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Cirrus Cloud Microphysics over Darwin, Australia

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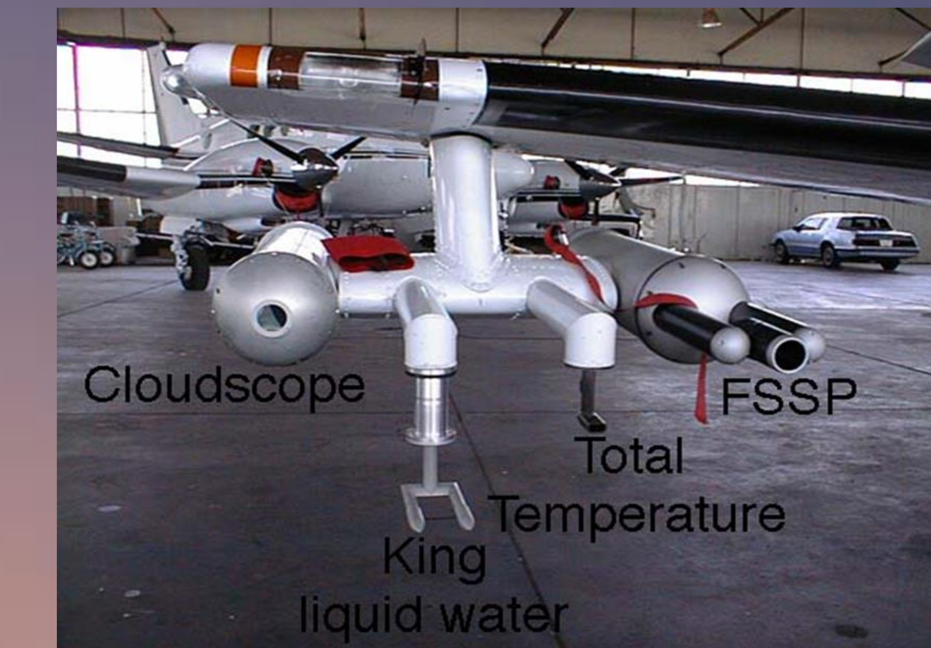

Abstract

Ice clouds, crucial to the understanding of both short- and long-term climate trends, are poorly represented in global climate models (GCMs). Cirrus clouds, one of the largest uncertainties in the global radiation budget, have been inadequately studied at low latitudes. Parameterizations exist for mid-latitude and tropical cirrus (Ivanova et al. 2001; McFarquhar et al. 1997). Due to climate sensitivity in the GCM with respect to cloud input, without robust parameterizations of cirrus clouds, the GCM is inaccurate over most output fields, including radiative forcing, temperature, albedo, and heat flux (Yao and Del Genio 1999).

Studies of the microphysical properties of tropical cirrus clouds may result in improved parameterizations for GCMs. Until ten years ago, there were no truly realistic cirrus clouds parameterizations for the different regions of the world in the global climate models (GCMs). A GCM requires information about ice particle diameter/maximum dimension (D), ice water content (IWC), and size distribution (SD) for small and large mode crystals.

This study uses the latest tropical Atmospheric Radiative Measurements (ARM) data to analyze the small and large crystals in cirrus clouds over Darwin, Australia.

Fig. 1 The FSSP and 2-DC instruments package (courtesy of NASA Airborne Science Program)

Objectives :

- Funded by the DOE- Atmospheric Radiation Measurements (ARM) Program, our goal is to help improve climate prediction through better representation of the tropical microphysical cirrus properties in the Global Climate Models (GCMs).
- New evidence in recent studies indicates that the Forward Scattering Spectral Probe (FSSP) may approximate the size distributions (SDs) of small ice crystals (with diameter D < 100 micrometers). Our efforts to parameterize the SDs in Tropical cirrus take advantage of existing Darwin FSSP data to evaluate the potential impact of small ice crystals, cruisal for the GCM parameterizations.

