Mid-Term Review
AOSC 200

Tim Canty

Class Web Site: http://www.atmos.umd.edu/~tcanty/aosc200

Topics for today:

Review
Review
Review
Review

Lecture 15
Oct 15 2019

What to study?

One way to break down the semester

1. Atmospheric Variables
2. Composition
3. Energy
4. Water

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One way to break down the semester

1. Atmospheric Variables
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Meteorological Observations

Temperature: A measure of the kinetic energy of molecules

Kinetic Energy: energy of motion

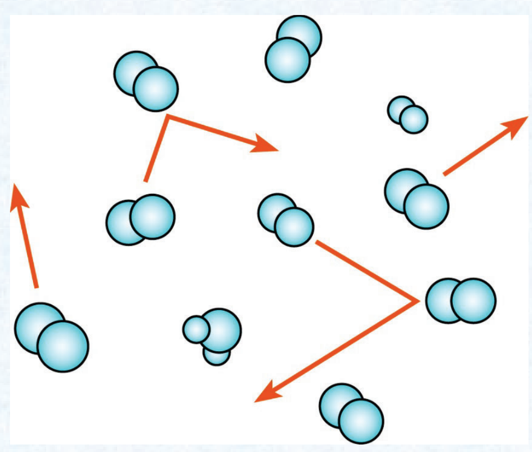


Fig 1-1 *Weather: A Concise Introduction*

Meteorological Observations

Celsius: melting point of water is 0°C and the boiling point is 100°C.

Fahrenheit: melting point of water is 32°F and the boiling point is 212°F.

Kelvin: similar to Celsius but the coldest temperature is 0K. (Kelvin scale never goes negative)

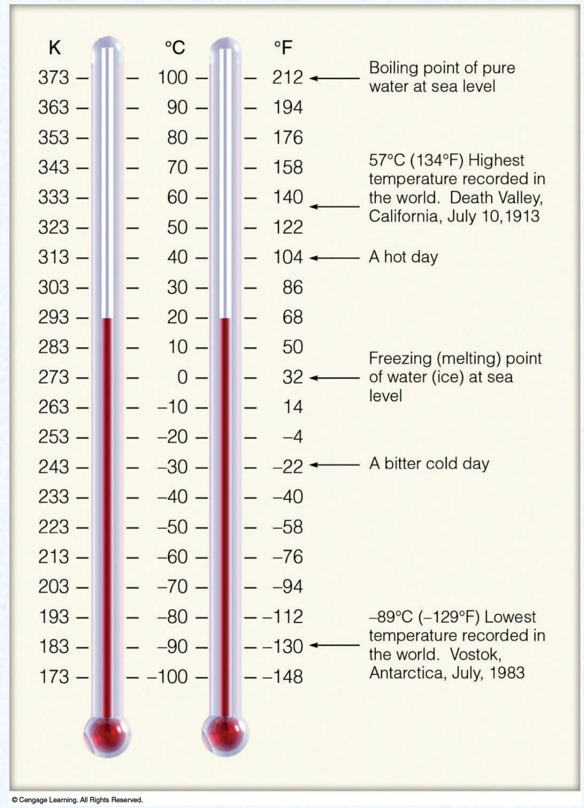


Fig 2.2: ***Essentials of Meteorology***

Understanding Pressure

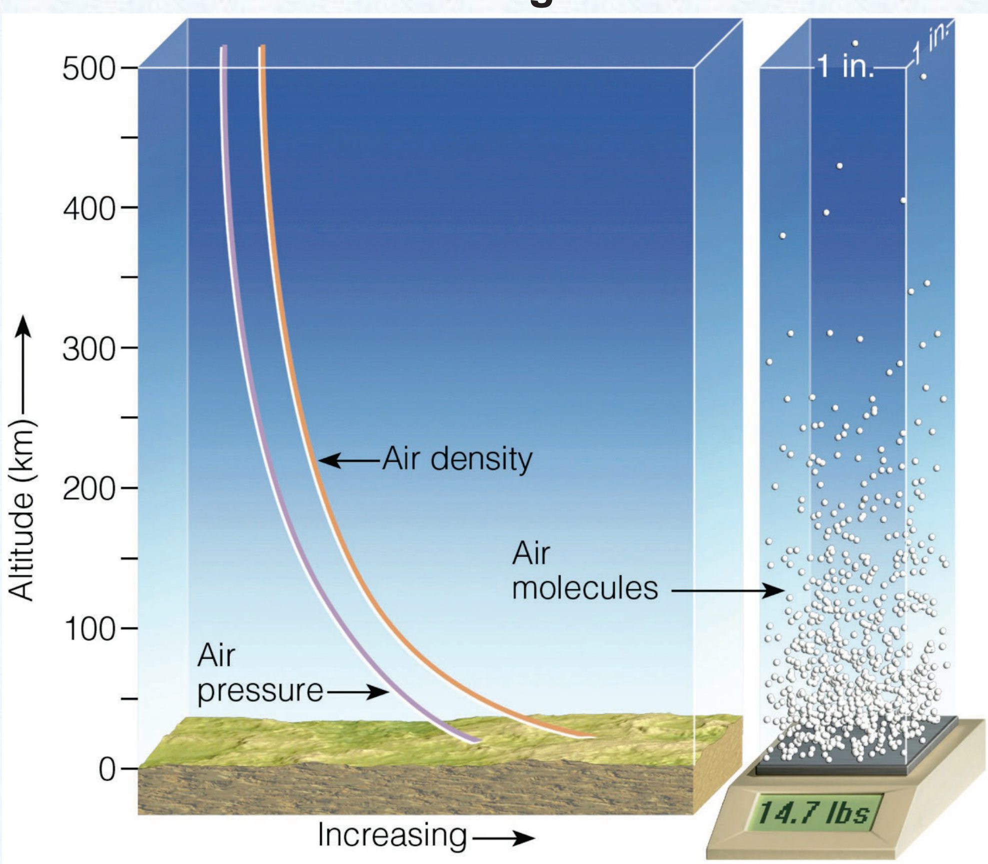


Fig 1.7: ***Essentials of Meteorology***

Weather Station Model

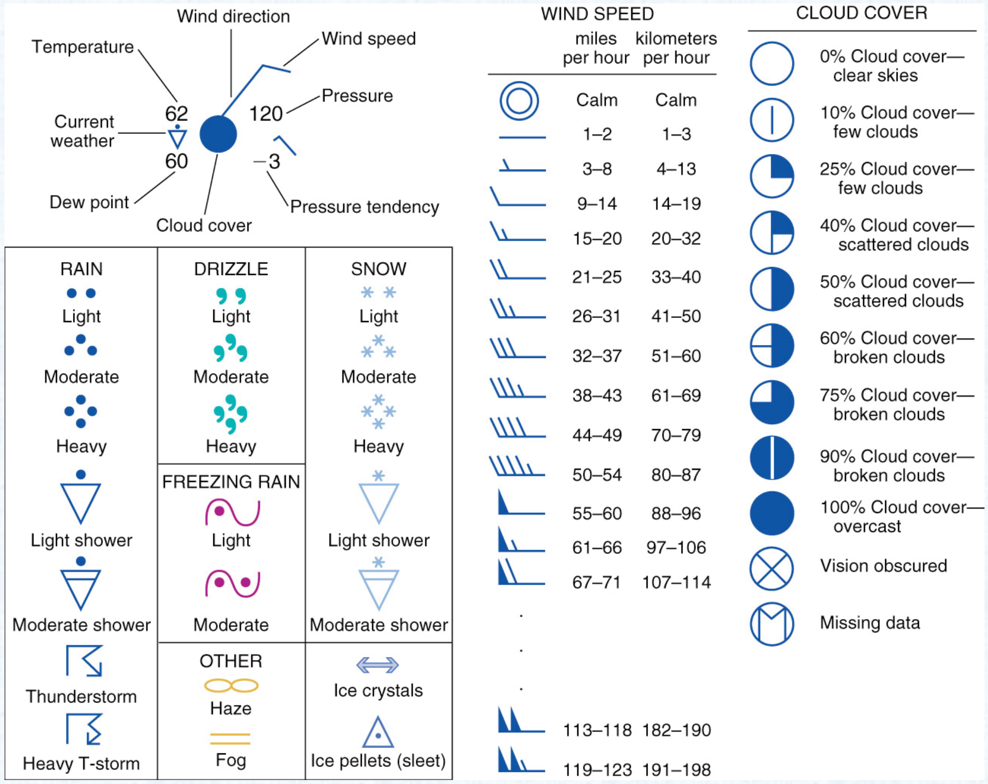
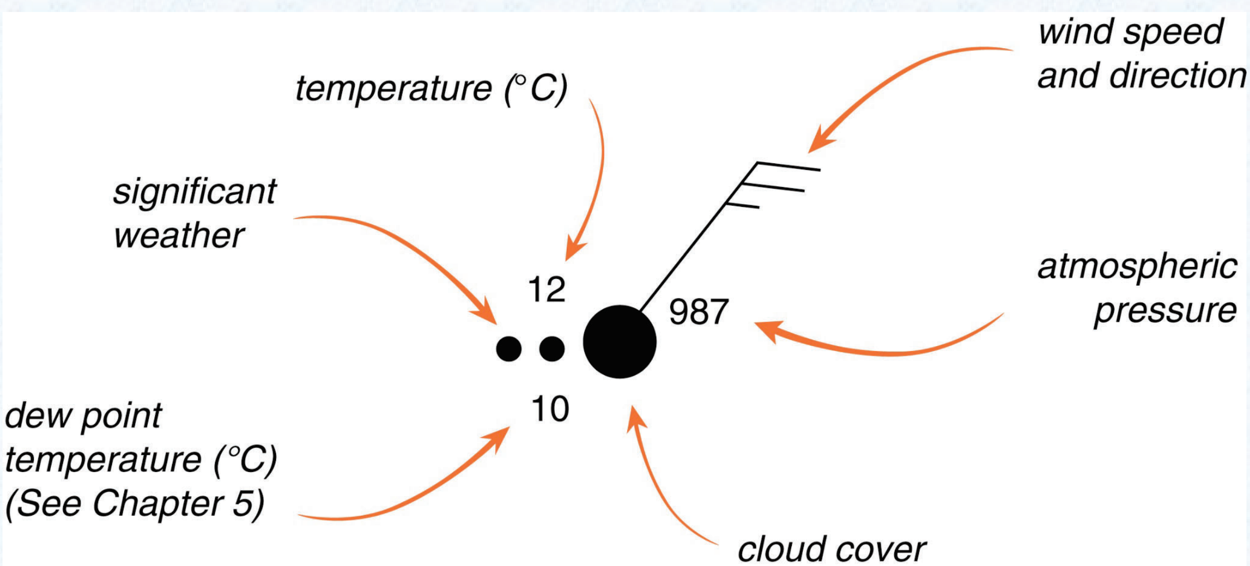


Fig 1-17 *Meteorology: Understanding the Atmosphere*

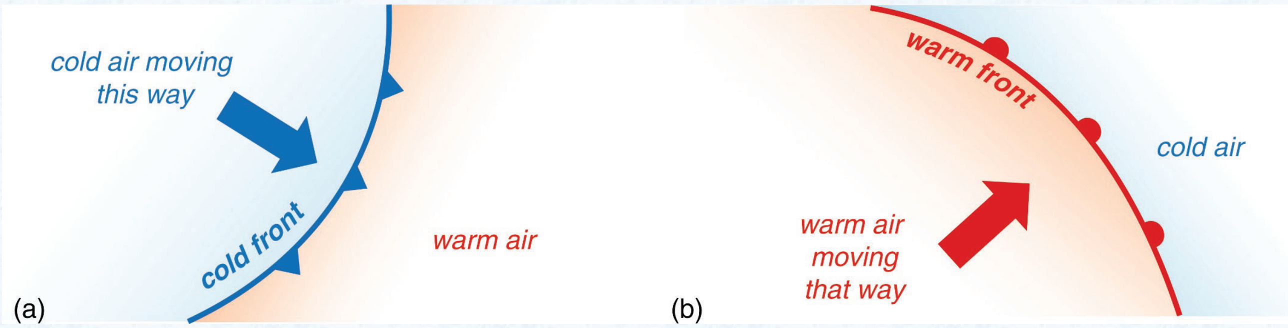
Weather Station Model



The weather station model tells you what the conditions are like at the surface

Fig 2-1-1 *Weather: A Concise Introduction*

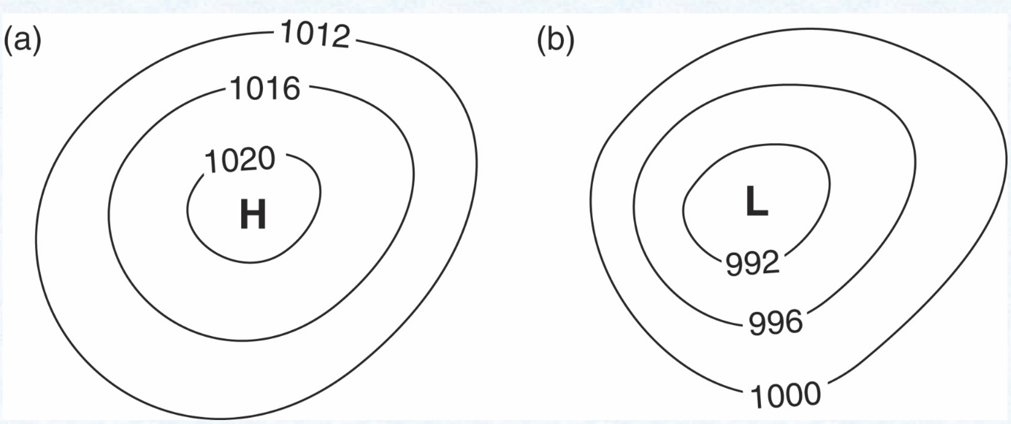
Temperature Fronts



Recognize the fronts by the symbols!!! You might have a black and white map (like on a test….hint hint!!) and can't rely on the colors to tell you which type of front you're looking at.

Fig 2-3 *Weather: A Concise Introduction*

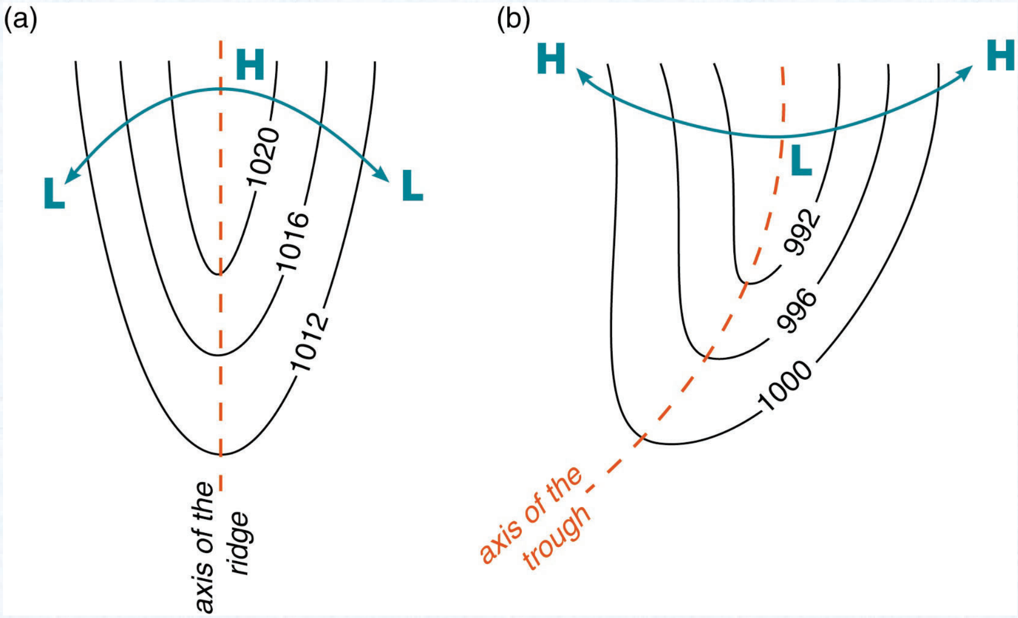
Pressure Maps



Closed contours define regions of high pressure and low pressure.

Fig 2-5 *Weather: A Concise Introduction*

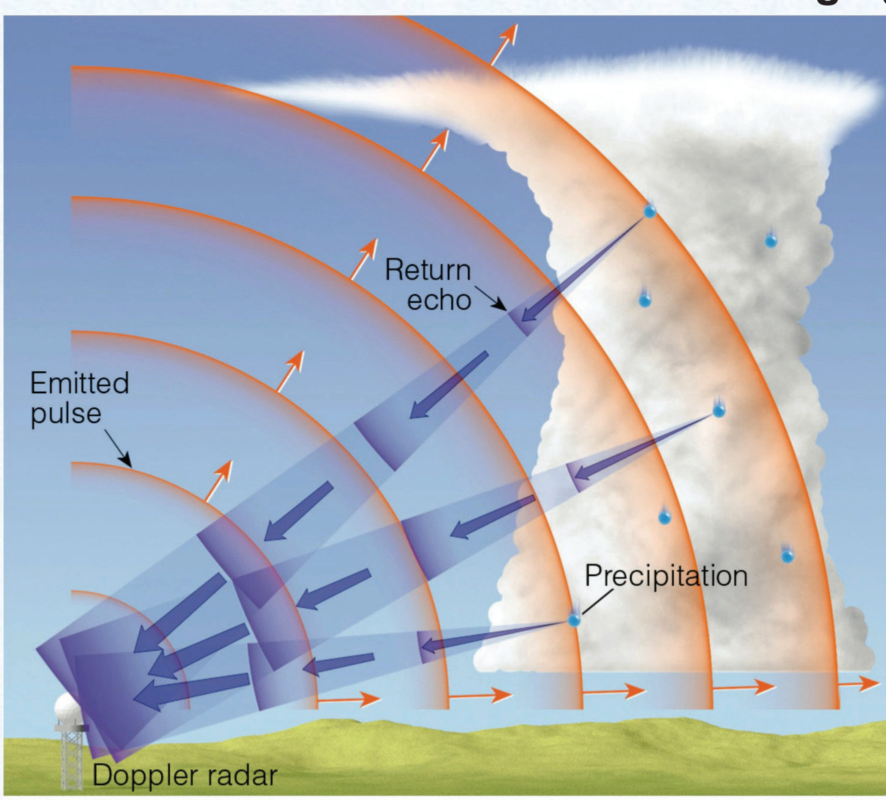
Pressure Maps



Isobars that aren't closed can still help us define regions of increasing ("ridges") and decreasing ("troughs") pressure.

