Abstract submission form

Speaker or corresponding author

First name	Lucian
Name	Ivan
Organisation	Canadian Nuclear Laboratories
Country	Canada
Email address	lucian.ivan@cnl.ca

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Evaluation of the Polydisperse Gaussian Model for Atmospheric Dispersion of Multiphase Flows

Lucian Ivan[1]; F. Forgues[1], W. Kaufmann[2], J.G. McDonald[2]

[1] *Canadian Nuclear Laboratories, Canada*
[2] *University of Ottawa, Canada*

Abstract

Accurate prediction of multiphase flows when particles are differentiated by a set of “internal” variables, such as size or temperature, can pose modelling and numerical challenges. Various computational models have been developed for the simulation of multiphase flows based on both Lagrangian and Eulerian formulations. Despite many successes, it can be argued that there is still a range of flow conditions for which the available models are confronted with difficulties. In particular, no attractive method exists for particle-laden flow regimes, as determined by the spatial and temporal variation of the mass fraction and flow Stokes number, between the traditional continuum and free-particle limits. Extremely dilute flows can be described efficiently using particle-tracking methods, i.e. Lagrangian approaches, while a more computationally affordable formulation for granular or “continuous” regimes is provided by field-based (Eulerian) methods. The dispersion of pollutants in the atmosphere is a particular example in which transition-regime particle-laden flows occur mainly due to the presence of very large domains in such problems. In the realm of nuclear safety and security, applications of interest include the dispersion of particles resulting from the detonation of a radiological dispersal device (RDD), the release of radioactive particulates from nuclear plants, or the tracking of atmospheric aerosols.

Motivated by the development of accurate Eulerian-based formulations that can provide an affordable computational cost and valid predictions over the complete range of particle mass fractions encountered in the simulation of such flows, the polydisperse Gaussian model (PGM) has been recently proposed [1]. The PGM is an extension to the classical Gaussian ten-moment model from gaskinetic theory for the treatment of a dilute particle phase with an arbitrary number of internal variables based on an entropy-maximization argument. The proposed model extension directly tracks the evolution of the variance of each internal variable, their covariances, and their covariance with the three components of the particle velocity. The resulting partial differential equations (PDEs) are robustly hyperbolic and have a full eigensystem expressed in closed form. The model can be shown to maintain a valid positive distribution function for physically valid initial-value problems, and it is amenable for efficient classical discretization techniques and application on modern large-scale parallel architectures.

This talk will provide an overview of the three-dimensional (3D) PGM model for atmospheric dispersion of multiphase flows and its extension to account for turbulent background flow. Numerical results will include the evaluation of the PGM model based on comparison to predictions obtained from classical Lagrangian, Gaussian plume and puff models, as well as predictions for the 2012 DRDC Suffield full-scale RDD experiments.

[1] F. Forgues et al. / Journal of Computational Physics 398 (2019) 108839