

SAVER.NET LIDAR NETWORK IN SOUTHERN SOUTH AMERICA

Pablo Ristori^{1*}, Lidia Otero¹⁻⁵, Yoshitaka Jin², Boris Barja³, Atsushi Shimizu², Albane Barbero⁴,
Jacobó Salvador¹⁻⁵, Juan Lucas Bali⁵⁻⁶, Milagros Herrera⁵, Paula Etala⁴, Alejandro Acquesta⁶,
Eduardo Quel¹, Nobuo Sugimoto², Akira Mizuno⁷

¹ Lidar Division, CITEDEF and UNIDEF (MINDEF - CONICET)

*Email: pablo.ristori@gmail.com

² National Institute for Environmental Studies (NIES), Japan

³ Universidad de Magallanes (UMAG), Punta Arenas, Chile

⁴ National Weather Service, Argentina

⁵ National Scientific and Technical Research Council (CONICET), Argentina

⁶ Crisis Modelling and Management Department, CITEDEF, Argentina

⁷ Atmospheric Environment Division, Solar-Terrestrial Environment Laboratory, Nagoya University, Japan

ABSTRACT

The South American Environmental Risk Management Network (SAVER-Net) is an instrumentation network, mainly composed by lidars, to provide real-time information for atmospheric hazards and risk management purposes in South America. This lidar network have been developed since 2012 and all its sampling points are expected to be fully implemented by 2017. This paper describes the network's status and configuration, the data acquisition and processing scheme (protocols and data levels), as well as some aspects of the scientific networking in Latin American Lidar Network (LALINET). Similarly, the paper lays out future plans on the operation and integration to major international collaborative efforts.

1 INTRODUCTION

In recent years, volcanic activity in the Andes Mountain Range have impacted many countries in the world, primarily Argentina and Chile. These hazards promoted mainly two atmospheric risk management projects (Ministry of Defense – Special Project N°31554/11 and the SAVER.Net Project.). The first project focused on the development of five lidar deployable stations. The stations were supplemented with ground base instrumentation to monitor atmospheric aerosols and gas constituents (SO₂, BrO, N₂O, O₃, HCHO, H₂O, by means of MAX-DOAS), solar radiation and meteorological variables. The main goal is the detection of suspended volcanic ash. For this purpose, stations have been strategically distributed across latitudes covering from

Patagonia 51°37'S in the South to the central Argentinean region in Buenos Aires from 31°33'S as the northern boundary.

The second project is funded by the government of Japan and provides support for development and assistance to third countries based on a joint funding provided by: Japan International Collaboration Agency (JICA) and the Japan Science and Technology Agency (JST). This support created a Science and Technology Research Partnership for Sustainable Development (SATREPS) to address global issues with practical benefits on both local and global society. The overarching objective of SAVER.Net is to develop an atmospheric hazard and risk management system in Southern South America; focused on aerosol detection and identification as well as monitoring of stratospheric ozone ultraviolet (UV) radiation levels.

This multinational support for science and technological development geared joint efforts between participating institutions: CITEDEF, NIES, UMAG, SMN and the Chilean Meteorological Service (DMC). A common goal across organizations is to use lidar data for providing risk management information.

2 Hardware description

The Lidar Division at CITEDEF installed the instrumentation on the stations, developing and constructing the lidars on standard 20 ft. containers. These containers are equipped with open hatches at the rooftop, two air conditioning systems, a local area network and electricity

connectivity. The roof on each container offers future expansion possibilities for installing additional instrumentation. The container includes office space since the lidar fills out one half of the container divided from the other half by a door.

The lidar network has nine instruments in total from which eight of them can measure depolarization at 532 nm and 355 nm; and one of them contains a telescope fiber-coupled to the spectroscopic box. Four of these instruments are prepared to measure inelastic Raman backscattering returns. And, two of them have high spectral resolution capabilities (HSRL) following the emission and detection scheme described by [1]. Table 1 shows the measurement capabilities.

