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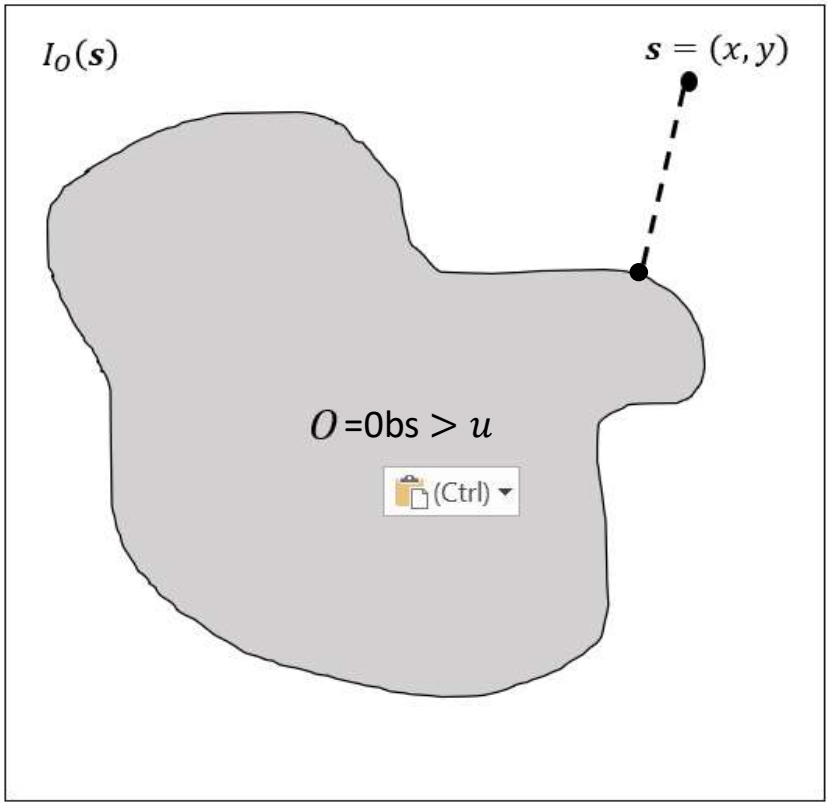
Spatial Verification: A New Spatial Alignment Error Summary

2020 International Verification Methods Workshop
16 November 2020
https://jwgfvr.univie.ac.at/

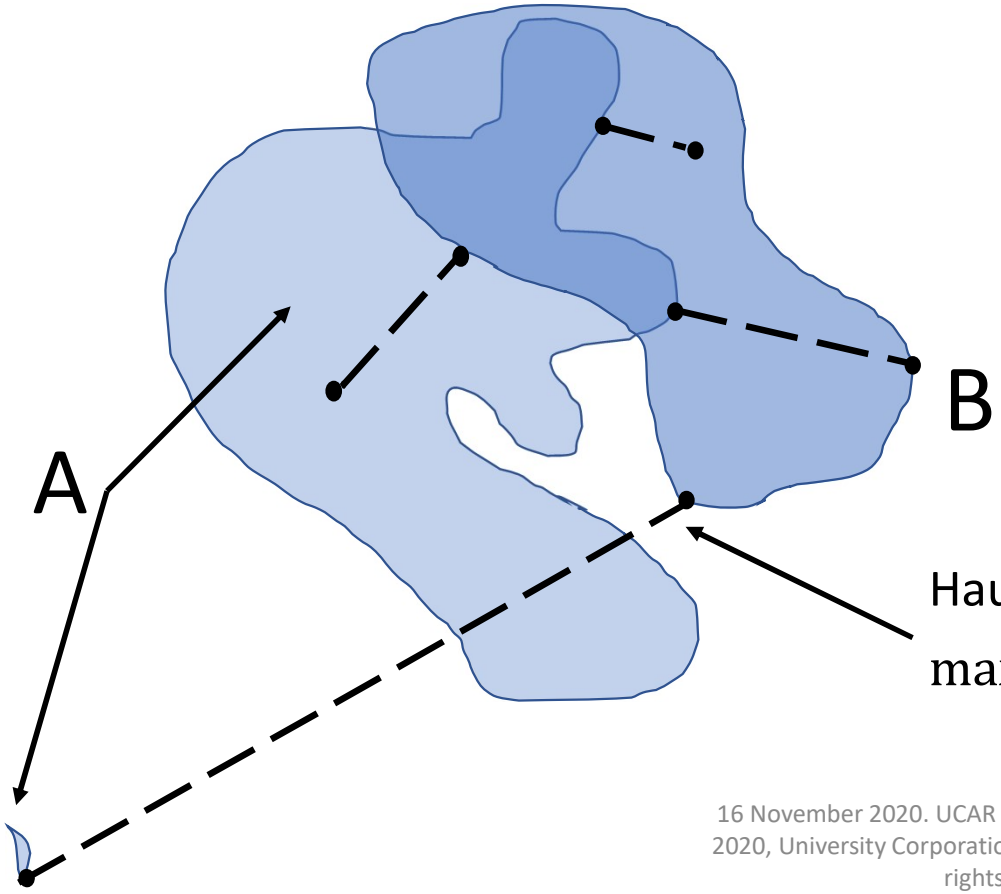
Spatial Verification: Binary fields

$I_O(\boldsymbol{s}) = 1$ 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 $d(\boldsymbol{s}, B)$.

