Micro-COPP: A Balloon-borne Package for Ice-Cloud Microphysics, Results from the BATAL Campaigns

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Ice Cloud Measurements during the Balloon measurement campaigns of the Asian Tropopause Aerosol Layer (BATAL)

Figure1. Flight preparation at TIFR Balloon Facility in Hyderabad, India

Motivation: The understanding of microphysical processes in the life cycle of ice clouds, and their representation in climate models, remain poor due to numerous factors, one being the lack of accurate measurements of microphysical properties (number concentration, size and shape distribution) of ice crystals with particle sizes less than 100 µm from the current generation probes (Heymsfield et al., 2022). Only a limited number of field campaigns have occurred over the Asian Summer Monsoon region to sample these clouds despite their high occurrence.

During the BATAL campaigns (Vernier et al., 2018), ice measurements were conducted from TIFR Balloon Facility in Hyderabad (17.47 °N, 78.58 °E), India using various balloon-borne sensors (Figure 2). A new instrument called **Micro-COPP** (Figure 3) was introduced in August 2018 for measuring the size and shape distribution of cloud particles.

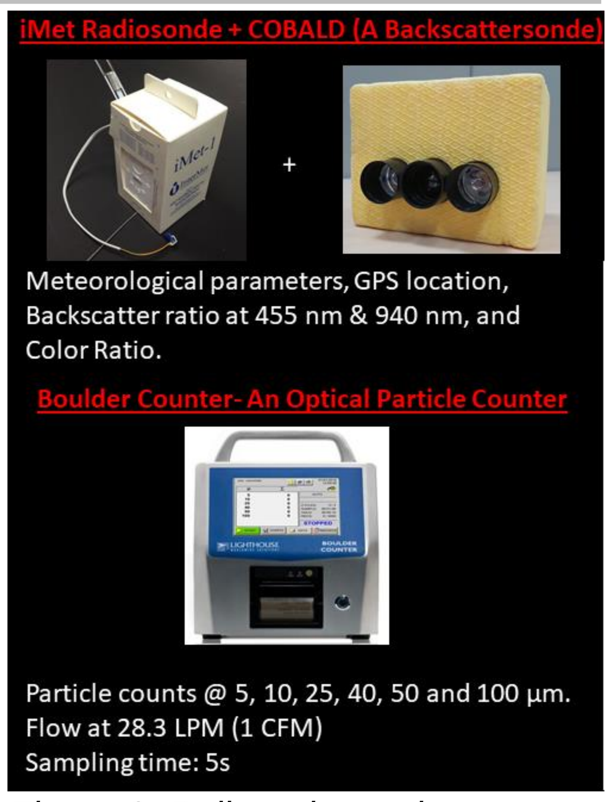

Figure 2. Balloon-borne instruments

Micro-Combination Optical Particle Probe (µCOPP)

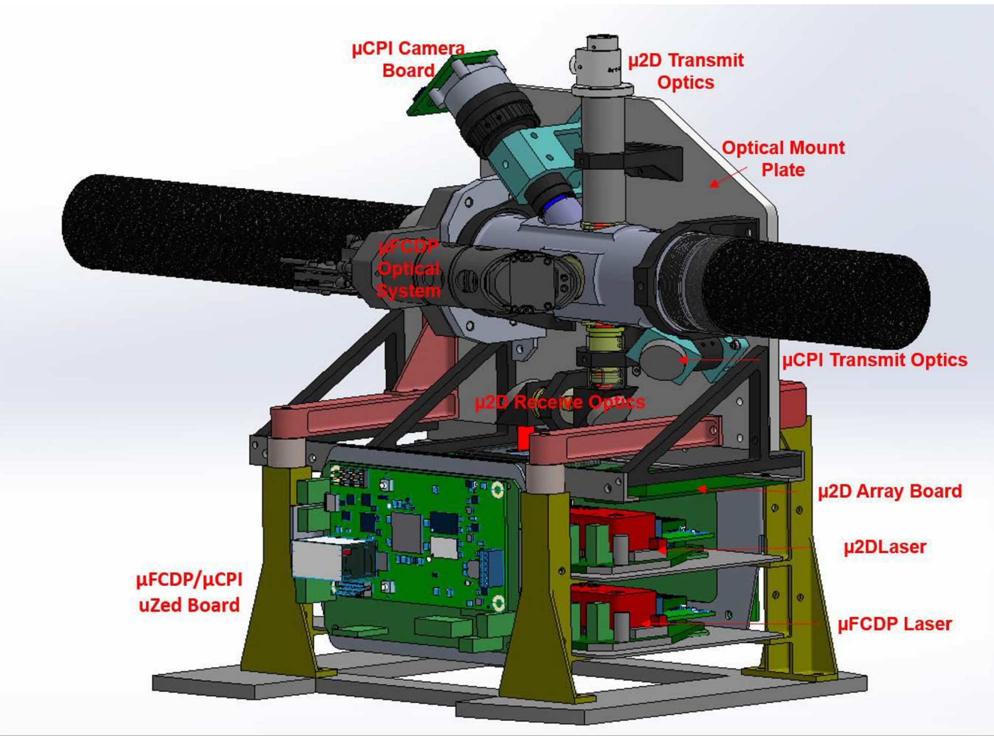

Figure 3. Solid model diagram of µCOPP

Table 1. Specifications of micro-COPP instruments

Instrument	Measurement Type	Sensor specs	Resolution	Measurement Range	Sampling Speed	Laser Wavelength
µCPI	Camera	1024 x 1024 8 bit gray scale	2.3 µm / pixel	2.3 µm to 2.3 mm	~30 fps	805 nm
µ2D	Imaging	128 bit Photodiode array	25 µm	25 µm to 3.2 mm	Continuous	658 nm
µFCDP	Forward Scattering	Signal and Qualifier Photodiode	1 µm	1 to 50 µm	Continuous	785 nm

