Study of Break Phase of Indian Summer Monsoon using Different Parameterization Schemes of RegCM4.3

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Abstract

The break phase of Indian summer monsoon (ISM) has a large impact on rain fed agriculture. Therefore, this study is considered for the simulation of break phases over Indian subcontinent during the period 2001-2005 using International Center for Theoretical Physics’ (ICTP) Regional Climate Model version 4.3 (RegCM4.3). Different convection schemes of RegCM4.3 are compared with high resolution rainfall of IMD and ERA15 wind vorticity at 850hPa for this simulation. Spatial and temporal distribution of these schemes sounds the good fitness for Grell convection scheme with less bias in percentage changes.

Keywords: Break phase, Parameterization scheme, RegCM4.3, Indian summer monsoon (ISM), IMD 0.25x0.25, ERA15.

1. Introduction

The Indian Summer Monsoon (ISM) on a sub-seasonal timescale undergoes through the period of reduced rainfall activity over central and north India. These intra-seasonal variations are termed as break phases of monsoon. An exhaustive survey by Ramamurthy (1969) for breaks of the Indian summer monsoon was carried out using 80 years with rainfall data and noted that in general most of the breaks occur with duration of about 3–5 days. The fluctuation of rainfall over the monsoon trough zone during peak monsoon months of July and August is divided between two spells: during the height of rains and intervals of drought (Blanford, 1886). In the peak monsoon months of July-August, the monsoon trough zone is interrupted for a consecutive days of Intervals of droughts, is called breaks of monsoon (Ramamurthy, 1969; Raghavan, 1973). Certain dynamic and thermodynamic characteristics of the monsoon circulation during break-monsoon conditions are investigated by Bhatla et al. (2004) and identified the changes in circulation characteristics and the adjoining seas that lead to break-situation aspects in the ISM. Raju et al. (2009) examined the changes in mean surface meteorological fields over India and the adjoining seas which lead to the break situation in the ISM.

 Break monsoon conditions are important for monsoon which contributes significantly to the intra-seasonal variability of the monsoon. A number of studies have been carried out to identify breaks phase, based on different criteria over regions of different spatial scales (Rajeevan et al., 2010; Gadgil and Joseph, 2003; Ramamurthy, 1969). Although the break criteria of low level pressure and wind patterns associated with rainfall anomaly used by IMD (Rao, 1976) is more significant rather than the rainfall distribution itself (Gadgil and Joseph, 2003). The studies of Ramamurthy (1969) and De et al. (1998) have identified the breaks during 1968–1997 using the same criteria. Rajeevan et al. (2010) identified the break spells on the basis of daily gridded rainfall dataset. Several studies have been carried out to understand Intra-seasonal variability associated with the ISM using Climate modeling and simulation (Taraphdar et al., 2010; Dash et al., 2014; Raju et al., 2015). Many attempts are made to evaluate model performance of different parameterization schemes (Raju et al., 2015; Kumar et al., 2014; Soniet et al., 2014) and to simulate ISM (Dash et al., 2014).

In the present study, the analysis regarding simulation of break phase over India using different parameterization schemes of Regional Climate Model version 4.3 (RegCM4.3) during the period 2001-2005 are considered. The break spells are considered on the basis of daily gridded rainfall data by Rajeevan et al. (2010), is presented in Table 1.

2. Data and Methodology

Latest version of International Center for Theoretical Physics (ICTP) RegCM4.3 data is used throughout this study. The initial conditions and lateral boundary forcing are the derived six hourly fields from ERA15 reanalysis, available with a horizontal grid of
1.5° latitude/longitude and 37 levels in the vertical. Twelve hourly 4D-Var data assimilation is used to improve model physics as compared with ERA-40 reanalysis. In this present study, convection schemes namely Kuo, Emanuel, Grell, Mix98 (Grell over land and Emanuel over the ocean), Mix99 (Grell over the ocean and Emanuel over Land) and Tiedtke are used to simulate the break phase in RegCM-4.3. The land surface scheme of Biosphere-Atmosphere Transfer Scheme (BATS) and boundary layer physics, following the non-local vertical diffusion scheme of Holtslag et al. (1990) is used for all sensitivity experiments. Model integration in the lateral boundary of 10 grid points is allocated for the buffer zone where an exponential nudging is used to combine the model fields and the boundary conditions (Giorgi et al., 1993). In this study, high resolution (0.25° x 0.25°) daily gridded rainfall of IMD, and ERA15 reanalysis wind at 850hPa is used over the core region (73°-82° E; 18°-28° N) of India for the duration of 2001-2005. The selected region for this study is considered as Taraphdar et al. (2010).

