A Multi-scale Study of the 23 October 2022 Southern England QLCS

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During the afternoon of 23 October 2022, a quasi-linear convective system (QLCS) developed and intensified over the English Channel and tracked north-northeastward into southern England, producing widespread damaging downburst winds. In general, early afternoon NOAA-20 NUCAPS sounding retrievals qualitatively indicated the strongest signal for severe thunderstorm and downburst occurrence over southern England.

INTRODUCTION AND OBJECTIVES

•During the afternoon of 23 October 2022, a quasi-linear convective system (QLCS) developed and intensified over the English Channel and tracked north-northeastward into southern England, producing widespread damaging downburst winds. The highest measured downburst wind gusts of the event occurred at 1) Army Aviation Centre (AAC) Middle Wallop, Hampshire (55 miles SW of London), with a wind gust of 54 kt (62 mph) recorded between 1500 and 1600 UTC and generated by a prominent bowing segment of the QLCS; 2) London Colney, Hertfordshire, with a wind gust of 56 kt (64 mph) recorded at 1640 UTC and generated by a pulse-severe cell east of the bowing segment of the QLCS.

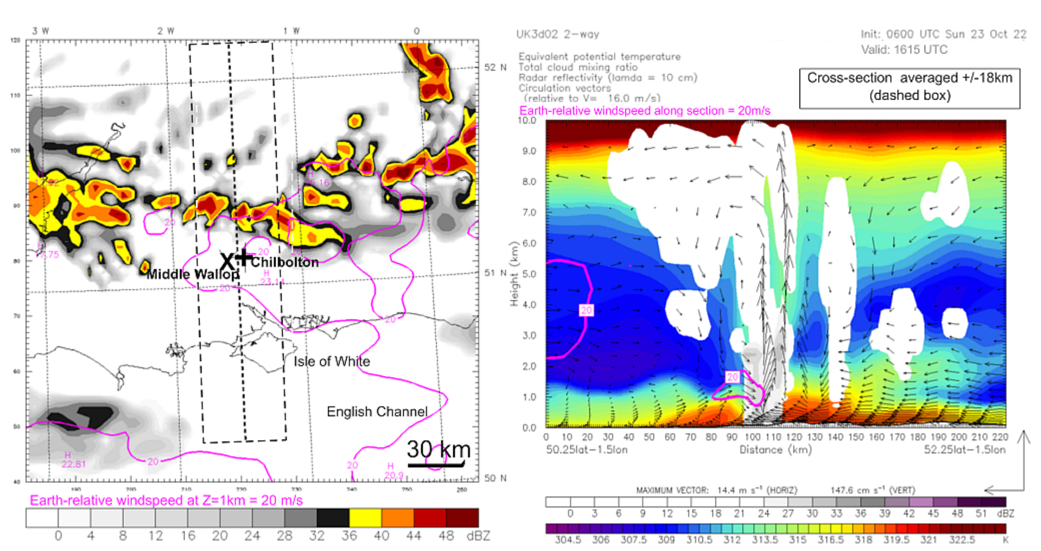


Figure 1. A deep convective storm with the potential to generate intense downdrafts and damaging downburst winds: plan view of WRF model-simulated radar reflectivity over southern England (left) and cross-section (right) at 1615 UTC 23 October 2022. Figure generated from a 2-way nested 9-3km/38 level convection-permitting WRF run initialised with Global Forecast System data. The cross-section is averaged over a 36km-wide box.

•Figure 1, a WRF-model simulation of the QLCS during phase 1, summarizes the favorable thermodynamic and dynamic factors that promoted strong outflow wind generation: 1) precipitation loading, 2) latent cooling, 3) negative buoyancy (F_{down}), 4) downdraft acceleration, 5) downshear wake entrainment, and 6) rear-flank circulation/rear-inflow jet. This research effort demonstrates how ground-based and satellite-based observational data can be combined for monitoring and forecasting applications and the scientific value added by synergistic analysis.

