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)

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**Scales of Atmospheric Motion:**

- based on time and space

- **Macroscale:** 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)

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**TABLE 7-1** Time and space scales for atmospheric motions

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Macroscale

**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)

**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

![Diagram of Sea Breeze](image)

**Mesoscale**

**Land Breeze:**
air over land cools quicker during the evening, develop H
result in reverse circulation
offshore wind

![Diagram of Land Breeze](image)
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

Mesoscale

Mountain Breeze:
Slopes cool faster after sundown
Flow from the mountains to the valley
Most common in winter, radiation cooling
Mesoscale

Chinook Winds:
Warm dry winds on the leeward slopes of mountains
Adiabatic warming
Eastward slopes of Rockies
Santa-Ana Winds, Southern California

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° through ~30° N/S circulation resembles Hadley model
Equator: rising air, condensation, heavy rainfall
ex. Rainforests in southeast Asia, equatorial Africa, Amazon Basin

20° through ~35° N/S Latitude air descends
Radiation cooling through the tropics
Coriolis turning, east-west movement by 25° latitude
3-Cell Circulation Model

20° through ~35° 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° through ~60° N/S Latitude **Westerlies**

Circulation not as clear as the Hadley Cells

Sporadic due to the migration of cyclones and anticyclones

60° through 90° 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

**Subtropical High:** 20°-35° N,S westerlies and trades originate

rate of convergence aloft exceeds surface divergence

semi-permanent circulation feature
Idealized Pressure Belts & Prevailing Surface Winds:

**Subpolar Low:** 50°-60° N,S Polar Front
westlies and polar easterlies converge

**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

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**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

Asian Monsoon:
Intense solar heating in summer
Orographic lifting
High precipitation
**Asian Monsoon:**
Siberian High dominates wind patterns
Cold, dry air, high pressure
Drives offshore flow

**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
100-500 km (60-300 miles)
1-2 km thick
Narrow ribbons of high speed air
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° N Latitude

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**Polar Jet Stream**

fast cold core of air embedded within a slower moving westerly flow
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 15º/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

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**Waves In The Westerlies**

smooth, calm jet stream, zonal flow upper air

Meander develops (Gulf Stream, rivers)
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

Generates cyclone at the surface

Wavy pattern = stormy

Flat pattern = little cyclonic activity
Global Winds & Ocean Currents

- Surface currents
  - Flow in response to average atmospheric circulation

\( \frac{1}{4} \) ocean currents, \( \frac{3}{4} \) atmospheric circulation
Ocean Gyres

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)

97-98 El Niño

Temperature Data from moored buoys

Sea surface topography from NASA satellites

Red = 30° C
Blue = 8° C
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, 1801-1612).

**El Nino**

Less hurricane activity in the Atlantic