Three Spatial Verification Techniques

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Abstract

Three spatial verification techniques are applied to two sets of reflectivity forecasts. One set is generated from performing a number of transformations (in space and intensity) to a given reflectivity field. The second set consists of 8 cases/days of 24hr reflectivity forecasts from wrf2caps, wrf4ncar, and wrf4ncep, all from Spring 2005. The main purpose of the study is to better understand various facets of the three verification methodologies.

Data 1: Fake_perturbed

Fake000 = Analysis from wrf2caps_2005053100.g240.f24.txt .

Fake001 = Shift 3→, −5 ↑   Fake002 = Shift 6→, −10 ↑

Fake003 = Shift 12→, −20 ↑   Fake004 = Shift 24→, −40 ↑

Fake005 = Shift 48→, −80 ↑

Fake006 = Fake003, ×1.5   Fake007 = Fake003, $-0.05\,in.$

Data 2: Sp2005 5/13, 5/14, 5/18, 5/19. 5/25, 6/1, 6/3, 6/4

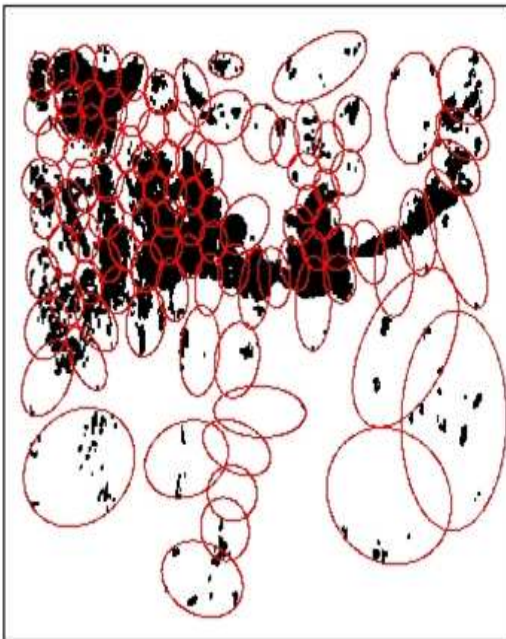## Methods: Cluster Analysis, Variogram, Optical Flow

Cluster Analysis

From statistics.

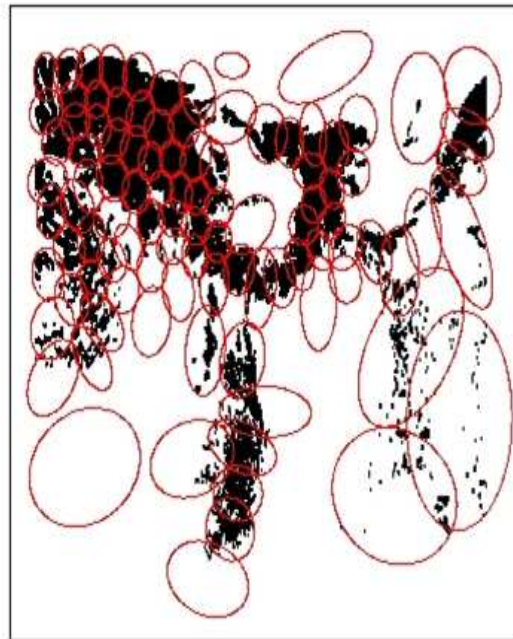Cluster the *joint* set of a forecast and observation field, in (x,y,z).
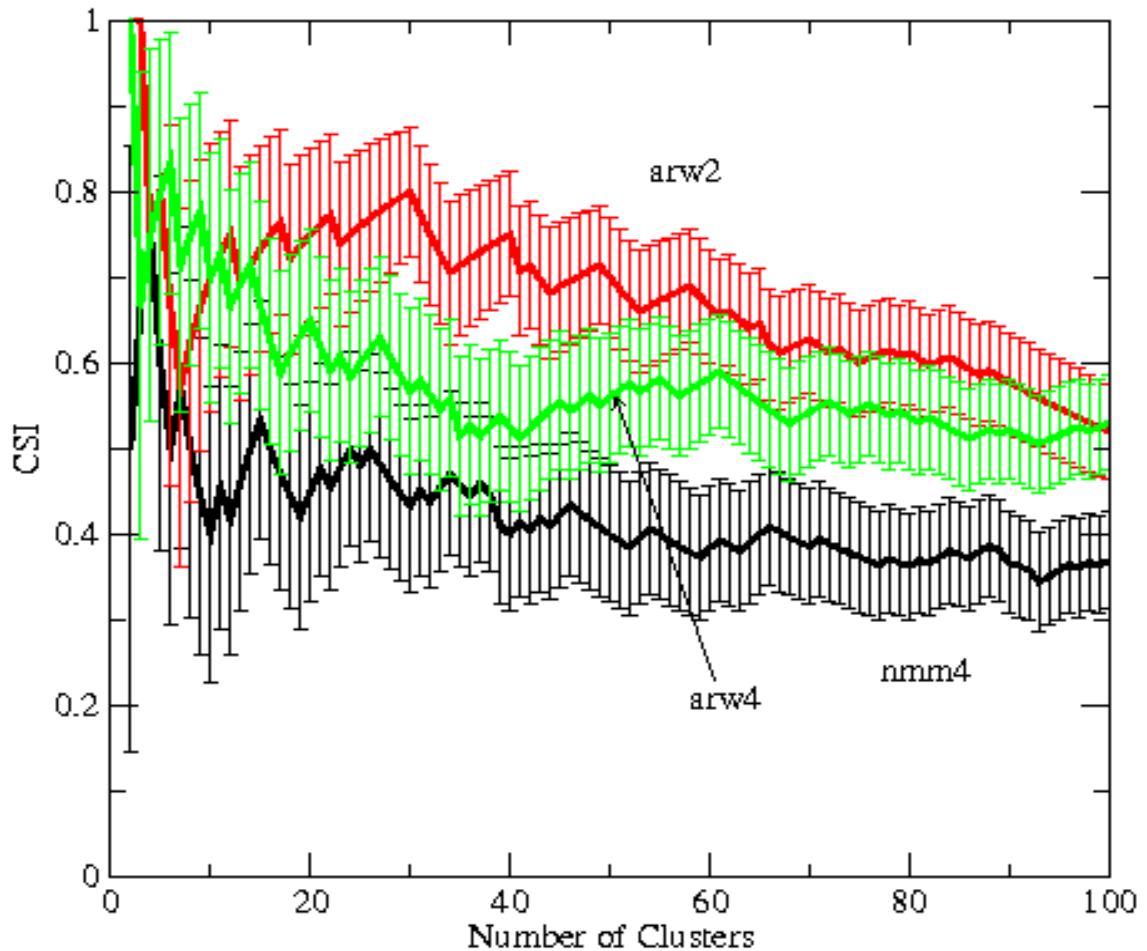
Cluster = object.

"Scale" = Number of clusters.

Obs 5/12, with kmeans ellipses

ARW2 5/11 with kmeans ellipses

Main "output":

E.g., On 5/11 arw2 (wrf2caps) is better across all scales.

- Marzban, C., S. Sandgathe, and H. Lyons 2008: An Object-oriented Verification of Three NWP Model Formulations via Cluster Analysis: An objective and a subjective analysis. Conditionally accepted at Monthly Weather Review.

- Marzban, C., S. Sandgathe, 2007: Cluster Analysis for Object-Oriented Verification of Fields: A Variation. Accepted by Monthly Weather Review.

- Marzban, C., S. Sandgathe 2006: Cluster analysis for verification of precipitation fields. Wea. Forecasting, Vol. 21, No. 5, 824-838.

