Cloud Dynamics

Sinking Air

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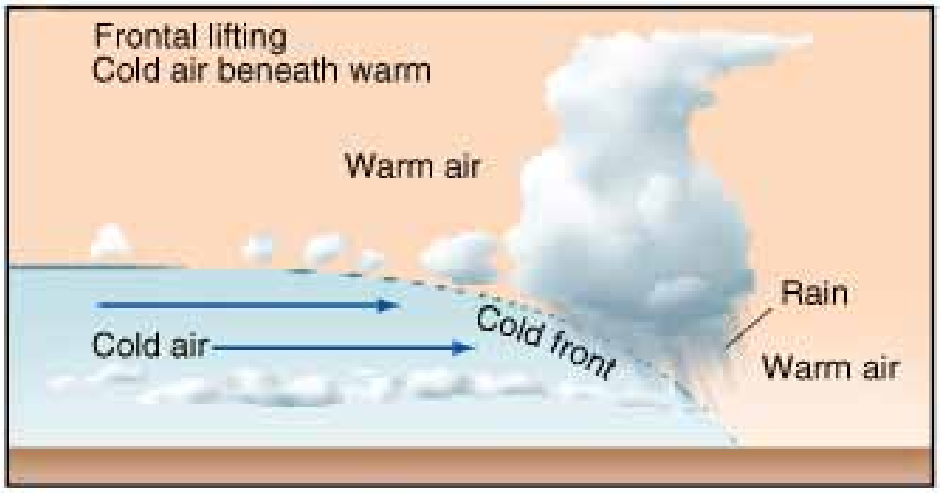
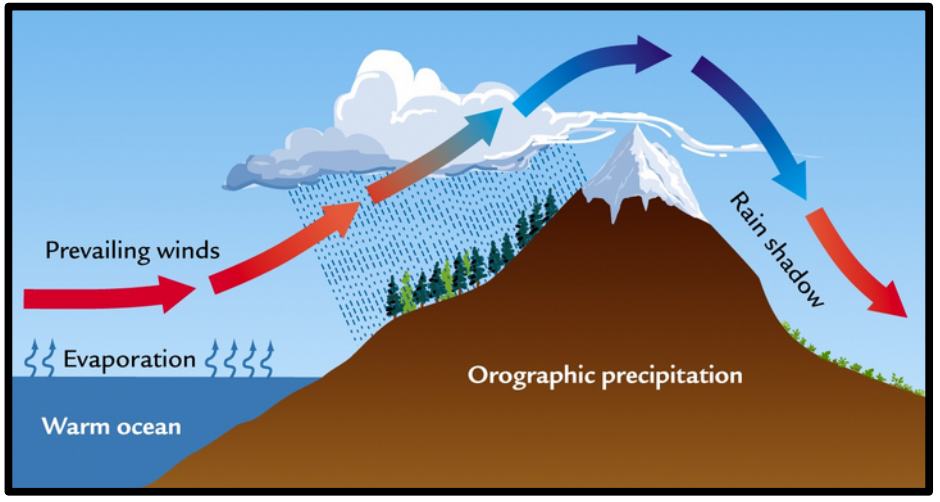
Thermals Rising Upward

Cloud Formation Processes

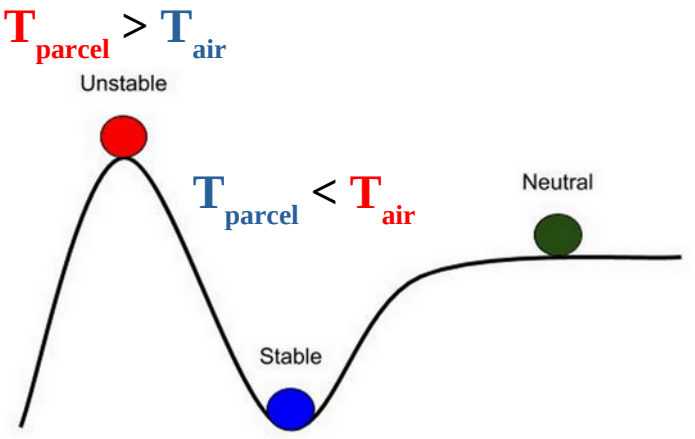
- Rising Air Due to:
  - Synoptic Lifting
    - (Low Pressure)
  - Mesoscale Lifting
    - (Jet Streaks)
  - Thermals
  - Fronts
  - Terrain

