Chapter 7: Circulation And The Atmosphere

Highly integrated wind system

Main Circulation Currents: series of deep rivers of air encircling the planet

Various perturbations or vortices (hurricanes, tornados, cyclones)

Scales of Atmospheric Motion:

-based on time and space

-**Macorscale**: encompass global wind patterns (westerlies, trades) through hurricanes (hours on up)

-**Mesoscale**: Tornados, thunder storms, local winds (minutes-hours)

-**Microscale**: wind gusts, dust devils (seconds – minutes)

TABLE 7-1 Time and space scales for atmospheric motions

Scale	Time Scale	Distance Scale	Examples
Macroscale			
Planetary	Weeks or longer	1000–40,000 km	Westerlies and trade winds
Synoptic	Days to weeks	100–5000 km	Midlatitude cyclones, anticyclones, and hurricanes
Mesoscale	Minutes to hours	1–100 km	Thunderstorms, tornadoes, and land–sea breeze
Microscale	Seconds to minutes	6 1 km	Turbulence, dust devils, and gusts

Macorscale

Planetary-scale: global winds stable for weeks to months

Synoptic-scale: weather map scale
migrating cyclones/anticyclones, hurricanes
days-weeks, 100s – 1000s km

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Mesoscale:

Small disturbances < 100 km, minutes-hours

Travel embedded within the larger macroscale circulation

ex. ((thunderstorm) hurricane) westerlies)

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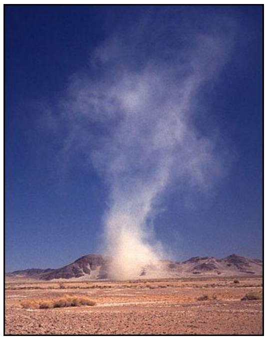
Microscale: wind gusts, dust devils (seconds – minutes)



(c)

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Mesoscale

All Winds: arise from pressure gradients resulting from unequal heating of the surface

Local Winds: arise from local pressure gradients

Sea & Land Breeze
Mountain & Valley Breeze
Chinook Winds
Katabatic Winds
Country Breeze
The Haboob

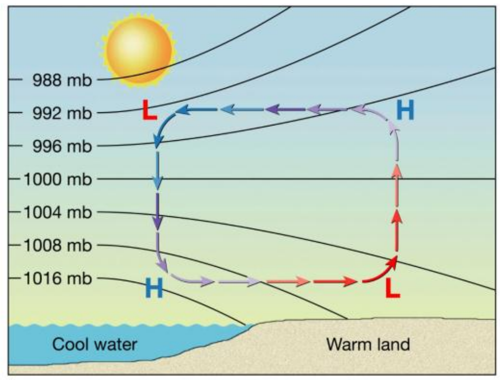
Mesoscale

Sea Breeze:

air over land expands as heated during day, develop L

temperature can decrease 5-10 deg. C

30 – 60 miles inland



(a) Sea breeze

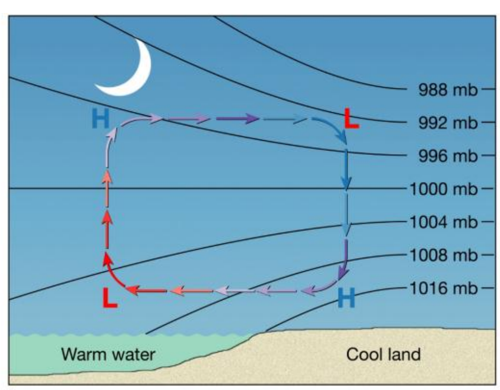
Mesoscale

Land Breeze:

air over land cools quicker during the evening, develop H

result in reverse circulation

offshore wind



(b) Land breeze

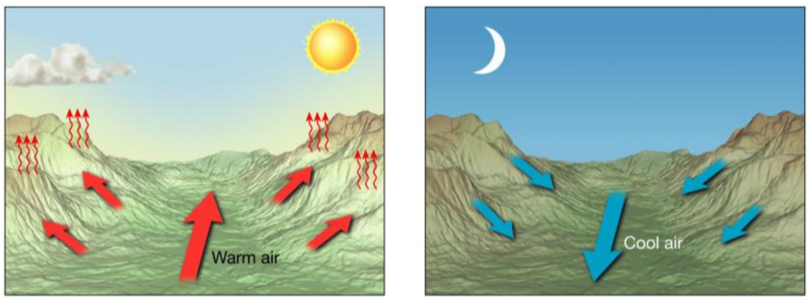
Mesoscale

Valley Breeze:

Slopes warm faster than air at same elevation over the valley

Flow from the valley to the mountains

Most common in summer, intense heating



(a) Valley breeze (b) Mountain breeze

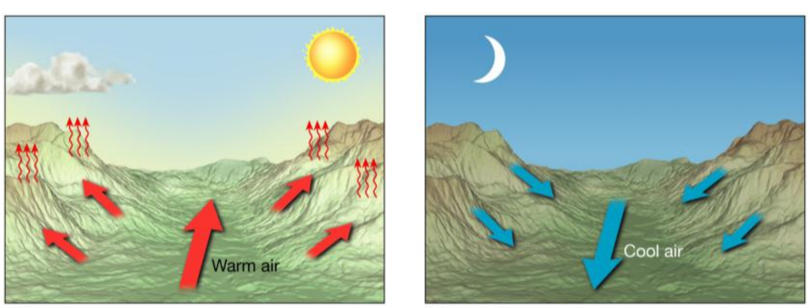
Mesoscale

Mountain Breeze:

