Spatial Forecast Verification methods overview

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SpatialVx: R package for performing spatial verification (in the works)

http://www.ral.ucar.edu/projects/icp/SpatialVx/

WRF/MET Tutorial, 23 – 24 January 2014
NCAR, Boulder, Colorado

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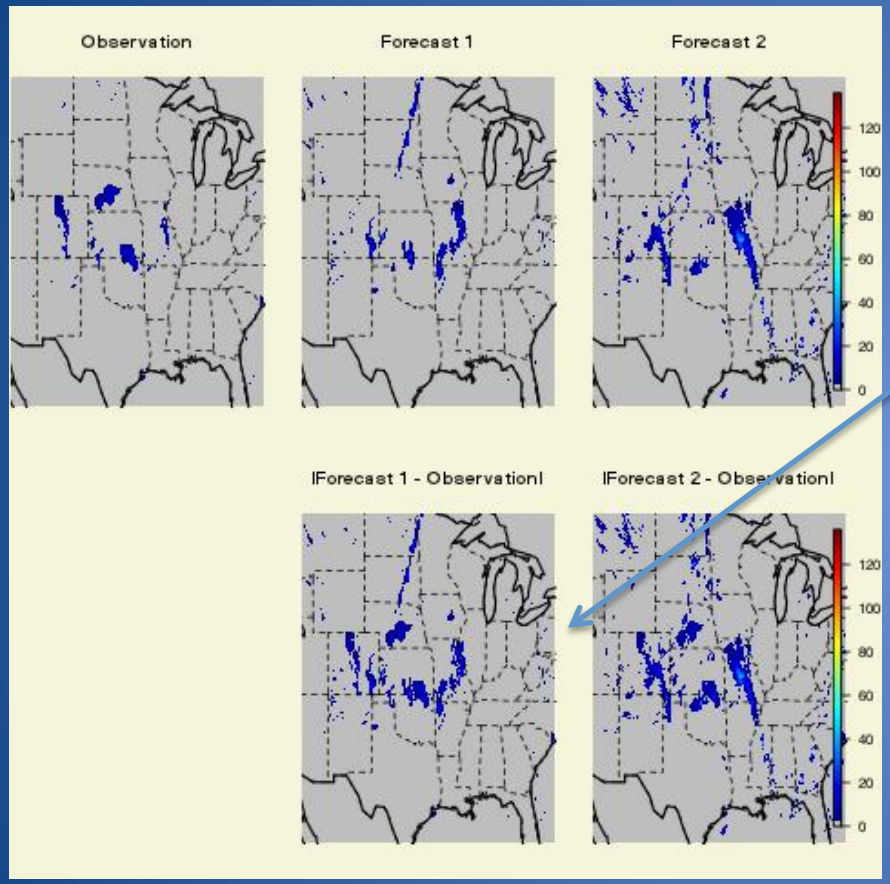
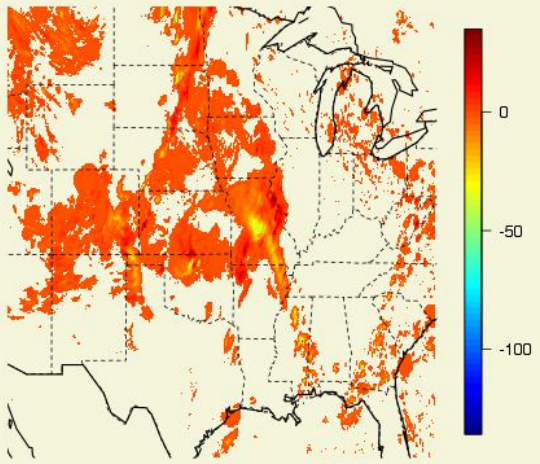
Spatial Prediction Comparison Test

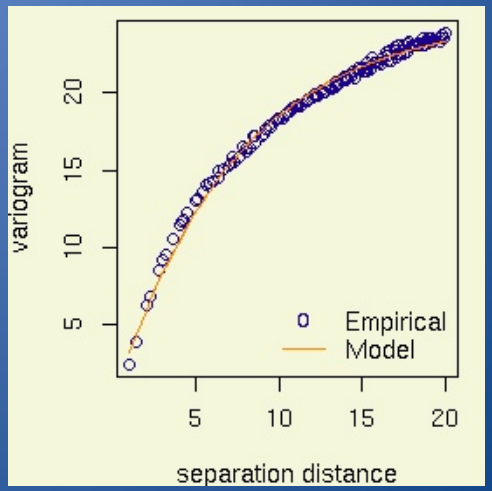


D1 D2

D = D1 – D2



Loss Differential Field



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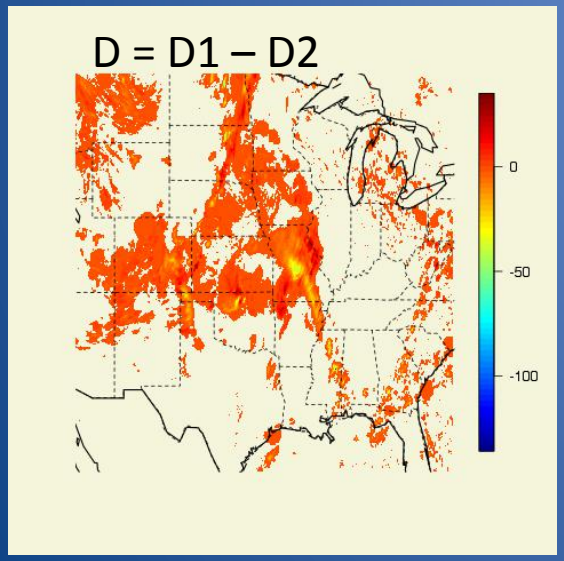
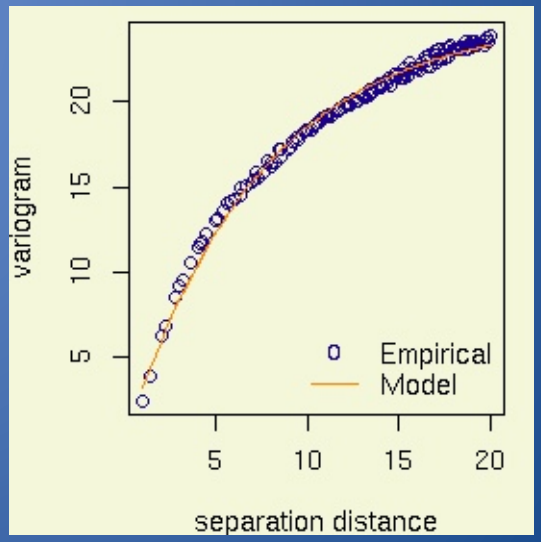
Spatial Prediction Comparison Test

Introduced by Hering and Genton (2011, *Technometrics*, **53**, 414 – 425)

Extension of the time series version introduced by Diebold and Mariano (1995, *J. Business and Economic Statistics*, **13**, 253 – 263).



