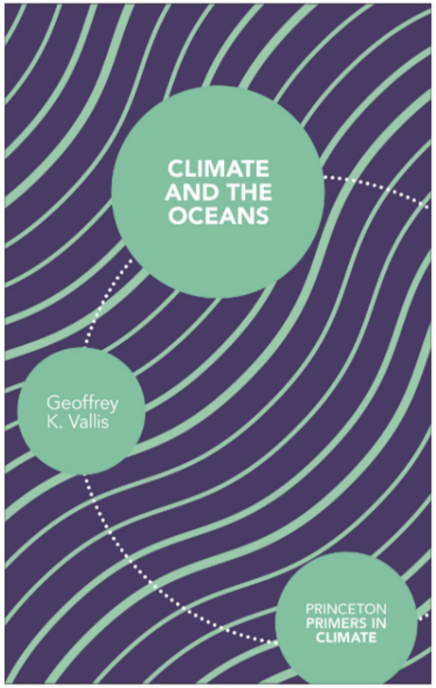
Climate and the Oceans: Basics & Descriptive Overview

AOSC 680

Ross Salawitch

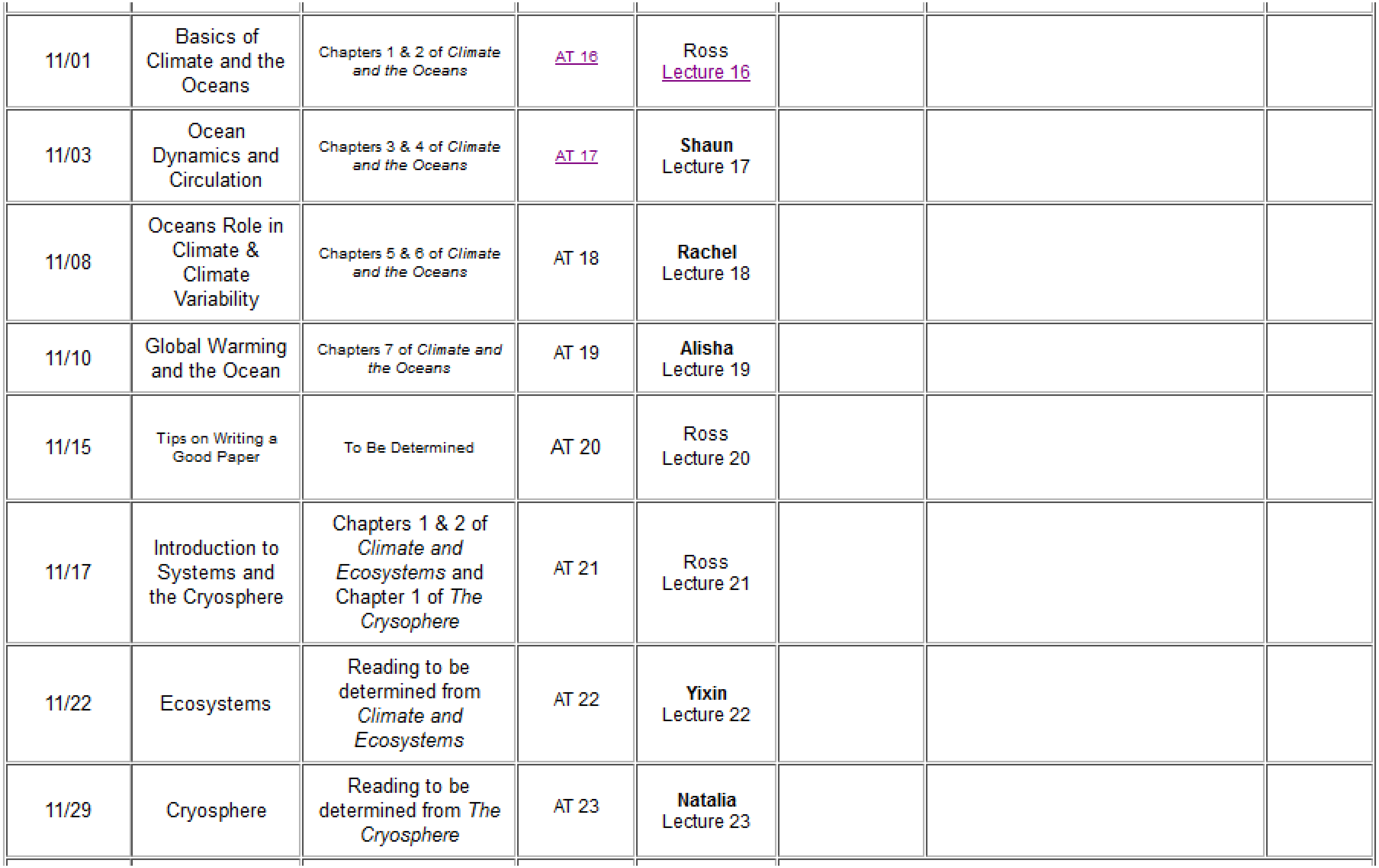
Class Web Sites:
http://www2.atmos.umd.edu/~rjs/class/fall2022
https://umd.instructure.com/courses/1327017



Lecture 16

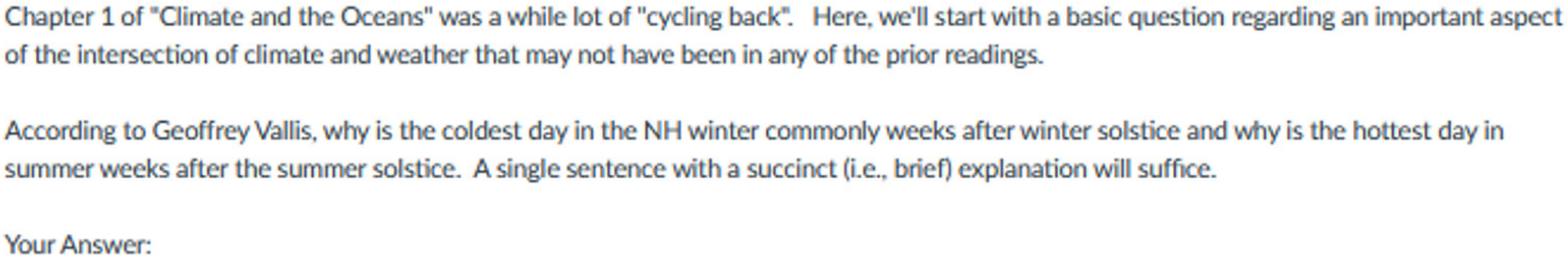
1 November 2022

Class Schedule



11/01	Basics of Climate and the Oceans	Chapters 1 & 2 of *Climate and the Oceans*	AT 16	Ross Lecture 16			
11/03	Ocean Dynamics and Circulation	Chapters 3 & 4 of *Climate and the Oceans*	AT 17	**Shaun** Lecture 17			
11/08	Oceans Role in Climate & Climate Variability	Chapters 5 & 6 of *Climate and the Oceans*	AT 18	**Rachel** Lecture 18			
11/10	Global Warming and the Ocean	Chapters 7 of *Climate and the Oceans*	AT 19	**Alisha** Lecture 19			
11/15	Tips on Writing a Good Paper	To Be Determined	AT 20	Ross Lecture 20			
11/17	Introduction to Systems and the Cryosphere	Chapters 1 & 2 of *Climate and Ecosystems* and Chapter 1 of *The Crysophere*	AT 21	Ross Lecture 21			
11/22	Ecosystems	Reading to be determined from *Climate and Ecosystems*	AT 22	**Yixin** Lecture 22			
11/29	Cryosphere	Reading to be determined from *The Cryosphere*	AT 23	**Natalia** Lecture 23			

Chapter 1: Introduction



Chapter 1 of "Climate and the Oceans" was a while lot of "cycling back". Here, we'll start with a basic question regarding an important aspect of the intersection of climate and weather that may not have been in any of the prior readings.

According to Geoffrey Vallis, why is the coldest day in the NH winter commonly weeks after winter solstice and why is the hottest day in summer weeks after the summer solstice. A single sentence with a succinct (i.e., brief) explanation will suffice.

Your Answer:

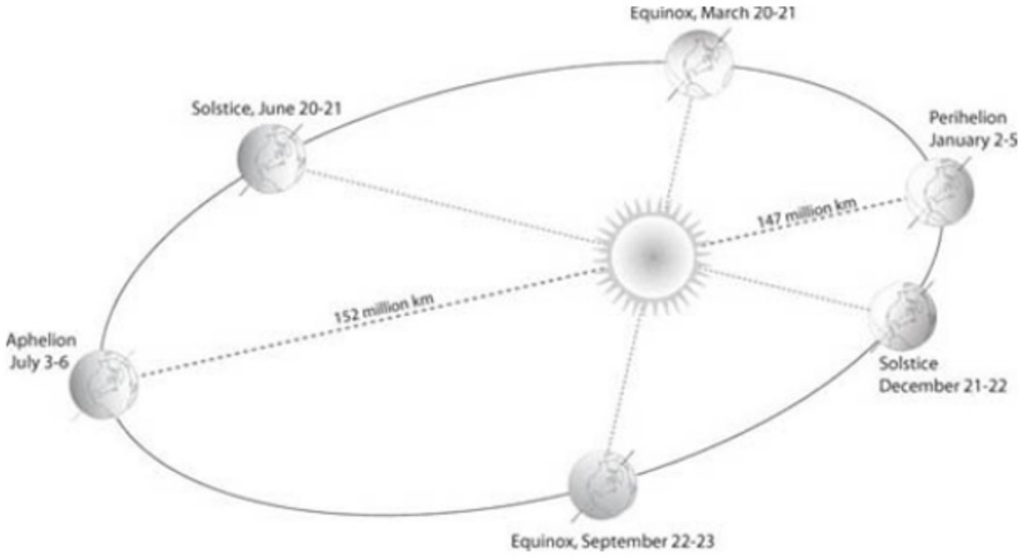
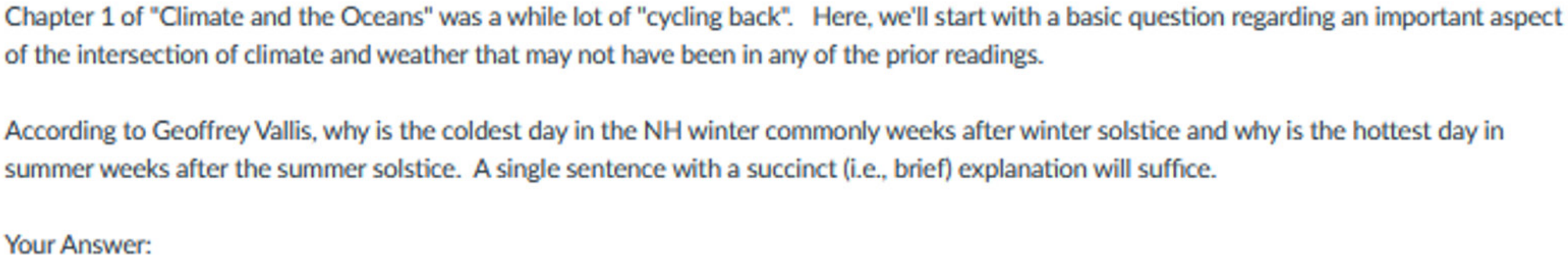


Figure 1.2. Earth's orbit around the sun and the march of the seasons. Earth's axis of rotation is at an angle with respect to the axis of rotation of Earth around the sun. The Northern Hemisphere's summer and the Southern Hemisphere's winter result when the North Pole points toward the sun, and the opposite season occurs six months later. The eccentricity is much exaggerated in the figure.

Climate And The Oceans

Chapter 1: Introduction



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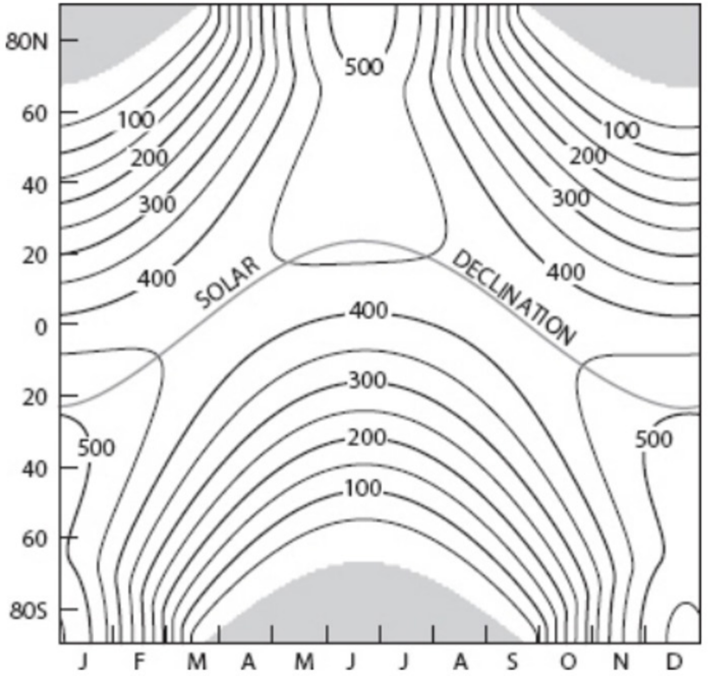
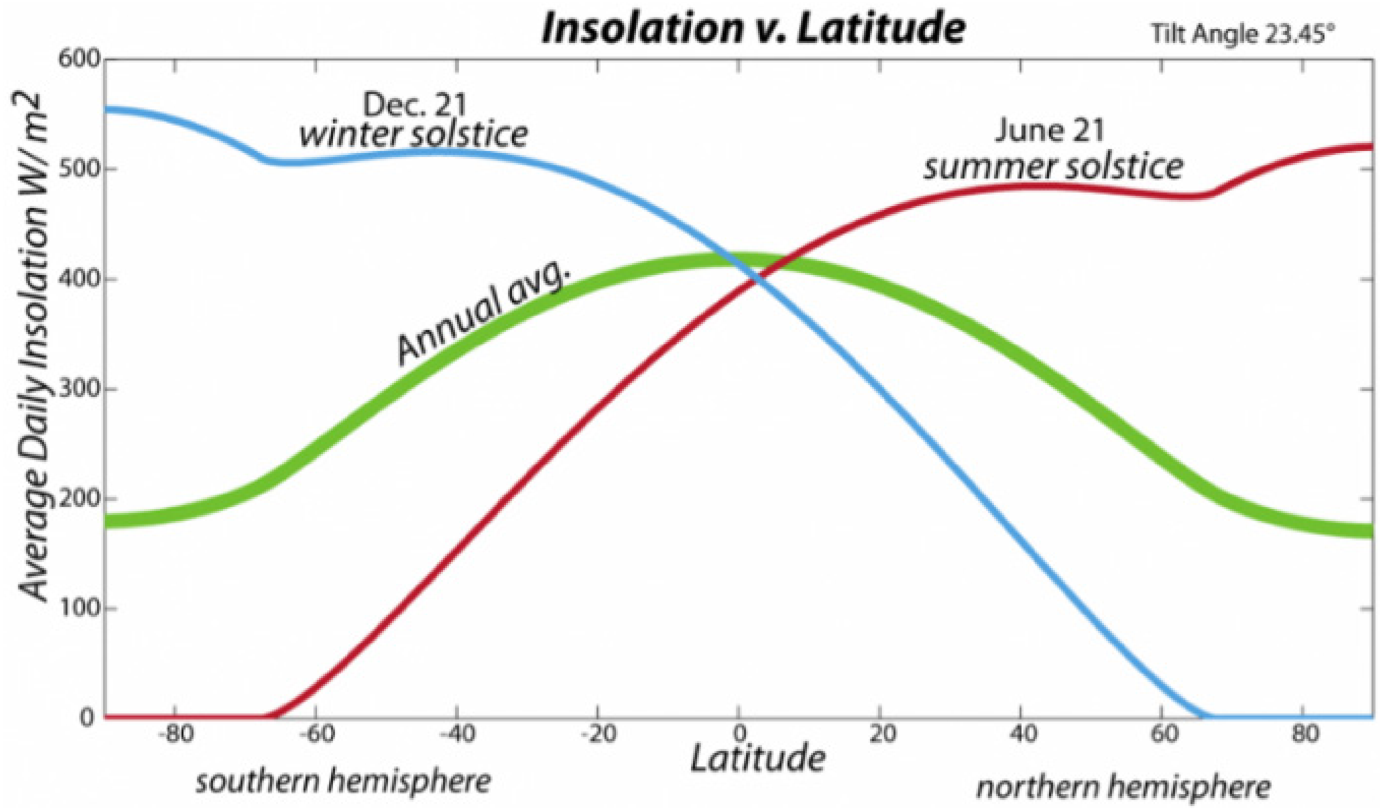


Figure 2.2. The seasonal variation of the zonally (or diurnally) averaged insolation at the top of the atmosphere.
The units are W m^{-2}.

Chapter 1: Introduction



Solar energy reaching the Earth varies with latitude, as shown above, and with the time of the year. Note that during the polar summers, the insolation is actually higher than it ever is at the equator — this is due to the increased day length; at the equator, half of the day is typically dark, with no sunlight, which brings down the daily average in comparison to the polar summer condition where there is 24 hours of sunlight.

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https://www.e-education.psu.edu/earth103/node/1004

Chapter 1: Introduction

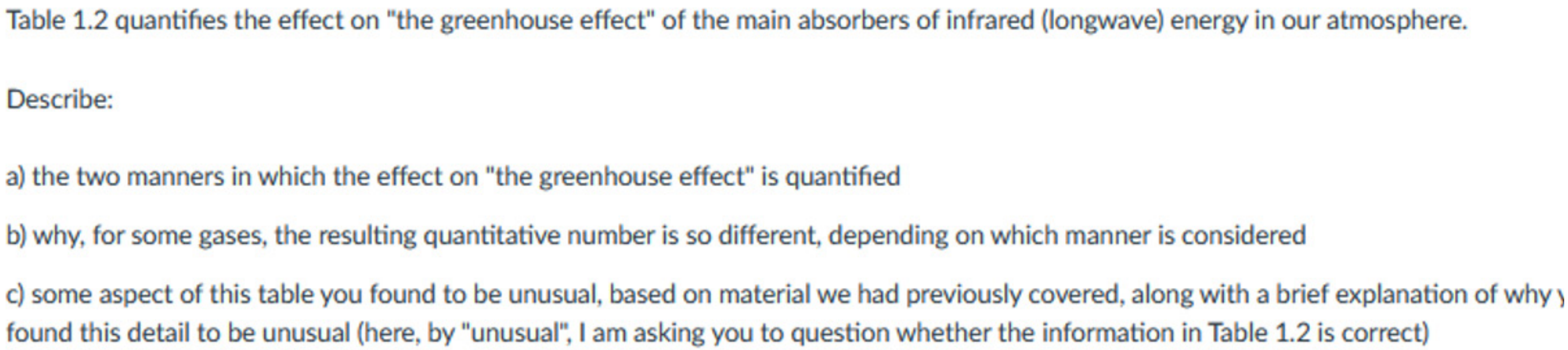


Table 1.2 quantifies the effect on "the greenhouse effect" of the main absorbers of infrared (longwave) energy in our atmosphere.

