Very High Resolution Model Simulations of Convective Cases

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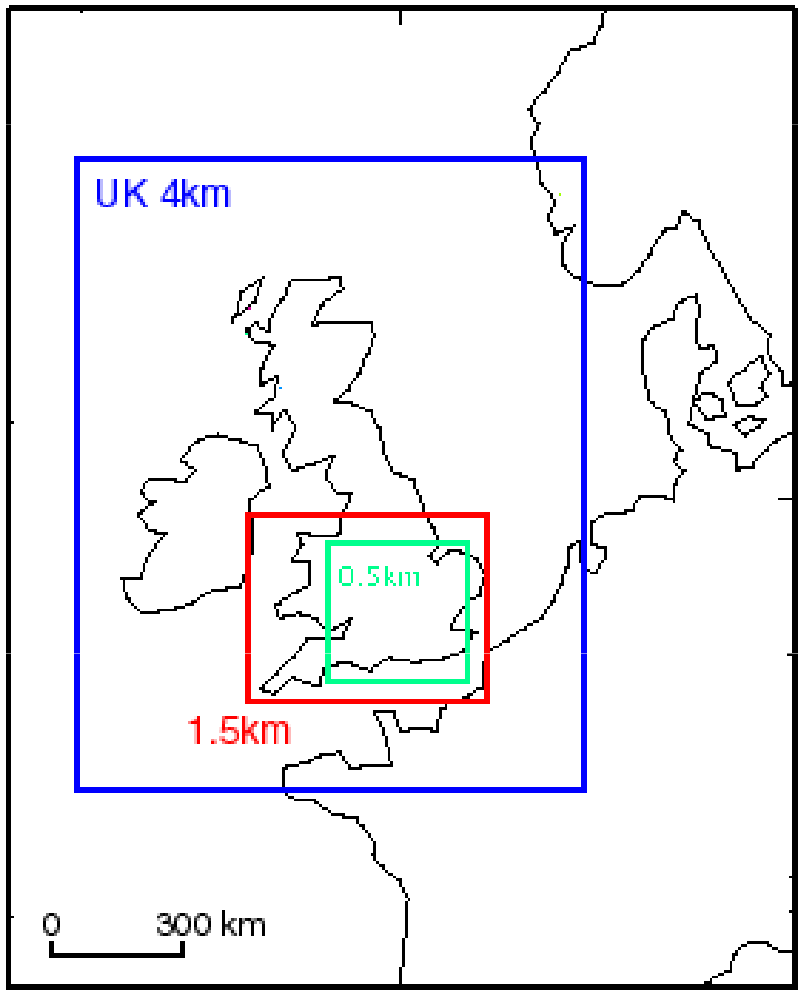
SRNWP Conference 17th May 2011

High Resolution Trial Models (HRTM) 500m Set Up

- The UKV has recently been introduced after extensive testing using a research 1.5km model, the HRTM.
- Runs without assimilation
- Relies on high resolution detail spinning up from lower resolution starting data.
- A suite of nested models with gridlengths 4km, 1.5km and 500m



HRTM 500m Configuration

Gridlength (~km)	4	1.5	0.5
Gridlength (deg)	0.036	0.0135	0.0045
Grid Size	288x360	360x288	600x600
Vertical Levels	70	70	70
Approx Top of Model (m)	40000	40000	40000
Run length	7hr (from T+1)	7hr (from T+1)	6hr (from T+2)
Timestep	100	50	10

Aims

- Improve our understanding of issues with the representation at storm permitting models, particularly at 1.5km
- Identify deficiencies and analyse how the model performs at higher resolutions
- Know that 1.5km is under resolved, one way to look at improving is to increase horizontal resolution
- Have a high resolution suite available
- Not intended to be used operationally, but still the first stages at looking at convection at higher resolution.

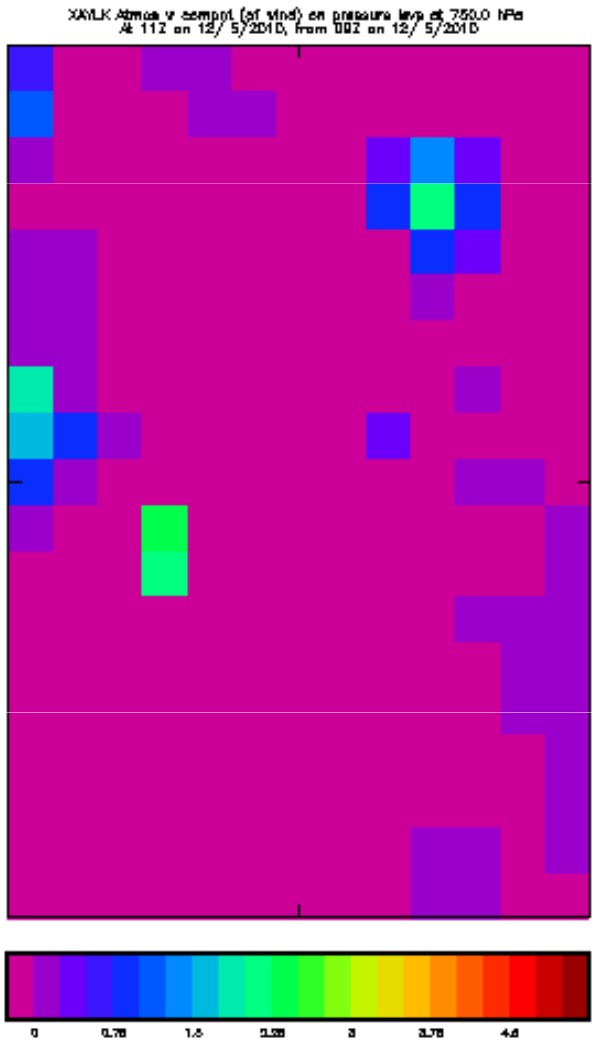
Issues with Explicit Representation of Convection

- No convection scheme in the 1.5km and 500m models
- Know that in principle very under-resolved - estimates of 50m gridlength needed
- Does surprisingly well in many situations. Clear benefit over models with parameterised convection.
- Expect problems with convection being represented on wrong scales/wrong magnitudes.
- Will depend on details of other parameterisations in model
- Numerical diffusion, stability, numerical errors
- Delays convective initiation

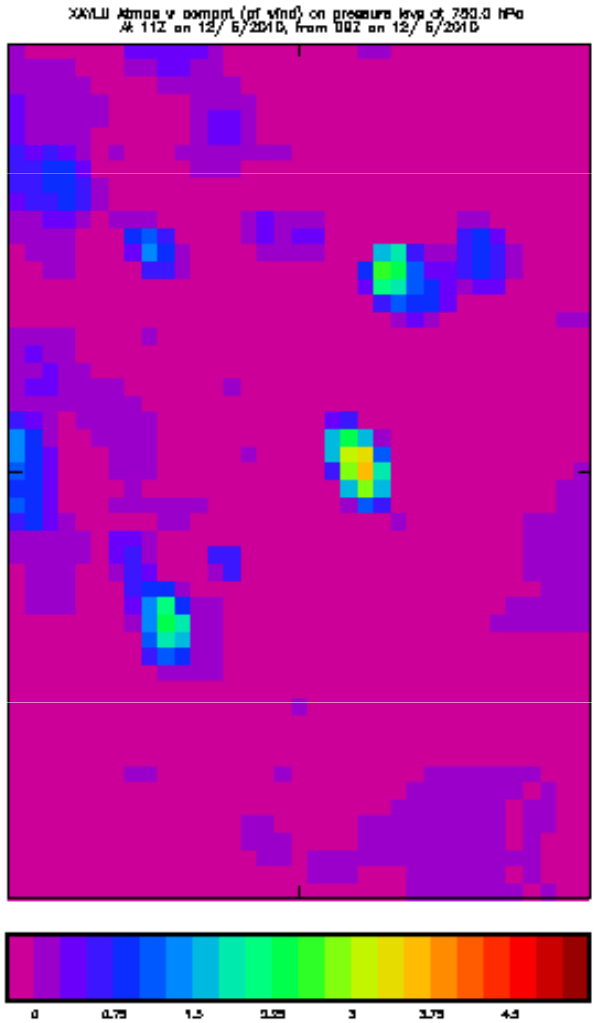
Problems with convection at high resolutions

- Too much grid scale structure- Only want to represent convection at about 4-5 times the gridlength to reduce grid point structure
- Showers often too intense
- Number and sizes of convective cells
- Consequences of being under-resolved but need to do what we can with parameterization of mixing

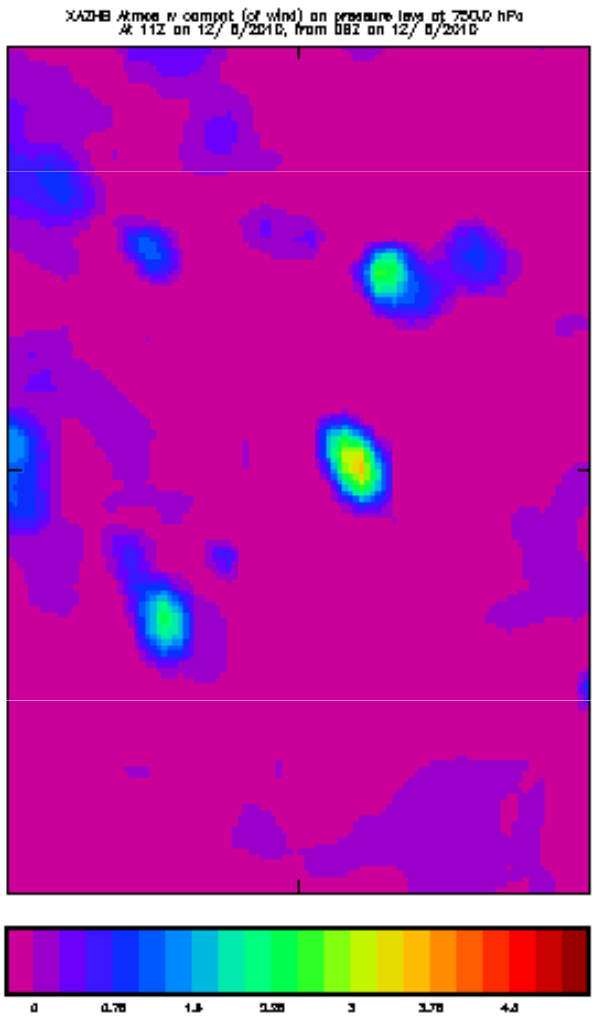
Gridscale structure in 750 hPa w 11UTC 12/05/2010 (scattered convection)



