Investigation 3A

Observation in Action

Objectives

The ocean is the largest water reservoir on Earth. It transports water and heat around the globe and is home to a vast number of unique species that we depend on not only for food but also to maintain our planet. Monitoring the ocean enables us to identify environmental threats, such as pollution, over-fishing, and habitat destruction, and to invest in conservation strategies and the sustainable use of the ocean's resources.

In this investigation, we will:

- Compare quantitative and qualitative observations
- Evaluate the applications of in-situ and remote sensing

Types of Observations

We describe the ocean with qualitative and quantitative observations. **Quantitative observations** use numbers to define the variables they measure, such as temperature, pressure, and current velocity. On the other hand, **qualitative observations** are descriptions without numbers, such as phytoplankton species. Both observations are essential to characterizing the ocean and how it changes over time.

1. _____ is a qualitative observation.

    a. Sea-surface temperature
    b. Sea level
    c. Whale behavior
    d. Salinity

2. A _____ observation is more subjective and open to interpretation.

    a. qualitative
    b. quantitative

Once we could only observe the ocean from the coasts, then from ships, and now from submersibles, buoys, and floats. Exploring the intricacies of the ocean is only possible with these recent advances in technology. Today, over 80% of the ocean remains unexplored due to challenges such as intense pressure, low visibility, and extreme cold. These conditions make it more difficult to investigate, sample, and predict changes in the ocean.

The Global Ocean Observing System (GOOS), part of the United Nations Educational, Scientific and Cultural Organization, defines and monitors 35 Essential Ocean Variables (EOV), listed in **Table 3A-1**. Three of them are in emerging fields.

Table 3A-1. Essential Ocean Variables

Acronym	Water Mass
Physics	Sea state, Sea ice, Sea-surface height, Sea-surface and sub-surface temperature, Surface and subsurface salinity, Surface and subsurface currents, Ocean bottom pressure
Biochemistry	Oxygen, nutrients, Inorganic carbon, Particulate matter, Nitrous oxide, Dissolved organic carbon
Biology and Ecosystems	Biomass and diversity of phytoplankton, zooplankton, and microbes,* Abundance and diversity of fish, marine turtles, marine mammals, seabirds, and invertebrates,* Cover and composition of hard coral, macroalgae, seagrass, and mangroves
Cross-disciplinary	Ocean color, Marine debris,* Ocean sound

**Fields for microbes, invertebrates, and debris are emerging [Adapted from GOOS, 2024]*

3. The EOVs in Table 1 are categorized by field, but oceanography is a cross-disciplinary field. _____ is categorized as a cross-disciplinary EOV because it can be used to quantify sediment content as well as phytoplankton abundance, and track harmful algal blooms.

    a. Sea surface temperature
    b. Sea state
    c. Ocean color
    d. Surface salinity

4. Ocean bottom pressure is an example of a _____ observation.

    a. qualitative
    b. quantitative

In-Situ Measurements

In 1991, the Intergovernmental Oceanographic Commission of UNESCO created GOOS to coordinate and regulate the collection of data about the ocean. GOOS develops observing tools, data collection systems, scientific analysis, and forecasts of ocean changes. **Figure 3A-1** shows the measurement devices, including floats, buoys, gliders, and platforms, that are part of GOOS. The measurements taken by these devices are considered **in-situ** measurements because they are obtained by an instrument in direct contact with the variable.

