Particle-based μ-physics: a probabilistic look at modeling clouds

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"Cloud and ship. Ukraine, Crimea, Black sea, view from Ai-Petri mountain"

(photo: Yevgen Timashov / National Geographic)

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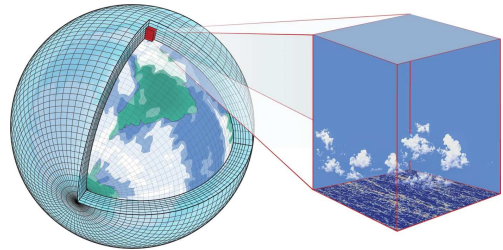
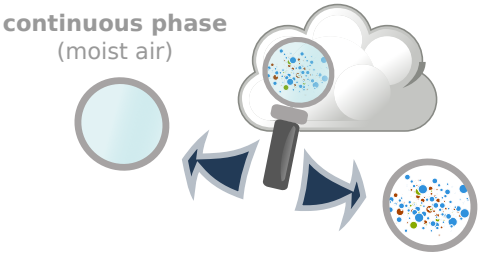


"Grid cells in a global climate model and a large-eddy simulation of shallow cumulus clouds at 5 m resolution"

(fig. from Schneider et al. 2017)

Eulerian vs. Lagrangian microphysics

Eulerian vs. Lagrangian microphysics



dispersed phase

(aerosol particles, cloud droplets, drizzle, rain, snow, ...)

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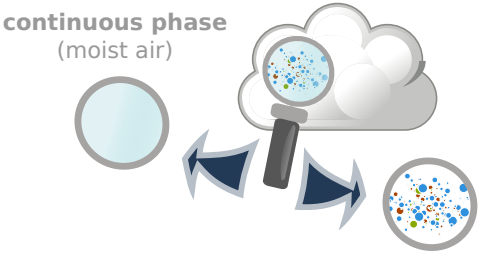

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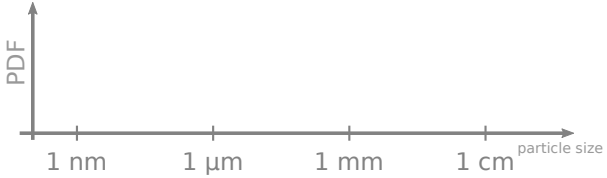

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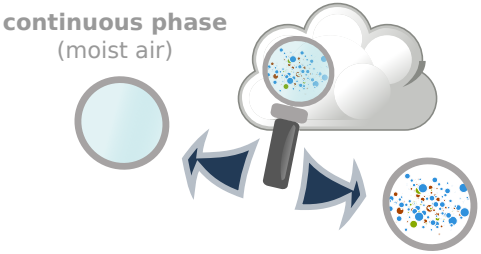

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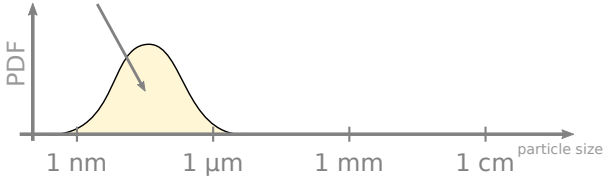

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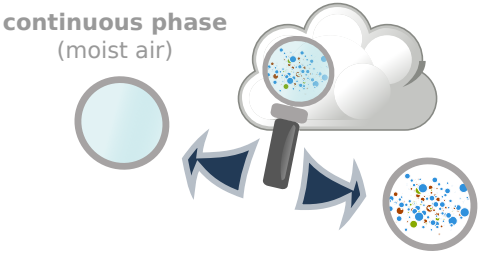

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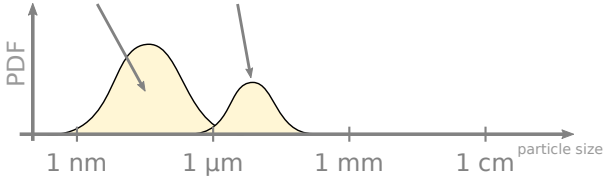

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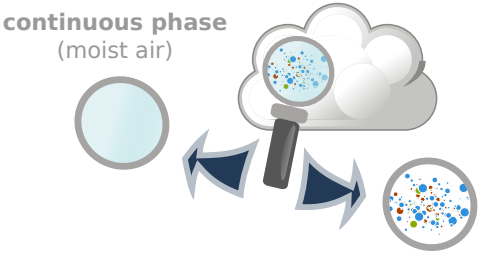