Describe:

a) the two manners in which the effect on "the greenhouse effect" is quantified

b) why, for some gases, the resulting quantitative number is so different, depending on which manner is considered

c) some aspect of this table you found to be unusual, based on material we had previously covered, along with a brief explanation of why found this detail to be unusual (here, by "unusual", I am asking you to question whether the information in Table 1.2 is correct)

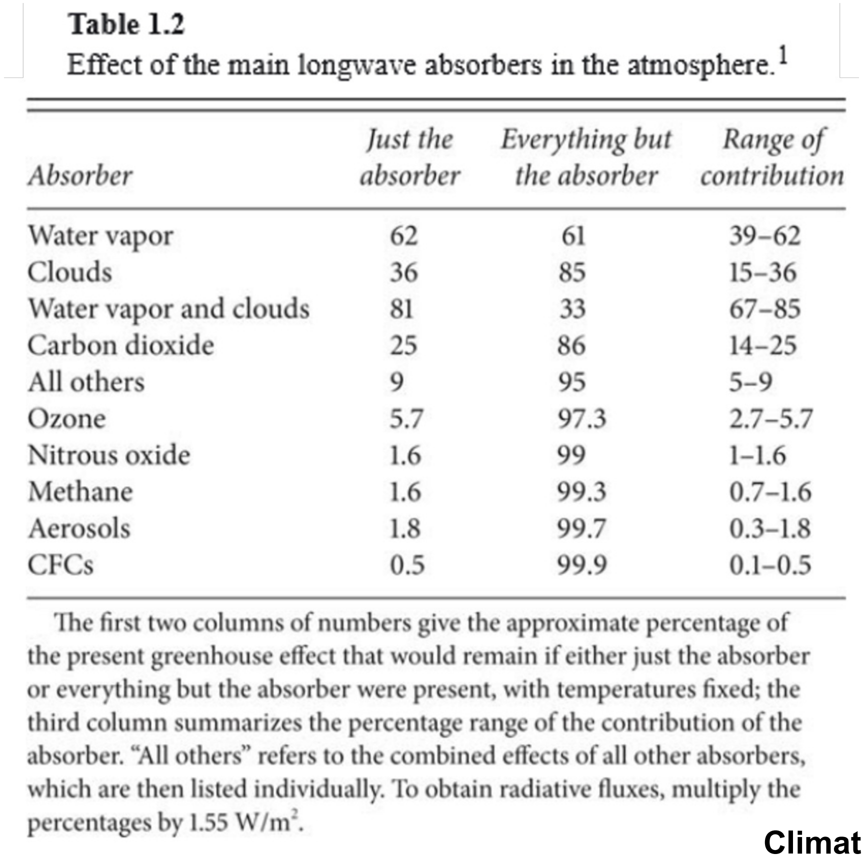


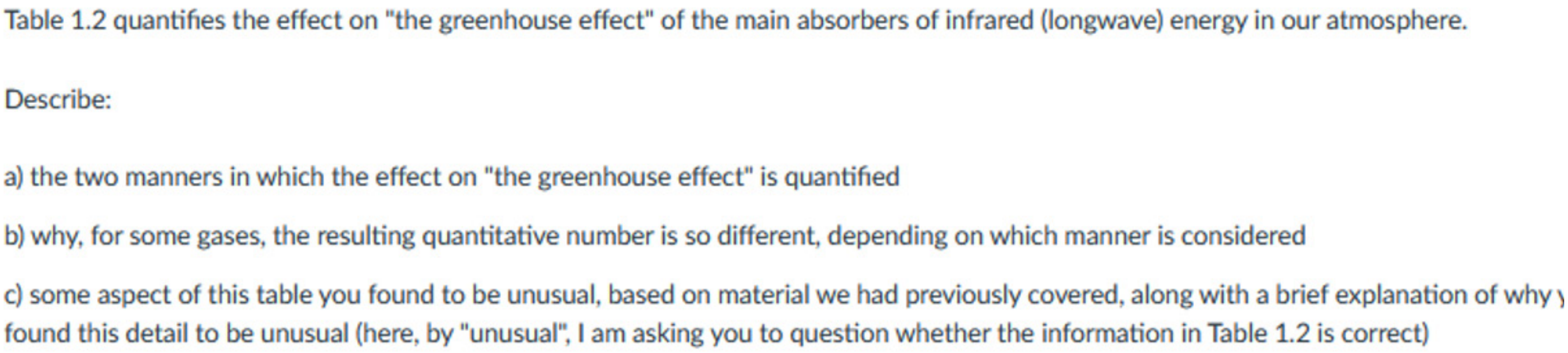
Table 1.2

Effect of the main longwave absorbers in the atmosphere.[1]

Absorber	*Just the absorber*	*Everything but the absorber*	*Range of contribution*
Water vapor	62	61	39–62
Clouds	36	85	15–36
Water vapor and clouds	81	33	67–85
Carbon dioxide	25	86	14–25
All others	9	95	5–9
Ozone	5.7	97.3	2.7–5.7
Nitrous oxide	1.6	99	1–1.6
Methane	1.6	99.3	0.7–1.6
Aerosols	1.8	99.7	0.3–1.8
CFCs	0.5	99.9	0.1–0.5

The first two columns of numbers give the approximate percentage of the present greenhouse effect that would remain if either just the absorber or everything but the absorber were present, with temperatures fixed; the third column summarizes the percentage range of the contribution of the absorber. "All others" refers to the combined effects of all other absorbers, which are then listed individually. To obtain radiative fluxes, multiply the percentages by 1.55 W/m^2.

Chapter 1: Introduction



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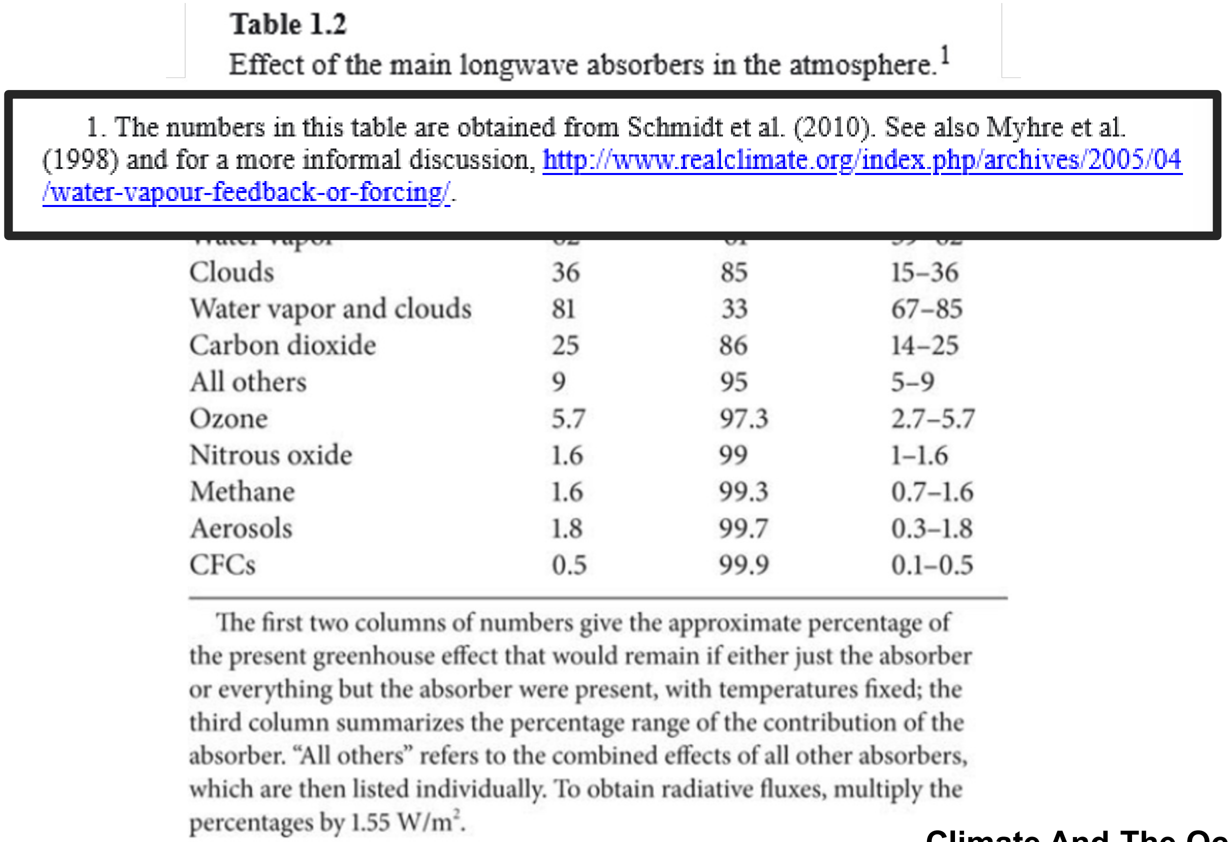

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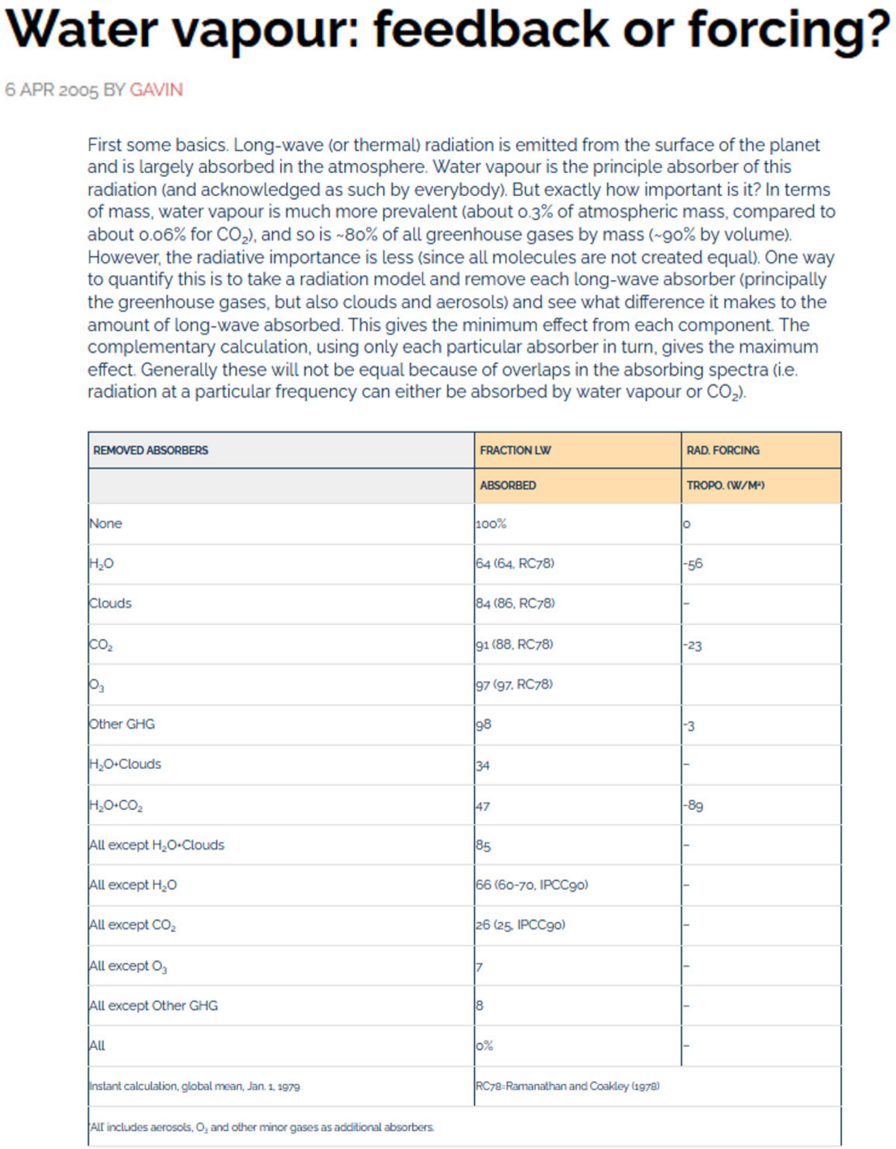
[1] The numbers in this table are obtained from Schmidt et al. (2010). See also Myhre et al. (1998) and for a more informal discussion, http://www.realclimate.org/index.php/archives/2005/04/water-vapour-feedback-or-forcing/.

Chapter 1: Introduction



Water vapour: feedback or forcing?

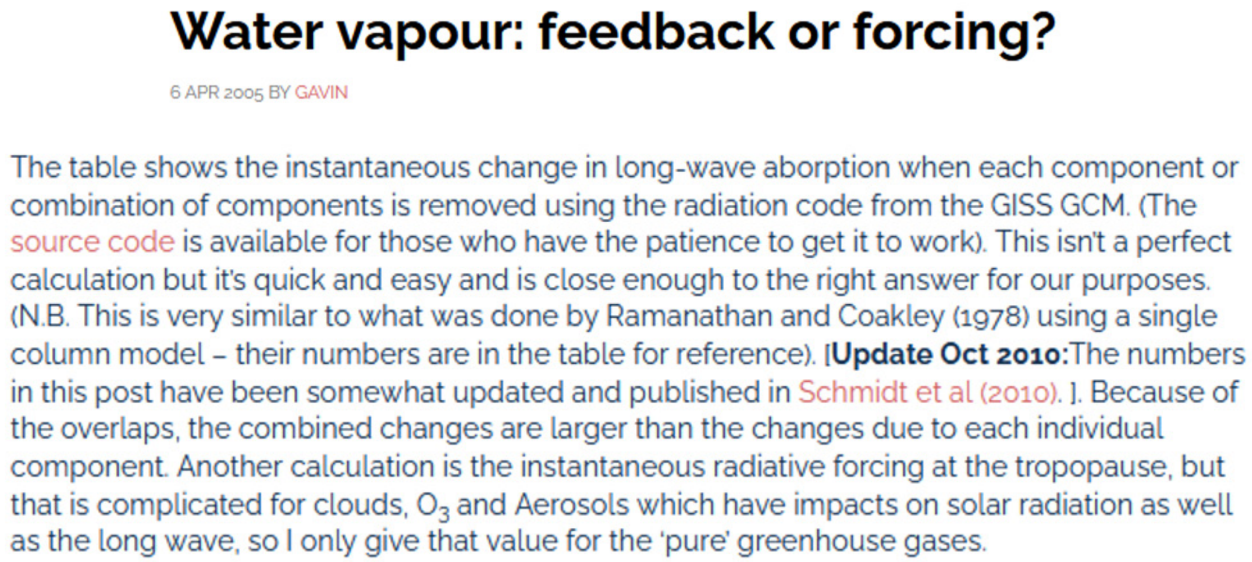
6 APR 2005 BY GAVIN

First some basics. Long-wave (or thermal) radiation is emitted from the surface of the planet and is largely absorbed in the atmosphere. Water vapour is the principle absorber of this radiation (and acknowledged as such by everybody). But exactly how important is it? In terms of mass, water vapour is much more prevalent (about 0.3% of atmospheric mass, compared to about 0.06% for CO_2), and so is ~80% of all greenhouse gases by mass (~90% by volume). However, the radiative importance is less (since all molecules are not created equal). One way to quantify this is to take a radiation model and remove each long-wave absorber (principally the greenhouse gases, but also clouds and aerosols) and see what difference it makes to the amount of long-wave absorbed. This gives the minimum effect from each component. The complementary calculation, using only each particular absorber in turn, gives the maximum effect. Generally these will not be equal because of overlaps in the absorbing spectra (i.e. radiation at a particular frequency can either be absorbed by water vapour or CO_2).

REMOVED ABSORBERS	FRACTION LW	RAD. FORCING
	ABSORBED	TROPO. (W/M^2)
None	100%	0
H_2O	64 (64, RC78)	-56
Clouds	84 (86, RC78)	–
CO_2	91 (88, RC78)	-23
O_3	97 (97, RC78)	
Other GHG	98	-3
H_2O+Clouds	34	–
H_2O+CO_2	47	-89
All except H_2O+Clouds	85	–
All except H_2O	66 (60-70, IPCC90)	–
All except CO_2	26 (25, IPCC90)	–
All except O_3	7	–
All except Other GHG	8	–
All	0%	–
Instant calculation, global mean, Jan. 1, 1979	RC78=Ramanathan and Coakley (1978)	
'All' includes aerosols, O_3 and other minor gases as additional absorbers.		

https://www.realclimate.org/index.php/archives/2005/04/water-vapour-feedback-or-forcing

Chapter 1: Introduction



Water vapour: feedback or forcing?

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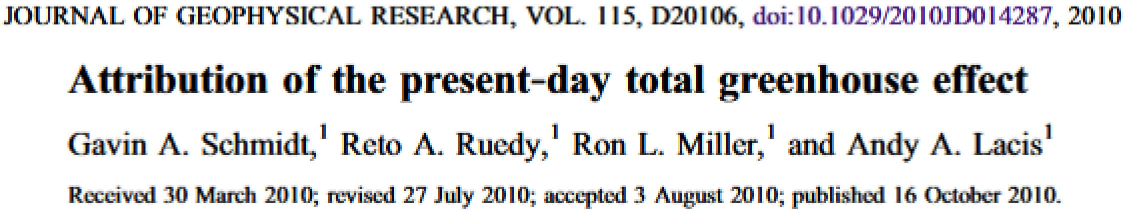
The table shows the instantaneous change in long-wave aborption when each component or combination of components is removed using the radiation code from the GISS GCM. (The source code is available for those who have the patience to get it to work). This isn't a perfect calculation but it's quick and easy and is close enough to the right answer for our purposes. (N.B. This is very similar to what was done by Ramanathan and Coakley (1978) using a single column model – their numbers are in the table for reference). [**Update Oct 2010:**The numbers in this post have been somewhat updated and published in Schmidt et al (2010).]. Because of the overlaps, the combined changes are larger than the changes due to each individual component. Another calculation is the instantaneous radiative forcing at the tropopause, but that is complicated for clouds, O_3 and Aerosols which have impacts on solar radiation as well as the long wave, so I only give that value for the 'pure' greenhouse gases.

https://www.realclimate.org/index.php/archives/2005/04/water-vapour-feedback-or-forcing

Chapter 1: Introduction



JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 115, D20106, doi:10.1029/2010JD014287, 2010

Attribution of the present-day total greenhouse effect

Gavin A. Schmidt,[1] Reto A. Ruedy,[1] Ron L. Miller,[1] and Andy A. Lacis[1]

Received 30 March 2010; revised 27 July 2010; accepted 3 August 2010; published 16 October 2010.

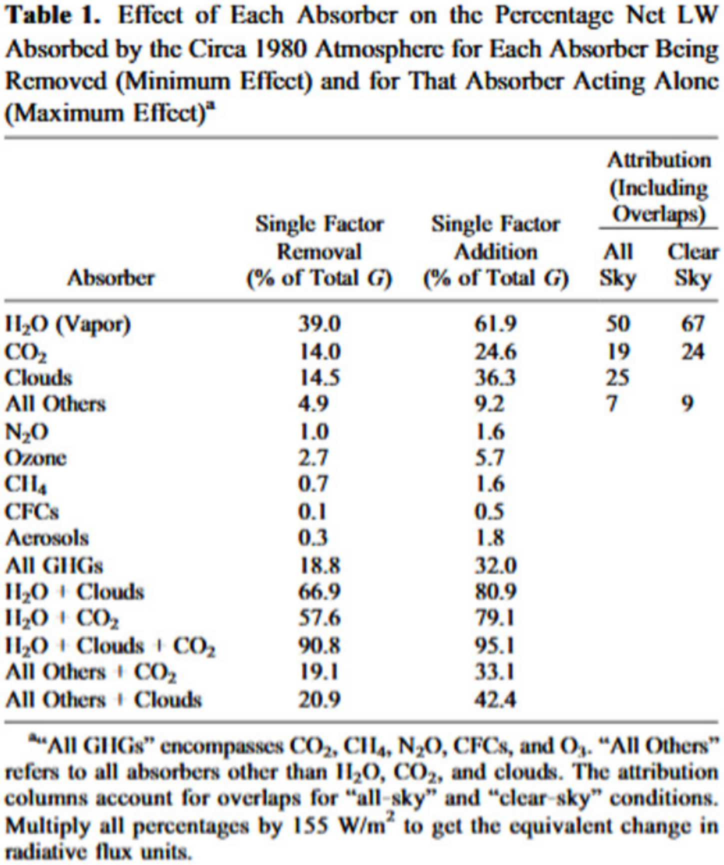


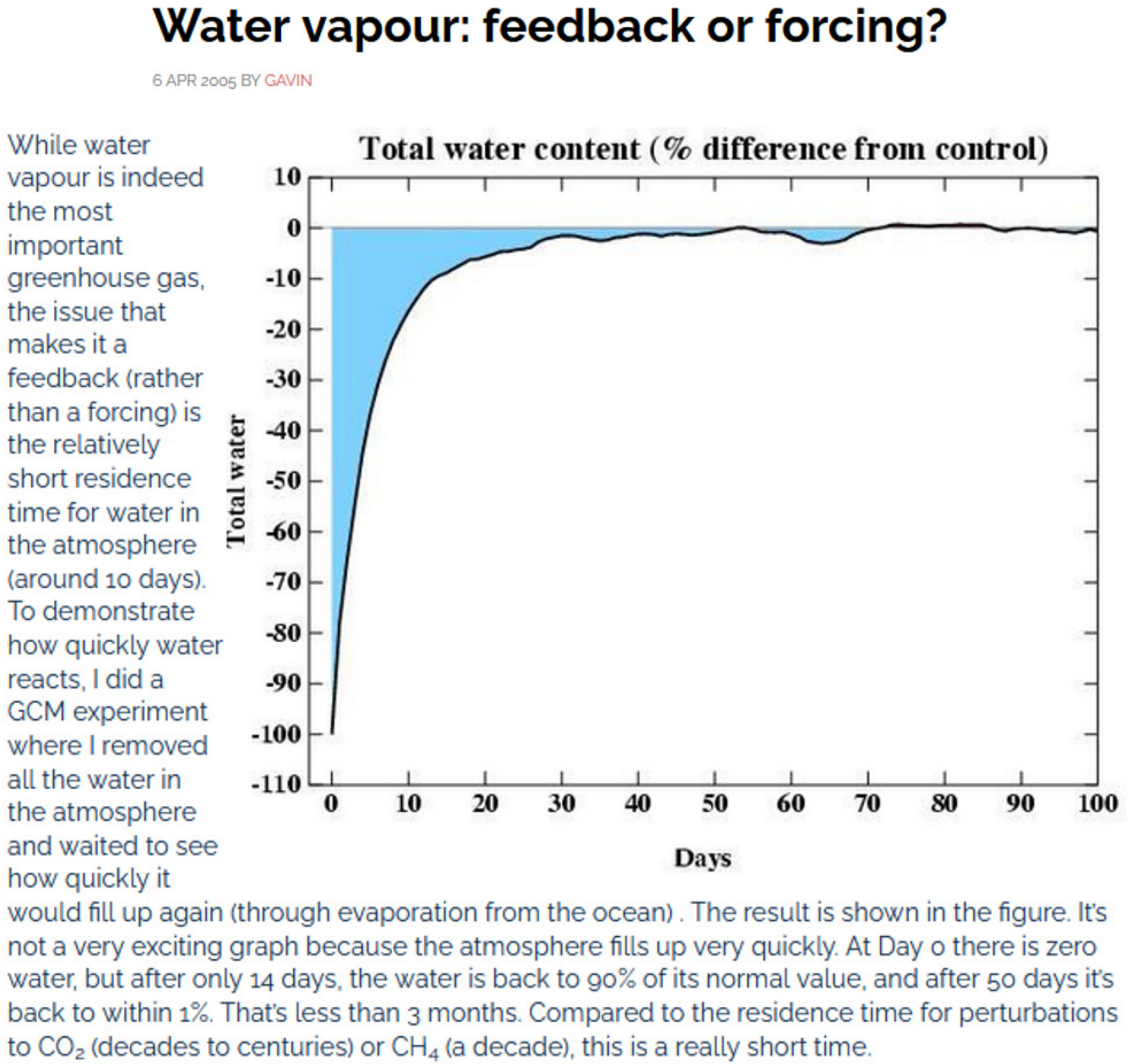
Table 1. Effect of Each Absorber on the Percentage Net LW Absorbed by the Circa 1980 Atmosphere for Each Absorber Being Removed (Minimum Effect) and for That Absorber Acting Alone (Maximum Effect)[a]

