Geosci. Instrum. Method. Data Syst. Discuss.,
doi:10.5194/gi-2015-39-AC2, 2016

Geoscientific Instrumentation Methods and Data Systems Discussions

Interactive comment on "European UV DataBase (EUVDB) as a repository and quality analyzer for solar spectral UV irradiance monitored in Sodankylä" *by* A. Heikkilä et al.

A. Heikkilä et al.

Anu.Heikkila@fmi.fi

Received and published: 17 June 2016

Answers from the authors to the Interactive comment on "European UV DataBase (EUVDB) as a repository and quality analyzer for solar spectral UV irradiance monitored in Sodankylä" by A. Heikkilä et al.

Anonymous Referee #2

Received and published: 4 March 2016

The comments are answered below in the following sequential manner: Q denoting the original comment; A denoting the authors' answer to the comment, and C denoting the corrections and amendments to the manuscript.

The authors wish to thank the Referee for his/her invaluable comments and suggestions that assisted in improving the manuscript. The authors also highly appreciate the suggestion on a follow-up study and aim at realizing and reporting on such a study.

General comment: Heikkilä et al., "European UV Database as a repository and quality analyzer for solar spectral UV irradiance monitored in Sodankylä" The authors describe the quality assurance (QA) methodology that is currently used with the solar spectral irradiance measurements. Their approach comprises several metrics that provide important supplemental information about the actual spectral data. This metadata, or, in the authors' terminology, "flags", allows the end-users to assess the reliability of the data. For those actually carrying out the measurements using a spectroradiometer, the QA is an invaluable tool for instrument maintenance and calibration,which is crucial for research based on data covering several decades. In my opinion, the manuscript is of relevance for the science community and suitable for publication in Geoscientific Instrumentation, Methods and Data Systems. I do, however, have a few comments and recommend a minor revision before publication.

Q1. The definition of high quality is discussed in the introduction but only references to literature (Webb et al. and Seckmeyer et al.) are provided. In my opinion, the manuscript would benefit from having a short qualitative description of what actually is considered "standard quality".

A1: We realize that this is likely a question of interest to the readers. Even though no actual standard has been developed, the scientific community does pursue high quality data by following the guidelines jointly prepared. These guidelines are included in the referenced literature. They comprise of lists of specifications for the instruments in use that must be fulfilled simultaneously, several methods for instrument characterizations and maintenance and - last but not least - a number of careful quality checks which should be performed by the operator. Unfortunately, describing the guidelines in full detail is beyond the scope of this paper. However, we have added a note on this issue in the chapter of Results and discussion.

C1: We have added the following paragraphs into the chapter "Results and discussion" and we have included the references therein in the References of the manuscript:

"The quality of solar spectral UV irradiance measurements has been addressed and exhaustively discussed ever since the launch of the first long-term monitoring programs in the late 1980's. While there is no actual standard up to date defining the requirements set to high quality solar UV irradiance data, a common understanding on the requirements is shared by the scientific community and documented in the reports prepared by international advisory groups (Webb et al. 1998, 2003; Seckmeyer et al. 2001, 2005, 2010).

In general, the required quality depends on the scientific question. These could be site specific issues or questions in a wider context, analyzing geographical differences and their causes, for example, as has been done by Seckmeyer et al. (2008a, 2008b). For these two studies, spectra with green flags have been used only. Alternatively, the analysis may focus on a specific question like estimating probability functions (Voskrebenzev et al, 2015), where more spectra with non-green flags may be included."

References:

Seckmeyer, G., Glandorf, M., Wichers, C., McKenzie, R., Henriques, D., Carvalho, F., Webb, A., Siani, A.-M., Bais, A., Kjeldstad, B., Brogniez, C., Werle, P., Koskela, T., Lakkala, K., Gröbner, J., Slaper, H., den Outer, P., & Feister, U. (2008a). Europe's darker atmosphere in the UV-B. Photochemical & Photobiological Sciences, 7(8), 925-930.

