A Microphysics Guide to Cirrus – Part II:

Climatologies of Clouds and Humidity from Observations

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Some results on cirrus clouds from:

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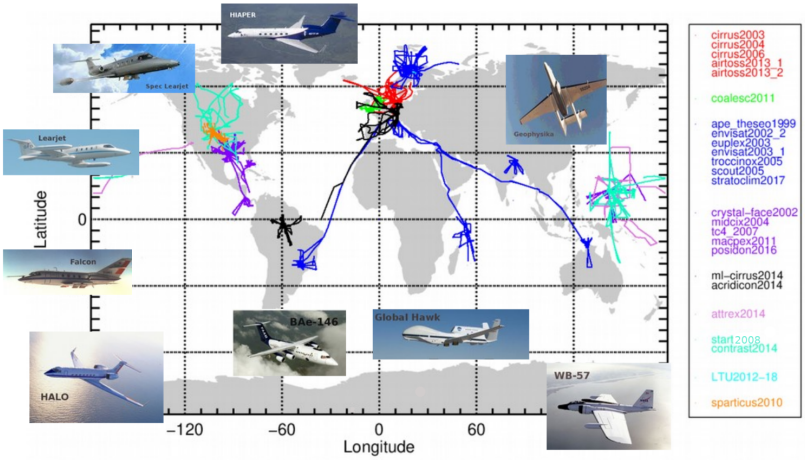
CLIMATOLOGIES OF CIRRUS CLOUDS

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 DATA BASE



24 campaigns (1999-2017), 185 flights ($\approx$ 200 h in cirrus): IWC, N_{ice}, RH_{ice}

Ice Water Content, Ice Crystal Number, Relative Humidity

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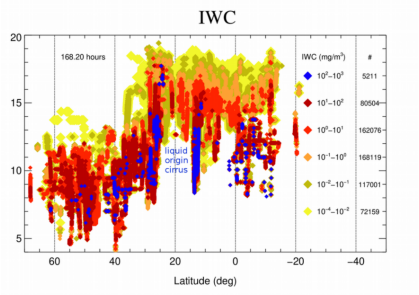
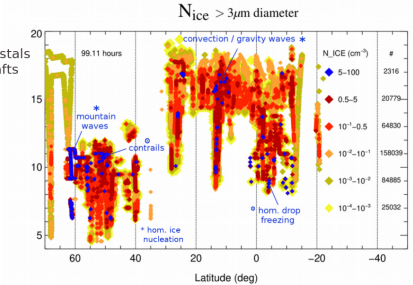
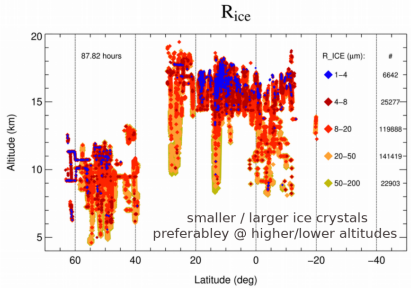
CIRRUS OBSERVATIONS: VERTICAL PORTRAYAL

many / few ice crystals
@ fast / slow updrafts







in-situ origin
liquid origin
cirrus preferably at higher / lower altitudes

Characteristics expected from simulations
(Cirrus Guide I, ACP) are visible in observations

IN-SITU AND LIQUID ORIGIN CIRRUS

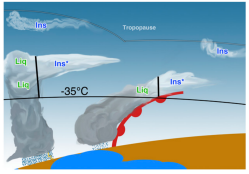
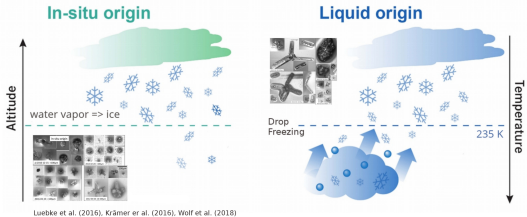


FIG. 5. Sketch of the cirrus cloud classification algorithm. The Liq refers to liquid-origin cirrus, Ins to in situ cirrus, and Ins* are liquid-origin cirrus that are erroneously classified by our algorithm as in situ. Gasparini et al. (2018)



