

EXERCISE 12

WIND

Objective: To map and study winds associated with high and low pressure areas.

Reference: Hess, Darrel. *McKnight's Physical Geography*, 10th ed., pp. 99–113.

PRESSURE GRADIENTS

Air moves horizontally when there is a difference in pressure from one place to another. The change in pressure over a given distance is called the **pressure gradient**, and the force exerted by this difference in pressure is known as the **pressure gradient force**.

As we saw in Exercise 11, pressure patterns are mapped with **isobars** (lines of equal pressure). Closely spaced isobars indicate a great change in pressure over a short distance. A “steep” pressure gradient such as this produces a strong pressure gradient force, and so the resulting wind will be relatively strong. On the other hand, isobars spaced far apart indicate a small change in pressure over a given distance. A “gentle” pressure gradient such as this produces a weak pressure gradient force, and so the resulting wind will be relatively weak.

WIND DIRECTION

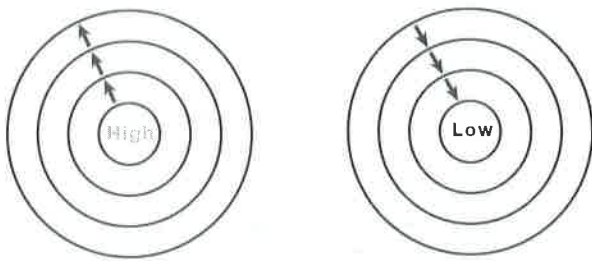
The initial propelling force behind wind is the pressure gradient force. Air begins to move “down” the pressure gradient, from high to low pressure, at right angles to the isobars (Figure 12-1a). However, the actual direction of the wind is influenced by two other factors: the Coriolis effect and friction.

At high elevations, above about 700 meters (about 2300 feet), the moving air encounters very little **friction**, but the **Coriolis effect** will deflect the path of the wind. The Coriolis effect (also referred to as the **Coriolis force**) deflects the path of free moving objects to the right in the Northern Hemisphere, and to the left in the Southern Hemisphere. Figure 12-1b shows that while the wind begins to blow down the pressure gradient, the Coriolis effect deflects the path of the wind about 90° to the right (in the Northern Hemisphere). In the upper atmosphere, the balance of the pressure gradient force and the Coriolis effect results in winds that blow approximately parallel to the isobars. These winds are called **geostrophic winds**.¹ In the Northern Hemisphere upper elevation winds tend to blow parallel to the isobars, clockwise around highs, and counterclockwise around lows.

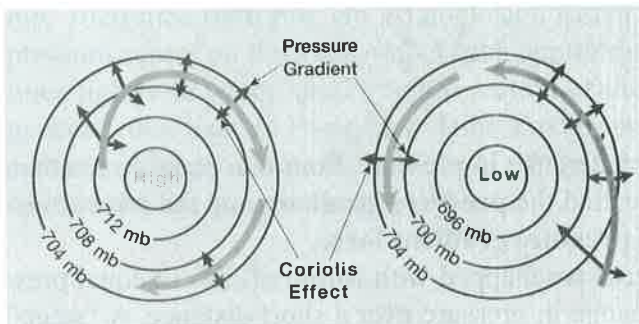
In the lowest parts of the atmosphere, friction becomes important (Figure 12-1c). Friction from the surface slows the wind, and so the Coriolis effect deflection is reduced (rapidly moving objects are deflected more by the Coriolis effect than slowly moving objects).

Near the surface, the balance of the pressure gradient force, Coriolis effect, and friction results in winds that diverge clockwise out of **highs (anticyclones)** and converge counterclockwise

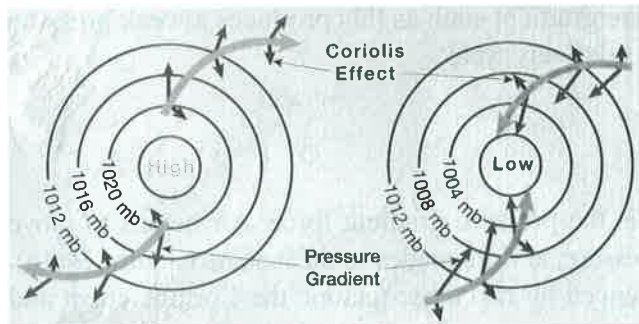
¹Strictly speaking, geostrophic wind is only found in areas where the isobars are parallel and straight; the term *gradient wind* is a more general term used to describe wind flowing parallel to the isobars. In this Lab Manual we use the term geostrophic to mean all wind blowing parallel to the isobars.



