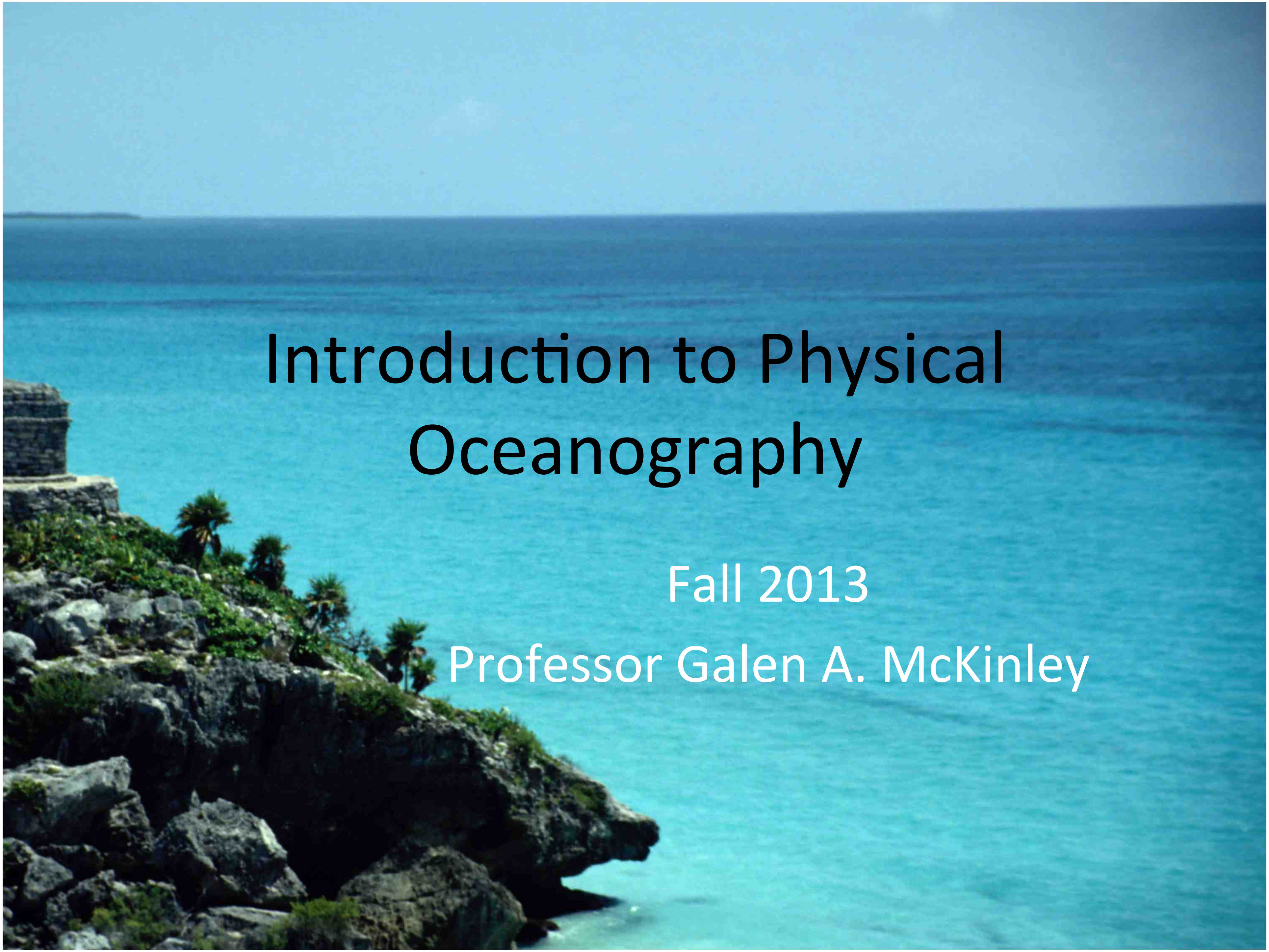
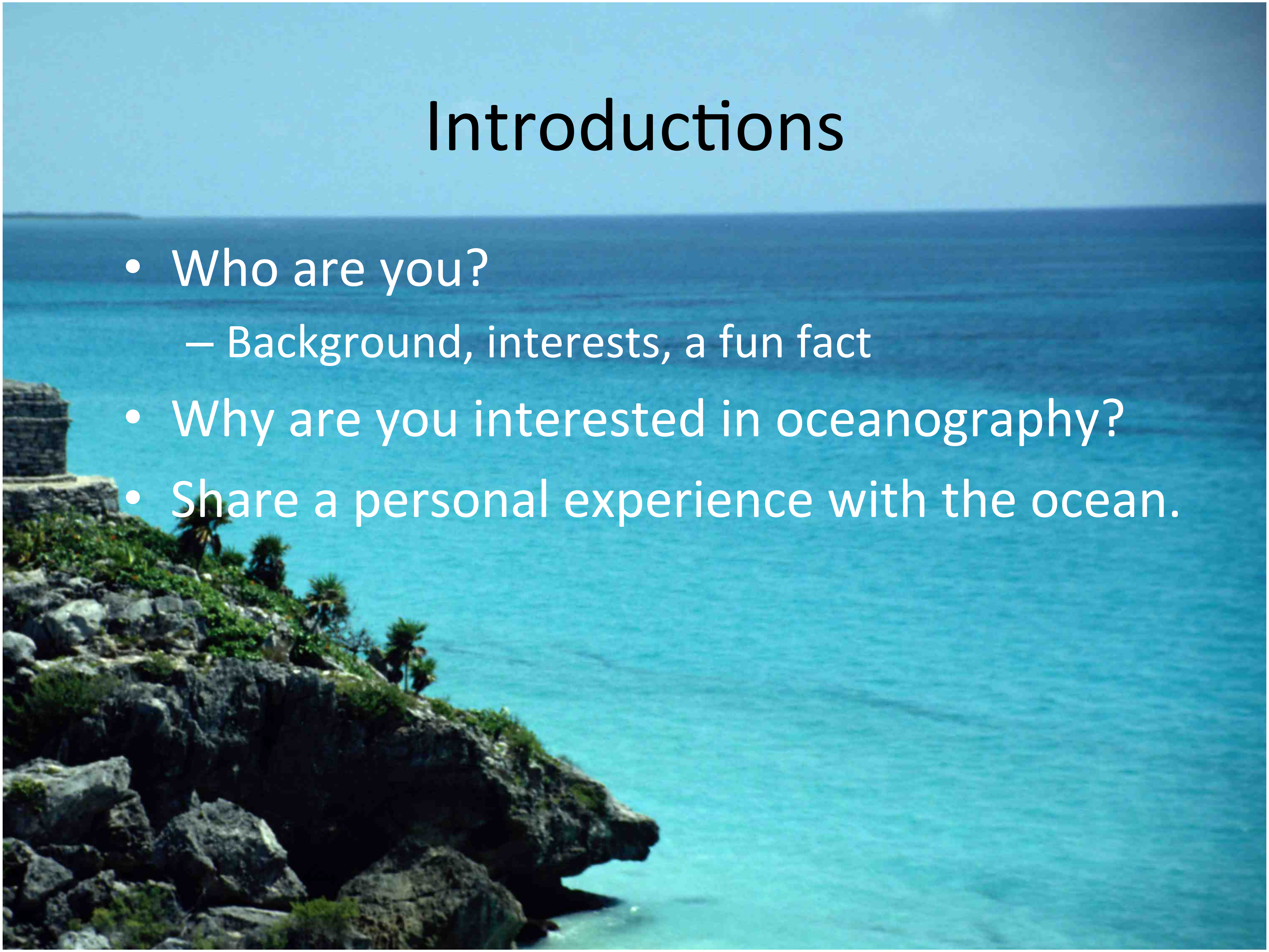

Introduction to Physical Oceanography
Fall 2013
Professor Galen A. McKinley

Introductions

- Who are you?
  - Background, interests, a fun fact
- Why are you interested in oceanography?
- Share a personal experience with the ocean.



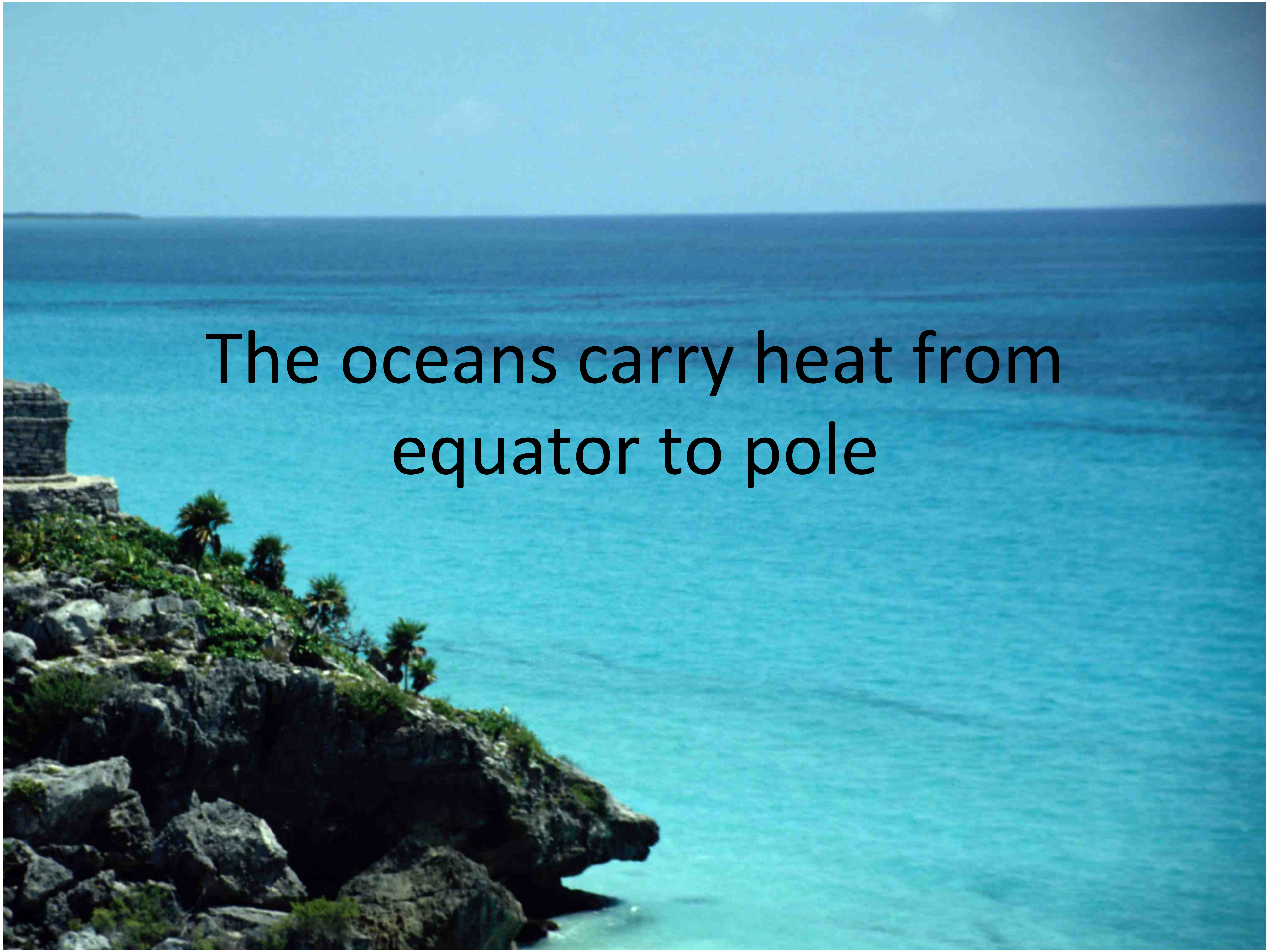
Why Oceanography?

