Multi-scale validation of high resolution precipitation products

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Relevance to workshop goals

- This work addresses the evaluation of several aspects of HRPP quality at various space and time scales
  - Methodology
  - Some preliminary results

→ Relevant to making recommendations to IPWG and IGOS/IGWCO regarding the *characteristics and suitable applications for HRPP*

Satellite precipitation estimates -- what do we especially want to get right?

Climatologists - mean bias

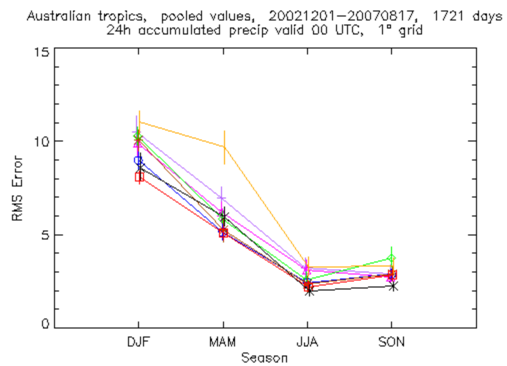
NWP data assimilation (physical initialization) - rain location and type

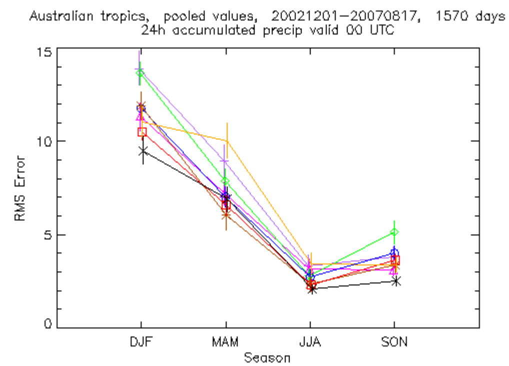
Hydrologists - rain volume

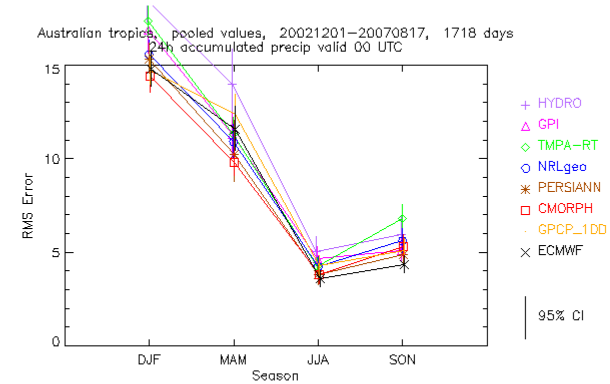
Forecasters and emergency managers - rain location and maximum intensity

RMS – seasonal verification at 1°, 0.25°, stations

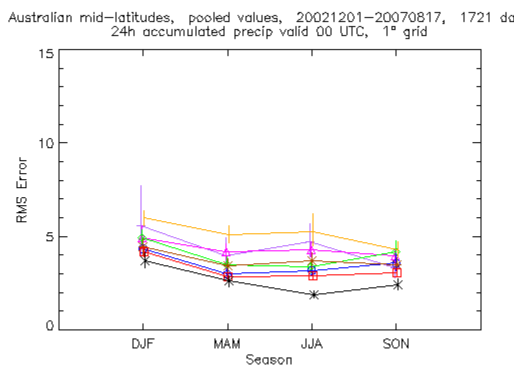
Tropics



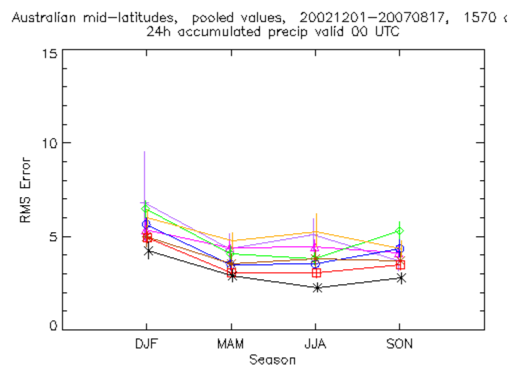




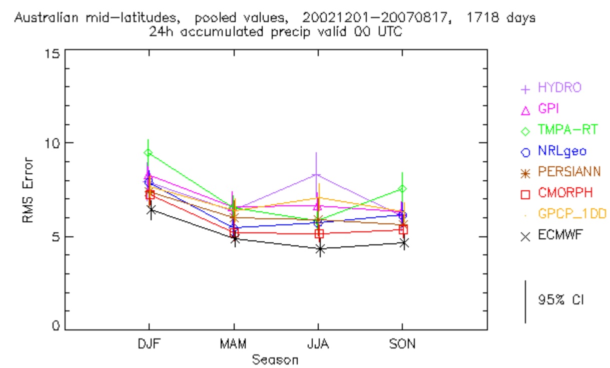
Mid-latitudes



1° grid



0.25° grid

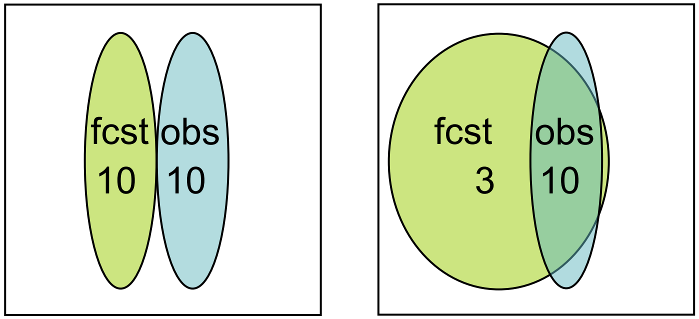


stations

More results on Australian validation web site http://www.bom.gov.au/bmrc/SatRainVal/sat_val_aus.html