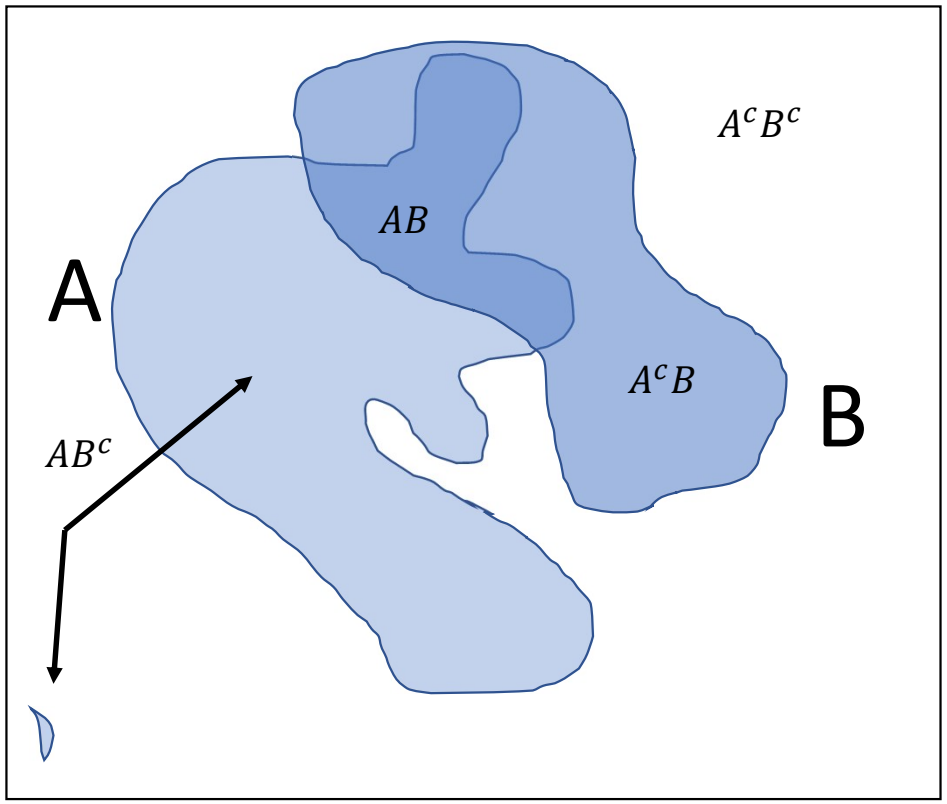
$$\mathrm{MED}(A, B) = \frac{1}{n_B} \sum_{\boldsymbol{s} \in B} d(\boldsymbol{s}, A)$$

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.

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

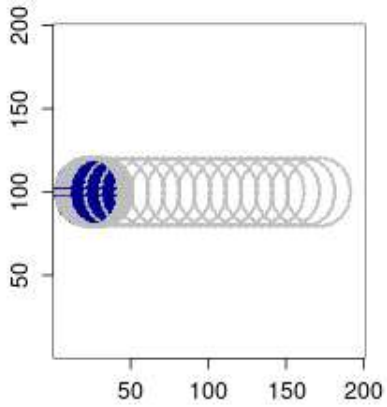
where

$$y = y_1 y_2$$

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

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

New bias/distance performance measure, G



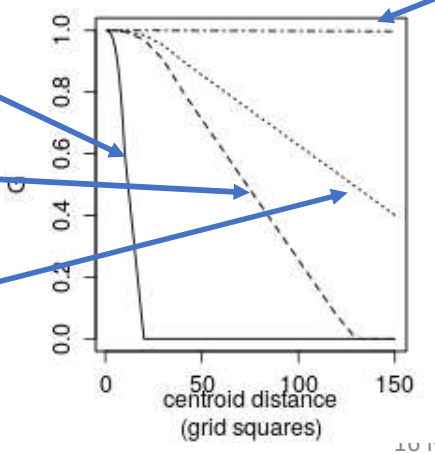
- $0 \leq G_\beta(A,B) \leq 1$
- $G_\beta(A,B) = 1$ is a perfect match between A and B.
- $G_\beta(A,B) = 0$ is a user's idea of a bad match.

