Importance of **ice particle size distribution** in predicting evolution of a mixed-phase stratiform cloud

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*with contributions from **ISDAC intercomparison team***

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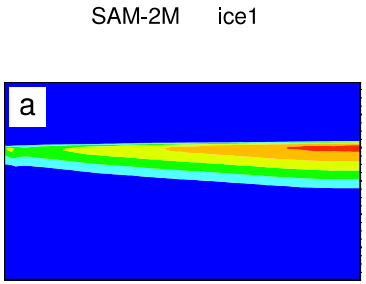
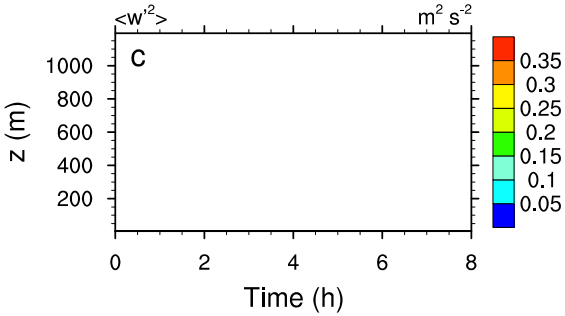


Case setup

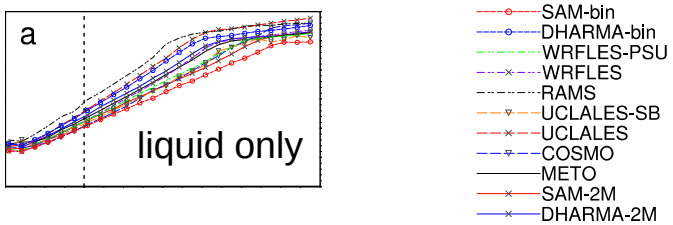
- Based on observations from the Indirect and Semi-Direct Aerosol Campaign (ISDAC)
- Constrained ice particle properties
  - Prescribed mass – capacitance, mass–max diameter, mass – fall speed relationships (very low density sheres)
- Unified radiation scheme
- Common domain size and resolution
- Three target ice concentrations (0, 1, and 4 L^{-1})



Imposed constraints have reduced but not eliminated inter-model spread in LWP and IWP. Why?

LWP differences are due to

- Dynamical cores (physics and/or numerics)
- Microphysics (liquid phase)



Participation: 11 submissions

- DHARMA-2M
- SAM-2M
- WRFLES
- UCLALES

Same micro-physics

- UCLALES-SB
- COSMO

Same micro-physics

- METO
- WRFLES-PSU
- RAMS

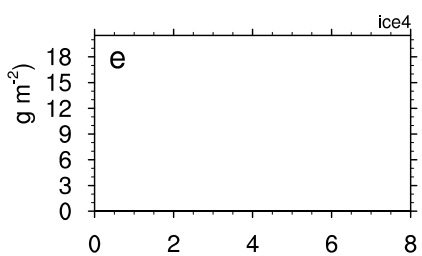
Bulk 2 moment microphysics

- DHARMA-bin
- SAM-bin

Bin (size-resolved) microphysics

low ice

high ice



IWP differences are due to

- Microphysics (size distribution, sublimations effect on N_i)

Ice microphysics dominates LWP and IWP evolution at high ice concentrations

Importance of ice size distribution assumptions

Bin schemes **predict** ice size distributions

Bulk schemes **assume** the shape of the size distribution:

