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Acoustic Agglomeration of Aerosol Particles in Benefit of RASA 2.0

Michael Swanwick, Lena Dubitsky, Kenneth McEnaney, Jessica Elliott, Clive Devoy, Jed Wilbur

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INTRODUCTION AND MAIN RESULTS

Existing radionuclide aerosol collection systems within the CTBT’s IMS operate near the noise floor of the gamma spectrometer measurement. Increasing the flow rate of radionuclide aerosol systems while meeting the CTBT’s specified collection efficiencies will increase particle collection and, potentially, decrease sample interval. Creare developed a detailed model of an agglomeration system designed for the particularly hard-to-collect small particles and low particle densities of interest. Our agglomeration model includes effects from orthokinetic, acoustic wake, particle collision efficiency, population balance, Brownian motion, and van der Waals forces to predict the statistical likelihood of any particle sticking to any other particle in the turbulent flow stream with high sound pressure.

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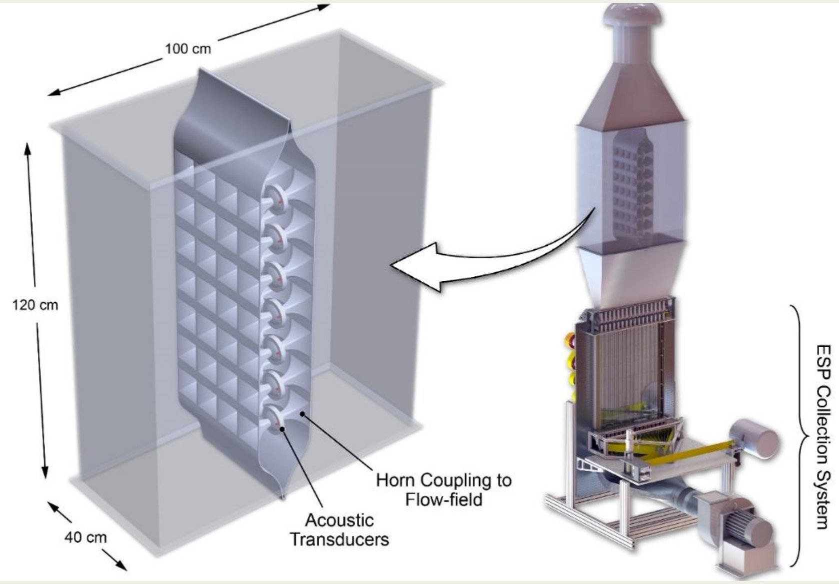
Introduction/Objectives

The RASA 2.0 program aims to improve atmospheric aerosol collection. Long-range (0.2 µm) particles are critical to monitoring radionuclide particle transport in the atmosphere. This particle size is the most difficult range to collect for both HEPA-style filters and electrostatic precipitator (ESP) systems. Agglomeration of 0.2 µm particles can assist in collection of these key particles.

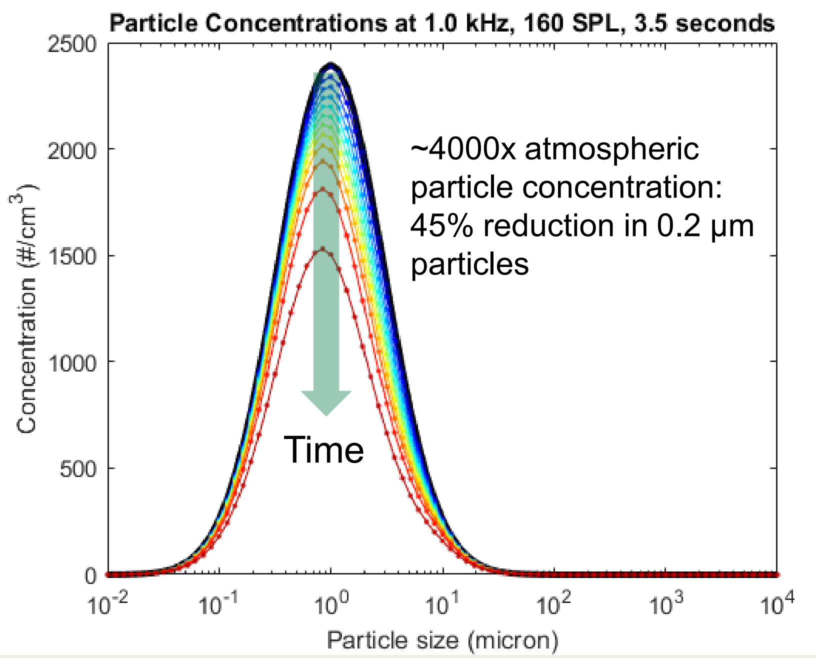
Objective: Determine feasibility of particle acoustic agglomeration to enhance small particle collection (target 10% particle count reduction). The acoustic agglomeration system can be installed at the inlet of an aerosol system to improve collection efficiency.



