2.8 Ozone

The ozone layer in the stratosphere filters out a large proportion of the sun’s harmful ultraviolet rays. Monitoring of stratospheric ozone is therefore extremely important, especially in view of the rate of ozone depletion – which has however been reduced in recent years thanks to international agreements.

Measurements in Switzerland

MeteoSwiss uses a variety of instruments to monitor ozone concentrations in the atmosphere over Switzerland.

At the Light Climatic Observatory (LKO) in Arosa, total ozone has been measured continuously since 1926 using Dobson and Brewer spectrophotometers. These instruments measure the transparency of the atmosphere to solar ultraviolet radiation at various wavelengths. This is used to calculate the total amount of ozone in the air column over Arosa. In addition, ozone profiles are derived using various methods of measurement and analysis. At Arosa, the Umkehr method (based on Dobson spectrophotometry) has been used since 1956 to obtain a rough ozone profile (6–9 vertical layers).

At Payerne, radio soundings have been used since 1968 to record ozone profiles directly with a high vertical resolution (approx. 50 m) up to an altitude of about 33 km. For this purpose, soundings are carried out three times a week, using an ozone sonde attached to an aerological balloon (2.7 Water vapour).

Since November 1994, the Institute of Applied Physics (IAP) at the University of Bern has operated a Ground-Based Millimeter Wave Ozone Spectrometer (GROMOS) to measure stratospheric and mesospheric ozone at altitudes ranging from 20 to 70 km. A second-generation instrument – the Stratospheric Ozone Monitoring Radiometer (SOMORA) – has been used operationally at Payerne by MeteoSwiss since 2002.

Satellite measurements play an important role in recording the global distribution of total ozone. For the application of satellite-based data in Switzerland, good spatial resolution is crucial. For example, the total ozone product, derived from Ozone Monitoring Instrument (OMI) data, offers a horizontal resolution of...
Total ozone
Long time series and their importance

Switzerland has a long history of ozone monitoring, going back to the first measurements at Arosa in 1926. Total ozone over Arosa has been determined on every sunny day virtually without interruption down to the present. Almost from the beginning of the time series, measurements have been carried out using the same type of instrument (Dobson). The global network for monitoring of the ozone layer is largely based on Dobson instruments. In the 1980s, a second type of instrument (Brewer) was developed in Canada. MeteoSwiss used its first Brewer device (B40) at Arosa in 1988. In subsequent years, two more Brewer instruments were installed. Total ozone over Arosa is currently measured by two Dobson and three Brewer spectrophotometers. To date, the global networks of Dobson and Brewer instruments have maintained independent calibration procedures. The former is based on the US reference instrument D083 and the latter on the reference triad in Toronto. Both networks produce almost identical results, with minor differences (1–3 %) depending on the season and latitude. These differences remain a subject of current research, and the 20-year parallel measurements carried out with Dobson and Brewer instruments at Arosa are of great importance in this regard.

Dobson spectrophotometers have been used to measure total ozone at Arosa for 80 years. The time series are mainly based on the three Dobson models D2, D15 and D101, and also on the redundant devices D7 and D62. The homogenized time series shown here was carefully derived using data from the various Dobson instruments (Staehelin et al., 1998; Zanis et al., 2006; MeteoSwiss, 2007). While the Dobson spectrophotometer still has to be operated manually, the Brewer device is fully automated (Komhyr, 1980). This is the world’s longest time series based on Dobson instruments. It makes it possible to study the state of the ozone layer before and after the beginning of anthropogenic influences, as well as interactions between ozone and the climate.

13 x 24 km. Swiss ozone monitoring data (Dobson/Brewer at Arosa, radio soundings at Payerne, microwave radiometry at Payerne and Bern) can make a decisive contribution to the validation of satellite-based data.

