

EARTH'S OCEAN

Objectives:

This course is an innovative study of the world ocean, delivering new understandings and insights into the role of the ocean in the Earth system. Collectively, the course components are directed towards helping you build your own *learning progression* in which webs of interconnected ideas concerning Earth's ocean grow and deepen over time. [Learning progressions are descriptions of successively more sophisticated ways of thinking that evolve as individuals learn about a topic over a broad span of time.]

After completing this investigation, you should be able to:

- Describe the importance of the ocean as part of the Earth system.
- Compare flat-map and global depictions of the Earth's surface.
- Use latitude and longitude to locate ocean features on an Earth globe.

Why Study the Ocean?

There are many reasons for studying Earth's ocean. People have travelled the ocean for millennia, many rely on it as a food source, and its surface is plied for commerce and recreation. The coastal zone has always attracted human habitation. Energy generation via tides, ocean currents, and off-shore wind farms have emerging potential. In the future, the ocean bottom will become a greater source of minerals and fuels. We maintain ocean outposts, such as oil platforms, for resource extraction and scientific investigations.

The importance of the ocean as a prime component of Earth's climate system is becoming strikingly clear. This is of special significance because the environmental observational record unequivocally shows warming of the global climate over the past half-century. Whether we live along the coast or thousands of kilometers inland, the climate variations and more frequent extremes in weather events that we experience or hear about reveal strong ocean connections. It is through the search for the causes of these energy-driven changes and extremes that the role of the ocean as the driver of global climate comes into focus. It is estimated that the world ocean has absorbed over 90% of the heat added to the warming Earth system in the past 50 years. In comparison, the atmosphere and the land surfaces have individually absorbed slightly more than 2%. [For details, see <http://www1.ncdc.noaa.gov/pub/data/cmb/bams-sotc/2009/bams-sotc-2009-brochure-lo-rez.pdf>.]

The ocean plays a key role in the global carbon cycle. In 2007, the Intergovernmental Panel on Climate Change (IPCC) estimated that the ocean absorbs 56.2% of the carbon dioxide of anthropogenic origin (via photosynthesis, cold surface water absorption, and deepwater sequestration). At the air/sea interface, the rising concentration of atmospheric CO₂ drives the net flux of carbon dioxide into the water.

1A - 2

Please note that the Internet addresses appearing in this Investigations Manual can be accessed via the “Learning Files” section of the course website. Click on “Investigations Manual Web Addresses”. Then, go to the appropriate investigation and click on the address link. We recommend this approach for its convenience. It also enables AMS to update any website addresses that were changed after this Investigations Manual was prepared.

Figure 1 shows the change in heat content over the past half century of the near-surface layer of the ocean where most of the warming has occurred. The implications of this change for weather and climate are considerable, as well as other impacts, including much of the observed sea-level rise resulting from the expansion accompanying the warming of seawater.

