13 Air Masses and Fronts

Learning Goals

After studying this chapter, students should be able to:

1. distinguish between the five major air masses (pp. 319–320);
2. outline the importance of air masses to weather (pp. 320–324); and
3. distinguish between warm fronts, cold fronts, and occluded fronts, and describe the weather associated with each (pp. 324–332).

Summary

1. **Air masses** are very large bodies of air with similar properties throughout. Air masses form as heat and water vapour are transferred between the air and the underlying surface.

2. Air masses form in large areas known as **source regions**. Good source regions are large areas of uniform surface type that normally experience high pressure. The polar latitudes and the tropical latitudes meet the criteria for air-mass source regions, but the mid-latitudes do not.

3. Air masses are classified based on their temperature and moisture content. This simple classification system gives five major types of air masses. A continental polar air mass, cP, is cold and dry. A continental Arctic air mass, cA, is very similar to a cP air mass, except that it is both colder and drier. A maritime polar air mass, mP, is cold and moist. A continental tropical air mass, cT, is warm and dry. A maritime tropical air mass, mT, is warm and moist.

4. Air masses are moved from their source regions by the upper airflow. As an air mass moves, it causes changes in the weather. It is also gradually transformed, ultimately losing its original character.

5. Cold, dry air masses (cA and cP) form over high-latitude continents and ice-covered oceans, especially in winter. These air masses are very stable because a radiation inversion usually forms at the surface where they develop. As these air masses move south, they warm from below and become less stable but, unless they also pick up water vapour, they are unlikely to produce much precipitation. In the winter, cP air can influence most of Canada and the United States. In the summer, cP air masses are less well-developed and remain farther north.

6. Cold, moist air masses (mP) form when cP air masses are modified as they move out over the northern regions of the Pacific and Atlantic oceans. These air masses will be a little warmer and much moister than cP air masses. They frequently affect the west coast of North America, but they occasionally affect the east coast of North America. The mountains of the west coast modify mP air masses, making them drier.

7. Warm, dry air masses (cT) form over the subtropical deserts in summer. This air is very unstable, but, because it is very dry and the unstable layer is shallow, precipitation is infrequent.

8. Warm, moist air masses (mT) form over the subtropical oceans. These air masses frequently invade the southeastern regions of North America. In summer, they bring heat, humidity, and frequent thunderstorms. In winter, the cooler ground makes these air masses stable, so they tend to bring fog or stratus cloud. **Dry lines** form where this air meets cT air in the south-central United States.

9. **Fronts** are narrow zones of transition between air masses. They are best represented as surfaces that slope up to at least the middle troposphere. Air temperature and dew-point temperature change rapidly across frontal zones. In addition, wind direction shifts, pressure drops, and bands of cloud and precipitation form.

10. **Cold fronts** occur where cold air is advancing and replacing warm air. **Warm fronts** occur where cold air is retreating and being replaced by warm air. Cold fronts slope more steeply than warm fronts. At cold fronts, the clouds are normally cumuliform, the precipitation is usually heavy, and thunderstorms are common. At warm fronts, the clouds are usually stratiform, and the precipitation is more moderate. These differences are thought to be due to the stability differences between the cold and warm frontal zones. The clouds and precipitation at warm fronts can be expected to last longer than those at cold fronts.

11. **Occluded fronts** lie between the low-pressure centre and the warm air in a mid-latitude cyclone. They are noticeable at the surface as a slight temperature change and a shift in wind direction. Because the occlusion process produces a trough of warm air aloft, or an upper front, occluded fronts bring a complex variety of clouds and precipitation.

12. It is possible for two types of occluded fronts to form. If the air behind the cold front rides over the air ahead of the warm front, a **warm-type occlusion** forms. If the air behind the cold front pushes under the air ahead of the warm front, a **cold-type occlusion** forms. In the former case, an upper-level cold front is created; in the latter case, an upper-level warm front develops.
13. Our ideas about the occlusion process are changing. Instead of the catch-up process suggested by the traditional model, it is now thought that occlusions form as the result of a wrap-up process involving the deformation of a rotating fluid that contains temperature gradients. In addition, whereas it had been thought that warm-type and cold-type occlusions developed due to temperature differences, it is now thought that they result from stability differences.

