Verification within Complexity: Comparing Spatial Fields

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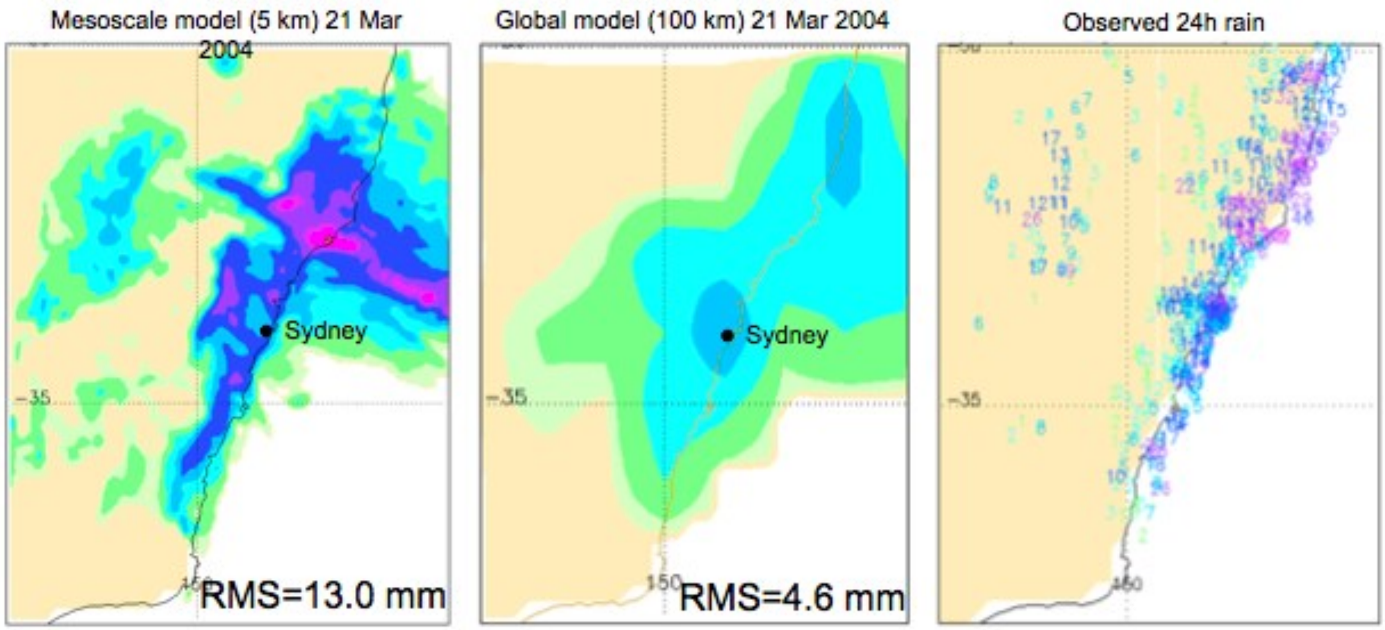
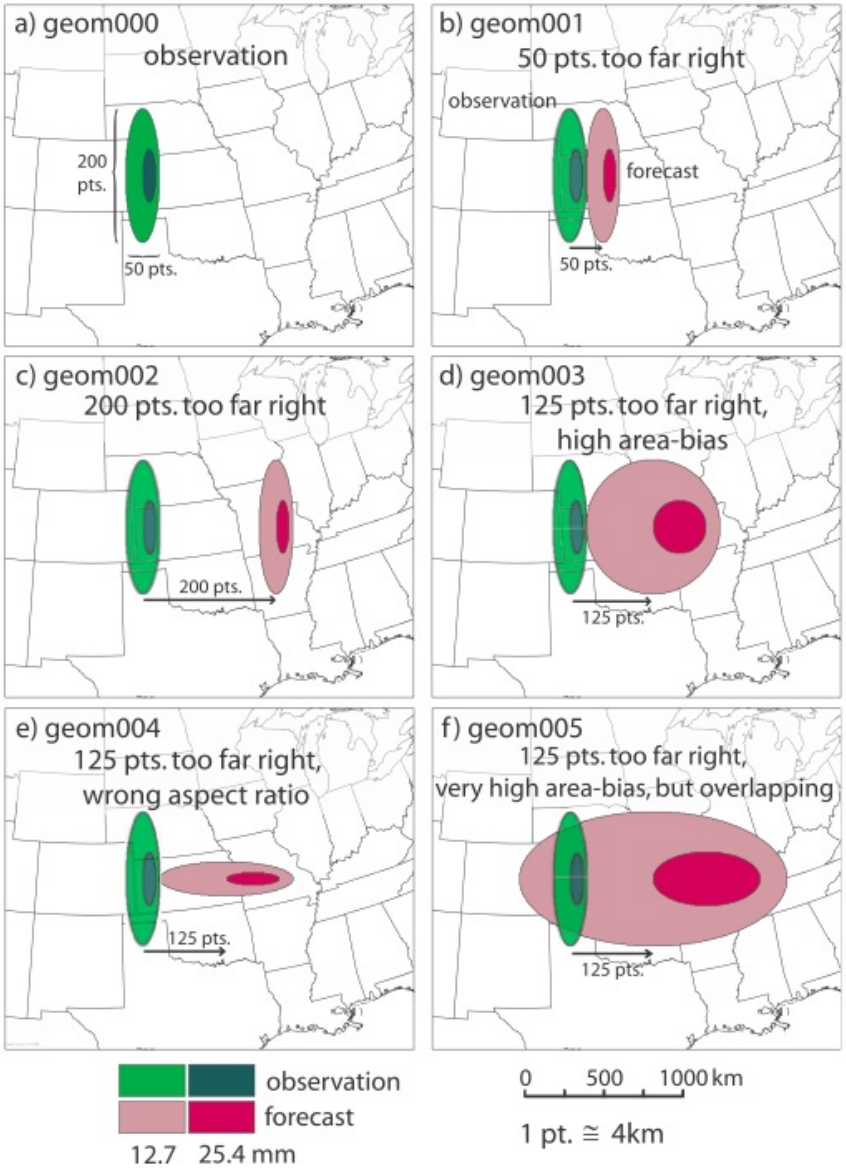
Forecasting from Complexity Workshop
Institute for Mathematics and its Applications (IMA)
Wednesday, 25 April 2018
Minneapolis, Minnesota, U.S.A.

Background



Above Figure from Beth Ebert

Background



Traditional score	geom001/002/004	geom003	geom005
Accuracy	0.95	0.87	0.81
Frequency bias	1.00	4.02	8.03
Multiplicative intensity bias	1.00	4.02	8.04
RMSE (mm)	3.5	5.6	6.9
Bias-corrected RMSE (mm)	3.5	5.5	6.3
Correlation coefficient	−0.02	−0.05	0.20
Probability of detection	0.00	0.00	0.88
Probability of false detection	0.03	0.11	0.19
False alarm ratio	1.00	1.00	0.89
Hanssen–Kuipers discriminant (H-K)	−0.03	−0.11	0.69
Threat score or CSI	0.00	0.00	0.11
Equitable threat score or GSS	−0.01	−0.02	0.08
HSS	−0.03	−0.04	0.16

