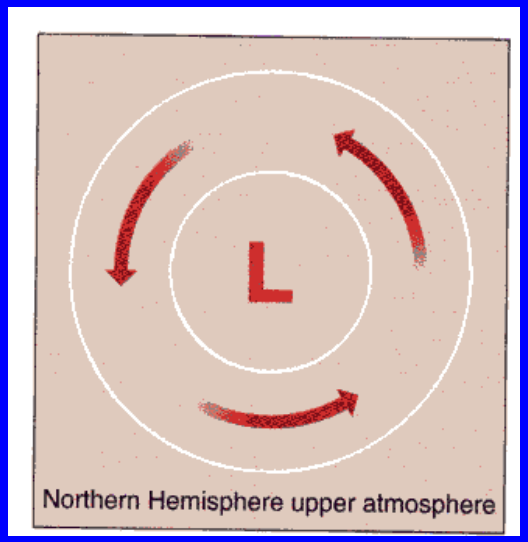
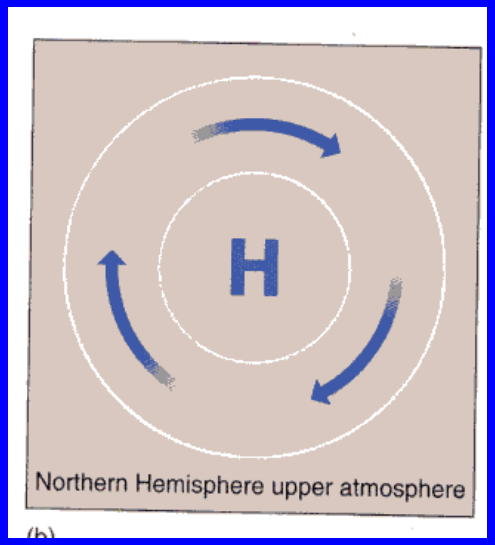
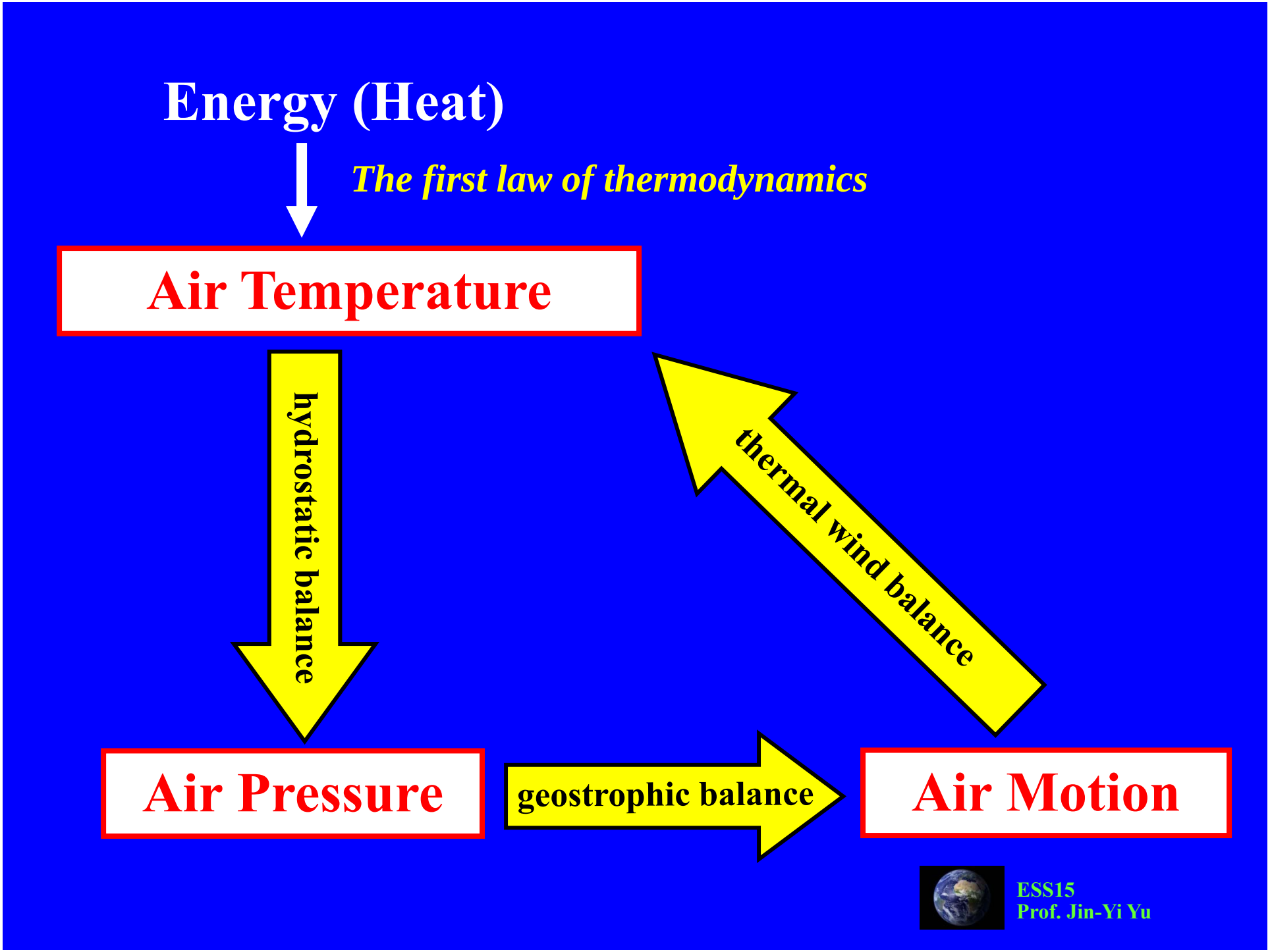
# *Lecture 8: Pressure and Wind*




- Pressure Distribution
- Forces Affect Wind
- Earth's Rotation → Coriolis Force
- Geostrophic Balance


Energy (Heat)
The first law of thermodynamics
Air Temperature
hydrostatic balance
thermal wind balance
Air Pressure
geostrophic balance
Air Motion
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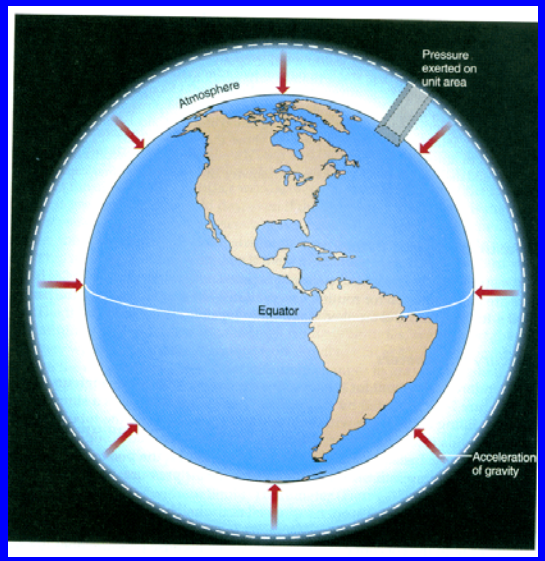
# Thermal Energy to Kinetic Energy




Pole

Eq

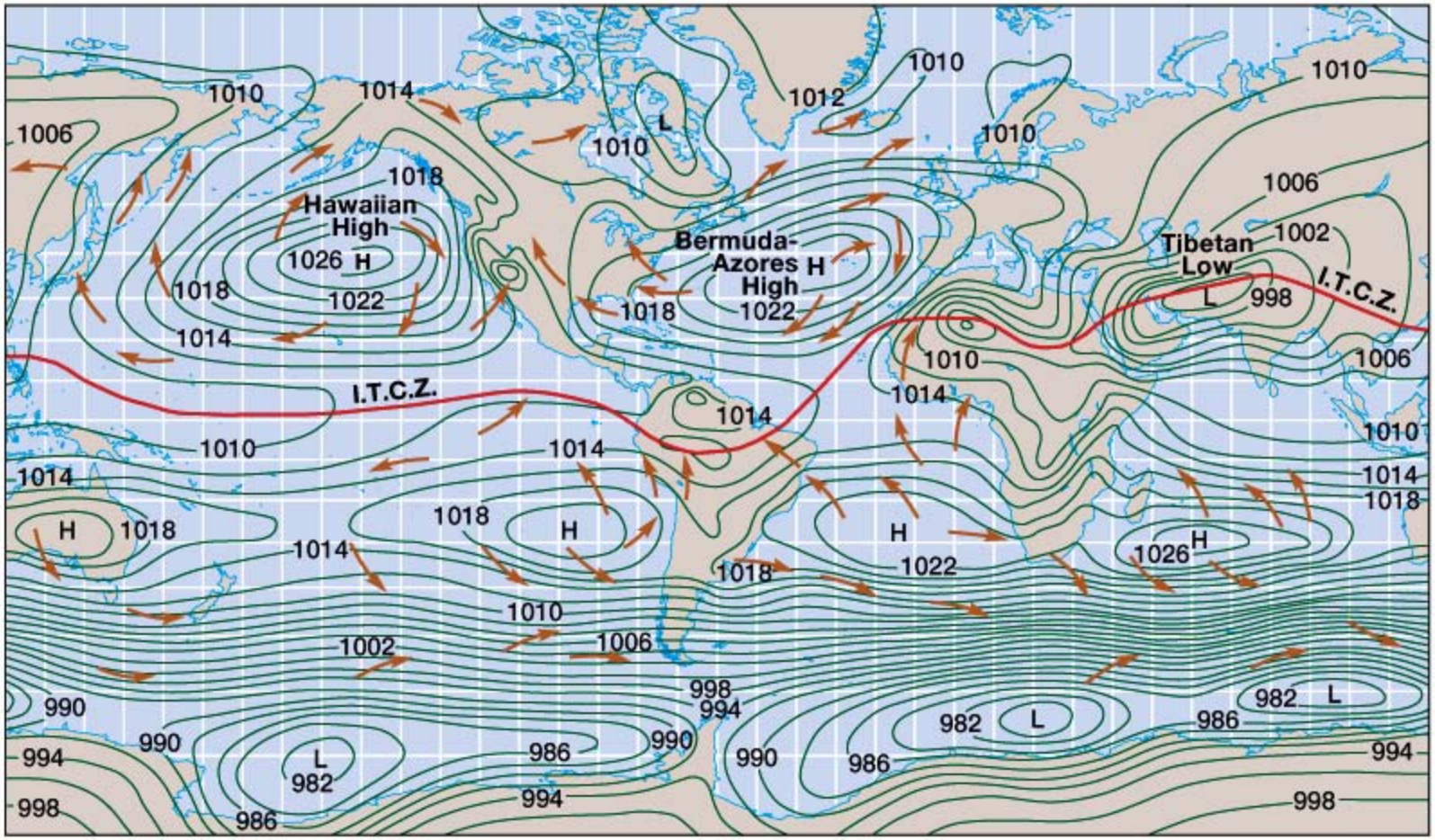
| | |
|---|---|
| cold | H (high pressure) |
| | pressure gradient force |
| warm | L (low pressure) |

(on a horizontal surface)

# Semi-Permanent Pressure Cells

- **The Aleutian, Icelandic, and Tibetan lows**
  - The oceanic (continental) lows achieve maximum strength during winter (summer) months
  - The summertime Tibetan low is important to the east-Asia monsoon
- **Siberian, Hawaiian, and Bermuda-Azores highs**
  - The oceanic (continental) highs achieve maximum strength during summer (winter) months

