ATM 10 Severe and Unusual Weather

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http://atm.ucdavis.edu/~grotjahn/course/atm10/index.html

Lecture topics:

- **Moisture**
  - Mixing ratio
  - Vapor pressure
  - Relative humidity
  - Saturation vapor pressure
  - Dew point temperature
- **Cloud types**
  - Four categories of common clouds
  - Unusual types

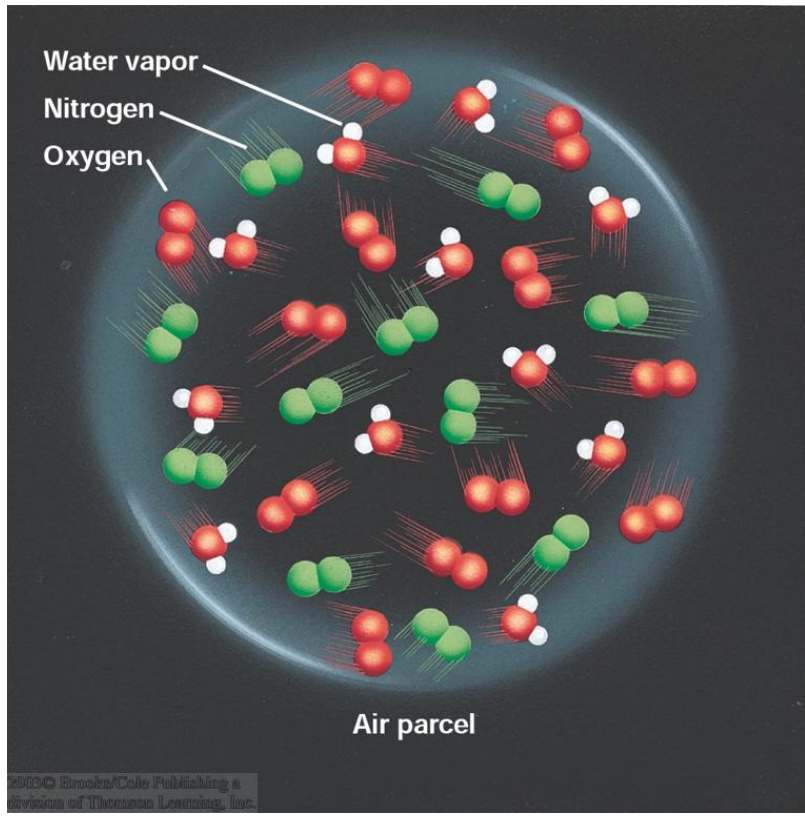
9+ different variables:

1. absolute humidity,
2. specific humidity,
3. **mixing ratio,**
4. **vapor pressure,**
5. **saturation vapor pressure,**
6. **relative humidity,**
7. wet-bulb temperature,
8. **dew point**,
9. frost point,
10. etc., etc., etc.

5 primary moisture variables

- We can whittle this list down!
- The most important variables from the list for this class are these 5:

1. mixing ratio (w),
2. vapor pressure (e),
3. saturation vapor pressure (es),
4. relative humidity (rh), and
5. dew point Td.



Water in the Atmosphere

- Water molecule is 2 H + O atoms
- Water can exist in atmosphere as any of 3 states:
  - gas (vapor);
  - liquid (drops and droplets); and
  - solid (ice).

