Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2015-42, 2016
Manuscript under review for journal Geosci. Instrum. Method. Data Syst.
Published: 18 January 2016

Geoscientific Instrumentation Methods and Data Systems Discussions
Open Access

Data flow of spectral UV measurements at Sodankylä and Jokioinen

J.S. Mäkelä[1*], K. Lakkala[1,2], T. Koskela[1], T. Karppinen[2], J.M. Karhu[2] , V. Savastiouk[4], H. Suokanerva[2], J. Kaurola[1], A. Arola[3], A.V. Lindfors[1], O. Meinander[1], G. Leeuw[1,5] and A. Heikkilä[1]

[1] {Finnish Meteorological Institute, Research and Development, 00101 Helsinki, Finland}

[2] {Finnish Meteorological Institute, Sodankylä, Finland}

[3] {Finnish Meteorological Institute, Kuopio, Finland}

[4] {IOS Inc, Toronto, Canada}

[5] {Department of Physics, University of Helsinki, 00014 Helsinki Finland}

[*]{now at: University of Jyväskylä, Jyväskylä, Finland}

Correspondence to: K. Lakkala (Kaisa.Lakkala@fmi.fi)

Abstract

We describe the steps that are used at the Finnish Meteorological Institute (FMI) to process spectral ultraviolet (UV) radiation measurements made with its three Brewer spectrophotometers, located in Sodankylä (67°N) and Jokioinen (61°N). The spectrum is measured many times a day, following a pre-programmed schedule. Multiple corrections are made to the data in near real time (dark current, dead time, stray light, noise spikes, temperature, and cosine correction) and quality control is also performed automatically. The Brewers are integrated into the operational control systems at FMI, allowing both quick responses to malfunctions and quick dissemination of the data products. Several data products are produced, including the near-real-time UV index and various daily dosages. The daily doses are calculated each morning for the previous day's data. Once per year the responses of the Brewers are recalculated, and the corrected data are uploaded to the European UV database hosted by FMI.

1

Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2015-42, 2016
Manuscript under review for journal Geosci. Instrum. Method. Data Syst.
Published: 18 January 2016

Geoscientific Instrumentation Methods and Data Systems Discussions
Open Access

1 Introduction

The Brewer spectrophotometer (Brewer) (Bais et al. 1996; Brewer, 1973) is originally degined to measure total ozone, but has also been developed to measure the spectral UV irradiance and sulfur dioxide (SO_2). At present there are over 220 instruments set up by research institutes all over the world (http://kippzonen-brewer.com/). These instruments form an important network for monitoring changes in the total ozone column and, e.g., are used as validation measurements for satellite retrievals. The Finnish instruments were set up in 1990 and 1995, in Sodankylä and Jokioinen, respectively, to respond to the need to monitor total ozone and UV radiation after the discorvery of the Arctic ozone loss. Nowadays, these spectral UV time series of over twenty years are unique and among the longest measured in the Arctic. The homogenized time series have been used for several international studies related to Arctic ozone loss (e.g., Bernhard et al. 2013; Manney et al. 2011; Knudsen et al. 1998), satellite data validation (Hassinen et al. 2008), biological (e.g., Lappalainen et al. 2010; Martz et al. 2009), material (Heikkilä 2014) and health research (Kazantzidis et al. 2009).

The high dynamical range of UV radiation reaching the surface of the Earth sets challenges to the instruments, which are designed to monitor both the short UV-B wavelengths (290-315 nm) and the longer UV-A wavelengths (315-400 nm). Also the Brewer is a versatile and an extremely complex instrument, with many intermediate steps and corrections in the processing chain from data acquisition to final data dissemination. High quality data can only be ensured after careful characterization of the instrument, correction of known measurement errors and careful quality control (QC) and quality assurance (QA). (Seckmeyer et al. 2001; Garane et al. 2006; Lakkala et al. 2008; Webb et al. 2003).

In particular, keeping a Brewer absolutely calibrated is difficult (Bernhard and Seckmeyer 1999, Webb et al. 1998). International campaigns are organized to evaluate the calibration and measurement procedures performed by different Brewers and institutes. The difficulty of the absolute calibration was seen in the last European Brewer comparison organized by the COST 1207 project in El Arenosil, Spain. There, 6 Brewers from 18 differed more than 10% from the reference, when using the calibration provided by the operator. During the comparison campaign, each instrument was recalibrated against a common calibration lamp. The

Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2015-42, 2016
Manuscript under review for journal Geosci. Instrum. Method. Data Syst.
Published: 18 January 2016

Geoscientific Instrumentation Methods and Data Systems Discussions

calibration procedure was performed by only one operator. The results showed that the difference between the two calibrations could be even more than 20%. When using the calibration based on the common lamp, the difference between most of the Brewers diminished to be within ± 6% (Julian Gröbner, personal communication). The remaining difference could result from different data correction and data processing procedures, e.g., differences in the way to take into account the temperature dependence and the angular response of the instrument.

