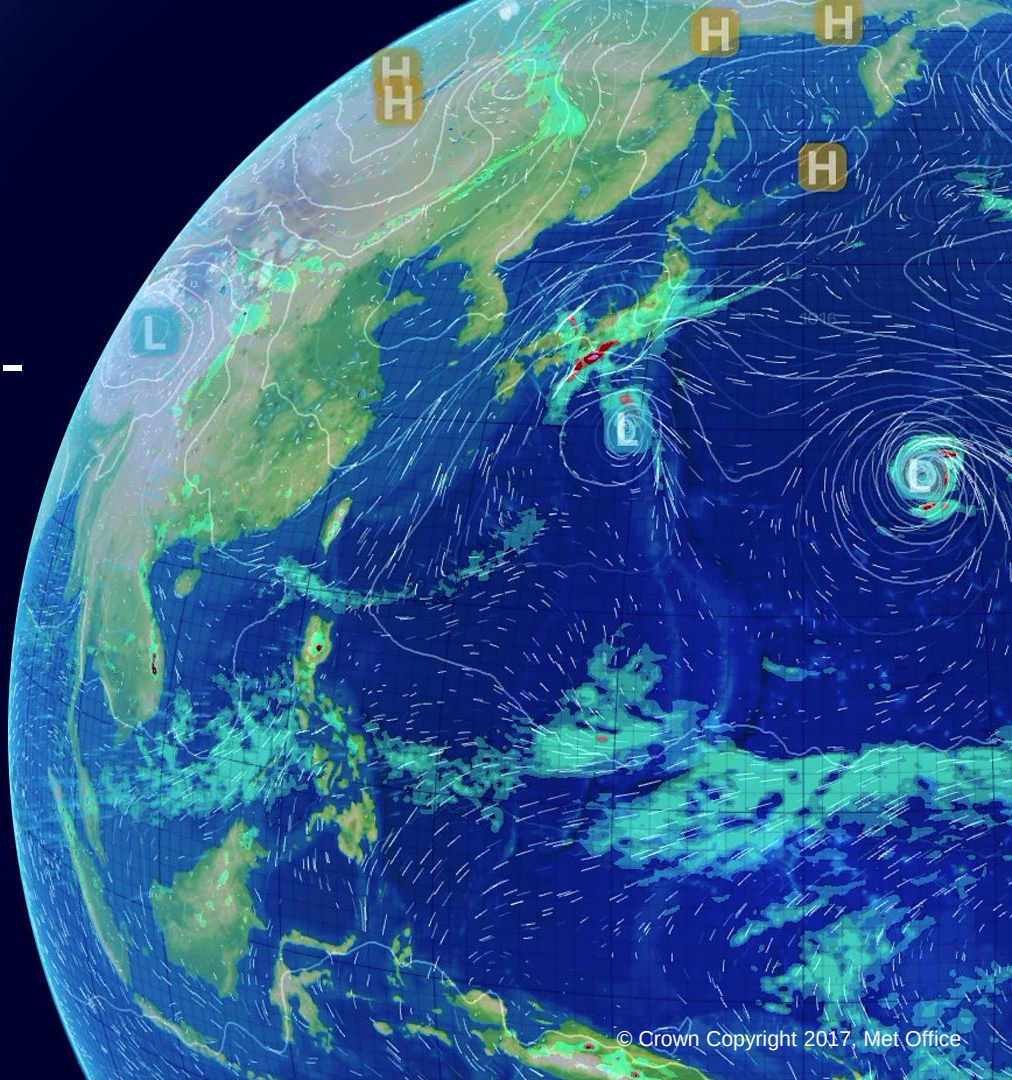
Generating probabilistic forecasts from convection-permitting ensembles

Nigel Roberts



Context for this talk

This is the age of the “convection-permitting” model ensemble

Met Office:

MOGREPS-UK UK 2.2km /12 members / T+54 / 6-hourly

More members, more detail, more frequency, longer forecasts, more data, more confusion, more headaches!

New post processing approach essential

Context for this talk

Post Processing Review Nigel Roberts and Marion Mittermaier

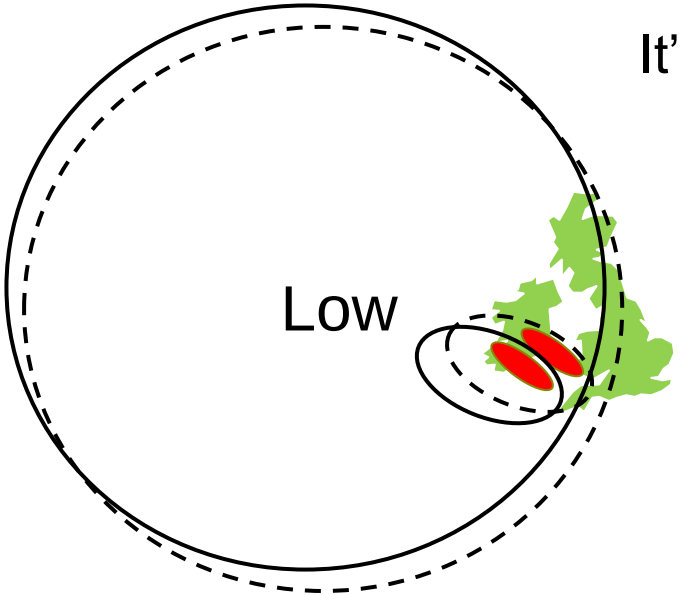
Presented to Met Office Science Advisory Committee (MOSAC) 2016

- **Single, integrated, modular processing chain**
- **Sequential application of:**
  'physical', 'statistical' and 'neighbourhood' processing
- **Probabilistic at the core – forecasts blended using probabilities**
- **Spot forecasts from probabilities**
- **Verification at every stage**

Science aspects

IMPROVER

Predictability and scale



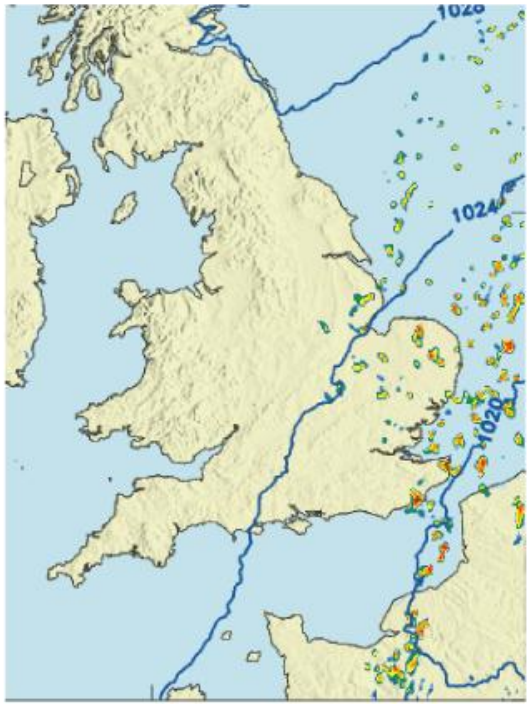
It’s all about scales!

Much less predictability at small scales

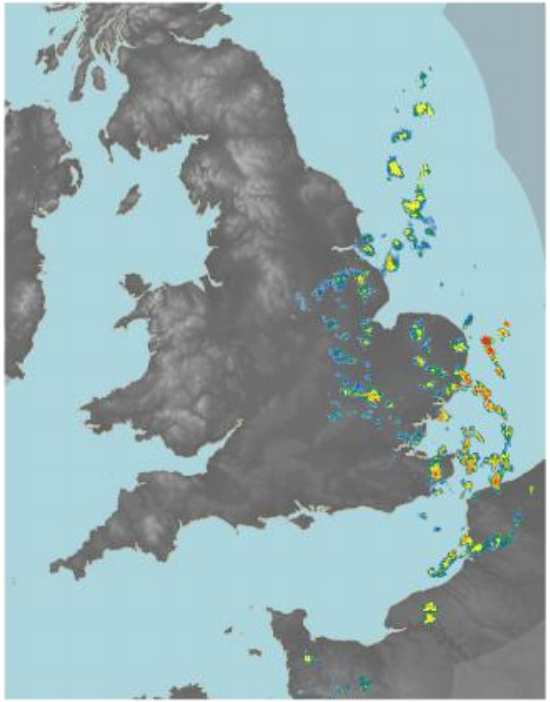
5% error over 1000 km = 100% error over 50 km

A lot of detail in a convection-permitting model

UKV model forecast



Radar for the same time



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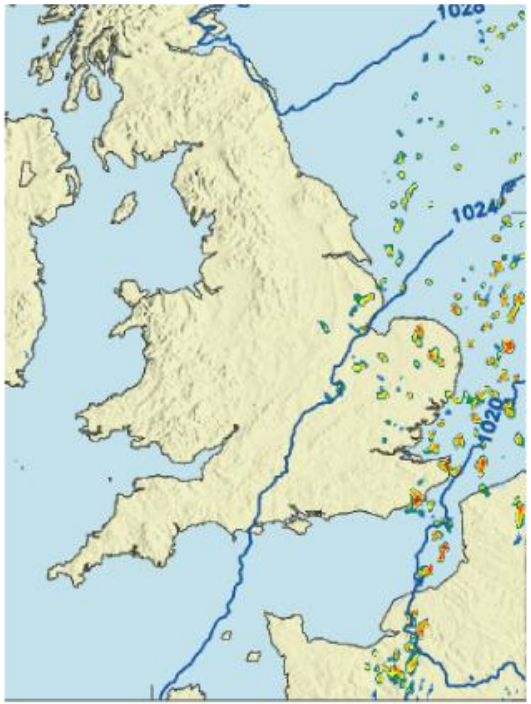

