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Comparing Distance Methods for Spatial Verification

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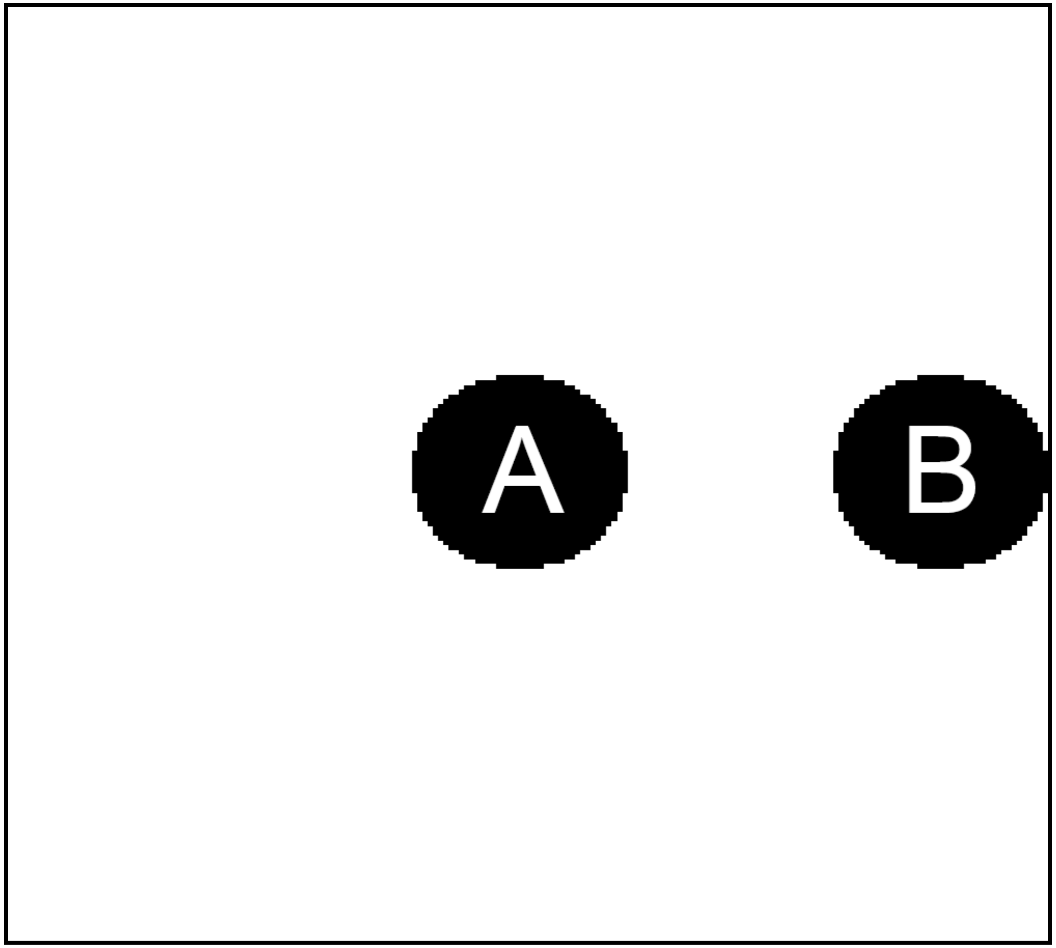
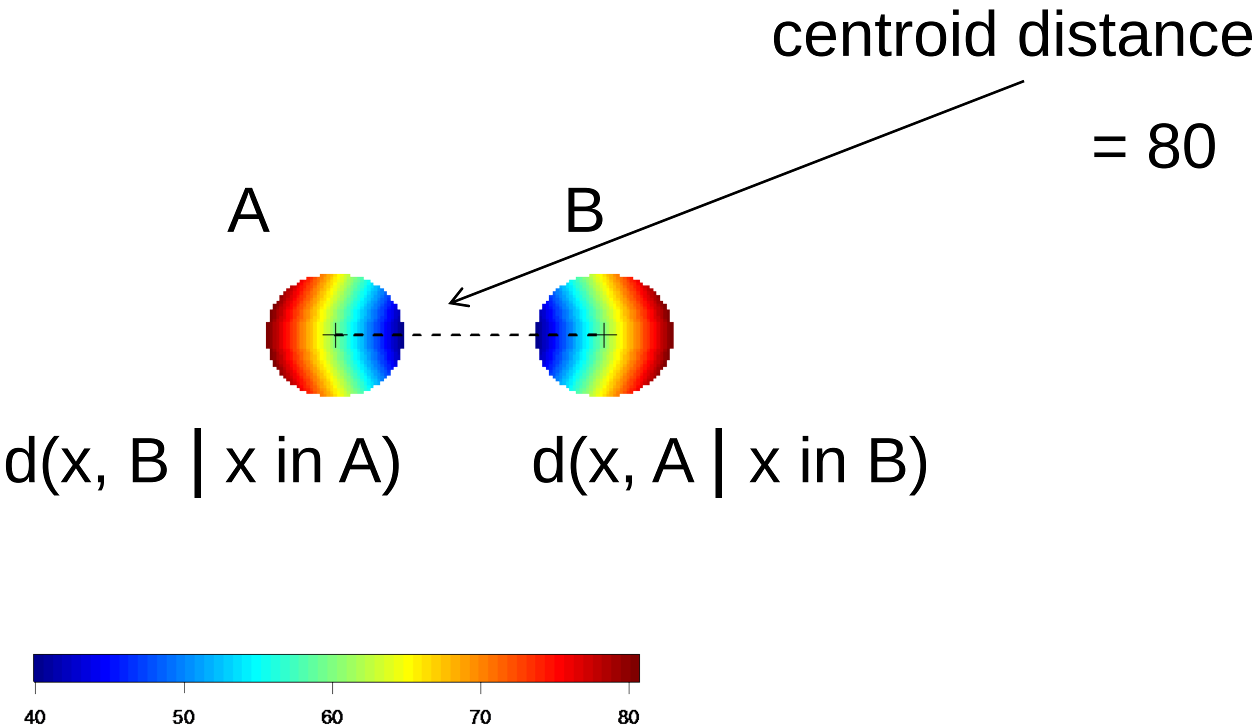

