Enhanced measurements with the ARM tethered balloon system at Oliktok Point during ICARUS

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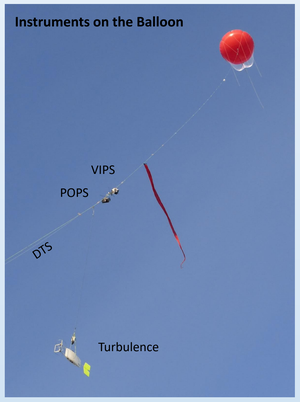
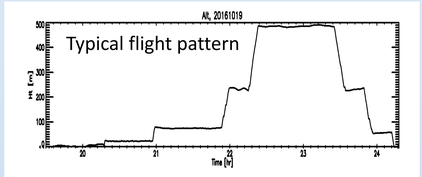
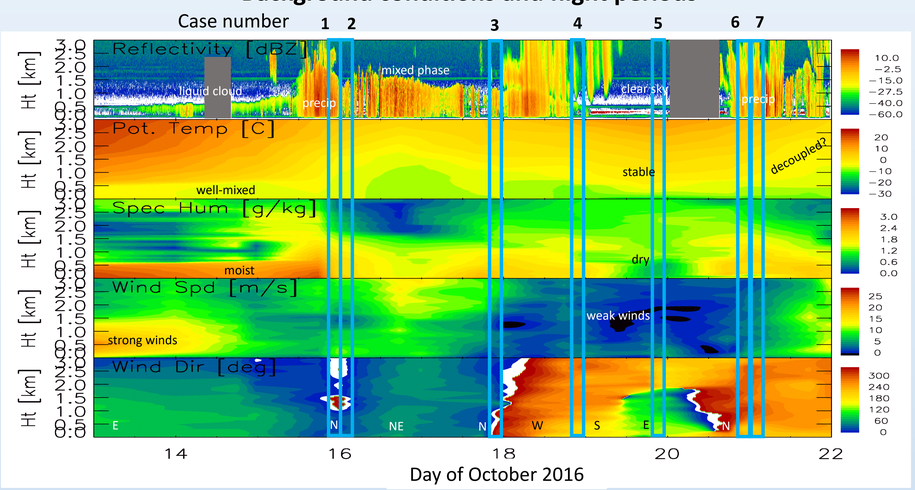
1:U. of Colorado, 2:NOAA, 3:NCAR, 4:U. of Leeds, 5:Sandia Nat. Lab.



The **Inaugural Campaigns for ARM Remote and Unmanned Systems** (ICARUS) were conducted during the spring-to-fall of 2016 at the Oliktok Point site. The ICARUS October campaign featured standard measurements from the ARM Tethered Balloon System (TBS), enhanced TBS measurements with guest instruments, and observations from DataHawk unmanned aircraft. Many of the enhanced measurements are featured here, along with their potential applications for process research and development of observational methods.

