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Analysis of In Situ and Liquid Origin Cirrus Clouds from Subtropical and Extratropical Campaigns: PREDICT and HIPPO

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Introduction

- Due to their widespread global coverage, cirrus clouds play an important role in the global radiative budget. Therefore, a deeper understanding of the formation of cirrus clouds will have a large impact on global climate modeling.

Scientific questions

- What are the microphysical differences between in situ and liquid origin cirrus clouds?
-How do the microphysical properties and particles size distributions vary between the northern hemisphere (NH) and southern hemisphere (SH)?

Background

- Ice supersaturations (ISS) where relative humidity with respect to ice (RHi) > 100% provide guidance for the presence of cirrus clouds.[a]

Cirrus cloud types:

1. *Liquid Origin* – form from the freezing of cloud droplets in mixed-phase clouds. [b]
2. *In Situ* – form homogeneously from ice.[b]

Data and methodology

1) HIAPER Pole-to-Pole Observations (HIPPO) global campaign (2009-2011) consists of 5 deployments, performed observations over the North America continent and the central Pacific Ocean from 87ºN to 67ºS.

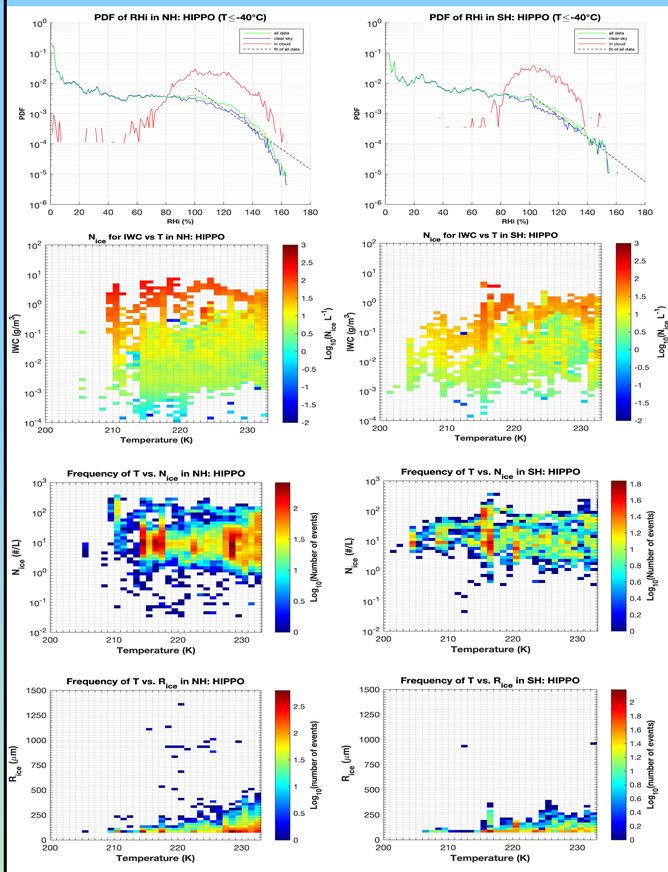
2) The Pre-Depression Investigations of Cloud-systems in the Tropic (PREDICT) campaign (2010) deployed the NSF Gulfstream V during hurricane season in the Atlantic Basin collecting observations for the development of tropical systems.

3) Observations from the PREDICT campaign are considered ***liquid origin cirrus cloud*** as the Tropics are dominated by convective vertical motions. HIPPO campaign mostly sample cirrus in extratropics, which are considered mostly ***in situ cirrus clouds*** due to slow synoptic scale vertical motions.

4) Temperature is restricted to **≤ -40°C**, this insures only ice particles exist and exclude supercooled liquid water.

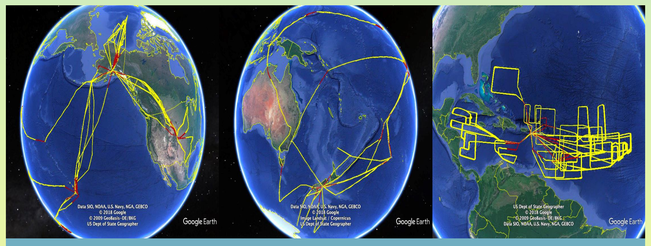
1. Microphysical properties

Northern Hemisphere *Southern Hemisphere*



- N_{ice} corresponds to number of ice particles and R_{ice} is mean radius of ice particles
- RHi in cloud and clear sky conditions are analyzed for $N_{ice} > 0$ and $N_{ice} \leq 0$ respectively.
- Best fit line for NH and SH follows exponential decay $\ln(RHi) = b + RHi * a$; where a = -0.077 and b = 2.746 for NH and where a = -0.083 and b = 2.951 for SH.
- RHi magnitudes in the NH and SH for in cloud range from 60% – 160% and 80% – 140%, respectively

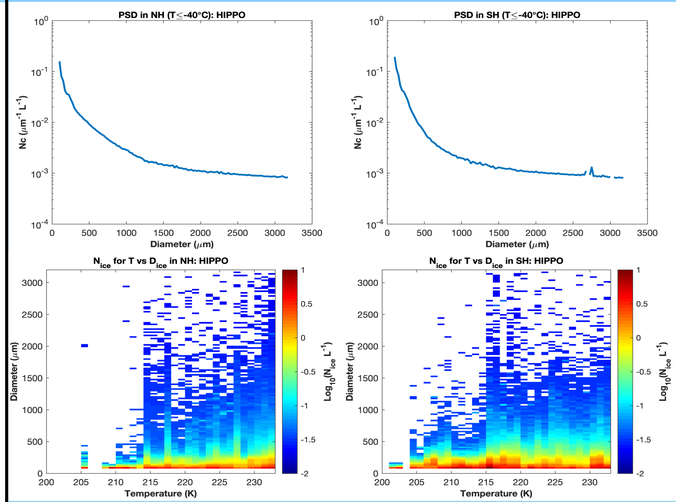
HIPPO 2-5 NH/SH Flight paths (47 Flights) **PREDICT (15 flight paths)**