Background

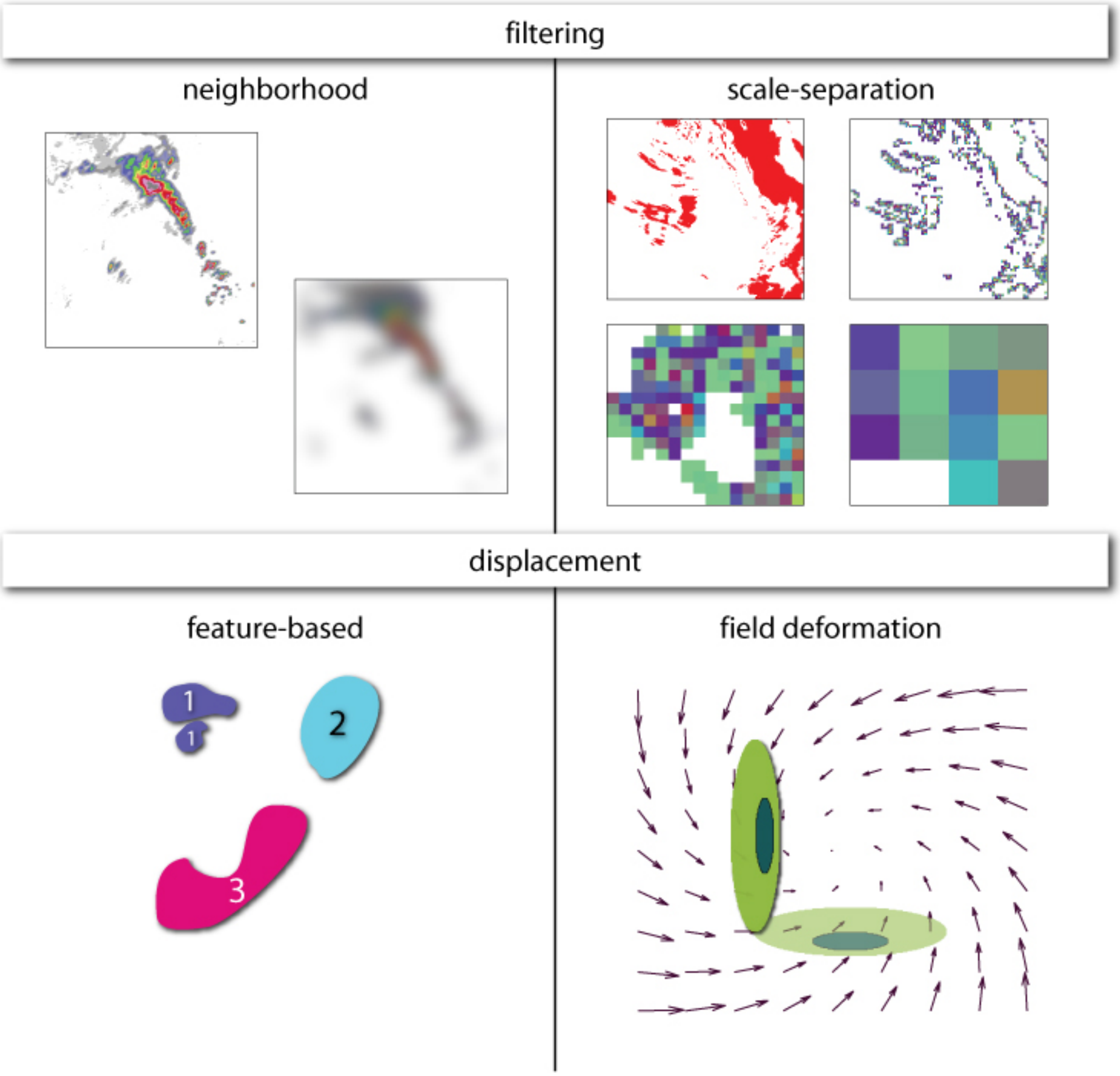


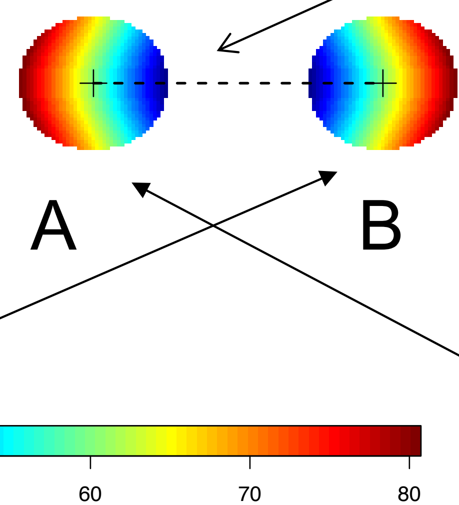
Fig. 2 from G. *et al*. (2010, [10.1175/2010BAMS2819.1](https://doi.org/10.1175/2010BAMS2819.1))

Distance Measures

Pratt's Figure of Merit (FoM) =

$$\text{FoM(A,B)} = \frac{1}{\max\{n(A), n(B)\}} \sum_{x \in B} \frac{1}{1 + \kappa d(x, A)}$$

centroid distance (CD)



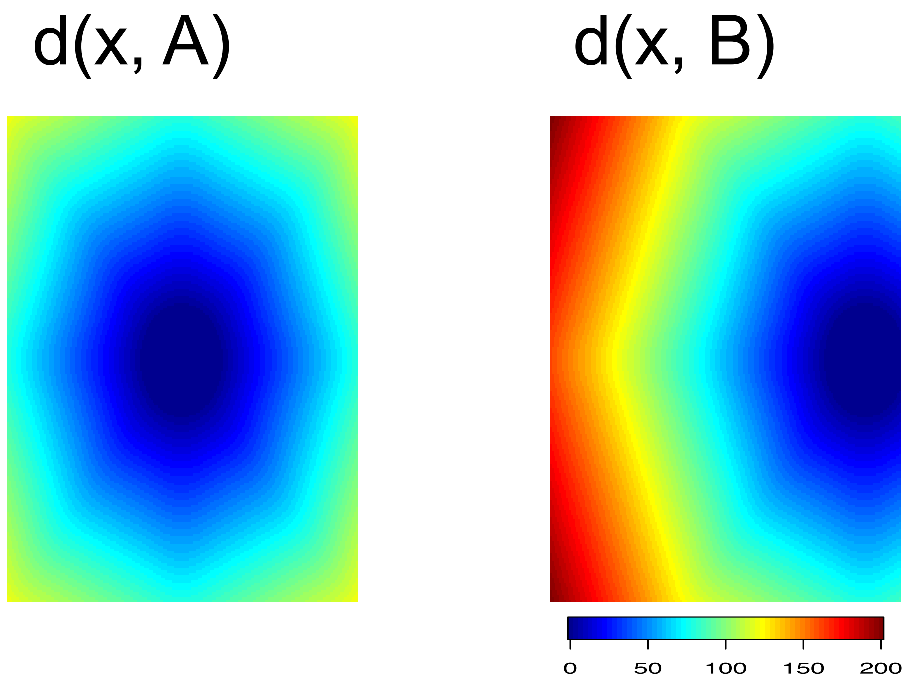
$$\text{MED}(A, B) = \frac{1}{n(B)} \sum_{x \in B} d(x, A)$$

$n(B)$ is the number of points in the set B.

$$\text{MED}(B, A) = \frac{1}{n(A)} \sum_{x \in A} d(x, B)$$

$n(A)$ is the number of points in A.

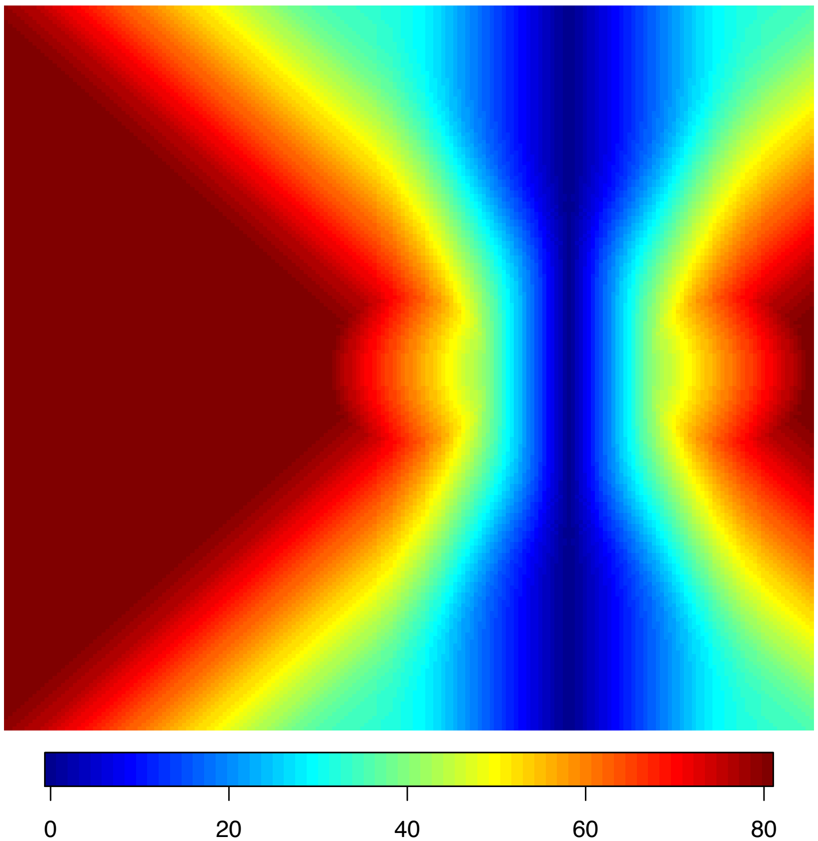
Distance Measures



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

Distance Measures

$$T = \left|\omega(d(x, A)) - \omega(d(x, B))\right|$$



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

$|N|$ is the size of the domain, D.

Baddeley's Δ Metric

- $p = 1$ gives the arithmetic average of T
- $p = 2$ is the usual choice
- $p = \infty$ gives the max of T (Hausdorff distance, H)

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 the picture here uses "∞" for the constant term.

