27 years of Brewer total ozone column measurements in Sodankylä

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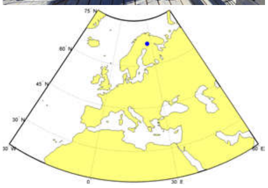
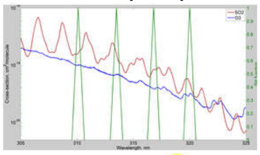
History of Brewer instruments in Sodankylä

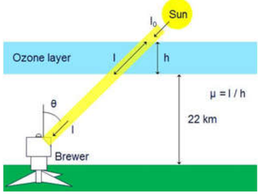


Brewer #037 has been operated in Sodankylä since May 1988. The instrument has been well maintained and frequently calibrated since to produce a high quality ozone time series now spanning over 27 years. In September 2012 a new double-monochromator Brewer was installed and after a difficult start has now been fully operational since November 2015.

One of only a few stations above the Arctic Circle Sodankylä Brewers produce valuable information about the evolution of arctic ozone layer and also provides a reference point for many satellite missions. The uniqueness is highlighted by the fact that the Sodankylä station is permanently staffed throughout the year. This allows a very fast response if there is any malfunction in the instruments. Since February 2015 both Brewers have been monitored by a database warning system with 30 minutes response time for missing data.

Measurement principle and data processing





Picture from http://kippzonen-brewer.com

The ozone retrieval is based on differential absorption at five wavelengths. The exact wavelengths are instrument specific but roughly 306.3, 310.1, 313.5, 316.8 and 320.0 nm. From the Beer-Lambert law we get relation between the direct radiation intensities measured (I_j) and the total ozone column X_{O3}

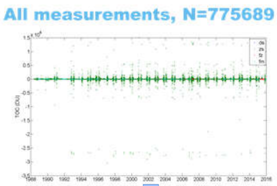
$$X_{O3} = \frac{\sum_{j=1}^{5} k_j \ln(I_{0j}) - \sum_{j=1}^{5} k_j \ln(I_j)}{\mu \sum_{j=1}^{5} k_j \alpha_j}$$

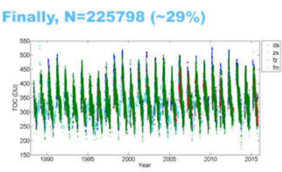
Here I_{0j} are extraterrestrial values for I_j and are determined at the calibration. Absorption coefficients α_j are calculated form the cross-sections at the instrument specific wavelengths with the instrument specific slit functions. Air mass factor μ is the ratio between the slant path and the vertical path through the ozone layer. Weighting coefficients k_j are defined so that the effects of aerosols and SO_2 are minimized. The intensities are corrected for the effects of Rayleigh scattering and for instrumental errors due to temperature and non linear photon counting. Changes in the responsivity of the instrument are monitored by regular measurements of internal halogen lamp.

In this work the processing was done using O3Brewer software. This dataset will be used to evaluate the performance of the EUBREWNET database retrieval algorithm.

In addition to direct sun (ds) measurements other measurement modes are zenith sky (zs), focused sun (fz) and focused moon (fm) measurements. In zenith sky the intensity directly from the zenith is measured. The retrieval is based on a complex polynomial fit between ds and zs measurements. This is the preferred measuring mode when the elevation angle is high but direct sun is blocked. Focused sun measurements are similar to ds-measurements but a diffuser, used to reduce the effect of pointing errors, is omitted. This gives better signal to noise ratio when solar elevation angles are low. Focused moon measurements are made especially during polar night when the solar measurements are impossible.

Quality assurance





Automatic data rejection criteria are partly based on common criteria adopted throughout the Brewer community and partly on observations during this work.

First criteria is standard deviation among five consecutive measurements. Big variability suggests variable cloud conditions. **The standard deviation** is limited to **2.5 DU** for solar measurements and to **5 DU** for moon.

When the solar elevation is low the measurements tend to get more unreliable. The **air mass factor** was limited to **3.8** (sza ~75) for ds-measurements, **3.5** for fm, **3** for zs and **6** for fz.

