NDACC Newsletter

Volume 6, August 2015

Network for the Detection of Atmospheric Composition Change

Exploring the interface between changing atmospheric composition and climate

The NDACC Newsletter is published by the NDACC Steering Committee. This is the sixth issue. The next issue is planned for mid 2016.

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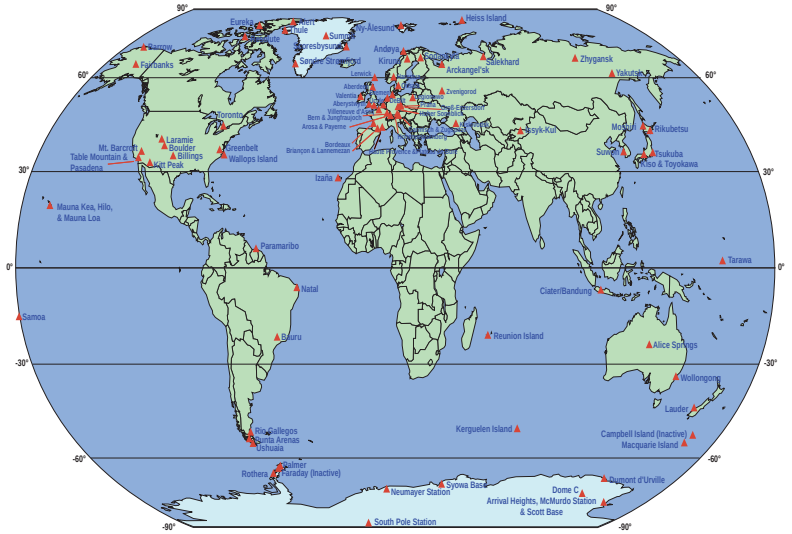
NDACC Sites



Cover photo: The water vapour lidar at Maïdo (Reunion Island) in operation.
Photo taken by Jean-François Mariscal, LATMOS/CNRS, Guyancourt, France.

Contents

Hot News

First Results of the Collaborative Carbon Column Observing Network (COCCON)

Researchers from Karlsruhe Institute of Technology (KIT, Karlsruhe, Germany) have for the first time used several mobile Fourier Transform Spectrometers for detecting the CO_2 emitted by a large metropolitan region in solar absorption spectra. The campaign was performed in June and July 2014 around Berlin, Germany, using five EM27SUN spectrometers (this type of spectrometer has been developed in a collaboration between researchers at KIT and Bruker Optics GmbH, Ettlingen). The results have been published recently and are currently accessible in AMTD (Frey et al., 2015, Hase et al., 2015). The advantage of this novel approach is to directly measure the column-averaged abundances that are insensitive to assumptions on vertical exchange as opposed to e.g. high precision surface in-situ measurements. However, due to the long atmospheric lifetime of CO_2 the expected column-averaged CO_2 enhancements are small compared to the background abundance, therefore the precision, instrument-to-instrument consistency and stability requirements are very high. The results prove the first successful demonstration of this novel approach.

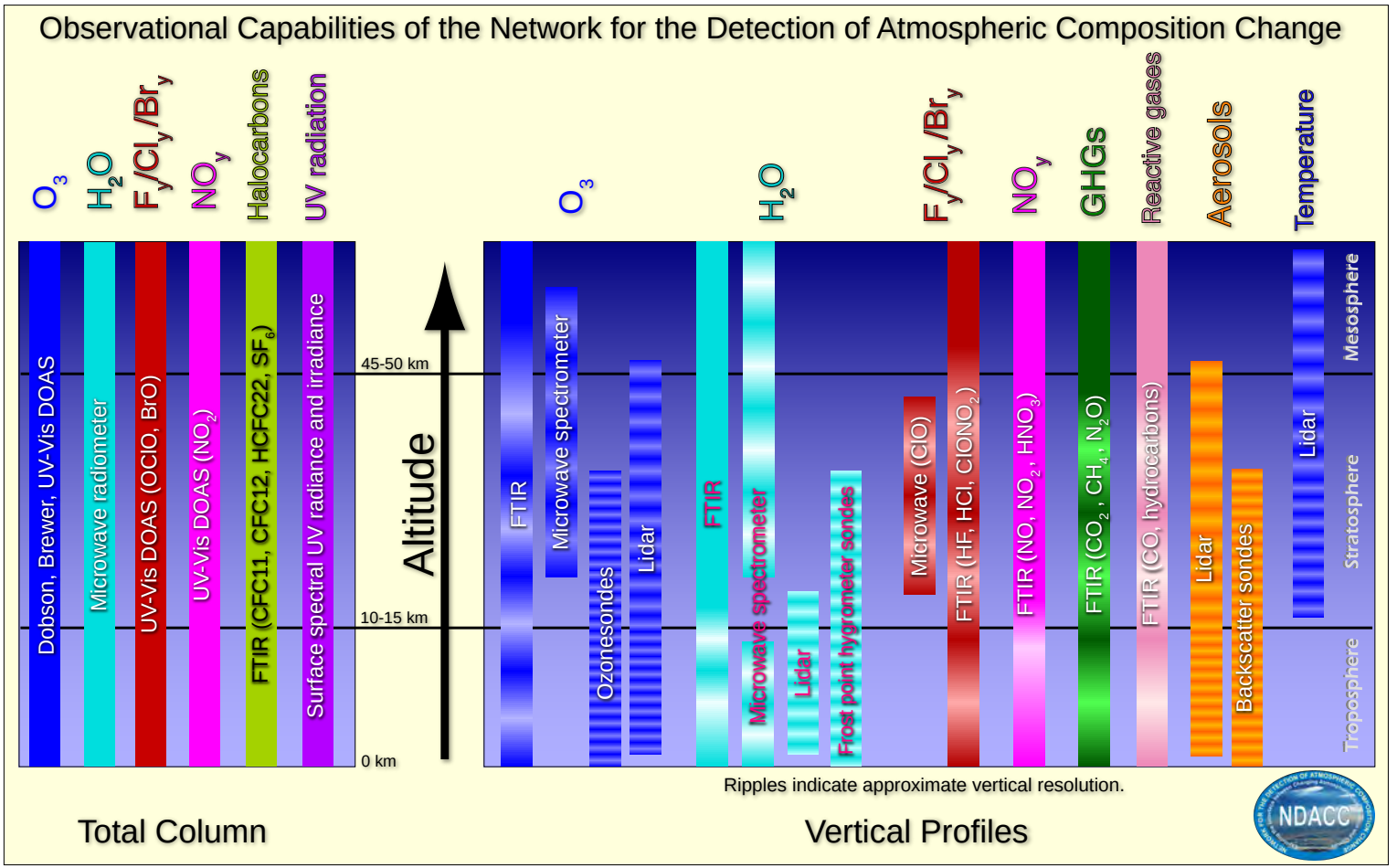
The KIT researchers now plan to initiate the new spectrometer type for highly accurate and precise observations of CO_2 and CH_4 around the globe by joining with other international collaborations. The emerging network is named COCCON (Collaborative Carbon Column Observing Network) and will complement the established TCCON network with stations in remote areas and through dedicated campaigns. It is foreseen to associate COCCON with the FTIR activities in NDACC's Infrared Working Group.

NDACC elects new co-chair

At the 2014 NDACC Steering Committee meeting in Brussels (3-5 November) Dr. Anne Thompson, Scientist at NASA's Goddard Space Flight Center (Maryland, USA) was elected Co-Chair of NDACC for a term from 2014-2017. Since 1998, Thompson has been the Principal Investigator of the SHADOZ (Southern Hemisphere Additional Ozonesondes) network that affiliated with NDACC in 2009. Thompson replaces Dr. Stuart McDermid of NASA's JPL, who retired last year. Thompson joins NDACC Co-Chair Martine De Mazière of the Belgian Institute for Space Aeronomy, who was elected in 2013 and who hosted the NDACC Steering Committee meeting in Brussels in November 2014.

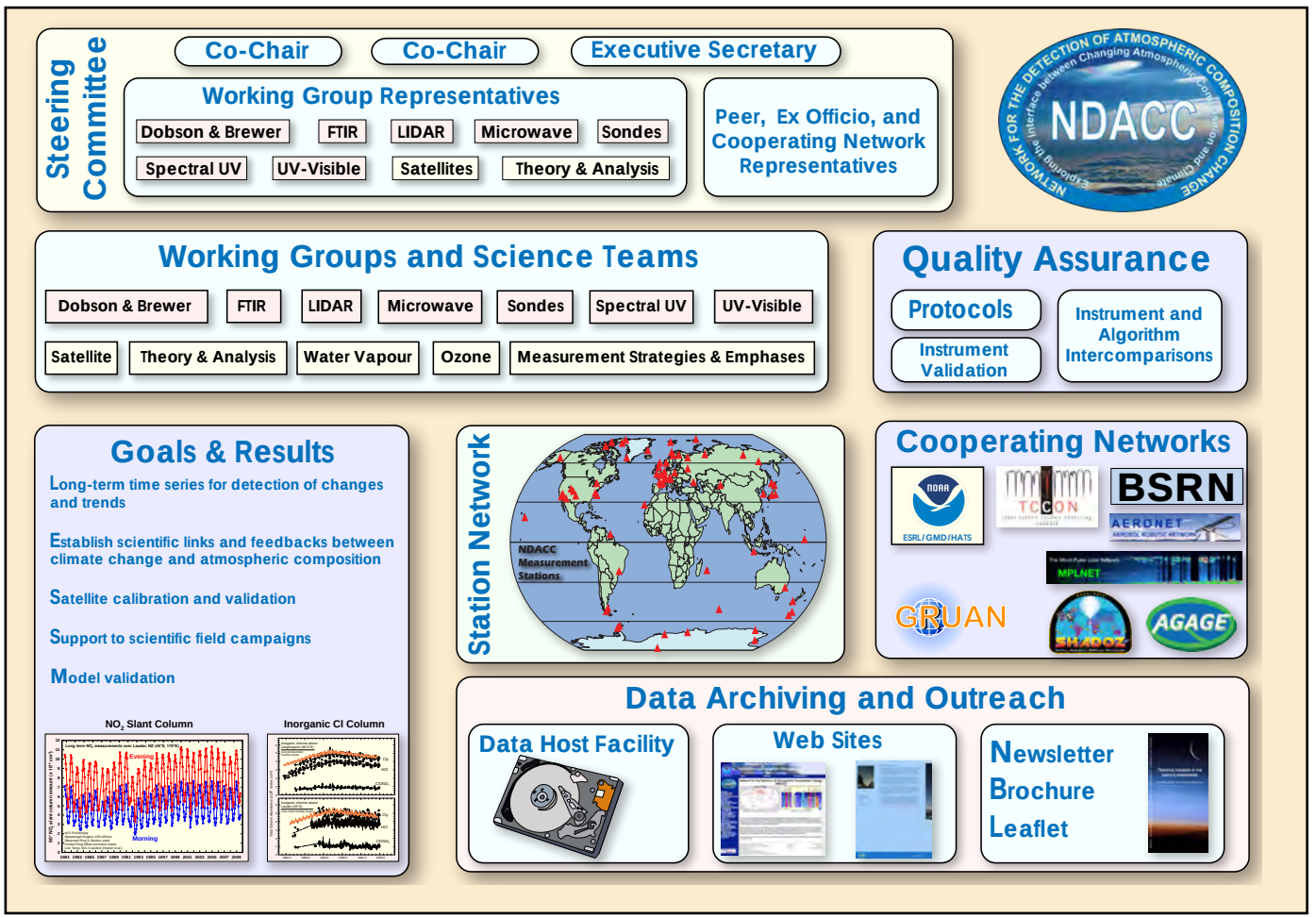
Observational Capability Chart

The NDACC Observational Capability Chart shows the wide range of species and parameters that are measured with NDACC instruments. Bars with uniform colour represent column measurements and bars with ripples show measurements that are vertically resolved. The denser the ripples, the better the vertical resolution.



NDACC Organisational Chart

The NDACC Organisational Chart shows how NDACC is governed by a Steering Committee and by Working Groups and Science Teams. Other important elements, such as the Data Host Facility, web site and outreach activities are also shown. Quality assurance form an important component of NDACC activities and there are agreements signed with Cooperating Networks.



Working Group web sites

Several NDACC Working Groups have their own dedicated web sites that are linked to from the main NDACC web site, http://www.ndacc.org

Working Group	Web site
Dobson and Brewer	http://www.eubrewnet.org
FTIR	http://www.acd.ucar.edu/irwg/
Lidar	http://ndacc-lidar.org/
Microwave	http://www.iapmw.unibe.ch/research/collaboration/ndsc-microwave/
Satellite	http://www.oma.be/NDSC_SatWG/Home.html
Sondes	http://www-das.uwyo.edu/~deshler/NDACC_O3Sondes/NDACC_O3sondes_WebPag.htm
Theory and Analyses	http://www.see.leeds.ac.uk/ndacc
UV/Vis	http://ndacc-uvvis-wg.aeronomie.be/
Spectral UV	http://www.ndsc.ncep.noaa.gov/UVSpect_web/
Water Vapour	http://www.iapmw.unibe.ch/research/projects/issi/index.html

News from the Ozone Working Group

Absorption Cross Sections of Ozone (ACSO)

Johanna Tamminen, Finnish Meteorological Institute, Helsinki, Finland,
Johannes Staehelin, Swiss Federal Institute of Technology Zurich, Switzerland,
Johannes Orphal, Karlsruhe Institute of Technology, Germany and
Geir Braathen, World Meteorological Organization

The activity "Absorption Cross-Sections of Ozone" (ACSO) started in 2008 as a joint initiative of the International Ozone Commission (IO_3C), the World Meteorological Organization (WMO) and the IGACO ("Integrated Global Atmospheric Chemistry Observations") O_3/UV subgroup to study, evaluate, and recommend the most suitable ozone absorption cross-section laboratory data to be used in atmospheric ozone measurements. The evaluation was basically restricted to ozone absorption cross-sections in the UV range with particular focus on the Huggins band. Up until now, the data of Bass and Paur published in 1985 (BP, 1985) are still officially recommended for such measurements. During the last decade it became obvious that BP (1985) cross-section data have deficits for use in advanced space-borne ozone measurements. At the same time, it was recognised that the origin of systematic differences in ground-based measurements (Dobson and Brewer spectrophotometers) of ozone required further investigation, in particular whether the BP (1985) cross-section data might contribute to these differences.

In ACSO, different sets of laboratory ozone absorption cross-section data (including their dependence on temperature) of the group of Reims (France) (Brion et al. 1993, 1998, Daumont et al. 1992, Malicet et al. 1995, abbreviated as BDM, 1995) and those of Serdyuchenko et al. 2014, and Gorshelev et al. 2014, (abbreviated as SER, 2014) were examined for use in atmospheric ozone measurements in the Huggins band.

In conclusion, ACSO recommends:

- The spectroscopic data of BP (1985) should no longer be used for retrieval of atmospheric ozone measurements.
- For retrieval with ground-based instruments of total ozone and ozone profile measurements by the Umkehr method performed by Brewer and Dobson instruments, data of SER (2014) are recommended to be used. When SER (2014) is used, the difference between total ozone measurements of Brewer and Dobson instruments is very small and the difference between Dobson measurements at AD and CD wavelength pairs are diminished.
- For ground-based Light Detection and Ranging (LIDAR) measurements the use of BDM (1995) or SER (2014) is recommended.
- For satellite retrieval the presently widely used data of BDM (1995) should be used because SER (2014) seems less suitable for retrievals that use wavelengths close to 300 nm due to a deficiency in the signal-to-noise ratio in the SER (2014) data set.

The work of ACSO also showed:

- The need to continue laboratory cross-section measurements of ozone of highest quality
- The importance of careful characterisation of the uncertainties in the laboratory measurements
- The need to extend the scope of such studies to other wavelength ranges (particularly to cover not only the Huggins band but also the comparison with the mid-infrared region)
- The need for regular cooperation of experts in spectral laboratory measurements and specialists in atmospheric (ozone) measurements.

A status report from the ACSO group is now posted on the Global Atmosphere Watch web site as a draft report open for comments until the end of August 2015. It can be found here: http://www.wmo.int/pages/prog/arep/gaw/documents/DRAFT_GAW_218a.pdf

Highlights from the 2014 WMO/UNEP Scientific Assessment of Ozone Depletion

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The Assessment Process

Every four years, a comprehensive scientific assessment of the state of the ozone layer is undertaken by an international group of experts. People in the ozone community know and use the resulting "yellow", "purple", "orange", "pink", and "green books". These assessments are mandated by the 1985 Vienna Convention for the Protection of the Ozone Layer, and by the 1987 Montreal Protocol on the Phase-Out of Ozone Depleting Substances (ODS). Under auspices of the World Meteorological Organization (WMO), and the United Nations' Environmental Programme (UNEP), about 250 people contribute in various capacities to the assessments. Figure 1 shows a large part of this group when they were together in June 2014, at the most recent of the "iconic" Les Diablerets Meetings in Switzerland. These meetings have always played an important part in formulating the assessments.

The ozone assessment process is simpler, the number of people involved is smaller, and focus is tighter, compared to the "big" Climate Assessments by the International Panel on Climate Change (IPCC), which appear on a seven-year cycle. For twenty years, NDACC has been supporting ozone- and IPCC assessments, both with long-term measurements and with scientific expertise. For the new 2014 ozone assessment, several chapter lead-authors, many authors, contributors, and reviewers come from the NDACC community. You can try to spot them in Figure 1.

The following highlights from the 2014 ozone assessment were picked with the author's "NDACC glasses" on. Of course, the choice is highly subjective. To see the larger picture, it is best to download the "Summary for Decision Makers" of the new assessment, or the much more comprehensive full assessment report (the "blue" book), which is also available since December 2014 (see WMO, 2014). Unlike the prior ones, the full report will not be available as a printed book!

As already shown in previous ozone assessments (WMO 2007, 2011), the Montreal Protocol has successfully stopped the production of nearly all ozone depleting substances (ODS). Ozone decline has ended, and ozone has leveled off in most parts of the stratosphere. Two major questions for the new assessment were: 1.) Are ozone depleting substances (ODS) continuing to decline as expected? 2.) Has ozone started to increase again? NDACC measurements have contributed to answers for both of these questions.

Evolution Of Ozone Depleting Substances

Chapter 1 of the new assessment (see WMO, 2014) concluded that ODS concentrations and the amount of inorganic chlorine in the stratosphere are continuing to decline more or less as expected. Measurements of HCl total columns at NDACC ground-based Fourier Transform InfraRed Spectrometer (FTIR) stations, for example, show a general decline of HCl columns since the late 1990s. Figure 2, adapted from a recent paper by Mahieu et al. (2014), largely demonstrates this. Especially in the lower stratosphere of the Northern Hemisphere, however, substantial variability is superimposed by transport variations. These advect older or younger stratospheric air, containing correspondingly more or less chlorine and HCl, that has been released from inert ozone depleting substances (see Newman et al. 2007; Mahieu et al. 2014). The ground-based FTIR measurements do not have the global coverage and the vertical profile information provided by satellite measurements like HALOE, ACE-FTS, or MLS, but they still provide an essential reference for the satellite instruments (most of which will not continue in the future), as well as long-term records in their own right.

A notable exception to the general decline of tropospheric ODS is carbon-tetrachloride (CCl_4), where tropospheric concentrations are not declining as much as expected since its production was discontinued. With the new assessment, it has become increasingly clear that there is incomplete knowledge of the sources of CCl_4. Additional sources are required to explain the observed slow decrease of CCl_4, see, e.g., Liang et al. (2014).

Updated Ozone Trends

Microwave radiometers and differential absorption laser radars (DIALs) can measure ozone in the upper stratosphere very well. In the NDACC framework, they have contributed long-term data for more than 20 years (see Steinbrecht et al. 2009, or Figure 1 of NDACC Newsletter 2013). Using these station data, in combina-

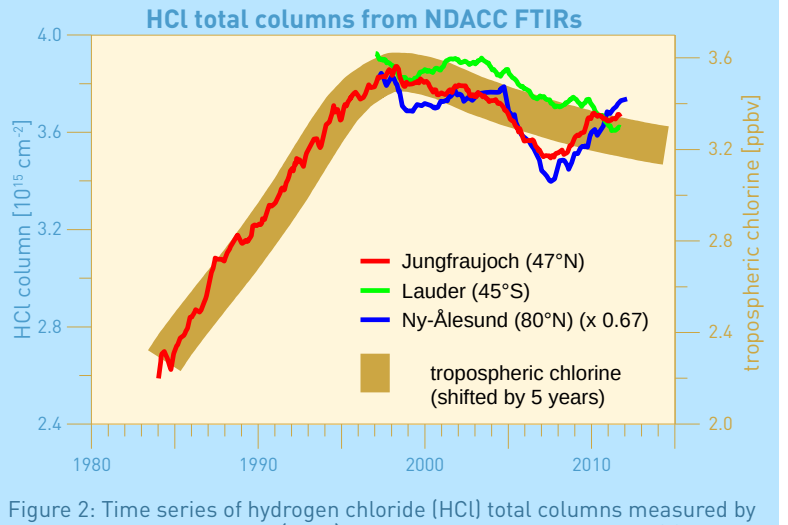

Figure 2: Time series of hydrogen chloride (HCl) total columns measured by Fourier Transform Infrared (FTIR) spectrometers at selected NDACC sites. Data are smoothed by a 36 month running mean. Ny-Ålesund columns are scaled down (x0.67). For comparison, the thick brown line shows the mixing ratio of inorganic chlorine from ozone depleting substances (ODS) in the troposphere, delayed by 5 years to account for the slow transport of ODS to the stratosphere and the subsequent release of chlorine. Most stratospheric chlorine ends up in HCl. Adapted from Mahieu et al. (2014).

tion with a number of satellite records, Chapter 2 of the new assessment was able to conclude that the first signs of significant ozone increases can now be seen in the upper stratosphere. Figure 3 shows the resulting overall ozone trend profiles, for the period before 1997, when ODS concentrations were increasing (left panel), and for the more recent period since 2000, when ODS concentrations were decreasing (right panel). The left panel shows the well-known declining trend of ozone, both in the upper stratosphere (near 40 km or 2 hPa), and in the lower stratosphere (near 20 km or 70 hPa). The observed decline (blue line) is reproduced by chemistry climate model simulations (yellow shaded area, from WMO 2011). The simulations show that the ozone decline is caused by ozone depleting substances (red line), with some mitigation coming from cooling of the stratosphere, due to increasing greenhouse gases, especially CO_2 (green line).

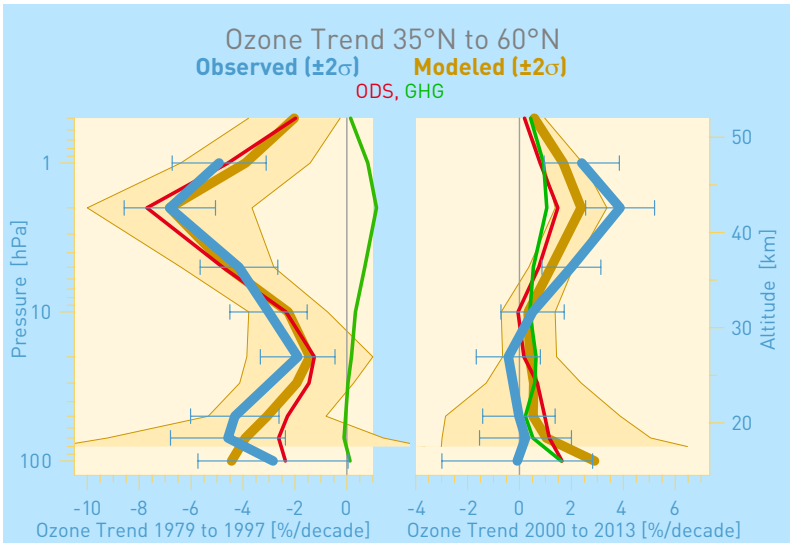

Figure 3: Vertical profiles of annual mean ozone trends over 35°N–60°N averaged over all available satellite and ground-based observations (blue) for the periods of stratospheric ODS increase (left) and ODS decline (right). Corresponding CCMVal-2 modeled trends (from WMO, 2011) are given for ODS changes only (red), GHG changes only (green), and both together (brown). The ±2 standard error uncertainty range for the trends is shown by the horizontal bars for the observations and by the yellow shading for the modeled overall trend. Adapted from WMO (2014).

The right panel of Figure 3 demonstrates that the situation has changed since 2000. Now chlorine is going down and the ozone observations show an increasing trend of ozone in the upper stratosphere, which is significant around 40 km or 2 hPa. Again, observed and simulated trend are quite consistent (blue line and yellow shaded area). The model simulations indicate that about half of the ozone increase is due to now declining ODS (red line), whereas the other half of the ozone increase is due to continuing emissions of greenhouse gases (CO_2) and resulting further cooling of the stratosphere (green line). Figure 3, thus, demonstrates one important connection between the ozone recovery expected for the next decades and climate change due to changing greenhouse gases, which are expected to keep increasing over the next decades. There are, of course, other connections and feedbacks, e.g. in the lower stratosphere.

More detailed investigations on the ozone trend profile can be found in the SI²N special issue (Hassler et al. 2014; Harris et al. 2014). The SI²N initiative was very helpful for the assessment, because it initiated additional iterations of satellite data processing and data merging, and it brought together analyses of ground-based data, e.g. from NDACC, and satellite data. Overall, the SI²N findings support the now increasing trend of upper stratospheric ozone, but they also show uncertainties that are not addressed in detail in the assessment.

For total column ozone, the assessment confirmed that the previous decline of ozone columns due to increasing ODS concentrations has been stopped since the late 1990s, as already reported by WMO 2007, and 2011. However, the new assessment

was not able to conclude that clear and significant increases of total column ozone have yet been observed over the last 10 to 15 years. There are some indications, e.g., the near global total ozone column (60°S to 60°N) seems to be going up, or a recent model study by Shepherd et al. (2014) finds that observed variations are consistent with the long-term evolution of ODS concentrations and meteorological variability. However, the latitudinal variation of the observed post-2000 total column trends is not consistent with expectations from decreasing ODS concentrations. Also, differences between the available data sets, and uncertainties in accounting for solar cycle and transport effects were considered large enough, so that no firm conclusions were drawn in the assessment about significant increases of total column ozone.

Importance Of Future Emissions

Although only using simulations by simple 2-dimensional models, Figure 4 gives a good overview of the main drivers for total ozone variations in past and future (Fleming et al. 2011; Portmann et al. 2012). Since the 1960s, increasing ODSs (blue line) have been the major driver for 3% to 4% lower columns of global total ozone (90°S to 90°N, black line for simulations, purple crosses for observed ozone). In some regions (e.g. Antarctic Ozone Hole, upper stratosphere), of course, much larger ozone depletion has occurred. The successful phasing out of ODSs means that their concentration is now slowly decreasing, and will return to pre-1960 levels by the end of the 21st Century. Note that the current decline of stratospheric chlorine is about three times slower than the rapid increase in the past (compare blue line in Figure 4).

