MULTIWAVELENGTH RAMAN LIDAR TO MONITOR VOLCANIC ASH AND AEROSOLS IN BARILOCHE INTERNATIONAL AIRPORT, ARGENTINA

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ABSTRACT

A monitoring station consisting of a new multi-wavelength lidar built by the Lidar Division of CEILAP for the measurement of volcanic ash, a sunphotometer added to the AERONET / NASA and a nephelometer was installed at the airport in San Carlos de Bariloche, Rio Negro, Argentina. The main objective is to provide information to help aerial authorities to determine the feasibility of air traffic due to the presence of volcanic ashes from the Puyehue volcano. The description of the instrument and some results are presented.

Keywords: lidar, volcanic ashes, Puyehue, sunphotometer, AERONET, Bariloche airport.

1. INTRODUCTION:

It is known that volcanic ash plumes affect air navigation in different ways. These interfere with the aircraft instruments, visibility, fuselage and engine reliability. In this regard, the recommendation of the ICAO (International Civil Aviation Organization) was to avoid encounters with volcanic ash [1].

On May 2, 2008, the Chaitén volcano (-42.814º S, -72.644º W, 962 m asl) erupted, injecting large amounts of ash in Patagonia Argentina affecting the province of Chubut significantly [2]. In that occasion the ICAO recommendation was followed, so all the flights were cancelled as a security measurement.

The eruption of the volcano Eyjafjallajokull in Iceland on April 14, 2010, which significantly affected the northern and western Europe, drove a great change in air navigation restrictions. A large part of European airspace was closed to air traffic by the aeronautical authorities between 15 and 20 April, reaching almost 75% of the European network. For that reason the aircraft and turbine manufacturers determined that their products withstand operations in atmospheres with ash density up to 2 $mg.m^{-3}$. That decision was accepted by the European NSAs (National Supervisory Authorities European) and ANSPs (Air Navigation Service Providers) [1]. The same decision was also approved in Argentina.

On June 4, 2011 the Puyehue volcano (-40.578º S, -72.116º W, 2240 m asl), located in Chile, erupted. The result was an intense eruption, that lasted months, with injections of great amounts of ash which were transported and dispersed throughout the Argentine Republic [3]. During several months the air traffic was suspended, in the areas near the volcano primarily. San Carlos de Bariloche international airport, Teniente Luis Candelaria (-41.149º S, -71.157º W, 846 m asl), was the most affected one, remaining inactive during 7 months. In January 2012, it was decided reopening the Bariloche airport due to there was a little reduction of the volcanic activity. For this reason it was requested to the Lidar Division of CEILAP the construction and the operation of a volcanic ash monitoring station to help determine the feasibility of flights. On February 1, 2012, the station began to operate in the Bariloche airport. This laboratory is an adaptation of an aerosol lidar, funded by JICA (Japan International Coordination Agency), and built by the Lidar Division [4]. The main instruments are a multi-wavelength aerosol Raman lidar, a sunphotometer included AERONET (AErosol RObotic NETwork) / NASA network and a nephelometer. Measured information is reported by the National Weather Service to the Airport authorities and airlines, Lidar Division website [5] and the AERONET website [6] in real time.

2. EXPERIMENTAL SITE:

2.1 Mobile Laboratory

The monitoring station was built in a 20 feets shelter. This station has two rooms: one for the lidar instrumentation and the other for the computers and operators. The lidar is conceived to perform vertical measurements. A chimney closed by a 6 mm glass window (85% transmission in the UV) at the rooftop protects the system from rain, dust, and direct sunlight.

The roof of the station has a CIMEL sunphotometer linked to the AERONET / NASA network. A view of the laboratory installation is shown on figure 1.

Figure 1. Mobile laboratory in a 20 feets shelter

2.2 Lidar Description

The system is designed to collect the fundamental, second and third harmonic atmospheric returns from a Nd:YAG laser. In addition the nitrogen Raman-shifted backscatter from the visible and UV laser wavelengths and the water vapor Raman-shifted backscatter from the UV laser wavelength is collected. The corresponding block diagram is shown on figure 2.

