

Interactive comment on “Airborne limb-imaging measurements of temperature, HNO_3 , O_3 , ClONO_2 , H_2O and CFC-12 during the Arctic winter 2015/16: characterization, in-situ validation and comparison to Aura/MLS” by Sören Johansson et al.

Anonymous Referee #2

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GENERAL COMMENTS:

The paper reports on the analysis of a large number of airborne measurements of atmospheric composition, taken by the infra-red limb-imaging Fourier Transform Spectrometer GLORIA during a number of flights campaigns in winter 2016/2017. The paper aims to be the reference document for all the 15 research flights of the three sub-campaigns in the overarching PSG campaign activity. It does this by providing a

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detailed analysis of all geophysical observables for flight number PSG 19 on 2017-03-13, and an overview of key findings from the remaining flights. The reason for selection of flight 19 is not explicitly given, but we guess this is likely because the combination of instrument performance and the prevalence of interesting atmospheric features was best for this day. Conversely, another flight (PSG 12 or 2016-03-31) is occasionally referenced, but not in as much details as PSG 19. For the other flights only a table with the median deviations and variances of the retrieved parameters with respect to the in-situ validation is given. This is mostly adequate, although some references to specific features in other flights are found in the text (i.e. on the influence of PSCs), which are therefore not illustrated (See Technical Comments).

The paper offers a very comprehensive literature reference to previous measurements campaigns by the GLORIA instrument, and it covers the changes/improvements both in instrument performance, as well as the performance of the retrieval processor. The latter includes a description of an improved handling of pointing error in the Level1 processor, which is a major component of the overall error budget. The paper is clearly structured in relevant sections, describing the campaign parameters and flight performance, the instrument performance (including references to the correlative in-situ validation datasets), the data processing scheme (retrieval processor), and a detailed overview of the measurements, errors, and comparisons to validating datasets from both satellite measurements (Aura MLS) and in-situ instruments on the same flight platform. This is followed by a short summary of the measurement performance from the remaining flights.

In summary: The paper is structured in a logical fashion. It covers all the topics one expects to be discussed in a reference paper on a multi-flight campaign with an updated instrument. It is generally well written, the Figures are of a high quality, and a comprehensive list of references is included, which allows the work to be put in the right context. My opinion is that the paper should be published in AMT, if the issues related to content and substance listed in the paragraph “Technical Comments” are resolved.

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It would also be desirable if the minor corrections on format and phrasing would be address, as this would make the paper more easily legible. Corrections are tagged by [page number/line number].

TECHNICAL CORRECTIONS:

[1/13] "... differences are mainly within the expected performance" "Event with stronger deviations are explained. ...". You need to quantify where you set the threshold between what you consider an "acceptable" overlap, and the onset of "unfavourable conditions" which consequentially prohibit a direct comparison. (On a sidenote, "mostly" would be better than "mainly" as you're describing a countable factor, but in general phrases like "mostly, mainly, or more or less" should be avoided in a scientific paper if at all possible.

[2/10] "Space-borne measurements...are limited in sampling and accuracy". Maybe say: "Current space-borne measurements..." to acknowledge the next generation of instrument, i.e. AtmoSat that will do much better.

[2/28] "...showed reasonable agreement...". Again, be specific. What does 'reasonable' mean, and how does the 'stage of development' affect this?

[3/2] "The scientific objectives...". This sentence/list is too long. It gets confusing. Why not write: "Among the scientific objectives of PSG campaign are: ... ; ... ; ... ; and ... Importantly, there should be a comma after "chlorine de-/activation[,] and de-/nitrification" or else the sentence implies that there is "chlorine de-/nitrification".

[3/14] "...corresponds to a displacement of the carrier...". Don't call the aircraft a carrier, call it the "aircraft", or the "platform". The expression 'displacement of the carrier' could be confused with the movement of carrier for the roof mirror inside your FTS instrument.

[4/25] "...onto the correct abscissa in space.". I don't understand this. Is this to correct for spherical aberration in a Gauss beam?