To enable Brewer data from around the world to be comparable, it is necessary to very carefully document the traceability of the calibration and how the data has been processed. Careful documentation should be part of routine QC/QA procedures at each site. This allows anyone to audit all steps which have been taken before delivering the data, and allows changes to be made in post-processing without starting everything from the beginning.

This paper documents the steps that are involved in the acquisition, processing, storage, and dissemination of data from the Finnish Brewers, located in Sodankylä and Jokioinen. The observatory at Jokioinen is in the process of being shut down, and the spectral UV measurements have been moved to Helsinki. Thus, this paper also serves as a historical description of the Jokioinen measurements. A detailed description will be given of the process flow from the raw photon counts to the calibrated spectral UV irradiances and UV products. We also describe the quality control and quality assurance systems that are used to ensure valid output. In a companion paper (Mäkelä et al. 2015, this issue) we describe how the calibration and homogenization of the data is made. In another companion paper (Heikkilä et al. 2015, this issue) we describe how the data are further processed in the EUVDB database.

2 Description of the stations

In Brewers of the Finnish Meteorological Institute (FMI) are operated at two sites: Sodankylä and Jokioinen. Below we briefly describe the site characteristics and which instruments are used at each site.

Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2015-42, 2016
Manuscript under review for journal Geosci. Instrum. Method. Data Syst.
Published: 18 January 2016

Geoscientific Instrumentation Methods and Data Systems Discussions
Open Access

2.1 2.1 The Sodankylä station (Brewer #037 and #214)

The Finnish Meteorological Institute‘s Arctic Research Centre is located at 67.37°N, 27.63°E, altitude 179 m above sea level, in Sodankylä. It has had an operating Brewer Mark II since 1990. The station is described e.g. in Lakkala et al 2003. The near surroundings are pine forest, and at the South-West flows the river Kitinen. The area is surrounded by a large peatland area in the East. There is snow cover from October to late April. The sun is just below the horizon from mid-December to mid-January. Temperatures are ranging from -40C in winter to +30C in summer.

Two Brewers are currently operated at this site: #037 and #214. They are located on the roof of the sounding station (see Figure 1). Brewer #037 has a single monochromator and the wavelength range is 290-325 nm. The instrument has a Teflon diffuser and the width of the slit function is 0.56 nm at FWHM. the later Brewer, #214, has been set up in 2012, in order to work in tandem with Brewer #037 and measure the longer wavelength part of the UV-radiation, as it measures the UV spectrum up to 365 nm. The slit function of the new Brewer is 0.55 nm at FWHM.

2.2 2.2 The Jokioinen station (Brewer #107)

The meteorological observatory in Jokioinen (60.82°N, 23.50°E) is at an altitude of 107 m above sea level. The observatory is located in a rural area surrounded by fields and mainly coniferous forest. The ground is covered by snow most of the time during December-March. Temperatures can range from -20C to +30C. The observatory will be shut down in the near future and the Brewer was moved to Helsinki in November 2015. The Brewer was located on the roof of the sounding station (see Figure 2 and Figure 3).

The FMI acquired the current Mk III Brewer #107 in the observatory in Jokioinen in 1995. Brewer #107 has a double monochromator. It collects UV radiation with a hemispherical field-of-view through a PTFE diffuser enclosed in a quartz dome. It originally operated in the wavelength range 286.5-363 nm, but the optics were changed in April 1997, and its wavelength range since then is 286.5-365- nm. The width of the slit function is 0.59 nm at FWHM.

Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2015-42, 2016
Manuscript under review for journal Geosci. Instrum. Method. Data Syst.
Published: 18 January 2016

Geoscientific Instrumentation Methods and Data Systems Discussions

3 Data processing

3.1 Obtaining raw data

Figure 4 shows the main data flow of the Brewers at FMI. The Brewers have their own operating computers, but the processing of all the data from both stations is done at a single central Unix server. The central computer checks the operational computers every 5 minutes. Any new data are uploaded, and UV data processing begins. The data products are stored at the central computer. Applications that use the data products (see Section 3.4) may access the central computer at any time and are given the latest valid data.

Each Brewer is associated with a nearby automatic weather station (AWS) which measures the visibility according to its own schedule (currently every ten minutes). This information and the total ozone calculated by the Brewer is used in the cosine correction procedure. As auxiliary measurements, a broadband UVB radiometer (Solar Light SL501A) and CM11 pyranometer (Kipp & Zonen), which measures global radiation (305–2800 nm), are synchronized to the Brewer measurements. The measurements of the operational SL501A radiometer of the site are used in non-realtime quality assurance procedures to identify erroneous measurements.