A
B

Mean Error Distance

MED(A, B) is the average distance from points in the set B to points in the set A



$MED(A,B) = \Sigma_x \, d(x, A \mid x \text{ in } B) \, / \, N_B$ $MED(B,A) = \Sigma_x \, d(x, B \mid x \text{ in } A) \, / \, N_A$

N_B is the number of points in the set B

Baddeley's Δ Metric

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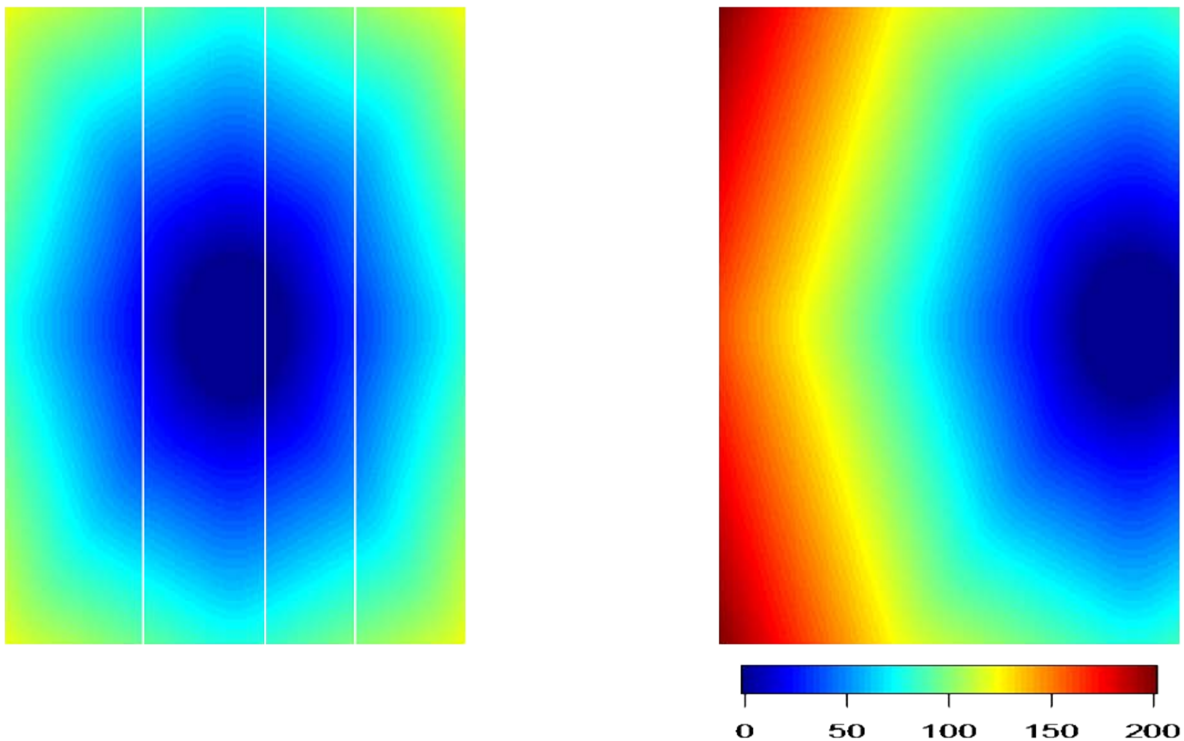
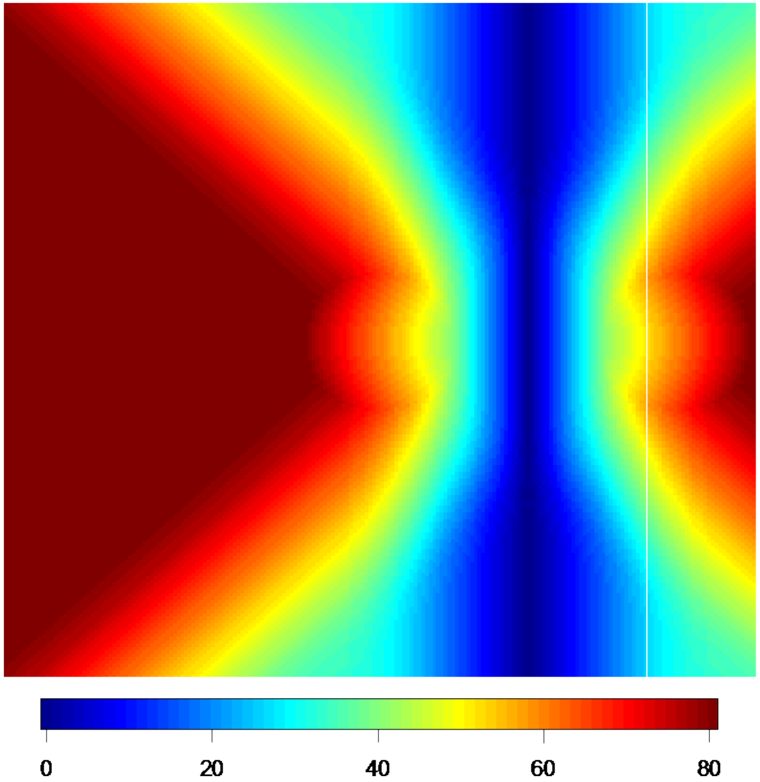
d(x, A) d(x, B)



