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Spatial Verification: A New Spatial Alignment Error Summary

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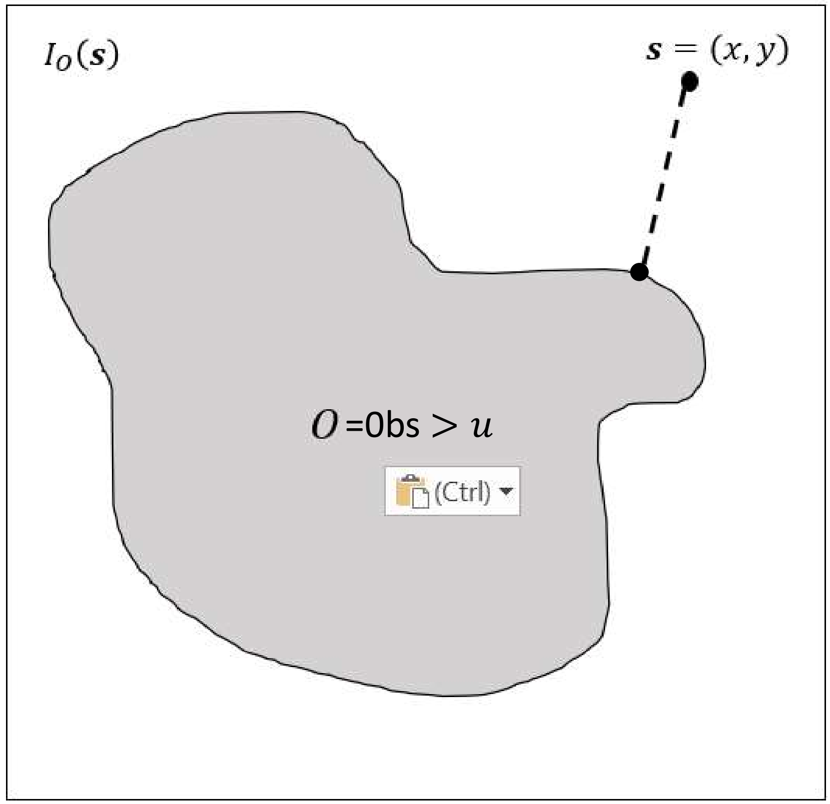
https://jwgfvr.univie.ac.at/

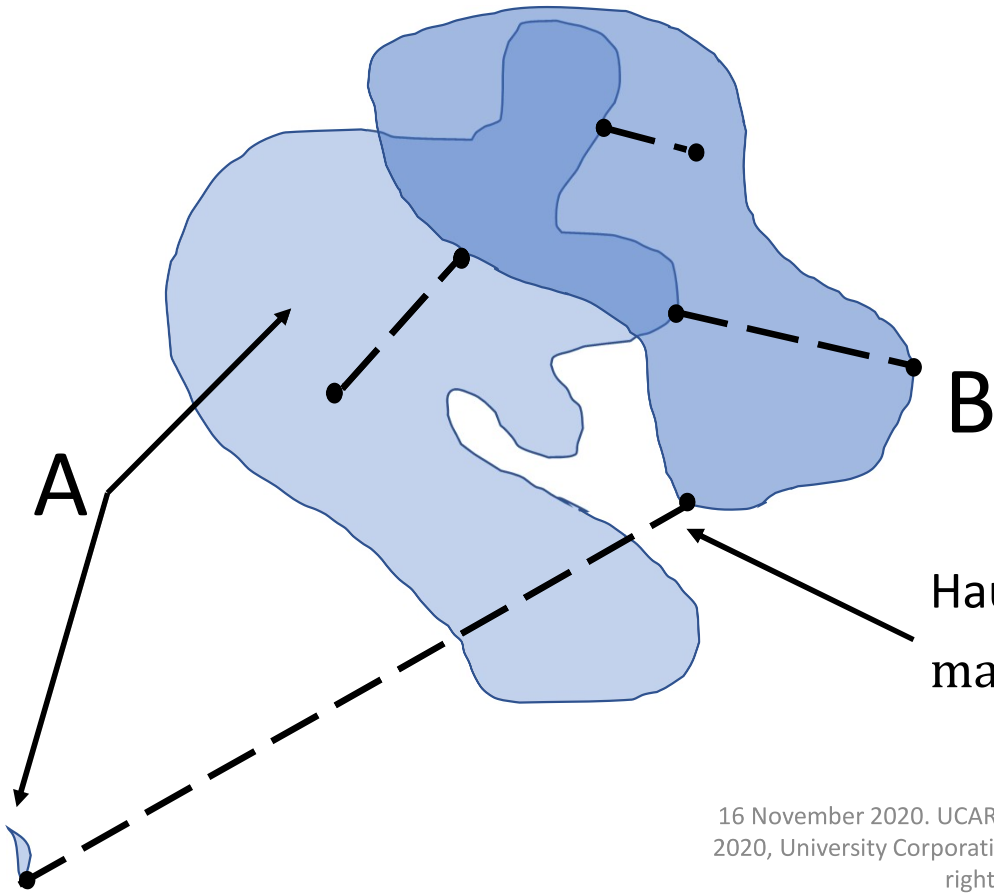
Spatial Verification: Binary fields

$I_O(\boldsymbol{s}) = 1$ if $Z(\boldsymbol{s}) > u$ for example
$I_O(\boldsymbol{s}) = 0$ otherwise

$\mathcal{D}$ ⟶



Spatial Verification: Binary fields



$d(\boldsymbol{s}, A)$ is the shortest distance from a grid point $\boldsymbol{s} \in \mathcal{D}$ to the nearest grid point in the set A. Similarly for $d(\boldsymbol{s}, B)$.