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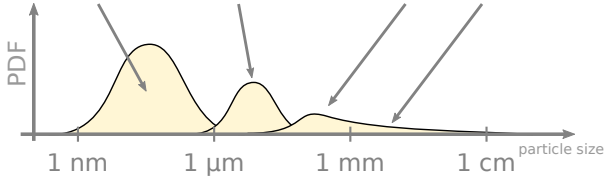

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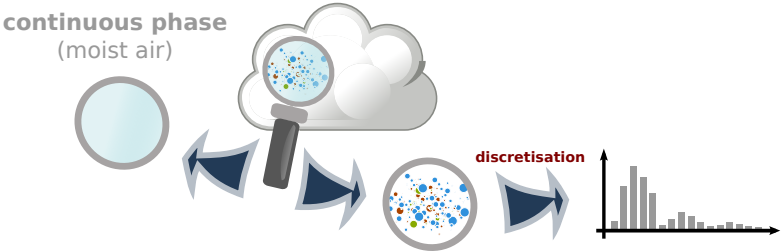

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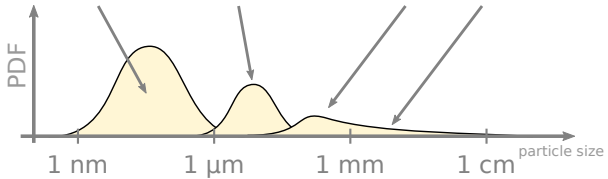

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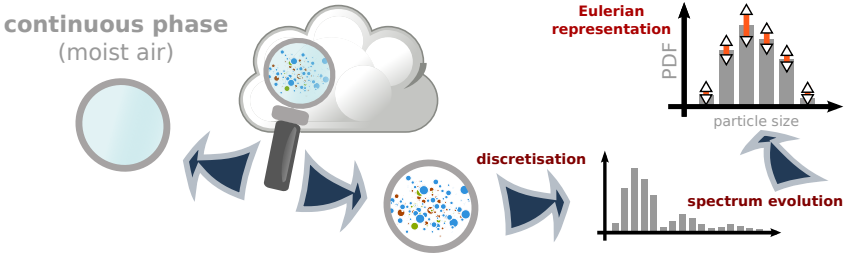

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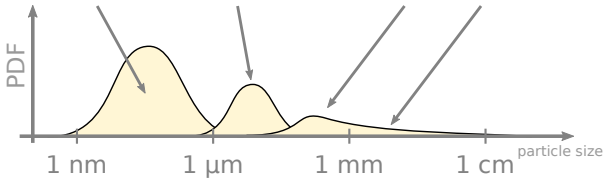

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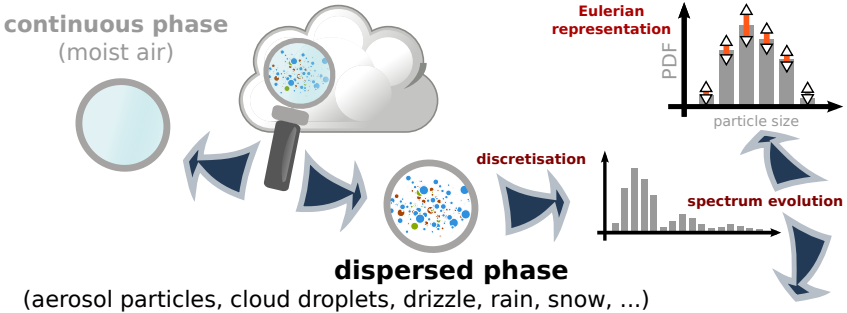


PDEs

ODEs

Lagrangian microphysics: early works (0D)

JOURNAL OF METEOROLOGY

THE GROWTH OF CLOUD DROPS IN UNIFORMLY COOLED AIR

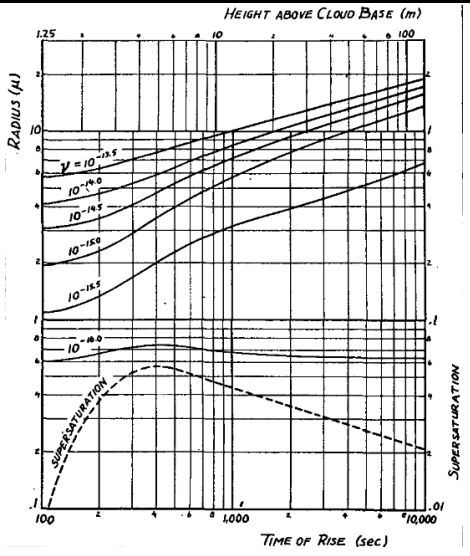
By Wallace E. Howell[1]