Absorber	Single Factor Removal (% of Total *G*)	Single Factor Addition (% of Total *G*)	Attribution (Including Overlaps)	
			All Sky	Clear Sky
H_2O (Vapor)	39.0	61.9	50	67
CO_2	14.0	24.6	19	24
Clouds	14.5	36.3	25	
All Others	4.9	9.2	7	9
N_2O	1.0	1.6		
Ozone	2.7	5.7		
CH_4	0.7	1.6		
CFCs	0.1	0.5		
Aerosols	0.3	1.8		
All GHGs	18.8	32.0		
H_2O + Clouds	66.9	80.9		
H_2O + CO_2	57.6	79.1		
H_2O + Clouds + CO_2	90.8	95.1		
All Others + CO_2	19.1	33.1		
All Others + Clouds	20.9	42.4		

[a] "All GHGs" encompasses CO_2, CH_4, N_2O, CFCs, and O_3. "All Others" refers to all absorbers other than H_2O, CO_2, and clouds. The attribution columns account for overlaps for "all-sky" and "clear-sky" conditions. Multiply all percentages by 155 W/m^2 to get the equivalent change in radiative flux units.

https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2010JD014287

Chapter 1: Introduction



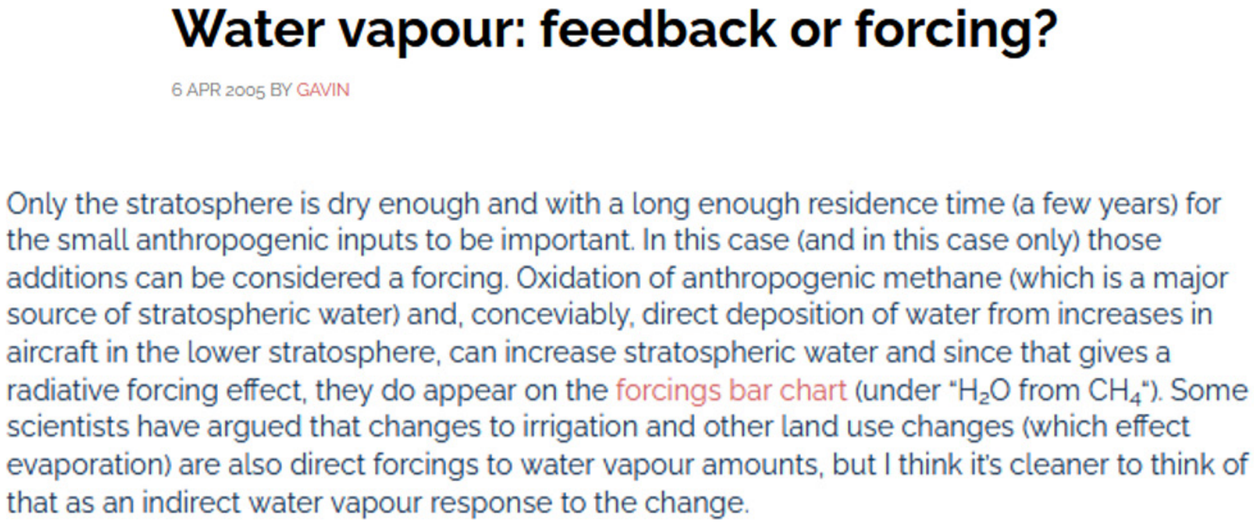
Water vapour: feedback or forcing?

6 APR 2005 BY GAVIN

While water vapour is indeed the most important greenhouse gas, the issue that makes it a feedback (rather than a forcing) is the relatively short residence time for water in the atmosphere (around 10 days). To demonstrate how quickly water reacts, I did a GCM experiment where I removed all the water in the atmosphere and waited to see how quickly it would fill up again (through evaporation from the ocean) . The result is shown in the figure. It's not a very exciting graph because the atmosphere fills up very quickly. At Day 0 there is zero water, but after only 14 days, the water is back to 90% of its normal value, and after 50 days it's back to within 1%. That's less than 3 months. Compared to the residence time for perturbations to CO_2 (decades to centuries) or CH_4 (a decade), this is a really short time.

https://www.realclimate.org/index.php/archives/2005/04/water-vapour-feedback-or-forcing

Chapter 1: Introduction



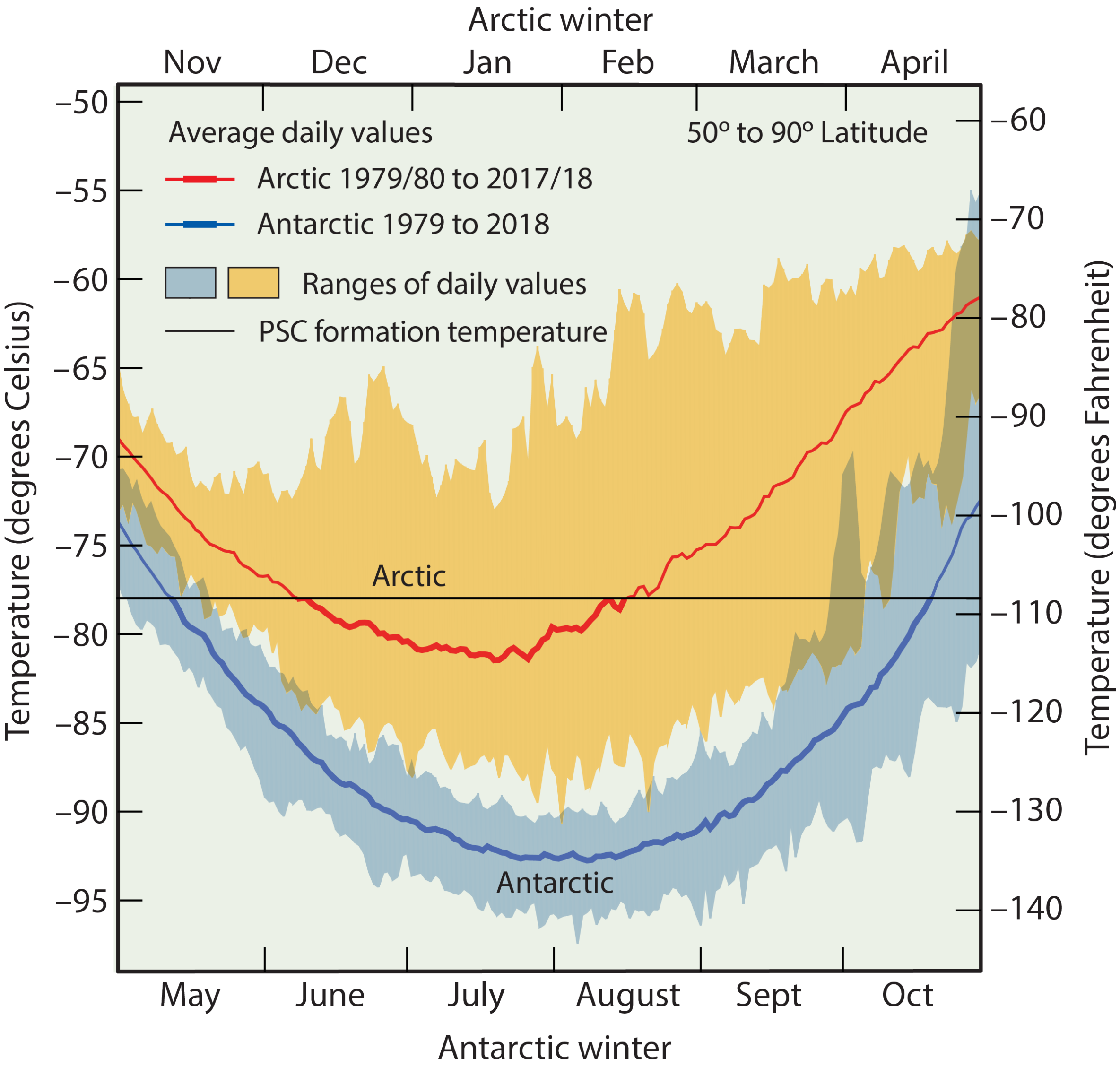
Water vapour: feedback or forcing?

6 APR 2005 BY GAVIN

Only the stratosphere is dry enough and with a long enough residence time (a few years) for the small anthropogenic inputs to be important. In this case (and in this case only) those additions can be considered a forcing. Oxidation of anthropogenic methane (which is a major source of stratospheric water) and, conceviably, direct deposition of water from increases in aircraft in the lower stratosphere, can increase stratospheric water and since that gives a radiative forcing effect, they do appear on the forcings bar chart (under "H_2O from CH_4"). Some scientists have argued that changes to irrigation and other land use changes (which effect evaporation) are also direct forcings to water vapour amounts, but I think it's cleaner to think of that as an indirect water vapour response to the change.

https://www.realclimate.org/index.php/archives/2005/04/water-vapour-feedback-or-forcing

Minimum Temperature: NH and SH Stratosphere



https://csl.noaa.gov/assessments/ozone/2018/twentyquestions.pdf

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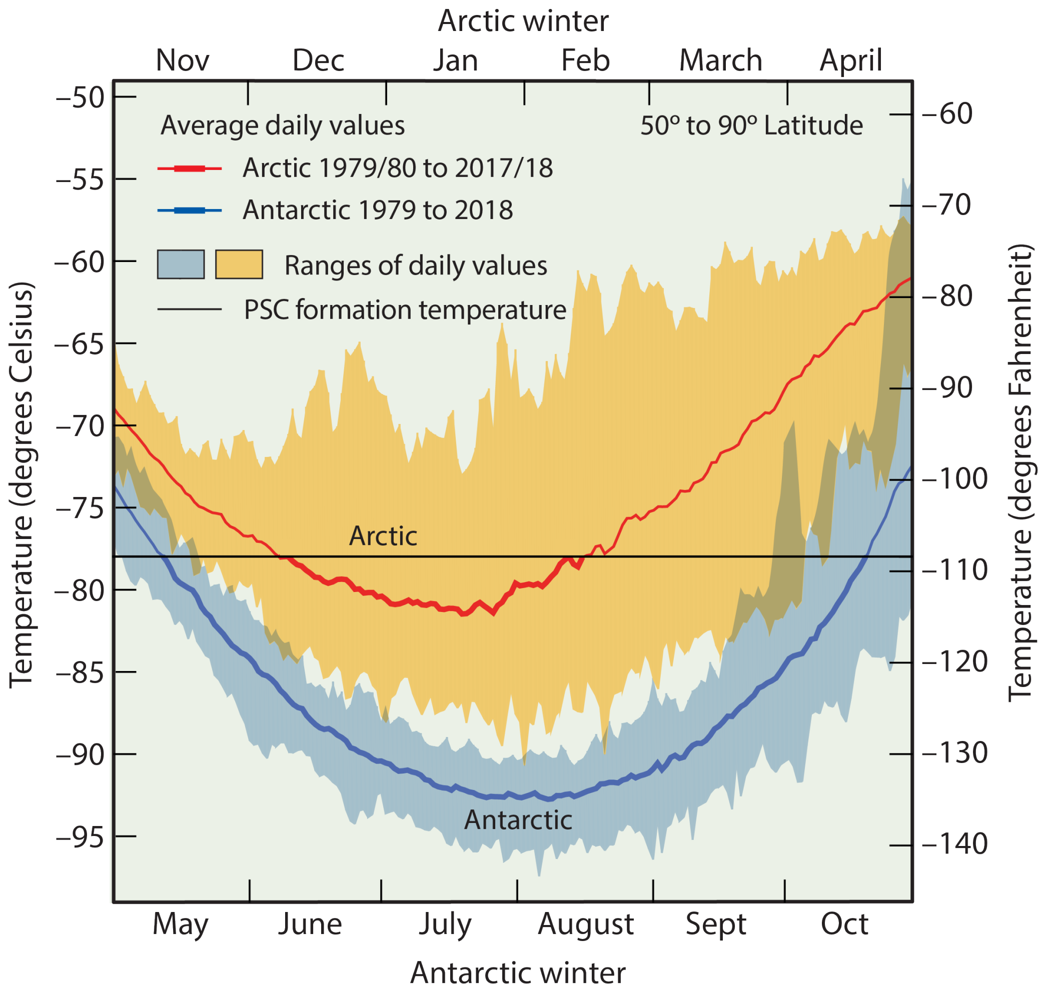
Minimum Temperature: NH and SH Stratosphere



These differences occur because northern polar latitudes have a greater prevalence of contrasting patches of ocean and high altitude land than southern polar latitudes, which creates more meteorological disturbances that warm the Arctic stratosphere.

https://csl.noaa.gov/assessments/ozone/2018/twentyquestions.pdf

Chapter 2: Descriptive Overview

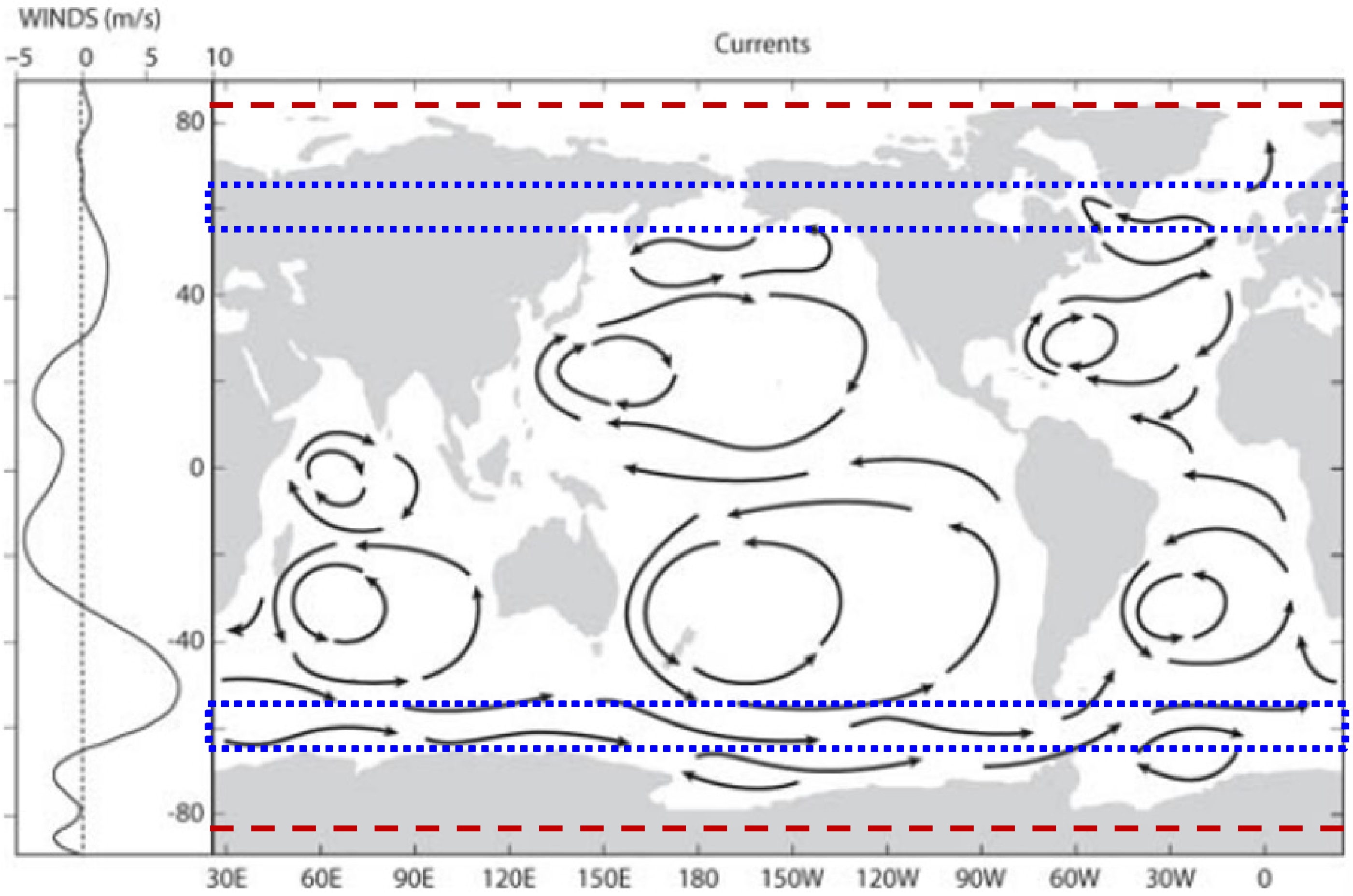
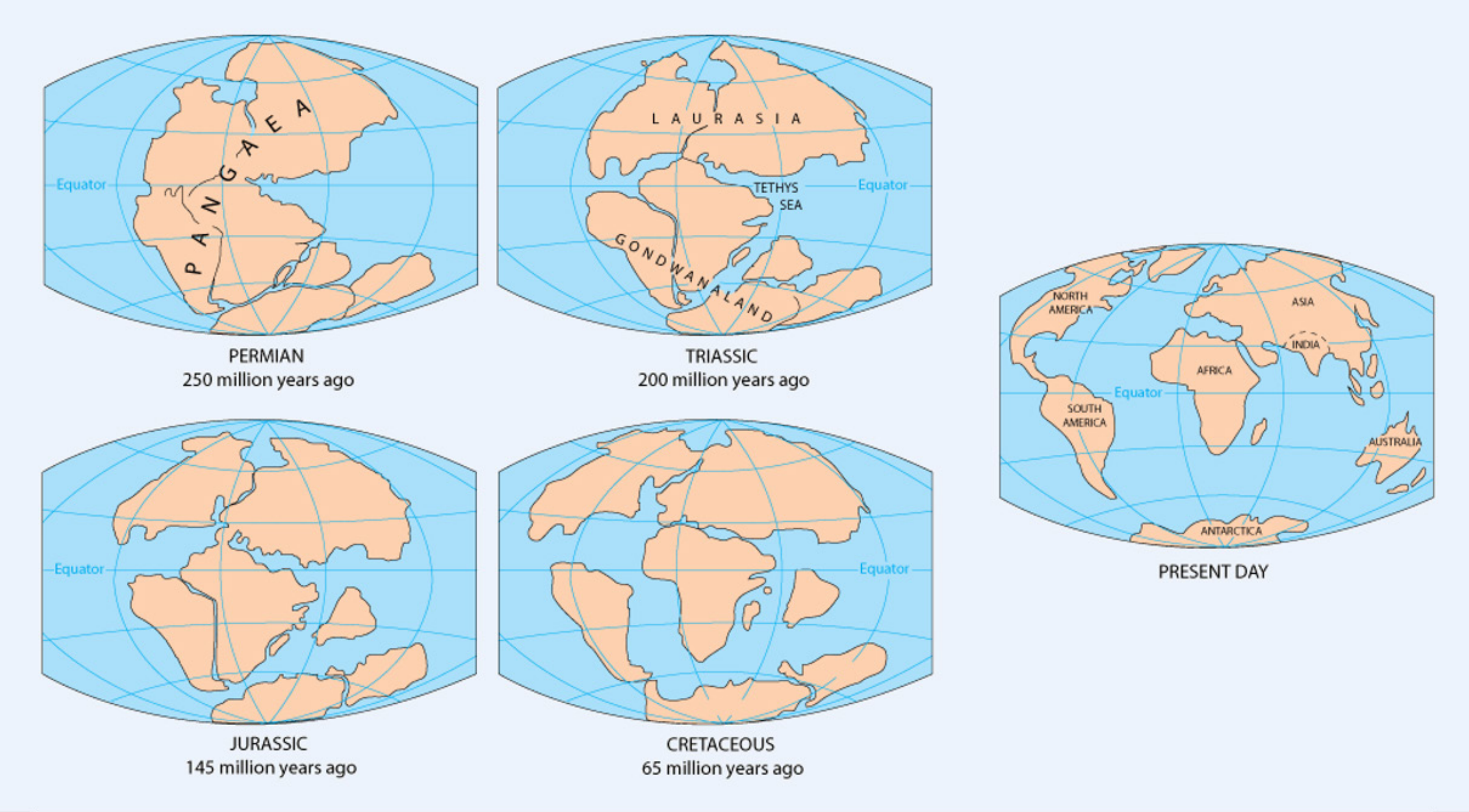


Figure 2.3. A schematic of the main surface currents of the world's oceans. The panel at the left shows the zonally averaged zonal (i.e., east–west) surface winds.

