Constraining Ice Cloud Microphysics Parameterizations in CAM5 Using SPartICus Observations

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Introduction

- Ice clouds play an important role on radiation, water vapor and precipitation.
- There are still large uncertainties in our understanding of ice cloud properties and processes and their treatments (parameterizations) in GCMs.
  - Ice crystal properties: size distribution, number and mass concentration, habit, density, etc.
  - Ice microphysics processes: e.g., autoconversion of cloud ice to snow (one of the most effective knobs in the tuning of GCMs)
- The goal of this study is to evaluate and constrain ice microphysics parameterizations in CAM5 using SPartICus observations.

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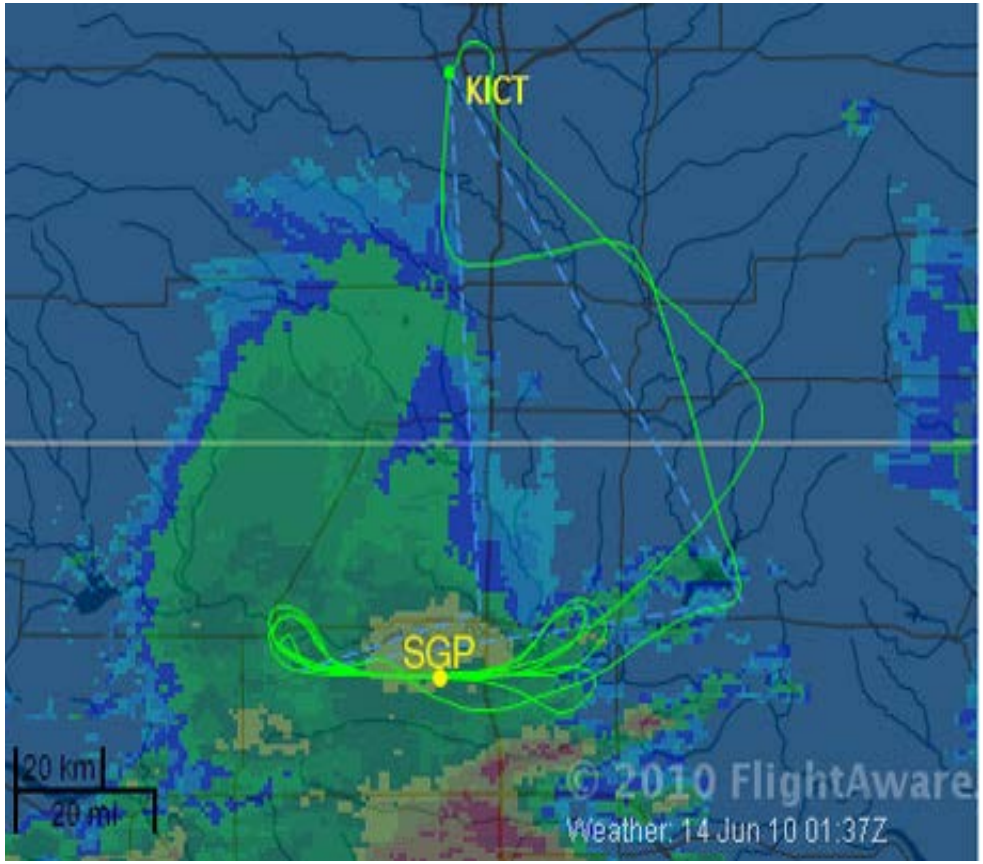
SPartICus: Small Particles In Cirrus Jan-June 2010

Routine aircraft in situ measurements in cirrus over ARM SGP and along NASA A-Train orbit

- Evaluate modeled statistics of Ni, IWC, RH, etc.
- Constrain the formation mechanism of ice crystals
- Constrain the aggregational growth of ice crystals



Anvil Investigation over the ARM SGP on 14 June 2010

new generation of probes designed to minimize artifacts due to ice shattering; relatively long-term statistics (~150 hours)

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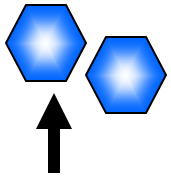
Cloud Microphysics Scheme in CAM5

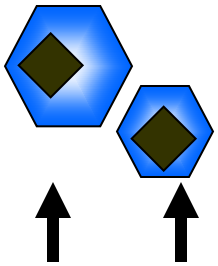
Morrison & Gettelman 2008; Gettelman et al. 2010

- Two-moment stratiform microphysics
  - Prognostic '*cloud mass*' and '*cloud droplet number*' (Γ-function size distributions)
  - Diagnostic 'precipitation mass' and 'precipitation droplet number'
  - Droplet and ice nucleation links to aerosols
  - Ice supersaturation and explicit vapor deposition
  - Other ice microphysics processes: autoconversion, accretion, sedimentation, sublimation, melting, etc.

Cirrus (Ice) Ice Nucleation

Ice Crystal Population





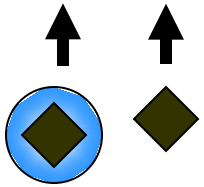
Homogeneous Freezing

Mainly depends on RH_i and T

Heterogeneous Freezing (Immersion, deposition, …)

Also depends on the material and surface area

Wet aerosol particles



+ Insoluble Material ("Ice Nuclei")

Multiple mechanisms for ice formation can be active.