- Oceans cover 71% of planet – a critical earth system component
- Climate – including variability and change on daily to geologic timescales
- Biosphere -- 50% of all species on Earth
- Critical resource for human civilization
- Natural phenomena -> human disaster

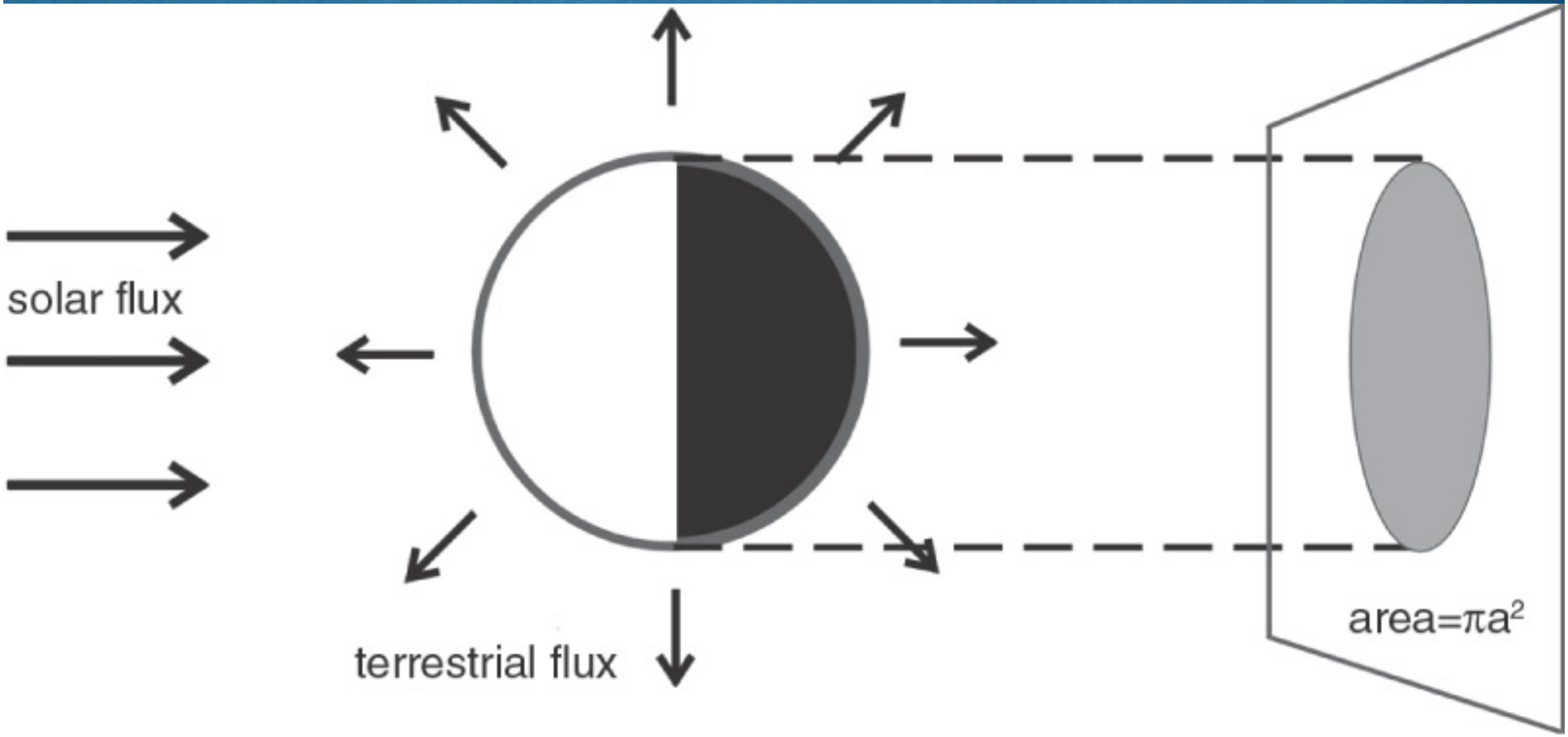
Our Focus

- Oceans in the climate system
  - Basic state, circulation, waves, tides
  - Interaction with the atmosphere
- Dynamics of a fluid on a rotating planet
  - How does the circulation come about?
- Climate variability and change
  - Circulation
  - Biogeochemistry – Primary productivity and Carbon cycling


Oceans in the climate system


The oceans carry heat from
equator to pole

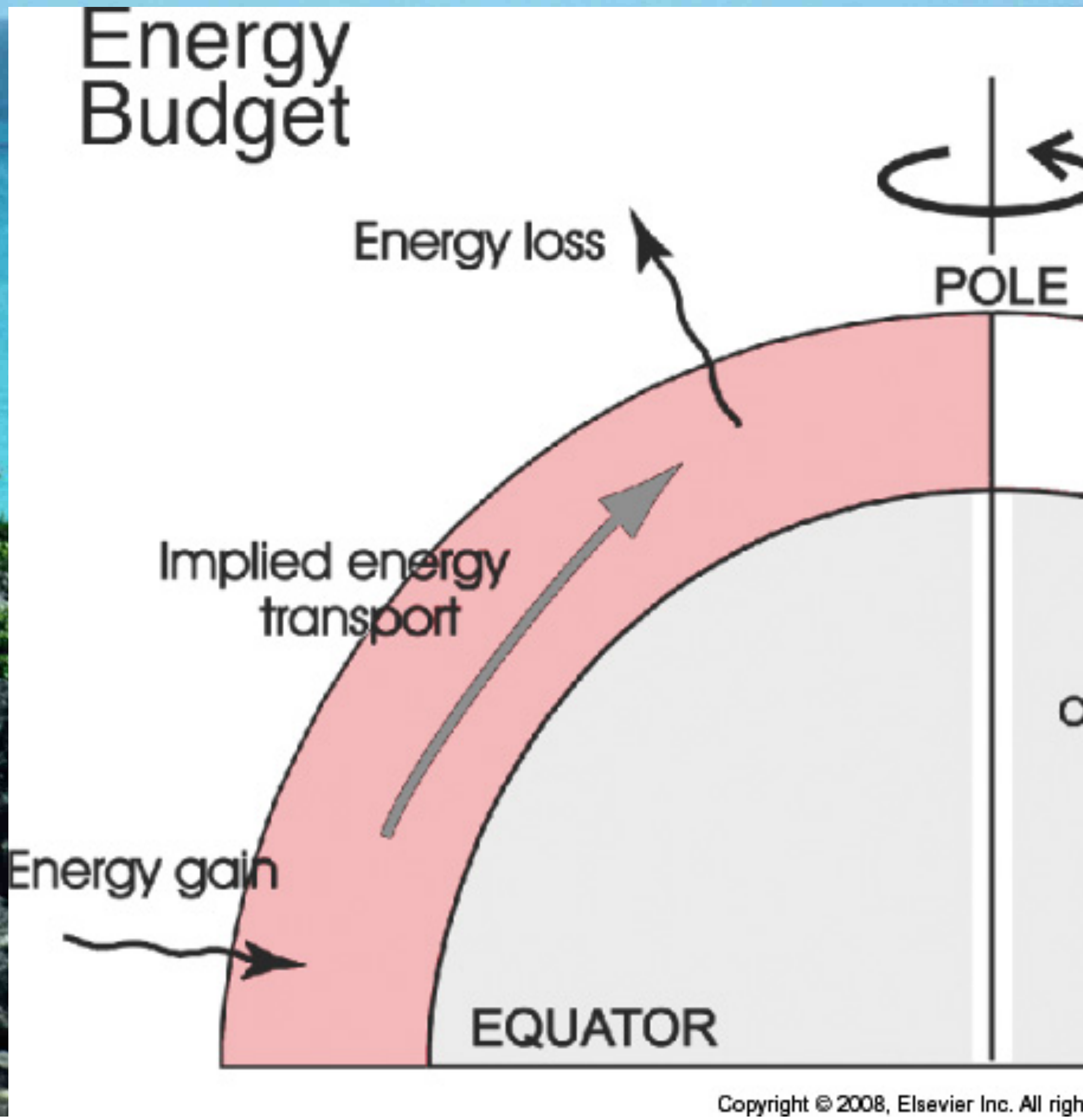
Earth is unevenly heated by the Sun



(Modified from Hartmann, 1994.)

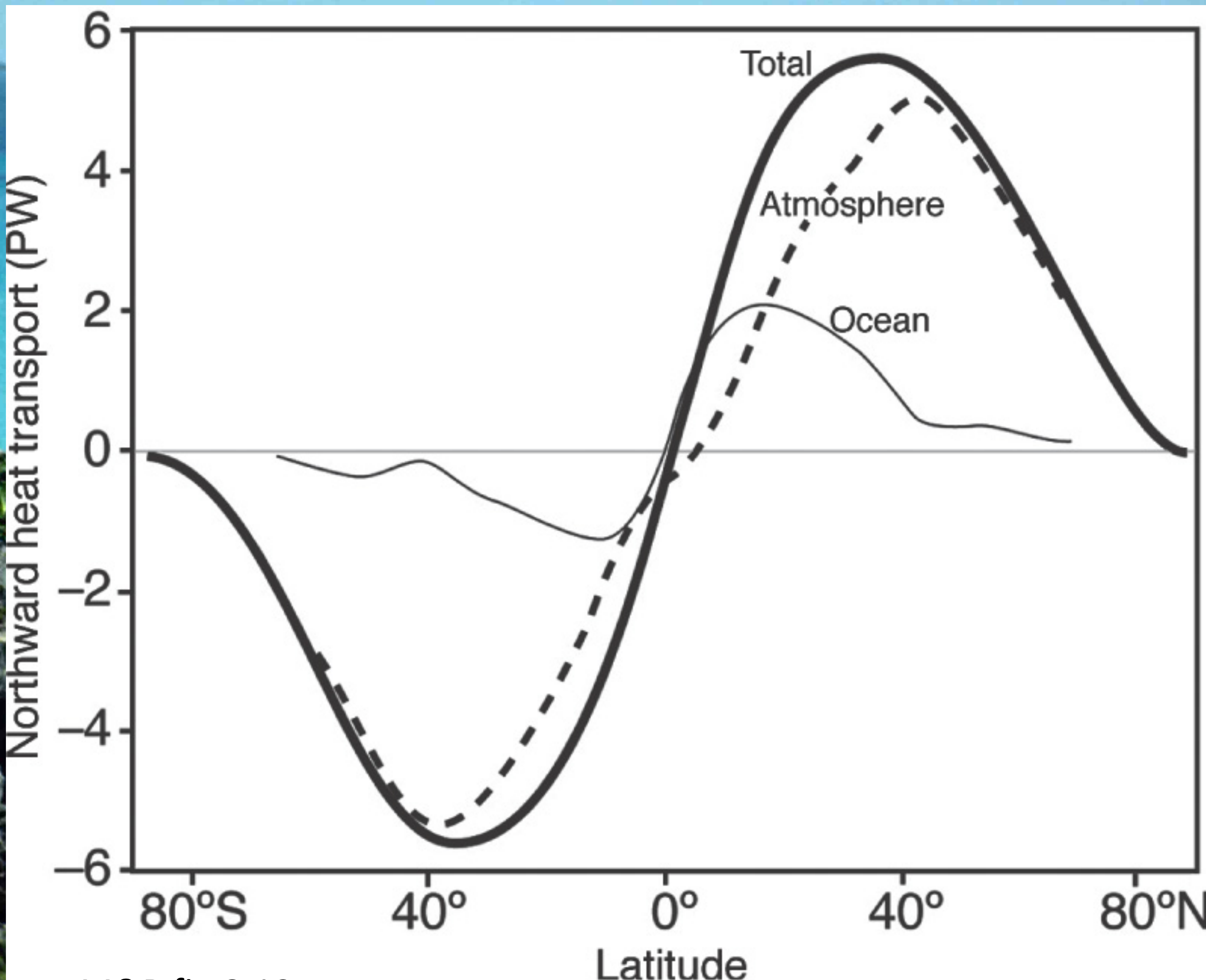
M&P fig 2.4

Motions of the Earth's fluid envelope carry much heat from tropics to pole.



