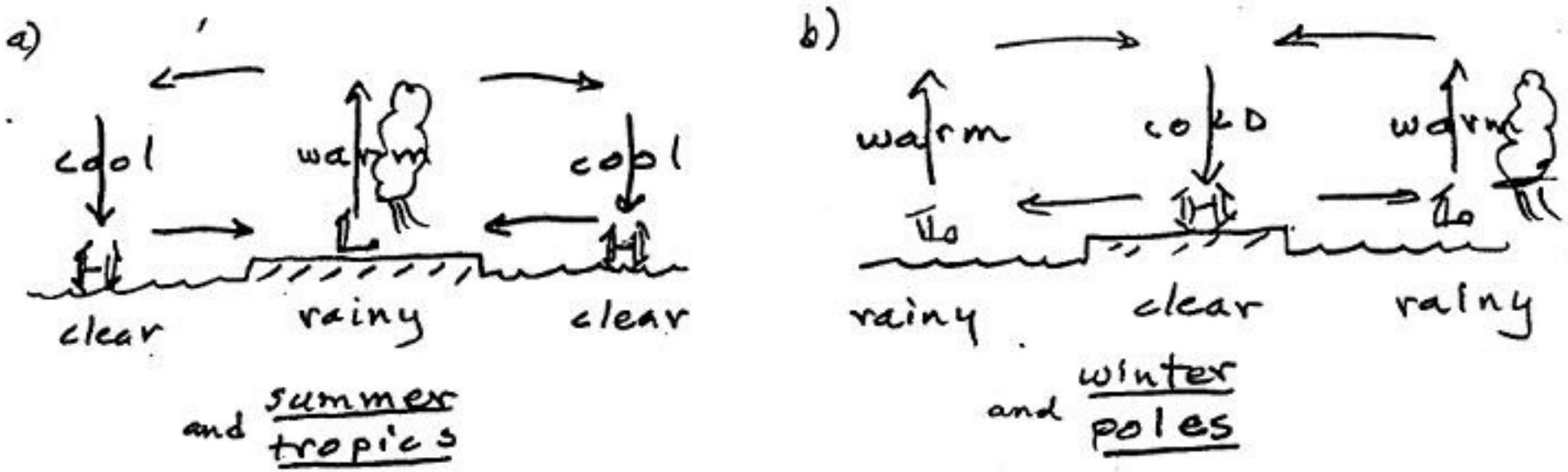


Figure 3.7. Idealized monsoon circulations corresponding to a) summer and the tropics, and b) winter and polar regions.

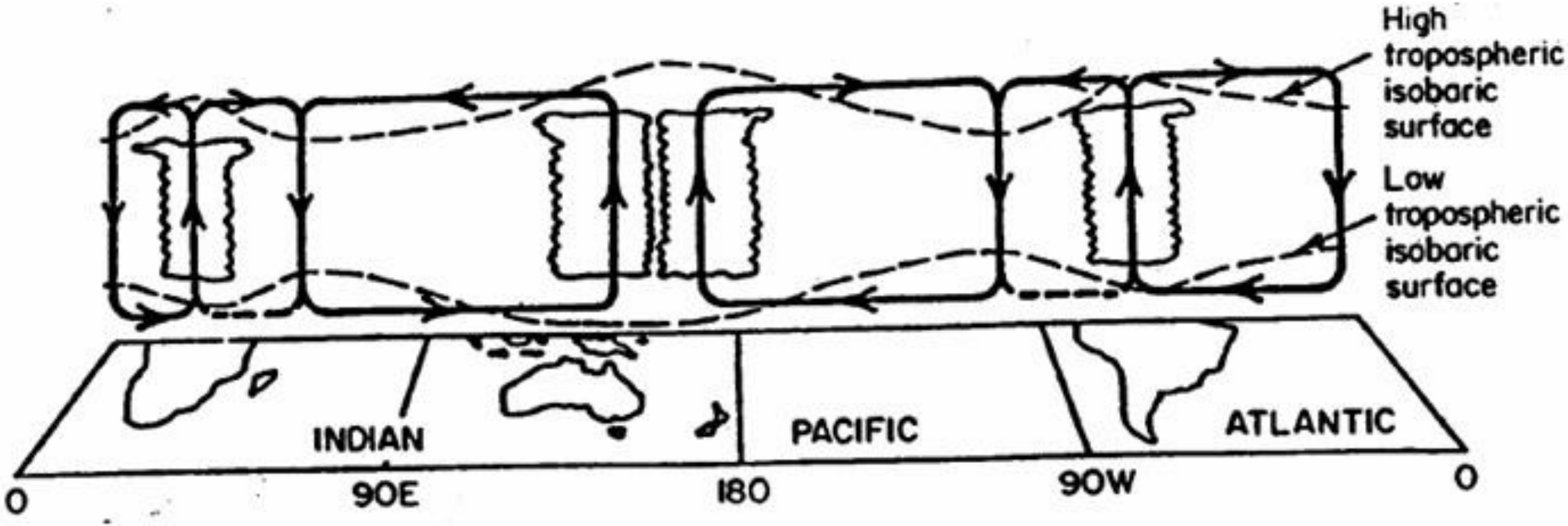


Figure 3.8 **Schematic view of the east-west Walker circulation along the equator indicating low-level convergence in regions of convection where mean upward motion occurs. [From Webster (1983).]**

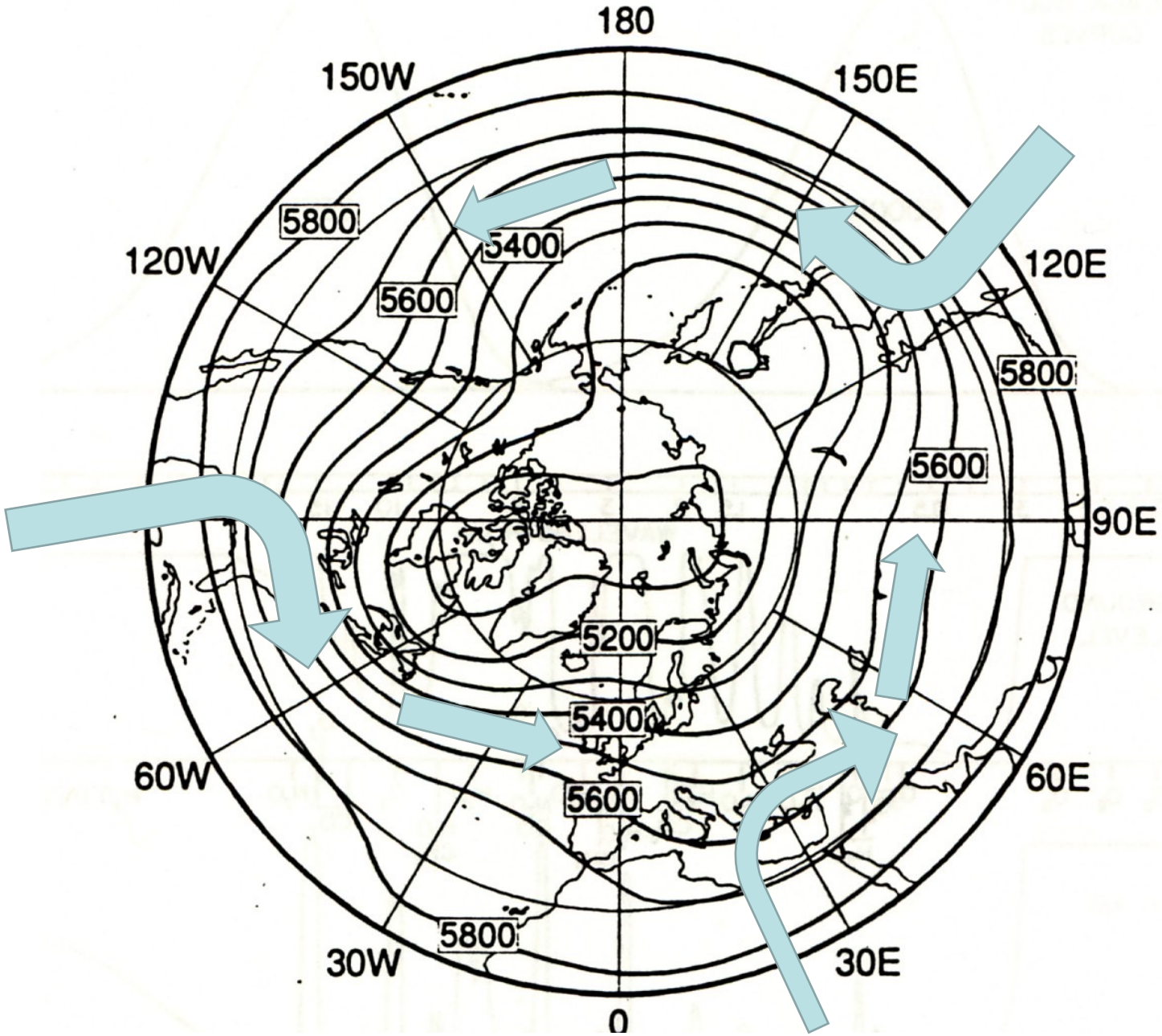


Figure 2.6. A Northern Hemisphere polar stereographic chart of 500 hPa geopotential height (in tens of meters) averaged for DJF, with contour interval 100 m. [Palmen and Newton 1969.]

Conservation of angular momentum in outflow from tropical convective centers over

- Amazonia
- Africa
- Indonesia (Maritime Continent)

