Experience with the radiometric traceability concept for the Network for Detection of Mesospheric Change (NDMC)

Max Reiniger[1], Christian Monte[1], Berndt Gutschwager[1], Jörg Hollandt[1], Paul Dekker[2], Steven van den Berg[2], Carsten Schmidt[3], Sabine Wüst[3], Michael Bittner[3]

[1]*Physikalisch-Technische Bundesanstalt (PTB), Berlin - Germany,*

[2]*VSL – Dutch Metrology Institute, Delft – The Netherlands,*

[3]*Deutsches Zentrum für Luft- und Raumfahrt (DLR), Oberpfaffenhofen - Germany*

Corresponding e-mail address: Max.Reiniger@ptb.de

We have implemented a radiometric traceability concept to provide calibrations to the NDMC. With transportable instruments we are able to calibrate the typically used GRIPS instruments in the spectral range from 1500 nm to 1600 nm with a thermal radiance source at radiance temperatures of around 110 °C. Here we present our experience with this concept exemplarily by the results of the calibration at two different NDMC sites.

INTRODUCTION

The NDMC [1] is an international network of currently 55 ground-based experiments with emphasis on observing the airglow emissions from excited OH- and O radicals as well as excited O_2 molecules in the mesopause region. About one third of these instruments are of the so-called GRIPS type (Ground-based Infrared P-branch Spectrometer) determining the rotational temperature of the OH(3-1) vibrational transition.

We focus on providing radiometric traceability to measurements of theses GRIPS instruments to determine the mesopause temperature with sufficiently low uncertainty to identify temperature changes at the level of 1 K per decade. By Monte-Carlo simulations we determined the required uncertainty in terms of the relative radiance responsivity calibration of the GRIPS instrument to achieve this goal. It needs to be better than 0.5 % (k=1) in the wavelength range between 1500 nm and 1600 nm. Furthermore, an absolute radiance responsivity calibration of the GRIPS instruments within the NDMC would allow the determination of the OH* radical concentration which is directly correlated to the concentration of atomic oxygen in the mesopause.

CALIBRATION CONCEPT

The emission measurements of the OH* radicals are performed between 1500 nm and 1600 nm at very low radiance levels (around 350 $Wm^{-1}sr^{-1}m^{-2}$ - equivalent to a blackbody radiance temperature of around 110 °C at 1550 nm) caused by their low density in the mesopause. At these radiance levels and wavelengths, the required radiance uncertainty was just achievable for laboratory-based calibration procedures at National Metrology Institutes. To obtain this low level of uncertainty for the NDMC in the field we developed a traceability concept **(Figure 1)** based on a radiometrically well-characterized Traveling Radiance SOurce (TRSO) and a likewise characterized Traveling Reference SPectrometer (TRSP).

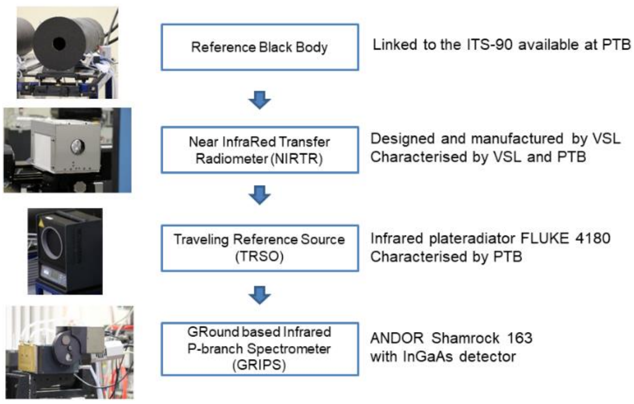

Figure 1. Calibration concept of the GRIPS instrument

We identified, characterized, optimized and calibrated two suitable instruments for this concept: a commercially available infrared plate radiator (Fluke 4180) as the TRSO and a GRIPS instrument (Andor Shamrock 163) typically used by DLR as the TRSP.

For the transfer of the spectral radiance scale from the primary radiance standards of the PTB [3] to the TRSO with lowest possible uncertainty a dedicated Near InfraRed Transfer Radiometer (NIRTR) has been developed by the VSL [2] which is able to detect the low radiance levels with a sufficiently good signal-to-noise ratio and matches closely the optical imaging properties of the GRIPS instruments.