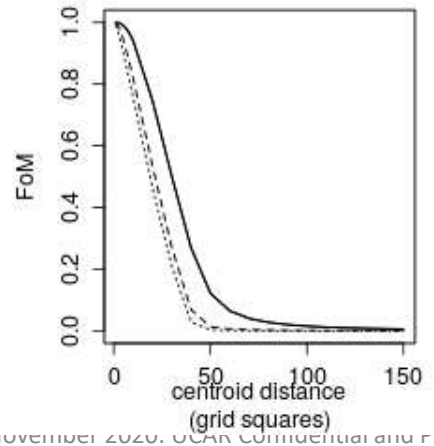
$\beta = N^3$

$\beta = N\sqrt{N}$

$\beta = \frac{N^2}{2}$

$\beta = N^2$





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)

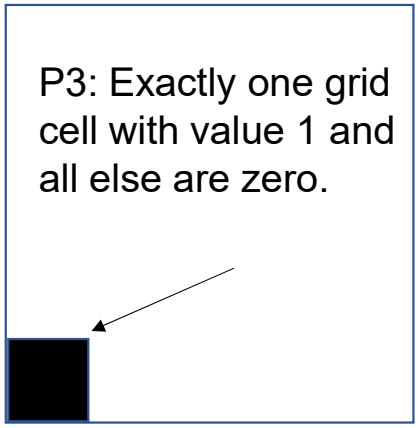
P2: $I_{P2}(\boldsymbol{s}) = 1$ everywhere

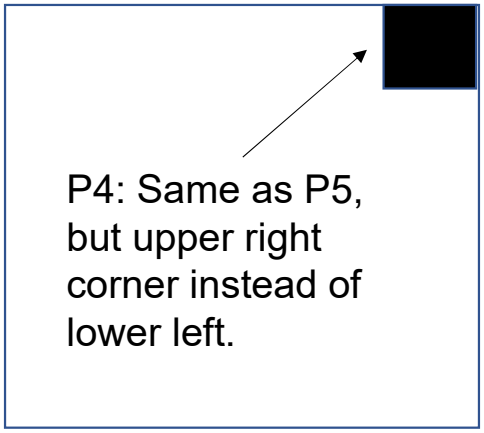
Other measures are generally either undefined or set, as a special case, to a very large number.

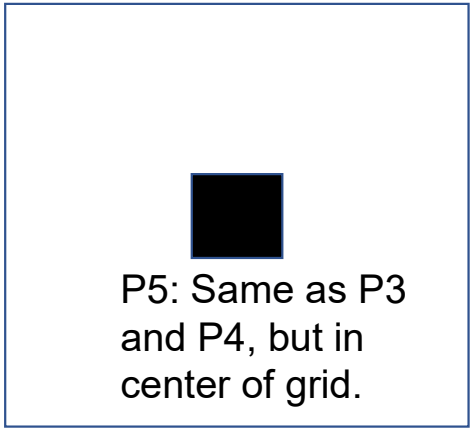
New geometric test cases are from G. et al. (2020, doi: 10.1175/MWR-D-19-0256.1)

New Geometric Test Cases

Pathological Cases

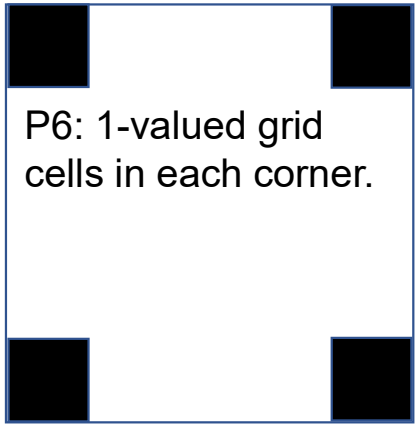


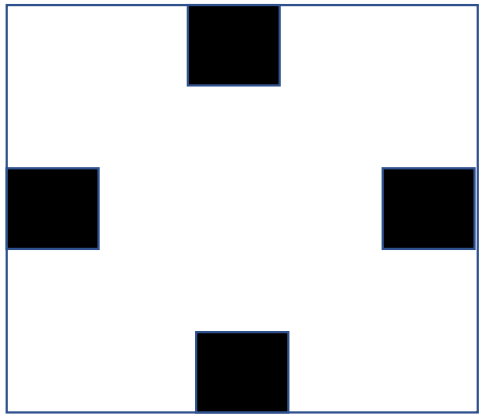




Going from no to one or a few event points.

