

Investigation 1B

Mapping the Ocean

Objectives

Exploring the ocean relies on various methods to display scientific information. Map projections, two-dimensional representations of a three-dimensional planet, are common and convenient ways to portray Earth's surface. But, like all graphical models, maps have their limitations. Over great distances, flat maps distort Earth's surface because our planet is not flat.

After completing this investigation, you should be able to:

- Investigate the ocean as a 3-D globe with Google Earth 3-D Viewer.
- Examine the Earth from above as it rotates.
- Identify and delineate the five major subdivisions of the world ocean.
- Explore ocean properties using the World Ocean Atlas 2023.

Mapping the Ocean

Most map projections are either considered conformal (all small features on Earth's surface retain their original shapes on the map) or equal-area (map portions of the same size everywhere on the map represent equal areas). The equirectangular projection is neither, but is very useful for certain properties (e.g. sea-surface temperature) over a broad geographical area.

The true relations of properties and locations can only be displayed on a map that approximates the real shape of our planet. A globe is both conformal and equal area, eliminating the distortions introduced by flat maps. It also provides an authentic representation of spatial relationships in three dimensions. Globes are particularly useful for investigating the effects of Earth's rotation on currents, the interaction of lunar and solar gravitational forces with the ocean, and forcing of the ocean by solar radiation.

Globes also have limits, displaying only half of the total surface at one time. However, computer models are often designed to zoom seamlessly between expansive global views and detailed local depictions. In this course, we utilize both flat maps and globes to investigate the global ocean and coastal areas.

We employ *Google Earth* to explore virtual 3-D perspectives, as seen in **Figure 1B-1**. (See the Summary section for more information on exploring *Google Earth*.)