Information on the vertical distribution of ozone is important since the processes of ozone production and destruction differ markedly in the troposphere and the stratosphere. The first estimates of the ozone profile were obtained by means of special Dobson measurements in the 1930s. However, this so-called Umkehr method, which has to be performed as the sun rises or sets, is very elaborate. This method of measurement yields only 6–9 layers, at altitudes between approx. 5 and 50 km. In addition, highly complex mathematical processing is required. For this reason, measurements could not be carried out on an operational basis until the 1950s. At Arosa, the Umkehr ozone profile series was initiated with the Dobson D15 instrument. In 1980, the automated D51 instrument came into operation. The Arosa Umkehr measurement series is the world’s longest and at the same time one of the few sources of information on vertical ozone distribution in the years 1955–1970, before the start of satellite observations. Since 1988, the fully automatic Brewer B40 instrument has similarly produced Umkehr ozone profiles. Major efforts are currently under way to homogenize these multiyear parallel measurement series. In the late 1960s, ozone profiles were also determined in situ for the first time using small ozone sondes. Measurements were first performed for two years at Thalwil (1966/67), and since 1968 the ozone sondes have been combined three times a week (Monday, Wednesday, Friday) with the meteorological radiosonde balloon activity at Payerne. The ozone profiles obtained exhibit a high vertical resolution (currently about 50 m) between the Earth’s surface and an altitude of 30–35 km.

Ozone profile 0 – 33 km
Long time series and their importance

Time series of monthly ozone concentrations at various pressure levels for the period 1967–2006, measured by ozone balloon soundings (Jeannet et al., 2007). A similar series based on Umkehr measurements at Arosa extends as far back as 1956, and series generated by the new microwave radiometry technology at Bern and Payerne go back to 1995. The complementarity of these various series is unique, allowing vital cross-comparisons to be made so as to assure the best possible quality for long time series, including satellite-based measurements. Accordingly, the Swiss ozone series mentioned are often used in scientific publications worldwide, e.g. the Scientific Assessment of Ozone Depletion reports published every four years by the WMO/UNEP.

Ozone soundings Payerne 1967 – 2006
Monthly ozone concentrations at three pressure levels
Ozone profile 20 – 70km
Long time series and their importance

In the early 1990s, a microwave radiometer known as the Ground-Based Millimeter Wave Ozone Spectrometer (GROMOS) was developed at the Bern University Institute of Applied Physics (IAP). Since 1994, it has been used to determine the ozone profile about every 30 minutes. The second-generation Stratospheric Ozone Monitoring Radiometer (SOMORA) was tested in parallel to the GROMOS instrument at Bern from January 2000, and it has been used operationally by MeteoSwiss at Payerne since 2002. Covering an altitude range of 20–70 km and with a high temporal resolution, this time series extending over more than 10 years augments the sounding data, as it also permits conclusions concerning the balloon burst height and short-lived processes in the stratosphere.

International integration

Measurements from Arosa (Dobson and Brewer) and Payerne (ozone soundings) are routinely supplied to the World Ozone and UV Radiation Data Center (WOUDC) in Toronto. These data together with data from the two microwave radiometers (GROMOS and SOMORA) are also fed into the NDACC. All the time series described above will be of major importance for future ozone monitoring. Internationally, the in situ and satellite-based ozone measurements are increasingly being integrated into models for use in the Integrated Global Atmospheric Chemistry Observation (IGACO) Strategy of the GAW programme. Under the joint EU/ESA environmental monitoring initiative – Global Monitoring for Environment and Security (GMES) – global and regional ozone maps are generated daily by the ESA on a pre-operational basis in the GMES Service Element PROMOTE (PROtocol MOniToring for the GMES Service Element on Atmospheric Composition).

Resources required

Ozone monitoring operations at Payerne and Arosa are assured under the legal mandate of MeteoSwiss and through Switzerland’s participation in the WMO Global Atmosphere Watch (GAW) programme.

Homogenized time series of ozone profiles determined by microwave radiometry at Bern and Payerne under an NDACC (Network for the Detection of Atmospheric Composition Change) programme. The volume mixing ratio (VMR) of the trace gas ozone reaches its peak at an altitude of around 35 km during the summer season, with values of approx. 8 parts per million (ppm). The ozone profiles also vary on daily to monthly timescales as a result of atmospheric transport processes. The annual cycle is clearly apparent in the distribution.