

The Greenhouse Effect

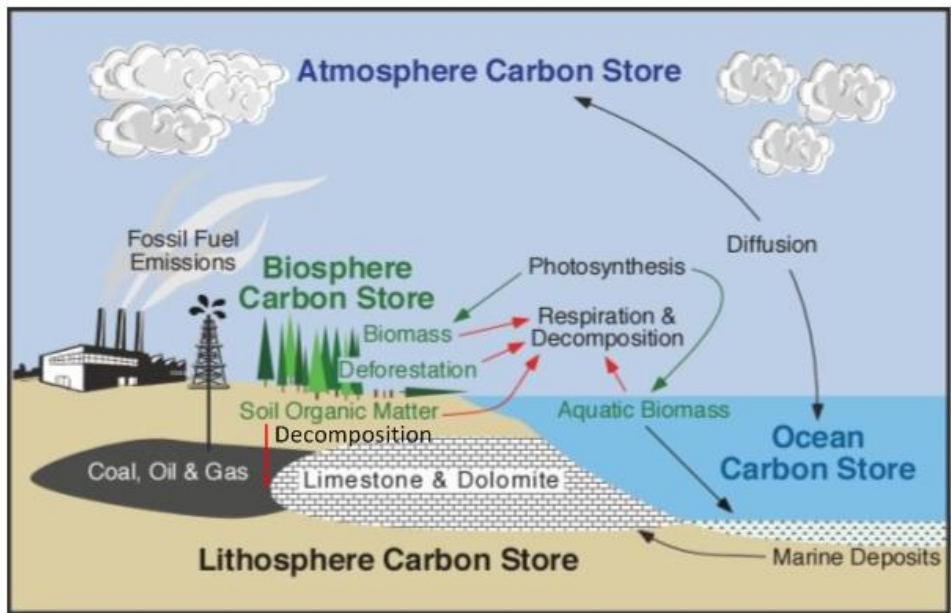
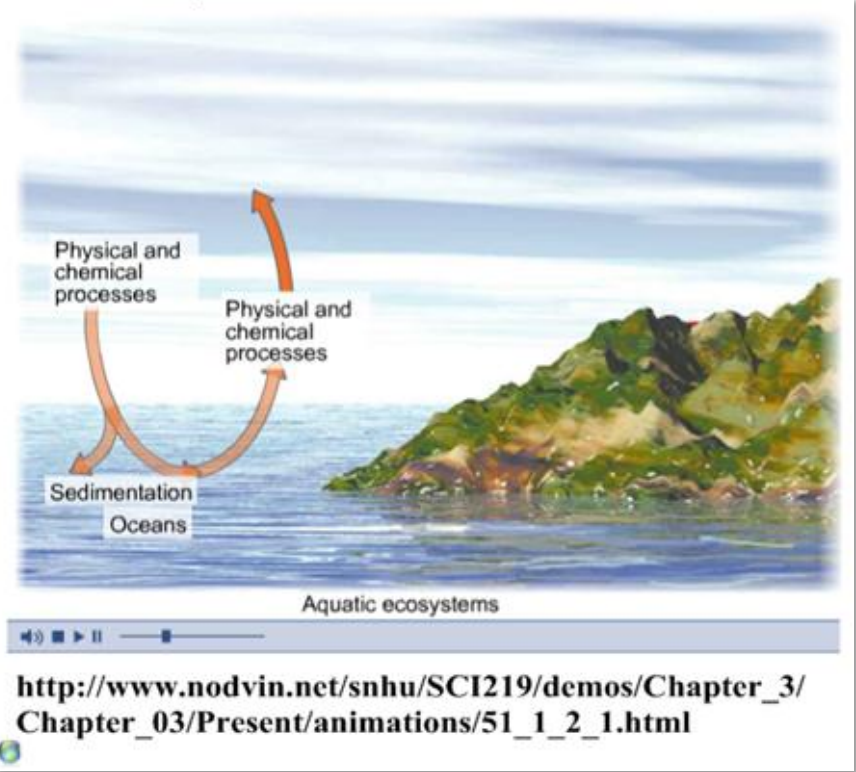
Stephen Taylor

Bandung International School

The Carbon Cycle

- Carbon exists in many forms:
- atmospheric gases (CO₂ and methane)
 - dissolved CO₂ in aquatic systems
 - organic carbon in living organisms
 - carbon deposits in the lithosphere, as minerals (carbonates) or fossil fuels.

Carbon cycle animation:



<http://www.physicalgeography.net/fundamentals/9r.html>

What are the *sources* of atmospheric CO₂?

What is the *sink* of atmospheric CO₂?

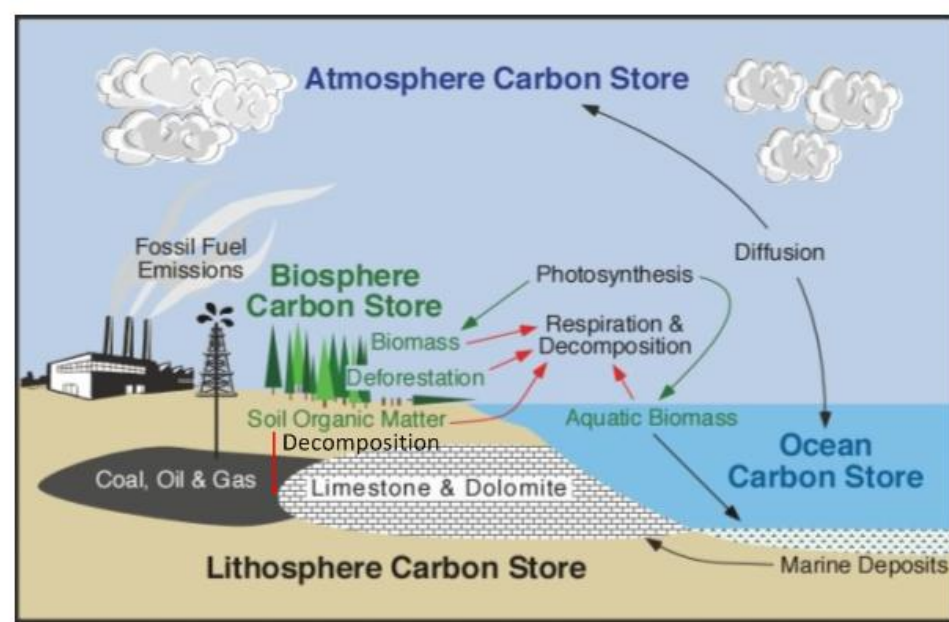
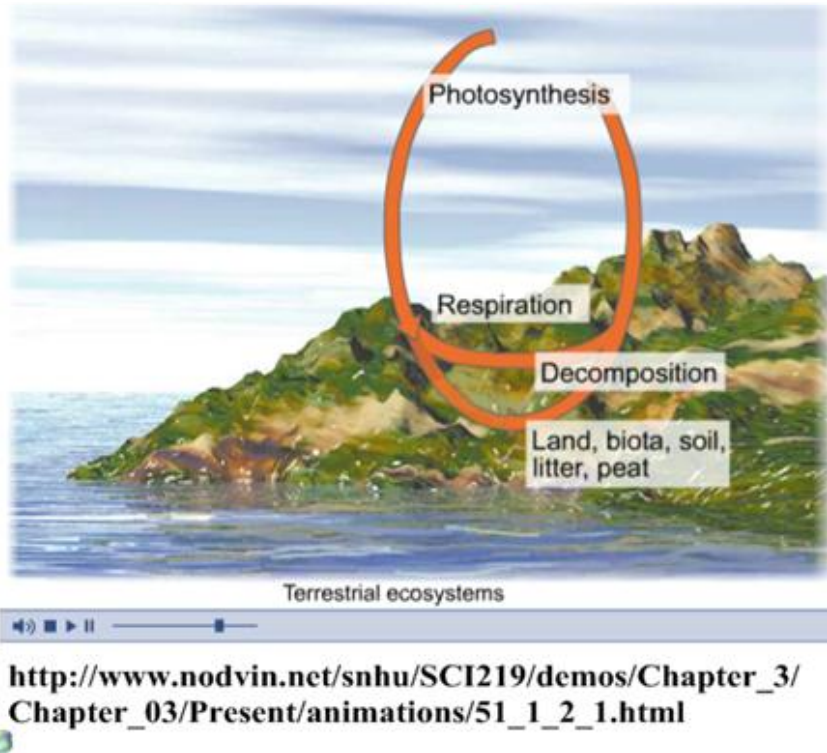
Which *processes* return C to the lithosphere?

The Carbon Cycle

Carbon exists in many forms:

- atmospheric gases (CO_2 and methane)
- dissolved CO_2 in aquatic systems
- organic carbon in living organisms
- carbon deposits in the lithosphere, as minerals (carbonates) or fossil fuels.

Carbon cycle animation:



<http://www.physicalgeography.net/fundamentals/9r.html>

What are the *sources* of atmospheric CO_2 ?

respiration, decomposition, diffusion, burning of fossil fuels (combustion)

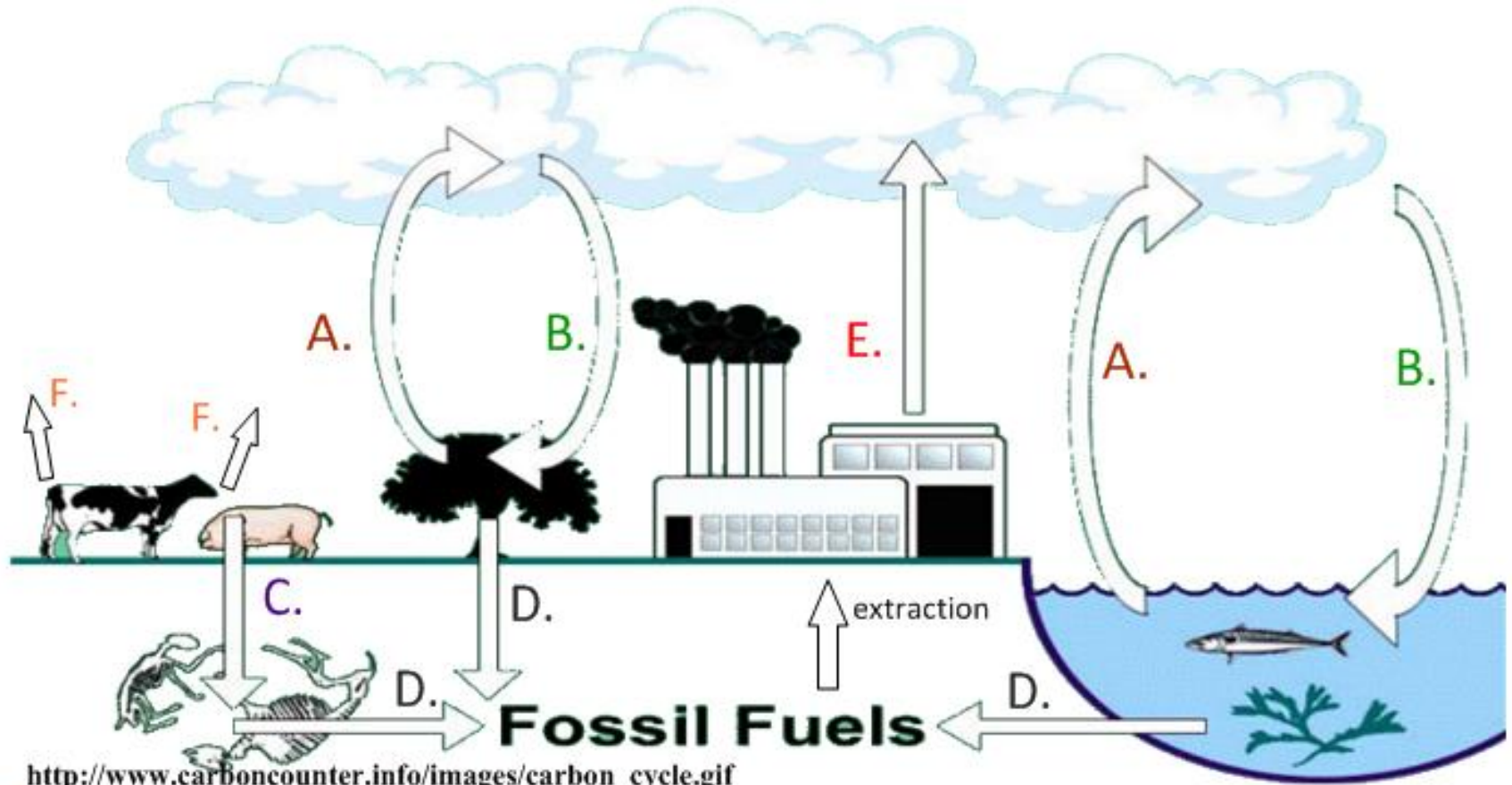
What is the *sink* of atmospheric CO_2 ?