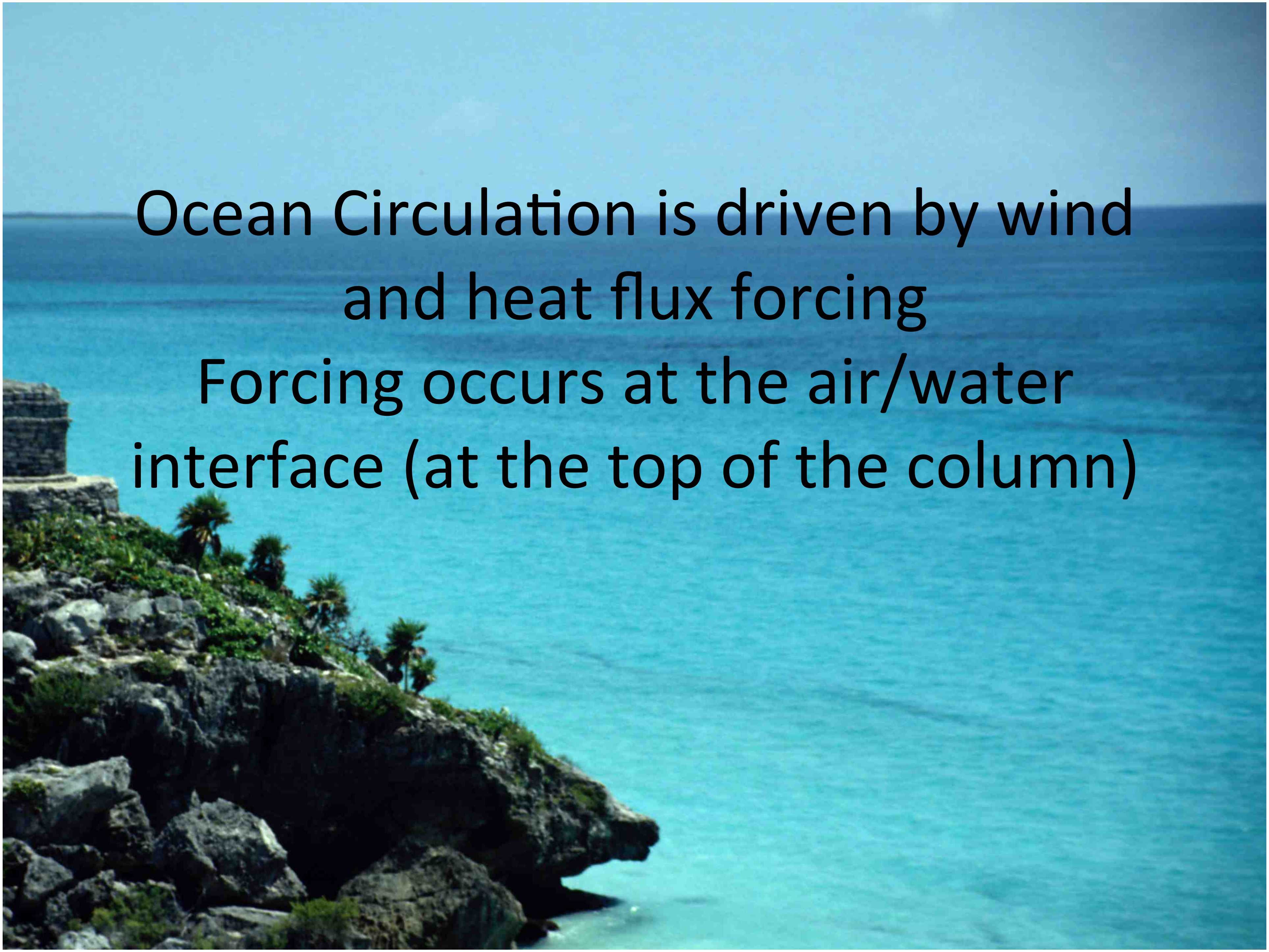
M&P fig 8.1

Global Heat Transport



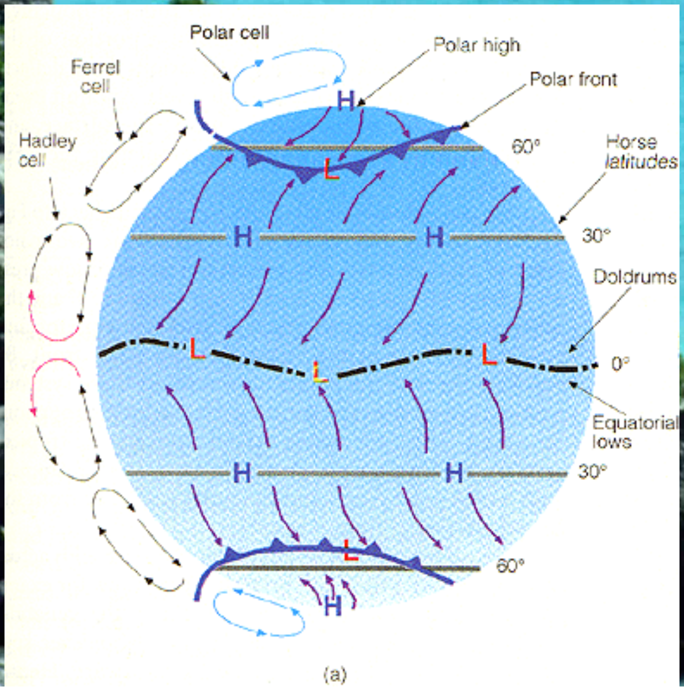
M&P fig 8.13

(From Trenberth and Caron (2001).)


Ocean Circulation is driven by wind
and heat flux forcing
Forcing occurs at the air/water
interface (at the top of the column)

Winds

- Winds blow over the ocean, exerting a frictional stress
- The water moves in response
- The response is strongly modulated by rotation



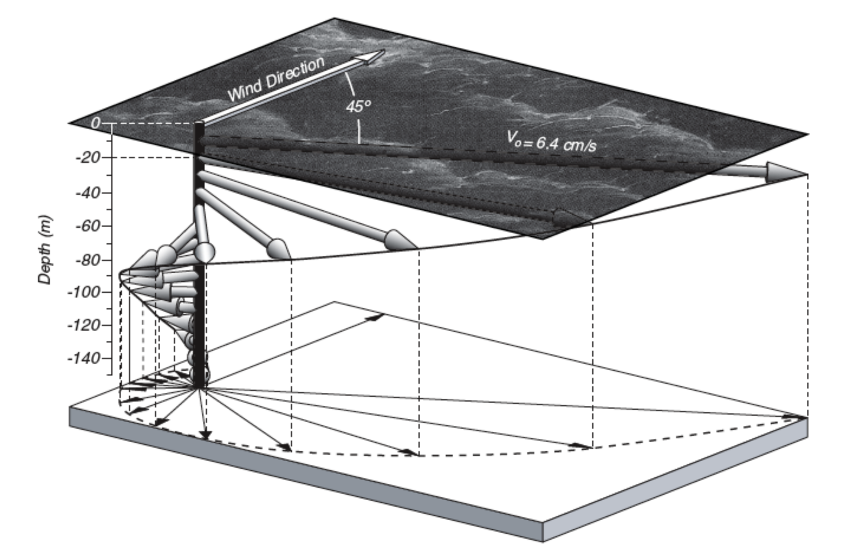
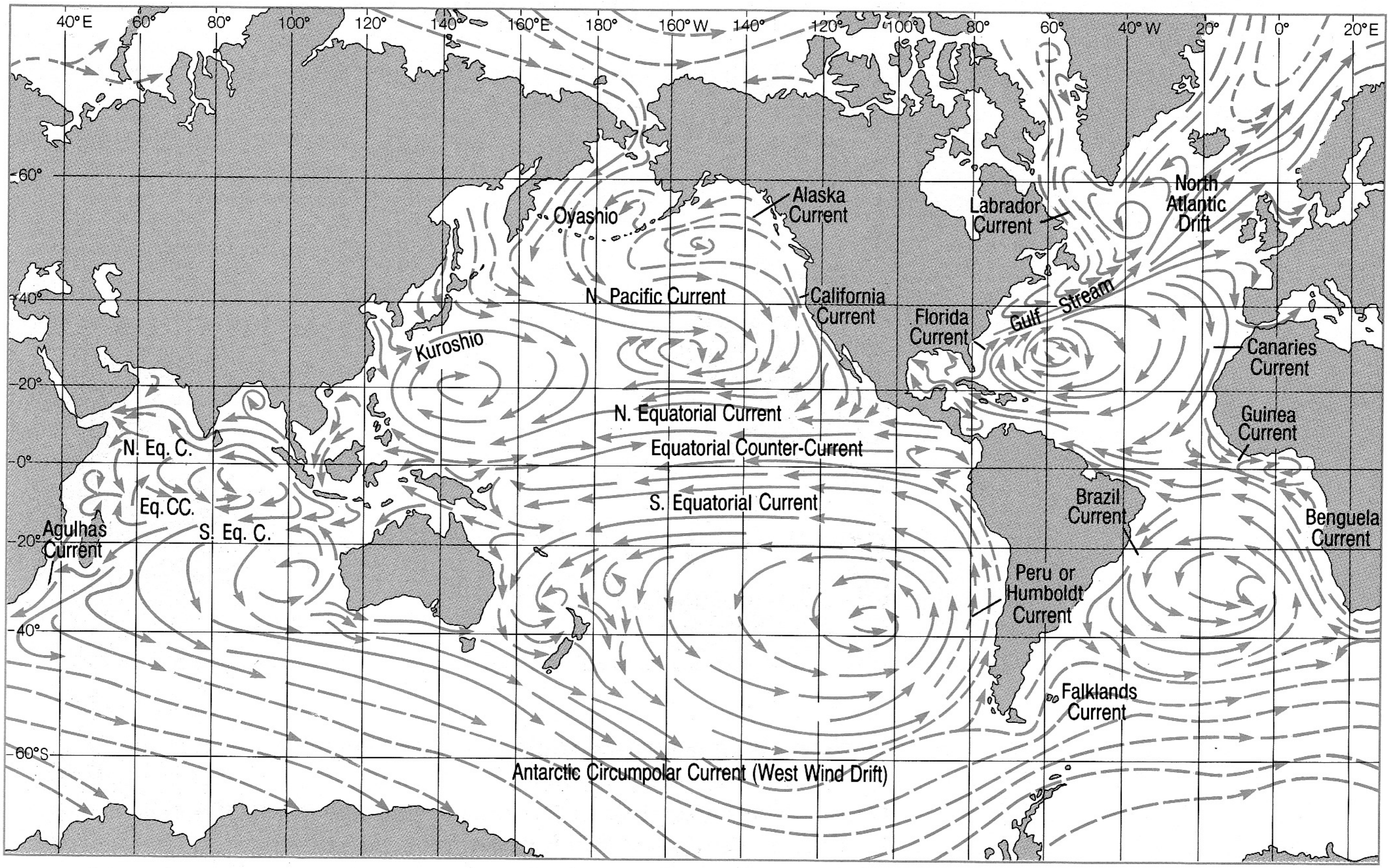
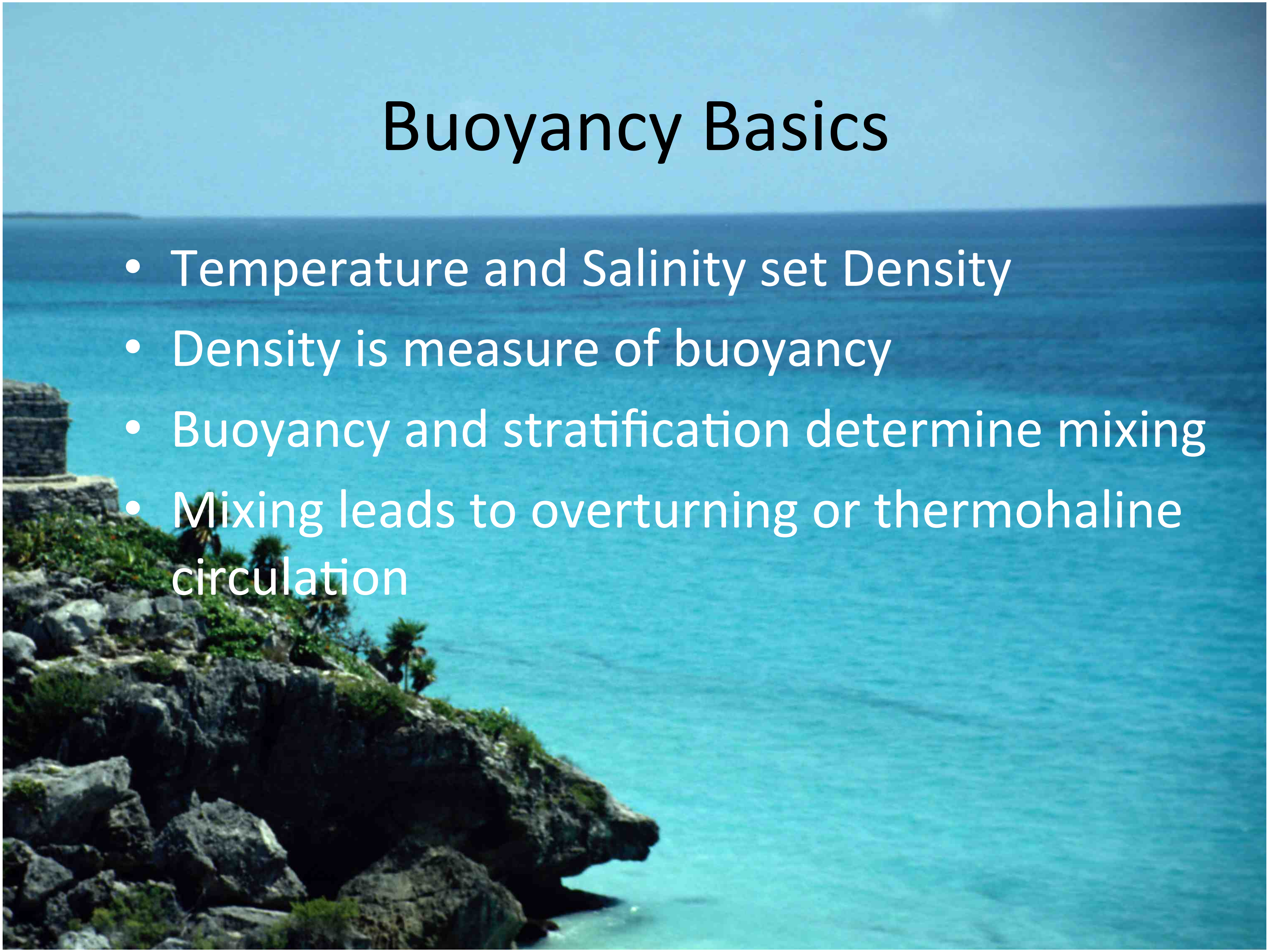


Figure 9.3. Ekman current generated by a 10 m/s wind at 35° N.



