Precipitation Types

• Rain
• Snow
  – growth of ice crystals through deposition, accretion, and aggregation.
• Freezing Rain
  – Rain freezes when it hits the surface.
• Sleet
  – Usually starts out as snow or ice.
  – Falls through a warm layer and melts.
  – Falls through a lower layer below freezing and freezes again. Common with warm fronts.
• Graupel
  – Growth of ice crystal through accretion.
  – Accretion not significant enough to be called snow.
Quick Quiz

• Question #1: What is the primary cause of the seasons?

• Question #2: When is the Earth the closest to the Sun?

• Question #3: What is the significance of an equinox?

• Question #4: What is the significance of a solstice?
General Circulation

• **Seasons**
  – Tilt of the Earth’s axis.
  – Equatorial regions receive much more solar energy than poles.

• Systems form and bring equatorial heat toward the pole and polar cold air toward the equator.

• One the long term, the Earth has a general circulation that is rather persistent.
  – What we (mid-latitude) think of as weather is generally the small-scale perturbations on the larger circulation.
Single Cell Model

- Hadley (1735)
- Trying to describe why sailors experienced zonal winds in the lower latitudes.
- Assumed planet was covered by a single ocean and a fixed sun that remained over the equator.
Single Cell Model

- Strong heating
- Air expanded vertically
- Diverged toward both poles
- Sank back to surface at the poles
- Returned to the equator.
Single Cell Model

- Rotation of earth caused deflection to right in N.H. and left in S.H..
- Differences in heating give rise to persistent large-scale motions.
  - Thermally direct circulations.
- Zonal winds can result from the deflection of meridional winds.
Three-cell model

- Ferrel (1865)
- Hadley: tropics and sub-tropics
- Ferrel: mid-latitudes (30-60°)
- Polar
Hadley Cell

- Strong solar heating at equator.
- Equatorial low and the ITCZ.
  - Inter-Tropical Convergence Zone
- Upper troposphere moves poleward to subtropics (20-30º).
- Air acquires increasing zonal component.
  - Very strong. Circles the earth several times.
Hadley Cell

- Air sinks toward surface as it cools.
- Forms sub-tropical high.
- Air warms adiabatically, results in warm, cloud free conditions.
  - Weak pressure gradients and light winds.
- Strongest in the winter when temperature gradient is the strongest.
Polar Cell

- Air mass moves from polar high to sub-polar low.
- Slightly warmer air at sub-polar locations rises.
- Very cold air at poles causes the polar high.
- Coriolis results in the polar easterlies.
Ferrel Cell

- Indirect cell
  - Caused by turning of the two adjacent cells.

- Coriolis results in Westerlies.
Three-cell vs. Reality

• Hadley cell does a good job of low latitude motions.
• Ferrel and polar cells not quite as well represented.
  – Central U.S. is dominated by a southerly flow during the summer.
  – Polar easterlies only emerge in long term averages.
• Upper level model is not realistic at all
  – Ferrel cell implies easterly motion in the upper troposphere: Overwhelming westerly wind.
• Three-cell model provides a starting point for a more detailed account.
  – Doesn’t consider land-ocean contrasts or topography.
Semi-permanent Cells

(a) January
Air Masses

- Air masses form when air remains over a given region of a substantial length of time.
- Air takes on characteristic of that region.
- Labeled by moisture (c,m), temperature (T,P,A).
- Why don’t characteristic air masses originate over mid-latitudes?
- What are boundaries between air masses called?
Fronts

• Fronts separate different air mass types.

• Thickness gradient defines the approximate location of the front.
  – Front is located on the warm side of the gradient.

• Type of front depends on movement of the colder air.
Fronts - Location

- Wind shift line
- Pressure trough
- Temperature discontinuity
- Dew Point temperature discontinuity
- Pressure tendency pattern
- Horizontal visibility variations
- Horizontal variation in precipitation type
Fronts – 5 types

• Cold

• Warm

• Stationary

• Cold Occlusion

• Warm Occlusion
Nomenclature

• Frontogenesis: Convergent low-level flow in the presence of a thickness gradient at low-levels.

• Frontolysis: Divergent low-level flow around an existing front.
Active/Inactive Fronts

- **Active front**: The warm air has a wind component with respect to the frontal motion towards the front.
  - Over a significant depth of the atmosphere.

- **Inactive front**: No warm air component towards the front.
Cold Front

- **Temperature**
  - Colder at the surface behind the front with lower thicknesses.

- **Dew Point**
  - Lower dew point temperatures found behind the front.

- **Winds**
  - South-Westerly ahead of front, often gusty near the front
  - Winds veer to north or northwest as front passes, and increase in strength.

- **Pressure tendency**
  - Pressure falls ahead of the front, rises behind the front.
  - Pressure trough exists along front.

- **Precipitation types**
  - Deep convection ahead, possible shallow convection behind.
Warm Front

• Temperature
  – Cold air ahead of warm front. Temperature gradient is smaller than cold front (friction).

• Dew Point
  – Lower dew points ahead of front, although larger RH values are typically found here.

• Winds
  – South-easterly to northeasterly ahead of front in cool air. Little gustiness.
  – Winds veer to southwest or south as front passes.

• Pressure tendency
  – Pressure falls ahead slowly ahead of warm fronts unless trough is intensifying rapidly.
  – Steady or slowly rising behind the front.

• Precipitation types
  – Often steady ahead of front. No precipitation behind.
Stationary Fronts

A

H

cold air

stationary front

warm air

B

H

cold air

stationary front

warm air

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Occlusion

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Occlusions

• Cold occlusion
  – Typical occluded front seen in North America.
  – See previous image.

• Warm occlusion
  – Overtaking cold front encounters colder air associated with the warm front.
  – Typically found along the west coast of continents.
    • Relatively cool maritime air over takes colder continental air associated with warm front.