Multi-scale validation of high resolution precipitation products

Beth Ebert

Centre for Australian Climate and Weather Research Bureau of Meteorology







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

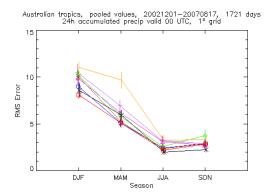


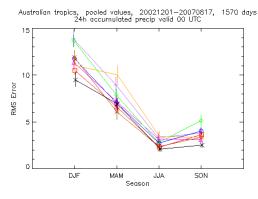
PEHRPP Workshop, Geneva, 3-5 December 2007

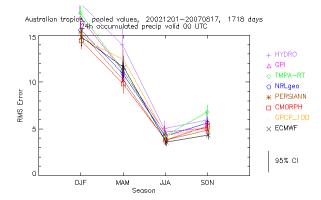
RMS – seasonal verification at 1°, 0.25°, stations





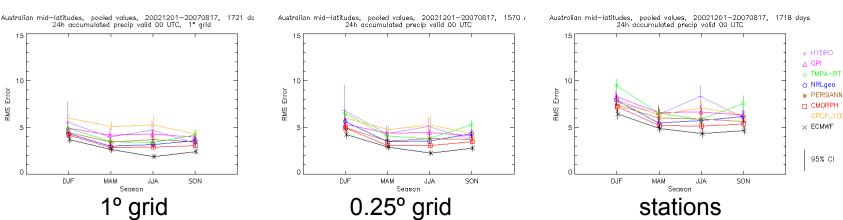






stations

Mid-latitudes





15

10

5

0

Error

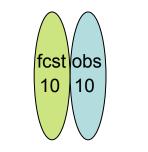
RMS

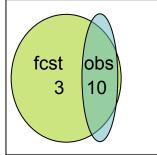
More results on Australian validation web site http://www.bom.gov.au/bmrc/SatRainVal/sat_val_aus.html

"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

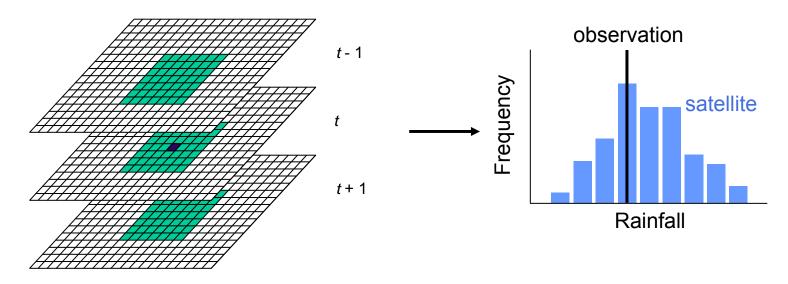
Low res forecast RMS ~ 2.7 POD~1, FAR~0.7 TS~0.3





"Fuzzy" verification methods

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



Evaluate using categorical, continuous, probabilistic scores / methods.



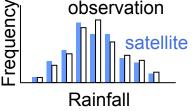
Fuzzy verification framework



Treatment of satellite precip data within a window:

- Mean value (upscaling)
- Occurrence of event* somewhere in window
- Frequency of event in window \rightarrow 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





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



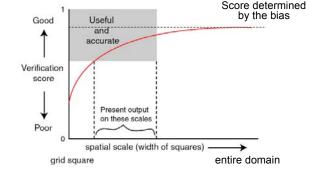
Zepeda-Arce, J., E. Foufoula-Georgiou, and K.K. Droegemeier, 2000: Space-time rainfall organization and its role in validating quantitative precipitation forecasts. *J. Geophys. Res.*, **105** (D8), 10,129-10,146.



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

Fractions skill score

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



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.



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.



