Direct Numerical Simulation of Aerosol Growth Processes in a Turbulent Mixing Layer

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Abstract: The complex interaction of turbulent mixing and aerosol growth processes in a canonical turbulent flow configuration is investigated by means of direct numerical simulation. A cold gaseous stream mixes with a hot stream of vapor in a developing mixing layer. Nanometer sized particles (droplets) nucleate as vapor becomes supersaturated and subsequently grow as more vapor condenses on their surface. Aerosol dynamics is solved with the Quadrature Method of Moments [R. McGraw, Aerosol Sci. Technol., 27:255-265 (1997)]. Aerosol moments advection is solved with a Lagrangian particles scheme. The results show that the highest nucleation rate region is located on the lean vapor (cool) side across the mixing layer, while particles experience a high growth rate on the rich vapor (hot) side. The effects of turbulence on particle dynamics are assessed by comparing the exact mean nucleation and growth rates with the rates evaluated from mean quantities (temperature and concentration). The nucleation rate evaluated from mean quantities tends to greatly over-estimate the mean particle number density. The growth rate evaluated from mean quantities is also higher than the exact mean value, but by a relatively small margin.

Keywords: Aerosol, Quadrature Method of Moments, Direct Numerical Simulation, Lagrangian Particles Scheme