Aerosol Effects on Localized Precipitation Events in Western Puerto Rico

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Abstract

Aerosols, born of either anthropogenic or natural sources serve as cloud condensation nuclei (CCN) upon which water droplets form. CCN and giant CCN (GCCN) in varying concentrations can change the properties of a cloud and ultimately delay or hasten precipitation. This research focuses primarily on data observed throughout the days of 30 May 2013 and 17 June 2013, where a localized storm produced over 50 mm of rain according to radar imagery, in Mayagüez, Puerto Rico (18.2011°N, 67.1397°W). Aerosol data attained from the University of Puerto Rico at Mayagüez (UPRM), including horizontal aerosol particle size distribution (PSD) data from Aerosol Robotic Network (AERONET) coupled with vertical ceilometer data provided a 3D picture of aerosols over the region. From this, the researcher is able to determine how aerosol size and concentration in addition to the planetary boundary layer, cloud base height, and mixing height impacts precipitation.

Dynamics and Aerosols

The dynamics of the environment can initiate precipitation by convergence of easterly trade winds with westerly sea breeze. Saharan dust is an aerosol combined with the hot air of the Saharan desert, which is carried over to the Caribbean from western Africa. The dust forms an atmospheric layer known as the Saharan Air Layer (SAL) which can have significant effects on the tropical weather of Puerto Rico. Aerosols may play an important role in precipitation development via microphysical processes which take place on the scale of the individual aerosol. These processes include condensation, collision, coalescence, and breakup.

Fig.1: Examples of natural aerosols (two left) and anthropogenic aerosols (two right). Two left: (Photographs copyright, Western Sahara Project, Jonathan Jessup) Two right: (Credit: iStockphoto/Patrick Herrera and *Air Pollution. Image Source: Top News Singapore*, respectively)

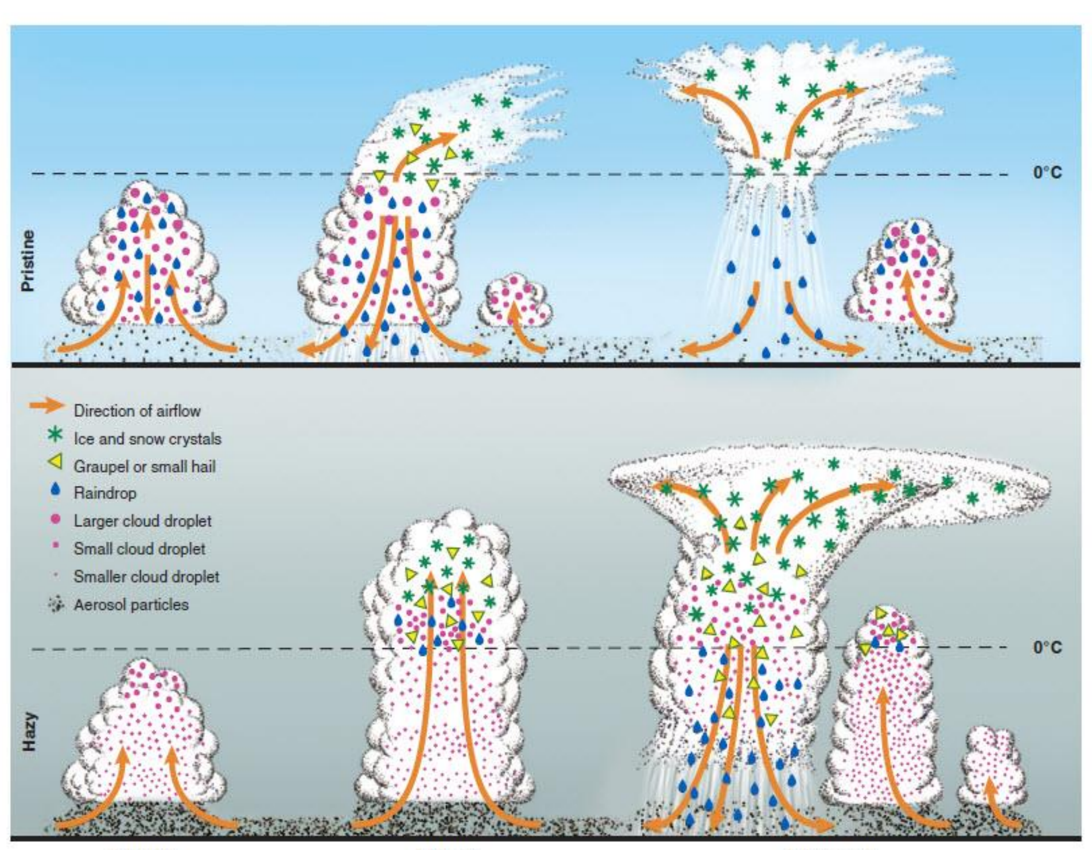

Fig. 2: Clouds and rainfall with a low concentration of particles (top) and a high concentration of particles (bottom) . GCCN in low concentration clouds tend to enhance rainfall, and CCN suppress it (Rosenfeld et al. 2008).