Method

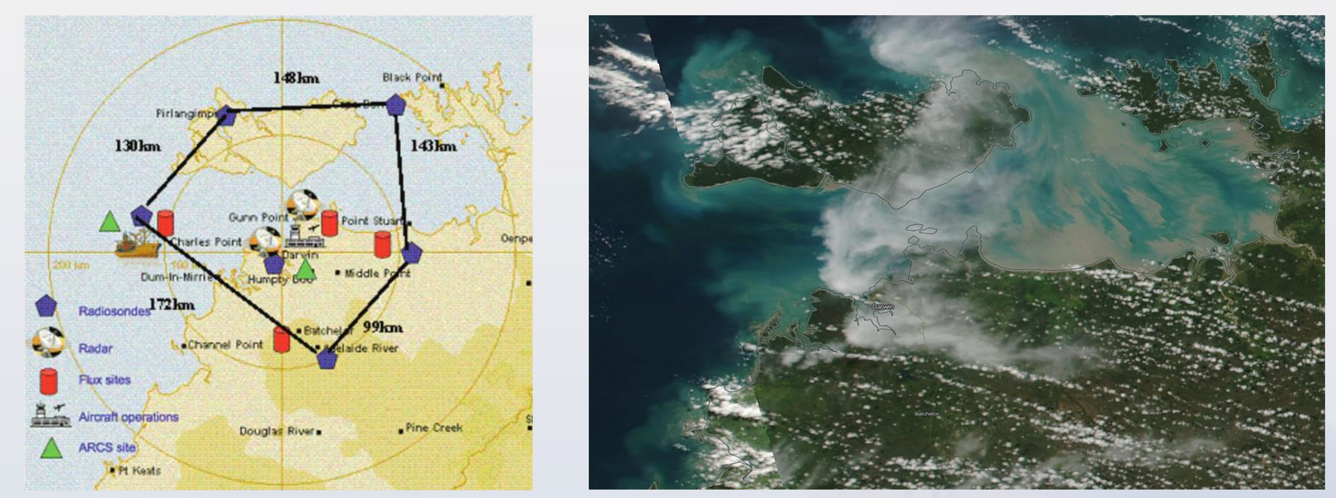

Fig. 2. Flight path and Satellite image of Darwin, April 9th 2016.

The data obtained from the DoE-ARM Darwin, Australia facility was plotted as SDs, which is the mean particle diameter (µm) plotted vs the concentration (#/L/µm) on a log – log scale.