Courtesy of Barahana & Nenes

Ice Nucleation Parameterizations in CAM5

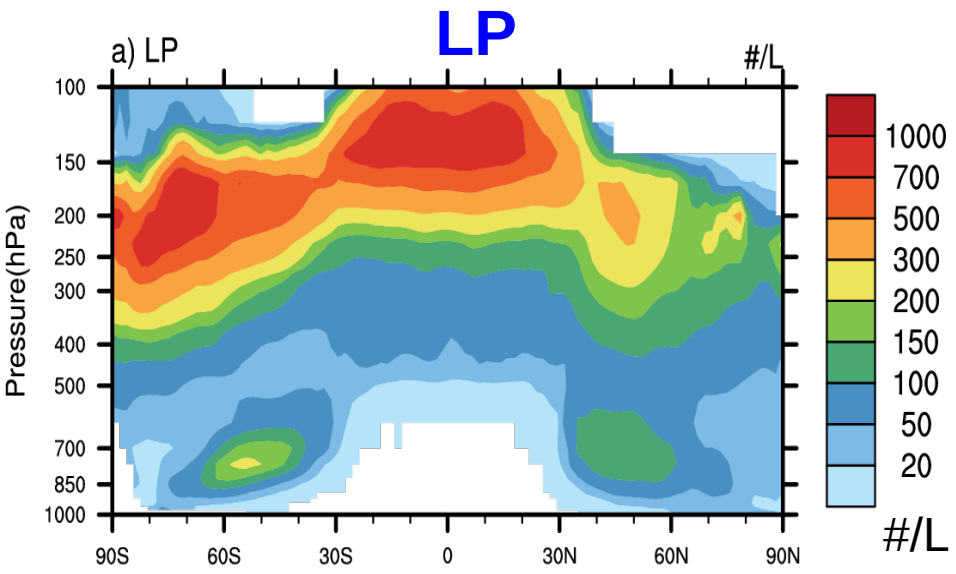
- *Liu and Penner (2005)*: consider the competition between homogeneous (HOM) and heterogeneous nucleation (HET) (hereafter **LP**).

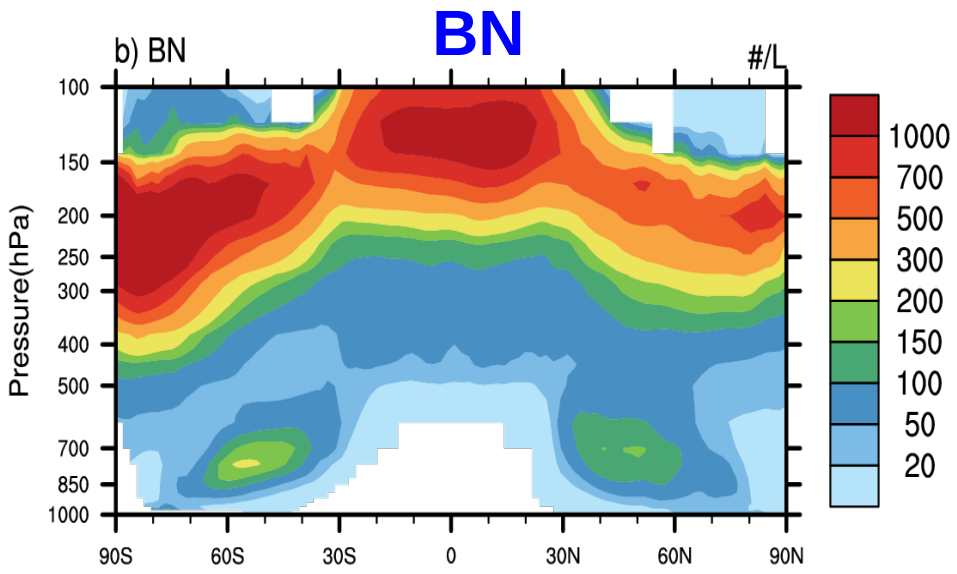
  LP-HET uses classical nucleation theory (CNT)

