When the rain falls between the gauges. How good is radar really at telling you what's happening on the ground?

Very preliminary results and an invitation to collaborate…

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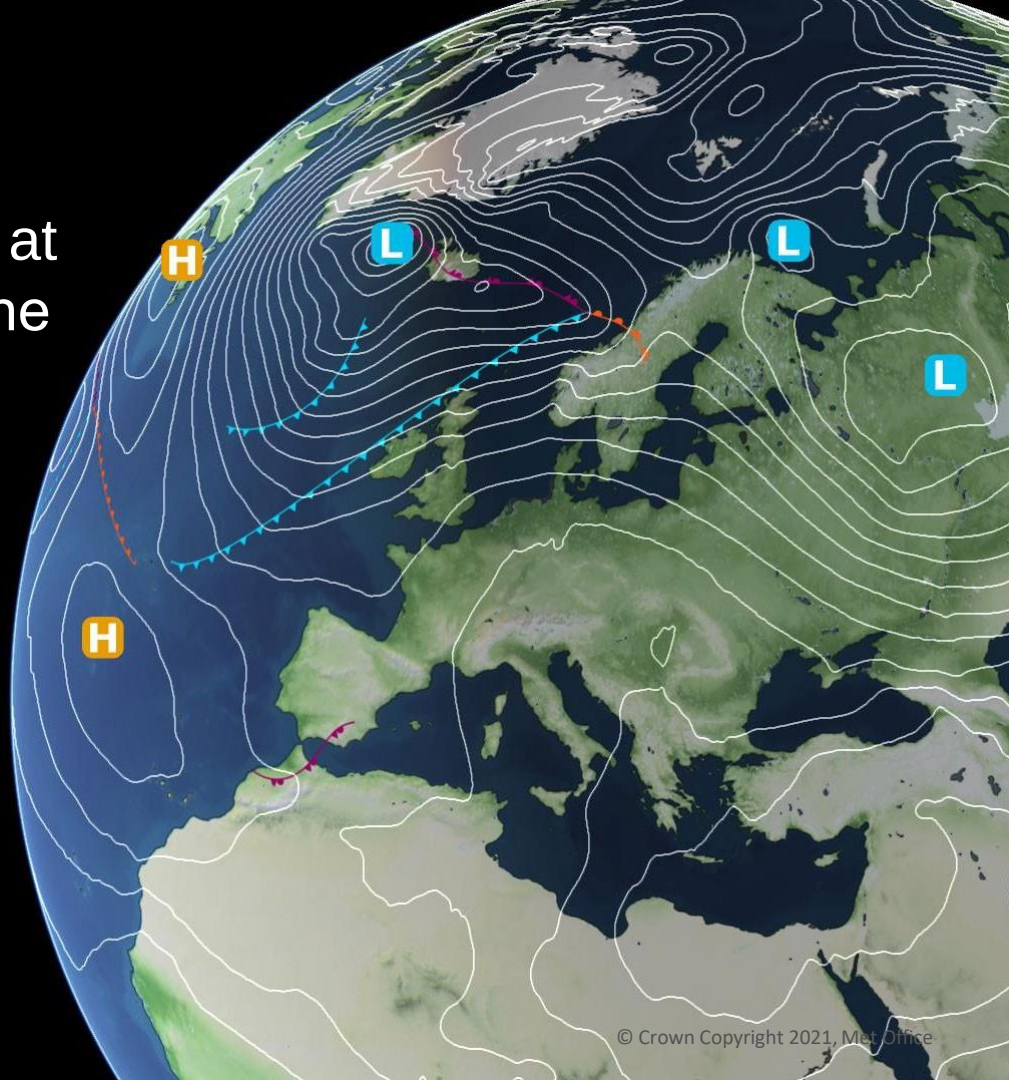
EWGLAM 2021



