An approach for characterizing Aerosol-Cloud Interaction by elastic lidar

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INTRODUCTION

Aerosol-Cloud interactions (ACIs) are one of the most important phenomena in atmospheric science and, however, they are still very poorly understood (IPCC, 2013), due to both the intrinsic complexity of the involved atmospheric components and instrumental limitations. Lidar systems, unlike many other instruments, enable temporal and vertical coincidence of cloud and aerosol measurements. This work presents a preliminary attempt to study aerosol-cloud interactions by means of a multi-wavelength elastic lidar, placed in Granada, Spain (37.16°N, 3.61°W, 680 asl), focusing on the characterization of ACIs as a function of the relative distance between aerosol and cloud layers. The study was conducted separately using two distinct wavelengths.

INSTRUMENTATION

GRANADA:

- Medium-size city in south-eastern Spain.
- Population: 300 000 inhabitants
- 50 km away from the Mediterranean basin and 200 km away from the African continent (Saharan desert)
- Main aerosol types: mineral dust, anthropogenic pollution and biomass burning

Lidar LR331D400 (Raymetrics):

- Radiation source Nd:YAG laser
- Emission: 355, 532, 1064 nm
- Cassegrain-desing telescope
- Pulse repetition: 10 Hz
- Detection used here: 532, 1064 nm
- EARLINET system since April 2005

METHODOLOGY

- Aerosol first indirect effect: change in the observed cloud optical and microphysical properties (optical depth, albedo, cloud droplet effective radius, …) as a function of the change in the aerosol load
- Integrated backscatter (IB): alternative optical property of the aerosol or cloud optical depth easily obtained from elastic lidar signals informing on the load of aerosol or cloud particles in the atmosphere:

$$IB_{part/cloud} = \int_{R1}^{R2} \beta_{part/cloud}(\mathrm{R})\,\mathrm{dR}$$

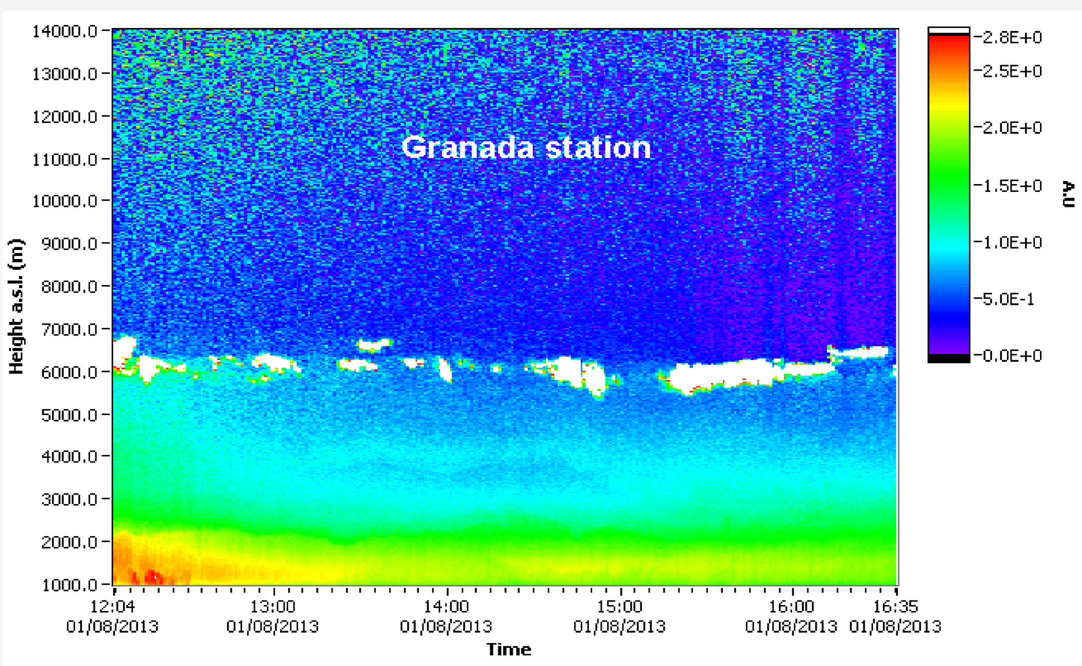
  where β is the elastic backscatter coefficient, and R1 and R2 respectively the lower and upper limit of cloud or aerosol layer
- Aerosol-cloud interaction (ACI): quantified by a relation between two proxies. Various forms are found in literature (e.g. Feingold et al., 2001; McComiskey et al., 2009; Lihavainen et al., 2010). From elastic lidar measurements, ACI index can be calculated as:

$$ACI_{index} = \frac{\partial LnIB_{cloud}}{\partial LnIB_{part}}$$

- interaction distance (*d*): vertical distance between the cloud base and the top of the underlying aerosol layer