Distance Measures

Zhu's metric (Z) from Zhu et al. (2011, doi: 10.1016/j.atmosres.2011.09.004)

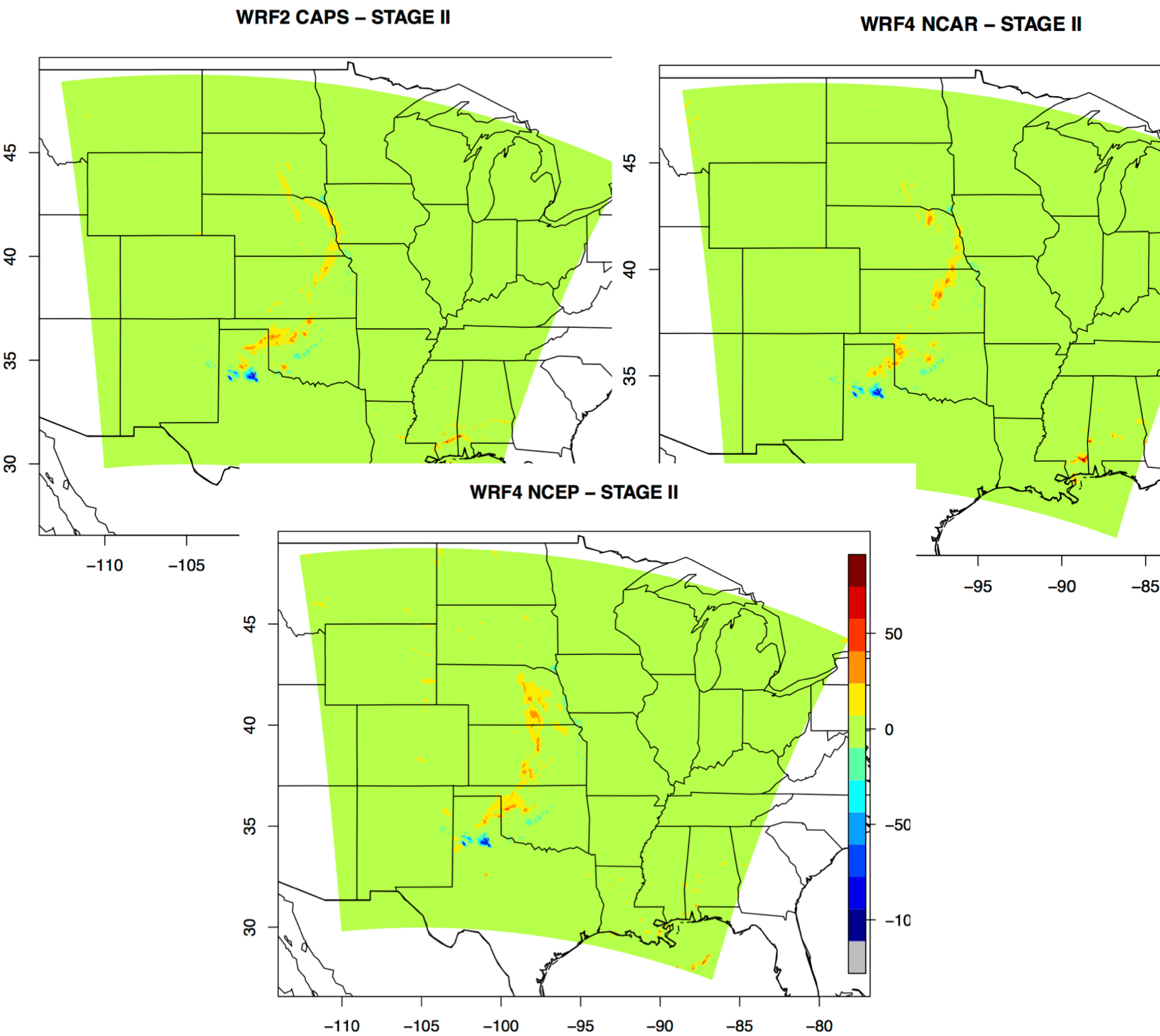
Between forecast F and observation O:

$Z = \lambda_1 D1 + \lambda_2 D2$

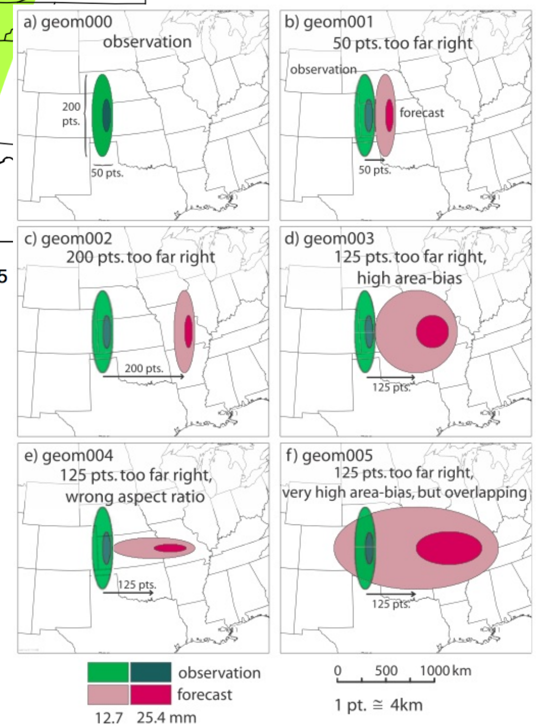
D1 = root sum of squared differences between the two binary fields (overlap measure)

D2 = MED(F, O) (or MED miss) provided the product of the number of points in either set is not zero. If no 1-valued points are in both F and O. Otherwise, it is set to a large number.

