The microphysical and radiative properties of tropical cirrus observed during TWP-ICE

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Motivation

In-situ data acquired during TWP-ICE by the Scaled Composites Proteus in aged cirrus, fresh anvils, and cirrus of unknown origin are used to investigate the following questions:

1. Are measurements of small crystal concentrations (maximum dimension D < 50 μm) affected by shattering on inlets/shrouds of probes?
2. Are measurements of size-resolved properties consistent with measurements from bulk probes?
3. How do statistical properties of fresh anvils differ from those of aged cirrus?
4. How do crystal shapes in fresh anvils differ from those in aged cirrus?
5. Can models be developed to describe crystal shapes of fresh anvils/aged cirrus from which single-scattering properties can be computed?

Small Crystal Concentrations

The Cloud and Aerosol Spectrometer (CAS) and Cloud Droplet Probe (CDP) measure concentrations of crystals with D < 50 μm using the same working principle (forward scattering) and look-up table. The CAS has a shroud and inlet, whereas the CDP does not (Figure 1 and 2).

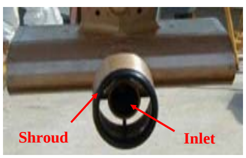

FIG 1: CAS with shroud and inlet indicated.

FIG 2: Diagram of CDP indicating open path design with no shroud or inlet.

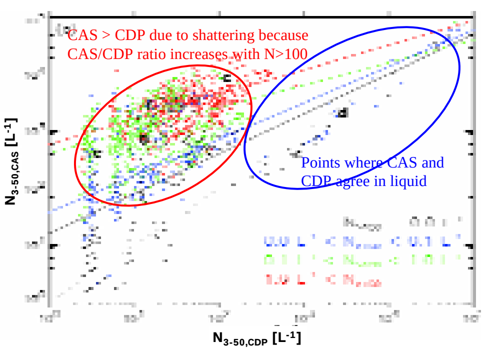

FIG 3: CAS concentration (3-50 μm) as function of CDP concentration with coloring corresponding to concentration of particles with D > 100 μm measured by Cloud Imaging Probe (CIP), N>100.

Results show CAS affected by shattering—need to determine if shattering exists for other forward scattering probes in other meteorological conditions

Comparing Size-Resolved/Bulk IWC

FIG 4: Sample images from CIP with hollows (out of focus images)

IWC Comparison

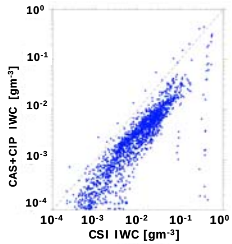

FIG 5: Korolev algorithm resizes hollows, but IWC derived from CIP SDs < IWC measured by Cloud Spectrometer and Impactor (CSI).

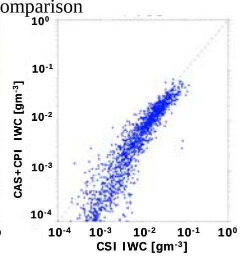

FIG 6: IWC derived from Cloud particle Imager (CPI) SDs closer to CSI bulk values.

CIP & CPI measure size distributions (SDs) for D > 50μm, but IWC from CPI more consistent with that from CSI.

Fresh Anvils versus Aged Cirrus

Bulk properties (effective radius, IWC, median mass diameter D_{mm}) are being compared according to strength of generating convection, anvil age, distance from core, etc.

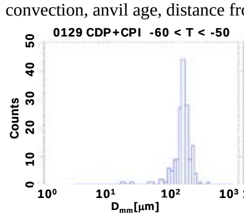

FIG 7: Frequency distribution of D_{mm} in aged cirrus sampled on 29 January 2006.

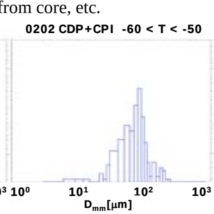

FIG 8: As in FIG 7 except for fresh anvils sampled on 2 February 2006.

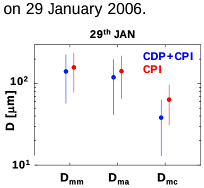

FIG 9: Distributions of median mass, area & number diameter (D_{mm}, D_{ma}, D_{mc}) for 29 Jan. aged cirrus case. Mean (circle) and one sigma.

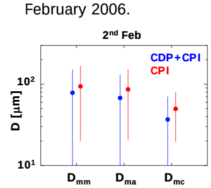

FIG 10: As in FIG 9, but for fresh anvil sampled on 2 Feb. 2006.

Comparison between properties of aged cirrus and fresh anvils shows small crystals more numerous in fresh anvils.