Variogram

From spatial statistics.
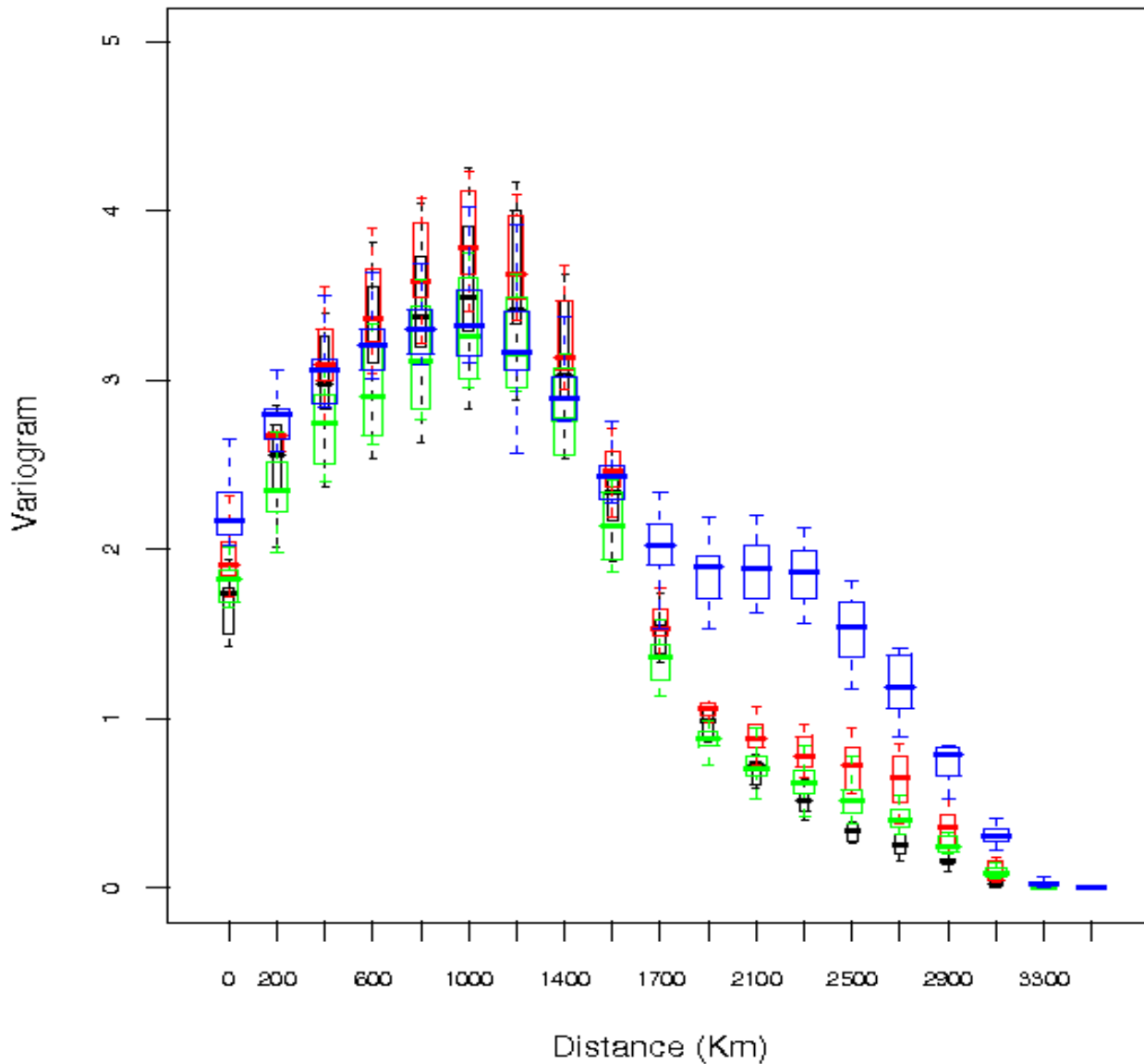
Measures texture.

Scale = Distance between points.

$$\gamma(\text{Distance}) = \frac{1}{2N} \sum_{\{i,j\}_{Distance}}^{N} (\mathbf{x_i} - \mathbf{x_j})^2 \, ,$$
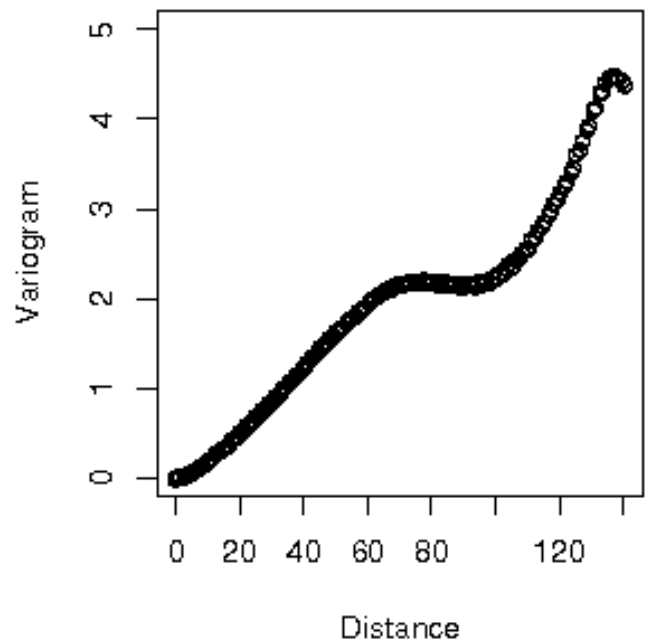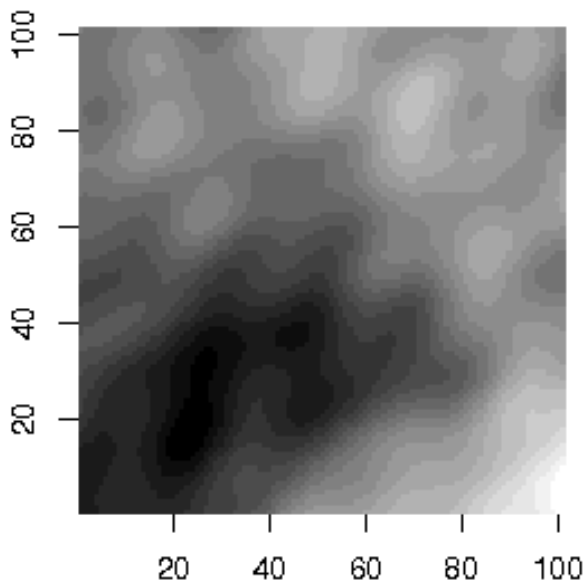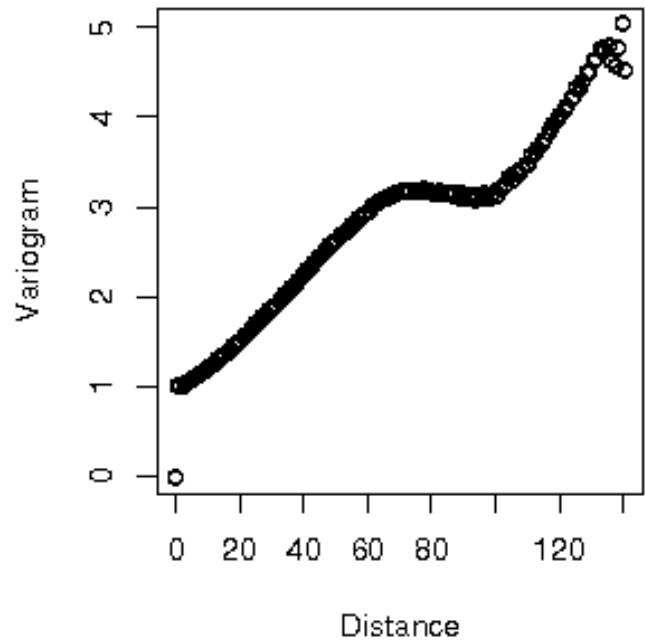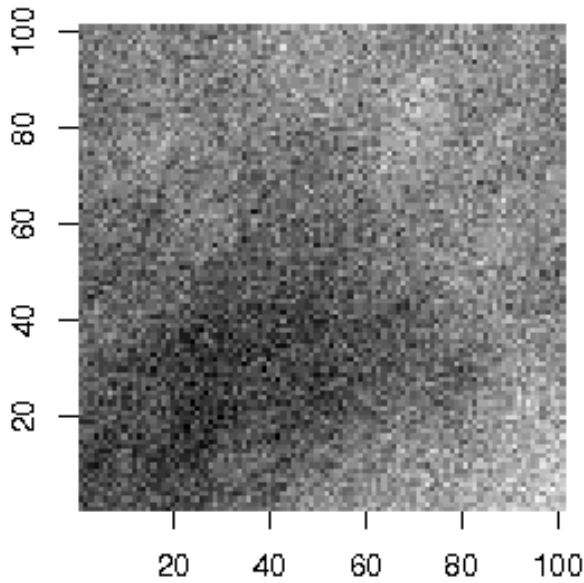
The effect of an object and boundary on variogram:
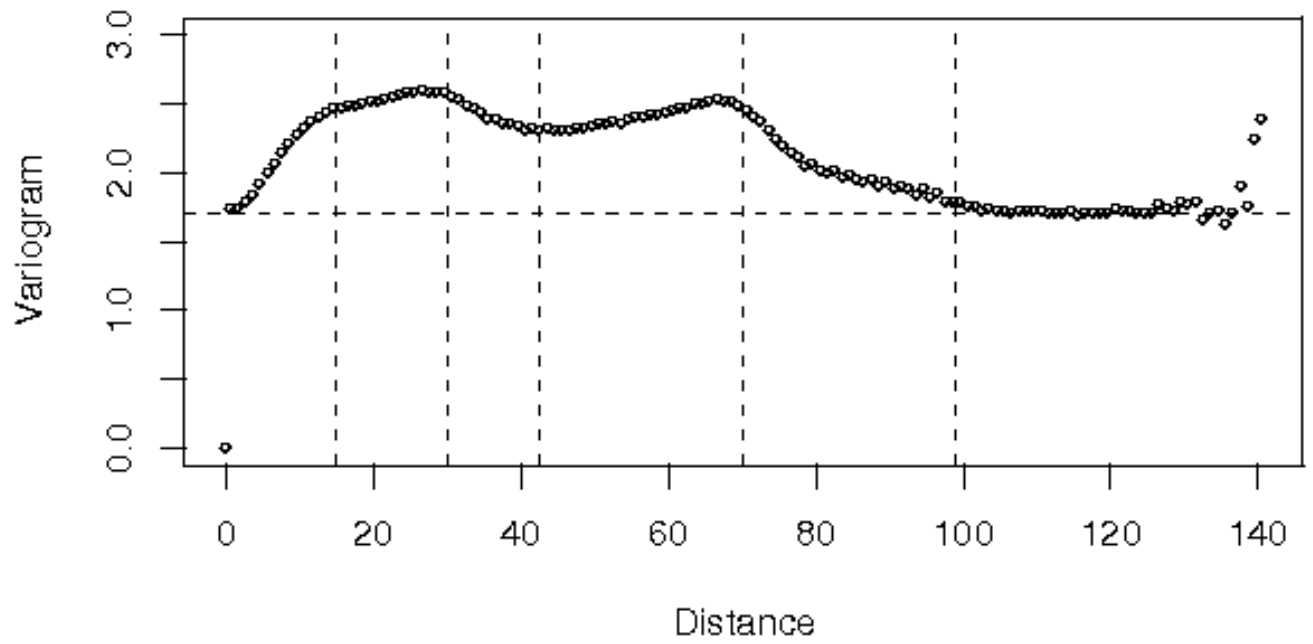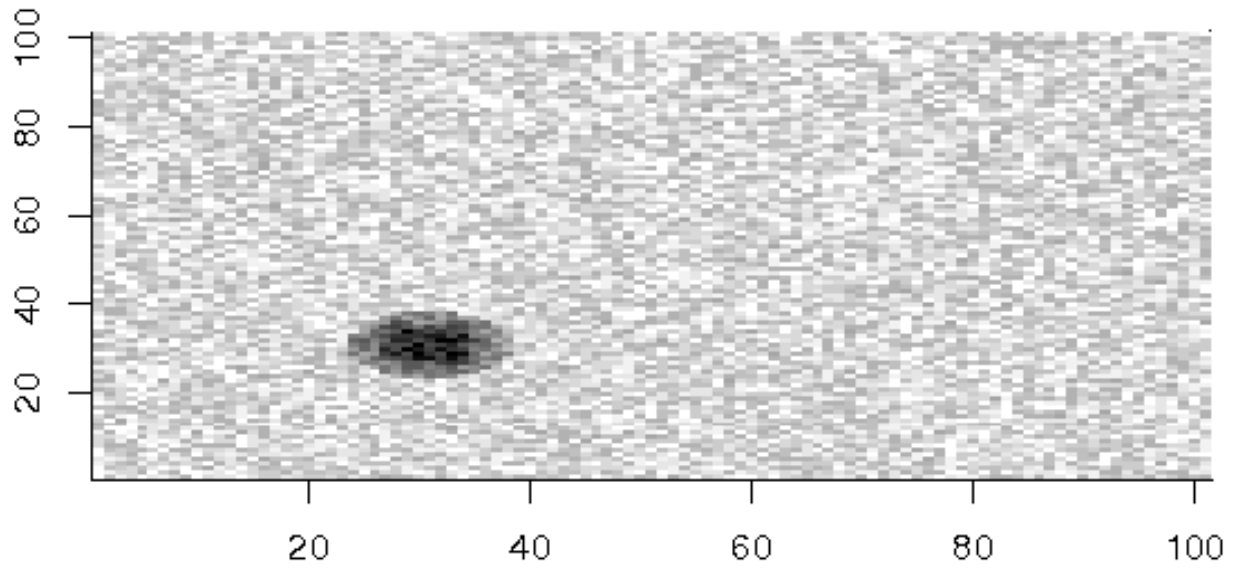
Main "output":