The Brewer operational computers work autonomously, and make measurements based on schedules that are predefined by the operator. Over the years, a variety of schedules have been used, and the schedules for the two sites have supported slightly different research targets at different times. For example, at Jokioinen, more frequent measurements have been made near sunrise and sunset, and at constant air masses, as well as at time of the smallest solar zenith angle (SZA). At Sodankylä, measurements have generally been spread out more evenly throughout the day. However, in terms of the long-term statistical quality of the data, these differences do not matter. At both sites, there has been a measurement at least every half hour during daylight (which can be short in the winter, in particular in Sodankylä due to its location just north of the Artic circle) and a measurement at midday. The exact number of measurements at Jokioinen, for example, may range from about 8 in winter to more than 30 in summer.

5

Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2015-42, 2016
Manuscript under review for journal Geosci. Instrum. Method. Data Syst.
Published: 18 January 2016

Geoscientific Instrumentation Methods and Data Systems Discussions
Open Access

The stability of the Brewer is monitored by measuring an internal lamp (typically about 2-5 times per day, see Figure 5) at the six wavelengths used for total ozone retrieval. The information about the stability is used for the post processing of total ozone measurements, during which the effect of changes in the instrument can be corrected. In addition, every three weeks a more extensive stability check is made using external 50 W lamps. Then, the whole UV wavelength range is measured, and possible drifts in the spectral response of the Brewer can be detected and corrected afterwards during the post processing of UV spectra.

3.2 Processing of spectral data

The spectral processing is done using custom-made software, which is based on the original software provided by the manufacturer, mostly perl and shell scripts. In addition to the near-real-time measurements, every morning the data from the previous day is reprocessed and checked, and all relevant databases updated. The algorithms have been described in detail by Lakkala et al. (2008), and only key points will be summarized here (see Figure 6).

Scans are performed from small to larger wavelengths. The Brewer also returns the dark current for each scan. The total scanning time is about 4 minutes for Brewer #037 and 5 minutes for Brewers #107 and #214 due to the larger wavelength range. The noise spikes are removed based on the method of Meinander et al. (2003). The dark current count is subtracted from measured counts. The dead time is measured daily, and the data are corrected using an iteration of an exponential function including the number of counts and the dead time values. The stray light is calculated as the average of all counts below 292 nm (#107 and #214) or 293 nm (#037). Since #107 and #214 have a double monochromator, the stray light counts are small, while the Sodankylä Brewer #037 has a single monochromator, and the stray light counts are larger (Bais et al. 1996).

The counts are then converted to irradiances by dividing the counts by the daily response. The determination of the daily response is briefly described in Lakkala et al. (2008) and is covered in more detail in the companion paper (Mäkelä et al. 2015, this issue). The temperature and cosine corrections are then made to the spectral irradiances.

Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2015-42, 2016
Manuscript under review for journal Geosci. Instrum. Method. Data Syst.
Published: 18 January 2016

Geoscientific Instrumentation Methods and Data Systems
Discussions

3.3 Data products

The Brewer UV spectra are used to calculate dose rates and daily doses using at least the following action spectra:

- Erythema (CIE weighting function, McKinlay et al. 1987)
- Skin cancer in mice corrected for human skin, 299 nm normalization (de Gruijl, F.R. and J.C. van der Leun, 1994)
- UVB non weighted 290-320 nm
- UVB non weighted 290-315 nm
- UVA non weighted 315-400 nm
- Generalized plant response (normalised at 300 nm) (Caldwell et al. 1986)
- DAN damage (Setlow 1974)
- Photosynthesis inhibition (Mitchell 1990)
- Spore dosimetry AS SIDv2.2 (Munakata et al. 2000)
- Previtamin D (CIE 2006)

In addition the UV index is calculated by multiplying the CIE erythemally weighted UV irradiance in Wm^{-2} by 40 (WMO 1997).

Data are uploaded to the following databases.

- The IDEAS database for quick and long-term quality control: every five minutes
- The FMI climate database (UVI index) every time a new UVI measurement is made.
- The EUBREWNET database for collaboration with the international Brewer community within the COST 1207 project: every 20 minutes (http://rbcce.aemet.es/eubrewnet)
- The database of the FMI-Arctic Research Centre (http://litdb.fmi.fi/): Sodankylä data, once a year
- The European UV database (http://uv.fmi.fi/uvdb/): once a year

3.4 IDEAS: Real-time QA and monitoring

In 2015 a new software has been introduced to facilitate both quick and long term quality control of data, and to improve the potential of the Brewers to work as real-time operational devices. IDEAS is a tool for cheking that the Brewer is functioning correctly. The Brewer itself makes several check measurements during the day, and these measured parameters are used to monitor the stability of the instrument.