"Fuzzy" (neighborhood) verification methods

- Don't require an exact match between forecasts and observations
  - Reduces "double penalty" - event predicted where it did not occur, no event predicted where it did occur
  - Rewards "close" forecasts
- Addresses uncertainties
  - Unpredictable scales
  - Uncertainty in observations

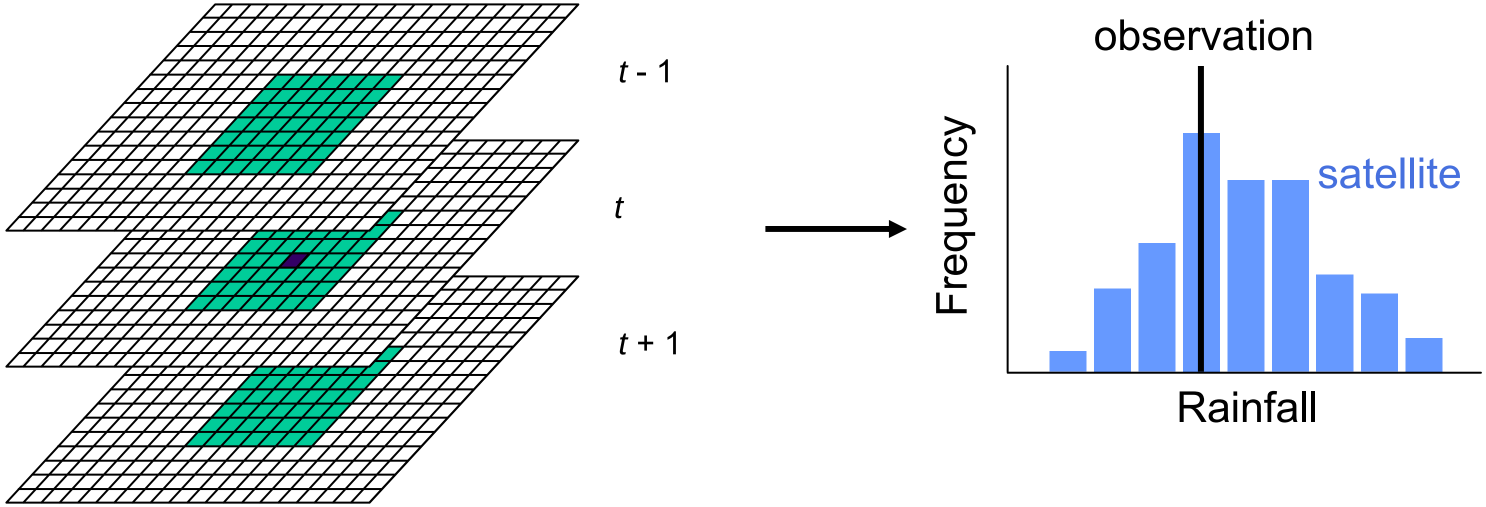


Hi res forecast
RMS ~ 4.7
POD=0, FAR=1
TS=0

Low res forecast
RMS ~ 2.7
POD~1, FAR~0.7
TS~0.3

"Fuzzy" verification methods

Look in a space / time neighborhood around the point of interest



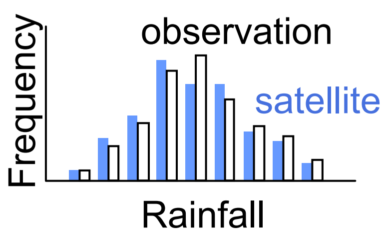
Evaluate using categorical, continuous, probabilistic scores / methods.

Fuzzy verification framework

Treatment of satellite precip 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 window to observations as well as satellite estimates



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

Fuzzy methods to address different questions

Q1: At what scales do the satellite rainfall amounts resemble the observations?

Method 1: Upscaling

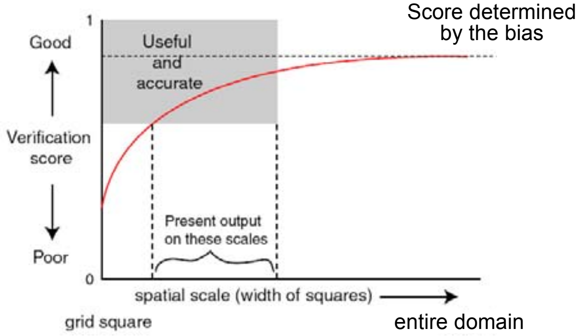
→ Average the pixels within successively larger windows and verify as usual

Zepeda-Arce, J., E. Foufoula-Georgiou, and K.K. Droegemeier, 2000: Space-time rainfall organization and its role in validating quantitative precipitation forecasts. *J. Geophys. Res.*, **105** (D8), 10,129-10,146.