causes local subtropical westerly jets

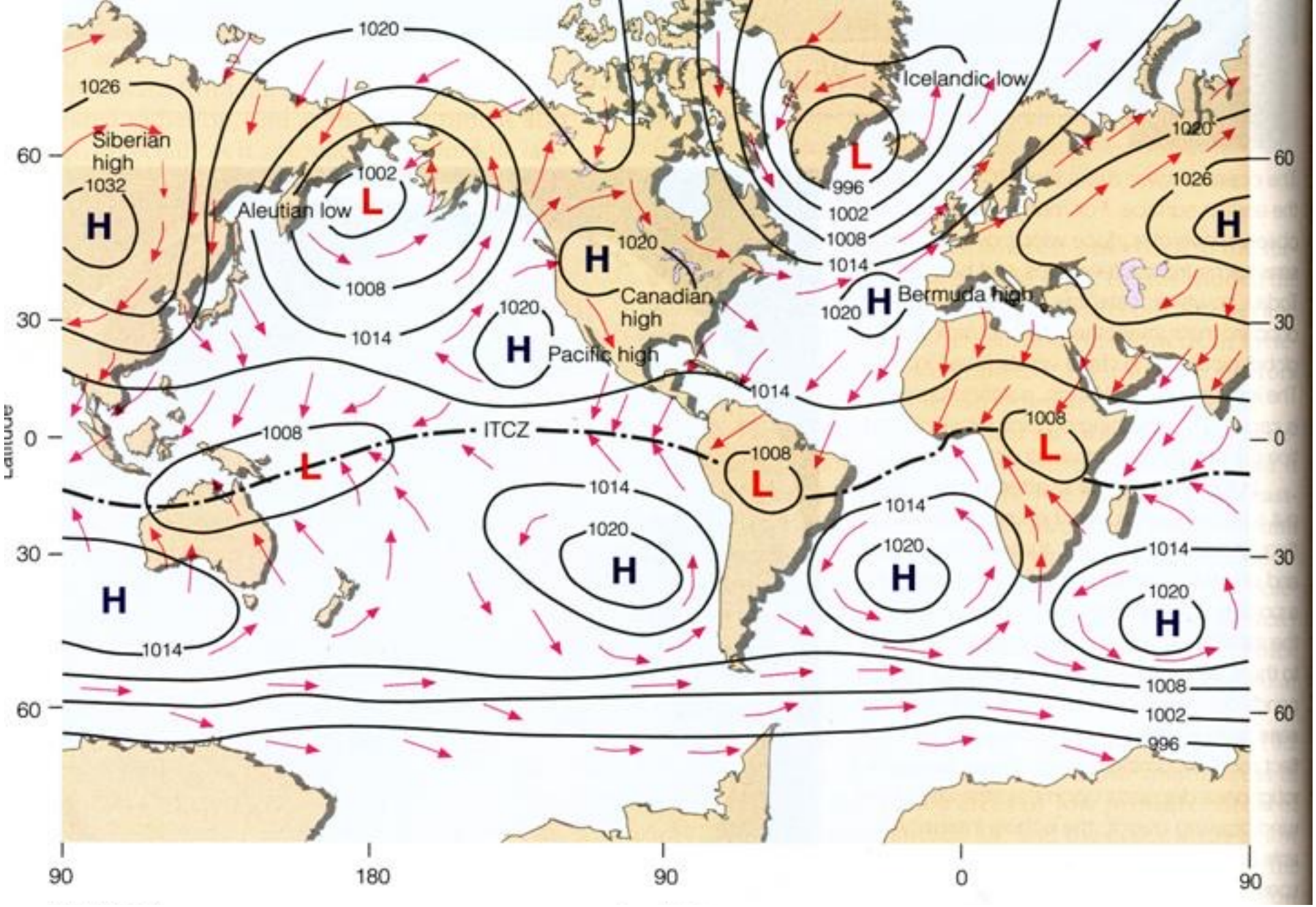


Figure 3.9a. January mean sea level pressure (hPa), and idealized surface winds [Ahrens].

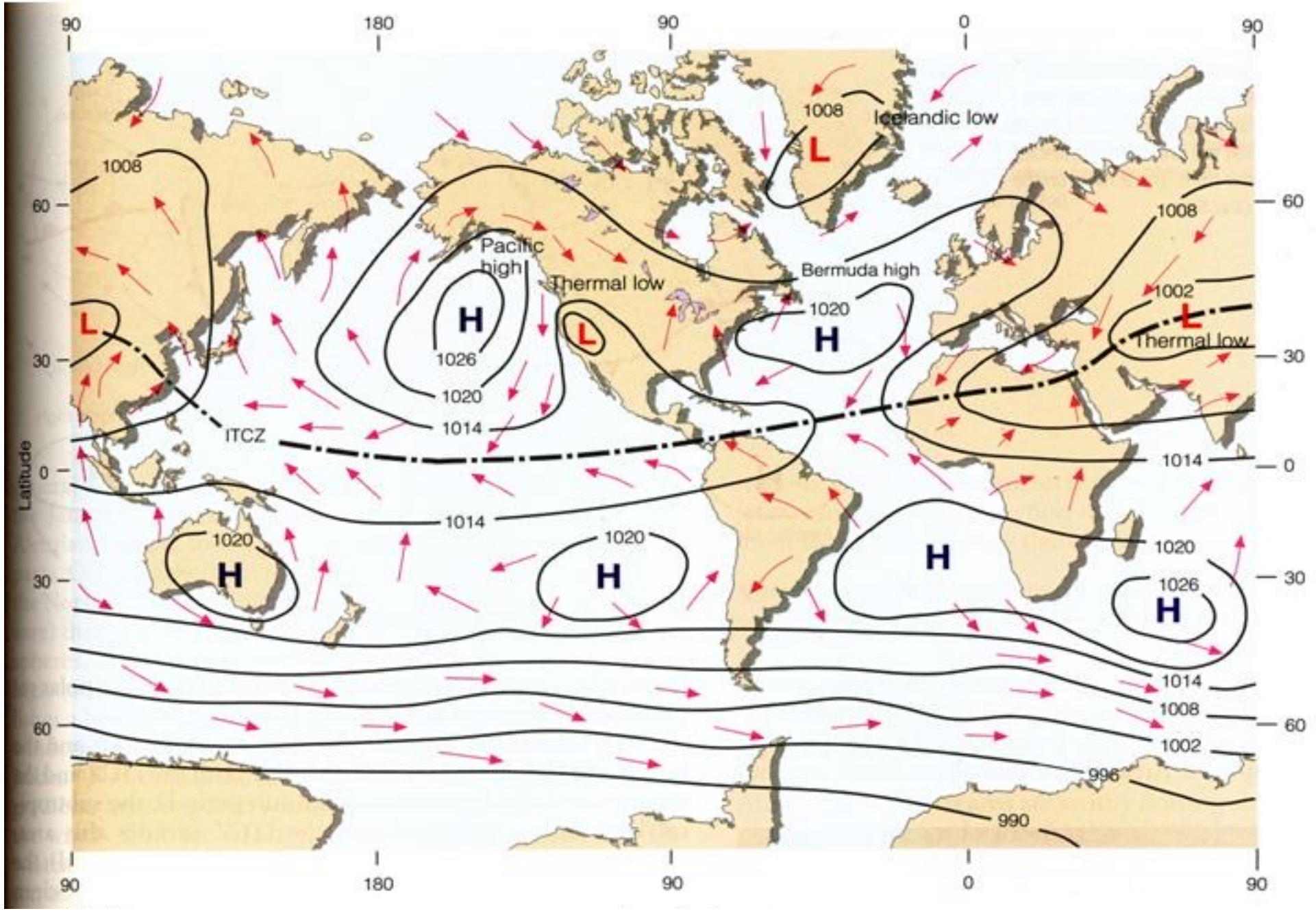
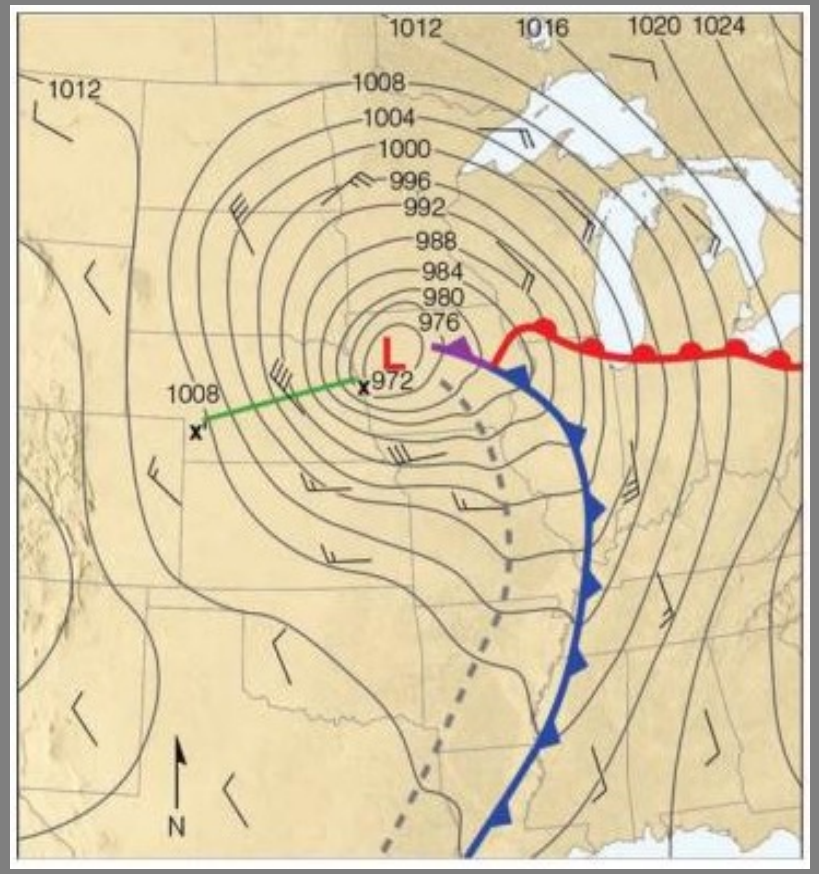


Figure 3.9b. July mean sea level pressure (hPa), and idealized surface winds [Ahrens].

The General Circulation, Part 2

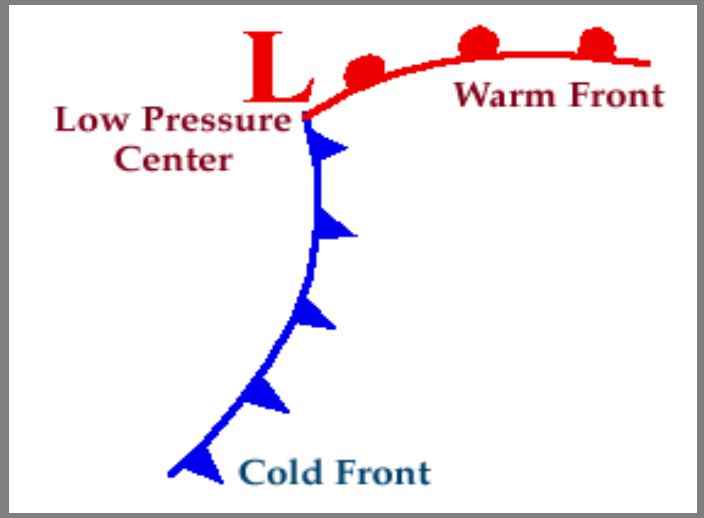
1. Atmospheric fronts
2. High and low pressure systems
3. The Hadley circulation
   trade easterlies, midlatitude westerlies
   (conservation of angular momentum)
3. Ocean gyres
4. Ekman transport and upwelling