ICP Phase 1

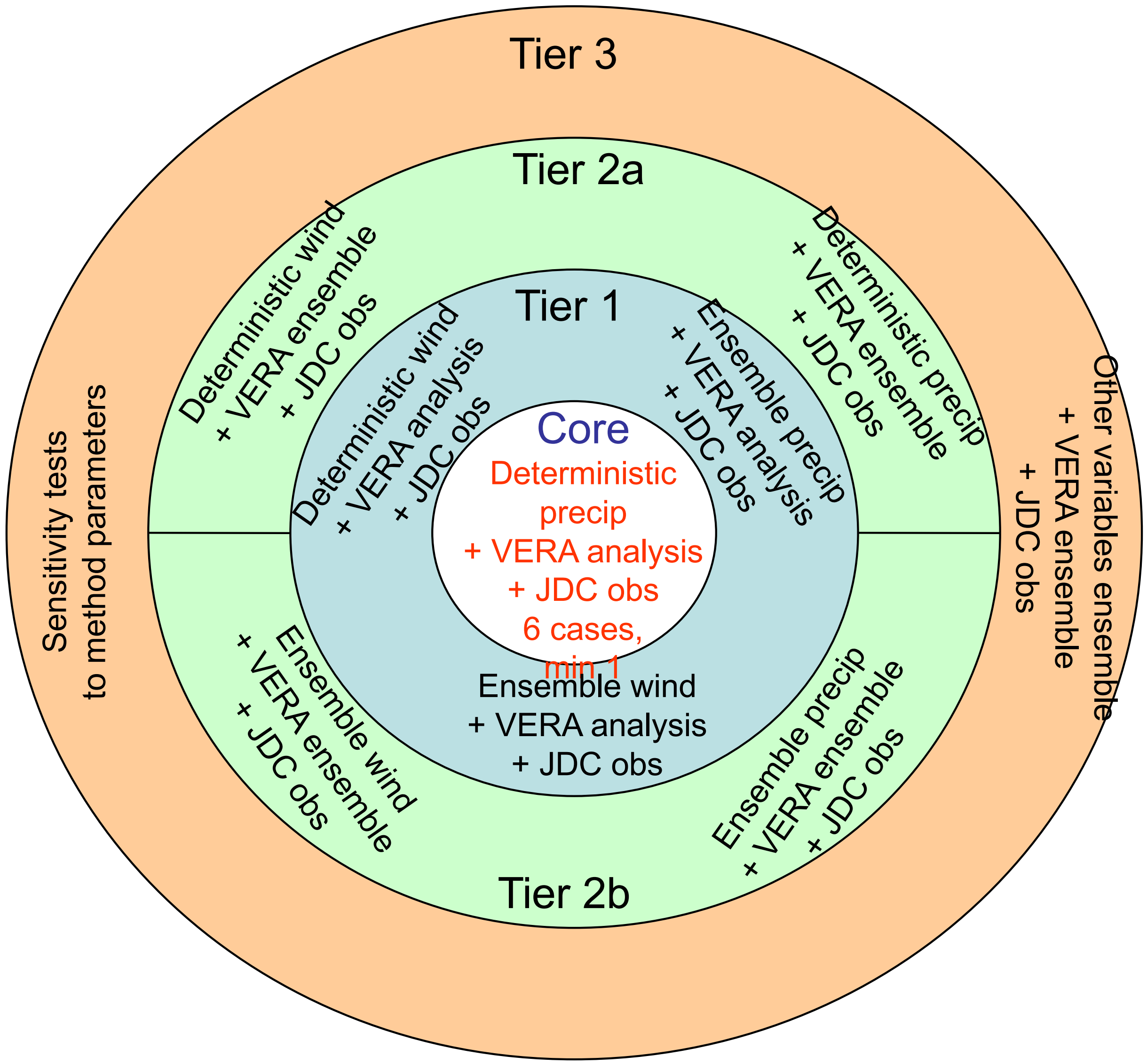


WRF2 CAPS – STAGE II
WRF4 NCAR – STAGE II
WRF4 NCEP – STAGE II



a) geom000
observation
200 pts.
50 pts.
b) geom001
50 pts. too far right
observation
forecast
50 pts.
c) geom002
200 pts. too far right
200 pts.
d) geom003
125 pts. too far right,
high area-bias
125 pts.
e) geom004
125 pts. too far right,
wrong aspect ratio
125 pts.
f) geom005
125 pts. too far right,
very high area-bias, but overlapping
125 pts.
observation
forecast
12.7 25.4 mm
0 500 1000 km
1 pt. ≅ 4km

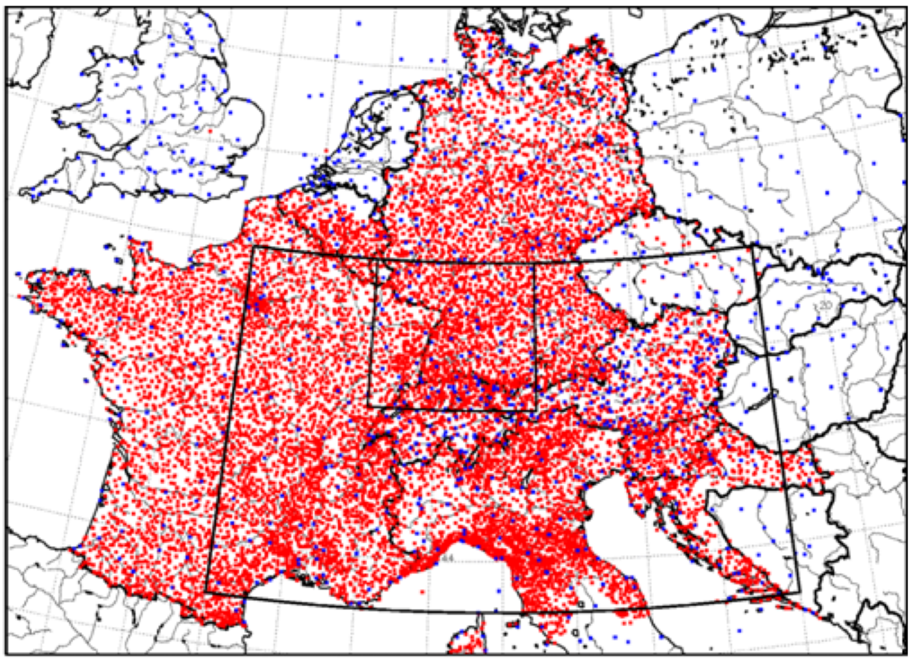
MesoVICT



Tier 3
Tier 2a
Tier 1
Core
Deterministic precip
+ VERA analysis
+ JDC obs
6 cases,
min 1
Deterministic wind
+ VERA analysis
+ JDC obs
Ensemble precip
+ VERA analysis
+ JDC obs
Ensemble wind
+ VERA analysis
+ JDC obs
Deterministic wind
+ VERA ensemble
+ JDC obs
Deterministic precip
+ VERA ensemble
+ JDC obs
Ensemble wind
+ VERA ensemble
+ JDC obs
Ensemble precip
+ VERA ensemble
+ JDC obs
Tier 2b
Sensitivity tests
to method parameters
Other variables ensemble
+ VERA ensemble
+ JDC obs

MesoVICT

WWRP COPS (RDP, Wulfmeyer, et al., 2008, BAMS) and D-PHASE (FDP, Rotach, et al., 2009, BAMS), data available: (http://cera-www.dkrz.de/WDCC/ui/Index.jsp)



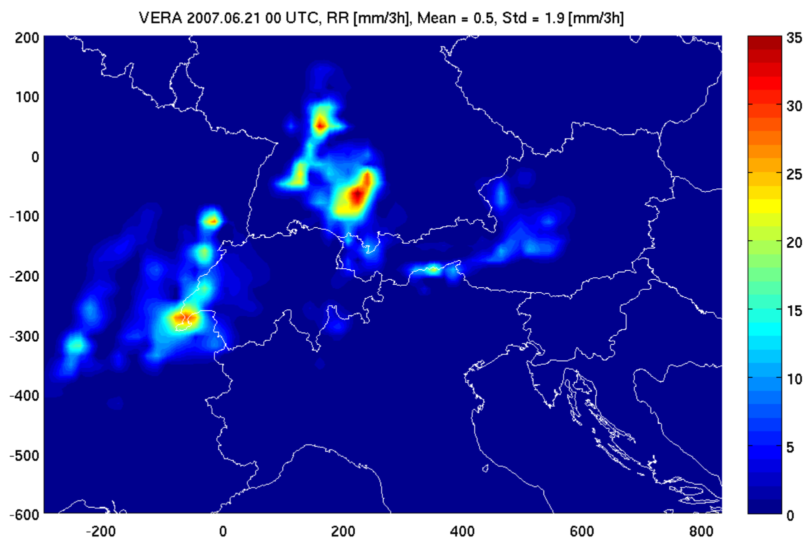
Observations-Joint D-PHASE COPS (JDC) data-set

- 32 data providers
- GTS-Stations: 1232
- NGTS-Stations: > 13000
- Mean station distance: GTS: ~ 36km
  GTS+Non-GTS: ~ 12km

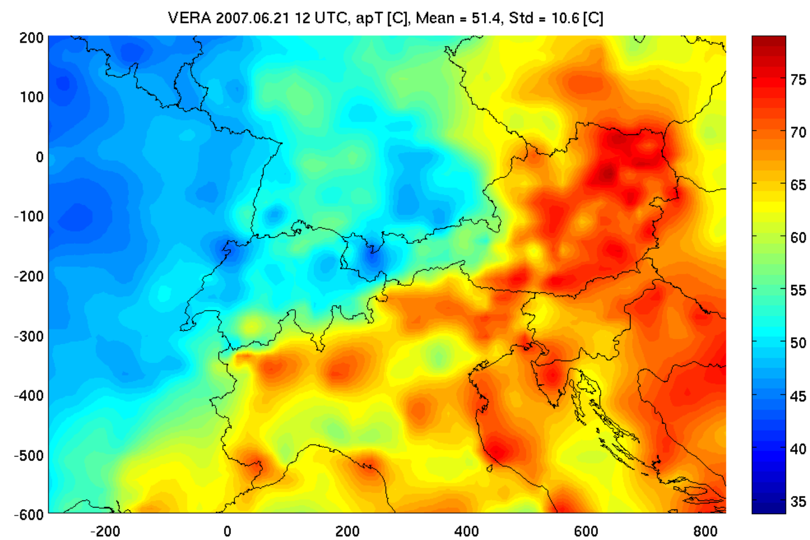
Frames: D-PHASE (large) & COPS (small) areas

MesoVICT

Case 1 **(core case)**: 20-22 June 2007 (COPS IOP case)
Storng convective developments north of the Alps followed by a cold front the next day. Cold air mass could not spill over the Alps.



Precipitation analysis for the 3h-period ending at 21 June 2007, 00 UTC.



Equivalent potential temperature analysis for 21 June 2007, 12 UTC.

