



# The Puyehue-Cordón Caulle Volcanic Eruption, June 2011: Water Vapor, Atmospheric Boundary Layer and Aerosol Temporal Evolution in Buenos Aires, Argentina

**Lidia Ana Otero, Pablo Roberto Ristori,**  
CEILAP (CITEDEF-CONICET), UMI-IFAECI-CNRS 3351  
Juan B. de La Salle 4397 - B1603ALO - Villa Martelli, Buenos Aires, Argentina  
Tel: +54 11 47098100 ext 1410, Fax: +54 11 47098122, E-mail: lidia1116@gmail.com  
and **Juan Vicente Pallotta, Ezequiel Eduardo Pawelko, Eduardo Jaime Quel**  
CEILAP (CITEDEF-CONICET), UMI-IFAECI-CNRS 3351  
Juan B. de La Salle 4397 - B1603ALO - Villa Martelli, Buenos Aires, Argentina  
Tel: +54 11 47098100 ext 1410, Fax: +54 11 47098122, E-mail: lidia1116@gmail.com

## SUMMARY

The 4th June 2011 a volcano eruption in the Puyehue – Cordón Caulle chain in the south central region of Chile released an important amount of ash to the atmosphere. The cloud reached Argentina, Uruguay, Brazil, South Africa and Australia blocking the aerial transport. A multiwavelength backscatter Raman LIDAR, developed and operational in Buenos Aires, at Centro de Investigaciones en Láseres y Aplicaciones, CEILAP (CITEDEF-CONICET), (34.5° S, 58.5° W) observed this event as well as satellites and ground-based systems of this monitoring station. The source of this lidar is a tripled Nd:YAG laser, collecting the nitrogen Raman backscattered returns from nitrogen at visible and ultraviolet wavelengths to retrieve the aerosol extinction and Ångström coefficient vertical distribution. It also measures the water vapor mixing ratio profile at the corresponding Raman-shifted backscattered return. Additional information such as satellite imaging, backtrayectories (HYSPLIT model) and aerosol optical depth (AERONET) were included on this study.

**Key words:** Raman Lidar, volcanic ash, atmospheric boundary layer.

## INTRODUCTION

Southern Patagonia is frequently affected by volcanic eruptions. These events disrupt the overall air quality; generate economic losses, harmful health and very serious problems in air navigation. In this paper we study an event the eruption of volcano Puyehue - Cordón Caulle in Chile. Aerosols ejected by this eruption affected Central Patagonia, and the Northern region of Argentina. These were also detected in several countries of the southern hemisphere. The data used for the study of this event were: a lidar system, a sunphotometer and satellite images.

## EVENT DESCRIPTION

The Puyehue-Cordón Caulle volcano located in Chile, north of Cardinal Samore International Pass (40.590° S, 72.117° W, 2240 m ABL) erupted on June 4, 2011. The first eruption emitted ashes to a maximum altitude 14,000 m, according to the Buenos Aires Volcanic Ash Advisory Center – (VAAC). The ash cloud remained above 12,000 m for the 5 and 6 June. The continuous emissions during these two days created an ash cloud that was spread over 1,900 km from Chile along the Argentinean Region.

## STATION DESCRIPTION

The Coaxial Multiwavelength Rayleigh and Raman Tropospheric Lidar System (MWRLS) [Otero et al., 2011] operates in the suburbs of Buenos Aires City at CEILAP

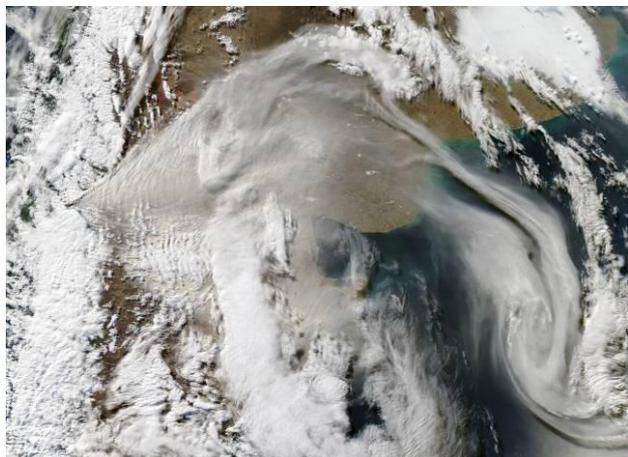
(Centro de Investigaciones en Láseres y Aplicaciones). This lidar was conceived to monitor range-resolved (80 m to 15 km AGL) aerosol optical properties from the IR to the near UV spectral region in the whole troposphere. Its emission system is a 10 Hz – 600 mJ (1064 nm) solid state Nd:YAG laser (Continuum Surelite III P-IV). The fundamental laser line is doubled and tripled to obtain 532 nm and 355 nm respectively. The backscattered radiation is collected by an f/2, 1 m focal length Newtonian telescope, focused into a 1 mm diameter optical fiber to achieve a field of view of 1 mrad. The detection unit is a dichroic/interference filter-based polychromator unit that separates the elastic and Raman-shifted backscattered radiation. The detection units are photomultiplier modules (Hamamatsu H6780-03) for the ultraviolet and visible wavelengths and a detector module (LICEL) based on an NIR enhanced Si-avalanche photodiode set (EG&G) for the infrared wavelength.