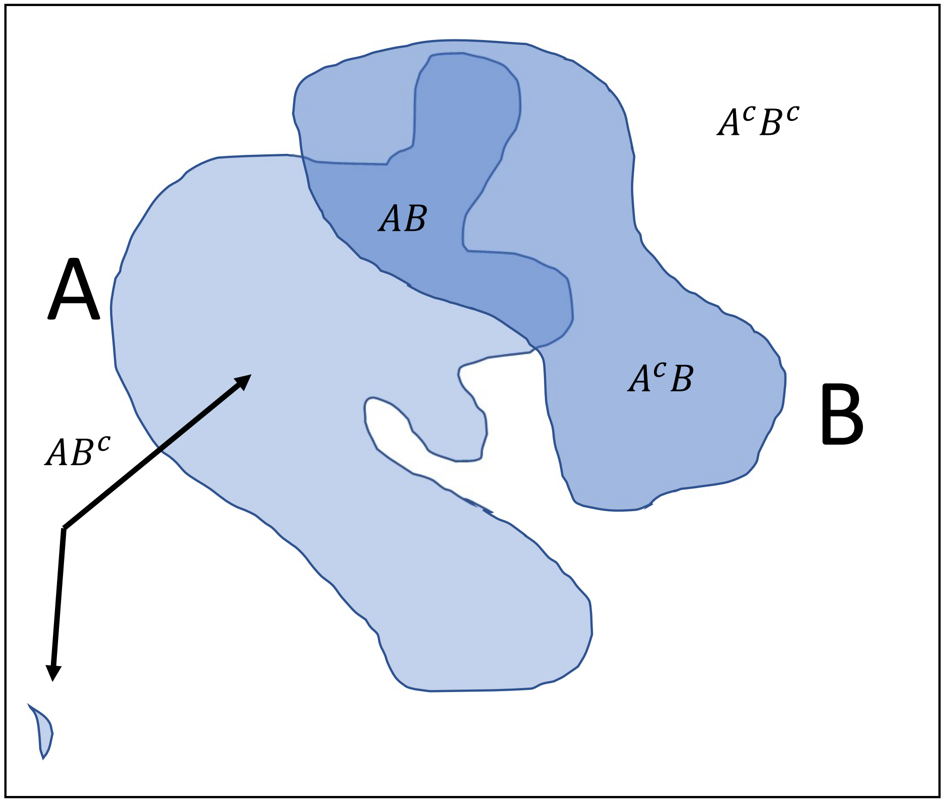
$$\mathrm{MED}(A, B) = \frac{1}{n_B} \sum_{\boldsymbol{s} \in B} d(\boldsymbol{s}, A)$$

G. (2017, doi: 10.1175/WAF-D-16-0134.1)

Hausdorff distance, $H(A, B) =$

$$\max\left\{\max_{\boldsymbol{s} \in A} d(\boldsymbol{s}, B), \max_{\boldsymbol{s} \in B} d(\boldsymbol{s}, A)\right\}$$

New bias/distance performance measure, G



n_A = number of grid points in A,
n_B = number of grid points in B,
n_{AB} = number of grid points in AB.