Fuzzy methods to address different questions

Q2: At what scales do the satellite rain frequencies resemble the observations?

Method 2: Fractions skill score



→ Compare fractional coverage of raining pixels in satellite and radar

Fractions Brier score $FBS = \frac{1}{N}\sum_{i=1}^{N}(P_{sat} - P_{obs})^2$

Fractions skill score $FSS = 1 - \frac{\frac{1}{N}\sum_{i=1}^{N}(P_{sat} - P_{obs})^2}{\frac{1}{N}\sum_{i=1}^{N}P_{sat}^{\ 2} + \frac{1}{N}\sum_{i=1}^{N}P_{obs}^{\ 2}}$

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Roberts, N.M. and H.W. Lean, 2007: Scale-selective verification of rainfall accumulations from high-resolution forecasts of convective events. *Mon. Wea. Rev.*, in press.

Fuzzy methods to address different questions

Q3: How close* is the nearest satellite-estimated event to an observed event?

Method 3: Multi-event contingency table method

→ Count a "hit" when at least one satellite pixel in the window meets the closeness criteria. Score using categorical statistics, e.g.,

HK = hit rate – false alarm rate

*close = distance, time, intensity, etc.

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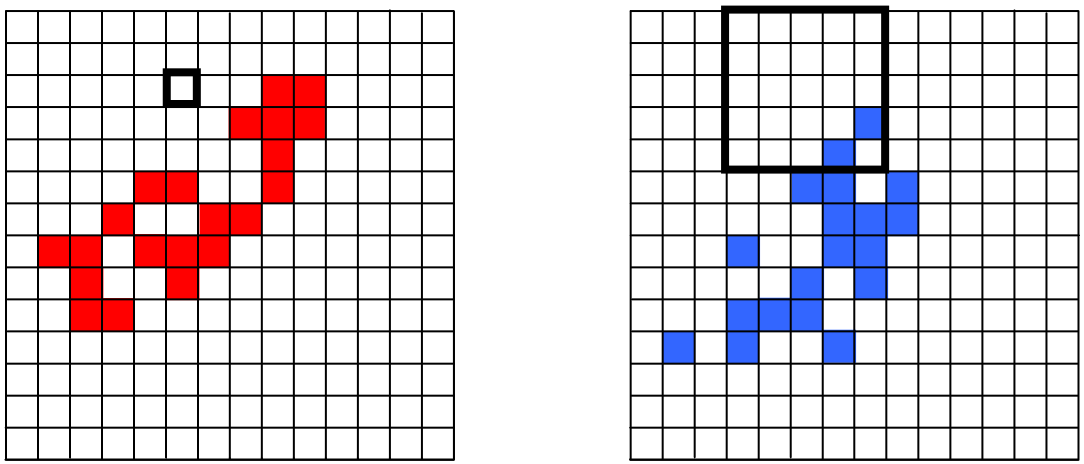
Atger, F., 2001: Verification of intense precipitation forecasts from single models and ensemble prediction systems. *Nonlin. Proc. Geophys.*, **8**, 401-417.

Fuzzy methods to address different questions

Q…: (many more)

Moving windows

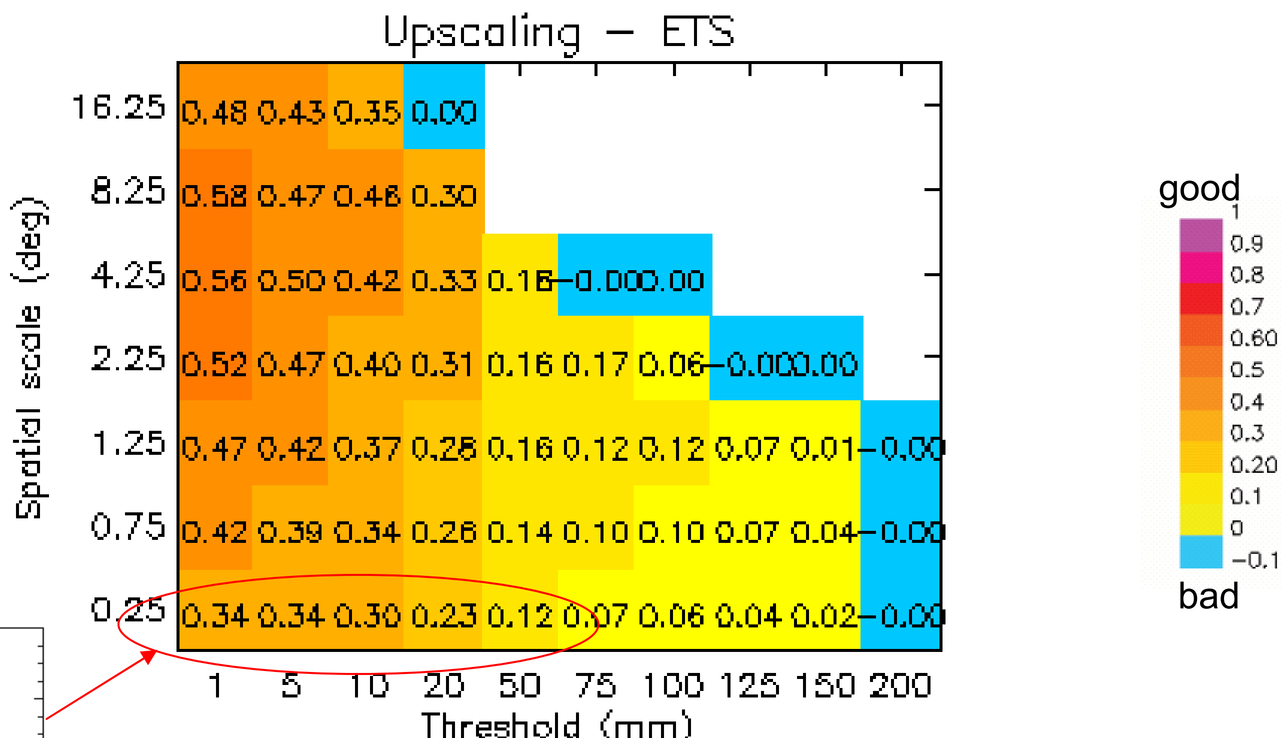
Accumulate scores as windows are moved through the domain

