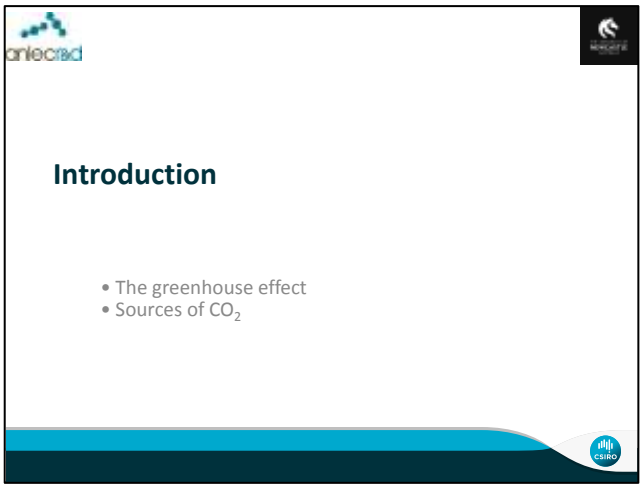
The greenhouse effect



Introduction

It is an undisputable fact that the carbon dioxide concentration in the atmosphere is increasing, see next page for the evidence.

There are of course many sources of the CO_2 in the atmosphere, they include volcanoes, decaying organic matter (leaves in autumn), exchange with dissolved CO_2 in the oceans, the combustion of fossil fuel, and of course many other minor contributions. There are also sinks for the CO_2 in the atmosphere, most prominent the growing organic matter (trees) and exchange with the oceans. All these processes are connected in a *very big* equilibrium. This equilibrium has been reasonably constant over the last few thousand years and significant changes only occurred over much longer time spans. However, in very recent times the concentration started to increase significantly and much more abruptly than in the past.

The *almost* universally accepted reason is the increased combustion of fossil fuel since the beginning of industrialisation. As we will see in the next few slides this is clearly a very likely interpretation of the observations.

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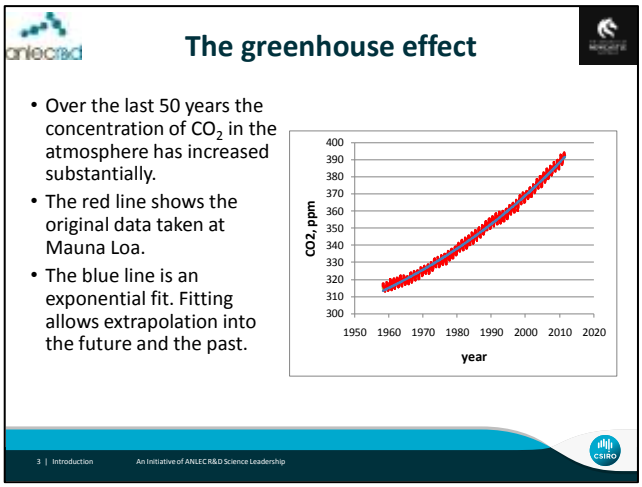
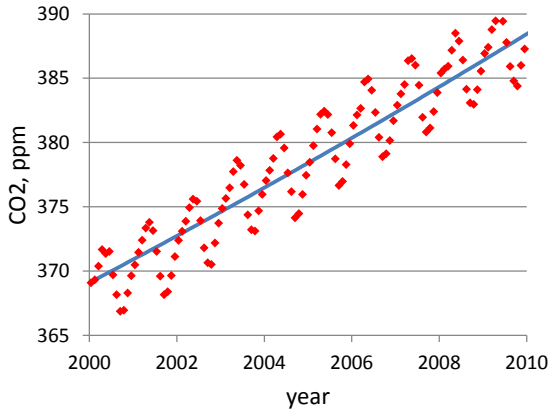


The concentration of CO_2 in the atmosphere over the last 50 years

The graph above shows the measured concentration of CO_2 in the atmosphere over the last 50 years. The increase is substantial in relative terms, approximately 25% over that time span.

