ESS 60A

Lecture 6. Atmosphere II

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Coriolis Force

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 $F = - 2 M \Omega \wedge V$

Where $M =$ mass (kg)

$\Omega =$ Angular speed (rad/s) (z axis)

$V =$ Speed vector of object (m/s)
Coriolis Effect

A “slow” Merry-Go-Round (1,000 miles/hr at equator)
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.

Upper Troposphere (free atmosphere)
Northern Hemisphere upper atmosphere

Geostrophic balance
Surface
Northern Hemisphere surface
 indian Ocean
(from Weather & Climate)
Cyclonic vs Anticyclonic

Rain
Cools at MAR
Condensation dew point
RH increases
Cools at DAR

Clear skies from the downdraft
Cold air compressed adiabatically, RH drops
Divergent flow

(from The Atmosphere)

\[ P = \rho R T \]
DAR = dry adiabatic rate.
Temperature changes with latitude

- Solar energy does not hit earth uniformly
  - Due to earth’s spherical shape and tilt

**Equator (a)**
- High concentration
- Little Reflection
- High Temperature

**Closer to Poles (c)**
- Low concentration
- Higher Reflection
- Low Temperature

From (a) to (c)
In diagram below

1 unit of surface area
(a) One unit of light is concentrated over one unit of surface area.

1.4 units of surface area
(b) One unit of light is dispersed over 1.4 units of surface area.

2 units of surface area
(c) One unit of light is dispersed over 2 units of surface area.
Two-cell convection

Simplified, smooth earth with no land/sea interactions and a slow rotation.

Equator is warmed by the sun more than the poles.

The warm, light air rises at the equator and spreads northward and southward.

The cool dense air sinks at the poles and spreads back toward the equator.

Two convection cells are formed.
**Why the cells?**

- Flow convergence.
- Coriolis force.
- Meets polar air

**Air rises, diverges, moves poleward, converges between 25 and 35°N (fingers).**

**Upper air convergence+cooling causes air to subside in subtropics.**

**Air pressure increases at the surface (HP), precipitation is low, RH drops, deserts.**

**Air diverges outward.**

**Equatorward, winds are light and variable (horse latitudes).**
Why the cells?

- Flow convergence.
- Coriolis force.
- Meets polar air

Surface air turns to the right. Pressure gradients between high at 30°N and equator creates easterly trade winds.

At equator, convergence occurs between northeast tradewinds NH and southeast SH to create InterTropical Convergence Zone (ITCZ) (pressure grad decreases).

The convergence creates a zone of calms, the “doldrums” (+5° to -5°).
Why the cells?

• Flow convergence.
• Coriolis force.
• Meets polar air

• Poleward side of subtropics, air deflected to the right to create westerly winds between 30° and 60°N.
• Loss of energy at poles creates cold air that subsides toward surface to create a dome of high pressure called Polar High.
• Air moving equatorward turns to the right to create polar easterlies.
Why the cells?

- Flow convergence.
- Coriolis force.
- Meets polar air

Doldrums

Polar easterlies collide with westerlies at 60°N to create subpolar low, LP, creates storms.

LP promotes precipitation. HP suppresses precipitation.
Idealized winds created by pressure gradients and Coriolis force.

Actual winds owing to land mass distribution and friction.
Surface Wind patterns

- Large winds due in part to pressures caused by global circulation of air
  - Left side of diagram
- Winds blow from high to low pressure
  - Right side of diagram
Pressure belts: The three-cell circulation model has the following pressure belts associated with it:

- **Equatorial Low** - A region of low pressure associated with the rising air in the ITCZ. Warm air heated at the equator rises up into the atmosphere leaving a low pressure area underneath. As the air rises, clouds and rain form.

- **Subtropical High** - A region of high pressure associated with sinking air in the horse latitudes. Air cools and descends in the subtropics creating areas of high pressure with associated clear skies and low rainfall. The descending air is warm and dry and deserts form in these regions.

- **Subpolar Low** - A region of low pressure associated with the polar front

- **Polar High** - A high pressure region associated with the cold, dry, dense air of the polar regions.
Jet stream and Rossby waves
Precipitation patterns

Doldrums: Hot → humid, no winds
Jet streams form in the upper troposphere at the junction between cold and warm converging air masses.

The pressure varies rapidly across that cold-warm transition, creating strong gradients, i.e. strong winds.
http://www.youtube.com/watch?v=DHrapzHPCSA&feature=related
http://www.suu.edu/faculty/colberg/Hazards/Weather/04_GlobalWind.html
How good is this model?

- The surface of the Earth is not uniform or smooth.
- There is uneven heating due to land/water contrasts.
- The wind flow itself becomes unstable and generate “eddies.”
- The sun doesn’t remain over the equator, but moves from 23.5 °N to 23.5 °S and back over the course of a year.

Weather and Climate

- Weather is what’s happening now with the atmosphere near the ground.
  - Temperature, pressure, cloudiness, precipitation, winds

- Climate is the average weather
  - Usually refers to long periods of time
  - Classified mainly by latitude and wet/dry
Causes of Climate Change

- The combination of periodic changes in the amount of sunlight reaching the Earth cause ice ages.
  - Milankovitch cycles
  - Doesn’t account for all climate variations
Rain Shadows

- Mountains force humid air to rise
- Air cools with altitude, clouds form and precipitation occurs (windward side)
- Dry air mass moves down opposite leeward side of mountain
Tropical Cyclone

- Giant rotating tropical storms
- Wind >119km per hour
- Formation
  - Strong winds pick up moisture over warm surface waters
  - Starts to spin due to Earth's rotation
  - Spin causes upward spiral of clouds
- Damaging on land
  - High winds
  - Storm surges
Santa Anna Winds

Santa Anna winds are warm and dry winds. In the desert region of the United States, high pressure pushes air off the plateaus forcing the air into narrow mountain valleys. As the air is forced through the valley it is compressed and warms. As the air warms the saturation point rises and its relative humidity drops.

Santa Anna winds are responsible for wildfires in southern California. The dry wind desiccates the surface and whips wildfires into raging fire storms.
Monsoon: Sea/Land-Related Circulation

- 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.
Air quality in high pressure systems

Move in at its farthest north location in the summer and expands in size. Under cloudless skies, insolation initiates photochemical reactions.
Midterm review