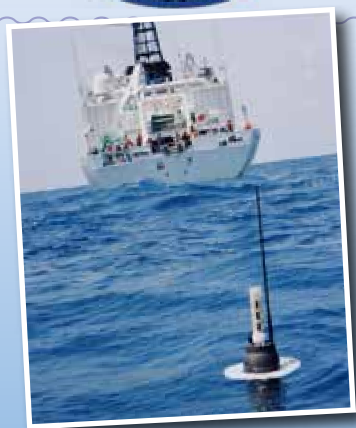
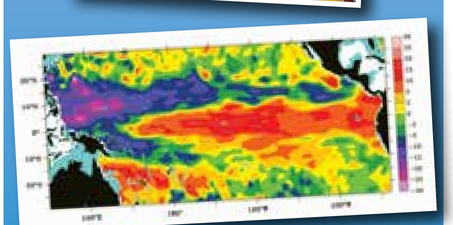
2014 Gulf of Mexico Expedition

Three Thousand Floats!





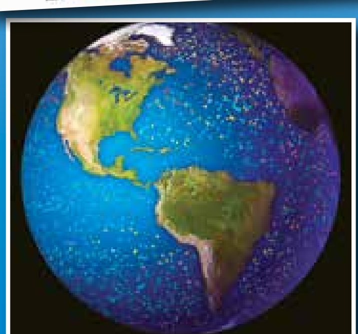


Image captions/credits on Page 2.

lesson plan

Grade Level

6-8 (Earth Science)(with adaptations for Grades 3-5 and 9-12)

Focus

Argo global temperature and salinity profiling floats

Focus Question

How can we make measurements that provide information about changes in Earth's ocean that might affect Earth's climate and weather?

Learning Objectives

- Students will interpret temperature and salinity profiles and trajectory diagrams based on data from Argo profiling floats to explain how variations in temperature and salinity at various depths are related to patterns of oceanic circulation, and how these patterns are related to regional climates.

Materials

- ❑ Computers with Internet access
- ❑ Copies of Appendix A, *How to Access Argo Float Data*; one copy for each student or student group

Audio-Visual Materials

- ❑ (Optional) Interactive white board

Teaching Time

Two 45-minute class periods; additional time may be needed for independent student work (see Learning Procedure, Step 6)

Seating Arrangement

Groups of two or three students

Maximum Number of Students

30

Key Words

Thermohaline circulation
Global ocean convection cycle
Temperature
Salinity
Density
Argo float

Background Information

Around the world, there is increasing concern about the impacts of changes in Earth's environment. Much of this concern is based on changes that have already happened such as rising sea level, decreasing Arctic sea ice cover, rapid warming in high latitude areas, and recent extreme weather. These events are the result of a combination of long-term changes and natural variability in circulation patterns of Earth's atmosphere and ocean. These circulation patterns are important because they are the primary processes that transfer heat from one place on Earth to another. Because events associated with global environmental change have serious impacts on human lives, communities, and economies, there is an urgent need to improve our understanding of circulation in the atmosphere and ocean, and how changes in circulation patterns are connected to changes in Earth's environment.

One of the most important processes that affects Earth's environment is the transfer of heat by ocean currents. While winds are primarily responsible for currents in the upper 100 meters of the ocean, deeper currents are driven by differences in the density of large seawater masses. Because the density of seawater is determined by temperature and salinity, density-driven currents are called thermohaline circulation (salinity is the concentration of salt and other inorganic compounds in seawater; haline means salty). On a global scale, thermohaline circulation drives a system of currents sometimes called "the global ocean convection cycle" that transfers heat and dissolved substances throughout Earth's ocean. For more information about the global ocean thermohaline circulation, please see http://

