At last, proof that higher spatial resolution precipitation forecasts are better

Marion Mittermaier, Nigel Roberts and Simon A Thompson

Outline

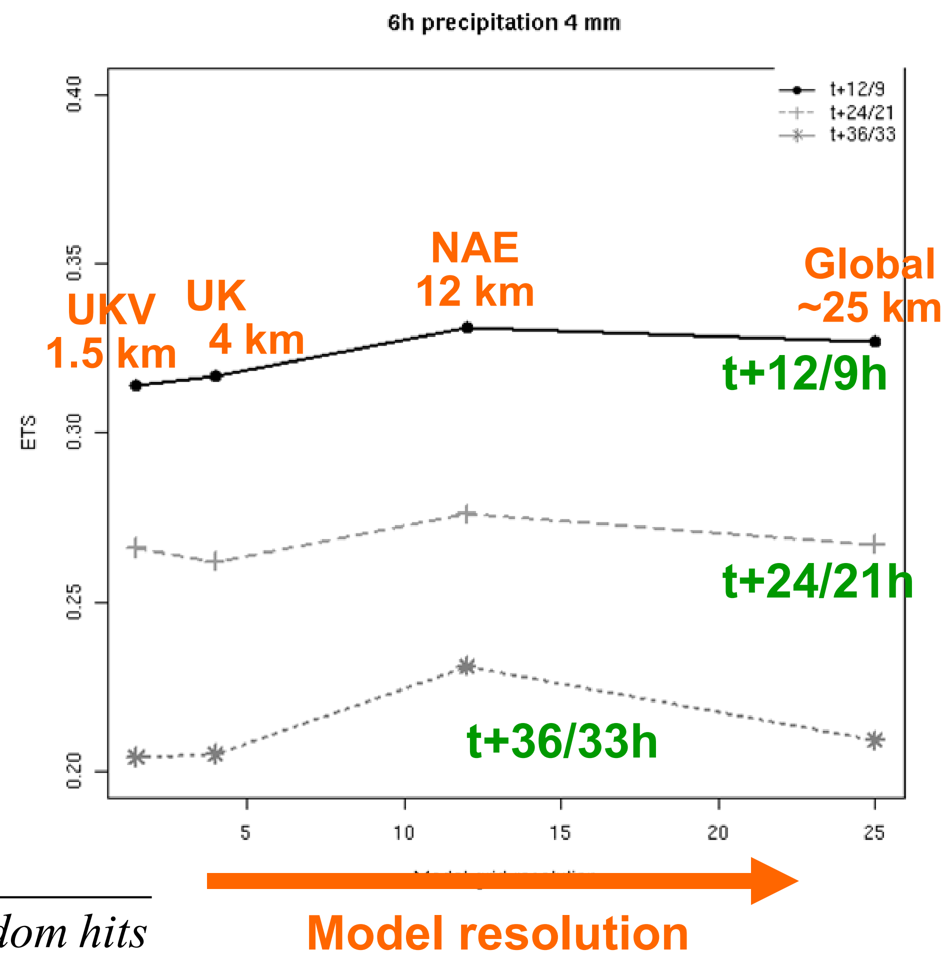
1. Introduction
2. Spatial verification methodology and Fractions Skill Score
3. Key findings from the NAE-UK4 long-term precipitation forecast assessment
4. The thorny issue of “what is truth”
5. Conclusions

Introduction

Does higher resolution give more skilful forecasts?

Apparently not! *Has it all been a waste of time?*

- April to Oct 2010
- Equitable Threat Score (ETS)
- Using Block 03 gauges



$$ETS = \frac{hits - random\ hits}{hits + false\ alarms + misses - random\ hits}$$

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Has this been measured the right way?

There are two main problems.