Fig 2-6 *Weather: A Concise Introduction*

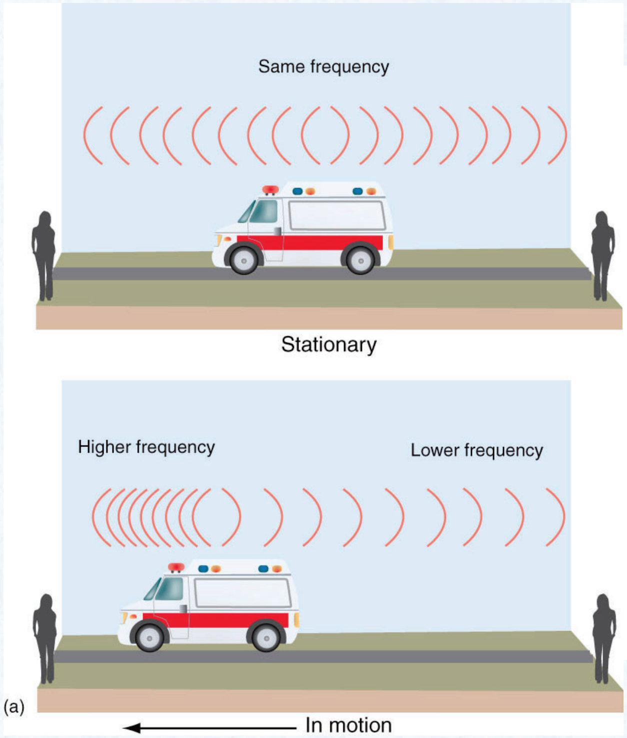
RADAR: RAdio Detection and Ranging

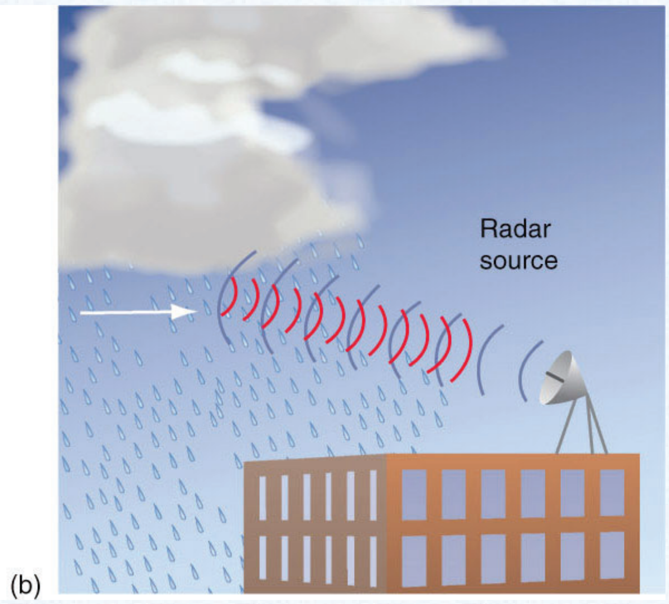


RADAR measures the time it takes for the signal to return

Fig 5.45: *Essentials of Meteorology*

RADAR: RAdio Detection and Ranging
Doppler

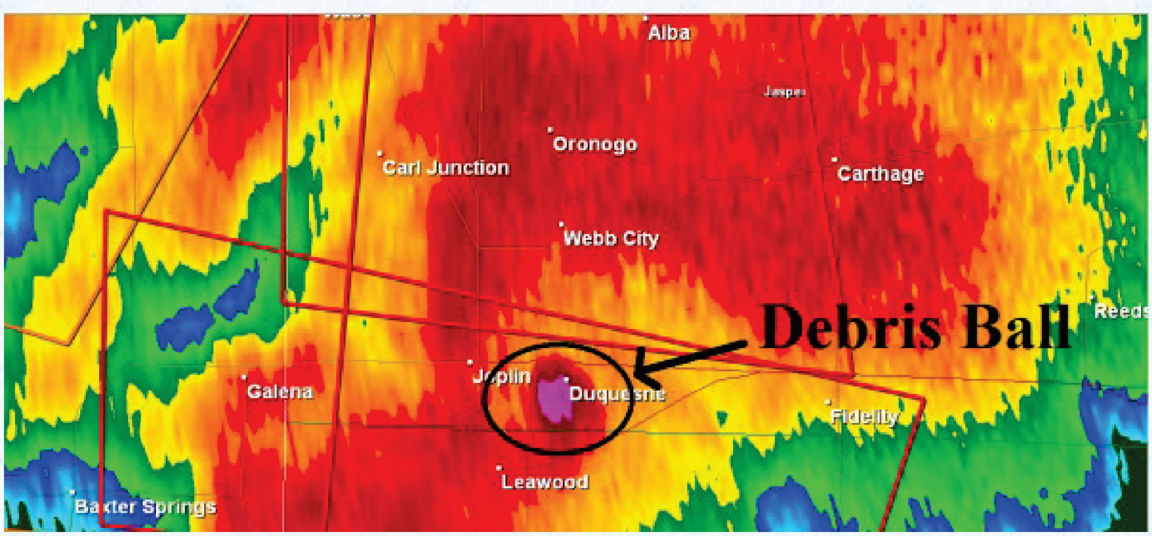




Doppler RADAR measures changes in the return signal

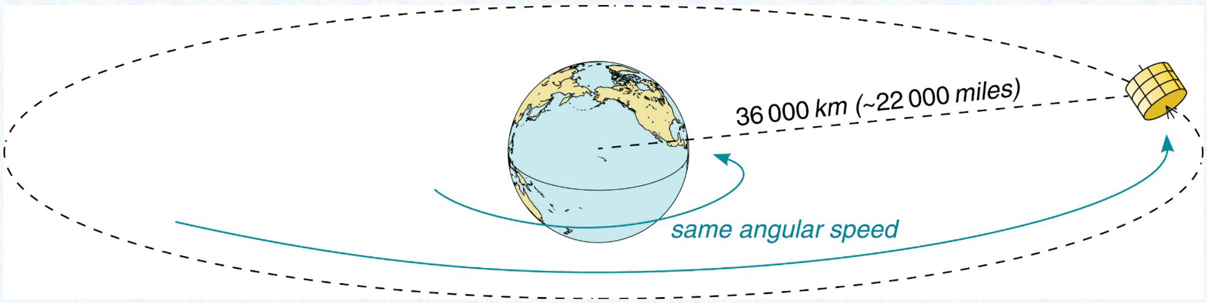
Fig 5-22 *Meteorology: Understanding the Atmosphere*

RADAR: RAdio Detection and Ranging
Dual Polarization



Can provide information about precipitation types
rain, hail, snow, sleet

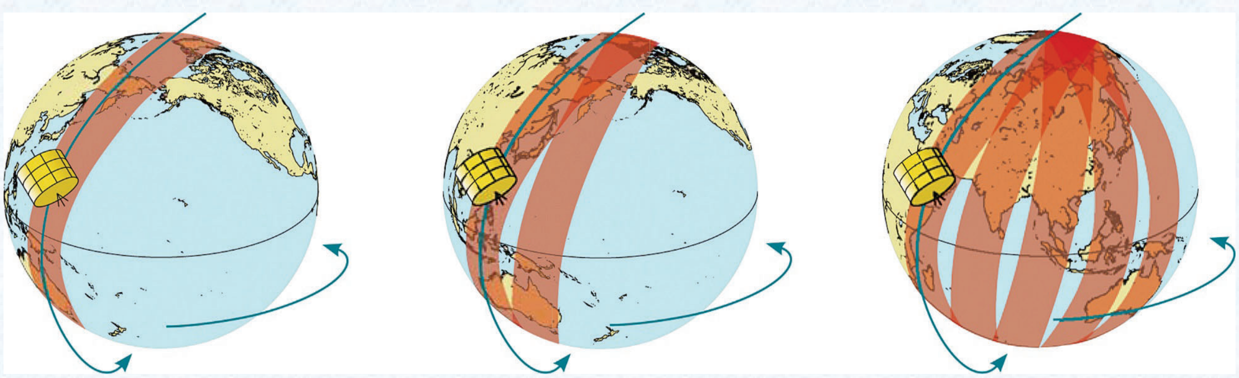
http://earthsky.org/earth/nws-upgrades-to-dual-polarization-radar-for-better-look-at-precipitation-tornadoes



Geostationary satellites: Orbits the Earth at the same angular speed as the Earth. They are “parked” in orbit over Earth and stay over the same location.

Provide a lot of information at all times but only at one location and have difficulty seeing the polar regions…

Fig 2-19 *Weather: A Concise Introduction*



Polar orbiting satellites: Travel over the poles. Orbits wrap around the Earth. Need to travel quickly to provide cover the globe. Can be very high resolution because they orbit closer to the surface than geostationary satellites

Problems: Data gaps in time and space.

Fig 2-24 *Weather: A Concise Introduction*

Satellite Imagery: Visible

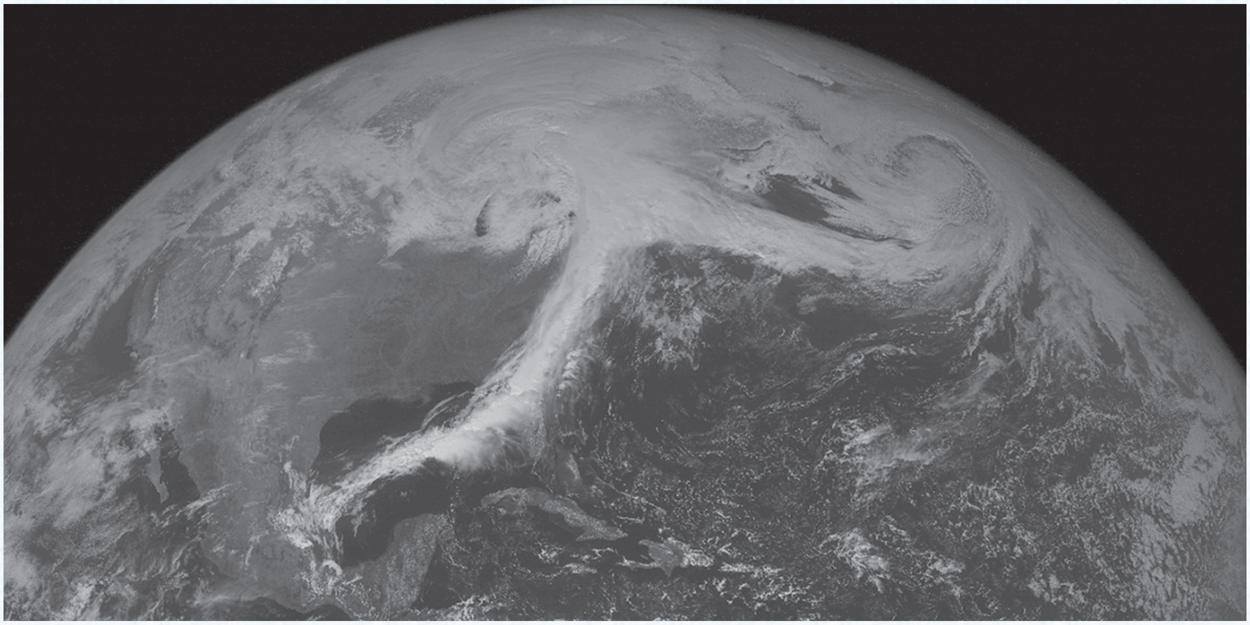


Fig 2-13 *Weather: A Concise Introduction*

Satellite Imagery: Infrared (heat)

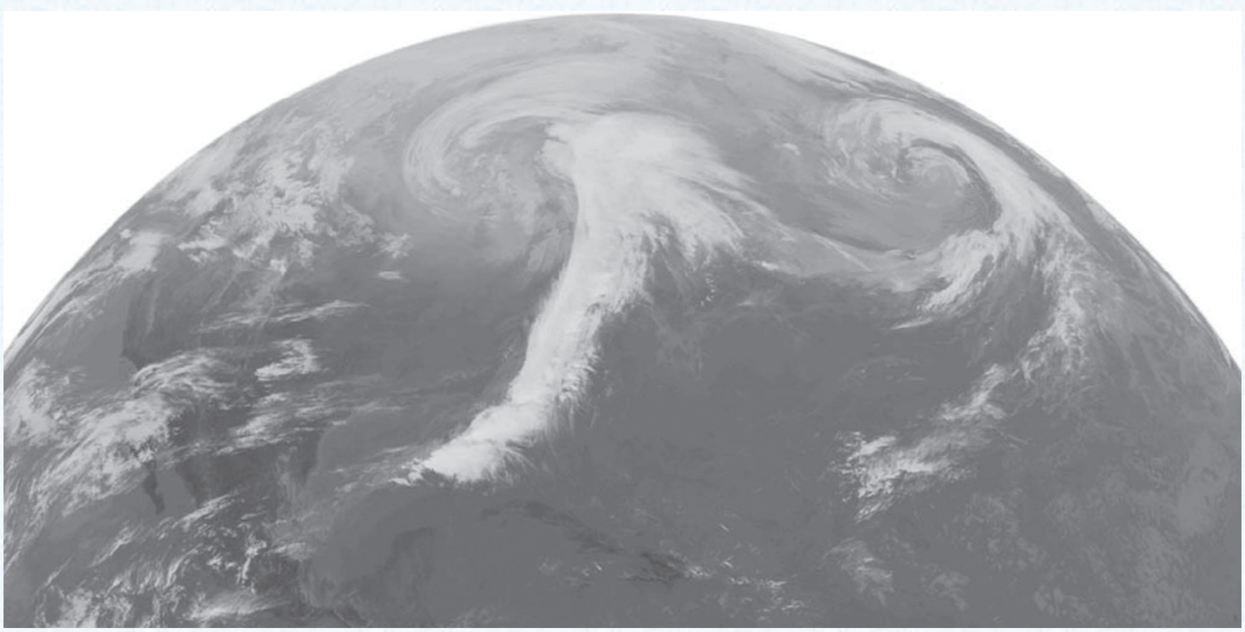


Fig 2-14 *Weather: A Concise Introduction*

Satellite Imagery: Water Vapor

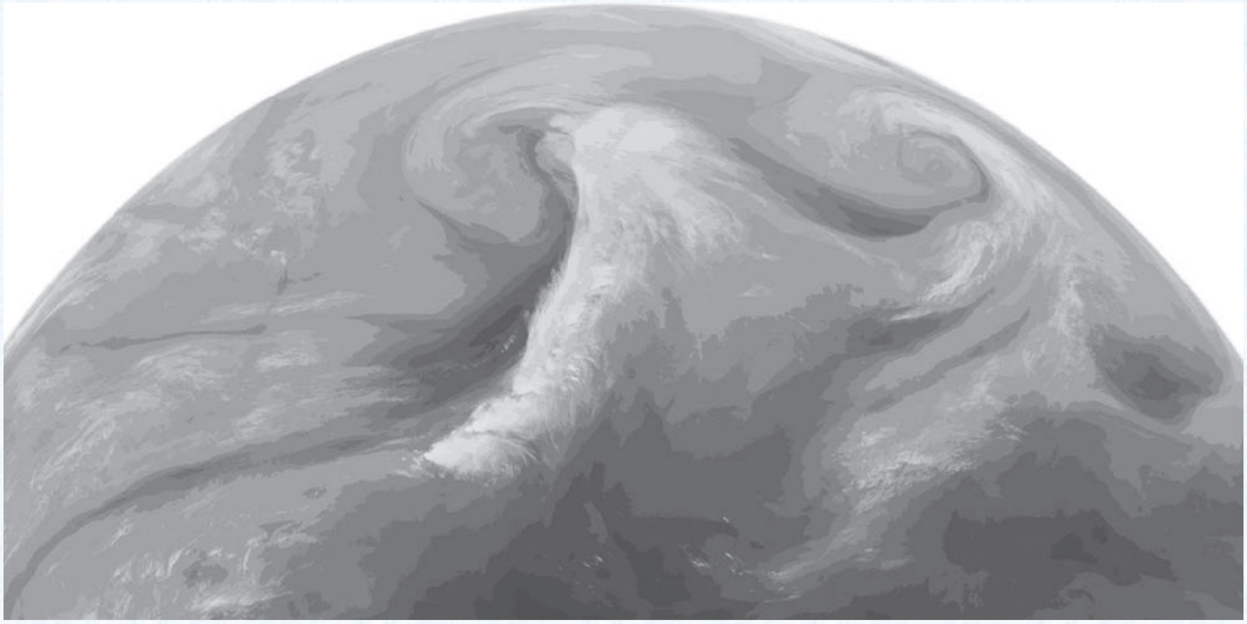


Fig 2-18 *Weather: A Concise Introduction*

What to study?

One way to break down the semester

1. Atmospheric Variables
2. **Composition**
3. Energy
4. Water

Atmospheric Composition (What are you breathing?)

TABLE 1.1 Composition of the Atmosphere near the Earth's Surface

PERMANENT GASES			VARIABLE GASES			
Gas	Symbol	Percent (by Volume) Dry Air	Gas (and Particles)	Symbol	Percent (by Volume)	Parts per Million (ppm)
Nitrogen	N_2	78.08	Water vapor	H_2O	0 to 4	
Oxygen	O_2	20.95	Carbon dioxide	CO_2	0.040	400*
Argon	Ar	0.93	Methane	CH_4	0.00018	1.8
Neon	Ne	0.0018	Nitrous oxide	N_2O	0.00003	0.3
Helium	He	0.0005	Ozone	O_3	0.000004	0.04**
Hydrogen	H_2	0.00006	Particles (dust, soot, etc.)		0.000001	0.01–0.15
Xenon	Xe	0.000009	Chlorofluorocarbons (CFCs)		0.00000002	0.0002

*For CO_2, 400 parts per million means that out of every million air molecules, 400 are CO_2 molecules.

**Stratospheric values at altitudes between 11 km and 50 km are about 5 to 12 ppm.

99.96% of the atmosphere "permanent gases"

Table 1.1: ***Essentials of Meteorology***

Atmospheric Composition (What are you breathing?)

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Helium	He	0.0005	Ozone	O_3	0.000004	0.04**
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These gases control the chemistry of the atmosphere "variable gases" or "trace gases"

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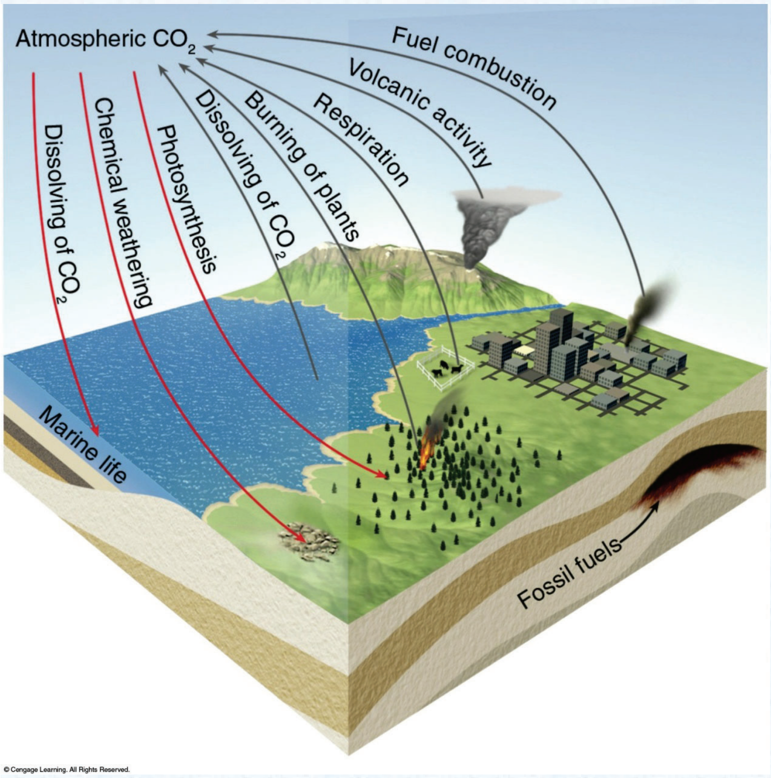
Table 1.1: ***Essentials of Meteorology***

Carbon Dioxide (CO_2) Cycle



One of the most talked about Greenhouse Gases.

Some CO_2 is produced naturally

Some CO_2 produced by human activity (anthropogenic)

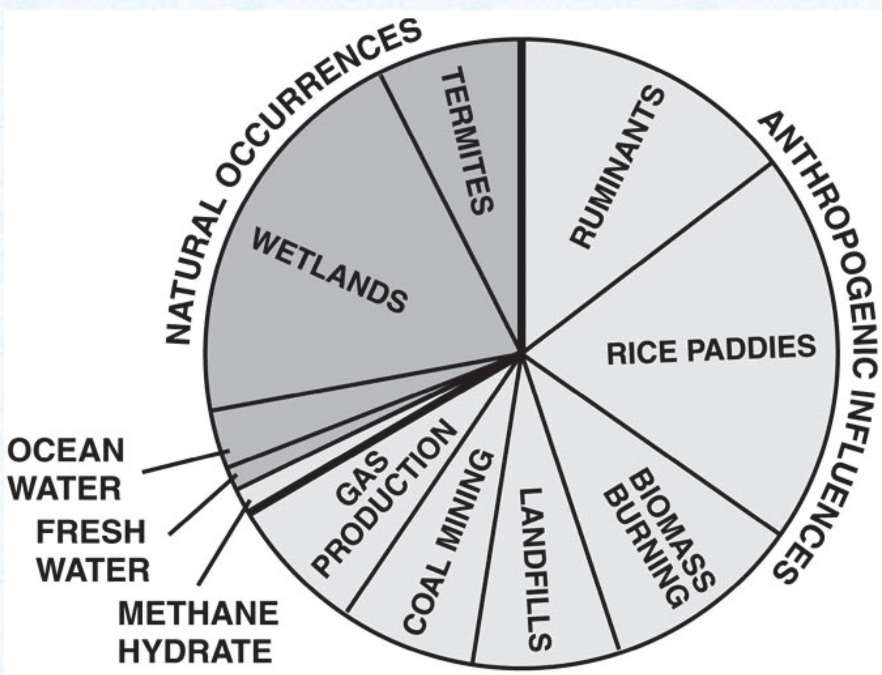
Once in the air, some CO_2:

