Climate, Climate Change Nuclear Power and the Alternatives

Climate, Climate Change Nuclear Power and the Alternatives

PHYC 40050

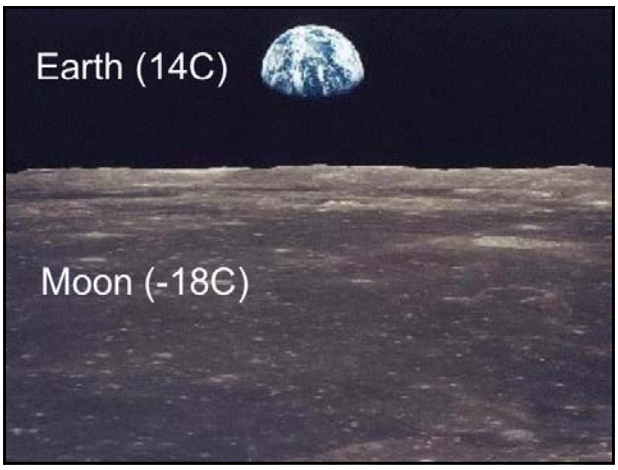
Peter Lynch

Meteorology & Climate Centre
School of Mathematical Sciences
University College Dublin

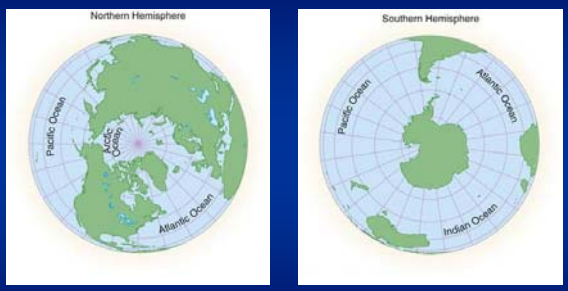
Lecture 1

The Composition and Structure of the Atmosphere

OUR HOME



COMPARISON OF HEMISPHERES



70% of the globe covered by water

Atmospheric Composition

COMPOSITION OF THE EARTH'S ATMOSPHERE

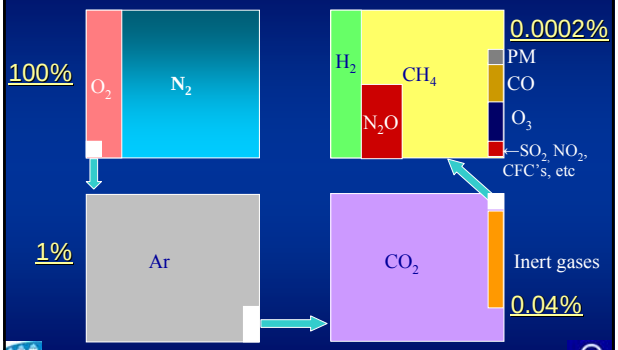


TABLE 1.1
Composition of the Atmosphere

Gas		Percentage by Volume
Nitrogen	~78%	78.08
Oxygen	~21%	20.95
Argon	~1%	0.93
Trace Gases		
Carbon dioxide	.04%	0.038
Methane		0.00017
Ozone		0.000004
Chlorofluorocarbons		0.00000002
Water vapor		Highly variable (0–4%)

ATMOSPHERIC COMPOSITION

- Molecular oxygen and nitrogen are major components – 99%
- Of the remaining 1% , 96% is the inert gas argon
- Of the remaining 4%, 93% is carbon dioxide
- All remaining gases – about 2 parts in 100,000 are known as trace species
- These gases control the chemistry of the troposphere

THE EARLY ATMOSPHERE

4.6 billion years ago:

