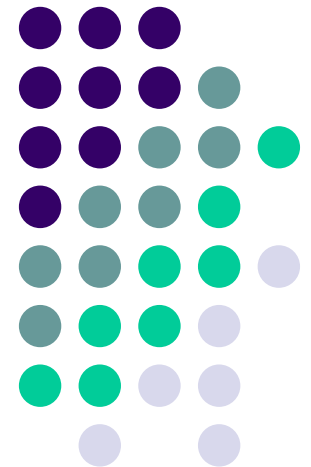
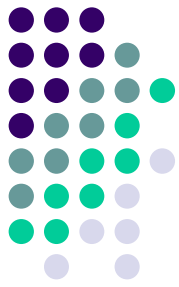


Fuzzy Forecast Verification

Beth Ebert
Bureau of Meteorology Research
Centre, Melbourne, Australia



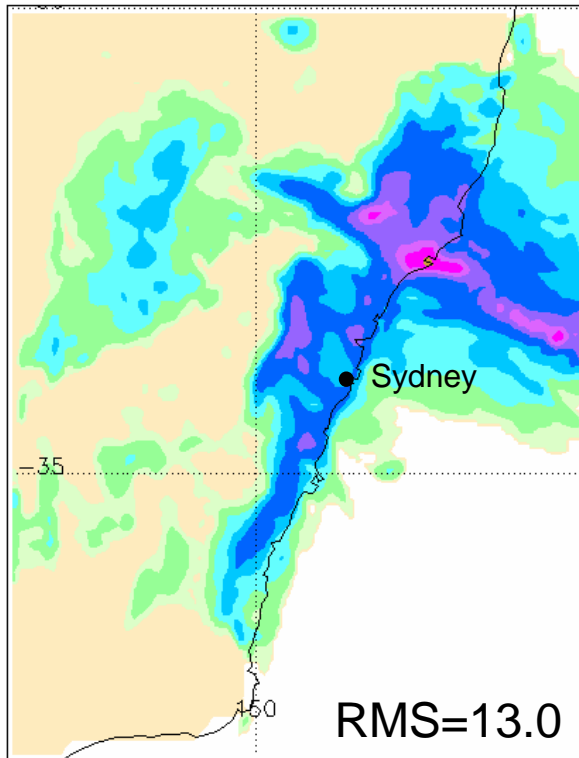
Thanks to Nigel Roberts (Met Office), Barbara Casati (RPN)



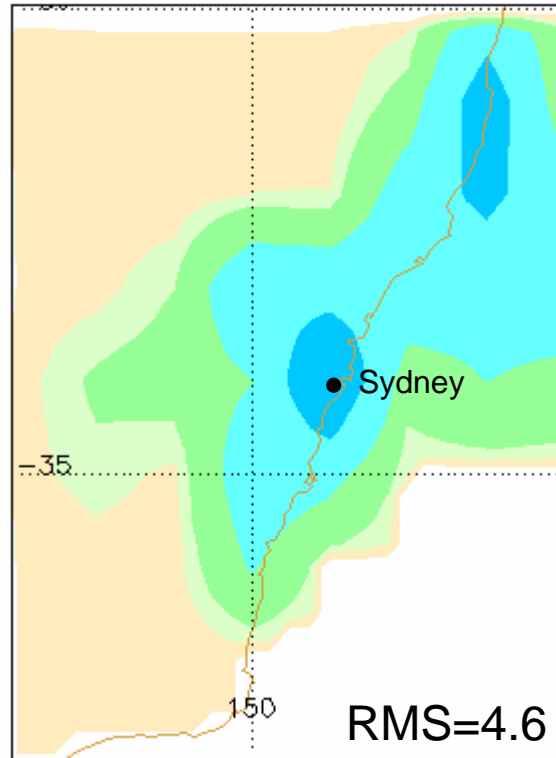
High vs. low resolution

Which rain forecast would you rather use?

