

ACTIVITY

The Atmosphere in the Vertical

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 actual soundings of the lower atmosphere.

Introduction

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.

Materials

Pencil, straight edge

Investigations

1. The accompanying figure on page 9, called a Stüve diagram, is designed to plot and interpret upper-air atmospheric data acquired by radiosondes. The ranges of atmospheric temperatures in Celsius degrees that can be plotted on the diagram ranges from -70 to _____. Air pressure is plotted in hectopascals (hPa) with values decreasing upward and the approximate altitude scale is in kilometres (km) above sea level. The lowest pressure that is labelled on the diagram is ____ hPa. This pressure is found

in the atmosphere at an altitude of about ____ km above sea level.

2. Plot on the Stüve diagram provided, the data points given below. Connect adjacent points with a solid straight line.

Altitude (km)	Temperature (° 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 vapour, and weather. According to the data provided in (2) above, the rate of tropospheric temperature decrease with altitude in the Standard Atmosphere is _____ degrees C per km.
5. Air pressure, which is very close to 1000 hPa 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 hPa (from 1000 hPa to 900 hPa) over a

vertical distances of about 1 km.

However, the 100-hPa pressure drop from 400 hPa to 300 hPa occurs over a vertical distance of about **(1) (2) (3)** km. The same pressure drop from 200 hPa to 100 hPa takes place over a vertical distance of nearly **(1)(2)(3)(4)(5)** km.

6. The diagram shows that air pressure of 500 hPa (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 hPa 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 Buffalo, NY at 00 Z 15 February 1996 (7 pm EST on 14 February). Plot these data points on the Stüve diagram. Connect adjacent points with a dashed straight line.

Pressure (hPa)	Temperature (°C)
100 hPa	-48.9 °C
200 hPa	-46.3 °C
300 hPa	-49.7 °C
400 hPa	-38.9 °C
500 hPa	-32.7 °C
700 hPa	-19.7 °C
850 hPa	-13.9 °C
976 hPa (surface)	-6.1 °C

9. Compare the Standard Atmosphere and Buffalo temperature profiles you drew on the Stüve diagram. At the time of observation, the troposphere over Buffalo 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 the 250-hPa pressure level in the Standard Atmosphere. At Buffalo, it was located at ____ hPa. The vertical thickness of the troposphere at Buffalo was **(greater) (less)** than the thickness of the Standard-Atmosphere troposphere.
11. 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.
- 12 This relationship means that on the average, on a global scale, the thickness of the troposphere **(increases) (decreases)** as the latitude increases.

Additional Activity -

Use of the Tephigram

- Repeat steps 2 and 8 from the previous activity by plotting the data on the simplified Tephigram form provided on page 10.

The tephigram is a complex tool used by Canadian meteorologists not to simply plot the data but to carry out a number of calculations and to use the data in a number of forecast applications.