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

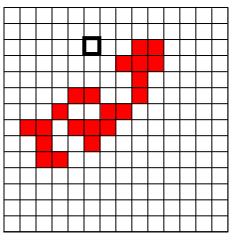
Q...: (many more)



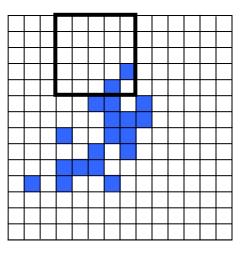
Moving windows



Accumulate scores as windows are moved through the domain



observation



satellite

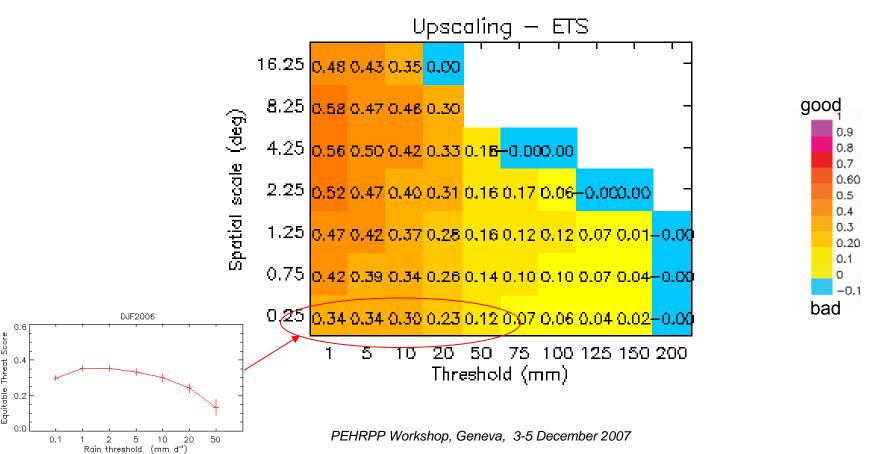


Multi-scale, multi-intensity approach



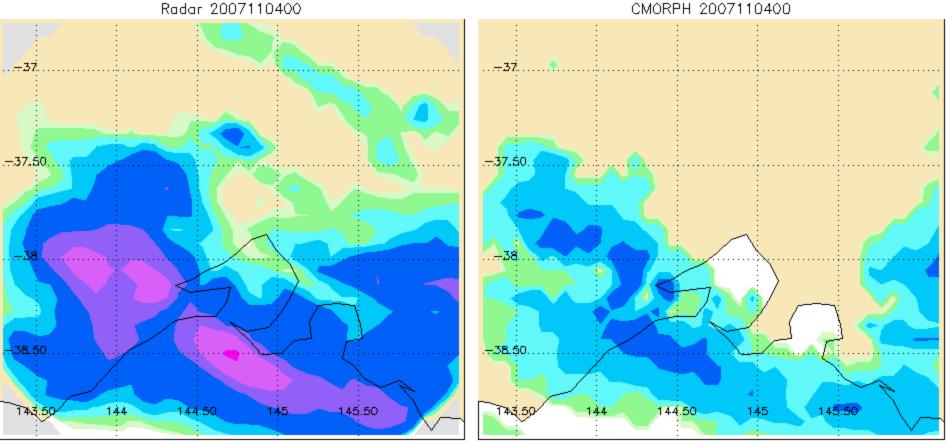
13

Performance depends on the scale and intensity of the event



Very high resolution case – hourly 8 km CMORPH





Melbourne heavy rain, 3 November 2007



PEHRPP Workshop, Geneva, 3-5 December 2007

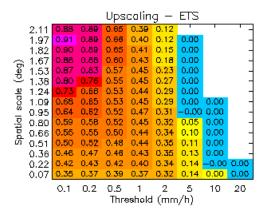
100 km

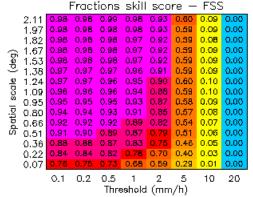
Very high resolution case – hourly 8 km CMORPH