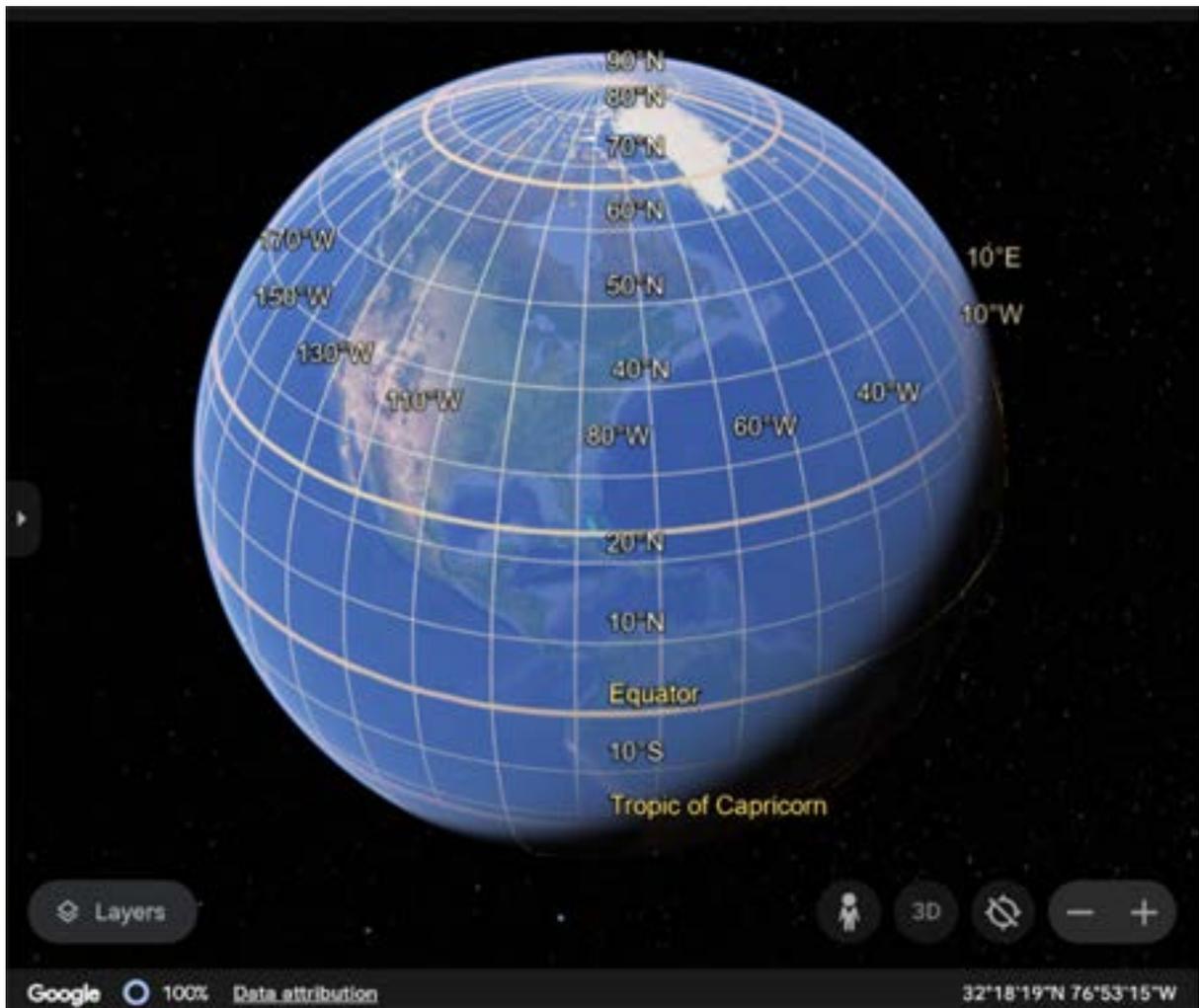


Figure 1B-1. Sample *Google Earth* 3-D Viewer image demonstrating a global view. [*Google Earth*, [Link 1B-1](#)]

1. Note the positions of Greenland and South America in Figure 1B-1 as seen from the *Google Earth* 3-D Viewer. The depictions of these locations can be assumed to be _____.
 - a. conformal
 - b. equal-area
 - c. both conformal and equal area
 - d. neither conformal nor equal area

2. As seen in *Google Earth*, Greenland is _____ South America.
 - a. much larger than
 - b. much smaller than
 - c. about the same size as

For an overview of map projections, go to [Link 1B-2](#).

Earth's Rotation

In addition to manipulating the Earth by size, resolution, and perspective, digital viewers allow for animation. Observing Earth's rotation in 3-D visualizations is especially important for the Earth system sciences, especially when investigating how Earth's rotation impacts the sense of motion at different latitudes.

To view Earth as seen from high above the equator, the North Pole, and the South Pole, click [Link 1B-3](#). The video begins centered on the white line of the equator with 40% of the rotating Earth's total surface visible. The other white lines are the Tropic of Cancer at 23.5°N and the Tropic of Capricorn at 23.5°S . Later, the Arctic Circle (67.5°N) and the Antarctic Circle (67.5°S) come into view. Start, stop, and re-start the video by using the control panel that appears on the screen.

3. From above the equator, Earth's rotation is causing any objects on the equator to move toward the east _____.
 - a. while curving to the right
 - b. while curving to the left
 - c. in a straight line

After observing Earth from above the equator, the video transitions to directly above the North Pole. From this vantage point, the Arctic Circle is represented by a concentric circle with the North Pole at its center.

4. As viewed from above the North Pole, any objects on Earth's surface (except directly at the North Pole) are carried in a _____ path by Earth's rotation.
 - a. diagonal
 - b. circular
 - c. straight
5. The sense of Earth's rotation from this view is _____ around the North Pole as seen from above.
 - a. counterclockwise
 - b. clockwise

The video transitions southward, passing over the equator to arrive at a point directly above the South Pole. The South Pole is positioned in the center of the circle representing the Antarctic Circle.

6. As viewed from above the South Pole, any objects on Earth's surface (except directly at the pole) are carried in a _____ path by Earth's rotation.
 - a. diagonal
 - b. circular
 - c. straight
7. Earth's rotation from this vantage point is _____.
 - a. counterclockwise

- b. clockwise

Earth's rotation appears quite different when seen from different vantage points. From the equator, the Earth's rotation is most apparent as it causes a rapid eastward motion. Observers near the poles, however, experience a different phenomenon. Here, Earth's rotation is virtually imperceptible, as they rotate in place with the planet.

As the course proceeds, you will learn that Earth's rotation has an immense impact on the circulation of the ocean.

Ocean Basins

Although the ocean is continuous, continents and other land barriers separate it into three expansive deep-water basins that extend northward from the ocean-dominated area surrounding Antarctica. This geographical confinement is among the reasons why the world ocean is divided into the Arctic, Atlantic, Indian, Pacific, and Southern Oceans.