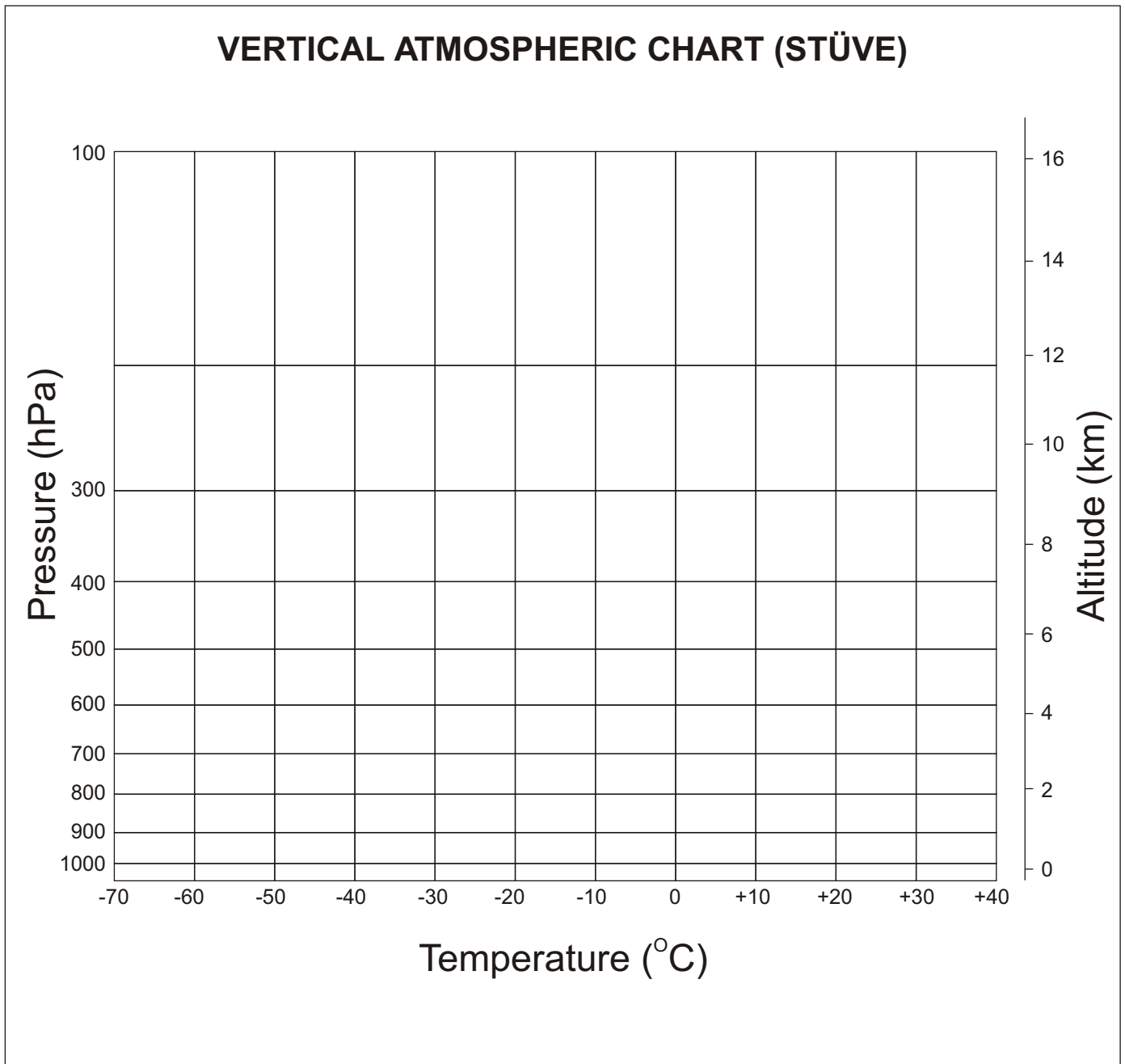


Figure 3 - Stüve diagram

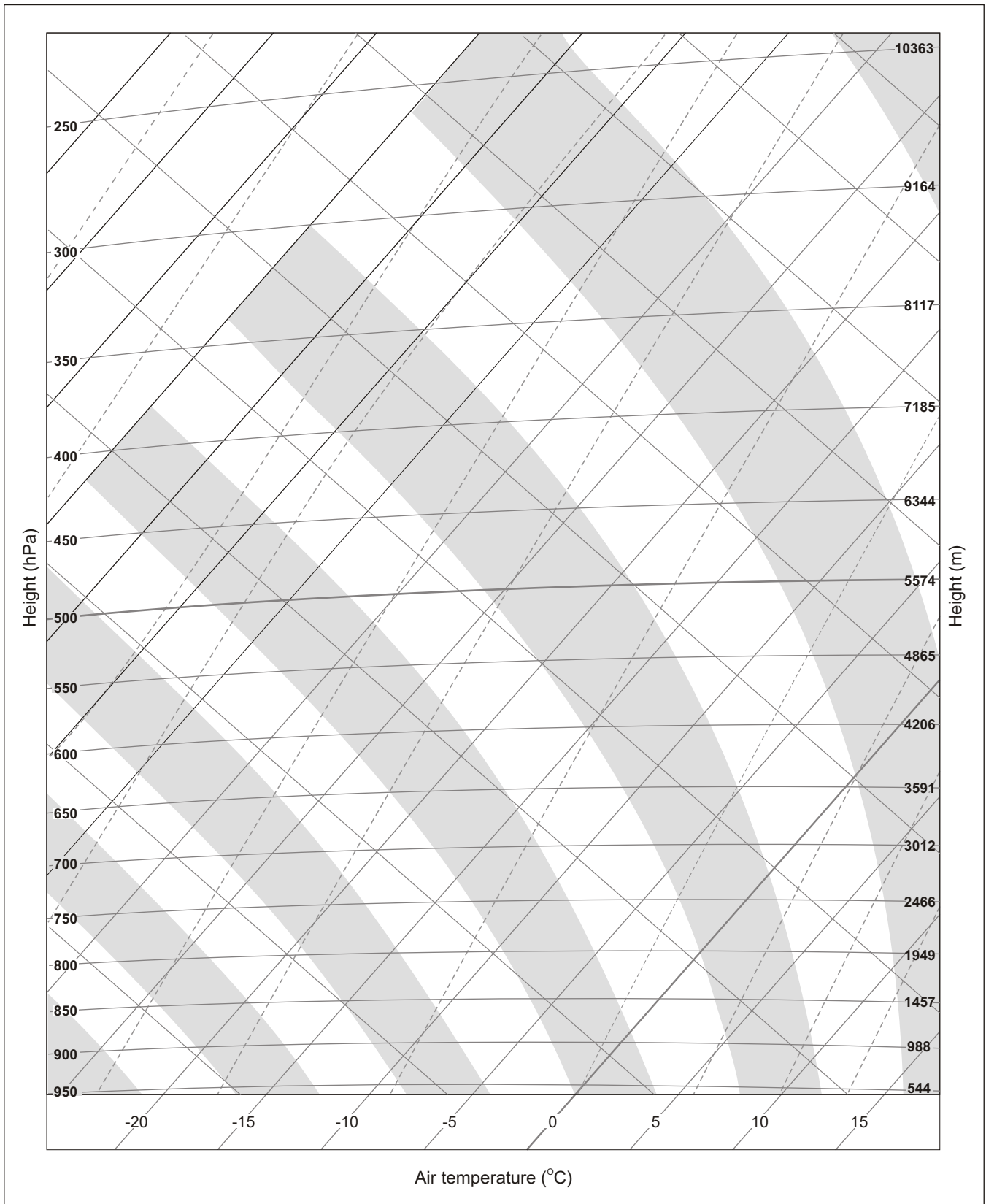


Figure 4 - The Tephigram

ACTIVITY

Upper-Air Weather Maps

After completing this activity, you should be able to:

- Describe the topography of upper-air constant-pressure surfaces based on height contours, including the identification of Highs, Lows, ridges, and troughs.
- Describe the general relationship between height contours and the average temperature of the underlying atmosphere.
- Describe the relationship between the height contours and wind direction on upper-air maps.

Educational Outcomes:

Weather as reported on surface weather maps provides us primarily with a two-dimensional view of the state of the atmosphere, that is, weather conditions observed at the Earth's surface. Atmospheric conditions reported on upper-air weather maps provide the third dimension, that