- stays there
- goes into ocean
- goes into land

CO_2 stays in the air for ~200yrs

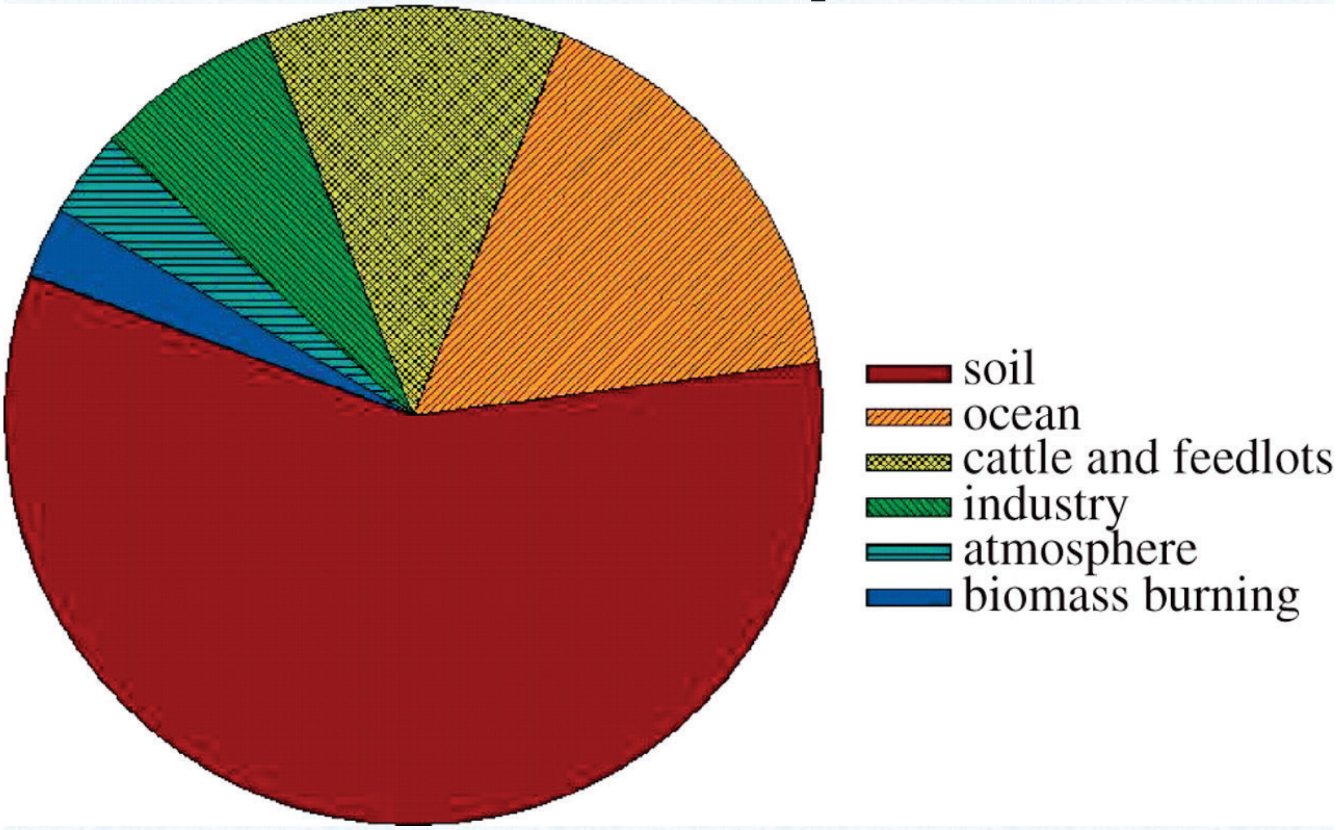
Fig 1.3: *Essentials of Meteorology*

Methane Sources and Sinks



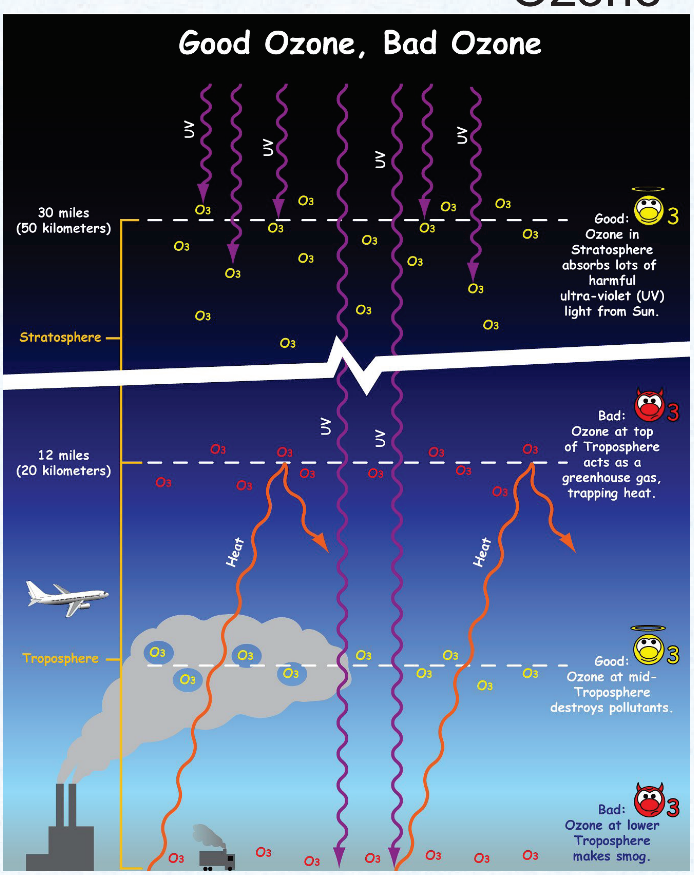
http://www.giss.nasa.gov/research/features/200409_methane/

Nitrous Oxide (N_2O)



http://rstb.royalsocietypublishing.org/content/367/1593/1157

Ozone



Absorbs UV radiation

Smog!!!

http://www.aoas.org/article.php?story=20080522125225466

Atmospheric temperature

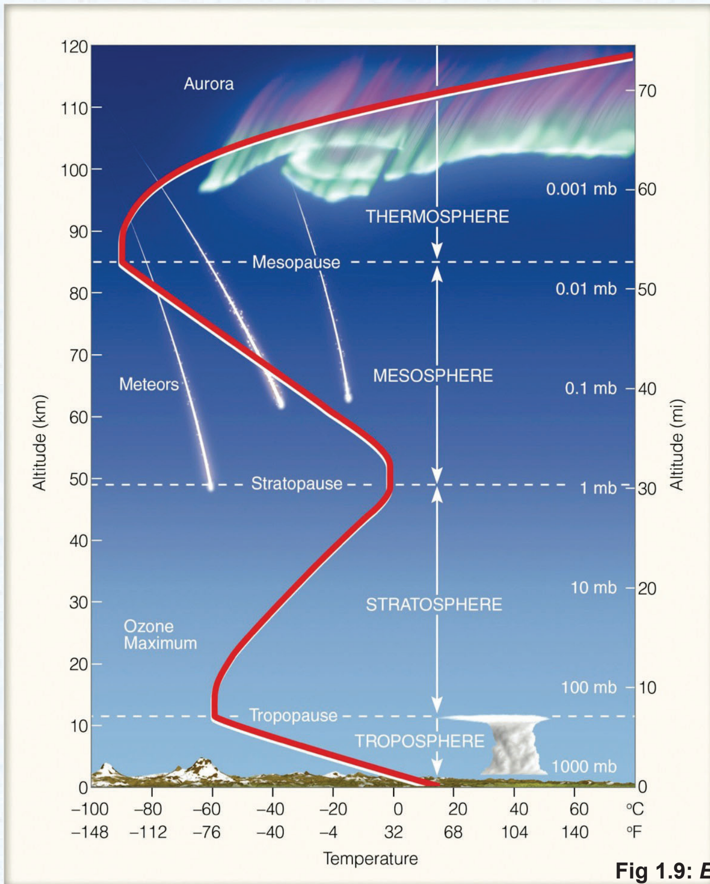


Fig 1.9: ***Essentials of Meteorology***

What to study?

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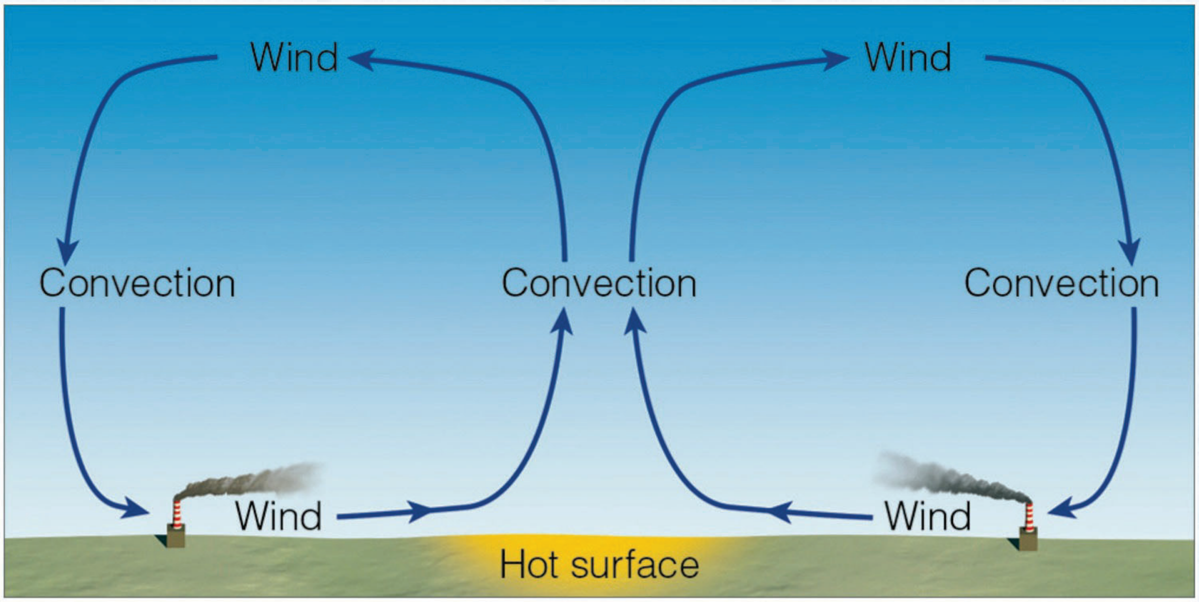
Energy Transfer: Conduction

- Conduction – requires contact, energy transferred from molecule to molecule
- Air is not a good conductor
- Metals are excellent conductors
- Very important at Earth's surface

Energy Transfer: Convection

- Convection – energy transferred by vertical movement of fluids (air is considered a fluid)
- Surface energy transferred upward by convection
- "Hot air rises and cool air sinks"
- Lava lamps are a good example of convection

Energy Transfer: Convection



Rising, hot air creates convective circulation

Thermals will eventually spread out, sink and move back to the starting point creating wind

Fig 2.7: *Essentials of Meteorology*

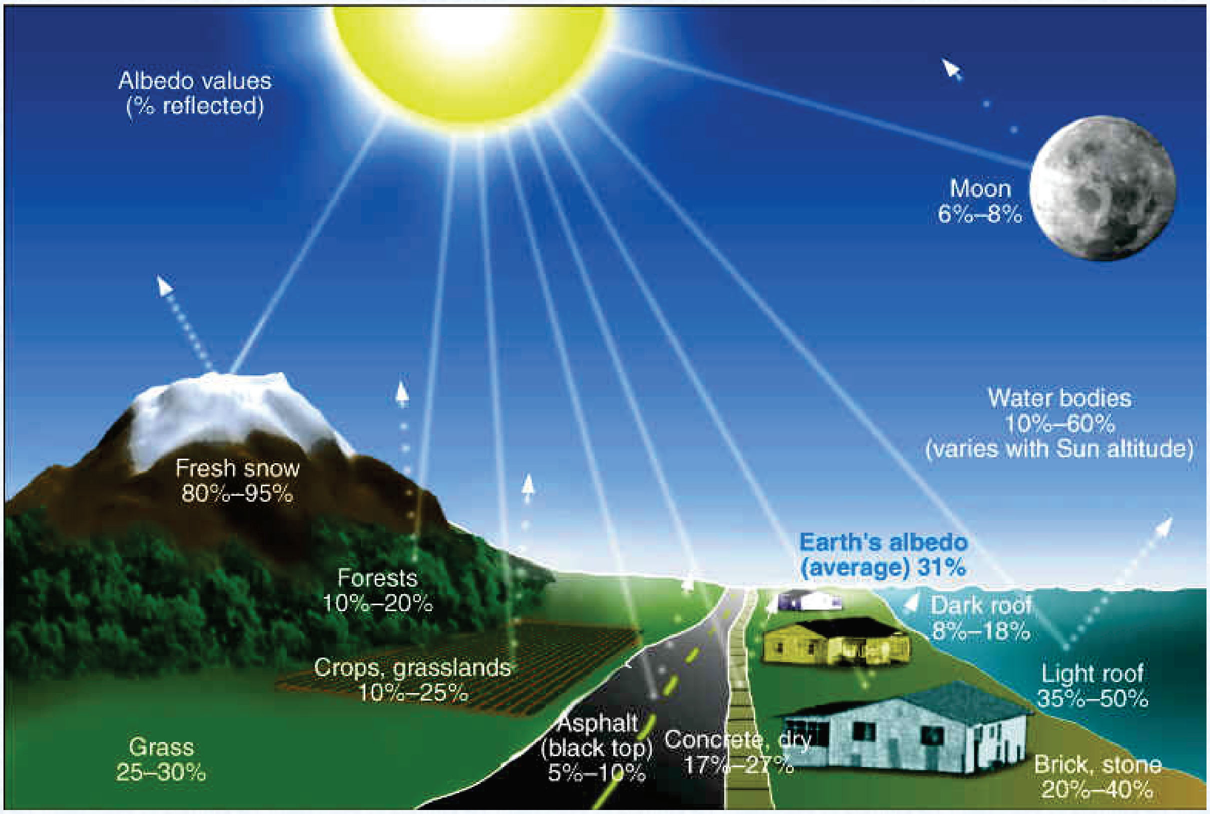
Energy Transfer: Radiation

Radiative Heat – heating due to electromagnetic radiation (waves of energy that move through space

Can be:

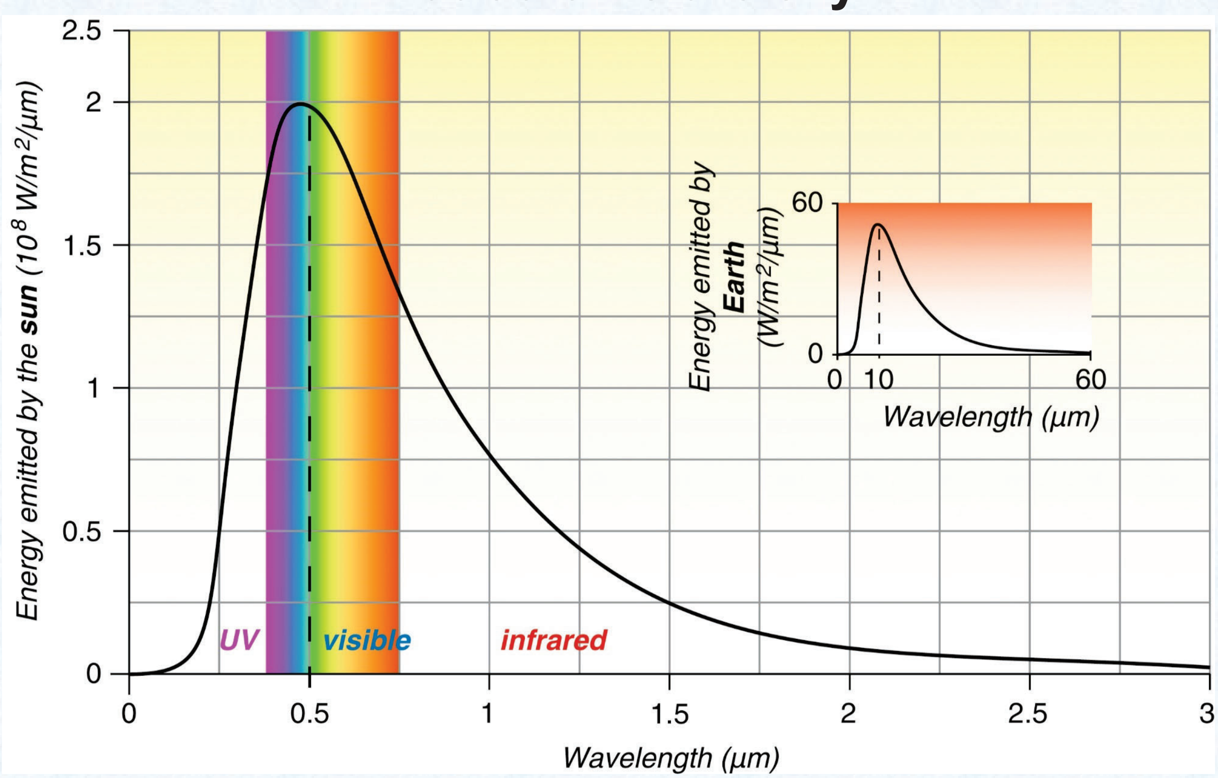
- **Absorbed**
- **Reflected**
- **Scattered**

Fig 4.4 *Weather: A Concise Introduction*



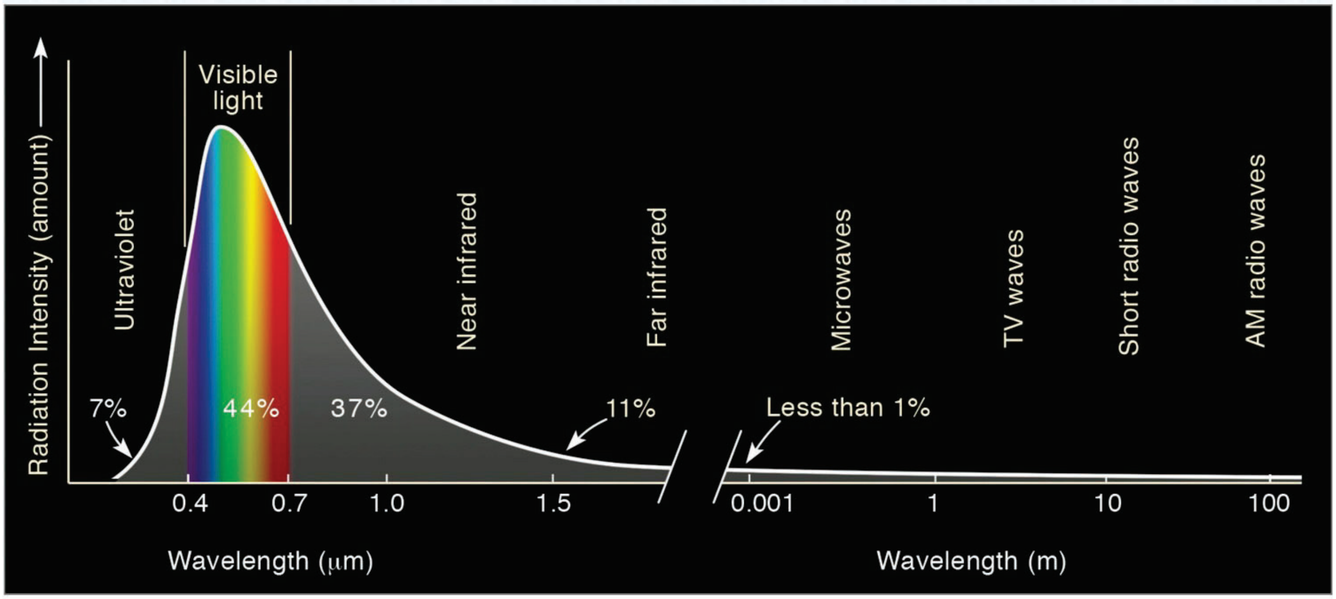
http://marineecology.wcp.muohio.edu/climate_projects_04/snowball_earth/web/WebpageStuff/albedo.html

What color is the sky?



N_2 and O_2 are really good at scattering shorter wavelengths

Solar Spectrum



The energy from the Sun peaks at 0.5 μm (the visible portion of the spectrum)

Fig 2.9: ***Essentials of Meteorology***

Atmospheric Absorption

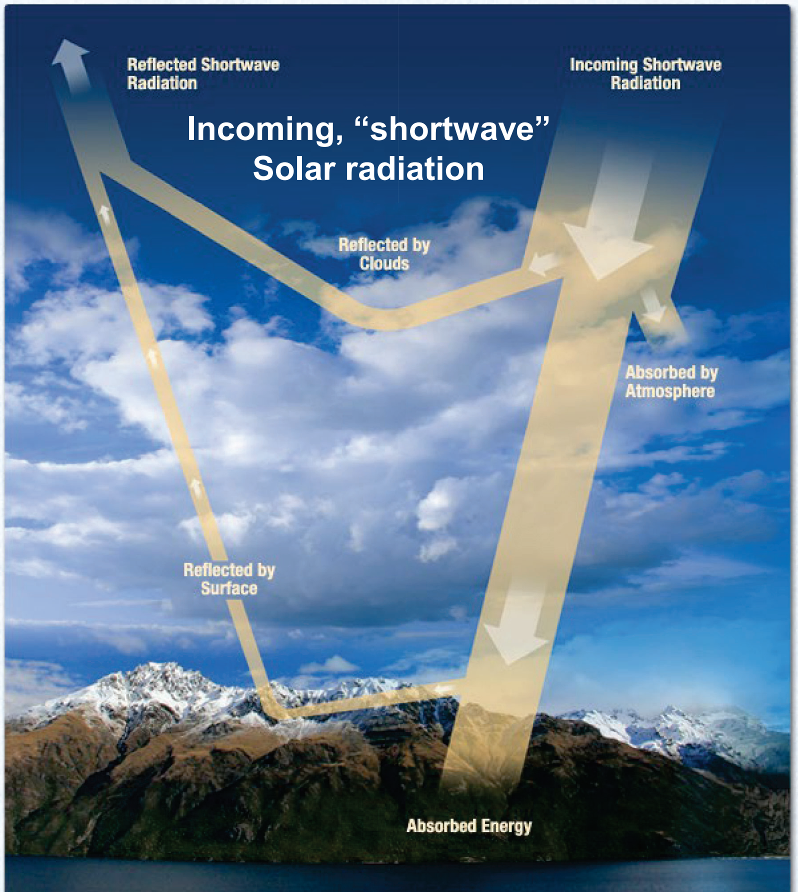
The Sun releases energy at shorter wavelengths (UV, visible, near-infrared)