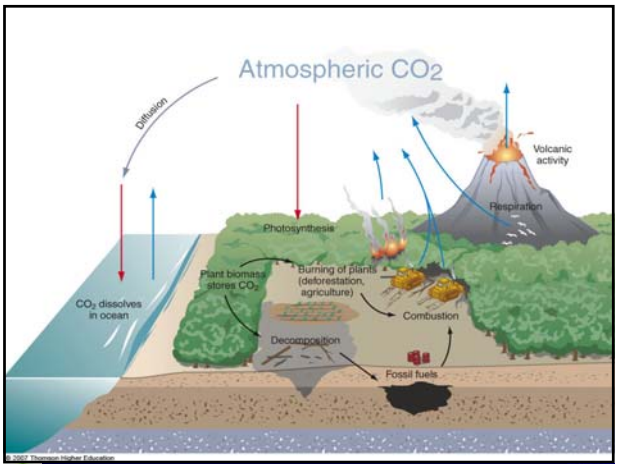
- Earth's gravity too weak to hold hydrogen and helium (unlike Sun, Jupiter, Saturn, Uranus)
- Earth's present atmosphere from volcanoes (outgassing)
  - Water vapor condensed to form oceans
  - CO_2 went into oceans and rocks
  - N_2
- Oxygen forms by break-up of water by sunlight, later from plants … photosynthesis.

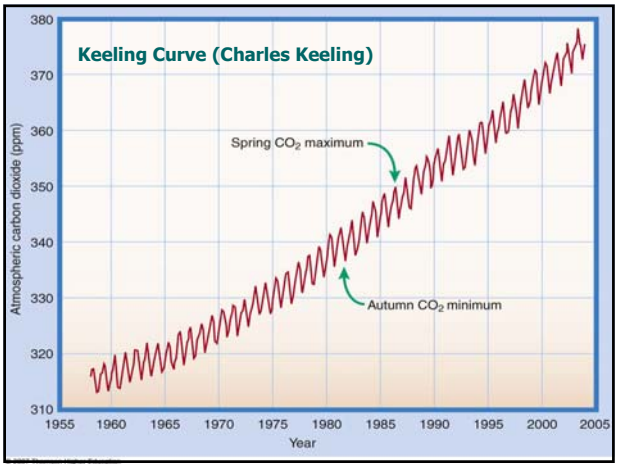
ATMOSPHERIC EVOLUTION

- Earth's early atmosphere consisted of Hydrogen (H), Helium (He), Methane (CH_4) and Ammonia (NH_3)
- As the earth cooled volcanic eruptions occurred emitting water vapour (H_2O), carbon dioxide (CO_2) and nitrogen (N_2).
- The molecular oxygen (O_2) in the current atmosphere came about as single celled algae developed in the oceans about 3 billion years ago.

ATMOSPHERIC EVOLUTION

- Oxygen is produced as a by-product of photosynthesis, the making of sugars from water vapor and carbon dioxide.
- This oxygen produces ozone (O_3) in the upper atmosphere which filtered out harmful ultraviolet radiation from the sun.
- This allowed plants and animals to develop on land.





CARBON DIOXIDE CYCLE

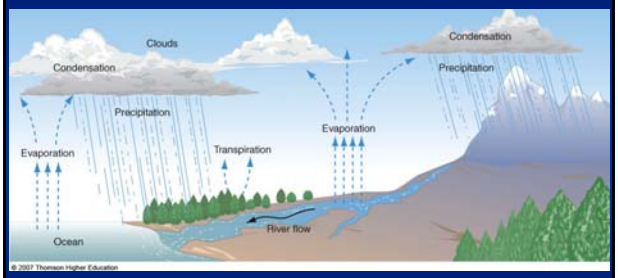
Sources

- Plant/animal respiration
- Plant decay
- Volcanoes
- Burning of fossil fuels
- Deforestation

