EUROPEAN STRATOSPHERIC MONITORING STATIONS /ALPS

Paul C. SIMON
Institut d'Aéronomie Spatiale de Belgique

Evidence of the reduction in ozone concentration which has occurred predominantly during the last decade at Northern mid-latitudes in wintertime, has been given by ozone trends derived from TOMS data. The major issue is therefore to understand the observed trends and to quantify with high accuracy the observed changes and the seasonal and interannual variations in the Earth's stratosphere at mid-latitudes, in relation to natural and anthropogenic perturbations.

This issue is presently addressed by a scientific effort which aims to establish coordinated ground-based observations together with satellite observations. The main disadvantage of satellite measurements arises from the difficulty in maintaining their calibration over a long period. Comprehensive ground-based measurements are therefore required to complement any global stratospheric observing system. They should be coordinated in a network which provides careful characterization of the instrumental performances, intercalibration of the measurements and comparisons of data retrieval techniques.

The project entitled "European Stratospheric Monitoring Stations/Alps" is based on the existing capabilities for high-quality ground-based remote measurements of stratospheric ozone and key ozone-related trace constituents at mid-latitude in Europe. It relies on the "Alpine Station" selected for the Network for the Detection of Stratospheric Change (NDSC) as the mid-latitude, Northern hemisphere site.

The Alpine Station is complemented, in the NDSC context, by secondary stations which bring highly valuable measurements required to strengthen and complement the observations performed at the two main stations, the "Observatoire de Haute Provence" (OHP) and the "International Scientific Station at the Jungfraujoch" (ISSJ).

The main objectives of this project are :

1. to make intensive coordinated ground-based observations to provide climatological measurements of ozone total amounts and vertical profiles, aerosol vertical distributions, ClO vertical profiles, NO_2, NO, reservoirs and long-lived tracers total amounts;
2. to provide validated ground-based measurement at mid-latitude to contribute to future stratospheric campaigns;
3. to study the seasonal and interannual variability of the measured trace species;
4. to study the aeronomic processes involved in atmospheric composition changes at mid-latitude;
5. to study the role of volcanic aerosols on ozone and NO_2 reduction observed after the Mt. Pinatubo eruption by the development of aerosol modelling;
6. to provide measurements to test and improve stratospheric models including heterogeneous processes and to validate the current and planned satellite observations of the stratosphere (e.g. UARS and ERS-2/GOME).

The experimental studies are based on the currently available measurements of ozone using lidars, microwave radiometry (MR), UV-visible absorption spectroscopy (UV-VIS), Fourier Transform Spectroscopy in the infrared (FTIR). The aerosols vertical distribution are obtained also by lidars. The ozone related species are measured by FTIR (NO_x, long-lived tracers, reservoirs), UV-VIS (NO_2) and MR (ClO).

Measurements which provide the most accurate vertical distributions of ozone are based on the Differential Absorption Lidar (DIAL) technique. These observations require essentially clear sky conditions.

Lidar observations are the most effective means to investigate the impact of the Pinatubo eruption on the stratospheric aerosol layer with respect to transport and decay.

Since 1986, the "Service d'Aéronomie" performed at the Observatoire de Haute-Provence (OHP), the current nighttime measurement of ozone vertical profiles in the 18-45 km altitude range with an integration time of 3 hours for the background aerosol conditions and a vertical resolution which varies from 0.5 to 6 km.

The reference wavelength at 532 nm has been used since 1980 to detect stratospheric aerosols. Aerosols represent a source of error in measurements of ozone profiles at the altitude of the aerosol layer particularly in the case of major volcanic eruptions such as the Mt. Pinatubo in June 1991.

Stratospheric aerosol lidar measurements have been carried out systematically at the IFU (Garmisch-Partenkirchen) since the end of 1976. The profile of scattering ratio and particle backscatter are obtained from the tropopause to 30 km altitude with an altitude resolution of 75 m.

Lidar measurements have to be accompanied by an aerosol model developed by IFU and based on balloon soundings made by the University of Wyoming, with optical particle counters. The model is used to convert backscatter ratio to other quantities (e.g. extinction, particle mass and surface).

The millimeter wave instruments which offer the great advantage of being able to perform atmospheric observations in cloudy weather conditions. In addition, millimeter wave radiometry is not affected by aerosols. The ability to infer altitude profiles of atmospheric trace gazes in the range of approximately 20 km to 70 km by microwave radiometry is based in its ability to examine collision broadened emission lines of atmospheric constituents with high frequency resolution. Millimeter wave measurements are also used to study the diurnal variations of ozone in the upper stratosphere and mesosphere. For ozone profiles, an altitude resolution of approximately 8-10 km can be obtained. Ozone radiometers are operated in Bern and in Bordeaux.

Microwave sounders are the only means to remotely detect the altitude profile of chlorine monoxide (ClO) and cloud water amount.

