Comparisons of explicit representation of convection in models with gridlengths between 100m and 4km with observations.

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Outline

- Explicit convection in UM
  - Benefits
  - Deficiencies
- Current & Future research
  - Improving convection in UKV
  - Higher resolution models
  - Use of observations

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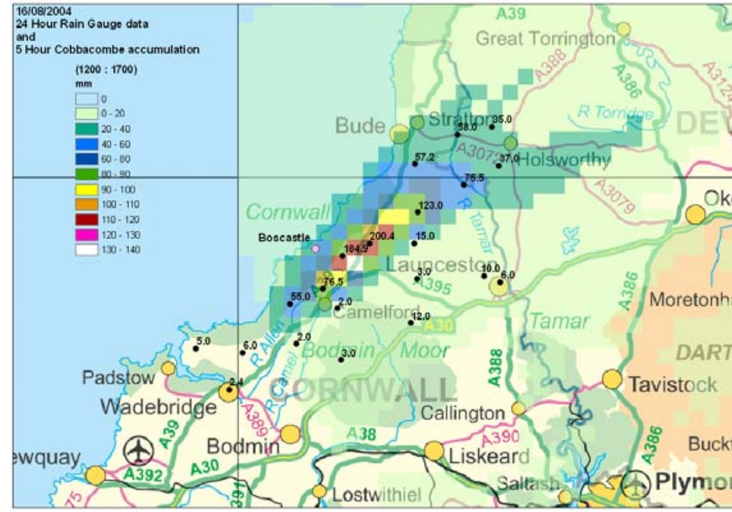
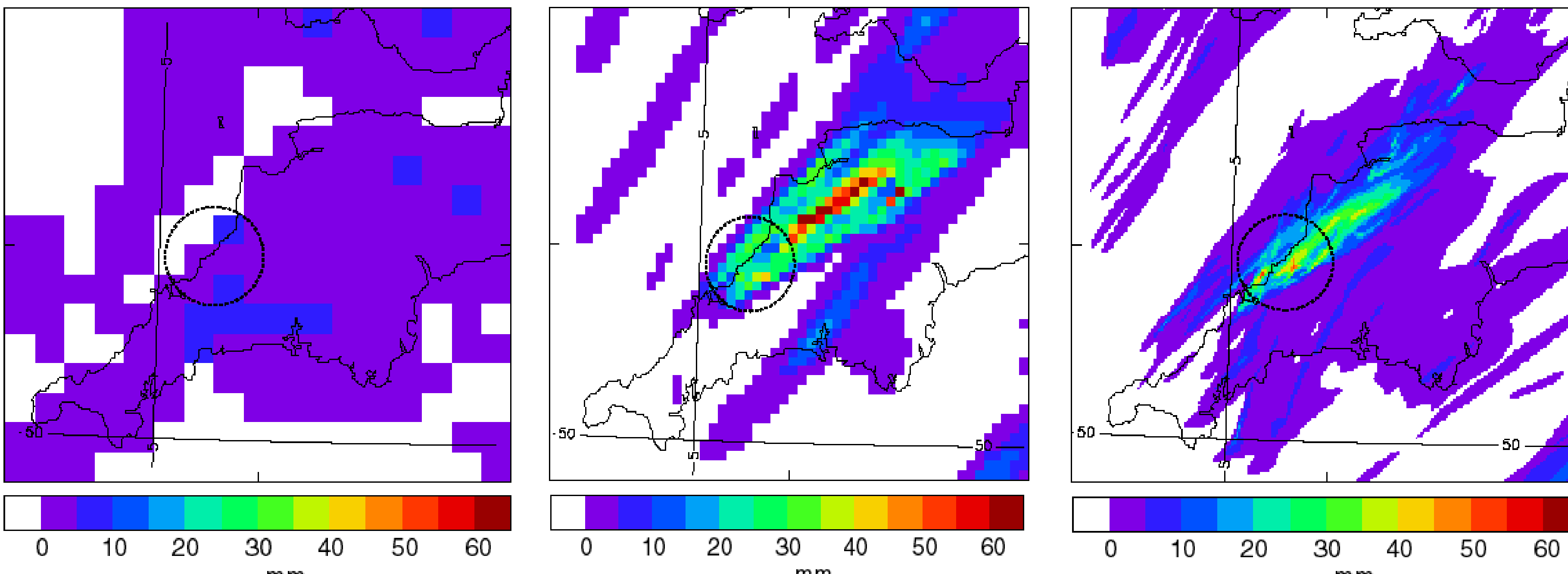
The Boscastle Flood
(Cornwall, SW England,
16th August 2004)



Rainfall accumulations

12-18 from 00 UTC 12km	12-18 from 00 UTC 4km	12-18 from 00 UTC 1km



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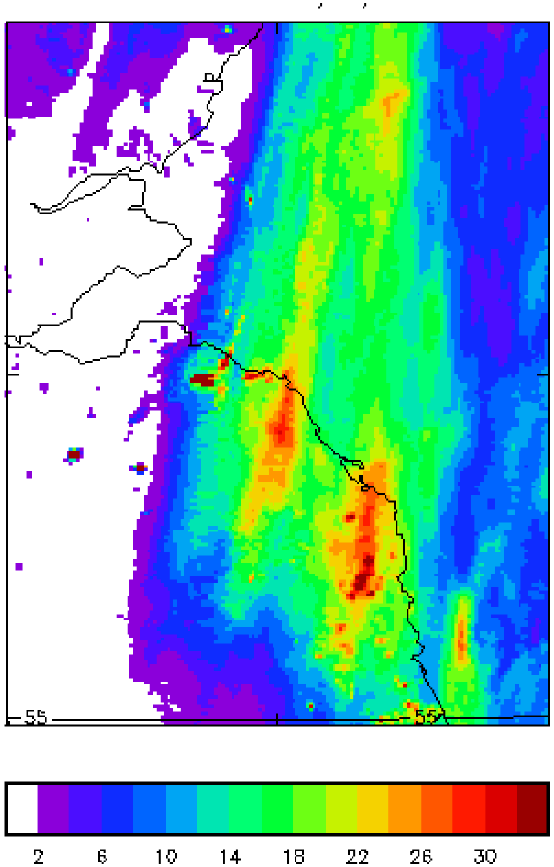
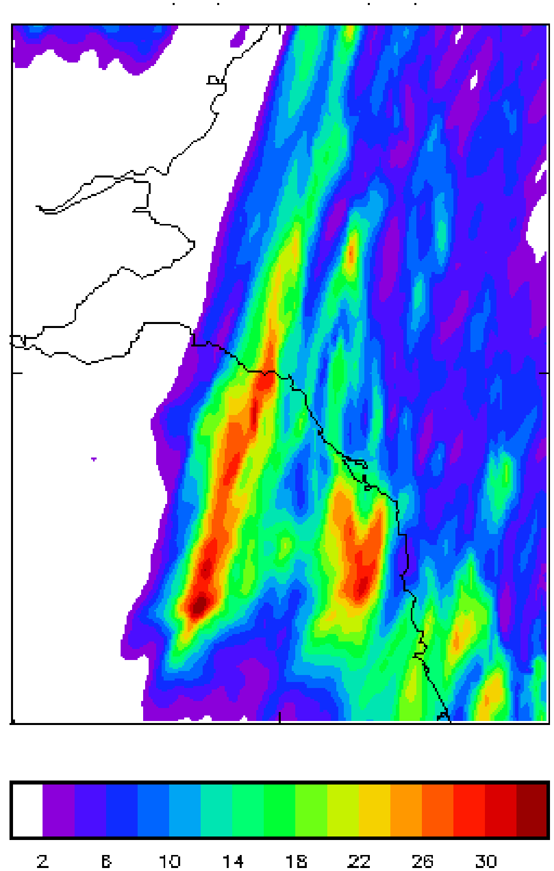
Snow Showers penetrating inland

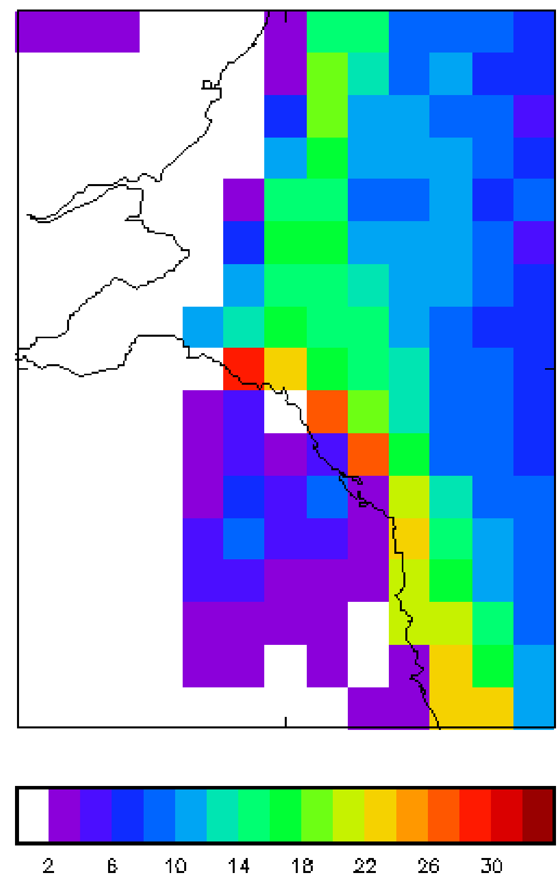
24 hour precip accumulation (mm) 25th Nov 2010



1km radar



UKV (1.5km)



NAE (12km)

Operational models

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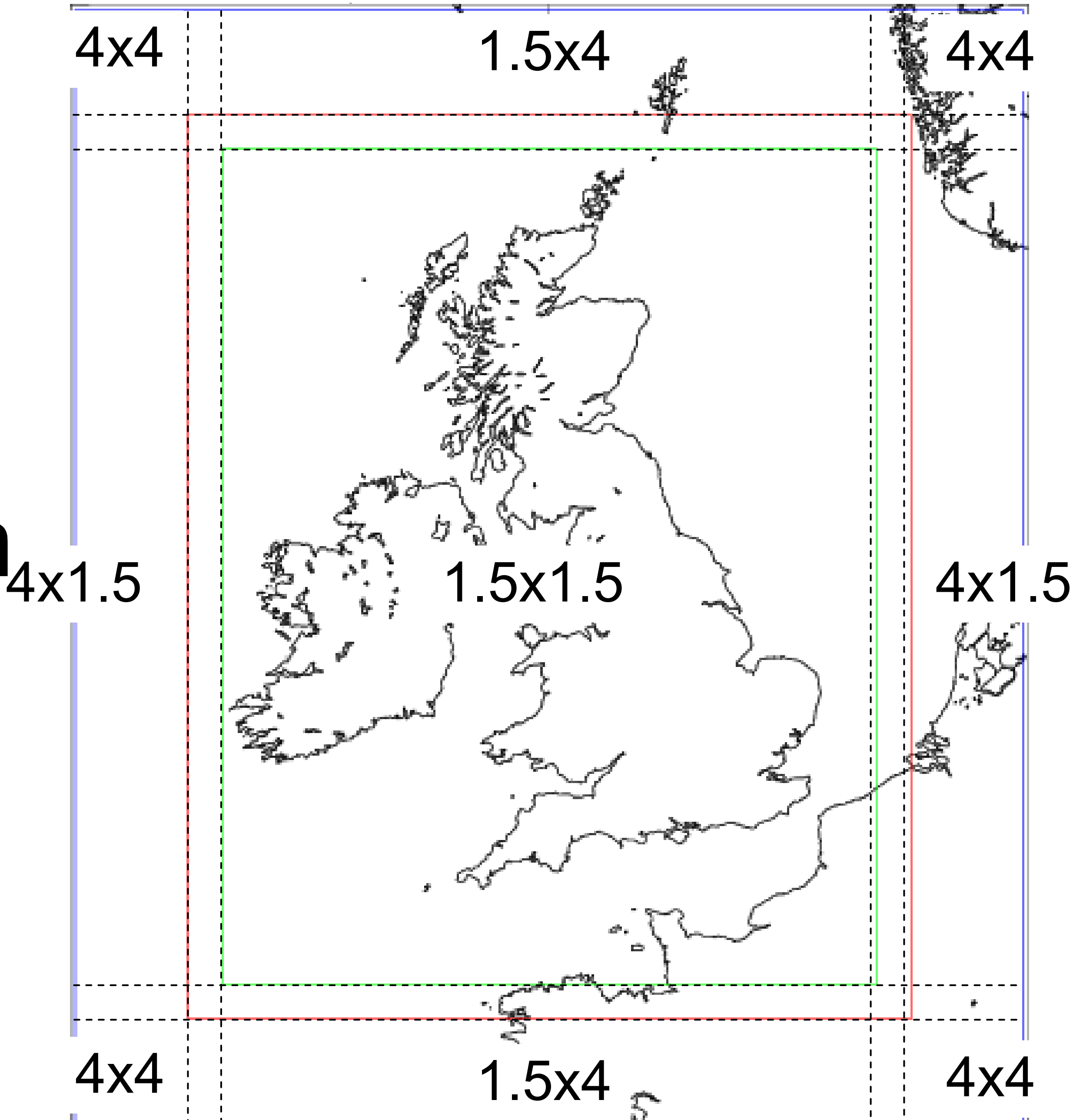
UKV Domain