Hypothesis

Based on background information, we can decipher that aerosols, such as the Saharan dust, can alter the properties of a cloud and influence precipitation as a result of its size and concentration within the cloud.

AERONET and Vaisala instruments

AERONET is a network of ground-based sun photometers which measure atmospheric aerosol properties. The measurement system is a solar-powered CIMEL Electronique 318A spectral radiometer that measures sun and sky radiances at a number of fixed wavelengths within the visible and near-infrared spectrum. The Vaisala CL51 Ceilometer employs pulsed diode laser LIDAR technology. The reflection of light, backscatter caused by haze, fog, mist, virga, precipitation, and clouds is measured as the laser pulses traverse the sky.

Fig. 3: Sunphotometer (left) and ceilometer (mid and right).
Left: (From science glossary at http://mynasadata.larc.nasa.gov)
Mid and right: (From http://ece.uprm.edu/noaa-crest/ceilometer.php

Methodology

Look for localized precipitation test cases in Mayagüez

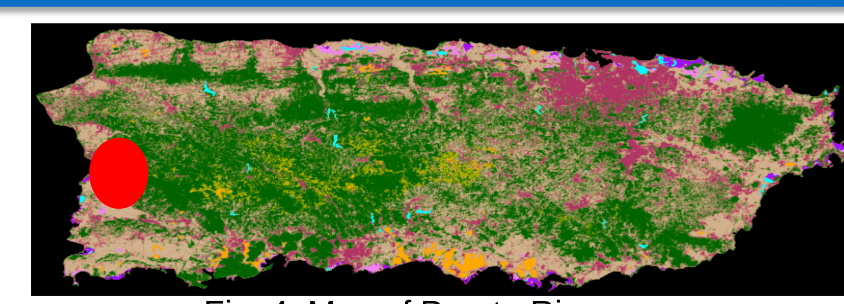

Fig. 4: Map of Puerto Rico.

