Wind Driven Ocean Circulation

Maury Project Module
American Meteorological Society

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The Maury Project

exploring the physical foundations of oceanography

The Maury Project is a teacher professional development program based on studies of the physical foundations of oceanography. It is directed towards improving teacher effectiveness in generating interest and understanding in science, technology, and mathematics among precollege students. The project is named after Matthew Fontaine Maury (1806-1873), considered by many as the father of oceanography.

The AMS has a long-term interest in precollege ocean education. It serves the atmospheric and related oceanic and hydrologic sciences, and publishes oceanographic research journals.

Major components of the Maury Project include (a) the identification and training of a cadre of master oceanographic education resource teachers who will assist the AMS in training other precollege teachers on the physical aspects of oceanography.
Maury Project Modules

- Density-Driven Ocean Circulation
- Wind-Driven Ocean Circulation
- Ocean Tides
- Ocean Tides on the Web
- Deep-Water Ocean Waves
- Coastal Upwelling
- Measuring Sea Level from Space
- Shallow-Water Ocean Waves
- Ocean Sound
- El Niño - La Niña
- AMS Pressure Blocks
Drop a bottle in the ocean.

Predict where does it end up?

Suppose you want to throw a bottle in the ocean.

1. Pick a location and mark with an X on your map.
2. Predict where you think your bottle will wash ashore. Mark with a Star on your map.

https://goo.gl/UbeJ7w
Historically a Very Difficult Question…
A Guarded Secret…

Explorers
https://goo.gl/jr6RbY

Whalers
https://goo.gl/jfhT4Y
Ben Franklin was the Colonial deputy Postmaster General (1753-1774) noticed that British vessels took days to weeks longer to cross the Atlantic than their American counterparts.

The British wanted to know why...
After consulting with his cousin, Timothy Folger, a whaling captain from Nantucket, published the map on left.

It is interesting that even after Franklin’s information, British authorities didn’t take advantage of the insight.

Ocean Studies Book p 156
There is a river in the ocean. In the severest droughts it never fails, and in the mightiest floods it never overflows. Its banks and its bottom are of cold water, while its current is of warm. The Gulf of Mexico is its fountain, and its mouth is in the Arctic Sea. It is the Gulf Stream.

From his *Physical Geography of the Sea*, 1855
Clearly there is movement, current in the ocean, but what causes the current?

NASA’s Perpetual Ocean
https://www.youtube.com/watch?v=xusdWPuWAoU
Winds and Ocean Currents

Do a little activity
Here’s what you are doing....

Place
- Desired map under water container
- Paper punches on the surface of the water

Blow
- Air with straw down the 0° line (the equator from the right side of the bowl to the left)

Observe
Try with multiple people doing....

Blow
- Blow with straw down the 0° line
- With additional straws, (and additional people) blow at 50-60° both north and south from left to right.
- Observe
Introduction: Wind-Driven Ocean Circulation

The two atmospheric circulations and the upper oceanic circulation are closely linked, with the sun being the ultimate source of energy for both circulations. Unequal heating of the atmosphere produces atmospheric circulation and wind. The wind blowing over the surface of the water drives the ocean's major surface currents. These currents, along with the wind, transfer heat from tropical regions to polar regions. When you finish observing, pick up and read Introduction: Wind Driven Ocean Circulation.
Gyres

Large circular wind driven currents found in the ocean basins

Gyre Locations determined by three factors
1. Earth’s Rotation
2. Location of Earth’s major wind belts
3. Continents

https://goo.gl/ZpD44B
Origin of Wind...
Atmospheric Heating and Cooling
Origin of Wind... Atmospheric **Heating** and Cooling

https://oceanservice.noaa.gov/education/tutorial_currents/media/supp_cur04c.html
Global Wind Patterns

https://goo.gl/VLJrkR
Earth’s rotation causes water to pile up on western side of ocean basin.
Coriolis Effect…
Another Effect of the Earth’s Rotation

Air and water are both deflected because of the earth’s rotation.

Clockwise in the Northern Hemisphere
Counterclockwise in the Southern Hemisphere

https://oceanservice.noaa.gov/education/kits/currents/media/supp_cur05b.html
Eckman Transport Spiral

In addition to surface effect, there is a dimensional effect, an almost corkscrew-like circulation pattern.
So the actual ocean currents are complicated...
So is finding our bottle hopeless?
Activity: Predicting the Patterns and Characteristics of Surface Ocean Currents

Introduction

When viewed from space, the surface currents of the major ocean basins can be seen to follow the prevailing wind systems that drive them. Contained by continental boundaries and deflected by the Earth’s rotation, these surface currents flow in large, roughly circular patterns called gyres. The gyres play an important role in redistributing heat from the low to the high latitudes, thus influencing ocean temperature, weather, and climate. The following activity investigates gyres by first looking at single surface currents and then building to a global perspective of ocean gyre circulation.

Materials

A set of current cards, a Global Ocean Basin Chart, and a Global Ocean Surface Current Chart.

Objectives

After completing this investigation, you should be able to:

- Describe the typical gyre circulation pattern found in each of the major ocean basins.
- Describe the relative speeds, temperatures, and directions of the currents comprising a typical gyre.

Method

1. Cut out the entire set of current cards. Sort them into four groups by Northern or Southern Hemisphere and Atlantic or Pacific Ocean basin. For example, all four Northern Hemisphere Atlantic cards should be in one group and all Southern Hemisphere Atlantic in another group.

2. Randomly choose one of these four groups. From the selected group, choose two current cards and examine the front of the cards. On the Global Ocean Basin Chart, pencil in these two currents. Flip the cards over and examine the information on the back, comparing and contrasting them to identify any similarities.