$$G_\beta(A,B) = \max\{1 - \frac{y}{\beta}, 0\}$$

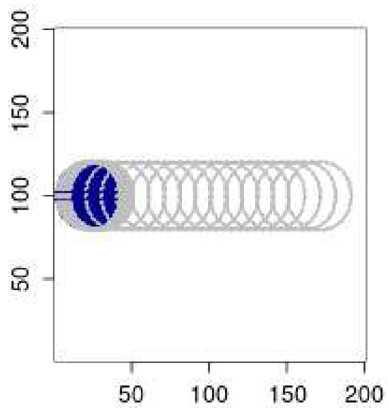
where

$$y = y_1 y_2$$

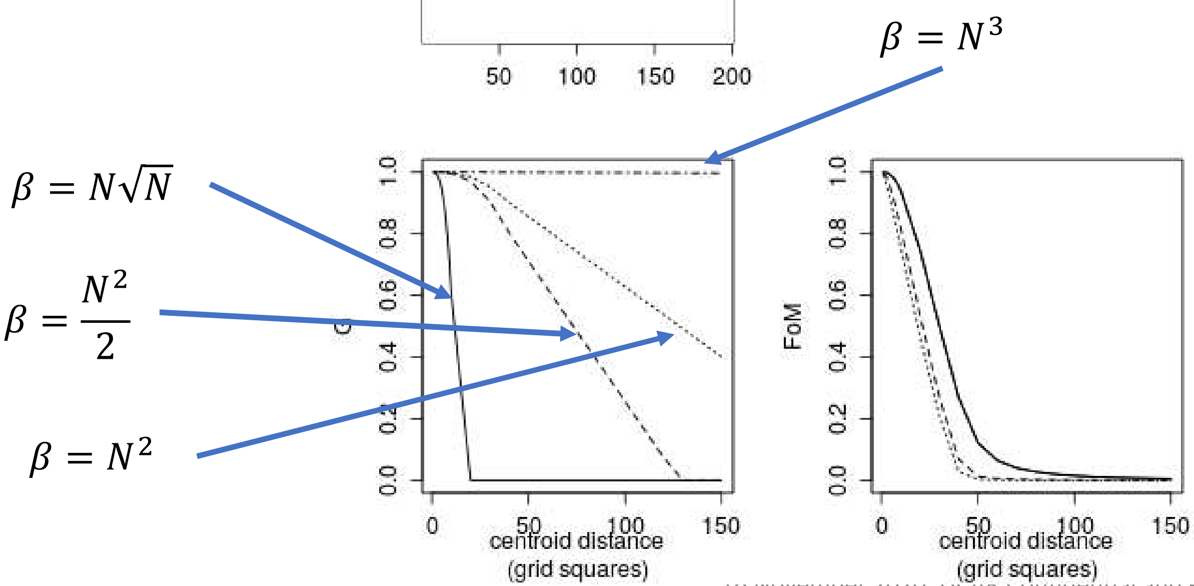
$$y_1 = n_A + n_B - 2n_{AB}$$

$$y_2 = \mathrm{MED}(A,B) \cdot n_B + \mathrm{MED}(B,A) \cdot n_A$$

New bias/distance performance measure, G



- $0 \leq G_\beta(A, B) \leq 1$
- $G_\beta(A, B) = 1$ is a perfect match between A and B.
- $G_\beta(A, B) = 0$ is a user's idea of a bad match.



Maximum value of y_1 occurs when $n_A + n_B = N$ and $n_{AB} = 0$

Maximum value of y_2 depends on specific distance map and domain.

New Geometric Test Cases

$$G_\beta(P_1, P_1) = 1 = G_\beta(P_2, P_2)$$

$$G_\beta(P_1, P_2) = G_\beta(P_2, P_1) = 0, \text{ using } \beta = \frac{N^2}{2}$$

Pathological Cases

P1: $I_{P1}(\boldsymbol{s}) = 0$ everywhere (Null Case)

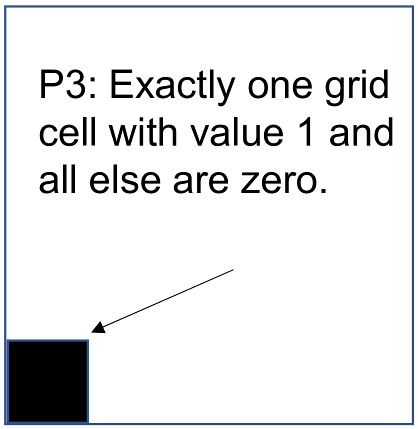
P2: $I_{P2}(\boldsymbol{s}) = 1$ everywhere

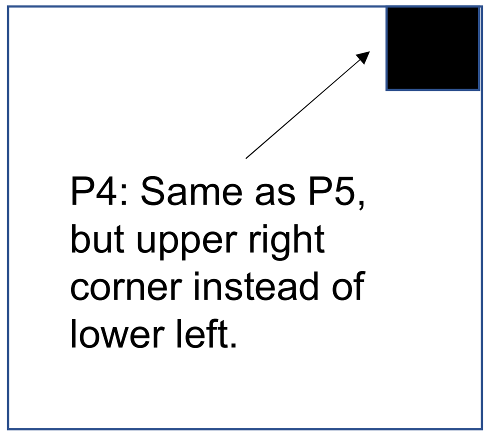
Other measures are generally either undefined or set, as a special case, to a very large number.

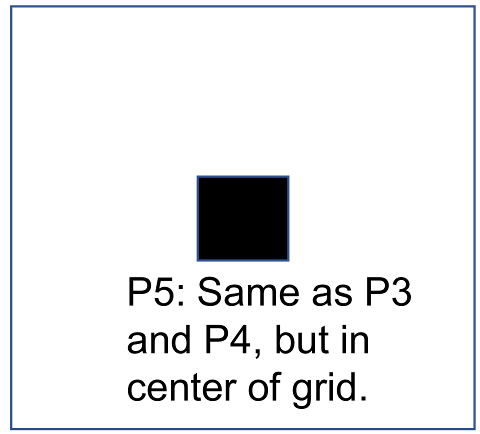
New geometric test cases are from G. et al. (2020, doi: 10.1175/MWR-D-19-0256.1)

New Geometric Test Cases

Pathological Cases

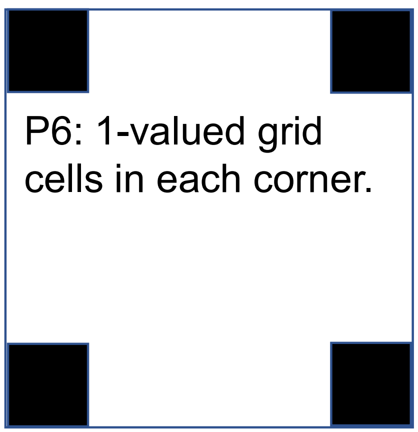


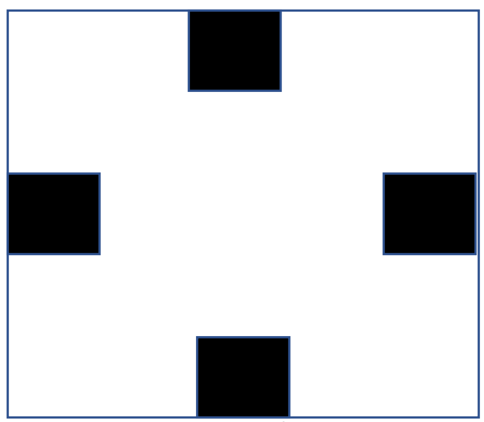




Going from no to one or a few event points.

Centroid for P6 and P7 is the same, so CDST(P6, P7) = 0 (perfect score!), but CDST(P3, P6) = CDST(P3, P7) is large.