To locate the boundaries of major ocean basins, go to The World Factbook ([Link 1B-4](#)). This U.S. Central Intelligence Agency (CIA) publication is generally recognized as the most up-to-date source of information on geographical and geopolitical information, including maps delineating major world regions.

8. For the Arctic Ocean, go to [Link 1B-5](#) "Arctic Ocean." Scroll down to the Map of the Arctic Ocean and click on "View Details." The lighter blue is the water of the Arctic Ocean and the white is the ice. The map shows that Greenland and Iceland are _____ surrounded by the Arctic Ocean.
 - a. partly
 - b. completely
 - c. not
9. Click back and scroll down to the [Introduction](#). Under [Background](#), it indicates that the Arctic Ocean is the _____ of the world's five ocean basins by surface area.
 - a. largest
 - b. second largest
 - c. second smallest
 - d. smallest
10. Scroll down to [Geography](#) and then to [Climate](#). The Arctic Ocean receives continuous _____ in the summer and continuous _____ in the winter.
 - a. sunlight ... darkness
 - b. darkness... sunlight
11. Go to [Link 1B-6](#) for the Atlantic Ocean. Scroll down to [Introduction](#). The Atlantic Ocean is the _____ of the ocean basins by surface area. Straddling the equator, it is divided into the North Atlantic and South Atlantic.
 - a. largest

- b. second largest
 - c. second smallest
 - d. smallest
12. Scroll down to Geography and the Area section. The Gulf of Mexico and Mediterranean Sea _____ considered to be part of the Atlantic Ocean.
- a. are
 - b. are not
13. Go to Link 1B-7 for the Indian Ocean and scroll down to the Background section. The Indian Ocean ranks as the _____ ocean basin.
- a. largest
 - b. second largest
 - c. third largest
 - d. fourth largest
14. Scroll up to the map and click on “View Detail.” The Indian Ocean is located mostly in the _____ Hemisphere.
- a. Southern
 - b. Northern
15. Go to Link 1B-8 for the Pacific Ocean then scroll down to Background. The Pacific Ocean is the _____ ocean basin. Scroll down to Area - comparative. The Pacific (North and South) covers 28% of Earth’s surface, essentially equal to our planet’s total land surface area.
- a. largest
 - b. second largest
 - c. second smallest
 - d. smallest
16. Go to Link 1B-9 for the Southern Ocean and scroll down to the Background section. Extending from Antarctica to 60°S latitude, the Southern Ocean is the _____ largest of the five ocean basins. The northern boundary of the Southern Ocean is also the southern boundary of the Atlantic, Indian, and Pacific Oceans.
- a. first
 - b. second
 - c. third
 - d. fourth

The Southern Ocean is not universally recognized but we consider it an ocean basin because it is distinct, bounded by land to the south with a well-defined current of water to the north, and is a unique ecological region. The U.S. Board on Geographic Names, the official standardizing body of geographic names for U.S. and Federal use, adopted the name “Southern Ocean” in 1999 to describe this body of

water. Its boundaries were defined by the International Hydrographic Organization in 2000 and coincide with the Antarctic Treaty Limit. NOAA and other Federal agencies comply with the decisions of the U.S. Board in the usage of the term Southern Ocean.

The five major ocean basin locations, expanses, and boundaries define how they interact with each other, the ocean at large and the hydrosphere, atmosphere, biosphere, and lithosphere.

Mapping the Ocean's Properties

The *World Ocean Atlas 2023* ([Link 1B-10](#)) provides maps of real-world data for important ocean properties, like temperature, salinity, and dissolved oxygen, as well as nutrients, like silicate, nitrogen, and phosphorus. We will explore these properties in later investigations.

We study properties of the ocean such as sea-surface temperature (SST), salinity, dissolved oxygen, and silica for a multitude of critical reasons. These properties offer insights into the ocean's physical and chemical characteristics, providing essential data for understanding and predicting climate patterns, weather systems, and marine ecosystems.

The following maps show the average values for temperature (°C), salinity (psu), dissolved oxygen (µmol/kg), and silicate (µmol/kg) in the surface water of the global ocean.

