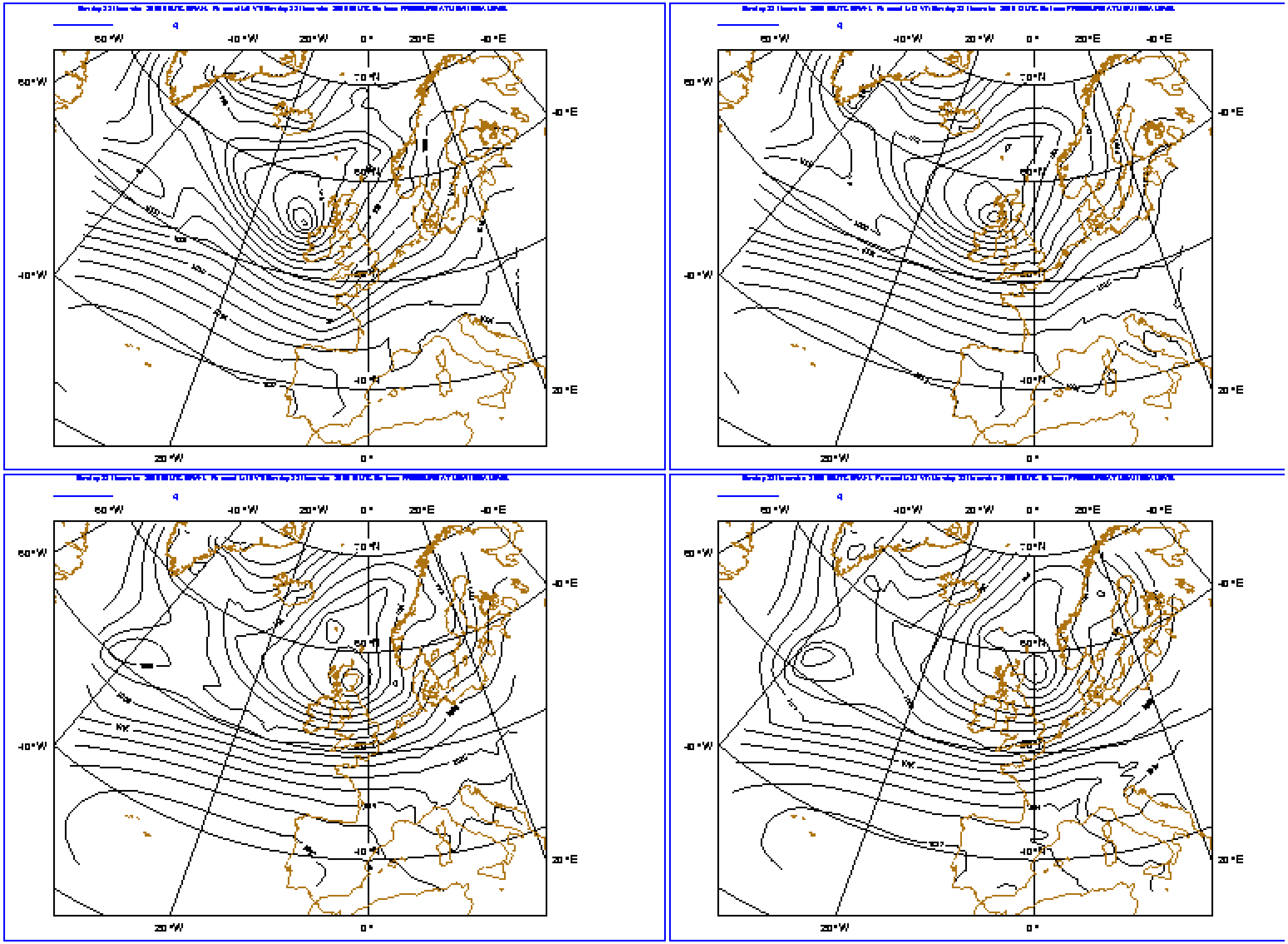
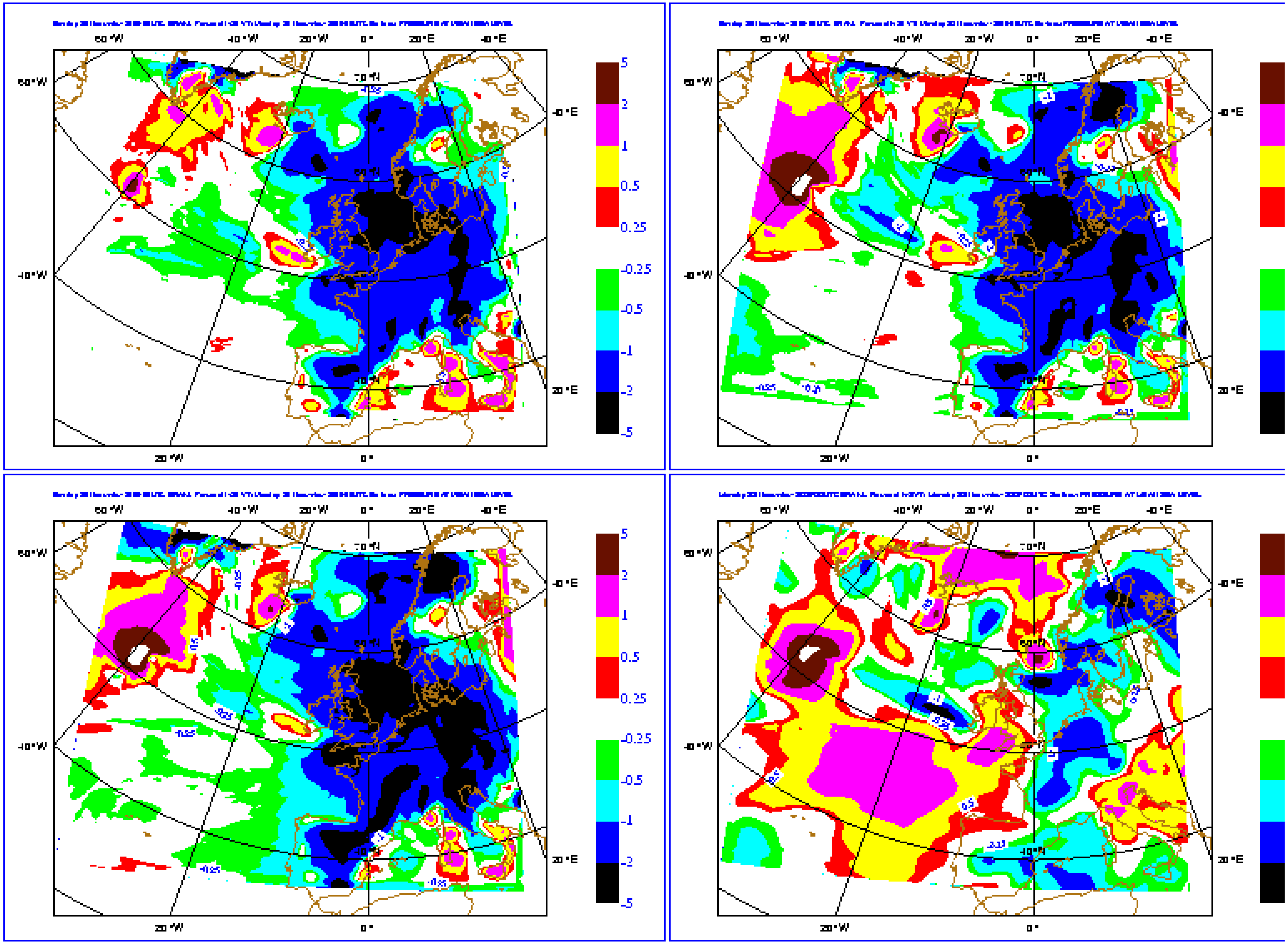
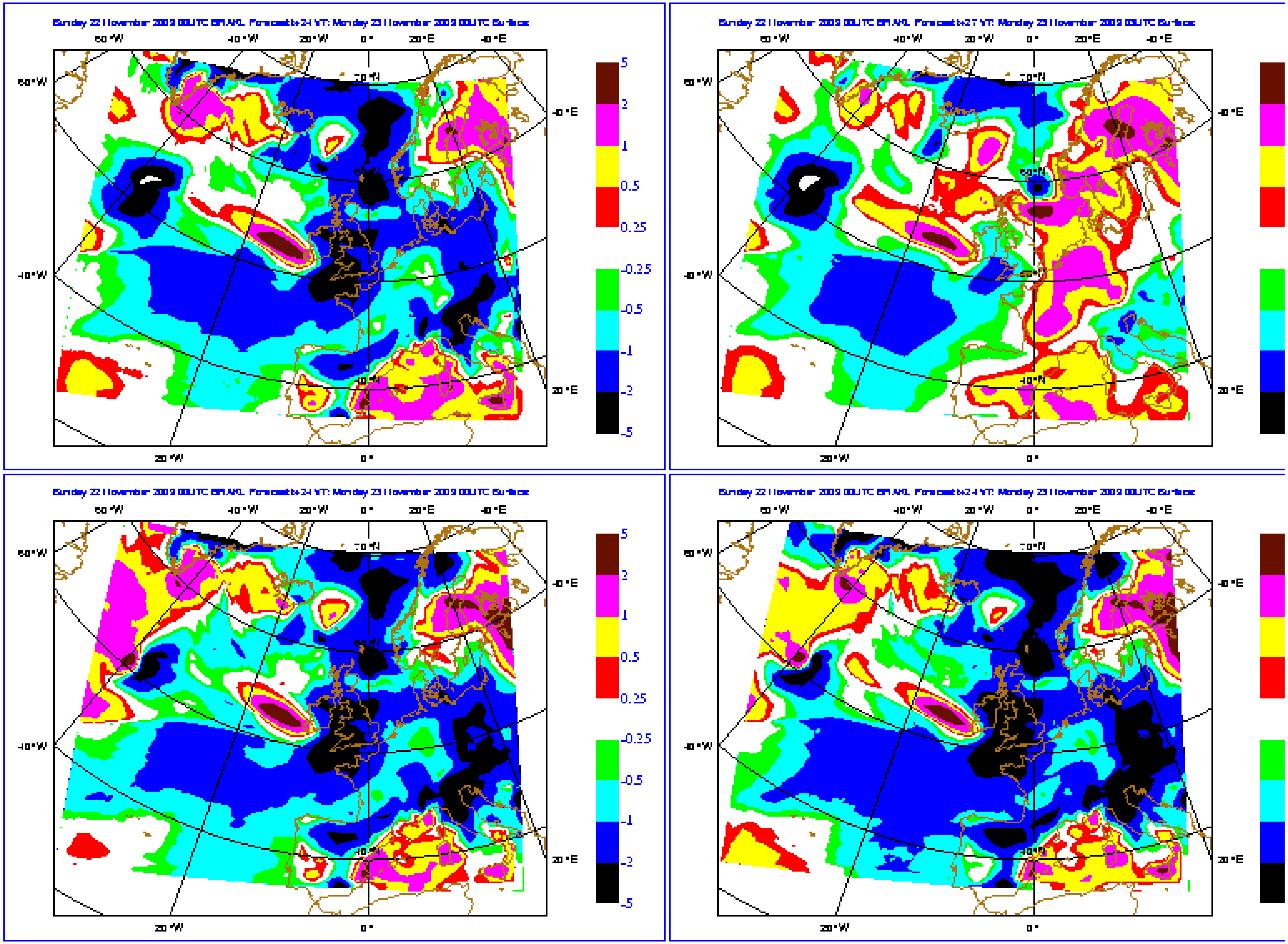
Nesting and LBCs, Predictability and EPS

Terry Davies, Dynamics Research, Met Office

Nigel Richards, Neill Bowler, Peter Clark, Caroline Jones, Humphrey Lean, Ken Mylne, Changgui Wang




60°W
40°W
20°W
0°
20°E
40°E
70°N
60°N
40°N
5
2
1
0.5
0.25
-0.25
-0.5
-1
-2
-5


Sunday 22 November 2009 00UTC Forecast t+24 VT: Monday 23 November 2009 00UTC Surface
Sunday 22 November 2009 00UTC Forecast t+27 VT: Monday 23 November 2009 03UTC Surface
Sunday 22 November 2009 00UTC Forecast t+24 VT: Monday 23 November 2009 00UTC Surface
Sunday 22 November 2009 00UTC Forecast t+24 VT: Monday 23 November 2009 00UTC Surface
60°W
40°W
20°W
0°
20°E
40°E
70°N
60°N
50°N
40°N
5
2
1
0.5
0.25
-0.25
-0.5
-1
-2
-5

Flow over obstacles

- Employ finite elements or adaptive mesh refinement (AMR) to refine (unstructured) grid around obstacle and in disturbed flow.
- Coarse resolution for steady/undisturbed flow.
- Use similar approach for flow around buildings.
- Obstacles ~10m, highest resolution grid length ~1m.
- 1km^2 domain using 1m resolution requires 10^6 points in horizontal. Far fewer if using mesh refinement only where needed.
- Explicit representation of edges/corners?
- What about features that present a challenge for grid-refinement? e.g. large tree near a building.
- Wind tunnel comparisons; not meteorology and dry.

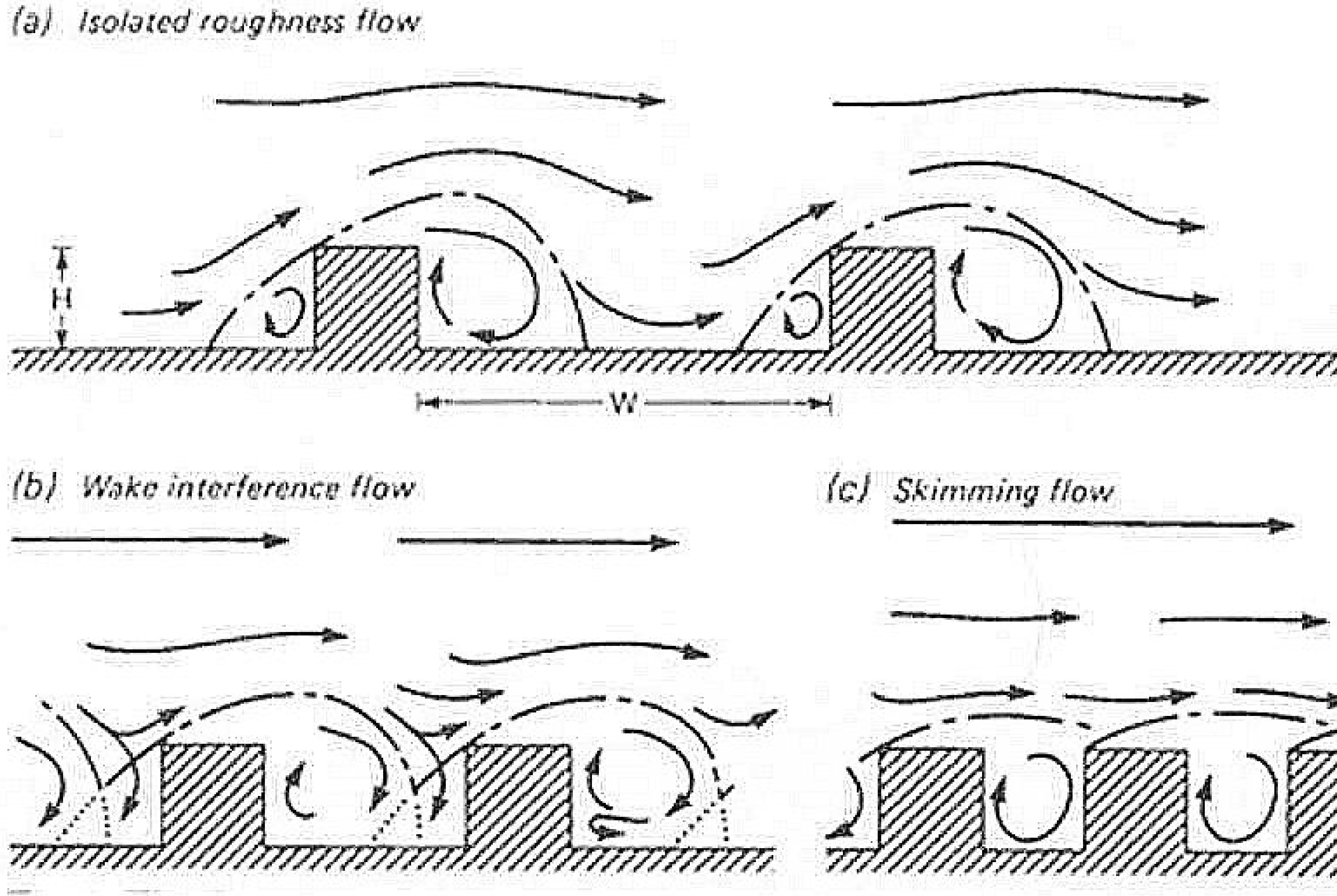
Urban scale modelling

- Air quality and airport models.
- How do we cope with a domain size of $10km^2$ with variable building density, orography and vegetation?
- Even with AMR, cannot afford to reduce grid-size to ~1m but perhaps can do ~10m.
- Flow around each obstacle now not modelled directly; finer details of the flow are NOT resolved.
- Interested in moist meteorology. Need parametrizations for surface roughness, turbulence, radiative forcing (diurnal cycle), cloud microphysics (for visibility if not for precipitation).
- AMR useful in adapting grid to more important features and/or processes.

