Multi-Scale Modeling of Meteorology and Air Quality over Southwest Asia

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Abstract: Southwest Asia, like many other regions, faces air quality challenges due to various factors such as industrialization, urbanization, and transportation. The application of meteorology and air quality models over Southwest Asia is an important step to gain insights into air pollution and its sources. In this work, the Comprehensive Air Quality Model (CAMx) offline-coupled with the Weather Research and Forecasting (WRF) model (version 4.3.1) has been applied to simulate air quality over triple-nested domains in Southwest Asia, United Arab Emirates, and Dubai, using 27-km, 9-km, and 3-km grid spacing, respectively. The baseline WRF-CAMx simulations are performed for several summer and winter months during 2017 to 2022. The results are intercompared to study inter-annual variability of meteorology and air quality and are evaluated against available observations to assess the model performance. The meteorological evaluation includes temperature (T2) and specific humidity at 2 meters (Q2), and wind speed (WS10) and direction (WD10) at 10 meters against the observations at 204 surface stations from the Meteorological Aerodrome Report (METAR), radiation variables from the Clouds and the Earth's Radiant Energy System (CERES), cloud variables from the Moderate Resolution Imaging Spectroradiometer (MODIS), and cloud and radiation variables from Atmospheric Infrared Sounder (AIRS). Sensitivity simulations are designed to study the effect of WRF options for microphysics, surface layer, land-surface, and convection, and the use of four-dimensional data analysis (FDDA) and deep soil nudging techniques on model predictions and identify the optimal configuration. Compared to the initial configuration and configurations used in sensitivity simulations, the optimal configuration shows the best performance. For example, T2 predictions are improved, reducing the cold bias for the winter month (mean bias from -0.8 ºC to -0.2 ºC) and increasing the index of agreement from 0.69/0.75 to 0.91/0.93 for the summer/winter months, respectively. WRF with the optimal configuration shows a good performance, which is used to drive CAMx, although the remaining Q2 bias may cause underprediction of dust emissions. The CAMx results are being evaluated against satellite products of column integrated pollutant concentrations and aerosol optical depth (AOD) such as CO column from the Measurement of Pollution in the Troposphere (MOPITT), tropospheric O_3, SO_2, and NO_2 column from the Ozone Monitoring Instrument (OMI) and O_3 from Atmospheric Infrared Sounder (AIRS) and AOD from MODIS. The results from this work will enable health and environmental impact assessments, inform policy development and decision-making, and foster regional cooperation to address air pollution challenges effectively in this area.

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