Analysis of aerosol hygroscopic properties by combination of lidar, microwave radiometer and radiosounding data

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Aerosol particles are a key component in the atmosphere regarding its contribution to climate change. They can affect the Earth-Atmosphere energy budget by means of direct and indirect effects. An improved knowledge about the effects of the size increase of the aerosol particles due to water uptake (hygroscopic growth) is necessary for better understanding these effects. It directly affects the scattering of radiation and also the indirect effect. There are already many in-situ studies about the hygroscopicity effects on the aerosol properties. Under ambient conditions, analysis have usually been performed using humidified nephelometers or humidified tandem differential mobility analyzers. These instruments present mainly two limitations: firstly, they are unable to provide accurate results above 85% relative humidity (RH); secondly, they modify the ambient conditions by drying the air sample and then re-exposing it to varying RH. Remote sensing systems can overcome these difficulties, e.g, by sampling the atmosphere without modifying ambient conditions. Moreover, they can also detect RH close to saturation, which is of great importance since the region between 85 and 100% RH is where particles are more affected by hygroscopic growth. The combination of aerosol backscatter (or extinction) and relative humidity profiles retrieved from remote sensing systems are the needed information to perform hygroscopic studies. For this purpose, it is necessary to detect an aerosol layer with a RH increase large enough to observe the variations in the growth factor while the same type of aerosol is present in the corresponding portion of the layer. In that sense, the detected increase in the backscatter (or extinction) would be associated with the change in aerosol size due to the water uptake but not to changes in aerosol composition.

In this study, a combination of Raman lidar, radiosounding (RS) and microwave radiometer (MWR) data over the city of Granada (37.16ºN, 3.60ºW and 680 m asl) has been used to analyse aerosol hygroscopic growth with increasing RH in the vertical profile. In order to guarantee that the same type of aerosol was present along the profile, only situations with a good mixing in the boundary layer were analysed. As a first step, a backtrajectory analysis was performed using the HYSPLIT model. Only when the origin of the air masses was independent of the altitude in the range of interest, the same type of aerosol might be present along the profile (Veselovskii et al., 2009). To confirm good mixing within the boundary layer, potential temperature (θ) and water vapour mixing ratio (*r*) profiles were obtained. Constant profiles of θ and *r* are considered as indicators of well mixed conditions within the boundary layer. Usually RH profiles are obtained from RS, however, in this analysis also a combination of lidar *r* profiles with MWR temperature profiles was used to obtain RH. The accuracy of these RH profiles was checked against RH from RS, thus the analysis of aerosol hygroscopic properties can be extended to cases when radiosoundings are not available. The hygroscopic growth factor is defined as

$$f(RH) = \frac{X_{\lambda}(RH)}{X_{\lambda}(RH_{dry})}$$

where X_{λ} represents whether the backscatter or the extinction coefficient. To obtain *f*(RH) it is necessary to combine the backscatter or extinction coefficient profiles provided by the lidar with the RH profiles. The reference RH_{dry} is usually chosen as the lowest value of the RH in the profile.

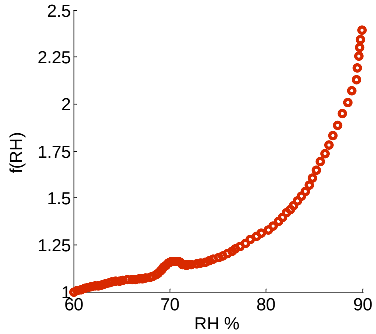

Figure 1. Hygroscopic growth factor for 22 July 2011 between 20:30 and 21:00 corresponding to a layer between 1200 and 2500 m asl. RH_{dry} = 60%.

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