7

Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2015-42, 2016
Manuscript under review for journal Geosci. Instrum. Method. Data Syst.
Published: 18 January 2016

The IDEAS software is also used e.g. to calculate the daily mean of total ozone, which can be directly submitted to databases. Every measurement of the Brewer and process of the operating software is recorded in addition to appropriate data files. These are stored as so-called B-files, and updated to the server in which IDEAS is running.

Two sample screenshots are shown (Figure7 and Figure 8) as an example of possible warnings and total ozone calculation and comparison with satellite (OMI-instrument) total ozone. IDEAS is integrated with the real-time 7/24 operational control system of FMI. Automatic warnings of malfunctions of the Brewer are generated within 20 minutes and sent to the control center. If the personnel there are unable to solve the problems, stand-by Brewer specialists can be alerted by text messages when needed.

4 Annual quality assurance

The responsivity times series of the Brewers are recalculated typically once a year. During the process, the drifts of the instruments or the calibration lamps are taken into account. The spectra are recalculated with the methods described in a companion paper (Mäkelä et al 2015, this issue). If necessary, a wavelength correction is made using the SHICRIVM algorithm (Slaper et al 1995). The dose rates are compared with reconstructed UV, model calculations of clear sky UV and global radiation, global radiation and broad band UV data in order to distinguish erroneous measurements. In addition each spectrum is checked by eye and bad measurements are excluded.

5 Conclusions

The FMI has operated Brewer spectrophotometers since the 1990's in two locations, Jokioinen and Sodankylä. During that time, FMI has implemented all corrections and improvements that have been identified by the Brewer community. The outputs are used to calculate multiple UV products which require spectral data. A special new focus is being put on real-time quality control, with the IDEAS software allowing warnings of malfunctions to be sent to operators very rapidly. Although the measurements at the Jokioinen station has

8

Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2015-42, 2016
Manuscript under review for journal Geosci. Instrum. Method. Data Syst.
Published: 18 January 2016

Geoscientific Instrumentation Methods and Data Systems Discussions
Open Access

been stopped, Sodankylä will continue to provide one of the longest continuous spectral UV time series in the world, and new time series will start in Helsinki.

Acknowledgements

Professor Esko Kyrö is acknowledged for starting the Brewer measurements at Sodankylä. We are grateful to the operators at Sodankylä and Jokioinen stations for daily maintenance and for performing the calibrations of the Brewers. We thank the Brewer community within the COST 1207 project for sharing expertise related to Brewer measurements.

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.

Bernhard, G., Dahlback, A., Fioletov, V., Heikkilä, A., Johnsen, B., Koskela, T., Lakkala, K. and Svendby, T.: High levels of ultraviolet radiation observed by ground-based instruments below the 2011 Arctic ozone hole, Atmos. Chem. Phys., 13, 10573-10590, www.atmos-chem-phys.net/13/10573/2013/ doi:10.5194/acp-13-10573-2013, 2013.

Bernhard, G. and Seckmeyer, G.: Uncertainty of measurements of spectral solar UV irradiance, J. Geophys. Res.,104, D12, 14,321-14,345, 1999.

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

Caldwell, M. M., Camp, L.B., Warner, C. W. and Flint, S.D.:Action spectra and their key role in assessing biological consequences of solar UV-B radiation change. In: Worrest, R.C. and M.M. Caldwell (Eds.): Stratospheric ozone reduction, solar ultraviolet radiation and plant life. Springer-Verlag, Berlin. 87-111, 1986.

CIE (International Commission on Illumination), Action spectrum for the production of previtamin D3 in human skin, CIE, 174, 2006.

Eleftheratos K., Kazadzis, S., Zerefos, C. S., Tourpali, K., Meleti, C., Balis, D., Zyrichidou, I., Lakkala, K., Feister, U., Koskela, T., Heikkilä, A. and Karhu, J. M.: Ozone and Spectroradiometric UV Changes in the Past 20 Years over High Latitudes, Atmosphere-Ocean, DOI: 10.1080/07055900.2014.919897, 2014.

Garane, K., Bais, A. F., Kazadzis, S., Kazantzidis, A., and Meleti, C.: Monitoring of UV spectral irradiance at Thessaloniki (1990–2005): data re-evaluation and quality control Ann. Geophys., 24, 3215–3228, 2006.

de Gruijl, F.R. and van der Leun, J. C.: Estimate of the wavelength dependency of ultraviolet carcinogenesis in humans and ist relevance to the risk assessment of a stratospheric ozone depletion. Health Phys., vol 67, 319-325, 1994.