Table 1 SAVER.Net and PE31554/11 Lidar Receiver and detection channels: p and s are parallel and perpendicular polarization; h is for High Spectral Resolution

Site / λ [nm]	355	387	408	532	607	1064
Bariloche	yes	yes	yes	yes	yes	yes
Aeroparque	p, s	no	no	p, s	no	yes
Cdo. Rivadavia	p, s	no	no	p, s	no	yes
Neuquén	p, s	no	no	p, s	no	yes
Río Gallegos	p, s	no	no	p, s	no	yes
Tucumán	p, s	no	no	p, s	no	yes
Pta. Arenas	p, s	yes	yes	p, s, h	yes	yes
Pilar-Córdoba	p, s	yes	yes	p, s, h	yes	yes
Villa Martelli	p, s	yes	yes	p, s, h	yes	yes

The Lidar emission sub-system in all cases is a Nd:YAG laser (at 1064 nm) doubled (at 532 nm) and tripled (at 355 nm). HSRL Lidars and the one installed in Punta Arenas are based on Continuum Surelite II – 10 Hz lasers. However, the lidar in the Bariloche site is based on a Quantel Brilliant B 20 Hz laser and the remaining of them are all based on Continuum Surelite I – 30 Hz lasers. See Table 2 for details on laser model, repetition rate and energy per pulse at 1064 nm.

Table 2 SAVER.Net and PE31554/11 Lasers: Quant. Stands for “Quantel”, Cont., for “Continuum”, and the Energy rating is for the fundamental wavelength

	Laser	Rep.rate	Energy
Bariloche	Quant. Brilliant B	20 Hz	360 mJ
Aeroparque	Cont. Surelite I	30 Hz	380 mJ
Comodoro. Rivadavia	Cont. Surelite I	30 Hz	380 mJ

Neuquén	Cont. Surelite I	30 Hz	380 mJ
Río Gallegos	Cont. Surelite I	30 Hz	380 mJ
Tucumán	Cont. Surelite I	30 Hz	380 mJ
Punta Arenas	Cont. Surelite II	10 Hz	675 mJ
Pilar-Córdoba	Cont. Surelite II	10 Hz	675 mJ
Villa Martelli	Cont. Surelite II	10 Hz	675 mJ

Figure 1 shows the lidar system installed in Punta Arenas, Chile (see Table 1).



Figure 1 Lidar system. Top shelf is the laser emitter, left side is the telescope receiver and first shelf is the detection and acquisition system.

The lidar receiver unit has a 200mm $f/5$ Newtonian telescope connected to spectroscopic box except at Bariloche station where the telescope is 200mm $f/10$ Cassegrain.

The detection units have Hamamatsu H10721 photomultiplier modules optimized for UV (-110) and for visible detection (-20). Infrared detection is done using Licel detector modules based on a 3mm effective area APD Si Detector thermoelectrically cooled. Transient recorders with split analog and photocurrent detection acquires backscatter signals. The analog inputs record the signals for all the elastic channels, except the depolarization channel at 355 nm. In this case, the signal is acquired in photon counting mode.

Lidars that are only elastic can be easily upgraded to include nighttime Raman detection in photon counting mode.

3 LIDAR OPERATION DESCRIPTION

The lidars were prepared to operate continuously under all weather conditions in the span of climate conditions from northern Argentina to sub Antarctic regions. Except the HRSLs that measure continuously, the other systems measure every 15 minutes during at least one-minute integrating profiles every 10 seconds (300 shots). This operation mode extends the flash lamp lifetime to one year for the lidar emission sub-system, with the exception of HSRL which requires six flash lamps per year due to their continuous operation.

The Lidar instruments are intended for continuous mode operation but also for intensive observing mode when specific hazardous events occur and then continuous profiling is required. This versatility allows for complementary operations of atmospheric modeling since datasets and level process data can be accessed remotely. Each lidar upload the data to a remote SFTP server every 15 minutes to assure almost real time transfer.