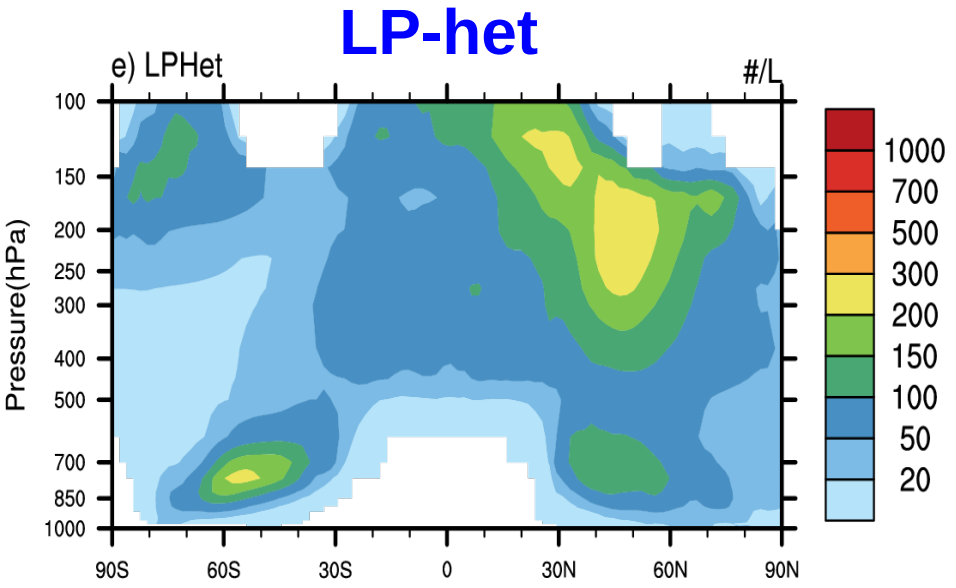
- *Barahona and Nenes (2009a,b)*: develop a framework that can use different heterogeneous ice nuclei (IN) spectra (CFDC measured IN; CNT), and consider the competition of HOM and HET (hereafter **BN**).

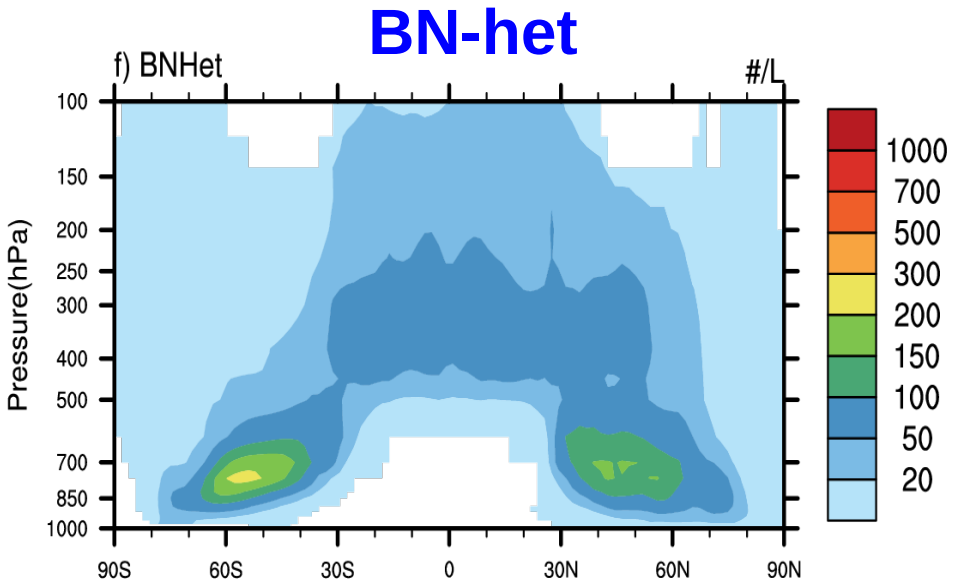
  BN-HET uses Phillips et al. (2008) from CSU CFDC