Measurements	Instruments	Range	Accuracy
Temperature	Rosemount Temperature Probe	T ≤ -40°C	± 0.5K
N_{ice}	2DC Ice Probe	> 62.5 μm	
Water Vapor	VCSEL Hygrometer		± 6%

2. Particle size distributions

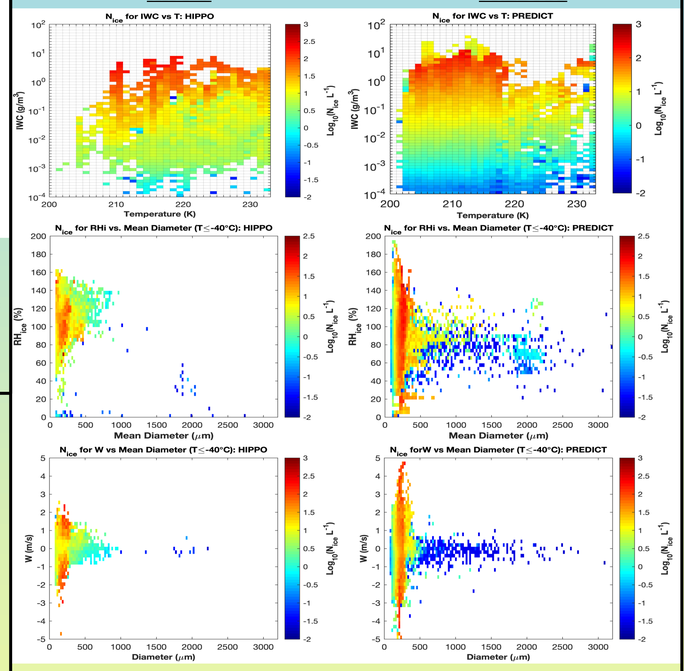
Northern Hemisphere *Southern Hemisphere*



- Particle size distributions (PSD) in the NH and SH exhibit similar profiles.
- In the SH, high concentrations of ice particles are found at colder temperatures than the NH.

3. Liquid vs. in situ origin cirrus clouds

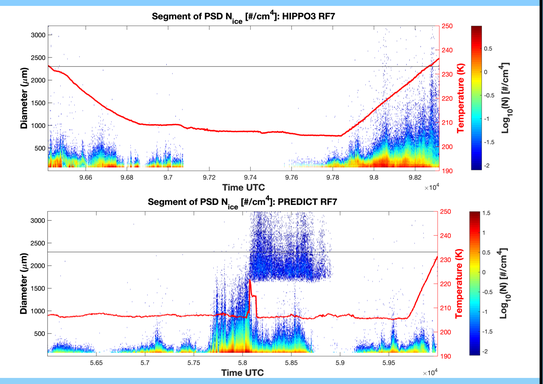
HIPPO *PREDICT*



- Liquid origin clouds produce a wider size distribution range as well as higher number concentrations of particles larger than 800 micron, likely due to accretion of ice particles that grow larger in size at the expense of number concentrations of ice particles, or due to faster particle growth due to vapor deposition. These two hypotheses are corroborated by the larger RHi values and higher vertical velocity seen in PREDICT campaign.
- Liquid origin clouds indicate a larger range in magnitudes of RHi and w.
- In liquid origin clouds, high and low N_{ice} concentrations correlate with high and low IWC, respectively.

4. PSD Time Series

Liquid vs. in situ origin cirrus clouds



- Horizontal line represents T = -40°C as threshold for cirrus clouds.
- The liquid origin cirrus cloud segment shows a cluster of large ice particles > 1500μm, corresponding to a sharp decrease in small particle concentrations, indicating the growth of large particles at the expense of small particles. This also corresponds to a sharp spike in temperature possibly from vapor deposition of small ice particles.
- The in situ segments exhibits large concentrations of small particles.

Conclusions

- RHi and IWC exhibit a wider distribution in magnitudes in the NH than the SH.
- Liquid origin cirrus clouds indicate a larger range of RHi, however this requires a wider distribution of vertical velocity.
- Due to the homogeneous freezing, in situ cirrus clouds exhibit a much smaller size distribution than liquid origin clouds.
- Liquid origin cirrus clouds indicate a strong correlation between N_{ice} and IWC and stronger vertical velocities.

Future work

- Analyze microphysical properties and size distributions of cirrus clouds for individual regions (i.e. Polar, Midlatitude, Sub-tropical, Tropical).
- Investigate the impact of aerosol concentrations on cirrus cloud characteristics in NH and SH.
- Investigate the role of aerosol particles in the size distributions of cirrus clouds in the NH and SH.

Acknowledgements:
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References:

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(b) Kramer, M., C. Rolf, A. Luebke, A. Afchine, N. Spelten, A. Costa, M. Zoger, J. Smith, R. Herman, B. Buchholz, V. Ebert, D. Baumgardner, S. Borrmann, M. Klingebiel, and L. Avallone. 2015: A microphysics guide to cirrus clouds – Part 1: Cirrus types. *Atmos. Chem. Phys.*, **15**, 31537-31586
(c) Diao, M,. M.A. Zondlo, A.J. Heymsfield and S.P. Beaton. "Hemispheric comparison of cirrus cloud evolution using in situ measurements in HIAPER Pole-to-Pole Observations", *Geophysical Research Letters*, doi:10.1002/2014GL059873, 2014.