New Geometric Cases

NCAR

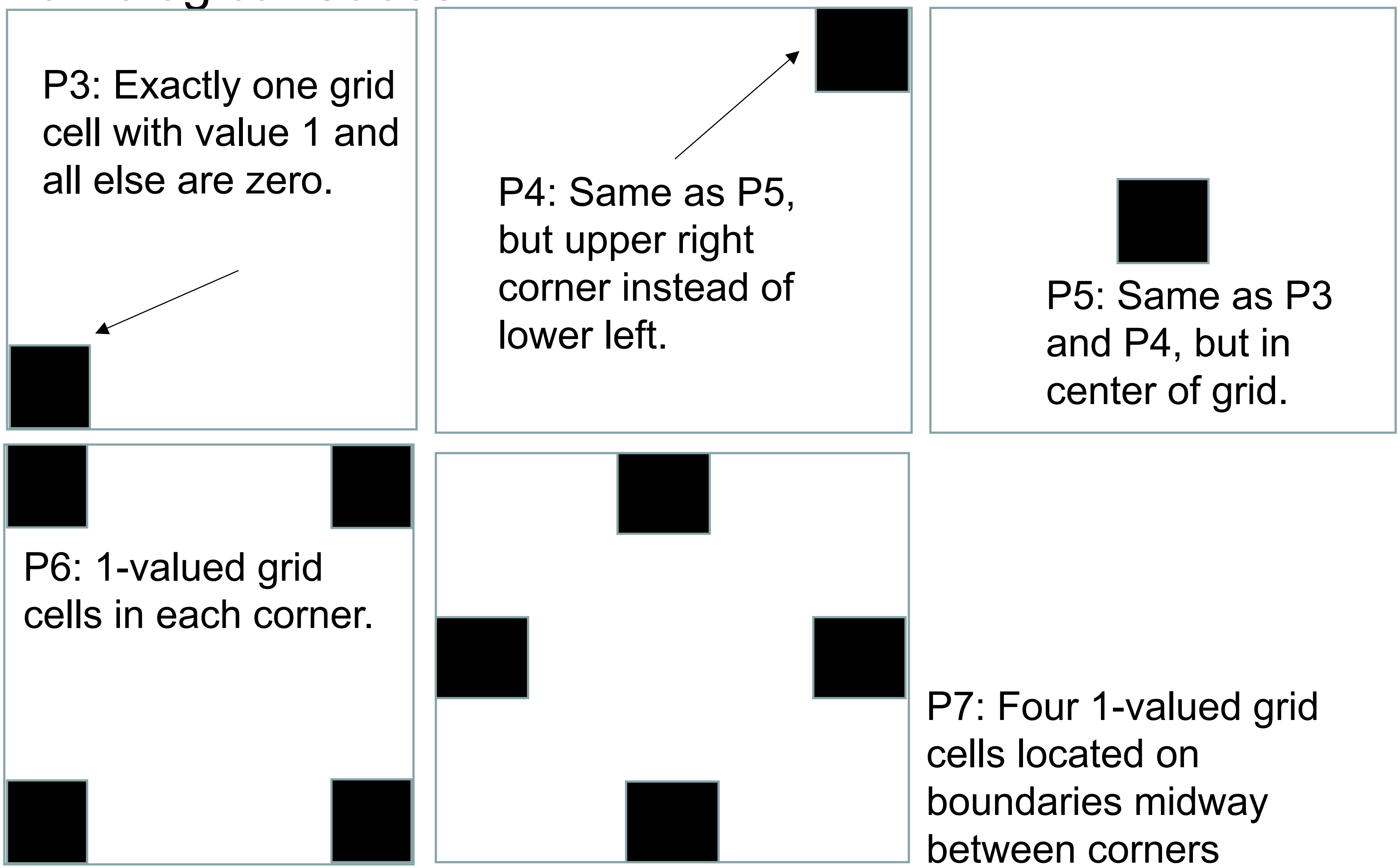
Pathological Cases

P1: Null Case

P2: Full Case

New Geometric Cases

Pathological Cases

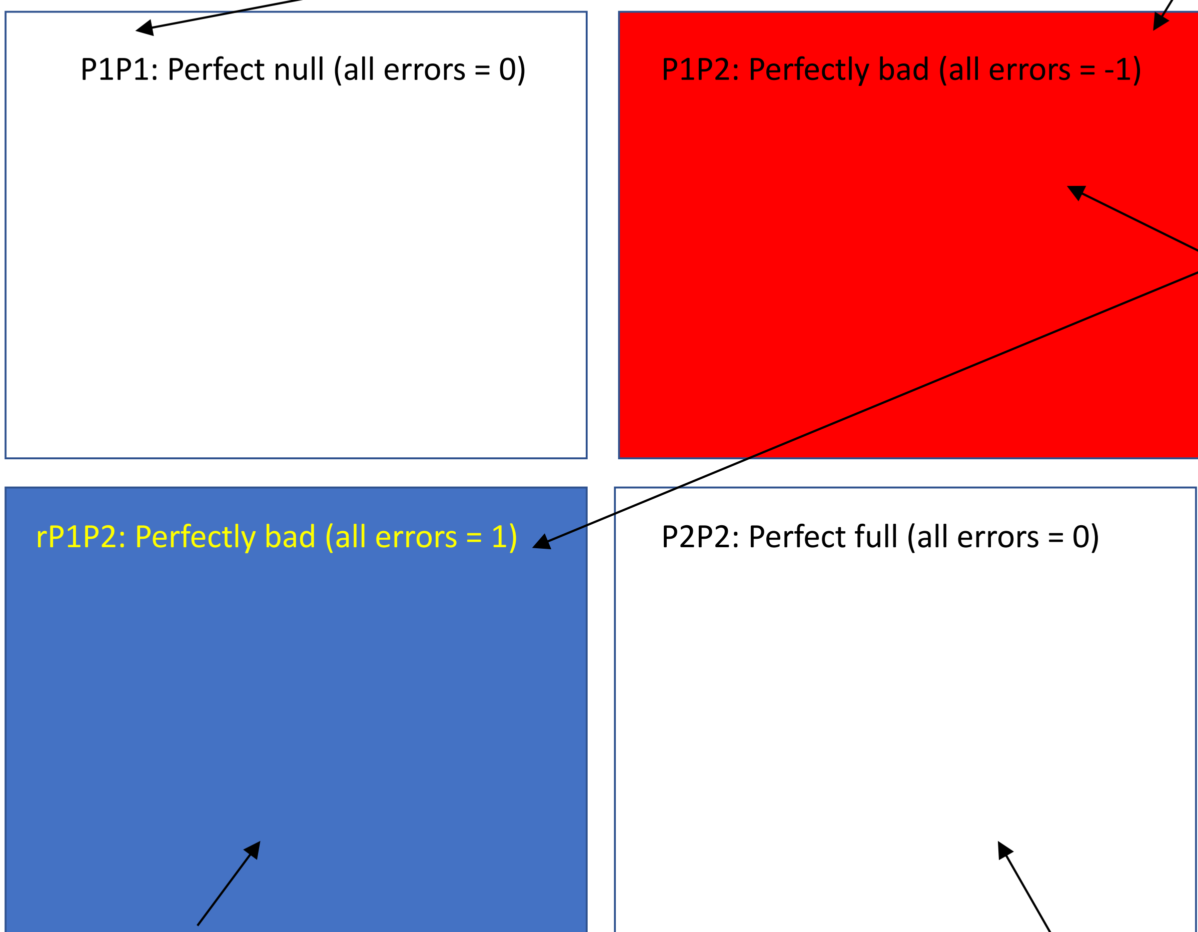


New Geometric Cases

NCAR

Δ = Đ = H = CD = MED = Z = 0.00, FoM undefined

FoM(P2, P1) undefined
MED(P2, P1) undefined



Δ = H = 400.00
Đ = 401.99
CD = 142.13
Z = 200

F – O

FoM(P1, P2) = 0.00
MED(P1, P2) = 400.00

Δ = Đ = H = CD = MED = Z = 0.00, FoM = 1.00

New Geometric Cases

NCAR

P1P3: Exactly one grid cell with error = -1 and all else are zero.

Δ = 246.29
Đ = 322.12, H = 400.00
CD = 1.41, Z = 100.50

FoM(P1, P3) = 0.00
MED(P1, P3) = 400.00

rP1P3: Exactly one grid cell with error = 1 and all else are zero.

FoM(P3, P1) undefined
MED(P3, P1) undefined

P1P4: Same as P1P3, but different placement of the error.

Δ = 246.29
Đ = 322.12, H = 400.00
CD = **282.84**, Z = 100.50

FoM(P1, P4) = 0.00
MED(P1, P4) = 400.00
MED(P4, P1) undefined

P1P5: Same as P1P3 and P1P4, but different placement of the error.

