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SYSTEMATIC STRATOSPHERIC OBSERVATIONS ON THE ANTARCTIC CONTINENT AT DUMONT D'URVILLE

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ABSTRACT

Results of different routine measurements performed in Dumont d'Urville (66°S, 140°E) since 1988 are presented. They include the seasonal variation of total ozone and NO_2 as measured by a SAOZ UV-Visible spectrometer, Polar Stratospheric Cloud observations by a backscatter lidar and more recently, vertical ozone profiles by ECC sondes and ozone and aerosols stratospheric profiles by a DIAL lidar. The particular results of 1991 in relation with the volcanic events of Mount Pinatubo and Mount Hudson, and the position of the polar vortex over Dumont d'Urville are discussed.

1. INTRODUCTION

Continuous observation of the polar stratosphere over Antarctica is performed since 1988 at the french base of Dumont d'Urville (66°S, 140°E). This programme, developped by the TAAF (terres Australes et Antractiques françaises), includes several instruments for the measurements of NO_2, O_3, aerosols and stratospheric clouds : The SAOZ instrument UV-Visible spectrometre which is operated continuously since 1988 provides NO_2 and O_3 total contents as well as indications on the presence of stratospheric clouds. In the frame of the POLE project (Polar Ozone Lidar Experiment) in cooperation with the IROE of Florence, lidar measurements of the vertical profile of aerosols and polar stratospheric clouds are performed since 1989 (Stefanutti et al.), with the addition since January 1991 of the ozone vertical distribution in the [5-40 km] altitude range. The lidar instrument provides high vertical resolution and temporal continuity, allowing thus to study the short term evolution of the stratosphere. Since 1991, ECC ozone soundings are also performed with an increased rate during the ozone destruction period. Parallely, radiosondes are launched daily for the measurement of local wind and temperature by the french Met. Office. Results of these various experiments over an extended period of time covering the first four years of operation will be presented here, with special attention given to the winter-spring periods characterized by the appearance of stratospheric clouds and depleted ozone contents. The observation above Dumont d'Urville of the volcanic events which occurred in 1991 - Mount Pinatubo and Mount Hudson - will also be discussed.

2. SAOZ OBSERVATIONS

A zenith sky looking broad band (300-600 nm) and high resolution (1 nm) UV-Visible spectrometer SAOZ (Système d'Analyse par Observations Zénithales) designed in Service d'Aéronomie, was installed in January 1988 and operated continuously since then. The recorded spectra are processed in real time. The results are transmitted by the satellite data collection system ARGOS for first evaluation and reanalysed later after reception of the data containing diskettes. Ozone is measured in the visible Chappuis bands (450-540 nm) twice a day at twilight between 87° and 91° SZA and retrieved after carefully removing interfering absorptions of O_4 at 477 and 576 nm, and H_2O at 505 and 590 nm. NO2 is calculated in the same way from its numerous narrow bands between 410 and 470 nm. In addition, the color of the zenith sky is investigated by calculating for each spectrum a color index, defined as the ratio between the fluxes observed at 550 and 350 nm.

The four and half years of results including the preliminary ones of 1992 up to mid-May, are displayed on figure 1. In average, during the period, ozone decreases progressively and more and more minima can be observed during the spring when the vortex approaches the station. NO_2 displays a marked seasonal variation with a maximum in summer during the polar day and a minimum in winter during the polar night, when the diurnal variation vanishes. The color of the zenith sky at twilight, expressed in term of color index (CI) also shows a systematic seasonal variation (redder in late automn and early winter, drifting towards the blue later) which can be explained by the progressive downward shift of the altitude of the minimum temperature and therefore of PSC formation. Larger blueings are observed in 1991 since August, which are interpreted by the arrival of low altitude volcanic aerosols likely released by the Mount Hudson

