University of Victoria | Graduate Studies

Notice of the Final Oral Examination for the Degree of Doctor of Philosophy

of

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"A Stochastic Bulk Model for Turbulent Collision and Coalescence of Cloud Droplets"

Department of Mathematics and Statistics

Wednesday, July 6, 2016
1:00 P.M.
David Turpin Building
Room A144

Supervisory Committee:
Dr. Boualem Khouider, Department of Mathematics and Statistics, University of Victoria (Supervisor)
Dr. Rod Edwards, Department of Mathematics and Statistics, UVic (Member)
Dr. Slim Ibrahim, Department of Mathematics and Statistics, UVic (Member)
Dr. Knut von Salzen, School of Earth and Ocean Sciences, UVic (Outside Member)

External Examiner:
Dr. Jason Milbrandt, Research Scientist, Canadian Meteorological Centre

Chair of Oral Examination:
Dr. Karen Courtney, School of Health Information Science, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

We propose a mathematical procedure to derive a stochastic parameterization for the bulk warm cloud micro-physical properties of collision and coalescence. Unlike previous bulk parameterizations, the stochastic parameterization does not assume any particular droplet size distribution, all parameters have physical meanings which are recoverable from data, all equations are independently derived making conservation of mass intrinsic, and the auto conversion parameter is finely controllable, and the resultant parameterization has the flexibility to utilize a variety of collision kernels. This new approach to modelling the kinetic collection equation (KCE) decouples the choice of a droplet size distribution and a collision kernel from a cloud microphysical parameterization employed by the governing climate model. In essence, a climate model utilizing this new parameterization of cloud microphysics could have different distributions and different kernels in different climate model cells, yet employ a single parameterization scheme.

This stochastic bulk model is validated theoretically and empirically against an existing bulk model that contains a simple enough (toy) collision kernel such that the KCE can be solved analytically. Theoretically, the stochastic model reproduces all the terms of each equation in the existing model and precisely reproduces the power law dependence for all of the evolving cloud properties. Empirically, values of stochastic parameters can be chosen graphically which will precisely reproduce the coefficients of the existing model, save for some ad-hoc non-dimensional time functions. Furthermore values of stochastic parameters are chosen graphically. The values selected for the stochastic parameters effect the conversion rate of mass cloud to rain. This conversion rate is compared against (i) an existing bulk model, and (ii) a detailed solution that is used as a benchmark.

The utility of the stochastic bulk model is extended to include hydrodynamic and turbulent collision kernels for both clean and polluted clouds. The validation and extension compares the time required to convert 50% of cloud mass to rain mass, compares the mean rain radius at that time, and used detailed simulations as benchmarks. Stochastic parameters can be chosen graphically to replicate the 50% conversion time in all cases. The curves showing the evolution of mass conversion that are generated by the stochastic model with realistic kernels do not match corresponding benchmark curves at all times during the evolution for constant parameter values. The degree to which the benchmark curves represent ground truth, i.e. atmospheric observations, is unknown. Finally, among alternate methods of acquiring parameter values, getting a set of sequential values for a single parameter has a stronger physical foundation than getting one value per parameter, and a stochastic simulation is preferable to a higher order detailed method due to the presence of bias in the latter.