1. Double penalty effect

- Errors are counted as false alarms and misses.
- Detail penalised, closeness not rewarded

2. Unskilful scales

- Grid-scale detail should not be believed
- Lorenz (1969) argued that the ability to resolve smaller scales would result in forecast errors growing more rapidly -> more noise

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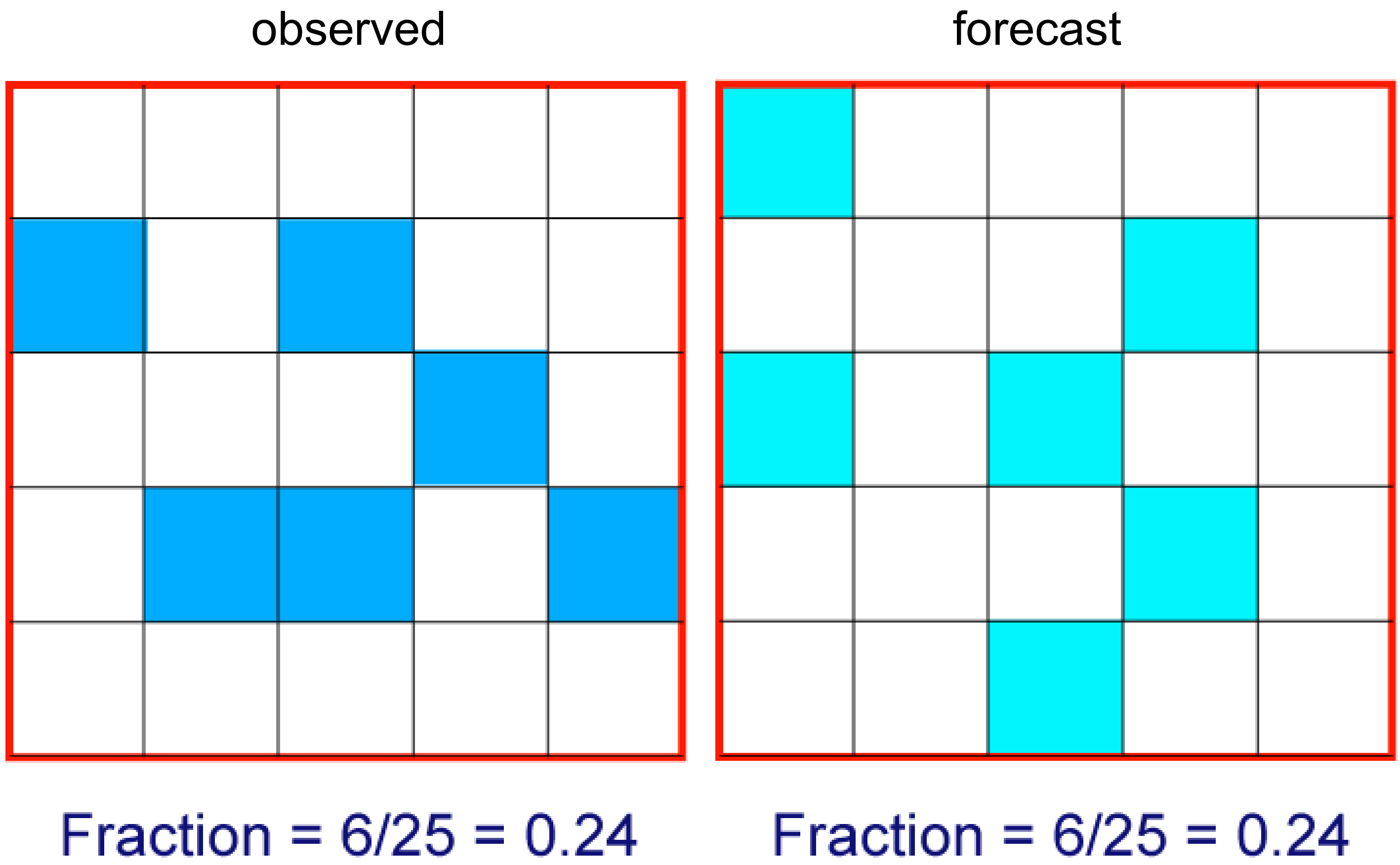
Spatial verification methodology

