Variability of the Particle Size Distributions observed at temperatures from -50°C to -30°C in tropical Mesoscale Convective Systems

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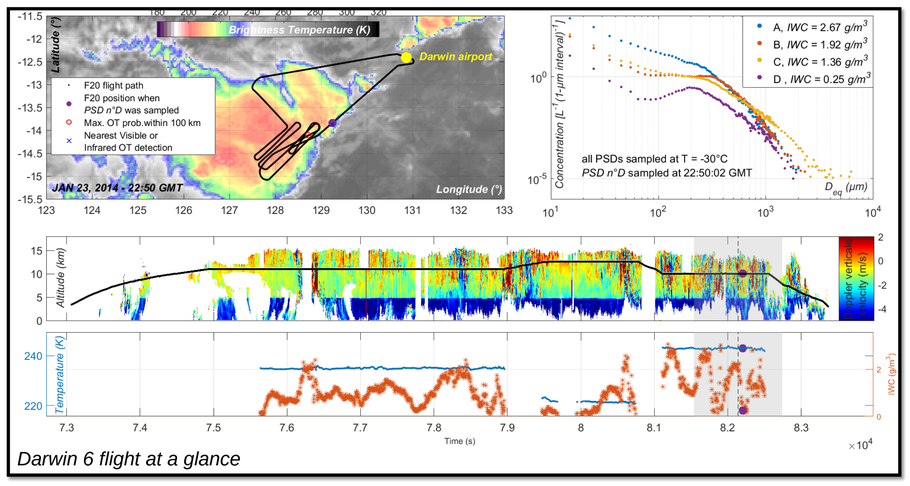
MOTIVATION

The purpose of this poster is to illustrate the variability in cloud microphysics observed in different locations across ***tropical MCSs*** sampled during the ***HIWC-HAIC project***. First analyses of the dataset revealed how the ice water content is distributed across the cloud in convective and stratiform areas [1], [2], [3]. This study pushes further the effort to correlate ***cloud microphysics*** and ***dynamics*** by investigating the variability in of situ measured ***Particle Size Distributions*** (PSD) across the cloud as a function of dynamical parameters derived from in-situ radar and satellite data. A case study is presented to exemplify the combined action of ***sedimentation and aggregation in the anvil***. The combined use of ***in situ*** and ***space-borne*** measurements enables the detailed microphysical observations to be placed into the anvil context at a larger scale.

METHODOLOGY

Input data: HIWC-HAIC data collected during the Darwin 2014 field campaign (17 flights)

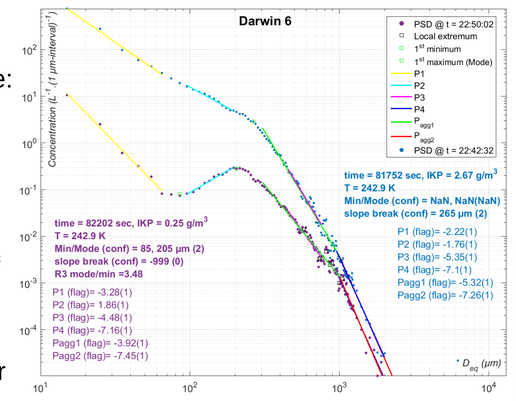


Darwin 6 flight at a glance

PSD are automatically analyzed to compute:

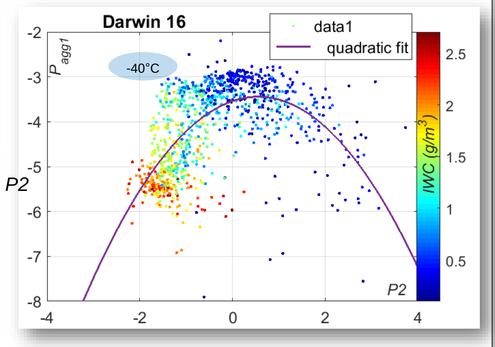
- power law fit on PSD segments
- presence of a ***mode***, ***concavity*** of PSD segments
- positions of the 1st minimum and the mode (if any)
- ratio of the cumulated 2D images area of crystals larger than 1300 *µm* to the cumulated area of all crystals (***S1300***)