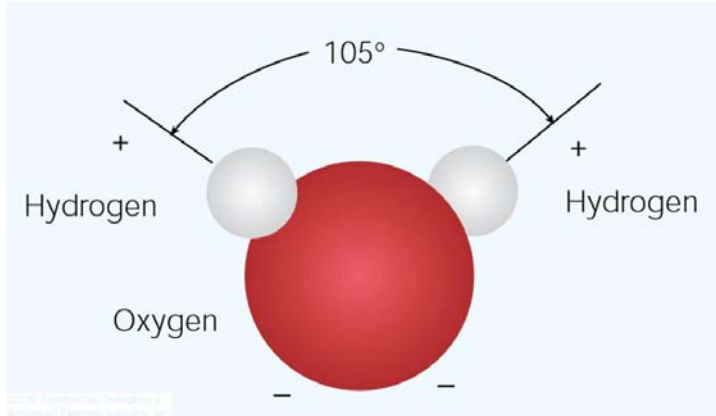


Fig. 5.1

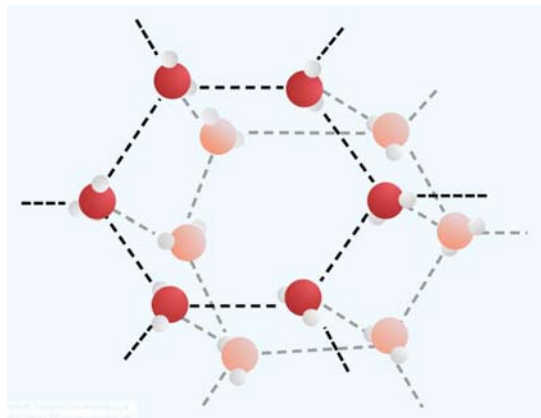


Fig. 5.2

Ice in the Atmosphere – part 1

- Water in solid state combines to form hexagonal (6-sided) shapes

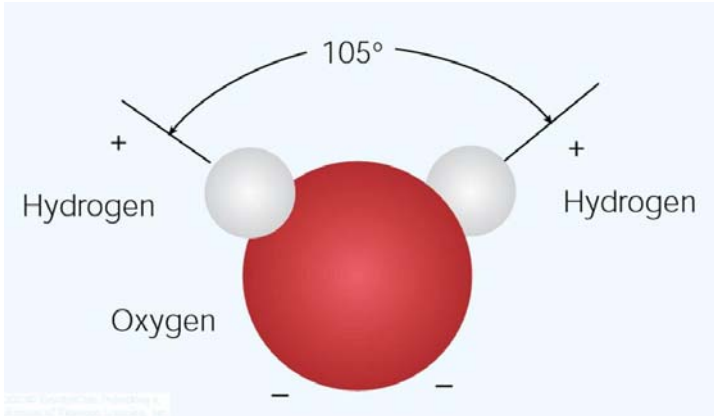
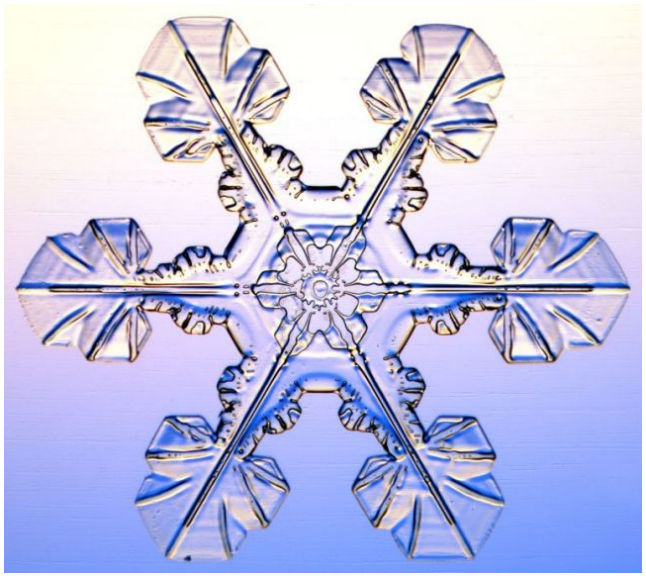


Fig. 5.1



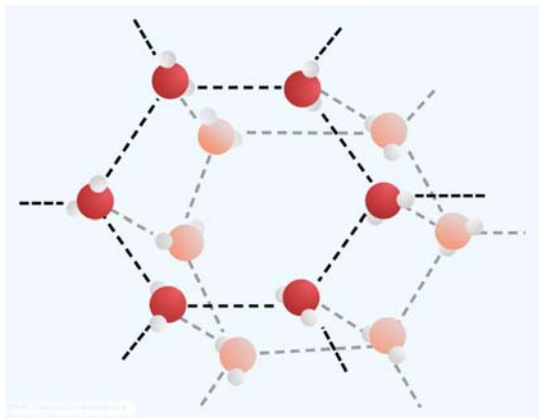
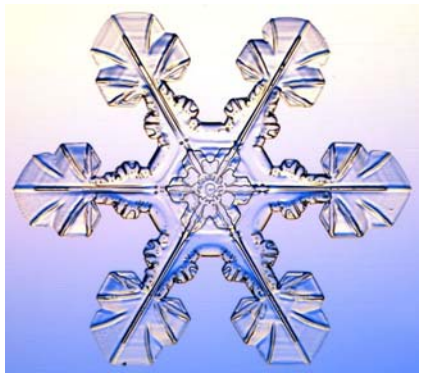
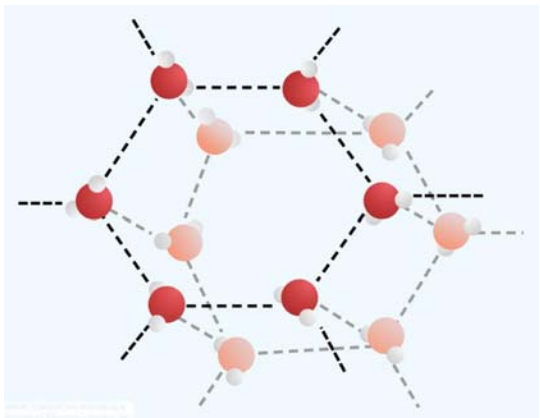