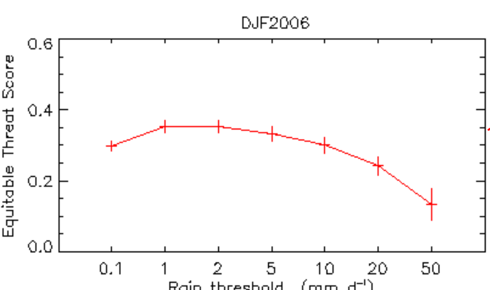


observation satellite

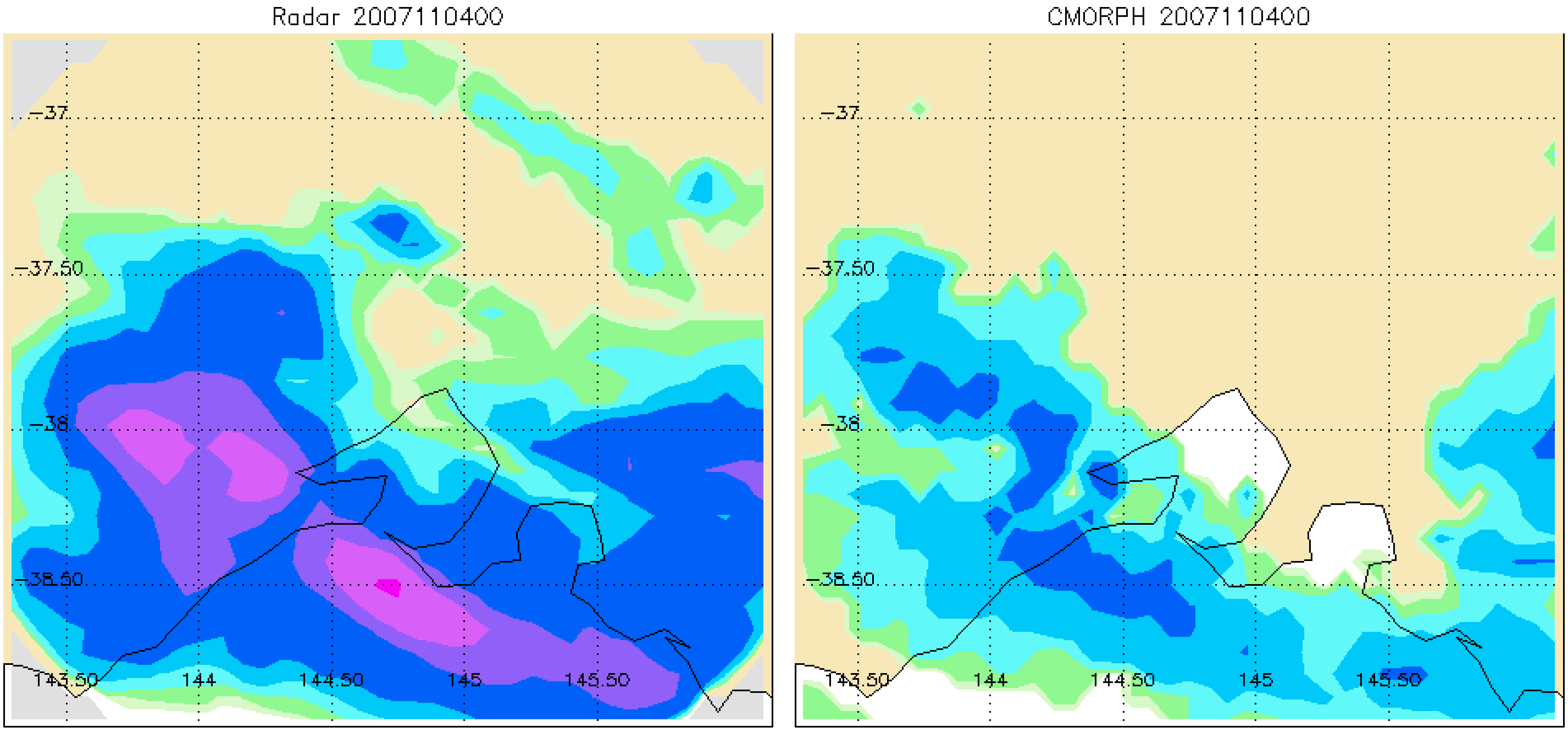
Multi-scale, multi-intensity approach

Performance depends on the scale and intensity of the event





Very high resolution case – hourly 8 km CMORPH



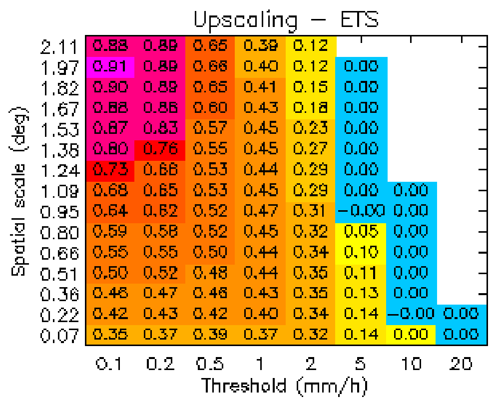
Melbourne heavy rain, 3 November 2007

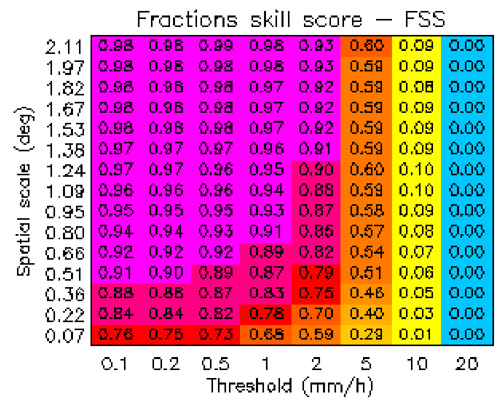
100 km

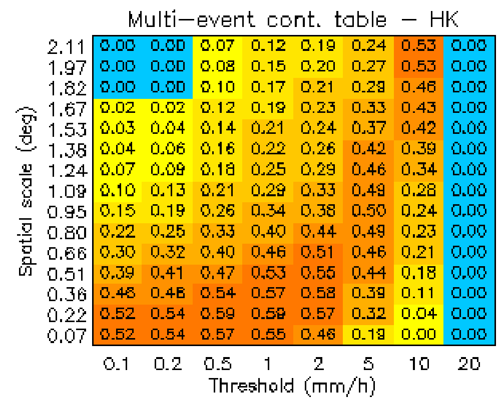
Very high resolution case – hourly 8 km CMORPH

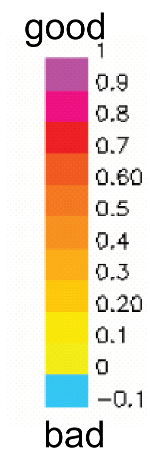
Fuzzy verification results for Melbourne aggregated for the 24 hrs on 3 Nov 2007

Δt = 0 (no temporal window)