Luebke et al. (2016), Krämer er al. (2016), Wolf et al. (2018)

Typical characteristics of cirrus types in the initial stage				
ORIGIN	IWC	N_{ice}	R_{ice}	weather system
slow updraft (*heterogeneous ice nucl.*) *mostly*				
IN-SITU	low	few	large	frontals systems (WCBs)
LIQUID	high	more	larger	
fast updraft (*homogeneous ice nucl.*) *mostly*				
IN-SITU	high	many	small	gravity waves, convection
LIQUID	high	more	small & larger	

IWC high/low: above/below the IWC median; N_{ice} few/more/many: below/in-between/above the 10 and 90% N_{ce} percentiles (see Figure 5).
R_{ice} small/large/larger: ice particles $\lesssim$ 20µm dominate the PSD / ice particles $\gtrsim$ 20µm dominate the PSD, max. size several hundred µm diameter / ice particles $\gtrsim$ 20µm dominate the PSD, max. size up to thousand µm diameter (PSD: particle size distribution).

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

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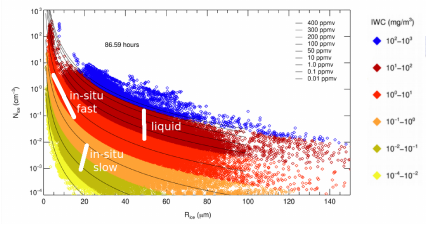
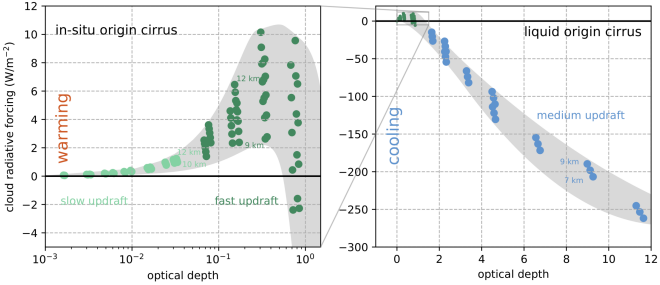
IN-SITU AND LIQUID ORIGIN CIRRUS

Simulated radiative forcing
for exemplary in-situ slow and fast updraft and liquid origin cirrus.





Cirus Guide II:

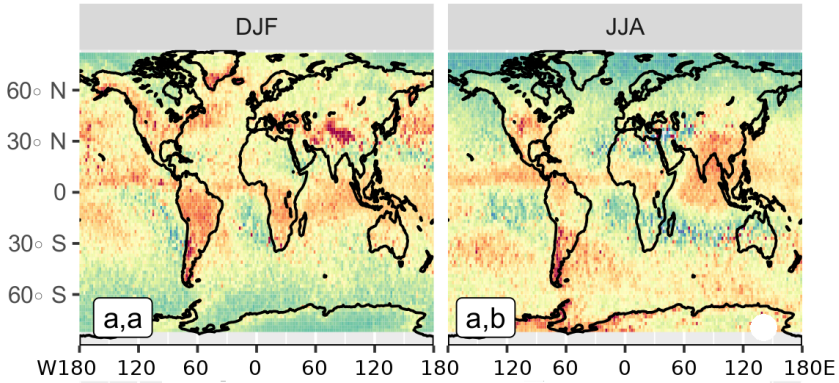
- **In-situ origin cirrus ➦ slight warming**
- **Liquid origin cirrus ➦ strong cooling effect**
- How well are they represented in global models?
- Partitioning between in-situ and liquid origin cirrus ?

