SOLAR CAMPAIGN: FIRST RESULTS OF OZONE PROFILE MEASUREMENTS AT RIO GALLEGOS (51º 55'S, 69º 14'W), ARGENTINA

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ABSTRACT

As a part of environmental studies in the southern hemisphere, the CEILAP Lidar Division in collaboration with different national and international institution has planned the SOLAR (Stratospheric Ozone Lidar of ARgentina) Campaign. The objective of this campaign is to monitor different atmospheric constituents using remote sensing techniques, mainly related with lidar, in southern part of Argentina. The most important and complex instrument involved in this campaign is a differential absorption lidar capable to produce precise and accurate measurements of the stratospheric ozone profiles. We present in this paper the first results of the SOLAR campaign held during August – November 2005 period (southern late winter-spring time) at Rio Gallegos (51º 55'S, 69º 14'W), Santa Cruz Province, Argentina, focusing on stratospheric ozone profiles measurements with the DIAL technique and UV radiation measurements. The border of polar vortex overpassed the station four times during the campaign, allowing us to register significant depletion in the ozone layer for these days. A set of passive sensors, likes UV radiometers to measure solar surface UV irradiance were also deployed. The anticorrelation between ozone depletion – UV increase at surface is reported.

1. INTRODUCTION

The behavior of trace constituents in the Earth's upper atmosphere, governed by chemical, dynamical, and radiative processes, is of particular importance for the balance of stratosphere and mesosphere. In particular ozone plays a dominant role by absorbing the short-wavelength UV radiation which might damage living organism and by maintaining the radiative budget equilibrium [1]. For those reasons ozone has been at the center of middle atmosphere research effort [2].

The Antarctic ozone depletion during the polar spring has been a well publicized indication that significant changes are being induced by man's chemical activities [3]. The ozone hole has started to develop each spring in the southern polar region in the early 1980's when total chlorine in the stratosphere reached a threshold value of 2 ppbv. During the past twenty years, this phenomenon has varied in size and with respect to the minimum total ozone value within the polar regions. . At some occasions, the polar vortex elongates and the ozone hole contained within the vortex crosses the continental part of South America. In these situations large inhabitant cities like Rio Gallegos (51º 55'S, 69º 14'W) are under the influence of the ozone hole or near its border, causing the increase of solar UV radiation at these places [4].

This reason together with the deployment of ground based lidar instruments for satellite validation inspired the SOLAR campaign (www.division-lidar.com.ar). The CEILAP Lidar Division in collaboration with Service d'Aéronomie in France and National Institute for Environmental Studies in Japan and different national institutions has carry out the SOLAR (Stratospheric Ozone Lidar of ARgentina) Campaign. It is supported by JICA (Japanese International Cooperation Agency).

The principal objective of this campaign is to study the ozone layer when the polar vortex crosses over the continental part of Argentina, in South America. The most important and complex instrument involved in this campaign is a differential absorption lidar capable of making precise and accurate measurement of the stratospheric ozone vertical distribution. An XeCl excimer laser emission at 308 nm is used for absorbed wavelength in the DIAL technique and the Nd-YAG laser 355 nm third harmonic line is employed as a reference wavelength. Six channels are used for the signal acquisition, four of them for the detection of elastically backscattered signal of the emitted wavelengths (high energy mode for the higher altitude ranges, attenuated energy for the lower ranges) and two corresponding to the first Stokes nitrogen Raman of the emitted wavelengths. The characteristics of different parts of this instrument are summarized in Table 1. A full description of this DIAL system together satellite comparison can be found in [4] and [5].

Table 1. DIAL system characteristics.

Subsystem	Specifications
Emitter	
Lasers	Lambda Physik LSX 210i excimer laser, 1-100 Hz repetition rate, 300 mJ maximum pulse energy at λ_{on} = 308 nm, 0.4 divergence beam, 4-20 ns pulse length.
	QUANTEL 980 Nd:YAG laser, 30 Hz repetition rate, 130 mJ maximum pulse energy at λ_{off} = 355 nm (third harmonic), 0.6 divergence beam, 3-5 ns pulse length.
Reception	
Telescopes	4 Newtonian configuration, Ø 48 cm, f/2. each one. Total reception area ~7238 cm^2
Optical fiber	HCG – M0940T, 0.94 mm effective diameter, 0.22 ± 0.02 numerical aperture (loss of 20%), 0.27 dB/km (@ 308 m) / 0.2 dB/km (@ 355 nm) attenuation.
Diffraction Grating	JOBIN-IVON I.S.A, 3600 lines/mm with 40% transmittance at 300 nm. Dispersion 0.3 nm/mm. Spectral band width 1 nm
Detection	
Photomultipliers	HAMAMATSU gated PMT for High energy channels
	HAMAMATSU Type H6780-03, low dark current, and adapted for photon-counting. Typical gain 10^6, typical luminous sensitivity 70A/lm
Amplifiers	Developed at CEILAP, 250 MHz BW, Amplification factor 10-30
Discriminators	Phillips 300 MHz BW.
Acquisition	Developed at Service d' Aéronomie. Six independent channels. High speed counters of 300 MHz, 1024 time gates / 1 µs. Max count rate 40/60 count/µs.

