Analysis of Inter-arrival Times of Aerosol Particles

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(Dated: April 18, 2017)

The goal of the project is to better quantify spatial correlations among aerosol particles by modifying an Aerodynamic Particle Sizer (APS) to have a microsecond temporal resolution. Data acquired from the APS will be compared to a Poisson distribution to conclude if the aerosol particles cluster in space.

I. INTRODUCTION

There is a question within the micrometeorlogical community of whether there are aerosol spatial correlations, or more colloquially, clumping. To investigate this process, particle detection events are viewed as elements of a time series and then spatial information is inferred from the ergodicity assumption of statistical physics [1]. Correlations in the spatial distribution of particles can cause an enhanced coagulation rate that is proportional to the degree of spatial correlation, which effects Global climate models, radiative transfer theories, and our concept of how size-distribution of aerosols evolve [1][2]. For example, the Beer-Lambert-Bouguer law of exponential attenuation is well established for perfectly random and absorbing obstacles dispersed in a volume, but does not apply in its traditional form for obstacles that have some statistical departure from perfect spatial randomness [2][3]. This is important for the transmission of electromagnetic radiation through the atmosphere [2].

It has been found that statistics for larger aerosol particles definitively follow a non-Poisson distribution [1], but other studies suggest that nanometer sized particles can be described using Poisson statistics [4]. Given a constant concentration of particles, c, in a volume, the probability of finding k particles in subvolume v is assumed to follow the probability distribution function for a Poisson distribution [5],

$$p_{\bar{k}}(k) = \frac{\bar{k}^k \exp(-\bar{k})}{k!}. \tag{1}$$

To determine if aerosol particles follow a Poisson distribution, most studies measure the total number number of particles arriving at several sizes in consecutive temporal intervals [5]. More precise results would be achieved if there was information about each individual aerosol and the surrounding environment, due to the fact that the particles undergo processes such as collision, coalescence and coagulation [5].

II. GOALS

This project starts by electronically modifying the output of an Aerodynamic Particle Sizer (APS) in order to resolve individual particle arrival times, then comparing the data to a Poisson distribution in order to analyze its randomness, or spatial variability. The APS currently reports the measurement integration time of accumulated particles in intervals ranging from 1 s and 1 h, but the goal with the given equipment will be to measure individual particle interarrival time to microscale resolution. Since around 1000 particles are detected per second, increasing the temporal sampling by six orders of magnitude will allow us to go from a perspective of arrival rates to explicitly resolving the interarrival times between each individual aerosol particle. Once better quality interarrival time for each aerosol is achieved, comparison of the interarrival times of different sized particles to an exponential distribution, corresponding to the wait time distribution in a Poisson process, will proceed to see if the particles follow the statistics of perfect spatial randomness. If they do not, then one can assume that the aerosol particles are clumping, but if they do fit the curve then it would be safe to say there is no clumping, at least on time-scales of a microsecond or longer. Regardless of the result, the information will be useful to the scientific community studying aerosol particles and therefore will result in publication if results are achieved.

III. METHOD

The TSI model 3321 Aerodynamic Particle Sizer accelerates the aerosol sample flow through an inlet orifice. The aerodynamic size of a particle determines its rate of acceleration, with larger particles accelerating more slowly due to increased inertia. As particles exit the nozzle, they cross through two partially overlapping laser beams in the detection area. Peak-to-peak time-of-flight is measured with 4-nanosecond resolution for aerodynamic sizing, which will be narrowed down to desired sample resolution by the start of the fall semester [6]. Calibration will consist of assuring that the APS is properly reading the inflow of particles using an air pump, aerosol nebulizer, and calibration particles. After calibration is completed, ambient aerosols will enter the APS to measure a data set of particle sizes that we can analyze based on relevant time-series statistics.

The statistical methods of the project will be executed in MATLAB. Codes will be written using pair-correlation function, statistical autocorrelation, Bayesian decomposition and other statistical tools to analyze the data.

IV. RESOURCES

The project requires the use of the Physics Department's TSI Aerodynamic Particle Sizer (APS) to size the aerosol particles and get their spatial information. The calibration equipment for the APS including an air pump, aerosol nebulizer, and calibration particles are already in the lab. Though currently stocked polystyrene latex spheres should be sufficient to complete the calibration procedure, it may be possible that newer spheres will need to be purchased. If necessary, Dr. Larsen has the funds to complete this purchase. MATLAB will be needed to process the data using statistical analysis. Access to this equipment is already acquired and will be housed in the research labs in the new science building. The project already has the necessary funding needed to achieve results.

V. TIMELINE

- September 2017: APS is up and running with electrical modifications, Calibration begins
- November 2017: Calibration finished and APS runs continually to form data set
- December 2017: Solid data set is achieved and beginning analysis
- February 2018: Results achieved by this point and beginning stages of paper
- early March 2018: Poster is made and ready for following conferences
- March 2018: SCAS and other relevant conferences
- end of March 2018: paper is complete and ready for publication (conditional)
- April 2018: Department and SSM poster sessions

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[4] On the Validity of the Poisson Assumption in Sampling Nanometer-Sized Aerosols Damit, B., Wu, C., Cheng, M. Aerosol Science and Technology, 48(5), 562-570 (2014).

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