Atmospheric and Oceanic Circulations

Physical Geography Lecture - GEOG B1

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Wind

Wind is driven by equatorial energy surpluses and polar energy deficits. Atmospheric circulation transfers energy and mass >>main medium of redistributing energy from 35° latitude to the poles >>also spreads pollutants worldwide. Ocean currents are responsible for redistributing heat in the equatorial zone between the 17th parallels.

Air Pressure and Pressure Relationships

Air pressure: the weight of the atmosphere described as force per unit area (like pounds per square inch) - it is key to understanding wind

Warm, humid air is associated with low pressure
Cold, dry air is associated with high pressure

Measuring Air Pressure

Barometer: instrument that measures air pressure in millibars (mb) - force per square meter of a surface area

All weather collecting stations use a barometer that is calibrated to a standard of normal sea level pressure - 1013.2 mb (29.92 inches of mercury)

See **Fig. 6.2 c** and **b** for the types of barometers and how they work.

Wind: Description and Measurement

Wind: horizontal motion of air across a surface - produced by differences in air pressure

See **Fig. 6.4**

Anemometer - measures wind speed in kmph and mph

Wind vane - determines wind direction

Winds are named for the direction from which they originate.

>>Example: from west = westerly / from south = southerly

Driving Forces Within Atmosphere

Four forces determine the speed and direction of winds:

1. Gravitational force
2. Pressure gradient force
3. Coriolis force
4. Friction force

Gravitational force - exerts uniform pressure on the atmosphere over all of Earth.
>>counteracts centrifugal force of Earth’s rotation
>>without gravity there would be no atmosphere

Pressure Gradient Force - I

Unequal heating of Earth’s surface causes high- and low- pressure areas of air. Where air masses of differing pressure near each other, a pressure gradient develops which leads to horizontal air movement

>>**Fig. 6.6 b**

Pressure gradient force - drives air from areas of higher barometric pressure (more-dense air) to areas of lower barometric pressure (less-dense air)

>>**Fig. 6.8 a**

Pressure Gradient Force - II

Vertical air movement: (see Fig. 6.8 a)

Strongly subsiding and diverging air movement is associated with high pressure (colder air)

Strongly converging and rising air movement is associated with low pressure (warmer air)

Isobar: an isoline plotted on a weather map to connect points of equal pressure >>gives a visual pattern of the pressure gradient

>>spacing between isobars indicates the intensity of the pressure difference, or pressure gradient (**Fig. 6.6 a** and **b**)

Coriolis Force

Coriolis force: a deflective force that makes wind travelling in a straight path appear to be deflected in relation to Earth's rotation

Earth rotates eastward, so: (see Fig. 6.7 a, b, and c)

- Northern Hemisphere - things appear to curve to the right
- Southern Hemisphere - things appear to curve to the left
- Directs the upper-level westerly winds from the subtropics to the polar regions
- Air movement in high- and low- pressure areas develops a rotary motion, and wind flowing between highs and lows flows parallel to isobars. Fig. 6.8 b

Friction Force

Friction force: drags on wind as it moves in the boundary layer
>>decreases with altitude (extends to about 500 m (1,600 ft.)
At the surface, the force of friction varies with topography, wind speed, time of day and year, and atmospheric conditions.
Rougher surfaces produces more friction

Physical Forces on Winds - I

See **Fig. 6.8 a**, **b**, and **c** for the combination of the pressure gradient, Coriolis, and friction forces.

Fig. 6.8 a: top and side view of air movement in high- and low- pressure system (without the Coriolis effect or friction, winds flow directly from high to low across the isobars)

Fig. 6.8 b: when Coriolis force is added, winds in the upper atmosphere flow around pressure areas, not directly from high- to low-pressure areas.

>>these **geostrophic winds** remain parallel to the isobars

Physical Forces on Winds - II

Fig. 6.8 c: at the surface, friction prevents geostrophic winds
Friction slows the wind and reduces the Coriolis effect.
Winds move across isobars, not parallel to them as in the upper atmosphere.