Shown in **Figure 1B-2**, sea-surface temperature serves as a fundamental metric for understanding and predicting climate dynamics. SST is essential for monitoring weather patterns, especially in the context of hurricane and storm predictions. Furthermore, it plays a central role in the study of climate change, as it indicates warming trends in the ocean. It influences ocean circulation and affects marine ecosystems, impacting the distribution and behavior of various species.

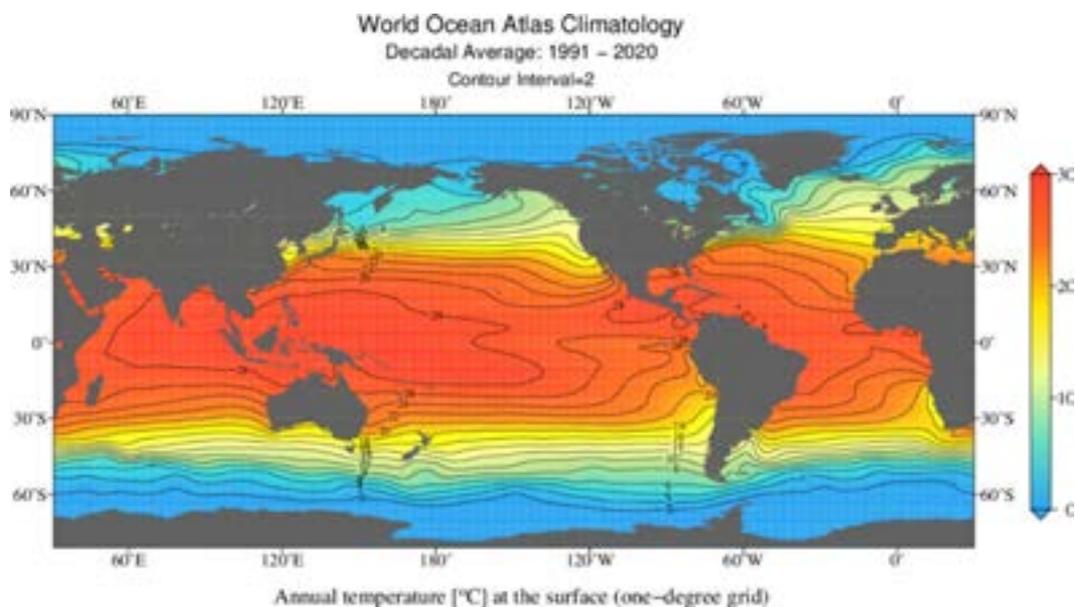


Figure 1B-2. Average ocean surface temperature, in degrees Celsius, from 1991 to 2020. [NOAA *World Ocean Atlas 2023*, [Link 1B-10](#)]

17. Examine the equatorial region on Figure 1B-2. The broadest expanse of sea-surface temperatures 28°C or higher is in the _____.

- a. Eastern Pacific Ocean off the coast of South America
- b. Indian and Western Pacific Oceans
- c. Atlantic Ocean

18. Examine the sea-surface temperatures in Figure 1B-2 between 30°N and 30°S on the western and eastern coasts of the Americas. Temperatures are highest along the _____ Coast of North America and the _____ Coast of South America.

- a. East and Gulf ... East
- b. West ... East
- c. East and Gulf ... West
- d. West ... West

Salinity plays a central role in regulating ocean circulation, which, in turn, influences global climate patterns. Variations in salinity, shown in **Figure 1B-3**, affect the density of ocean water, driving the movement of deep and surface currents and, consequently, heat distribution across the planet.