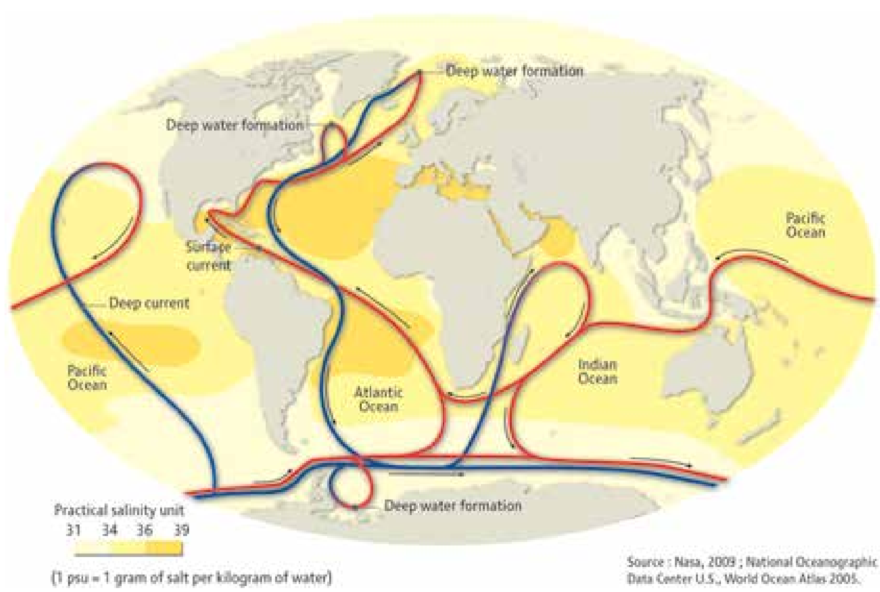
Images from Page 1 top to bottom:
A PROVOR float shortly before recovery by the Japanese coastguard vessel *Takuyo*.
http://www.argo.ucsd.edu/Takuyo_deployment_1.jpg

An Argo float being deployed from a research ship.
http://www.argo.ucsd.edu/ArgoGoesOver.jpg

Argo measures the variations in sea level due to temperature and salinity changes. This figure from Argo data shows the change in sea level in December 2009 during an El Nino episode.
http://www.argo.ucsd.edu/Argo_brochures.html

The Argo Program is a global array of 3,500 free-drifting instruments, spaced about every 3° of latitude and longitude, moving up and down in the water column from the sea surface to 2,000 meters (6,500 feet) every 10 days, and making up to 1,000 measurements of temperature, salinity, and depth during every ascent to the sea surface. Argo provides the first-ever global-scale, all-weather subsurface observations of the oceans.
http://www.argo.ucsd.edu/Argo_brochures.html

Deep-ocean Thermohaline Circulation (THC)



Thermohaline circulation is a 3-dimensional flow involving surface and deep ocean waters, which is driven by differences in water temperature and salinity. (Image source: NOAA/NCDC).

Source: http://www.grida.no/publications/rr/blue-carbon/; A new Rapid Response Assessment report released 14 October 2009 at the Diversitas Conference, Cape Town Conference Centre, South Africa. Compiled by experts at GRID-Arendal and UNEP in collaboration with the UN Food and Agricultural Organization (FAO) and the UNESCO International Oceanographic Commissions and other institutions, the report highlights the critical role of the oceans and ocean ecosystems in maintaining our climate and in assisting policy makers to mainstream an oceans agenda into national and international climate change initiatives Cartographer/Designer: Riccardo Pravettoni, UNEP/GRID-Arendal.
http://www.grida.no/graphicslib/detail/thermohaline-circulation_5959

