European Metrology
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Improving the measurements used to protect atmospheric ozone

Atmospheric ozone protects the Earth from harmful UV radiation. However, human activity has depleted atmospheric levels, weakening this ‘protective shield’. Spectrophotometers which measure ozone are based on designs from the 1970s and 1980s, while instrumentation offering the potential for improved measurements lacked metrological verification for the long-term monitoring and accuracy required to help protect this important molecule.

Europe’s National Measurement Institutes working together

The European Metrology Research Programme (EMRP) brings together National Measurement Institutes in 23 countries to address key measurement challenges at a European level. It supports collaborative research to ensure that measurement science meets the future needs of industry and wider society.

Challenge

Ozone, comprised of three linked oxygen atoms, is generated in the stratosphere by the action of solar radiation on oxygen gas, and absorbs 99% of the sun's biologically harmful UV-B radiation (280 - 315 nm) that is a cause of skin cancers in humans. A rare molecule, it is concentrated in a band around 20-25 km above sea level, the 'ozone layer'. Its levels are measured by spectrophotometers, or spectroradiometers, in a square column (1 cm^2) stretching from the Earth's surface to the edge of space. If all the ozone in this 'Total Ozone Column' (TOC) was compressed at 0 °C under 1 atmospheric pressure it would measure approximately 3 mm in depth.

In 1976, it was discovered that ozone was being destroyed by chemicals released through anthropogenic activities and in 1987 the Montreal International Treaty was introduced to phase out substances responsible for ozone depletion. Due to this protocol ozone is expected to recover to 1980 levels by the mid-21st century, but longer periods of observation are necessary to both monitor its status and assess the effects of climate change on its levels.

However, established monitoring networks use different instrument types, such as Dobson or Brewer spectrophotometers, that produce small but significant differences in data, impeding the merging of results from different networks. In addition, 'stray light' generated in these instruments by solar radiation can mask the weaker ozone signals, requiring correction factors to resolve.

Improved instrumentation was required with greater accuracy and long-term stability to reliably measure this important molecule.

Solution

During the atmoz project, an array spectroradiometer, the BTS2048-UV-S, developed by Gigahertz–Optik, was extensively characterised. Capable of measurements of solar output at step increments <0.2 nm across the full UV spectrum, instead of at only a few wavelengths as per the Brewer or Dobson spectrophotometers, it offered increased reliability for TOC retrieval. In addition, the compact instrument incorporated 6 different filters to reduce the stray-light effects.

The spectroradiometer also participated in an intercomparison campaign at Izaña, Tenerife, organised by the Izaña Atmospheric Research Center of the Spanish Meteorological Agency (AEMET) and the World Radiation Center (PMOD-WRC), where new instruments and techniques developed within the project were compared to well-established Dobson and Brewer spectrophotometer methods and the world travelling standard QASUME. Results of the intercomparison demonstrated that the BTS2048-UV-S produced high quality data for TOC measurements with deviations of less than 1.5% from most other instruments in most situations and not exceeding 3% from established TOC measurement systems such as Dobson or Brewer.

Impact

Gigahertz–Optik is a world-leading provider of instruments and solutions for challenging light measurements in all optical areas, including the UV, general LED lighting to more specialised applications like LiDAR laser power and waveform measurements. The company acknowledge the benefit gained from the knowledge of the project's consortium, and added new capabilities to their BTS2048-UV-S instrument for ozone measurements, such as a sun-tracker, an improved software algorithm for TOC derivation, and a collimator for direct solar measurements.

Following the end of the atmoz project in 2017, the array spectroradiometer was further tested for long-term (> 1 year) stability in a measurement campaign at the DWD meteorological observatory in Germany, part of the global ozone monitoring network, and the PMOD/WRC at Switzerland, part of the European Brewer Network. No change in the instrument's responsivity was observed during the whole measurement campaign period, demonstrating its robustness and accuracy.

Now marketed by Gigahertz–Optik as the BTS-Solar, it is the first array spectroradiometer that has been validated for quality and precision TOC measurements, and has since been used in the EURAMET project BIOSPHERE, which examined the effects of extra-terrestrial radiation on the ozone layer.

The use of spectroradiometers, like the BTS-Solar, will provide greater certainty in ozone measurements, help enforce the Montreal Treaty, and protect the ozone that 'shields' the Earth from damaging UV radiation.

Traceability for atmospheric total column ozone

The atmoz project evaluated differences between the reference Dobson and Brewer spectrophotometers used by ozone monitoring networks, generated corrections to improve their performance and developed tools to ensure greater accuracy in this field.

Two intercomparison campaigns were performed where new instruments and techniques developed within the project were compared to well established Dobson and Brewer spectrophotometer methods.

Along with a new software tool to assess the overall uncertainty of ozone measurements by different network instruments, a new tuneable radiation source (TuPS) was developed and validated, providing fast in-field characterisation of Dobson spectrometers.

The project also developed a prototype high-resolution array spectroradiometer system, ERMIS, and demonstrated its ability to accurately measure total column ozone in the atmosphere.

Outputs have provided greater certainty for networks measuring ozone which will allow a greater confidence in assessing the recovery of this important protective molecule.

The BTS-Solar array spectroradiometer deployed at the 19ENV04 EMPIR MAPP field campaign at Izaña, Tenerife, September 2022

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