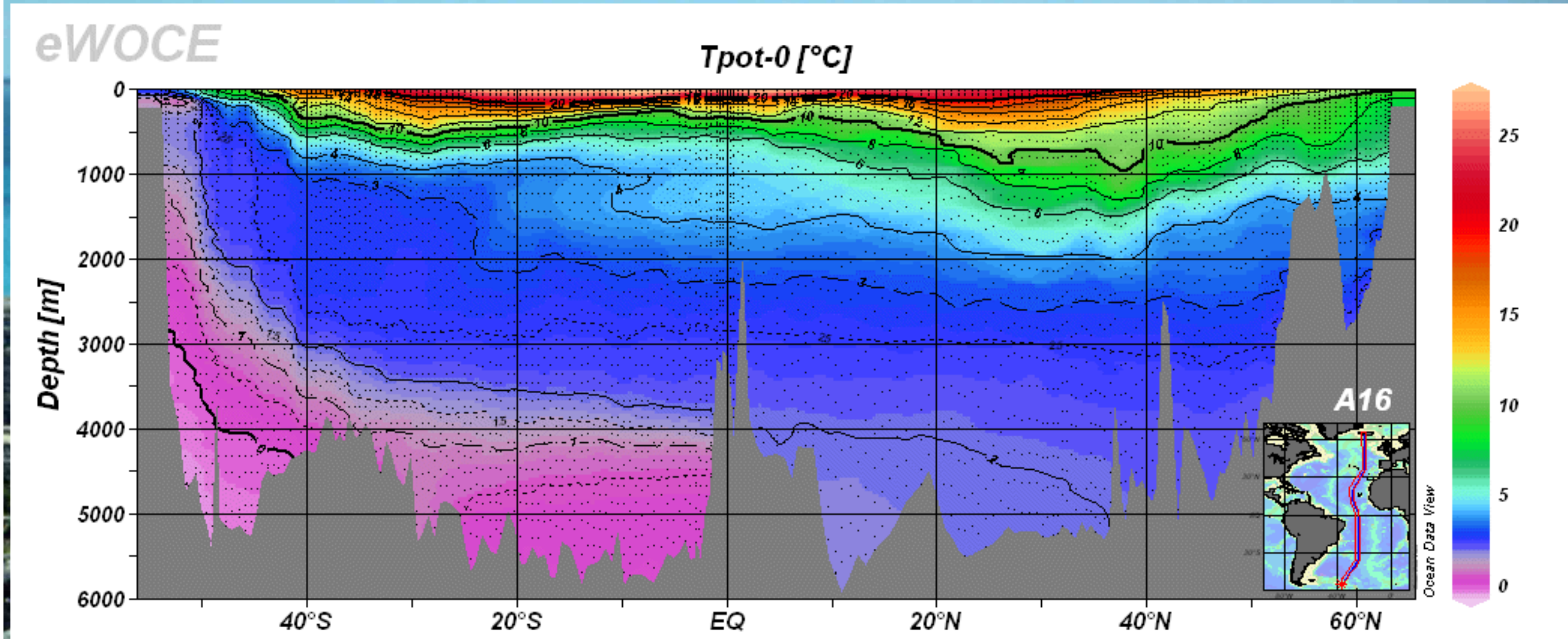
Open University, Ocean Circulation, Fig 3.1

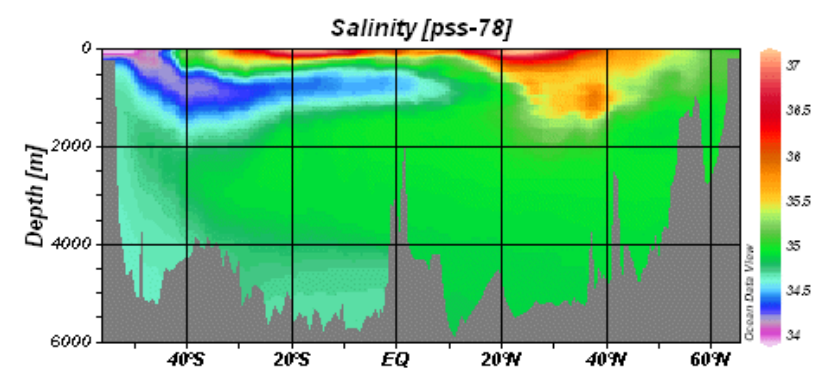
Buoyancy Basics

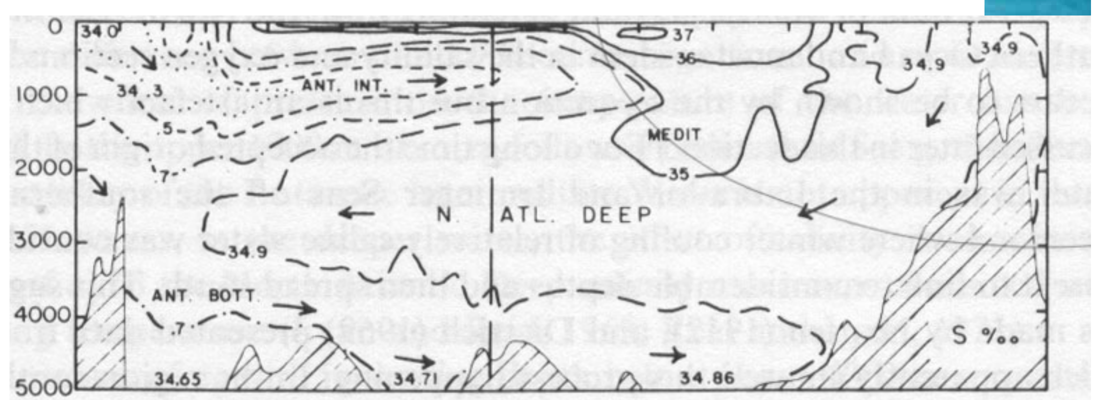


- Temperature and Salinity set Density
- Density is measure of buoyancy
- Buoyancy and stratification determine mixing
- Mixing leads to overturning or thermohaline circulation

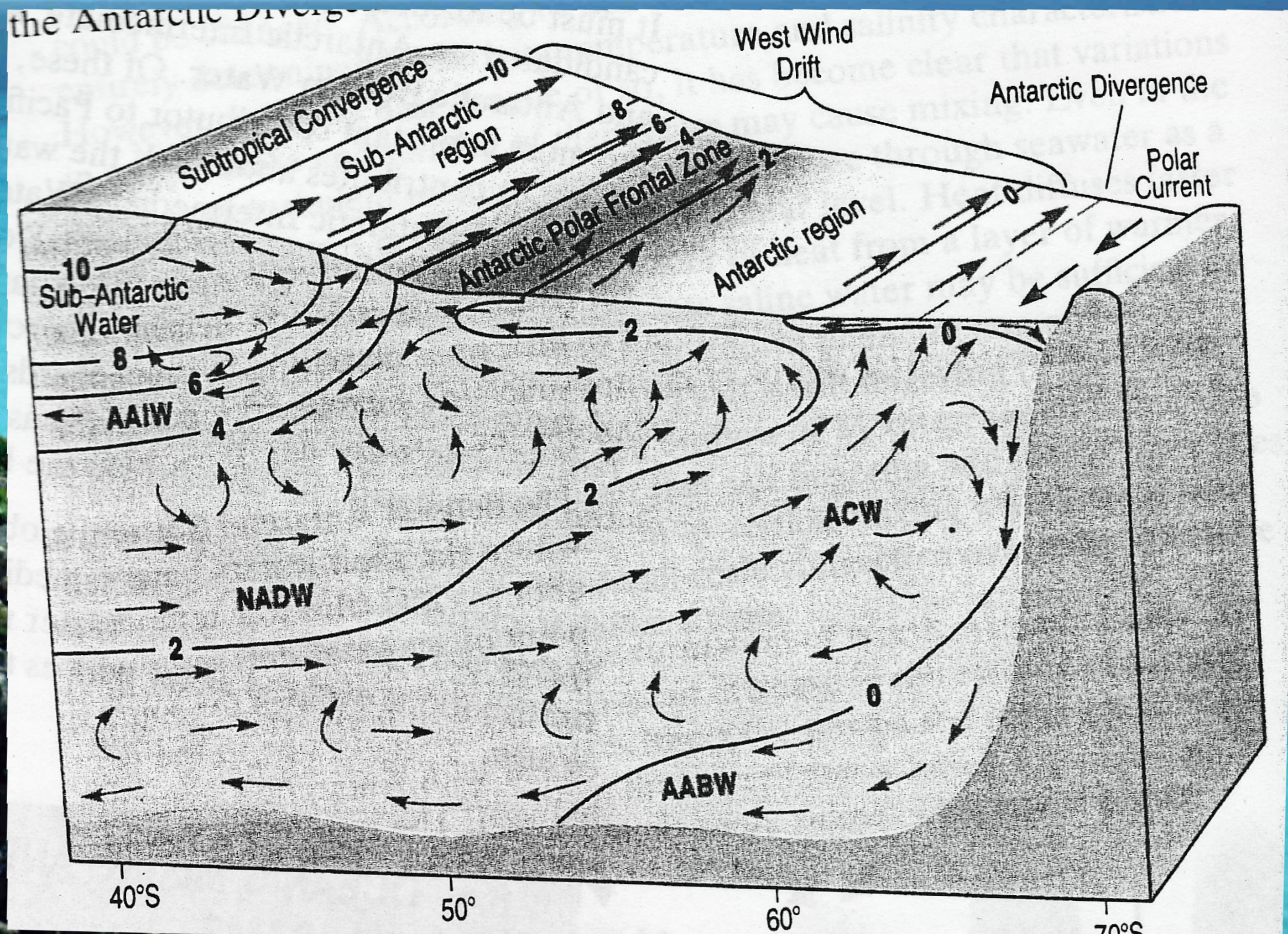
An oceanographic section



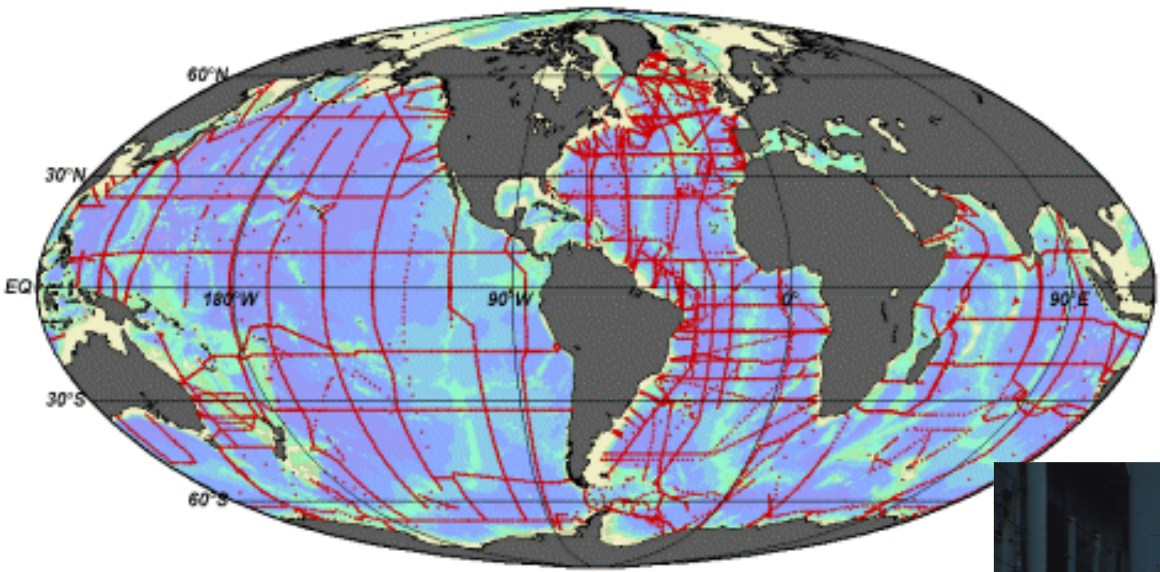


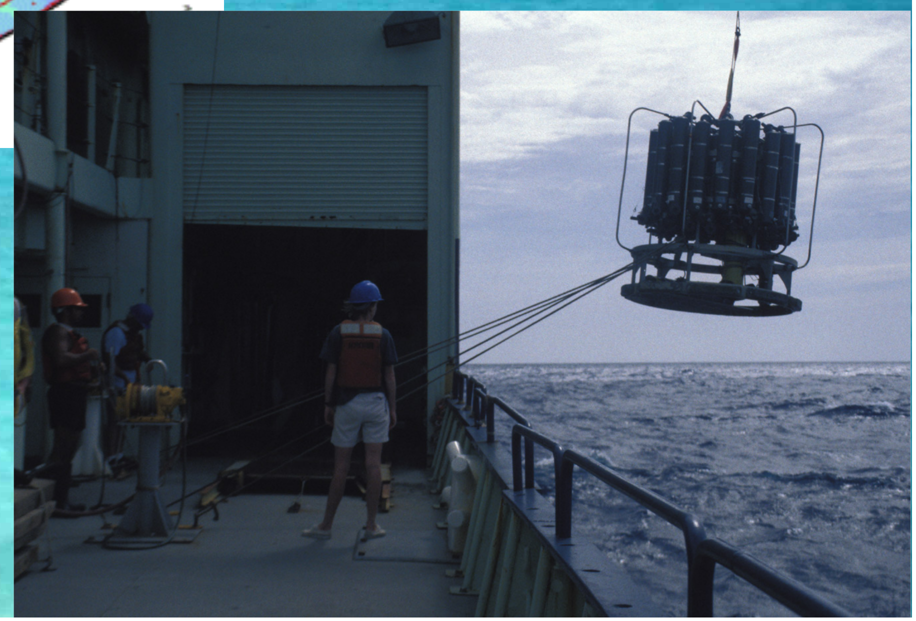


Antarctic water masses



WOCE: World Ocean Circulation Experiment (1990-2002)