At the same time, human activities result in increasing atmospheric concentrations of other long lived trace gases, especially CO_2 from fossil fuel use, N_2O from emissions and fertilizers used in agriculture, and CH_4 from wetlands, farming, and meat production. All these trace gases will have significant influences on the future evolution of the ozone layer. Figure 4 demonstrates that these are about as large as the past effect of ODS. We should not ignore them!

CO_2 acts on stratospheric ozone mainly by radiative cooling of the stratosphere, and warming the troposphere (climate change). This generally slows gas-phase ozone destruction cycles and results in increased ozone (compare green lines in Figure 3). In addition, tropospheric warming means enhanced wave activity in the atmosphere. This is expected to speed up the global Brewer-Dobson

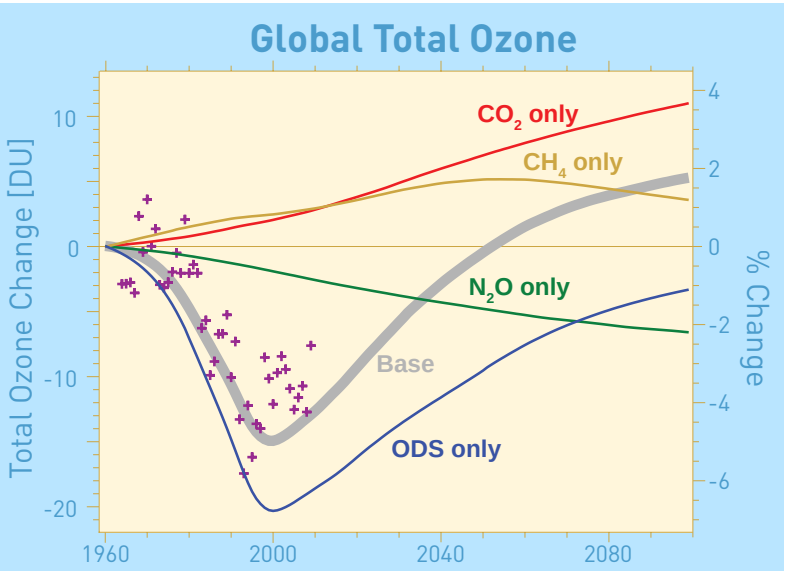

Figure 4: Model-simulated global and annual average total ozone response to changes in CO_2 (red line), CH_4 (brown line), N_2O (green line), and ozone depleting substances (ODS, blue line). The total response to ODS and greenhouse gases combined is shown as the thick grey line. The responses are taken relative to 1960 values. Future greenhouse gas concentrations are based on the IPCC SRES A1B (medium) scenario. Ground-based total ozone observations (base-lined to ≈1970) are shown as purple cross symbols. Adapted from Fleming et al. (2011), and WMO (2014).

circulation, which transports ozone (and other trace gases) from the tropical stratosphere to higher latitudes (e.g., Chapter 4 of WMO 2014). Both factors contribute to a general ozone increase at most latitudes and altitudes due to increasing CO_2 in the future (red line in Figure 4).

N_2O is also a greenhouse gas. In addition, N_2O is broken up in the stratosphere, where enhanced NO_x results in ozone destruction (green line in Figure 4). By 2070, N_2O may well be the most important ozone depleting substance. The most complex effects on ozone are coming from enhanced CH_4. CH_4 is an important greenhouse gas. It is also a source of water vapor (H_2O) in the stratosphere, which then affects ozone by enhancing HO_x ozone destruction cycles. However, HO_x (and NO_x) also tie up chlorine, which might otherwise destroy ozone. In addition, H_2O is important for radiative balance and temperatures in the lower stratosphere. To complicate matters, enhanced CH_4 (and other volatile organic compounds) together with enhanced NO_x can result in ozone production in the troposphere and lowermost stratosphere (smog chemistry). In Figure 4, the overall effect expected for CH_4 increases is an increase of total column ozone (brown line).

Clearly, emissions of all the gases in Figure 4 will have a significant influence on the ozone layer in this century. Accurate monitoring of ozone and the other gases, therefore, will remain an important task, also in the next decades. Since our capacity for satellite observations of many stratospheric trace gases will shrink considerably over the next years (hardly any limb sounders!), NDACC instruments will become an even more important (and quite cost-effective) part of our global observing system.

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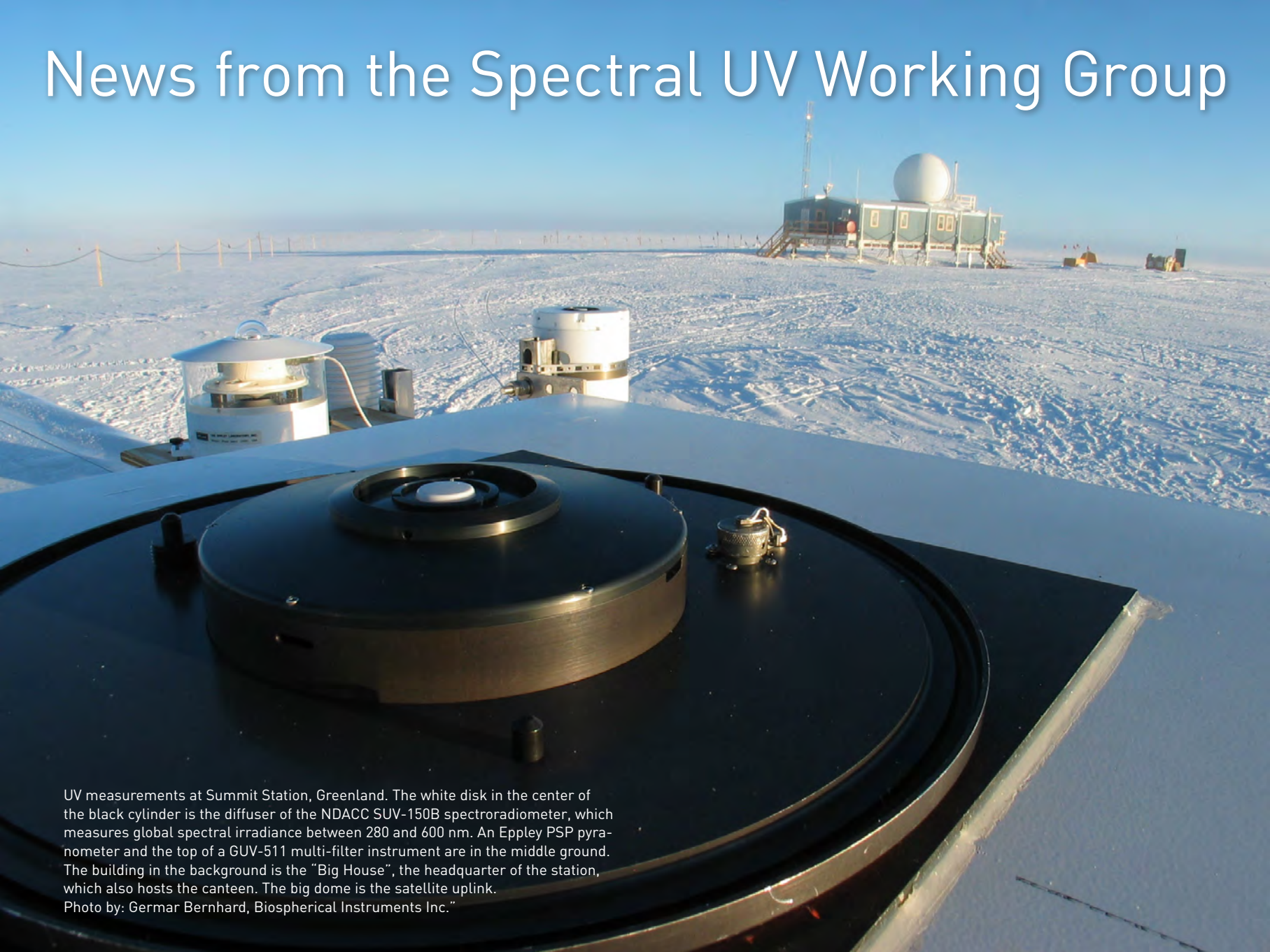
News from the Spectral UV Working Group



UV measurements at Summit Station, Greenland. The white disk in the center of the black cylinder is the diffuser of the NDACC SUV-150B spectroradiometer, which measures global spectral irradiance between 280 and 600 nm. An Eppley PSP pyranometer and the top of a GUV-511 multi-filter instrument are in the middle ground. The building in the background is the "Big House", the headquarter of the station, which also hosts the canteen. The big dome is the satellite uplink.
Photo by: Germar Bernhard, Biospherical Instruments Inc."

Latitudinal difference of UVB and UVA radiation derived from NDACC measurements

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Richard McKenzie, National Institute of Water and Atmospheric Research, Lauder, New Zealand

Latitudinal variations in annual doses of UV-B and UV-A have recently been assessed using data from NDACC UV spectroradiometers. The original motivation of this study was to provide data for assessing the effects of UV radiation on materials (Kotkamp et al., 2014). The interpretation of these data has subsequently been expanded and used in the 2014 assessment on "environmental effects of ozone depletion and its interactions with climate change" prepared for the United Nations Environment Programme (Bais et al., 2014).

For the sites considered in this study, annual UV-B (280 – 315 nm) and UV-A (315 – 400 nm) doses were derived from at least 10 years of measurements. As expected, doses are generally largest close to the equator and smallest at high latitudes (Figure 1). Doses at high-altitude sites (South Pole, Mauna Loa, Boulder and Summit) are larger than for sites located at similar latitudes but at sea level. This is most obvious when comparing data from Barrow (71.3° N; 8 m altitude) and Summit (72.6 ° N; 3202 m altitude), where the annual doses of UV-B and UV-A at the latter site are about 58% and 83% larger due to higher elevation and different surface reflectivity, respectively. Surface reflectivity in the order of 0.98 also contributes to the relatively large doses at the South Pole and Summit, while attenuation of UV radiation by aerosols is responsible for the relatively low dose at Tokyo. Latitudinal gradients are stronger in the UV-B than the UV-A region, partly because photons travel a longer path through the atmosphere for the lower solar elevations prevailing at higher latitudes, allowing greater absorption of UV-B radiation by ozone. Another factor contributing to the difference in gradients of UV-B and UV-A is the relatively small ozone column in the tropics. As a consequence, the ratio of annual dose of UV-B/UV-A is roughly 0.03 close to the equator, 0.02 at mid-latitude sites, and less than 0.02 at high latitudes (Figure 1, lower panel). It is interesting to note that the UV-B/UV-A ratios are not very different in polluted locations, such as Tokyo, compared with clean-air sites, suggesting that the optical depth of aerosols in the UV-B is not very different from that in the UV-A region, and/or that the wavelength dependence of the single scattering albedo throughout the UV region is small.

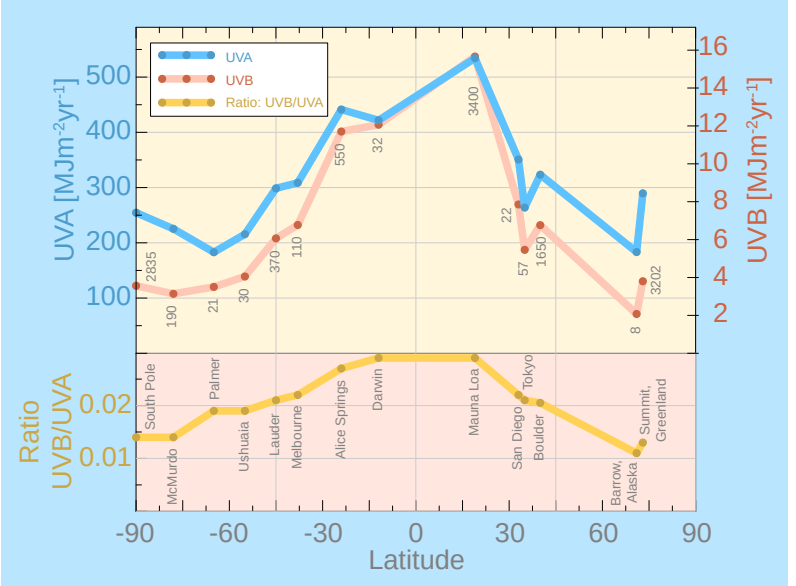

Figure 1: Latitudinal variation of UV-A and UV-B annual dose (top) and the ratio of UV-B/UV-A dose (bottom). The numbers in the upper panel indicate the station's altitude in metres above sea level.

Additional information on the variability of UV irradiance in Europe has been compiled by Seckmeyer et al. (2008).

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Intercomparison of NDACC UV spectroradiometers

Stefan Riechelmann and Gunther Seckmeyer, Univ. of Hannover, Germany

Abstract

An NDACC blind intercomparison campaign of UV spectroradiometers has been conducted in Hannover, Germany, to assess the ability of the participating research groups to perform long term measurements of spectral solar ultraviolet irradiance. In addition to the group that operated the mobile NDACC reference UV instrument from the Leibniz Universität Hannover (DEH), an Austrian group from the University of Natural Resources and Life Sciences, Vienna (AUW), a Chilean group from the Universidad de Santiago de Chile (CHS) and a French group from the Lille University of Science and Technology (FRL) participated in the campaign. Synchronised spectral scans of the solar irradiance have been performed between 5 July and 7 July 2014 between 3 and 20 hours UTC. Measurements during situations with low cloud cover and direct irradiance not blocked by clouds showed deviations between the DEH reference instrument and the AUW instrument of 2-3% between 300 and 390 nm. The deviations between the DEH reference instrument and the AUW and CHS instrument is similarly low on average. However, the ratio between CHS and DEH is not as smooth as the ratio of the AUW and FRL instruments in comparison to the reference, and deviations between 0% and 6% occurred through the day. The FRL instrument deviates systematically by about 8% from the reference instrument, which can be explained to a large extent by differences of the standard lamps used for the calibration, but which requires further investigations. For wavelengths below 305 nm the deviations between all instruments increase due to the wavelength uncertainties of

about ± 0.05 nm, which is still within the specification range set by NDACC. Overall the intercomparison revealed a satisfactory agreement and there is no indication of severe problems in the quality of the NDACC UV data for the participating instruments.

The participants at the campaign (from left to right): Raul Cordero, Gunther Seckmeyer, Frederique Auriol, Colette Brogniez, Fanny Minvielle-Thomas (not present in the picture),Hendrik Brast, Stefan Riechelmann, Michael Schrempf, Ansgar Stührmann, Jasmina Hadzimustafic, Michael Fitzka

Participants and location of the intercomparison

The campaign took place at the Institute for Meteorology and Climatology (IMuK) and at the Institute of Vocational Sciences in the Building Trade (IBW), Leibniz Universität Hannover.

Campaign Protocol

A blind instrument comparison campaign according to NDACC standards has been carried out by the Institute of Meteorology and Climatology of the Leibniz Universität Hannover between 5 July and 7 July 2014. During the campaign the guidelines for instrument intercomparison campaigns provided by the NDACC were followed in order to ensure NDACC standards were met. The document encourages new participants to perform an informal intercomparison preceding the formal blind intercomparison in order to "[...] avoid the situation of formal (first-time) intercomparisons resulting in little communication among investigators and an insufficient learning experience [...]". Therefore, the participants agreed to perform a short informal campaign from 1 July to 4 July 2014 previous to the blind campaign.

Table 1: List of persons and groups that participated at the intercomparison campaign in Hannover 2014.

Role	Operators	Institute	Abbreviation
Referee	Gunther Seckmeyer Stefan Riechelmann	Leibniz Universität Hannover	-
Participant #1	Ansgar Stührmann Michael Schrempf Hendrik Brast	Leibniz Universität Hannover	DEH
Participant #2	Raul Cordero	University of Santiago de Chile	CHS
Participant #3	Colette Brogniez Frederique Auriol Fanny Minvielle-Thomas	Lille University of Science and Technology	FRL
Participant #4	Michael Fitzka Jasmina Hadzimustafic	University of Natural Resources and Life Sciences, Vienna	AUW

In Table 1 the participating groups and their members are listed. In addition to the group that operated the mobile NDACC reference UV instrument from the Leibniz Universität Hannover (DEH), a group from the University of Natural Resources and Life

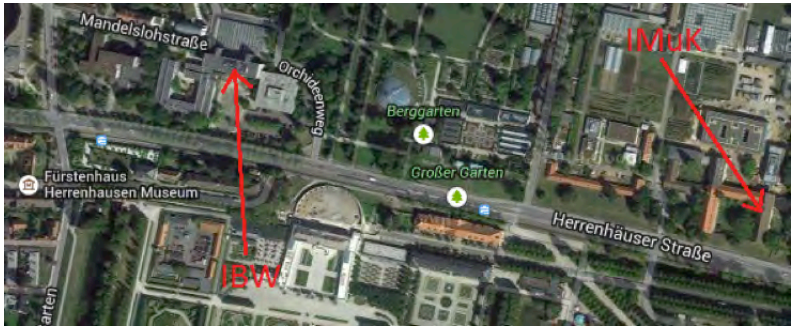


Figure 1: Map of the campaign measurement location. The measurement platforms of the IBW and the IMuK are about 600 m apart from each other. All participating spectroradiometers were set up on the IBW platform, auxiliary measurements like allsky camera images and pyranometer measurements were performed on a regular basis at the IMuK platform.

Sciences, Vienna (AUW), a group from the Universidad de Santiago de Chile (CHS) and a group from the Lille University of Science and Technology (FRL) participated in the campaign. All participating spectroradiometers were set up at the measuring platform of the Institute of Vocational Sciences in the Building Trade (IBW) of the Leibniz Universität Hannover.

During the blind campaign the participants were not allowed to exchange their data. In order to provide comparable measurements the specifications given in Table 2 had to be fulfilled by all participants. The measurements were performed in the wavelength region between 280 and 400 nm with wavelength steps of 0.25 nm. The time between subsequent wavelength steps was set to two seconds. The system clock of each measurement PC was synchronised hourly to the time of the Global Positioning System (GPS). A complete measurement was performed every half hour beginning at 3:30 UTC and ending at 19:30 UTC. The time between 8 and 9 UTC on each day could be used to perform an instrument calibration. Since the all instruments have different slit functions (see Figure 2) the measurements were normalised to a 1-nm

Table 2: List of measurement specifications fulfilled by the participants.

Quality	Quantity
Reference time	Coordinated Universal Time (UTC)
Wavelength range	280 - 400 nm
Sampling interval	0.25 nm, 2 s per sampling
Output bandwidth	1 nm (by convolution of measured spectra)
Measurement frequency	2 per hour, begin of measurement at minute 0 and minute 30
Start/end time	3:30 UTC / 19:30 UTC
Calibration	Each day between 8 and 9 UTC
Data submission	On the day after the measurement at 12 UTC

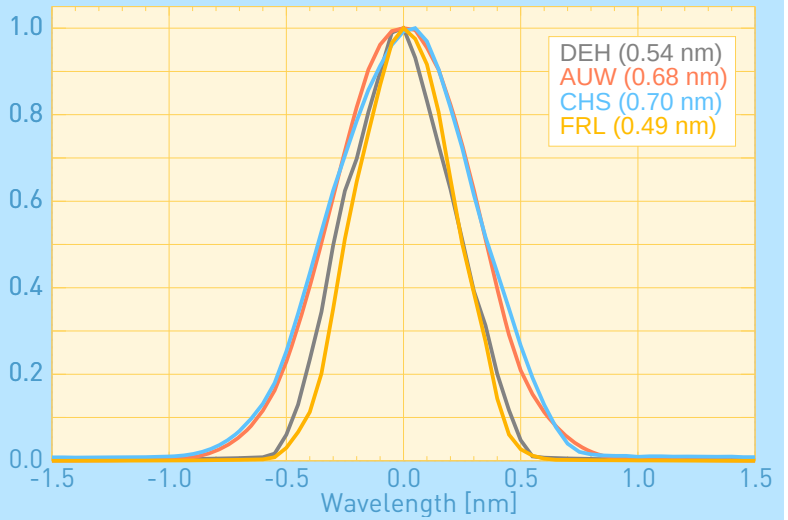


Figure 2: Instrument slit function with the resulting bandwidth of the participating instruments prior to the convolution. The slit functions have been determined with a HeCd-Laser in case of the FRL instrument and with HgAr pencil lamps in case of the DEH, AUW and CHS instruments, respectively.

bandwidth prior to the submission of the data to the referees.

The participants from AUW, FRL and DEH calibrated their instruments using their own standard calibration procedures and based on their own calibration lamps. The CHS group used the calibration facilities provided by the DEH group and therefore was not calibrated independently from the reference instrument. However, it is planned to operate the Chilean instrument with an identical setup as the reference instrument in future. So far no data from Chile have been submitted to the NDACC database.

Campaign Results

During the blind intercomparison campaign measurements were conducted on three consecutive days with mostly broken cloud conditions. The four measuring spectroradiometers were placed together on the IBW platform. In addition to the measurements performed at the IBW, pyranometer measurements and allsky camera images are captured on a regular basis at the IMuK platform, which is located in a distance of about 600 m to the IBW platform. The global and diffuse irradiance measured with pyranometers at the IMuK is shown in Figure 3. Based on these measurements two almost cloudless situations were chosen for the instrument comparison (8 UTC at 5 July and 12 UTC at 6 July).

Spectral comparison of global irradiance

Two situations with low cloud cover and direct irradiance not blocked by clouds are shown in Figure 4. The measurements were performed on 5 July at 8 UTC at a solar zenith angle (SZA) of 49° and on 6 July at 12 UTC at an SZA of 30°. The deviation between the DEH reference instrument and the AUW instrument is less than 2-3% between 300 and 390 nm under these conditions. The deviations between the DEH reference instrument and the CHS instrument is similarly low on average. However, the ratio between CHR and DEH is not as smooth as the ratio of the AUW and

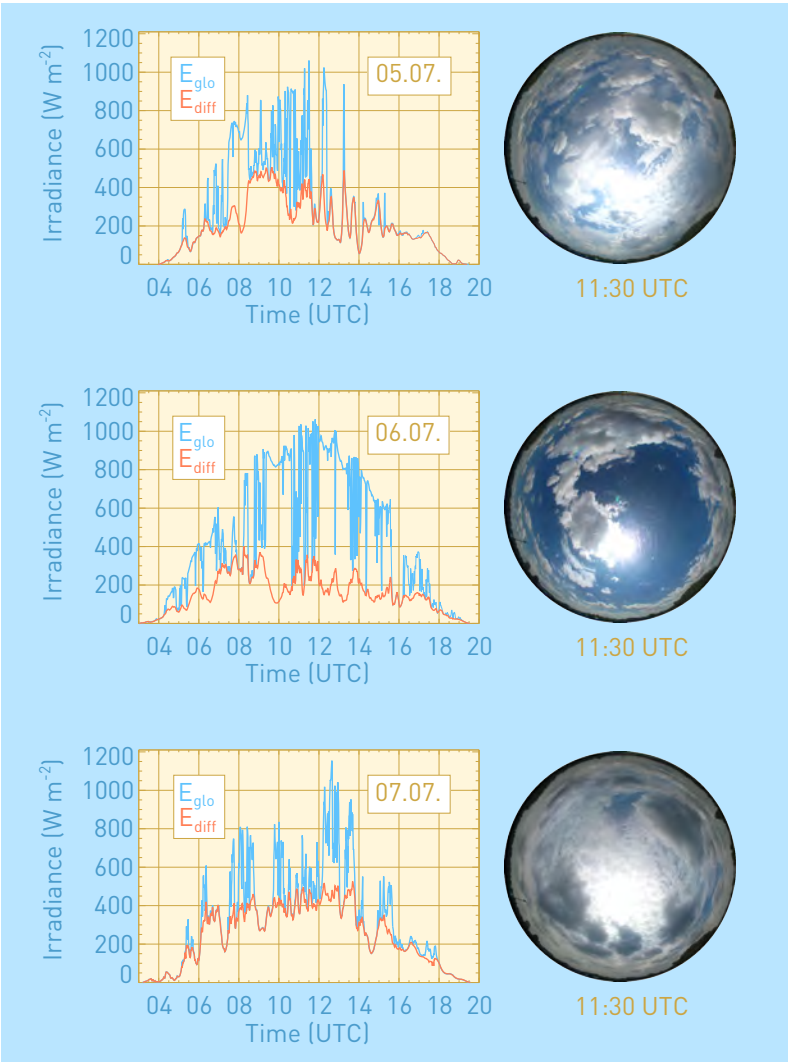


Figure 3: Global and diffuse irradiance measured with pyranometers at the IMuK from 5 July to 7 July 2014. The allsky pictures show the cloud situations at around noon time of the corresponding day.

FRL instruments in comparison to the reference. Comparing the two measurements shown in Figure 4, it is obvious that the difference is systematic and therefore differences in the instrument slit function and wavelength misalignments are likely the cause for this behaviour. The FRL instrument deviates by about 8% from the reference instrument independent on the time of the day. This deviation is to a large extent caused by differences in the calibration lamps and requires further investigations in the future. For wavelengths below 305 nm the deviations between all instruments increase due to the wavelength uncertainties of about ±0.05 nm, which is still within the specification range set by NDACC. It can be recognised that wavelength misalignment FRL deviation is resulting in lower irradiance, whereas the CHS and the AUW show higher irradiance compared to the reference instrument.

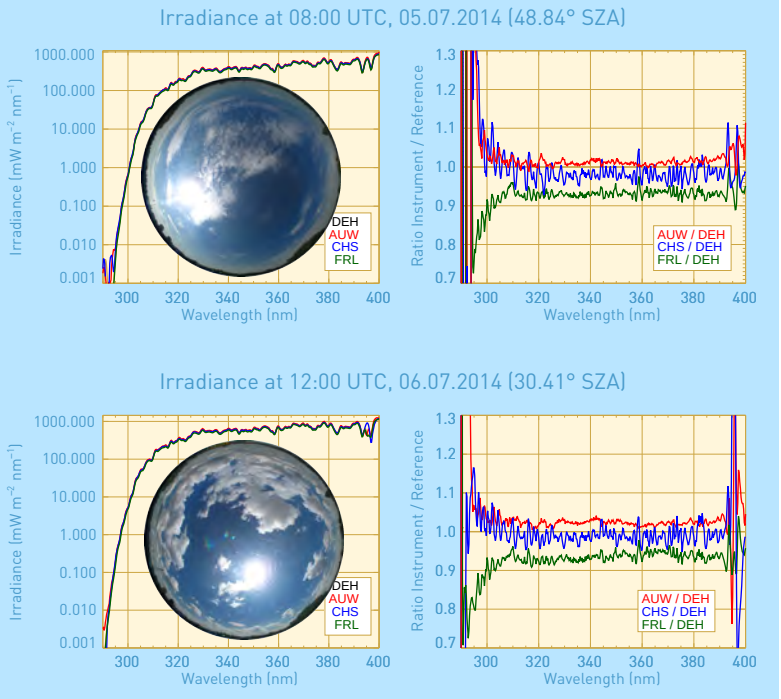


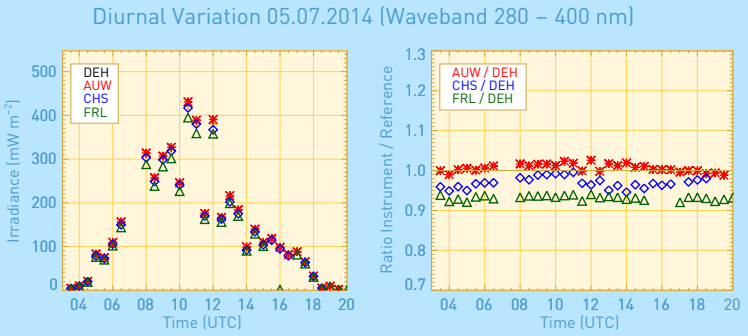
Figure 4: Spectral irradiance measured with the four spectroradiometers at 8:00 UTC on 5 July 2014 and 12:00 UTC on 6 July 2014. On the left hand side the absolute values are shown on a logarithmic scale. In addition, an allsky picture is displayed, showing the cloud situation at the beginning of the measurements. On the right hand side the measurements performed with the AUW, CHS and FRL instrument are shown as a ratio to the DEH NDACC spectroradiometer.