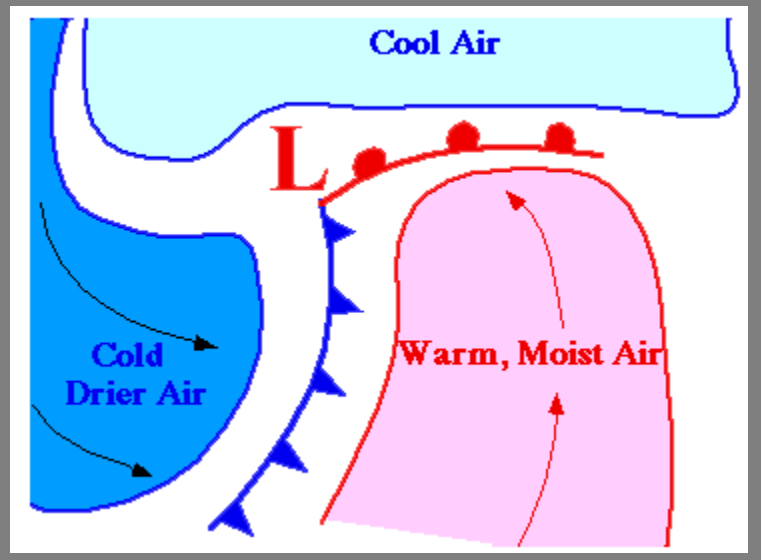
Structure of a mid-latitude front

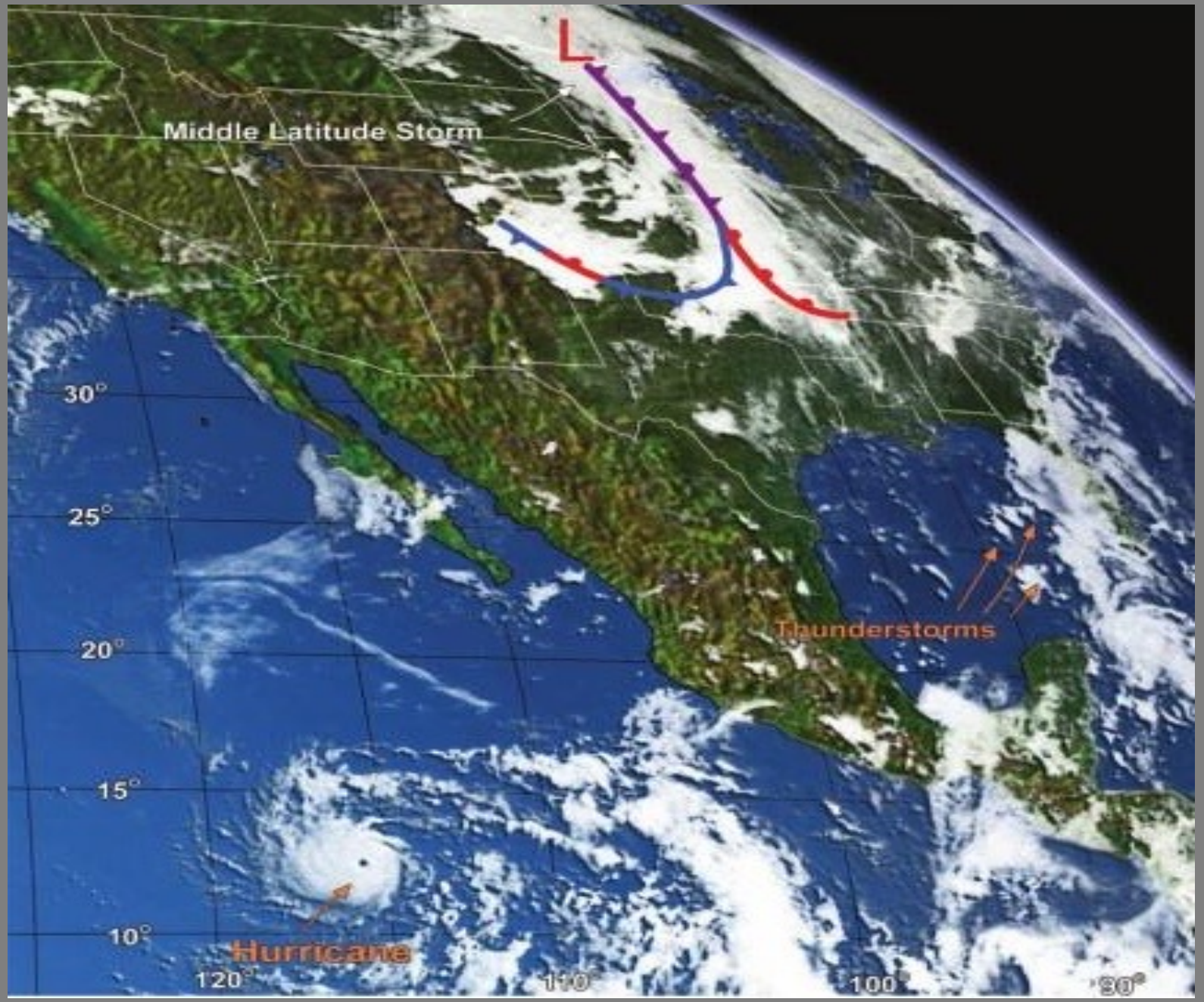


- The leading edge of a transition zone that separates cold air from warm air. Its length is much greater than its width.

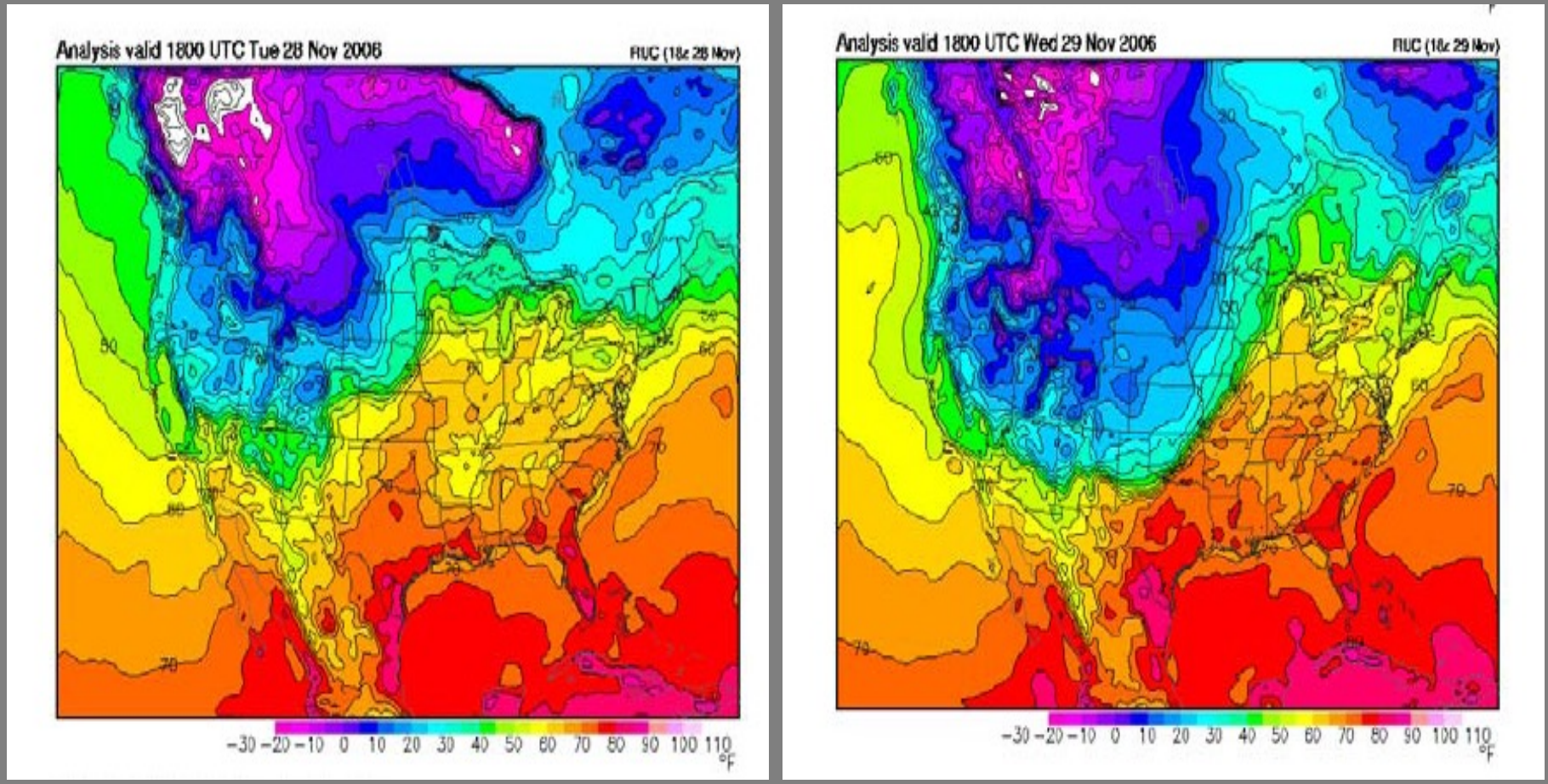
Cold and Warm Fronts





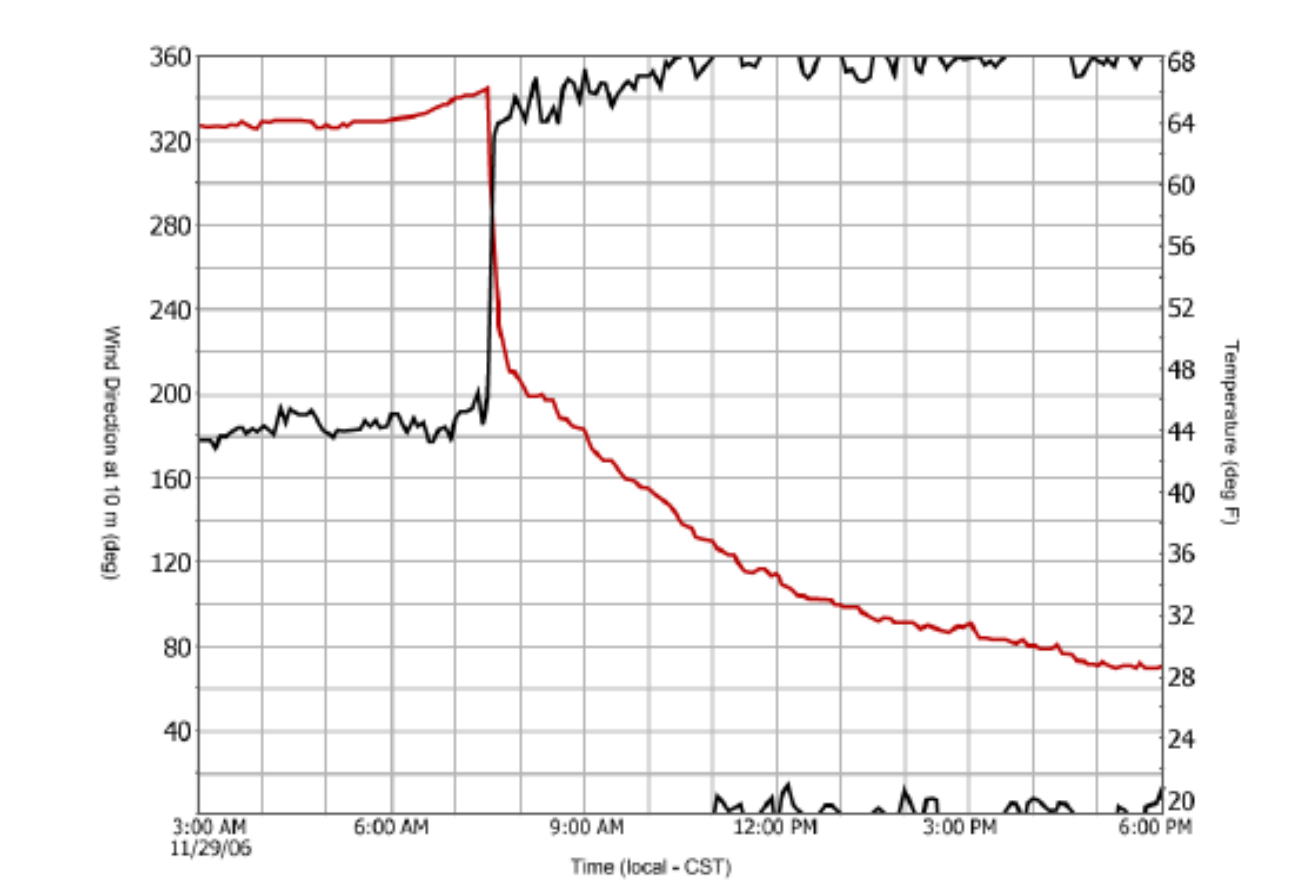

L
Middle Latitude Storm
30°
25°
20°
15°
10°
Thunderstorms
Hurricane
120°
110°
100°
90°