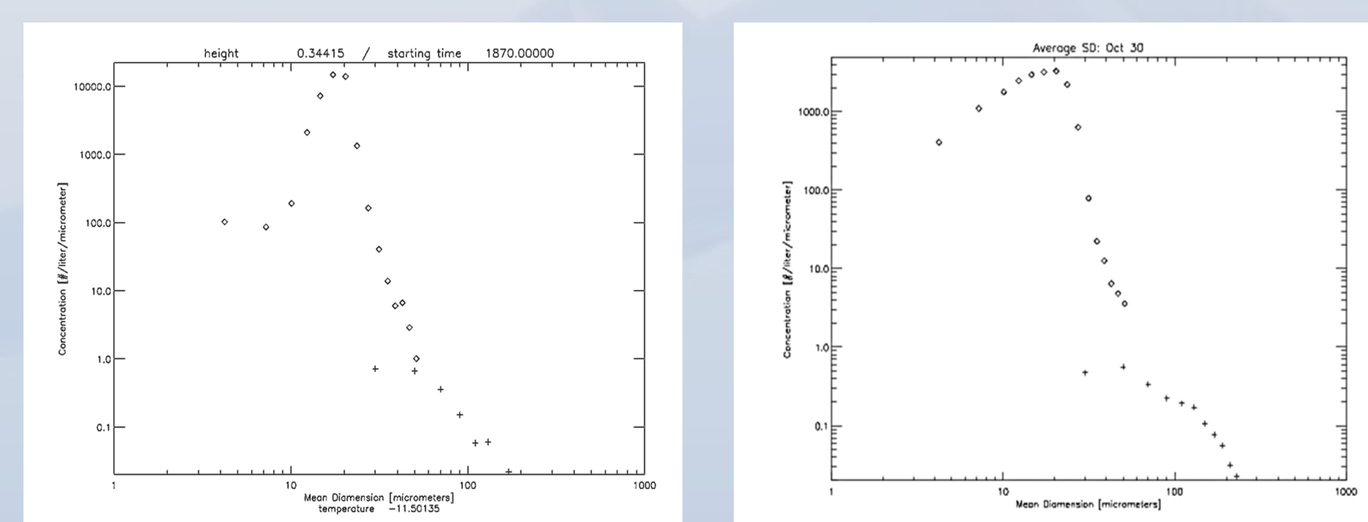

Fig. 3. Average of statistically relevant SDs from Flight on April 9, 2016

The analyzed cirrus size distributions are consistent with the degree of bimodality typical for tropical cirrus clouds. Analyzing the sample distributions for the Darwin flight, we found that the best-fit line for the small mode crystals as well for the large mode is the gamma function. Furthermore, the data points to different mechanisms from which the mid-latitude and tropical cirrus clouds are generated.

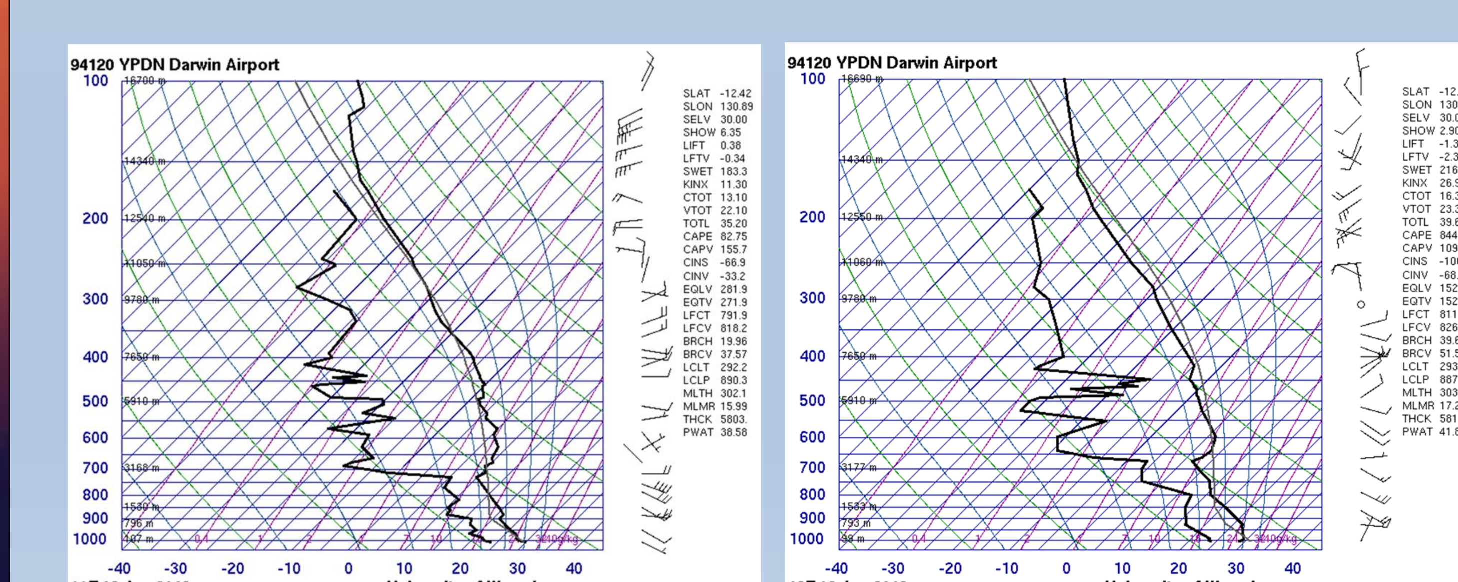

Fig. 4. Sounding data for Darwin at 00Z and at 12Z. There is a decent amount of cape 844.6 J/kg leading to the convective roll cloud in the afternoon. The tropopause is located at 14,000m.