# Sea Level Pressure (July)

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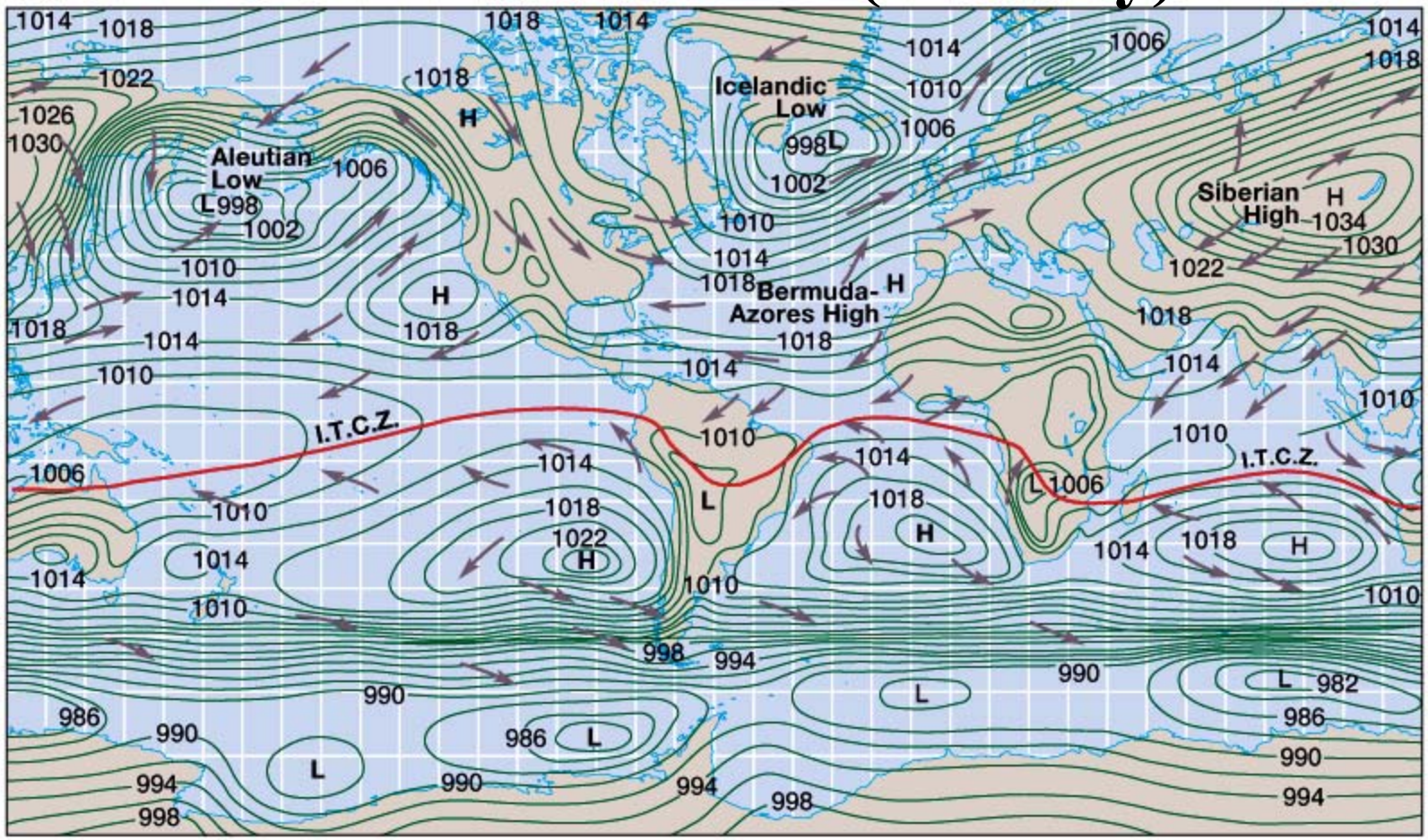
# Sea Level Pressure (January)

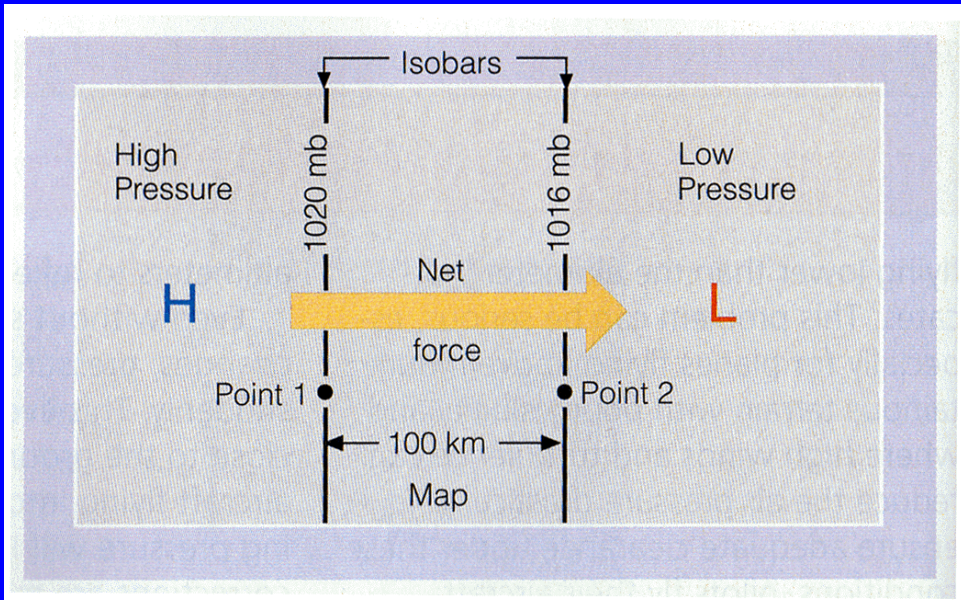


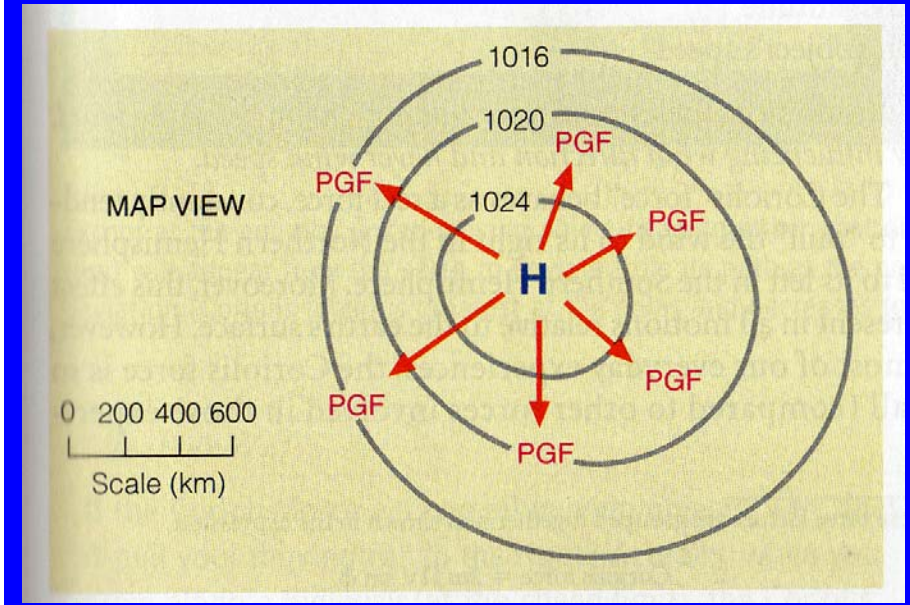
***Wind is moving air.***

# Force that Determines Wind

- Pressure gradient force
- Coriolis force
- Friction
- Centrifugal force

# Pressure Gradient Force

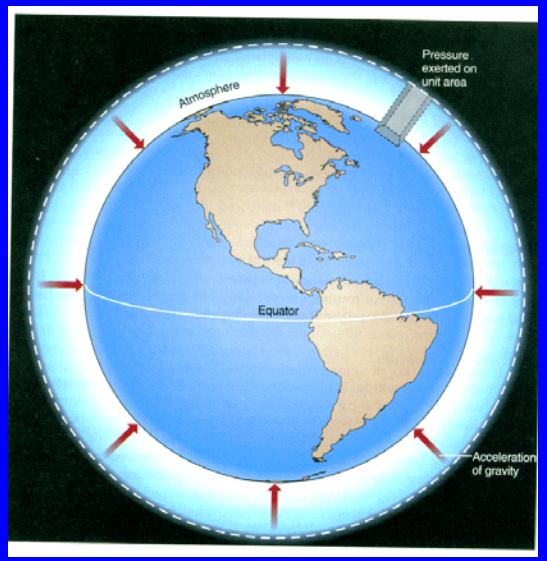



**(from Meteorology Today)**

- PG = (pressure difference) / distance
- Pressure gradient force goes from high pressure to low pressure.
- Closely spaced isobars on a weather map indicate steep pressure gradient.

# Thermal Energy to Kinetic Energy




Pole

Eq

**cold**

**warm**

**H** (high pressure)

pressure gradient force

**L** (low pressure)

(on a horizontal surface)

# Balance of Force in the Horizontal

H (high pressure)

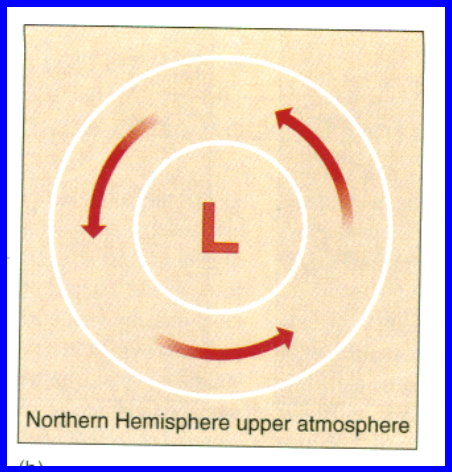
pressure gradient force

L (low pressure)

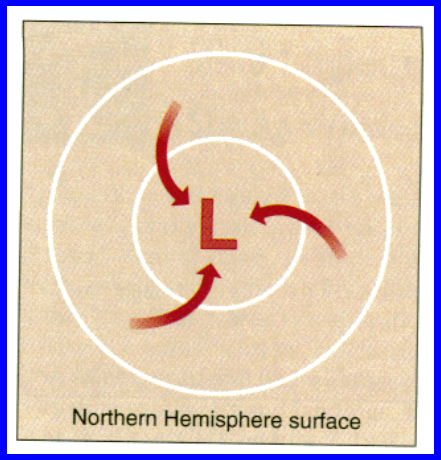
Can happen in the tropics where the Coriolis force is small.

geostrophic balance

geostrophic balance plus frictional force




Upper Troposphere (free atmosphere)