Lawson (2019)

Micro-COPP is a lightweight (~4 kg) instrument developed for measuring the microphysical properties of cloud particles from an Unmanned Aerial Vehicle (UAV) and balloon platforms (tethered or high-altitude balloon). It is a miniaturized version of commercially available instrument from SPEC Inc., called Hawkeye that was developed for NASA Global Hawk UAV and used during NASA's ATTREX mission (Woods et al., 2018). Micro-COPP consists of three miniaturized cloud particle probes, viz., a Fast Cloud Droplet Probe **(µFCDP)**, a two-dimensional optical array probe **(µ2D)** and a high-resolution Cloud Particle Imager **(µCPI)**.

RESULTS from the BATAL Campaigns

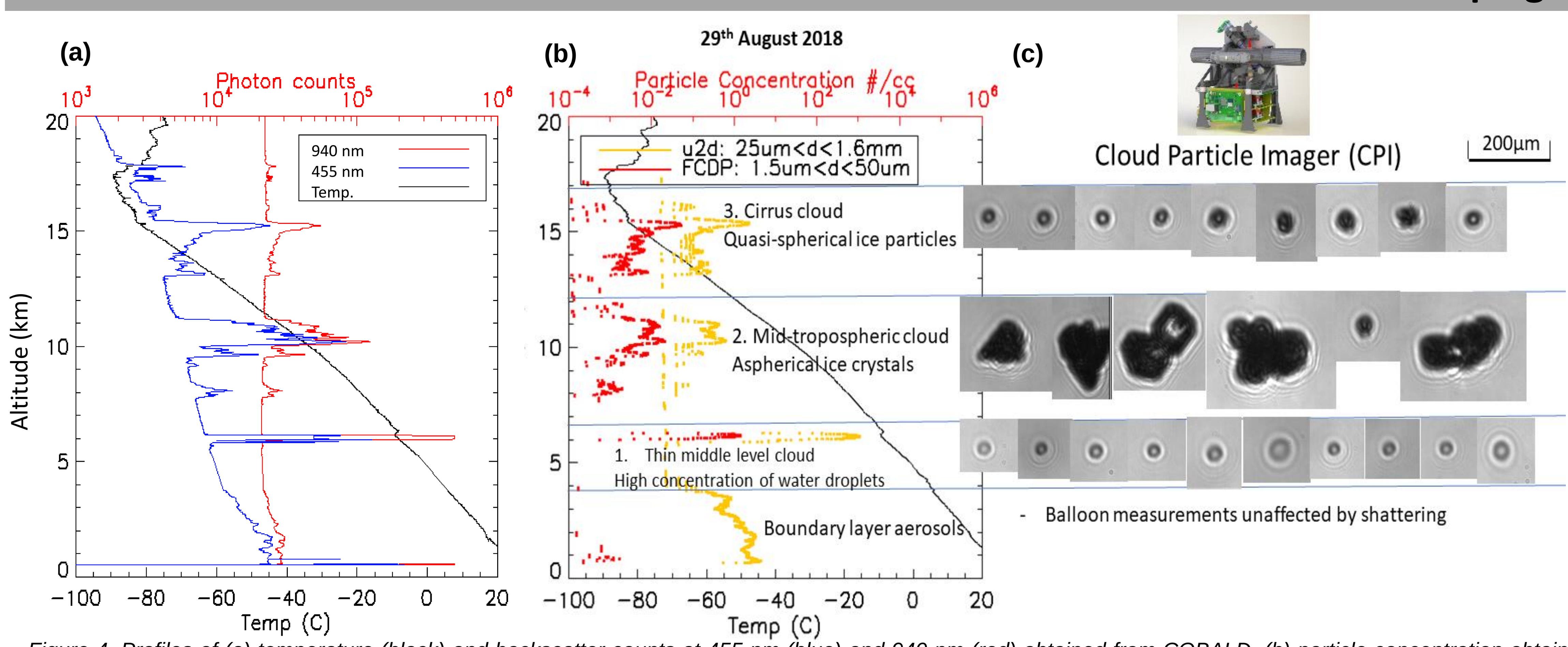

Figure 4. Profiles of (a) temperature (black) and backscatter counts at 455 nm (blue) and 940 nm (red) obtained from COBALD, (b) particle concentration obtained from µFCDP (red) and µ2D (yellow) and (c) particle shapes from µCPI measured during 29 August 2018 balloon flight.