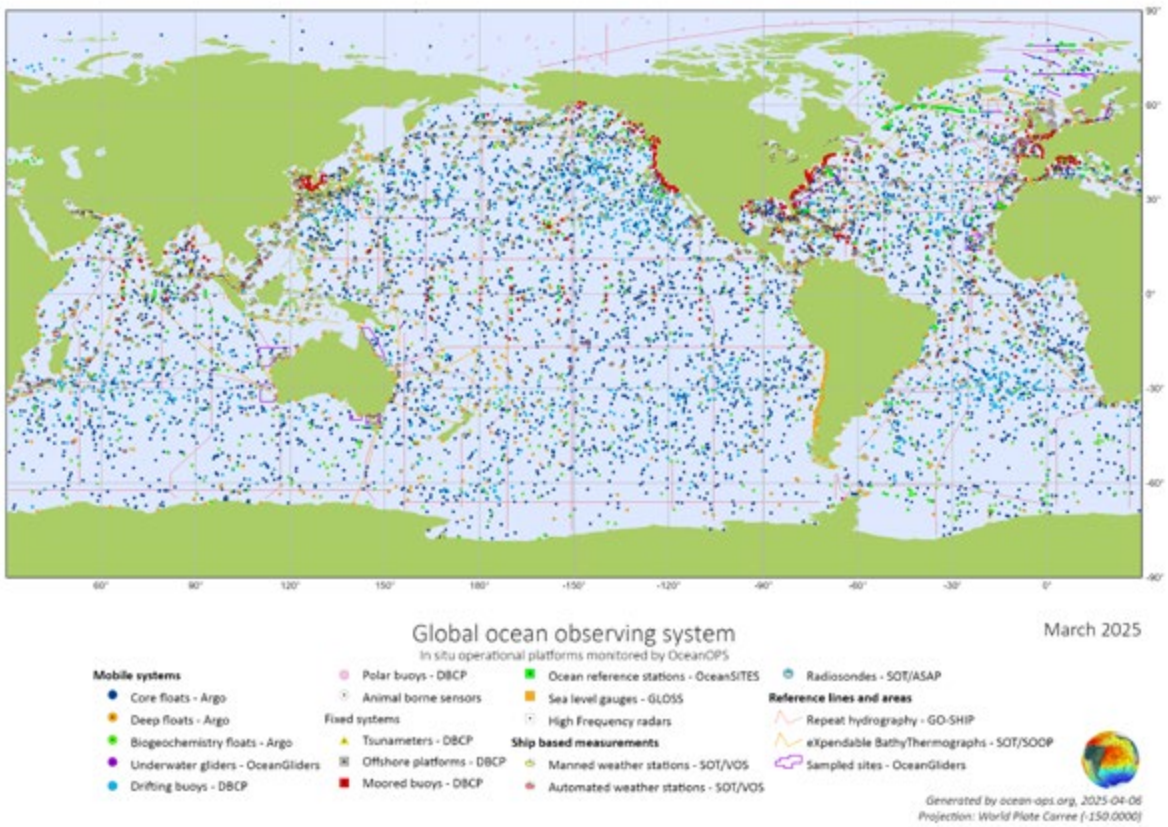

Figure 3A-1. A variety of devices from many organizations allow us to observe the ocean. [Ocean OPS 2025] .

The light blue dots in Figure 3A-1 are drifting buoys that make up the Global Drifter Program, one component of GOOS, which aims to maintain a global 5° x 5° gridded array of ocean surface measurements. These drifters provide real-time, in-situ ocean and atmosphere measurements, like ocean current speed and direction, sea-surface temperature, atmospheric pressure, wind, wave height, and salinity. **Figure 3A-2** is a record from a drifter currently in the western Atlantic.

