AMS Cloud physics - 234

Advanced Study Program — Developing Scientific Leaders of the Future — NCAR

Hemispheric comparison of cirrus cloud evolution using in situ measurements in HIAPER Pole-to-Pole Observations

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• Cirrus cloud and ice supersaturation

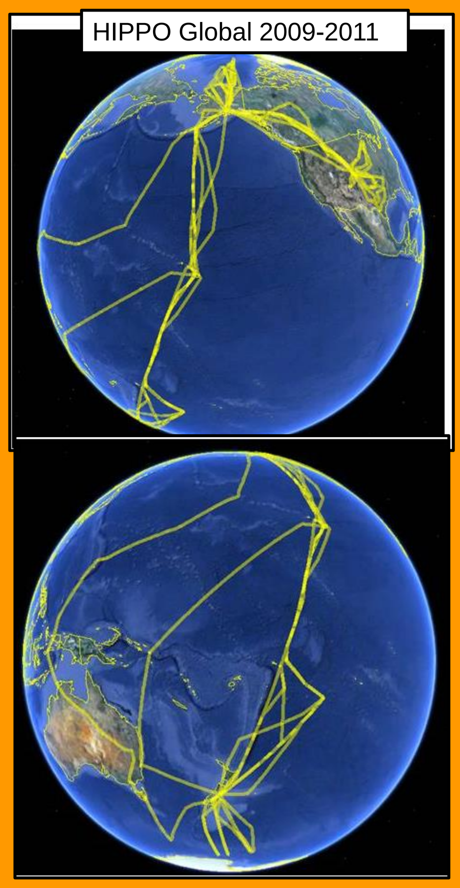
Cirrus clouds have large but highly uncertain impacts on Earth's climate [*Chen et al. 2000*]. However, due to lack of datasets with both microscale resolution and global coverage, it is unclear if hemispheric differences exist in cirrus cloud microphysical properties and their evolution. Here we compare the time evolution of cirrus clouds' horizontal segments: ice crystal regions (ICRs) and ice supersaturated regions (ISSRs) at temperature (T) ≤ - 40 °C and show different result with previous studies.

VCSEL hygrometer on the NSF Gulfstream V research plane

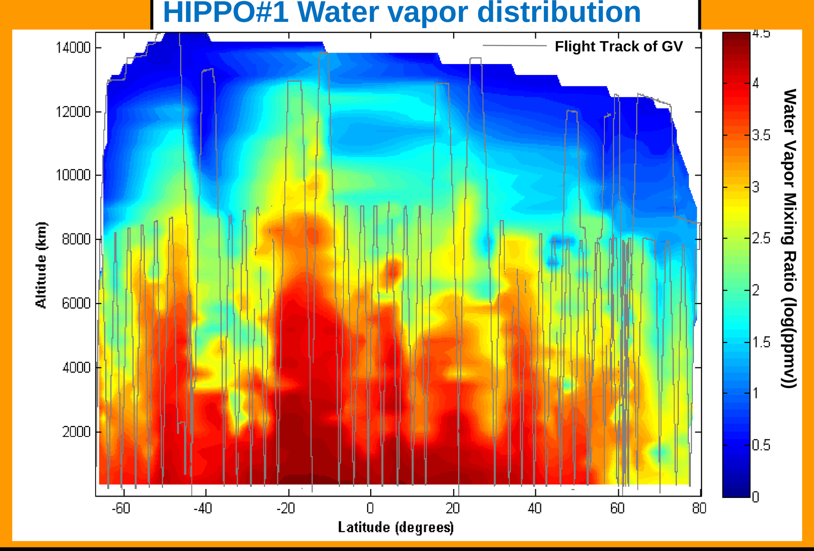
HIAPER Pole-to-Pole Observations (HIPPO) Global campaign (2009-2011)

Latitudinal: 87°N to 67°S
Vertical: ~600 transects from surface to the upper troposphere and lower stratosphere (UT/LS)
Resolution: ~200 m
Duration: HIPPO ~400 hr
Here HIPPO deployment #2 – 5 are used, with ice crystal measurements.