photosynthesis, some diffusion into aquatic systems

Which *processes* return C to the lithosphere?

decomposition of organic matter, marine deposits of carbonates

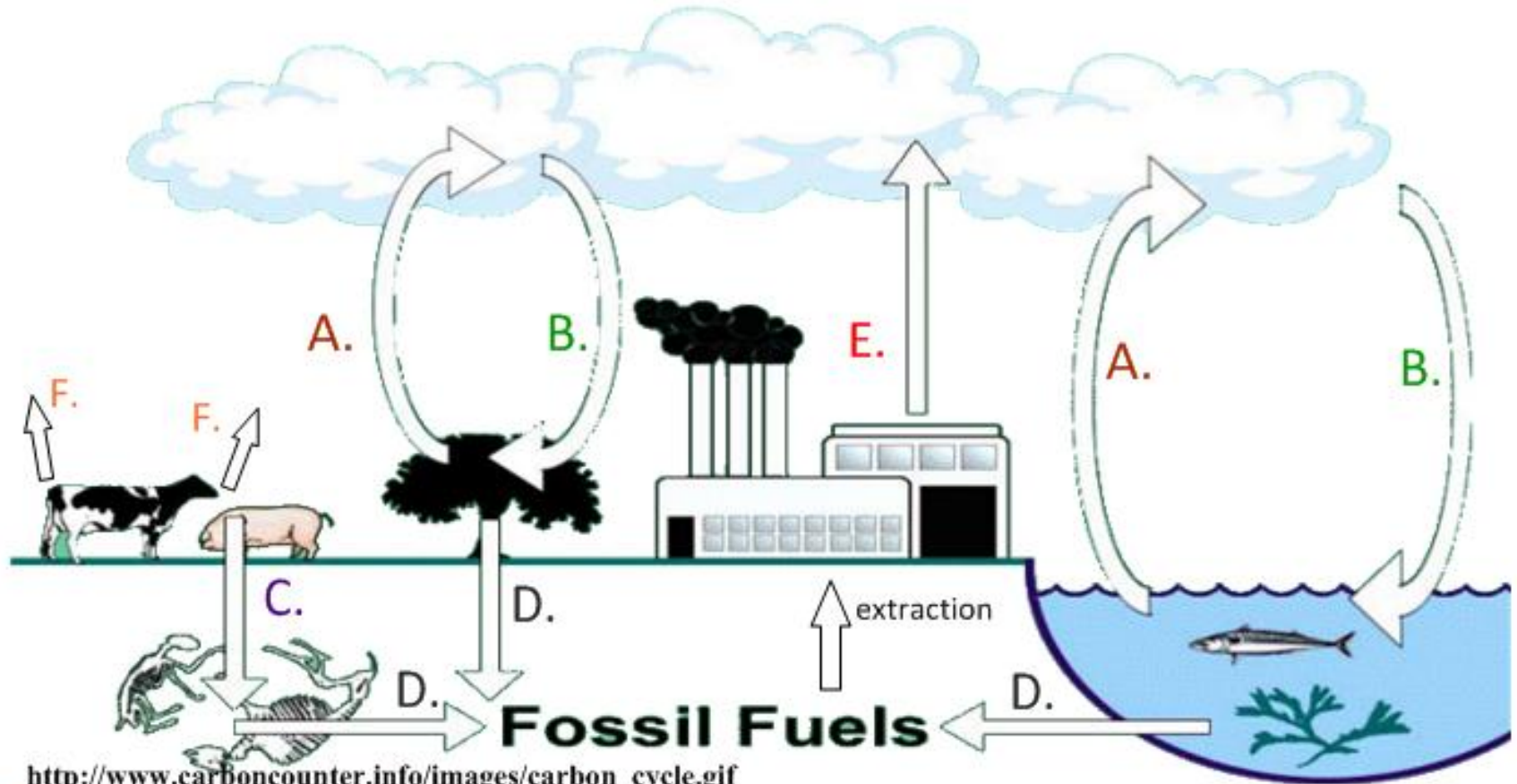
A simplified carbon cycle



http://www.carboncounter.info/images/carbon_cycle.gif



A simplified carbon cycle



http://www.carboncounter.info/images/carbon_cycle.gif

A. Respiration

B. Photosynthesis (carbon fixation)

C. Decomposition

D. Fossilisation

E. Combustion

F. Methane emissions

Solar radiation has a wide range of wavelengths:



short wavelength (high-energy)
radiation emitted from the Sun

some heat lost to space

some radiation reflected
back to Earth by greenhouse gases

longer wavelength
(lower-energy)
radiation re-emitted from
the surface

ozone

troposphere

radiation strikes Earth



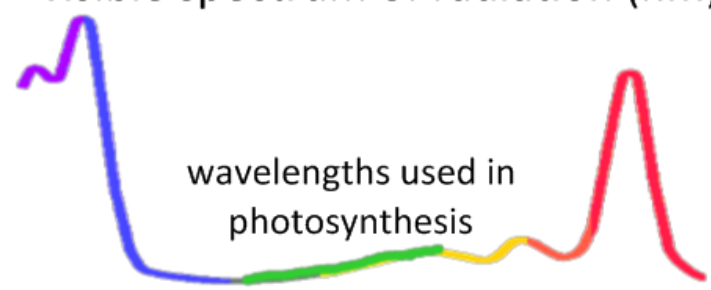
UV
high-energy
harmful

400 500 600 700 800
visible spectrum of radiation (nm)

infra-red
low-energy
heat

absorbed by the
ozone layer
(more on this later)

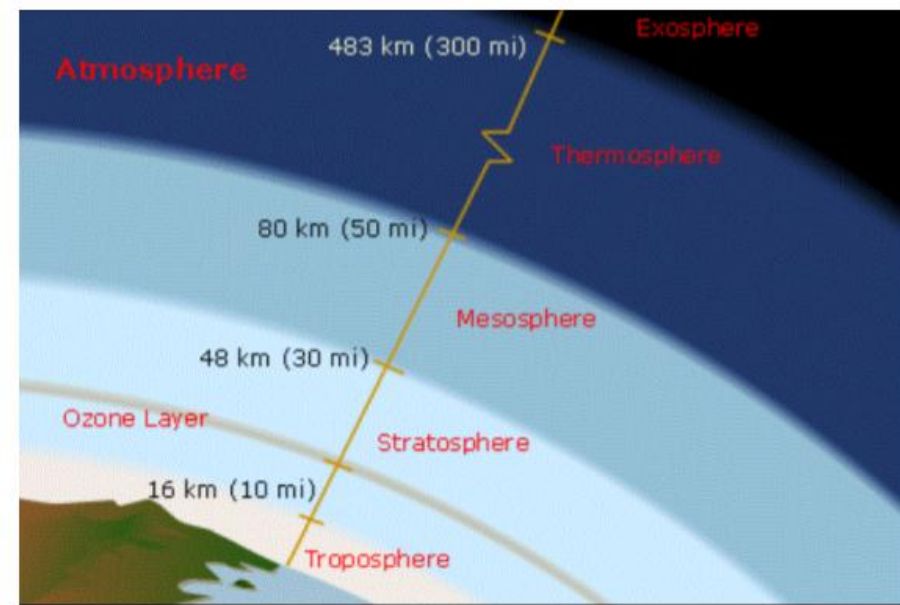
wavelengths used in
photosynthesis



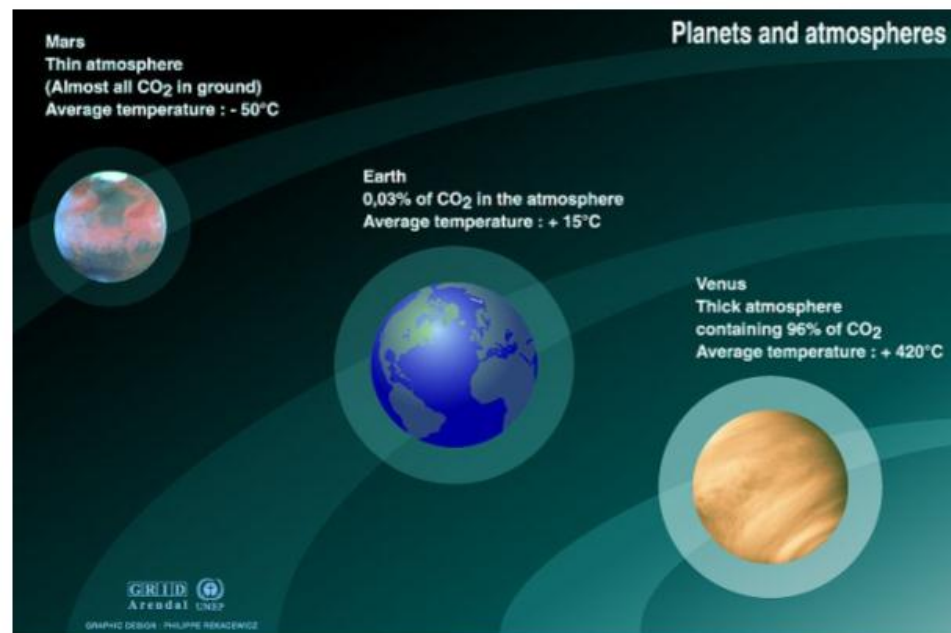
Greenhouse gases are trapped in the troposphere layer, up to 16km above the Earth's surface.