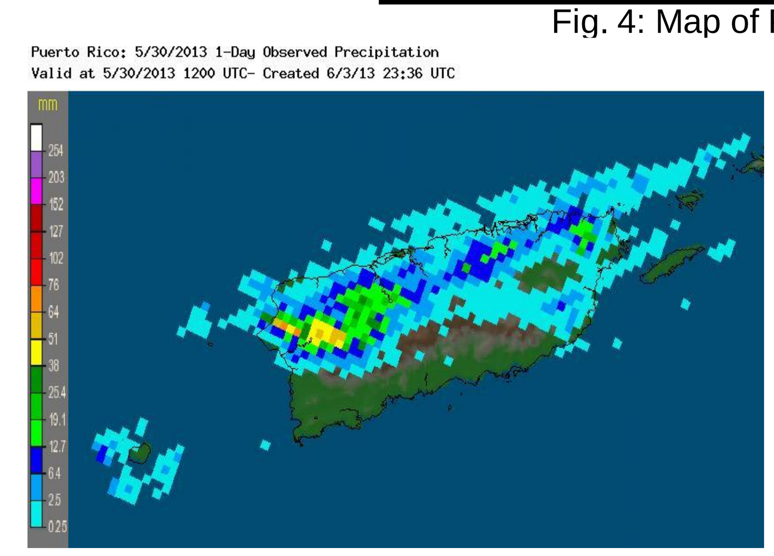

Fig. 5: Radar precipitation data for 30 May 2013

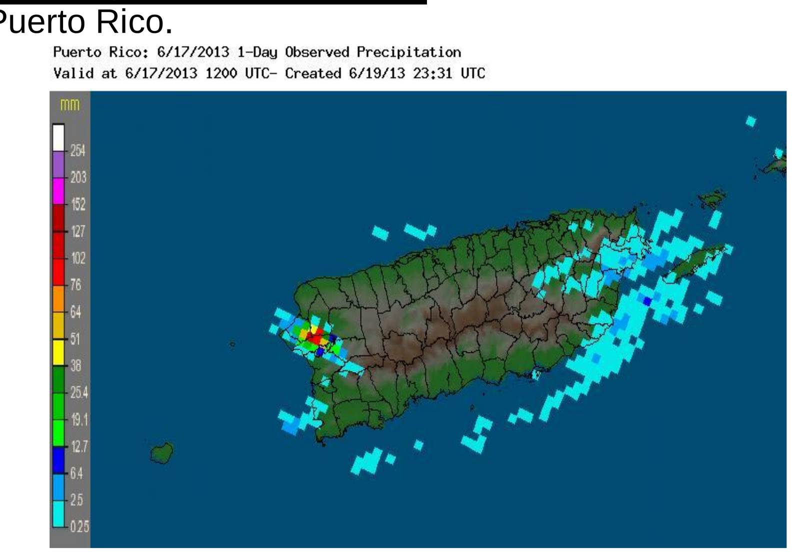

Fig. 6: Radar precipitation data for 17 June 2013

Analyze AERONET PSD horizontal data and Vaisala vertical PSD data before or during event