Distance maps for A and B. Note dependence on location within the domain.

Baddeley's Δ Metric

$T = | d(x, A) - d(x, B) |$



- p = 1 gives the arithmetic average of T
- p = 2 is the usual choice
- p = ∞ gives the max of T (Hausdorff distance)

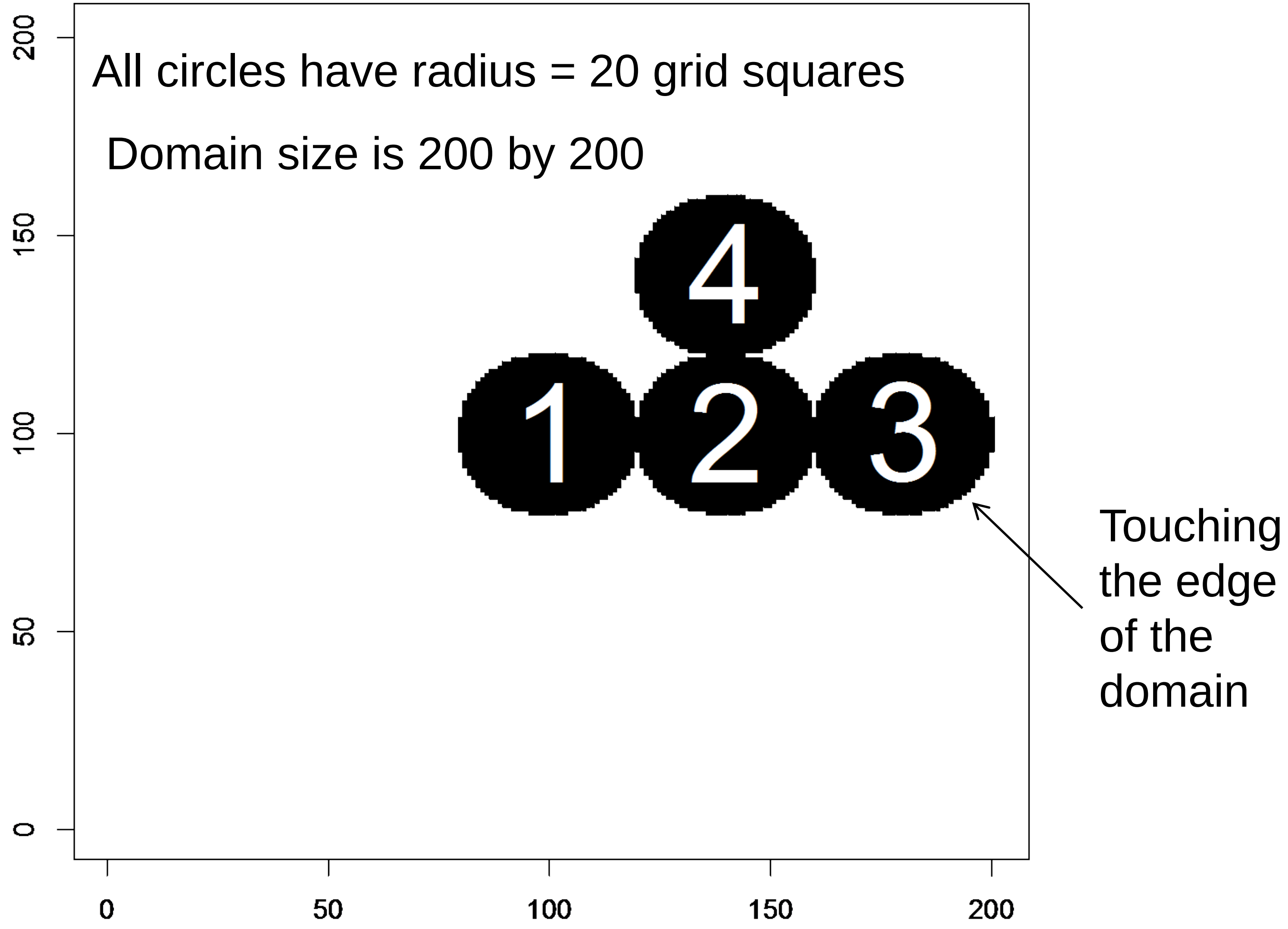
Δ is the L_p norm of T

d(x, A) and d(x, B) are first transformed by a function ω. Usually,
ω(x) = max(x, constant), but all results here use ∞ for the constant term.