4km

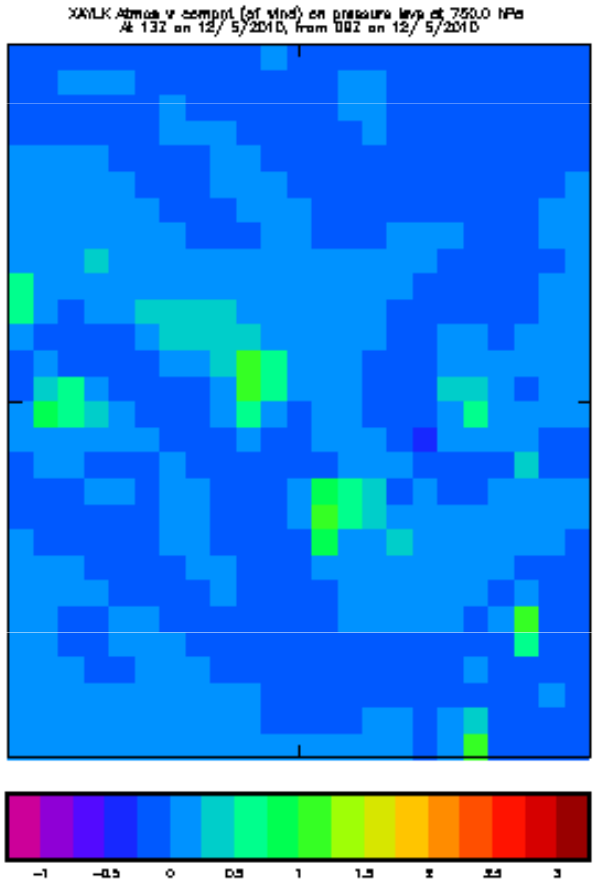


1.5km

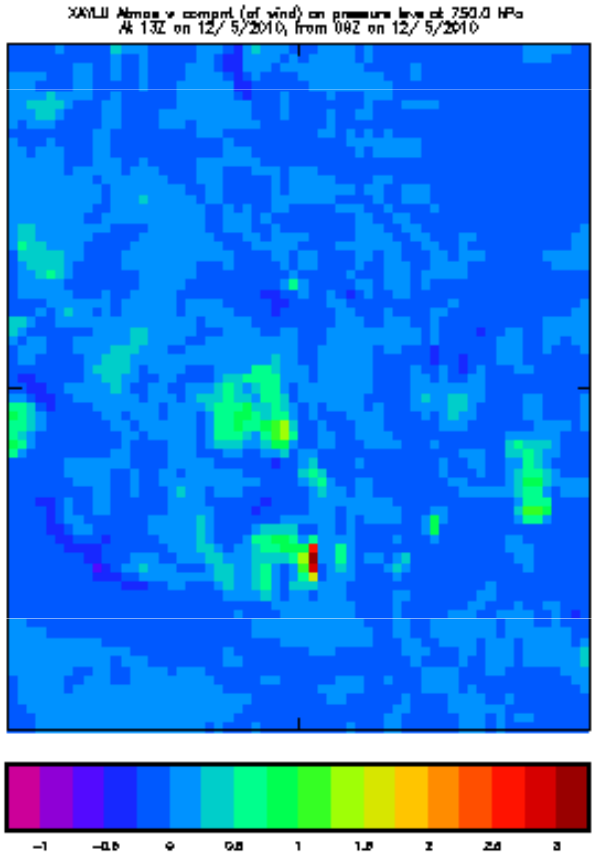


500m

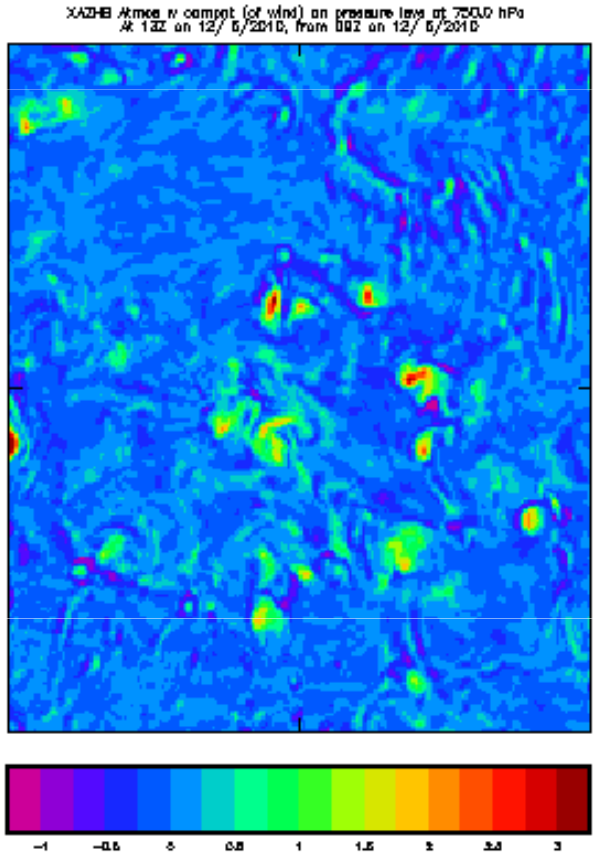
Gridscale structure in 750 hPa w 13UTC 12/05/2010



4km

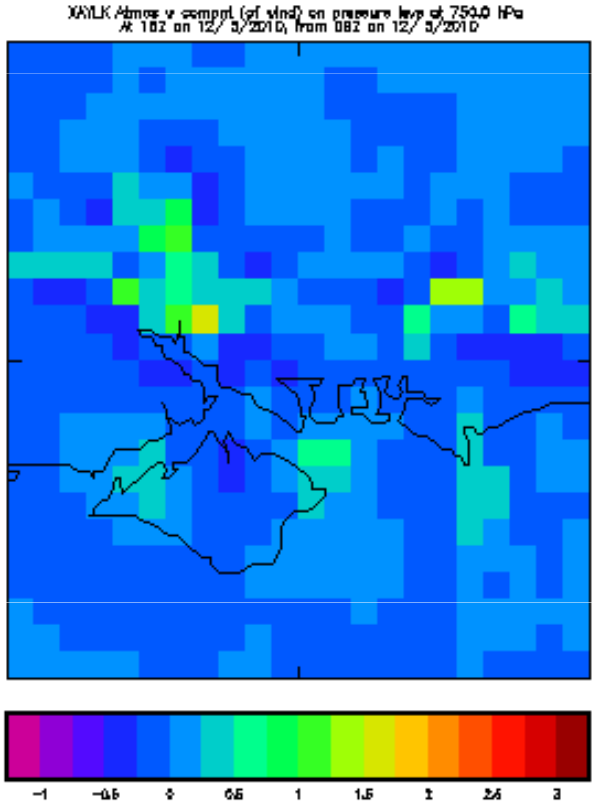


1.5km

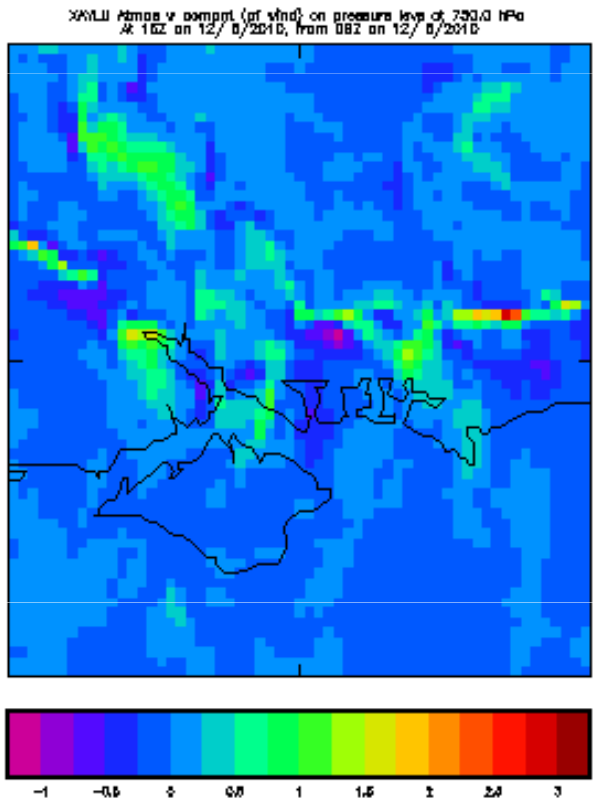


500m

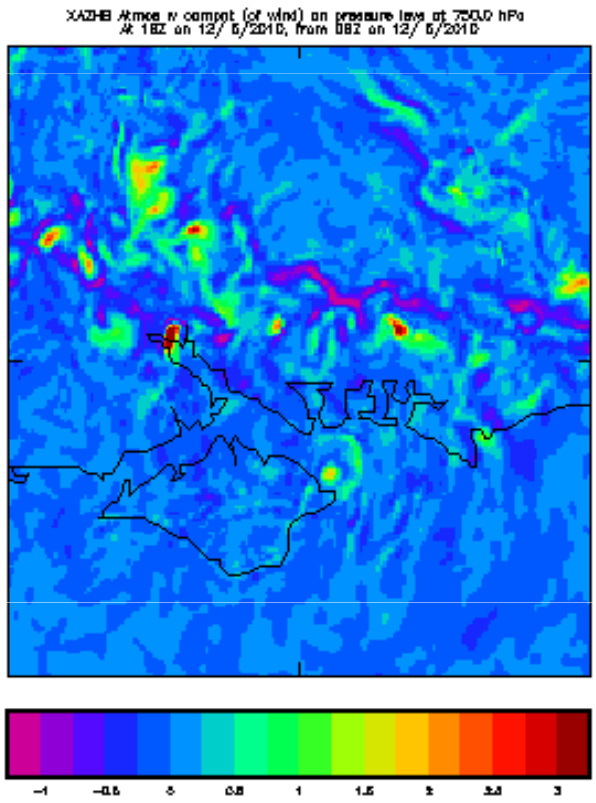
Gridscale structure in 750 hPa w 16UTC 12/05/2010



4km



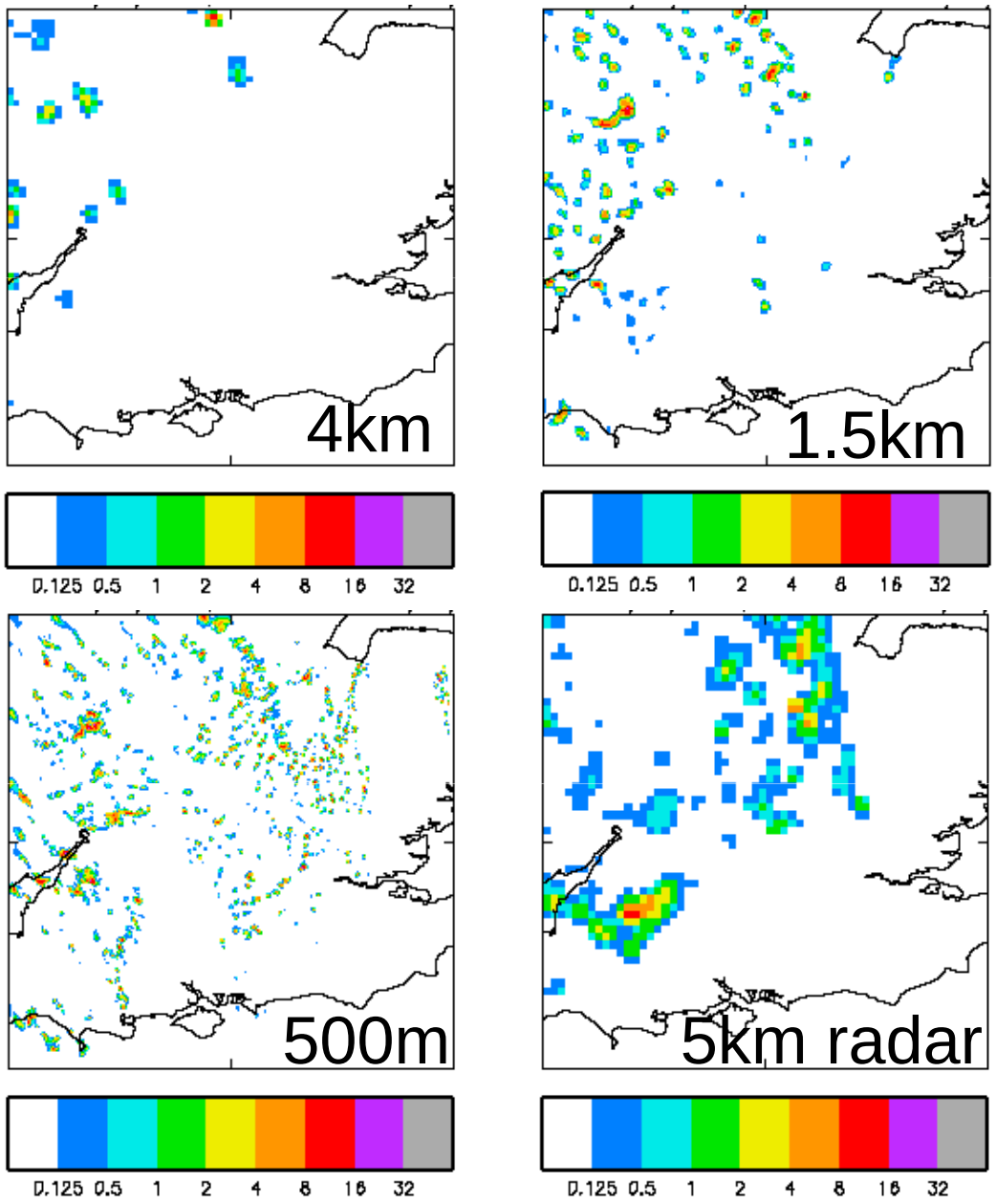
1.5km



500m

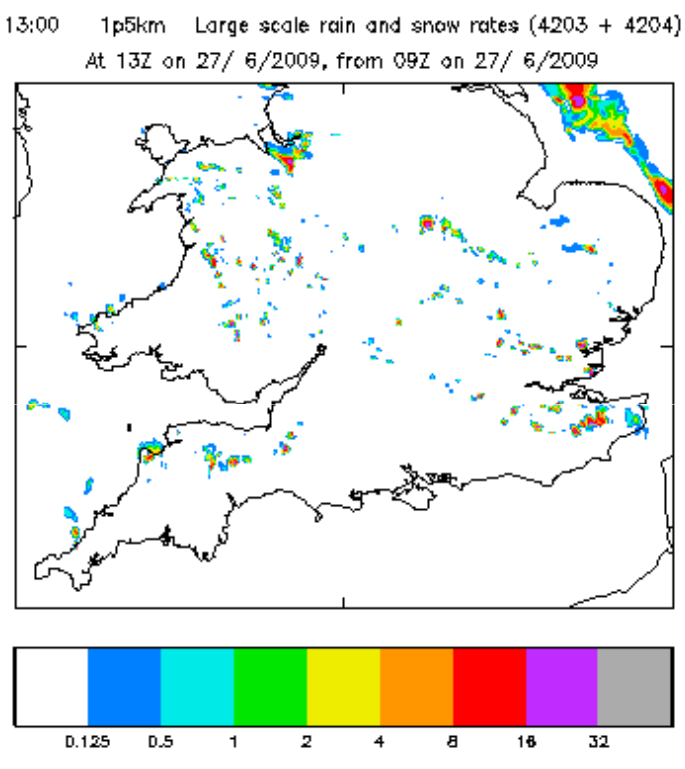
The “Measles” Effect

- Several small, intense cells
- Particularly for cases with outbreaks of shallow convection
- As the horizontal resolution is increased the coverage of precipitation may improve but the cells decrease in size
- 11UTC 14th April 2008, T+7 forecast