Seckmeyer, G., Pissulla, D., Glandorf, M., Henriques, D., Johnsen, B., Webb, A., Siani, A.-M., Bais, A., Kjeldstad, B., Brogniez, C., Lenoble, J., Gardiner, B., Kirsch, P., Koskela, T., Kaurola, J., Uhlmann, B., Slaper, H., den Outer, P., Janouch, M., Werle, P., Gröbner, J., Mayer, B., de la Casiniere, A., Simic, S., & Carvalho, F. (2008b). Variability of UV irradiance in Europe. Photochemistry and Photobiology, 84(1), 172-179.

Voskrebenzev, A., Riechelmann, S., Bais, A., Slaper, H., & Seckmeyer, G. (2015). Estimating probability distributions of solar irradiance. Theoretical and Applied Climatology, 119(3-4), 465-479.

Q2. Likewise, a brief description of the Brewer and its nominal operating mode(s) would be good to have. Perhaps the authors could also describe some of the routine operation challenges, if any, that can or could be effectively tackled by using the QA system rather than on-site routines.

A2: We agree with the Referee as we realize that this could be of interest to the readers.

C2: We have added a brief general description on the nominal operating modes of Brewer, reading as follows:

The Brewer spectrophotometer is primarily used to measure atmospheric total column ozone and solar spectral UV irradiance (Bais et al., 1996; Brewer, 1973). In addition, its measurements may be used to derive atmospheric sulphur dioxide SO2 (Cappellani and Bielli, 1995), nitrogen dioxide NO2 (e.g. Cede et al. 2006; Diémoz et al. 2014), and aerosol optical depth (Gröbner et al. 2001; Kazadzis et al. 2005; Marenco et al. 2002). The instrument consists of foreoptics to collect photons of solar UV radiation, a monochromator to separate the irradiance (photons) into spectral components at specific wavelengths, a photomultiplier tube as a radiation detector, and a sun tracker to follow the position of the Sun in the sky. Brewer#037 MkII spectrophotometer in Sodankylä employs a single monochromator, Rejection of stray light is more challenging to the single than to double monochromators, especially at wavelengths below 305 nm (Bais et al., 1996). The wavelength range of the instrument in 290-325 nm.

The Brewer spectrophotometer is designed to operate fully automatically following a schedule predefined by the operator. The schedule contains command strings, each meaning a measurement or an instrumental test performed by the Brewer. Measurement of solar UV irradiance spectrum is scheduled to take place at least every half an hour, typically every twenty minutes. Measurements for total column ozone are done between the UV scans, either as direct sun, zenith sky or focused sun measurements, depending on the air mass (Karppinen et al., 2016). The schedules have slightly changed over time but the main principles have stayed as described above. Currently, the schedule is defined for each day separately to optimize the number of measurements. Between the sky measurements, the spectrometer makes tests, which are used as quality control (QC) tools to monitor, for instance, the performance of the motors aligning the optics and the photomultiplier tube detecting the photons.

References:

Bais, A., Zerefos, C. and McElroy, C.: Solar UVB measurements with the double- and single-monochromator Brewer Ozone Spectrophotometers, Geophys. Res. Lett., 23, 833–836, 1996.

Brewer, A. W.: A replacement for the Dobson spectrophotometer?. Pure Appl. Geophys., 106-108, 919–927, 1973.

Cappellani, F. and Bielli, A.: Correlation between SO2 and NO2 measured in an atmospheric column by a Brewer spectrophotometer and at ground-level by photochemical techniques, Environmental Monitoring and Assessment, Vol 35, 2, 77-84, 1995. Cede, A., J. Herman, A. Richter, N. Krotkov, and Burrows, J.: Measurements of nitrogen dioxide total column amounts using a Brewer double spectrophotometer in direct Sun mode, J. Geophys. Res. 111, D05304, doi:10.1029/2005JD006585, 2006.

Diémoz, H., Siani, A. M., Redondas, A., Savastiouk, V., McElroy, C. T., Navarro-Comas, M., and Hase, F.: Improved retrieval of nitrogen dioxide (NO2) column densities by means of MKIV Brewer spectrophotometers, Atmos. Meas. Tech., 7, 4009-4022, doi:10.5194/amt-7-4009-2014, 2014.

