Modeling ice-liquid partitioning in mixed phase Arctic stratus

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Indirect Semi-Direct Aerosol Campaign Science questions:

- How do properties of the arctic aerosol during April differ from those measured during the MPACE in October?
- To what extent do the different properties of the arctic aerosol during April produce differences in the microphysical and macrophysical properties of clouds and the surface energy balance?
- To what extent can cloud models and the cloud parameterizations used in climate models simulate the sensitivity of arctic clouds and the surface energy budget to the differences in aerosol between April and October?
- How well can long-term surface-based measurements at the ACRF NSA locale provide retrievals of aerosol, cloud, precipitation, and radiative heating in the Arctic?

Aerosol effects in a mixed phase cloud versus an all liquid cloud:

- Ice – liquid partitioning largely determines mixed phase cloud persistence and properties
- Aerosol affect ice nucleation in addition to droplet nucleation thus affecting ice – liquid partitioning.
- Spatial variability could be more important – ice and liquid are not mixed uniformly in nature but are in many GCMs
- Is model representation adequate for simulating these effects? Does aerosol effect depend on microphysical representation? System for Atmospheric Modeling (SAM; Khairoutdinov et al. 2003) options
  - Single moment scheme (ice-liquid partitioning by temperature)
  - Two moment (Morrison's) scheme (number and mass mixing ratios for droplet and ice particles;
  - Size resolved (bin) microphysics (Khain et al. 2005; Fan et al. 2009)

ISDAC versus M-PACE (spring vs fall)

- Surface conditions are different (more extensive ocean water during M-PACE => larger surface fluxes)
- Cloud dynamics is different (surface flux driven M-PACE clouds, radiatively driven ISDAC)
- Will the responses to changes in aerosol be different?

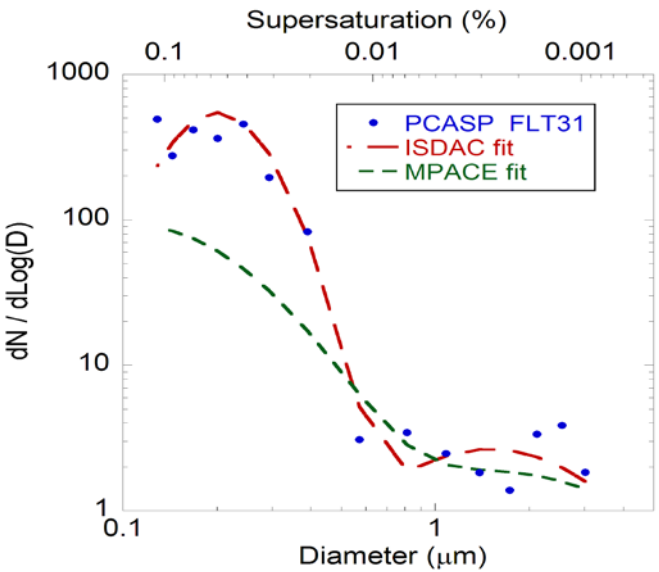
Aerosol properties: ISDAC versus M-PACE

- Aerosol properties are different:

