Cyclone Tracks

Extratropical cyclones are steered by the global circulation, including the prevailing westerlies at mid-latitudes and the meandering Rossby-wave pattern in the jet stream. Typical **storm tracks** (cyclone paths) of low centers are shown in Fig. 13.5. Multi-year climate variations (see the Climate chapter) in the global circulation, such as associated with the El Niño / La Niña cycle or the North Atlantic Oscillation (NAO), can alter the cyclone tracks. Mid-latitude cyclones are generally stronger, translate faster,

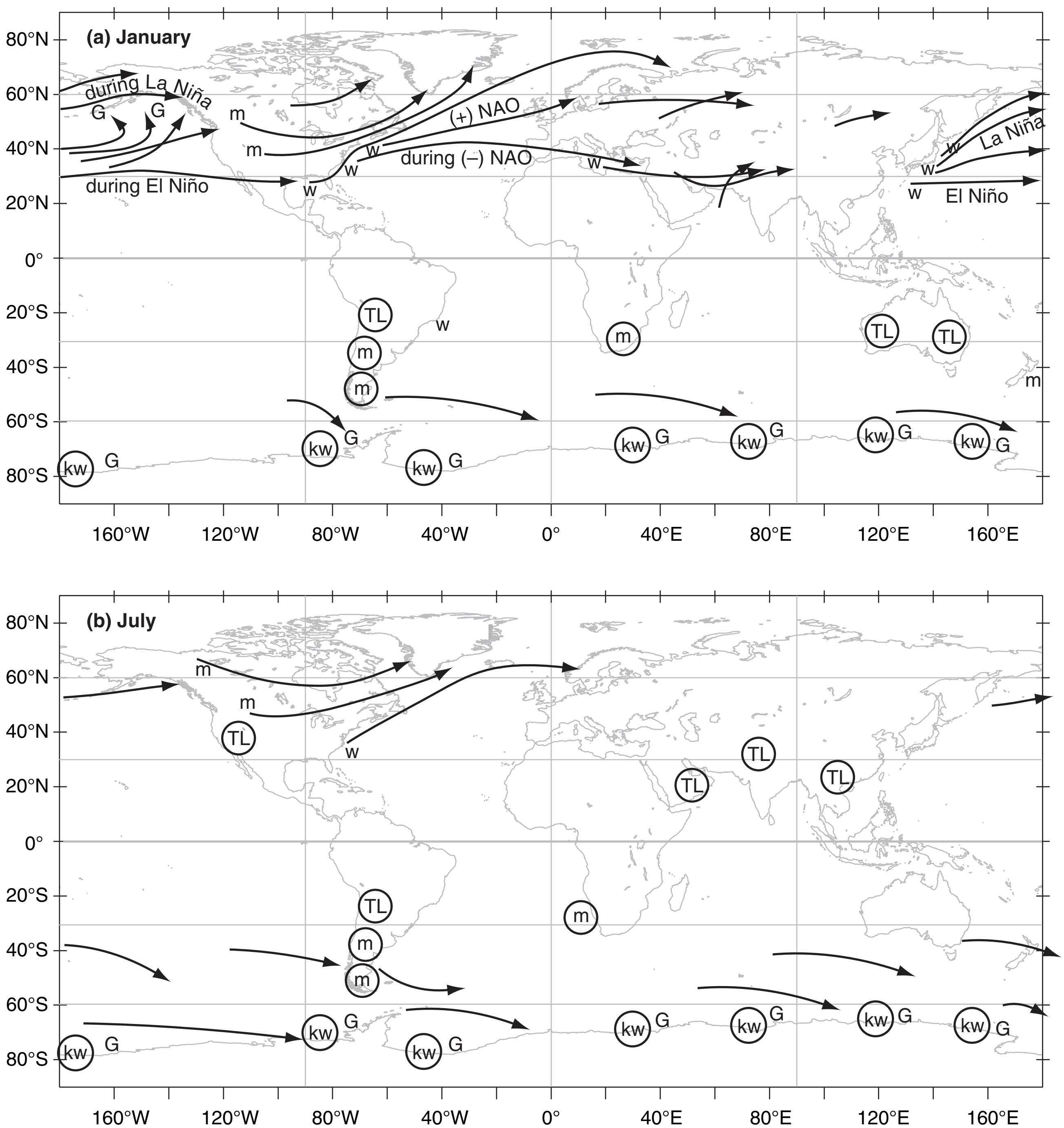

Figure 13.5 (below)
Climatology of extratropical cyclone tracks (lines with arrows) for (a) January and (b) July. Other symbols represent genesis and decay regions, as explained in the text. Circled symbols indicate stationary cyclones.

and are further equatorward during winter than in summer.

One favored cyclogenesis region is just east of large mountain ranges (shown by the "m" symbol in Fig. 13.5; see **Lee Cyclogenesis** later in this chapter). Other cyclogenesis regions are over warm ocean **boundary currents** along the western edge of oceans (shown by the symbol "w" in the figure), such as the **Gulf Stream** current off the east coast of N. America, and the **Kuroshio Current** off the east coast of Japan. During winter over such currents are strong sensible and latent heat fluxes from the warm ocean into the air, which adds energy to developing cyclones. Also, the strong wintertime contrast between the cold continent and the warm ocean current causes an intense baroclinic zone that drives a strong jet stream above it due to thermal-wind effects.

Cyclones are often strengthened in regions under the jet stream just east of troughs. In such regions, the jet stream steers the low center toward the east and poleward. Hence, cyclone tracks are often toward the northeast in the N. Hemisphere, and toward the southeast in the S. Hemisphere.