850 hPa (mb) Temperature



Rapid Update Cycle (RUC) model initial temperature (degrees F) analysis at 1800 UTC on (top) 28 November and (bottom) 29 November

Frontal Passage evident in Meteorogram



Meteorogram for Norman, OK mesonet site showing wind direction at 10 m (black) and temperature at 1.5 m (degrees F for red) for the 9 hr period from (CST 09UTC) on 29 November to 00 UTC on 30 November

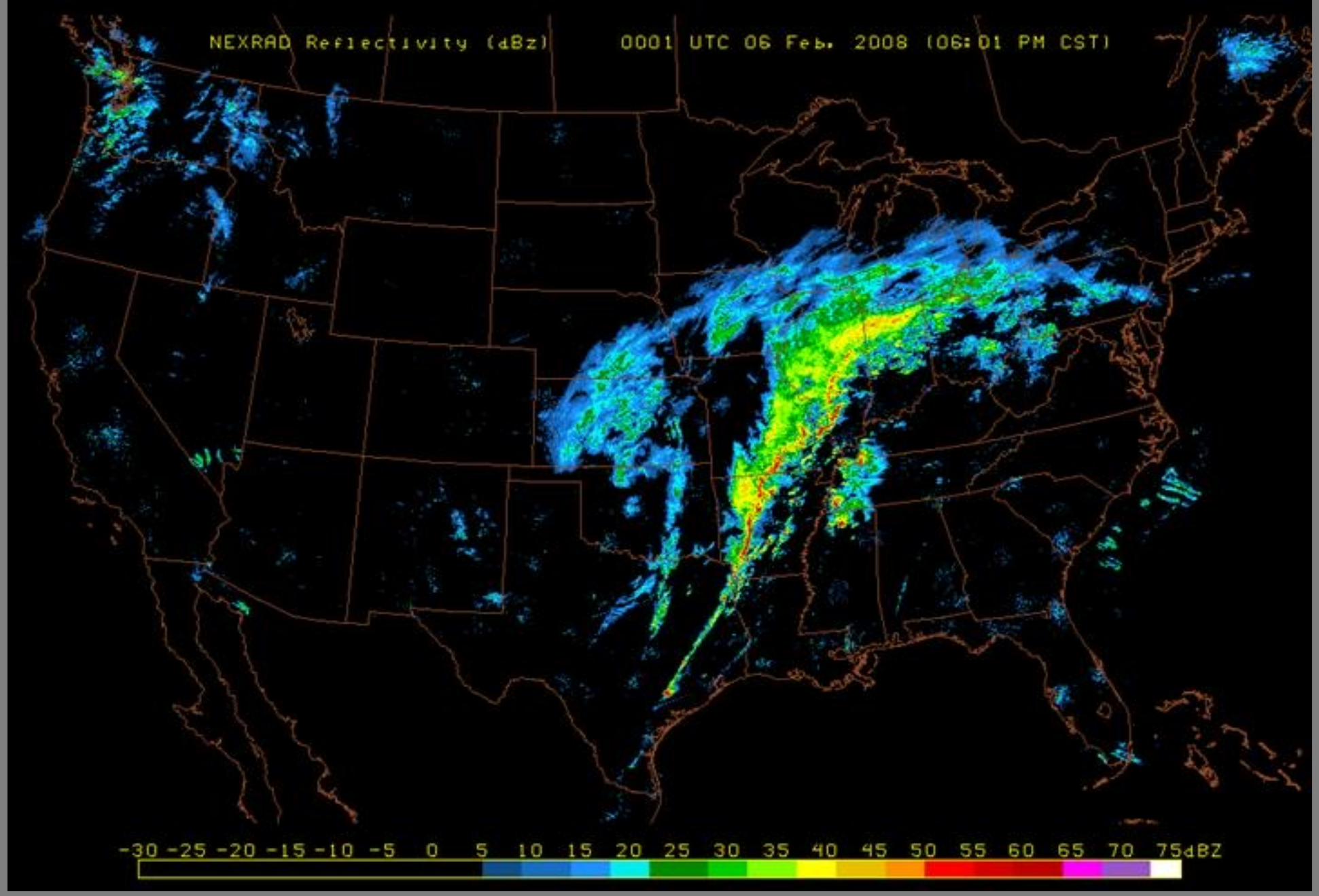
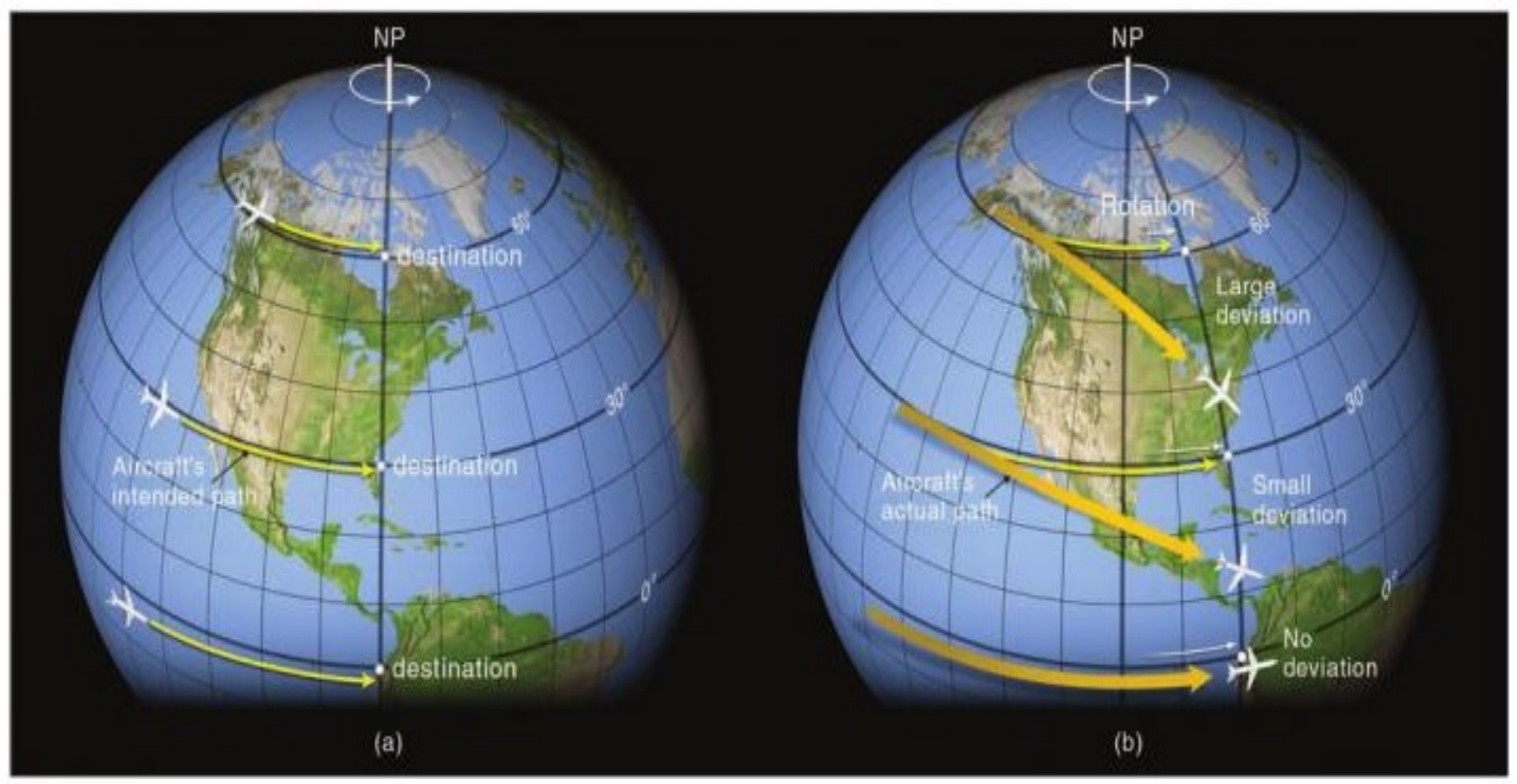


Figure 3.4. Composite U.S. radar reflectivity at 0000 UT February 6, 2008 (6 pm CST February 5). Reflected power (color) is proportional to the intensity of precipitation.

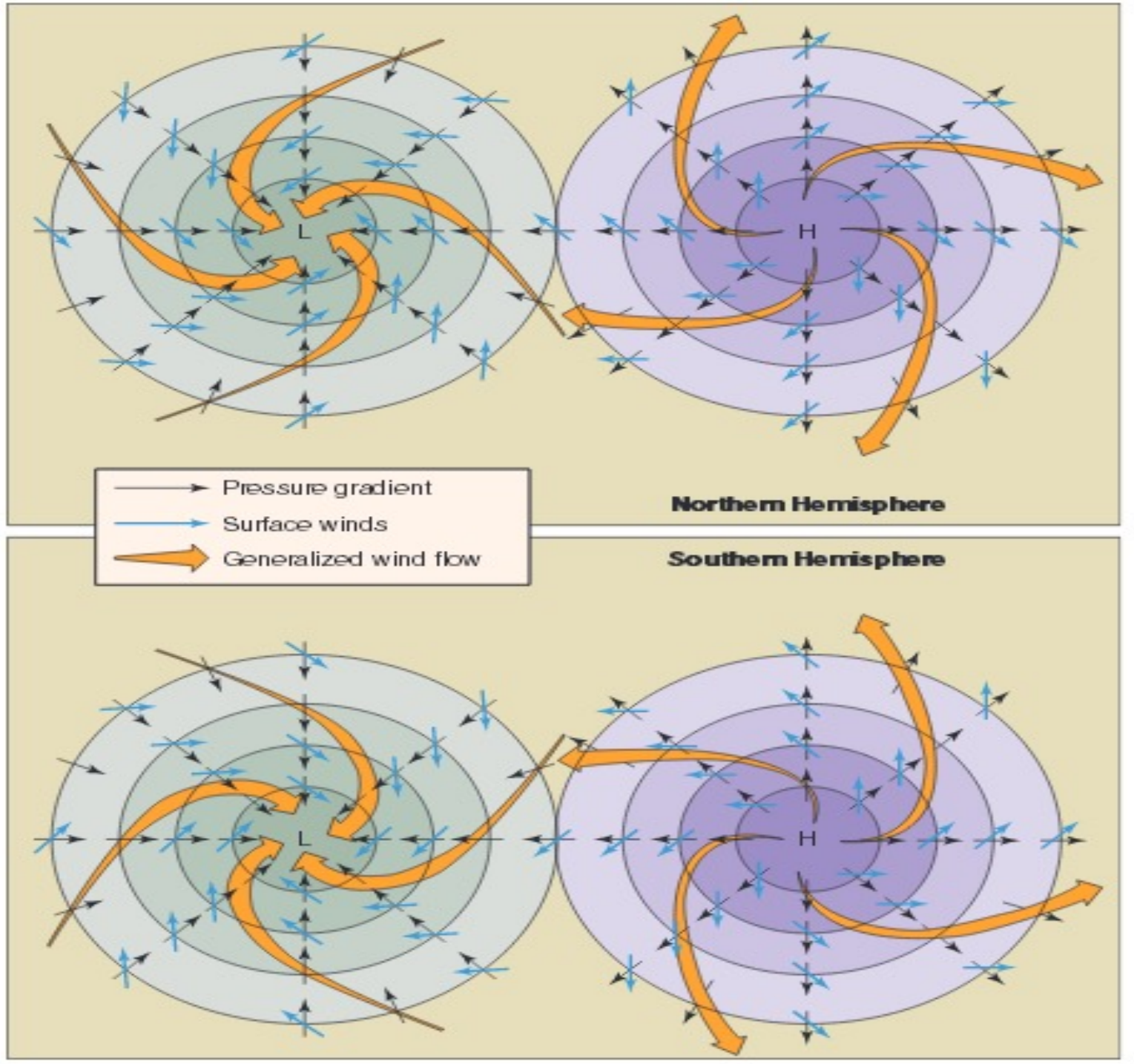
What is the Coriolis effect?