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Convection in the UKV

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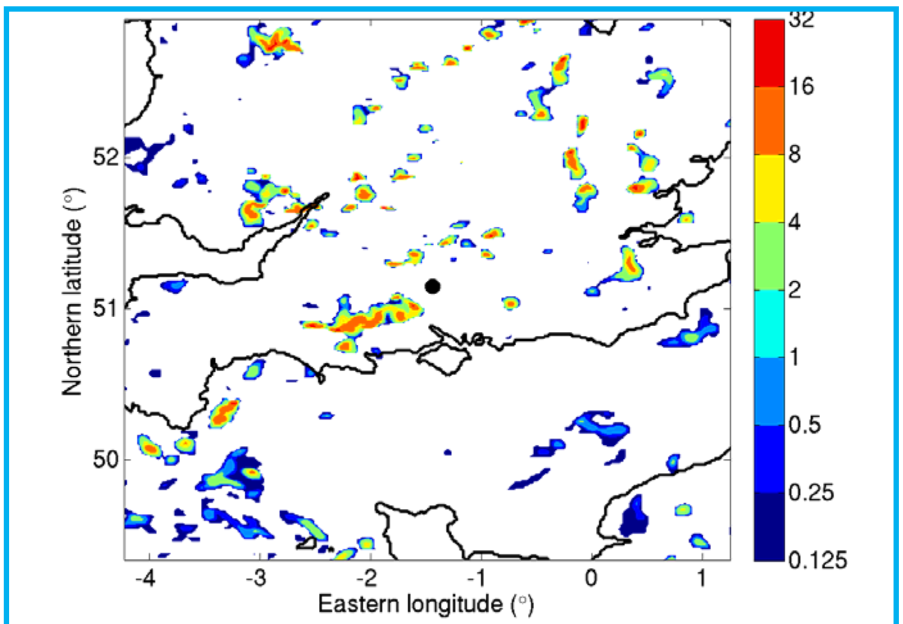
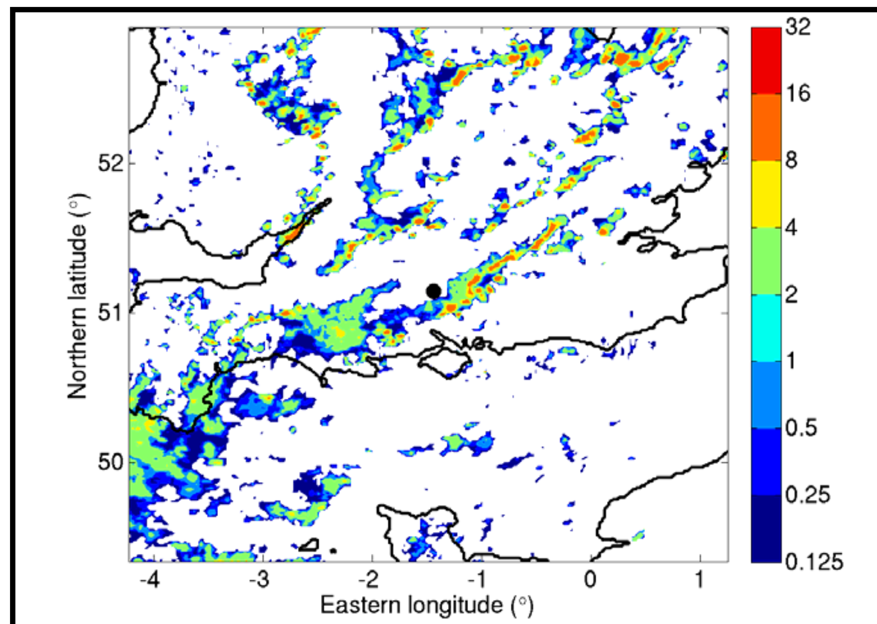
- At 1.5 km grid length, convection is still under-resolved.
- Individual cells are often too large, too far apart, with too much heavy rain and a lack of light rain.

UKV



RADAR



Precipitation rates (mm/hr) on 14 UTC on 25th August 2012

Average cell diameter (km)

(averaged over 22 convective cases)

Threshold (mm/hr)	Radar	UKV
0.125	7.81	16.04
0.25	6.32	13.21
0.5	5.58	11.71
1.0	4.42	9.93
2.0	3.28	7.95
4.0	2.57	5.96
16.0	2.13	3.37

(Emilie Carter)

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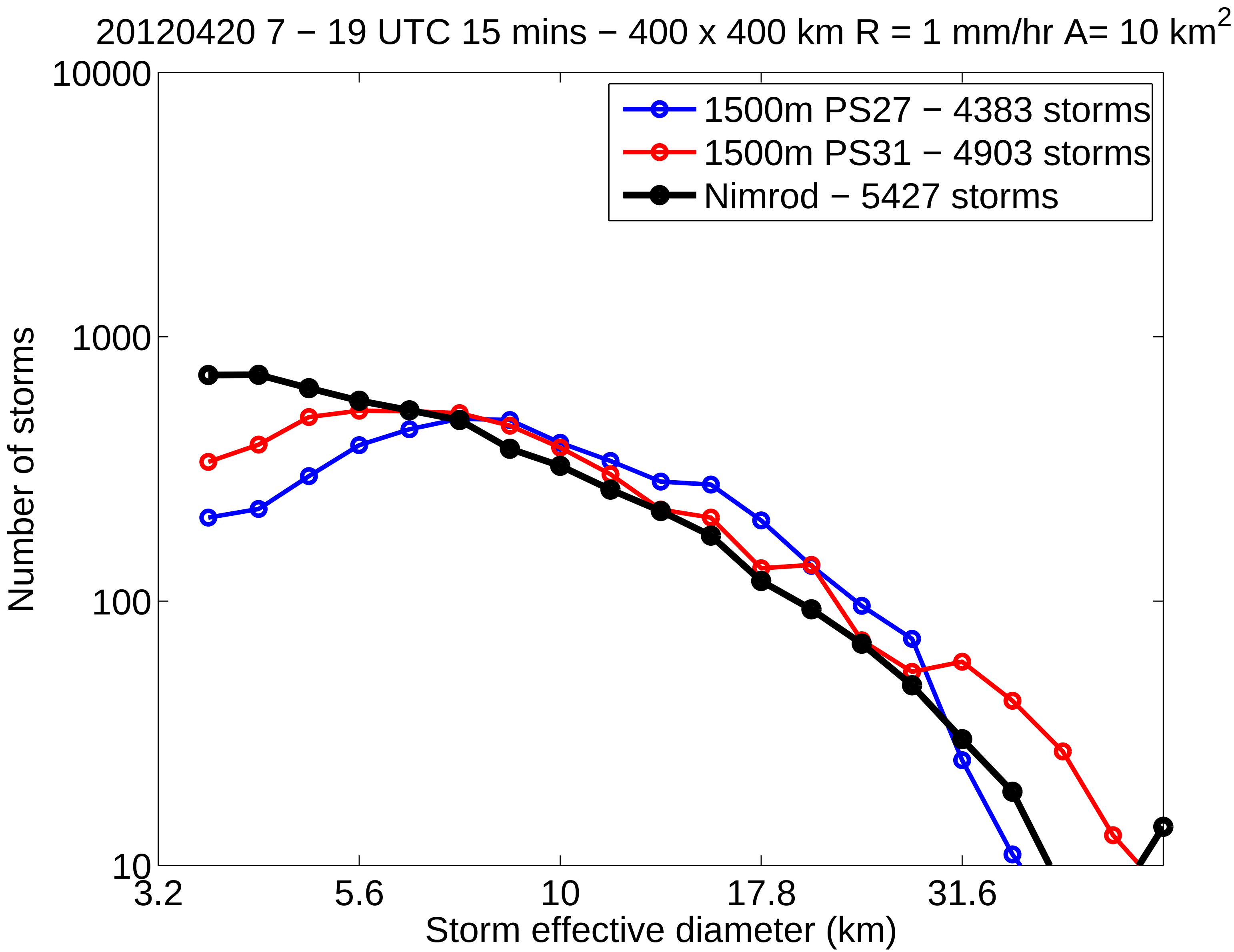

Kirsty Hanley

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Current research

- UKV (1.5km) performs reasonably well
  - Better than coarser resolution
  - Not perfect

- To improve UKV forecasts we need to understand the model better

- Higher resolution models (gridlength < 1.5km)

  - Improve UKV – understand model better
  - How the model performs at higher resolution

- Use of observations
  - DYMECS
  - Constrain
  - COPE

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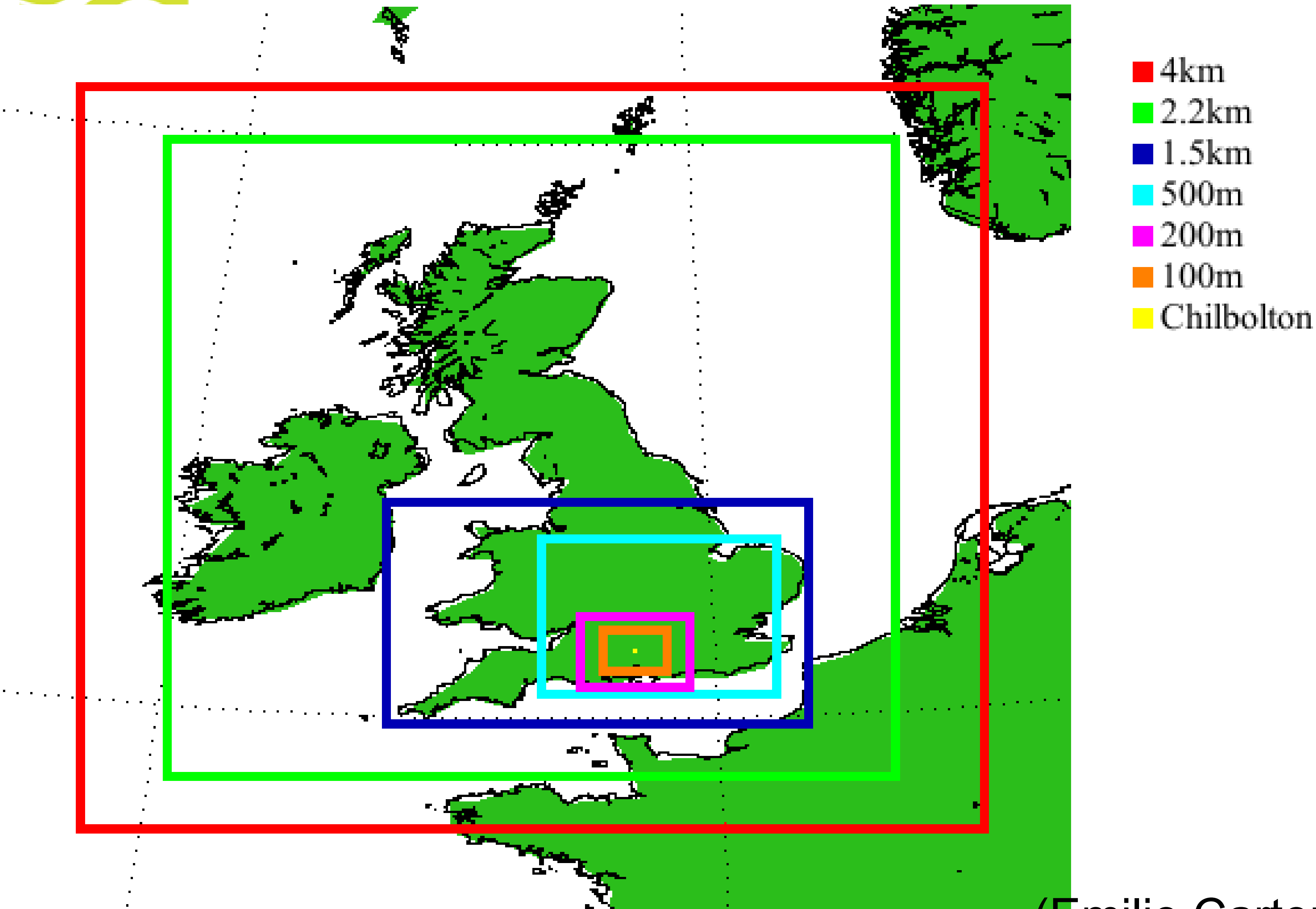
HRTM 100m Configuration



