Electronic Supplementary Material (ESI) for Environmental Science: Atmospheres.


# *Supplementary material - Introducing a new airborne research facility in Australia: New airborne research facility observes sensitivity of cumulus cloud microphysical properties to aerosol regime over the Great Barrier Reef*

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## Section S1

## Aircraft instrumentation

Table S1 Instrumentation installed onboard Cessna 337 during the Mar-Apr 2023 Cooling and Shading campaign

| Location | Instrument | Manufacturer | Model | Measured quantity | Range |
|---|---|---|---|---|---|
| **Aerosol Instrumentation System** | | | | | |
| Rack in cabin | mSEMS | Brechtel | 9404 | Aerosol Particle Size Distribution (PSD) | selectable 5 - 375 nm |
| Rack in cabin | aMCPC (SEMS) | Brechtel | 9403 | Aerosol Particle Size Distribution (PSD) | 7-2,000 nm |
| Rack in cabin | MCPC | Brechtel | 1720 | Particle number concentration | 7-2,000 nm |
| Rack in cabin | MCPC (heated) | Brechtel | 1720 | Inorganic particle number concentration | 7-2,000 nm |
| Underwing pod | mOPC | Brechtel | 9405 | Aerosol Particle Size Distribution (PSD) | 0.16 – 3 µm |
| Underwing pod | Isokinetic inlet | Airborne Research Australia | Custom | Inlet for aerosol particles | |
| Underwing pod | Inlet 3-way valve | Brechtel | 3V | select from sample or air from inside pod | |
| Underwing pod | Vacuum pump- Nafion Dryer Circuit | Brechtel | N/A | Used in nafion drying circuit | |
| Underwing pod | Nafion Dryer | Permapure | MD700 | Dries OPC air sample flow | |
| Underwing pod | Nafion Dryer | Permapure | MD700 | Dries cabin air sample flow | |
| Rack in cabin | Neutraliser - Soft X-ray | Brechtel | 9002 | aerosol charge neutraliser used with mSEMS | |
| Rack in cabin | TAP- Black carbon | Brechtel | 2901 | light absorption and estimated black carbon | wavelengths 467, 528, 652 nm |
| Rack in cabin | Vacuum pump - TAP | Thomas | 70060071 | | |
| Rack in cabin | Vacuum pump - MCPC1 | Thomas | 70060071 | | |
| Rack in cabin | Vacuum pump - MCPC2 | Thomas | 70060071 | | |
| Rack in cabin | UHSAS | Droplet Measurement Technologies | UHSAS-G | 0.06-1um | 60 nm – 1 µm |
| Rack in cabin | Thermodenuder heater (300 degC) | Neptech | QUEEN-7053-50CM-000 | Pre-treatment for non-volatile CN | |
| **Meteorology Instrumentation System** | | | | | |
| Wing | ARIM-200 probe | Aventech | ARIM-S200 | 3D wind, T, RH, Airspeed | |
| Wing | ARIM-200 probe Anti-ice | Aventech | ARIM-S201 | 3D wind, T, RH, Airspeed | |
| Cabin | Vectrax 10 module | Aventech | AIMMS30 | 3D wind, T, RH, Airspeed | |
| Cabin | MetTrack display | Aventech | AIMMS31 | 3D wind, T, RH, Airspeed | |
| Underwing pod | IMU / GPS | OXTS | XNAV650 | GPS position /Attitude | |