$$S = \frac{\bar{D}}{\sqrt{\mathrm{var}(\bar{D})}}$$



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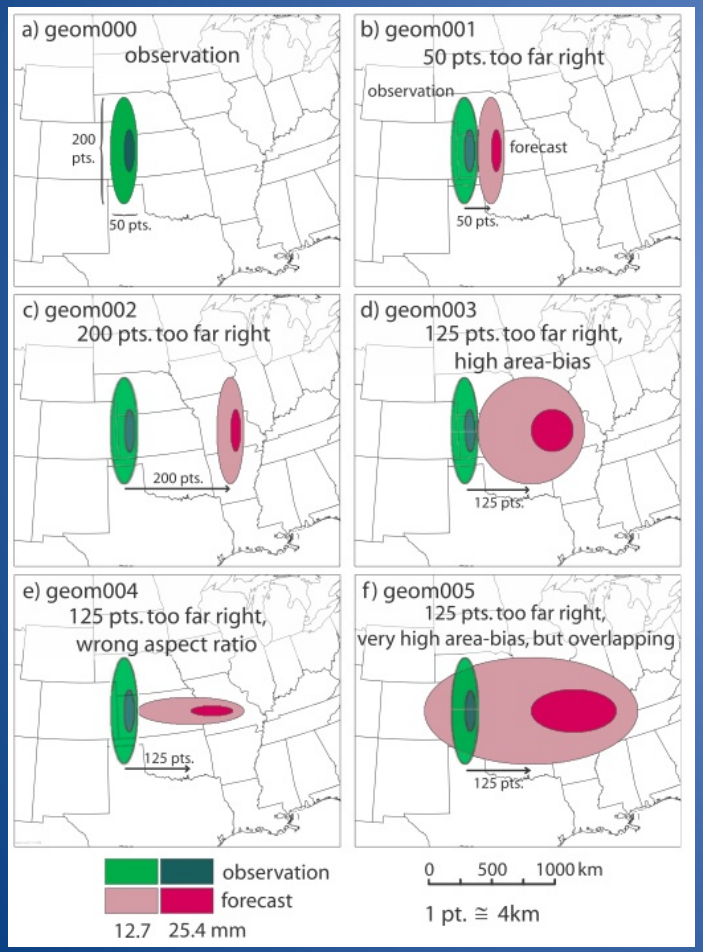
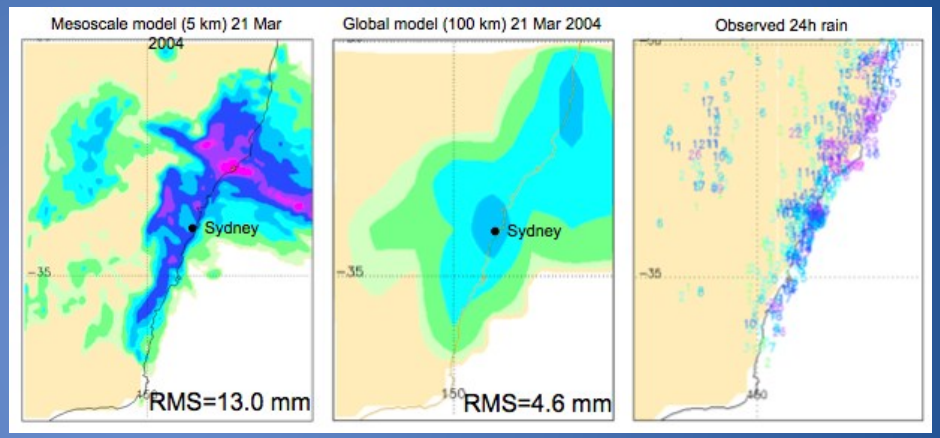
Spatial Prediction Comparison Test

Accounting for Location Errors and Reducing Effects of Small Scale Errors





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

Above Figure from Beth Ebert

Fig. 1 and Table 2 from Ahijevych *et al*. (2009, *WAF*, **24**, 1485 – 1497)

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Spatial Prediction Comparison Test

Accounting for Location Errors and Reducing Effects of Small Scale Errors

Above Figure from Johan Lindström

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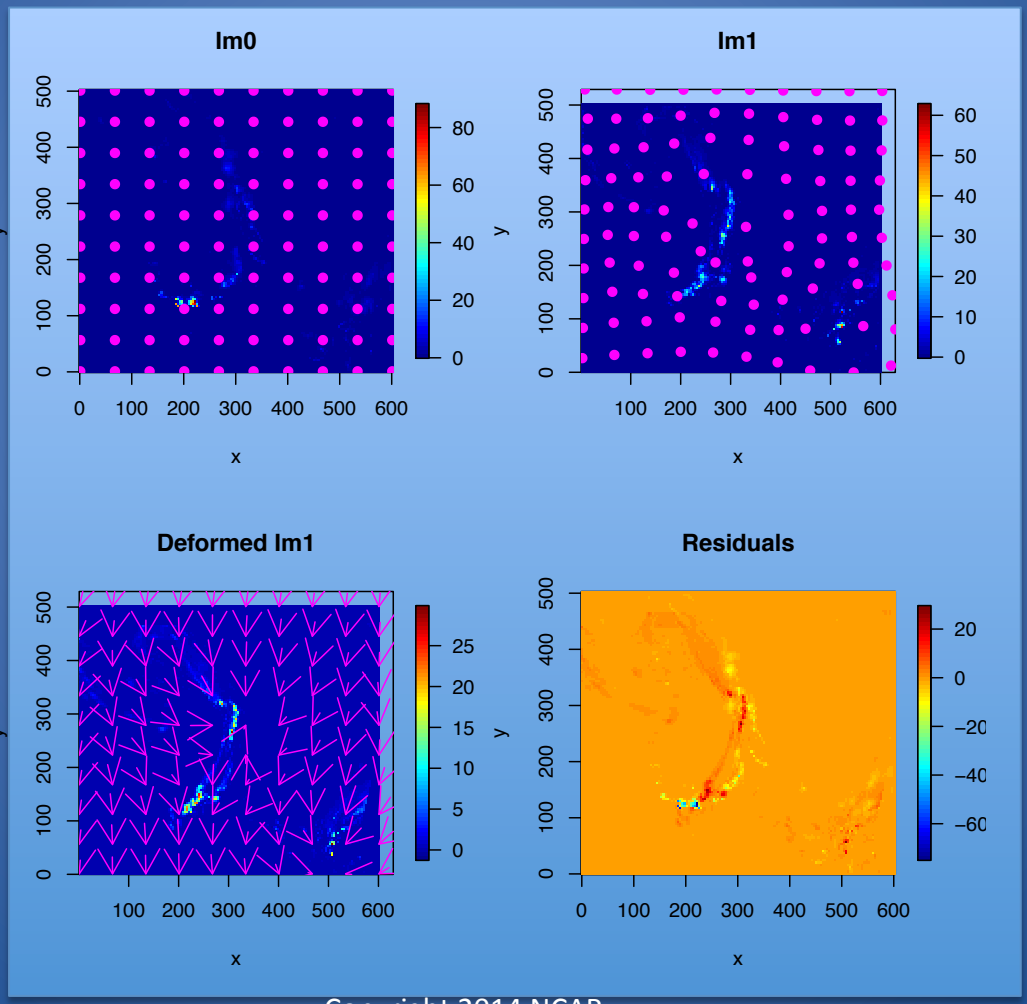
Spatial Prediction Comparison Test

Accounting for Location Errors and Reducing Effects of Small-Scale Errors



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Spatial Prediction Comparison Test