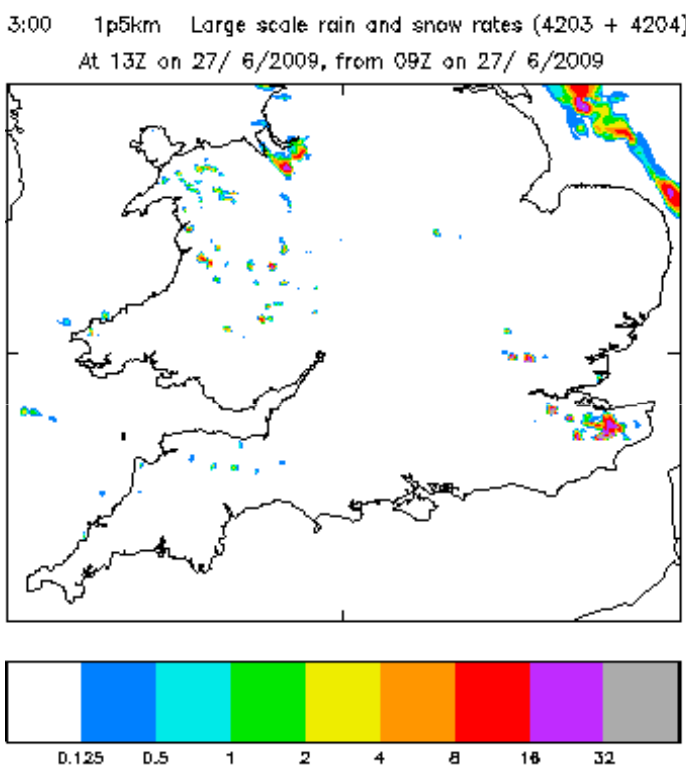


Mixing Options

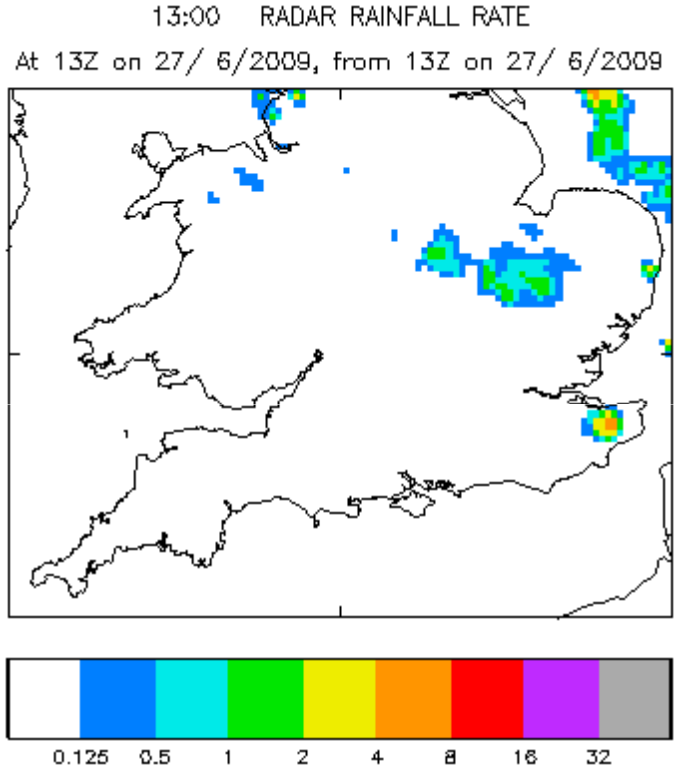
- Vertical Mixing
  - Option that allows vertical mixing to the boundary layer top or to the top of the domain
  - The measles effect in the UKV has been found to be related to the depth of the vertical mixing



1.5km Vertical mixing to BL top



1.5km Vertical mixing to top of domain



5km RADAR

Mixing Options

• Smagorinsky Subgrid Turbulence Scheme

•The scheme has been implemented so that it can be activated in the horizontal only (2D), leaving the BL scheme to mix in the vertical, or in both horizontal and vertical (3D).

• In the 3D scheme, the local BL scheme is used with the diffusion coefficients replaced by those calculated using the turbulence scheme.

• Options available to adjust the constant c_s

Description

•Based on 3D Smagorinsky-Lilly Large-Eddy Model (LEM) where viscosity is

$$\nu = (c_s \Delta)^2 S = \lambda_0^2 S$$

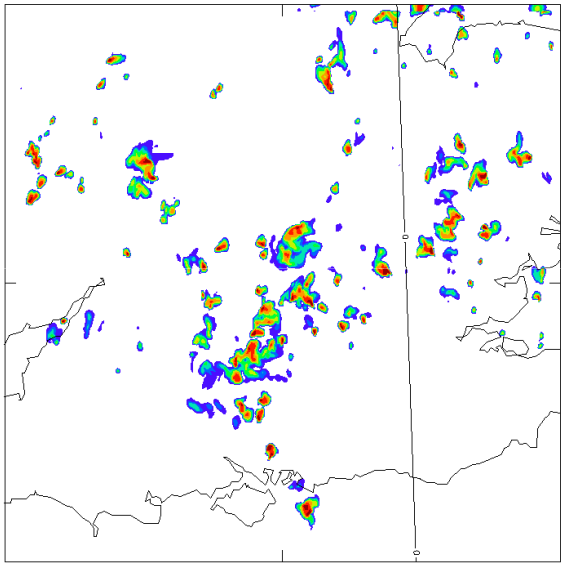
Here $\boldsymbol{c_s}$ is a constant, Δ is the grid spacing and

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

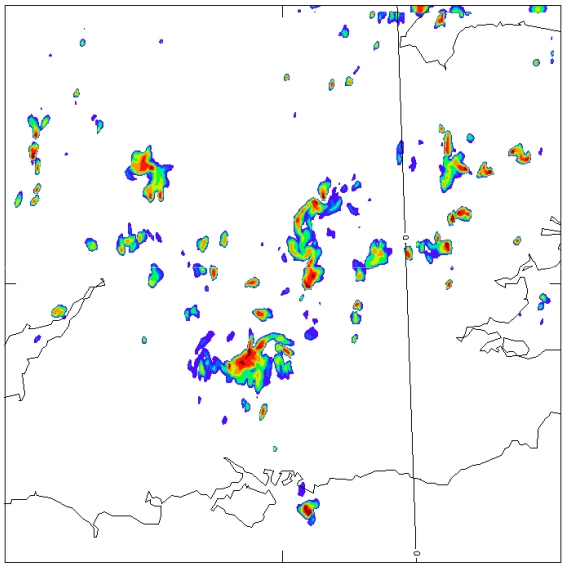
•The constant $\boldsymbol{c_s}$ is specified
- •The smaller the value, the finer the resolved scales
- •Choose optimal value