Sinks

- Plant photosynthesis
- Oceans
- Carbonates

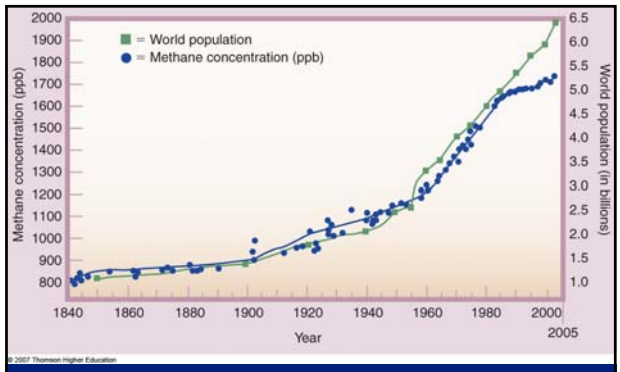
HYDROLOGICAL CYCLE



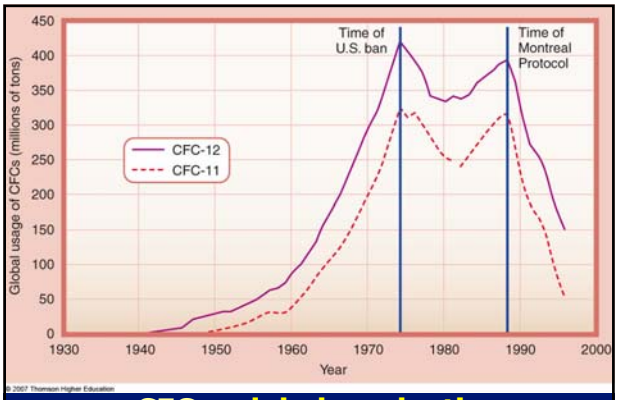
HYDROLOGICAL CYCLE

- Water is everywhere on earth
- It is in the oceans, glaciers, rivers, lakes, the atmosphere, soil, and in living tissue
- All these 'reservoirs' constitute the ***hydrosphere***
- The continuous exchange of water between the 'reservoirs' is called the hydrological cycle
- The hydrological cycle is powered by the Sun
- It comprises
  - Evaporation and transpiration
  - Precipitation
  - Percolation into ground
  - Run-off to the sea

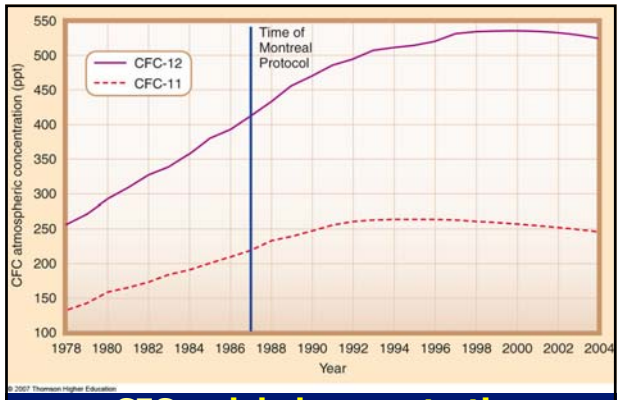
Trace Constituents



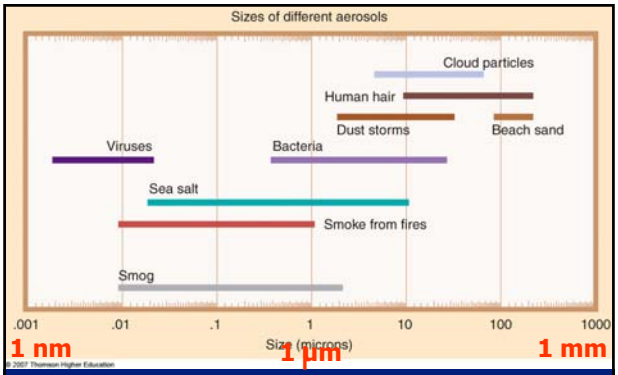
Methane and world population



CFCs: global production



CFCs: global concentration



Aerosols: particle sizes

AEROSOLS

- Particles suspended in the atmosphere
- Diameters of microns – one millionth of a meter.
- Modify the amount of solar energy reaching the surface.
- Act as condensation nuclei for cloud droplets.

