A Microphysics Guide to Cirrus – Part II:
Climatologies of Clouds and Humidity from Observations

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Climatologies of Cirrus Clouds

from airborne in-situ and satellite remote sensing observations

- The climatologies serve as a guide to the properties of cirrus clouds.
- The new in-situ data base provides insights into boreal mid-latitudes and the tropics.
- The satellite-borne data set offers global and regional overviews.
AIRBORNE IN-SITU OBSERVATIONS

24 campaigns (1999-2017), 185 flights (~200 h in cirrus): IWC, N_{ice}, R_{H,ice}

Ice Water Content, Ice Crystal Number, Relative Humidity
**CIRRUS OBSERVATIONS: VERTICAL PORTRAYAL**

Characteristics expected from simulations (Cirrus Guide I, ACP) are visible in observations.
**IN-SITU AND LIQUID ORIGIN CIRRUS**

![Diagram showing in-situ and liquid origin cirrus](image)

**Typical characteristics of cirrus types**
in the initial stage

<table>
<thead>
<tr>
<th>ORIGIN</th>
<th>IWC</th>
<th>N_{ice}</th>
<th>R_{ice}</th>
<th>weather system</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>slow updraft</strong> (heterogeneous ice nucl.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IN-SITU LIQUID</td>
<td>low</td>
<td>few</td>
<td>large</td>
<td>frontals systems (WCBs)</td>
</tr>
<tr>
<td>IN-SITU LIQUID</td>
<td>high</td>
<td>more</td>
<td>larger</td>
<td></td>
</tr>
<tr>
<td><strong>fast updraft</strong> (homogeneous ice nucl.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IN-SITU LIQUID</td>
<td>high</td>
<td>many</td>
<td>small</td>
<td>gravity waves, convection</td>
</tr>
<tr>
<td>IN-SITU LIQUID</td>
<td>high</td>
<td>more</td>
<td>small &amp; larger</td>
<td></td>
</tr>
</tbody>
</table>

IWC high/low: above/below the IWC median; N_{ice} few/more/many: below/intermediate/above the 10 and 90% N_{ice} percentiles (see Figure 3).

R_{ice} small/large/larger: ice particles \( \lesssim 20\mu m \) dominate the PSD / ice particles \( \gtrsim 20\mu m \) dominate the PSD, max. size several hundred \( \mu m \) diameter / ice particles \( \gtrsim 20\mu m \) dominate the PSD, max. size up to thousand \( \mu m \) diameter (PSD: particle size distribution).

Refinement of results from Cirrus Guide I (ACP) and Luebke et al. (2016)
Cirrus Guide II:

- In-situ origin cirrus ➜ slight warming
- Liquid origin cirrus ➜ strong cooling effect
- How well are they represented in global models?
- Partitioning between in-situ and liquid origin cirrus?

Simulated radiative forcing
for exemplary in-situ slow and fast updraft and liquid origin cirrus.
**SATELLITE REMOTE SENSING DATA BASE**

N_{ice} (2006 - 2016)

**DARDAR N-ice**

Currently best view of global distribution of N_{ice}
COMPARING IN-SITU AND SATELLITE $N_{\text{ice}}$

Climatologies of frequencies in 1K T-bins

(data from five field campaigns)

- Overall good agreement between in-situ and DARDAR-$N_{\text{ice}}$
- The excess of $N_{\text{ice}}$ by a factor of 1.73 in DARDAR is caused by the retrieval method
**N_{ice} FROM SATELLITE**

Global climatology of frequencies across the entire T-space

2006 – 2016

- Half of the cirrus clouds are found in the temperature range 224 - 242 K
- This warmest cirrus layer and contain significant amount of liquid origin cirrus
N_{ice} FROM SATELLITE

Regional and seasonal medians

<table>
<thead>
<tr>
<th>Region</th>
<th>in-situ adj. DARDAR-Nice</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( N_{ice} ) (cm(^{-3}))</td>
</tr>
<tr>
<td></td>
<td>all Temp.</td>
</tr>
<tr>
<td>Arctic</td>
<td>0.036</td>
</tr>
<tr>
<td>Mid-lat North</td>
<td>0.057</td>
</tr>
<tr>
<td>Tropics</td>
<td>0.070</td>
</tr>
<tr>
<td>Mid-lat South</td>
<td>0.057</td>
</tr>
<tr>
<td>Antarctica</td>
<td>0.050</td>
</tr>
<tr>
<td>Global</td>
<td>0.056</td>
</tr>
</tbody>
</table>

(most frequent median \( N_{ice} \): median for the temperature range containing 50\% of the cirrus clouds)

- good agreement between most frequent in-situ and DARDAR-Nice medians - except tropics and Arctic
- seasonal medians do not greatly vary
CONCLUSIONS

- The global median $N_{ice}$ of the most frequent cirrus is $0.031 \, \text{cm}^3$, in good agreement between satellite and in-situ observations.

- Regarding the frequent appearance of liquid origin cirrus together with their strong cooling effect is a motivation to investigate their influence on the overall cirrus radiative forcing on climate - do they switch the sign from warming to cooling?