Accounting for Location Errors and Reducing Effects of Small Scale Errors

Loss at each point =

Distance from original location of each point to warped location

Loss at each point between observation value and warped value

G. (2013, *MWR*, **141** (1), 340 – 355)

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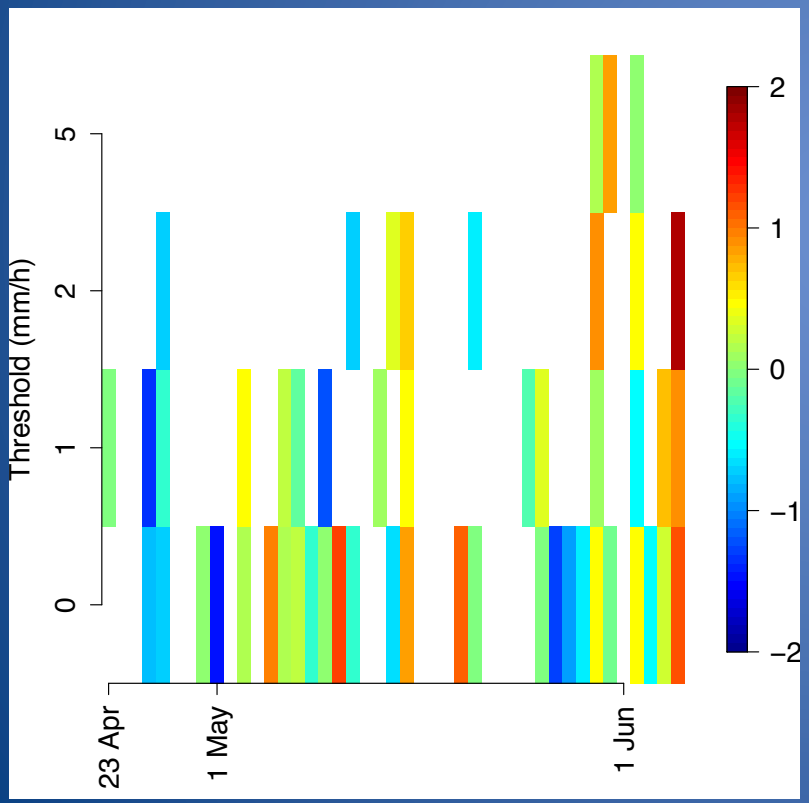
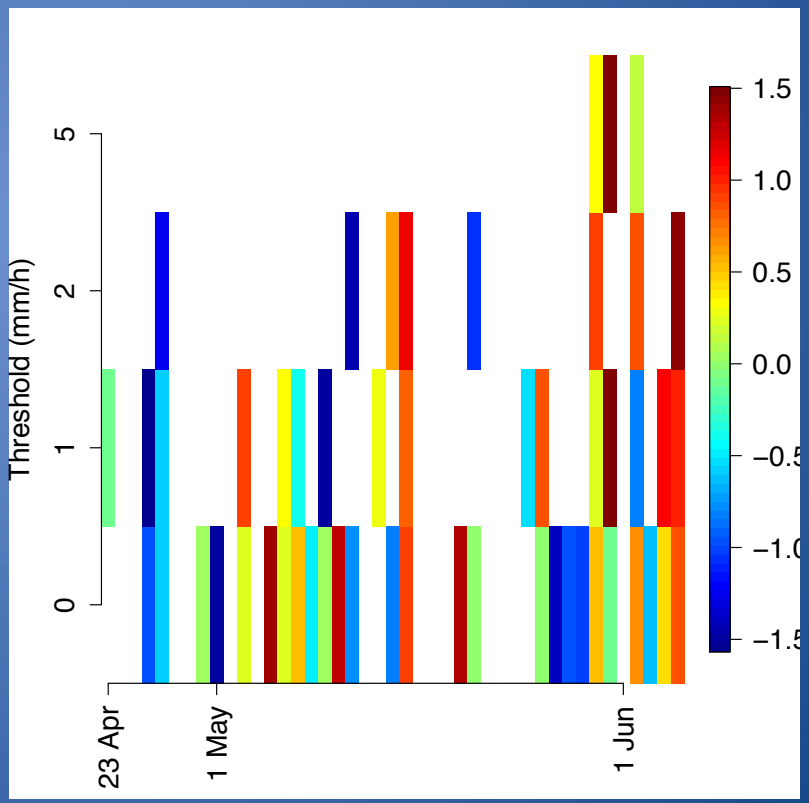
Spatial Prediction Comparison Test

