

Marine Climate Change in Australia

Impacts and Adaptation Responses **2009 REPORT CARD**

Climate Change

Elvira S Poloczanska¹ Anthony J. Richardson^{1,2,3}

¹Climate Adaptation Flagship, CSIRO Marine and Atmospheric Research, PO Box 120, Cleveland Qld 4163, Australia

²University of Queensland, School of Mathematics and Physics, St Lucia, QLD 4072

³The Ecology Centre, University of Queensland, St. Lucia, QLD 4072

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Lead author email: Elvira.Poloczanska@csiro.au

In 2007, the IPCC stated “**warming of the climate system is unequivocal, based on evidence from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level**” (IPCC 2007).

The Greenhouse Effect

The ‘greenhouse effect’ is one of many physical, chemical and biological natural processes that shape Earth’s climate. The greenhouse effect plays a major part in creating our warm environment around the Earth’s surface. The atmosphere, consisting primarily of nitrogen (78%) and oxygen (21%), is essentially transparent to incoming (shortwave) solar radiation and to the longwave radiation emitted from the Earth’s surface. Around 30% of the incoming solar radiation is reflected back to space by clouds, aerosols (small particles in the atmosphere) and light coloured regions of the Earth (e.g., covered by snow, ice or desert) and the rest is absorbed by the Earth’s surface and, to a lesser extent, the atmosphere and re-emitted as longwave radiation (see Le Treut et al. 2007 for more detailed explanation; Figure 1). Other constituents of the atmosphere, such as water vapour, carbon dioxide (CO₂) and trace gases like methane and nitrous oxide, are largely transparent to the incoming solar radiation but absorb and re-emit longwave radiation. Some of the longwave radiation is emitted back to space but some is trapped by the blanket of greenhouse gases in the atmosphere resulting in a warming of the Earth’s surface. Water vapour and CO₂ are the most important and abundant of the greenhouse gases. Water vapour is not well mixed in the atmosphere so its effects can vary regionally. For example, in humid regions where is a lot of water vapour in the air, the greenhouse effect can be large. Clouds (also water vapour) can be warming or cooling, as they absorb radiation

(warming) but also reflect incoming solar radiation (cooling). Other important greenhouse gases include methane (CH₄), nitrous oxide (N₂O), and halocarbons (see Forster et al. 2007). These are present in the atmosphere in trace amounts but have a large impact on warming due to their radiation absorption characteristics and long residence times. Humans release greenhouse gases through activities such as fossil fuel burning and deforestation which intensify the blanketing effect in the atmosphere.

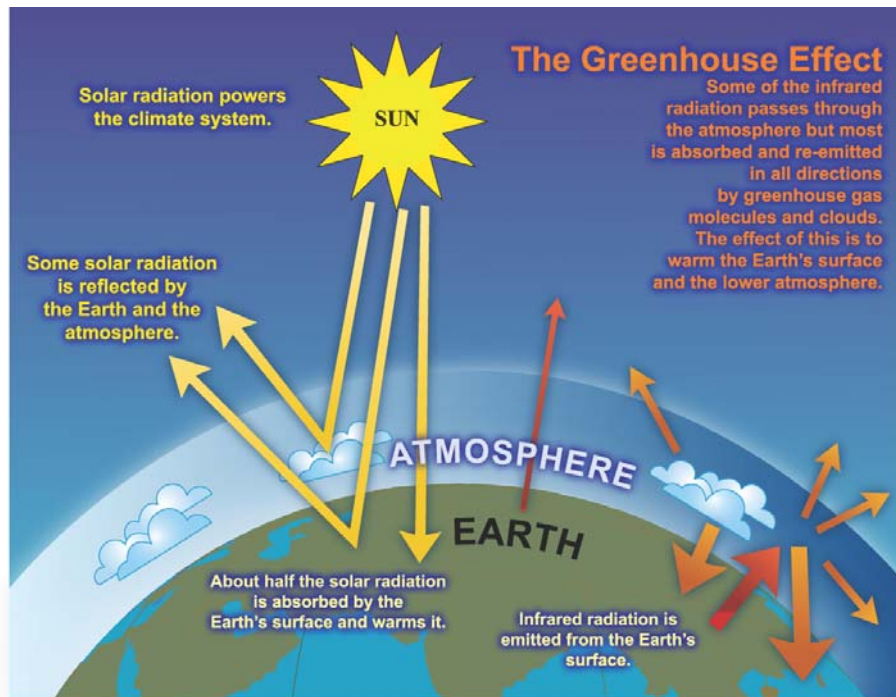


Figure 1. An idealised model of the natural greenhouse effect from Le Treut et al. 2007. See text in Le Treut et al. 2007 for more detailed explanation.