Table 2. Details of balloon flights launched during the BATAL campaigns

Year	August 2017	August 2018			July 2019		
Flight type -> Instrument	HF1	HF2	HF1	HF2	HF3	HF1	HF2	ZF3
COBALD	X	X	X	X	X	-	-	X
Boulder Counter	-	X	X	-	-	X	X	-
µCOPP	-	-	X	X	X	X	X	X

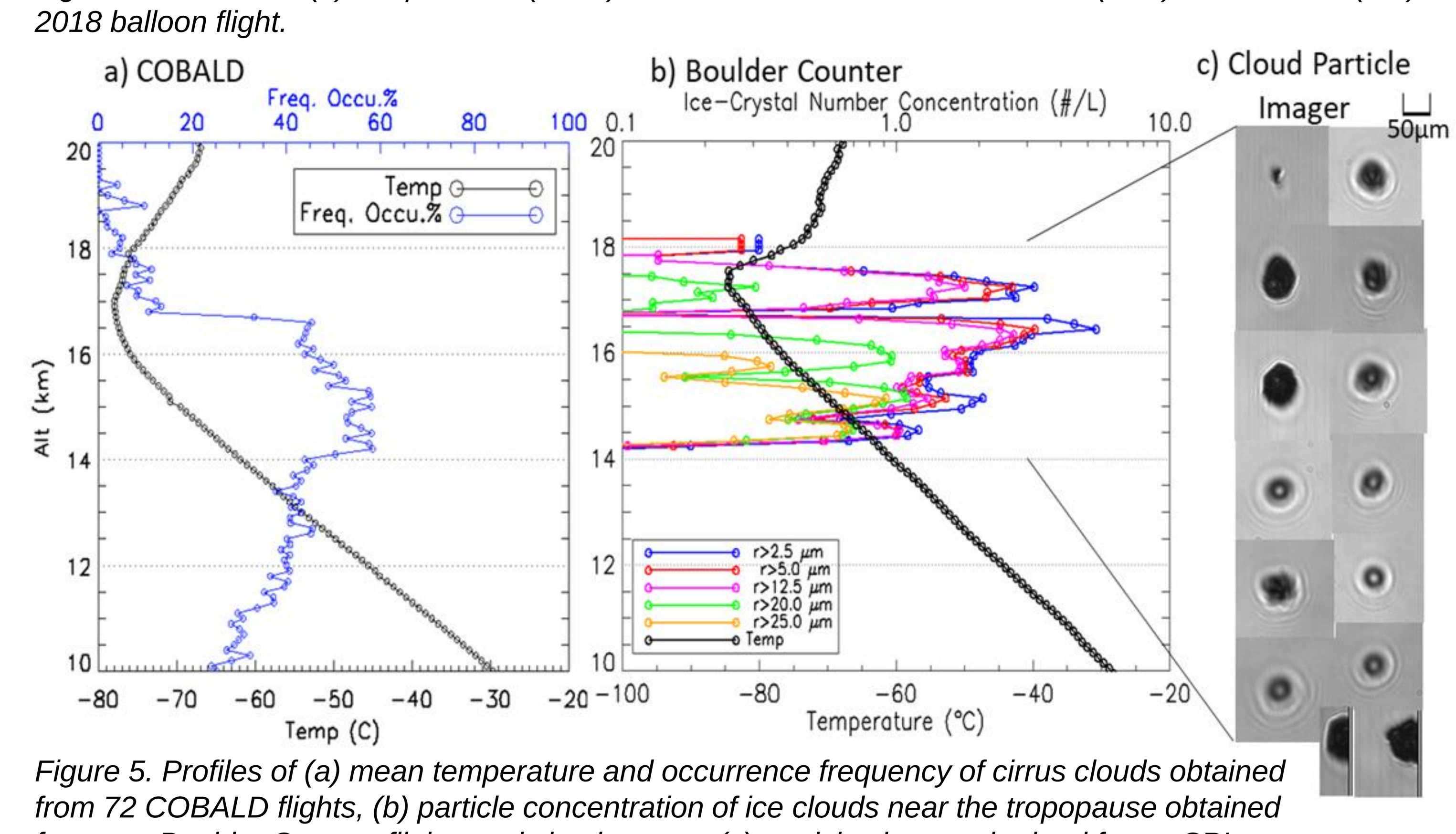

Figure 5. Profiles of (a) mean temperature and occurrence frequency of cirrus clouds obtained from 72 COBALD flights, (b) particle concentration of ice clouds near the tropopause obtained from two Boulder Counter flights and simultaneous (c) particle shapes obtained from µCPI.

Summary

- Micro-COPP onboard high-altitude balloons provided size and shape distributions of cloud particles over Hyderabad during August 2018 and July 2019.
- Multiple layers of clouds were detected by Micro-COPP are consistent with COBALD backscatter measurements.
- Thin cirrus clouds near the cold-point tropopause at extremely cold temperature (~-85° C) were often observed with ice crystals smaller than 100 µm in size.
- Cloud Particle Imager (CPI) onboard the Micro-COPP revealed the presence of quasi-spheroid ice crystals in these thin cirrus clouds.

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