Very importantly, the increase is not linear but approximately exponential. The blue line is an exponential fit of the concentration curve. Exponential growth is possible over short time periods, it *cannot* be maintained over long periods of time, in modern parlance, it is not sustainable. (Interestingly, it appears that economists still believe in sustainable growth.)



The figure displays an enlarged view of the last 10 years, featuring the monthly averages. The ups-and-downs are due to the seasonal decay and growth of plants resulting in maximal CO_2 concentration during winter and minimal atmospheric concentration during summer. The figure shows the large swings due to natural causes and on top the continuous increase due to anthropogenic release of additional CO_2.

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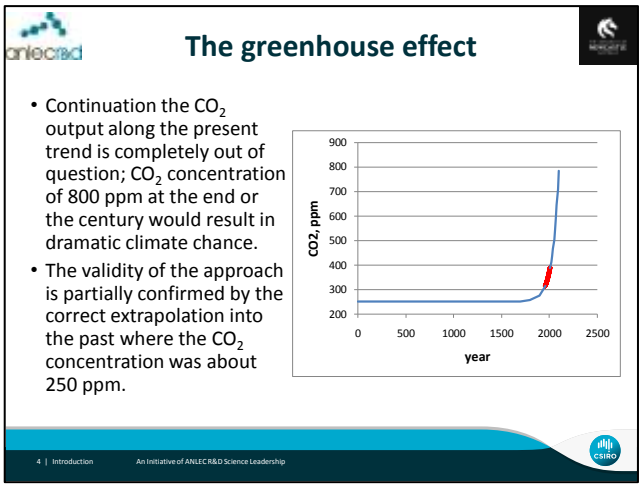


Extrapolation of the CO_2 concentration into the future

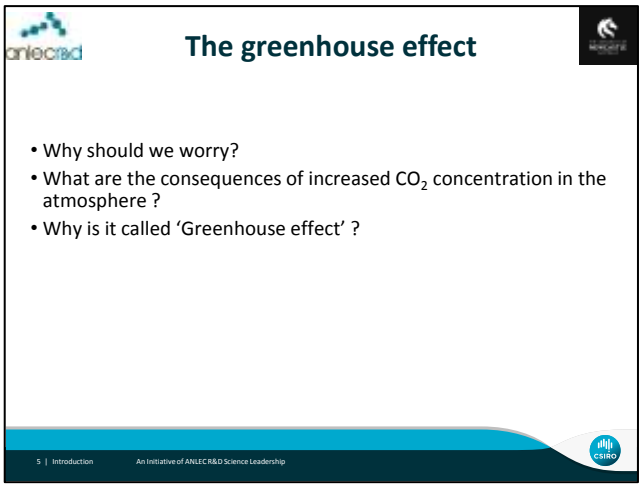
Fitting an appropriate function to the measured CO_2 data allows extrapolation into the future as well as the past. This has been done in the PowerPoint page above, the red markers are the measured data, and the blue line is the extrapolation into the past and the future.

The value for the extrapolation into the past can be compared with the actual history; it coincides well with a CO_2 concentration of about 250ppm. This gives some limited validity to the approach.

The extrapolation into the future, of course, is only valid if nothing changes in the underlying processes. The predicted values of approximately 800ppm by 2100 makes it absolutely clear that something rather dramatic will happen. Either humanity manages to reduce the CO_2 output significantly or the climate will be completely different.

The first option might be very expensive but it is clearly the preferred one not only because it is certainly much cheaper as well.

The greenhouse effect



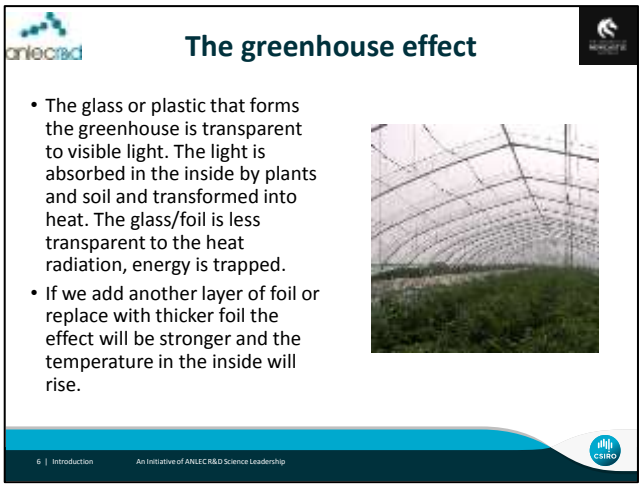
Increasing CO_2 concentration in the atmosphere

