SUBCONTINENTAL SCALE SOURCE/SINK INVERSION OF ATMOSPHERIC CO_2 AND INTERANNUAL VARIABILITY IN CO_2 GROWTH RATES

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ABSTRACT
A Time Dependent Inverse (TDI) model is used to estimate CO_2 fluxes for 64 regions of the globe from atmospheric data in the period January 1988–December 2001. These estimated are then used for understanding interannual variability in fluxes and simulating the CO_2 concentrations at various sites. The NIES/FRCGC transport model driven by interannually varying meteorology is used in both part of the analysis. Estimated atmospheric CO_2 concentrations agree closely with those observed at various sites globally.

INTRODUCTION
The measurements of atmospheric CO_2 contain information on both the intensity of industrial activities (fossil fuel consumption, land–use etc.) and the biogeochemical cycling of carbon by the terrestrial biosphere and the oceans. Thus sources/sinks inversions of atmospheric CO_2 have allowed us to probe the effect of several atmospheric phenomena, such as climate oscillations and volcanic eruptions, on the global carbon cycle. In this study, we first summarize our results for the climate controls on land/oceanic carbon cycle [*Patra et al.,* 2005a,b] and then discuss the observed interannual variability in CO_2 concentrations [*Patra et al.,* 2005c].

RESULTS
This TDI model is a modified version of that used in TransCom-3 studies (methodology based on *Rayner et al.,* [1999]), which has increased spatial resolution and uses interannually varying NCEP/NCAR meteorology. Atmospheric data at 87 stations are selected from the GLOBALVIEW-CO_2 dataset for TDI model calculation. The interannual variability in CO_2 fluxes from land and ocean regions are analyzed in details recently. We find strong connections between CO_2 flux anomalies with the El Niño Southern Oscillation (ENSO) in the tropics. During warm ENSO phase, enhanced release of CO_2 fluxes are recorded from the land regions as a combined effect of reduced photosynthesis due to water stress, and greater heterotrophic respiration under hotter air temperature. The oceanic flux variability in tropics is mainly related to the upwelling strength. The magnitude of climate controls due to Arctic and North Atlantic Oscillations (AO and NAO) is smaller over the mid- and high latitudes for both land and oceans.

We established that the El Niño induced climate variations in the tropics and large scale forest fires in the boreal regions to be the main causes for anomalous atmospheric-CO_2 growth rates observed at Mauna Loa (MLO). For example, high CO_2 growth rate of 2.8 ppm yr^{-1} in 2002 at MLO can be predicted fairly successfully by using the correlations between (1) the peak-to-trough amplitudes in ENSO index and tropical flux anomaly, and (2) anomalies in CO_2 flux and fire burned area from the boreal regions. We suggest that the large and interannual changes in CO_2 growth rates can mostly be explained by the natural climate variability. Our analysis also shows that the decadal average growth rate, linked primarily to the human activities, is fluctuating by ±1.5 ppm yr^{-1} around the mean rate of 1.7 ppm yr^{-1} over the past 20 years, which was only about the half during the 1960s (Patra et al., 2005c).

Finally, we show comparisons of forward model simulations of "known" CO_2 sources and inverse model predicted fluxes at several locations. The known sources are seasonally varying oceanic flux [*Takahashi et al.,* 2002], a flux-neutral terrestrial ecosystem [*Randerson et al.,* 1997], and fossil fuel emission [*Marland et al.,* 2003]. Fig. 1 shows the time series (observed and modelled) of CO_2 concentrations at Barrow, MLO, Tutuila (data used in inversion), Hateruma, Cape Point, Tierra del Fuego (data not used in inversion). Two inverse modelling frameworks are used here: the control inversion for 64-regions, and 22-region inversion. It is clearly seen that the interannual variations in both the trends and seasonal cycles are simulated more closely by using the inversion fluxes. At several stations, however, the simulated seasonal amplitude appeared somewhat greater than observed when known flux values are used (with apparent phase mismatches). These results give us confidence on the derived fluxes and its interannual variability by inversion of atmospheric CO_2 data. These simulations will be checked further with different transport

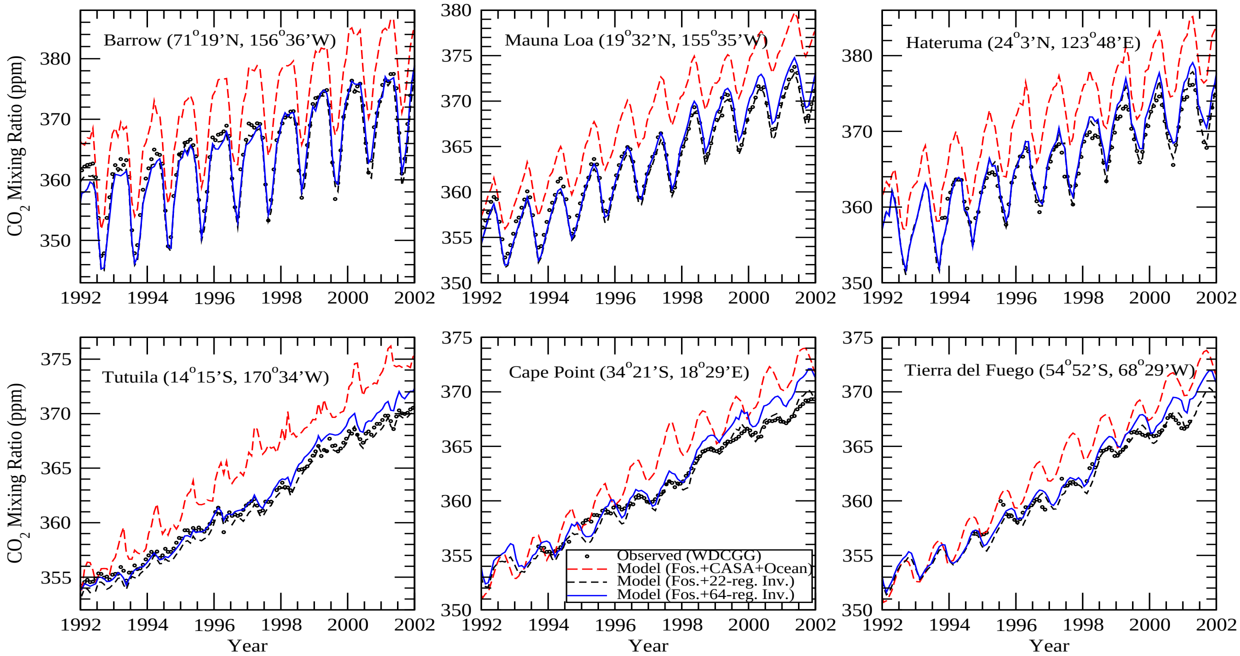

Fig. 1: Timeseries of observed and simulated CO_2 concentrations are shown at six stations (3 each in northern and southern hemisphere). Monthly mean 'observed' values are constructed from WDCGG (http://gaw.kishou.go.jp/wdcgg.html) archive, and NIES/FRCGC model simulated values are obtained using three different fluxes; (1) long-dashed line: using estimated distribution and magnitude of fluxes for fossil fuel emission [*Marland et al*., 2003], neutral terrestrial biosphere [*Randerson et al.,* 1997] and oceanic exchange [*Takahashi et al.,* 2002], (2) dashed line: Fossil fuel emission and corrected fluxes for 11 land and 11 ocean regions using TDI model, (3) solid line: Fossil fuel emission and corrected fluxes for 42 land and 22 ocean regions using TDI model .

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