DATA AND METHODOLOGY: SATELLITE, RADAR, AND NWP MODEL ANALYSIS

•The NOAA-Unique Combined Atmospheric Processing System (NUCAPS) is an enterprise algorithm that retrieves atmospheric profile environmental data records (EDRs), and is applied and evaluated for both a daytime and nocturnal severe convective windstorm cases. NUCAPS is also the primary algorithm for the operational hyperspectral thermal IR and microwave sounders (i.e. Advanced Technology Microwave Sounder (ATMS), Cross-track Infrared Sounder (CrIS)). The ATMS and CrIS instruments are deployed on the NOAA-operational low earth orbit (LEO) Joint Polar Satellite System (JPSS)-series satellites.

NUCAPS Enterprise Algorithm

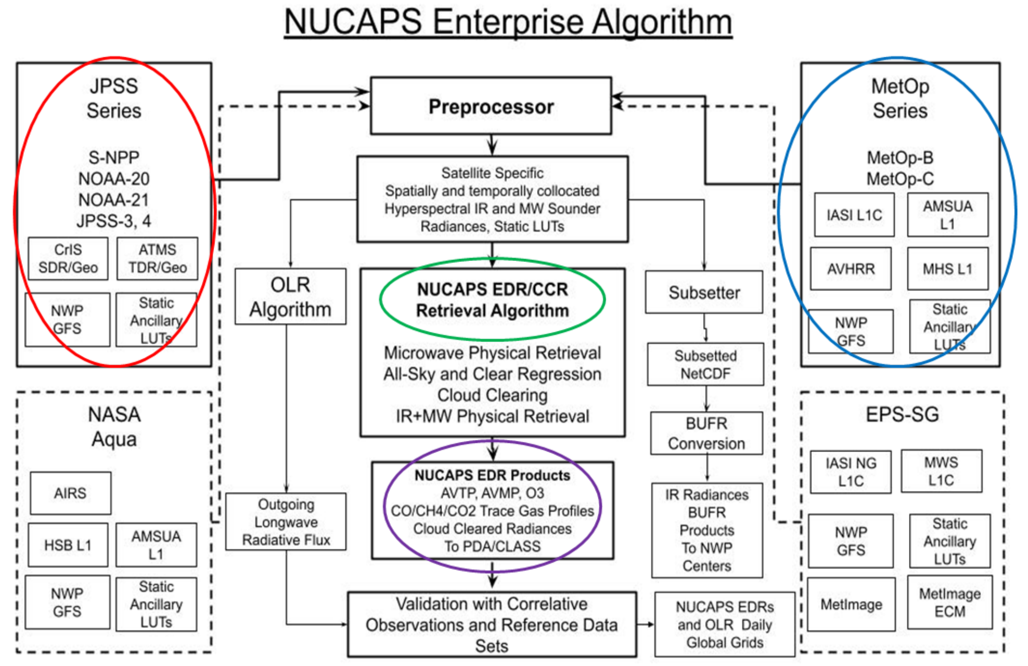


Figure 2. Graphical summary of the NUCAPS enterprise algorithm.