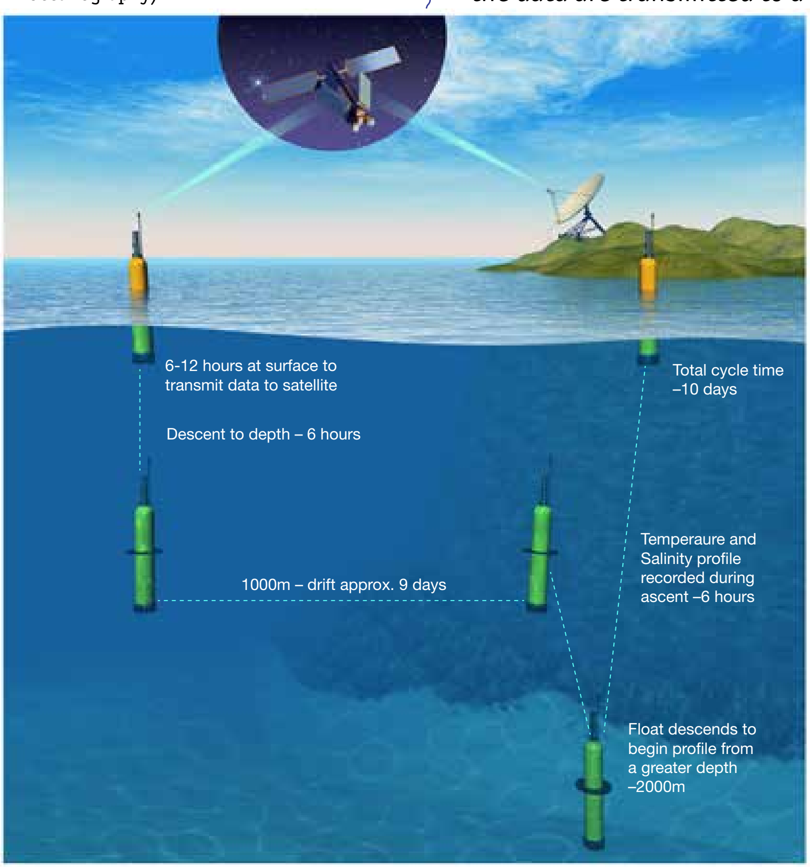
oceanservice.noaa.gov/education/tutorial_currents/05conveyor2.html and http://oceanexplorer.noaa.gov/okeanos/edu/leadersguide/media/09whydoweexplore.pdf (page 18).

To improve our understanding of the global ocean thermohaline circulation, we need many measurements of temperature and salinity at different depths from many locations in Earth's ocean, over long periods of time. Making such measurements over an entire planet is a task that is beyond the scientific, technical and financial abilities of any single country. For this reason, research agencies of more than 30 nations have joined with six agencies of the United Nations in an Integrated Global Observing Strategy (IGOS) to provide reliable environmental data about significant global environmental conditions and processes to support decision-making that can improve human welfare and reduce risks from environmental degradation. For more information on IGOS, please see http://www.un.org/earthwatch/about/docs/igosstr.htm.

The Argo logo was created by Rod Stott, who lives in East Yorkshire, England. He is a retired, professional technical illustrator, until recently he worked for British Aerospace.
http://www.argo.ucsd.edu/pictures.html#logo

An important part of the IGOS strategy for improving our understanding of the global ocean thermohaline circulation is a global array of data-gathering floats called Argo. These floats are designed to drift freely in the ocean and to periodically make measurements of temperature and salinity in a column of water that extends from the surface to a depth of 2,000 meters. Once the measurements are made, the data are transmitted to a satellite, which also determines the float's geographic location. The satellite relays the data to shore-based data assembly centers that make the data publically available.

Argo Park and Profile Cycle
(Courtesy of Scripps Institution of Oceanography)

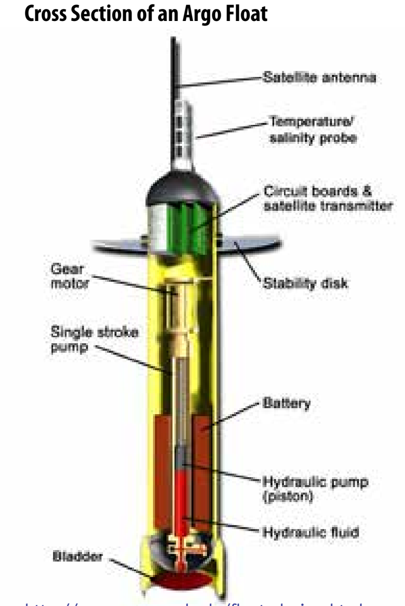


When an Argo float is first deployed, it descends to a "parking depth" (typically 1,000 meters) by adjusting the float's density so that it is neutrally buoyant at the desired depth (neutrally buoyant means that the density of the float is the same as the density of the surrounding seawater). After drifting at the parking depth for ten days, the float rises to the surface over a period of about 6 hours. As it rises, the float measures temperature, salinity, and external pressure (the pressure measurement provides a way to estimate the depth at which the temperature and salinity measurements were made). After transmitting the data to the satellite, the float returns to its

What does an Argo float look like?

