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Atmospheric Measurement Techniques Discussions

Interactive comment on "CRISTA-NF measurements during the AMMA-SCOUT-O_3 aircraft campaign" *by* K. Weigel et al.

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We thank referee #2 for the time and effort spent on reading the paper and providing the comments. Below please find the reply to every comment.

Answers to general comments:

The paper describes the measurements taken with the airborne CRISTA-NF spectrometer during the AMMA SCOUT-O3 campaign in Africa during 2006, and the application of the JURASSIC forward model and retrieval scheme to extract profiles of various species.

While there is nothing particularly wrong with the paper, it has to be said that neither is there anything particularly new in it. The CRISTA-NF instrument and H2O retrievals have been described in Hoffmann et al. 2009 (although not for this campaign) and the JURASSIC forward model/retrieval scheme has been applied to numerous different instruments: this paper doesn't appear to add anything to what has been previously explained. However, since this is a special issue on limb-sounding, this paper probably serves as a useful illustrative example.

We thank the referee that he regards the paper as an useful illustrative example. The JURASSIC forward model/retrieval is not new itself but various aspects of the retrieval have been improved with respect to Hoffmann et al. 2009. Now, radiance from another channel of CRISTA-NF is used in order obtain integrated spectral windows distributed over a wider spectral range. This allows us to retrieve not only water vapor volume mixing ratios, aerosol extinction, tangent heights and radiometric offset as in Hoffmann et al. 2009 but additionally O_3, HNO_3, PAN, CCl_4 and temperature. In this paper, we also present comparisons to in situ measurements for the first time.

To emphasize these changes we will add the sentence: "The new retrieval scheme is based on 9 integrated spectral windows allowing to retrieve an extended set of trace gases and temperature fields with high vertical resolution (up to 500 m). Retrieval results are shown for temperature, water vapor (H_2O), ozone (O_3), nitric acid (HNO_3), peroxyacetyl nitrate (PAN), carbon tetrachloride CCl_4), and aerosol extinction." to the abstract (Page 924, Line 8–10). Additionally we will explain the differences in the Introduction (Page 925, Line 25): "The new retrieval scheme uses 9 ISWs from channel L6, in contrary to the retrieval scheme presented by Hoffmann et al. 2009, which uses 3 ISWs from channel H5. The higher number of ISWs from a wider spectral range allows us to retrieve not only water vapor volume mixing ratios, aerosol extinction, tangent heights and radiometric offset as in Hoffmann et al. 2009 but

additionally O_3, HNO_3, PAN, CCl_4 and temperature."

I accept that the main emphasis is on technique (as in AMTD) rather than validation but I am left unconvinced that the CRISTA-NF retrievals perform any better than climatology - the comparisons shown are qualitative and not with instruments sampling the same atmosphere. As part of a campaign, I would expect a wider variety of measurements to be available.

Although AMMA is a large campaign it remains difficult to find other measurements for the direct comparison to CRISTA-NF results due to the following reasons:

- The balloon measurements (which do provide H_2O, O_3, NO_2 and CCl_4 measurements) were based in Niamey and not in Ouagadougou like M55-Geophysica. There is also no temporal coincidence between balloon measurements and M55-Geophysica flights T2, L5 or T3, where CRISTA-NF results are available and the M55-Geophysica flies close to Ouagadougou and Niamey (Cairo et al. 2010).
- There where no in situ measurements of PAN and HNO_3, a comparison of the sum of PAN and HNO_3 to NO_y in situ measurements from SIOUX is not possible without measurements of NO_2, N_2O_5, and $ClONO_2$, which are unfortunately not available from in situ instruments on M55-Geophysica (Cairo et al. 2010).
- There were no AMMA MIPAS-STR retrieval results available when we performed the comparisons.

As the referee observed correctly we have therefore not claimed to perform a validation. The temporal and spatial coverage of the CRISTA-NF and in situ measurements is limiting the possibilities for intercomparisons. Nevertheless we are certain that the CRISTA-NF data provide much more informations about the atmospheric composition

than a climatology at the place and time where the measurements took place.

Also, while the attempt at a full error analysis is commendable, there is a noticeable lack of any mention of the potential errors due to horizontal structure in the line-of-sight, ie the robustness of the assumption of horizontal homogeneity in the forward model, particularly when coupled with the claim that fine vertical structure is retrievable. The use of "Total Error" for comparisons is also rather naive: for example, spectroscopic uncertainties - a significant contribution to the total error budget - would presumably not contribute to the differences between forward and backward scans. However, since this is not a validation paper, I just make these comments for the benefit of the authors in case they plan on further publications.

We will include the error due to the horizontal structure of the atmosphere on Page 936, Line 17–27: "Other possible error sources are effects of an insufficient representation of aerosol extinction, thin clouds, the horizontal structure along the LOS, remaining effects of detector relaxations or of the determination of the spectral resolving power, undetected stray light and spikes, and uncertainties in the line-by-line reference model."