5/13/2005: observed, wrf2caps, wrf4ncar, wrf4ncep

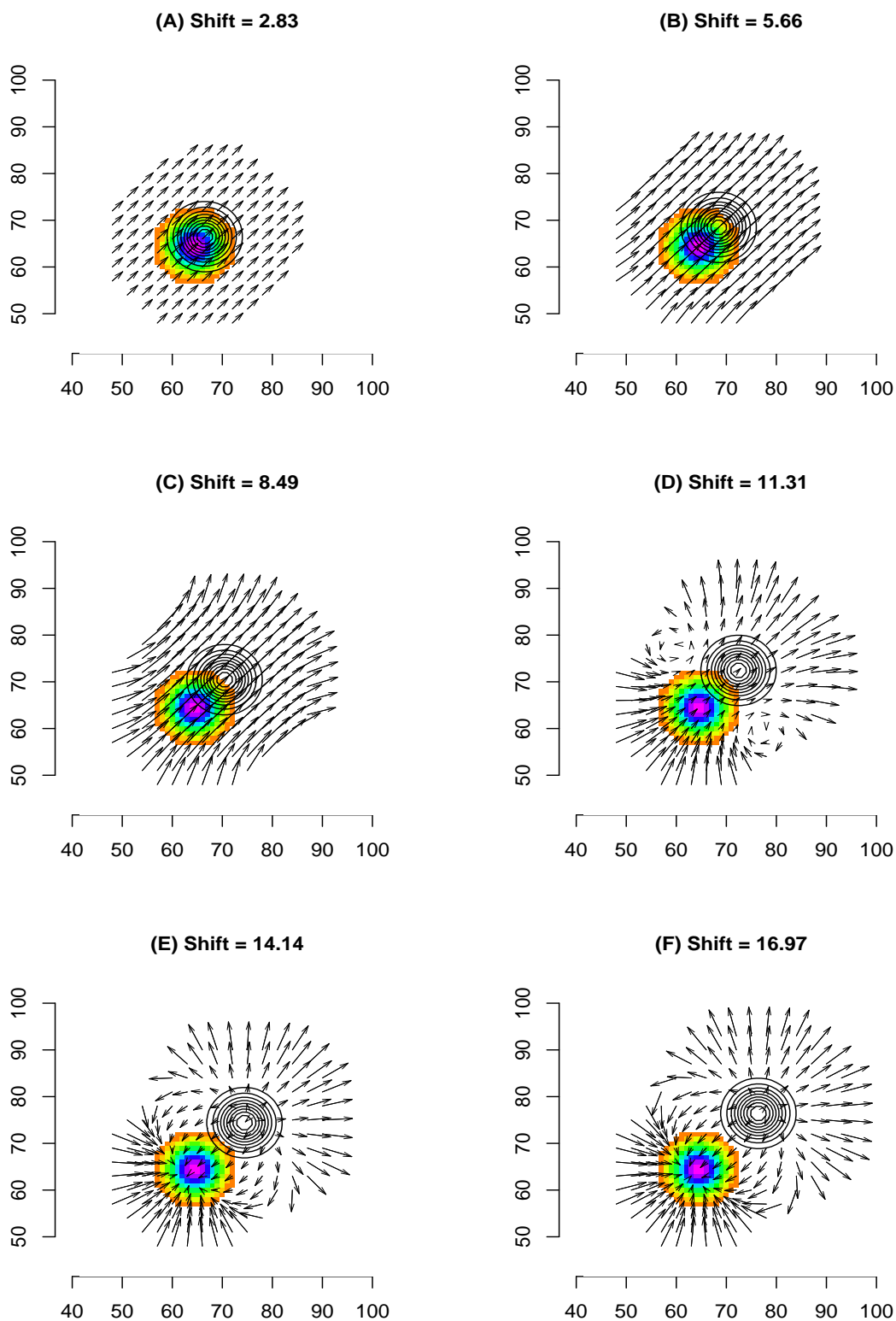E.g., On 5/13 wrf4ncep is worse, on larger scales.