Carol Halliwell

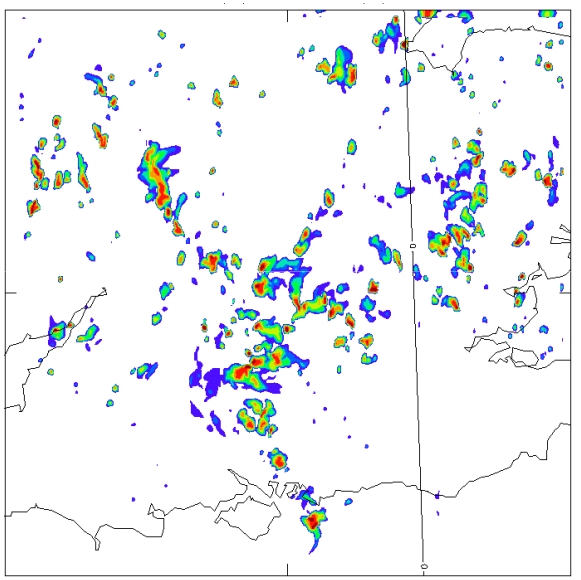
7th September 2010 13UTC



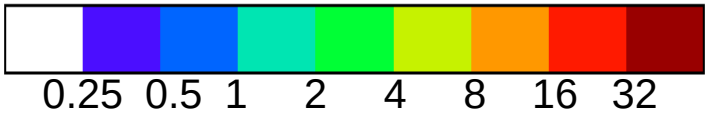
500m 2D Smag Cs=0.2

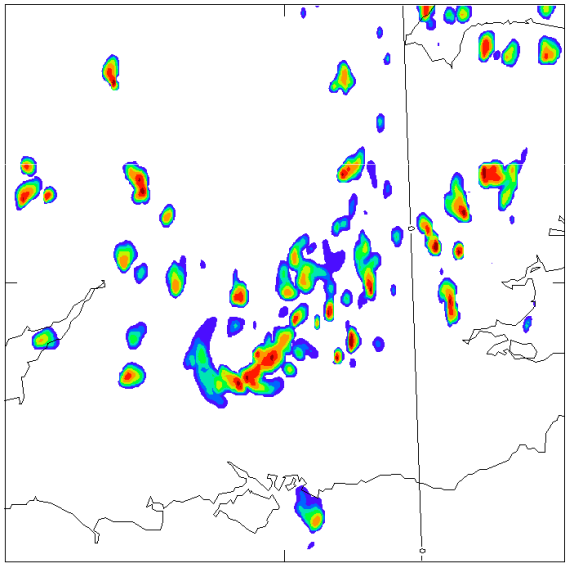


500m 3D Smag Cs=0.2

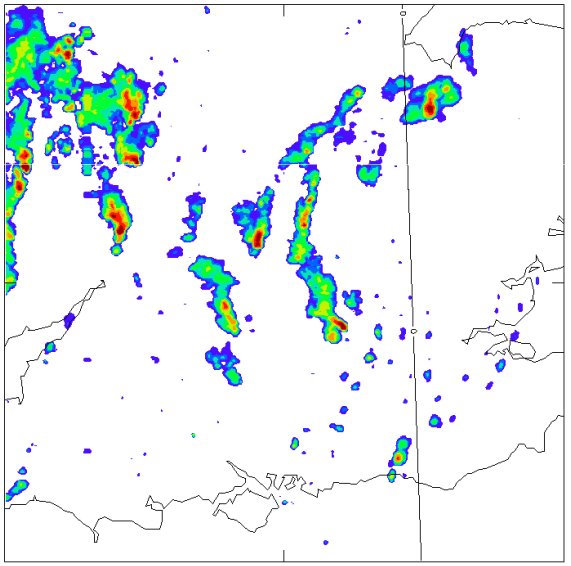


500m no mixing above BL



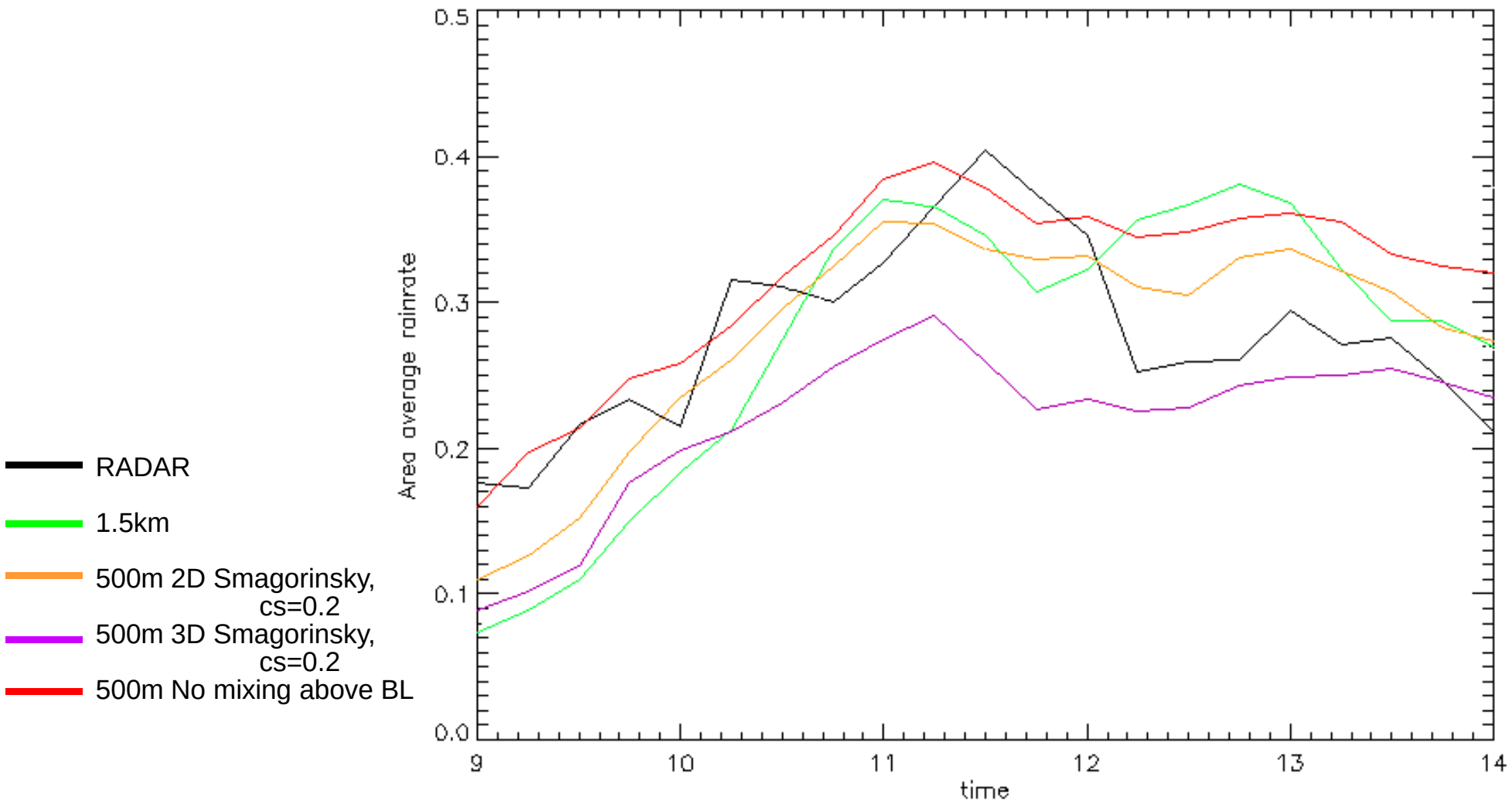


1.5km



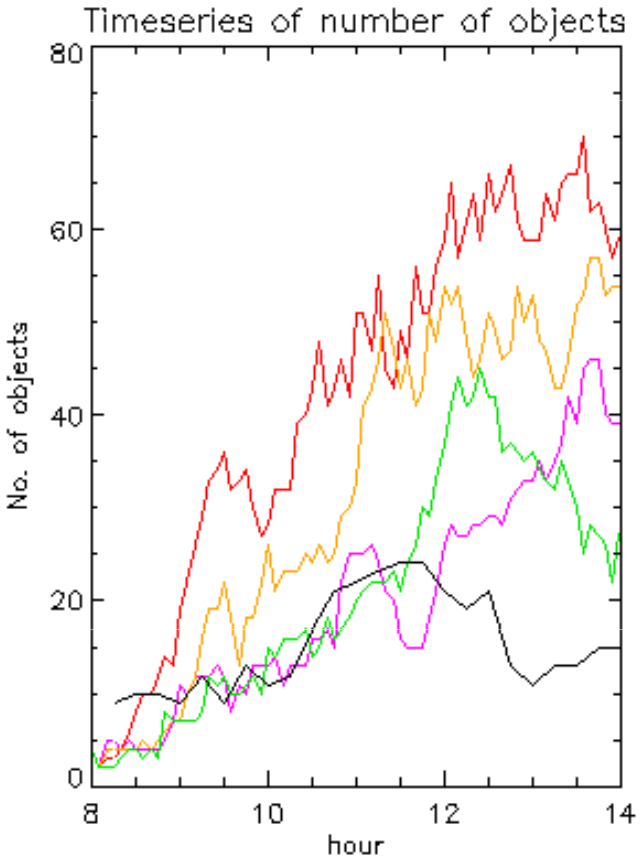
1km RADAR

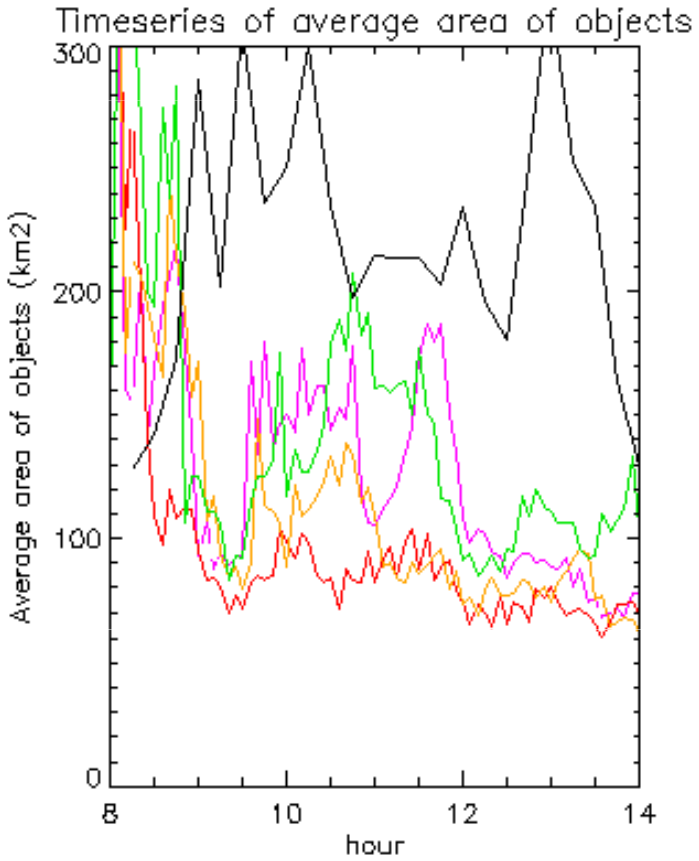
Domain averaged precipitation rates against time- 7th September 2010