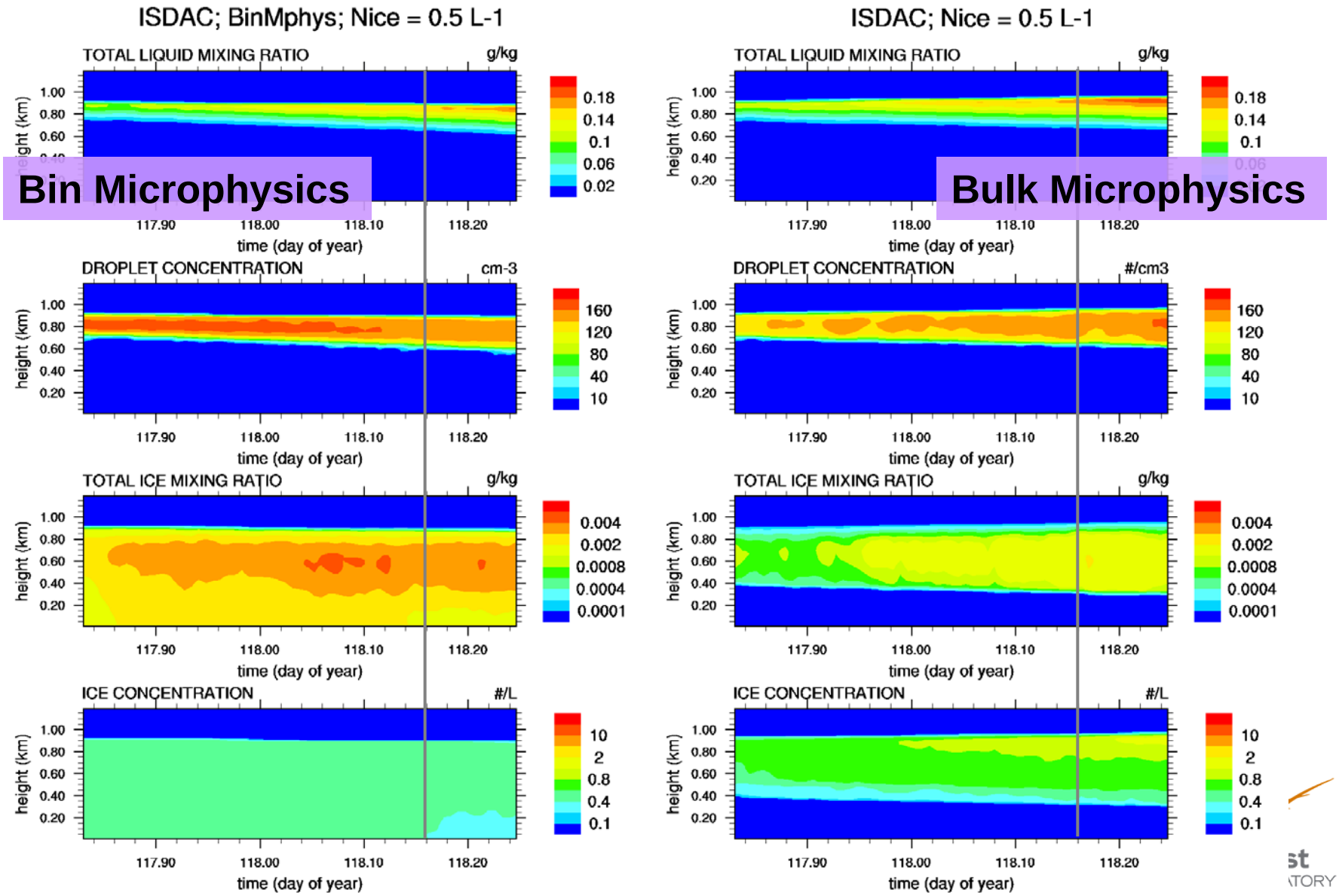
ISDAC cases are more polluted, have higher aerosol and droplet number concentrations but …

could have comparable or lower ice particle concentrations

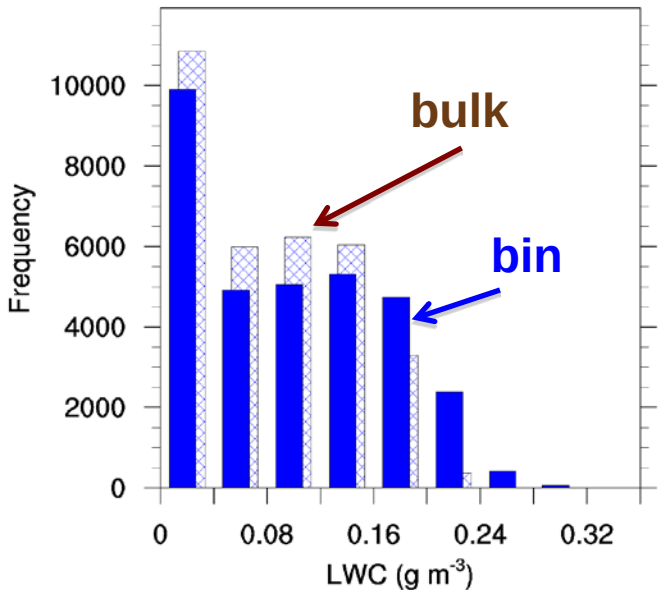
- **<u>Approach:</u>**
- Use fitted lognormal distributions and assumed composition for the CCN
- Constrain ice nucleation mechanisms to reproduce the observed ice particle concentration.