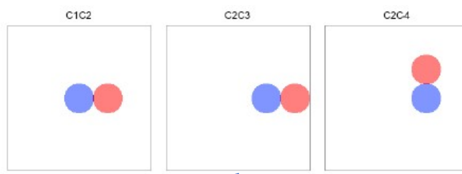


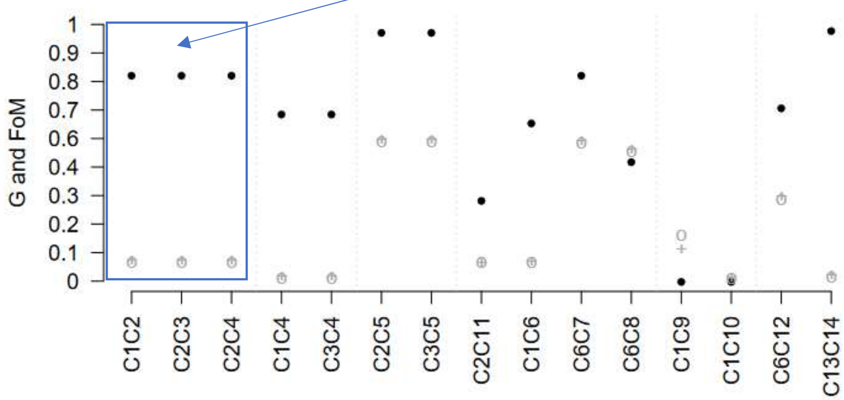
$G_\beta \approx 1$, but slightly less than 1, for all of the comparisons involving these cases, as well as against P1.

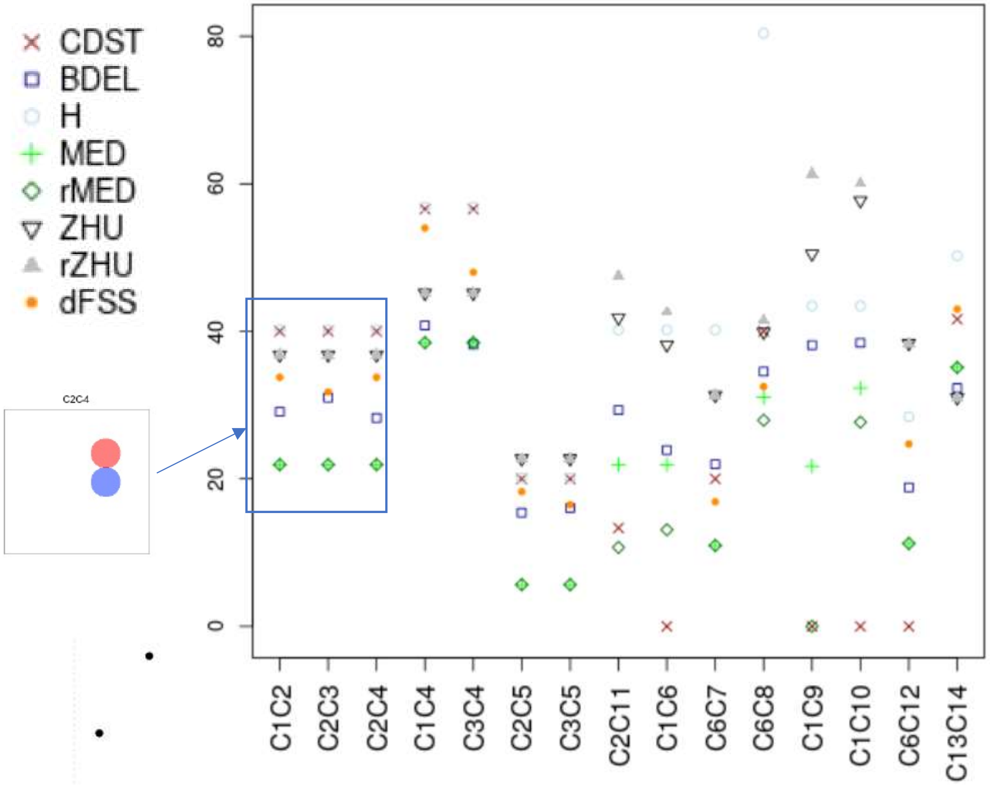
P7: Four 1-valued grid cells located on boundaries midway between corners

Black solid circles are G_β values using $\beta = \frac{N^2}{2}$, gray circles are FoM(A, B) and gray “+” is FoM(B, A).