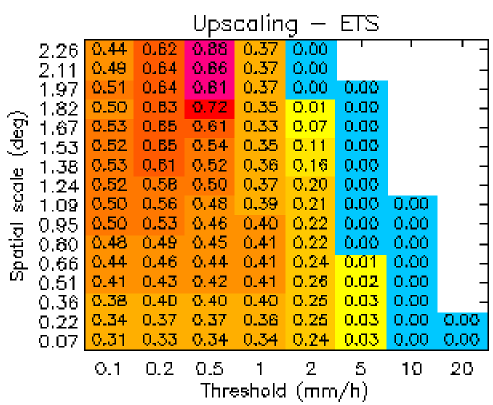


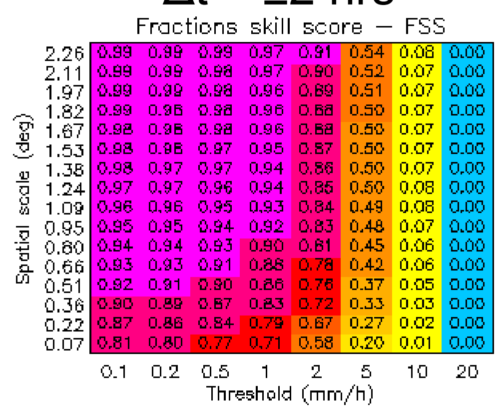


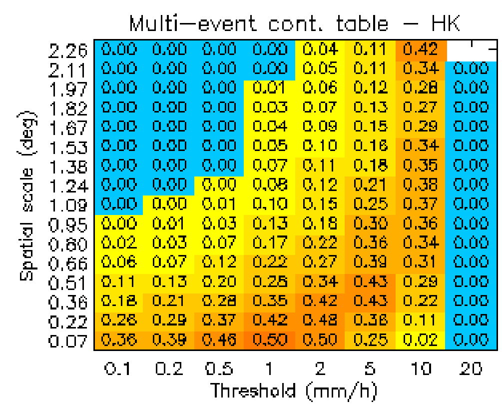




Δt = ±2 hrs

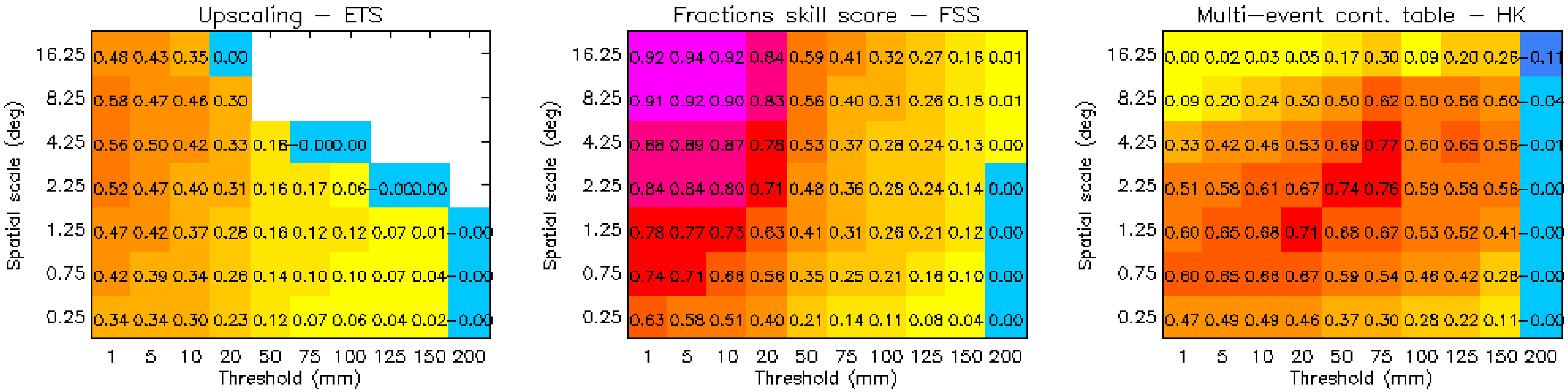


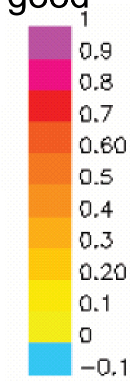




