Progress Report on The SI^{2}N Initiative on Past Changes in the Vertical Distribution of Ozone

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Introduction

In early 2011, a joint initiative was started under the auspices of SPARC, the International Ozone Commission (IO_3C), the ozone focus area of the Integrated Global Atmospheric Chemistry Observations (IGACO-O3) programme, and the Network for Detection of Atmospheric Composition Change (NDACC). To aid digestion, an acronym of acronyms, SI^{2}N, was adopted. A report on the first workshop was published in SPARC Newsletter 37 (Harris et al., 2011). This and much other information is available on the SI^{2}N website (http://igaco-o3.fmi.fi/VDO/index.html).

The main objective of SI^{2}N is to assess and extend the current knowledge and understanding of measurements of the vertical distribution of ozone, with the aim of providing input to the next WMO/UNEP Scientific Assessment of Ozone Depletion anticipated for 2014. No detailed mechanism for achieving this goal was agreed upon at the first workshop, though great enthusiasm was shown for tackling the issue. Rather, six working groups were identified that would coordinate and promote activities in their areas, with a view to meeting a year or so later to review progress. This report is the summary of the second SI^{2}N workshop.

Working Group progress

Two ‘new’ long-term datasets of ozone profiles from satellites will be released in 2012. First, a consistent retrieval will be applied to all the BUV and SBUV instruments, covering the period from 1970 to 2011. This record will be unique in that it will be based on a single instrument type. It will provide valuable information about ozone changes in the middle and upper stratosphere as well as in the total column. Second, the SAGE record (comprising SAGE I/II/III and SAM II) has been analysed using the same retrieval for all four solar occultation instruments and will cover the period from 1979 to 2005. Significant improvements are expected for the SAGE I and SAM II records, most notably as a result of a new altitude registration for SAGE I to avoid the long-standing need to use an empirical adjustment (Wang et al., 1996). Both these developments are significant steps forward and will lead to much better knowledge of changes in the vertical ozone distribution over the last 30-40 years.

The problem with the new SAGE record is that it ends in 2005. It is thus important to be able to extend the record from that time – this inevitably involves ‘merging’ datasets (see below). Several approaches are being developed and tested, all of which are promising, but none of which is proven. From a purely instrumental view, there are advantages to using instruments with similar characteristics. OSIRIS (limb scatter) and GOMOS (stellar occultation) are prime candidates as they measure in a similar spectral region (GOMOS is also an occultation instrument), have good temporal overlaps with SAGE II, and measure on an altitude-based grid like SAGE, thus avoiding the use of meteorological fields to transpose between pressure and altitude coordinates. Preliminary time series have been produced and show real promise, particularly at altitudes between about 20 and 50 km and latitudes between 50°S and 50°N. Further work is required on quantifying the uncertainties associated with the merging of data, and to see whether it is possible to extend the analysis outside this region.

Since the early 2000's several other instruments have measured ozone. In addition to OSIRIS, ODIN (launched 2001) carries the microwave sounder SMR. ENVISAT (launched 2002) has three atmospheric chemistry experiments which all measure ozone: GOMOS (stellar occultation), MIPAS (thermal emission), and SCIAMACHY (limb scatter). Unfortunately, communication with ENVISAT was lost in April 2012 and measurements may have ceased. Since 2004, the SCISAT mission carried ACE-FTS and MAESTRO (both solar occultation) and the AURA platform carried the MLS instrument (microwave). A great deal of work is being done to assess the quality of these ozone measurements made over the last decade or so. This is being done through the SPARC Data Initiative and as part of projects supported by a number of space agencies. These studies will also lead to combined datasets of the vertical distribution of ozone.

The level of agreement is generally encouraging, and the comparisons are clearly leading to a greater understanding of any problems associated with individual instruments. Again, the region of reasonable agreement is at altitudes between 20 and 50 km and latitudes between 50°S and 50°N. Outside this region, the measurements are fundamentally harder for most instruments and the natural variability is higher, so there is a limit to the improvements that can be reasonably expected. However, the overall picture was encouraging, with the various presentations giving a strong impression that agreement within 5%, and quite possibly 2-3%, is possible between different instruments over much of the stratosphere.

A similar impression is given by comparisons of satellite measurements with NDACC lidar measurements (e.g., Nair et al., 2012). These show good stability as well as good agreement. It would be valuable to extend these comparisons to include measurements with other ground-based instruments (microwave, infrared and Umkehr) that measure in different altitude ranges and with different vertical resolutions. An important factor when making these comparisons (and when merging data sets) is to allow for the diurnal variation in ozone, which occurs in and above the upper stratosphere.

Umkehr measurements have been made at many sites by either Dobson or Brewer instruments, with some of the records going back to the 1950s or '60s. However, aside from a few stations with good records, their full potential has not been realised. A major part of the SI^2N activity is thus to improve the existing records by applying and validating new algorithms and by increasing the number of stations reporting the full data files. It is particularly hoped that the coverage by the Brewer network will increase significantly. An important issue is how to use the overall record effectively as many individual records are short, so that there is a real need to homogenise and merge the data correctly.