Sun=Short wavelength, incoming, downwelling, more energy

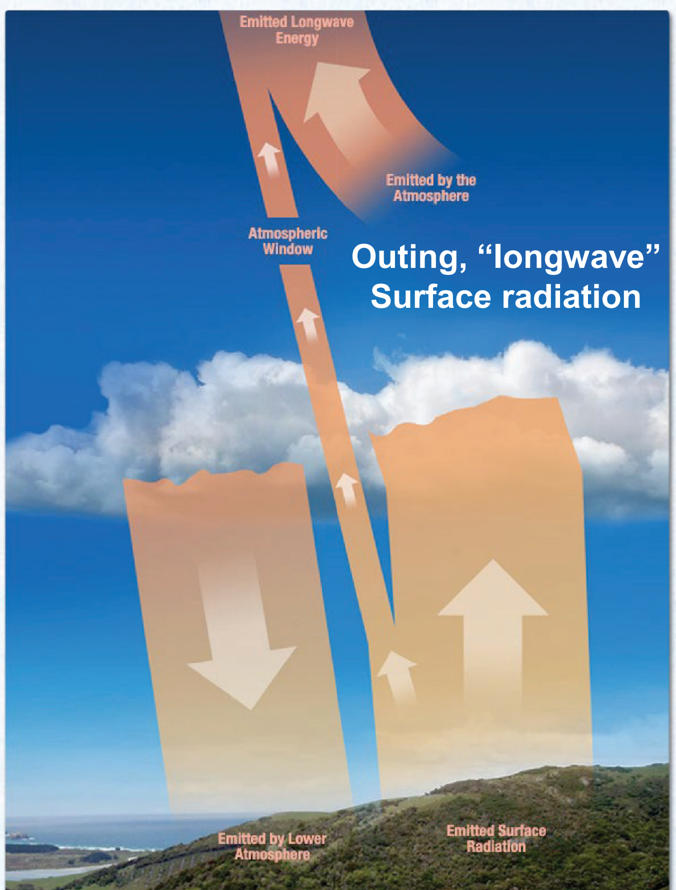
The Earth releases energy at longer wavelengths (IR)

Terrestrial=Thermal, outgoing, long wavelength, upwelling, less energy

Fig 2.10, 11: ***Essentials of Meteorology***



http://missionscience.nasa.gov/ems/13_radiationbudget.html



http://missionscience.nasa.gov/ems/13_radiationbudget.html

Atmospheric Absorption

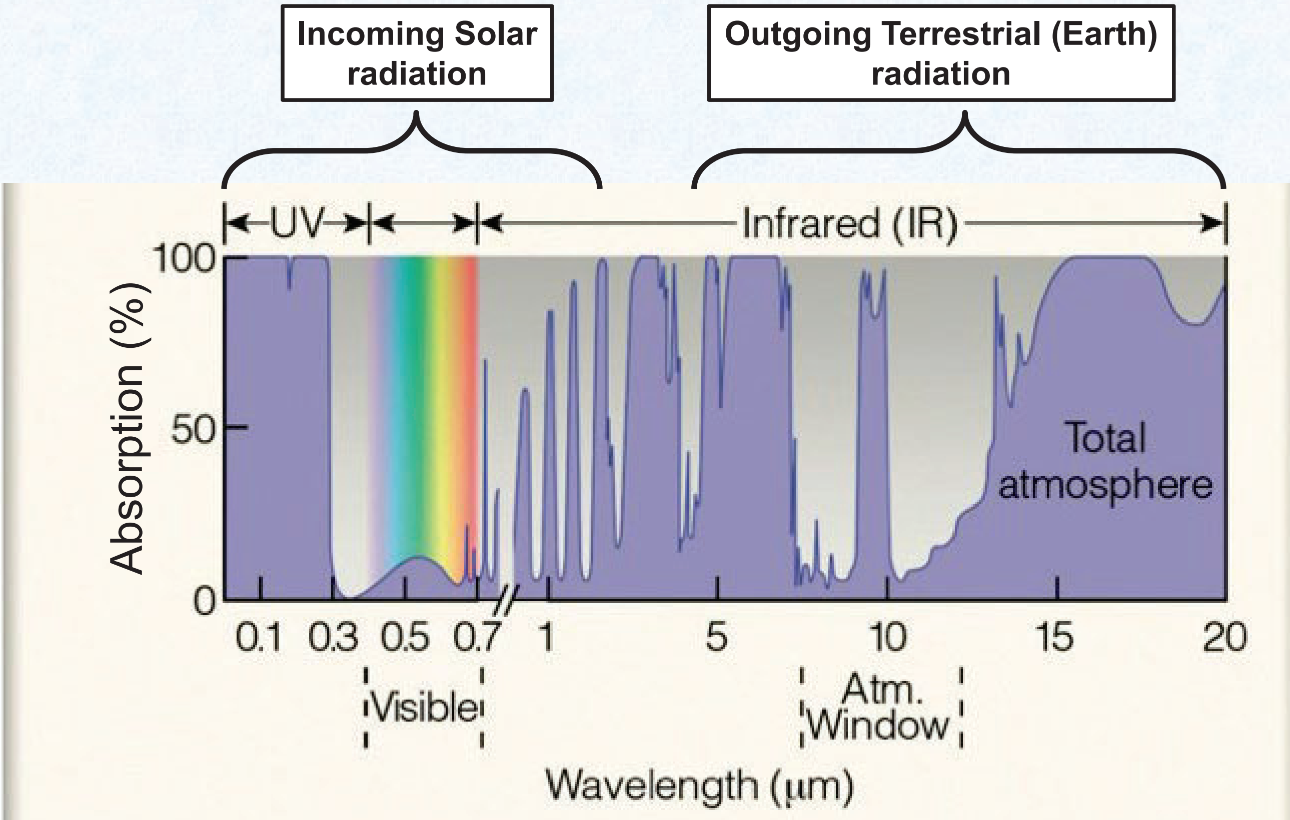


Fig 2.11: ***Essentials of Meteorology***

Atmospheric Absorption from O_2 and O_3

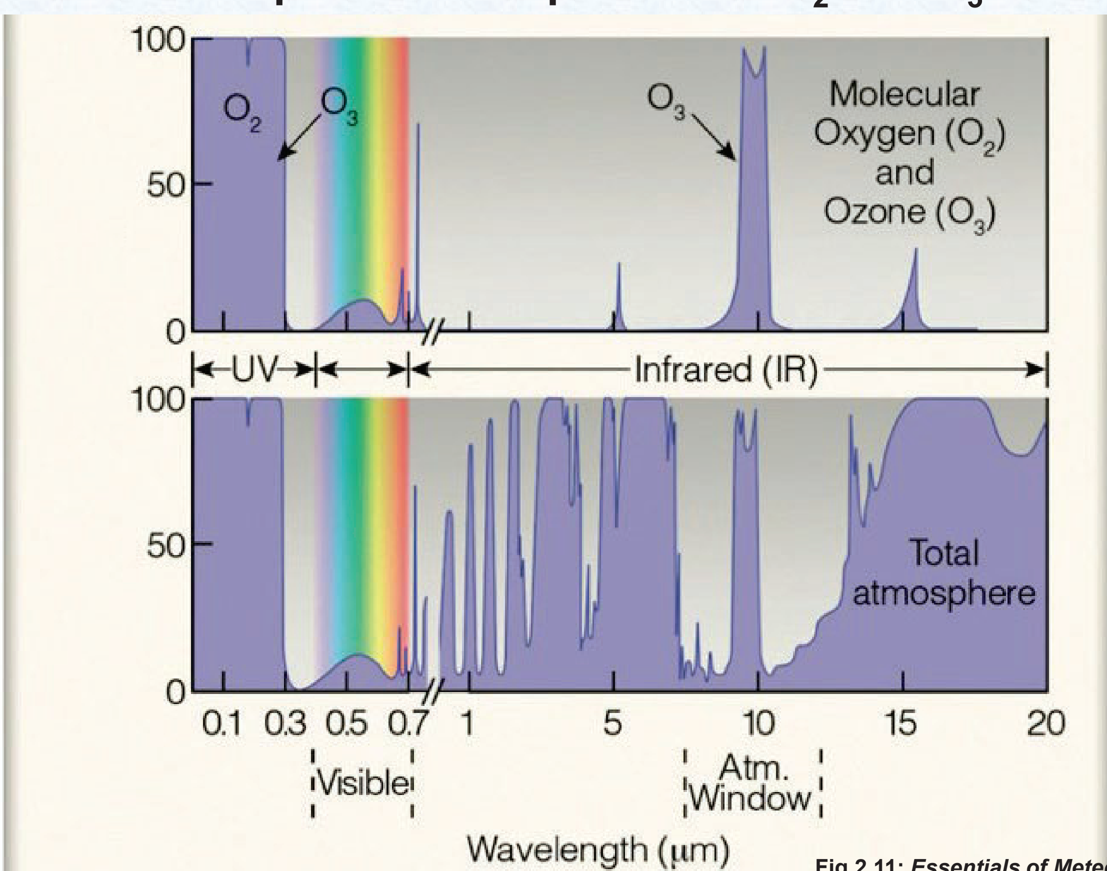


Fig 2.11: ***Essentials of Meteorology***

Atmospheric Absorption from CH_4

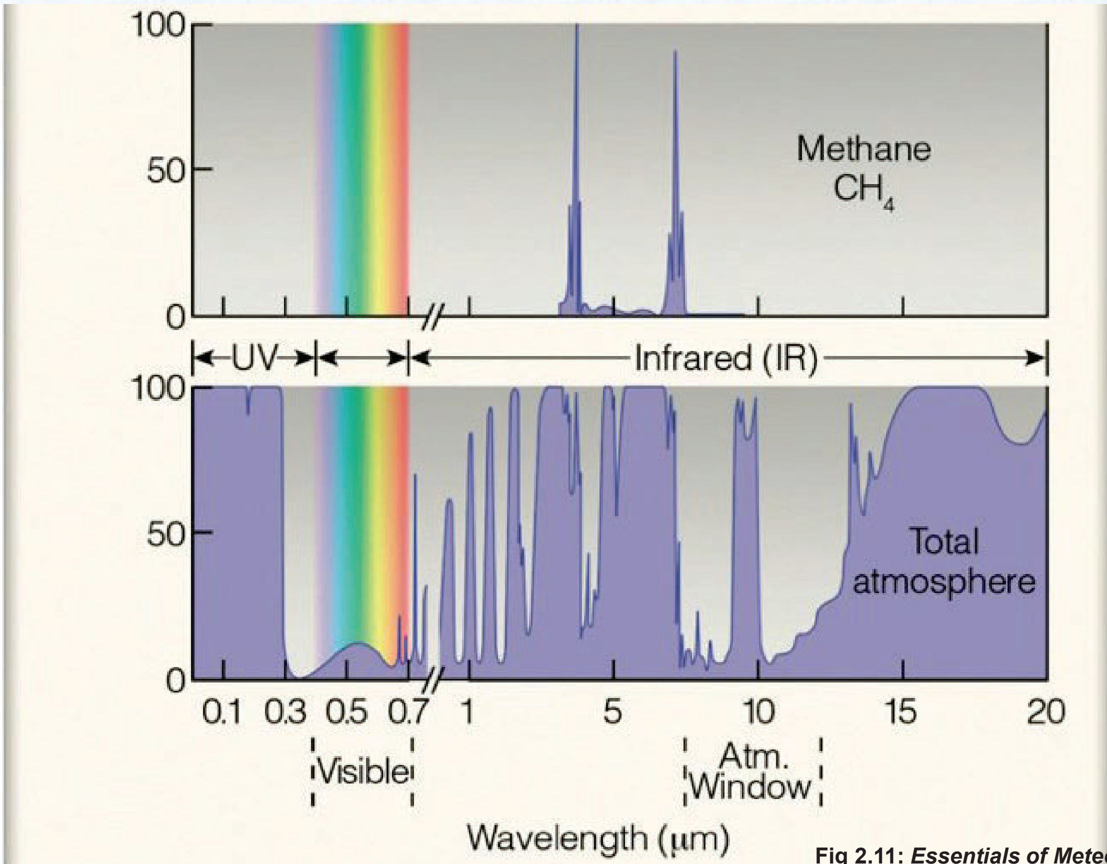


Fig 2.11: ***Essentials of Meteorology***

Atmospheric Absorption from N_2O

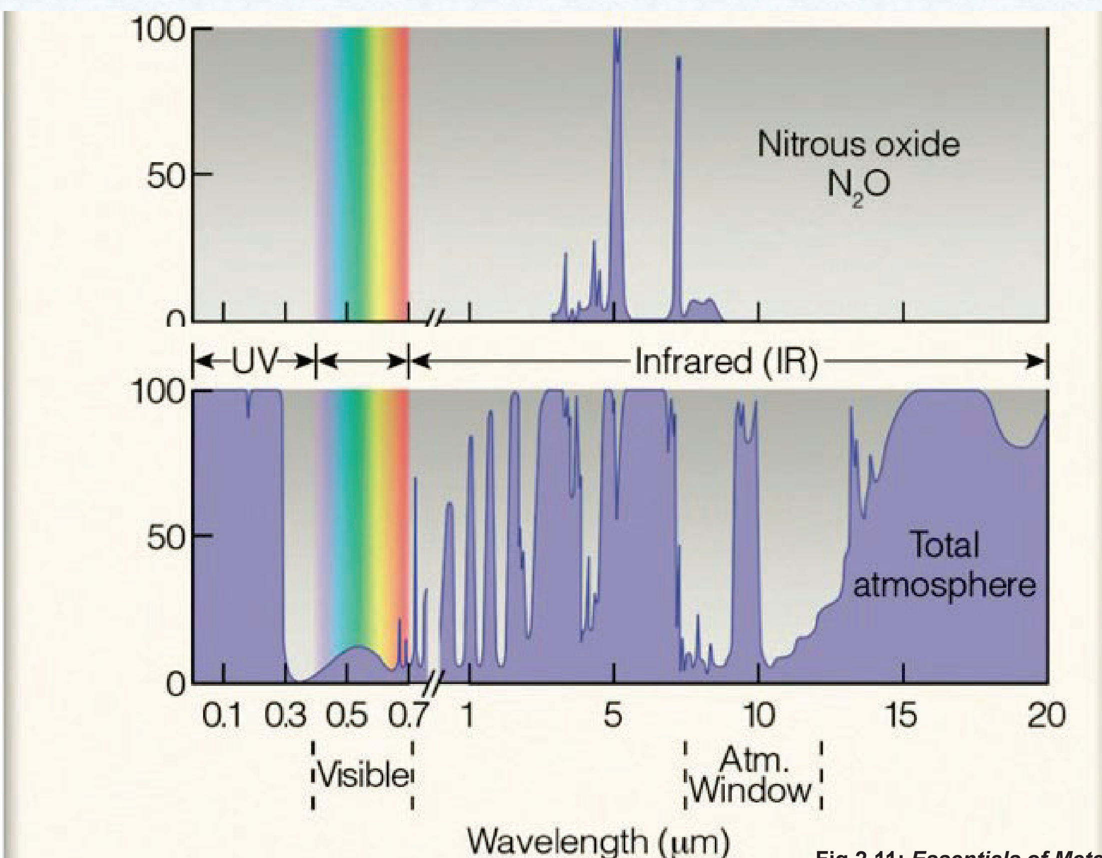


Fig 2.11: ***Essentials of Meteorology***

Atmospheric Absorption from CO_2

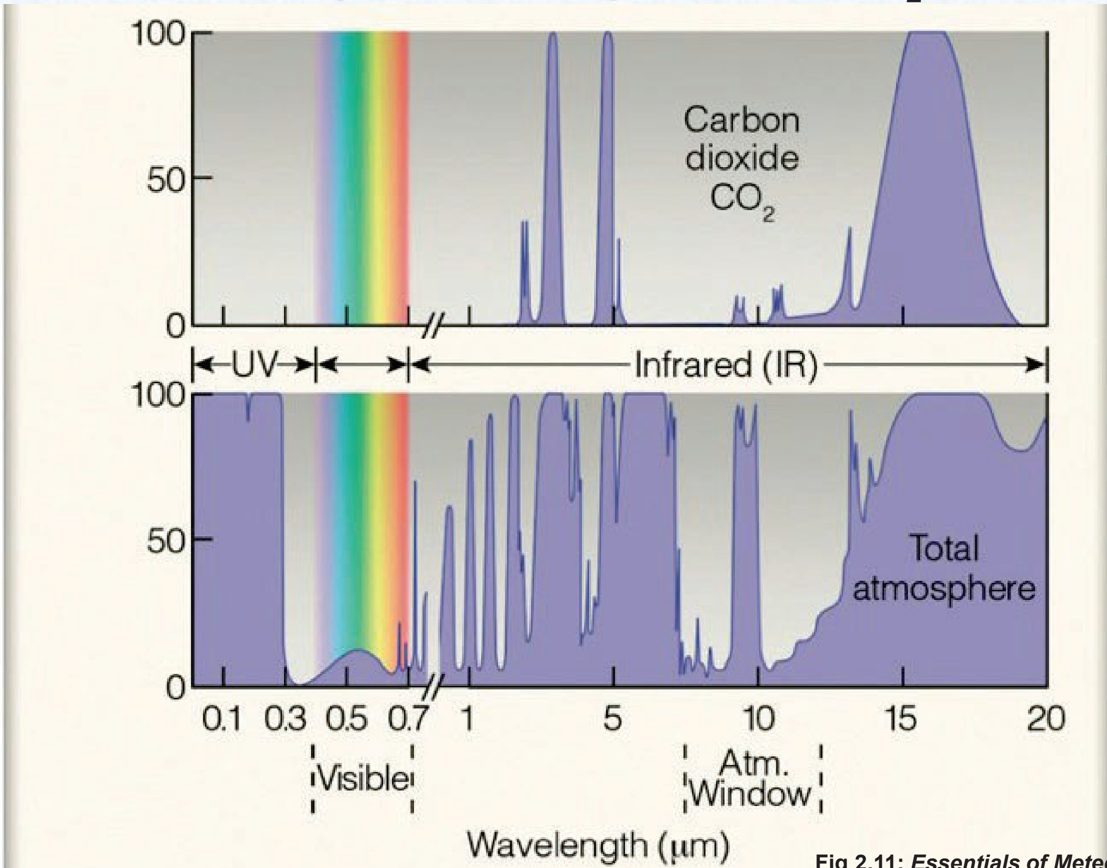


Fig 2.11: ***Essentials of Meteorology***

Atmospheric Absorption from H_2O

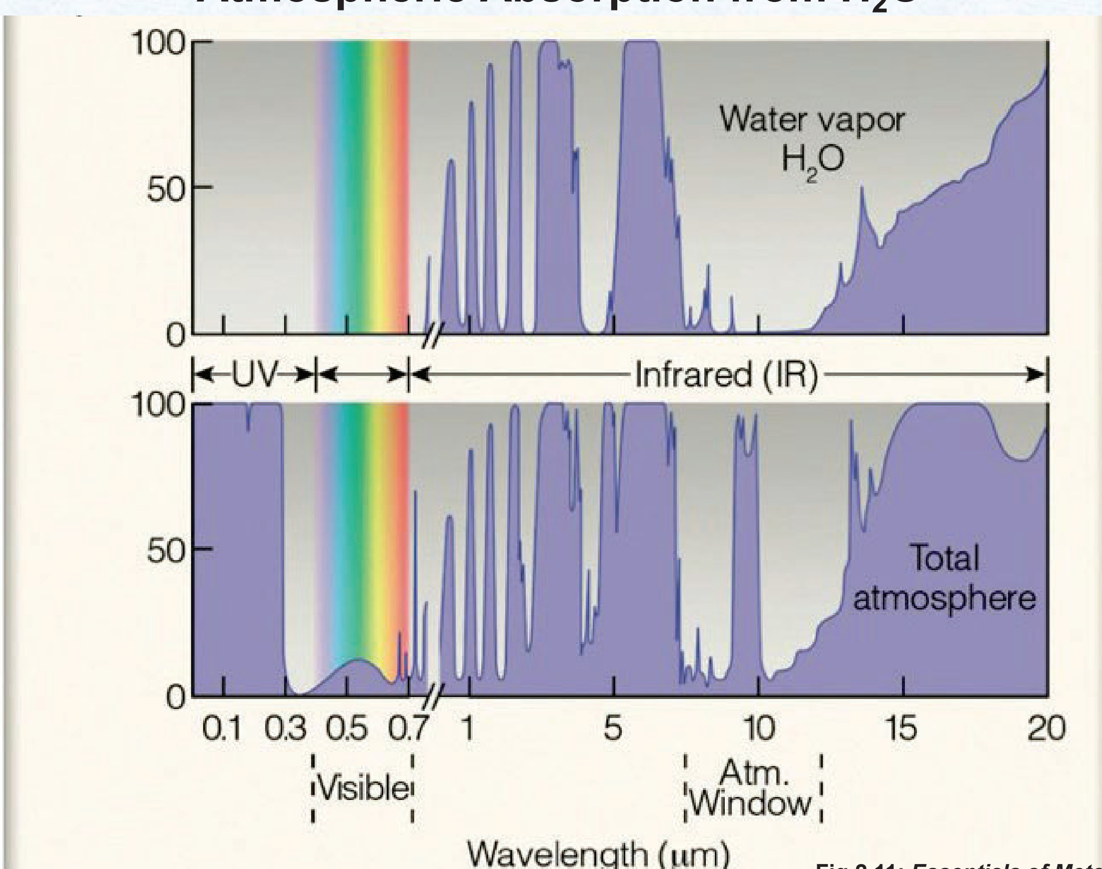
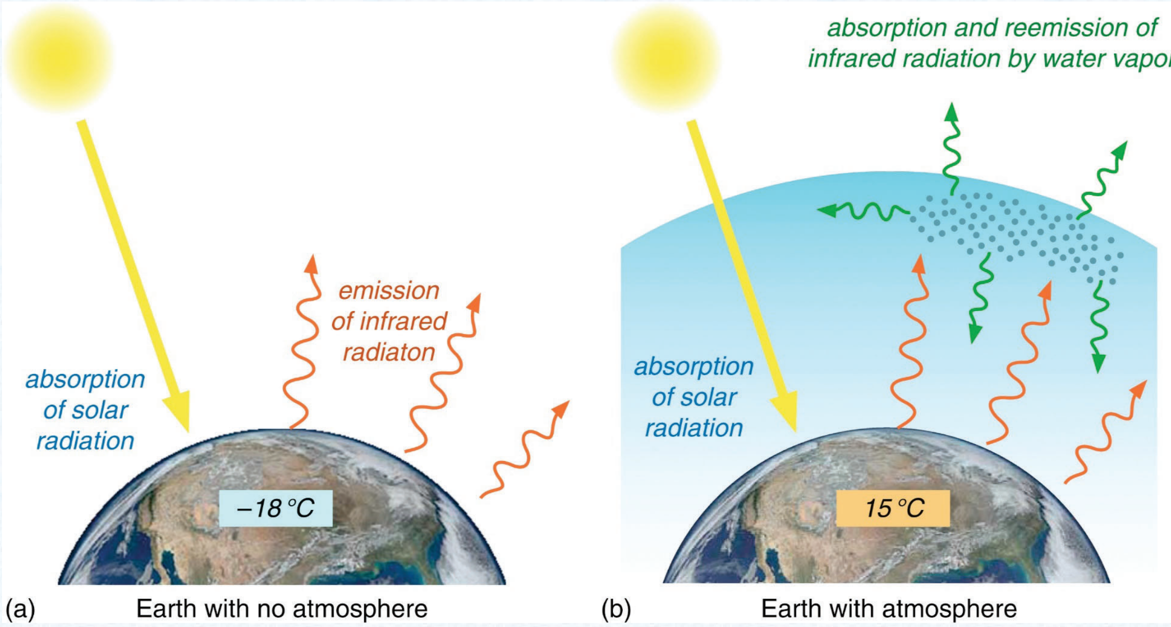


