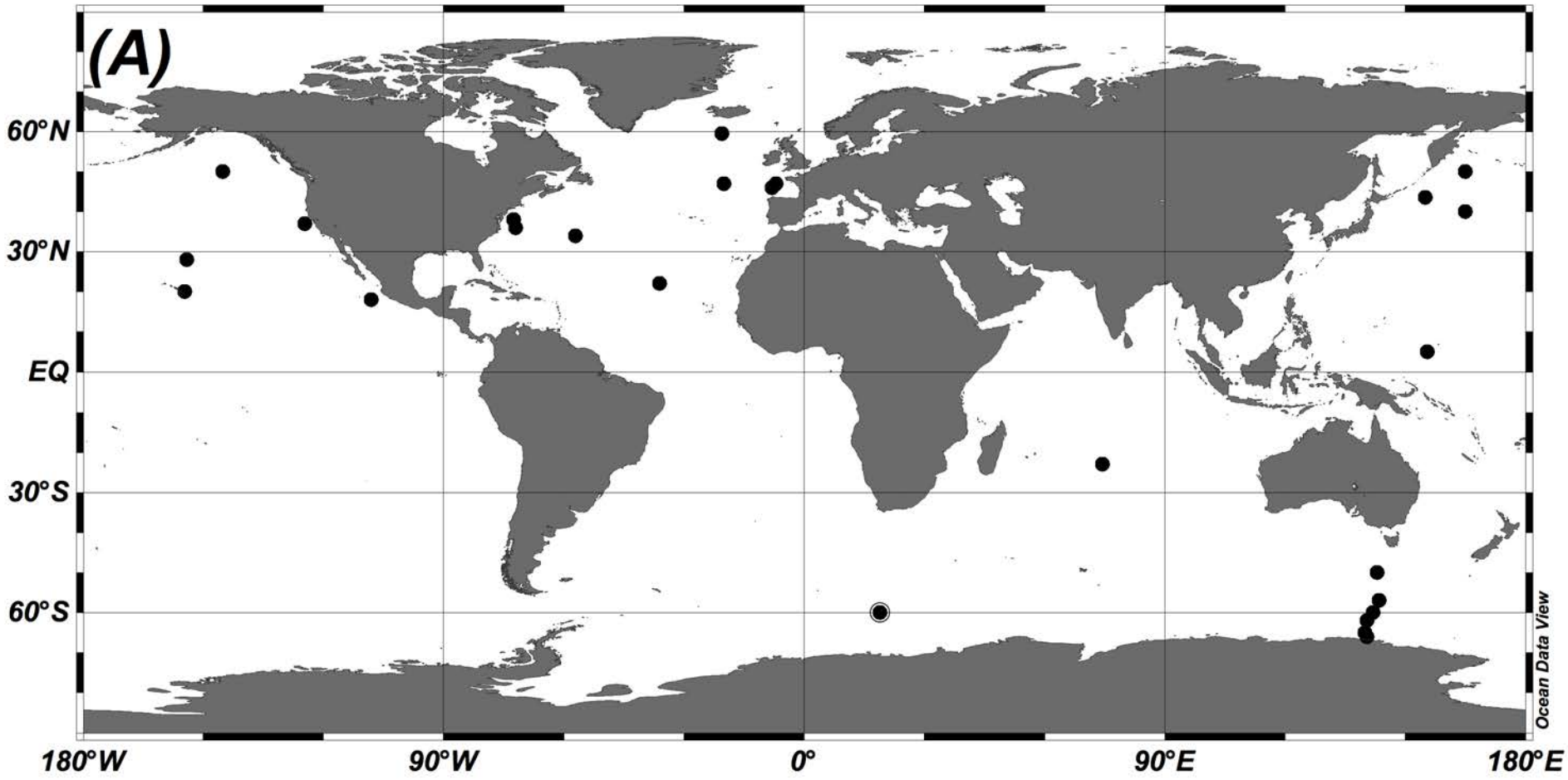


Trace elements and their isotopes

GEOSECS + 20 to 30 years

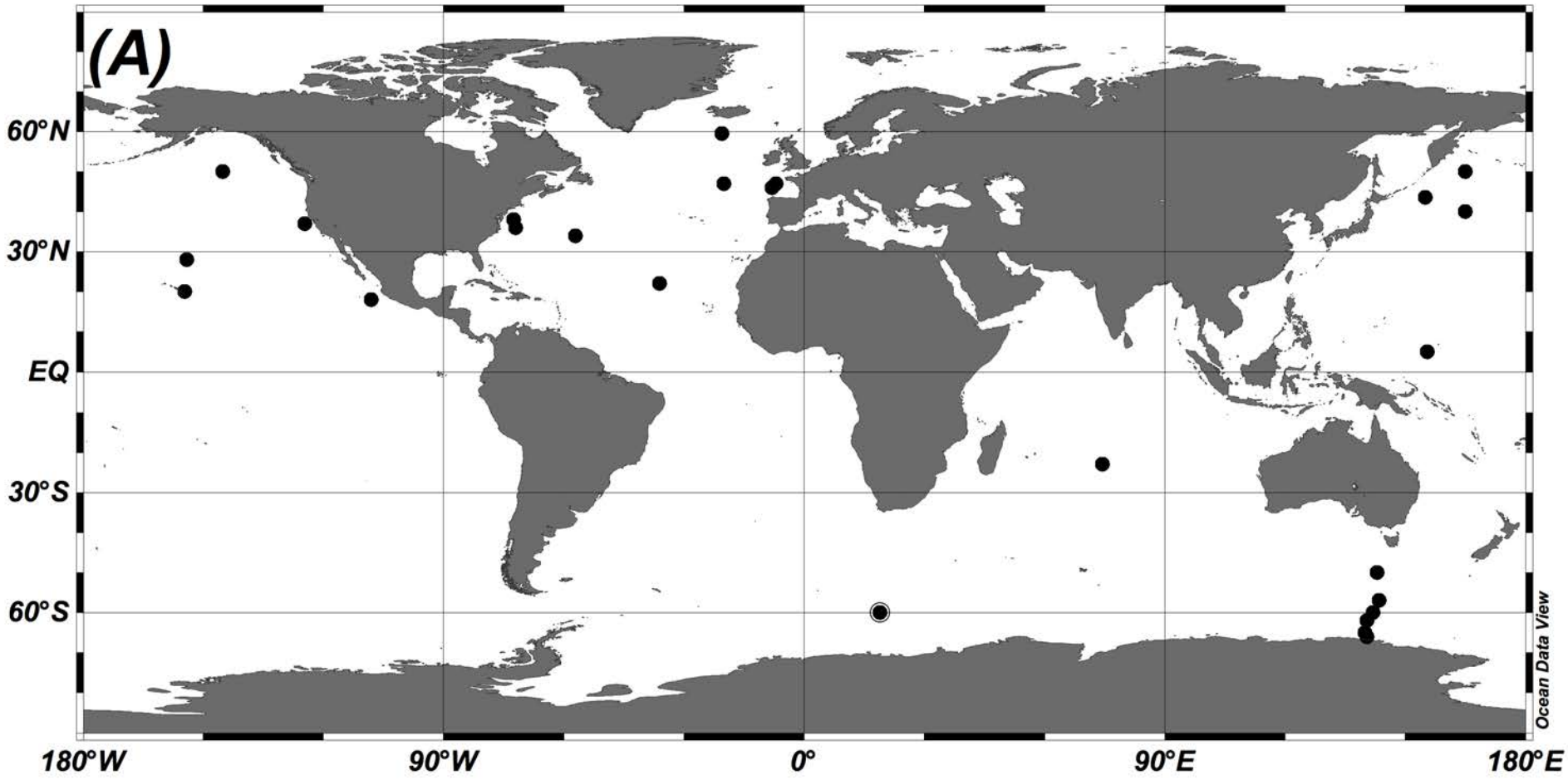
History repeats itself (there is a lesson here)

Two decades of work on **iron** was insufficient to characterize its biogeochemical cycle



Stations as of 2003 with dissolved Fe data to depths > 2000 m - Compiled by Payal Parek
Reproduced from Anderson et al., 2014

Two decades of work on **iron** was insufficient to characterize its biogeochemical cycle