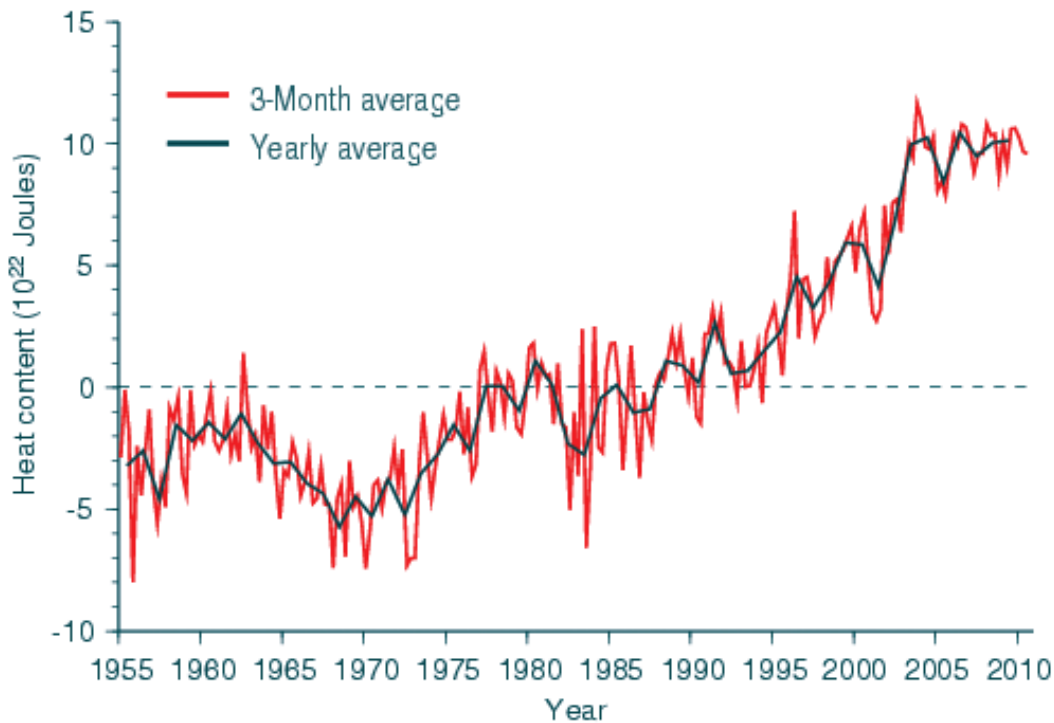


Figure 1.
Changes in heat content (in Joules) of top 700 m of global ocean from 1955 to April-June 2010.
[National Oceanographic Data Center/NOAA]

Please note that **Figure 1** and all other Investigations Manual images are also available on the course website. To view these images, click on the “Investigations Manual Images” link on the website, go to the row containing the appropriate investigation name, and then select the appropriate figure within that row. For example, to view Figure 1 online, go to the row labeled “1A” and then select “Fig. 1”.

By absorbing over a quarter of the carbon dioxide released into the atmosphere by the burning of fossil fuels, the world ocean is slowing the rate at which global warming would otherwise be occurring. But this absorption is changing the chemical state of the ocean in other ways likely to produce dire consequences, including the acidification (lowering the pH) of seawater that is already impacting marine ecosystems.

An Earth System Approach:

This course employs an Earth system perspective and is guided and unified by the *AMS Ocean Paradigm*. The Earth system consists of subsystems—hydrosphere (of which the ocean is the major component), cryosphere, atmosphere, geosphere, and biosphere—that interact in orderly ways, described by natural laws. In this course, we examine the ocean’s properties and processes from the perspective of the Earth system, which is both holistic and global in scope. We will explore subsystem interactions, the flow and conversion of energy and materials, and how human activity impacts and is impacted by the ocean.

Included in this *AMS Ocean Paradigm* are the elements of the Earth system approach.

The AMS Ocean Paradigm

Earth is a complex and dynamic system with a surface that is more ocean than land. The ocean is a major component of the Earth System as it interacts physically and chemically with the other components of the hydrosphere, cryosphere, atmosphere, geosphere, and biosphere by exchanging, storing, and transporting matter and energy.

By far the largest reservoir of water on the planet, the ocean anchors the global hydrological cycle—the ceaseless flow of both water and energy within the Earth system. As a major component of all other biogeochemical cycles, the ocean is the final destination of water-borne and air-borne materials.

The ocean’s range of physical properties and supply of essential nutrients provide a wide variety of marine habitats for a vast array of living organisms.

The ocean’s great thermal inertia, radiative properties, and surface- and deep-water circulations make it a primary player in Earth’s climate system.

Society impacts and is impacted by the ocean. Humans rely on the ocean for food, livelihood, commerce, natural resources, security, and dispersal of waste.

Humankind’s intimate relationship with the sea calls for continued scientific assessment, prediction and stewardship to achieve and/or maintain environmental quality and sustainability.

1. Components of the Earth system (e.g., hydrosphere, geosphere) interact in [(random) (orderly)] ways as described by natural laws.