Sub-gridscale effects

Met Office

- Details in the unresolved scales can have significant impact on larger scales and not only near truncation.
- Sub-gridscale variations at the surface (e.g. orography, coastlines, surface features etc) perhaps become more significant as resolution increases since these may trigger the (partially) resolved processes.


(a) Isolated roughness flow
H
W
(b) Wake interference flow
(c) Skimming flow

Under-resolved flows

- For environmental flows over complex terrain, often unable to resolve all features or details of flows.
- Terrain and coasts "fractal-like". Increasing resolution introduces new features.
- Insufficient resolution for many features.
- AMR or variable resolution used to adapt grid to more important features and/or processes? e.g. 1km resolution used for part (say 1/4) of UK 4km domain where convection is expected.

High resolution NWP and downscaling

- 1-10km resolution. Needs to be non-hydrostatic.
- Parametrization of convection a problem; generally assumes ensemble of plumes.
- If a parametrization is used there is a tendency for convection to be too widespread and too frequent.
- If convection is explicit then updraughts (vertical velocities of several metres per second or more) develop at the grid-scale which, at say >1km, is unphysical (and should be unacceptable).
- Real updraughts <1km. Numerical convergence studies suggest convergence in model behaviour at around 100-200m.

Short-range NWP

- Short-range (i.e deterministic, 1-2 days) NWP somewhat easier than longer range global NWP or climate modelling. Stop before errors become too large.
- Limited area models (LAMs) constrained by driving data (lateral boundary conditions, lbcs).
- Increasing resolution gives more local detail near the surface and increased skill of near surface quantities (screen temperature, 10m wind, visibility, precipitation).

UK short-range NWP

Ensembles

MOGREPS-R

24 -> 18 km
(represent uncertainty)

Convection-permitting

UKV 1.5 km
(represent storms etc)

Convection-permitting Ensemble

Why?

Because we can?

Are there good scientific reasons?

How?

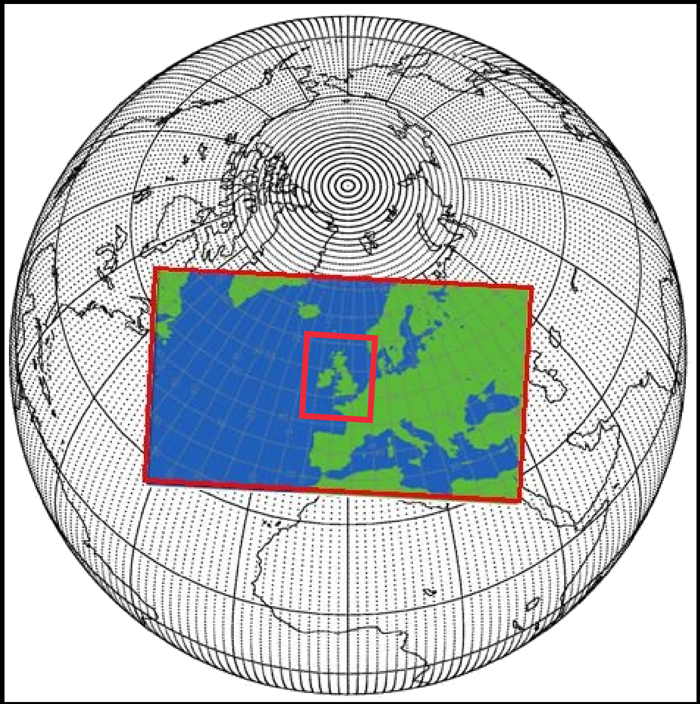
Convective-scale Ensembles Project

R&D deliverable - To demonstrate the capability for routine running of a convective scale ensemble. March 2012.

Embed UKV forecasts in selected MOGREPS-R members.

Like COSMO-LEPS (Moltini *et al* QJ 2001) but at storm-permitting resolution

No UKV perturbations at this stage



Convective-scale Ensembles Project

R&D deliverable - To demonstrate the capability for routine running of a convective scale ensemble. March 2012.

Embed UKV forecasts in selected MOGREPS members.

Even with intended computer upgrade, we could only run a few members.

Small ensemble should represent the full ensemble.

Target ~12 to 36 hours ahead.

Case study approach.

Reasons why a 1.5 km downscaling ensemble is a good idea for the UK
(focus on convection here)

Must have a model that can ‘explicitly represent’ convection

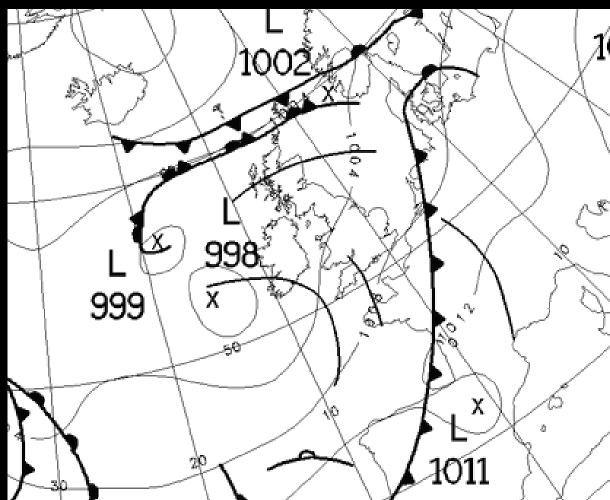
Area of convective activity typically controlled by mesoscale dynamics and instability. (PV anomalies, fronts, dry filaments etc)

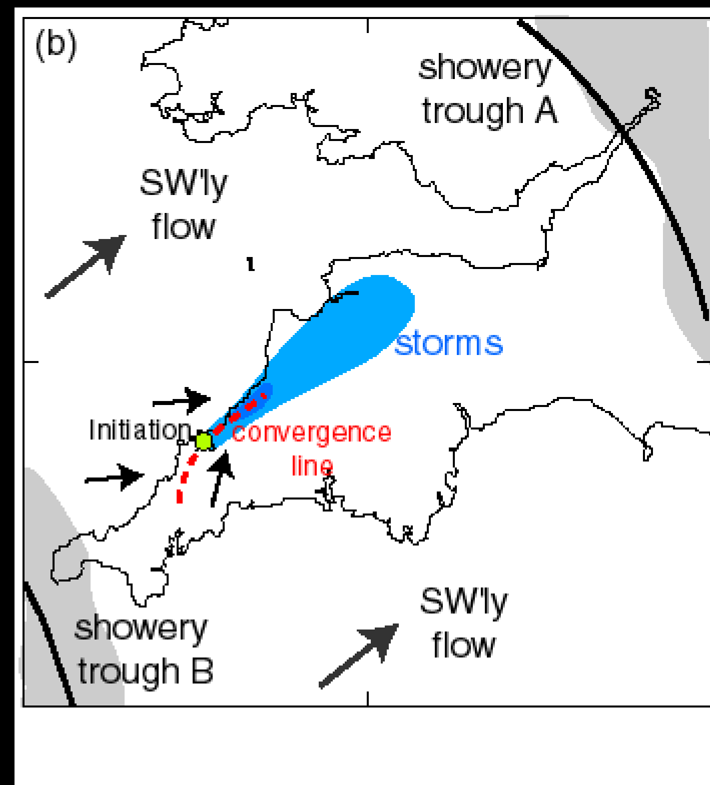
Local organisation (e.g. convergence due to topography) is predictable if mesoscale dynamics sufficiently correct

Strong correlation between nested resolutions. Capturing uncertainty in the mesoscale dynamics is crucial.

The Boscastle flood
16th August 2004

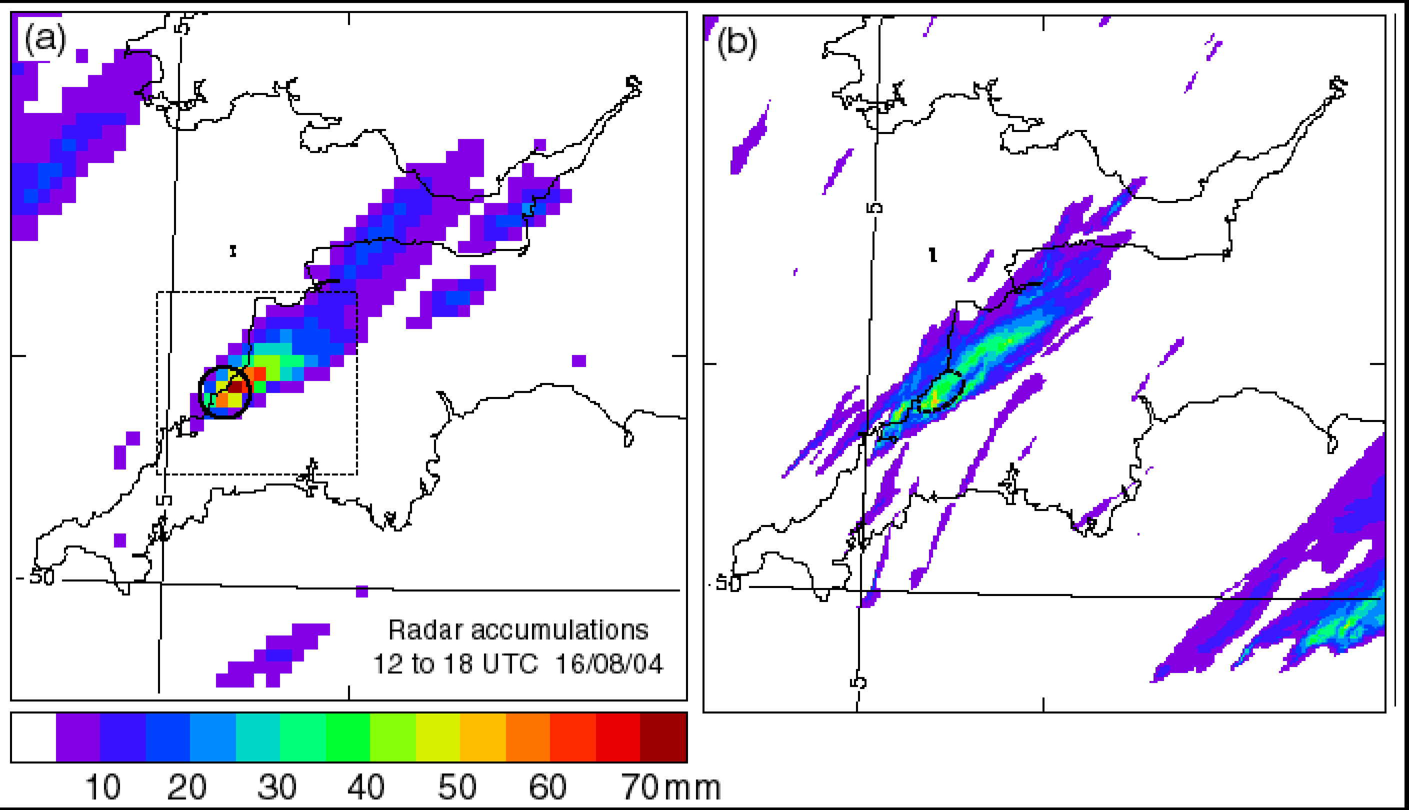
12 UTC 16th





Nigel Roberts

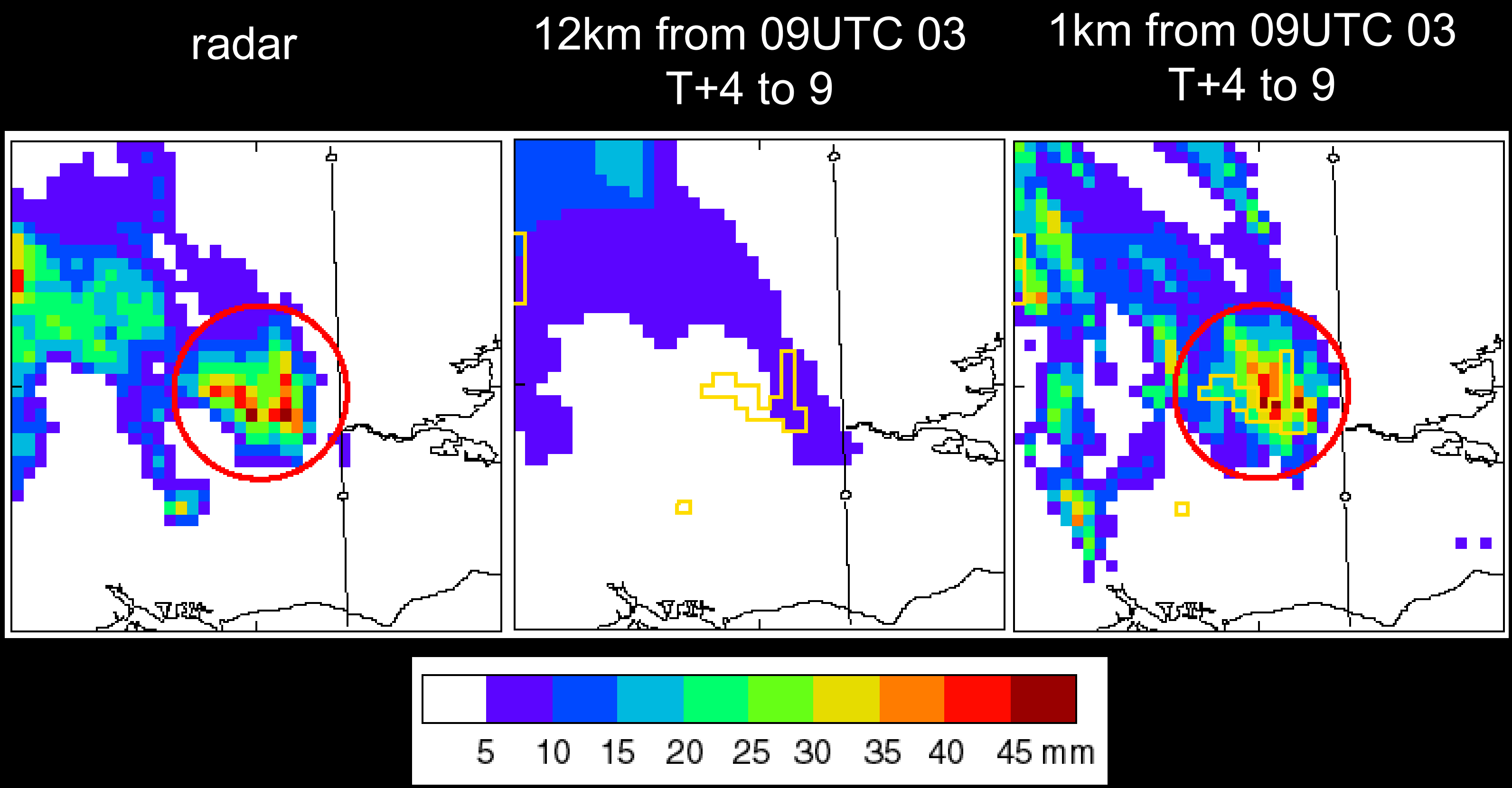
The Boscastle flood
16th August 2004



Severe flooding   24h accumulation > 1 in 200 year return period

Nigel Roberts

Flooding in London
3rd August 2004



5-hour accumulations projected on 5-km grid

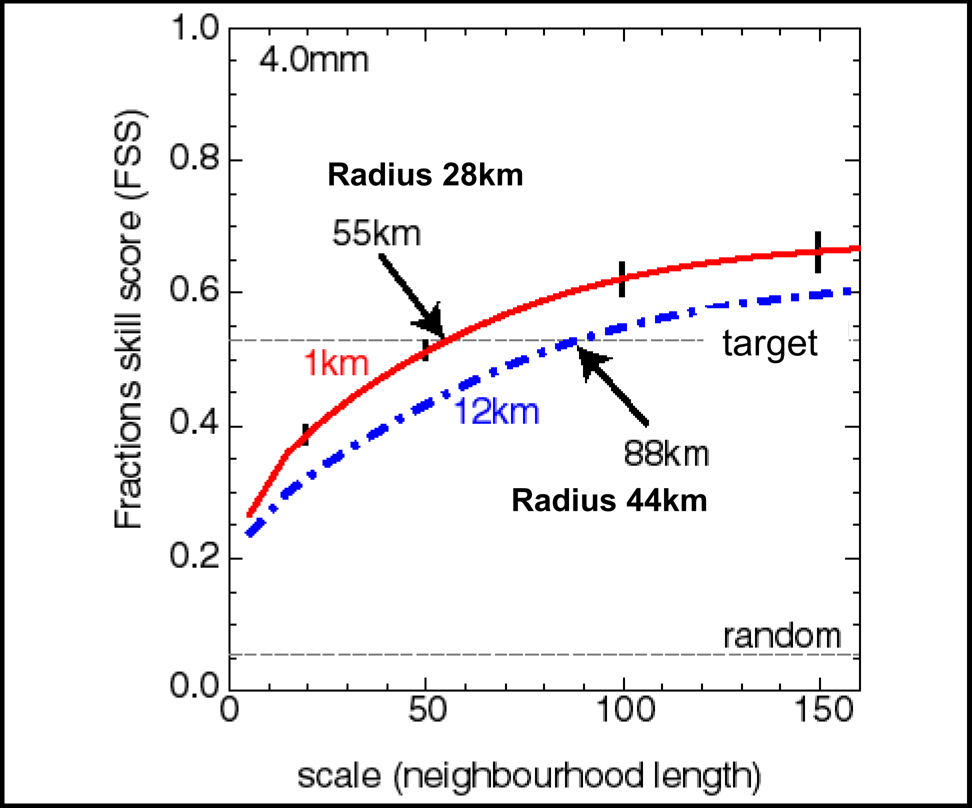
Nigel Roberts

Measuring the skill

From a sample of 40 forecasts of convective rainfall events

4-hour accumulations
T+2 to T+6

Starting from same 12-km fields. No additional data assimilation at 1 km. (1km at disadvantage of having to spin up)

