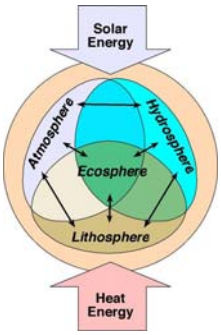
Climate and Ecosystem Roadmap

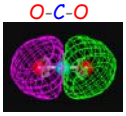


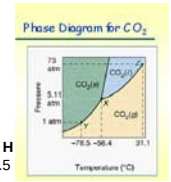
We wish to know:

- **Where we are going?**
  - Tie together 2 sections of class – Earth Science, Biology
  - Climate warming, acid rain, lost tropical rainforests
- **Why we should care?**
  - Remember Ben's Introduction…
- **How do we get there?**
  - Facts and concepts (and, dispelling "truth")

1. FACTS

O-C-O



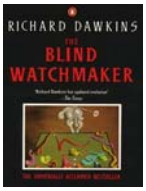


Physical constants of CO_2:

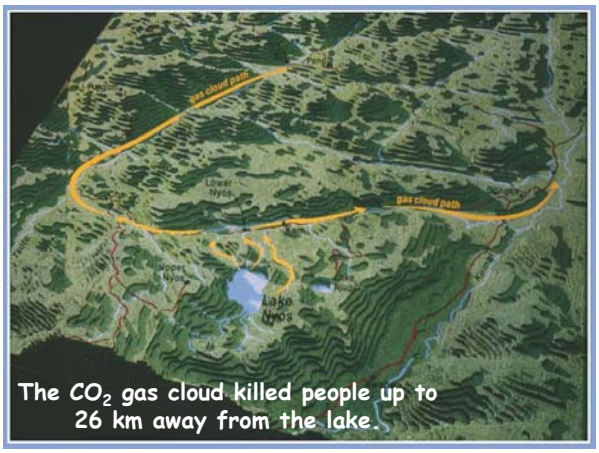
Mol. Weight	Density	mag. sus.	ref. index	Cp	delta H
44.01	1.799	-21.0	1.663	29.14	-110.5

2. CONCEPTS

"Life is like a blind watchmaker"



Lake Nyos, Cameroon
Exploded in 1986, killed ~2000 people



The CO_2 gas cloud killed people up to 26 km away from the lake.

1. Fact/Concept ratio Low = ?

Philosophy

2. Fact/Concept ratio High = ?

Engineering, Medicine

Scientific Concepts:

1. Standing Stock
2. Mass Balance
3. Material Flux Rate
4. Residence Time = Stock/Flux Rate
5. Negative/Positive Feedback

Climate Change

1. How do we know it's happening?
   -- Easy, just look around
2. What do the skeptics say?

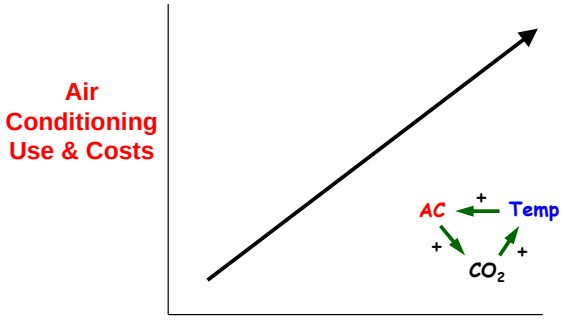
Lay-person's view -- *doubt and uncertainty*

Professional approach
-- *uncertainty and deception*

We don't care who made the watch, we just want to know how it works !