(Emilie Carter)

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Differences between models

	UKV	500m	200m	100m
Vertical levels	70	140	140	140
timestep	50s	10s	6s	3s
RH crit	0.91 smoothed to 0.8	0.97 smoothed to 0.9	0.97 smoothed to 0.9	0.99 smoothed to 0.9
Stable boundary layer mixing scheme	SHARPEST over sea; MES tails over land	SHARPEST function (RiSc)	SHARPEST function (RiSc)	SHARPEST function (RiSc)
Subgrid turbulence scheme	2D	3D	3D	3D

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Analysis

- How does the model perform as the gridlength decreases?
- What are the problems?
- How can we best utilise observations?
  - NIMROD radar
  - DYMECS
    - Statistical evaluation of the properties of convective cells over 40 cases using data obtained using the Chilbolton RADAR.
  - Constrain
    - cold-air outbreaks off the North West coast of Scotland.
  - COPE (Summer 2013)
    - following the life cycle of individual clouds or clouds at different stages of development along SW Peninsula convergence lines.

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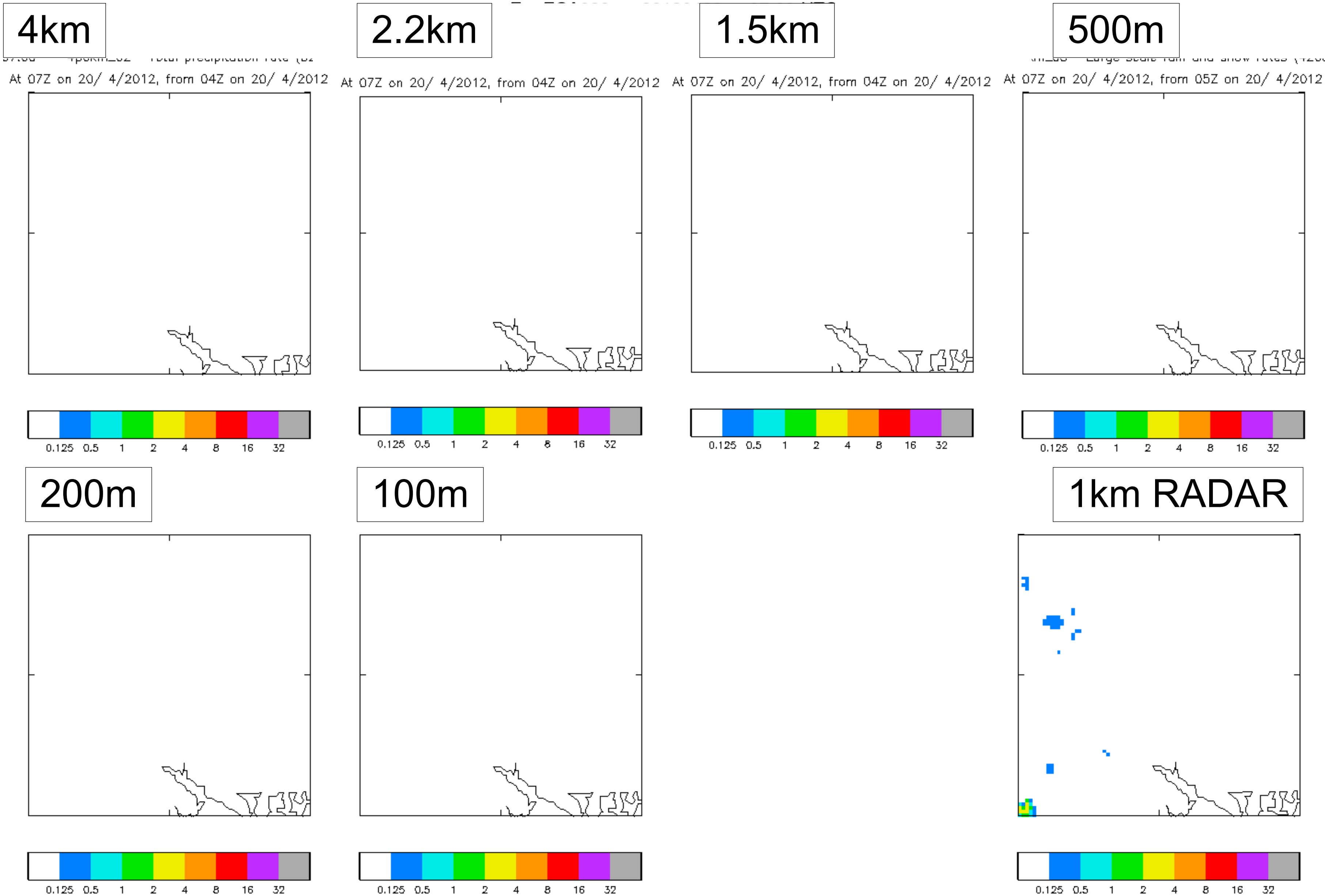
Precipitation rate (20th April 2012)



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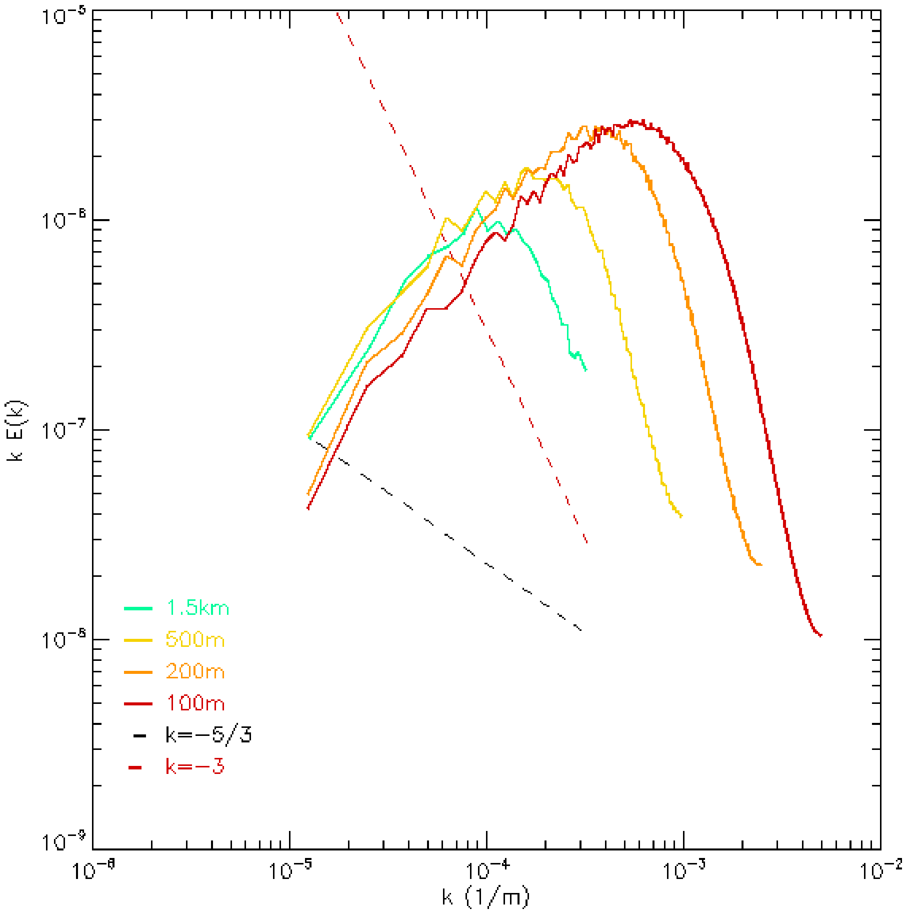
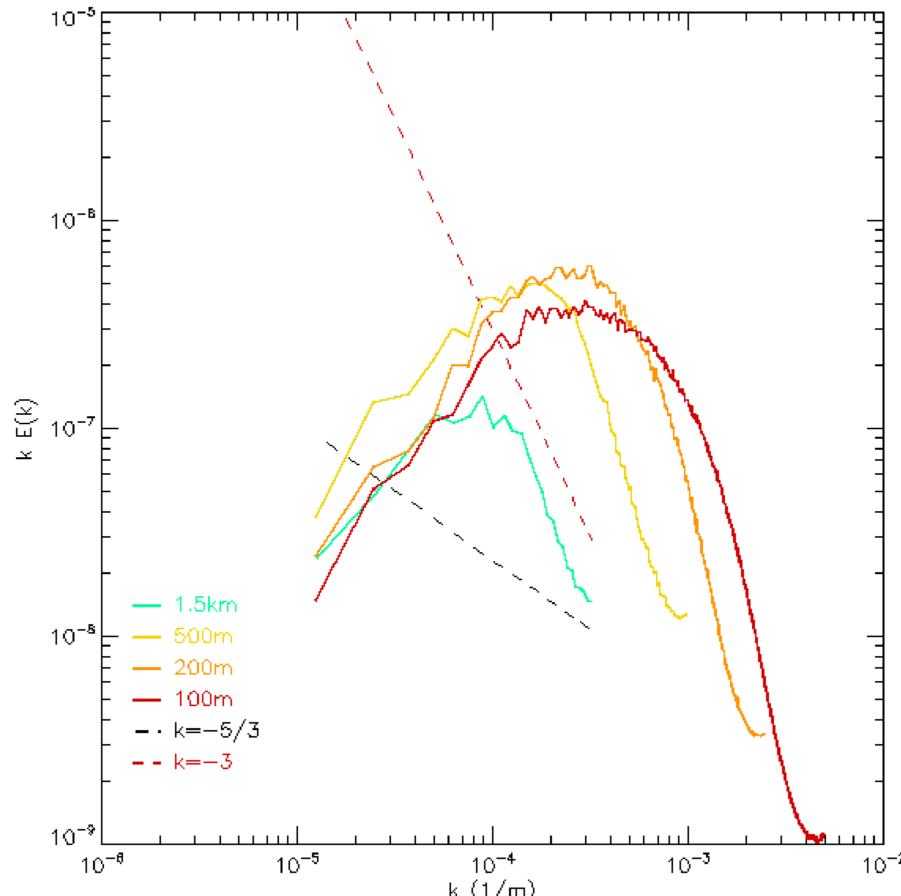
w spectra