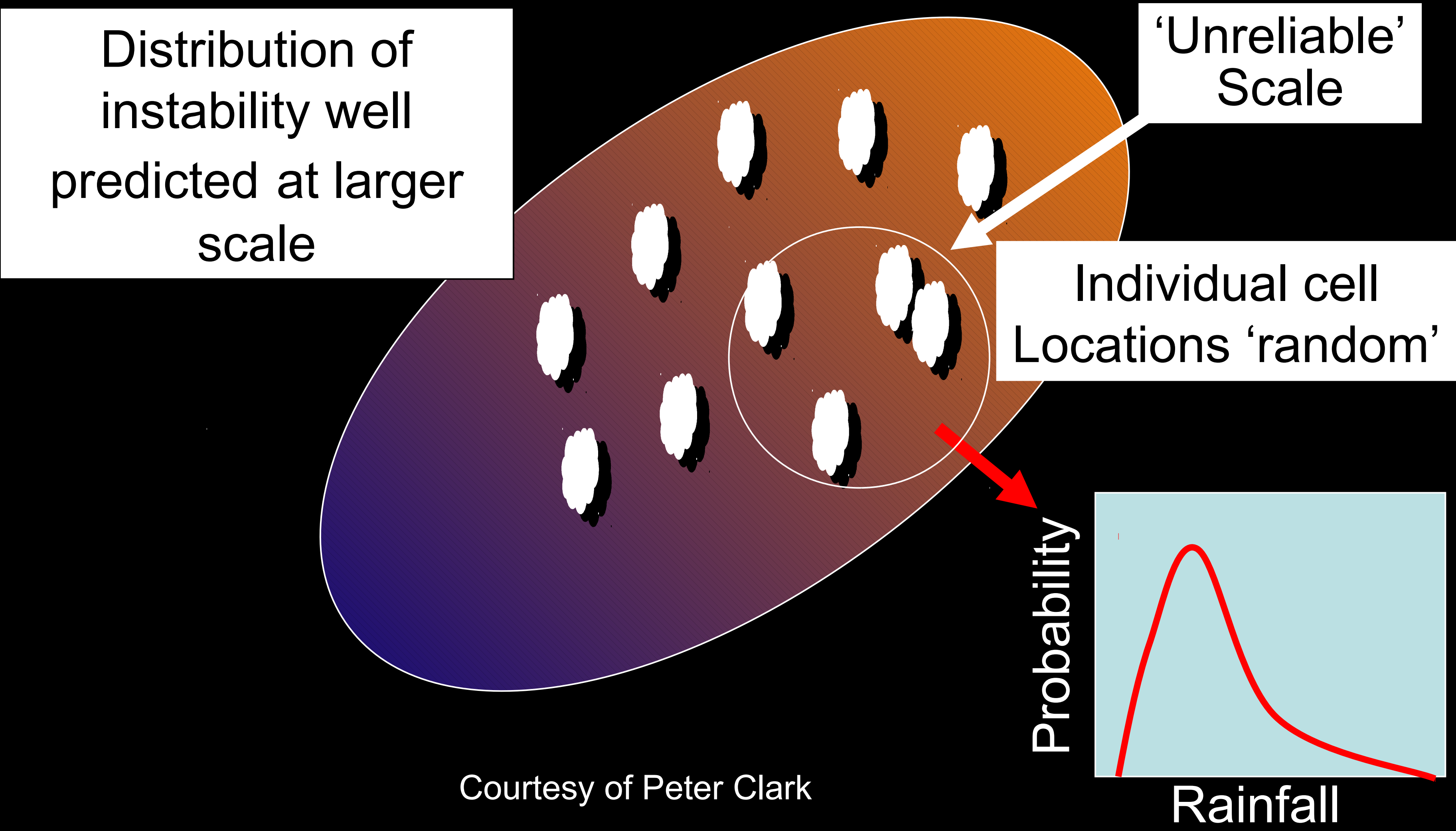


Scale-selective verification methodology

Roberts and Lean, MWR, 2008

Nigel Roberts

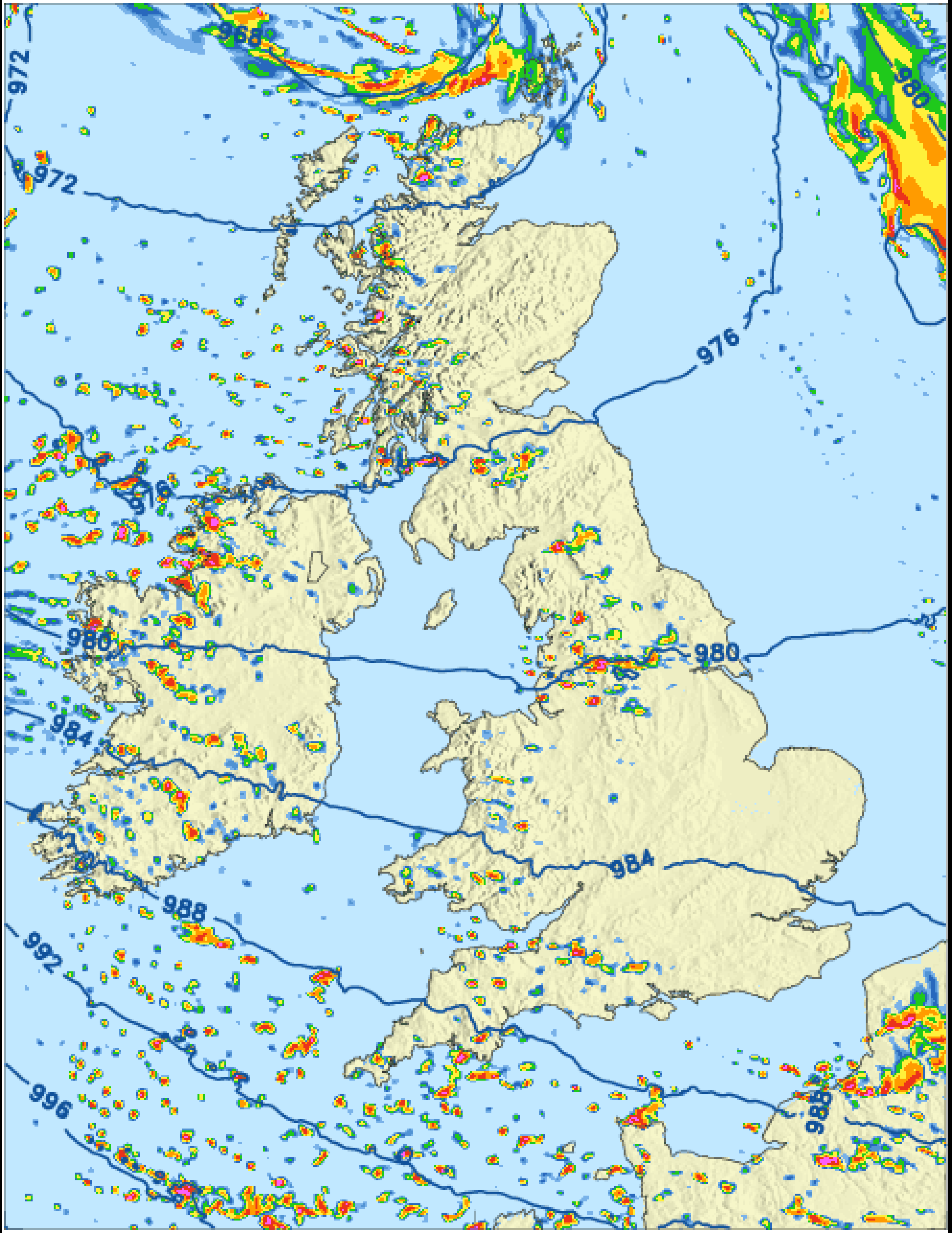
We shouldn't believe high-resolution at face value (at or near the grid scale)



Courtesy of Peter Clark

Met Office

UKV op Precipitation rate [mm/hr] and PMSL
Wednesday 0300Z 04/11/2009 (t+6h)



0.1 – 0.25 0.25 – 0.5 0.5 – 1 1 – 2
2 – 4 4 – 8 8 – 16 16 – 32
32+ mm/hr

Met Office

Consequence of uncertainty in forecasting local weather (e.g. pdf for showers)

We don't need an ensemble to produce a probability forecast

Nearby grid squares provide plausible alternative scenarios – and can therefore be treated as ensemble members

The so called 'neighbourhood' approach. Works well.

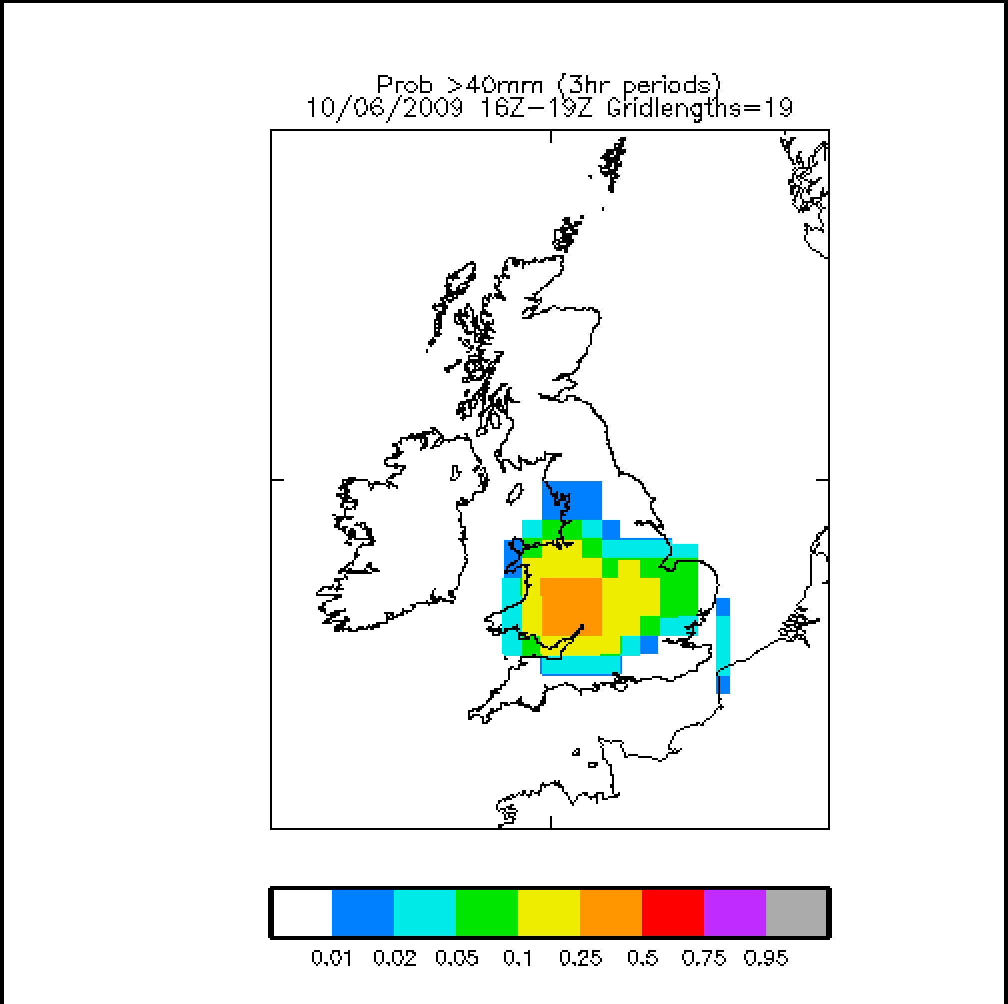
How big should the neighbourhood be?

Rain can be on/off. What if the forecast does not develop a significant storm anywhere?