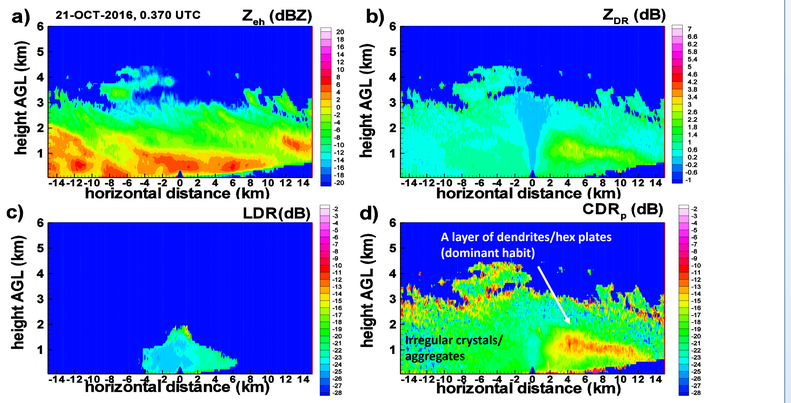


Background conditions and flight periods



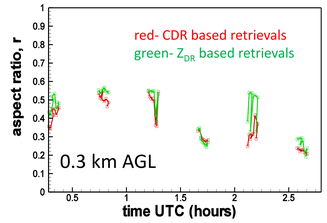
Ice Crystal Habits and Shapes

Radar based measurements/estimates



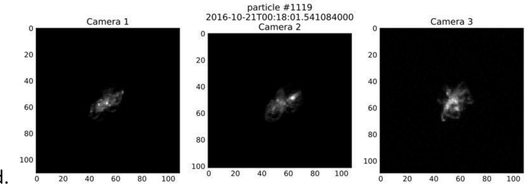
K_a-band SACR measurements taken on 00:22 UTC 21 October 2016 (45° azimuth RHI) during 7th TBS flight. Reflectivity (a), differential reflectivity (b), and linear depolarization ratio (c) are measured directly, and circular depolarization ratio (CDR) is obtained from combined ZDR and co-polar correlation coefficient ρ_{hv} data.

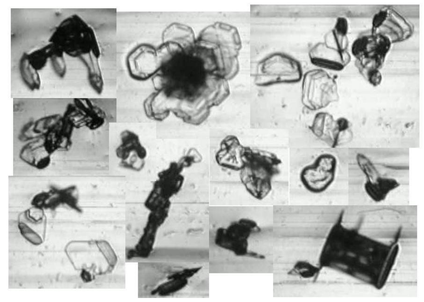
Particle aspect ratio (i.e., minor-to-major dimension ratios) retrievals using Z_{DR} and CDR SACR data on 21 October 2016. CDR based retrievals are significantly less sensitive to particle orientation (compared to Z_{DR} retrievals).



In situ based measurements/estimates

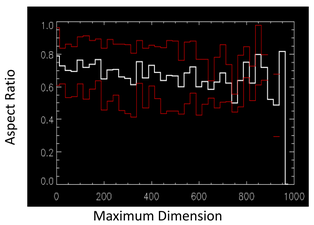
Ground-based Multi-Angle Snowflake Camera (MASC) images during the 7th TBS flight indicate irregular shaped and aggregated particles as a dominant habit. Occasional plate type crystals are observed.





VIPS measurements show mostly unrimed irregular and aggregated particles with some pristine shape crystals (0.2-0.5 km)

The balloon-borne Video Ice Particle Sampler (VIPS) measurements indicate that particle mean aspect ratios do not exhibit significant dependence on particle size



Atmospheric Profiles, Mixing, and Aerosols

Measurements

A collection of measurements were made from the tethered balloon system (TBS):

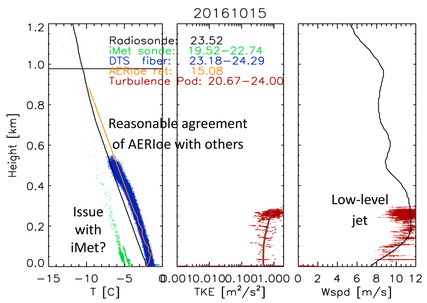
1) Turbulence package: Sonic anemometer oriented into wind with motion correction mounted at one height.
2) iMet Radiosonde: Multiple TBS-mounted radiosonde packages with temperature measurement.
3) Distributed Temperature Sensing (DTS): Fiber optic system for measuring temperature along the full tether.
4) Printed Optical Particle Sensor (POPS): Measures aerosol size distribution using an aspirated sampling system.