is, conditions at various altitudes above the Earth's surface. Hence, for a more complete understanding of the weather, both surface and upper-air weather maps need to be consulted.

Materials:

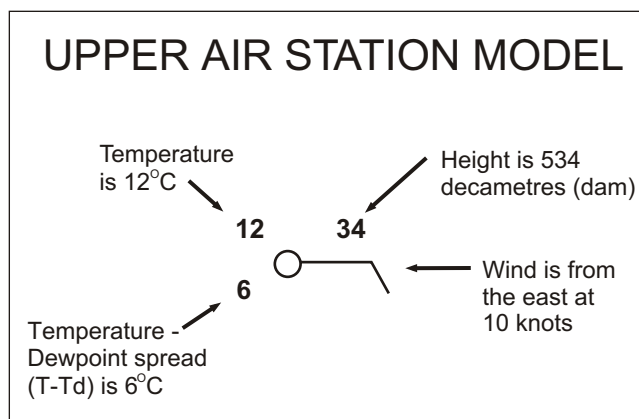
Pencil

Investigations:

1. Upper-air weather maps differ from surface weather maps. Whereas surface weather conditions are plotted on a map

of constant altitude (normally sea-level), upper-air weather conditions are plotted on maps of constant air pressure. The altitude at which the particular pressure is located is reported on these maps. Every 12-hours, upper-air maps are drawn for various pressure levels including, for example, 850 hPa, 700 hPa, 500 hPa, and 250 hPa. The data for these maps are obtained from rawinsonde reports. Rawinsondes are radiosondes which are tracked by radio to provide additional information on horizontal wind speeds and directions.

