Physics and Chemistry of the Earth 89–90 (2015) 65–72

Contents lists available at ScienceDirect

Physics and Chemistry of the Earth

journal homepage: www.elsevier.com/locate/pce

Study on the association of green house gas (CO_2) with monsoon rainfall using AIRS and TRMM satellite observations

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ARTICLE INFO

Article history:
Received 10 December 2014
Received in revised form 24 March 2015
Accepted 23 April 2015
Available online 16 May 2015

Keywords:
Monsoon rainfall
CO_2
AIRS
TRMM
Anomalies
ENSO

ABSTRACT

Monsoon water cycle is the lifeline to over 60 per cent of the world's population. Throughout history, the monsoon-related calamities of droughts and floods have determined the life pattern of people. The association of Green House Gases (GHGs) particularly Carbon dioxide (CO_2) with monsoon has been greatly debated amongst the scientific community in the past. The effect of CO_2 on the monsoon rainfall over the Indian–Indonesian region (8–30°N, 65°–100°E) is being investigated using satellite data. The correlation coefficient (R_{xy}) between CO_2 and monsoon is analysed. The R_{xy} is not significantly positive over a greater part of the study region, except a few regions. The inter-annual anomalies of CO_2 is identified for playing a secondary role to influencing monsoon while other phenomenon like ENSO might be exerting a much greater influence.

1. Introduction

Monsoon has puzzled scientists, intelligentsia and the common man since time immemorial. On geological time scales, paleoclimatic data and simulations with climate models indicate significant and periodic changes in monsoon strength (Prell and Kutzbach, 1987). Its erratic and unpredictable behaviour has largely put the efforts made to forecast and predict it difficult till date. Further, studying the implications of global warming on monsoon and its variability adds to the complexity in solving the monsoon puzzle.

Asian monsoon and associated floods and droughts directly impact the life of billions of people and the economies of many Asian countries (Dairaku and Emori, 2006) and thus, the response of South Asian monsoon dynamics to elevated atmospheric greenhouse gas concentrations is an issue of both scientific and societal importance (Ashfaq et al., 2009). Carbon dioxide is a major greenhouse gas in the atmosphere and plays a significant role in warming the earth by radiative forcing through entrapment of outgoing long-wave radiations from the earth to the space. The concentration of CO_2 has increased by 31 per cent since pre-industrial times, from 280 ppm by volume (ppm) to more than 370 ppm today and half of these increase has been since 1965 (Karl and Trenberth, 2003). There are many feedback processes in the nature that can either amplify or diminish the climate response to increase in greenhouse gases (Trenberth, 1999). So, it is important to study the response of the Asian summer monsoon with gradual increase of the atmospheric CO_2 concentration (Hu et al., 2000).

So far, various attempts have been made to explore the intricate interaction between global warming and monsoon rainfall through the application of General Circulation Models (GCMs). Simulation of the Asian monsoon circulation has proven to be a critical test of the ability of GCMs in simulating the tropical climate variability. The predicted changes in local precipitation vary considerably between models (Allen and Ingram, 2002). These models simulate the large-scale climatological features in response to global forcing such as land–sea distribution, orography and differential heating reasonably well (Lal et al., 2001). However, in IPCC assessment in 1990 when a set of GCMs were compared in their representation of present climate and climate with double CO_2 concentration at sub-continental or regional scales, regional climate assessments were found to be unsatisfactory because of coarse resolution, excluded climate system feedbacks, errors in simulated present-day regional features, and wide inter-model range of simulated regional climate change (Kittel et al., 1998).

Previous climate-modelling studies have shown greater mean south Asian summer monsoon rainfall attributable to climate change caused by increase of atmospheric CO_2 concentration (Houghton et al., 1990). In this regard, Rajendran and Kitoh (2008) have investigated the impact of future climate change on the Indian summer monsoon using a super-high resolution global

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http://dx.doi.org/10.1016/j.pce.2015.04.004
1474-7065/