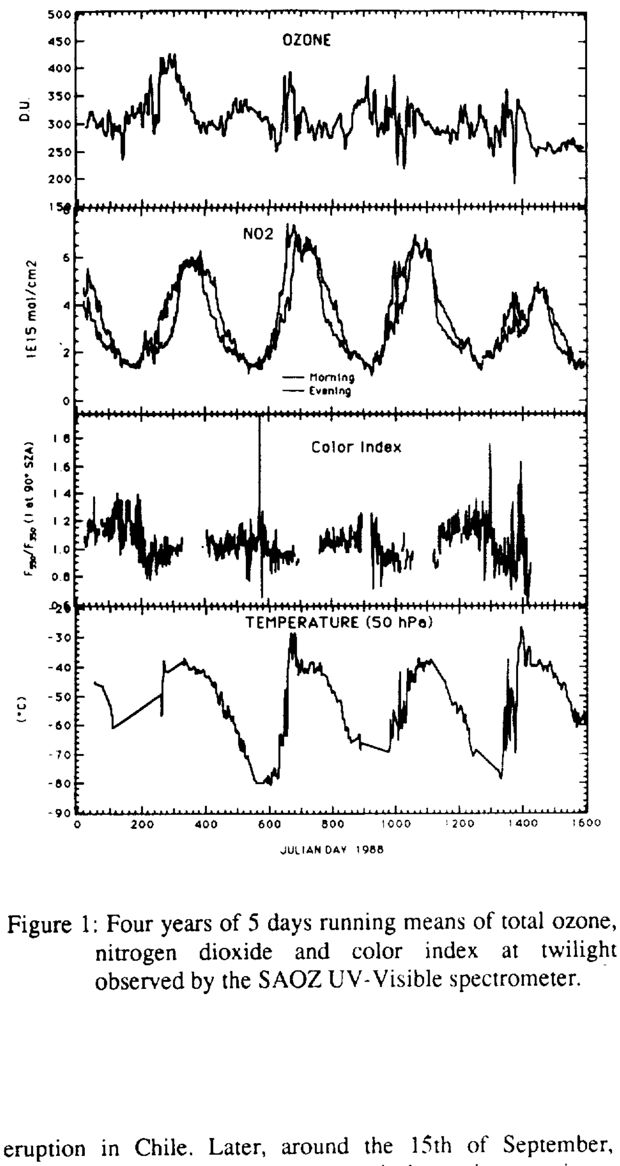

Figure 1: Four years of 5 days running means of total ozone, nitrogen dioxide and color index at twilight observed by the SAOZ UV-Visible spectrometer.

eruption in Chile. Later, around the 15th of September, another aerosol cloud appears to reach the station, causing a reddening of the color index. The large CI fluctuations strongly correlated with the movements of the polar vortex and therefore with the 50hPa temperature and total ozone, indicate that this cloud is located outside the vortex and never penetrates inside. The measured total ozone decrease associated with the reddening of the color index is due to an artefact due to the upward drift of the scattering layer. Although located at higher altitudes and therefore little affected by this effect, NO_2 is dramatically reduced compared to the previous years and does not increase before the arrival of the permanent daylight. This is believed to be the result of the heterogeneous destruction of N_2O_5 onto aerosols particles, which operates during the night only and not during the permanent daylight period.

3. POLAR OZONE LIDAR EXPERIMENT

Polar stratospheric clouds observations

The first step of the POLE experiment, organized under an Italian - French cooperation programme for Antarctic research was the implementation at Dumont d'Urville of an elastic backscatter lidar designed for both tropospheric clouds and stratospheric clouds measurements. The system (Sacco et al.,1989) operated at 532 nm with a linearly polarized laser pulse and a repetition rate of 4 HZ. Signals on both parallel and perpendicular polarization planes relative to the emitted laser radiation were collected. In January 1991, this system was replaced by a multiwavelength differential lidar instrument meant to measure both the aerosols and polar stratospheric clouds with a higher repetition rate (10HZ), and the ozone vertical distribution in the 5-40 km altitude range (Stefanutti et al., 1991).

The signature of three types of scattering layers are observed on the lidar data in the range 8 - 35 km : background aerosols, cirrus clouds at lower altitudes and polar stratospheric clouds which are expected to form over the whole altitude range above the tropopause during winter, when the temperature drops below 195°K. Detection of PSC starts around mid-June and ends around mid-September, although most of them are seen in July and August. The interannual dependance of PSC sighting depends highly on the local meteorological conditions at Dumont d'Urville for the presence of low tropospheric clouds precludes the detection of clouds located at higher altitudes. In particular, only a few measurements were possible in August 1991, due to the bad weather conditions which prevailed during this month. The PSC are generally observed between 13 and 25 km with a scattering ratio varying from 2 to 6. Differentiation of the type of PSC measured with the temperature is made difficult by the bursting of the radiosondes ballons generally above 18 km during winter time. Nervertheless, the depolarization ratio values allow to distinguish between clouds formed by spherical or non spherical particles. This is illustrated by the case of August 3rd 1989 where two PSC clouds were detected at 20 km and 25 km respectively, above a cirrus cloud located at 9 km altitude range (figure 2). Both PSC show a scattering ratio of 3 but the higher one is characterized by a depolarization ratio of 25 % as compared to less than 5 % for the lower one. The relatively high value of the scattering ratio for the former cloud may indicate the presence of a type II PSC according to the classification of Toon (Toon et al., 1990).