Fig 2.11: ***Essentials of Meteorology***

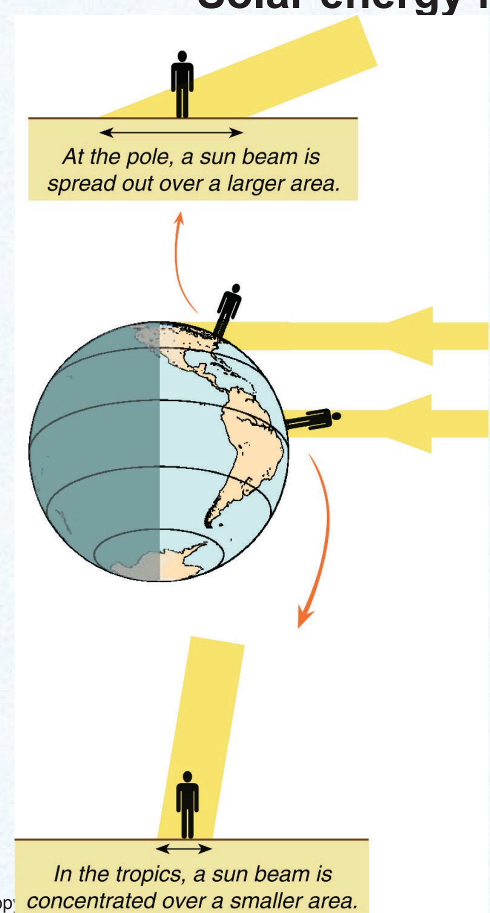
Earth with the Greenhouse Effect



What happens when the "blanket gets too thick?
This is called the "enhanced greenhouse effect"

Fig 4.7: ***Weather: A Concise Introduction***

Solar energy reaching the Earth's surface



Sunlight in the tropics is more intense because the sun is higher in the sky than near the polar regions.

Less solar energy makes it through the atmosphere to the poles than the equator.

The polar regions have a higher albedo than the tropics. Why?

All of these together lead to an energy imbalance

Fig 4.8: ***Weather: A Concise Introduction***

Solar energy reaching the Earth's surface

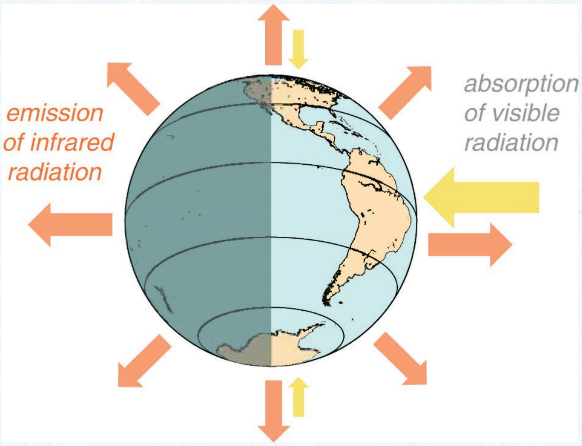


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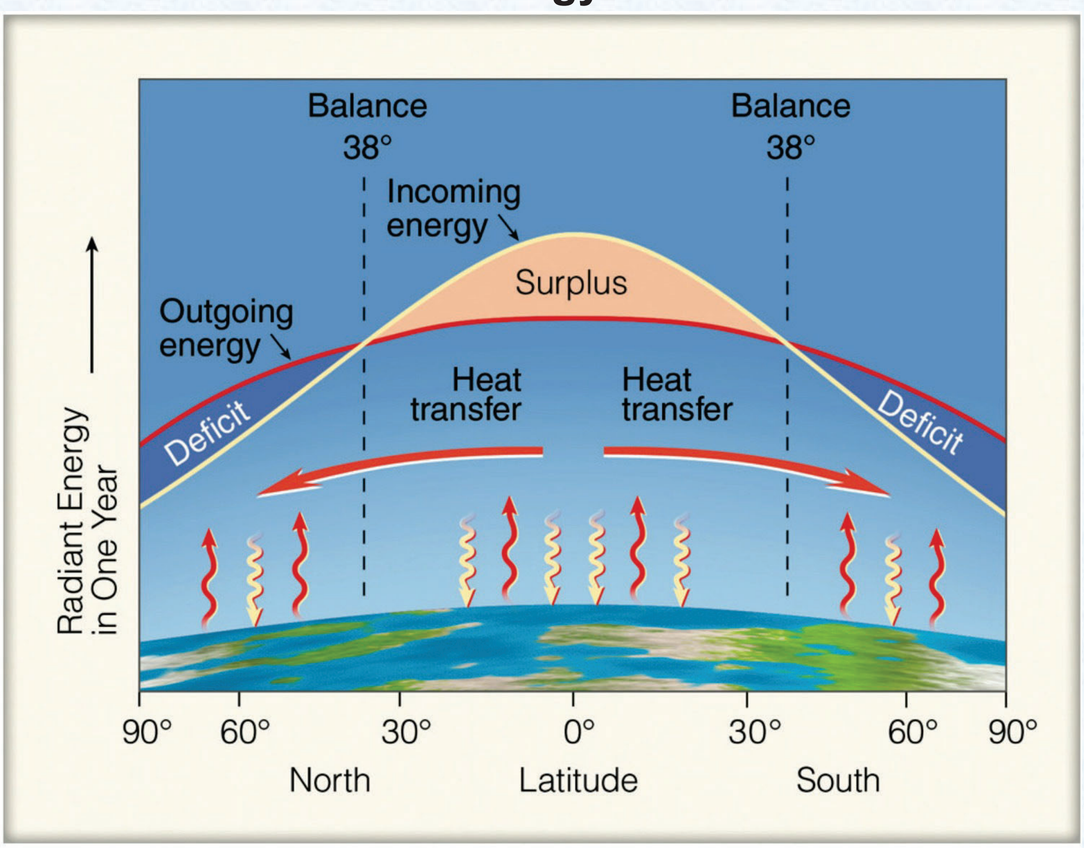
Fig 4.9: *Weather: A Concise Introduction*

Global Energy Balance



The Seasons

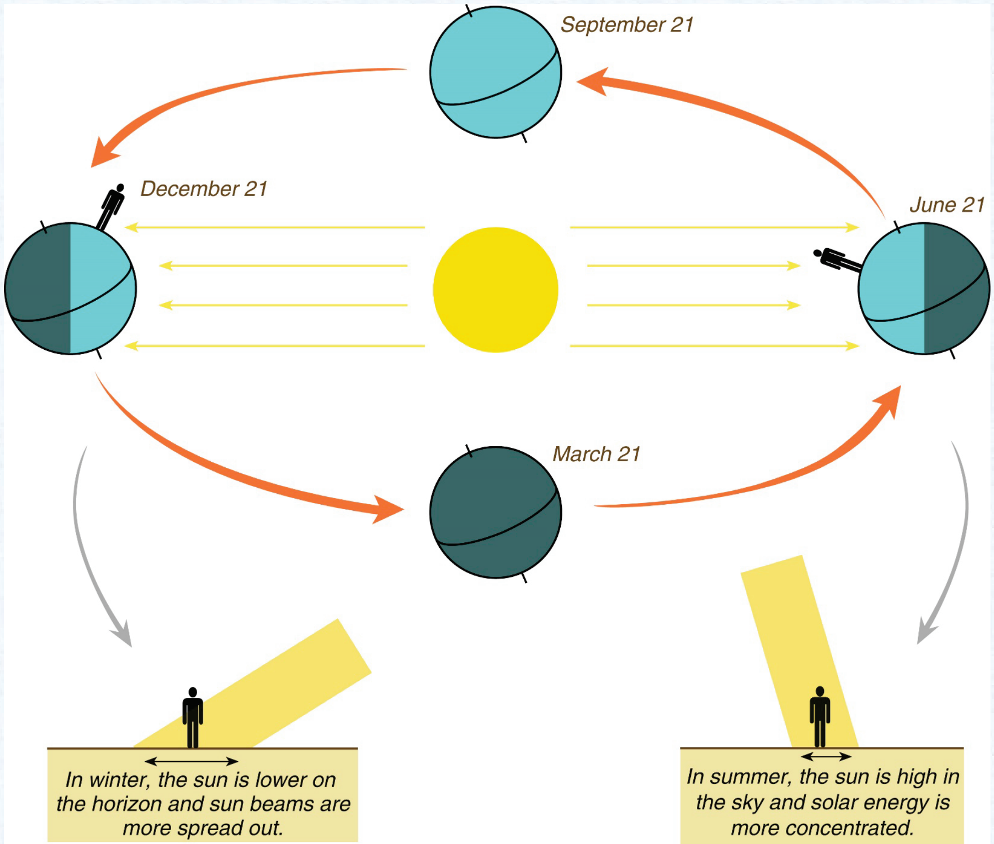
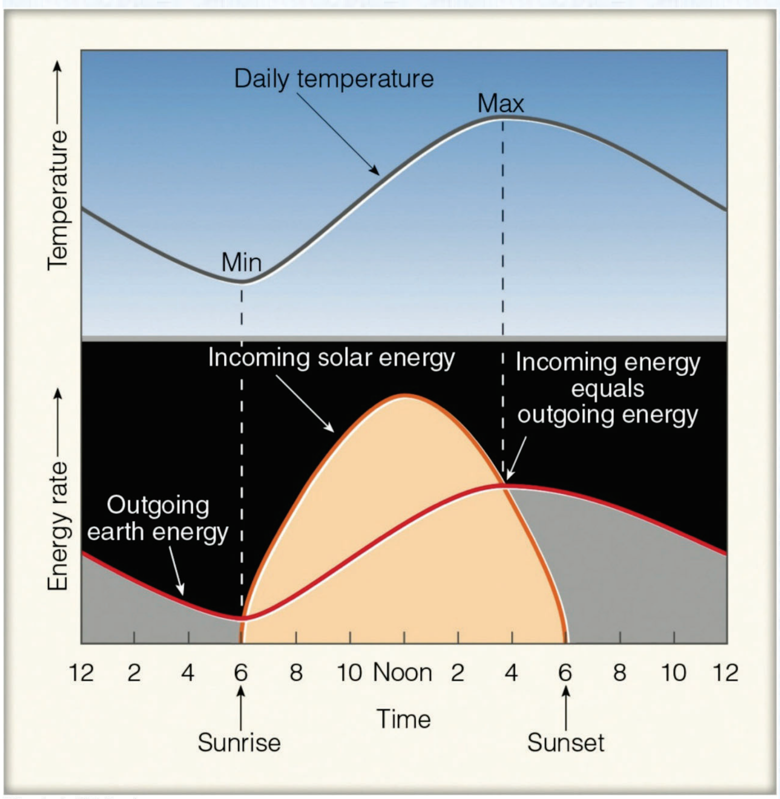


Fig 4.11: ***Weather: A Concise Introduction***

Daily Temperatures



Solar energy is most intense at noon.

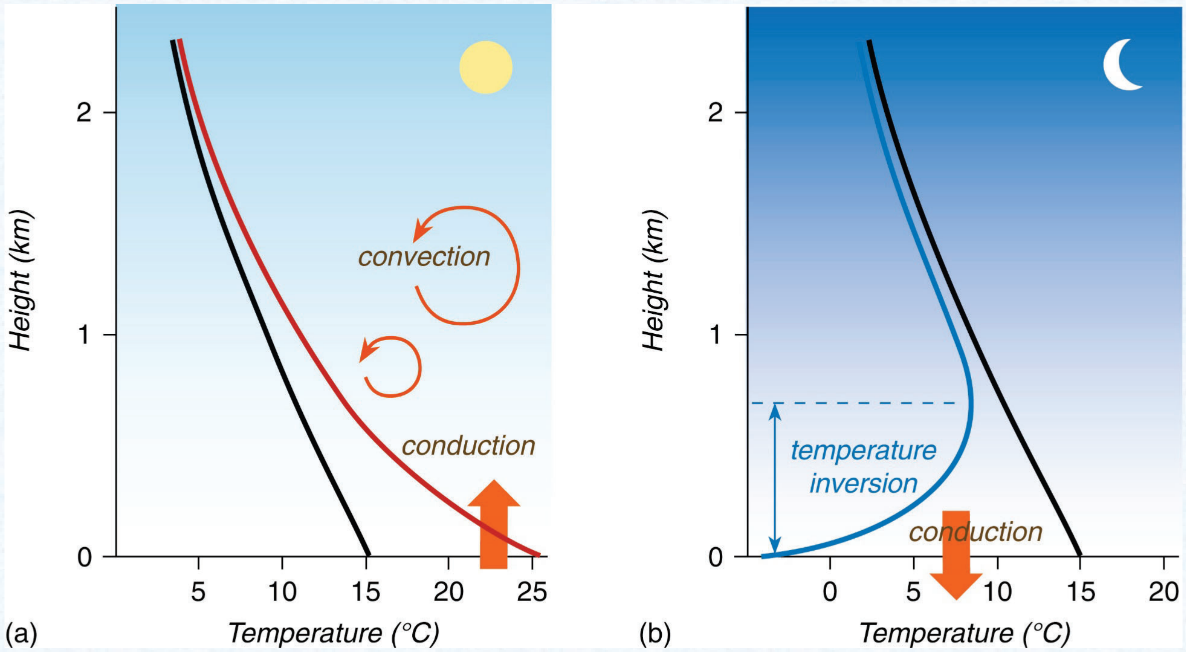
Suns rays are more "focused" at noon.

Solar radiation (incoming radiation) greater than surface radiation (outgoing radiation) until later in afternoon.

Lowest temperature occurs shortly after sunrise when outgoing radiation is greater than incoming.

Fig 3.2: ***Essentials of Meteorology***

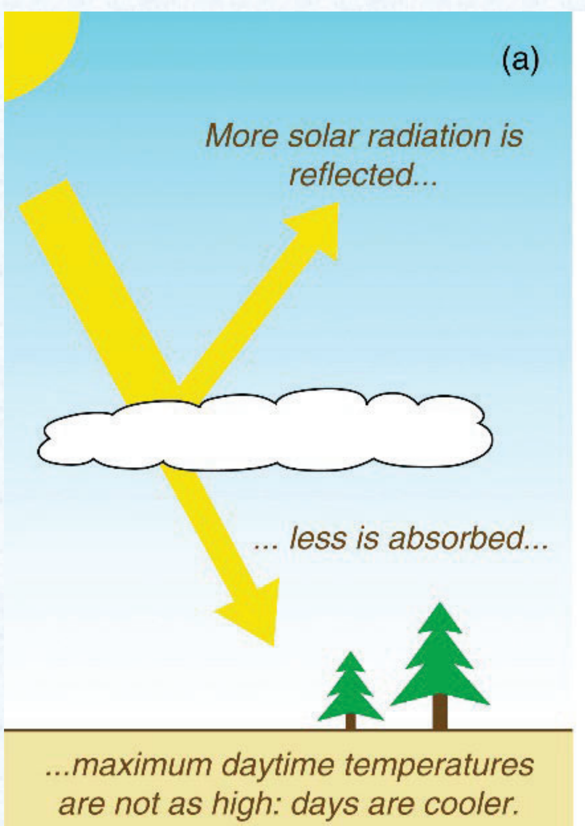
Daily Temperatures



Daily temperature changes are largest near the surface

Fig 4.14: ***Weather: A Concise Introduction***

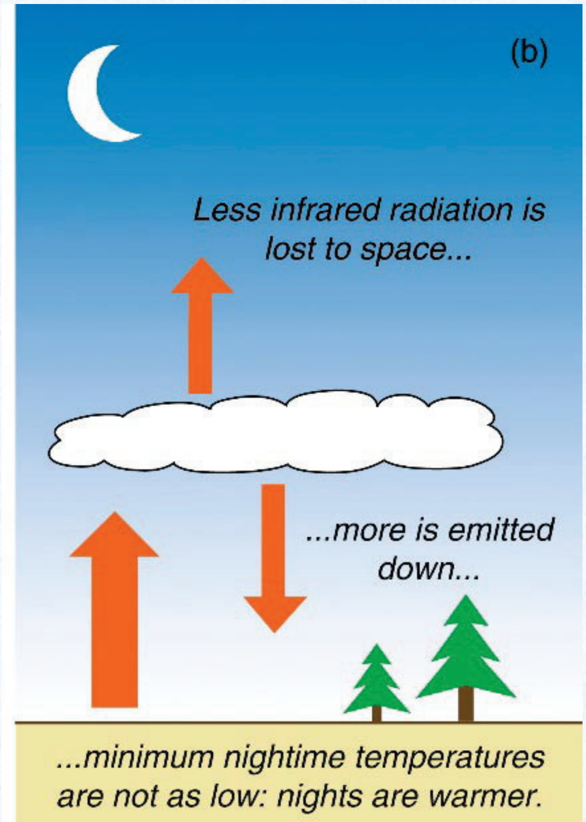
Daytime Temperatures: Clouds



Clouds have a high albedo and will reflect incoming solar radiation

Fig 4.15: ***Weather: A Concise Introduction***

Nighttime Temperatures: Clouds



Clouds prevent heat from surface from going out to space

Fig 4.15: ***Weather: A Concise Introduction***

How is temperature affected by:

- **Altitude**
- **Latitude**
- **Surface type**
- **Proximity to water**

What to study?

