The 5th Research Meeting of Ultrahigh Precision Meso-scale Weather Prediction

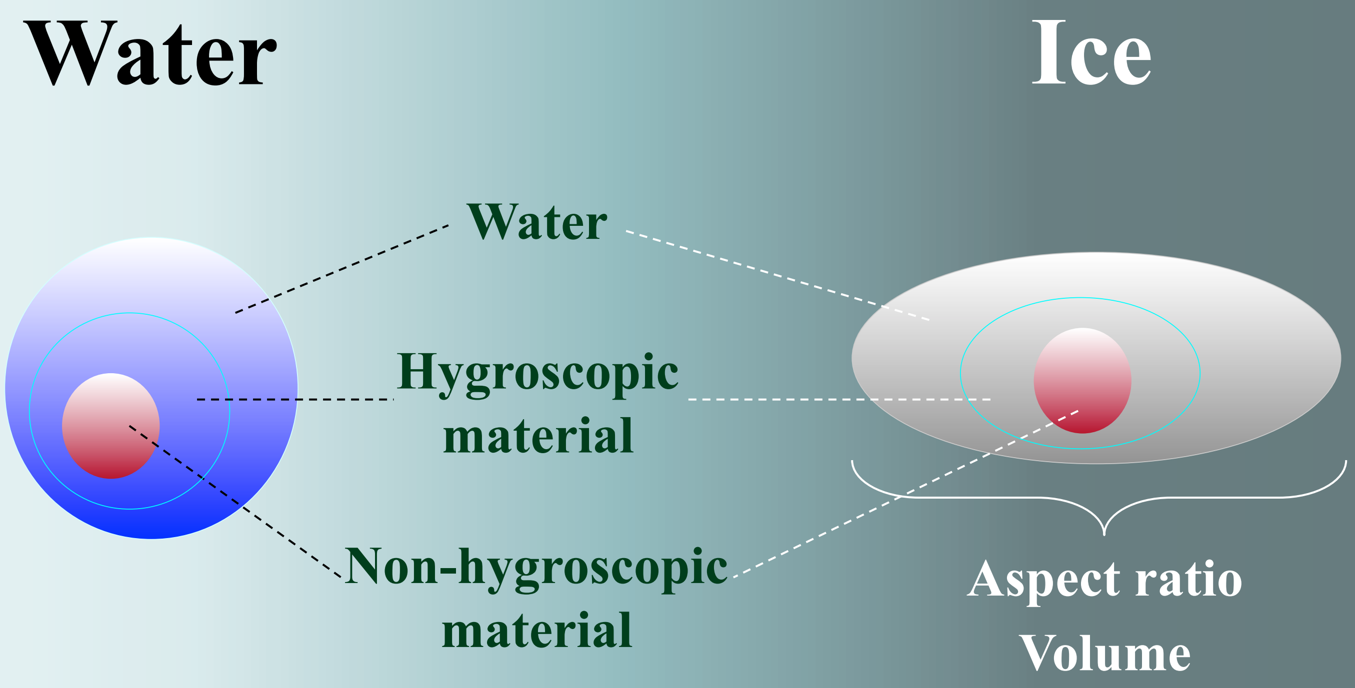
Cloud simulation with multi-dimensional bin-microphysics model

