FIRST RESULTS OF CIRRUS CLOUDS PROPERTIES BY MEANS OF A POLLY^{XT} RAMAN LIDAR AT TWO MEASUREMENT SITES

Kalliopi – Artemis Voudouri[1], Elina Giannakaki[2,3], Mika Komppula[2] and Dimitris Balis[1]

[1]Laboratory of Atmospheric Physics, Physics Department, Aristotle University of Thessaloniki, Greece
kavoudou@auth.gr
[2]Finnish Meteorological Institute, P.O.Box 1627, FI-70211, Kuopio, Finland
[3]Department of Environmental Physics and Meteorology, Faculty of Physics, University of Athens, Greece

ABSTRACT

Geometrical and optical characteristics of cirrus clouds using Raman lidar Polly^{XT} measurements at different locations are presented. The Polly^{XT} has been participated in two long-term experimental campaigns, one close to New Delhi in India and one at Elandsfontein in South Africa, providing continuous measurements and covering a wide range of cloud types. First results of cirrus cloud properties at different latitudes, as well as their temporal distributions are presented in this study. An automatic cirrus clouds detection algorithm is applied based on the wavelet covariance transform. The measurements at New Delhi performed from March 2008 to February 2009, while at Elandsfontein measurements were performed from December 2009 to January 2011.

1 INTRODUCTION

Cirrus clouds that are classified as high clouds have been characterized as having a significant double role in the Earth's climate system, by cooling or heating the Earth [1]. Thus systematic monitoring and detailed characterization of their geometrical and optical properties at different geographical locations is important in global climate analysis.

Active remote sensing as lidar instruments are a useful tool for providing measurements of vertical distribution of the optical properties of cirrus clouds. The most obvious advantage of lidar in cloud research is the opportunity of continuously monitoring of the cloud evolution and the high spatial resolution. Elastic backscatter and Raman lidars have been used for the retrieval of the geometrical and the optical properties of cirrus clouds already mentioned in literature [2]. From the reflected and transmitted polarized components of the backscattered light the profile of the depolarization ratio can be obtained as well, providing significant information about the sphericity of the retrieved particles and thus their liquid or solid phase. However, measurements can be restricted to those days with the presence of low clouds and rain.

Long term studies of cirrus clouds and comparisons between different measurement sites are limited. The aim of this work is to present lidar derived statistical results on geometrical and optical properties of cirrus clouds in two subtropical areas, estimating their dependence on geographical locations.

2 METHODOLOGY

The processing of the measurements and the detection of cirrus clouds geometrical boundaries was made by an automatic algorithm. This algorithm is based on a wavelet covariance transform (WCT) that is used to detect discontinuities in lidar signal as the base and the top of the cloud, with respect to the signal to noise ratio. This method is based on seeking high correlation between lidar signal and the Haar wavelet [3]. The WCT is performed to the range corrected signal, after subtracting the zero and the background measurement and after normalization with a maximum value below 1km. The normalization guarantees the applicability of the method at all atmospheric conditions. The dilation was chosen to be 225m, proportional to the cloud geometry. A threshold of -0.1 was used as a detection value [3]. The base of the cloud is defined one height bin below the altitude at which the wavelet is lower than the chosen threshold and the top is defined in the upper symmetric area.

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Lidar profiles were checked before analyzed based on signal to noise ratio, specifically SNR was chosen to be greater than 2 for the cirrus detection.

Once the cirrus boundaries are detected, the cloud optical depth can be determined by integrating the particle extinction coefficient within the cloud boundaries. The effect of multiple scattering which is a function of the cloud height, the receiver field of view (FoV), the size and shapes of ice-crystals [4] will also be calculated in next steps of our analysis.

The WCT derived profile on 25th of February 2010 at Elandsfontein station is presented. The cloud base was calculated at 7.15km from the raw signal, while the base identified by WCT method was 7.03km. The cloud boundaries identified by WCT method is in good agreement with the cloud boundaries observed by the range corrected signal at 1064nm as shown in Fig.1 (left).

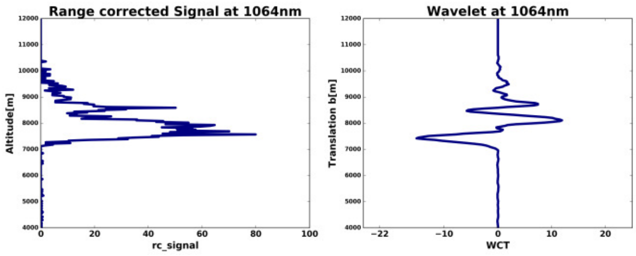

Figure 1: (left) Normalized range-corrected lidar signal at channel 1064nm and (right) resulting covariance transform as a function of translation b at dilation a=225 m. The specific WCT profile feature is used to identify cloud layers.