Several optimisations of the GRIPS were necessary to reach these low uncertainties. The most important improvements are a temperature stabilised enclosure and a temperature stabilised aperture system to minimize the size-of-source effect (SSE) of the GRIPS. Furthermore, we have investigated the long-term stability of different types of the TRSO with the NIRTR.

RESULTS

With this calibration concept and the improved and metrologically well characterized instruments we were able to calibrate the GRIPS instruments with uncertainties (k=2) from 0.8% to 1.2% **(Figure 2)**

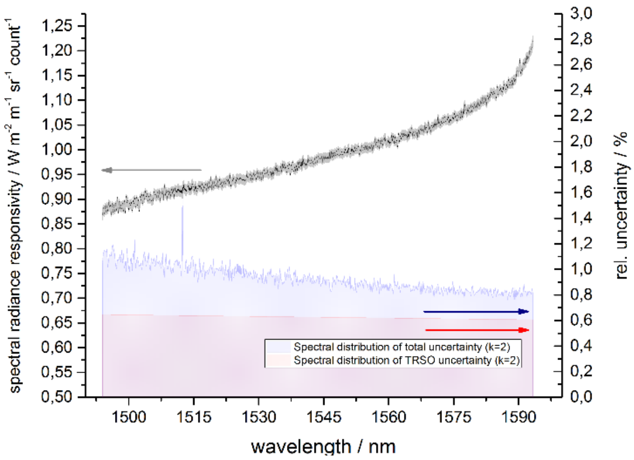

Figure 2. Result of the spectral radiance responsivity calibration of the GRIPS instrument and its uncertainty.

We have validated the long-term stability of the GRIPS calibration with multiple calibrations of the same instruments at different sites within different measurement campaigns. The deviation between the calibration which took place at Oberpfaffenhofen (OPN) and at the Environmental Research Station Schneefernerhaus (UFS) at Zugspitze are shown in Figure 3. The deviation between these two calibrations is well within the combined uncertainty. This clearly shows that there is practically no significant impact of the transport of the calibration instrumentation and that the calibration concept is able to provide sufficiently good traceability to the NDMC. Part of the radiometric characterization of the TRSP was, additionally, the wavelength calibration which was done with a high precision narrowband tuneable laser source in combination with an integrating sphere. These measurements provide precisely the wavelength scale but, furthermore, give information about spectral straylight and the spectral response function of the instruments. This enables a spectral deconvolution of the measured spectra and thus an improved determination of the required line intensities.

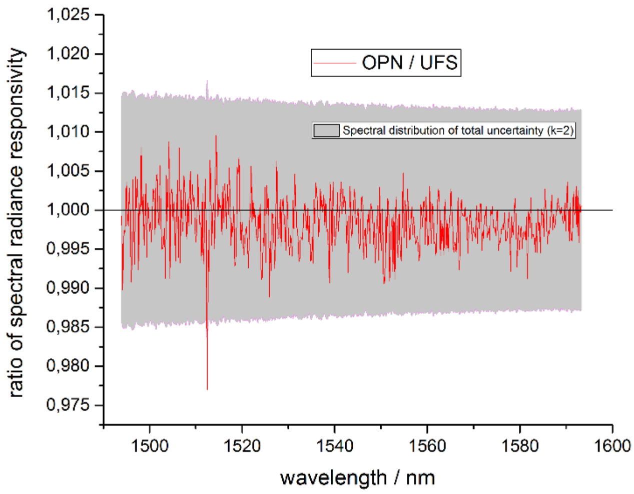

Figure 3. Ratio of spectral radiance between to measurement campaigns which took place at OPN and UFS.

CONCLUSION

We will show the results of the first on-site calibrations with the combination of TRSP and TRSO with respect to their transportability, radiometric stability and the achievable uncertainties

REFERENCES

1. https://ndmc.dlr.de
2. S. van den Berg et al., Traceability of the Network for Detection of the Mesospheric Change (NDMC) to radiometric standards via a Near Infrared Filter Radiometer, 2018, J. Phys.: Conf. Ser. **972** 012006.
3. I. Müller et al., Calibration capabilities at PTB for radiation thermometry, quantitative thermography and emissivity, 14th Quantitative InfraRed Thermography Conference, 2018, 10.21611/qirt.2018.015.