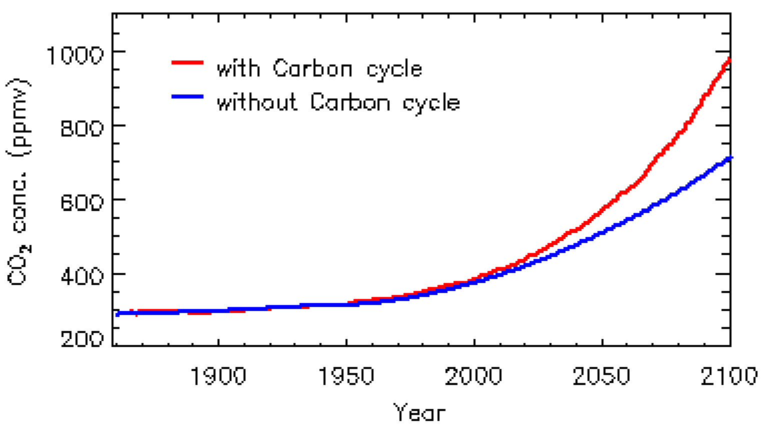
The Hadley Centre

Results from carbon cycle experiments
www.met-office.gov.uk/research/hadleycentre/models/carbon_cycle/results_trans.html

Predictions of accelerated climate change

Climate models predict that, as future atmospheric carbon dioxide concentrations increase, due to fossil fuel emissions and deforestation, the temperature of the planet will also increase. In most studies, this temperature increase is estimated in two stages. Firstly, a model of the carbon cycle is used to calculate the future atmospheric concentrations of carbon dioxide. Secondly, the climate change is calculated using a separate global climate model using these estimates of carbon dioxide rise as input, with no feedback from climate change to the carbon cycle. However, in reality, climate change will alter the, much larger, natural carbon cycle and this can feed back on the climate change itself. Warming soils may emit more carbon, and die back of vegetation may return carbon dioxide to the atmosphere. A warmer ocean will take up less carbon dioxide from the atmosphere. Furthermore, vegetation patterns move in response to climate change. For instance, the tree line is predicted to move poleward in the northern hemisphere. For the first time, the Hadley Centre has coupled a representation of the carbon cycle to a full climate model and made predictions of climate change that incorporate climate-induced changes in the carbon cycle. This has led to some radical new insight into the climate system.

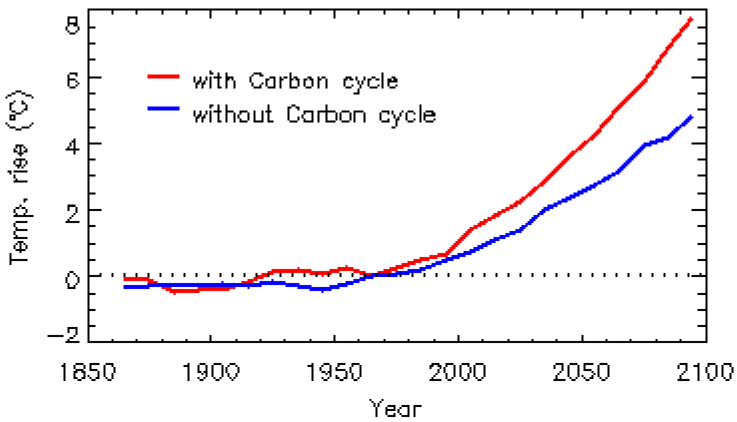


Simulated atmospheric concentrations (parts per million by volume) of carbon dioxide when the two-way interaction between climate and the carbon cycle is included (red line). For comparison, the results obtained when climate is not allowed to feed back onto the carbon cycle are also shown (blue line). Prior to 1990, historical emissions were used. Beyond 1990, emissions followed those in the IPCC IS92a scenario without sulphate aerosols.

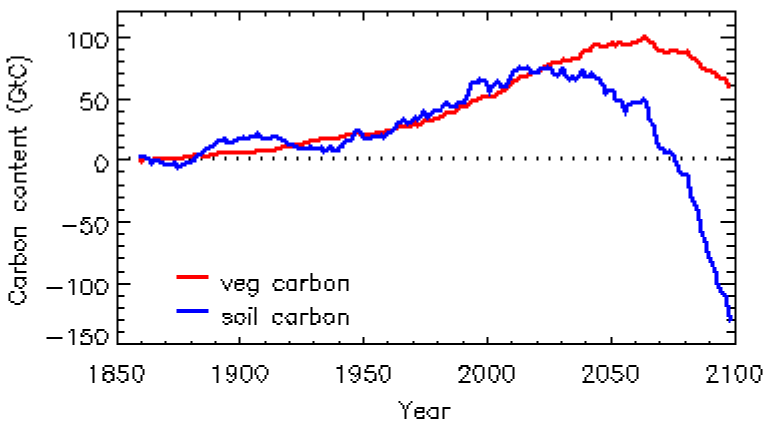
The figure shows the atmospheric carbon dioxide concentration predicted by the coupled carbon-cycle climate model using greenhouse-gas emissions prior to present day and IPCC business-as-usual (IS92a) emissions thereafter. The present-day carbon dioxide concentration simulated by the model is in good agreement with observations. The slight differences are probably due in part to inaccuracies in the historical carbon emissions due to land-use changes (for instance, forest regrowth), and in part due to other forcings of climate (such as sulphate aerosols and natural forcings) not being included in this simulation, (but which are included in simulations discussed in the next session). The seasonal cycle of atmospheric carbon dioxide is also well simulated by the model

