First of all, we thank reviewer 2 for his/her efforts in carefully reviewing our manuscript and his/her constructive comments.

Point-by-point answers to the comments of reviewer 2

General comments

Reviewer 2: *The number of cases studied is very small. Although 20 promising scenes were identified only six are shown in the manuscript. The authors should include the remaining cases, not as additional examples (except maybe in the supplement), but in order to have more cases to discuss and compare the results.*
Authors: Our intention by providing an approximate number of promising cases (20) was to give the reader an impression of how many cases can be expect when applying our current (pre-) selection method to a data set of several months. This does not mean, that we have thoroughly analyzed all of these 20 cases in detail which would make a significant amount of extra work. The focus of our study is on "demonstrating the benefits of simultaneous NO2 and XCO_2 measurements rather than on most accurate flux estimates" or on quantifying emissions of an as large as possible number of targets. Therefore, we do not see the immediate necessity to significantly lengthen the paper which also agrees with our interpretation of review 1 stating that "overall, this work is sufficient to demonstrate the value of coincident NO2 and CO2 satellite observations for estimating emissions".

Furthermore, we think that discussing these cases without showing them would be little helpful. As discussed, we use the NO_2 measurements "... to i) identify the source of the observed XCO_2 enhancements, ii) to exclude interference with potential additional remote upwind sources, iii) to manually adjust the wind direction, and iv) to put a constraint on the shape of the observed CO_2 plumes." All of these points, except the last, make use of the shown NO_2 maps. This means, when not showing the scenes, the reader would not be able to follow important parts of the analysis.

In case reviewer 2 is curious about !preliminary! results, we have added six more images at the end of this document.

Reviewer 2: *The manuscript lacks a detailed comparison of the examples and discussion of the result. A broad summary is given in the conclusions, but this should be moved to a designated section.*
Authors: Our manuscript is basically following the IMRaD (Introduction, Methods, Results, and Discussion, *https://en.wikipedia.org/wiki/IMRAD*, Hall, 2012) organizational structure which became the most prominent norm for the structuring of a scientific research article. We only slightly adapted the naming of the section headings of the first hierarchy level: *Methods* became *Data sets and methods* and *Discussion* became *Summary and conclusions.* Renaming the *Method* section is uncritical and many journals prefer heading

style variants like *Methods and materials*, *Materials and methods*, or similar for the *Method* section. Usually, the *Discussion* section includes a summary and the conclusions. Both may or may not be part of the *Discussion* section or separate sections on the same hierarchy level as the *Discussion* section. Therefore, we agree, that the heading *Summary and conclusions* may be misleading and we renamed it to *Discussion and conclusions*. We wanted to keep "Conclusions" within the heading because the ACP template suggests to have a *Conclusions* top-level section.

We do not agree that this section does not include a thorough discussion of the results. Within this section, we compare our results with emission data bases and (in the revised version) also emission estimates of Nassar et al. (2017)): "For Moscow, we derived a cross-sectional flux of $76\pm33\,\mathrm{MtCO_2/a}$ which agrees (within its uncertainty) with ODIAC 2012 emissions of $102\,\mathrm{MtCO_2/a}$ ($88\,\mathrm{MtCO_2/a}$ for 08/2016) but not with EDGAR emissions of $195\,\mathrm{MtCO_2/a}$", "... this estimate agrees with EDGAR emissions of $23\,\mathrm{MtCO_2/a}$ but not with ODIAC emissions of $4\,\mathrm{MtCO_2/a}$", etc. We also discuss scenario specific potential reasons for differences: "... it is interesting to note that Georgoulias et al. (2019) found a strongly increasing trend ... for the tropospheric NO_2 concentrations in Baghdad ... hinting at strongly increasing CO_2 emissions in Baghdad ...", "... it shall be noted that GFED's emission estimate for the same time interval but one day before the OCO-2 overpass amounts to $252\,\mathrm{MtCO_2/a}$", low wind speed, acute angle of wind direction, etc. Additionally, we discuss the largest contributions to the total uncertainty, the potential effect of co-emitted aerosols, the differences between the emission data bases, the potential difference between cross sectional flux and source emission, etc. This means, whilst the *Results* section basically describes what is shown in the figures, several points within the *Summary and conclusions* section go far beyond a broad summary.