There are a number of processes that interact to determine Earth's climate such as the thermal heat capacities and reflective properties (albedo) of the oceans and land masses, atmospheric circulation, cycling of water between the land and ice caps, rivers, oceans and atmosphere, and cycling of carbon dioxide (Figure 2; see Le Treut et al. 2007 and Forster et al. 2007 for more detailed explanation). The biosphere (living things) also plays an important role. Alteration to any part of the climate system will have knock-on effects for the other parts and can result in important 'feedback' loops which can amplify or diminish climate forcing. An example is the 'ice-albedo feedback' where warming temperatures cause melting of the highly reflective ice and snow sheets revealing darker surfaces that absorb more heat thus increasing warming, and so on.

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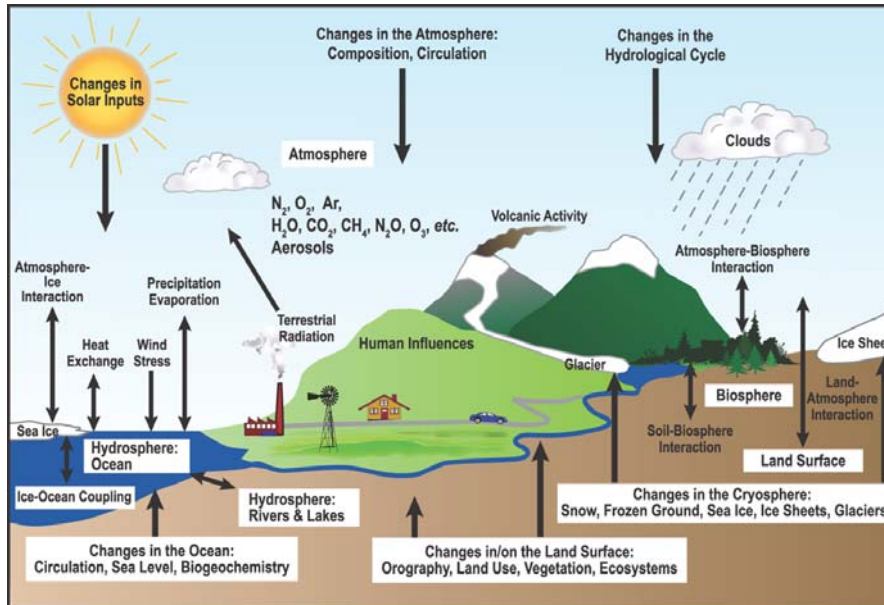


Figure 2. Schematic view of the components of the climate system, their processes and interactions. From Le Truet et al. 2007

Anthropogenic emissions

There are three fundamental ways that the radiation balance of the Earth can be changed 1) altering incoming solar radiation through changes in Earth's orbit or alignment relative to the sun; 2) changing the fraction of solar radiation reflected back from the Earth's surface by changes in cloud cover, vegetation cover or snow cover; and 3) altering the longwave radiation outgoing from the atmosphere for example, by changing greenhouse gas concentration.

Human activities (anthropogenic emissions) have led to a build up of CO₂ and other greenhouse gases in the atmosphere, hence increased warming. CO₂ is well mixed throughout the atmosphere and has a long residence time, so emissions remain in the atmosphere for hundreds of years. High accuracy measurements of CO₂ in the free atmosphere have been obtained from the top of the Mauna Loa volcano in Hawaii since 1958 (Keeling, 1961, 1998, Le Treut et al. 2007). Measurements show the steady increase in CO₂ since 1958 (Figure 2). This global increase in atmospheric CO₂ concentrations are due primarily to fossil fuel use, with land-use change (eg deforestation) providing another significant but smaller contribution (Le Treut et al. 2007).

Measurements of historical atmospheric CO₂ concentrations can be obtained for air bubbles trapped in polar ice cores (Forster et al. 2007). For 10,000 yrs leading up to 1750, the 'start' of the Industrial Revolution, atmospheric CO₂ levels remained within the range 280 ± 20 ppm (Sabine et al. 2004, Le Treut et al. 2007). Since 1750, levels have increased by 37% and were measured at 387 ppm in 2009. In 2008 alone, global greenhouse gas emissions increased by 2%. Atmospheric concentrations of other greenhouse gases, namely methane and nitrous oxide are also increasing and also attributable to human activities such as agriculture, landfill, fertiliser use, fossil fuel burning and industrial processes (Forster et al. 2007). Abundances of well-mixed greenhouse gases in the atmosphere over the last decade are greater than at any time over the past 1 million years (Le Truet et al. 2007).