Comparison between LP and BN scheme

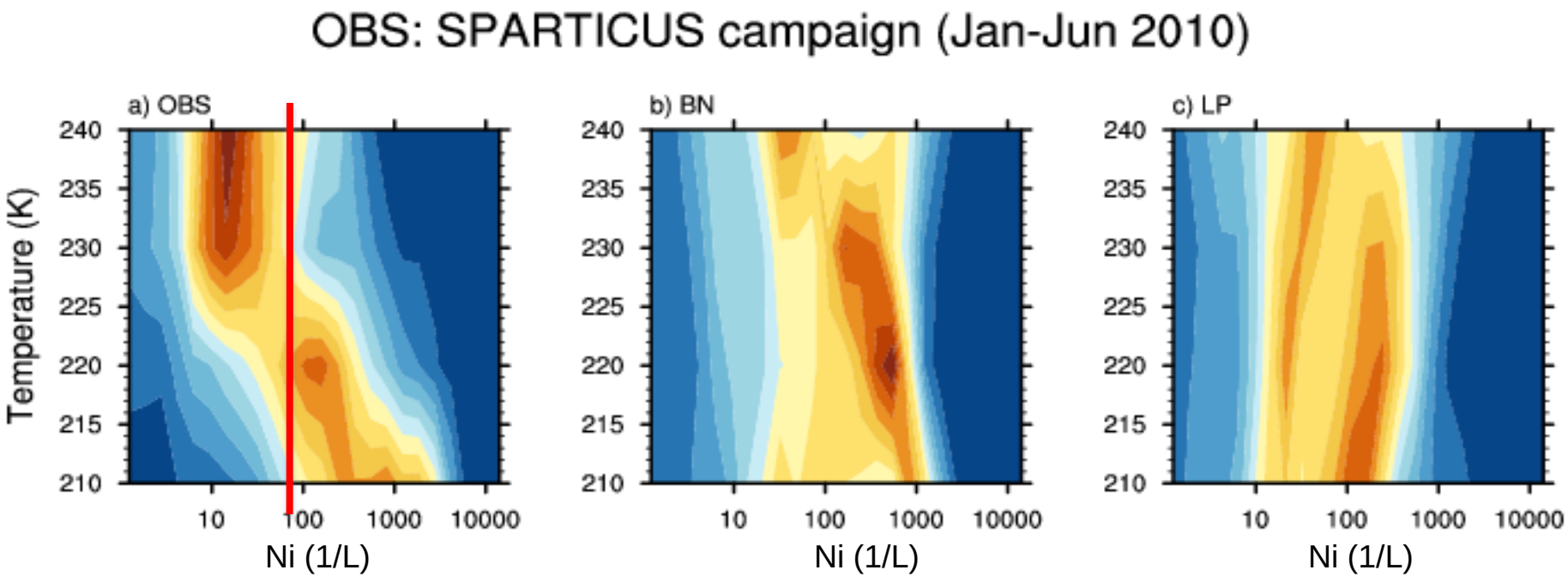








bi-PDF (Ni,T)

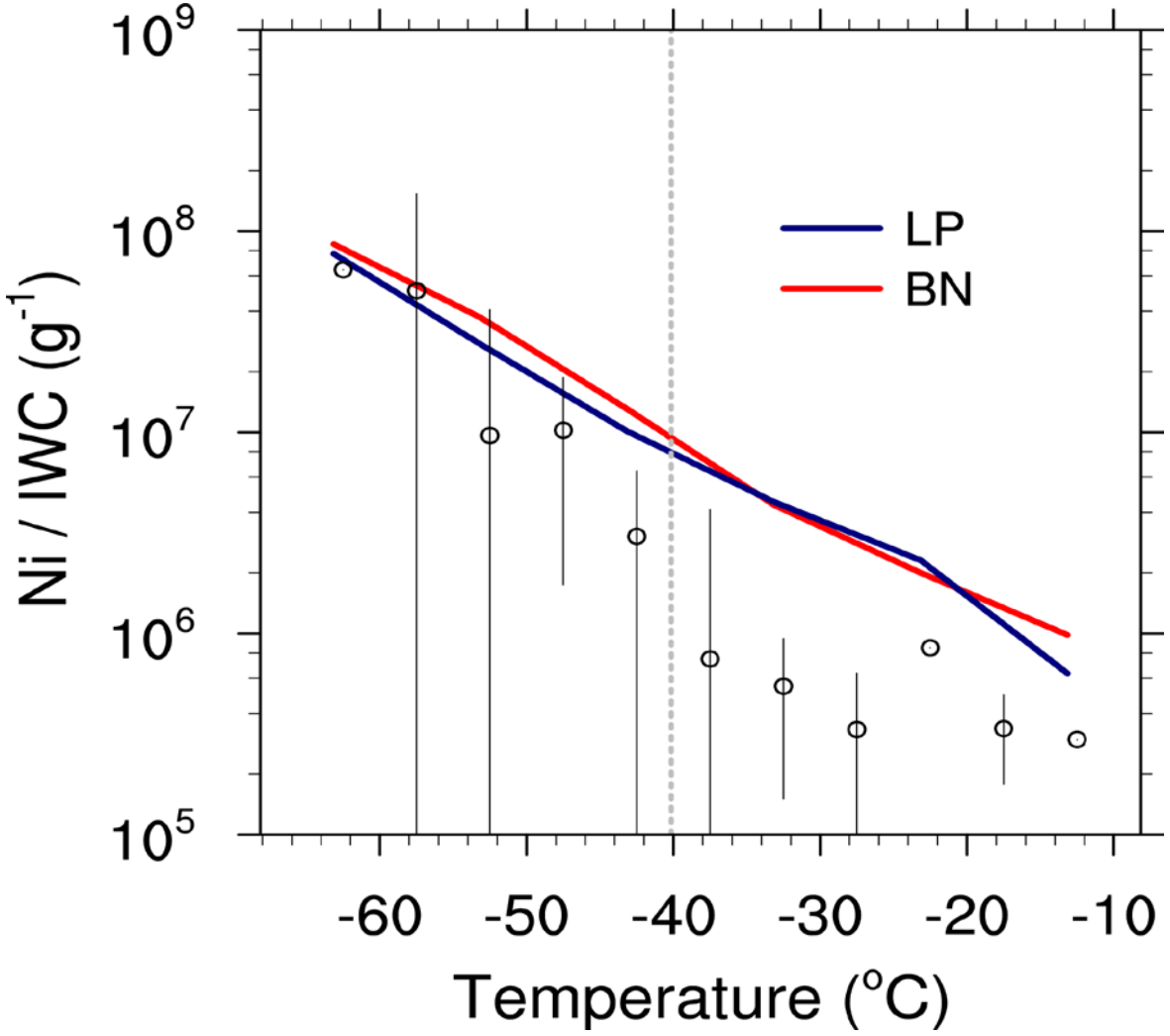


Obs **BN** **LP**

Instantaneous model output at every 3 hrs over SGP site from Jan-June

BN : Dominated by homogeneous nucleation
LP : Heterogeneous nucleation important

N_i / IWC vs. Temperature



CAM5 : removed mixed-phase clouds and anvil clouds;

