Session 5.

CHARACTERISTICS OF OCEAN CURRENTS
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The Ocean: A Driving Force for Weather and Climate

Video Source: NASA Goddard (https://www.youtube.com/watch?v=6vgvTeuoDWY)
What are ocean currents?

• An ocean current is a massive movement of ocean water that is caused and influenced by various forces.
• Ocean currents impact humankind and the biosphere due to their influence on climate.
• Ocean currents also affect people in other ways. As an example, a knowledge of ocean currents is essential to the reduction of fuel consumption and time spent at sea.
What are ocean currents caused by

The major factors that determine the direction and speed of ocean currents can be divided into three types:

1. Tides,
2. Winds, and
Currents Caused by Tides

• Tidal currents occur in conjunction with the rise and fall of the tides and are the only type of currents affected by the interactions of the earth, sun, and moon.

• Tidal currents are predictable and change in a very regular pattern.

• They are usually the strongest currents in coastal regions but are no direct importance to the circulation of the ocean waters.
Currents Caused by Tides (continued)

- In the entrance to a bay or in a river, the tidal current is on the reversing or rectilinear type.
- Out in the open sea, tidal currents change direction continually. Such currents are called rotary currents.

Graphic source: NOAA
Currents Driven by Winds

• The second factor that drives ocean currents is winds. Winds drive currents that are at or near the ocean's surface.

• Winds drive currents near coastal areas on a localized scale, and in the open ocean on a global scale.

Global Atmospheric Circulation
https://cimss.ssec.wisc.edu/
The last, but not the least, factor that drives currents is thermohaline circulation, i.e., a process driven by density differences in water due to temperature and salinity in different parts of the ocean. Currents driven by thermohaline circulation occur at both deep and shallow ocean levels and move much slower than tidal or wind-driven currents.
Groups of Ocean Currents by Water Depths

1. Ocean Surface Currents
   Primarily driven by winds, resulting in horizontal and vertical movement.

2. Ocean Deep Currents
   The result of density differences in water which is controlled by the difference in temperature and salinity.

Graphic source: NOAA /Ocean Explorer
Groups of Ocean Currents by Water Temperatures

1. **Warm-water Currents**
   Warm water currents form near the equator creating a warmer climate near the coastlines.

2. **Cold-water Currents**
   Cold water currents on the other hand form near the poles and travel towards the equator creating cooler climate near the coastlines.

Graphic source: NOAA
Special Ocean Current Systems

• The equatorial currents system
• Western and eastern boundary currents
• The Antarctic Circumpolar Current and
• The Arctic Ocean
Equatorial Currents System

Every ocean, except the Arctic Ocean, has a North Equatorial Current, a South Equatorial Current and an Equatorial Counter Current. The North and South equatorial currents flow from east to west. The Equatorial Counter Current is located between the North and South equatorial currents and flows in opposition to them, that is, from west to east.
## Ocean Boundary Currents Systems

<table>
<thead>
<tr>
<th>Boundary Currents</th>
<th>Atlantic Ocean</th>
<th>Pacific Ocean</th>
<th>Indian Ocean</th>
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<tbody>
<tr>
<td></td>
<td>North</td>
<td>South</td>
<td>North</td>
</tr>
<tr>
<td>Western</td>
<td>Gulf Stream (warm)</td>
<td>Brazil Current (warm)</td>
<td>Kuroshio (warm)</td>
</tr>
<tr>
<td>Eastern</td>
<td>Canary Current (cold)</td>
<td>Benguela Current (cold)</td>
<td>California Current (cold)</td>
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</table>
The Antarctic Circumpolar Current (ACC) is an ocean current that flows clockwise from west to east around Antarctica. An alternative name for the ACC is the West Wind Drift.
Arctic Ocean

There are no primary currents in the Arctic Ocean although there is a circumpolar flow. The Labrador Current (cold) and the East Greenland Current (cold) are outlets of the Arctic Ocean into the North Atlantic Ocean.
Ocean Currents Measurements

- Eulerian Measurement Method
  - Current meters deployed on moorings
  - Vertical profiling of horizontal currents using acoustic doppler current profiler (ADCP)
- Lagrangian Measurement Method
  - surface current measurement: Drifters
  - subsurface current measurement: Ocean Gliders and Argo profiling floats
- Remote Mapping of Sea Surface Currents
  - Using high-frequency (HF) Doppler radar networks
Eulerian Measurement Systems

• The Eulerian method is ideal for measuring temporal changes at multiple depths at representative or key sites, particularly for long-term time-series research, monitoring and data assimilation modeling.

• Eulerian surface current measurements using shore-based high-frequency (HF) radar systems provide spatial maps of surface current data.
Moored Current Meters

• Eulerian measurements involve describing fluid flow by measuring the speed and direction of the fluid at one point only.

• In this method, an instrument is anchored in the ocean at a given location, and the water movement is measured as it flows past the instrument.

An oceanographer deploys a current meter in the 1920s while working in Alaska. (source: NOAA/National Ocean Service)
An acoustic Doppler current profiler (ADCP) is a instrument that scientists use to measure how fast water is moving across an entire water column.
Applications of ADCP

Depending on the applications, ADCP can be distinguished among:

• Moored ADCP,
• Ship-mounted,
• Side-looking,
• Towed ADCP, or
• Lowered ADCP.

graphic source: http://www.rowetechinc.com/img/blog/adcp_applications/adcp_deployments_clean.png
Moored ADCP

- Surface Moored ADCP
- Subsurface Moored ADCP
Surface Moored ADCP

• Surface moorings (deep water) – typically utilizes an ADCP, up or down-looking, to measure currents.