Greenhouse gases include:

- water vapour
- carbon dioxide (CO₂)
- methane (CH₄)
- nitrous oxide (NO₂)



http://www.pacificislandtravel.com/nature_gallery/atmosphere.html



Sources: Calvin J. Hamilton, Views of the solar system, www.planetspaces.com; Bill Arnett, The nine planets, a multimedia tour of the solar system, www.aeds.org/bills/nineplanets.html

<http://www.grida.no/climate/vital/01.htm>



The presence of greenhouse gases is vital to the evolution and survival of life on Earth.

Greenhouse gases trap radiation within the troposphere, raising temperatures.

Without the **natural greenhouse effect**, the temperature of the Earth would not be warm enough to sustain life.

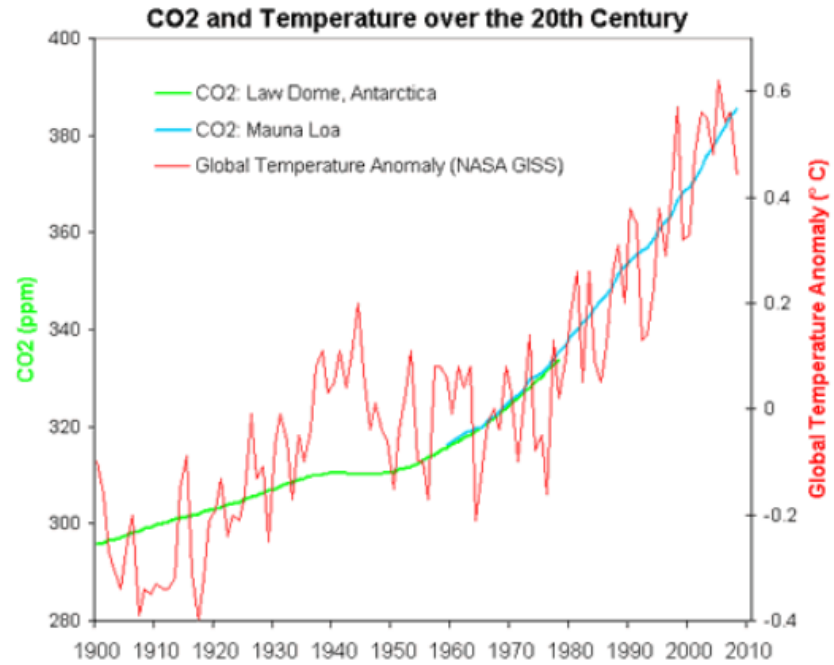
Elevated levels of greenhouse gases are **strongly correlated** with an **enhanced greenhouse effect**:

As levels of CO₂, methane, water vapour and oxides of nitrogen increase, more radiation is reflected back to Earth instead of being lost to space.

Anthropogenic = *human-caused*

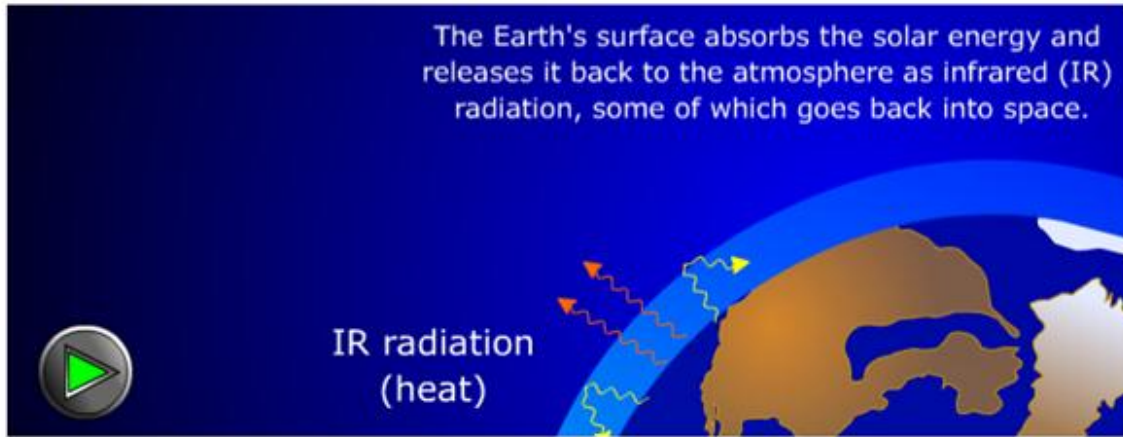
Which gases in the table have the potential to cause the most damage?

Although we see **correlation**, where do scientists find the evidence for a **causal relationship**?

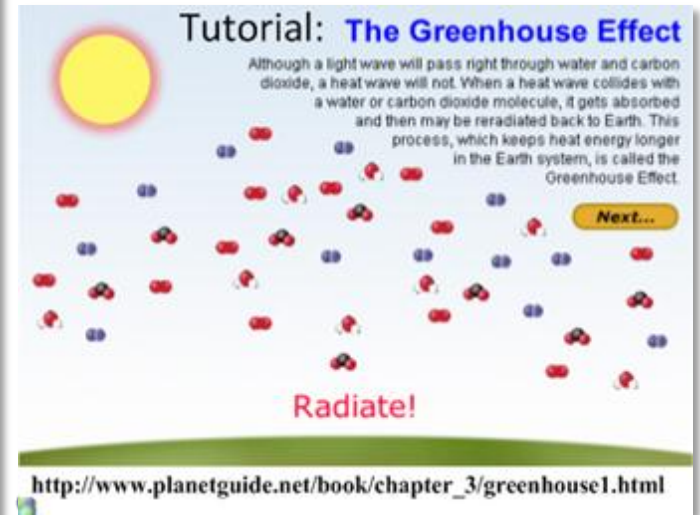


<http://www.skepticalscience.com/The-CO2-Temperature-correlation-over-the-20th-Century.html>

More greenhouse effect tutorials:

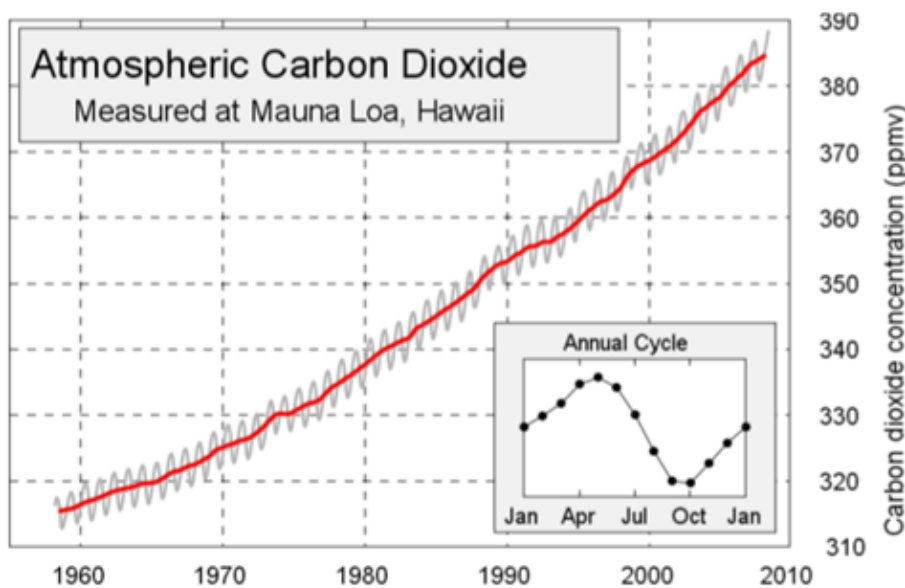


<http://earthguide.ucsd.edu/earthguide/diagrams/greenhouse/>



http://www.planetguide.net/book/chapter_3/greenhouse1.html

What is the evidence for increasing levels of CO₂ in the atmosphere?



<http://icestories.exploratorium.edu/dispatches/ipy-the-next-generation/>

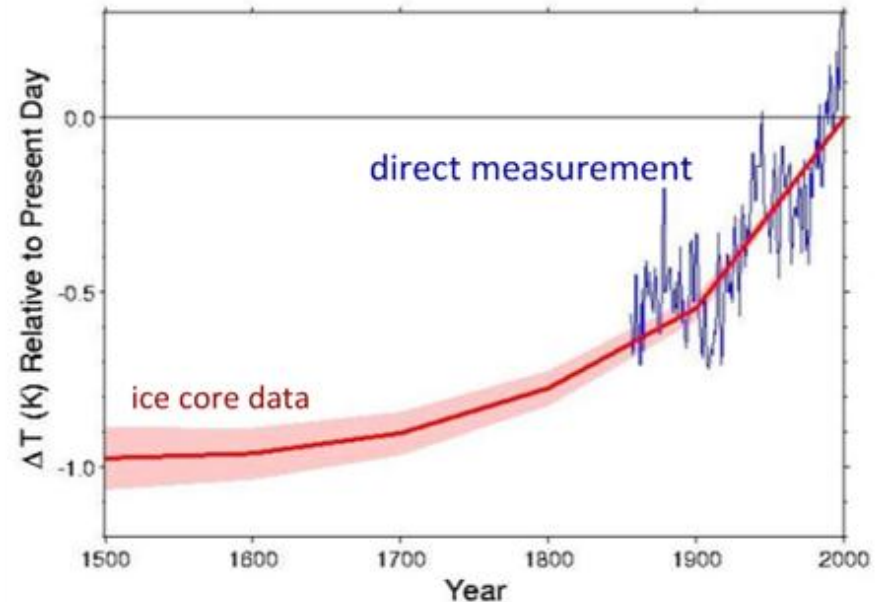
Recent data has been easy to collect experimentally.

Over 40 years, Charles Keeling measured atmospheric CO₂ from his observatory in Mauna Loa, Hawaii, and the 'Keeling Curve' has become an icon of climate science.

It shows a clear trend and annual cycles and many field stations use a standardised method.

Historical data takes more effort to collect and is more variable in the reliability of the results produced.

Ice cores are a good source of CO₂ data, where researchers can analyse the CO₂ concentration of air bubbles trapped in the ice and estimate year based on the depth of the core.