Akihiro Hashimoto

Meteorological Research Institute

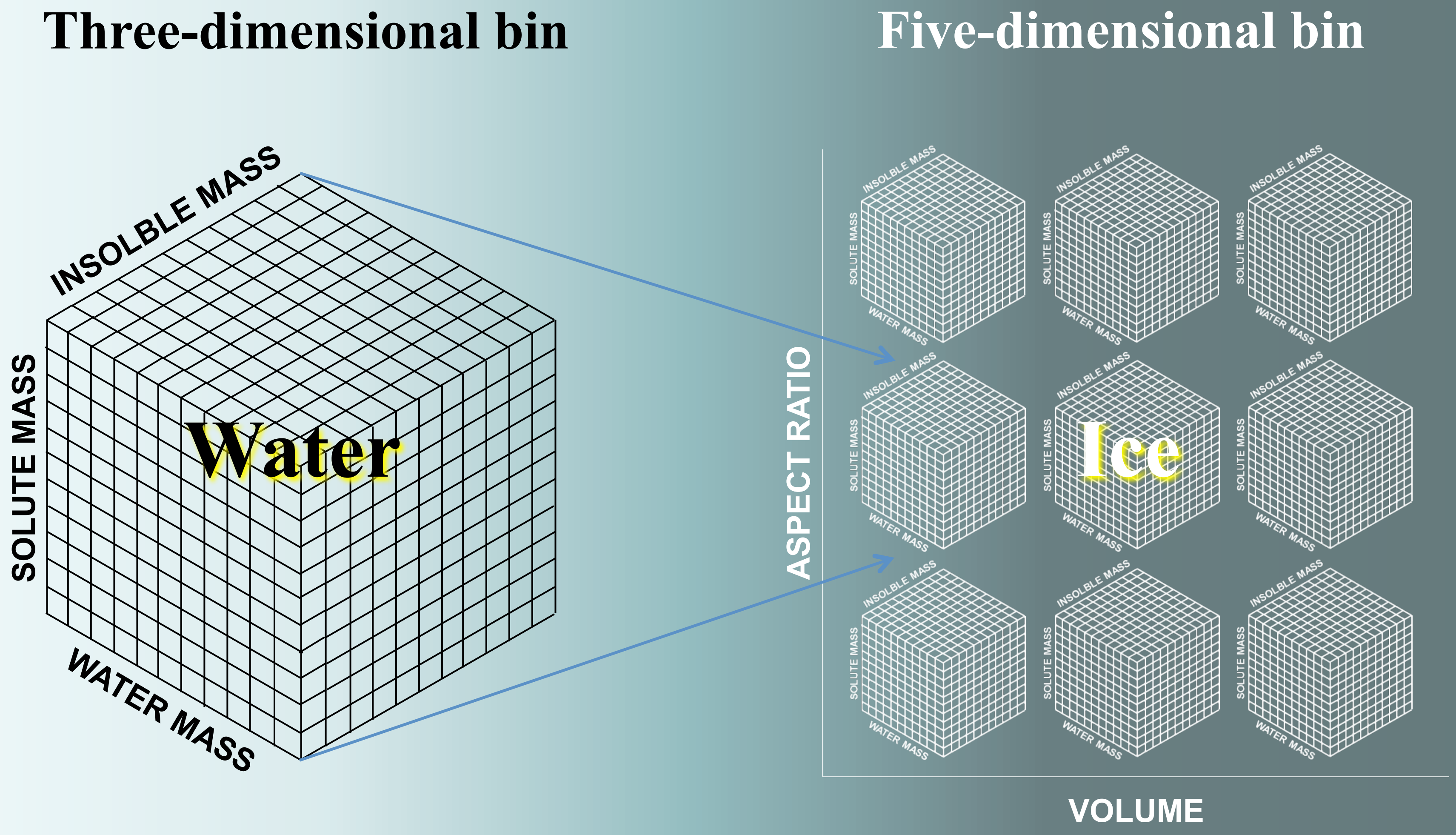
March 9, 2015 (Mon) 9:00～17:40
Venue: Nagoya University, Higashiyama Campus, E&S Hall (E&S Building)

Physicochemical properties of hydrometeor



Three properties — **Five properties**

Eulerian framework



Prognostic variables

$$x_j = \begin{cases} \text{mass of water} \\ \text{mass of aerosol I} \\ \text{mass of aerosol II} \end{cases}$$

$$\frac{\partial f_i}{\partial t} = \sum_{j=1}^{n} \frac{dx_j}{dt} \frac{\partial f_i}{\partial x_j}$$

$$f_i = \begin{cases} \text{total number concentration} \\ \text{total potential energy} \\ \text{total temperature} \\ \text{total mass of water} \\ \text{total mass of aerosol I} \\ \text{total mass of aerosol II} \\ \text{total mass of chemical element I} \\ \text{total mass of chemical element II} \\ \text{total mass of chemical element II} \\ \text{total mass of chemical element IV} \\ \text{total mass of chemical element V} \\ \text{total mass of chemical element VI} \end{cases}$$

$$y_j = \begin{cases} \text{mass of water} \\ \text{volume} \\ \text{aspect ratio} \\ \text{mass of aerosol I} \\ \text{mass of aerosol II} \end{cases}$$

$$\frac{\partial g_i}{\partial t} = \sum_{j=1}^{n} \frac{dy_j}{dt} \frac{\partial g_i}{\partial y_j}$$

$$g_i = \begin{cases} \text{total number concentration} \\ \text{total potential energy} \\ \text{total temperature} \\ \text{total volume} \\ \text{total aspect ratio} \\ \text{total mass of water} \\ \text{total mass of aerosol I} \\ \text{total mass of aerosol II} \\ \text{total mass of chemical element I} \\ \text{total mass of chemical element II} \\ \text{total mass of chemical element II} \\ \text{total mass of chemical element IV} \\ \text{total mass of chemical element V} \\ \text{total mass of chemical element VI} \end{cases}$$