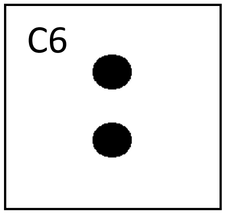
Circle Cases

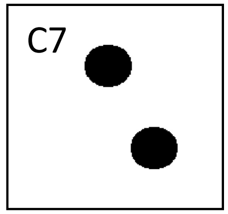


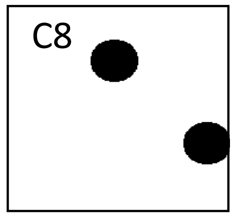


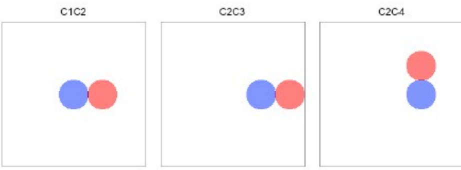


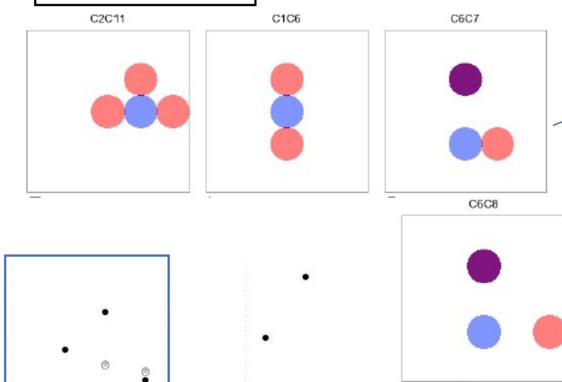
Circle Cases

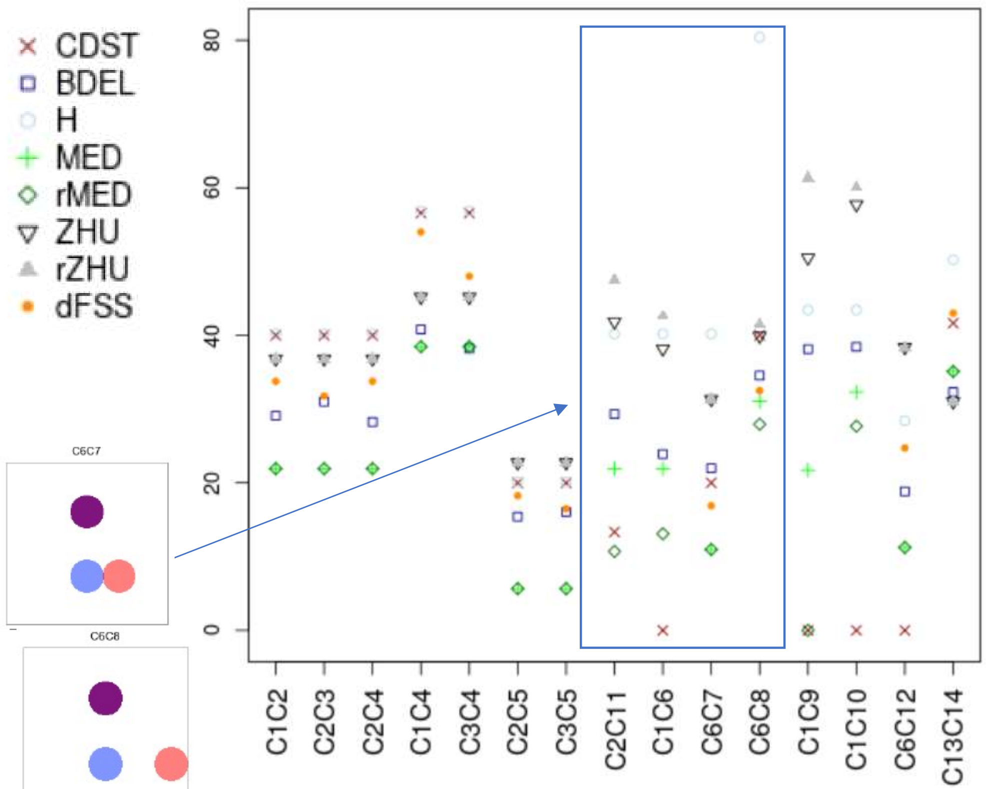


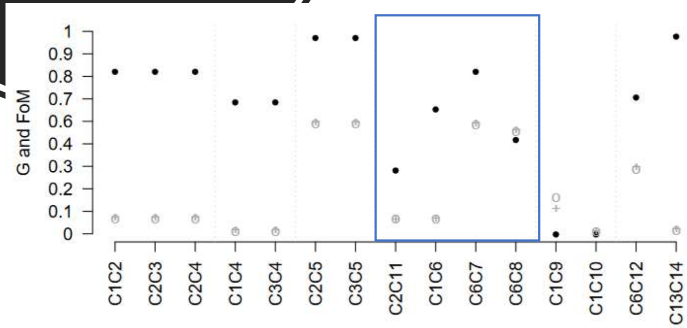