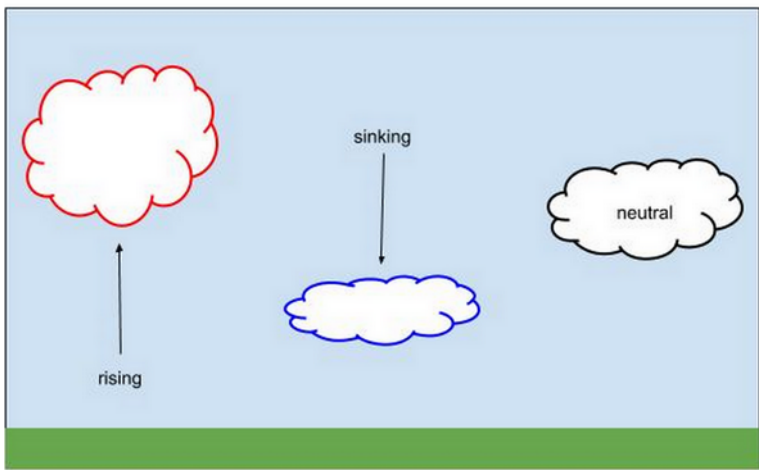




Atmospheric Stability and Vertical Motion

- Stability: Resistance of the atmosphere to vertical motion.
- Air motions are governed by atmospheric stability.
  - Unstable: Rapid Vertical Motion
  - Stable: Limited Vertical Motion
  - Neutral: No Change





How does the parcel and air temperature (T) compare for neutral stability?