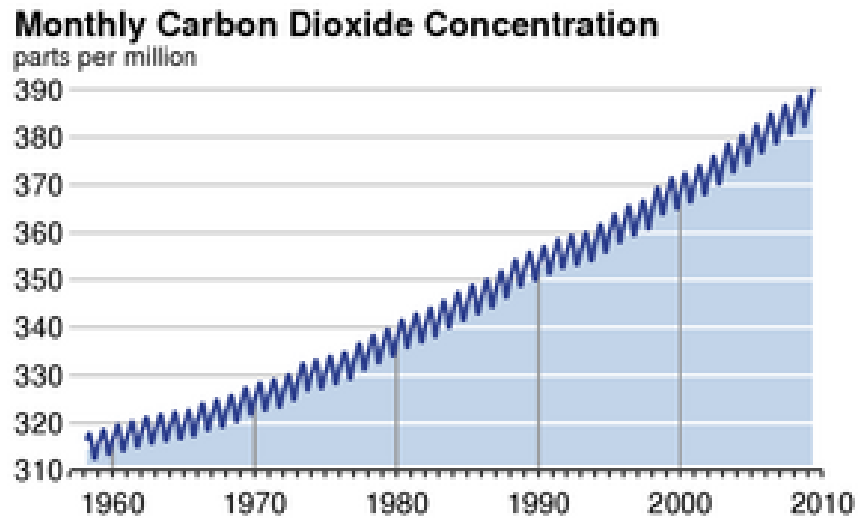


Figure 2. Monthly carbon dioxide concentration at Mauna Loa, Hawaii. The annual fluctuations in the line show the effect of the large land masses with plant cover in the Northern Hemisphere. Atmospheric CO₂ levels drop slightly in the Northern Hemisphere summer, when plants are actively growing and photosynthesising so using CO₂, and increase in the winter when plants lose leaves or die back. Source: <http://scrippsco2.ucsd.edu/>

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Over 70% of our Earth's surface is covered by ocean. The southern hemisphere is dominated by ocean; 80% of the southern hemisphere is ocean. Our oceans play a key role in climate regulation with energy (heat) and gases and aerosols are in a constant exchange between the oceans and atmosphere. The relative heat capacity of the oceans is 1000 times greater than the atmosphere; so the oceans store considerable amounts of thermal energy and oceanic circulation is important for redistributing heat around the globe. Oceans net heat uptake since 1960 is around 20 times greater than the atmosphere (Bindoff et al. 2007). Ocean temperatures have warmed by 0.1°C from the surface to 700m depth over the period 1960-2003, representing a considerable amount of heat (Bindoff et al. 2007). This leads to thermal expansion of the ocean and therefore contributes to sea-level rise - see Church 2009 (Sea-level Rise). Climate change will affect ocean climate in a number of ways including rising sea-level, altered storm and wave regimes and changes to stratification and mixing of the water column (Figure 3).

The second key process influencing the ocean's ability to take up CO₂ is the biological pump. Marine biodiversity has a substantial influence on atmospheric CO₂ levels as it mediates the transfer of carbon to the deep ocean through 'the biological pump'. Through photosynthesis, plants in the surface ocean fix CO₂ and produce oxygen; this maintains a concentration gradient between the atmosphere and the ocean so that CO₂ continually diffuses into the surface ocean from the atmosphere. The carbon that is fixed in phytoplankton is slowly (~1000 years) transferred to the deep ocean floor through food chains (for example phytoplankton being consumed by zooplankton that live deeper in the water column and so on), and the release of detritus (e.g., faecal material, remains dead plants and animals) – called the 'biological pump'. Complex feedback loops exist between ocean biodiversity and our atmospheric climate modulate the biological pump. For example, climate change will affect the size and type of primary producers in the surface layers of the ocean, promoting smaller species that are likely to reduce the effectiveness of the biological pump, so that less carbon is removed from surface ocean layers and the ocean will absorb less CO₂ resulting in more remaining in the atmosphere to intensify global warming. In other words climate change impacts on phytoplankton, at the base of most marine food chains, has the potential, in turn, to accelerate global climate change.

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