

Interactive comment on “The Ultraviolet Visible Hyperspectral Imaging Spectrometer (UVHIS), and high-resolution NO₂ mapping from its first airborne observation” by Liang Xi et al.

Anonymous Referee #1

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Comments to amt-2020-225 titled, ‘The Ultraviolet Visible Hyperspectral Imaging Spectrometer(UVHIS), and high-resolution NO₂ mapping from its first airborne observation’

This manuscript the first measurements from an airborne instrument, UVHIS, which measures backscattered light in the UV and visible parts of the electromagnetic spectrum. It includes instrument characteristics and background, data processing/calibration steps, and results from a NO₂ VCD retrieval from its research flight near Feicheng, China. This paper fits the scope of AMT and would be a welcome read to the AMT audience for a new capability for high spatial resolution trace gas observations in a new region of the world. However, before publishing, this manuscript requires the

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addressing of technical corrections that cause some concern, expansion of details in places, and some improvement on the quality of the writing. While most the comments are minor and related to the writing, I do recommend revisions in the major category because of the concern about the VCD measurement (which may be correct but needs more details to describe to convince the reader) and a great expansion of the mobile DOAS description. Detailed comments on those are below.

Major comments: There are concerns about the actual calculation of the NO₂ VCD as described in Sect 4.3. It is hard to tell what the VCD actually represents in the calculation. Is it a total column VCD? If so, the stratospheric details are missed. However, as it is stated that the stratospheric column is assumed stable during the flight from the reference and is canceled out leads the reader to believe it is not a total column. If it's just the below aircraft column, please state this and ensure the proper accounting for the distinction in the AMF and VCD calculation (e.g., Lamsal et al., 2017 is a great example that shows the breakdown of how these components are calculated).

Lamsal, L. N., Janz, S. J., Krotkov, N. A., Pickering, K. E., Spurr, R. J. D., Kowalewski, M. G., Loughner, C. P., Crawford, J. H., Swartz, W. H. and Herman, J. R.: High-resolution NO₂ observations from the Airborne Compact Atmospheric Mapper: Retrieval and validation: High-Resolution NO₂ Observations, *Journal of Geophysical Research: Atmospheres*, 122(3), 1953–1970, doi:10.1002/2016JD025483, 2017.

Line 157-158: Pertaining to the spatial and temporal variability of the stratosphere being stable. This is maybe close to correct for a 3 hours flight, however there are changes in the SZA which will impact the slant column difference between the measurement and the reference. This could be estimated with a geometric calculation of the slant path with an assumed stratospheric amount between the reference and the measurement. It likely is small.

Lines 306 and 288: The mean slant column fitting error of 4.8×10^{15} molecules cm⁻² and mean total value of error of 2.6×10^{15} molecules cm⁻² for the VCD column with a

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range going down to 1×10^{15} molecules cm^{-2} does not seem to work out mathematically unless the AMF error is zero (which it is not) and the AMF must be ~ 2 (which seems to be below that for most cases) and the error of the reference itself is 100% which is stated as 1×10^{15} . Please check this math.

Line 17: the error of 2.6×10^{15} is not the fitting error as stated. It is the error based on all sources of uncertainty.

Are there literature references for the mobile-DOAS measurements? If not, then details on the specifics of that measurement need to be greatly expanded upon as well as the zenith-sky NO_2 retrieval in Sect 6.2. Especially details on the uncertainty and what the VCD represented vertically (just the troposphere? Stratosphere?).

In Figure 2, there are lines that are repeated in the northern half of the raster. Can this be described? Does this impact the comparisons to the mobile DOAS measurements? Please describe this overlap in the paper as this is what is shown in the NO_2 data. The details should be discussed in the paper.

Minor comments:

Line 108: The mobile DOAS measurements are not shown in Figure 5 as stated. However, are shown in Figure 11. Consider adding the location of these measurements in Figure 2 to show where the mobile DOAS measurements were taken. Additionally, in Lines 288-290: technical details about mobile DOAS measurements are not mentioned before this. Discuss these points within Sect 6.2.

Line 28: What is the intended meaning behind 'that NO_x attracts large attention'. Please elaborate with some details and examples.

Line 54: add 'of NO_2 ' after spatial distribution to clarify that this is the gas of interest in this paper.

Lines 67-68. Figure 1 only shows the optical bench for one of the channels and not all three as implied by the text. Please fix to the text saying that Figure 1 shows the optical

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bench for channel 3 and that the other two are similar.

Line 86-87: reword this sentence to say that spectral and radiometric calibration in the laboratory were done prior to flights to reduce errors in spectral analysis. There shouldn't be a need to state it as 'very necessary'.