Slopes cool faster after sundown

Flow from the mountains to the valley

Most common in winter, radiation cooling



(a) Valley breeze (b) Mountain breeze

Mesoscale

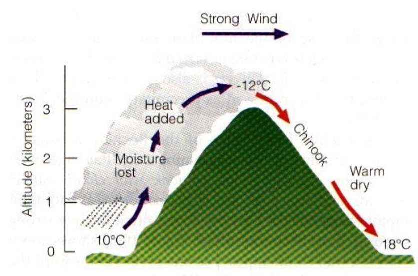
Chinook Winds:

Warm dry winds on the leeward slopes of mountains

Adiabatic warming

Eastward slopes of Rockies

Santa-Ana Winds, Southern California



Mesoscale

Katabatic (Fall) Winds:

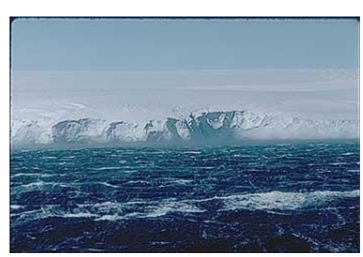
Cold dense air over highland area

Descends, displacing less dense air

Attain velocities capable of destruction

ex. Mistral (French Alps – Med. Sea)

bora (Yugoslavia – Adriatic Sea)



Mesoscale

Country Breeze:

Urban heat island leads to warmer temps at night

Air moves from surrounding country side to city

Traps pollutants in the center of the city

Mesoscale

Haboob:

Intense dust storms caused by downdrafts associated with fast moving thunderstorms in arid regions

Tucson, AZ

The Haboob occurs in the southwest US.
Texas and Arizona.
Lubbock, Texas.

Global Circulation: **Macorscale**:

1. **Single-Cell Circulation Model**

   Proposed by George Hadley 1735

   Good approximation for a non-rotating earth

2. **3-Cell Circulation Model**

   1920's 3-cell circulation was proposed in each hemisphere

   more realistic description of global winds

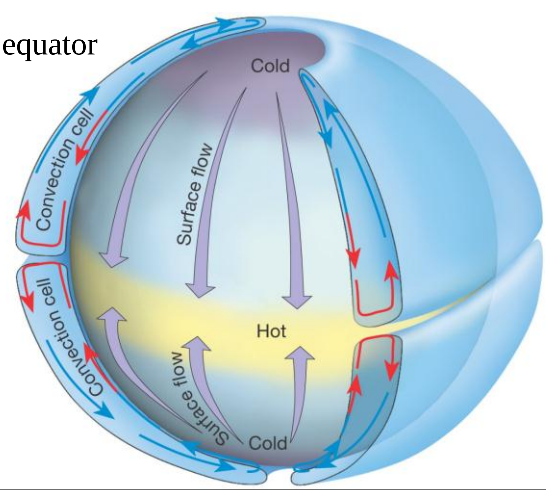
Single-Cell Circulation Model

Unequal heating at the equator and poles

Rise at the equator to the tropopause

Flow to the poles where, air cools and sinks to the surface

Surface flow back to the equator

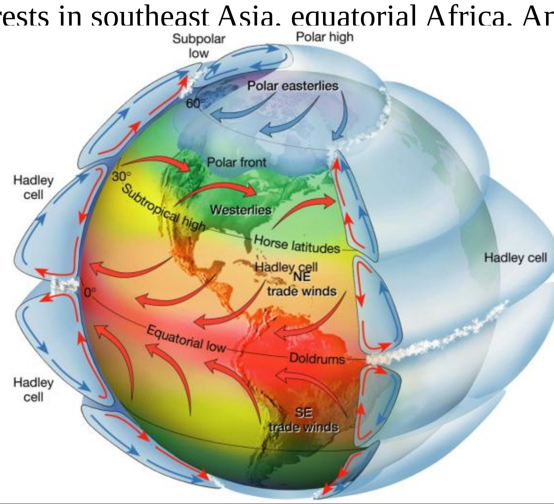


3-Cell Circulation Model

0^o through ~30^o N/S circulation resembles Hadley model

Equator: rising air, condensation, heavy rainfall

ex. Rainforests in southeast Asia, equatorial Africa, Amazon Basin

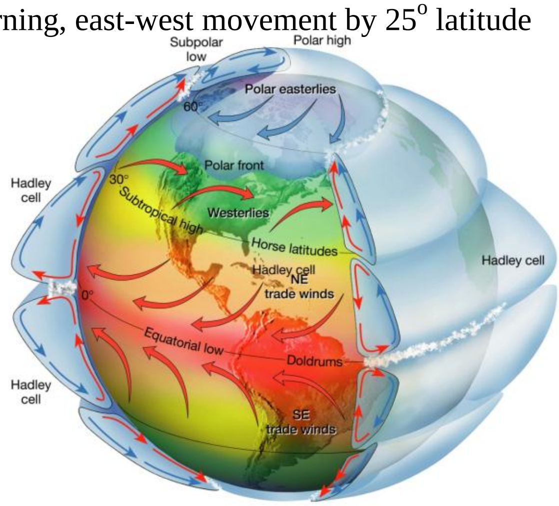


3-Cell Circulation Model

20^o through ~35^o N/S Latitude air descends

Radiation cooling through the tropics

Coriolis turning, east-west movement by 25^o latitude



3-Cell Circulation Model

20^{o} through ~35^{o} N/S Latitude air descends

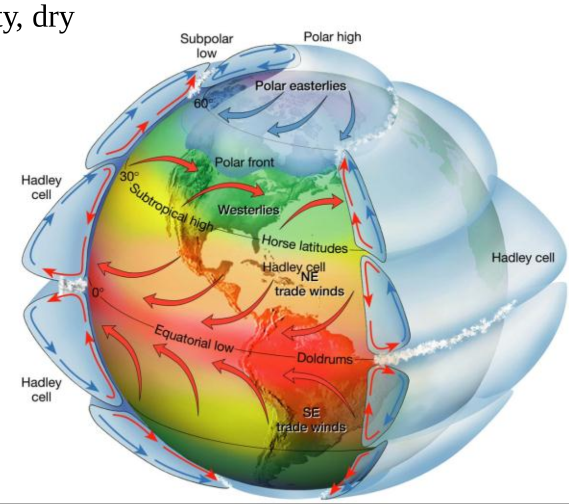
Warms adiabatically, moisture released around the equator