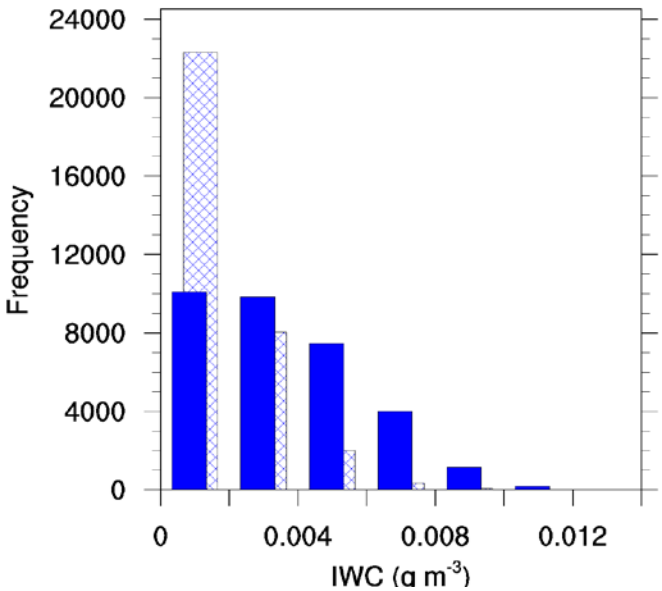


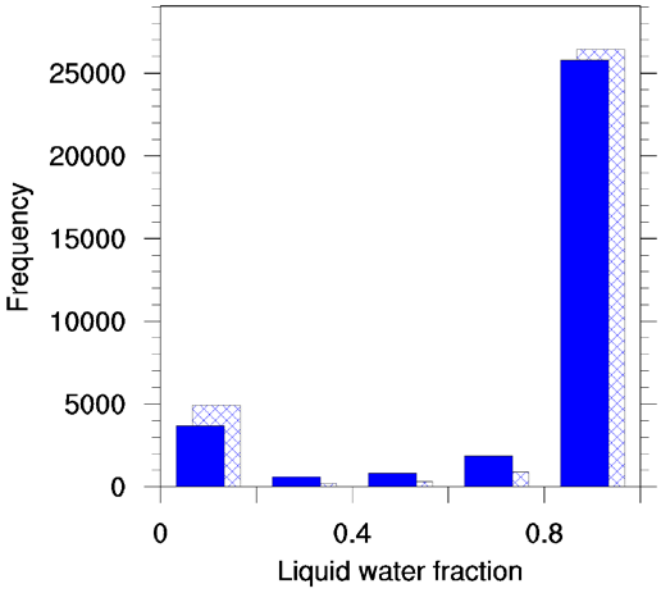
Base runs with bin and bulk microphysics have similar cloud structure

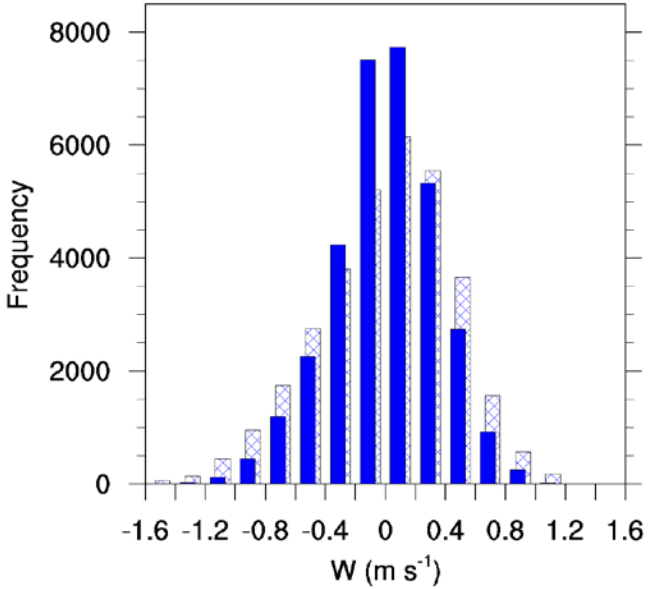


Cloud layer statistics (590 to 790 m)