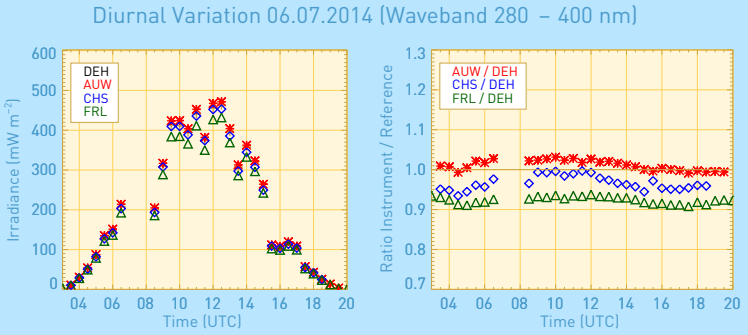
Variations through the day

For the evaluation of the diurnal differences of the participating instruments compared to the reference instrument the diurnal global irradiance integrated over the wavelength interval of 280 to 400 nm is shown in Figure 5. The AUW instrument shows the smallest deviations compared to the DEH reference with differences between -1% and 3% over the course of the day.

The CHS instrument shows deviations in the range from 0% to 6% compared to DEH. These deviations are not constant with time, while the deviations of the DEH instrument relative to the AUW and the FLR instruments remain fairly constant. The reason for the variation of the deviation between the CHS and the DEH instrument are not known. Possible explanations are instabilities of the sensitivity of the photomultiplier and/or a larger cosine error of the CHS input optics; cosine error may lead to deviations that change through the day (Cordero et al 2008b) as those shown in Figure 6. However, this hypothesis could not be assessed due to the high amount of cloudiness during the campaign.

The FRL instrument shows a mostly constant deviation of -7 to -9% compared to the DEH reference instrument. This deviation is most likely caused by the absolute calibration process. The secondary calibration lamp used by DEH (SL469) was calibrated prior to the campaign at the IMUK based on a single primary calibration lamp (PL529) which is traceable to the national stand-





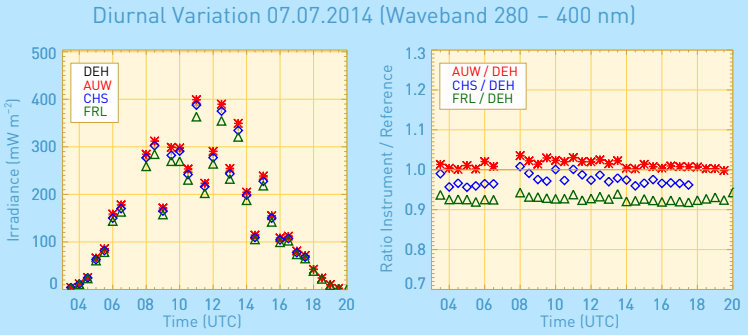


Figure 5: Diurnal variation of the global irradiance integrated over the wavelength interval of 280 to 400 nm. The absolute values are shown on the left hand side and the ratio between participants and reference instrument are shown on the right hand side.

ard provided by the Physikalisch Technische Bundesanstalt (PTB). The FRL calibration lamps are certified by the National Institute of Standards and Technology (NIST). During the calibration process both DEH and FRL lamps are mounted in an optical axis with the entrance optics and are placed in the distance provided by the calibration certificate of the particular calibration lamp (70 cm in case of PTB calibrated lamps and 50 cm in case of NIST calibrated lamps). In order to compare the absolute calibration of the FRL and the DEH instrument, measurements of two FRL and the DEH lamp were performed with the FRL instrument. It was found that the calibration certificates of the lamps differ from each another by about 4% (Figure 6). In addition, an internal comparison with three newly bought primary lamps of the DEH group (PL556,

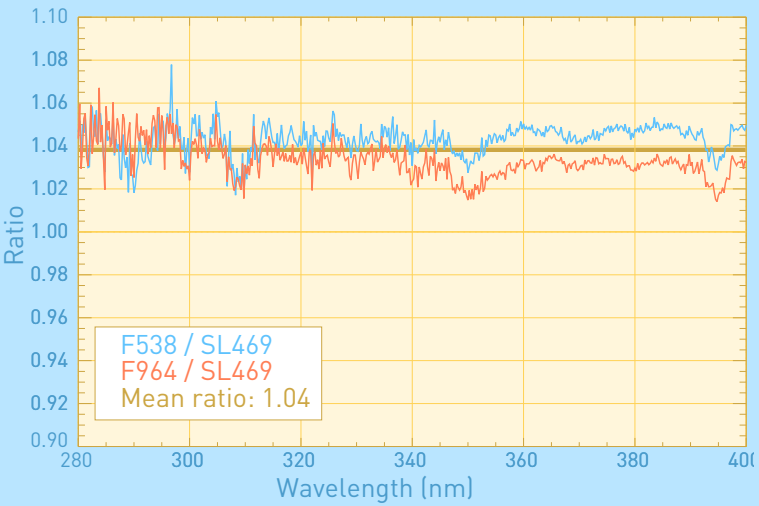


Figure 6: Ratio of FRL responsivity measurements performed with three different calibration lamps. The lamps with the identification number F538 and F964 are used by the French participants during their absolute calibration process. Lamp SL469 is used by the German group for their absolute calibration. A difference of about 4% between French and German calibration lamps is apparent.

PL569, PL573) has been performed after the campaign. The calibration of the secondary lamp SL469 derived by the primary lamp PL529 deviates less than 1% from the calibrations derived by the three new lamps (Figure 7). This indicates that the secondary calibration lamp used by the DEH group during the NDACC campaign is trustworthy. The 4% difference between DEH and FRL calibrations can still be caused by differences between lamp calibration certificates provided by different national institutes. Such a behaviour has been found in earlier investigations. The close agreement between the AUW and DEH measurement results suggests that it might to be a good idea to raise the FRL standard by 4% to achieve a closer agreement of the measurements within the NDACC. Nevertheless, even if the FRL standard is raised by 4%, there are 3 to 5% difference remaining between the FRL instrument and the DEH instrument. Therefore, it is not yet recommended to adjust the FRL standard, but to further try to find the reason for the remaining instrument difference.

In Figure 8, the UV index calculated from the measured spectra is shown. During the three campaign days UV indices of up to 6 have been measured. Despite some outliers for small UV indices below 0.2 the deviations of AUW, CHS and FRL are about the same as seen for the integration over the whole UV range. The global irradiance integrated over the UVB range (280 - 315 nm) and the UVA range (315 – 400 nm) is shown in Figure 9 and Figure 10, respectively. Again, the deviation compared to the reference instrument is about the same as for the integration over the whole

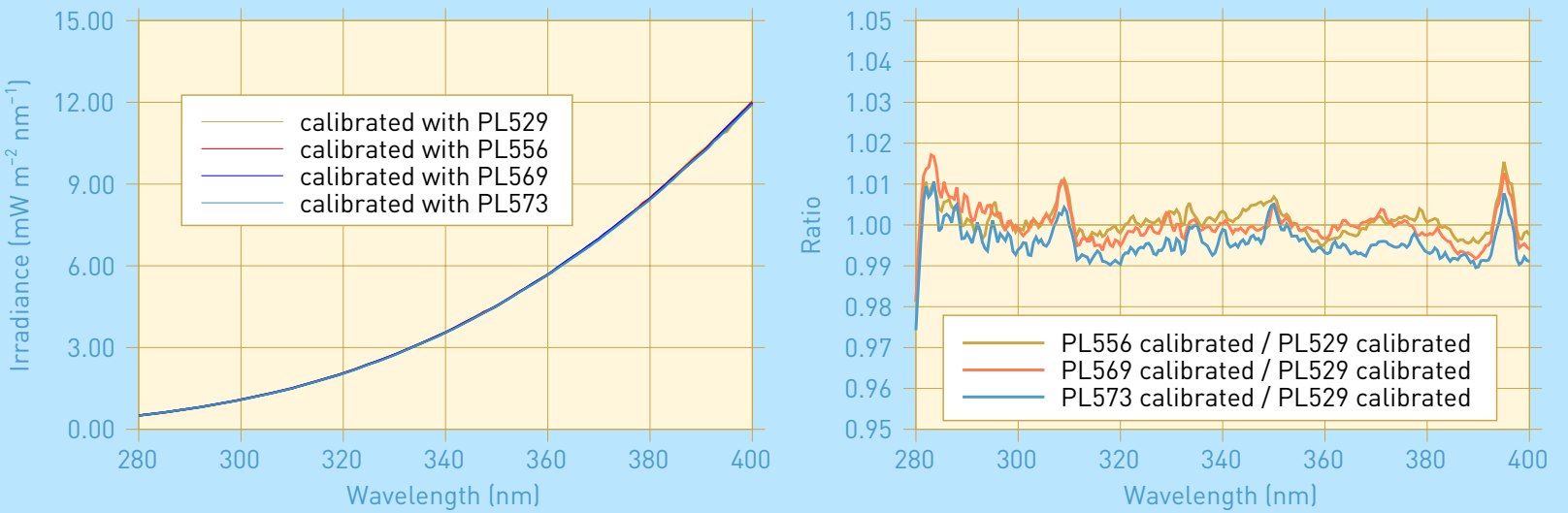
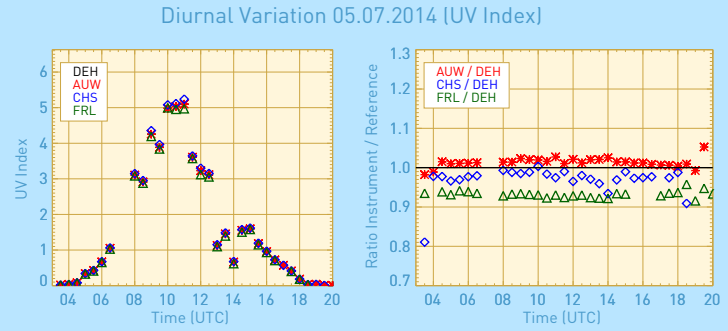
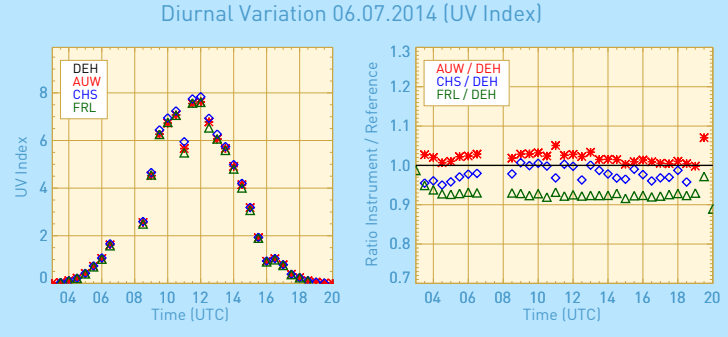


Figure 7: On the left hand side the irradiance of the DEH calibration lamp SL469 is shown, calibrated based on four different primary lamps (PL 529, PL556, PL569 and PL573). On the right hand side the irradiance of this lamp based on PL556, PL569 and PL573 is divided by the irradiance based on PL529. The deviation between the calibrations is less than 1%.





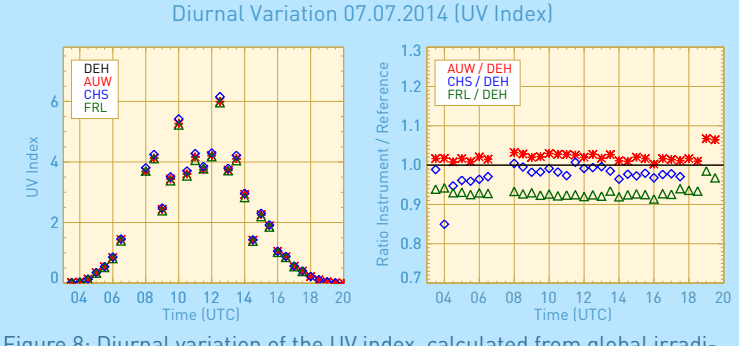
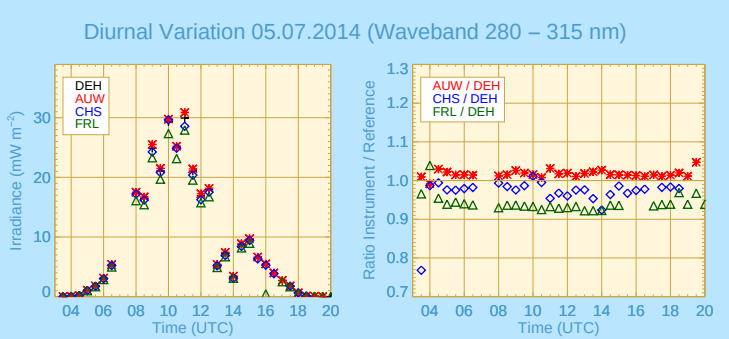
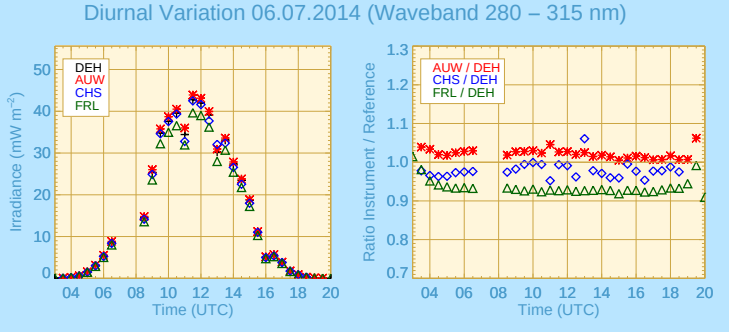


Figure 8: Diurnal variation of the UV index, calculated from global irradiance measurements performed with the four instruments on 5 to 7 July. The absolute values are shown on the left hand side and the ratio between participants and reference instrument are shown on the right hand side.





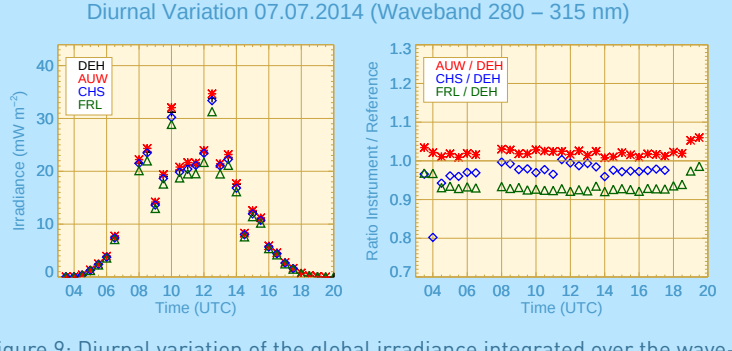
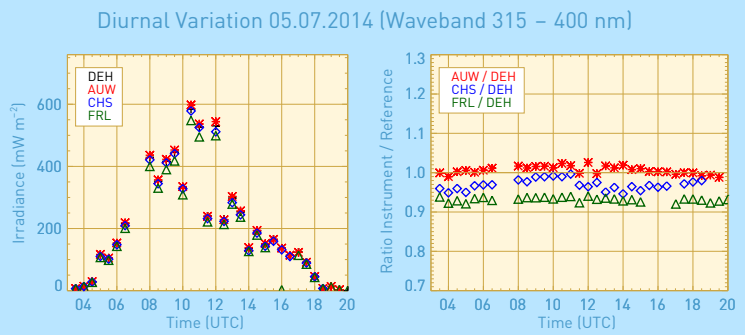
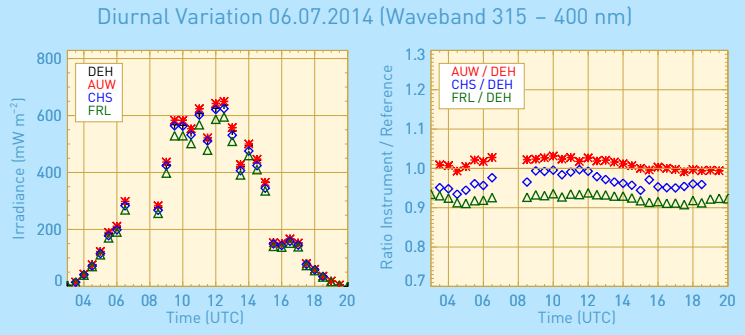


Figure 9: Diurnal variation of the global irradiance integrated over the wavelength interval of 280 to 315 nm. The absolute values are shown on the left hand side and the ratio between participants and reference instrument are shown on the right hand side.





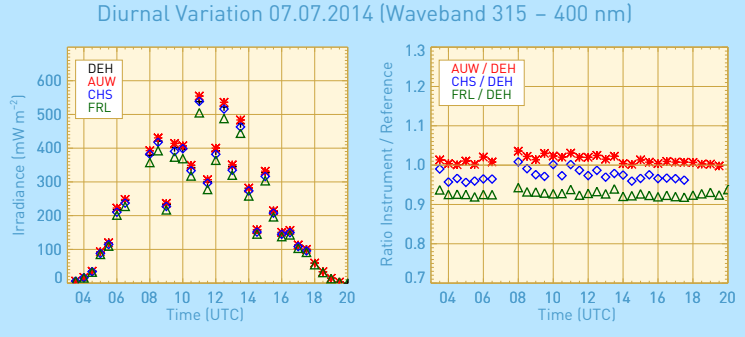


Figure 10: Diurnal variation of the global irradiance integrated over the wavelength interval of 315 to 400 nm. The absolute values are shown on the left hand side and the ratio between participants and reference instrument are shown on the right hand side.

UV range shown in Figure 5. This suggests that no wavelength dependent diurnal shift is occurring.

Conclusion

The results of the intercomparison show that the spectral irradiance measured by the AUW instrument deviates less than 3% from the reference instrument for a large variety of measuring conditions, which is well within the NDACC specifications and is very satisfactory. The CHS instrument deviates by less than 6% from the reference instrument. However, the DEH facilities for absolute calibration were used for the CHS instrument and therefore the instrument was not calibrated independently during the campaign. The Chilean group intends to employ a lamp housing for field calibration purposes which is a direct "clone" of the housing used by the DEH group. The CHS group is therefore encouraged to continue its effort for building up an independent calibration system. At a later stage the performance of the calibration should be assessed. In addition, the shift of the diurnal deviation also indicates a cosine error which needs to be checked. The FRL instrument showed that the instrument reads up to 9% lower spectral irradiance for all measurements of the three campaign days. It has been found that about 4% of this difference is due to a systematic difference of the calibration lamps. Even if the systematic difference of 9% would remain, this does not imply a significant error for the UV monitoring with the NDACC, because the difference remained constant with time. Nevertheless this difference requires further investigations by the FRL group.

In summary the intercomparison revealed a satisfactory agreement and there is no indication of severe problems in the quality of the NDACC UV data for the participating instruments.

News from the Dobson and Brewer Working Group

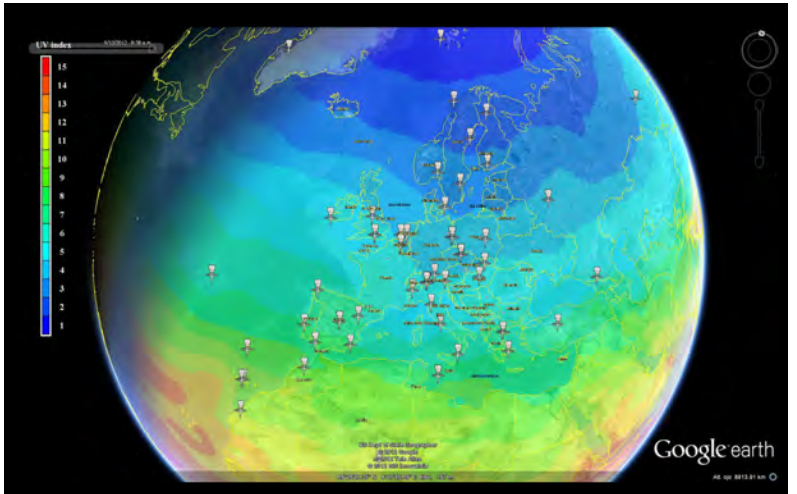
Instruments taking part in the Brewer intercomparison in Arosa, Switzerland, July 2014.
Photo: Geir Braathen

EuBrewNet – A European Brewer Network and its global impact on the Brewer community

John Rimmer, University of Manchester, U.K. and
Volodya Savastiouk, International Ozone Services, Toronto, ON, Canada

The fully automated Brewer Spectrophotometer, the successor to the Dobson spectrophotometer which pioneered the ozone column measurements from the ground for most of the 20th century, has provided high quality total ozone column data for more than 30 years and is now deployed at most of the ground based total ozone column (TOC) monitoring stations. It is also capable of measurements of ozone vertical profiles (Umkehr method), spectral UV radiation and aerosol optical depth in the UV (AOD-UV), as well as columns of other trace constituents such as sulphur dioxide and nitrogen dioxide. Out of the more than two hundred instruments throughout the world, there are around fifty Brewer spectrophotometers deployed within Europe (some already since the early 1980s), independently operated by national agencies. This represents not only a significant proportion of the total global monitoring effort, but also an extremely valuable European resource of co-located TOC, UV and AOD-UV measurements which has been considerably underused due to the lack of coordination and harmonisation between the respective agencies, where each was duplicating efforts to try to achieve independently best practice and accuracy. The co-location of these measurements is crucial for providing consistent data for research into radiative transfer and forecasting models, however the previously existing disparity severely restricted the overall utility of European data.

EuBrewNet is coordinating Brewer Spectrophotometer measurements of ozone, spectral UV and aerosol optical depth (AOD) in the UV within Europe through a formally managed European Brewer Network capable of delivering a consistent, spatially homogeneous European data resource, significant for the World Meteorological Organisation (WMO), the World Ozone and UV Data Centre (WOUDC), the International Ozone Commission (IO_3C), the Intergovernmental Panel on Climate Change (IPCC), and the ozone trend assessment panels. EuBrewNet scientists are working together to improve and standardise characterisation and calibration of the instruments and also to centrally process the data into near real time, and longer term, records with a common, centralised quality control procedure. All Brewer spectrophotometers that are part of NDACC have now been fully incorporated into EuBrewNet. This will strengthen the quality of the data from these instruments and once the standard processing of all Brewers have been implemented more Brewers with long data records will



A UV index map showing the location of stations participating in the EuBrewNet network.

qualify for NDACC data submission.

A series of short term scientific missions (STSMs) has provided much of the experimental results behind this and has provided networking opportunities for early stage researchers. Most notable STSMs include investigations into spectral UV cosine correction and temperature dependance, as well as characterisation of the polarisation effects from the slant quartz window. Advancements in NO_2 calculations using MKIV Brewers will lead to inclusion of this atmospheric parameter to the suite of the Brewer network products.

The data will be automatically transferred from the stations into a new central database hosted by AEMET where the processing and quality control will be applied. Successful trials are already being carried out and once the database becomes fully live, data will be available to registered users for scientific use.

Already, EuBrewNet has grown beyond Europe with the addition of, NOAA, Environment Canada and the University of Tasmania and is working to assist with training in the RAII region (Asia). Other affiliates include York University, Toronto, International Ozone Services and Kipp and Zonen, who manufacture the Brewer Ozone Spectrophotometer.

Further information can be found at http://www.eubrewnet.org and http://www.cost.eu/COST_Actions/essem/Actions/ES1207.

News from the Sonde Working Group

Thomas Schmidt, meteorologist of the 2012 overwintering crew, launching an ozonesonde from the roof of the Neumayer III station during stormy weather conditions on 5 September, 2012. © Stefan Christmann.

Ozonesonde Data Series Homogenisation

Project Status as of 15 December 2014

Bryan Johnson, NOAA Global Monitoring Division, Boulder, CO, USA

This is the second progress report for the Ozonesonde Data Series Homogenisation Project. The original report, published in the NDACC newsletter from September, 2013 (Volume 5), outlined the primary steps for homogenizing long term ozonesonde data sets in order to reach the general goals of the SPARC/IO$_3$C/IGACO-O$_3$/NDACC "Initiative on Past Changes in the Vertical Distribution of Ozone". Though progress has been slow and fallen behind the original schedule new software editing tools and techniques have emerged at several sites that greatly reduces the time and effort to read, edit, and apply corrections to old and current ozonesonde profiles in order to create a homogenised record. Within the last year, 15 ozonesonde sites have completed new data sets. Eight of the completions are from sites submitting data to NDACC. The success and efficiency in using the ozonesonde editing software has helped in proceeding with new project goals, which will be focusing more time towards collaboration, coaching, and publications. The homogenisation project goals and a timeline, briefly outlined below, was discussed during a December 1, 2014 teleconference meeting led by Herman Smit.

- December 31, 2014: Coaches contact assigned ozonesonde stations on progress and level of assistance desired.
- January 1 – April 30, 2015: Continue data processing.
- June, 2015: Workshop with coaches and select number of station personnel on progress with data processing.
- June 30, 2015: ~ Completion of 25-30 selected long-term ozonesonde sites (out of 55 total) and ready for evaluation.
- June – December, 2015: Validation and evaluation of data sets by satellite products.
- October-December, 2015: Key manuscripts for publication should be submitted.
- January, 2016: Ozone experts meeting and plans for next JOSIE intercomparison campaign.

New software examples

At NOAA in Boulder, Colorado USA, the enormous task of reviewing and editing individual ozonesonde profiles led to the development of SkySonde Processor (Language: C, Programmer: Allen Jordan) beginning in 2011. The current version for post-processing NOAA balloon flights recalculates data fields from raw fields present in the files, shows default and custom profile plotting, edit/flag any bad data fields, and make final output files for distribution. There are many advanced processing features, including the ability to offset and smooth the pressure field and recalculate every field dependent upon pressure. The total column ozone calculation can be adjusted by changing the altitude where profile integration stops and the residual ozone amount is added. Total column values are displayed numerically and graphically along with the OMI satellite from NASA and NOAA Dobson total column ozone. The most recent addition to the program now allows downloaded Earth Observing System (EOS) Microwave Limb Sounder (MLS) coincident overpass profiles from NASA for ozone mixing ratio and water vapour mixing ratio. Averaging kernels are applied for better comparisons with respect to the satellite sensitivity.

Environment Canada has developed REPO (Language: C, Programmer: Jonathan Davies) for reading older WOUDC format files,

removing normalisation factors that were applied to older sonde data, then applying the appropriate corrections. REPO has the advantage that it is designed to work in batch mode: the input is a batch file of filenames with flags indicating the corrections to be applied to each file.

