Reply to Anonymous Referee #1 review of manuscript acp-2021-456

Impact of COVID-19 pandemic related to lockdown measures on tropospheric NO2 columns over Île-de-France

Andrea Pazmino on behalf of all co-authors

We warmly thank Anonymous Referee #1 for the interest that he showed in our work and for the time spent on its evaluation. Your valuable comments have helped us to improve our manuscript. Please find our answers to your comments (in red)

This study addresses the influence of physical distancing, due to the COVID-19 pandemic, in NO2 concentration over Île-de-France. The manuscript has very interesting results and performs a good comparison with similar studies.

Main questions

Line 117: Please, detail or add some reference about this quality assurance.
Recently Verhoelst et al., 2021 validated total, stratospheric and tropospheric columns of NO_2 of TROPOMI against consolidated ground-based data. In the case of tropospheric NO_2, the TROPOMI's quality assurance value (QA) higher than 0.75 is used to remove cloudy scenes presenting cloud radiance fraction higher than 0.5, snow- or ice-covered scenes, and problems in the retrieval. In our study, we have decided to use a less restrictive threshold of 0.5 to enhance the number of days taken into account and not to bias the results to clear day conditions. In order to evaluate the impact on SAOZ and TROPOMI comparison using a less restrictive QA, the monthly mean tropospheric NO_2 above Paris of TROPOMI was computed considering only data with QA>0.75 (Figure 1, bottom panel) and results of QA> 0.5 of the paper were included in the upper part of the figure. Only SAOZ coincident days with TROPOMI are taken into account to compute the monthly mean.

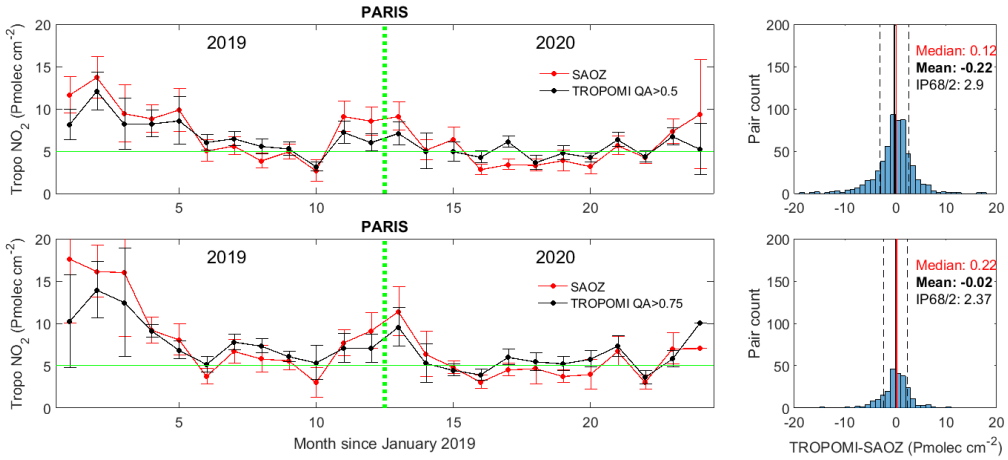

Figure 1: Left panels: Monthly mean tropospheric NO_2 and 2σ standard error above Paris measured by ground-based SAOZ instrument (red lines) and TROPOMI satellite instrument (black lines) with QA>0.5 (upper panel) and QA>0.75 (bottom panel). Right panels: Histogram of TROPOMI-SAOZ differences for TROPOMI QA >0.5 (upper panel) and QA>0.75 (bottom panel). Vertical lines represent the median, mean and dispersion by the half of the 68% interpercentile (IP68/2).

A similar evolution of tropospheric NO_2 is observed using QA>0.5 or 0.75. Approximately twice as much TROPOMI data is considered for QA>0.5 than QA>0.75. The median value of the difference is of the same order of magnitude and the dispersion is slightly higher for QA>0.5.

The comparison of the two TROPOMI datasets is presented in Figure 2. The monthly mean values present similar seasonal evolution within 2σ except on December 2020 where only one value is observed for QA>0.75.

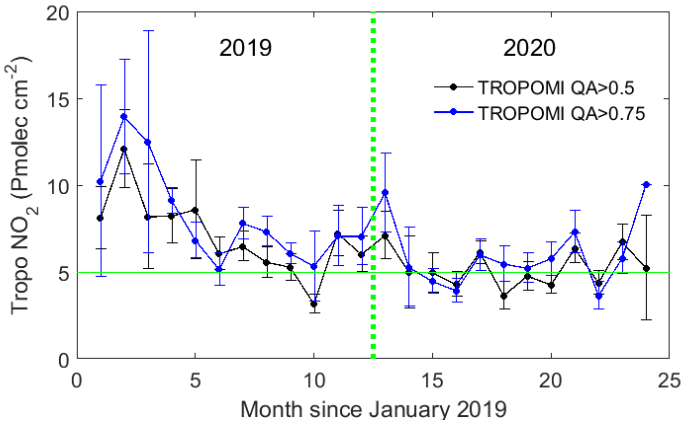

Figure 2: Monthly mean tropospheric NO_2 and 2σ standard error above Paris measured by TROPOMI satellite instrument with QA>0.5 (black lines) and QA>0.75 (blue lines)

As a conclusion of this discussion, we decided to keep the TROPOMI data with a QA above 0.5 for this study.