RESULTS

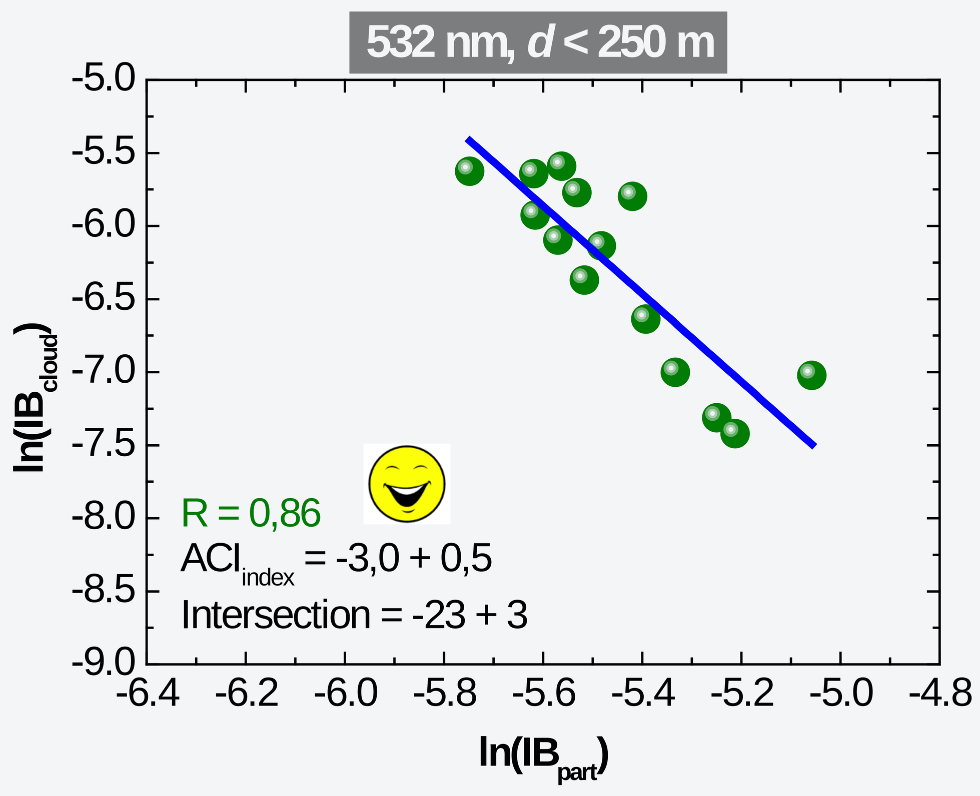
- Granada database recorded (Feb. 2007 - May 2014) according to EARLINET protocol, aiming at characterizing aerosol only, regardless of cloud properties
- Cases fulfilling the requirements (aerosol+cloud) = very small portion of the database
- Lidar signal averaged over 10 mins
- Out of 520 backscatter profiles meeting the requirements, only 35 (7%) could be used as most data failed during processing to generate valid lidar profiles. In the remaining cases, laser beam could not penetrate clouds resulting in very noisy profiles about clouds, disabling the use of the Klett-Fernald method
- Valid data split into two distance categories: *d*<=250 m and *d*>250 m
- All profiles correspond to days with predominant mineral dust aerosol, with influence of anthropogenic pollution