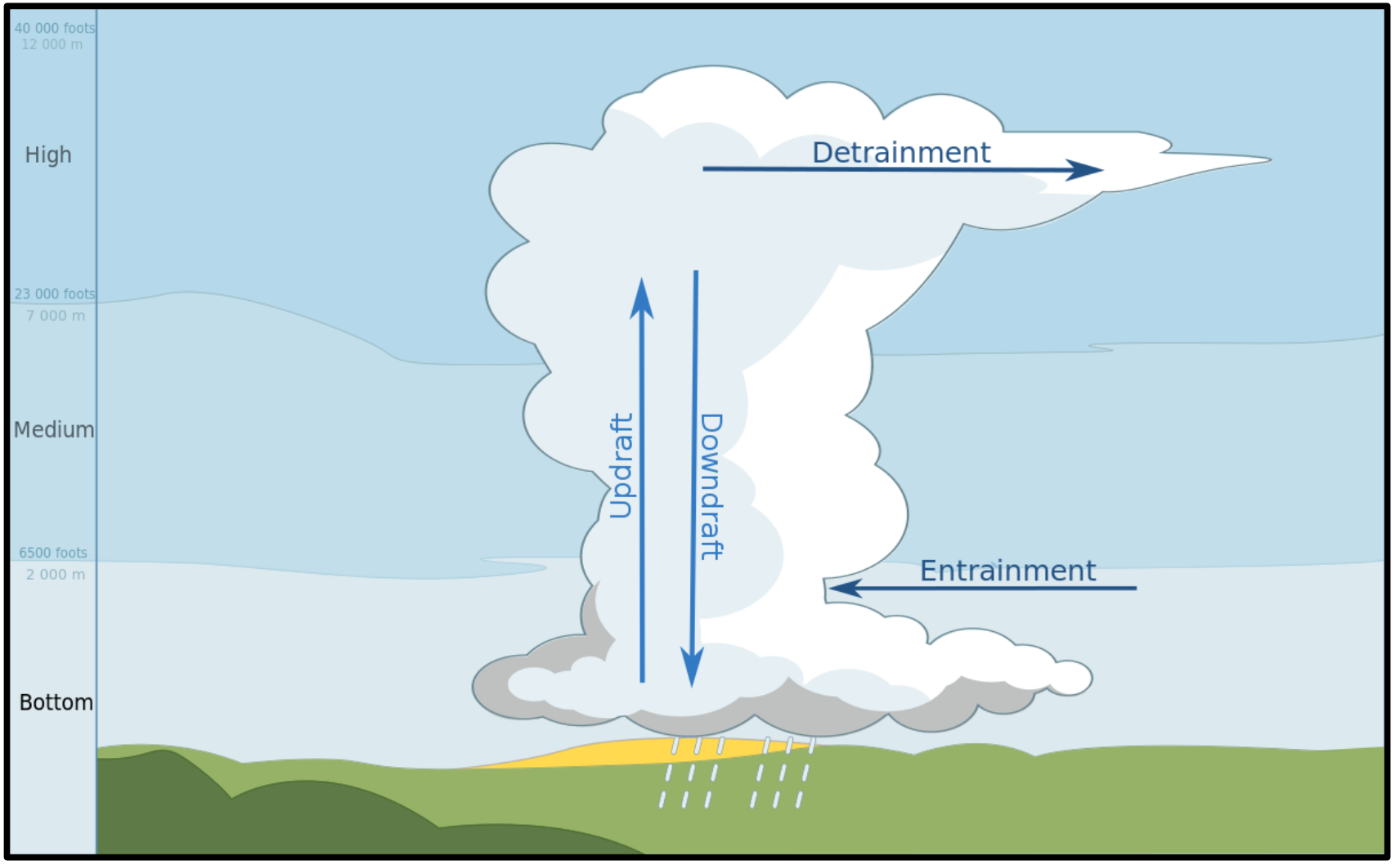
Effects of Latent Heating on Vertical Motion

- Condensation and freezing release latent heat.
  - Cloud Air Warms Slightly
  - Warming Produces Buoyancy
  - Buoyancy Causes the Air to Rise

Cloud Entrainment and Detrainment

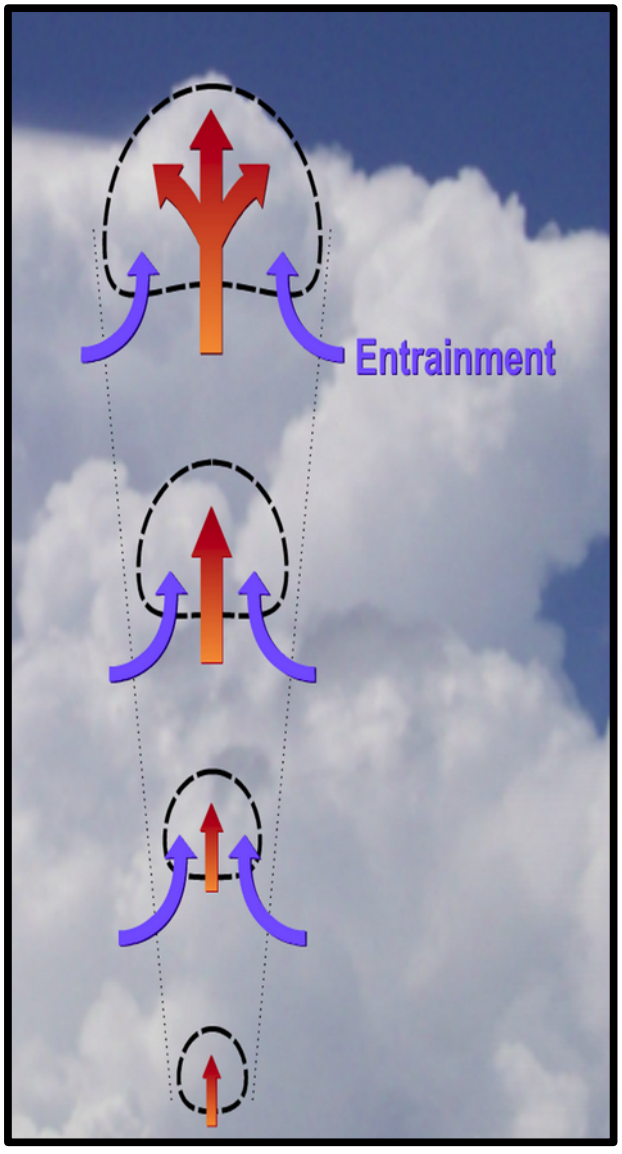
- Air within the cloud mixes with air around the cloud because of turbulent air motions due to the cloud air going up through the environment.
  - Entrainment is outside air entering the cloud.
  - Detrainment is cloudy air leaving the cloud.
- Cloud air is saturated, surrounding air is unsaturated.
- Mixed air is unsaturated, so cloud particles evaporate.