Environment Canada is also developing SNDPRO 2 (Language: C, C++, and Python, Programmer: Jonathan Davies) The program is set up to work with unique data formats such as different ozonesonde versions from DigiCORA systems. Similar to SkySonde , the goal is to generate clean raw data and be able to run editing calculations from that level. The New SNDPRO 2 reads in .MWX files from the Vaisala MW41 sounding system for viewing and editing with onscreen capability for selecting and editing data points and outputs WOUDC format files.

Ozone uncertainty

An essential aspect of this homogenisation is the estimation of expected uncertainties. The basic idea of the ozonesonde homogenisation process is to remove all known bias effects from the measured instrumental parameters in order to determine the partial pressure of ozone during a vertical balloon sounding. It is assumed that after removal of all the measured parameter biases and inhomogeneity, the remaining uncertainties of the corrected values are random and follow Gaussian statistics in error propagation. New data profiles now have a column added for the uncertainty in ozone partial pressure. The primary uncertainty sources and procedures to follow to quantify them are given by Herman Smit and the O3S-DQA panel in the "Guide Lines for Homogenisation of Ozone Sonde Data – Version 2.0: 19 November 2012" available at:
http://www-das.uwyo.edu/~deshler/NDACC_O3Sondes/O3s_DQA/O3S-DQA-Guidelines%20Homogenization-V2-19November2012.pdf.

Environment Canada's REPO also includes code added by David Tarasick to calculate measurement uncertainty for each flight from the estimated errors in pump flow, temperature measurement, background estimation, etc., and also includes the error introduced by the radiosonde pressure uncertainty. Ambient pressure errors can shift the profile and result in a significant error in the ozone profile at upper altitudes.

The current primary goal of completing 25-30 homogenised and validated ozonesonde data sets from selected stations by December, 2015 will be a major step set toward providing satellite and ozone modeling groups with a valuable data set. The new developments in ozonesonde editing tools will also benefit the ozonesonde community with faster, better methods to process new incoming data and upload them to the NDACC and WOUDC databases.

Lagrangian trajectories applied to instrument comparisons between platforms

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Abstract

A Lagrangian approach has been developed (J. Staufer, PhD thesis at ETH Zürich) to compare the ozone observations from instruments on different platforms in the UTLS (Upper Troposphere Lower Stratosphere within defined criteria in space and time. In two recent papers (Staufer et al., 2013, 2014), the so-called MATCH method recently developed to compare the MOZAIC commercial airlines measurements with the regular ozone soundings from different stations is described. Different tests have been completed to optimise the matching criteria and to validate the method, in particular the self-match of the MOZAIC measurements is reported in these publications. The method is applied to different stations from the NDACC network and shows an improvement of the UTLS data quality in the last decades compared to common reference (MOZAIC).

Methodology

Trajectory models describe the path of an air parcel over a finite time and are widely used to study dynamical and chemical processes in the atmosphere, for example to determine pathways of pollution export (Stohl et al., 2002) or to derive ozone loss rates in the Arctic vortex (Rex et al., 1998).

Commercial aircraft spend a large fraction of their flight time in the UTLS, therefore the low ozone concentration and the large horizontal and vertical ozone gradients in the UTLS are challenging for this approach. The first step of this work has been to develop a trajectory model that enables a detailed comparison of operationally-flown ozonesondes from a large number of launch sites with MOZAIC aircraft measurements. The trajectory model selected is LAGRANTO (Wernli and Davies, 1997) driven by 6-hourly wind fields from ECMWF's ERA-Interim reanalysis with a of 1° × 1° horizontal resolution and 61 hybrid vertical levels.

The method is illustrated in Figure 1 for an ozonesonde launched at Payerne: the air parcels backward trajectories (grey lines)

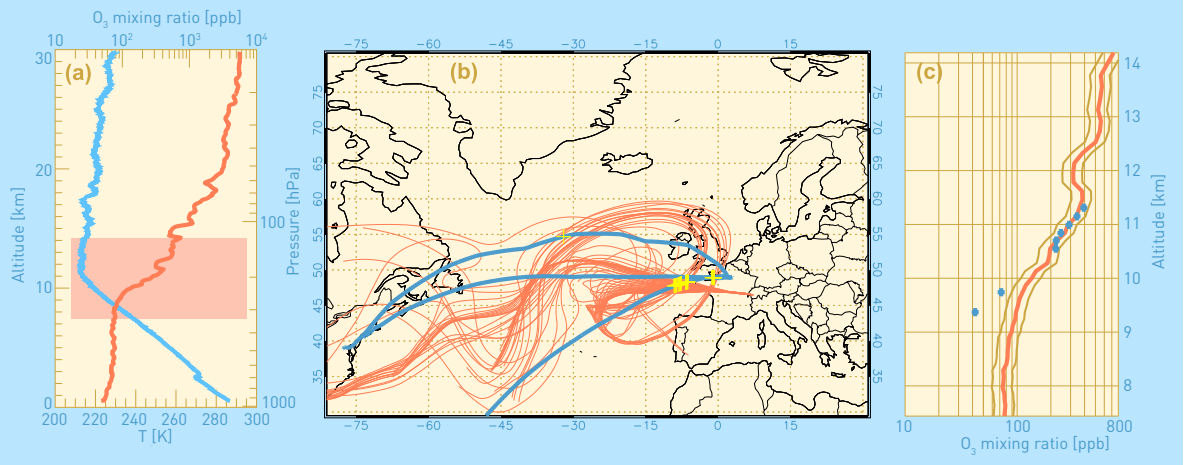

Figure 1: (a) Ozone (orange) and temperature (blue) profiles measured at Payerne on 18 April 1995, the pink area indicating the UTLS. (b) Plot of the 6-day backward trajectories (orange lines) and the flight paths of three MOZAIC aircraft (blue lines). Yellow crosses denote the matches. (c) Ozone as function of altitude observed by the sonde in the UTLS, each blue dot denotes the weighted mean of the aircraft observations.

converging onto the ozone sonde profile at different altitudes were previously measured by MOZAIC aircraft along their flight paths (blue lines).

The tropopause was at about 10 km altitude with a temperature of 218 K, marking the transition into a nearly isothermal stratosphere while O_3 increases sharply across the tropopause (Figure 1 a). Backward trajectories calculated from Payerne match MOZAIC aircraft over the Atlantic ocean west of the French coast (Figure 1 b). The weighted mean is calculated for each trajectory and compared to the ozone measurements of the sounding at initialisation of the respective trajectory (Figure 1 c). The measurements above 10 km agree fairly well, whereas the two points below show pronounced differences. The aircraft observations for these two points are found in western France (around 40 ppb) and southeast of Greenland (around 70 ppb), respectively. This result shows that matches in the troposphere are more critical than those higher up in the stratosphere.

In order to find appropriate values for the matching criteria and to obtain an estimate of the accuracy of the MATCH approach, this technique has been applied to the data provided by the same instruments type, termed "self-match". Zero differences would be expected if the trajectories were noise-free, the observed species a real passive tracer and if the uncertainties of the measurements were negligible. For the self-match analysis in this work, only trajectories "connecting" two different MOZAIC aircraft within ±6 days have been used. To test the sensitivity to the matching criteria, for each trajectory the horizontal matching radius r and the vertical criterion $\delta\theta$ (difference in potential temperature between trajectory and aircraft) has been varied. The root mean square of the relative differences of ozone has been calculated for a set of trajectories. Figure 2 (left panel) illustrates the difference profiles obtained for three sets of matching criteria with r in the range 50–100 km and $\delta\theta$ in the range 0.25-1 K: no significant dependence on r and $\delta\theta$ is found. The middle panel of Figure 2 shows the difference for the forward (blue), respectively backward (black) trajectories which shows that the time "reversal" doesn't make a major effect.

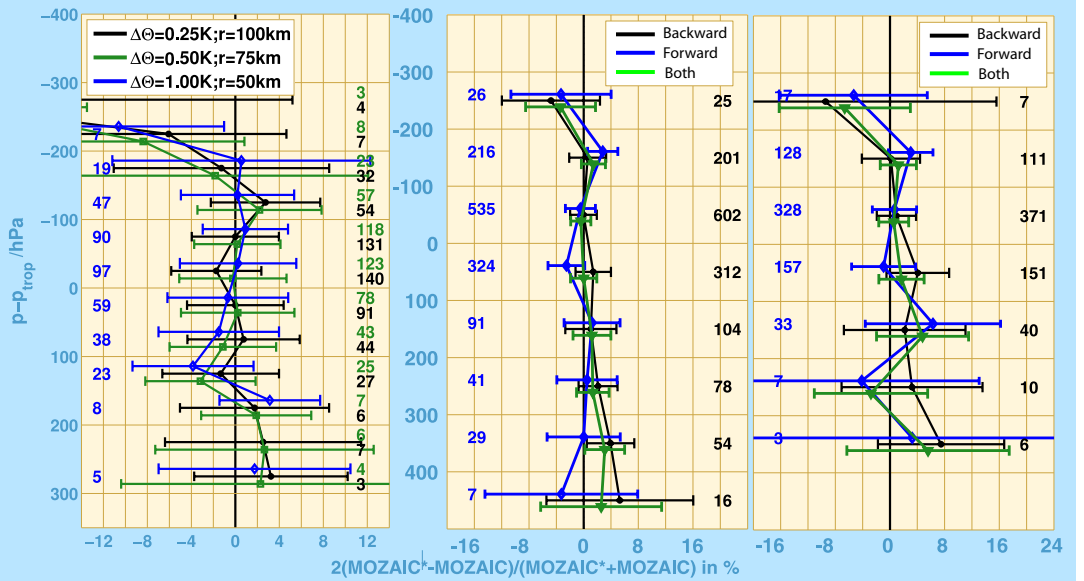

Figure 2: Illustration of the difference profiles obtained between MOZAIC aircrafts measurements. 6 days trajectories for the years 2000 – 2001 have been used in these sensitivity analyses. Left panel: sensitivity to different matching criteria. Middle panel: sensitivity between forward and backward trajectories. Right panel: similar to the central panel but without the first day matches to test the sensitivity to the length of the trajectories.

Finally the right panel is similar to the middle panel but the first ±24 hours have been excluded from the analysis which shows the increase of the uncertainty for longer duration trajectories. With these tests of the "self-match" of MOZAIC data, it is concluded that ozone could be considered as an adequate passive tracer resulting in an uncertainty of about ±2% and that this approach is adequate for the comparison of multiple platforms.

Results

In the first paper, Staufer et al (2013) present the method and its application based on the Payerne ozone sounding series covering the MOZAIC period 1995 – 2009. Within this time period, the ozonesonde type has changed from Brewer- Mast to ECC in September 2002. The analysis clearly shows the improvement of the measurements quality in the UTLS with the ECC sondes as well as for example the effect of the normalisation of the ozone profiles for the BM sondes. Different results in regards to the season, to the difference between forward and backward trajec-

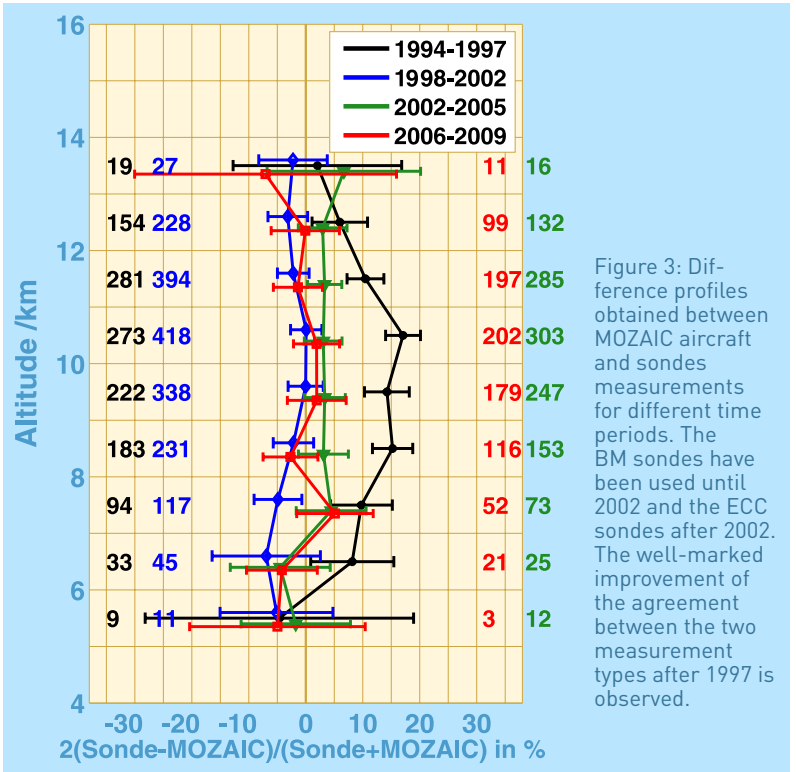

Figure 3: Difference profiles obtained between MOZAIC aircraft and sondes measurements for different time periods. The BM sondes have been used until 2002 and the ECC sondes after 2002. The well-marked improvement of the agreement between the two measurement types after 1997 is observed.

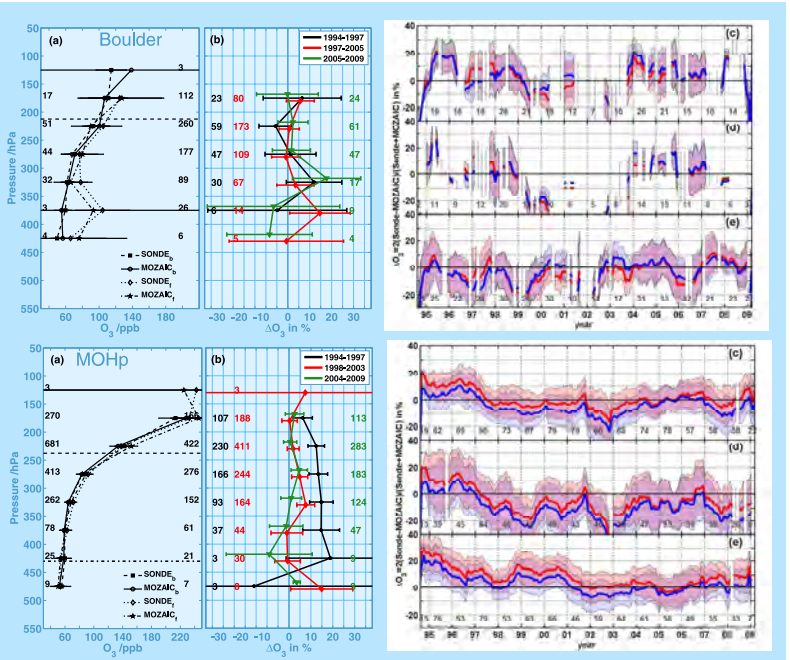

Figure 4: Results for the Boulder and Hohenpeissenberg NDACC station. (a) mean UTLS ozone profiles from the sondes and the airplanes differentiating forward and backward trajectories. (b) Average difference profiles for three time periods. Time series of the differences between partial ozone columns for the LS (c), a narrow tropopause band (d), and the UT (e) . The colours red (blue) refer to normalised (not normalised) profiles to an independent total ozone column. Numbers indicate the number of matches.

tories as well as the length of the trajectories are found in this paper. One example of the results is illustrated in Figure 3 which presents the difference profile between the MOZAIC and sondes data with respect to altitude for different time periods. These are distinguished with the colour code, BM sondes were used until 2002 and ECC sondes after 2002. A clear bias is observed at the tropopause levels between the MOZAIC and the sondes data sets before 1997 whose origin is not clear.

In the second paper by Staufer et al (2014), the method has been applied to 28 ozone sounding sites, half of them being part of the NDACC network. The distribution of the MOZAIC flights being a preponderant factor for this type of analysis, the stations are not all equally sampled over space and time. Therefore the interpretation of the results has to be made with cautiousness of these differences. Figure 4 illustrates the results for the NDACC stations Boulder and Hohenpeissenberg. Boulder is at the edge of the MOZAIC-covered domain dominantly "sampled" with forward trajectories reaching aircraft flying over the continental US territory. Hohenpeissenberg is located at the centre of the MOZAIC domain, which explains the difference in the number of coincident data and the continuity of the times series.

The general tendency of an improved agreement between the sondes and the aircraft data is clearly shown in the analysis of the different stations. Differences of up to 25% in the mid-1990s have decreased to around 5–10% in subsequent years for most of the stations.

Conclusion

The MATCH technique gives promising results for the comparison of instruments on different platforms and asks for further developments. A good trajectory model and a comprehensive "self-match" validation allows to better identify and relax the coincident criteria to improve the statistical significance of the results by increasing the number of matches. In the PhD thesis, the method has been extended to comparison between sounding stations and satellite profiles which allows an extension to the global network with a more homogenised distribution of the matches over the globe.

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News from the Infrared Working Group

The Jungfraujoch Station in the Bernese Alps.
Photo courtesy of: http://www.jungfrau.ch

Atmospheric circulation changes identified thanks to ground-based FTIR monitoring of hydrogen chloride (HCl)

Emmanuel Mahieu, University of Liège, Belgium, Martyn Chipperfield, University of Leeds, U.K., Justus Notholt, University of Bremen, Germany and Thomas Reddmann, Karlsruhe Institute of Technology, Germany

Monitoring the success of the Montreal Protocol on substances that deplete stratospheric ozone is one of the primary tasks of the NDACC network. Among the various techniques involved, giving access to numerous relevant parameters, the ground-based FTIR instruments contribute significantly by providing total and partial columns of key tropospheric and stratospheric constituents. Indeed, high-resolution solar infrared spectra contain the signatures of a suite of halogenated organic source gases. The current list includes CFC-11, CFC-12, HCFC-22, HCFC-142b, CCl_4, CF_4, SF_6 (e.g., Krieg et al., 2005; Zander et al., 2008; Rinsland et al., 2012; Mahieu et al., 2013a; Mahieu et al., 2014a) and efforts are ongoing to expand this list. In addition, the respective evolutions of the inorganic chlorine and fluorine loadings in the stratosphere are also accessible to this technique through observations of the main reservoirs, i.e. hydrogen chloride (HCl) and chlorine nitrate ($ClONO_2$), hydrogen fluoride (HF) and carbonyl fluoride (COF_2). Time series and trends of all these species have been reported and analyzed in successive studies, notably allowing characterising from the ground the rapid increase of inorganic chlorine (Cl_y) in the Earth's stratosphere (e.g., Zander et al., 1987; Rinsland et al., 1991, 1996; Reisinger et al., 1995), following large emissions of anthropogenic halogenated source gases during the 1970s to 1990s. Later, studies involving several NDACC ground-based FTIR stations provided evidence for a stabilisation of HCl and $ClONO_2$ around the mid-1990s (Rinsland et al., 2003), and then a near-global characterisation of the Cl_y decrease at rates close to 1%/yr in both hemispheres at 17 sites between 80°N and 78°S (Kohlhepp et al., 2012).

Recently, Mahieu et al. (2013b) concentrated on the post-peak evolution of HCl using the latest observations available from the Jungfraujoch station (Swiss Alps, 46.5°N) and from a composite satellite partial column time series based on infrared solar occultation measurements performed by HALOE (Halogen Occultation Experiment, onboard UARS; Russell et al., 1993) until 2005 and by ACE-FTS (Atmospheric Chemistry Experiment-Fourier Transform Spectrometer, onboard SCISAT; Bernath et al., 2005) from 2004 onwards. Although this study confirmed for the 1997-2007 time period the amplitude of the downward trend determined by Kohlhepp et al. (2012), both the ground-based and satellite data sets revealed a significant re-increase (at the 2σ level of uncertainty) of the HCl reservoir in the Northern Hemisphere mid-latitude stratosphere after 2007. This feature was unexpected given the well documented and smooth decrease of total organic chlorine in the troposphere (e.g. WMO 2010, 2011). At that time it was possible to exclude that a change in the partitioning among the main inorganic chlorine reservoirs was responsible for the HCl upturn since the Jungfraujoch time series combining HCl and $ClONO_2$ columns also exhibited a significant increase of Cl_y after 2007. Possible causes for this HCl upturn include a change in atmospheric circulation or the substantial contribution of new unknown chlorine-bearing source gases to the organic chlorine budget monitored by the AGAGE and NOAA/ESRL in situ networks.

These observations and questions stimulated a follow up study including data from other NDACC stations to check whether the recent HCl increase was a global atmospheric feature. We also

used the GOZCARDS satellite data set (merging measurements of HALOE, ACE-FTS and Aura/MLS; Froidevaux et al., 2013) in order to confirm the ground-based observations and to get information on the altitude range where the changes were taking place as well as simulations by the state-of-the-art 3-D chemistry transport models SLIMCAT and KASIMA (Kohlhepp et al., 2012).

The paper reporting about these investigations has recently been published in Nature (Mahieu et al., 2014b) and the main findings are as follows:

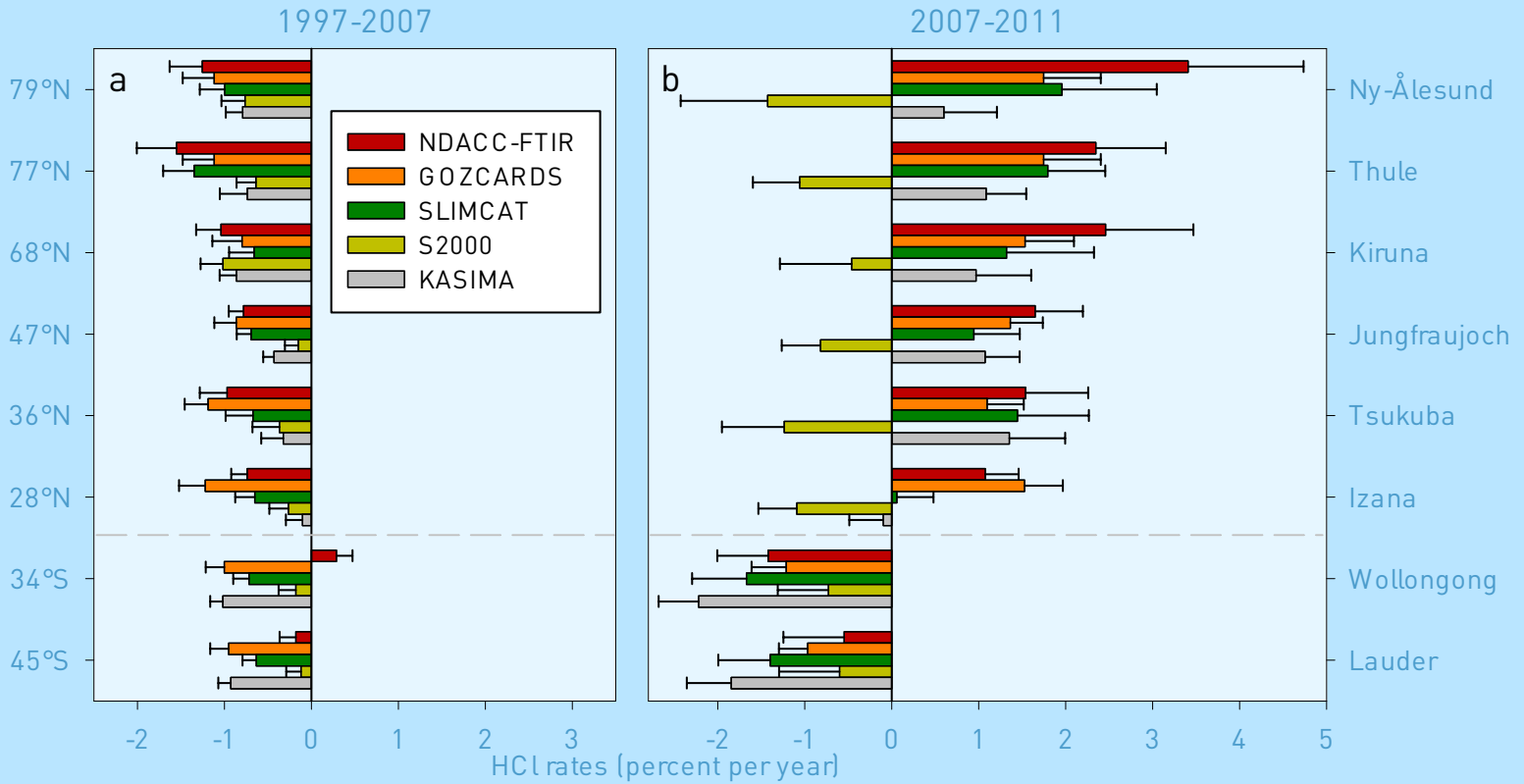

Figure 1. HCl relative rates of changes in %/yr determined for the 1997-2007 (panel a) and 2007-2011 (panel b) time periods, from the various observational and modeled data sets (see colour key for their identification) at eight NDACC stations and latitudes. The error bars correspond to the 2σ level of uncertainty (from Mahieu et al., doi:10.1038/nature13857, 2014b).

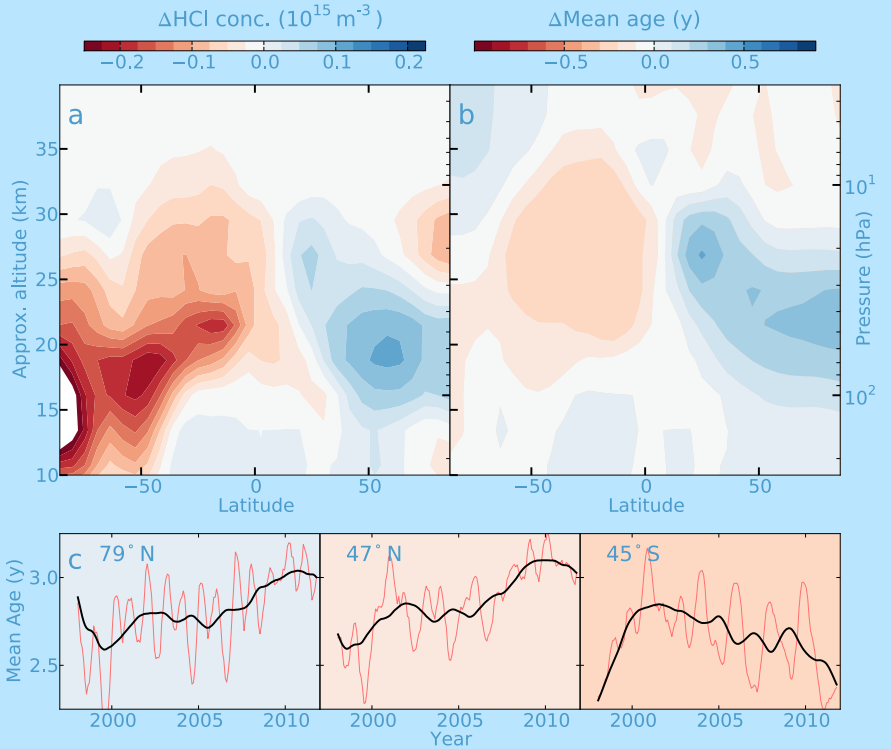

Figure 2. Mean differences of the HCl concentration (panel a) and age-of-air (panel b) between 2010/2011 and 2005/2006 as a function of altitude and latitude, as derived from the standard SLIMCAT run (from Mahieu et al., doi:10.1038/nature13857, 2014b).

