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Understanding neighborhood scale variability of fine particulate matter in megacity Delhi during post-monsoon and winter

Farzaneh Taksibi[1] and Tabish Ansari[2]

[1]Campus Fryslan, Groningen University, Leeuwarden, Netherlands (f.taksibi@rug.nl)

[2]Campus Fryslan, Groningen University, Leeuwarden, Netherlands (t.u.ansari@rug.nl)

Fine particulate matter or $PM_{2.5}$ varies greatly in space and time depending on the profile of its emission sources, geographical terrain, and meteorological conditions. While the spatiotemporal variability of $PM_{2.5}$ over larger regions has been well studied, in this study we focus particularly on the neighborhood-scale spatial variations of $PM_{2.5}$ within the megacity of Delhi by exploiting hourly observations from 23 ground-based stations within the city for the post-monsoon and winter period. First, we derive the difference between the $PM_{2.5}$ concentrations at most polluted and least polluted stations and find their correlation against the average $PM_{2.5}$ in the city at both hourly and daily timescales. We find significant correlations between the maximum difference and average concentration for all three months. The differences between stations are generally higher in November and December as compared to October for the same average $PM_{2.5}$ concentrations. Overall, the most frequent maximum difference between stations is found to be 75 µgm-3 at hourly scale and 100 µgm-3 at daily scale. There are several instances of maximum difference of $PM_{2.5}$ concentrations between stations exceeding 300µgm-3, which highlights the disparity between the neighborhoods. Second, we found that, on average, the maximum and minimum difference in $PM_{2.5}$ occur at 2am (176 μgm^{-3}) and 3pm (37 μgm^{-3}) for October, 6am (400 μgm^{-3}) and 6pm (45 μgm^{-3}) for November and 6pm (200 μgm^{-3}) and 7am (104 μgm^{-3}) for December respectively. We hypothesize that the low difference across stations in the afternoons in October and November is due to increased boundary layer mixing at this time of the day. This concentration parity across neighborhoods is not achieved in the afternoons of December due to relatively low boundary layer height even during daytime. To confirm this, we performed WRF model simulations at 1km spatial resolution over Delhi for the three-month period to derive station-specific boundary layer height. Third, we calculated hourly concentration gradients (in μgm^{-3} per km) between each station by dividing the difference between their concentrations by their physical distance. We found the highest concentration gradient for each day along with its vector (direction) and time of the day when it occurs. We finally identified the most persistent vector along which $PM_{2.5}$ concentrations change most quickly. Our results highlight the tremendous air pollution disparity between neighborhoods in the megacity of Delhi and stress the need for more granular, neighborhood-scale air quality early warning systems to protect public health.