Temperature and Salinity

EPS131, Introduction to Physical Oceanography and Climate

Dept of Earth and Planetary Sciences, Harvard University

Eli Tziperman

Eli Tziperman

Energy balance and the greenhouse effect

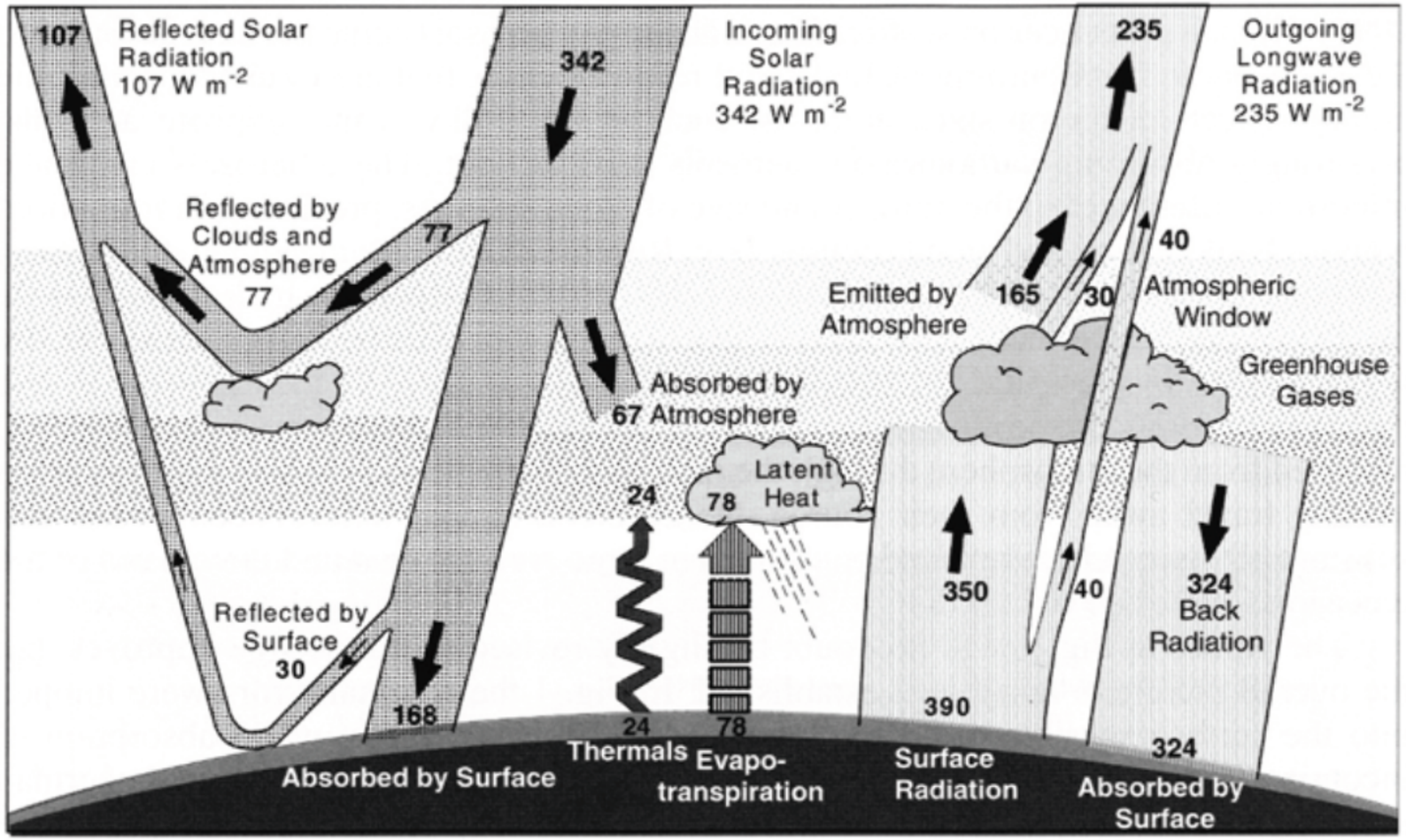
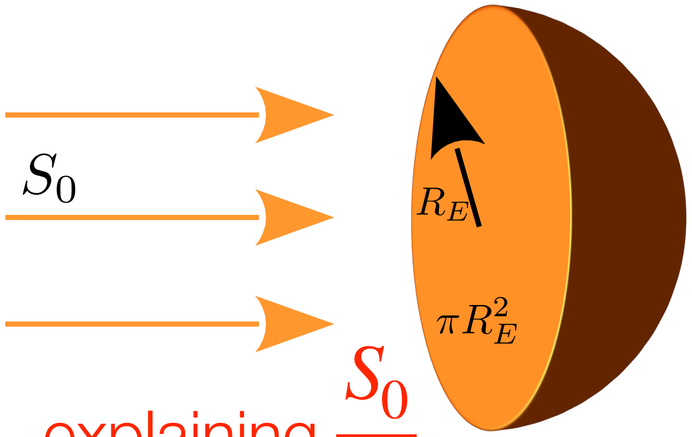


FIGURE 9.4. Earth's energy balance (from Trenberth, K.E., and D.P. Stepaniak, 2004: The flow of energy through the Earth's climate system. **Q.J.R.Meteorol.Soc.**, **130**, 2677-2701).

energy balance and greenhouse effect showing main fluxes

Eli Tziperman

Energy balance and the greenhouse effect



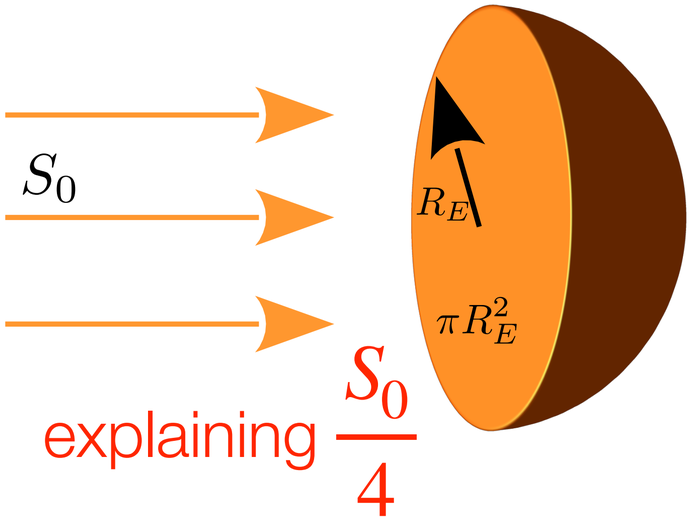
explaining $\frac{S_0}{4}$

$$B(\lambda, T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda k_B T}} - 1}.$$

Planck's radiation law

Eli Tziperman

Energy balance and the greenhouse effect

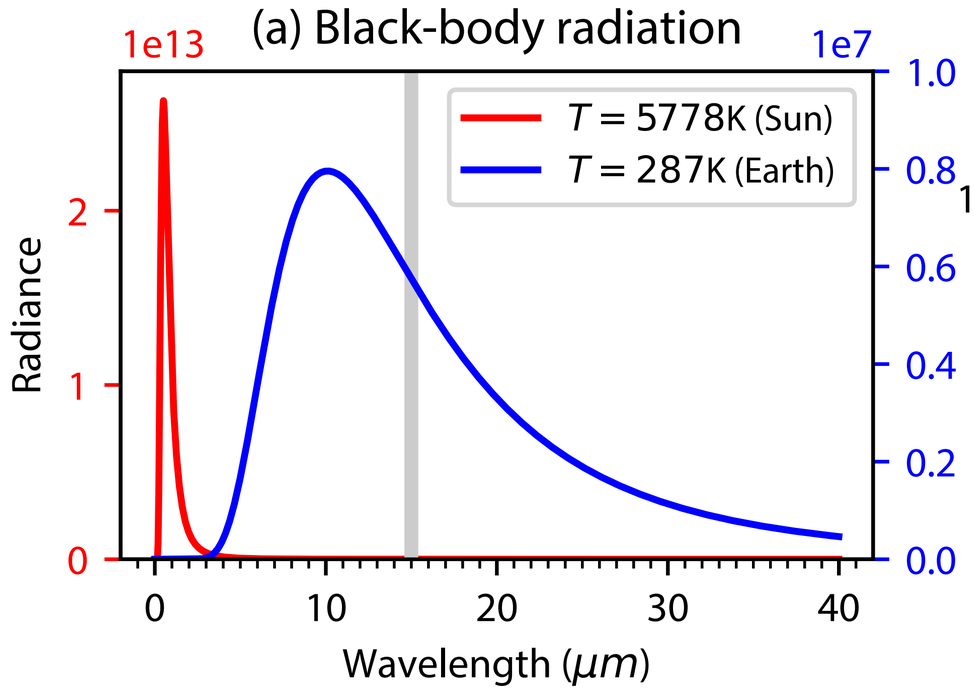


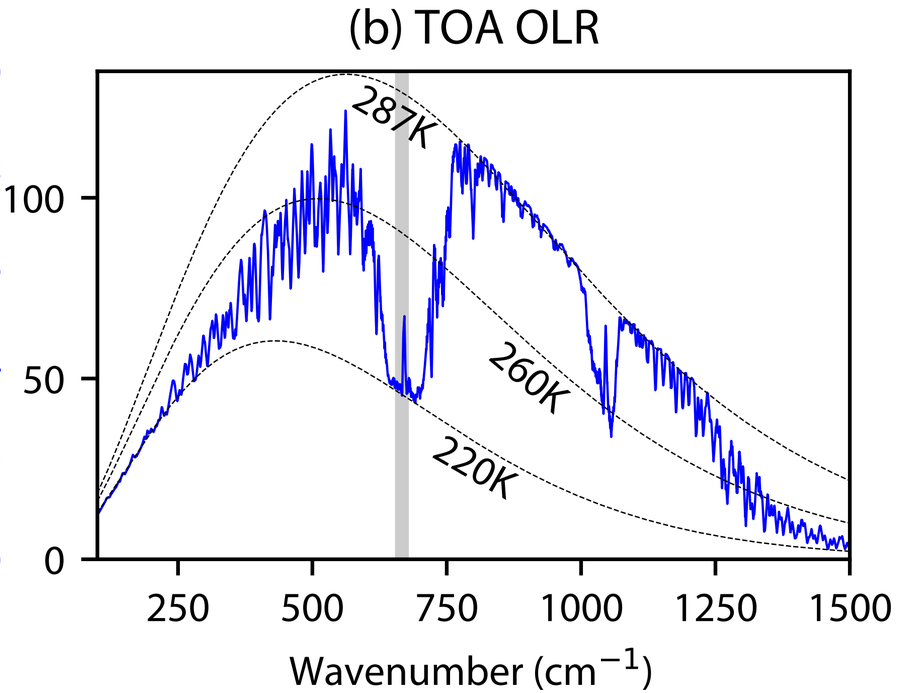
explaining $\frac{S_0}{4}$

$$B(\lambda, T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda k_B T}} - 1}.$$

Planck's radiation law

longwave (LW) vs shortwave (SH) and the CO_2 absorption window





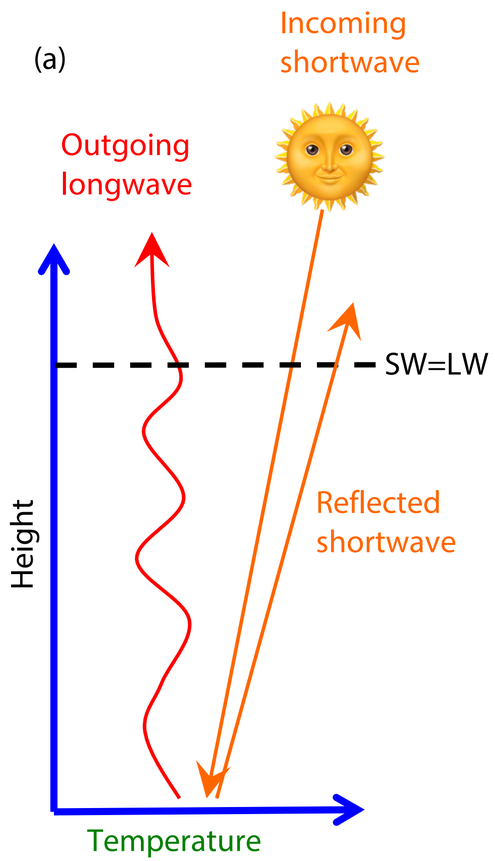
notes

section 1, greenhouse

see following two slides

Eli Tziperman

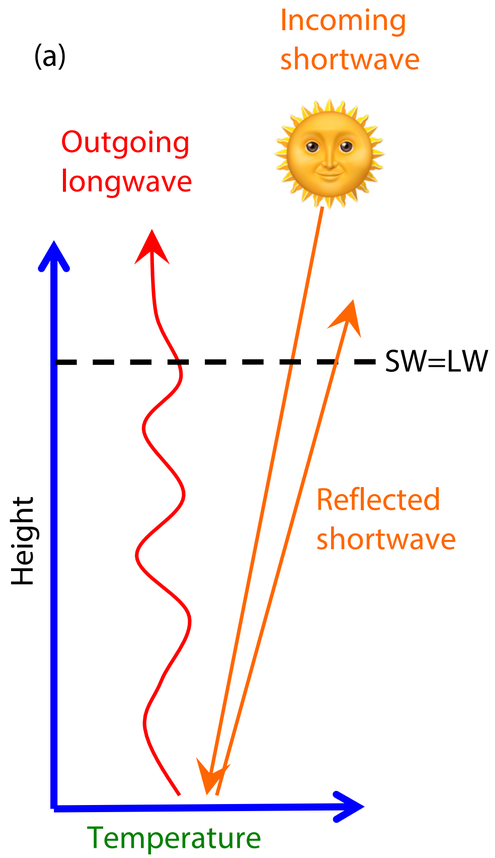
Energy balance and the greenhouse effect



