Combination of mechanisms responsible for the missing carbon sink By using bottom-up approach

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Summary

Nearly half of the carbon emitted to the atmospheres through deforestation, fossil fuel combustion, and cement manufacture remains in the atmosphere. The remainder of the carbon emitted through these human activities is stored in carbon sinks in the oceans and in terrestrial ecosystems. Measured atmospheric CO_2, ^{13}C, and O_2/N_2 distributions indicate that during the past two decades, a substantial fraction of the carbon sink has been on land, in the temperate and boreal latitudes of the Northern Hemisphere. However, the mechanisms and the detailed spatial pattern of this Northern Hemisphere terrestrial sink remain elusive. "Missing" carbon sink has become a required endeavor for global carbon cycle modelers. Quantifying these sinks and understanding the underlying mechanisms are top priorities for understanding Earth's major biogeochemical cycles and for establishing how changes in their magnitude could affect the future trajectory of atmospheric CO_2 concentration.

Accounting for the global carbon balance, the magnitude of this " missing " carbon is about 1.6 PgC/yr for global scale and 0.33 PgC/yr for U.S. in the 1980's. Several potential mechanisms has been proposed to explain this missing carbon, such as CO2 fertilization, climate change, nitrogen deposition, land use change, forest regrowth et al. Two major Strategies of modeling have been applied and both make great progresses of our understanding of carbon cycle. Top-down approach uses atmospheric tracer and inversion model to simulate the carbon source sinks based on kinds of observation network data (Gurney 2001, Bousquet 2003, Roedenbeck 2003, and Le quere 2003, Baker 2006). Bottom-up approach is the one using ecosystem process model, forcing by the climate, ecosystem data to mechanistically simulate the carbon flux. The estimates are based on mechanistic hypotheses about the processes that control the fluxes, and this is the largest advantage over inversion model. Considering the complexity of ecosystem, most of ecosystem model can't handle all the potential mechanisms to reproduce the real world. Thus, the missing carbon still is well known. For many years, researchers have believed that the dominant sink mechanism is the fertilizing effects of increased CO_2 concentrations in the atmosphere and the addition to soils of fixed nitrogen from fossil-fuel burning and agricultural fertilizers. However, a recent analysis of long-term observations of the change in biomass and growth rates, made by the US Forest Service, suggests that such fertilization effects are much too small to explain more than a small fraction of the observed sink in the US. In addition, long-term experiments in which small forest patches and other land ecosystems have been exposed to elevated CO_2 levels for extended periods show a rapid decrease of the fertilization effect after an initial enhancement. Houghton et al suggest on a leading candidate--historical changes in land use--for the United States. Hutts et al. uses an ecosystem demography model to project the future of U.S carbon sink and pointed out that forest re-growth after 1920, land use and fire suppression are main cause of carbon sink in US. Their projection indicates that

the ecosystem recovery processes primarily responsible for the contemporary U.S carbon sink will slow over the next century, resulting in a significant reduction of the sink. One interesting comprehensive experiment using ecosystem models by Hadley, IPSL, and UMD to investigation the mechanisms of co2 fertilization, climate change effect on carbon cycle is the projecting future climate feedback on global carbon cycle. Hadley model predict land will become a carbon source in the next century, resulting in higher co2 concentration and high temperature increasing, while IPSL predict the land will continue to absorb carbon and have a much week positive feedback. UMD prediction has a modest land source. The sensitivities simulation in UMD experiments suggest that different CO2 fertilization strengths explain part of the UMD-IPSL differences and soil decomposition and turnover time explain partly the UMD-Hadley differences in the coupled runs. Rather than narrow the range between such simulations, we had better firstly better understand the fundamental mechanisms that control the carbon sinks. The uncertainties that must be addressed include the magnitude of CO_2 uptake in the Southern Ocean and the worldwide impact of fertilization and land-use changes.

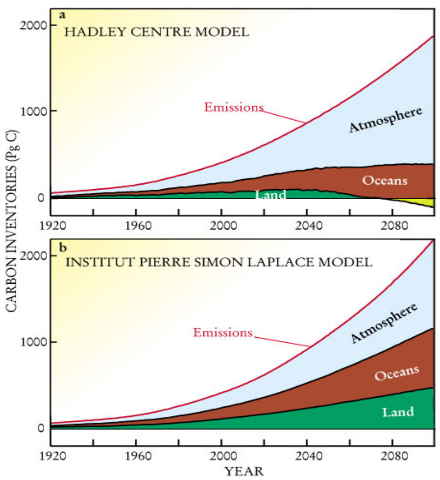

Figure 1: Future distribution of carbon from fossil-fuel emissions, as estimated by (a) the Hadley Centre model and (b) the Institut Pierre Simon Laplace model. The two models differ strongly in their sensitivity to global warming. The primary difference is the land sink, which is far weaker in the Hadley model and actually becomes a source of carbon (yellow-green area) by the century's end.

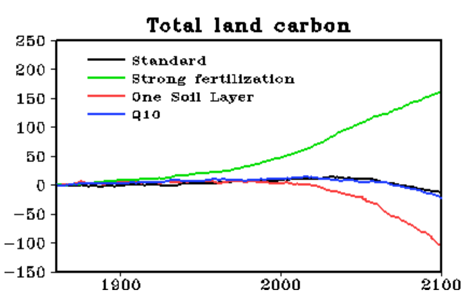

Figure 2. Total land carbon change (PgC) since 1860 in four fully coupled runs: the standard run three sensitivity experiments: strong CO2 fertilization effect, single soil layer, and high soil decomposition rate dependence on temperature (Q10 = 2.2 for all soil layers, blue).

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