Comment on amt-2021-286
Anonymous Referee #2

Referee comment on "Quantification of lightning-produced NO x over the Pyrenees and the Ebro Valley by using different TROPOMI-NO 2 and cloud research products" by Francisco Javier Pérez-Invernón et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2021-286-RC2, 2022

The authors have analysed several convective systems around the Pyrenees in order to estimate the production of lightning NOx based on TROPOMI NO2 observations. The Pyrenees are chosen as they are particularly suited for this kind of analysis. While I disagree here (see below), the paper contributes to the scientific question how much NOx is produced by lightning, and it matches the scope of AMT.

The study is generally well written, but there are some inconsistencies and probable bugs in the presented data. The authors thus have to cautiously check the presented data, correct the existing bugs, and update the LNOx estimates (and, if needed, discussion and conclusion) accordingly. In addition, they should consider the additional comments listed below.

# General comments

1. Study region
As indicated in the title and at several places in the manuscript (e.g. line 70), the Pyrenees are meant to be the focus of this study. In the manuscript, the line of argument is that over the Pyrenees (a) lightning frequency is high, and (b) NOx background is low, and therefore the Pyrenees are an ideal region for this kind of study. In the presented figures, however, most flashes are observed South or North of the Pyrenees, where also significant boundary layer pollution is present, in particular over large cities like Barcelona, Zaragoza, or Toulouse. This weakens the argumentation considerably, and I am not convinced that the study region is a good choice for studying LNOx from satellite, as the uncertainty of background NOx and the possible uplift of boundary layer pollution severely affect the overall uncertainties.

2. Background
As most events are not observed over the Pyrenees, the NOx background might be considerably larger in general. The potential uplift of boundary pollution might bias the observed NO2 over the lightning pixels. In addition, also the non-flashing pixels over deep convection might be affected by the advection of LNOx.

The inclusion of two different NO2 products is quite illustrative. For instance, the differences in the estimated stratospheric column between the products are far larger than
the given uncertainty of the tropospheric background. Please comment on this.

3. "Lost" NOx
As far as I understood, the study only focuses on cloudy pixels. So in case of LNOx produced within a convective system that disappeared by the time of the TROPOMI overpass, the LNOx would be overlooked in the described procedure, while the respective flashes are included. Consequently, PE is biased low. This seems to actually happen on 29 April.
I propose to skip 29 April, as there are only few TROPOMI observations available, and the extension of the study area to large parts of France is also confusing.
In addition, this effect has to be included in the discussion and the overall uncertainty estimate.

Effects 2 and 3 go in different directions, are hard to quantify, and will increase the overall PE uncertainty.

# Inconsistencies and possible bugs

- Please be consistent with respect to units. Column densities are given in petamolec per cm² in the text, but in molec per m² in the figures which makes direct comparisons difficult.

- Please check tables 1 and 2:
  - Mean Vstrat is quite large (> 8e15 molec/cm² for DLR), while the maps in Fig. 6ff shows values < 4e15 molec/cm².
  - The 30th percentile of Vtropbck is listed as 9.5e15 molec/cm² for DLR. This would be a quite considerable tropospheric pollution. Please check.

- Please check Figs. 10 and 11. The number of flashes displayed in the figures is considerably different, while the numbers listed in Tables 1 and 2 are almost the same for 28 May. Please also check for the other days.

# Minor comments

Line 8: Over the Pyrenees, the NO2 background is low indeed. But for the investigated events over the Ebro valley, this is not the case, see e.g. http://www.tropomi.eu/data-products/nitrogen-dioxide

Lines 31-34: "Nadir-viewing satellite instruments ... estimate the column densities of NO2 over thunderstorms" - I think this is too fuzzy. The satellite instruments measure spectra. This allows quite accurate quantification of NO2 slant column densities. The conversion into vertical column densities is the main challenge, involving further input data (like cloud fraction and surface albedo, so this might be denoted as an "estimate". But usually, the retrieval focusses on cloud free conditions. Focussing on thunderstorm clouds instead is a quite different and challenging setup which should be pointed out here.

Lines 45-46: I propose to flip the order: "The horizontal resolution at nadir is 3.6 km × 7.2 km before 6 August 2019, while it is 3.6 km × 5.6 km thereafter."

Figure 1: I propose to show a map of tropospheric NO2 instead in order to assess the "clean background" issue.

Line 70: "8 deep convective systems in the Pyrenees": The number of actual flashes over the Pyrenees is quite low. The presented events reveal highest lightning activity South and North of the Pyrenees, with several anthropogenic sources present (e.g. Barcelona, Toulouse).
Section 2.3: I think it is quite bold to estimate "the" tropospheric background NOx column (!) from one day of aircraft measurements (in-situ measurements at 12 km!). The authors should discuss the limitations and uncertainties of this approach in more detail and compare with model results.

Eq. 1: Please specify which quantities are dependent on space (TROPOMI pixel) and which quantities are just scalar (means, percentiles). For this you might use Copernicus style where vectors and matrices are shown in bold type. Please also explain how the total PE is calculated (spatial mean or summation over which area/pixels?).

Eq. 3: Stratospheric VCD and AMF are provided for each TROPOMI pixel. So the stratospheric correction can be performed for each pixel as well. I see no reason to calculate the average here.

Lines 227-231: Several events are outside the Pyrenees, with considerably higher background NOx. In addition, in case of deep convection, tropospheric pollution might be uplifted and transported over considerable distances. So the local tropospheric background estimate over the clean Pyrenees can at best be considered as a lower limit.

Line 251: Please explain why the DLR product is missing.

Line 509: Please list the existing and the new methods here.

- Figs. 6ff: Maps of stratospheric AMF and VCD are not that informative. Listing these values in tables 1&2 would be sufficient, but the numbers listed there need to be checked. Instead, I would like to see maps of AMF_LNOx here.

- Fig. 12 needs some further explanations:
  - how was the median calculated?
  - what is the meaning of color?