Add snow in CAM5

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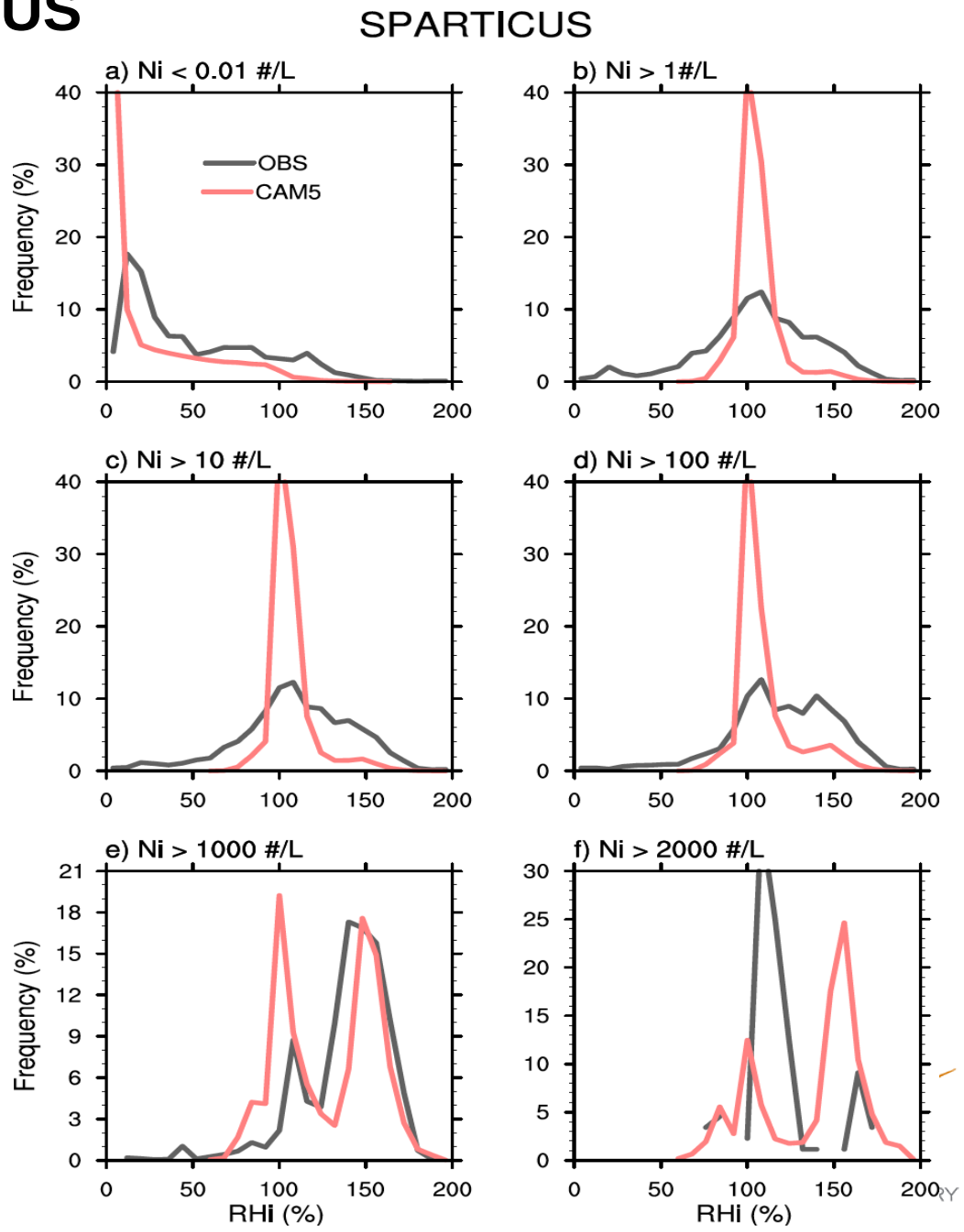
RHi PDF during SPARTICUS