| | | | | | |
|---|---|---|---|---|---|
| Rack in cabin | Hygrometer- power unit | Buck Research Instruments | 1011C | | |
| Underwing pod | Hygrometer - sensor | Buck Research Instruments | 1011C | dew point temperature | |
| **Radiation Instrumentation System** | | | | | |
| Wing | Net radiometer | Apogee | Net radiometer SN-500 | Net radiation | 385 - 2105 nm (upward-looking), 295 - 2685 nm (downward-looking) |
| Rack in cabin | data logger | Campbell scientific | CR1000X | datalogger for radiometer | |
| **Cloud Microphysics Instrumentation System** | | | | | |
| Fuselage | camera | Milesight | MSC5375PD | Video - Upward | |
| Wing | camera | Milesight | MSC5375PD | Video - Forward down | |
| Wing | camera | Milesight | MSC5375PD | Video - Down | |
| Underwing pod | camera | Milesight | MSC5375PD | Video - Forward | |
| Rack in cabin | camera recorder + 2TB HDD | HikVision | DS-MP5604N | | |
| Wing | CCP/CIPg | Droplet Measurement Technologies | CCP | Cloud Particle Size Distribution (PSD) | 15 - 960 µm |
| Wing | CCP/CDP | Droplet Measurement Technologies | CCP | Cloud Particle Size Distribution (PSD) | 3 - 50 µm |
| Wing | CCP/Hot-wire | Droplet Measurement Technologies | CCP | Liquid Water Content (LWC) | 0 - 3 g/m3 |
| Wing | Cloud Combination Probe (CCP) Anti-ice | Droplet Measurement Technologies | CCP | | |
| **Data processing, storage, & Display** | | | | | |
| Rack in cabin | fanless computer | NEXCOM | ATC 8110 | Data acquisition | |
| Cabin | Rear seat monitor | Aplex | ARCDISS-115 | instruments display | |
| Rack in cabin | Network time server | Time Machines Corporation | TM1000A -GPS NTP time server | GPS based time to nanosecond accuracy | |
| Rack in cabin | Unmanaged Network Switch | Weidmuller | IE-SW-EL10-8GTPOE-2GESFP | | |
| Cabin | Laptop | Dell | Lattitude 14 | | |
| **Power supply system** | | | | | |
| Rack in cabin | Power distribution board | | | | |
| Rack in cabin | 240V inverters | | | Power assumes 95% efficient | |
| Rack in cabin | 28V to 12V Transformer(s) | | | Power assumes 95% efficient | |