Met Office

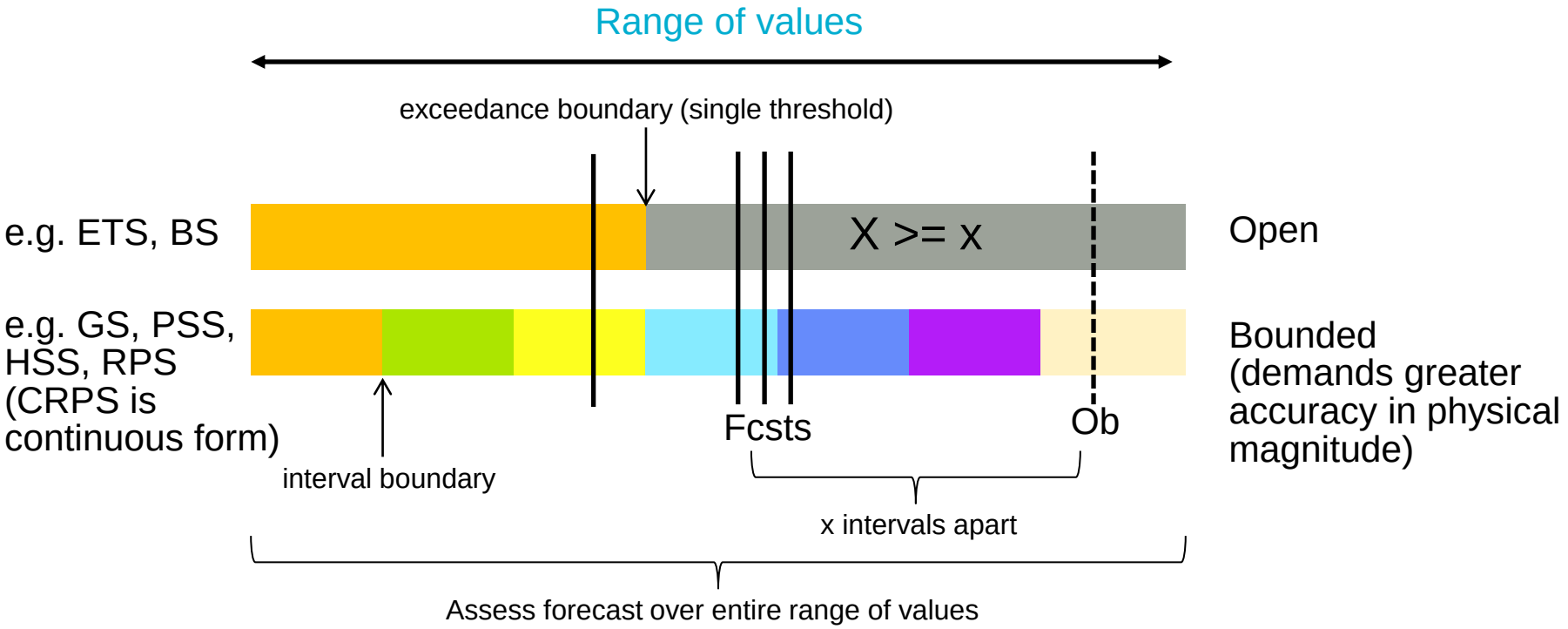
Issue: FSS and HiRA based precipitation scores often disagree.
FSS uses radar data and HiRA uses gauges.
Hypothesis: The observations, not the score, are the single biggest driver for these differences.
Test: Verify the radar against the gauges using HiRA

Outline

1. What is the problem?
2. Overview of Ranked Probability Score and High Resolution Assessment (HiRA)
3. Examples from this summer illustrating the sampling.
4. Initial analysis of model and radar RPS.
5. Hydrological examples where this observations dilemmas has emerged.
6. Initial summary and where next

Open-ended or distribution

Much tougher if forecast is assessed within a bounded range

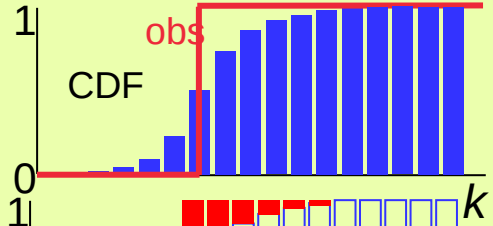


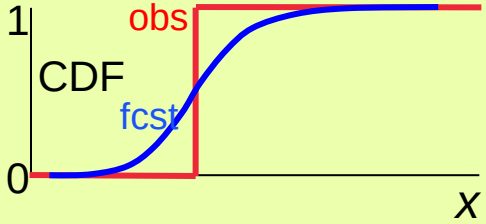
Ranked Probability Score and HiRA

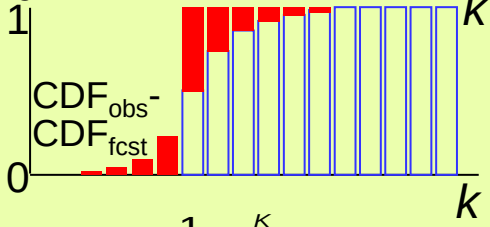
(Mittermaier 2014, Mittermaier and Csima 2017)

Variable	Thresholds
1h precipitation	0.25 0.5 1.0 2.0 4.0 8.0 16.0 32.0 64.0 mm/h

