Investigation 1A

Observing the Atmosphere

All Manual figures can be enlarged or printed by clicking on the figure to open it in a new browser tab or window.

Objectives

Weather is the state of the atmosphere at a particular time and place, defined by variables that are routinely observed and recorded. Observations are collected, analyzed, and made publicly available by the *National Oceanic and Atmospheric Administration*'s (NOAA) *National Weather Service* (NWS). Weather observations define the current state of the atmosphere and allow us to study its processes and forecast future weather. Weather variables are directly measured and remotely sensed by radar and satellites, allowing us to create a more comprehensive picture of the atmosphere.

Throughout the course, we will utilize resources collected on the public website *Weather Studies Maps & Links* (Link 1A-1). We recommend bookmarking this site for future use.

After completing this investigation, you should be able to:

- Contrast quantitative and qualitative observations
- Identify important weather variables
- Explain the benefits and drawbacks of in-situ and remote-sensing measurements
- Examine the different methods of collecting measurements

Scientific Observations

The atmosphere is described using both qualitative and quantitative scientific observations. **Qualitative observations** are descriptions of variables, usually expressed without numbers. On the other hand, **quantitative observations** use numbers, either counted or measured, to define the variables they describe (for example, temperature, pressure, and humidity).

1. _____ is a qualitative observation.

    a. Amount of precipitation
    b. Solar radiation percentage
    c. Surface pressure
    d. Description of the weather

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

    a. qualitative
    b. quantitative

These observations are all important to characterize Earth's atmosphere, but the models that forecast the weather must have numeric variables.

The weather in any location cannot be captured by only one variable. For example, if you look at temperature alone, a sunny and rainy day could be described as having the same weather, which would be misleading. Variables such as humidity, precipitation, and cloud cover make the weather drastically different even if the temperature is the same. All the variables must be taken into account to understand the weather. **Table 1A-1** shows an abbreviated list of weather variables.

Table 1A-1. Weather Variable Examples

Altitude	Weather Variables
Surface Weather	Temperature, wind speed and direction, water vapor, relative humidity, pressure, dewpoint, precipitation type and amount, visibility, surface radiation budget, air quality
Upper-Air Weather	Temperature, wind speed and direction, water vapor, relative humidity, pressure, dewpoint, cloud properties, cloud cover, Earth's radiation budget, lightning

Adapted from WMO, Link 1A-2

We observe the weather qualitatively ourselves on a daily basis: how warm or cold it is, if it is muggy or dry, if the sky is blue and cloud free or dark with clouds, if it is raining, or if it is snowing. We also collect exact, quantitative observations with thermometers and rain gauges, and in the last hundred years, we have relied on radar and satellites to observe national and global patterns.

3. Air quality is continually observed at the surface to _____.

   a. monitor the pollutants emitted by aircraft
   b. track water vapor in the atmosphere
   c. assess health risks associated with air pollution
   d. determine the effect of air pollution on global cloud cover

In-situ Measurements

Variables that can be directly measured are defined as **in-situ** measurements. In-situ is Latin for "in position," and in-situ measurements are obtained by an instrument in direct contact with the variable. In-situ measurements can often be collected by simply stepping outside. Any measurement that can be made by an instrument on the ground, in the atmosphere, or in the ocean is an in-situ measurement.

4. _____ is an example of an in-situ measurement.

   a. Monitoring weather patterns from a satellite
   b. Analyzing historical climate data records
   c. Measuring precipitation with a rain gauge
   d. Calculating ice sheet thickness from satellite images

The National Oceanic and Atmospheric Administration (NOAA) collects atmospheric observations using surface weather stations and oceanic observations using floats spread over the global ocean. NOAA's National Weather Service (NWS) collects in-situ measurements using the Automated Surface Observing System (ASOS), which consists of more than 900 instrument arrays that monitor weather conditions up to 12 times an hour. An example instrument array is shown in **Figure 1A-1**.