1.5km
500m
200m
100m



1 – 2 km



5 - 6 km

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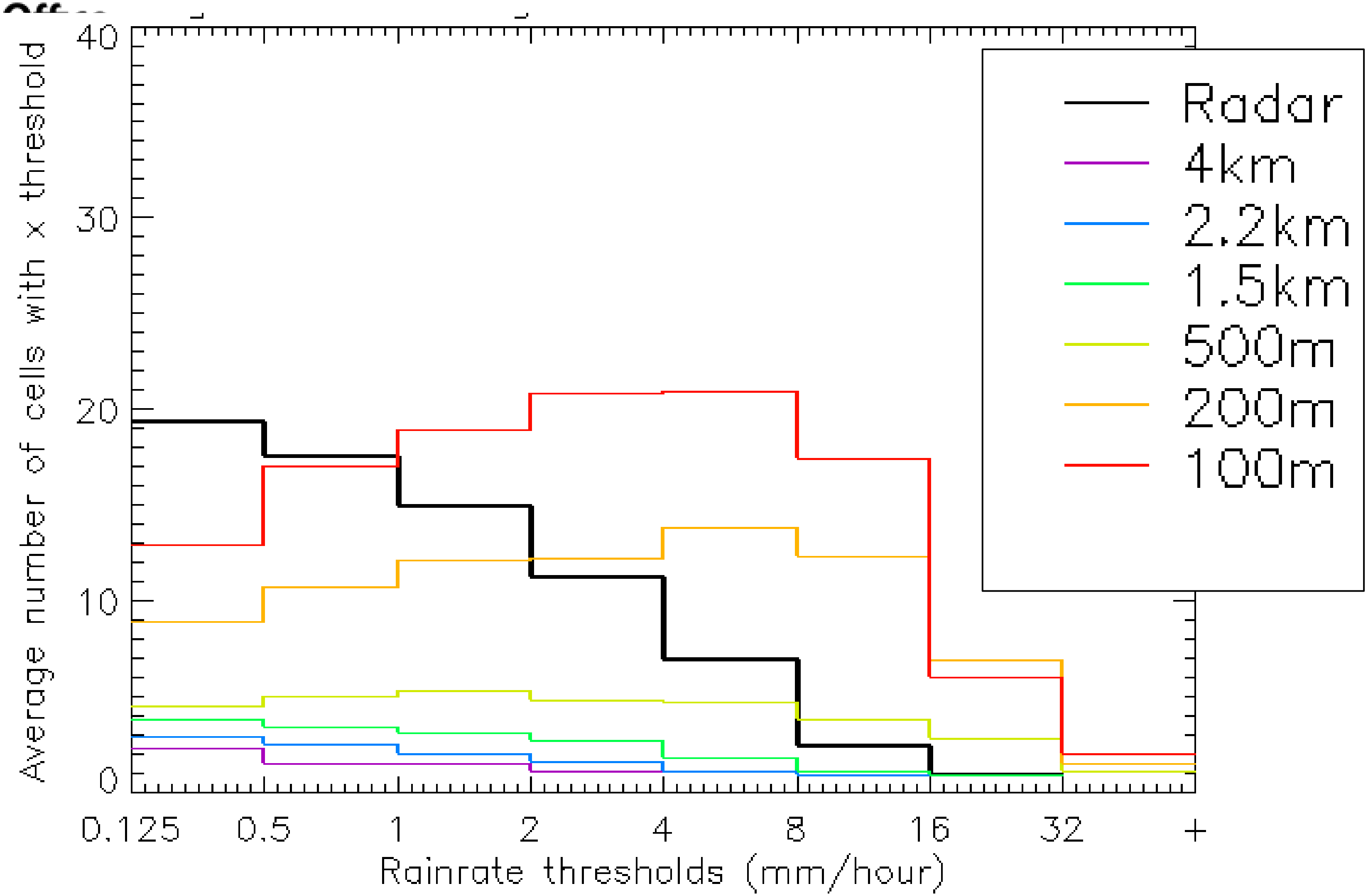
Average number of cells



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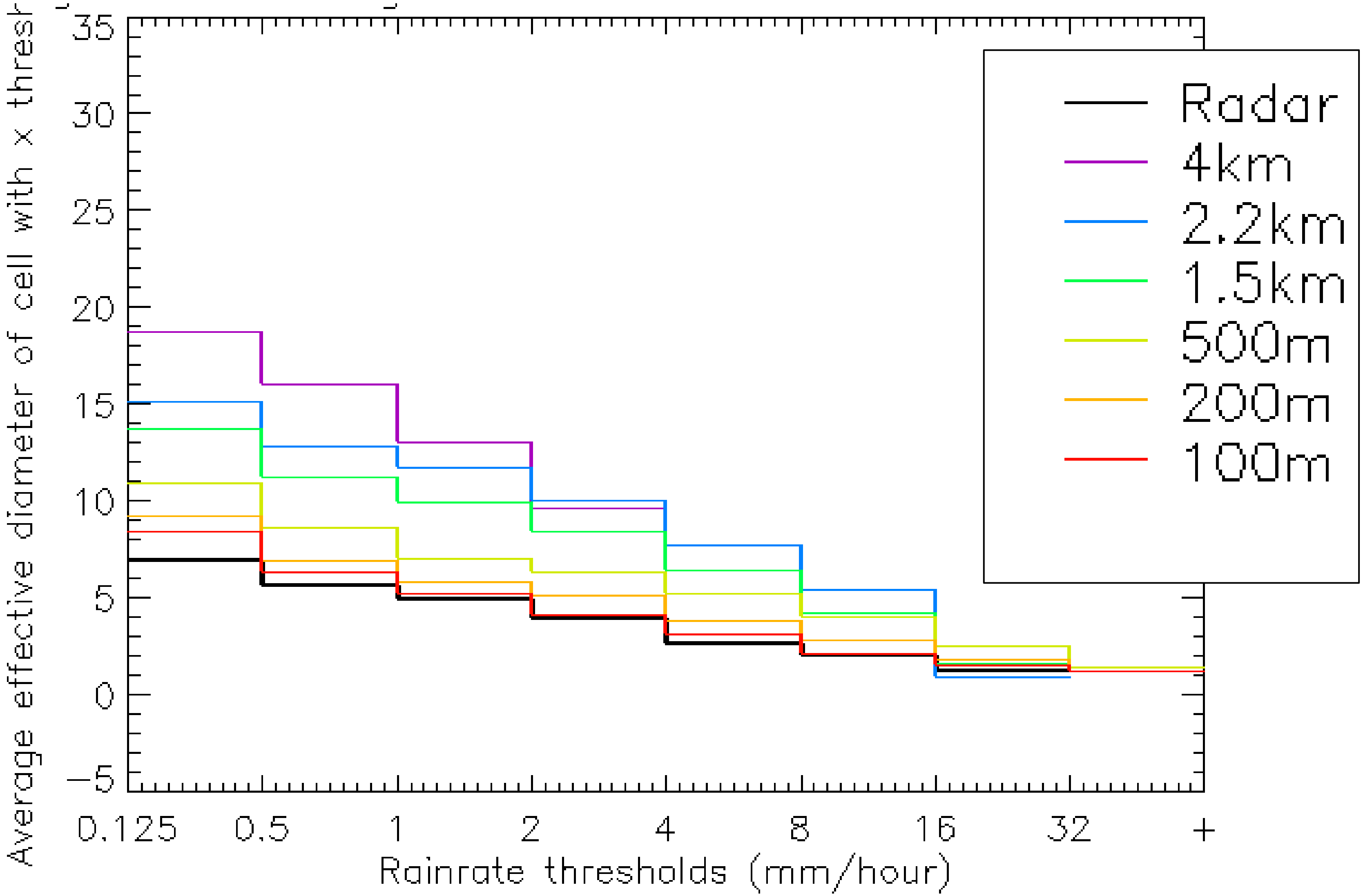
Effective diameter of cell



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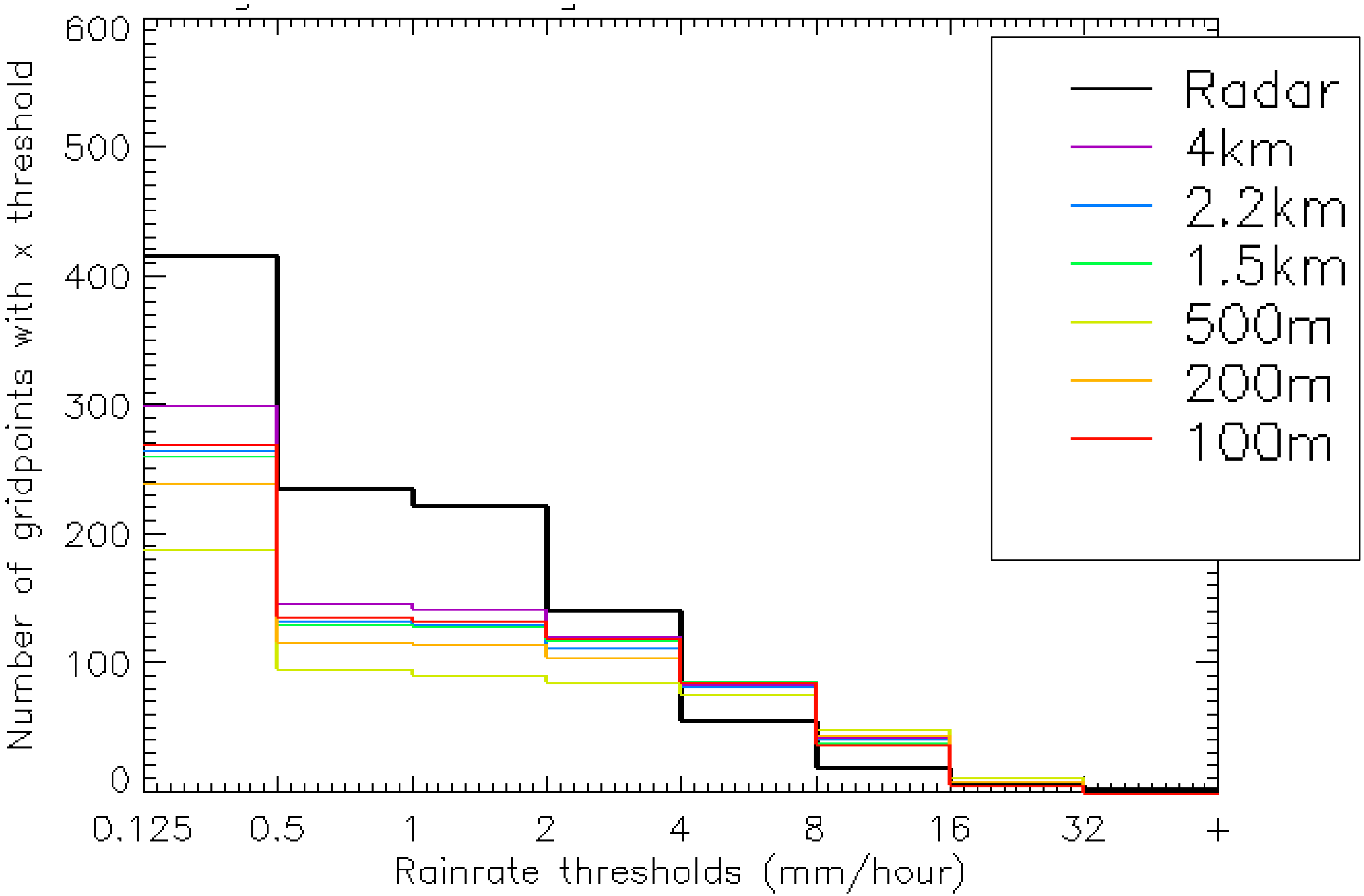
Average area covered