Modeller interested overall performance or pdf







$$CRPS = \int_{-\infty}^{\infty} (P_{fcst}(x) - P_{obs}(x))^2 dx$$

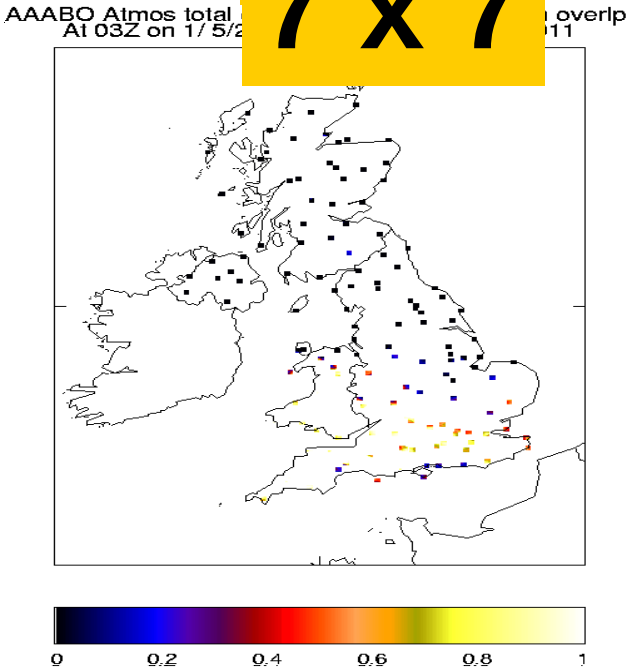
Perfect score = 0

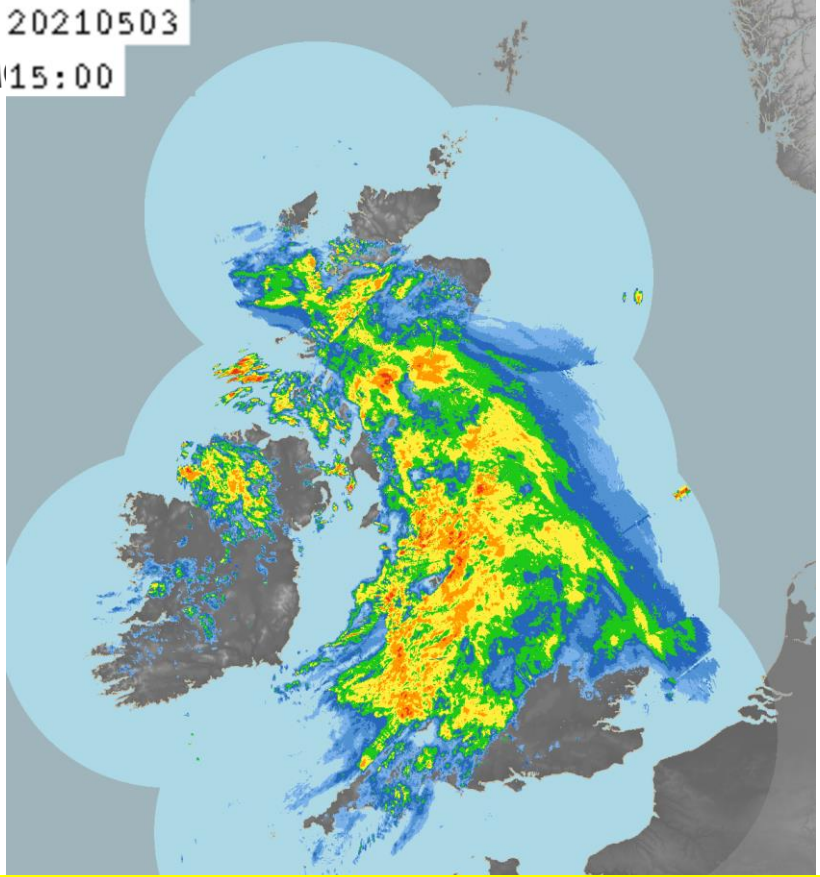
$$RPS = \frac{1}{K-1} \sum_{k=1}^{K} (CDF_{fcst,k} - CDF_{obs,k})^2$$