Compare fractional coverage over different sized areas



Threshold exceeded where squares are blue

Courtesy of Nigel Roberts

The Fractions Skill Score (FSS) for comparing fractions with fractions

Roberts and Lean (2008), Roberts (2008), Mittermaier and Roberts (2010)

Mean square error for the fractions – variation on the Brier score

$$\text{FBS} = \frac{1}{N}\sum_{j=1}^{N}(p_j - o_j)^2$$

FBS (Fractions Brier Score)

$0 \leqslant p_j \leqslant 1$ forecast fractions

$0 \leqslant o_j \leqslant 1$ radar fractions

N number of points

Skill score for fractions/probabilities - Fractions Skill Score (FSS)

$$\text{FSS} = 1 - \frac{\text{FBS}}{\frac{1}{N}\left[\sum_{j=1}^{N}(p_j)^2 + \sum_{j=1}^{N}(o_j)^2\right]}$$

Courtesy of Nigel Roberts

Characteristics of the FSS

Range from 0 to 1 → 0 for zero skill, 1 for perfect skill

Typically increases with spatial scale (always for large sample)

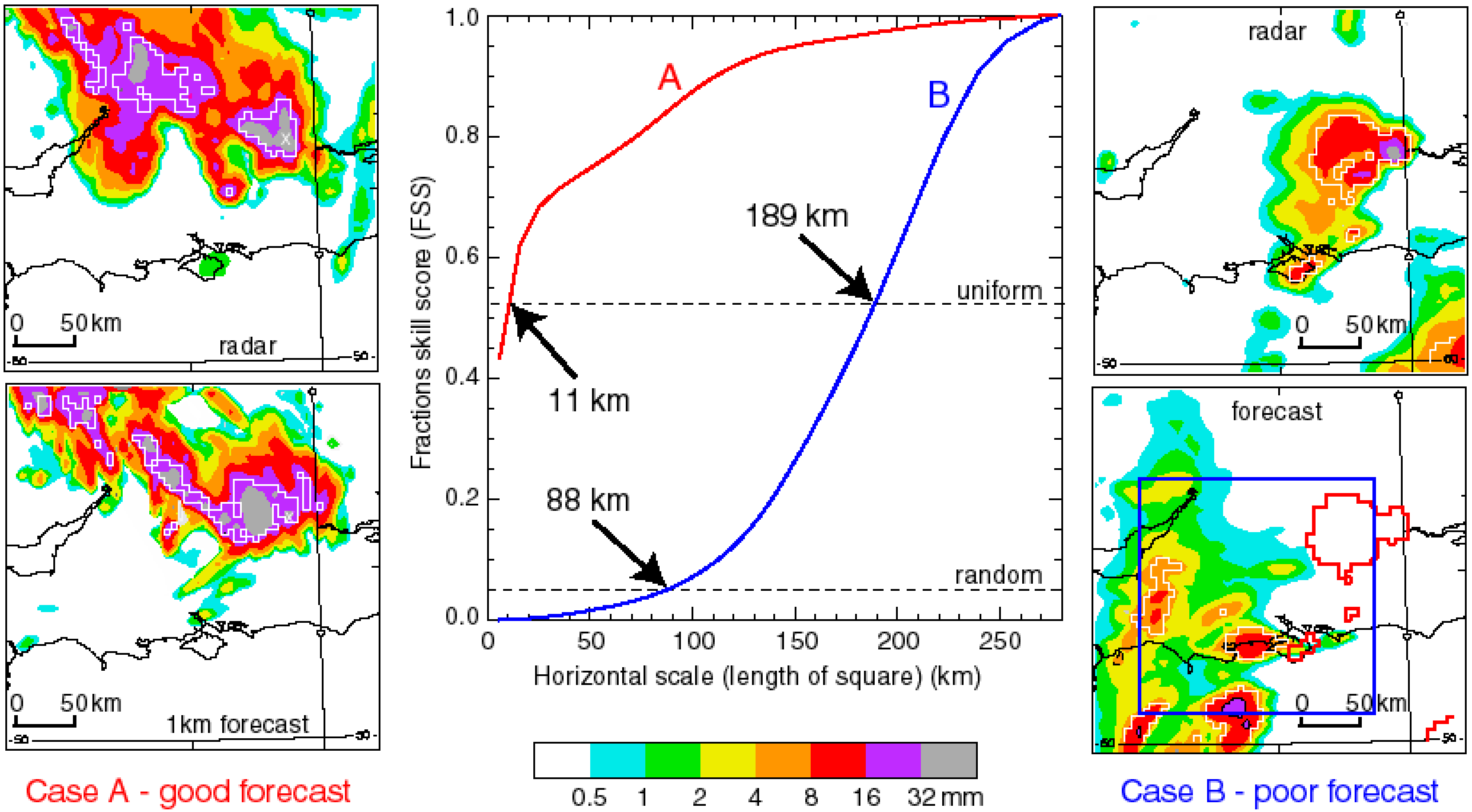
Only asymptotes to 1 in the domain average limit if the forecast is **unbiased or for frequency thresholds**. Typically < 1 for physical thresholds.