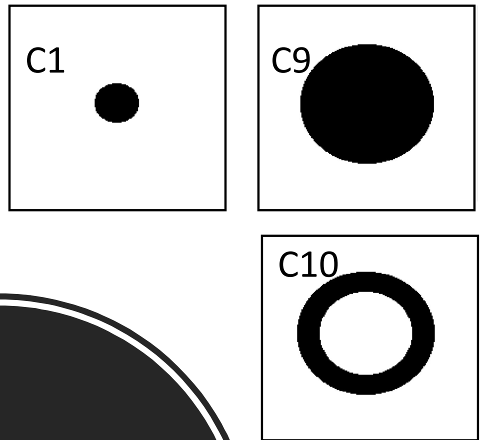


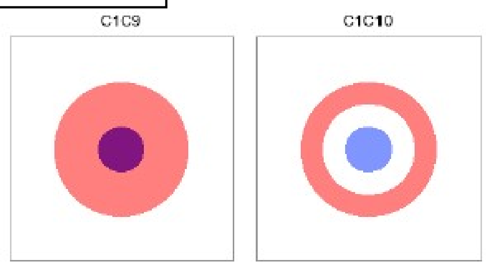


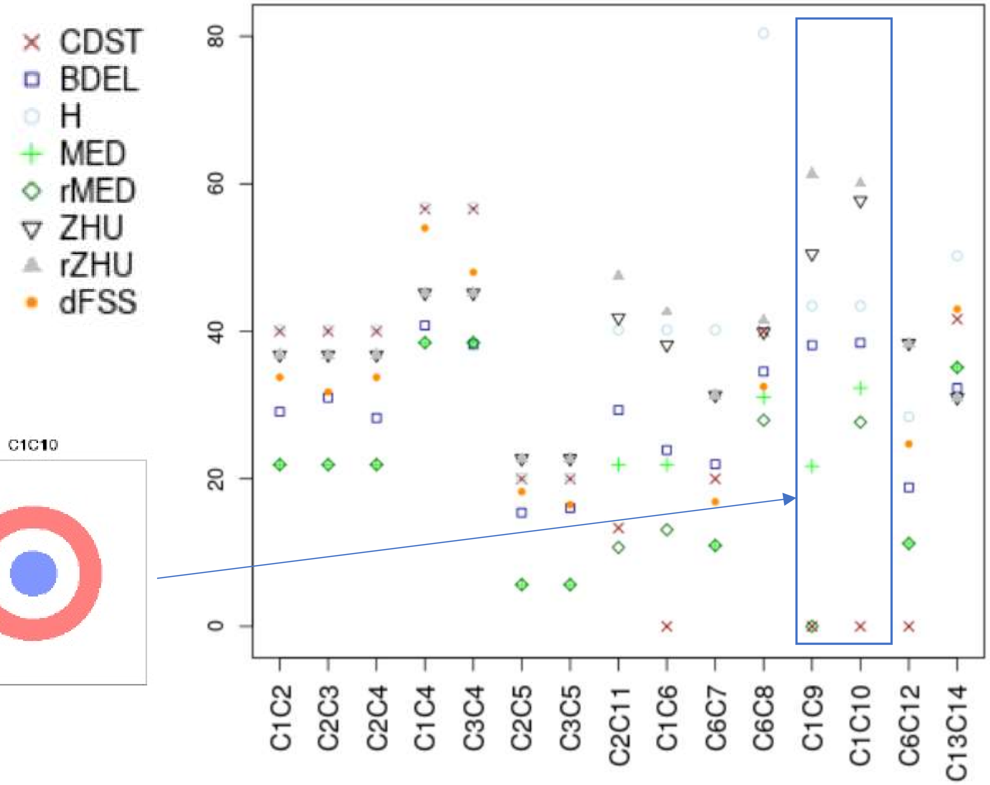


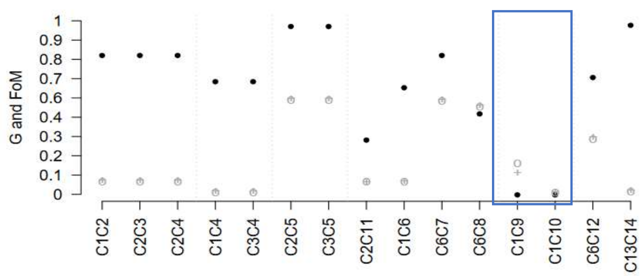
Black solid circles are G_β values using $\beta = \frac{N^2}{2}$, gray circles are FoM(A, B) and gray "+" is FoM(B, A).