Fig. 5.2

Ice in the Atmosphere – part 2

- Ice has several forms in the atmosphere, all of which have 6-sided symmetry





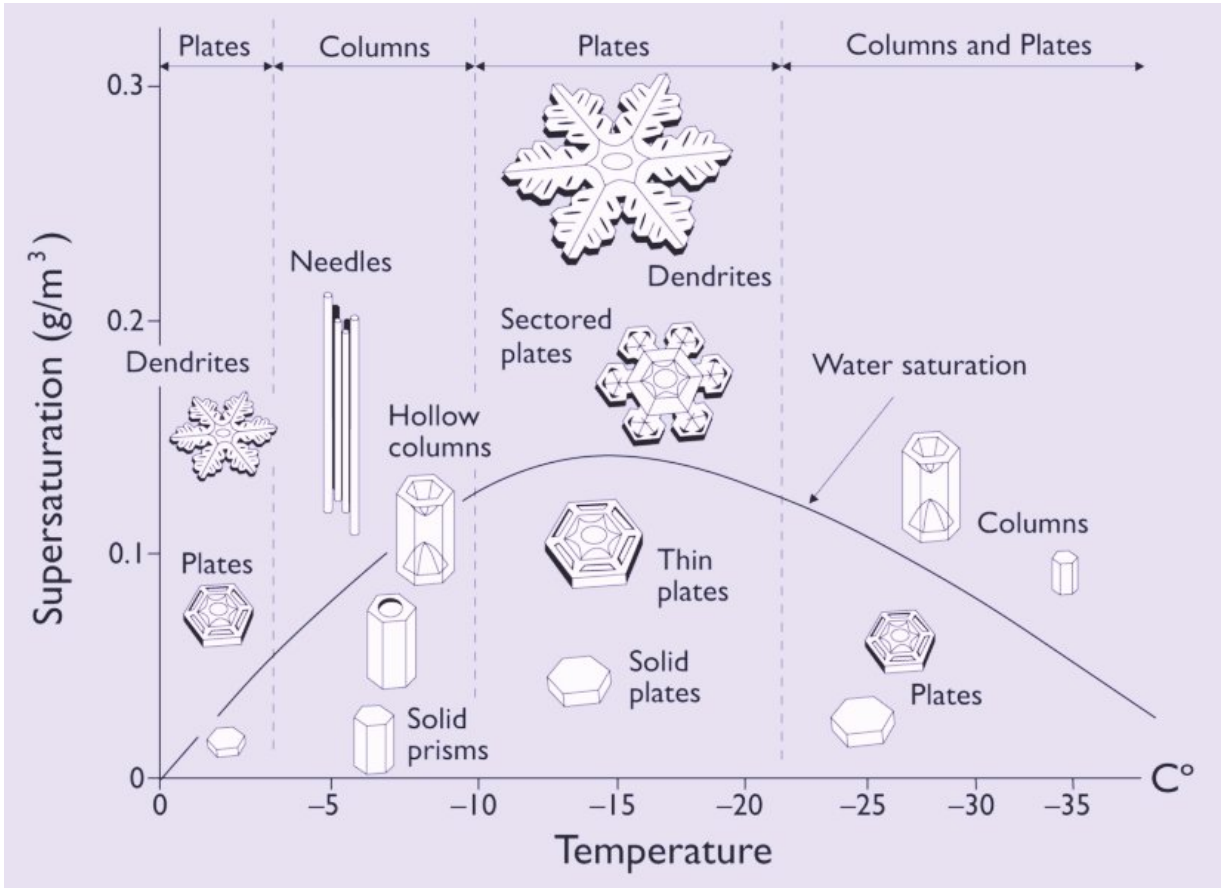
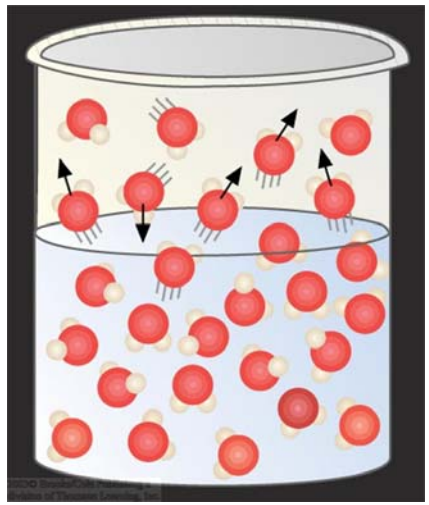
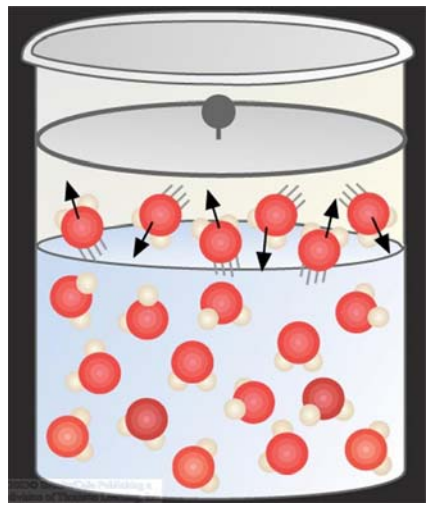


Fig. 5.2

4 Transitions and Saturation

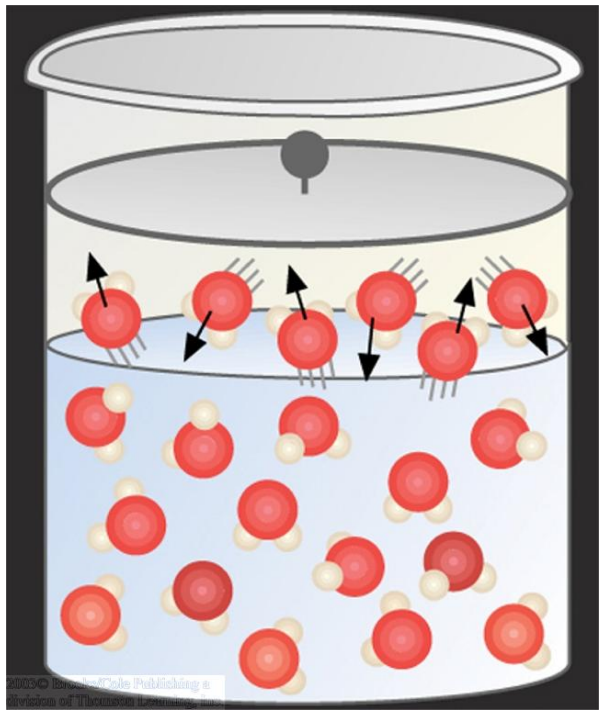
- Water molecules are constantly being exchanged across an interface: Example: air – liquid water - air
- Evaporation: liquid to vapor
- Condensation: vapor to liquid
- Sublimation: solid (ice) to vapor
- Deposition: vapor to solid (ice)
- Saturation: where number of molecules going from one state equals number going the opposite way.