Cyclones in the Northern Hemisphere typically evolve during a 2 to 7 day period, with most lasting 3 - 5 days. They travel at typical speeds of 12 to 15 m s^{-1} (43 to 54 km h^{-1}), which means they can move about 5000 km during their life. Namely, they can travel the distance of the continental USA from coast to coast or border to border during their lifetime. Since the Pacific is a larger ocean, cyclones that form off of Japan often die in the Gulf of Alaska just west of British Columbia (BC), Canada — a cyclolysis region known as a **cyclone graveyard** (G).

Quasi-stationary lows are indicated with circles in Fig. 13.5. Some of these form over hot continents in summer as a monsoon circulation. These are called **thermal lows** (TL), as was explained in the General Circulation chapter in the section on Hydrostatic Thermal Circulations. Others form as quasi-stationary lee troughs just east of mountain (m) ranges.

In the Southern Hemisphere (Fig. 13.5), cyclones are more uniformly distributed in longitude and throughout the year, compared to the N. Hemisphere. One reason is the smaller area of continents in Southern-Hemisphere mid-latitudes and subpolar regions. Many propagating cyclones form just north of 50°S latitude, and die just south. The region with greatest cyclone activity (cyclogenesis, tracks, cyclolysis) is a band centered near 60°S.

These Southern Hemisphere cyclones last an average of 3 to 5 days, and translate with average speeds faster than 10 m s^{-1} (= 36 km h^{-1}) toward the east-south-east. A band with average translation speeds faster than 15 m s^{-1} (= 54 km h^{-1}; or > 10°

INFO • North American Geography

To help you interpret the weather maps, the map and tables give state and province names.

