Project Atmosphere Canada

MODULE 11

The Atmosphere Aloft

Teacher's guide

Canadian Meteorological and Oceanographic Society
La Société Canadienne de Météorologie et d'Océanographie

Environment Canada
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Canada

Project Atmosphere Canada

Project Atmosphere Canada (PAC) is a collaborative initiative of Environment Canada and the Canadian Meteorological and Oceanographic Society (CMOS) directed towards teachers in the primary and secondary schools across Canada. It is designed to promote an interest in meteorology amongst young people, and to encourage and foster the teaching of the atmospheric sciences and related topics in Canada in grades K-12.

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On behalf of
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Contents

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MODULE 11 **The Atmosphere Aloft**

INTRODUCTION

Clouds, along with their motions, changes, and precipitation, provide visible evidence that the part of the atmosphere directly impacting our lives extends from the surface upwards for many kilometres. They also demonstrate connections between weather at the Earth's surface and conditions and processes occurring aloft. For a more complete understanding of weather and weather systems, the third dimension of the atmosphere must be brought into consideration. Meteorologists regularly monitor the atmosphere aloft to determine its vertical and horizontal structure.

Many properties of air vary dramatically upward through the atmosphere. Because the sun's rays readily pass through the clear atmosphere to warm the surface, the atmosphere is strongly heated from below. Thus, the highest temperatures are typically at the Earth's surface, decreasing as altitude increases. This layer of decreasing temperatures, ranging from 6 to 16 km in depth is called the *troposphere* or "weather layer'. Above the troposphere a layer of constant temperature is encountered; farther aloft, the air temperature increases as much of the ultraviolet portion of incoming solar radiation is absorbed at the altitudes where ozone formation and dissociation are taking place. These combined (constant and increasing temperature) layers form what is called the stratosphere or "stable layer'. The boundary between the troposphere and the stratosphere where the temperature stops decreasing and becomes constant is termed the *tropopause*.

Both air pressure and air density decrease with an increase in altitude. Air pressure is the weight per unit surface area of an air column extending to the top of the atmosphere. Therefore, atmospheric pressure is greatest at sea level. Because air is highly compressible, as readily seen by inflating a tire, it is also most dense at the bottom of the atmosphere. The weight of the overlying atmosphere compresses the air near the surface more than does the lesser weight of overlying air at upper levels. The result is that air pressure and air density initially decreases very rapidly, then more slowly, with altitude. Half of all air molecules are within only 5.5 km of sea level. The next one-quarter of the atmosphere is approximately located between 5.5 and 11 km.

Clouds and weather systems provide visual evidence of the atmosphere's third dimension. Early attempts to scientifically probe the atmosphere above the Earth's surface involved instruments attached to or carried aloft by kites, balloons, and airplanes. Current practice involves the use of *radiosondes,* instrument packages carried aloft by balloons. Information concerning temperature, humidity and pressure is transmitted by radio back to the launch site. The rising radiosondes can also be tracked to give wind information at the various levels. In this way, routine measurements are made twice daily at stations around the world.

The graphical plot which depicts the change of temperature with height is called the *temperature profile* curve and in Canada the temperature profile is depicted on a form called a *tephigram.* Data received from a radiosonde is plotted on the tephigram as shown in the examples on figures 1 and 2.

