

Activity: The Atmosphere in the Vertical

Educational Outcomes:

The atmosphere has thickness as well as horizontal extent. For a more complete understanding of weather, knowledge of atmospheric conditions in the vertical is necessary. Air, a highly compressible fluid, is held to Earth by gravity and thins rapidly upward. The atmosphere is heated primarily from below, is almost always in motion, and contains a substance (water) that undergoes frequent phase changes.

After completing this activity, you should be able to:

- Describe the vertical structure of the atmosphere in the troposphere (the "weather" layer) and in the lower stratosphere.
- Compare the "Standard Atmosphere" with an actual observed sounding of the lower atmosphere.

Materials: Pencil, straight edge.

Investigations:

1. **Figure 1**, called a Stüve diagram, is designed to plot and interpret upper-air atmospheric data acquired by radiosondes. The atmospheric temperatures in Celsius degrees that can be plotted on the diagram range from -80 to _____ $^{\circ}\text{C}$. Air pressure is plotted in millibars (mb) with values decreasing upward and the approximate altitude scale is in kilometers (km) above sea level. The lowest pressure that is labeled on the diagram is _____ mb. This pressure is found in the atmosphere at an altitude of about _____ km above sea level.
2. Plot on the Figure 1 Stüve diagram the data points given below. Connect adjacent points with solid straight line segments or use colored line segments.

Altitude (kilometers)	Temperature (degrees C)
--------------------------	----------------------------

0	+15.0
11	-56.5
16	-56.5

3. You have drawn the temperature profile of the lower portion of what is called the **Standard Atmosphere**. The Standard Atmosphere describes average conditions of the atmosphere in the vertical. The portion of the Standard Atmosphere from the surface to 11 km depicts the lowest layer of the atmosphere, called the _____, or “weather layer” where most clouds form. Above 11 km where temperatures remain steady with altitude is the lower portion of the _____, or “stable layer.” The boundary between the two layers is called the tropopause.
4. The actual troposphere is characterized generally by decreasing temperature with altitude, significant vertical motions, appreciable water vapor, and weather. According to the data provided in (2) above, the rate of tropospheric temperature decrease with altitude in the Standard Atmosphere is _____ C degrees per km. This is also called the free atmosphere lapse rate or that of air well away from Earth’s surface.
5. Air pressure, which is very close to 1000 mb at sea level in the Standard Atmosphere, decreases most rapidly with altitude in the lowest part of the atmosphere. The diagram shows that near sea level the air pressure drops 100 mb (from 1000 mb to 900 mb) over a vertical distances of about 1 km. However, the 100-mb pressure drop from 400 mb to 300 mb occurs over a vertical distance of about **[(1)(2)(3)]** km. The same pressure drop from 200 mb to 100 mb takes place over a vertical distance of nearly **[(1)(2)(4)]** km.
6. The diagram shows that air pressure of 500 mb (half that at sea level) occurs at an altitude of about _____ km.
7. Because air pressure is determined by the weight of the overlying air, half of the atmosphere by weight or mass is above the altitude where the air pressure is 500 mb and half of it is below that altitude. In other words, half of the atmosphere by weight or mass is within _____ km of sea level. According to the diagram, 90% of the atmosphere by weight or mass is within _____ km of sea level.