Cell Statistics- 7th September 2010

threshold 2mm/hr





RADAR

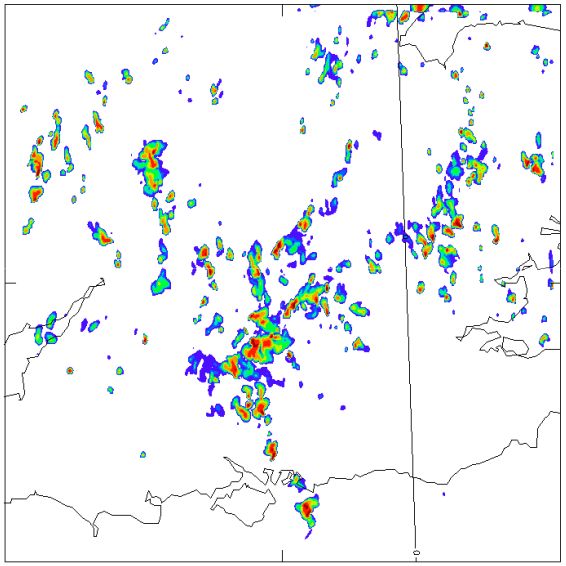
1.5km

500m 2D Smagorinsky, cs=0.2

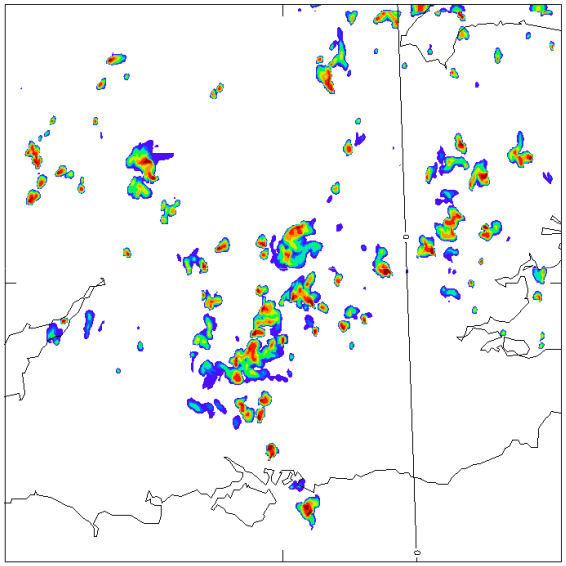
500m 3D Smagorinsky, cs=0.2

500m No mixing above BL

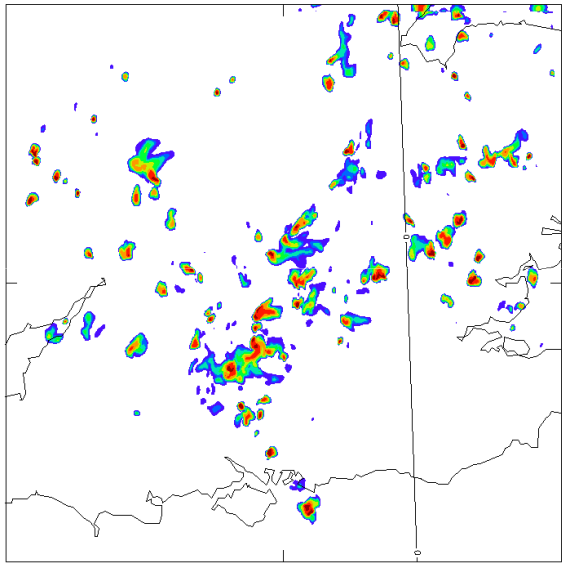
7th September 2010 13UTC



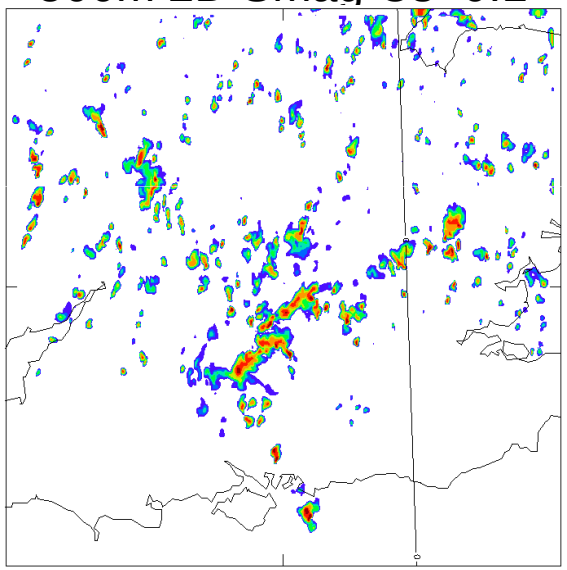
500m 2D Smag Cs=0.1



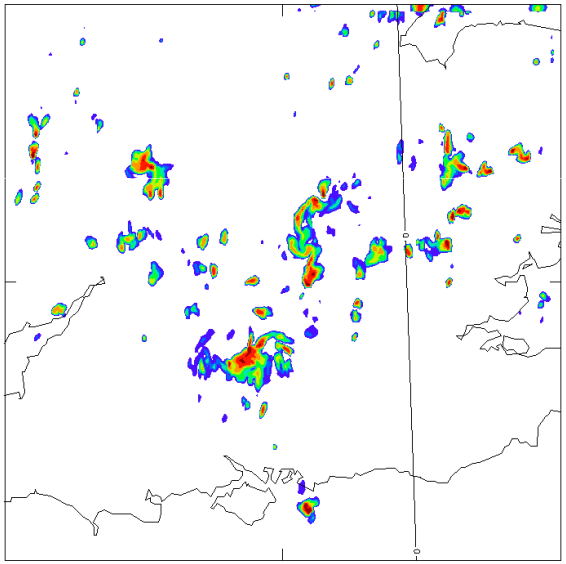
500m 2D Smag Cs=0.2



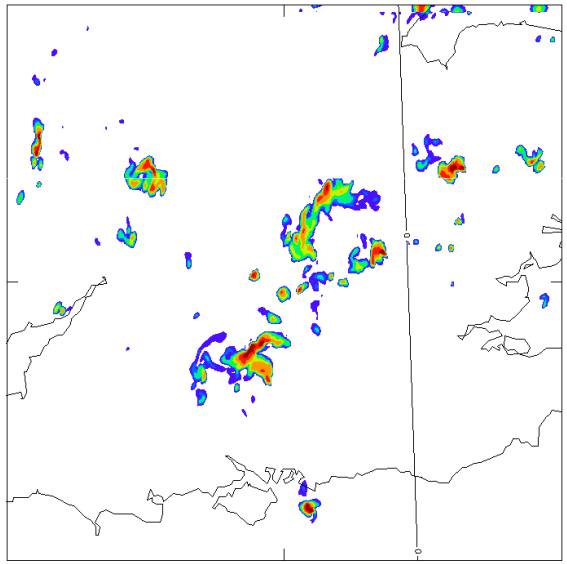
500m 2D Smag Cs=0.4



500m 3D Smag Cs=0.1

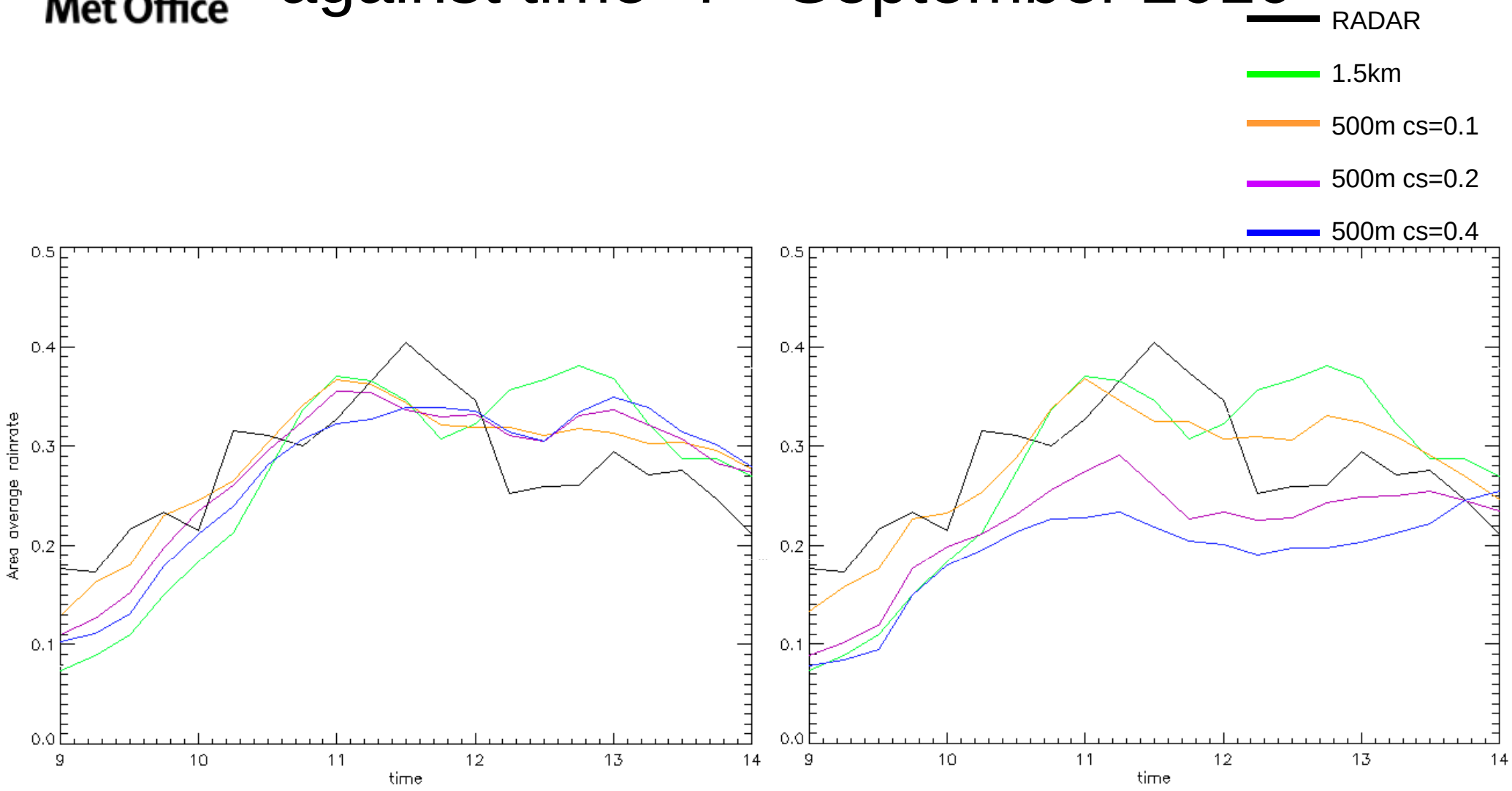


500m 3D Smag Cs=0.2



500m 3D Smag Cs=0.4

Domain averaged precipitation rates against time- 7th September 2010



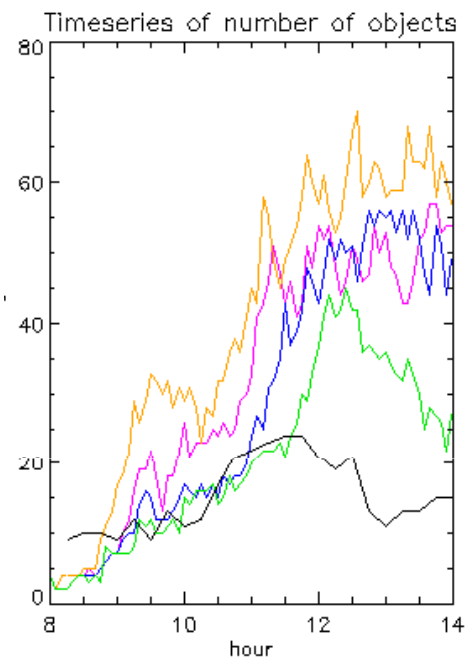
2D Smagorinsky Scheme

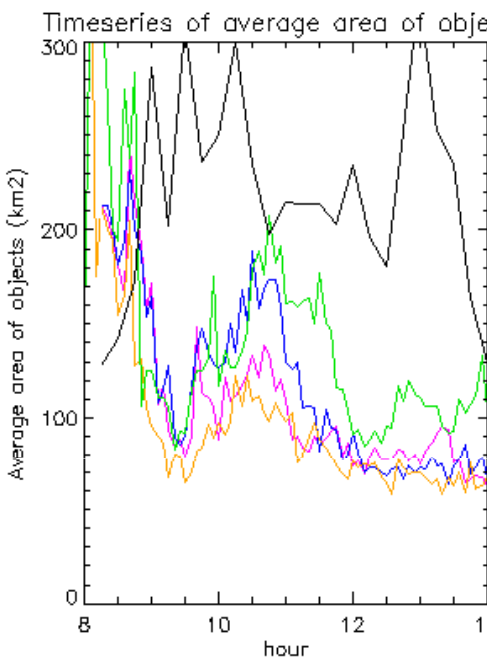
3D Smagorinsky Scheme

Cell Statistics- 7th September 2010

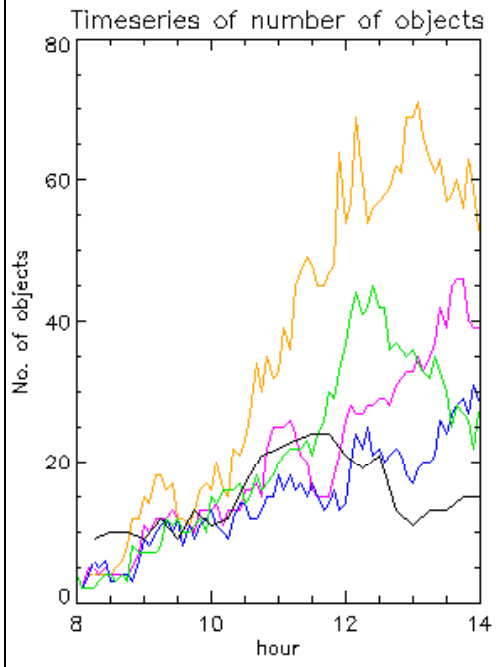
threshold 2mm/hr

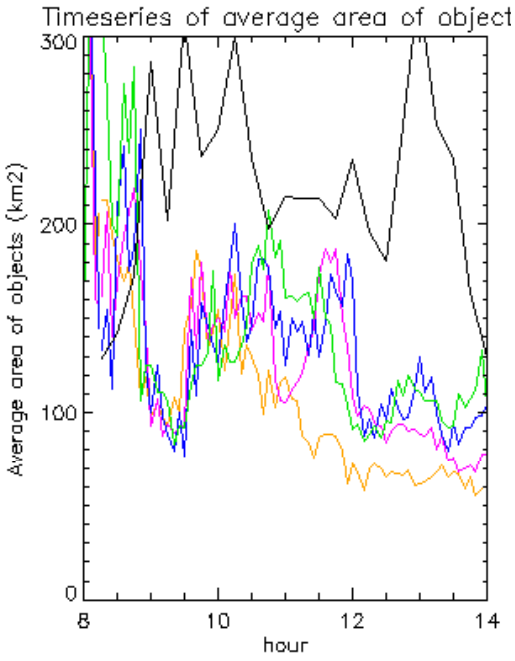
RADAR
1.5km
500m cs=0.1
500m cs=0.2
500m cs=0.4