Wavelength setting of the Brewer is frequently checked by measuring an inner mercury lamp. If the micrometer was found to be more than **3 steps** (0.018 nm) off the measurements before that were omitted as it is possible they were made with a wrong wavelength setting.

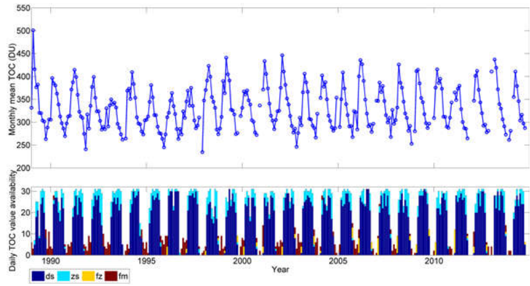
Filters 4 and 5 are usually not needed in high latitudes and they were found to be a sign of misbehavior of the Brewer, Thus all the ds-measurements made using these filters were omitted.

On the other hand all the **fz-measurements made without any attenuation filter** were found to be quite far off so they were also omitted.

All **fm-measurements** made when **solar zenith angle was less than 95 degrees** were omitted as the scattered solar light probably corrupted the measurement.

All remaining measurements with retrieved **total ozone column (TOC) below 0 DU** were omitted as obviously faulty, Visual inspection still needs to be done to ensure that only highest quality data will be delivered to the WOUDC data base.

Data availability



Ds measurements 45%

Zs measurements 10%

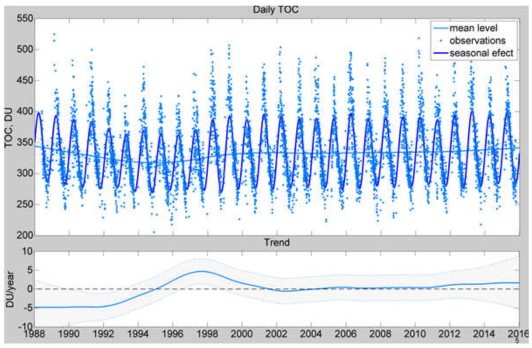
Fz measurements 1%

Fm measurements 4%

The daily value here is the daily mean of all the measurements of the best available type that cleared the rejection criteria. The different measurement types are ranked in order of quality so that direct sun measurements are considered first, then zenith sky, focused sun and focused moon.

As the summer months are quite well covered it is evident that winter months are hard to monitor with a Brewer spectrophotometer at high latitudes. This is true for all the optical instruments relying on sun as the light source. More focus should be put on to making sure that good quality focused sun and focused moon measurements are done close to and during the polar night. Overall 60 % of the days are covered with Brewer measurements in Sodankylä.

Time series analysis using Dynamic Linear Model (DLM)



To analyze trends in the time series a dynamic linear model was created using the tools from Laine et al. (2014). The method is described in more detail in poster P44 by Tamminen et al. (QOS2016-300). Preliminary model consists of variables for the ozone mean level, local trend, seasonal oscillation and autoregressive term. All terms are allowed to vary in time but the level. Early results suggest that the lowest point was 1995 and then there was a sudden upturn for five years before years of high variability with no significant trend.

Summary

- Total ozone column time series in Sodankylä now spans 28 years
- A new double-monochromator Brewer has been installed to work alongside Brewer #037
- Automatic rejection rules were made to clean up the time series but visual inspection is needed to ensure the quality
- High latitude stations struggle with low solar elevations to get higher data coverage
- Preliminary trend analysis suggest decline in total ozone before 1995 and a sudden recovery between 1996 and 2001.

Future work

- Including all the data to the EUBREWNET database
- Comparison of data products from O3Brewer and database
- Improving the dynamic linear model with better parametrization and by adding explanatory proxy variables

Acknowledgements

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References

Laine, M., Latva-Pukkila, N., and Kyrölä, E.: Analysing time-varying trends in stratospheric ozone time series using the state space approach, Atmos. Chem. Phys., 14, 9707-9725, doi:10.5194/acp-14-9707-2014, 2014.