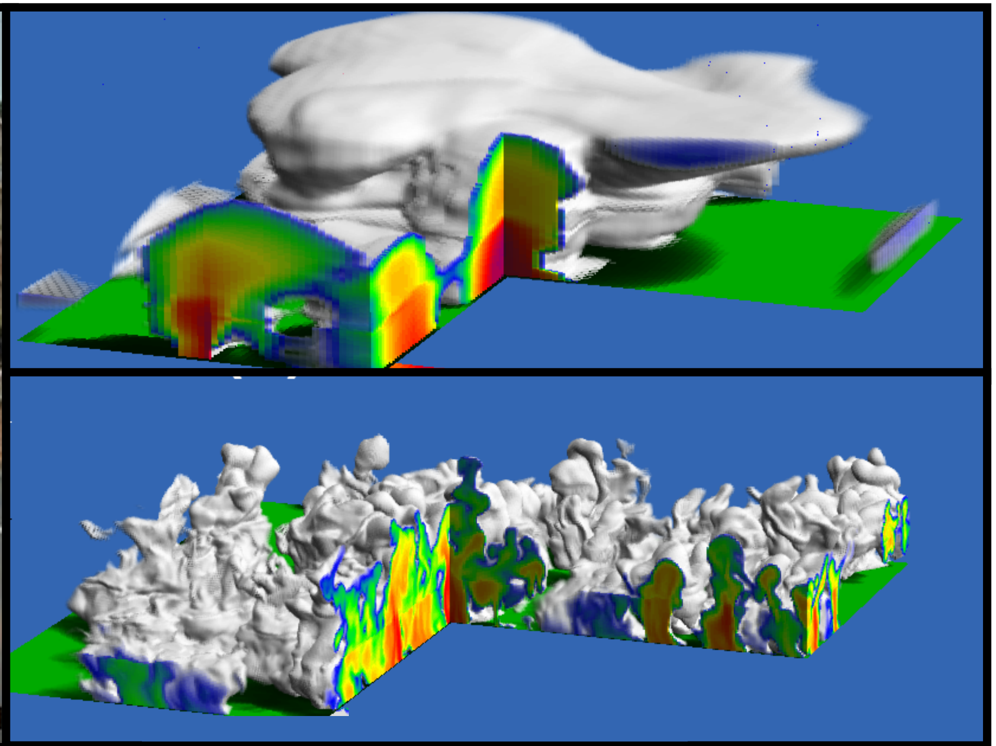


The DYMECS project

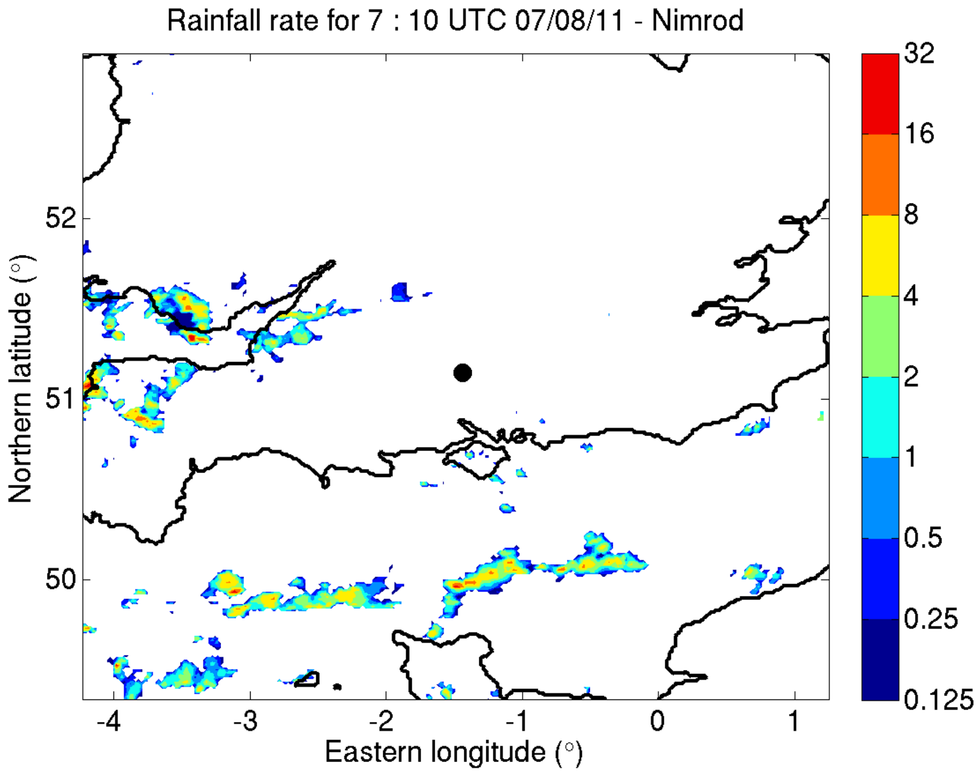
A statistical approach for the evaluation of convective storms in high-resolution models

Thorwald Stein, Robin Hogan, John Nicol, Robert Plant, Peter Clark
University of Reading
Kirsty Hanley, Carol Halliwell, Humphrey Lean
MetOffice@Reading

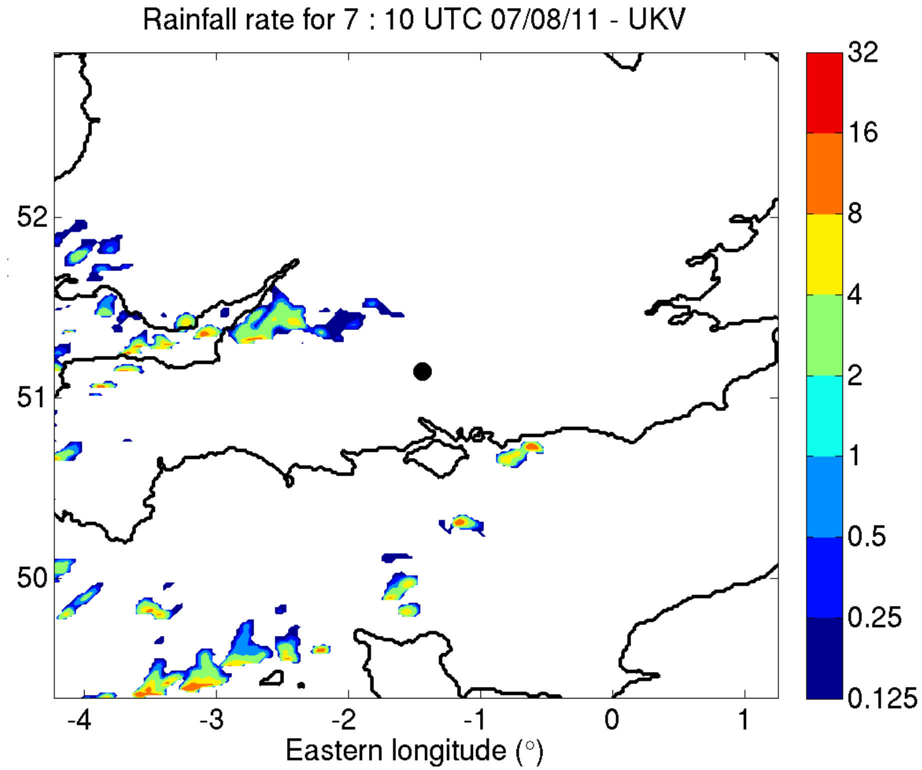
Convection-permitting models (e.g. UKV) struggle with timing and characteristics of convective storms