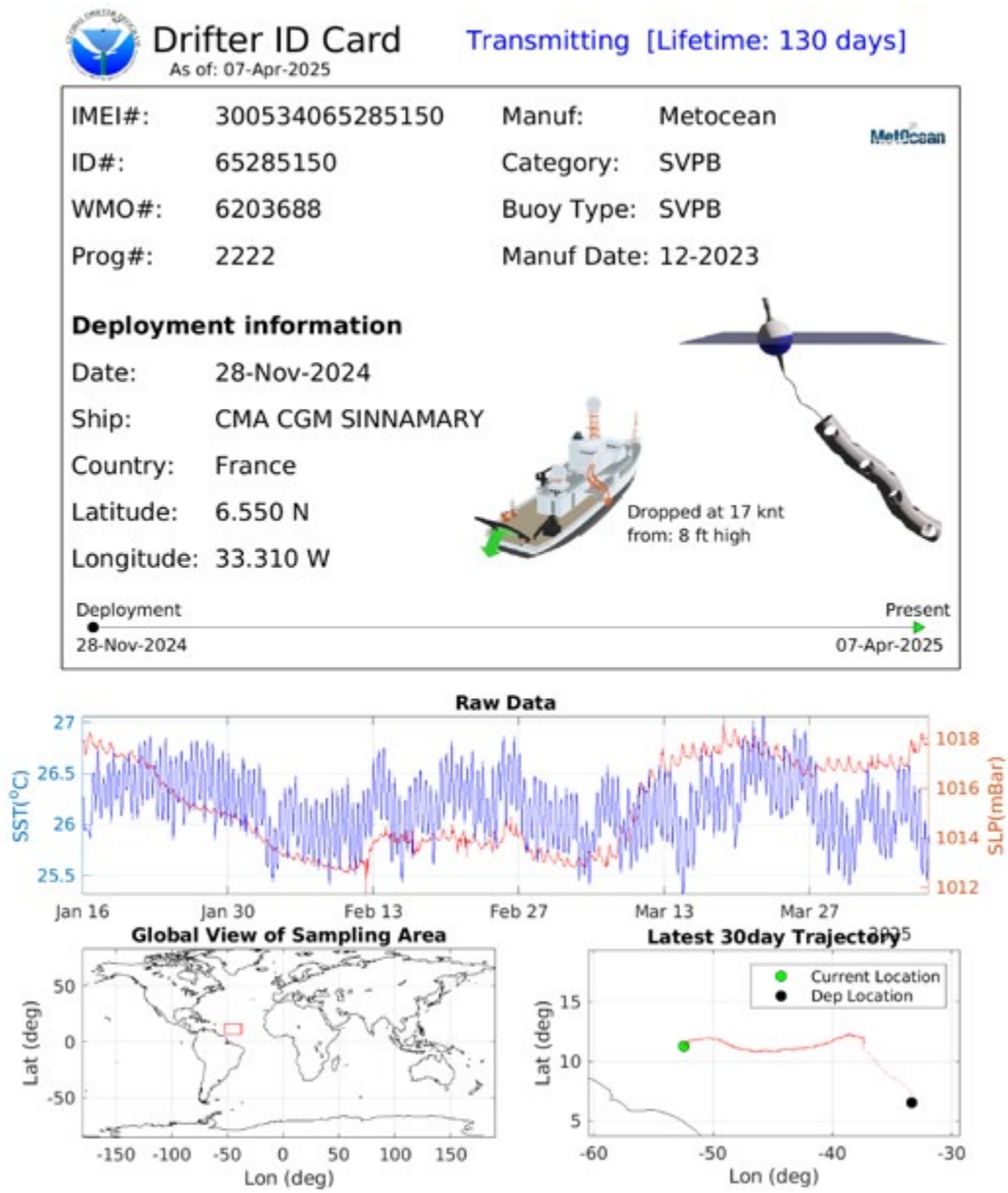

Figure 3A-2. Drifter #65285150 ID Card, with identifying information, surface temperature and pressure data, and maps of its path from 28 NOV 2024 to 7 APR 2025. [AMOL GDP Array, 2025]

5. Figure 3A-2 shows the sea level pressure trend (red) _____ from 1–20 March 2025.

   a. increased
   b. decreased
   c. held steady

6. The observations collected by this drifter, including SST and sea level pressure (SLP), are _____.

   a. qualitative
   b. quantitative

7. This drifter was dropped in the _____ and floated _____, providing a record of the conditions

along its path.

a. Atlantic ... east
b. Atlantic ... west
c. Pacific ... east
d. Pacific ... west

Drifters are valuable because of the amount and density of the data they collect, but they are limited to the surface ocean. Profiling floats and gliders provide in-situ observations below the surface, but their coverage is limited.

A major element of GOOS is the Argo Project, an international effort begun in 2000. It provides a quantitative description of the upper ocean and the patterns of variability from months to decades, especially heat and water storage and transport. The initial goal, which was surpassed in October of 2007, was to deploy more than 3000 profiling floats around the ocean. The Argo Program now includes floats, buoys, gliders, and platforms, mapped as dark blue circles in Figure 3A-1, that collect continuous data throughout the ocean.