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



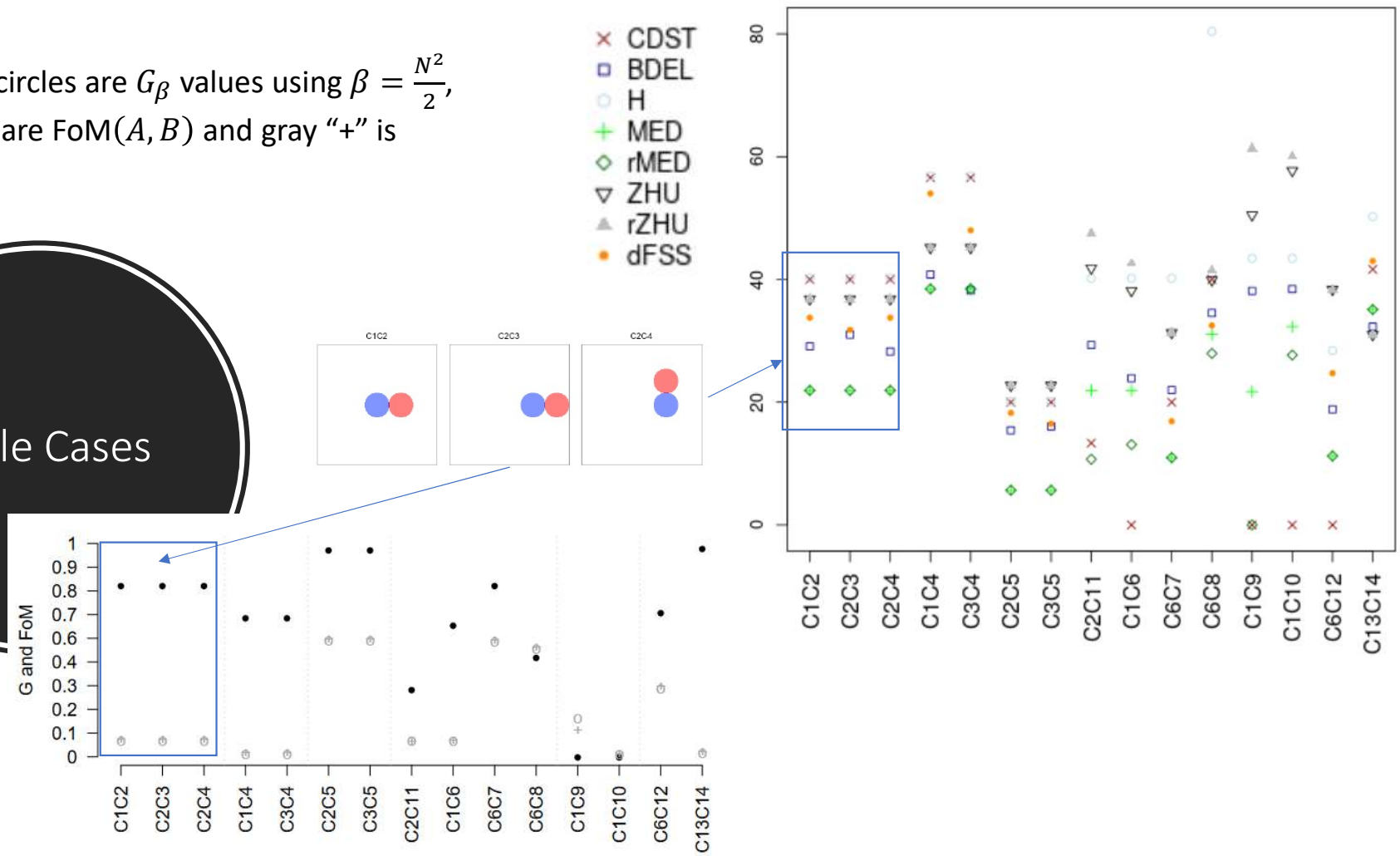


$G_\beta \approx 1$, but slightly less than 1, for all of the comparisons involving these cases, as well as against P1.