1A - 4

2. The ocean is a [***minor***]***major***] component of biogeochemical cycles (e.g., the water cycle) operating as part of the Earth system.
3. The ocean has [***little or no***]***a major***] influence on Earth's weather and climate.
4. As embodied in the *AMS Ocean Paradigm* and described earlier in the **Why Study the Ocean?** section, the ocean's central role in Earth's climate system and climate change is evidenced by the strong absorption of [***heat***]***carbon dioxide***]***heat and carbon dioxide***] in seawater. This has resulted from increased concentrations of atmospheric carbon dioxide due to the burning of fossil fuels.

Exploring Locations on Earth:

Exploring the ocean in the Earth system relies on various methods for displaying scientific information, including map projections.

Map projections (two-dimensional representations) printed on flat sheets of paper or viewed on screens are common and convenient ways to portray features of Earth's surface. Road maps, topographic maps, and weather maps are examples. But, like all graphical models, maps have their limitations. Over great distances, flat maps do not faithfully represent Earth's surface because our planet is not flat. The greater the portion of Earth's rounded surface being depicted on a map, the greater the distortion.

Maps covering major portions of Earth's surface are typically constructed for either ***conformality*** (whereby all small features on Earth's surface retain their original shapes on the map) or to preserve ***equal areas***, that is, map portions of the same size everywhere on the map represent equal areas. Flat maps cannot be both conformal and equal-area at the same time. For a detailed discussion of map projections, go to:

<http://erg.usgs.gov/isb/pubs/MapProjections/projections.html>.

As noted earlier, the Internet addresses appearing in this Investigations Manual can be accessed via the "Learning Files" section of the course website. Click on "Investigations Manual Web Addresses". Then, go to the appropriate investigation and click on the address link. We recommend this approach for its convenience. It also enables AMS to update any website addresses that were changed after this Investigations Manual was prepared.

Maps are used extensively in oceanography and often depict vast areas of Earth's curved surface. Global-scale projections exhibit considerable distortion because the entire surface of the planet, which is essentially a sphere, is being projected onto a flat surface. Nonetheless, such depictions can be extremely useful—although the user should be aware of their strengths and limitations. ***Conformal maps*** are often adequate for depicting the configuration of some property. **Figure 2** is an example of a conformal map. It is a Mercator-type conformal projection that maintains the shapes of small regions and has lines of latitude and longitude forming a rectangular grid. Its major strength is that it preserves angles; that

is, any straight line drawn on a Mercator map is a line of constant bearing (same direction). This attribute is of immense significance in ocean navigation. The map's major weakness is that surface area is greatly exaggerated at higher latitudes, a characteristic of Mercator maps.