One way to break down the semester

1. Atmospheric Variables
2. Composition
3. Energy
4. **Water**

The Water Cycle

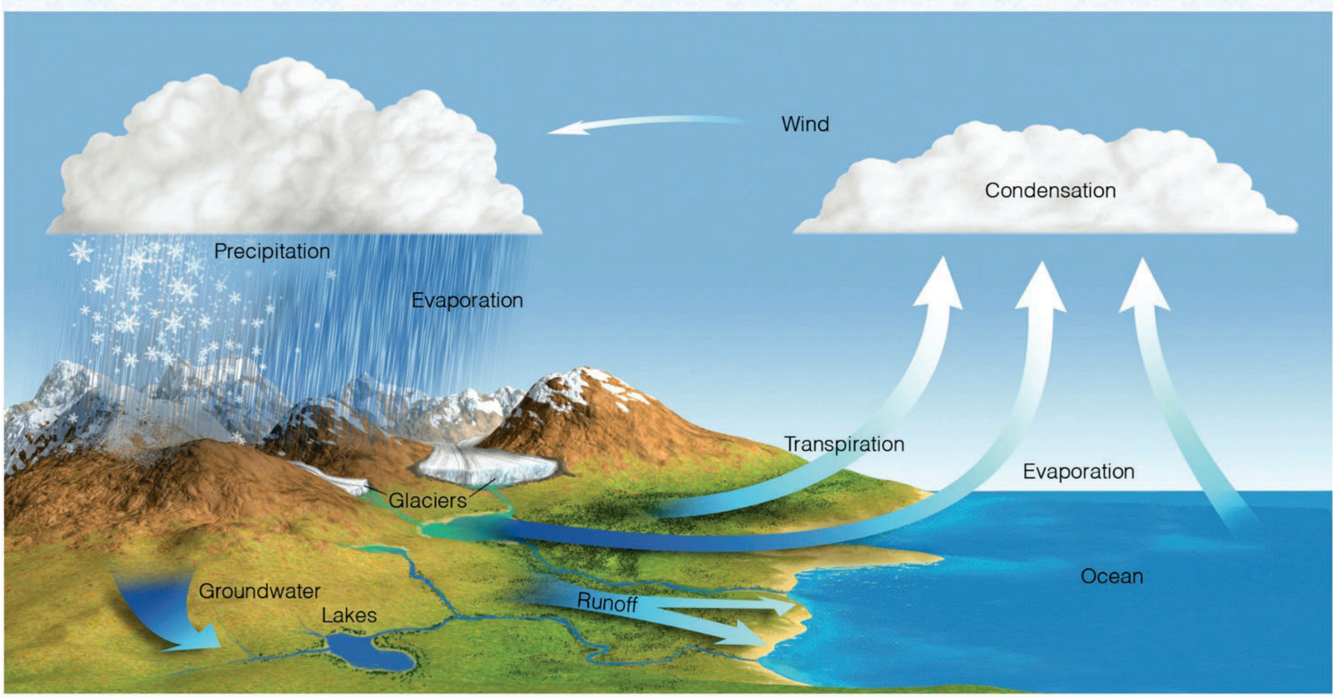


Fig 4.1: ***Essentials of Meteorology***

Energy Transfer

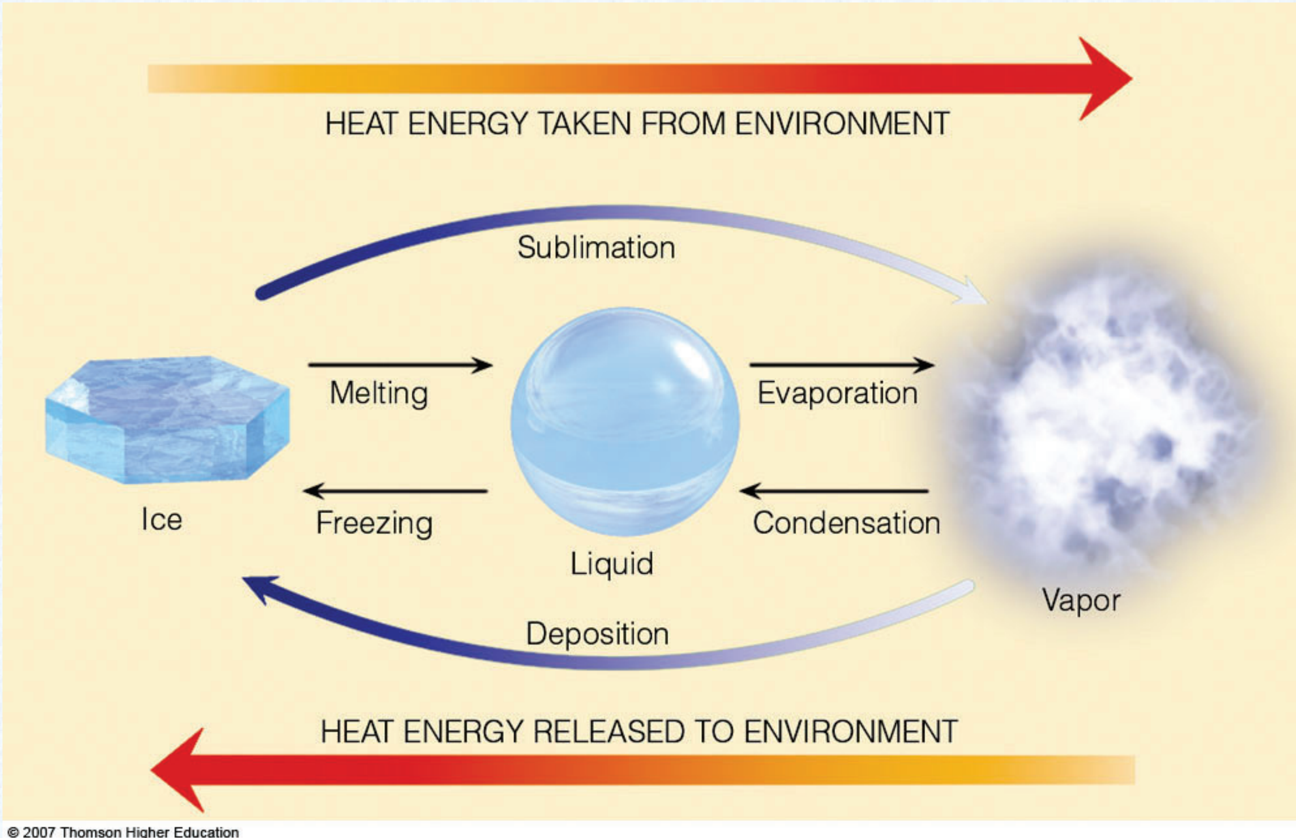


Fig 2.3: ***Essentials of Meteorology***

The Water Cycle

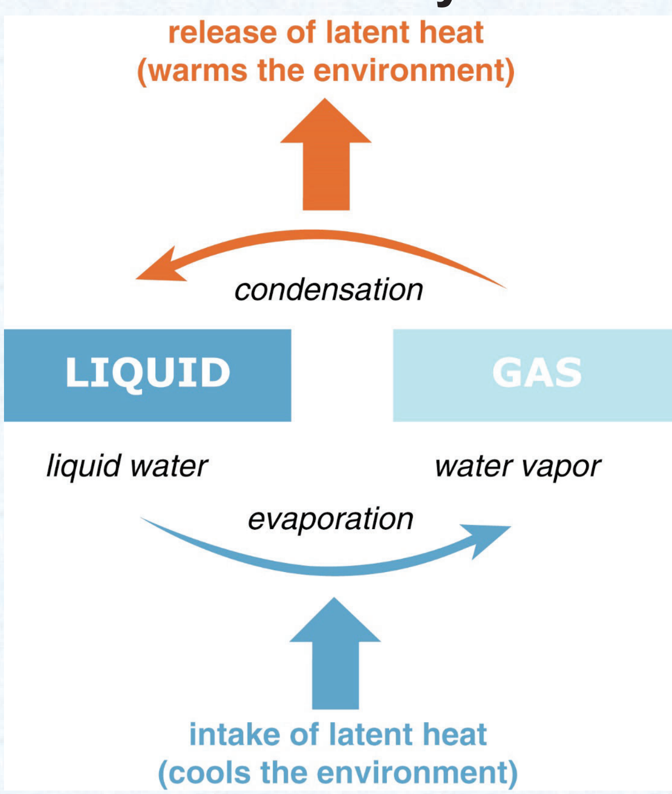


Fig 5.1 *Weather: A Concise Introduction*

Specific Heat

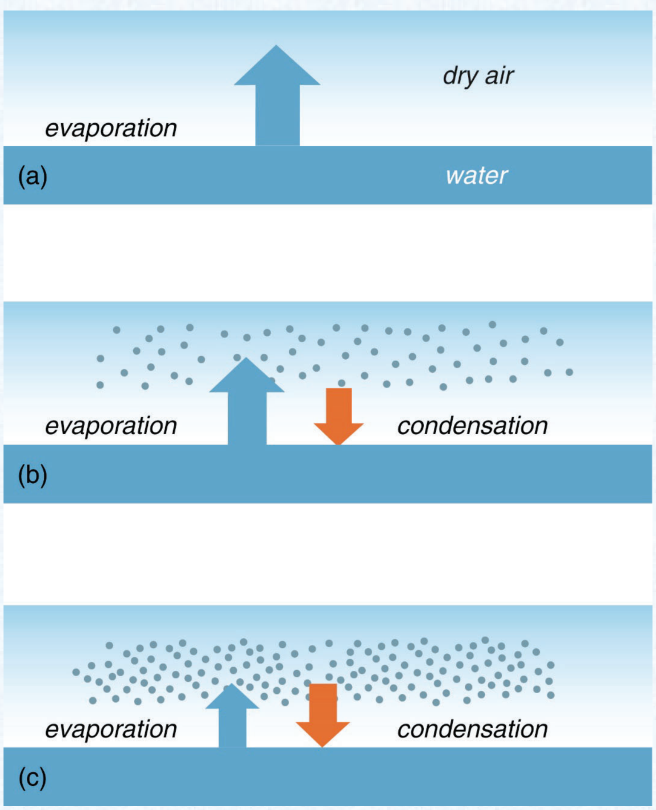
Substance	Specific Heat (cal/g/° C)	Specific Heat (J/kg/° C)
Water	1.0	4,186
Ice	0.50	2,093
Air	0.24	1,005
Sand	0.19	795

The specific heat of a substance is the amount of heat required to increase the temperature of 1 gram of the substance 1° C

Water takes longer to heat (and cool) than dirt

Table 2-1 *Meteorology: Understanding the Atmosphere*

Saturation



Water evaporates and enters dry air

Eventually, some of the water vapor hits the surface through collisions and random motion (condensation)

When evaporation and condensation are equal the air is said to be saturated

Fig 5.3 *Weather: A Concise Introduction*

Two ways to get water to condense

1) Decrease the air temperature
2) Increase the amount of water vapor

Vapor Pressure

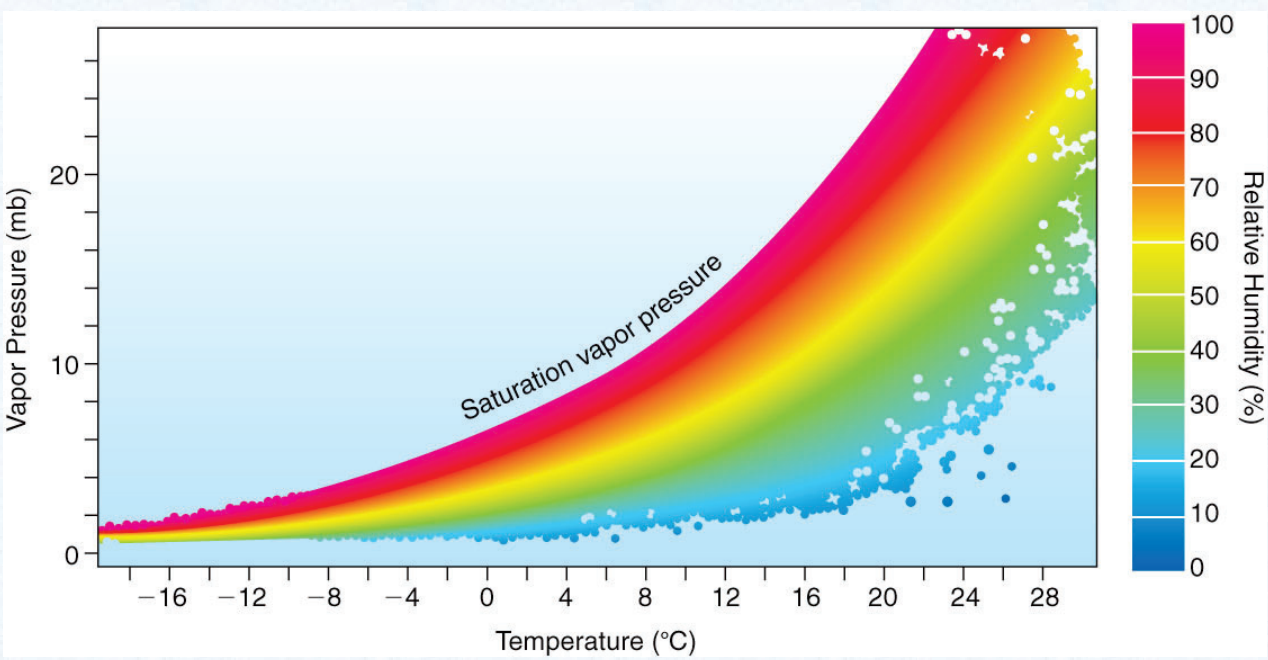
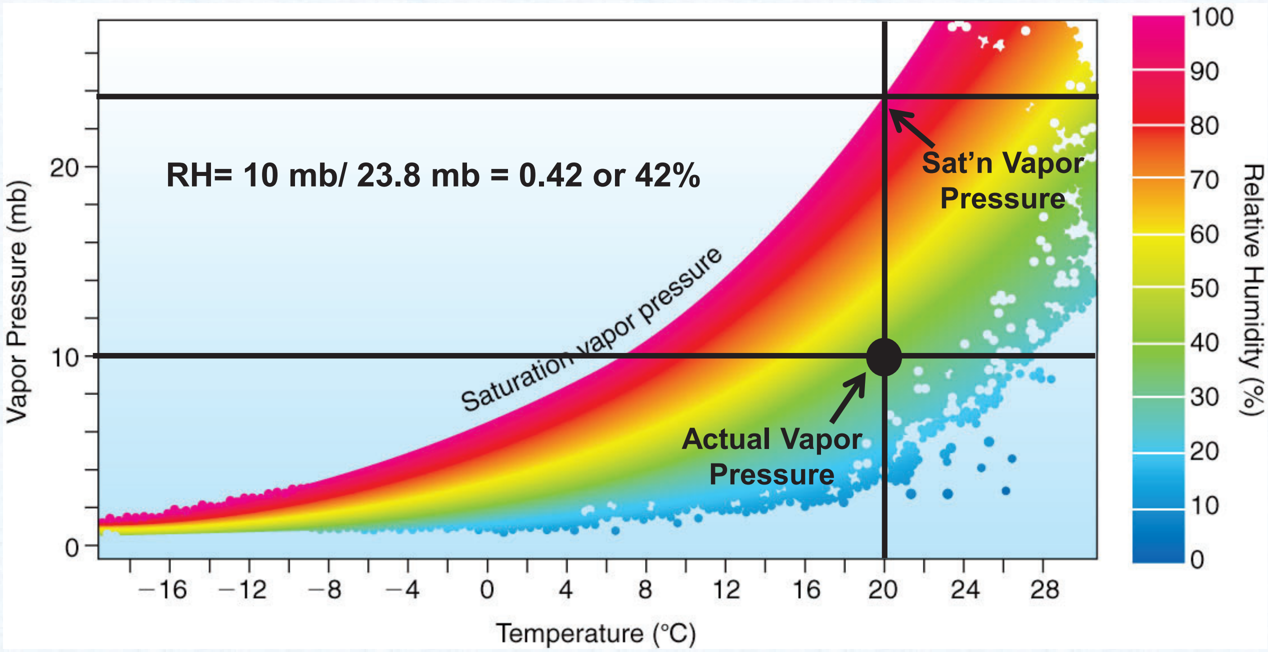


Fig 4-3 *Meteorology: Understanding the Atmosphere*

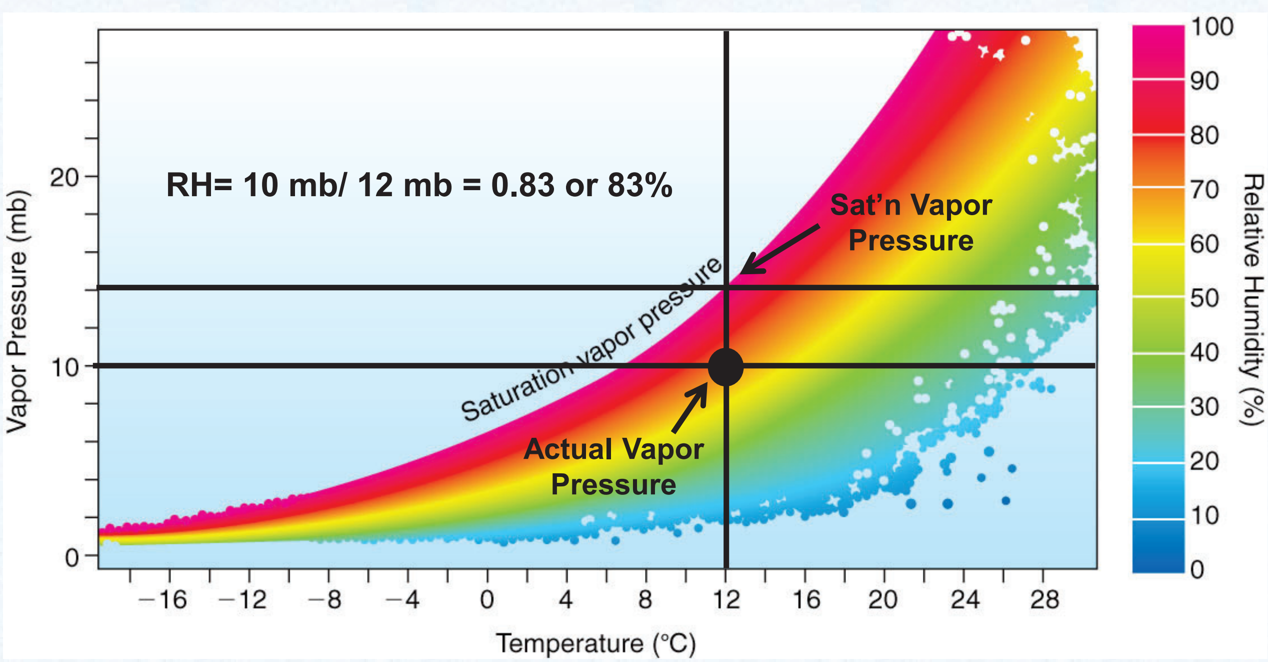
Relative Humidity



Relative humidity: the ratio of the saturation vapor pressure divided by the actual vapor pressure

Fig 4-3 *Meteorology: Understanding the Atmosphere*

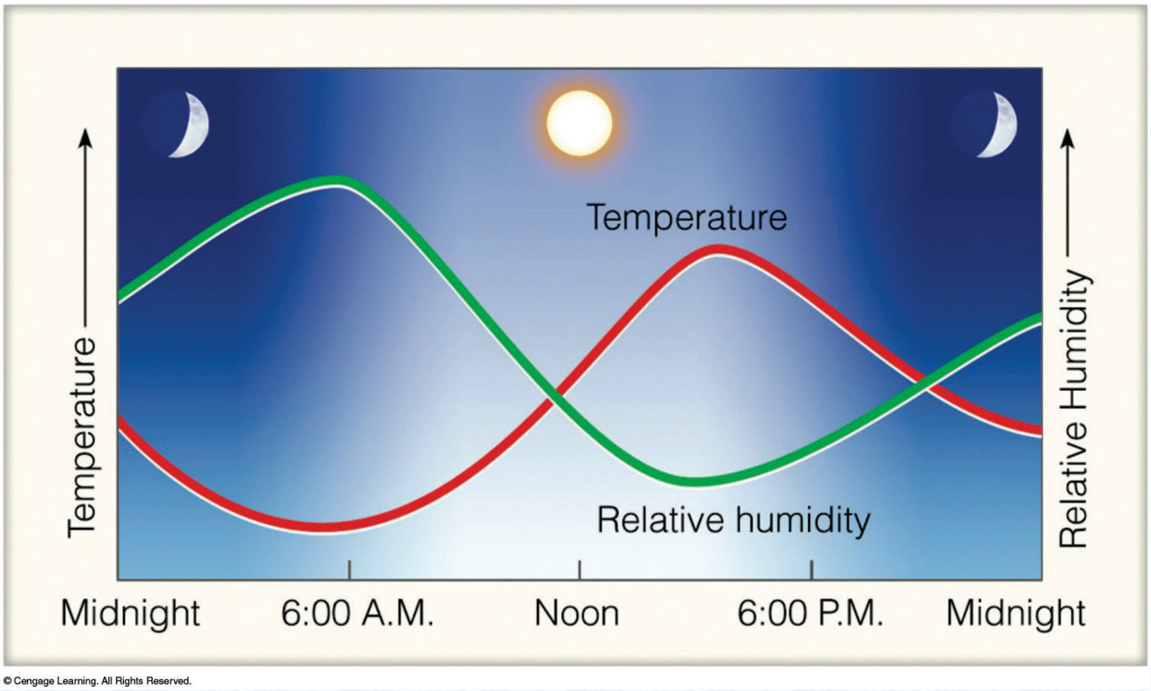
Relative Humidity



As temperature drops, relative humidity rises
The air can't "hold" as much water

Fig 4-3 *Meteorology: Understanding the Atmosphere*

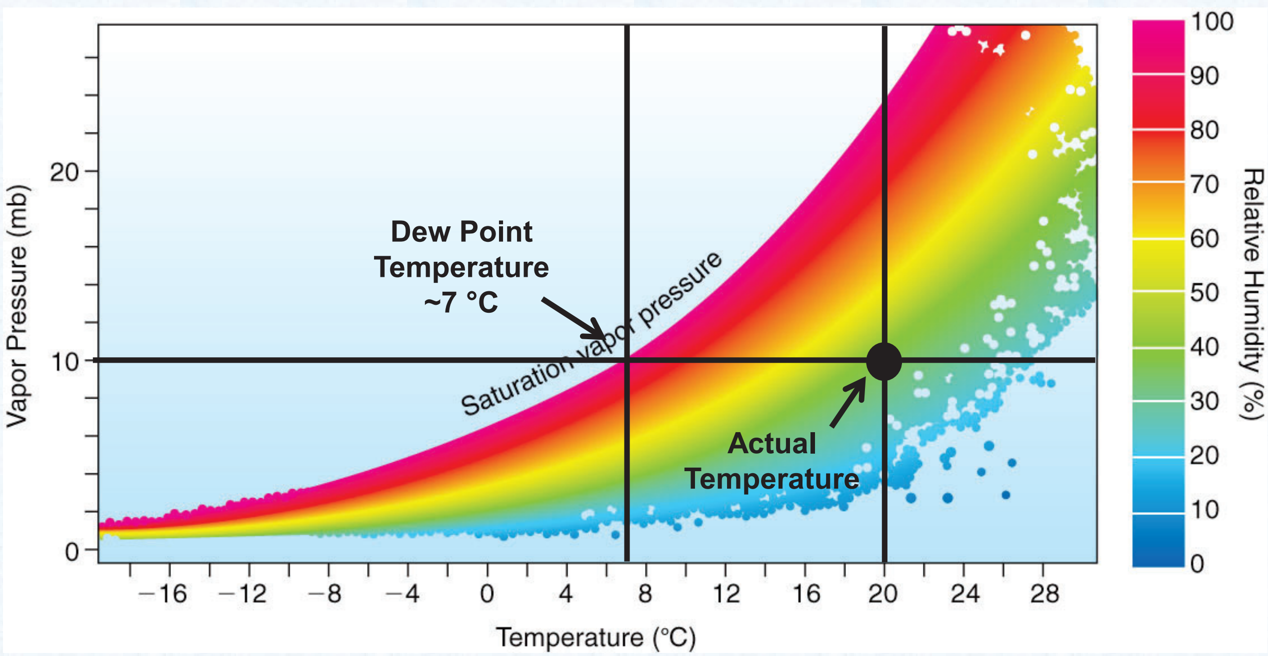
Relative Humidity



Temperature and relative humidity are "anti-correlated"