**Section S2.**

**The strategy of measurements with the research aircraft during the Marine Cloud Brightening campaign**

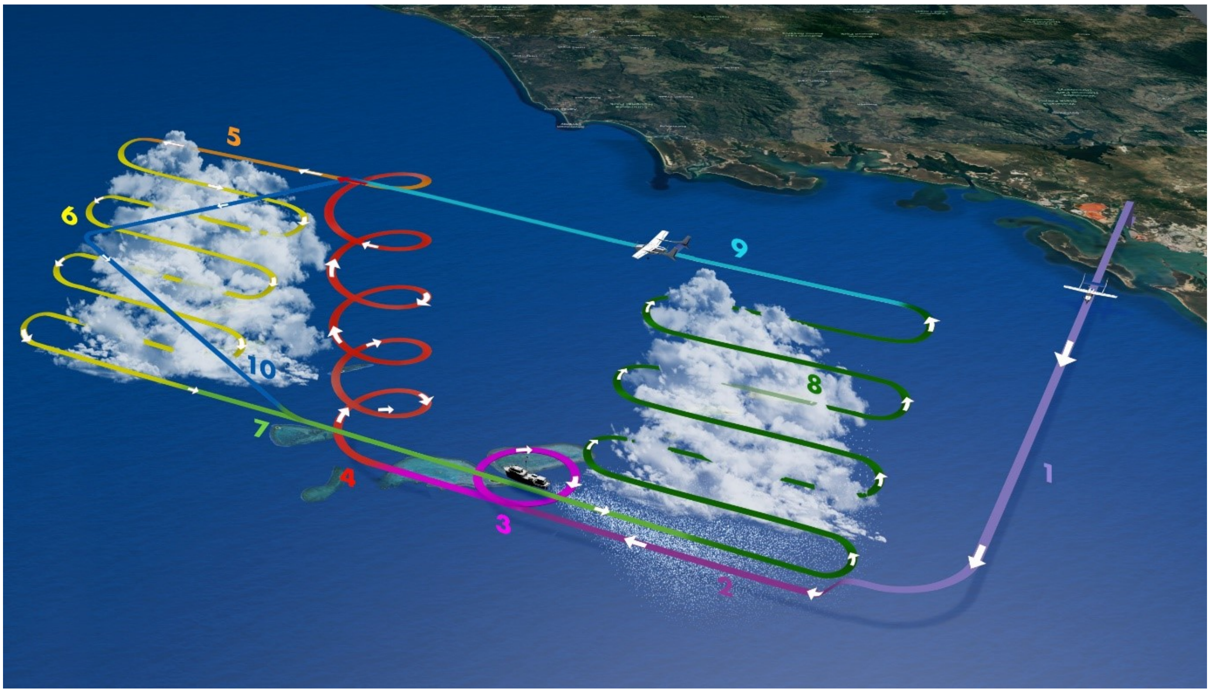


*Figure S1. Schematic figure of the flight pattern during MCB campaign.*

1. *Transfer from the Gladstone airport to the reef: Low-level flight for monitoring aerosols and thermodynamics on the way. (Not higher than 1000 ft).*
2. *Descend to 300 ft into the plume towards the vessel.*
3. *Comparison with ship measurements circling twice around it at a low level.*
4. *Vertical ascending spiral windward of the ship to avoid the sea spray plume. The spiral ascending is performed with a full rate of ascent at a bank angle of 15˚ to 2000 ft above cloud tops, or 10,000', whatever comes first.*
5. *Radiation measurements above clouds before descending through cloud tops.*
6. *Descend by doing cloud cross-sections to establish cloud background (~ 5 steps, no more than 1000' vertical spacing), including base and below base passes.*
7. *Fly into the plume downwind of the ship just below the cloud base, finding ingestion to the cloud base.*
8. *Ascending by doing cloud cross-sections to document seeding signatures from cloud base to top.*
9. *Radiation measurements above clouds.*
10. *Descend only through clouds for another case. Not more than -1000 fpm in the cloud.*

**Section S3**

**Calculated Cloud Microphysical Properties**

*From the DSD measured with CCP-CDP and CCP-CIP, the following cloud microphysical properties were calculated:*

- Number concentration of cloud droplets - $N_d$ ($cm^{-3}$):

$$N_d = \int_{1.5\mu m}^{25\mu m} N(r)dr \qquad (1)$$

where, $N$ is the particle concentration in size range of the probe bin, and $r$ *is* the particle radius (µm).

- Cloud Water Content - CWC ($g\ m^{-3}$):

$$CWC = \frac{4\pi}{3}\rho \int_{1.5\mu m}^{25\mu m} r^3 N(r)dr \qquad (2)$$

where, $\rho$ is the particle density. The density of water ($1\ g\ cm^{-3}$) is used in calculations since our measurements were performed in temperature above 0 °C.

- Cloud Droplet Effective Radius- $r_e$ (µm):

$$r_e = \frac{\int_{1.5\mu m}^{25\mu m} r^3 N(r)dr}{\int_{1.5\mu m}^{25\mu m} r^2 N(r)dr} \qquad (3)$$

- Drizzle Water Content - *DWC* ($g\ m^{-3}$):