Argo floats weigh about 40 kg and consist of an aluminum cylinder that is about 1.3 m long and about 20 cm diameter. An antenna is attached to the top of the cylinder, along with temperature and salinity sensors. An inflatable bladder is attached to the bottom of the float inside a protective cover. With the bladder empty, the float has the same density as seawater at the parking depth. When oil is pumped into the bladder, the float rises to the surface. When oil is pumped out, the float returns to the parking depth.

Cross Section of an Argo Float

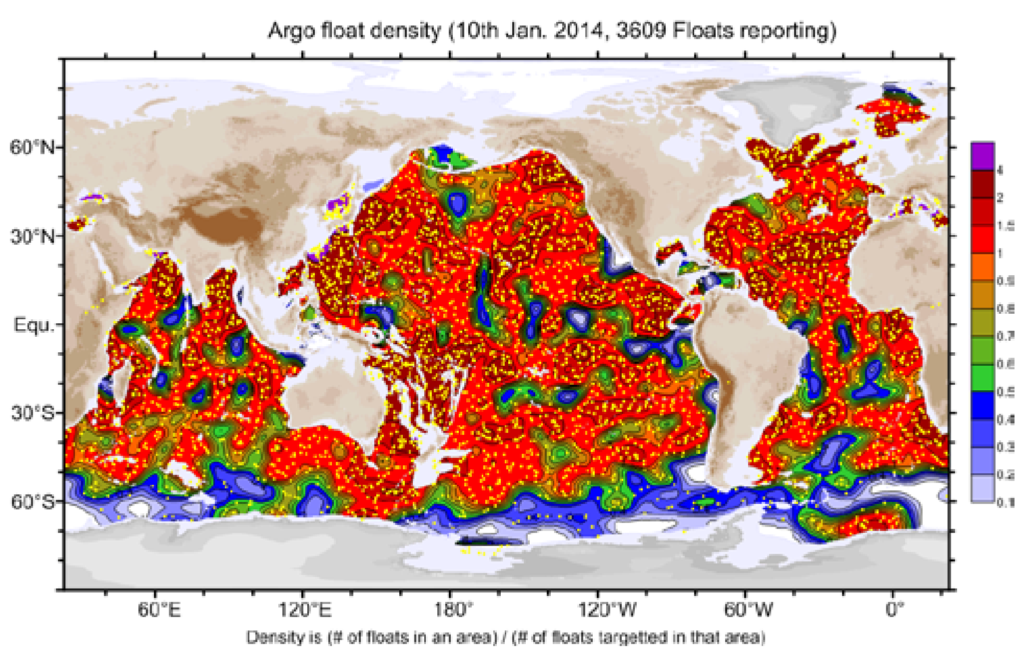


http://www.argo.ucsd.edu/float_design.html

parking depth to repeat the cycle. The difference in location between one cycle and the next provides a way to estimate the velocity of ocean currents at the parking depth. Argo floats are battery powered, and are designed to make about 150 of these cycles over the lifetime of an individual float. More than 3,000 Argo floats have been deployed at locations around the globe. The entire Argo array provides about 100,000 temperature/salinity profiles and velocity measurements per year.

Argo floats cost about $15,000, and have been purchased by 28 countries involved with the project. The floats are deployed from ships or aircraft by the countries that purchased them. Argo floats can be handled by a single individual, who can launch the float while the vessel is underway. This makes Argo float deployment an ideal candidate for "vessels of opportunity;" ocean-going ships that often have periods during which they are transiting between ports or projects. Using this concept, several Argo floats will be deployed into previously unreachable areas in the Gulf of Mexico as part of the 2014 Gulf of Mexico Expedition aboard the NOAA Ship *Okeanos Explorer* (please see http://oceanexplorer.noaa.gov/okeanos/explorations/ex1402/welcome.html for more information about this expedition). Essentially, these Argo floats can be thought of as instruments that continually explore temperature, salinity and external pressure in the ocean over space and time.