Δ = **320.51**
Đ = 322.12, H = 400.00
CD = **141.42**, Z = 100.50

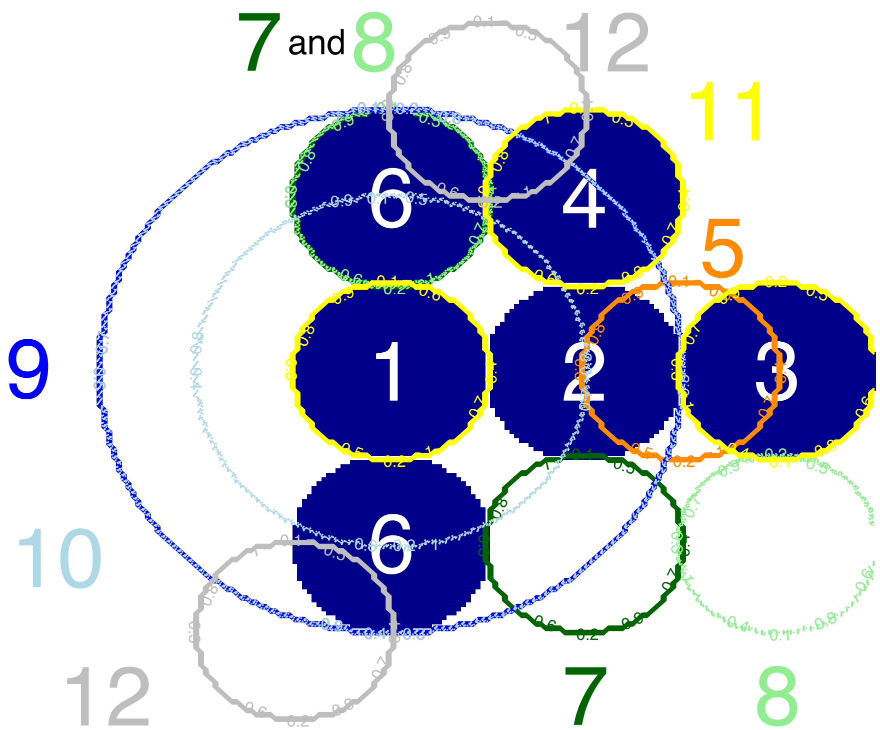
P2P5: Same as P1P5 but the one grid square is the only non-error.

F – O

FoM(P1, P5) = 0.00
MED(P1, P5) = 400.00
MED(P5, P1) undefined

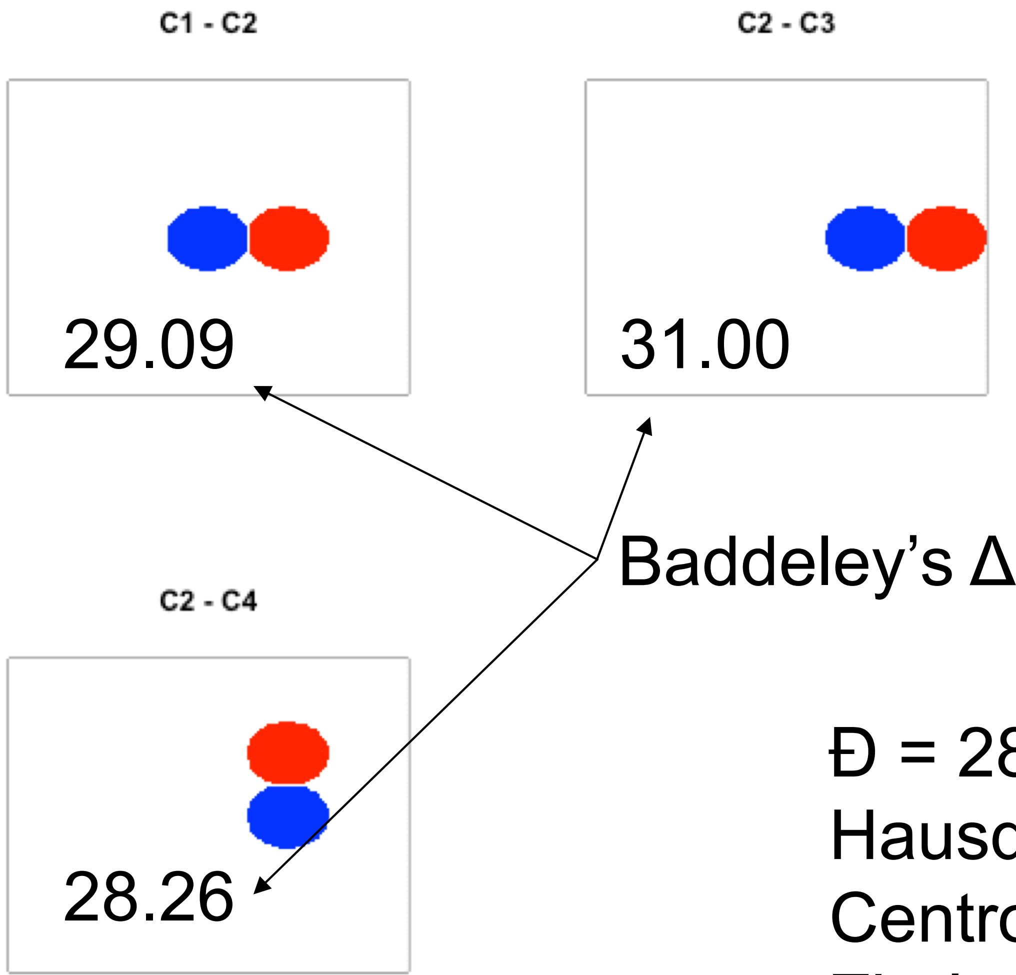
Δ = 86.21
Đ = 86.62, H = 142..13
CD = 0.71, Z = 140.44
FoM(P2, P5) = 0.01
MED(P2, P5) = 0.00, MED(P5, P2) = 80.88

New Geometric Cases



Circle Cases

New Geometric Cases

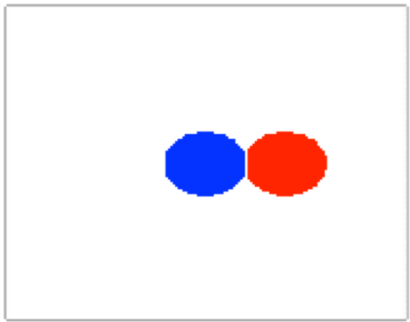


F – O

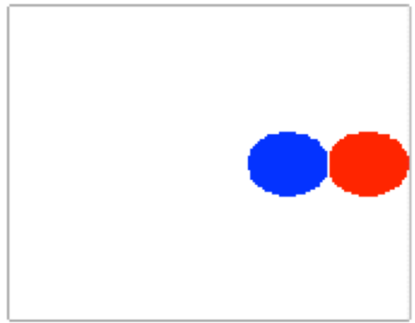
Đ = 28.84
Hausdorff = 40.20
Centroid distance = 40.00
Zhu's metric = 36.81