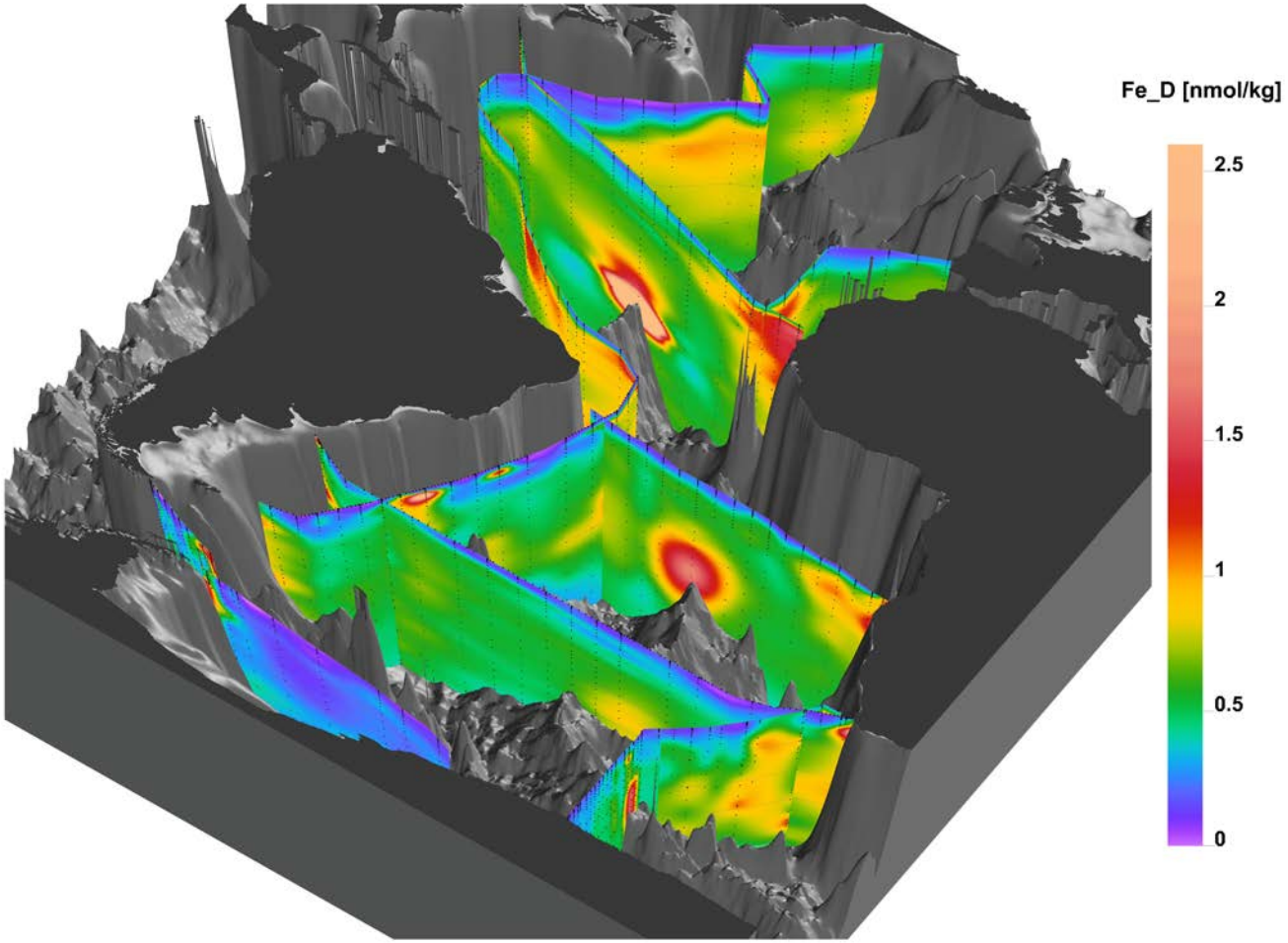


Situation ca. 2000 was even worse for other trace elements and isotopes. A new strategy was needed.

GEOTRACES: Timeline – Selected milestones
Lesson: Be patient

2000	Initial discussions and planning for “GEOSECS-II”
2001	Special session & Town Hall to assess interest
2003	International planning workshop – define goals
2004	SCOR accepts oversight
2005	Initiate data management
2006	Complete science plan
2006	Initiate intercalibration
2007	Pilot studies – International Polar Year
2010	Launch main field program
2014	Release of first data product
2015	Launch synthesis initiative