Blue Hill Meteorological Observatory, Harvard University[2]

(Manuscript received 10 June 1948)

ABSTRACT

Recent studies of precipitation, aircraft icing, and visibility through fog have focussed attention on the physical constitution of clouds, a subject to which knowledge of the drop-size spectrum and its origin would be an important contribution. The drop-size spectrum resulting when air containing condensation nuclei is uniformly cooled may be computed, leading to a differential equation for the growth of a cloud drop which cannot be integrated analytically. A numerical method of integration is therefore employed.



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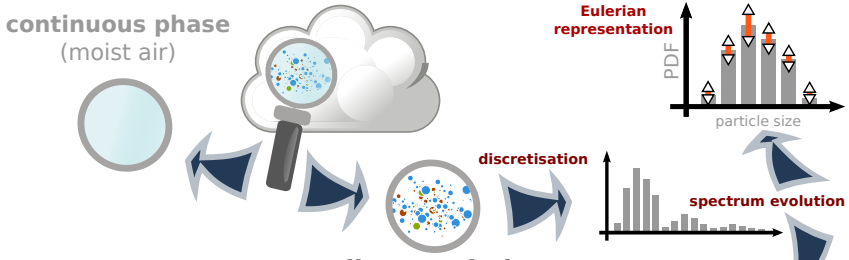

PDEs

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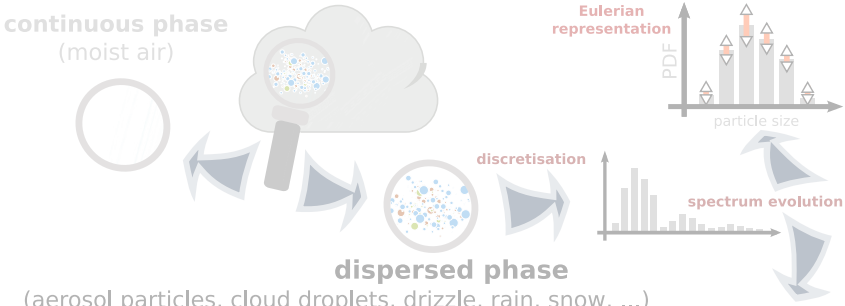

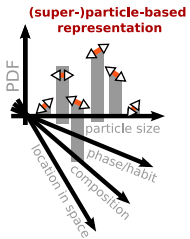

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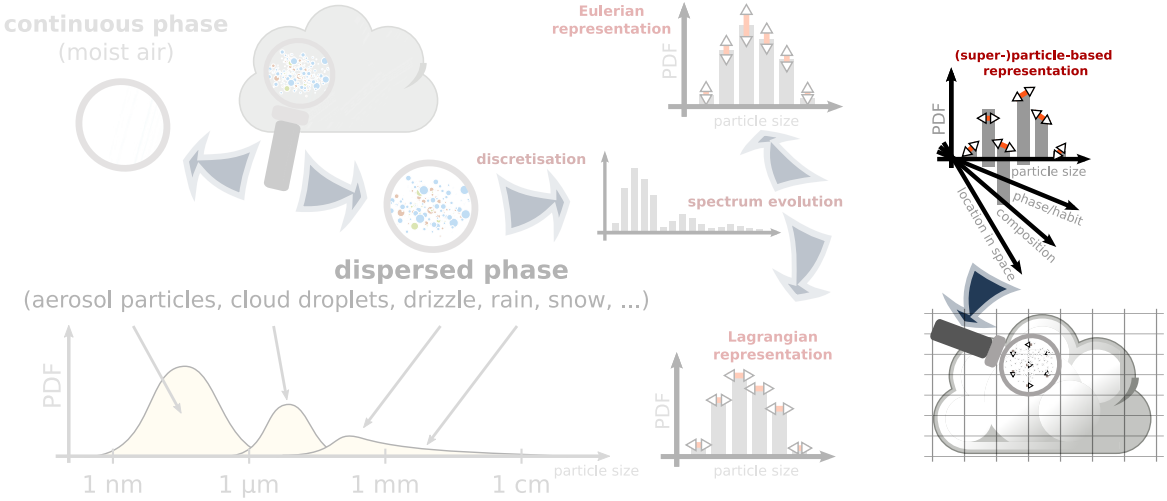