Entrainment and Detrainment Location



Effects of Cloud Entrainment

- Mixing at the cloud boundary results in evaporation, which is a cooling process.
- Cooling increases air density, causing it to sink.
- The sinking offsets some of the cloud rising motion.
- Dryer air works its way toward the interior of the cloud and will eventually stop the updraft.



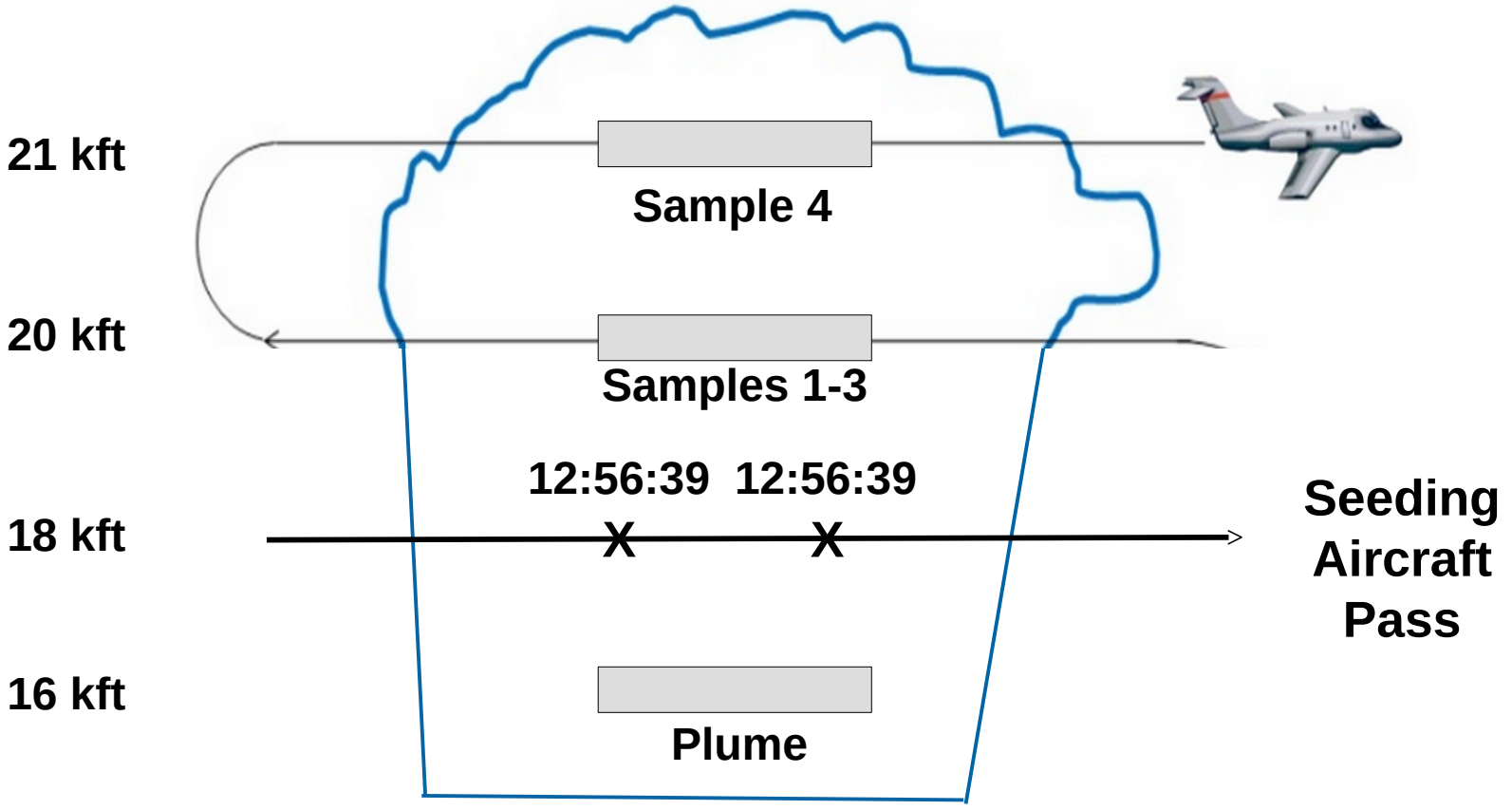
Precipitation Loading of Clouds

- Precipitation loading refers to the effect of condensed water in the updraft.
- Cloud particles are pulled downward by gravity.
- Particles have increasing drag as they grow.
- Combined drag of all particles slows the upward moving air in the cloud (“updraft”) and reverses the flow from upward to downward (“downdraft”).