<http://www.ncdc.noaa.gov/paleo/borehole/core.html>



Plot annual fluctuations and long-term trends for one of these sites:



32°9' N, 117°3' W

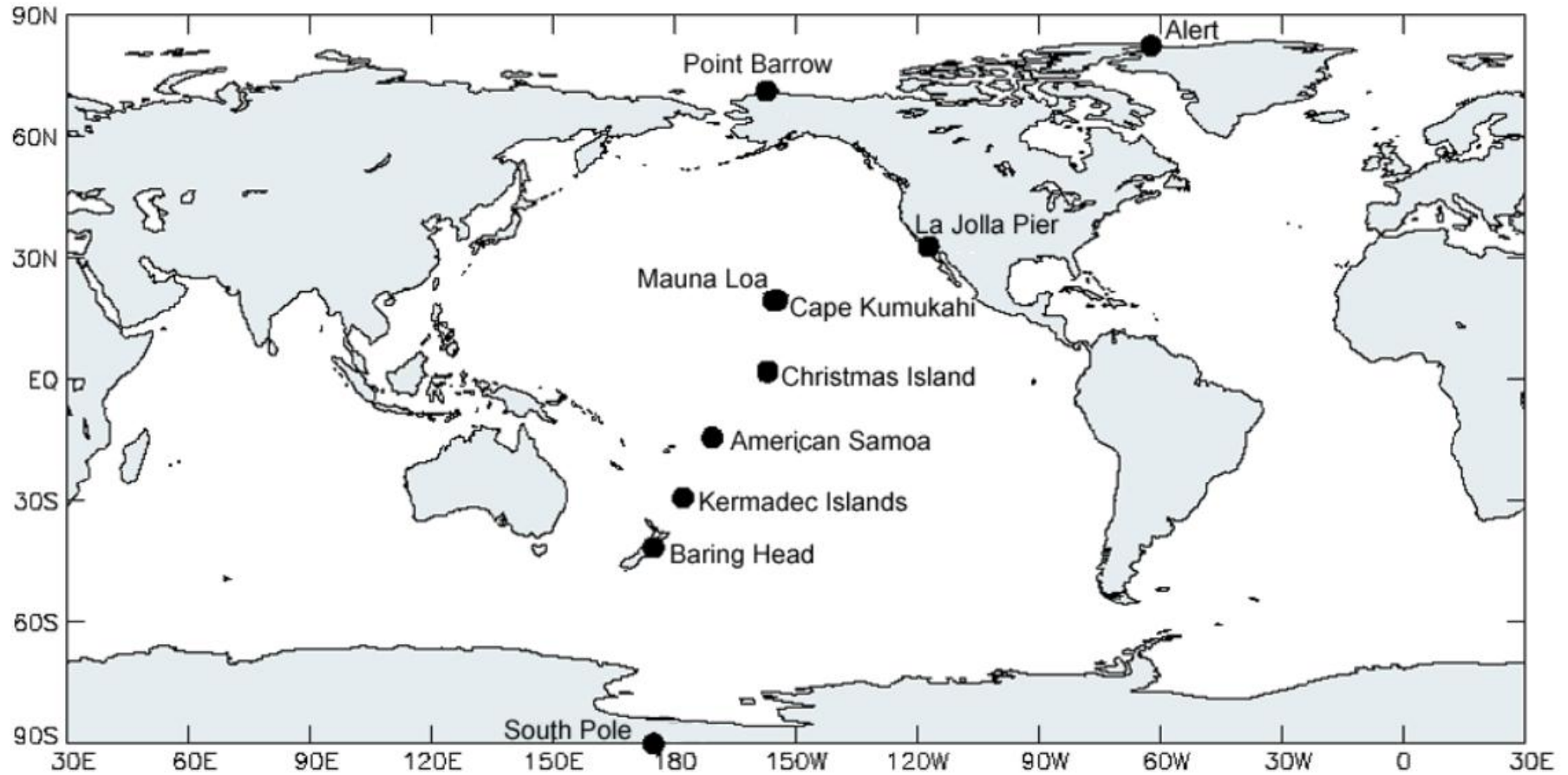


19°32' N, 155°35' W



89°59' S, 178E

Scripps Institution of Oceanography monitoring sites



<http://cdiac.ornl.gov/trends/co2/sio-keel.html>



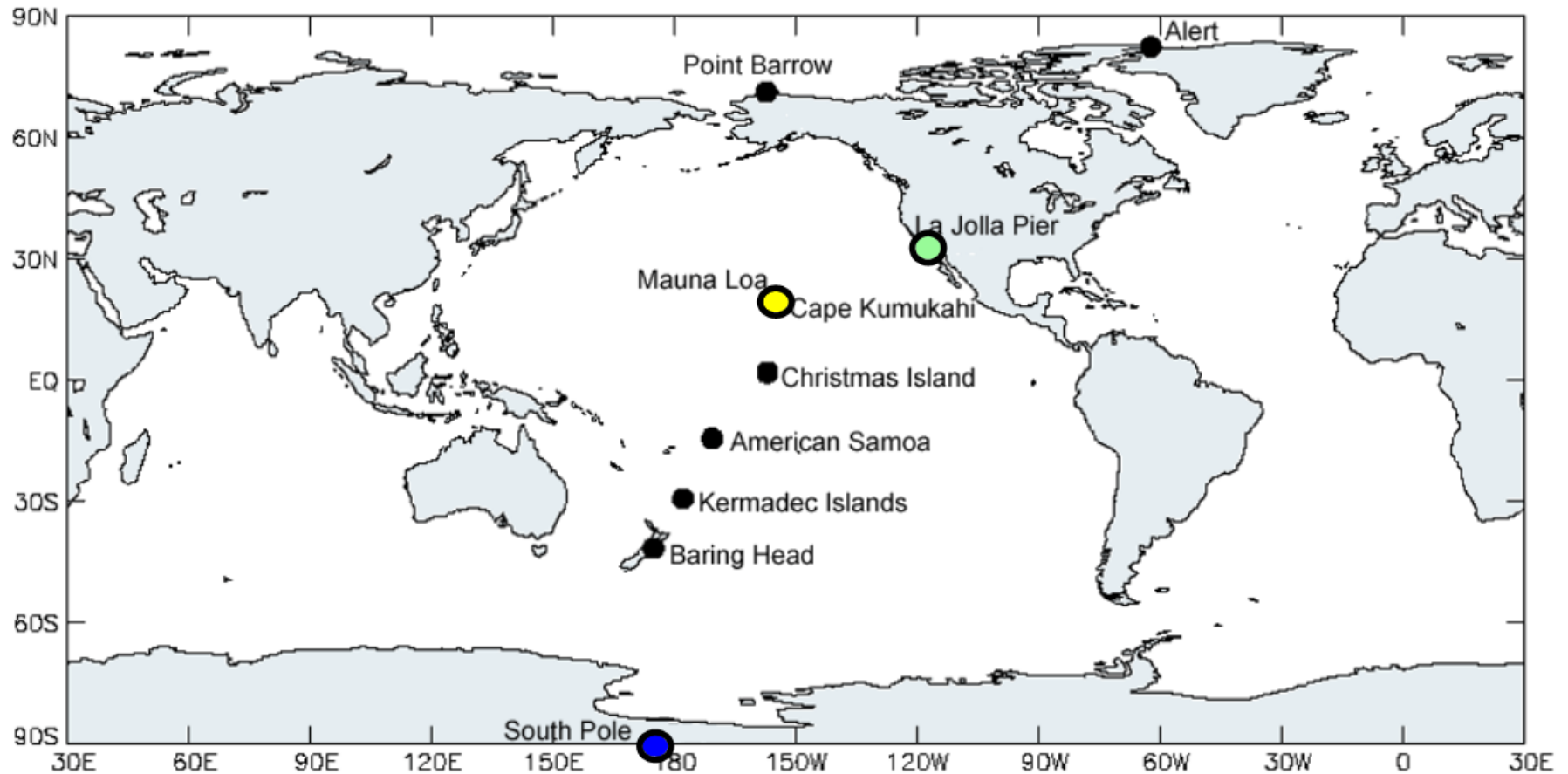
Plot annual fluctuations and long-term trends for one of these sites:

● La Jolla Pier
32°9' N, 117°3' W

● Mauna Loa, Hawaii
19°32' N, 155°35' W

● The South Pole
89°59' S, 178E

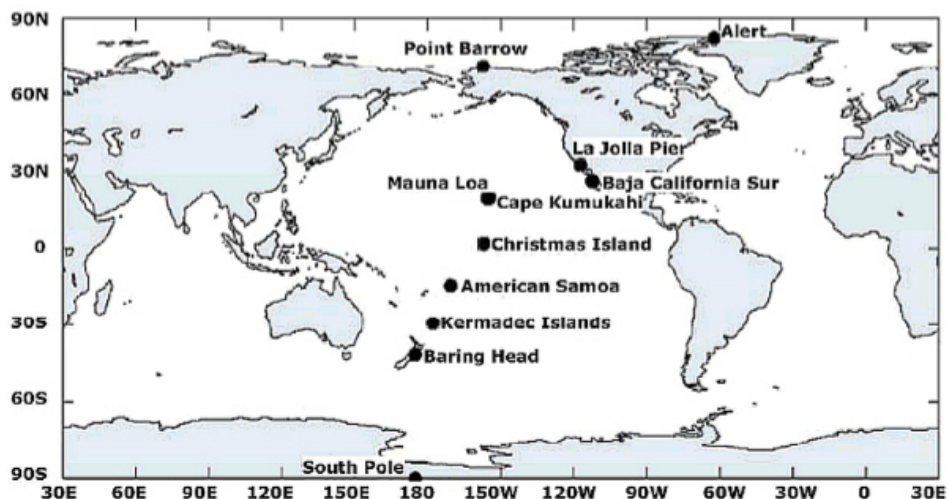
Scripps Institution of Oceanography monitoring sites



<http://cdiac.ornl.gov/trends/co2/sio-keel.html>



Data analysis task: Atmospheric CO₂ measurements



<http://cdiac.ornl.gov/trends/co2/sio-keel.html>

Visit the webpage and make notes on:

- Station name
- Coordinates
- Period of record
- Situation (type of environment)

The Carbon Dioxide Information Analysis Centre (CDIAC) has a huge database of information regarding carbon dioxide measurements.

In this task, use one set of data from their field observatories in this list:

<http://cdiac.ornl.gov/trends/co2/sio-keel.html>

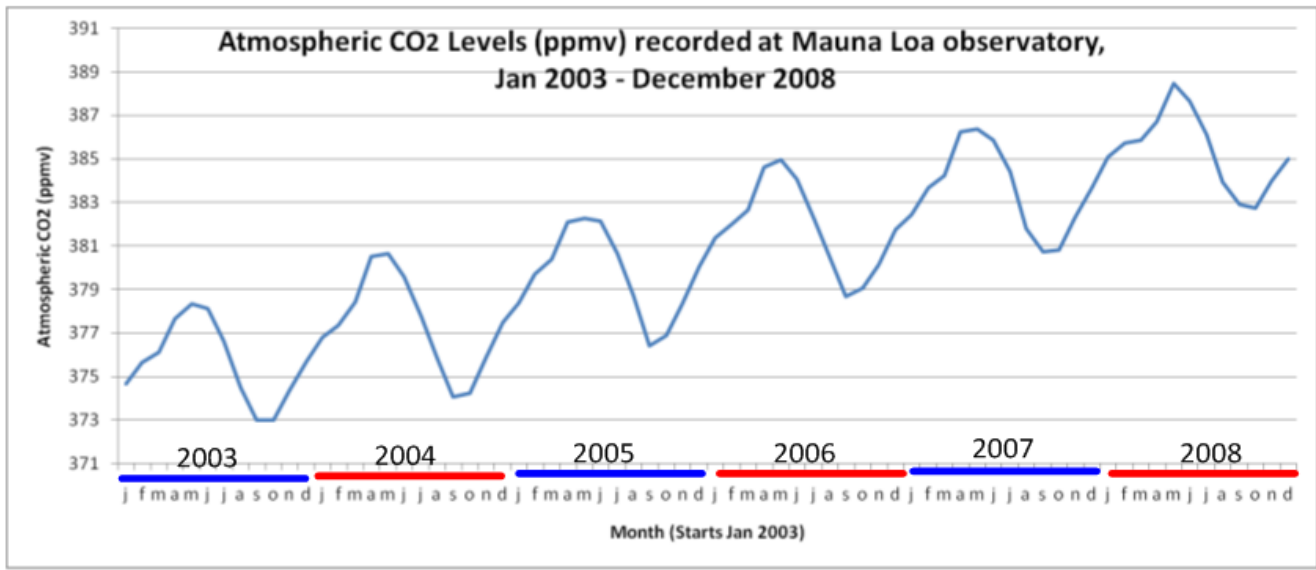
Using the spreadsheet:

- Open the digital data page
- Select all data for the past 5 years
- Paste into Excel (one giant row)
- Adjust the spreadsheet to make sure that all columns and rows are correct
- Produce a line graph, presented to meet requirements for Presenting Processed Data

Look at the graphics for the overall trends. What trends can you see?