2. Plotted on upper-air maps are air temperature (T) (in °C), temperature - dewpoint spread (T-Td) (in °C), wind speed (in knots), wind direction, and height of the pressure surface above sea-level (in decametres). The temperature dewpoint spread is determined by subtracting the dewpoint temperature Td from the air temperature T, i.e. (T-Td). If the spread is 4 degrees C or less there is a strong likelihood of sufficient moisture being present to allow the formation of cloud. Become familiar with the upper-air station model depicted below.



3. Figure 5 is the 500-hPa map analysis for 12Z (7 am EST), 17 August 2000. The information is assembled from the 500-hPa level of each station's reports at the same observation time. The 500-hPa map is often employed by meteorologists because of its importance in revealing the direction of the steering winds, that is, the winds that steer weather systems across the Earth's surface. (The letter "Z" in the map's date and time is the symbol used to denote UTC Universal Coordinated Time also referred to as GMT Greenwich Mean Time.)
4. Solid lines on the 500-hPa map join locations where 500-hPa is at the same altitude. These lines, called *contours of height*, are drawn at intervals of 6 decametres (dam). At 12Z, 17 August 2000, the lowest reported height for a pressure reading of 500-hPa was _____ decametres (dam), and the highest reported height was _____ decametres. Remember to add the first digit to the plotted values.
5. The 500-hPa map and other constant-pressure upper-air maps are similar to topographic maps. That is, the contour pattern reveals the "hills" and valleys" of the constant-pressure surface. In general, the 500-hPa surface (the surface where the air pressure is 500-hPa) occurs at a **(higher) (lower)** altitude over Canada than over the United States.
6. Closed contour lines on constant-pressure upper-air maps identify topographic highs and lows. The closed 558-dam contour line on this map over the Gulf of Alaska encloses **(lower) (higher)** 500-hPa elevations. Therefore, the contour line encloses a topographic **(low) (high)**.
7. The wave pattern of most contour lines consists of topographic ridges and troughs, that is, elongated crests and depressions, respectively. A broad **(trough) (ridge)** appears on the Figure 5 map over eastern Canada. A **(trough) (ridge)** appears over Alberta.
8. A column of cold air is denser than a column of warm air. Hence, air pressure decreases more rapidly with altitude in cold air than in warm air. The height of the 500-hPa surface is lower where the underlying air is relatively **(cold) (warm)** and higher where the underlying air is relatively **(cold) (warm)**. The air below the 500-hPa Low in Figure 5 is **(colder) (warmer)** than the air below the surrounding higher 500-hPa surfaces.
9. Dashed lines on the 500-hPa map are called the *100-500 hPa thickness lines* which represents the thickness of the layer between the 500-hPa level and the 1000-hPa level in decametres. Normally, the greater the thickness of the layer the warmer the temperature of a column of the air within that layer. The interval between thickness lines is 6 dam. The general decline in temperature at 500 hPa as latitude increases is accompanied by a(n) **(increase) (decrease)** in the altitude of the 500-hPa surface.
10. Suppose that on 16 August 2000 at 12Z you were to board an airplane and fly directly from Quebec City to Atlanta,

