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

Alexander Ukhov¹, Suleiman Mostamandi¹, Johannes Flemming², Arlindo DaSilva³, Nick Krotkov³, Can Li³, Yasser Alshehri¹, Anatolii Anisimov^{1,4}, Vitali Fioletov⁵, Chris McLinden⁵, Illia Shevchenko¹, and Georgiy Stenchikov¹

¹King Abdullah University of Science and Technology, Division of Physical Sciences and Engineering, Thuwal, Saudi Arabia (alexander.ukhov@kaust.edu.sa)

²European Centre for Medium-Range Weather Forecasts, Reading, UK

³NASA Goddard Space Flight Center, Greenbelt, MD, USA

⁴Marine Hydrophysical Institute, Russian Academy of Sciences, Sevastopol, Russia

⁵Air Quality Research Division, Environment Canada, Toronto, ON, Canada

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 PM_{2.5} and underestimate PM₁₀ concentrations. In the coastal areas, MERRA2 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 PM_{2.5}. The contribution of sea salt into PM can reach 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.