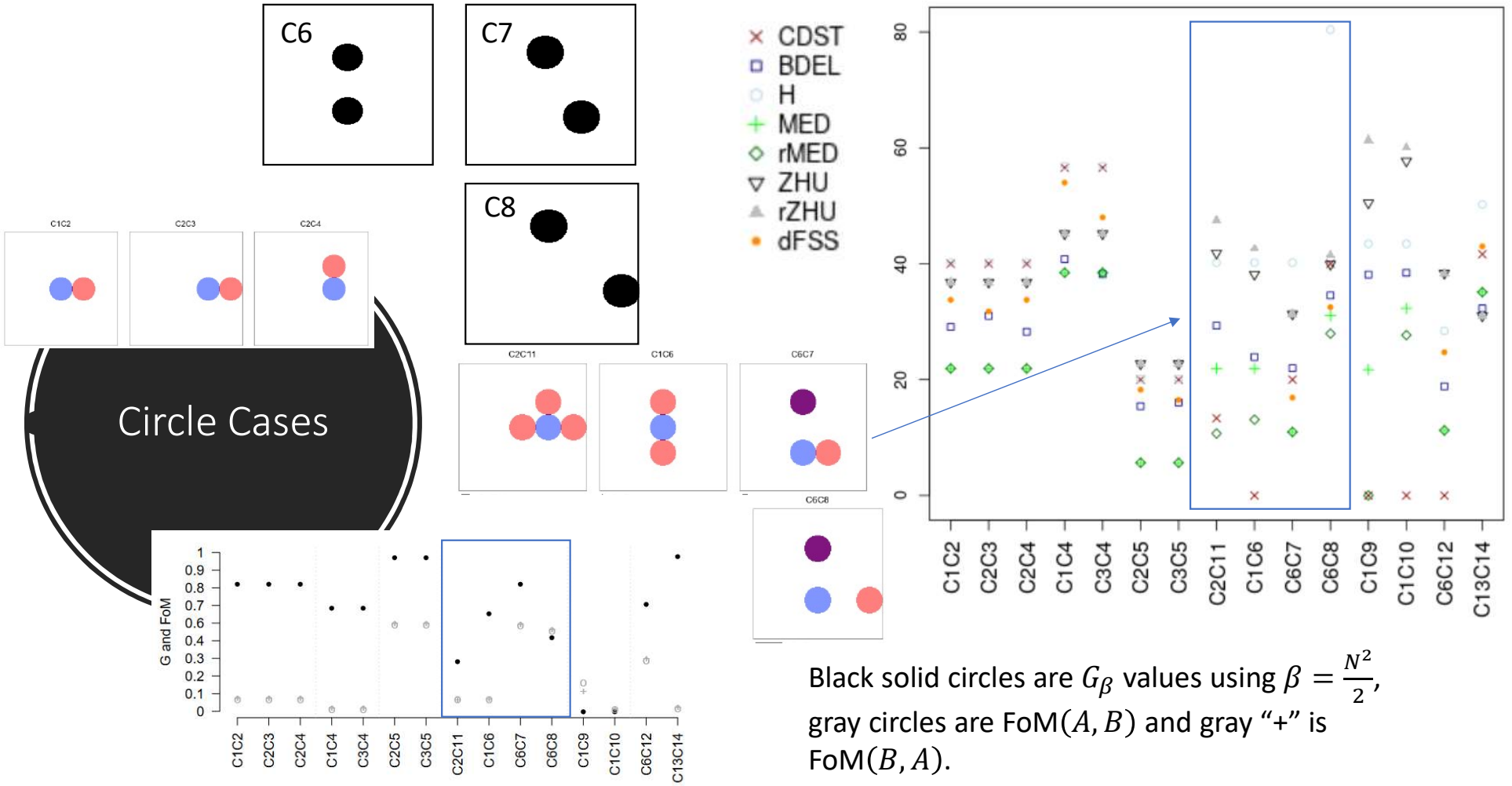
P7: Four 1-valued grid cells located on boundaries midway between corners

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



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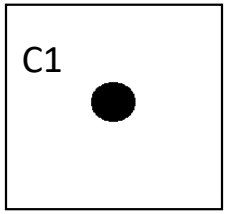
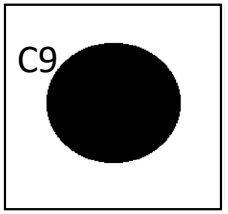
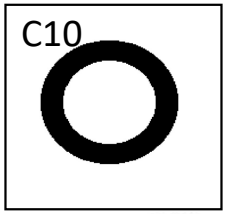
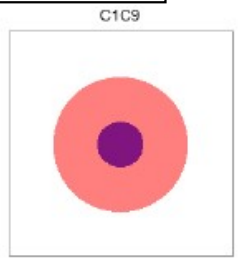
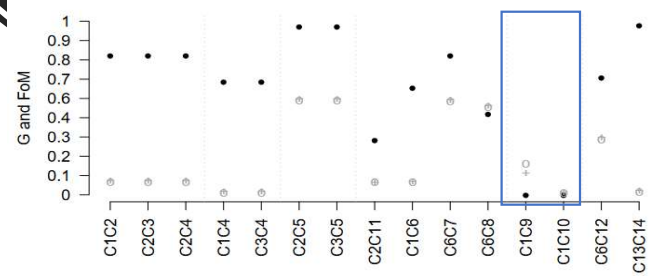