New Geometric Cases

C1 - C2

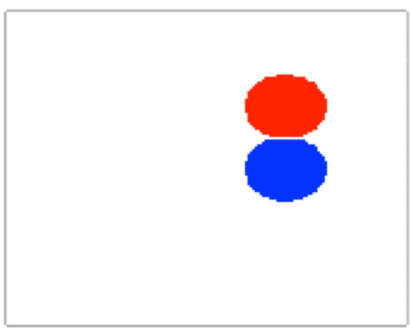


C2 - C3



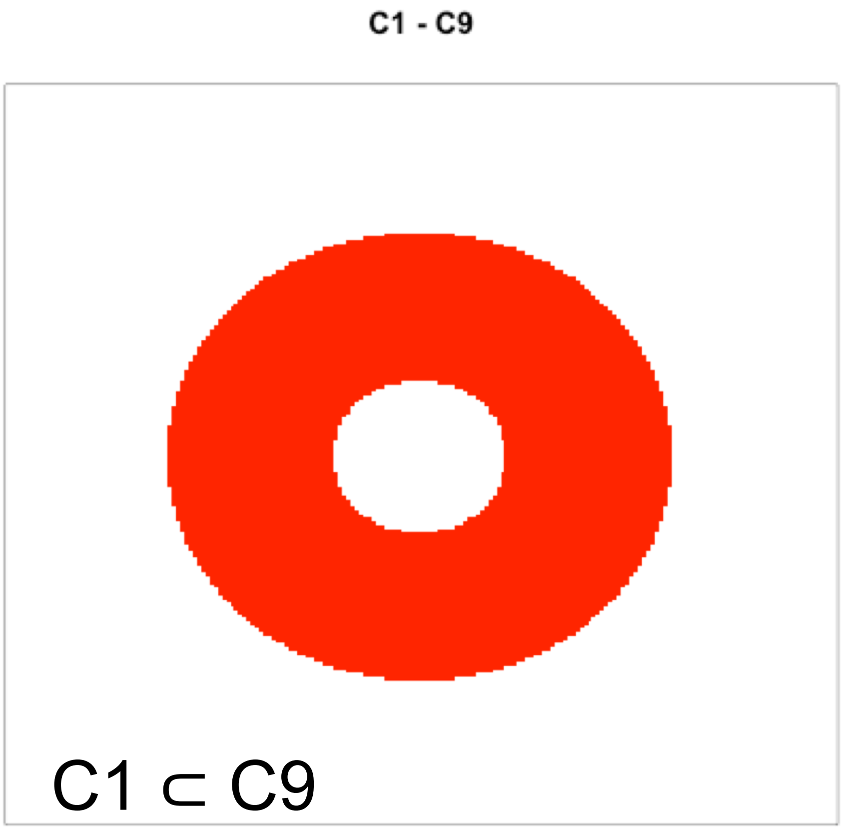
F – O

C2 - C4



MED(False Alarm) = MED(Miss) = 21.92
FoM(False Alarm) = FoM(Miss) = 0.07

New Geometric Cases



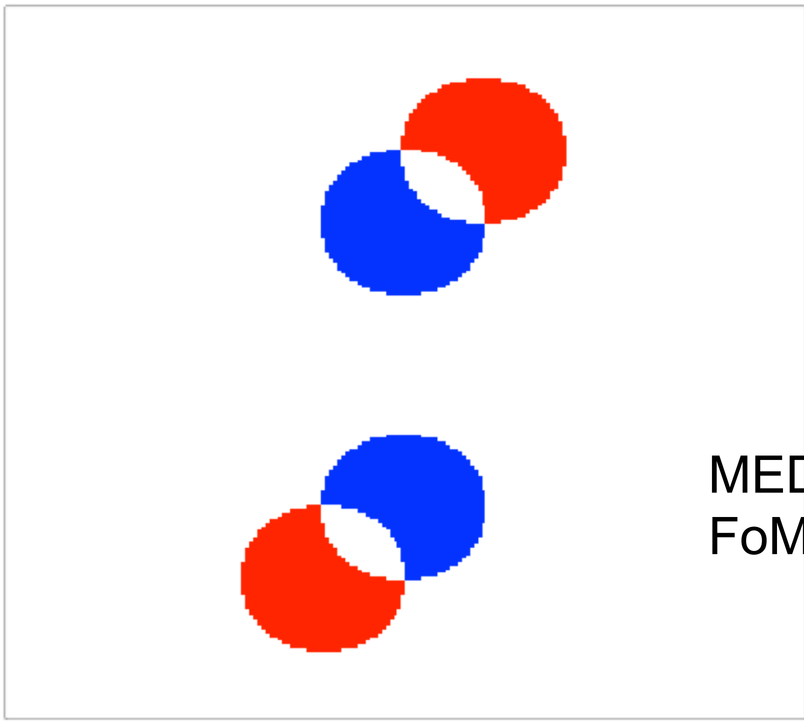
F – O = C1 – C9

Baddeley's Δ = 38.13
Ð = 38.17
Hausdorff = 43.43
Centroid distance = 0.00
Zhu's metric = 50.5

MED(Miss) = 21.72
MED(False Alarm) = 0.00
FoM(Miss) = 0.12
FoM(False Alarm) = 0.18

New Geometric Cases

C6 - C12

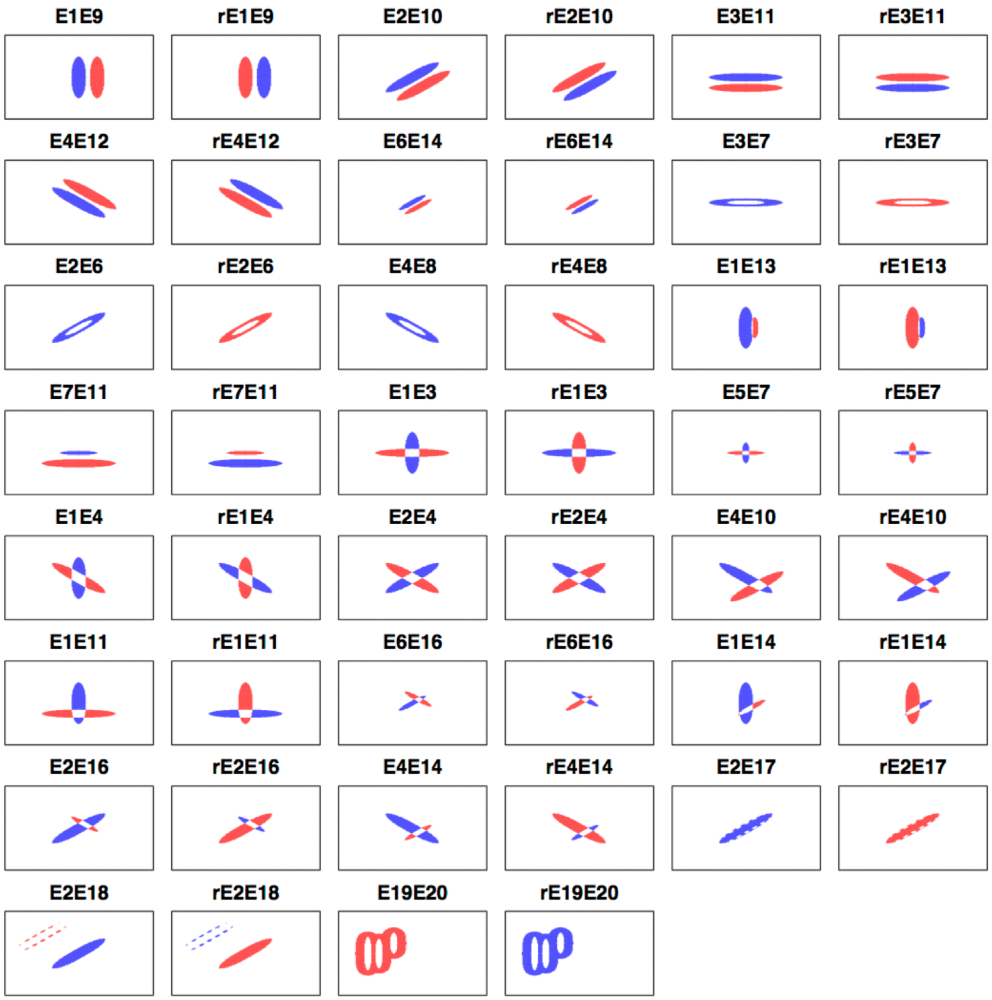


Δ = 18.84
Đ = 18.85
H = 28.43
CD = 0.00
Z = 38.36

MED(Miss) = MED(False Alarm) = 11.24
FoM(Miss) = FoM(False Alarm) = 0.32

F – O = C6 – C12

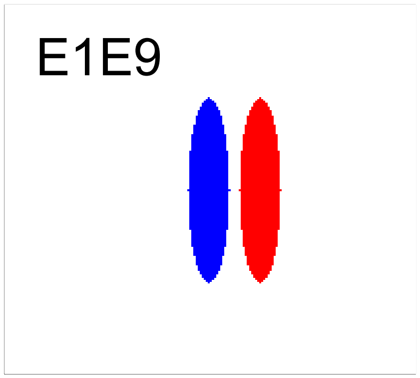
New Geometric Cases



Complex Terrain Cases

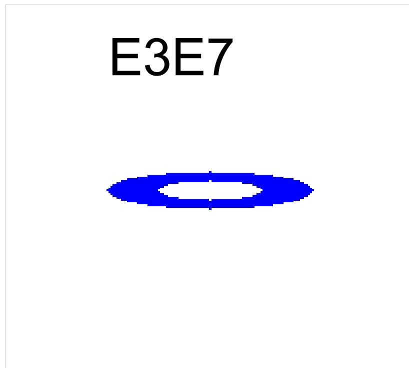
New Geometric Cases

Δ = 22.53
Ð = 22.52, H = 25.13
CD = 25.00, Z = 36.41



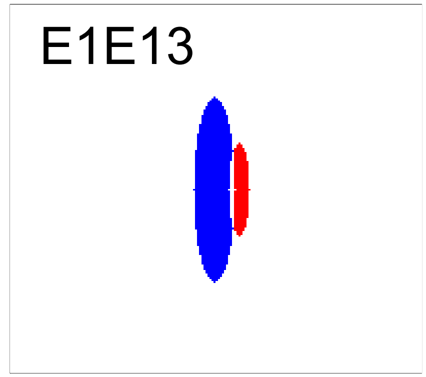
FoM = 0.05
MED = 17.09

Δ = 14.15
Ð = 14.18, H = 25.13
CD = 0.00, Z = 20.02



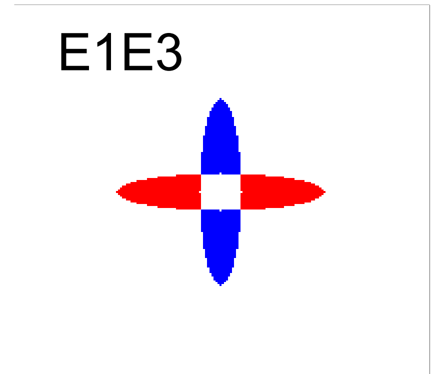
FoM(Miss) = 0.5
FoM(False Alarm) = 0.25
MED(Miss) = 0.00
MED(False Alarm) = 5.86