Presenting spatial uncertainty in deterministic forecasts

Probability of exceeding 40 mm in 3 hours somewhere within a 36 km square

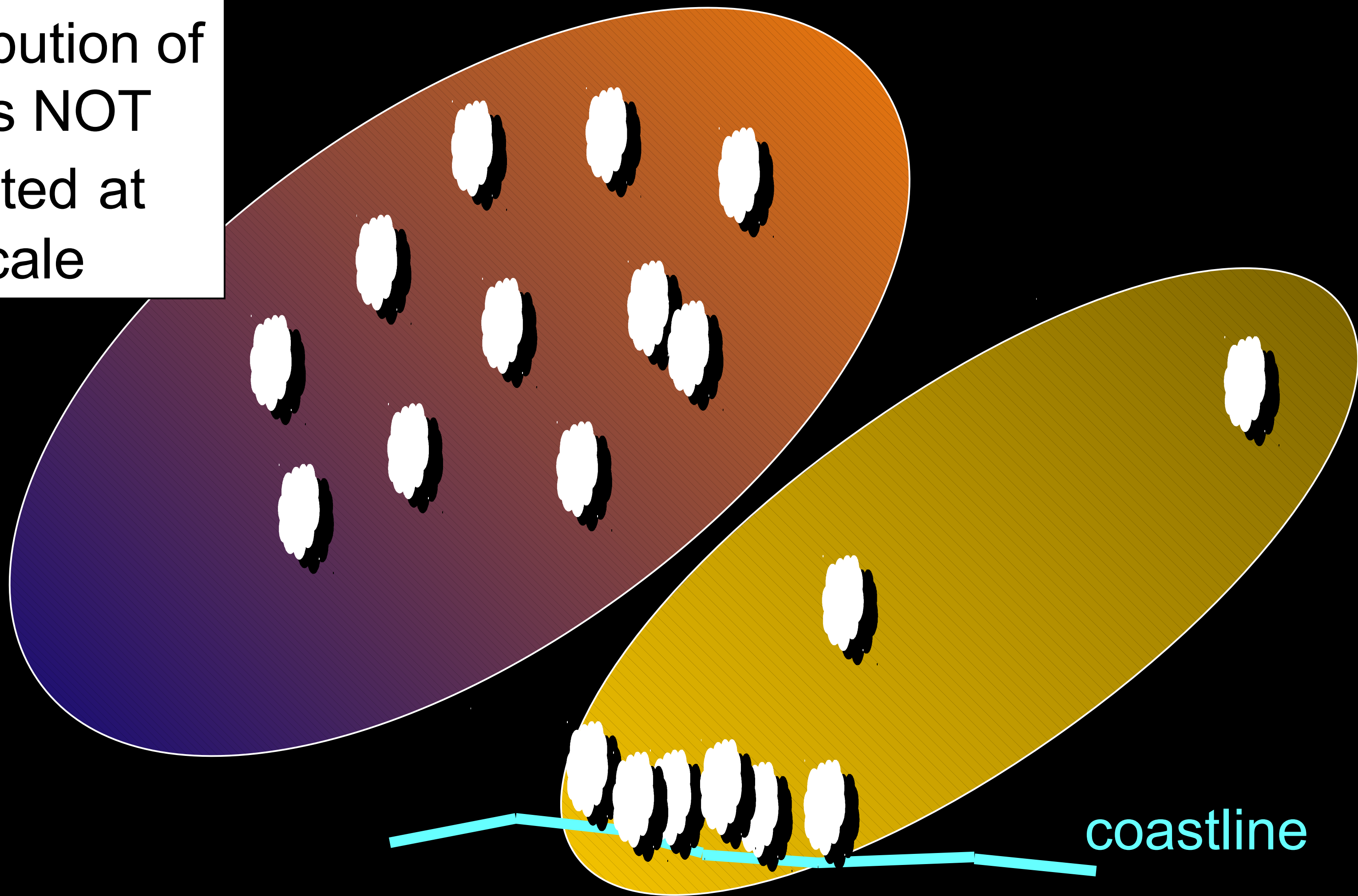
Given a spatial uncertainty of 50 km



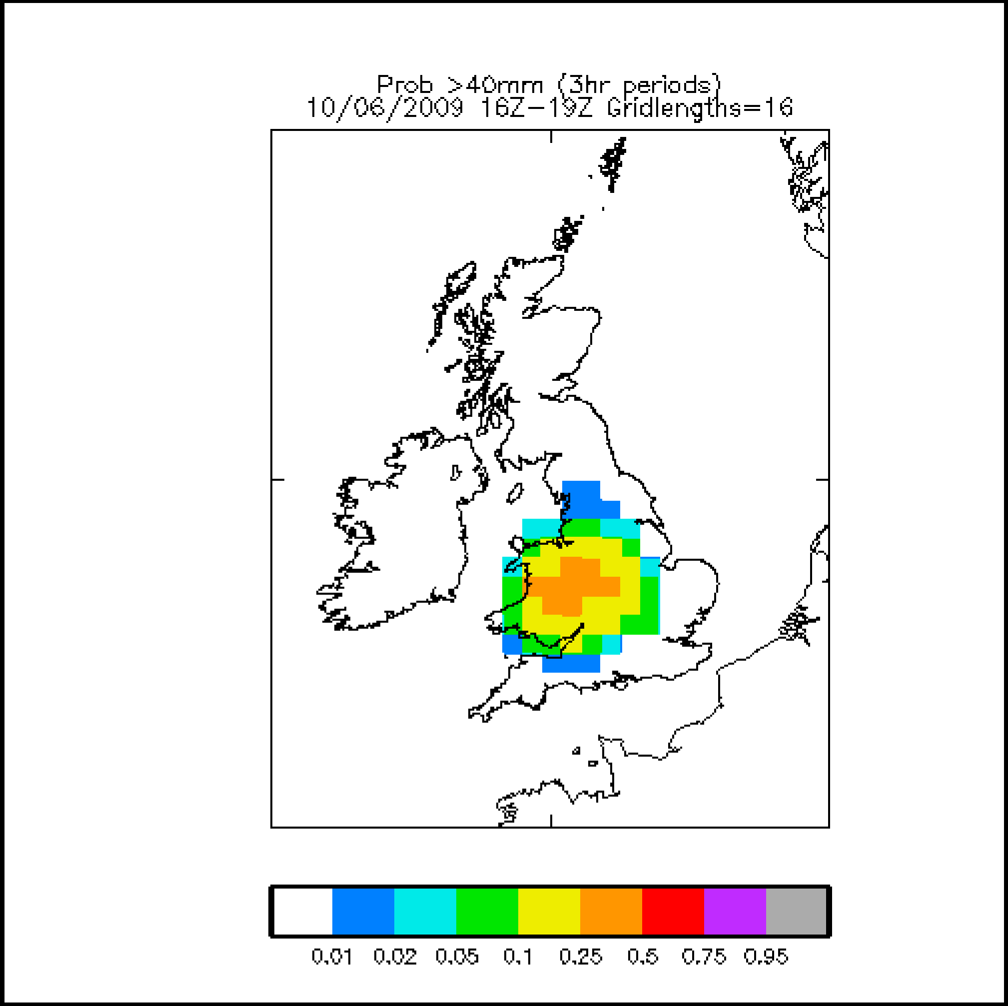
Nigel Roberts

We shouldn't believe high-resolution at face value

What if distribution of instability is NOT well predicted at larger scale



A change in the character of the forecast?



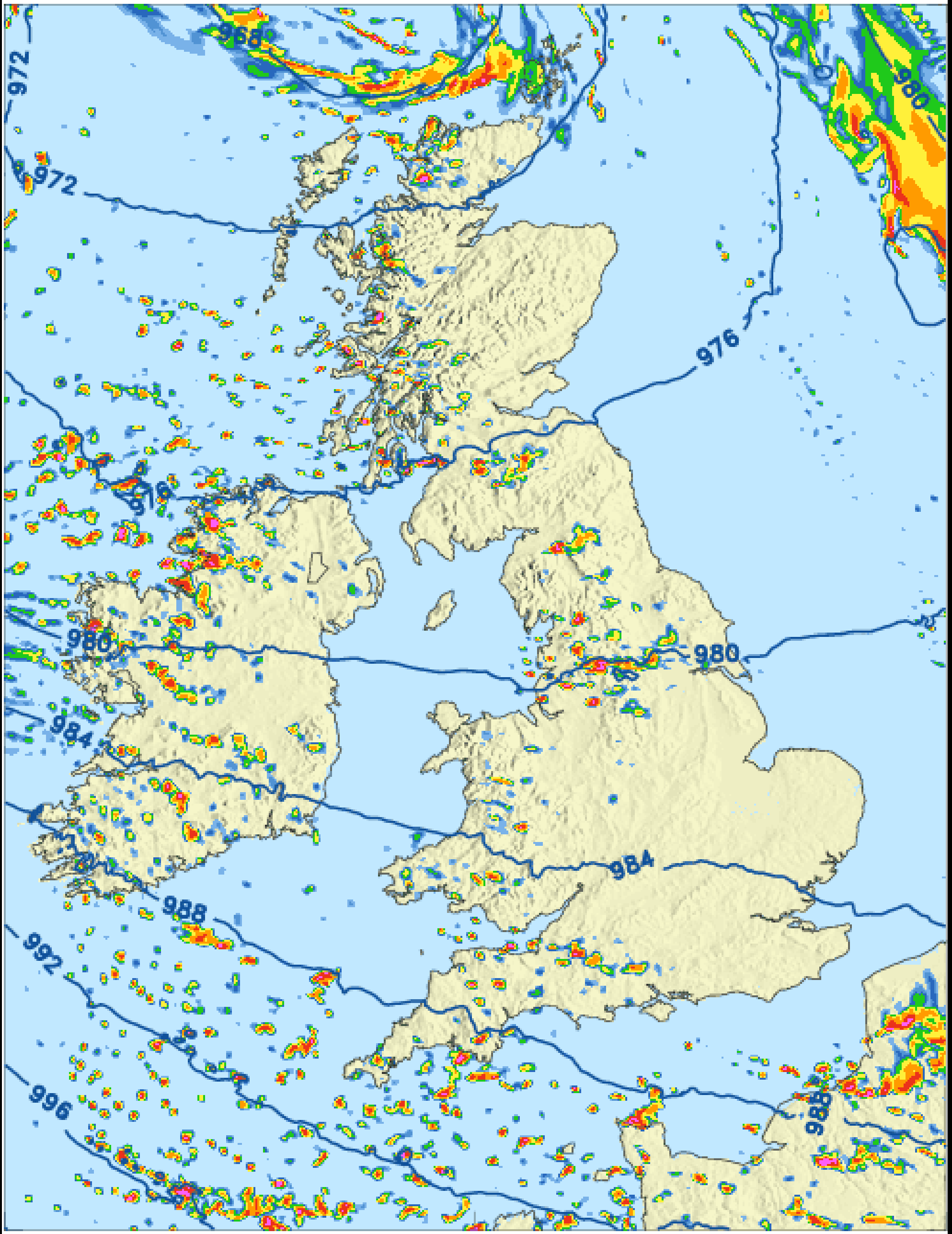
Time-lag ensemble helps

Mittermaier, QJ, 2007

Where does this uncertainty come from?

Met Office

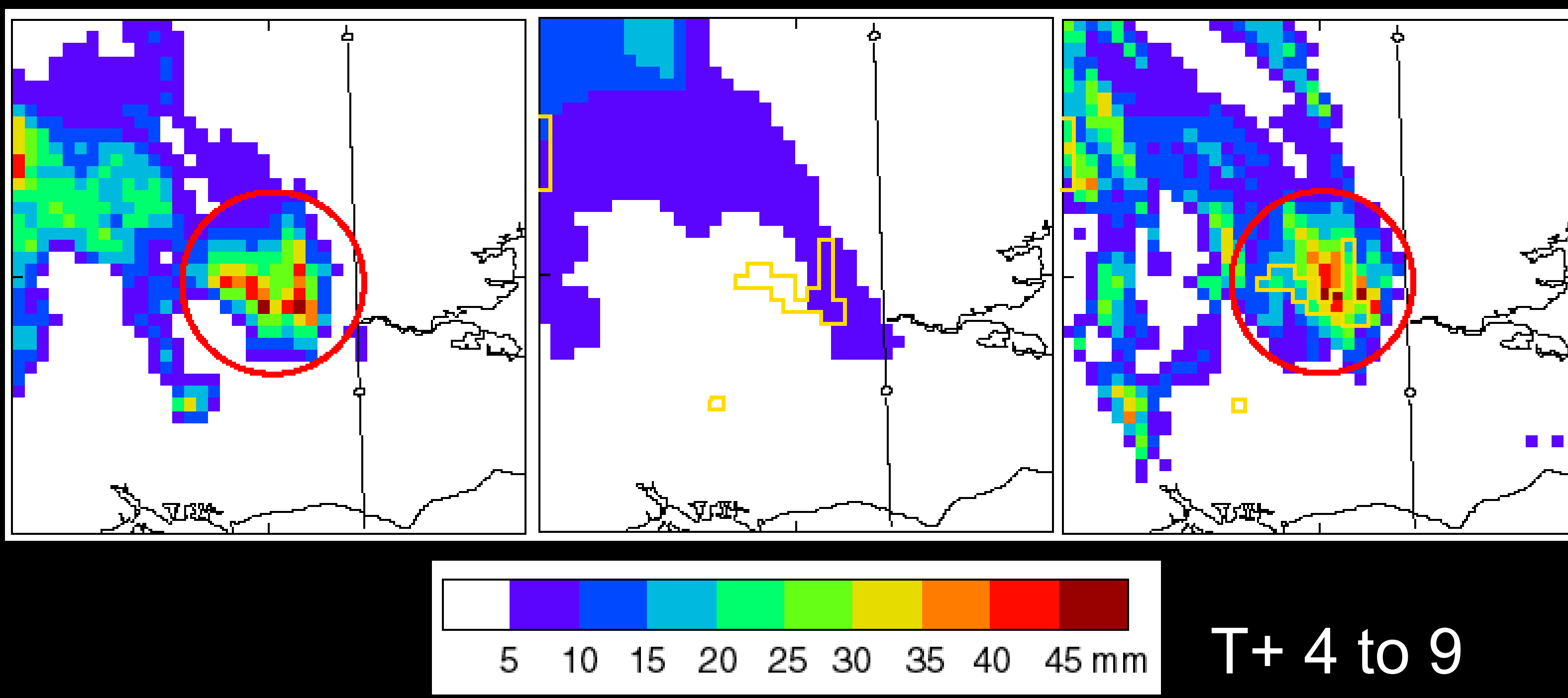
UKV op Precipitation rate [mm/hr] and PMSL
Wednesday 0300Z 04/11/2009 (t+6h)



0.1 – 0.25 0.25 – 0.5 0.5 – 1 1 – 2
2 – 4 4 – 8 8 – 16 16 – 32
32+ mm/hr

Forecast variability
3rd August 2004

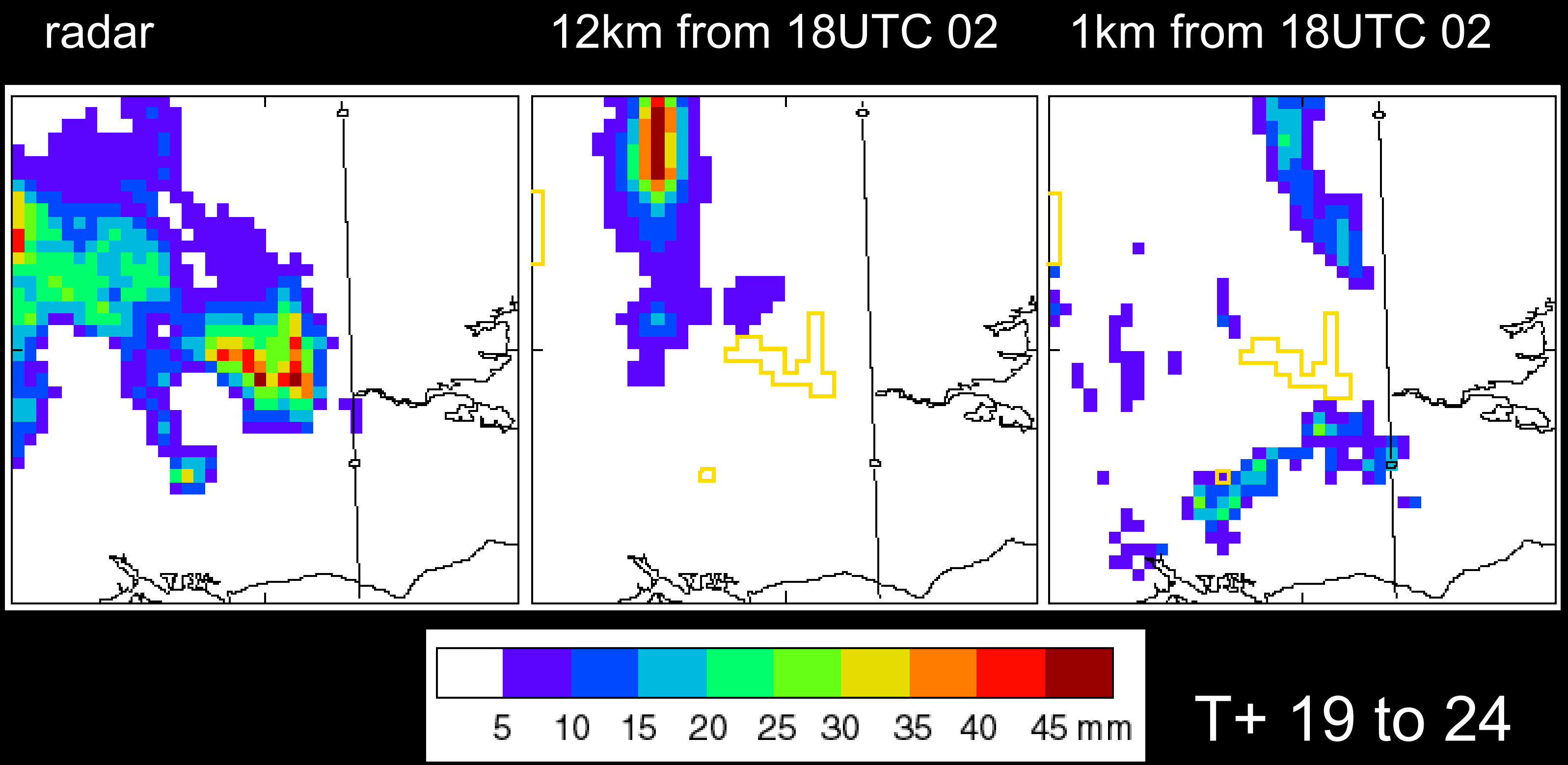
radar | 12km from 09UTC 03 | 1km from 09UTC 03



