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Quantifying the contribution of Long-Range Transport to PM, NO_x, and SO_2 loadings at a suburban site in the North-Western Indo Gangetic Basin

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We investigate the climatology of air masses arriving at the IISER Mohali Atmospheric Chemistry facility (30.67°N, 76.73°E; 310 m amsl) through 3-day backtrajectories arriving at 20 m above ground level for the period August 2011-November 2012. IISER Mohali is a suburban site in the North-Western Indo Gangetic Basin. The trajectories are computed in ensemble mode twice daily with an arrival time of 2:30 pm local time (daytime) and 4:30 am local time (nighttime) using the HYSPLIT 4 model with the National Oceanic and Atmospheric Administration's GDAS file as meterological input data. Due to the close proximity of the site to the Himalayan mountain range the trajectory output is found to be very sensitive to the models input data. IISER Air Quality station is located in the IGB at an altitude of 310 m amsl approximately 20 km south west of the Shivalik hills, but the model terrain height for the site in the ensemble run output varies between 200 m amsl and 3500 m amsl for the GDAS dataset and 200 m amsl to 5000 m amsl for the reanalysis dataset. We conclude that the GDAS dataset performs better than than reanalysis dataset for our site and selected only those trajectories from the trajectory ensemble for cluster analysis, for which the terrain height in the model output was $<$ 400 m amsl for IISER Mohali (in the IGB) and $>$ 400 m amsl for Shimla (a site located at an altitude of 1000 m amsl in the mountains 60 km north east of Mohali).

We subjected the trajectories to hierarchical, and non-hierarchical (K-means) clustering and found that the air mass transport to our station can be characterised by 10 distinct airflow patterns; 3 of which occur only during the monsoon season. For pre-monsoon season (March-June), post-monsoon season (Sept-Nov) and winter season (Dec-Feb), air mass transport to our site is predominantly from the west. Direct transport of north westerly air masses to our site is subdivided into three clusters (slow, medium and rapid) while other clusters are attributed to south westerly air currents or arise from the fact that westerly air masses are deflected and descend along the slope of the Himalayan mountain range and reach our site from the north or south-east. A local recirculation cluster is found to occur particularly during wintertime when stagnant conditions with windspeeds $<$ 1 m/s can presist for several days.

We find that several air pollutants measured at the IISER Mohali air quality station are significantly influenced by regional transport and long range transport during pre-monsoon (March-June) and post-monsoon (Sept-Nov) season. This is particularly true for PM10 where the highest loadings (730 μg/m^3) are found in air masses with rapid air mass transport from a north western direction during pre-monsoon season. In medium and slow transport from the NW we observe 260 μg/m^3 and 210 μg/m^3 PM10 respectively. The lowest PM10 loading during pre-monsoon season are associated with local recirculation of air masses (170 μg/m^3) and air masses with a long residence time over the eastern IGB (190μg/m^3). For NO_x, SO_2 and CO the lowest concentrations are observed in air masses influenced by rapid long range transport from the NW (4.7, 2.6 and 220 ppbv respectively) while the highest NO_x, SO_2 and concentrations are observed in air masses transported with slow or medium speed from the NW (7.1, 5.2 and 380 ppbv respectively). During winter season local and regional sources are found to dominate over long range transport, with long range transport accounting for less than 30 $\%$ of the observed variablity in the chemical composition of the air masses. During monsoon season removal of pollutants through wet deposition dominates the measured concentrations.

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