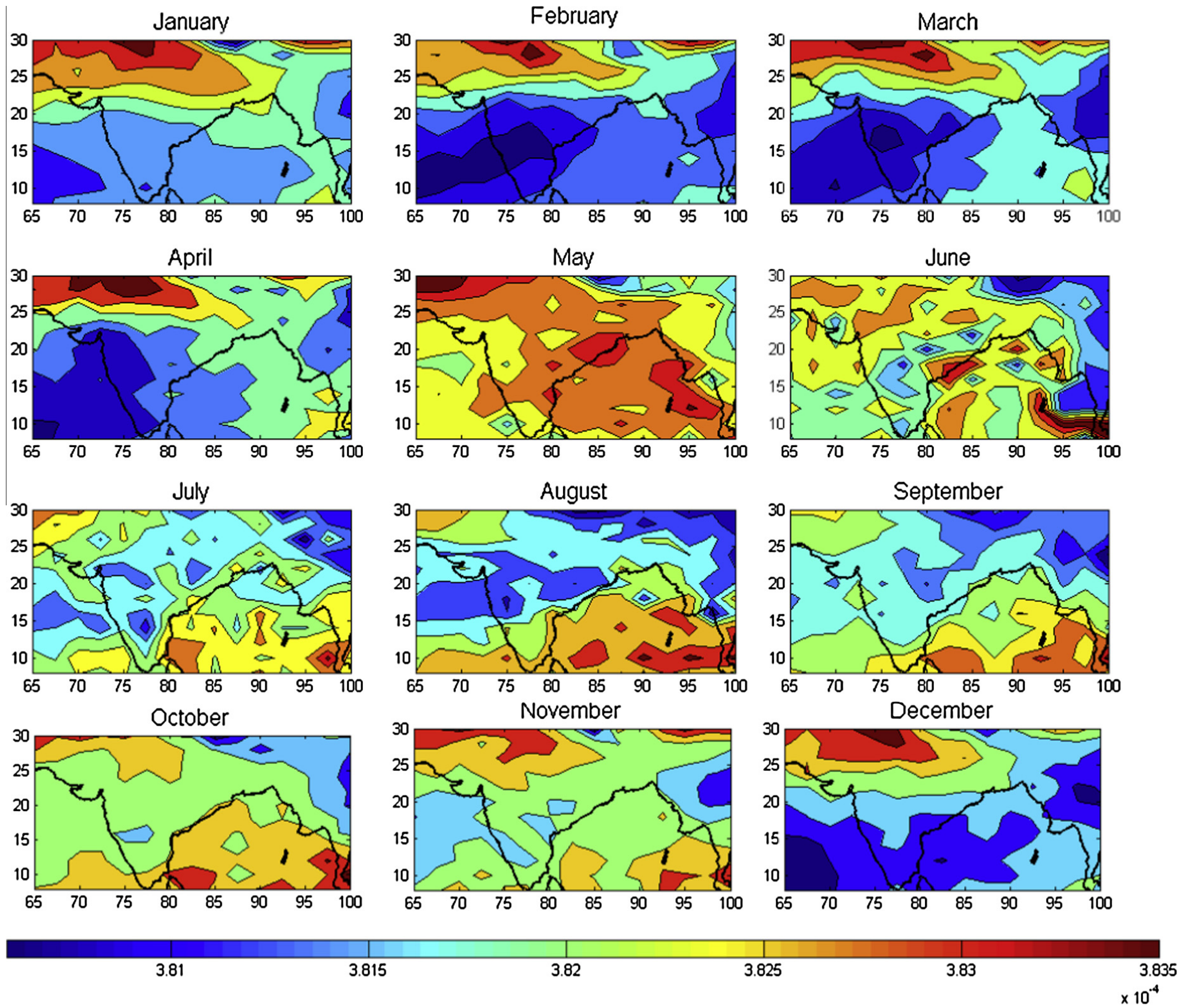

Fig. 1. Monthly average CO_2 concentration (in mole fraction) during 2003–2009.

general circulation model which shows widespread but spatially varying increase in rainfall over the interior regions, significant reduction in orographic rainfall over the west coasts of Kerala and Karnataka and eastern hill regions of Assam. They strongly suggest the consideration of fine-scale processes (orography, evaporation, moisture content and circulation) for accurate assessment of local and regional-scale vulnerability to climate change. In another study by Lal et al. (2001) on CCSR/ NIES AOGCM model suggests that 10–15% increase in area averaged summer monsoon rainfall over India subcontinent, a 5–25% decrease in winter rainfall and a greater variability in the date of onset of summer monsoon. Ashrit et al. (2001) investigated the susceptibility of ENSO-monsoon relationship to a greenhouse warming using model (ECHAM4/OPYC). Their study suggests a reduced impact of El-Nino event on monsoon largely due to heating of the Eurasian landmass and enhanced moisture. In a similar attempt, Turner et al. (2007) found the distinct irregular and periodic regime in ENSO behaviour in a modelled future climate.

The simulation models show that the number of rainy days and the intensity of rainfall on a rainy day may change in future in response to global warming. The increase in the mean summer monsoon precipitation is due to increased moisture from the Indian Ocean, caused by warmer Sea Surface Temperatures (SSTs) in the ocean basin (Meehl and Arblaster, 2003). May (2004) found that the increase of the summer monsoon rainfall in the Indian region is caused by an intensification of the atmospheric moisture transport into the region, presumably counterbalanced to some extent by a decrease in the cycling rate of water vapour (Douville et al., 2002). The increase in the summer monsoon rainfall is attributed to a projected intensification of the heat low over northwest India, the trough of low pressure over the Indo-Gangetic plains and the land–ocean pressure gradient during the established phase of the summer monsoon (Kripalani et al., 2007).

However, there are a number of studies which do not conform to the above mentioned viewpoint and found a suppression of the South Asian Summer Monsoon as a result of enhanced greenhouse gas forcing (Ashfaq et al., 2009; Kitoh et al., 1997; May, 2004; Ueda et al., 2006; Stowasser et al., 2009; Cherchi et al., 2011). According to May (2004), the weakening of the summer monsoon flow is due to a pronounced warming of the SSTs in the central and eastern tropical Pacific and the associated alterations of the Walker circulation. The weakening of the summer monsoon flow is possibly due to an intensification of precipitation over the equatorial western Pacific, forcing an anomalous descending circulation over the eastern equatorial Indian Ocean and suppressing the cross-equatorial monsoon flow (Stowasser et al., 2009). On the other hand, the weakening of the summer monsoon flow is also explained by a reduction of the meridional thermal gradient in the Asian region due to a pronounced warming over the tropics in the middle-to-upper troposphere (Ueda et al., 2006).

So, it is necessary to identify the role of GHGs especially CO_2 over the Asian monsoon region by observation based study as