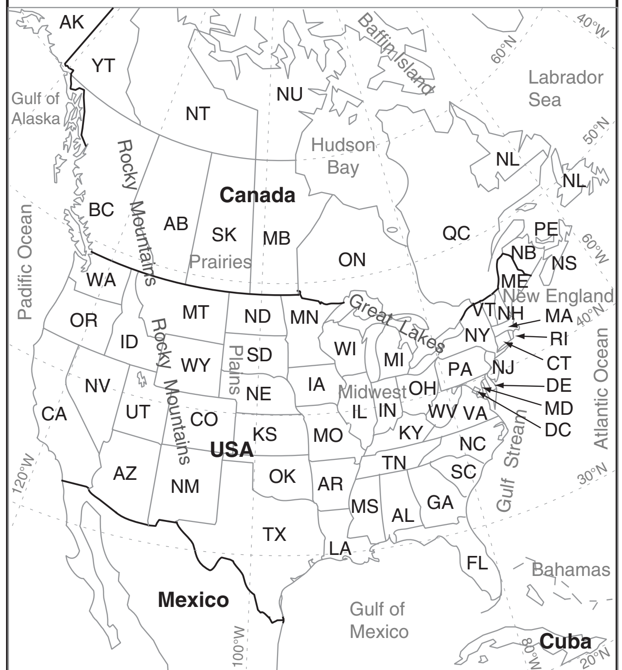

Figure b.

Canadian Postal Abbreviations for Provinces:

AB	Alberta	NT	Northwest Territories
BC	British Columbia	NU	Nunavut
MB	Manitoba	ON	Ontario
NB	New Brunswick	PE	Prince Edward Isl.
NL	Newfoundland & Labrador	QC	Quebec
NS	Nova Scotia	SK	Saskatchewan
		YT	Yukon

USA Postal Abbreviations for States:

AK	Alaska	MD	Maryland	OK	Oklahoma
AL	Alabama	ME	Maine	OR	Oregon
AR	Arkansas	MI	Michigan	PA	Pennsylvania
AZ	Arizona	MN	Minnesota	RI	Rhode Isl.
CA	California	MO	Missouri	SC	South Carolina
CO	Colorado	MS	Mississippi	SD	South Dakota
CT	Connecticut	MT	Montana	TN	Tennessee
DE	Delaware	NC	North Carolina	TX	Texas
FL	Florida	ND	North Dakota	UT	Utah
GA	Georgia	NE	Nebraska	VA	Virginia
HI	Hawaii	NH	New Hampshire	VT	Vermont
IA	Iowa	NJ	New Jersey	WA	Washington
ID	Idaho	NM	New Mexico	WI	Wisconsin
IL	Illinois	NV	Nevada	WV	West Virginia
IN	Indiana	NY	New York	WY	Wyoming
KS	Kansas	OH	Ohio	DC	Wash. DC
KY	Kentucky				
LA	Louisiana				
MA	Massachusetts				

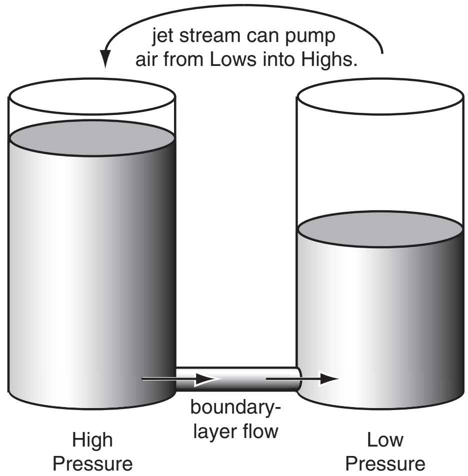

Figure 13.6
Two tanks filled with water to different heights are an analogy to neighboring high and low pressure systems in the atmosphere.