Saturation versus Temperature

- Before a cloud can form, air must become saturated.
- That maximum amount water vapor in the air depends on the temperature
- A parcel of warm air can hold more water vapor than a cold air parcel. Note: the mass of air in the parcel that is not water is the same.
- Important implications for hurricanes



Describing Atmospheric Moisture

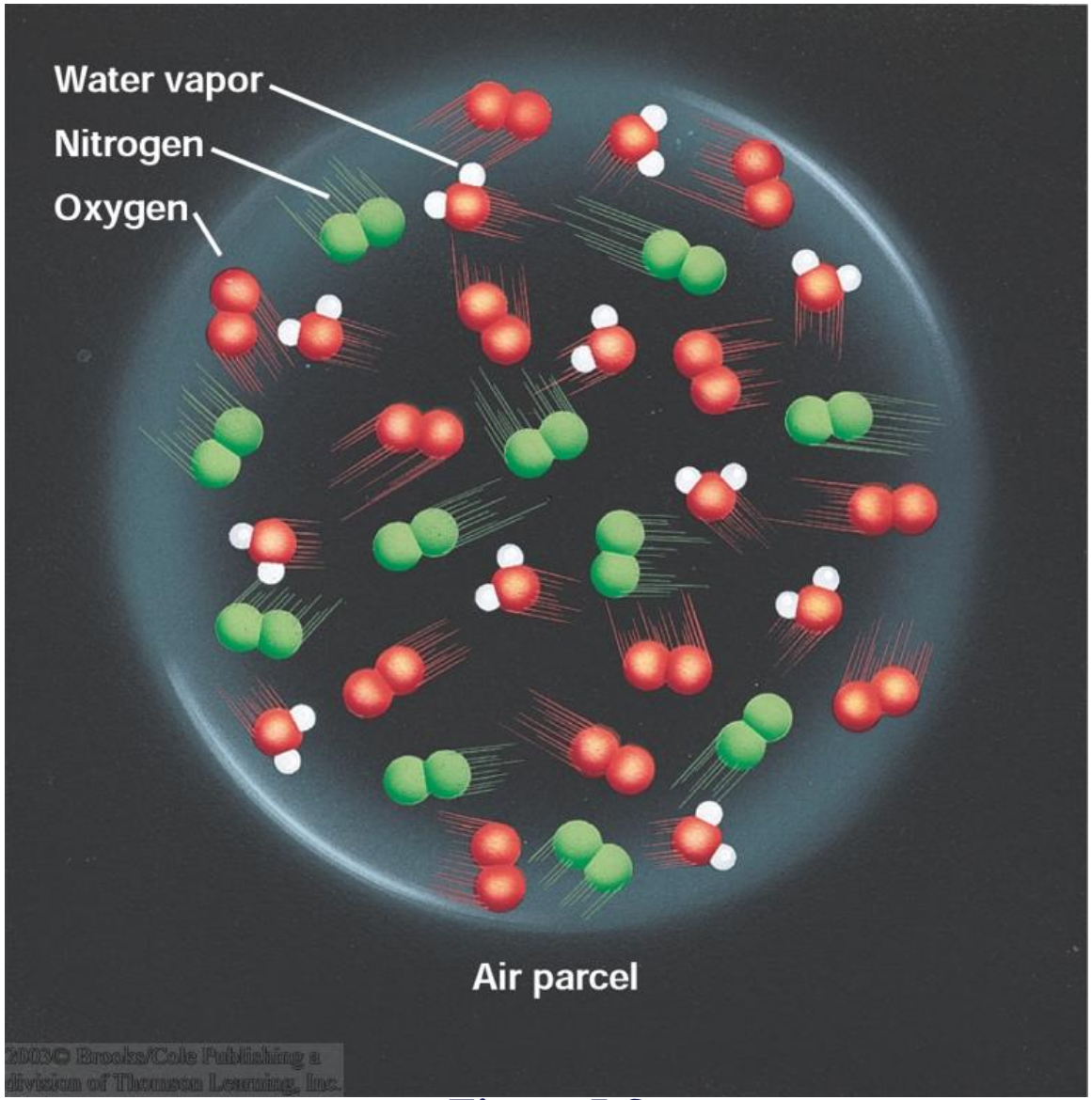


Figure 5.6

Atmospheric water vapor has been defined several different ways.