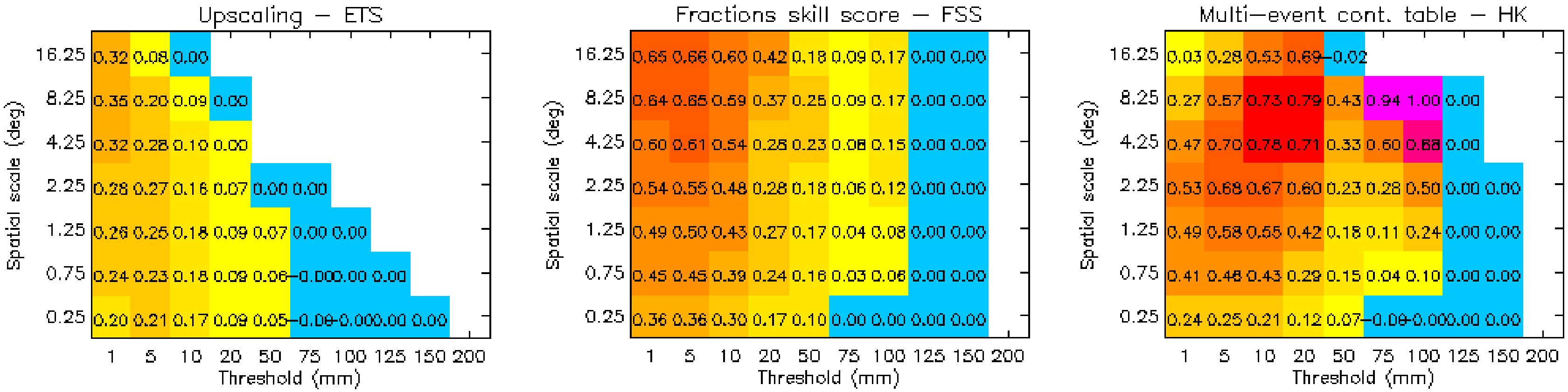
Lower resolution case – daily 3B42RT

Summer - Dec 2005 - Feb 2006





Winter – June-Aug 2006



Lower resolution case – daily 3B42RT

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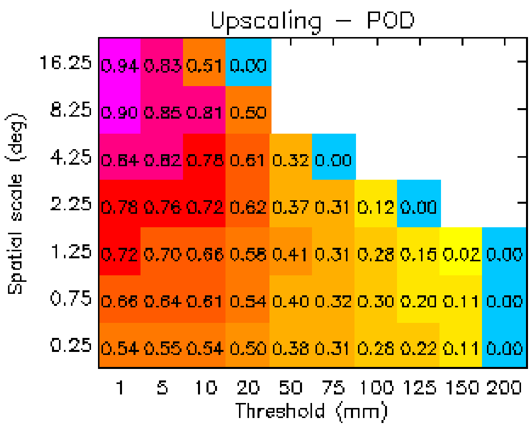

