Assessment of Air Pollution in the Middle East Using Reanalyses Products and High-resolution WRF-Chem Simulations

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The Middle East is notorious for high air pollution that affects both air-quality and regional climate. The Middle East generates about 30% of world dust annually and emits about 10% of anthropogenic SO2. In this study we use Modern-Era Retrospective analysis for Research and Applications v.2 (MERRA-2), Copernicus Atmosphere Monitoring Service Operational Analysis (CAMS-OA) data assimilation products, and a regional Weather Research and Forecasting model (10 km resolution) coupled with Chemistry (WRF-Chem) to evaluate natural and anthropogenic air pollution in the ME. The SO2 anthropogenic emissions used in WRF-Chem are updated using the independent satellite SO2 emission dataset obtained from the Ozone Monitoring Instrument (OMI) observations onboard NASA EOS Aura satellite. Satellite and ground-based aerosol optical depth (AOD) observations, as well as Particulate Matter (PM) and SO2 in situ measurements for 2015-2016, were used for validation and model evaluation.

Although aerosol fields in regional WRF-Chem and global assimilation products are quite consistent, WRF-Chem, due to its higher spatial resolution and novel OMI SO2 emissions, is preferable for analysis of regional air-quality over the ME. We found that conventional emission inventories (EDGAR-4.2, MACCity, and HTAP-2.2) have uncertainties in the location and magnitude of SO2 sources in the ME and significantly underestimate SO2 emissions in the Arabian Gulf. CAMS reanalysis tends to overestimate PM2.5 and underestimate PM10 concentrations. In the coastal areas, MERR2 underestimates sulfate and tends to overestimate sea salt concentrations. The WRF-Chem’s PM background concentrations exceed the World Health Organization (WHO) guidelines over the entire ME. The major contributor to PM (~75–95%) is mineral dust. In the ME urban centers and near oil recovery fields, non-dust aerosols (primarily sulfate) contribute up to 26% into PM2.5. The contribution of sea salt into PM can rich up to 5%. The contribution of organic matter into PM prevails over black carbon. SO2 surface concentrations in major ME cities frequently exceed European air-quality limits.