Can **define an 'acceptable' value of FSS** which is halfway between random skill (FSS = observed frequency) and perfect skill (FSS=1)

In idealised experiments **FSS_{target} is reached at a scale that is twice the length of the spatial error** in the forecast

Courtesy of Nigel Roberts

Real examples



Courtesy of Nigel Roberts

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Comparing the UK4 and NAE

"An unsophisticated forecaster uses statistics as a drunken man uses lamp-posts – for support rather than for illumination. "--After Andrew Lang

NAE-UK4 long term assessment

- 41 months of forecasts (~5000) assessed using radar accumulations.
- For time series consider 25 km neighbourhood size.
- Determine whether **UK4 is statistically significantly better than NAE.**
- Assess the use of **radar composites as truth** for **long-term monitoring**.
- Consider the use of **frequency thresholds.**
- Consider skill as a function of the **diurnal cycle.**

Thanks to Rob Darvell for help with VER stats files.

A short note on statistical significance …

- When comparing two models against the same truth the easiest way to test whether model A is better than model B is to **test whether the difference in the scores is significant**.

- The test statistic: $$T = \frac{\overline{D}}{s_D / \sqrt{n}}$$

  where $\overline{D}$ is the mean of the differences in scores

  and s_D is the standard deviation.

- Test the null hypothesis that H_0: $\mu 1 = \mu 2$ where H_0 is rejected if $t <= t_{n-1,\alpha/2}$ or $t >= t_{n-1,\alpha/2}$.

FSS (neighbourhood size)