These are compared with other measurements and derived products:

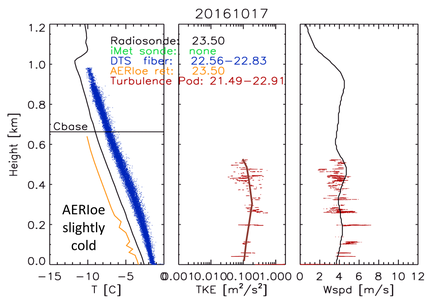
Standard Radiosonde: Two profiles per day of temperature, moisture, winds.
AERIoe: Optimal Estimation based retrieval of temperature profile from AERI measurements

The combined standard and enhanced instruments operated on the TBS offer the ability to examine numerous boundary layer properties and processes, and to assess associated retrievals from ground-based instruments:

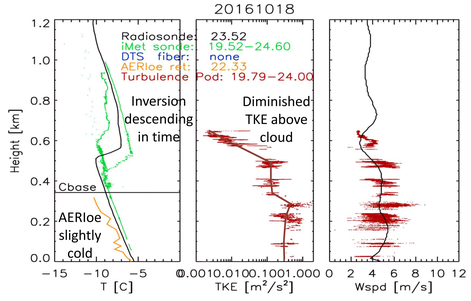
- Vertical thermodynamic structure and stratification
- Turbulent mixing associated with clouds and wind shear
- Vertical distribution of the aerosol size distribution
- IR retrievals of temperature profiles
- Radar retrievals of turbulence and vertical/horizontal winds (not shown)



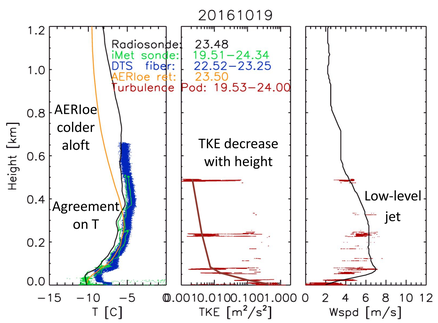
Case 1&2: On-shore winds, weakly precipitating, surface coupled stratiform cloud

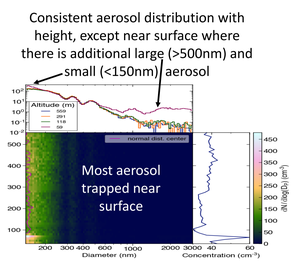


Case 3: On-shore weak winds, weakly precipitating, surface coupled stratiform cloud

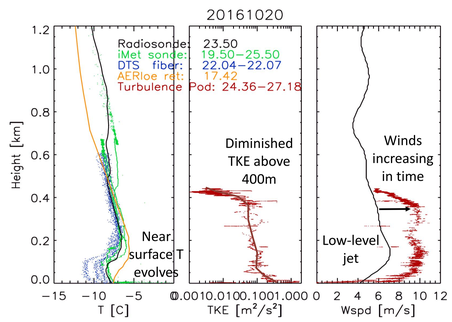


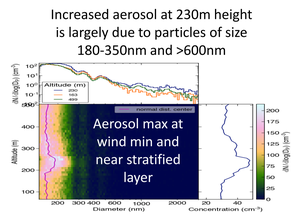
Case 4: Off-shore weak winds, very thin surface coupled stratus cloud





Case 5: Weak along-shore winds, dry and clear with stable boundary layer

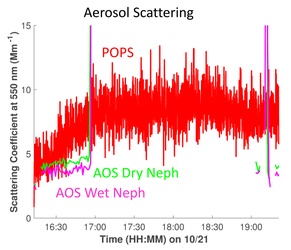




Case 6&7: On-shore winds, deeper precipitating system. Decoupled?

Comparing Aerosol Measurements

Measurements from the Aerosol Observing System are compared with POPS observations made from the top of the AOS container. Objective is to understand the POPS measurements.



POPS scattering is initially similar to AOS nephelometer measurements but then increases as the laser temperature cools. T-dependency must be addressed.

POPS size distribution is shifted to larger sizes than UHSAS by 100-150nm; this may be due to the offset as a function of laser temperature. However, the range of sizes and individual modes agree will with the HTDMA. Need to sort this out.