# Report from the SPARC-LOTUS Workshop in Helsinki

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**Dates:**
**2 - 3 June 2022**

**Organizing Committee:**
**Irina Petropavlovskikh, Sophie Godin-Beekmann, Daan Hubert, Viktoria Sofieva, Robert Damadeo and Birgit Hassler**

**Meeting venue:**
**FMI, Helsinki, Finland**

**Number Of Participants:** **33 (ECR: 7)**

**Event Website:**
https://trends2020.fmi.fi/program.html

**Sponsors:**

LOTUS, SPARC, International Ozone Commission, NDACC, World Meteorological Organization, Global Atmosphere Watch

## Introduction

The Long-term Ozone Trends and Uncertainties in the Stratosphere (LOTUS) workshop with two half-day sessions took place as a side meeting to the 11th International Workshop on Long-Term Changes and Trends in the Atmosphere (TRENDS2020) in Helsinki, 30th May 3rd June, 2022. LOTUS is a SPARC activity since 2016 (https://www.sparc-climate.org/activities/ozone-trends/). The first session consisted of several talks while the second day focused on discussing potential new activities and research in preparation for a proposal for the third phase of LOTUS.

## Workshop summary

The first session was opened by **Sophie Godin-Beekman**. She gave a brief overview of the LOTUS phase 1 and 2 activities and presented the most recent results on ozone profile trends. The main outcome of the first phase of LOTUS was the so-called LOTUS report (SPARC/IO3C/GAW, 2019), which described in detail trends derived from various merged ozone profile datasets, from which also combined trends and uncertainties were derived. This report provided important input to the 2018 World Meteorological Organization (WMO) ozone assessment (Braesicke and Neu *et al.*, 2018). The profile trends have been updated to the end of 2020 as part of the phase 2 activity. Positive trends attributed to ozone recovery are observed in the upper stratosphere at all latitudes (see Figure 17) confirming prior results. Statistically non-significant trends were observed in the middle and lower stratosphere. Extending the ozone datasets by four years and an improved regression model led to reduced uncertainties in the trend estimates.

**Roeland van Malderen** reported on the harmonization of long-term ozone sonde data records. To date, data from 43 stations worldwide have been involved in the harmonization efforts. This activity was guided by the O3S-SDQA (Ozone Sonde Data Quality Assessment Activity) since 2011. Corrections to the station data depend on the electrochemical concentration cell (ECC) sonde type, sensing solution, pump efficiency, and total ozone normalization among others. Uncertainties can be thus reduced from 10-20% down to 5% (troposphere/stratosphere) and 10% (tropopause

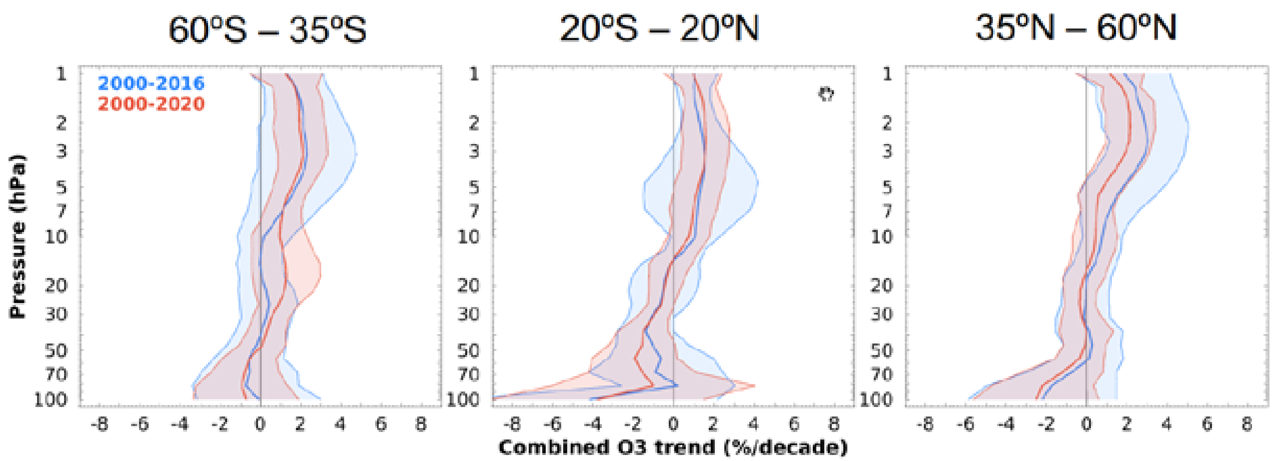


***Figure 17:*** *Combined ozone trends from seven merged satellite datasets during the period up to 2016 (blue) and up to 2020 (red). Uncertainties (shaded area) are given in 2σ. From Godin-Beekmann et al. (2022).*

region). Long-term trends derived from the harmonized sonde datasets are now in better agreement with Lidar (Light Detection and Ranging) and satellite-derived trends. Reprocessing also helped in reducing the drop-off in sonde total columns observed at selected stations after 2013 (Stauffer *et al.*, 2020). Data from 15 additional stations are in the pipeline to be harmonized and added to the database.