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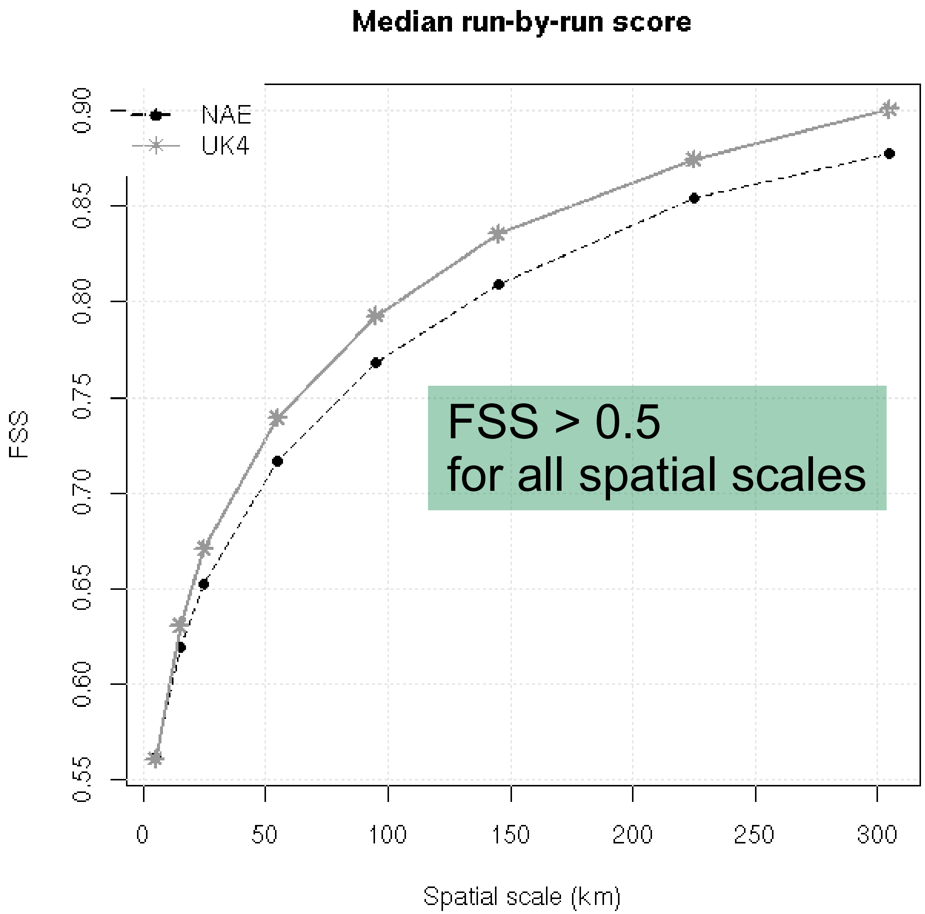
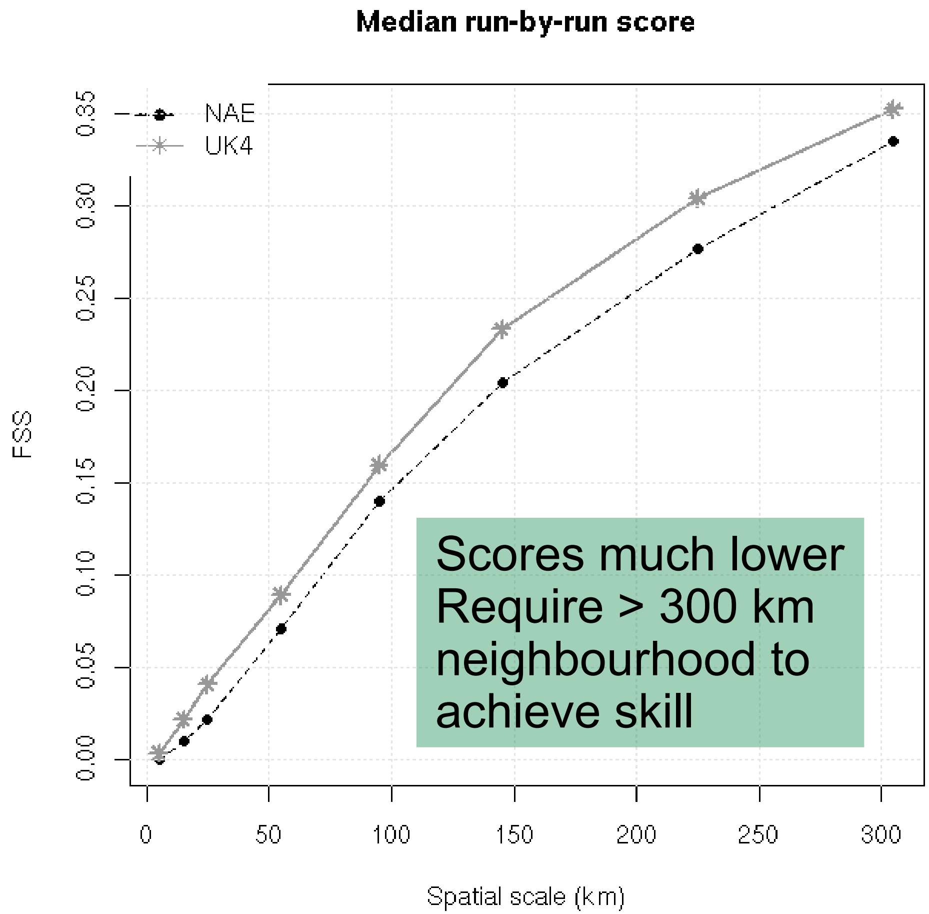
0.5 mm/6h