Δ = 17.98
Ð = 17.84, H = 40.2
CD = 12.00, Z = 27.16



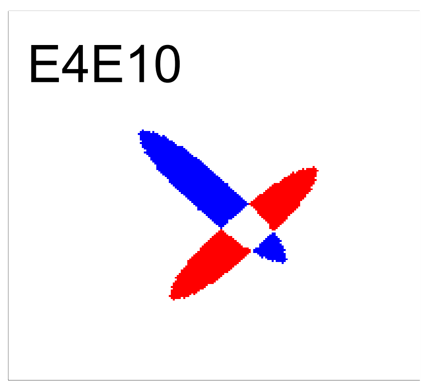
FoM(Miss) = 0.19
FoM(False Alarm) = 0.14
MED(Miss) = 3.10
MED(False Alarm) = 12.01

Δ = 23.51
Ð = 23.53, H = 40.2
CD = 0.00, Z = 27.16



FoM = 0.34
MED = 13.30

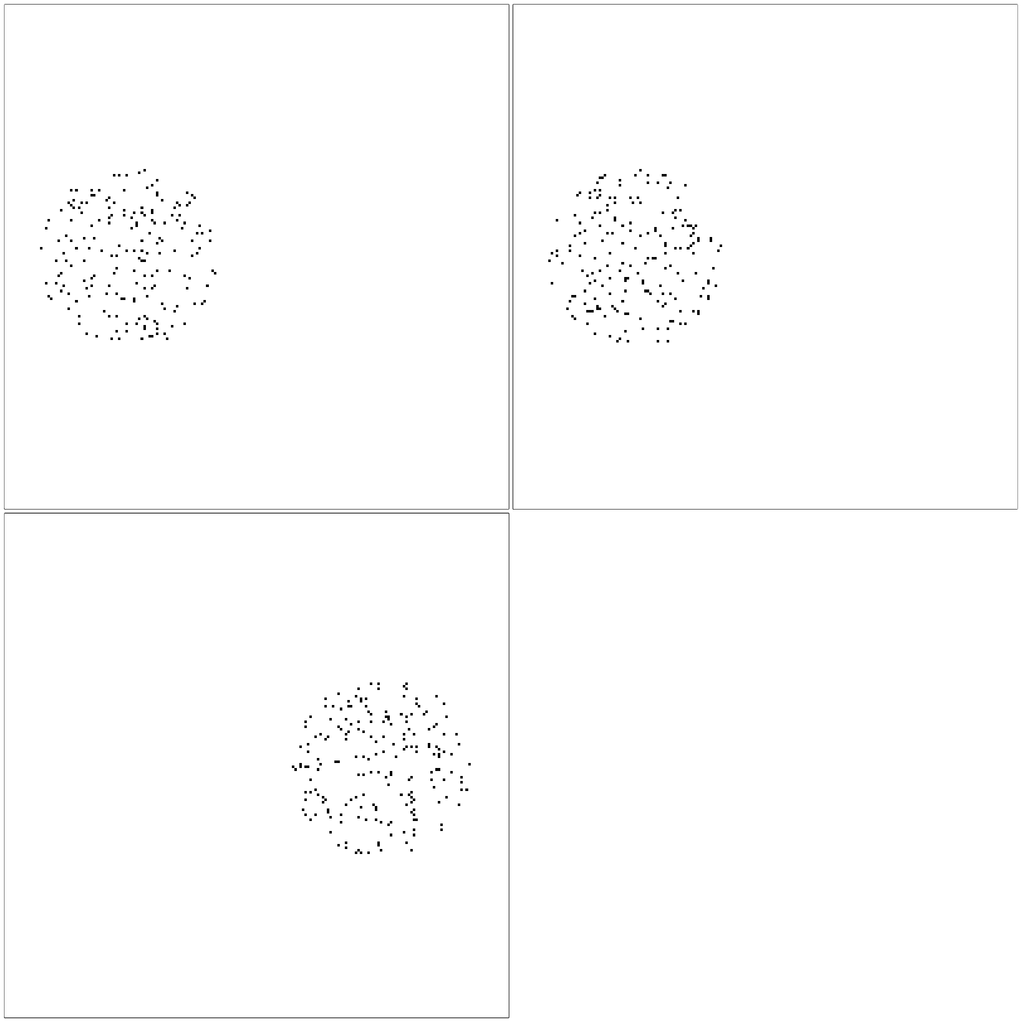
Δ = 32.16
Ð = 31.18, H = 65.38
CD = 25.00, Z = 35.23



FoM(Miss) = 0.32
FoM(False Alarm) = 0.30
MED(Miss) = 14.08
MED(False Alarm) 20.76

F – O

New Geometric Cases

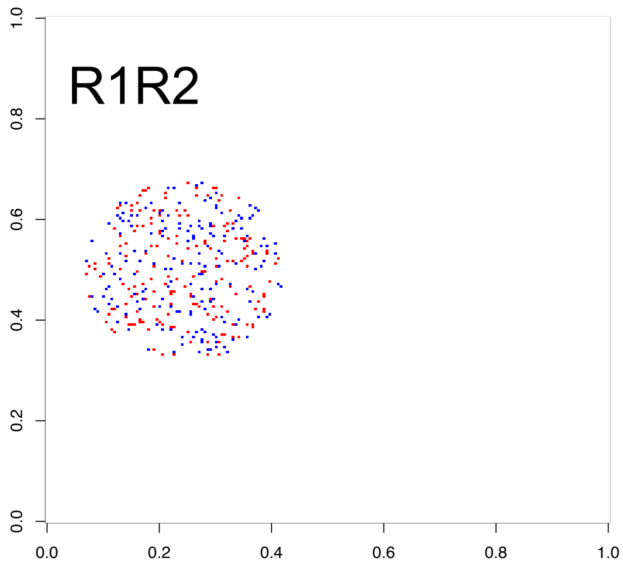


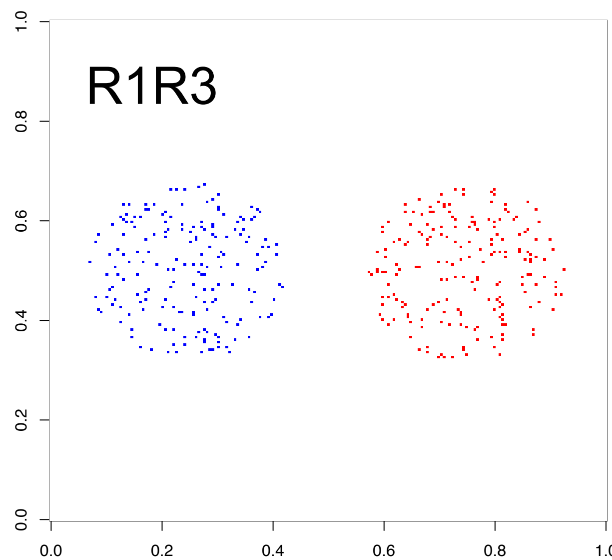
Random Rain Cases

New Geometric Cases

Random Rain Cases

Δ = 1.91
Đ = 1.78, H = 9.12
CD = 1.30, Z = 10.59
FoM = 0.62
MED(False Alarm) = 2.37
MED(Miss) = 2.56





Δ = 63.39
Đ = 63.49, H = 104.42
CD = 99.11, Z = 45.06
FoM = 0.00
MED(False Alarm) = 70.04
MED(Miss) = 70.60

New Geometric Cases

NCAR

Additional Cases include:

- Holes (inverted C1 and C2)
- C1C4 with noise added
- C1C4 with P3 added
- C1C4 with P5 added

Summary

- Overview paper of project accepted to BAMS (available at Early online release: https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-17-0164.1).
- Special Collection of Papers for Monthly Weather Review
- SpatialVx (R package for performing many of the spatial methods; still in beta form—use at your own risk!)
- All test cases and other information (including preliminary results) available at MesoVICT web site (https://ral.ucar.edu/projects/icp/)
- New geometric cases available soon (paper in progress).

Thank you

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https://ral.ucar.edu/staff/ericg/