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Intra-seasonal variability of atmospheric CO_2 concentrations over India during summer monsoons

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HIGHLIGHTS

- Intraseasonal variability in the atmospheric CO_2 concentrations over India.
- CO_2 concentration varies in synchrony with the active and break spells.
- CO_2 anomalies are strongly negative(positive) during the break(active) period.

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ABSTRACT

In a study based on a data assimilation product of the terrestrial biospheric fluxes of CO_2 over India, the subcontinent was hypothesized to be an anomalous source (sink) of CO_2 during the active (break) spells of rain in the summer monsoon from June to September (Valsala et al., 2013). We test this hypothesis here by investigating intraseasonal variability in the atmospheric CO_2 concentrations over India by utilizing a combination of ground-based and satellite observations and model outputs. The results show that the atmospheric CO_2 concentration also varies in synchrony with the active and break spells of rainfall with amplitude of ± 2 ppm which is above the instrumental uncertainty of the present day techniques of atmospheric CO_2 measurements. The result is also consistent with the signs of the Net Ecosystem Exchange (NEE) flux anomalies estimated in our earlier work. The study thus offers the first observational affirmation of the above hypothesis although the data gap in the satellite measurements during monsoon season and the limited ground-based stations over India still leaves some uncertainty in the robust assertion of the hypothesis. The study highlights the need to capture these subtle variabilities and their responses to climate variability and change since it has implications for inverse estimates of terrestrial CO_2 fluxes.

1. Introduction

"Intra-seasonal oscillations (ISO)" in the context of Indian Summer Monsoon (ISM, June to September) is generally a term used to describe the subseasonal variability (viz., a ~20–60 day periodicity) of various meteorological parameters related to the summer monsoon rainfall over India. It generally corresponds to the intermittent spells of active rainy periods of a few days to few weeks long followed by a break over the Indian subcontinent (Wang et al., 2005). These systematic periods of rainy and non-rainy days not only affect the total precipitation over the monsoon region (Goswami et al., 2006) but also have an influence on the terrestrial biosphere and carbon cycle variability over India (Valsala et al., 2013; Tiwari et al., 2014; Ravi Kumar et al., 2014b; Revadekar et al., 2016).

In our earlier work, the impact of summer monsoon rainfall ISO on the Indian subcontinental terrestrial ecosystem were hypothesized to be due to an interplay of corresponding scale variability in the various meteorological parameters such as humidity, rainfall,

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surface temperature, soil moisture and photosynthetically active radiation (PAR, Valsala et al., 2013). The hypothesis put forth was that during the active period, due to the cloud cover and the lack of PAR, there could be a slowdown in the photosynthesis. Together with this a hike in the heterotrophic respirations in response to the sudden rain events could lead the biosphere to be an anomalous source of CO_2. During the preceding break, the clearer skies and a surplus of PAR on a relatively wet soil leads the biosphere to be an anomalous sink of CO_2. Although this conclusion was arrived at based on data constrained biospheric NEE flux models, a validation of this hypothesis was not possible mainly because there were no direct measurements of '*CO_2 fluxes*' from the Indian region which are sufficiently long and high enough resolution to analyze such intra-seasonal oscillations. In this study, we attempt an alternative way of verifying the ISO of CO_2 fluxes over India by directly analyzing the corresponding scale variability in the atmospheric CO_2 concentrations. In this way, confirmatory evidence can be gleaned by utilizing the data from existing ground based measurements of atmospheric CO_2 over India as well as measurements based on instruments mounted onboard satellites (Ravi Kumar et al., 2014b; Tiwari et al., 2014).

Monitoring and analyzing the atmospheric CO_2 collected by the ground based observation network is ultimately important in regions like India because the satellite measurements are not capable of seeing the column concentrations of CO_2 through the clouds during the monsoon season. Because of this, during the summer monsoon period (June to September, JJAS hereinafter), the Indian subcontinent has huge data gaps in the observed CO_2 from satellite (Takagi et al., 2014). The same is the case for chlorophyll measurements as well (e.g., Murtugudde et al., 1999; Waliser et al., 2005). The ground based observations of CO_2 are also lacking at present except at a few key stations in operation for multiple years, for example, Tiwari et al. (2014) reported the continuous monitoring of atmospheric CO_2 from a station close to the western peninsular India and is providing atmospheric CO_2 in the boundary layer at weekly resolutions for past four years.