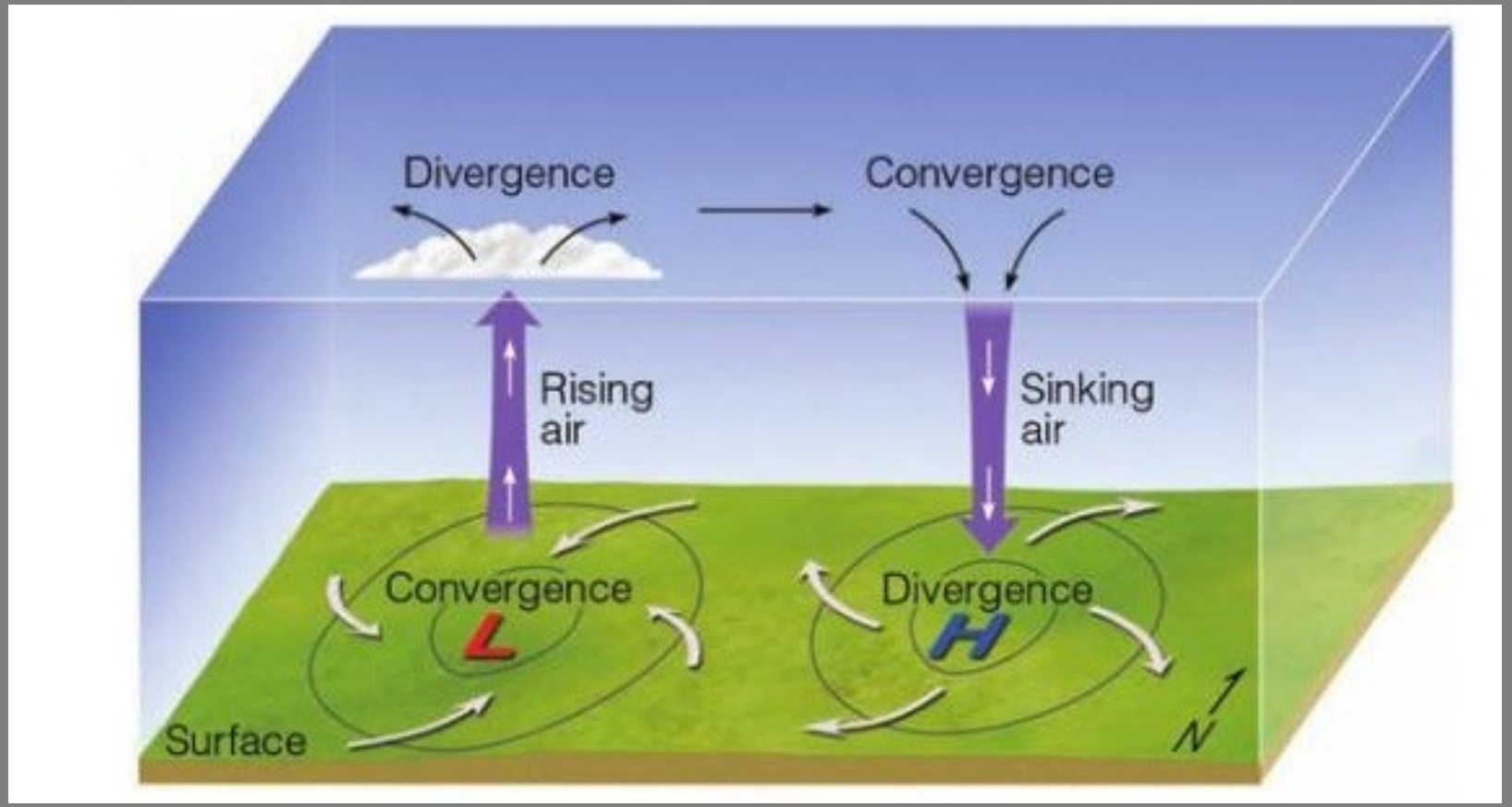
- The Coriolis effect is an apparent force that is due to the rotation of the Earth (we are in an accelerating coordinate system).
- Objects are deflected to the right of their intended path in the Northern Hemisphere
- And to the left of their intended path in the Southern Hemisphere

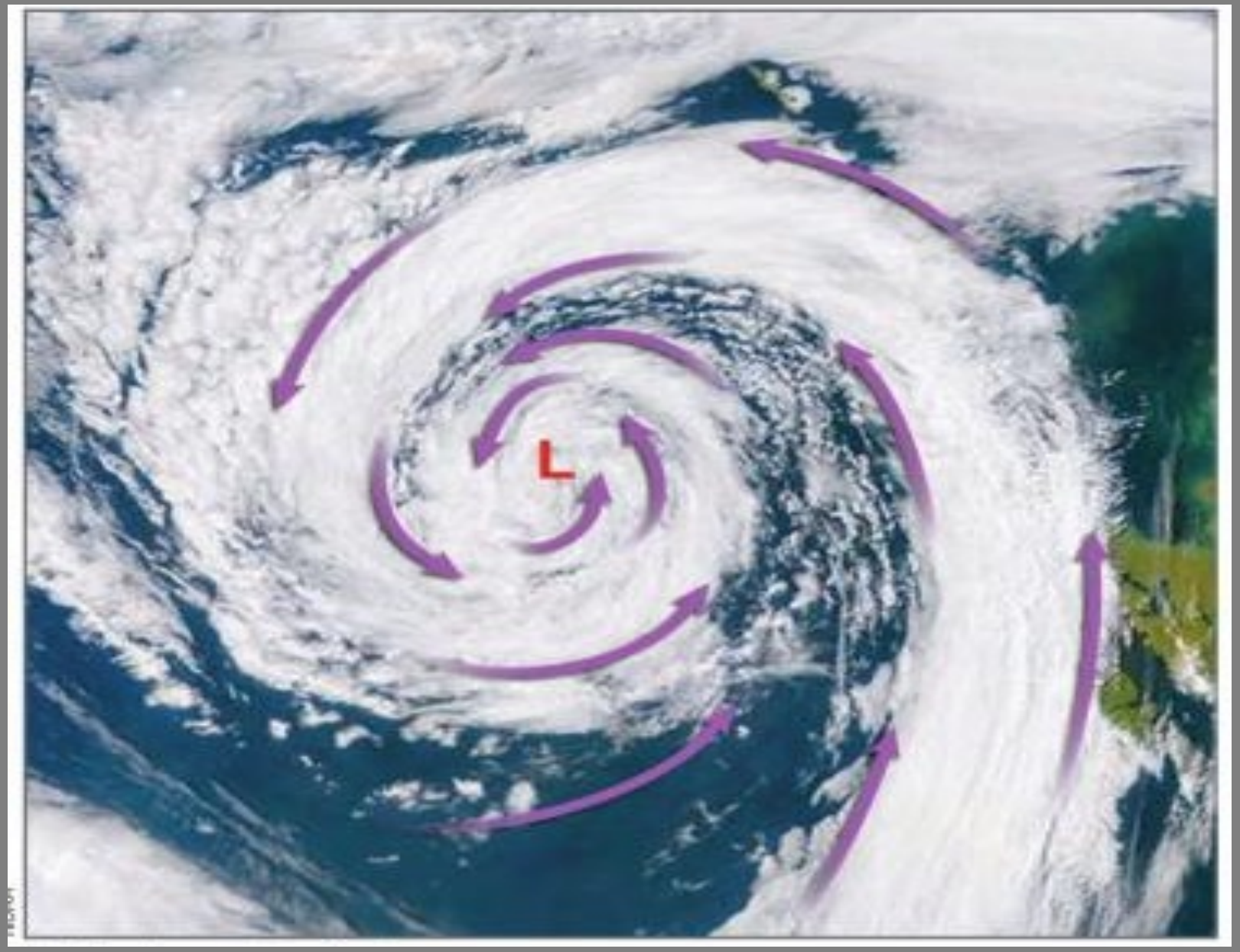

NP
destination
Aircraft's intended path
destination
destination
(a)
NP
Rotation
Large deviation
Aircraft's actual path
Small deviation
No deviation
(b)

Circulation Patterns

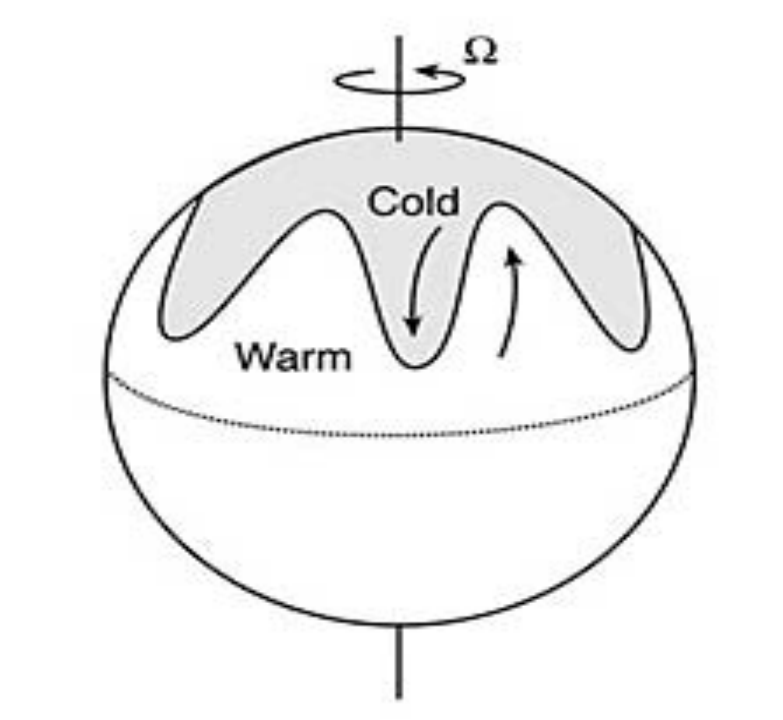
- Circulation pattern around high and low pressure systems in the Northern Hemisphere
- Around a low pressure the circulation is inward and counterclockwise
- Around a high pressure the circulation is outward and clockwise


