Radiative forcing of Atmospheric Brown Clouds over the Indo-Gangetic Plains

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Abstract

Atmospheric brown clouds (ABCs) are a dense and extensive pollution layer and have significant implications on air quality, agriculture, water cycle, and regional climate. The objective of the present study is to observe seasonal and spatial variations in the occurrence of ABCs and its radiative effects. The Indo-Gangetic plain (IGP) is the most populated region of India, which is an extended region in the foothills of the Himalayas. The IGP is one of the ABCs hotspots over the globe. The frequency of ABCs’ occurrences and radiative forcing were calculated using data from seven ground-based remote sensors situated across the IGP. The frequency of ABCs’ occurrences and radiative forcing were calculated using data from seven ground-based remote sensors situated across the IGP. We have used total ~ 5000 days of Level-2 aerosol measurements from seven AEROSol Robotic NETwork (AERONET) stations (Karchi, Lahore, Jaipur, New Delhi, Kanpur, Gandhi college and Dhaka University) for the period 2000-2019. An algorithm based on the optical properties of aerosols is used to defined extreme pollution events (ABCs days) for each site. Further, we have used spectral dependance of aerosol optical depth (AOD) and absorption optical depth (AAOD) to characterize aerosol types during ABCs days over IGP. The results show unique features of ABC occurrences over the IGP. In general, the maximum frequency of ABCs days is found during pre-monsoon seasons over all the sites. However, other seasons have specific features over specific locations, for example, the maximum occurrence of ABCs days was found over Delhi during pre-monsoon (65%), followed by Delhi during pre-monsoon (61.29%), Kanpur in pre-monsoon (44.29%). Further, we have used the Santa Barbara DISORT Atmospheric Radiative Transfer (SBDART) model to calculate aerosol radiative forcing (ARF) during ABCs days on all sites of study.

Data & Methods

AERONET is a network of automatic sun/sky scanning radiometers distributed globally. It provides optical and micro-physical properties of aerosol like AOD, AERI, SSA, asymmetry parameter (ASF) and volume size distribution. The daily level 2.9 (quality assured) data products are retrieved at all 7 AERONET stations over the study area. The data for each station is available for the following time period: Karachi (01-01-2007 to 31-12-2018), Lahore (01-01-2006 to 31-12-2018), Jaipur (2001-01-2011 to 31-12-2018), Delhi (01-01-2006 to 31-12-2018), Jaipur (01-01-2009 to 31-12-2018), Gandhi-college (01-01-2006 to 31-01-2018) and Dhaka-University (01-01-2012 to 31-12-2018). For the same temporal resolution Modern Era Retrospective analysis and Research and Applications-2 (MERRA-2) derived gridded daily averaged aerosol optical depth (AOD) on 1° x 1° spatial resolution over the sites. The MERRA 2 AOD and AAOD data are validated at each station with AERONET data. Radiative forcing is also calculated by using SBDART model during ABC days.

Results & Discussions

Frequency of Atmospheric Brown Clouds Days

Table 1 Frequency of ABCs days (extreme pollution events) in percentage. Here, Ns is the total number of days of data analyzed and N is the total number of ABCs days.

<table>
<thead>
<tr>
<th>Location</th>
<th>Winter</th>
<th>Pre-monsoon</th>
<th>Post-monsoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Karachi</td>
<td>129</td>
<td>40</td>
<td>266</td>
</tr>
<tr>
<td>Lahore</td>
<td>154</td>
<td>50</td>
<td>227</td>
</tr>
<tr>
<td>Jaipur</td>
<td>120</td>
<td>28</td>
<td>91</td>
</tr>
<tr>
<td>Delhi</td>
<td>69</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td>Kanpur</td>
<td>52</td>
<td>32</td>
<td>125</td>
</tr>
<tr>
<td>Gandhi</td>
<td>50</td>
<td>28</td>
<td>57</td>
</tr>
<tr>
<td>Dhaka</td>
<td>70</td>
<td>28</td>
<td>58</td>
</tr>
</tbody>
</table>

Figure 1: ABCs days’ frequency over IGP during winter, pre-monsoon and post-monsoon seasons.

The analysis of the occurrence of extreme pollution days for each season over IGP is carried out by separating out the days when daily mean AOD => 0.3 and AAOD =>10% of AOD [2].

Classification of aerosols during extreme pollution events

During winter, the western IGP (Karachi, Lahore) and Jaipur show a high concentration of mixed type aerosols (>60%). Pre-monsoon is dominated by dust coming from the desert regions. The western IGP (Karachi, Lahore, Delhi, Kanpur) shows a high concentration of dust during pre-monsoon. The dominance of dust was observed to decrease over Gandhi-college and Dhaka- University where mixed type aerosols dominate during Pre-monsoon (57%) and 40% respectively [1].

Aerosol Radiative forcing during ABC Days

ARF calculated by SBDART model using AOD and AAOD over the IGP region. Radiative forcing of ABCs is negative at both the satellite (SRF) and top of the atmosphere (TOA), whereas it is positive in the atmosphere (ATM). In magnitude, it was found minimum in the pre-monsoon season at TOA. However, other seasons have specific features over specific locations. In the winter season, radiative forcing is maximum over Kolkata, Delhi, SRF, and ATM, which are -13.81 Wm², -50.90 Wm², and +37.09 Wm² respectively. In pre-monsoon season, radiative forcing is maximum at Delhi (+9.59 Wm²) at TOA. In post-monsoon season radiative forcing maximum at Gandhi-college (+11.30 Wm²) at TOA. Generally, as we can see from moving toward western to eastern IGP found increasing trends of ARF at SRF, ATM and TOA in magnitude. This due 1 increasing higher aerosol loading in eastern IGP. We also found similar trends of ABC frequency at each station over IGP.

Figure 4: Aerosol radiative forcing aerosols during (a) Winter, (b) Pre-monsoon, (c) Post-monsoon seasons during ABC days over the IGP.

Conclusions

- Results indicate that the highest occurrence of pollution days were observed over eastern IGP. The eastern IGP receives higher aerosol loading than western IGP which indicates local contribution over the region.
- It was observed that pre-monsoon is dominated by dust aerosols while winter and post-monsoon received highest contribution from biomass burning.
- Our result shows eastern part shows large radiative forcing over the IGP.

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References