[4/27] "...different temperatures.". What temperatures? Are you using cooled, heated

or ambient targets? The temperature differences between the calibration targets, and their relation to the Brightness Temperature in the limb will affect your calibration errors (mainly the gain).

[4/Fig.1] The colours in the legend are unclear. I.e. I can't tell PSG19-21 apart, which is critical because PSG 19 is your main flight. Also, on the legend there are at least 4 flights in different hues of blue, but I can only see 1 blue track on the map. Incidentally, you also refer to flight PSG 12 on several occasions in the paper (i.e. Fig.2) so you should probably highlight this one as well on the map.

[5/17] "...a precision of $0.7\% \times \text{VMR} \pm 0.35\text{ppmv}$ ". I'm not sure this makes sense. In a format $X \pm Y$, Y is the "precision", so how can you have a value for precision that has itself a precision attached to it? I guess you're talking about a statistical analysis of an ensemble of measurement precisions. If so maybe worth to clarify.

[5/30] "precision of X and an uncertainty of Y". Again, same as above: "uncertainty" = "precision"

[6/22] "...radiation transfer model ... optimized for highly resolves spectra". I think they are generally called "radiative" transfer models. Also, the spectral resolution of a RTM is usually constrained by computational resources alone, not the algorithm, so I don't understand how the RTM can be "optimized" for high resolution.

[7/9] "... a constant (H₂O) profile of 10ppmv is used". Even in the Troposphere? That could have a big impact on your simulated radiances because it would significantly change the opacity at the far end of your pencil beam (Tropospheric 'continuum').

[7/16] "calibration errors" and "pointing errors" are listed twice.

[9/7] "With this method...". I find this entire sentence confusing. Radiometric calibration errors are not attributed to gain and offset, but they result in gain and offset errors. They are attributed to things like errors in temperature knowledge, non-blackbody emissivities, standing waves, etc.

[9/9] “LOS errors are estimated...”. Again, I don’t fully understand what you did here. This is important, as the handling of LOS errors are a dominant error source according to you, so it needs to be crystal clear how they have been handled. (i.e. is the 0.05deg perturbation the variance of all unperturbed profile retrievals?)

[9/13] “...the related temperature error”. I presume this is the T error in the ECMW data?

[9/28] “... the diagonal element of each averaging kernel row...”. This is an incorrect definition of the degrees of freedom in the retrieval. To start with, a vector (AVK row) can’t have a diagonal element per definition. Please review!

[10/16] “This stop allowed for higher altitudes of the HALO aircraft...”. It’s not the stop that makes the plane fly higher. How about: “HALO reaches its peak ceiling altitude immediately before each refuelling stop, when the airframe is at its lightest. It’s only at these phases of the flight that the flight altitude is high enough to sample subsided polar... ”.

[12/Fig.3] The flight track in the vicinity of waypoints A and B is not very visible. Could you use lighter colours?

[13/Fig.4] The axes of panels c) and f) (vertical resolution) should be capped at 1.5km (or even 1km instead of 3.0km. This would better resolve the profile variations at the altitudes that actually matter.

[14/2] “...caused by changes in the atmospheric state...”. Why is that? Changes in refracted path if the temperature/density is incorrect?

[14/8] “For flights between...” and following sentences: I think I understand what you are saying, but I had to read this section many times over before it became clear to me. Could you rephrase it in a less convoluted way?

[15/Fig. 5]: I can’t tell the dark blue and the black dots apart in my A4 printout. Please use high contrast colours, i.e. red and black.

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[17/4] “This is the same regions, where the HNO₃...”. I have the impression that the HNO₃ mismatch peaks at 17:00h, while the O₃ mismatch peaks at 16:00h. Is that really the same air-parcel? On the same note: Why are AIMS and FAIRO comparisons plotted on what are really quite different time-scales in their respective panels.

[18/?] “Baffin Bay”. Where is Baffin Bay located in Fig 3? Not really common knowledge.

[18/?] General comment to this paragraph: You really should mention the good agreement between spatial features observed in O₃ and HNO₃. This is what you would expect from atmospheric chemistry, and the fact that you actually see it is an important self-validation of your results!