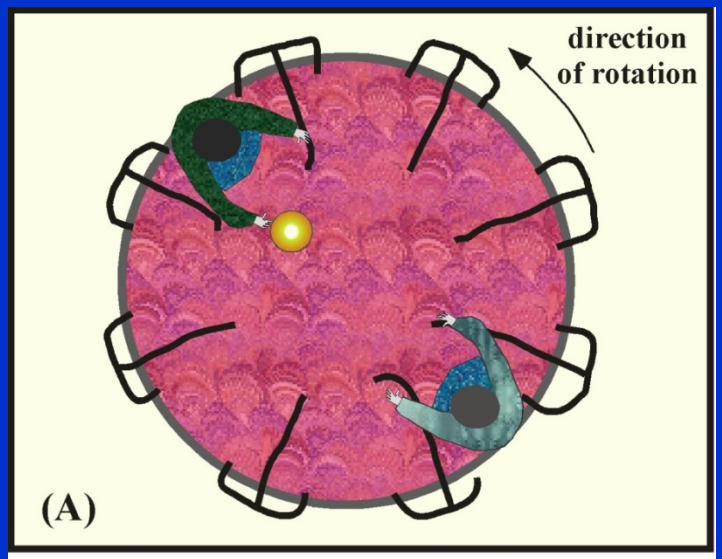

Surface

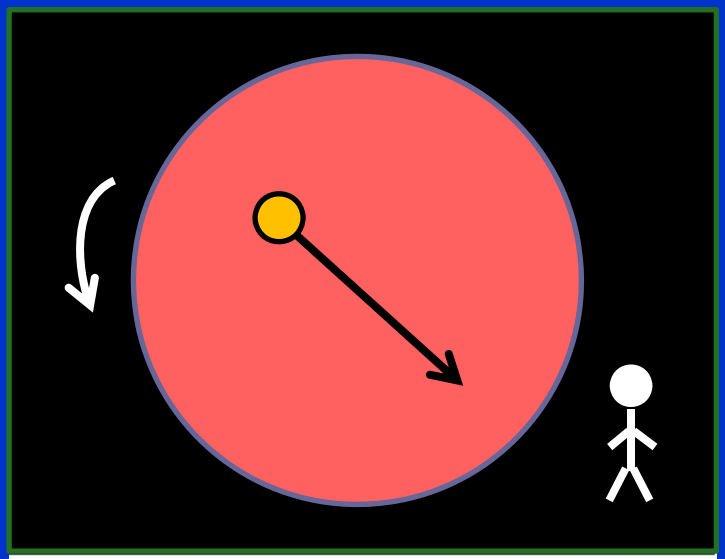
(from *Weather & Climate*)

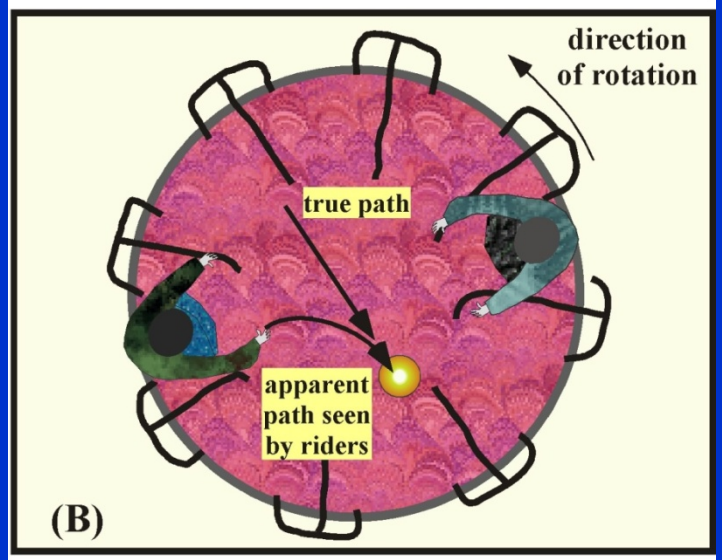
# Force that Determines Wind

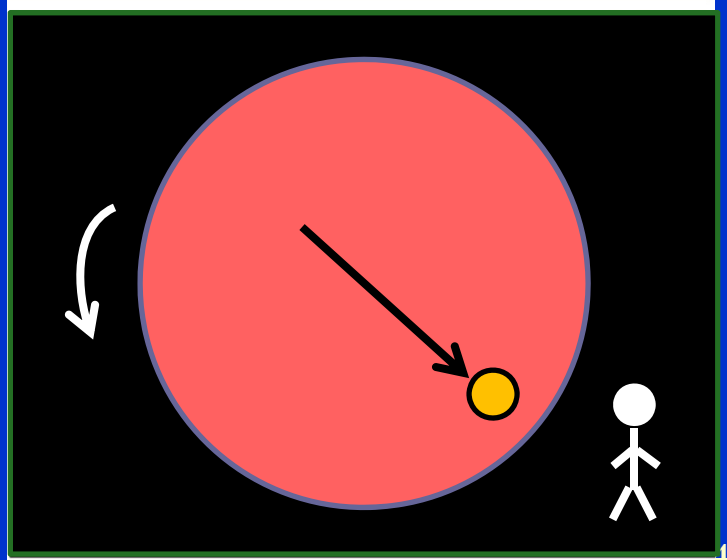
- Pressure gradient force
- **Coriolis force**
- Friction
- Centrifugal force

# Example on a Merry-Go-Around

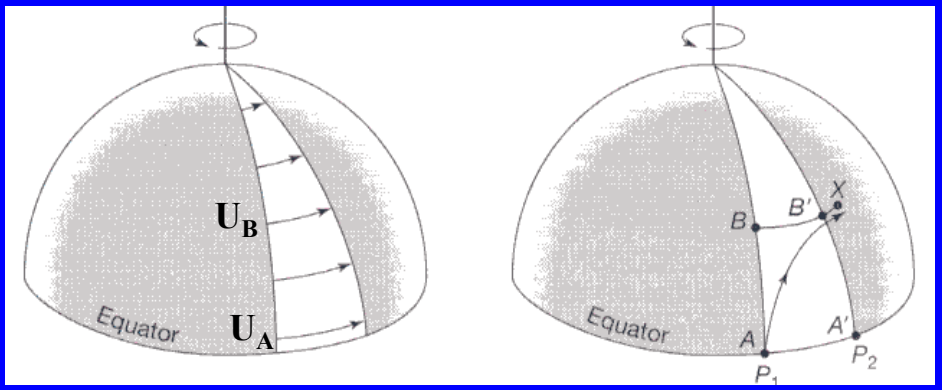




# Coriolis Force




(from *The Earth System*)

- First, Point A rotates faster than Point B ($U_A > U_B$)

➔ $U_A > U_B$

➔ A northward motion starting at A will arrive to the east of B

➔ It looks like there is a "force" pushing the northward motion toward right

➔ This apparent force is called "Coriolis force":