**Stacey Frith** and **Jeannette Wild** gave an overview of the merged SBUV (Solar Backscatter Ultraviolet Radiometer) ozone profile data from NASA and NOAA, respectively. The NASA MOD (Merged Ozone Data) adjusts the various SBUV instruments by improving their spectral calibrations and by accounting for instrumental orbit drifts and diurnal variations before merging. Comparisons of upper stratospheric trends derived from NASA MOD v2 with Aura MLS (Microwave Limb Sounder) show good agreement. The NOAA COH (Cohesive Data) uses overlapping periods to remove biases between instruments. The new v2 of NOAA COH shows better consistency with NASA MOD v2 and Aura MLS than with MOD v1. The use of a tropospheric ozone climatology in MOD V2 is likely responsible for larger biases between the NASA and NOAA merged data at the lowest altitudes, particularly in the tropics.

Results of the S-NPP (Suomi National Polar-orbiting Partnership) OMPS (Ozone Mapping Profile Suite) satellite limb profile (OMPS-LP) comparisons against co-incident homogenized ozone sonde records from the TOAR-II HEGIFTOM (Harmonization and Evaluation of Ground-based Instruments for Free Tropospheric Ozone Measurements) archive were presented by **Yue Jia**. Co-authors found that the OMPS-LP record exhibits a negative trend above 20 km, while MLS v5 tends to show a positive trend. Based on previous studies, the MLS record has no detectable drift. The altitude- and latitude-dependent evaluation of OMPS-LP v2.5 data finds the largest drift (about 5 %/decade) at midlatitudes and 30-40 hPa in the tropics.

**Robin Bjorklund** reported on long-term ozone profile measurements with different ground-based instruments located at Lauder, New Zealand. NIWA (National Institute of Water and Atmospheric Research) is running the NDACC (Network for the Detection of Atmospheric Composition Change) supersite at Lauder operating an FTIR (Fourier transform infrared) spectrometer, Lidar, a microwave spectrometer, ozone sondes, and a Dobson (Umkehr) spectrophotometer. Detailed comparisons show that the biases between the various instruments are on the order of 4 to 10% after accounting for differences in the vertical resolution of the different instruments and methods.

Increasing surface ozone and tropospheric ozone in Antarctica and possible drivers of the increases since 1992 were presented by **Pankaj Kumar**. The ozone increases were found to be a common feature in different locations across Antarctica. Backward trajectory analyses linked the increasing ozone levels in the lower-middle troposphere across Antarctica to the long-range transport from the nearby continents, where human-driven pollution is rising, and to increasing ozone transport from the stratosphere. More data and modelling efforts are needed to understand the drivers of the increasing surface and tropospheric ozone and evaluate the impact of the increasing surface ozone on both the Antarctic climate and beyond.

An overview of future ozone and UV surface irradiance changes due to increasing greenhouse gases based on chemistry-climate model (CCM) runs, was given by **Kostas Eleftheratos**. The reduction in UV surface radiation will be mainly due to ozone recovery during the first half-century while increasing cloud cover play a stronger role in the second half of this century. The albedo decrease in the polar region will be the dominant contributor to reduced polar UV exposure in the latter half of this century.

**Kleareti Tourpali** discussed ozone trends and variability derived from CCMI-2020 Ref D1 models (Chemistry-Climate Model Initiative - 2020). The trend results are quite similar to those from the past CCMI Phase-1 Ref C2 model runs and are consistent with observed trends.

As part of the TRENDS2022 workshop, additional talks on updated ozone datasets and ozone trends derived from satellite and ground-based data as well as model data were given (https://trends2020.fmi.fi/program.html). Some of the results from these talks were also summarized in the presentation by Sophie Godin-Beekmann (see above) and found their way as well into the current WMO ozone assessment to be published by the end of 2022.

On the second day, new potential topics and activities for the third phase of LOTUS were discussed. The third phase shall provide important input to the next WMO ozone assessment in four years (2026). Six preliminary themes were identified for Phase 3:

1. Trend analysis techniques (e.g. dynamical linear model, other variants of multiple linear regressions like Lasso, and new proxies and alternative altitude coordinates, e.g. relative to tropopause height),
2. Partial column trends (e.g. consistency between total column and stratospheric/tropospheric column trends),
3. Trends in the UTLS,
4. Improved consistency between satellite and ground-based data,
5. Polar ozone trends,
6. Interconnections between temperature and ozone trends.

Extended discussions were carried out on potential collaboration with other activities, *e.g.* SPARC OCTAV-UTLS (Observed Composition Trends And Variability in the Upper Troposphere and Lower Stratosphere), IGAC TOAR II (Tropospheric Ozone Assessment Report II), and SPARC ATC (Atmospheric Temperature Changes and their Drivers) to broaden the view as part of the new SPARC strategy. **Andrea Steiner** (co-lead of ATC) and **Peter Hoor** (co-lead of OCTAV-UTLS) attended the LOTUS meeting and provided valuable input to this discussion.

## References


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