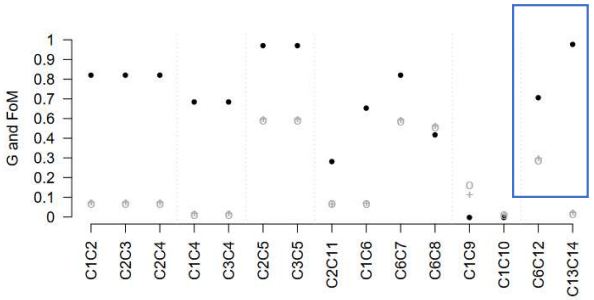


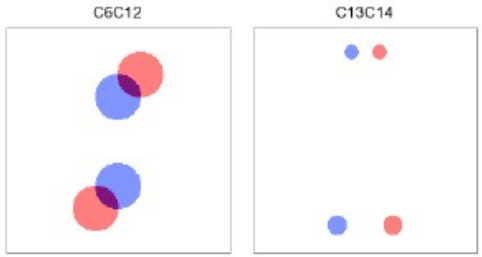


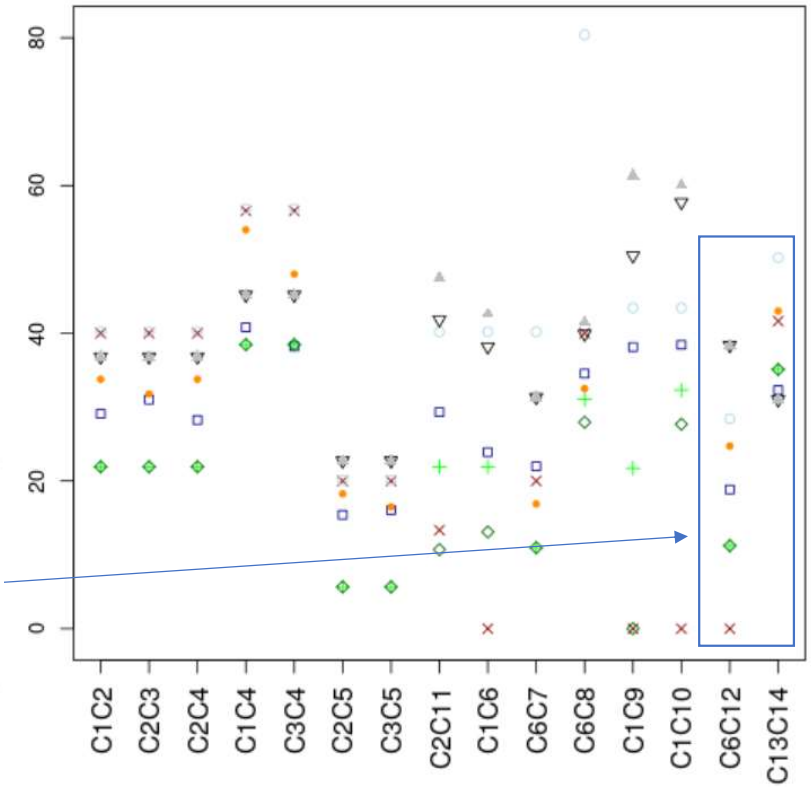


Black solid circles are G_β values using $\beta = \frac{N^2}{2}$, gray circles are FoM(A, B) and gray "+" is FoM(B, A).