HIPPO Global 2009-2011



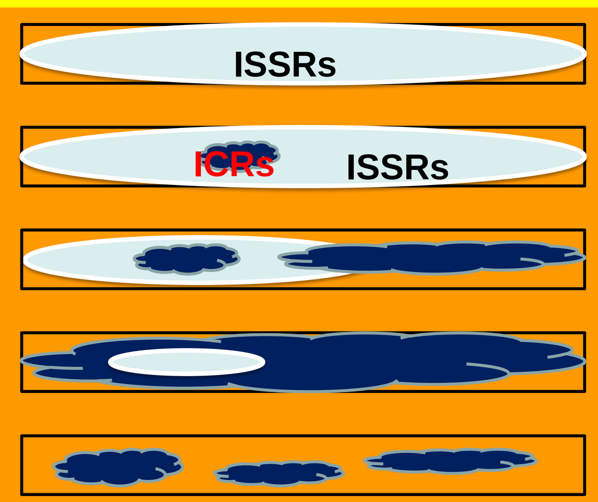
HIPPO#1 Water vapor distribution



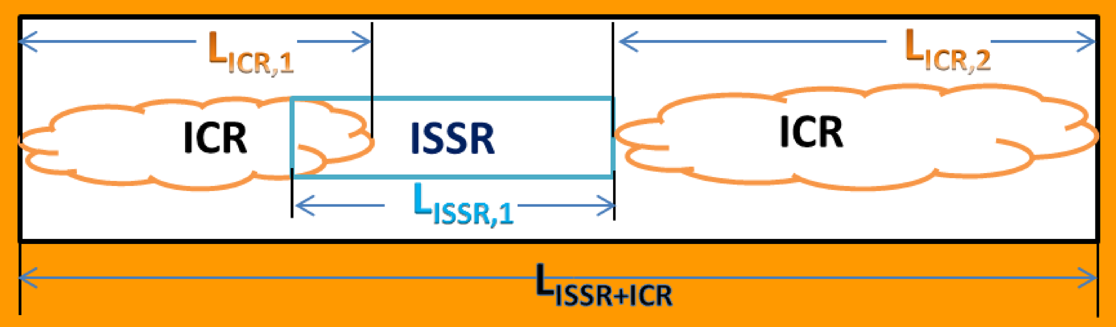
GV instruments	Measurement	Accuracy	Precision
VCSEL hygrometer	Water vapor (Zondlo et al., 2010)	6%	≤ 1%
2-DC	Ice particle number density (Nc) and mean diameter (Dc)	Measurement range: 25-1600 μm (Korolev et al., 2011)	

• Definitions of ice crystal regions (ICRs) and ice supersaturated regions (ISSRs)

Phase 1: Clear-sky ISSRs
Phase 2: Ice crystal nucleation
Phase 3: Ice crystal early growth
Phase 4: Ice crystal later growth
Phase 5: Sedimentation/evaporation



one ISSR + ICR sample



References:

[1] Diao, M., Zondlo, M. A., Heymsfield, and A. J., Beaton. Hemispheric comparison of cirrus cloud evolution using in situ measurements in HIAPER Pole-to-Pole Observations. Geophysical Research Letters, 41, 10.1002/2014GL059873, 2014.

[2] Diao, M., Zondlo, M. A., Heymsfield, A. J., Beaton, S. P. and Rogers, D. C.: Evolution of ice crystal regions on the microscale based on in situ observations, Geophysical Research Letters, 40, 3473-3478, doi:10.1002/grl.50665, 2013.