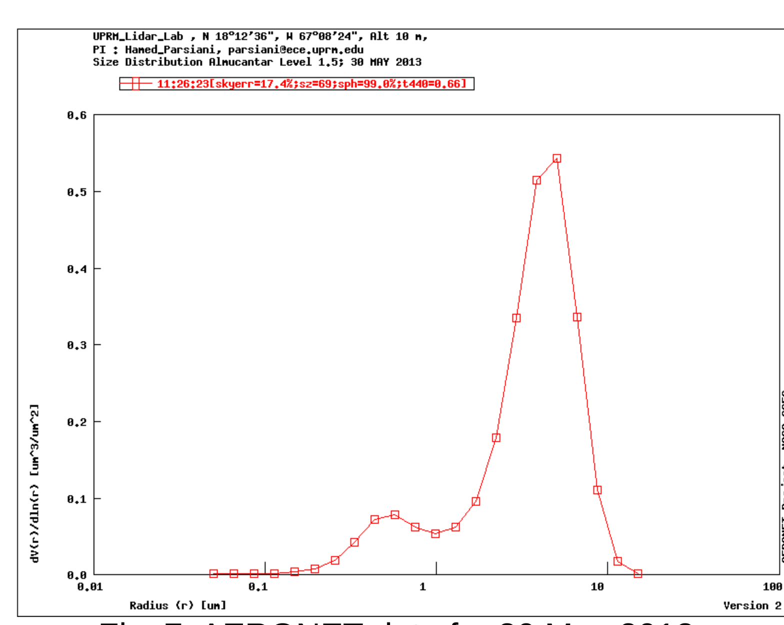

Fig. 7: AERONET data for 30 May 2013

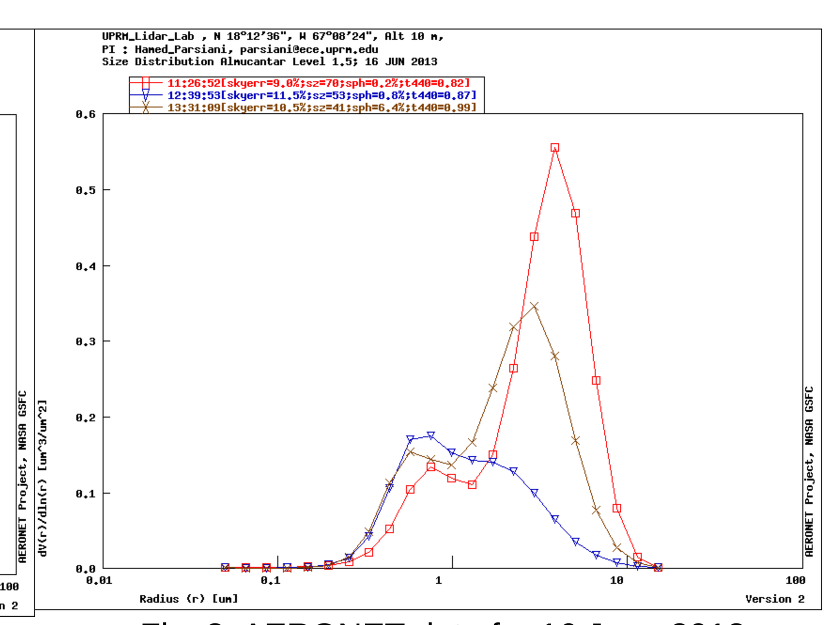

Fig. 8: AERONET data for 16 June 2013

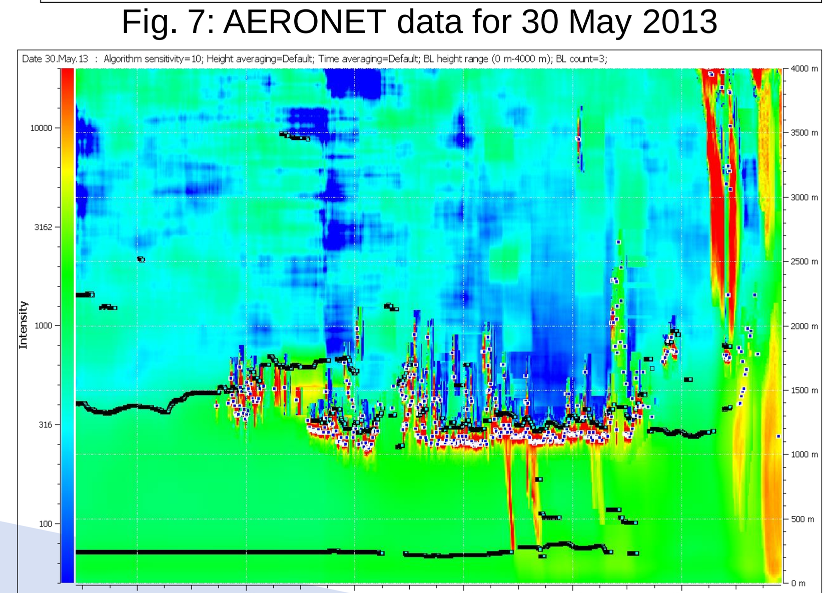

Fig. 9.: Ceilometer on 30 May 2013

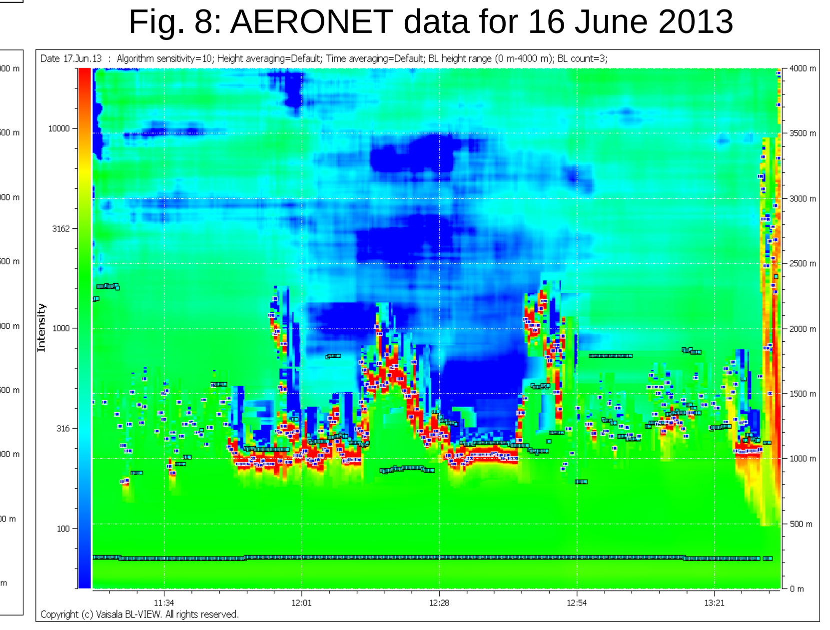

Fig. 10: Ceilometer on 17 June 2013

Analyze AERONET PSD horizontal data and Vaisala vertical PSD data after the event (where available)

