OCE/MPO 603
Introduction to Physical Oceanography

Dr. Lisa Beal
lbeal@rsmas.miami.edu
Room MSC 328
My background and research

- born in United Kingdom
- PhD at National Oceanography Centre, Southampton, UK
- Postdoc at LDEO, Columbia University, NY
- Postdoc at Scripps Institution of Oceanography, UCSD, CA
- Assistant to Full Professor at RSMAS
My background and research

Western boundary current structure, variability, and transport

Circulation of the western Indian Ocean, including Somali Current and Agulhas Current systems

Ocean observations: velocity, temperature, salinity, sound speed

Global thermohaline / overturning circulation

The role of the ocean, in particular the Agulhas System, in climate and climate change
Some important concepts about the Ocean and Oceanography

Oceanography is a relatively young science. Pretty much everything that was known about the physical oceans could be written in one book back in 1942 (The Oceans: Sverdrup, Johnson, and Fleming).

The theory of the wind-driven ocean (Sverdrup, Stommel, Munk) came about in 1950.
The wind stress and the rotation of the planet produce an ocean current to the right of the wind in the northern hemisphere.

This creates a gyre with a narrow, fast western boundary current.
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The theory of the deep circulation (Stommel) came about in 1958 and is still being refined today.
The global abyssal circulation largely results from deep convection and sinking of surface waters in the North Atlantic and in the Weddell Sea (black circles) and upwelling of deep waters through the thermocline (aided by topography) elsewhere in the world’s oceans (Stommel 1958).
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Full-depth profiles of ocean density (giving water mass and flow characteristics) were made possible with the invention of the CTD (Brown, Hamon) in 1955.
Conductivity-Temperature-Depth (CTD)
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Full-depth profiles of ocean water properties (giving density and geostrophic flow) were made possible with the invention of the CTD (Brown, Hamon) in 1955.

The first numerical ocean model (Bryan, Cox) was in 1969.
Many of today's ocean and climate models can be traced back to Bryan and Cox's model.
Some important concepts about the Ocean and Oceanography II

Measurements with global coverage began when SeaSat was launched in 1978 to monitor SST, waves, sea ice, wind speed and direction. But measurements restricted to the surface.
In 1978, NASA's Jet Propulsion Laboratory built an experimental satellite called SEASAT to test a variety of oceanographic sensors including imaging radar, altimeters, radiometers, and scatterometers.
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Direct measurements of ocean velocity from moving ships were made possible in 1980 (Joyce, Pinkel), through the invention of an acoustic current meter. Full depth profiles after 1990.
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Direct measurements of ocean velocity from moving ships were made possible in 1980 (Joyce, Pinkel) through the invention of the ADCP and only to full depth after 1990 (L-ADCP).

In 1992 a pop-up float was developed that could be satellite-tracked (ALACE – Davis, Webb), leading to the profiling float.
1. Float deployed by ship or aircraft

2. Slow descent to 2000 metres
   6 hours at 10 cm/s

3. Drift for 9 days with ocean currents

4. Oil pumped from internal reservoir to inflate external bladder causing float to rise

5. Temperature & salinity profile recorded during ascent

6. Up to 12 hours at surface to transmit data to satellite

7. Oil pumped back to internal reservoir
   New cycle begins

8. Data sent to weather and climate forecasting centres around the world
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 Global drifter and ARGO arrays reached density circa 2004 (Niiler, Roemmich): A new era of global ocean observation.
A few more important concepts about the Ocean and Oceanography

- The ocean is not well known.
- We can now describe the time-average circulation of the ocean fairly well, but have only begun to describe its variability.
- The equations describing a turbulent ocean subject to chaotically variable winds and uneven solar forcing on a rotating planet are complex and unsolvable (without simplifying assumptions). Observations are essential for understanding the ocean.
- Lack of observations and sampling errors are insurmountable in oceanography and can lead to misleading concepts.
- Oceanographers are relying more and more on large data sets from satellites, floats, and moorings and less and less on observations collected from ships.
The ocean is an integral part of the climate system
Many climate modes are driven by coupled Ocean-atmosphere feedbacks

1. El Niño-Southern Oscillation (ENSO)
2. North Atlantic Oscillation (NAO)
3. Pacific Decadal Oscillation (PDO)
4. Indian Ocean Dipole (IOD)
5. SubAnnular Mode (SAM)
Atlantic Multi-decadal Oscillation (AMO)

Driven by variability of the Atlantic Meridional Overturning Circulation? Linked to sea ice?
The Agulhas leakage fauna as a measure of Indian Ocean advection into the Atlantic.

Marine Isotopic Stages, T-I to T-VI refer to the major glacial terminations.

The oxygen isotope 

22

4

The 

3

16–18

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8

3

2

1

4

9

2

5

6

7

10

12

14

Tropical–subtropical Agulhas leakage fauna

The relative abundance of

h

The relative abundance of

r


Agulhas Current/leakage

“leakage”

ice volume

sea surface temperature

Agulhas Current/leakage implicated in rapid glacial terminations
The ocean helps to regulate global warming, through uptake of anthropogenic heat and CO2 - but will it continue to do so?