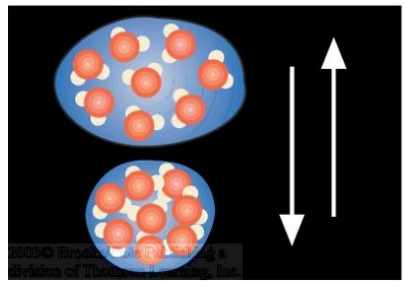
These terms include absolute humidity, specific humidity, mixing ratio, vapor pressure, and relative humidity.

a

Mixing Ratio (w)

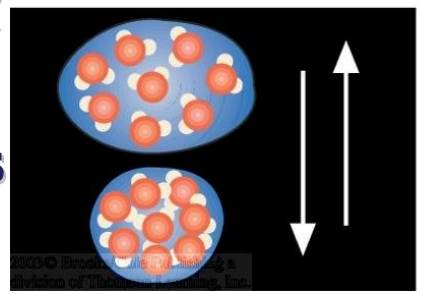
Figure 5.8

Specific humidity equals the mass of vapor divided by total mass of air in a parcel, and is not affected by changes in parcel volume.



Mass of Parcel	Mass of H_2O Vapor	Specific Humidity
1 kg	1 g	1 g/kg
1 kg	1 g	1 g/kg

Mixing Ratio (w) **is the mass of water vapor divided by the mass of DRY air in a given parcel of air. w is not affected by changes in parcel volume.**



Mass of Dry Air	Mass of H_2O Vapor	Mixing Ratio
1 kg	1 g	1 g/kg
1 kg	1 g	1 g/kg

Saturation mixing ratio (w_s) - Clouds

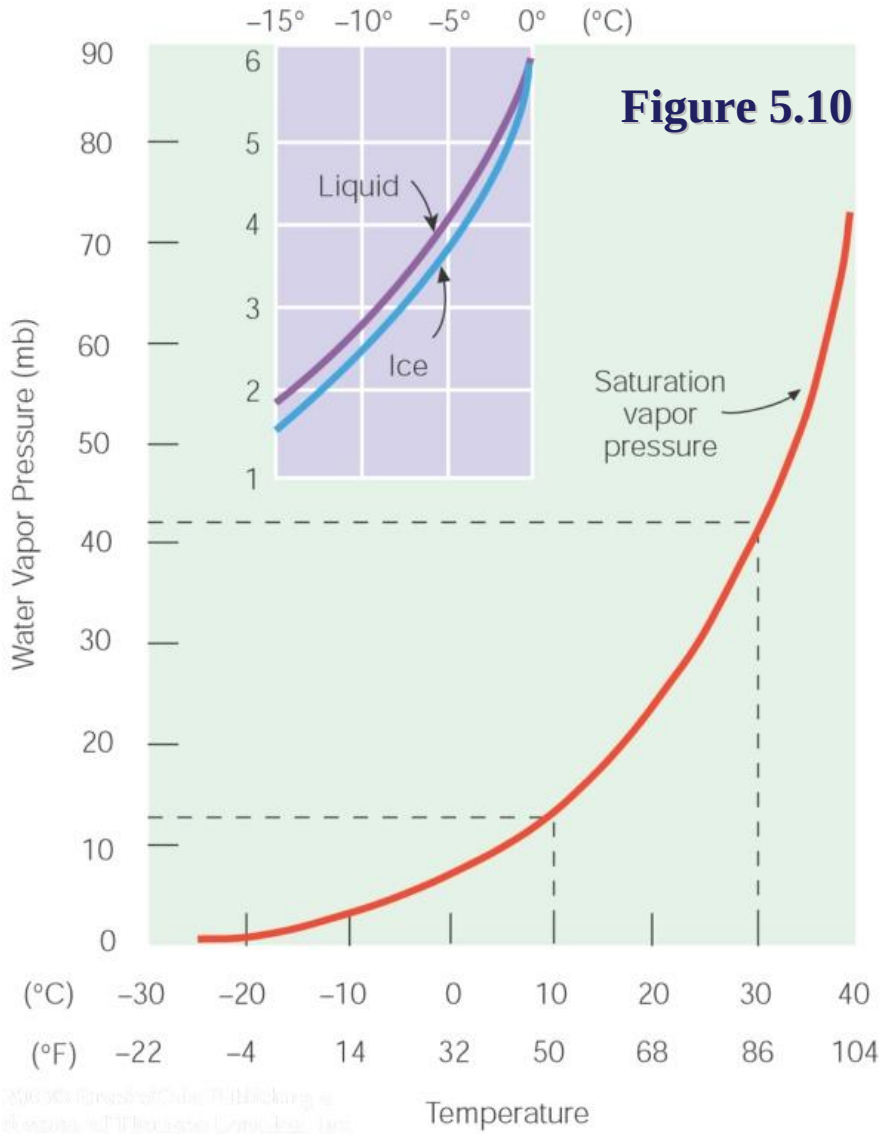
- For air parcel: w is constant whether you warm the air parcel or change its altitude
- The saturation mixing ratio (w_s) is the mixing ratio saturated air would have.
- W_s changes with T and with P
- A cloud forms when a parcel of air changes T and/or P until the mixing ratio equals the saturation mixing ratio.

Vapor pressure (e)

- Recall: Pressure is force per unit area.
- Actual vapor pressure is only that force exerted by the water vapor molecules in a parcel of air. – so, it is independent of the surrounding dry air pressure.
- As temperature goes up, e increases.
- When more water molecules are present, e increases.