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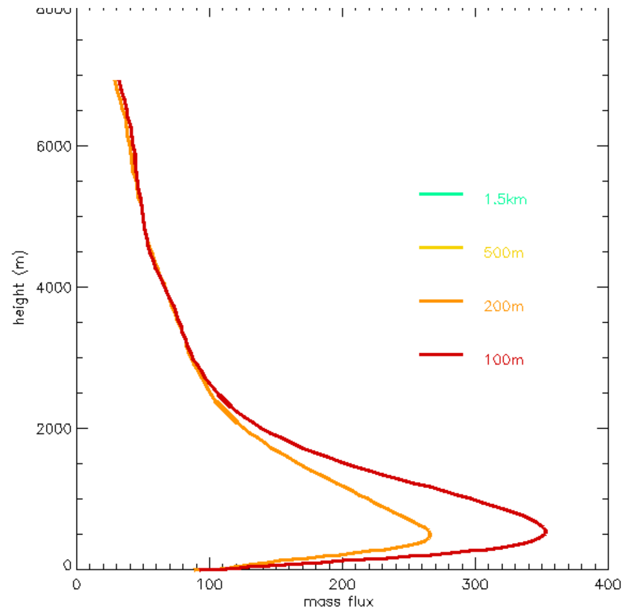
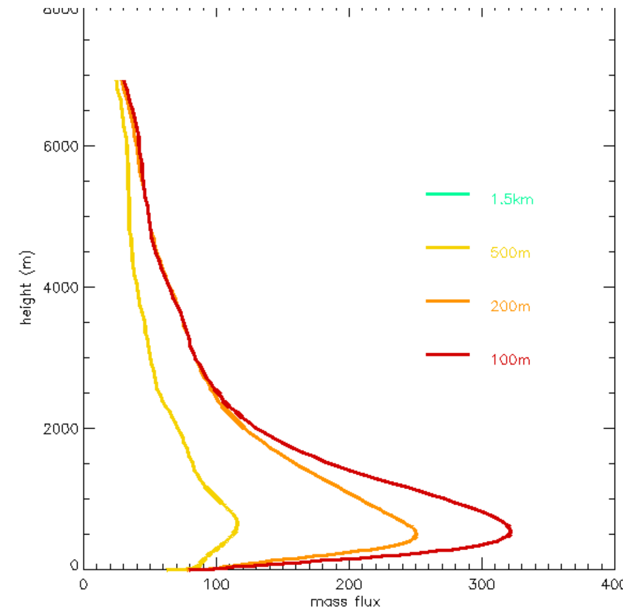
Aggregated onto 200m grid



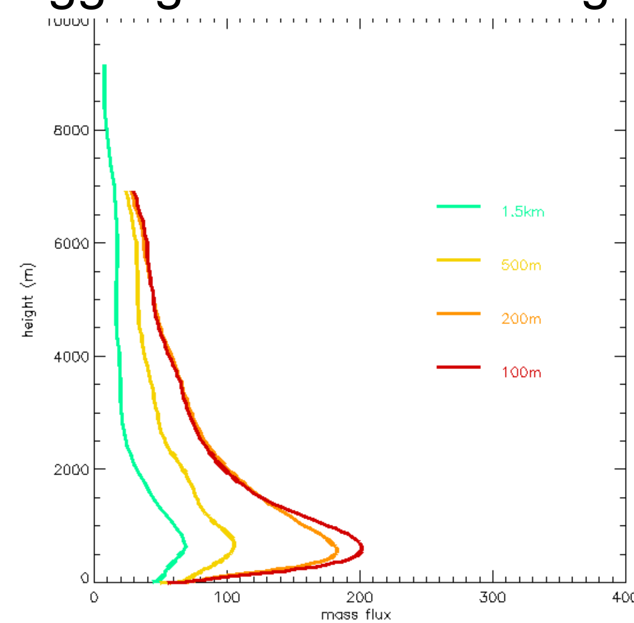
Aggregated onto 500m grid



Upward explicit mass flux

- 1.5km
- 500m
- 200m
- 100m

Aggregated onto 1.5km grid



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How can we improve representation of convection in UKV (and higher resolutions)?

- Understand the model better
- Compare model with observations

- Can we adapt the existing model?
- Are there missing processes?
- How can we optimise the model representation of convection?

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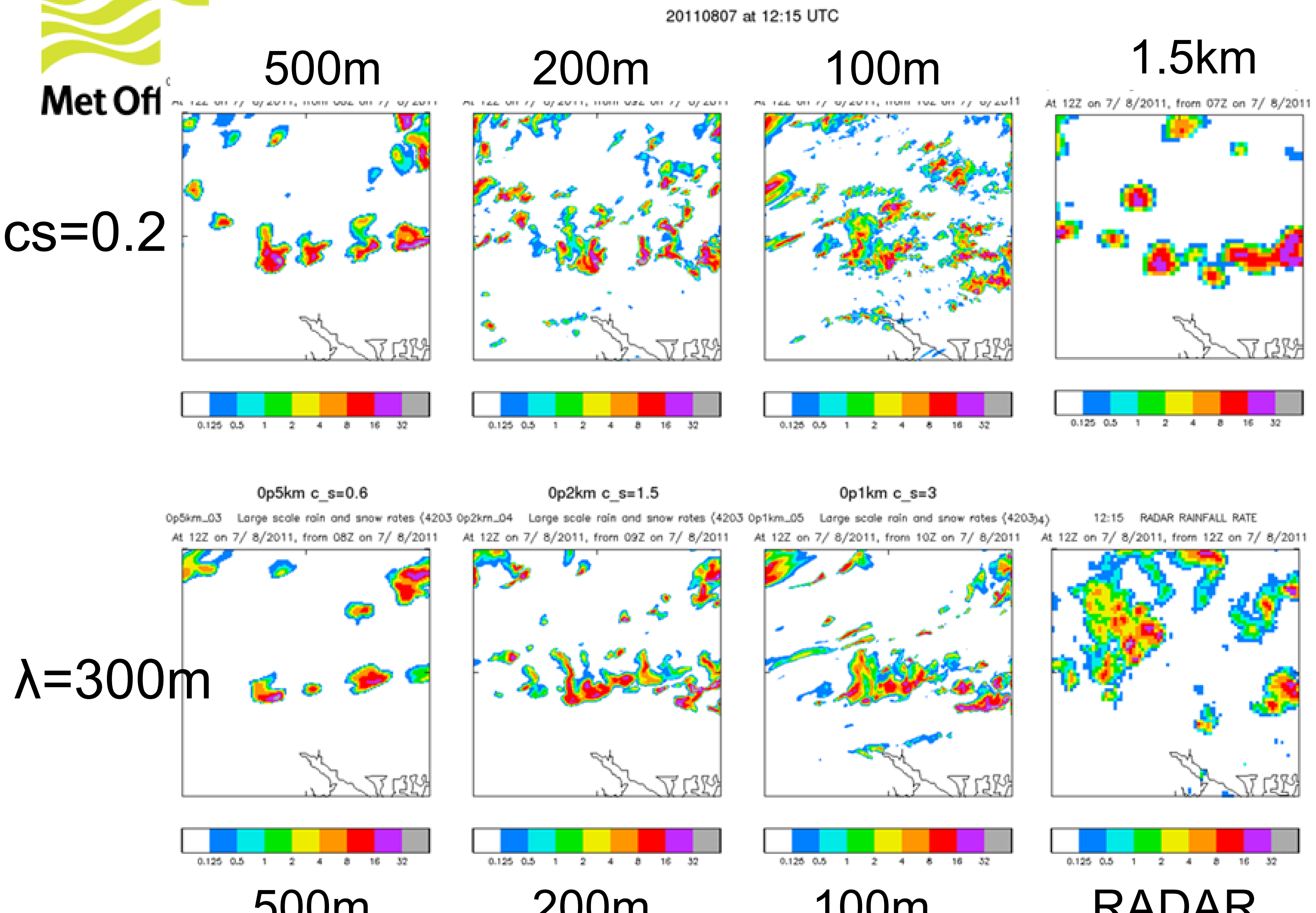
Change in mixing length

(Emilie Carter)



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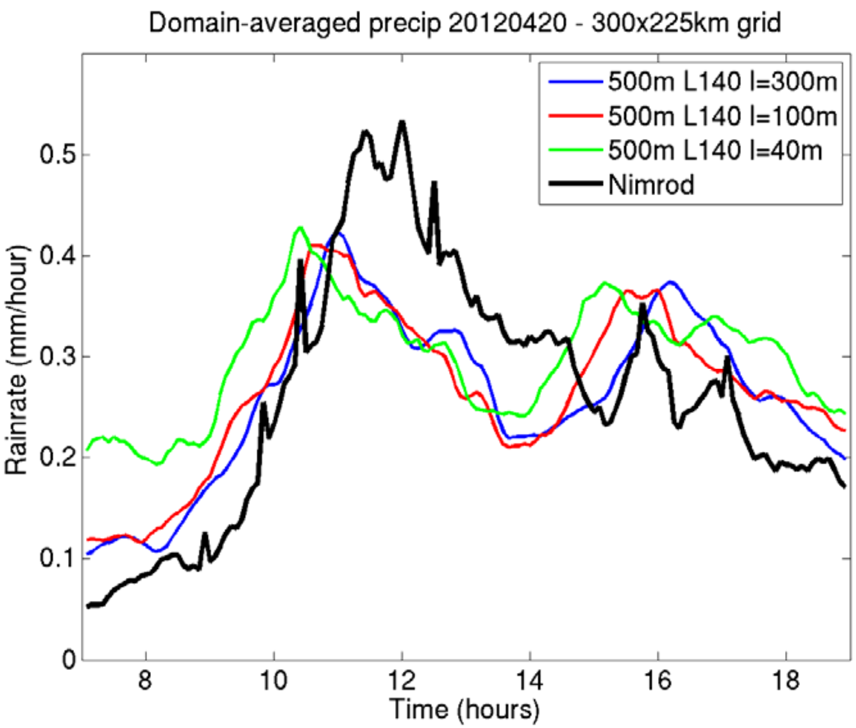
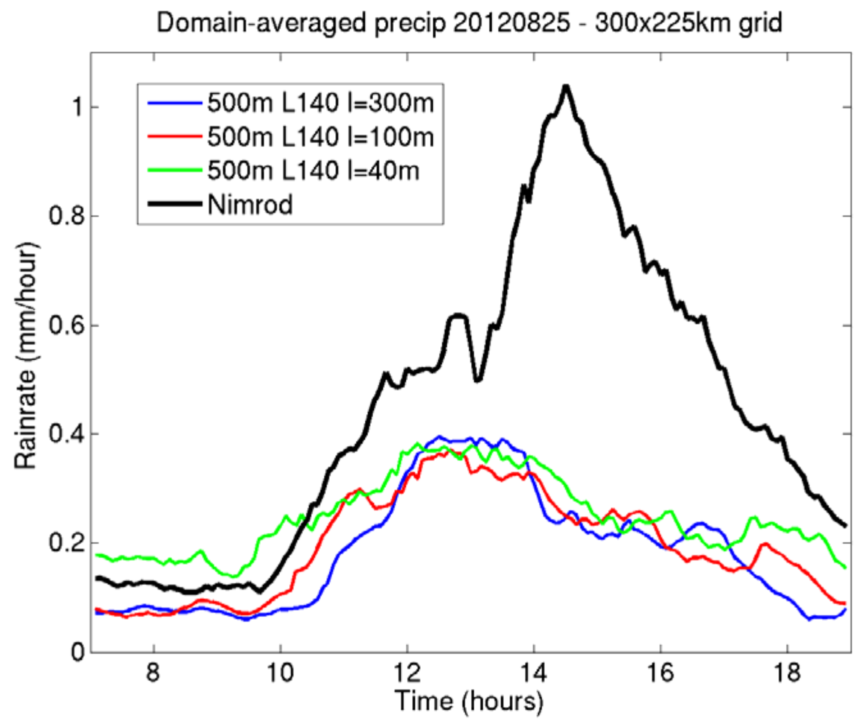
Domain averaged precipitation