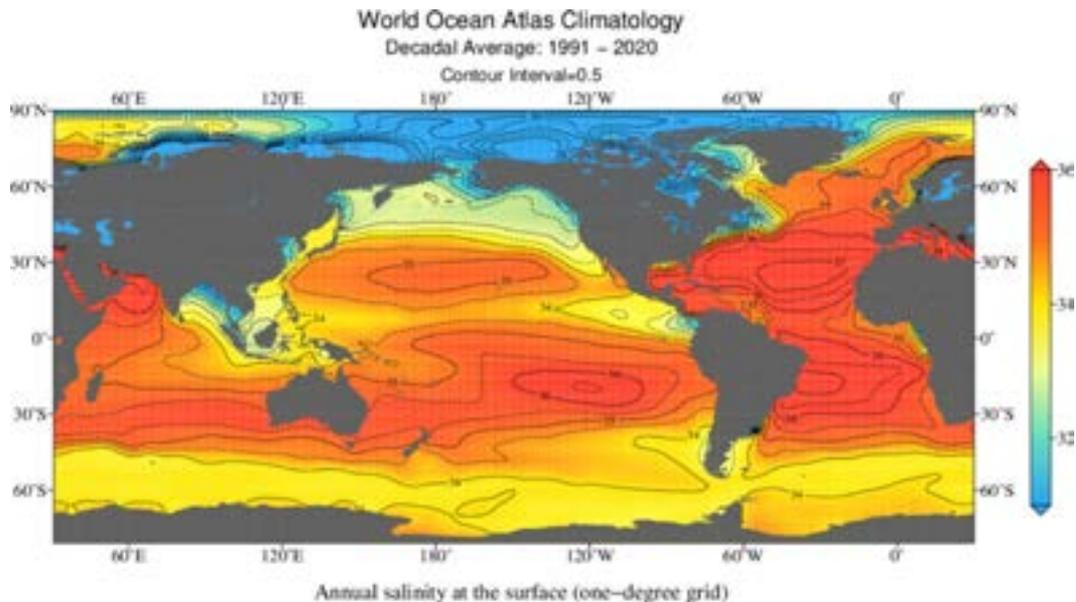


Figure 1B-3. Average ocean surface salinity from 1991 to 2020. [NOAA *World Ocean Atlas* 2023, [Link 1B-10](#)]

19. Salinity is a unitless measure of the concentration of dissolved salt in water. The ocean basin with the highest surface salinity in Figure 1B-3 is the _____.

- a. Southern Ocean
- b. Indian Ocean
- c. Atlantic Ocean
- d. Pacific Ocean

Figure 1B-4 shows the patterns of dissolved oxygen concentration in the surface ocean. Dissolved oxygen is vital for the survival of many types of marine life, including fish and invertebrates. It serves as a

key indicator of water quality, reflecting the health and balance of an ecosystem.

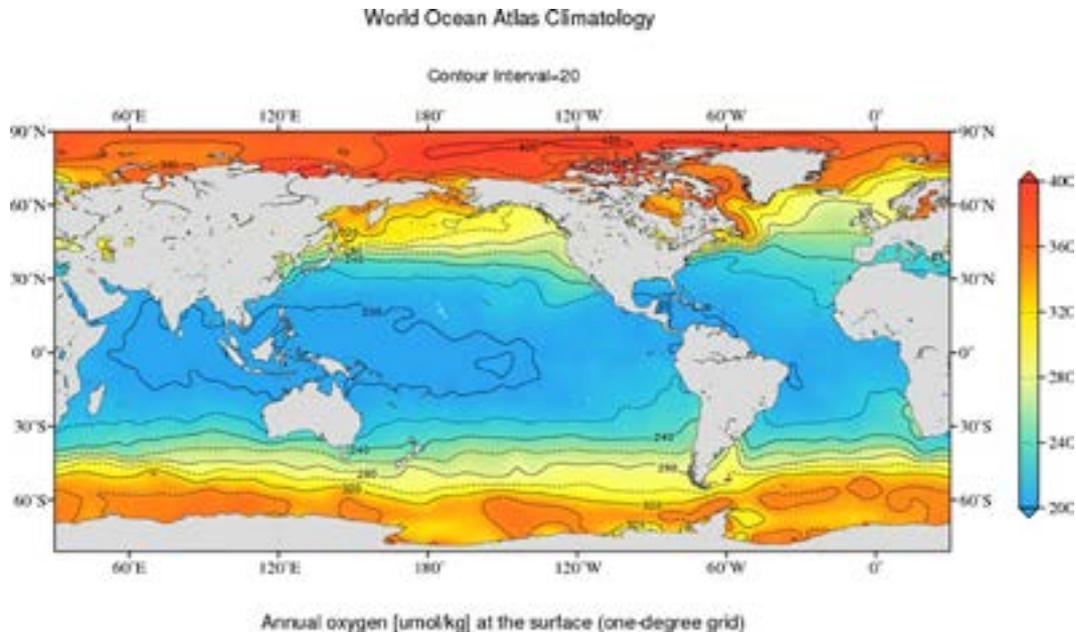


Figure 1B-4. Average ocean surface dissolved oxygen concentration ($\mu\text{mol/kg}$). [NOAA *World Ocean Atlas* 2018, [Link 1B-10](#)]