Figure 1A-1. Automated surface-observing stations collect in-situ measurements at the surface. [*Weather Studies* textbook, Figure 2.14]

These stations collect information like sky conditions, surface visibility, precipitation, temperature, and wind conditions on Coordinated Universal Time (UTC), or Zulu (Z) time. UTC is 5 hr ahead of Columbia, SC, which is in Eastern Standard Time (EST), so the 1656Z timestamp is 1:56 p.m. EST local time (12:56 p.m. CST, 11:56 a.m. MST, 10:56 a.m. PST, etc.). **Table 1A-2** is an example of raw data collected by an ASOS array in Columbia, SC from 1656Z to 1856Z on 9 January 2024. ASOS observations are supplemented by volunteer observers within the NWS *Cooperative Observer Program* (COOP) who collect and provide additional observations.

Table 1A-2. ASOS observations

Time (Z)	Temperature (°F)	Dewpoint Temperature (°F)	Relative Humidity (%)	Wind Direction (degrees from North)	Wind Speed (kts)	Sea Level Pressure (mb)
1/9/24 1656	67	64	90.09	170	25	999.6

Time (Z)	Tempera-ture (°F)	Dewpoint Temperature (°F)	Relative Humidity (%)	Wind Direc-tion (degrees from North)	Wind Speed (kts)	Sea Level Pressure (mb)
1/9/24 1721	67	65	93.29	170	21	998.4
1/9/24 1756	67	65	93.29	170	20	997.0
1/9/24 1856	67	65	93.29	160	21	994.8

Iowa Environmental Mesonet, Link 1A-3

5. All of the observations in Table 1A-2 are _____.

   a. qualitative
   b. quantitative

6. Typically, an ASOS report occurs every _____. Reports are created more often when severe weather occurs, as was the case in Columbia on 9 January at 1721Z.

   a. 10 min
   b. 30 min
   c. 1 hr
   d. 2 hr

7. For Columbia, on 9 January, the thunderstorm began to worsen between 1656Z and 1756Z. This is evident by the high wind speeds, and a _____.

   a. decrease in air temperature
   b. decrease in dewpoint temperature
   c. change in wind direction
   d. decrease in sea level pressure

These observations are transmitted to the local NWS office, plotted on maps, and then analyzed. This allows meteorologists to see spatial patterns in the data. **Figure 1A-2** is an analyzed map of sea level pressure data of the Southeast on 9 January 2024 at 18Z.