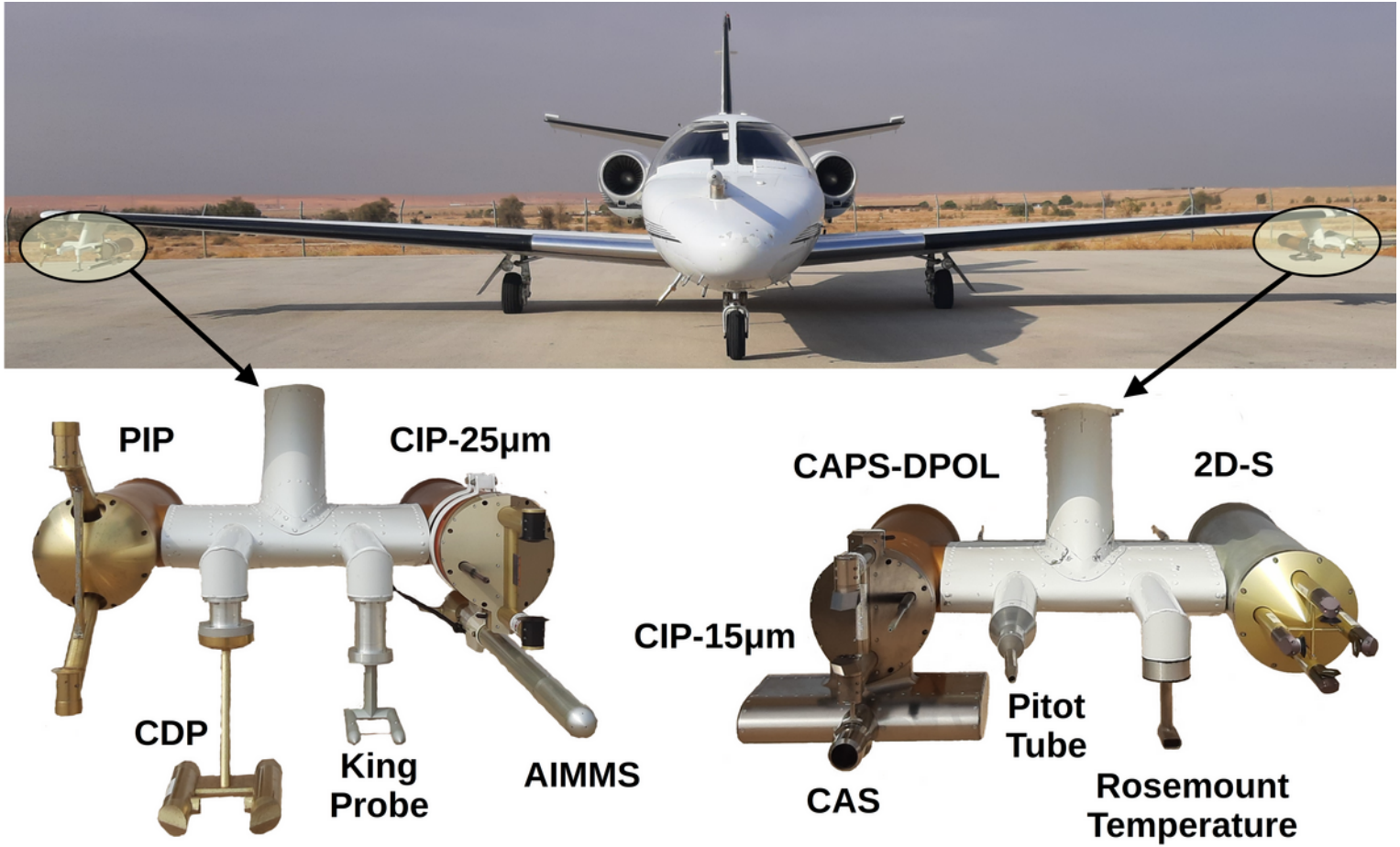
Downdraft Effects on Clouds

- As downdraft air moves through sub-saturated air more evaporation cooling occurs.
- Cooling causes the air to accelerate downward.
- Downdraft spreads out horizontally as it nears the ground.
- Leading edge of spreading air (“gust front”) lifts air ahead of it, which may cause new clouds to form.