20. Compare Figure 1B-4 patterns of dissolved oxygen concentration in ocean water with sea-surface temperature patterns in Figure 1B-2. The concentration of dissolved oxygen _____ as sea-surface temperature decreases. Therefore, the concentration of dissolved oxygen in the surface ocean is highest in the _____.
- decreases ... Indian Ocean
 - increases ... Indian Ocean
 - decreases ... Arctic Ocean
 - increases ... Arctic Ocean

Shown in **Figure 1B-5**, silica is an important nutrient in the ocean, especially for diatoms and microalgae that use it to build their skeletal structures. Silica is fairly low in most surface regions of the ocean except around river mouths, glaciers, submarine volcanoes, and specific ocean floor sediments.

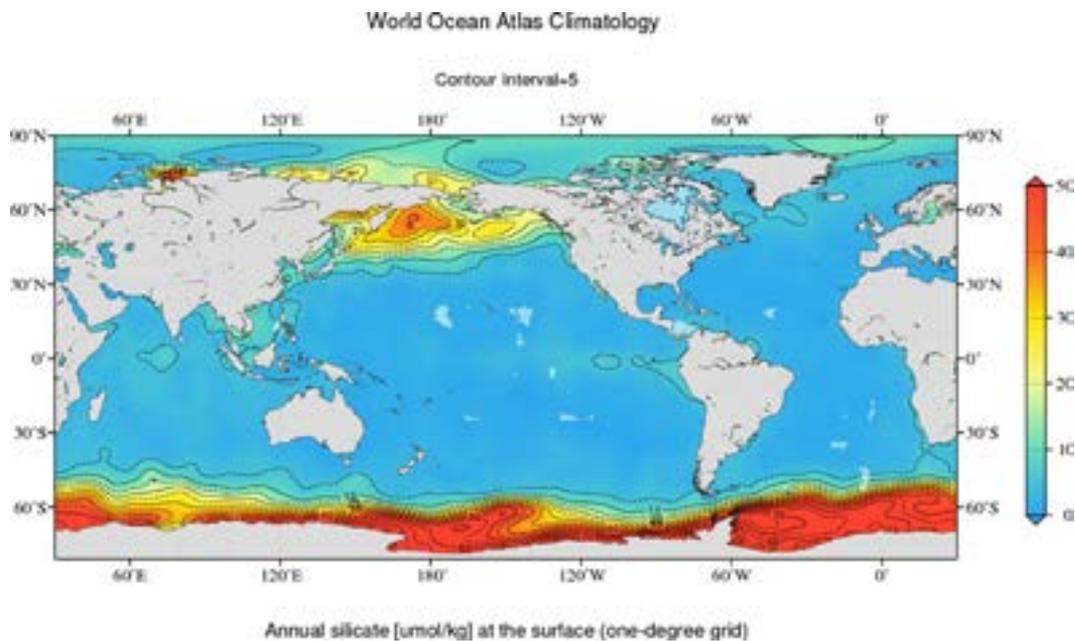


Figure 1B-5. Average ocean surface silicate concentration ($\mu\text{mol/kg}$). [NOAA *World Ocean Atlas 2018*, [Link 1B-10](#)]

21. The concentration of silicate in Figure 1B-5 is highest _____.
- in the northern Pacific and Southern Oceans
 - in broad areas of the Arctic Ocean
 - in the equatorial Indian Ocean
 - throughout the Atlantic Ocean

With maps, such as those presented in Figure 1B-2 to Figure 1B-5, we can begin to understand the ocean's layout and properties.

Summary

Exploring the ocean relies on various methods for displaying scientific information, including the use of flat map projections and globes. *Google Earth* provides both conformal and equal area views while enabling us to seamlessly move locations and zoom from global to local views. The world ocean can be divided into five major basins, the Atlantic, Pacific, Indian, Arctic, and Southern Oceans. The *World Ocean Atlas* presents one visual representation of many different ocean properties across the Globe.

References

- Boyer, T. P., and Coauthors, 2019: *World Ocean Atlas 2018*, dissolved oxygen ($\mu\text{mol/kg}$). NOAA National Centers for Environmental Information, accessed 28 October 2021, <https://accession.nodc.noaa.gov/NCEI-WOA18>.
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