Also at CEILAP, there is installed a CIMEL sunphotometer of AERONET (AEROSOL ROBOTIC NETWORK). This is a worldwide network of automated ground-based instruments providing spectral aerosol optical depth (AOD), inversion products of other aerosol optical properties, such as single scattering albedo (SSA) and aerosol size distributions [Holben et al., 1991].

Typically the sunphotometers take measurements of the direct sun radiance at eight spectral channels (340, 380, 440, 500, 670, 870, 940 and 1020 nm) with triplet observations per wavelength and diffuse sky radiances at four spectral channels (440, 670, 870 and 1020 nm). For our study, we used Level 1.5 (cloud-screened) data.

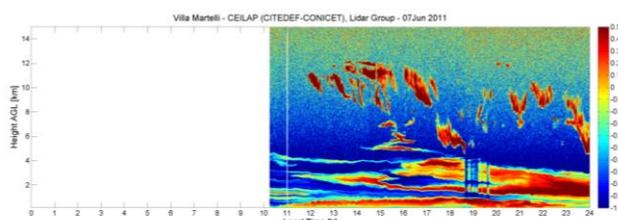
**RESULTS**

Figure 1 shows an AQUA satellite image from June 8, 2011 where it is possible observed the ash plume arriving to Buenos Aires.

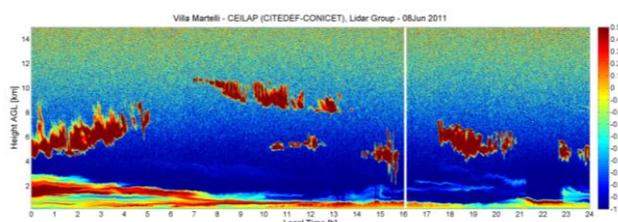


**Figure 1. AQUA June 8, 2011 18.30 UTC.**

Figure 2 shows the first lidar measurement of volcanic ashes over Buenos Aires on June 7, 2011. Figure 3 shows the evolution of these measurements over June 8, 2011. Both Figures display the attenuated aerosol backscatter in arbitrary units and logarithmic scale at 1064 nm. On both figures it is possible to observe the aerosol layers and the atmospheric boundary layer evolution. These transported aerosol layers reached a maximum height of 7 km on the 7<sup>th</sup> June and 3 km during the 8<sup>th</sup> June. Above these layers some cloud can be observed. The deposition of these layers is evidenced as a negative slope of the ashes height versus time. Aerosol intrusion into the convective boundary layer is also observed.



**Figure 2. Aerosol Backscatter at 1064 nm, June 7, 2011.**

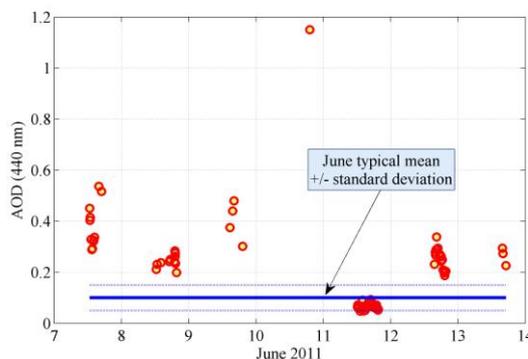


**Figure 3. Aerosol Backscatter at 1064 nm, June 8, 2011.**

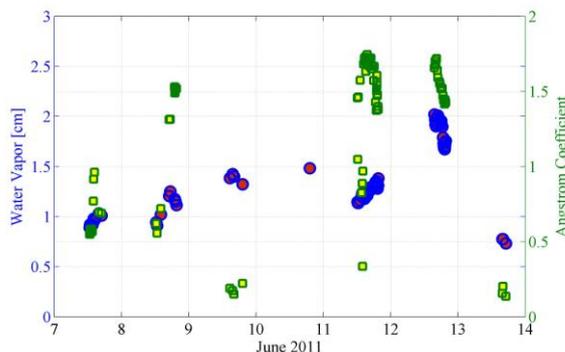
Figure 4 shows the aerosol optical depth (AOD) temporal evolution measured at 440 nm using the collocated AERONET sunphotometer. It is important to note that AOD values exceed 4 times the typical average for June.