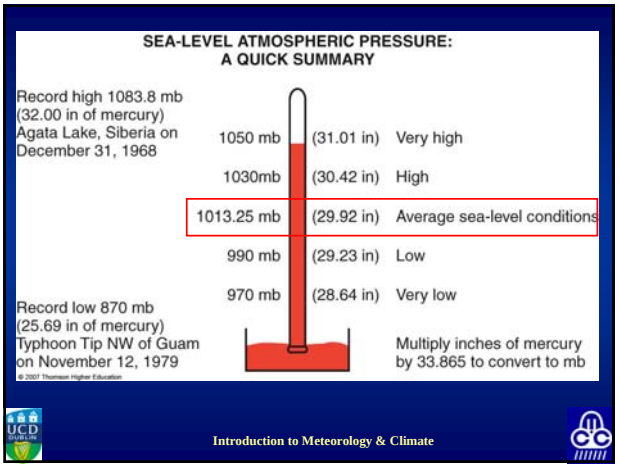
PRIMARY SOURCES:

- Sea salt spray
- Wind erosion
- Volcanoes
- Fires
- Human activity

PRESSURE AND DENSITY

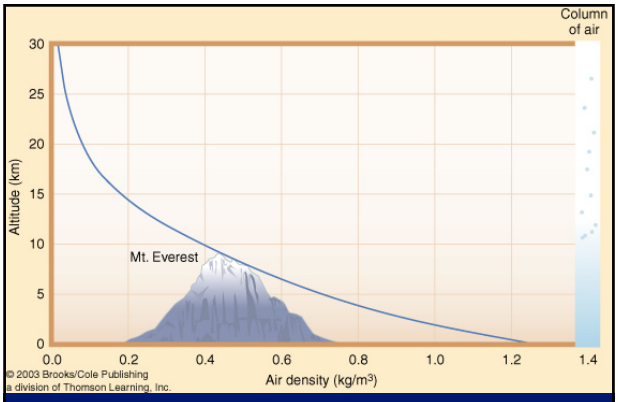
- **Pressure** is the force exerted on a given area.
- Air pressure results when air molecules move and collide with objects.
- Air pressure is exerted in all directions.

- **Density** is the concentration of molecules, or mass per unit volume.
- The pressure, density, and temperature of a gas are all related to each other.

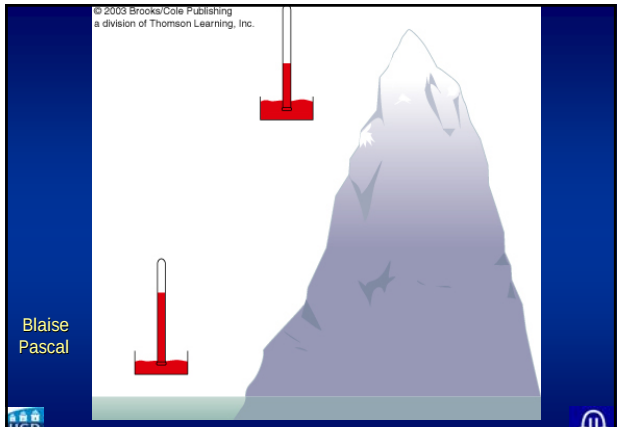


PRESSURE AND ALTITUDE

- Pressure is measured in terms of inches of mercury, or in **millibars** or **hectopascals**.
- Average sea-level pressure is 29.92 inches of mercury or 1013.25 millibars (hPa).
- Atmospheric pressure always decreases with increasing altitude.
- The air pressure measured on top of the Sugar Loaf is always less than the pressure in Kilmacanogue.
- To subtract the effect of station elevation, air pressure is corrected to report what it would be at sea level (**sea level pressure**)



Density decreases exponentially with height



ATMOSPHERIC PRESSURE

- Pressure at a point is the weight of air above that point.
- A column of air of cross-section 1 square metre weighs about 10 tonnes !
- In still air, two factors determine the pressure – temperature and density
- Ideal gas law:
  Pressure = Constant x Density x Temperature
- Pressure decreases with altitude.

ATMOSPHERIC DENSITY

- The concentration of molecules in measured in terms of density, or mass per unit volume.
- Density at sea level for temperature of 15°C is about 1.2 kilograms per cubic metre.
- Density decreases with altitude.