1.1 Objectives of SOLAR Campaign

The main objectives of this campaign are to contribute to the analysis of the behavior of: 1) *stratospheric ozone profiles* using a differential absorption lidar (DIAL) system and to analyze the polar vortex crosses over the south of the continent 2) *water vapor profiles* in the troposphere using a Raman lidar; 3) *aerosol profiles in the troposphere*, using a backscattering lidar system, and 4) to obtain *ground measurements of UV radiation* with different kinds of passive sensors.

All these instruments were deployed in the city of Río Gallegos (51,5 S, 69,1 W), in southern part of South America where the number of clear nights necessaries to make lidar measurements are higher in comparison with other cities of southern Patagonia [7].

In this paper will be summarized the ozone profiles measurements using DIAL technique and corresponded UV radiation only.

2. MEASUREMENTS

During the ozone hole period at austral spring, between August –November 2005, intensive measurements of ozone profile were made. A total of 26 ozone lidar profiles were measured during this period. Four of them showed reduction in ozone content as result the cross of polar vortex that encloses the ozone hole, over Rio Gallegos city. In Figure 1, we see two lidar measurements of ozone concentration for August 15 (circles) and August 19 (triangles). The first one correspond to normal ozone condition as we can be see in TOMS image for this day (Fig. 1 circles) with 294 DU total ozone column.

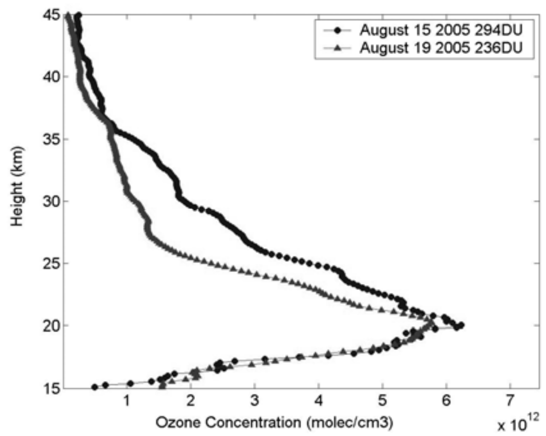

Fig 1. Lidar ozone profiles in Rio Gallegos

Four days later (August 19) ozone reduction in 22 – 34 km layer was observed (triangles). Total ozone column for this day was 236 DU, near the edge of ozone hole as can be checked from TOMS image for this day.

The UV index suffered an increment of 21% for August 19 with respect to August 15 as the result of ozone reduction. The measured UV index for these days with EKO MS-210D biometer is showed in Fig 2 together with the TUV radiative transfer model (Madronick et al.) calculation for the correspond days (see figure caption Fig.2).

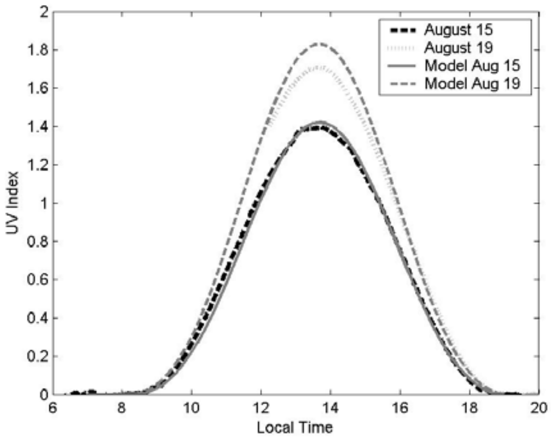

Fig. 2. UV index for August 15 (dashed black line), August 19 (dotted grey line), TUV model for August 15 (grey line), TUV model for August 19 (dashed grey line)

The strongest reduction of ozone column over Río Gallegos during the 2005 spring was observed on October 8 with total ozone column of 196 DU calculated from the integration of an ozone profile based the lidar measurement and the US Standard 1976. . This value represents a 45% reduction in total ozone column with respect to mean total ozone value outside ozone hole for this month (350 DU). The lidar profile measured for this day is shown in Figure 3 (dashed line) together with the ozone profile measured on October 17 (dotted line) witch corresponds to normal ozone conditions outside the ozone hole (357 DU). The climatologic profile (black line) from SAGE II measurements is also shown in the figure It corresponds to the mean of SAGE II ozone measurements outside the ozone hole for the 1995-2004 period. The OMI image for this day shows the ozone hole elongated over South America confirming the overpass of ozone depletion area over the measurement site.