Figure 5 shows the water vapor, measured with the 940 nm sunphotometer line, and Angstrom Coefficient [Angstrom, 1929; Otero et al., 2006] calculated using the six AOD

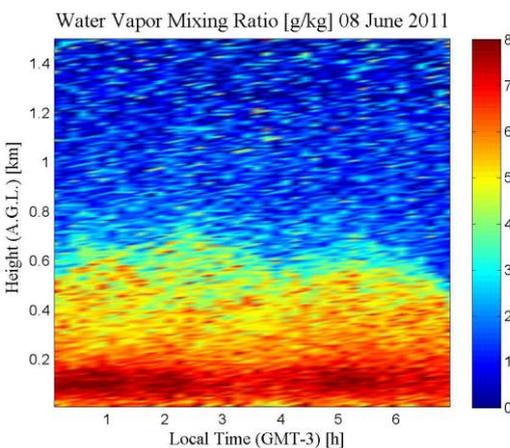
sunphotometer measurements. From 7 to 12 June the water vapor signal displays a slight increase, remaining practically constant during the day. Instead, the Angstrom coefficient that is related to the aerosol mean radius, presents a significant daily and day-to-day variability. Figure 6 shows the water vapor mixing ratio temporal evolution calculated using the Raman Lidar profiles at 387 nm and 408 nm.



**Figure 4. Aerosol optical depth temporal evolution.**



**Figure 5. Water Vapor and Angstrom Coefficient temporal evolution.**

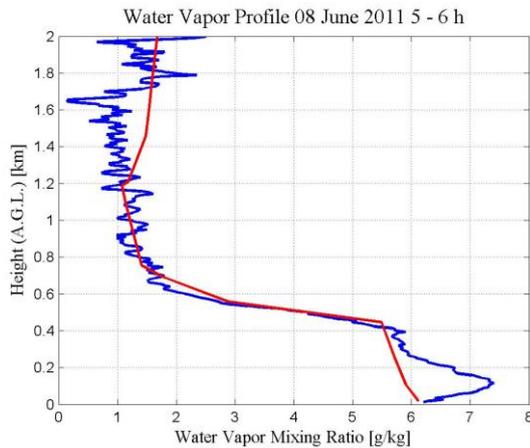


**Figure 6. Water Vapor Mixing Ratio [g/kg].**

It is possible to observe that the water vapor mixing ratio is nearly constant at each altitude during the night. This may indicate that the hygroscopy of volcanic ash remained invariant during the measurement.

Finally, Figure 7 shows the averaged water vapor mixing ratio profile from 05.00 to 06.00 AM (local time) measurements. The profile was compared to a radiosonde measurement, done at 30 km from the lidar station at 09.00 AM local time. This

explains the lack of agreement at lower altitudes. However, for higher altitudes there is a better agreement.



**Figure 7. Water Vapor Mixing Ratio [g/kg]. Comparison between lidar measurement in blue (average 05.00 to 06.00 AM) and radiosonde measure in red (09.00 AM).**

### CONCLUSIONS

The first results of volcanic ashes measurements over Buenos Aires are presented. The amount of particulate matter was transported from Patagonia to Buenos Aires City with significant satellite tracking drawbacks due to the lack of visibility because of the presence of clouds throughout the region. LIDAR measurements provided information about optical and geometrical thickness of the aerosol layers, and

also showed the moment at which they began to mix with the atmospheric boundary layer, giving an indication of the beginning of the ash dry deposition.

### ACKNOWLEDGMENTS

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### REFERENCES

- Ångström, A. (1929), On the atmospheric transmission of sun radiation and on dust in the air, *Geografis Annal.*, 2,156-166.
- Holben B., T. F. Eck, I. Iutsker, D. Tanre, J. P. Buis, A. Setzer, E. Vermote, J. A. Reagan, Y. Kaufman, T. Nakajima, F. Lavenu, I. Jankowiak, and A. Smirnov (1991), AERONET-A federated instrument network and data achieve for aerosol characterization, *Remote Sens.*, 12, 1147-1163.
- Otero L., P. Ristori, B. Holben, E. Quel (2006), Aerosol Optical Thickness at ten AERONET – NASA stations during 2002, *Opt. Pura Apl.* 39 (4) 355-364.
- Otero, L., P. Ristori, E. Pawelko, J. Pallotta, E. Quel (2011), Six-Year Evolution of Multiwavelength Lidar System at CEILAP. V Workshop on Lidar Measurements in Latin America, *Opt. Pura Apl.*, 44, 13-18.