Doppler Vertical Velocity is averaged over a box around the aircraft (from 2 km above to 2 km below the aircraft, over 1 km along flight path): referred to as ***mean Vz*** in the poster

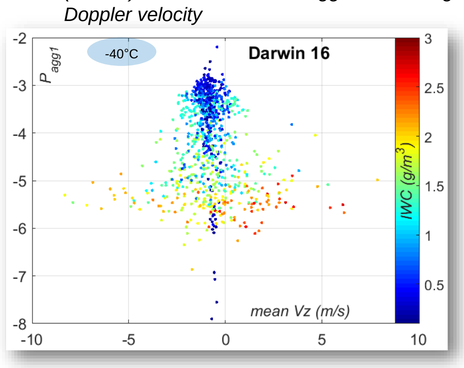


Size interval (*µm*)	Slope label
[10 - 70]	P1
[90 - 200]	P2
[450 - 750]	P3
[950 - 2000]	P4
[300 - 1000]	Pagg1
[1000 - 3000]	Pagg2

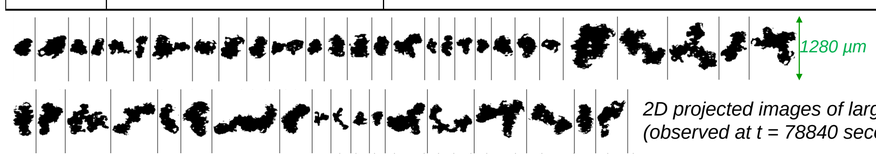
(right) : relation between Pagg1 and P2



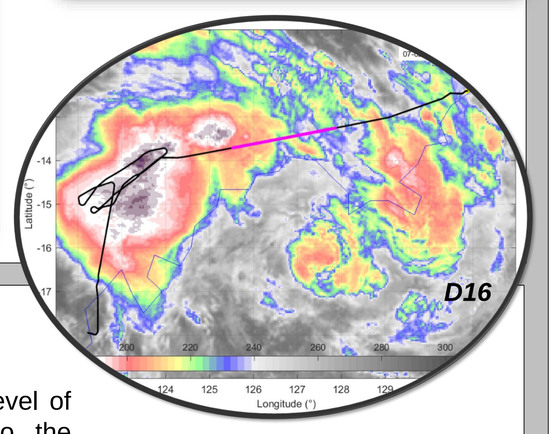
(bottom): relation between Pagg1 and averaged Doppler velocity



Type	Instruments	Quantity	Comments
In situ	microphysics probes (2D-S, PIP)	PSD [1], IWC, 2D projected images of ice particles	5-sec averaged (~1km)
	95 GHz cloud research radar (RASTA)	Doppler vertical velocity (Vz) in the vertical column across the flight path [4], [5]	5-sec averaged (~1km)
Space-borne	MTSAT-1R	IR brigthness temperature, Overshooting Top positions [6]	temporal resolution 10 minutes spatiale resolution 16km²



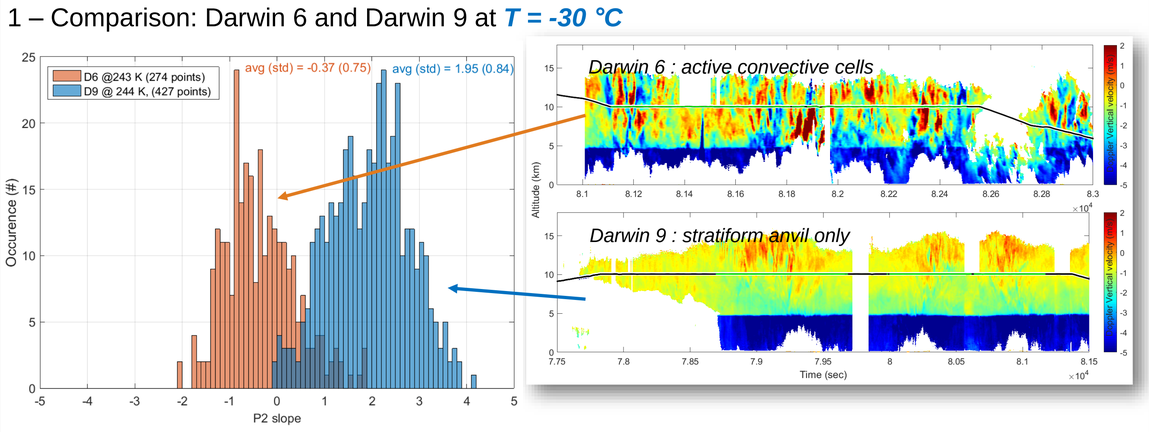
2D projected images of large crystals seen by the 2D-S during Darwin #16 flight (observed at t = 78840 seconds, typical of zone 2 below)