Gröbner, J., R. Vergaz, V. E. Cachorro, D. V. Henriques, K. Lamb, A. Redondas, J. M. Vilaplana, and Rembges, D.: Intercomparison of aerosol optical depth measurements in the UVB using Brewer spectrophotometers and a Li-Cor spectrophotometer,

Geophys. Res. Let. 28, 1691-1694, 2001.

Karppinen, T., Lakkala, K., Karhu, J. M., Heikkinen, P., Kivi, R., and Kyrö, E.: Brewer spectrometer total ozone column measurements in Sodankylä, Geosci. Instrum. Method. Data Syst., 5, 229-239, doi:10.5194/gi-5-229-2016, 2016.

Kazadzis, S., Bais, A., Kouremeti, N., Gerasopoulos, E., Garane K., Blumthaler, M., Schallhart, B. and Cede A.: Direct spectral measurements with a Brewer spectroradiometer: Absolute calibration and aerosol optical depth retrieval, Appl. Opt., 44(9), 1681 – 1690, 2005.

Marenco, F., A. di Sarra, and De Luisi, J.:Methodology for determining aerosol optical depth from Brewer 300-320-nm ozone measurements, Appl. Opt., 41, 1805-1814, 2002.

In Discussion, we have also inserted the following paragraph dealing with the potential use of the QA tools to meet the operational challenges:

"Currently, the QA tools of the EUVDB are mainly used to complement the on-site QC routines. In addition, they could be used to remotely monitor the performance of the instrument at an unmanned station. If the spectra were automatically uploaded into the EUVDB, the QA flags of the database could alert on a problem with the wavelength setting (Shift1, Shift2), or snow/dirt covering the entrance optics of the instrument and blocking the incoming radiation (Start_irr, Spike_shape, Too low irradiance). They could be also used to separate scans made under changing cloud conditions (Spike_shape, Moving clouds), in case the data is used for validation of near-real time satellite data or model calculations. As one solar UV scan takes up to 3 minutes, the cloud conditions may change during the scan, affecting the reliability of the comparison."

Q3. (Results and discussion) Does the number of spectra (4656-6724) refer to the annual measurements? Why does this vary? Instrument trouble or do you only carry out measurements when certain criteria are met?

A3: Yes, the number of spectra refer to the annual number of scans of solar spectral UV irradiance. The annual amount of scans vary due to several reasons, including instrument trouble. Five main factors affecting the annual number of collected scans may be distinguished:

1. Brewer #037 has been calibrated for total column ozone measurements according to the list given in the table below (published in Karppinen et al 2016). Some of the calibrations have been performed at the home site of the instrument (Sodankylä) whereas some of them have been realized at other sites within measurement intercomparison campaigns. Calibration performed in Finland (in Sodankylä or in Jokioinen) has caused a break of 5-7 days into the time series of the solar UV scans. The gap caused by an intercomparison campaign is longer, typically from 2 weeks to 1 month. The lengths and timings of these gaps vary from year to year, resulting in variability in the amount of solar UV scans collected annually at the home site of Brewer #037.

1988 April Sodankylä 1989 June Sodankylä 1990 June Sodankylä 1993 November Izaña 1994 September Jokioinen 1995 June Sodankylä 1996 October Izaña 1997 July Sodankylä 1998 June Jokioinen 1999 June Jokioinen 2000 June Tylosand 2001 June Jokioinen 2002 June Sodankylä 2003 June Sodankylä 2004 June Jokioinen 2005 June Sodankylä 2006 June Jokioinen 2007 May Sodankylä 2008 June Jokioinen 2009 June Sodankylä 2009 December Izaña 2011 November Izaña 2013 November Izaña

2. Brewer #037 has been calibrated for UV irradiance by performing lamp measurements in the optical laboratory of the Arctic Research Center of the Finnish Meteorological Institute in Sodankylä. Typically, the frequency of these measurements has been 6-8 weeks. However, there are year-to-year differences in the frequency due to, for instance, the availability of personnel capable of performing the measurements.