Argo core floats operate on a 10-day cycle as shown in **Figure 3A-3**. The battery-powered autonomous floats sink from the ocean surface to a *parking depth* of 1000 m (3280 ft.), where the floats are neutrally buoyant in the water column. For 9 days, the floats remain at their parking depth, passively collecting data as they drift with the ocean currents. They then sink quickly to a depth of 2000 m (6550 ft.) before ascending to the surface over a period of about 6 hr. As the floats ascend, they can record pressure, temperature, salinity, and other variables depending on their sensors. In this short period, up to 200 data points are taken and stored in the Argo system as a profile of the water column. Upon reaching the ocean surface, the data are transmitted to satellites, along with the corresponding latitude and longitude. The floats then start their next cycle.

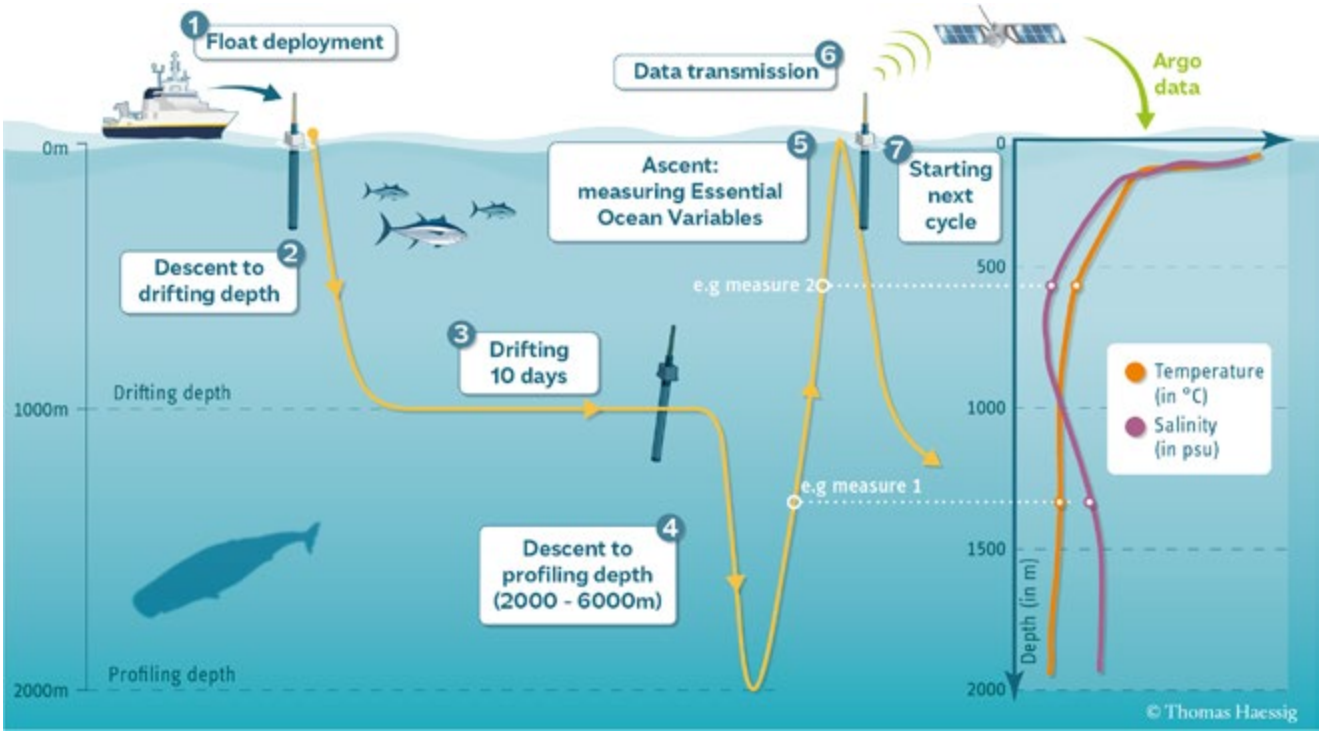

Figure 3A-3. Argo floats collect data from the upper layers of the ocean in 10 day cycles. [T. Haessig, ARGO, 2020, with permission]