(a) Pressure Gradient Force only



(b) Upper Atmosphere—Pressure Gradient Force and Coriolis Effect



(c) Lower Atmosphere—Pressure Gradient Force, Coriolis Effect, and Friction

Figure 12-1: The direction of wind flow associated with high and low pressure cells in the Northern Hemisphere. (a) If pressure gradient force were the only factor influencing wind direction, air would flow down the pressure gradient away from high pressure and toward low pressure, crossing the isobars at right angles. (b) In the upper atmosphere (above about 700 meters [2300 feet]) an approximate balance develops between the pressure gradient force and the Coriolis effect deflection, resulting in geostrophic wind blowing parallel to the isobars. (c) Near the surface, friction slows the wind (which results in less Coriolis effect deflection) and so wind diverges clockwise out of a high and converges counterclockwise into a low. (From Hess, *McKnight's Physical Geography*, 10th ed.)

into **lows (cyclones)** in the Northern Hemisphere. In the Southern Hemisphere, winds are deflected in the opposite direction.

GENERAL CIRCULATION PATTERNS

At the global scale, the four most prominent components of the general circulation of the atmosphere are associated with the **Hadley cells** (Figure 12-2). This pair of large convection cells is driven by the warm surface conditions in equatorial latitudes. Warm air rises near the equator in the **intertropical convergence zone (ITCZ)**, an area of generally low pressure and cloudy conditions. This air descends at about 30° north and south latitude in the **subtropical highs (STH)**, areas of high pressure and clear, dry conditions.

Two surface wind systems diverge from the STHs, the **westerlies** (blowing from the west) in the midlatitudes and the **trade winds** (blowing from the east) within the tropics. The

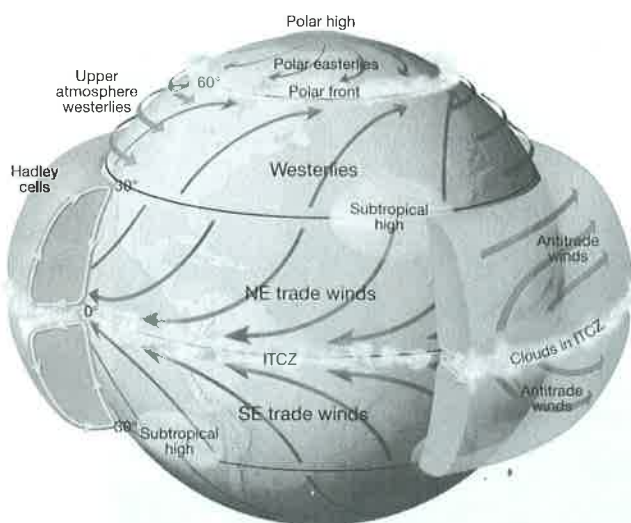


Figure 12-2: Idealized global circulation patterns in the atmosphere. Air rises in the Hadley Cells in the ITCZ and descends into the subtropical highs. The subtropical highs are the source of the surface trade winds and westerlies. (From Hess, *McKnight's Physical Geography*, 10th.)

upper atmosphere westerlies, including the high velocity **jet streams**, generally flow from west to east, as do the upper atmosphere trade winds (the **antitrade winds**).

INDICATING WIND ON WEATHER MAPS

Wind direction is indicated on weather map station models with a shaft that points *into* the wind. Wind direction is described as the direction *from* which the wind is blowing, so a “westerly” wind is blowing from the west, and an “easterly” wind is blowing from the east. Occasionally, wind direction is described in terms of an **azimuth**—the number of degrees clockwise from north (so north = 000° [or 360°]; east = 090°; south = 180°; west = 270°; and so on).

The wind speed is shown with “feathers” on the wind direction shaft. The wind speed, in **knots**, is determined by adding up the number of feathers (a “knot” is one nautical mile per hour, which equals 1.15 statute mph or 1.85 km/hr). Each full feather represents an increase in wind speed of ten knots. Half-feathers are used to represent five knots, and a solid triangular flag is used to represent 50 knots. For example, the following station model indicates wind from the northwest at 25 knots:



When mapping upper atmosphere winds, wind direction shafts and feathers are often used without the rest of the station model (this is done occasionally when mapping surface wind patterns as well). Figure 12-3 shows a pair of satellite maps of the northeastern Pacific Ocean showing forecast surface and upper atmosphere winds. The centers of three pressure cells have been marked on the surface map. The 300 mb level is the elevation in the atmosphere where the pressure has decreased to 300 mb. This typically is at an altitude of around 9 kilometers (30,000 feet). The west coast of North America is visible along the right side of each image. The dark areas are ocean, and the white areas are clouds.