Decrease relative humidity, dry

Major desert systems

Sahara, North Africa

Great Australian Desert

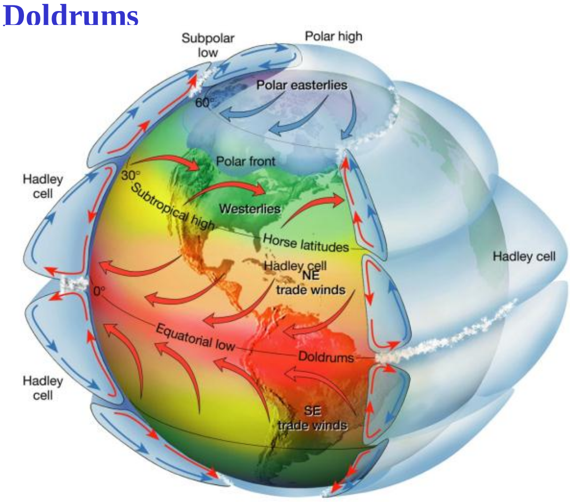


3-Cell Circulation Model

Piling of air = **high pressure** at the surface

Diverging air at the surface, weak winds **Horse Latitudes**

NE & SE Trade Winds, Doldrums

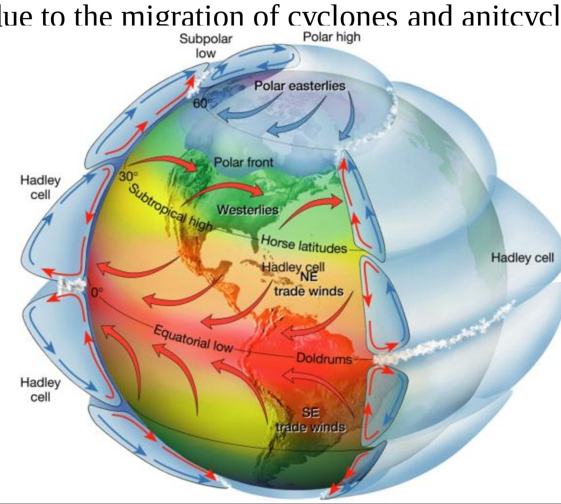


3-Cell Circulation Model

30^{o} through ~60^{o} N/S Latitude **Westerlies**

Circulation not as clear as the Hadley Cells

Sporadic due to the migration of cyclones and anitcyclones



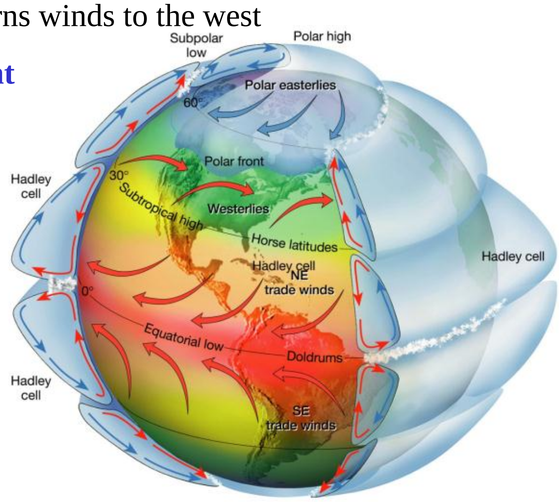
3-Cell Circulation Model

60^{o} through 90^{o} N/S Latitude **Polar Easterlies**

Cold dense air sinking and diverging at surface

Coriolis turns winds to the west

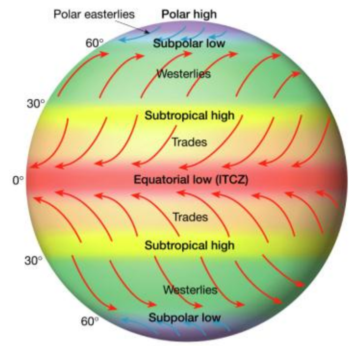
Polar Front



Idealized Pressure Belts & Prevailing Surface Winds:

Homogeneous Surface

Equatorial Low (ITCZ): NE, SE Trades converge, warm, moist



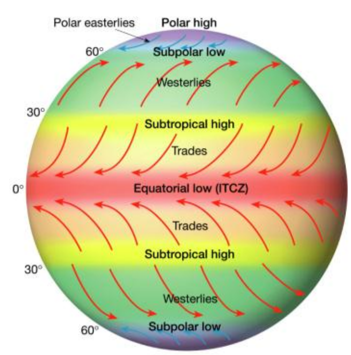
(a)

Idealized Pressure Belts & Prevailing Surface Winds:

Subtropical High: 20^o-35^o N,S westerlies and trades originate

rate of convergence aloft exceeds surface divergence

semi-permanent circulation feature

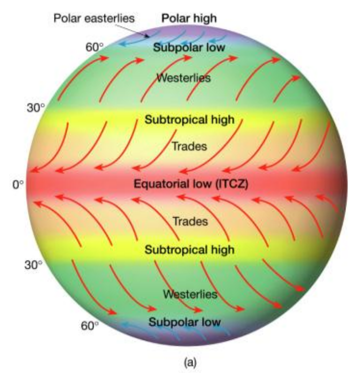


(a)