Simulated RHi peaks at 100% with smaller standard deviation

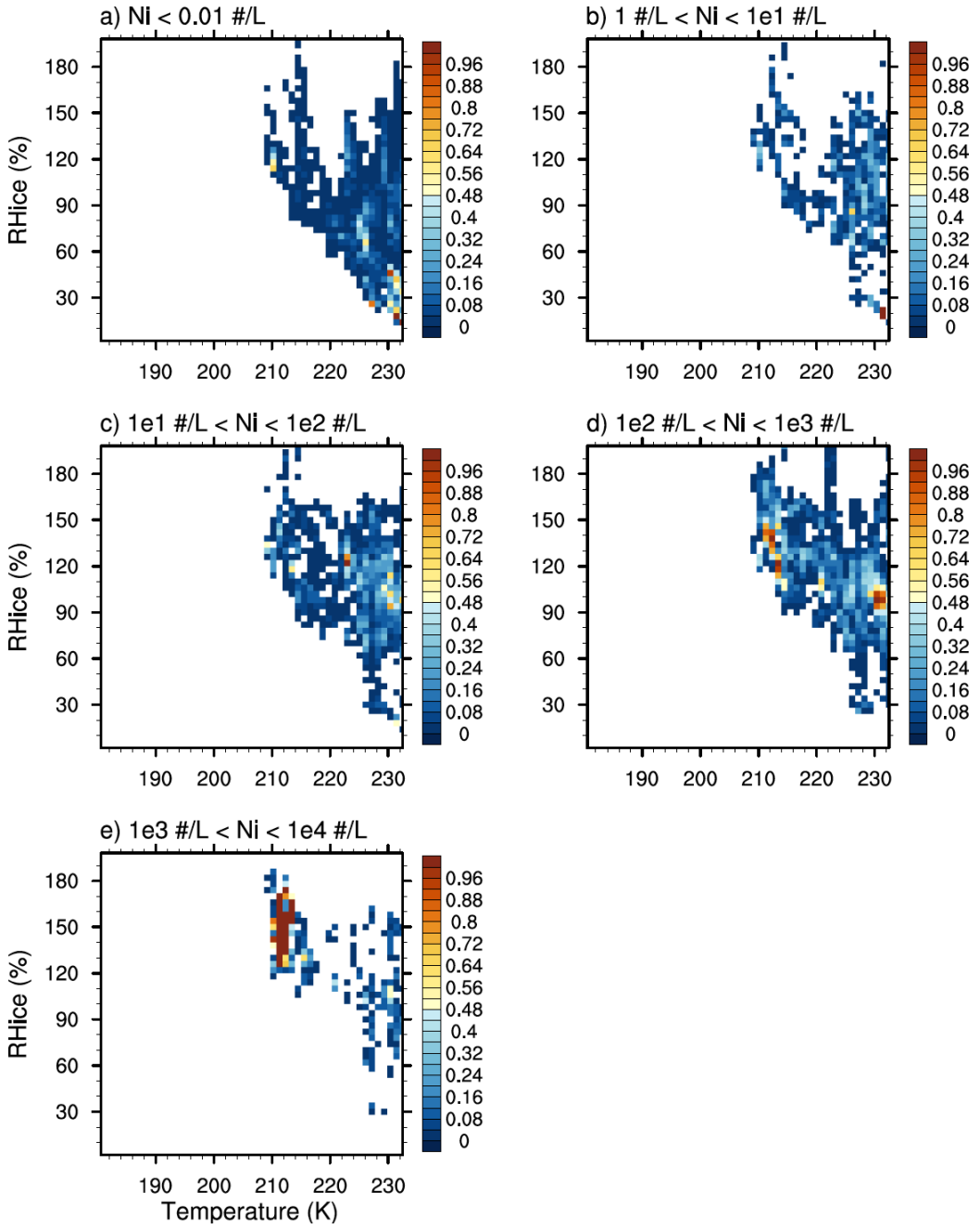
Very high supersaturation when Ni > 1000 #/L in both OBS and CAM5