Chapter 2: Descriptive Overview



PERMIAN
250 million years ago

TRIASSIC
200 million years ago

JURASSIC
145 million years ago

CRETACEOUS
65 million years ago

PRESENT DAY

Figure 2.1. Schematic of the configuration of the oceans and continents over the past 225 million years, since the breakup of the supercontinent Pangea. Source: Adapted from USGS (http://pubs.usgs.gov/gip/dynamic/historical.html).

Image from https://pubs.usgs.gov/gip/dynamic/historical.html

Chapter 2: Descriptive Overview

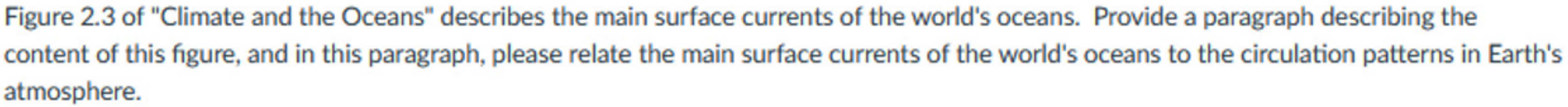
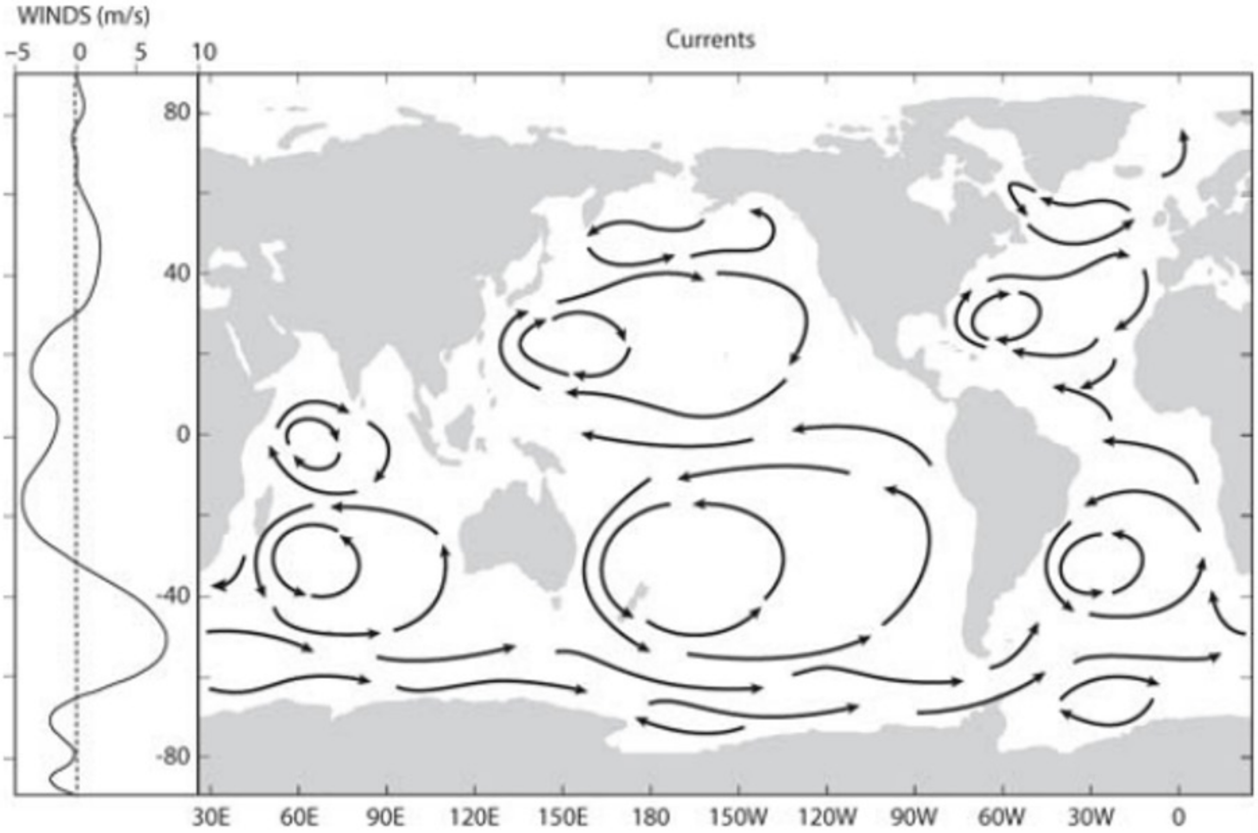


Figure 2.3 of "Climate and the Oceans" describes the main surface currents of the world's oceans. Provide a paragraph describing the content of this figure, and in this paragraph, please relate the main surface currents of the world's oceans to the circulation patterns in Earth's atmosphere.



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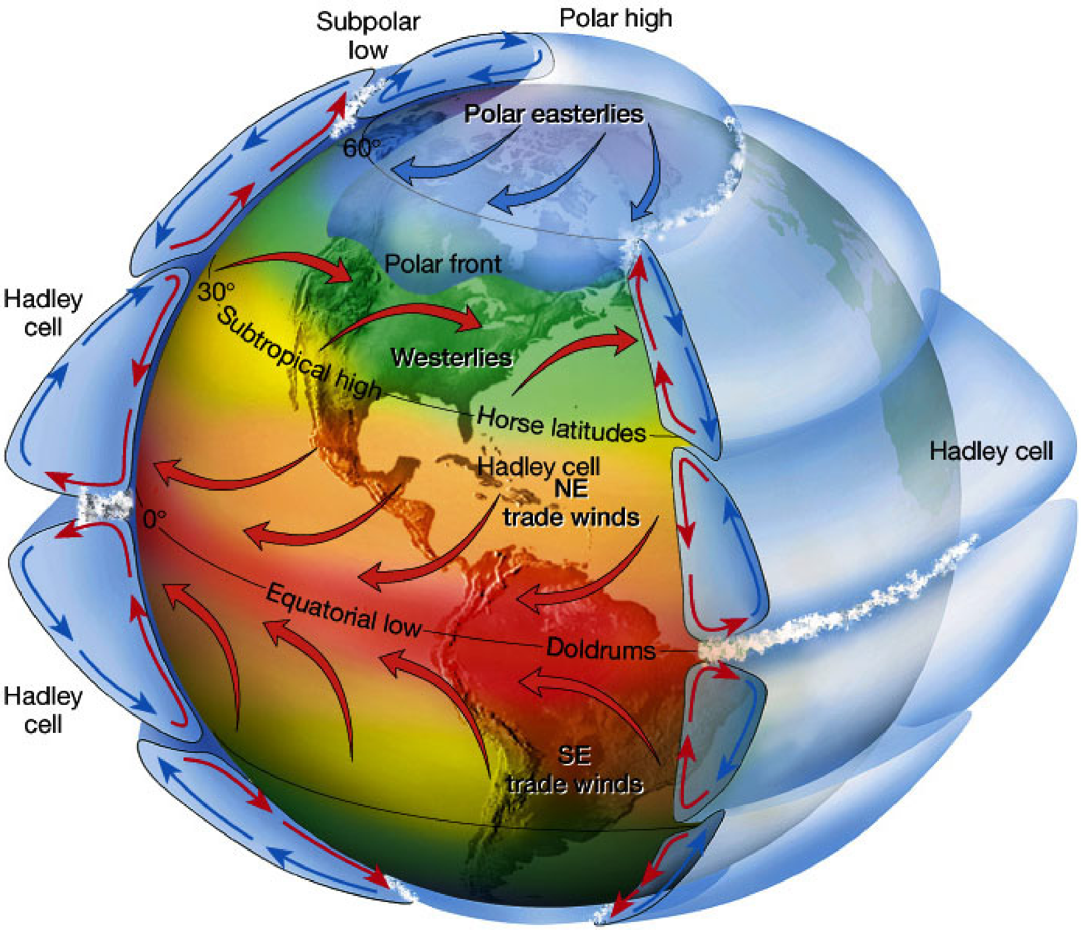


http://www.ux1.eiu.edu/~cfjps/1400/circulation.html

Chapter 2: Descriptive Overview

Figure 2.5 is a schematic of the vertical structure of the ocean. Provide three paragraphs, describing in 2 to 3 sentences per paragraph the key characteristic of each of these three vertical regions. In each paragraph, please use the "name" of the region on the opening sentence, then follow with some information important for the region.

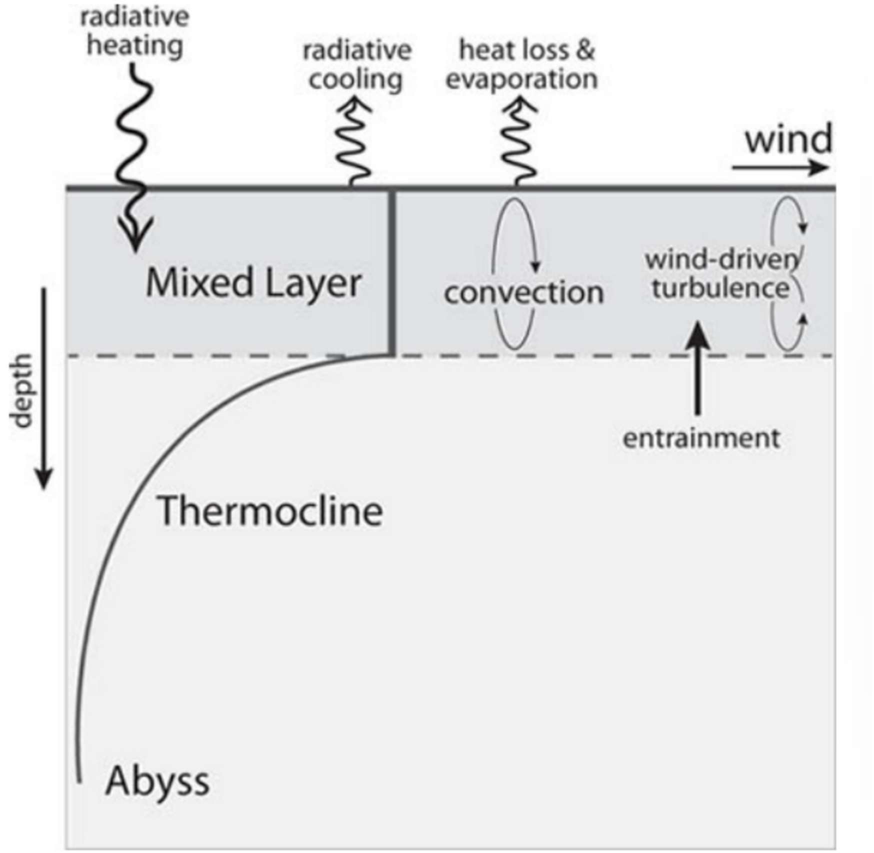


Figure 2.5. Schematic of the vertical structure of the ocean, emphasizing the mixed layer. In the mixed layer, typically 50–100 m deep, turbulence and convection act to keep the temperature relatively uniform in the vertical. Below this layer, temperature changes over a depth of a few hundred meters, in the *thermocline*, before becoming almost uniform at depth, in the *abyss*. Adapted from Marshall and Plumb, 2007.

Chapter 2: Descriptive Overview

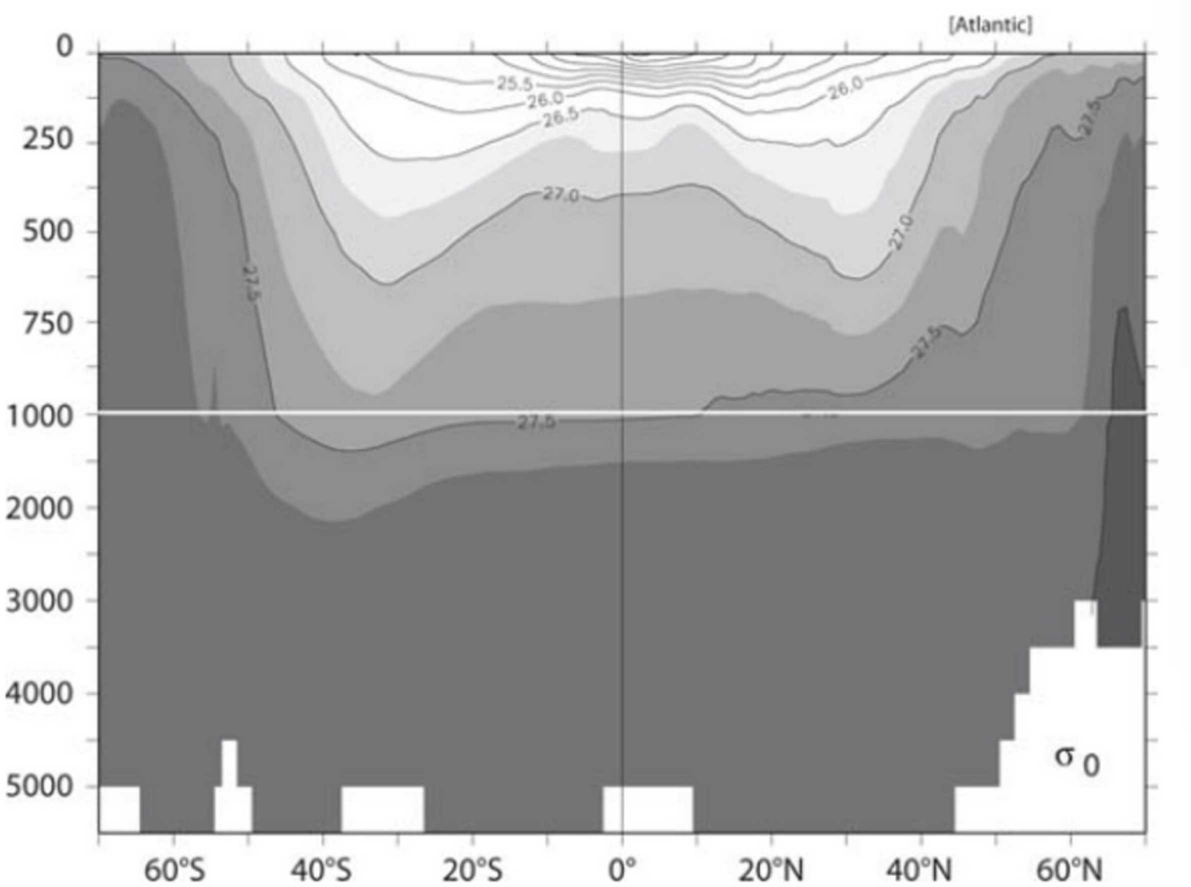


Figure 2.4. The zonally averaged density in the Atlantic Ocean. Note the break in the vertical scale at 1,000 m.[3]

Chapter 2: Descriptive Overview

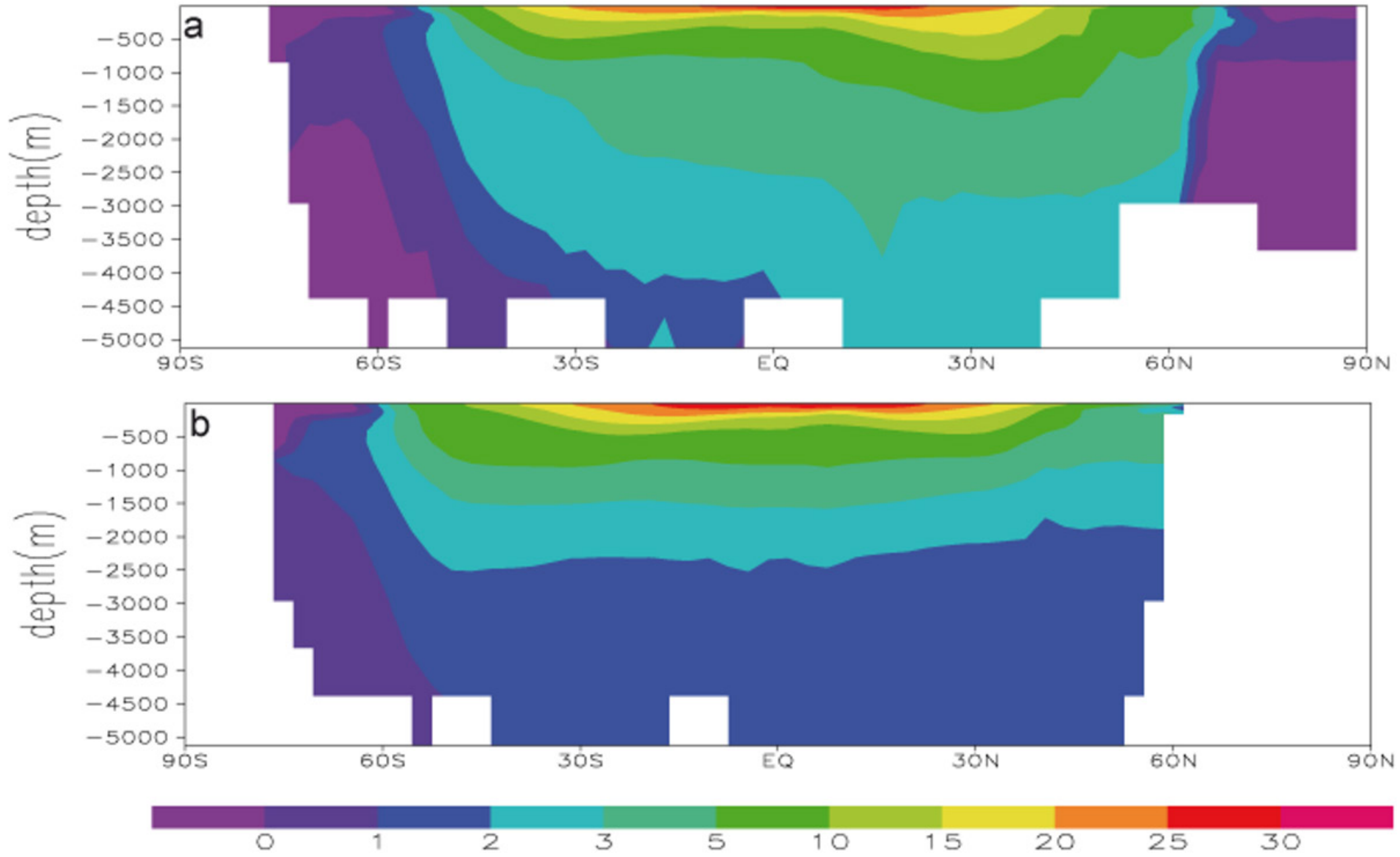


Figure 1.13: Temperature (°C) averaged over all latitudes (i.e. zonal mean) in (a) the Atlantic and in (b) the Pacific. Data source: from Levitus (1998).