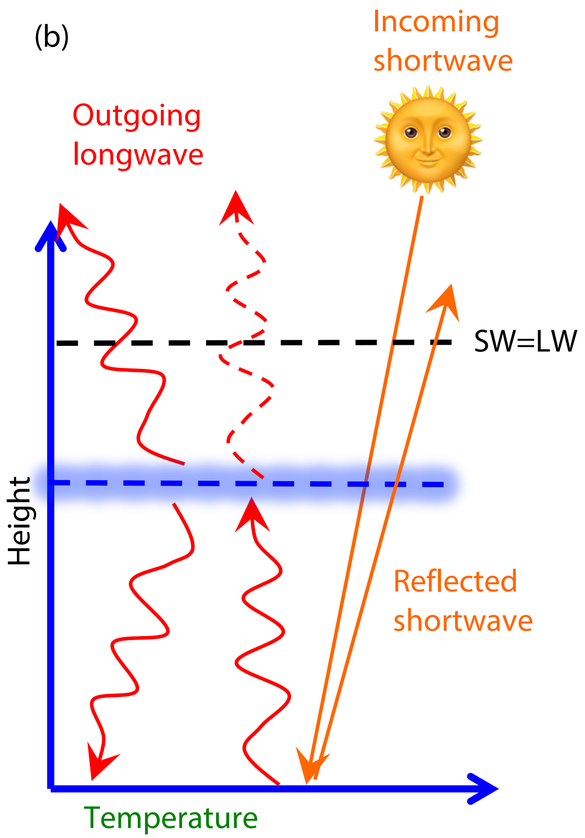
no atmosphere

Eli Tziperman

Energy balance and the greenhouse effect



no atmosphere

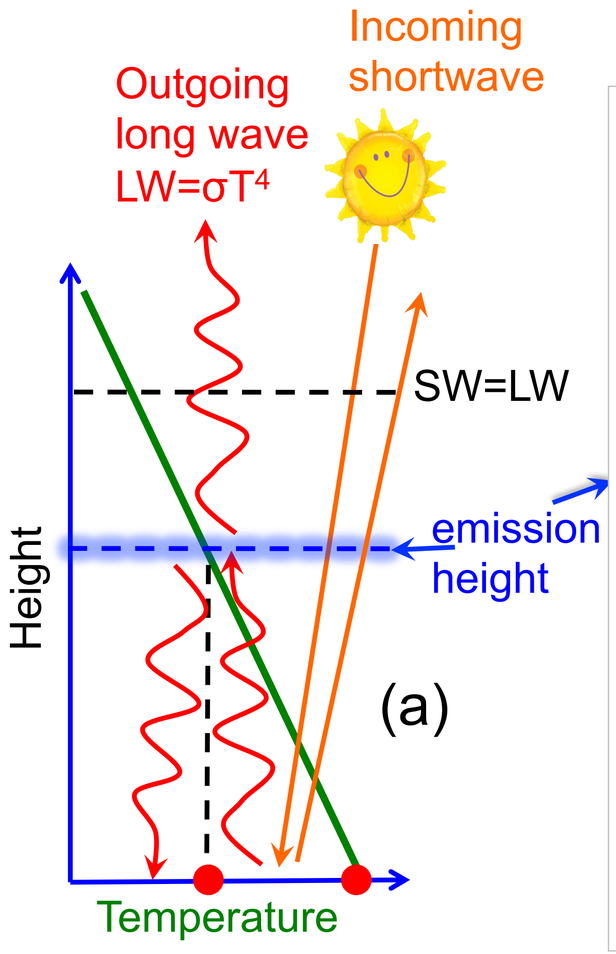


with atmospheric (natural) greenhouse effect

mini-quiz surface temperature

The Anthropogenic Greenhouse Effect

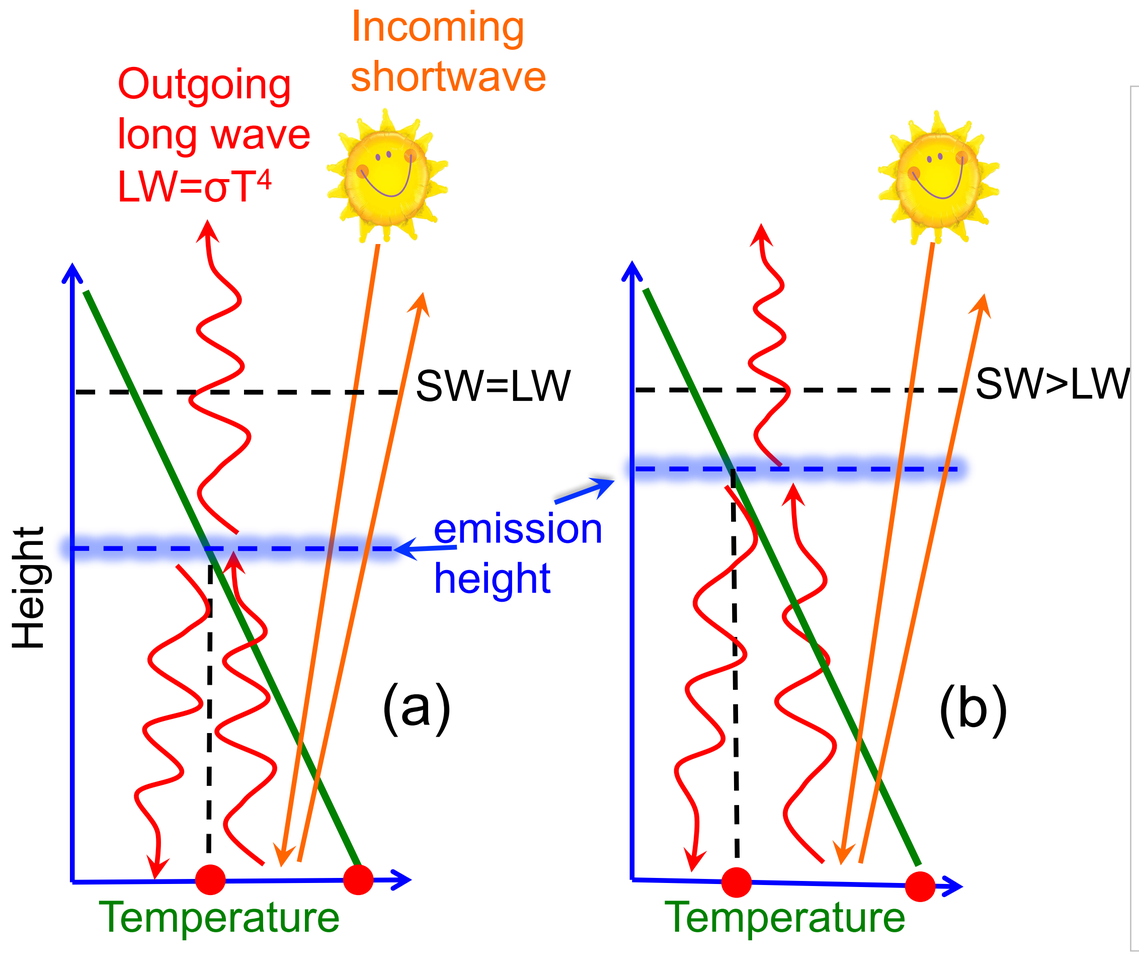
add a continuous atmospheric temperature profile



- Level of last absorption: where most of the radiation emitted upward escapes to space without being absorbed again
- Increasing greenhouse gas ➡ raising the emission level/level of last absorption ➡ Earth radiates from a colder temperature ➡ Energy balance is broken: LW < SW ➡ Temperature must adjust

The Anthropogenic Greenhouse Effect

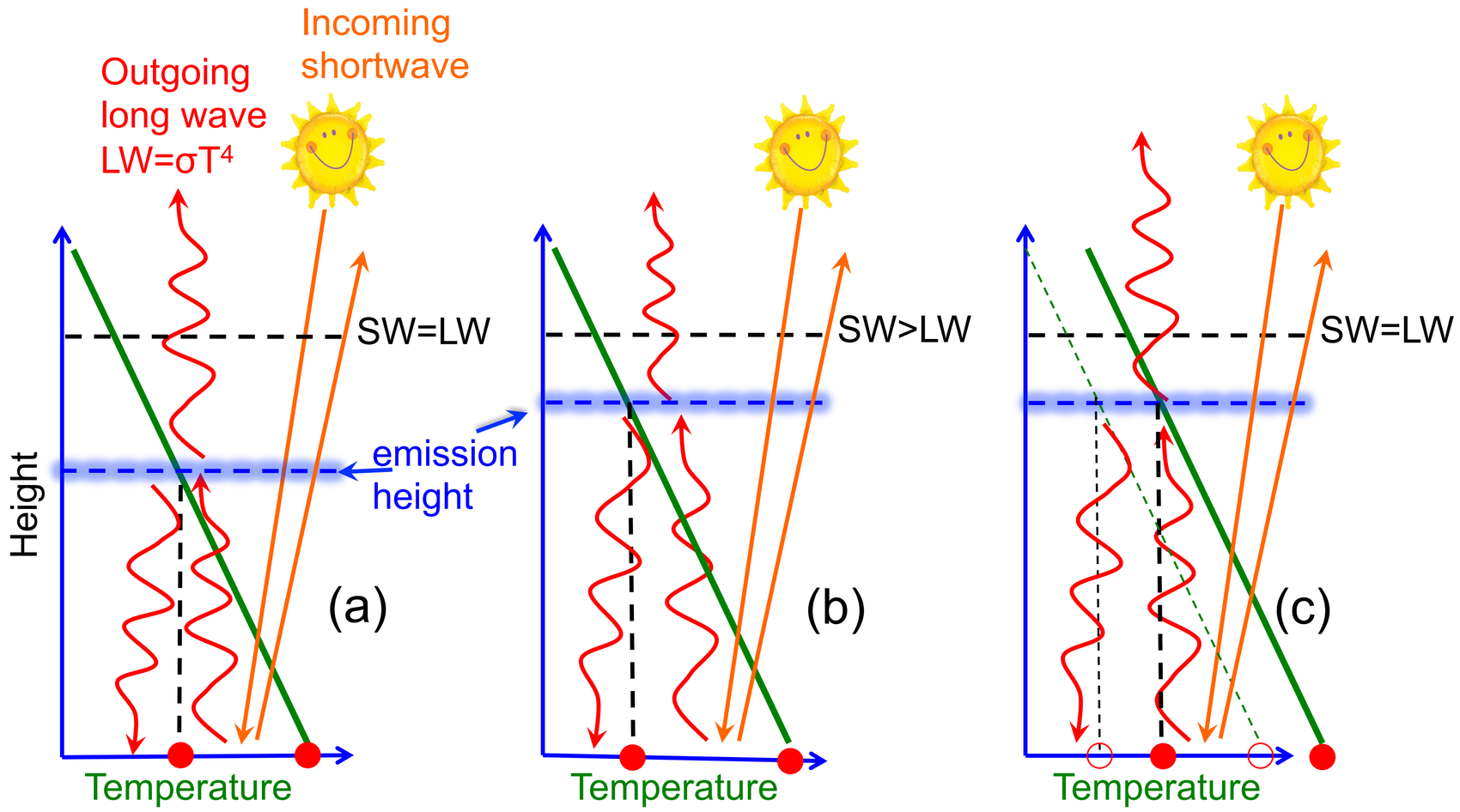
add a continuous atmospheric temperature profile



- Level of last absorption: where most of the radiation emitted upward escapes to space without being absorbed again
- Increasing greenhouse gas ➡ raising the emission level/level of last absorption ➡ Earth radiates from a colder temperature ➡ Energy balance is broken: LW < SW ➡ Temperature must adjust

The Anthropogenic Greenhouse Effect

add a continuous atmospheric temperature profile



- Level of last absorption: where most of the radiation emitted upward escapes to space without being absorbed again
- Increasing greenhouse gas ➡ raising the emission level/level of last absorption ➡ Earth radiates from a colder temperature ➡ Energy balance is broken: LW < SW ➡ Temperature must adjust

mini-quiz emission level

Eli Tziperman

A calculation of the expected sea level rise due to ocean warming

https://gis2.harvard.edu/services/project-consultation/project-resume/sea-level-change-global-warming

Eli Tziperman

A calculation of the expected sea level rise due to ocean warming

https://gis2.harvard.edu/services/project-consultation/project-resume/sea-level-change-global-warming

Eli Tziperman

A calculation of the expected sea level rise due to ocean warming

https://gis2.harvard.edu/services/project-consultation/project-resume/sea-level-change-global-warming

https://www.vanityfair.com/news/2006/05/warming200605

Eli Tziperman

A calculation of the expected sea level rise due to ocean warming

https://gis2.harvard.edu/services/project-consultation/project-resume/sea-level-change-global-warming

https://www.vanityfair.com/news/2006/05/warming200605

https://www.vanityfair.com/news/2006/05/warming200605

Eli Tziperman

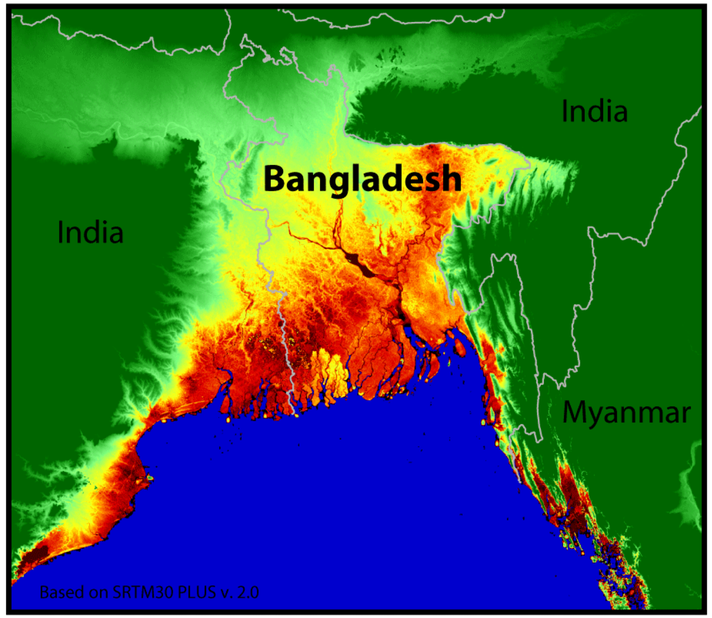
A calculation of the expected sea level rise due to ocean warming

https://gis2.harvard.edu/services/project-consultation/project-resume/sea-level-change-global-warming