Sampling Seeded Plumes: Saudi 2023/2024
31 March 2024

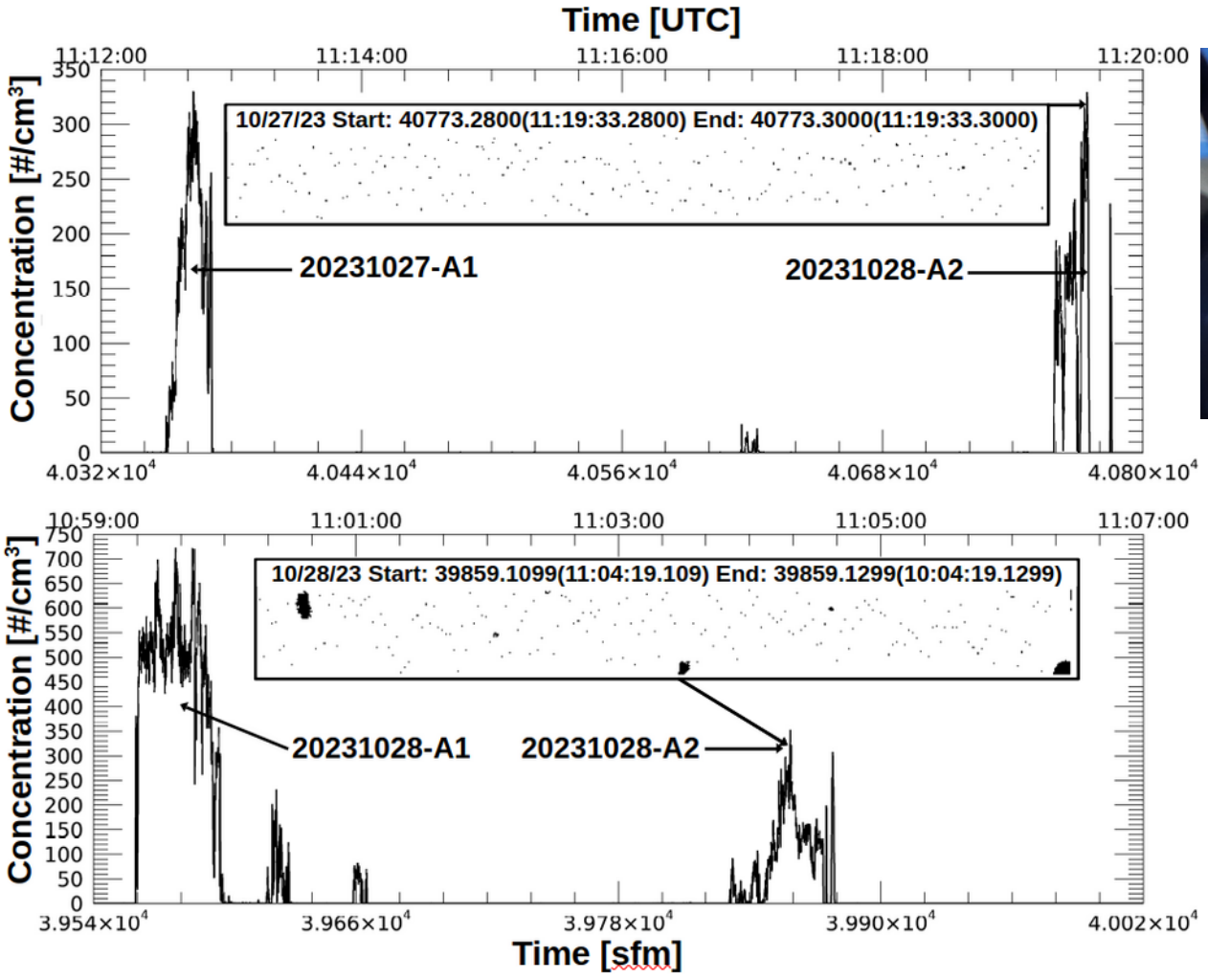


Saudi 2023/2024 IOP: Data Set



The SARPEC intensive operational periods (IOP1/IOP2) occurred in the 2023 summer and 2023 fall, concurrent with the seasonal precipitation maximum in central, Saudi Arabia. In-situ measurements of cloud microphysics properties are obtained using the North Dakota Citation Research Aircraft, which included a Precipitation Imaging Probe (PIP), Cloud Droplet Probe (CDP), King Hot-wire Liquid Water Content Probe (King Probe), a Cloud Imaging Probe with 25 µm diodes (CIP-25µm), an Aircraft Integrated Meteorological Measurement System (AIMMS), a Cloud, Aerosol, a Precipitation Spectrometer with Depolarization (CAPS-DPOL) that contains a Cloud and Aerosol Spectrometer (CAS) and a Cloud Imaging Probe with 15 µm diodes (CIP-15µm), a Pitot Tube, a Rosemount Temperature probe and a two-dimensional Stereo (2D-S) Probe.