2017	Second data product
2019	Mid-life review

GEOTRACES Discoveries – Prominent Fe sources from ridges and margins



Data: Cyril Abadie, Eric P Achterberg, Hein J de Baar, Andrew Bowie, Kenneth W Bruland, Kristen N Buck, Fanny Chever, Tim Conway, Gideon M Henderson, Seth John, Maarten Klunder, Patrick Laan, Francois Lacan, Christopher Measures, Rob Middag, Abigail Noble, Micha J A Rijkenberg, Mak A Saito, Christian Schlosser, Peter N Sedwick, Charles-Edouard Thuroczy, Jingfeng Wu
Graphics: Reiner Schlitzer

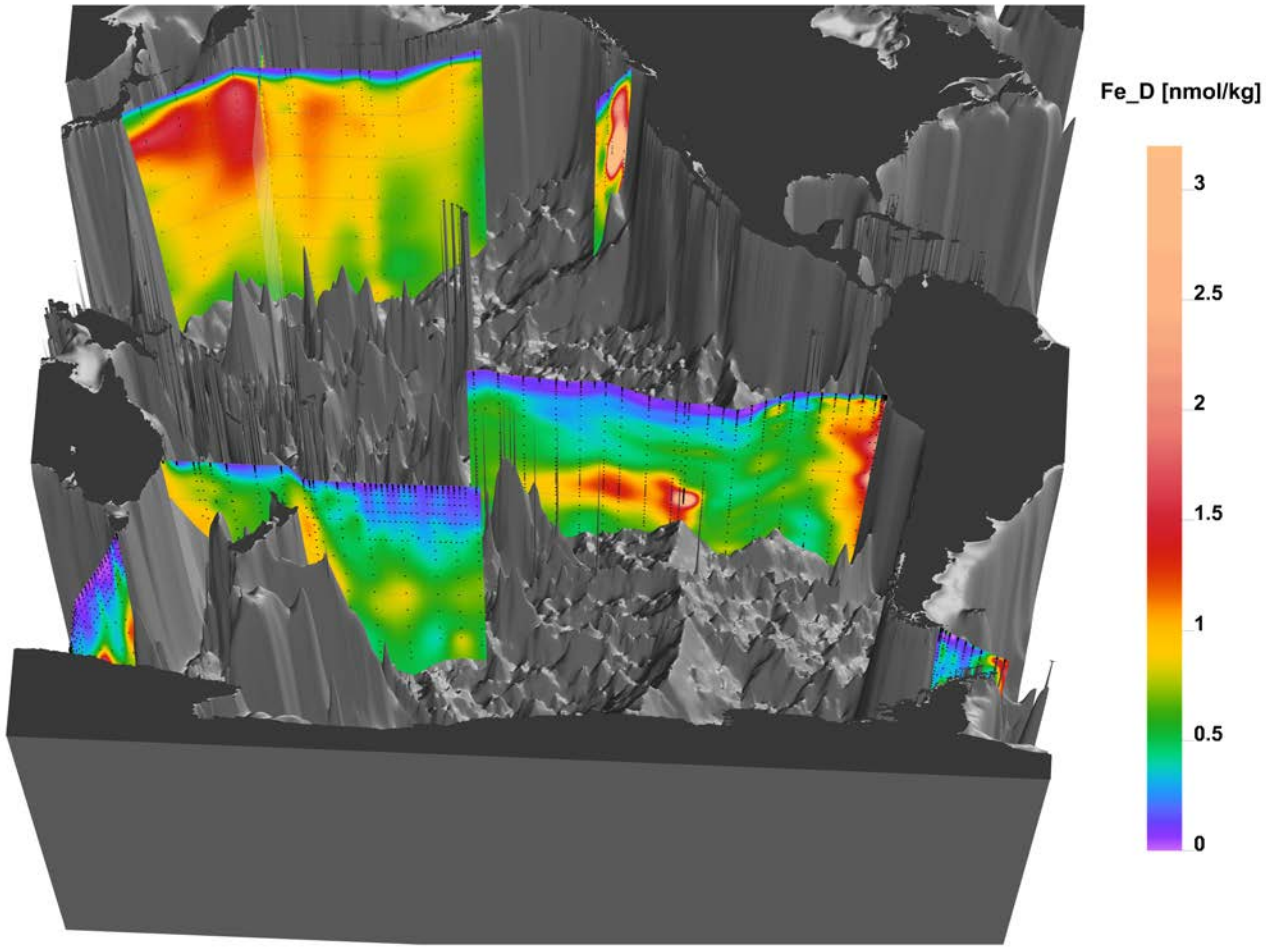
Fe residence time is so short that its distribution is dominated by its sources