- As shown in Figure 1a, HCl negative rates of changes are found at the eight NDACC sites for 1997-2007 (in red), in agreement with the satellite data (in orange); SLIMCAT and KASIMA model simulations using ERA-Interim meteorology and surface source gases mixing ratios from the WMO A1 scenario confirm these trends in sign and amplitude (in green and grey, respectively).
- For 2007-2011, we observed a contrasting situation, with NDACC, GOZCARDS, SLIMCAT and KASIMA showing significant increases of HCl in the Northern Hemisphere, at rates up to 3%/yr, while the various data sets consistently show HCl decreases in the Southern Hemisphere.
- A dedicated SLIMCAT run (denoted S2000, light green) used constant 6-hourly winds of 2000, from 2000 onwards, to study the impact of atmospheric dynamics. Clearly, this run does not produce the HCl increase in the Northern Hemisphere (Fig. 1b) and since the only difference between the standard and S2000 SLIMCAT run resides in the meteorological forcings, we conclude that these are responsible for the HCl upturn.

Stratospheric circulation changes have been evaluated using an indicator of mean age-of-air available in both models as an idealised tracer with a linearly increasing tropospheric mixing ratio. Figure 2 shows the spatial distribution of the HCl concentration and mean age-of-air changes between 2005/2006 and 2010/2011, as derived from the standard SLIMCAT run. These plots indicate an obvious asymmetry between both hemispheres, with a clear correlation in the lower stratosphere between the HCl increase/decrease over the time period under investigation and a slower/faster Brewer-Dobson circulation.

The slower and specific transport pathways followed by the air masses over the recent years in the Northern Hemisphere has allowed a longer exposure to strong ultraviolet radiation responsible of the photolysis of the source gases, ultimately resulting in a larger relative conversion into the reservoir species.

The most important point is that by combining the NDACC observations with state-of-the-art CTM simulations, we can conclude that the recent HCl increase which occurred in the Northern Hemisphere over 2007-2011 does not

result from rogue emissions of chlorinated source gases. Hence, the Montreal Protocol is well on track and will lead to an overall reduction of the stratospheric chlorine abundance required to ensure ozone recovery in the decades to come. Our study also underlines the constant need for reliable long-term monitoring of the stratospheric composition, both from the ground and from space.

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Identifying fire plumes in the Arctic with tropospheric FTIR measurements and transport models

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Fires release trace gases in the atmosphere, such as carbon monoxide (CO), hydrogen cyanide (HCN), and Non-Methane HydroCarbons (NMHCs), including ethane (C_2H_6), acetylene (C_2H_2), methanol (CH_3OH), formic acid (HCOOH), and formaldehyde (H_2CO). These species can be transported to the Arctic (Shindell et al., 2008) and affect tropospheric chemistry (Tilmes et al., 2011), oxidizing power (Olson et al., 2012), and radiative transfer (Wang et al., 2011) of this sensitive polar region, which has been warming rapidly over the past century (Lesins et al., 2010). The frequency and intensity of biomass burning are strongly linked to climate change, and constitute a large source of the variability in Arctic tropospheric composition. However, our knowledge concerning transport, emissions from fires and sources of Arctic pollution remains incomplete. Our recent study investigates pollution from biomass burning events that occurred in extratropical forests and were transported to the high Arctic with two sets of FTIR measurements, located in Eureka (Nunavut, Canada, 80°05'N, -86°42'W) and Thule (Greenland, 76°53'N, -68°74'W) (Viatte et al., 2015).

Biomass burning tracer species: CO, HCN, and C_2H_6 total columns measured at Eureka and Thule from 2008 to 2012 are shown on the left and right panels, respectively, of Figure 1 (next page). They exhibit strong seasonal cycles, reflecting the importance of chemistry and transport processes in their Arctic budget. In addition to these cycles, simultaneous enhancements of the CO, HCN, and C_2H_6 total columns can be seen in their day-to-day variabilities, such as in April and July 2008 (red circles, Figure 1), and in August 2010 (green squares, Figure 1).

Fire events are identified in the FTIR time series by selecting all days that have simultaneous enhancements of these three primary tracers. Using this methodology, ten biomass burning events have been identified as reaching Eureka and eight at Thule, between 2008 to 2012. In order to match the biomass burning candidate events identified in the time series with actual plumes, it is necessary to find the source fires and show that the plumes generated there are capable of travelling to the Arctic stations where they were observed. Figure 2 shows an example of the source attribution and the travel duration of a plume that reached Eureka on the 10th of July, 2008. As a priori information, STILT footprints (Stochastic Time-Inverted Lagrangian Transport model) are generated to show the source region influencing an atmospheric measurement at Eureka, which for that day is located in Eastern Russia (light blue region inside the red box, Figure 2a). Then the FIRMS map (Fire Information for Resource Management System, which provides MODIS hot spot data) is used to verify

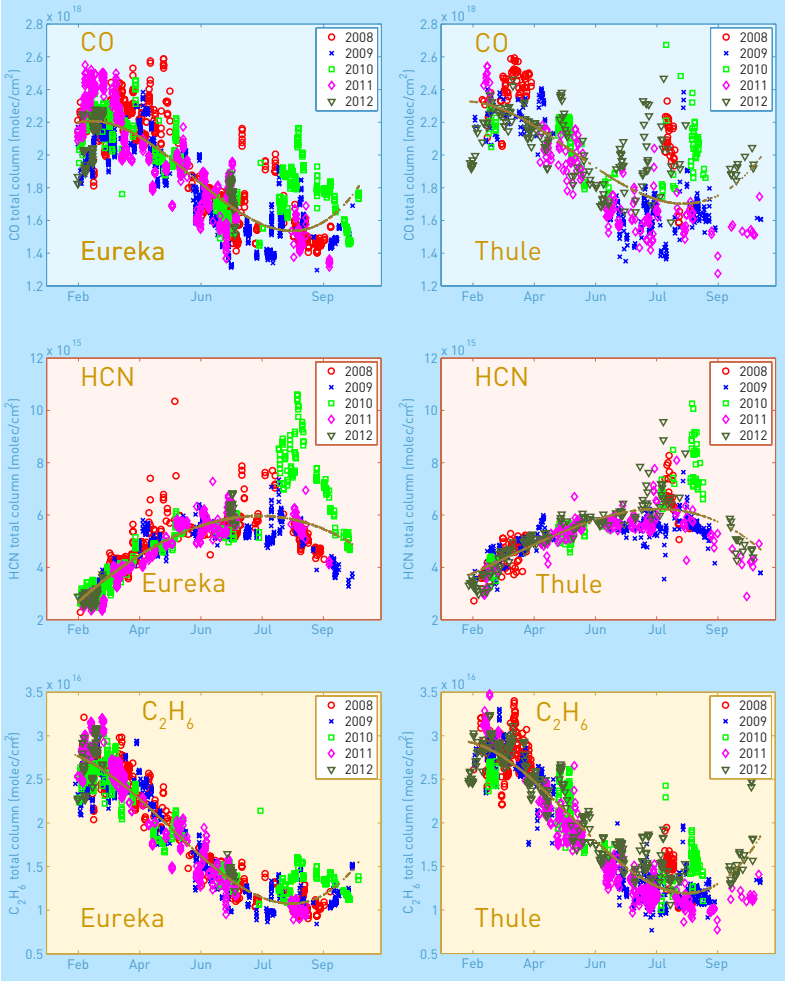

Figure 1: Annual cycles of multiyear CO, HCN, and C_2H_6 total columns measured at Eureka (left panels) and Thule (right panels) from 2008 to 2012. The brown lines represent the polynomial fits to the data.

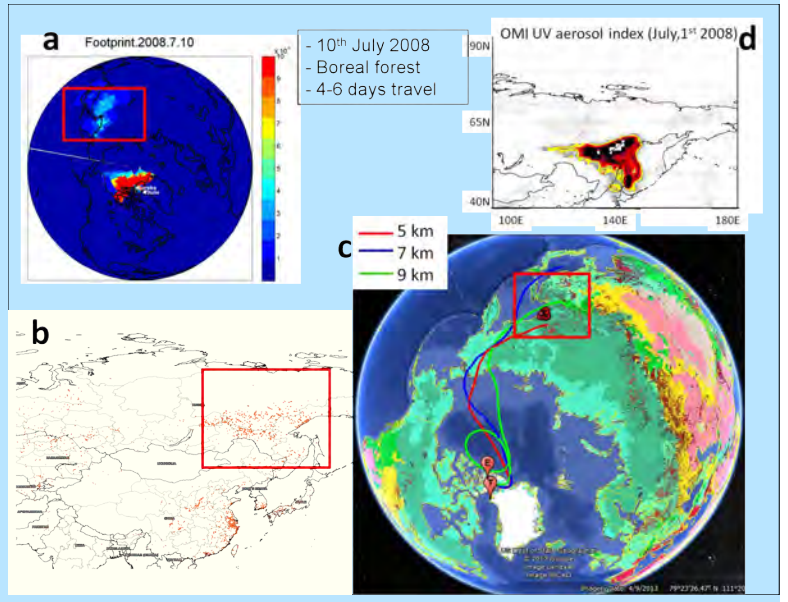

Figure 2: Example of attribution of fire source region and transport time for the event number 3, detected at Eureka on the 10th of July, 2008. a) STILT footprints for that day, b) MODIS fire hot spots, c) HYSPLIT backtrajectories ending that day, d) OMI UV aerosol index for that day.

that a significant fire event occurs in that specific region, within a 10-day period (red dots in Figure 2b). To assess the travel duration of that plume from the fire region to Eureka, an ensemble of HYSPLIT back-trajectories (Hybrid Single Particle Lagrangian Integrated Trajectory Model) is generated, for several travel times, end times of the calculated trajectories, and air-parcel altitudes. In Figure 2c, airmasses ending at Eureka at 5, 7, and 9 km (red, blue, and green lines, respectively) on July 10th, come from the fire region (red box). Then finally, the OMI (Ozone Monitoring Instrument) aerosol index map is used to confirm the presence

of a significant fire event in that region, as shown in Figure 2d (coloured area within the red box). Consistent results from these multiple data sets provides confidence in the attribution of trace gas enhancements to specific fire events.

To improve our knowledge concerning the dynamical and chemical processes associated with Arctic pollution from fires, the two sets of FTIR measurements were compared to the Model for Ozone and Related chemical Tracers, version 4 (MOZART-4, Emmons et al., 2010). The 2008 time series of daily mean CO, HCN, C_2H_6, C_2H_2, CH_3OH, and H_2CO total columns measured by the FTIRs at Eureka and Thule (Figure 3, blue and green dots, respectively), and calculated by MOZART-4 at these two sites (Figure 3, black and red dashed lines, respectively) are used to compare their seasonal cycles. This year was chosen because the April and July biomass burning events have been studied during the ARCTAS (Arctic Research of the Composition of the Troposphere from Aircraft and Satellites) campaign.

In winter, CO, HCN and C_2H_2 total columns estimated by MOZART-4 agree very well with the FTIR measurements, leading to high confidence in the transport mechanisms in the model, since it is the major process controlling the Arctic budget of these long-lived gases. However, for C_2H_6 which is also a long-lived tracer, the underestimation of its concentrations by MOZART-4 in winter confirms an underestimation in anthropogenic emissions in the model. Also we note that in spring and summer, the overestimation of modelled concentrations suggest that loss processes for HCN are missing, confirming that its sinks are not well quantified (Zeng et al., 2012). The CH_3OH seasonal cycle estimated by MOZART-4 exhibits the best agreement with the observational data sets at Eureka. Focusing on the July 2008 biomass burning event, the CH_3OH enhanced concentrations are well captured by the model, suggesting that its fire emissions are correct. For CO

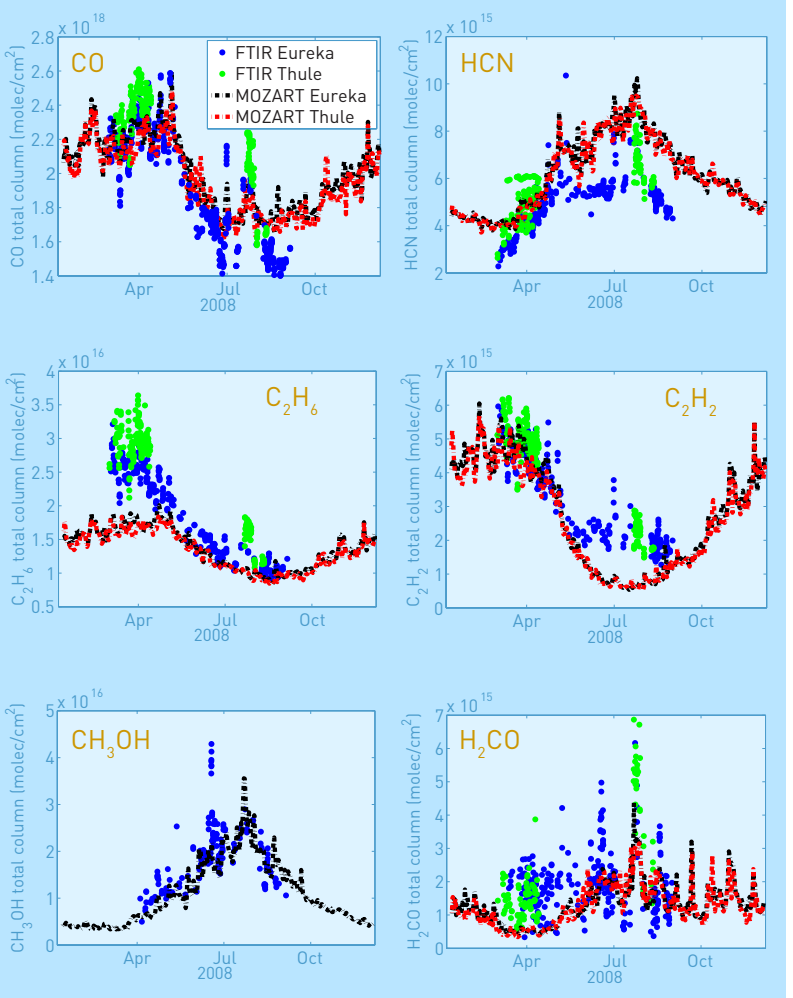

Figure 3: Timeseries of CO, HCN, C_2H_6, C_2H_2, CH_3OH, and H_2CO total columns measured by the FTIRs at Eureka (blue) and Thule (green) and calculated by MOZART-4 at Eureka (black) and Thule (red) for 2008.

and H_2CO, enhancements estimated by the model are too low compared to the measurements. This might indicate that their fire emissions are too low in the model. In contrast, the modelled and measured HCN enhancements are in good agreement. For C_2H_6 and C_2H_2, the modelled enhancements are extremely low compared to the measurements, indicating missing sources.

These results indicate that long-term and continuous measurements of Arctic tropospheric composition are important for quantifying emissions from fire plumes transported from lower latitudes and improving the prediction of trace gas concentrations and variability in chemical transport model simulations. This would help in assessing the atmospheric impact of biomass burning pollution on the Arctic climate system. Further, that mid-latitude land use and pollution sources are changing we can expect increased pollution and biomass burning events. The warming Arctic is rapidly changing independently. We should expect transport pathways from mid-latitudes to the Arctic to carry more pollutants northward. Our ability to observe and model these events will be critical to our evaluation of the overall anthropogenic effects on the Arctic regions.

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News from the UV-Visible Working Group

The 7th International DOAS Workshop was held from 6 to 8 July 2015 at the Royal Belgian Institute of Natural Sciences, Brussels, Belgium. Photo: Jeroen van Gent.

7th International DOAS Workshop

Karin Kreher, Bodeker Scientific, Alexandra, New Zealand and
Michel van Roozendael, Belgian Institute for Space Aeronomy (BIRA-IASB), Brussels, Belgium

The 7th International DOAS Workshop was held from 6 to 8 July 2015 at the Royal Belgian Institute of Natural Sciences in Brussels. The workshop was dedicated to recent advances in DOAS research, from instrumental and algorithmic developments to applications in various fields of atmospheric research including a discussion session on future directions. The workshop attracted 105 attendees, and 43 oral presentations and 65 posters were presented during the three days. Further details including the programme can be found at https://events.oma.be/indico/event/1/.

The versatility of the DOAS technique was demonstrated in copious presentations with a number of contributions reinforcing a progression from stratospheric monitoring to tropospheric studies such as further developments in imaging techniques and air quality studies. The main sessions focused on the following topics: New instrumental concepts, improvements in data retrievals, aerosols and clouds, halogens, urban applications, airborne observations and campaigns, and satellite retrievals and validation. The importance of long-term monitoring and associated networks, such as NDACC, providing high-quality time series for the validation of the upcoming satellite missions and for trend analysis, were also high-lighted.

We furthermore took the opportunity to attach a one-day meeting of the NDACC UV-Visible Spectroscopy Working Group hosted by IASB-BIRA to review the status of the current network of measurement sites and to further elaborate on the outcomes of the DOAS workshop. Topics covered were the importance of maintaining the existing long-term monitoring infra-structure within the NDACC network for trend analysis and validation efforts including plans for future activities such as further development and homogenisation of MAX-DOAS retrieval techniques with a focus on the validation of upcoming satellite missions (e.g. the European Sentinel-4 &-5 missions and the American TEMPO mission). Plans for the CINDI-2 inter-comparison campaign proposed for September 2016 at Cabauw, Netherlands, and other future campaigns were discussed. Members of the Pandora team also participated and the suggestion to develop a close collaboration between the NDACC UV-Visible Network and the Pandonia Network (http://www.pandonia.net/) was very positively received by all.

News from the Lidar Working Group

The lidar at Río Gallegos, Argentina, in operation. Photo: Elian Wolfram, CEILAP (CITEFA-CONICET), Buenos Aires, Argentina

Standardised Definitions and Reporting of Vertical Resolution and Uncertainty for the NDACC Lidar Ozone and Temperature Data

Thierry Leblanc, Jet Propulsion Laboratory, California Institute of Technology, Wrightwood, CA, USA.

As part of NDACC, over 20 ground-based lidar instruments are dedicated to the long-term monitoring of atmospheric composition and to the validation of space-borne measurements of Earth's atmosphere from environmental satellites (e.g., EOS-Aura, ENVISAT, NPP, Sentinel). In networks such as NDACC, the instruments use a wide spectrum of methodologies and technologies to measure key atmospheric parameters such as ozone, temperature, water vapor, etc.. One ensuing caveat is the difficulty to archive measurement and analysis information consistently within all research groups (or instruments). Yet the need for consistent definitions has strengthened as datasets of various origin (e.g., satellite and ground-based) need increased quality control and thorough validation before they can be used for long-term trend studies or be ingested together in global assimilation systems. Within the NDACC Lidar Working Group, a few studies have shown, for example, the impact on ozone of using different definitions of vertical resolution 1,2, or have estimated the impact of various corrections on temperature 3, but little work was done to facilitate a standardisation of the definitions and approaches relating to vertical resolution and uncertainty budget.

In order to address such need for consistency within NDACC lidar data, several NDACC lidar collaborators, led by NDACC Lidar Working Group co-chair T. Leblanc, have joined forces through the formation in 2011 of an International Space Science Institute (ISSI) International Team of Experts (http://www.issibern.ch/aboutissi/mission.html). The objective of this working group (henceforth "ISSI Team") was to provide scientifically meaningful recommendations for the use of standardised definitions of vertical resolution and standardised definitions and approaches for the treatment of uncertainty in the NDACC ozone and temperature lidar data retrievals. Ultimately, the recommendations were designed so that they can be implemented consistently by all NDACC ozone and temperature lidar investigators. This article summarises the achievements and recommendations of the ISSI Team in view of their future implementation within the NDACC lidars.

NDACC-lidar Standardised Vertical Resolution

Generally speaking, vertical resolution, as provided by the lidar investigators in the archived NDACC data files, is an indicator of the vertical filtering applied to the lidar signals or to the species profiles in order to reduce high frequency noise typically produced at the signal detection level. Because the signal-to-noise ratio varies with altitude, the amount of applied filtering usually depends on altitude, with more filtering being applied at higher altitudes. Over the years, NDACC lidar PIs have been providing temperature and ozone profiles using a wide range of vertical resolution schemes and values. Furthermore, the definition of vertical resolution used appears to differ significantly... until now. The ISSI Team reviewed the various vertical resolution schemes and definitions in use by the NDACC PIs, and agreed on the recommendation of two standardised definitions for use in the future NDACC-archived data files.

The first "standardised" definition of vertical resolution recommended by the ISSI Team is based on the response to a Finite Impulse-type perturbation (namely, a Kronecker-Delta Function for smoothing operations, and a Heaviside Step Function for differentiation operations). The standardised definition of vertical

resolution in this case is given by $\Delta z = \delta z * H_{FWHM}$, where H_{FWHM} is the Full-Width at Half-Maximum (measured in data points) of the smoothed and/or differentiated response to the finite-impulse perturbation applied to the unsmoothed and/or undifferentiated signal. Following this definition, an unsmoothed signals yield the finest possible vertical resolution $\Delta z = \delta z$ (one sampling bin). This definition allows multiple smoothing occurrences to be treated analytically in a simple and exact manner, as the final reported vertical resolution rigorously reflects the effect of multiple smoothing occurrences. The reporting of vertical resolution in the NDACC data files following this second definition was recommended by the ISSI Team because it is already widely used in the lidar community and has a lot of commonalities with the vertical resolution driven by the averaging kernels of optimal estimation methods for passive remote sensing.

Another definition to be used by NDACC ozone and temperature lidar relates to digital filtering theory 4. When we apply a Laplace Transform to a set of filtering coefficients, we obtain the Transfer Function which, when divided by the ideal Transfer function, yields the gain of the filter in the frequency-domain. The cut-off frequency is defined as the frequency at which the transfer function equals 0.5. The recommended standardised NDACC-lidar definition of vertical resolution is the cut-off frequency converted back to the physical domain, i.e., expressed in the vertical dimension. It is given by the relation $\Delta z = \delta z/(2fc)$ where δz is the lidar's sampling resolution and fc is the cut-off frequency. Examples of the use of a boxcar window of varying width are shown in Figure 1 for actual temperature profiles measured by the JPL lidar at Mauna Loa Observatory, Hawaii. Similarly to the impulse response-based definition, an unsmoothed signal yields the finest possible vertical resolution $\Delta z = \delta z$ (one sampling bin). One advantage of a standardised vertical resolution definition based on cut-off frequency is that it reflects the actual impact of filtering on geophysical perturbations independently of the type of filter used. For example, it is particularly useful for gravity waves studies from lidar temperature measurements, because it can provide, through the transfer function, spectral information that can help interpreting quantitative findings on the amplitude and wavelength of lidar-observed waves. This type of information is not available when using the impulse response-based definition. Another advantage is that in the case of multiple smoothing occurrences, the product of the transfer function computed for each occurrence is easily computed, and the resulting values of standardised vertical resolution are again conceptually, theoretically and numerically exact. In the case of the NDACC ozone lidars, the Differential Absorption Lidar (DIAL) technique often combines the process of smoothing with the process of differentiating the ratio of the signals collected at the absorbed and non-absorbed wavelengths.

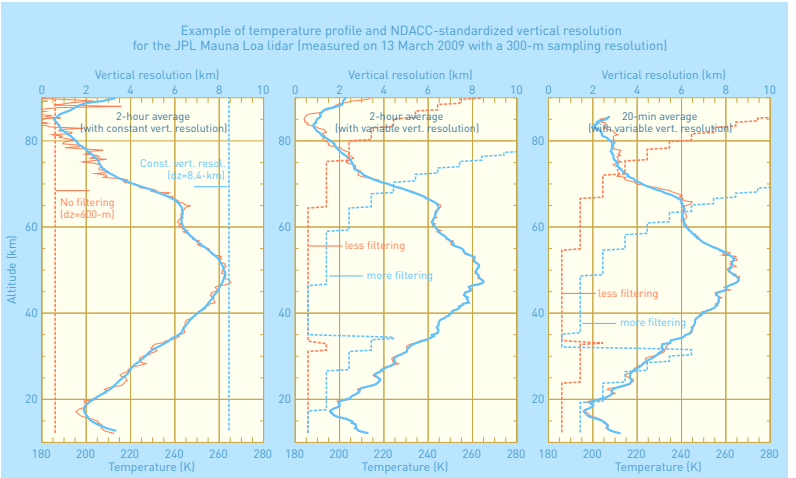

Figure 1. Examples of temperature profiles provided art various NDACC-standardised vertical resolutions. Note that the values of vertical resolution have a wide range, but all values reflect the same standardised definition, based on digital filter theory (cut-off frequency)

The application of the digital filter theory in this case is similar to that of smoothing filters.

Each recommended definition of vertical resolution yields its own numerical values, i.e., for a same set of filter coefficients, the reported standardised vertical resolution has two different numerical values, depending on the definition used. However, the standardised definitions were chosen so that these numerical values remain very close, i.e., within 10% to 20%.

NDACC-lidar Standardised Ozone and Temperature Uncertainty Budget

As mentioned previously, the second objective of the ISSI Team was to recommend standardised definitions and approaches for the treatment of uncertainty in the NDACC lidar ozone and temperature lidar retrievals. Again, the recommendations were designed so that they can be implemented consistently by all NDACC ozone and temperature lidar investigators.

The definitions of uncertainty recommended to be used for all NDACC lidar measurements is combined standard uncertainty. It originates in the two internationally recognised reference documents endorsed by the Bureau des Poids et Mesures (BIPM), namely the International Vocabulary of Basic and General Terms in Metrology (commonly abbreviated "VIM") 5, and the Guide to the Expression of Uncertainty in Measurement (commonly abbreviated "GUM") 6. These two documents and their supplements provide a complete framework to the treatment of uncertainty. The particular case of "standard uncertainty" is defined in the VIM as "the measurement uncertainty expressed as a standard deviation".

The treatment of uncertainty in the ozone and temperature lidar retrievals depends on the choice of the theoretical equations used as well as their implementation to the real world, i.e., after considering all the caveats associated with the design, setup, and operation of an actual lidar instrument. There is therefore no unique answer or solution, but the ISSI Team made specific efforts to produce a set of actionable recommendations and suggest generic approaches that can be adapted to all cases.

The same theoretical equation, namely the "lidar equation" 7, is used to retrieve an ozone number density profile in the troposphere or stratosphere using the DIAL technique 8, and a temperature profile in the stratosphere and mesosphere using the density integration technique 9. The parameters impacting the retrievals relate to the propagation and backscattering of the laser light emitted by the lidar, and therefore include a number of atmospheric species and their scattering and/or absorption properties. Furthermore the lidar equation relates to the number of photons collected on the lidar detectors rather than the raw lidar signals recorded in the data files. Therefore, several signal correction procedures and numerical transformations related to the instrumentation must be included as well. The effects of the data recorders, namely the sky and electronic background noise and the signal saturation (pile-up effect) must be taken into account.