Idealized Pressure Belts & Prevailing Surface Winds:

Subpolar Low: 50^o-60^o N,S Polar Front

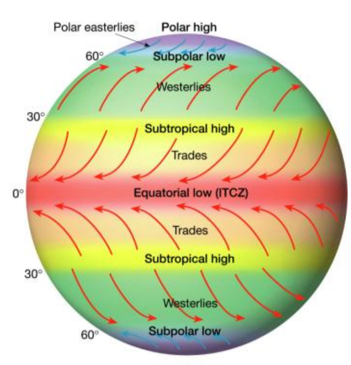
westerlies and polar easterlies converge



Idealized Pressure Belts & Prevailing Surface Winds:

Polar High: Radiation cooling, more dense air, higher pressure

origination of Polar Easterlies

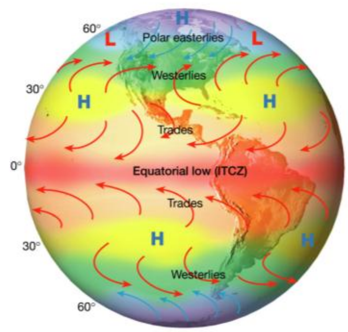


Semi-permanent Pressure Systems (The real world):

Non-uniform surface

SH Subpolar Low: true zonal distribution of pressure

NH zonal pressure belts replaced by semi-permanent cells

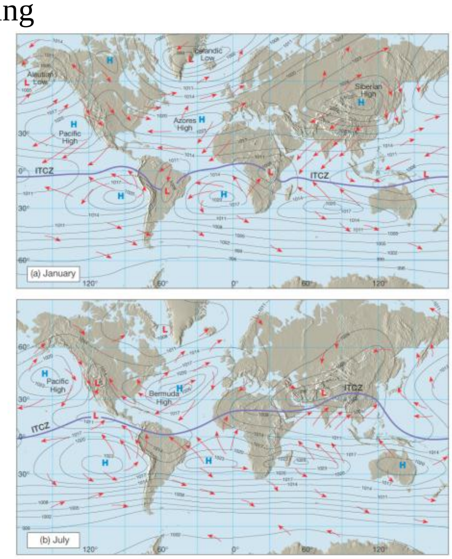


(b)

Semi-permanent Pressure Systems (The real world):

Migration zone of maximum heating

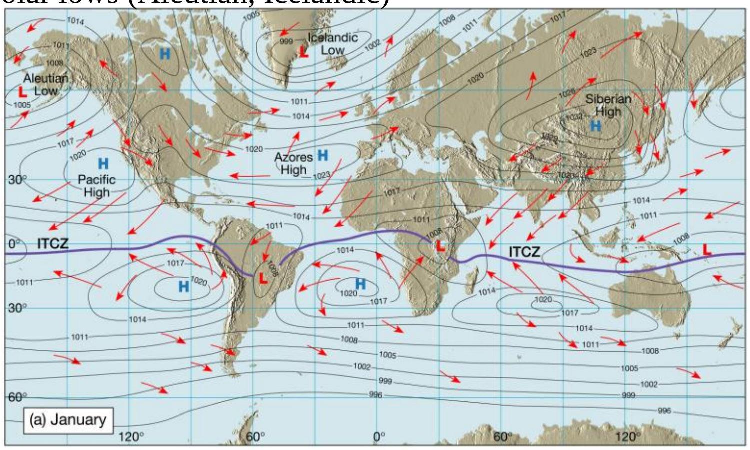
Differential heating between land and water



January Winds & Pressure

Subtropical highs (Siberian, Azores, Pacific)

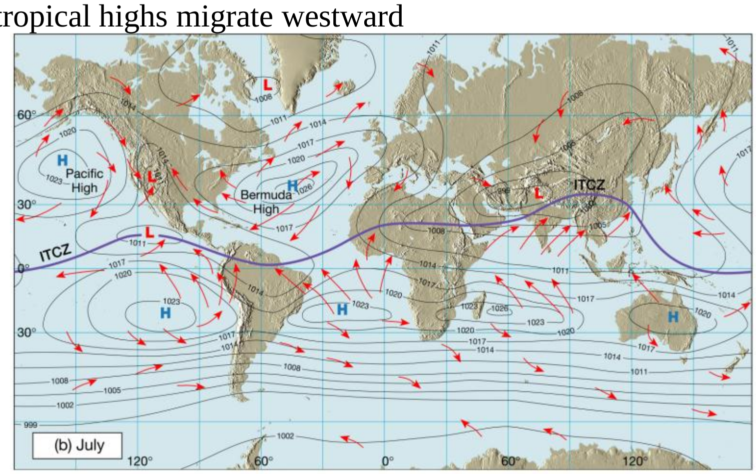
Subpolar lows (Aleutian, Icelandic)



July Winds & Pressure

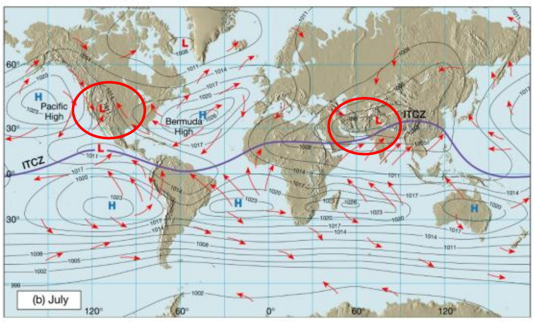
Subtropical continental highs replaced by low pressure cells