Table 1: Break spells of Indian summer monsoon.

<table>
<thead>
<tr>
<th>Years</th>
<th>Break spells</th>
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</thead>
<tbody>
<tr>
<td>2001</td>
<td>31J-2A, 26A-30A</td>
</tr>
<tr>
<td>2002</td>
<td>4J-17J, 21J-31J</td>
</tr>
<tr>
<td>2003</td>
<td>-</td>
</tr>
<tr>
<td>2004</td>
<td>10J-13J, 19J-21J, 26A-31A</td>
</tr>
<tr>
<td>2005</td>
<td>7A-14A, 24A-31A</td>
</tr>
</tbody>
</table>

3. Result and Discussion

For the purpose of break study, the considered region is represented as Fig 1. The rectangular box is indicated as the core region (73°-82° E; 18°-28° N) of India. The spatial distribution of the break period for rainfall and vorticity of wind at 850hPa is showing the composite break spell (Rajeevan et al., 2010) for the duration of 2001-2005 (Fig 1a-b). Fig 1a represents the break phase with the reduction in precipitation rate over the core region which extends westwards and possesses the region of the monsoon trough zone, north and central Bay. An increase in precipitation rate is also observed over the Peninsular India in this phase. This may be due to the excessive solar insolation low pressure zone builds up over northwest part India. This low pressure zone gradually extends to eastward direction of India with the time of advance of monsoon. This extends continue until it forms an extended low pressure zone in west to east direction running parallel to the Himalayan foothills. This is referred as the monsoon trough. Monsoon trough shows periodical movements to the north and south of its normal position. When it moves north and lies close to the Himalayan foothills, there is a remarkable change in the rainfall pattern over India. The rain cease abruptly over the plains of northern India, but increase equally with intensity over the foothills and north-east India during break phase of monsoon (Das, 2009). The relative vorticity (Fig 1b) at 850hPa is appeared over the head of the Bay of Bengal (BoB) and Himalayan foothills. A wide area of core region is faced clear absences of wind vorticity at low level and a few regions near foothills of Himalaya, showing weak vorticity which is going to be absent. A significant weak vorticity over the core region is also represents in 850hPa with ERA15 reanalysis. The low level vorticity centered on the head of Bay of Bengal and extends along the monsoon trough are prominent feature for rain over core region, are clearly absent here. Fig 1b also shows that the Low level jet (LLJ) is weak over Arabian Sea and consequently over core region during break spells. The weakening of cross-equatorial flow and the LLJ during the break could also lead to less air-sea exchange and a reduction of water vapor in the atmosphere (Bhatla et al., 2004). This break composite is signifying a weak lower level vorticity which lies in the Himalayan foothills, depicts in Fig 1b. Most of the region depicts clear absence of vorticity over the mentioned region (Taraphdar et al., 2010). These features of the break spell are compared with the model simulated data as shown in Fig 2 for six convection schemes. Spatial distribution of RegCM4.3 model simulation in different convection schemes represents well in Fig 2b-g. IMD rainfall for the break spell over the particular core region is shown in Fig 2a, which depicts the lack of rainfall over the wide area of central India. Most of the region depicts rainfall of less than 0.5 mm for composite break spells. This may be due to the relative vorticity of wind at lower level of 850hPa which has an important role for break phase simulation (Taraphdar et al., 2010). On the other side, model simulated rainfall of Kuo, Mix98 and Grell convection schemes (Fig 2b,c,g) simulated well with IMD rainfall. But in all cases the lack of rainfall is simulating over a wide range of the core region; and region related to 73-74° E and 18-22° N are simulating the rainfall of 2 mm or higher. Mix99, Tiedtke and Emanuel (Fig 2d,e,f) convection schemes are performed poorly to simulate the break phase. These schemes are not following the distribution pattern of IMD rainfall. The model simulated lower level vortex distributions (Fig 3) for these convection schemes are also following the pattern of ERA15 reanalysis. However, the vorticity distributions (Fig 3) at 850hPa are in good agreement with observed pattern (Fig 1b).
Fig 1: Composites of (a) IMD rainfall and (b) ERA15 wind vorticity at 850 hPa during 2001-2005. Rectangular (73°-82°E; 18°-28°N) over central India indicates the core region of India.