One important recommendation by the ISSI team is to propagate all the individual, independent uncertainty components in parallel through the data processing chain. It is only after the final signal transformation is applied (i.e., leading to the actual values of ozone number density or temperature) that the individual uncertainty components are combined together to form the combined standard uncertainty, the primary and mandatory variable of the new NDACC-lidar-standardised ozone and temperature uncertainty budget. The expression of the individual uncertainty components and their step-by-step propagation through the ozone and temperature data processing chains was thoroughly estimated by the ISSI Team. The validity of the approach and correctness

of the recommended expressions were quantitatively verified using simulated lidar signals and Monte Carlo experiments. The complete uncertainty propagation expressions and the validation experiments are detailed in the ISSI-Team Report10.

For the ozone DIAL retrieval, the sources of uncertainty identified by the ISSI Team are:

1. Random noise associated with signal detection
2. Uncertainty due to saturation correction (photon-counting mode only)
3. Uncertainty due to background noise extraction
4. Uncertainty due to channel merging procedure
5. Uncertainty due to the a priori use of ozone cross-sections
6. Uncertainty due to the a priori use of Rayleigh cross-sections
7. Uncertainty due to the a priori use of air number density (or temperature and pressure)
8. Uncertainty due to the a priori use of NO_2 absorption cross-sections
9. Uncertainty due to the a priori use of NO_2 number density (or mixing ratio)
10. Uncertainty due to the a priori use of SO_2 absorption cross-sections (UV only)
11. Uncertainty due to the a priori use of SO_2 number density (or mixing ratio)
12. Uncertainty due to the a priori use of O_2 absorption cross-sections (at shorter UV wavelengths)

The term a priori here does not mean that the ozone DIAL retrieval uses a variational/optimal estimation method (it does not), but simply means that the information comes from ancillary (i.e., non-lidar) measurements, and is input as "truth" in the data processing chain for use in the various lidar signal corrections needed. Not all of the above sources are necessarily needed, depending on the instrument configuration. All the above sources except detection noise imply correlated terms in the vertical dimension, which means that covariance terms must be taken into account when vertical filtering is applied. In addition, if the same detection hardware is shared by two channels, the covariance terms must be taken into account when dependent channels are combined (e.g., signal merging). When computing the ozone cross-section differentials and the interfering gases' cross-section differentials, the covariance terms should also be taken into account if the same ancillary datasets are used for the "ON" and "OFF" wavelengths.

For the temperature retrieval, the sources of uncertainty identified by the ISSI Team are:

1. Random noise associated with signal detection
2. Uncertainty due to saturation correction (photon-counting mode only)
3. Uncertainty due to background noise extraction
4. Uncertainty due to channel merging procedure
5. Uncertainty due to the a priori use of ozone cross-sections
6. Uncertainty due to the a priori use of ozone number density (or mixing ratio)
7. Uncertainty due to the a priori use of Rayleigh cross-sections
8. Uncertainty due to the a priori use of air number density (or temperature and pressure)
9. Uncertainty due to the a priori use of NO_2 absorption cross-sections
10. Uncertainty due to the a priori use of NO_2 number density (or mixing ratio)
11. Uncertainty due to the a priori use of temperature tie-on at the top of the profile
12. Uncertainty due to the a priori use of acceleration of gravity
13. Uncertainty due to the a priori use of molecular mass of air

Again the term a priori here simply means that the information comes from ancillary measurements, and is input as "truth" in the data processing chain for use in the signal corrections, and again, not all of the above sources are necessarily needed, depending on the instrument configuration.

An example of a full ozone uncertainty budget in the case of the JPL ozone DIAL at Mauna Loa Observatory, Hawaii, is given in Figure 2. A good example of the importance of using a rigorous formulation is illustrated by comparing the uncertainty components owed to Rayleigh cross-sections (orange dash curves) and air number density (cyan long-dash curves) for the measured ozone number density (middle plot, expressed in percent) and derived ozone mixing ratio (right plot, expressed in ppmv). These two components are of the same order of magnitude throughout the entire lidar altitude range, i.e., from 1% in the lower stratosphere to less than 0.1% in the middle and upper stratosphere (middle plot). However, these two components show a very different behavior on the mixing ratio uncertainty plot (right plot). This is because an additional air number density uncertainty term is needed to account for the conversion from measured number density to derived mixing ratio using ancillary temperature and pressure data (typically, radiosonde, results from NWP forecast/analysis or reanalysis).

As part of the ISSI team recommendations, every identified source of uncertainty should be reported in the NDACC-archived metadata file. Though not mandatory, providing quantitative informa-

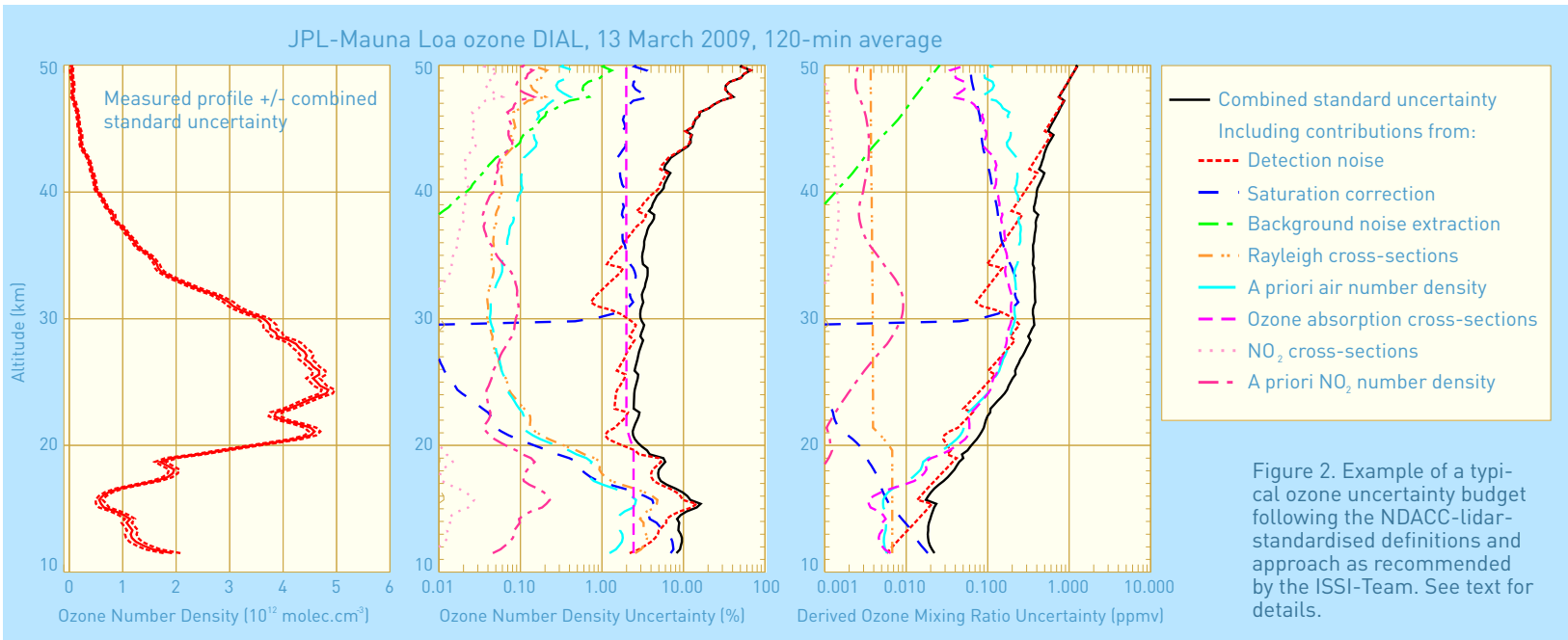

Figure 2. Example of a typical ozone uncertainty budget following the NDACC-lidar-standardised definitions and approach as recommended by the ISSI-Team. See text for details.

tion on the ancillary datasets used for signal corrections is highly recommended. The best estimate of the ozone (or temperature) combined standard uncertainty must be reported in the NDACC-archived lidar data files, whether or not the NDACC-standardised uncertainty budget approach recommended by the ISSI Team is used. The ISSI Team also recommends reporting, whenever possible, the individual standard uncertainty components that contribute to the reported ozone or temperature combined standard uncertainty.

Typical NDACC ozone and temperature lidar profiles are given as a function of altitude and for an averaging time period ranging between a few minutes and several hours. The ISSI Team recommends that information on individual uncertainty components should include the uncertainty source's expected degree of correlation in both the altitude and time dimensions. The ISSI Team formulated basic recommendations on how to use the reported information when using a large set of profiles from the same lidar instrument (for example to produce an ozone or temperature climatology). Each reported individual uncertainty component must be first computed separately using the provided degree of correlation in altitude and time, and then combined. For example, uncertainty owed to detection noise (random behavior) should be computed differently than uncertainty owed to the saturation correction (systematic behavior).

Finally, the ISSI Team reviewed several aspects of lidar data processing impacting the data processing. The results are detailed in the ISSI-Team Report and include:

1. Recommendations on how to handle specific uncertainty sources and corrections
2. Recommendations on how to handle uncertainty associated with fundamental physical constants
3. A non-exhaustive list of ancillary datasets currently available (e.g., climatologies such as WACCM and GOZCARDS, satellite and balloon-borne measurements, and assimilation models) and their uncertainty
4. A comparison of the newest absorption cross-section datasets available (e.g., Univ. of Bremen spectroscopy data for ozone) with older datasets already in use by the atmospheric science community
5. A brief review of the Rayleigh cross-section formulas
6. Recommendations on how to handle uncertainty owed to co-location.

Uncertainty components due to particulate extinction and backscatter were not investigated by the ISSI Team. These terms are very small in a "clean" atmosphere, which is mostly true above 35 km and in most cases of tropospheric ozone DIAL measurements with a small wavelength differential. When present and non-negligible (for example after a large volcanic eruption), their contribution is highly variable from site to site, time to time, and highly dependent on the nature and quantity of the particulate matter at the time of measurement, which precludes the ISSI-Team from providing standardised expressions. However, the ISSI team is very aware that these terms certainly deserve full attention, and is urging for the formation of another Team of expert specifically dedicated to this topic. Finally, because every lidar instrument is unique, not all sources of uncertainty could be investigated by the ISSI-Team. For sources not treated in the ISSI team Report, the ISSI team recommends that the NDACC lidar investigators use the same generic approach as that used by the ISSI team, and simply add those unidentified components to the uncertainty budget following the same definitions, methodologies, and propagation principles.

Implementation of the ISSI Team recommendations within the NDACC-lidar community

The ISSI-Team developed tools to support the implementation of the NDACC-standardised definitions of vertical resolution

across the NDACC lidar groups. These tools consist of ready-to-use "plug-in" routines written in IDL, FORTRAN and MATLAB that can be inserted into the NDACC lidar PIs' data processing software each time a smoothing operation occurs in the data processing chain. The subroutines' input is the filter coefficients and their output is the value of vertical resolution following the digital filter-based or impulse response-based standardised definition. The computed values were validated by the ISSI-Team using Monte-Carlo experiments for several NDACC ozone and temperature data processing softwares. The experiments consisted of producing simulated lidar signals containing noise with frequencies covering the whole spectrum, analyzing the simulated signals to retrieve temperature or ozone, and then comparing the retrieved profiles with the original profiles used to simulate the lidar signals. Besides validating the proper computation of standardised vertical resolution, these experiments show that the computed NDACC-standardised vertical resolution does not necessarily correspond to the width of the filtering window.

Because of the complexity of the ozone and temperature lidar uncertainty budgets, it is not possible to provide plug-in routines for uncertainty similar to those provided for vertical resolution. However, the approach, definitions, and propagation expressions are fully detailed in the ISSI Team Report and can be used by the PIs as needed. The approach and formulations were quantitatively verified using Monte-Carlo experiments involving simulated lidar signals. In this case the purpose of the experiments was to propagate normally distributed perturbations of the input parameters contributing to the ozone or temperature uncertainty budget, and verify that the data processing algorithms compute values of ozone or temperature standard uncertainty that are equal to the ozone or temperature standard deviation obtained from the set of perturbed signals. The results of these experiments are fully detailed in the ISSI-Team report.

A final draft of the ISSI-Team Report was just made available to the NDACC PIs for review and refinement. A final version is expected to be available in the summer 2015, and published in the form of a WMO/NDACC Report. Several peer-review articles will also cover all aspects of the ISSI team work (publication expected in 2015). The progress in the implementation of the ISSI Team recommendations to the actual NDACC data files will greatly depend on the individual NDACC PIs' will to comply. At least half of the NDACC ozone and temperature datasets are expected to be compliant with the recommendations before the end of 2015. Backward compatibility is the main limiting factor for a prompt switch to the new definitions. In some cases, a complete reprocessing of the entire dataset may be necessary, involving measurement back to one or two decades in some cases. An update on the completion of this implementation will be given in next year's NDACC newsletter.

Acknowledgements

The ISSI Team would like to thank the International Space Science Institute for sponsoring the Team meetings in Bern, Switzerland, in 2011, 2012 and 2013. The first ISSI-Team Meeting involved 15 participants from the NDACC lidar community as well as other interested research communities. Three other meetings were later held in 2012 and 2013. The members of the ISSI Team who have contributed to the final report are: Robert Sica (UWO, Canada), Anne van Gijsel (KNMI, Netherlands), Sophie Godin-Beekmann (CNRS, France), Alexander Haefele (Meteoswiss, Switzerland), Giggi Liberti (CNR, Italy), Thomas Trickl (KIT, Germany), Guillaume Payen and Franck Gabarrot (LACy, France).

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News from the Microwave Working Group

Zimmerwald observatory located at 46.88°N, 7.47°E and 905.5 masl. Photo: Geir Braathen

Four Years of High mid-Stratospheric Ozone over Lauder, and the Dynamical Connection to Changes in the Tropics

Gerald E. Nedoluha[1], Ian S. Boyd[2], Alan Parrish[3], Michael R. Gomez[1], Lucien Froidevaux[4]

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The Microwave Ozone Profiling Instrument (MOPI1) has provided ozone (O_3) profiles for the NDACC at Lauder, New Zealand, since 1992 using the technique described in Parrish et al. (1992). In Figure 1 we show the annual average O_3 anomaly at 10 hPa from the MOPI measurements and for data from four different satellites (SAGE II, HALOE, UARS MLS, and Aura MLS) near the latitude of Lauder (45°S). The MOPI instrument observed a positive O_3 anomaly in the mid-stratosphere (~10 hPa) from August 2009 through July 2013, a result which is confirmed by Aura MLS observations during this period. During this period the mean monthly O_3 anomaly at 10 hPa is 0.32 ppmv, only 7 of the 47 measurement months show a negative anomaly, and the 3-month smoothing never shows a negative anomaly. This period ends with a sharp drop in O_3 in August 2013.

Coincident measurements from the Aura Microwave Limb Sounder (MLS) show that these high O_3 mixing ratios are strongly correlated with high nitrous oxide (N_2O) mixing ratios, as is shown in Figure 2. This positive correlation between O_3 and N_2O could best be understood as resulting from dynamical variations. Using a 2D model it was shown by Nedoluha et al. [2015a] that slower ascent resulted in more N_2O being photodissociated and oxidised to produce NO_x (while reducing N_2O), and the increased NO_x destroyed more ozone (thus reducing O_3).

As is shown in Figure 2, the beginning of the high O_3 and high N_2O period at Lauder (and throughout this latitude band) occurs nearly simultaneously with a sharp decrease in O_3 and N_2O at the equator, and the period ends nearly simultaneously with a sharp increase in O_3 and N_2O at the equator. At a somewhat shorter timescale than the ~4-year O_3 anomaly much of the variation in both O_3 and N_2O is clearly driven by the QBO. The connection between the QBO signal in O_3 and NO_y (which is affected by N_2O) was recognised in SAGE II data by Chipperfield et al. [1994], who

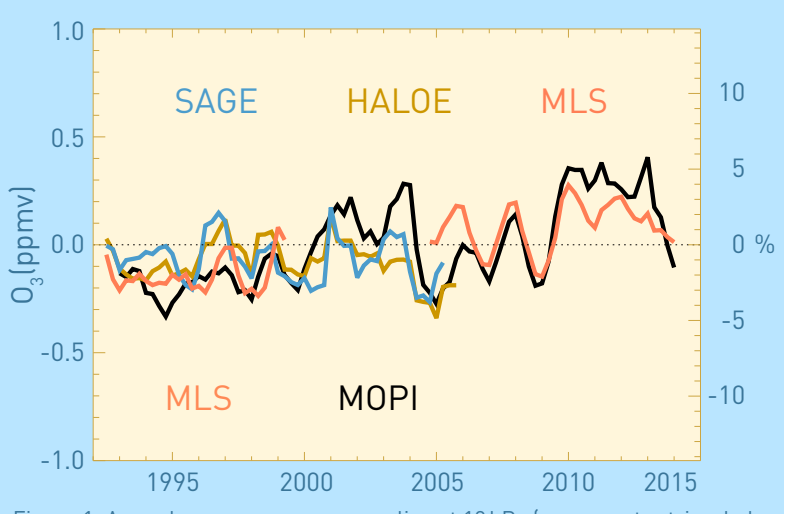

Figure 1. Annual average ozone anomalies at 10 hPa (or nearest retrieval altitude) shown 4-times annually (January-December, April-March, July-June, and October-September). Results are shown for SAGE (blue), HALOE (dark yellow), UARS and Aura MLS (both orange), and MOPI1 (black). Satellite measurements (latitudinal averages from 40°S-50°S) have been offset so that the average ozone matches that of MOPI1 during the period of coincidence.

pointed out that it was the result of QBO modulation of the vertical advection, with faster ascent resulting in larger O_3 mixing ratios in the mid-stratosphere.

The high O_3 and high N_2O in the mid-stratosphere at Southern mid-latitudes from 2009-2013 suggests that air was transported into this region from the tropical lower stratosphere more quickly during this period, thus decreasing the amount of photodissociation and oxidation of N_2O. At the same time, air was being transported more slowly into the tropical 10 hPa region. This work is described in Nedoluha et al. [2015b].

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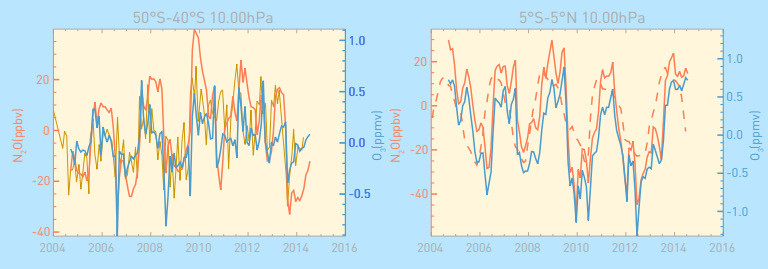

Figure 2 - Monthly average anomalies for N_2O (orange) and O_3 (blue) as measured by MLS at 10 hPa within 5° of the Lauder latitude (45°S) (left) and within 5° of the equator (right). The left hand plot also shows the monthly average O_3 anomalies (based on the 2004-2014 averages) for MOPI (dark yellow). The right hand plot also shows (dashed red line) the 30 hPa QBO index in m/s, using the same numerical scale as the N_2O in ppbv.

The MOPI1 instrument at Lauder.

Cooperating Networks

Update on SHADOZ

Anne M. Thompson, NASA/Goddard Space Flight Center, Greenbelt, MD, USA
and Bryan Johnson, NOAA Global Monitoring Division, Boulder, CO, USA

In 2014, the NDACC-affiliated SHADOZ (Southern Hemisphere Additional Ozonesondes) network (Figure 1) has been re-activating stations where data gaps appeared in the 2008-2010 period. In addition, all 2013 SHADOZ data, more than 300 profile data sets, were delivered to the World Ozone and UV Data Centre (woudc.org). Data gaps appear for a variety of reasons including equipment obsolescence, equipment failures, logistical difficulties, budget gaps, shortage of trained personnel. Two of the stations that resumed operations recently are San Cristóbal (Galapagos, Ecuador, Figure 2) and Natal, Brazil (Figure 3).

San Cristóbal, Galapagos (1°S, 90°W) is a meteorological network site operated by INAMHI (Instituto Nacional de Meteorología

Figure 1. SHADOZ stations that operated within the 2011-2014 period. Data are at the website http://croc.gsfc.nasa.gov/shadoz.

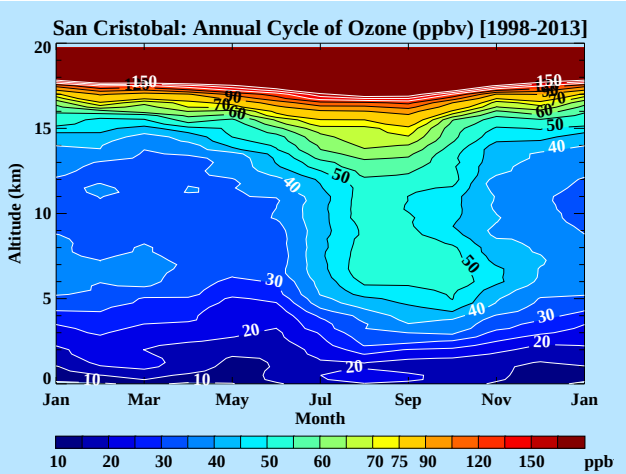

Figure 2. Seasonal ozone climatology in the lower stratosphere and troposphere over San Cristóbal. Summaries are based on monthly averaged SHADOZ data collected between 1998 and 2013.

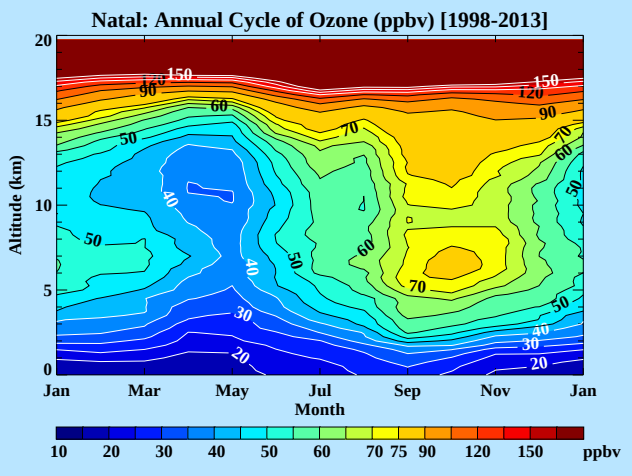

Figure 3. Seasonal ozone climatology in the lower stratosphere and troposphere over Natal. Summaries are based on monthly averaged SHADOZ data collected between 1998 and 2013.

Figure 4. Ozonesonde launches by Prof. Maria Cazorla and students, with B. Johnson and P. Cullis at USFQ, Quito, Ecuador, in May 2014.

Figure 5. Ozonesonde launches by Prof. Maria Cazorla and students, with B. Johnson and P. Cullis at USFQ, Quito, Ecuador, in May 2014.

e Hidrología) of Ecuador. The site began ozonesonde balloon launches in March, 1998 as part of the Soundings of Ozone and Water Vapor in the Equatorial Region (SOWER) field campaign and later became a SHADOZ site. Regular ozone soundings continued up until 2009. In May 2012, NOAA visited INAMHI headquarters in Quito, as well as the meteorological site at San Crisotóbal, requesting permission to launch ozonesondes (one every 2 weeks) using their new Vaisala Digicora radiosonde system and also to meet with new field personnel on ozonesonde procedures. A second visit in May 2014 established an additional collaboration with the Universidad San Francisco de Quito (USFQ). Professor María Cazorla, founder of the Institute of Atmospheric Research at USFQ and a 2010 PhD graduate of Penn State University, has facilitated NOAA's communications and shipping to Ecuador.

Dr. Bryan Johnson, SHADOZ Co-I, and Patrick Cullis (with NOAA) helped Prof. Cazorla's group to set up and carry out the first balloon launches for a USFQ ozonesonde program (Figures 4 and 5) to investigate PBL height and vertical structure of the atmosphere over the high-altitude site at Quito. In addition, USFQ recently dedicated the Galapagos Science Center in San Cristóbal through a partnership with the University of North Carolina for research related to the island's ecosystems.

The first ozonesonde station in the tropics is the SHADOZ station at Natal, Brazil, which started operations in 1978, sponsored by INPE (the Brazilian Space Agency), later joining SHADOZ in 1998. Coincidentally, the quadrennial CACGP/IGAC (Commission for Atmospheric Chemistry and Global Pollution)/(International Global

Figure 6. SHADOZ PI Anne Thompson and Archiver Jacquie Witte at the Natal area ozone launch station, September 2014, with Dr. Oksana Tarasova, WMO/GAW, and Natal Station Operators F. R. da Silva and T. Bezerra Penha.

Figure 7. From a visit to the Saõ Martins observatory in Rio Grande do Sul, where INPE and Santa Maria Federal University collaborate on ozone and other atmospheric research. Prof. Damaris Pinheiro Kirsch is shown with Dr. Thompson and a NASA AERONET Cimel and a Brewer total ozone instrument.

Atmospheric Chemistry project) Symposium was held in Natal from 22-26 September 2014. Two presentations with SHADOZ data, one comparing sondes to OMPS satellite retrievals near the tropopause, were made by SHADOZ Archiver/Webmaster Jacquie Witte. The Natal station manager, Francisco Raimundo da Silva, presented a poster on the long-term total ozone record at Natal. During the CACGP/IGAC, Natal Station Manager da Silva hosted Dr. Anne Thompson, SHADOZ PI, and Jacquie Witte along with the WMO/GAW Chief Oksana Tarasova at the present INPE launch station, some 40 km north of Natal at a clean marine site, Maxaranguape (Figures 5 and 6).

Prior to the Natal visit SHADOZ PI Anne Thompson visited an ozone site that operated in the 1990s and would like to affiliate with SHADOZ (Figure 7). In contrast to Natal, Santa Maria in the southern state of Rio Negro do Sul, is sub-tropical and inland so impacts of dynamics on ozone near the sub-tropical jet can be detected. The host at Santa Maria, Prof. Damaris Kirsch Pinheiro of the Federal Univ of Santa Maria (UFSM) with UFSM-INPE colleague Dr. Nelson Rodrigues, showed Dr. Thompson around the INPE ozone lab at UFSM. In addition, the three traveled about an hour outside of Santa Maria to a remote observatory site operated jointly between INPE and UFSM at Saõ Martins. Illustrated is an overview of an observing station at Saõ Martins along with Drs. Thompson and Pinheiro at the Brewer and AERONET Cimel instruments already operational.

GRUAN activities update

Peter Thorne, Maynooth University, Co. Kildare, Ireland and
Greg Bodeker, Bodeker Scientific, Alexandra, New Zealand

Much has happened within GRUAN (GCOS Reference Upper Air Network) in the past couple of years and much of this activity has served to strengthen the cooperation with NDACC activities and sites. A few of the most salient developments are highlighted in this newsletter article. Further details can be found by visiting http://www.gruan.org or in the recently accepted BAMS article (Bodeker et al., 2015). Sites interested in participating in GRUAN should email the GRUAN Lead Centre at gruan.lc@dwd.de. Scientists wishing to contribute can also join task teams or work with the science coordinators to further GRUAN science. Please email peter@peter-thorne.net for more information.