Hassinen S., Tamminen, J., Tanskanen, A., Koskela, T., Karhu, J. M., Lakkala, K. and Mälkki, A.: Description and Validation of the OMI Very Fast Delivery Products, J. Geophys. Res., 113, D16S35, doi:10.1029/2007JD008784, 2008.

Heikkilä, A., Methods for assessing degrading effects of UV radiation on materials, Finnish Meteorological Institute Contributions, 111, ISBN 978-951-697-843-0, Unigrafia Oy, Helsinki, 2014.

Heikkilä, A., Kaurola, J., Lakkala, K., Karhu, J.M., Kyrö, E., Koskela, T., Engelsen, O. Slaper, H. and Seckmeyer, G., European 1 UV DataBase (EUVDB) as a repository and quality analyzer for solar spectral UV irradiance monitored in Sodankylä, submitted to Geoscientific Instrumentation, Methods and Data Systems, this issue. 2015.

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.

Kazantzidis, A., Bais, A., Zempila, M., Kazadzis, S., den Outer, P., Koskela, T. and Slaper, H.: Calculations of the human Vitamin D exposure from UV spectral measurements at three European stations, Photochem. Photobiol. Sci., 2009, 8, 45-51, 2009.

Knudsen, B., Larsen, N., Mikkelsen, I., Morcette, J.-J., Braahten, G., Kyrö, E., Fast, H., Gernand, H., Kanzawa, H., Nakane, H., Dorokhov, V., Yushkov, V., Hanse, G., Gil, M. and ShearmanR.:. Ozone depletion in and below the Arctic vortex for 1997. Geophys. Res. Lett., 25, 627-630, 1998.

Lakkala, K., Kyrö, E. and Turunen, T: Spectral UV Measurements at Sodankylä during 1990–2001, Journal of Geophysical Research, 108, D19, 4621, doi:10.1029/2002JD003300, 2003.

Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2015-42, 2016
Manuscript under review for journal Geosci. Instrum. Method. Data Syst.
Published: 18 January 2016

Geoscientific Instrumentation Methods and Data Systems Discussions

Lakkala, K., Arola, A., Heikkilä, A., Kaurola, J., Koskela, T., Kyrö, E., Lindfors, A. V., Meinander, O., Tanskanen, A., Gröbner, J. and Hülsen. G.: Quality assurance of the Brewer spectral UV measurements in Finland, Atmos. Chem. Phys., 8, 3369–3383, 2008.

Lappalainen N., Huttunen, S., Suokanerva, H., Lakkala, K.: Seasonal acclimation of the moss *Polytrichum juniperinum Hedw*. to natural and enhanced ultraviolet radiation, Environ Pollut., 158, 3, 891-900, 2010.

Manney G., Santee M., Rex M., Livesey N., Pitts M., Veefkind P., Nash E., Wohltmann I., Lehmann R., Froidevaux L., Poole L., Schoeberl M., Haffner D., Davies J., Dorokhov V., Gernandt H., Johnson B., Kivi R., Kyrö E., Larsen N., Levelt P., Makshtas A., McElroy T., Nakajima H., Parrondo M., Tarasick D., von der Gathen P., Walker K. and Zinoviev N.: Unprecedented Arctic ozone loss in 2011, Nature, 478, 469–475, doi:10.1038/nature10556, 2011.

Martz F., Turunen, M., Julkunen-Tiitto, R., Lakkala, K. and Sutinen, M.-L.: Effect of the temperature and the exclusion of UVB radiation on the phenolics and iridoids in *Menyanthes trifoliata L.* leaves in the subarctic, Environmental Pollution, 157, 3471-3478, 10.1016/j.envpol.2009.06.022, 2009.

McKinlay, A. F. and Diffey, B. L.: A reference action spectrum for ultraviolet induced erythema in human skin. CIE Research Note, CIE-Journal, Vol. 6, No.1(17-22), 1987.

Meinander, O., Josefsson, W., Kaurola, J., Koskela, T. and Lakkala, K.: Spike detection and correction in Brewer spectroradiometer ultraviolet spectra, Opt. Eng. 42, 6, 1812–1819, 2003.

Mitchell, B.G., "Action Spectra for ultraviolet photoinhibition of Antarctic phytoplankton and a model of spectral diffuse attenuation coefficients", In Response of Marine Phytoplankton to Natural Variations in UV-B Flux, (Edited by G. Mitchell, I. Sobolev and O. Holm-Hansen), Proc. of Workshop, Scripps Institution of Oceanography, La Jolla, CA, April 5, 1990

Munakata, N., Kazadzis, S., Bais, A.F., Hieda, K., Rontó, G., Rettberg, P., and Horneck, G.: Comparisons of spore dosimetry and spectral photometry of solar-UV radiation at four sites in Japan and Europe. Photochem. Photobiol. 72, 739-745, 2000.