Fresh Anvil vs. Aged Cirrus Crystal Shapes

Figure 11 is on the next page

FIG 11: Representative crystals imaged by CPI during 12 km altitude leg flown through aged cirrus on 29 Jan. 2006. Bullet rosettes and aggregates dominate.

Figure 12 is on the next page

FIG 12: As in FIG. 11, but in fresh anvil 2 Feb. Bullet rosettes absent and plates/aggregates dominate.

Statistically significant differences in shapes of large crystals seen in fresh anvils/aged cirrus; small crystals always predominantly quasi-spheres.

Crystal Shape Models

FIG 13: Observed (left) and idealized (right) aggregates of bullet rosettes

FIG 14: Observed (left) and idealized (right) aggregates of plates

FIG 15: Idealized plate aggregates with different aggregation index (AI)

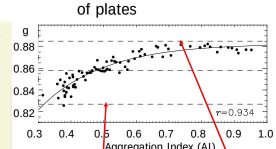

FIG 16: Dependence of g on AI for plate aggregates; g for plates and aggregates of bullet rosettes also indicated

Idealized scattering properties between fresh anvils and aged cirrus significant from a climate and remote sensing perspective.

References/Acknowledgments

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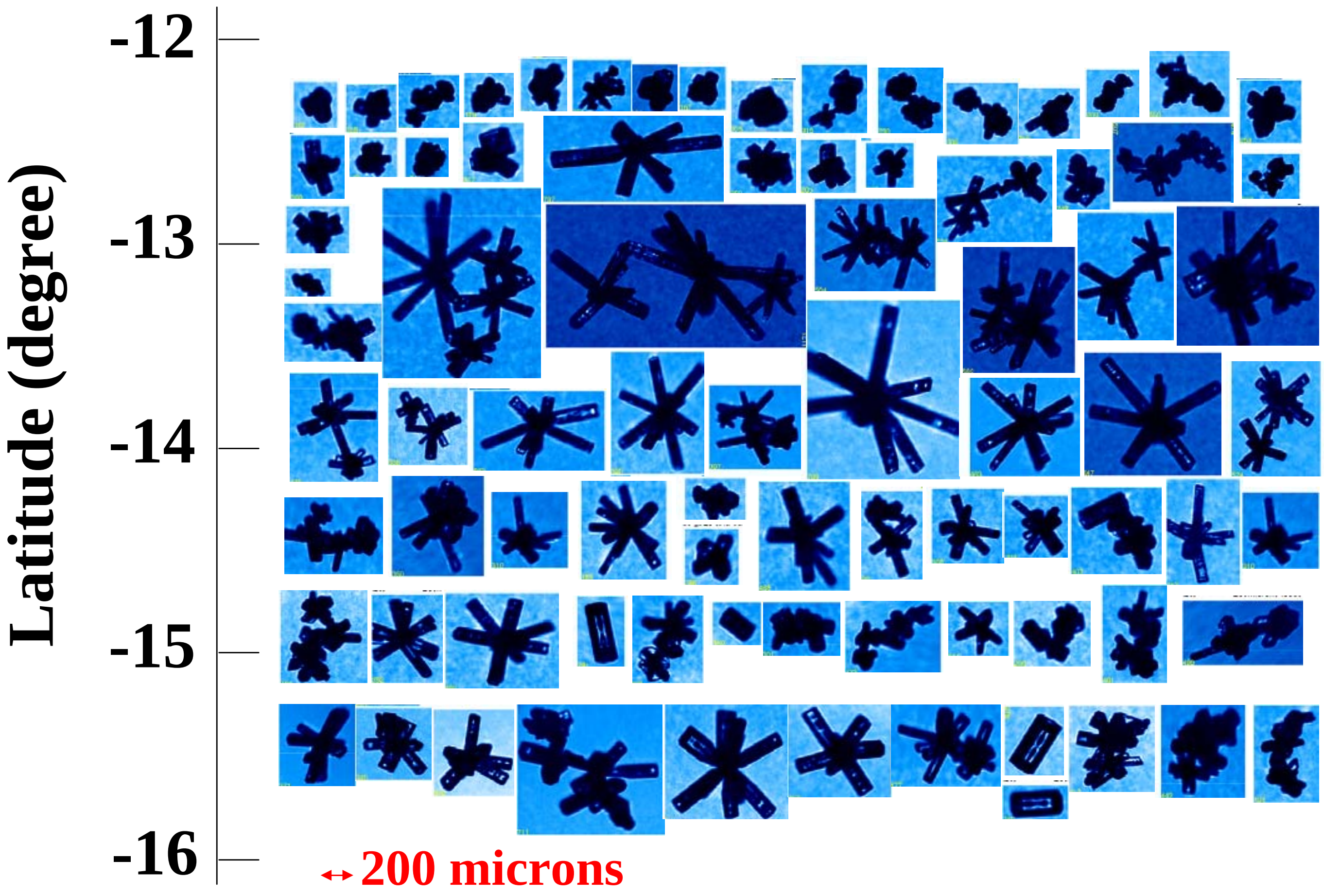

FIG 11: Representative crystals imaged by CPI during 12 km altitude leg flown through aged cirrus on 29 Jan. 2006. Bullet rosettes and aggregates dominate.