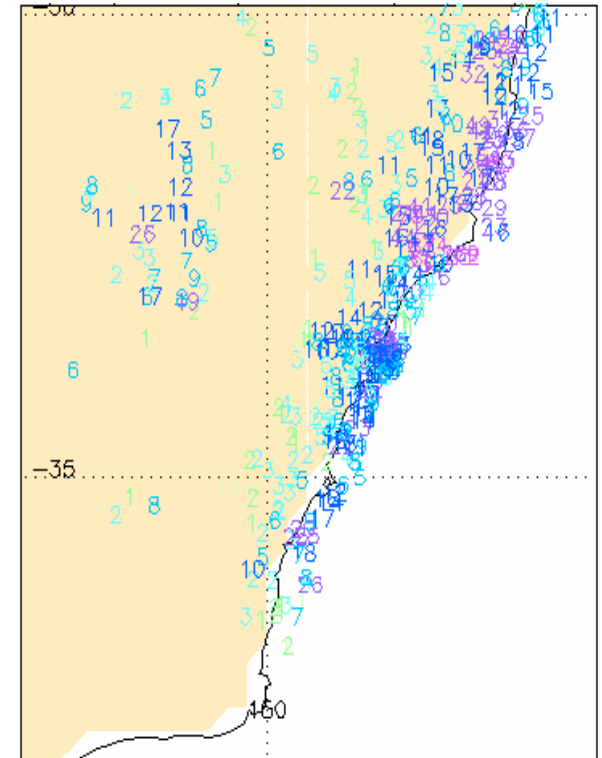
Mesoscale model (5 km) 21 Mar 2004

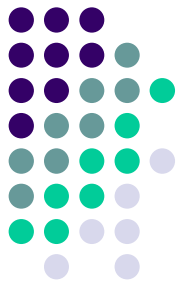


Global model (100 km) 21 Mar 2004



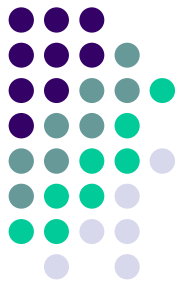
Observed 24h rain





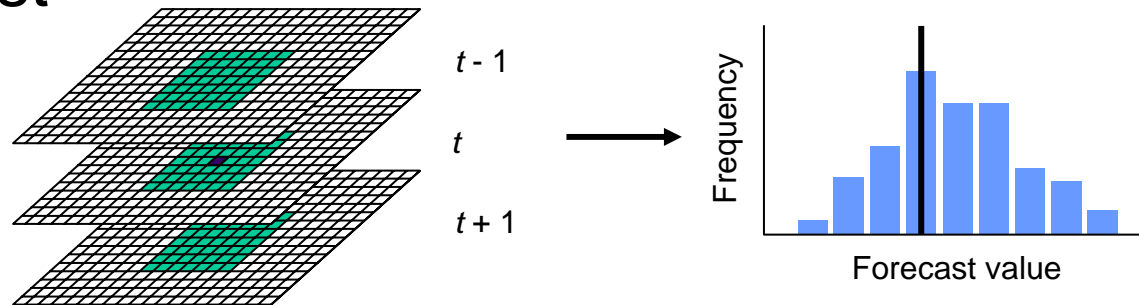
What makes a useful forecast?

- Resembles the observations on the broader scale
- Predicts an event somewhere near where it was observed
- Predicts the event over the same area (i.e., with the same frequency) as observed
- Has a similar distribution of intensities as the observations
- Looks like what a forecaster would have predicted if she'd had knowledge of the observations

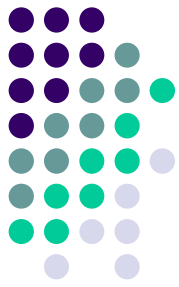


"Fuzzy" verification methods

- Don't require an exact match between forecasts and observations
 - Unpredictable scales
 - Uncertainty in observations
- Look in a space / time neighborhood around the point of interest



- Evaluate using categorical, continuous, probabilistic scores / methods



"Fuzzy" verification methods

- First (?) suggested by H. Brooks at 1998 Mesoscale Verification workshop
 - Brooks et al. (1998)
 - Zepeda-Arce et al. (2000), Weygandt et al. (2004)
 - Atger (2001)
 - Damrath (2004)
 - Casati et al. (2004)
 - Germann and Zawadski (2004)
 - Rezacova et al. (2005)
 - Theis et al. (2005)
 - Roberts and Lean (2005)

This conference:

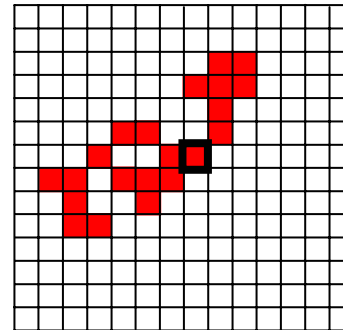
- *Wernli, Paulat, & Frei*
- *Casati & Wilson*
- *Mittermaier*



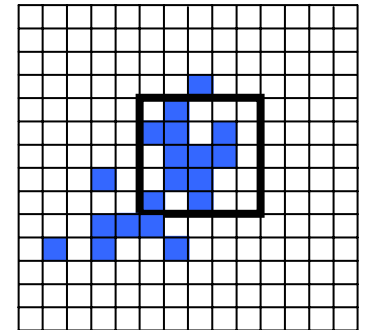
Fuzzy verification framework

Fuzzy methods use one of two approaches to compare forecasts and observations:

single observation –
neighborhood forecast

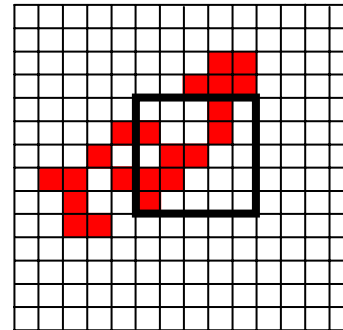


observation

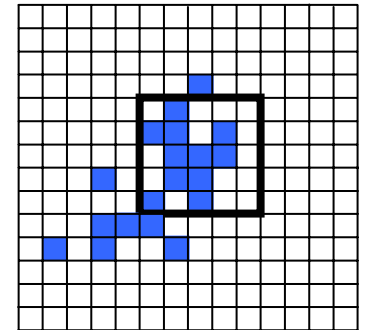


forecast

neighborhood observation –
neighborhood forecast



observation



forecast



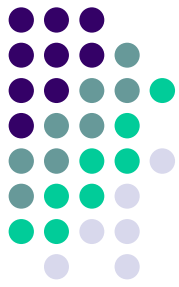
Fuzzy verification framework

Treatment of forecast data within a window:

- Mean value (upscaling)
- Occurrence of event* somewhere in window
- Frequency of event in window → probability
- Distribution of values within window

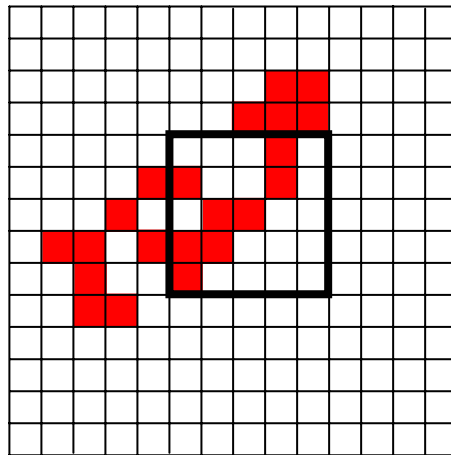
May apply to observations as well as forecasts
(neighborhood observation-neighborhood forecast approach)

* *Event* defined here as a value exceeding a given threshold, for example, rain exceeding 1 mm/hr

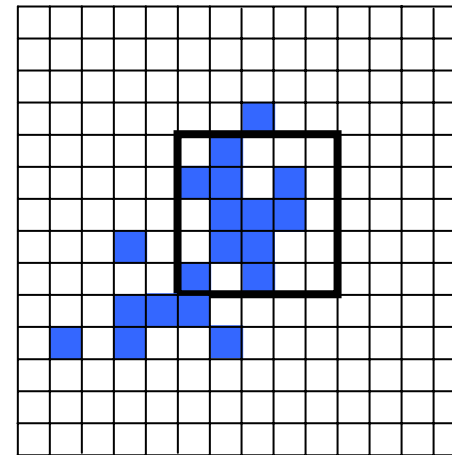


Example: Fractions skill score (Roberts and Lean 2005)

Compares fractional coverage in forecast with fractional coverage in observations



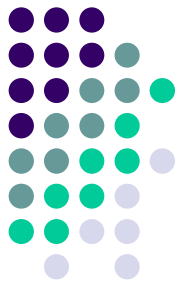
observation



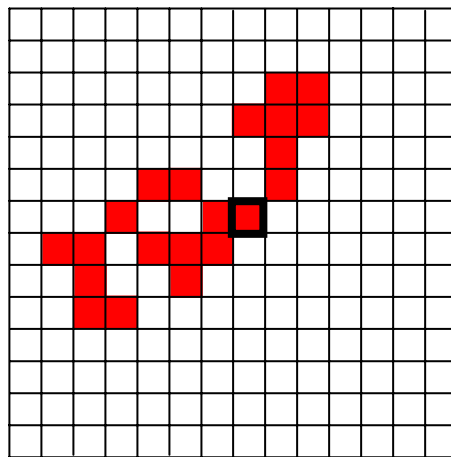
forecast

$$\text{FSS} = 1 - \frac{\frac{1}{N} \sum_{i=1}^N (P_{fcst} - P_{obs})^2}{\frac{1}{N} \sum_{i=1}^N P_{fcst}^2 + \frac{1}{N} \sum_{i=1}^N P_{obs}^2}$$

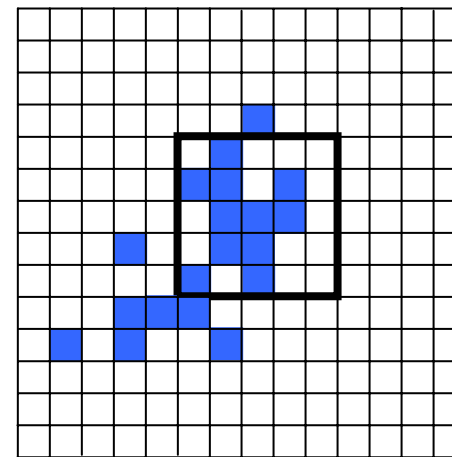
Example: Multi-category contingency table (Atger 2001)