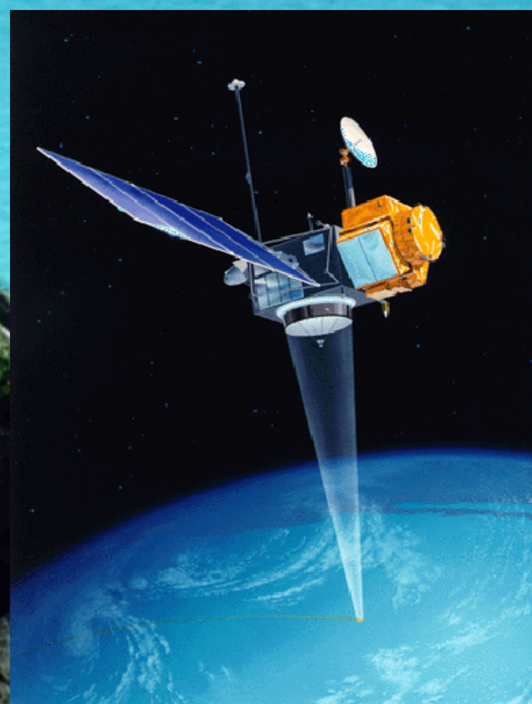


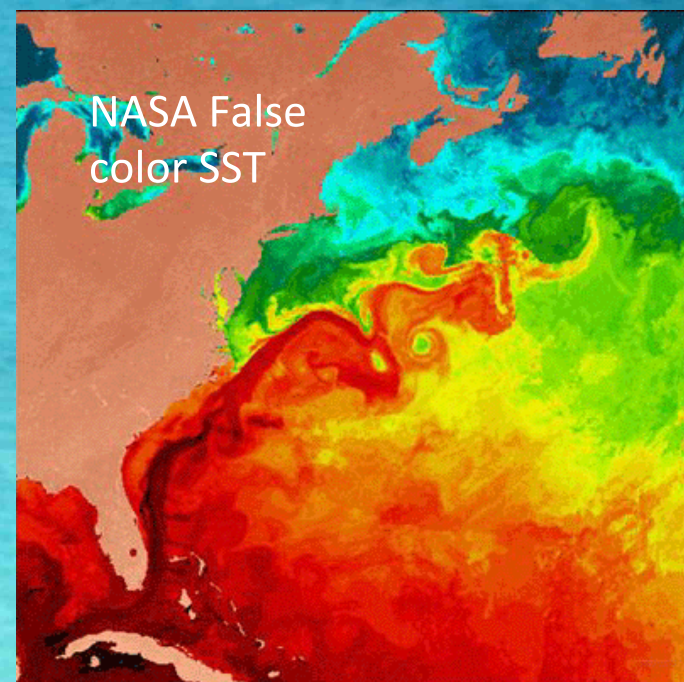
First systematic, global hydrographic survey


The ocean is vastly undersampled

Impression of smooth flow is erroneous

- The traditional view of a smooth, steady flow is largely due to insufficient observation of variability