Clear source signatures:

- Dust
- Sediment
- Hydrothermal
- Rivers

Source:
www.eGEOTRACES.org

GEOTRACES Discoveries – Prominent Fe sources from ridges and margins



Data: Hein J de Baar, Andrew Bowie, Philip Boyd, Kenneth W Bruland, Michael Ellwood, Josh Helgoe, Seth John, Maarten Klunder, Pier van der Merwe, Tomoharu Minami, Jun Nishioka, Hajime Obata, Tomas Remenyi, Saeed Roshan, Peter N Sedwick, Yoshiki Sohrin, Bettina Sohst, Charles-Edouard Thuroczy, Claire P Till, Ashley Townsend, Emily Townsend, Jingfeng Wu, Kathrin Wuttig, Linjie Zhengg
Graphics: Reiner Schlitzer

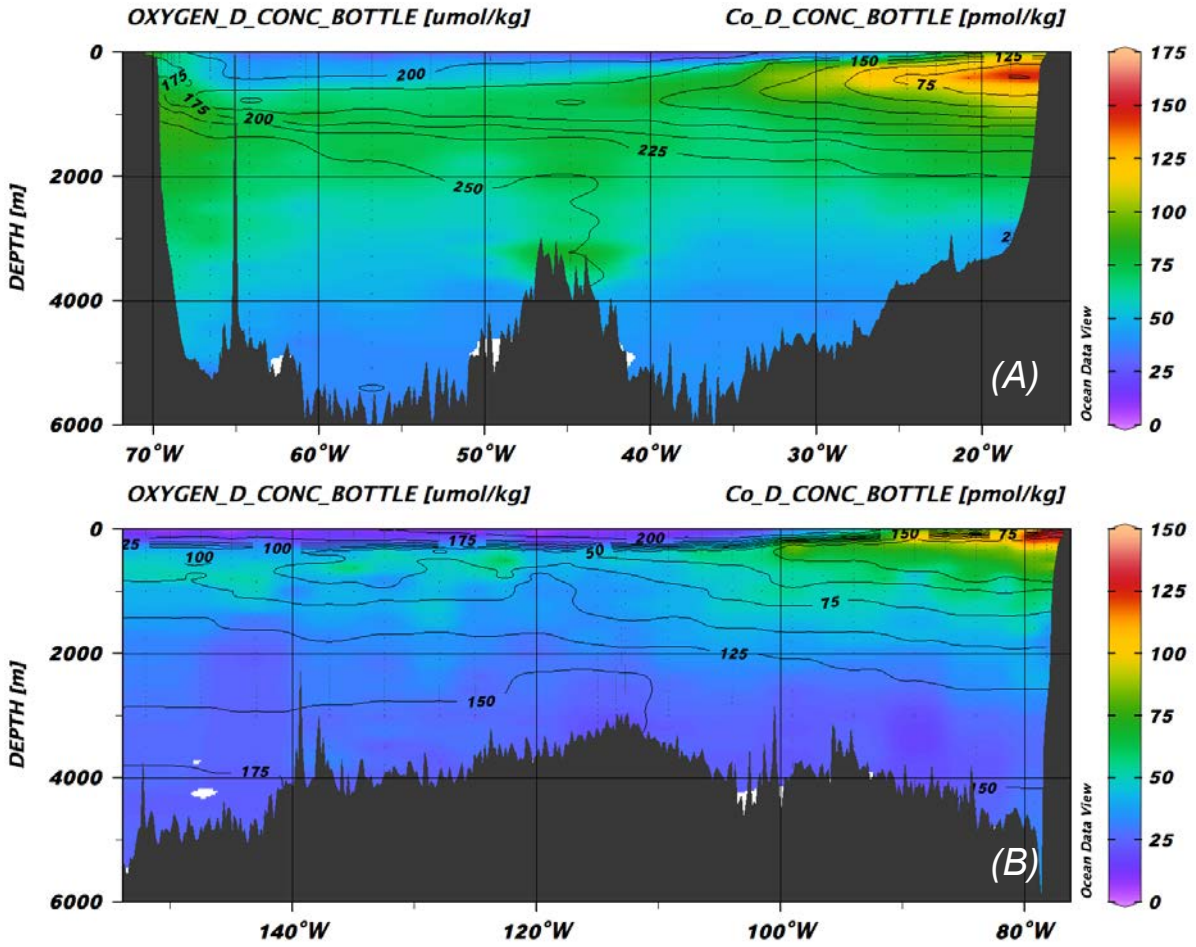
Fe residence time is so short that its distribution is dominated by its sources

