# Air Quality around the Arabian Peninsula

**Researchers Study Net Ozone Production and Its Relationship to Nitrogen Oxides and Volatile Organic Compounds in the Marine Boundary Layer around the Arabian Peninsula**

*Edited from a published paper by Dr. Ivan Tadić, Max Planck Institute for Chemistry*

**The Problem:** The presence of a large amount of oil resources around the Arabian Peninsula has led to an increase in urbanization and industrialization of the region. The result has been massive population growth that has made the Middle East a hot spot for air pollution. Unique meteorological conditions such as intense solar radiation and high temperatures/ aridity, along with strong anthropogenic emissions of volatile organic compounds (VOCs) and nitrogen oxides ($NO_x$) from on- and offshore petrochemical industries, dense ship traffic, fossil energy, production for air conditioning & desalination, and urban development, are expected to further intensify in the future in the Arabian Peninsula. This will contribute to photochemical ozone ($O_3$) production in the area, making it is necessary to understand the sources of $NO_x$ and $O_3$ around the Arabian Peninsula for atmospheric chemistry studies. $NO_x$ is the primary precursor for tropospheric $O_3$, secondary organic aerosols, and photochemical smog in urban areas. The main ground-based sources of nitric oxide (NO) and nitrogen dioxide ($NO_2$) are fossil fuel combustion and bacterial processes in soils. Ozone is a secondary pollutant that is photochemically formed in the troposphere from its precursors, $NO_x$ and VOCs. Ozone is an important greenhouse gas and an atmospheric oxidant. Its presence in the troposphere causes adverse health conditions, notably respiratory diseases, and also reduces crop yields. $NO_x$ and $O_3$ mixing ratios vary from less than 20 pptv (parts per trillion by volume) and ppbv (parts per billion by volume), respectively, in pristine conditions such as the remote marine boundary layer (MBL) to several hundreds of ppbv in regions with heavy automobile traffic, international shipping lanes (for $NO_x$), and downwind of urban areas (for $O_3$). This study helps characterize ozone and $NO_x$ in the MBL around the Arabian Peninsula.

**The Solution:** From late June to early September 2017, the *Kommandor Iona* research and survey vessel sailed from Toulon (France) to Kuwait and back to perform gas-phase and particle measurements in the region. The instrumentation used to conduct these measurements was housed in five laboratory containers on the front deck of the vessel. Kuwait, at the northern end of the Arabian Gulf, marked the turning point of the cruise before the ship headed back to Toulon. Ozone was measured during the journey using a 2B Tech Model 202 Ozone Monitor. The elimination of potential interferences from water vapor and particles during ozone measurements was achieved through the use of a Nafion tube and Teflon filter. The ozone monitor was zeroed ten times during the measurement campaign with measurements of $O_3$ occurring from 22 June to 1 September 2017.

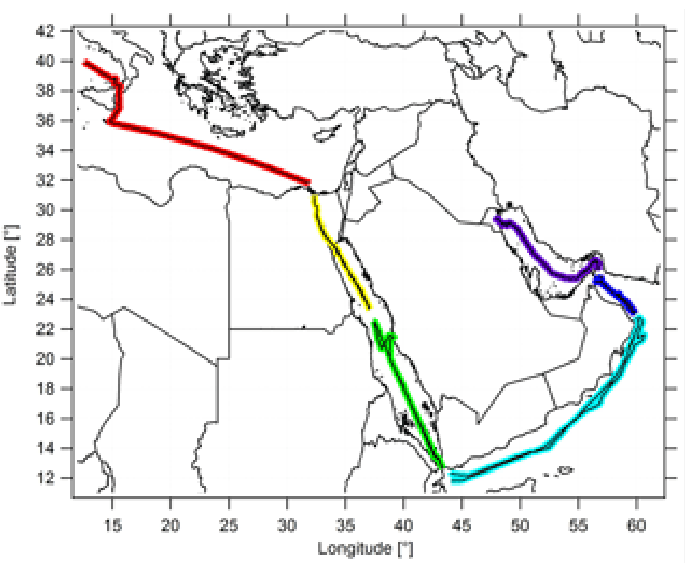


**Figure 1.** The path of the *Kommandor Iona* during both legs of the cruise around the Arabian Peninsula.

Wherever possible the *Kommandor Iona* sailed with the wind coming from the bow so that stack emissions from the ship would not contaminate the air being measured. 21% of the sampling time was potentially contaminated by the ship's