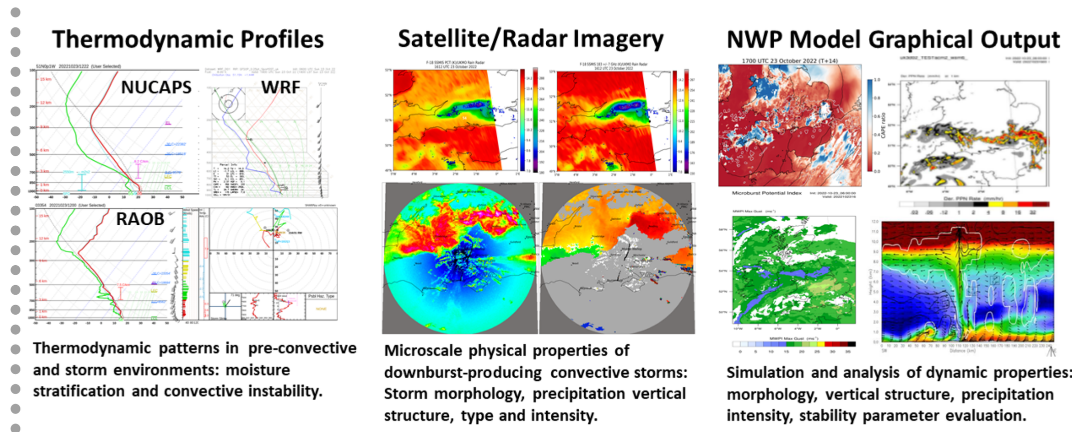
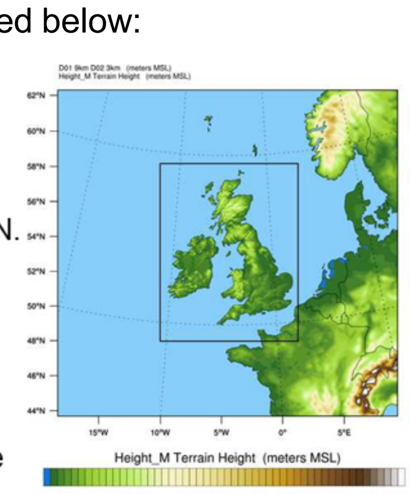


Figure 3. Graphical summary of data analysis and methodology.

•Figure 3 illustrates the rigorous inter-comparison process employed to infer and extract the most important physical processes that sustained the QLCS and fostered intense outflow winds. The most important steps in the evaluation process entail pattern recognition, parameter evaluation, and feature identification applying coincident sounding retrieval and satellite, radar and NWP model 2-D plan-view images to build a three-dimensional conceptual model.

•The Met Office/Jules Regional Atmosphere and Land configuration version 2 (RAL2M; Bush et al. 2023) of the Unified Model (UM) was used to create a downscaled 2.2 km grid length with 90 vertical levels simulation of the event initiated at 0300 UTC 23 October 2022. The UCL WRF-model run configuration is described below:

- WRF-ARW 4.2.x (modified code)
- Init GFS 06Z 0.25 deg ptiles
- 9-3km/45L (lowest ~40m)
- Deep Cu OFF, GRIMS shallow Cu ON.
- WSM6 single moment physics (inc graupel)
- ACM2 local/non-local PBL
- Noah LSM
- 1-way nesting (concurrent, every time step)



PHASE 1: HAMPSHIRE BOW ECHO AND SUPERCELL

•The first phase of the QLCS lifetime over southern England entailed its track from the English Channel northward into Dorset and Hampshire between 1430 and 1500 UTC. The QLCS developed a prominent bowing segment on its western (left) flank over the English Channel that persisted during its track through south-central England. The squall line bow echo ("SLBE") merged with a supercell storm over Bournemouth near 1445 UTC and then proceeded north-northeastward into Hampshire, producing a series of tornadoes and severe downbursts between 1500 and 1600 UTC.