Satellite measurements on the other hand provide the spatially varying column concentrations of atmospheric CO_2 at very high resolutions (Takagi et al., 2014). Recently, using the datasets from AIRS satellite, Li et al. (2010), Wang et al. (2011), and Jiang et al. (2012) showed the response of mid-tropospheric CO_2 concentrations to large-scale climate drivers such as the El Niño-Southern Oscillation (ENSO), Madden–Julian oscillation (MJO), Semiannual Oscillation (SAO), and tropospheric biennial oscillation (TBO). Jiang et al. (2010) showed that the Walker circulation changes can modulate CO_2 concentrations in the mid-troposphere. Jiang et al. (2012) indicated that there is more (less) CO_2 in the central Pacific and less (more) CO_2 in the western Pacific during El Niño (La Niña) events. Ravi Kumar et al. (2014b) used the AIRS retrieved CO_2 data over the Indian subcontinent to study the relationship with the climate parameters during different seasons. Therefore combining the satellite retrieved atmospheric column concentration of CO_2, ground based station observations and data constrained model concentrations, we can attempt to study the intra-seasonal oscillations of CO_2 concentrations over the Indian subcontinent.

The significance of analyzing the atmospheric CO_2 variability within the monsoon season can be highlighted in the following context; (a) The recent aircraft based observations using commercial airliners have offered glimpses of tropospheric CO_2

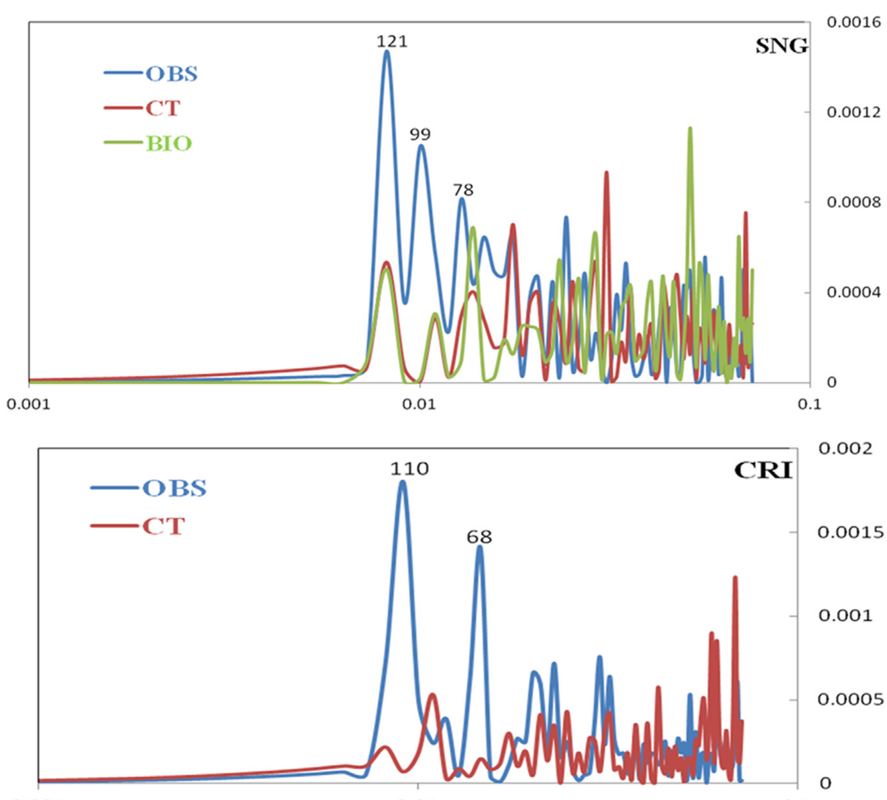

Fig. 1. Power spectrum of de-trended and de-seasonalized observed (OBS) surface atmospheric CO_2 concentrations at Sinhagad (SNG) and Cape Rama (CRI) are shown together with correspondingly calculated power spectrum from the CarbonTracker (CT). Biospheric (BIO) NEE from CarbonTracker are shown over the SNG grid. SNG observations span from the period 2011 to 2013. CT data are from 2000 to 2011. The power spectrum of biospheric fluxes (NEE) is for SNG. The x-axis is in logarithmic units of power and y-axis is the variance preserving spectra. The periods (in days) of selected spectral peaks are marked.