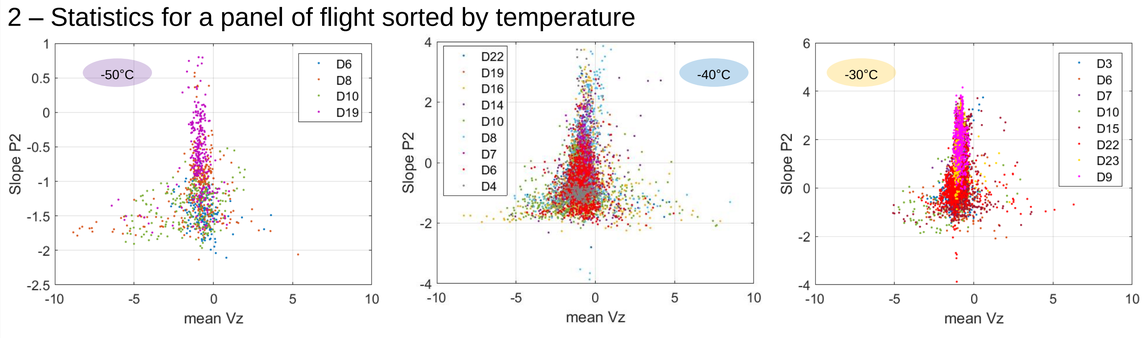
RESULTS

Convective *vs* stratiform areas: distinct microphysical features

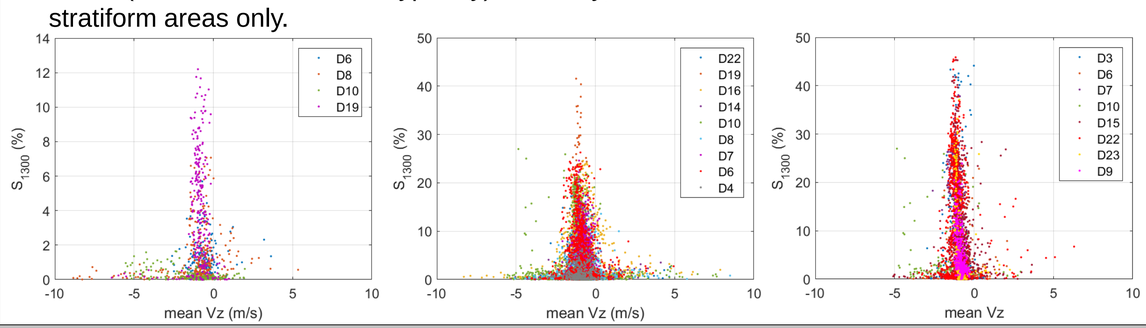
1 – Comparison: Darwin 6 and Darwin 9 at ***T = -30 °C***



2 – Statistics for a panel of flight sorted by temperature



➔ The existence of a distinctive mode (***P2*** >0) is generally associated with stratiform zones (-1 < ***mean Vz*** < 0 m/s typically). Similarly, ***S1300*** maximum values are found in stratiform areas only.