3. Use these relationships, and the limited information contained on the two real cards, to predict the location and characteristics of the other two currents in the same basin and hemisphere. On the Global Ocean Basin Chart, check your predictions by examining the remaining two cards. If your predictions are correct try to determine why they were right and why they were not.

4. Use the Global Ocean Surface Current Chart, and Global Ocean Basin Chart, in your predictions of these three currents and their temperatures. If your predictions are not correct, try to determine why they were wrong and draw in the

5. a. All of the first group of cards have been examined. Select the next two cards from the other basin in the same hemisphere. From this select only one card. Examine both sides of the card and on the chart:

   - Locate and identify the gyre.
   - Location and characteristics of the other three currents in this hemisphere. On the chart, pencil in lightly these three currents and their general location as you predict them. Check your predictions by examining the cards and make any changes on your chart.

   b. In turn, each of the two groups of cards from the opposite hemisphere have been examined. Follow the same procedure above, selecting one card from the second group to make your predictions. Again use the Global Ocean Surface Current Chart, and Global Ocean Basin Chart, in your predicted currents and their characteristics.
Make a Prediction for the Major Ocean Gyres (currents)
Where do you think they are found?

With the Maury activities, there is lots of versatility, room for creative implementation
● Take one paper of each color.
● Cut apart the cards. Put in piles by color.
● Follow the directions on pages 5-6 of teacher guide.
● Use blue colored pencils for cool/cold currents and red for warm/warming currents (draw arrows to represent currents.)
Check the cards to see if you were right and what other information you could glean from the cards.
After you’re done, check out the questionnaire/formative assessment with the activity.
1. The Trade Winds that prevail between the equator and a latitude of 30 degrees have strong east to west components. Ocean currents under the Trade Winds flow generally in the \( \text{same} \) (opposite) direction.

2. The Prevailing Westerlies found between a latitude of 30 and 60 degrees are winds that have a strong west to east component. Ocean currents under the Prevailing Westerlies flow generally in the \( \text{same} \) (opposite) direction.

3. The ocean currents driven by these prevailing wind systems are deflected by continental boundaries to help form the gyres. The one latitude where blocking continental boundaries are lacking is \( 0 \) (30 N) (30 S) (60 N) (60 S).

4. The ocean gyres in the major ocean basins form large, roughly circular, closed currents which are centered at a latitude of approximately \( 0 \) (30) (60) degrees.

5. As seen from space, the gyre circulation patterns in the Northern Hemisphere show a \( \text{clockwise} \) (counterclockwise) flow. In the Southern Hemisphere, these gyre circulations are \( \text{clockwise} \) (counterclockwise).

6. Near Perth, located on the west coast of Australia, the ocean gyre current flows from the direction of the \( \text{Equator} \) (South Pole).
7. In ocean gyres, regardless of hemisphere, warm water is transported poleward in the (eastern) (western) region of each ocean basin. The cold currents from the higher latitudes are found in the (eastern) (western) region of each ocean basin.

8. Near Peru, located on the west coast of South America, the ocean gyre current is (warm) (cold).

9. In ocean gyres, regardless of hemisphere, the faster currents are found in the (eastern) (western) region of each ocean basin. The slower currents are found in the (eastern) (western) region of each ocean basin.

10. Near Tokyo, Japan, the ocean gyre surface current is (fast) (slow).
11. Locate the North Indian Ocean on the Global Ocean Surface Current Chart. There is no permanent gyre there since the ocean basin does not extend into the latitudes of the current-driving Prevailing Westerlies. Another contributing factor is the seasonal reversing of the surface currents due to the influence of the (steady trade winds) (seasonally reversing monsoon winds).

12. In the Southern Hemisphere, the strong Prevailing Westerly winds and the lack of blocking land in the southern region of all the major ocean basins contribute to the formation of a circumpolar current around Antarctica called the West Wind Drift. According to the information on the activity card, these factors help make this current the (fastest) (largest volume) in the world ocean.

13. The surface circulation of the ocean is primarily a consequence of the interaction between the Sun, the atmosphere and the ocean. From what you have learned in this activity, explain why.
Movement of water moves energy from the equator to the poles
Western side of basin narrow, fast moving, deep current
Eastern side of basin broad, shallow, slow current
Tropics pile water up on western margin of ocean basin... Steady trade winds and westward flowing equatorial currents...
Equatorial currents result in equatorial counter currents

El Niño and La Niña and Cyclical weather patterns

https://goo.gl/U6p8sD
Upwelling... Bioproductivity in the Oceans

https://oceanservice.noaa.gov/facts/upwelling.html
Notice colder, upwelling areas along California’s and Peru’s coastal regions.
So, where is your bottle?

Message in a Bottle

Suppose you want to throw a bottle in the ocean.

1. Pick a location and mark with an X on your map.
2. Predict where you think your bottle will wash ashore. Mark with a Star on your map.
The Great Pacific Ocean Garbage Patch
Cool Teacher Professional Development Opportunities

- PolarTREC - Arctic or Antarctica
- Earthwatch TEACH Earth – Mexico, Ecuador, USA
- American Wilderness Leadership School (AWLS) – Jackson Hole, WY
- The Maury Project – Annapolis, MD
- Project Atmosphere – Kansas City, MO
- Forestry Institute for Teachers (FIT) – central/northern CA
- NOAA Teacher at Sea – various shipboard expeditions
- Library of Congress Teaching with Primary Sources (TPS) – Washington DC
- On the Farm – American Farm Bureau – various locations (OR, TX, KS, NY)
Survey and Teacher’s Guide

Please complete the participant’s questionnaire....
A wonderful resource is...

Joseph Moran 3rd Edition

ISBN-10  1-878220-49-9

Or