Reviewer 2: *Furthermore, the results of the flux estimates without including NO2 fields in the fit should be shown in the results and not only briefly mentioned in the conclusions (P15, L6ff).*
Authors: We modified the corresponding paragraph which now reads: "We repeated the flux estimation of all shown scenarios with such a setup and got fluxes of $61\pm27\,\mathrm{MtCO_2/a}$, $63\pm46\,\mathrm{MtCO_2/a}$, $75\pm29\,\mathrm{MtCO_2/a}$, $35\pm9\,\mathrm{MtCO_2/a}$, $166\pm44\,\mathrm{MtCO_2/a}$, and $119\pm28\,\mathrm{MtCO_2/a}$ for the Moscow, Lipetsk, Baghdad, Medupi/Matimba, Australian wildfires, and Nanjing scenario, respectively. The derived fluxes are consistent within their uncertainty with our main results shown in Tab. 1, but the uncertainty contribution due to the noise in the XCO_2 data increased by 34% from $4.7\,\mathrm{MtCO_2/a}$ to $6.3\,\mathrm{MtCO_2/a}$ on average."

Reviewer 2: *The connection between this study and the proposed CO2M mission, which is emphasized in the abstract and the conclusions, is not well presented. The authors used the NO2 fields to identify the location of the source outside the OCO-2 swath and to screen for potential sources upstream. Both will not be possible with the CO2M mission, if CO2 and NO2 instrument* *would have the same swath as currently proposed. In addition, it might also not be necessary for CO2M to use NO2 to identify the source outside the swath, because CO2M's swath will be significantly wider than OCO-2's swath. A major advantage of the NO2 observations is likely the potential for improving the fit of the Gaussian (see previous comment), which should be presented more prominently.*

Authors: As summarized in the abstract (and the last section), we use the NO_2 measurements not only for these two purposes but also to adjust the wind direction and to constrain the shape of the CO_2 plumes. CO2M will have a much wider swath compared to OCO-2, so that there is a good chance to see large parts of the plume including the location of the source plus potential upwind sources within the swath even if the NO_2 instrument would only cover the same swath as the CO_2 instrument. Additionally, it has not yet been finally decided how large the swath width of the NO_2 instrument will be, i.e., there is a chance that it might become wider than the CO_2 instrument. As discussed within the conclusions, "the noise of the XCO_2 retrievals contributes only with $1\,MtCO_2/a$ to $8\,MtCO_2/a$ to the total error". This error enhances by about 34% when ignoring the NO_2 measurements. In other words, for the method as presented, other error components are clearly dominating which is why we put the fit improvement not more into focus. However, this will change for CO2M, because "the meteorology related uncertainties will reduce (Varon et al., 2018) because deviations from steady state conditions can average out and are, therefore, less critical if the entire plume structure is sampled rather than only a cross-section". In this case, the uncertainties introduced by the XCO_2 retrievals will become more important and the "imaging capabilities (of CO2M) will reduce the uncertainty of the inferred emissions due to measurement noise simply because of the increased number of soundings. Additionally, simultaneous XCO_2 and NO_2 observations from the same platform will allow stricter constraints on the plume shape."

Specific comments

Reviewer 2: *P2, L5ff: Consider re-formulating, e.g.: "... to halve [...] emissions each decade after reaching peak emissions in 2020"*

Authors: The sentence now reads: "Actions need to be taken to halve anthropogenic greenhouse gas emissions (including CO_2) each decade after reaching peak emissions in 2020 (Rockström et al., 2017)."

Reviewer 2: *P2, L21-23: Consider to remove, because the detailed chemistry seems not relevant for the study.*

Authors: We would prefer to keep the paragraph as is, because the complex chemical relations are the reason for potential differences in the plume shape of CO_2 and NO_2.