8. The primary function of an Argo float is to _____.

    a. record ocean depth over large areas
    b. measure essential ocean variables
    c. record the location of ships
    d. count local fish populations

9. Argo floats spend most of their time at a depth of 1000 m to _____.

    a. record mid-depth ocean data
    b. maintain a constant temperature
    c. maximize their ability to communicate with satellites
    d. measure the most biologically active layer

10. According to the profile on the right side of Figure 3A-3, salinity and temperature changed most drastically between _____ m.

    a. 0 and 200
    b. 200 and 500
    c. 500 and 1000
    d. 2000 and 1500

The new Deep Argo Mission began in 2018 with the goal of profiling the ocean to depths of up to 6000 m. These new floats, green circles in Figure 3A-1, provide the opportunity to study the ocean's total heat content and circulation patterns important to ocean modeling.

Remote Sensing

Often, in-situ measurements are expensive, time-consuming, incremental instead of continuous, and difficult to collect, so we also collect ocean data from a distance. This is called **remote sensing**, which includes images and measurements taken by airplanes and satellites.

Satellites may be the most useful tool in detecting EOVs. Satellites in orbit around Earth can sense radiation at different wavelengths and take high-resolution photographs that can be processed to determine variables such as cloud cover, ocean current speed and direction, and sea-surface temperature (SST). **Figure 3A-4** is a full-color, high-resolution visible light photograph of the East Coast from the NOAA GOES-East Satellite. The far left side of the image is filled in with infrared imagery because it is still dark in that area.