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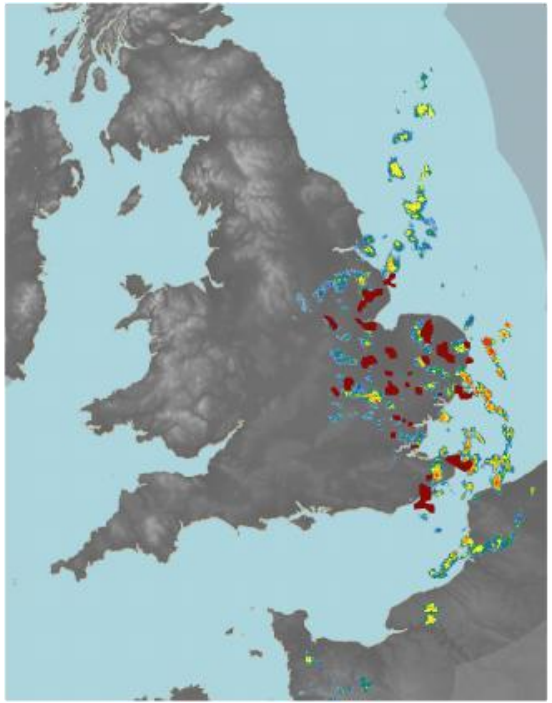

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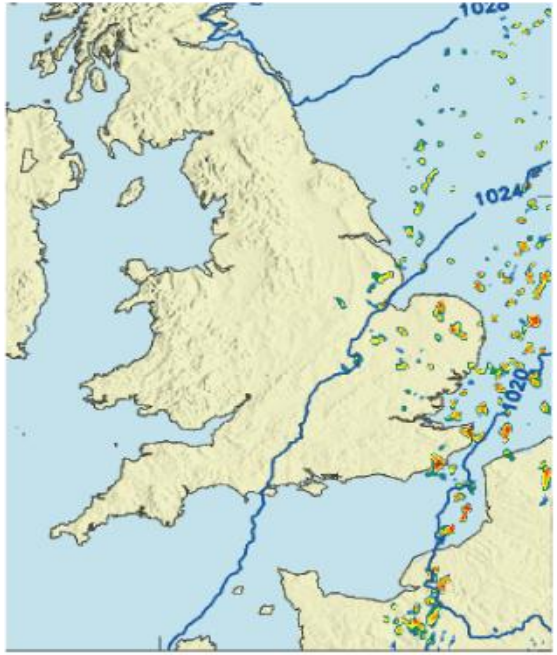
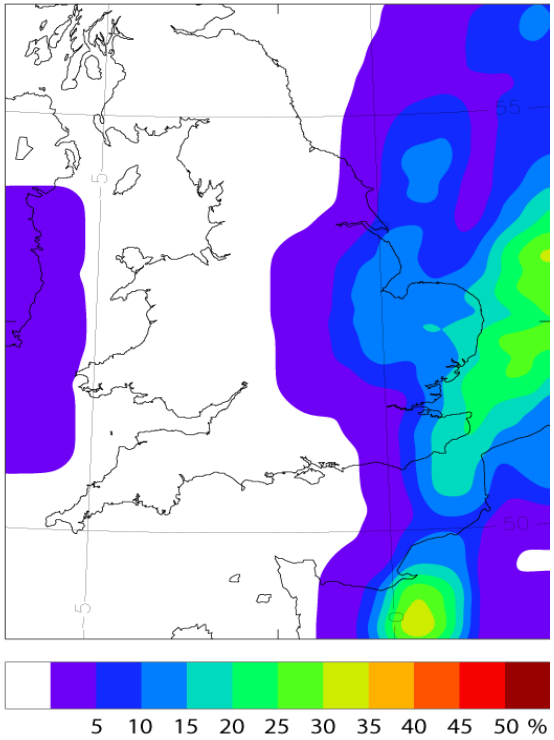
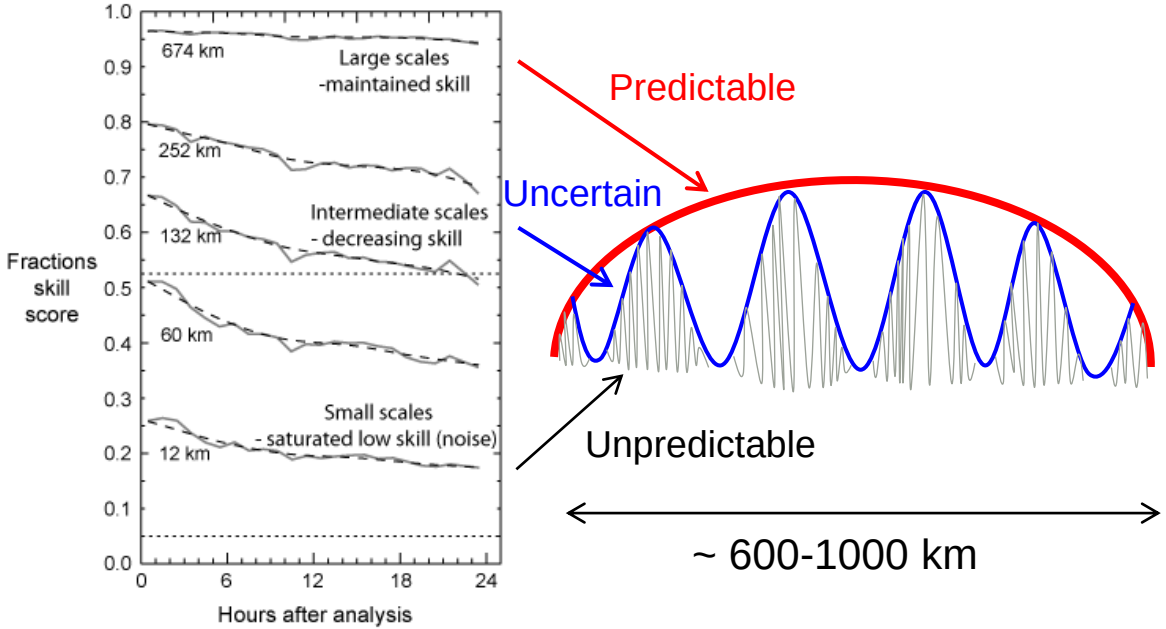


Better as probabilities



Ensembles and scales of interest

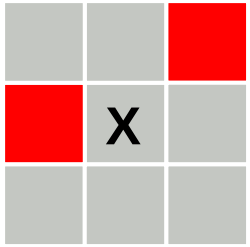


Predictable scales (large synoptic) – no need for an ensemble

Uncertain scales (mesoscale) – ensemble needed

Unpredictable scales (individual showers) – large ensemble needed (how?)

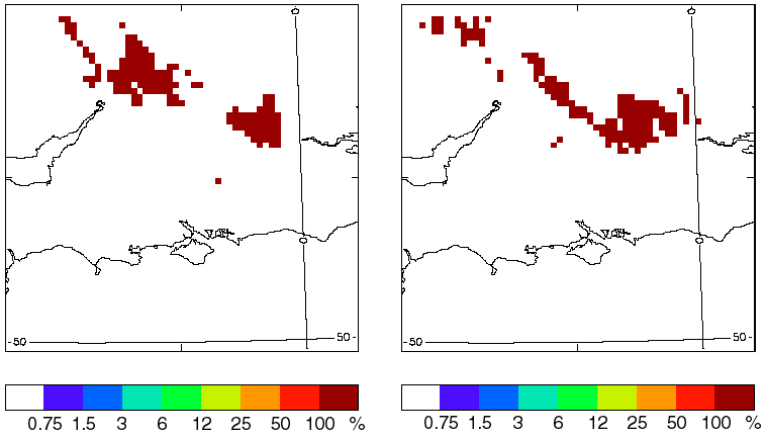
Neighbourhood processing for unpredictable scales



e.g. 3x3 neighbourhood

What happens at a particular model grid square is equally likely to occur at nearby grid squares

Probability at **X** = 2/9 = 22%



A deterministic forecast becomes a 9-member ensemble (or 25 member ensemble using a 5x5 neighbourhood etc)

Could apply to an ensemble

A 9x9 neighbourhood and 12-member ensemble = 972 members

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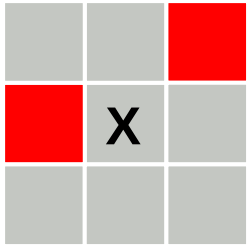