Beyond present day, the carbon dioxide concentration in the coupled carbon-cycle climate model increases faster than that predicted by previous models which neglected carbon-cycle feedbacks. As a result, when the link between the carbon cycle and climate is included, greater increases in temperature are predicted over the next century. The rise in global mean surface land temperature between 2000 and 2100 (see figure, right) is around 3 °C greater when the climate is allowed to interact with the carbon cycle, compared to models which omit the link.

The reasons behind this faster increase of atmospheric carbon dioxide are two-fold. Firstly, the model predicts that as temperatures rise, the amount of carbon dioxide emitted from the soils will increase rapidly; much more rapidly than can be counteracted by the increased growth of vegetation. This is because this "soil respiration" is governed by the breaking down of carbon in the soil by microbes whose activity is observed to increase exponentially with temperature. Hence, soil carbon levels all over the world start to decline rapidly from about 2050 as this carbon is released back to the atmosphere as carbon dioxide.



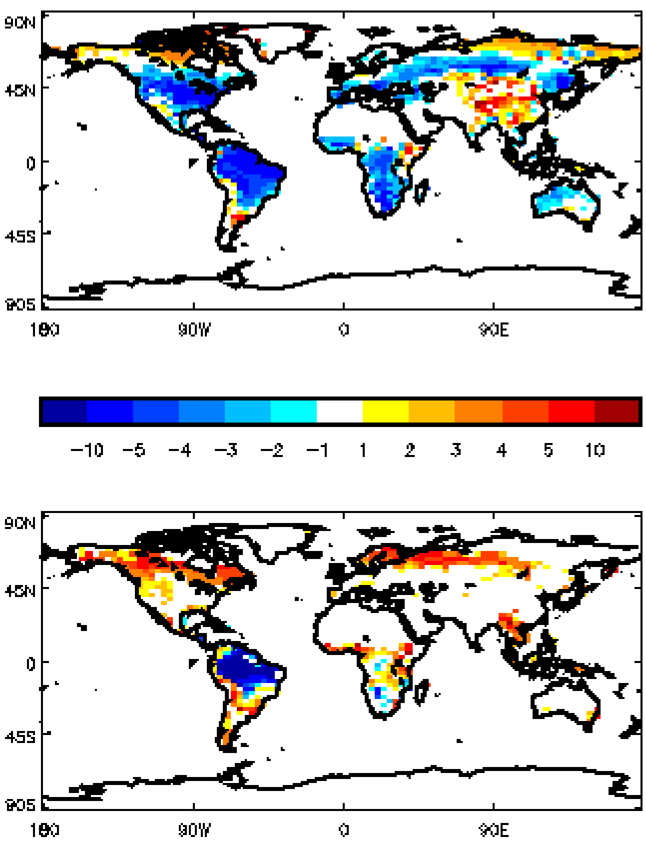
Simulated global mean temperature rise over land with and without carbon cycle feedback, as described in the previous figure.



Simulated changes in the global total soil and vegetation carbon content (Gt C) between 1860 and 2100. 1 Gt C is 1 giga-tonne of carbon, equal to 1 billion tonnes of carbon.

Secondly, the model predicts that, in the second half of this century, vegetation carbon storage in South America will begin to decline as a result of the die back of the Amazon forest, which is caused by regional warming and drying (direct anthropogenic deforestation is not included). Around the middle of the century, the land biosphere as a whole switches from being a weak sink for carbon to a strong source, mainly due to the rapid loss in soil carbon beyond 2050. In total, between the middle of the 19th century and the end of the 21st century, the combined effects of climate change and increases in atmospheric carbon dioxide concentration are predicted to reduce global soil and vegetation carbon storage by around 100 Gt C. The total global changes in soil and vegetation carbon are shown in the previous figure (above). This figure (left) shows maps of the change in terrestrial carbon content between 2000 and 2100.

These results are presented by **Cox et al. [2000]**.



Patterns of change in the carbon content of soil (top) and vegetation (bottom) predicted by the carbon cycle climate model between 1860 and 2100.