Reviewer 2: *P2, L27: Add the resolution of the NO2 instrument.*
Authors: The most important specifications (for our study) of the NO_2 instrument are listed in Sec. 2.2 ("... spatial resolution of 3.5 km×7 km at nadir ...").

Reviewer 2: *P2, L29: Clarify the term "localized small scale".*
Authors: The sentence now reads: "... which can be attributed to localized (up to city-scale) emissions ..."

Reviewer 2: *P3, L10f: Consider changing "The data set ..." to "The product ..." to make it clear that the filtering is part of the OCO-2 L2 Lite product.*
Authors: Done.

Reviewer 2: *P4, L1: Please explain the term "viewing angle corrected". Are these geometric air mass factors?*
Authors: In this context, we are interested in the scatter of the slant (not vertical) columns, which is why we corrected only for the viewing angle but not the solar zenith angle, i.e., NO_2 slant columns have been corrected for the viewing angle dependent change in the geometric air mass factor. Correcting for changes in the viewing angle is necessary because, otherwise, the inferred scatter would comprise not only changes due to instrumental noise but also the variability of the viewing angle.

Reviewer 2: *P4, L4-9: The paragraph might be easier readable, if it first explains the approach used in this study and briefly contrasts it the "normal" approach.*
Authors: We have the impression that describing first what we have done, renders the description of the "normal" approach a bit superfluous. However, we added "usually" to the first sentence, suggesting that an alternative method will be presented in the following: "In order to extract the tropospheric vertical columns, usually, first the stratospheric contribution ..."

Reviewer 2: *P4, L13: It would be useful to have the time difference between OCO-2 and Tropomi for the six examples presented in the manuscript.*
Authors: The actual time differences per scenario are shown in the figures and the figure captions read: "... and time difference between OCO-2 and S5P overpass are also listed."

Reviewer 2: *P4, L22: Please specify if three times lower resolution is temporal, spatial or both and, if spatial resolution, if it is grid cell area or length. Maybe it's better to just write the resolution of the product.*
Authors: The sentence now reads: "This data archive provides also an uncertainty estimate of the wind information from an ensemble statistic but at a reduced resolution of $0.5^\circ \times 0.5^\circ \times$three hours."

Reviewer 2: *P5, L7-8: This is not a constraint on the width of the CO2 Gaussian function, if CO2 and NO2 values are fitted simultaneously, but using the same width for fitting both CO2 and NO2 Gaussian function. It would be a constraint if the NO2 plume is fitted first and afterwards the CO2 plume is fitted using the coefficient obtained from the NO2 fit.*
Authors: We now decribe more precisely how we constrain the FWHM fit by NO_2 only: "We force the FWHM to be constrained entirely by the NO_2 measurements by setting the CO_2 part of the corresponding Jacobian artificially to zero. However, we expect only little differences to a combined FWHM fit because of the lower relative noise of the NO_2 measurements."

Reviewer 2: *P5, L13: Please clarify if a Level-2 or Level-3 product is used for the fit.*
Authors: We use the co-located XCO_2 and NO_2 values as described in Sec. 2.3 for the fit. This means the XCO_2 values are those given in the OCO-2 L2 product and the NO_2 values correspond to averages within the CO_2 footprints. Because of OCO-2's much finer spatial resolution, most of the NO_2 averages are being build from a single S5P sounding only. The sentence now reads: "Specifically, the co-located NO_2 and XCO_2 values ..."