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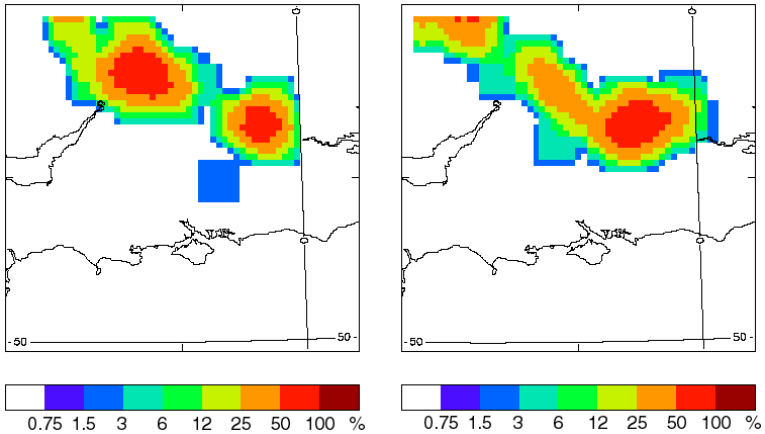

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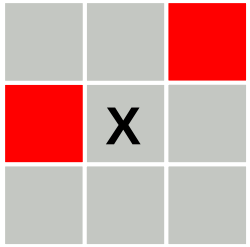

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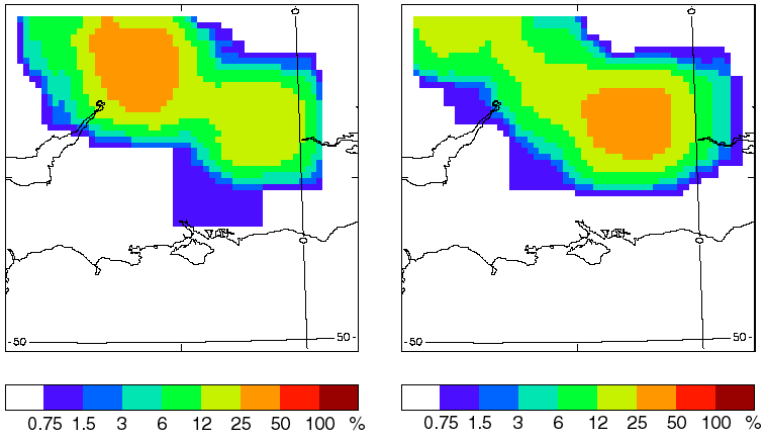

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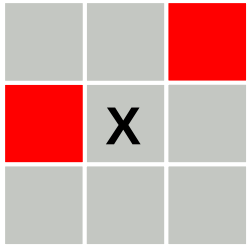

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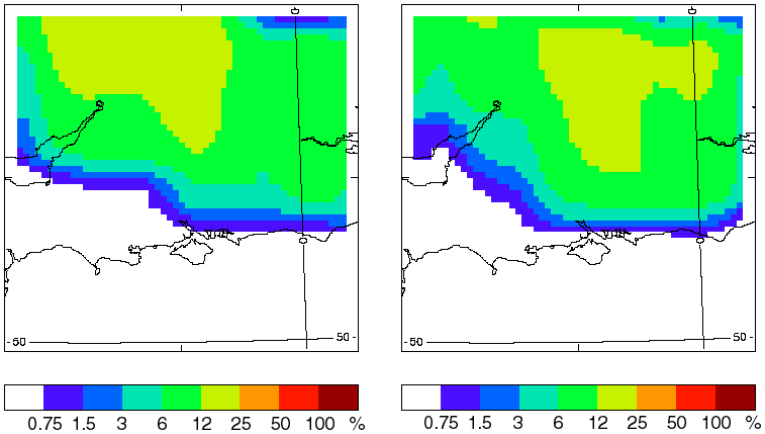

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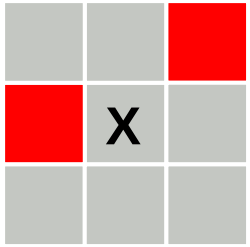

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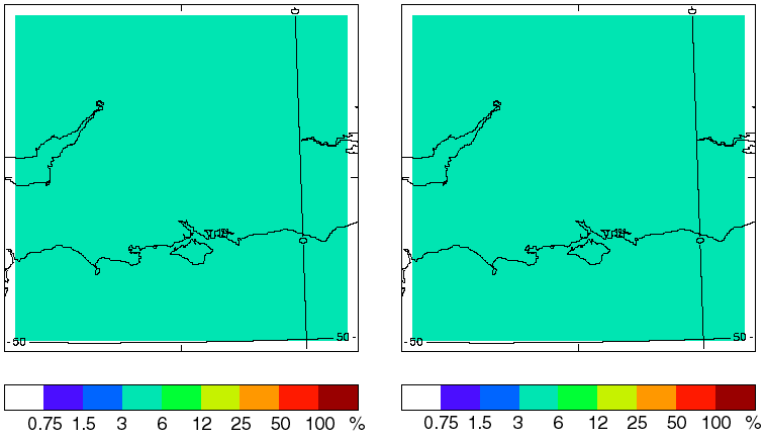

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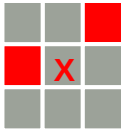
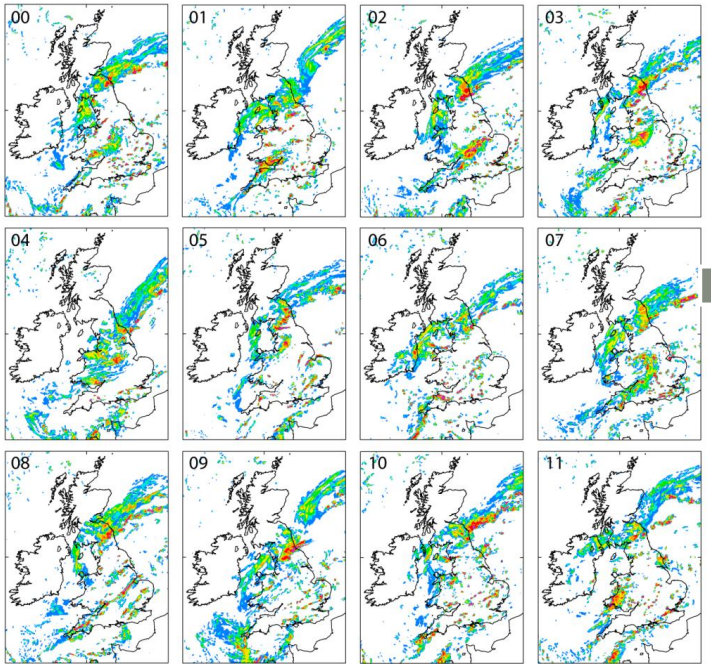
Making a probability forecast (MOGREPS-UK)

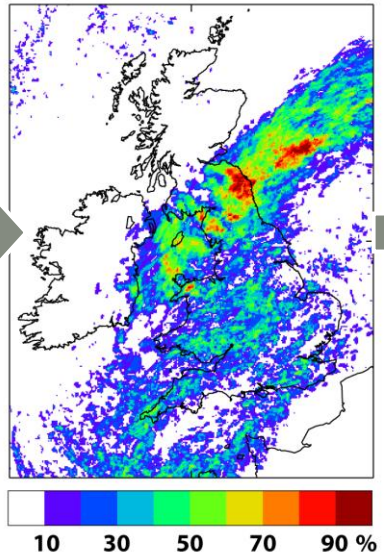
Ensemble + neighbourhood



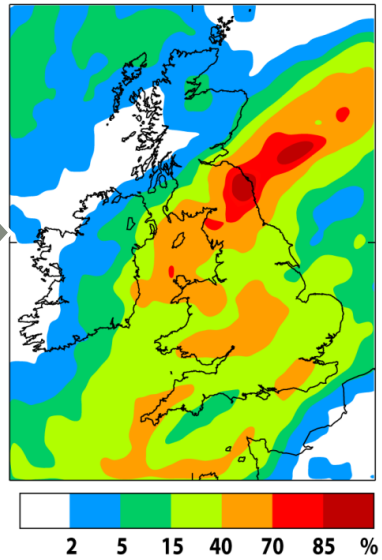
MOGREPS-UK - 54-hr forecasts every 6 hours.
12 members, 2.2km grid spacing, embedded in global ensemble MOGREPS-G



Gaps because of under-sampling



More sensible probabilities with additional neighbourhood processing

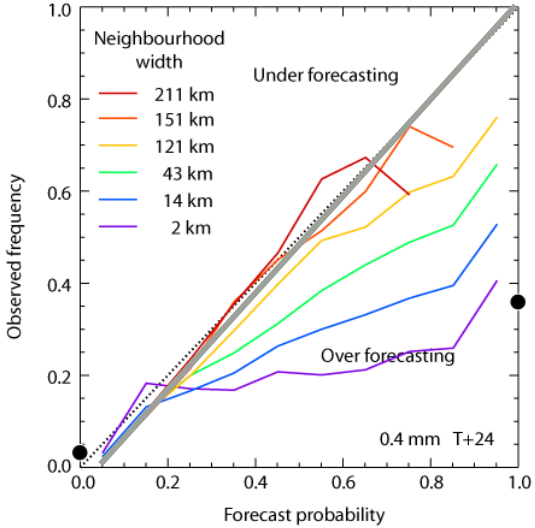


How do we know what size neighbourhood to use? 3x3, 7x7, 11x11, 51x51 ??