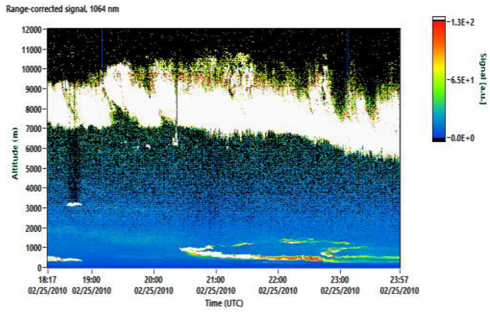

Figure 2: Range corrected backscatter signal at 1064nm observed with Polly^{XT} on 25th of February 2010 at Elandsfontein station.

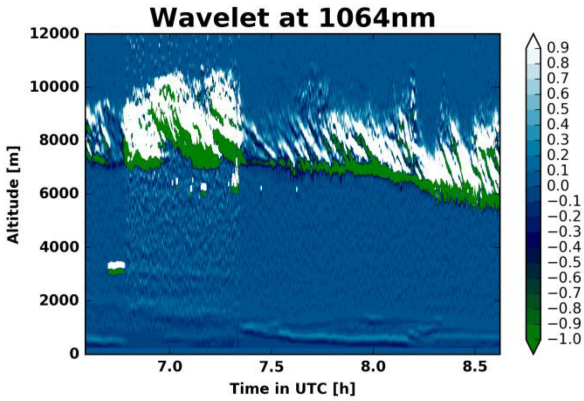

Figure 3: Cirrus cloud evolution as determined from the Polly^{XT} observations by applying the WTC on 25th of February 2010 at Elandsfontein station.

3 LIDAR SYSTEM AND MEASUREMENT SITE

The transportable Raman lidar Polly^{XT} supplied by the Finnish Meteorological Institute (FMI) has been operated to perform continuous measurements of different kind of clouds.

Full description of the system is provided in literature [5] and [6]. Polly^{XT} is equipped with a Nd:YAG laser emitting at 1064nm, which after doubling and tripling the frequency, emits at the wavelengths of 532 and 355nm respectively. The vertical resolution of the signal profiles is 30m and all measurements are available online at http://polly.tropos.de. The system was operating automatic and almost full time during the period 2008-2011.

The Polly^{XT} has participated in two campaigns in different sites over the word, within the framework of the EUCAARI project [7], covering a wide range of clouds. Measurements have been performed in Gual Pahari (28°260N, 77°090E, 243 m a.s.l) in India from March 2008 to March 2009, and in Elandsfontein (26°15´S, 29°26´E, 1745 m a.s.l) about 150km from Johannesburg in South Africa from December 2009 to January 2011. The experimental sites of different latitudes provide a better analysis of the different cirrus properties. In this study only nighttime data are considered.

4 RESULTS

During the period March 2008 to January 2011 65 night-time measurements of cirrus clouds were performed and analyzed. Only night-time data were analyzed in order to retrieve the optical properties with Raman method. The occurrence of cirrus clouds is about 16% of the total observation (only nighttime measurements were consider) and cirrus are located between 8km and 11km height typically. Missing data are attributed to low SNR. The geometrical parameters analyzed were obtained as mean values for the cloud. Fig. 4 presents an overview of the cirrus measurements during the analyzed period. As it can be seen no seasonal pattern, can be concluded.

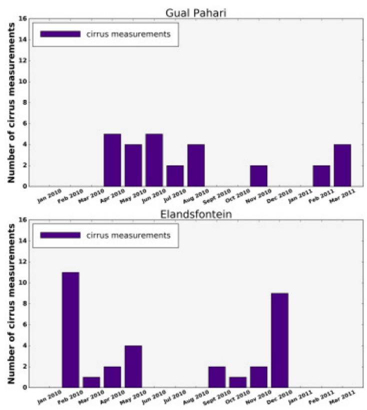

Figure 4: Occurrence of the measured cirrus clouds over Gual Pahari during the period 2008-2009 (left) and Elandsfontein during the period 2009-2010(right).

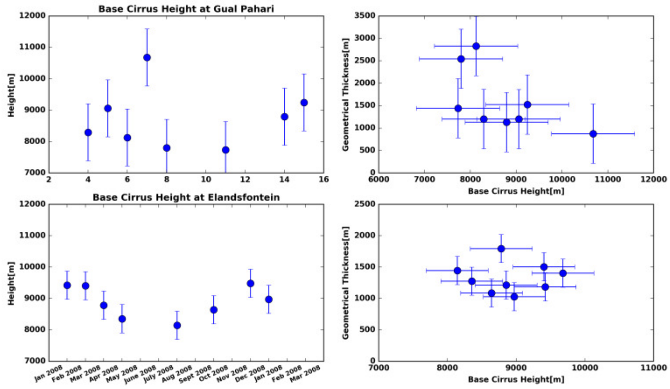

Figure 5: Variations of monthly mean base altitudes of Cirrus clouds at the two measurement sites (right). Dependence of cirrus cloud thickness on altitude cirrus base (left). The standard deviation from the mean value is also presented.