T+ 4 to 9

Nigel Roberts

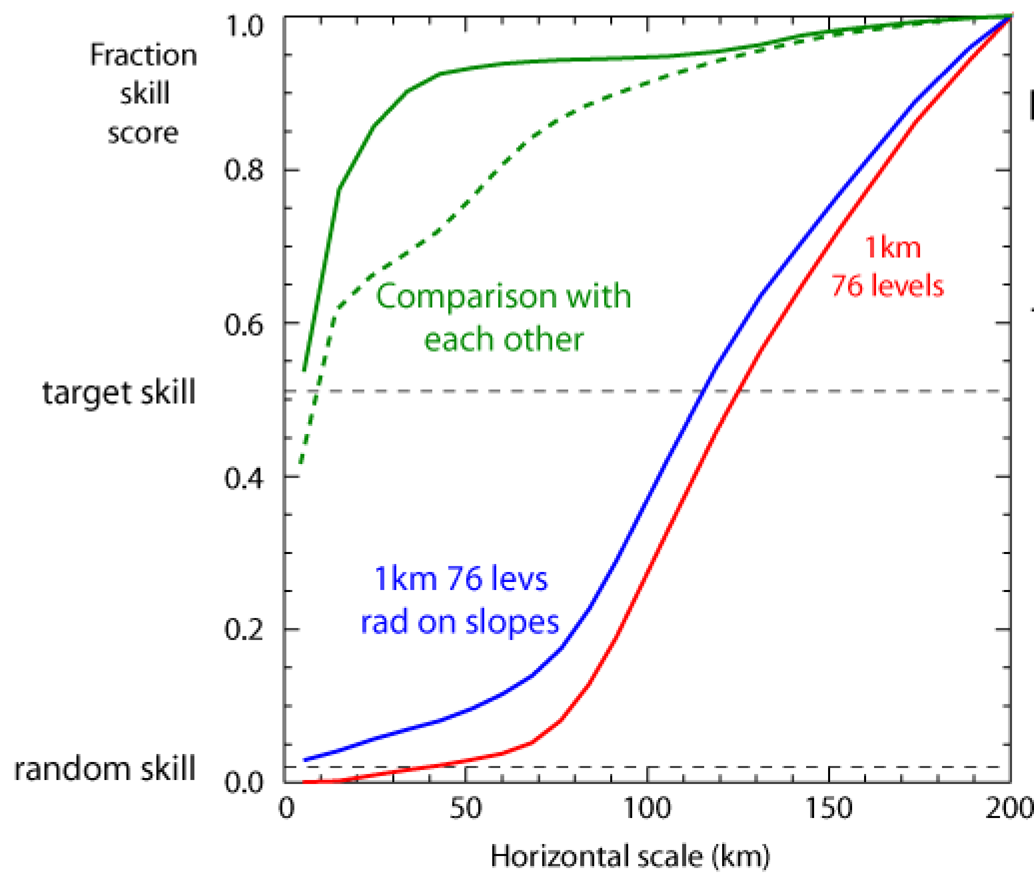
Forecast variability
3rd August 2004



T+ 19 to 24

Nigel Roberts

What about changes to model formulation



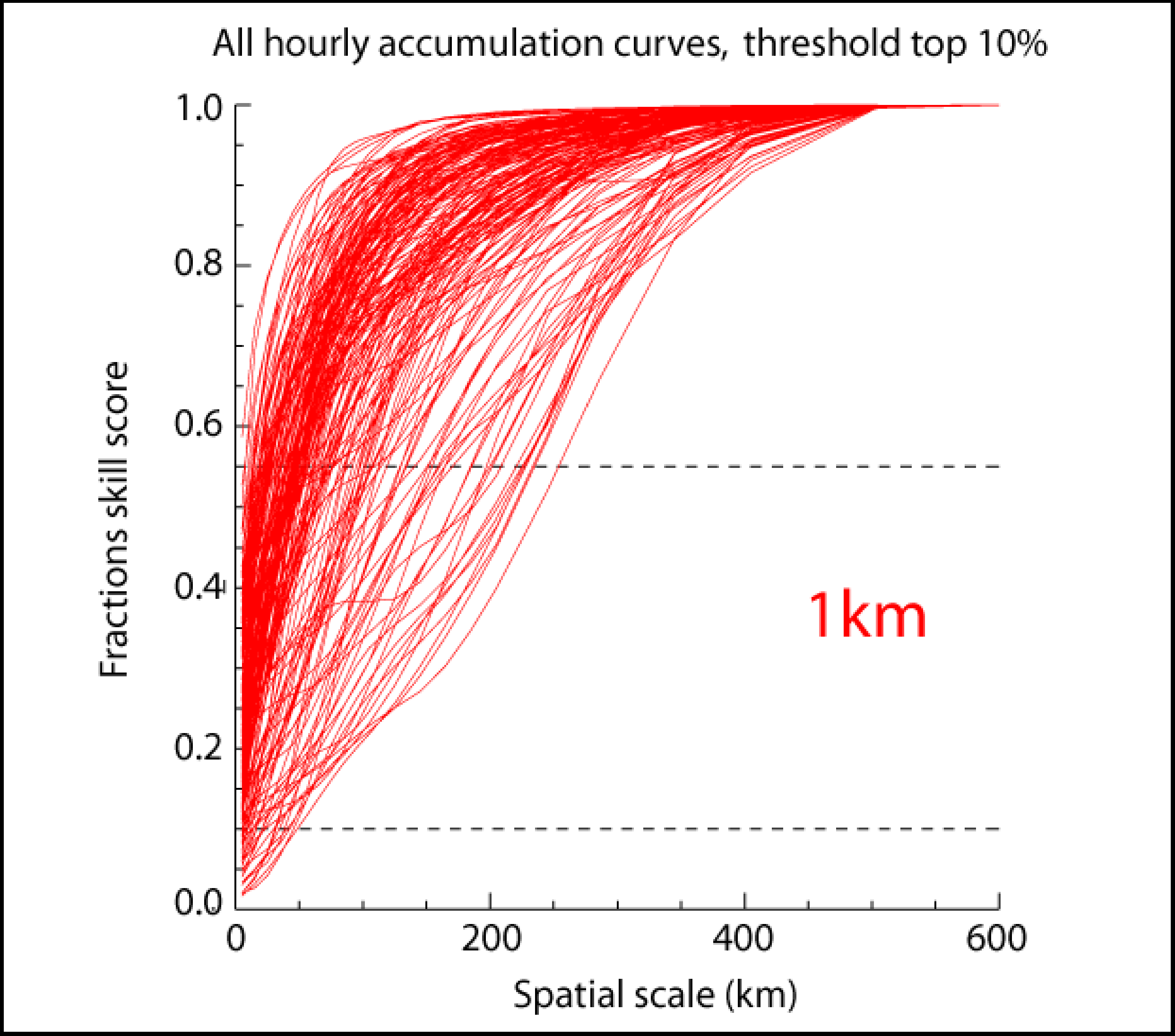
Less difference between forecasts and mostly at smaller scales

- but more impact on skill

Gross error not corrected

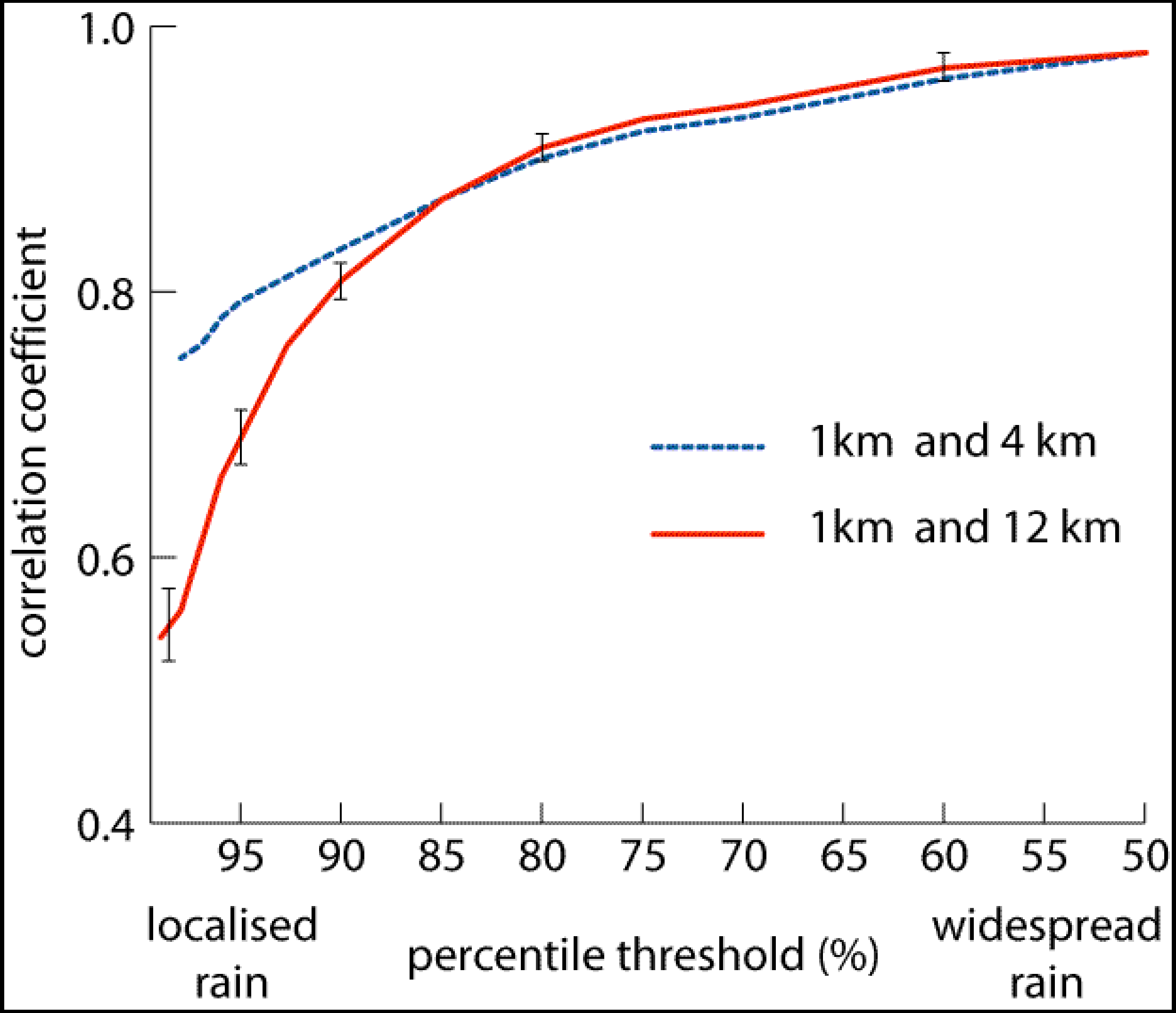
19th June 2005

Resolution-dependent variation in skill



Nigel Roberts

Correlation in skill between resolutions



Nigel Roberts

Two sources (scales) of uncertainty (scales may overlap)

1. Mesoscale dynamics - troughs, fronts, frontal waves, dry filaments ...
2. Local or storm effects – sea breeze, outflow boundaries, local convergence, storm dynamics, storm interactions, gravity waves, urban heat island, elevated heating, cirrus shielding …

Ignore the mesoscale dynamics at your peril – because if that is wrong the local effects could be irrelevant!

It’s like finding a fish!