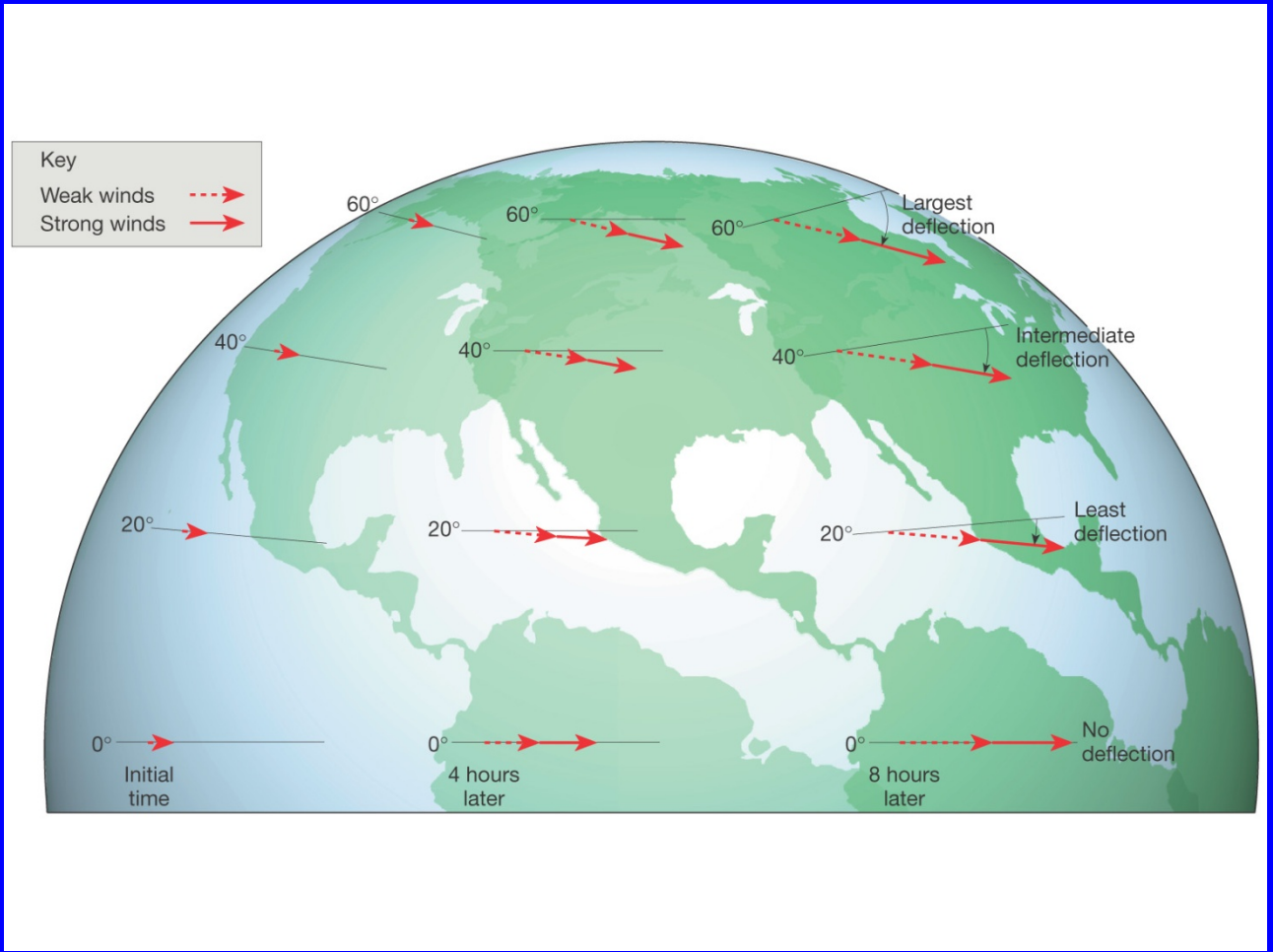
**Coriolis Force = $f\,V$**

**where $f = 2*\Omega*\mathrm{Sin(lat)}$ and $\Omega = 7.292 \times 10^{-5}$ rad $s^{-1}$**

# Coriolis Force

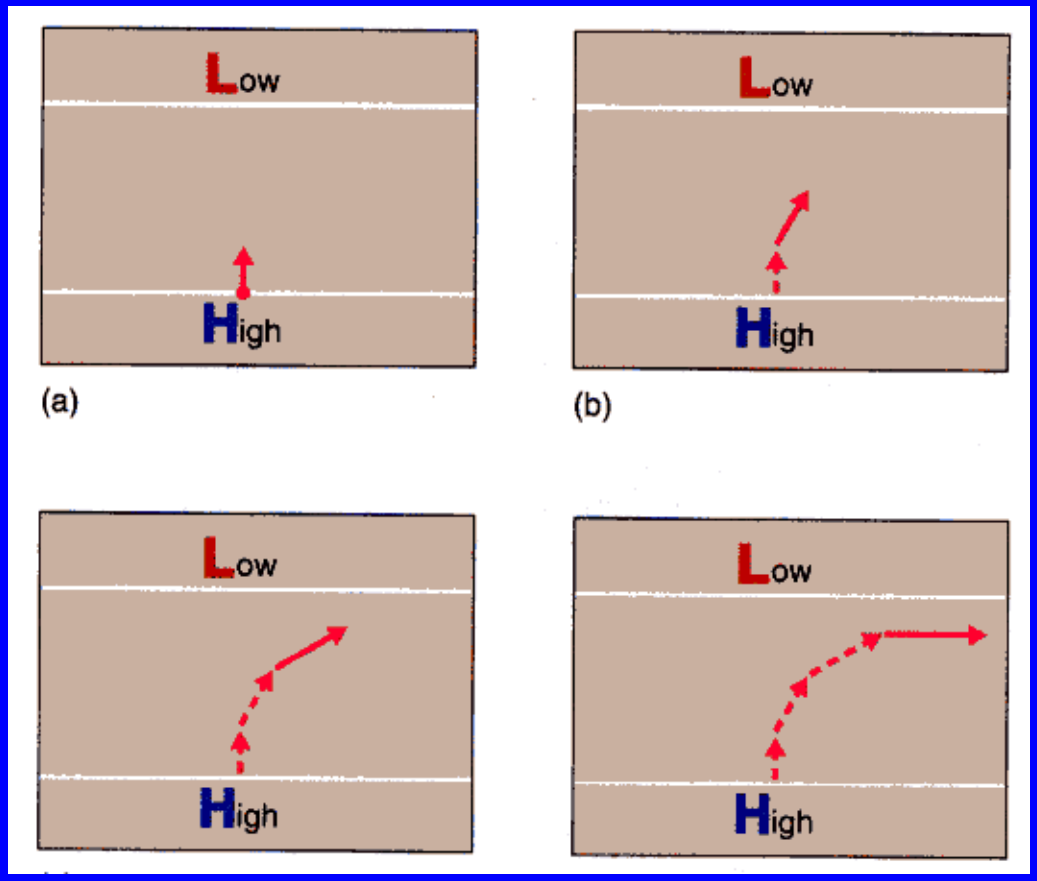
- Coriolis force causes the wind to deflect to the right of its intent path in the Northern Hemisphere and to the left in the Southern Hemisphere.
- The magnitude of Coriolis force depends on (1) the rotation of the Earth, (2) the speed of the moving object, and (3) its latitudinal location.
- The stronger the speed (such as wind speed), the stronger the Coriolis force.
- The higher the latitude, the stronger the Coriolis force.
- The Corioils force is zero at the equator.
- Coriolis force is one major factor that determine weather pattern.

# Coriolis Force Change with latitudes



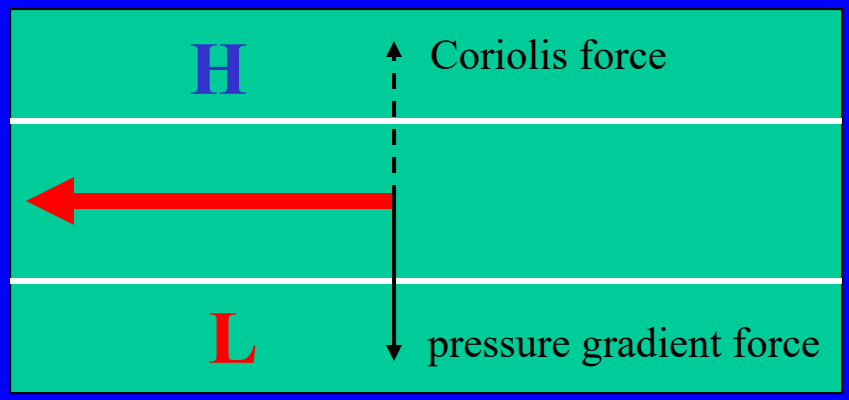

(from *The Atmosphere*)

# How Does Coriolis Force Affect Wind Motion?




(from *Weather & Climate*)

# Geostrophic Balance




- By doing scale analysis, it has been shown that large-scale and synoptic-scale weather system are in geostropic balance.
- Geostrophic winds always follow the constant pressure lines (isobar). Therefore, we can figure out flow motion by looking at the pressure distribution.

# Force that Determines Wind

- Pressure gradient force
- Coriolis force
- **Friction**
- Centrifugal force

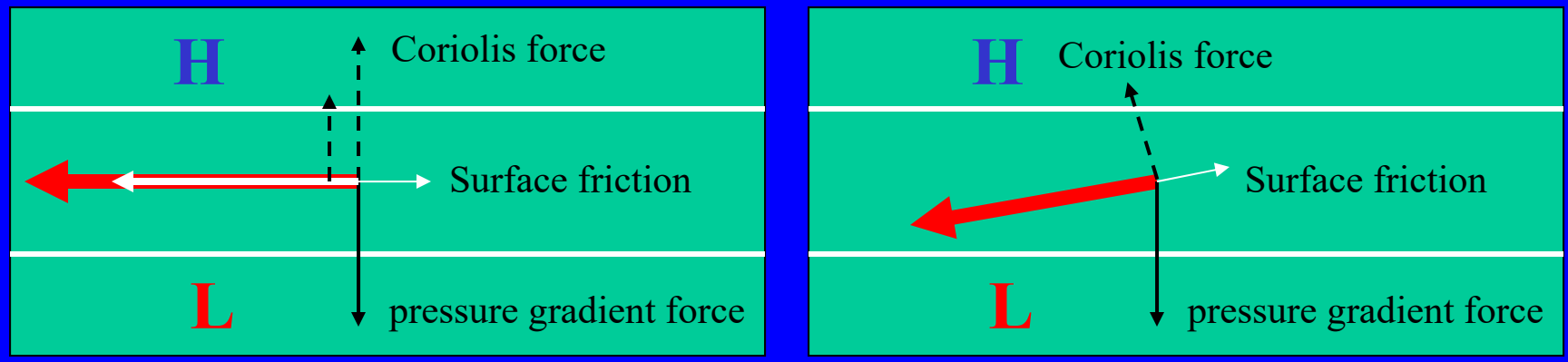
# Surface Friction

- Friction Force = c * V

  c = friction coefficient

  V = wind speed

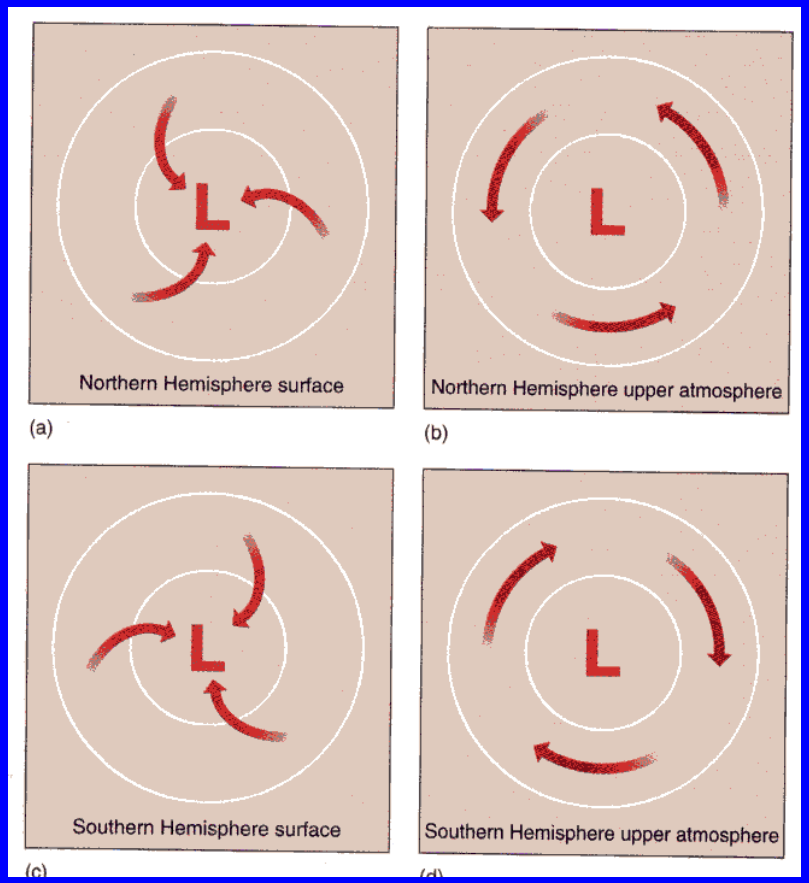
# Frictional Effect on Surface Flow



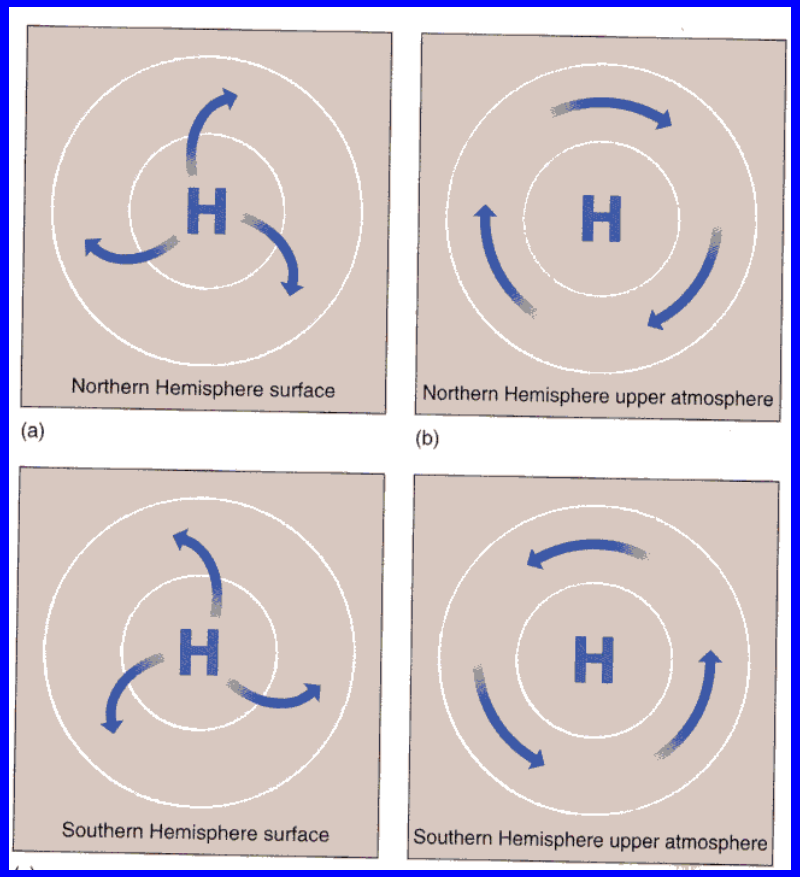

- Surface friction force slows down the geostrophic flow.
- The flow turns into (out of) the low (high) press sides.
- Convergence (divergence) is produced with the flow.