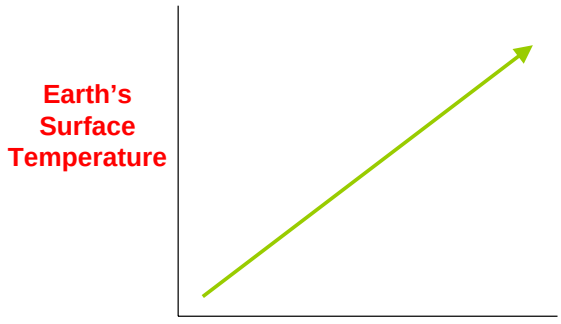
#1

Understand? *Believe?*



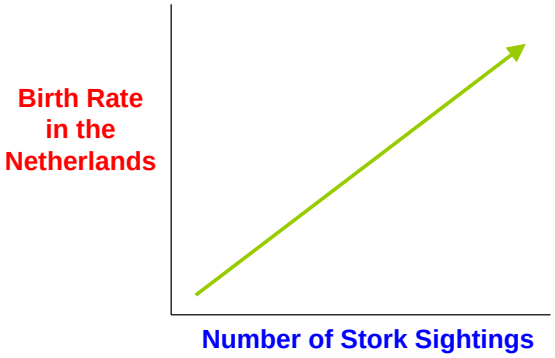
#2

Understand? *Believe?*



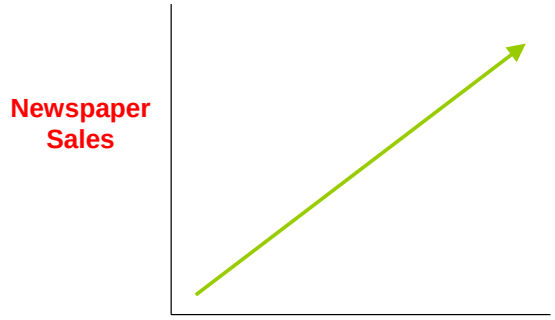
#3

Understand? *Believe?*



#4

Understand? *Believe?*



How does it work?

1. Mechanism OK
   Size/Impact OK
   (temperature & air conditioning costs)

2. Mechanism OK
   Size/Impact too Small
   (temperature & sun spots, # words written by YOU)

3. Mechanism Bad
   (birth rate & stork sightings – correlation is NOT causation)
   Hey, it's all BS! (Babies and Storks…)

The Atmosphere

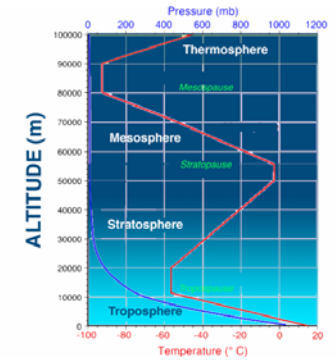
What we wish to learn today:

1. What is the structure of our atmosphere?
2. What is the composition of our atmosphere?
3. How does the atmosphere circulate?
4. What is the difference between weather and climate?

Structure of the Modern Atmosphere

Pressure (blue line)
Force exerted per unit area - the standard unit of measure is now the pascal (Pa), but in meteorology the millibar is still used:
(1 mb = 100 Pa; 1000 mb ~ 1 bar ~ 1 atm = is 0.1 GPa)

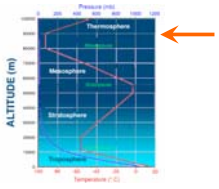
Temperature (red line)
A measure of the average kinetic energy of the molecules comprising a substance.

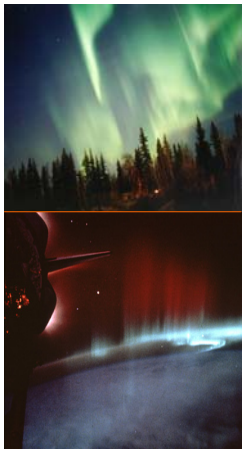


Thermosphere

The air is extremely thin in the **thermosphere**, and a small change in energy can cause a large change in temperature.

When the sun is active, the thermosphere can reach 1,500°C or higher. The Earth's thermosphere also includes the region called the **ionosphere**, which is filled with charged particles, which cause the aurora borealis.

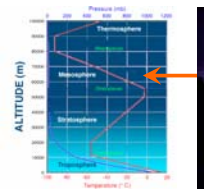




Mesosphere

In the Earth's **mesosphere**, the air is relatively well-mixed and the temperature decreases with altitude.

The atmosphere reaches its coldest temperature of around -90°C in the mesosphere. This is the layer in which a lot of meteors burn up while entering the Earth's atmosphere, producing "falling stars".

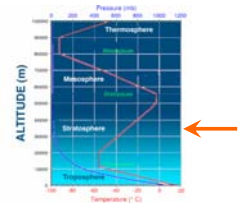


Noctilucent clouds (blue-white) over Finland.

Stratosphere

In the Earth's **stratosphere**, temperature increases with altitude. This increase is caused by ozone molecules that absorb UV radiation and thus heat the air.