Cirrus origin	N_{ice} (cm^{-3})	R_{ice} (µm)	IWC (mg/m^3)	z tropop. (km)	cirrus layers
in-situ slow	0.001-0.02	15-25	0.01-0.5	12.5	3 layers: 10-12 km
in-situ fast	0.1-5	5-15	0.1-7.5	12.5	5 layers: 9-12 km
liquid	0.05-2	50-70	30-375	10	3 layers: 7-9 km

SATELLITE REMOTE SENSING DATA BASE

N_{ice} (2006 - 2016)

DARDAR N-ice



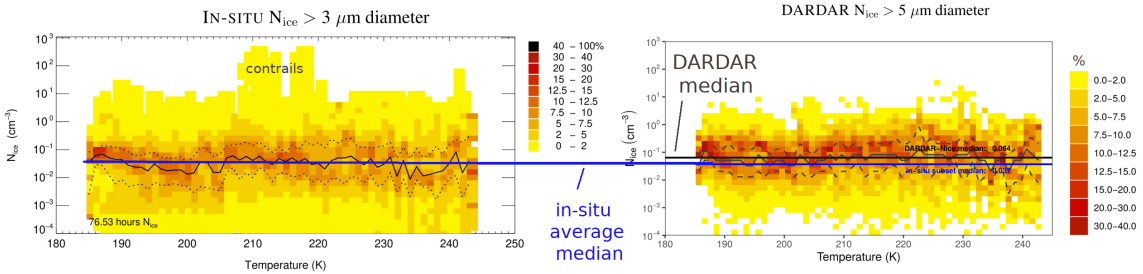
Sourdeval et al. (2018), ACP

➤ Currently best view of global distribution of N_{ice}

Comparing in-situ and satellite N_{ice}

Climatologies of frequencies in 1K T-bins

(data from five field campaigns)



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

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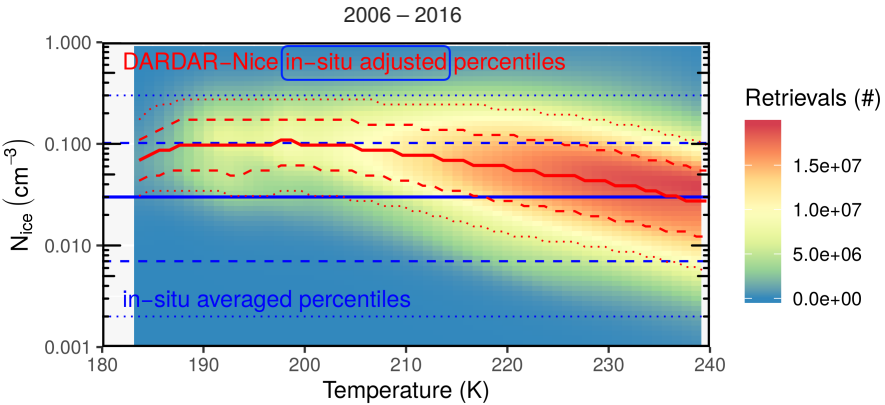
N_{ice} FROM SATELLITE

Global climatology of frequencies across the entire T-space

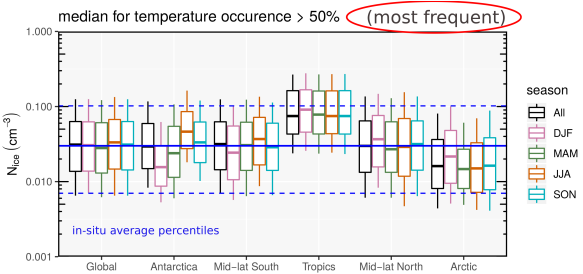


- Half of the cirrus clouds are found in the temperature range 224 - 242 K
- This warmest cirrus layer and contain significant amount of liquid origin cirrus

N_{ice} FROM SATELLITE

Regional and seasonal medians

Region	in-situ adj. DARDAR-Nice N_{ice} (cm^{-3}) medians			
	all Temp.	T-int weighted	most frequent	T-range
Arctic	0.036	0.023	0.016	230-242 K
Mid-lat North	0.057	0.040	0.030	227-242 K
Tropics	0.070	0.067	0.074	197-221 K
Mid-lat South	0.057	0.043	0.031	227-242 K
Antarctica	0.050	0.045	0.029	222-242 K
Global	0.056	0.046	0.031	224-242 K



(most frequent median N_{ice}: median for the temperature range containig 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 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 ?