Circle Cases







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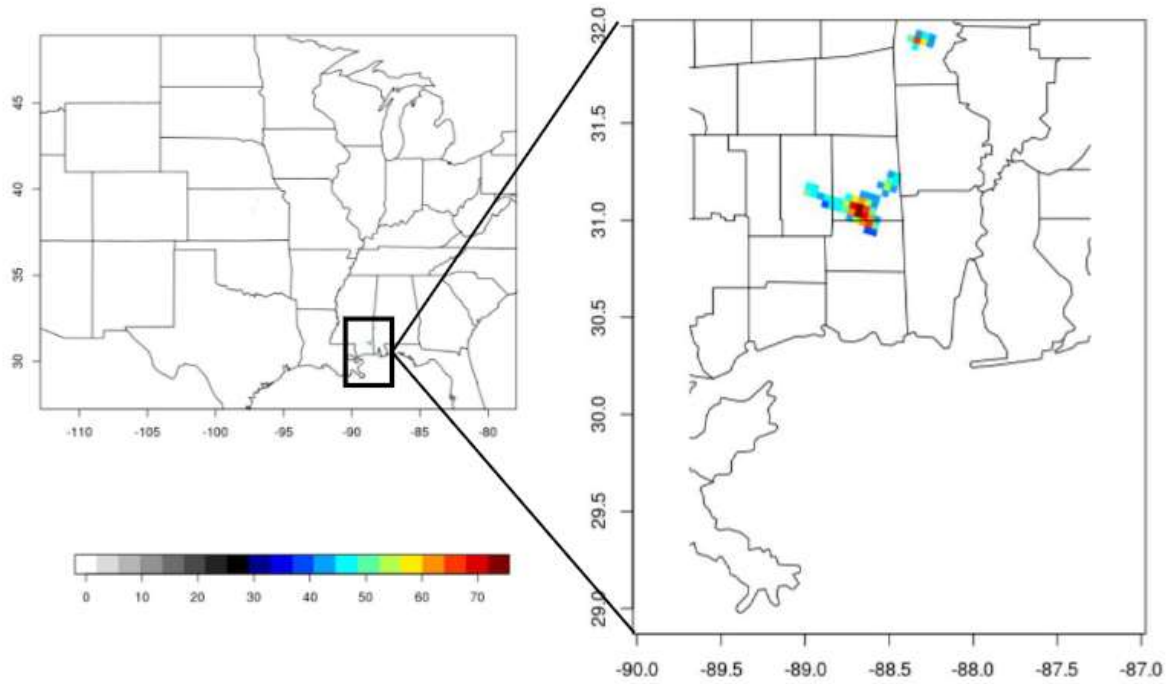
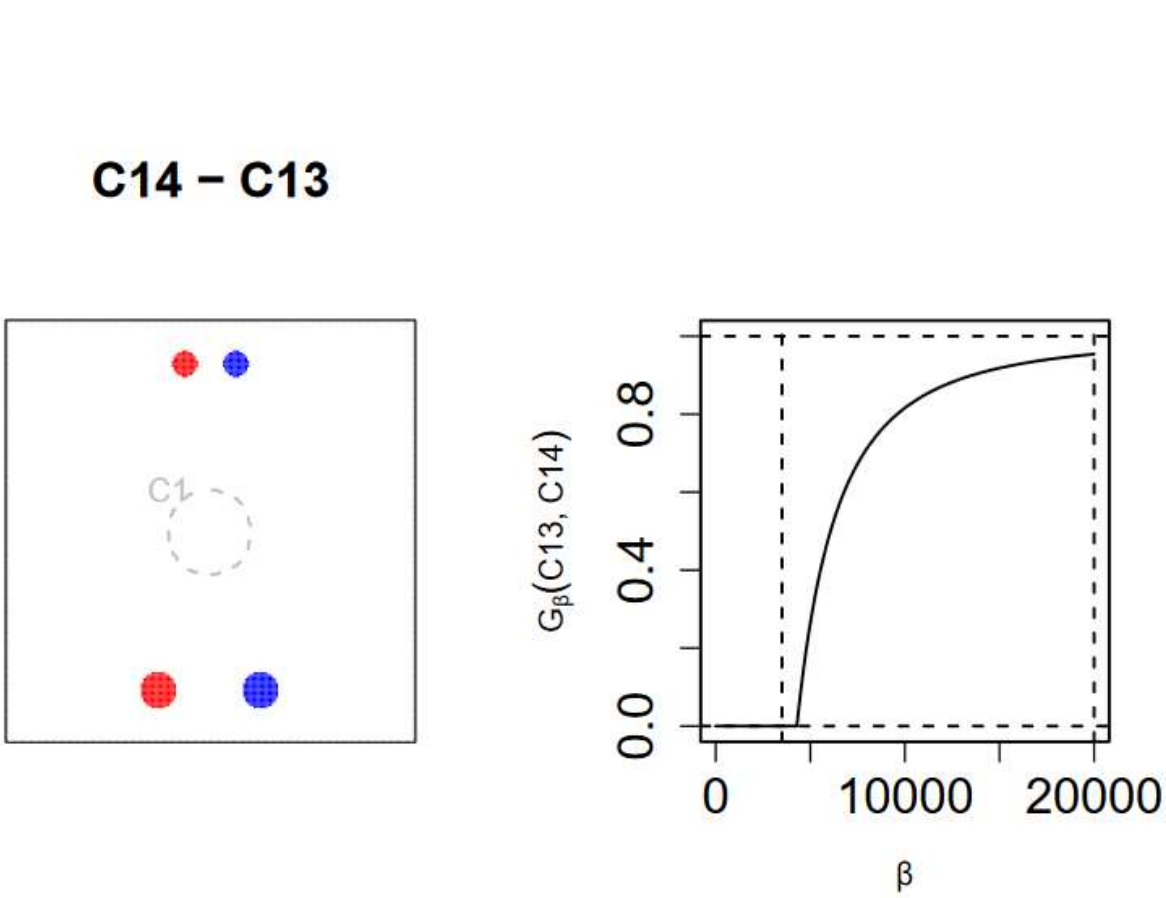
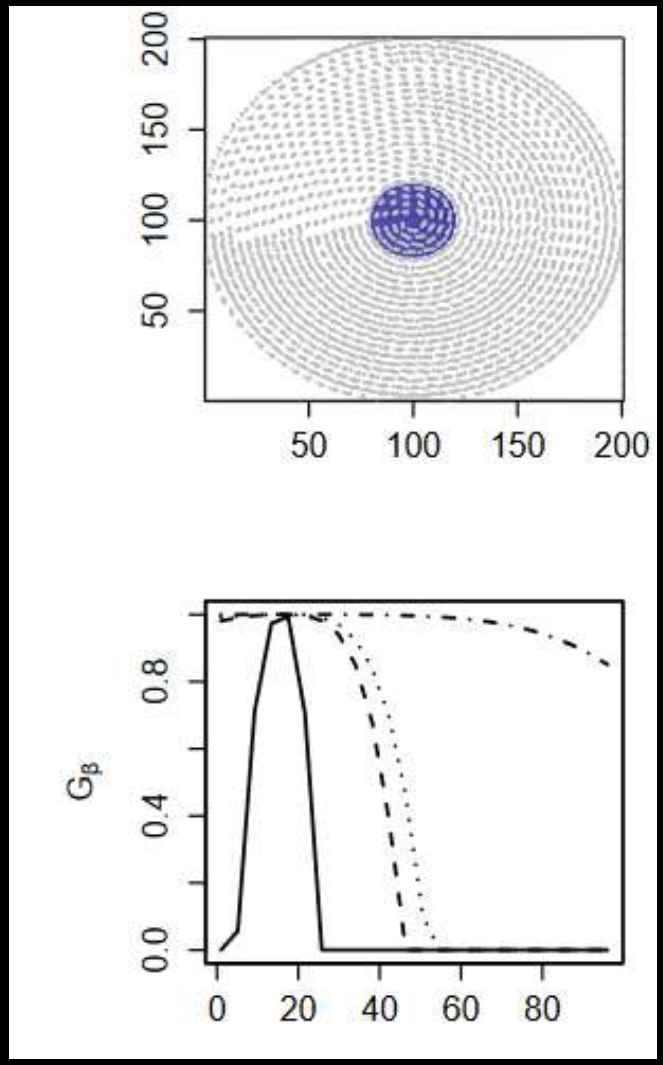