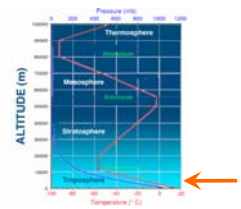
Ozone is concentrated around an altitude of 25 kilometers in the "ozone layer". Ozone protects life from harmful UV radiation -- *the "ozone hole" is different from climate warming.*



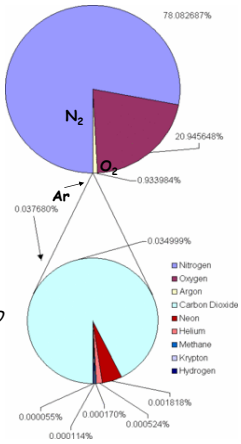
Troposphere

The **troposphere** is the layer in contact with the Earth's surface, and hence its temperature structure is determined by energy transmitted to and from the surface.

Weather occurs in the troposphere.



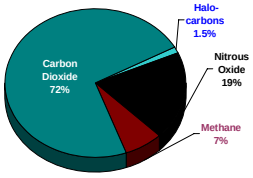
Atmospheric Composition



Main constituents:

N_2	78.08%	780,800 ppmv
O_2	20.95%	209,500 ppmv
Ar	0.93%	9,300 ppmv
CO_2	*0.036%*	*380 ppmv**

**99% of greenhouse gases, excluding H_2O*



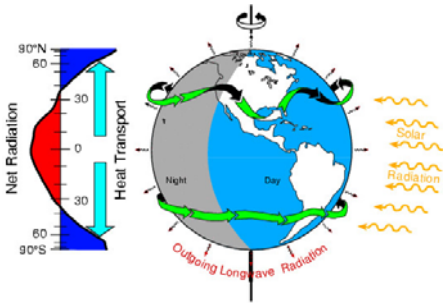
Anthropogenic Greenhouse Gases and *Global Warming Potential*

Water (vapour) is a greenhouse gas that accounts for 95% of the natural greenhouse effect, leaving ~5% for anthropogenic gases shown.

Greenhouse gases	Chemical formula	Pre-industrial concentration	Concentration in 1994	Atmospheric lifetime (years)***	Anthropogenic sources	Global warming potential (GWP)*
Carbon-dioxide	CO_2	278 000 ppbv	358 000 ppbv	Variable	Fossil fuel combustion Land use conversion Cement production	1
Methane	CH_4	700 ppbv	1721 ppbv	12,2 +/- 3	Fossil fuels Rice paddies Waste dumps Livestock	21**
Nitrous oxide	N_2O	275 ppbv	311 ppbv	120	Fertilizer industrial processes combustion	310
CFC-12	CCl_2F_2	0	0,503 ppbv	102	Liquid coolants Foams	6200-7100 ****
HCFC-22	$CHClF_2$	0	0,105 ppbv	12,1	Liquid coolants	1300-1400 ****
Perfluoromethane	CF_4	0	0,070 ppbv	50 000	Production of aluminium	6 500
Sulphur hexa-fluoride	SF_6	0	0,032 ppbv	3 200	Dielectric fluid	23 900

Energy on Earth – *review*

Energy is input from the sun and is moved from low latitudes to high latitudes through the atmosphere and ocean currents.

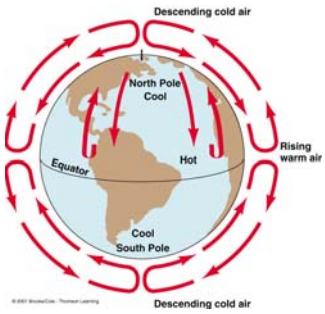


IPCC WG1

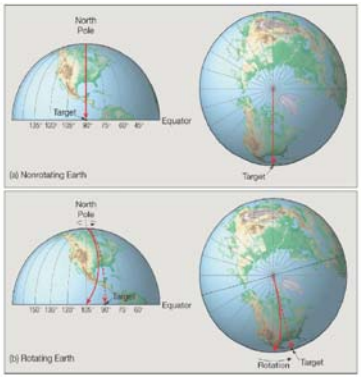
Atmospheric Circulation without Coriolis effects

If Earth did not rotate and had no continental land masses, the wind system would be simple: *rising air at the equator moves toward the poles, cools, and returns at lower altitude toward the tropics.*

This general circulation is called a 'Hadley Cell'.



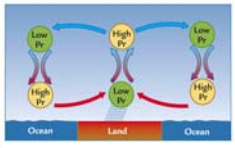
A Rotating Planet and the Coriolis Effect



Once air has been set in motion it undergoes a deflection from its path, as seen by an observer on the surface.