# Surface Geostrophic Flow

## Cyclonic Flow




## Anticyclonic Flow




(figures from *Weather & Climate*)

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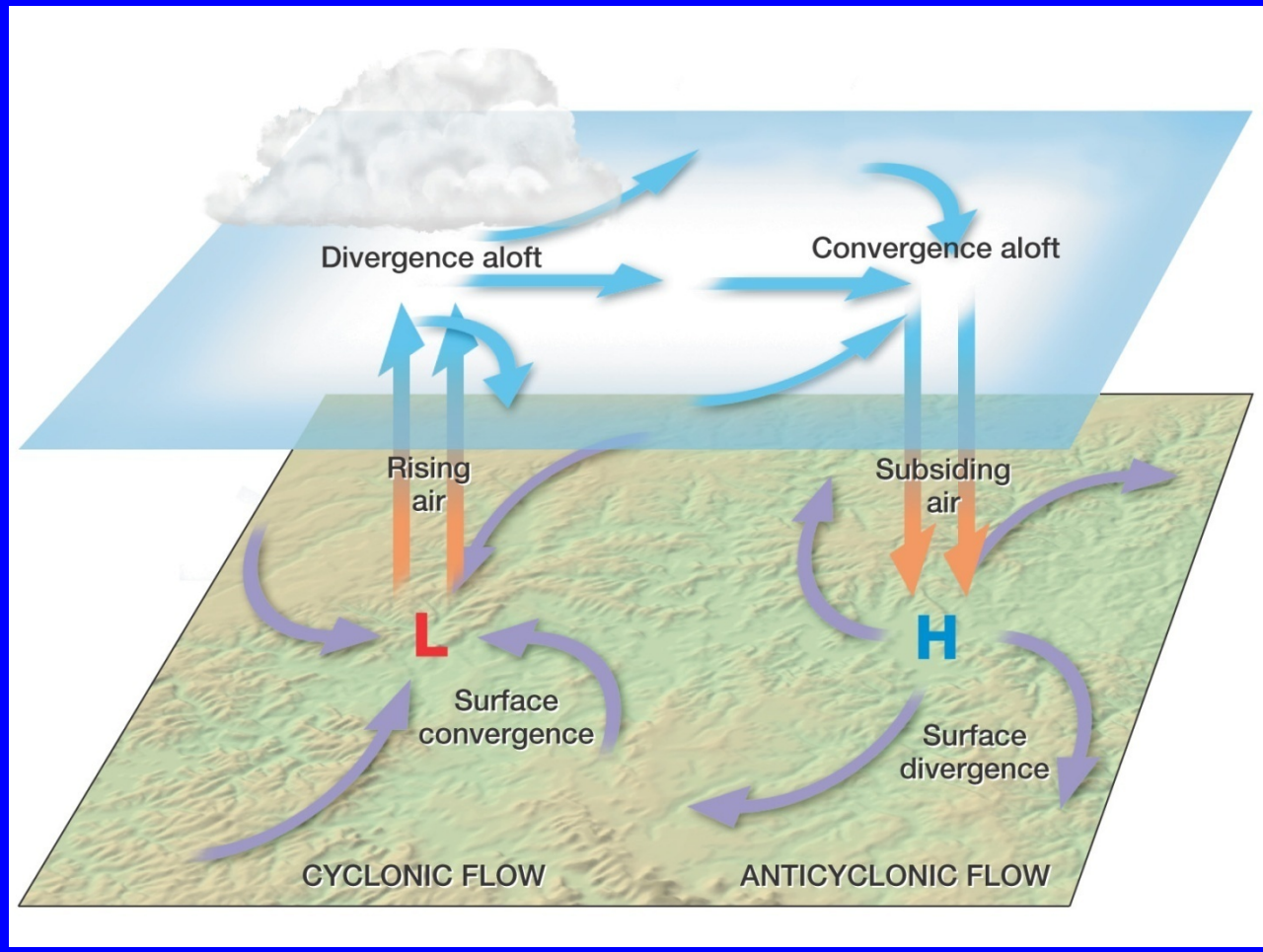
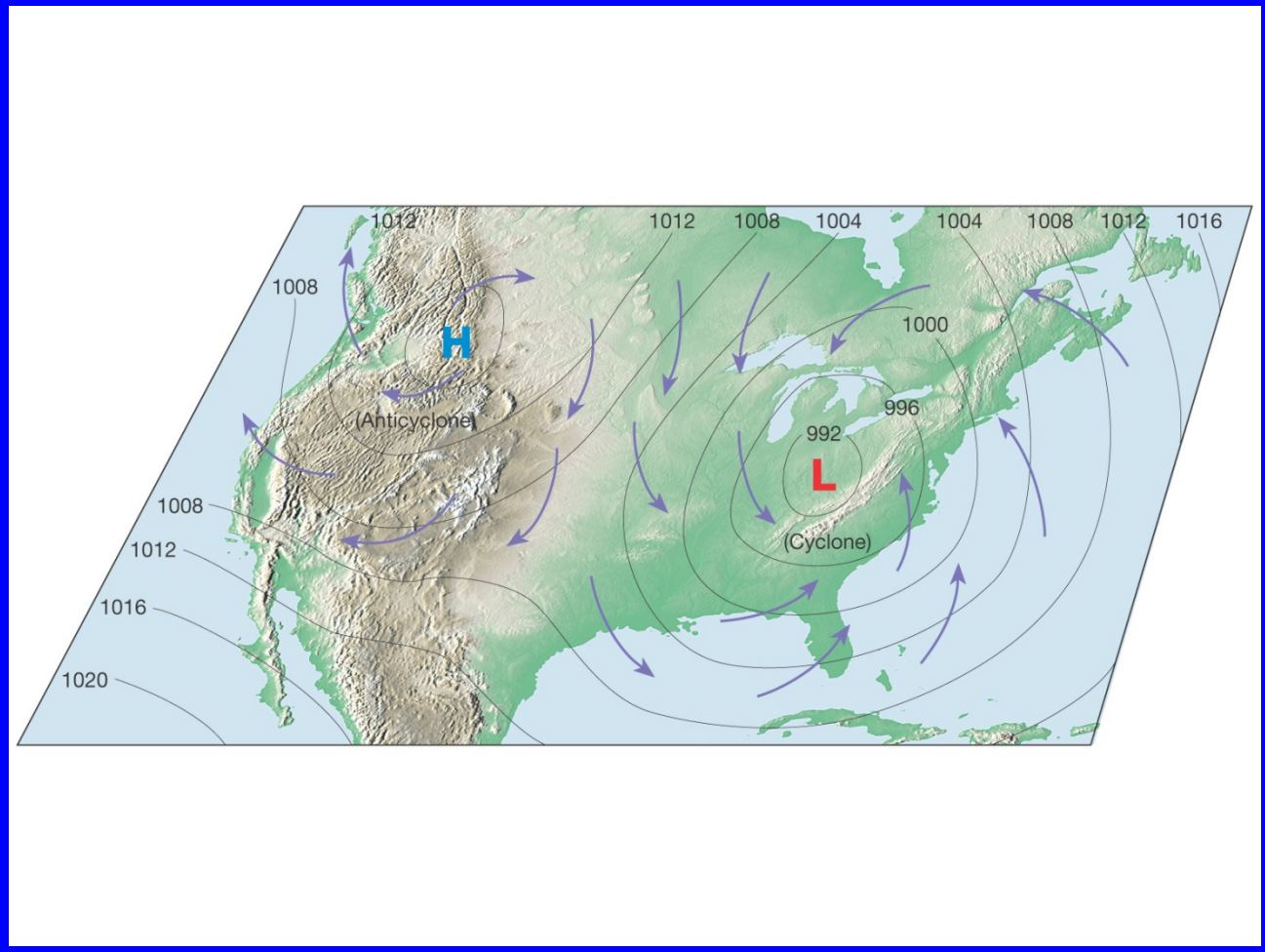



(from *The Atmosphere)*

# Surface High and Low Pressure Systems

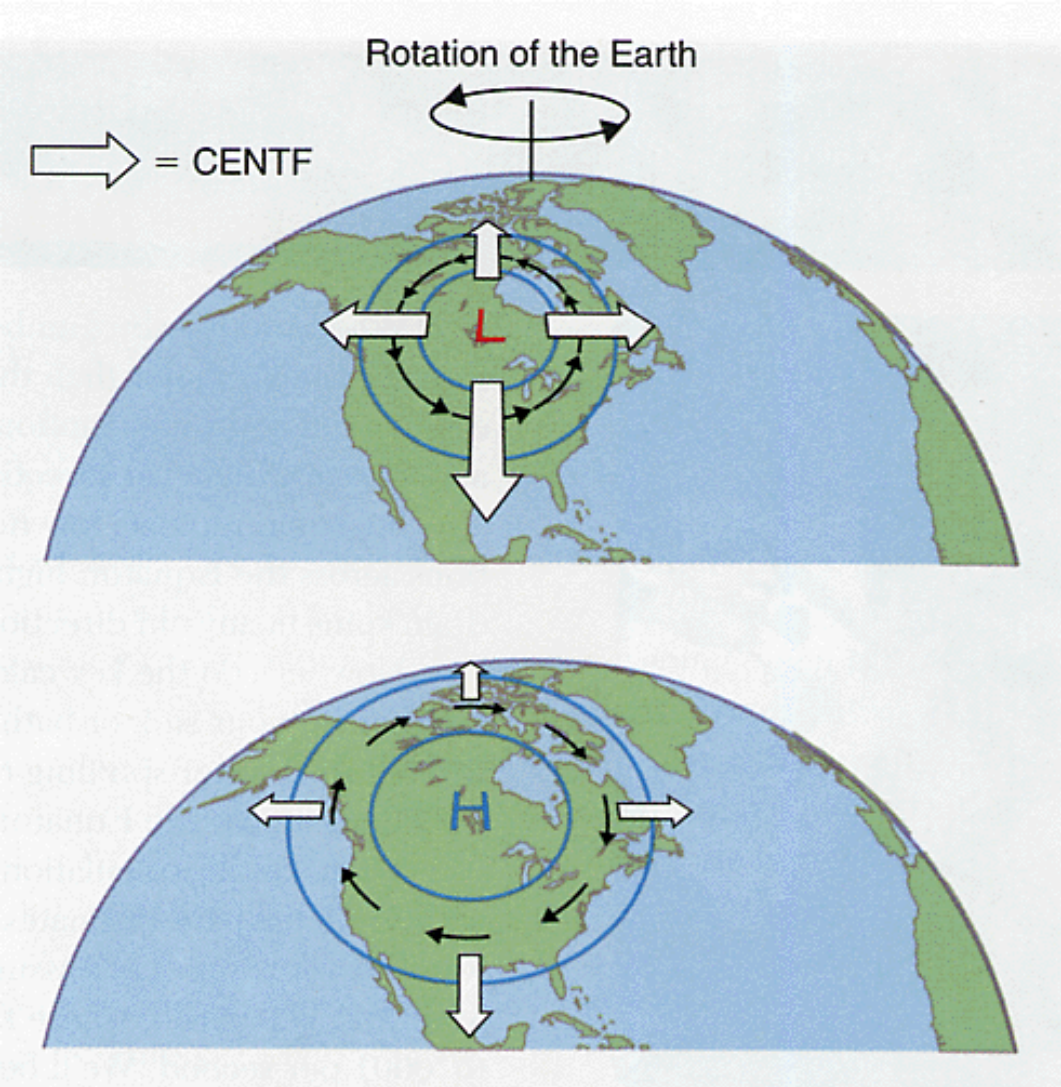



**(from *The Atmosphere*)**

# Force that Determines Wind

- Pressure gradient force
- Coriolis force
- Friction
- **Centrifugal force**

# Centrifugal Force




(from *The Atmosphere*)

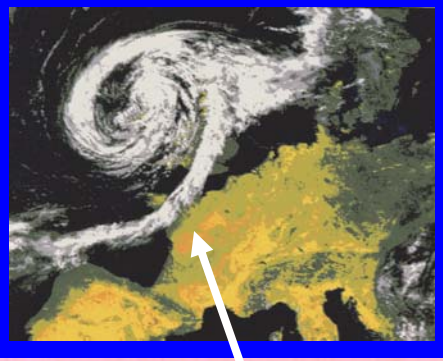
- The force that change the direction (but not the speed) of motion is called the centrifugal force.