Clear source signatures:

- Dust
- Sediment
- Hydrothermal
- Margins

Source:
www.eGEOTRACES.org

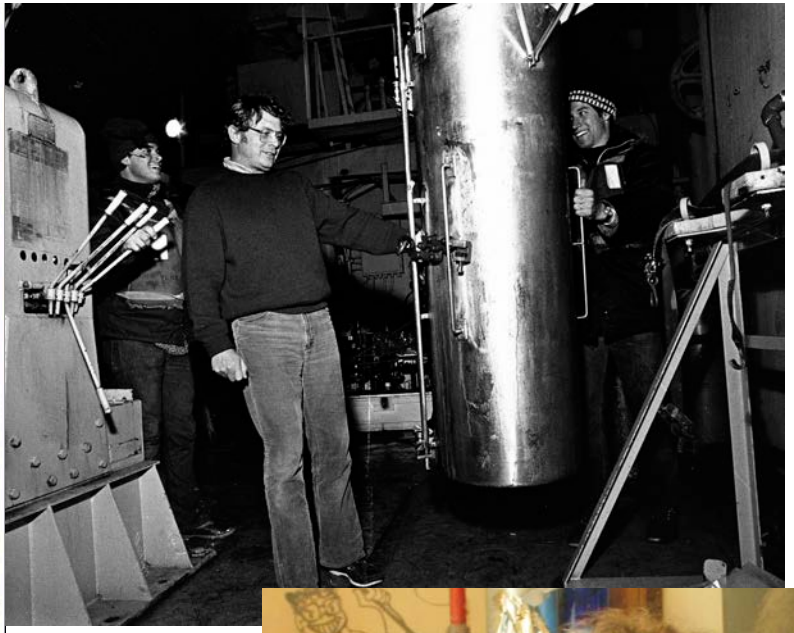
GEOTRACES Discoveries – Dual behavior of Co



- Dominant source in shelf & upper slope sediments
- Cycles with P in the upper water column (nutrient)
- Scavenged by Mn in deep water
- Residence time
  - ~ 7 yrs in upper 250 m
  - ~1000 yrs in deep sea
- Most Co in pelagic sediments derived from upper ocean

Top: Atlantic zonal Co section (*Noble et al., 2017*)
Bottom: Pacific zonal Co section (*Hawco et al., 2016, 2018*)