Reviewer 2: *P5, L22: The equation would be more readable without the unit conversions. The equation could be split in two.*
Authors: We removed the unit conversions from Eq. 2 and rephrased the paragraph which now reads:

Integration over the Gaussian enhancement results in the cross-sectional CO_2 flux F_{CO_2} (mass of CO_2 per time) of the plume depending on the FWHM a_4, the amplitude of the XCO_2 enhancement a_7, the effective wind speed v_e within the plume normal to the OCO-2 orbit, and the number of dry air particles in the atmospheric column n_e:

$$F_{\mathrm{CO_2}} = \frac{1}{2} \sqrt{\frac{\pi}{ln(2)}} \, \frac{M_{\mathrm{CO_2}}}{N_A} \; n_e \; a_4 \; a_7 \; v_e$$

Here, M_{CO_2} is the molar mass of CO_2 (44.01 g/mol) and N_A the Avogadro constant ($6.02214076 \cdot 10^{13}\,\mathrm{mol}^{-1}$).

...

For a hydrostatic atmosphere with a standard surface pressure of 1013hPa, n_e is about $2.16 \cdot 10^{25}\,\mathrm{cm}^{-2}$ and the cross-sectional CO_2 flux F_{CO_2} (Eq. 2) in units of $\mathrm{MtCO_2/a}$ becomes approximately

$$F_{\mathrm{CO_2}} \approx 0.53 \; \frac{\mathrm{MtCO_2}}{\mathrm{a}} \; \frac{a_4}{\mathrm{km}} \; \frac{a_7}{\mathrm{ppm}} \; \frac{v_e}{\mathrm{m/s}}$$

given that the FWHM a_4, the amplitude of the XCO_2 enhancement a_7, and the effective wind speed v_e are provided in the units km, ppm, and m/s, respectively. As n_e approximately scales with the surface pressure, Eq. 3 may be easily adapted to other meteorological conditions.

Reviewer 2: *P5, L27: Does the OCO-2 product have not air columns that could be used instead?*
Authors: We are using the bias corrected "lite" product which does not include dry air columns but we have to read the ECMWF data in order to obtain the wind information anyhow.

Reviewer 2: *P6, L3: Please add how sensitive the factor (i.e. 0.53) is to surface pressure, to provide a range in which this approximation might be used.*
Authors: We added: "As n_e approximately scales with the surface pressure, Eq. 3 may be easily adapted to other meteorological conditions."

Reviewer 2: *P6, L24: Please state typical values for the uncertainty of the wind speed in the ERA5 data.*
Authors: The sentence now reads: "The uncertainties of the wind components are read from the ECMWF ERA5 data archive resulting in total wind speed uncertainties ranging from 0.18 m/s to 0.33 m/s for the analyzed scenarios."

Reviewer 2: *P7, L5: Are the 100 co-locations for Level-2 or Level-3?*
Authors: The XCO_2 values are as in the OCO-2 L2 product and the NO_2 values correspond to averages within the CO_2 footprints (see also discussion above and Sec. 2.3).

Reviewer 2: *P15, L1ff: The major advantage of the NO2 instrument here would be the wider swath and thus having CO2 instrument with a wider swath should bring the same advantage without the need for an additional NO2 instrument. The authors should consider discussing if (or why not) having a CO2 instrument with a wide swath is (not) an option.*
Authors: As visible in the figures and briefly mentioned in Sec. 3.1 ("... larger relative noise of the XCO2 retrievals ..."), the noise of the NO_2 retrievals is about 5 times lower than for XCO_2 relative to the expected enhancements. This will drastically improve the plume detection and also allow to better constrain the plume shape. Additionally, the background variability due to natural sources/sinks is much larger for XCO_2 than for NO_2. We modified parts of the abstract, introduction, and summary and conclusions in order to emphasize the difference in the noise performances.

Within the abstract and similarly within the introduction, one now can read: "However, regional column-average enhancements of individual point sources are usually small compared to the background concentration and its natural variability and often not much larger than the satellite's measurement noise. ... It has a short lifetime of the order of hours so that NO_2 columns often greatly exceed background and noise levels of modern satellite sensors near sources which makes it a suitable tracer of recently emitted CO_2."

Within the discussion we added: "Despite less strict quality filtering is needed, peak enhancements of NO_2 columns near sources can be retrieved from satellites with much lower relative noise than this is the case for XCO_2."

