Geosci. Instrum. Method. Data Syst. Discuss., 5, C110–C117, 2015
www.geosci-instrum-method-data-syst-discuss.net/5/C110/2015/

Geoscientific Instrumentation Methods and Data Systems Discussions

Interactive comment on "A compact receiver system for simultaneous measurements of mesospheric CO and O_3" *by* P. Forkman et al.

Anonymous Referee #1

Received and published: 4 November 2015

Forkman et. al. present in their manuscript "A compact receiver system for simultaneous measurements of mesospheric CO and O3" a novel design of a millimeterwave radioometer aimed at simultaneous measurements of O3 and CO. They also describe the calibration of the measurements spectra and how to retrieve information about O3 and CO from it. They proceed to give a error analysis and compare the measurements to measurements from the satellite instrument EOS-MLS on the AURA satellite.

General:

The presentation of the receiver design, aiming at users rather than millimeterwave specialists is interesting and also much needed. Development, design and construction of a millimeterwave instrument is a risky venture, especially for non-experts. Hence a

blueprint for an affordable and working receiver design would help much, especially in the view of the lack of satellite instruments measuring the middle atmosphere in the near futures.

Also the possibility to measure two gases simulteanously without changing the LO frequency is interesting in order to simplify the instrument design.

However I see some severe limitation to the presented design as outlined below.

CO as a tracer has been used by others, e.g. Funke et.al (2009). Please refer to some of the recent scientific history when attempting to interpret CO profiles and to justify why measurements of mesospheric CO is interesting.

I recommend the PfD thesis of Dr. Hoffmann (2012) for a detailed account of the interpretion of measurements of CO by ground-based millimeterwave radiometry.

Generally the connection to existing work is very cursory and not sufficient. For both gases CO and O3 exist a number of instruments measuring O3 or CO, so neither measurements are new. The advantages and disadvantages of the presented instrument are only little discussed and not related to other measurement principles.

The manuscript should be published after a major revision.

Introduction

The discussion of existing work related to millimeterwave measurements of Ozone and CO is by far not complete. A few examples, not an exhaustive literature research:

Palm et al (2010) describe an Ozone instrument (OZORAM) with emphasis to the mesosphere. They used EOS-MLS on the AURA satellite and the SABER instrument on the TIMED satellite to compare the OZORAM results to satellite measurements and found, that MLS-measurements (version 2.2) is not comparing well to OZORAM at 70 km altitude and above, whereas SABER measures similar values. From Palm et.al (2010) I would conclude that the MLS measurements in version 2.2 were not able to measure O_3 as high as 70 km. Has this changed in the new version?

Boyd (2007) also discusses an ozone instrument measuring at 110 GHz and also discusses comparison to MLS.

Hocke (2007) provides yet another comparison of a millimeterwave measurements of Ozone at 142 GHz and also compares to a profiles obtained from several satellite instruments, including MLS.

Connor (1994) and Connor (1995) discussed millimeterwave radiometry at 110 GHz and the error analysis in great detail.

Especially the latter publication of Connor sets a baseline for error discussion of retrievals of O_3 from millimeterwave instruments and should not be left out. The findings sould also be discussed refering to this publication.

Studer et.al. (2013) has not been published in AMT but only in discussions and a final publication is not foreseen. For the described instrument, GROMOS, there are other publications which might be more appropriate.

A similar lack in history can be stated for CO measurements by ground based millimeterwave radiometry. Recent experiments include Biagio (2010) and de Zafra (2004). Kuenzi and Carlson (1982) used the same frequency to measure atmospheric CO.

Please complete the discussion of measurements of O_3 and CO by means of ground-based millimeterwave radiometry and put your instrument into context of the existing scientific literature. This is also valid for the discussion of the results and the conclusion.

Page 319

I dont quite understood why the authors choose frequency switching as the Dicke switch method opposed to the total power calibration used for other instruments. The method restricts the bandwith, hence is the reason that the instrument cannot measure

O_3 in the lower and middle stratosphere, I would doubt that the method is appropriate for the measurement of O_3. Because a large part of O_3 is below the lower boundary of the measurement I would be concerned about varying attenuation due to O_3. Yet the authors did not mention how they deal with it.

It seems that the instrument could measure in Total Power mode (load-switching) also. Is this true? Please discuss the advantages of the frequency method with reference to the load-switching mode, in particular because the frequency-switching method places severe restrictions to O_3 measurements.

CO is only abundant in the polar region. In the presence of sun light, it is removed quickly from the mesosphere. Hence the possibility to measure CO and O_3 simultaneously is not interesting in mid latitudes or tropical regions.

The integration time for one measurement is quite long for O_3 in the mesosphere, given that the transisition between night and day is more or less instantaneous. The measurement would last over the terminator, so mixing two very different states in the mesosphere occurs.

page 321

line 16 For the radiometers ASTRID and KONRAD, is there any publication describing those instruments?

line 20 It took a while to understand, that "Sect. 3.3" refers to this publication and not to the publication of Elgered and Jarlemark (1998). Please append the sentence with 'In Sect. 3.3 of this publication we describe the use ...' or similar to spare the reader a bit of flipping to and fro.

Page 322

HITRAN 2004 is used in this study for the line parameters. Why not using one of the later catalogs, i.e. HITRAN 2008 or HITRAN 2012? Please justify. It should be a simple exercise to exchange the spectral data base and rerunning the whole time series.

Page 323, line 15ff: Are you using an iteration method for solving this equation or do you assume a linear forward model?