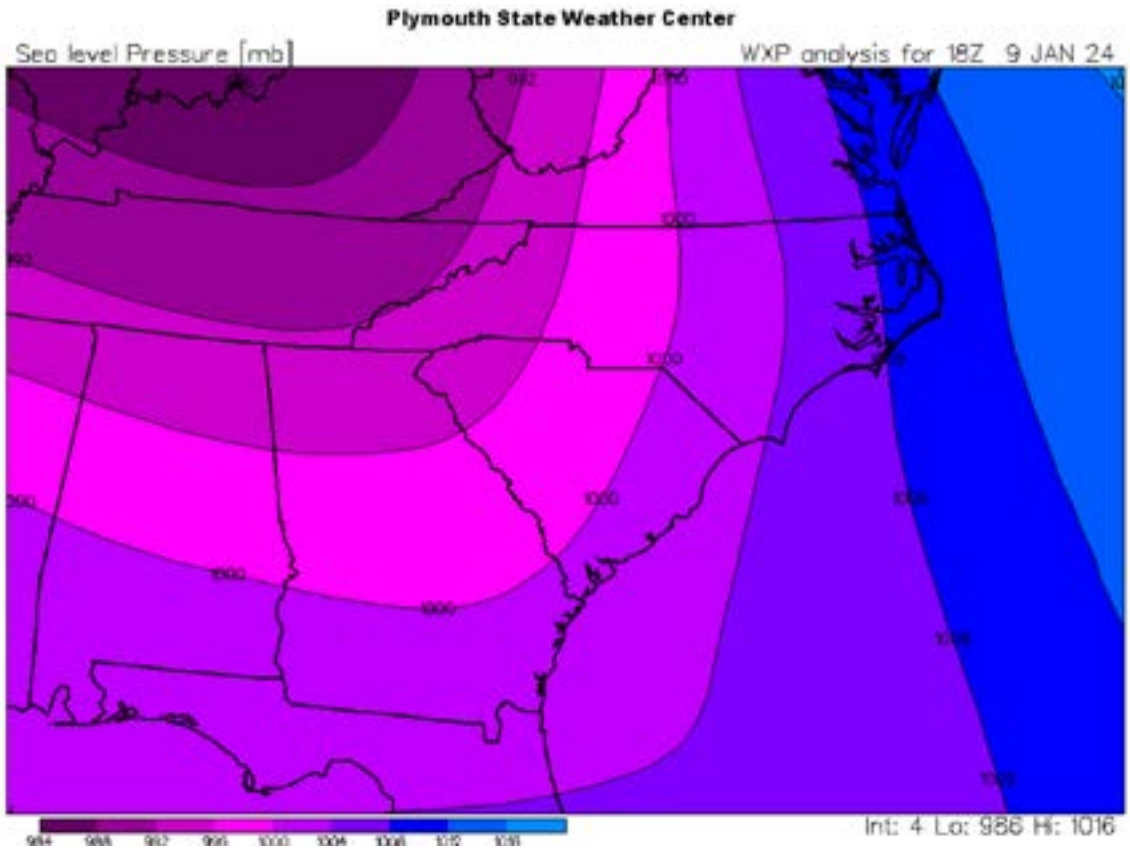

Figure 1A-2. Analyzed map of sea level pressure in the southeastern U.S. at 18Z on 9 JAN 2024. [PSWC, Link 1A-4]

If you are having trouble reading the colors on the maps in these studies, please access the free ***Visolve*** *software at* Link 1A-5.

8. In Figure 1A-2, Columbia, in central South Carolina, is shaded in light purple, meaning its sea level pressure was between _____ mb.

   a. 988 and 992
   b. 992 and 996
   c. 996 and 1000
   d. 1000 and 1004

You will learn to do this type of analysis in *Investigation 1B*.

Another source of in-situ atmospheric observations are *radiosondes*, small instrument packages, which measure upper-air conditions, carried aloft by balloons filled with either hydrogen or helium. Radiosondes are released daily at 00Z and 12Z from 92 stations across the U.S. (more often when there is severe weather). Radiosondes typically measure temperature, dewpoint, pressure, and GPS location while ascending to an altitude of about 35 km (22 mi.), and descend with a parachute when the balloon bursts. A map of the stations that collect upper-air data can be found at *Weather Studies Maps & Links* (Link 1A-1), Upper Air, "Available Upper-Air Stations." A radiosonde release is shown in **Figure 1A-3**.

Figure 1A-3. Radiosonde balloon carrying an instrument box upward. [WIMSE, Link 1A-6]

9. Because radiosondes are attached to balloons as they ascend through the atmosphere, they may travel horizontally more than 300 km (186 mi.). The transmission of GPS positions allows meteorologists to calculate _____.

   a. wind speed and direction
   b. precipitation type and amount
   c. the solar radiation budget
   d. air quality and atmospheric composition

In-situ measurements offer a range of advantages in scientific research and environmental monitoring. They can provide real-time data, allowing researchers to monitor changes as they occur, which is particularly valuable during sudden events. In-situ measurements are known for their high precision and accuracy, as they allow for direct and close-up observation and yield detailed, localized information. They are also flexible and customizable for specific research needs, making them adaptable to various scientific objectives.

Conversely, in-situ measurements can be resource-intensive and time-consuming, requiring personnel, equipment, and logistical support for data collection in the field. Additionally, in-situ measurements may not be practical in remote or hazardous environments.