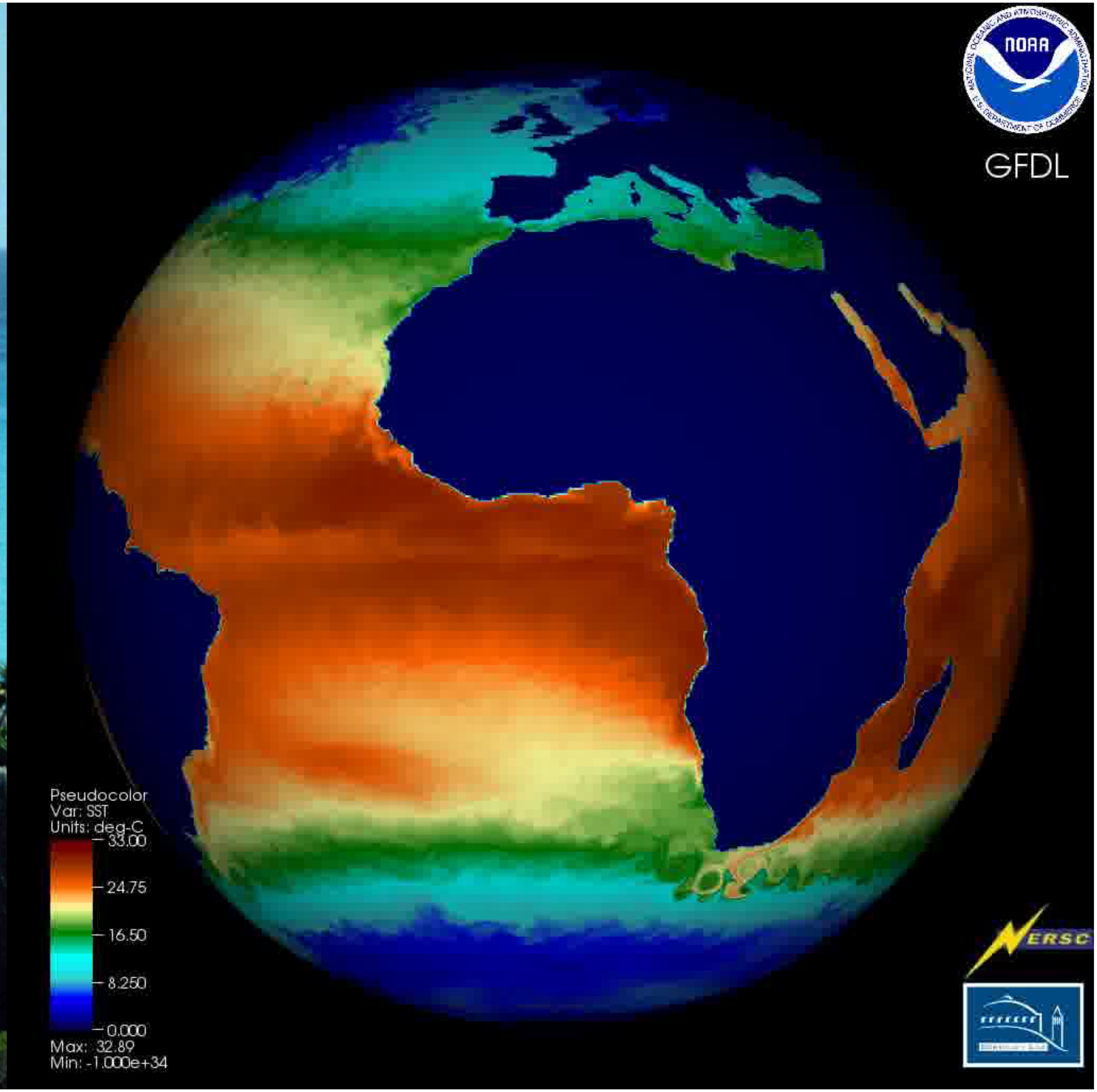


1 year coupled climate simulation

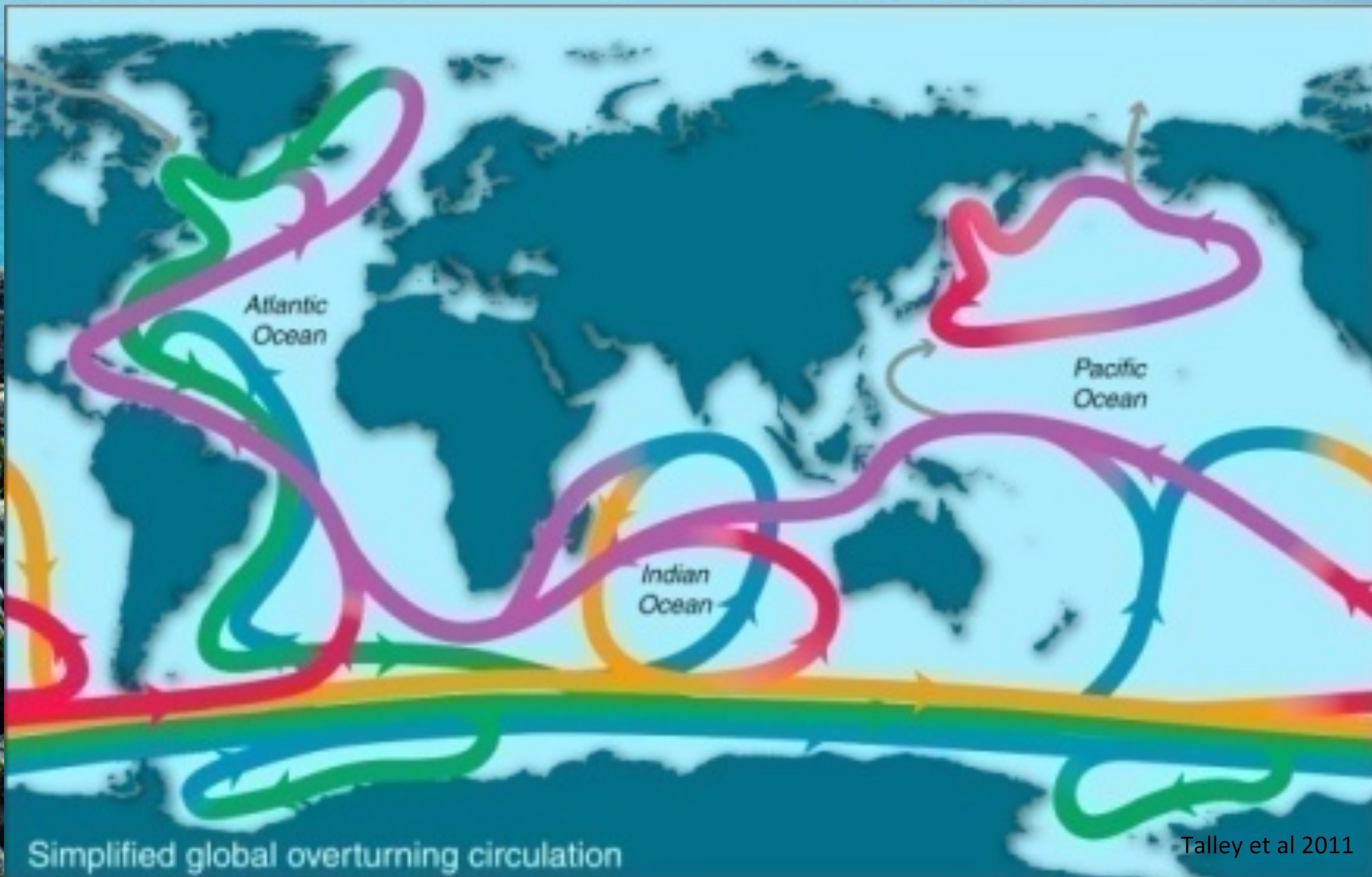
Ocean: 0.1° to 0.25°

Atmosphere: 1°

http://www.aos.wisc.edu/~galen/research.html

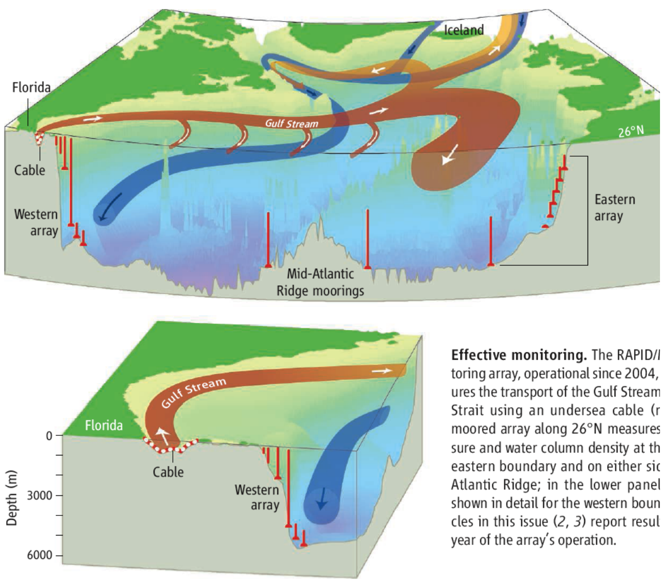


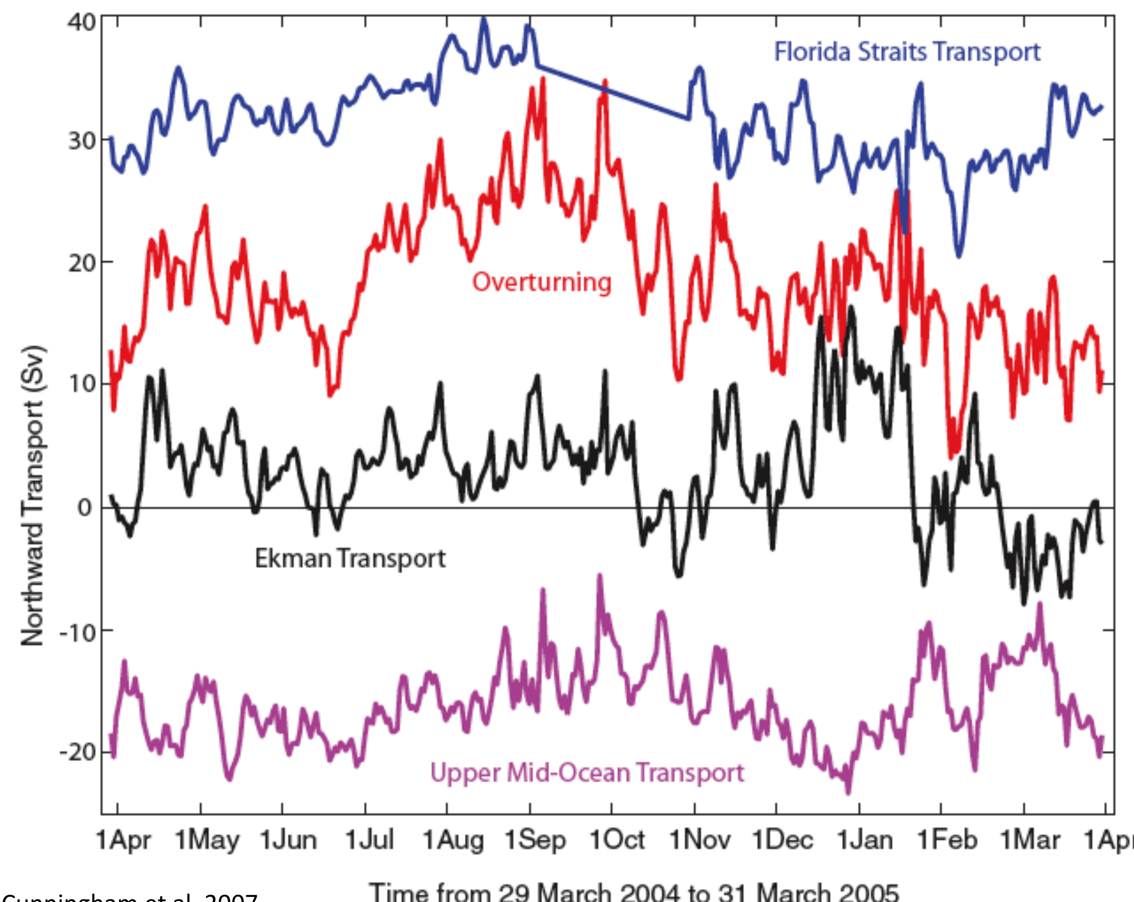
Simplified overturning circulation



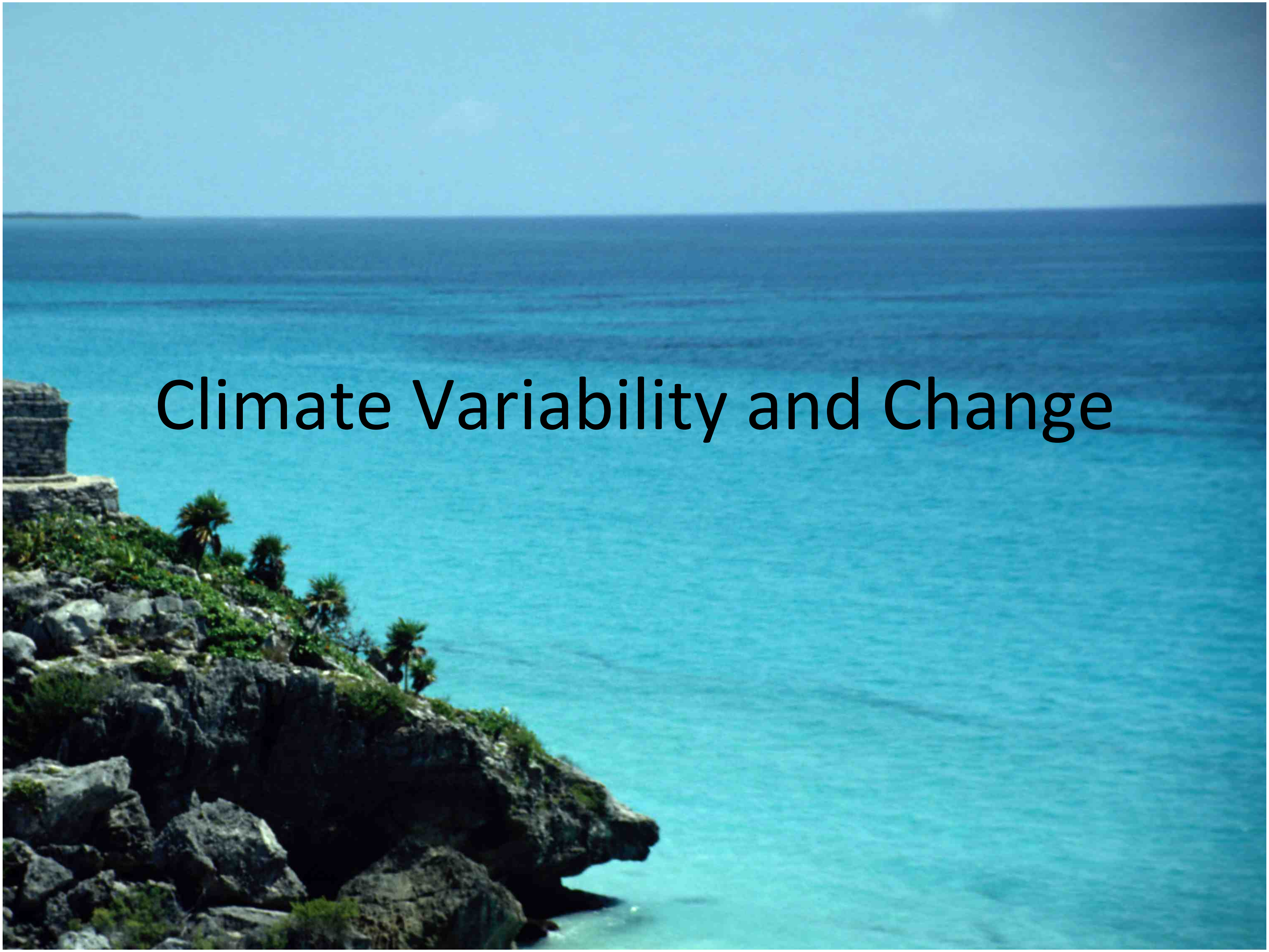
TALLEY

Variability in the thermohaline circulation in the North Atlantic

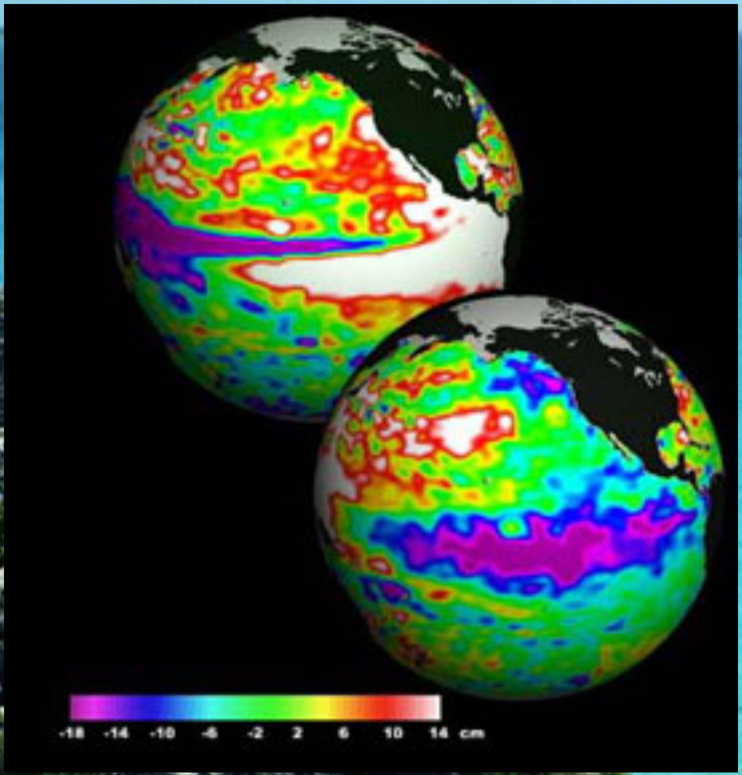


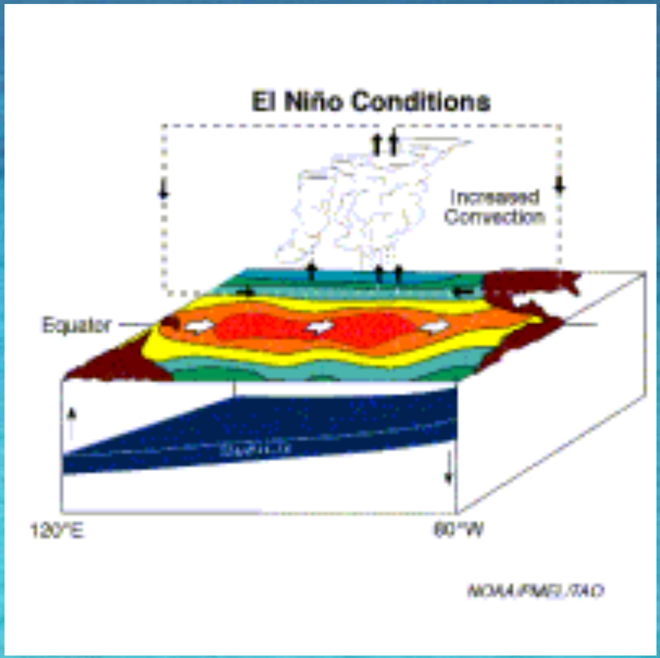


Cunningham et al. 2007