$$\Delta(A, B) = \Delta(B, A) = \left[\Sigma_{x \text{ in Domain}} | d(x, A) - d(x, B) |^p \right]^{1/p} / N$$

N is the size of the domain

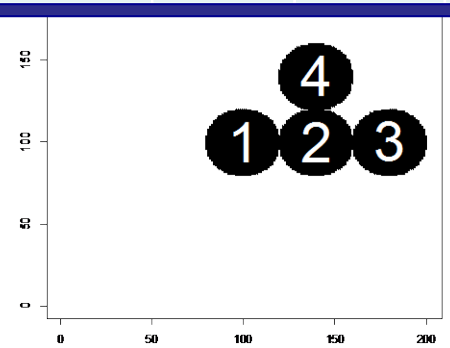
Contrived Examples: Circles



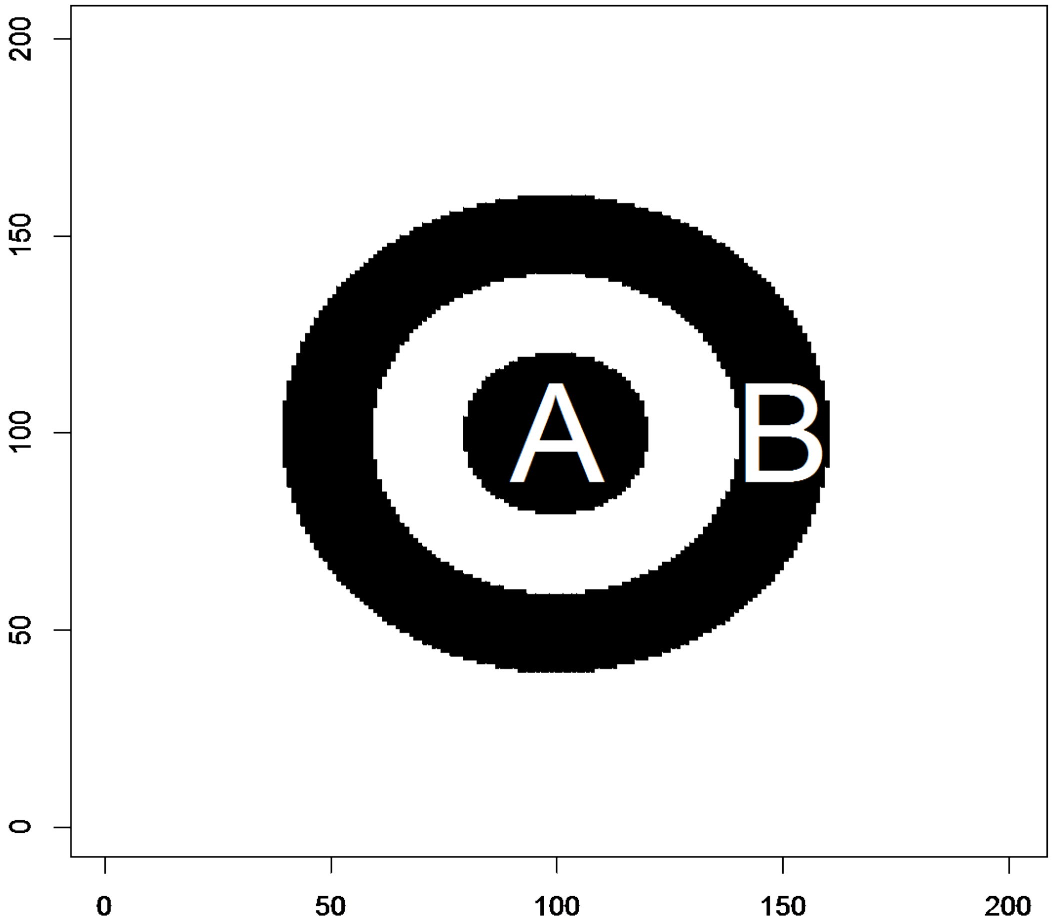
Contrived Examples: Circles

A	B	MED(A, B)	rank	MED(B, A)	rank	Δ(A, B)	rank	cent dist.	rank
1	2	22	2	22	1	29	2	40	2
1	3	62	4	62	3	57	6	80	4
1	4	38	3	38	2	41	5	57	3
2	3	22	2	22	1	31	3	40	2
2	4	22	2	22	1	28	1	40	2
2	1, 3, 4	11	1	22	1	29	2	13	1
3	4	38	3	38	2	38	4	57	3