http://www.climate.be/textbook/chapter1_node12.html

Chapter 2: Descriptive Overview

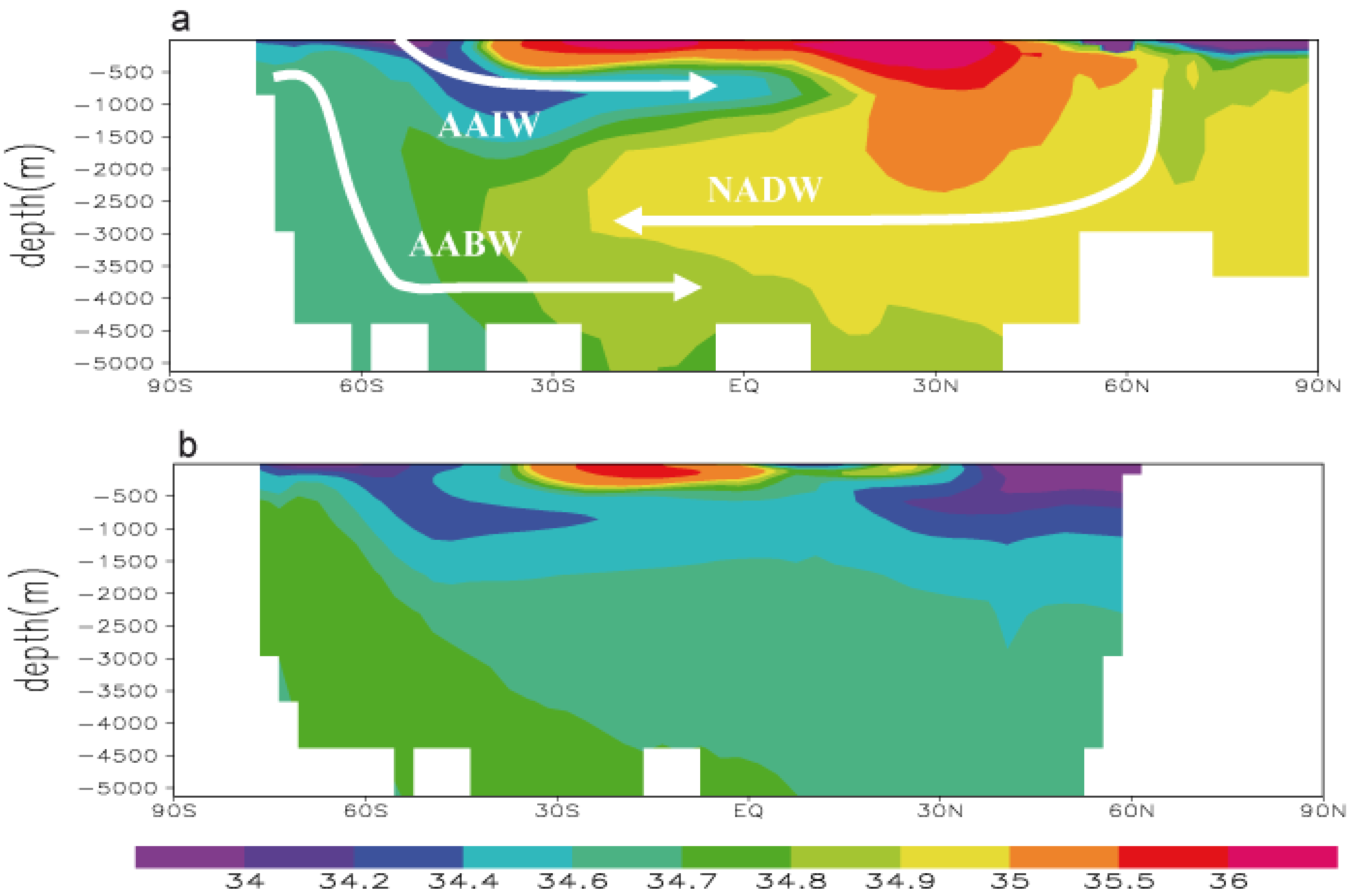


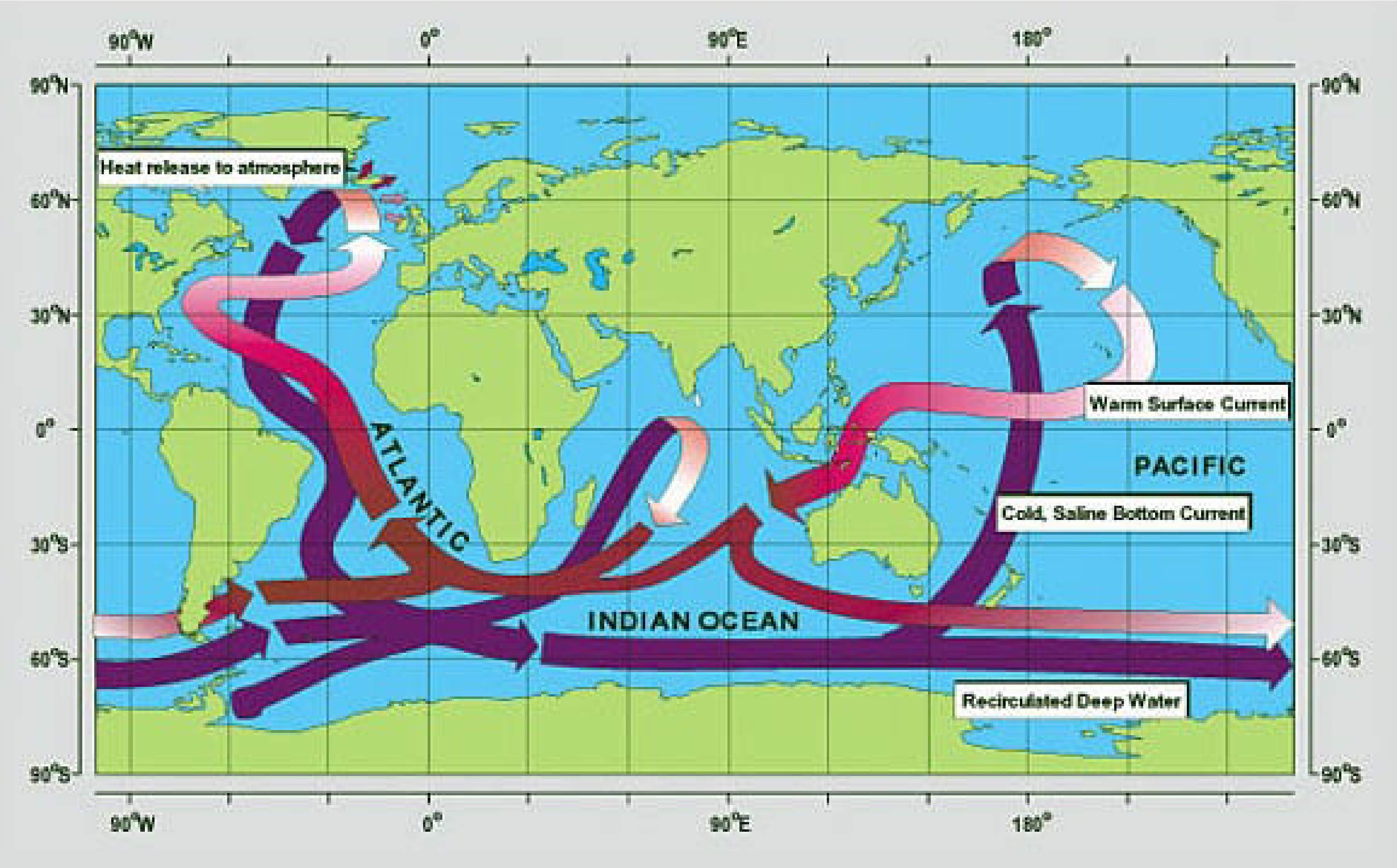
Figure 1.14: Salinity (psu) averaged over all latitudes (i.e. zonal mean) in (a) the Atlantic and in (b) the Pacific. The schematic paths of three important water masses are shown for the Atlantic. Data source: from Levitus (1998).

AAIW: Antarctic Intermediate Water AABW: Antarctic Bottom Water

NADW: North Atlantic Deep Water

http://www.climate.be/textbook/chapter1_node12.html

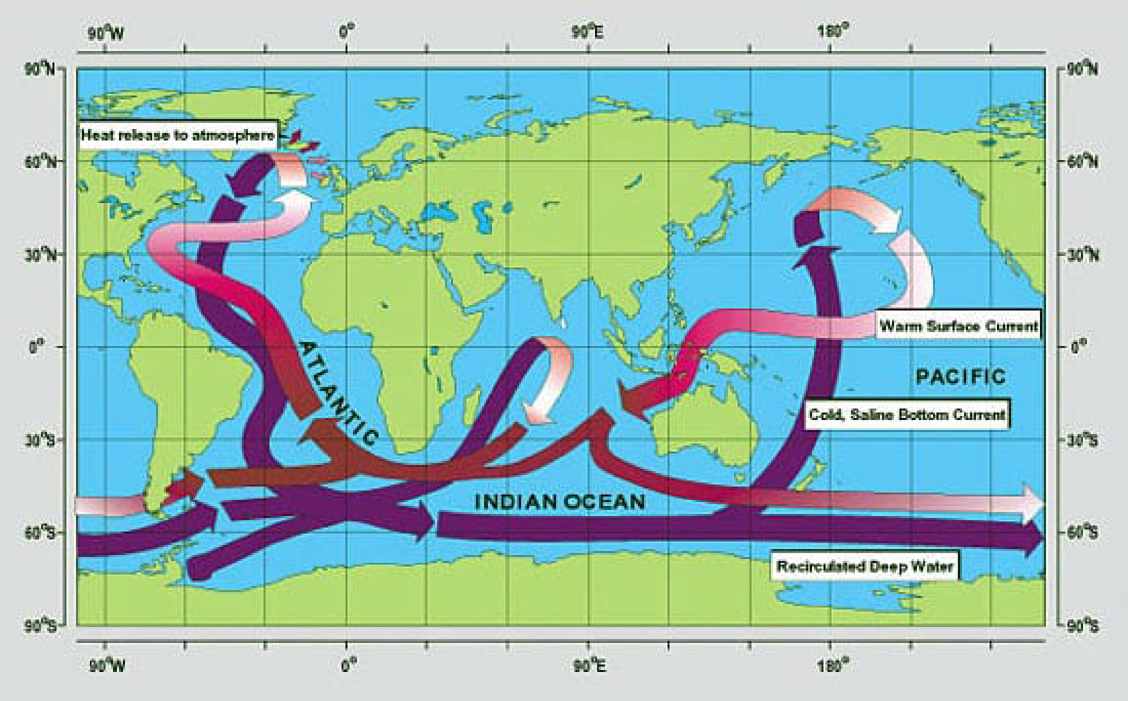
Ocean Heat Transport



A schematic diagram of the global ocean circulation pathways, sometimes referred to as the "Ocean Conveyor."
(W. Broecker, modified by E. Maier-Reimer)

https://www.whoi.edu/oceanus/feature/the-once-and-future-circulation-of-the-ocean

Ocean Heat Transport

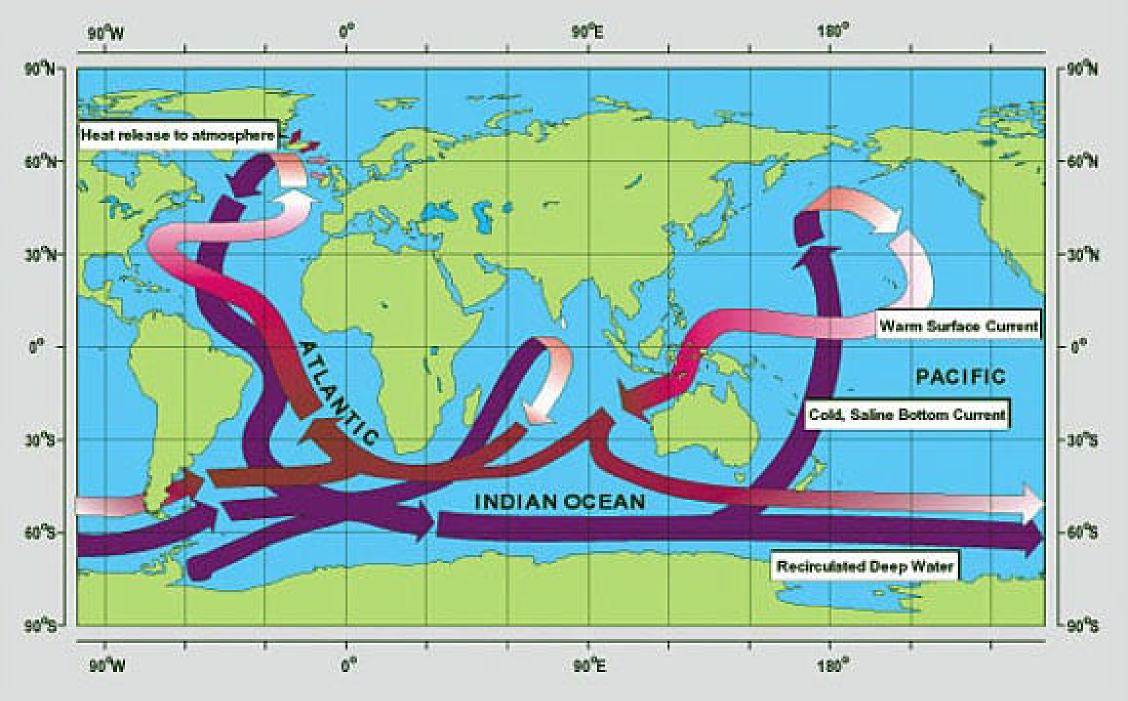


In North Atlantic, cold surface waters sink to the abyss, and salty, warm surface and near-surface currents, including the Gulf Stream, flow northward from the tropics to replace them. When the warm waters reach high latitudes, they release heat to the atmosphere and warm the region. The waters become colder and less buoyant. They sink to continue this grand ocean overturning, which is approximately equal to 20 times the combined flow of all the world's rivers.

This overturning circulation carries a tremendous amount of heat northward, while also generating a huge volume of cold, salty water—which we call North Atlantic Deep Water. After descending, this great mass of water flows southward, filling up the deep Atlantic Ocean basin and eventually spreading into the deep Indian and Pacific Oceans.

https://www.whoi.edu/oceanus/feature/the-once-and-future-circulation-of-the-ocean

Ocean Heat Transport



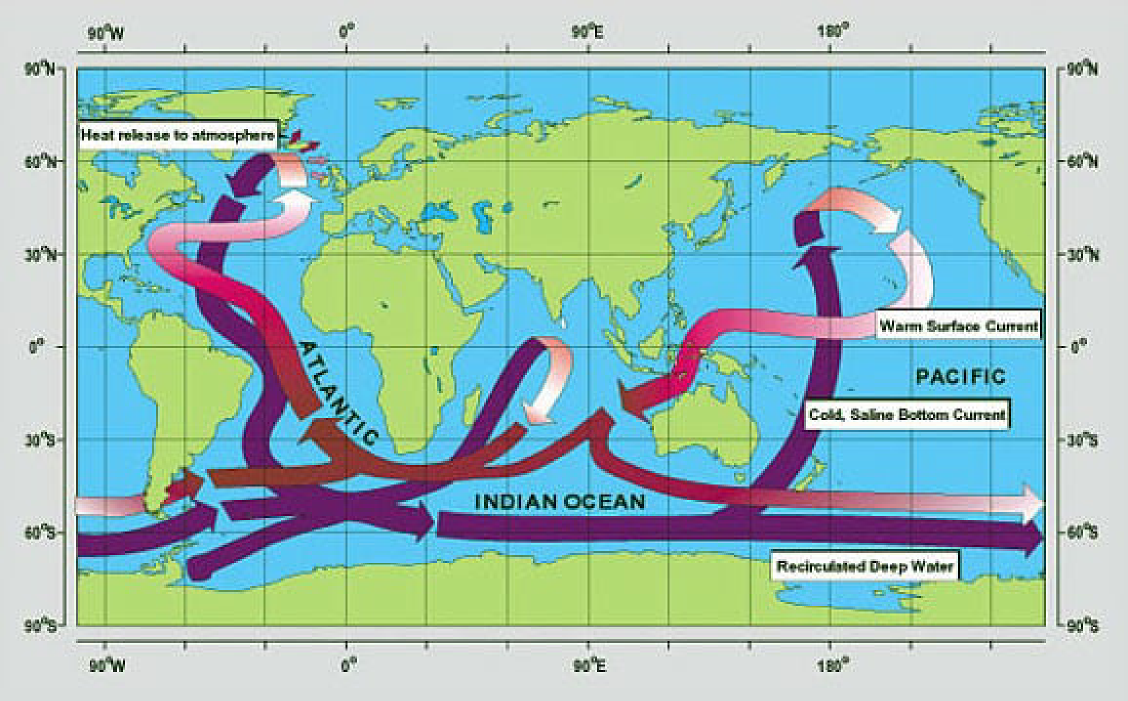
We and other paleoceanographers have found evidence for very different patterns of ocean circulation in the past. This evidence come from clues that are preserved in sediments deposited on the seafloor over tens of thousands of years. The sediments contain fossilized shells of foraminifera—ocean-bottom-dwelling, single-celled organisms the size of sand grains. The shells contain differences in trace elements and carbon isotopes, which reflect different seawater conditions at the times when the foraminifera were alive and growing.

The foraminifera analyses showed us where and when different types of water masses formed in the past. Water masses similar to today's North Atlantic Deep Water seemed to have intensified and diminished in the past—sometimes sinking deeply and spreading to fill the North Atlantic basin and beyond, and sometimes sinking only to intermediate depths and spreading to a far lesser extent.

The carbon isotopes and trace elements, however, don't provide information on how fast or how vigorously these different water masses circulated. To investigate that, we used a different set of clues preserved in deep-sea mud, based on the "clock" inherent in the radioactive decay of naturally occurring **uranium** in seawater to its daughter isotopes, **protactinium** and **thorium**.

https://www.whoi.edu/oceanus/feature/the-once-and-future-circulation-of-the-ocean

Ocean Heat Transport



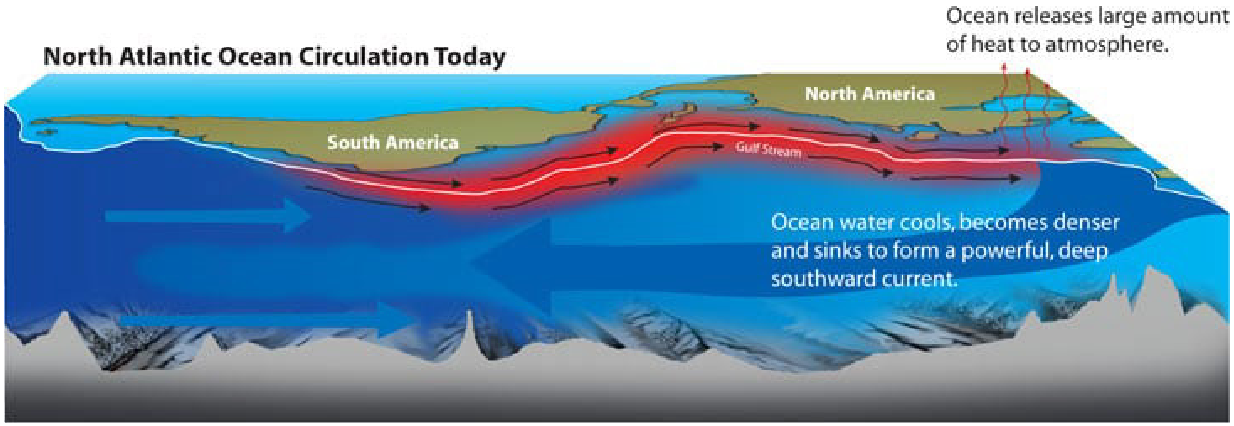
Both chemically adhere to particles in the ocean that sink to the seafloor. Thorium is inherently “stickier;” however, so it is removed from seawater within decades, while protactinium remains in seawater for centuries.

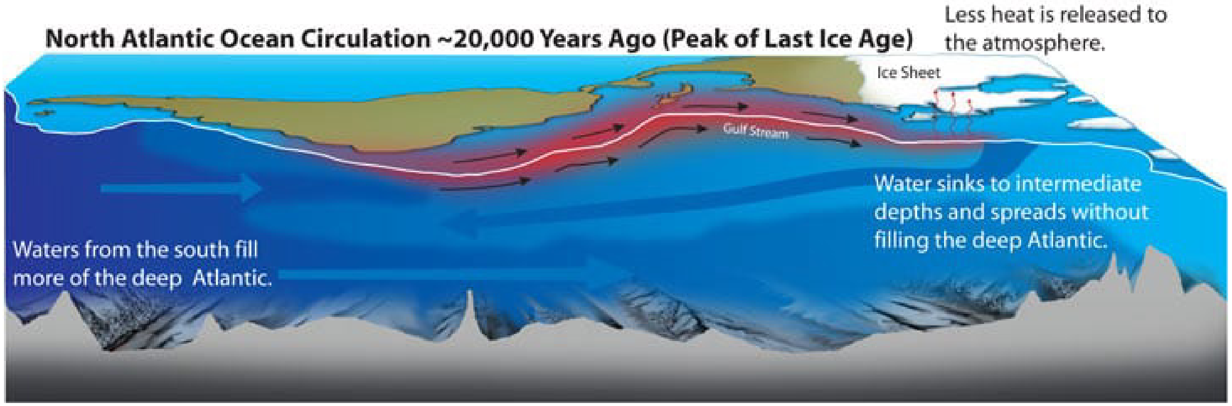
As a result, about half of the **protactinium** produced in North Atlantic water today lasts long enough in the water column to be exported into the Southern Ocean by the ocean’s overturning system. At times when the rate of overturning circulation slows, the proportion of protactinium buried in North Atlantic sediments increases. Thus, **the ratio of protactinium-to-thorium levels in the sediments tells the story of past changes in how fast North Atlantic Deep Water was produced and exported by the overturning circulation**.