Using **your own graph**, explain the annual cycles in the data.

Analysing atmospheric CO₂ data:



Mauna Loa, Hawaii

Period of record: 1958-2008

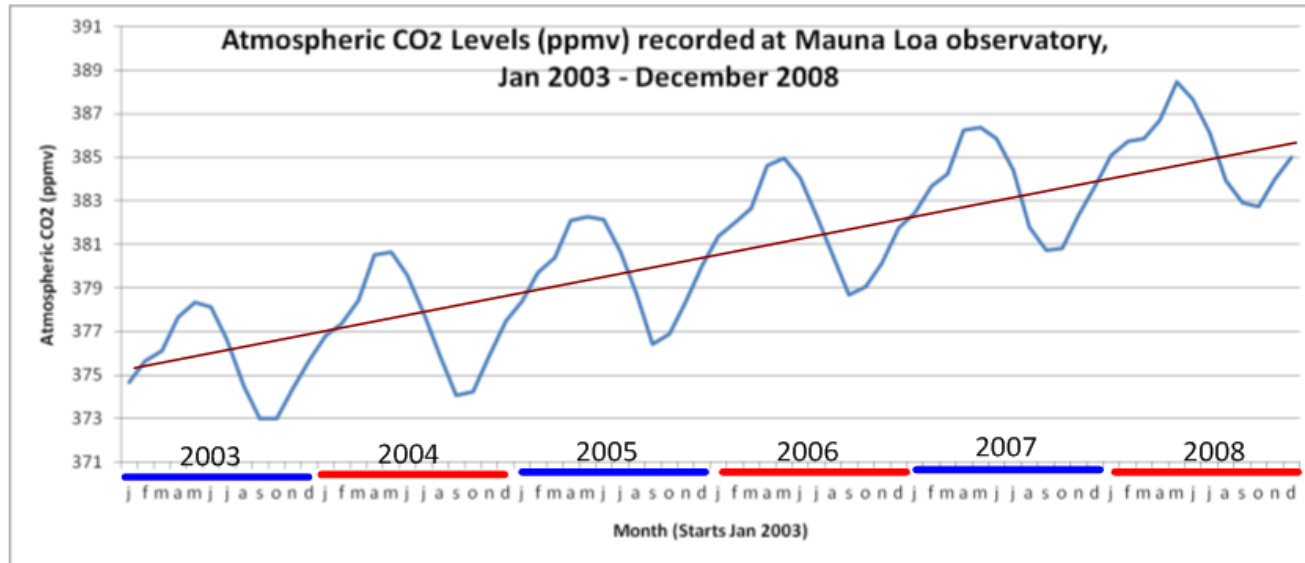
Barren lava field of an active volcano

<http://cdiac.ornl.gov/trends/co2/sio-keel.html>

Trend:

Annual fluctuations:

Analysing atmospheric CO₂ data:



Mauna Loa, Hawaii

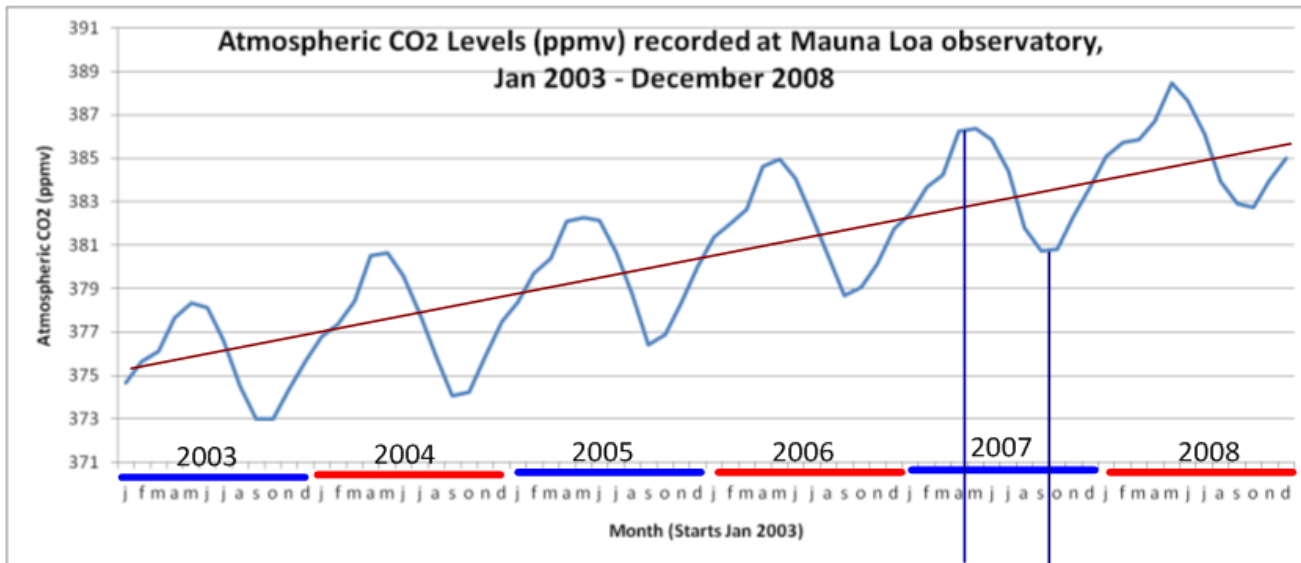
Period of record: 1958-2008

Barren lava field of an active volcano

Trend: *There is an increase in atmospheric CO₂ at Mauna Loa, year-on-year*

Annual fluctuations:

Analysing atmospheric CO₂ data:



Mauna Loa, Hawaii

Period of record: 1958-2008

Barren lava field of an active volcano

Trend: *There is an increase in atmospheric CO₂ at Mauna Loa, year-on-year*

Annual fluctuations: *Annual troughs in CO₂ correspond with northern-hemisphere summers. The northern hemisphere has the greatest land mass and at this time of the year, more trees and others plants in leaf. This increased amount of foliage leads to increased photosynthesis, and therefore a greater sink of CO₂ from the atmosphere. Annual peaks correspond with winters.*

Use this database to search for ice-core data:

NOAA Satellite and Information Service
National Environmental Satellite, Data, and Information Service (NESDIS) U.S. Department of Commerce

National Climatic Data Center
U.S. Department of Commerce

WDC for Paleoclimatology

Home • Research • Data • Education • What's New • Features • Perspectives • Site Map

Search NCDC

Ice Core Data Search

Use this form to search our online Ice Core data collection. The search results will be presented as a list of matched files, which can then be clicked for transfer to your computer. For more information visit our [Ice Core](#) pages.

Start Search Reset Form Help Match Limit: 50 100 250 500

Site Name

Latitude/Longitude

Altitude (m)

Sites with Data for Calendar Years ≤ ≥

Variable

Investigator

Country

[Other Searches](#)

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http://hurricane.ncdc.noaa.gov/pls/paleo_dev/fm_createpages.treering
Page Generated: Wednesday, 27-Aug-2008 08:38:05 pm EDT by paleo@noaa.gov
Please see the [Paleoclimatology Contact Page](#) or the [NCDC Contact Page](#) if you have questions or comments.

http://hurricane.ncdc.noaa.gov/pls/paleo/fm_createpages.icecore

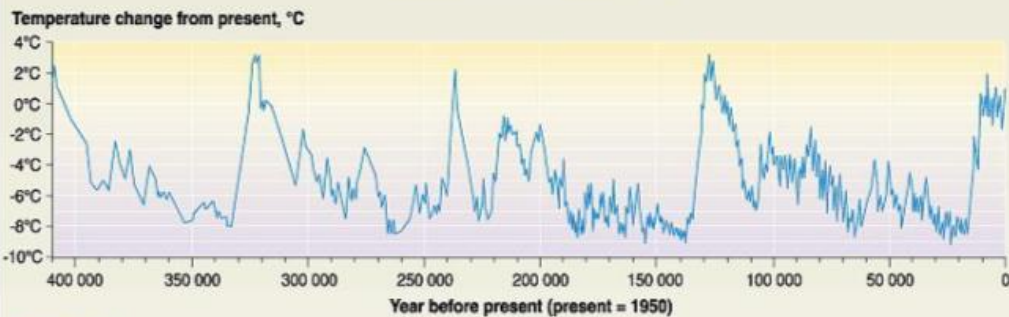
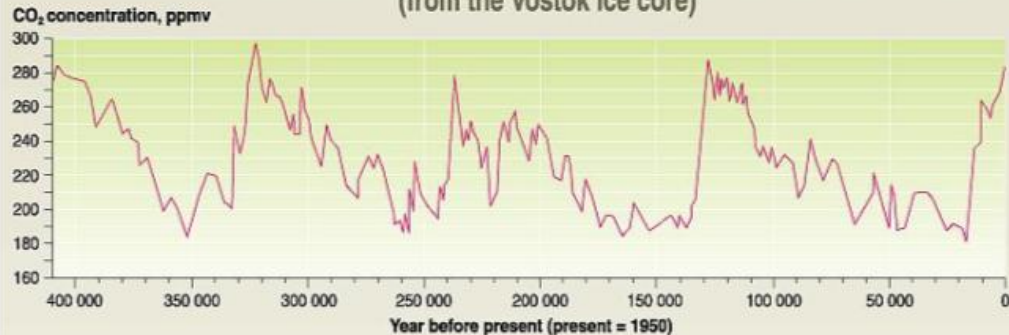
Another chance to use databases in IB Biology



Scientists inspecting an ice core

<http://www.treehugger.com/ice-core-inspection.jpg>

Temperature and CO₂ concentration in the atmosphere over the past 400 000 years (from the Vostok ice core)



GRID Arendal UNEP

Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 400 000 years from the Vostok ice core in Antarctica, *Nature* 399 (3 June), pp 429-436, 1999.