OBS data from DRH from January to June 2010

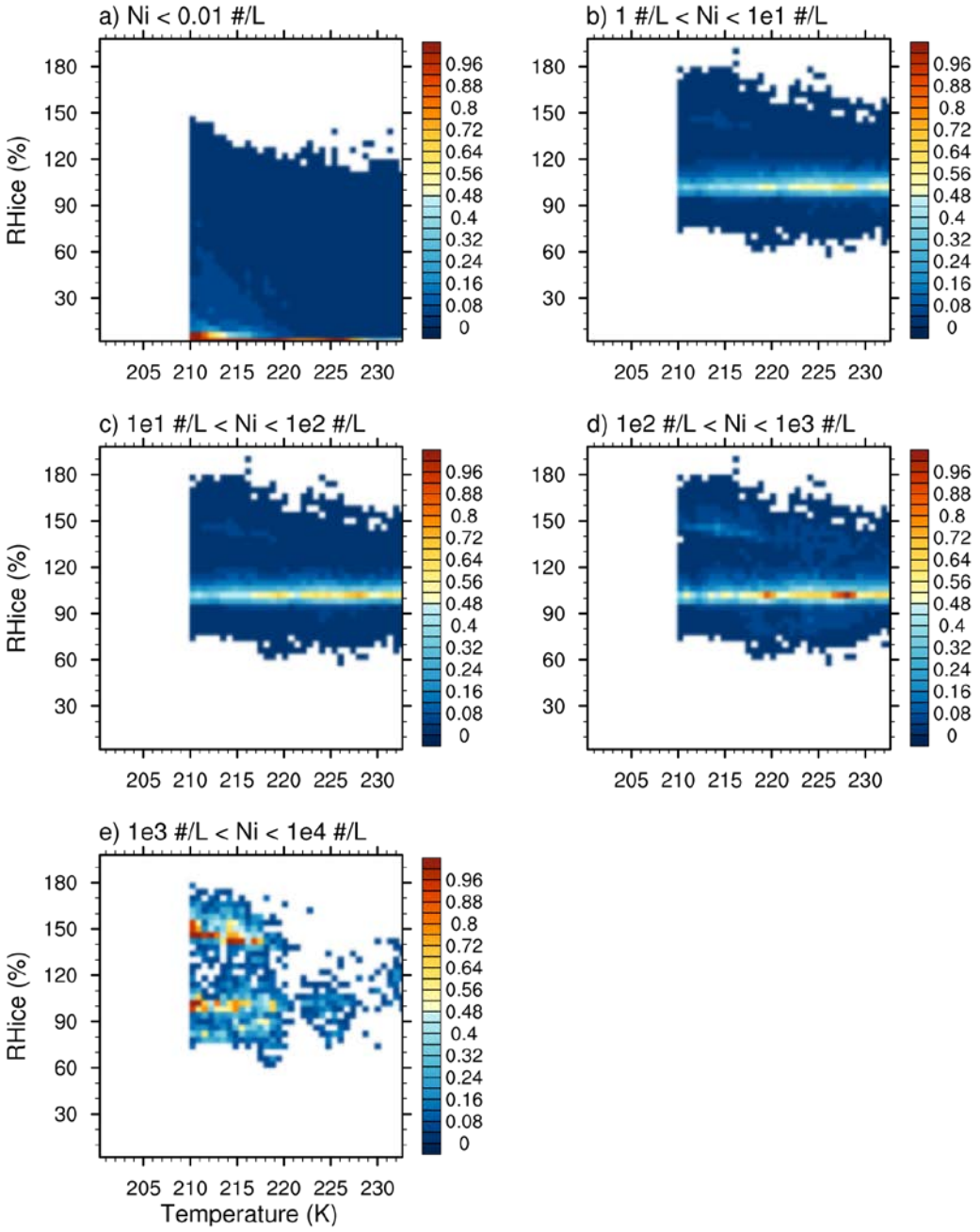


SPARTICUS OBS

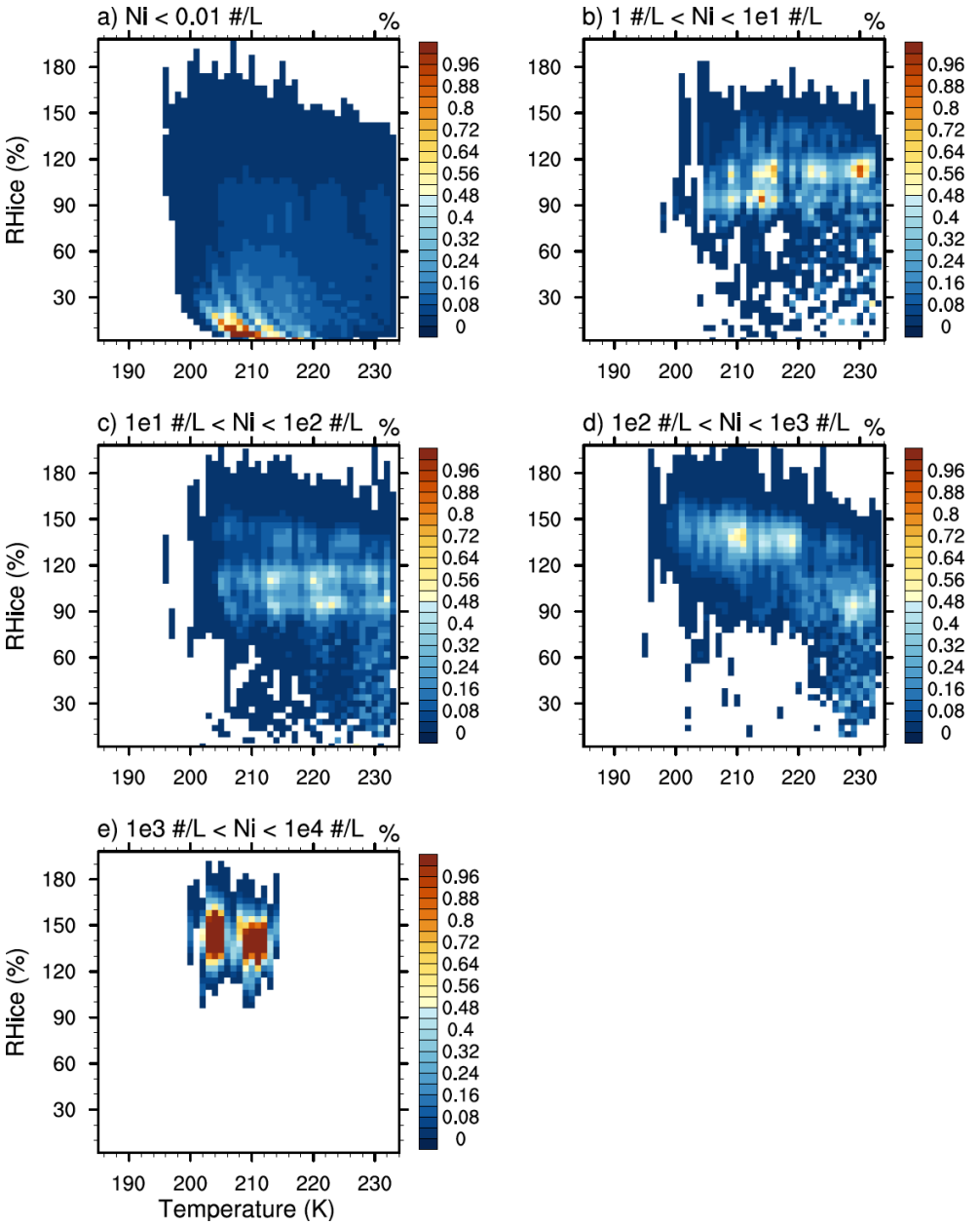
bi-PDF (RHi and T)