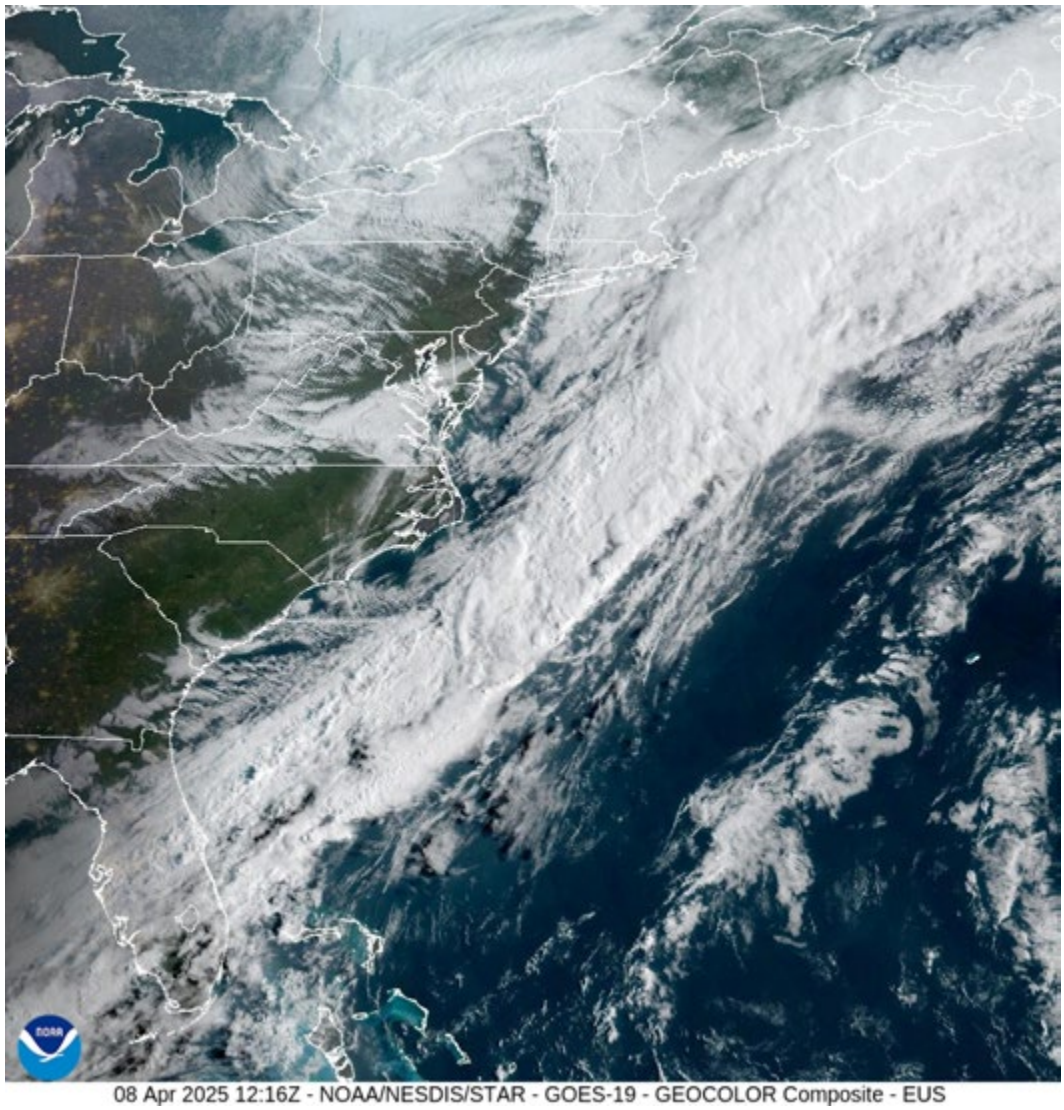

Figure 3A-4. Visible light image from the NOAA GOES-East satellite on 8 APR 2025. [GOES-East, 2025]

11. Looking at Figure 3A-4, what are two observations you can make?

    a. SST and cloud cover type
    b. Sea state and ocean current speed
    c. Cloud cover type and ocean color
    d. Ocean color and SST

12. These two observations are _____.

    a. qualitative
    b. quantitative

Other data types, including SST and bathymetry, are assessed by examining the shading and colors in various types of satellite imagery. SST is calculated from the amount of infrared radiation in the ocean's surface layer. These wavelengths are detected by Moderate Resolution Imaging Spectroradiometer

(MODIS) instruments on NASA's Terra and Aqua satellites. **Figure 3A-5** is a map of SST created from multiple satellite images on 8 April 2025. The colors range from 0°C in dark purple to 32°C in dark red.

