

# Changes in tropospheric nitrogen dioxide vertical column densities over Japan and Korea during the COVID-19 using Pandora and MAX-DOAS

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Using the measurements from ground-based remote sensing instruments, we investigated the changes in tropospheric nitrogen dioxide vertical column densities (NO<sub>2</sub> TropVCD) over Japan and Korea before and after the COVID-19 pandemic. Three sites for MAX-DOAS (Yokosuka, Cape Hedo, and Gwangju) and one site for Pandora (Busan) were selected for this study because these sites have been in operation for more than five years, allowing the results caused by COVID-19 in 2020 to be compared with previous reference years, 2015–2018 (2016–2018 for Busan) and 2019. To elucidate the relationship of NO<sub>2</sub> TropVCD with human activity during 2020, Google mobility data was also used as a proxy of transportation and industry activity. Because the behavior of NO<sub>2</sub> also depends on the meteorological variables, we also investigated the difference in meteorological fields from ERA5 along with spatial distribution of NO<sub>2</sub> TropVCD from Ozone Monitoring Instrument (OMI) satellite. During the Chinese New Year holidays, the NO<sub>2</sub> TropVCDs at three urban sites showed a rapid decrease due to less business and industry activities, then the level of NO<sub>2</sub> VCD slowly recovered but was consistently lower than the level of before the Chinese New Year holidays due to shorten NO<sub>2</sub> lifetime or low emission rate. During the periods of spontaneous social distancing in Korea (March–May) and Japan (April–May), decreasing activities of transportation and industry, especially in Japan, was obvious. NO<sub>2</sub> TropVCD in Busan and Gwangju showed a moderate correlation with the industrial sector, whereas that in Yokosuka showed moderate correlation with both the transportation and industrial sector. The monthly difference between reference years and 2020 showed that the average reduction in three urban sites was pronounced in May to September with high mean normalized bias (MNB; –48% to –32%) compared to the cold season (–27% to –11%). The difference in monthly variation of NO<sub>2</sub> TropVCD with reference years will be discussed in terms of meteorological variables, such as wind speed, temperature, and downward UV radiation.

Keywords: Tropospheric nitrogen dioxide vertical column densities , MAX-DOAS, Pandora, COVID-19