IDEAL GAS LAW

- The relationship between pressure, temperature, and volume is given by the ideal gas law:

$$p = R \rho T$$

where p = pressure
R = the gas constant
ρ = (Greek letter rho) density
T = temperature

IDEAL GAS LAW

- Knowing the Ideal Gas Law, you should be able to say what happens to one variable if a change in one of the others occurs (while the third remains constant).
- E.g., what happens to pressure if density increases (temperature constant)?

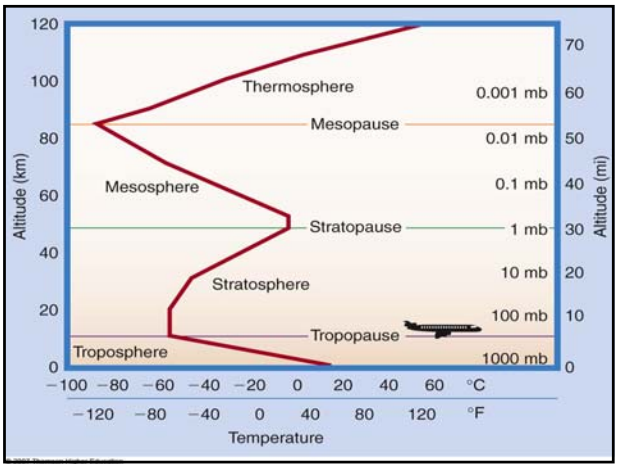
STRATIFICATION OF THE ATMOSPHERE

ATMOSPHERIC LAYERS

- The atmosphere can be divided up according to pressure (500 mb layer is about halfway up in the atmosphere).
- The atmosphere can also be divided up according to temperature (which does not follow a simple relationship with height).
- Averaging out temperature values in the atmosphere, we identify four layers.

ATMOSPHERIC LAYERS

- **Troposphere –** temperature decreases with height
- **Stratosphere –** temperature increases with height
- **Mesosphere –** temperature decreases with height
- **Thermosphere –** temperature increases with height



TROPOSPHERE

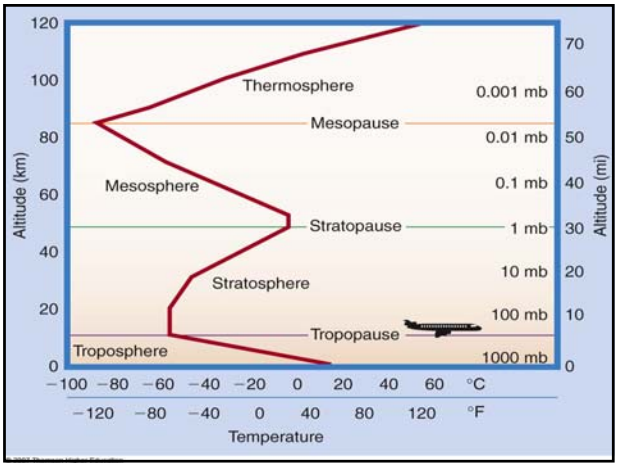
- From the surface up to about 12km (varies with latitude and season – higher in Summer, and in the tropics).
- Temperature decreases with height because the troposphere is heated by the surface and not directly by sunlight.
- Almost all of what we call "weather" occurs in the troposphere.
- Contains 80% of the atmosphere's mass

STRATOSPHERE

- Between about 12km and 50km.
- Temperature increases with height because the ozone layer absorbs ultraviolet light and warms up as a result.
- Lack of mixing and turbulence.
- Very little exchange occurs between the stratosphere and troposphere (but it is important where it does).
- 99.9% of the atmospheric mass below the stratopause.

MESOSPHERE & THERMOSPHERE

- Mesosphere between 50km and 85km.
- Thermosphere goes up and up and up: there is no clear separation between the thermosphere and interplanetary space.
- The highest temperatures in the atmosphere are found in the thermosphere due to high energy radiation being absorbed by gases.
- Ionosphere (charged gas atoms) that reflects radio waves, and aurora are here.