3. The operating software of Brewer #037 seizes up from time to time. This may have resulted in a loss of several UV scans, depending on how quickly the operator has

noticed the jam. The software has been under long-term development by the supplier IOS Inc. over the years, resulting in a number of updated versions of the software with enhanced operational reliability. Some of the versions have been more prone to seize up than the others. Hence, the number of jams due to the software varies from year to year. Recently, this issue has been addressed by incorporating the measurements into the operative 24/7 control system of the FMI observational services. The system alerts immediately in case of malfunctions so that the measurements can be restarted and no large gaps are formed in the daily data set (Mäkelä et al. 2016).

4. The frequency the Brewer #037 performs solar UV scans is regulated by the predefined schedules. The schedules have been updated over the operational years. Unfortunately, there has been no system to keep track on the changes made in the schedules. Improved sampling of the diurnal cycle of the solar UV irradiance has been one of the objectives when redefining the schedules. The number of scheduled daily UV scans has therefore likely increased over the years. This could be verified by examining the days with uninterrupted sky measurements for the daily number of scans. While an exhaustive analysis would have been beyond the scope of this study, we selected two pairs of uninterrupted measurement days in June and July in 1991 and 2014. The result was as follows:

16891 17 Jun 1991 Number of spectra: 24 (first: 00:26:31 UTC; last: 20:22:36 UTC)
16814 16 Jun 2014 Number of spectra: 31 (first: 00:19:24 UTC; last: 21:42:20 UTC)

19891 17 Jul 1991 Number of spectra: 23 (first: 00:38:53 UTC; last: 19:44:39 UTC)
19814 16 Jul 2014 Number of spectra: 31 (first: 00:35:10 UTC; last: 20:40:48 UTC)

The daily amount of UV scans is indeed larger in 2014 than in 1991.

5. The QC/QA procedures reject part of the measured spectra as erroneous. All data submitted to EUVDB is subject to final (Level 2) QA including wavelength correction employing the program ShicRIVM. All the scanned spectra are also visually inspected and compared against ancillary broadband and modelled UV data (Lakkala

et al. 2008), and clearly erroneous spectra are rejected. Typically five to ten spectra are rejected at that stage. This QA procedure has been followed since 2005. The minimum number of annually rejected spectra per year since 2005 is one (in 2010 and in 2014). The corresponding maximum number of spectra is 16 (in 2007). Over the years 1990-2004, the number of spectra rejected at the final stage of QA has been larger. Especially during the first few operational years, there were problems with the data transfer, for instance, resulting in occasional corruption of transferred data files, which increased the number of rejected scans.

All of the above mentioned factors introduce variability to the annual number of collected scans of solar UV irradiance. We estimate that the first three factors are more significant than the last two. The bar chart below shows the development of the annual number of spectra. The inter-annual variability is large, but the number appears to have grown from the 1990's (please see the supplementary Fig. 1).

We have rewritten the first paragraph of Chapter 3 and included a brief explanation to the variability of annual amounts of scans, as we can see that this might be of interest to the readers.

References:

Karppinen, T., Lakkala, K., Karhu, J. M., Heikkinen, P., Kivi, R. & Kyrö, E. (2016). Brewer spectrometer total ozone column measurements in Sodankylä. Geoscientific Instrumentation, Methods and Data Systems Discussions, 2016, 1-18. doi:10.5194/gi-2015-41

Lakkala, K., Arola, A., Heikkilä, A., Kaurola, J., Koskela, T., Kyrö, E., Lindfors, A., Meinander, O., Tanskanen, A., Gröbner, J. & Hülsen, G. (2008). Quality assurance of the Brewer spectral UV measurements in Finland. Atmospheric Chemistry and Physics, 8(13), 3369-3383.

Slaper, H., Reinen, H., Blumthaler, M., Huber, M. & Kuik, F. (1995). Compar-

ing groundâĂŘlevel spectrally resolved solar UV measurements using various instruments: A technique resolving effects of wavelength shift and slit width. Geophysical Research Letters, vol. 22, no. 20, pp. 2721-2724.

C3: We have added the following text in the beginning of the Chapter 3:

The annual amount of scans vary due to several reasons. Five main factors affecting the annual number of collected scans may be distinguished, described briefly in the following:

“1. Annual maintenance and calibrations for total column ozone measurements have caused breaks of varying durations in the solar UV measurements. Calibration performed in Finland (in Sodankylä or in Jokioinen) has caused a break of 5-7 days into the time series of the solar UV scans. The gap caused by an intercomparison campaign abroad has been longer, typically from 2 weeks to 1 month. The lengths and timings of these gaps vary from year to year, resulting in variability in the amount of solar UV scans collected annually at the home site of Brewer #037.