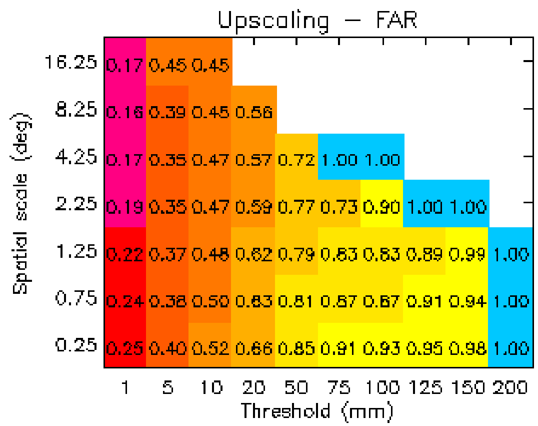

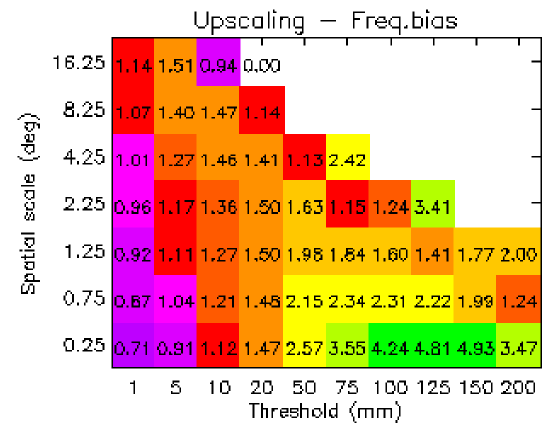

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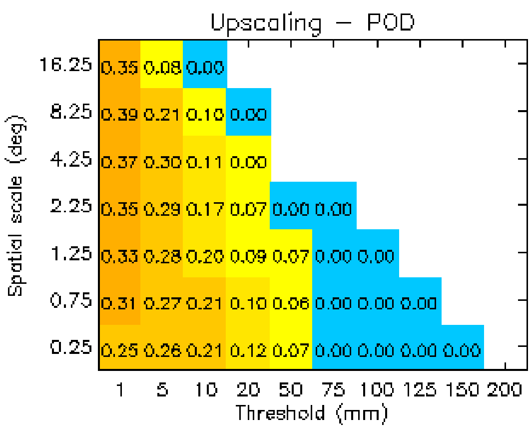
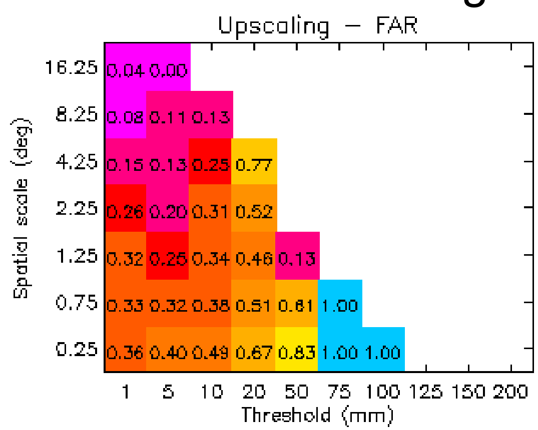
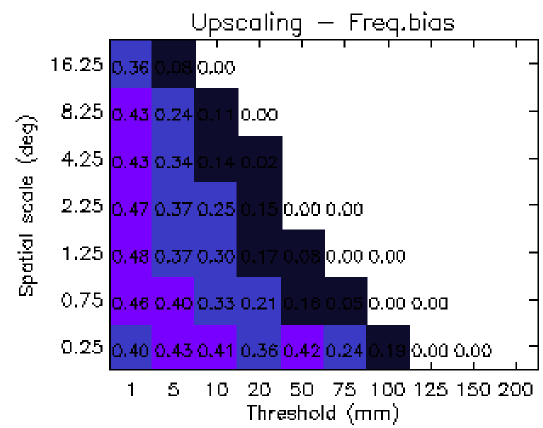






Recommendations

- Use fuzzy (neighborhood) verification methods to quantify which scales and intensities have useful skill
- Multiple methods and metrics can address many aspects of accuracy for:
  - rain amount ← direct approaches
  - rain event occurrence ← categorical approaches
  - rain area / frequency ← probabilistic approaches

Thank you!

Manuscript and fuzzy verification code (IDL) available from
http://www.bom.gov.au/bmrc/wefor/staff/eee/beth_ebert.htm

Verification at high resolution - issues

Precipitation characteristics

- Greater variability at short time/space scales

Surface data

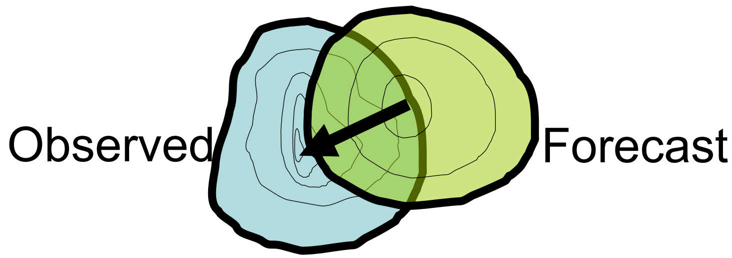
- Rain gauges
  - Most sample daily rainfall
  - Spatial representativeness errors
- Radar
  - Biases, beamfilling, overshoot, attenuation, AP, etc.
  - Great space/time coverage
- Optimal strategy – gauge-corrected radar

Weaknesses and limitations

- Less intuitive than object-based methods
- Imperfect scores for perfect forecasts for methods that match neighborhood forecasts to single observations
- **Information overload** if all methods invoked at once
  - Let appropriate decision model(s) guide the choice of method(s)
- Even for a single method …
  - there are lots of numbers to look at
  - evaluation of scales and intensities with best performance depends on metric used (CSI, ETS, HK, etc.). Be sure the metric addresses the question of interest!