Mäkelä, J.S., Lakkala, K., Meinander, O., Kaurola, J. Koskela, T., Karhu, J.M., Karppinen, T., Kyrö, E., Leeuw, G. and Heikkilä, A.: In search of traceability: Two decades of calibrated Brewer UV measurements in Sodankylä and Jokioinen, submitted to Geoscientific Instrumentation, Methods and Data Systems, this issue, 2015.

Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2015-42, 2016
Manuscript under review for journal Geosci. Instrum. Method. Data Syst.
Published: 18 January 2016

Setlow, R.B.: The wavelengths in sunlight effective in producing skin cancer: A theoretical analysis. Proc.Natl.Acad.Sci., U.S.A. 71:3363-3366, 1974.

Slaper, H., Reinen, A. J., Blumthaler, M., Huber, M., and Kuik, F.: Comparing ground-level spectrally resolved solar UV measurements using various instruments: A technique resolving effects of wavelength shift and slit width, Geophys. Res. Lett., 22, 2721–2724, 1995.

Webb, A., Gardiner, B., Leszczynski, K., Mohnen, V. A., Johnston, P., Harrison, N. and Bigelow, D.: Quality Assurance in Monitoring Solar Ultraviolet Radiation: the State of the Art. World Meteorological Organization (WMO), Global Atmosphere Watch Report, 146, 2003.

Webb, A. R., Gardiner, B. G., Martin, T. J., Leszczynski, K., Metzdoff, J., Mohnen, V. A. and B. Forgan, Guidelines for site quality control of UV monitoring, Rep.Ser. 126, Environ. Pollut. Monit. And Res. Programme, World Meteorol. Organ., Geneva, 1998.

WMO (World Meterorological Organization), Report of the WMO-WHO Meeting of Experts on UVB Measurements, Data Quality and Standardisation of UV indicies, Global Atmopshere Watch Report No. 95, 1997.

12

Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2015-42, 2016
Manuscript under review for journal Geosci. Instrum. Method. Data Syst.
Published: 18 January 2016

Geoscientific Instrumentation Methods and Data Systems Discussions
Open Access

Figure 1. View of Sodankylä observatory. The Brewer is located on the roof in the enclosure on the left.

Figure 2. View of Jokioinen observatory. The Brewer is located on the roof in the enclosure on the left.

14

Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2015-42, 2016
Manuscript under review for journal Geosci. Instrum. Method. Data Syst.
Published: 18 January 2016

Geoscientific Instrumentation Methods and Data Systems Discussions
Open Access

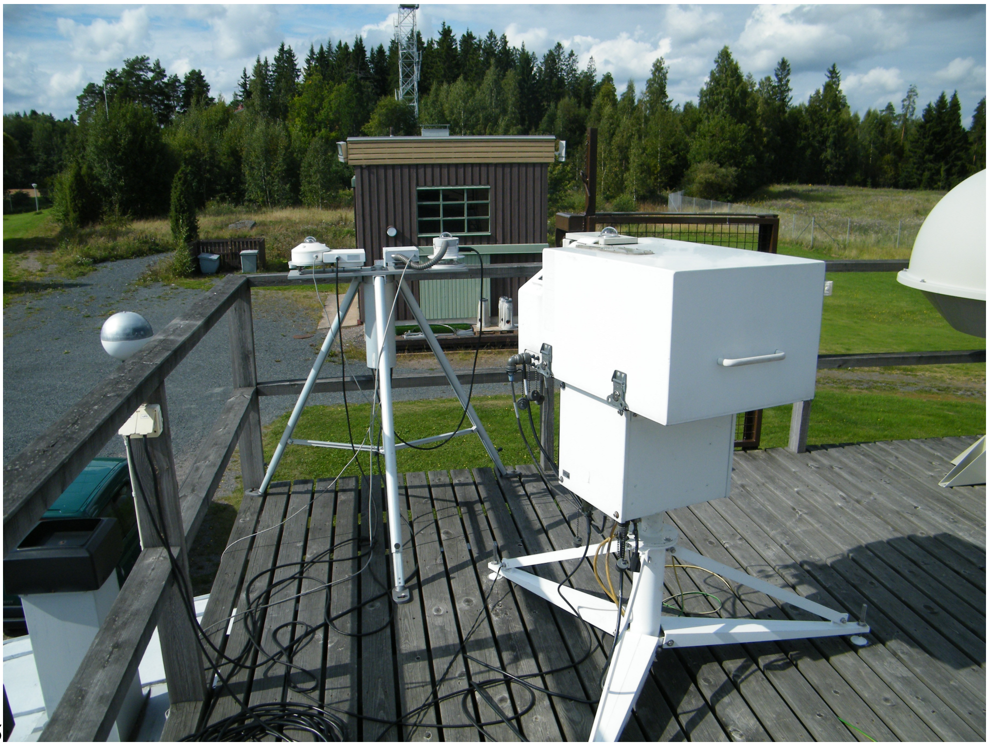


Figure 3. Close up of Brewer # 107 on the roof of the Jokioinen observatory.