2. Brewer #037 has been calibrated for UV irradiance by performing lamp measurements in the optical laboratory of the Arctic Research Center of the Finnish Meteorological Institute in Sodankylä. Typically, the frequency of these measurements has been 6-8 weeks. However, there are year-to-year differences in the frequency due to, for instance, the availability of personnel capable of performing the measurements.

3. The operating software of Brewer #037 seizes up from time to time. This may have resulted in a loss of several UV scans. The software has been under long-term development by the supplier IOS Inc. over the years, resulting in a number of updated versions of the software with enhanced operational reliability. Some of the versions have been more prone to seize up than the others. Hence, the number of jams due to the software varies from year to year.

4. The frequency the Brewer #037 performs solar UV scans is regulated by pre-defined

schedules. The schedules have been updated over the operational years. Improved sampling of the diurnal cycle of the solar UV irradiance has been one of the objectives when redefining the schedules. The number of scheduled daily UV scans has therefore increased over the years.

5. The on-site QC/QA procedures reject part of the measured spectra as erroneous. All data submitted to EUVDB is subject to final (Level 2) QA including wavelength correction employing the program ShicRIVM. All the scanned spectra are also visually inspected and compared against ancillary broadband and modelled UV data (Lakkala et al. 2008), and clearly erroneous spectra are rejected. Typically five to ten spectra are rejected annually at that stage. This QA procedure has been followed since 2005. The minimum number of annually rejected spectra per year since 2005 is one (in 2010 and in 2014). The corresponding maximum number of spectra is 16 (in 2007). Over the years 1990-2004, the number of spectra rejected at the final stage of QA has been larger.

All of the above mentioned factors introduce variability to the annual number of collected scans of solar UV irradiance. The first three factors may be estimated more significant than the last two."

We have also added the following references in the list of references:

Karppinen, T., Lakkala, K., Karhu, J. M., Heikkinen, P., Kivi, R. & Kyrö, E. (2016). Brewer spectrometer total ozone column measurements in Sodankylä. Geoscientific Instrumentation, Methods and Data Systems Discussions, 2016, 1-18. doi:10.5194/gi-2015-41

Lakkala, K., Arola, A., Heikkilä, A., Kaurola, J., Koskela, T., Kyrö, E., Lindfors, A., Meinander, O., Tanskanen, A., Gröbner, J. & Hülsen, G. (2008). Quality assurance of the Brewer spectral UV measurements in Finland. Atmospheric Chemistry and Physics, 8(13), 3369-3383.

Slaper, H., Reinen, H., Blumthaler, M., Huber, M. & Kuik, F. (1995). Comparing groundâĂŘlevel spectrally resolved solar UV measurements using various instruments: A technique resolving effects of wavelength shift and slit width. Geophysical Research Letters, vol. 22, no. 20, pp. 2721-2724.

Q4: (Results and discussion, page 10, lines 22-28) The authors state that a detailed examination of the selected cases provides a more profound understanding of the function and performance of the QA methodology. While I agree that a closer look at the data does help in understanding why a certain flag is there, I don't think a small number of cases is sufficient for generalisation. Are you really sure that you would have arrived to the same conclusions if you had selected different spectra? Wouldn't it be much more useful to collect all spectra with, e.g., Shift1 GREY flag and analyse why the algorithm (built-in to the QA) cannot make any conclusions about wavelength scale shifts? Something like this would be an excellent topic for a follow-up study.

A4: We agree with the Referee on his/her view that the case study presented here cannot result in a comprehensive analysis on the performance of the QA tools. For a deliverable of this kind, the study should exhaustively include all the spectra in the database. Alternatively, a representative sample of spectra could be used. Indeed, retrieval and investigation of all spectra flagged as GREY for a particular quality indicator, like Shift1 targeted to detect the shifts in the wavelength scale, would be extremely interesting. We highly appreciate this suggestion and will certainly aim at a follow-up study on the topic.