Accounting for Location Errors and Reducing Effects of Small Scale Errors

$\bar{D}$



S



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Methods Overview

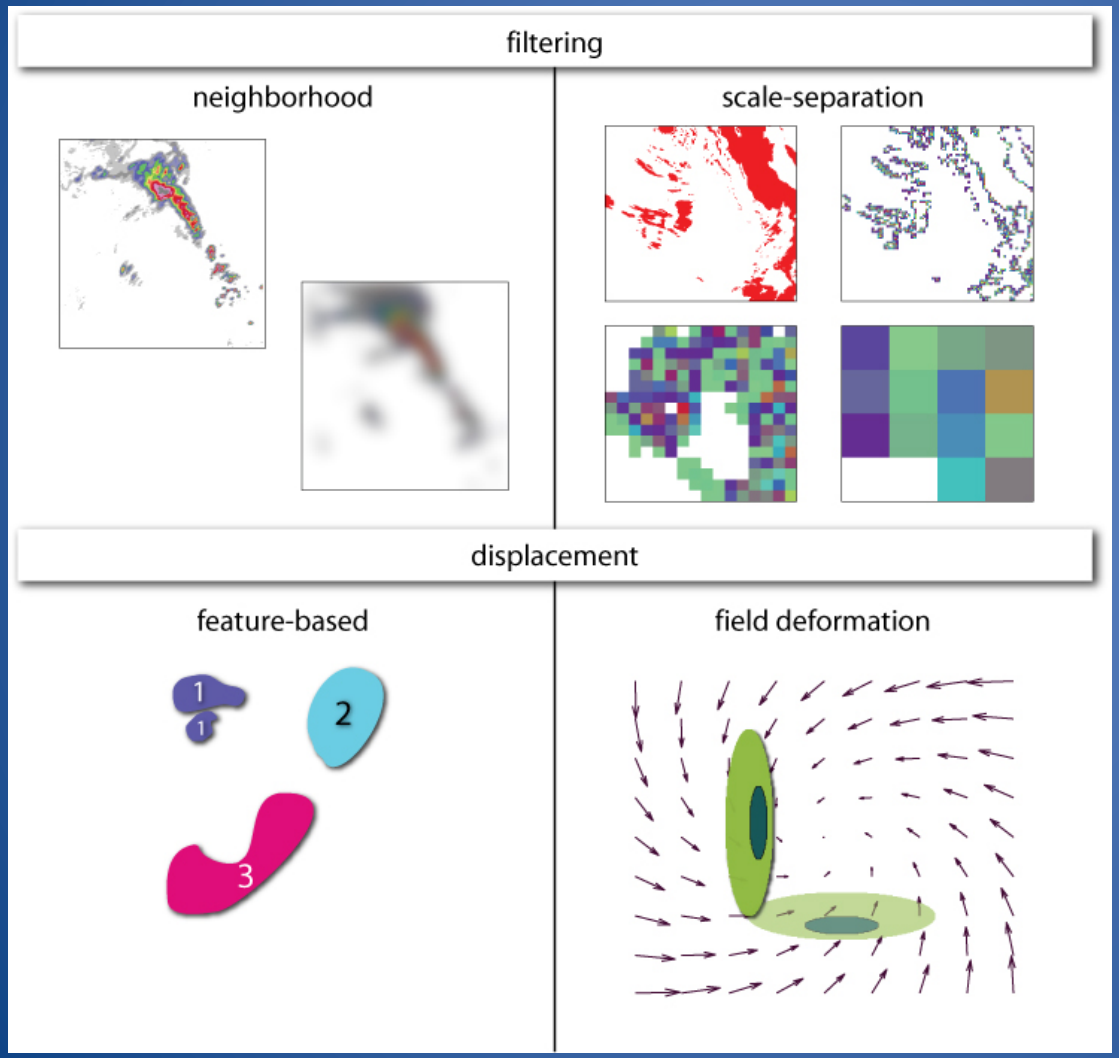

Fig. 2 from G. *et al*. (2010, *BAMS*, **91** (10), 1365 – 1373)

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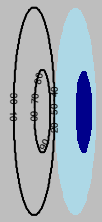
Filter Methods: Smoothing

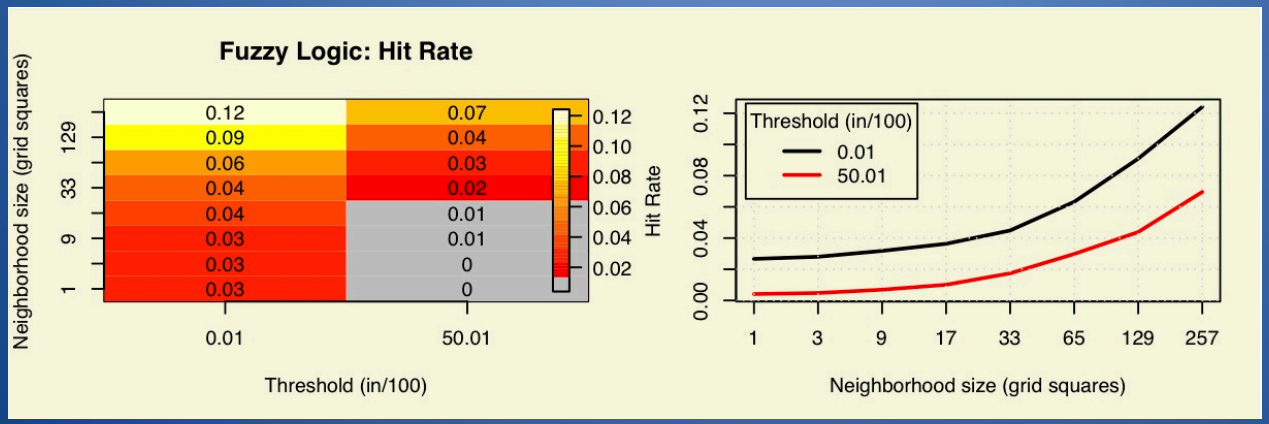
50 grid points displacement error



The fuzzy logic approach compares smoothed indicator fields:

a new contingency table where
hits = sum of the minima between the two fields at each (smoothed) grid point.

misses = sum of the minima between the smoothed indicator of the observed field and 1 – the smoothed indicator of the forecast field, and so on (cf. Ebert 2008, *Meteorol. Appl.*, **15**, 51 - 64).



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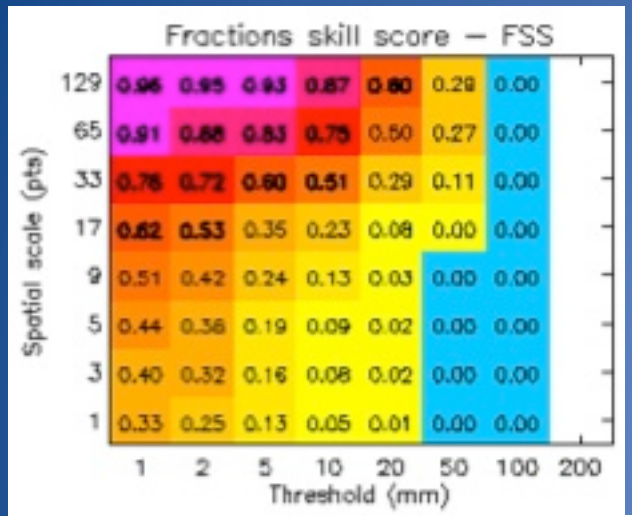
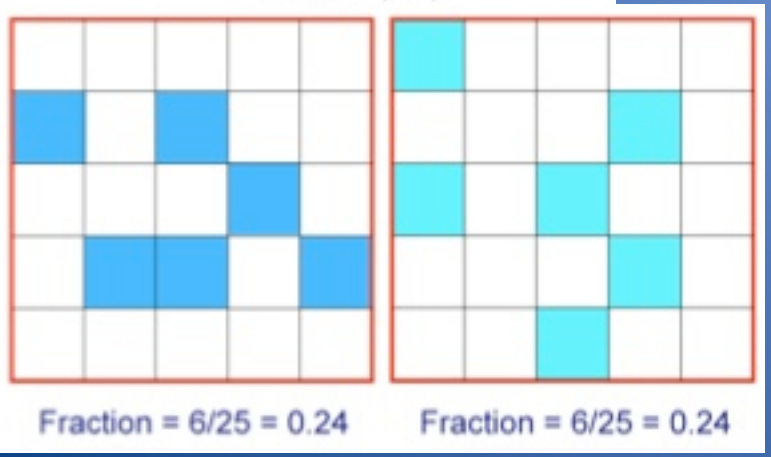
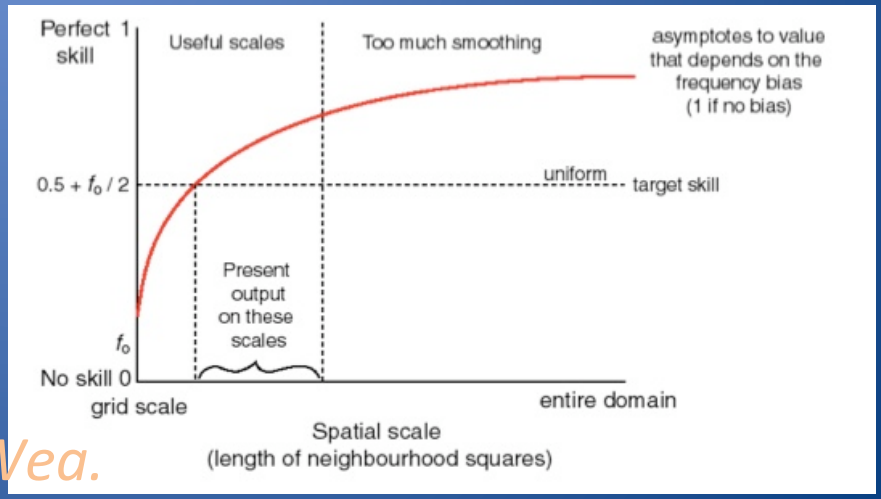
Filter Methods: Smoothing Fractions Skill Score (FSS)





$$\mathrm{FSS} = 1 - \frac{\sum_{s=1}^{n} \left(\hat{p}_s - p_s\right)^2}{\sum_{s=1}^{n} \hat{p}_s^2 + \sum_{s=1}^{n} p_s^2}$$

$p_s, \hat{p}_s$ are the fraction of events in a neighborhood centered on point s.