• In the case of down-looking systems, the ADCP can be installed at the surface or below the surface.

• For up-looking systems the ADCP is installed below the surface and measures currents towards the surface.
Subsurface Moored ADCP

• Subsurface moorings are typically anchored to the sea floor.
• Most oceanographic applications systems are up-looking and measure currents and waves.
• There are some applications where the ADCP is installed on the sea floor and in a down-looking orientation in order to conduct boundary layer studies.
Ship-mounted ADCP

- Ship-mounted ADCP is often referred as shipboard ADCP (SADCP).
- The SADCP is a hull-mounted ADCP which measures the velocity of the upper-ocean currents below the ship. When used in conjunction with the ship’s heading and navigation data, absolute currents in the upper ocean can be determined.
Side-looking ADCPs are typically utilized in large channels and in harbors to monitor currents. Flow can be determined by knowing the water level and bathymetry.

Graphic source: http://www.teledynemarine.com
Lowered ADCPs

In order to obtain full-depth ocean velocities one or two ADCPs are lowered on a wire to some distance above the seabed and raised back to the surface. While the ADCPs are in the water they use acoustic pings to collect short (order 100m) velocity profiles measured in the frame of reference of the moving instruments.
Lagrangian Measurement Systems

• Surface drifters
• Subsurface floats: Used primarily in the deep ocean.
Surface Drifters

A drifter is an oceanographic device floating on the sea surface typically tracked by satellite to study ocean currents and other parameters such as water temperature and salinity.
Subsurface Floats

Argo is a global array of profiling floats that measures the temperature and salinity of the upper 2000 m of the ocean. This allows continuous monitoring of the temperature, salinity, and velocity of the upper ocean.
Ocean Gliders

An ocean glider is an autonomous, unmanned underwater vehicle equipped with a wide variety of sensors to monitor temperature, salinity, currents, and other ocean conditions.
Ocean Gliders

Ocean gliders use large moveable fins and a large on-board battery pack to gently change its buoyancy that allows the glider to slowly move up and down through the water.
High Frequency Radar System

High frequency (HF) radar systems utilize high frequency radio wave to measure the speed and direction of ocean surface currents (the top 1-2 m of the water column).

image credit: NOAA/IOOS
High Frequency Radar System

Depending on the radio frequency, HF radar antennas (typically in pairs) can measure surface currents with horizontal resolutions from 500 m to 6 km up to 200 km off the coast.

http://boon.ucdavis.edu/current_plots.html
References

- https://doi.org/10.1175/JPO-D-15-0046.1
For the purpose of familiarizing yourself with major ocean currents, visit NOAA’s Web application, “JetStream Max” at [https://www.weather.gov/jetstream/currents_max](https://www.weather.gov/jetstream/currents_max)

**Note:** Uncheck the check-box labelled “All Currents” as shown in the image to the left before you use the application.
READING ASSIGNMENTS
Satellite Applications for Geoscience Education

Satellite Applications for Geoscience Education is a distance-learning course for G6-12 educators that seeks to leverage satellite observations with teachers connection to students to raise society's understanding of Earth's dynamic air and water systems. Much of the content is static and accessible without the Internet but some activities and nearly all the resources require Internet access.

The material in this course represents a collaborative effort between Atmospheric, Remote Sensing and Geology experts from the University of Wisconsin and Ocean experts from the University of Washington. This collaboration was funded by the National Science Foundation. 2010 updates were funded by the National Oceanic and Atmospheric Administration. Unless otherwise cited, featured imagery was produced at the UW-Madison Space Science and Engineering Center.

The development of this course began with a Curriculum Design Summit in November 2006 where science teachers convened with University...
Satellite Applications for Geoscience Education – Ocean Currents

**Oceanography » Ocean Currents**

**In this lesson you will learn:**
- What currents are and what causes them
- Where ocean currents are located
- What ocean currents accomplish
- Why we are able to identify ocean currents in satellite images
- How to identify and track the movement of ocean currents in satellite imagery

**Time requirement**
This lesson will take you approximately **30 minutes** to complete.
Welcome,

The Ocean Motion website provides resources developed for inquiring minds both in and outside the classroom, for reading level grades 9-12 (Flesch-Kincaid).

This web site contains a comprehensive review of the surface circulation of Earth’s ocean and classroom investigations appropriate for various disciplines at the high school level.

The site features a toolbox of satellite and model data, quick evaluation quizzes and a timeline of ocean explorers to inspire investigation of ocean surface current patterns and how they relate to issues of navigation, weather/climate, natural hazards and marine resources.

The blue navigation bar at the top of each screen contains the project resources listed below:

**Quizzes** – Users may take an online quiz consisting of several questions. When they submit their responses online, a pop-up window appears that shows the correct response to each question and provides additional, clarifying information.

**Background** – An in depth reference describing the what, when and where of ocean surface currents. The content of this section was adapted from DataStream Ocean and used with permission of the American Meteorological Society.
DataStream Ocean was developed as a high school teacher training course.

**Background - Timeline** – A timeline shows how humans have used ocean surface currents to navigate the globe for exploration and commerce as well as study the environment.

**Impact** – Articles describe how ocean surface currents affect each of our lives through climate variability, natural hazards, and marine resources.

**Gathering Data** – Descriptions of the tools used to observe ocean surface currents including satellites, flotsam, HF Radar, buoys and historical ship drift data.

**Researchers/Applications** - The Ocean Motion project
References

• A Direct Determination of the World Ocean Barotropic Circulation
  https://doi.org/10.1175/JPO-D-15-0046.1

• Surface geostrophic currents from altimetry
It’s time for a break!!!