A SIMULATION OF CARBON CYCLE EMPLOYED BY A 2-D ATMOSPHERIC TRANSPORT MODEL

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ABSTRACT

Carbon flux distribution was simulated between 90°S and 90°N during from 1981 to 1997. It was confirmed there was a terrestrial C sink in the area of mid-high latitude of north hemisphere. Some effect factors to Carbon flux, as ENSO, volcano activity, surface temperature etc. were analyzed also.

A 2-dimension atmospheric chemistry and transport model has been modified to an atmospheric transport model to study a CO_2 source and sink distribution. Horizontally, the model includes the domain from 90°S to 90°N, with a resolution of 5°. Vertically, the model includes 21 levels from the ground to 20 km, with a resolution of 1 km. Therefore, the grid points of the model were 36×21 totally. When tested the model, seasonal variation of atmospheric CO_2 at different altitude from the GAW station's observation data was used as the gauge for vertical transport. ^{85}Kr, a tracer gas, surface concentration difference inter-hemisphere was used as a criterion for horizontal transport. The steadiness of model was also examined. The change trend of global CO_2 concentration was simulated during the period from 1950 to 1998. The good agreement between the modeled and observed data from Mauna Loa and South Pole was found. Two data sets, the initial C flux data set and the observation atmospheric CO_2 concentration data, are needed. For the first set, we synthesized statistic data for fossil fuel emission [*Marland et al*., 1999], land use change [*Houghton and Hackler,* 2002], output data from an oceanic carbon cycle model [Jin 1998] and two terrestrial carbon cycle models [*Sitch,* 2000, *Ito* 2001], and allocated the totaled data to each ground cell. For the second set, data products from Global View [2001] were employed. To get the best possible distribution of carbon fluxes, through altering the import data of carbon fluxes to eliminate the discrepancy between simulated CO_2 data and those from observation. And in the most grids, the difference between modeled and measured should be below 0.25ppmv, with few exceptions (<0.5ppmv). An additional requirement in the calculation is the difference for output of last two steps should be less than 0.1. It appears a good agreement between the modeled and observed in most grids. In order to avoid the relatively large simulation errors in polar areas, we selected the main domain from 60° S to 60° N as the area of research. The slight deviation shown in the polar areas, especially the grids of 60° S. This could probably induce some errors in this inverse study. As the original carbon flux in high latitude area is relatively small, we conclude that errors originated here could be rather limited.

Carbon flux distribution between 60° S and 60° N for the period of 1981-1997 was studied with this inverse model (Fig. 1, did not show here). During this period, mid-high latitude area of North Hemisphere was a major source region of atmospheric CO_2. Fossil fuel emission dominates the CO_2 release in this region (30-60°N), with an average annual emission of about 4.5 GtC [*Marland et al*., 1999]. The second big CO_2 source region was the equatorial area (20°S-20°N), with oceanic emission of about 0.75GtC in 1990 [*Takahashi et al.,* 1997]. Another important carbon source in this region is land-cover change; *Houghton and Hackler* [2002] estimated that, in 1990 CO_2 emissions from land-use change in Tropical Africa, Central America, South and Southeast Asia could amount to 2.0GtC/yr. Data for mid-high latitude area of South Hemisphere indicate that this region is a weak sink of atmospheric CO_2. We attribute this sink to geographic distribution of oceans in this area. The pattern of carbon flux distribution, coupled with known fluxes from fossil fuel combustion and ocean, strongly indicated the possible terrestrial carbon sink located in Northern Hemisphere (north of 30°N). Taking into account the CO_2 uptake of oceans from this region (about 0.6 GtC/yr, Jin 1998), we estimate that this possible terrestrial sink could be about 0.8GtC/yr, which is higher than the sink to ocean.

There is considerable inter-annual variability in both the total amount and the spatial distribution of Carbon flux (Fig.2, did not show here). During the period of 1982/83, 1986/87, 1991-1993/94 were years of ENSO. There are strong fluctuations in the rate of atmospheric CO_2 increase during ENSO episodes. Variation in C flux distribution was also found during ENSO episodes. Take the case of 1982 for an example comparing the average flux distribution of 1981, 1984 and 1985 (Fig. 3, did not show). In 1982, C flux from equatorial area was much

lower than that of other years, while CO_2 release from 40° to 55° N shown opposite trend, with higher flux than other years. It is plausible to attribute the change in equatorial area to the oceans as *Feely et al.* [1987] reported that C emission from equatorial Pacific largely stopped in 1982. Then the flux increase from 40° to 55° N could probably be related to the fluctuation in land biosphere activity, as flooding and droughts in the different areas could restrain the C uptake of the terrestrial ecosystems. Possible explanation for such variation is that fluctuations in temperature, precipitation and other factors, caused by ENSO and other episodes, have influenced the terrestrial and oceanic C cycle processes. Another effect factor is volcano eruption. After the eruption of Pinatubo volcanic, in 1991, the increase rate of atmospheric CO_2 dropped. Generally, decline in surface temperature due to aerosols emitted by the eruption, is believed to be a major reason for this decrease of C flux.

The relationship between C flux and meteorological factors such as temperature and precipitation, were investigated with statistic method. C flux in the area of 40°-50° N, which included relatively large land area, showed negative correlation with temperature. But this relation was not obviously in other latitude zones. As expected, no much distinct correlation was found, due to the limitation of 2-D model and observation data, and the complexity of C cycle. Numerical experiments showed also that the diffusion coefficient, wind speed and CO_2 concentration data could all influence the results from inverse study.

The inverse research could provide some information about carbon sources and sink. Owing to the limitation of current model, further investigation is still necessary for more understanding of carbon cycle. Possible improvements could include further polish of transport simulation, development of a 3-dimension model and more support data from process-based models. To divide the calculated carbon fluxes into different sources and sinks, a possible way is to apply this inverse study to $\delta^{13}C$ cycle, which could be very information if adequate monitoring data become available.

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