$$DWC = \frac{4\pi}{3}\rho \int_{25\mu m}^{125\mu m} r^3 N(r)dr \qquad (4)$$

***Section S4***

***Type of clouds sampled***

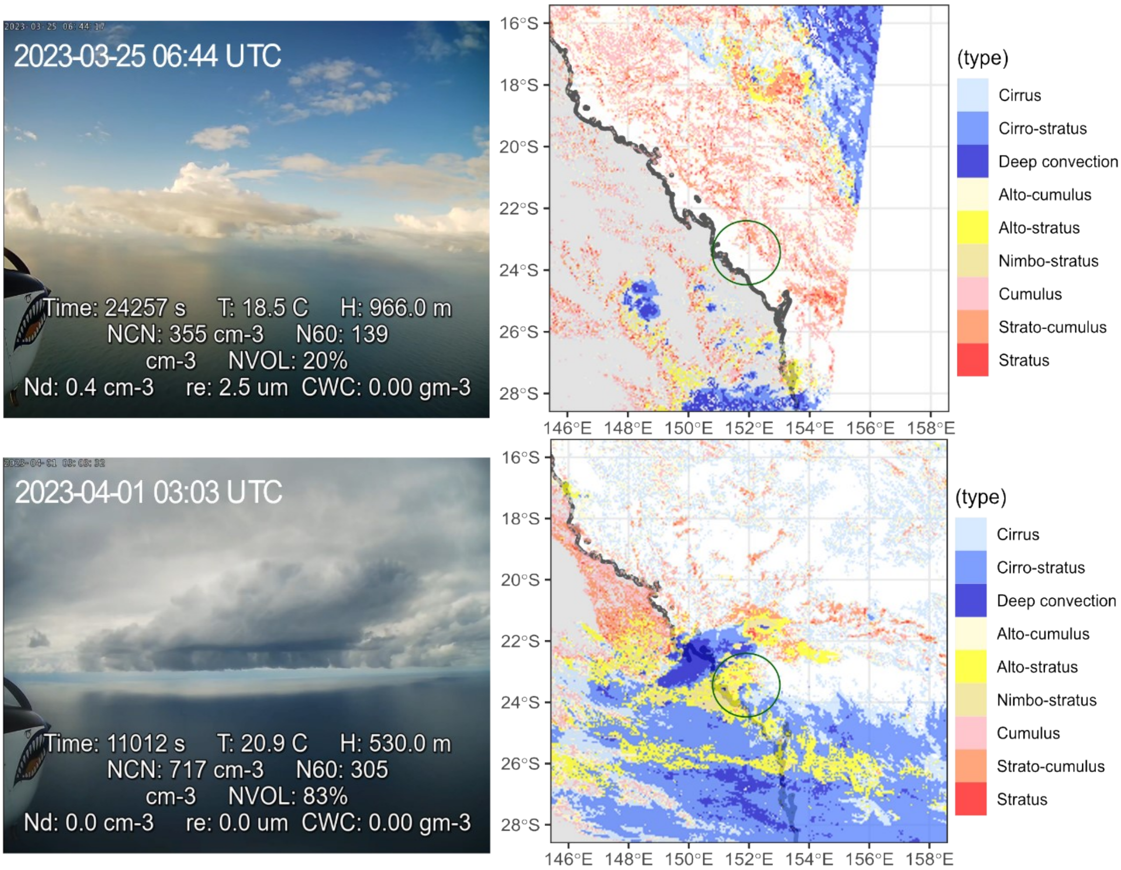


Figure S2 Images captured by the pod camera of the clouds sampled during March 25 and April 01 2023, and cloud-type (The International Satellite Cloud Climatology Project ISCCP) plots derived from from Himawari-8 satellite data for the respective flights