Compares occurrence of event in forecast with observed occurrence of event

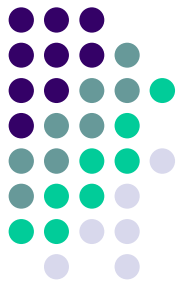


observation



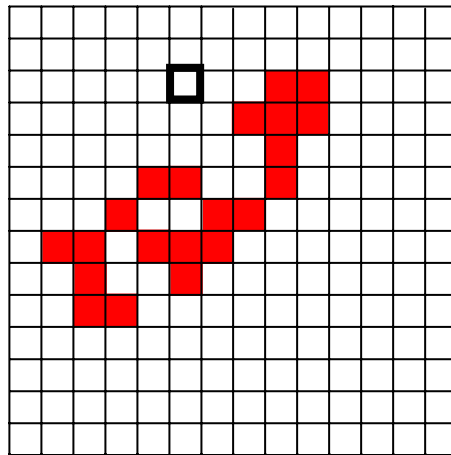
forecast

Hit = at least one forecast event in vicinity of observed event

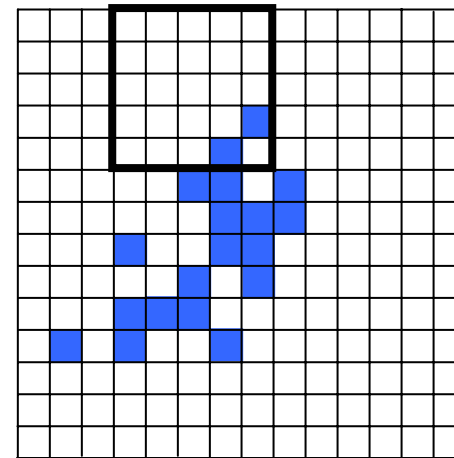


Moving windows

Accumulate scores as windows are moved through the domain

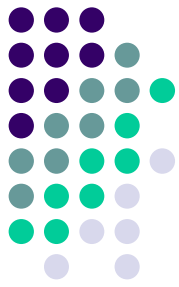


observation



forecast

Decision models



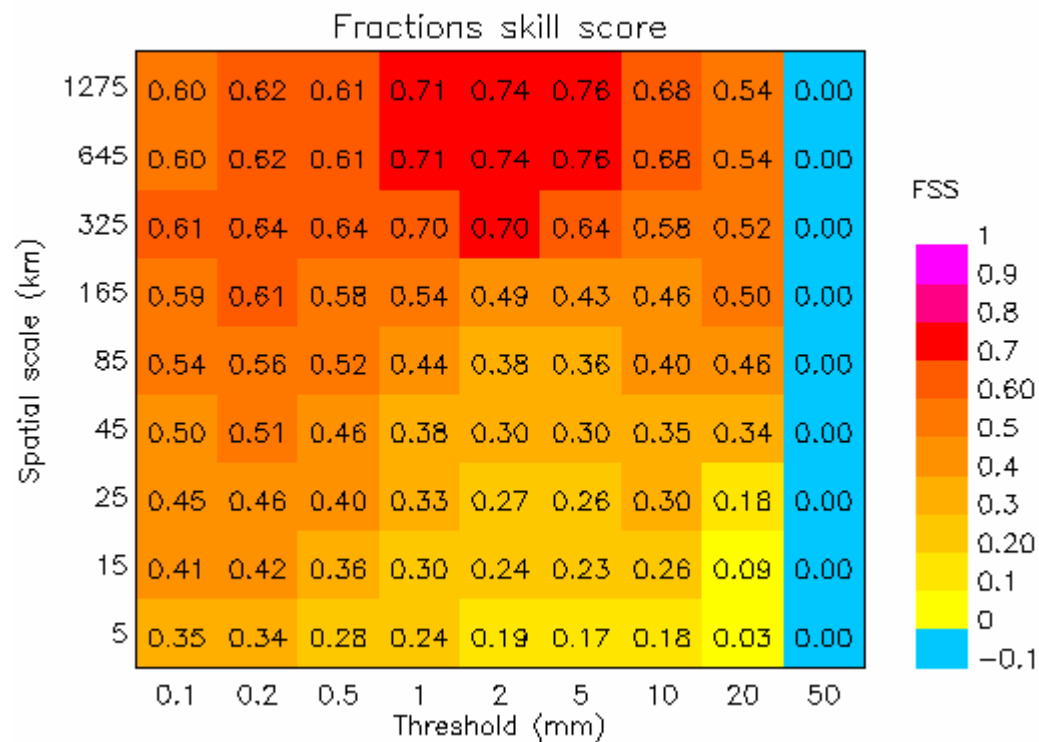
Fuzzy method	Matching strategy*	Decision model for useful forecast	Metrics
Upscaling (Zepeda-Arce et al. 2000; Weygandt et al. 2004)	NO-NF	Resembles obs when averaged to coarser scales	BIAS, CSI, ETS
Minimum coverage (Damrath 2004)	NO-NF	Predicts event over minimum fraction of region	POD, FAR, ETS
Fuzzy logic (Damrath 2004), joint probability (Ebert 2002)	NO-NF	More correct than incorrect	POD, FAR, ETS
Fractions skill score (Roberts and Lean 2005)	NO-NF	Similar frequency of forecast and observed events	FSS
Pragmatic (Theis et al. 2005)	SO-NF	Can distinguish events and non-events	BS, BSS
CSRR (Germann and Zawadzki 2004)	SO-NF	High probability of matching observed value	CSRR
Multi-event contingency table (Atger 2001)	SO-NF	Predicts at least one event close to observed event	ROC, value
Practically perfect hindcast (Brooks et al. 1998)	SO-NF	Resembles forecast based on perfect knowledge of observations	CSI _y , CSI _x
Intensity-scale (Casati et al. 2004)	NO-NF	Lower error than random arrangement of obs	SS
Area-related RMSE (Rezacova et al. 2005)	NO-NF	Similar intensity distribution as observed	RMSE

