Geophysical Research Abstracts
Vol. 12, EGU2010-13257, 2010
EGU General Assembly 2010

The Global Carbon Cycle: It's a Small World

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Predicting future atmospheric concentrations of carbon dioxide (CO2), together with the impacts of these changes on global climate, are some of the most urgent and important challenges facing mankind. Modelling is the only way in which such predictions can be made, leading to the current generation of increasingly complex computer simulations, with associated concerns about embedded assumptions and conflicting model outputs. Alongside analysis of past climates, the GCMs currently represent our only hope of establishing the importance of potential runaway positive feedbacks linking climate change and atmospheric greenhouse gases yet the incorporation of necessary biospheric responses into GCMs markedly increases the uncertainty of predictions.

Analysis of the importance of the major components of the global carbon (C) cycle reveals that an understanding of the conditions under which the terrestrial biosphere could switch from an overall carbon (C) sink to a source is critical to our ability to make future climate predictions. Here we present an alternative approach to assessing the short term biotic (plant and soil) sensitivities to elevated temperature and atmospheric CO2 through the use of a purely physical analogue. Centred on the concept of materially-closed systems containing scaled-down ratios of the global C stocks for the atmosphere, vegetation and soil we show that, in these model systems, the terrestrial biosphere is able to buffer a rise of 3oC even when coupled to very strong CO2-temperature positive feedbacks. The system respiratory response appears to be extremely well linked to temperature and is critical in deciding atmospheric concentrations of CO2. Simulated anthropogenic emissions of CO2 into the model systems showed an initial corresponding increase in atmospheric CO2 but, somewhat surprisingly, CO2 concentrations levelled off at ca. 480 p.p.m.v., despite continuing additions of CO2. Experiments were performed in which reversion of atmospheric temperatures, or cessation of CO2 additions, showed rapid and proportionate decreases in atmospheric CO2 concentrations. The results indicate that short term terrestrial feedbacks are not sufficient to induce a CO2-temperature runaway scenario and suggest that predictions of atmospheric CO2 by current GCMs may under-estimate the CO2 fertilisation effect on plants and, hence, over-estimate future atmospheric CO2 increases. Perhaps, more importantly, the experiments show that the impacts of imposed elevated CO2 and temperature increase can be reversed. Whilst clearly representing a simplified version of terrestrial CO2 dynamics, it is proposed that closed system research represents a new form of test-bed for validation of processes represented within digital global CO2 models.