The forces combine so that at the surface, winds flow around pressure centers, forming enclosed areas, called pressure systems or pressure cells

High- and Low-Pressure Systems -I

Northern Hemisphere

Surface winds spiral out from high-pressure areas in a clockwise direction, forming an **anticyclone**, and spiral into low-pressure areas in a counterclockwise direction, forming a **cyclone**.

Southern Hemisphere

Surface winds spiral in the opposite direction, but the names are the same.

See **Fig. 6.8 b** and **c** for examples of the spiraling pattern in both hemispheres

High- and Low-Pressure Systems -II

See **Fig. 6.9**

When you involve the upper level winds:

- In a high-pressure system, there is vertical air motion, a downdraft, where the air sinks into the system to replace the air moving out of the high-pressure cell.
  >>forms clear skies
- In a low-pressure system, there is an updraft as converging air is pushed up
  >>forms cloudy / stormy skies

Primary Pressure Areas & Their Winds

There are four primary pressure areas in the Northern Hemisphere, and a similar set exists in the Southern Hemisphere.
Two of the pressure areas are stimulated by thermal factors:

- Equatorial low (ITCZ)
- Polar Highs
- Two of the areas are formed by the displacement of air:
- Subtropical highs
- Subpolar lows

Equatorial Low / ITCZ: Warm & Rainy

At the equator:

- The high sun angle and consistent daylength result in less-dense, warm, ascending air with surface winds converging along the entire equator.
- As warm moist air rises, the air expands and cools, producing condensation and heavy rainfall. (**p. 147** - **6.1b**)
- This equatorial low (or trough) is the **intertropical convergence zone** (**ITCZ**).
- The ITCZ slowly shifts during the year. See **Fig. 6.10** / **6.2** on **p. 147**

Trade Winds

Trade winds (**trades**): winds converging at the equatorial low

Northeasterly trade winds blow in the Northern Hemisphere

Southeasterly trade winds blow in the Southern Hemisphere

Trade winds exist within an area called a Hadley cell.

See diagrams on **pp. 146-147** - **6.1a** / **6.1b**

Subtropical Highs: Hot & Dry

Between 20° and 35° latitude in both hemispheres, there are broad high-pressure zones, called subtropical highs.

>>zones have

hot, dry air and clear skies (see **Fig. 6.11**)

These highs are formed when air above is pushed downward, and it heats by compression as it descends.

>>air is dry because most

moisture was removed as it rained out in the ITCZ >>winds calm

Again, see diagrams on **pp. 146-147** - **6.1a** / **6.1b**

Earth’s major deserts mostly occur within this subtropical belt.

Westerlies

Air diverging within the subtropical highs generate the Trade winds, which flow toward the equator, and the **westerlies**, which flow west and toward the poles.
>>See **Fig. 6.11**
Westerlies are less consistent that the Trades.
In both hemispheres, they are stronger in the winter and weaker in the summer.

Again, see diagrams on **pp. 146-147** - **6.1a** / **6.1b**

Subpolar Lows: Cool & Moist

Subpolar lows occur where the warm, moist westerlies meet the cold, dry air from the polar regions.

This area where contrasting air masses meet is called the **polar front**.

>>encircles Earth between 50°-60° north and south

Warm air is displaced upward above the cool air at the polar front.

>>leads to condensation and precipitation

Again, see diagrams on **pp. 146-147** - **6.1a** / **6.1b**

Polar Highs: Frigid & dry

Polar high-pressure cells are weak, and they receive little energy from the sun put it into motion.

These atmospheric masses have variable, cold and dry easterly winds that move away from the poles, descending and diverging clockwise in the Northern Hemisphere, and counterclockwise in the Southern Hemisphere.

The southern Antarctic High is stronger and more persistent than the Arctic High.

Again, see diagrams on **pp. 146-147** - **6.1a** / **6.1b**

Upper Atmospheric Circulation

To map the upper-atmosphere pressure and winds, we plot a **constant isobaric surface** set to 500mb (an undulating surface with ridges of high-pressure and troughs of low-pressure) - the isolines represent the altitude in meter, or feet, where the 500 mb pressure occurs.

See **Fig. 6.12 a**, **b** and **c**

At the highs, winds slow and converge aloft which results in a downdraft and divergence below.