https://www.vanityfair.com/news/2006/05/warming200605

https://www.vanityfair.com/news/2006/05/warming200605

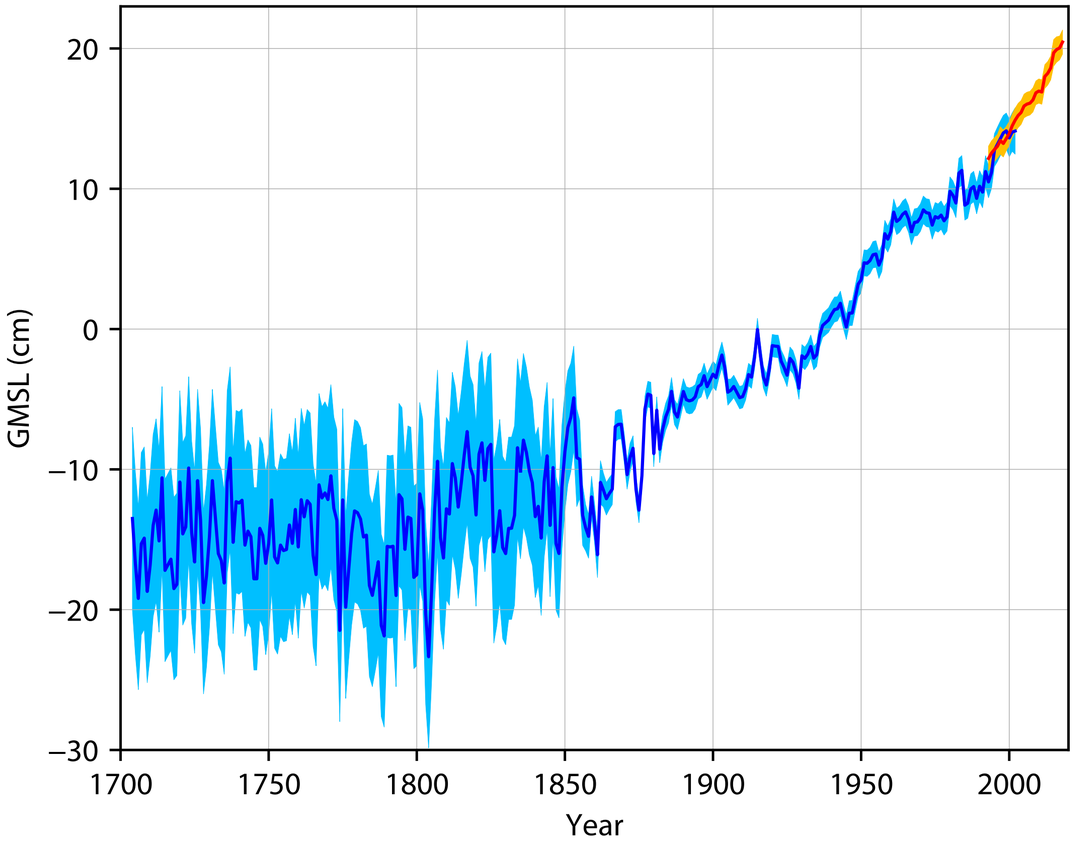
Sea Level Risks - Bangladesh



https://de.wikipedia.org/wiki/Datei:Bangladesh_Sea_Level_Risks.png

Eli Tziperman

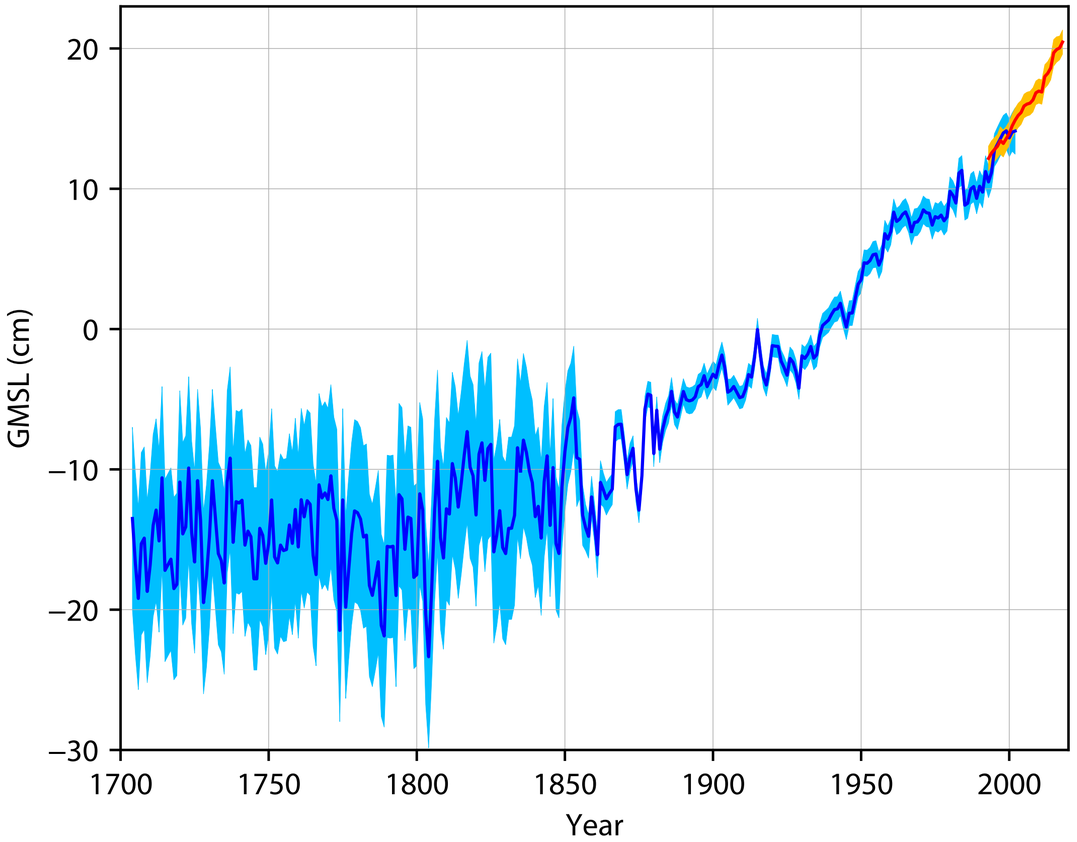
Sea level rise due to ocean warming



last 300 years

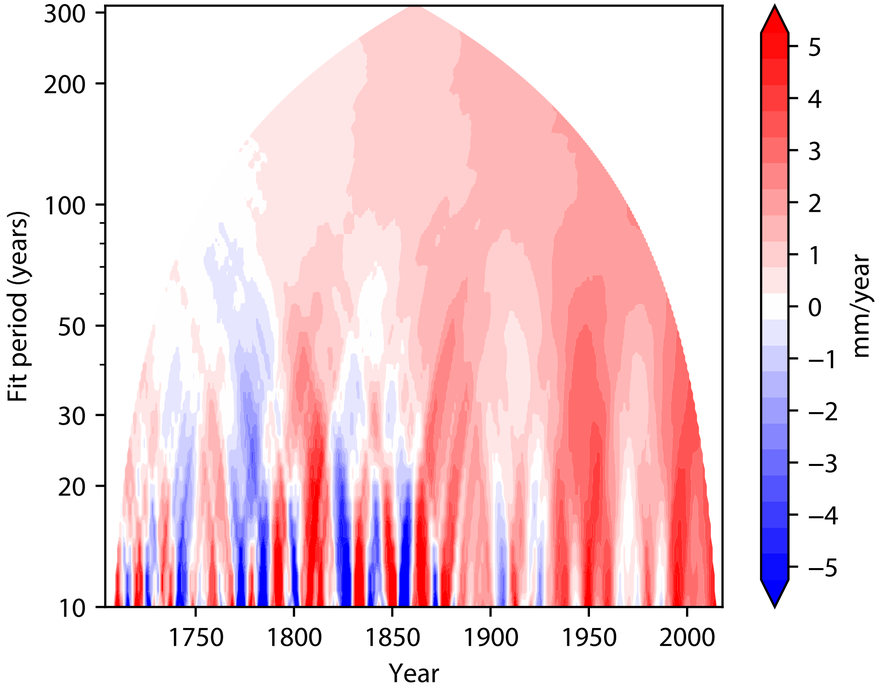
Eli Tziperman

Sea level rise due to ocean warming



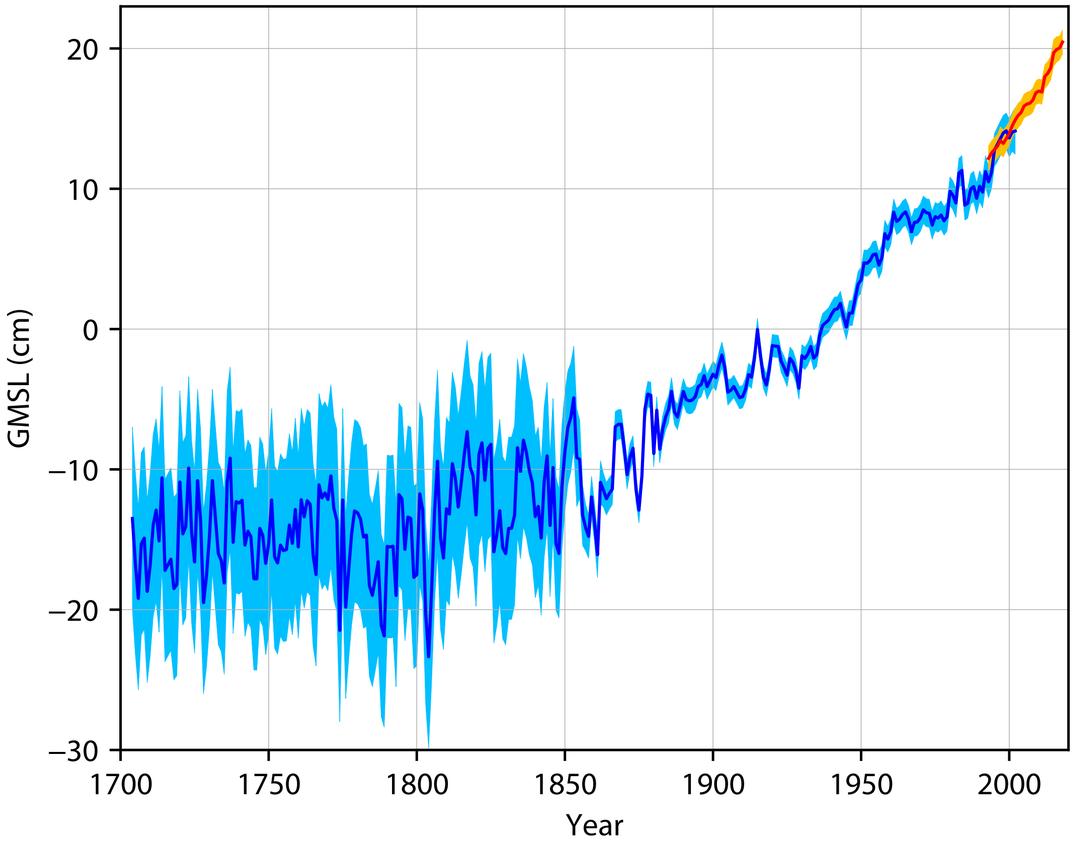
last 300 years

sea level trends as a function of averaging period and time



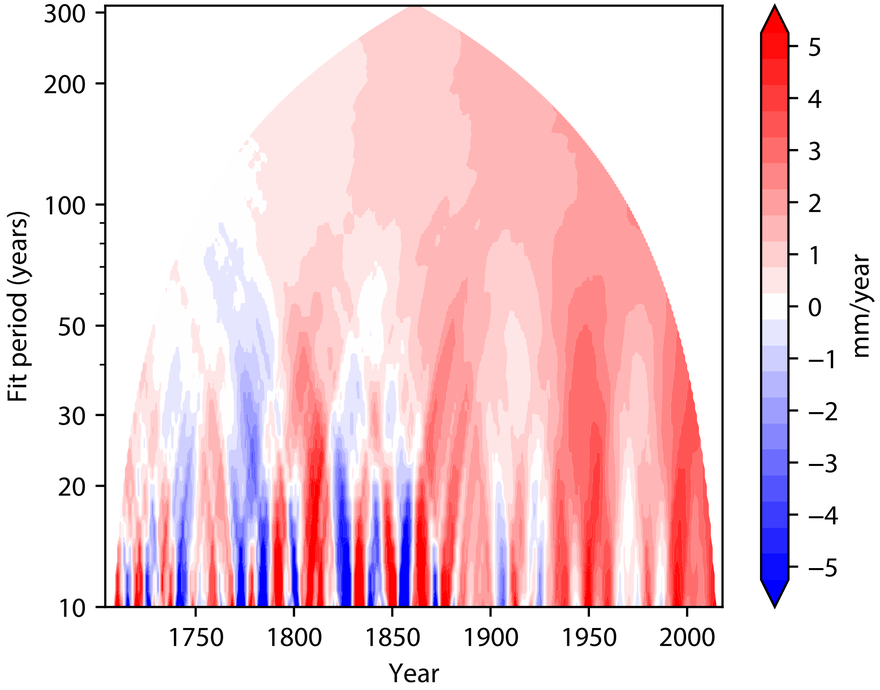
Eli Tziperman

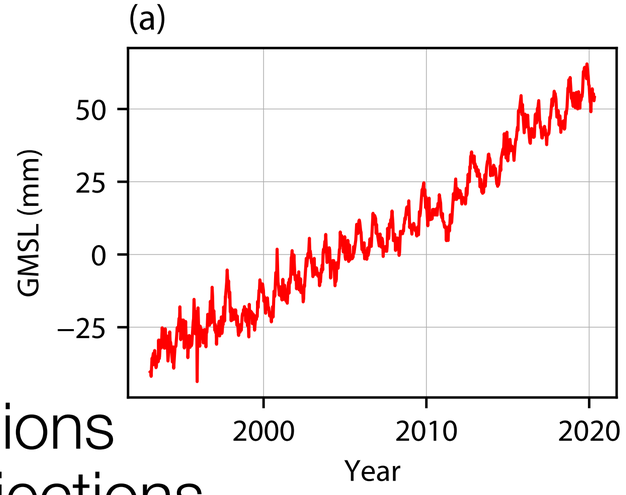
Sea level rise due to ocean warming

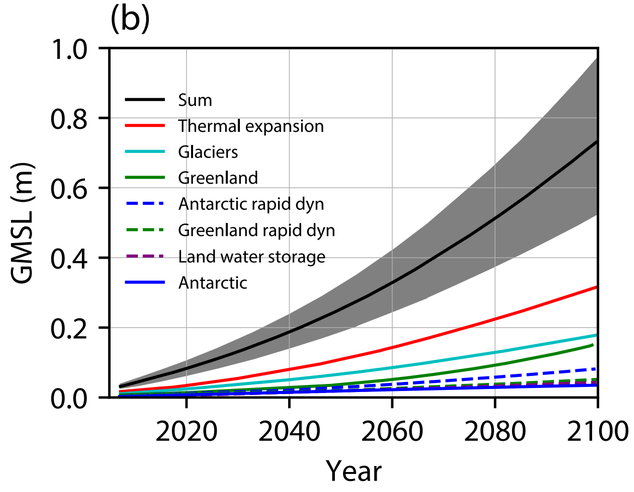


last 300 years

sea level trends as a function of averaging period and time