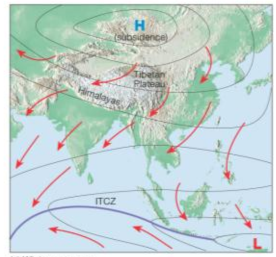
Subtropical highs migrate westward



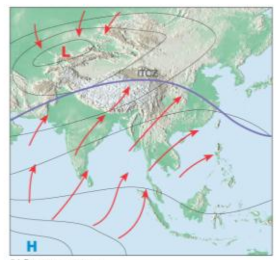
Monsoon Circulation: seasonal reversal in winds
Winter: wind blows from the land to the sea, dry
Summer: wind blows from the sea to the land, wet

Asian Monsoon
North American Monsoon





(a) Winter monsoon

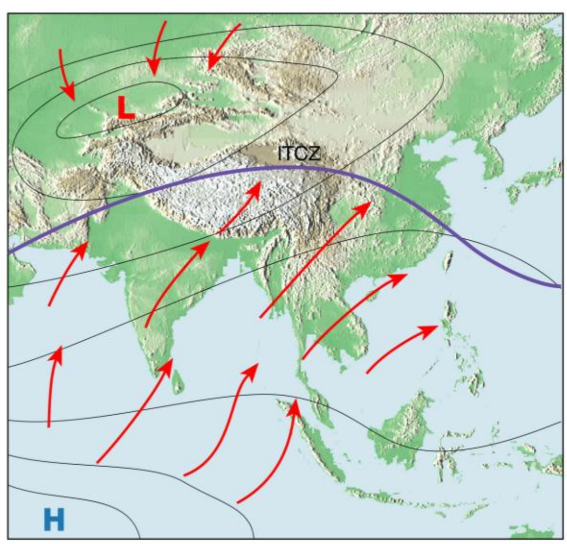


(b) Summer monsoon

Asian Monsoon:
Intense solar heating in summer

Orographic lifting

High precipitation

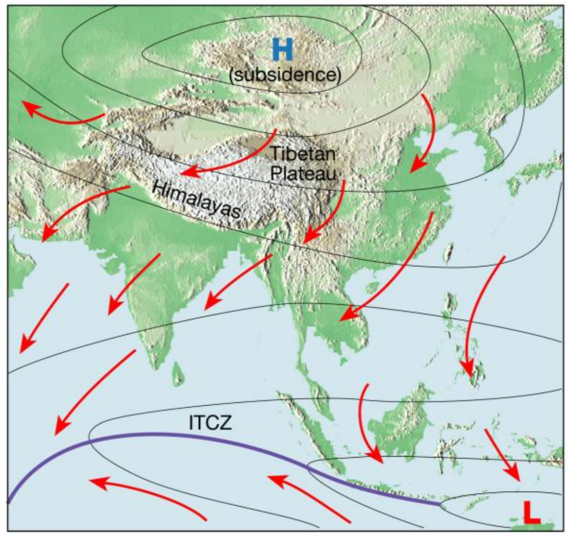


(b) Summer monsoon

Asian Monsoon:
Siberian High dominates wind patterns

Cold, dry air, high pressure

Drives offshore flow



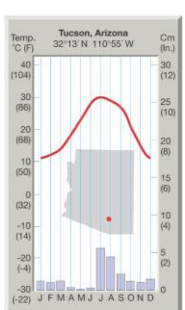
(a) Winter monsoon

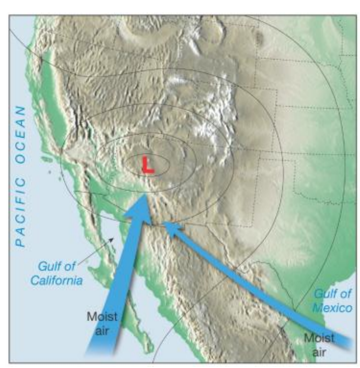
North American Monsoon

Thermal low pressure system

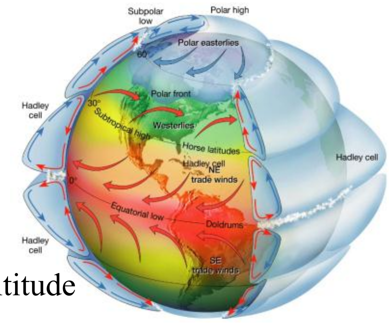
Draws moisture from Gulf of Mexico and Gulf of California

Precipitation Arizona, New Mexico, NW Mexico





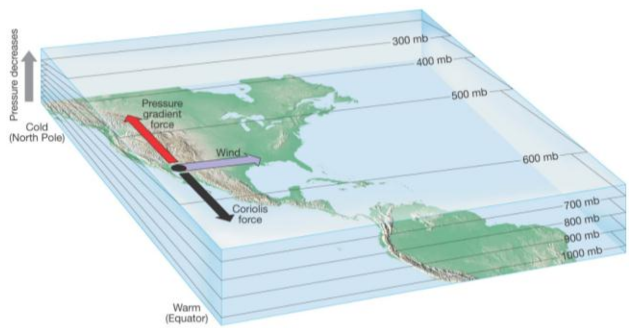
The Westerlies



Surface flow and flow aloft

Geostrophic balance

Pressure gradient force increase with altitude up to the tropopause



Jet Stream

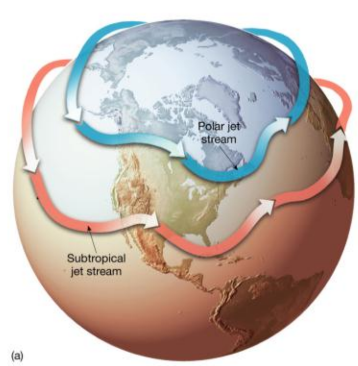
contained within the westerly flow

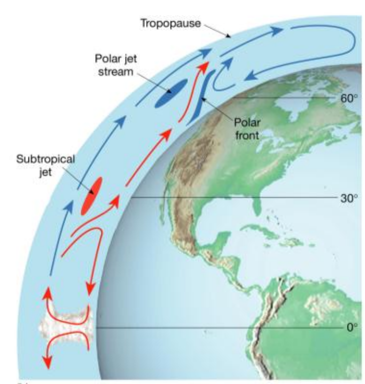
Narrow ribbons of high speed air

100-500 km (60-300 miles)