When we compared ocean circulation records to records of climate since the peak of the last ice age 20,000 years ago, we confirmed that the rate of ocean overturning, with its northward heat transport, has a critical influence on climate. When North Atlantic Deep Water filled the deep ocean and spread southward vigorously, the climate of the North Atlantic region was warm and generally stable. When North Atlantic Deep Water filled less of the Atlantic and did not spread southward extensively, the climate was generally cold and more variable.

https://www.whoi.edu/oceanus/feature/the-once-and-future-circulation-of-the-ocean

Ocean Heat Transport



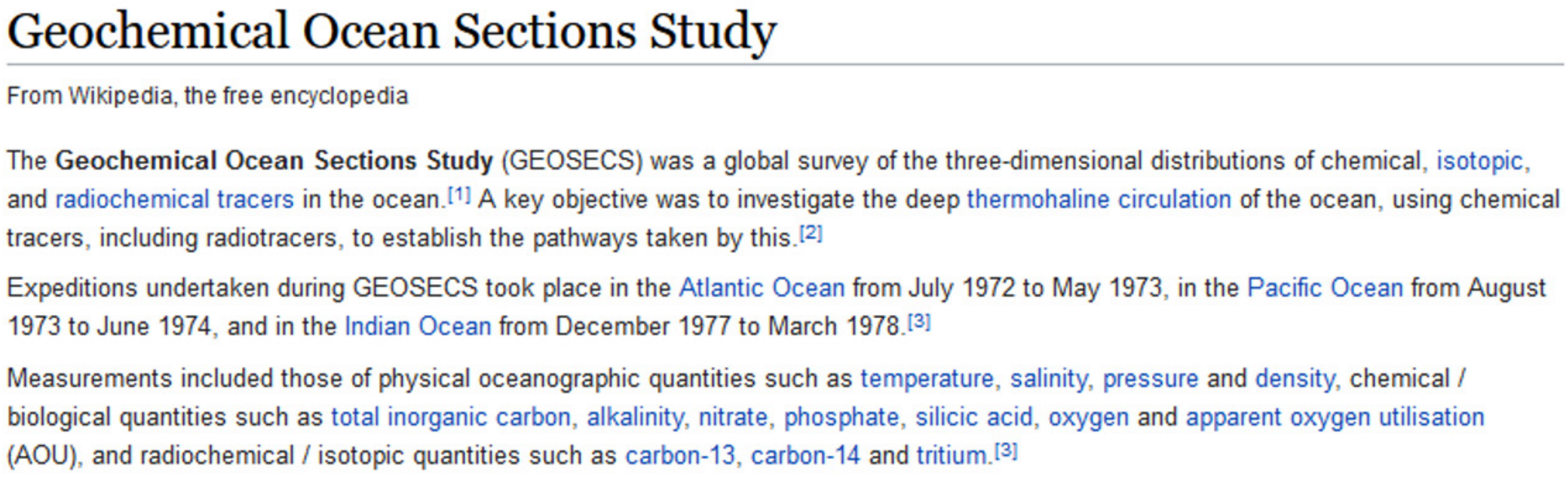


Today (top), the ocean's overturning circulation carries a tremendous amount of heat northward, warming the North Atlantic region. It also generates a huge volume of cold, salty water called North Atlantic Deep Water—a great mass of water that flows southward, filling up the deep Atlantic Ocean basin and eventually spreading into the deep Indian and Pacific Oceans.

Paleoceanographers have found evidence for very different patterns of ocean circulation in the past. About 20,000 years ago (bottom), waters in the North Atlantic sank only to intermediate depths and spread to a far lesser extent. When that occurred, the climate in the North Atlantic region was generally cold and more variable. (Illustration by E. Paul Oberlander, Woods Hole Oceanographic Institution)

https://www.whoi.edu/oceanus/feature/the-once-and-future-circulation-of-the-ocean

GEOSECS (Geochemical Ocean Sections Study)



Geochemical Ocean Sections Study

From Wikipedia, the free encyclopedia

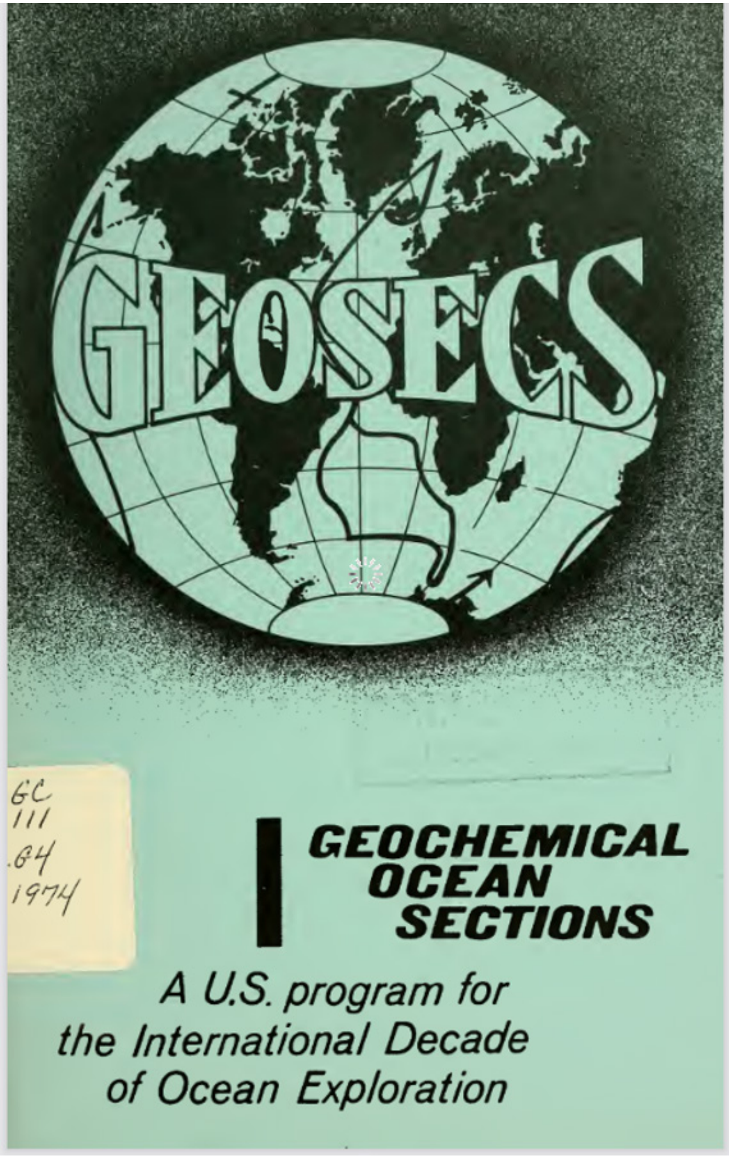
The **Geochemical Ocean Sections Study** (GEOSECS) was a global survey of the three-dimensional distributions of chemical, isotopic, and radiochemical tracers in the ocean.[1] A key objective was to investigate the deep thermohaline circulation of the ocean, using chemical tracers, including radiotracers, to establish the pathways taken by this.[2]

Expeditions undertaken during GEOSECS took place in the Atlantic Ocean from July 1972 to May 1973, in the Pacific Ocean from August 1973 to June 1974, and in the Indian Ocean from December 1977 to March 1978.[3]

Measurements included those of physical oceanographic quantities such as temperature, salinity, pressure and density, chemical / biological quantities such as total inorganic carbon, alkalinity, nitrate, phosphate, silicic acid, oxygen and apparent oxygen utilisation (AOU), and radiochemical / isotopic quantities such as carbon-13, carbon-14 and tritium.[3]

https://en.wikipedia.org/wiki/Geochemical_Ocean_Sections_Study

GEOSECS (Geochemical Ocean Sections Study)



GEOSECS

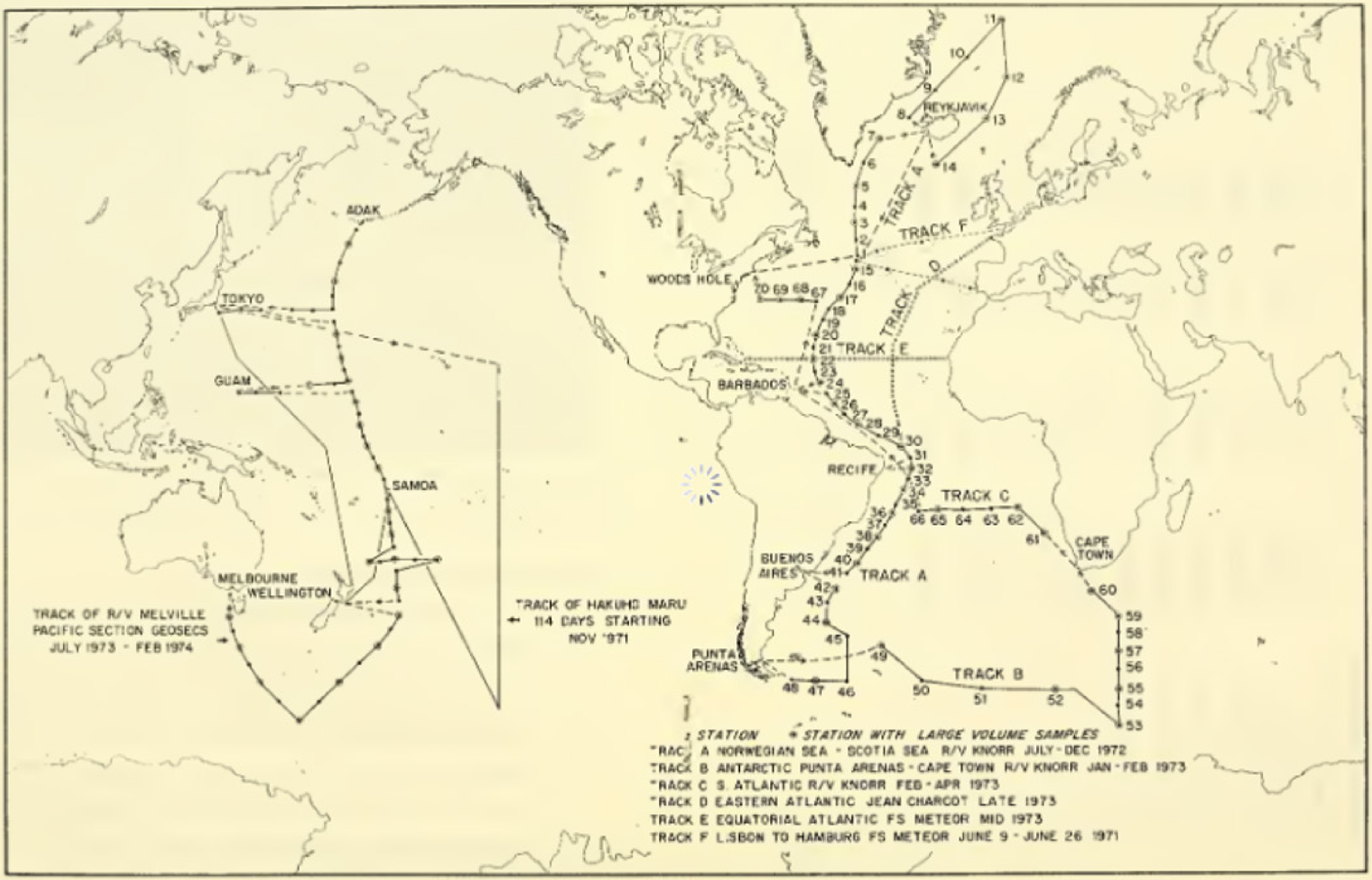
I GEOCHEMICAL OCEAN SECTIONS

A U.S. program for the International Decade of Ocean Exploration

R/V KNORR, a 240' AGOR class research vessel equipped with cycloid propulsion, will be at sea nearly a full year as it sails from the Arctic to the Antarctic on the Atlantic Cruise of the GEOSECS project. The ship is the most modern in the fleet operated by Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, U. S. A. A subsequent Pacific Cruise will be made by her sister ship, R/V MELVILLE, operated by Scripps Institution of Oceanography, La Jolla, California, U. S. A.

https://odv.awi.de/fileadmin/user_upload/odv.awi.de/user_upload/odv/data/GEOSECS/GeochemicalOceanSections.pdf

GEOSECS (Geochemical Ocean Sections Study)



TRACK OF R/V MELVILLE
PACIFIC SECTION GEOSECS
JULY 1973 - FEB 1974

TRACK OF HAKUHO MARU
114 DAYS STARTING
NOV '971

STATION · *STATION WITH LARGE VOLUME SAMPLES*

TRACK A NORWEGIAN SEA - SCOTIA SEA R/V KNORR JULY - DEC 1972
TRACK B ANTARCTIC PUNTA ARENAS - CAPE TOWN R/V KNORR JAN - FEB 1973
TRACK C S. ATLANTIC R/V KNORR FEB - APR 1973
TRACK D EASTERN ATLANTIC JEAN CHARCOT LATE 1973
TRACK E EQUATORIAL ATLANTIC FS METEOR MID 1973
TRACK F LISBON TO HAMBURG FS METEOR JUNE 9 - JUNE 26 1971

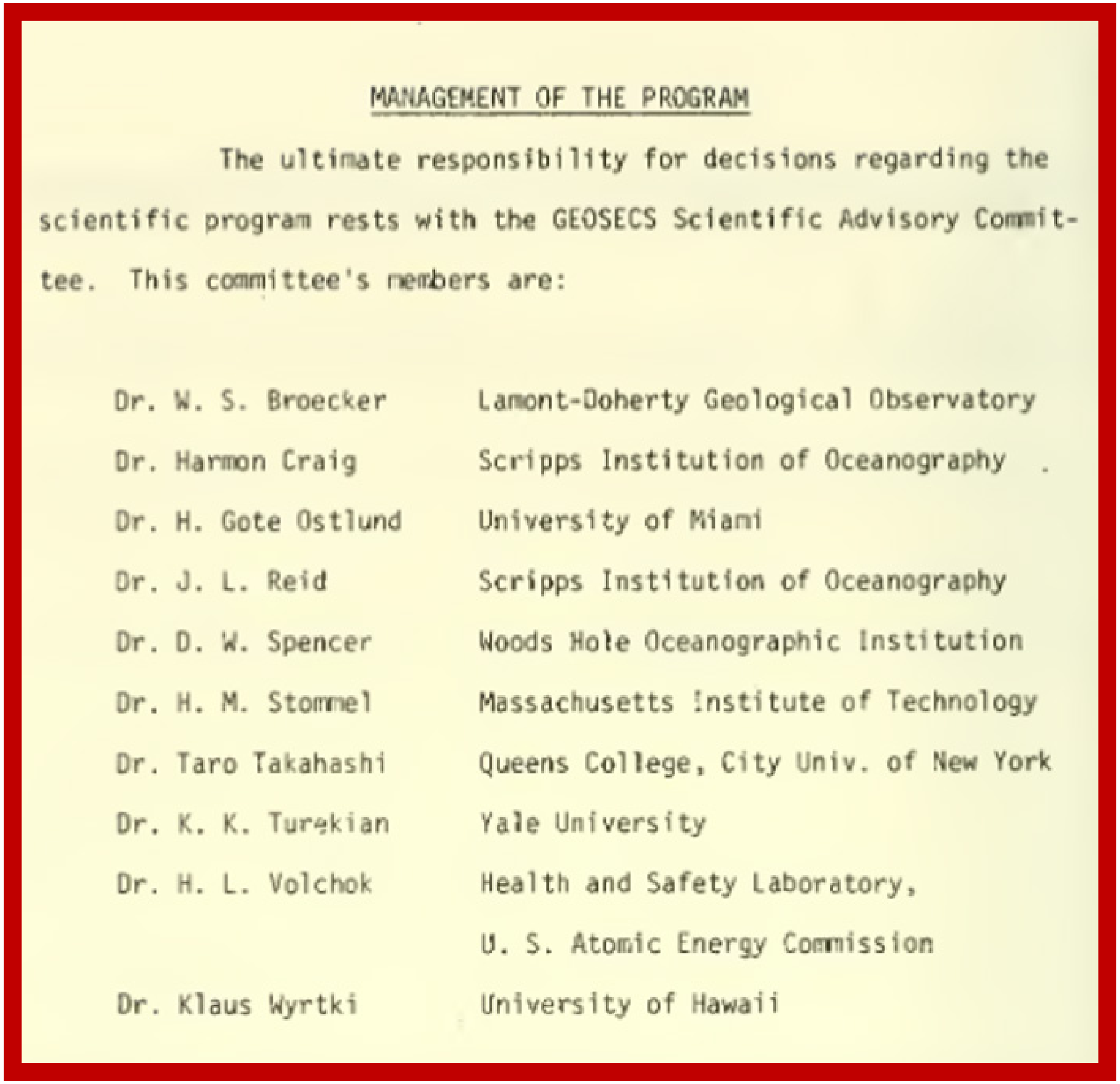
PROPOSED GEOSECS CRUISE TRACKS

OCT 1, 1971

Figure 4

https://odv.awi.de/fileadmin/user_upload/odv.awi.de/user_upload/odv/data/GEOSECS/GeochemicalOceanSections.pdf

GEOSECS (Geochemical Ocean Sections Study)



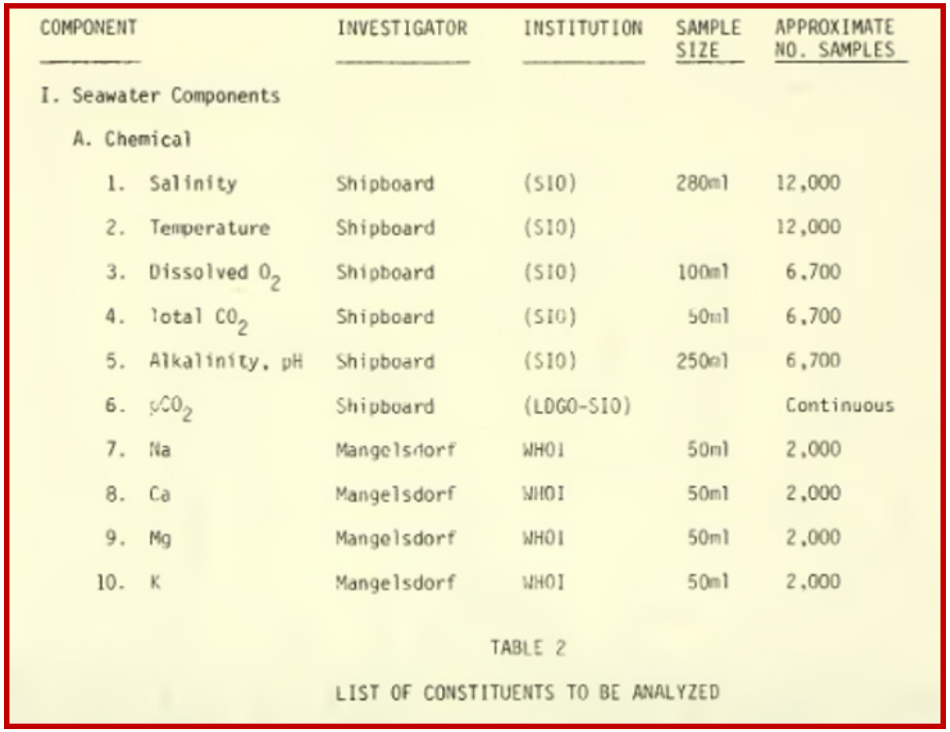
MANAGEMENT OF THE PROGRAM

The ultimate responsibility for decisions regarding the scientific program rests with the GEOSECS Scientific Advisory Committee. This committee's members are:

Dr. W. S. Broecker	Lamont-Doherty Geological Observatory
Dr. Harmon Craig	Scripps Institution of Oceanography
Dr. H. Gote Ostlund	University of Miami
Dr. J. L. Reid	Scripps Institution of Oceanography
Dr. D. W. Spencer	Woods Hole Oceanographic Institution
Dr. H. M. Stommel	Massachusetts Institute of Technology
Dr. Taro Takahashi	Queens College, City Univ. of New York
Dr. K. K. Turekian	Yale University
Dr. H. L. Volchok	Health and Safety Laboratory, U. S. Atomic Energy Commission
Dr. Klaus Wyrtki	University of Hawaii

https://odv.awi.de/fileadmin/user_upload/odv.awi.de/user_upload/odv/data/GEOSECS/GeochemicalOceanSections.pdf