Saturation Vapor Pressure (e_s)

- Recall: Pressure is force per unit area.
- Saturation vapor pressure is only that force exerted by the water vapor molecules in a parcel of air – when the air is saturated.
- As temperature goes up, e_s increases.
- When e_s = P (or greater) then water boils



Relative Humidity (rh)

- Measures ratio of number of molecules of water vapor present divided by the number needed for saturation and expressed as a %
- Saturated air as rh = 100%
- $rh = 100 * (w / w_s)$ and $rh = 100 * (e / e_s)$
- Unlike mixing ratio, rh varies as a parcel changes its T, P, and/or altitude.
- Like mixing ratio, rh increases when water molecules added to the air.

Dewpoint - T_d

- Temperature at which air becomes saturated without changing the water vapor present or changing the pressure.
- Important uses:
  - Good indicator of water vapor content of air
  - When T and T_d are similar, rh is high
  - T_d used on charts to see important properties of the air and air parcels.

Test your understanding:

Patagonia T=280, T_d=280

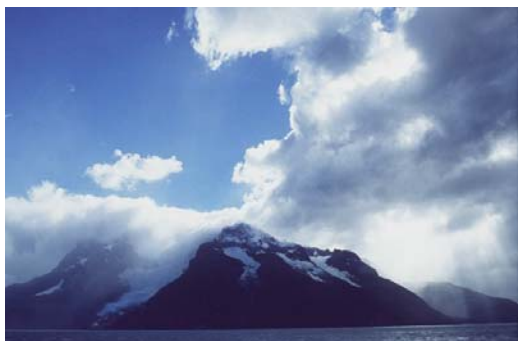
LaCampana T=320 T_d=290

Both sites are near sea level.

1. Which has higher mixing ratio? B
2. Which has higher vapor pressure? B
3. Which has higher rh? A

A: raining in Patagonia

B: sunny La Campana (Chile)



Common Cloud Categories

10 Common Cloud Types

- 10 combinations of these 5 names:
- Cirrus : wispy or hair-like (often high)
- Alto: middle elevation
- Stratus: sheet-like or layered.
- Cumulus: puffy, heaped or vertical~horizontal
- Nimbus: precipitating

4 Common Cloud Groups

Table 6.2 The Four Major Cloud Groups and Their Types

1. High clouds
   - Cirrus (Ci)
   - Cirrostratus (Cs)
   - Cirrocumulus (Cc)
2. Middle clouds
   - Altostratus (As)
   - Altocumulus (Ac)
3. Low clouds
   - Stratus (St)
   - Stratocumulus (Sc)
   - Nimbostratus (Ns)
4. Clouds with vertical development
   - Cumulus (Cu)
   - Cumulonimbus (Cb)

Elevations of Common Cloud Groups

Table 6.3 Approximate Height of Cloud Bases above the Surface for Various Locations

CLOUD GROUP	TROPICAL REGION	MIDDLE LATITUDE REGION	POLAR REGION
High Ci, Cs, Cc	20,000 to 60,000 ft (6,000 to 18,000 m)	16,000 to 43,000 ft (5000 to 13,000 m)	10,000 to 26,000 ft (3000 to 8000 m)
Middle As, Ac	6500 to 26,000 ft (2000 to 8000 m)	6500 to 23,000 ft (2000 to 7000 m)	6500 to 13,000 ft (2000 to 4000 m)
Low St, Sc, Ns	surface to 6500 ft (0 to 2000 m)	surface to 6500 ft (0 to 2000 m)	surface to 6500 ft (0 to 2000 m)

Table 6.2 The Four Major Cloud Groups and Their Types

1. High clouds
   - Cirrus (Ci)
   - Cirrostratus (Cs)
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2. Middle clouds
   - Altostratus (As)
   - Altocumulus (Ac)
3. Low clouds
   - Stratus (St)
   - Stratocumulus (Sc)
   - Nimbostratus (Ns)
4. Clouds with vertical development
   - Cumulus (Cu)
   - Cumulonimbus (Cb)

*Un*common Cloud Categories

Table 6.4 Common Terms Used in Identifying Clouds

TERM	LATIN ROOT AND MEANING	DESCRIPTION
Lenticularis	(*lens, lenticula,* lentil)	Clouds having the shape of a lens or an almond, often elongated and usually with well-defined outlines. This term applies mainly to cirrocumulus, altocumulus, and stratocumulus
Fractus	(*frangere,* to break or fracture)	Clouds that have a ragged or torn appearance; applies only to stratus and cumulus
Humilis	(*humilis,* of small size)	Cumulus clouds with generally flattened bases and slight vertical growth
Congestus	(*congerere,* to bring together; to pile up)	Cumulus clouds of great vertical extent that from a distance may resemble a head of cauliflower
Calvus	(*calvus,* bald)	Cumulonimbus in which at least some of the upper part is beginning to lose its cumuliform outline
Capillatus	(*capillus,* hair; having hair)	Cumulonimbus characterized by the presence in the upper part of cirriform clouds with fibrous or striated structure
Undulatus	(*unda,* wave; having waves)	Clouds in patches, sheets, or layers showing undulations
Translucidus	(*translucere,* to shine through; transparent)	Clouds that cover a large part of the sky and are sufficiently translucent to reveal the position of the sun or moon
Incus	(*incus,* anvil)	The smooth cirriform mass of cloud in the upper part of a cumulonimbus that is anvil-shaped
Mammatus	(*mamma,* mammary)	Baglike clouds that hang like a cow's udder on the underside of a cloud; may occur with cirrus, altocumulus, altostratus, stratocumulus, and cumulonimbus
Pileus	(*pileus,* cap)	A cloud in the form of a cap or hood above or attached to the upper part of a cumuliform cloud, particularly during its developing stage
Castellanus	(*castellum,* a castle)	Clouds that show vertical development and produce towerlike extensions, often in the shape of small castles