1-2 km thick

200-400 km/hr (120 – 240 mi/hr)



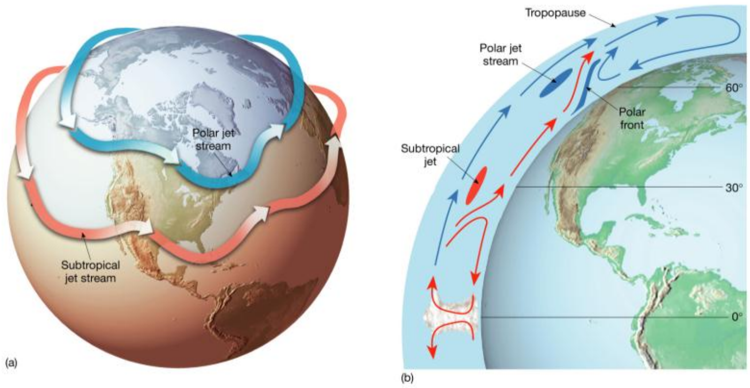


Jet Stream

originate from large temperature gradients at the surface

Fronts (linear temperature gradient feature)

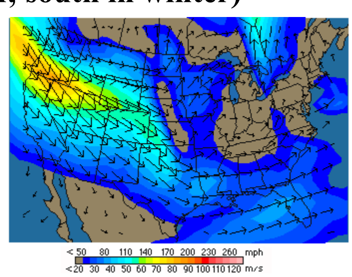
Polar Front = Polar Jet Stream (Mid-Lat-Jet Stream)

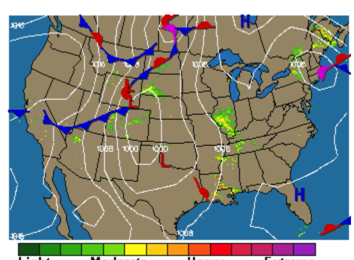


Polar Jet Stream

migrates seasonally (north in summer, south in winter)

Cold winter ~ 30^{o} N Latitude





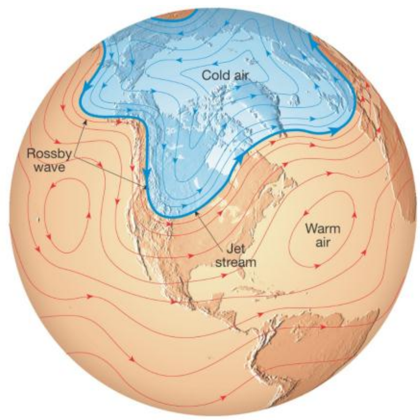
Waves In The Westerlies

upper air flow meanders

longest wavelengths range between 4000 – 6000 km (Rossby Waves)

3-6 would encompass the globe

stationary or migrate slowly



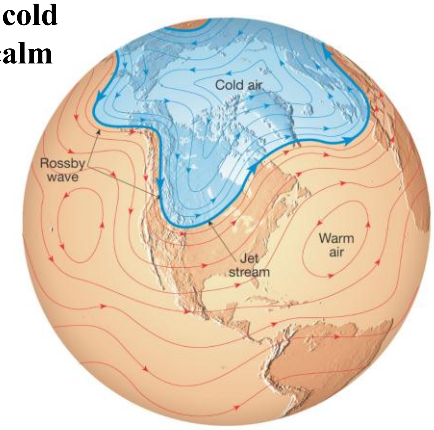
Waves In The Westerlies

shorter waves in middle and upper troposphere associated with cyclones, eastward migration 15^{o}/day

Migration of jet stream

equatorward = stormy, cold

poleward = warm, calm

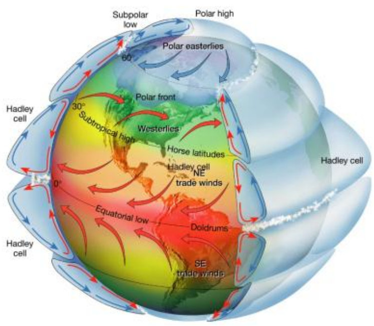


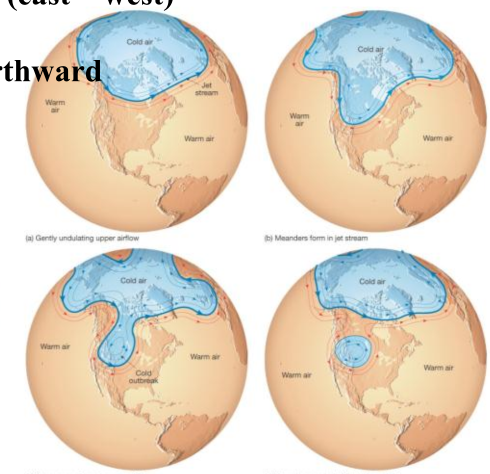
Waves In The Westerlies

circulation in the tropics (Trade winds, hadley cells) is meridional

Westerlies are generally zonal (east – west)