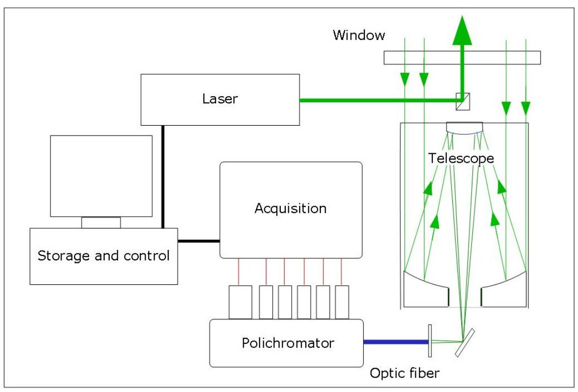

Figure 2. block diagram of the lidar system.

2.2.1 Emission system

The transmitter is a flash-pumped Nd:YAG laser (Brillant model from Quantel). It delivers short pulses (5 ns) of linearly polarized radiation (> 90 %) at a repetition rate of 30 Hz. The energies at the fundamental, second and third harmonic are 350 mJ (1064 nm), 150 mJ (532 nm) and 90 mJ (355 nm) respectively. This laser was chosen because of its relative high energy per pulse at the visible wavelength (used for Raman backscatter detection) and its degree of polarized emission (for aerosol depolarization studies). The laser beam is redirected to the atmosphere by a right angle prism.

2.2.2 Receiver

The backscattered light is collected using a Celestron C8-A XLT Schmidt-Cassegrain telescope with a primary and secondary mirror diameter of 203 and 68.58 mm, respectively, and a focal length of 2032 mm. This telescope has maximum efficiency in the visible and minimum in the ultraviolet.

In the focus of the telescope, an optical fiber acts as a field stop and carries the light collected to the polychromator system. Future reforms in the lidar instrument will include polarization analysis.

2.2.3 Polychromator setup

It is a 6-channel polychromator system consisting of lenses, dichroic and interference filters. The elastic backscattered wavelengths (Rayleigh and Mie scattering at 355, 532 and 1064 nm) and the Raman backscattered wavelengths created from the interaction of the 355 and 532 nm laser emissions with the atmospheric nitrogen and water vapor molecules are discriminated [7]. The polychromator scheme is presented on figure 3.

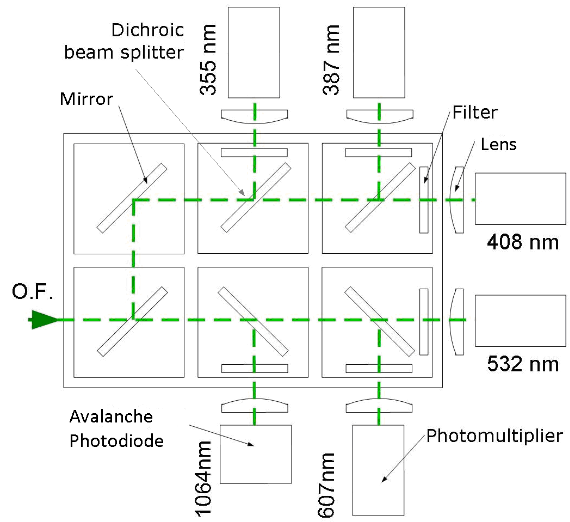

Figure 3. Polycromator block diagram

The photodetectors used in the polychromator system are: Hamamatsu H6780-03 (355, 387 and 408 nm), H6780-20 (532 and 607 nm) and an EG&G APD - based Licel unit (1064 nm).

2.2.4 Acquisition, control and storage

The signals are acquired using three Licel transient recorder modules model TR-20-160 AP. These systems operate at 20 MSPS achieving a spatial resolution of 7.5 m. Raman signals are recorded using the photon-counting inputs with a counting rate of 250 MHz. Elastic signals are connected to the analog inputs and digitalized by a 12 bit A/D converter. The module performs internal summation of multiple profiles up to a maximum of 4096. Final records are sent using the system Ethernet connection to the main computer that stores the data. This computer also controls the laser, turning it on and off at fixed periods of time in order to increase the lifetime of the flash lamps.

The data is transmitted to the Lidar Division using a wireless LAN. In case of failure, a 3G cellular connection performs the data transfer automatically.

2.3 Sunphotometer

A CIMEL sunphotometer model CE318NE performs direct solar measurements of the aerosol load at 8 different wavelengths (340, 380, 440, 500, 675, 870, 1020, 1640 nm). This instrument is associated to the AERONET / NASA network [8]. In order to characterize the ashes, the AOT (Aerosol Optical Thickness), Ångström coefficient and the mean square radius of aerosol can be used.