The importance of horizontal structures for retrievals of atmospheric quantities from limb measurements is currently discussed by several authors (e.g. Kiefer et al. 2010, Pukite et al. 2010). Two dimensional are only feasible with interleaving lines of sight and have the biggest advantages if strong horizontal gradients are present, e.g. at the edge of the polar vortex. For the CRISTA-NF measurements presented here, interleaving lines of sight are not available. It is difficult to estimate the errors caused by the 1-D assumption but we do not expect much stronger horizontal gradients perpendicular to the flight direction than the ones shown along the flight path for L5.

The term 'total error' was used here to distinguish the error over the total covariance

used from the different error components. We do not claim that it covers all possible errors which should be clear from the discussion on Page 936, Line 17–27. We will also mention the error due to the horizontal structure there (see above). To clarify this further we will use the term ”covariance error” instead of ”total error” in the corrected version.

The large differences between forward and backward spectra (which are not larger than the error shown in Fig. 3) are mainly due to noise and the position of the lowest tangent altitude included in the retrieval (i.e. the altitude below which the a priori influence is dominant, which is about 10 km but differs between forward and backward profile for profile 87). The corresponding error components are the noise and the smoothing error, which are among the leading error components. This is discussed on Page 935 Lines 3–4.

Answers to MINOR COMMENTS/TYPOS/GRAMMAR:

*P924 L6: suggest ”*tangent* altitude range” for clarity.*
We will follow the suggestion of the reviewer.

*P925 L4: change to ”optics *are* adapted”*
We will correct the text.

*P925 L11: change to lower case ”emphasis *on*...”*
The upper case was chosen because of the acronym SCOUT-O_3. We will write: ”the ’Stratosphere-Climate links with emphasis On the UTLS-O_3’ (SCOUT-O_3) project”, to clarify this.

P925 L14: (and multiple later occurrences) change ”Quagadougo” to ”Ouagadougou” (also mis-spelled as ”Quagodougou” elsewhere)
We will correct the text.

P925 L11: Any particular reason for focusing on this particular flight L5?
Yes, to explain the focus on flight L5, we will add the following sentences to P925 L11: ”Flight L5 was chosen because on this flight CRISTA-NF has the best data quality of all local flights (i.e. fewest clouds and no complicated flight maneuvers). We decided to focus on a local flight because the main focus of the AMMA campaign and hence the in situ measurements was on the local flights.”

P926: It would be helpful to mention at this point that CRISTA-NF views perpendicularly to the flight direction since this is key to performing a 1D rather than a 2D retrieval.
We will follow the suggestion of the reviewer and include the sentence: ”CRISTA-NF views perpendicular to the flight direction. ” and change the ”This” to ”The” at the beginning of the following sentence and explaine the difference between the horizontal resolution along and perpendicular to the LOS afterwards (see other review).

P926: Suggest ”Helium cooling also results in an excellent signal-to-noise ratio for the limb-observations ...”
We will follow the suggestion of the reviewer.

P928 L2: ”dominated by H2O” ? From Fig2 it seems that H2O contributes only about a third of the total radiance, CO2 and O3 contributions being comparable. I assume H2O becomes dominant at lower altitudes.
The referee is right that H_2O is not the dominant emitter for all altitudes. We will change the text to: ”a significant fraction of the measured radiance is caused by H_2O

at lower altitudes"

p928 L3: spurious "(?)" - missing a reference here?
The referee assumed correctly that references (to Offermann et al.(2002) and Schaeler and Riese (2001)) are missing. This was caused by a spelling mistake in the label and will be corrected.

P929 L3: "maximum a posteriori ... solution" . Needs to have "likelihood" or some other noun before "solution" to make sense.
The term "maximum a posteriori solution" is used e.g. by Rodgers (2000, pp.66).

P930 L6: "In addition ... have been defined." I don't understand what this sentence means. Are these percentage SDs used instead of the climatological SDs? Replacing them at some altitudes? Taken literally, it seems you just define the percentage SDs but don't say anything about using them.
We use the maximum of the percentage SDs and the climatological SDs, to clarify this ", which are used if they exceed the climatological standard deviation" will be added at P930 L7.

P930 L16: Remove paragraph indentation before "where ..."
The indentation will be removed.

P930 L16: Change "standard deviations" to singular to match "is" and "altitude"
We will correct the text.

P931 L16, L18: suggest changing "that means" to "i.e."

We will follow the suggestion of the reviewer.

P931: It would be useful to explicitly state how many profile levels you have in your analysis (totalled over the four ranges).
There are 63 profile levels. For clarification we will modified P931 L14 to: "a vertical grid with 63 levels and a vertical step varying with altitude."