Gamma size distribution $$f_D(D) = A D^{\nu} \exp(-\lambda D)$$

Exponential size distribution $$f_D(D) = N_0 \exp(-\lambda D)$$

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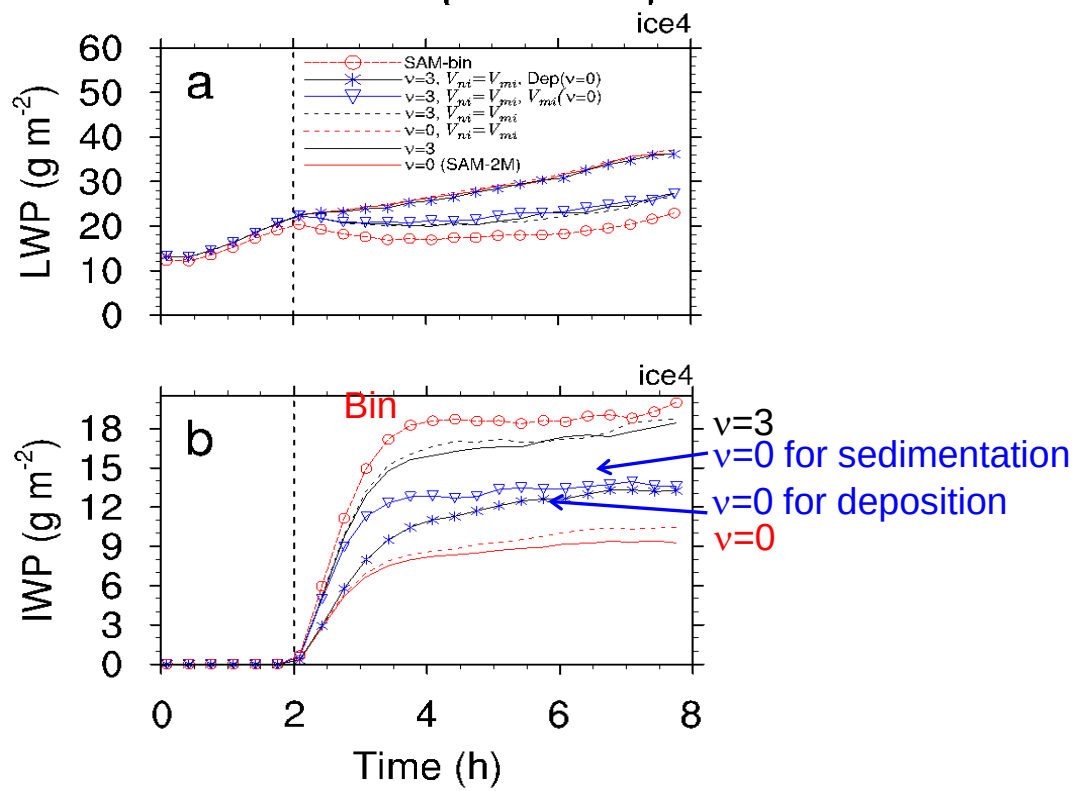
Mass-based distribution $$f_m(m) = A_m \exp\left(-\lambda_m m^{1/3}\right) \quad = A D^2 \exp(-\lambda D)$$

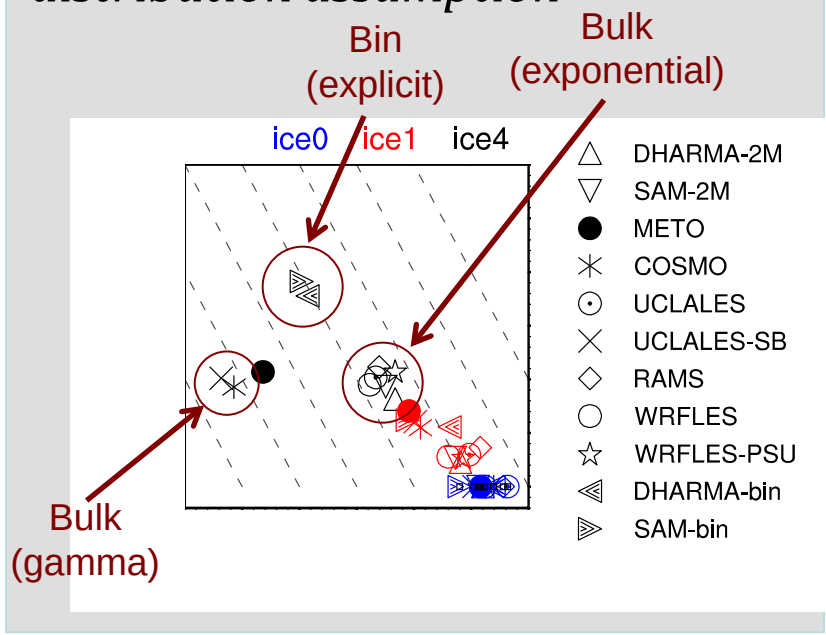
Processes affected by ice PSD shape

- Depositional growth and sublimation
- Sedimentation of mass and number concentrations



ISDAC LES Intercomparison:
Importance of ice size distribution assumptions

Key findings

- Confirmed ***first order importance*** of predicting correct ***liquid phase cloud*** (challenging for GCMs in the Arctic) and ***ice number concentration*** (always challenging) .
- ***Constrained setup*** revealed the ***importance of ice size distribution***
- ***Exponential ice size spectrum*** (a common default assumption in bulk Schemes) ***is too broad*** and can underestimate ice water path by a factor of 2.
- Size distribution effects on both **deposition growth** and **sedimentation** are important

Liquid-to-ice partitioning is a strong function of ice size distribution assumption