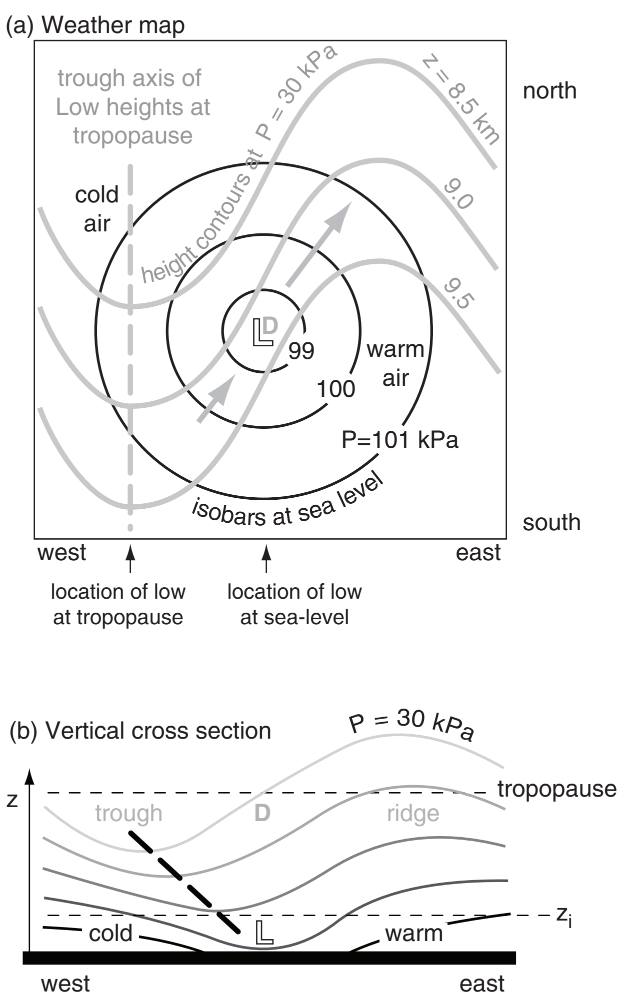

Figure 13.7
(a) Two N. Hemisphere weather maps superimposed: (thin black lines) sea-level pressure, and (grey lines) 30 kPa heights. Jet-stream winds (thick grey arrows) follow the height contours (b) East-west vertical cross section through middle of (a). Heavy dashed line is trough axis. L indicates low center at surface, and D indicates divergence aloft. (Pressure and height variations are exaggerated.)

longitude day^{-1}) extends from south of southwestern Africa eastward to south of western Australia. The average track length is 2100 km. The normal **cyclone graveyard** (G, cyclolysis region) in the S. Hemisphere is in the **circumpolar trough** (between 65°S and the Antarctic coastline).

Seven stationary centers of enhanced cyclone activity occur around the coast of Antarctica, during both winter and summer. Some of these are believed to be a result of fast **katabatic** (cold downslope) winds flowing off the steep Antarctic terrain (see the Fronts & Airmasses chapter). When these very cold winds reach the relatively warm unfrozen ocean, strong heat fluxes from the ocean into the air contribute energy into developing cyclones. Also the downslope winds can be channeled by the terrain to cause cyclonic rotation. But some of the seven stationary centers might not be real — some might be caused by improper reduction of surface pressure to sea-level pressure. These seven centers are labeled with "kw", indicating a combination of **k**atabatic winds and relatively **w**arm sea surface.

Stacking & Tilting

Lows at the bottom of the troposphere always tend to kill themselves. The culprit is the boundary layer, where turbulent drag causes air to cross isobars at a small angle from high toward low pressure. By definition, a low has lower central pressure than the surroundings, because fewer air molecules are in the column above the low. Thus, boundary-layer flow will always move air molecules toward surface lows (Fig. 13.6). As a low fills with air, its pressure rises and it stops being a low. Such **filling** is quick enough to eliminate a low in less than a day, unless a compensating process can remove air more quickly.

Such a compensating process often occurs if the axis of low pressure **tilts** westward with increasing height (Fig. 13.7). Recall from the **gradient-wind** discussion in the Atmospheric Forces and Winds chapter that the jet stream is slower around troughs than ridges. This change of wind speed causes divergence aloft; namely, air is leaving faster than it is arriving. Thus, with the upper-level trough shifted west of the surface low (L), the divergence region (D) is directly above the surface low, supporting cyclogenesis. Details are explained later in this Chapter. But for now, you should recognize that a westward tilt of the low-pressure location with increasing height often accompanies cyclogenesis.

Conversely, when the trough aloft is **stacked** vertically above the surface low, then the jet stream