Page 323, line 1: The baseline ripple is often caused by a Fabry-Perot effect (In the Conclusion you write: 'Standing waves arising from reflections...') in the optical path and is described as a cos function. I would not consider a polynomial appropriate to model such a function. Why do you not use sinoids to model the baseline ripple, especially because it is straight forward to include it in the forward model and also in the K-matrix.

Please add a section showing the spectrum with and without the modeled baseline ripple and its effect to the retrieved profiles.

Page 324 line 16ff

I would expect the spectrometer to exhibit spectral leaking, i.e. the spectrometer channels have a response function which extends over more than one channel. Is this accounted for by providing a correlation between channels or is the spectral leaking modeled separately in the forward model?

page 327 line 11-18. I think this explanation, that the CO profile reflects the movement of the air is a bit short. Especially in summer, I doubt that at 57°N the reversal of the residual circulation is measured, but rather the CO poor air in mid-latitudes.

The variations on a daily base and shorter may be caused by movements of the polar vortex, but other causes are already possible, e.g. the effect of gravity waves.

Page 328 ff

I do not fully understand the error discussion. What do the authors mean by accuracy and precision (I know the concepts, but can not understand how they derive those figures).

Page 329

I would think that errors spectroscopy provides also cause a large systematic uncertainty, possibly even larger. In the light of the authors former statement, that the line positions of the O3 line is off by a fair amount, I would hesitate to put too much trust into the other line parameters.

Figure 8: Comparing the upper panel of figure 8 (CO timeseries) with the AVK of CO in figure 9, I wonder where the enhancement in 90 km is really appearing. The AVK rather show, that the instrument is not sensitive at this altitude.

Hoffmann et.al. (2011) discuss very detailed the interpretation of the AVK and results from ground based millimeterwave radiometry. Especially the problem of the non-uniqueness of the Voigt profile due to the strong temperature broadening from higher altitudes is not mentioned there. Please include and discuss there findings with respect to your CO results.

Hoffmann et. al. (2011) present extensive work on the comparison of CO measured by MLS and ground bases millimeterwave radiometry. Please relate your discussion to the results presented in this work.

Page 331 line 11: I would think, the most severe drawback of the frequency switching method is the small bandwidth, with restricts the measurements to the upper stratosphere and mesosphere only.

Page 331 line 21 - 26 At least Palm (2010) and Hoffmann (2011) do not use a single absorption to model the troposphere but use a model similar to the one presented here in order to adjust for the tropospheric attenuation in their retrievals. They also include the troposphere in the forward model and retrieve its absorption simultaneously with the O3 or CO profiles.

Technical comments:

Page 322 Line 13 'a channels response' -> 'a channel response'

Page 325 line 20: 'Both these values ...' -> 'Both values ...'

Page 327 line 11: '...cover...' -> '...covers...'

Figure 8 The title of the upper figure is clipped

Biagio, C. D.; Muscari, G.; di Sarra, A.; de Zafra, R. L.; Eriksen, P.; Fiocco, G.; Fiorucci, I. & Fuà, D. Evolution of temperature, O3, CO, and N2O profiles during the exceptional 2009 Arctic major stratospheric warming as observed by lidar and millimeterâĂŘwave spectroscopy at Thule (76.5°N, 68.8°W), Greenland JOURNAL OF GEOPHYSICAL RESEARCH, 2010, 115, D24315

Boyd, I. S.; Parrish, A. D.; Froidevaux, L.; von Clarmann, T.; Kyrölä, E.; Russell III, J. M. & Zawodny, J. M. Ground-based microwave ozone radiometer measurements compared with Aura-MLS v2.2 and other instruments at two Network for Detection of Atmospheric Composition Change sites J. Geophys. Res, 2007, 112, D24S33

Connor, B. J.; Siskind, D. E.; Tsou, J. J.; Parrish, A. & Ellis E. Remsberg, E. Ground-based microwave observation of ozone in the upper stratosphere and mesosphere J. Geophys. Res, 1994, 99, 16757 - 16770

Connor, B. J.; Parrish, A.; Tsou, J.-J. & McCormick, M. P. Error analysis for the ground-based microwave ozone measurements during STOIC J. Geophys. Res, 1995, 100, 9283 - 9291

Hocke, K.; Kämpfer, N.; Ruffieux, D.; Froidevaux, L.; Parrish, A.; Boyd, I.; von Clarmann, T.; Steck, T.; Timofeyev, Y. M.; Polyakov, A. V. & Kyrölä, E. Comparison and synergy of stratospheric ozone measurements by satellite limb sounders and the ground-based microwave radiometer SOMORA Atmos. Chem. Phys., 2007, 7, 4117 - 4131

Hoffmann, C. G. Application of CO as a tracer for dynamics in the polar winter middle atmosphere – A study based on ground-based microwave observations in Kiruna Universität Bremen, 2012 http://nbn-resolving.de/urn:nbn:de:gbv:46-00102610-19

Palm, M.; Hoffmann, C. G.; Golchert, S. H. W. & Notholt, J. The ground-based MW radiometer OZORAM on Spitsbergen – description and status of stratospheric and

mesospheric O3-measurements Atmos. Meas. Tech., 2010, 3, 1533 - 1545

Funke, B. et al: Carbon monoxide distributions from the upper troposphere to the mesosphere inferred from 4.7 μm non-local thermal equilibrium emissions measured by MIPAS on Envisat, Atmos. Chem. Phys., 9, 2387–2411, doi:10.5194/acp-9- 2387-2009, 2009.

de Zafra, R. L. & Muscari, G. CO as an important high-altitude tracer of dynamics in the polar stratosphere and mesosphere J. Geophys. Res., 2004, 109, D06105

Interactive comment on Geosci. Instrum. Method. Data Syst. Discuss., 5, 311, 2015.