P932 L23: change "One" to "one"
We will correct the text.

P932 L24: suggest hyphenating: "instrument-related"
We will follow the suggestion of the reviewer.

P933 L26 (and P934 L4): change "convoluted" to "convolved"
We will correct the text.

P934 L5: suggest changing "continued" to "extended"
We will follow the suggestion of the reviewer.

P934 L13: change "is taken..." to "are taken ..."
We will correct the text.

P934 L18: insert space between "O3" and "for"
We will correct the text.

P937 L3: saying that the vertical resolution reaches 500m for some altitudes is slightly

misleading. What Fig 5 seems to show to me is that the resolution for H2O is about 1km for most altitudes, with some fluctuations due, presumably, to numerical artifacts.
The fluctuations of the resolution are mainly caused by varying measurement altitudes due to the roll movements of the aircraft rather than numerical noise. During this flight the pointing was not stabilized. To clarify the changes in resolution plots for all profiles for the retrieved trace gases are added to the supplement. The pointing for the profile shown in Fig. 5 can be approximated from the positions of the peaks of the AVK. Nevertheless the ideal resolution of 500 m is seldom reached, therefore we will modify the sentence to:"The resolution reaches often values better than 1 km and can be 500 m in the ideal case." To explain the reason for the fluctuations we will add the sentence: "Fluctuations in the resolution are mainly cause by a varying altitude sampling due to roll movements of the aircraft."

P937 L13: Is a resolution of 20km useful for HNO3 and O3? 20km seems to be equivalent to the thickness of the layer containing most of the atmospheric HNO3 and O3 in which case there is almost no vertical resolution at all. So saying "better than 20km" seems to mean "capable of resolving some vertical structure".
The admittedly high value of 20 km is only the upper threshold, the resolution is often better. This can be seen in Fig 5b for one profile. For clarification, plots displaying the resolution for all profiles for the retrieved trace gases will be added to the supplement (Fig 15, see below). To clarify this we will change Page 937 Line 13 to: "The upper threshold for the resolution is set to 20km for HNO3 and O3 and 3 km for all other retrieval variables; the lower and upper thresholds for the measurement contribution are 0.8 and 1.2, respectively. In the following, only retrieval results meeting these quality criteria are displayed."

P937 L18: Suggest removing "for": "Like the CRISTA-NF ..."
"Like for" will be replaced by "As for"

P938 L23: Change "stareboard" to "starboard"
We will correct the text.

P940 L20 (also "descend" in P941 L26): Change "ascend" and "descend" to "ascent" and "descent"
We will correct the text.

P943 L3: Change "well to in situ" to "well with in situ".
We will correct the text.

Fig 5 caption: caption refers to "measurement content" but figure legend uses "measurement contribution"
We will replace "content" by "contribution" in the caption of Fig. 5 to agree with the text in Fig. 5 and i.e. P933, L1. (On P931 L2 it will become obsolete after reformulating the sentence, see reply to referee #1.)

Figs 7 etc: where the horizontal axis is time, it would be useful to also have at least an approximate indication of corresponding horizontal distance.
The distance to the starting point (Ouagadougou airport) will be added as a second x-axis in addition to the time axis (see example for Fig. 7 below).

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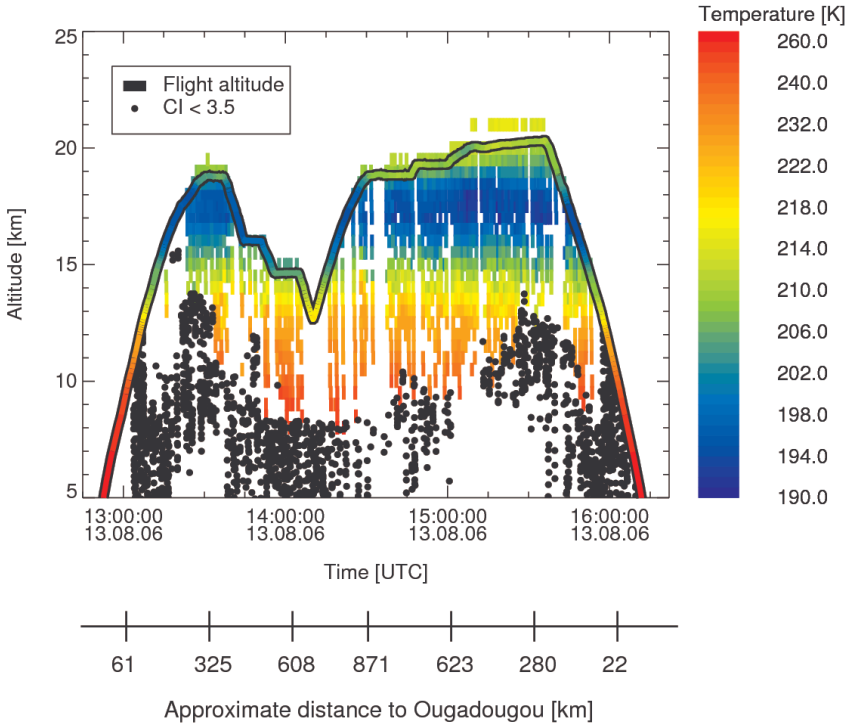