Hashimoto, A. 2014: Development of sophisticated bin-microphysics model, *Low Temperature Science*, **72**, 71-78. (in Japanese with English abstract and figure captions) http://hdl.handle.net/2115/55019

Microphysical processes

表2：モデルで考慮される微物理過程.
Table 1：Microphysical processes involved in the model.

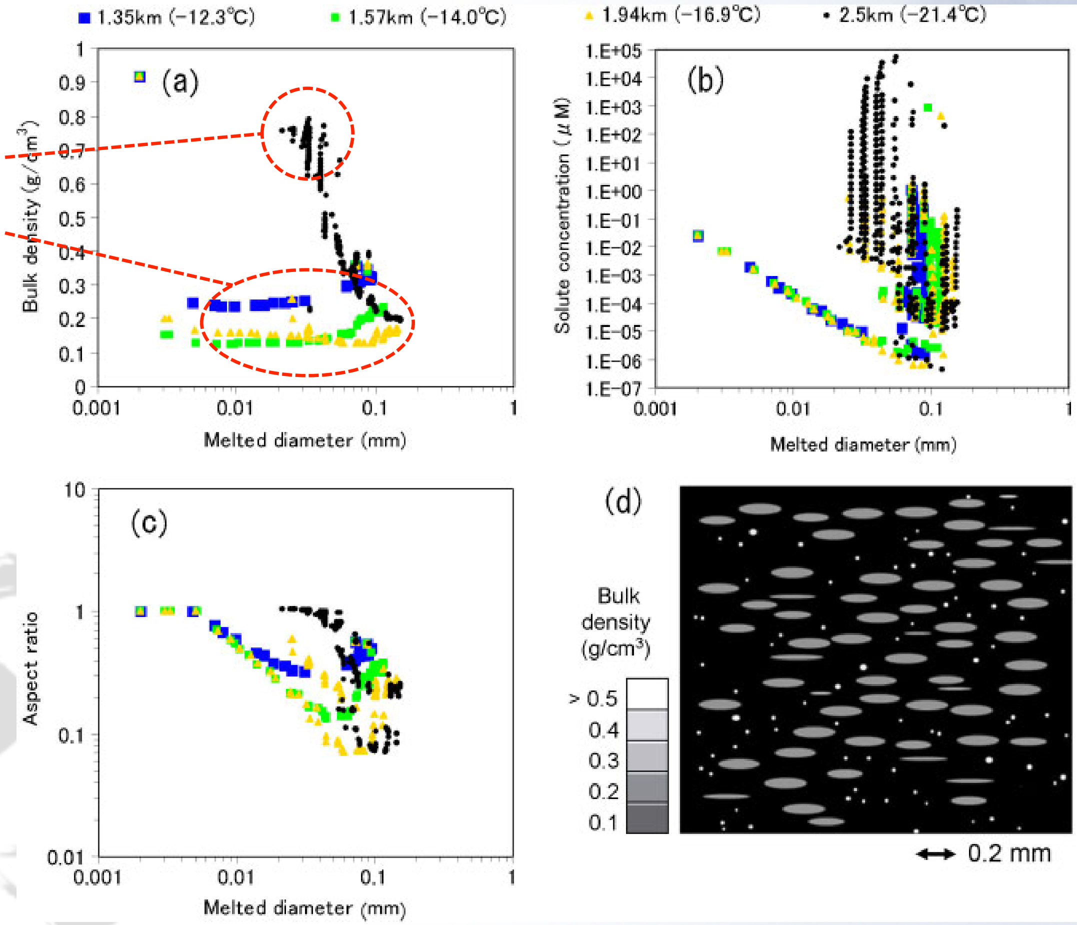
	Production terms	Microphysical processes
Liquid phase	$\left(\frac{dx_j}{dt}\right)_{m_j}$	Droplet nucleation Condensational growth/Evaporation Collision coalescence/breakup Spontaneous breakup
Solid phase	$\left(\frac{dy_j}{dt}\right)_{m_j}$	Ice nucleation Depositional growth/Evaporation Aggregation Spontaneous breakup
Liquid and Solid phases	$\left(\frac{dx_j}{dt}\right)_{m_j}, \left(\frac{dy_j}{dt}\right)_{m_j}$	Riming Melting