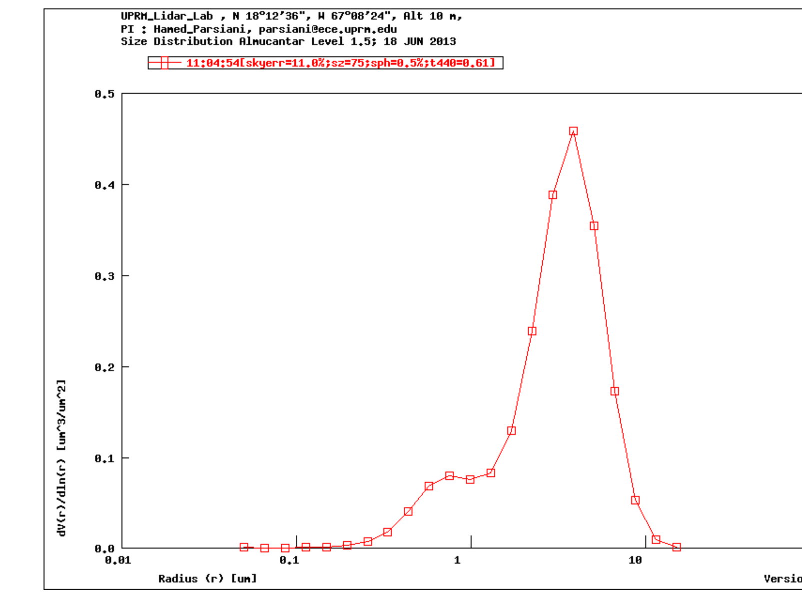

Fig. 11: AERONET data on 18 June 2013

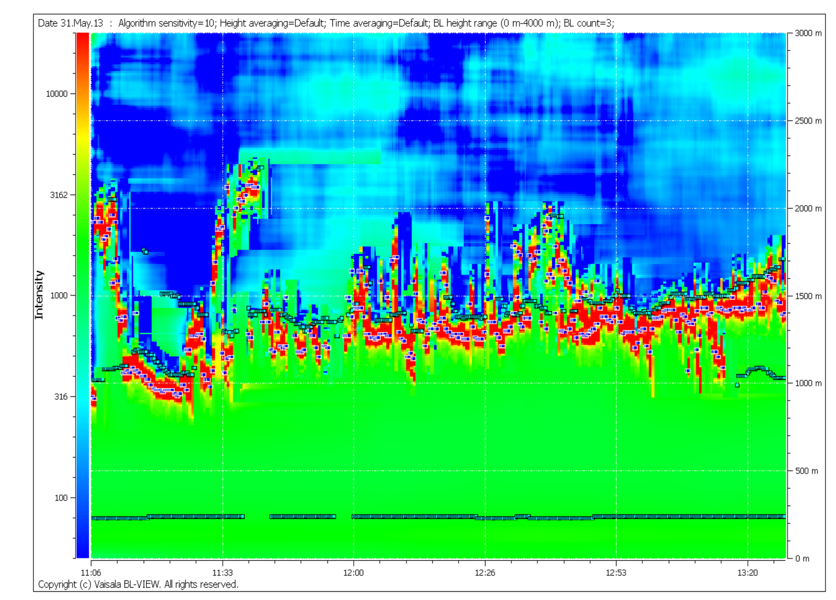

Fig. 12: Ceilometer data on 31 May 2013

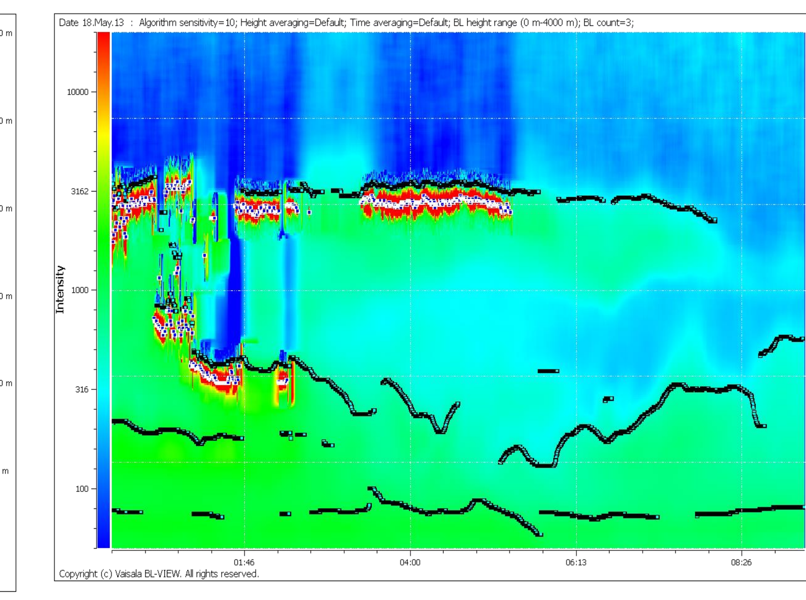

Fig. 13: Ceilometer data on 18 June 2013

What do we notice?

Conclusions

Results from the PSD data in both days suggest that the fine, smaller aerosols of a cloud will suppress precipitation while the coarse, bigger aerosols will trigger more precipitation. Therefore, the aerosols with larger radii contain heavier droplets and will tend to create more rainfall. Based on the ceilometer data, we can conclude that clouds with a greater concentration of aerosol particles will rise up and have a higher cloud base height in the planetary boundary layer because each of those smaller particles is still trying to coalesce into raindrop size. Whereas, a cloud with less concentration but more larger particles will trigger precipitation earlier.

References

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