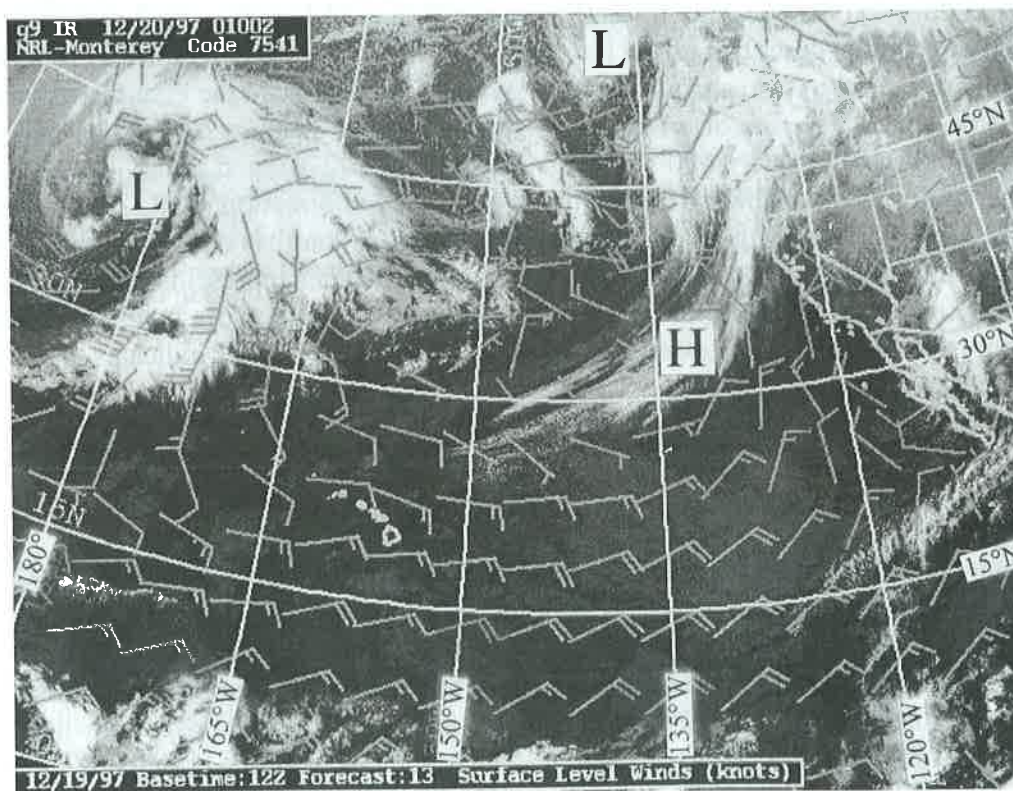
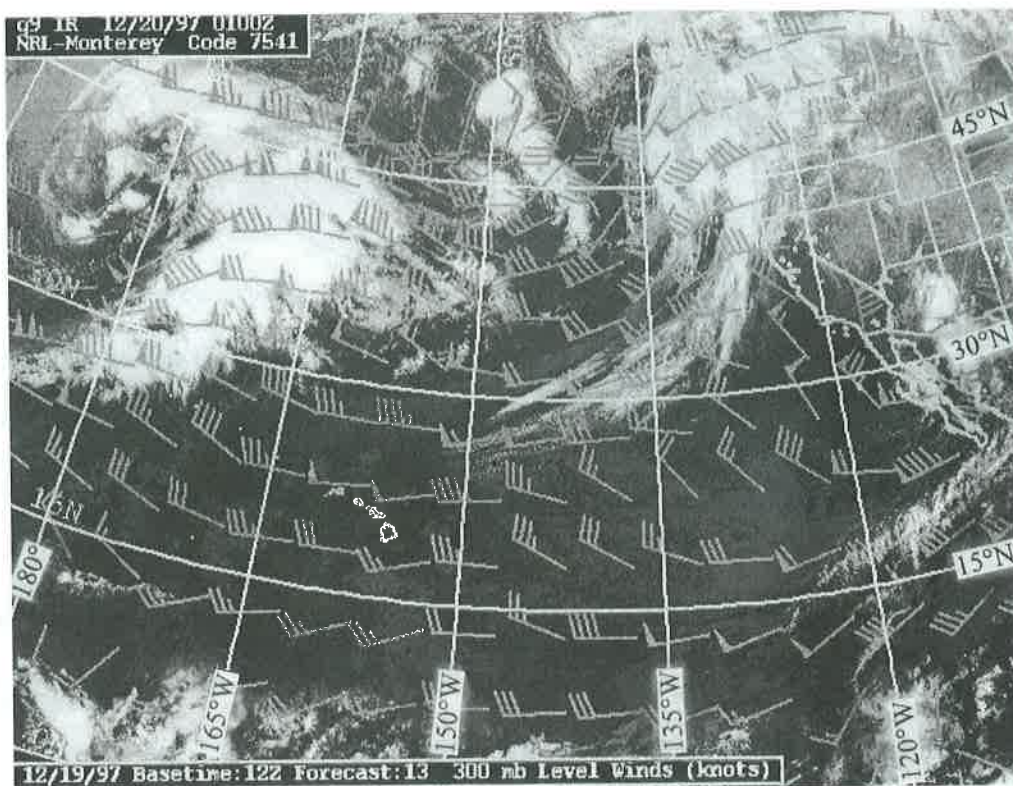


Figure 12-3: Forecast upper atmosphere wind at 300 mb level (top image) and surface wind (bottom image) in North Pacific on 12/20/97. (Images courtesy of Naval Research Laboratory, Marine Meteorology Division)