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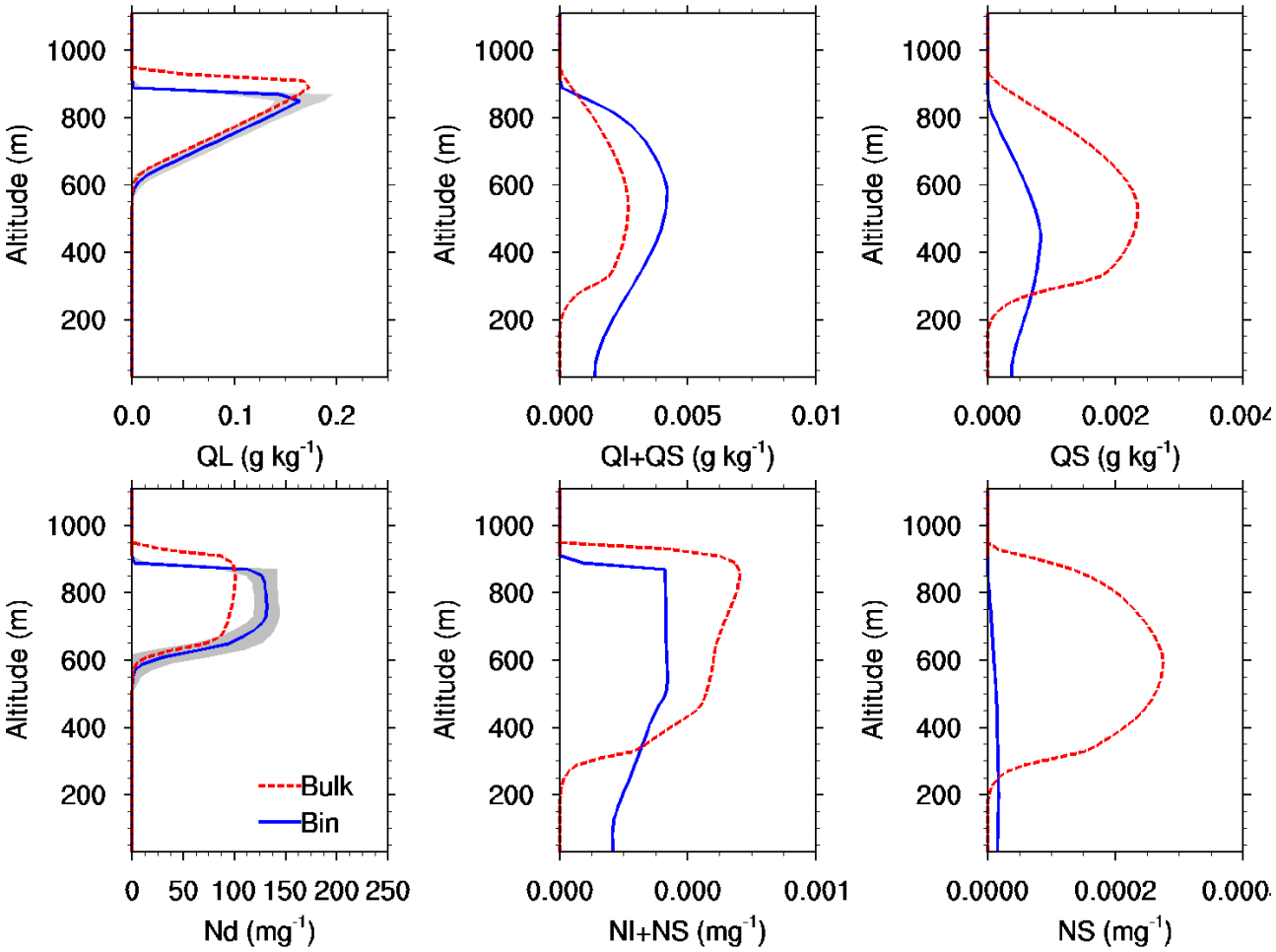
Simulated mean profiles: Bin versus bulk microphysics



liquid **ice + snow** **snow**

- Liquid and frozen water mixing ratios are similar
- Ice – snow partitioning is different