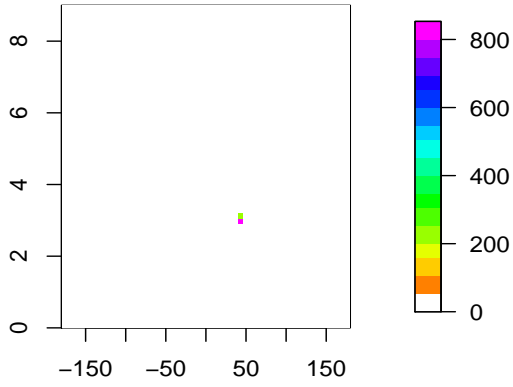- Marzban, C. and S. Sandgathe 2008: Verification with variograms. Conditionally accepted by Wea.

Forecasting.

Optical Flow

From machine vision/ motion estimation.

Math: 2 images $\rightarrow$ vector field mapping one to the other.

Scale = size of window = W.

(A) Shift = 2.83

(B) Shift = 5.66

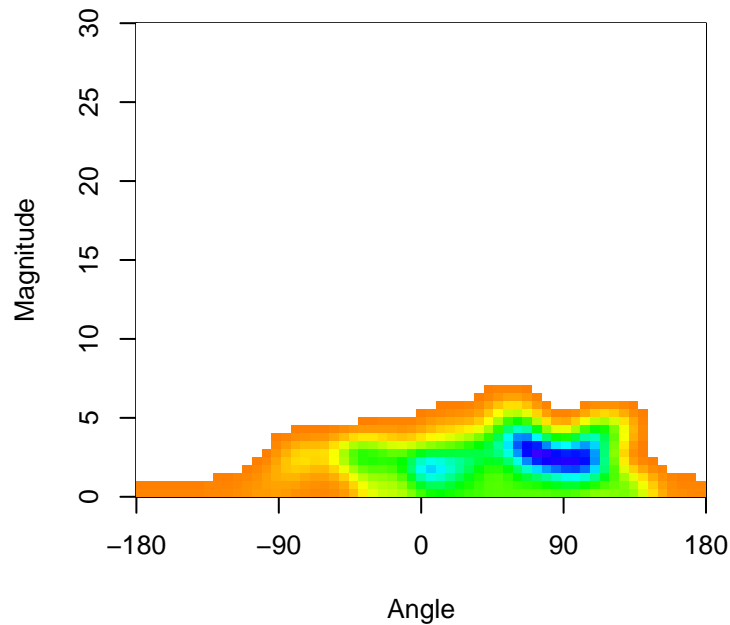**(C) Shift = 8.49**

(D) Shift = 11.31

(E) Shift = 14.14

(F) Shift = 16.97

(A) Shift = 2.83

(B) Shift = 5.66
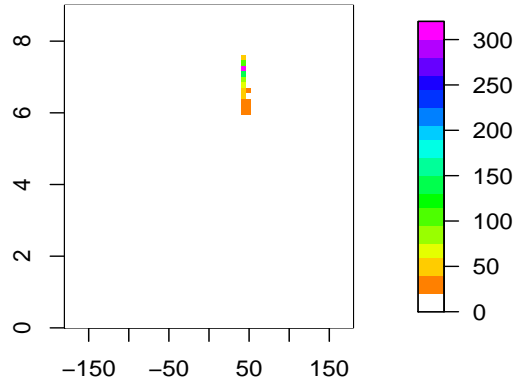
(C) Shift = 8.49
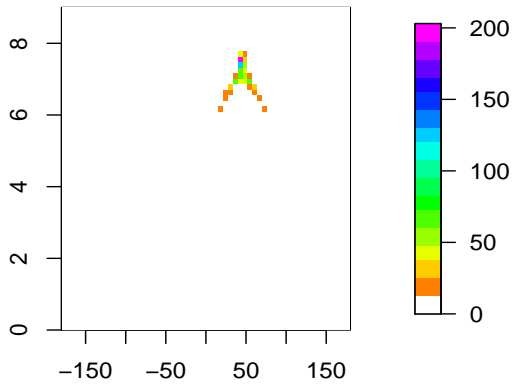
(D) Shift = 11.31
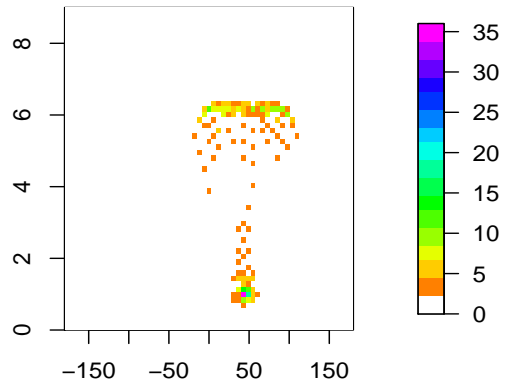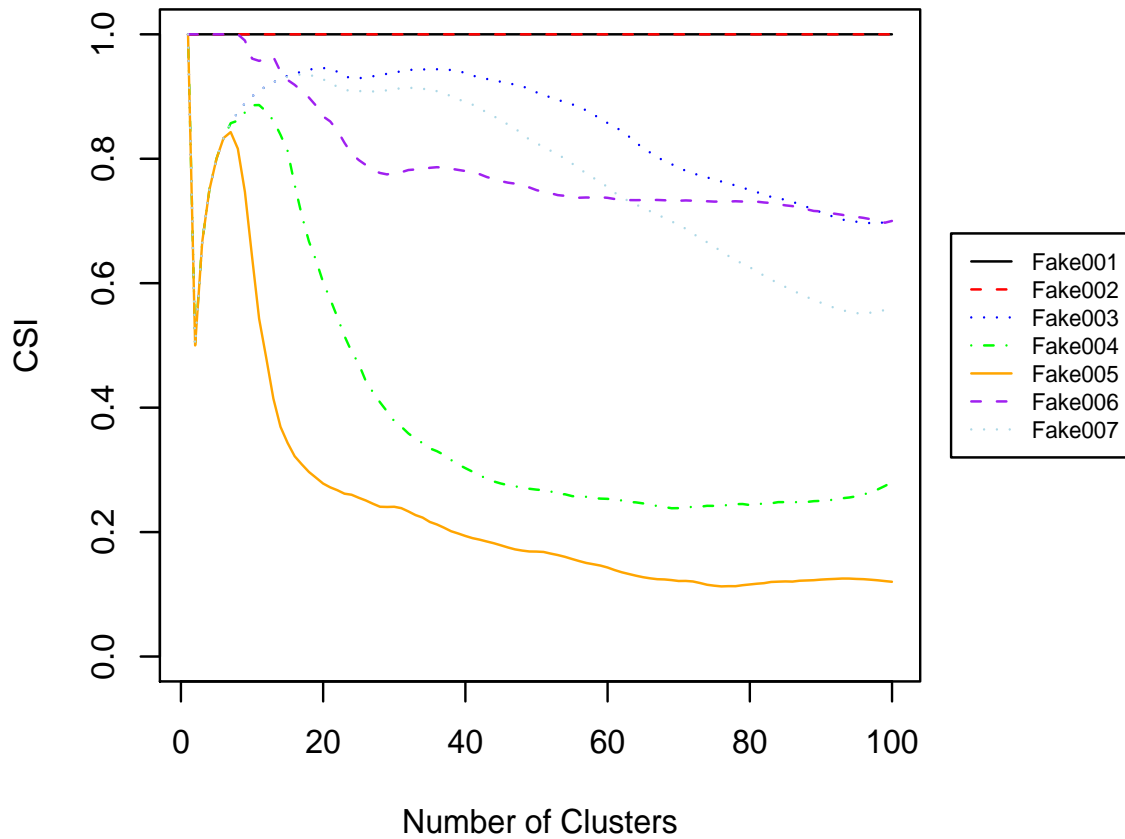
(E) Shift = 14.14
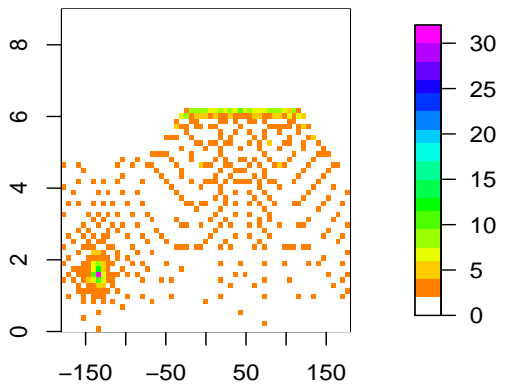
(F) Shift = 16.97