***Section S5***

***Additional Vertical profile of APSDs***

*March 25, 2023*

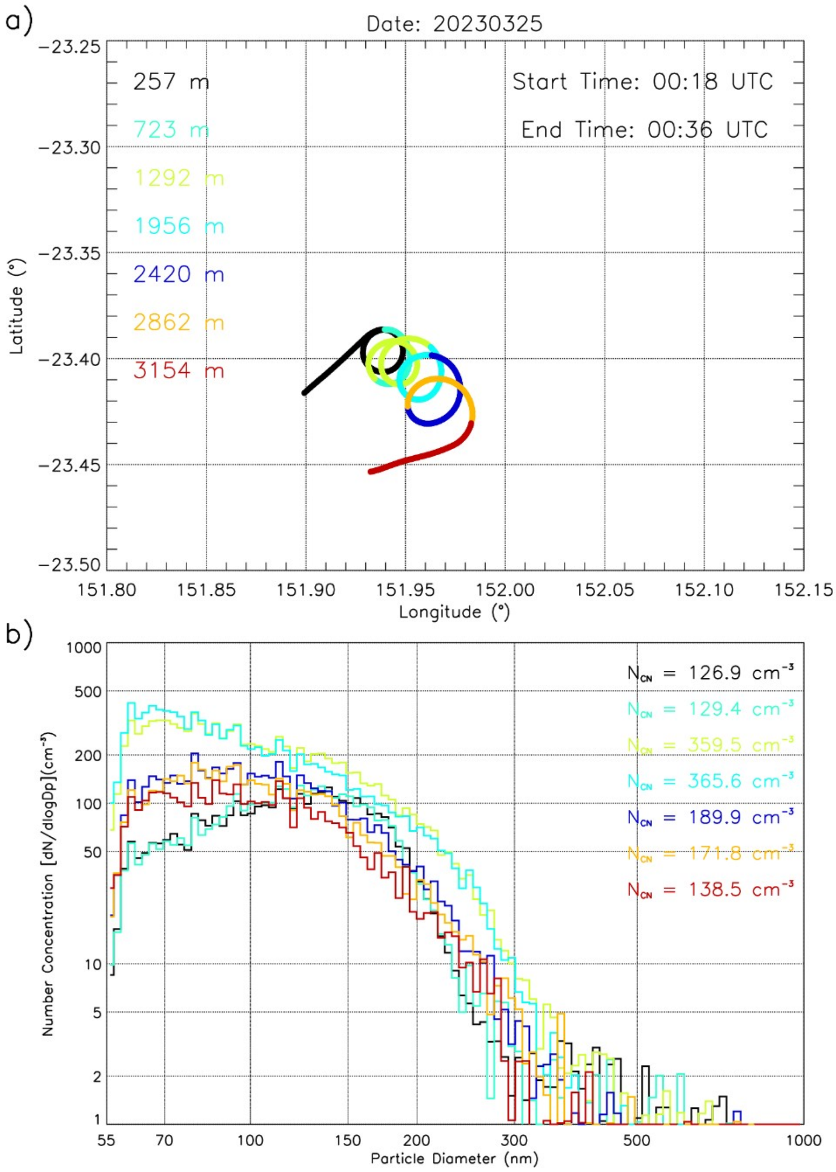


Figure S3 a-b). Aerosol particle size distribution measurements in a vertical ascending spiral on March 25, 2023.

*April 01, 2023*

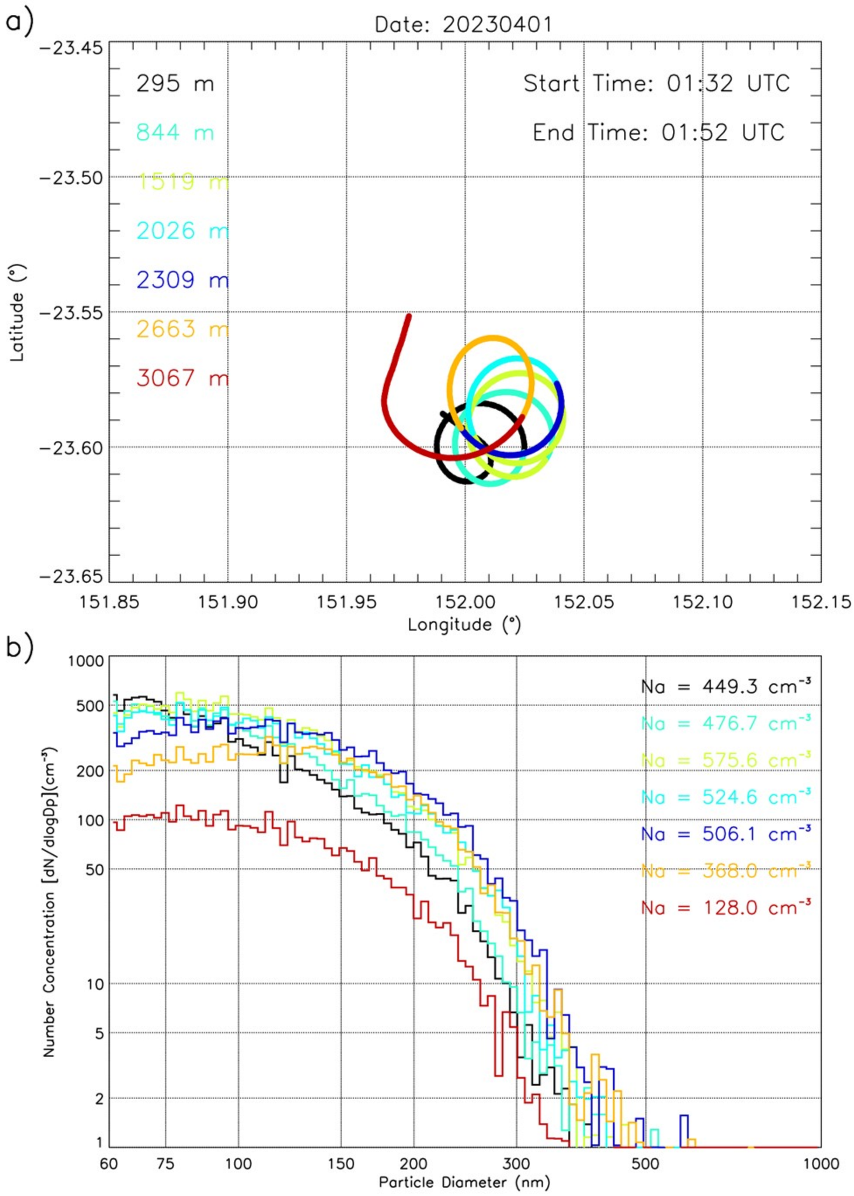


Figure S4 a-b). Aerosol particle size distribution measurements in a vertical ascending spiral on April 01, 2023.