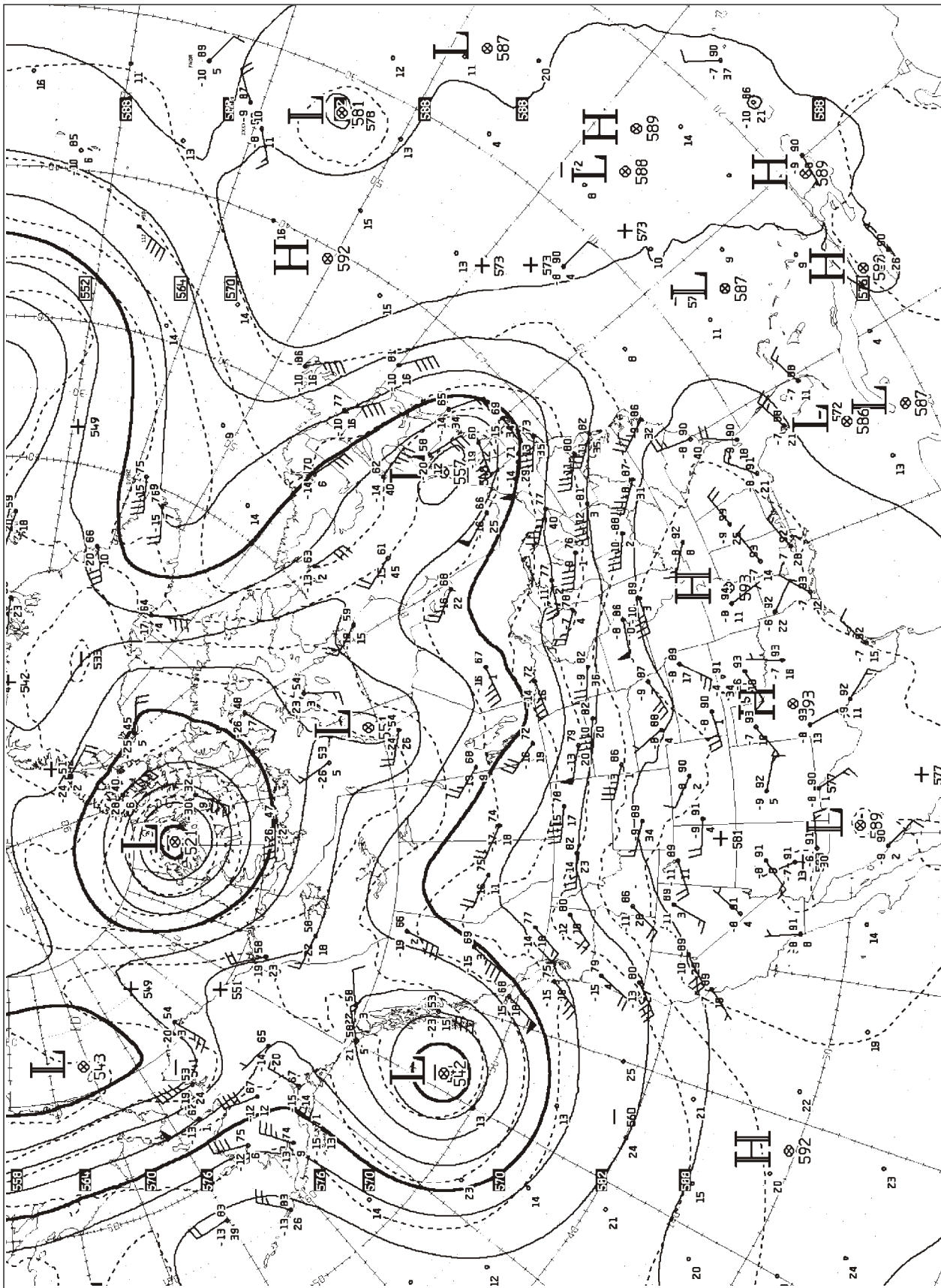


Figure 5 - 500-hPa map analysis for 12Z (7 am EST), 17 August 2000

Georgia. En route, the plane cruises along the 500-hPa surface. Flying from Quebec to Atlanta, the aircraft's cruising altitude **(increase) (decreases) (does not change)**. At the same time, the temperature of the atmosphere below the aircraft **(rises) (falls)**.

11. A relationship exists between the orientation of height contours and horizontal wind direction on 500-hPa maps, especially at higher wind speeds. As seen in Figure 5, wind direction is generally **(perpendicular) (parallel)** to nearby contour lines.

Optional Upper-Air Map Activity

A physical, three-dimensional model depicting the relief of an upper-air map may be constructed by transferring the map to construction material of moderate thickness. The following procedure indicates how such a model can be assembled.

1. Enlarge the modified version of the 500-hPa map provided in figure 6 by about 175% using a photocopy machine. Make 12 copies of the enlarged map.
2. Glue the maps onto pieces of thin corrugated cardboard. The use of cardboard from boxes used to deliver pizzas is suggested if it not too thick and hence not easily cut with scissors.
3. On one of the mounted maps, cut out the areas inside of the closed 522-decameter contour lines. Align and glue the map with the hole onto an uncut copy of the map.
4. Cut out and discard the lower-altitude portions of successive mounted maps along 528-, 534-, 540-, 546-, 552-, 558-, 564-, 570-, 576-, 582-, and 588-decametre contour lines. Glue the remaining successive map pieces in sequence, one on top of the other, to produce a stepped relief map assembly.
5. Examine the assembled map from different angles, including looking straight down to see the full map. Turn to the Upper-Air Weather Maps activity and refer to the model as you answer or review your answers to the investigations. Be sure to compare the positions of the Lows, ridges, and troughs as they appear on the map and in the model.