This technique is used by the University of Bern, at the ISSJ since the beginning of 1992. ClO spectra are observed at the frequency of 204 GHz.

On the other hand, a microwave radiometer working at the frequency 278 GHz, (Millitech Co.) has been installed by the Observatoire de Bordeaux on the Plateau de Bure, in the Alps, between the OHP and the ISSJ. Since October 1992, this instrument is operated on an automatic mode. The diurnal variation of ClO is detected by daily integration of the data over intervals of 4 hours and then integrating each interval over 15 to 20 days. The high altitude diurnal variation of ozone is also detected using an O_3 line existing very close to the ClO line.

Very high resolution absorption Fourier Transform Spectroscopy (FTS) in the infrared has been successfully used in stratospheric monitoring since many years by the University of Liège. Some stratospheric constituents have been discovered by this technique. It is particularly well adapted to measuring the total column abundances of reservoir species like HCl, HNO_3, $ClONO_2$ and determining their trends, when applicable.

IR observations have been performed at the ISSJ for more than 40 years for species such as CH_4, N_2O, CO, HNO_3,... The current FTIR measurements are considered as the state of the art of measurements for this spectroscopic technique.

Comprehensive measurements have been made for the total vertical column densities of HCl, HF, CH_4, CO, N_2O, C_2H_6, C_2H_2, HNO_3, $ClONO_2$, SF_6, OCS, NO, NO_2, CF_2Cl_2, CHF_2Cl and HCN. Trends have been determined for HCl, HF, CH_4, CO, N_2O, C_2H_6, SF_6, HNO_3, and OCS.

Measurements are currently performed with an unapodized resolution limit between 0.005 and 0.0025 cm^{-1}. Interferograms are recorded in 1 to 5 minutes. Column abundances are derived either by the equivalent width method or by non-linear least-squares curve fitting.

UV-visible absorption spectroscopy is presently performed with photodiode array spectrometers by the "Institut d'Aéronomie Spatiale". These give O_3 and NO_2 column abundances from zenith sky observations at sunrise and sunset and, for clear sky conditions, from direct sunlight observations. Comparisons with nearby Dobson and Brewer spectrometers have been initiated including the longest available time series of ozone observations in Arosa .

Stratospheric ozone is currently decreasing much faster over Northern mid-latitudes than predicted by gas phase chemistry models. It is generally accepted that this ozone reduction is caused by heterogeneous chemistry either connected with disturbances of the stratospheric chemistry over the polar region or caused by stratospheric aerosols during hemispheric transport. This project will investigate the effects of the Mt. Pinatubo eruption on ozone and NO_2 reduction. A very large majority of the key constituents involved in heterogeneous processes are measured simultaneously. The data will be interpreted by means of a recently developed two-dimensional model, which includes heterogeneous reactions on the surface of sulphuric acid aerosols at all latitudes.

Another related project concerning the Arctic stations in Spitsbergen and Thule (Greenland) is coordinated by R. Neuber from the Alfred Wegener Institut in Bremerhaven (Germany).

This project will be partly funded by the Environment Programme of the European Community (DG XII).

TABLE 1 : List of stations and mesured species

Observatoire de Haute Provence		44°N, 6°E, Alt. 600 m
Lidar	Ozone	Service d'Aéronomie du
Lidar	Aerosol	CNRS
Dobson	Ozone	Univ. de Reims
International Scientific Station at the Jungfraujoch		46.5°N, 8°E, Alt. 3580 m
FTIR	Reservoirs, O_3, NO_x, N_2O CH_4, CFCs,...	Univ. de Liège, Inst. d'Aéronomie Spatiale and Univ. de Reims
UV-visible	Ozone NO_2	Inst. d'Aéronomie Spatiale
Microwave	ClO H_2O (total)	Univ. Bern
Plateau de Bure		44.5°N, 5.9°E, Alt. 2500 m
Microwave	ClO	Observatoire de Bordeaux
Universität Bern		47°N, 8°N, Alt 550 m
Microwave	Ozone	
Garmisch Partenkirchen		47.5°N, 11.1°E, Alt 730 m
Lidar	Aerosol	IFU
Hohenpeissenberg		47.8°N, 11.0°E, Alt. 975 m
Lidar	Ozone	
Brewer	Ozone	Deutsche Wetter Dienst
Dobson	Ozone	
Arosa		46.7°N, 9.7°E, Alt. 1860 m
Dobson	Ozone	ETH Zürich
Brewer	Ozone	
Payerne		46.8°N, 6.9°E, Alt. 491 m
Sondes	Ozone	
Observatoire de Bordeaux		45°N, 0.5°W, Sea level
Microwave	Ozone	
Dobson	Ozone	
L'Aquila		43°N, 12°E, Alt. 600 m
Lidar	Ozone	University l'Aquila
Lidar	Aerosol	