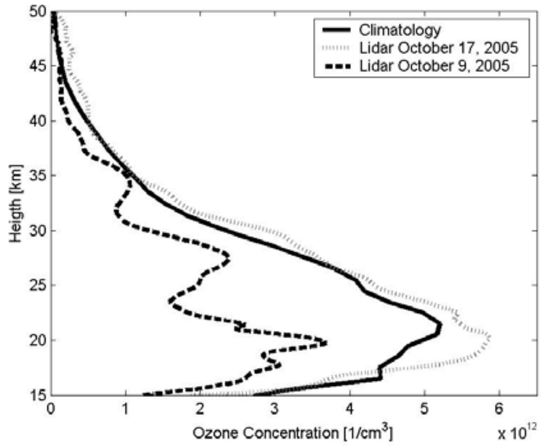

Fig. 3 Lidar ozone profile inside (dashed line) and outside (grey dotted line) ozone hole in Rio Gallegos. Climatologic profile for October from SAGE II data (black line).

Fig. 4 shows the relative difference between the climatological SAGE profile and the lidar profile obtained on October 9, 2005, defined as (SAGE-LIDAR)/SAGE. We see a strong reduction of ozone content with a maximum of 65% reduction at 23.5 km.

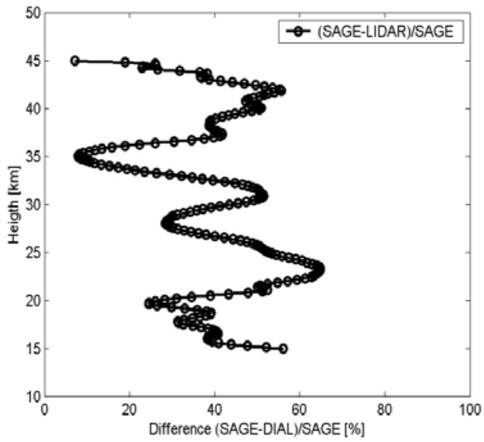

Fig. 4. Relative difference between lidar profile of October 9, 2005 and SAGE II climatology profile

The UV measurement by the moderated narrow band radiometer GUV-541 manufactured by Biospherical Inc. shows an increase by a factor 4.7 at 305 nm between October 8 and October 11 (Fig. 5) at solar noon. TOMS values for these days are 166 DU on Oct. 8 and 331 DU on Oct. 11. The latter day was a clear one with total ozone column near the mean value of approximately 350 DU for this latitude in October**.**

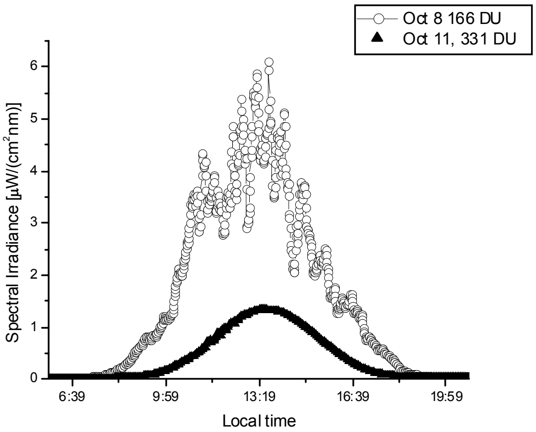

Fig 5. GU541 305 nm Channel for October 8 (open circles) and October 11 (triangles)

3. CONCLUSIONS

In this article we have described the DIAL instrument involved in the SOLAR campaign. The preliminary results of ozone lidar measurements are presented. These were taken during August - November 2005, as part of the first intensive period of the SOLAR campaign.

The border of polar vortex crosses the latitude of the station four times, which lead to the registering of significant depletion in the ozone layer especially on October 9 2005 when a 45% reduction in total ozone column with respect to normal conditions was measured. The stronger reduction of ozone content with respect to climatological SAGE II profile was seen at 23.5 km with a reduction in ozone of 65% .

As passive sensors, UV radiometers measured the solar UV irradiance at surface. The anticorrelation between ozone depletion – UV increase at surface was registered. The UV index showed a 21% increase between August 15 and August 19 at solar noon. During October 8 ozone hole intrusion over Río Gallegos, the 305 nm channel of GUV 541 radiometer registered a factor 4.7 increase at solar noon with respect to October 11, which was considered as typical day outside ozone hole for this latitude and season.

The SOLAR campaign has scheduled a new intensive measurement period during August – November 2006, with routing measurements between January – July 2006.

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