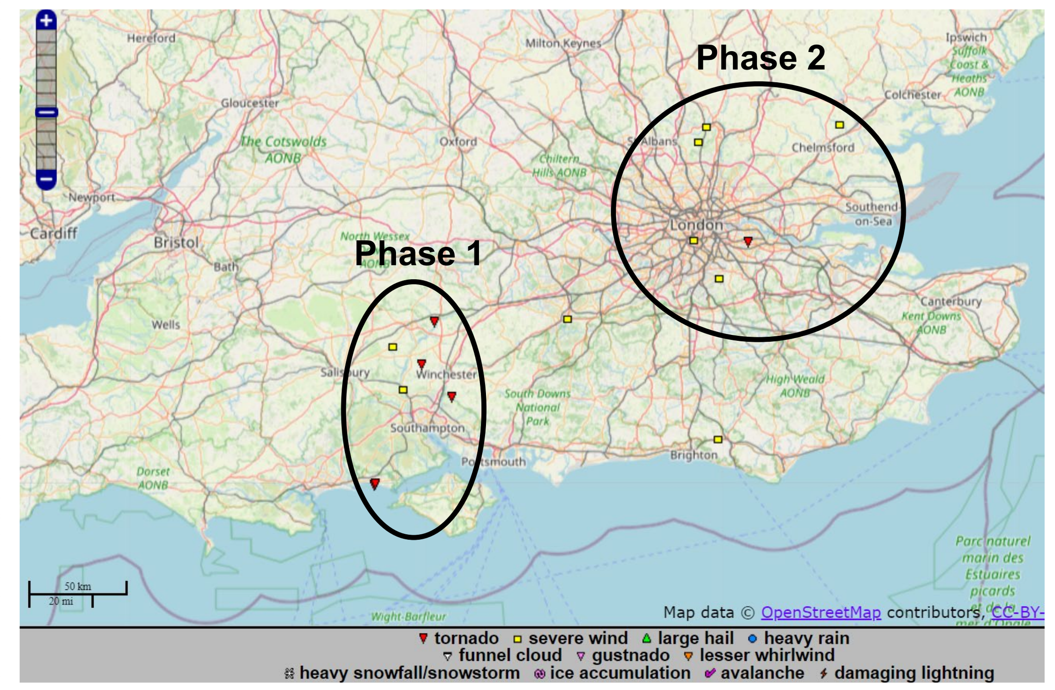


Figure 4. ESWD storm reports over Great Britain on 23 October 2022.

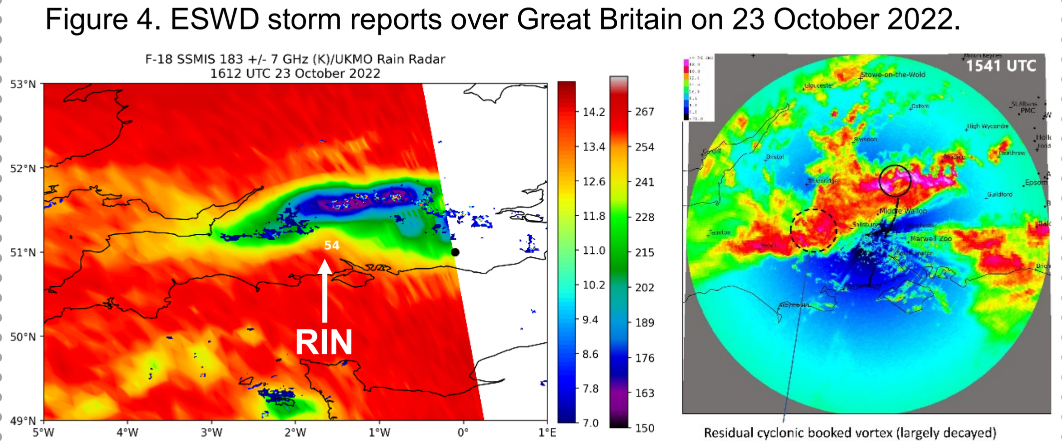


Figure 5. F-18 SSMIS 183 +/- 7 GHz brightness temperature with overlying UKMO radar rain rate at 1612 UTC (left) and Dean Hill, UK radar reflectivity at 1541 UTC 23 October 2022 (right). "RIN" denotes a rear-inflow notch. Black dots in the radar image mark the location of reported damage.