Tracers in the Sea – 1982
Wally set the standard for **synthesis** of findings

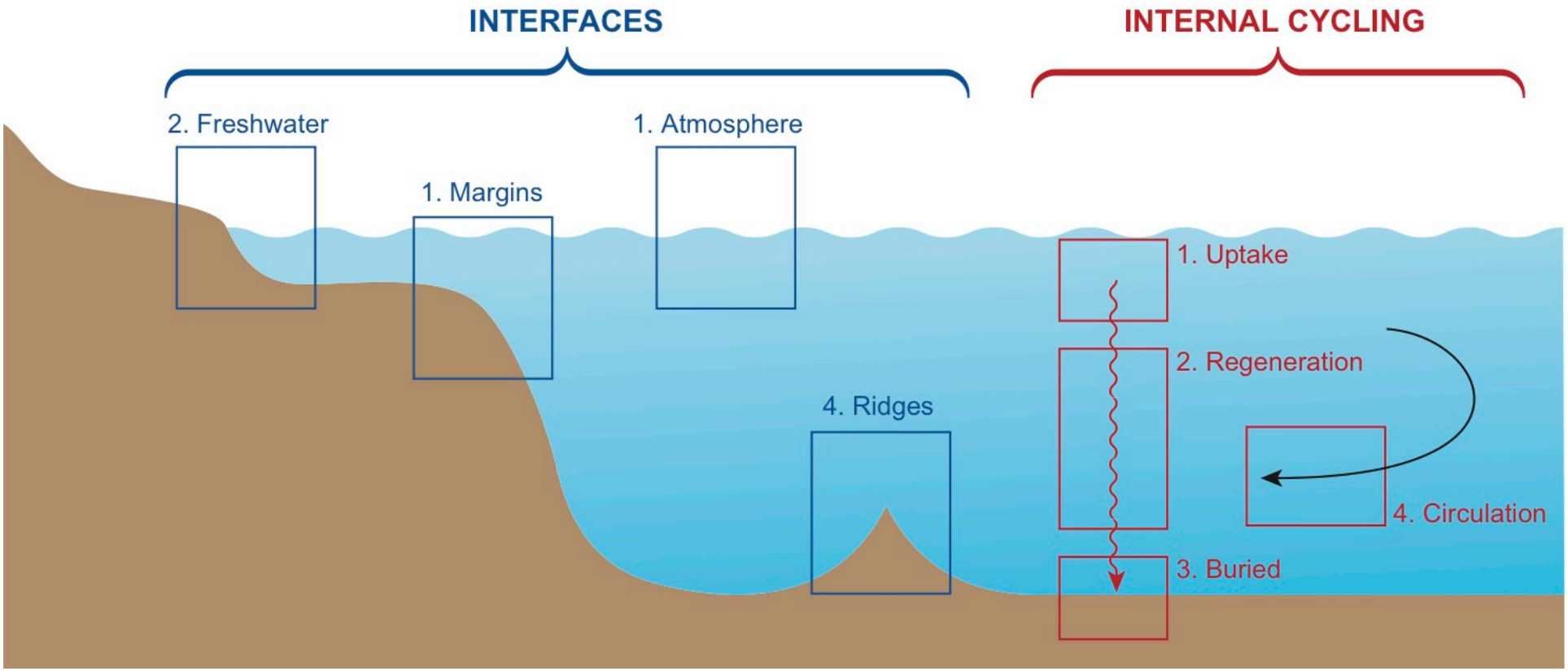


Aboard the Knorr

In his Lamont Office

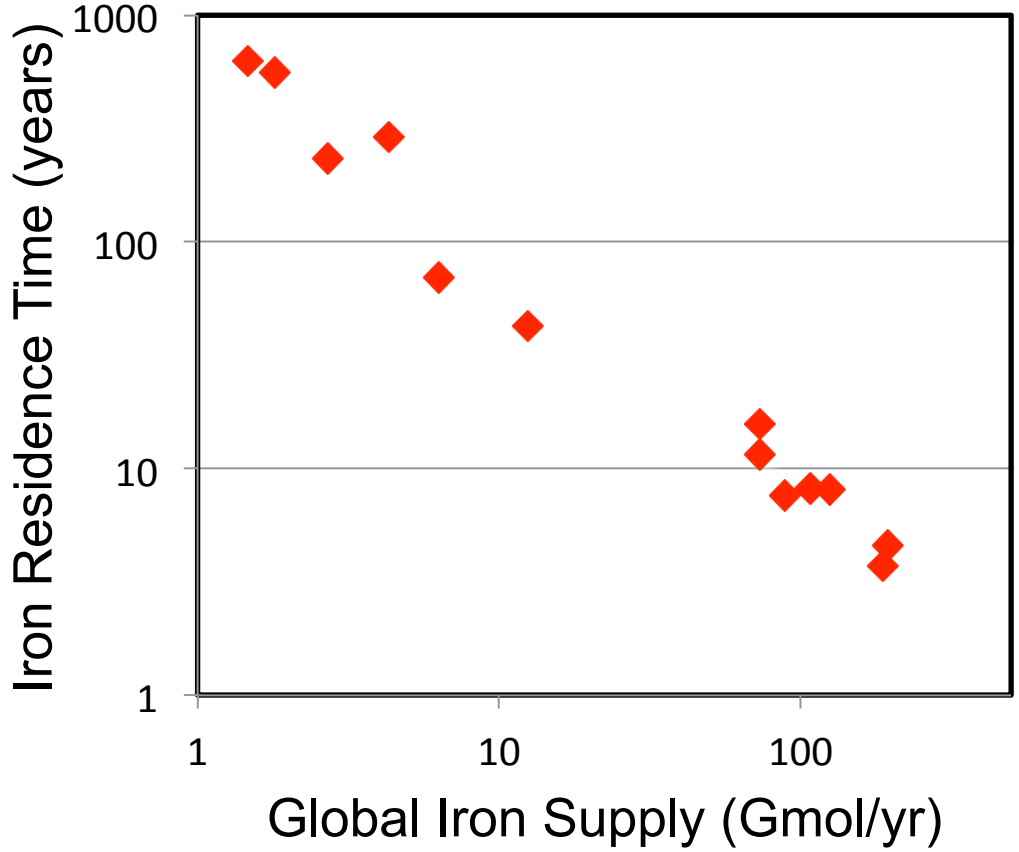
Photos from Patty Catanzaro

GEOTRACES Synthesis Themes/Goals: Identify processes and quantify fluxes



- Inputs and outputs at the interfaces of the ocean
- Internal cycling within the ocean

