Investigation 1A

Observing the Atmosphere

Helpful Tips

- *Click on figure images for a larger image, which can be printed or edited*
- *Learn about the* online reader's capabilities
- *Bookmark* Weather Studies Maps & Links*, a collection of helpful links for this course and afterward*
- *For assistance with the colors on the figures in these investigations, use the free Visolve software*
- *As the course proceeds, we use NWS terminology for national geographic regions*

Objectives

Weather is the short-term state of the atmosphere at a particular time and place, defined by variables that we routinely observe and record. Observations are collected, either directly or remotely, by people, weather stations, radars, and satellites. These observations of weather variables help us understand the current state of the atmosphere and provide a record of the past, allowing us to discover patterns in the atmosphere's processes. This comprehensive picture of the atmosphere enables us to forecast future weather.

In this investigation, we will:

- Contrast quantitative and qualitative observations
- Identify important atmospheric 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, such as cloud or precipitation types, or how the temperature feels (e.g. warm or cold). On the other hand, **quantitative observations** use numbers, either counted or measured, to define the variables they describe, such as temperature or wind speed.

1. _____ is a qualitative observation.

    a. Amount of precipitation
    b. Solar radiation percentage
    c. Surface air pressure
    d. General description of the weather

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

a. qualitative
b. quantitative

All observations are important to characterize Earth's atmosphere, however, the models that replicate the atmosphere for us to study, as well as forecast the weather, must have numeric variables.

A single variable cannot fully capture the weather. 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, wind speed, and cloud cover make the weather drastically different even when the temperature is the same. Many variables must be taken into account to understand the weather. **Table 1A-1** presents a collection of variables for the weather.

Table 1A-1. Essential Climate Variables for Weather

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 cover and other properties, Earth's radiation budget, lightning

Adapted from WMO

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

Humans have collected weather observations throughout our history. Along with qualitative observations such as "it is pleasant out" or "it is windy today," we have recorded quantitative measurements with thermometers and rain gauges, among other tools. In the last hundred years, we have added radar and satellites, spanning regions, nations, and the globe.

In-situ Measurements

Variables 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. Any measurement that can be made by an instrument in the ground, the atmosphere, or the ocean is an in-situ measurement.

4. _____ is an in-situ measurement.

a. Monitoring weather patterns from a satellite
b. Analyzing historical descriptions of climate
c. Measuring the amount of precipitation with a rain gauge
d. Surveying Arctic polar ice with radars from airplanes

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.

ASOS 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 Eastern Standard Time (EST), so 0Z is 7 p.m. EST the day before, as well as 6 p.m. CST, 5 p.m. MST, 4 p.m. PST, 3 p.m. AKST, and 2 p.m. HST, all the day before. Weather maps are often analyzed at 0Z and 12Z, so 12Z translates to 7 a.m. EST, 6 a.m. CST, 5 a.m. MST, 4 a.m. PST, 3 a.m. AKST, and 2 a.m. HST. During Daylight Savings Time, which occurs from the second Sunday in March to the first Sunday in November, UTC is 4 hr ahead of EDT.

Table 1A-2 is an example of raw data collected by an ASOS at Dallas/Fort Worth International Airport, TX from 1553Z to 1953Z on 20 November 2025, which was from 9:53 a.m. to 1:53 p.m. CST locally. 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

Date/Time (CST and Z)	Temperature (°F)	Dewpoint Temperature (°F)	Visibility (mi.)	Wind Direction (degrees from North)	Wind Speed (kts)	Sea Level Pressure (mb)
11/20/25 0953 CST 1553Z	68	66	9	135	7	1015.8

Date/Time (CST and Z)	Temperature (°F)	Dewpoint Temperature (°F)	Visibility (mi.)	Wind Direc-tion (degrees from North)	Wind Speed (kts)	Sea Level Pressure (mb)
11/20/25 1053 CST 1653Z	69	67	9	270	5	1015.8
11/20/25 1153 CST 1753Z	65	62	2.5	90	7	1015.4
11/20/25 1253 CST 1853Z	65	62	5	45	3	1013.9
11/20/25 1353 CST 1953Z	66	63	10	135	7	1012.7

NWS

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

   a. qualitative
   b. quantitative

6. As seen in Table 1A-2, a routine ASOS report occurs every _____. Reports are generated more often when severe weather occurs.

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

7. At Dallas on 20 November, the weather observation indicated a thunderstorm with light rain at 1653Z and a thunderstorm with rain at 1753Z. During this hour, 0.83 in. of rain was recorded and the temperature _____.

   a. fell by 10°F
   b. fell by 4°F
   c. rose by 4°F
   d. rose by 10°F

8. At the same time, the wind shifted _____ and the visibility _____.

   a. from due east to due west … decreased
   b. from due east to due west … increased
   c. from due west to due east … decreased
   d. from due west to due east … increased

These observations are transmitted to the local NWS office, plotted on maps, and analyzed, which

enables us to see spatial patterns. **Figure 1A-2** is an analyzed map of sea level pressure data of the southern plains on 20 November 2025 at 18Z, which aligns with the third time stamp in Table 1A-2. The pressure lines are separated by 4 mb.