Scattered showers



Larger-scale convection



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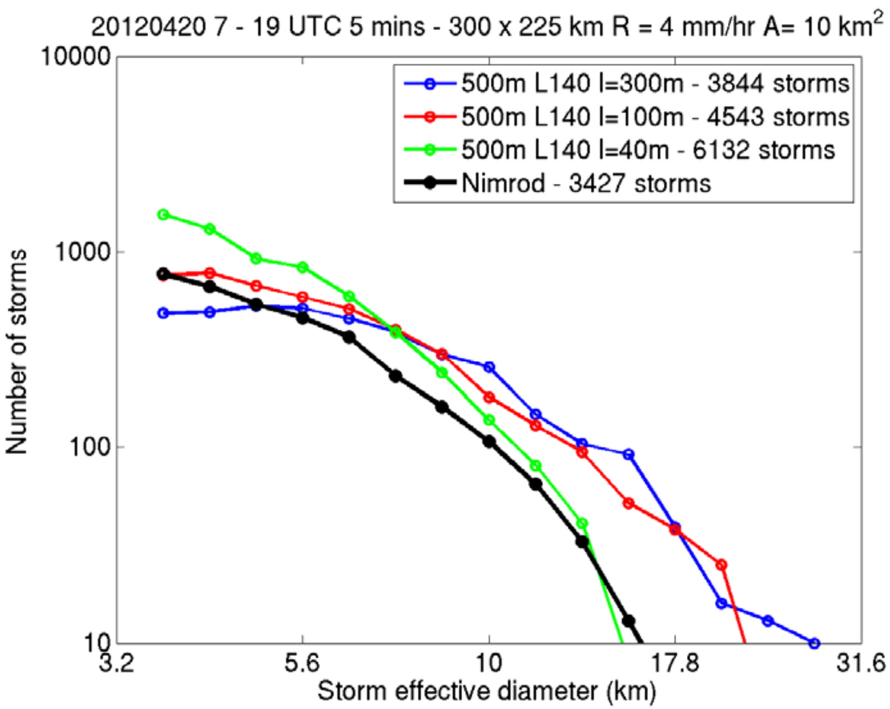
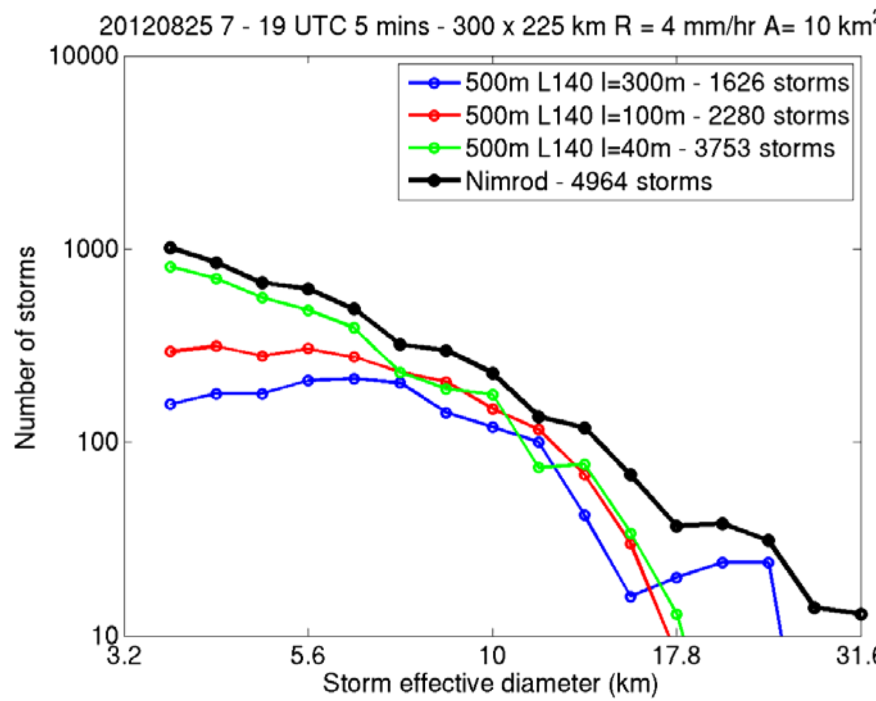
Storm effective diameter vs. number of storms

Scattered showers



Larger-scale convection



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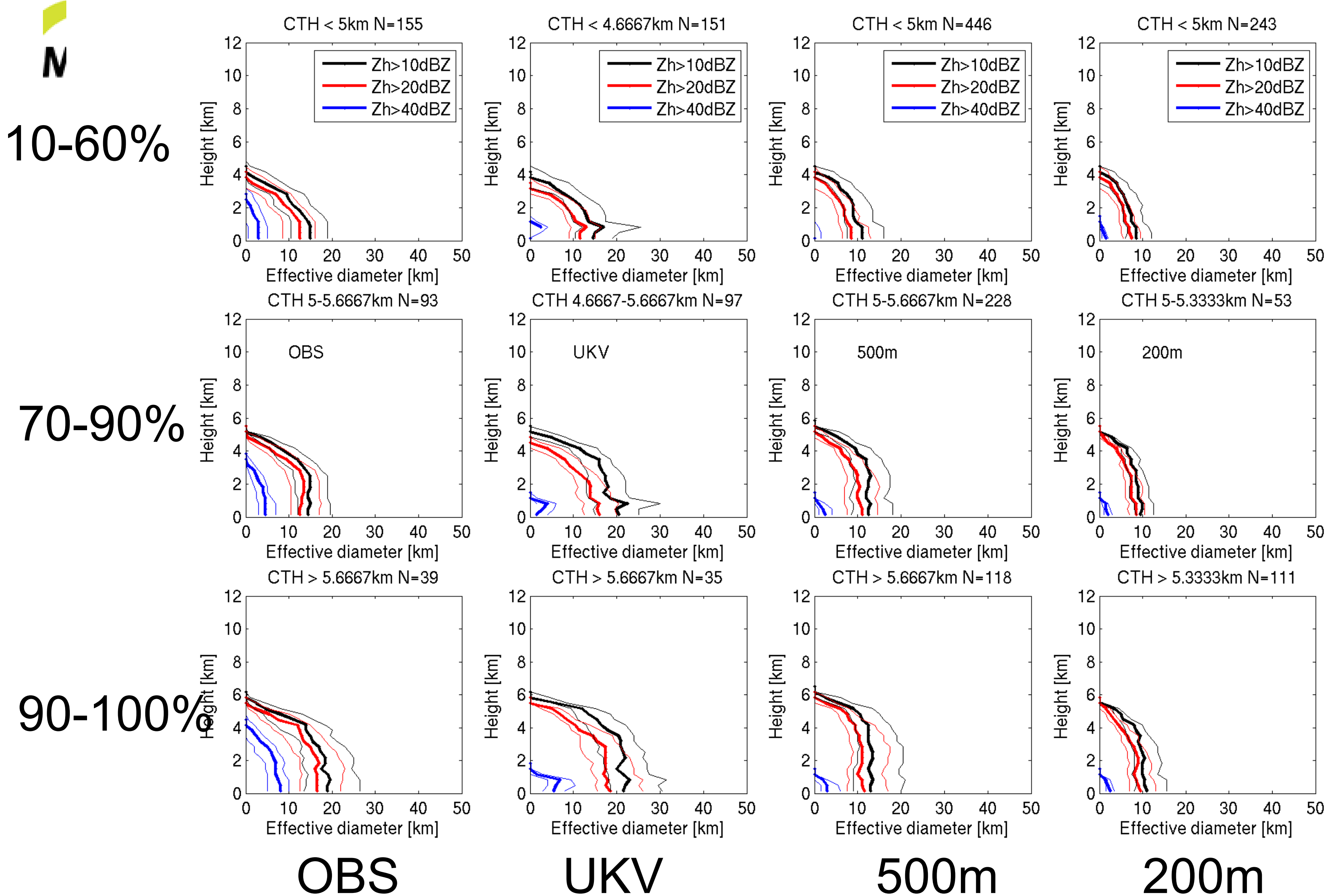
3D structure – 20th April 2012



(Thorwald Stein)

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Summary

- On average, the UKV is better than the coarser resolution models at forecasting convection
  - It represents convection explicitly.
  - It's not perfect
    - e.g. the model does not correctly reproduce the observed sizes of the convective cells.

- To improve the representation of convection, we need to understand the model better.

- We have started experimenting with versions of the UM with gridlengths down to 100m for representing convection.
  - We have some indications that the 100m and 200m models are more similar to each other .
  - The behaviour of the models is very sensitive to the subgrid mixing scheme.

- We want to make use of the available observations.

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Future work

- Future observational work
  - Use of the 3D radar scans (Thorwald Stein)
  - Calculate vertical velocities from the Chilbolton 3D scans (Jon Nicol).
  - More detailed analysis of the cell statistics.
- Future modelling work
  - Aim to optimise the model representation of the convection at all resolutions including work on the subgrid mixing and microphysics.
  - Shallow convection scheme?
  - Stochastic backscatter?

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Questions?

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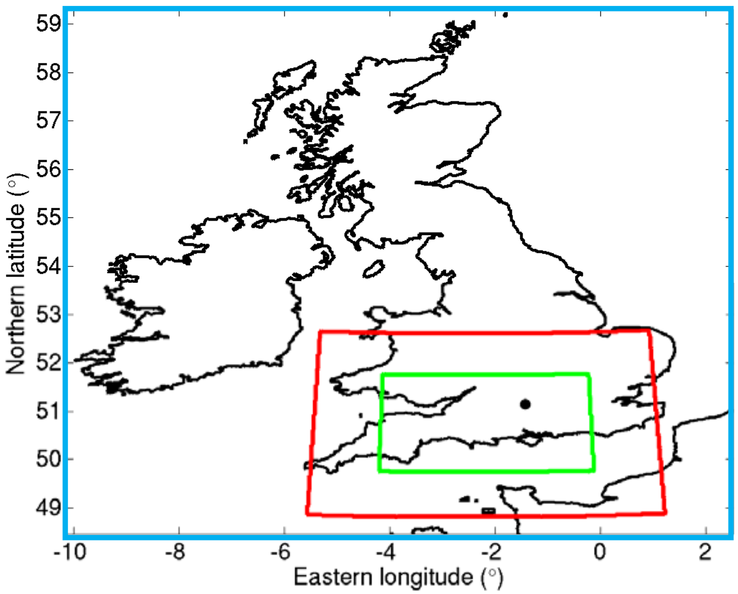
Model setup – UM vn7.8

Set of nested models.



UKV – 1.5km grid length,
70 vertical levels,
2D subgrid turbulence scheme,
BL mixing in vertical.

500m model – 500x425 km,
140 vertical levels,
3D subgrid turbulence scheme.

200m model – 300x225 km,
140 vertical levels,
3D subgrid turbulence scheme.

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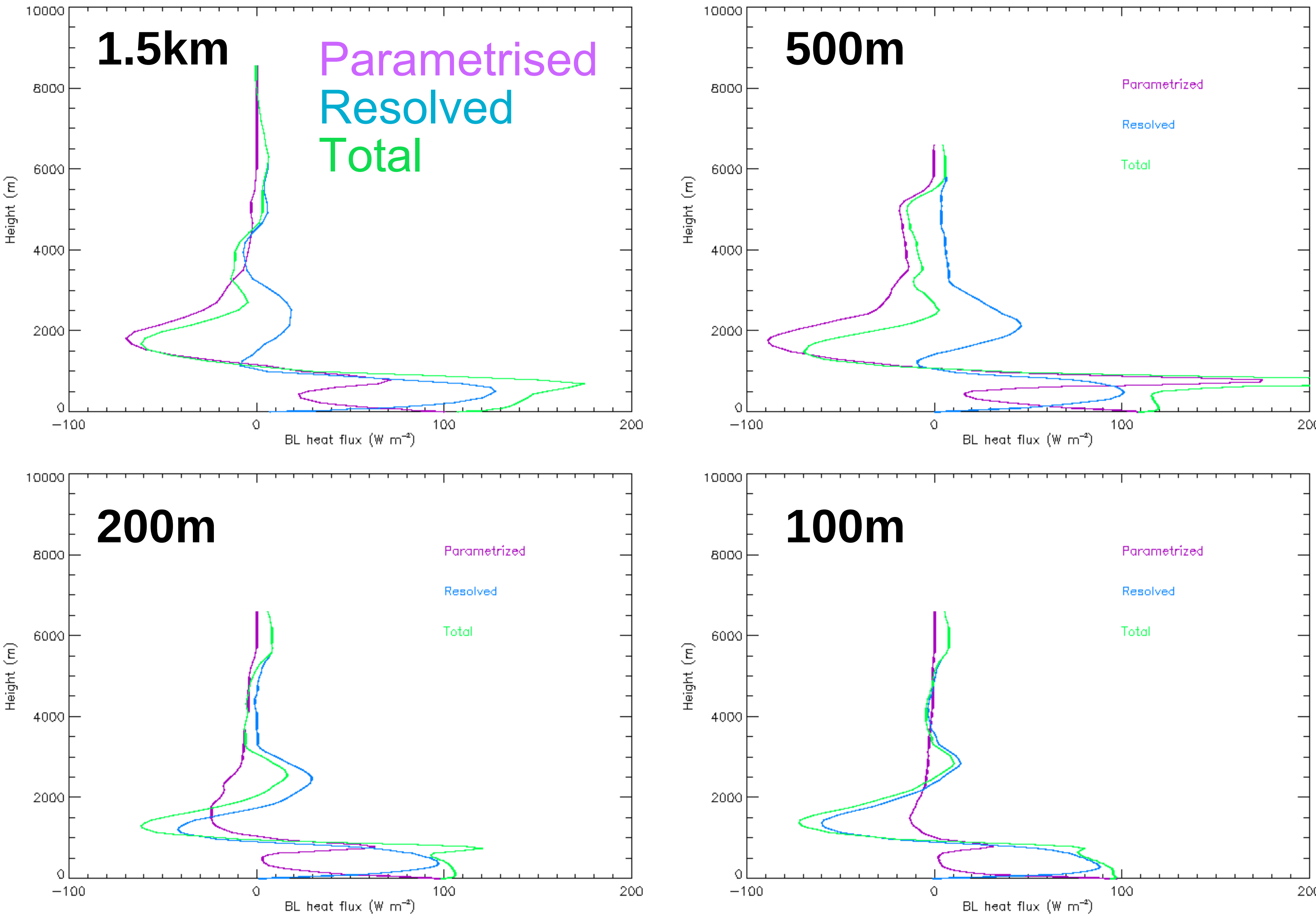
Heat fluxes



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Forecaster's view

- Can suffer from generating diurnal convective storms too late and when it does they can be too large/intense.
- Produces showers that are too few, widely spaced and too large/intense, particularly on days when showers should be intense but small.
- Can over-estimate rain rates and, hence, accumulations in modestly deep instability where the instability extends above the freezing level. This may be due to the mixed phase processes being overly active.
- Can generate excessive diurnal Cu/Sc (and associated light showers) over land when forecast profiles show deep (150mb) mixed layer and only very shallow Cu when LFC is reached. Linked to UKV trying to resolve cloud at the lower limit of its resolution.