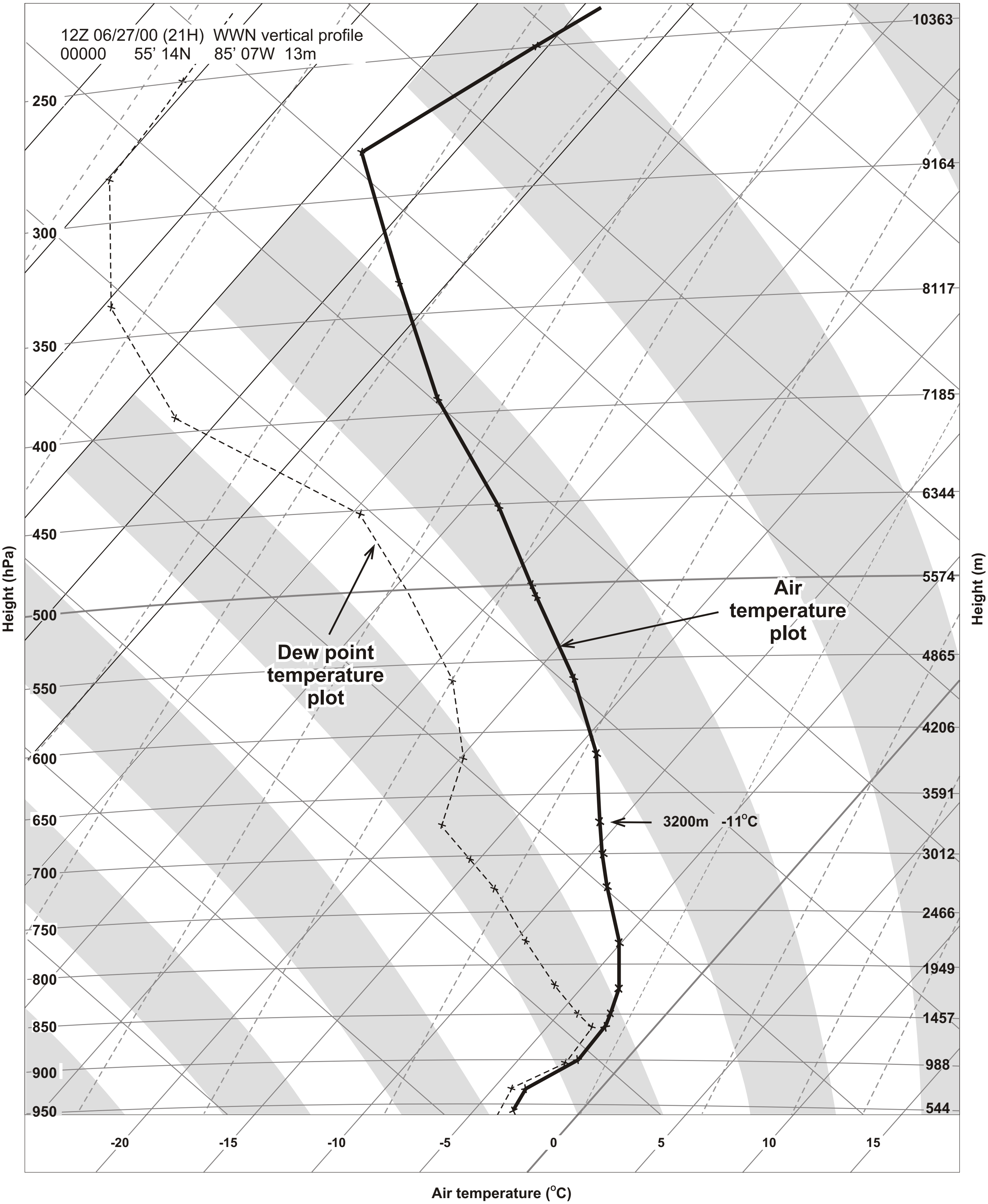

Figure 1 - A Tephigram plot of the vertical temperature profiles of the air temperature (solid line) and dew point temperature (dashed line) in stable air. The vertical heights shown on the Tephigram are above Mean Sea Level values.