Remote Sensing

Because in-situ measurements can be expensive, time-consuming, and difficult (or impossible) to collect, we rely on technology to collect weather data from a distance. This is called **remote sensing** and includes radar and satellite imagery.

Radar is often used to detect precipitation, and Doppler radar can detect which direction storms are moving. A radar system obtains information about wind and precipitation by sending a burst of energy and then "listening" for any energy that reflects back after hitting an object. When the energy hits an object, like rain, snow, hail, flocks of birds, or insects, it is scattered in all directions. A small fraction of this scattered energy is "heard" by the radar and recorded. Computers analyze the returned "noise" to create radar images, which are typically shown with weather forecasts. We will learn more about Doppler radar in *Investigation 7B*.

10. Radar "listens" for energy reflected off objects through the atmosphere. To avoid as much interference as possible, radars are generally aimed above the tallest trees. Radar would not record _____.

    a. flock of migrating birds
    b. rainfall from a thunderstorm
    c. water vapor in the lower troposphere
    d. sleet falling from a cloud

Figure 1A-4 is a map of the radar imagery at 18Z on 9 January 2024, the same time as Figure 1A-2. The scale on the left shows reflectivity in decibels (dB) of reflectivity (Z) on an exponential scale, with low values in green and high values in dark red and pink. The higher the reflectivity, the more precipitation is expected.

Figure 1A-4. Radar imagery with a storm showing 10–60 dBZ, implying higher precipitation rates in the southern stretch of the storm, at 18Z on 9 JAN 2024.

11. Figure 1A-4 is a composite map of all the radar signals from across the continental U.S. and shows

a large winter storm over much of the eastern half of the country. The radar imagery shows that _____ has the highest reflectivity, so we can infer it has the highest precipitation rates at 18Z.

a. Texas
b. New York
c. Illinois
d. Georgia

Radar is especially important in detecting extreme weather, such as thunderstorms, tornadoes, and hurricanes, because it can sense changes in storm rotation and speed.

However, the distance that radar can cover is limited by elevation changes and the curvature of the Earth because the beams of energy sent by radar travel in straight lines and can be blocked by any large object. The range of a radar is greater when it is placed in the highest location relative to the surrounding land surface, but their maximum range is about 200 km (124 mi.).

Another way to observe Earth's atmosphere is through satellites. These satellites take high-resolution photographs of Earth at different wavelengths that can then be processed to determine variables such as cloud cover, wind speed and direction, temperature, and water vapor concentration. These images are a useful addition to radar because they can cover large areas and provide an overview of the current conditions.

Visible light images are valuable for tracking weather patterns, monitoring vegetation health, and observing human activities such as urbanization and deforestation. However, they are dependent on daylight and clouds can mask the ground. Pairing them with images of the same area gives a more complete image.

Figure 1A-5 is a full-color high-resolution visible light photograph of the northern U.S. and Canada from the NOAA GOES-East Satellite at 1802Z on 9 January 2024.

Figure 1A-5. Visible light image from the NOAA GOES-East satellite at 1802Z on 9 JAN 2024. [Link 1A-7]

12. A limitation of visible satellite imagery is that it _____.

    a. cannot capture images during daylight hours
    b. is only available from ground-based cameras
    c. is ineffective in detecting cloud cover
    d. cannot capture images during nighttime

13. What observation could be made from this visible light satellite image?

    a. Temperature
    b. Precipitation amount
    c. Cloud cover
    d. Humidity

14. This observation is _____.

    a. qualitative
    b. quantitative

Satellites carry many types of sensors and are not limited to visible light. In particular, infrared (meaning longer than red) wavelengths show weather variables like water vapor, cloud height, and cloud composition.

Summary

Observing weather variables is essential to understanding current weather and predicting future weather. Two types of observations, quantitative and qualitative, are necessary for understanding the atmosphere and weather. Remote sensing and in-situ measurements are valuable methods for monitoring the atmosphere and scientific research. These two types of measurements complement each other, and their combination provides a more holistic understanding of weather variables.