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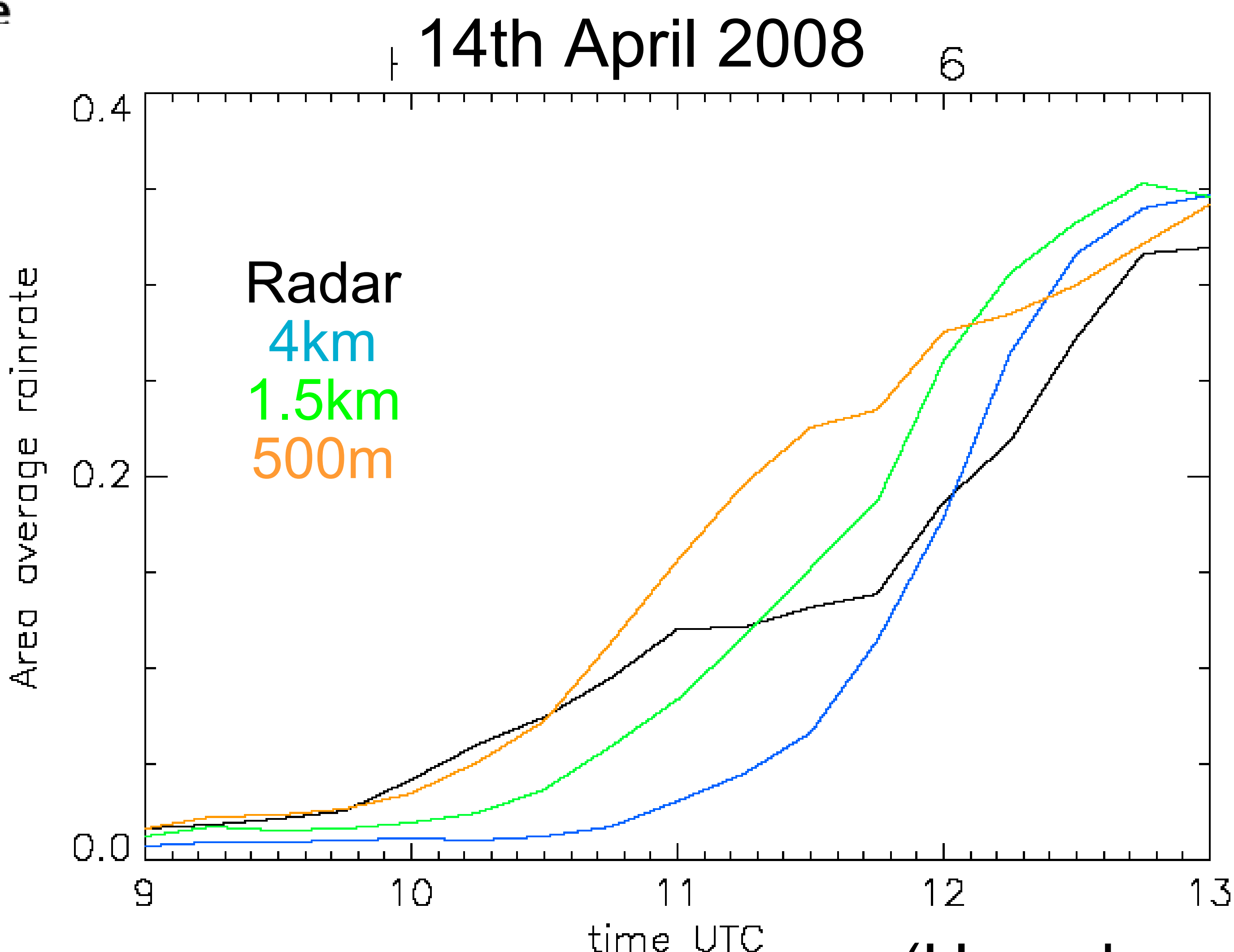
Delay in initiation



(Humphrey Lean)

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(Smagorinsky) subgrid turbulence scheme in UM

- Diffusion coefficients

$$\nu = \lambda^2 S f_m(Ri) \qquad \nu_h = \lambda^2 S f_h(Ri)$$

$$S_{ij} = \frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \qquad S = \left\| S_{ij} \right\| / \sqrt{2} = \left(\frac{1}{2} \sum_{i,j,1,3} S_{ij}^2 \right)^{1/2}$$

$$\frac{1}{\lambda^2} = \frac{1}{\lambda_0^2} + \frac{1}{\left[k \left(z + z_0 \right) \right]^2}$$

($\bullet_0 = c_s \Delta$)

- (2D) Replace horizontal diffusion coefficients with variable
- (3D) Replace vertical (local BL scheme) coefficients.

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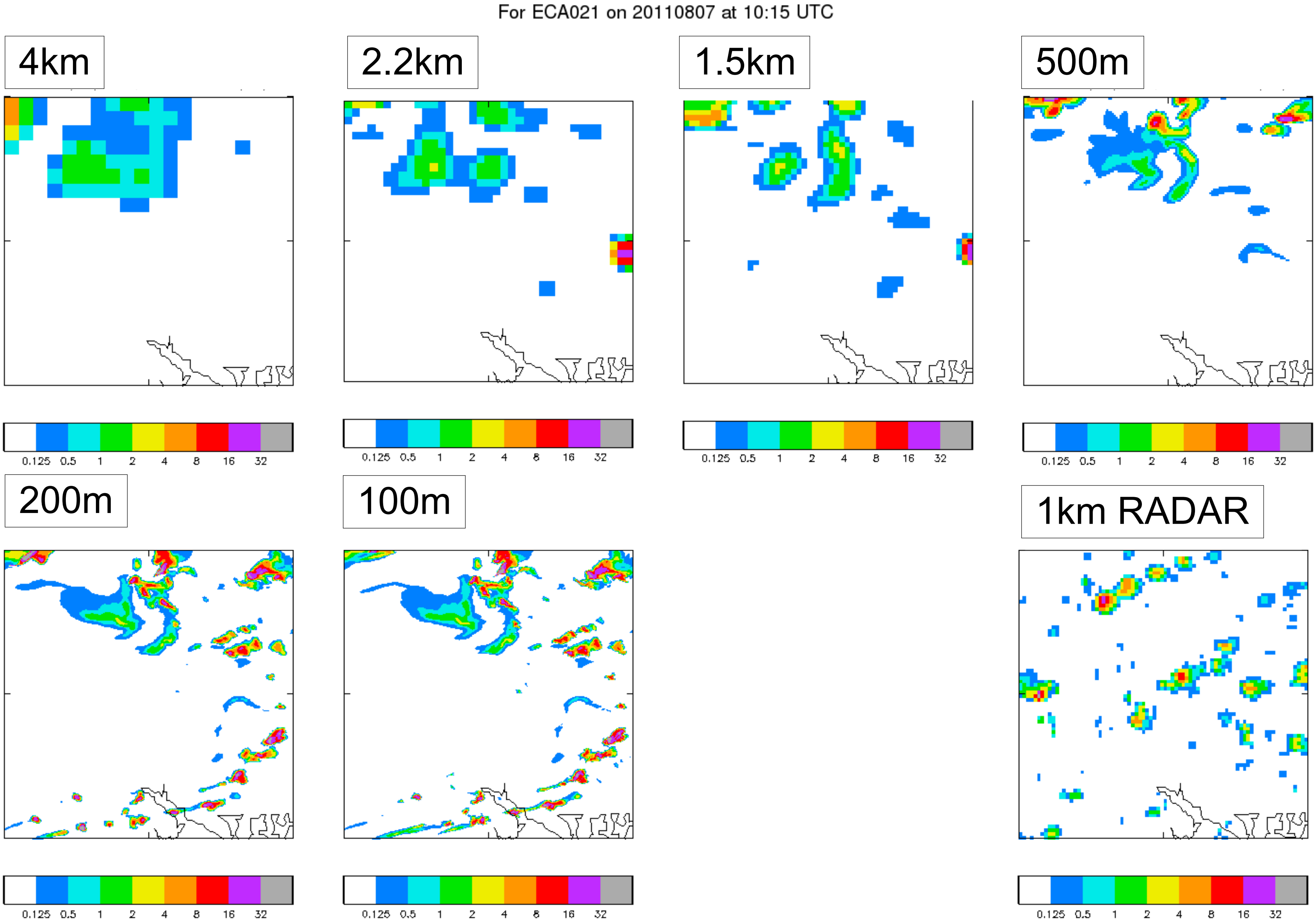

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DYMECS

- Collaborative project between the University of Reading and MetOffice@Reading.
  - (Robin Hogan, Bob Plant, Thorwald Stein, Kirsty Hanley, Jon Nicol, Humphrey Lean, Carol Halliwell, (Emilie Carter))
- Data collected mostly over summer 2012
  - data analysis continuing until the end of 2013.
- The key concept is statistical evaluation of the properties of convective cells over 40 cases using data obtained using the Chilbolton RADAR.
- Track convective cells using Nimrod radar data
  - steer the Chilbolton radar to scan one or more cells of interest.
- The data gathered can be used to
  - derive macrophysical properties (cell size and cloud topheight)
  - microphysical properties (rain rate, mean drop size, hail intensity and cloud icewater content)
  - dynamical properties (turbulent kinetic energy and where possible thevertical velocity and momentum flux),
  - all as a function of the time into the cell lifecycle.