Fig. 1. Modifies Fig. 7 with distance to Ouagadougou as second x-axis

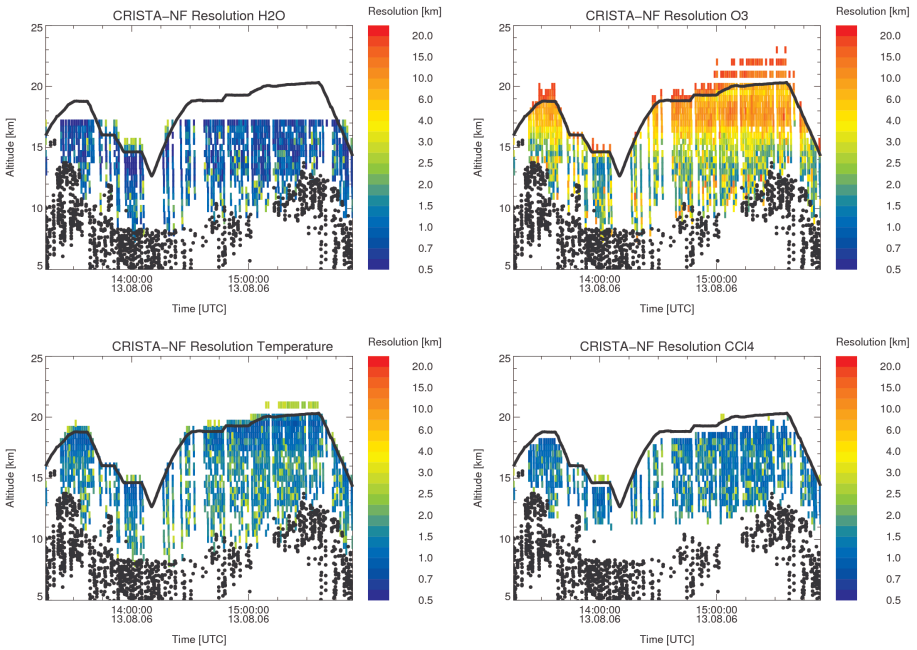

Fig. 2. CRISTA-NF resolution for all profiles during flight L5 for H2O, O3, temperature and CCl4.

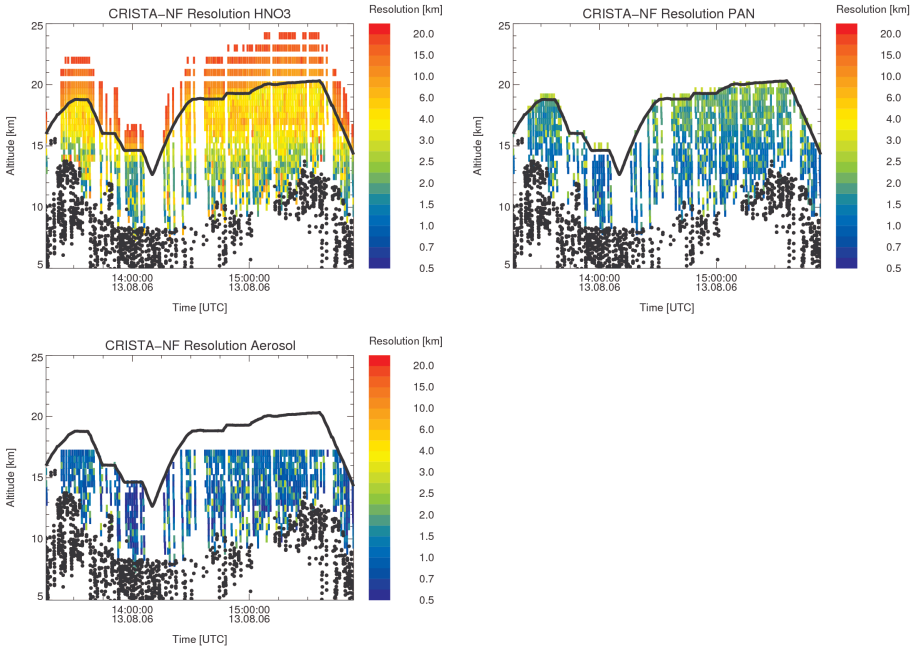

Fig. 3. CRISTA-NF resolution for all profiles during flight L5 for HNO3, Pan and aerosol extinction.