1. **Troposphere-** literally means region where air "turns over" -temperature usually decreases (on average ~6.5°C/km) with altitude

Tropopause

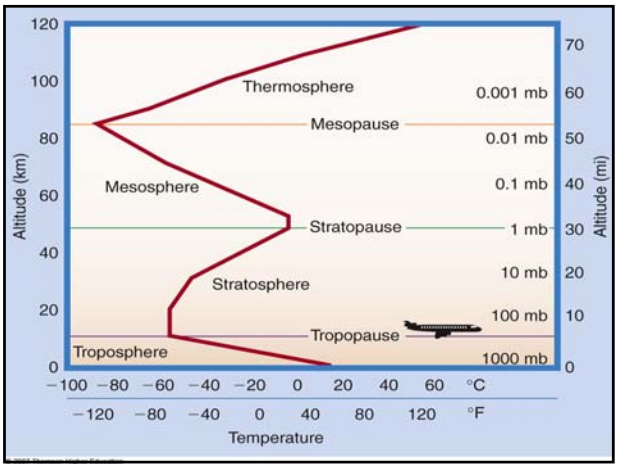
2. **Stratosphere-** layer above the tropopause, little mixing occurs in the stratosphere, unlike the troposphere, where "turbulent mixing" is common

Stratopause

3. **Mesosphere-** defined as the region where temperature again decreases with height.

Mesopause

4. **Thermosphere-** region with very little of the atmosphere's mass. High energy radiation received by the thermosphere: high temperatures. Very low density (not much "heat" felt).



In meteorology we often refer to altitude as a certain pressure value rather than height.

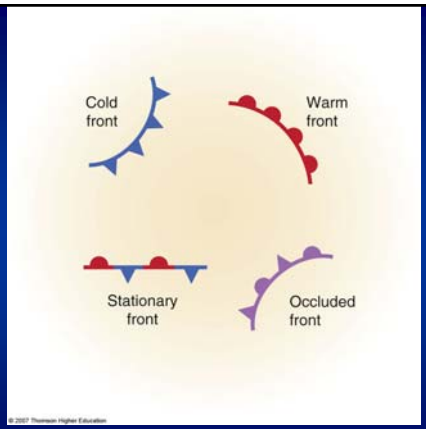
The atmosphere moves mainly on constant pressure surfaces (isobaric surfaces)

850 mb ≈ 1500 m (5000 ft)
700 mb ≈ 3000 m (10,000 ft)
500 mb ≈ 5500 m (18000)
300 mb ≈ 9000 m (30,000)

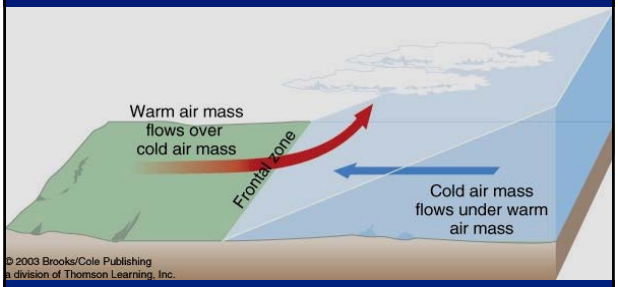
Introduction to Weather Maps

ATMOSPHERIC FRONTS

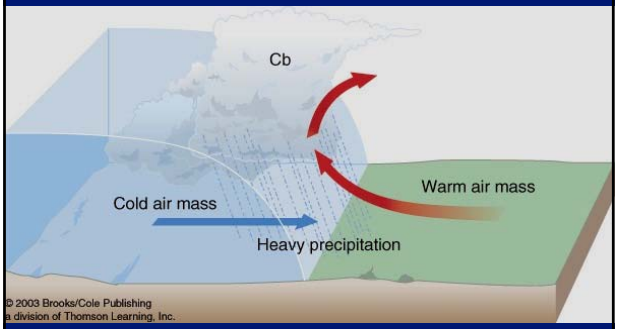
- **Front** – a boundary between two regions of air that have different meteorological properties, e.g. temperature or humidity.
- **Cold front** – a region where cold air is replacing warmer air.
- **Warm front** – a region where warm air is replacing colder air.
- **Stationary front** – a front that is not moving.
- **Occluded front** – a front where warm air is forced aloft.