- Model storms too regular (circular and smooth)
- Not enough small storms (smaller than 40 km^2)
- Model storms have typical evolution (not enough variability)

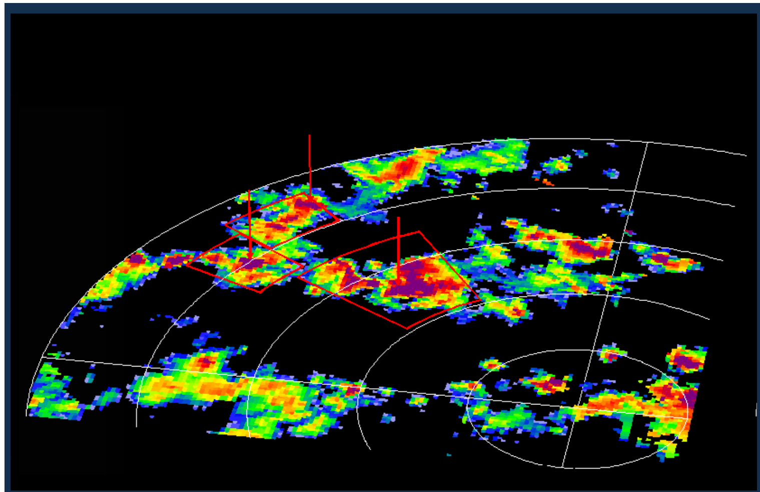
MetOffice rainfall radar network

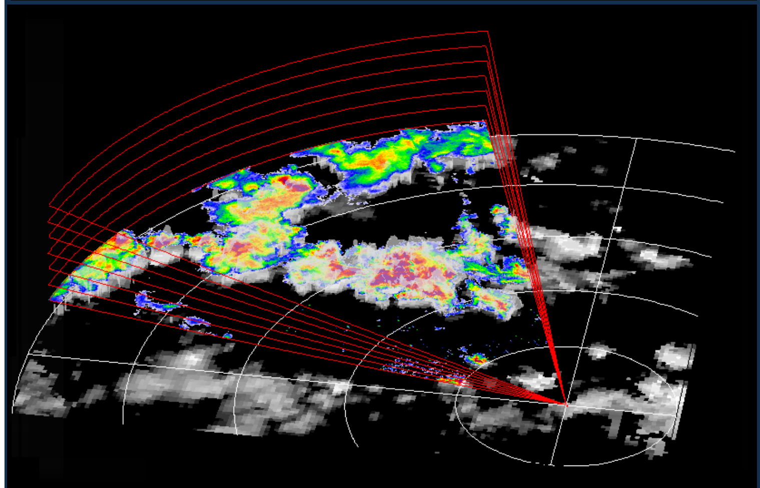


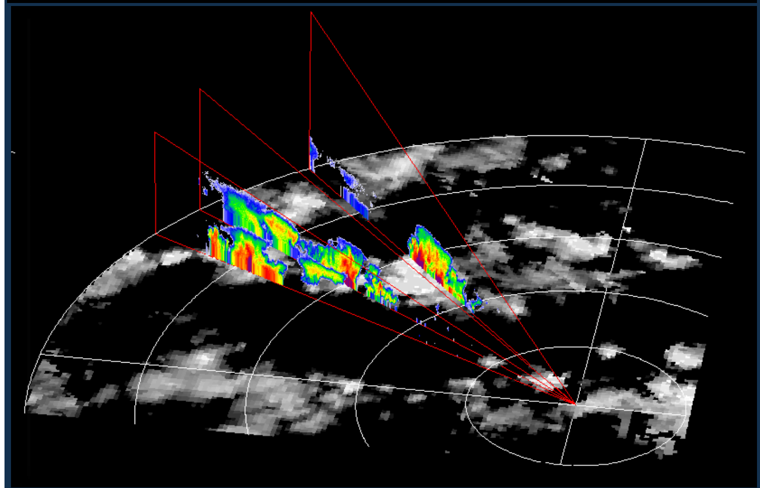
MetOffice 1.5km model



Original slide from Kirsty Hanley







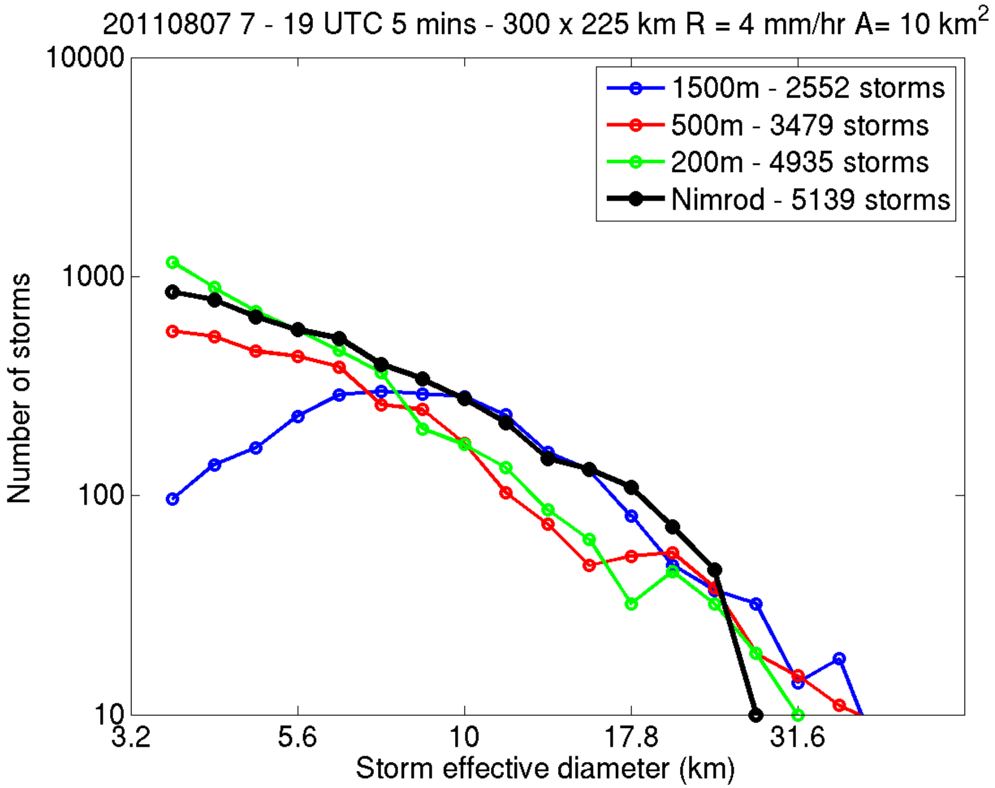
DYMECS: Improve understanding of representation of convective storms in models