Reviewer 2: *P15, L22: Please explain the term "steady state conditions" in the paper.*
Authors: The first occurrence of this term is at P6 L12 and we modified it to "... under steady state (temporally invariant) conditions ...".

Reviewer 2: *Figure 1-6: The corrected wind arrow looks very subjectively. It might help to draw the arrow centered on the XCO2 swath where the arrow should be a perpendicular to the plume.*
Authors: We do not quite understand the suggestion of the reviewer because non of the arrows should be perpendicular to the plume. For the analyzes of the Gaussian enhancement, we are not considering the across track dimension of the OCO-2 swath. This means, all values are referenced by its distance in flight direction (or time) as plotted in Fig. 1-6c. In the along track dimension, the origin of the arrows is determined by the position of the maximum of the Gaussian XCO_2 fit. In the across track dimension a more or less arbitrary sounding is selected.

Reviewer 2: *Table 1: Mention that the single sounding uncertainty (0.4-0.7 ppm) provided the OCO-2 product was used for computing the flux uncertainty, because evaluation with TCCON found a significant larger value (1.3 ppm).*
Authors: The table caption now reads: "... the XCO_2 precision as reported in the data product, and the NO_2 precision as reported in the data product."

Reviewer 2: *Table 1: Add to the columns that estimated cross sections are instantaneous; EDGAR and ODIAC are annual or monthly emissions.*
Authors: We added to the table caption: "Note that the cross-sectional flux results correspond to the instantaneous time of the overpass' whilst EDGAR and ODIAC emissions are annual or monthly averages; GFED emissions correspond to six hourly averages (see Sec. 2.4)."

Technical corrections

Reviewer 2: *P1, L10: XCO2 was already defined in line 3*
Authors: We removed the second occurrence.

Reviewer 2: *P5, L5: Consider changing "... first degree polynomial (i.e. a linear polynomial) ..." to "... a linear polynomial ...".*

Authors: Done.

Reviewer 2: *P5, L6: Consider adding commas before "accounting" and after "values".*
Authors: Done.

References

Georgoulias, A. K., van der A, R. J., Stammes, P., Boersma, K. F., and Eskes, H. J.: Trends and trend reversal detection in 2 decades of tropospheric NO_2 satellite observations, Atmospheric Chemistry and Physics, 19, 6269–6294, https://doi.org/10.5194/acp-19-6269-2019, URL `https://www.atmos-chem-phys.net/19/6269/2019/`, 2019.

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Figures (!preliminary!)

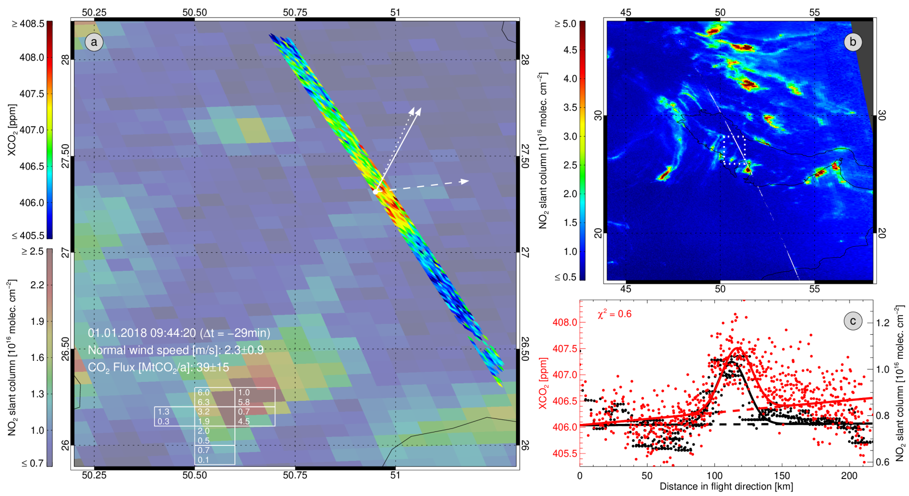

Figure 1: As paper Fig. 1 but for Bahrain on January 1, 2018.