[18/7] “...subsided deactivated ClONO₂”. A large presence of the reservoir gas ClONO₂ is a sign of “deactivated” ClO, and should therefore probably be called “activated” ClONO₂.

[21/22] “... numerous flights in January 2016, which have been affected by PSCs...”. This merit a separate Figure, and a short paragraph. It constitutes a separate, unique scientific finding of the campaign. Because the paper is aiming to be the reference publication of all flight in PSG, this should not be demoted to a mere side-not, just because it's not visible in the example flight PGS 19. You make a reference to a “supplement” that contains these additional plots, which I presume are part of the special edition, but I don't have access to this supplement, and neither will anyone that downloads your article as a standalone document from a research database a few years down the line. To make the paper useful in the long term, this link should either be omitted, or at the very least you will have to reference it (with full DOI information) in the text.

[23/17] “This lower resolution does not resolve spatially confined enhancements in these trace gases.” MLS is still sensitive to the filament enhancements, even if it can't resolve them. If you re-grid the data carefully, i.e. by applying the MLS averaging kernels to your measurements, the observed VMR values should match. Are you com-

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paring the peak VMR values from a high vertical resolution IR measurements with a low vertical resolution MSR measurement? In this case, the discrepancy is indeed to be expected, but it's not strictly because the MLS can't see it, but because the MLS measurements contains information from (O3-depleted) polar stratospheric air. So, you're comparing apples with pears.

[23/13] "...which is lower compared to... previous IR limb sounders". Why is that?

[23/17] Again, "rather" is a very meek and unspecific term. Your closing sentence should have some clout. How about: "GLORIA measurements with unprecedented spatial resolution over the Arctic region will form the basis for many future case studies on ..."

FORMAL (MINOR) CORRECTIONS:

General remarks: - Use of punctuation is not always consistent, especially commas - Use a digit divider for large numbers (i.e. 15'000, or 15,000. Pick whatever you prefer, but be consistent) - Be consistent with ligatures (i.e. limb-scanning vs. limb scanning,

[Title] Capitalisation of "Characterisation" after a colon.

[1/14] "stronger" "larger"

[2/1] Repetition of "region of". Capitalisation of Upper Troposphere Lower Stratosphere.

[2/5] The acronym GLORIA has been defined before.

[2/22] Define STR in MIPAS-STR

[2/26] Define ESSenCe

[3/7] "These 18 PSG research flights, each with a duration of approximately 10 hours, cover the entire period of the Arctic winter and provide a unique dataset"

[3/14] Repetition of "48 x 128 interferograms are recorded every 13 s"

[5/3] "enhanced" "improved"

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[5/11] “also allow” “assure”

[5/13] “. . . a detection limits of X, a precision of Y, and an accuracy of Z”

[5/16] Missing “is” in “which [is] based on. . .”

[6/6] Convoluted description of the MLS viewing geometry. Just say: “The along track scanning radiometers scan the limb every 165km.”

[8/18] You explicitly reproduce the numbers of all errors from the literature, except for O3 and H2O line intensities (Flaud et al.). Would be more consistent to include them as well.

[10/27] HALO “left” or “exited” these air masses (“departed” implies an untimely demise of the aeroplane). “decreasing down to” “decreasing to”.

[10/31] “. . .for dates and times of PSG flights, filtered by. . .”

[11/37] “to significantly change” “to vary significantly”

[11/11] “It can be seen that the shapes of the . . . profiles differ significantly from. . .”

[11/19] “most” “mostly”, or better “predominantly”

[11/27] “This simultaneously illustrates the amount of data that. . . , and allows the characteristics. . .”

[15/12] Confusing, because high/low applies to both T and altitude in the same sentence. Maybe: “. . .from higher temperatures (240K) at lower altitudes, down to temperatures as low as 205K at flight altitude”.

[16/17] Remove “likewise”; It has no meaning in this sentence.

[16/21] “implied” “visible”, “evident”, “shown”

[19/8] Typo: “stratopsheric” “stratospheric”

[21/18] Missing word: “median [difference] gives”

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