C4: The sentences on lines 22-28 in Chapter 3 (Results and discussion) has been rephrased to make the scope of the study more clear as follows:

"Analysis on the statistics of the flag information is obviously an efficient way to get an overall view on different aspects of the data quality. However, the detailed examination of the selected cases as described above gives a more profound insight into the function and performance of the QA tools implemented in the database. Specifically, an understanding on the metrics and categorization used by the different quality indicators helps the data provider and the user in analysing and using the data in a meaningful way. Clearly, the indicators provide an added value to the data set." -> "Analysis on the mere statistics of the flag information is obviously an efficient way to get an overall view on different aspects of the quality of the data of interest. However, a detailed examination of selected cases as described above is apt to give an even more profound insight into the data studied and the special characteristics therein. Specifically, an understanding on the metrics and categorization used by the different quality indicators helps the data provider and the user in analysing and using the data in a meaningful way. Clearly, the indicators provide an added value to the data set."

We have also added the following paragraph in the end of Conclusions, to further clarify the scope and limitations of the study:

"The analysis on the performance of the QA tools and the conclusion drawn in this study are strictly valid only for the particular data set studied, i.e., solar spectral UV irradiance measured by Brewer #037 in Sodankylä over the years 1990-2014. Further studies on the performance of the QA tools of the EUVDB should therefore cover a number of measurement sites and instruments. A follow-up study still focusing on the Sodankylä Brewer #037 UV data in its unique setting at a high latitude site is also planned. The study is intended to focus on the GREY flags for each quality indicator separately, to investigate the performance of the algorithm in these undetermined cases exclusively. Compatibility of cloudiness conditions determined by the QA tool and synoptic cloud observations would be another interesting topic for a further study."

Q5. (Conclusions) Are the gaps in the time series not recorded in the EUVDB? Would it not be extremely useful for the end-users to quickly find out that there are no spectra for the time they are interested in?

A5: The time gaps as such are not recorded in the database. However, large gaps may be detected in the graphical and tabular presentations on the monthly amounts

of scans on a subpage of "Site list" giving site specific information on each station. The presentations on the page are based on PL/SQL tools operating into the Oracle database. The data retrieved for the availability of data by using these tools could be also used to compile information on the lack of data. This might be indeed a convenient feature in the database. Alternatively, this information could be collected and made available in a form of a simple list on the time periods with no data, supplemented with an explanation for the lack of data.

C5: We have added a paragraph dealing with the gaps in the time series and the annual variability therein in Chapter 3 (Results and discussion). In addition, Chapter 2 now includes a paragraph describing the tabular and graphical summaries on the monthly amounts of data submitted into the database. In this context, it is now also mentioned that the gaps may be inferred from the summaries. The paragraph inserted in Chapter 2 (Materials and methods) in section "QA tools and flagging" reads as follows:

"The EUVDB contains a specific subpage listing all the sites and instruments registered into the database. The page provides site and instrument specific information for the users of the data. In addition, it gives tabular and graphical summaries on the monthly amounts of solar UV spectra submitted to the database. The summaries may be used as indicators on the availability of data. The database user may find the summaries very helpful since they allow quick browsing of the availability of data, prior to actual data retrieval. They can be also used in an inverse manner to infer amounts of missing data, i.e., gaps in the time series."

Q6:. (Conclusions) There were 23% of GREY flags for the overall quality. The authors state that the majority of these indefinite conclusions could be traced to restrictions in the radiative transfer model FastRT that could not handle solar zenith angles above 84 degrees. Are there better models or has your quality flag analysis highlighted a gap in our knowledge? In both cases, these indefinite cases would probably be of high interested for modellers working on radiative transfer at higher latitudes.

A6: The performance of 1-d radiative transfer models may be enhanced by replacing the plane-parallel layers of the atmosphere with a pseudo-spherical model of the atmosphere. This has been also realised in FastRT, improving its performance at high solar zenith angles (sza) and extending the usability of the model up to sza of at least 84 degrees. The earliest versions of libRadtran (the basis of FastRT), in comparison, performed well up to 80 degrees (Mayer et al. 2007).