Uncertainty about iron emphasizes need for better fluxes and residence times



- Output from 13 global ocean biogeochemical models
- Two orders of magnitude uncertainty (range among models)

Tagliabue et al., 2016

GEOTRACES Synthesis: Quantifying fluxes and comparing different approaches

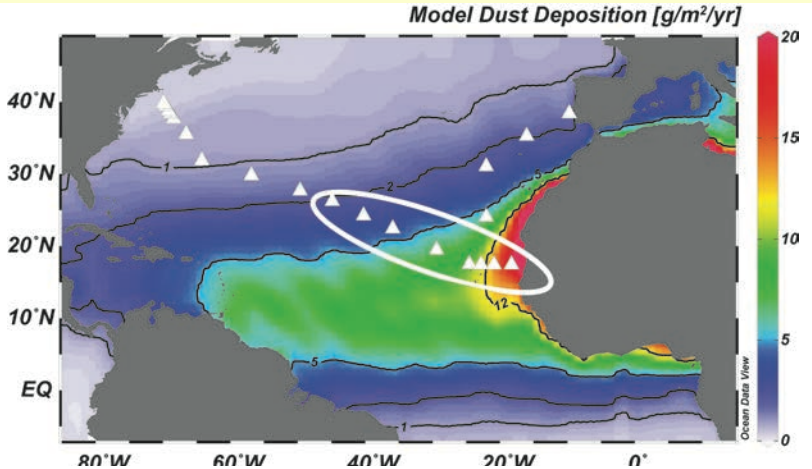
How well can we quantify dust deposition to the ocean?

R. F. Anderson[1,2], H. Cheng[3,4], R. L. Edwards[3], M. Q. Fleisher[1], C. T. Hayes[5], K.-F. Huang[6], D. Kadko[7], P. J. Lam[8], W. M. Landing[9], Y. Lao[10], Y. Lu[11], C. I. Measures[12], S. B. Moran[13], P. L. Morton[9], D. C. Ohnemus[14], L. F. Robinson[15] and R. U. Shelley[16]

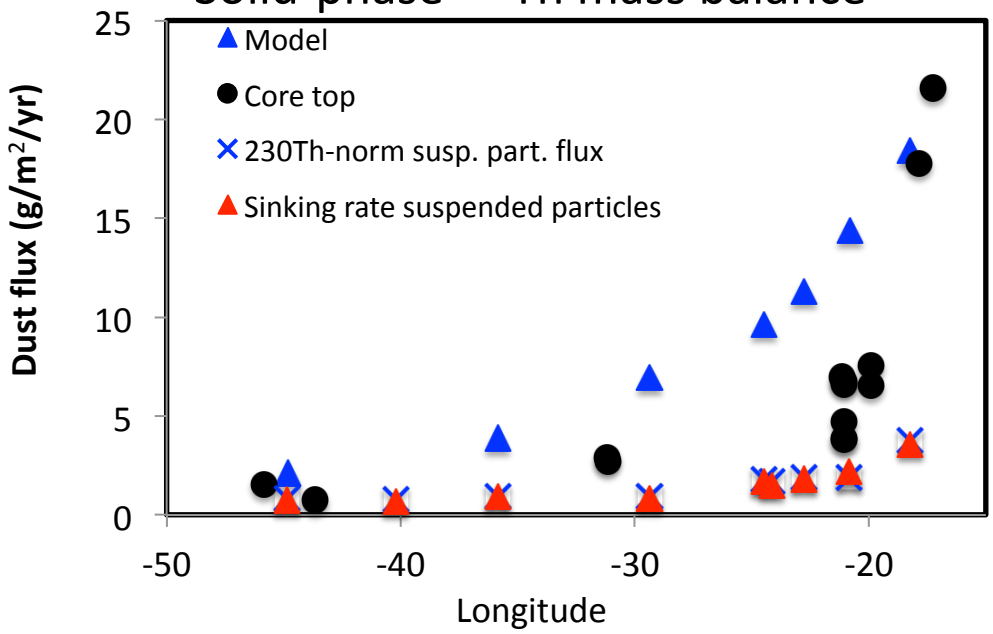
[1]Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY 10964, USA
[2]Department of Earth and Environmental Sciences, Columbia University, New York, NY 10027 USA
[3]Department of Earth Sciences, University of Minnesota,

Comparison of 8 methods to estimate dust flux.