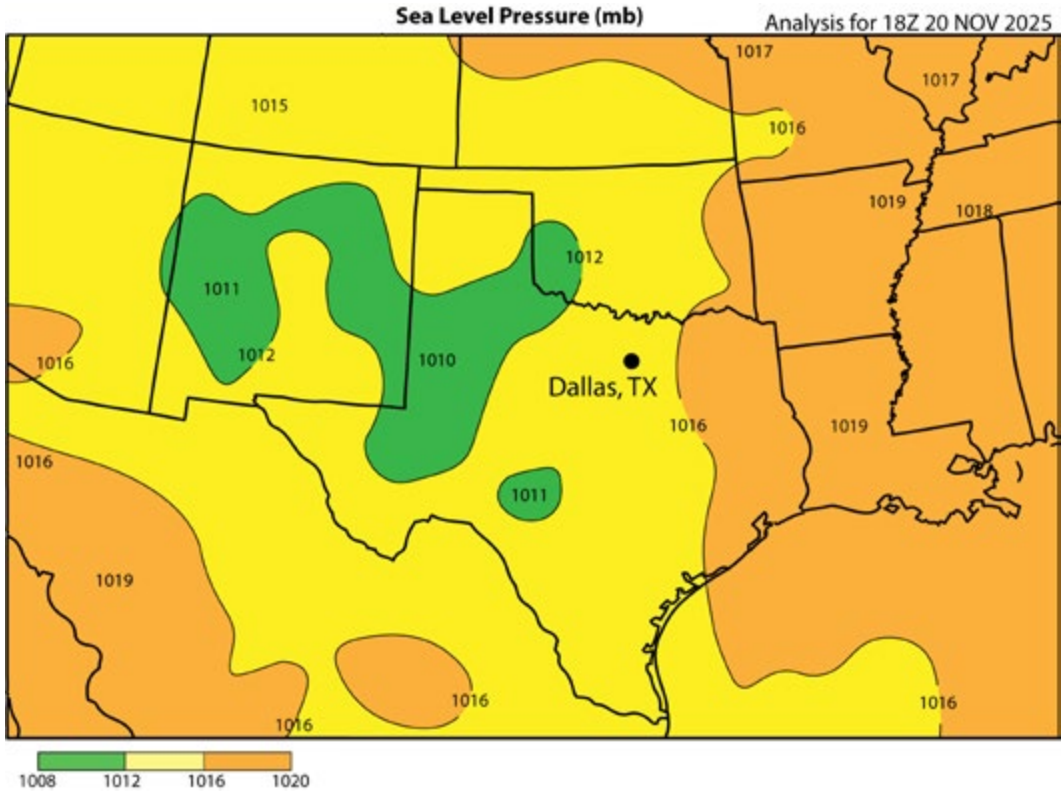


Figure 1A-2. Analyzed map of sea-level pressure in the U.S. at 18Z on 20 NOV 2025.

9. In Figure 1A-2, the isobar east of Dallas is _____ mb.

   a. 1012
   b. 1016
   c. 1020
   d. 1024

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

Another source of in-situ atmospheric observations are radiosondes, small instrument packages that measure upper-air conditions and are carried aloft by balloons filled with either hydrogen or helium. Radiosondes are released, as seen in **Figure 1A-3**, twice daily at 00Z and 12Z from 92 stations across the U.S., and more often during severe weather. Radiosondes typically measure temperature, dew-point, pressure, and location via GPS while ascending to an altitude of about 35 km (22 mi.), and then 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, in the Upper Air section, via “Available Upper-Air Stations.”



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

10. 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 their location allows us 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, providing real-time data, which allows for the changes to be monitored as they occur and is particularly valuable during rapidly changing events such as thunderstorms and tornadoes. In-situ measurements are also precise, with detailed, localized information. They can also be flexible for different research needs.

Conversely, in-situ measurements can be resource-intensive and time-consuming, requiring personnel, equipment, and logistical support to be placed and maintained. They can also be limited by remote or hazardous environments, such as in the path of a storm or the depths of the ocean.

Remote Sensing

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

Radar is often used to detect precipitation, and Doppler radar can detect the 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*.

11. Radar “listens” for energy reflected off objects moving 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 20 November 2025, 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 greater the reflectivity, the greater the precipitation rate.