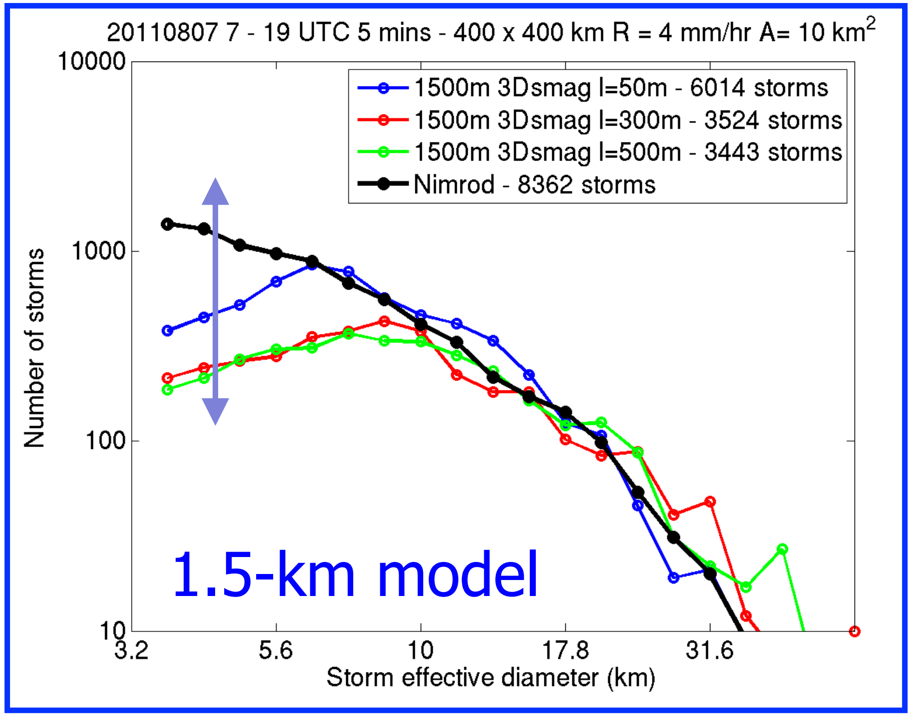
Track storms in Met Office rainfall radar data and model surface rainfall rate for storm-size distribution and life-cycle analysis.

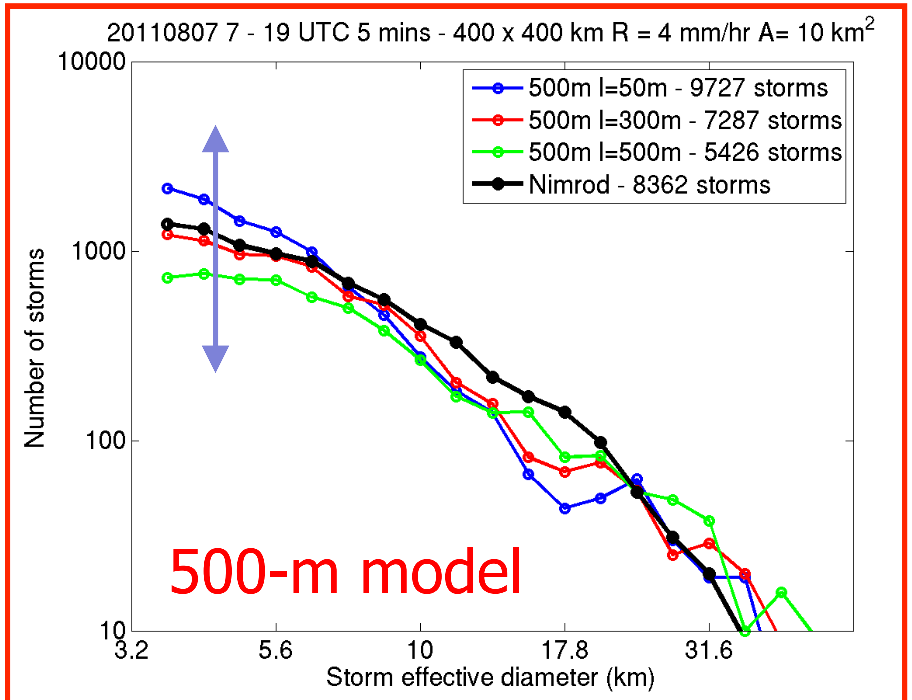
Reconstruct 3D storm volumes from Chilbolton scans of tracked storms and relate to storm volumes in model reconstructed from simulated radar reflectivity.

Retrieve updraft strength and width from Doppler velocities in Chilbolton RHI scans using mass-continuity approach and compare with model updraft statistics in storms.

Storm size distribution





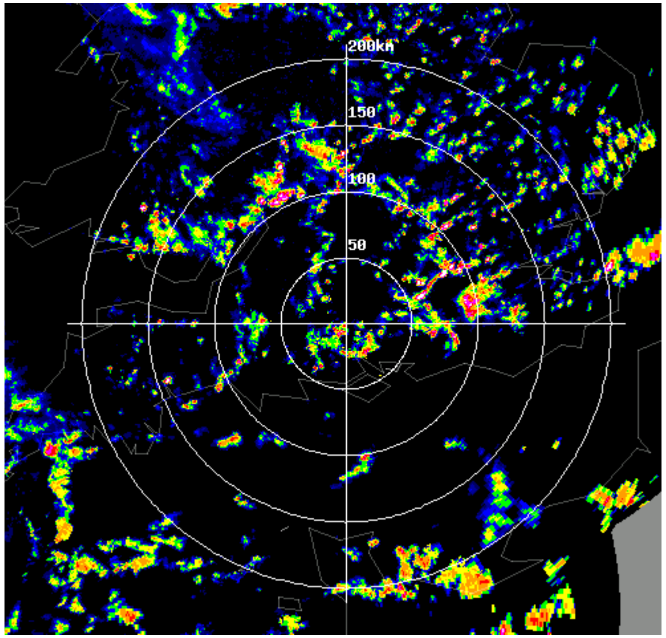


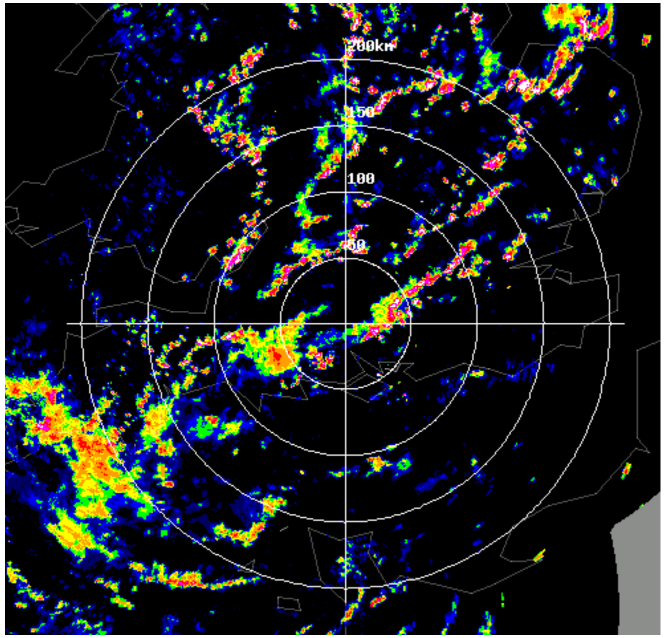
Smagorinsky mixing length plays a key role in determining the number of small storms

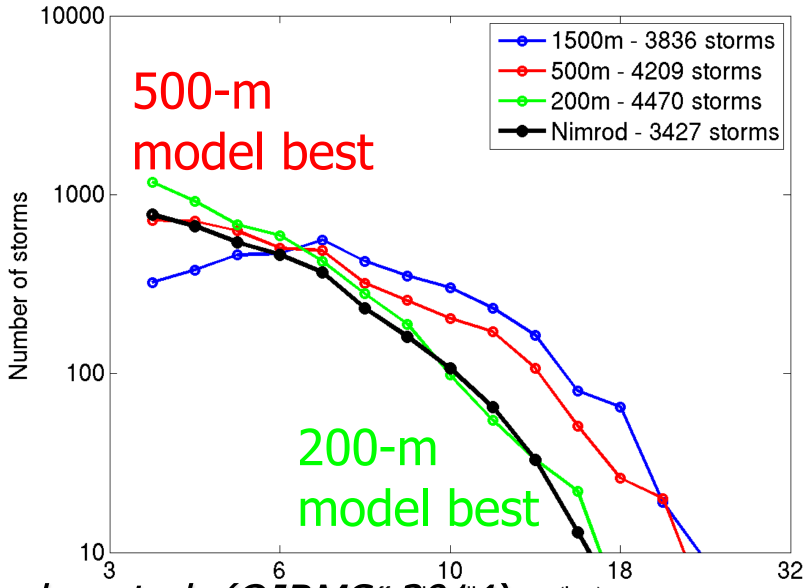
Hanley et al. (QJRMS, 2014)