There are many different ways to download data from Argo floats. The "Argo data beginner's guide" (http://www.argo.ucsd.edu/Argo_date_guide.html) provides some general guidelines. The EuroArgo Web site has several tutorial pages that explain data from specific floats. This



Map courtesy Howard Freeland, Fisheries and Oceans Canada, Institute of Ocean Sciences. http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/argo/images/EarthDensity.gif lesson provides an introduction to the Argo float program and how to interpret data from Argo floats.

Learning Procedure

1. To prepare for this lesson:
   (a) Review background information about Argo profiling floats at http://www.argo.ucsd.edu/About_Argo.html

   (b) Review background information about the 2014 Gulf of Mexico Expedition (http://oceanexplorer.noaa.gov/okeanos/explorations/ex1402/welcome.html). While it is not directly focused on the Argo program, this expedition provides the opportunity to launch Argo floats in previously unreachable areas of the Gulf of Mexico, as well as an opportunity to acquaint students with the activities of 21st century ocean explorers. Essentially, these Argo floats can be thought of as instruments that continually explore temperature, salinity and external pressure in the ocean over space and time.

2. If necessary, introduce or review the concepts of density and salinity, and how the density of seawater is affected by temperature and salinity. Ask students to brainstorm reasons that temperature and salinity of seawater might be different in different locations. Ask students what they think happens when seawater in polar regions becomes colder. Students should infer that density increases causing the colder seawater to sink, and that this sinking might create water movements that we call currents. In very general terms, describe the global ocean convection cycle, and ask students to speculate on why this cycle might be important. The key concepts are that changes in density cause masses of ocean water to be transported around the globe, and this circulation transfers heat and dissolved substances from one part of the Earth to another. Be sure students make the connection between heat transfer and climate.

3. Briefly discuss the importance of understanding circulation patterns of the ocean and atmosphere, focusing on the need for many observations from many different locations. Introduce the Argo float program, and the basic observation cycle of Argo floats (see above). Briefly describe the 2014 Gulf of Mexico Expedition and how it provides an opportunity to deploy new Argo floats in the Gulf of Mexico. You may also want to discuss how 21st century ocean exploration differs from exploration in prior centuries, including greatly improved technological capabilities that include telepresence, which allows many explorers to participate in the expedition without actually being aboard the ship.

4. Work through the "Understanding Argo data" Web page (http://www.euroargo-edu.org/explore/argoeu_3a.php#h5) with students. This may be done with an interactive white board, computer stations, or (if computers and internet connections are not available) by copying portions of the Web page for distribution to students or student groups.

Important points to note include:

- A temperature or salinity profile consists of the measurements made during one excursion from 2,000 meters depth to the surface.
- The charts of temperature and salinity profiles include all measurements since the float was deployed. The earliest (oldest) profiles are blue, while the most recent profiles are deep red and brown.
- The recent surface temperature is much greater than the temperature at 2,000 m depth. This can be explained by the most recent location, which is southwest of Spain in the Mediterranean outflow (you can get this information by clicking on the image labeled "Trajectory of float 6900211").
- There is a pronounced thermocline in recent profiles between 200 m depth and the surface.
- Looking at all the profiles together, the temperature range near the surface is roughly 8°C, which is much larger than the range of about 2°C at 2,000 m depth.
- The differences in temperature between earlier and later profiles are most pronounced at depths between roughly 600 m and 1,500 m. Possible explanations include the fact that earlier profiles were made at higher latitudes where temperatures are lower, and that later profiles may have been influenced by outflows of warm water from the Mediterranean region.
- Surface salinity in recent profiles is higher than salinity at 2,000 m depth. The explanation for this observation is that the effect of increased salinity, which is associated with increased density, is partially offset by higher temperatures that are associated with decreased density. Increased salinity near the surface in more recent profiles is probably due to evaporation, as well as the inflow of more saline water from the Mediterranean region. Lower salinity in earlier profiles may have also been influenced the inflow of fresh water from rain and melting snow.
- There are pronounced haloclines in recent profiles that are not seen in earlier profiles.
- Looking at all the profiles together, the salinity range near the surface is much greater than the range at 2,000 m depth. Possible explanations are the influence of evaporation at the surface, as well as the influence of rainfall and snowmelt.