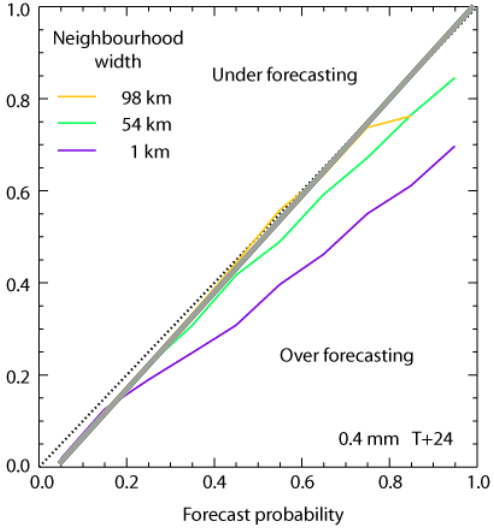
UKV and MOGREPS-UK verification
Feb to Aug 2013

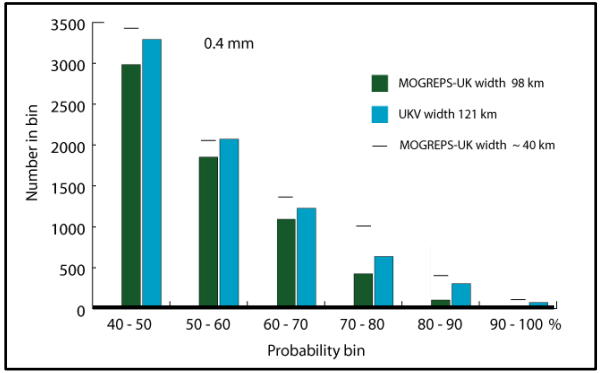
Around 300 rain gauges, 4 forecasts per day

1.5 km deterministic (UKV)



2.2 km 12-member downscaling ensemble (MOGREPS-UK)





Similar findings to Bouallegue and Theis (Met Apps 2013) and Duc et al (Tellus 2013)

What does neighbourhood processing do for precipitation forecasts ?

1. Introduces spatial uncertainty – increases the ensemble spread

-Essential for a deterministic forecast (which has no uncertainty unless time-lagged)
- Should be small effect for a well spread large ensemble

2. Filling in gaps due to under-sampling (shouldn't change inherent spread)

-Essential for a small ensemble, less necessary for a large ensemble
-Essential for a deterministic forecast (although a special case)

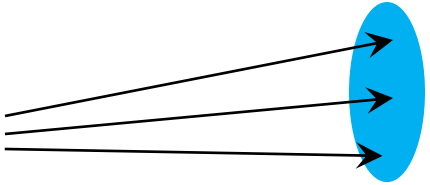
Benefit to both ensemble and deterministic forecasts but in different ways

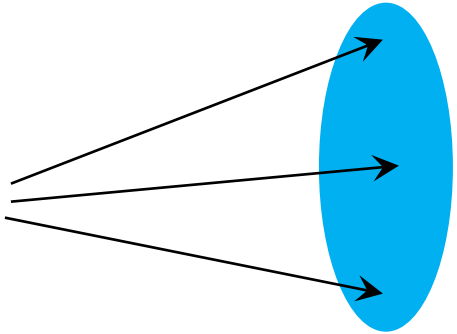
3. Allows blending between ensembles/models or time-lagging on appropriate scales

-Seamless forecasting

How large should the neighbourhood be?

The neighbourhood size should depend on the spatial ensemble spread





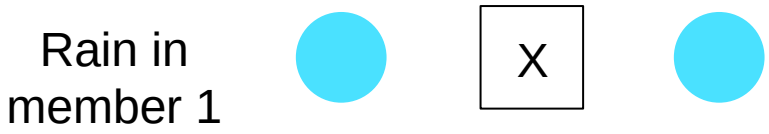
More ‘gaps’ to fill. More possible storm locations - bigger neighbourhood

Provided that ensemble has appropriate spread at larger scales (spans the blue area).

If we don’t adapt the neighbourhood size to the spatial spread we are not letting the ensemble define the spread – but are contriving spread.
(merits or otherwise of that depend on the ability of the underlying ensemble to capture larger-scale uncertainty, and our philosophy about tampering with the ensemble spread!)

Adapt the neighbourhood size to the spatial ensemble spread (rather than being a fixed size)

Want the neighbourhood to fill the gaps and no more



Consider different sized neighbourhood squares centred at point X

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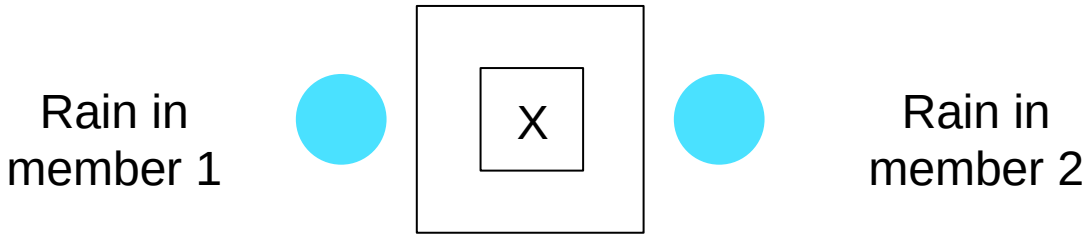

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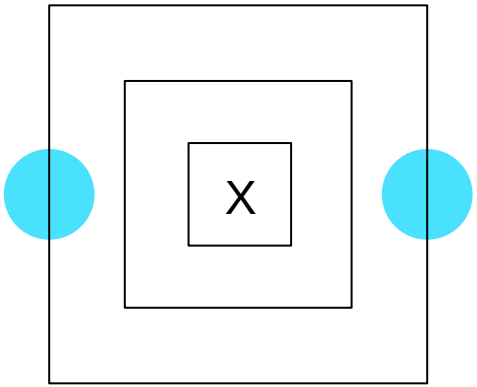
Rain in member 1

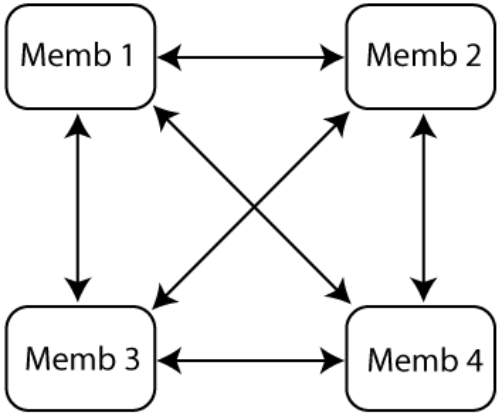


Rain in member 2

Consider different sized neighbourhood squares centred at point X

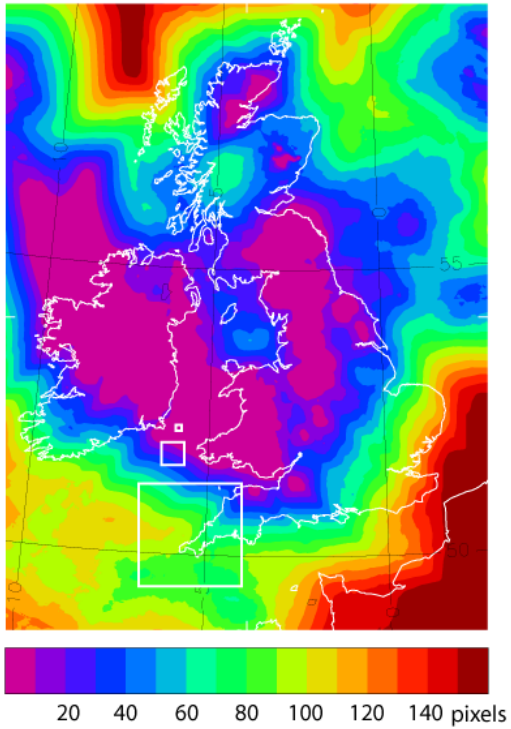
Do this for all points

Creating a neighbourhood size map



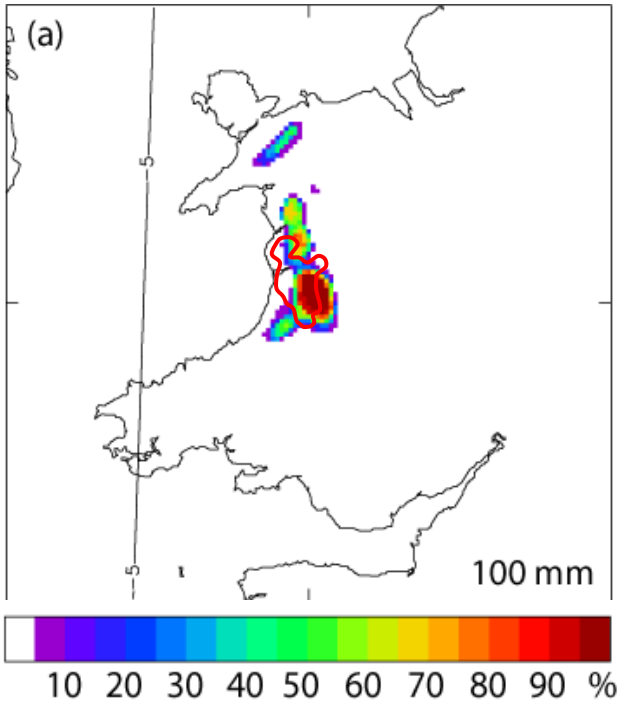
12 members = 66 comparisons

Use the mean/median value at each grid point to give neighbourhood map (simplest)