The following paragraph was removed at the end of Section 2.1.2.

"The data have been filtered using the quality assurance value higher than 0.5."

and replaced by

In his validation paper against consolidated ground-based data, Verhoelst et al., 2021 was using TROPOMI's tropospheric columns of NO_2 with a quality assurance value (QA) higher than 0.75 to remove cloudy scenes presenting cloud radiance fraction higher than 0.5, snow- or ice-covered scenes, and problems in the retrieval. In our study, we have decided to use a less restrictive threshold of 0.5 in order to enhance the number of days and to avoid biasing the results towards clear day conditions. This resulted in doubling the number of data taken into account. The monthly mean NO_2 tropospheric columns of TROPOMI present similar seasonal evolution within 2σ for both QA (not shown).

Is there some previous validation of ERA-5 data over Île-de-France?
ERA 5 surface wind over Europe have been validated with wind observations from 245 stations in Europe, including two stations in Ile de France (Molina et al., 2021). The conclusion is that ERA5 is able to reproduce the wind speed from hourly to monthly time frequencies for any location in Europe with a Pearson's correlation coefficient varying from 0.6 to 0.85 in hourly scale and 0.9 to 0.95 in 24-hourly scale.

Reference
Molina, M. O., Gutiérrez, C., and Sánchez, E.: Comparison of ERA5 surface wind speed climatologies over Europe with observations from the HadISD dataset, Int. J. Climatol., 1–15, joc.7103, https://doi.org/10.1002/joc.7103, 2021.

The following phrase and the corresponding reference was introduced in L142 of the paper
ERA 5 surface wind over Europe have been validated with wind observations from 245 stations in Europe, including two stations in Ile de France (Molina et al., 2021). The conclusion is that ERA5 is able to reproduce the wind speed from hourly to monthly time frequencies for any location in Europe with a Pearson's correlation coefficient varying from 0.6 to 0.85 in hourly scale and 0.9 to 0.95 in 24-hourly scale.

Is it possible to add information about the variation of physical distancing rate observed during the four stages (P1, P2, P3, and P4)? Such information can help the discussion presented in sections 4.1 and 4.2.
The following phrase was added in L203 as well as the Table
"Table 2 shows different periods in 2020 related to restrictions imposed by French government to limit COVID19 propagation.

Table 2. The four periods in 2020 shown in Figure 3 and the related restrictions imposed by the French government to limit the COVID19 propagation.

Periods in 2020		Restrictions
P1	1 Jan to 16 March	Not any
P2	17 March to 10 May	1st lockdown: non-essential stores, schools, cultural establishments, etc closed. Only displacements <1km and with a certificate are authorised. Teleworking is strongly suggested.
P3	11 May to 29 October	Gradual lifting of restrictions: schools and non-essential stores opened with imposed physical distancing and masks. Possible displacement without certificate. A curfew was imposed mid-October. Teleworking is still recommended.
P4	31 October to 15 December	2nd lockdown: schools opened but universities still closed. Some activities are allowed: Some non-essential stores opened with strong restrictions. Some restrictions as displacement of 1km maximum are relaxed at the end of November.

The variation of wind speed and direction is a relevant factor to demonstrate the pollutants dispersions. However, to provide a better discussion about the meteorological influence more parameters could be presented like temperature, rainfall rate, the occurrence of thermal inversions, atmospheric boundary layer height.
It is true that many others meteorological parameters could have at least an indirect impact on NO_2 columns. Nevertheless, we decided to restrict our study to the main influencing parameters such as wind speed and direction, for which a direct physical relationship with NO_2 column densities can be established. For instance, boundary layer height does not directly affect NO_2 column densities, as they are by definition invariant against vertical mixing. In addition, the impact of precipitation on NO_2 is expected to be lower than for highly soluble compounds (SO_2, PM_{10}). The impact of temperature is more indirect, as a tracer of different air mass types (continental versus oceanic). Even if some statistical relationships may be established with these parameters, we preferred here to restrict to the much more straightforward wind related parameters.

How were the different characteristics of each season considered? Could they have been responsible for the variations in the values found?
In this study, only the first major lockdown period during mid-March and mid-May (Mach 17th-May 10th) called P2 was analysed quantitatively for deducing differences in NO_2 columns with respect to a reference period. Since this period is shorter than a season, seasonal variation was neglected.