A web server manages and centralize the data through an interactive portal where quick-looks are refreshed illustrating backscattering profiles and lidar retrieved aerosol parameters. The actual quick looks and NetCDF profiles are processed at NIES and have the same format as AD-Net profiles. The online data processing algorithms are described in [2].

4 LIDAR OPERATION SITES

The lidar site location followed several criteria. Some of them are:

- The operation of the lidar should be performed by members of the SAVER.Net Project (in this case CITEDEF, SMN, UMAG)
- The site location should be as close as possible to main airports.
- The chosen region for installation should contribute improved knowledge on aerosol's optical and microphysical properties as well as their spatial distribution.
- The lidar network contours the Andean volcanic belt of Argentina and Chile in Patagonia where several active volcanoes can be found.

Detailed location of the lidar sites can be seen on Table 3 and figure 2

Table 3 SAVER.Net and SP 31554/11: Operation sites

Lidar Station	Latitude	Longitude
Bariloche	41° 08' 50"S	71° 9' 51"W
Aeroparque	34° 33' 51"S	58°25' 02"W
Cdo. Rivadavia	45° 47' 32"S	67°27' 46"W
Neuquén	38° 57' 08"S	68° 08' 13"W
Río Gallegos	51° 36' 42"S	69° 18' 26"W
Tucumán	26° 47' 14"S	65° 12' 25"W
Pta. Arenas	53° 08' 04"S	70° 52' 49"W
Pilar-Córdoba	31° 40' 03"S	63° 52' 58"W
Villa Martelli	34° 33' 21"S	58° 30' 23"W

With the exception of CEILAP at CITEDEF Villa Martelli (Argentina) and Punta Arenas (Chile), the sites are collocated to radiosondes launches on SMN sites.



Figure 2 Lidar operation sites. To complete the network, Córdoba and Tucumán will be installed on the first quarter of 2017

5 DATA ANALYSIS

One of the main goals of SAVER.Net is to provide operational aerosol information supporting governmental agencies operations for hazards and risk analysis and prevention. For research purposes, lidar datasets are combined to other instrumental datasets (e.g. co-located sun-photometers, radiometers and meteorological stations).

The algorithms to provide lidar information were originally written in MatLab and IDL. Recently, the entire processing platform was upgraded to Python as single open source language to ensure wide distribution and sharing process. The

algorithms will deliver in pseudo-real time dynamic structures like atmospheric boundary layer and cloud height and aerosol layers. They will also differentiate spherical from non-spherical backscatters.

In terms of retrieval of aerosol concentration, the network will implement those known and current available inversion methodologies [3-8] that can provide an operative solution in pseudo-real time.

By project ends in March 2018 the groups involved in the network will develop a web based platform to distribute datasets and products tailored to risk managers, governmental agencies involved in hazard mitigation and risk assessment [9].

6 LIDAR OPERATION, TRAINING, AND MAINTENANCE

The instruments are designed to measure continuously but the operator should be ready to deal with shutting down (e.g., to prevent damage due to hail or strong storm) and similarly to restarting the system (e.g., after a blackout lasting longer than the UPS capacity) when necessary. Instruments may also require optical realignment and signal optimization as well as basic maintenance. For this reason, researchers involved leading the lidar development have started training local lidar operators so that after installing and repairing; realigning and other simple routinely measures can be developed by on-site operators.. Furthermore, short courses on lidar signal processing are being prepared to train operators, forecasters and managers on demand of high level data product. Training courses are continuously evolving and improving to cover the majority of data-network users. Recent efforts between the lidar division at CEILAP-CITEDEF and the SMN have focused on preparing distance learning courses in specific topics of SMN interest. Finally, an operation handbook is being prepared for basic on-site operation and maintenance rules and procedures.

7 CONCLUSIONS AND PERSPECTIVES

Currently seven of nine lidars of the SAVER.Net are operating across different regions of Argentina and Chile. By March 2017 it is expected to have the last two lidars installed on their final locations. This final milestone will fulfill an unprecedented

effort to provide a fully operational monitoring network from which several governmental agencies will benefit. After network completion analysis of lidar datasets will be implemented for aerosols transport from local and regional transport events in Argentina and Chile. This way SAVER.Net will contribute and integrate LALINET and other international efforts.