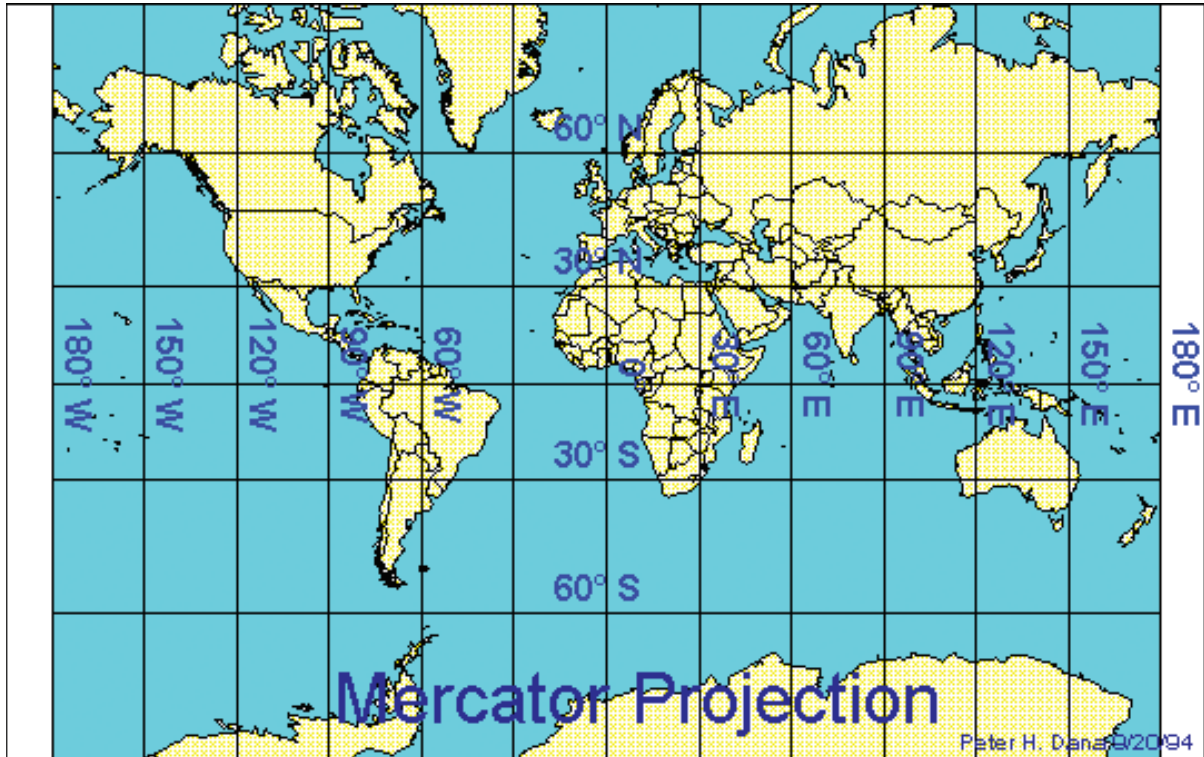


Figure 2.
Sample Conformal Map. [Used with permission of the author, Peter H. Dana, The Geographer's Craft Project, Department of Geography, The University of Colorado at Boulder, © 1999 Peter H. Dana]

5. Figure 2 is a Mercator flat map. An important property of such conformal maps is that lines of latitude and longitude are **[(*straight and perpendicular to each other*)(*curved*)]**.
6. Because distortion increases away from the equator, the map in Figure 2 shows another common feature of Mercator projections, that is, the distance between adjacent lines of latitude **[(*decreases*)(*remains the same*)(*increases*)]** as latitude increases toward polar regions.

Equal-area maps portray the extent of properties while maintaining a constant scale of areas. **Figure 3** is one type of equal-area world map. Equal-area maps are limited by the curvature of longitude and/or latitude lines that distorts shapes.