Line 142. As different seasons are considered, why the mid-altitude of the convective boundary layer was considered always as 950hpa?

As explained before, only P2 restrictive lockdown period was considered and the mid-altitude of convective BL is appropriate within this period. This choice only affects the height level for which the wind data are taken from meteorological analysis. This height level needs to be located somewhere within the convective boundary layer. In Figure 3 (Figure 3.5 of Dieudonné, 2012), the time series of daily maximum BL height between July 2009 and February 2011 calculated from Rayleigh lidar measurements at Qualair station in Paris, co-located to the SAOZ instrument are shown. The BL values were selected considering only clear (red points) and cloudy sky days. The black line corresponds to the rolling 30-day average. The figure shows clearly the variation of the BL over Paris as a function of season. These measurements are only available for a limited period in 2009-2011. They confirm the variation of the boundary layer as a function of season between 1.5 and 2.5 km, our choice seems appropriate. Within the convective boundary layer, wind variations are smaller than for example close to the surface. Choosing the height level at the exact middle of the boundary layer would much complicate the analysis and make results less transparent than choosing a fixed height level.

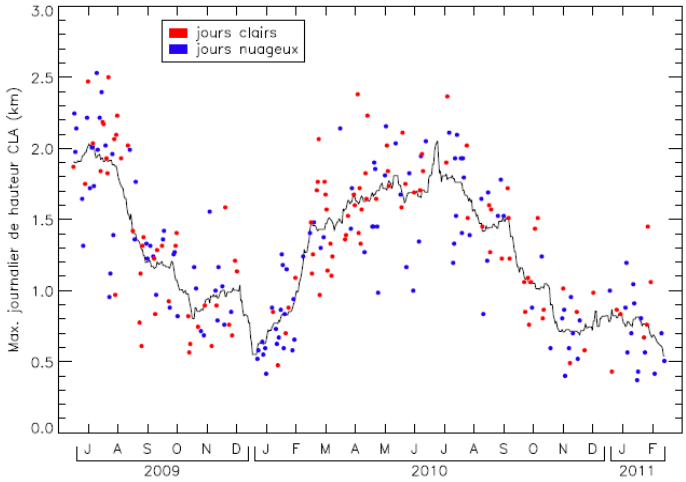

Figure 3. Time series of daily maximum Boundary layer height observed by the lidar of the Qualair station in Paris, with clear / cloudy days in red / blue. The black line represents the rolling 30-day average (Dieudonné, 2012).

Reference

Elsa Dieudonné. Analyse multi-instrumentale de l'influence de la variabilité de la hauteur de couche limite sur la distribution verticale des oxydes d'azote en région parisienne. Physique Atmosphérique et Océanique [physics.ao-ph]. Université Pierre et Marie Curie - Paris VI, 2012. Français. tel-00807665

Technical questions

Figure 2: Please, add the units in the legend.
The figure 2 was changed as follows:

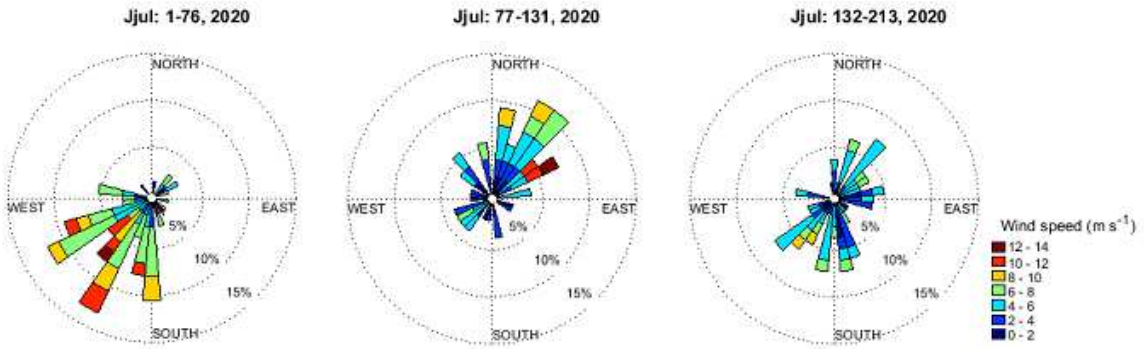

Figure 2: From left to the right: wind rose from 12 UT ERA5 data before (1/1-16/3), during (18/3-10/5) and after (11/5-31/7) the 1st lockdown in France in 2020. **The color indicates the wind speed in m s^{-1}. The frequency in % is showed by the circles.**

Line 228: "11 and 14 UT"
Done

Figure 4: Please, use the same labels in the x-axis of the upper and lower panel.
Done

Line 248: "11 and 14 UT"
Done