*NO-NF = neighborhood observation-neighborhood forecast,
SO-NF = single observation-neighborhood forecast

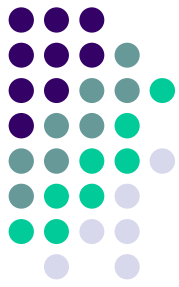


Multi-scale, multi-intensity approach

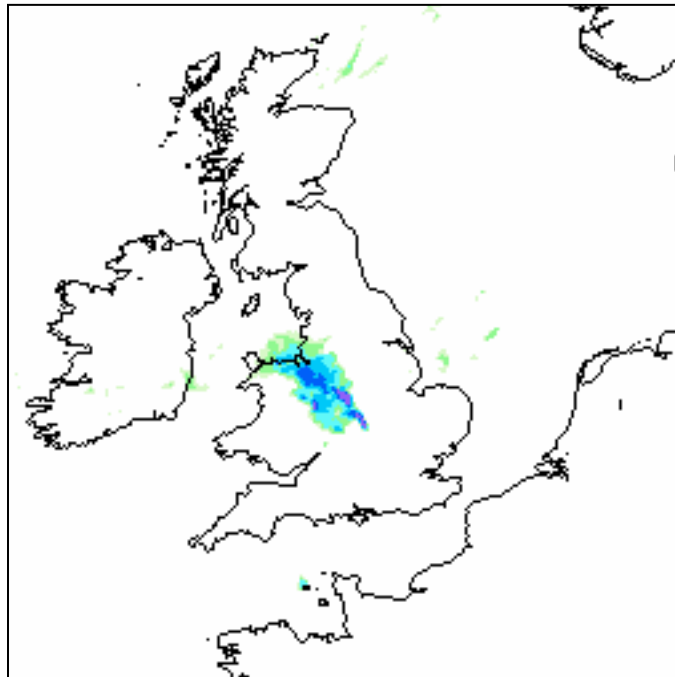
- Forecast performance depends on the scale and intensity of the event



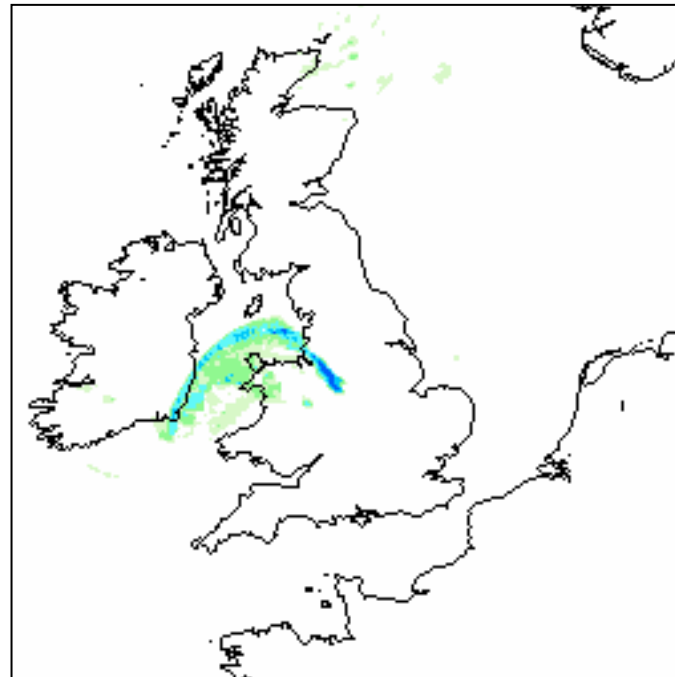
Case study



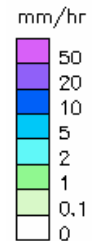
Heavy rain event at 1500 UTC on 29 May 1999