Meanders transfer energy northward





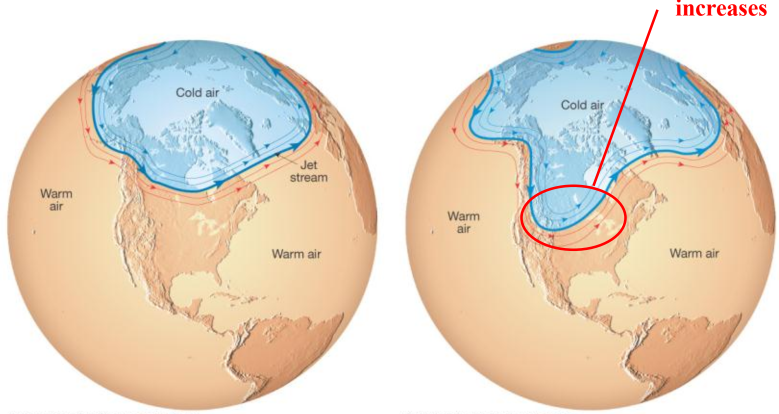
(a) Gently undulating upper airflow
(b) Meanders form in jet stream
(c) Strong waves form in upper airflow
(d) Return to a period of flatter flow aloft

Waves In The Westerlies

smooth, calm jet stream, zonal flow upper air

Meander develops (Gulf Stream, rivers)

Temperature gradient increases

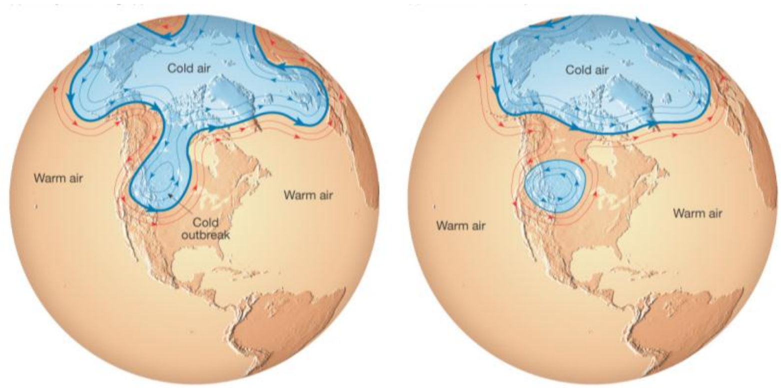


(a) Gently undulating upper airflow
(b) Meanders form in jet stream

Waves In The Westerlies

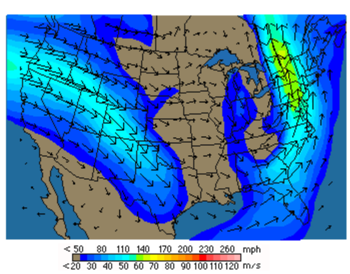
meander continues to develop until enough energy has been exchanged to reduce the temperature gradient

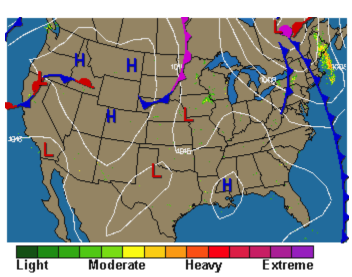
Organize into isolated low (cyclonic) systems