(a) satellite observations and (b) RCP8.5 projections

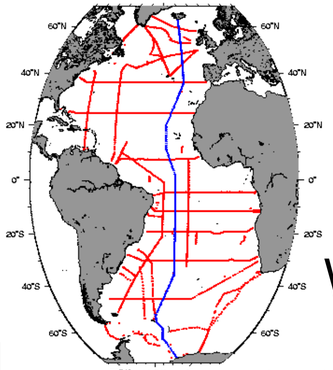
Notes

section 2, sea level

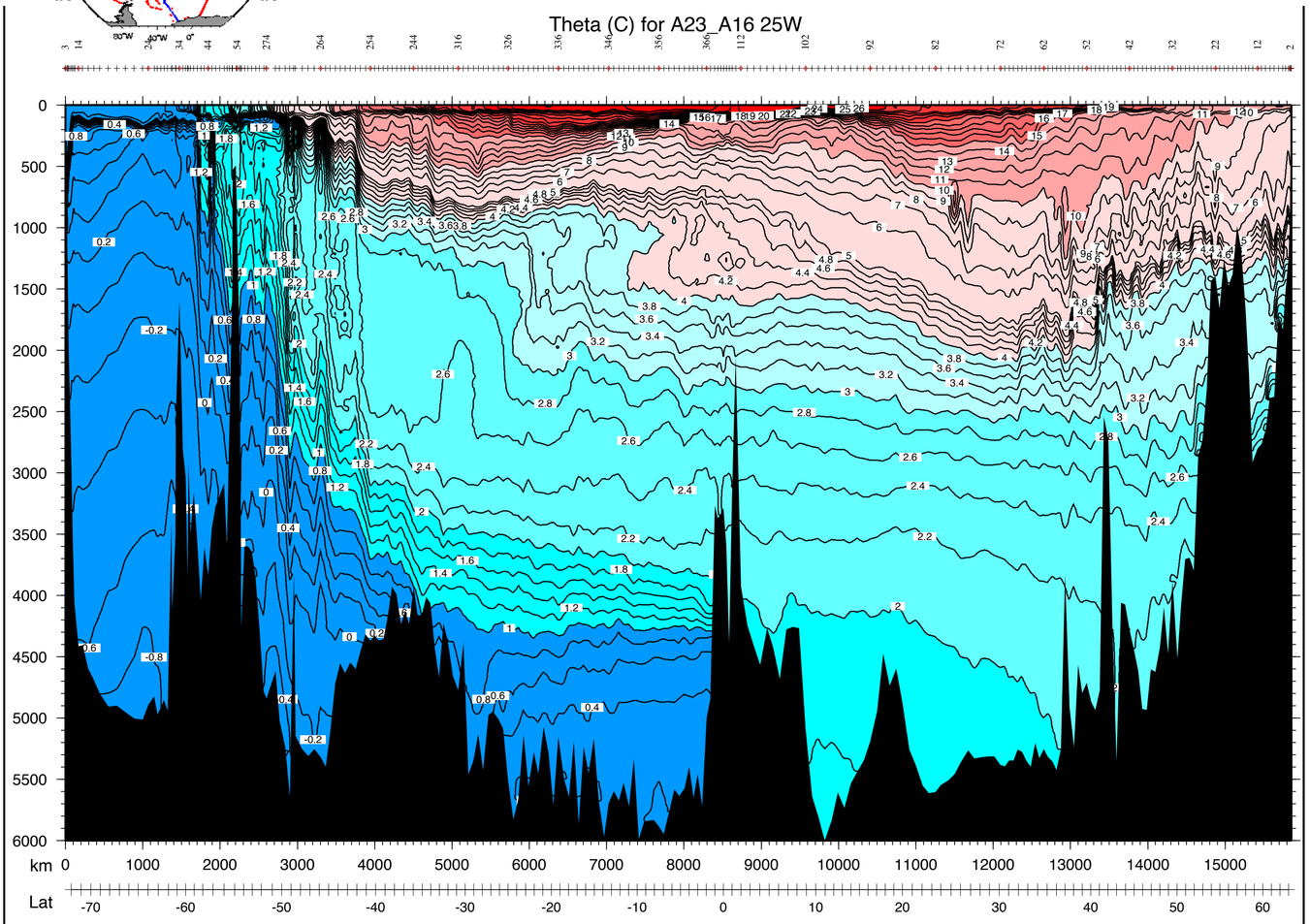
mini-quiz sea level

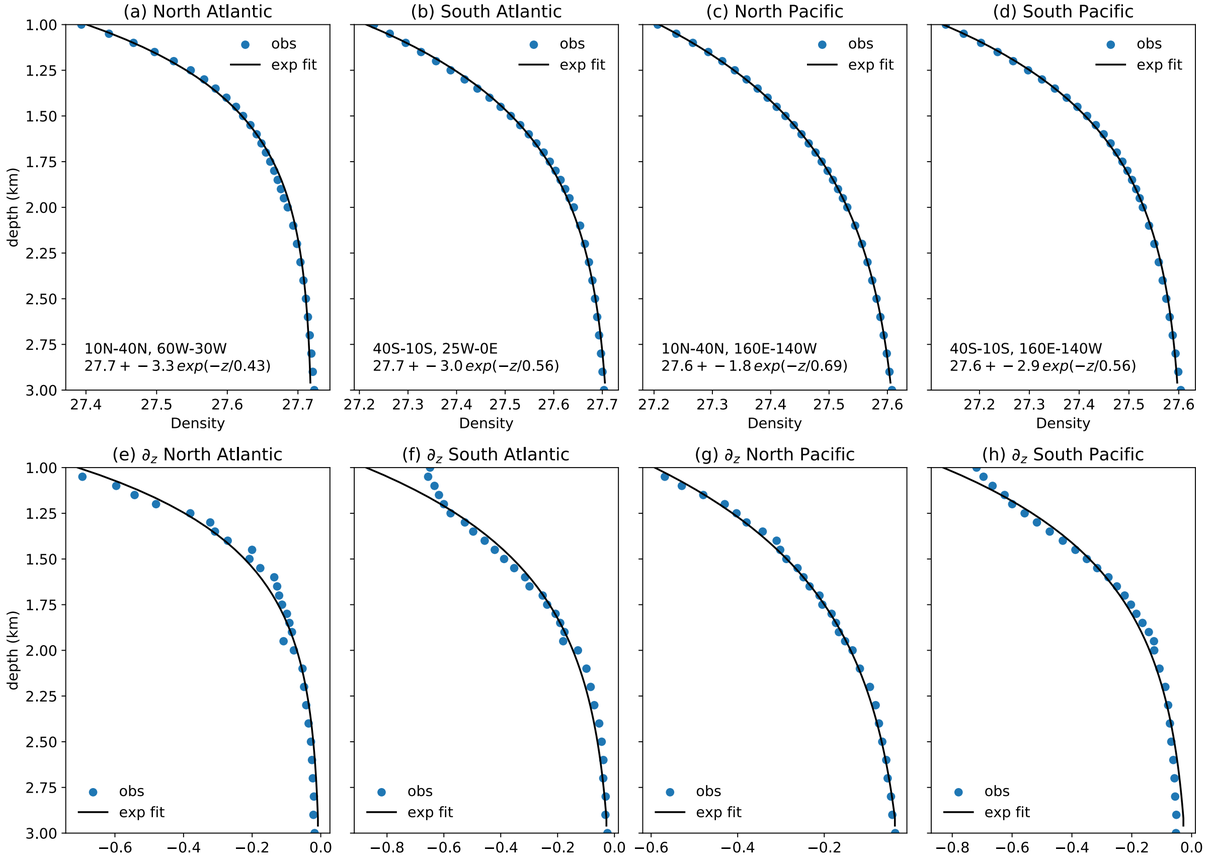
Eli Tziperman

On the deep exponential stratification: abyssal recipes



WOCE atlas





Miller, Yang, Tziperman 2020
after Munk 1966

Eli Tziperman

On the deep exponential stratification: abyssal recipes

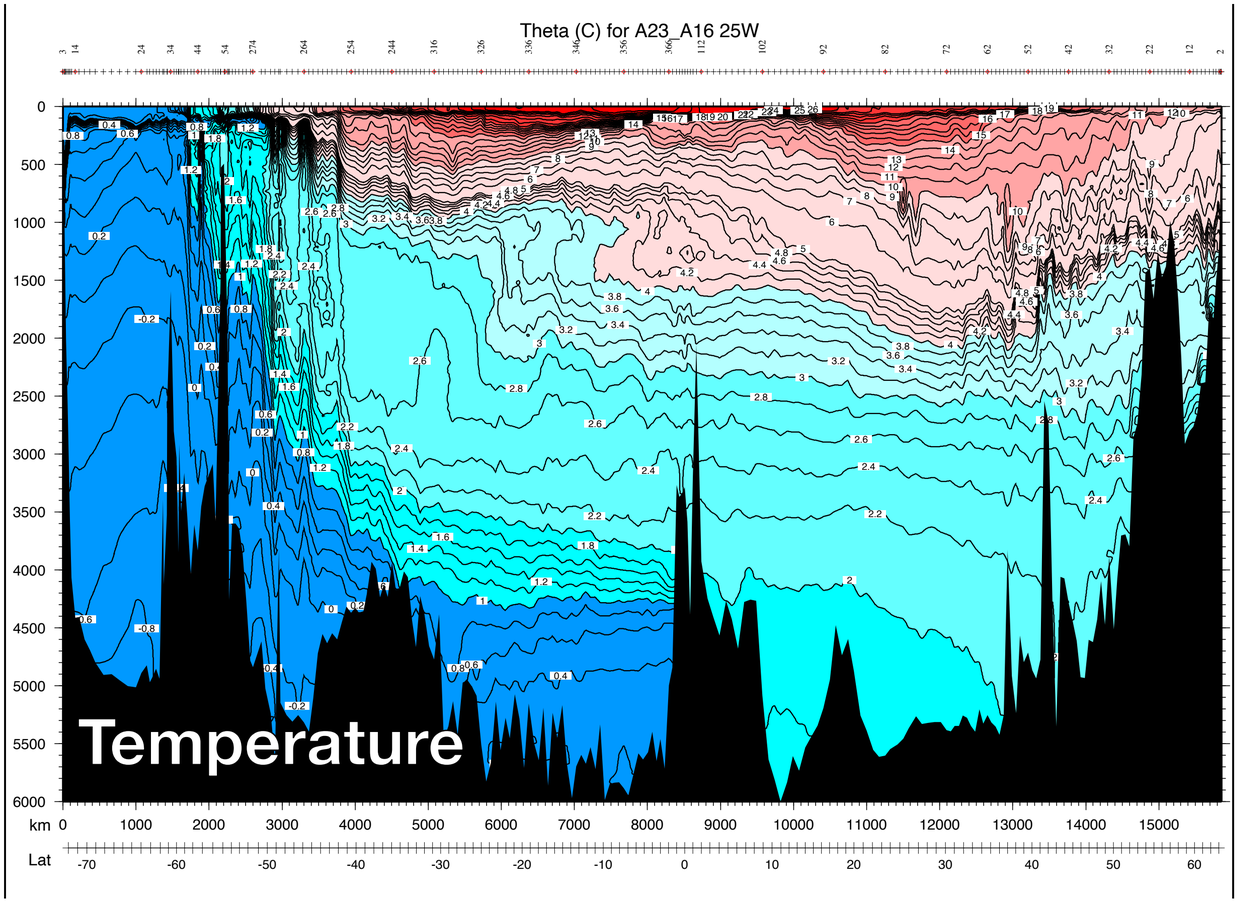
notes

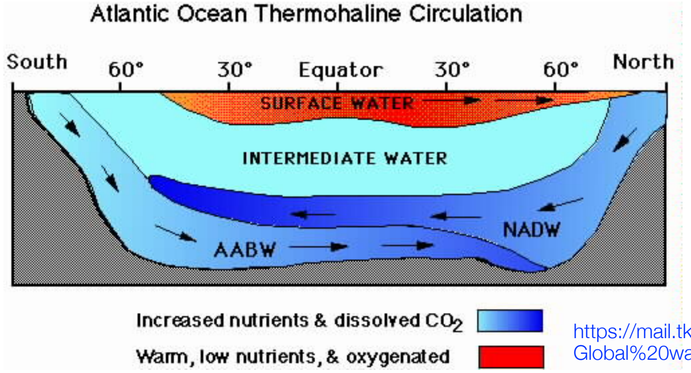
section 3, abyssal recipes

mini-quiz abyssal recipes

Eli Tziperman

Evaporation–Precipitation and ocean salinity changes



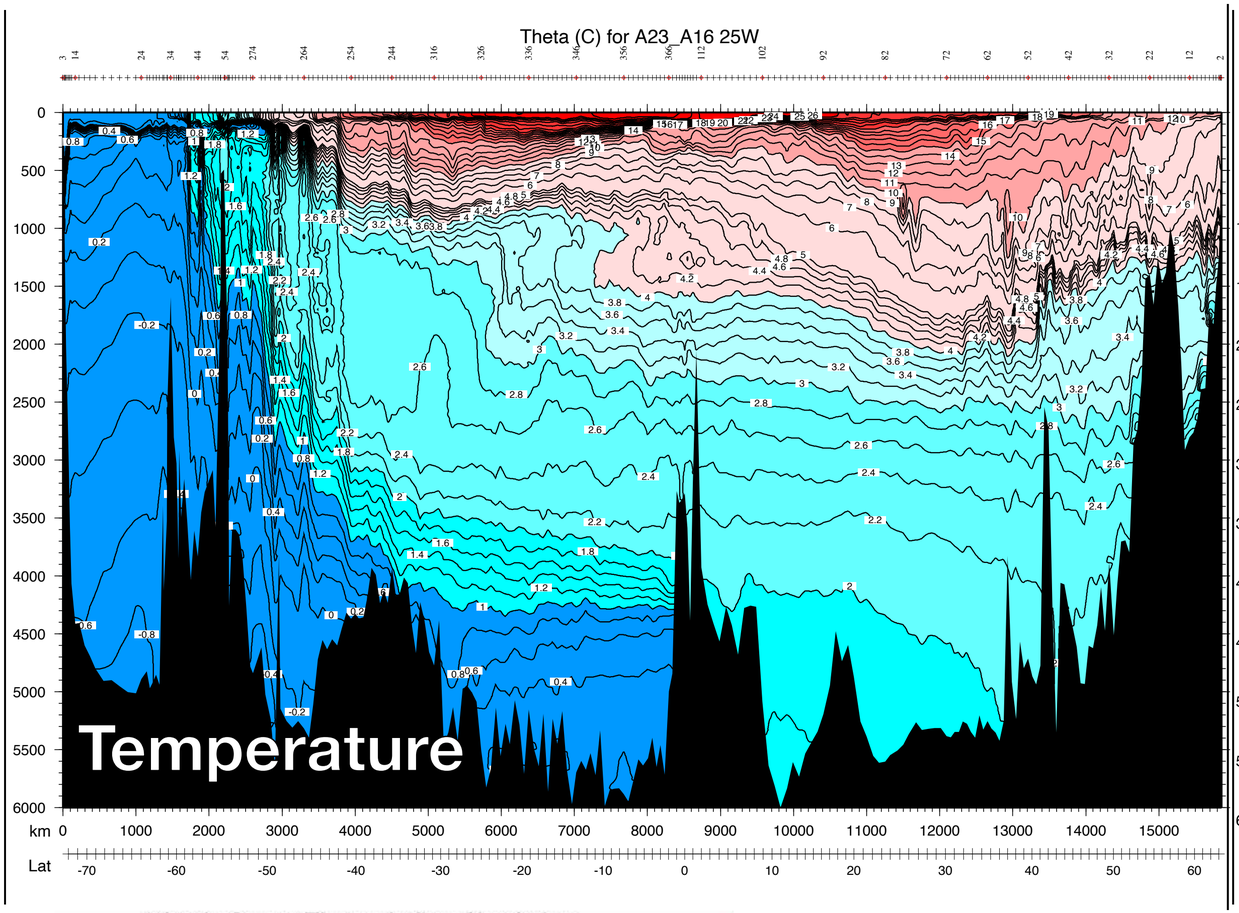


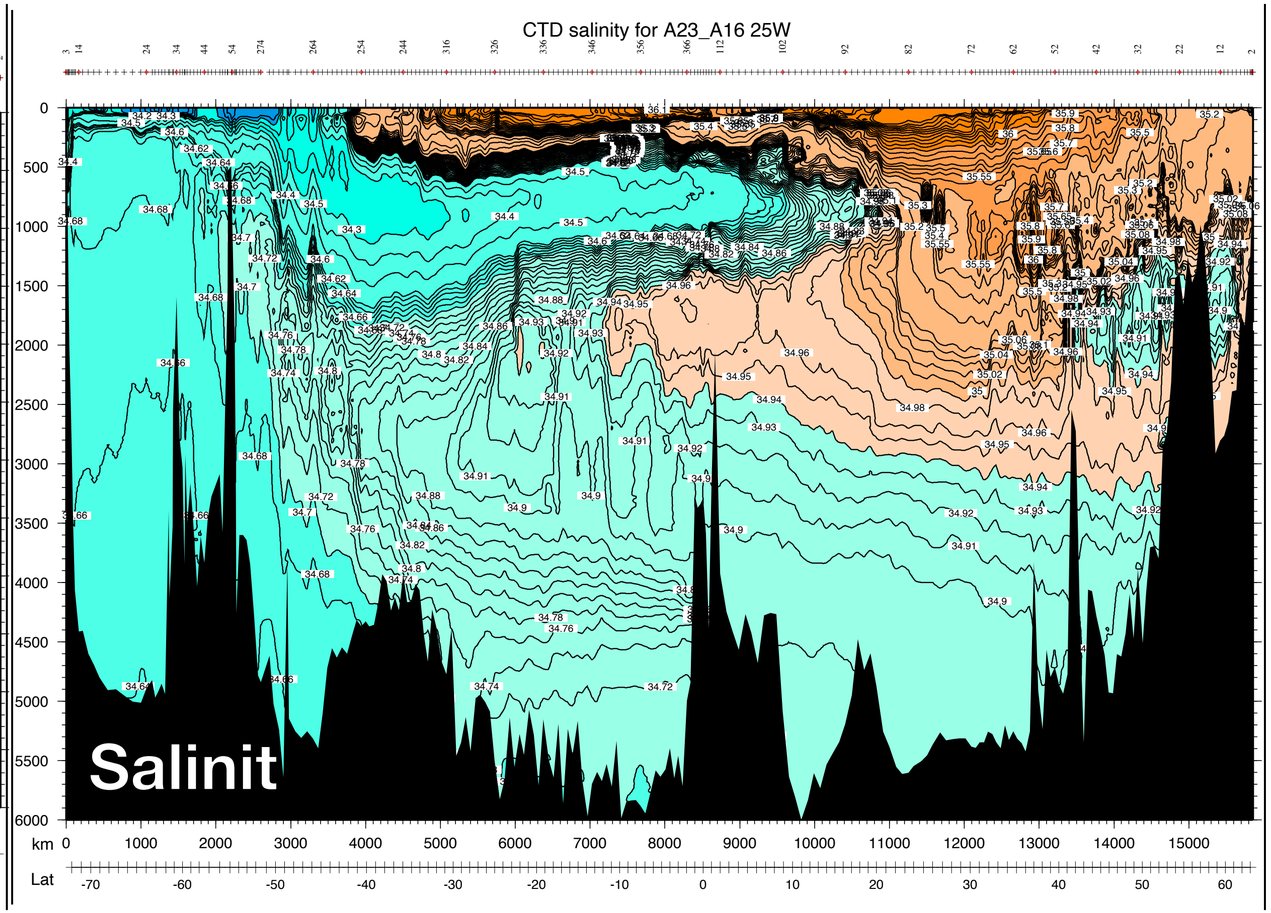
https://mail.tku.edu.tw/086138/EnvFutures/WebPages/Global%20warming/Thermohaline%20Circulation.htm