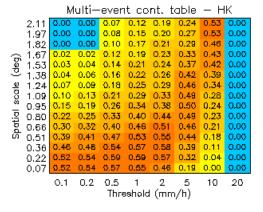


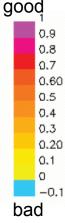
Fuzzy verification results for Melbourne aggregated for the 24 hrs on 3 Nov 2007

 $\Delta t = 0$ (no temporal window)









			Ups	calin	g –	ETS		
2.26	0.44	0.62	0.88	0.37	0.00		1	
2.11	0.49	0.64	0.86	0.37	0.00			-
1.97	0.51	0.64	0.61	0.37	0.00	0.00		-
_ 1.82	0.50	0.83	0.72	0.35	0.01	0.00		-
8 1.67 9 1.53	0.53	0.85	0.61	0.33	0.07	0.00		-
ै 1.53	0.52	0.85	0.54	0.35	0.11	0.00		-
4 70	0.53	0.61	0.52	0,36	0.16	0.00		-
al 1.38 1.24 1.09 1.09 1.09 1.09 1.09 0.80	0.52	0.5B	0.50	0.37	0.20	0.00		-
	0.50	0,56	0.48	0,39	0.21	0.00	0.00	-
	0.50	0.53	0.46	0.40	0.22	0.00	0.00	-
	0.48	0.49	0.45	0.41	0.22	0.00	0.00	-
J 0.66	0.44	0.46	0.44	0.41	0.24	0.01	0.00	-
o 0.51 ^م	0.41	0.43	0.42	0.41	0.26	0.02	0.00	-
0.36	0.38	0.4D	0.40	0.40	0.25	0.03	0.00	-
0.22	0.34	0.37	0.37	0.36	0.25	0.03	0.00	0.00
0.07	0.31	0.33	0.34	0,34	0.24	0.03	0.00	0.00
	0.1	0.2	0.5 Thre	1 aebold	2	5 /b)	10	20
	Threshold (mm/h)							

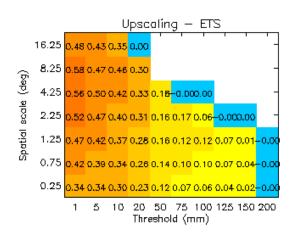
 $\Delta t = \pm 2$ hrs

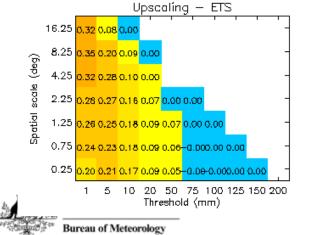
Fractions skill score — FSS)
2.26	0.99	0.99	0.99	0.97	0.91	0.54	0.08	0.00
2.11	0.99	0.99	0.98	0.97	0.90	0.52	0.07	0.00
1.97	0.99	0.99	0.98	0.96	0.89	0.51	0.07	0.00
_ 1.82	0.99	0.96	0.98	0.96	0.68	0.50	0.07	0.00
្លា 1.67	0.98	0.98	0.98	0.96	0.88	0.50	0.07	0.00
୍ଷି 1.67 ଟ୍ରି 1.67 ପ୍ର 1.53	0.98	0.9B	0.97	0.95	0.87	0.50	0.07	0.00
	0.98	0.97	0.97	0,94	0.86	0.50	0.07	0.00
ซี 1.24	0.97	0.97	0.96	0,94	0.85	0.50	0.08	0.00
ຍ 1.38 ອີ 1.24 % 1.09	0.96	0,96	0.95	0,93	0.84	0.49	0.08	0.00
	0.95	0.95	0.94	0.92	0.83	0.48	0.07	0.00
0.95 0.60 0.66 0.51	0.94	0.94	0.93	0.90	0.81	0.45	0.06	0.00
a 0.66	0.93	0.93	0.91	0.88	0.78	0.42	0.06	0.00
۵.51 ^۵	0.92	0.91	0.90	0.86	0.76	0.37	0.05	0.00
0.36	0.90	0.89	0.87	0.83	0.72	0.33	0.03	0.00
0.22	0.87	0.86	0.84	0.79	0.67	0.27	0.02	0.00
0.07	0.81	0.80	0.77	0.71	0.58	0.20	0.01	0.00
	0.1	0.2	0.5	1	2	5	10	20
	Threshold (mm/h)							