2.4 Nephelometer

The TOPAS (acronym of Turnkey Instruments Ltd. Optical Particle Analysis System) is a particle monitor nephelometer designed to perform continuous measurements of airborne particles. This system is able to discriminate TSP (Total Suspended Particles), PM_{10}, $PM_{2.5}$ and PM_1. In addition it has an internal filter to perform an additional gravimetric calibration. Its detection limit is 10^{-5} mg / m^3 and its measuring range reaches 6 mg / m^3. This system is certified by the United Kingdom Environmental Agency's Monitoring Certifications Scheme. It has an internal memory to record up to 45.5 days for standalone mode and a PC connection to transfer the acquired information.

3. CASE STUDY MARCH 3, 2012

On March 3, 2012, an important aerosol layer was observed from the ground level up to 1.5 km. Figure 4 shows the attenuated backscatter for this day. The profiles were measured at 1064 nm, with a temporal and spatial resolution of 10 s and 7.5 m.

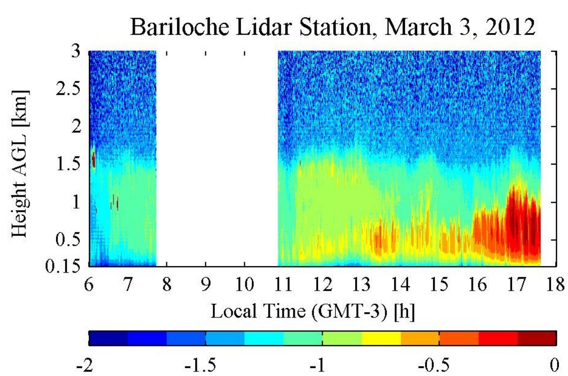

Figure 4. Lidar backscatter profiles at 1064 nm (6 s averaging time, 7.5 m spatial resolution) with volcanic ashes on March 3.

This aerosol layer had low but persistent AOT values during the day. After 13 h an important amount of aerosols arrived to the region increasing the optical thickness of this layer as seen in the 500 nm sunphotometer channel on figure 5. It is important to notice that the AOT increased 10 times its value from 0.04 to 0.4.

Even if this measurement just reached level 1.0 in AERONET database, this is probably due to a calibration problem on several wavelengths. However 500 nm line presented consistent values in time from the installation time up to date.

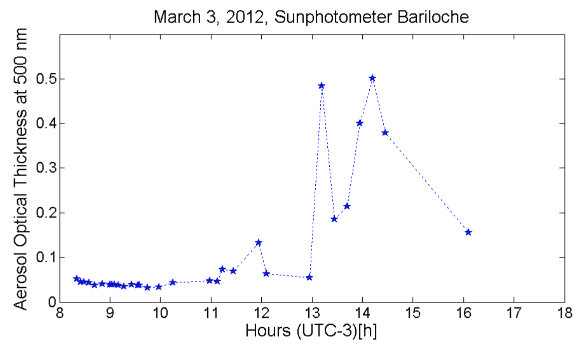

Figure 5. Aerosol Optical Thickness evolution for March 3 of 2012.

The lidar shows at this time an air mass arriving first from very low altitudes and then rising inside the previous aerosol layer.

This kind of episodes in which an important amount of volcanic ashes is lifted from the ground and is transported horizontally for several kilometers following specific corridors is quite frequent in Bariloche. One of the most important reasons is the high amount of dust deposited on the ground and the importance of thermal winds in the region. These episodes have a completely different nature that the previous ones studied by our division [2, 3]. It must be noticed that these cases are of special danger for aviation since they reduce very fast ground visibility, increases the low level aerosol load and also generates ground deposition over the airport runway.

4. SUMMARY AND FUTURE PERSPECTIVES

A lidar system constructed by the Lidar Division of CEILAP was installed in Bariloche International Airport and began to operate on February 1 of 2012. The lidar instrument is used initially to perform aerosol measurements in a semi-automatic mode controlled by the National Weather Service. The CIMEL sunphotometer data will be also used to characterize the aerosol type through AOT and Ångström Coefficient. The aerosol size distribution calculated by AERONET inversion algorithms is expected to provide more accurate information to the national weather service, airport and the airlines about the risk of flying and landing over the region. To evaluate the risk of landing at the airport a particle nephelometer was also installed.

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