Fig. 5 presents the defined monthly cirrus base and its correlation with the cirrus thickness. Base heights showed a broad (7.5-11km) distribution. Results indicate that geometrical thickness spreads from 0.8 to 3km, with an average value of 1.5km. Results derived from other studies show that mean thickness can vary at different latitudes. In Thessaloniki, Greece, cloud thickness range from 1 to 5 km with mean value of 2.7 ±0.9 km [8], while in China, calculated thickness confined to a range of 0.8–4 km [9]. The dependence of cirrus cloud thickness on the altitude cirrus base is also presented in Fig. 5, showing greater variation for lower cirrus base at Gual Pahari. The geometrical thickness of cirrus clouds depends on the formation mechanism, the cloud altitude and the cloud temperature and should be further examined. Mean values of cirrus base and geometrical thickness are presented in Table 1.

Table 1: Mean values and standard deviation of cirrus base and thickness for Gual Pahari and Elandsfontein.

	Gual Pahari (28°26N, 77°09E)	Elandsfontein (26°15´S, 29°26´E)
Base, km	*8.7±0.9*	*8.9±0.45*
Thickness, km	*1.6±0.6*	*1.3±0.2*

5 CONCLUSIONS

Lidar derived data at two different latitude experimental sites (Gual Pahari and Elandsfontein) were processed in order to evaluate the geometrical and optical properties of cirrus clouds. An automated cloud detection algorithm was applied to determine the cloud base and top height and the cloud thickness and showed a good efficiency in detecting clouds. Cirrus clouds were detected at 16% of the nighttime measurements that were analyzed with an average mid-cloud height of 8.5km. Similar geometrical mean values were derived for both subtropical areas, while properties showed greater distribution at Gual Pahari. The dependency of cirrus clouds thickness on temperature will be further examined.

Optical properties of cirrus clouds i.e. backscatter and extinction coefficient profiles and depolarization ratio will be retrieved in next steps of our research.

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References

[1] Liou K.N., 1986: The influence of Cirrus on Weather and Climate Process: a Global Perspective, *Monthly Weather Review*, **114**, pp.1167-1199

[2] Ansmann, A., Wandinger U., Riebesell M., Weitkamp C., Michaelis W., 1992:Independent measurement of extinction and backscatter profiles in cirrus clouds by using a combined Raman elastic backscatter lidar, *Appl. Opt.*, **31**, 7113–7131

[3] Baars H., Ansmann A., Engelmann R., Althausen D., 2008: Continuous monitoring of the boundary-layer top with lidar, *Atmos. Chem. Phys.*,**8**, 7281-7296

[4] Eloranta, E., 1998: Practical model for the calculation of multiply scattered lidar returns, *Appl. Opt.*, ***37***, 2464–2472, doi:10.1364/ao.37.002464.

[5] Althausen D., Engelmann R., Baars H., Heese B., Ansmann A., Muller D., Komppula M., 2009: Portable Raman lidar PollyXT for automated profiling of aerosol backscatter, extinction, and depolarization. *J.Atmos Ocean Tech* **26**:2366-2378. Doi10.1175/2009JTECHA1304.1

[6] Engelmann R., Kanitz T., Baars H., Heese B., Althausen D., Skupin A., Wandinger U., Komppula M., Stachlewska IS, Amiridis V., Marinou E., Mattis I., Linne H., Ansmann A., 2015: EARLINET Raman lidar PollyXT: the next generation. Atmos Meas Tech Discuss **8**:7737-7780. doi10.5194/amtd-8-7737-2015

[7] Kulmala, M., Asmi, A.,Lappalainen, H.K., et al.: General overview: European Integrated project on Aerosol Cloud Climate and Air Quality interaction (EUCAARI) – integrating aerosol research from nano to global scales, 2011: *Atmos. Chem. Phys.*, **11**, 13061-13143, doi:10.5194/acp-11-13061-2011

[8] Giannakaki, E., Balis, D.S., Amiridis, V., Kazadzis, S., 2007. Optical and geometrical characteristics of cirrus clouds over a Southern European lidar station. *Atmos. Chem. Phys.* **7**, 5519–5530.

[9] Wang, Jin, Zhang, Lei, Huang, Jianping, Cao, Xianjie, Liu, Ruijin, Zhou, Bi, Wang, Hongbin, 2013. Macrophysical and optical properties of mid-latitude cirrus clouds over a semi-arid area observed by micro-pulse lidar. *J. Quant. Spectrosc. Radiat. Transf.* **122**, 3–12.