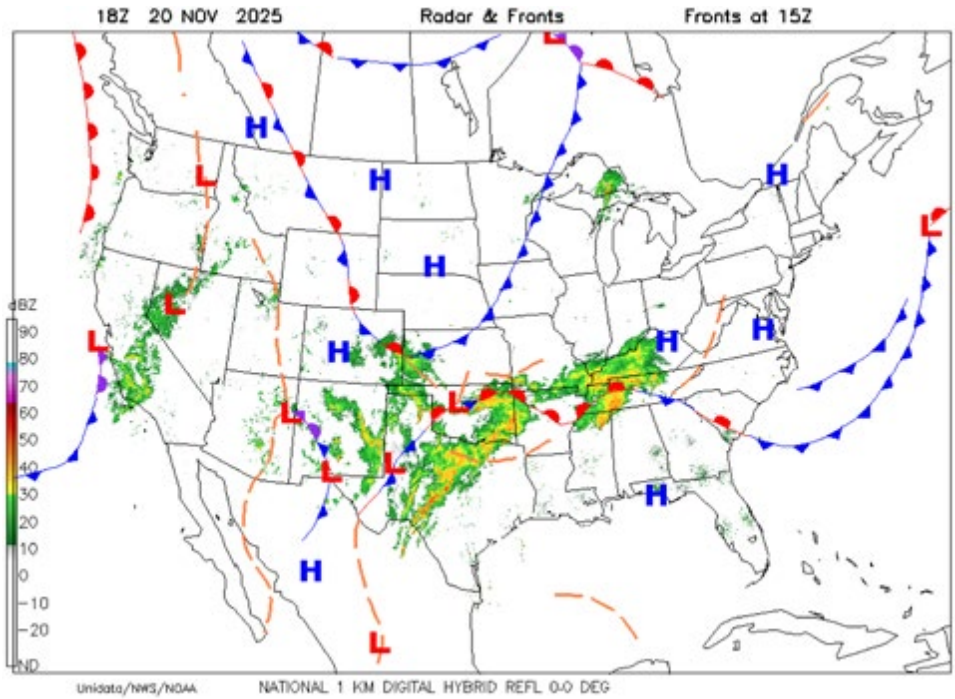


Figure 1A-4. Radar imagery with a storm showing 10–60 dBZ, implying higher precipitation rates in the southern stretch of the storm, at 18Z on 20 NOV 2025. Fronts are from 15Z.

12. Figure 1A-4 is a composite map of all the radar signals from across the continental U.S. and shows a line of rainstorms from southwestern Texas through northwestern Arkansas. This precipitation is most often closest to regions with a(n) _____.

    a. L (low pressure)
    b. H (high pressure)

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 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 its maximum range is about 200 km (124 mi.).

Another way to observe Earth's atmosphere is through satellites, which take high-resolution images of Earth at different wavelengths that can 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 on a global scale.

Visible light images are valuable for tracking weather patterns, monitoring vegetation health, and observing human activities such as urbanization and deforestation. However, they depend on daylight, and high or thick clouds can obscure everything below them.

Figure 1A-5 is a high-resolution GeoColor composite image of North America that combines a full-color visible light (0.47 and 0.64 nm) image from the NOAA GOES-East Satellite at 18Z on 20 November 2025. While the U.S. was experiencing daylight at this time, if the image were at night, the GeoColor image would add another wavelength (0.86 nm) to show lights during hours of darkness.



Figure 1A-5. Visible light image from the NOAA GOES-East satellite at 18Z on 20 NOV 2025. [GOES]

13. From Figure 1A-5, you can see Dallas' _____.

    a. temperature
    b. pressure
    c. cloud cover
    d. wind speed

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 forecasting future weather. Both quantitative and qualitative observations are necessary for understanding the atmosphere and weather. In-situ measurements and remote sensing are how we monitor the atmosphere. They complement each other and, when combined, provide a more holistic understanding of weather.

References

Figure 1A-2 – Plymouth State Weather Center, 2025: Surface data map, sea level pressure [mb]. Plymouth State University, accessed 24 November 2025, https://vortex.plymouth.edu/myowxp/sfc/ovrmap-a.html.

Figure 1A-3 – Wyoming NASA Space Grant, 2024: High-altitude balloon program. Accessed 14 January 2025, https://wyomingspacegrant.org/balloonprogram/ballooning101/step5-launch/.

Figure 1A-5 – GOES-East, 2025: GeoColor composite. NOAA NESDIS STAR, accessed 21 November 2025, https://cdn.star.nesdis.noaa.gov/GOES18/ABI/SECTOR/gwas/GEOCOLOR/.

Table 1A-1 – GCOS, 2025: About essential climate variables. World Meteorological Organization, accessed 14 January 2025, https://gcos.wmo.int/site/global-climate-observing-system-gcos/essential-climate-variables/about-essential-climate-variables.

Table 1A-2 –NWS, 2025:Weather observations for the past three days at Dallas/Fort Worth International Airport, TX from 1553Z to 1953Z on 20 November 2025. Accessed 21 November 2025, https://forecast.weather.gov/data/obhistory/KDFW.html.