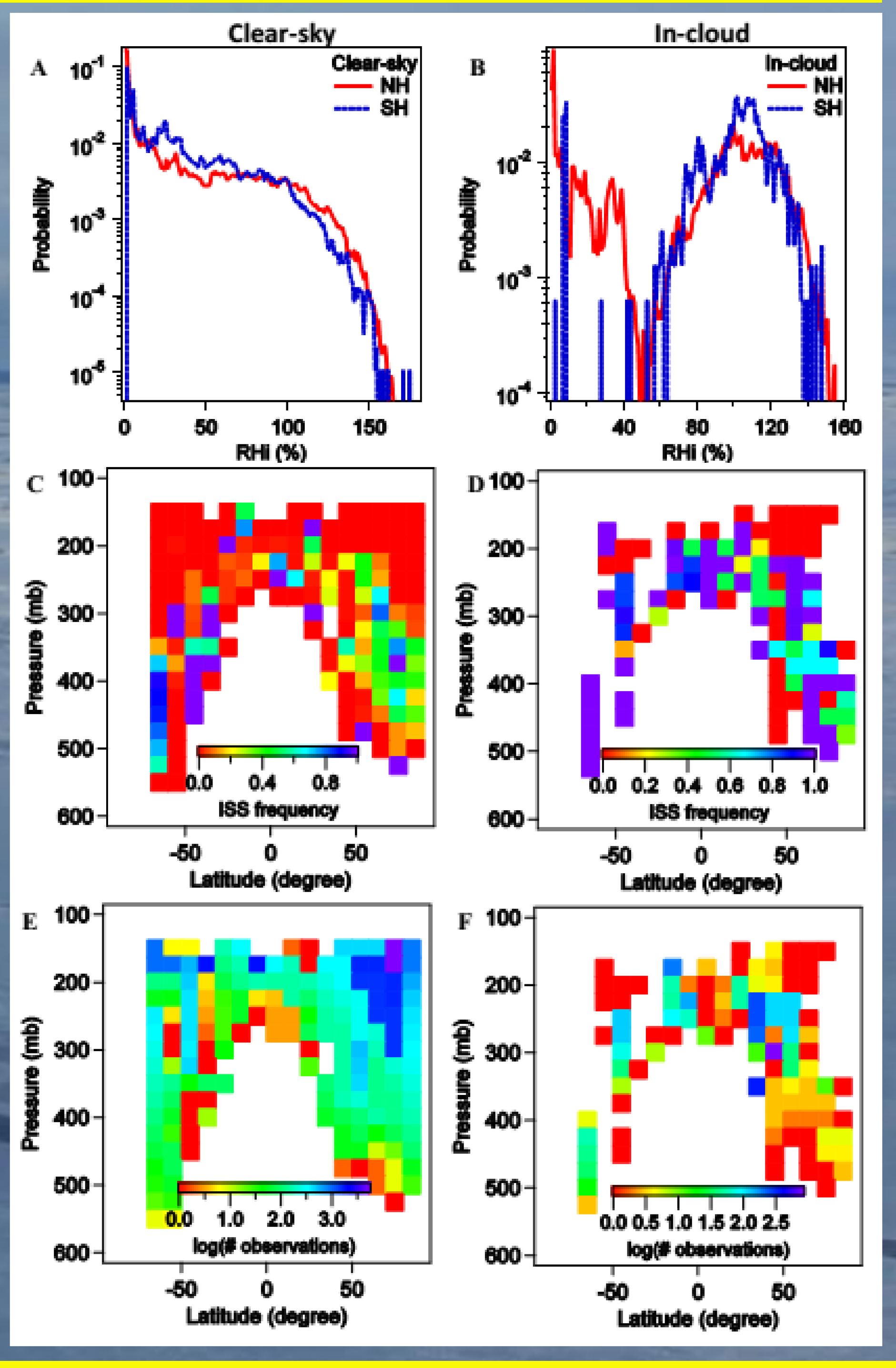
[3] Diao, M. Zondlo, M. A., Heymsfield, A. J., Avallone, L. M., Paige, M. E., Beaton, S. P., Campos, T. and Rogers, D. C. Cloud-scale ice supersaturated regions spatially correlate with high water vapor heterogeneities. *Atmos. Chem. Phys. Discuss*., 13, 22249–22296, 2013.