L
H
Pressure gradient
Surface winds
Generalized wind flow
Northern Hemisphere
Southern Hemisphere
L
H


Divergence
Convergence
Rising
air
Sinking
air
Convergence
L
Divergence
H
Surface
N


L

Atmospheric Circulations transfer cold air equatorward and warm air poleward



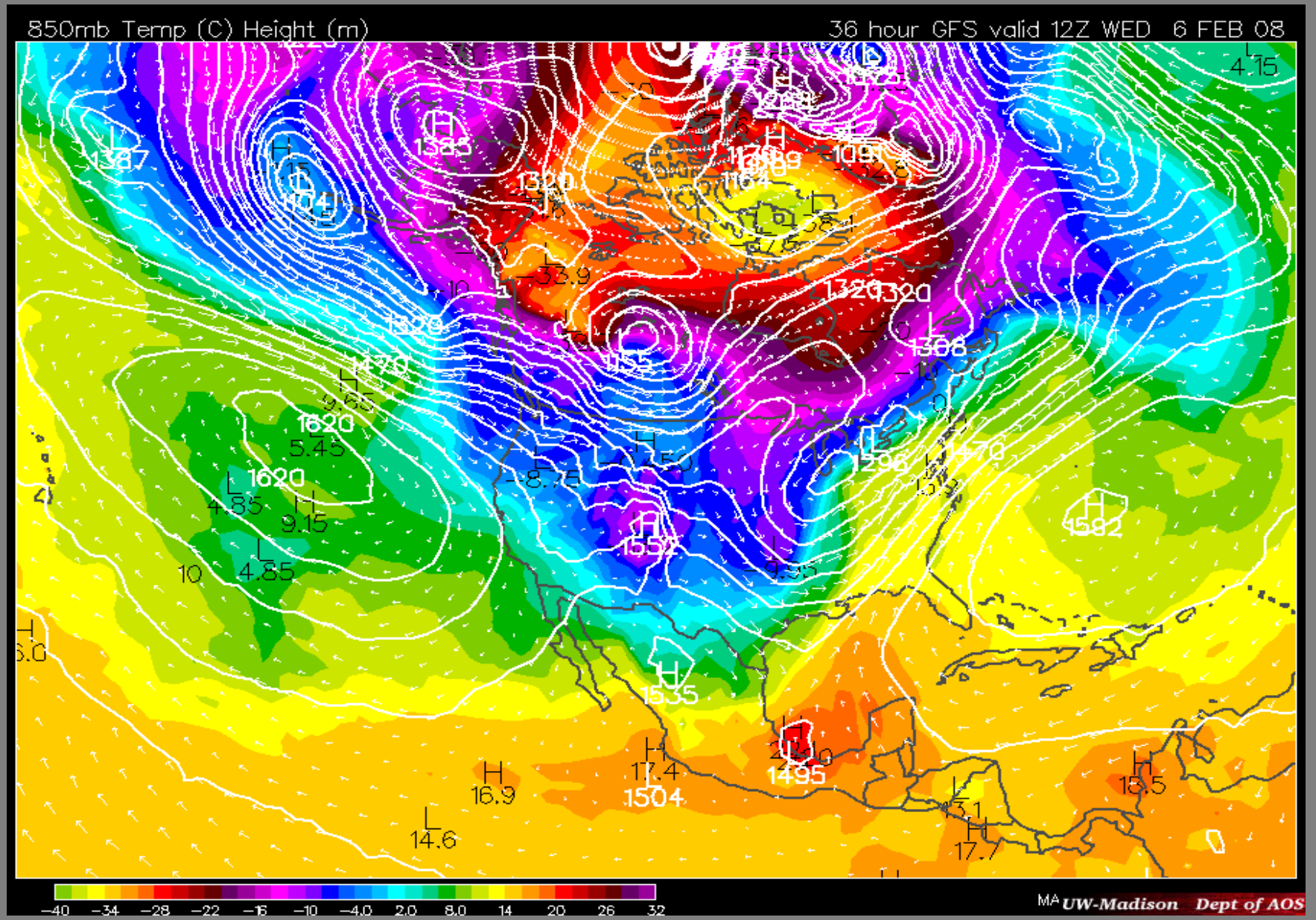


Figure 3.5b. GFS 24 hour forecast valid at 0000 UT February 6, 2008 - temperature in ^{o}C (color bar).

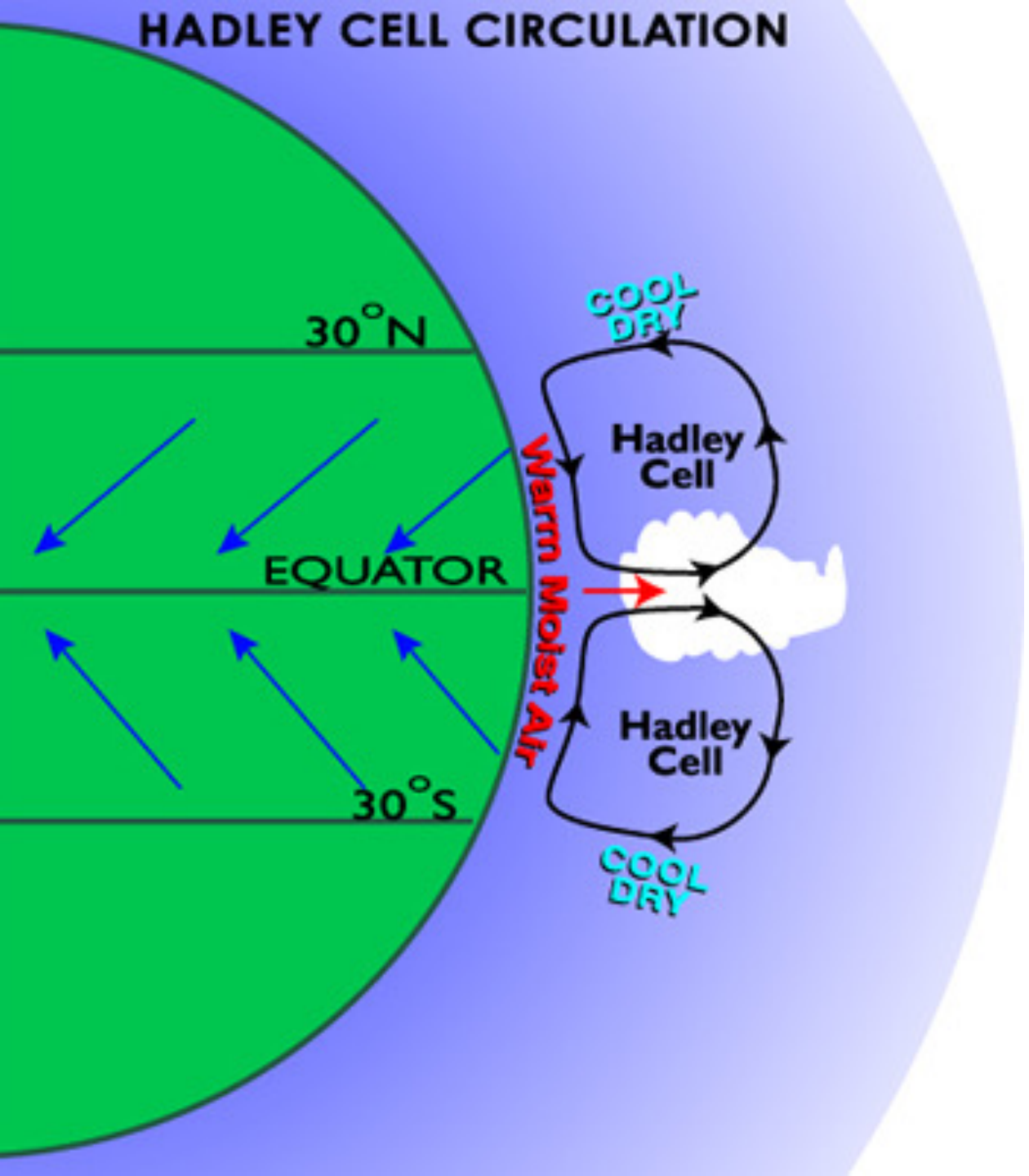
The Hadley Circulation

Subtropical deserts

The atmosphere also transports angular momentum

Trade easterlies

Midlatitude westerlies



Angular momentum = $r\ u_e$

At the equator
$r = 6367$ km
$u_e = 450$ m/s

At the poles
$r=0$, $u_e = 0$

Poleward motion aloft → westerlies near tropopause (subtropical westerly jet)

Equatorward motion → easterlies near surface (trade easterlies)

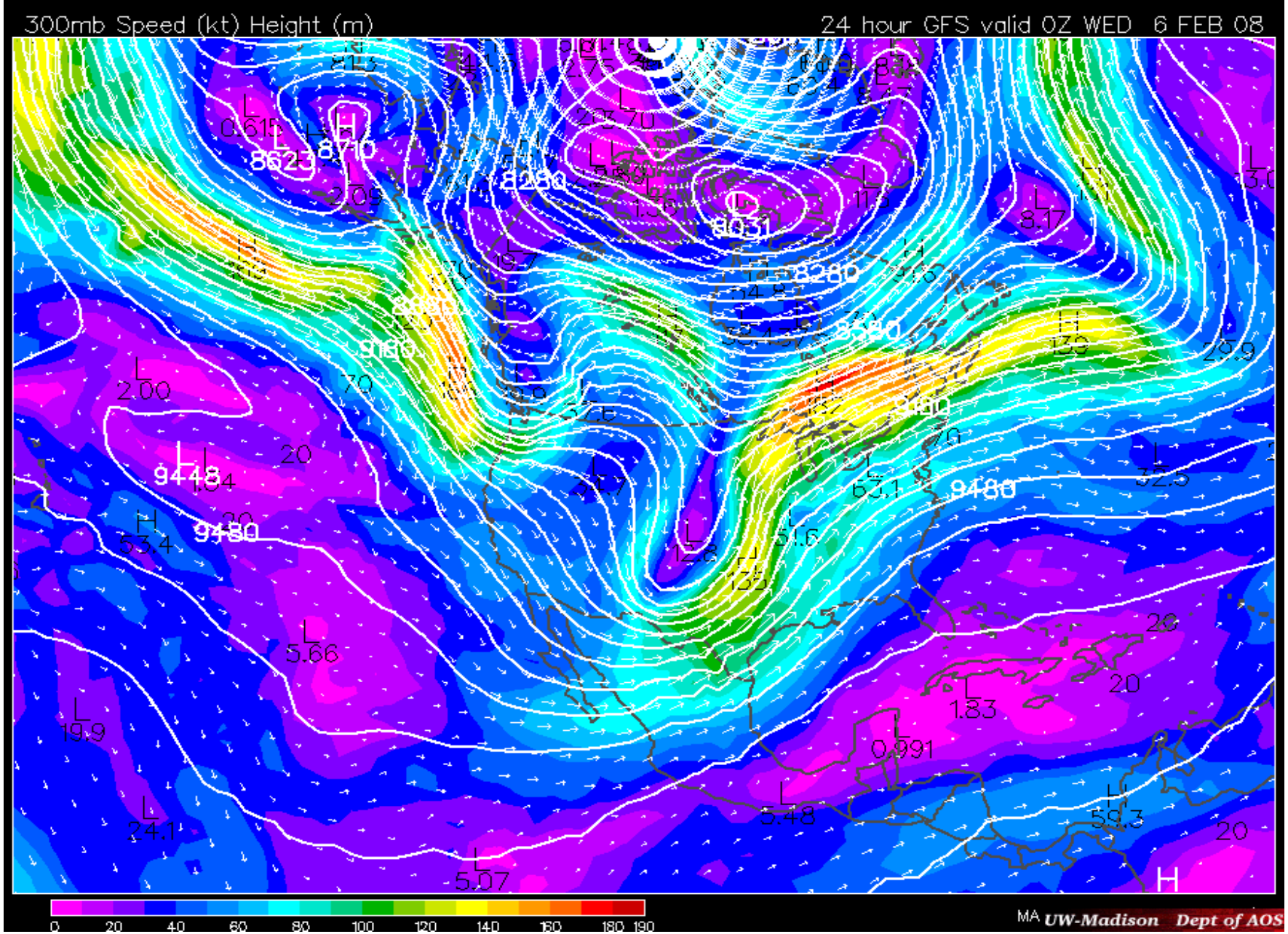


Figure 3.5a. GFS 24 hour forecast valid at 0000 UT February 6, 2008 (6 pm CST February 5) of 300 hPa geopotential height, contour interval 60 m, and isotachs (color) in knots.