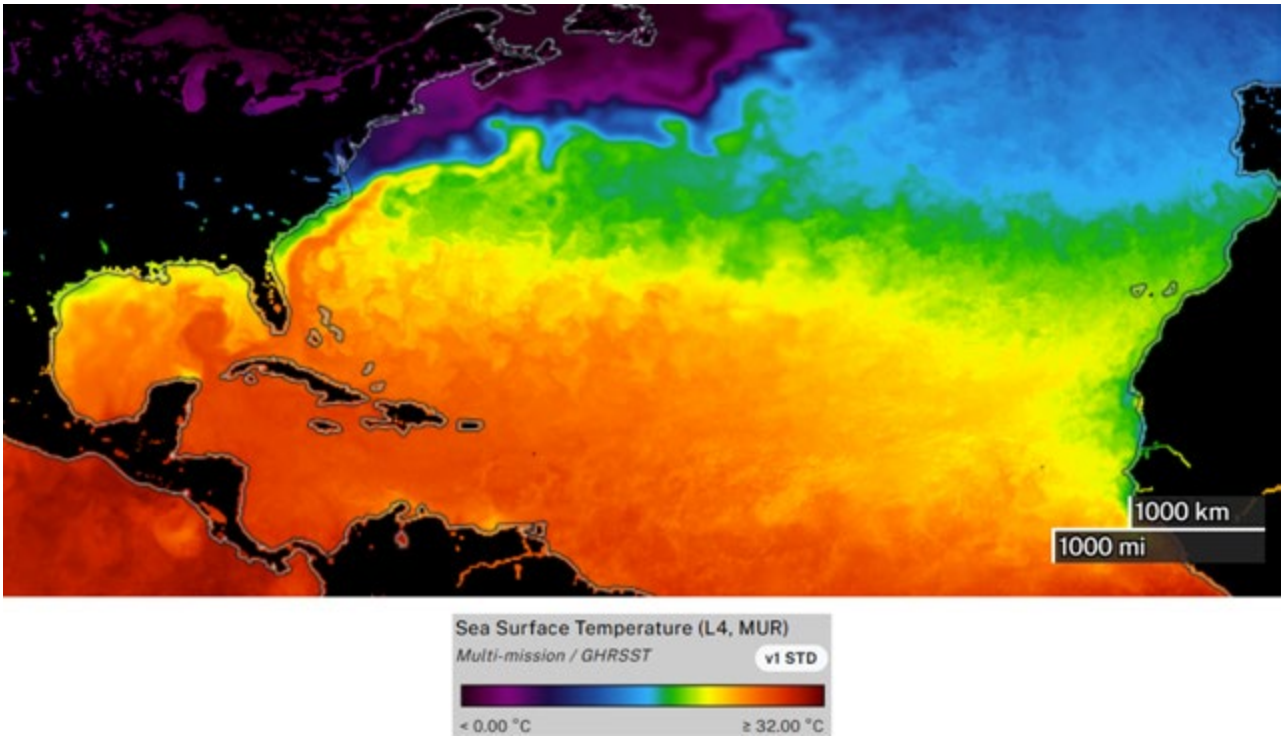

Figure 3A-5. Sea-surface temperature (°C) for 8 APR 2025 for the North Atlantic. [NASA Worldview, 2025]

13. According to Figure 3A-5 and the drifter's path in Figure 3A-2, the North Equatorial current travels _____, transporting _____ water.

    a. east to west ... warm
    b. east to west ... cold
    c. west to east ... warm
    d. west to east ... cold

14. Examine the SST of the Gulf Stream Current, visible in Figure 3A-5, which flows along the coast from Florida to Maine before moving eastward into the open ocean. The Gulf Stream transports _____ water as it flows.

    a. warm
    b. cold

Advancements in remote sensing technology have been significant, and NASA continues to enhance satellite coverage. The launch of GOES-19 on 7 July 2024 introduced new and improved instruments into orbit.

Often, in-situ and remotely sensed data are combined to decrease uncertainty and reveal patterns in the data. This process of comparing in-situ data to remotely sensed data is called ground-truthing. It is necessary for robust and accurate observations and is often used for modeling the present and future ocean conditions.

Summary

Essential Ocean Variables are measurements that assess the current state of the ocean and are used to model future conditions. Both quantitative and qualitative observations are collected directly by in-situ sensors and remote sensing, often with satellites. This combination creates a more complete picture of the ocean and provides significant information about ocean processes. Even with all of these measurement techniques, much of the ocean has never been explored.

References

Figure 3A-1 – Ocean OPS, 2025: Global ocean observing system: In situ operational platforms monitored by OceanOPS. Accessed 7 April 2025, https://www.ocean-ops.org/board.

Figure 3A-2 – Global Drifter Array, 2025: #64295220 Drifter ID Card as of 07-Apr-2025. Accessed 7 April 2025, https://www.aoml.noaa.gov/phod/gdp/interactive/drifter_array.html.

Figure 3A-3 – Haessig, T., 2020: Argo float cycle. ARGO, accessed 8 April 2025, https://argo.ucsd.edu/wp-content/uploads/sites/361/2020/06/float_cycle_1.png, with permission.

Figure 3A-4 – GOES 19 Imagery, 2025: GOES-19 geocolor composite - EUS. Accessed 8 April 2025, https://cdn.star.nesdis.noaa.gov/GOES19/ABI/SECTOR/eus/GEOCOLOR/.

Figure 3A-5 – NASA Worldview, 2025: Multi-mission/GHRSST Sea Surface Temperature. Accessed 8 April 2025, https://worldview.earthdata.nasa.gov/.

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