2D Smagorinsky Scheme

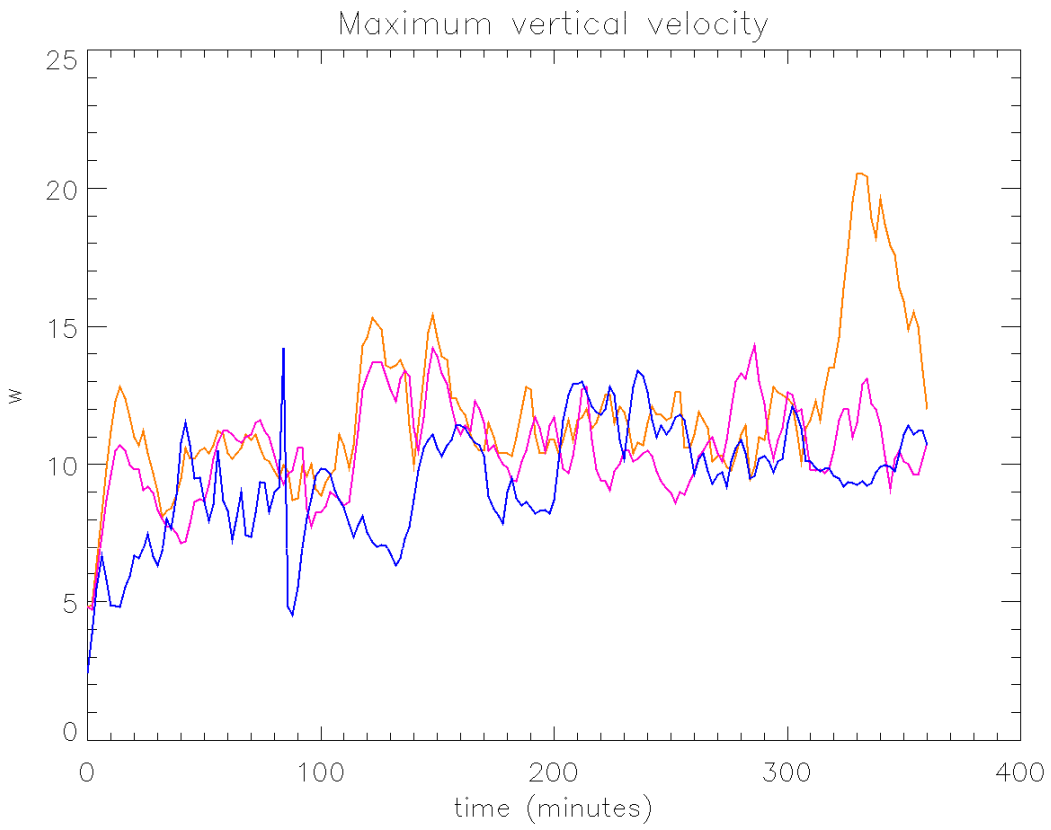




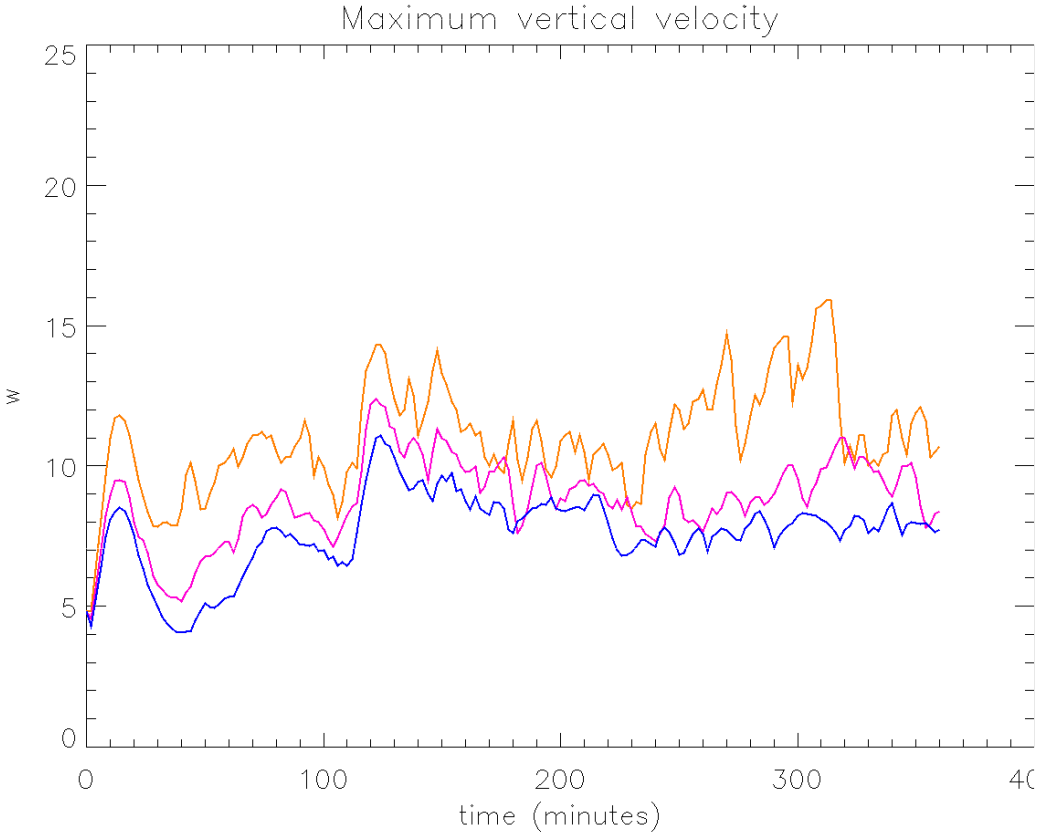
3D Smagorinsky Scheme

Maximum vertical velocity- 7th September 2010

500m cs=0.1
500m cs=0.2
500m cs=0.4



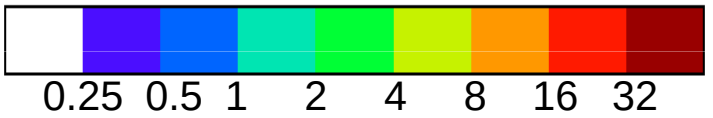
2D Smagorinsky Scheme

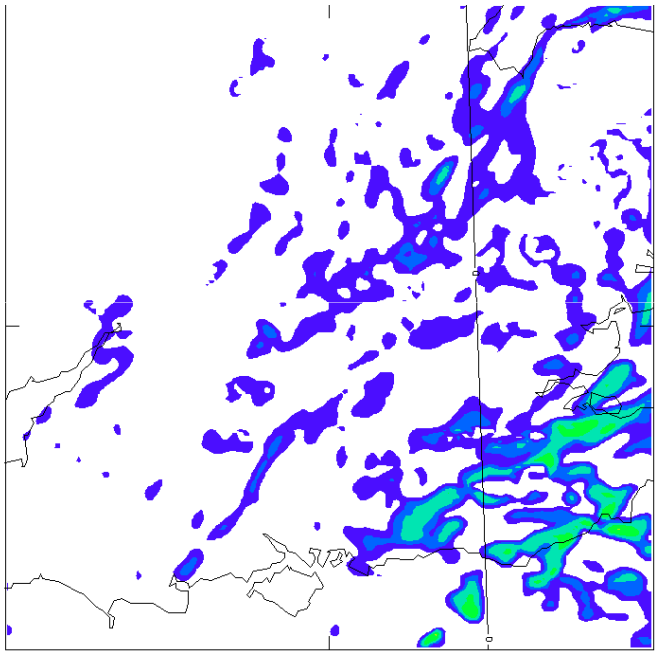


3D Smagorinsky Scheme

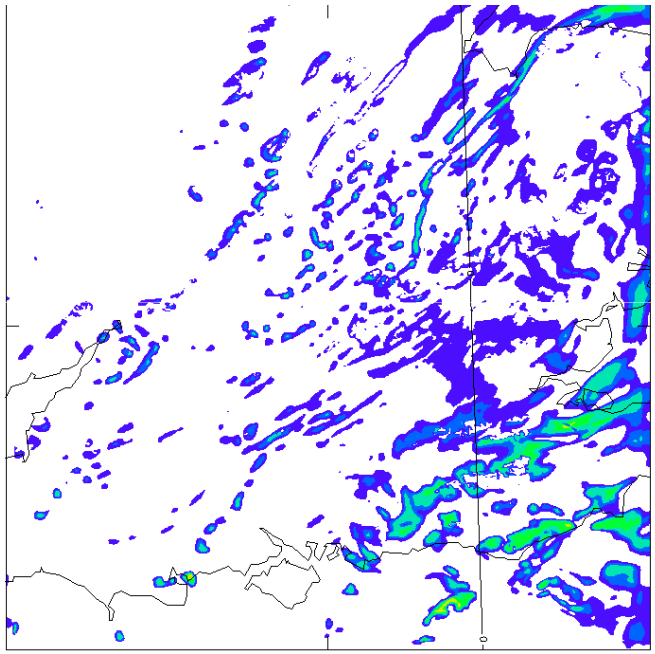
8th February 2010 at 12UTC

- One of the snow events last year
- Under-resolving convection

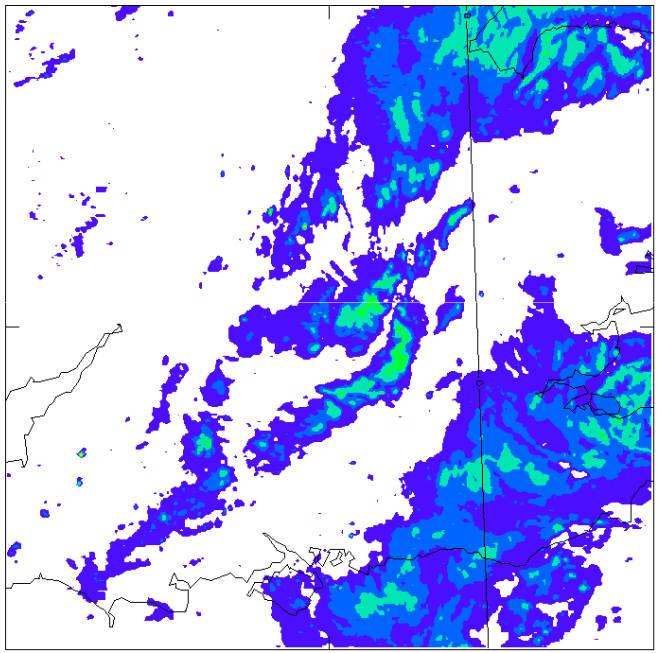




1.5km



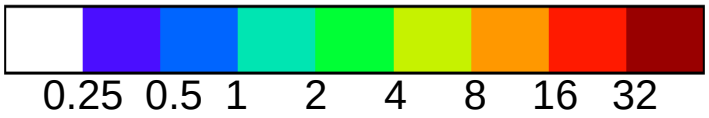
500m 3D Smag Cs=0.2

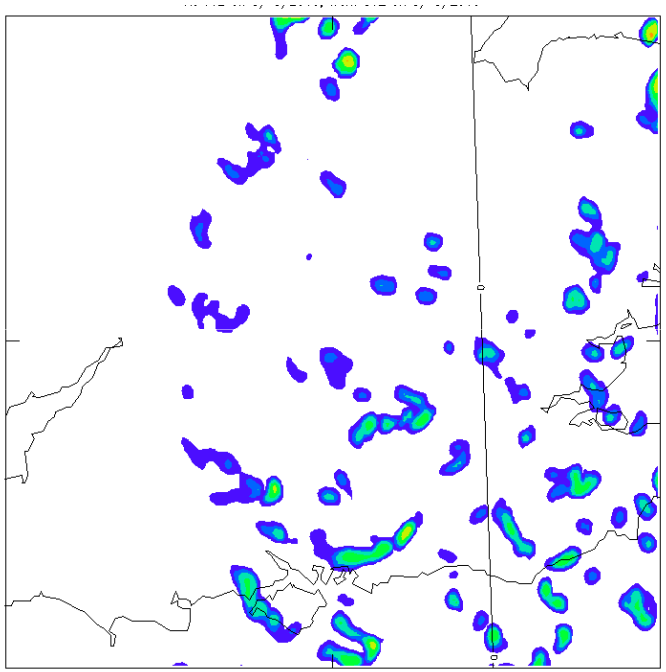


1km RADAR

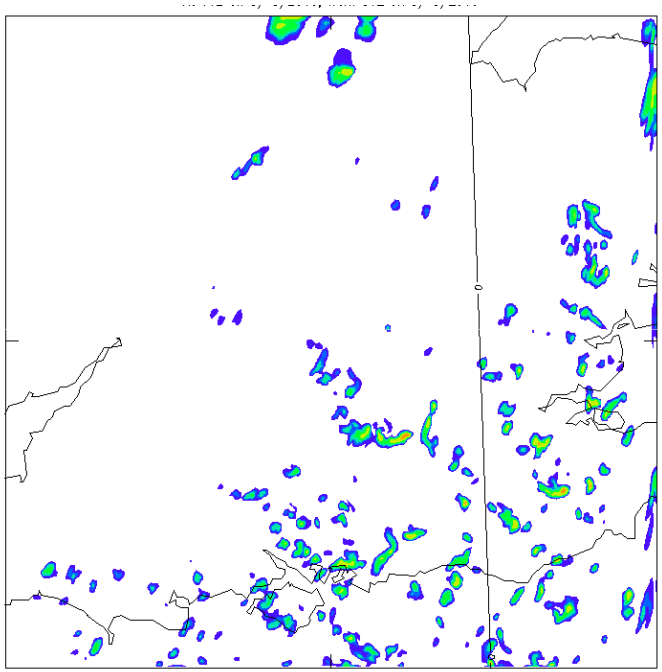
3rd May 2010 at 11UTC

- Several small convective cells

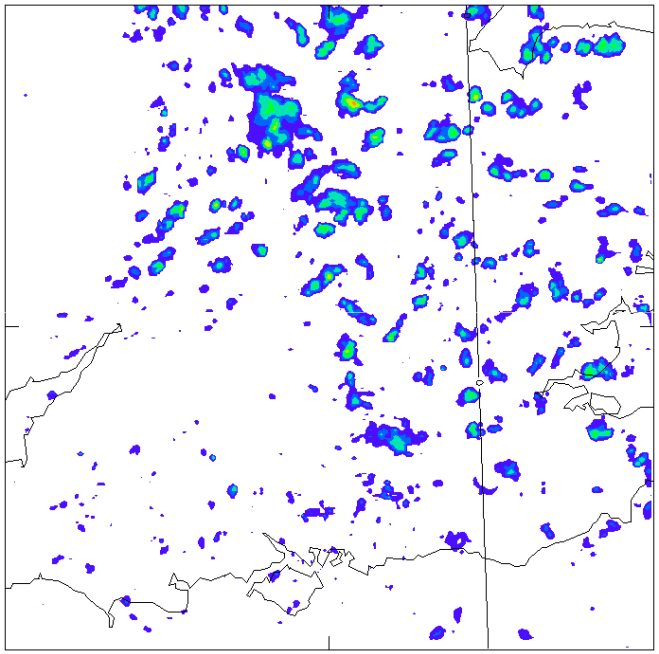




1.5km



500m 3D Smag Cs=0.2



1km RADAR

Conclusions

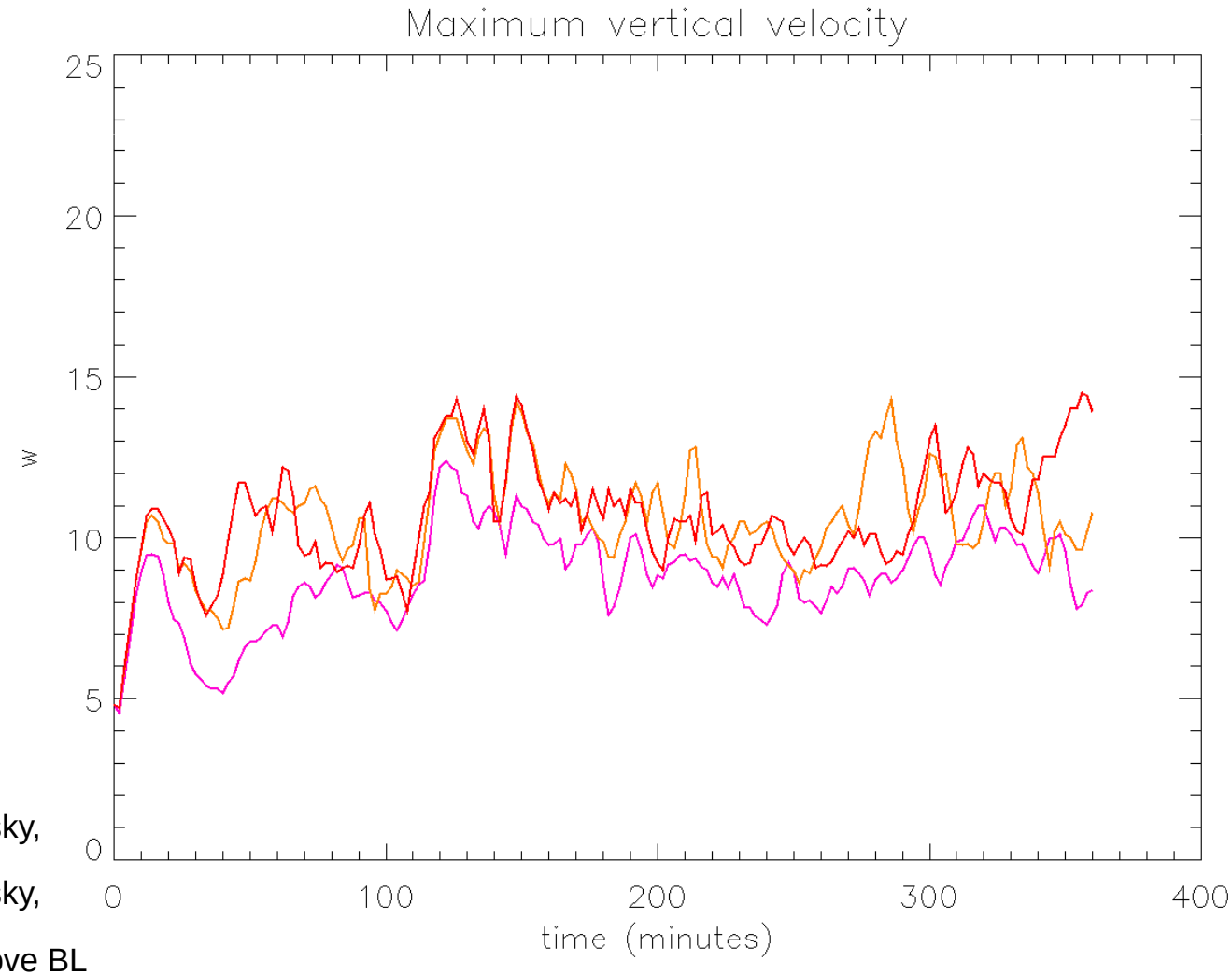
- Overall the 500m model does reasonably well
- Still under-resolving convection, 500m has a tendency to break up and not converge
- Implication of 1.5km may look good just because the gridlength is too long