(c) Strong waves form in upper airflow

(d) Return to a period of flatter flow aloft



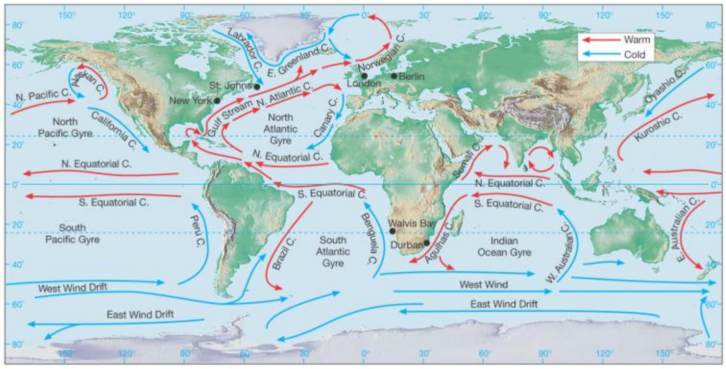


Waves In The Westerlies

wavy pattern = stormy

flat pattern = little cyclonic activity

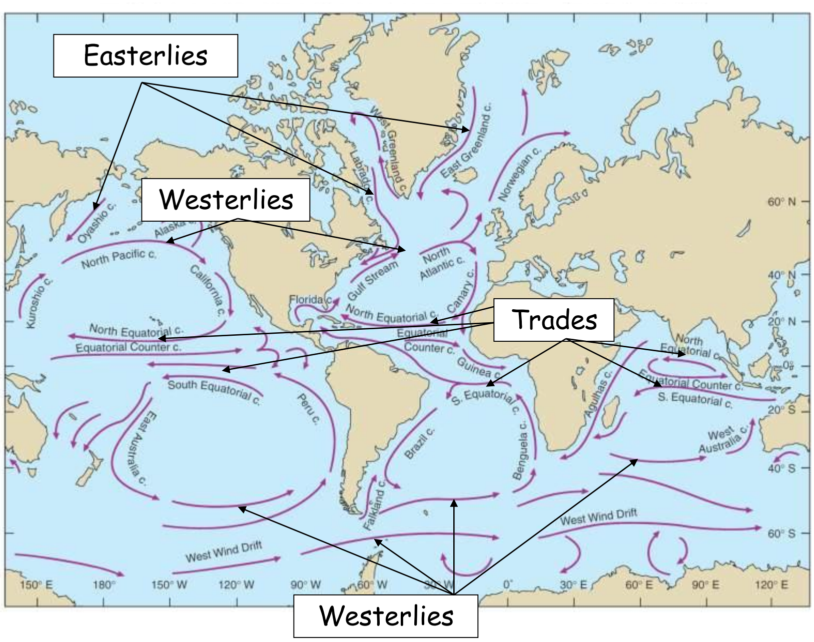
Global Winds & Ocean Currents



- Surface currents
  - Flow in response to average atmospheric circulation

¼ ocean currents, ¾ atmospheric circulation

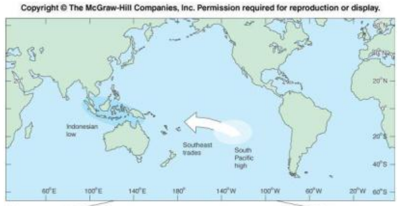
Major Wind Driven Surface Currents

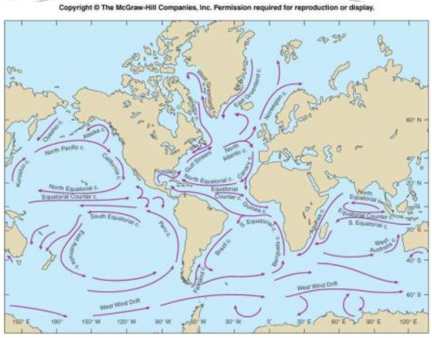


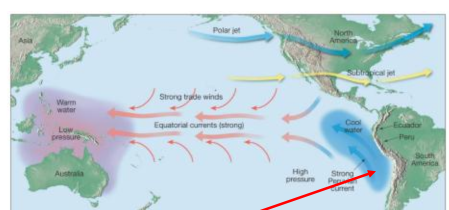
El Niño–Southern Oscillation (ENSO)

- Anomalous climactic events
- Occur every three to seven years
- Coupled interaction between ocean and atmosphere in the tropical Pacific
  - Collapse/weakening of southeast trade winds
  - Surface warm pool in western Pacific moves eastward
  - Upwelling shuts down off west coast of South America

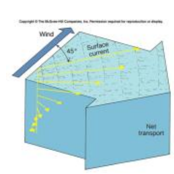
Southern Oscillation (Typical Year)



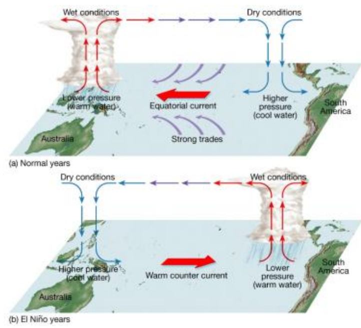


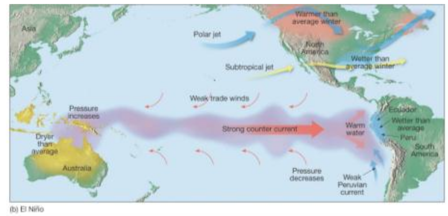


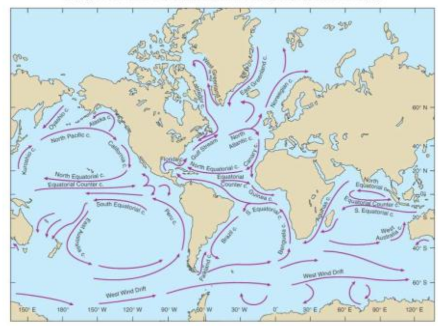
Upwelling: nutrient rich bottom water brought to the surface



Southern Oscillation (El Nino Year)

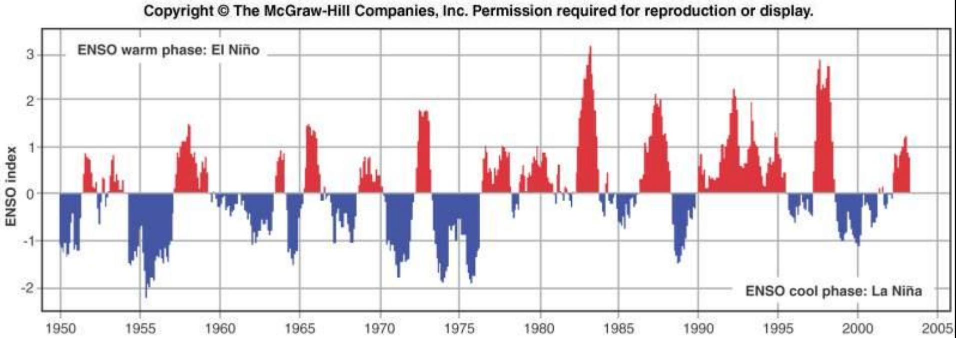






El Niño–Southern Oscillation = Red or warm phase

La Niña = Blue or cool phase



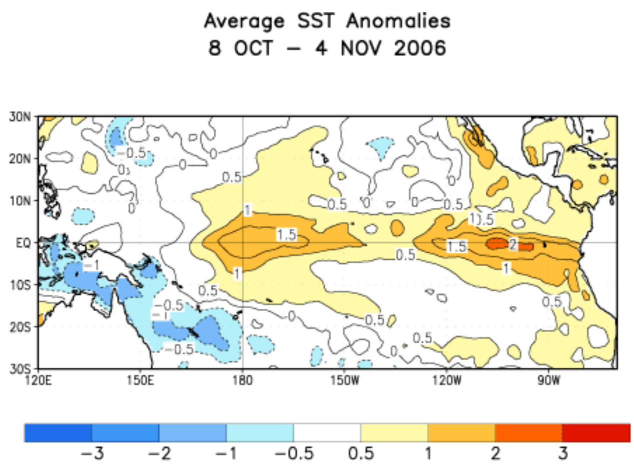


Figure 1. Average SST anomalies (°C) for the four-week period 8 October-4 November 2006. The SST anomalies are computed with respect to the 1971-2000 base period means (Xue et al. 2003, J. Climate, 16, 1601-1612).

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/index.html