Main "output":

W=60
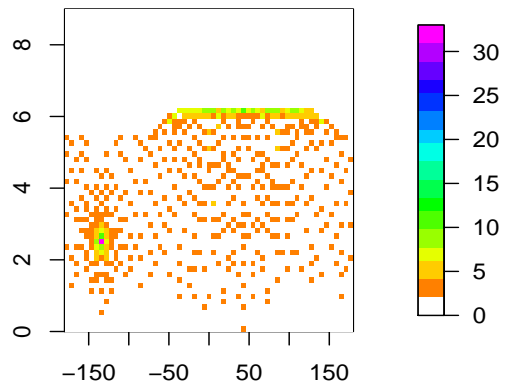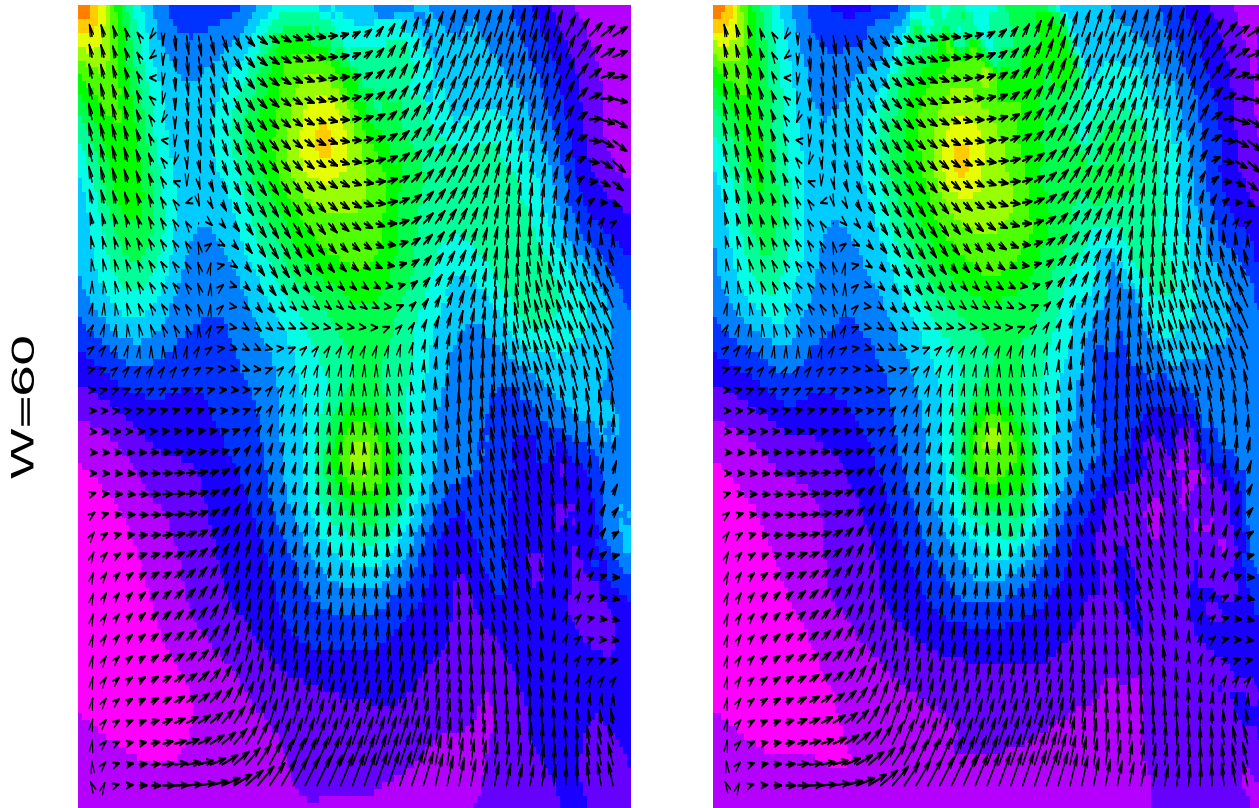
(2) W = 60

E.g., There is a preponderance of vectors in the north direction (direction

error), about 3-4 grid points in length (displacement error).

- Marzban, C., D. Lennon, and S. Sandgathe 2008: Optical Flow for verification. Submitted to Weather

Cluster Analysis for Fake Perturbed

- CSI falls (bad) with larger shifts; more so on larger scales (left) than on smaller scales (right).

- Similarly, for additive error in intensity.

- For multiplicative error in intensity, CSI falls but differently.

Variogram for Fake Perturbed
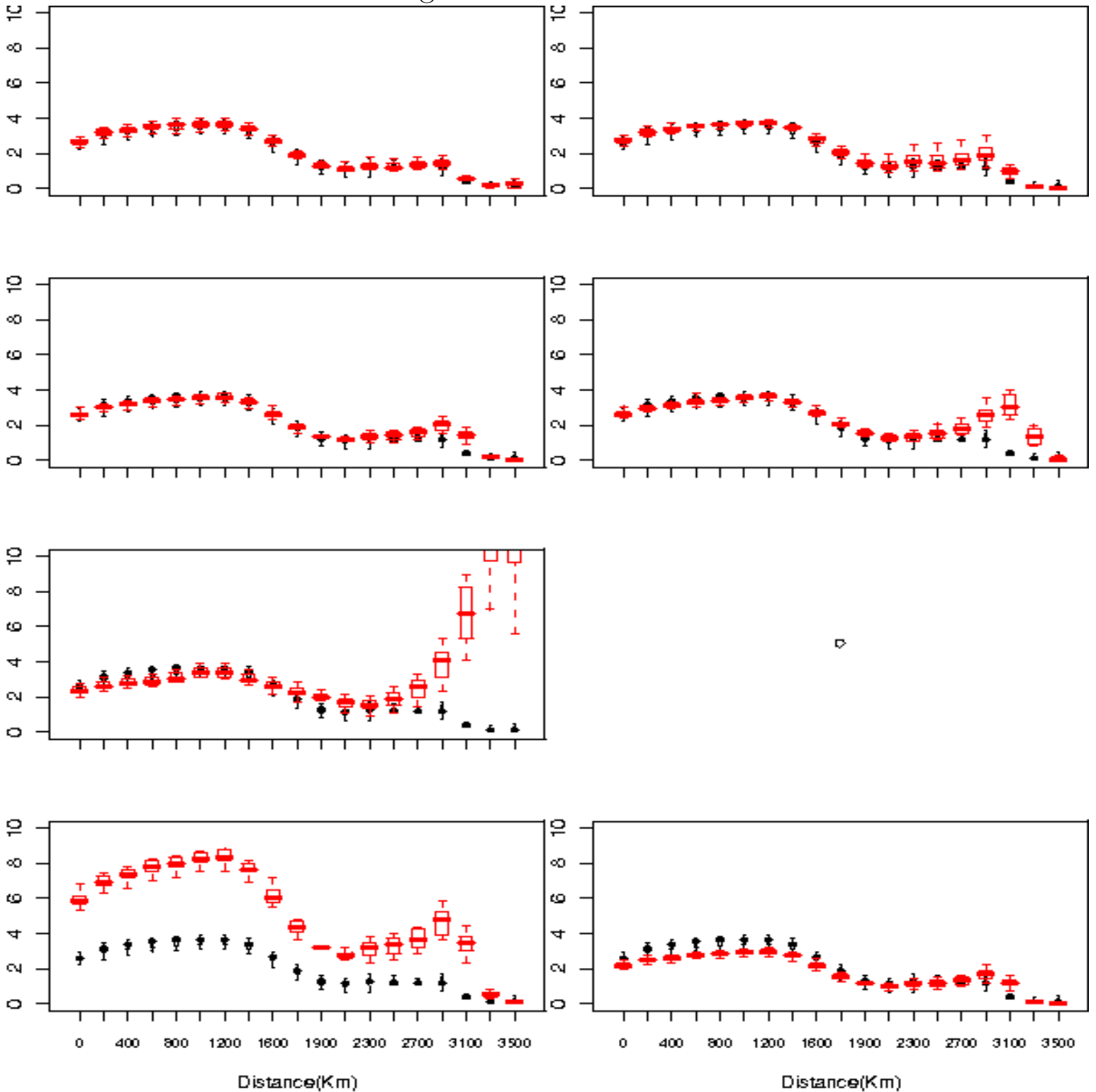
- Variogram is unaffacted by shifts (except on large scales - edge effect)

- It increases (bad) with multiplicative error in intensity.