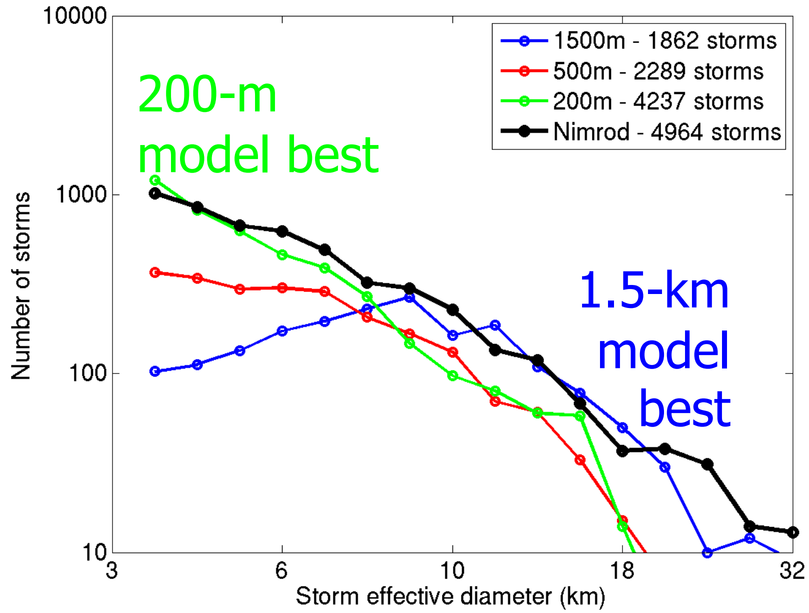
Shower case

Deep case









Hanley et al. (QJRMS, 2014)

Storm life cycles

Cumulative fraction of total rainfall:

UKV does not get enough rainfall from short-lived storms.

200m and 100m simulations lack long-lived events.

Area-integrated rainfall:

Cycle shows too high AIR for weighted-average storm in UKV and 500m.

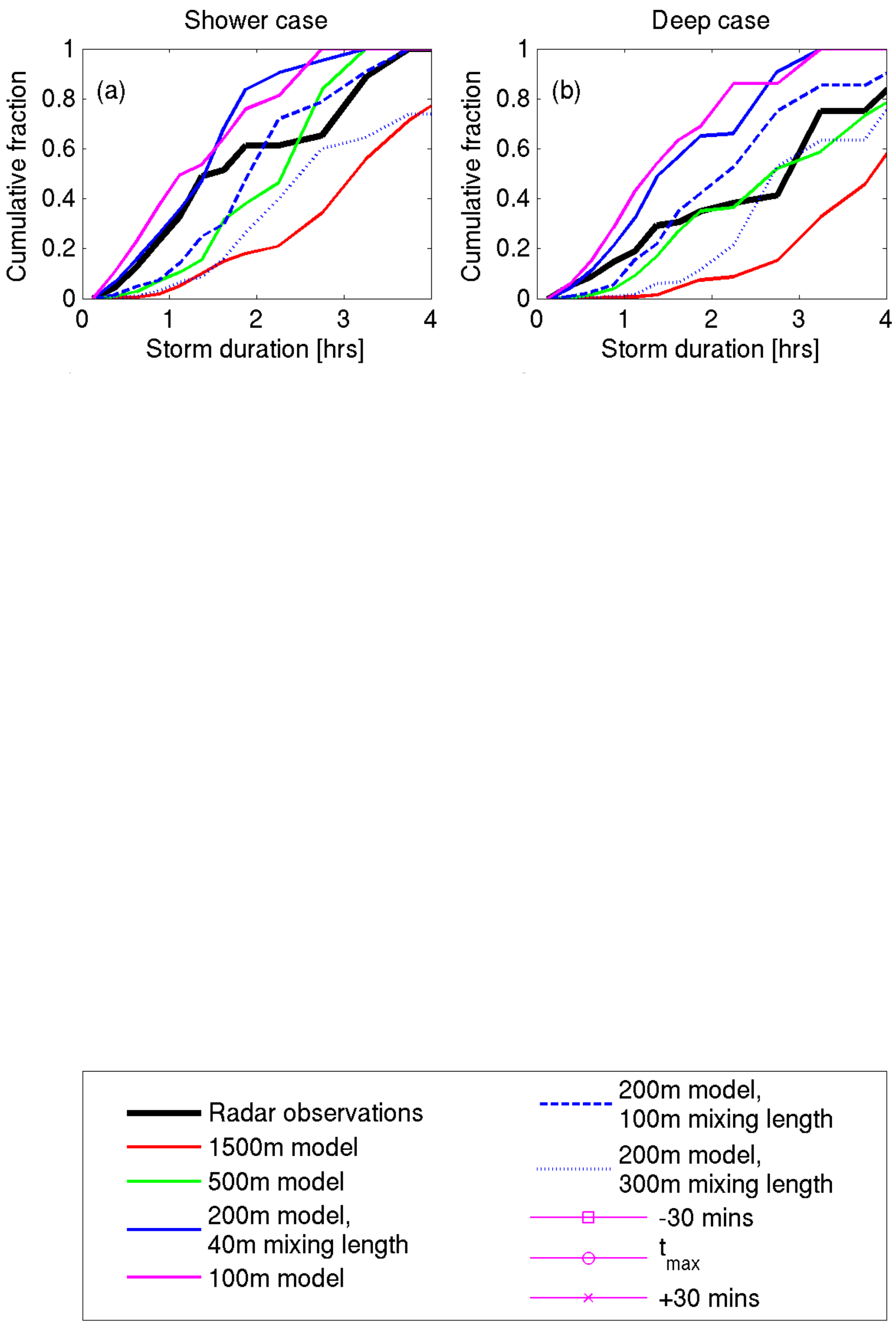
200m and 100m simulations comparable to radar but too weak at time of peak AIR.

Area-vs-Rainfall cycle:

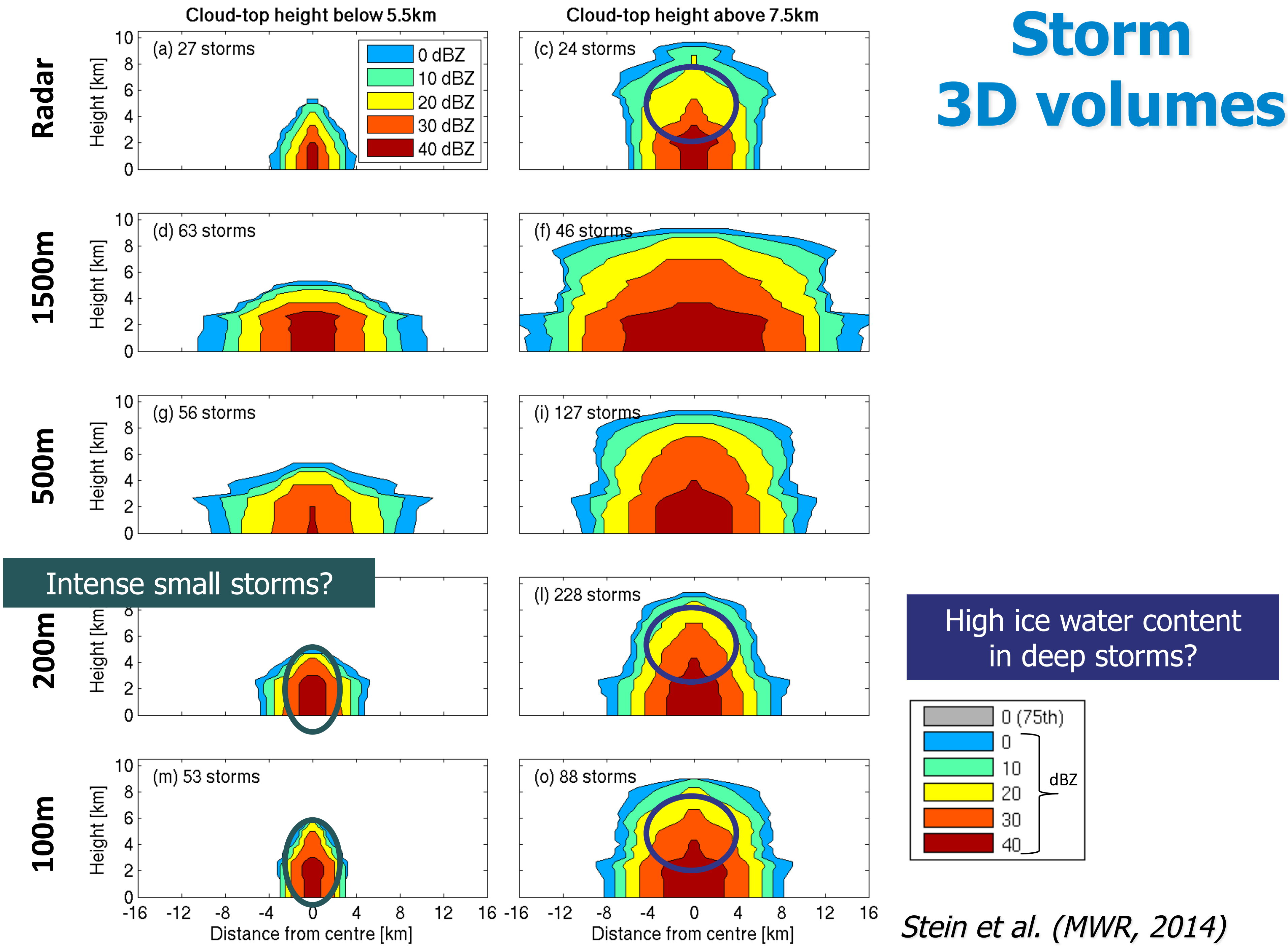
UKV produces slightly weaker rainfall rates over a much larger area than observed.

200m and 100m simulations have comparable rainfall but too small areas.

Stein et al. (BAMS, in review)

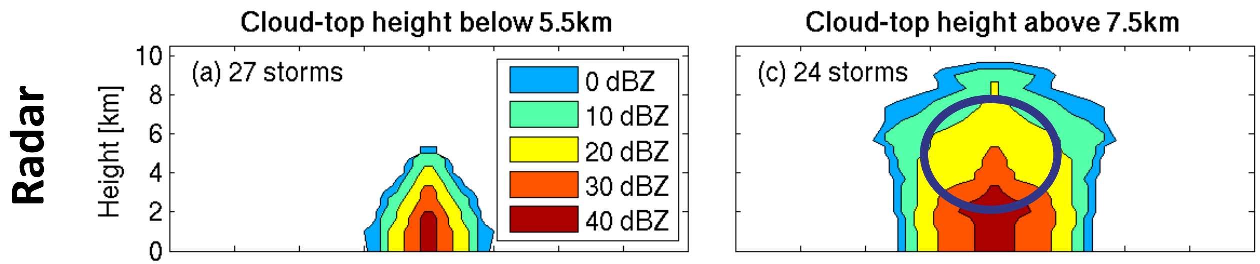


Storm 3D volumes



Stein et al. (MWR, 2014)

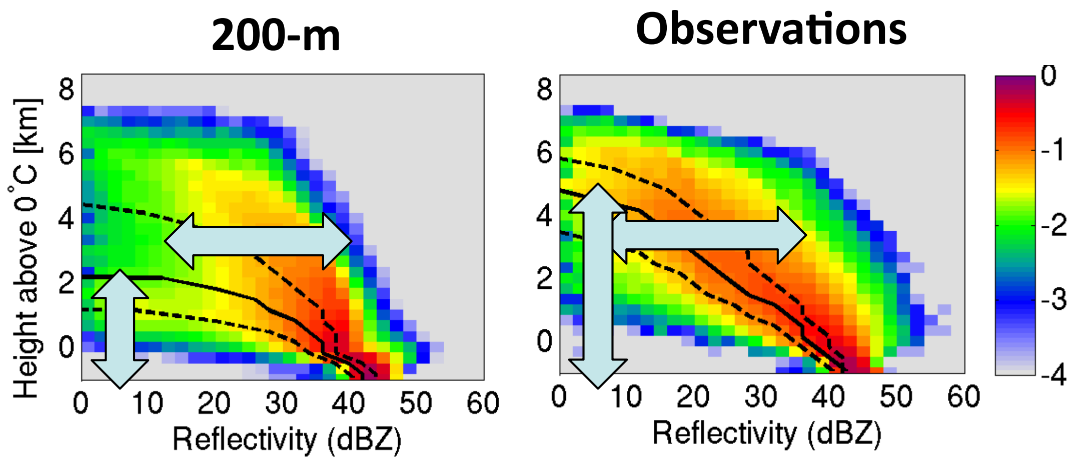
Storm 3D volumes



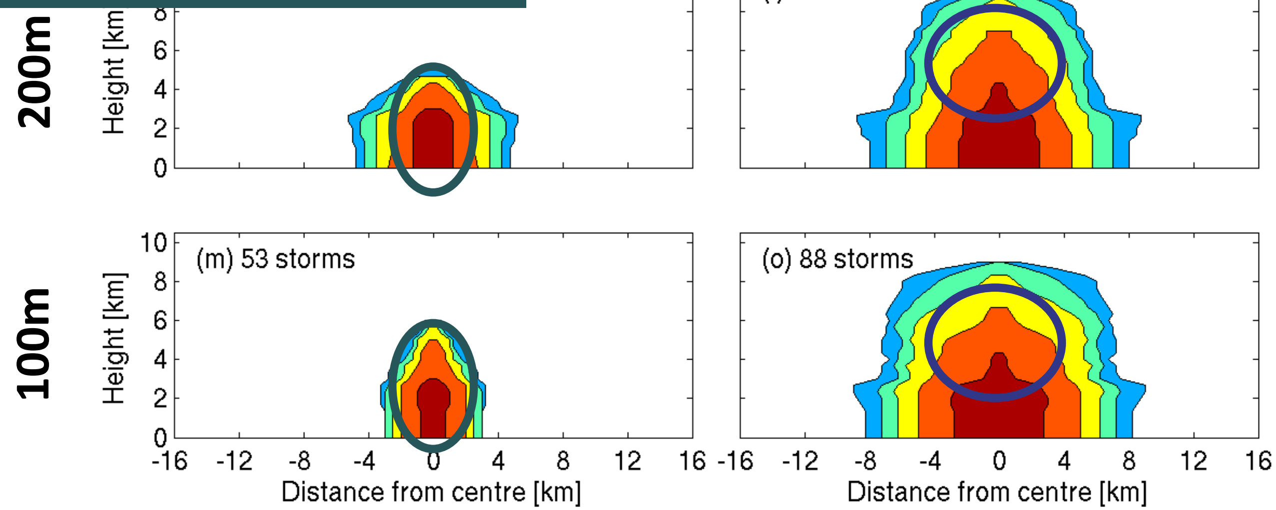
Reflectivity distribution with height:

Model is more likely to have reflectivities above 30-dBZ for a given height than observations.