16 mm/6h



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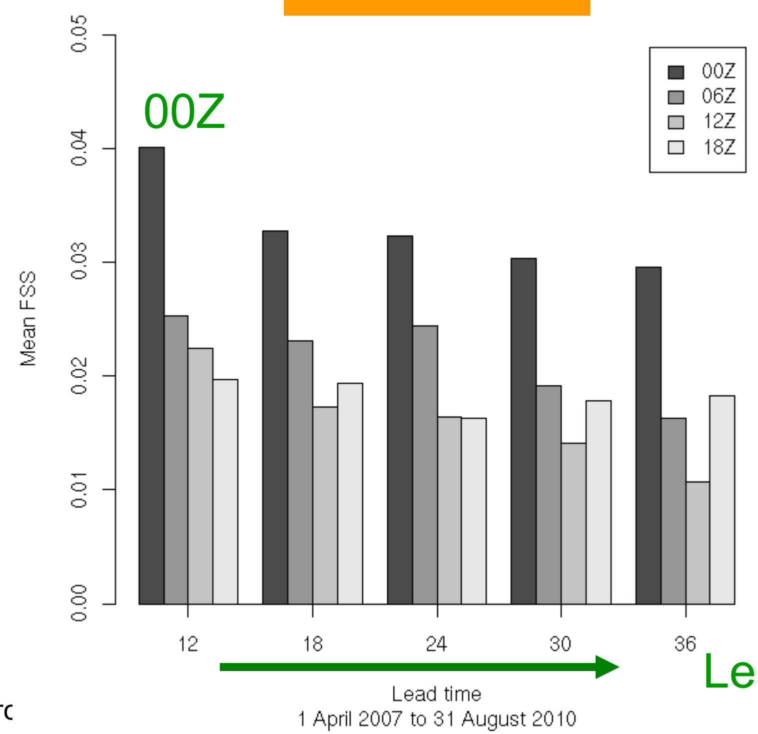
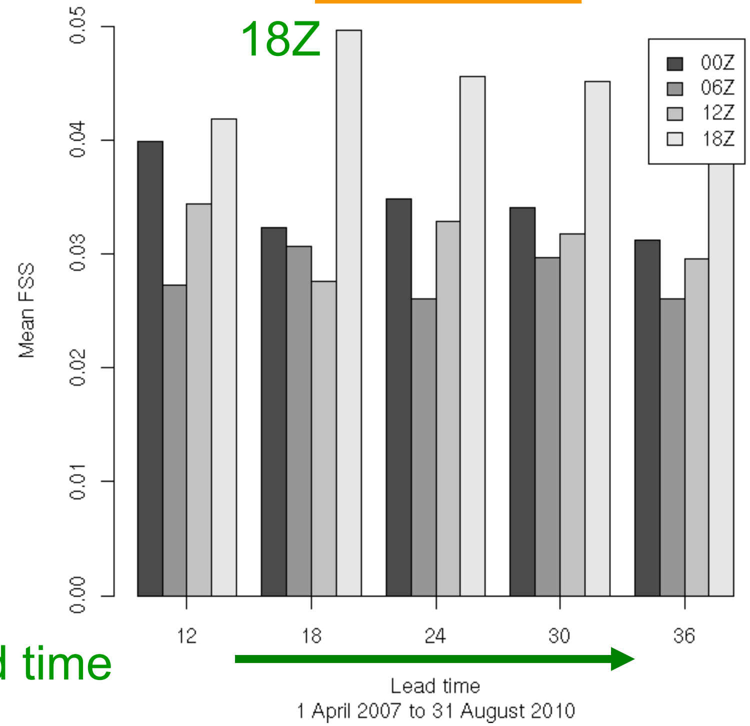
Diurnal cycle

- Higher resolution beneficial for diurnal cycle, especially triggering of afternoon convection.
- UK4 –NAE FSS always positive (better) but **bigger for larger thresholds**.
- For < 2 mm/6h score differences bigger for 18-00Z accumulations; > 4 mm/6h 12-18Z score differences biggest.