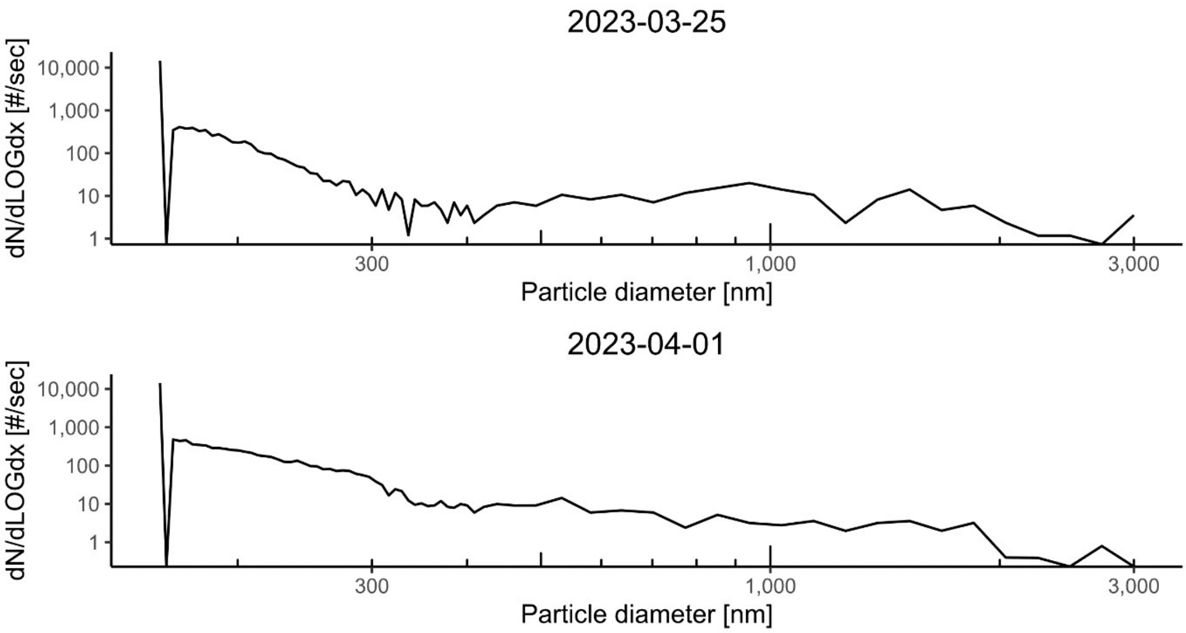


Figure S5 a-b). Aerosol particle size distribution measurements collected at low levels (~300 m) using a miniaturised Optical Particle Counter (9405 mOPC; Brechtel, USA).