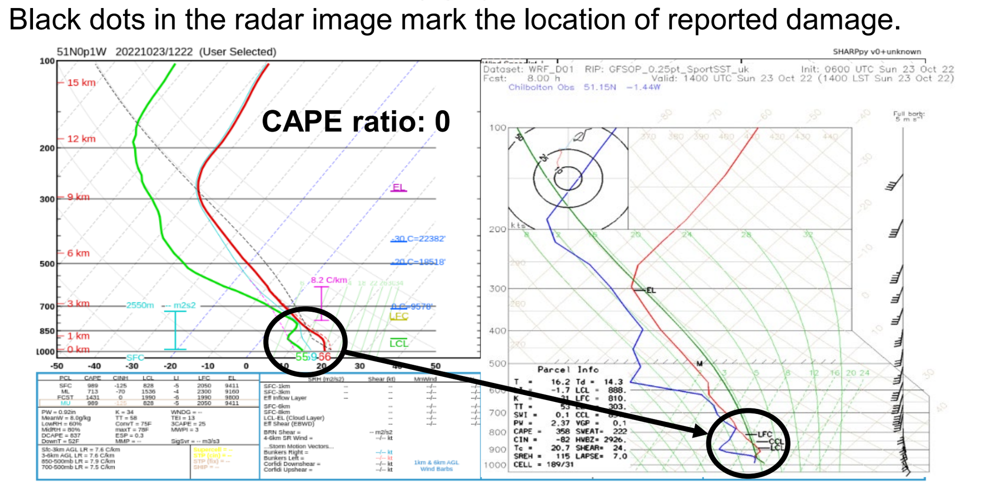


Figure 6. NUCAPS and WRF model sounding comparison over Hampshire.

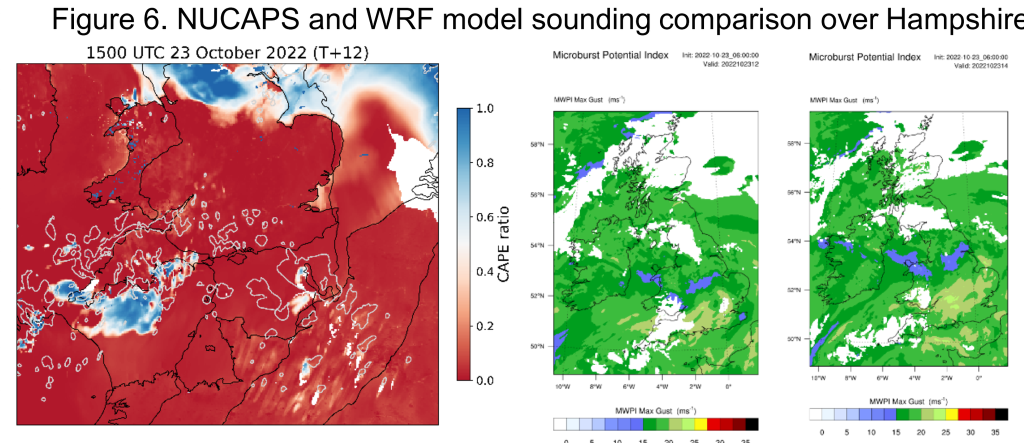


Figure 7. CAPE ratio diagnostic (1 - (SBCAPE/MUCAPE)) map from the UM forecasts of the 23 October 2022 QLCS (left) and WRF model-derived MWPI maps (right). Reds indicate environments suitable for surface-based convection, blues indicate environments suitable for elevated convection.

PHASE 2: LONDON/SE ENGLAND BOW ECHO

•The second phase of the QLCS lifetime entailed its track from Wiltshire-Berkshire-Kent, merger with a supercell over Greater London, and then northward into the Midlands between 1600 and 1800 UTC. The QLCS developed a prominent bowing segment west of London that persisted during the remainder of its track. The QLCS-supercell merger resulted in a cluster of pulse-severe storms that produced a succession of downbursts over Hertfordshire between 1640 and 1740 UTC. During this period, a prominent stratiform precipitation region, with embedded elevated convective storm activity, propagated in the wake of the pulse storm cluster.