Fig 4.7: ***Essentials of Meteorology***

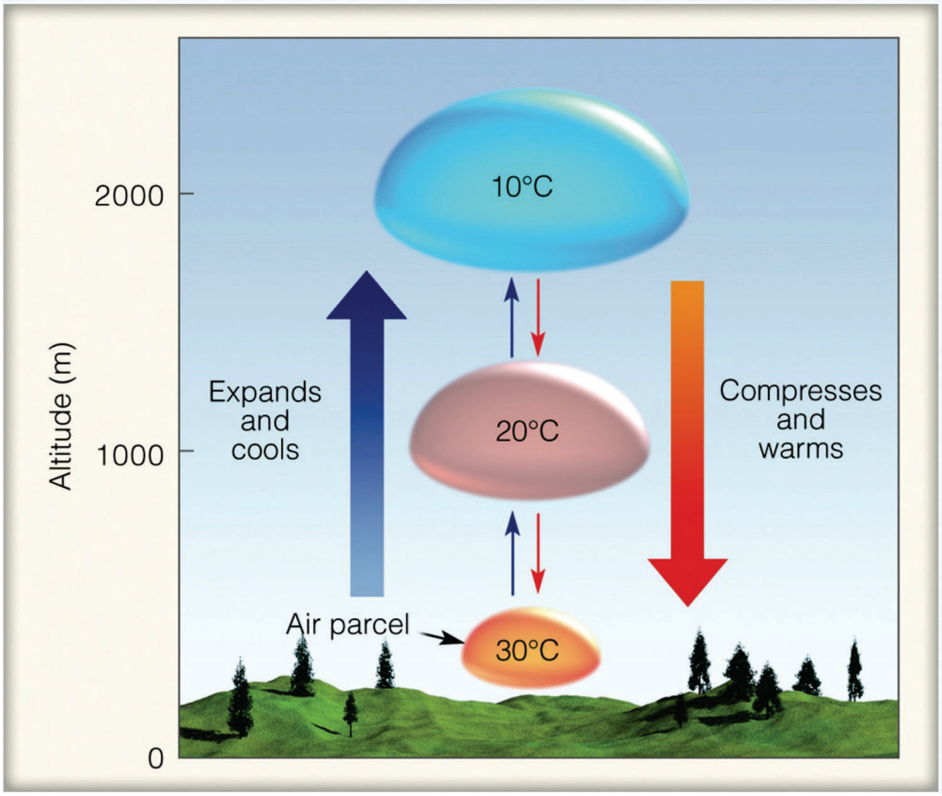
Saturation



Dew Point: the temperature air has to be cooled to for saturation to occur
Dew point is a measure of how much water vapor is in the air

Fig 4-3 *Meteorology: Understanding the Atmosphere*

Dry Adiabatic Lapse Rate



If the air is very dry, it will cool by 10°C for every km in altitude

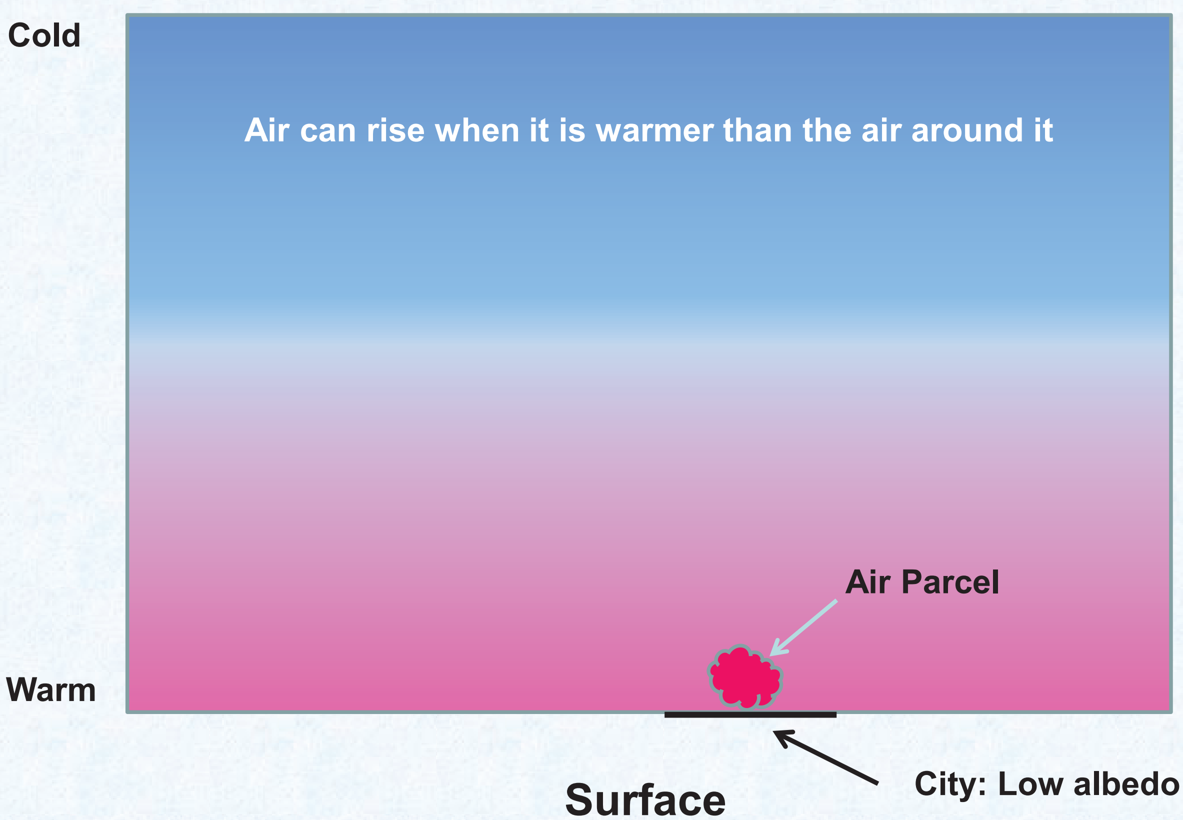
This is called the dry adiabatic lapse rate

The air expands and cools as it rises

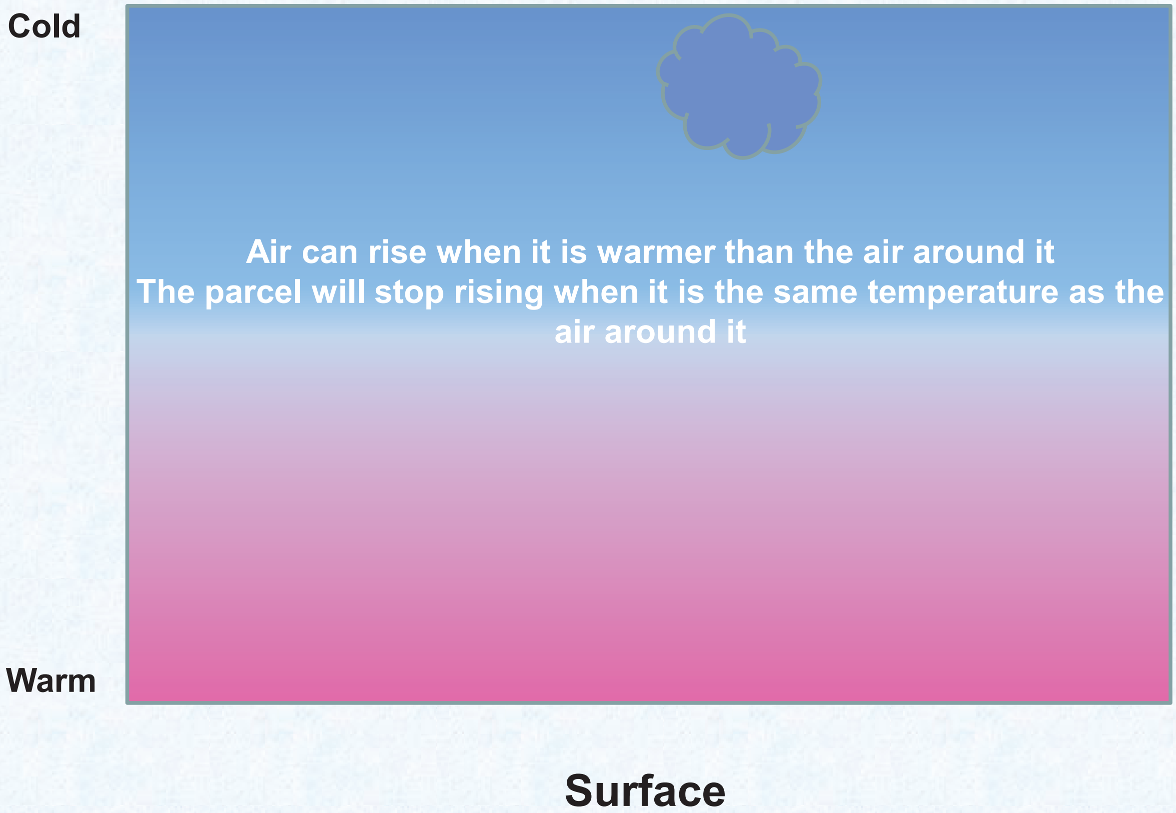
It contracts and heats as it sinks

Fig 5.2: ***Essentials of Meteorology***

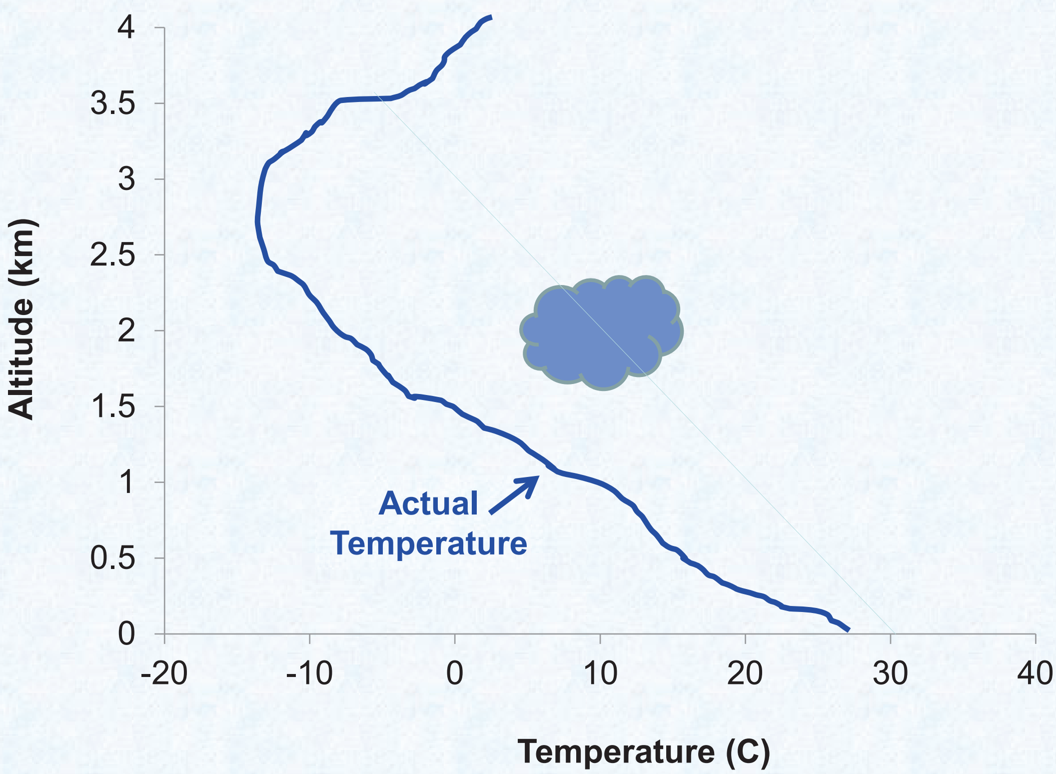
Unstable Air



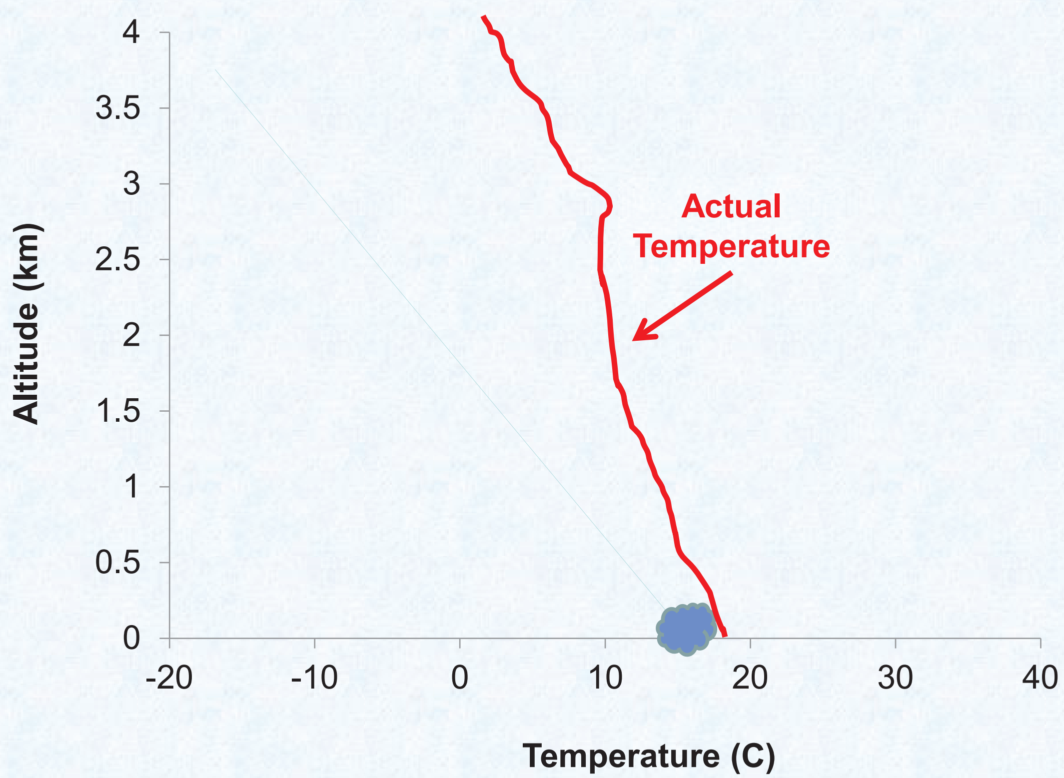
Unstable Air



Lapse Rate: Unstable Atmosphere



Lapse Rate: Stable Atmosphere



Putting it all together

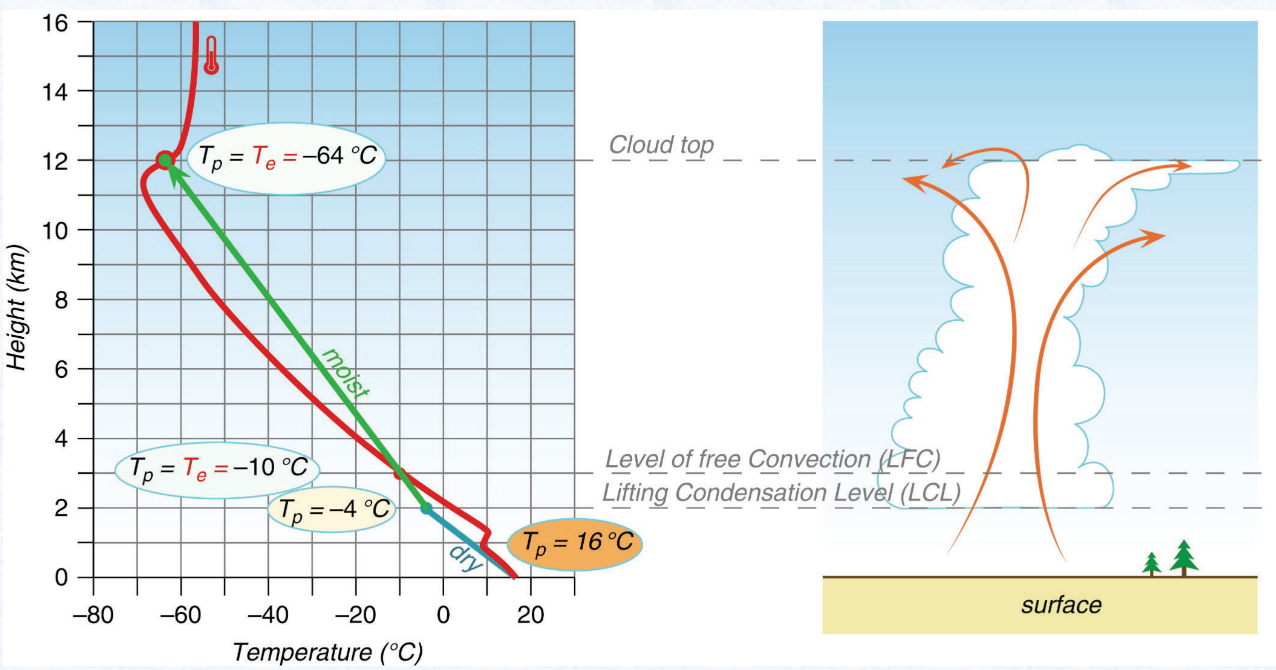
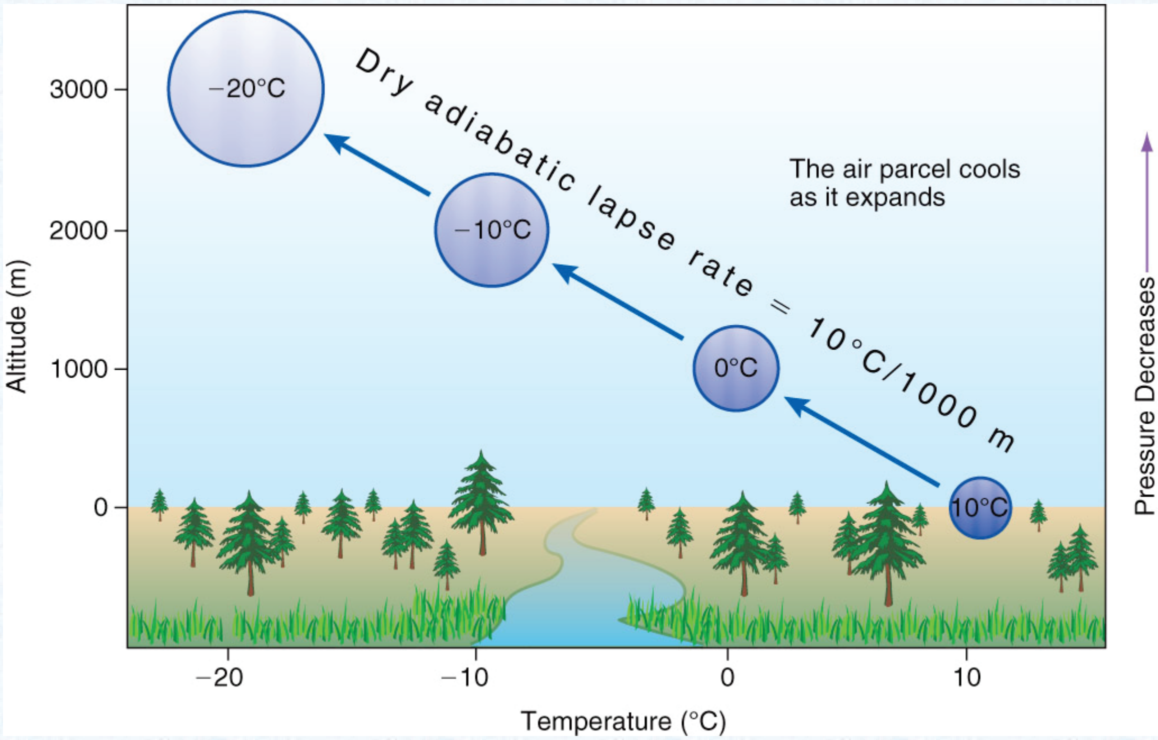


Fig 6.22 *Weather: A Concise Introduction*

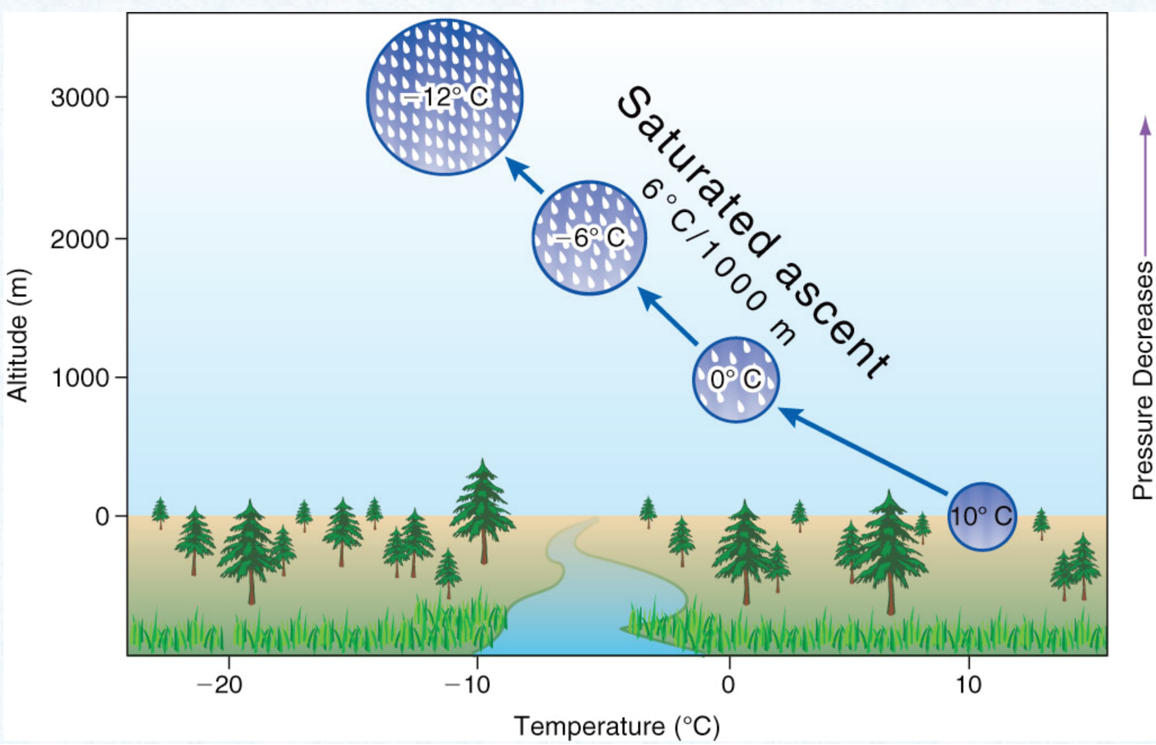
Lapse Rate



Dry adiabatic lapse rate: if no cloud forms, air will cool at 10°C per kilometer.