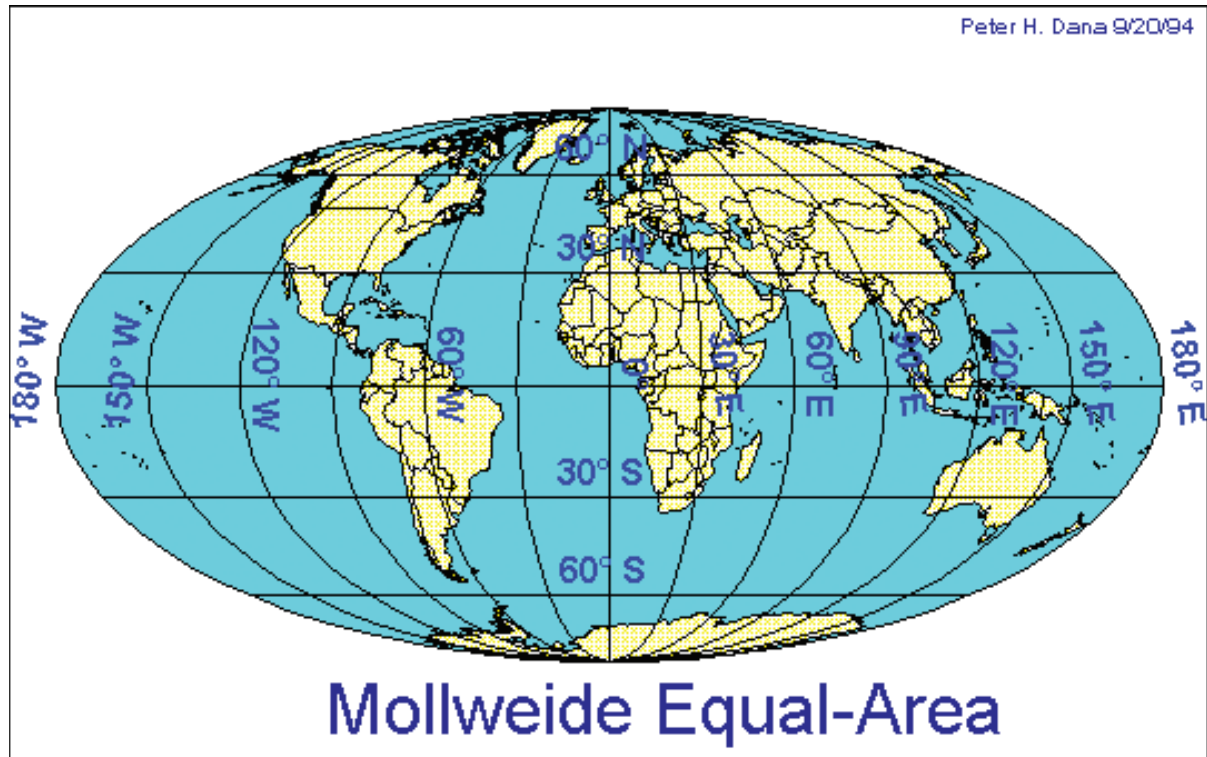


Figure 3.

Sample Equal-Area Map. [Used with permission of the author, Peter H. Dana, The Geographer's Craft Project, Department of Geography, The University of Colorado at Boulder, © 1999 Peter H. Dana]

7. Figure 3 is an equal-area projection. Compare the apparent sizes of Greenland and South America in Figures 2 and 3. The Figure 2 Mercator map depiction suggests that they are about the same size whereas on the Figure 3 equal-area map, it is clear that Greenland is ***[(much larger than)(about the same size as)(much smaller than)]*** South America.

Adding the Third Dimension - A Global View:

Whereas flat maps are essential and useful tools in Earth system studies, the true relations of properties and Earth locations can only be displayed on a map that approximates the real shape of our very nearly spherical planet—a globe. A globe is both conformal and equal area in its representation of Earth's surface and its features, thereby eliminating the distortions introduced by flat map projections. It also provides an authentic representation of spatial relationships in three dimensions. This 3-D attribute is particularly useful in making models relating Earth to the Sun and Moon, investigating the effects of Earth's rotation, and exploring the impacts of external forcings (radiational and gravitational) on the Earth system. A globe is especially useful in an ocean studies environment because it eliminates a potentially major obstacle to learning: distortion. It can be challenging to separate real patterns (or relationships) on a map from those patterns (or relationships) that appear simply because of the distortion. In other words, a globe can be a great way to put the Earth system

into a more realistic perspective. (Globes are not without their limitations, however. Globes of normal size display features with relatively little detail. Another problem is that they are not as portable as flat maps!)

In this course, we utilize both flat maps and globes in our investigations of the Earth system. The *Ocean Studies* globe will be employed to introduce and reinforce the basic understandings of Earth system science and to provide comparisons with the more common flat-map depictions.

Go 3-D: Hold your inflated *Ocean Studies* globe in front of you at eye level with the North Pole (coinciding with the inflation stem) pointing up. Examine the geographic coordinate grid of lines printed on the globe. These are the east-west parallels of latitude and north-south meridians of longitude. The equator (the 0-degree latitude line) is the latitude circle having the greatest circumference on this spherical globe and defines a plane that is perpendicular to Earth's rotational axis. The equator divides Earth into two equal hemispheres, the Northern Hemisphere and the Southern Hemisphere. A series of other east-west lines are drawn at regular north-south intervals; these are the parallels of latitude. They are labeled along the north-south 180° longitude line (in the central Pacific Ocean). Generally, latitudes in the Northern Hemisphere (equator to North Pole) are reported as degrees North (or N) or as positive (+) values, while those from the equator to South Pole are degrees South (or S) or minus (-). [On the globe, all latitudes (N or S) are marked positive.]