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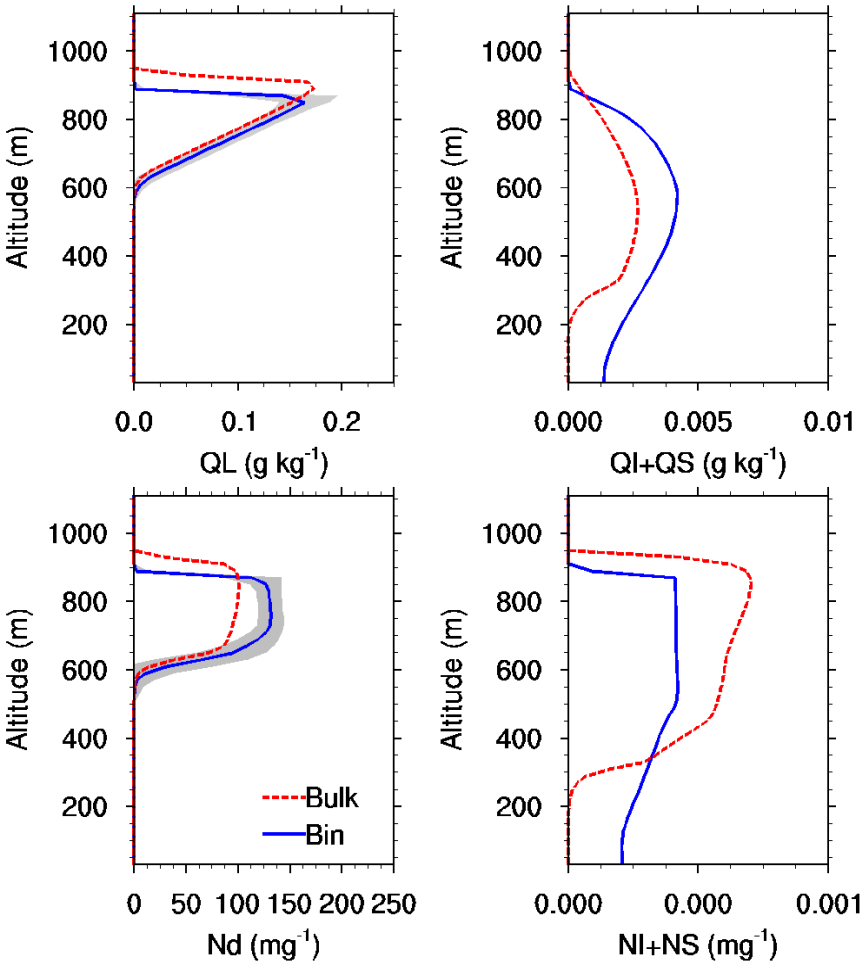
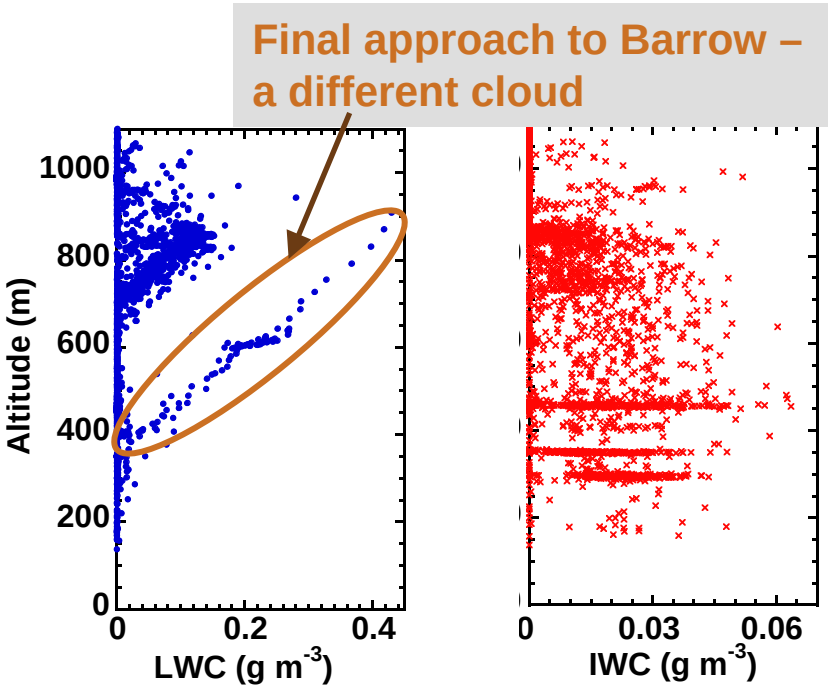
Is modeled cloud structure realistic ?

model



liquid **ice + snow**

observations



- observations show similar vertical structure
- model LWC is slightly higher, IWC is several times lower