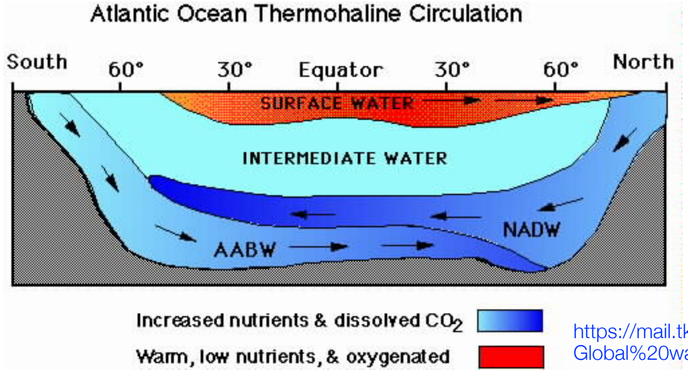
WOCE atlas

Eli Tziperman

Evaporation–Precipitation and ocean salinity changes





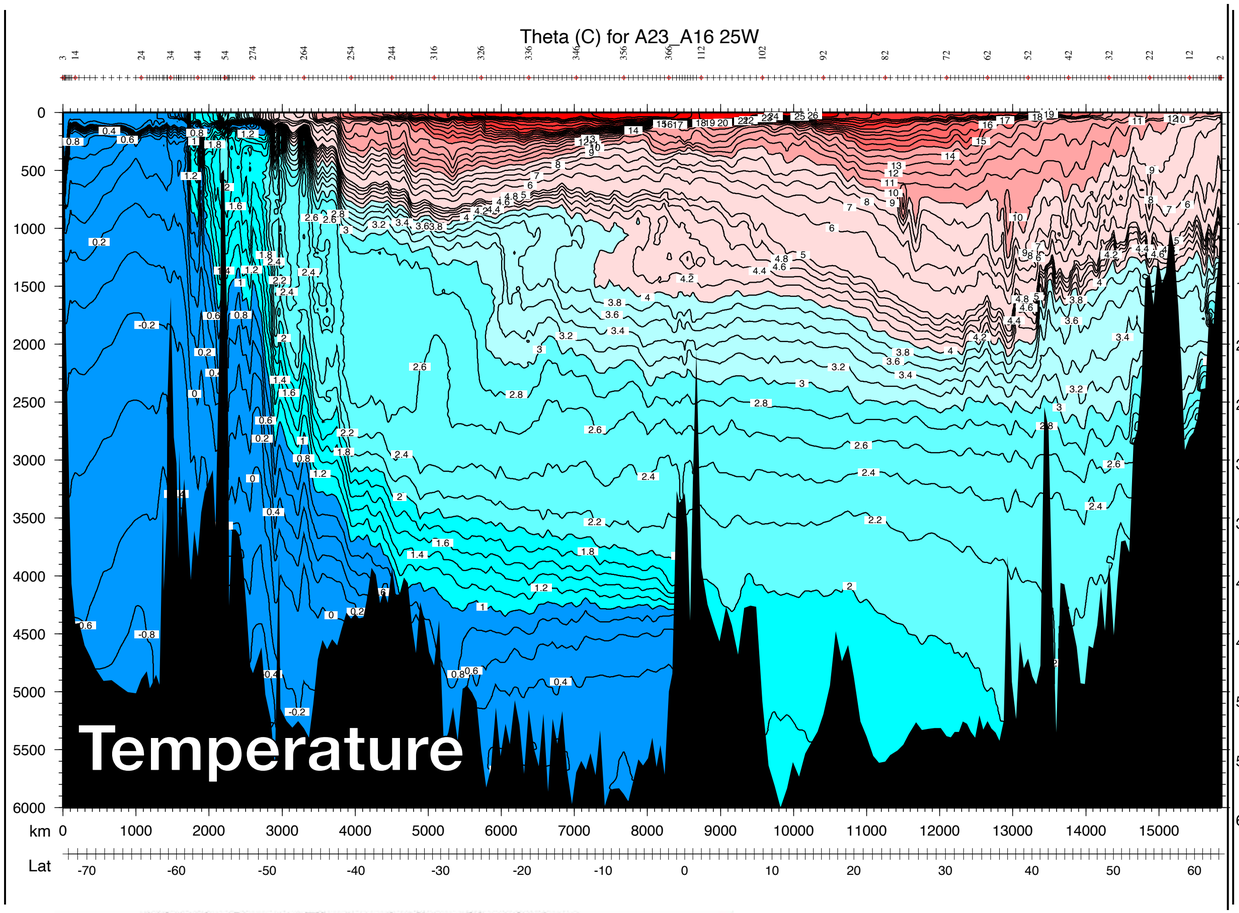


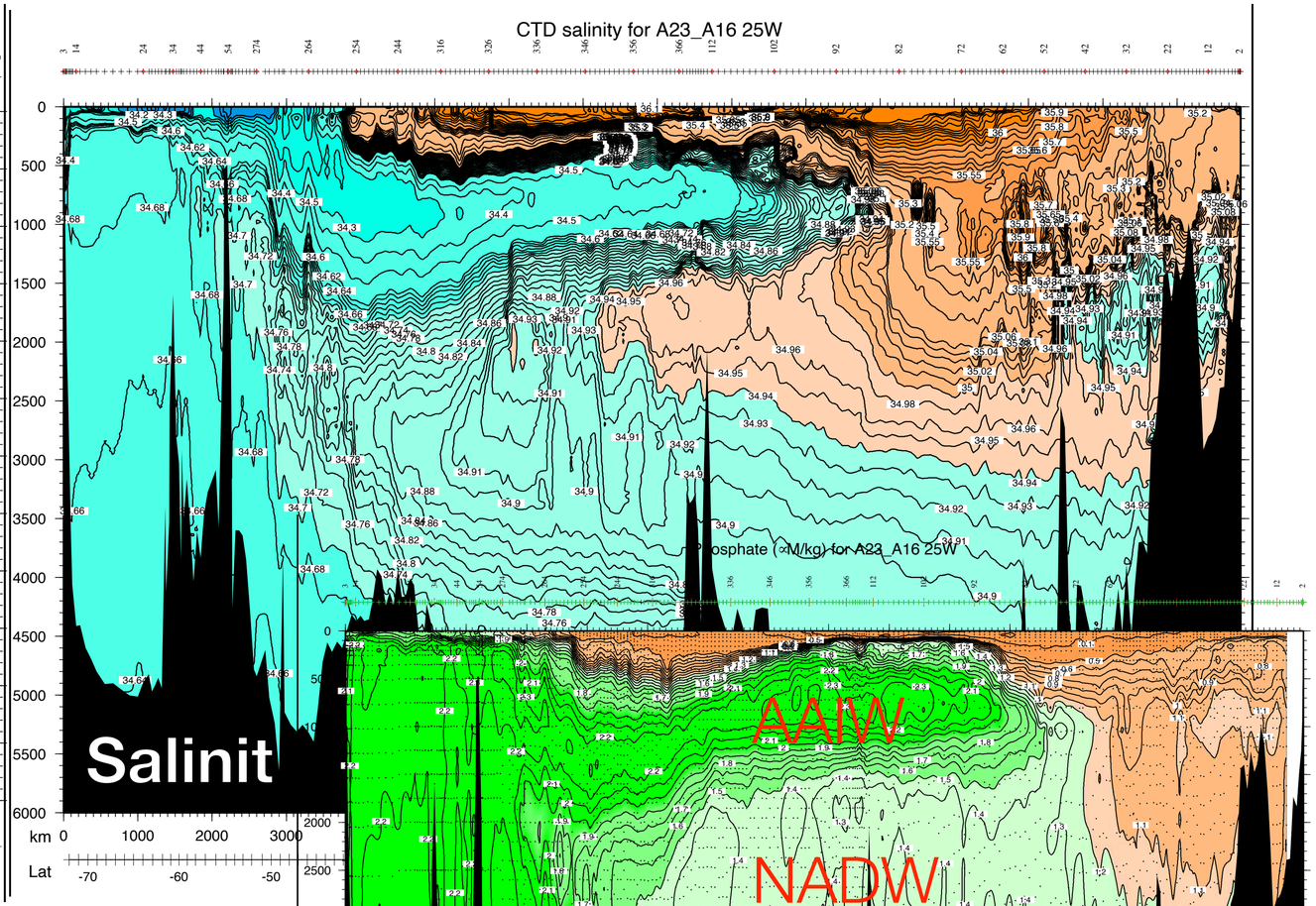
https://mail.tku.edu.tw/086138/EnvFutures/WebPages/Global%20warming/Thermohaline%20Circulation.htm

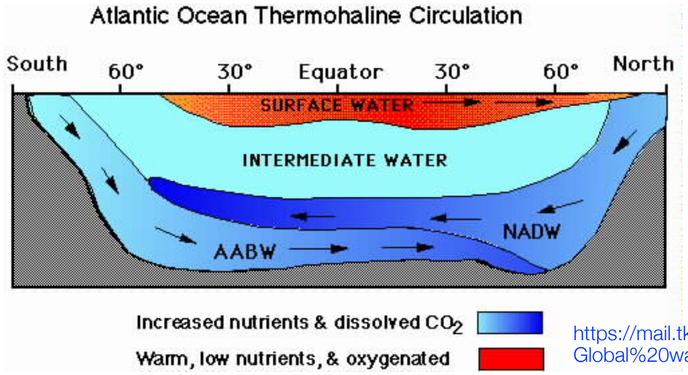
WOCE atlas

Eli Tziperman

Evaporation–Precipitation and ocean salinity changes





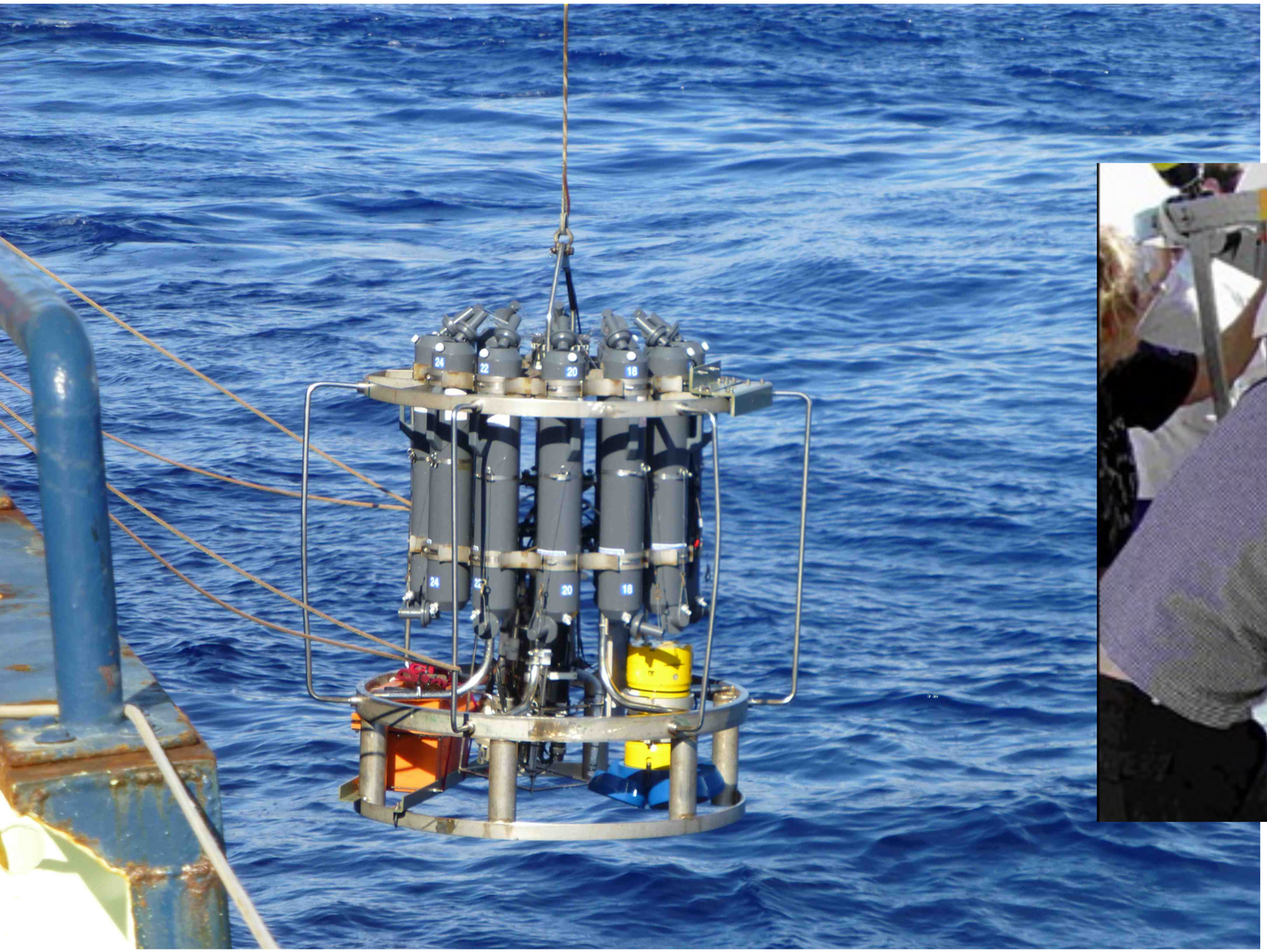


https://mail.tku.edu.tw/086138/EnvFutures/WebPages/Global%20warming/Thermohaline%20Circulation.htm

WOCE atlas

Eli Tziperman

Evaporation–Precipitation and ocean salinity changes



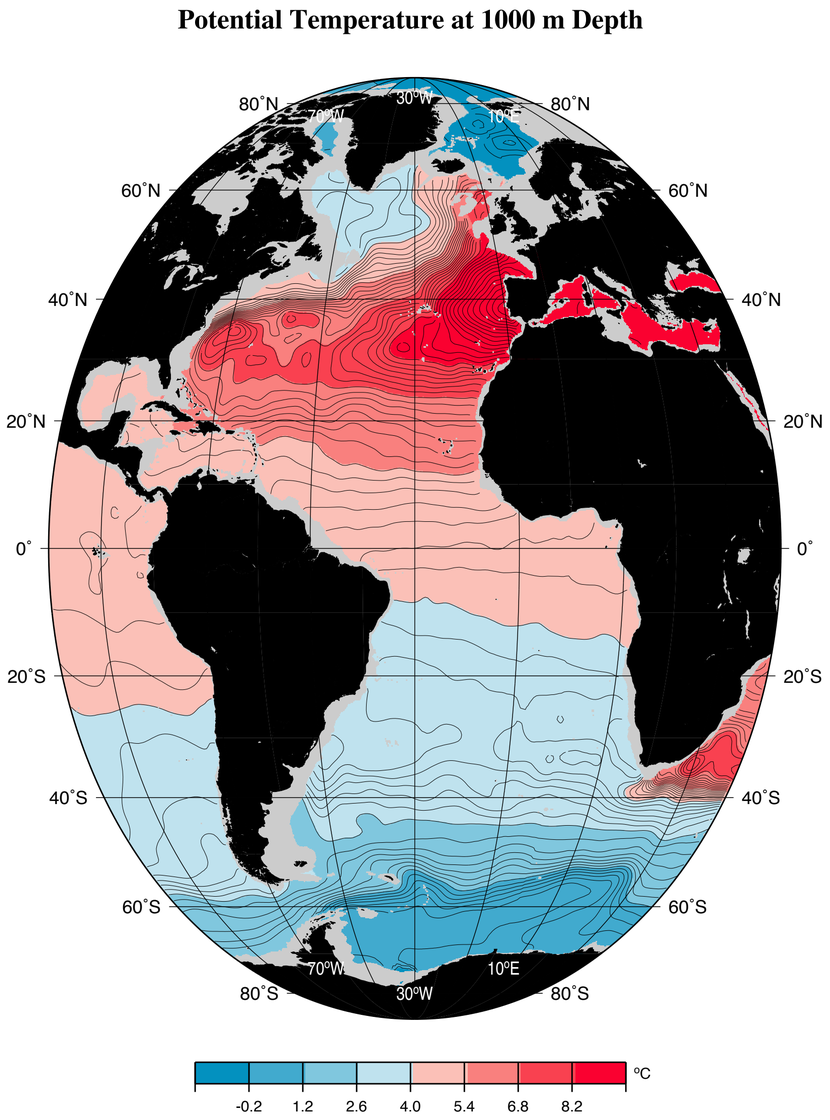
https://earthobservatory.nasa.gov/blogs/fromthefield/tag/spurs-2/page/4/

https://www.wm.edu/news/stories/2009/study-shows-vims-professors-on-cutting-edge-001.php