ACKNOWLEDGEMENTS

The researchers would like to acknowledge the support of the National Weather Service Lidar Operators, the Japan Science and Technology Agency (JST) / Japan International Cooperation Agency (JICA), the Science and Technology Research Partnership for Sustainable Development (SATREPS), CITEDEF and the Ministry of Defense of Argentina. The authors would like to thank the collaboration of Yuji Misu, Francisco González, Juan Carlos Dwornickzak, Osvaldo Vilar, Marcelo Ferrari, Rodrigo Videla, Mario Proyetti, Sebastián Papandrea, Guillermo Acosta, Fernando Chouza, Andrea Pereyra, Evangelina Martorella, Raúl D'Elía, Jorge Codnia, Laura Azcárate, Francisco Manzano, Claudio Libertelli, Hernán Ciminari, Carlos Pacheco, Fabián Jeric, Joaquín Miranda, Juan Carlos Condori, Marcelo Bustos, Martín Lateralra, Raúl Rodríguez, and the CITEDEF machine shop for their collaboration on the construction and update of the lidar systems and related subsystems.

REFERENCES

- [1] Z. Liu, I. Matsui, and N. Sugimoto: High-spectral-resolution lidar using an iodine absorption filter for atmospheric measurements, *Opt. Eng.*, **38**, 1999.
- [2] Shimizu A., Nishizawa T., Jin Y., Kim S-W., Batdorj D. and Sugimoto N.: Evolution of a lidar network for tropospheric aerosol detection in East Asia. *Opt. Eng.*, **56(3)**, 31219-1-12, 2017
- [3] Kudo R., Nishizawa T. and Aoyagi T: Vertical profiles of aerosol optical properties and the solar heating rate estimated by combining sky radiometer and lidar measurements, *AMT*, **9(7)**, 3223-3243, 2016.

- [4] Lopatin A: Enhanced Remote Sensing of atmospheric aerosol by joint inversion of active and passive remote sensing observations, PhD thesis.
- [5] J. Wagner, A. Ansmann, U. Wandinger , P. Seifert , A. Schwarz , M. Tesche ,A. Chaikovsky , and O. Dubovik: Evaluation of the Lidar/Radiometer Inversion Code (LIRIC) to determine microphysical properties of volcanic and desert dust, *AMT*, **6(7)**, 1707-1724, 2013.
- [6] Ansmann A., Seifert P., Tesche M. and Wandinger U.: Profiling of fine and coarse particle mass: case studies of Saharan dust and Eyjafjallajökull/Grimsvötn volcanic plumes, *Atm. Chem. Phys.* , **12(20)**, 9399-9415, 2012
- [7] Ristori, P., L. Otero, J. Fochesatto, P.H. Flamant, E. Wolfram, E. Quel, R. Piacentini, and B. Holben. 2003: “Wavelength Dependence and Variability of Atmospheric Aerosols in the Buenos Aires area using Sun Photometer Measurements”, *Optics and Laser in Engineering*, **40**, 91-104.
- [8] Otero, L., P. Ristori, G. J. Fochesatto, E. Wolfram, J. Porteneuve, P.H. Flamant, and E. Quel. “First Aerosol Measurements with a Multiwavelength Lidar System at Buenos Aires, Argentina”. 2004: Peer reviewed articles presented at the *22nd International Laser Radar Conference*, Matera, Italia, ESA SP561, Vol. II, ISBN 92-9092, ISSN 0379-6566, 769-772.
- [9] Webley P., D. Atkinson, R. Collins, K. Dean, G. J. Fochesatto, K. Sassen, C. Cahill, C. Flynn and K. Mazutani. 2008: “Predicting and Validating the tracking of a volcanic ash cloud during the 2006 eruption of Mt. Augustine Volcano”. *Bull. Amer. Meteor. Soc.* 1647-1658.