- The differences in salinity between earlier and later profiles are most pronounced at depths between roughly 600 m and 1,600 m. Possible explanations are related to the inflow of more saline water from the Mediterranean, as well as the combined influence of temperature and salinity. In earlier profiles, temperature decreased more or less steadily from the surface to 2,000 m; but in later profiles the temperature was more or less constant between 600 m and 1,500 m so density changes in this range were primarily due to salinity differences, and more saline waters (with higher density) were found at greater depths.

5. From the "Understanding Argo data" Web page, click on "To display data from a specific float, follow this link." at the top of the page. A new page will open titled "The Euro-Argo Float Selection." Click on the float icon that is closest to the southeast coast of the U.S. A pop-up window will open titled "Float 6900451." Click on "Float data and more information." A new page will open titled "Interpreting data from float no.6900451."

   Work through this page with your students. Note that this float is no longer in operation, but recorded 204 profiles between its launch on June 24, 2006 and its last transmission on January 17, 2012.

   In the temperature profiles there was relatively little change between the surface to 2,000 m in earlier profiles compared to changes of about 25°C in later profiles. The main difference between earlier and later salinity profiles is that in earlier profiles, the salinity increased with increasing depth to about 400 m and was more or less constant to 2,000 m; while in later profiles the salinity decreased from the surface to about 1,000 m, and then was more or less constant to 2,000 m.

   The time series charts show that the float crossed into a different water type in roughly the summer of 2008. Comparing the analysis maps with the trajectory map, it is clear that the eastward turn when the float was southeast of Labrador would have taken it into much warmer and more saline waters.

6. Look at records from other floats in the Argo network. You may choose to do this as a class, or as individual or group assignments in class or as homework depending upon time available and students' level of comfort with this subject matter. Instructions for accessing Argo float data are provided in Appendix A. Comparing data from floats in widely different geographic locations (particularly floats in different latitudes) should begin to give a feel for how temperature and salinity profiles vary on a global scale. Refer to the diagram of the global thermohaline circulation above, and try to select floats

whose trajectories may include different parts of the global conveyor belt. Discuss patterns that students notice in the trajectories and profiles, emphasizing the relevance of these patterns to the transfer of heat by the global ocean convection cycle, and the importance of heat transfer processes to Earth's climate.

The BRIDGE Connection

www.vims.edu/bridge/ - Scroll over "Ocean Science Topics," and click on "Physics" for resources about ocean currents and observing systems; click on "Atmosphere" for resources about climate change.

The "Me" Connection

Have students write a brief essay about how they are personally affected by global ocean circulation.

Connections to Other Subjects

Mathematics, English Language Arts

Assessment

Individual or group assignments and class discussions provide opportunities for assessment.

Adaptations for Other Grade Levels

Grades 3-5: Focus on trajectory data from Argo floats as an introduction to ocean currents and interactions between the biosphere, hydrosphere and atmosphere.

Grades 9-12: Have students explain how data from Argo floats could be used along with results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change, and illustrate their explanation with actual data from at least five Argo floats.

Extensions

Have students visit http://oceanexplorer.noaa.gov/okeanos/explorations/ex1402/welcome.html to find out more about the 2014 Gulf of Mexico Expedition.