GRUAN event at WMO Congress

The 17th World Meteorological Congress took place from 25 May to 12 June 2015 in Geneva. On 2 June there was an information event on GRUAN. The event comprised:

- Welcome – Director, GCOS Secretariat (Dr Carolin Richter)
- Welcome – PR of Germany (Prof Gerhard Adrian) : Host country of the GRUAN Lead Centre
- Introduction – Head GRUAN Lead Centre (Dr Ruud Dirksen)
- Presentation – PR of New Zealand (Mr Peter Lennox) : Host country of Lauder GRUAN site
- Presentation – Rep. of Japan (Mr Masaya KONISHI) : Host country of Tateno GRUAN site
- Presentation of GRUAN site certification certificates
- Discussion

Representatives of several stations received their certificates as certified GRUAN stations:

- Lauder, New Zealand (Photo 1)
- Lindenberg, Germany
- Payerne, Switzerland
- Sodankylä, Finland (Photo 2)
- Potenza, Italy
- Boulder, Colorado, USA
- Ny-Ålesund, Spitsbergen, Norway

Photo 1. Professor Stephen Briggs, Chairman of the GCOS Steering Committee, handing out the GRUAN Certificate to Lauder, represented by Peter Lennox, Permanent Representative of New Zealand with WMO.

Photo 2. Professor Stephen Briggs, Chairman of the GCOS Steering Committee, handing out the GRUAN Certificate to Sodankylä, represented by Jussi Kaurola, FMI.

Network status

GRUAN has started to formally certify candidate sites as stated above. At the same time efforts have been undertaken to expand the network. In early 2015 a total of 7 new candidate sites were added to the roster following expressions of interest from Russia, Singapore and Australia (five candidates including Davis, the first candidate site in Antarctica) (Figure 3). These additions help to provide a more equitable spread of stations but further efforts are needed to bring in more stations in poorly sampled or climatically important regions, such as Africa and South America.

GRUAN data products update

GRUAN data products have the following scientific requirements:

- That the raw data and measurement metadata are retained in a secure archive such that they can be reprocessed at any time in the future to generate a revised final data product.
- That all aspects of the measurement processing are open and transparent.

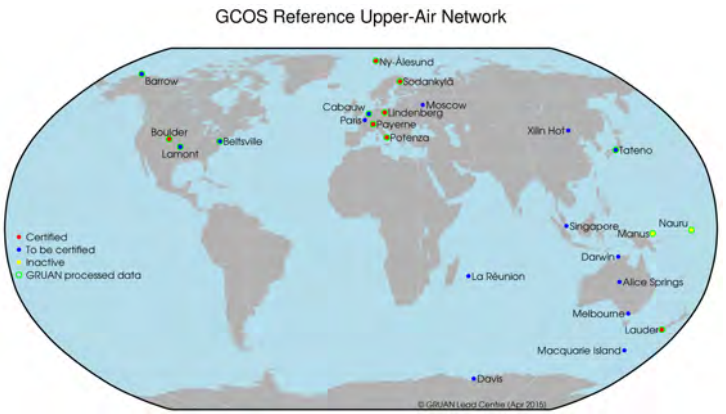

Figure 3. GRUAN sites status as at April 2015. Several of the certified or candidate sites also belong to one or more of the NDACC, GAW or TCCON networks.

- That the measurements are traceable to SI units or accepted community standards.
- That the uncertainty in every processing step is identified, assessed and robustly quantified (commensurate with the Guide to Uncertainties in Measurements, JCGM 2008) to provide a comprehensive estimate of the uncertainty on each measurement and, in the case of profile measurements, at each point in the measured profile.

In 2014 the Vaisala RS-92 radiosonde temperature, pressure, humidity and wind data became the first formal GRUAN data product. The GRUAN Lead Centre have fully characterised this instrument and implemented data processing that is fully open and transparent with uncertainties calculated at every data point in the profile (Dirksen et al., 2014). Uncertainties from several aspects of the measurement process are included in the total uncertainty (Figure 4).

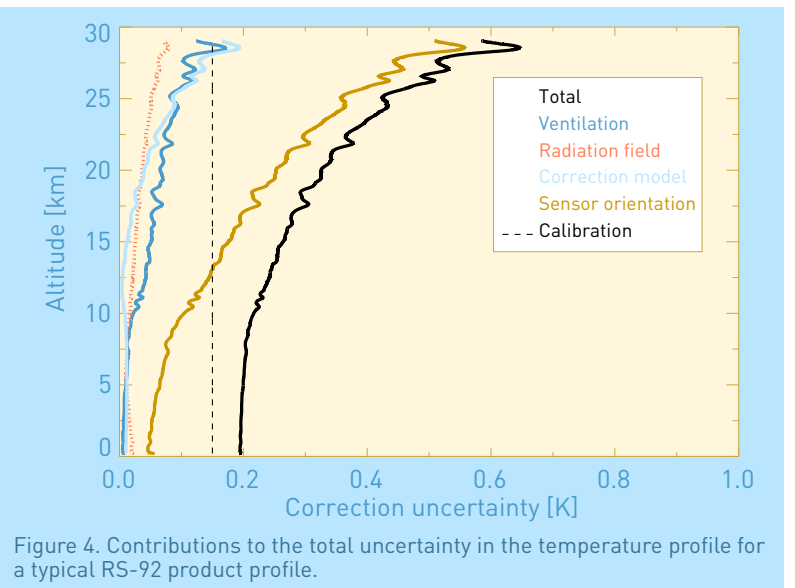

Figure 4. Contributions to the total uncertainty in the temperature profile for a typical RS-92 product profile.

Work is ongoing to develop several additional products in the near future including several additional radiosondes, ozonesondes, frostpoint hygrometers, lidars, microwave radiometers, FTS etc. In many cases this product development is being led, or significantly contributed to, by NDACC teams and their members. This will have the benefit of ensuring a degree of consistency between NDACC and GRUAN measurements using the same observing techniques.

GAIA-CLIM

In 2014 the European Commission had a space science call for use of sub-orbital measurement capabilities to better characterise space-borne instruments. The European chairs of GRUAN, NDACC and TCCON responded to this call to submit a proposal viz. GAIA-CLIM. This project was successful and started in March 2015. It covers:

- Mapping observational capabilities
- Developing reference quality products from various instruments
- Accounting for co-location effects and impacts
- Use of Data Assimilation
- Creation of a virtual observatory of co-locations
- Identifying gaps in knowledge, capabilities and coverage

Further information on the project can be found at http://www.gaia-clim.eu.

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HATS (NOAA/ESRL/GMD Halocarbons and other Atmospheric Trace Species) Network

James Elkins, NOAA Global Monitoring Division, Boulder, Colorado, USA

The National Oceanic and Atmospheric Administration's Earth System Research Laboratory (NOAA/ESRL) maintains a global in situ and flask network for the measurement and analysis of halocarbons and other atmospheric trace gases. The network started in 1977 with three trace gases (nitrous oxide, CFC-11, CFC-12) at five flask locations, and has grown to include over 40 trace gases at over 30 locations and airborne campaigns that include both flask and in situ monitoring. The purpose of this work is to study atmospheric trace gases that affect climate change, stratospheric ozone depletion, and air quality from observations at NOAA and cooperating stations. Some atmospheric trace gases (e.g., SF_6) are used as atmospheric clocks to provide important information on atmospheric transport. Areas of common interest with NDACC include the (1) species measured by Fourier Transform Infrared Spectrometers (halocarbons, O_3, HCl, HF, CO, N_2O, CH_4), water vapour, ozone, and Lidar instruments; and (2) collocated stations at Barrow, Boulder, Mauna Loa, Summit, American Samoa, Palmer, and South Pole.

The analyses of flask samples and in situ data are conducted within the Global Monitoring Division (GMD) in Boulder, Colorado, USA. Through collaborations with the National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF), NOAA/ESRL operates a number of in situ and flask collection instruments from NASA and NSF high-altitude, manned, and unmanned (UAS) aircraft up to 21 km, and balloon platforms up to 32 km. These measurements have been associated with high-altitude campaigns that have spanned the globe since 1991. HATS began vertical profiling

of many trace gases from flask samples collected on NOAA-operated, small aircraft (<25,000 ft asl) in 2004. These measurements now include 25 sites.

The HATS Network measures over 40 trace gases in the atmosphere, including nitrous oxide (N_2O); chlorofluorocarbons (CFCs, CFC-11, -12, -113, -115); hydrochlorofluorocarbons (HCFCs, HCFC-22, -141b, -142b); hydrofluorocarbons (HFCs, HFC-134a, 143a,152a, 125, 32, 227ea, 365mfc); methyl halides (CH_3Cl, CH_3Br, CH_3I); chlorinated ($CHCl_3$, CH_3CCl_3, CCl_4, C_2Cl_4, CH_2Cl_2); and brominated ($CHBr_3$, CH_2Br_2) solvents; sulfur gases (COS, SF_6); and selected hydrocarbons (C_2H_2, C_3H_8, nC_4H_{10}, C_5H_{12}, nC_5H_{12}, C_6H_6, nC_6H_{14}). Water vapour (H_2O) and ozone (O_3) also have been measured on NASA airborne campaigns since 2005. In situ atmospheric H_2, CO, and CH_4 are measured at Summit, Greenland, and during most high-altitude airborne campaigns.

NOAA HATS provides data to calculate atmospheric indices, including the Annual Greenhouse Gas Index (AGGI), Ozone Depleting Gases Index (ODGI), equivalent effective chlorine, total bromine, and total fluorine in the atmosphere. This research has resulted in numerous peer-reviewed publications, and has contributed to international assessments of climate and ozone depletion. Data are available via anonymous ftp, and discussions are available at the HATS website. For more information, contact Jim Elkins (James.W.Elkins@noaa.gov).

Figure 1: HATS Stations. Circles=flask sites, boxes=in situ sites, planes=airborne sites. For more details: see http://www.esrl.noaa.gov/gmd/hats/network.php. Credit ESRL GMD

Report from the NDACC Data Host Facility

Jeannette Wild and Roger Lin, National Oceanic and Atmospheric Administration National Center for Environmental Prediction (NOAA/NCEP), Camp Springs, MD, USA

Data Submissions

The number of data files stored in the NDACC Data Host Facility (DHF) continues to increase at an appreciable rate. Figure 1 shows the total number of files stored in the DHF and Figure 2 shows the number of new files submitted every year.

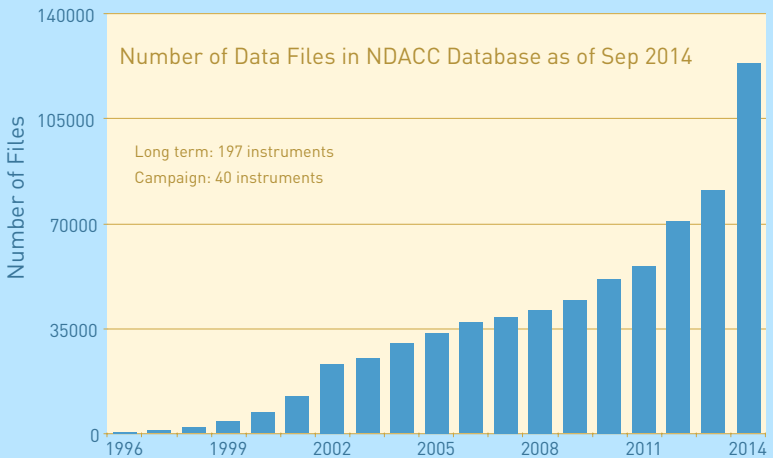


Figure 1: Number of data files stored in the NDACC Data Host Facility. The rapid increase from 2013 to 2014 is related to the transition to HDF files. When data is stored in HDF format, the data becomes more granulated, and the number of files increases.

Data availability

The NDACC web page http://www.ndacc.org has several visualisations of the contents of the NDACC database: The NDACC Observational Capabilities Chart (available here) depicts a high-level overview of NDACC's core measurements; the Measurements and Analyses Directory (click here) gives a listing and short description

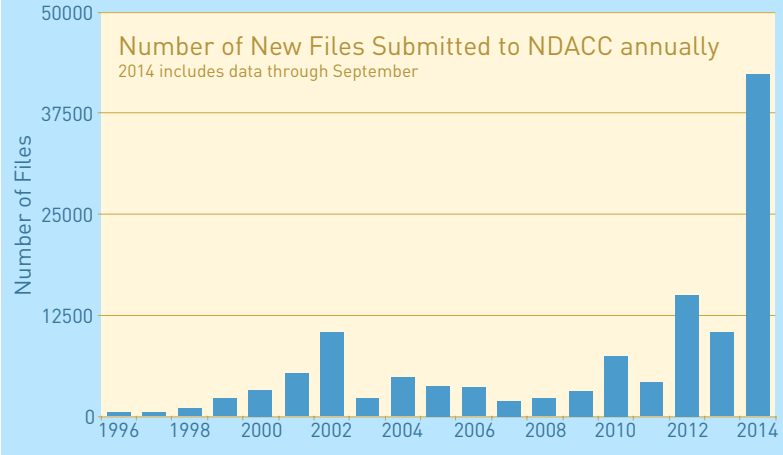


Figure 2: Number of new data files submitted to the NDACC Data Host Facility annually. The large number of files submitted in 2014 is related to the transition to HDF files. When data is stored in HDF format, the data becomes more granulated, and the number of files increases.

of the instruments; the Data Table (click here) gives a range of dates of data in the database with a direct link to the public data sets; and the Instrument Measurement Charts (click here) gives a table of species where one can click on the species of interest and obtain an in-depth review of data availability per month. The number of files transferred from the NDACC Data Host Facility is on the order of tens of thousands of files per month. The statistics for the last eight years is shown in Figure 3.

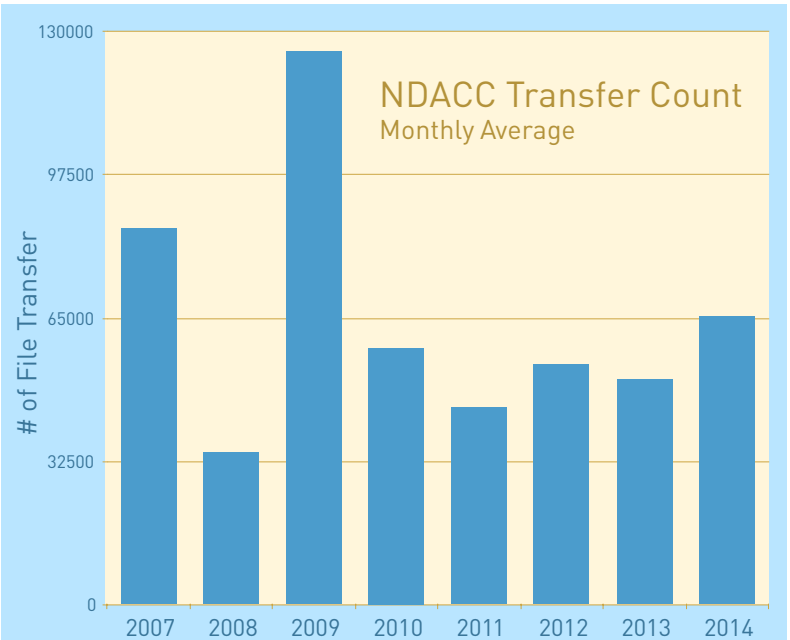


Figure 3: Number of files transferred per month from the NDACC Data Host Facility. The counting is done from one Steering Committee to the next, so the averaging period might not always cover exactly 12 months.

Rapid Delivery Data

Several groups (especially in the context of NORS, see separate article in this Newsletter) submit rapid delivery data to the NDACC database. These are available within a month or two of measurement, and may be revised before submission into the standard, fully verified NDACC catalogue. These data are available in the public FTP area at ftp://ftp.cpc.ncep.noaa.gov/ndacc/RD.

NDACC Relevant Projects

NORS
Network of Remote Sensing
Ground-Based Observations in support
of the Copernicus Atmospheric Service

The NORS project has resulted in NDACC being a key contributing network to the Copernicus Atmospheric Monitoring Service.

Martine De Mazière and Bavo Langerock, Belgian Institute for Space Aeronomy, Brussels, Belgium

The EU FP7 NORS project (Demonstration Network Of ground-based Remote Sensing Observations in support of the Copernicus Atmospheric Service; nors.aeronomie.be) ran from November 2011 to end of November 2014. It was built around four pilot NDACC stations (Ny-Ålesund, the Alpine station, Izaña and Île de La Réunion, see Figure 1) and the four main remote sensing observation techniques in NDACC: FTIR and UV-VIS DOAS and MAXDOAS spectrometry, microwave radiometry and DIAL. It focused on a selected series of target species:

- Tropospheric and stratospheric ozone columns and vertical profiles up to 70 km altitude;
- Tropospheric and stratospheric NO_2 columns and profiles;
- Lower tropospheric profiles of NO_2, H_2CO, aerosol extinction;
- Tropospheric and stratospheric columns of CO;

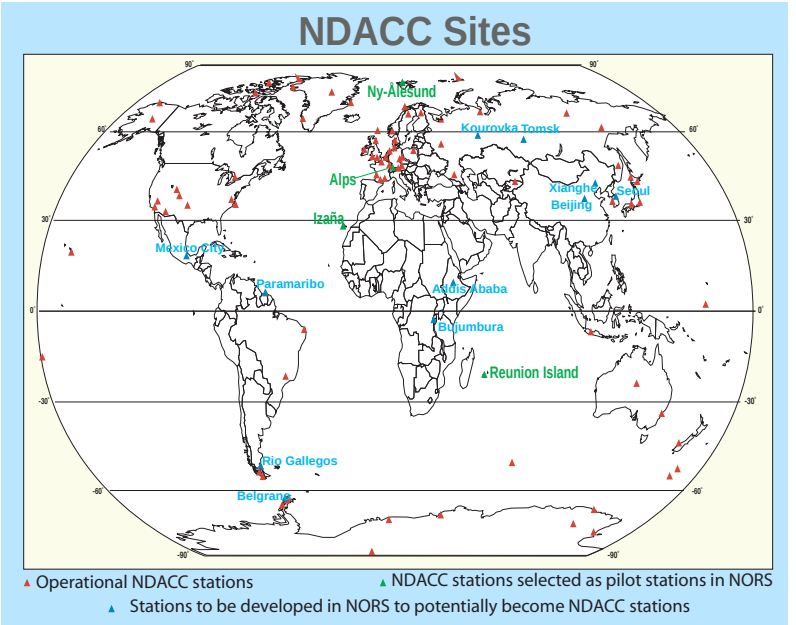


Figure 1. Map of stations taking part in the NORS project. The red triangles show operational NDACC stations. The green triangles are stations that already are operational in NDACC and that have been selected as pilot stations in NORS. The blue triangles denote stations that have an active measurement programme and that are capable of NRT data delivery, but they are not part of the NDACC Network.

- Tropospheric and stratospheric columns of CH_4.

It has achieved all the objectives and even reached out to more stations than the ones involved in the project consortium:

- A Rapid Data Delivery System that is fully operational for the NORS stations and target products, and that is also adopted by other existing and new NDACC stations and for more target products (e.g., MWR H_2O and FTIR NO_2). This system enhances

the visibility and the use of the ground-based remote sensing data (NDACC) in general. It can be considered an important progress in the ground-based remote sensing community. We also see that some teams submit the data at a faster pace (daily, weekly, ..) than the monthly pace: we can expect that more NDACC partners will shorten the delay of data submission in the near future.

- Optimised GEOMS HDF templates for the submission of the NORS/NDACC data. One advantage of the standardisation of the format is that erroneous data submission is easily detected. This serves the homogeneity and better usability of the NDACC database.
- Improved maturity and quality assurance of the NORS target MAXDOAS products at the NORS stations, and integration of these products in the NDACC database and the Rapid Data Delivery System. This is the case today for the MAXDOAS aerosol data at Xianghe, for example.
- As to MAXDOAS data, significant progress in cloud detection, classification and distinction from aerosol.

Figure 2. Screenshot of a login session at the NORS Validation Server.

- Better characterisation of the information content and uncertainties of the NORS target products, including user documentation. This will be very valuable for all uses of NORS-type data: modelling, satellite validation, process and trend studies. These documents are publicly available on the NDACC database and on the NORS Validation Server.
- Better understanding and documentation of the differences between products from different remote-sensing techniques for the same geophysical parameter. In particular, for HCHO and NO_2 from FTIR and UV-Vis spectrometry, and for CO from mid- and near-infrared Fourier-transform spectrometry.
- A compilation of evaluations of satellite data used in the MACC assimilation analyses, versus NORS products. This has helped understanding the quality of the MACC products.
- Homogeneous and harmonised re-analysed time series of NORS products since 2003, compliant with the progress made in the project as to the data products. These time series support the quality assessment of the reanalysis in MACC.
- Tropospheric column data at demonstration sites, derived from the integration of surface in-situ data with representativeness information and model profiles. The methodology to derive these data is also a result of this project. Integrated in-situ profiles (and intermediate results) are available for FTIR CO, O_3 and CH_4 data at Jungfraujoch and Izaña and for MAXDOAS lower tropospheric columns of NO_2 at Jungfraujoch, from http://lagrange.empa.ch/NORS_browser/ .
- Integrated ozone profiles and tropo- and stratospheric column data at NORS sites. The methodology and S/W to derive these data is also a result of this project and is available.
- A Web-based server (http://nors-server.aeronomie.be) for the validation of the target MACC products, that is fully operational and that has already been extended to additional target products (like MWR H_2O and FTIR NO_2) and several more NDACC sites.
- The demonstration of quality assessment of the MACC products, including the reanalysis, using ground-based remote sensing

data. The use of the NORS/NDACC data in the MACC reports for the validation of the NRT global atmospheric composition service has been increasing with every issue of the report (http://www.copernicus-atmosphere.eu/services/aqac/global_verification/validation_reports/).

- A spin-off of the NORS project is that the comparison algorithms and the interface developed for the NORS Validation Server will be largely re-usable for validation purposes of atmospheric composition satellite data. This means that an Atmospheric Satellite Validation Server can easily be 'derived' from the NORS Validation Server, with a minimal effort. This will be very beneficial for supporting the Copernicus Sentinel missions.
- The atmospheric communities (ground-based, satellite and model communities) are much better aware of NDACC, and of its value.
- Additional NDACC stations in other continents are under development; they adopt from the start the expertise gained in NORS. Some are already submitting data, even in Rapid Delivery mode, to the NDACC database. Several operational NDACC stations have joined the rapid delivery to the database .

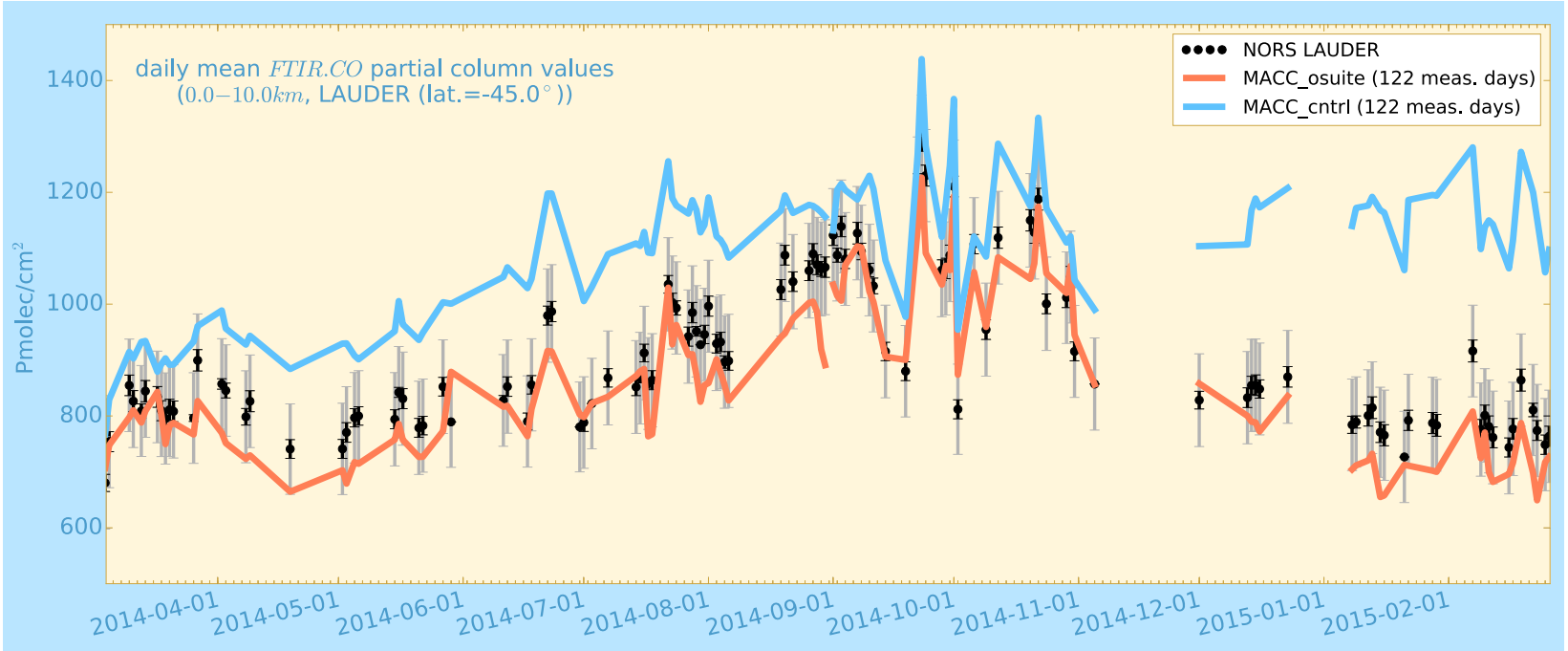


Figure 3. Comparison between FTIR timeseries of CO partial columns between 0 and 10 km at Lauder compared to the comparable operational MACC output (MACC_osuite, assimilation with IASI-A,B and MOPPIT) and MACC_cntrl (control model without assimilation). The random uncertainty is indicated in black, the total uncertainty in grey (random+systematic). The MACC osuite and control model were updated on 1 September 2014.

The NORS validation service has been integrated in the MACC-III project (http://www.copernicus-atmosphere.eu/services/aqac/global_verification/), and will be integrated in the operational CAMS that will start at the end of 2015. The big issue is the availability of the data: Copernicus at the moment does neither fund the acquisition nor the processing of the raw data. But it will fund work dedicated to consolidate, quality-control, format and improve dissemination of the corresponding observational data streams according to the requirements of CAMS. This, to our opinion, should be an important incentive to continue the NDACC operations and to continue the rapid data delivery to CAMS.

It is a major achievement of NORS that NDACC has made progress towards a more operational network, and is now recognised as being an essential contributing network for the validation of the Copernicus Atmospheric Monitoring Service.