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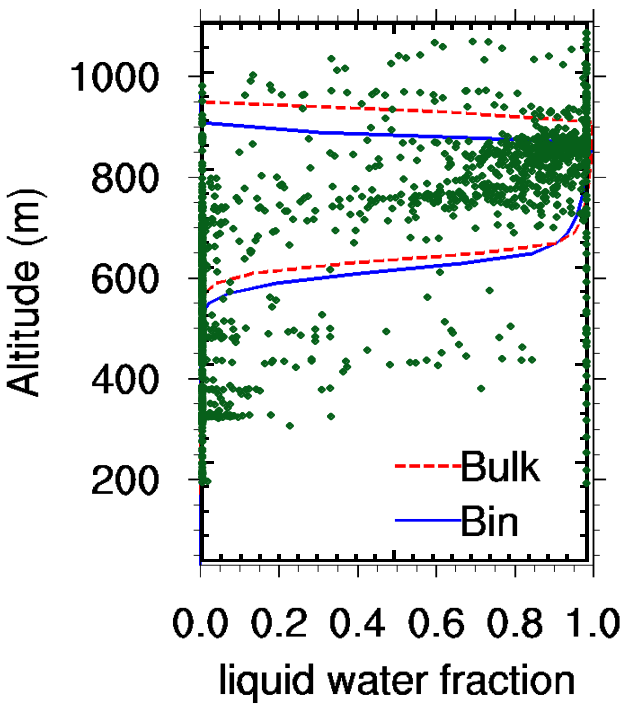
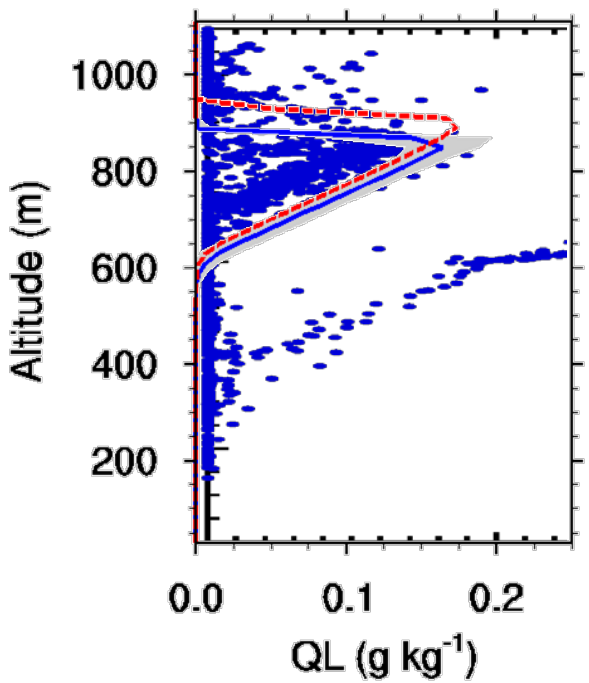
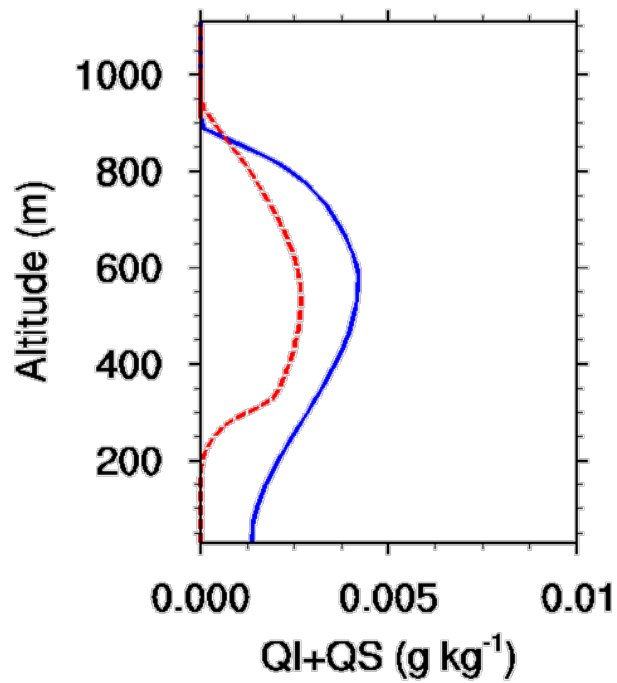
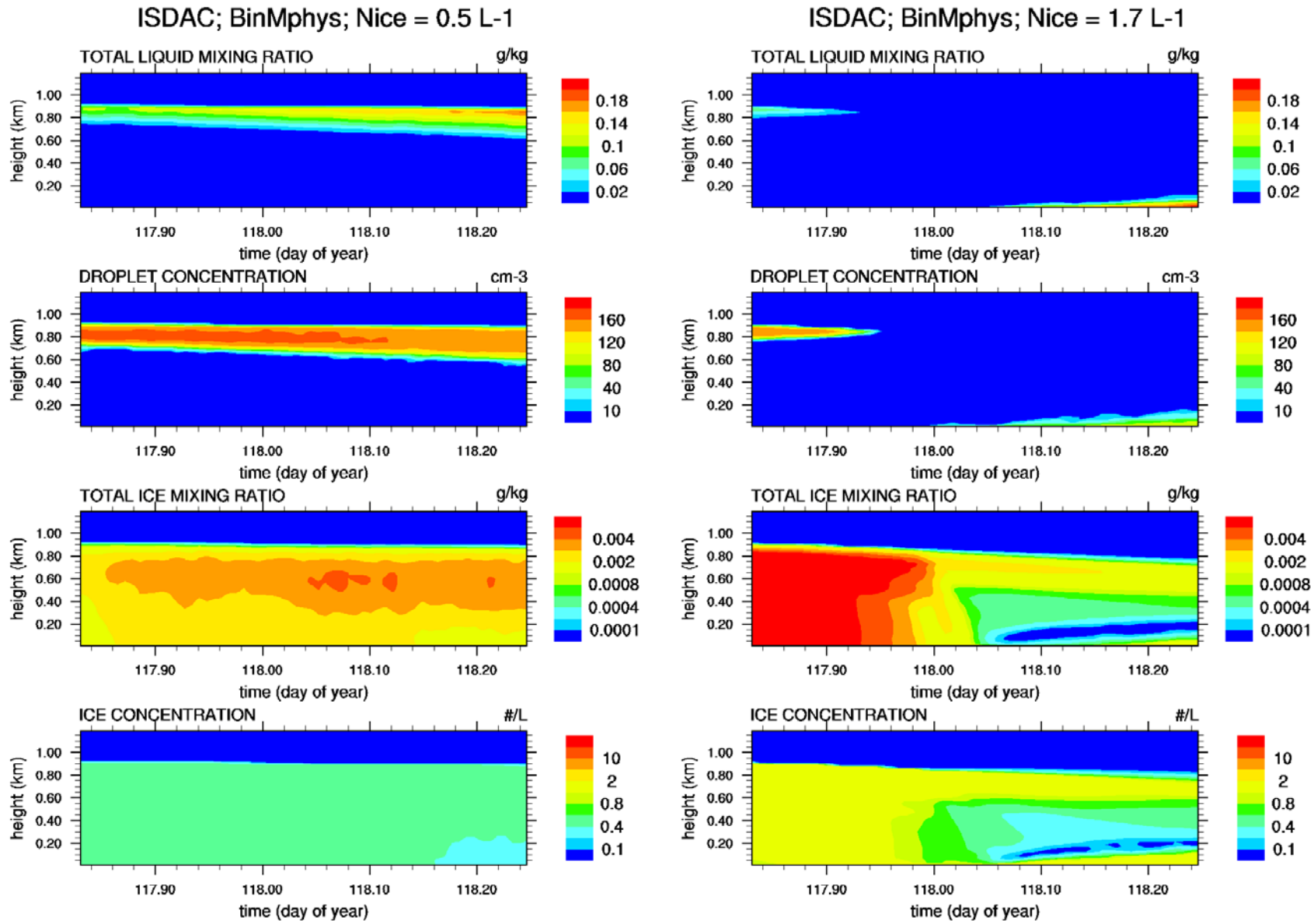
Liquid water fraction



