International monitoring programmes for ozone and substances controlled by the Montreal Protocol: an introduction

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Global ozone monitoring programmes

- 1ˢᵗ long-term total ozone measurements started in the late 1920s based on the Dobson spectrometer. More spectrometers deployed at global scale during IGY (1957).
- Ozone sondes long-term measurements initiated in early 1960s
- Strong enhancement of ozone-related monitoring activities after the discovery of the Antarctic ozone hole (1985).

Now, monitoring of ozone, UV and related species is based on a variety of techniques deployed on the ground and on satellite, with contribution of a variety of networks.
Ground-based ozone networks

GAW ozone (1988)
- **Total ozone**: Dobson, Brewer, SAOZ
- **Ozone profile**: ozone sondes

M. Tully, J. Rimmer, A. Thompson, F. Madonna and T. Kralidis talks

NDACC (1991)
- **Total ozone**: Dobson, Brewer, UV-Visible spectrometers, FTIR
- **Ozone profile**: ozone sondes, lidar, microwave, FTIR

M. De Mazière talk
Ground-based techniques for monitoring ozone total content and vertical distribution

- Dobson
- FTIR spectrometer
- Brewer
- MAXDOAS UVVIS spectrometer
- Ozonesonde
- Microwave spectrometer
- O$_3$ DIAL
- SAOZ UVVIS spectrometer
Other contributing networks

**Pandonia**: cost-effective and easy to deploy groundbased UV-Visible spectrometers performing sun, moon and sky observations of O$_3$, NO$_2$, SO$_2$ and formaldehyde (ESA & NASA)

**SHADOZ (Southern Hemisphere ADditional OZonesondes)**
Operation of ozonesonde stations in the tropics, subtropics, and the southern hemisphere with a central archive location.

**IAGOS**: In-service Aircraft for a Global Observing System
Measurement of ozone, CO, H$_2$O,... in the free troposphere and UTLS. Profiles during aircraft takeoff and landing
Monitoring of surface UV

Surface UV measurements (UV-B & UV-A)
- Spectral UV: spectrophotometer
- Broadband photometers (UV-B, UV-A, UV-E)

World Calibration Center:
PWMOD, DAVOS (Switzerland)

Total stations
- Spectroradiometer >50
- Broadband radiometer >130

Courtesy: J. Gröbner
Monitoring of Ozone Depleting Substances

- Pioneering measurements of CFC-11 by Lovelock (1972)
- In-situ sampling by the NOAA and AGAGE networks
- ODS total content by FTIR remote sensing
Satellite missions

After the pioneer BUV instrument on board Nimbus 4 (1970), a variety of satellite instruments have been launched for the monitoring of ozone total content and vertical distribution, and related species.

Nadir satellites

Limb-viewing satellites

Talks from K. Jucks, C. Zehner, Pengfei Ma
Global ozone products & services

Merged ozone data sets

Total ozone
- NASA SBUV MOD, NOAA SBUV Merged, GSG (GOME, SCIAMACHY, and GOME-2A), GTO (GOME-type Total Ozone Essential Climate Variable), MSR (Multisensor reanalysis)
- WOUDC data (Environment Canada)

Ozone profile

Nadir: SBUV MOD & SBUV COH

Copernicus Atmosphere Service (CAMS)
- Total ozone & UV fields based on the assimilation of ozone & UV satellite data
- Ozone and UVI forecast

NASA ozone watch
Image, data, and information for atmospheric ozone
https://ozonewatch.gsfc.nasa.gov/
Calibration & comparison activities

Ground-based networks are crucial for the calibration of ground-based measurements and satellite missions validation activities.

Dobson calibration

NDACC lidar intercomparison

Cross-validation of satellite missions by a SAOZ UV-Visible spectrometer

Also: important work on ozone sondes homogenization – ASOPOS 2.0 report on QA/QC of O3S (H. Smit, A. Thompson, R. van Malderen)
Tracking changes in Ozone, ODS and UV

Total ozone (WMO, 2018)

CFC-11 emissions
Rigby et al., 2019

UV irradiance
Fountoulakis et al., 2016
Conclusion

• Long-term monitoring activities invaluable for tracking ozone, UV, and ODS changes, and their link with climate change
• Ground-based monitoring essential for the validation of new satellite missions, also for cross-validation of successive missions
• Important also for ozone evaluation in the UTLS and lowermost stratosphere
• Synergy between long-term evaluation of satellite and ground-based measurements
• Wealth of measurements used in the various Assessments on the state of the ozone layer since 1989 (SAP, EEAP), and other reports e.g. SPARC
• Necessity to maintain the ground-based networks on the long-term with possibly enhancing networks’ capacity in the tropics and Southern Hemisphere.
Thank you for your attention!