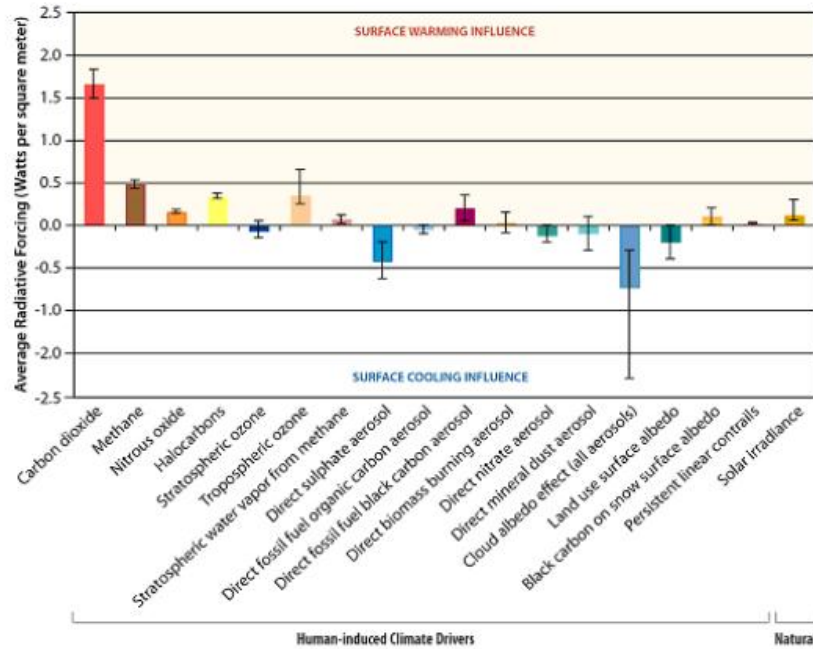
<http://www.grida.no/climate/vital/index.htm>

Drill deeper:

Find out how researchers generate CO₂ data from trapped gas bubbles in ice cores. How do they estimate temperature?

What are the relative warming and cooling effects of various gases?

Climate Influence Between 1750 and 2005



Source: IPCC 2007 WGI Table 2.12; Figure: Union of Concerned Scientists
http://www.ucsusa.org/global_warming/science_and_impacts/science/CO2-and-global-warming-faq.html

Although many gases, *natural* and *anthropogenic*, play a role in the enhanced greenhouse effect, scientists are most concerned about **carbon dioxide**, **methane** and **nitrous oxides**.

Where other gases, such as CFCs have more potential for damage, they are produced in smaller amounts.

The main greenhouse gases

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 ₂ O	275 ppbv	311 ppbv	120	Fertilizer industrial processes combustion	310
CFC-12	CCl ₂ F 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

Note : pptv= 1 part per trillion by volume; ppbv: 1 part per billion by volume, ppmv: 1 part per million by volume

* GWP for 100 year time horizon. ** Includes indirect effects of tropospheric ozone production and stratospheric water vapour production. *** On page 15 of the IPCC SAR. No single lifetime for CO₂ can be defined because of the different rates of uptake by different sink processes. **** Not global warming potential (i.e., including the indirect effect due to ozone depletion).



Source: IPCC radiative forcing report, 'Climate change 1996. The science of climate change, contribution of working group I to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

<http://www.grida.no/climate/vital/05.htm>



The focus on CO2 is understandable:

- it remains in the atmosphere for extended lengths of time
- it is produced in huge quantities
- it is familiar and easy to communicate its importance to the public

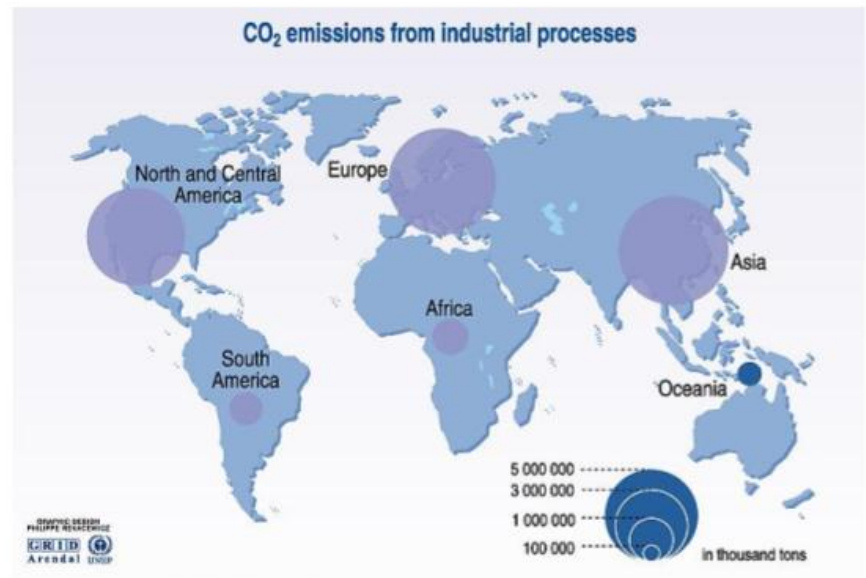
UN Environmental Programme: Useful Stats and Graphs

Some great resources here to relate environmental impacts to poverty and human issues.

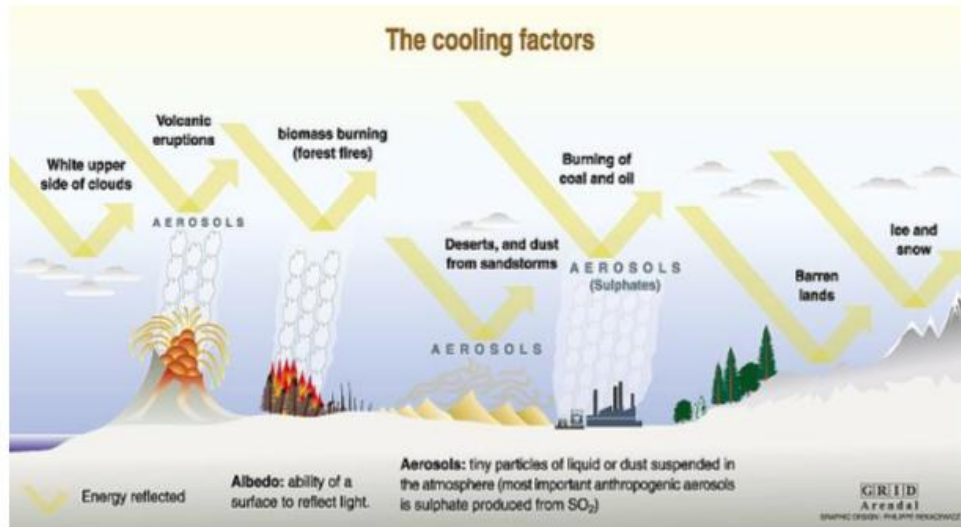


The Environment and Poverty times:
How are the effects of environmental change impacting the lives of those in developing nations and in poverty?

<http://www.grida.no/publications/et/ep6/>

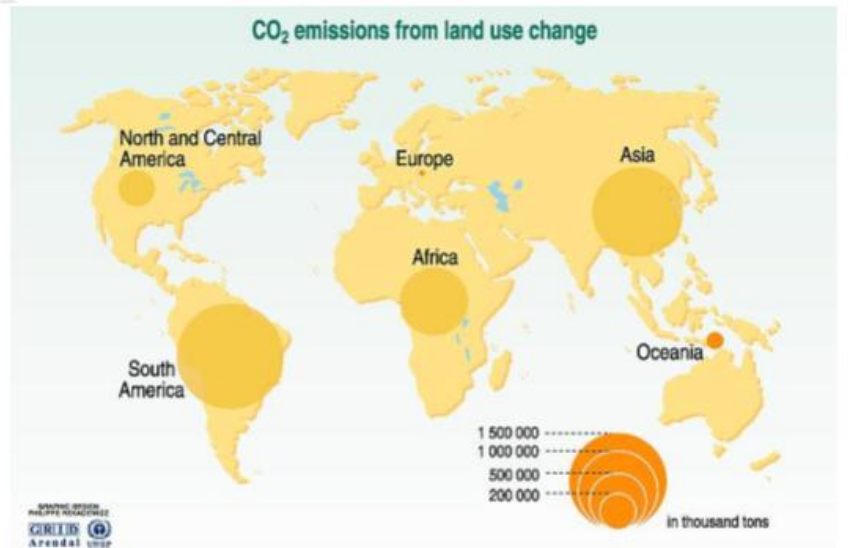


Source: United Nations framework convention on climate change (UNFCCC).
<http://www.grida.no/climate/vital/09.htm>



Sources: Radiative forcing of climate change, the 1994 report of the scientific assessment working group of IPCC, summary for policymakers, WMO, UNEP, L.D. Denny Harvey, Climate and global environmental change, Prentice Hall, Pearson Education, Harlow, United Kingdom, 2000.

<http://www.grida.no/climate/vital/14.htm>

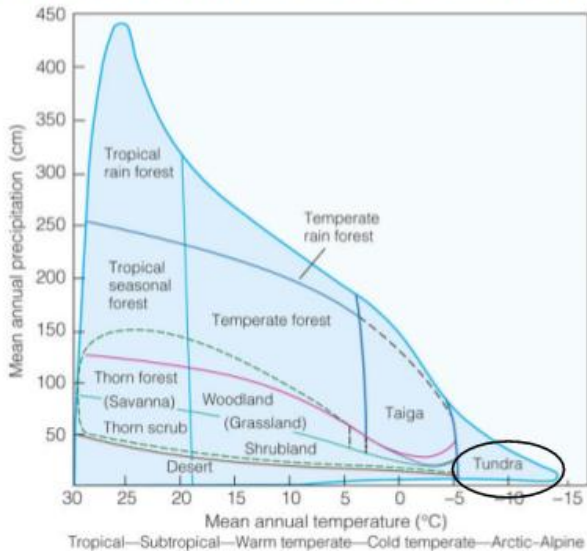


Source: Climate Change Information 18, UNEP/AC, 1997.
<http://www.grida.no/publications/vg/climate/page/3064.aspx>

What are the consequences of global temperature increases on arctic ecosystems?

Increased global temperatures will result in a shift of characteristics of the world's biomes.

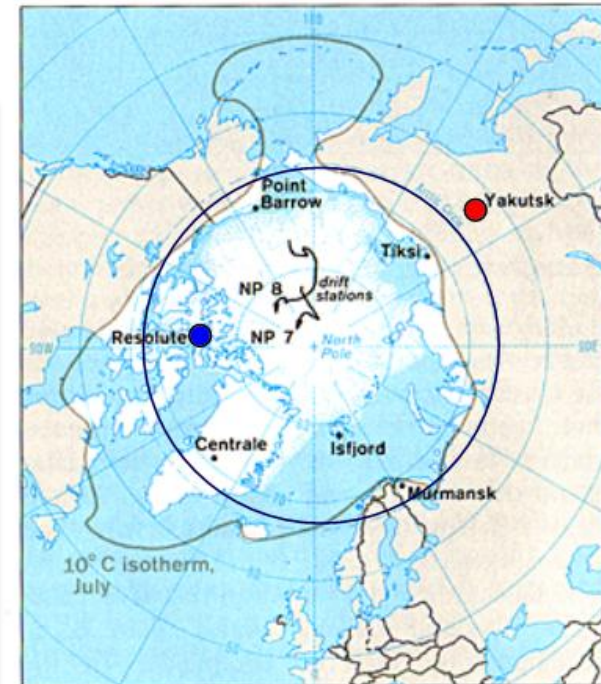
Critically, geographical regions will develop the characteristics of their warmer neighbouring biomes: the niches present in the area will no longer exist in the same form, resulting in a change in populations.