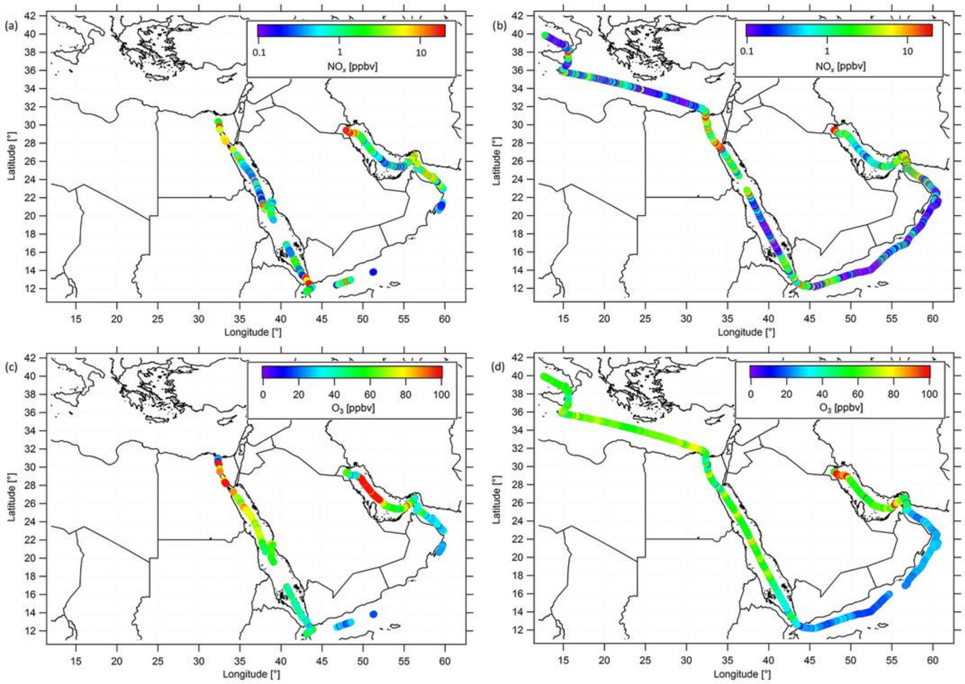


**Figure 2.** Ship cruises with color-scaled $NO_x$ mixing ratios during **(a)** the first and **(b)** the second leg, and color-scaled $O_3$ mixing ratios during **(c)** the first and **(d)** the second leg.

exhaust – of which 87% was on the first leg of the cruise. During the second leg the ship sailed against the wind and most of the data was free of stack contamination.

**Results:** A detailed emission density analysis showed that NOx emissions on and around the Arabian Peninsula are amongst the highest worldwide. $NO_x$ mixing ratios varied over three orders of magnitude with the lowest values around 50 pptv and the highest values around 10 ppbv. Due to a large number of pollution sources in the region around the Arabian Peninsula such as passing ships, highly urbanized areas, and on- and offshore petrochemical processing, $NO_x$ levels were rarely as low as those found in remote locations, such as over the South Atlantic where $NO_x$ levels may be under 20 pptv. The highest concentrations of $NO_x$ were observed around areas with strong anthropogenic influence or in the vicinity of passing ships. Ozone mixing ratios varied from values of less than 20 ppbv, detected over the Arabian Sea, to 170 ppbv during severe pollution events. The Arabian Sea is the only region that represents remote MBL conditions for ozone. The next lowest ozone concentrations were observed over the Gulf of Oman where the median and mean concentrations were 31.5 and 34 ppbv, respectively. Extreme $O_3$ events were observed over the Arabian Gulf with maximum mixing ratios of up to 170 ppbv when the wind was blowing from Kuwait/Iraq. Over the Mediterranean, the northern Red Sea, and the southern Red Sea the median $O_3$ mixing ratios were 61.5, 64.2, and 46.9 ppbv, respectively. The highest average $O_3$ mixing ratio was over the Arabian Gulf (74 ppbv) followed by the north Red Sea (63.4 ppbv).

Concentration ranges of both $NO_x$ and $O_3$ clearly showed anthropogenic influence in the MBL. $NO_x$ was highest over the Arabian Gulf, the northern Red Sea, and the Oman Gulf. The lowest $NO_x$ values were observed over the Arabian Sea and over the southern Red Sea during the second leg of the cruise. $O_3$ mixing ratios were highest over the Arabian Gulf. There was a latitudinal gradient in ozone concentrations in the Red Sea with the highest values toward the north. The lowest regional $O_3$ mixing ratio was over the Arabian Sea, which is broadly comparable to remote MBL conditions in the Northern Hemisphere.

Click here to view the full paper:
https://acp.copernicus.org/articles/20/6769/2020/


*The Model 202 Ozone Monitor*

**The 2B Tech Instrument's Role:** Measurements of the ozone mixing ratio during both legs of the cruise were made by the Model 202 Ozone Monitor. The instrument is equipped with an internal Nafion assembly called a DewLine which allows the instrument to eliminate any potential water vapor interference from the ozone measurements. This was very important in the context of this study as the humidity was high while sampling at sea around the Arabian Peninsula. The Model 202 is approved by the US EPA as a Federal Equivalent Method (FEM) for measuring ambient ozone concentrations, allowing the instrument to provide highly accurate measurements in the ppbv range experienced around the Arabian Peninsula. The low power requirements and portability of the Model 202 also made the instrument uniquely suited to be deployed in the remote setting on the *Kommandor Iona*.

**The Bottom Line:** For projects requiring highly accurate ozone measurements in a small and robust package, the Model 202 is the perfect solution. The instrument has dimensions of 3.5 x 8.5 x 11 inches and weighs 5.5 lbs. while offering an accuracy of 1.5 ppbv or 2% of the reading (whichever is greater). The Model 202 can be upgraded with a cold weather package (cold weather pump and lamp heater) to operate in temperatures as low as -20 °C. The instrument can also be upgraded with an optional GPS, Bluetooth for wireless data transmission, a 4-20 mA current output, and a rack-mount enclosure. The low power consumption of the Model 202 makes it possible to operate the instrument using an external battery for field applications in remote locations. Please contact 2B Technologies to discuss using the Model 202 for your application.

sales@twobtech.com www.twobtech.com (303)273-0559