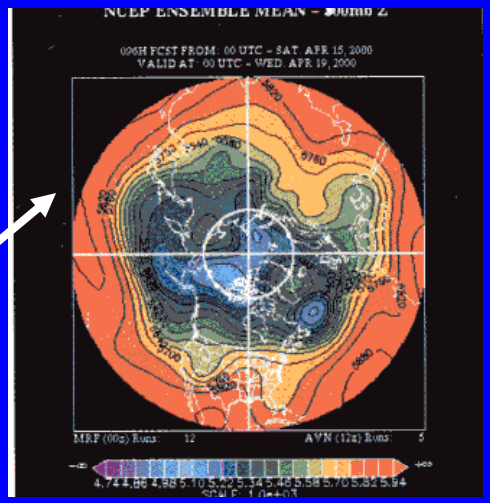
- Centrifugal Force = $V^2$ / R.

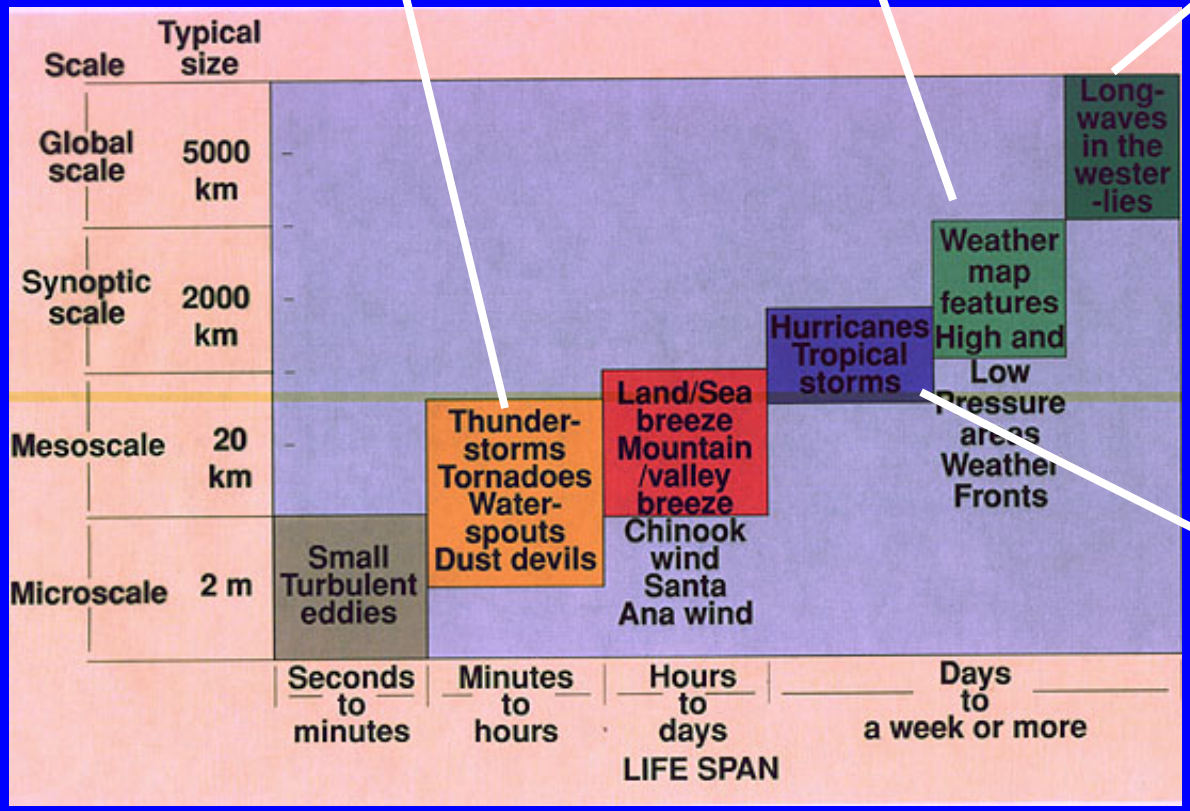
V = wind speed

R = the radius of the curvature

# Scales of Motions in the Atmosphere






*(from Meteorology Today by C. Donald Ahrens © 1994 West Publishing Company)*

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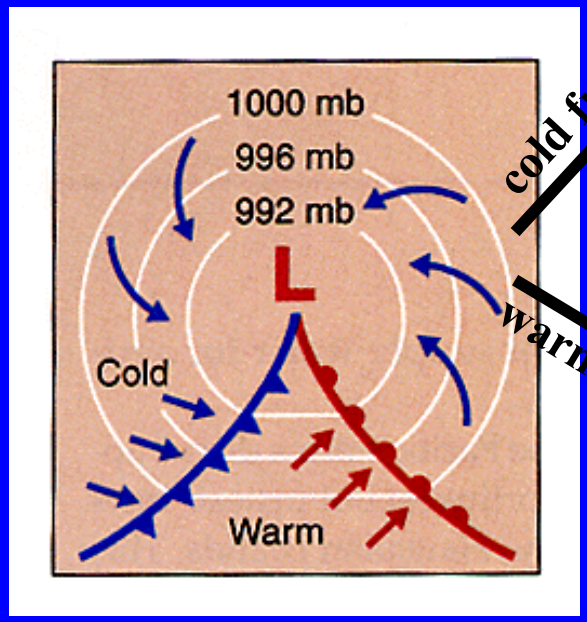
# Cold and Warm Fronts

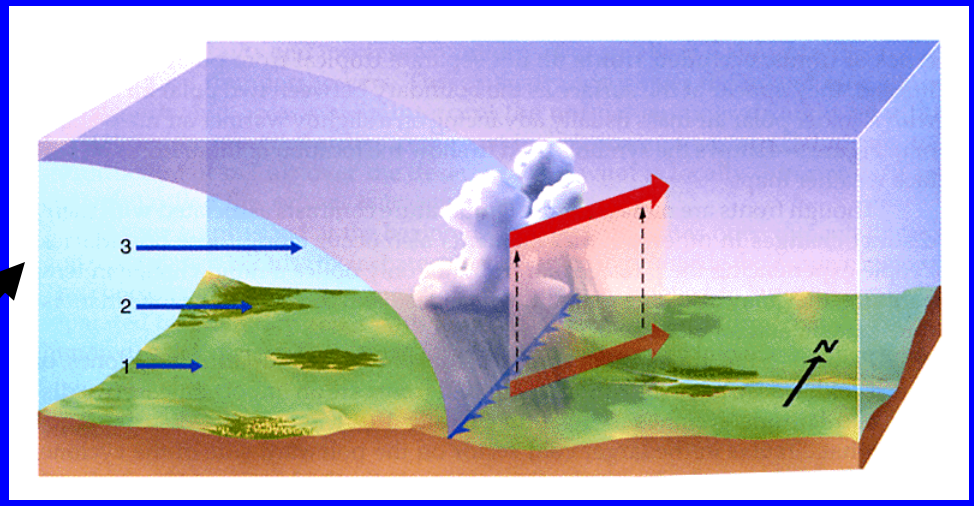
Mid-Latitude Cyclone

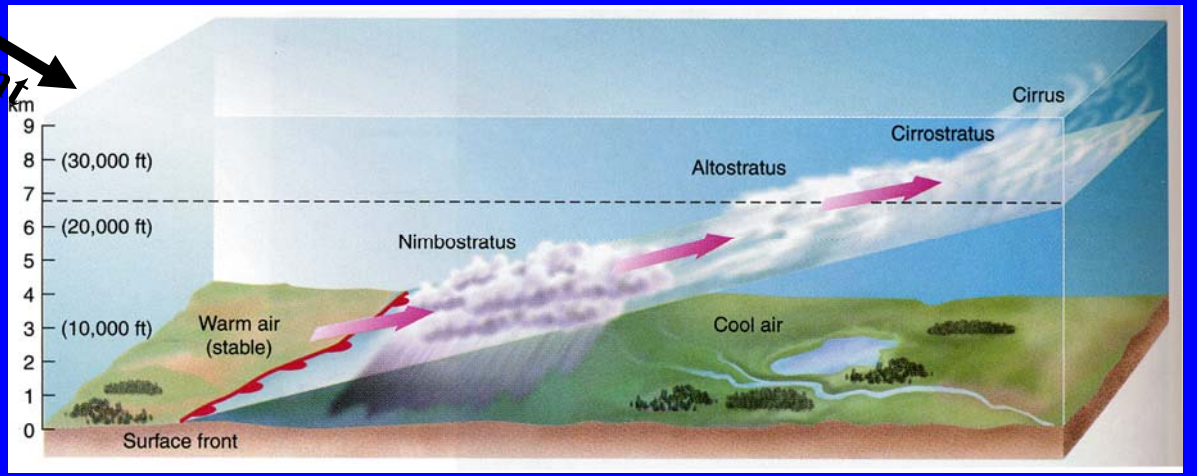



(From *Weather & Climate*)