Flight is distinctly bimodal – the large mode (2DC) continues along the same slope as the small mode (FSSP) and is lacking a distinct peak. Observed ice crystal shapes used to calculate ice mass equivalent spheres, Dm: 23.7% columns and irregular, 64.7% bullet rosettes, and 41.6% planar polycrystals.

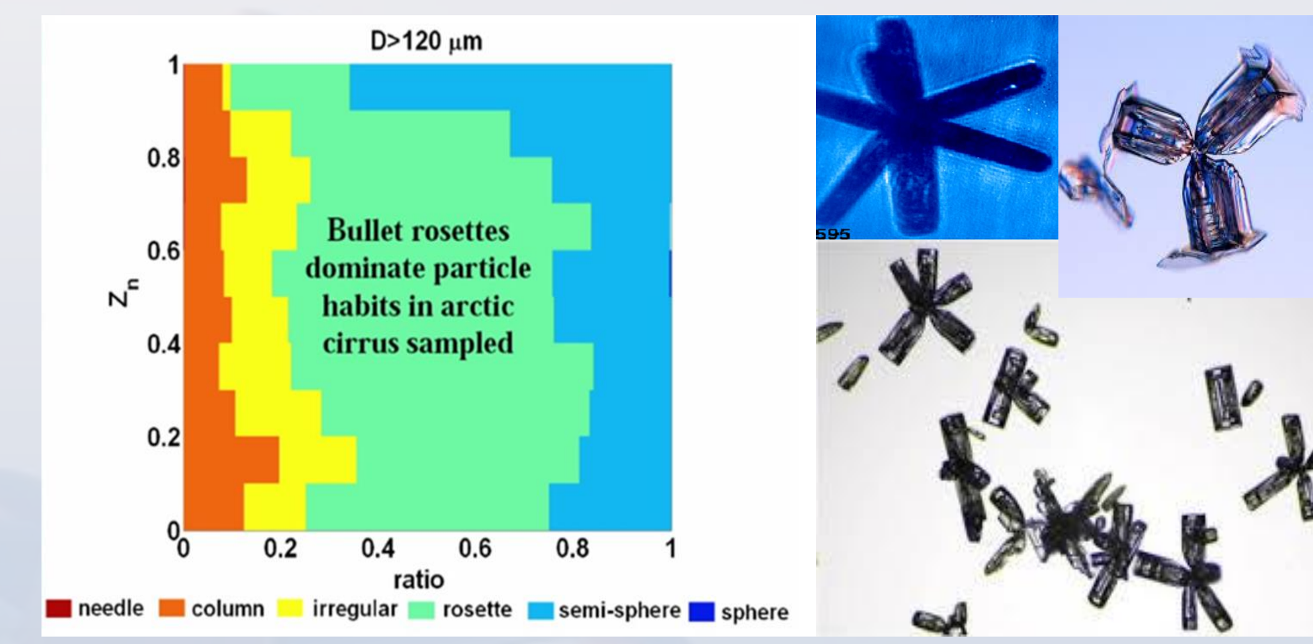

Fig. 5. Crystal types observed during the flight and example of bullet rosettes; the predominant type observed during the flight.

Conclusions

- The SDs of Darwin experiment point to the different mechanisms by which they are formed – as well as the differences to mid-latitude and tropical formation methods.
- Mid-latitude cirrus are typically a by-product of convective systems and turbulence, while tropical cirrus are produced by gentler lifting mechanisms.
- The formation of tropical cirrus may be linked to the non-classical formation of SDs observed during the flight.
- In mixed-phase clouds, SDs coexist with ice particles and therefore interactions between coalescence and ice crystal aggregation and accretion must be studied.
- Further research is crucial to understanding the relationships between cloud microphysics, SDs, T, and IWC in ice- and mixed-phase clouds.

References:

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