- Mostly unaffected by additive error in intensity.

Optical Flow for Fake Perturbed

$(3 \rightarrow, 5 \downarrow \quad \Rightarrow \quad \theta = -59° , \text{magnitude} = 5.8)$
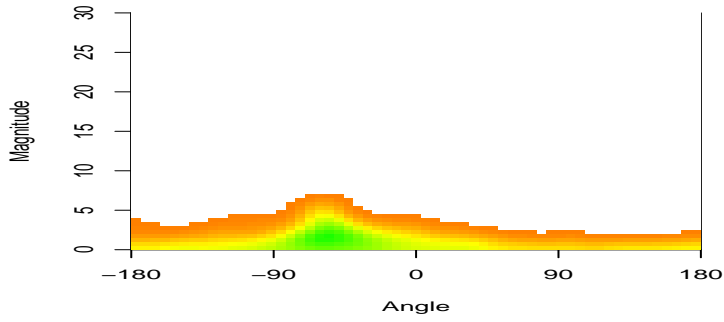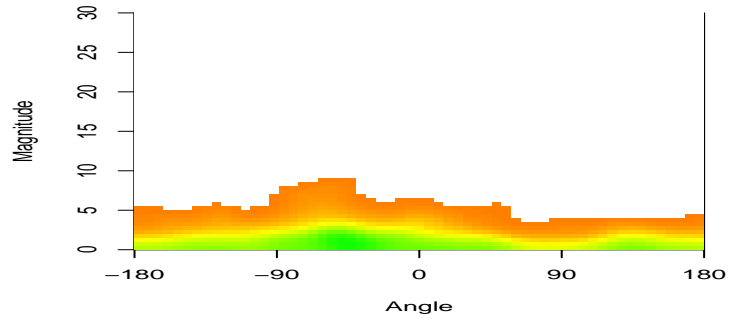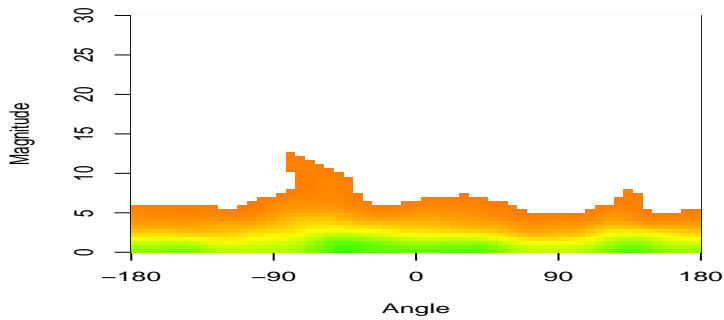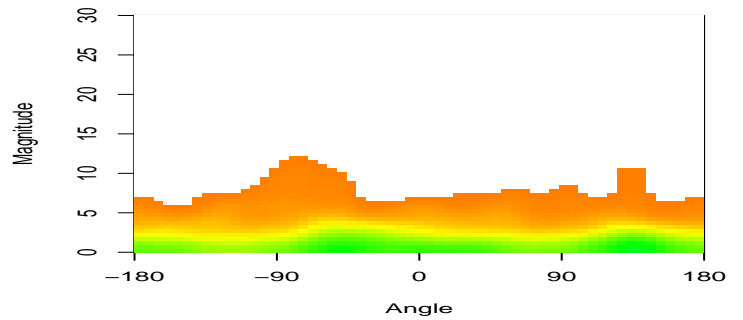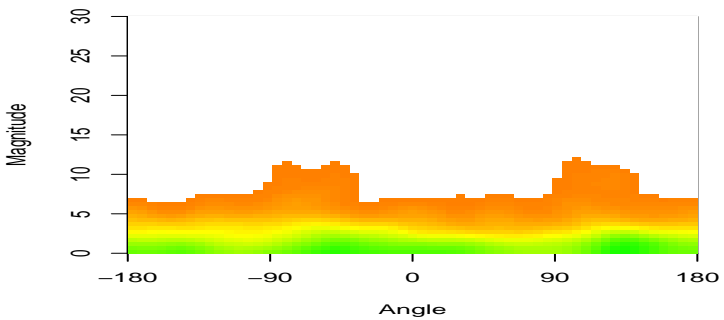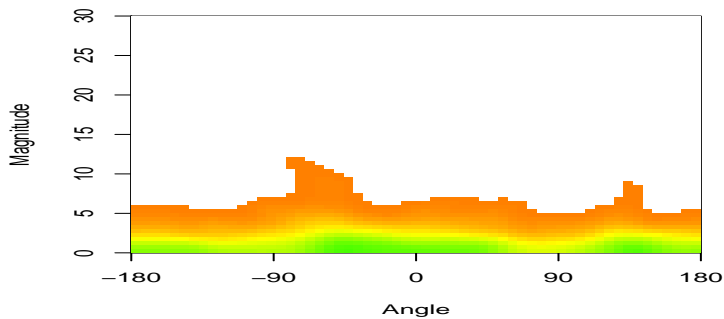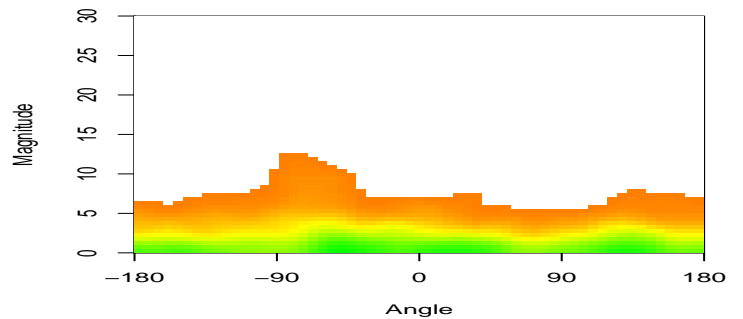
- There is a preponderance of vectors in the south-south-east direction.

- Magnitude of OF vectors is unaffected by multiplicative error in intensity.

- but increases (bad) with additive error.

Shift (and Intensity error) versus Scale
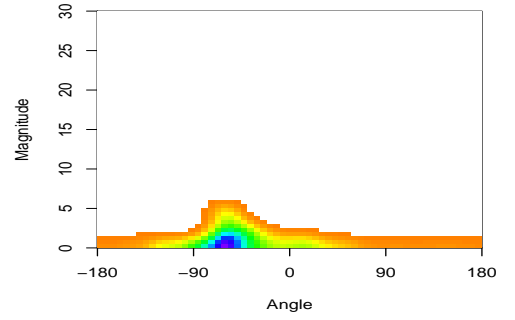
Small Scale	Medium Scale	Large Scale

(1) W = 20
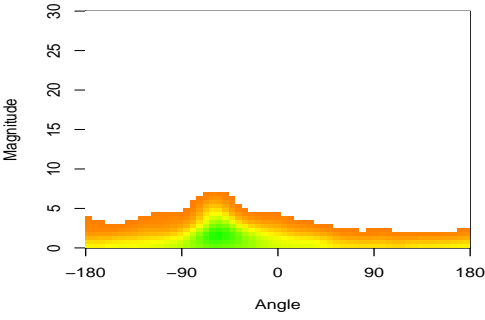
(1) W = 40
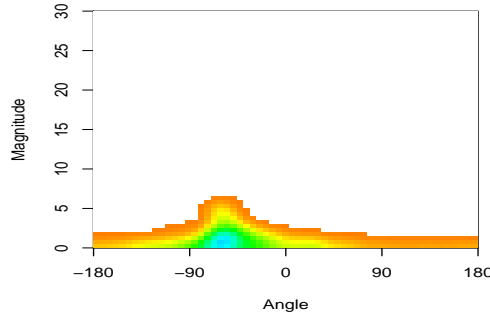
(1) W = 60