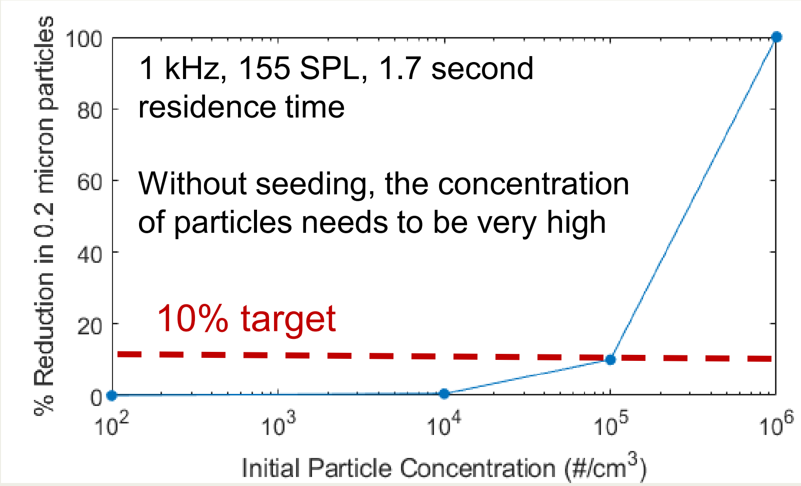
Methods/Data

We analytically model the expected particle agglomerations via a population balance model, accounting for the effects of orthokinetic interactions, acoustic wake, turbulence, Brownian motion, van der Waals and Coulomb forces.

Key variables: particle residence time, inlet particle concentration, sound frequency and pressure level.



Results/Conclusion



At typical atmospheric concentrations (10–100 particles/cm^3), achieving a 10% reduction in 0.2 µm particles using acoustic agglomeration is extremely difficult, even when increasing sound pressure levels and sound frequency.

Our analysis demonstrates that achieving high agglomeration is possible with the addition of water seed particles (1 – 5 µm water droplets at a flow rate of 5 liters/hour), especially when combined with a longer residence time.