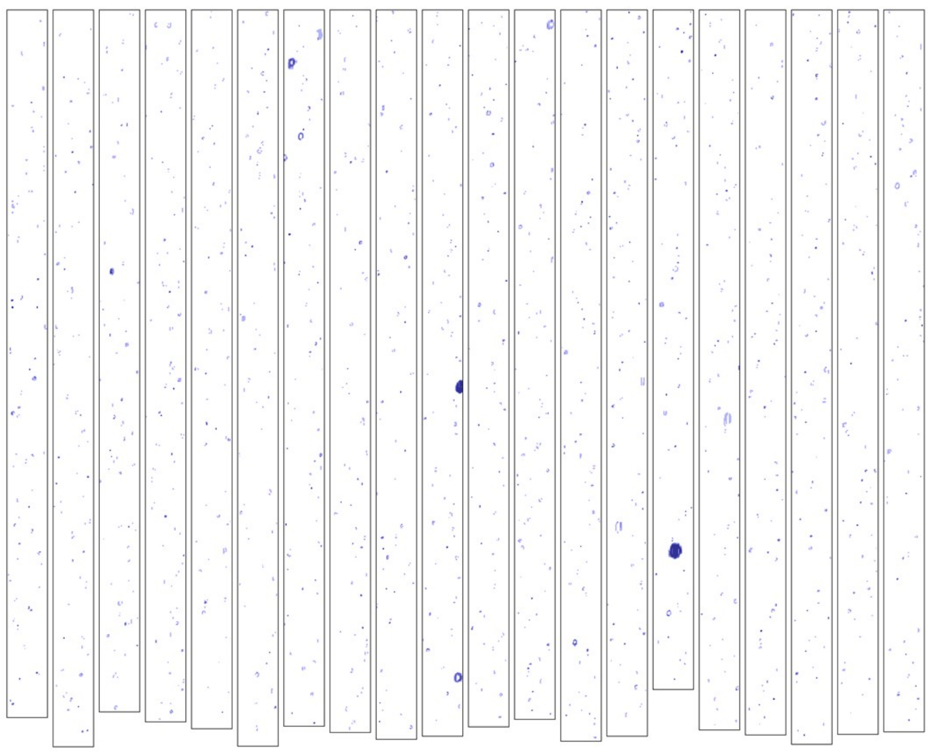

Figure S6. CCP-CIP image correspondent to a cloud pass with $r_e$ = 12.4 µm at altitude of ~ 3000 m when rain starts (*DWC* > 0.05 g $m^{-3}$) on April 1.

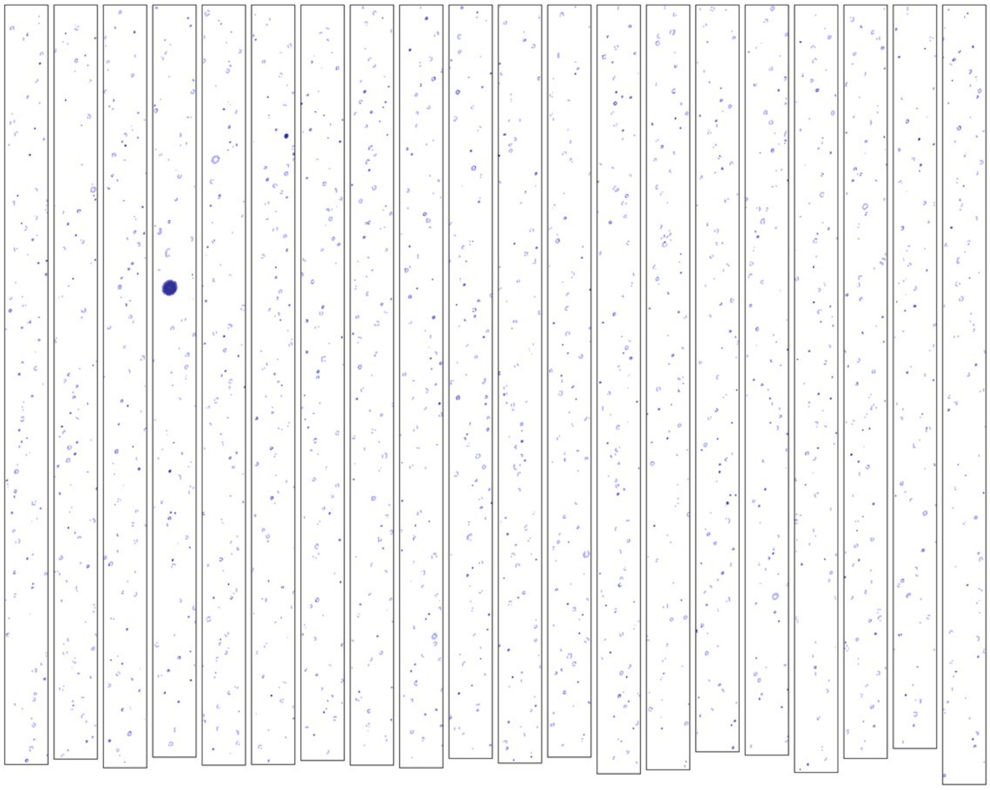

Figure S7. CCP-CIP image correspondent to a cloud pass with $r_e$ = 14.3 µm at altitude of ~ 1800 m when rain starts (*DWC* > 0.05 g $m^{-3}$) on March 25.