Multí—event cont. table — HK									
	2.26	0.00	0.00	0.00	0.00	0.04	0.11	0.42	' -
	2.11	0.00	0.00	0.00	0.00	0.05	0.11	0.34	0.00
	1.97	0.00	0.00	0.00	0.01	0.06	0.12	0.28	0.00
\sim	1.82	0.00	0.0D	0.00	0.03	0.07	0.13	0.27	0.00
(deg)	1.67	0.00	0.0D	0.00	0.04	0.09	0.15	0.29	0.00
ত	1.53	0.00	0.0D	0.00	0.05	0.10	0.16	0.34	0.00
	1.38	0.00	0.00	0.00	0.07	0.11	0.18	0.35	0.00
scale	1.24	0.00	0.00	0.00	80.0	0.12	0.21	0.38	0.00
8	1.09	0.00	0.00	0.01	0,10	0.15	0.25	0.37	0.00
7	0.95	0.00	0.01	0.03	0.13	0.18	0.30	0.36	0.00
÷Ě	0.80	0.02	0.03	0.07	0,17	0.22	0.36	0.34	0.00
Spatial	0.66	0.06	0.07	0.12	0.22	0.27	0.38	0.31	0.00
D1	0.51	0.11	0.13	0.20	0.28	0.34	0.43	0.29	0.00
	0.36	0.18	0.21	0.28	0.35	0.42	0.43	0.22	0.00
	0.22	0.26	0.29	0.37	0.42	0.48	0.36	0.11	0.00
	0.07	0.36	0.39	0.46	0,50	0.50	0.25	0.02	0.00
		0.1	0.2	0.5	1	2	5	10	20
	Threshold (mm/h)								