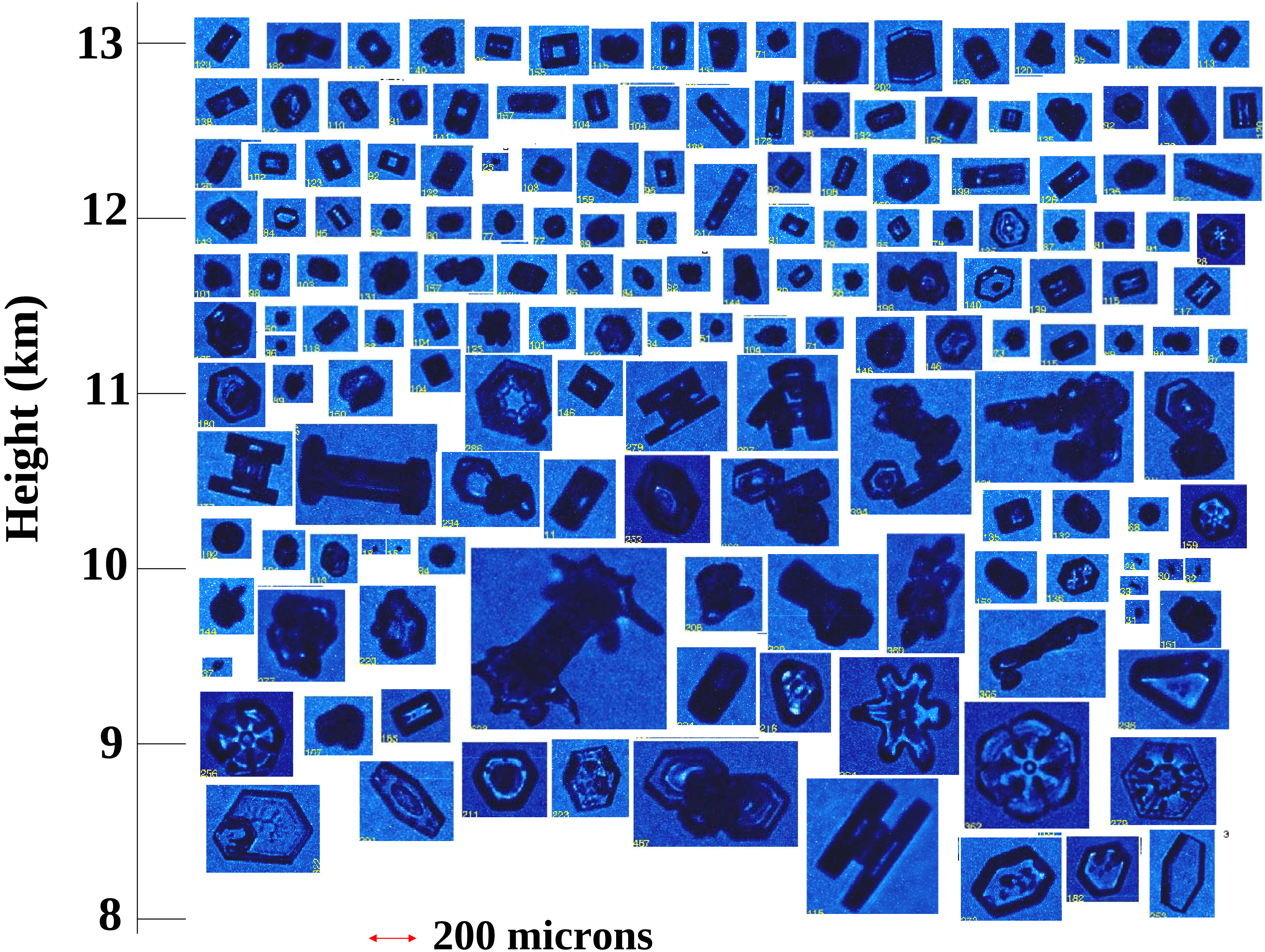

FIG 12: As in FIG. 11, but in fresh anvil 2 Feb. Bullet rosettes absent and plates/aggregates dominate.