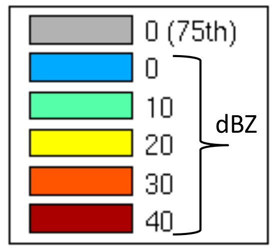
Model also generates high rainfall rates from shallow storms too frequently.



Intense small storms?

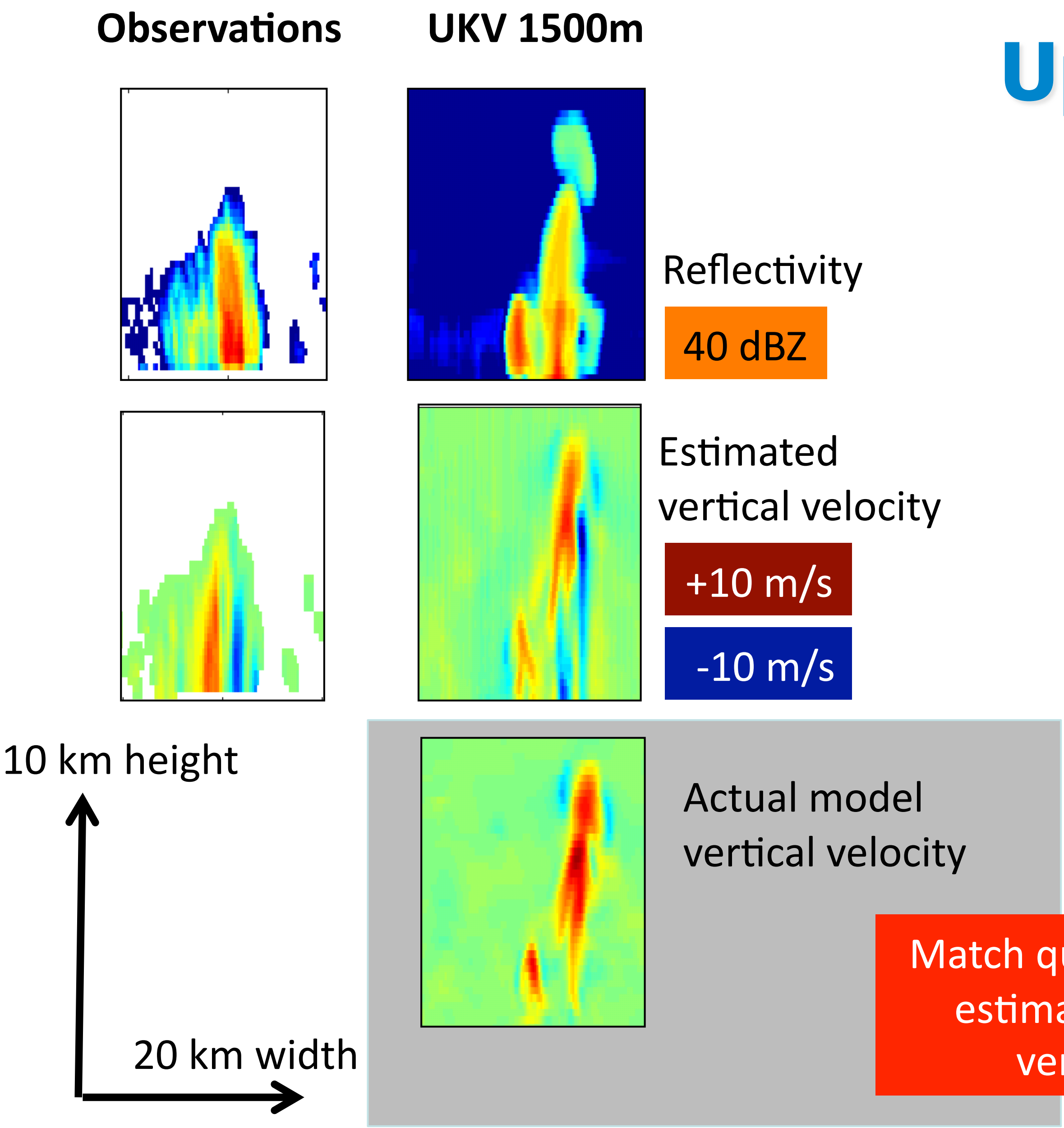


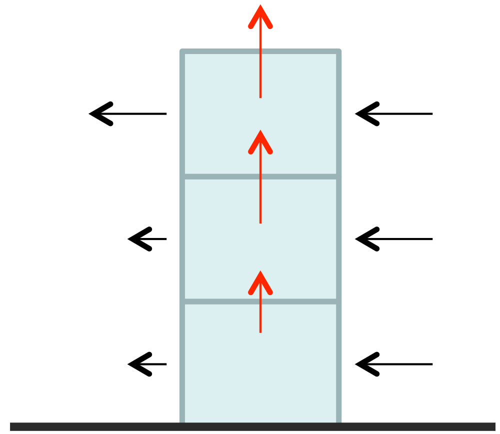
High ice water content in deep storms?



Stein et al. (MWR, 2014)