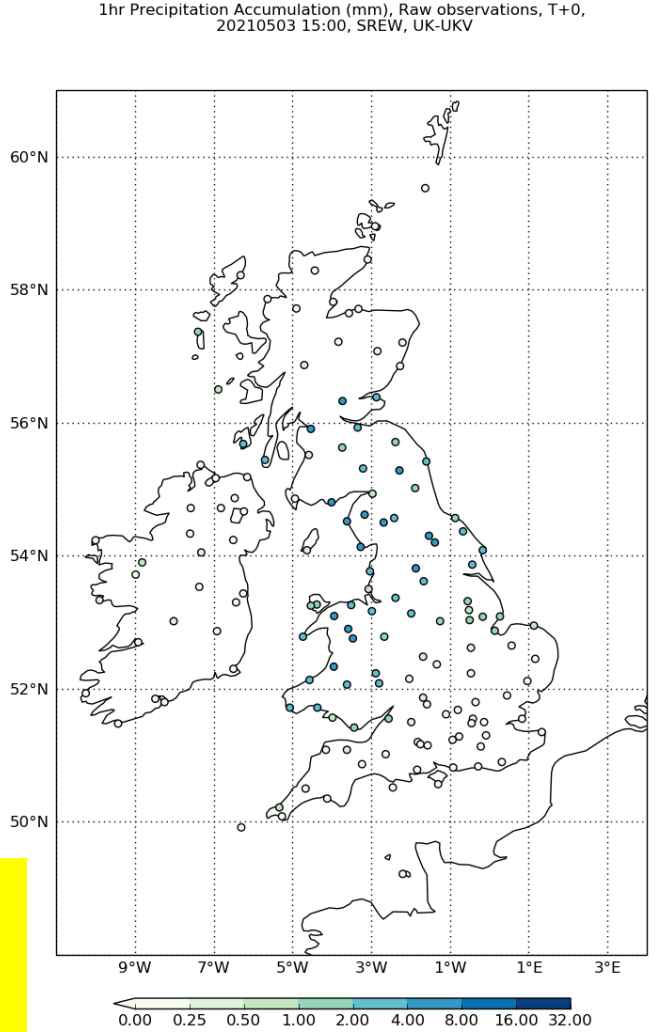
K = discrete threshold categories

Perfect score = 0

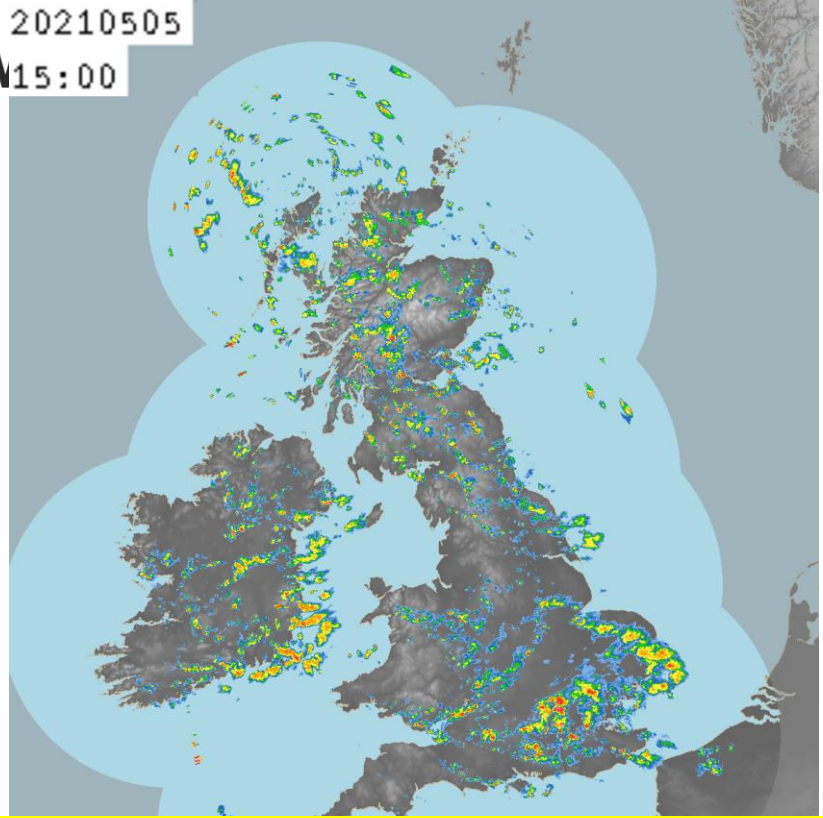
7 x 7

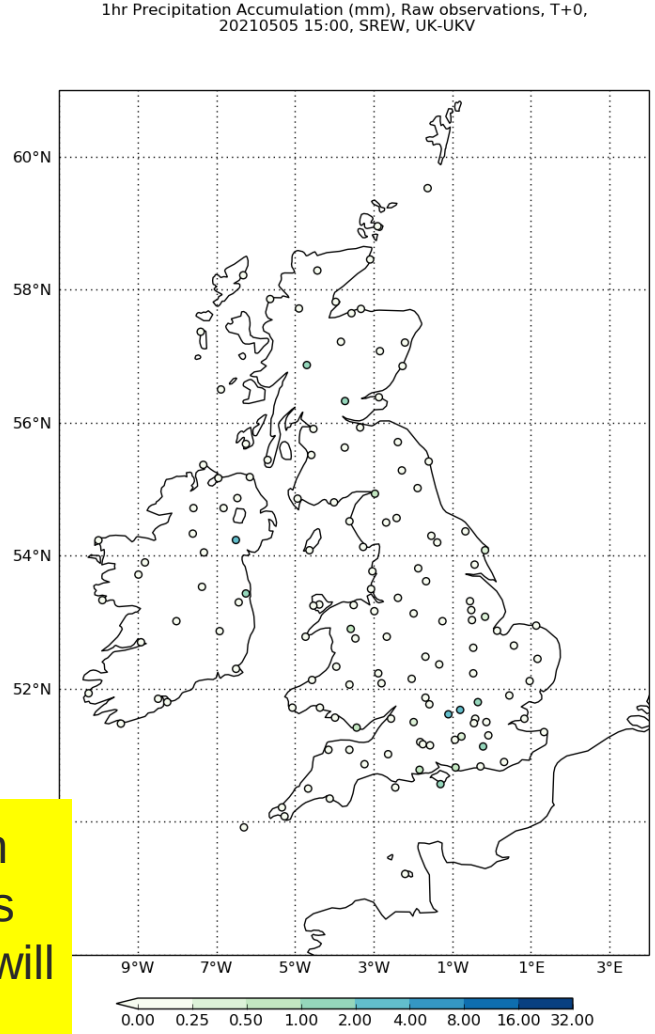






This is fairly wide spread rain fairly well sampled by the gauges but there are differences along the edges of the system





The convection is sampled to some extent in the south but it looks like a lot of the showers are falling between gauges, i.e. the gauges will portray the rainfall as a much sparser field.