Because it divides Earth into two equal parts, the equator is called a *great circle*. A series of other great circles appears on the globe passing through the North and South Poles. These are lines of longitude and represent angular measurements around Earth in an east/west direction. They are measured from an arbitrarily chosen line termed the *Prime Meridian*, a longitude line (half of a great circle) running between North and South Poles and passing through Greenwich, England. Values of longitude are printed along the equator from the Prime Meridian (0 degree longitude), increasing to the left as degrees West (or W) or to the right as degrees East (or E) until they meet in the central Pacific at 180 degrees, also called the *International Date Line*. [Note: Longitudes to the east of the Prime Meridian are sometimes reported positive (+) and those to the west negative (-).] The 0 degree and 180 degree longitude lines are segments of the same great circle dividing the globe into the Eastern and Western Hemispheres.

8. Any place on Earth's surface can be specified by latitude and longitude. The deepest point on the world ocean floor is the Challenger Deep, about 11,000 m (36,100 ft) below mean sea level located at 11.3 degrees N and 142.2 degrees E in the Mariana Trench. Locate and label this place on your globe with a marking pen. It is located in the [(Indian)(North Pacific)(South Pacific)(Southern)] Ocean.
9. Locate and compare Greenland and South America on the globe. Greenland is actually [(much larger than)(about the same size as)(much smaller than)] South America. This is consistent with the depictions on the Figure 3 equal-area map.

1A - 8

10. Distance along a globe's surface is the same in all directions, so distances between two locations on Earth can be easily estimated. This is possible because the distance of one longitude degree measured along the equator or one latitude degree measured along a meridian is approximately 111 km (69 statute mi). [Because these are measured along great circles, this distance is determined by dividing Earth's circumference (about 40,000 km or 24,900 mi) by 360°.] Find the approximate distance between San Francisco, CA, and Tokyo, Japan by first determining the length of a string held taut on the globe between the two locations. Laying this length of string along the equator or a meridian would show that the number of degrees it represents is [~~(77)~~~~(87)~~~~(97)~~].
11. Multiplying the number of degrees by 111 km indicates your measurement represents a distance of [~~(8,547)~~~~(9,657)~~~~(10,767)~~] km (5313 mi).
12. While standing and bending forward, hold your globe at about waist level and oriented so you are looking directly down on the North Pole. Note the relative amounts of land and ocean you can see. Then turn the globe over until you are looking down on the South Pole. Note the relative amounts of land and ocean seen in this view. As seen from above the two poles, the Northern Hemisphere consists of more [~~(water)~~~~(land)~~] surface than does the Southern Hemisphere. (However, both the Northern and Southern Hemispheres' surfaces are more water than land. No matter how you look at it, Earth is a water planet!)
13. Now hold the globe at eye level. Twist and turn it until you achieve the maximum water view. The Earth looks most like a water planet when you are viewing it from in space directly over a spot on the planet's surface at approximately at [~~(30 degrees S and 70 degrees E)~~
~~(55 degrees N and 40 degrees E)~~
~~(20 degrees S and 150 degrees W)~~].

Summary:

There are many reasons for studying Earth's ocean. The *AMS Ocean Paradigm* describes the role of the ocean as a major component of the Earth System. The world ocean is an extremely valuable natural resource that provides food, is used for transportation and commerce, invites recreational use, and is a source of minerals and energy. It is a primary component and main driver of Earth's climate system. Its role in climate change is especially significant because of the strong absorption of heat and carbon dioxide in seawater resulting from increased concentrations of atmospheric carbon dioxide due to the burning of fossil fuels.

Exploring the ocean relies on various methods for displaying scientific information, including the use of flat-map and global map projections. The geographic coordinate system makes it possible to specify any place on Earth's surface by latitude and longitude. Global depictions have the added value of providing authentic representation of spatial relationships in three dimensions.