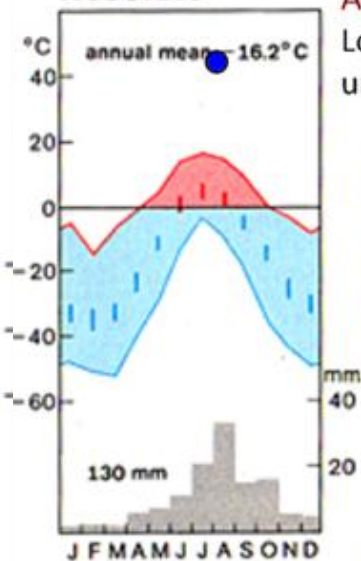
Let's look at the **arctic ecosystems** as an example of an environment under threat.

As temperatures and precipitation increase, there will be a shift in species present as new species migrate into the area to take advantage of new niche opportunities.

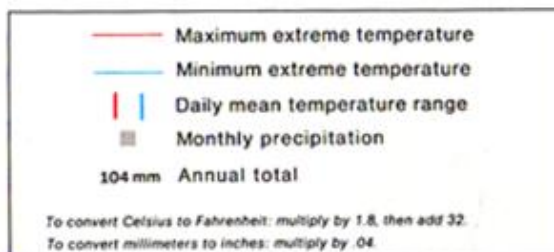
The Arctic (including Arctic circle):



Resolute



A regular polar ice-cap climograph:
Low precipitation and temperatures under 0°C all year.



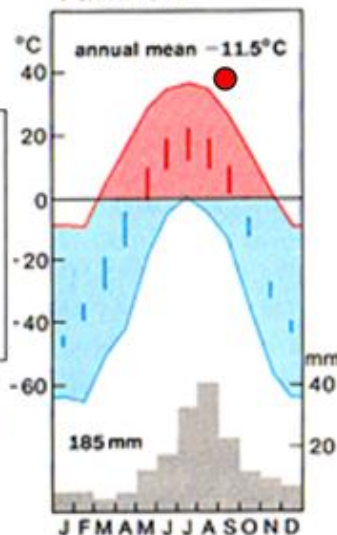
A sub-arctic climograph:

Higher annual precipitation and rainfall.

The future of the arctic ecosystems.

http://en.wikipedia.org/wiki/Climate_of_the_Arctic

Yakutsk

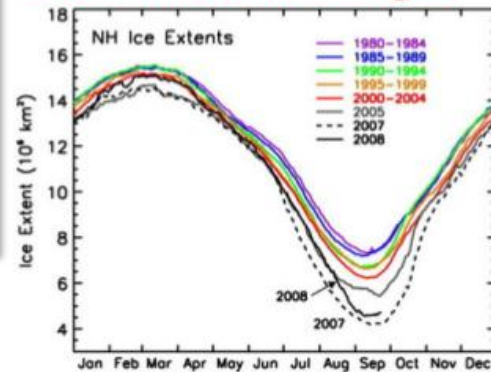


The Arctic Report Card



Produced annually by NOAA, the report card outlines climate data and changes in local physical and biological characteristics.

Seasonal sea-ice changes:



Year-on-year decrease of summer sea-ice coverage leads to habitat loss.

Key issues:

- Sea-ice and habitat loss
- Increased decomposition and release of organic matter from permafrost (further release of CO₂)

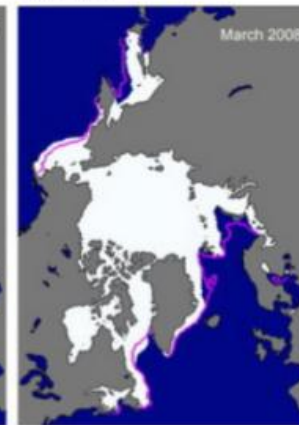
But:

- Redistribution of plant and animal species:
 - coniferous forests moving into arctic areas, more photosynthesis and sink of CO₂
 - migration of animal species, leading to food scarcity for arctic predators
 - fisheries changing structure from ice-requiring species to sub-arctic species (interspecific competition)
 - pest species are more successful, including bacteria and other pathogens

Summer 2007



Winter



Summer 2008



<http://www.arctic.noaa.gov/reportcard/seaice.html>

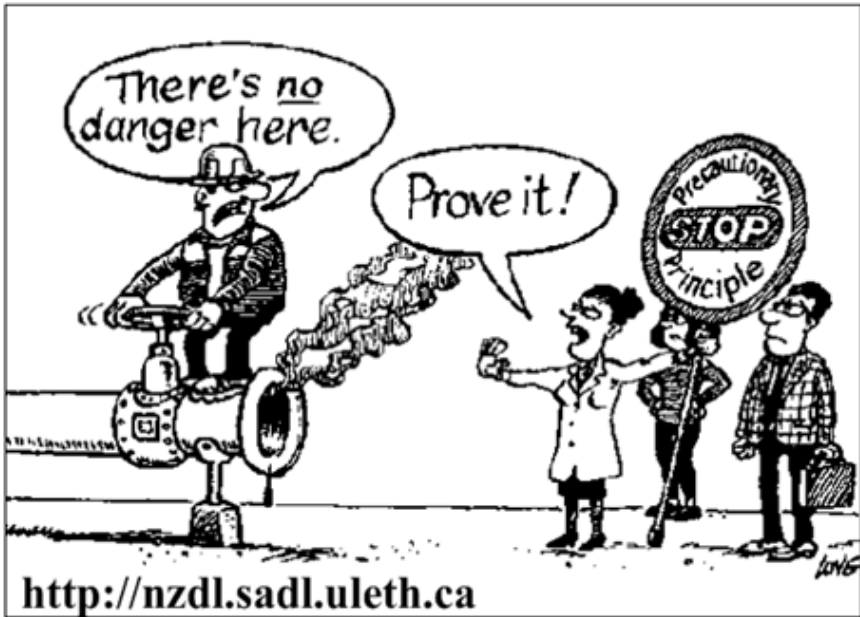


The Precautionary Principle:

If there is a chance that an action **may do harm** to people or the environment, it should be **stopped until it is proven safe**.

The **burden of proof** lies on those whose actions may possibly do harm.

It is their responsibility to provide evidence before they are allowed to carry on with their actions.



<http://nzdl.sadl.uleth.ca>

From the Wingspread statement:

*"When an activity raises **threats of harm to human health or the environment**, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. In this context the **proponent of an activity, rather than the public, should bear the burden of proof.**"*

"Not having the evidence is that something might be a problem is not a reason for not taking action."

Caroline Raffensperger at Bioneers discusses the Precautionary Principle:



<http://www.youtube.com/watch?v=yAsH4Q7Njy8>

In the case of **global warming**, we are collecting evidence daily that suggests that there is an **anthropogenic component** to the **enhanced greenhouse effect**.

The **precautionary principle** dictates that we should **take action to reduce the human impacts on greenhouse gases as we gather more evidence** for or against anthropogenic cause. This way, if (and it looks ever more likely) we prove a human impact, we have taken steps early to reduce harm.

If we do not take action and anthropogenic cause is proven, we have done more damage to the environment in the meantime.

The **burden proof** lies on all those individuals and organisations whose actions may be contributing to the problem.

Regardless of one's position on the climate change 'debate', it is the responsibility of all of us to be informed and to **take steps towards a more sustainable, harm-reducing future**.

"First, do no harm"

Primum non nocere

The hippocratic oath taken by doctors:
how does it relate to the precautionary principle?



image source unknown

Evaluating the Precautionary Principle:

How can we, as an international community, decide to do the right thing?

What are the pros and cons of taking action now, in line with the precautionary principle?



How do we demonstrate the **precautionary principle** in our day-to-day decision making?

How does it apply to policy-makers' decisions in:

- food safety?
- medicine?
- genetics and bioethics?
- economics?



BioEthics Education Project:
<http://www.beep.ac.uk>

Try some of these resources:

Environmental Ethics

What value does the environment have? Which area? Farmland, rainforest, desert, meadow, river, mountain, tundra or sea? And to whom? Do we value it because it is useful or because it has a value in of itself?

These are some of the questions environmental ethicists hope to answer, and quickly, because the extent of the human population and its associated technology mean we are now able to cause more damage than ever before.

These pages address the following issues:

- Biodiversity
- Pollution
- Climate change
- Conservation

Poll

Does this rainforest flower have most value for you because:

- all plants have value?
- it provides the ingredients for a drug used to treat childhood cancers?
- it is pretty?



Submit

IN THIS SECTION

BIODIVERSITY



POLLUTION



CLIMATE CHANGE



CONSERVATION

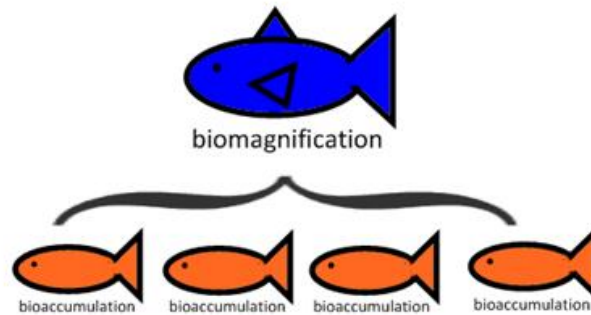


More resources:



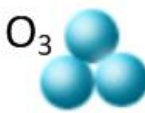
ADVANCING SCIENCE. SERVING SOCIETY

http://www.aaas.org/news/press_room/climate_change/



The following slides are from the presentation
Impacts of Humans on Ecosystems
from
Option G: Ecology and Conservation

Ozone (O₃) in the stratosphere absorbs UV radiation.



The high concentration of ozone (O₃) in this layer **absorbs over 93% of all UV radiation** which reaches Earth.

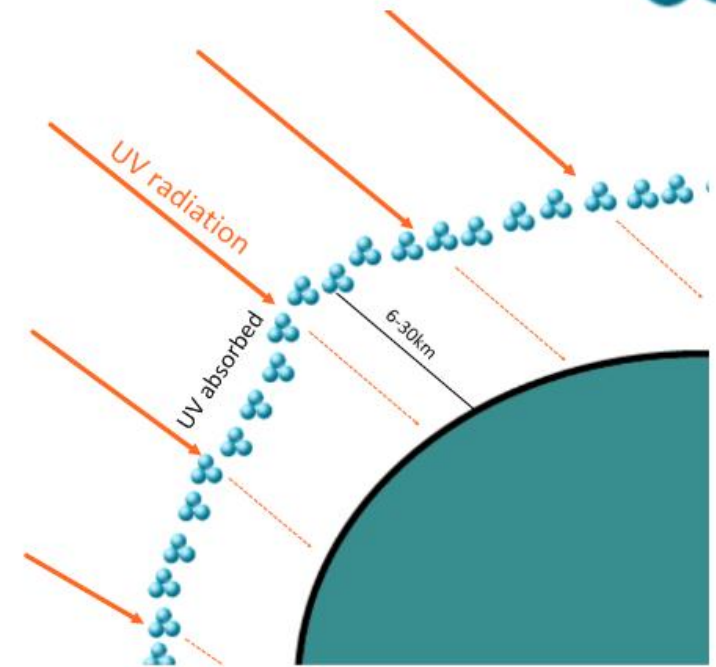
The ozone can be **depleted by chemical gases, including CFC's** (chlorofluorocarbons). These aggregate over polar regions and the cold temperatures allow for the depletion of the ozone layer by splitting CFC molecules, using UV.