• Ice supersaturation frequency in the Northern and Southern Hemispheres

Probability distribution of ISS in clear-sky (left) and in-cloud (right)

ISS frequency 25 mb×10° grids

Total number of observations

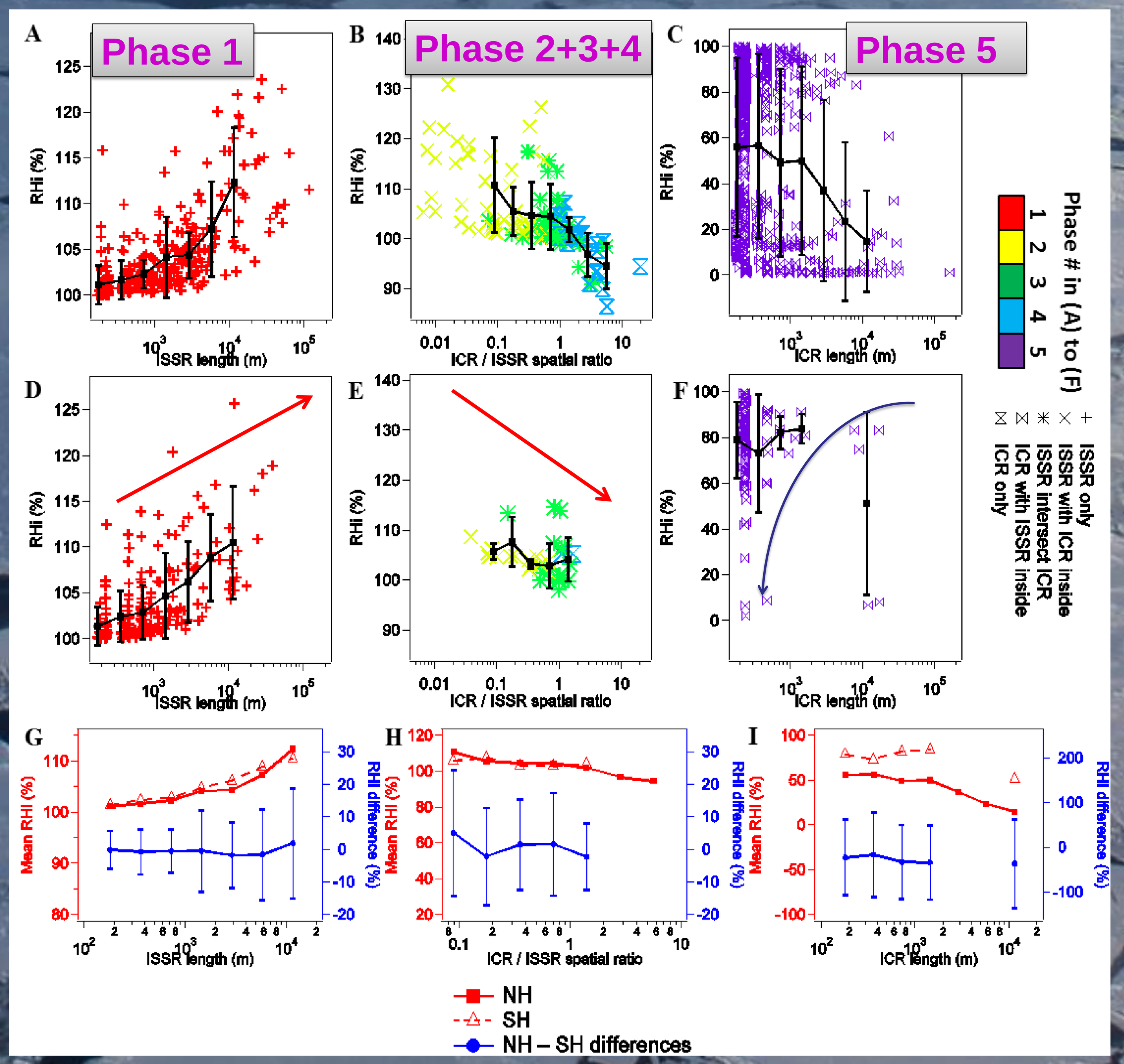