> 0.5 mm/6h



> 4 mm/6h



Lead time

L(FSS>0.5) for 10% threshold and 0.5 mm/6h

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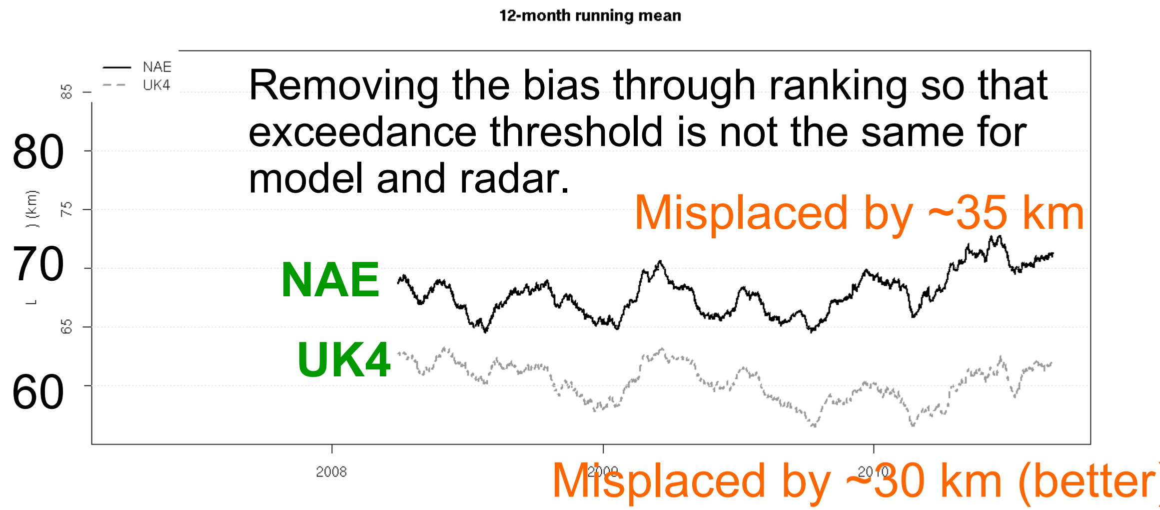
The expectation is that through model improvements L(FSS>0.5) DECREASES over time….. or at least stays constant

10% threshold

Metric is impacted through the physical exceedance threshold applied at the grid scale.



0.5 mm/6h

From Mittermaier *et al* 2010

Concluding remarks

Interpretation of verification statistics

- Long-term monitoring requires a **stable baseline**.
- If there are changes in bias in both the forecast and the verifying observations it becomes difficult to attribute changes in the verification results to source.
- We **expect the model bias to change (improve!)** and have some understanding of the impact of model upgrade changes on the frequency bias through the trialling and parallel suites.
- This sort of information for changes made to radar processing is not widely known/accessible.

Key findings

- Based on 41 months of forecasts (~5000) 6-h **UK4 precipitation forecasts are statistically significantly better than NAE at all lead times.**
- **Recommend that FSS or L(FSS>0.5) (the so-called "skilful spatial scale") be used as metric** for measuring precipitation forecast skill, *but* using **frequency thresholds**.
- Despite the use of frequency thresholds **the lack of stability of a radar baseline could jeopardise the use of radar for long-term monitoring** for precipitation forecast skill, except in a comparative sense.
- **Frequency thresholds are preferred.** They encompass the full range of precipitation and all rain is counted.

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Thanks for listening!

A long-term assessment of precipitation forecast skill using the Fractions Skill Score.
Mittermaier M., N. Roberts and S. A. Thompson.
Accepted *Meteorol. Apps*. August 2011.