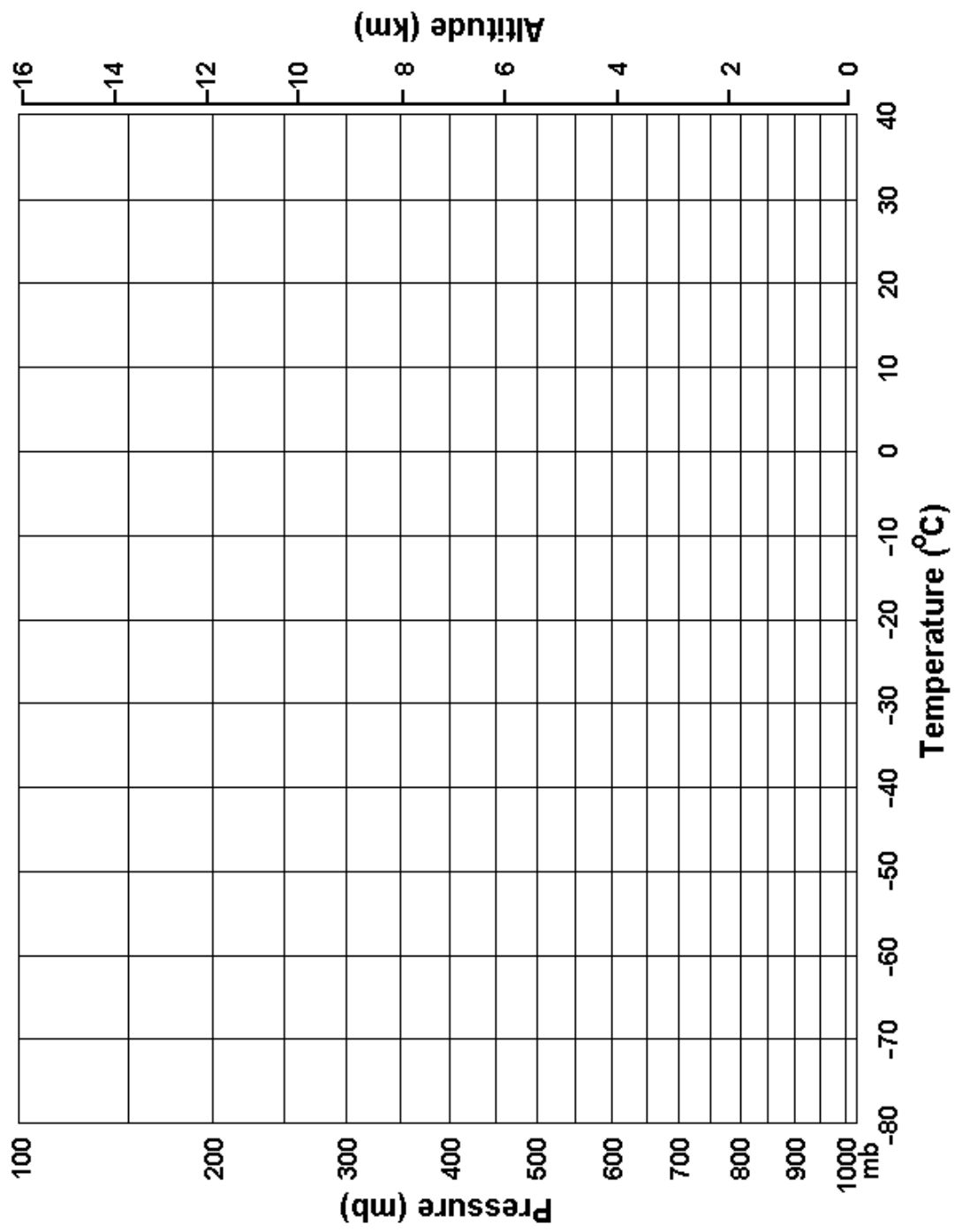
8. Upper-air observational data are collected twice every 24 hours at nearly 100 North American stations. The following data were measured by a radiosonde at Green Bay, WI at 12Z 23 January 2011 (6 am CST on 23 January):

<u>Pressure (mb)</u>	<u>Temperature (C)</u>
100	-51.1
200	-47.7
300	-57.3
400	-42.9
500	-31.3
700	-19.1
850	-21.5
1000 (surface)	-21.7

Plot these data points on the Figure 1, Stüve diagram. Connect adjacent points with dashed straight line segments or solid lines of contrasting color.

9. Compare the Standard Atmosphere and Green Bay temperature profiles you drew on the Stüve diagram. At the time of observation, the troposphere over Green Bay was generally **[(warmer)(colder)]** than specified by the Standard Atmosphere.
10. According to the plotted temperature profiles, the tropopause (found at the base of the stratosphere where temperatures are steady or increase with an increase in altitude) is located at about 225 mb pressure in the Standard Atmosphere. At Green Bay, it was located at _____ mb. This pressure occurred at an altitude of about _____ km.
11. The vertical thickness of the troposphere at Green Bay was **[(greater)(less)]** than the thickness of the Standard-Atmosphere troposphere.
12. These profiles illustrate the general relationship between average tropospheric temperature and the vertical extent of the troposphere; that is, the **[(warmer)(colder)]** the troposphere, the thinner it is.
13. This relationship means that on the average, on a global scale, the thickness of the troposphere **[(increases)(decreases)]** as the latitude increases.

Vertical Atmospheric Chart (Stüve)



Real World Applications

After a moderately cool beginning to the month of June, a heat wave struck the central and eastern U.S. in time for the beginning of (astronomical) summer. These temperatures were reflected in radiosonde profiles such as this one from Long Island, New York near the summer solstice. **Figure 2** is the Stüve diagram from the OKX radiosonde measurements of 00Z 21 June 2012 (8 pm EDT the previous night). The heavy black curve to the right on the Stüve is the temperature profile. The surface air temperature at launch time was 30 °C (86 °F). (On this Stüve diagram, no altitude values are shown.)

On the Figure 2 Stüve diagram, plot the points from the first part of the activity that define the Standard Atmosphere. Connect those points with dashed straight line segments or solid colored lines. Label that curve “Standard Atmosphere”.