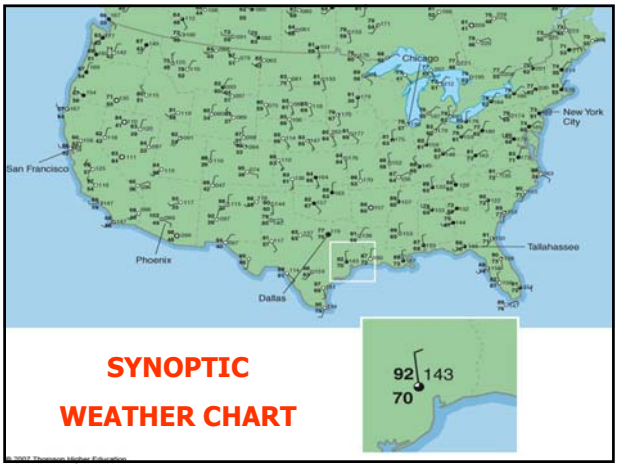


WARM FRONT

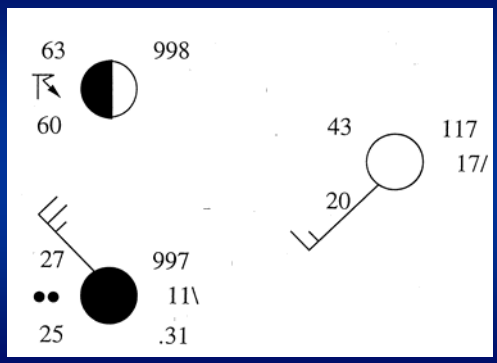


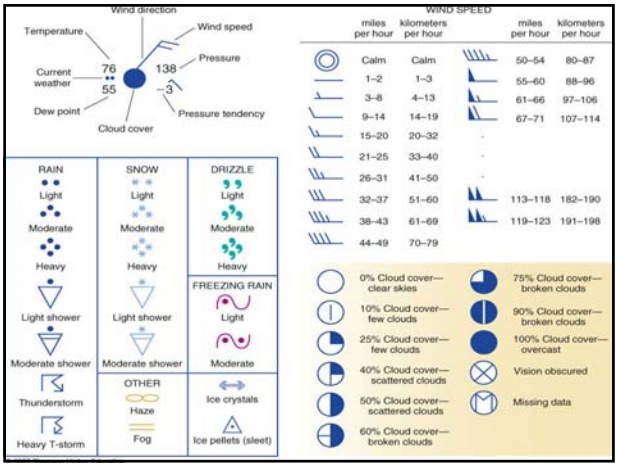
COLD FRONT





WEATHER PLOTTING SYMBOLS

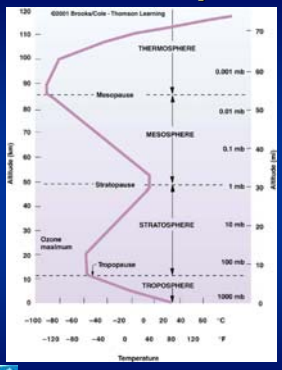




METEOROLOGICAL TIME

- All weather reports are labelled using Coordinated Universal Time (UTC), also called Greenwich Mean Time (GMT), and also denoted Zulu (Z).
- Zulu is the time along the 0º longitude line, which runs through Greenwich.
- Meteorology uses the 24 hour clock which omits the use of a.m. and p.m. (0900 = 9 a.m., 2100 = 9 p.m.)

Revision: Layers of the Atmosphere



- Hot top: oxygen absorbs sunlight
- Warm middle: ozone absorbs ultraviolet (UV)
- Warm surface: land and ocean absorb sunlight

End of Lecture 1