measuring salinity: conductivity, temperature, depth (CTD) and sampling bottles

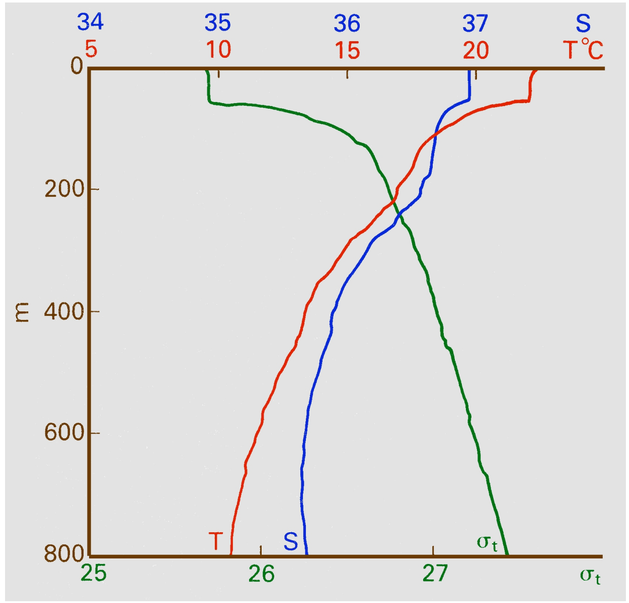
Eli Tziperman

Evaporation–Precipitation and ocean salinity changes

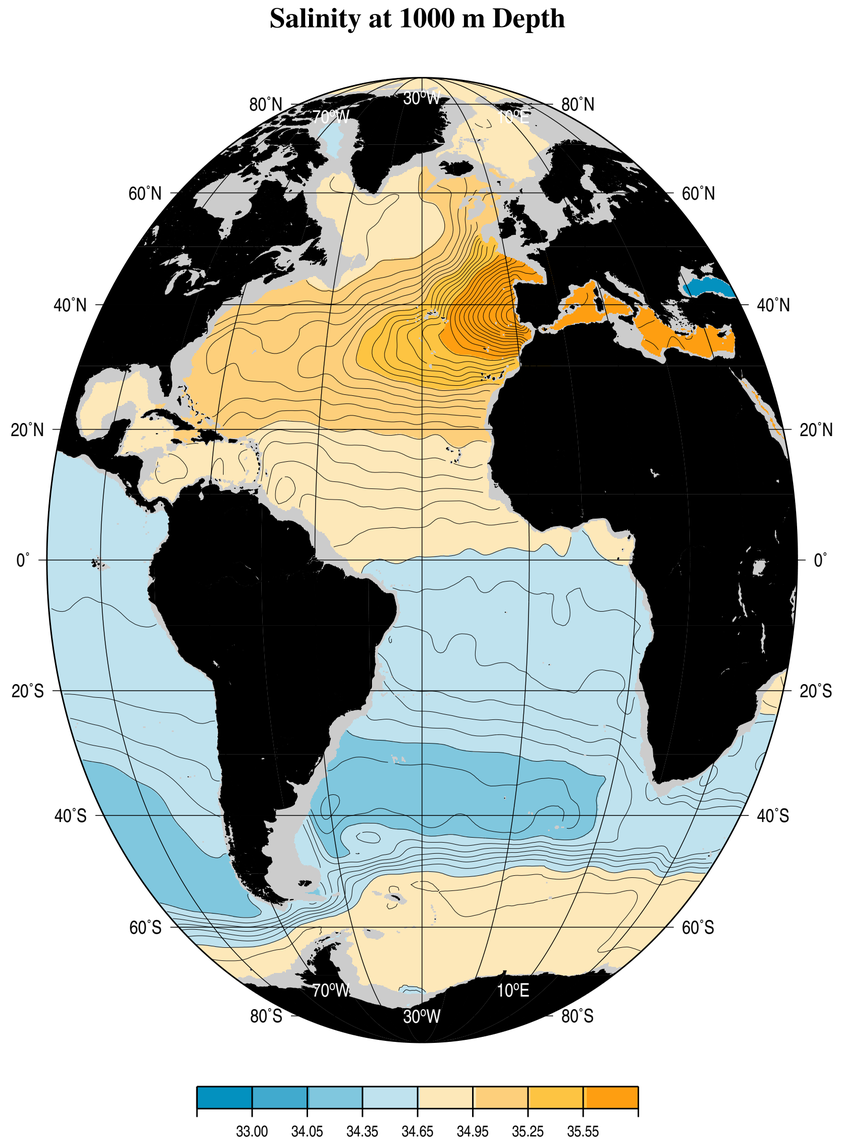


WOCE atlas

http://whp-atlas.ucsd.edu/atlantic/maps/stddep_sort/stddep_1000.htm



source unknown



The mediterranean outflow high salinity, high temperature “tongue”

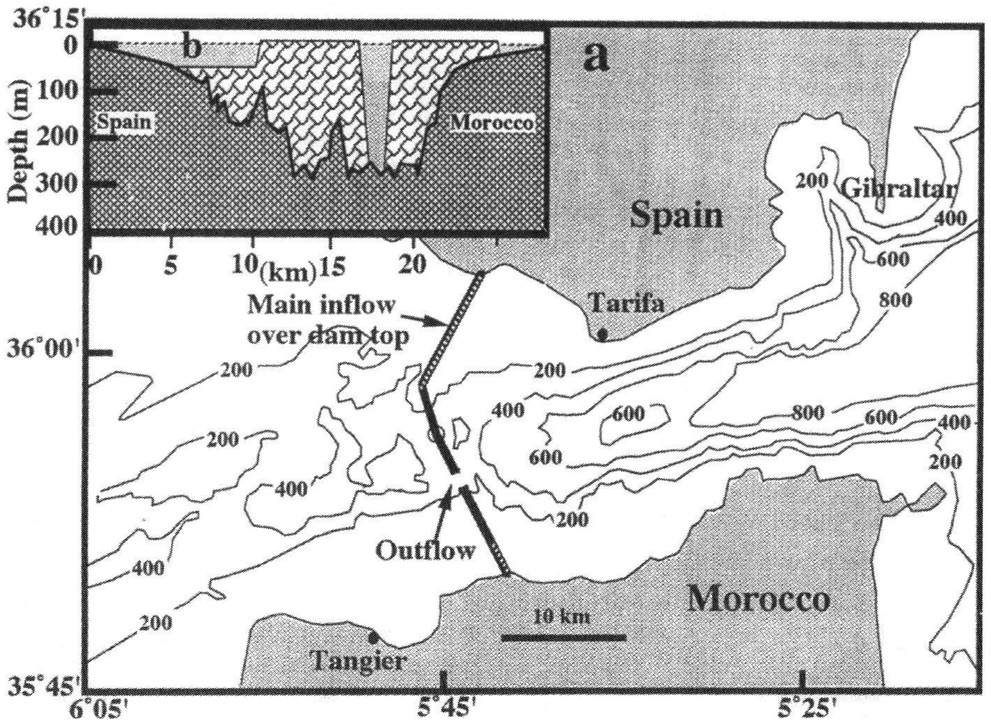
Evaporation–Precipitation and ocean salinity changes

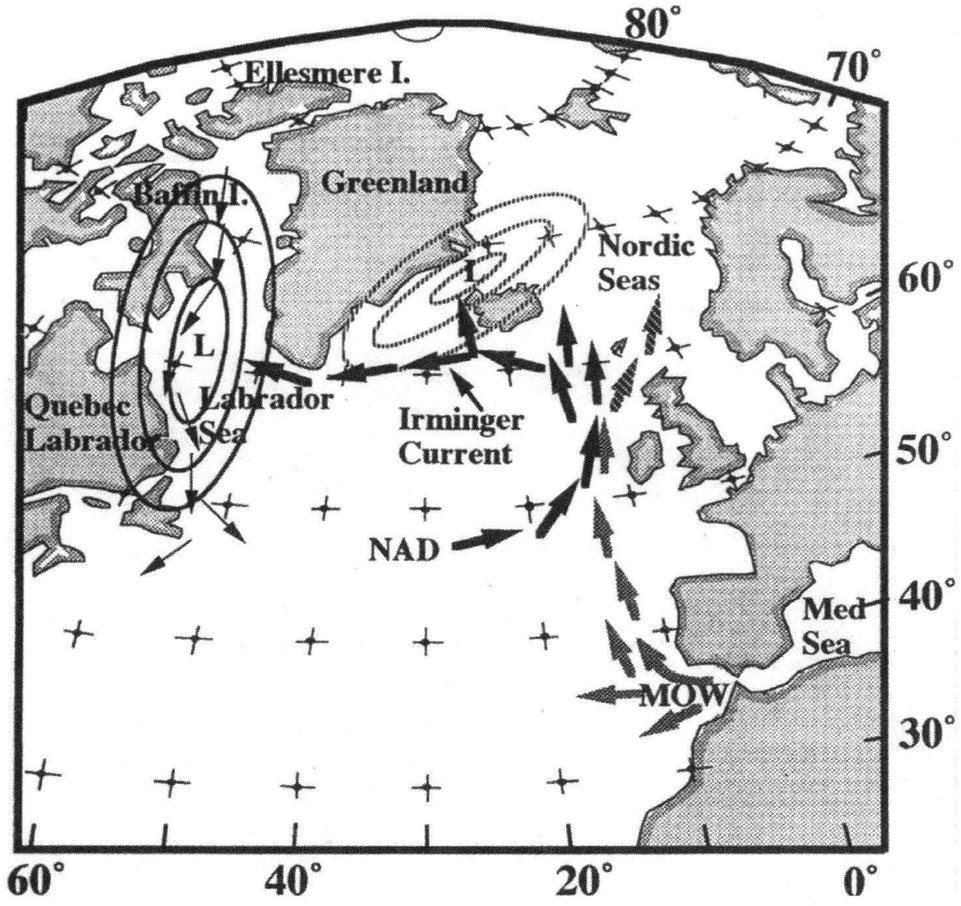
EOS

Climate Control Requires a Dam at the Strait of Gibraltar

PAGES 277, 280–281

R. G. Johnson





Evaporation–Precipitation and ocean salinity changes

https://www.youtube.com/watch?v=lAupJzH31tc

Brinicle, Underwater Icicle "Finger of Death"

Evaporation–Precipitation and ocean salinity changes

https://www.youtube.com/watch?v=lAupJzH31tc

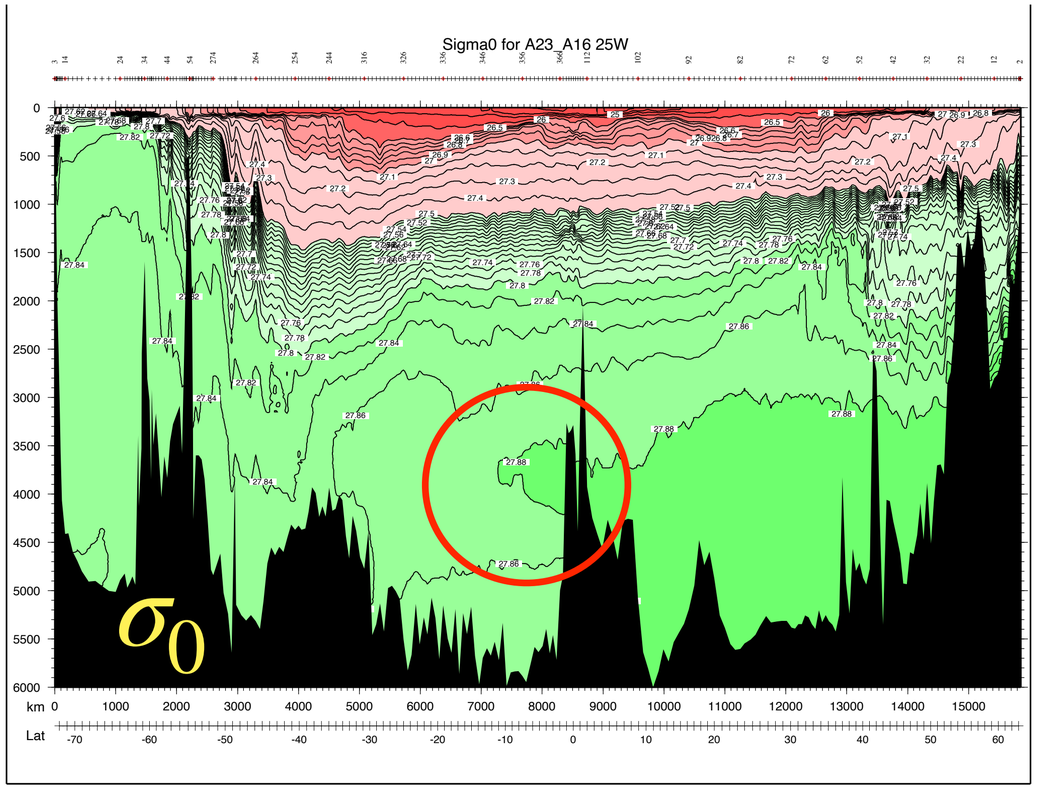
Brinicle, Underwater Icicle "Finger of Death"