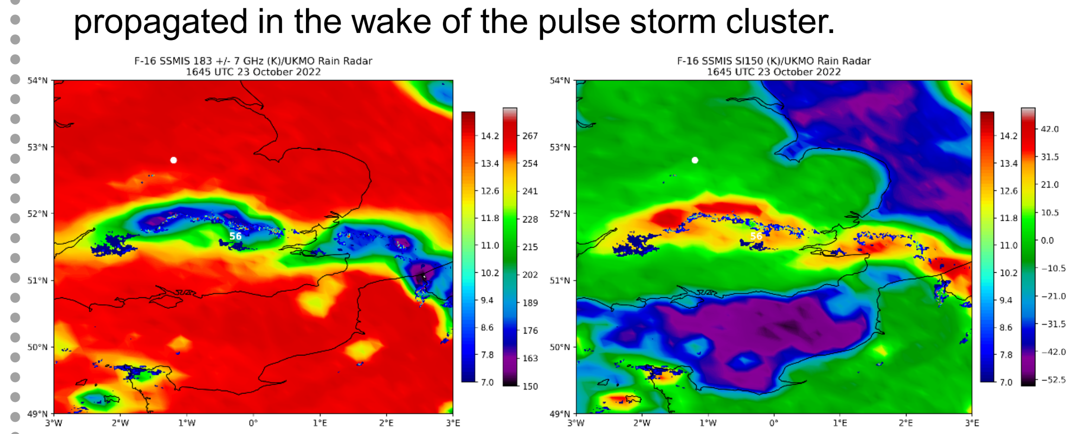


Figure 8. F-16 SSMIS 183 +/- 7 GHz brightness temperature (left) and 150 GHz scattering index (SI, right) with overlying UKMO radar rain rate at 1645 UTC.

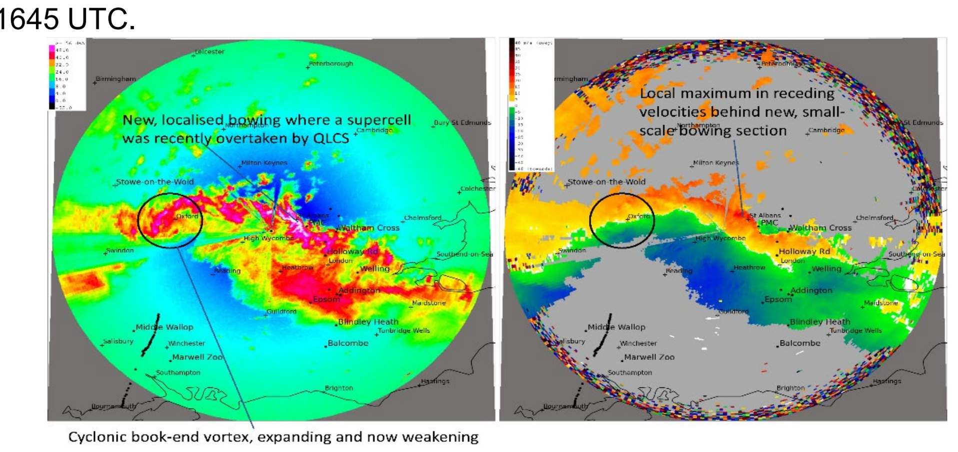


Figure 9. Chenies, UK radar reflectivity (left) and velocity (right) at 1631 UTC 23 October 2022. Black dots mark the location of reported damage.