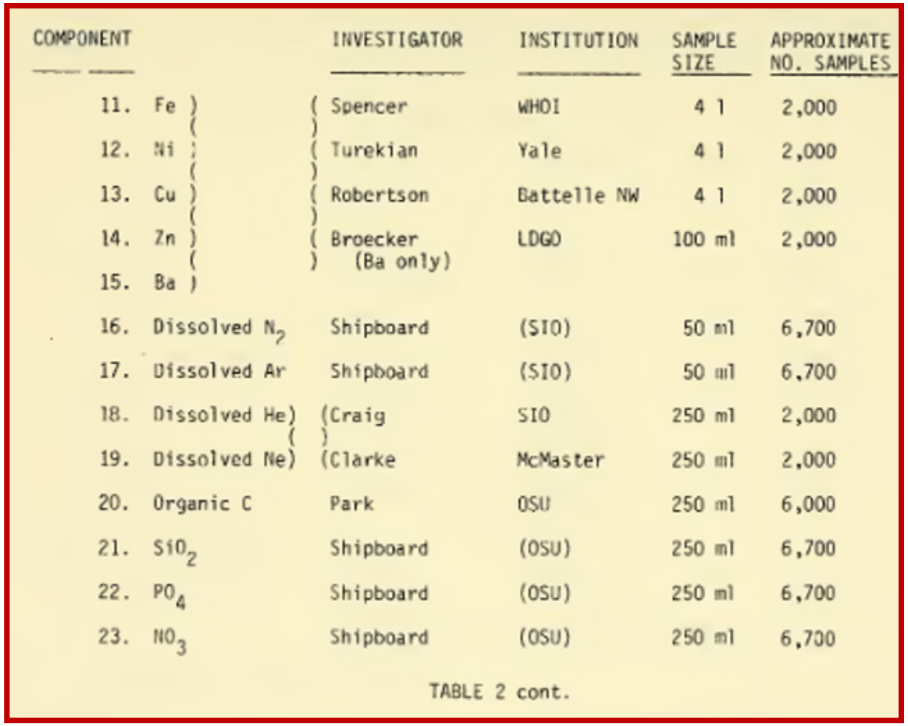
GEOSECS (Geochemical Ocean Sections Study)



COMPONENT	INVESTIGATOR	INSTITUTION	SAMPLE SIZE	APPROXIMATE NO. SAMPLES
I. Seawater Components				
A. Chemical				
1. Salinity	Shipboard	(SIO)	280ml	12,000
2. Temperature	Shipboard	(SIO)		12,000
3. Dissolved O_2	Shipboard	(SIO)	100ml	6,700
4. Total CO_2	Shipboard	(SIO)	50ml	6,700
5. Alkalinity, pH	Shipboard	(SIO)	250ml	6,700
6. pCO_2	Shipboard	(LDGO-SIO)		Continuous
7. Na	Mangelsdorf	WHOI	50ml	2,000
8. Ca	Mangelsdorf	WHOI	50ml	2,000
9. Mg	Mangelsdorf	WHOI	50ml	2,000
10. K	Mangelsdorf	WHOI	50ml	2,000

TABLE 2

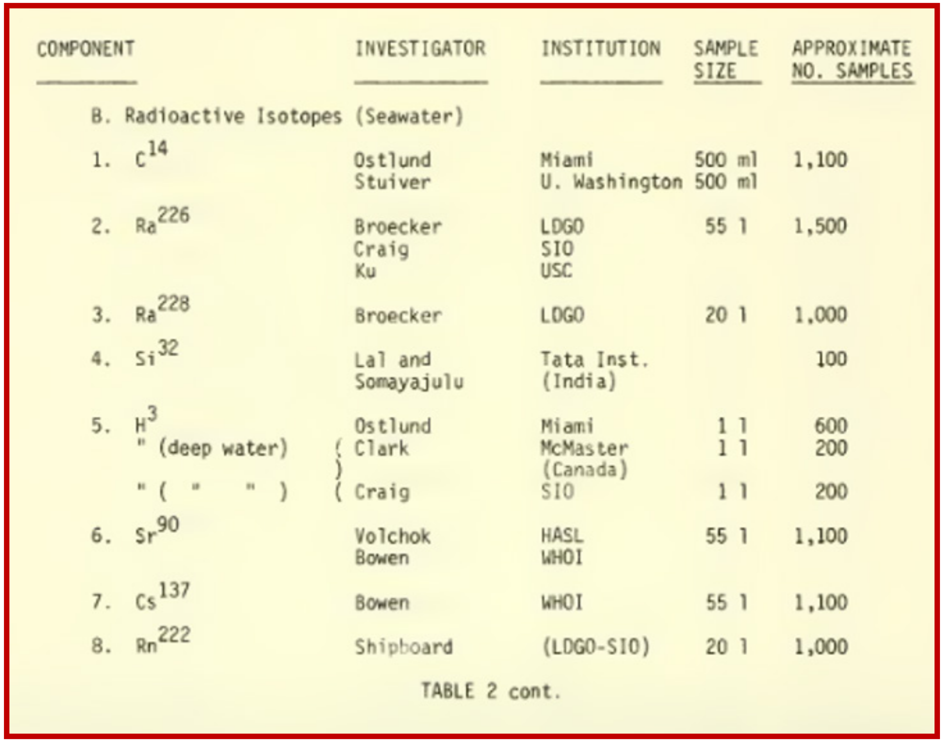
LIST OF CONSTITUENTS TO BE ANALYZED



COMPONENT	INVESTIGATOR	INSTITUTION	SAMPLE SIZE	APPROXIMATE NO. SAMPLES
11. Fe	Spencer	WHOI	4 l	2,000
12. Ni	Turekian	Yale	4 l	2,000
13. Cu	Robertson	Battelle NW	4 l	2,000
14. Zn	Broecker (Ba only)	LDGO	100 ml	2,000
15. Ba				
16. Dissolved N_2	Shipboard	(SIO)	50 ml	6,700
17. Dissolved Ar	Shipboard	(SIO)	50 ml	6,700
18. Dissolved He	Craig	SIO	250 ml	2,000
19. Dissolved Ne	Clarke	McMaster	250 ml	2,000
20. Organic C	Park	OSU	250 ml	6,000
21. SiO_2	Shipboard	(OSU)	250 ml	6,700
22. PO_4	Shipboard	(OSU)	250 ml	6,700
23. NO_3	Shipboard	(OSU)	250 ml	6,700

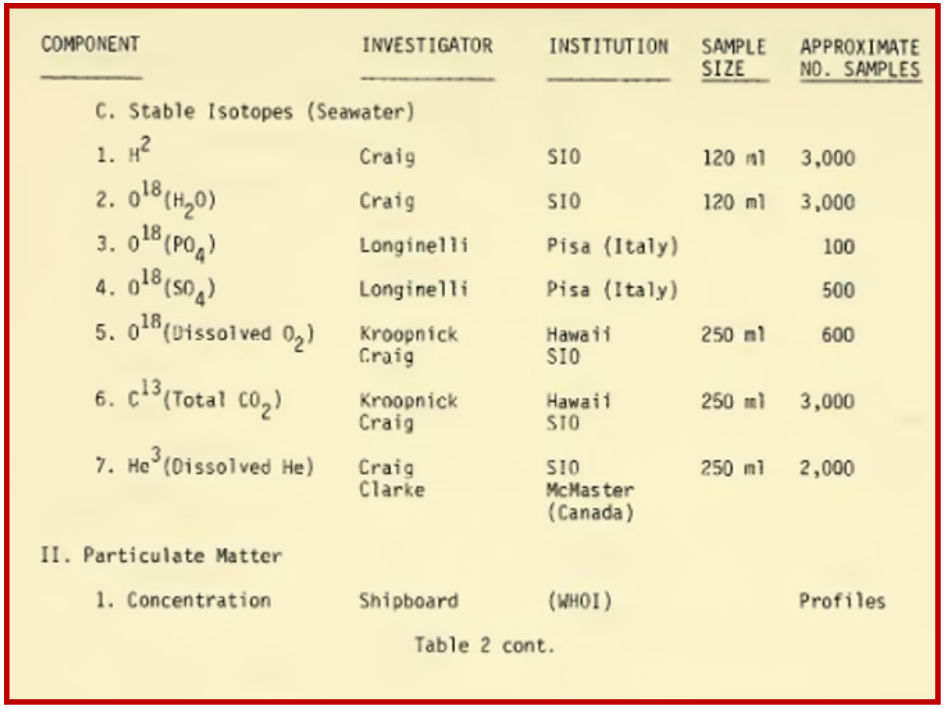
TABLE 2 cont.

https://odv.awi.de/fileadmin/user_upload/odv.awi.de/user_upload/odv/data/GEOSECS/GeochemicalOceanSections.pdf



COMPONENT	INVESTIGATOR	INSTITUTION	SAMPLE SIZE	APPROXIMATE NO. SAMPLES
B. Radioactive Isotopes (Seawater)				
1. C^{14}	Ostlund Stuiver	Miami U. Washington	500 ml 500 ml	1,100
2. Ra^{226}	Broecker Craig Ku	LDGO SIO USC	55 l	1,500
3. Ra^{228}	Broecker	LDGO	20 l	1,000
4. Si^{32}	Lal and Somayajulu	Tata Inst. (India)		100
5. H^3	Ostlund	Miami	1 l	600
" (deep water)	Clark	McMaster (Canada)	1 l	200
" (" ")	Craig	SIO	1 l	200
6. Sr^{90}	Volchok Bowen	HASL WHOI	55 l	1,100
7. Cs^{137}	Bowen	WHOI	55 l	1,100
8. Rn^{222}	Shipboard	(LDGO-SIO)	20 l	1,000

TABLE 2 cont.



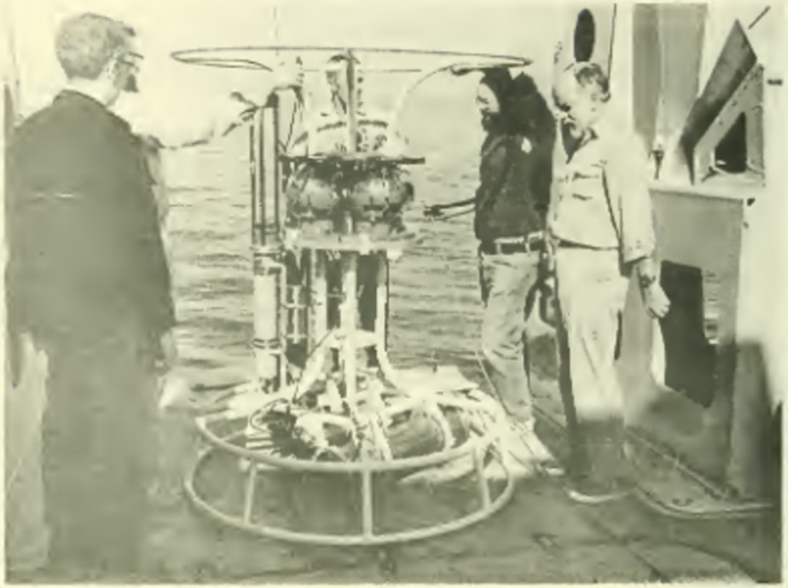
COMPONENT	INVESTIGATOR	INSTITUTION	SAMPLE SIZE	APPROXIMATE NO. SAMPLES
C. Stable Isotopes (Seawater)				
1. H^2	Craig	SIO	120 ml	3,000
2. $O^{18}(H_2O)$	Craig	SIO	120 ml	3,000
3. $O^{18}(PO_4)$	Longinelli	Pisa (Italy)		100
4. $O^{18}(SO_4)$	Longinelli	Pisa (Italy)		500
5. O^{18}(Dissolved O_2)	Kroopnick Craig	Hawaii SIO	250 ml	600
6. C^{13}(Total CO_2)	Kroopnick Craig	Hawaii SIO	250 ml	3,000
7. He^3(Dissolved He)	Craig Clarke	SIO McMaster (Canada)	250 ml	2,000
II. Particulate Matter				
1. Concentration	Shipboard	(WHOI)		Profiles

Table 2 cont.

https://odv.awi.de/fileadmin/user_upload/odv.awi.de/user_upload/odv/data/GEOSECS/GeochemicalOceanSections.pdf

GEOSECS (Geochemical Ocean Sections Study)

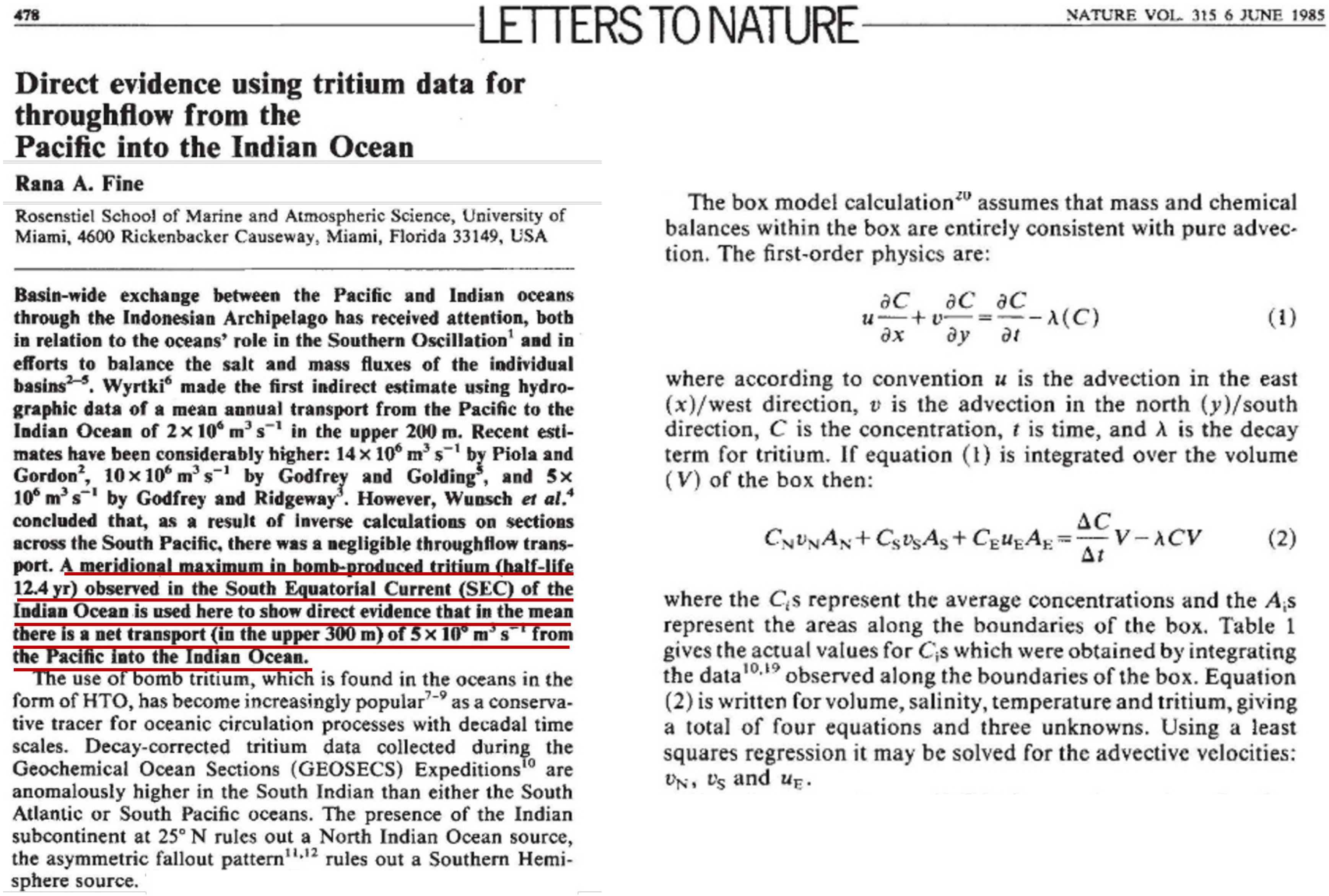
Derek W. Spencer of Woods Hole Oceanographic Institution, a member of the GEOSECS Executive Committee, and Arnold Bainbridge of Scripps Institution of Oceanography, project director, man the control console during a GEOSECS test cruise.



An empty rosette showing the laser nephelometer, glass sphere encapsulated batteries and bottom package containing bottom pinger, oxygen probe and salinity-temperature-depth profiler was photographed during a GEOSECS test cruise.

https://odv.awi.de/fileadmin/user_upload/odv.awi.de/user_upload/odv/data/GEOSECS/GeochemicalOceanSections.pdf

GEOSECS (Geochemical Ocean Sections Study)



478 LETTERS TO NATURE NATURE VOL. 315 6 JUNE 1985

Direct evidence using tritium data for throughflow from the Pacific into the Indian Ocean

Rana A. Fine

Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, Florida 33149, USA

Basin-wide exchange between the Pacific and Indian oceans through the Indonesian Archipelago has received attention, both in relation to the oceans' role in the Southern Oscillation[1] and in efforts to balance the salt and mass fluxes of the individual basins[2–5]. Wyrtki[6] made the first indirect estimate using hydrographic data of a mean annual transport from the Pacific to the Indian Ocean of $2\times10^6\ \mathrm{m^3\,s^{-1}}$ in the upper 200 m. Recent estimates have been considerably higher: $14\times10^6\ \mathrm{m^3\,s^{-1}}$ by Piola and Gordon[2], $10\times10^6\ \mathrm{m^3\,s^{-1}}$ by Godfrey and Golding[5], and $5\times10^6\ \mathrm{m^3\,s^{-1}}$ by Godfrey and Ridgeway[3]. However, Wunsch *et al.*[4] concluded that, as a result of inverse calculations on sections across the South Pacific, there was a negligible throughflow transport. A meridional maximum in bomb-produced tritium (half-life 12.4 yr) observed in the South Equatorial Current (SEC) of the Indian Ocean is used here to show direct evidence that in the mean there is a net transport (in the upper 300 m) of $5\times10^6\ \mathrm{m^3\,s^{-1}}$ from the Pacific into the Indian Ocean.

The use of bomb tritium, which is found in the oceans in the form of HTO, has become increasingly popular[7–9] as a conservative tracer for oceanic circulation processes with decadal time scales. Decay-corrected tritium data collected during the Geochemical Ocean Sections (GEOSECS) Expeditions[10] are anomalously higher in the South Indian than either the South Atlantic or South Pacific oceans. The presence of the Indian subcontinent at 25° N rules out a North Indian Ocean source, the asymmetric fallout pattern[11,12] rules out a Southern Hemisphere source.