Notes

section 4, salinity

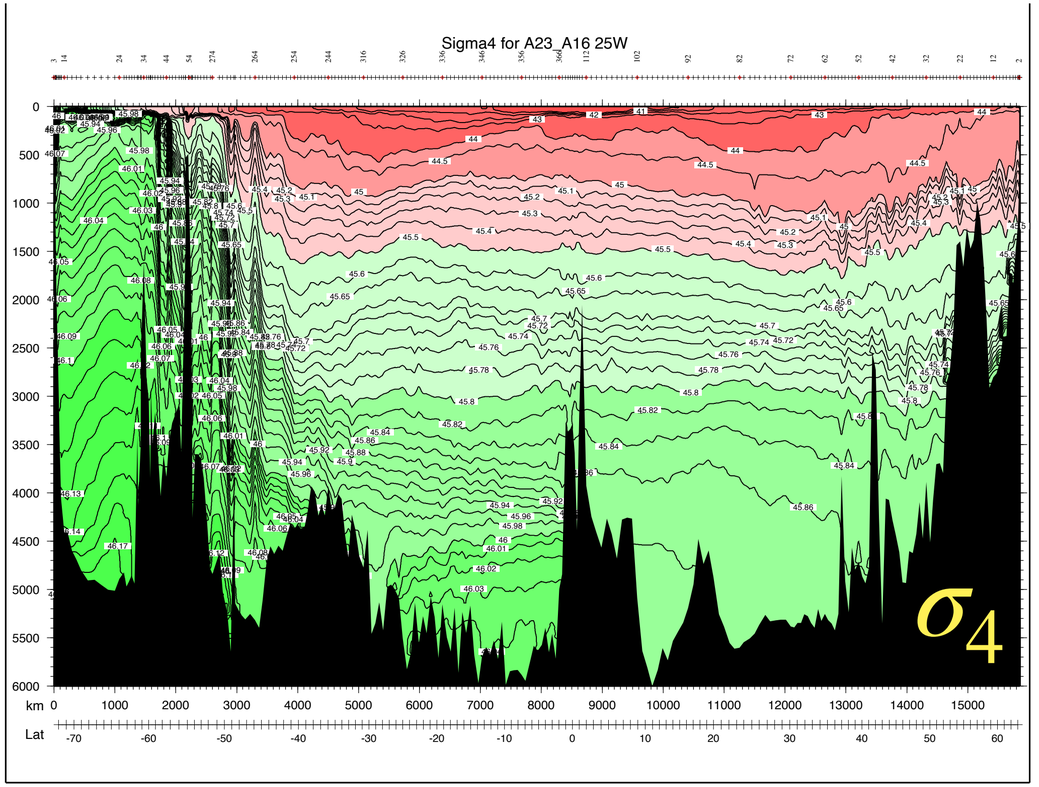
Eli Tziperman

Density, potential density, and the equation of state



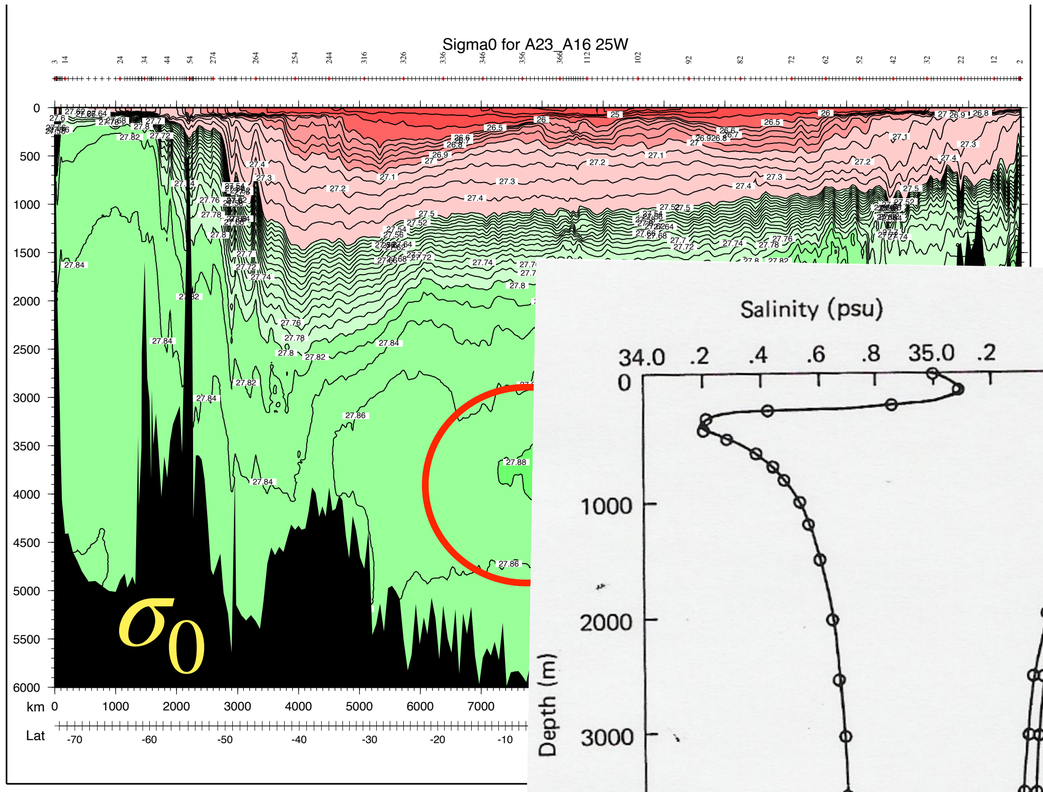
WOCE atlas

http://whp-atlas.ucsd.edu/atlantic/sections.htm



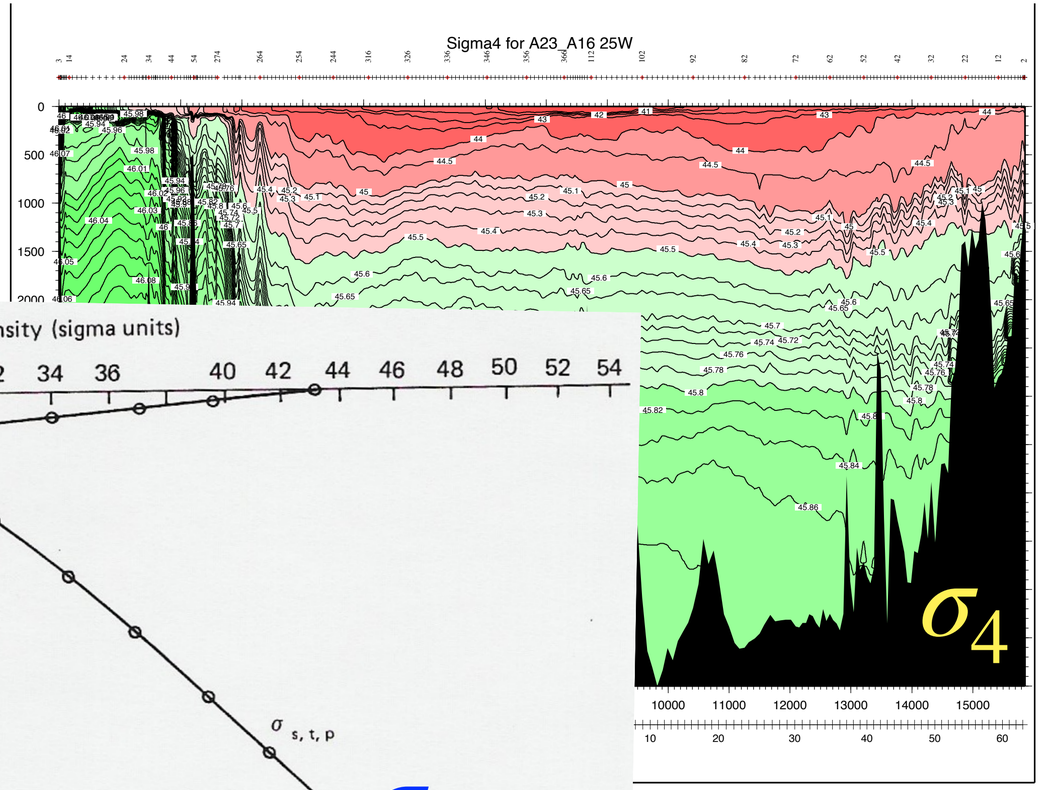
Eli Tziperman

Density, potential density, and the equation of state



WOCE atlas

http://whp-atlas.ucsd.edu/atlantic/sections.htm



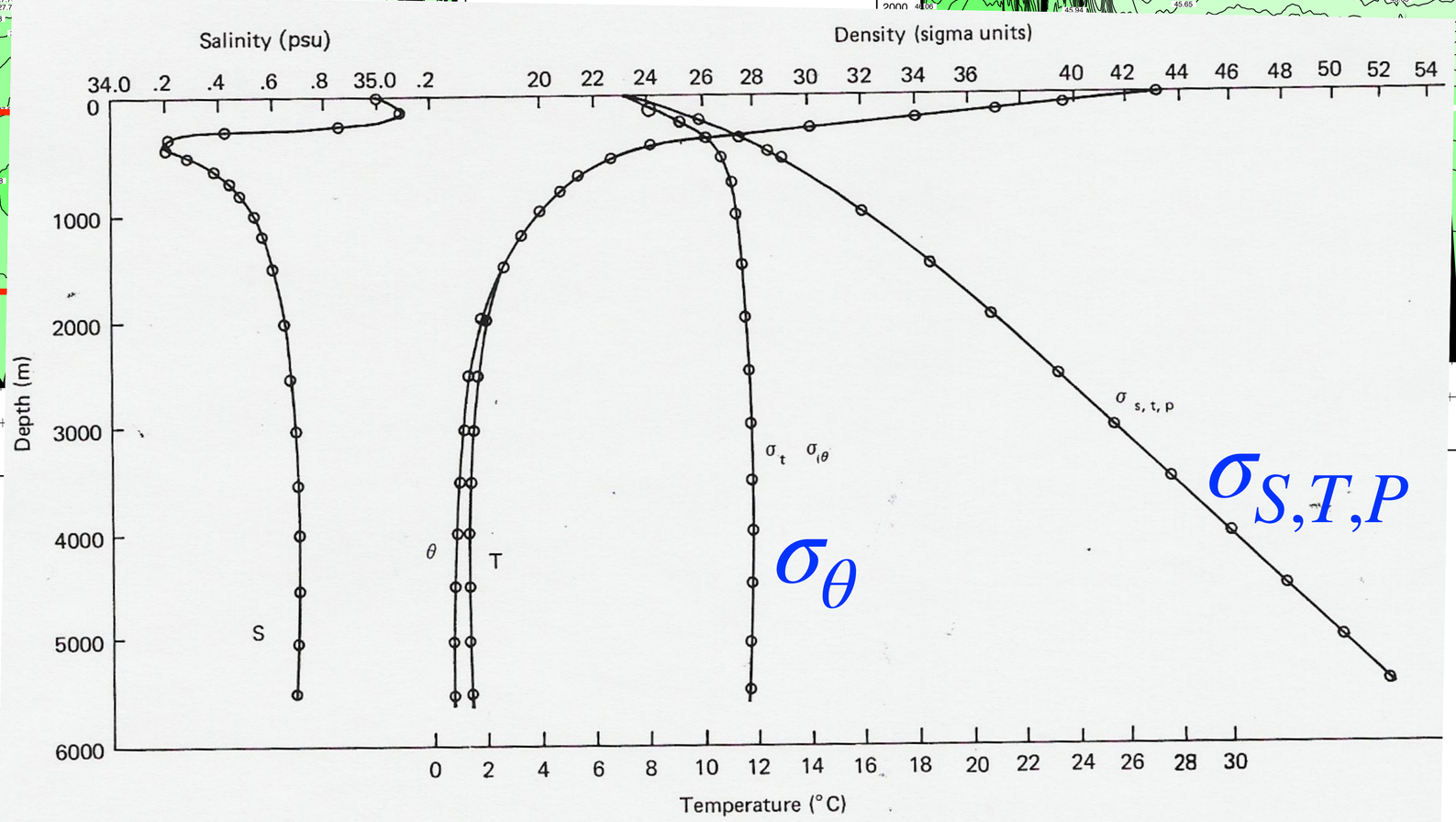


Figure 2.4 Salinity, potential temperature, in situ temperature, σ_θ, σ_t, and $\sigma_{S,T,p}$ -for a station in the North Pacific at 17° N and 162° W. (See Table for numerical values.)

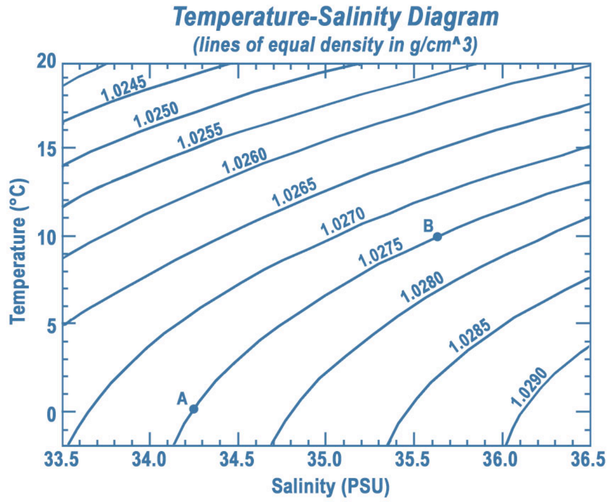
mini-quiz: calculate the T, S, ρ of a water mass that is a mix of two others.

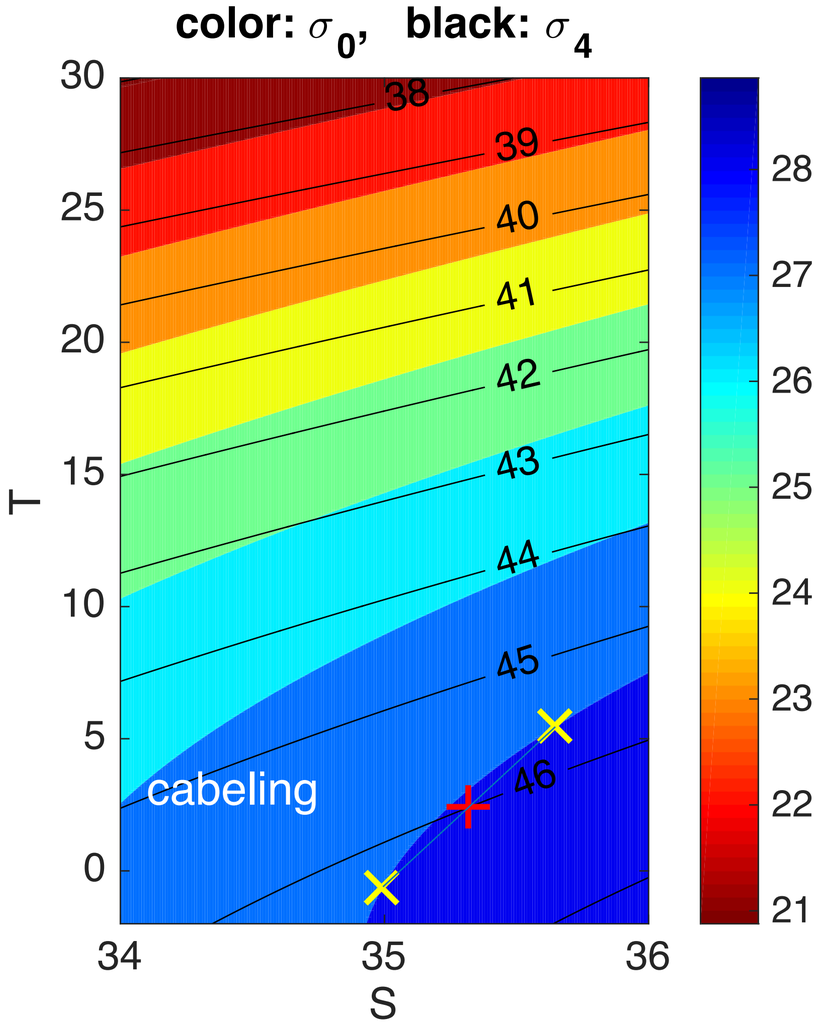
Notes

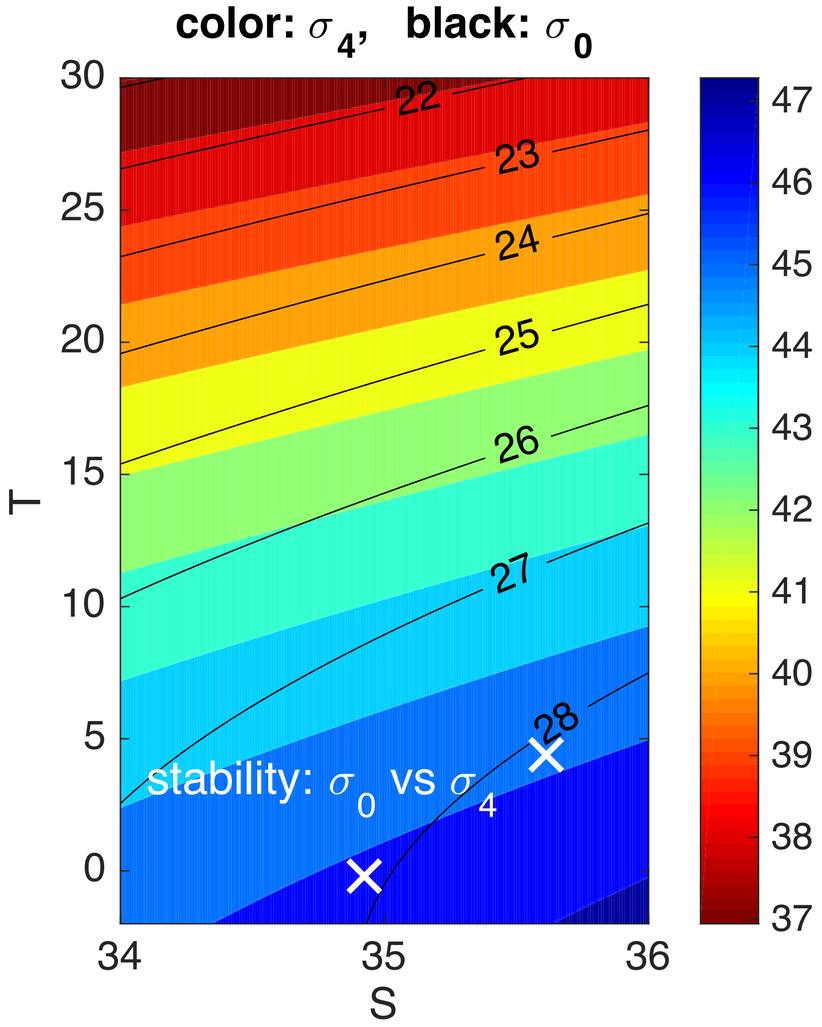
section 6, equation of state
(use following slides)