Roberts and Lean (2008, *Mon. Wea. Rev.* , **136**, 78 – 96)

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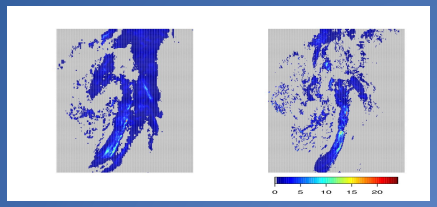
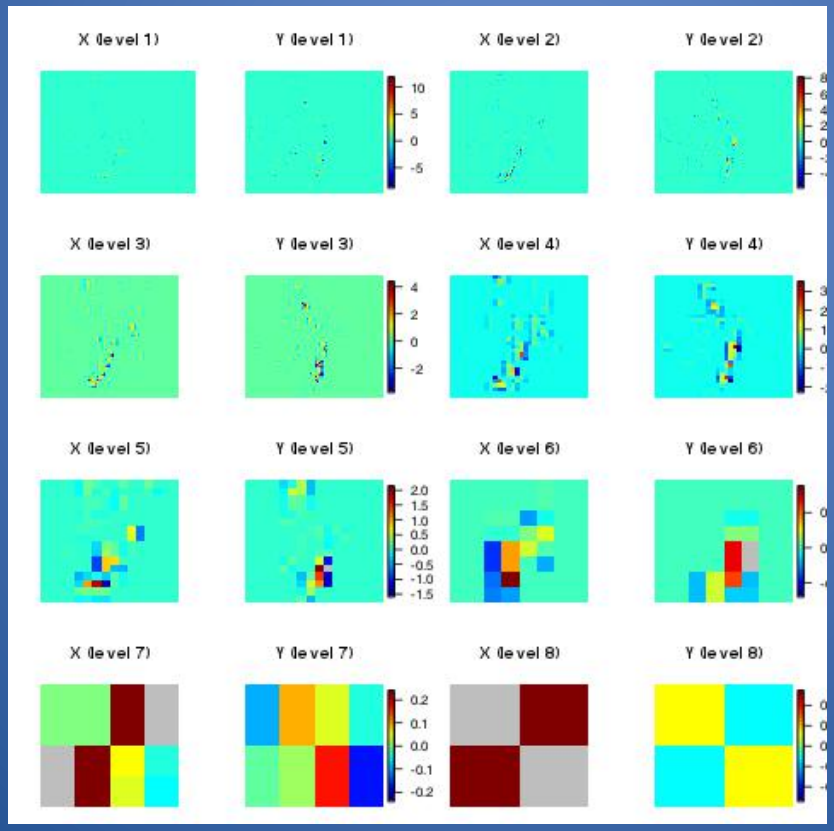
Filter Methods: Scale separation





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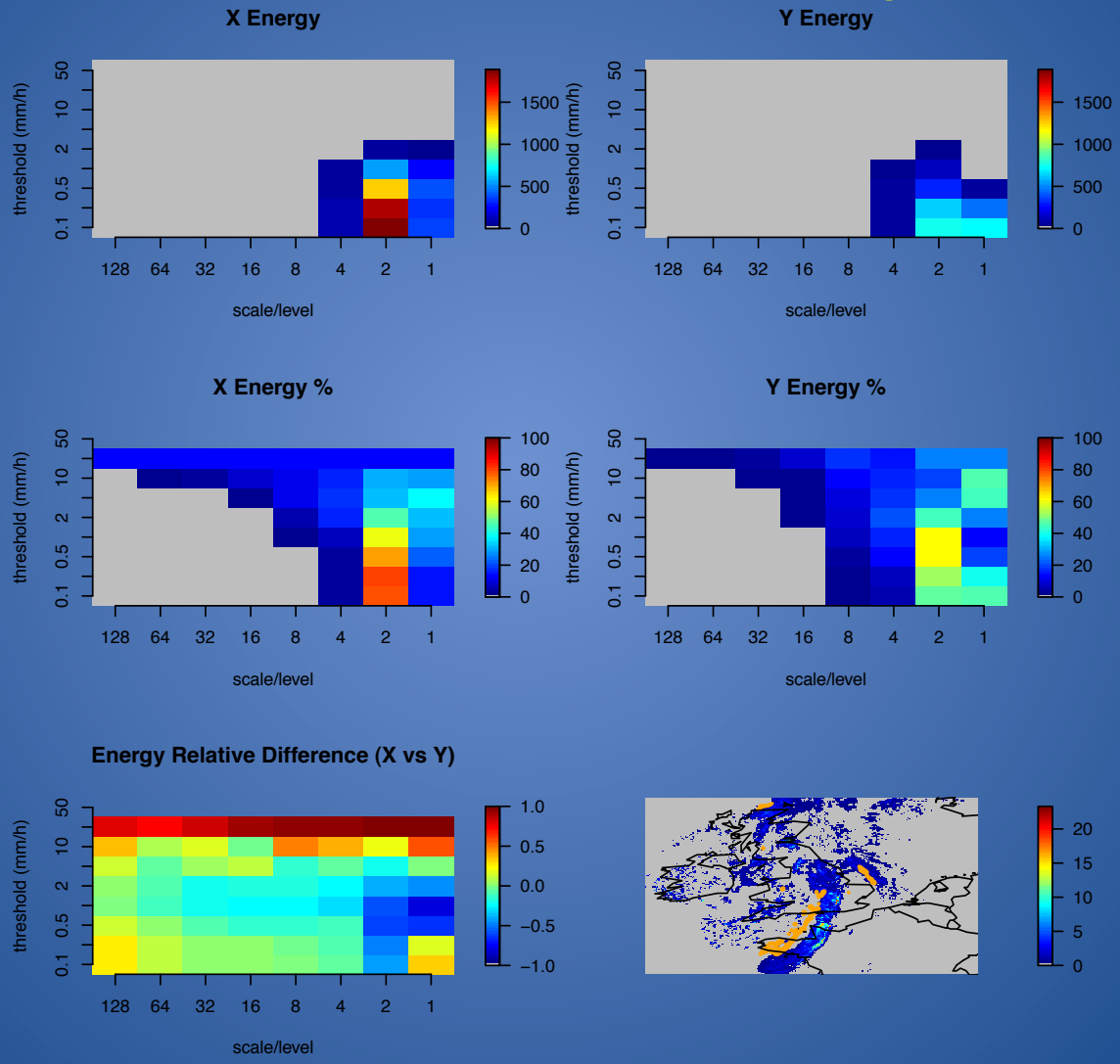
Filter Methods: Scale separation