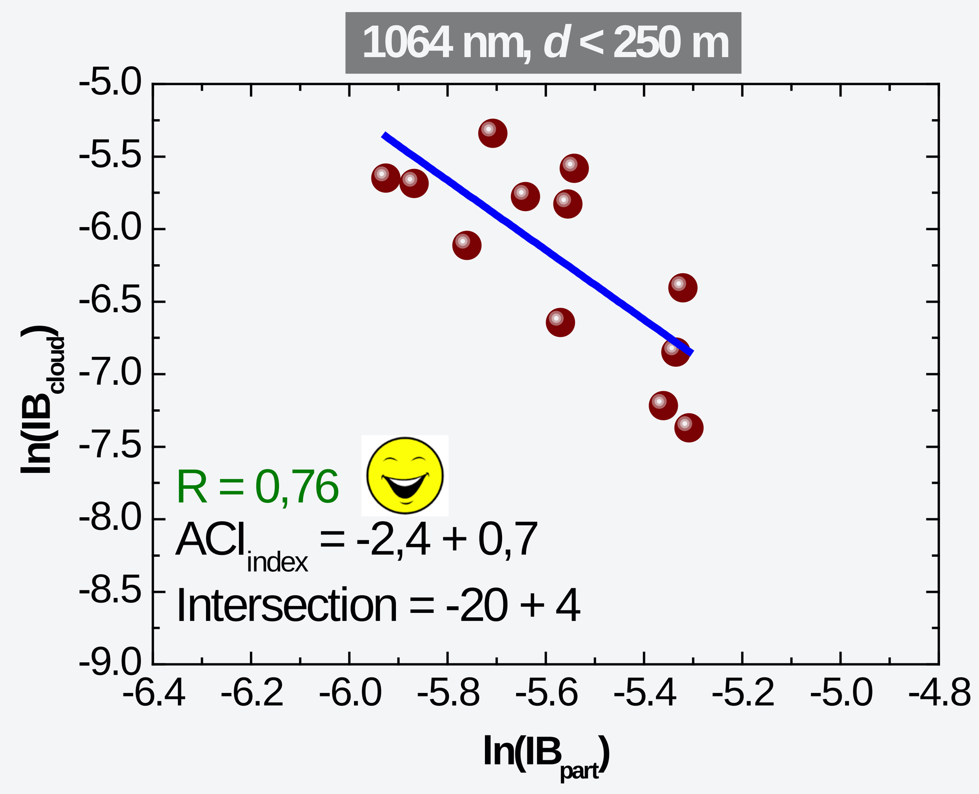


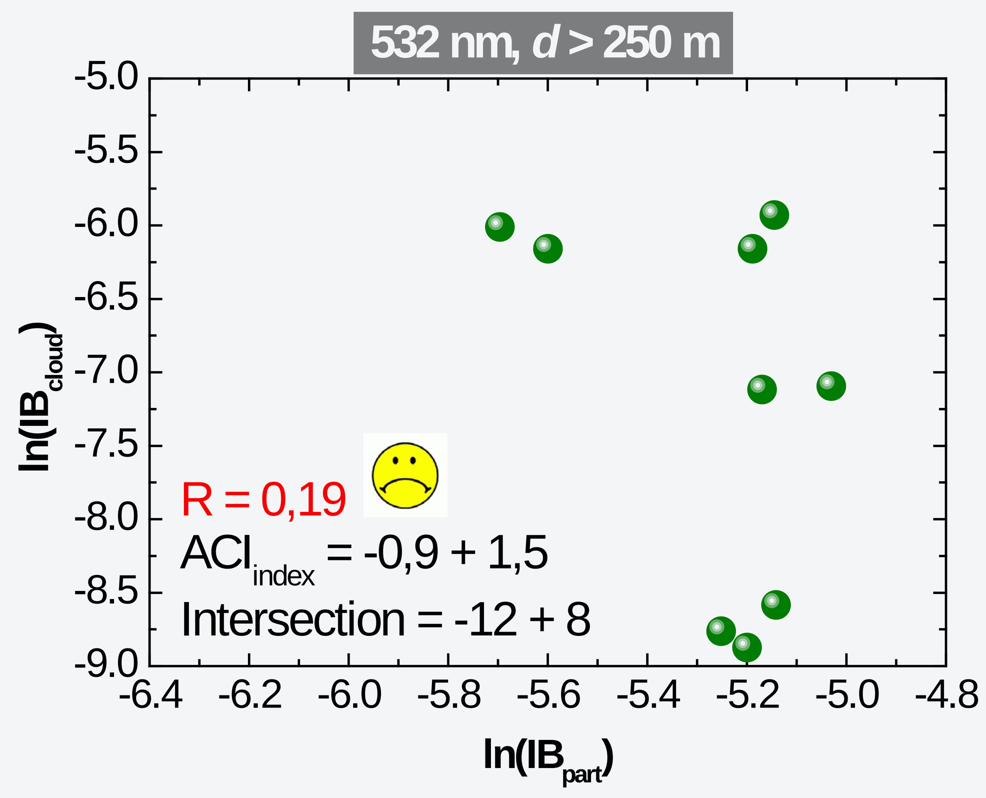
Example of a time series of the range corrected signal at 532 nm used in the study