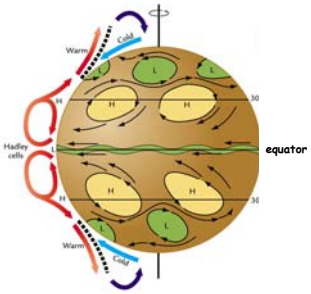
It is deflected to the right by the Coriolis force in the northern hemisphere, and is deflected to the left in the southern hemisphere.

Actual Circulation of the Atmosphere

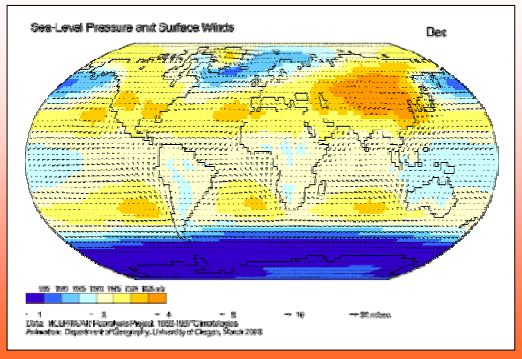


Heating and Earth's rotation combine to drive differences in air pressure that create 3 Hadley cells in each hemisphere.

This multi-cell circulation produces high and low pressure cells, and produces the "trade winds" and the "jet-stream".

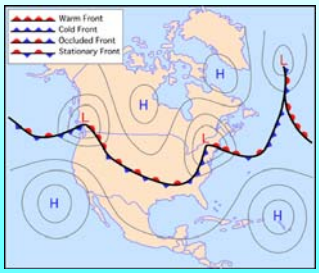


Monthly sea-level pressure and surface winds



From http://geography.uoregon.edu/envchange/clim_animations/index.html

Weather Patterns – are driven by variable high and low pressure cells



- Weather patterns are more complex than the global circulation
- Areas of high and low pressure change the weather frequently

Weather *versus* Climate

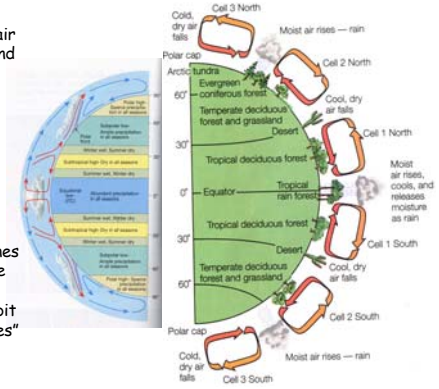
Weather describes the current atmospheric conditions at a particular place, such as temperature, precipitation, wind, humidity, and pressure.

Climate describes the general weather patterns expected in a particular place such as Michigan or the Arctic or the tropics. In other words, "climate is the statistical average of weather over time".

Climate may also describe large-scale weather patterns over long time frames, such as the "Ice Age climate".

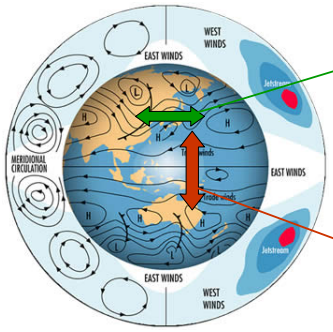
Climate Zones and Biomes

The direction of air flow and ascent and descent of air masses in Hadley cells determines Earth's climatic zones.



These climate zones in turn control the plant and animal species that inhabit large-scale "biomes" on Earth.

Time Constants for Atmospheric Mixing



East-west mixing at mid latitudes takes ~ 3-4 weeks

North-south mixing across the equator takes ~ 1 year

Australian Government, Bureau of Meteorology

Summary:

1. Different layers of our atmosphere perform different functions related to heat balance (greenhouse gases) and weather.
2. Greenhouse gases have different warming potentials, which is a function of how much radiation they absorb and their residence time in the atmosphere. Changes in the amounts of these gases are important for global warming.
3. The atmosphere mixes relatively quickly, and transports large amounts of heat around the globe. This rapid mixing is what makes greenhouse gas emissions a "global problem".
4. Stable patterns of atmospheric circulation (modified by Coriolis effects) lead to consistent "climate zones", which control the general distribution of plants and animals in Earth's "biomes".