(2) W = 20
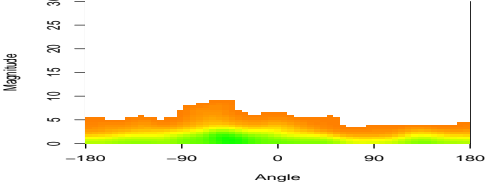
(2) W = 40
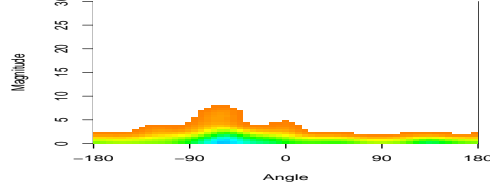
(2) W = 60
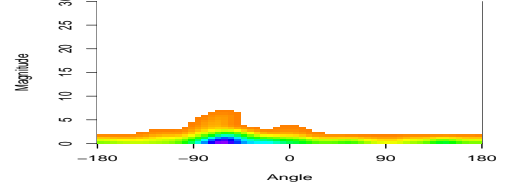
(3) W = 20
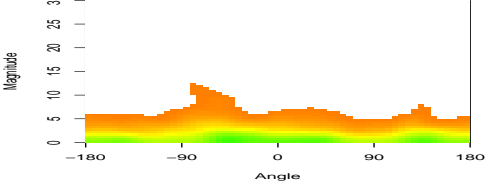
(3) W = 40
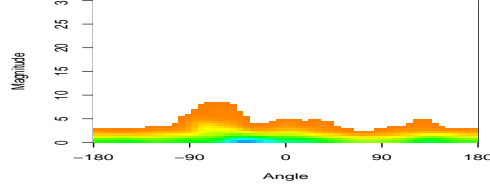
(3) W = 60
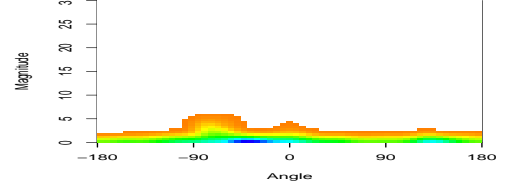
(4) W = 20
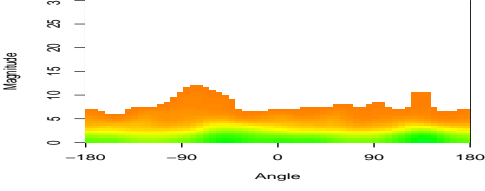
(4) W = 40
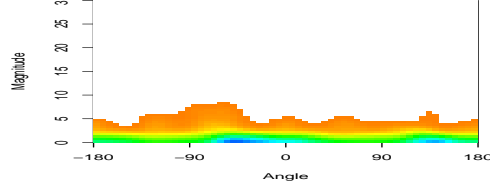
(4) W = 60
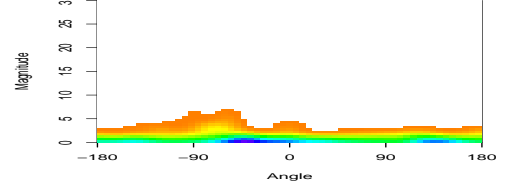
(5) W = 20
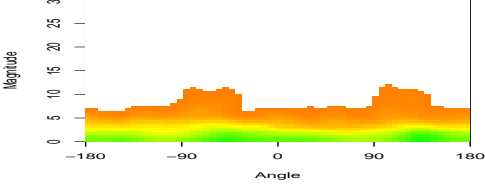
(5) W = 40
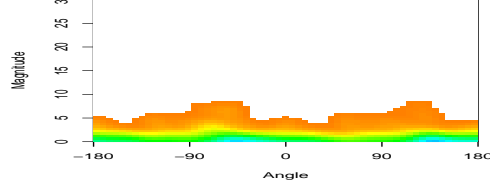
(5) W = 60
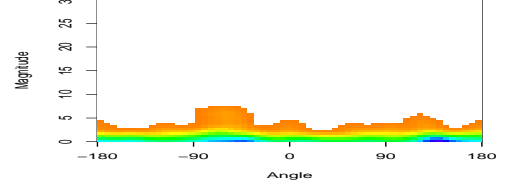
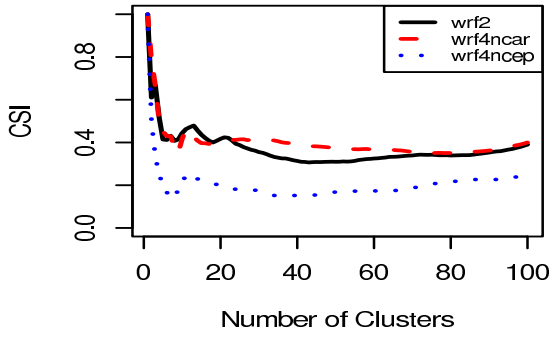**(6) W = 20**
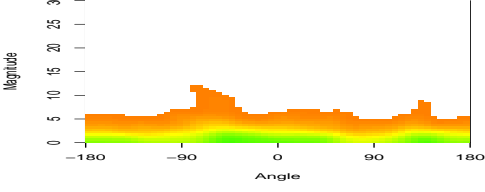
(6) W = 40
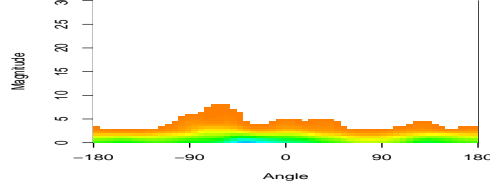
(6) W = 60
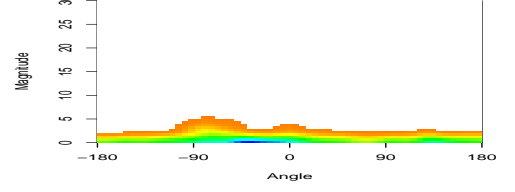
(7) W = 20
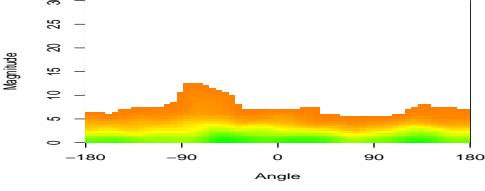
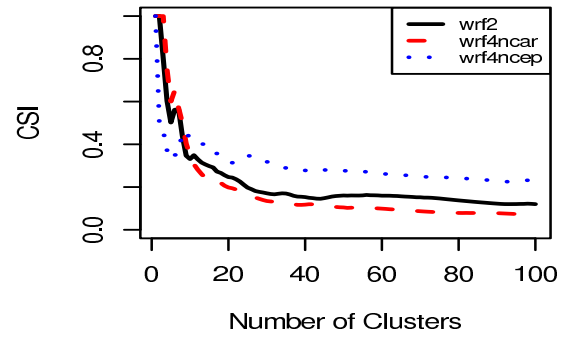**(7) W = 40**
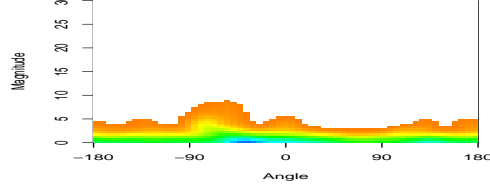
(7) W = 60
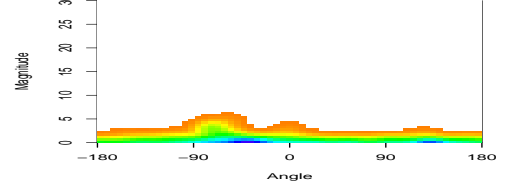
Cluster Analysis for sp2005

