

How Can We Use Lidar And Radar To Monitor Aerosol-Cloud Interaction?

Clouds have an important role in the climate system: their ability to scatter solar radiation and absorb/emit thermal IR radiation makes them a significant regulator of the Earth's radiation budget. According to the latest report published by the Intergovernmental Panel on Climate Change (IPCC), aerosols and their interactions with clouds continue to contribute to the largest uncertainty of the total radiative forcing estimate. The first aerosol indirect effect, or albedo effect (Twomey, 1974), has a well established underlying physical basis. Increasing amount of aerosols results in an elevated number of nuclei for cloud droplet formation, thus the concentration of cloud droplets is higher but the cloud droplet effective radius becomes smaller, which leads to a higher cloud albedo. This happens if all other parameters, mainly the amount of available liquid water, are kept constant. A broad range of strategies has been used to study the first aerosol indirect effect (e.g., McComiskey & Feingold, 2012). Some observation strategies have used remote sensing instruments at specific sites, sometimes combining them with *in situ* measurements. Others have analysed airborne data from short-lived field campaigns. Further, many approaches have focused on satellite remote sensing to examine the aerosol effect on a global scale. The wide scope of methods and scales used makes it difficult to quantitatively compare result from different studies with precision.

In this paper, we propose an alternative method of aerosol-cloud interaction observations. The main goal is to define a fast and easily applicable way of identifying cases where a change in the aerosol environment causes a change in the cloud. In this scheme we attempt to use (as far as possible) the observed signal from lidar and radar, in order to bypass the complexity and uncertainty associated with different retrieval techniques. For an aerosol proxy we propose to use the attenuated backscatter and to obtain information about changes in the cloud we use the radar reflectivity factor combined with the extinction coefficient at the cloud base. To retrieve the extinction coefficient we use a stable lidar profile inversion (Klett, 1981) with a correction for multiple-scattering effects. We perform a series of tests on the retrieved extinction in order to quantify the accuracy and precision of the obtained values. Together with radar reflectivity the extinction coefficient is used to estimate the size of cloud droplets in the lower part of the cloud only.

We expect to observe aerosol-cloud interactions when the attenuated backscatter below the cloud is increasing at the same time as the radar reflectivity factor is increasing. To make sure that the increase in the reflectivity factor is caused by an increased number of cloud droplets and not by the droplets size we have to introduce a third parameter - in this case the extinction coefficient - that will provide information about the size of particles. In case of the influence of aerosol on a cloud droplet size we expect to see a decrease in the extinction coefficient at the cloud base. A number of factors, such as meteorology or cloud drop microphysical properties, can influence changes in a cloud. For that reason we put a constraint on the liquid water path. This limitation ensures that the variability in the cloud will be primarily due to changes in microphysical properties associated with the variation in aerosols. Further, we limit the cases only to non-precipitating clouds with no drizzle present by putting a

constraint on the value of the radar reflectivity factor (we only process data if the $Z < -20\text{dBZ}$). In next step we will divide processed data into aerosol activation zones. This will be done by identifying updrafts and downdrafts close to the cloud base with the Doppler velocity.

Although this method is based on a synergy of remote sensing instruments, we use widely available systems for a quick and efficient evaluation of the aerosol influence on the cloud. The main advantages of this scheme include fast data processing and a possibility to apply this framework easily at new or existing observational sites. Moreover, this approach enables processing large time series of data and is less restrictive in cases selection than most microphysical cloud properties retrieval algorithms used to obtain cloud droplet size in previously performed studies. We plan to implement this framework over the cloud profiling sites of the ACTRIS network in Europe to enable monitoring of the aerosol-cloud interaction close to real-time. We believe that obtaining data in the same format over multiple regions will allow for more studies of this phenomena and will result in a better understanding of the interactions between aerosols and clouds.

References:

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