14th AMS
Cloud Physics

P 106

Untangling Microphysical and Dynamical Effects in Precipitation Formation

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Introduction—

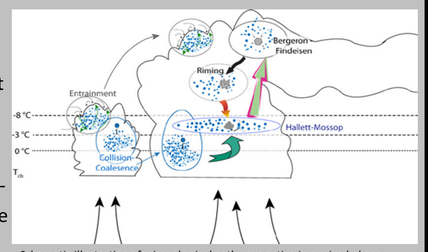
The Convective Precipitation Experiment (COPE), a joint UK-US field campaign, took place in the southwestern peninsula of the UK during the summer of 2013. The overarching objective of COPE was to study convective clouds that produce heavy rain that lead to flash floods and to improve forecasts by better understanding and representing interactions of cloud microphysics and dynamics in numerical models.

COPE-MED — (Microphysics and Entrainment Dependencies)

COPE-MED was a US-led portion of the larger COPE campaign designed to investigate how changes in relative strengths of microphysical pathways affect precipitation formation.

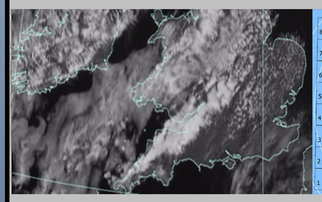
How do differences in the strength of the warm rain process impact, directly and through ice multiplication, the development of convective precipitation?

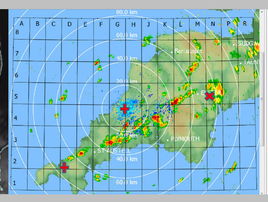
Does the formation of rain through warm processes result in higher production of precipitation by 'kick-starting' ice processes due to multiplication?



Schematic illustration of microphysical pathways active in a mixed phase convective cloud

Field Campaign—





Southwestern UK
July 3—August 28

5 mixed phase:
350—1000 cm^{-3}

7 warm rain only:
up to 50+ dBZ!

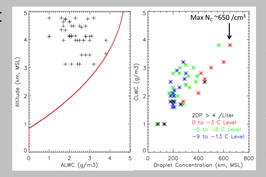
Clouds and storms tend to form along line oriented along spine of peninsula as convergence boundaries interact with the local topography. Largest precipitating events occur as cells propagate along line (typically to NE) as new cells form on the upwind side of the line.

Measurement Assets:

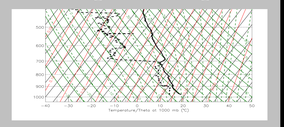
The UK NCAS *X-band* fast scanning dual-polarization radar anchored the ground-based measurements in the center of the domain. Operators at the radar helped direct two research aircraft: the UK BAe-146 and the US/NSF UWYO King Air. Both were instrumented for cloud physics in situ measurements, the UWKA also carried a vertically pointing polarimetric cloud lidar (WCL) and a *W-band* Doppler cloud radar (WCR).

Aug 02 Case—

The UWKA made 48 cloud penetrations over 2.5 hours, through ascending cloud tops from 2 to 4 km above cloud base. Observed cloud droplet concentrations were as large as 650 cm^{-3} within regions of LWC ~90% adiabatic. Rarely did large particle concentration exceed 4 L^{-1}.



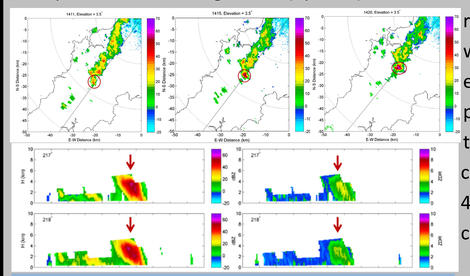
Sounding from Aug02



C_B~890 mb, T_B~+12C, T_T~-13C

Lid at 700 mb (0 C) that eroded throughout the day. Significant drying above lid.

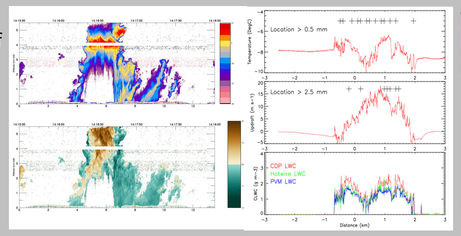
Example of a cell forming on SW (upwind) side of line on Aug02. This cell was visible on the radar for ~15-20 minutes, during which time the UWKA made two passes at the –8 C level. During the second penetration, ground radar indicated at the level of the UWKA a +50 dBZ echo collocated with high ZDR, in excess of 4 dB. Consistent with elevated, supercooled raindrops.