Obs 20050513
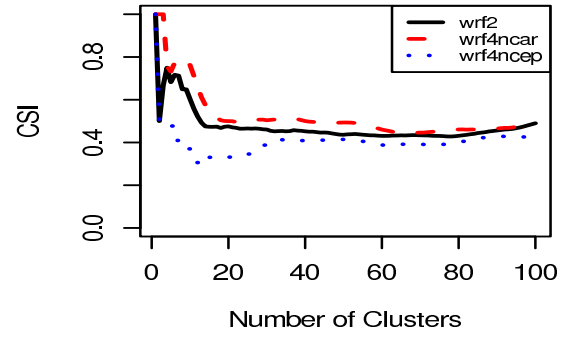
CSI / Number of Clusters

Legend: wrf2, wrf4ncar, wrf4ncep

Obs 20050514

CSI / Number of Clusters

Legend: wrf2, wrf4ncar, wrf4ncep

Obs 20050518

CSI / Number of Clusters

Legend: wrf2, wrf4ncar, wrf4ncep

Obs 20050519

CSI / Number of Clusters

Legend: wrf2, wrf4ncar, wrf4ncep

Obs 20050525

CSI / Number of Clusters

Legend: wrf2, wrf4ncar, wrf4ncep

Obs 20050601

CSI / Number of Clusters

Legend: wrf2, wrf4ncar, wrf4ncep

Obs 20050603

CSI / Number of Clusters

Legend: wrf2, wrf4ncar, wrf4ncep

Obs 20050604

CSI / Number of Clusters
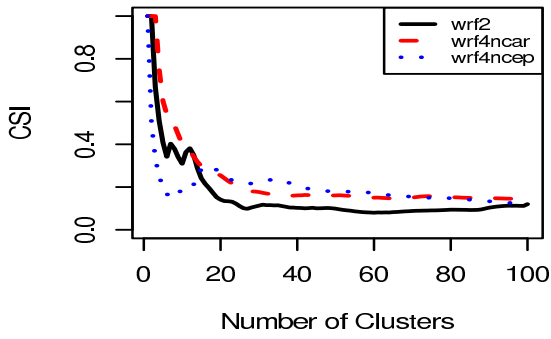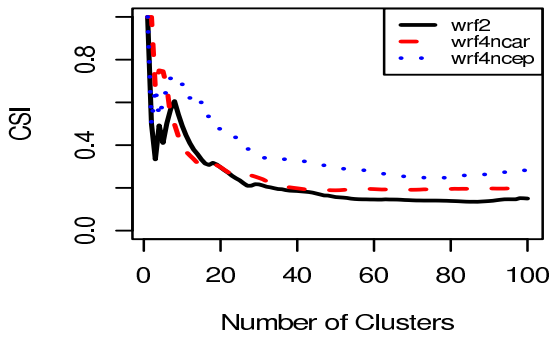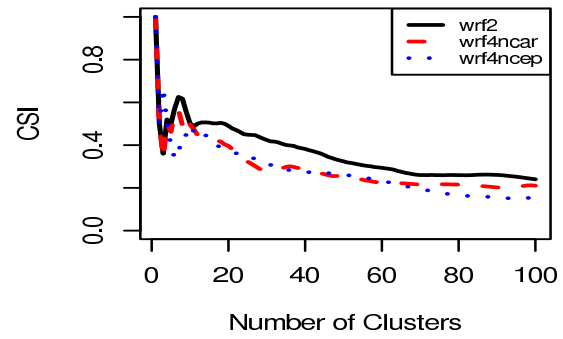
Legend: wrf2, wrf4ncar, wrf4ncep

Variogram for sp2005

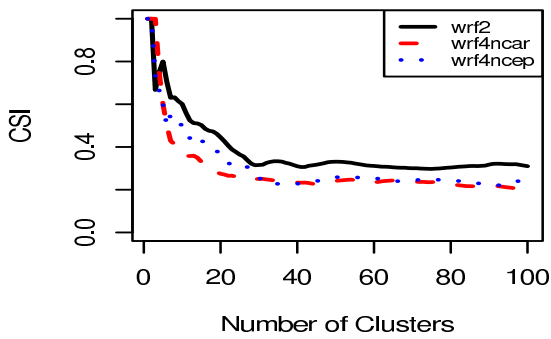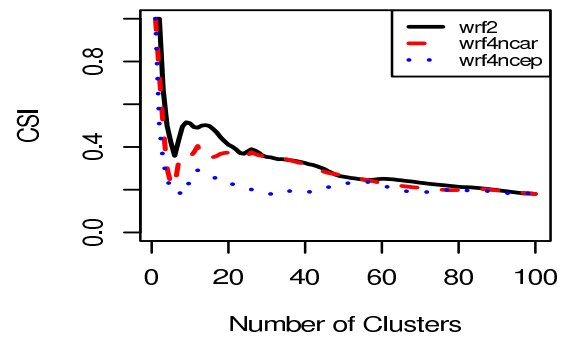observed, wrf2caps, wrf4ncar, wrf4ncep

Optical Flow for sp2005
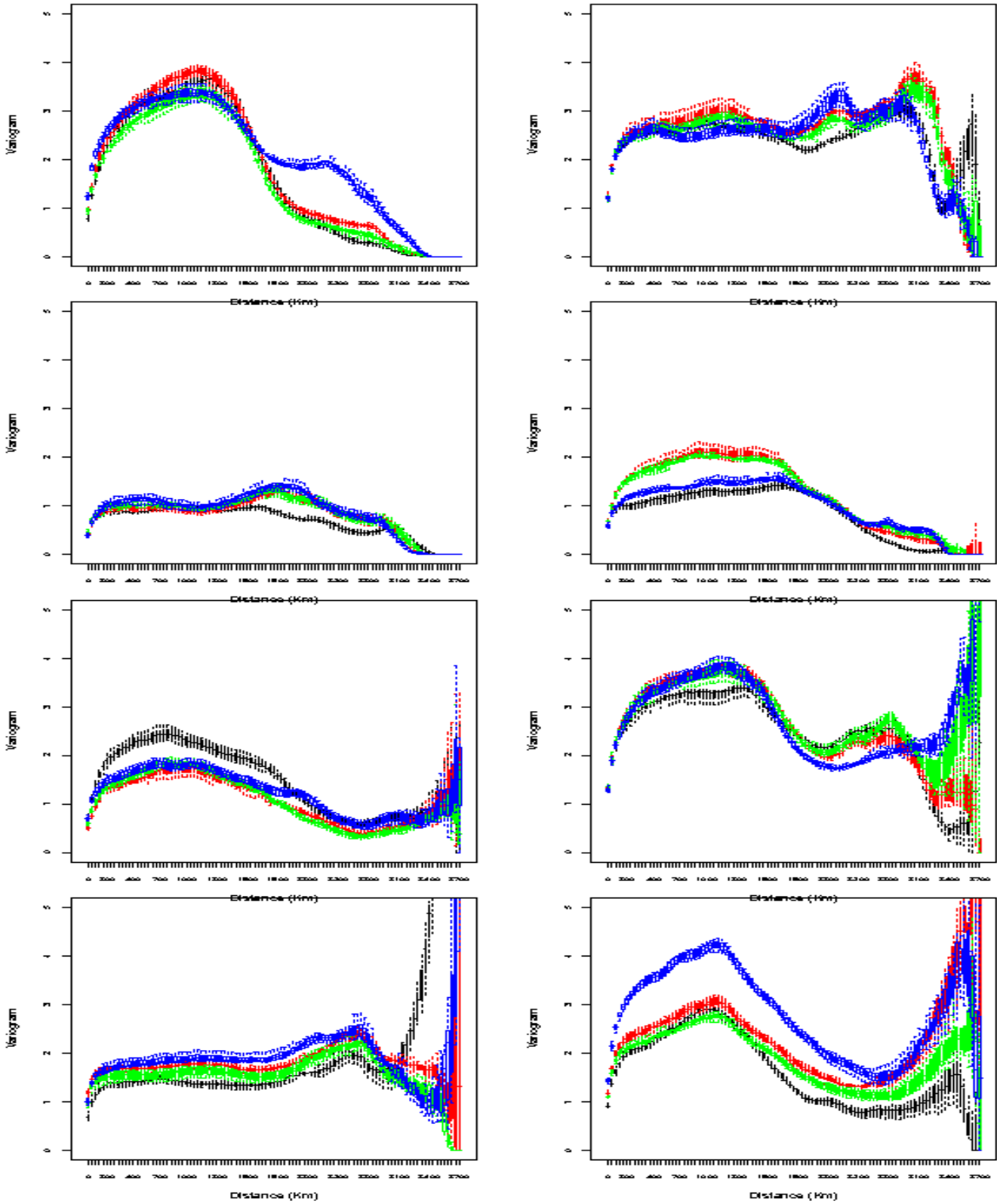
Conclusion

Based on Fake_perturbed data:

- Cluster Analysis properly captures displacement and intensity errors on different spatial scales.

- Variogram measures mostly multiplicative error in intensity.

- Optical flow measures mostly displacement error, for now.

Based on sp2005 data:

- Too complex to summarize.

- But, all is good!