1. Compare the Long Island and Standard Atmosphere temperature profiles you drew on the Figure 2 Stüve diagram. At the time of observation, the troposphere over Long Island was generally [**warmer**]~~(colder)~~ than specified by the Standard Atmosphere.
2. According to the plotted temperature profiles, the tropopause (found at the base of the stratosphere where temperatures are steady or increase with an increase in altitude) is located at about 225 mb pressure in the Standard Atmosphere. At Long Island on this profile, it was located at about _____ mb. The vertical thickness of the troposphere over Long Island was [**greater**]~~(less)~~ than the thickness of the Standard-Atmosphere troposphere.

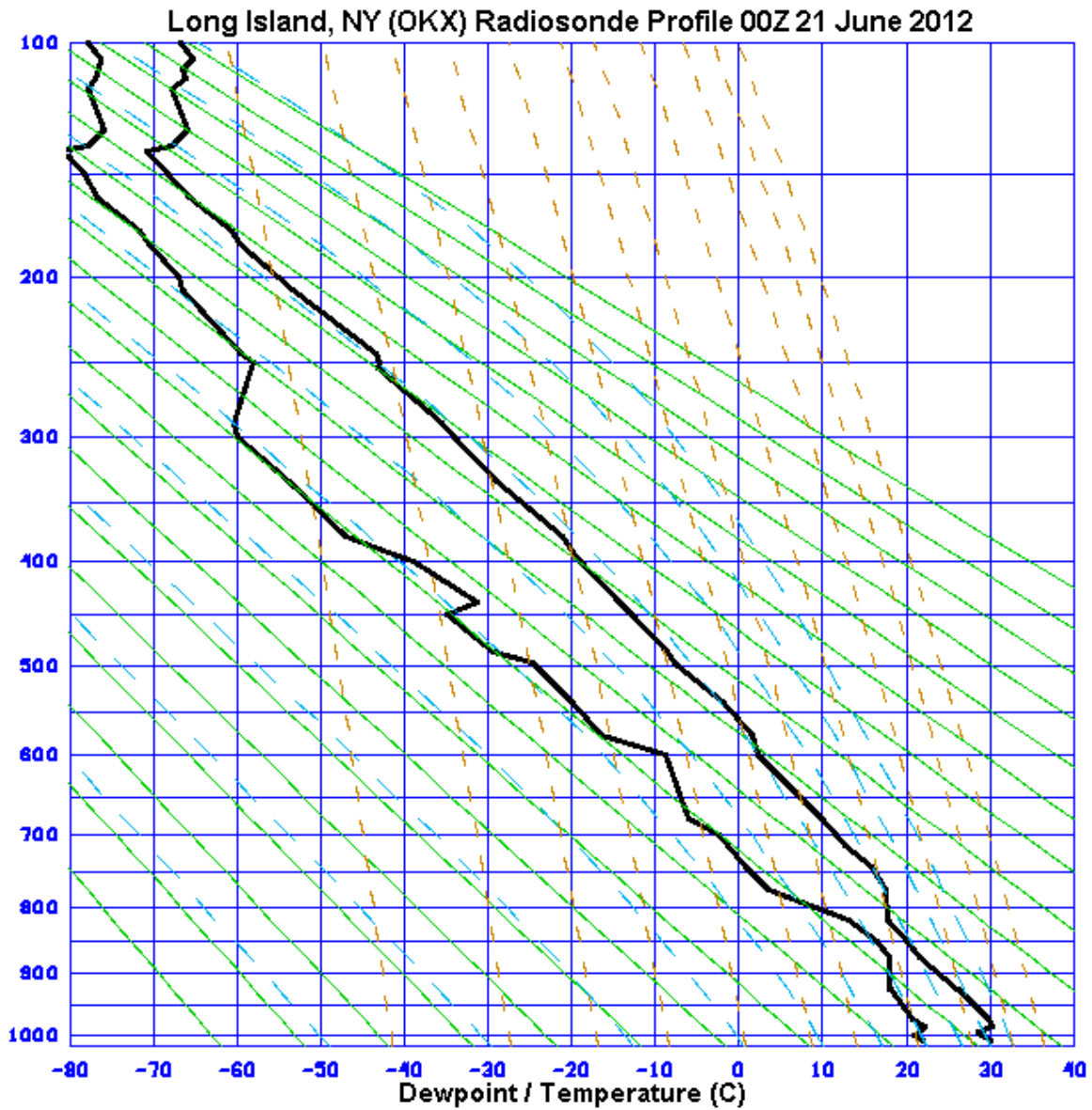


Figure 2. OKX Stüve diagram of 00Z 21 June 2012 [NCEP/NOAA].