The concentration of carbon dioxide, or CO_2, in the atmosphere is increasing substantially and is predicted to increase much more in the not too far future. The absolute concentration of CO_2 in the atmosphere is small with only 300-400ppm which translates to 0.3-0.4%; clearly CO_2 is a minor gas. On top of that, as prominent 'sceptics' hasten to point out, CO_2 is odourless and colourless and at these very low concentrations it is absolutely non-toxic. It appears that there is clearly no point in worrying about the 'slight' increase?

However, in spite of the above, increasing concentrations of CO_2 will, indisputably, result in higher temperatures on the planet (what is not 100% clear, and disputable, is how much that increase is expected to be).

CO_2 and water and many other gases are so-called greenhouse gases; they act like a greenhouse, keeping the surface of the planet at the temperature it has. A simple observation supports this: on a bright sunny day on top of a mountain, say Mt Kosciusko, it is much cooler than lower down in a valley or at the beach, even if one is closer to the sun and thus might expect rather higher temperature. The atmosphere acts like a blanket, keeping things under it warm. If we make the blanket more efficient, it will get warmer. For good reasons we do not talk about the blanket effect, rather of the greenhouse effect.

The greenhouse effect

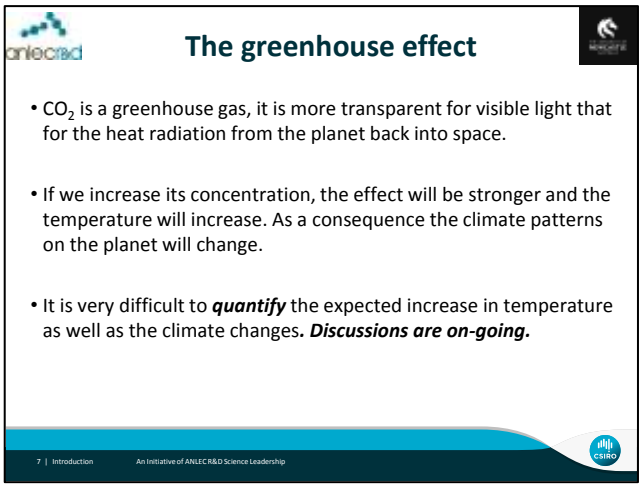


The Greenhouse

The expression 'greenhouse effect' is very appropriate, the principle is essentially the same as with a real greenhouse.

- The plastic or glass sheet of a greenhouse is transparent to the white light emitted by the sun. (The white light constitutes the largest fraction of the energy of sun light).
- The transmitted light is absorbed by the surface, the soil, and the plants in the greenhouse.
- The absorbed light energy is transformed into heat energy, thus the surface gets warmer.
- The warm surface radiates back energy in the shape of infrared radiation. Some of that radiation is absorbed by the plastic of the greenhouse and remains inside the greenhouse. This is why it is warmer inside.
- If we increase the thickness of plastic of the greenhouse, the back-radiation is reduced while the absorption is not affected, the balance is changed and the temperature will rise.
- Imagine the following: A gardener installing a thicker sheet of plastic on his greenhouse and the temperature in his greenhouse increases. Along comes a 'sceptic' and assigns this increase of temperature to sunspots.