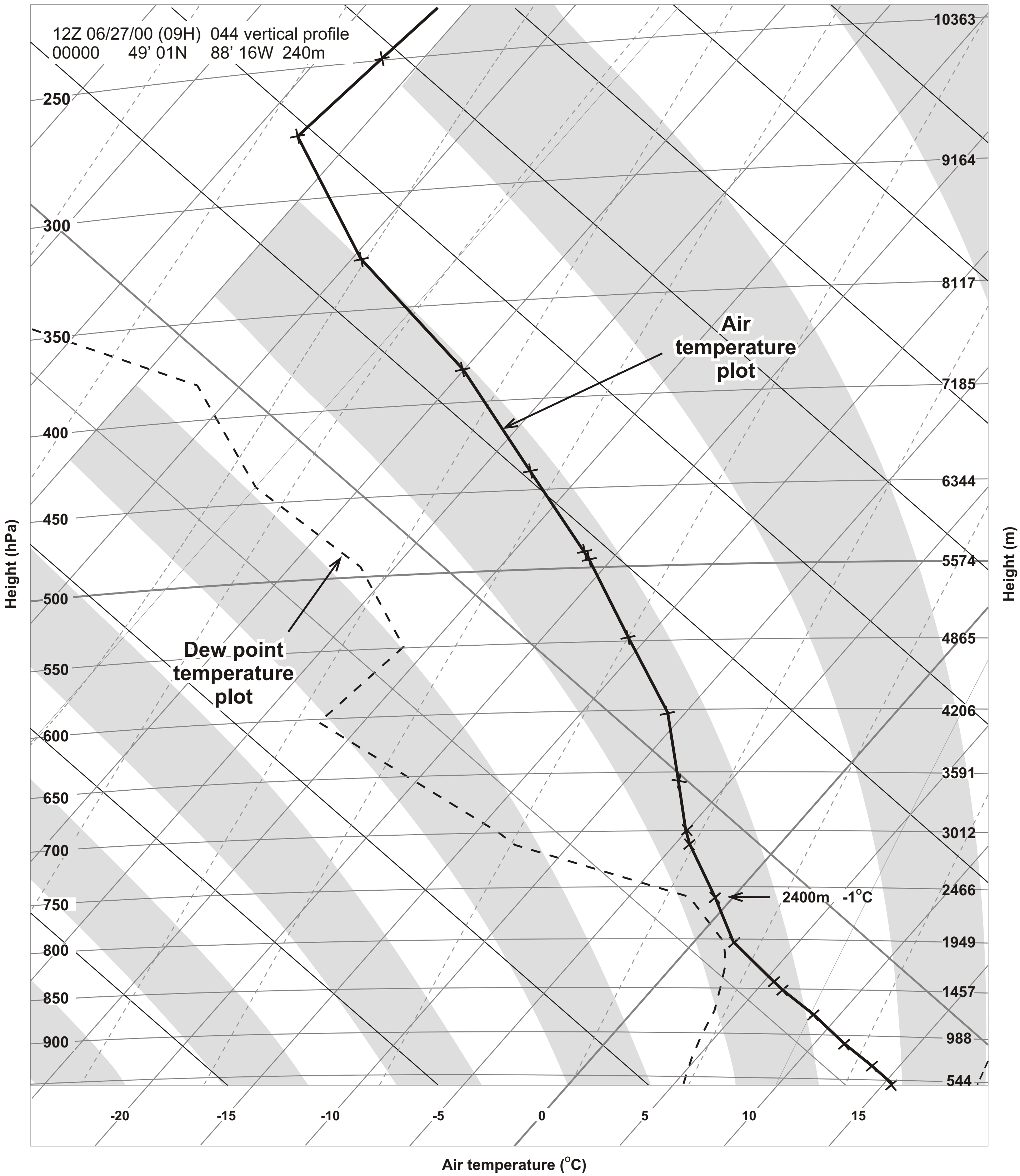

Figure 2 - A Tephigram plot of the vertical temperature profiles of the air temperature (solid line) and dew point temperature (dashed line) in unstable air. The vertical heights shown on the Tephigram are above Mean Sea Level values.

BASIC UNDERSTANDINGS

1. The sunlit Earth's surface heats the atmosphere above, so the temperature in the lowest layer of the atmosphere decreases with altitude. The average surface temperature of the Earth is 15 degrees Celsius. At 11 km, the average temperature is -56.5 degrees Celsius.