An example – flooding in Wales

Same principles apply to any threshold or variable



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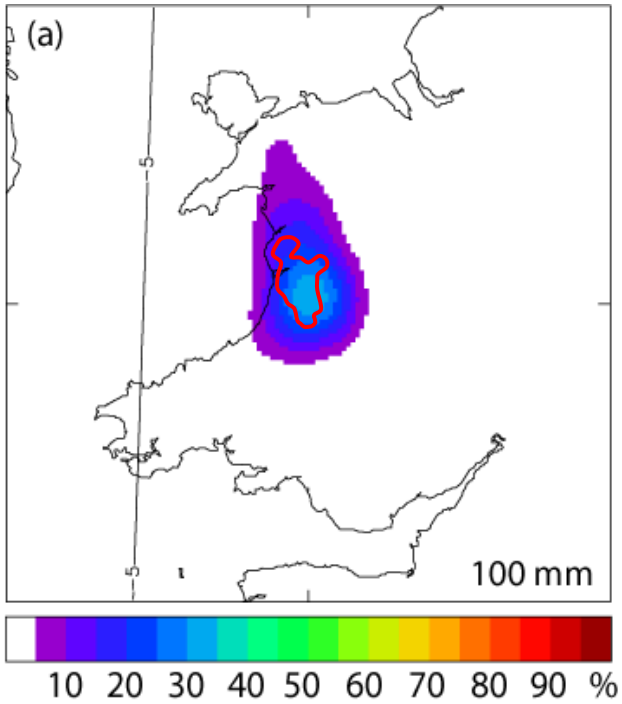

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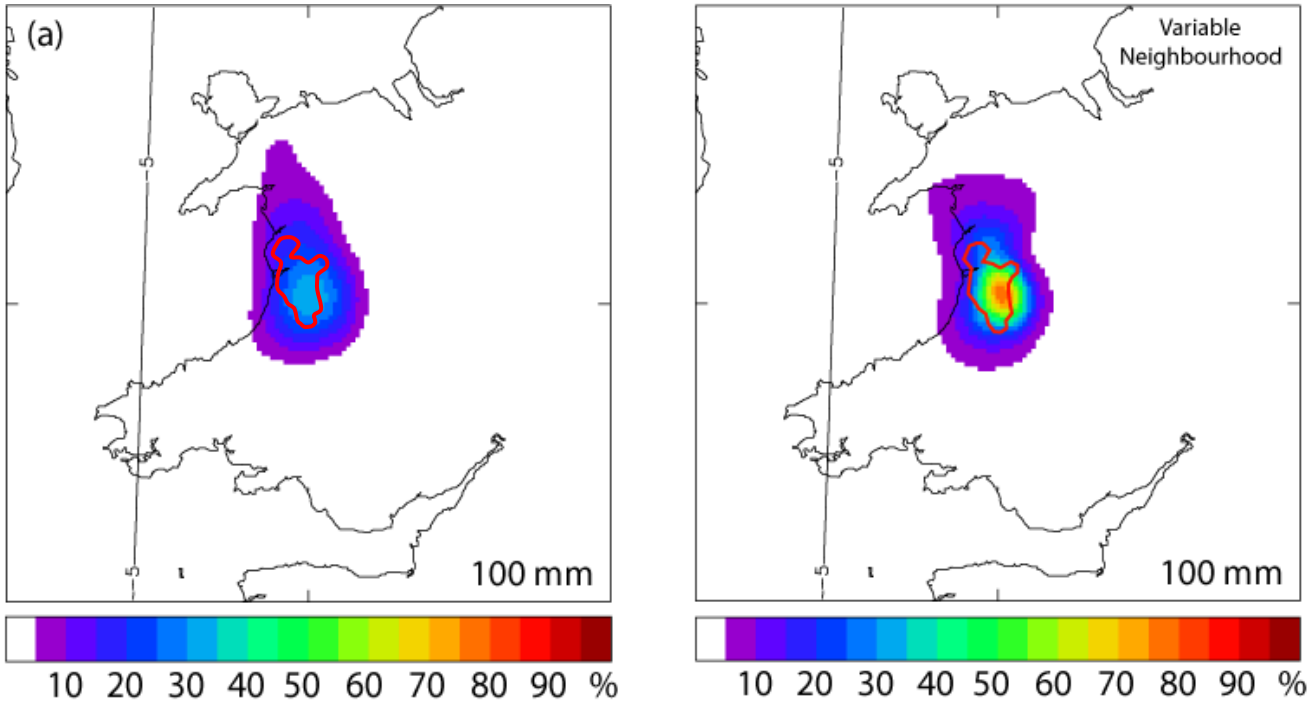
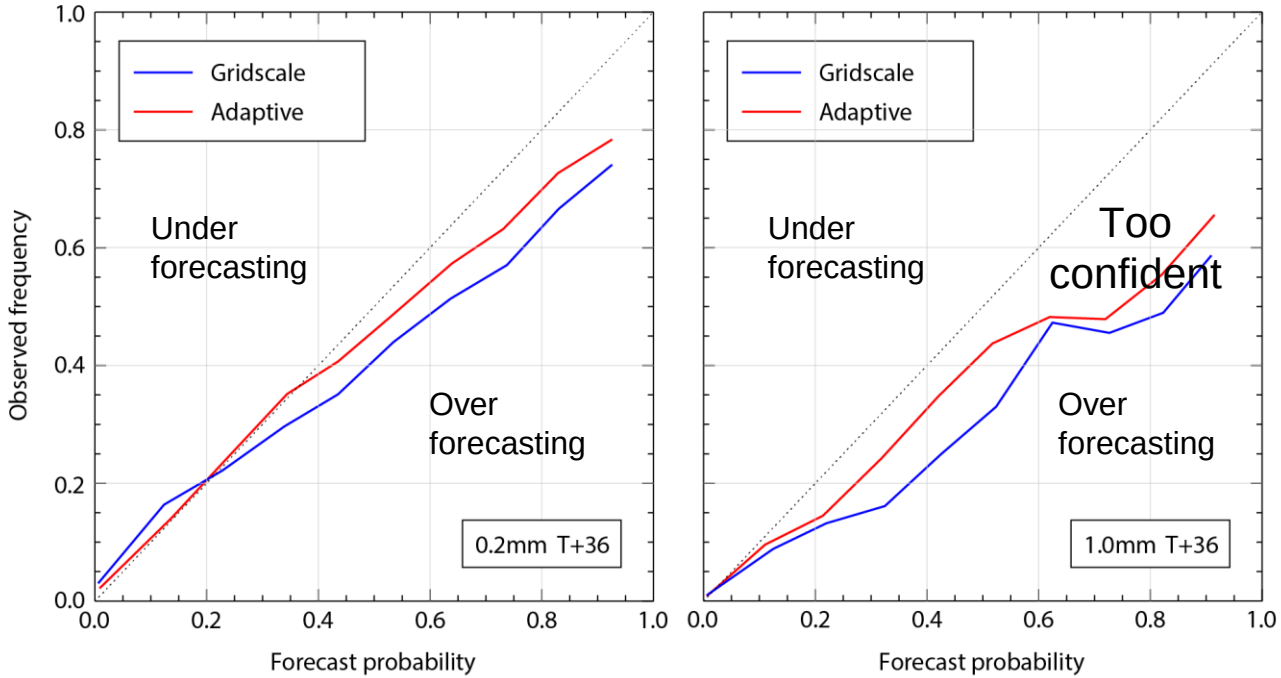