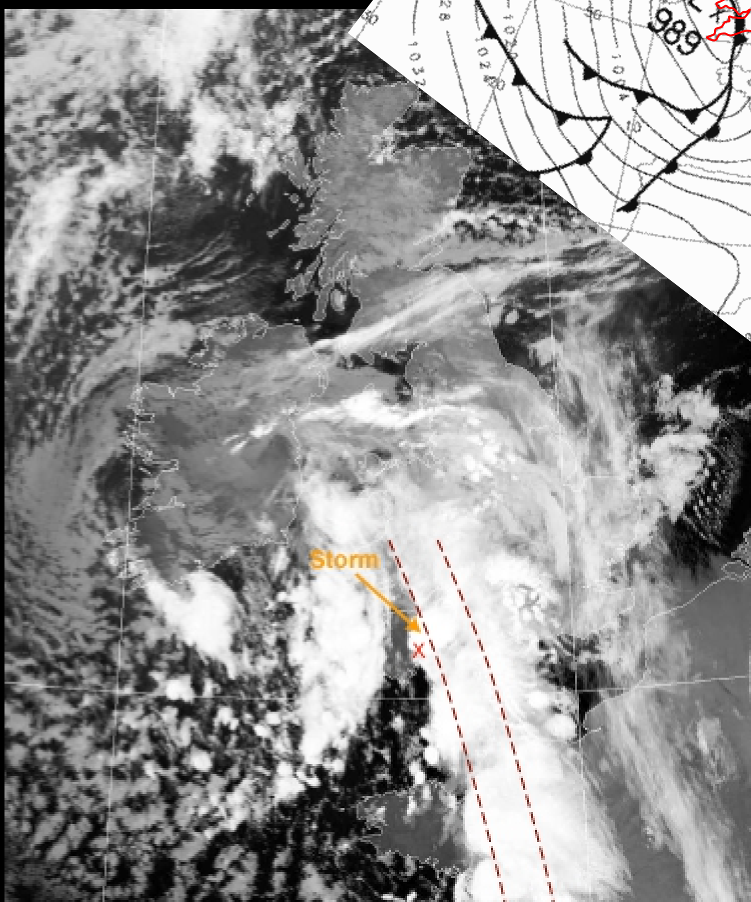
First case
Hailstorm in Ottery

Dramatic thunderstorm
Very localised
Flash floods in Otter Valley

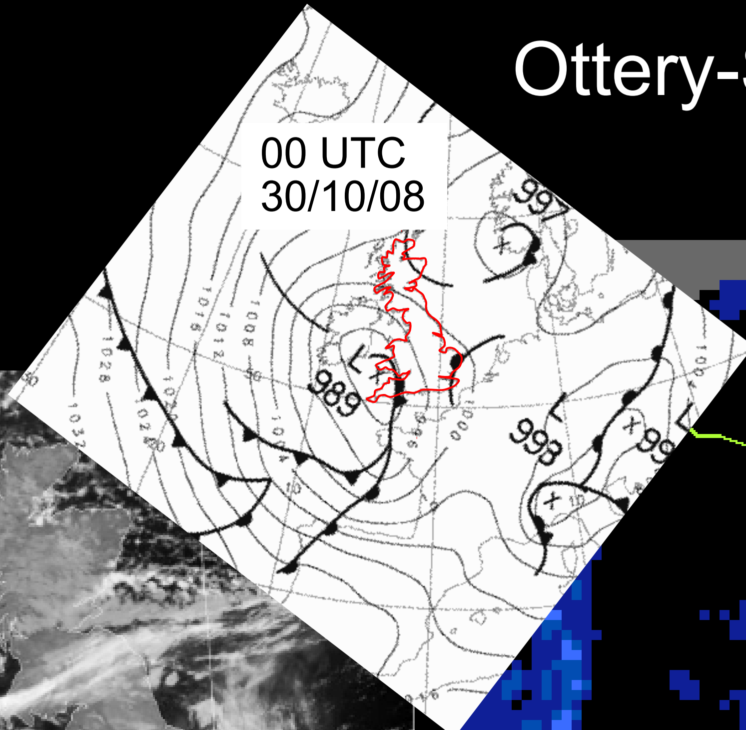
Courtesy of Ken Mylne

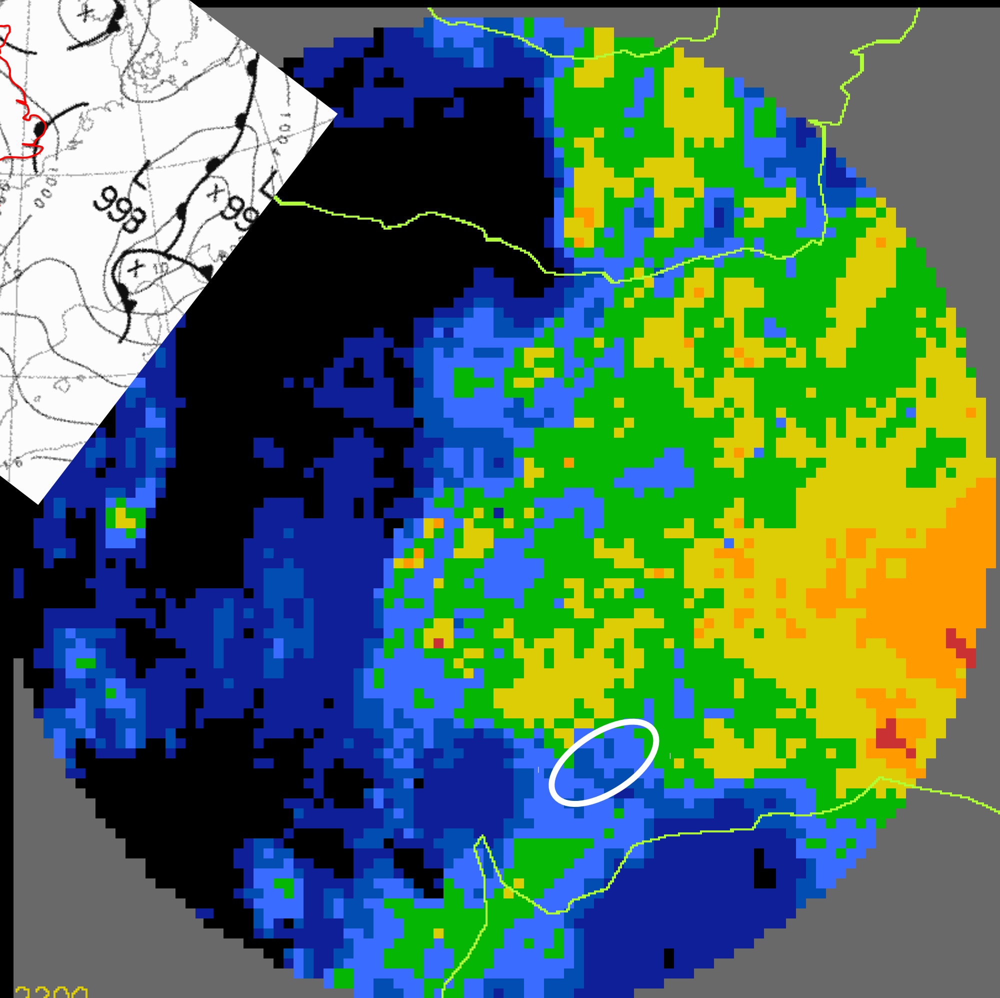
Ottery-St-Mary storm

01:46



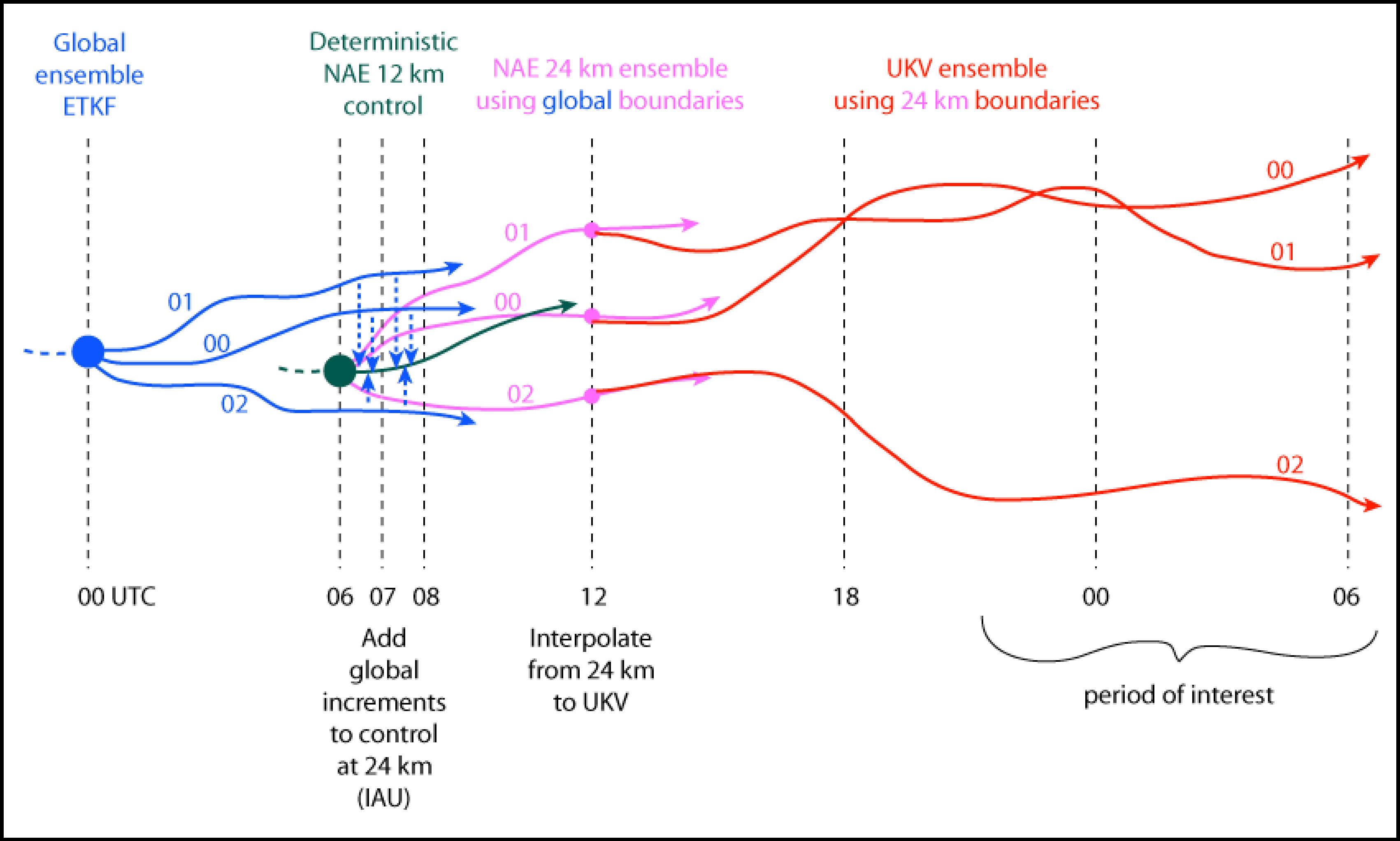
Frontal zone





Radar sequence courtesy of Ken Mylne

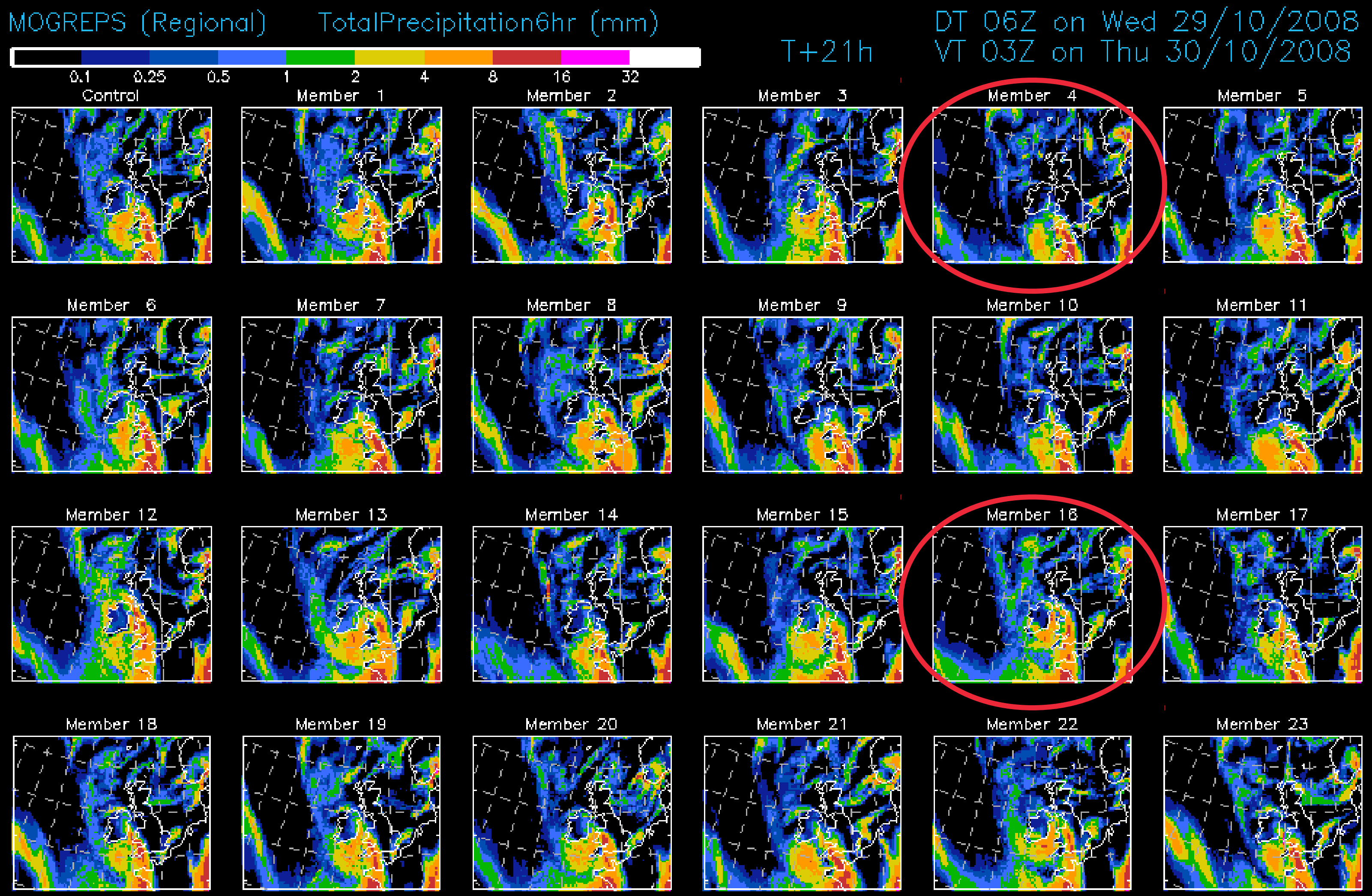
How the UKV ensemble was run



Thanks to Neill Bowler and Changgui Wang

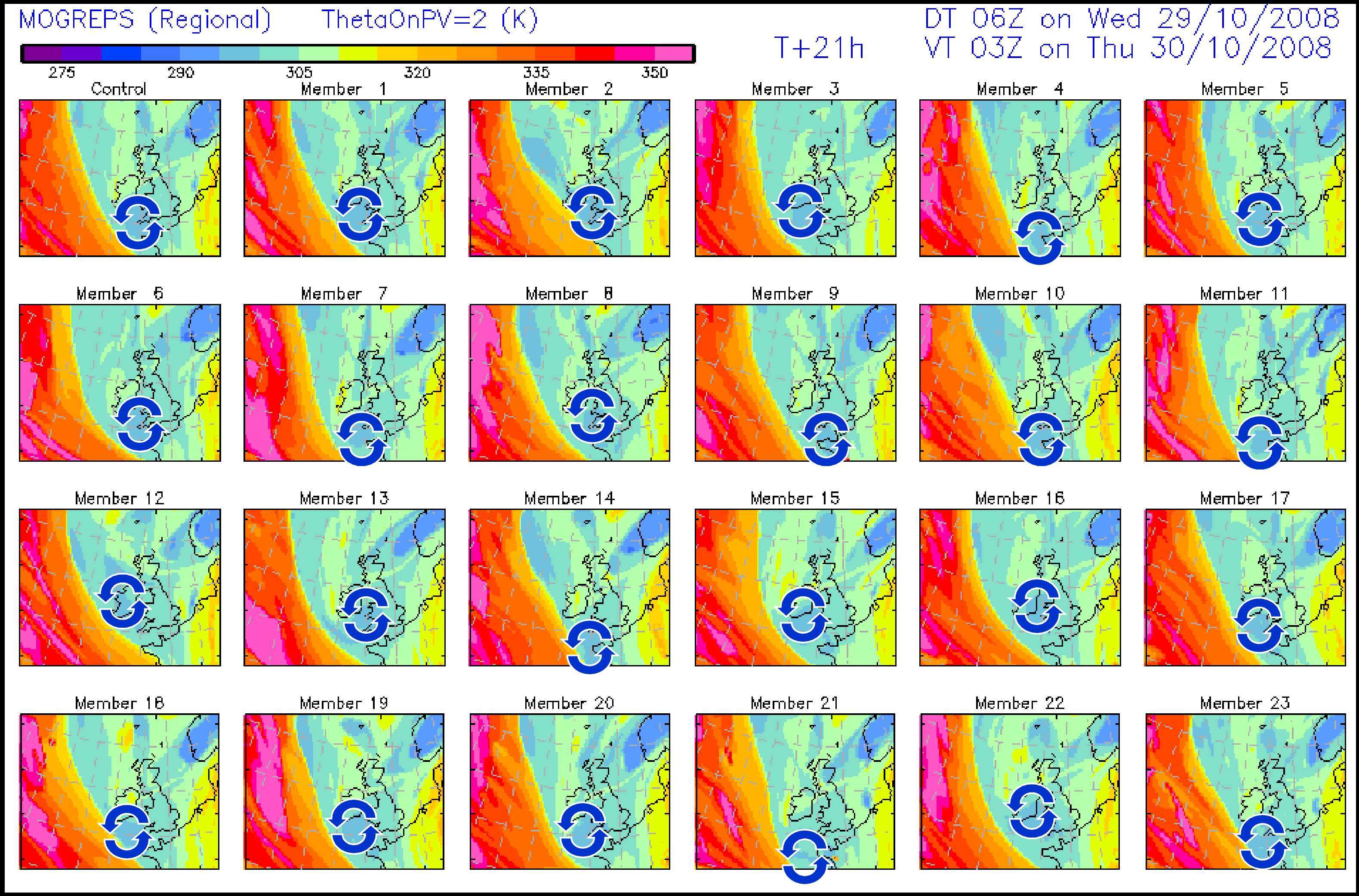
Nigel Roberts

MOGREPS-R output



Courtesy of Caroline Jones

MOGREPS-R output

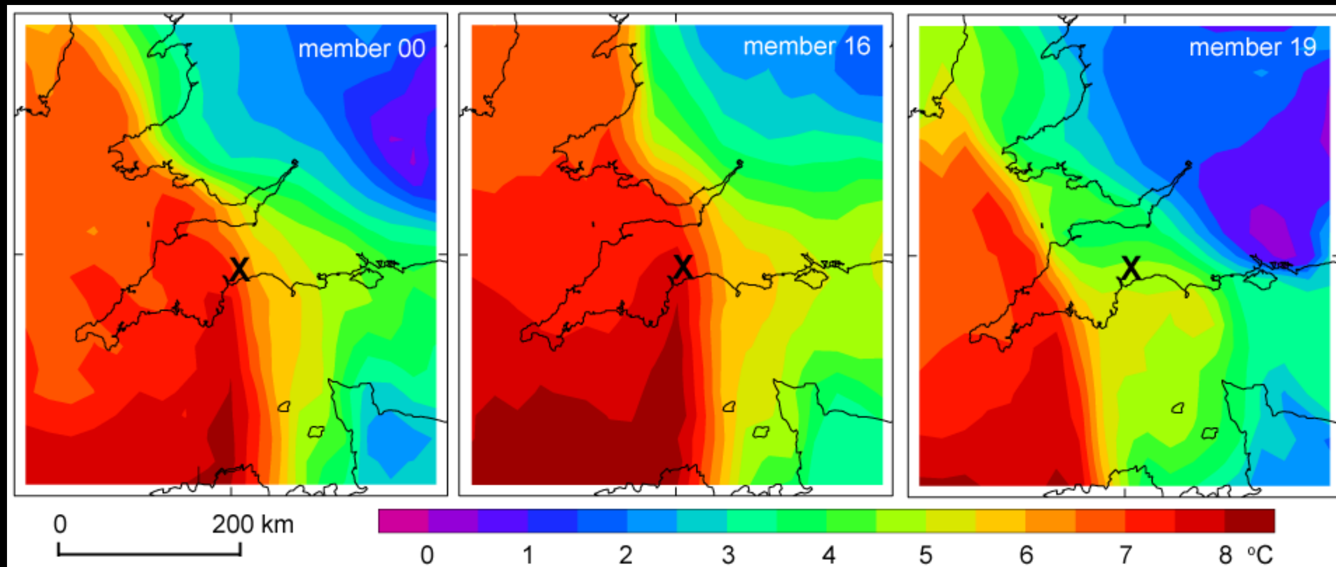


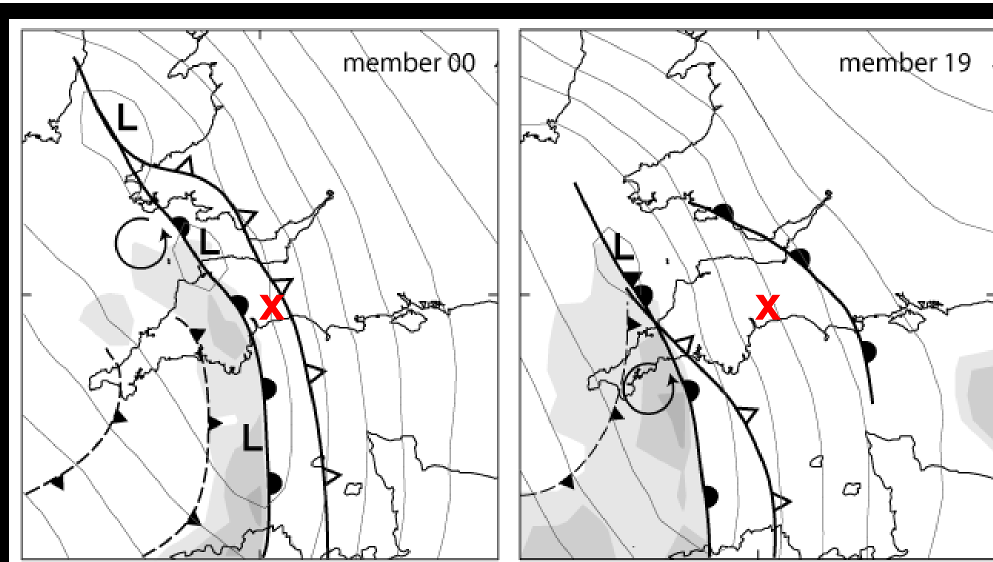
Courtesy of Caroline Jones

MOGREPS output 00 UTC 30/10/08