If comparisons are made after centering the two binary fields on a new, square grid (201 by 201), then Δ is 28.84 for 1 vs 2, 2 vs 3 and 2 vs 4



Circle and a Ring

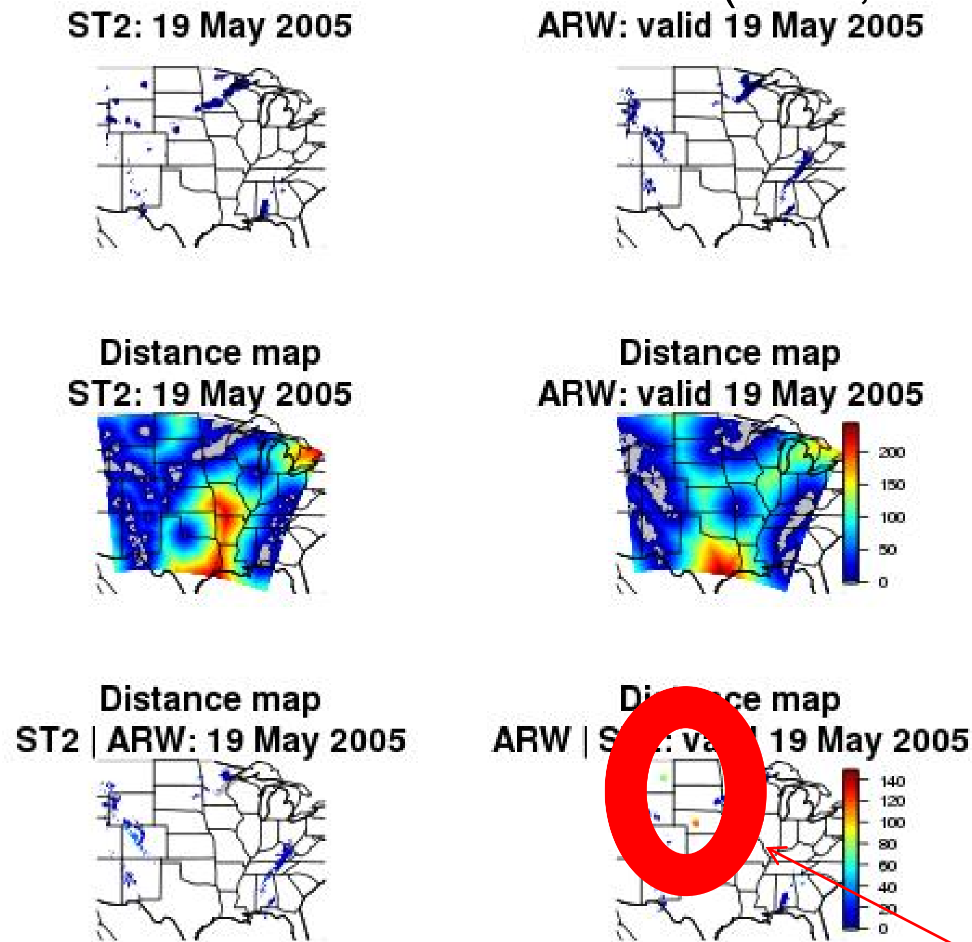


MED(A, B) = 32
MED(B, A) = 28
Δ(A, B) = 38

centroid distance = 0

Mean Error Distance

MED(ST2, ARW) ≈ 15.42 is much smaller than MED(ARW, ST2) ≈ 66.16



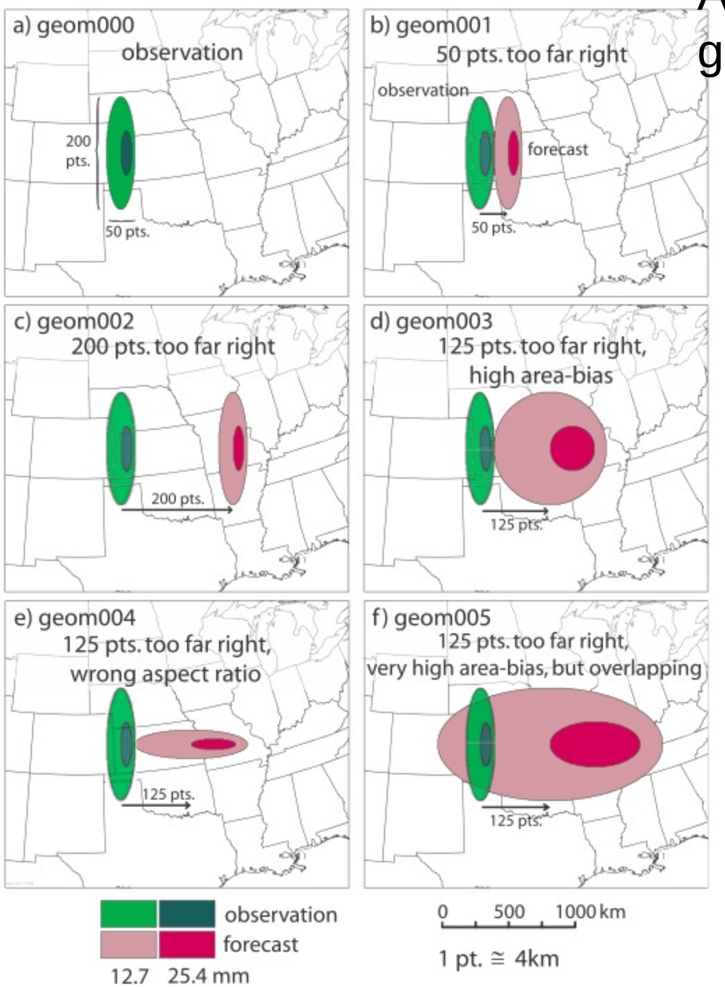
High sensitivity to small changes in the field!

Good or bad quality depending on user need.

Fig. 2 from G. (2016 submitted to WAF, available at: http://www.ral.ucar.edu/staff/ericg/Gilleland2016.pdf)

Missed Areas

Geometric ICP Cases



Avg. Distance from green to pink

Avg. Distance from pink to green