Updraft retrieval



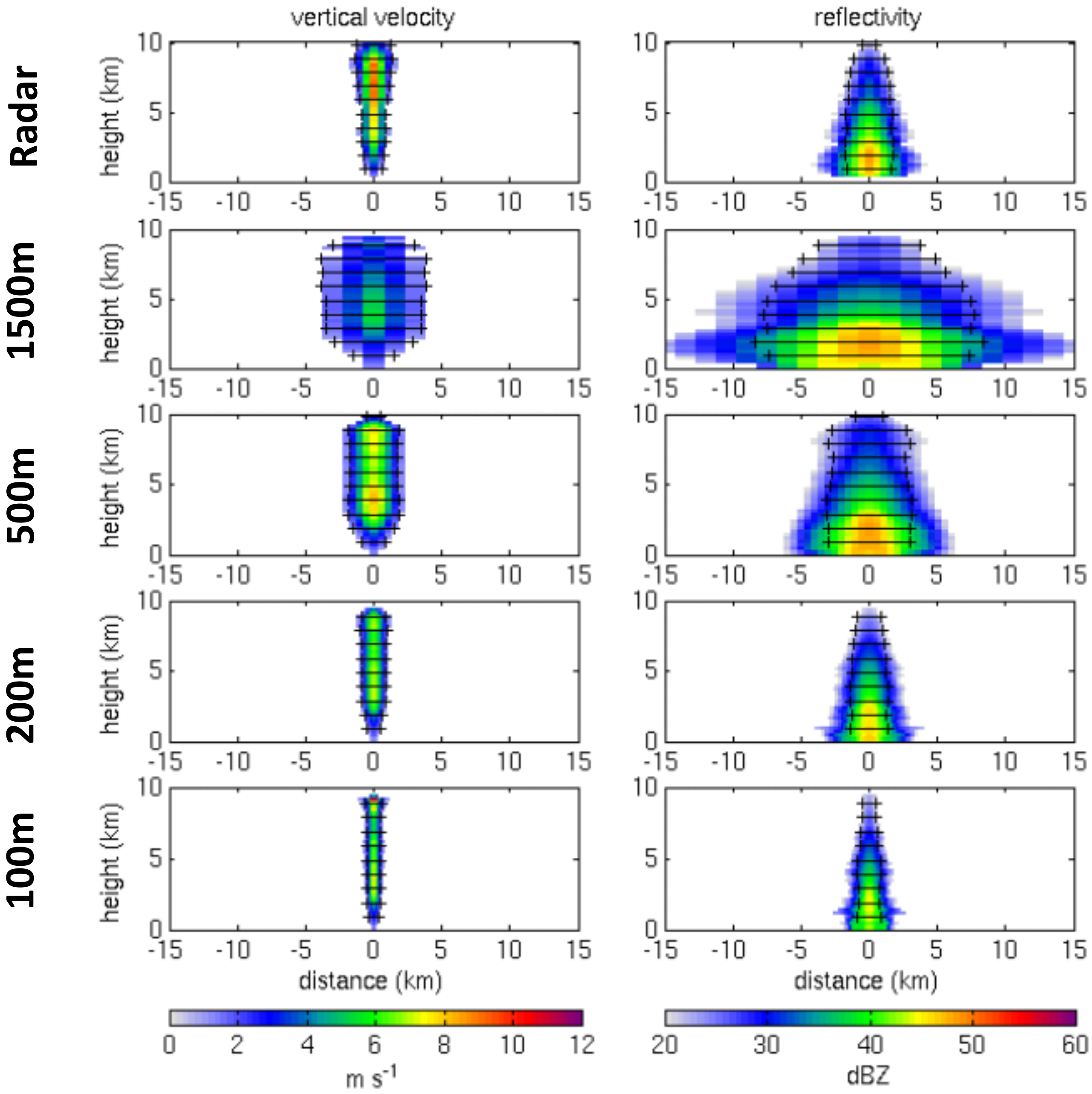


Estimate vertical velocity from vertical profiles of radial velocity, assuming zero divergence across plane.

Match quantiles of model 2D estimates to model true vertical velocities

(John Nicol et al., in prep.)

Distribution of vertical velocity with height

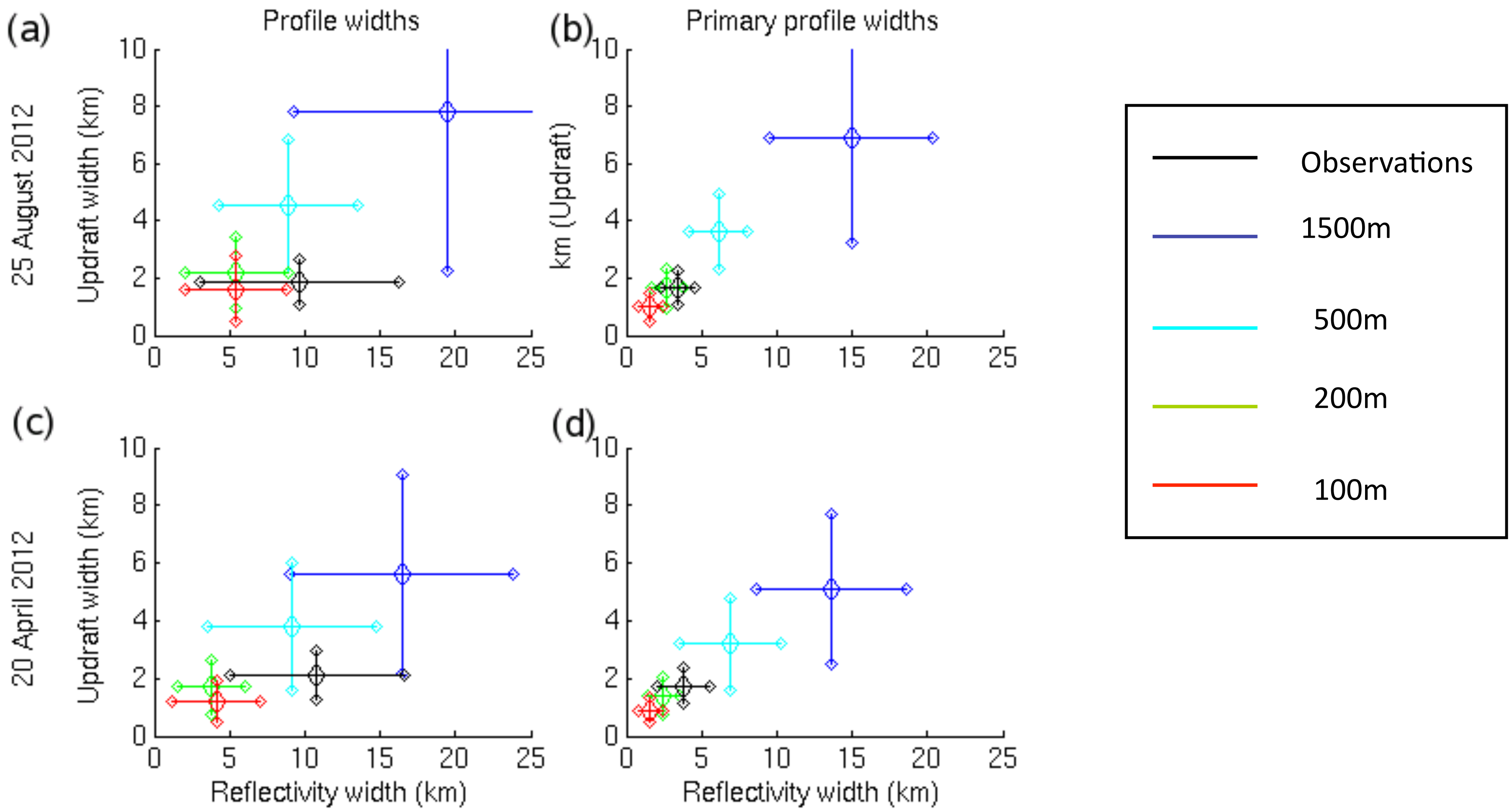


Vertical velocity and reflectivity distributions as function of radius from centre of updrafts. Set to zero where: w>1m/s, Z>20dBZ AND where values start increasing again. "primary profile"

1200-1600UTC 25/08/12.
Black traces - mean widths for 1m/s and 20dBZ.

(John Nicol et al., in prep.)

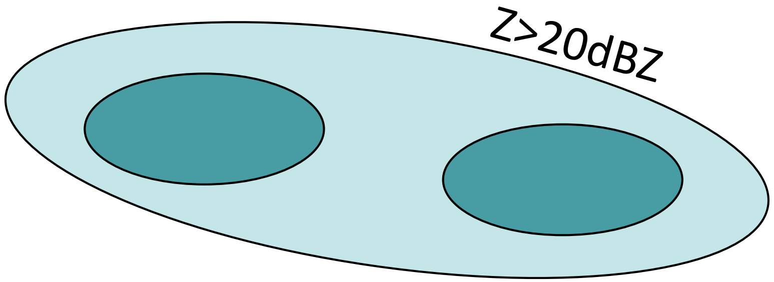
Cloud width versus updraft width



Primary (monotonic) cloud widths proxy for updraft width

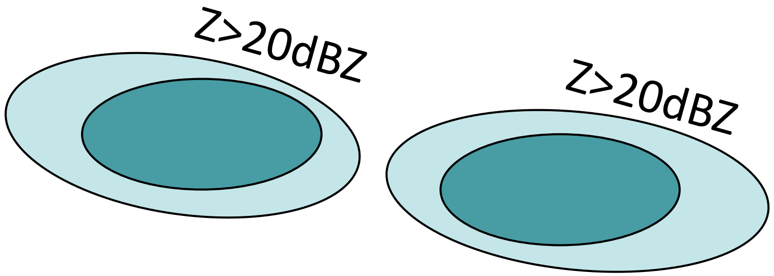
(John Nicol et al., in prep.)