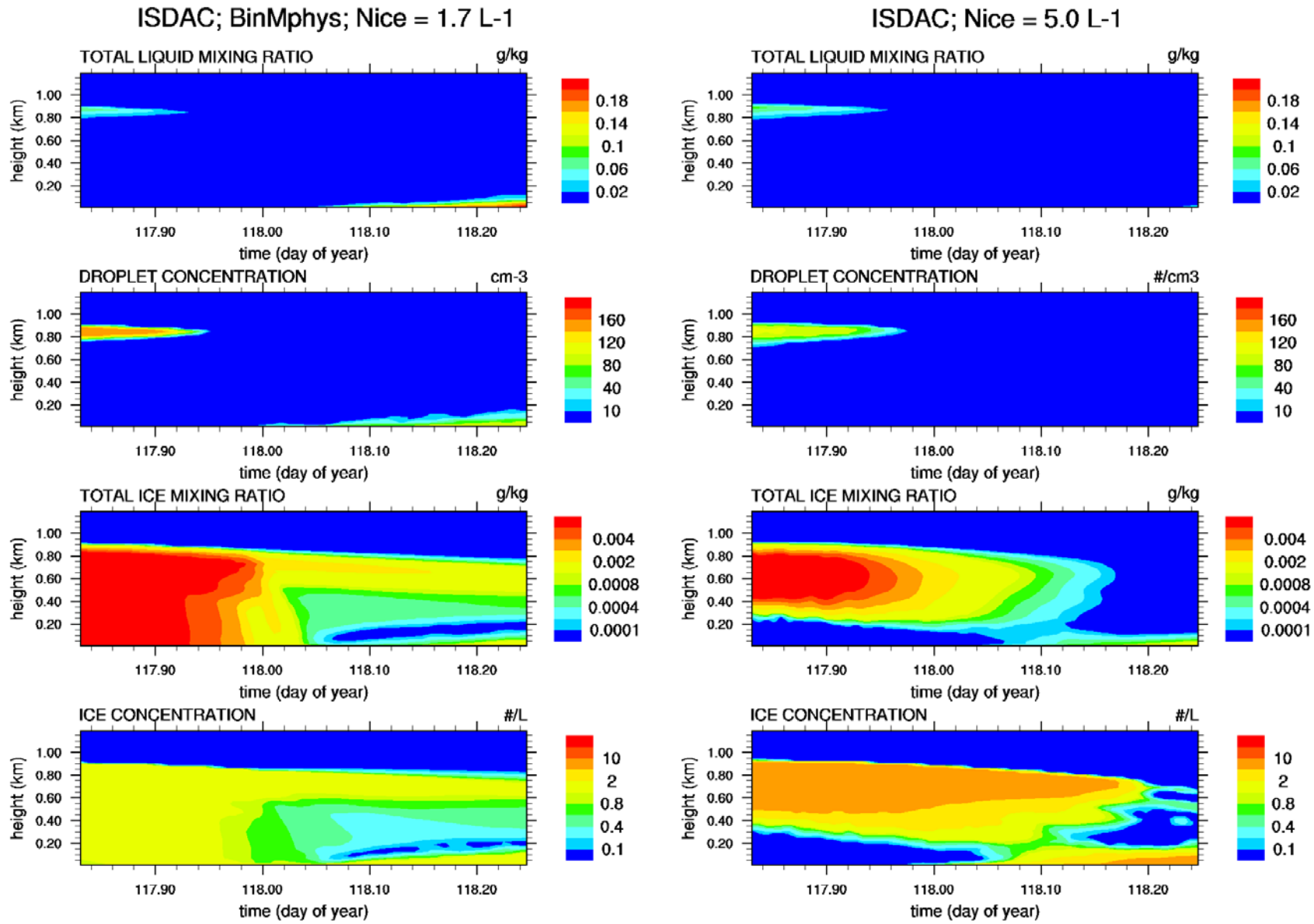




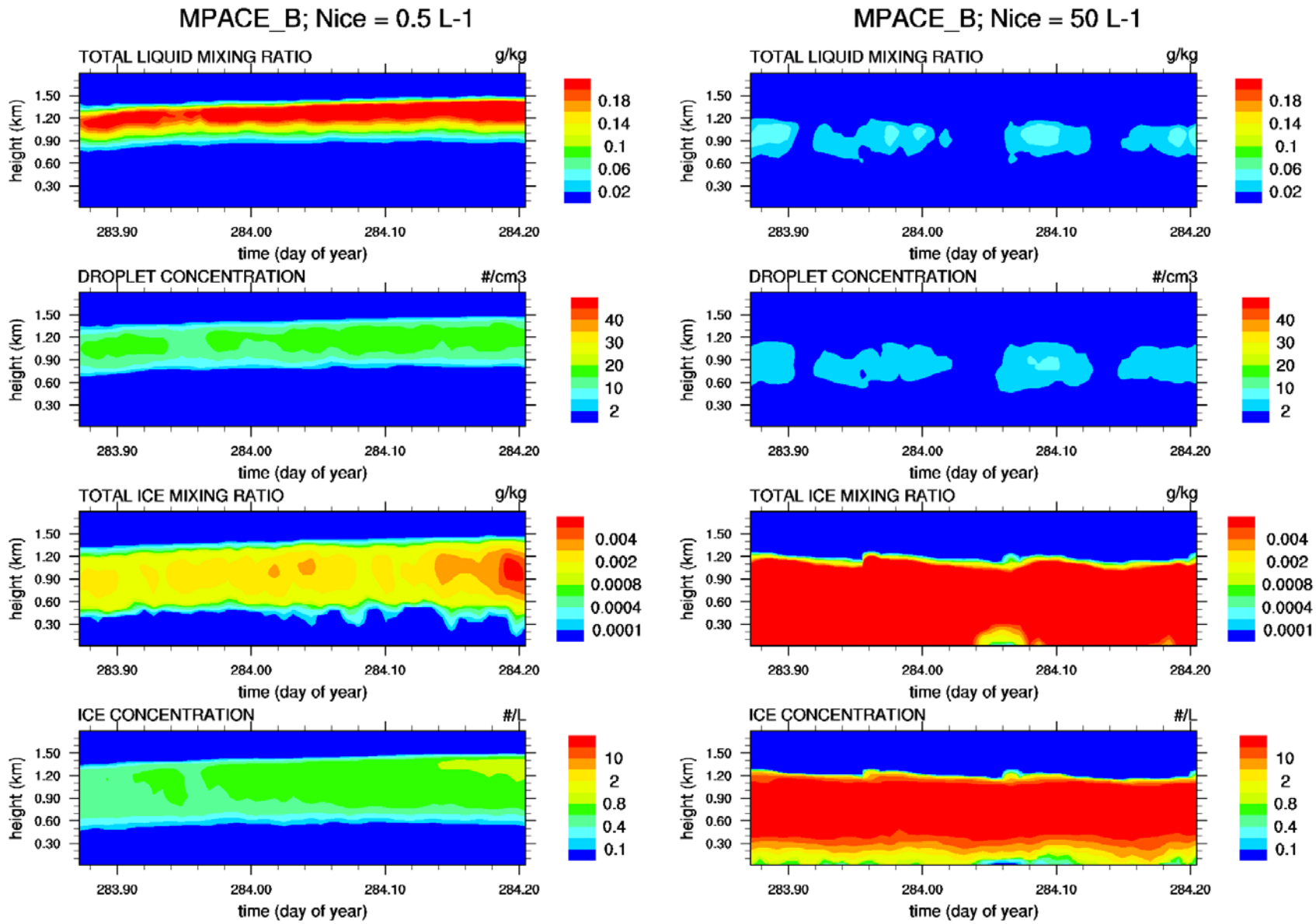
ISDAC April 26
Liquid phase extremely sensitive to ice concentration



Bulk microphysics shows qualitatively similar sensitivity to ice concentration



With strong surface forcing (e.g., MPACE case), cloud is less sensitive to ice concentration



Summary

- Cloud response to changing ice particle concentration depends strongly on cloud type

  Radiatively driven clouds (ISDAC) are more sensitive than those driven largely by surface flux (MPACE)

- While some minimum complexity in microphysics representation is needed, two moment and size resolved (bin) scheme provide qualitatively similar sensitivities to constrained changes in ice particle concentrations.

  Many details are different, however. Are those important?