Case	MED(A, Obs)	rank	MED(Obs, A)	rank
1	29	2	29	1
2	180	5	180	5
3	36	3	104	3
4	52	4	101	2
5	1	1	114	4

Values rounded to zero decimal places

Table from part of Table 1 in G. (2016, submitted to WAF)
Fig. 1 from Ahijevych *et al*. (2009, *WAF*, **24**, 1485 – 1497)

Geometric ICP Cases

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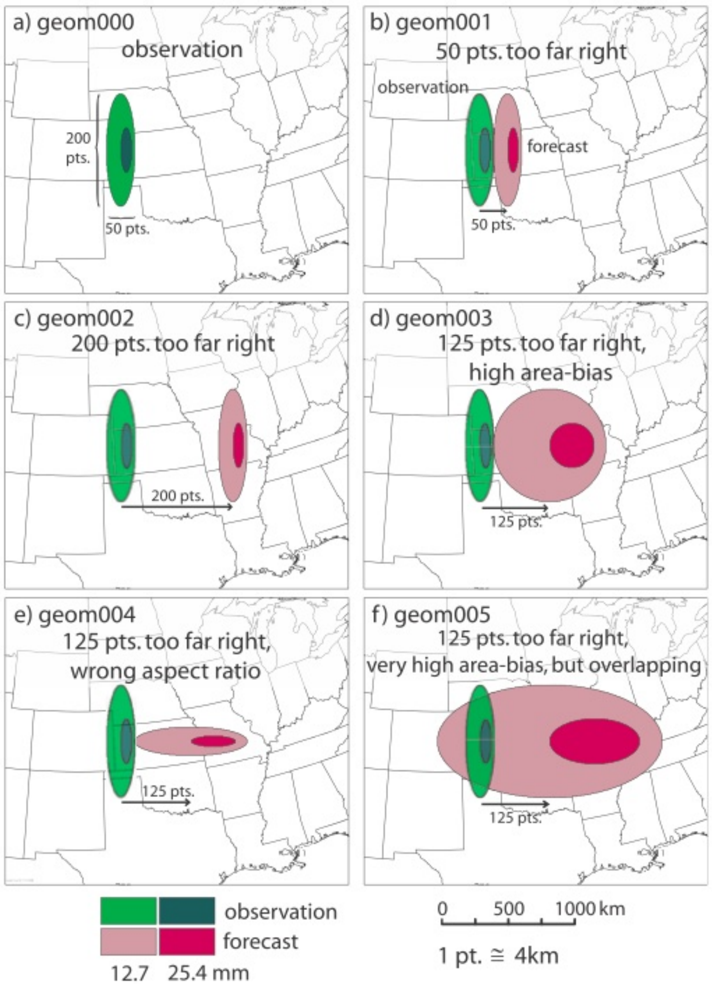

Case	MED(A, Obs)	rank	MED(Obs, A)	rank
1	29	2	29	1
2	180	5	180	5
3	36	3	104	3
4	52	4	101	2
5	1	1	114	4

Case	Δ(A, Obs)	rank
1	45	1
2	167	5
3	119	3
4	106	2
5	143	4

Values rounded to zero decimal places

Table from part of Table 1 in G. (WAF, 2017)

Fig. 1 from Ahijevych *et al*. (2009, *WAF*, **24**, 1485 – 1497)