The main event of 1991 with respect to aerosols measurements is the eruption of mount Pinatubo in the Philippines in June 1991. Some unusually very strong aerosols events were detected on the 532 nm channel around the 20th of July during a period of cold temperature, according to the radiosonde measurement which unfortunately stopped at 18 km on that day. The absolute

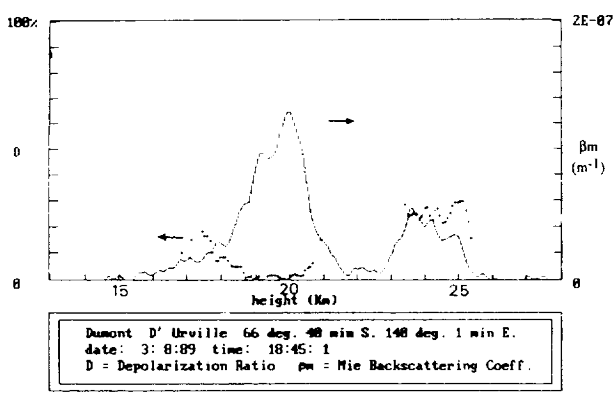

Figure 2: Depolarization ratio (dotted line) and Mie backscattering coefficient (solid line) versus latitude as measured on August 3rd 1989

value of the scattering ratio observed is questionable because of the bad quality of the lidar signals on this channel at that time. Backward trajectory studies are underway in order to see whether this strong event might be related to an early arrival of the Pinatubo cloud in this region. Really cold temperature period (with T < 195°K) ended in Dumont d'Urville around the 25[th] of August. The signature of the Pinatubo cloud is seen without ambiguity on the lidar signals on the 4[th] of September as shown on figure 3, which represents the scattering ratio observed at 532 nm on that day, with the corresponding temperature profile. No lidar measurements were obtained during the last 15 days of August due to the bad weather as already mentionned. After the beginning of September, the cloud was seen sporadically up to the beginning of October when it was finally present at

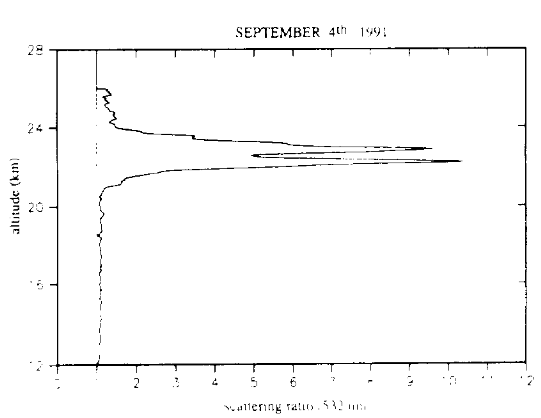

Figure 3 a : First observation of the Pinatubo Volcanic Cloud in Dumont d'Urville on September 4th 1991 : scattering ratio measured on the 532 nm channel.

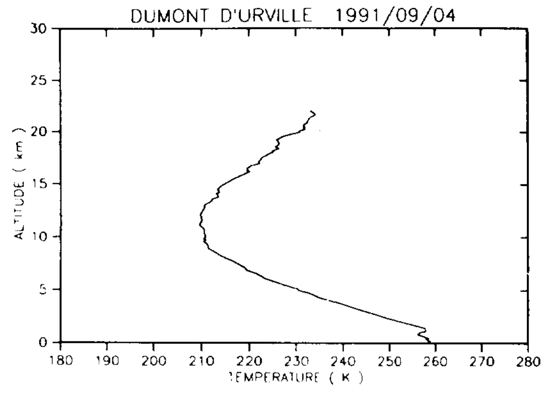

Figure 3 b : Temperature profile of September 4th 1991

each measurement. As in other latitudes (Godin et al., this issue), the aerosol layer presents a very high variability (see figure 4 which represents scattering ratios obtained with the off-line wavelength of the ozone measurements at 355nm). Its altitude is also quite high (22-24 km), as compared to measurements made during the EASOE campaign at around the same latitude in the Arctic. On the 8[th] of October, no aerosol layer was detected above 12 km and very low ozone content was measured by both the ECC sonde and the lidar (see next section) which shows quite clearly that the polar vortex was above Dumont d'Urville on this day and that the Pinatubo cloud had not penetrate the vortex until then.