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html Click on the links to Lesson 8 for interactive multimedia presentations and Learning Activities on ocean currents.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

What's a CTD?
(from the NOAA Ship *Okeanos Explorer* Education Materials Collection, Volume 2: How Do We Explore?) http://oceanexplorer.noaa.gov/okeanos/edu/collection/media/hdwe-WCCTD56.pdf

Focus: Measuring physical properties of seawater for ocean exploration

Students explain how a CTD is used aboard the *Okeanos Explorer* to reveal patterns that help ocean explorers answer questions about the natural world; and analyze and interpret data from the *Okeanos Explorer* to make inferences about relationships between density, salinity, temperature, and pressure of seawater.

Other Resources

The Web links below are provided for informational purposes only. Links outside of the Ocean Explorer web site have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://oceanexplorer.noaa.gov/okeanos/explorations/ex1402/welcome.html – Web site for the 2014 Gulf of Mexico Expedition

http://www.argo.ucsd.edu/index.html – Web site for the global Argo program

http://www.aoml.noaa.gov/phod/argo/ – Web site for the U. S. Argo program

Next Generation Science Standards

ESS2D: Weather and Climate

Performance Expectation MS-ESS2-6.
Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

Science and Engineering Practices
Developing and Using Models
- Develop and use a model to describe phenomena.

Disciplinary Core Ideas
ESS2.C: The Roles of Water in Earth's Surface Processes
- The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.

- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.

ESS2.D: Weather and Climate

- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns.

Crosscutting Concepts

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.

Connections to Common Core State Standards

Literacy in Science and Technical Subjects

RST.6-8.1: "...support analysis of science and technical texts."

SL.8.4: "Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning..."

Mathematics

5.G Graph points on the coordinate plane to solve real-world and mathematical problems.

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
The Earth has one big ocean with many features.

Fundamental Concept c. Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of the Earth's rotation (Coriolis effect), the Sun, and water density differences. The shape of ocean basins and adjacent land masses influence the path of circulation.
Fundamental Concept h. Although the ocean is large, it is finite and resources are limited.

Essential Principle 3.
The ocean is a major influence on weather and climate.

Fundamental Concept a. The ocean controls weather and climate by dominating the Earth's energy, water and carbon systems.

Fundamental Concept f. The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water.

Essential Principle 6:
The ocean and humans are inextricably interconnected.

Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7.
The ocean is largely unexplored.

Fundamental Concept d. New technologies, sensors, and tools are expanding our ability to explore the ocean. Scientists are relying more and more on satellites, drifters, buoys, subsea observatories, and unmanned submersibles.

Fundamental Concept e. Use of mathematical models is now an essential part of ocean sciences. Models help us understand the complexity of the ocean and of its interaction with Earth's climate. They process observations and help describe the interactions among systems.

Send Us Your Feedback

In addition to consultation with expedition scientists, the development of lesson plans and other education products is guided by comments and suggestions from educators and others who use these materials. Please send questions and comments about these materials to: oceanexeducation@noaa.gov.

For More Information

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Design/layout: Coastal Images Graphic Design, Mt. Pleasant, SC.

Credit

Appendix A
How to Access Argo Float Data

1. Point your Web browser to: http://www.argodatamgt.org/Access-to-data

2. In the menu on the left side of the page, select "Argo data selection." A window will appear that features a world map with lots of green dots that represent the last known location of Argo floats. You can zoom into a specific area of interest using the zoom bar and navigation arrows on the left side of the map.

3. Click on a green dot to display information about the float that the dot represents (if nothing happens, you may need to zoom in so the dots are larger). A pop-up window will appear that gives identifying information about the float, its last reported position, the date of its last report (in year/month/day format), and a link named "Station informations."

4. Click on the "Station informations" link. A new window will open showing a map with the trajectory (path) of the float since it was deployed. Each blue dot on the map shows the location of a single float cycle, numbered so that the oldest (first) cycle is number 1. The data table above the map gives additional details including the institution that owns the float, whether the float is still active, the first and last dates on which data were received from the float (in day/month/year format), and links to details of each float cycle that has been completed.

5. Scroll down the page to find temperature and salinity profiles, as well as other graphics that illustrate data from the float. Note that pressure in decibars is approximately equivalent to depth in meters.