Verification results from adaptive neighbourhood

	95.35	2.89	1.36	0.27	0.12 %
	95.98	2.99	0.77	0.19	0.07



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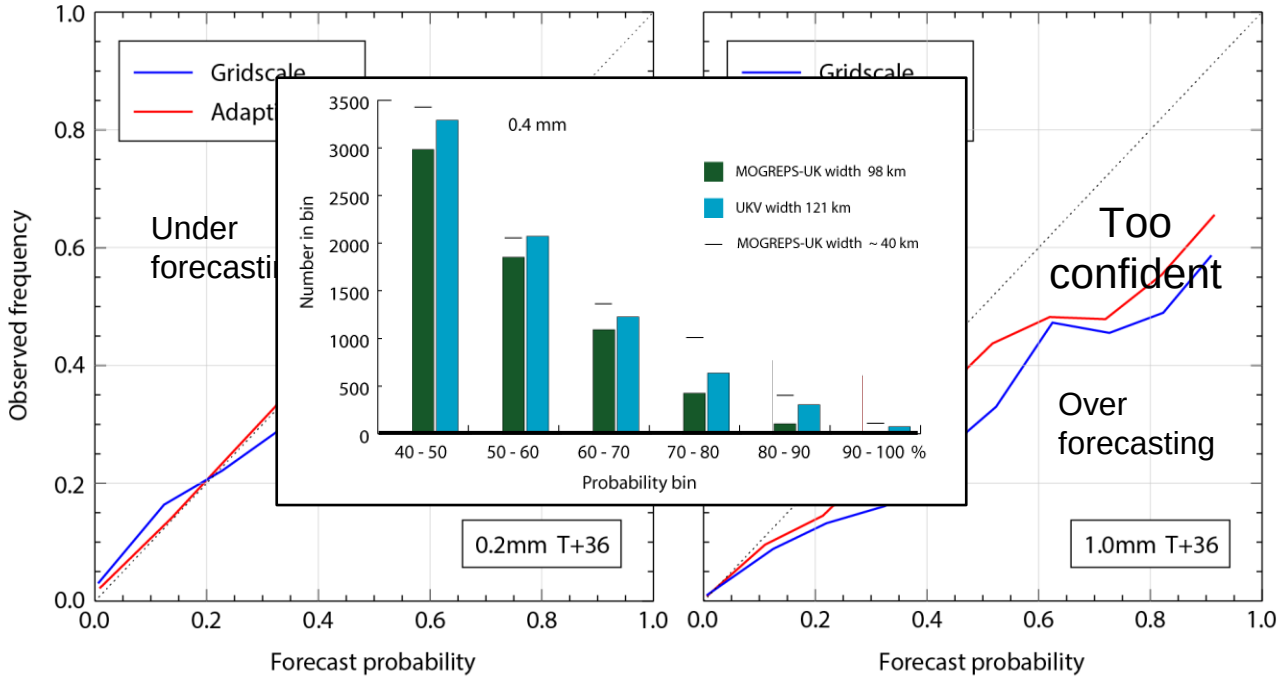

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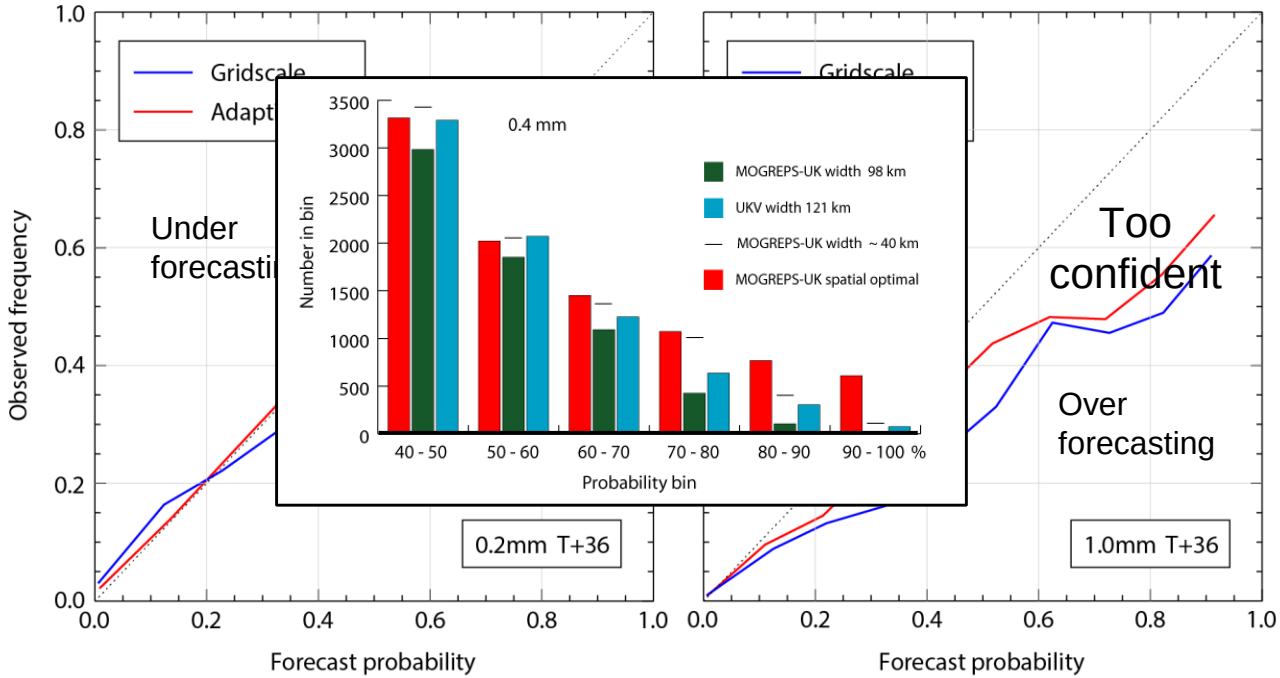
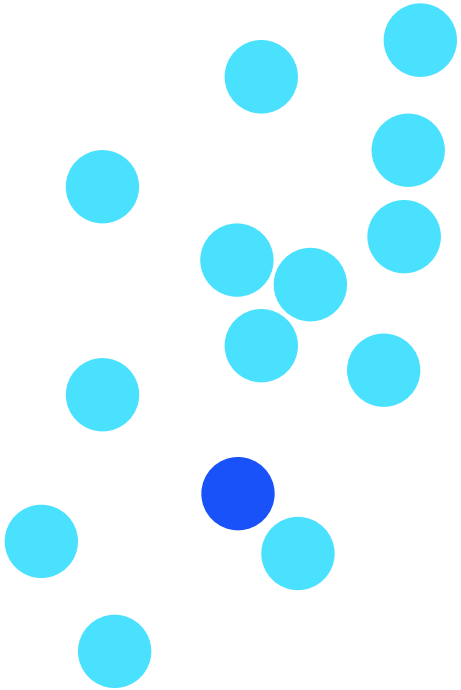


Met Office

Does the ensemble indicate the true uncertainty?
- the skill-spread relationship
- think spatial!



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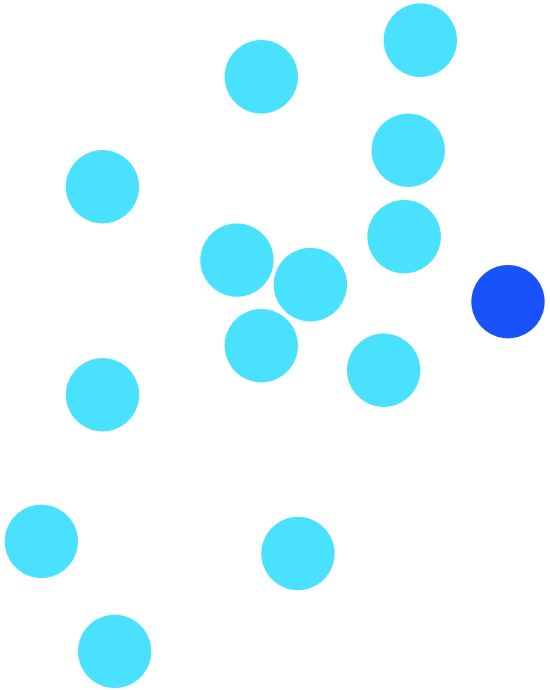