Intensity-Scale



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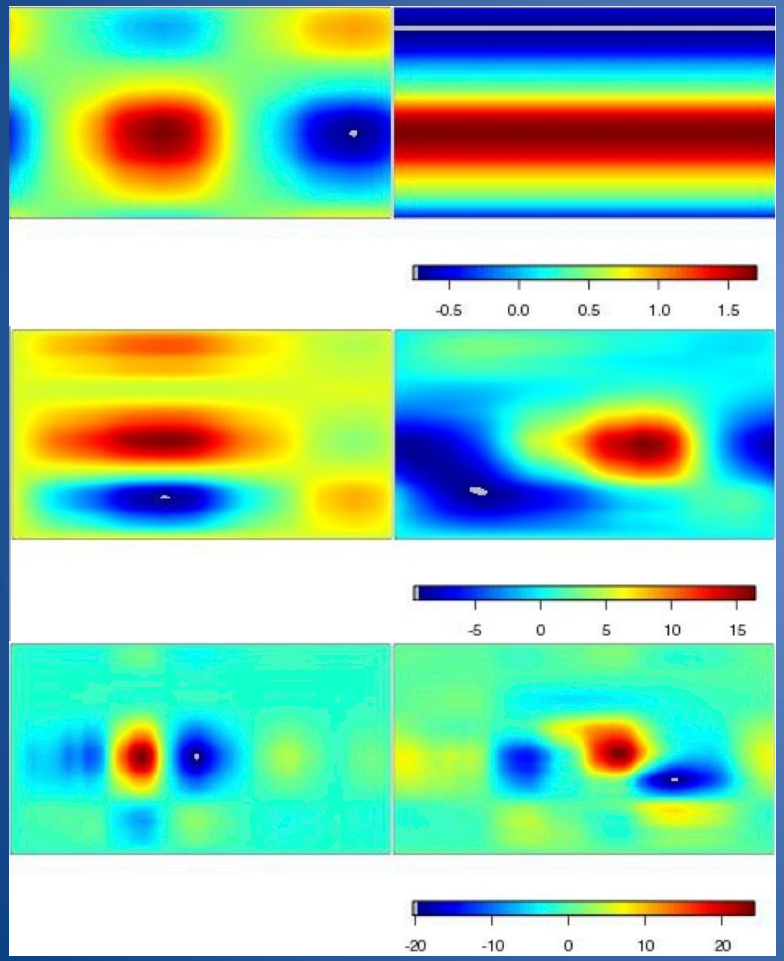
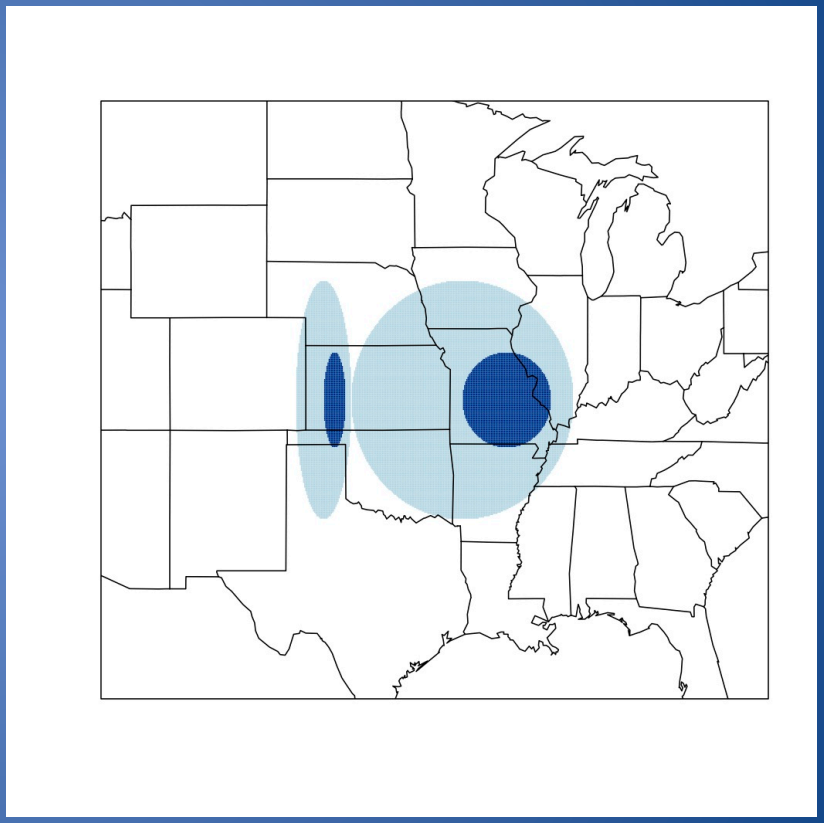
Filter Methods: Scale separation

Wavelets





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Displacement Methods: Binary Image Metrics

- Perfect score (zero) only when verification and forecast are identical: M(A,B)=0 only if A=B.
- Symmetry ensures that answer does not depend on order of comparison: M(A,B)=M(B,A)
- Triangle inequality ensures that results are not overly sensitive: M(A,B) much lower than M(A,C), then M(B,C) is appropriately large.

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Displacement Methods: Binary Image Metrics

Examples of some binary image measures and **metrics**

- **Hausdorff Metric**
- **Baddeley's Δ Metric**
- Pratt's Figure of Merit (FOM)
- **Forecast Quality Index (FQI, also incorporates intensity information)**
- Minimum separation distance

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Displacement Methods: Baddeley's Δ Metric