Effect of Winds on the Ocean

- Trade easterlies gather water westward
- Midlatitude westerlies push water eastward
- Continental boundaries make for closed gyres

- Ekman transport (pushes upper ocean to right in NH)
- Equatorward atmospheric flow on the west coasts of continents causes offshore transport and upwelling of cold, nutrient-rich water from below

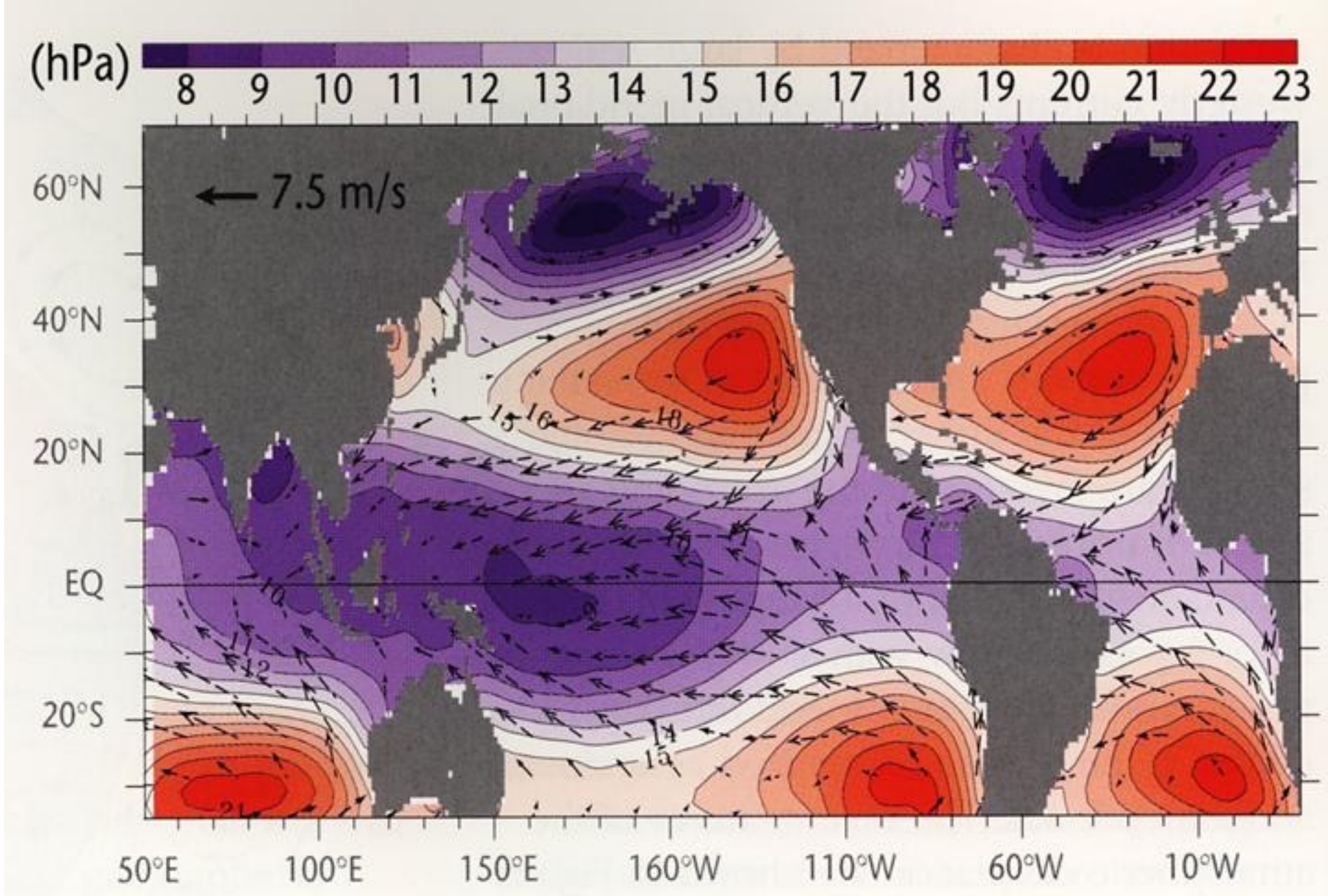


Figure 3.10. Annual mean sea level pressure anomaly and surface wind vectors.

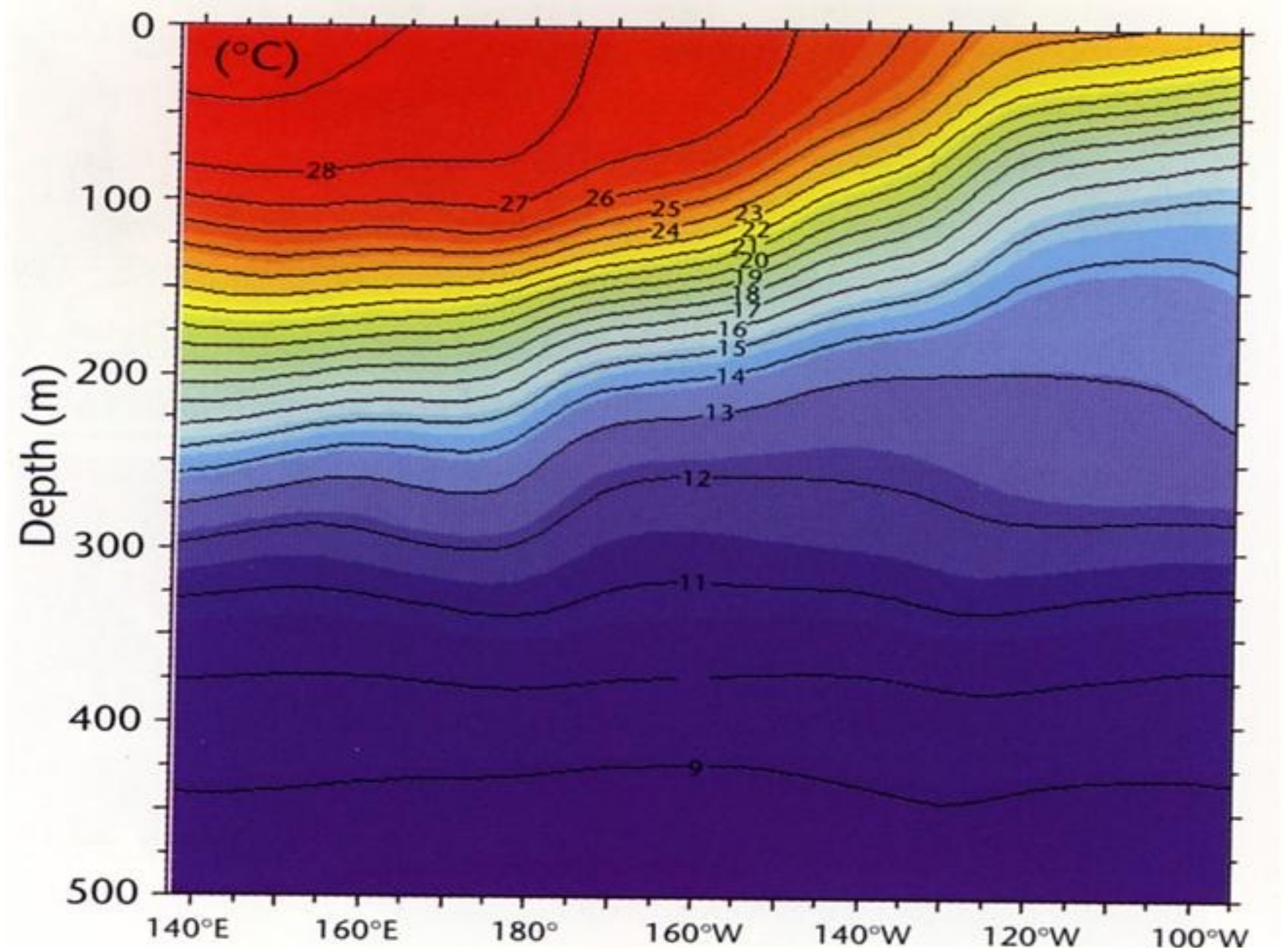


Figure 3.13. Vertical section along the equatorial Pacific showing the sloping thermocline, contour interval 1 K [www.cpc.noaa.gov].