At the lows, winds accelerate and diverge aloft which results in an updraft and convergence below.

Jet Streams

Jet streams: irregular, concentrated bands of wind occurring at multiple locations (see locations on **pp. 146-147** - **6.1a** / **6.1b**

>>influence surface weather systems

>>core speeds can exceed 300 kmph (190 mph)

>>weaken during summer / strengthen during winter

Polar jet stream: meanders between 30° and 70° latitude at the tropopause along the polar front

Subtropical jet stream: flows between 20° and 50° latitude at the tropopause

See **Fig. 6.14 a** and **b**

Regional Winds

Monsoon: seasonally shifting wind system - involves an annual cycle of returning precipitation with the summer sun

Example: Asian Monsoon Pattern in Northern Hemisphere (**Fig. 6.15 a** and **b**)

- Winter conditions / dry season - ITCZ moves south of equator - cold, dry air moves south out of higher latitude Asian landmasses
- Summer conditions / wet season - ITCZ shifts north of the equator - warm, moist winds flow into Asian landmasses from the Indian Ocean

Human Influences to Monsoons

It’s complicated:

- Warmer temperatures from increased greenhouse gasses can increase monsoon precipitation….
- HOWEVER, increased concentrations of aerosols (principally sulfur compounds / black carbon) can decrease monsoon precipitation
- Further study is needed to see exactly how human activity influences monsoons

Local Winds - I

Land and sea breezes: local winds along coastlines caused by different heating characteristics of land and water

- Daytime sea-breeze conditions: higher temperature on land means lower pressure / lower temperature over water means higher pressure → cooler air is pulled on land by developing thermal low = *onshore breeze*
- Nighttime land-breeze conditions: temperature and pressure situations are reversed = *offshore breeze*

See **Fig. 6.16**

Local Winds - II

Mountain and valley breezes: local winds resulting from the following -

Daytime valley-breeze conditions: valley gains heat energy rapidly during day - leads to a valley breeze moving up the slopes

Nighttime mountain-breeze conditions: mountain air cools rapidly at night - leads to cooler air flowing down the mountain slopes to the valley

Example: Santa Ana winds

See **Fig. 6.17**

Ocean Currents

Ocean currents are driven by the atmospheric circulation around subtropical high pressure cells. See **Fig. 6.18**

Oceanic circulation systems are called **gyres**.

What shapes the currents?

- Frictional drag of wind
- Coriolis force of deflection
- Density differences caused by temperature and salinity

Equatorial Currents

Trade winds drive ocean surface waters westward along equator.
Waters pile up against eastern shores of continents.
The waters then head north or south in strong currents, flowing in tight channels.
Circle back around and then south or north along the western shores of continents.
See **Fig. 6.18**

Upwelling and Downwelling Flows

When surface water is swept away from a coastline, an **upwelling current** occurs >> cooler water rises from greater depth to replace vacating water

>>upwelling currents are nutrient rich

When there is an accumulation of water, excess water gravitates downward in a **downwelling current**

>>deep currents

that flow vertically and then along ocean floor

Thermohaline Circulation - Deep Currents

Thermohaline Circulation:

Warm, salty water from the equator mixes with colder polar waters.

As it cools, it sinks and flows south, joining the deep ocean currents.

These currents are not being pushed by surface winds, so they are slower and carrying large volumes water.

A complete circuit of this system can take 1,000 years.

See **Fig. 6.20**

Natural Oscillations - I

The oceans experience multi-year oscillations, or changes, in wind and current patterns.

Example: **El Niño-Southern Oscillation** (**ENSO**)

- Generally the Pacific Ocean currents flow from east to west, with the trade winds, near the equator (See **Fig. 6.21 a**).
- For unexplained reasons, pressure patterns and surface ocean temperatures shift - trade winds start to weaken and blow from west to east - upwelling along the coast of Peru is blocked (See **Fig. 6.21 b**).

Natural Oscillations - II

Other oscillations that can last for weeks, a season, a year, or multiple years:
> La Niña - ENSO’s cool phase
> Pacific Decadal Oscillation
> North Atlantic / Arctic Oscillations