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The DYMECS project: Evaluating convective storms in NWP models

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Introduction

Although better than the previous generation of 10km scale models, convection-permitting models regularly fail to reproduce the timing and intensity of observed convective storms. By tracking convective storms in real time with the Chilbolton Advanced Meteorological Radar (CAMRa), storm volumes and updrafts can be retrieved at scales smaller than 300m throughout a storm life cycle. Rather than using a single case study, the DYMECS project (Dynamical and Microphysical Evolution of Convective Storms) evaluates the Met Office Unified Model (MetUM) for its physical representation of convective storms based on statistics gathered over more than 1,000 storms observed with CAMRa.

Storms were scanned automatically by coupling a storm-tracking algorithm with a scan scheduler to operate the radar. The scan strategy performed vertical scans (RHIs) through cores of high reflectivity, before collecting horizontal scans (PPIs) at several elevations through a group of storms (see Figure 1).

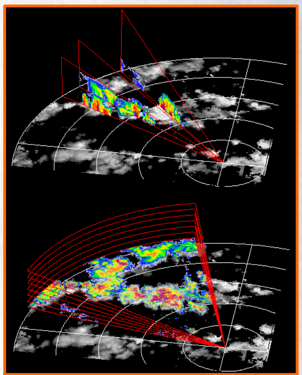

Figure 1. Top: RHI scans performed through cores of high rainfall rates. Bottom: PPI sector scans at different elevations through a group of storms.

Storm morphology

3D volumes of radar reflectivity were reconstructed from the CAMRa PPI sector scans (Figure 2) and similar storm volume reconstructions were realised for the MetUM using simulated 3D radar reflectivity fields. Stein et al. (2014) thus showed that at 1500m grid length storm size is overestimated by a factor 1.5-2, while at 200m storm size is slightly narrower than observed. These results are sensitive to the treatment of sub-grid turbulence however, such that broader storms are simulated if the turbulence parameterisation scheme has a greater mixing length scale (Hanley et al., 2015; Stein et al., 2015).

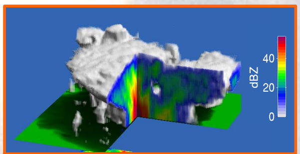

Figure 2: Radar volume reconstruction showing the 0 dBZ isosurface in grey and a cut-out of radar reflectivity in colour for storms observed with CAMRa (adapted from Stein et al., 2015).

Recently, a 3D radar composite has been developed using the Met Office's operational radar network (Scovell and Al-Sakka, 2016). The 3D composite data are available for the entire UK, every 5 minutes, allowing the study of storm morphological evolution (Figure 3). In the observations (blue), from 1200 UTC onwards, more than 50% of the storms have cloud top heights above 8km, and storms are about 1.5 times wider at 1800 UTC than at 1200 UTC. In the 1500m simulation (green), only after 1500 UTC do more than 50% of storms reach above 8km, and storms are about 1.5 times broader than observed. In the 200m simulation (red), clouds reach 8km from 1200 UTC onwards, as observed, but storms are typically too narrow by about a factor 1.5. This can be related to a lack of organisation of storms (Hanley et al., 2015; Stein et al., 2015).

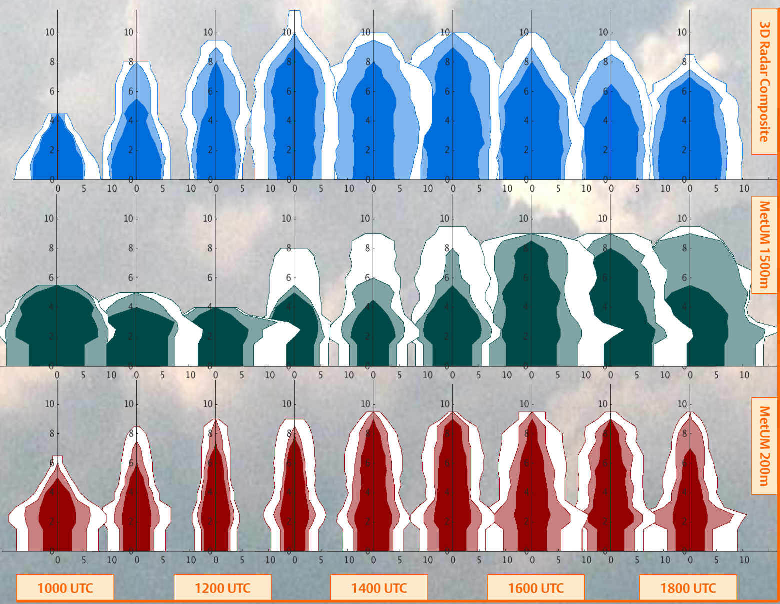

Figure 3: Storm effective radius and height in km (mirrored in the y-axis) based on 0 dBZ contours of storms observed and simulated at every hour from 1000-1800 UTC on 25 August 2012. A storm is identified if it has Zmax>32dBZ over an area of at least 4 km². Contours indicate the 25th (filled, dark), 50th (filled light), and 75th (white) percentile widths. Top: Met Office 3D radar composite. Middle: MetUM 1500m simulations. Bottom: MetUM 200m simulations.

Updraft evaluation

Updrafts are retrieved from Doppler winds in the RHI scans, using a weighted average between a top-down and bottom-up retrieval based on the mass-continuity equation. Single Doppler retrievals underestimate the updraft strength due to the missing wind component perpendicular to the radial winds. Comparison of a 1D retrieval using the MetUM horizontal wind fields against the true *w* provides a scaling function to correct for this statistically (Nicol et al., 2015). Averaged over many updrafts, the MetUM 1500m simulation generates updrafts that are weaker and broader than observed, resulting in a mass flux that is an order of magnitude too large (Figure 4, adapted from Stein et al., 2015). For the 200m simulation, the representation of updraft strength and width compares well against observations, but the results are again very sensitive to the model sub-grid turbulence mixing scheme.

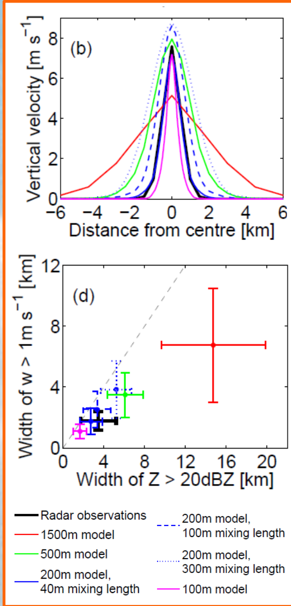

Figure 4: Updraft statistics from CAMRa radar observations and MetUM simulations. Top: Updraft strength as a function of distance from peak updraft. Bottom: Mean and standard deviation of core width as determined by thresholds of 20 dBZ radar reflectivity and 1 m s^{-1} updraft velocity.

Summary

- **High-resolution radar observations are used to evaluate the representation of convective storms in NWP models in DYMECS.**
- **At 1500m grid length, the MetUM produces updrafts and storm structures that are at least 1.5 times broader than observed.**
- **At 200m grid length, the MetUM compares best against observations, but results are sensitive to sub-grid turbulence parameterization.**
- **A 3D composite derived from the Met Office operational radars allows for routine evaluation of evolving storm characteristics.**
- **Ongoing work using CAMRa Doppler spectrum width will target turbulent regions surrounding updrafts.**

References

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