Geometric ICP Cases

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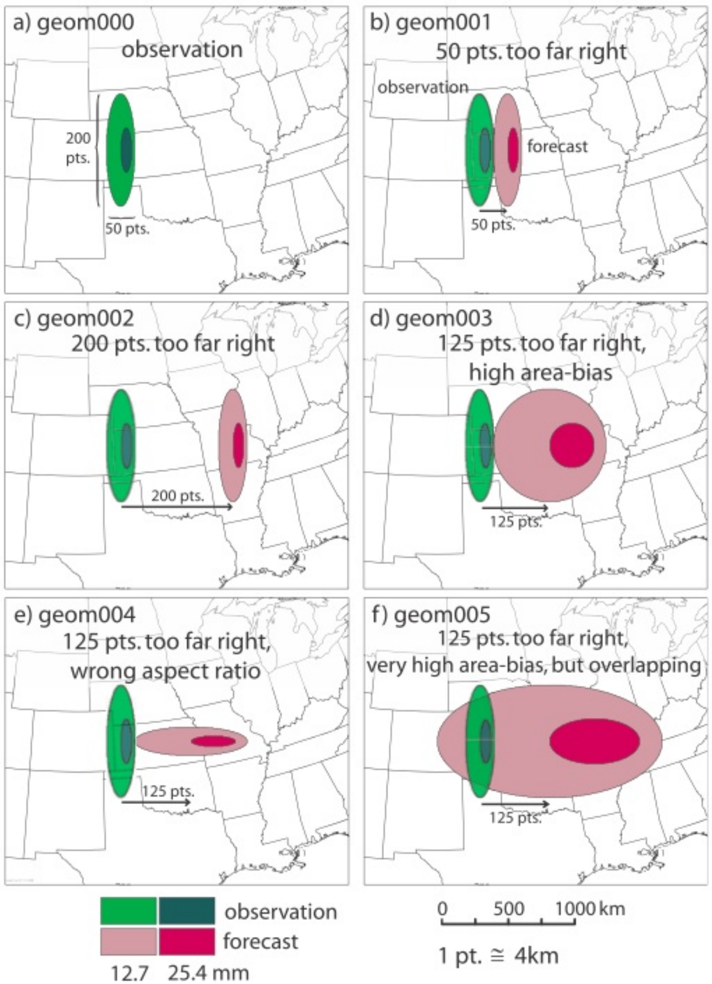

Case	Δ(A, Obs)	rank
1	45	1
2	167	5
3	119	3
4	106	2
5	143	4

After centering fields and expanding grid to 601 by 601

Case	Δ(A, Obs)	rank
1	43	1
2	161	5
3	114	3
4	96	2
5	146	4

Values rounded to zero decimal places

Table from part of Table 1 in G. (WAF 2017)
Fig. 1 from Ahijevych *et al*. (2009, *WAF*, **24**, 1485 – 1497)

Mean Error Distance

- Magnitude of MED tells how good or bad the “misses/false alarms” are.
- Miss = Average distance of observed non-zero grid points from forecast.
  - Perfect score: MED(Forecast, Observation) = zero (no misses at all)
    - All observations are within forecasted non-zero grid point sets.
  - Good score = Small values of MED(Forecast, Observation)
    - all observations are near forecasted non-zero grid points, on average.
- False alarm = Average distance of forecast non-zero grid points from observations.
  - Perfect score: MED(Observation, Forecast) = zero (no false alarms at all)
    - All forecasted non-zero grid points fall overlap completely with observations.
  - Good score = Small values of MED(Observation, Forecast)
    - all forecasts are near observations, on average.
- Hit/Correct Negative
  - Perfect Score: MED(both directions) = 0
  - Good Value = Small values of MED(both directions)