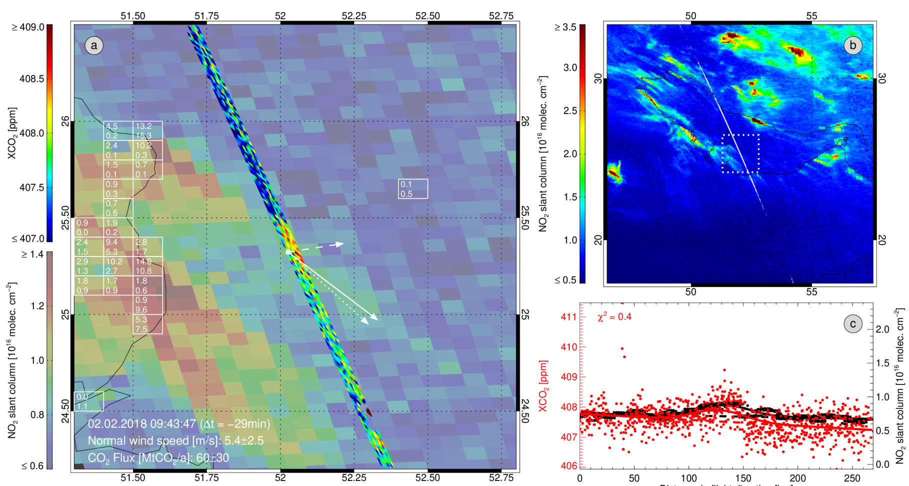

Figure 2: As paper Fig. 1 but for Qatar on February 2, 2018.

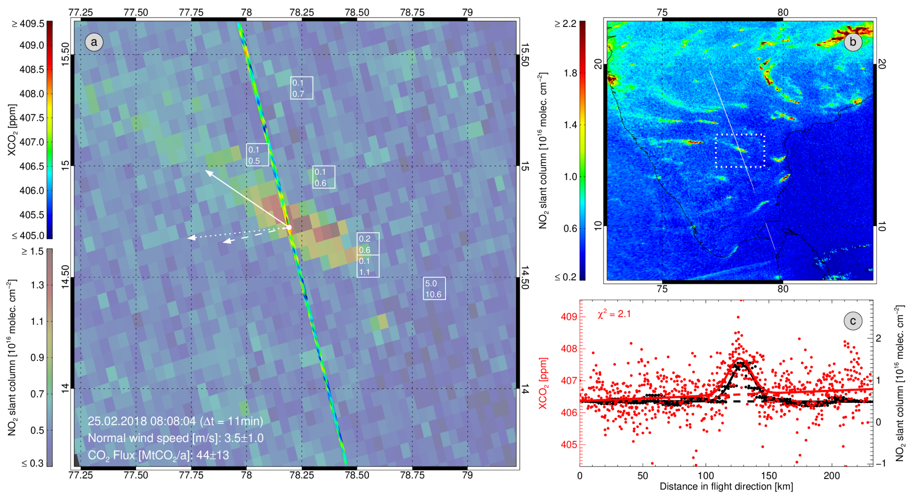

Figure 3: As paper Fig. 1 but for India on February 25, 2018.