G_β is designed to address issues apparent with other distance-based measures for larger-scale features. However, an appropriate (low) choice of β allows the measure to be useful for small-scale events, such as severe thunderstorm activity.

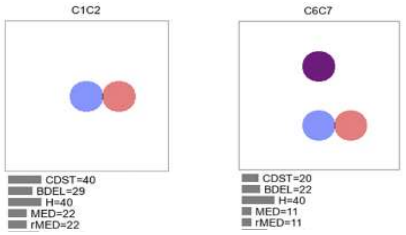
In this case, the largest contiguous event area is about 360 grid squares. Multiplying that by an egregious translation error of 20 grid squares gives a β value that works well for the example above.



The example above demonstrates the kind of game that one can play to help identify a useful choice of β. The choice of $\beta = \frac{N^2}{2}$ yields a G_β value that is close to one, which may be appropriate. $G_\beta = 0$ using the choice from the previous, slide,



Summary



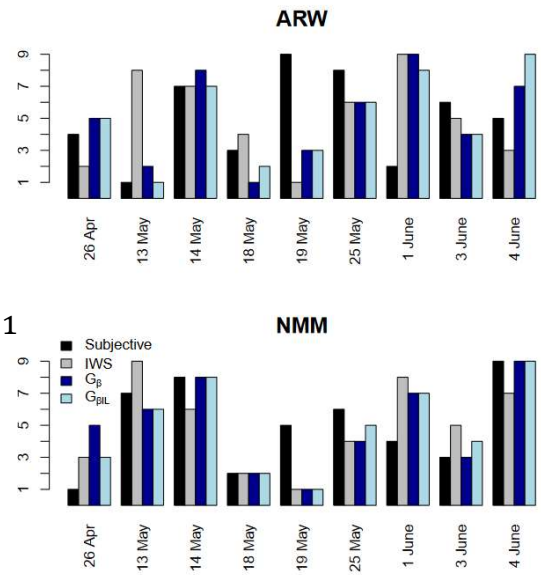
	Handles Pathological Cases well?	No positional effects?	Sensitive to frequency bias?	Useful for rare events?	Reward partial perfect match?	Correctly penalize despite partial perfect match?
G_β*	Yes	Yes	Yes	Yes	No	Yes
Centroid distance	No	Yes	No	No	No	No
Baddeley's Δ	No	No	Yes	No	Yes	No
Hausdorff	No	Yes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