• Hemispheric comparison of RHi evolution

NH

SH

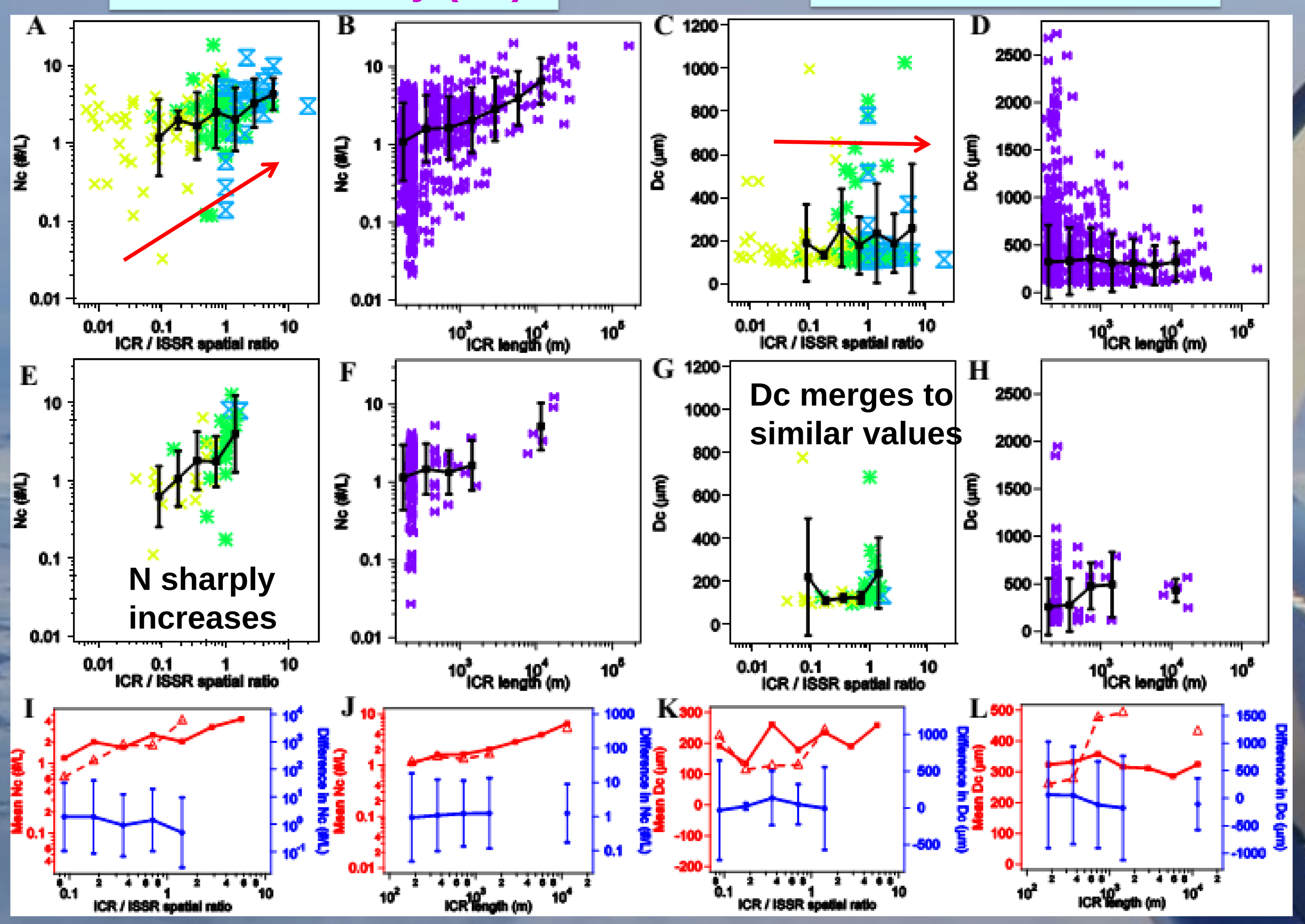
NH – SH *d*RHi and 95% interval



• Ice crystal number density (Nc) and mean diameter (Dc) evolution

Number density (Nc)