3-d radiative transfer models like MYSTIC and McArtim (validated by Mayer et al. (2009) and Deutschmann et al. (2011), respectively) are more accurate than capable of simulating solar UV irradiance even up to 91 degrees. Up to date these kinds of models remain too compute-intensive to be run on a server upon an Oracle database.

We agree with the Referee on the point that the cases flagged as GREY in the database should form a highly interesting data set, potentially useful for model development and validation.

References:

Deutschmann, T., Beirle, S., Frieß, U., Grzegorski, M., Kern, C., Kritten, L., Platt, U., Prados-Román, C., Puki, J. & Wagner, T. (2011). The monte carlo atmospheric radiative transfer model McArtim: Introduction and validation of jacobians and 3D features. Journal of Quantitative Spectroscopy and Radiative Transfer, 112(6), 1119-1137.

Mayer, B., Seckmeyer, G., & Kylling, A. (1997). Systematic longâĂŘterm comparison of spectral UV measurements and UVSPEC modeling results. Journal of Geophysical Research: Atmospheres, 102(D7), 8755-8767.

Mayer, B., Hoch, S., & Whiteman, C. (2010). Validating the MYSTIC three-dimensional radiative transfer model with observations from the complex topography of arizona's meteor crater. Atmospheric Chemistry and Physics, 10(18), 8685-8696.

C6: The following paragraph and the references therein has been added into the manuscript (in Discussion) to enlighten the performance of FastRT limiting below szas

of 84 degrees and to emphasize the usability of the cases flagged as GREY in model development and validation:

"The cases flagged as GREY in the database represent a highly interesting data set that could benefit model development and validation. The performance of 1-d radiative transfer models may be enhanced by replacing the plane-parallel layers of the atmosphere with a pseudo-spherical model of the atmosphere. This has been also realised in FastRT, improving its performance at high solar zenith angles and extending the usability of the model up to sza of at least 84 degrees. The earliest versions of libRadtran (the basis of FastRT), in comparison, performed well up to 80 degrees (Mayer et al. 2007). 3-d radiative transfer models like MYSTIC and McArtim (validated by Mayer et al. (2009) and Deutschmann et al. (2011), respectively) are more accurate than capable of simulating solar UV irradiance even up to 91 degrees. Up to date, these kinds of models remain too compute-intensive to be run on a server upon an Oracle database. With the ever advancing computer efficiencies, this may not be the case in the future."

We have also added the following references in the list of references:

Deutschmann, T., Beirle, S., Frieß, U., Grzegorski, M., Kern, C., Kritten, L., Platt, U., Prados-Román, C., Puki, J. & Wagner, T. (2011). The monte carlo atmospheric radiative transfer model McArtim: Introduction and validation of jacobians and 3D features. Journal of Quantitative Spectroscopy and Radiative Transfer, 112(6), 1119-1137.

Mayer, B., Seckmeyer, G., & Kylling, A. (1997). Systematic longâĂŘterm comparison of spectral UV measurements and UVSPEC modeling results. Journal of Geophysical Research: Atmospheres, 102(D7), 8755-8767.

Mayer, B., Hoch, S., & Whiteman, C. (2010). Validating the MYSTIC three-dimensional radiative transfer model with observations from the complex topography of arizona's meteor crater. Atmospheric Chemistry and Physics, 10(18), 8685-8696.

Q7. (Table 2 and 3) Have you compared the cloudy flag with synoptic observations?

Do they agree?

A7: Synoptic cloud observations (cloudiness in octas) are available for Sodankylä for the time period 1 Jan 1990 – 4 Feb 2008. Estimates on cloudiness given by an AWS (Automatic Weather Station) are also available starting from 4 Feb 2008 until today. The synoptic observations have been done every three hours until Jun 15, 2001. During the time period 16 Jun 2011 – 9 May 2006, the observation for 02:40UTC has not been done due to changes in the manpower at the observatory. Since 10 May 2006, until Sep 1 2006, the observations for the nighttime hours 20:40UTC, 23:40UTC, and 02:40UTC are not available for the weekends. Starting from Sep 2 2006, the nighttime observations are not available for any day of the week. Since 1 Jan 2008, also the synoptic observation for 17:40UTC is missing. The temporal resolution of the AWS data is 10 minutes.