Fig 2: Composites rainfall during break phase of IMD and six convection schemes over the region 73°-82°E; 18°-28°N during 2001-2005.
The inherent difference/bias of these different schemes might be reflected with correlation coefficient (COR) and Root Mean Square Error (RMSE) of rainfall for break phase. Therefore, COR and RMSE are computed for break phases of rainfall analysis (Fig 4). Fig 4a-b represent that the convection scheme Grell is indicating highest COR (0.26) and lowest RMSE (1.3) along with the spatial distribution (Fig 2) compared to other schemes. Convection scheme namely Kuo, Mix99 and Emanuel are shows the poor correlation compared to Grell scheme. Mix98 and Tiedtke schemes are performed negative COR and high RMSE. These analyses are enough to bring out the reasonability of model simulation in contrasting of

Fig 3: Composites wind vorticity at 850hPa during break phase of convection schemes in RegCM-4.3. Rectangular box (73°-82°E; 18°-28°N) in central India indicates the core region of India.
break phases. Further the percentage changes are computed and displayed in Fig 5. Convection schemes Kuo, Mix98, Mix99 and Emanuel are depicted only negative percentage i.e. these convections schemes are showing underestimation compared to observe over the core region. Tiedtke and Grell schemes are performed positive and negative percentage both. The representation of these small data sets does not lending easily from Fig 5. However, Tiedtke performs poorly with weak COR and high RMSE (Fig 4).

Analysis of percentage changes is graphically represented in Fig 6. For the comparison among the several datasets, the box plot is useful to display the several datasets into several small boxes. For Kuo
scheme, the line between the lowest adjacent limit and the top of the box is two-third of the data with 5-95 percentile, i.e. two-third of the data falls between the box and the median. And the one-third between the median and down of the box. The line between the top of the box and the upper adjacent limit represents the final two-third of the data observation. Most of the schemes are performed a wide negative sense (except Tiedtke and Grell) along with the different position of its data arrangement. Tiedtke convection scheme and Grell scheme are fitted well with X-axis as compared to others schemes. But in Fig 4, Tiedtke scheme is performed poor compared to the Grell scheme along with a wide range of percentile changes (Fig 6). Grell convection scheme is performed good compared to other schemes with less bias. As a mass flux schemes, Grell scheme treats clouds as the two steady-state circulation events namely updraft and downdraft. No mixing occurs between the cloud and the environment except at the top and bottom of the circulations, with no entrainment or detrainment along the edges of the cloud. This scheme implements convective adjustment in accordance with quasi-equilibrium assumption, in which convective clouds act to stabilize the environment as fast as large-scale processes destabilize it (Gianotti et al., 2011), which might be responsible for good agreement to the observations over India Land region.

4. Conclusions

This is a base study to simulate scheme performance during break phases over India with different convection schemes of ICTP’s RegCM-4.3. For this purpose high resolution dataset of IMD, ERA15 and RegCM4.3 are used for 5 years simulation. The inherent difference/bias of different convection scheme is reflected from COR and RMSE of rainfall for break phase. The above discussion indicates that the simulation characteristics of Grell scheme for break phase simulation is sound well in respect of statistical COR and RMSE of rainfall. Simulation of percentage changes of rainfall is also represented statistically in Box plots to represent lowest value, highest value, median value, and the size of the first and third quartile graphically. Out of six convection scheme, Grell scheme sound good with the observe data of IMD rainfall and ERA15 wind vorticity at 850hPa as compared to the other schemes.

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References