Met Office

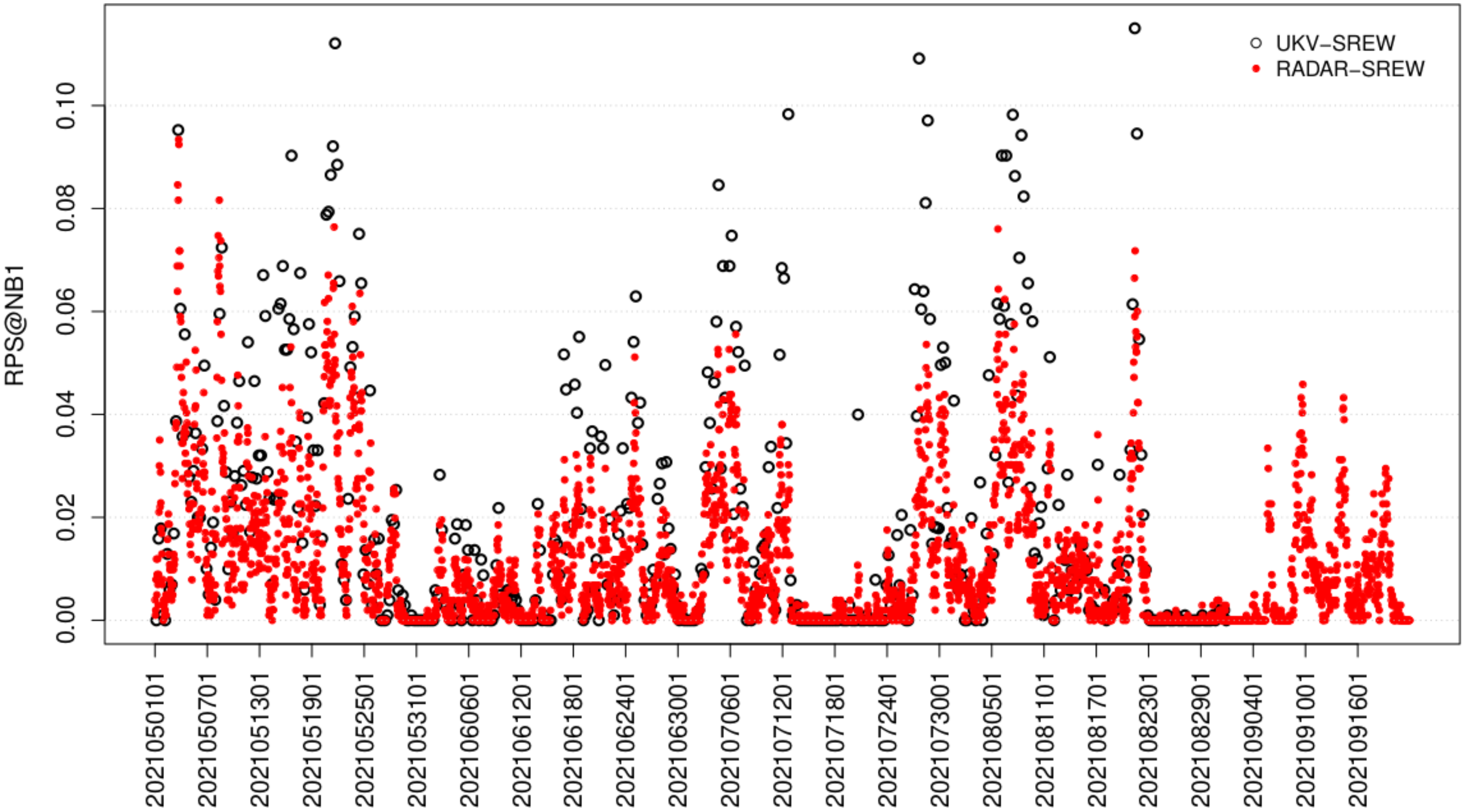
UKV T+1h for 03, 09, 15, 21 UTC runs
Hourly radar

RPS time series

RPS scales with the rainfall amount.