- Cells are still getting smaller as the horizontal resolution is increased, at what stage will it start to converge?
- 500m appears to be very sensitive to mixing
- Very much a work in progress!

Future work

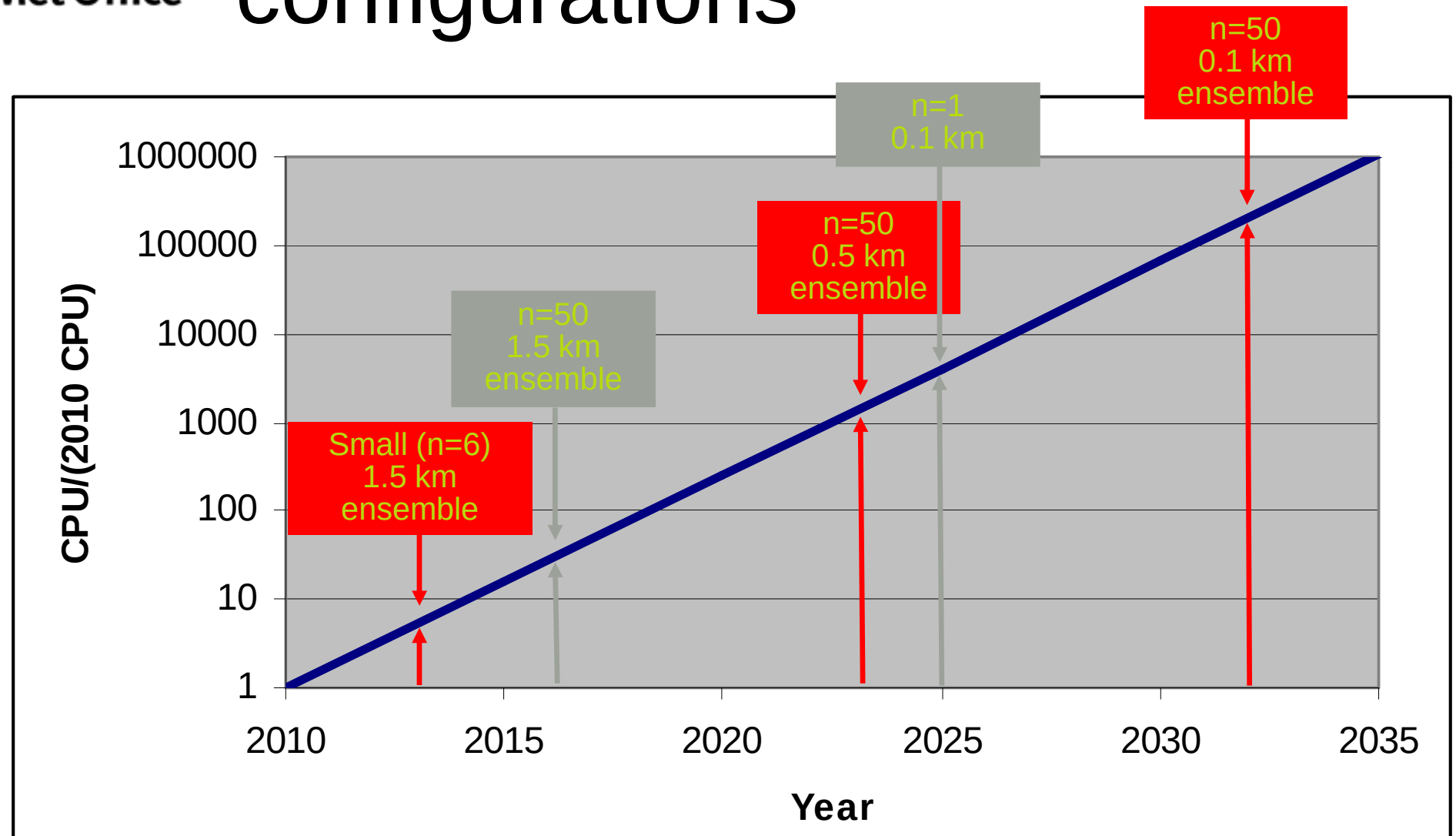
- Set up a 100m model
- Emphasize use of observations to elucidate if scales of convection are wrong.
- Systematically compare scales of convection at various gridlengths 2.2km - 100m.
- Continue testing more convective cases
- Investigate how the soil moisture effects the representation of convection
- Continue investigating different mixing options and parameterisations to improve representation at 1.5km

Questions

Maximum vertical velocity- 7th September 2010



Possible UK model configurations

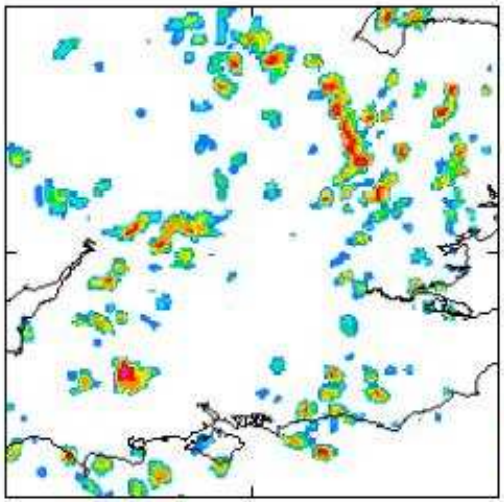


Assumes Moore's Law continues with 15 month doubling time

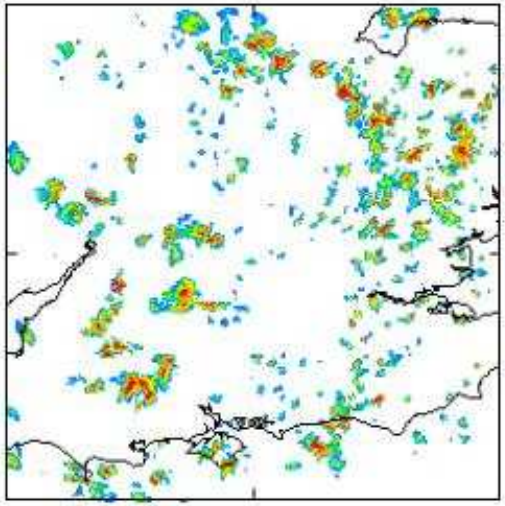
(It probably won't!)

14th April 2008 at 13UTC

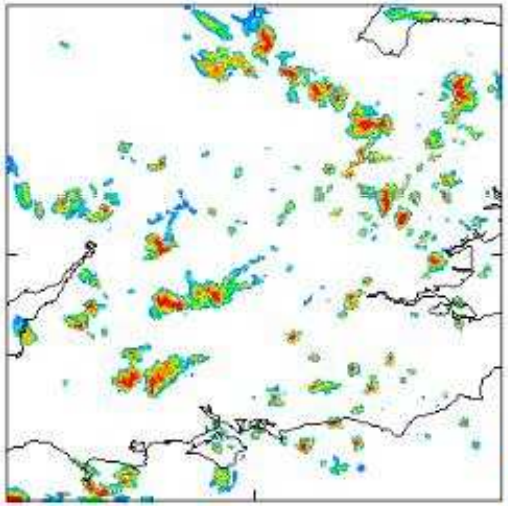
Met Office



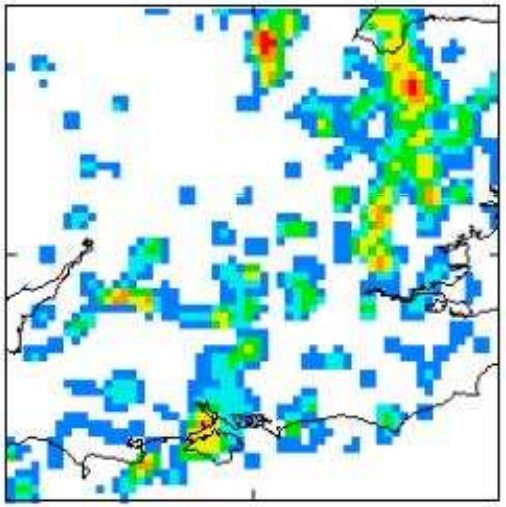
(a) Mixed to the boundary layer (1.5km)