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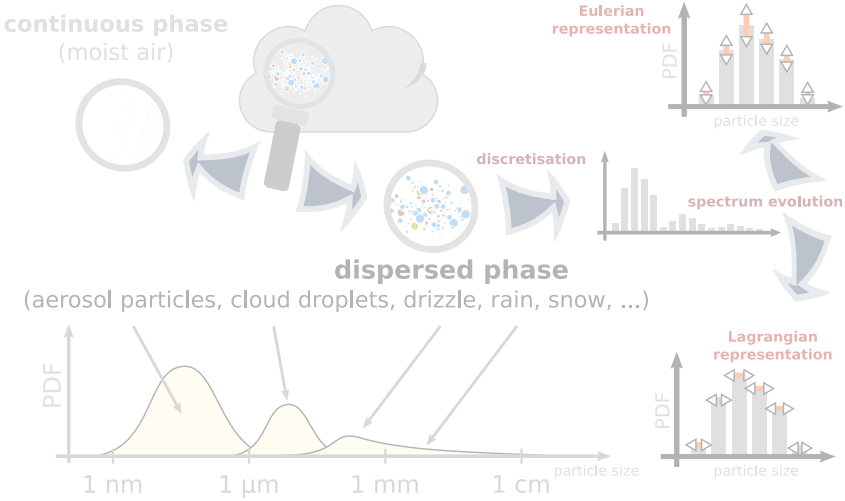

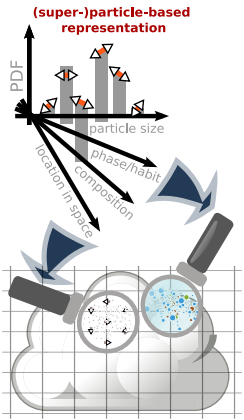

Lagrangian microphysics: early works (3D)

JOURNAL OF THE ATMOSPHERIC SCIENCES

A Numerical Experiment on Stochastic Condensation Theory

TERRY L. CLARK AND W. D. HALL

National Center for Atmospheric Research,[1] Boulder, CO 80307

(Manuscript received 30 August 1978, in final form 20 November 1978)

ABSTRACT

A three-dimensional numerical model is used to study the effect of small-scale supersaturation fluctuations on the evolving droplet distribution in the first 150 m above cloud base. The primary purpose of this research is to determine whether the irreversible coupling between the thermodynamics and dynamics due to finite phase relaxation time scales τ_s is sufficient to produce significant small-scale horizontal variations in supersaturation. Thus, the paper is concerned only with this internal source for thermodynamic variability. All other source terms, such as the downgradient flux of the variance of thermodynamic fields, have purposely been neglected.

Lagrangian particle experiments were run in parallel with the basic Eulerian model. The purpose of these experiments is to relax some of the microphysical parameterization assumptions with respect to assumed distribution shape and as a result add credibility to the results of distribution broadening.

Eulerian vs. Lagrangian microphysics: a (probabilistic) breakthrough

pre-2009:

„advantage of the full-moving size structure is that core particle material is preserved during growth ... second advantage ... it eliminates numerical diffusion ... [but] nucleation, coagulation ... cause problems ... the full-moving structure is not used in three-dimensional models" [a]

„the use of a fixed grid allows for an easy implementation of collision processes, which is not possible for a moving grid (Lagrangian) approach" [b]

[a] Jacobson 2005: Fundamentals of Atmospheric Modeling

[b] Simmel & Wurzler 2006: Condensation and activation in sectional cloud microphysical models

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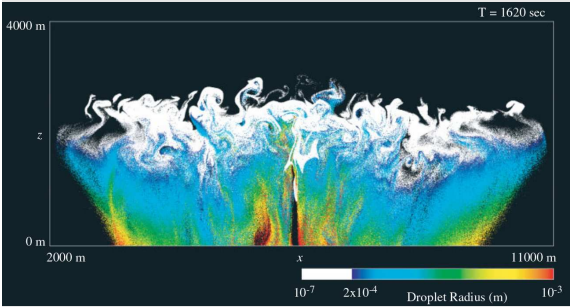
Shima 2009: Monte-Carlo particle-based collision algorithm for cloud simulations



Super-droplet simulation of a shallow convective cloud

(figure: Shima et al. 2009, QJRMS)

[a] Jacobson 2005: Fundamentals of Atmospheric Modeling

[b] Simmel & Wurzler 2006: Condensation and activation in sectional cloud microphysical models