T+18 - selected members

θ_w

950 hPa

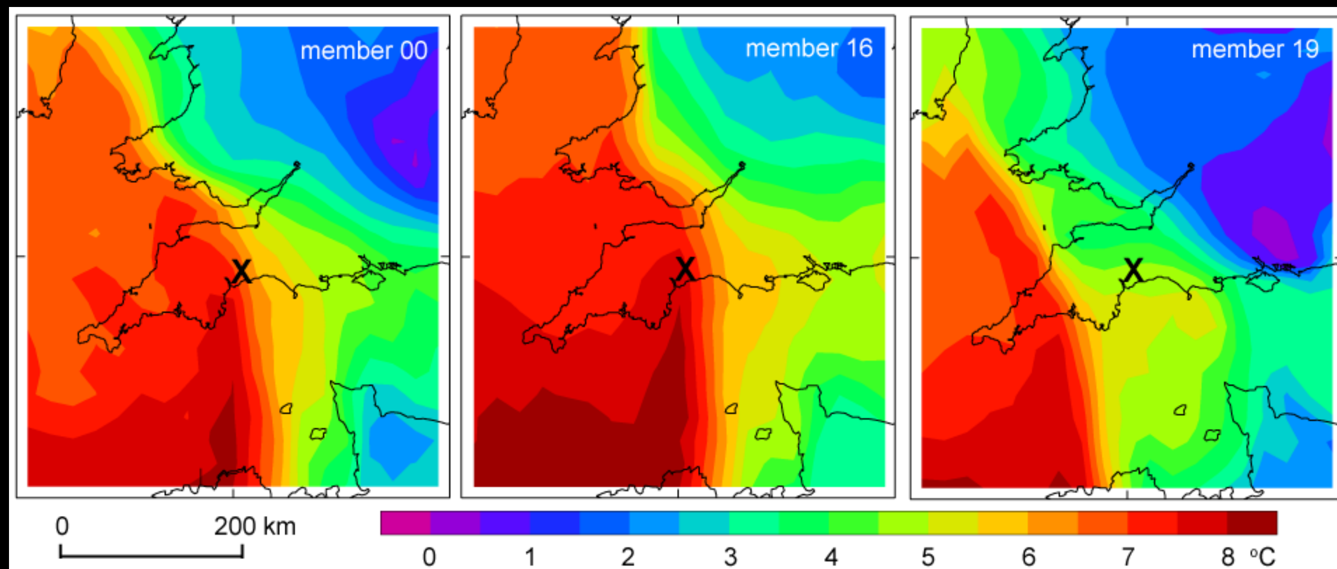




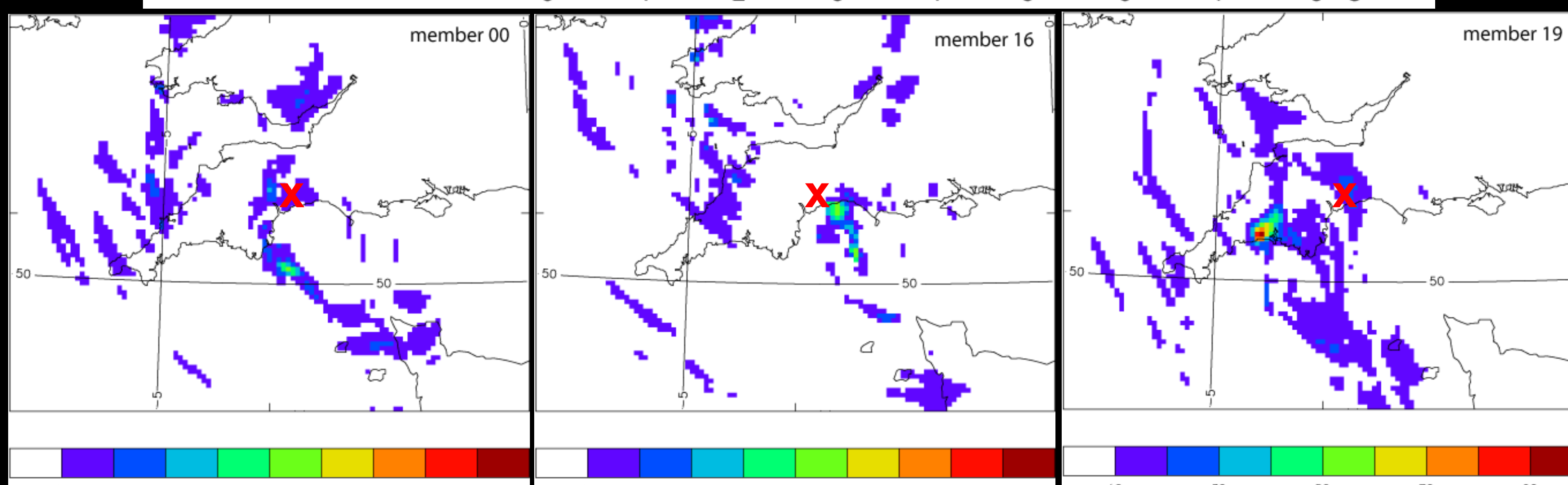
Nigel Roberts

MOGREPS output 00 UTC 30/10/08 (top)
UKV 6-hour accumulations (bottom)

Met Office



Highest
6-hour totals

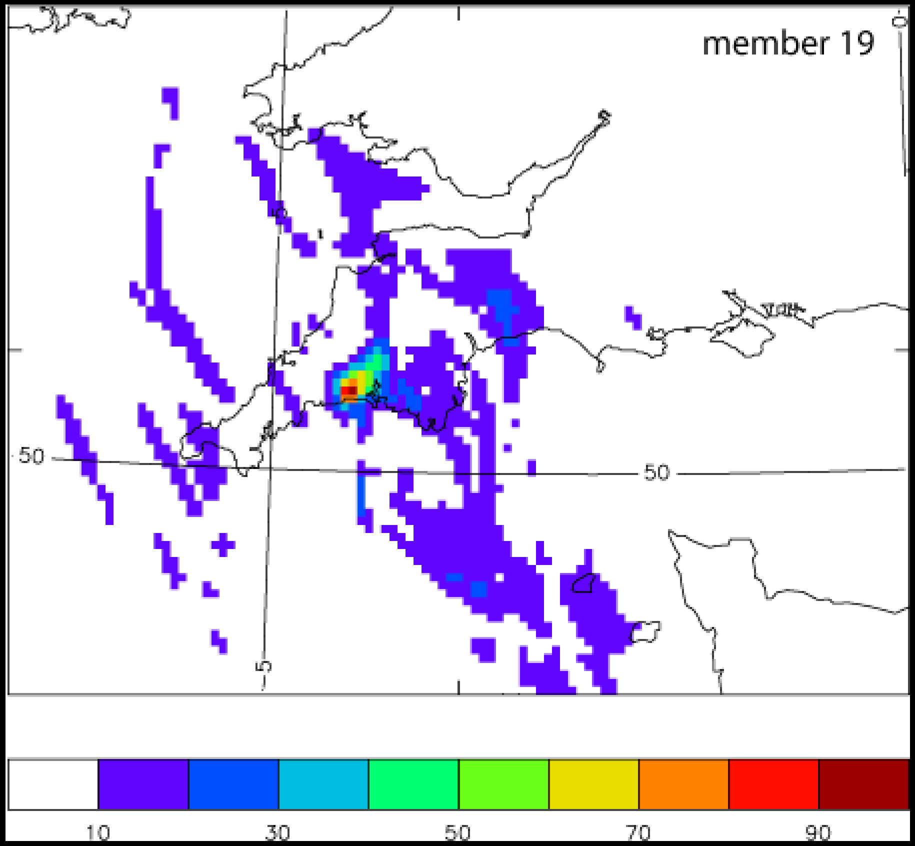


55 mm 55 mm 96 mm

Computed on 4.5km grid – Changgui Wang

Nigel Roberts

Highest 6-hour accumulations at each pixel (3 members)

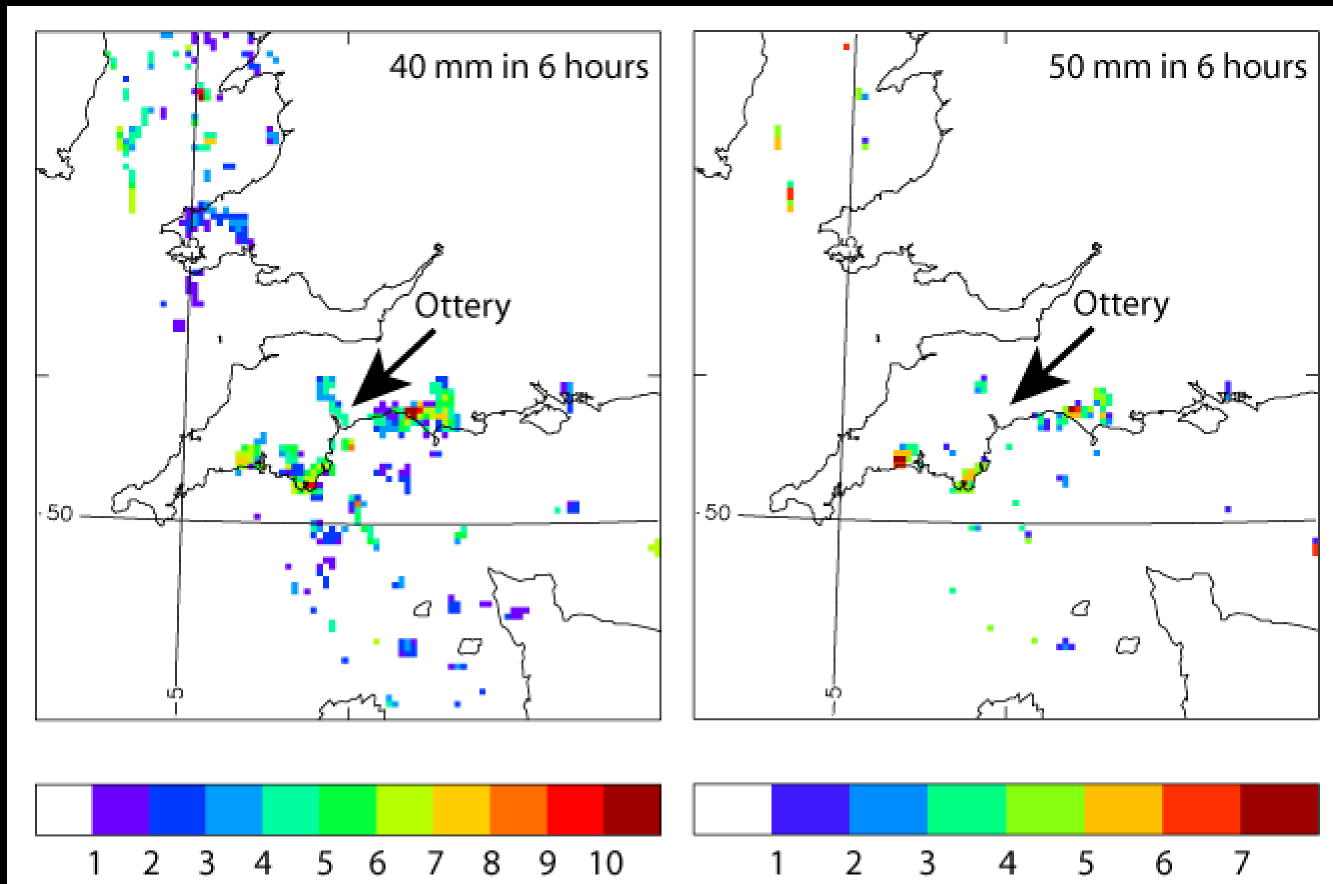


Nigel Roberts

All pixels exceeding critical thresholds

‘Extreme’ threshold for
surface water flooding

1 in 10 years



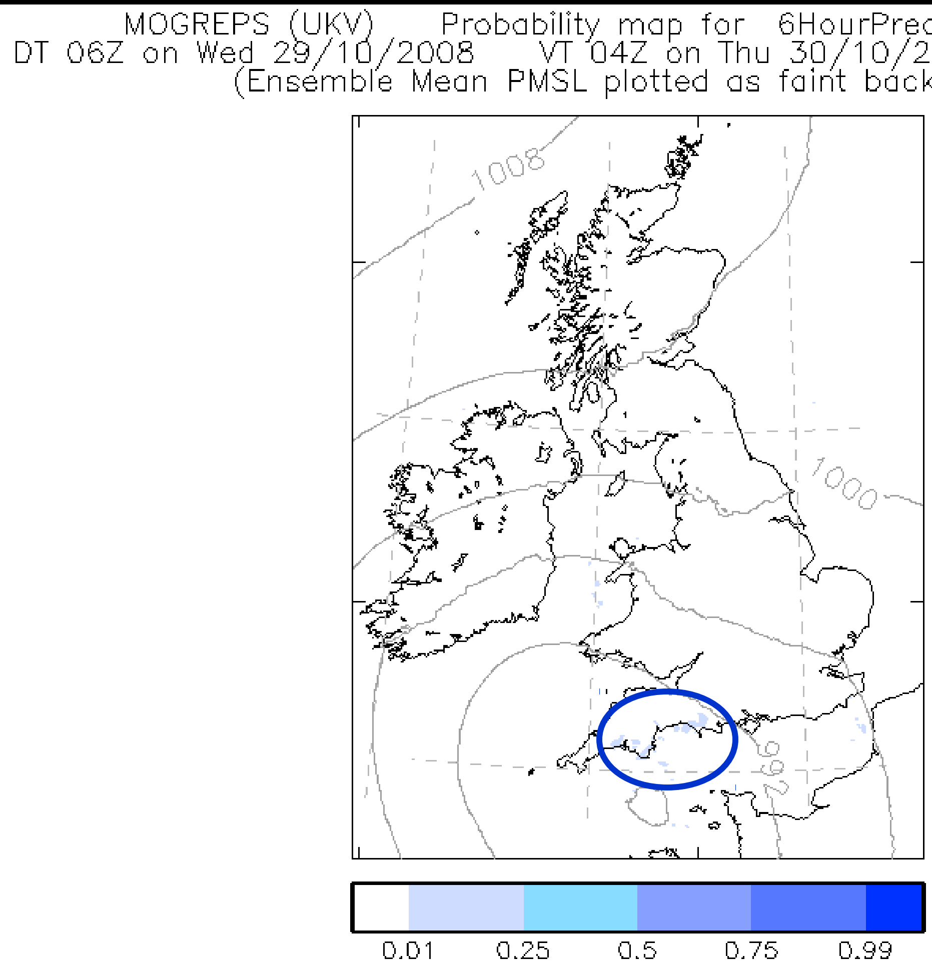
1 in 30 years

Computed on 4.5km grid – Changgui Wang

Nigel Roberts

Probability of exceeding 40mm in 6 hours. Standard MOGREPS-R processing.