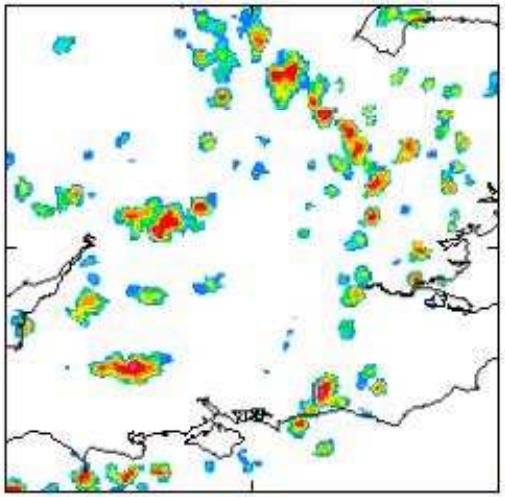
(b) 2D Smagorinsky, mixed to the boundary layer (500m)



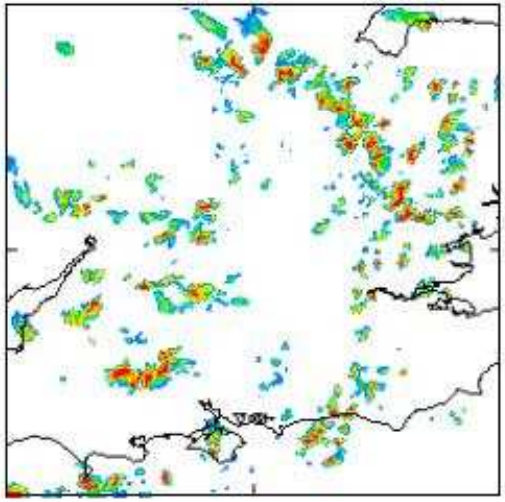
(c) 3D Smagorinsky (500m)



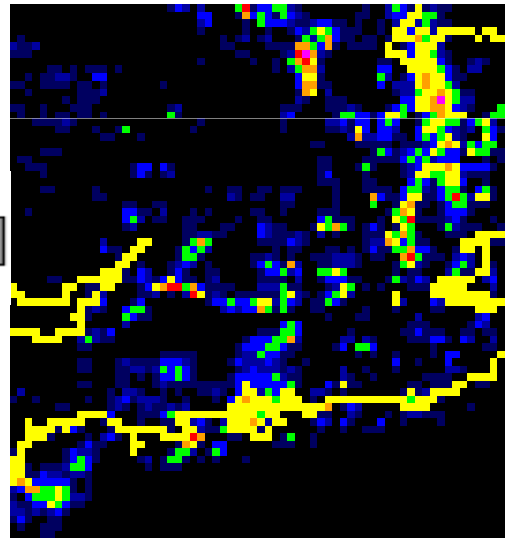
(d) RADAR



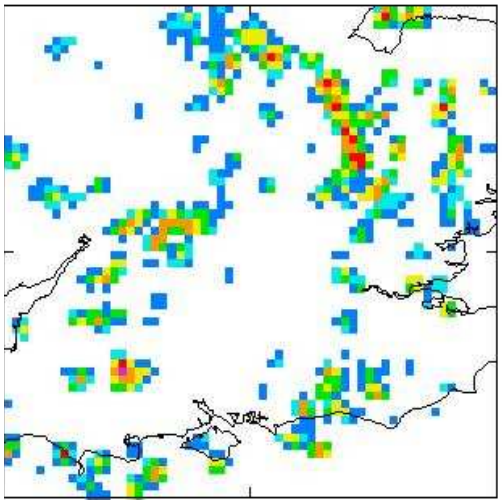
(e) Mixed above the boundary layer (1.5km)



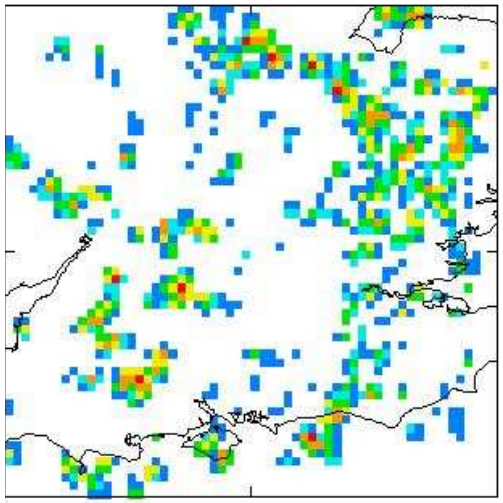
(f) 2D Smagorinsky, mixed above the boundary layer (500m)



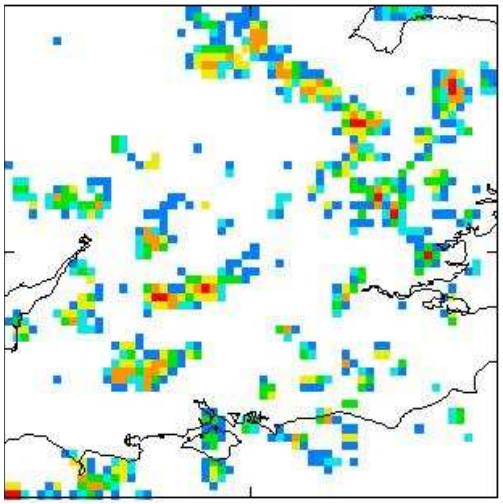
14th April 2008 at 13UTC



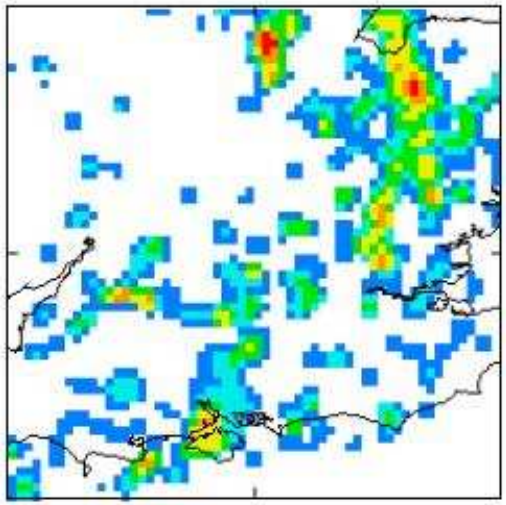
(a) Mixed to the boundary layer (1.5km)



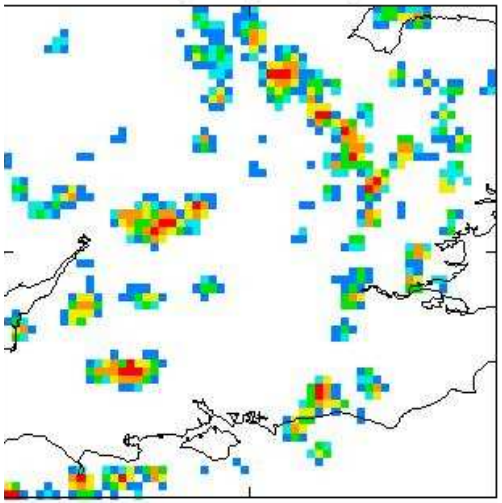
(b) 2D Smagorinsky, mixed to the boundary layer (500m)



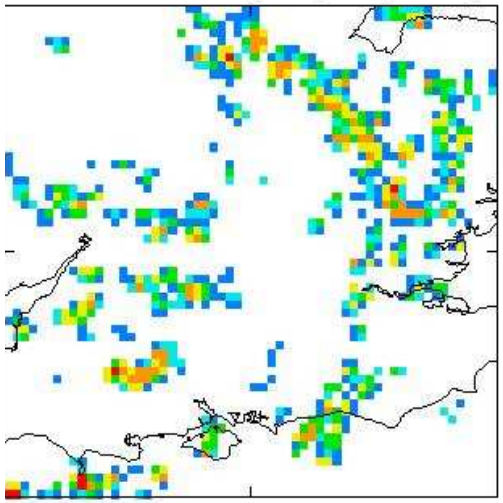
(c) 3D Smagorinsky (500m)



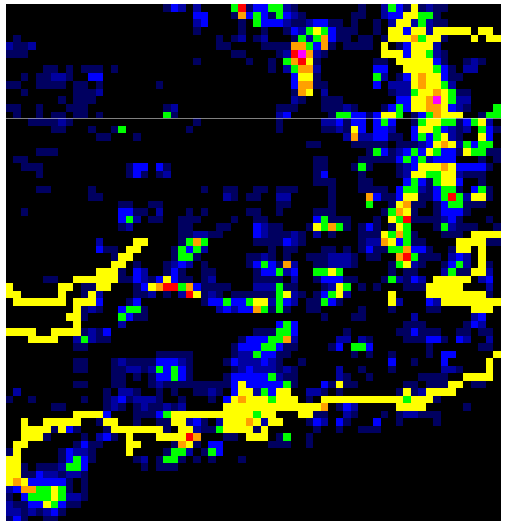
(d) RADAR



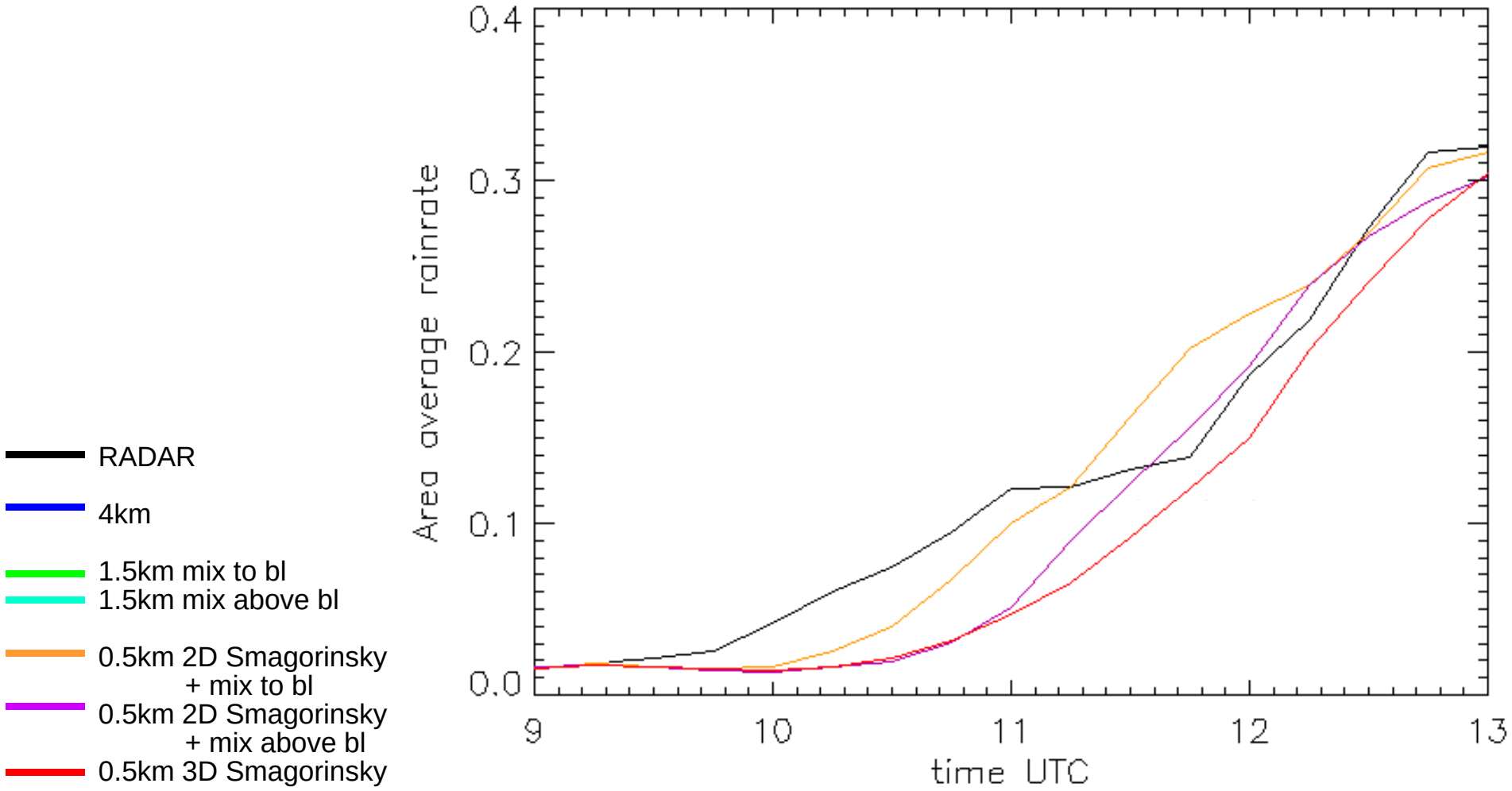
(e) Mixed above the boundary layer (1.5km)



(f) 2D Smagorinsky, mixed above the boundary layer (500m)



Precipitation rates against time- 14th April 2008



Increased vertical resolution