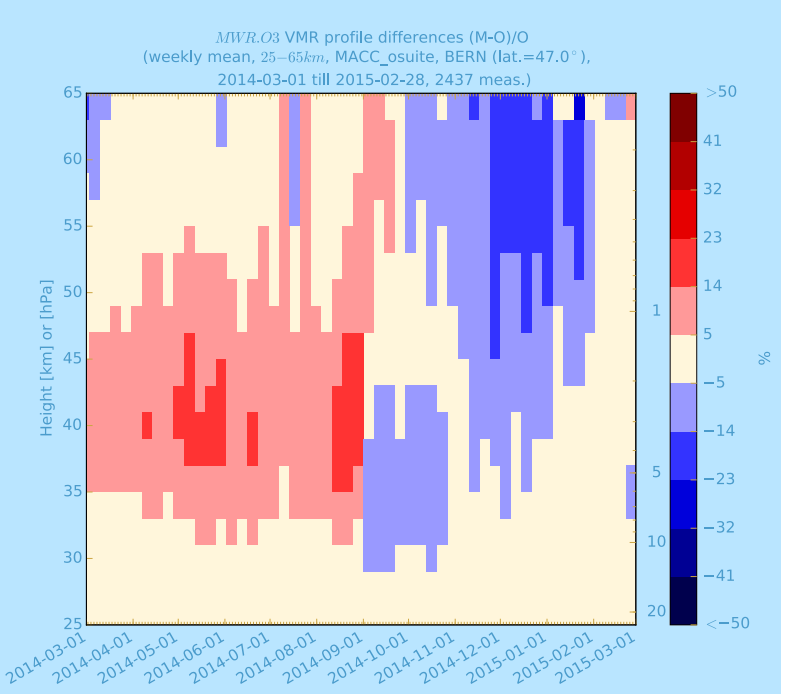


Figure 4. Timeseries of vertical profile comparisons between the microwave ozone radiometer at Bern (relative diff (MACC-MWR)/MWR in %). In September 2014 the MACC operational model was updated.

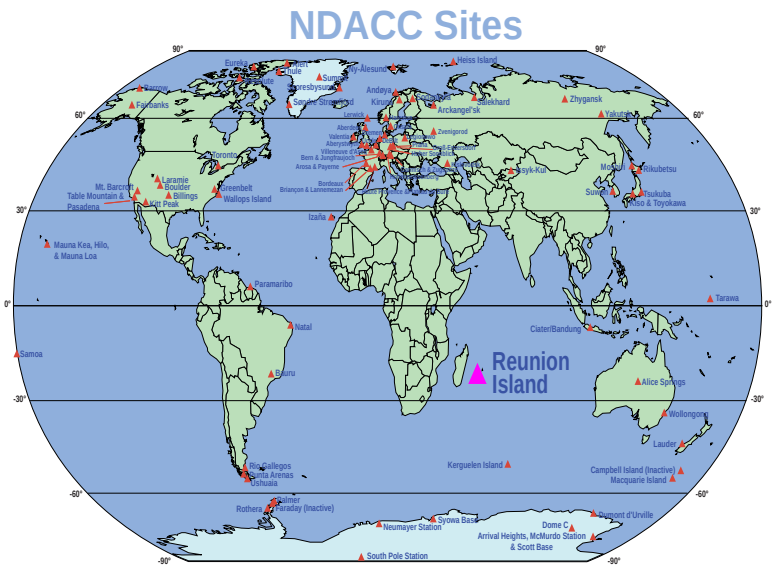
Station Highlights

The Maïdo Observatory, Reunion Island

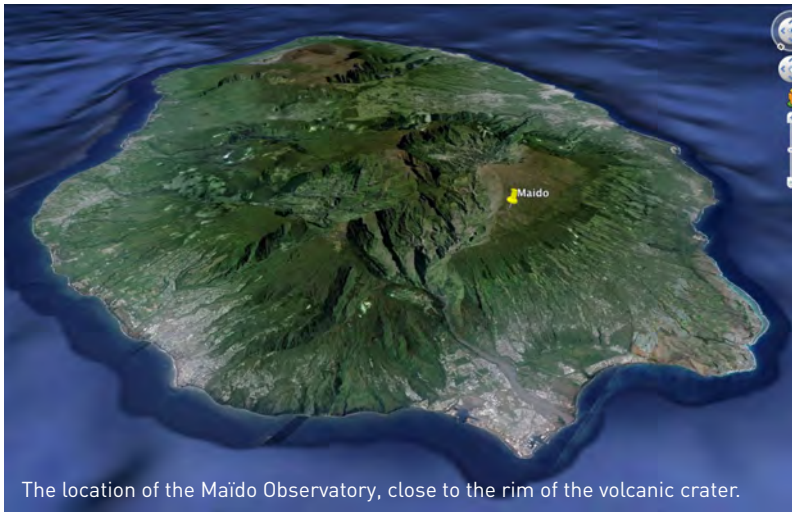
Jean-Pierre Pommereau, LATMOS/CNRS/UVSQ, Guyancourt, France

After several year delays due to the many constraints of building a high altitude observatory in an environment protected area, the NDACC lidars and other measurements started at Maïdo in October 2012.

NDACC atmospheric observations at Reunion Island in the South West Indian Ocean at 55.5°E, 21°S, already started in the early



Map of NDACC stations highlighting Reunion Island.



The location of the Maïdo Observatory, close to the rim of the volcanic crater.

90's with a combination of stratospheric Rayleigh lidar, UV-Vis, UV spectrometers, FTIR and radio-sondes all operated at sea level at St Denis University and Gillot airport within a new OPAR structure (Observatoire de Physique de l'Atmosphère de la Réunion) formed in 2012 within the Observatoire des Sciences de l'Univers de la Réunion (OSU-R). Due to the interest of atmospheric measurements in the Southern Tropics and the very limited number of observations available at this latitude several other lidar systems (tropospheric and stratospheric ozone and aerosols lidars) as well as other remote sensing and in situ instruments have been progressively developed and deployed on the campus of Saint Denis, at sea level.

But much more important was the decision made in the early 2000's to build a high altitude observatory, well above the bound-

ary layer, at the top of the Maïdo mountain. After more than ten years of administrative delays, road rienforcement and building construction, the observatory officially opened in October 2012 and a number of new instruments, particularly powerful lidars, installed at the new observatory. Today, operated at Maïdo are: DIAL tropospheric and stratospheric ozone lidars, temperature Rayleigh and water vapour Raman lidar, the wind lidar of LATMOS, the NDACC FTIR of the Belgian IASB-BIRA and three Microwave radiometers of the University of Bern for long testing (MIAWARA for Water Vapour, WIRA for Wind and GROMOS for Ozone). Coming soon will be also a UV-Vis spectrometer and an Optical Depth Sensor of LACy-LATMOS. For evaluating all these measurements, a NDACC comparison campaign is planed in late 2014 or early 2015 hosting the NASA GSFC lidar. Meanwhile the IASB-BIRA TCCON FTIR, the SAOZ UV-Vis and meteorological and ozone LACy radio-sondes observations at sea level will be continuing at Saint Denis and Gillot allowing exploring the difference with the high altitude Maïdo.

Altogether, the Maïdo measurements are expected to provide a unique data set in the Southern Tropics of long term atmospheric dynamic and chemistry observations of the troposphere and the stratosphere in the context of climate change in the southern hemisphere (temperature, ozone, UV Radiation, H_2O, GHG, aerosols...) for NDACC and cooperative networks, for French and Foreign local partners, and for ESA, EUMETSAT and NASA satellite validation: OMI, AURA, ENVISAT, METOP (IASI, GOME-2), MEGHATROPIQUES, ADM-AEOLUS.

Technical information on Maïdo facility

The total surface of observatory area including road access, scientific container area, parking, building, electrical station, is 6600 m^2. The surface of the building is 600 m^2 among which 173 m^2

View of Maïdo the observatory building from the SE in the presence of convection in the volcanic crater.

for the lidars, 129 m^2 for other scientific rooms (FTIR, Micro Wave Radiometer, in situ measurements), 300 m^2 for bedrooms, meeting room, and storage and ancillaries (water plant, power supply, secondary diesel power supply unit). A total of 164 m^2 of scientific areas is available on the roof for measurement heads above the scientific labs. Two 12 m 40 ft container area equipped with water and electricity are also available for hosting equipment for field campaigns. The access road is sized for big container trucks. Two dedicated radio links and optical fibres are connecting the station to telephone and data link networks.

Contacts

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Table 1. Instruments operating and planned at Maïdo observatory

Network	Instrument	Principal Investigator	Dates	Parameters
NDACC NORS	Brucker 125HR FTIR	BIRA-IASB, M. de Mazière	2002	O_3, HNO_3, HCl and other trace species
NDACC Candidate	DIAL O_3 Tropo	LACy V. Duflot	1998	O_3 Tropo
NDACC- NORS	DIAL O_3 Strato	LACT-LATMOS, T. Portafaix, S. Godin Beekman	2000	O_3 Strato
NDACC	Lidar T°C-H_2O	LACy-LATMOS, A. Hauchecorne; P. Keckhut, V. Duflot	2012	Temp Strato H_2O UTLS
Non NDACC	Wind lidar	LATMOS A. Hauchecorne	2014	Wind dir and speed
NDACC	Microwave MIAWARA	U. Bern, N. Kampfer	2014	Water vapour
Non NDACC	Microwave WIRA	U. Bern ,N. Kampfer	2014	Wind direction ans speed
NDACC	Microwave GROMOS	U. Bern, N. Kampfer	2014	Ozone
Non NDACC	ODS	LATMOS, JP Pommereau	2015	Cloud altitude and thickness
NDACC candidate	Mini-SAOZ	A. Pazmino/ T. Portafaix	2015	O_3 and NO_2 columns

Table 2. Instruments operating at Saint Denis and Gillot

Network	Instrument	Principal Investigator	Dates	Parameters
TCCON NORS	Brucker 125HR FTIR	BIRA-IASB, M. de Mazière	2002	CO_2
NDACC SAOZ GAW	SAOZ	LATMOS-LACy, A.Pazmino, T. Portafaix	1993	O_3, NO_2 column
NDACC-SHADOZ	Modem RS	LACy, F. Posny	1992	O_3, T°, H_2O, wind
NDACC Candidate	UV-B	LOA, C. Brognez	2009	UV radiation

Meetings

Report from the Ninth Meeting of the Ozone Research Managers of the Parties to the Vienna Convention for the Protection of the Ozone Layer

Michael Kurylo, Goddard Earth Sciences, Technology, and Research (GESTAR) Program, Universities Space Research Association, Goddard Space Flight Center, National Aeronautics and Space Administration, Maryland, USA

The Conference of the Parties to the Vienna Convention requires that the Ozone Secretariat of the United Nations Environment Programme, in cooperation with the World Meteorological Organization, convene a meeting of the Ozone Research Managers of the Parties to the Vienna Convention every three years. These meetings have the expressed purpose of reviewing all aspects of international research and monitoring programs within the Party Nations pertinent to the Vienna Convention and its Montreal Protocol on Substances that Deplete the Ozone Layer. The full report from each ORM meeting must be provided to the Conference of the Parties and include specific recommendations regarding international actions for improved research as well as its coordination and networking. On a similar schedule, the Montreal Protocol requires that three Assessment Panels (Scientific, Environmental Effects, and Technology and Economics) review the latest information in their respective areas and report their findings at the Meeting of the Parties to the Montreal Protocol.

The ORM meeting reports are highly complementary to the WMO-UNEP Assessments, but have a distinctly different purpose. The Assessments enable the Parties to evaluate control measures under the Montreal Protocol and are communication devices between the research community (striving for better understanding) and decision makers (seeking informed action). However, the Assessments are neither policy recommendations nor research planning documents but provide input for both. The ORM reports, on the other hand, specifically address research and monitoring needs in light of scientific understanding from the assessments and do make detailed recommendations to the Parties.

The 9th ORM meeting was held in Geneva, Switzerland (14-16 May 2014), six months prior to meeting of the Conference of the Parties as required. The meeting began with the election of Co-Chairs for the meeting. Mike Kurylo (USRA/GESTAR) and Gerrie Coetzee (SAWS) were unanimously selected for these positions. The Introductory Session on Issues Pertinent to the Vienna Convention followed with a review of the recommendations from the 8th ORM Meeting in 2011 and of the activities under the Vienna Convention Trust Fund for Research and Systematic Observations. Subsequent sessions covered

- The State of the Ozone Layer and Interactions between Ozone Layer Depletion and Climate Change,
- International Monitoring Programmes,
- Satellite Research and Monitoring, and
- National and Regional Reports on Ozone Research and Monitoring

These presentations by leading international scientists provided the underlying bases for the ORM recommendations. The latter were formulated within the framework of four overarching goals that were in turn developed against the background of the 2014

Scientific Assessment of Ozone Depletion. These overarching goals are as follows:

- Over the decades, research has clearly shown that ozone layer depletion, and its projected recovery, and changes in climate are intricately linked. This strong coupling requires that climate changes be encompassed in efforts to protect the ozone layer.
- Observational capabilities for both climate and ozone layer variables must be maintained and enhanced and the observations and analyses of both types of variables should be conducted together whenever possible.
- The Vienna Trust Fund for Research and Systematic Observations needs to be continued, enhanced, and better targeted to support the above goals, thereby making it more effective in addressing some of the identified issues.
- A continued dedication to build capacity to meet these goals is essential. The expansion of scientific expertise expands the geographical areas for measurements and data archival of the key variables related to the ozone layer and changing climate.

Extensive discussions towards establishing specific recommendations in the areas of Research Needs, Systematic Observations, Data Archiving and Stewardship, and Capacity Building followed. These discussions were greatly aided by Discussion Leaders and Rapporteurs in each area.

- Research Needs: G. Bodeker & J. Pyle; P. Newman & A. R. Ravishankara
- Systematic Observations: W. Steinbrecht & J.-C. Lambert; P. K. Bhartia & N. Larsen
- Data Archiving and Stewardship: M. De Mazière & J. Rimmer; S. Montzka & S. Netcheva
- Capacity Building: A.-L. Ajavon & G. Braathen; Anne Thompson & Matt Tully

A framework summary the current state of research, understanding, and implementation was provided for each area. Specific accomplishments in each area in addressing the recommendations from the 8th ORM Meeting were summarised. Highlights of the recommendations include:

1. Research Needs

- Chemistry-climate interactions and monitoring the Montreal Protocol
  - ✓ Inclusion of ozone in climate models
  - ✓ Continued research to investigate possible changes in the Brewer-Dobson Circulation and their effects on atmospheric composition
  - ✓ Construction of long-term data records (ozone, trace gases, atmospheric state variables) for assessing trends and interpreting changes
  - ✓ Improved quantification of ozone vertical trends
- Processes influencing stratospheric evolution and links to climate
  - ✓ Studies of the effects of non-ODS gases in ozone depletion chemistry
  - ✓ Continuation of laboratory measurements in photochemistry, kinetics, spectroscopy – including the critical evaluation of the data obtained
  - ✓ Studies of the processes that control the atmospheric distribution of aerosols and their chemical and radiative impacts, and an assessment of proposed geoengineering measures
- UV Changes and other impacts of ODS changes
  - ✓ Disaggregation of factors affecting UV radiation at the ground
  - ✓ Impacts of UV changes on human health, ecosystems, and materials
  - ✓ Environmental effects of ODS substitutes and their degradation products on human health and the environment

2. Systematic Observations

- Continuation of limb emission and solar occultation satellite observations
  - ✓ Critical for global vertical profiles of ozone- and climate-related trace gases
- Continuation of ground-based observing stations with long-term data records for both stratospheric and tropospheric composition
  - ✓ Concerns expressed regarding the steady decrease in the number of stations worldwide

- Critical needs for other atmospheric measurements
  - ✓ Monitoring in key geographical regions for troposphere-stratospheric exchange
  - ✓ Monitoring of stratospheric aerosols to allow analysis of their effects on stratospheric transport
  - ✓ Observations to unravel the increasing impacts of N_2O and CH_4 on ozone as ODSs decline
  - ✓ Measurements of emerging ODS substitutes
  - ✓ UTLS measurements of dynamical tracers to examine possible changes in atmospheric circulation
  - ✓ Long-term surface UV measurements
  - ✓ Evaluation of new (more cost effective) measurement technologies for increasing observational capacity on a global basis

3. Data Archiving and Stewardship

- More cost efficient and effective data archiving
  - ✓ Automated data submission with centralised processing and QA schemes
  - ✓ Stewardship and succession in data base management are critical
  - ✓ Digitisation of historical data for inclusion in modern data bases
  - ✓ Enhances linkages among data centres
  - ✓ Other specific recommendations as given in the full report

4. Capacity Building

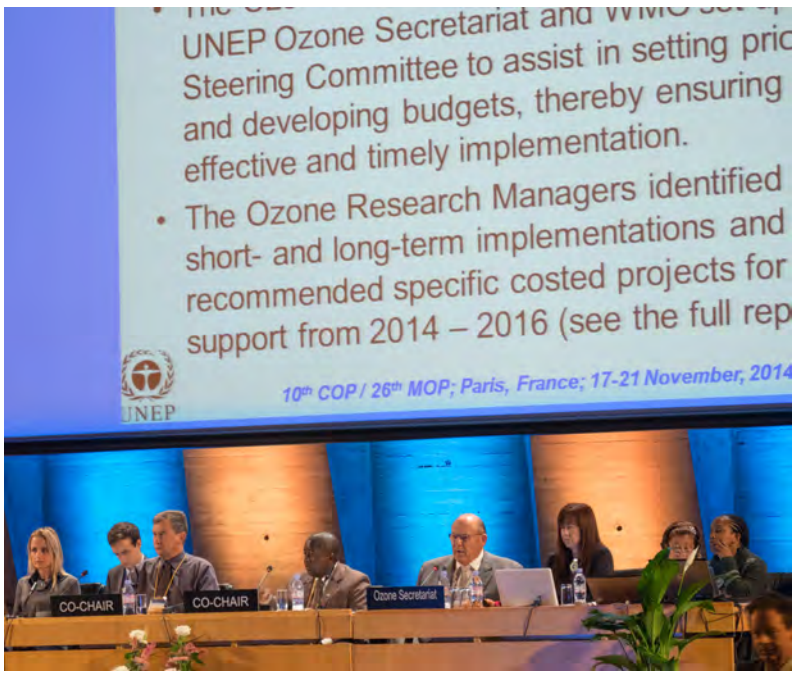
- Continued need for training courses for station operators in developing countries
- Establishment of Fellowships for students from developing countries
- Maintaining the quality of the WMO/GAW global ozone observing system through the continuation and expansion of regular calibrations and intercomparisons
- Ozonesonde intercomparisons and reprocessing of ozonesonde data need to be conducted with greater regularity

The recommendations discussions concluded with a focus on the accomplishments and future of the Vienna Convention Trust Fund for Research and Systematic Observation. Although important activities including calibrations, intercomparisons and a training course have been implemented under the Trust Fund to date, and, despite the fact that these exercises have been useful and successful, the amount of funds in the Trust Fund is not sufficient to make substantial and sustainable improvements to the global ozone observing system. It was agreed that, rather than inviting the Parties to contribute funds to the Trust Fund in a general and routine manner, it would be better to ask for support for well-defined and well-budgeted, concrete activities, with clear explanations of their necessity, expected outcomes and benefits. There was agreement that such an approach will make it clear to the donors what the "return on the investment" will be, and help to raise more funds in the future.

It was proposed and agreed that WMO and the Ozone Secretariat should establish an Advisory Committee for the Trust Fund to aid in the development of a long-term strategy and implementation objectives and priorities. There was unanimous agreement that the objectives be developed in the light of the four Overarching Goals given above. In addition to the long-term strategy, a short-term action plan needs to be developed that takes into account the most urgent needs of the global ozone observing system and will make the best possible use of the money currently in the fund. The Ozone Research Managers identified both short- and long-term implementations and recommended specific costed projects for priority support from 2014 – 2016, as detailed in the full report. The full 9th ORM meeting report is available as WMO Global Ozone Research and Monitoring Project, Report No. 54 on the following web site:

http://www.wmo.int/pages/prog/arep/gaw/documents/Final_9ORM_No_54_web.pdf

A brief summary of the report and its recommendations was presented by M. Kurylo at the joint meeting of the 10th Conference of the Parties to the Vienna Convention and 26th Meeting of the Parties to the Montreal Protocol in Paris (17-21 November, 2014).



Dr. Michael Kurylo giving a report on the 9th ORM meeting at the 10th Conference to the Parties to the Vienna Convention for the Protection of the Ozone Layer, Paris, 19 November 2014.

Recent NDACC Steering Committee Meetings

The 2013 Steering Committee Meeting, Frascati

The annual meeting of the international Steering Committee (SC) for NDACC was held at the ESRIN facility of the European Space Agency in Frascati, Italy from 30 September to 4 October. The local host was Dr. B. Bojkov. At this meeting Dr. Martine De Mazière, Belgian Institute for Space Aeronomy, was elected as new Steering Committee Co-Chair, replacing Dr. Geir Braathen, World Meteorological Organization, who had served as Co-chair since his election at the Andøya (Norway) meeting in 2004.

Participants at the 24th NDACC Steering Committee meeting held in Frascati, Italy from 30 September to 4 October 2013.

In addition to the regular discussion on network operations, there were presentations by invited scientists:

- Torsten Fehr, ESA spoke about ESA Validation activities
- Jean-Christopher Lambert, on behalf of Michel van Roozendael, spoke about the ESA Climate Change Initiative (CCI). The Ozone_CCI Climate Research Data Package (CRDP) contains all the data products that have been generated within the project. The data base is hosted on a freely accessible ftp site and is organised according to three types of ozone products: Total ozone products (TC=Total Column), Nadir ozone profile products (NP=Nadir Profile) and Limb ozone profile (LP=Limb Profile) products. More information can be found here: http://www.esa-ozone-cci.org/?q=node/160
- Bojan Bojkov spoke about the essential role of in situ observations for satellite data quality.
- Volodya Savastiouk spoke about the EuBrewNet COST Action where 45 Brewer stations from 18 countries take part. The aim is that European Brewers will operate as a network rather than as individual stations.

The 2014 Steering Committee Meeting, Brussels

The annual meeting of the international Steering Committee (SC) for NDACC was held at the Belgium Science Policy Office in Brussels. One of the first items on the agenda was the election of a new SC Co-Chair to replace Dr. I. S. McDermid, who recently retired from the NASA Jet Propulsion Laboratory. Dr. Anne M. Thompson of the NASA Goddard Space Flight Center, an internationally recognised expert in atmospheric measurements and the Principal Investigator for the highly successful SHADOZ ozone sonde network, was unanimously elected to fill this vacancy. Dr. Thompson joined Dr. Martine De Mazière of the Belgium Institute for Space Aeronomy in keeping the following 2.5 days of presentations and discussions on track for addressing key issues pertinent to Network implementation.

Agenda items included a detailed report from the NDACC Data Host Facility on data archiving status and data utilisation. This was followed by reports from the various Working Group (WG) Representatives on the SC (Dobson and Brewer, FTIR, Lidar, Microwave, Sondes, Spectral UV, UV/Visible, Satellites, Theory and Analysis, and Water Vapor). These reports highlighted WG activities and/or meetings during the past year, summarised NDACC measurement and analysis activities not identified in the agenda for separate presentation, described proposals (pending and received) seeking NDACC affiliation, and outlined possible new sites for consideration. Subsequent reports from representatives of the NDACC Cooperating Networks (AERONET / MPLNET, AGAGE, BSRN, GRUAN, NOAA HATS, SHADOZ, and TCCON) focused on new Coordinating Network activities and initiatives pertinent to NDACC interests and to possible future collaborations. A number of miscellaneous business discussions followed covering such items as NDACC involvement in various international projects, improved NDACC communications, future strategies and implementation, and the

Participants at the 25th NDACC Steering Committee meeting held in Brussels, Belgium from 3 to 5 November 2014.

scheduling of future SC meetings. The venue for the 2015 SC meeting will be at the Scripps Institute of Oceanography (La Jolla, CA, USA), a research site for the AGAGE Cooperating Network.

Following the close of the 2014 NDACC SC meeting, most SC members attended the following 2.5 days of the NORS/NDACC/GAW Workshop. The principal objective of the NORS project is to improve the quality and validation of the products delivered by the Copernicus Atmospheric Service (CAS), using independent ground-based remote sensing data from NDACC. NORS focused on a selection of NDACC data that have high priority in the different domains of CAS, namely 'ozone and UV', 'air quality' and 'climate'. The research planned in NORS aims at tailoring these NDACC products to the needs of CAS. It includes a full characterisation of the products and an evaluation of the consistency between the ground-based data and the satellite data assimilated in the CAS production chain. The successes of both the NDACC SC Meeting and the NORS/NDACC/GAW Workshop were greatly facilitated by their coordinated scheduling and by the participation of many international scientists having common interests in both NDACC and the NORS Project.

Participants at the NORS workshop held in Brussels, Belgium, from 5 to 7 November 2014, back-to-back with the NDACC Steering Committee meeting.

Upcoming NDACC Steering Committee Meetings

The next NDACC Steering Committee meeting will take place 12-16 October 2015 at the Scripps Institution of Oceanography in La Jolla, CA. Ray Weiss has volunteered to act as local host for this meeting. The plenary sessions will run Monday through midday Thursday. There will be a possible tour of Ray Weiss' laboratory on Thursday afternoon, and a possible site visit to Table Mountain and the NASA Dryden Aircraft Operations Facility (DAOF) in Palmdale on Friday.

The Scripps seaside forum where the meeting will be held.

The international Network for the Detection of Atmospheric Composition Change (NDACC) was formed to provide a consistent, standardised set of long-term measurements of atmospheric trace gases, particles, and physical parameters via a suite of globally distributed sites.

The principal goals of the network are:

- To study the temporal and spatial variability of atmospheric composition and structure in order to provide early detection and subsequent long-term monitoring of changes in the physical and chemical state of the stratosphere and upper troposphere; in particular to provide the means to discern and understand the causes of such changes.
- To establish the links between changes in stratospheric ozone, UV radiation at the ground, tropospheric chemistry, and climate.
- To provide independent calibration and validation of space-based sensors of the atmosphere and to make complementary measurements.
- To support field campaigns focusing on specific processes occurring at various latitudes and seasons.
- To produce verified data sets for testing and improving multidimensional models of both the stratosphere and the troposphere.

The primary instruments and measurements of NDACC are:

- Ozone lidar (vertical profiles of ozone from the tropopause to at least 40 km altitude; in some cases tropospheric ozone will also be measured)
- Temperature lidar (vertical profiles of temperature from about 30 to 80 km)
- Aerosol lidar (vertical profiles of aerosol optical depth in the lower stratosphere)
- Water vapour lidar (vertical profiles of water vapour in the lower stratosphere)
- Ozone microwave (vertical profiles of stratospheric ozone from 20 to 70 km)
- H_2O microwave (vertical profiles water vapour from about 20 to 80 km)
- ClO microwave (vertical profiles of ClO from about 25 to 45 km, depending on latitude)
- Ultraviolet/Visible spectrograph (column abundance of ozone, NO, and, at some latitudes, OClO and BrO)
- Fourier Transform Infrared spectrometer (column abundances of a broad range of species including ozone, HCl, NO, NO_2, $ClONO_2$, and HNO_3)
- Ozone and aerosol sondes (vertical profiles of ozone concentration and aerosol backscatter ratio)
- UV spectroradiometers (absolutely calibrated measurements of UV radiance and irradiance)

Contacts

For more information, please go to the NDACC web site (http://www.ndacc.org) or contact the co-chairs:

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