Key Terms

Air mass A large body of air, thousands of square kilometres in size, throughout which the temperature and humidity are similar in the horizontal direction. (p. 317)

Cold-type occlusion An occlusion in which the air behind the cold front pushes under the air ahead of the warm front. (p. 331)

Dry line A boundary separating warm, moist air from warm, dry air. (p. 324)

Frontogenesis A process that increases a temperature gradient and forms a front. (p. 327)

Frontolysis A process that leads to the dissipation of a front. (p. 327)

Lake-effect snows Snowfall that occurs downwind of large, unfrozen lakes. (p. 321)

Occluded front A front that separates a cold air mass from a cool one, and the low pressure centre from the warm air in a mid-latitude cyclone. (p. 330)

Occlusion A process that gradually separates the centre of low pressure from the warm air in a mid-latitude cyclone. (p. 330)

Source region A very large area of uniform surface type over which air can remain stagnant long enough to form an air mass. (p. 318)

Stationary front A front along which there is no significant movement. (p. 326)

Trowal An acronym for "TROugh of Warm air ALoft." (p. 331)

Warm-type occlusion An occlusion in which the air behind the cold front rides over the air ahead of the warm front. (p. 331)

Answers to Selected Review Questions (p. 334)

1. **How do air masses form?**

   Air masses form as energy and water are transferred between Earth's surface and air layers in contact with the surface.

3. **How do mountains influence the movement and modification of air masses?**

   Mountains can block the movement of air masses. Mountains can warm an air mass as it sinks through them.

5. **How do mP air masses form? What type of weather is associated with mP air masses? How can mP air masses be modified?**

   mP air masses form when cP air masses are modified as they move over oceans. Moist conditions and cloud cover are associated with mP air masses. mP air masses can be modified as they move through mountains and lose their moisture as precipitation on the windward side.

7. **Why is mT air likely to bring thunderstorms in summer and fog or stratus cloud in winter?**

   mT air masses are unstable and the unstable layer at the surface is relatively deep therefore causing thunderstorms. In winter an mT air mass is cooled from below and becomes stable. This cooling can produce advection fogs or, if winds are strong enough to produce mixing, stratus clouds.

9. **How is air different on either side of a dry line? How is it the same?**

   Air is moist on one side of a dry line but dry on the other side. Air is warm on both sides of a dry line.

11. **How are fronts identified on weather maps?**

    Fronts are identified on weather maps by identifying locations experiencing changes in temperature, changes in dew-point temperature, changes in wind direction, clouds and precipitation, and a decrease in pressure (kinks in isobars).

13. **How and why do the clouds and precipitation associated with cold fronts differ from those associated with warm fronts?**

    At cold fronts, the clouds are normally cumuliform, the precipitation is usually heavy, and thunderstorms are common. At warm fronts, the clouds are usually stratiform, and the precipitation is more moderate. These differences are accounted for by the fact that the air in cold frontal zones is normally unstable but the air in warm frontal zones is stable.

15. **How does the structure of a warm-type occlusion differ from that of a cold-type occlusion? What are two possible explanations for this difference in structure?**

    In a warm-type occlusion, the air behind the cold front rides over the air ahead of the warm front. In a cold-type occlusion, the air behind the cold front pushes under the air ahead of the warm front. Two possible explanations relate to the differences in density between the air masses (caused by different temperatures) and the differences in stability between the air masses.

Study Questions

For suggested answers, see below.

1. What are two key purposes for classifying air masses?
2. How and where do lake-effect snows develop?
3. What conditions can lead to frontogenesis?
4. Why are frontal boundaries sloping surfaces?
5. Why does the west coast of North America rarely experience true cold-front weather?

Answers to Study Questions

1. Classification makes it simple to distinguish between the air masses on either side of a front. Classification also makes it easy to keep track of an air mass's temperature and moisture characteristics. (p. 319)

2. Lake-effect snows occur when a cP air mass is warmed from below and picks up moisture from the unfrozen Great Lakes. Warming makes the air unstable, the instability leads to the formation of clouds, and the clouds release moisture as snow. The snows are common downwind of the Great Lakes. (p. 321)

3. Frontogenesis can occur due to convergence at the surface along a temperature gradient. In addition, any process that causes heating on the warm side of the gradient or cooling on the cold side of the gradient can strengthen the gradient and produce, or strengthen a front. (p. 327)

4. Due to its higher density, the cold air on one side of a front will slide under the warmer air on the other side of the front. As the cold air flows beneath the warm air, it is turned by the Coriolis force. (p. 327)

5. The Pacific Ocean causes very cold air to warm, thus reducing the contrast in temperature across the cold front. (p. 329)