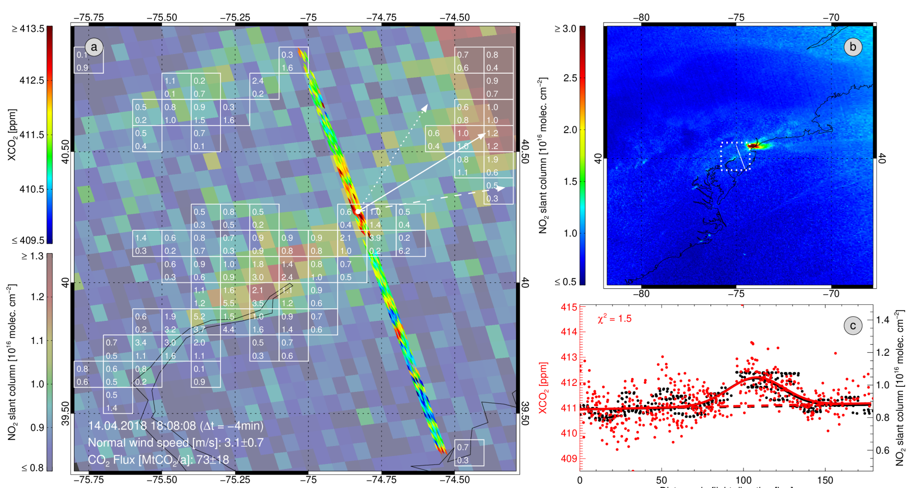

Figure 4: As paper Fig. 1 but for the USA on April 14, 2018.

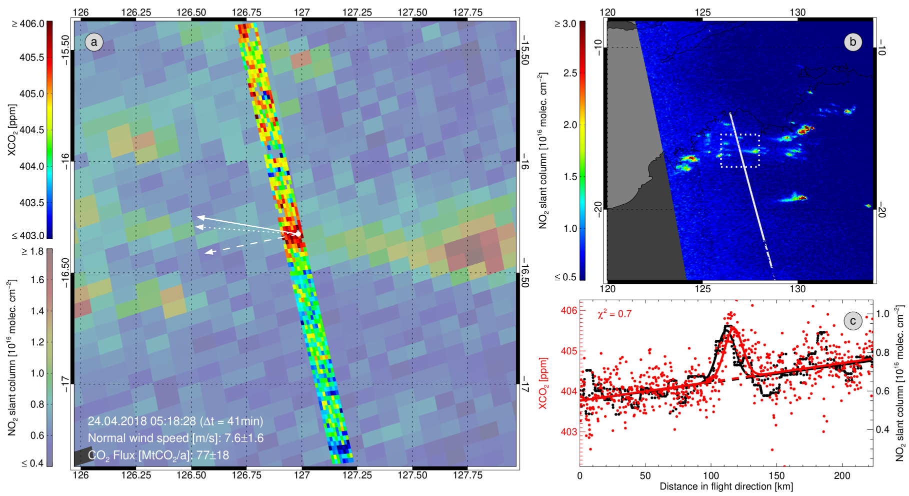

Figure 5: As paper Fig. 1 but for Australia on April 24, 2018.

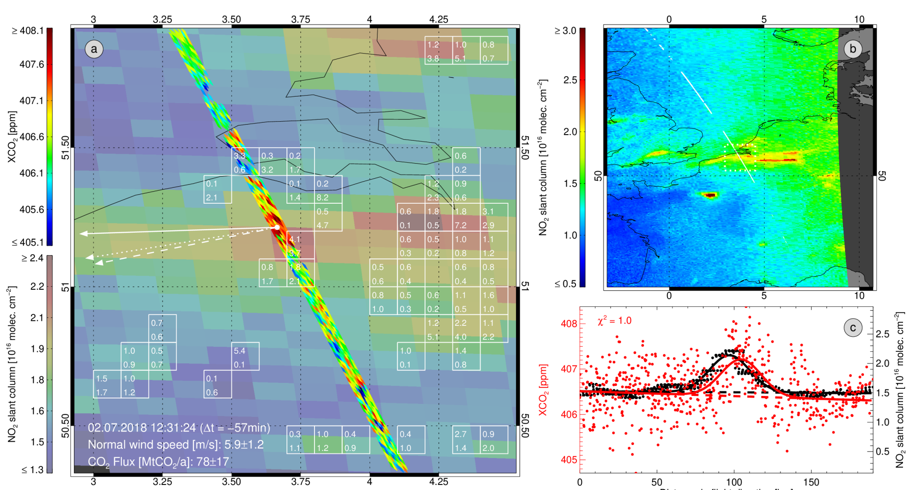

Figure 6: As paper Fig. 1 but for Belgium on July 2, 2018.