Eli Tziperman

Density and the equation of state

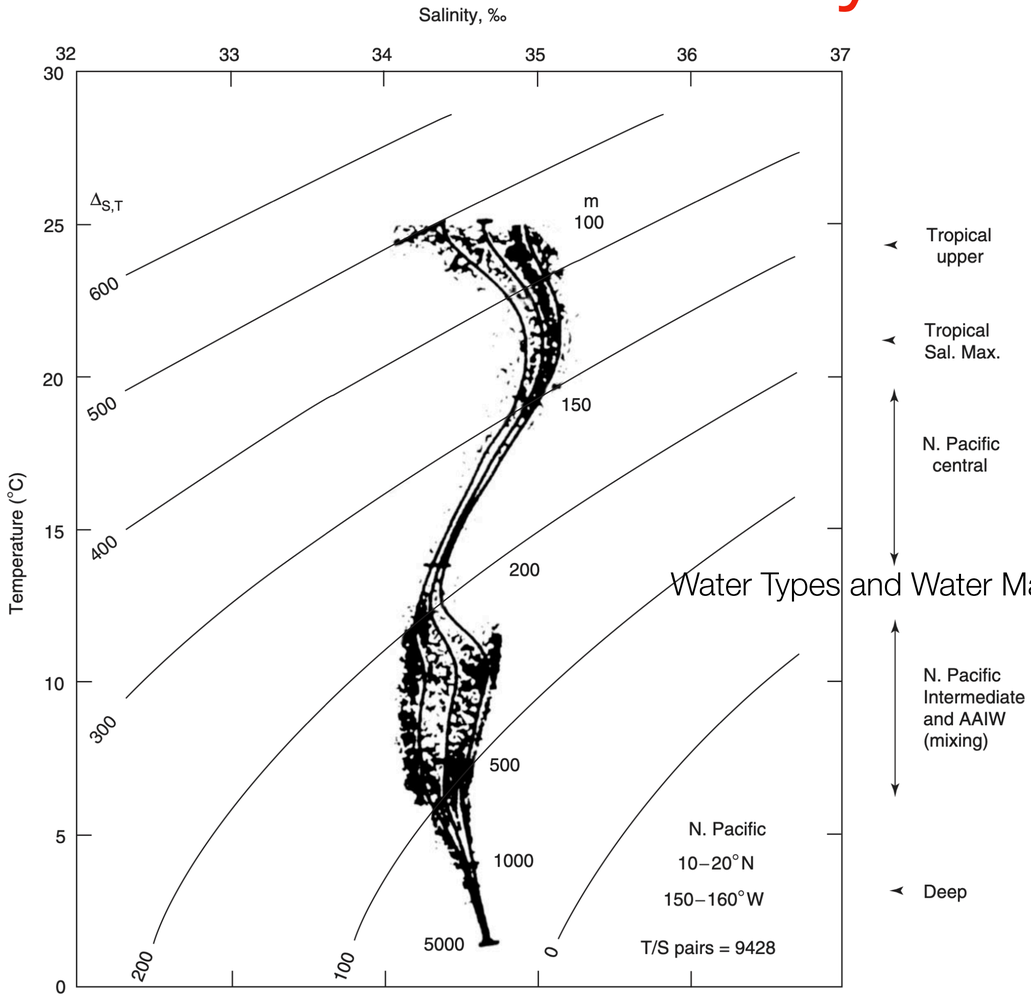


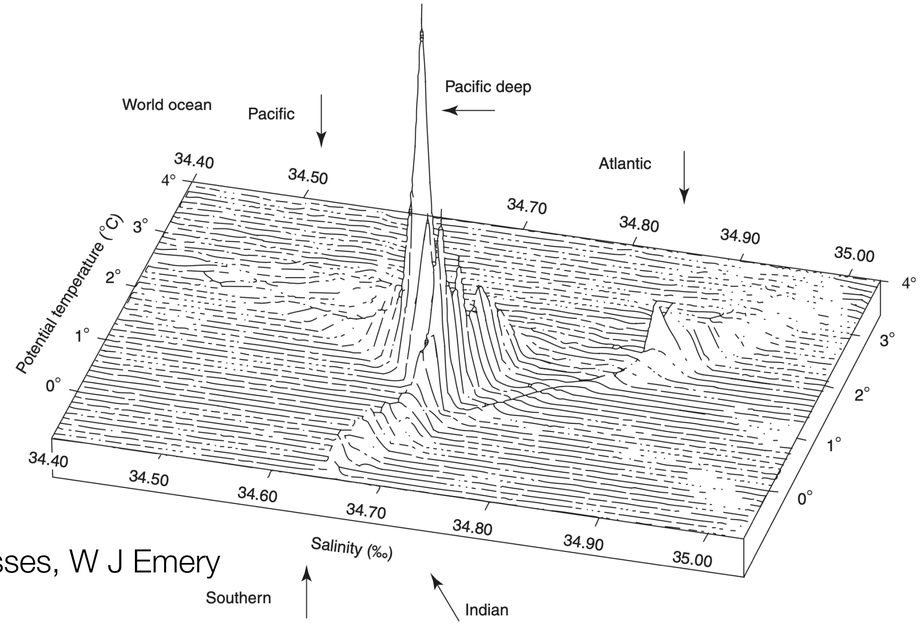




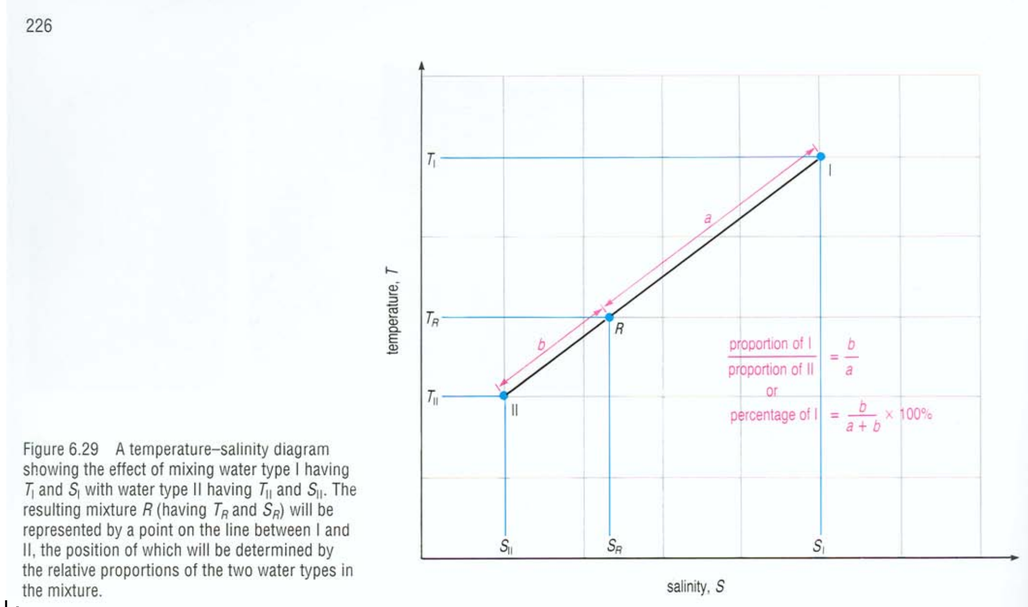
Eli Tziperman

Density and the equation of state





Water Types and Water Masses, W J Emery



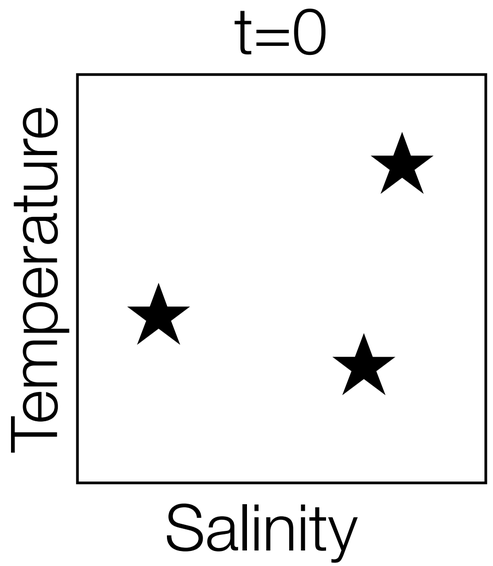
226

Figure 6.29 A temperature–salinity diagram showing the effect of mixing water type I having T_I and S_I with water type II having T_{II} and S_{II}. The resulting mixture R (having T_R and S_R) will be represented by a point on the line between I and II, the position of which will be determined by the relative proportions of the two water types in the mixture.

open university oceanography book

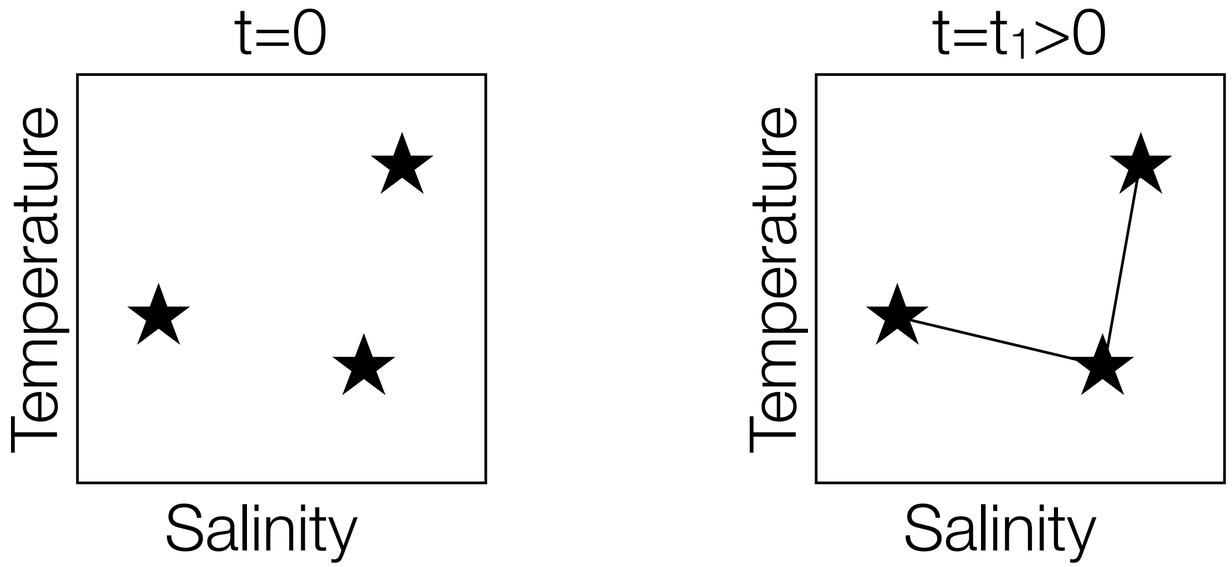
Eli Tziperman

Mixing of three water masses



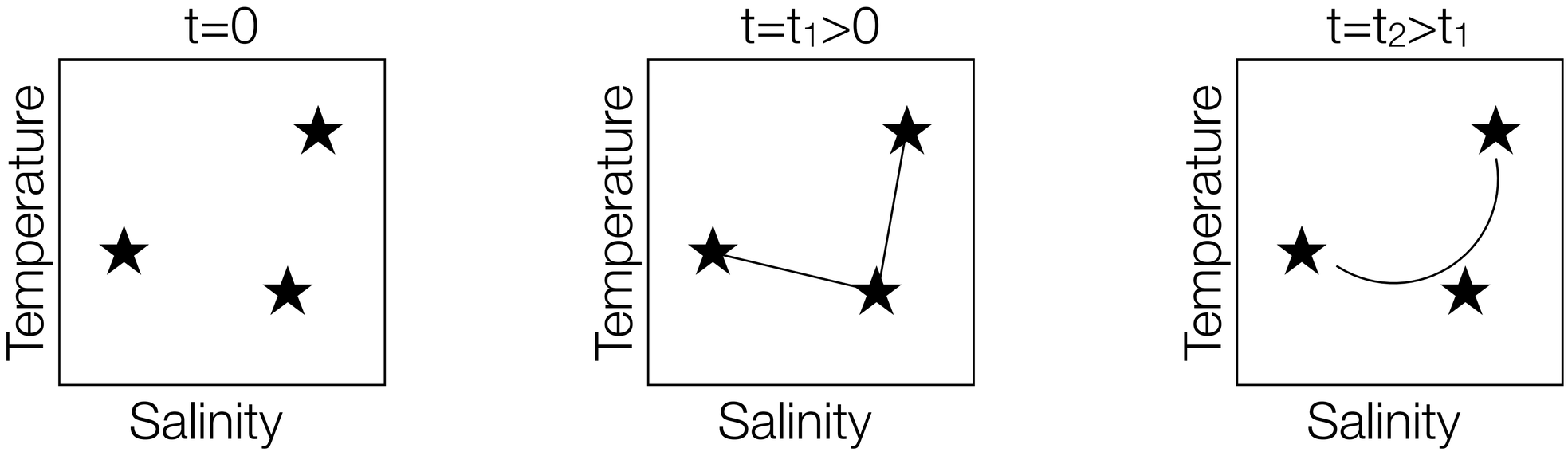
Eli Tziperman

Mixing of three water masses



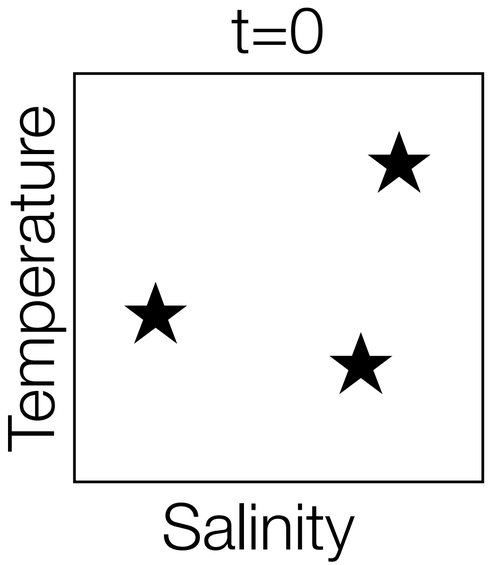
Eli Tziperman

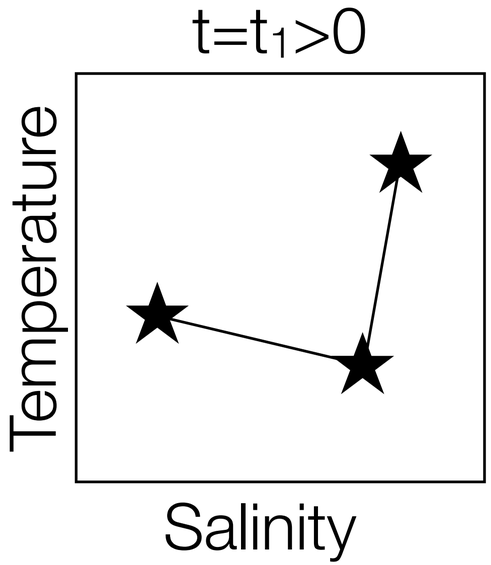
Mixing of three water masses

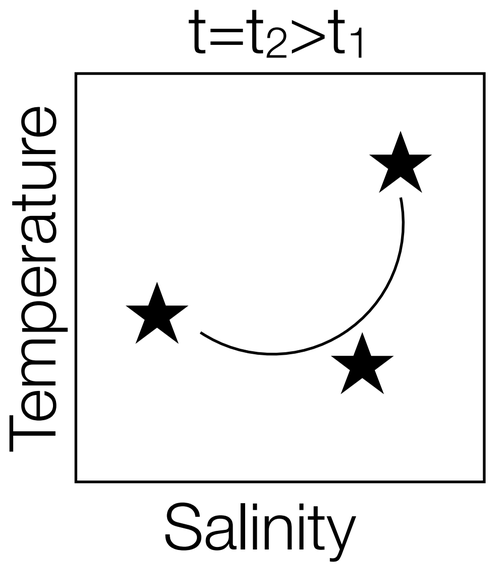


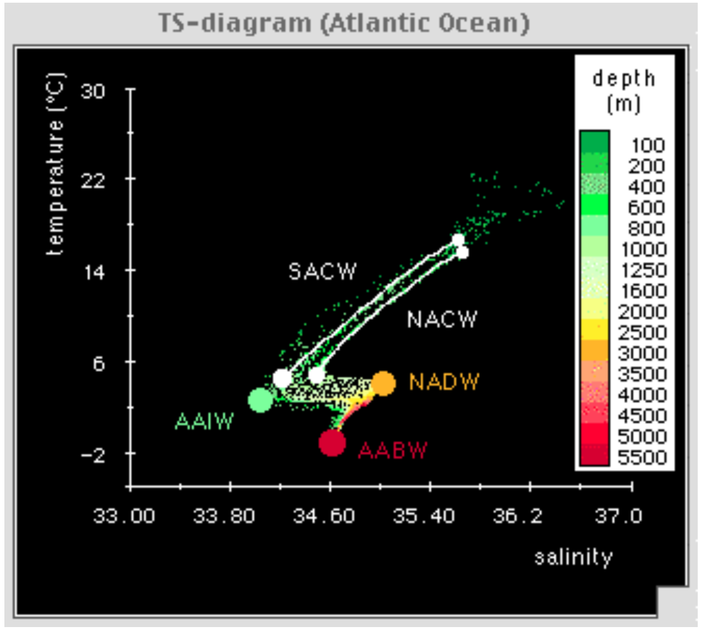
Eli Tziperman

Mixing of three water masses









http://www.physocean.icm.csic.es/ShelfCoast/chapter10-ca.html