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Atmospheric Measurement Techniques Discussions

Interactive comment on "Characterization of blackbody inhomogeneity and its effect on the retrieval results of the GLORIA instrument" *by* Anne Kleinert et al.

Anne Kleinert et al.

anne.kleinert@kit.edu

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We thank the referee J. Taylor for reviewing the paper and the valuable comments. Our answers to the comments are given below. Relevant referee comments are inserted *in italics*.

General Comments: The study focuses on the impact of temperature and emissivity uncertainties of the on- board radiometric reference standards and does not address other sources of uncertainty in the calibration or retrieval algorithms, which may or may not be more significant contributors to the overall uncertainty. While a comprehensive uncertainty analysis of all contributors is not the focus of this study, it would be helpful

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to briefly indicate if the onboard reference standard temperature and emissivity uncertainties are expected to be the primary source of uncertainty for the retrieved quantities and to note their relative significance with respect to the other identified sources of uncertainty (calibration and retrieval).

The uncertainties of the calibration blackbody are comparable to other instrument uncertainties (e.g. detector non-linearity and instrument offset). Further relevant sources of uncertainty for the retrieval are the quality of the spectroscopic data and the impact of interfering species.

We have added an additional section at the end of section 2 (page 5, line 29) where these points are briefly discussed:

"2.4 Other sources of uncertainty

Uncertainties in the gain function do not only come from uncertainties of the temperature and emissivity of the blackbody but also from uncertainties in the determination of the detector non-linearity and the instrument self-emission (offset). These uncertainties are currently estimated to about 2 - 3 % (k=2). Further characterization is under way in order to reduce these uncertainties in future processing versions.

Beside the uncertainties in the calibrated spectra, the quality of the retrieval results also relies on the quality of the spectroscopic data and the impact of interfering species in the selected microwindows. Spectroscopic uncertainties are, however, systematic over time and cancel out in case of trend analyses. Furthermore, the quality of the spectroscopic data may improve in the future. Some interfering species impose uncertainties within the troposphere in the same order as the blackbody inhomogeniety. Further improvements on the retrieval are likely able to reduce these.

With the current data processing and retrieval setup, the blackbody temperature uncertainties are estimated to be one of the leading sources of uncertainty, together with other uncertainties in the gain determination and the impact of interfering species.

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Since the other major sources of uncertainty are expected to be reduced with better instrument characterization and an optimized retrieval setup, the focus of this study is on the impact of the blackbody temperature uncertainties on the retrieval results relevant for the detection of climate relevant trends."

The uncertainty coverage factor (k) is only specified in one instance in the manuscript (page 10, line 11), and it is not clear if this is for the total uncertainty in the GLORIA blackbody temperature when using VIRST as a transfer standard and the VLTBB as a radiometric standard, or if it is the uncertainty of the of only the VIRST measurement, or the VLTBB as a source. "The typical uncertainty at -40 °C at a wavelength of 10 μm is 100 mK (k=2)."

This is indeed the total uncertainty in the GLORIA blackbody temperature when using VIRST as a transfer standard and the VLTBB as a radiometric standard. This is now stated more clearly on page 10, line 10:

"The typical uncertainty for the GLORIA blackbody surface radiation temperature at -40 °C at a wavelength of 10 µm is 100 mK (k=2) and is decreasing for higher temperatures.

Given the identified importance of traceability to the SI, it would be useful to utilize expanded uncertainty notation throughout, with the coverage factor (k) explicitly noted when an uncertainty is specified. Alternatively, a brief note that all uncertainties are of a specified coverage factor or confidence unless otherwise noted would be sufficient.

At the end of the introduction, we have included the general statement that all uncertainties given in the text shall be understood as 1 σ values if not indicated otherwise.

Page 2, line 5, sentence added: "All uncertainties given in the text shall be understood as 1 σ values if not indicated otherwise."

Specific Comment: Section 4.1 Equation 18 and figure 6 assume that the effective emissivity is constant with wavenumber. Providing a statement regarding the expected spectral variability of Nextel 811-21 and/or uncertainty within the spectral range of the

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GLORIA measurement would be a useful clarification.

We have added a statement on the expected spectral variability of Nextel 811-21 in the relevant spectral range on page 10, line 30:

"This slope can only be real if either the wall coating has a significant slope or if the temperature non-uniformity within the measured area is of a similar magnitude as the slope, i.e. 200 mK. The coating Nextel 811-21 can be safely assumed to have a constant value of 0.97 in the spectral range from 500 cm^{-1} to 1500 cm^{-1} with only a slight spectral variability within a given uncertainty of about 0.01 but no significant overall spectral trend or slope (Adibekyan et al., 2017).

In order to exclude a temperature non-uniformity in the order of 200 mK, lateral scans were performed with VIRST ..."

Specific Comment: Section 5 The conclusion would be further strengthened by explicitly noting what level of climate trends can be detected and over what time period, given the uncertainties in the GLORIA retrieved products discussed in the manuscript. Additionally, please consider including a summary statement in the conclusion that clearly states whether the total uncertainty in the retrieved products is expected to be driven by the temperature and emissivity uncertainties in the onboard radiometric references (the subject of this manuscript), or if other uncertainty contributors in the radiometric and spectral calibration or retrieval algorithms are expected to be the dominant uncertainties.

We have changed the conclusions accordingly (starting page 15, line 7):

"In order to be able to resolve typical trends in atmospheric species as temperature, ozone, and water vapor, the retrieval errors should remain below 20 % of the trend. To observe decadal trends, the resulting maximum tolerable temperature deviation of the blackbody temperature from the mean value for a typical correlation length of 10 vertical detector pixels is at 200 mK with a target of 100 mK. The target value is mostly

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reached for the blackbodies used for the calibration of GLORIA.

With the current data processing and retrieval setup, the temperature and emissivity uncertainties of the GLORIA blackbodies are among the leading sources of uncertainties, together with the uncertainty of the detector non-linearity determination and the instrument offset determination. Spectroscopic uncertainties and interfering species can have an impact of similar magnitude on the retrieval results. The latter sources of uncertainty can be reduced by further instrument characterization and an optimized retrieval setup, such that the uncertainties of the calibration blackbodies may become the leading error source."

Editorial comment: Section 1, line 10 I believe that 'earth' should be capitalized in this context

Yes, corrected.

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