2. The average rate at which temperature decreases in the vertical ("lapse rate") is 6.5 degrees Celsius per 1000 metres throughout the lowest layer in the atmosphere that extends to 11 km. This temperature pattern is a property of the "Standard Atmosphere" and is known as the standard lapse rate.

3. The *troposphere* is the layer of the atmosphere nearest the Earth's surface and is the layer in which most weather occurs. In the troposphere air temperature generally decreases with altitude.

4. Above about 11 km, the temperature remains constant at an average temperature of -56.5 degrees C for several kilometres before rising with an increase in altitude up to about 50 km. This layer is called the *stratosphere*. The protective ozone layer is within the stratosphere.

5. The boundary between the top of the troposphere and bottom of the stratosphere is the *tropopause.*

6. Atmospheric pressure is the weight of a column of overlying air extending to the top of the atmosphere acting on a unit of area.

7. In the air pressure units routinely used in meteorology, the average pressure at sea level is 1013.25 hectopascals (hPa). This pressure is equivalent to the pressure exerted at the base of a column of mercury 29.92 inches or 76 centimetres high.

8. Near sea level, atmospheric pressure decreases with altitude by about 100 hPa for every 1000 metres. The pressure decreases most rapidly near the surface and less rapidly as altitude increases.

9. Approximately one-half of the atmosphere by mass or weight (found between sea level and the height at which air pressure level is 500 hPa) is within 5.5 km of the Earth's surface. The tropopause is located at about 250 hPa, so that roughly three-quarters of the atmosphere by mass or weight is found in the troposphere.

10. Weather systems are almost entirely tropospheric phenomena.

11. Air motions that accompany weather systems, along with air mass differences, cause temperature and pressure variations that differ from the average conditions of the Standard Atmosphere.

12. Radiosondes lifted by balloons are launched twice daily from many locations, measuring temperature, pressure and humidity as they rise through the atmosphere to altitudes typically reaching 30 km above sea level. Tracking the horizontal motions of these devices also provides wind information.

13. Meteorologists employ a variety of charts to represent the vertical structure of the atmosphere based on radiosonde data.

These charts can provide information including the probable existence of clouds, cloud thickness, and atmospheric stability or instability.

14. Upper-air data can be employed to draw essentially horizontal maps depicting atmospheric conditions at different levels above sea level. These levels are usually defined by a certain pressure value, so the resulting charts are called *constant-pressure maps.* Upper-air constant-pressure maps are routinely drawn at 850, 700, 500, and 250 hPa.
15. Plotted data on upper-air constant-pressure maps typically display temperature, dewpoint, and wind speed and direction conditions. Another important value reported is the altitude above sea level at which the designated map pressure occurred over each station.
16. Among the typical analyses made on upper-air maps is the drawing of height contours to determine the topographical relief of the particular map's constant pressure surface. The high and low height areas on a constant- pressure map correspond closely to high and low pressure areas that would be present if a constant-altitude map had been drawn at the average height of that chosen pressure level.
17. The 850-hPa level generally occurs near 1500 m. This level reflects temperature and humidity patterns in the free atmosphere associated with a weather system.
18. An 850-hPa map is used by meteorologists for observing humidity and temperature *advections* - movements of higher or lower values of water vapour or heat energy into a region.
19. The 700-hPa level generally occurs near 3000 m. This level reflects the wind patterns that steer individual thunderstorms, so it is used by meteorologists for predicting thunderstorm motion and intensification.
20. The 500-hPa level generally occurs near 5500 m. This level represents the mid-troposphere circulation pattern and is used by meteorologists to predict the movement and intensification of large-scale weather systems (surface highs and lows).
21. The 250-hPa levels occurs near 10300 m. Depending on the time of year and the latitude, the highest horizontal wind speeds in the atmosphere are typically found near this level.
22. The 250-hPa map is used by meteorologists to identify wind flow patterns that intensify or weaken large-scale weather systems and move them along.
23. Upper atmospheric information is essential to fully understand weather system structure, movement, and change.