Cautionary notes: The physical relief map you have constructed has a greatly exaggerated vertical to horizontal scale. Also, the stepped relief presented in the model is contrary to the actual continuous sloping of the existing pressure surface.

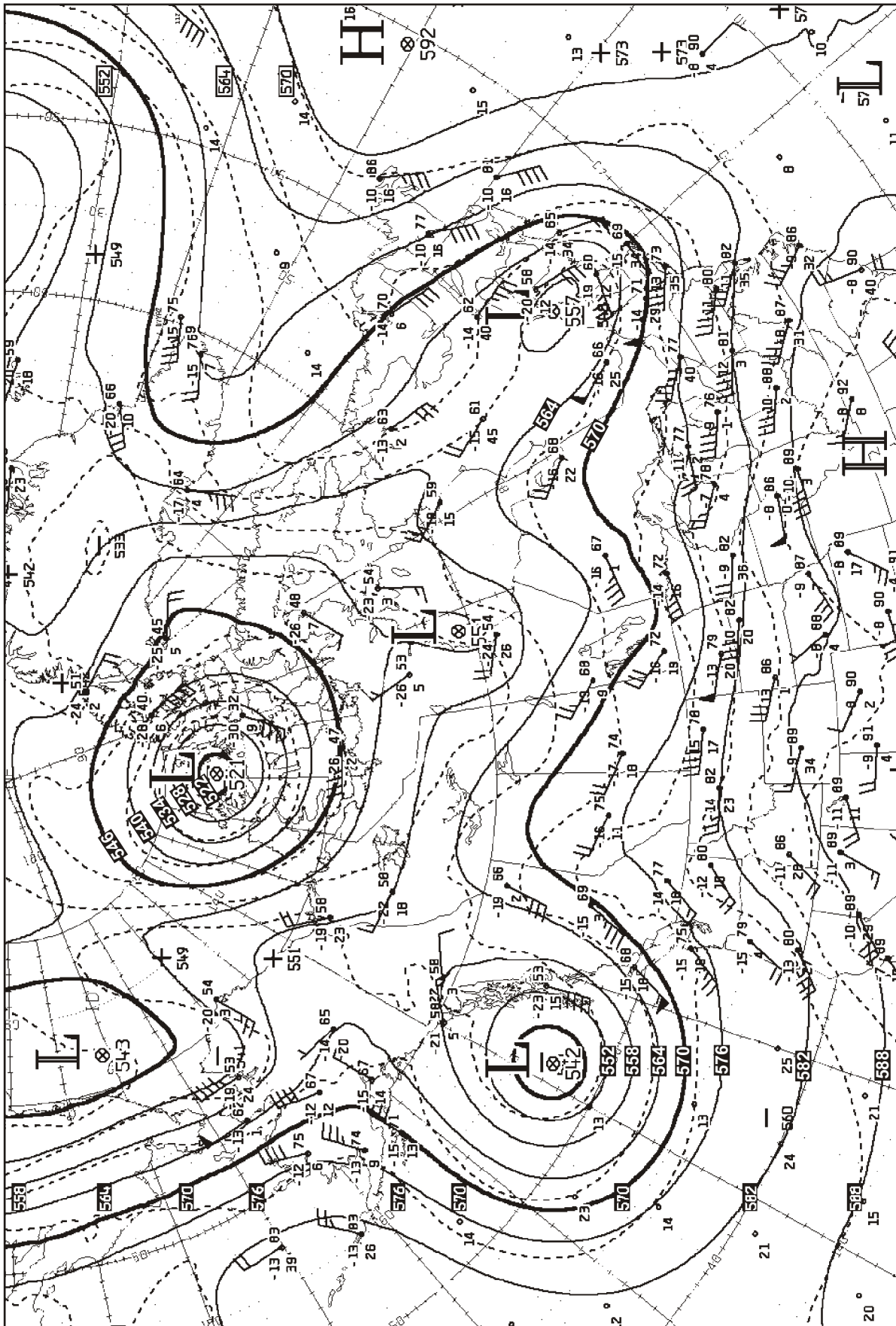


Figure 6 - 500-hPa map analysis for 12Z (7 am EST), 17 August 2000