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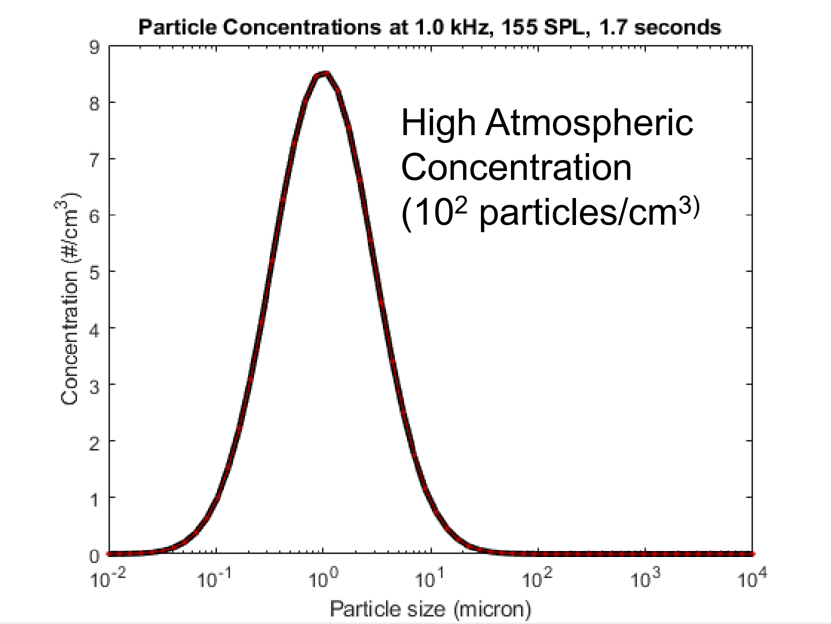
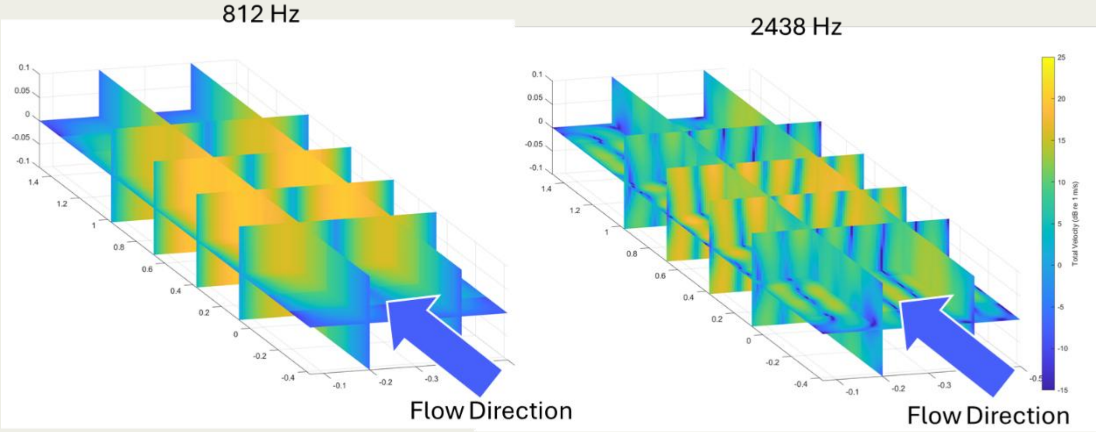
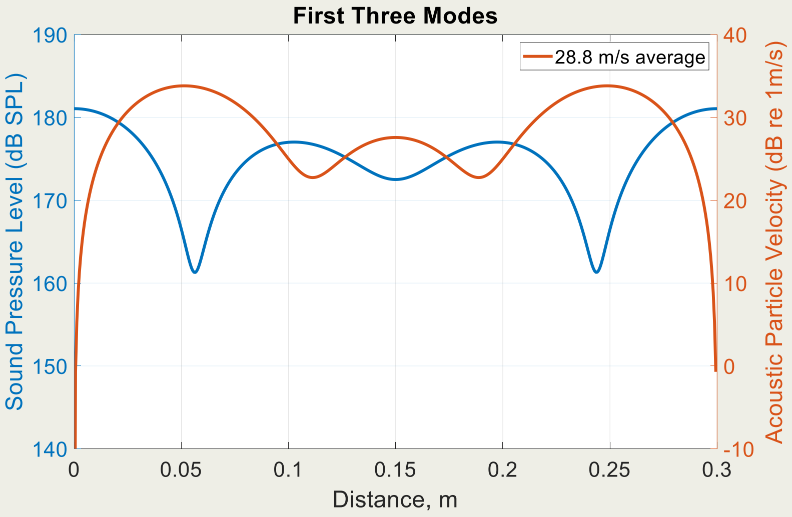
Backup Images

Particle Size Distributions for 10^2 Particles/cm^3 at 1 kHz and 155 SPL as a Function of Time. The initial distribution is shown as the thick black line. The red line is the final distribution at the end of the particle residence time (1.7 s or the equivalent of 1000 m^3/hr flow rate)





3D Model of the Acoustic Velocity in the Agglomeration System. The X, Y and Z axis are in meters and color plot is the magnitude of the Acoustic Velocity Vector (dB re 1 m/s).



Acoustic Pressure and Velocity Profiles When Exciting Three Resonant Modes (at 400 W Total). The simplified waveguide model is an analytical model that we use to predict the performance of a given transducer candidate to inform inputs for the more complex finite element model. This initial model predicts the response of a transducer driving a plane wave tube. This simplification is reasonable for transducers near the center of the array but will over predict performance near the array edges to keep the solution from "exploding". We incorporate the effects of acoustic absorption by adding an imaginary component to the sound speed.

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