CLIMATE CHANGE
PAST AND FUTURE
CLIMATE AND CO2 IN THE ATMOSPHERE

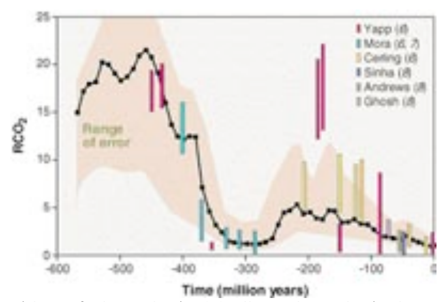
CalSpace

Calspace Courses

Carbon Dioxide through Geologic Time

Introduction

Since of the Earth's atmosphere is out-of-balance with the conditions expected from simple chemical equilibrium, it is very hard to say what precisely sets the level of the carbon dioxide content in the air throughout geologic time. While scientists are fairly certain that a 100 million years ago carbon dioxide values were many times higher than now, the exact value is in doubt. In very general terms, long-term reconstructions of atmospheric CO_2 levels going back in time show that 500 million years ago atmospheric CO_2 was some 20 times higher than present values. It dropped, then rose again some 200 million years ago to 4-5 times present levels--a period that saw the rise of giant fern forests--and then continued a slow decline until recent pre-industrial time.



History of Atmospheric CO_2 through geological time (past 550 million years: from Berner, **Science,** 1997). The parameter RCO_2 is defined as the ratio of the mass of CO_2 in the atmosphere at some time in the past to that at present (with a pre-industrial value of 300 parts per million). The heavier line joining small squares represents the best estimate of past atmospheric CO_2 levels based on geochemical modeling and updated to have the effect of land plants on weathering introduced 380 to 350 million years ago. The shaded area encloses the approximate range of error of the modeling based on sensitivity analysis. Vertical bars represent independent estimates of CO_2 level based on the study of ancient soils.

Carbon Cycling, Plate Tectonics and Organic Matter Burial

Most scientists agree that carbon dioxide has decreased over the last 200 million years because of speeding up of the passage of carbon atoms from their volcanic sources into sediments. As we learned in the last section, to lower the CO_2 content one needs fresh rocks to provide calcium, and it also helps to bury organic matter.

Fresh rocks are provided through plate collisions and mountain building, that is, uplift of land and a drop in sea level. On the whole, there has been a trend to make more mountains during the last 100 million years, and especially since the last 40 million years. This is seen in the strontium isotope content of marine carbonates. The type of strontium derived from igneous rocks on land has increased relative to the type of strontium from other sources.

Organic matter is buried in swamps (plant remains turn into coal) and in continental margins (marine algal remains become hydrocarbons). The climate cooled as the planet acquired mountain ranges (like the Himalayas) and as sea level dropped. Trade winds became more vigorous. Coastal upwelling of nutrients in coastal waters increased. Thus, more organic matter was buried along the coasts of continents. Also, an increase in the amount of mud from the rising mountains helped to bury the organic matter.

As time went on carbon dioxide was more readily turned into sedimentary carbon and the planet cooled some more. Methane hydrate could have formed on the sea floor, trapping methane and denying another source of carbon to the ocean-atmosphere system. (The exception might perhaps have been during sporadic release of this methane, followed by strange jumps in climate.)

Carbon Cycle and Computer Models

So many processes have to be considered in the carbon cycle that it is extremely difficult to keep them in mind, and impossible to calculate without building a computer model to simulate them. Scientists interested in the carbon cycle have built a number of such models over the years. Such models can have between 50 and 100 interacting equations describing all the different processes of the carbon cycle that are relevant to the problem of how carbon dioxide changes through geologic time.

To what extent should the answers generated from such models be trusted? Consider this: if there are a dozen processes which we need to understand, and we only grasp each process within an error of 20 percent, the sum-total of the error adds to more than 200 percent! That is, if we now state that the content of carbon dioxide in the air so many million years ago had to be X, the true answer could be anywhere between 3 times X (200% more than stated) and X divided by 3 (200% less). Even if we make the reasonable assumption that half of the errors will cancel, we still get roughly a factor of two error on either side of the uncertainty statement. Thus, at the present state of knowledge, computing the answers will get us ballpark estimates and overall trends but not much more. Now you can appreciate why the range of errors plotted in the figure above are so large.

back to top