The greenhouse effect



The Greenhouse Effect

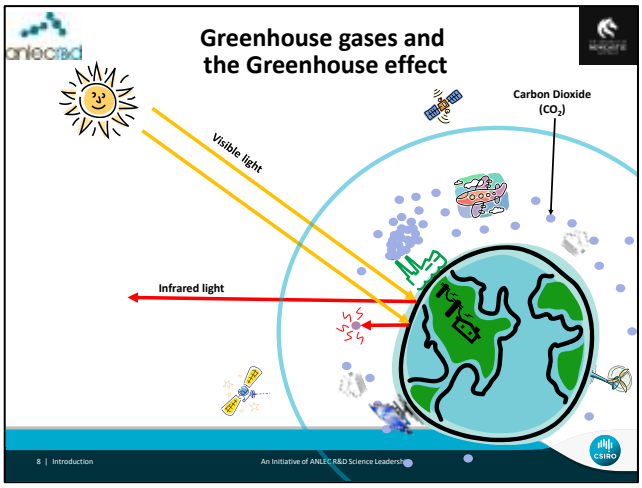
All gases in the atmosphere act to different degrees as greenhouse gases, similar to the plastic sheet of the real greenhouse.

Why do we concentrate on CO_2 as a greenhouse gas? Water for example is a very powerful greenhouse gas and nobody seems to worry about it. The reason is that water does not accumulate it is continuously removed as rain, overall the composition of the atmosphere is very constant. It is mainly the concentration of CO_2 that increases with time; see the graph on page 2. As we have seen this increase results in a better greenhouse or warmer temperature and subsequently significant changes in climate.

The weather is an extremely complex process. As we all know it is very difficult to predict the weather for more than a few days in advance. It is obviously much more difficult to predict the long term consequences of the greenhouse effect.

Should we stop worrying about and acting against greenhouse gas emissions and global warming because we cannot precisely predict the climate changes for any part of the planet?

The greenhouse effect



The Greenhouse Effect

The slide is a schematic diagram of the planet, its atmosphere and its interaction with solar radiation.

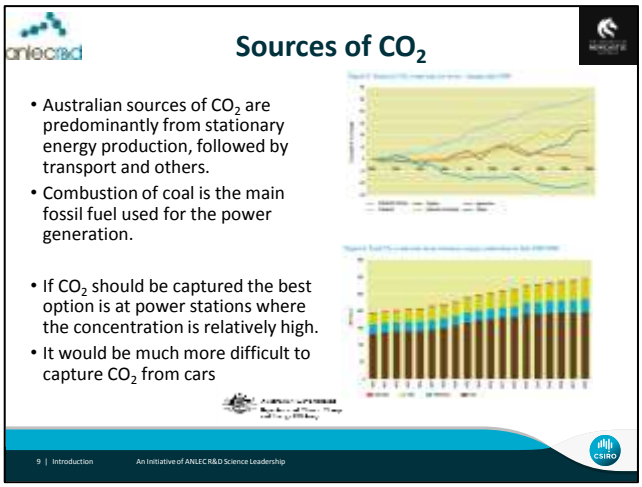
The atmosphere is very transparent for visible light (yellow in the Figure) which reaches the surface of the planet unhindered. The light is absorbed and transformed into heat. We can feel that by exposing a hand to the sunlight on a cold day.

The warm surface of the planet re-emits infrared light (red in the Figure). The atmosphere absorbs some of this infrared light and thus keeps us warm. More infrared light is absorbed for increasing concentration of CO_2, thus keeping us warmer. Enormous amounts of energy are passing through the atmosphere every day and the amount of extra absorbed infrared light is actually very small, but sufficient to change the climate.

An additional remark: the atmosphere forms a much thinner layer that suggested in the Figure above. The Troposphere (the lowest part of the atmosphere where we live and where the weather happens) is a about 10km thick. On a globe of 30cm diameter it would be about 0.2mm or 2-3 times the thickness of human hair.

The earth's atmosphere is a thin film and needs to be looked after carefully.

The greenhouse effect



Sources of CO_2 in the atmosphere

In order to reduce the CO_2 output we need to identify the large producers of CO_2 and also find out the output can be reduced best.

Energy production and transport are major sources of CO_2 in Australia. Using less energy and cycling instead of driving would be very efficient ways for the reduction of the CO_2 output but unfortunately they both are not very likely options.

Capturing the CO_2 with subsequent sequestering is another, maybe, more realistic option. This is much easier at a stationary and large source of CO_2 and thus coal fired power stations are the most prominent candidates for CO_2 capture.