Cloud width versus updraft width



Observations:

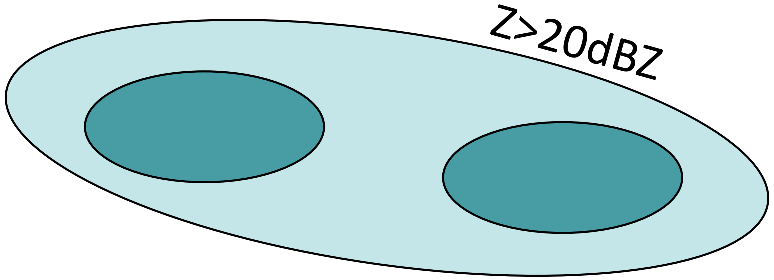
Individual primary (monotonic) reflectivity profiles are joined up by larger cloud region with Z>20dBZ.



200m and 100m simulations:

Individual primary (monotonic) reflectivity profiles remain isolated cells even when monotonicity is relaxed.

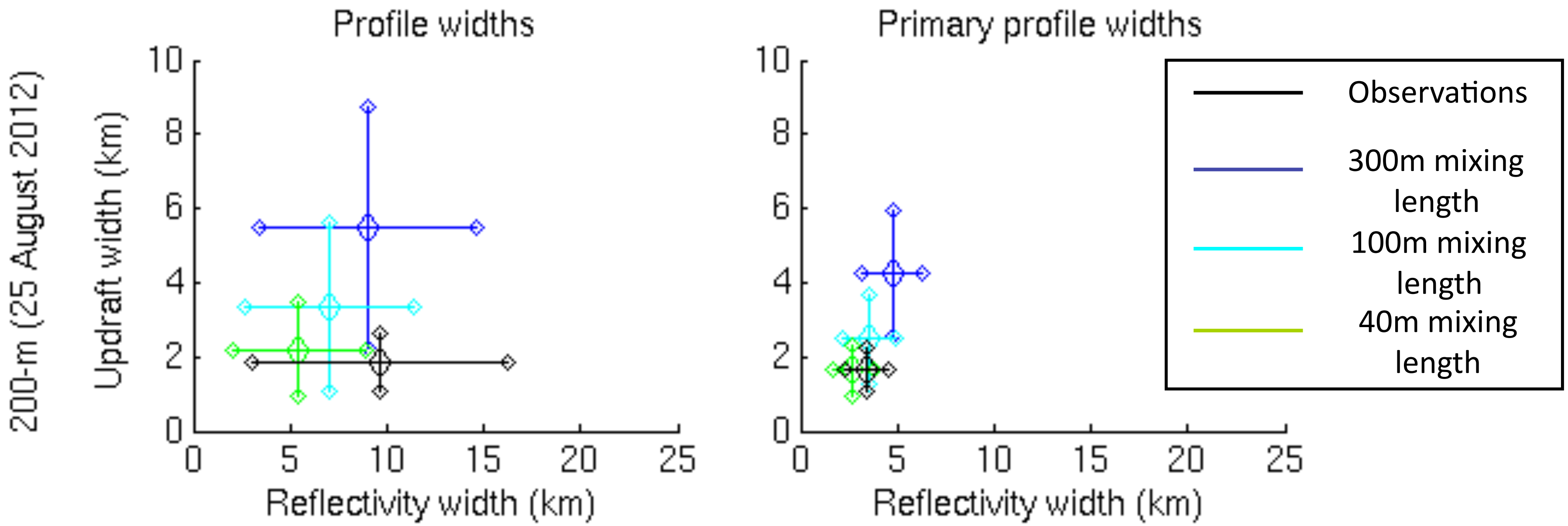
Cloud width versus updraft width



Observations:

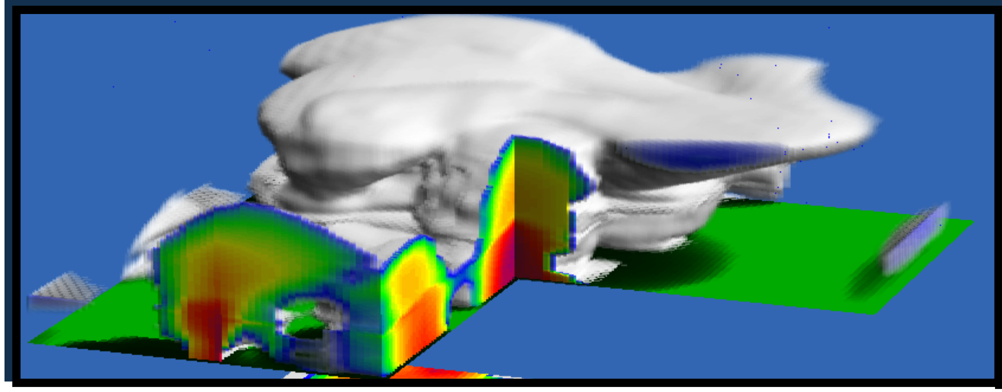
Individual primary (monotonic) reflectivity profiles are joined up by larger cloud region with Z>20dBZ.

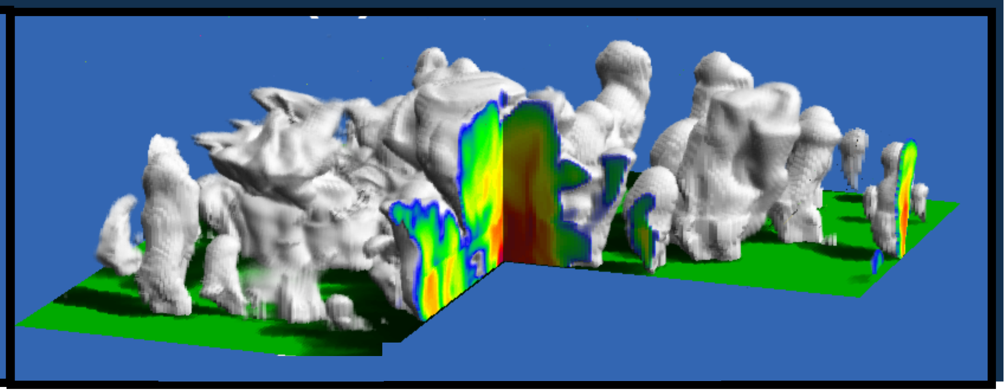
Isolated primary profiles may be more likely joined up with increased mixing length



Is 200m good enough?

- 1500m and 500m simulations clearly under-represent small storms and short-lived events, which through their large number contribute significantly to total rainfall.
- 200m and 100m simulations produce comparable storm-area statistics and life cycles, but miss some long-lived, large storms.
- Deep storm structures are generally represented well in 200m and 100m simulations.
- Small (and shallow) storms produce too high rainfall rates in the 200m and 100m simulations.
- Updraft widths in 200m simulation compare well with observations but are too narrow in 100m simulation.
- The representation of convective storms is very sensitive to the turbulent mixing length.





Future of DYMECS framework

- We are in the "turbulent grey zone": will even higher resolution (50m?) solve some of the issues of the 200m and 100m simulations?
- Can we improve models with more appropriate turbulent mixing schemes (do we have enough explicit turbulence, see Humphrey Lean's talk)?
- Can we learn from LES of deep convection to understand the lack of convergence in updraft statistics between 200m and 100m grid length?
- To what extent does the statistical convergence depend on model dynamics – will the conclusions change with ENDGame?
- How important is the microphysics scheme – too high IWC in storm cores but too little cloud-ice surrounding the cores (fall speed, Kalli Furtado, Met Office)?
- Next step for observations: What controls the size and structure of thunderstorms (Matt Feist PhD project)?