Contiguous Rain Area (CRA) entity-based approach for verifying high resolution forecasts

- Define *entities* using a threshold
- Horizontally translate the forecast until a *pattern matching* criterion is met

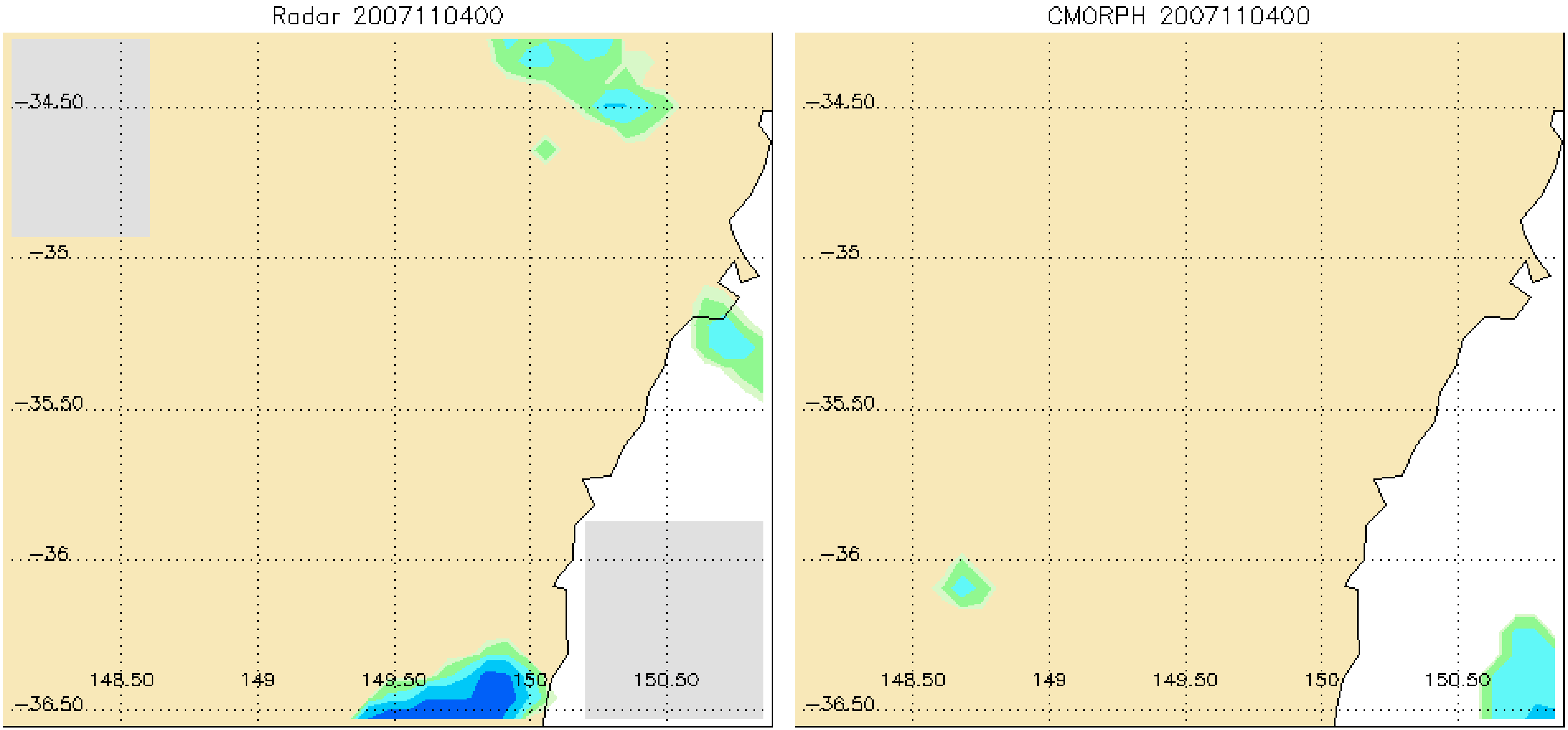


- Displacement is the vector difference between the original and final locations of the forecast
- Compare properties of whole objects

Comparison of verification strategies

Fuzzy verification	Entity-based verification
• Handles messy fields and discrete objects	• Handles discrete objects only
• Assessment across multiple scales	• Holistic assessment on scale of object
• Fairly intuitive	• Very intuitive
• Completely objective	• Some choice of parameters
• Can be extended to time domain	• Can be extended to time domain
• Offers many decision models	• Gives location error and total error decomposition

Very high resolution case – hourly 8 km CMORPH



Sydney heavy rain, 3 November 2007

Very high resolution case – hourly 8 km CMORPH

Fuzzy verification results for Sydney aggregated for the 24 hrs on 3 Nov 2007

Δt = 0 (no temporal window)