Hashimoto, A. 2014: Development of sophisticated bin-microphysics model, *Low Temperature Science*, **72**, 71-78. (in Japanese with English abstract and figure captions) http://hdl.handle.net/2115/55019

Ascending parcel simulation

Frozen drops

Plate-like crystals



Initial condition

T = 0.5 °C

P = 1000 hPa

RH = 50 %

Figure 4. Plots of melted diameter *versus* (a) bulk density, (b) solute concentration and (c) aspect ratio of simulated ice particles at the 1.35-km (−12.3 °C; blue squares), 1.57-km (−14.0 °C; green squares), 1.94-km (−16.9 °C; orange triangles) and 2.5-km (−21.4 °C; black circles) levels. Only the particles with number density greater than one per 10-mol air are plotted. (d) Illustration of simulated ice particles at the 2.5-km level. Particles are drawn at random positions in the plane so that their numbers reflect the simulated number density. Ellipses with horizontally long axes indicate oblate spheroids. Bulk density is denoted by the brightness.

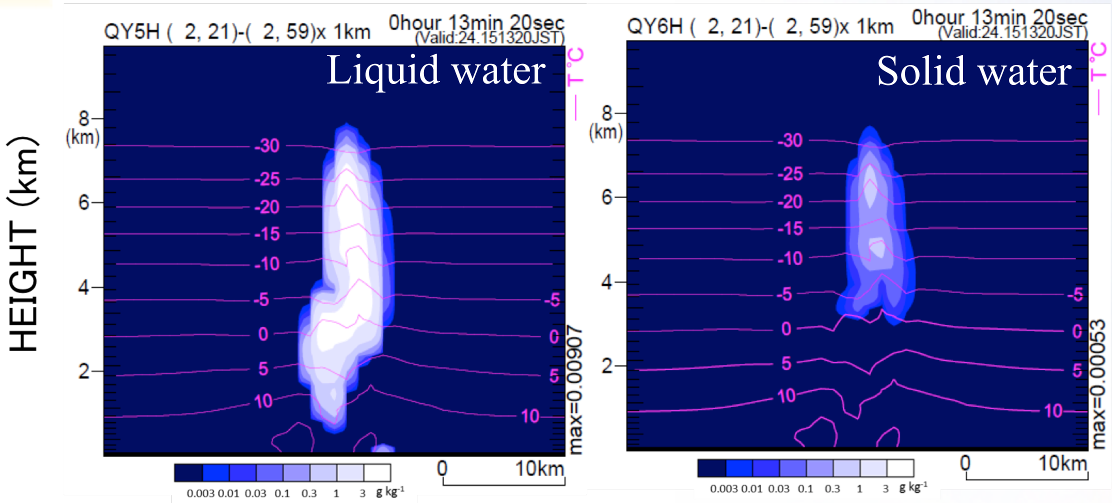
Misumi,R.,A.Hashimoto,M.Murakami,N.Kuba,N. Orikasa,A.Saito,T.Tajiri,K.Yamashita,and J.-P. Chen (2010) M icrophysical structure of a developing convectivesnow cloudsimulatedbyanimprovedver- sionofthemulti-dimensionalbinmodel.Atmos. Sci. Let., 11,186-191.doi:10.1002/asl.268.