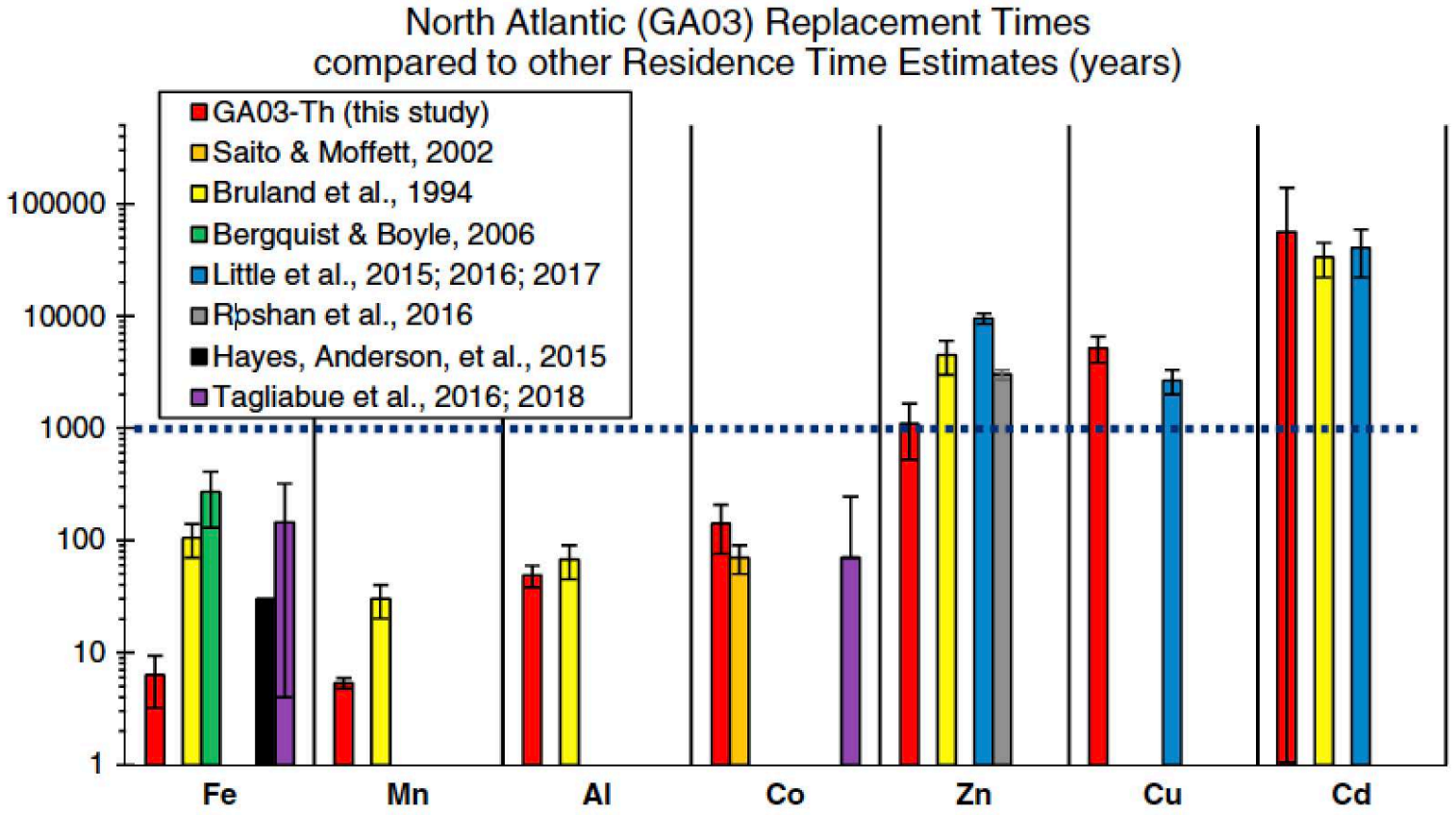
Phil. Trans. Roy. Soc. A, 2016



Solid-phase ^{230}Th mass balance



GEOTRACES Synthesis: Combining trace elements & radionuclides to estimate residence times



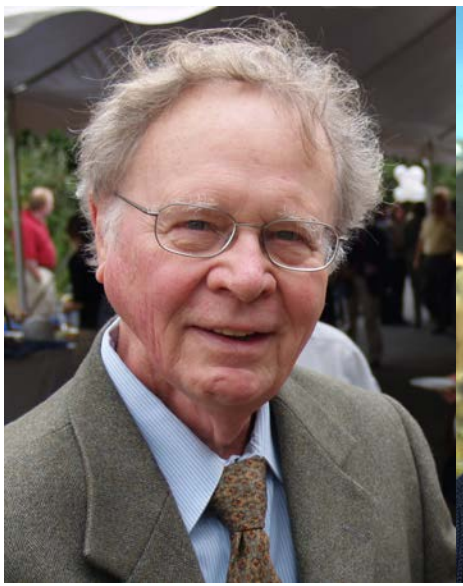
Full water column replacement times (red bars):
Shorter than previous estimates for Fe and Mn

Hayes et al., GBC, 2018

GEOTRACES Synthesis: Current and future work

- Many studies quantifying fluxes and residence times.
- Micronutrient speciation and bioavailability
- Identifying new processes not yet in models

Following the spirit of GEOSECS synthesis led by Wally Broecker




GEOSECS Original Panel Members

Wallace S. Broecker	Lamont-Doherty Geological Observatory
Harmon Craig	Scripps Institution of Oceanography
H. Göte 0stlund	University of Miami
P. Kilho Park	Oregon State University
Joseph L. Reid	Scripps Institution of Oceanography
Derek W. Spencer	Woods Hole Oceanographic Institution
Henry M. Stommel	Massachusetts Institute of Technology
Taro Takahashi	California Institute of Technology* (LDEO)
Karl K. Turekian	Yale University
Herbert L. Volchok	Atomic Energy Commission

From Turekian, 1970, JGR Intro to special issue on GEOSECS test station