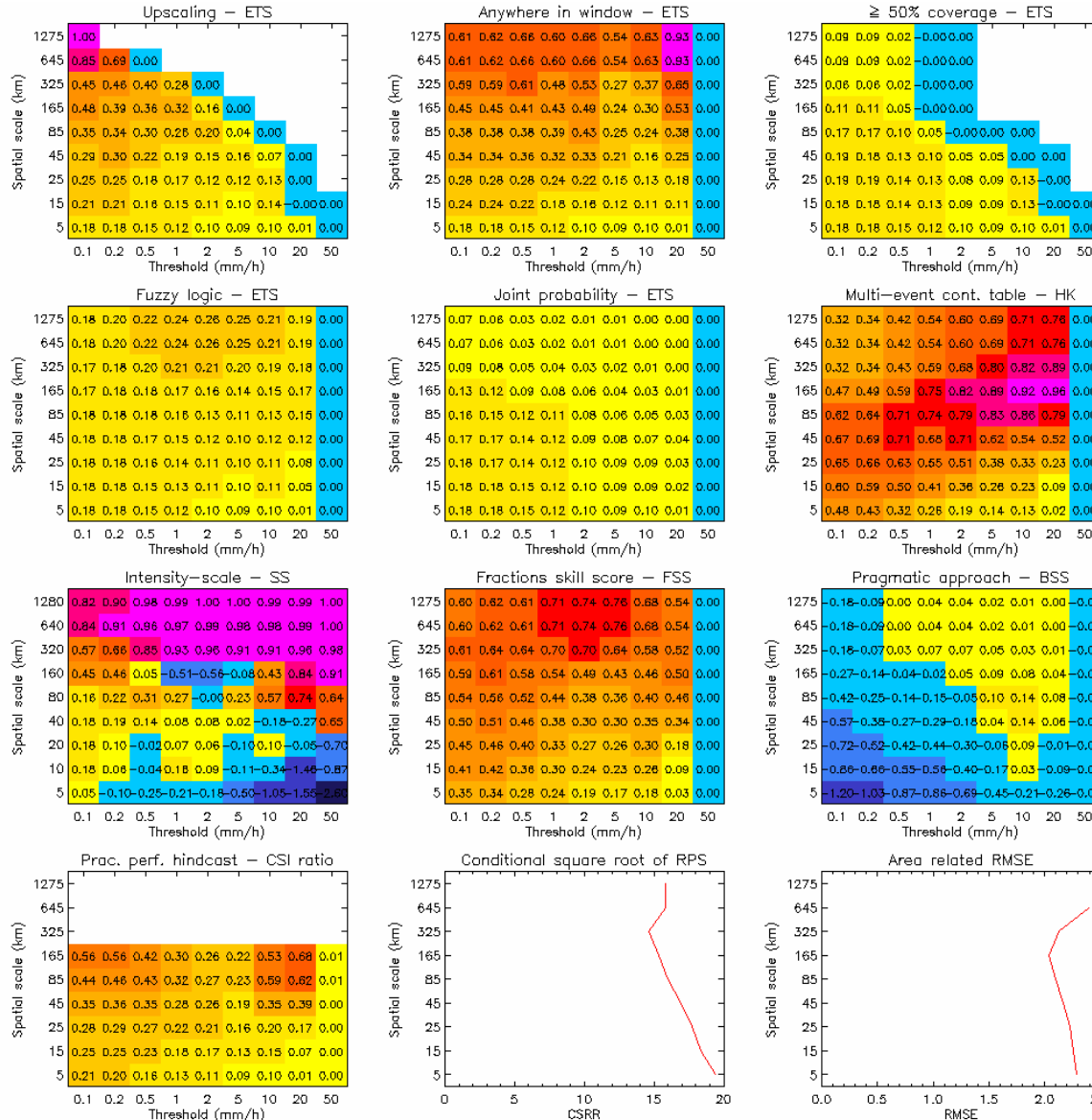
observed (Nimrod)



3h forecast



Fuzzy verification results



Interpretation

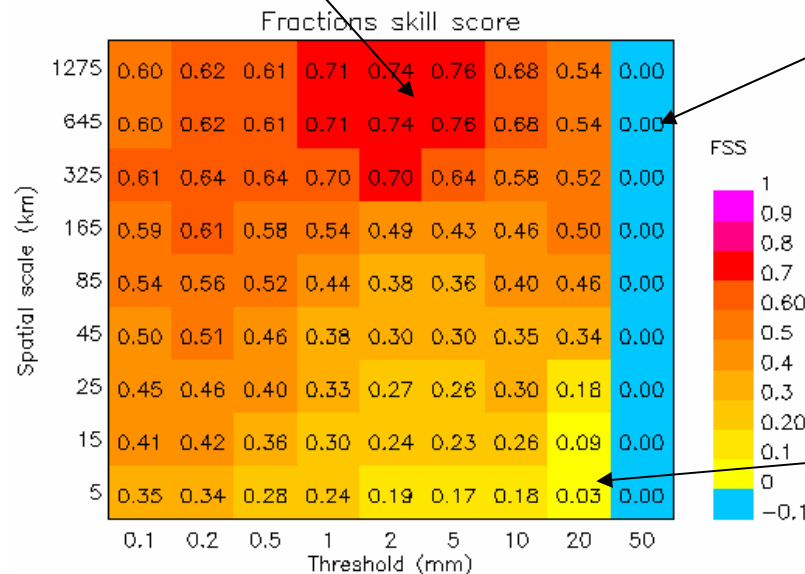
Fractions Skill Score



Decision model – Useful forecast has similar frequency of forecast and observed events within a spatial window

