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Chemistry and Transport of Atmospheric Trace Constituents over the Indian Subcontinent

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Trace constituents in the Earth's atmosphere, e.g., ozone (O_3), volatile organic compounds (VOCs), nitrogen oxides (NOx), and fine particulate matter ($PM_{2.5}$) significantly influence the air quality and climate. Despite strong natural and anthropogenic emissions, the observations in India have typically been limited to few chemical species at coarse spatio-temporal resolutions. In this regard, we have performed high-resolution (12km x 12km) simulations employing the Weather Research and Forecasting model coupled with Chemistry (WRF-Chem v4.5.1). Model simulations have been evaluated comprehensively against recent field measurements, chemical reanalysis (CAMS, MERRA-2), and satellite retrievals (TROPOMI). Model successfully reproduced the key features seen in the regional and seasonal distributions of O_3, $PM_{2.5}$, and related tracers. While CO, NO_2, VOCs, and $PM_{2.5}$ over the Indo-Gangetic Plain (IGP) are strongly enhanced during winter, the O_3 production is most intense in the pre-monsoon. Interestingly, even after turning off the anthropogenic emissions, the CO levels over the IGP remained greater by a factor of 3 than that over other regions of India. This result signifies a key role of the oxidation of hydrocarbons and dynamics in governing the CO distribution. The contribution of natural emissions to ozone formation is simulated to be particularly high over eastern and northeastern regions (~15-20 ppbv), when compared to other parts of India (~5-10 ppbv). The natural emissions also perturbed the atmospheric oxidative capacity significantly by consuming the OH radical. The aerosol-radiation interaction is seen to be a key process in affecting ozone production by as much as 5 ppbv during winter. Some key limitations in the model performance have also been found out, such as in estimating biogenic VOCs over India and overestimation of NOx over the Indian Ocean. Comparisons with satellite and field measurements are being exploited to better constrain the anthropogenic and natural emissions and improve the model performance over India.