Hypothesis 1: Days with less coverage have larger radar errors

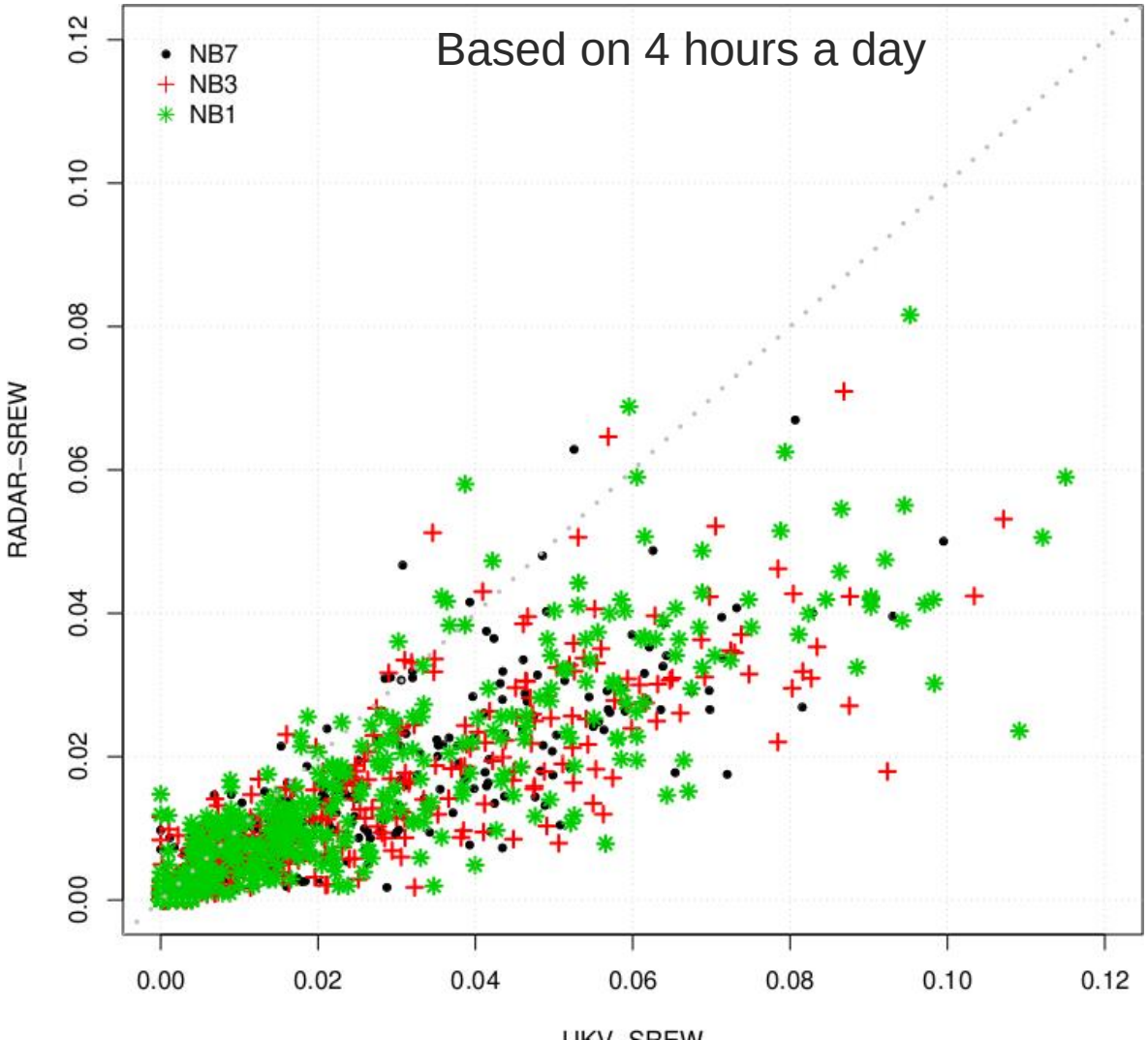
Note: this is an aggregate score over all stations in the hour.



Relationship between UKV RPS and Radar RPS

There are times when the radar RPS is larger than the model RPS.

The plot does suggest that there is a systematic reduction in magnitude of the error with neighbourhood size.