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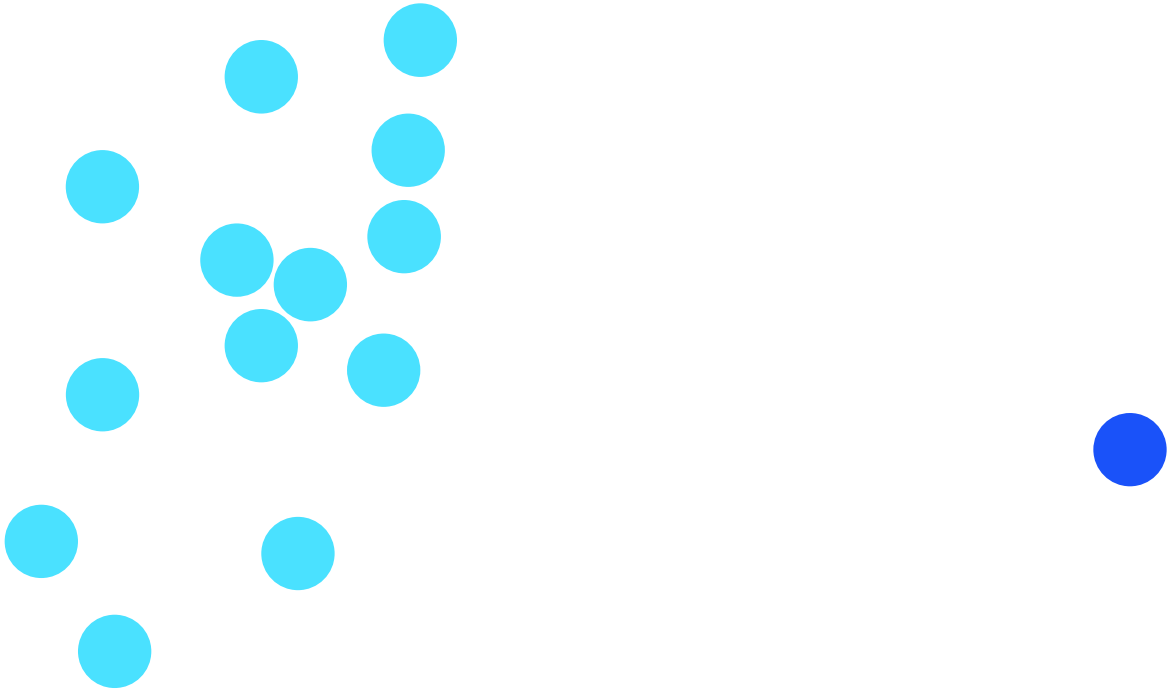
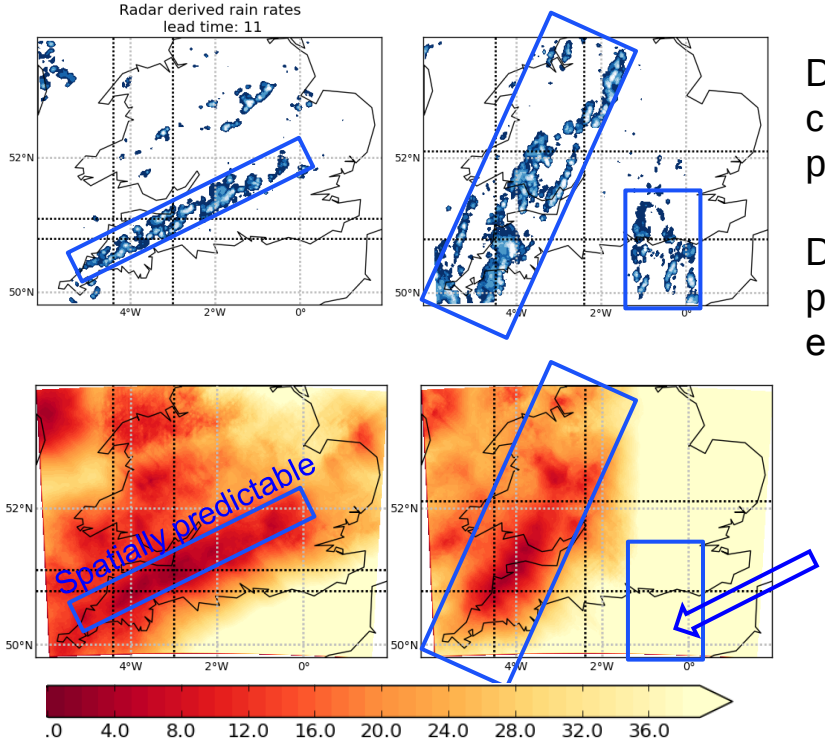


Use ensemble to give information about spatial uncertainty and verify spatially



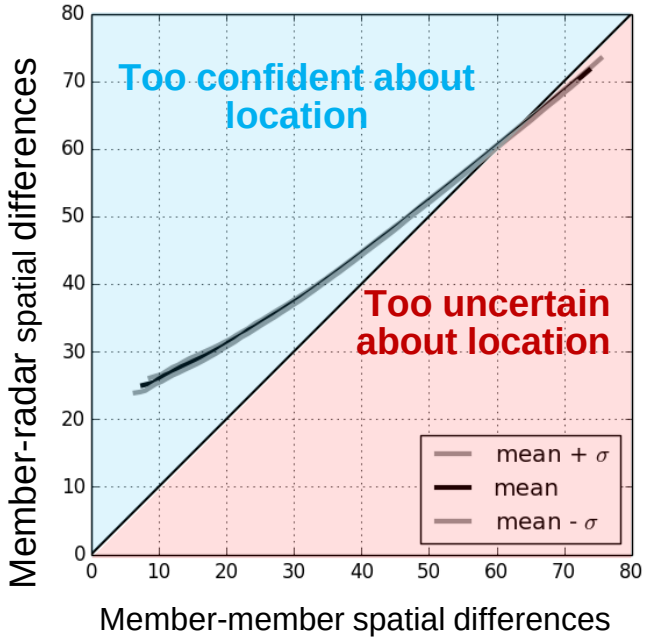
Dey et al, 2016, QJ “A new method for the characterization and verification of local spatial predictability for convective-scale ensembles.”

Dey et al, 2016, QJ “Assessing spatial precipitation uncertainties in a convective-scale ensemble”

Courtesy of Seonaid Dey

Quantitative measure of ensemble spatial skill-spread

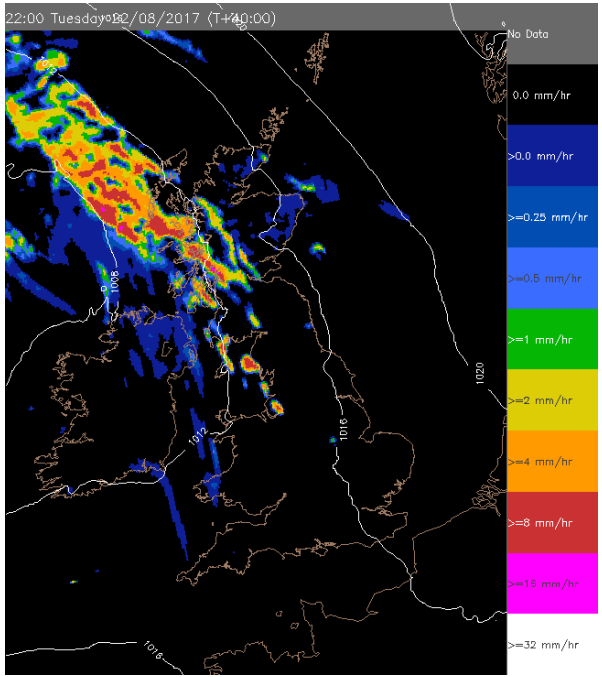
MOGREPS-UK, hourly instantaneous rain rates, three months of data (June, July, August 2013)



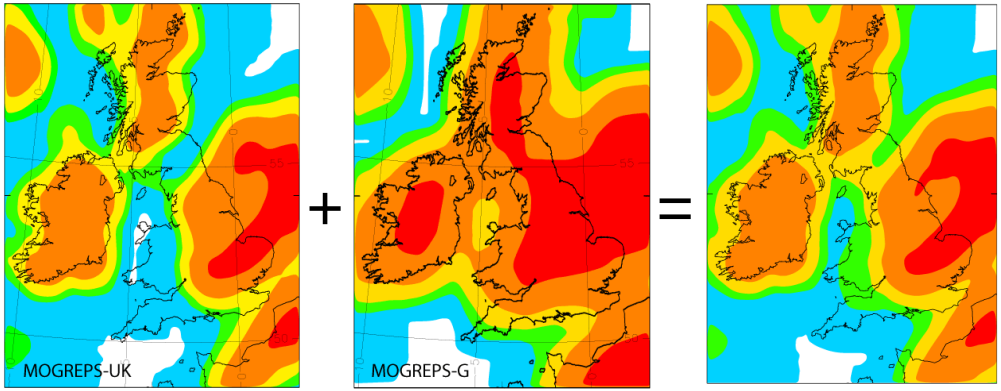
- Overall doing a reasonable job
- Somewhat too confident about where rain will occur
- Useful tool for evaluating spatial predictability from ensemble

Courtesy of Seonaid Dey

Blending or time-lagging using probabilities



Smoothly varying probabilities of rain occurring



80% 20%

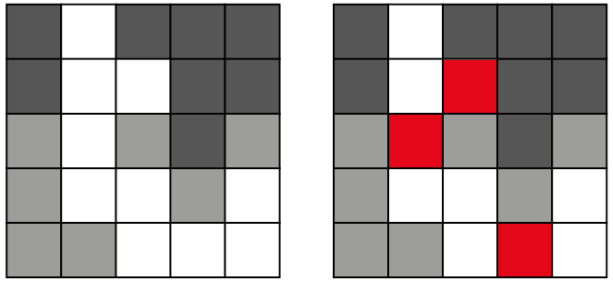
Requires compatible variables and a suitable filter length (neighbourhood x ensemble size) and weighting.