Climate Variability and Change

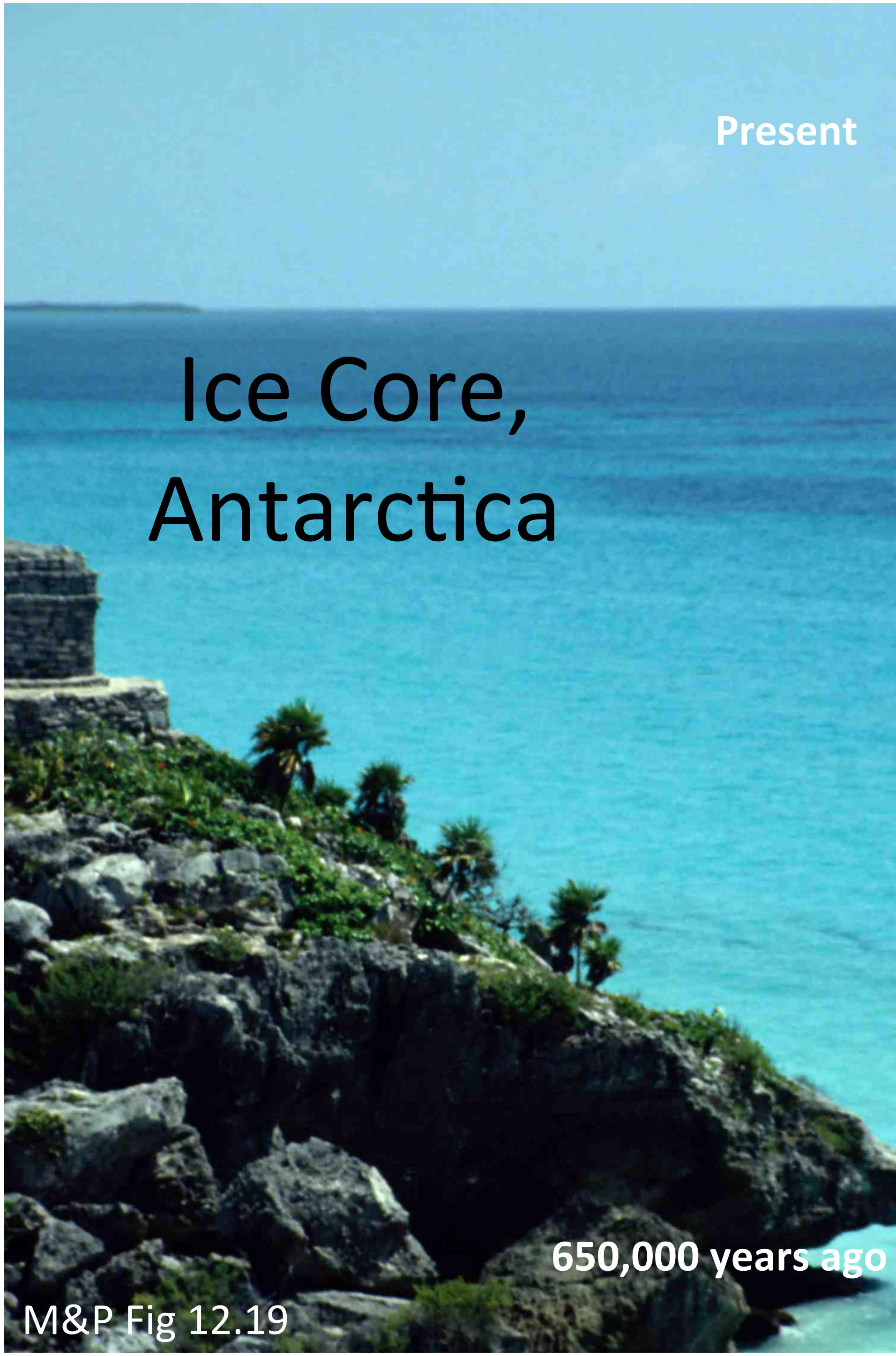
El Nino / Southern Oscillation



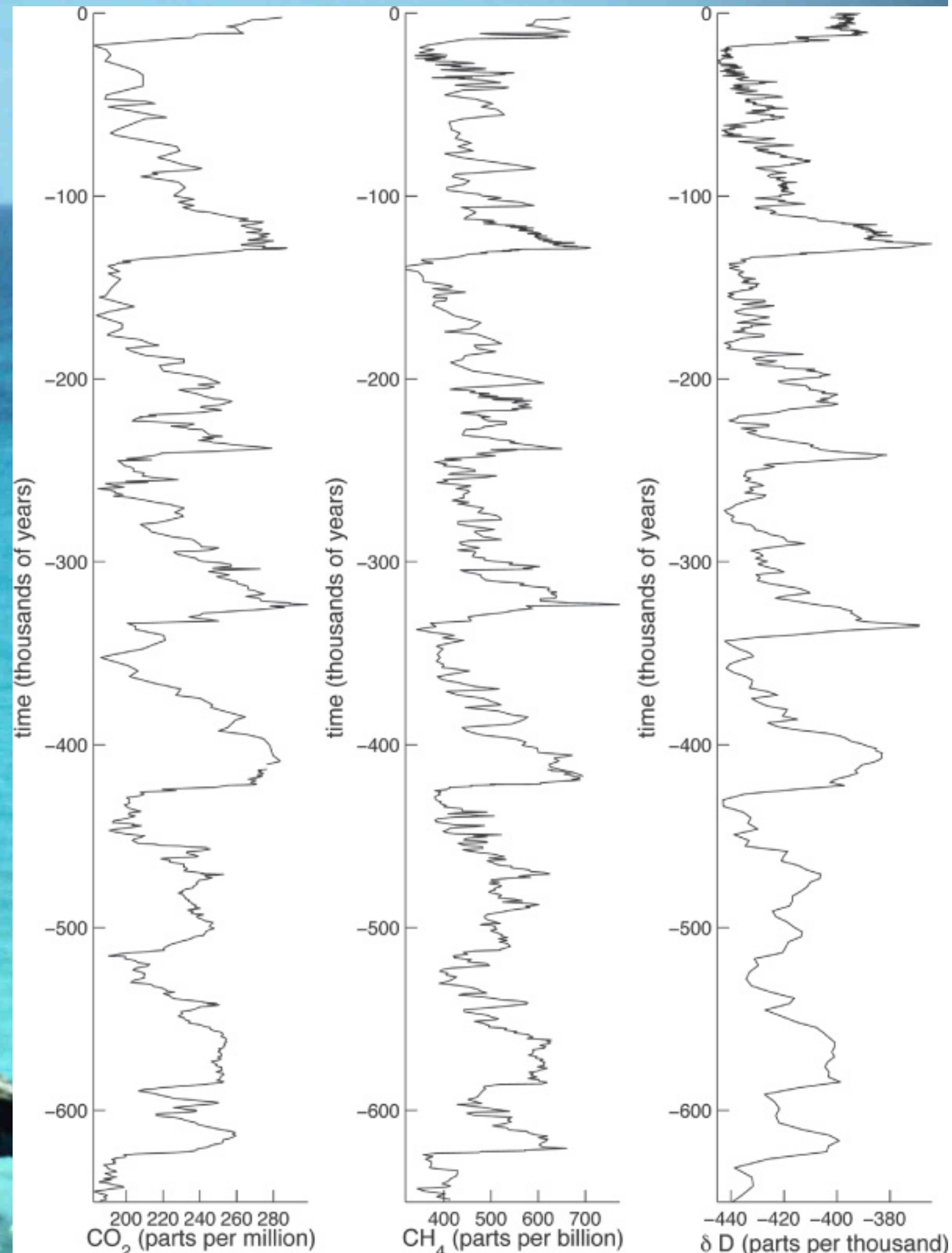


http://www.cpc.noaa.gov/products/precip/CWlink/MJO/enso.shtml

Ice Core, Antarctica

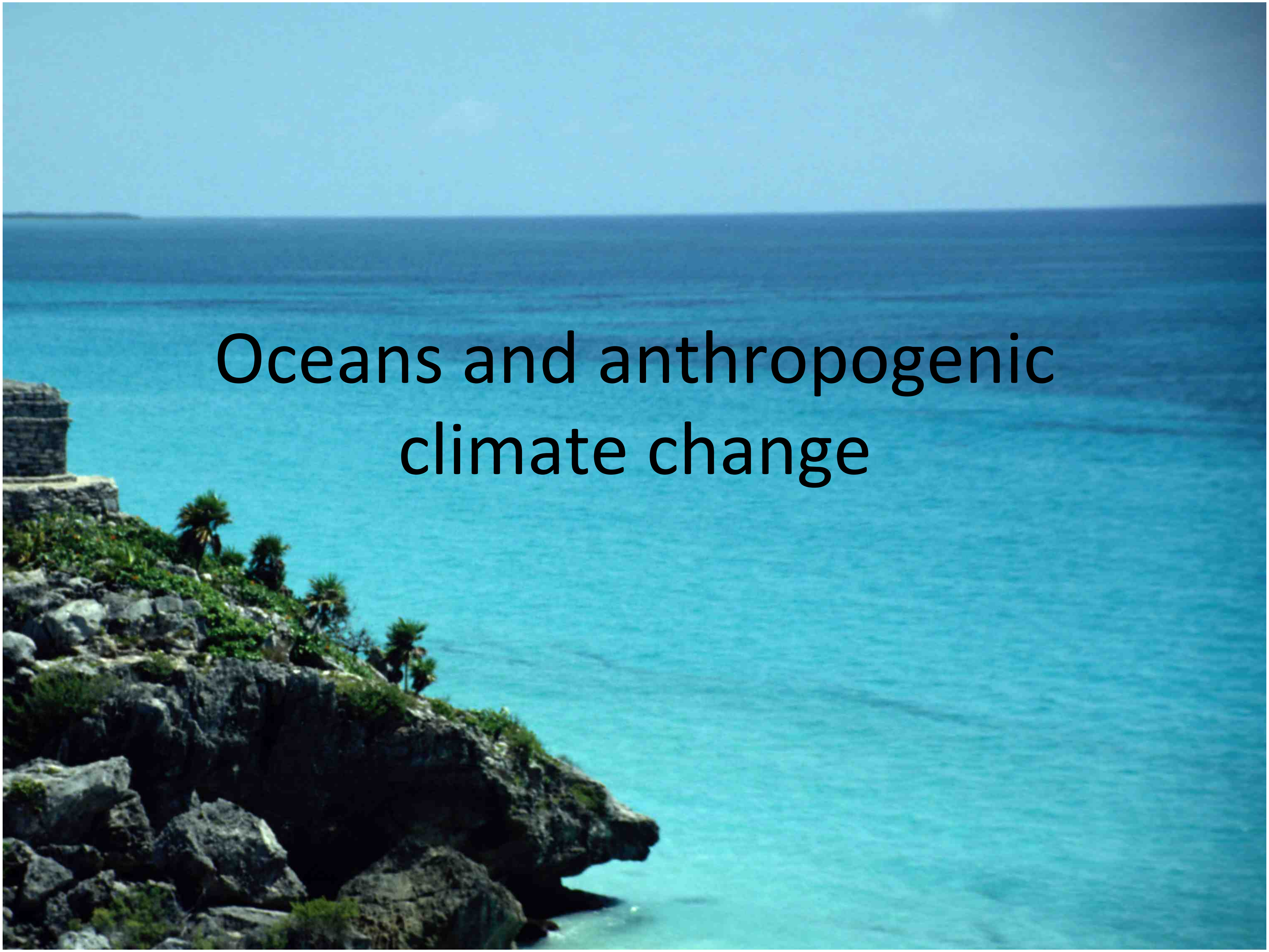


Present



650,000 years ago

M&P Fig 12.19


Oceans and anthropogenic
climate change

Ocean’s large heat capacity allows substantial modulation of climate warming

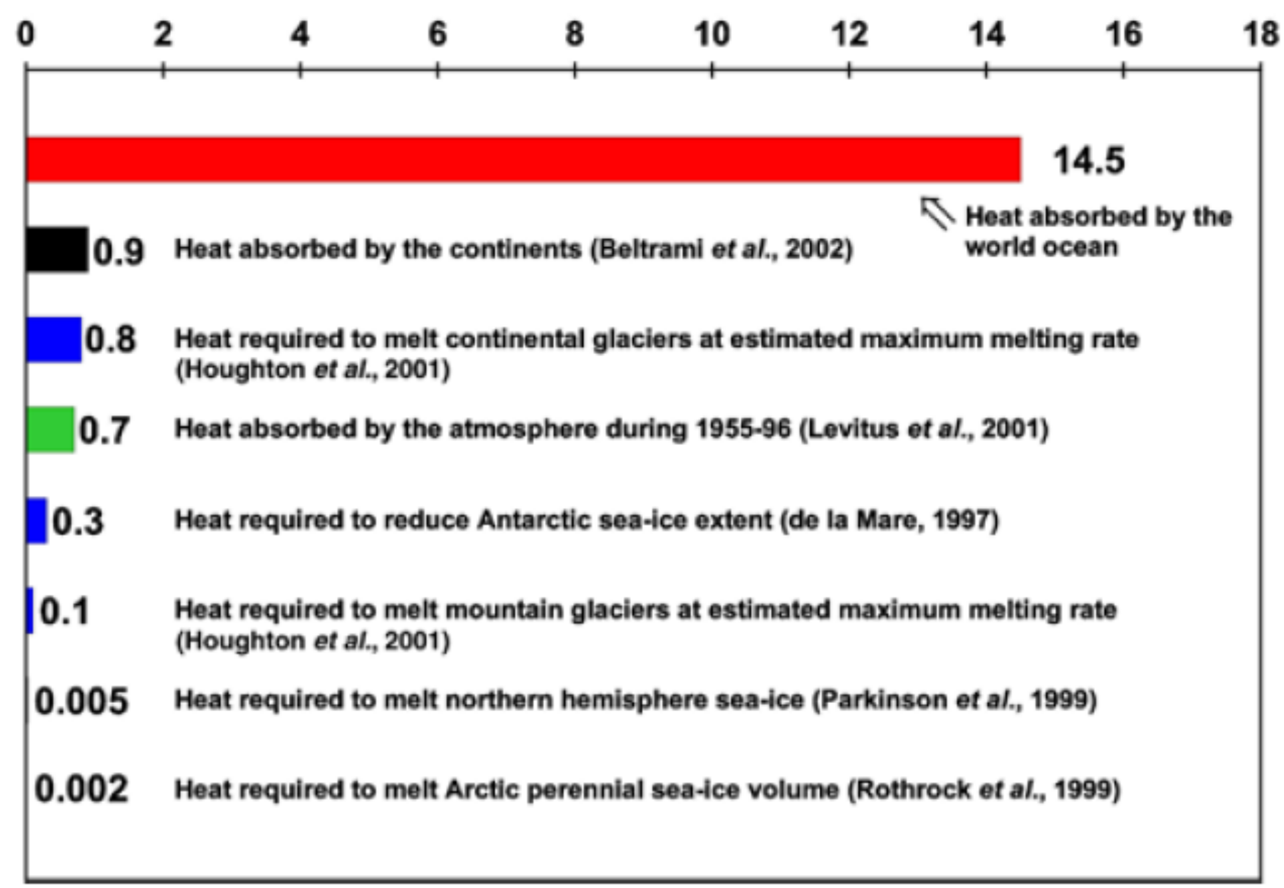
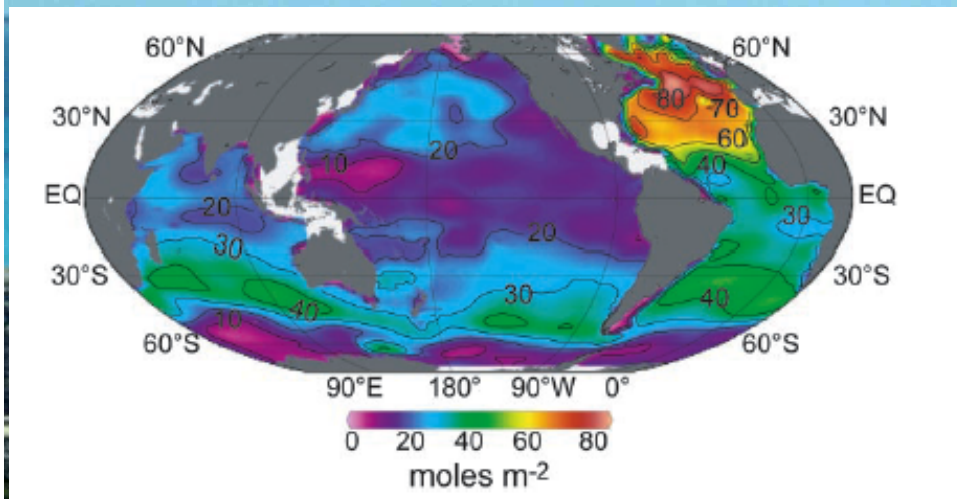
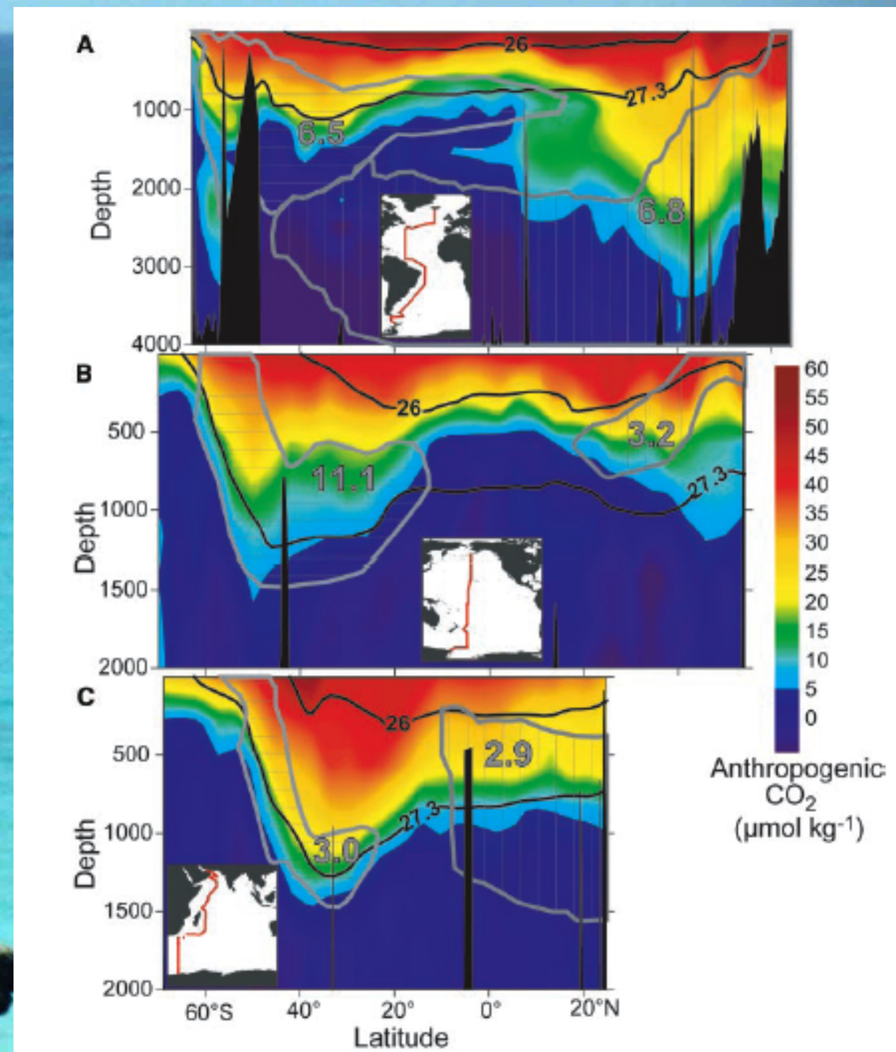