Need to re-think for UKV ensemble



Each pixel

~ 1/24 chance

(perhaps 2/24)

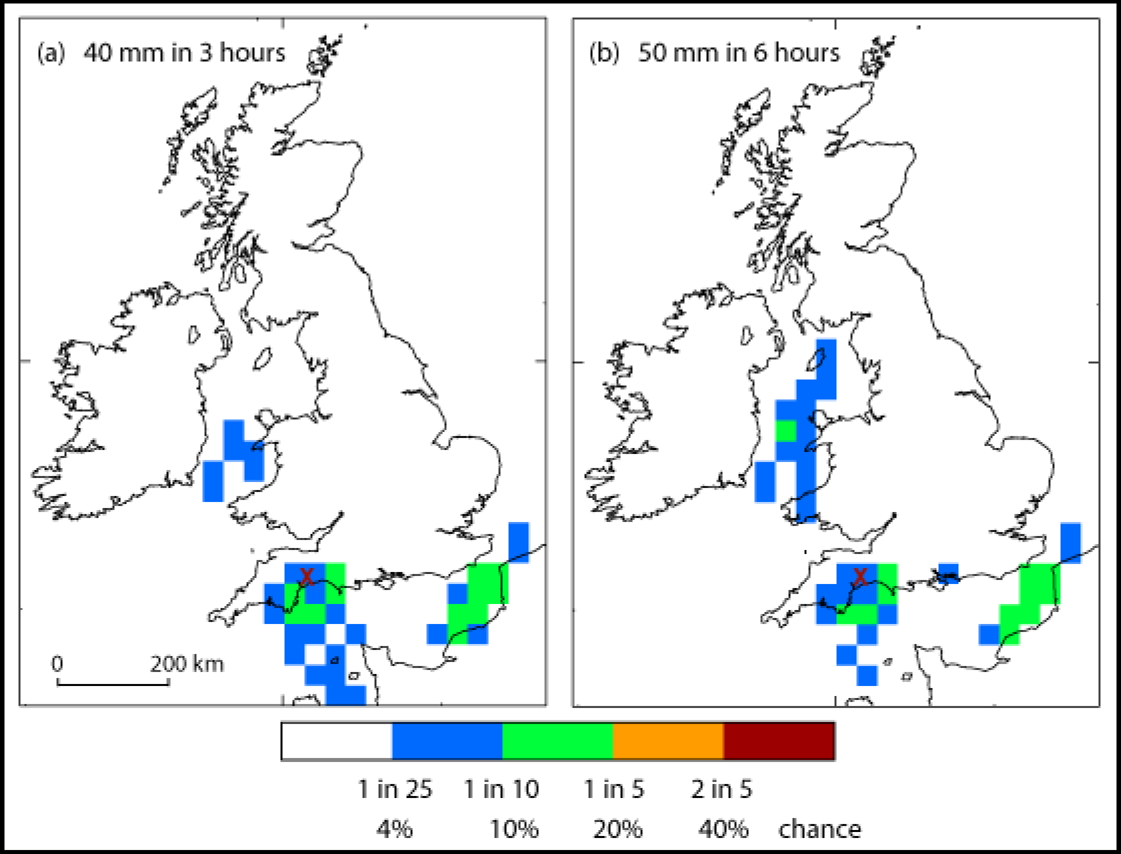
= 4% (or 8%)

Perhaps ~4000 possible pixel locations and only 24 members

(uncertainty over 150x60 km)

Nigel Roberts

Probabilities within areas



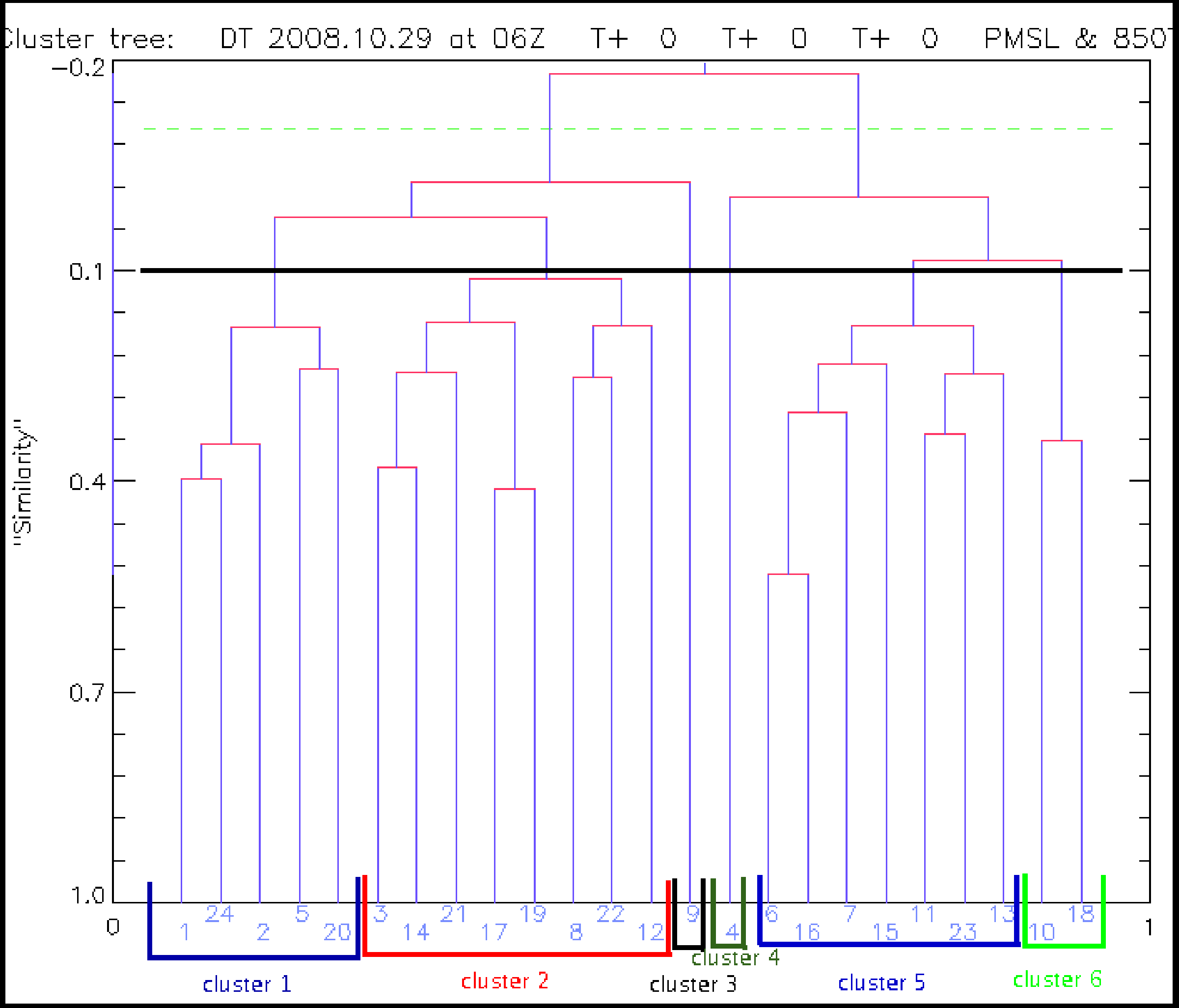
UKV – all 24 members + neighbourhood approach to each

Met Office

Need to reduce ensemble size

Clustering Dendrogram

Take representative member from each cluster – nearest the mean



Caroline Jones

Are the representative members better than a random selection?

Met Office

MOGREPS-R ensemble

Needs to be done for UKV – but how?

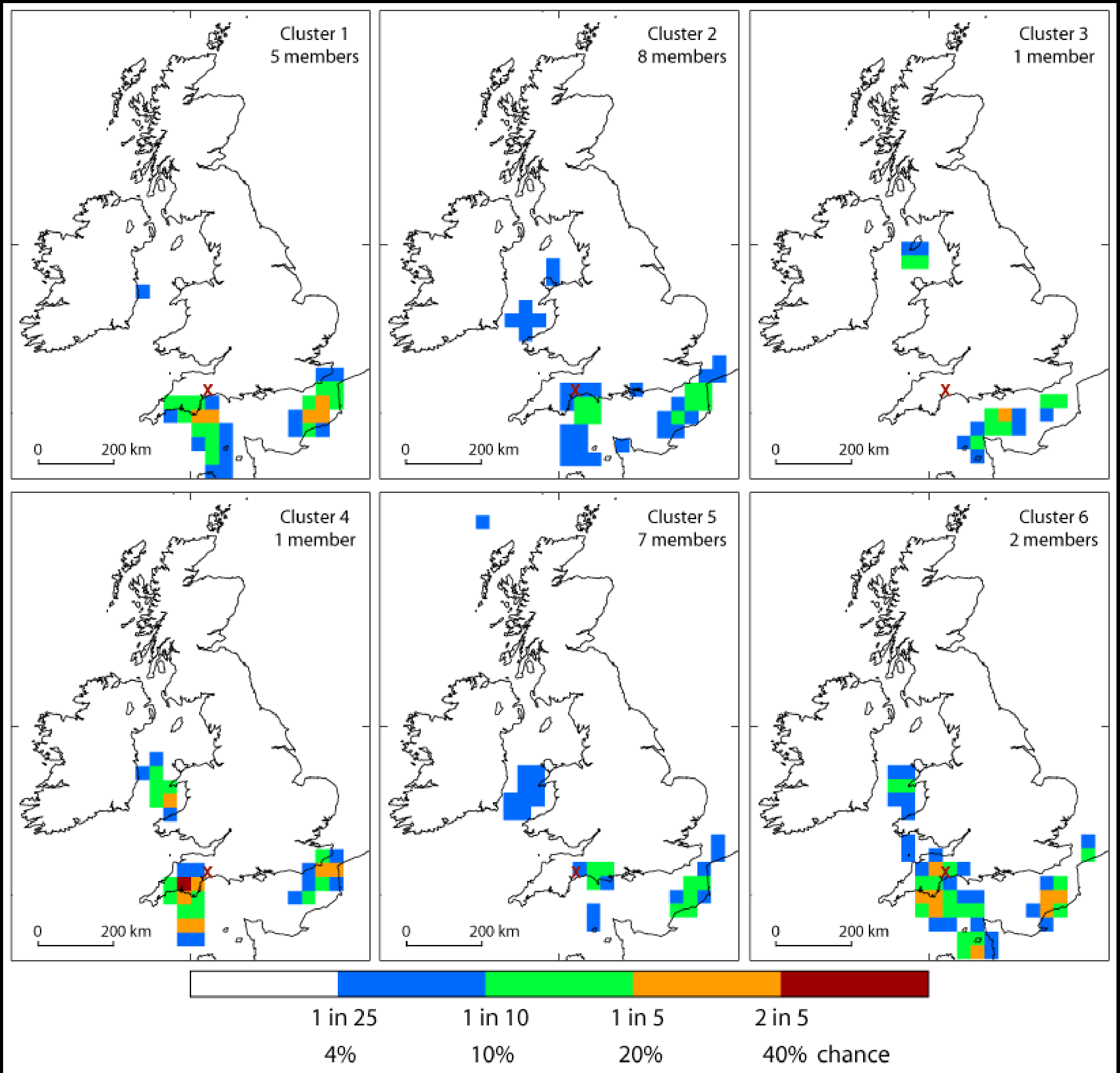
Cluster	Pmsl	θ_w	Pmsl	θ_w
	(Cluster mean – Ens mean)^2		Spread	
All members			59974.8	34551.9
Representative members	14314.3	6212.28	52177.9	30999.0
Random 1	14930.7	6405.82	54227.4	30519.3
Random 2	17495.6	6892.22	52222.9	30019.0

But… Some random selections have better means! What proportion?

Not enough spread in selection?

Caroline Jones

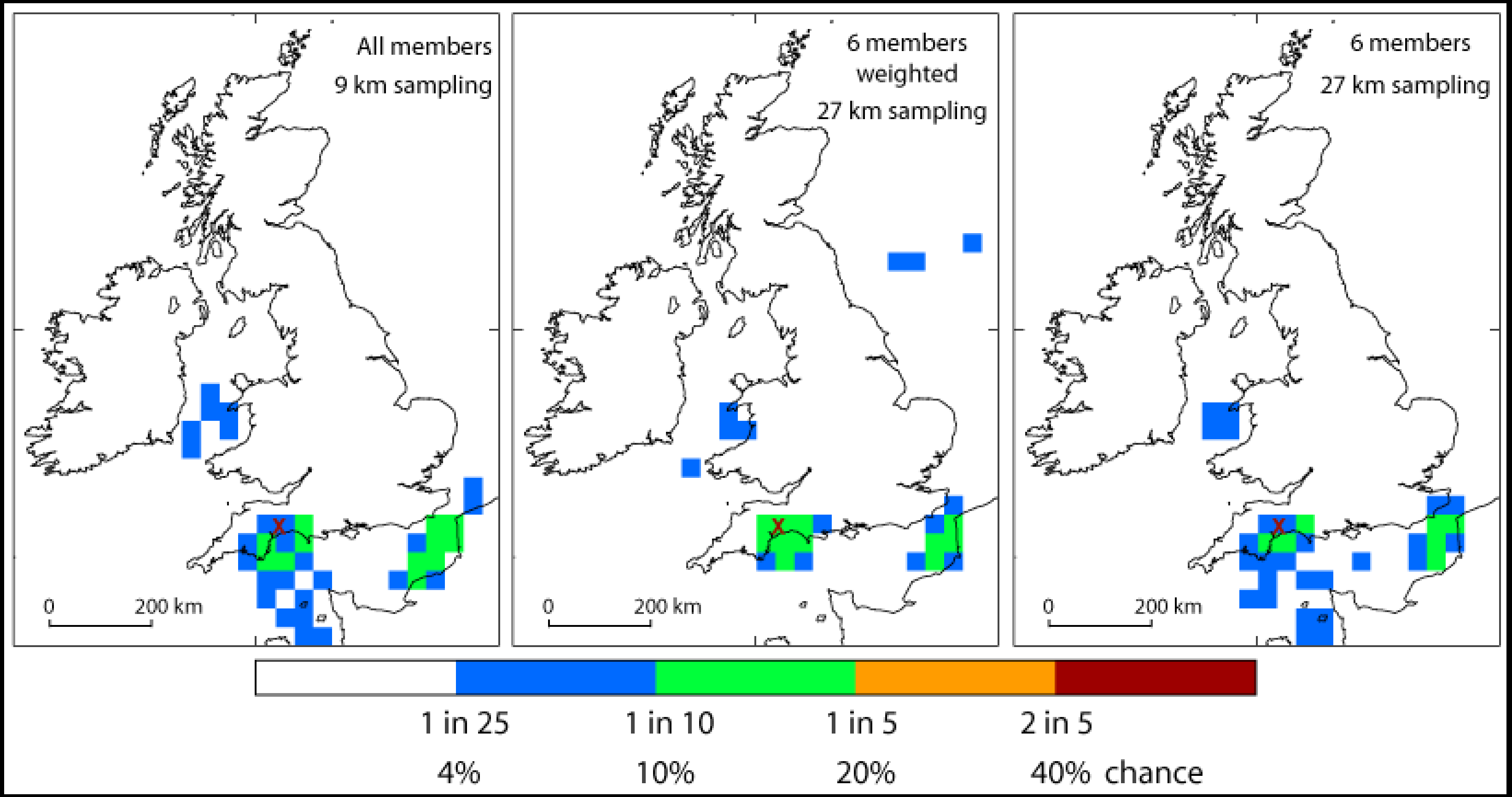
Probabilities for each cluster



Nigel Roberts

Met Office

Are the representative members as representative as they could be?



Need to examine both current and new (e.g. spatial) member selection methods

Nigel Roberts

Met Office

Convective-scale Ensembles Project

Take advantage of the benefits of high resolution (UKV) and sample the uncertainty in the mesoscale dynamics (MOGREPS-R) to give improved probabilistic forecasts of local weather.

There's plenty to think about and do!

Met Office

Thanks for listening.