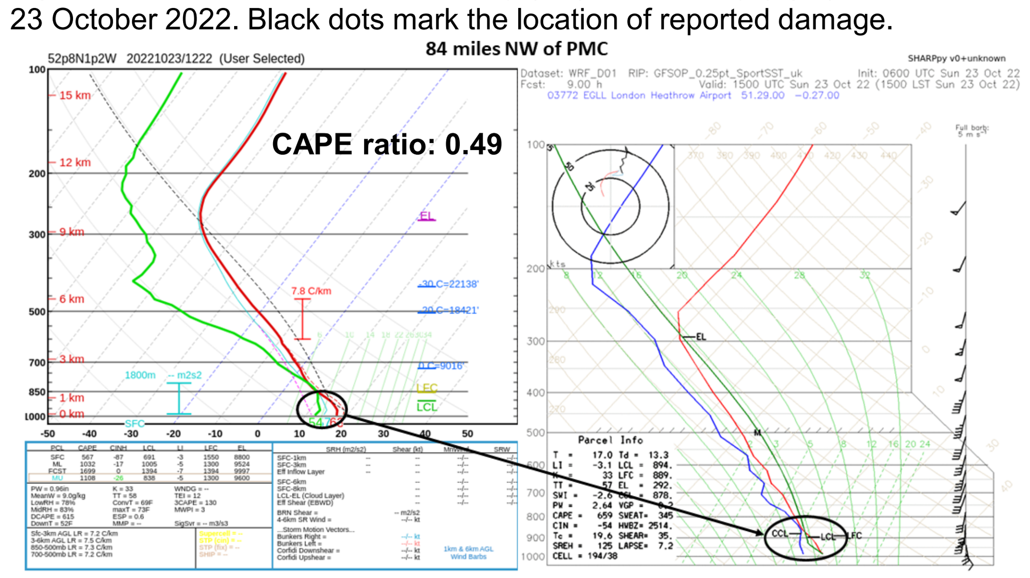


Figure 10. NUCAPS and WRF model sounding comparison over London.

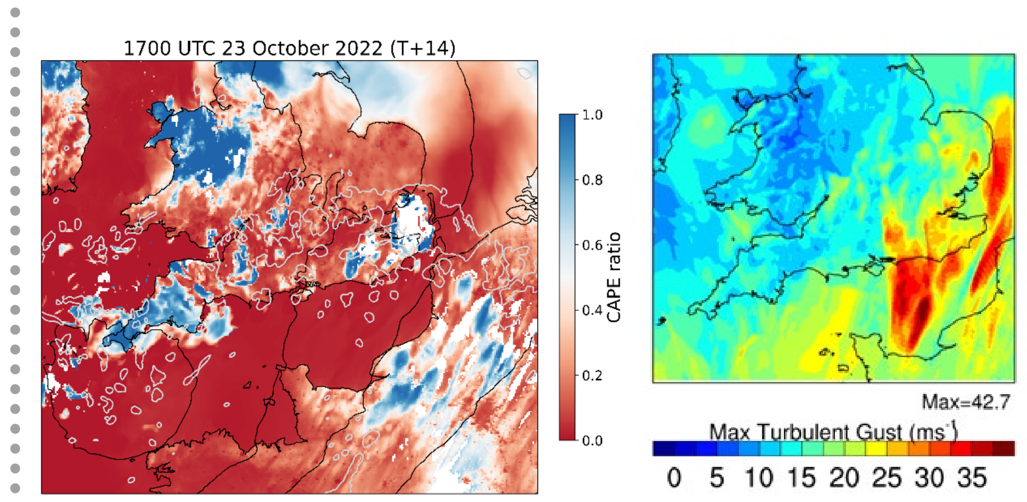


Figure 11. CAPE ratio diagnostic at 1700 UTC (left) and WRF model-derived max turbulent gust map at 1800 UTC (right) 23 October 2022. Reds indicate environments suitable for surface-based convection, blues indicate environments suitable for elevated convection. The gray contours show the 30 dBZ model reflectivity, and the black contours the MSLP.

DISCUSSION AND CONCLUSIONS

•In general, the early afternoon (1222 UTC) NOAA-20 NUCAPS sounding qualitatively indicated the strongest signal for severe thunderstorm and downburst occurrence over southern England:

•Close agreement between the boundary layer structure ("inverted-V") as resolved by the NUCAPS soundings and WRF profiles and the MWPI gust potential as calculated from NUCAPS and the WRF model.

•Strong relationship between high rain rates as indicated by UKMO radar and the very low MW brightness temperatures (BTs) apparent in both the consecutive F-18 and F-16 overpasses.

•Low BTs also correspond well with the high integrated graupel values, suggesting that intense downdrafts and resulting downbursts were forced by ice precipitation loading and melting, as well as unsaturated air entrainment into the mixed-phase precipitation core.

•Diagnostics to determine the environment that the convection formed in, from Flack et al. (2023), show that the event was initially surface-based. However, as time progressed and the convective cores stabilized the environment the rear of parts of the QLCS had elements of elevated instability influencing the convection.

•This elevated instability may help explain the increased precipitation rates within the stratiform region of the QLCS and investigations are still ongoing.

•Future work will consist of further exploration of the role of squall line-supercell mergers in the enhancement and promotion of severe straight-line winds and tornadogenesis in close proximity. This phase of the study will likely entail higher resolution model simulations that are more sensitive to precipitation phase and concentration and boundary layer turbulence.

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