Mean diameter (Dc)

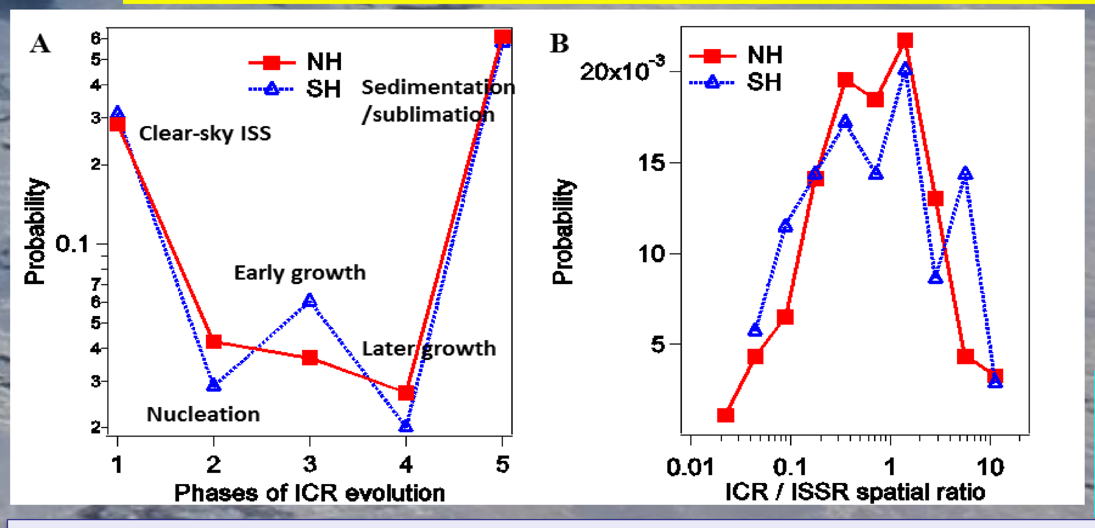


Growth rate of a single ice crystal

$$\frac{dD_{ice}}{dt} = \frac{1}{D_{ice}}(S_{v,out} - S_{v,eq}) * G_i(T,P)$$

Both NH and SH show: [1] ice crystal number density continues to increase throughout the growth of ICRs; [2] mean diameter of ice crystals merging into a constant value as ice crystals grow, which agrees with the theory of ice crystal growth rate.

Relative lifetime of five phases for ISSR+ICR



Percentage of each phases	NH	SH
Clear-sky ISS	28%	31%
Coexisting ISSR+ICR	11%	11%
Subsaturated ICRs	61%	58%

Comparable to previous simulations of 30%, 10% and 60% (Spichtinger and Gierens, 2009).

Conclusions:

1. Similar clear-sky ISS frequencies were observed in the NH and SH, as well as similar mean RHi, Nc and Dc along the five-phase evolution of ISSRs and ICRs.
2. Similar relative timescale of each of five phases between the NH and SH.
3. This result is different from the observations of *Ovarlez et al.* [2002] which showed that the clear-sky ISS frequency is higher in the SH than NH.

Implications to understanding hemispheric differences in cirrus cloud formation and evolution

1. Hemispheric comparisons are sensitive to the sampling domain and resolution (Kahn *et al*. 2009), which points out the importance of additional in situ observations across large longitudinal and latitudinal domains.
2. Even though the aerosol optical depth in the SH is ~1 order of magnitude smaller than that in the NH (Clarke and Kapustin, 2010), no strong hemispheric differences were observed HIPPO. Question: whether the hemispheric differences in aerosol loading would directly influence the formation and evolution of ice crystals, or whether the SH has sufficient amount of efficient ice nuclei.
3. Future study needs to address individual factors: e.g., large scale dynamics, seasonal variability, land versus ocean differences, and aerosol indirect effects.