Line 38: Is this the first space-borne sensor ever in China or the first space-borne sensor related to air quality or trace gases?

Line 126: clouds were mentioned as filtered out. However, in the rest of the paper it says that the conditions were cloud free. Were there clouds to be filtered? If so, state where and how cloudy it was. If not, state that cloud filtering was not needed for these measurements due to clear skies. Same comment with the sun glint on water if applicable.

Line 165: Please revise to say something like 'and the properties that influence radiative transfer of light through the atmosphere' instead of 'and the radiative transfer'

Line 184: Please clarify which MODIS AOD product was used.

Line 184: What was the AOD measured from MODIS was during the flight? Please add this detail into the manuscript.

Line 187: Please justify why SSA of 0.93 and asymmetry factor of 0.68 are used.

Line 226: Is [28] a referring to a reference? Please fix.

Consider consolidating Figures 6, 8, and 9 into one figure.

Line 258: The difference in adjacent flight lines are not 'biases' but rather 'artifacts' of the changing NO_2 VCDs due to temporal variation.

Section 6 would benefit from a more descriptive title, like ' NO_2 VCD Assessment' rather than 'Discussion'

Lines 324-325. How do these results change if only considering points with a stricter

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temporal window between the mobile and aircraft measurements?

In line 323, the difference between the mobile DOAS measurements and the airborne measurements is described as an 'overestimate' of mobile DOAS measurements, but in the conclusions and abstract it is stated as an 'underestimate' by the aircraft. Please be consistent in this description in the manuscript.

Figure 2: the black dots are hard to see. Please change the color and/or symbol to make the points of interest stand out.

Instead of having Table 2, could those results be translated into Figure 3(a) somehow? If keeping Table 2, then be more descriptive in the caption to say these are FWHMs at these wavelengths/angles.

Lines 110-113: This text is redundant. These details were already stated in the previous paragraph.

Similarly, the first two paragraphs in Section 5 appear to be redundant. Please consolidate into one paragraph without repeating details already stated.

There are grammar mistakes throughout the manuscript. These errors will need to be fixed before publication but I expect will be evolving in revisions. Some grammar and other writing fixes are located at the bottom of this review to help give examples as to the types of errors found. They are not a full edit.

Below are non-mandatory comments to address, but suggestions that could be interesting to investigate if the authors were up for adding these details:

Consider a more concise title, such as, 'The first high-resolution NO₂ observations from the Ultraviolet Visible Hyperspectral Imaging Spectrometer (UVHIS)'.

Does EMI capture this area? Or TROPOMI? It would be interesting to show some comparisons to those data products, especially since the flight was early afternoon on a cloud free day.

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What does Feicheng City look like if mapped on a color scale that only extends to 5x10¹⁵. Are there spatial patterns captured? It is hard to see any patterns in Figure 10 in that area due to the color scale expanding to much larger pollution scales. Perhaps a second panel in this figure would be interesting.

Figure 7: consider adding a true color image of this line to compare with the surface reflectance and AMF.

Can you comment on applications of the other channels for UVHIS? Are there plans for other products in the future?

Writing edits: Line 31: delete 'well' Line 36: Delete 'and' Line 41: change 'for investigation of' to 'to investigate the' Line 42: 'researches' should be 'researchers' Line 64: change 'at wavelength' to 'with the wavelength ranges of' Line 77: insert 'the' between 'improve' and 'signal-to-noise' Line 77: insert 'the' before 'CCD' Line 79: delete 'all' Line 79: 'basically temperature consistent' is casual more than technical. What is the temperature consistency? Line 101: it should be flight lines 'are' provided Line 108: Delete 'basically' Line 116: Add 'The' in front of 'NO₂ vertical column density' Line 130: delete 'and across-track direction' Line 154: it should be Reference spectra 'were' acquired Line 156: change 'detector' to 'position' Line 173: vertical profiles, and surface reflectance. (delete etc.) Line 185: data near the flight area 'are' available Line 195: AMFs 'are' plotted for 'the' research flight Line 206: Change 'industry' to 'industrial' Line 212: Results of this test 'are' shown in Fig. 6, 'and' indicate Line 226: delete 'the' Line 227: less scattered light 'passes' through (recommend deleting solar, too). Line 233: Based on 'a' previous study 'from' Tack Line 234: delete 'the' before 'changing' Line 234: change 'among other' to 'in comparison to' Line 239: Delete 'It is obvious that the' and change 'increase' to 'increases' Line 240: shorter wavelengths are more 'likely to be' scattered Line 241: delete 'before NO₂ layer' Line 273: delete 'the' Line 318: delete 'It is obvious that'