Carbon Cycle and Greenhouse Warming:

Currently about half the carbon dioxide that is released by human activities stays in the atmosphere as a trend in atmospheric carbon content in GigaTonnes carbon per year. We can account for only a portion of the carbon that is taken out of the atmosphere, and it has been suggested that a large terrestrial sink of carbon must exist in the Northern Hemisphere. Oceanic sinks are estimated by using pCO_2 measurements and reasonably well-validated flux laws not unlike the aerodynamic formulas for heat, moisture, or momentum exchange at the surface.

Recently, several papers have come out that use: measurements of CO_2 at a variety of stations around the world, atmospheric transport efficiencies computed from GCM studies, and the known source and sink terms. With these inputs they can estimate the geographical distribution of the terrestrial source term as an inverse problem like the following carbon conservation equation for the atmosphere.

$$V \quad pCO_2 \approx known\,sources + unknown\,sources$$

If you have the spatial distribution of observed pCO_2 , and you know how the circulation transports air around, say in the form of a linearized transport operator, and you have some known sources, then you can estimate the distribution of the unknown sources and their magnitude. Atmospheric CO_2 in the Northern Hemisphere is about 3 ppm greater than those in the Southern Hemisphere. Estimates from GCM transport calculations suggest that the interhemispheric difference in CO_2 should actually be bigger than this, because 90% of the anthropogenic sources are in the Northern Hemisphere, so we infer a terrestrial or oceanic sink of carbon in the Northern Hemisphere of about 3 Gtonnes yr^{-1}. (e.g. Tans, et al. 1990). Extrapolations of interhemispheric differences into the past suggest that the anomalous N.H. sink has always existed and that trends in the N.H. sink are small compared to trends in the fossil fuel source of carbon dioxide (Conway and Tans 1999). Nonetheless, the annual cycle in CO2 in the Northern Hemisphere has been increasing with time. This annual variation has to do with the annual cycle of growth and decay of vegetation. Randerson et al.(1999) suggest that this increased annual cycle has to do with earlier warming in spring in high latitudes and greater uptake of carbon during the growing seaosn. So the pool of carbon that participates in the annual cycle is increasing.

Fan, et al.(1998) did this for the Northern Hemisphere and found a whopping 1.7 Gtonne yr^{-1} sink of atmospheric carbon over North America. This has big implications if it is true, since it would mean North American is a net sink of atmospheric carbon. This result is likely wrong, however. A European group did a similar calculation and found that the biggest sink is in northern Asia (Bousquet, et al. 1999a,b). They found a sink for North America of 0.5 and a sink for Asia of 1.5 Gtonnes yr^{-1}. Evidence in recent years has suggested that the largest contribution to the asymmetry probably comes from terrestrial uptake

Sarmiento et al.(1998) investigated the importance of changed oceanic circulation, as simulated by Manabe and coworkers, in the uptake of carbon. In the southern oceans, for example, it does not warm as much as the global average, so the southern oceans would continue to take in more carbon than would be predicted with a model without ocean transports. On the other hand, the model also predicts freshening of the surface waters, which will tend to stabilize the surface and reduce the uptake of carbon. In their model the decreased uptake of carbon by geochemical processes is balanced by an increase in the efficiency of the biological pump, but I can't understand their explanation of how this works and why. It all seems pretty uncertain, however. Their conclusion is that it is important to understand changes in the southern ocean circulation and how the biological pump will respond to these changes.

A fair amount of uncertainty still exists in the carbon budget, which will need to be reduced for purposes of effective international regulation of fossil carbon release (Tans and Wallace 1999), if such regulation actually goes forward.

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