Circle Cases









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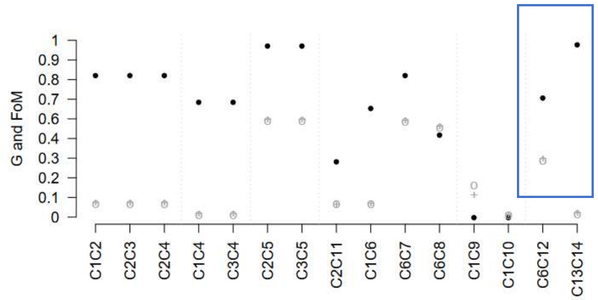
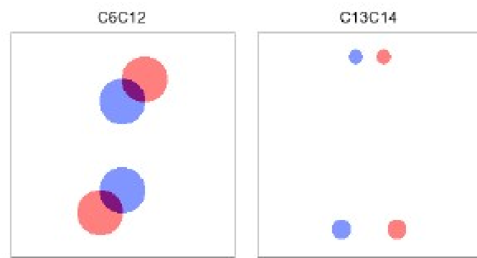
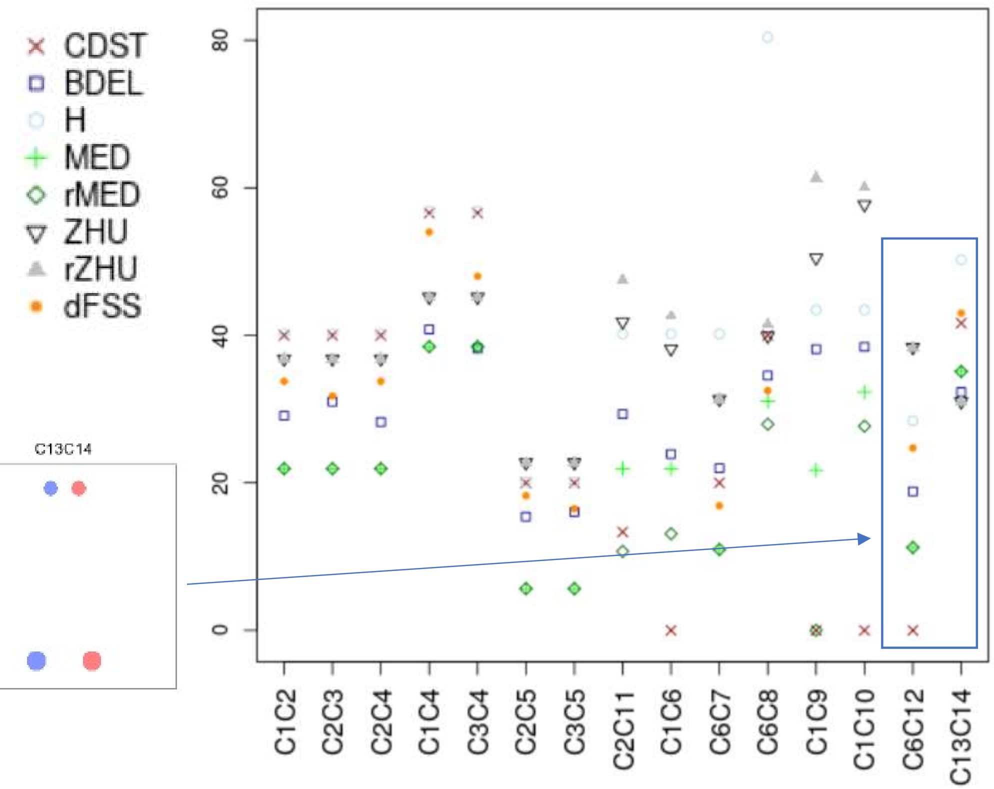
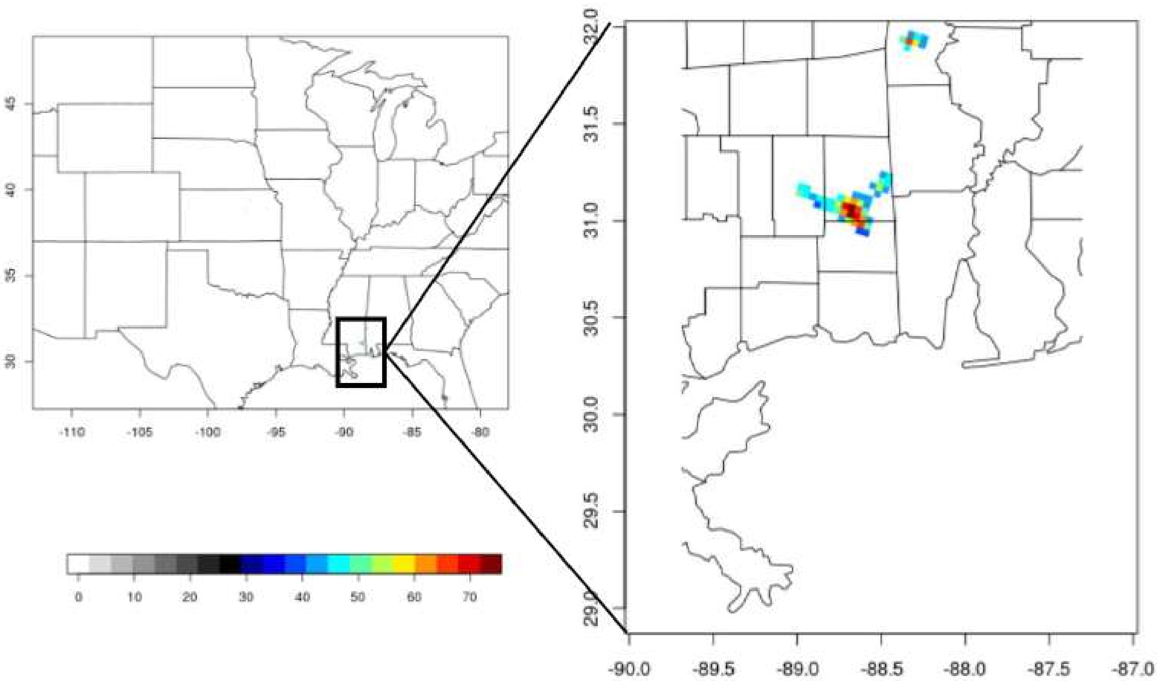
Circle Cases



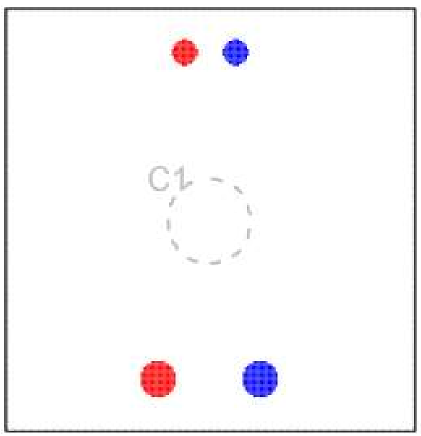


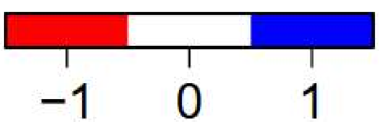


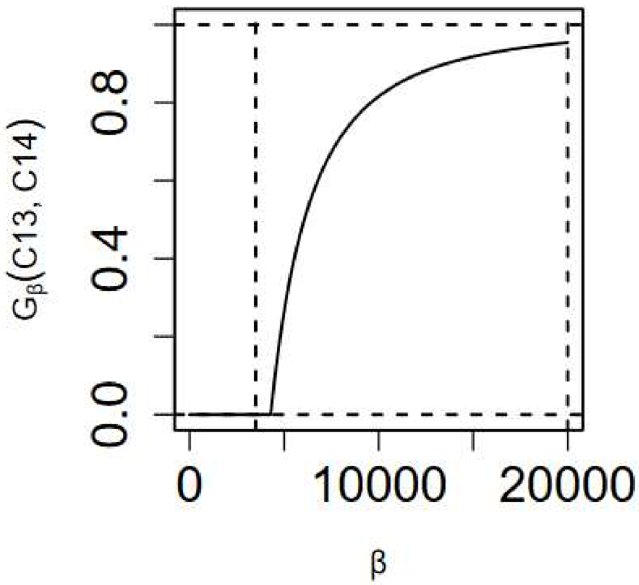
Black solid circles are G_β values using $\beta = \frac{N^2}{2}$, gray circles are FoM(A, B) and gray “+” is FoM(B, A).