2-D idealized simulation

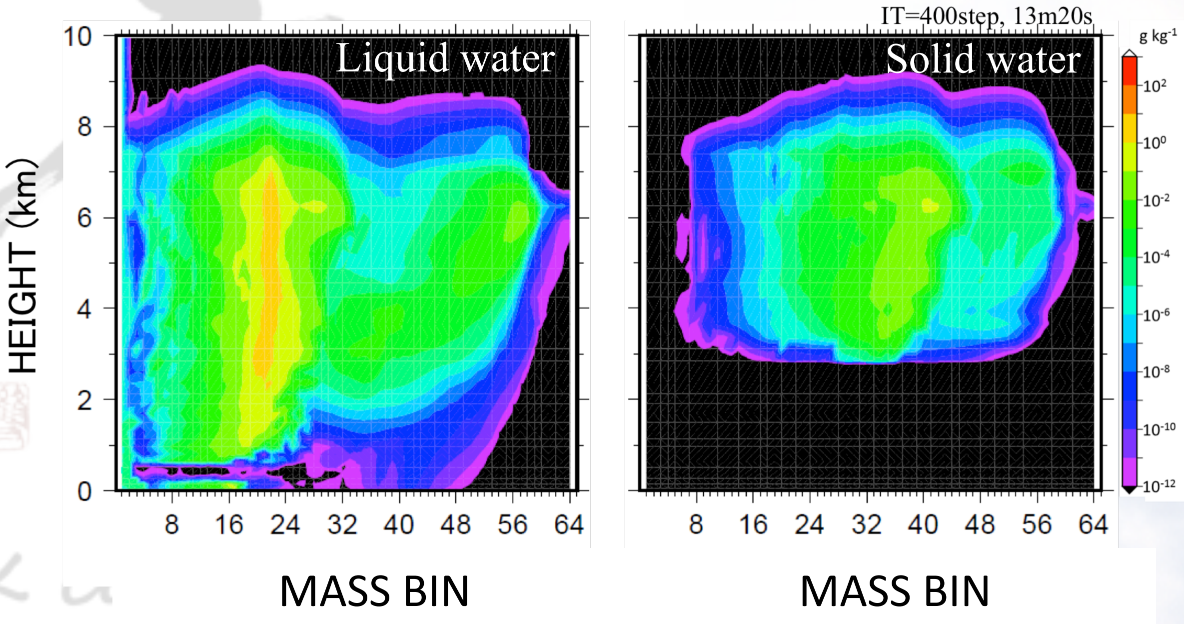
16x10 MPI

80x3x38 spatial grids

64x3x8x8x3 bins

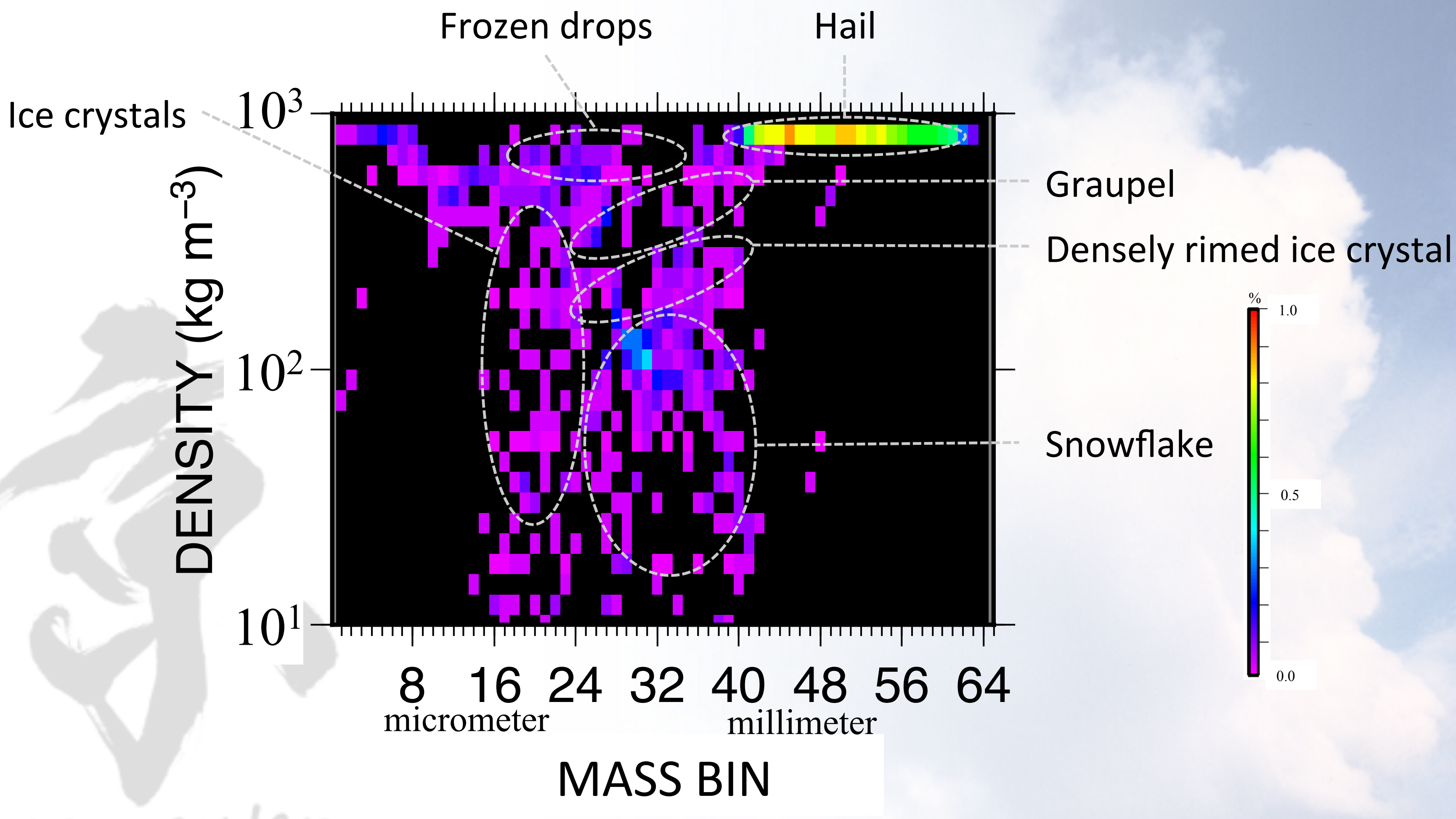


Mixing ratio

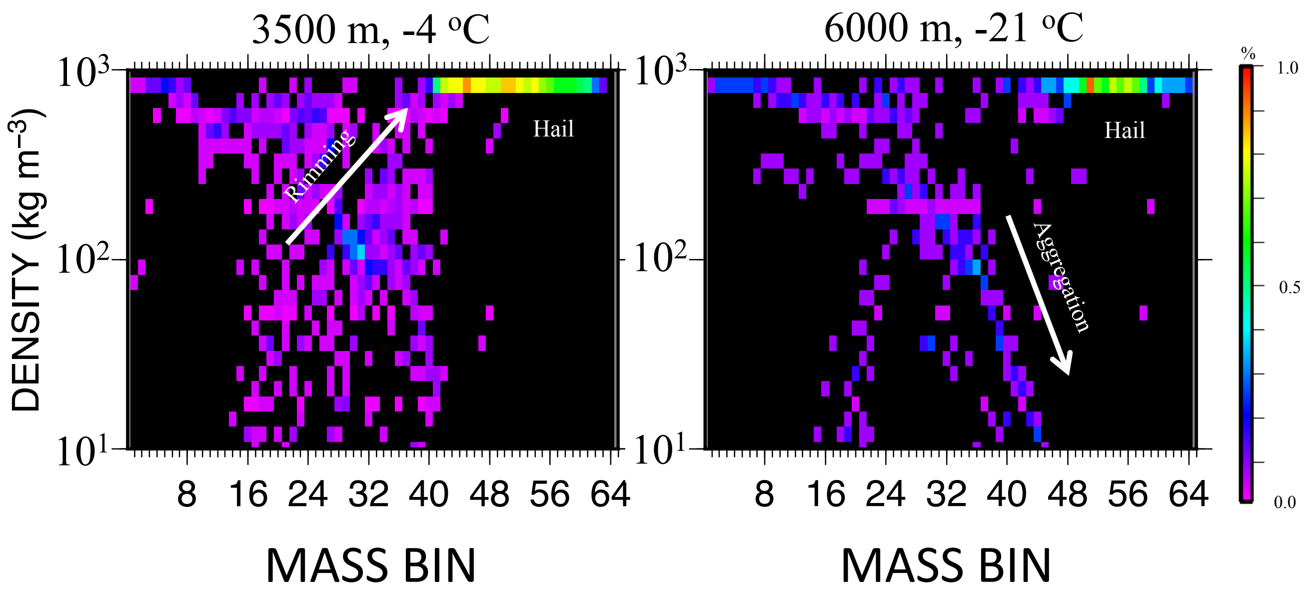


Number concentration

Mass-Density Diagram



Mass-density spectra



Potential applications

Microphysical interpretation of in-situ and remote-sensing observations of cloud

Reference model of bulk microphysics

Ongoing works

Verification of modules

Preparation of 3-D realistic simulation