Water versus Ice Cloud

Florida Everglades © R. Grotjahn

Photo © R. Grotjahn

Cirrus Types

© R. Grotjahn

Desolation Pks, CA © R. Grotjahn

Altocumulus

Mt. Rainer © R. Grotjahn

Stratus

Wairikori Beach New Zealand © R. Grotjahn

Big Sur, CA © R. Grotjahn

Altostratus & stratus

Nimbostratus

Paria Canyon © R. Grotjahn

Wilson’s Prom, Australial© R. Grotjahn

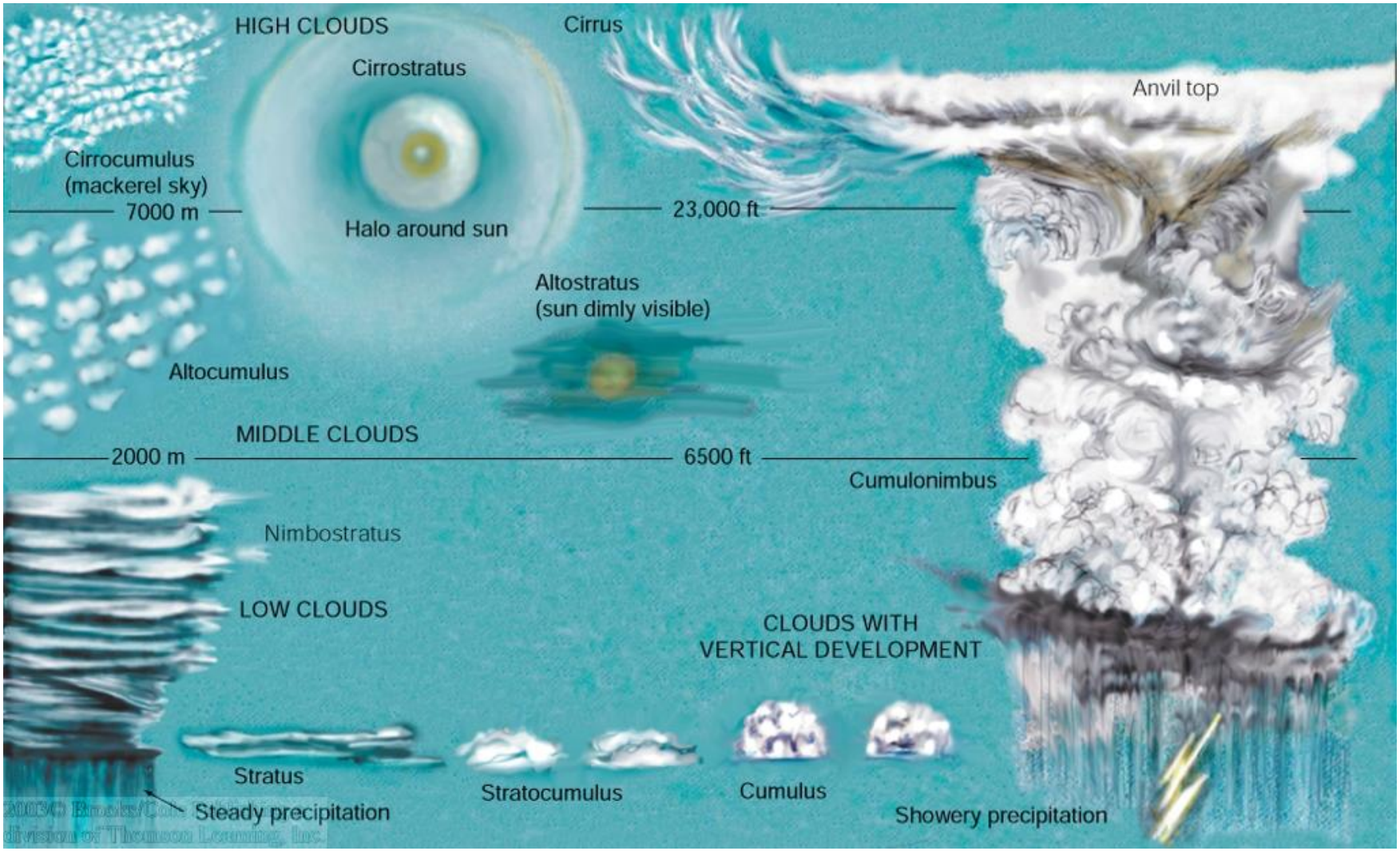
Mt. Cook, NZ © R. Grotjahn

Stratocumulus, cumulus

Photo © R. Grotjahn

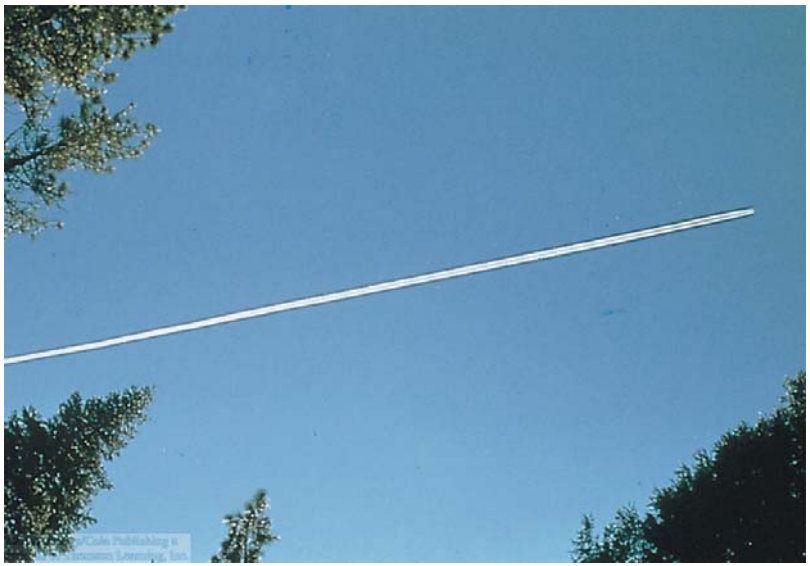
Cumulus congestus, cumulonimbus