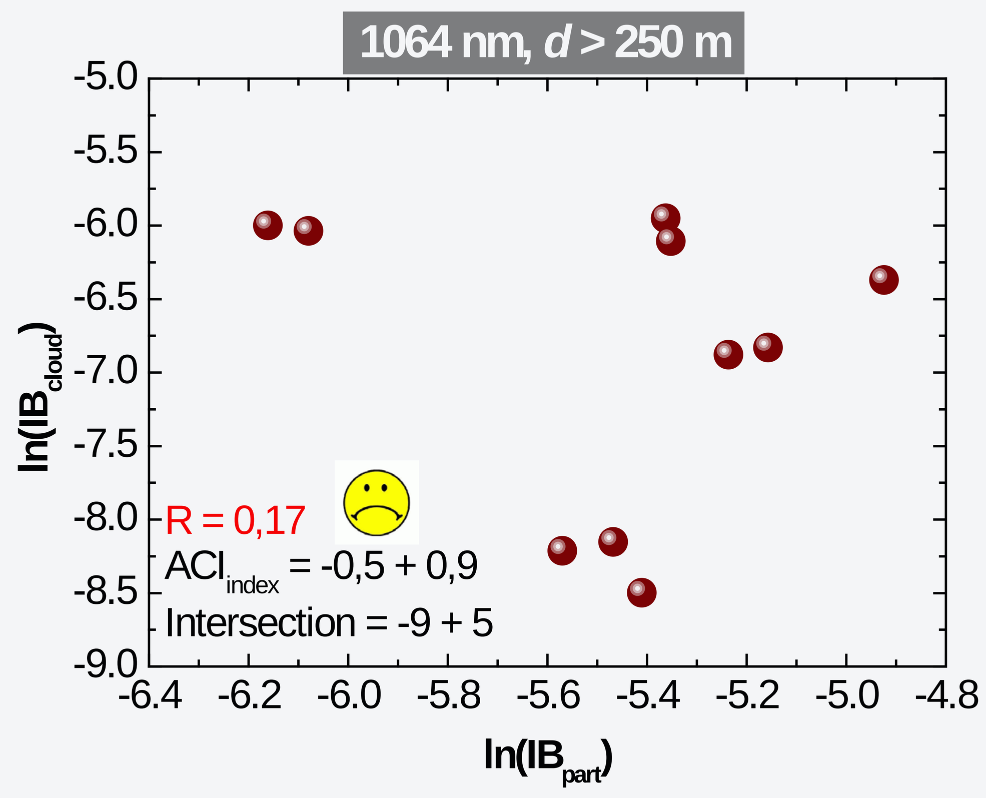
- Cases used:

Date	Time UTC	Predominant aerosol type	AERONET daily data
July 7, 2012	14.30-14.40	Mineral dust	$AE_{440-870}$ = 0.24 ± 0.05 FMF = 0.22 ± 0.02
August 1, 2013	12.20-15.20	Mineral dust	$AE_{440-870}$ = 0.31 ± 0.04 FMF = 0.26 ± 0.02
August 5, 2013	12.40-12.50	Mineral dust	$AE_{440-870}$ = 0.36 ± 0.05 FMF = 0.28 ± 0.02









Correlation between IB_{cloud} and IB_{part}: less data scatter for the smaller *d* . ACI is high at small *d*, and weak at large *d*.

Due to the lack of more *d* categories it can not to be excluded that some interaction remains even when the layers are not totally coupled.

Difference between the two channels: ACI is more noticeable at 532 nm (R=0.86, ACI=-3.0 ± 0.5) than at 1064 nm (R=0.76, ACI=-2.4 ± 0.7) Since the days used were influenced by anthropogenic pollutants, this could be explained by the spectral dependency of aerosol backscattering.

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CONCLUSIONS

- First attempt to study aerosol-cloud interactions by using elastic lidar over Granada
- As expected, the interaction is higher at small interaction distances
- Noticeable difference between the 532 and 1064 nm channel at highlighting ACI. Behavior expected to be stronger when dealing with more spectrally dependant aerosols.
- In order to improve our understanding on aerosol-cloud interactions, more intervals of *d*, and hence, more profiles are required. Most lidar database are recorded with the only purpose of studying the aerosol, without consideration of cloud properties, which renders the data less useful in ACI studies. To pave the way for a more comprehensive understanding of ACI, it is needed to implement a new measurement protocol specially aimed at the study of aerosol-cloud interactions.
- Future work: to incorporate Micro Wave Radiometer information to derive cloud effective radius. ACI will be derived from the relationship between cloud effective radius and aerosol integrated backscatter

ACKNOWLEDGEMENTS: This work was supported by the University of Granada through the contract "Plan Propio. Programa 9. Convocatoria 2013"; by the Andalusian Regional Government through projects P10-RNM-6299 and P12-RNM-2409; by the Spanish Ministry of Economy and Competitiveness through projects CGL2010-18782 and CGL2013-45410-R; and by EU through ACTRIS project (EU INFRA-2010-1.1.16-262254).