Multi-scale Modeling of Air Quality and Greenhouse Gases over Greater Boston, Part I: Evaluation of Regional to Local Predictions Using Surface and Satellite Data

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Air pollution and climate change are two major public health concerns in densely populated urban areas, especially for socioeconomically disadvantaged communities. Accurate predictions of criteria air pollutants, including ground-level ozone (O_3) and fine particulate matter ($PM_{2.5}$), and greenhouse gases, are of great research and policy interest in Greater Boston. In this work, the Weather Research and Forecasting model coupled with Chemistry and Greenhouse Gases (WRF-Chem-GHG) is applied for July 2022 and January and July 2023 to assess its capability of reproducing atmospheric observations and its sensitivity to spatial grid resolution. A triple-nested domain is designed at grid spacings of 12-, 3- and 1-km over eastern U.S., part of northeastern U.S., and Greater Boston, respectively. The anthropogenic emission input is based on the 1-km Neighborhood Emission Mapping Operation (NEMO) and point source emission from the US EPA National Emission Inventory (NEI) for the year of 2019. A comprehensive model evaluation is conducted for meteorological variables, air pollutants, and cloud-radiation variables using surface observations and satellite retrievals in terms of discrete statistics and spatiotemporal variations. The result analyses will focus on Greater Boston centered in Chelsea, Brookline, and Boston at a 1-km grid resolution. The results show improved performance for both O_3 (from -19.4% to -16.9%) and $PM_{2.5}$ (from -9.7% to -0.8%) in July 2022 over Greater Boston as the grid resolution progressively increases from 12-km to 1-km. The remaining biases are possibly attributed to the cold bias in temperature predictions, uncertainties in emissions of precursors such as emissions of volatile organic compounds and nitrogen oxides, and primary emissions such as emissions of organic carbon and unspeciated $PM_{2.5}$. The results in this work will not only inform model performance and sensitivity to grid spacing for future model improvements but also provide the meteorological conditions and chemical concentrations above the roof level to drive the hyperlocal scale simulations in Part II of this study.

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