Greatest skill for light rain, large scale

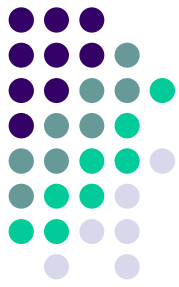
No skill at heaviest rain rate (none fcst)



Little skill for heavy rain, small scales

Interpretation

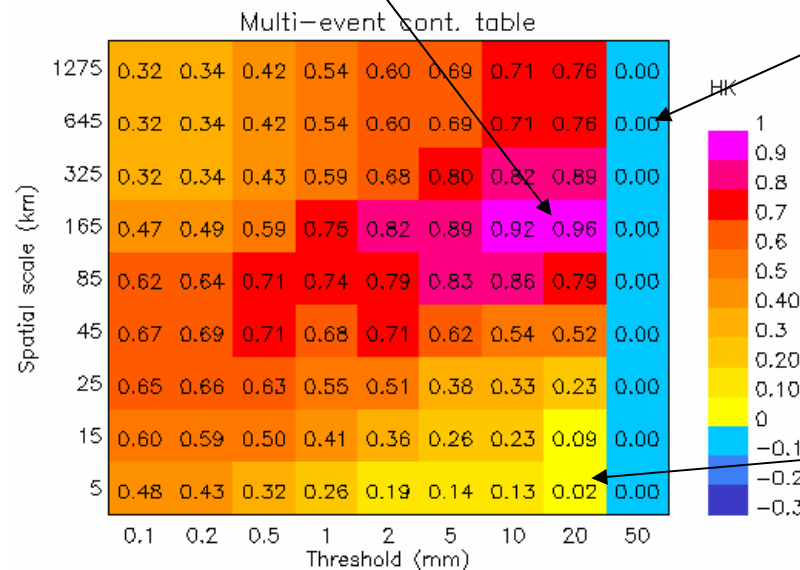
Multi-event contingency table



Decision model – Useful forecast predicts at least one event close to the observed event

Greatest skill for heavy rain, moderate scale

No skill at heaviest rain rate (none fcst)

