Reversible and irreversible impacts of greenhouse gas emissions in multi-century projections with a comprehensive climate-carbon model

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Currently, about a quarter of the anthropogenic CO_2 emitted into the atmosphere is absorbed by the surface ocean and causes a reduction in pH, thus, ocean acidification leads to an alteration in the calcium carbonate precipitation equilibrium.

We assess the long-term impacts of 21st century greenhouse gas emissions on climate and ocean acidification with the NCAR CSM1.4-carbon model on both the global and the regional scale. Emission commitment scenarios with zero emissions after 2100 AD and 21st century emissions of 1800 (High case), 900 (Low), and 0 gigatons of carbon (Hist) are run up to the year 2500 AD. In the High case, atmospheric CO_2 remains above 580 ppm and 30% of carbon emissions are still airborne by 2500. Consequently, the perturbations in carbonate chemistry persist. Undersaturation of the Arctic surface ocean with respect to aragonite, a mineral form of calcium carbonate secreted by marine organisms, is imminent and remains widespread for centuries. System time lags and physical-biogeochemical coupling often cause largest impacts to accrue after emissions have been stopped. The volume of supersaturated water providing habitat to calcifying organisms is reduced from preindustrial 40% to 25% in 2100 and to 10% in 2300.

The precautionary principle requires to reduce carbon emissions to keep atmospheric CO_2 below about 450 ppm, thereby avoiding the risk of large-scale ecosystem disruption. We conclude that emission trading schemes, related to the Kyoto Process, should not permit trading between emissions of relatively short-lived agents and CO_2 given the irreversible impacts of anthropogenic carbon emissions.

2.685-2.671 Ga Himalayan-type orogeny in the northern Teton Range, Wyoming, USA

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The Archean gneisses in the northern Teton Range record one of the earliest Himalayan orogenies on Earth. Features consistent with formation by collision of thick continental crust include high P metamorphism and juxtaposition of terranes with different provenances and distinct metamorphic and structural histories. The structurally higher gneisses contain pelitic gneiss with kyanite and mafic garnet granulites that record P, T conditions of ~12 kbar and 950°C. These gneisses have strongly negative initial εNd values and pelitic gneiss contains abundant detrital zircons with ages as old as 3.5 Ga. In contrast, P, T are lower in the structurally lower gneisses. Rare pelitic rocks contain only sillimanite and only the most Fe-rich amphibolites contain garnet. These gneisses also have positive initial εNd values and lack ancient detrital zircons. SHRIMP U-Pb zircon ages indicate that peak metamorphism occurred at ca. 2685 Ga. Abundant leucogranite gneisses crop out extensively in the area. They record the latest foliations in the range but generally lack the earlier isoclinal folds. They were emplaced after peak metamorphism between 2.83 and 2.71 Ga and obliterate many of the tectonic contacts. The chemistry and the positive εNd values of the leucogranites suggest that they were melted from the metagreywackes of the structurally lower gneisses. The presence of the Himalayan-type orogeny in the Teton Range implies that by 2.68 Ga at least some continental blocks were cool enough that they could support crustal doubling and that modern-style plate tectonics were operating by 2.68 Ga.