Figure 3. Estimates of Earth’s heat balance components (10^{22} J) for the 1955–1998 period.

Levitus et al. 2005

Oceans absorb anthropogenic CO_2



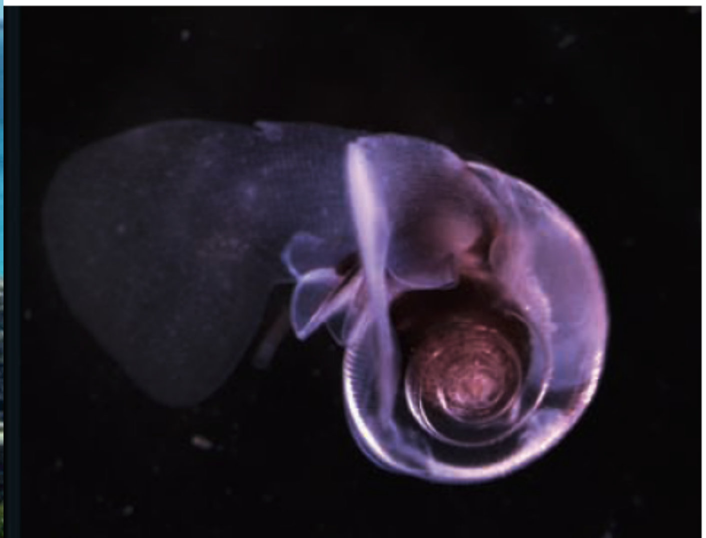


48% of anthropogenic carbon since 1800 has been absorbed

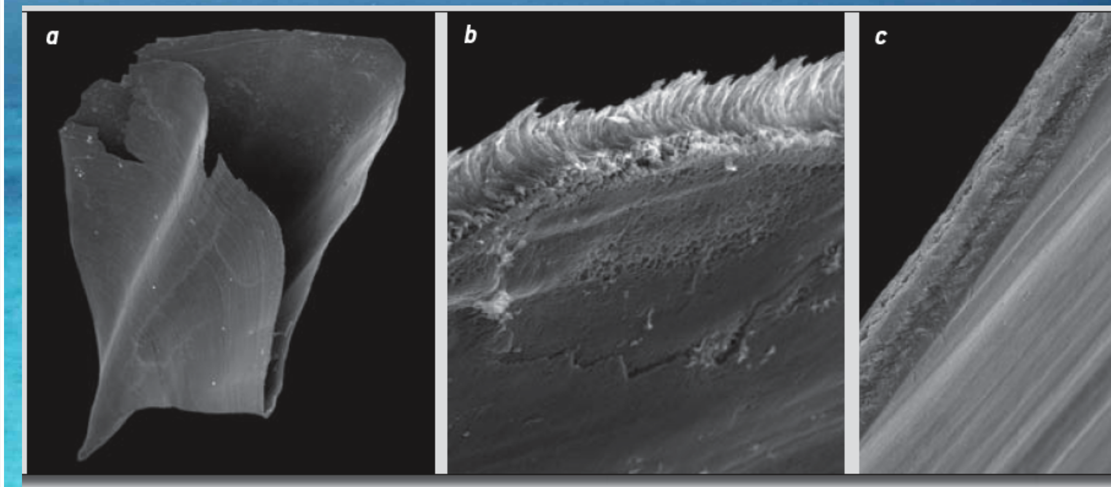
~25% of current annual output is absorbed

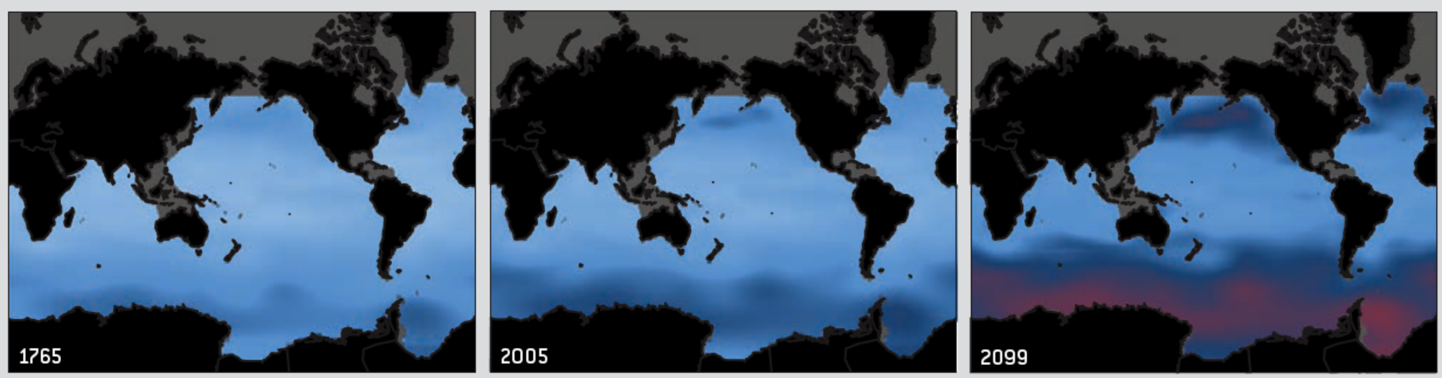
Sabine et al. 2004

But the uptake also drives acidification – ecological impacts?



Pteropod (*Limacina helicina*)





Before the Industrial Revolution (*left*), most surface waters were substantially "oversaturated" with respect to aragonite (*light blue*), allowing marine organisms to form this mineral readily. But now (*center*), polar surface waters are only marginally oversaturated (*dark blue*). At the end of this century (*right*), such chilly waters, particularly those surrounding Antarctica, are expected to become undersaturated (*purple*), making it difficult for organisms to make aragonite and causing aragonite already formed to dissolve.

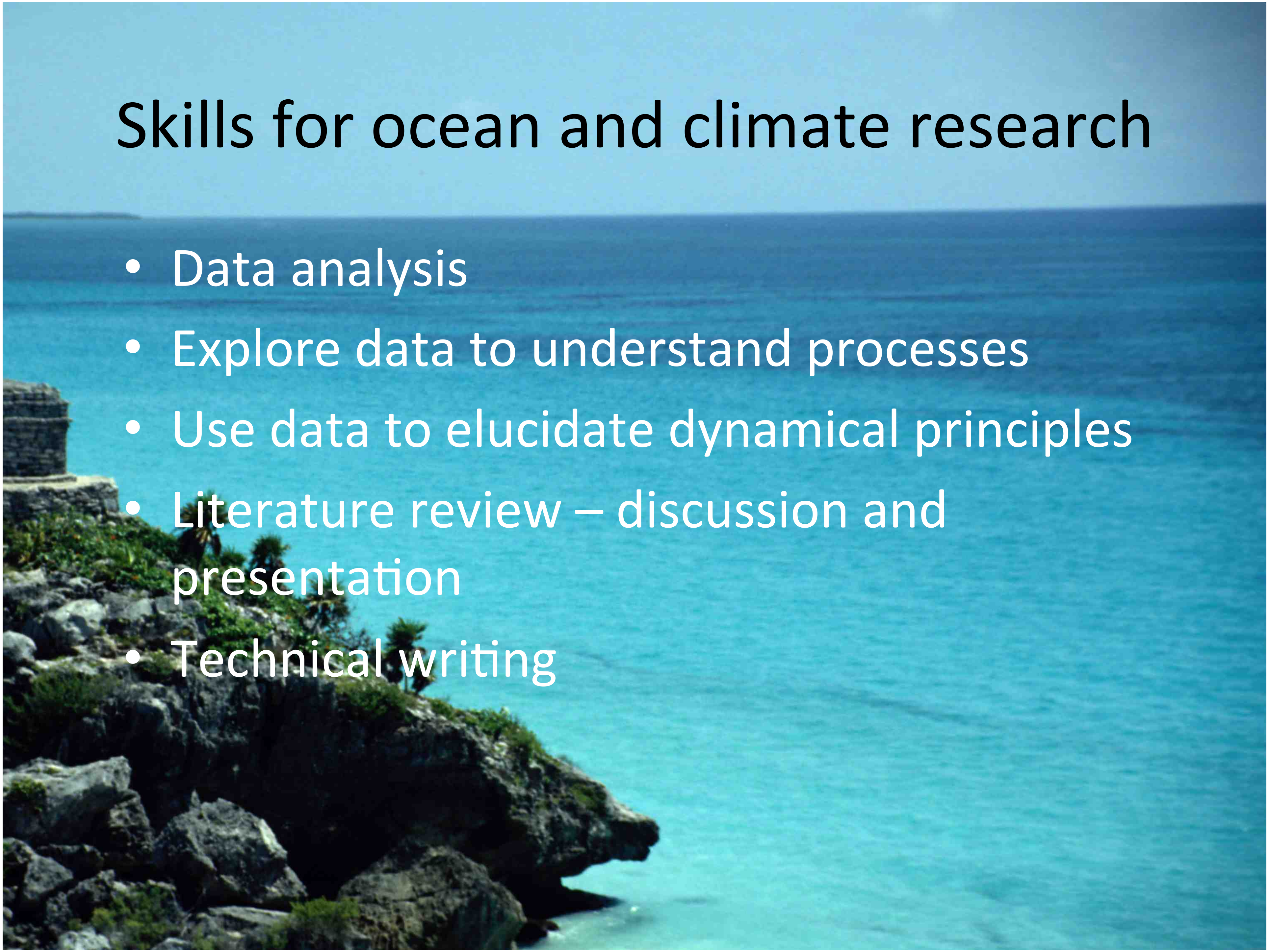
Doney 2006

Summary

- Ocean is integral to the climate system. It carries substantial heat from equator to pole.
- Circulation can be explained by Navier Stokes on a rotating sphere, forced by winds and buoyancy fluxes at the surface
- The ocean is vastly undersampled
- The flow is not smooth -- Eddies are everywhere
- The large heat capacity of the ocean affords it “memory” important on anthropogenic timescales
- The ocean’s role in the carbon cycle is critical to understanding and predicting anthropogenic climate change

Current Research

- Knowledge of the ocean is rapidly expanding
- We will read and discuss papers this semester
- Student pairs will lead the discussion
- Everyone is expected to participate each time – your participation will be noted, and you may be called on at random


Skills for ocean and climate research
• Data analysis
• Explore data to understand processes
• Use data to elucidate dynamical principles
• Literature review – discussion and presentation
• Technical writing

Syllabus Review

- Please also read carefully before next class.
- Scheduling conflicts should be identified and discussed immediately