15

Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2015-42, 2016
Manuscript under review for journal Geosci. Instrum. Method. Data Syst.
Published: 18 January 2016

Geoscientific Instrumentation Methods and Data Systems
Open Access
Discussions

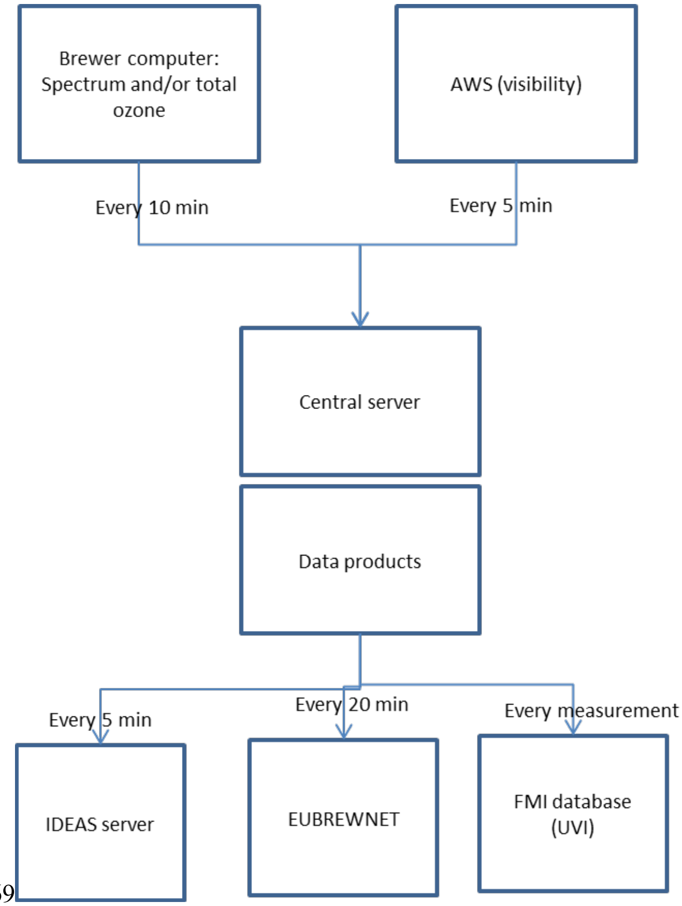


Figure 4. Main data flow of Brewer measurements at the FMI.

16

Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2015-42, 2016
Manuscript under review for journal Geosci. Instrum. Method. Data Syst.
Published: 18 January 2016

Standard lamp R6 (0 sec)

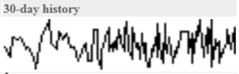
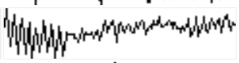
File name	Count	Serial	Expected (+/-20)	Measured	30-day history
B25915.037	12	#037	1670	1874	
B25915.107	10	#107	470	452	
B25915.214	13	#214	240	236	

Figure 5. The stability of the Brewers can be traced e.g. by using the R5 and R6 values of the internal standard lamp (output from IDEAS).