Fig 3-19 *Meteorology: Understanding the Atmosphere*

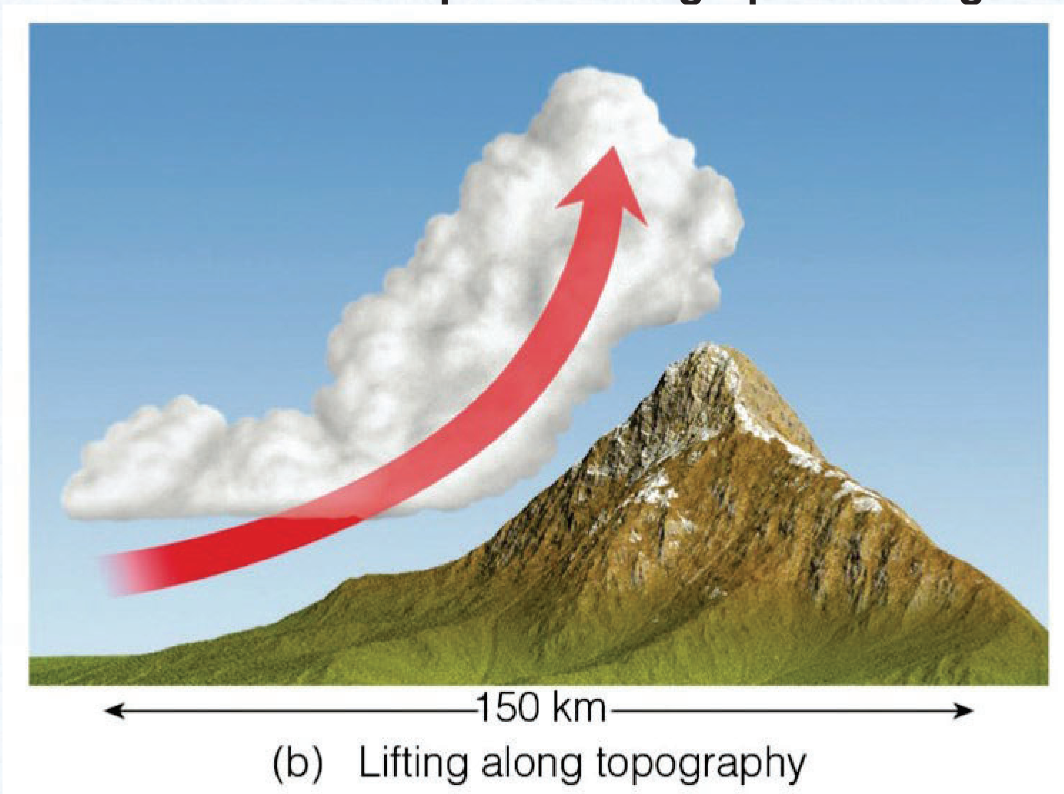
Saturated Adiabatic Lapse Rate



Once water begins to condense, latent heat is released. The air parcel cools at a slower rate (6°C per kilometer)than if the air parcel was dry

Fig 4-14 *Meteorology: Understanding the Atmosphere*

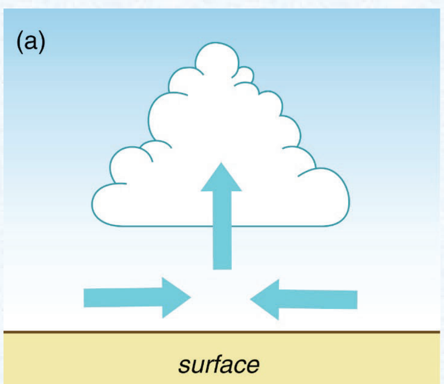
Cloud Development: Orographic Lifting



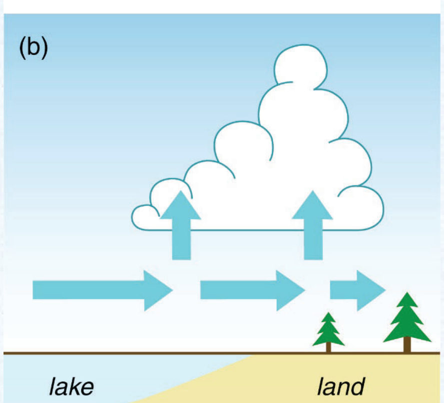
Air is forced up the side of a mountain and cools as it rises

Fig 5.10: ***Essentials of Meteorology***

Cloud Development: Convergence



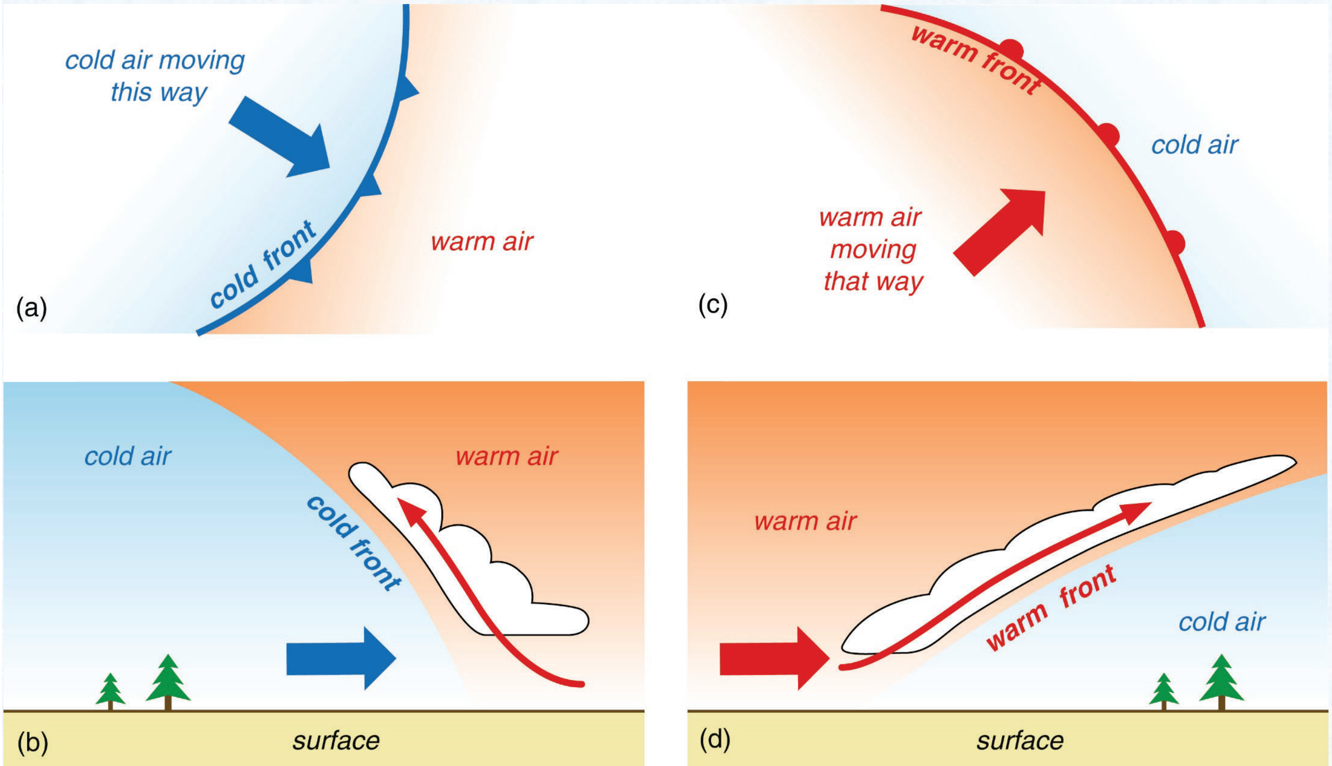
When wind meets from different directions, the air in between has no place to go but up



When the leading edge of the wind slows down, the wind behind "piles up"

Fig 6.11 *Weather: A Concise Introduction*

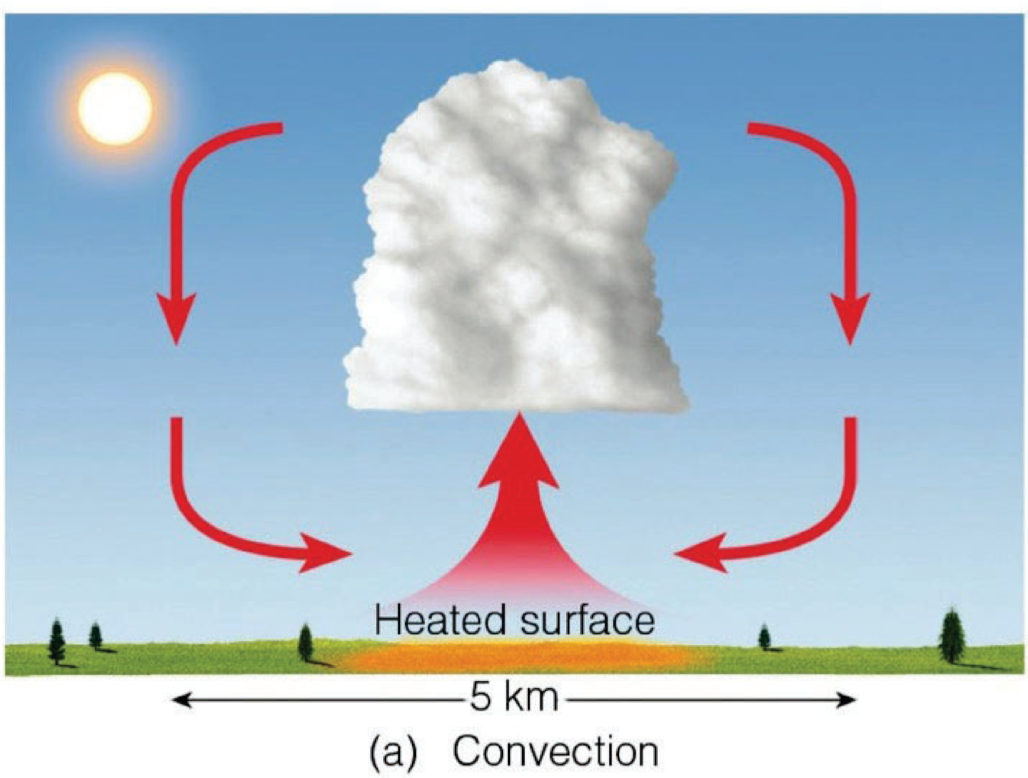
Cloud Development: Frontal Lifting



Warm air will ride up over cold air

Fig 6.12 *Weather: A Concise Introduction*

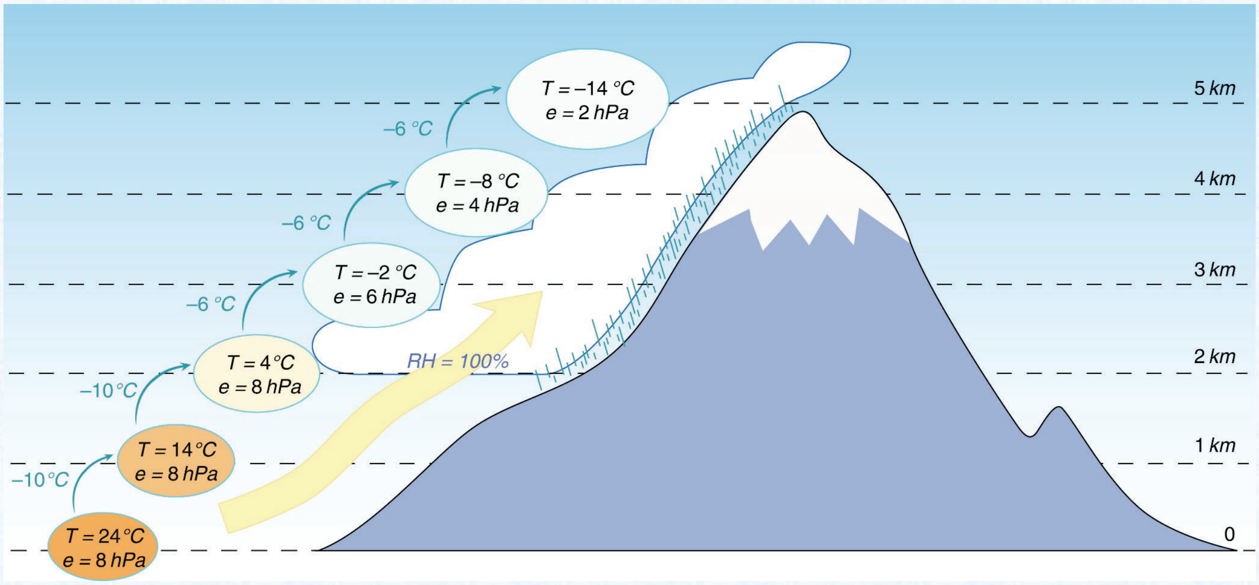
Cloud Development: Convection



As surface air is warmed by the sun, it becomes less dense and rises

Fig 5.10: ***Essentials of Meteorology***

Real World Example

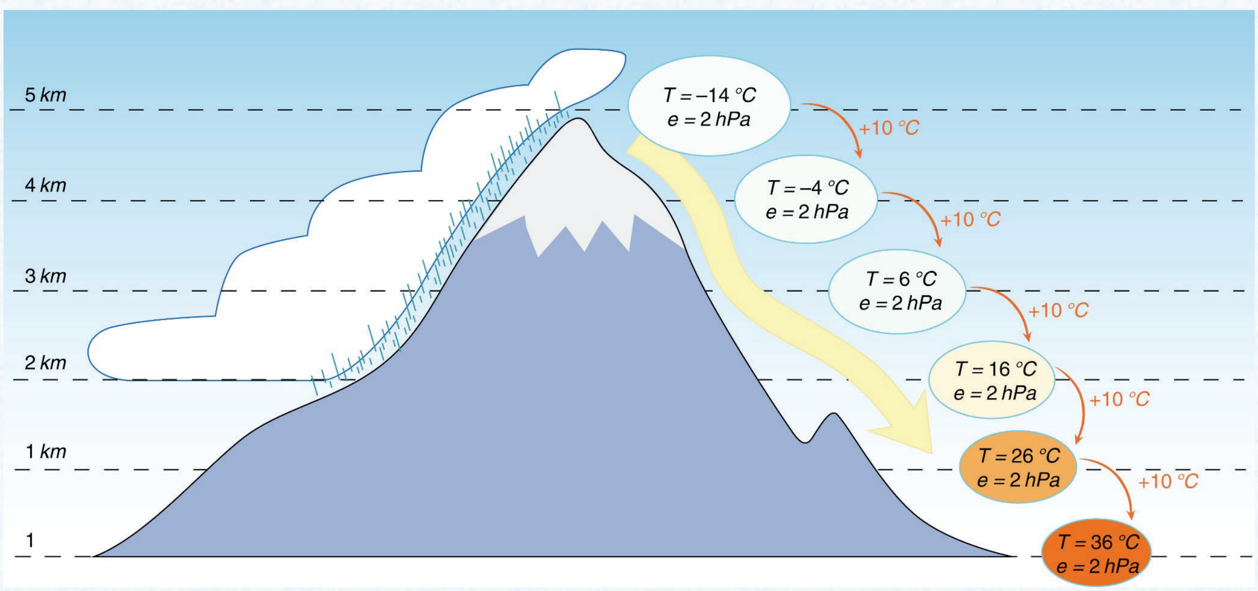


As air rises up a mountain side, it cools at the dry adiabatic lapse rate

Once it reaches saturation, it cools at the saturated lapse rate. Also, precipitation (rain or snow) falls out of the cloud and the vapor pressure decreases

Fig 6.7 *Weather: A Concise Introduction*

Real World Example



The air parcel has lost a lot of water. As it sinks down the mountain side, the air in the parcel warms and dries out the cloud.

The parcel warms only at the dry lapse rate.

When the parcel reaches the ground, it's warmer than when it started

Fig 6.8 *Weather: A Concise Introduction*

Fog types and how they're formed

- **Radiation**
- **Upslope**
- **Advection**
- **Evaporation (Steam)**

Clouds!!!

TABLE 4.1 The Four Major Cloud Groups and Their Types

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

Cloud groups have sub-categories

Table 4.1: *Essentials of Meteorology*

Clouds!!!

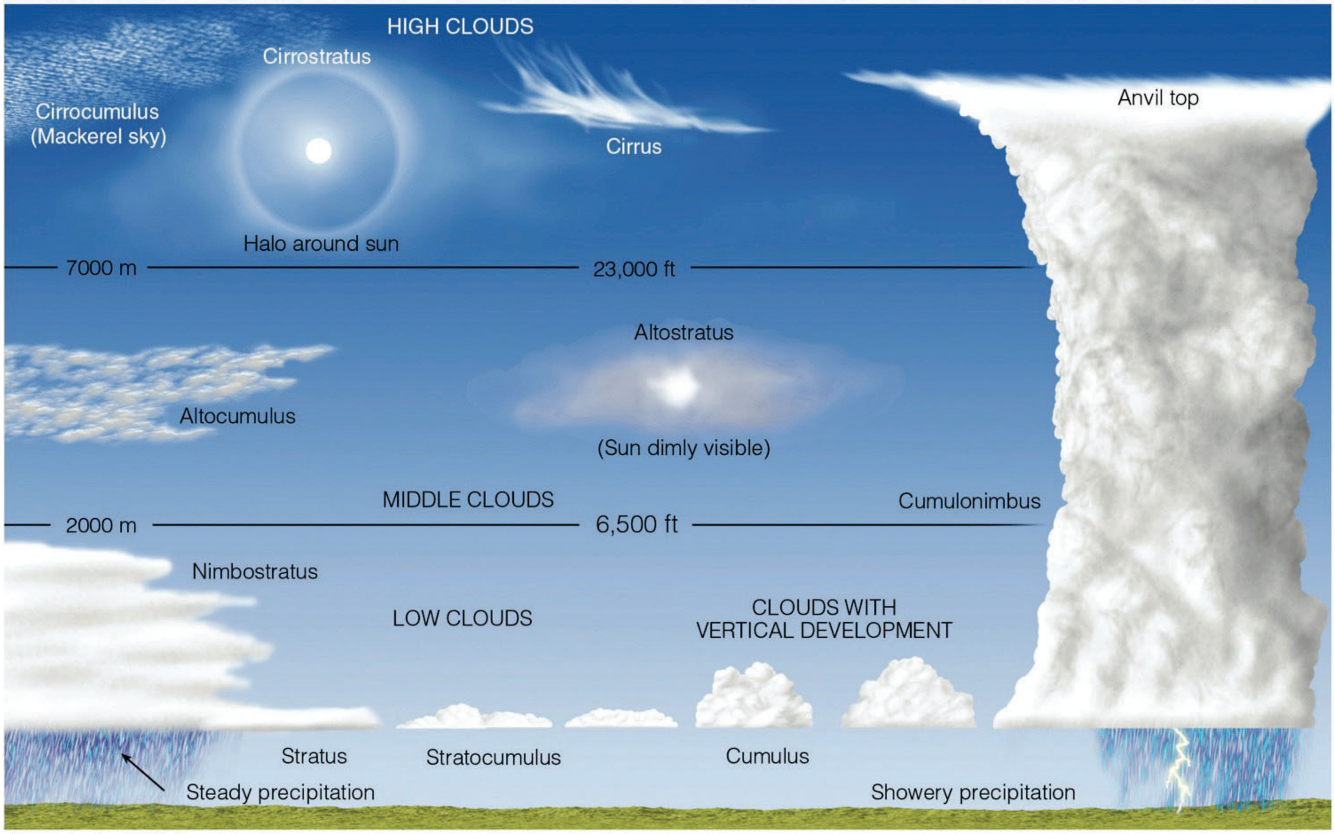


Fig 4.36: ***Essentials of Meteorology***