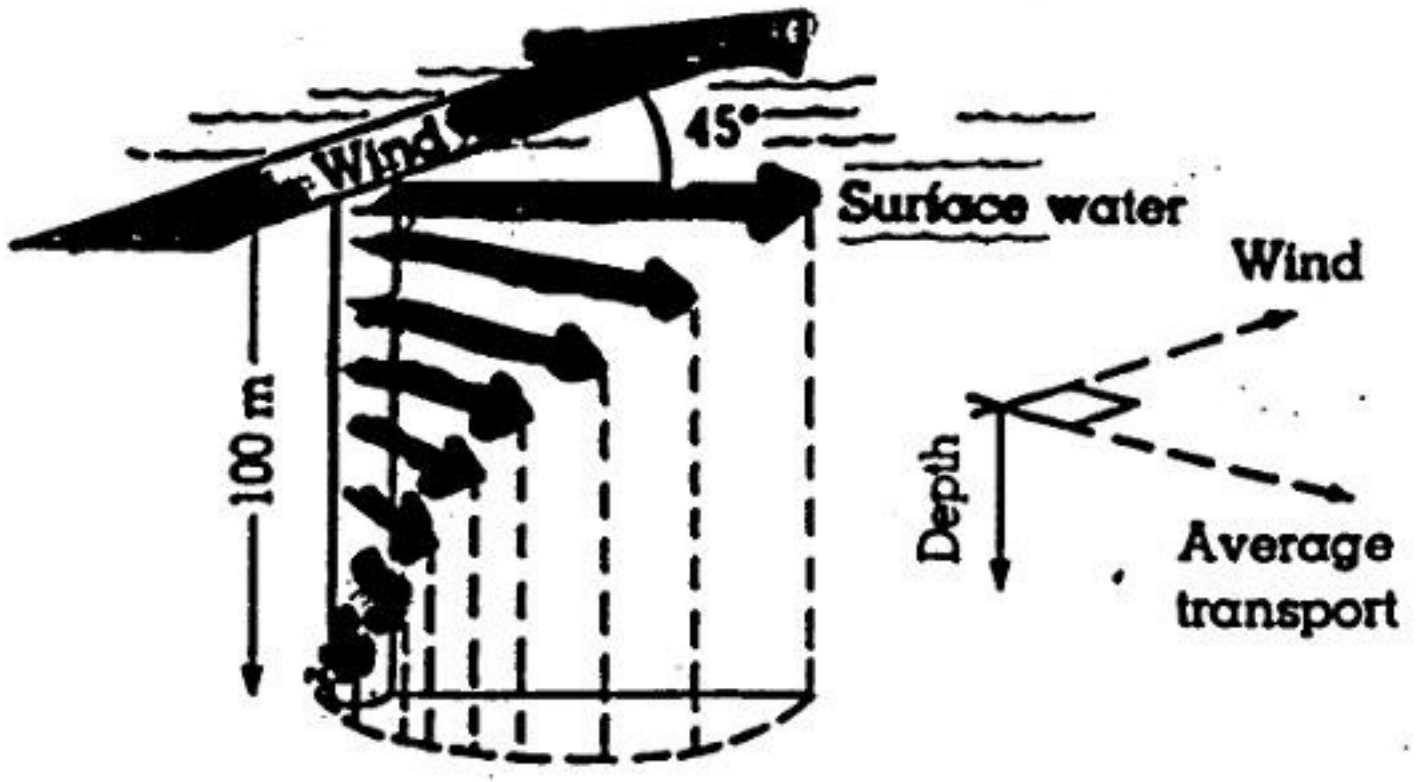


Figure 3.11. The Ekman spiral in the upper layer of the ocean for the Northern Hemisphere [Ahrens].

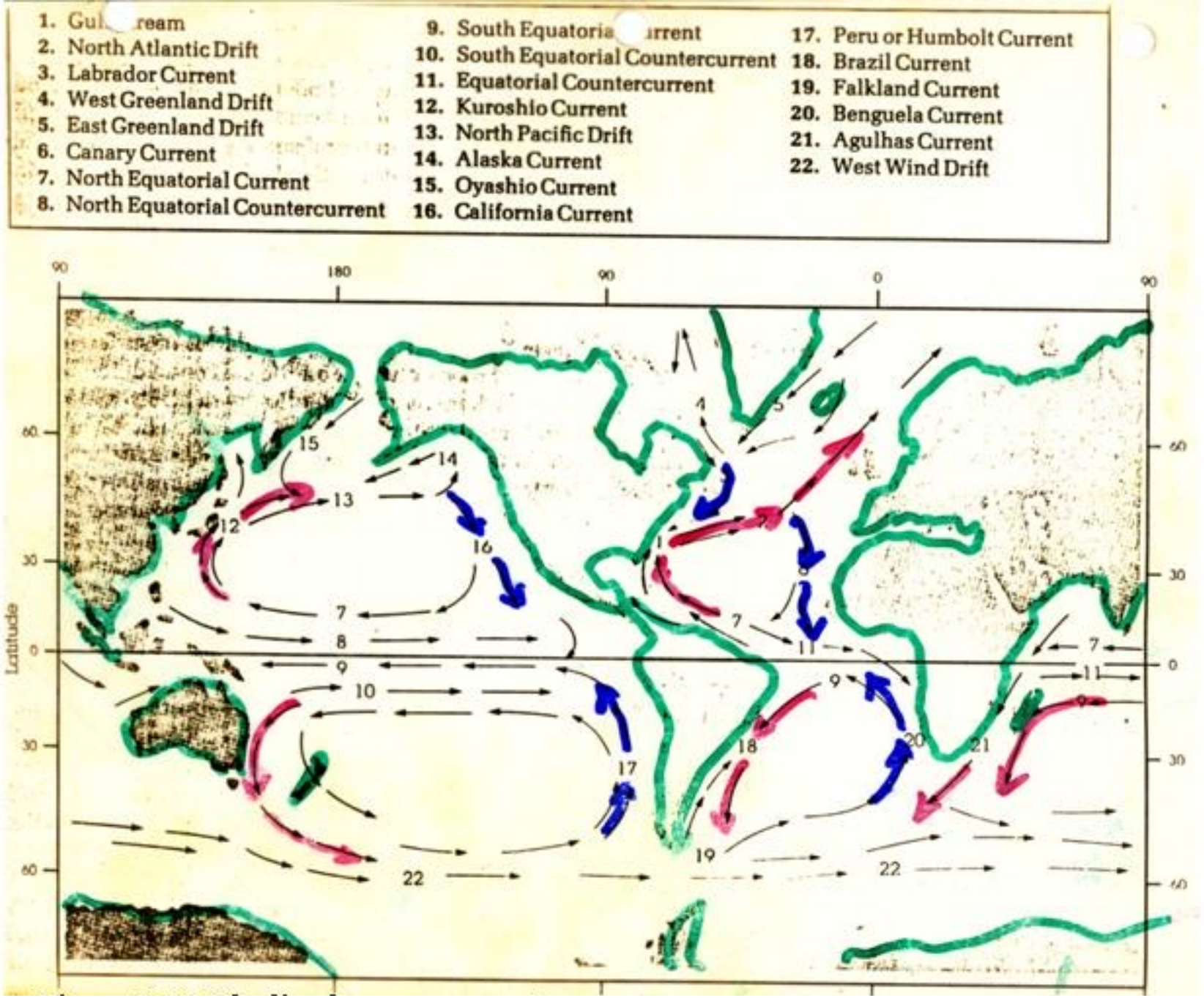


Figure 3.12 Idealized ocean currents [Ahrens].

Summary of primary aspects of the atmospheric general circulation

The features of the general circulation can be built up from a few basic principles:

1) Differential heating leads to differences in density, with light air rising, and cool air sinking.
2) Molecules will diverge out of warm, expanded air columns onto cold, contracted air columns, causing higher surface pressure under cold air and lower surface pressure under warm air.
3) Monsoons circulations arise due to continental-scale heating differences, with rising over hot land in the summer and sinking over the cold land in winter.
4) Rising motion creates clouds and rain, while sinking motion creates clear air.
5) In the tropics air flows from high to low pressure (the Walker Circulation).
6) In the extratropics, the Coriolis effect causes air to curve to the right in the NH and to the left in the SH.
   In the NH this causes counterclockwise flow into a low and clockwise flow out of a high.
7) Midlatitude westerlies and subtropical easterlies are a consequence of angular momentum transport in the Hadley circulation.
8) These chronic winds drive currents which close into gyres due to the presence of continents.
9) Over the cool eastern subtropical oceans, high pressure systems cause equatorward (along-shore) flow along the west coasts of continents. This leads to offshore Ekman transport and upwelling of nutrient-rich cold water from below.

Next Topic:
the thermohaline circulation

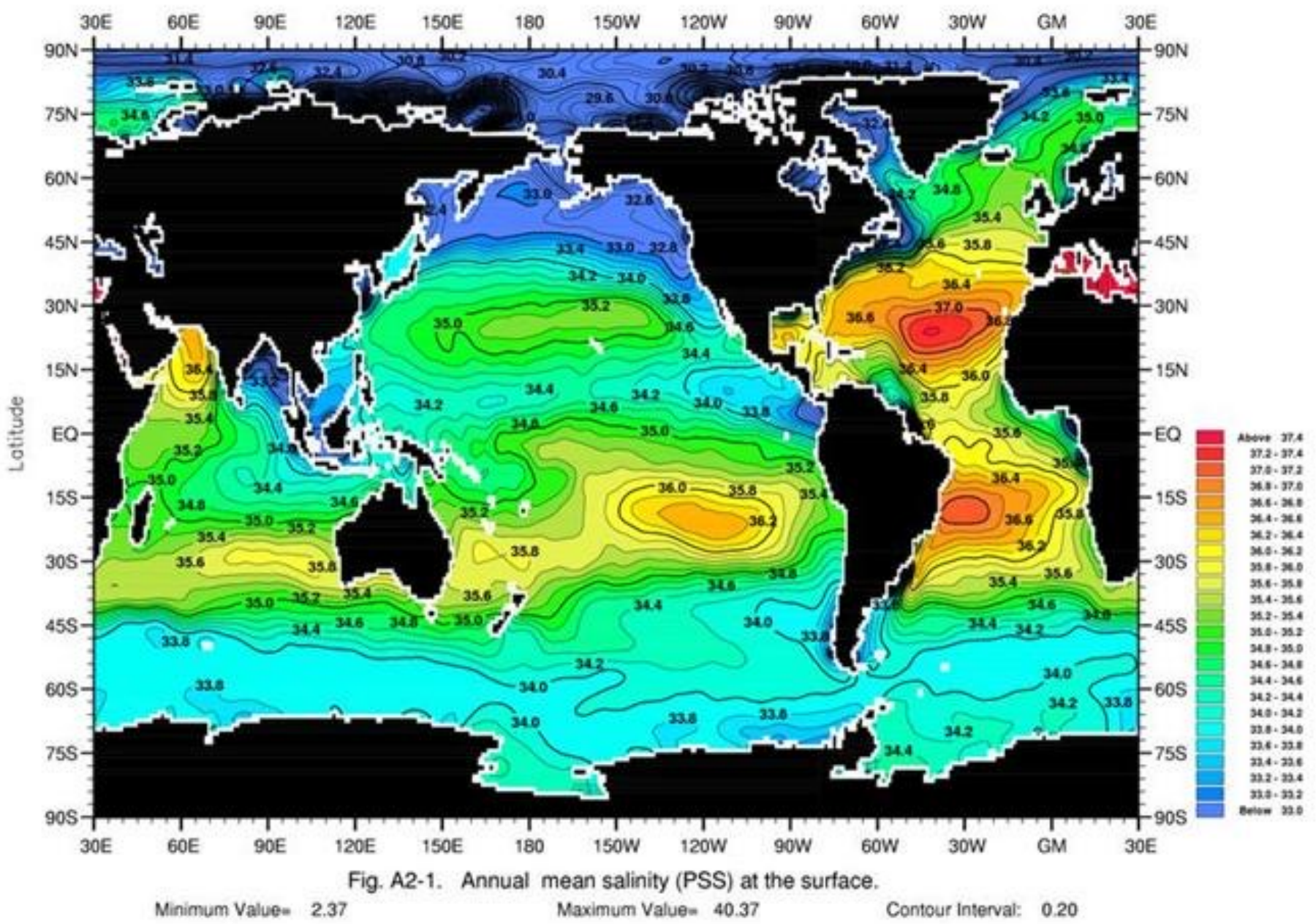


Fig. A2-1. Annual mean salinity (PSS) at the surface.

Minimum Value= 2.37 Maximum Value= 40.37 Contour Interval: 0.20

Figure 3.14. Average surface salinity during August, contour interval 0.2 ppt [World Ocean Atlas 2001].