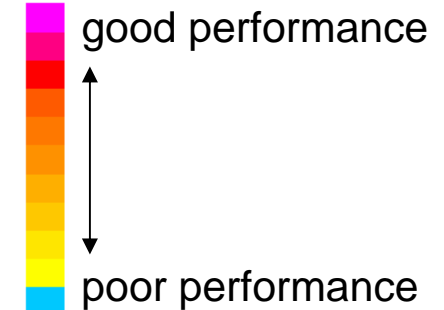
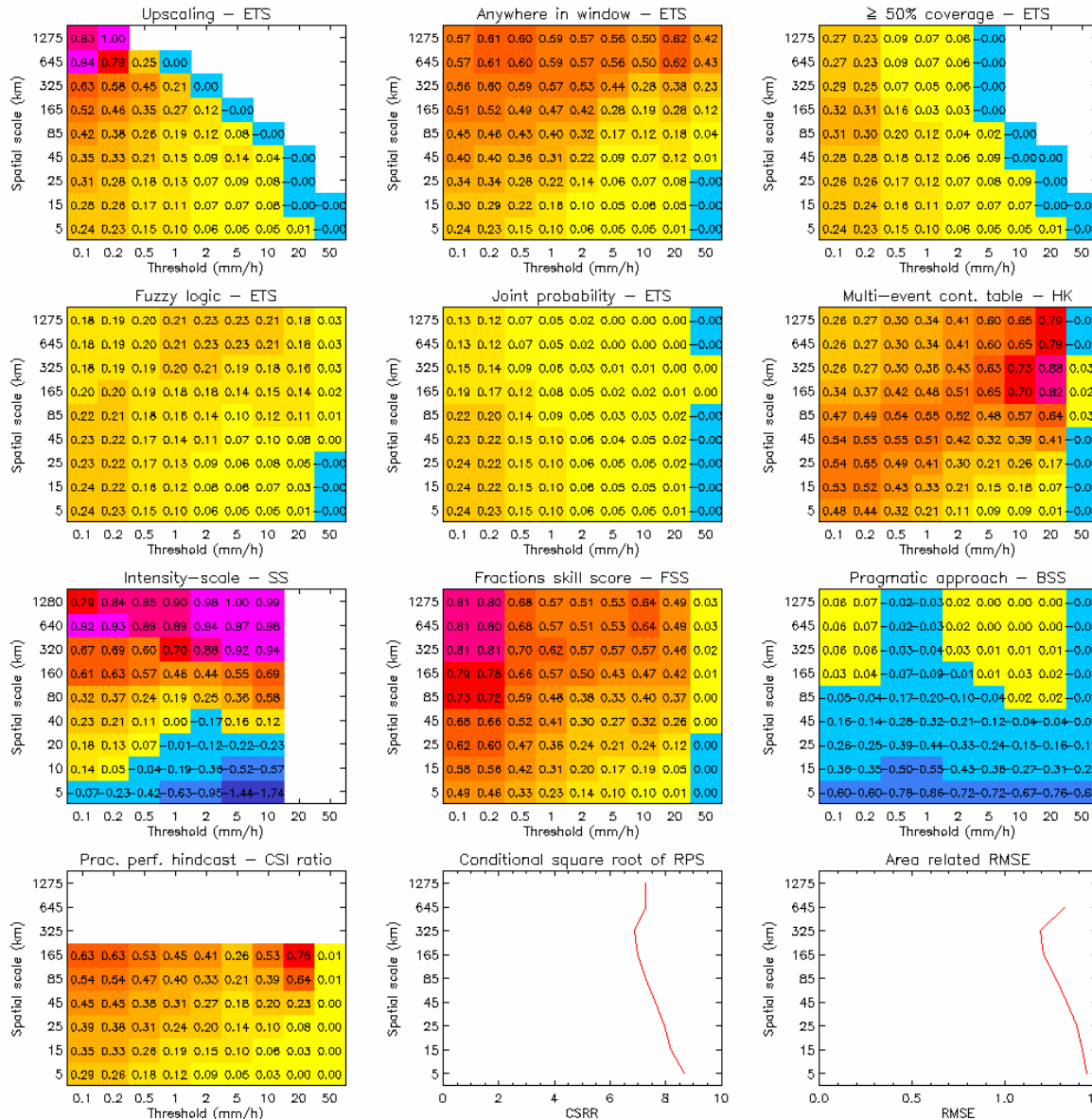


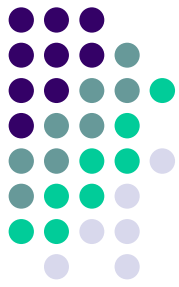
Little skill for heavy rain, small scales

Aggregation over many events



6 rain events over UK
(Casati et al. 2004)





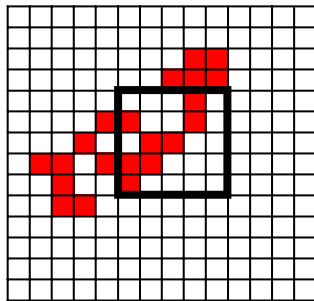
Advantages of fuzzy verification

- Suitable for discontinuous fields like precipitation
- Can give good results for forecasts that verify poorly using exact-match approach
- Results match with our intuition
- Can be used to compare forecasts at different resolutions
- Knowing which scales have skill suggests the scales at which the forecast should be presented and trusted
- Multiple decision models and metrics
 - Direct approach → verification of intensities
 - Categorical approach → verification of binary events
 - Probabilistic approach → verification of event frequency

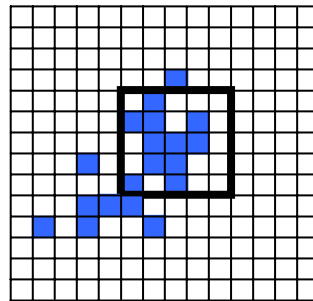
Design-your-own verification



Neighborhood observation –
neighborhood forecast

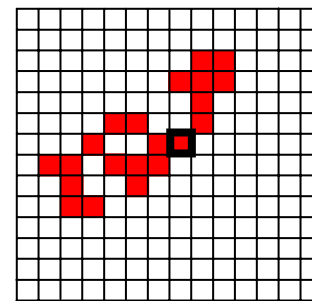


observation

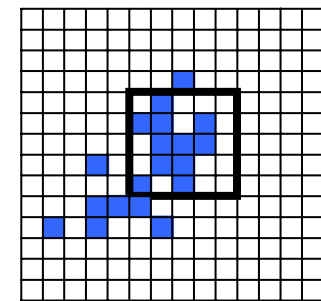


forecast

Single observation –
neighborhood forecast



observation



forecast

- categorical scores
 - POD, FAR, ETS, etc.
- probabilistic methods
 - BS, RPS, reliability, ROC, etc.
- continuous scores
 - RMSE, MAE, etc.

- categorical scores
 - POD, FAR, ETS, etc.
- probabilistic methods
 - BS, RPS, reliability, ROC, relative value, etc.



Thank you!