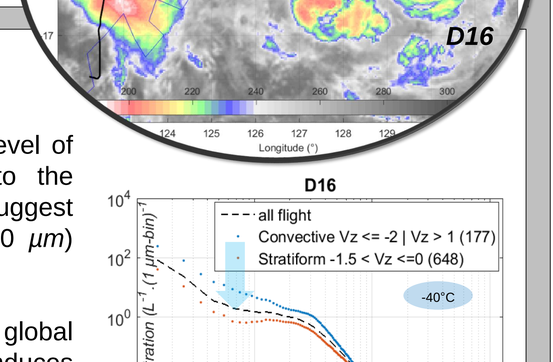
Anvil aging: microphysical considerations

The variability in PSD may be explained by the following microphysical mechanisms:

1. ***Convective cells*** pump ice crystals vertically up to the level of neutral buoyancy where they spread out horizontally into the stratiform areas. PSD collected within convective regions suggest that ice populations are dominated by small particles (< 300 *µm*) grown by ***vapor diffusion.***

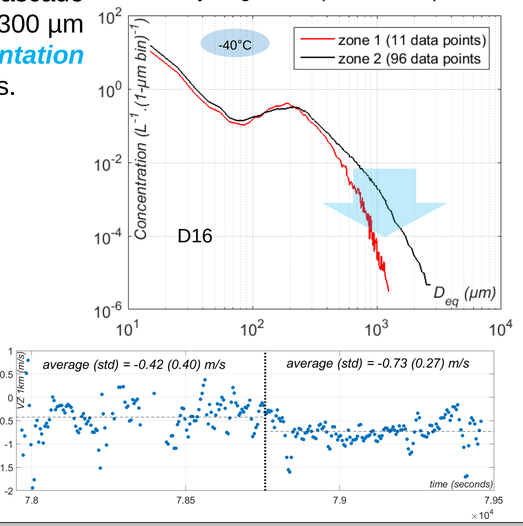
2. In the ***stratiform areas***, ***sedimentation*** creates a global downward motion of the ice particles. Fall speed differential induces ***cascade aggregation*** : slow particles are collected by fast particles falling from upper layers. Small particles segment is depleted while the concentration of particles larger than 500 µm increases. This is corroborated by the flattening of the PDS in the 50-300 µm size range (P2 ≈ 0) and the increase in concentration of millimetric crystals. This is also supported by past studies reporting aggregates in anvils close to convection (*e.g.* [7], [8], [9])

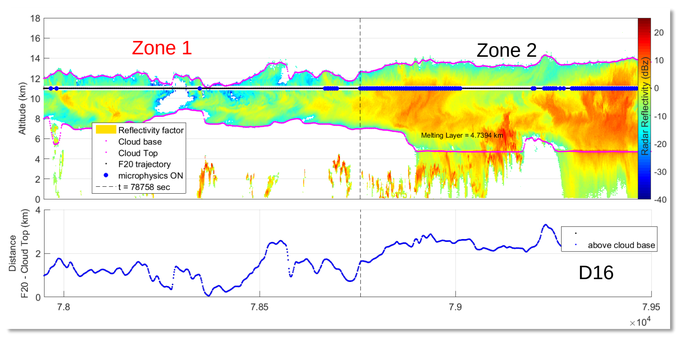
3. Once the anvil detached from its parent convection (advection into remote areas or decay of the convective cell), the cascade aggregation mechanism weakens. PSD feature a dip in the 50-300 µm size range and low concentrations of large crystals. ***Sedimentation*** and ***sublimation*** may be the dominant scavenging mechanisms.



(above) Median PSD calculated for two subsets collected in convective and stratiform areas of Darwin #16

(below) Median PSD calculated for two stratiform subsets:
Zone 1 : cloud edges (detached anvil)
Zone 2 : younger anvil (still attached)





CONCLUSIONS & PERSPECTIVES

This study highlights the role of ***aggregation*** in the transition zone between convective and stratiform MCS regions leading to the formation of supermillimetric particles in MCS anvils at temperatures as cold as -40°C. This mechanism may explain the depletion of crystals smaller than 300 µm and results suggest a ***pronounced effect in the 50 – 200 µm*** size range at the temperatures considered. It supports previous studies reporting on the role of aggregation on vertical distribution of large particles in tropical anvils.

Further analysis is required to better quantifying the proposed mechanism (eg. fall speed *vs* size distribution, distance to parent convection in space and time). A comparison between these in situ observations and ***numerical simulations with detailed microphysics*** would help quantifying the aggregation process (aggregation efficiency as a function of size for particle smaller than 300 µm.

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