We have not carried out any systematic comparison between synoptic/automatic estimates on cloudiness, but we realize that this would be a very interesting topic for a study. For the time period 1 Jan 1990 - 4 Feb 2008, the temporal resolution of 3 hours does not allow finding a representative estimate for every solar UV irradiance scan. The 10-min data from AWS, however, may provide estimates reasonably representative for all the moments of solar spectral UV measurements. We will definitely aim at looking into the issue in our further studies.

C. We have added the following sentence in the end of Conclusions:

“Compatibility of cloudiness conditions determined by the QA tool and synoptic cloud observations would be another interesting topic for a further study.”

– Some minor comments:

Q8: (Abstract, page 1, lines 22-24): The sentence "Spectra scanned by..." is very complex. Could be simplified.

A8: We agree with the Referee on this point. The sentence has been now simplified.

C8: We have simplified the expression and described the contents of the study more precisely by replacing the sentence by two new sentences as follows:

Spectra scanned by the Brewer#037 MkII spectroradiometer in Sodankylä (67.37 °N, 26.63 °E) over the years 1990-2014 and uploaded into the database are examined using the inherent QA tools of the database.

-> We confine the study on the data measured by Brewer#037 MkII spectroradiometer in Sodankylä (67.37 °N, 26.63 °E) in 1990-2014. The quality indicators associated with the UV irradiance spectra uploaded into the database are retrieved from the database and subjected to a statistical analysis.

Q9: (Introduction, page 3, lines 21-22: I do not understand the sentence "The quality indicators are examined for their frequency in general..." Do you refer to "occurrence"?

A9: Indeed, our intension was to examine exactly the occurrence of the different quality indicators.

C9: The sentence has been rephrased as follows:

“The quality indicators are examined for their frequency in general, and for selected case spectra in detail.” -> “The quality indicators are examined for their values (i.e.: colors), and the frequency distribution of the colors, denoting different categories of quality, are derived for each indicator. In addition, selected case spectra, representing different categories of quality, are studied in detail.”

Interactive comment on Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2015-39, 2016.

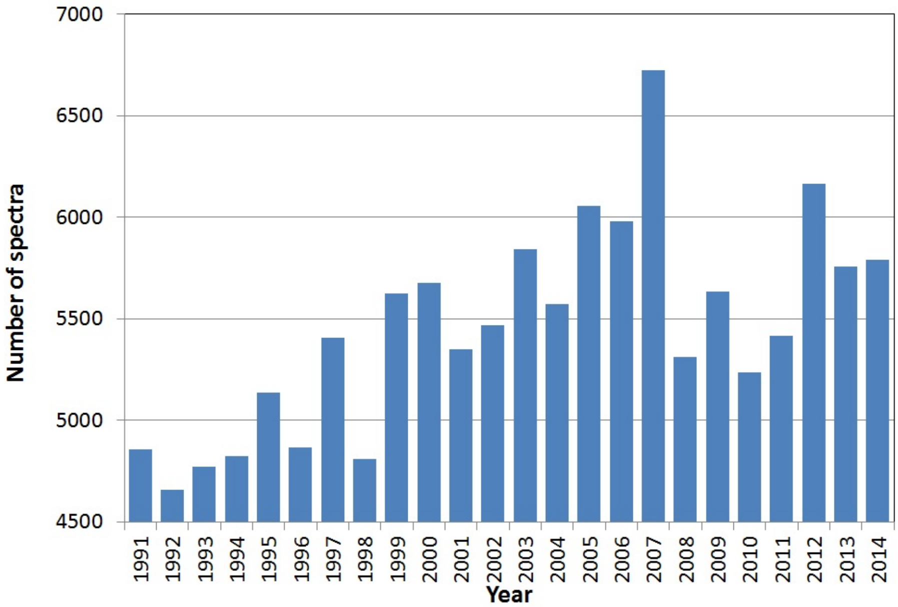

Fig. 1. Number of solar UV irradiance spectra measured annually by Brewer #037 in Sodankylä in 1990-2014