The aim of the ozonesonde working group is to provide a revised, homogeneous dataset with corrections being applied for biases related to instrumental changes (such as sonde type or electrolyte solution) in those cases where comparisons or laboratory experiments provide strong evidence for such corrections. This exercise should result in a significantly improved ozonesonde record, giving more solid information about the atmospheric changes that have occurred, as well as a better dataset for comparison with satellite measurements.

Merging and homogenisation of data sets

The general issue of 'merging' or 'homogenising' datasets was discussed at some length and with real feeling. In an ideal world, one instrument would have provided global measurements for several decades without any change in instrumental performance or quality. However, in the real world, SAGE II with its 21-year record is the only one to come close (1984-2005) in the lower stratosphere, although it is noteworthy that the ODIN satellite, launched in 2001 with the OSIRIS and SMR instruments, is still operational after 11 years. Even with these long records, measurements from several instruments are needed to provide truly multi-decadal records. The situation is noticeably simpler when several versions of the same instrument type are used successively, such as the SBUV instruments, which together have made continuous records since 1979. The situation is not fundamentally different for ground-based instruments as they are either replaced (ozonesondes being the extreme case, with a new sonde for each measurement) or adjusted. These changes tend to have local effects, but sometimes changes are introduced across networks and so have effects over larger areas.

At first glance, a distinction can be drawn between ‘merging’ and ‘homogenisation’ by describing the former as the formation of a master dataset by collating several different datasets, and describing the latter as the formation of a master data set by joining a series of measurements made by the same type of instrument. However, in practice this distinction is blurred when one considers that factors such as different platforms with varying orbit characteristics or small variations in instrument design (e.g., wavelength range, sonde electrolyte solution) can lead to equally large differences in ozone as variations in instrument type (e.g., limb vs. occultation, sonde manufacture). In both cases, great care is needed when compiling these master datasets, and the compilation benefits enormously when instrumental expertise is included in the process. Finally, the concept of the ‘best’ dataset is not particularly useful. Each will have its own strengths and weaknesses and is thus more or less suited to addressing a particular scientific issue. In particular, it is clearly advantageous to have datasets with different spatial and temporal coverages.

An example in a parallel field is the development of the new time series for stratospheric temperatures based on the Stratospheric Sounding Unit instruments (SSU), which gives strikingly different results to the previous version (Wang et al., 2012). The challenges in providing a self-consistent record were remarkably similar - satellites with drifting orbits, individual sensor degradation, changing background atmosphere, etc. But the lessons are the same – careful instrumental analysis and statistically rigorous determination of adjustments leads to useful long-term datasets.

Within the SI^2N initiative, the aim is to move forward on both fronts, with better understood instrumental records and with improvements in methods of joining them. Validation of each measurement record by other measurements will be integral to this, but it has to be recognised that merely comparing datasets reduces their independence to some degree, and it is very important that any adjustments to the core datasets are based on solid instrumental grounds wherever possible. In this regard, for example, the new retrieval of the SAGE I record is welcome, as previously an empirical correction to its altitude registration had to be used (Wang et al., 1996). Without such solid reasoning, we risk fooling ourselves about how firmly our results are based.

The Way Ahead

In order to provide valuable information for consideration in the WMO-UNEP 2014 Scientific Assessment of Ozone Depletion, it was decided to organise a special issue of a journal in which most of the individual on-going studies would be published. Additionally, three overview papers would be prepared covering Measurements, Validation, and Analysis and Interpretation. Discussions are progressing well with the Copernicus journals, Atmospheric Chemistry and Physics (ACP), Atmospheric Measurement Techniques (AMT) and Earth System Science Data (ESSD), and the details of the SI^2N Special Issue (special editors, dates, etc.) will be announced soon.

This approach has a number of advantages:

1. It is fully peer-reviewed, with the journal review process being strengthened for the overview papers by merging it with the normal report review process (extra reviews and a meeting).
2. The use of open access journals means that the whole process is transparent and open to public scrutiny. All the material is readily accessible.
3. The scientists involved get full credit for their efforts in terms of publications (not always the case with reports or assessments), without having to write separate papers.

4. The joint special issue means that papers covering more technical issues (AMT) and more scientific issues (ACP) can be published jointly with the databases (ESSD) making the process more traceable.
5. While the general shape is quite clear, there is no need to precisely define the limits of the material included and so new developments will be easy to include either in the overview papers or in the WMO-UNEP Assessment itself.
6. The facility for publishing supplementary material gives the opportunity to make more of the underlying analyses widely available.

The first overview paper will summarise the measurements themselves and will include information about the instruments and the algorithms used to convert a measurement signal into atmospheric quantities. The lead author will be Birgit Hassler. The Validation paper will describe the methodologies used to validate or evaluate long-term measurements using existing data and provide an assessment of the agreement (or otherwise) between time series along with a rigorous error analysis. The lead author will be Jean-Christopher Lambert. The third overview paper on Analysis and Interpretation will describe and assess the merged products that are used for time series analysis, as well as the time series analyses of the long-term datasets. The lead author will be Neil Harris. It is important to note that these will be overview papers, with the emphasis on summarising and assessing information available in other papers and reports.

A review meeting focusing on these three overview papers will be held in September 2013, with the papers submitted a couple of months earlier so that the regular journal review process can take place before the meeting. The special issue itself will open much earlier, hopefully by the time this report is published. In this way, the overview papers can take full account of the published literature and themselves be subject to a clear and transparent peer review process.

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