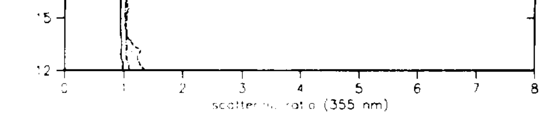

Figure 4 : Evolution of the scattering ratio measured on the 355nm channel in September - October 1991

Ozone lidar measurements

In order to obtain ozone measurements in the 5 to 40 km altitude range, two pairs of wavelengths are used: 289 nm and 299 nm for the measurements in the troposphere and 308 nm and 355 nm for the stratosphere. Only stratospheric ozone measurements will be discussed in the following section. The first profiles were obtained in April 1991. They show a rather good agreement with the ECC ozone profiles above 15 km (figure 5). In September 1991, all the measurements made by the various instruments are characterized by a high variability with a very good correlation between the temperature, the amount of ozone and the amount of aerosols observed. This is the clear signature of overpasses of the polar vortex above Dumont d'Urville as low amounts of ozone correspond to cold temperature profiles and to the absence of high stratospheric aerosol layer. Parallely, an additional cloud located around 10-12 km is seen on each lidar measurements undependantly of the position of the vortex. This cloud, seen also by SAOZ is probably related with the Mt Hudson

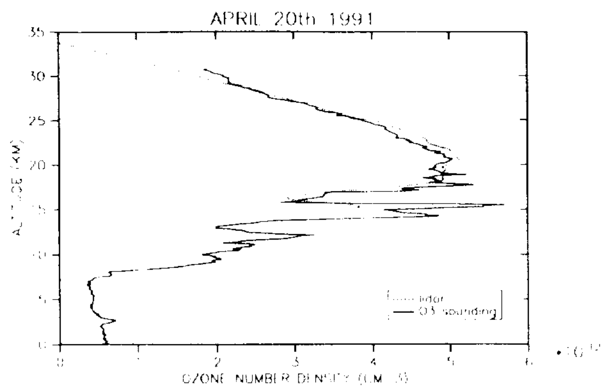

Figure 5 : Comparison of the ECC sonde and Lidar ozone measurement on the 20th of April

eruption in Chile. On the 8th of October, as already mentionned, a perturbed ozone profile was detected by both the lidar and the ECC sondes (figure 6), although the measurement made by the lidar is higher than the ECC one by around 30% between 17 and 25 km, which is probably due to the non coincidence of the two measurements in a period when ozone was very variable. The total ozone amount measured by the SAOZ is 150 Dobson Units, which is the lowest measurement ever made in Dumont d'Urville during this four year period (figure 1). The DIAL instrument being build for nighttime operation only, the ozone lidar measurements stopped during the Summer season and resumed in March 1992.

4. CONCLUSION

The various routine measurements made in Dumont d'Urville since 1988 allow to follow accurately the evolution of the stratospheric conditions which prevail on this location at the edge of the polar vortex. In particular, the observation of the volcanic events which occured in 1991, show that, while the low cloud of Mount Hudson could be seen independantly of the polar vortex position after September

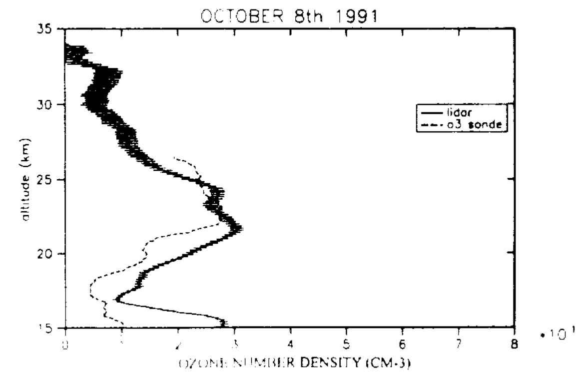

Figure 6 : Comparison of the ozone vertical profiles measured by the ECC sonde and the lidar on the 8th of October

1991, the higher and stronger cloud of Pinatubo did not penetrate the vortex until mid October. Parallel measurements of the total amount and vertical profile of ozone show clearly the decline of this constituent in the lower stratosphere during September, up to the 8th of October when very low values were measured by all the instruments. These results demonstrate the possibility of implementing a station as defined in the frame of the NDSC (Network for Detection of Stratospheric Changes) with rather sophisticate instruments, on a remote location like the Antarctic continent.

REFERENCES

Stefanutti L., M. Morandi, M. Del Guasta, S. Godin, G. Mégie, J. Brechet and J. Piquart (1991): Polar Stratospheric Cloud Observations over the Antarctic Continent at Dumont d'Urville, J. of Geophys. Res., 96, D7, 12975-12987

Sacco V.M, F. Castagnoli, M. Monrandi and L. Stefanutti (1989): Elastic Backscattering Lidar System for Measurements in Antarctica, Opt. and Quantum Electr., 21, 215

Toon O.B., E.V. Browell, S. Kinne, and J. Jordan (1990): An Analysis of Lidar Observations on Polar Stratospheric Clouds, Geophys. Res. Lett., 17 (4), 393, 1990

Godin S., G. Mégie, C. David, V. Mitev, D. Haner, Y. Emery, C. Flesia, V. Rizi, G. Visconti, L. Stefanutti (1992): Ozone, aerosols and polar stratospheric clouds measurements during the EASOE campaign, this issue