Summary of major cloud types



Odd clouds – Part 1

Noctilucent clouds



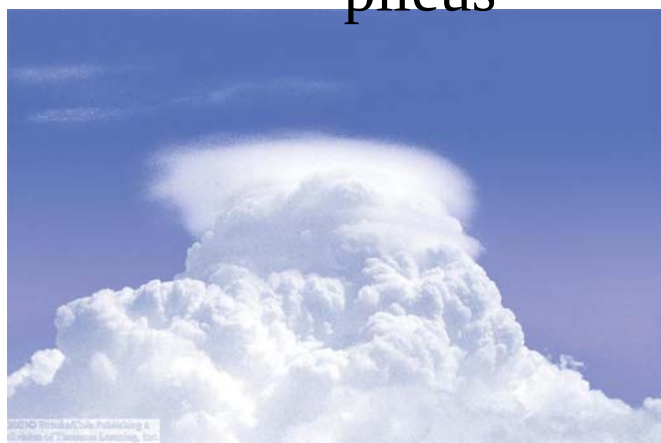
Nacreous clouds

Odd clouds: Forced-uplift clouds

Wasatch Front UT © R. Grotjahn

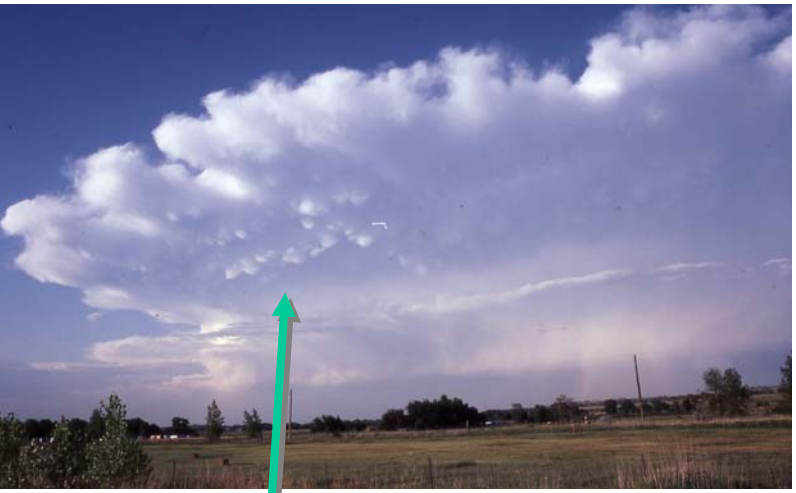
Gibraltor © R. Grotjahn

pileus



Odd clouds: severe weather

Marshall CO © R. Grotjahn



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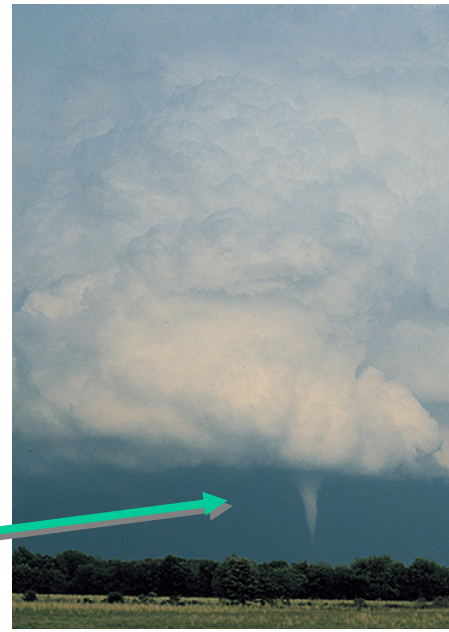

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Most Common: Altocumulus

Catskill Creek. T. Cole

End of lecture 3