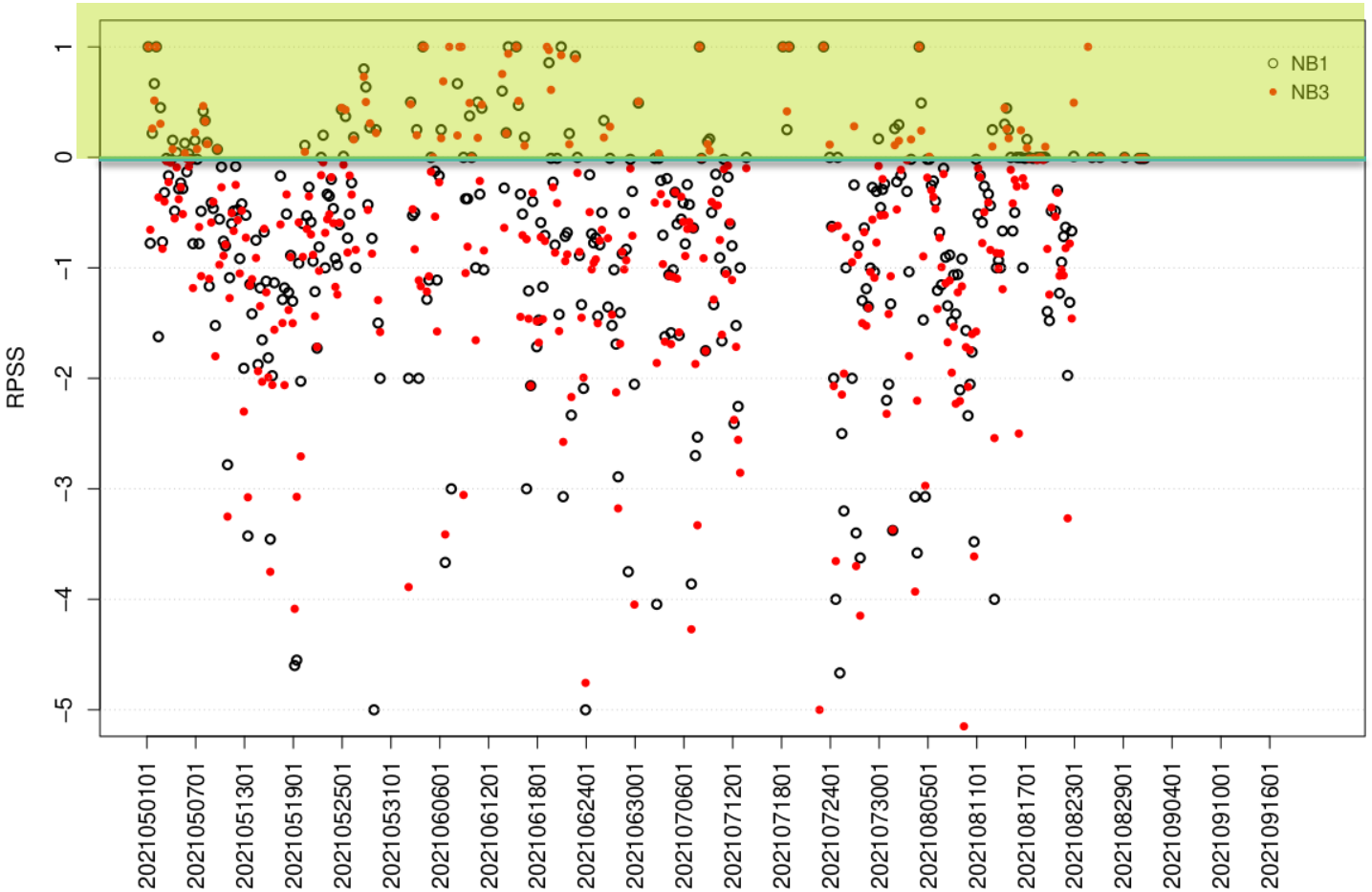


RPSS for UKV relative to radar RPS

$1 - RPS_{fc} / RPS_{rad}$

Would expect $RPS_{fc} > RPS_{rad}$ so that RPSS < 0, i.e. **forecast should be less skilful than the radar!**

Several instances where $RPS_{fc} < RPS_{rad}$ (RPSS > 0)!!!
This is somewhat unexpected.



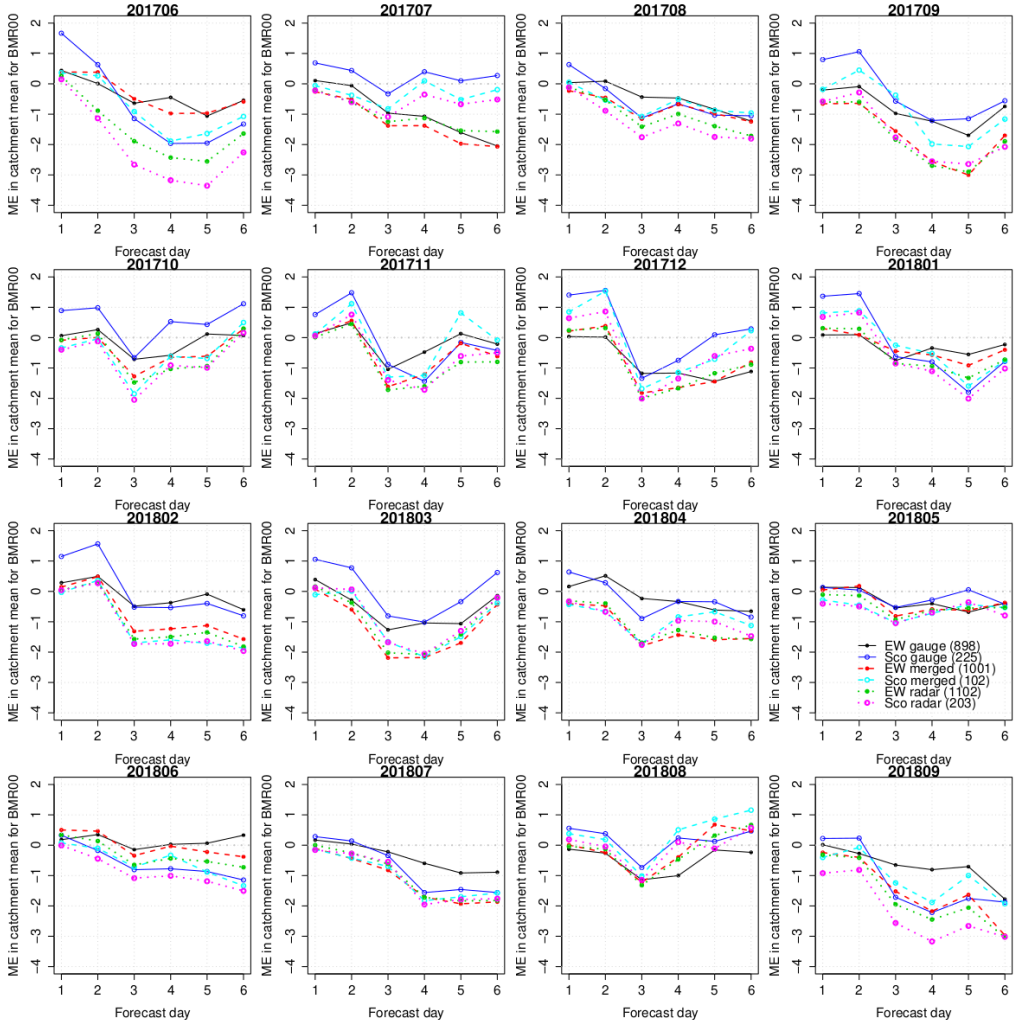
Aggregated daily catchment average precipitation mean error

catchments in brackets ()

Based on ensemble control member split by month and as a function of forecast day against radar, gauge and a merged product.