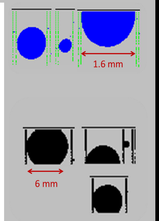


1415: One minute after time of first penetration (and during time of second) by UWKA—top to ~5 km , elevated ZDR column to above 4 km, highest reflectivity at 4 km

(BELOW) The UWKA passed ~1 km underneath the top of the growing turret, encountering 18 m s^{-1} updraft in the center of cloud and several large raindrops, the largest of which was 6 mm in diameter! Raindrops were found throughout the cloud (not confined to edges) and little or no ice was present in the cloud.

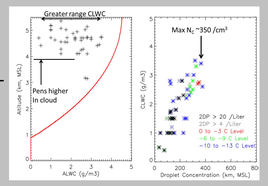
Low concentrations of moderate to large raindrops were observed throughout Aug02. Very little ice was produced on this day



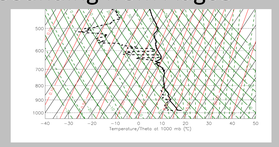


Aug 03 Case—

The UWKA made 40 cloud penetrations on Aug03. The penetrations were again near the tops of ascending turrets, above about 4 km (-8 C). The UWKA encountered a much broader range of CLWCs with significantly fewer cloud droplets (350 cm^{-3}) and significantly more large particles (up to 40 L^{-1}).



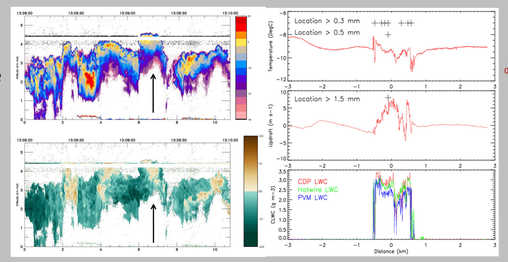
Sounding from Aug03

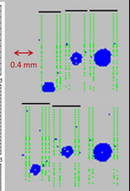


C_B~890 mb, T_B~+12C, T_T~-14C

Slightly more stable than Aug02, this likely account for weaker observed updrafts (5-8 m s^{-1}, compared to 12-20 m s^{-1} on Aug02). Note absence of a lid and more moisture near cloud top.

(BELOW) The UWKA passed through the tops of growing turrets. Like Aug02, the clouds were organized along a line, but on this day the cells were more densely packed along that line as can be seen from the WCR profiles. The cells more readily produced precipitation resulting in higher concentrations of smaller particles and more ice.



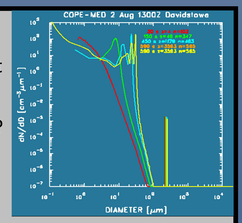


RECORD BREAKING DROP!!!

The panel to the left shows an image of a 6 mm raindrop imaged from the OAP-2DP on the UWKA on a penetration on Aug02. Drops as large as 8 mm have been reported in the literature by Beard et al (1986) and Hobbs and Rangno (2004). However, all of these observations were made at or below cloud base within tropical convective clouds. To our knowledge, this is the largest ever reported drop within a mid-latitude convective cloud and the first ever reported observation of a ***super-cooled giant raindrop***.

Discussion—

1. How do we explain such large raindrops in rapid ascent (Aug02)? Mixing from multiple thermals? There exists no evidence of previous thermals from either aircraft or from ground-based radar. Single parcel model is unable to explain the growth of large drops even when seeding cloud base with 100+ μm drops.
2. Drops 2-3 mm were common on Aug02, but only in clouds with updraft > 10 m s^{-1}...what role does lofting play for large droplet growth and supplying ample CLWC?
3. Aug03 has less cloud droplets (by half) yet produces *no raindrop observations with D>1 mm*. Also, on Aug03, significantly more ice is produced and the mass of precipitation is significantly larger than compared to observations from Aug02. Aug02 produces more rain *through warm processes* but is almost devoid of ice; despite both days having similar thermodynamics...
4. What role do cloud-cloud interactions play for the development of precipitation, and particularly ice at relatively warm temperatures? On Aug03 clouds were 'packed' tightly and ice was produced readily. Does such close proximity of other clouds promote ice multiplication through secondary processes?



1D model ascent, seeding cloud base with 10 L^{-1} of 200 um droplets, note no substantial growth of those droplets occurs during ascent through the cloud.

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