Mean Error Distance

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MesoVICT core cases

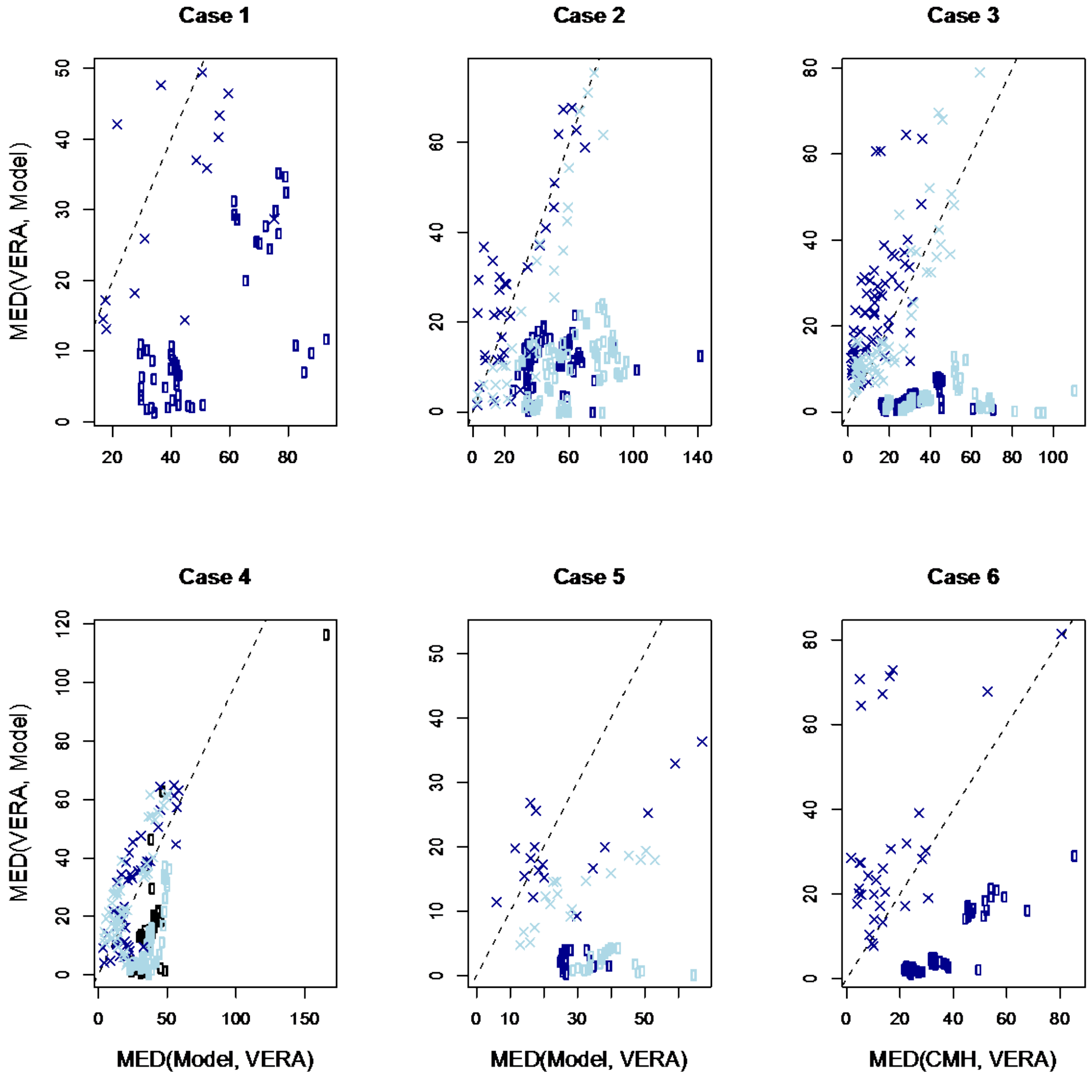
CMH

CO2

Threshold

o = 0.1 mm h^{-1}

× = 5.1 mm h^{-1}



Misses

False Alarms

MED Summary

- Mean Error Distance
  - Useful summary when applied in both directions
  - New idea of false alarms and misses (spatial context)
  - Computationally efficient and easy to interpret
- Properties
  - High sensitivity to small changes in one or both fields
  - Does not inform about bias per se
    - Could hedge results by over forecasting, but only if over forecasts are in the vicinity of observations!
  - No edge or position effects (unless part of object goes outside the domain)
  - Does not inform about patterns of errors
  - Does not directly account for intensity errors (only location)
  - Fast and easy to compute and interpret
- Complementary Methods include (but not limited to)
  - Frequency/Area bias (traditional)
  - Geometric indices (AghaKouchak et al 2011, doi:10.1175/2010JHM1298.1)

Baddeley's Δ Metric Summary

- Sensitive to differences in size, shape, and location
- A proper mathematical metric (therefore, amenable to ranking)
  - positivity ($\Delta(A, B) \geq 0$ for all A and B)
  - identity ($\Delta(A, A) = 0$ and $\Delta(A, B) > 0$ if $A \neq B$)
  - symmetry ($\Delta(A, B) = \Delta(B, A)$)
  - triangle inequality ($\Delta(A, C) \leq \Delta(A, B) + \Delta(B, C)$)
- Sensitive to position within the domain
  - Issue is overcome by centering (the pair of binary fields together) on a new square grid.
- Upper limit bounded only by domain size
  - Any comparisons across cases needs to be done on the same grid.
  - Grid should be square and comparisons should be done with object(s) centered on the grid.

Centroid Distance Summary

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- Is a true mathematical metric. So, conducive to rankings.
- Not sensitive to position within a field (or orientation of A to B; i.e., if A and B are rotated as a pair, the distance does not change)
- No edge effects
- Gives useful information for translation errors between objects that are similar in size, shape and orientation.
- Not sensitive to area bias
- Not as useful otherwise.
- Should be combined with other information.

- Thank you
- Questions?

- Gilleland, E., 2017. A new characterization in the spatial verification framework for false alarms, misses, and overall patterns. Weather Forecast., 32 (1), 187 - 198, DOI: 10.1175/WAF-D-16-0134.1.