Model often has the largest over-forecast bias against the gauge analysis. Opposite against radar, merged somewhere in the middle.

Which is right/best?!

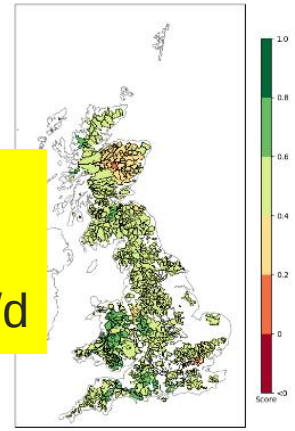
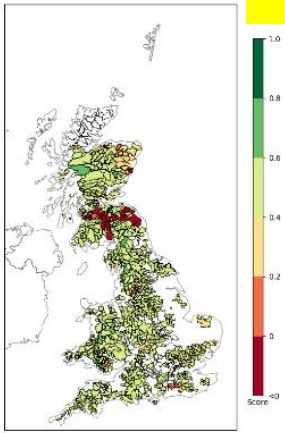
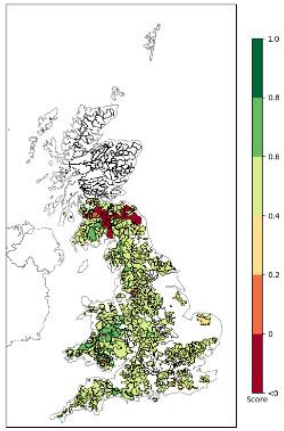
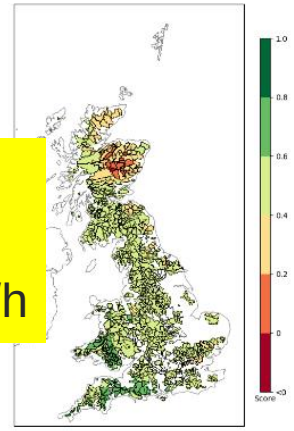
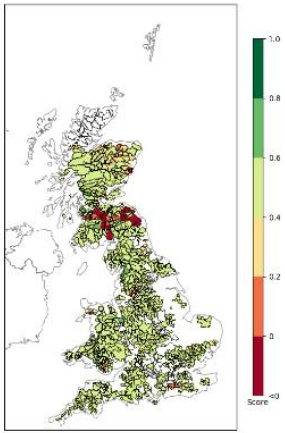
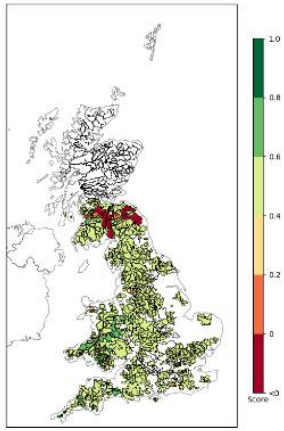


Ensemble-based catchment-scale verification example

- Comparing scores for the same forecasts against three different precipitation “truth” types, one being a blend of the other two.
- Merged product does mitigate against the deficiencies of both but is also susceptible to radar “issues” filtering through to the score calculations
- Model ends up verifying “best” against gridded gauge product…?
- We need observation error estimates.
- How do we get them?
- Could ML be something to consider?

Mittermaier et al., in prep.

BSS

	Gauge	Radar	Merged
Y1 D1 Daily 0.5 mm/d			
Y1 D1 Hourly 0.5 mm/h			

Where to next?

We know **radar has errors and gauges are not perfect** but **gauges *are* at ground level** and **radars only provide an approximation of what may be falling to the ground**. (Recall that a 1 deg radar beam is already more than 1 km above the ground at around 60 km from the radar!).

We know from e.g. vertically pointing radar studies that rain at a point is far more intermittent than what we want to believe at times (especially in the UK!).

The hypothesis is that this is particularly problematic for times when radar is actually suggesting that it is *not* raining (i.e. **drizzle at the sub-detection level or below lowest beam**) and for rain (of variable intensity) when there is **sub-cloud dry layers and/or evaporation** which acts to remove all the rain before it can reach the ground. The former impacts public perception but is of less relevance to understanding rain volumes. The latter is important when it comes to ensuring that the model is producing the right rainfall amounts.

Whilst **visually eyeballing radar fields alongside model precipitation fields remains a valuable subjective verification method**, it is possible/likely/probable that using radar to determine the precipitation extent may be overestimating the rain extent in terms of whether it is actually raining at ground level.

Rain gauges are very sparse but represent the only option for establishing with some certainty that it is raining at the ground (at that point!) (Aside: gridded gauge analyses make lots of assumptions about what is happening between gauges which is also potentially wrong, especially under more convective conditions)

The reality is that we need radar to help us get some estimate of the rain areal extent. **The question is really to what degree radar rainfall fields provide a good indicator of rainfall extent and whether we can really trust any verification of this areal extent as a reliable indicator for understanding surface-precipitation biases without observation uncertainty bounds.**

Met Office

Thanks for listening!

Thoughts?

Comments?

Looking for interested parties to continue to explore this topic in a systematic way.