The box model calculation[20] assumes that mass and chemical balances within the box are entirely consistent with pure advection. The first-order physics are:

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=\frac{\partial C}{\partial t}-\lambda(C) \qquad (1)$$

where according to convention u is the advection in the east (x)/west direction, v is the advection in the north (y)/south direction, C is the concentration, t is time, and λ is the decay term for tritium. If equation (1) is integrated over the volume (V) of the box then:

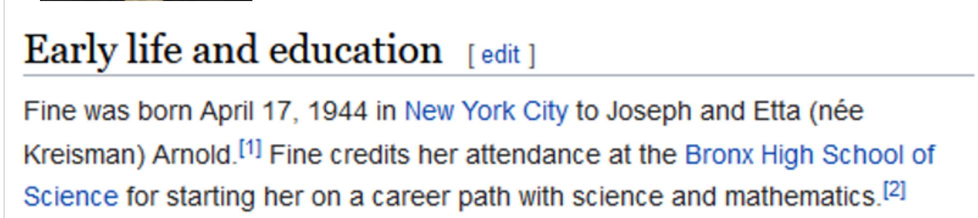
$$C_N v_N A_N + C_S v_S A_S + C_E u_E A_E = \frac{\Delta C}{\Delta t}V - \lambda CV \qquad (2)$$

where the C_is represent the average concentrations and the A_is represent the areas along the boundaries of the box. Table 1 gives the actual values for C_is which were obtained by integrating the data[10,19] observed along the boundaries of the box. Equation (2) is written for volume, salinity, temperature and tritium, giving a total of four equations and three unknowns. Using a least squares regression it may be solved for the advective velocities: v_N, v_S and u_E.

https://www.nature.com/articles/315478a0.pdf?platform=hootsuite

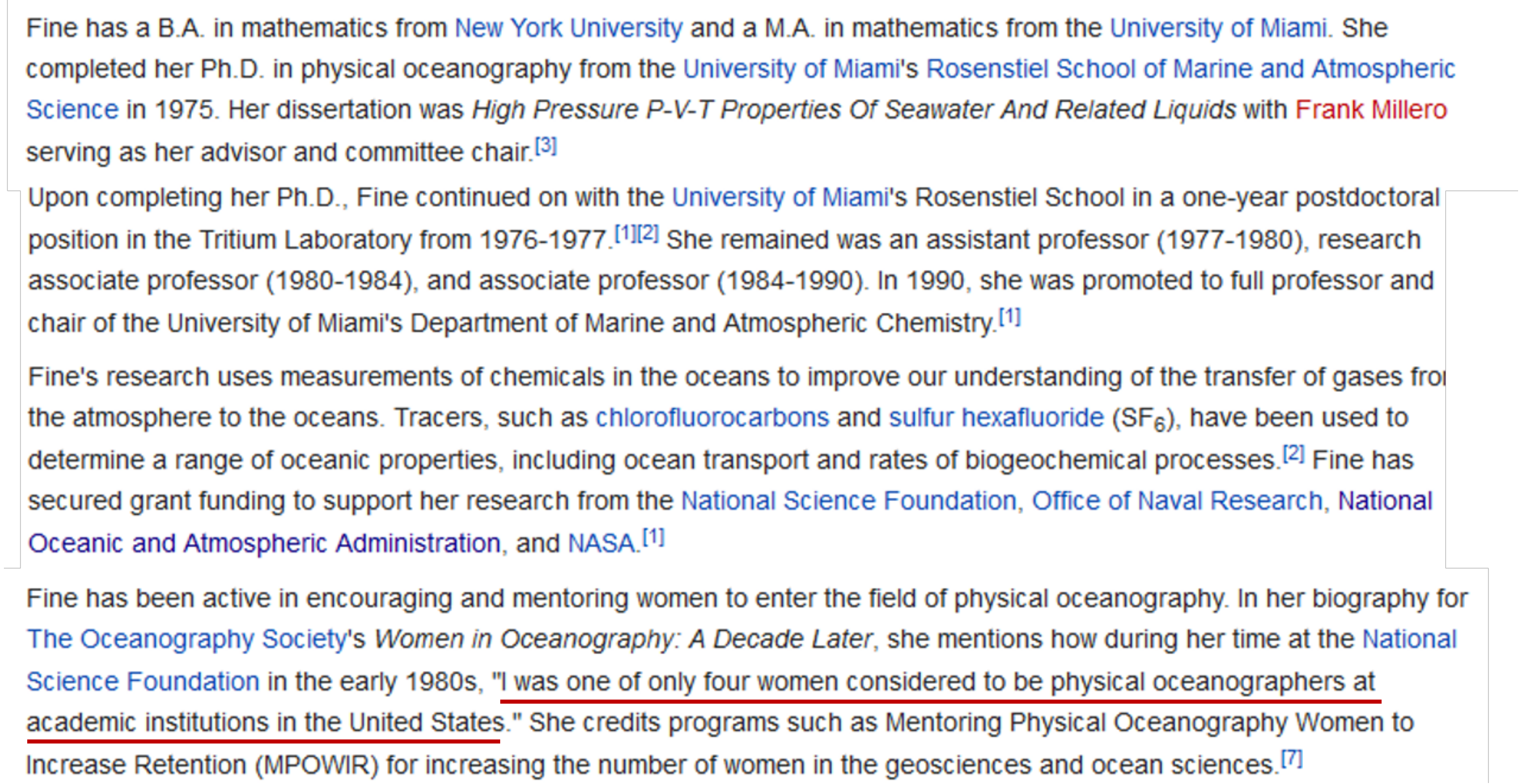
Rana Fine

Institutions	University of Miami's Rosenstiel School of Marine and Atmospheric Science
Thesis	*"High Pressure P-V-T Properties Of Seawater And Related Liquids"* (1975)
Doctoral advisor	Frank Millero



Early life and education [edit]

Fine was born April 17, 1944 in New York City to Joseph and Etta (née Kreisman) Arnold.[1] Fine credits her attendance at the Bronx High School of Science for starting her on a career path with science and mathematics.[2]



Fine has a B.A. in mathematics from New York University and a M.A. in mathematics from the University of Miami. She completed her Ph.D. in physical oceanography from the University of Miami's Rosenstiel School of Marine and Atmospheric Science in 1975. Her dissertation was *High Pressure P-V-T Properties Of Seawater And Related Liquids* with Frank Millero serving as her advisor and committee chair.[3]

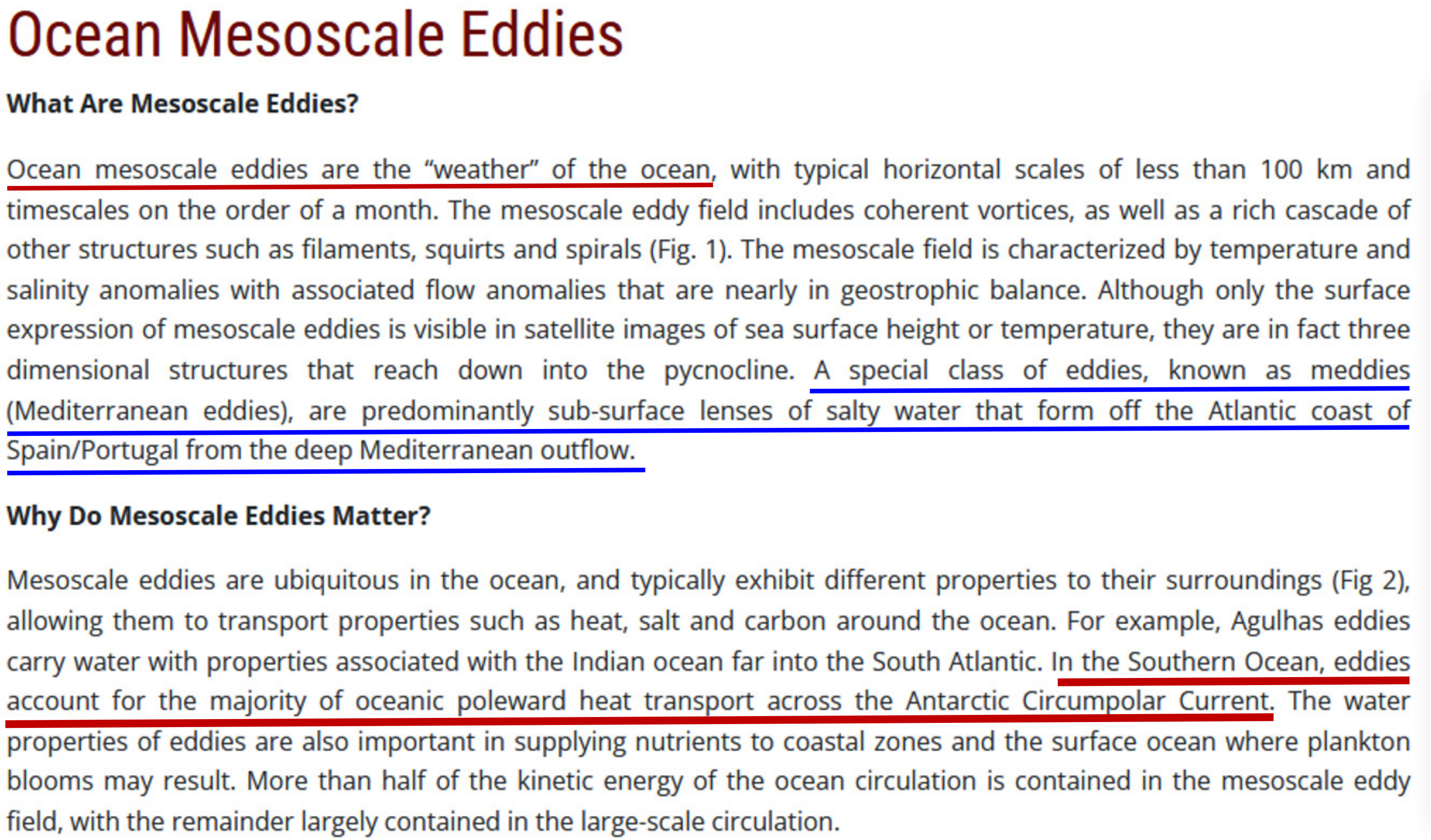
Upon completing her Ph.D., Fine continued on with the University of Miami's Rosenstiel School in a one-year postdoctoral position in the Tritium Laboratory from 1976-1977.[1][2] She remained was an assistant professor (1977-1980), research associate professor (1980-1984), and associate professor (1984-1990). In 1990, she was promoted to full professor and chair of the University of Miami's Department of Marine and Atmospheric Chemistry.[1]

Fine's research uses measurements of chemicals in the oceans to improve our understanding of the transfer of gases fro the atmosphere to the oceans. Tracers, such as chlorofluorocarbons and sulfur hexafluoride (SF_6), have been used to determine a range of oceanic properties, including ocean transport and rates of biogeochemical processes.[2] Fine has secured grant funding to support her research from the National Science Foundation, Office of Naval Research, National Oceanic and Atmospheric Administration, and NASA.[1]

Fine has been active in encouraging and mentoring women to enter the field of physical oceanography. In her biography for The Oceanography Society's *Women in Oceanography: A Decade Later*, she mentions how during her time at the National Science Foundation in the early 1980s, "I was one of only four women considered to be physical oceanographers at academic institutions in the United States." She credits programs such as Mentoring Physical Oceanography Women to Increase Retention (MPOWIR) for increasing the number of women in the geosciences and ocean sciences.[7]

https://en.wikipedia.org/wiki/Rana_Fine
https://aquarius.oceansciences.org/cgi/peo_teams.htm?id=science

Ocean Eddies



Ocean Mesoscale Eddies

What Are Mesoscale Eddies?

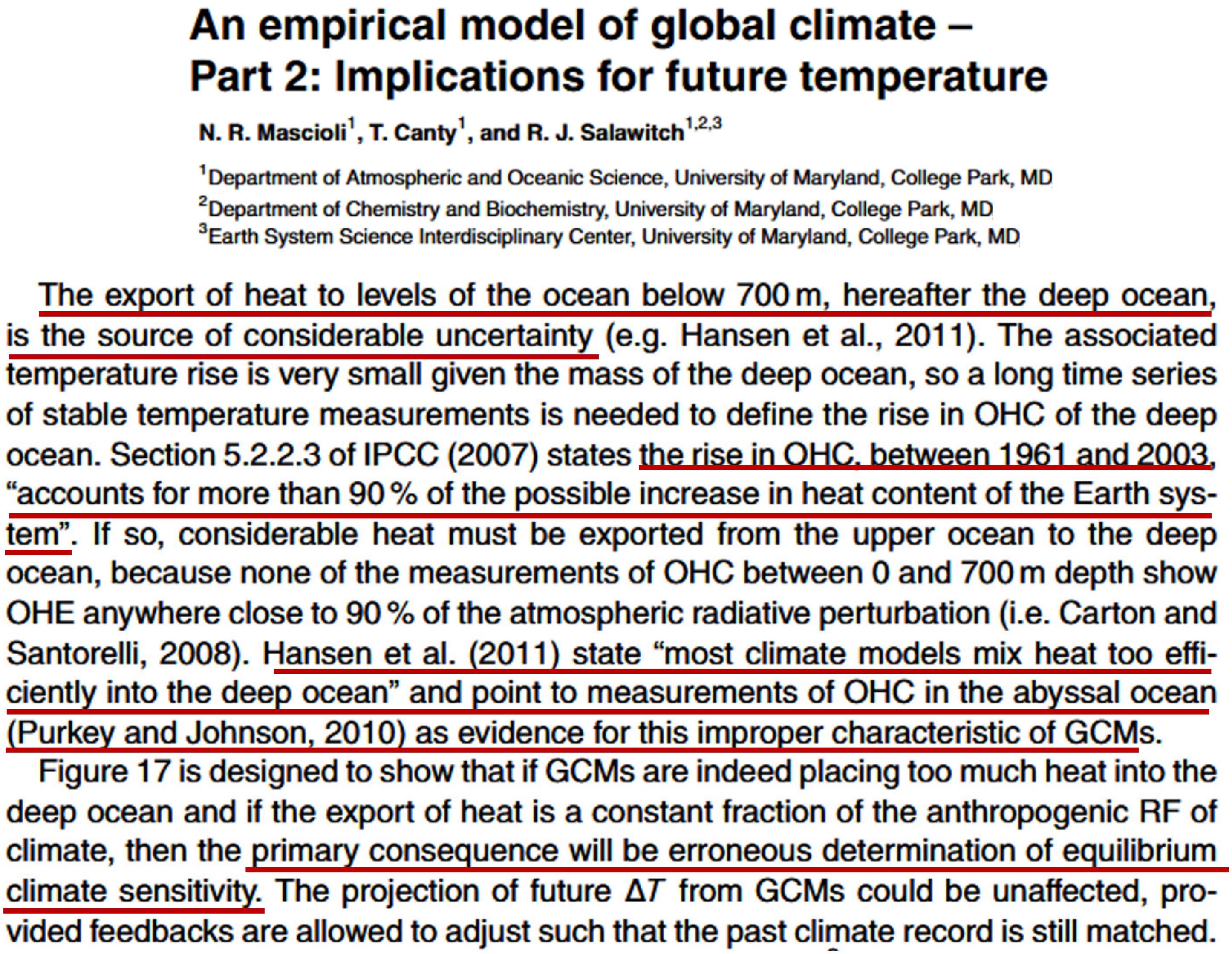
Ocean mesoscale eddies are the “weather” of the ocean, with typical horizontal scales of less than 100 km and timescales on the order of a month. The mesoscale eddy field includes coherent vortices, as well as a rich cascade of other structures such as filaments, squirts and spirals (Fig. 1). The mesoscale field is characterized by temperature and salinity anomalies with associated flow anomalies that are nearly in geostrophic balance. Although only the surface expression of mesoscale eddies is visible in satellite images of sea surface height or temperature, they are in fact three dimensional structures that reach down into the pycnocline. A special class of eddies, known as meddies (Mediterranean eddies), are predominantly sub-surface lenses of salty water that form off the Atlantic coast of Spain/Portugal from the deep Mediterranean outflow.

Why Do Mesoscale Eddies Matter?

Mesoscale eddies are ubiquitous in the ocean, and typically exhibit different properties to their surroundings (Fig 2), allowing them to transport properties such as heat, salt and carbon around the ocean. For example, Agulhas eddies carry water with properties associated with the Indian ocean far into the South Atlantic. In the Southern Ocean, eddies account for the majority of oceanic poleward heat transport across the Antarctic Circumpolar Current. The water properties of eddies are also important in supplying nutrients to coastal zones and the surface ocean where plankton blooms may result. More than half of the kinetic energy of the ocean circulation is contained in the mesoscale eddy field, with the remainder largely contained in the large-scale circulation.

https://www.gfdl.noaa.gov/ocean-mesoscale-eddies/

Deep Ocean Temperature



An empirical model of global climate – Part 2: Implications for future temperature

N. R. Mascioli[1], T. Canty[1], and R. J. Salawitch[1,2,3]

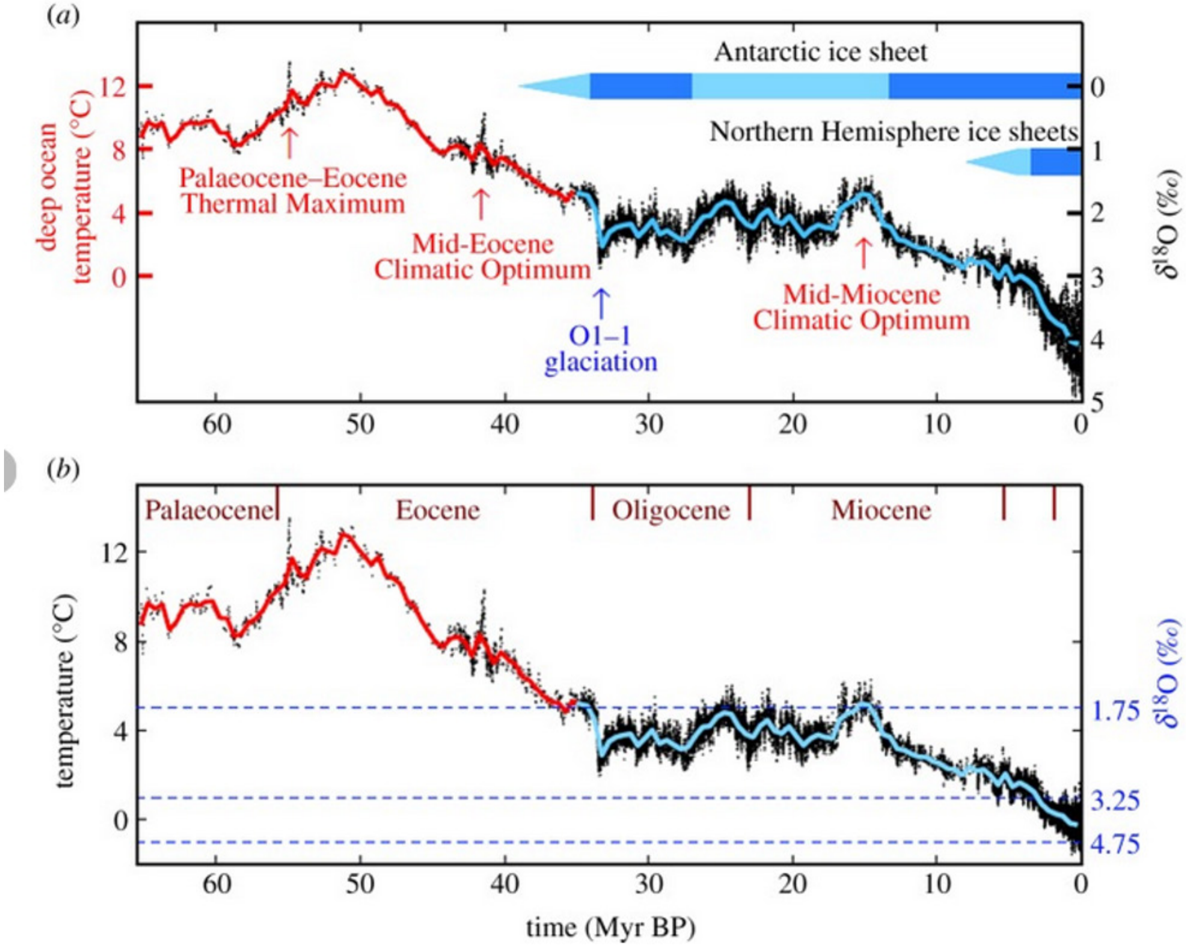
[1]Department of Atmospheric and Oceanic Science, University of Maryland, College Park, MD
[2]Department of Chemistry and Biochemistry, University of Maryland, College Park, MD
[3]Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD

The export of heat to levels of the ocean below 700 m, hereafter the deep ocean, is the source of considerable uncertainty (e.g. Hansen et al., 2011). The associated temperature rise is very small given the mass of the deep ocean, so a long time series of stable temperature measurements is needed to define the rise in OHC of the deep ocean. Section 5.2.2.3 of IPCC (2007) states the rise in OHC, between 1961 and 2003, "accounts for more than 90 % of the possible increase in heat content of the Earth system". If so, considerable heat must be exported from the upper ocean to the deep ocean, because none of the measurements of OHC between 0 and 700 m depth show OHE anywhere close to 90 % of the atmospheric radiative perturbation (i.e. Carton and Santorelli, 2008). Hansen et al. (2011) state "most climate models mix heat too efficiently into the deep ocean" and point to measurements of OHC in the abyssal ocean (Purkey and Johnson, 2010) as evidence for this improper characteristic of GCMs.

Figure 17 is designed to show that if GCMs are indeed placing too much heat into the deep ocean and if the export of heat is a constant fraction of the anthropogenic RF of climate, then the primary consequence will be erroneous determination of equilibrium climate sensitivity. The projection of future ΔT from GCMs could be unaffected, provided feedbacks are allowed to adjust such that the past climate record is still matched.

https://acp.copernicus.org/preprints/12/23913/2012/acpd-12-23913-2012.pdf

Deep Ocean Temperature



(a) Global deep ocean δ18O from Zachos et al. [4] and (b) estimated deep ocean temperature based on the prescription in our present paper. Black data points are five-point running means of the original temporal resolution; red and blue curves have a 500 kyr resolution. Coarse temporal sampling reduces the amplitude of glacial–interglacial oscillations in the intervals 7–17, 35–42 and 44–65 Myr BP.

https://www.researchgate.net/figure/a-Global-deep-ocean-d18O-from-Zachos-et-al4-and-b-estimated-deep-ocean-temperature_fig1_256666715
See also https://cp.copernicus.org/articles/17/1483/2021/