cold front

warm front

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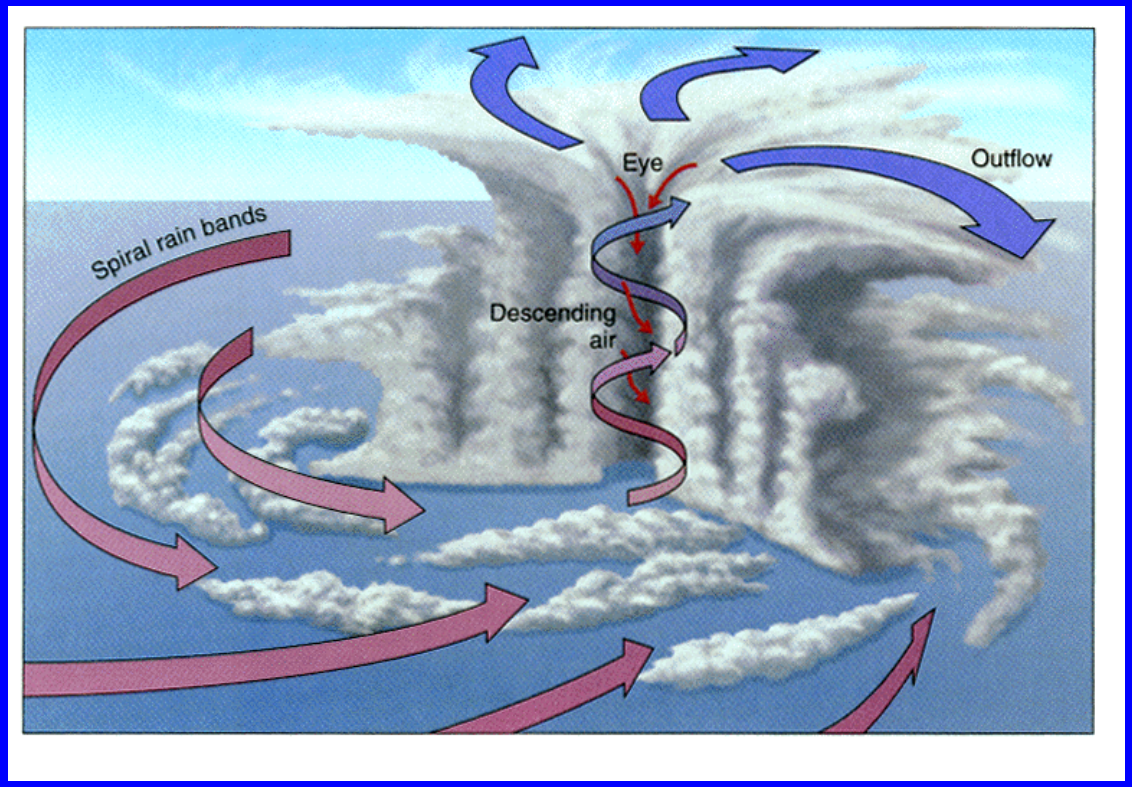
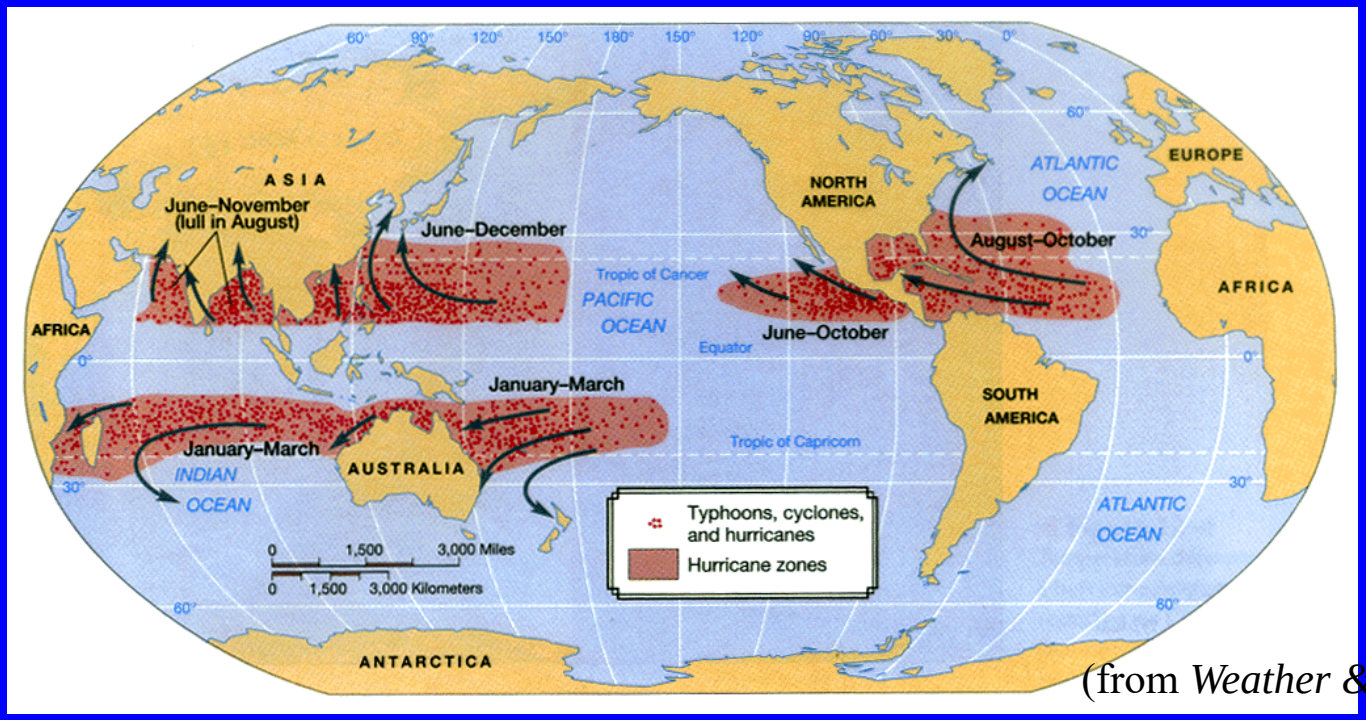
# Tropical Hurricane




(from Understanding *Weather & Climate*)

- The hurricane is characterized by a strong thermally direct circulation with the rising of warm air near the center of the storm and the sinking of cooler air outside.

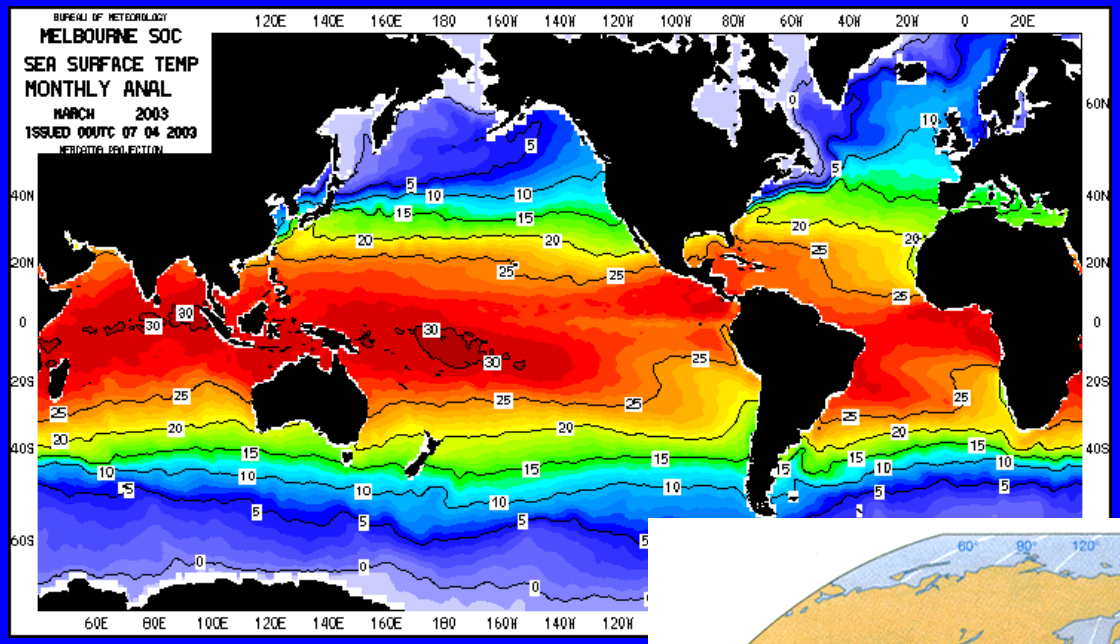
# Naming Convention



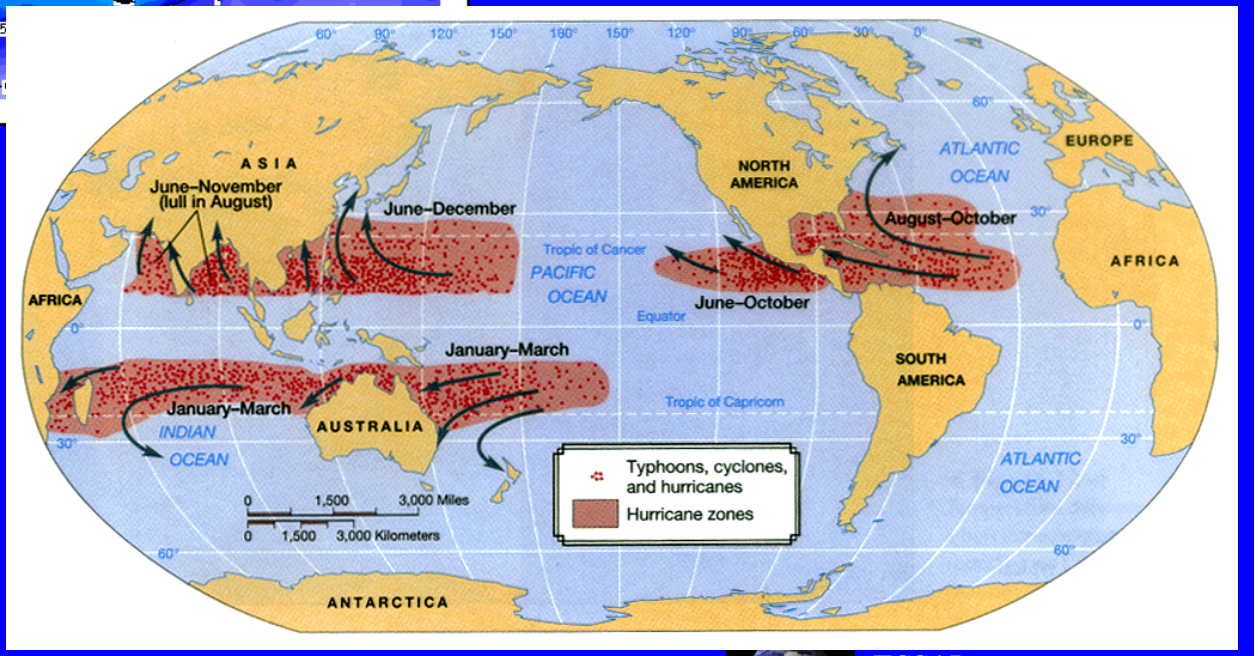

(from *Weather & Climate*)

- ***Hurricanes:*** extreme tropical storms over Atlantic and eastern Pacific Oceans.
- ***Typhoons:*** extreme tropical storms over western Pacific Ocean.
- ***Cyclones:*** extreme tropical storms over Indian Ocean and Australia.

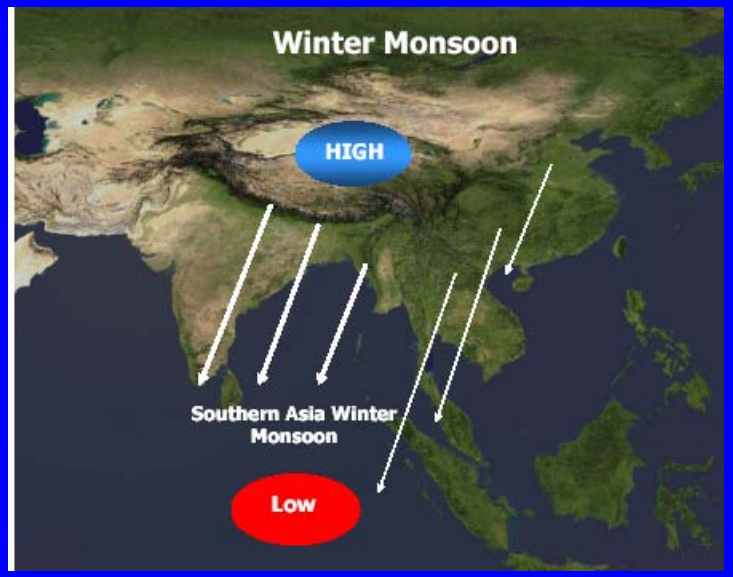
# Ocean Temperature And Hurricane



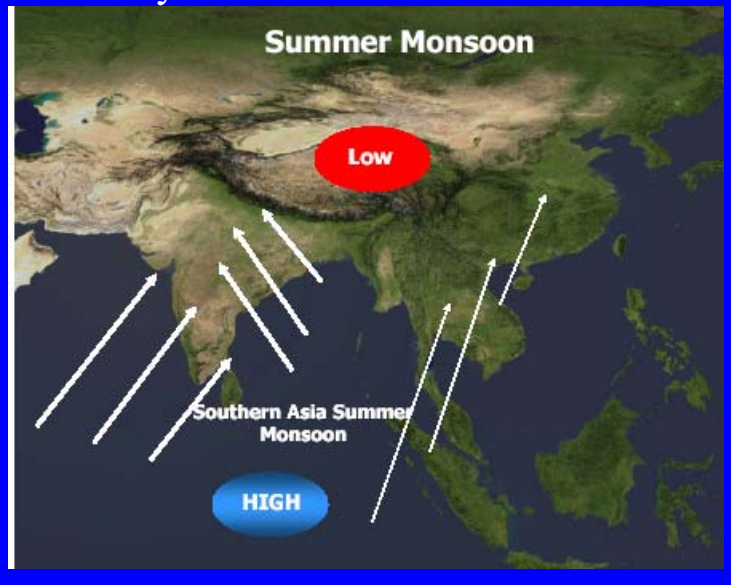

- Hurricanes form over large pools of warm water.