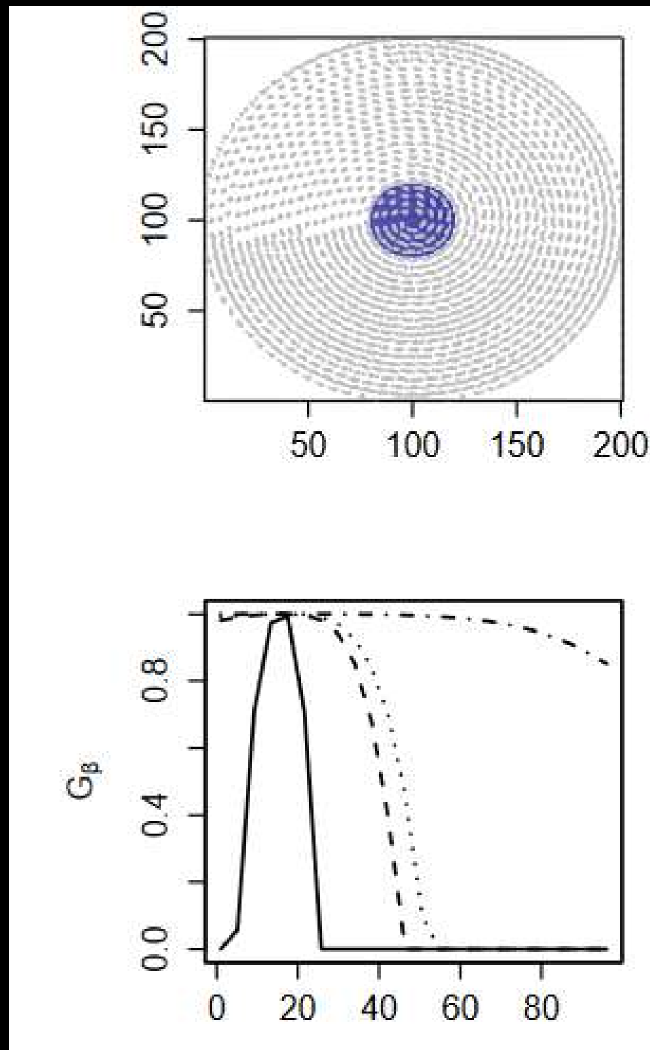

45
40
35
30
-110
-105
-100
-95
-90
-85
-80
0
10
20
30
40
50
60
70
32.0
31.5
31.0
30.5
30.0
29.5
29.0
-90.0
-89.5
-89.0
-88.5
-88.0
-87.5
-87.0

C14 – C13

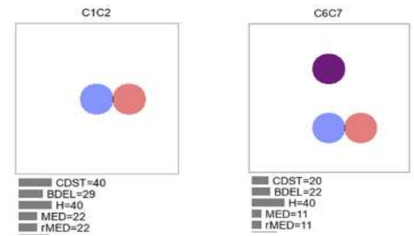







200
150
100
50
50
100
150
200
Gβ
0.0
0.4
0.8
0
20
40
60
80

Summary

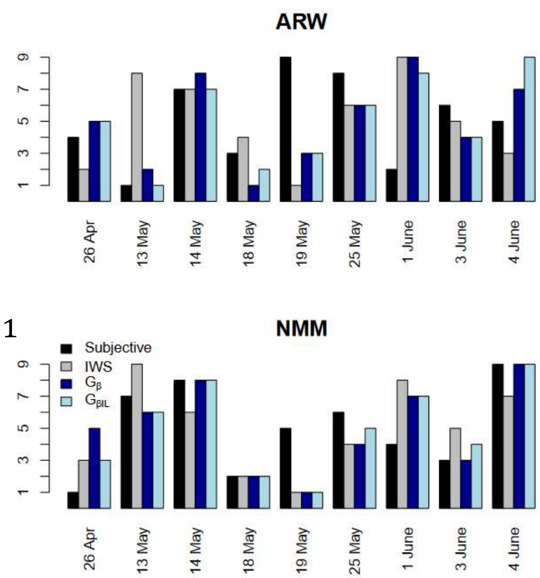


	Handles Pathological Cases well?	No positional effects?	Sensitive to frequency bias?	Useful for rare events?	Reward partial perfect match?	Correctly penalize despite partial perfect match?
G_β*	Yes	Yes	Yes	Yes	No	Yes
Centroid distance	No	Yes	No	No	No	No
Baddeley's Δ	No	No	Yes	No	Yes	No
Hausdorff	No	Yes	No	Yes	No	No
MED**	No	Yes	No	Yes	Yes	Yes
FoM	No	Yes	Yes	Unclear	No	Yes

*Answers may depend on choice of β
**Answers may depend on the asymmetry of MED (i.e., may only be true in one direction but always true if looking at both directions.

Thank you

Using $\beta = \frac{N}{2}$ and threshold of 2.1 $\text{mm} \cdot \text{h}^{-1}$



This presentation mostly covers the material in the paper below. For questions, I can be reached at the email address from my home page at: https://ral.ucar.edu/staff/ericg/

Gilleland, E., 2020. Novel forecast performance metrics for high-resolution verification sets. Submitted to *Advances in Statistical Climatology, Meteorology and Oceanography* (in review; temporarily available at: https://ral.ucar.edu/staff/ericg/Gilleland2020.pdf)