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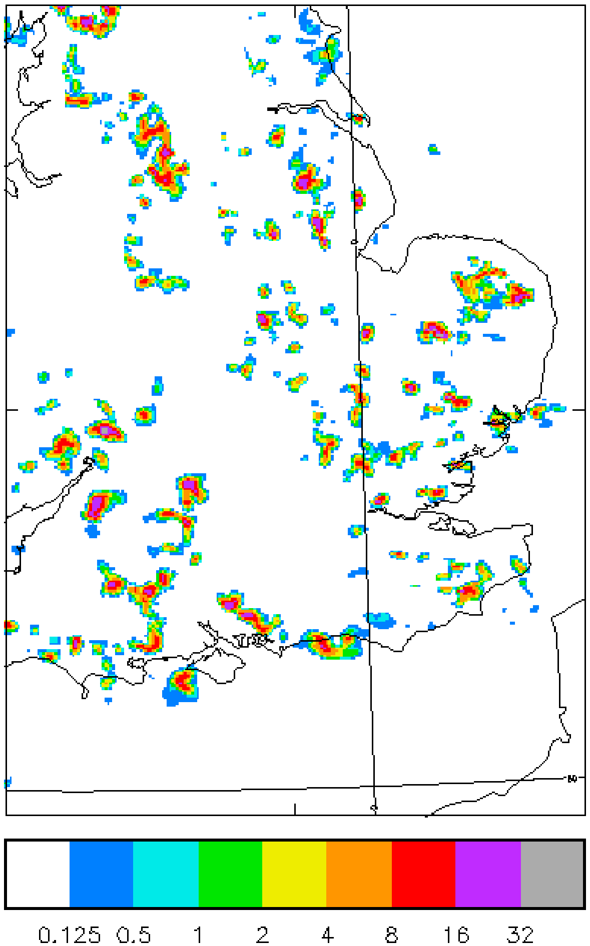
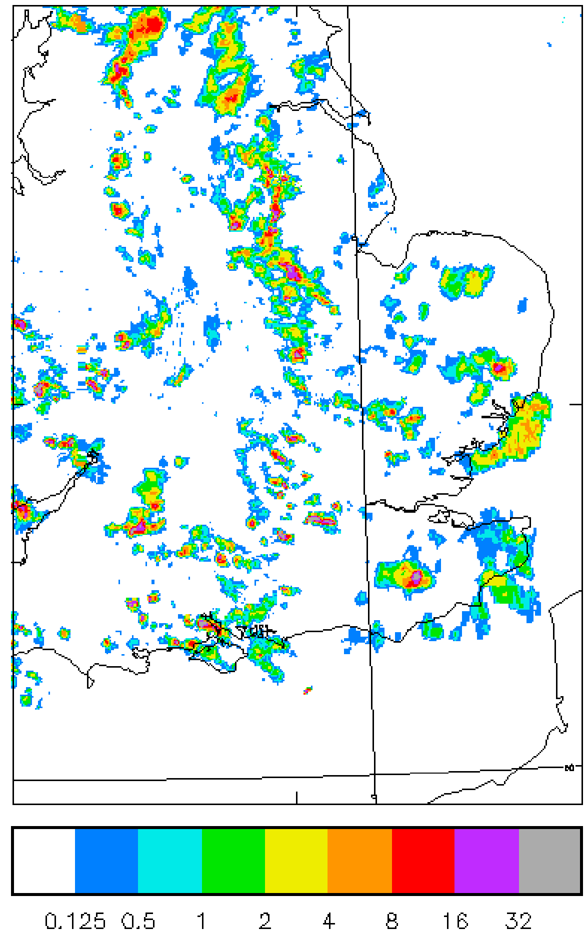
“UKV” 1.5km UK Model convection

1.5km model



Radar



15 UTC 12th April 2012

- Convective cells too large and too intense.
- Not enough light rain.

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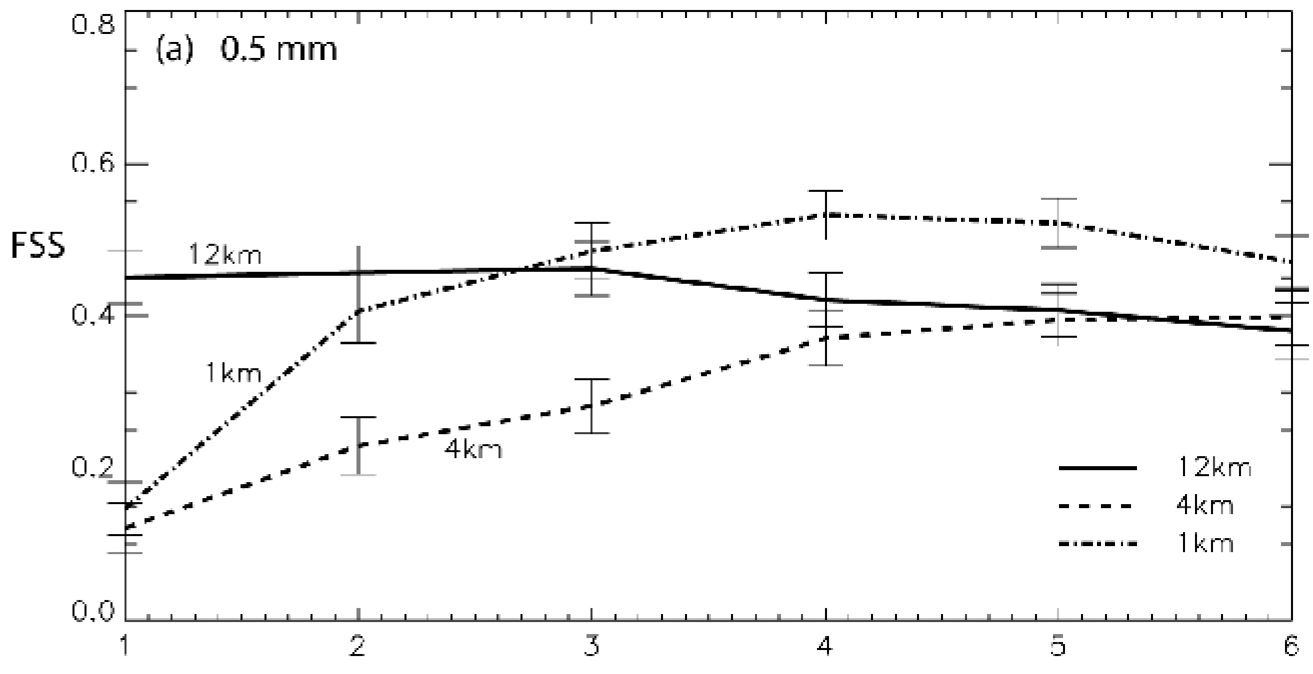
Scale selective Skill Scores
(Nigel Roberts*)



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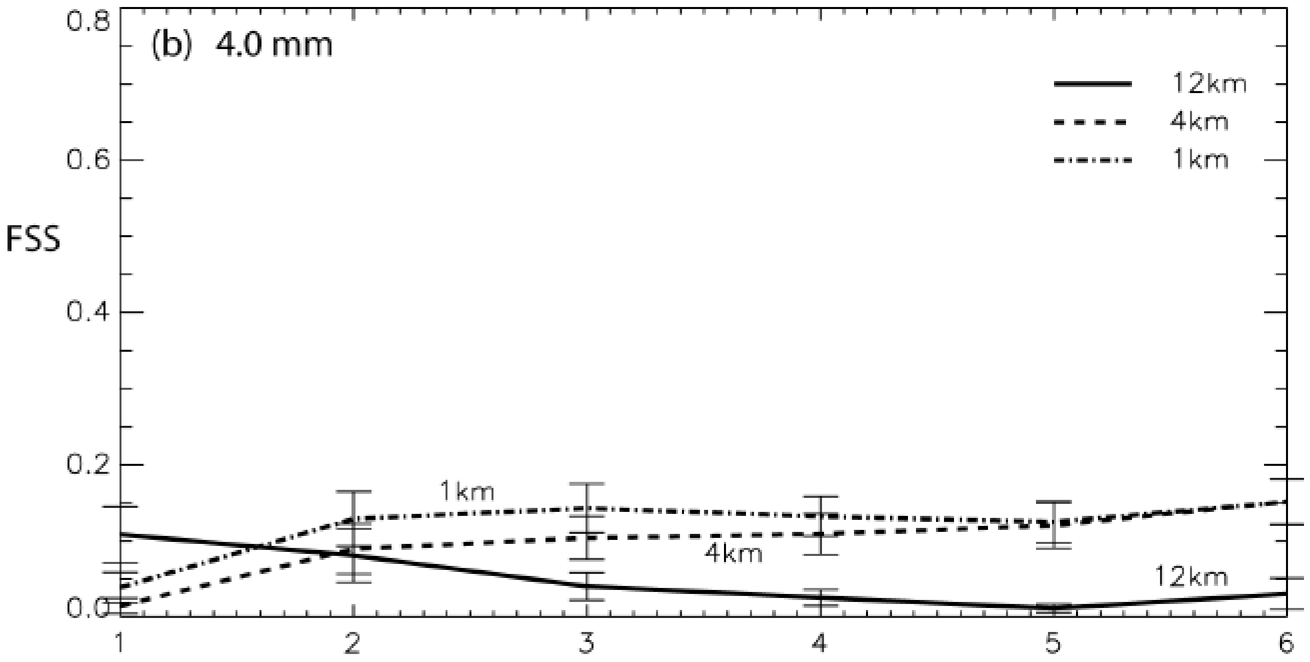
Scale selective Skill Scores



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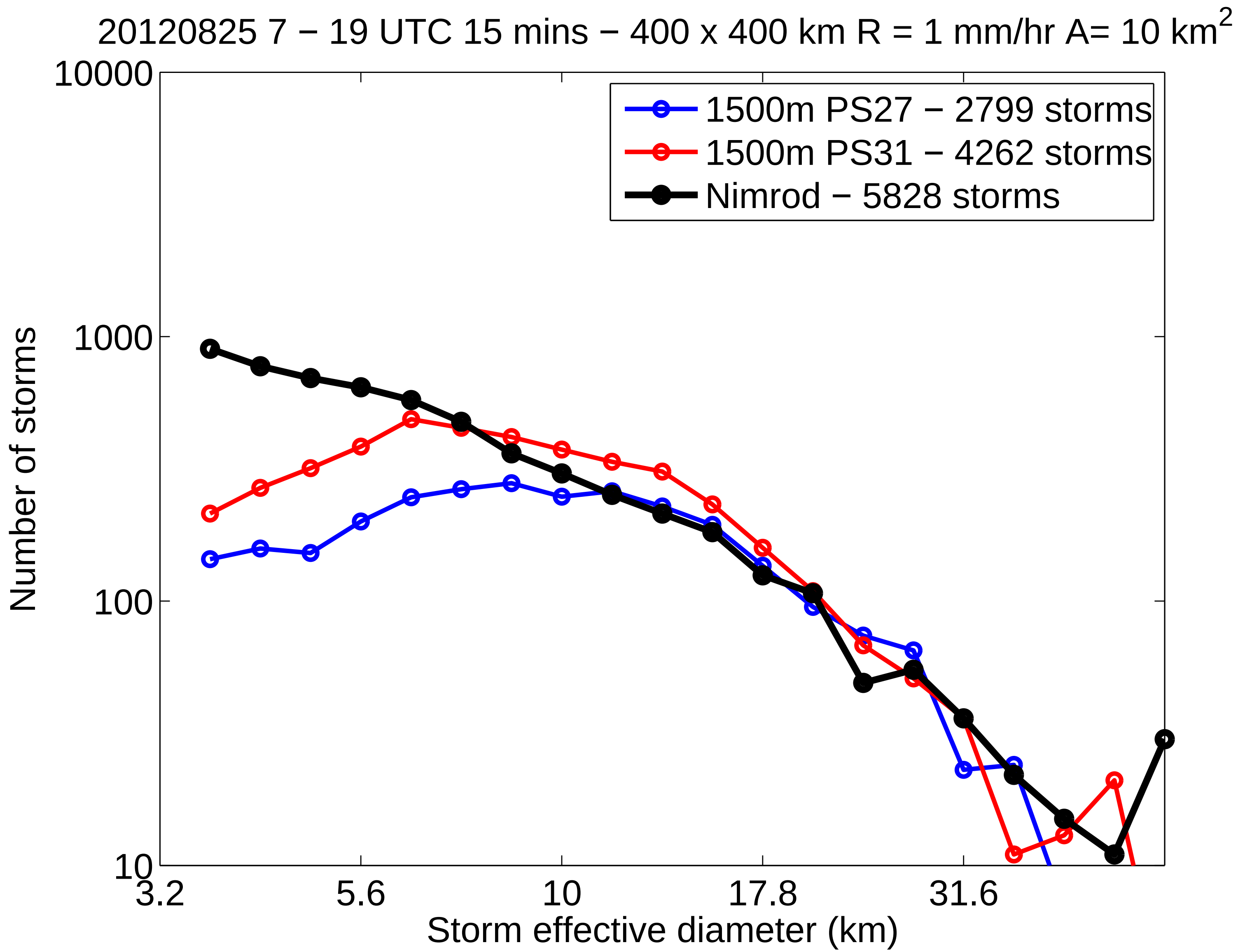

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