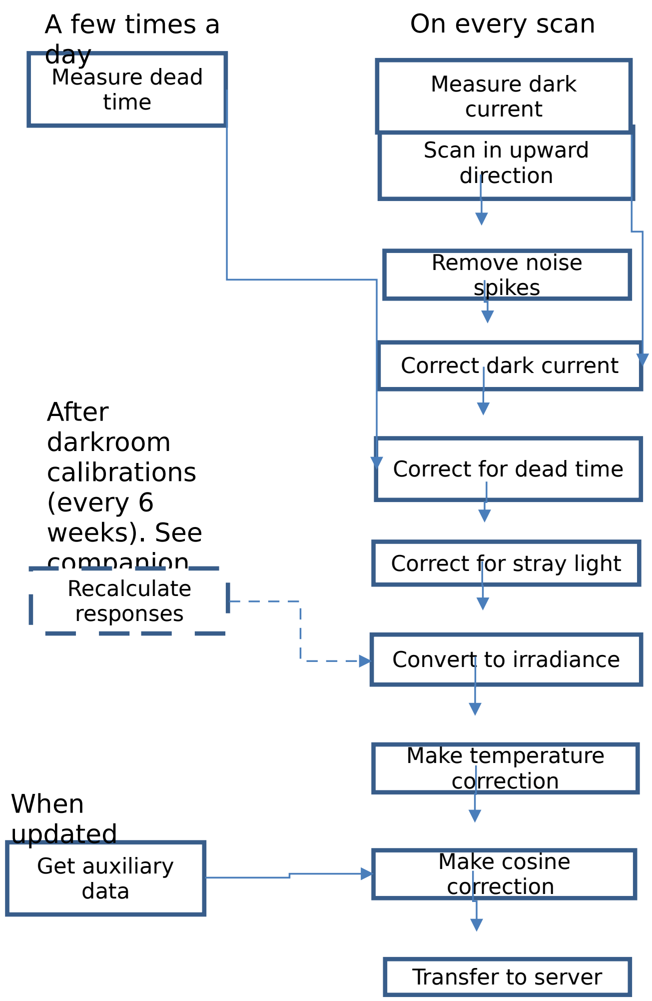


Figure 6. Detailed data flow of Brewer UV measurements at FMI.

Geosci. Instrum. Method. Data Syst. Discuss., doi:10.5194/gi-2015-42, 2016
Manuscript under review for journal Geosci. Instrum. Method. Data Syst.
Published: 18 January 2016

Geoscientific Instrumentation Methods and Data Systems
Open Access
Discussions

Critical warnings from b-files' comments for days between 2015257 and 2015259 (1 sec, 10 rows)

Type	Comment	count	priority	fname	location	serial	time	value	min	max
fz:	Suppressed oscillation of filter wheel.	7	5	B25715.107	Jokio	#107	05:04:32		1	-1
fz:	Suppressed oscillation of filter wheel.	7	5	B25815.107	Jokio	#107	05:33:54		1	-1
fz:	COUNTS TOO HIGH - aborting	6	5	B25815.107	Jokio	#107	05:35:05		1	-1
ds:	DS intensity too low (13/cy), skipping.	9	99	B25815.037	Sodan	#037	05:39:58		1	-1
ds:	DS intensity too low (23/cy), skipping.	30	99	B25715.037	Sodan	#037	05:41:44		1	-1
ds:	DS intensity too low (28/cy), skipping.	16	99	B25915.037	Sodan	#037	05:43:34		1	-1
ds:	DS intensity too low (54/cy), skipping.	9	99	B25715.214	Sodan	#214	05:38:43		1	-1
ds:	DS intensity too low (77/cy), skipping.	11	99	B25915.214	Sodan	#214	05:46:57		1	-1
rl:	2015 257 22 21 02 New value set for watermark LOOP.RUN.TIME: 699.000025 millisec.	6	5	B25815.214	Sodan	#214	22:09:48		1	-1
rl:	2015 256 22 28 01 New value set for watermark LOOP.RUN.TIME: 673.000050 millisec.	7	5	B25715.214	Sodan	#214	22:10:07		1	-1

Figure 7. Sample output from IDEAS software. Critical warnings. This information can be sent to operators in real time.

Ozone comparison with OMI for the last week (0 sec, 21 rows)

Location	Serial	Date	YYYYJJJ	OMI ozone	Brewer ozone	Percent difference	Cloudiness range (of 8)	Cloudiness most of the day	Average T	Visibility range, km	Average pressure, hPa
Jokioinen	107	2015-09-15	2015258	291+/-3	294+/-1.8	-1.0	0-0	0	16.1	20-20	1014
Sodankyla	037	2015-09-15	2015258	290+/-4	299+/-1.3	-3.0	0-0	0	15.0	20-20	1020
Sodankyla	214	2015-09-15	2015258	290+/-4	306+/-1.3	-5.2	0-0	0	15.0	20-20	1020
Jokioinen	107	2015-09-14	2015257	292+/-4	298+/-2.5	-2.0	0-0	0	16.0	20-20	1024
Sodankyla	037	2015-09-14	2015257	292+/-4	301+/-3.4	-2.9	0-0	0	14.6	20-20	1024
Sodankyla	214	2015-09-14	2015257	292+/-4	310+/-3.1	-5.8	0-0	0	14.6	20-20	1024
Jokioinen	107	2015-09-13	2015256	299+/-3	300+/-2.7	-0.3	0-0	0	16.1	20-20	1029
Sodankyla	037	2015-09-13	2015256	290+/-2	294+/-3.6	-1.3	0-0	0	15.1	20-20	1030
Sodankyla	214	2015-09-13	2015256	290+/-2	303+/-3.2	-4.2	0-0	0	15.1	20-20	1030
Jokioinen	107	2015-09-12	2015255	293+/-5	302+/-5.9	-2.9	0-0	0	16.9	11-20	1035

Figure 8. Sample output from IDEAS software. Comparison of measured ozone to reference ozone from OMI satellite.

19