The result is more harmful UV radiation reaching the Earth's surface, where it can cause damage to living things and contribute to global warming.

NASA explanation:



<http://www.youtube.com/watch?v=qUfVMogIdr8>

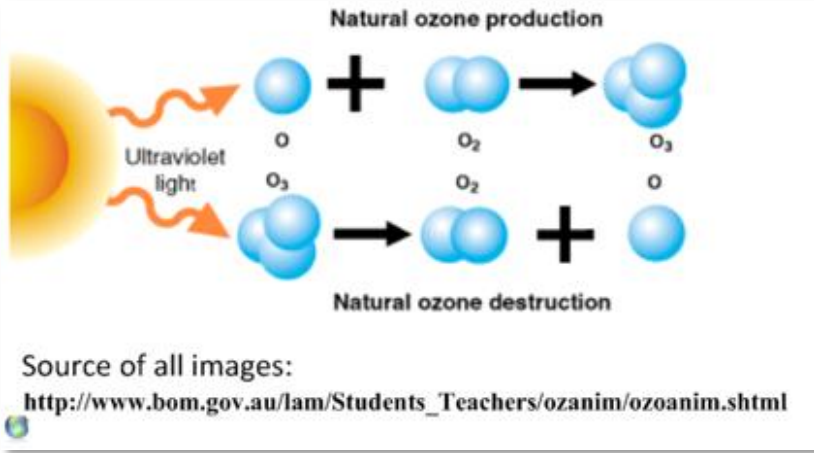


Ozone layer shielding the planet:



<http://svs.gsfc.nasa.gov/vis/a000000/a000800/a000834/index.html>

CFC's deplete the ozone layer

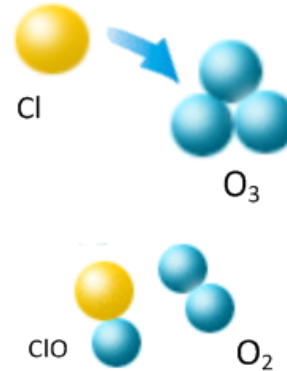


There is a natural balance of ozone creation and destruction due to UV radiation in the atmosphere. The ozone layer is maintained at safe levels.

When CFC's are released into the atmosphere, they speed the depletion of the ozone layer.



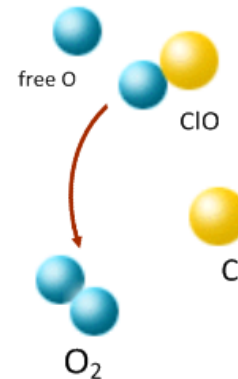
1. UV radiation splits CFC molecules.



3. Chlorine splits ozone molecules into O_2 and ClO (chlorine monoxide).



2. This releases chlorine molecules.

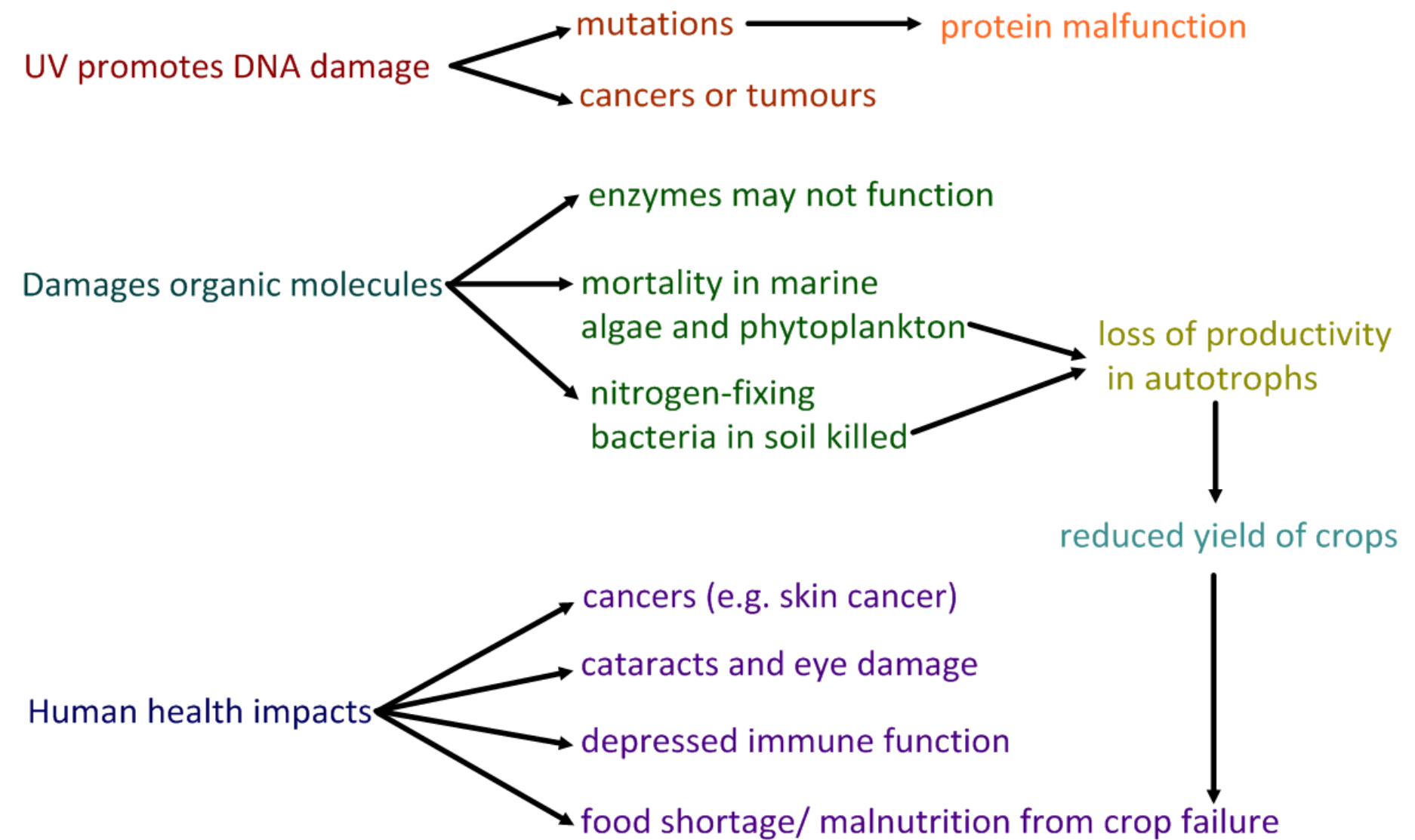


4. Chlorine then binds free oxygen atoms and is released.

5. Chlorine goes on to split more ozone molecules. It can split up to 100,000 molecules. At that rate, natural ozone production cannot compensate.



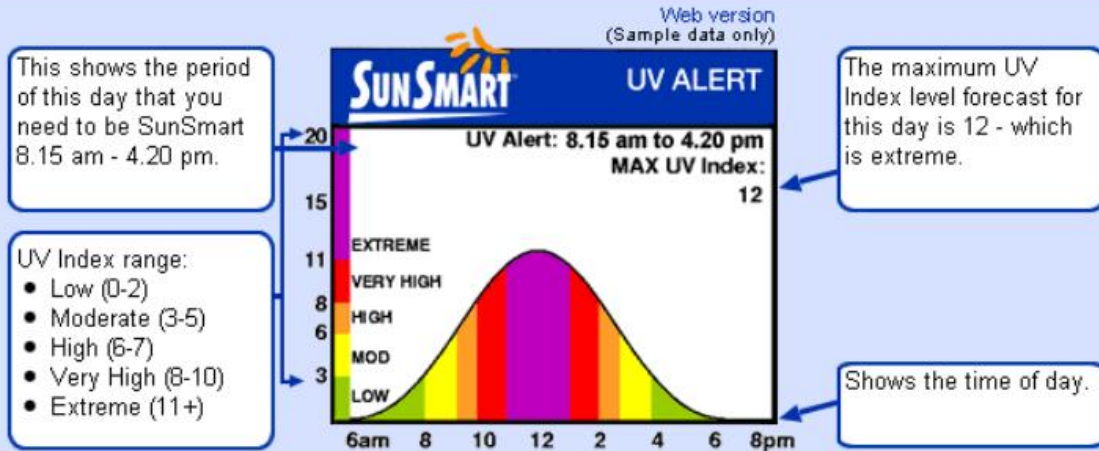
Elevated levels of UV are harmful to living organisms and biological productivity.



Stay safe in the sun!

Check the UV Alerts (if they exist) for your area.

How to read the UV Alert



From:



Australian Government
Bureau of Meteorology

http://www.bom.gov.au/info/about_uv.shtml

Protect yourself from harmful UV radiation.

UV Index

11+ Extreme

8, 9, 10 Very High

6, 7 High

3, 4, 5 Moderate

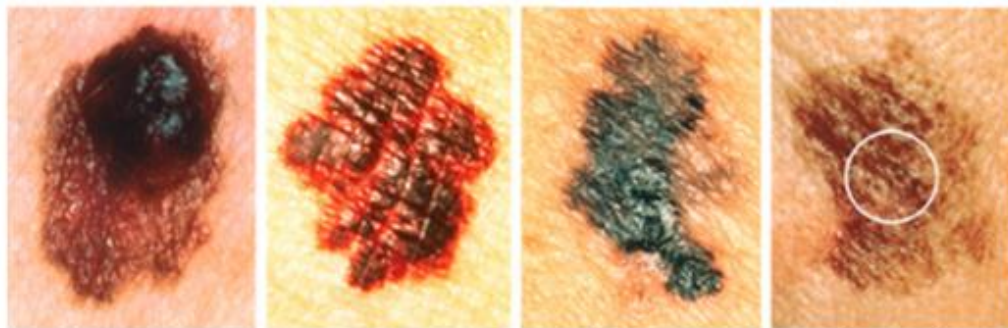
1, 2 Low

Protect Yourself in 5 Ways

- Slip on sun-protective clothing
- Slap on SPF30+ sunscreen. Reapply every two hours
- Slap on a broad-brimmed hat
- Seek shade
- Slide on wrap-around sunglasses

Sun protection is generally not needed unless outside for extended periods

Check for skin cancer:



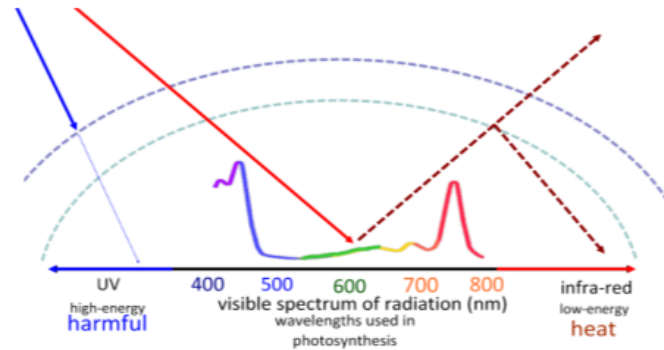
Asymmetry

Border irregularity

Color

Diameter:
¼ inch or
6mm

<http://64.143.176.9/library/healthguide/en-us/support/topic.asp?hwid=aa78799>



For more IB Biology resources:

<http://sciencevideos.wordpress.com>