Changing $PM_{2.5}$ and Related Meteorology Over India From 1950-2014: A New Perspective From a Chemistry-climate Model Ensemble

Sarah Hancock[1], Arlene M. Fiore[1,2], Daniel M. Westervelt[1,3], Gus Correa[1], Jean-François Lamarque[4]

[1]Lamont-Doherty Earth Observatory of Columbia University, [2]Department of Earth and Environmental Sciences, Columbia University, [3]NASA Goddard Institute of Space Studies, [4]National Center for Atmospheric Research

Surface $PM_{2.5}$ concentrations in India have increased dramatically as emissions have risen in recent years. The role of meteorological factors in this increase is unclear, mainly due to a lack of long-term observations over the region. A novel 11-member ensemble of historical (1950-2014) simulations from the Community Earth System Model version 2 -Whole Atmosphere Community Climate Model version 6 (CESM2-WACCM6), which includes interactive aerosol and gas-phase chemistry in the atmosphere coupled to ocean-sea ice-land models, offers an unprecedented opportunity to examine simulated daily $PM_{2.5}$ and meteorology for 20th century climates that can arise due to “climate noise” under the same historical greenhouse gas and air pollutant emission trajectories. Each ensemble member differs only in its initial conditions of the climate state. We systematically examine, decade-by-decade, the changes in $PM_{2.5}$ and its relationships with wind speed, surface temperature inversions, boundary layer height, and relative humidity in four cities in India: Bengaluru, Kolkata, Mumbai, and New Delhi. While surface $PM_{2.5}$ increases during all months in each of the four cities, seasonal cycles shift across all ensemble members, particularly in more recent decades. New Delhi, for instance, shows a July-August $PM_{2.5}$ peak in the 1950s, but by the 1980s, a second wintertime peak emerges that eclipses the initial summertime peak by the 2000s. Correlations between $PM_{2.5}$ and meteorological variables vary between cities, seasons, and years. For example, the correlation between $PM_{2.5}$ and average surface wind speed in Kolkata from February through May decreases from 0.6 in 1950 to -0.2 in 2014, while correlations are always weak in June through September ($r < 0.2$). In Mumbai, the same June-September correlation is consistently between 0.4 and 0.5. By providing statistical power to separate the role of 20th century changes in meteorology versus in air pollutant emissions, our simulations corroborate the dominant role of air pollutant emissions on poor air quality in India. Our India-focused analysis highlights key differences by region, season, and $PM_{2.5}$ composition that could inform air quality planning.