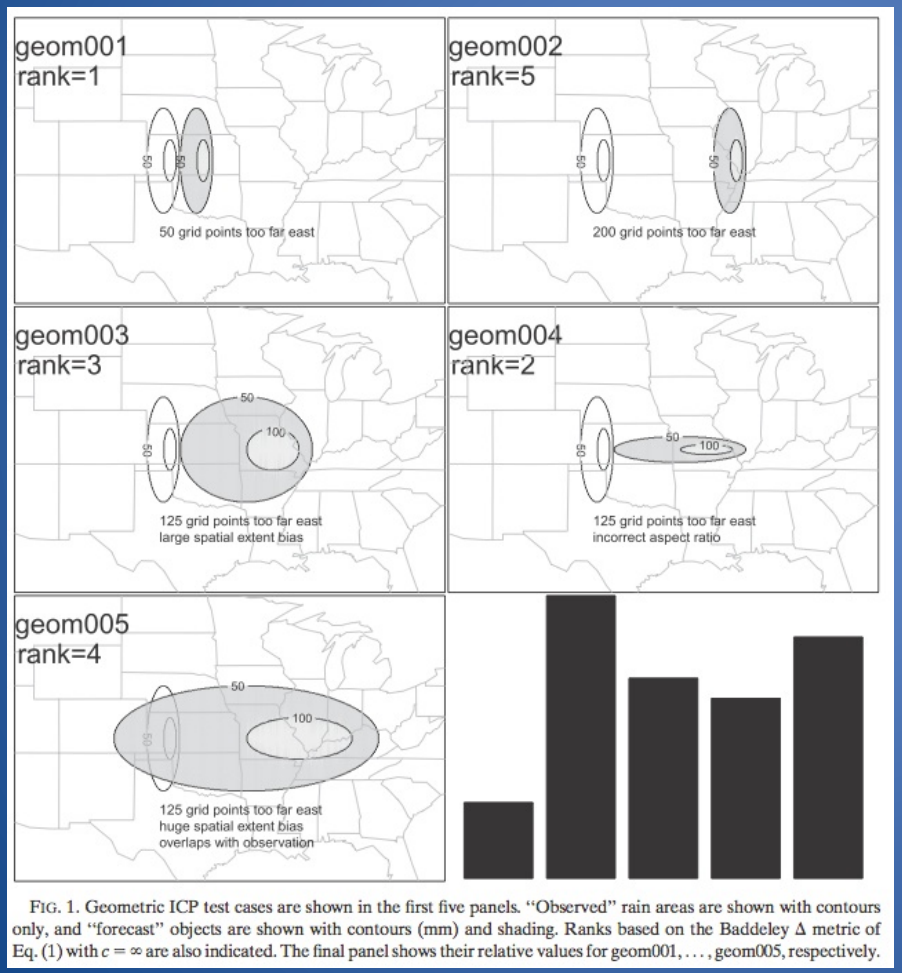

FIG. 1. Geometric ICP test cases are shown in the first five panels. "Observed" rain areas are shown with contours only, and "forecast" objects are shown with contours (mm) and shading. Ranks based on the Baddeley Δ metric of Eq. (1) with $c = \infty$ are also indicated. The final panel shows their relative values for geom001, . . . , geom005, respectively.

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From G. (2011, *WAF*, **26**, 409 - 415)

Geometric Indices

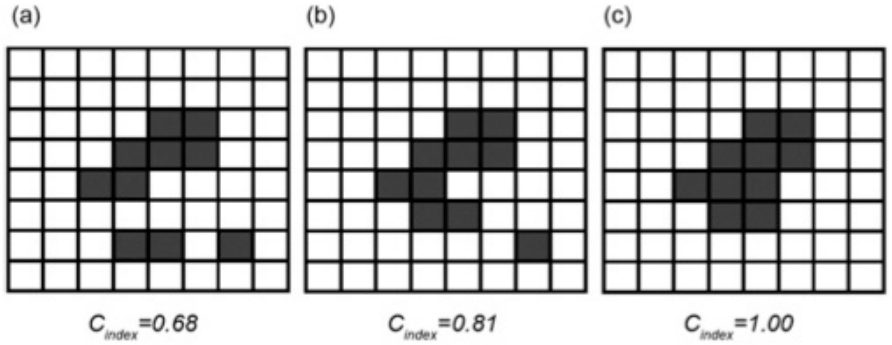

FIG. 3. The connectivity index (C_{index}) for three patterns.

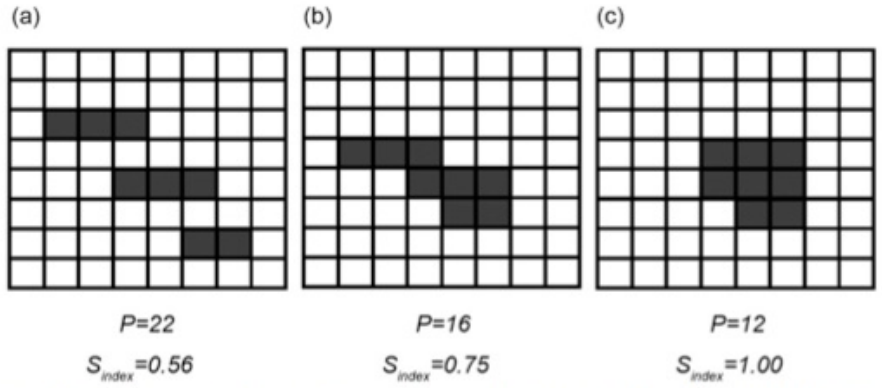

FIG. 7. The perimeter and S_{index} of 3 patterns that consist of 8 pixels with a P_{min} = 12: (a) P = 22, (b) P = 16, and (c) P = 12.

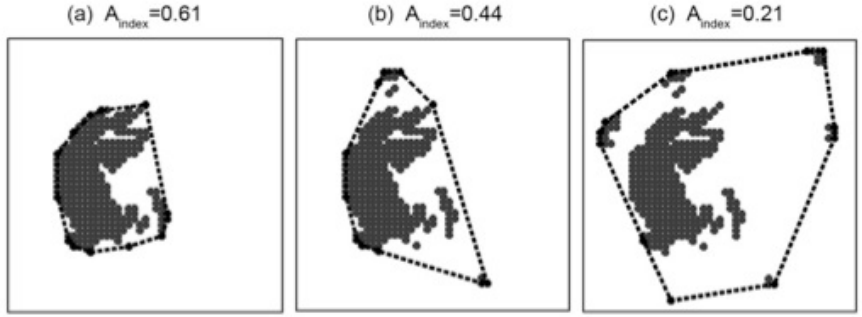

FIG. 9. The A_{index} for three example patterns: (a) A_{index} = 0.61, (b) A_{index} = 0.44, and (c) A_{index} = 0.21.

AghaKouchak *et al*. (2011, *J. Hyrdometeorology*, **12**, 274-285)

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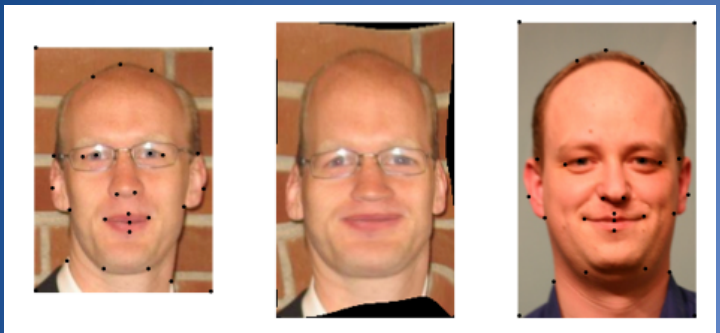
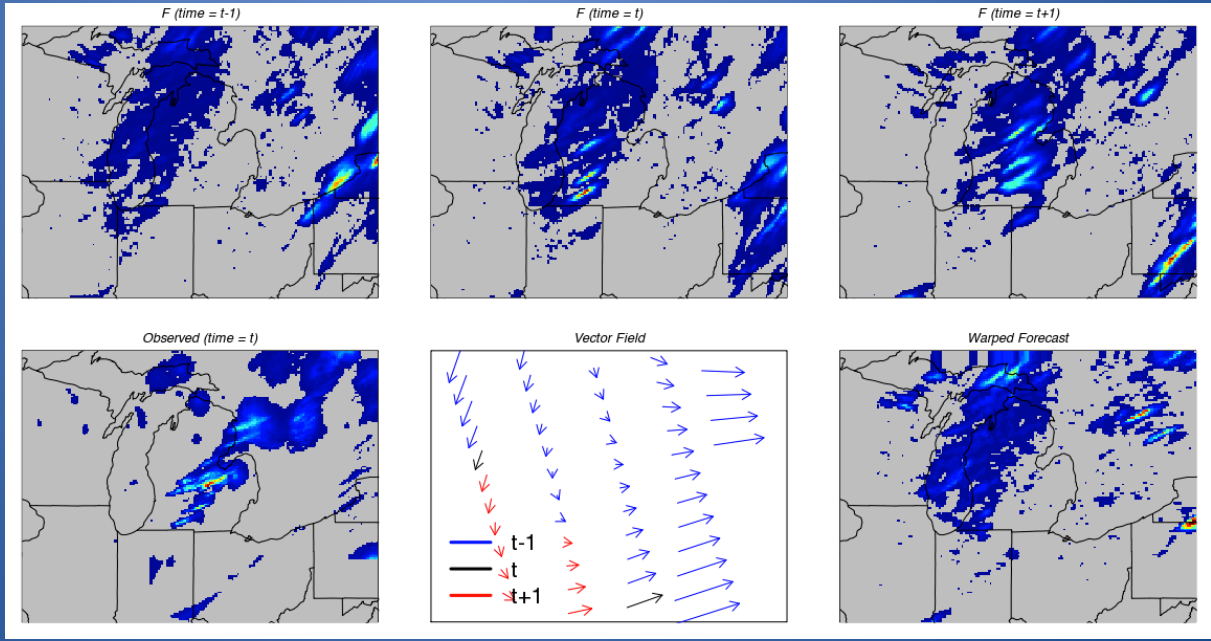
Displacement Methods: Field deformation



Reduction in RMSE is over 50% after applying the (space-time) warp.