# *Monsoon:* Sea/Land-Related Circulation




Courtesy of Kevin G. Cannariato

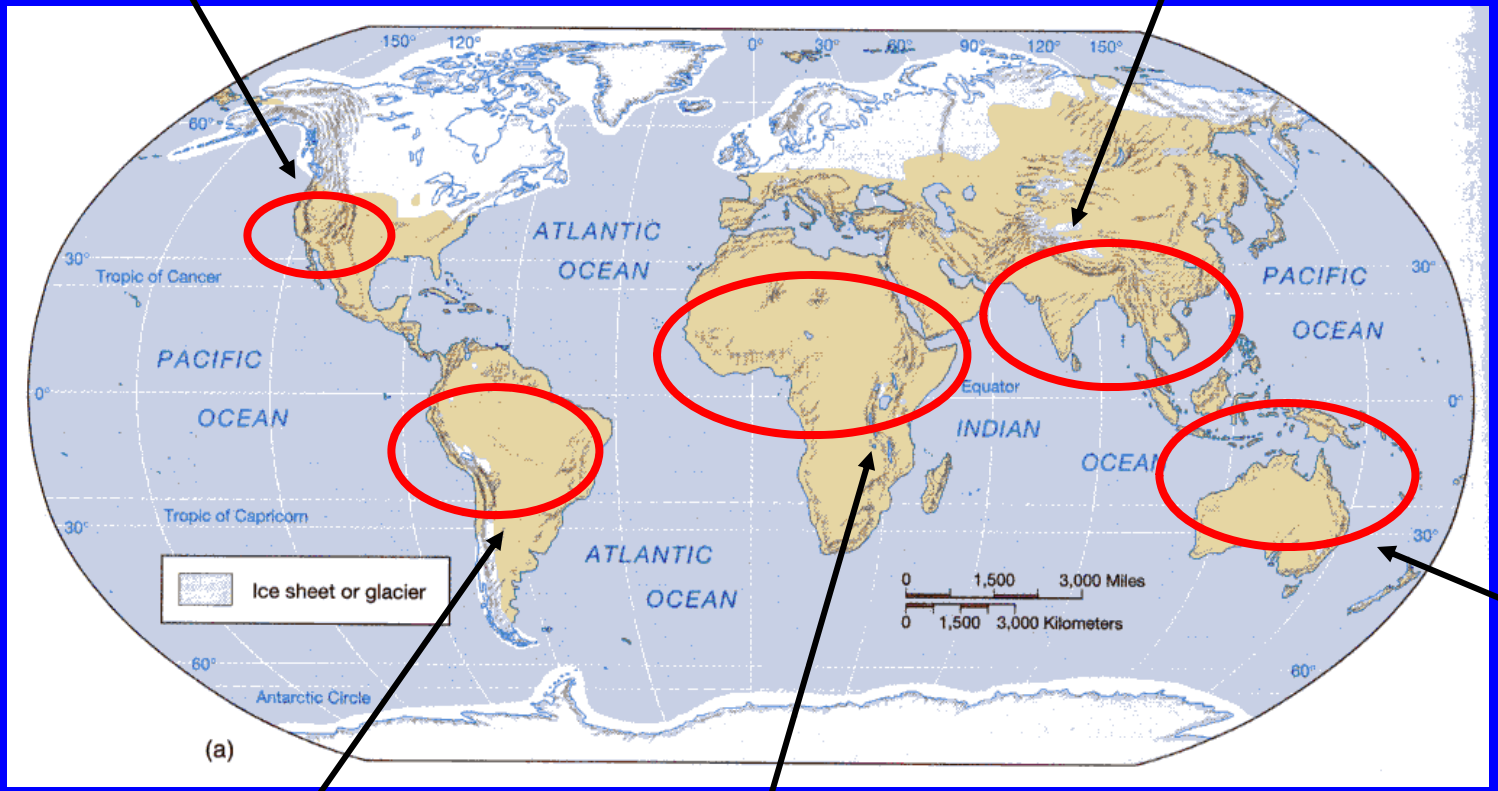



- Monsoon (Arabic "season")
- Monsoon is a climate feature that is characterized by the ***seasonal reversal in surface winds***.
- The very different heat capacity of land and ocean surface is the key mechanism that produces monsoons.
- During summer seasons, land surface heats up faster than the ocean. Low pressure center is established over land while high pressure center is established over oceans. Winds blow from ocean to land and bring large amounts of water vapor to produce heavy precipitation over land: A rainy season.
- During winters, land surface cools down fast and sets up a high pressure center. Winds blow from land to ocean: a dry season.

# How Many Monsoons Worldwide?

North America Monsoon

Asian Monsoon




Australian Monsoon

South America Monsoon

Africa Monsoon

(figure from *Weather & Climate*)

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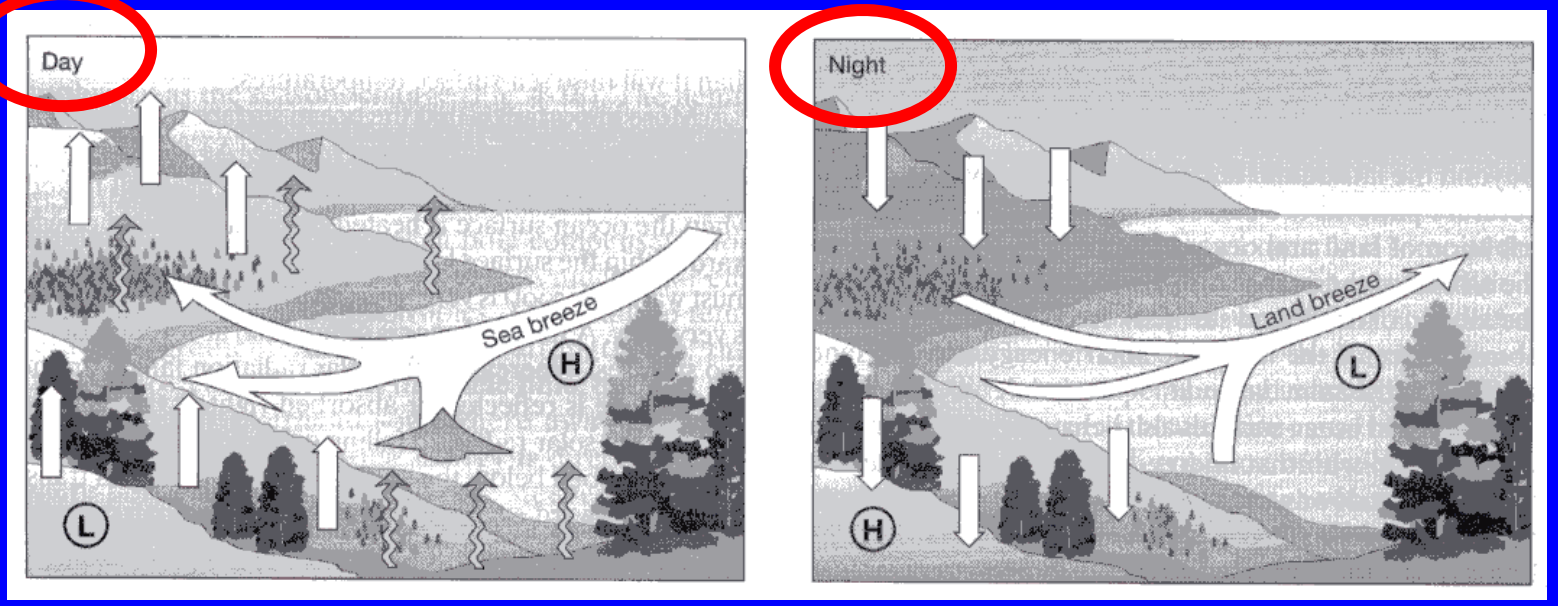
# Sea/Land Breeze




- Sea/land breeze is also produced by the different heat capacity of land and ocean surface, similar to the monsoon phenomenon.
- However, sea/land breeze has much shorter timescale (day and night) and space scale (a costal phenomenon) than monsoon (a seasonal and continental-scale phenomenon).

(figure from *The Earth System*)

# Santa Ana Wind

This is a picture of Fremont Canyon, located in the Santa Ana Mountains in Orange County. This canyon is known for its extremely high winds during Santa Ana wind events, where the winds can gust over 100 MPH during very strong Santa Ana wind events (picture from the Orange County Register).

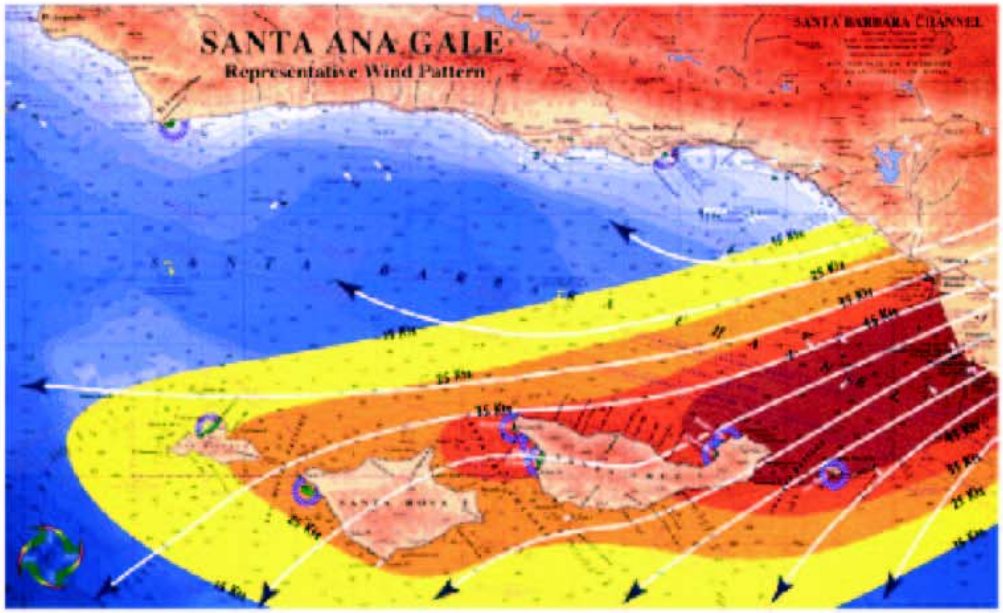
## DEFINITION

**Strong warm and dry winds blow over the southern California from the Great Basin, with speeds exceed 25 knots (46 km/hr).**

# Generation Mechanism


(from NASA's Observatorium website)

# Santa Ana Wind




Santa Ana Guide ©1999 Channel Crossings Press

Santa Ana winds on February 9, 2002
NASA MISR observation

# Diurnal and Seasonal Variations

**Diurnal variation:**

Stronger Santa Ana wind at night and weaker Santa Ana wind on the day.

**Seasonal Variation:**

Occurs most frequently in winter (November to March).