Match scales based on spatial uncertainty

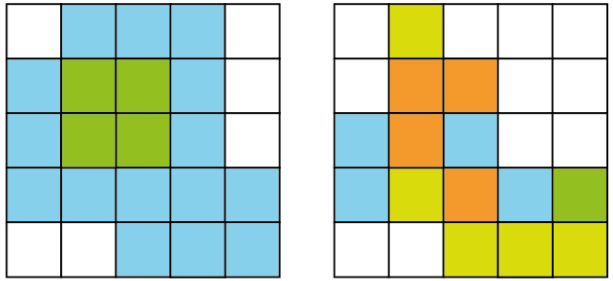
Seamless prediction

Still may require additional calibration

Topography and neighbourhoods

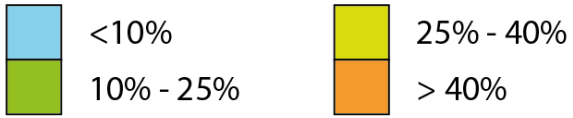


3x3 neighbourhood

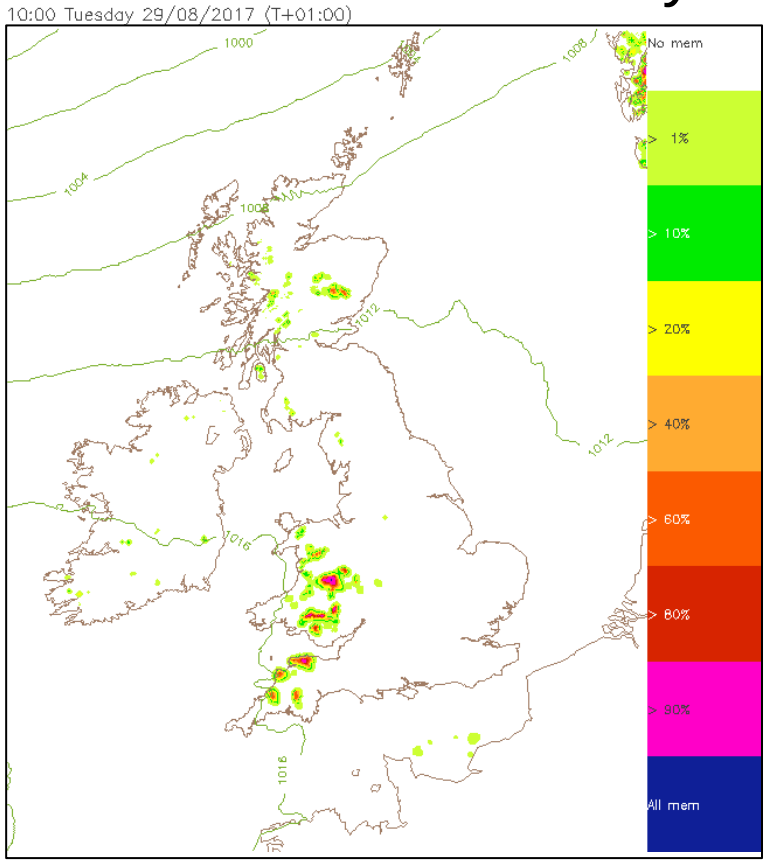


3x3 neighbourhood

adjust for topography



Visibility < 350m



Neighbourhood accounts for topography

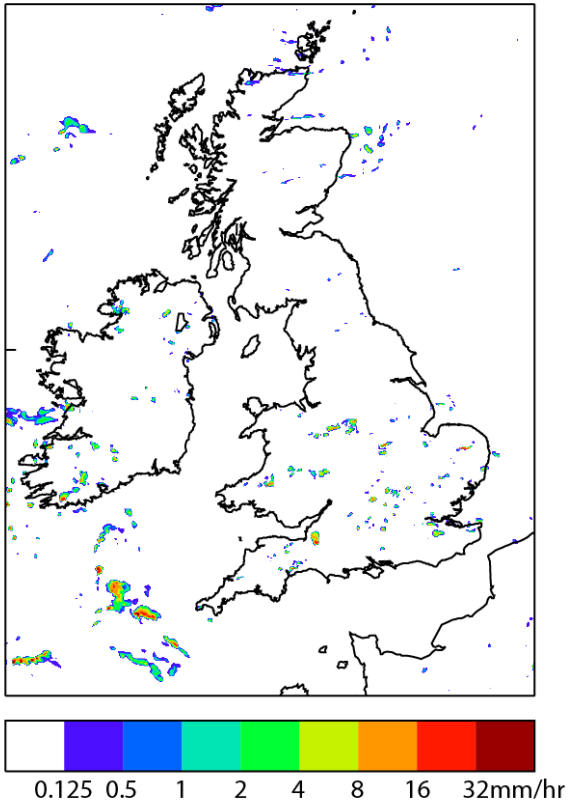
Courtesy of
Stephen Moseley

Include a temporal or spatial tolerance

Probability of rain occurring at 17UTC

Scattered showers – appropriate neighbourhood means that probabilities are small at any particular location

Step out door at 17UTC probably won't get wet – but is that helpful?



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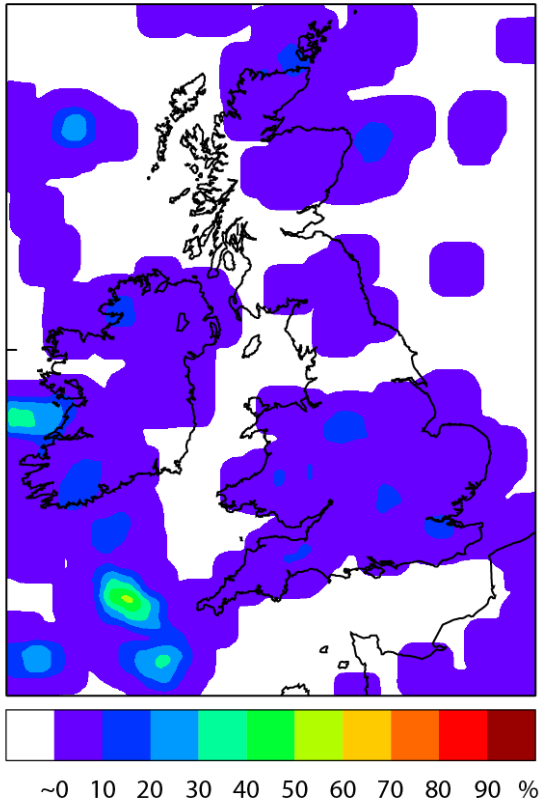


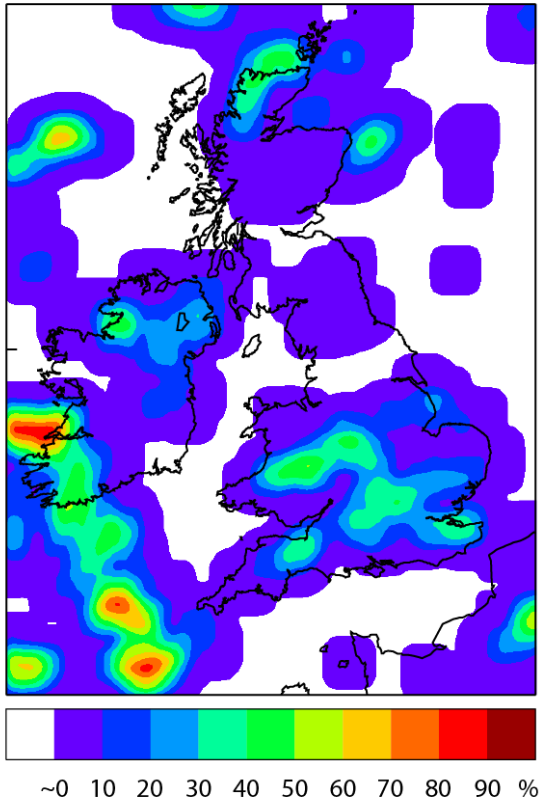
Include a temporal or spatial tolerance

Probability of rain occurring at 17UTC

More appropriate for rare but more severe
- Lightning or tornadoes (as done in the US Storm Prediction Centre)

Increases high probabilities
-Better “ensemble resolution”

-Probabilities large enough to be acted on, even if not so geographically (or temporally) specific



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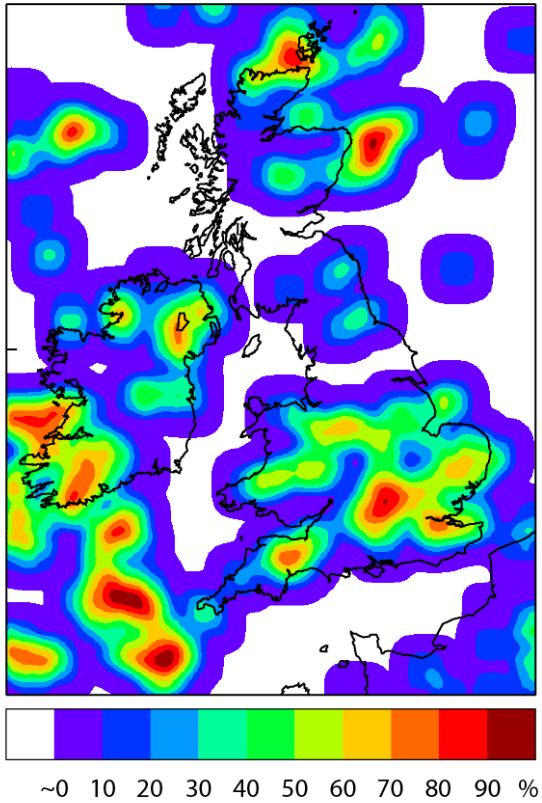

Some conclusions

Neighbourhood processing brings huge improvement to deterministic convection-allowing NWP precipitation forecasts and provides probabilistic output

Neighbourhood post processing is needed to account for under sampling – and it also improves performance of convection-permitting ensembles

MOGREPS-UK ensemble able to give a useful indication of the spatial uncertainty in precipitation forecasts

Spatial skill-spread verification indicates that MOGREPS-UK is somewhat overconfident about rainfall positioning – agrees with subjective view of forecasters

New experimental approach to make neighbourhood sizes adapt to the spatial ensemble spread – doesn't need training, doesn't change the spatial spread of the underlying ensemble (won't contaminate science changes)