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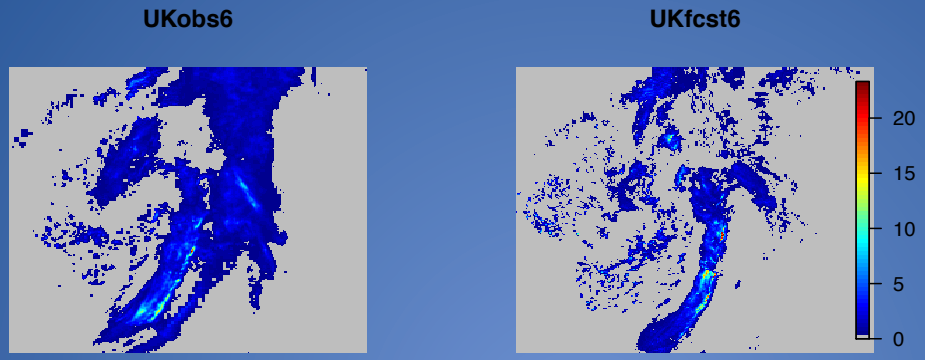
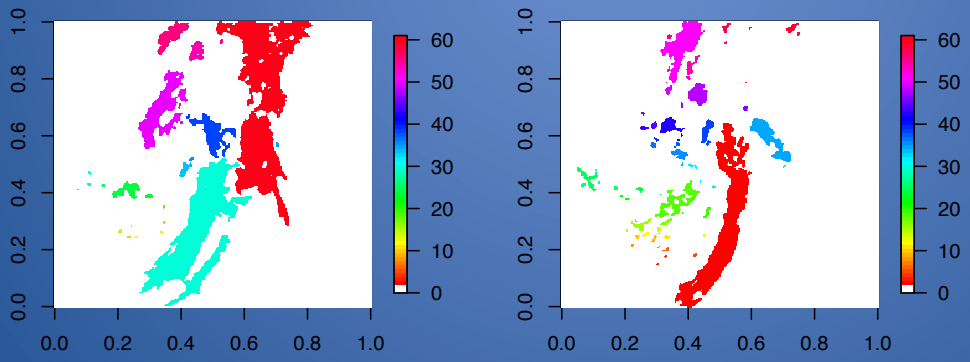
Displacement Methods: Feature-based





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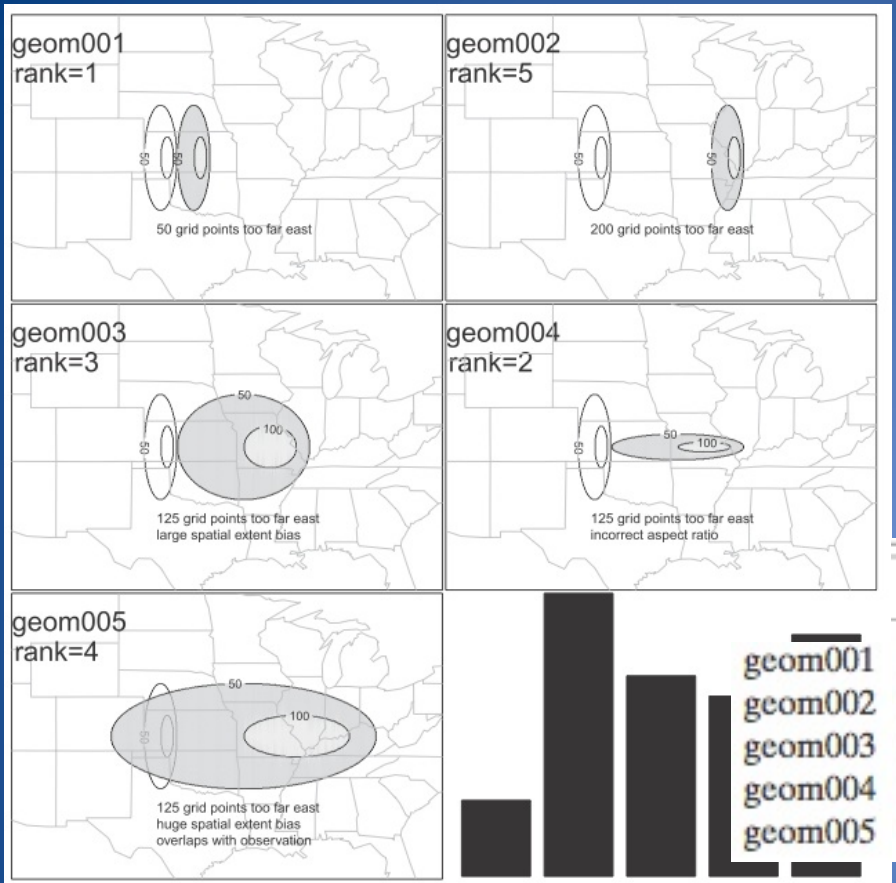

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Δ	Δ rank	DAS rank	MODE rank
44.98	1	1	1
167.34	5	2	5
118.52	3	5	3
106.5	2	4	4
142.86	4	3	2

From G. (2011, *WAF*, **26**, 409 - 415)

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Final Remarks

- R software package: `SpatialVx` (not yet ready for prime time)
- Spatial Forecast Verification Inter-Comparison Project (ICP)
  http://www.ral.ucar.edu/projects/icp
- ICP web page
  - List of references relevant to spatial forecast verification, as well as the ICP special collection in *WAF*.
    - See, e.g., review papers:
      - Ahijevych *et al*. (2009),
      - G. *et al*. (2010, 2010 *BAMS*),
      - Brown *et al*. (2012),
      - G. (2012): brief but more recent review.
  - ICP test cases available (geometric, perturbed and real)
  - Sign up to receive emails about the ICP
- ICP2 to begin soon, and to be called the Mesoscale Verification Intercomparison over Complex Terrain (MesoVICT) Project
  - New test cases
  - Includes: ensembles (forecast and observation), realistic meteorological cases over multiple time points, complex terrain, more variablesTech Note describing project plans:

Dorninger, M., M.P. Mittermaier, E. Gilleland (more) , 2013: MesoVICT: Mesoscale Verification Inter-Comparison over Complex Terrain. NCAR Technical Note NCAR/TN-505+STR, 23 pp, DOI: 10.5065/D6416V21.

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