SPARTICUS
CAM5



SPARTICUS CAM5 - with a statistical cirrus macrophysics scheme (Karcher and Burkhardt 2008) and coupled with microphysics

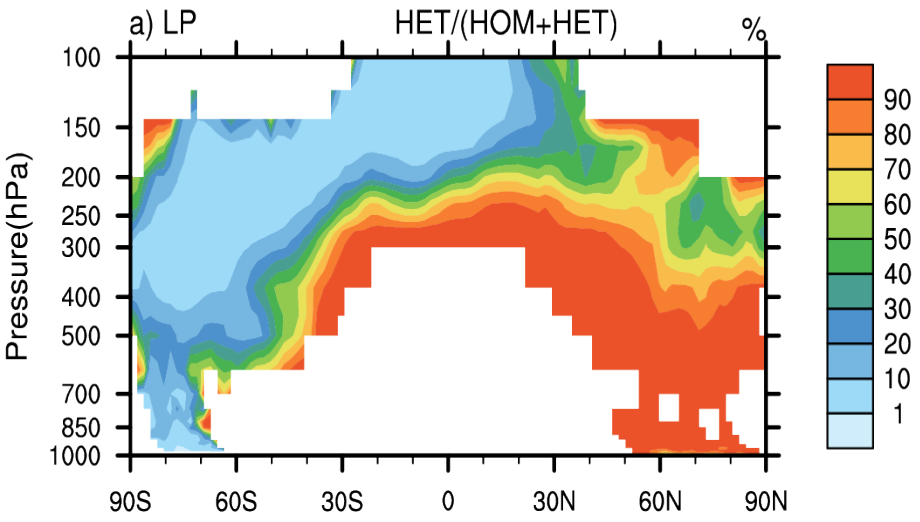


Summary

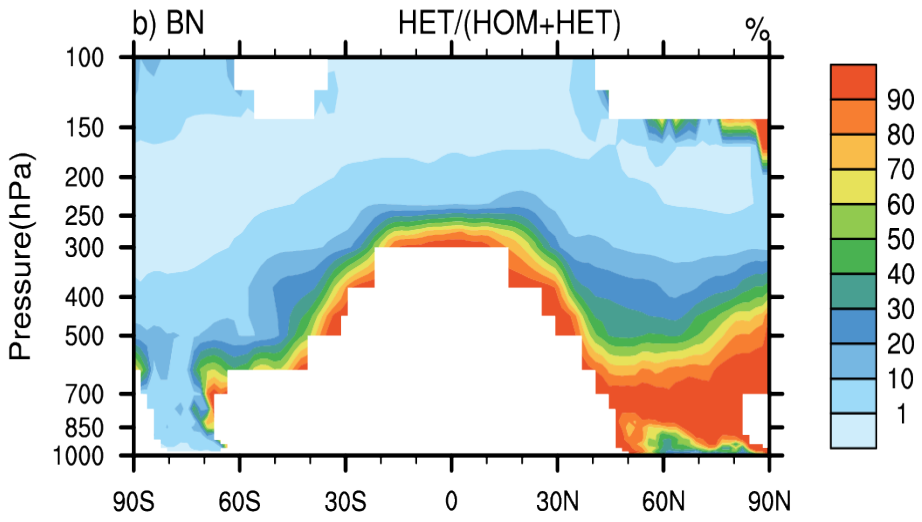
- Homogeneous nucleation may dominate ice nucleation in cirrus clouds at T < -40 C over SGP site during the SPartICus.
- CAM5 reproduces some statistical features of Ni vs T, Ni/IWC vs. T, RHi-PDF observed during the SPartICus. However, it
  - Underestimates frequency of occurrence of low Ni (<30/L)
  - Ni and Ni/IWC are too high at T > -40 C
  - In-cloud RHi-PDF too narrow
- Future work with CAM5:
  - Improve the aggregational growth of ice crystals
  - Evaluate statistical cirrus macrophysics scheme in CAM5

Comparison between LP and BN scheme

LP



BN



Relative contribution of Ni from homogeneous and heterogeneous nucleation in the combined case (LP and BN)