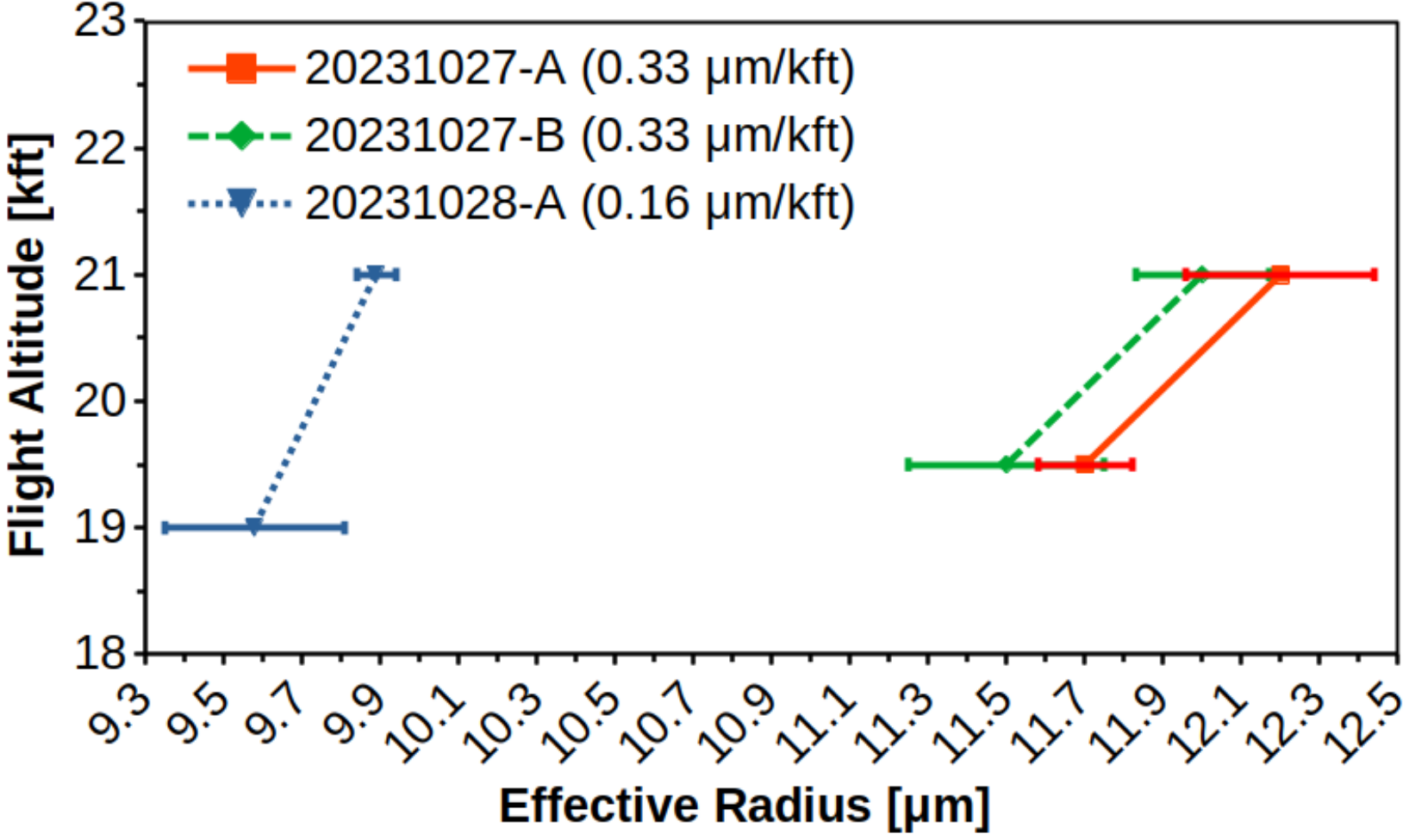
Saudi 2023/2024: 27 & 28 October 2023



Top: Image showing the 20231024-A1 cloud taken from the North Dakota Citation Research Aircraft at 10:58:45 (39,525 sfm) UTC .

Left: Time series (10 Hz) plots showing sampling of cloud convective core A on 27 (top) & 28 (bottom) October 2023, with CIP (25 µm) images.

Saudi 2023/2024: 27 & 28 October 2023



Plots showing effective radius vertical change in cloud cores sampled in the Central (bottom) region of Saudi Arabia.

MedEd Convection Module

- Principles of Convection I: Buoyancy and CAPE

  (http://www.meted.ucar.edu/mesoprim/cape/)

- Likely need to create account using University email address.