THE SCIENCE OF CLIMATE CHANGE

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Greenhouse gases and the climate system: Some Facts (1)

- Temperature is regulated through processes of reflection (by atmosphere, clouds and land's surface) of the incoming solar radiation and by absorption and re-emission - by the greenhouse gases - of part of the infrared radiations emitted by the Earth;
- If not, the earth will be colder (less 33°C on average);
- The « greenhouse effect » (planetary warming mechanism) is thus a natural phenomenon.

Greenhouse gases and the climate system : Some Facts (2)

- The main greenhouse gases (GHG):
  - See the list : importance of the concentration of these gases and their Global Warming Potential (GWP). Note that while CO_2 can be redistributed between the different reservoirs, the other gases can be destroyed by chemical reactions;
  - Water vapour also absorbs part of the infrared radiation and is the main GHG. But its amount cannot be changed by human activities.

Greenhouse gases and the climate system : Some Facts (3)

- The role of clouds and aerosols :
  - Globally clouds have a cooling effect on the earth but in the tropics, heavy clouds may warm the regional climate;
  - Aerosols –particularly sulfates and carbon particles, resulting from desert dusts, biomass burning, volcanoes, have a global cooling effect but mainly at regional scales.

Radiative forcing

- The radiative forcing is the change in the balance between radiation coming into the atmosphere and radiation going out ;
- A positive radiative forcing (which is now the case) induces a general warming of the surface.

The Carbon Cycle

- Three main reservoirs of carbon exists : the atmosphere, the oceans and the soil and land biota (see figure), the last two ones being the more important.
- Small changes in the main reservoirs could have large effects on the atmospheric concentration; the release of just 2% of the carbon stored in the oceans would double the amount of atmospheric CO_2.
- Carbon is exchanged between the different reservoirs at timescales that range from a year to decades (surface exchanges) and millenia (with deep ocean and soils). Thus the return to equilibrium can take some time

What is happening (1)?

- The enhanced greenhouse effect : CO_2
  - Since the Industrial Revolution, the amount of atmospheric CO raised by 30% (from 280 ppmv around 1700 to about 370 ppm actually);
  - Carbon dioxide increases each year by about 1.5 ppmv which adds about 3.3 gigatonnes to the atmospheric carbon reservoir per year. However, the oceans absorb about 2 Gt per year;
  - Human activities responsible for this are mainly fossil fuels combustion (6 Gt per year) and changes in land use and deforestation (about 1.5 Gt per year). These two activities are respectively concentrated in the northern and southern hemispheres.

What is happening (2)?

- The enhanced greenhouse effect : CH_4
  - Since 1800, its concentration in the atmosphere has more than doubled (from 0.7 ppmv to 1.7 ppmv in 1995) with a rate of increase of about 0.6% per year;
  - The main natural source of methane is wetlands (115 millions of tons per year) while the human sources (330-400 Mt per year) are natural gas and petroleum industry (100), enteric fermentation (85) and rice cultivation (60) as well as wastes disposals and treatment.
- Since 1850, a change in the radiative forcing of 3 W/m^2 has been observed, representing about 1% of the energy coming from the sun.

What is happening (3)?

- The global mean surface temperatures increased by 0.6±0.2°C over the 20th century. The 1990s was the warmest decade and 1998 the warmest year in the instrumental record (1861-2000);
- « There is new and strong evidence that most of the warming observed over the last 50 years is attributable to human activities » (IPCC, 2001);
- Other observed changes during the 20th century are:
  - Increase of the global mean sea level at an average rate of 1 to 2 mm per year;
  - Decrease in the snow cover by 10% since the 1960s;
  - Thinning of the Arctic sea ice by 40% and decreased extent by 10-15% since the 1950s. General retreat of non polar glaciers;
  - Increased precipitation by 5-10% in the Northern hemisphere, while in other regions, a decrease is observed (West Africa, Mediterranean)

All these changes are consistent with a warming climate.

What is happening (4)?

- Recent regional changes in climate, particularly increases in temperature, have already affected hydrological systems and terrestrial and marine ecosystems in many parts of the world.
  - More frequent, persistent and intense El Niño events during the last 20 to 30 years compared to the previous 100 years;
  - Longer growing season (by about 1 to 4 days per decade) during the last 40 years in the Northern Hemisphere and specially at higher latitudes;
  - Shifts poleward and up in elevation for plants, insects, birds and fish;
  - Earlier plant flowering, early bird arrival, earlier dates of breeding season and earlier emergence of insects in the Northern hemisphere;
  - Increased coral bleaching, in relation with El Niño events.

  The probability that the observed changes could occur by chance alone is negligible.

Climate Change and Climate Variability

- For the IPCC, Climate Change refers to a statistically significant variation in either the main state of the climate or in its variability, persisting for an extended period (typically decades or longer). In the UNFCCC (art.1) it is defined as « a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which in addition to natural climate variability observed other comparable time periods »;
- Climate variability (IPCC) refers to variations in the main state and other statistics (standadr deviations, occurrence of extremes) of the climate on all temporal and spatial scales.

Climates of the past

- Over the last 400,000 years, the Earth's climate has been unstable with a succession of glacial and interglacial (warmer) periods.
- These changes have been attributed to changes in the orbit of the Earth (Milankovitch theory);
- However, available data show, for the last 160,000 years, a great coincidence between the temperature variations and the variations in the atmospheric concentration of carbon dioxide and methane. During 3 interglacial (-325,000; -240,000 and –125,000 years) atmospheric CO_2 content was higher (around 300 ppmv) than the actual natural level (280 ppmv). During the last period (Eemian), estimated temperatures were about 2°C higher than now and sea level was 5 to 7 m higher than the actual level.

Projections for the future (1)

- Carbon dioxide concentrations, global average surface temperature and sea level are projected to increase under all IPCC scenarios (SRES) during the 21st century;
  - By 2100, CO_2 concentrations could range from 540 to 970 ppm
  - Between 1990 and 2100, global surface temperature could increase of 1.4 to 5.8°C;
  - Global mean sea level is projected to rise by 0.09 to 0.88 m between 1990 and 2100 but with significant regional variations.
- Global average annual precipitation is projected to increase. However there will be regional differences with increases and decreases projected to be 5 to 20%.

Projections for the future (2)

- Increased atmospheric concentrations of GHG will induce:
  - Changes in daily, seasonal, inter-annual and decadal variability. For example, many models predict more El Niño likemean conditions in the tropical Pacific;
  - Changes in frequency, intensity and duration of extreme events such as more hot days, heat waves, heavy precipitation and few cold days. Many of these changes would lead to increased risks of floods and drougths in many regions.
- GHG forcing could set in motion large-scale, high impact, non-linear and potentially abrupt changes in physical and biological systems over the coming decades to millenia. For example:
  - Risks of thermohaline circulation shutdown beyond the year 2100.

The Intergovernmental Panel on Climate Change (IPCC)

- Created by the World Meteorological Organization (WMO) and the United Nations Environmental Programme (UNEP) in 1988;
- Its purpose is to assess the state of knowledge on the various aspects of climate change, mainly through a transparent process;
- Three working groups : WGI on science, WG II on impacts, adaptation and vulnerability and WGIII on mitigation.

To have more information

- Bjorke, S. A., Seki, M. (eds) (Vital Climate Graphics. The Impacts of Climate Change. UNEP-GRID
- Houghton, J. (1997) Global Warming. The complete briefing. Cambridge University Press
- Watson, R.T. and the Core Writing Team (2001) Climate Change 2001. Synthesis Report. IPCC.
- http://www.ipcc.ch