EGU25-5690, updated on 03 Jun 2025
https://doi.org/10.5194/egusphere-egu25-5690
EGU General Assembly 2025

Quantifying Sulfur Dioxide Emissions from Industrial Activities by a Helicopter-borne System and TROPOMI in the Southern Arabian Peninsula

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Sulfur dioxide (SO_2) is an air pollutant that is toxic to humans and, as a precursor to sulfuric acid, has far-reaching consequences for the environment and climate. Anthropogenic emissions are responsible for two-thirds of total SO_2 emissions into the atmosphere. Stricter regulations and technical developments, such as the installation of desulfurization systems in coal-fired power plants, are reducing emissions in parts of the world such as Europe. However, inventories show a stagnation in emissions in the Middle East region in recent years. In the global SO_2 catalogue provided by NASA, satellite instruments such as TROPOMI (onboard Sentinel-5P) assign many point sources in this region to the production of oil and gas. Two of these hotspots are detected in the southern Sultanate of Oman.

As part of the METHANE-To-Go-Oman campaign in 2023, for the first time the helicopter-borne probe HELiPOD (weight 325kg, length 5m) was used to determine SO_2 emissions from selected oil and gas facilities in Oman. The HELiPOD was equipped with a UV fluorescence instrument (Envea AF22e) to measure SO_2 in-situ with high precision (1ppb), as well as with a precise wind measurement system. The entire SO_2 plume from selected facilities was sampled at different altitudes (50 m to 2000 m) at variable distances (1 km to 4 km) downwind from the source. Flight pattern were designed on a day-to-day basis based on actual wind speed and wind direction measured with a ground-based Doppler wind lidar (Streamline XR, Halo Photonics).

In this study, top-down derived SO_2 mass flux estimates based on HELiPOD data are presented for six selected point sources from the oil and gas industry in northern and southern Oman. Subsequently, these top-down estimates are compared to bottom-up emission inventories available for the region. In addition, TROPOMI data from the years 2018 to 2023 are analyzed to investigate the temporal development of SO_2 point sources in the whole Middle East area. The satellite data show a very good temporal coverage and we were able to identify a new emission source in the northern part of Oman in 2023. In the present global SO_2 catalogue provided by NASA this source is not yet included. The signal strength of this northern source is similar to the southern hotspots in the years before. The HELiPOD mass flux estimates also confirm the

significant decrease in emissions between 2021 and 2023 from one of the two hotspots in the southern Oman based on TROPOMI data. In general, our study indicates low SO_2 emissions from the oil and gas industry in Oman compared to other countries in the Middle East.