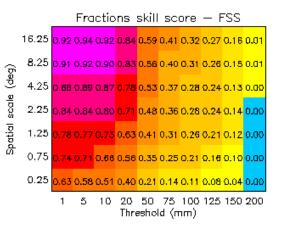


Lower resolution case – daily 3B42RT

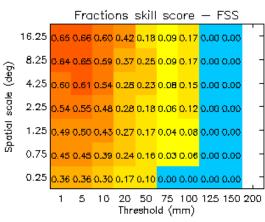


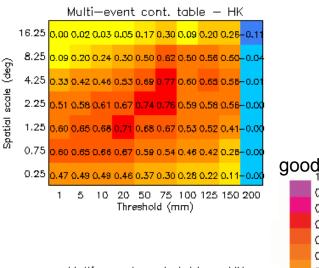


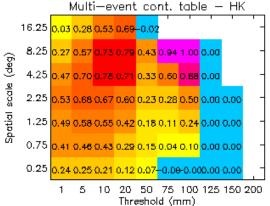




Winter – June-Aug 2006







PEHRPP Workshop, Geneva, 3-5 December 2007

0.9

0.8

0.60 0.5

0.4

0.20

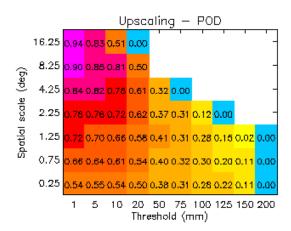
-0.1

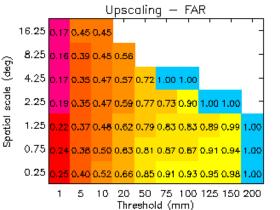
0.1

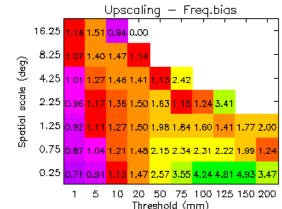
0

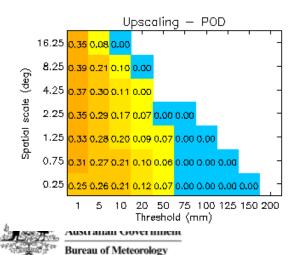
bad

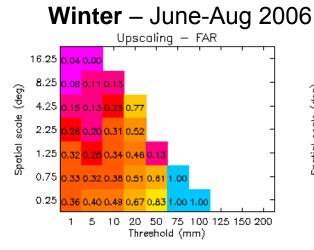
Lower resolution case – daily 3B42RT

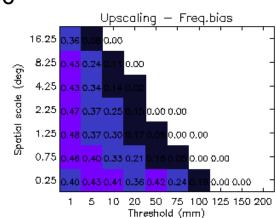












Summer - Dec 2005 - Feb 2006

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 \leftarrow categorical approaches
 - rain area / frequency ← probabilistic approaches







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



PEHRPP Workshop, Geneva, 3-5 December 2007

Surface data

Greater variability at short time/space scales

Verification at high resolution -

- Rain gauges
 - Most sample daily rainfall

Precipitation characteristics

- Spatial representativeness errors
- Radar

issues

- Biases, beamfilling, overshoot, attenuation, AP, etc.
- Great space/time coverage
- Optimal strategy gauge-corrected radar





Weaknesses and limitations



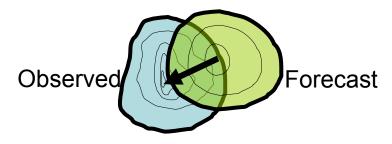
- Less intuitive than object-based methods
- Imperfect scores for perfect forecasts for methods that match neighborhood forecasts to single observations
- Information overload if all methods invoked at once
 - Let appropriate decision model(s) guide the choice of method(s)
- Even for a single method ...
 - 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

- Handles messy fields and discrete objects
- Assessment across multiple scales
- Fairly intuitive
- Completely objective
- Can be extended to time domain
- Offers many decision models

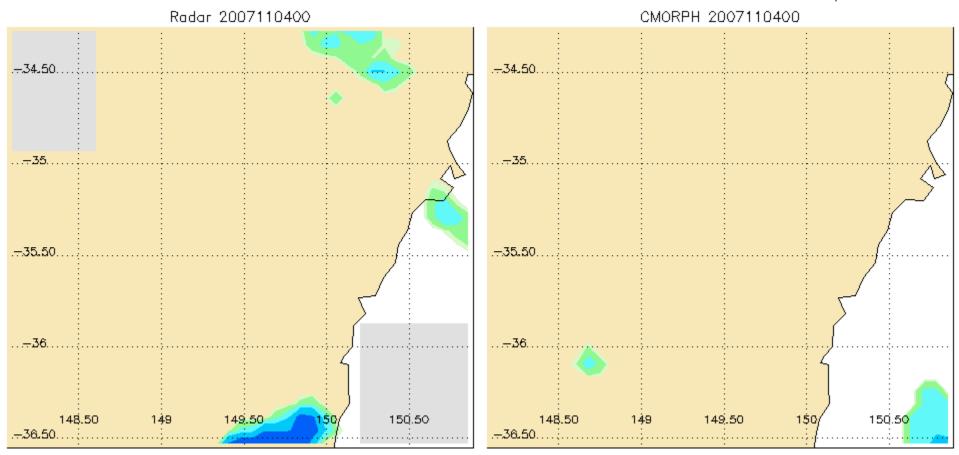
Entity-based verification

- Handles discrete objects only
- Holistic assessment on scale of object
- Very intuitive
- Some choice of parameters
- Can be extended to time domain
- Gives location error and total error decomposition



Very high resolution case – hourly 8 km CMORPH





Sydney heavy rain, 3 November 2007



PEHRPP Workshop, Geneva, 3-5 December 2007

Very high resolution case – hourly 8 km CMORPH



Fuzzy verification results for Sydney aggregated for the 24 hrs on 3 Nov 2007 $\Delta t = 0$ (no temporal window)

