Verification via Optical Flow

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History

- 2006: IED detection, via change-point detection.
- 2006: I asked V. Lakshmanan "What's hot in image-processing?"
- 2006: Lak said "Optical Flow".
- 2006: I did some simulation - looked like verification.
- 2006: Specifically, similar to Scott's approach.
- 2007: Here we are.

- Applications: robotics, image enhancement, moving-target indication, passive navigation, nowcasting (Bowler, Pierce, Seed), surveillance, ..., and here: verification.

- History: Psychologist J.J. Gibson noted that apparent movement of visual field caused by a pilot's movement is used directly as a cue by the pilot to estimate his own velocity.

The proposal/goal

Employ optical flow to compute the motion in the flow

$$\text{Forecast} \rightarrow \text{Observation/Analysis}$$

The output:
- A 2d vector field
- it's summary measures.

Plan

- The Math behind optical flow.

- Illustration on synthetic data.

- Illustration on reflectivity data.

The Math

$$I(x + dx \ , \ y + dy, \ t + dt)$$
$$= I(x, y, t) + \frac{\partial I}{\partial x}dx + \frac{\partial I}{\partial y}dy + \frac{\partial I}{\partial t}dt + ...$$

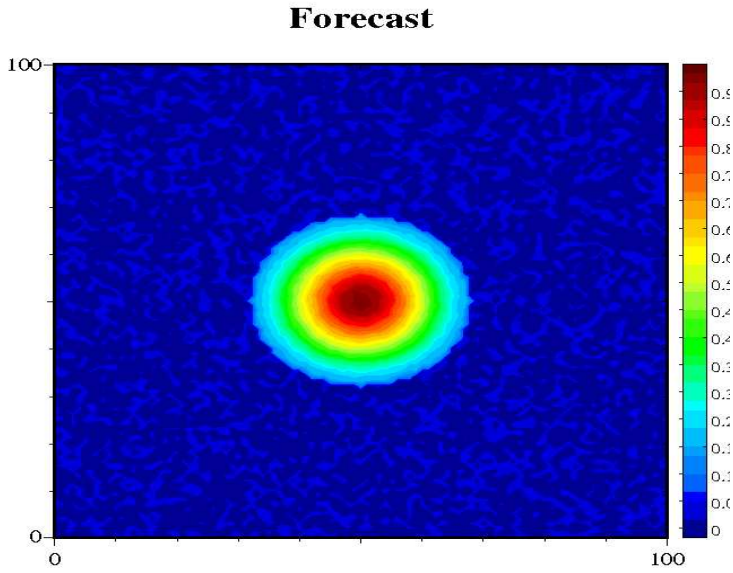
Suppose
$(x, y) \rightarrow (x + dx, y + dy), dt$ later.
$I(x + dx, y + dy, t + dt) = I(x, y, t)$

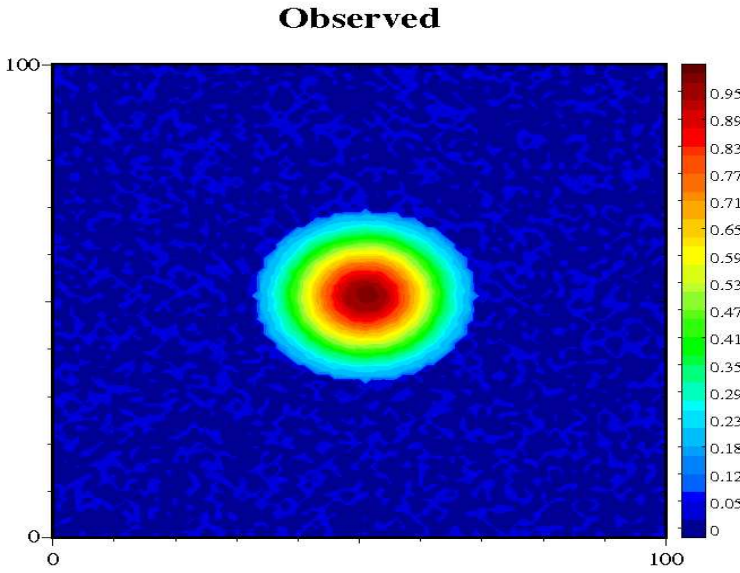
Then $\quad \frac{\partial I}{\partial x}\, u + \frac{\partial I}{\partial y}\, v = -\frac{\partial I}{\partial t}$

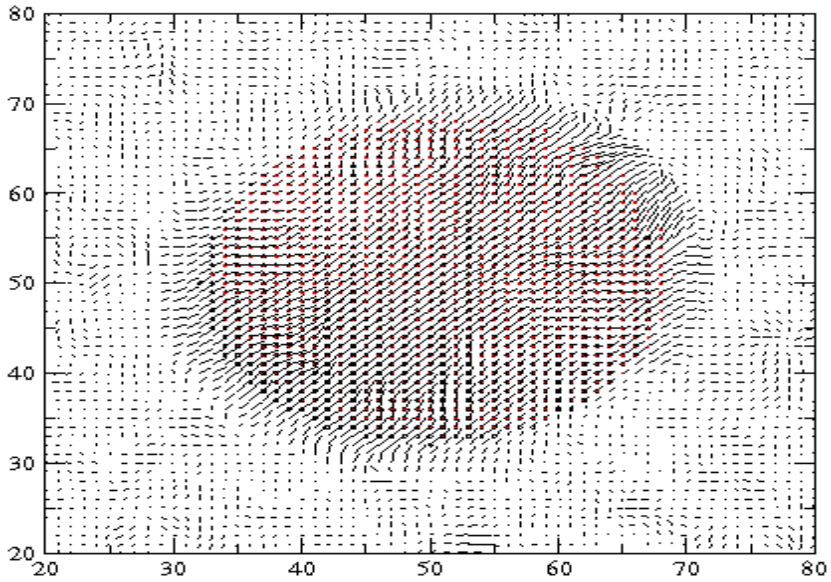
where $\quad u = \frac{\partial x}{\partial t} \qquad v = \frac{\partial y}{\partial t}$

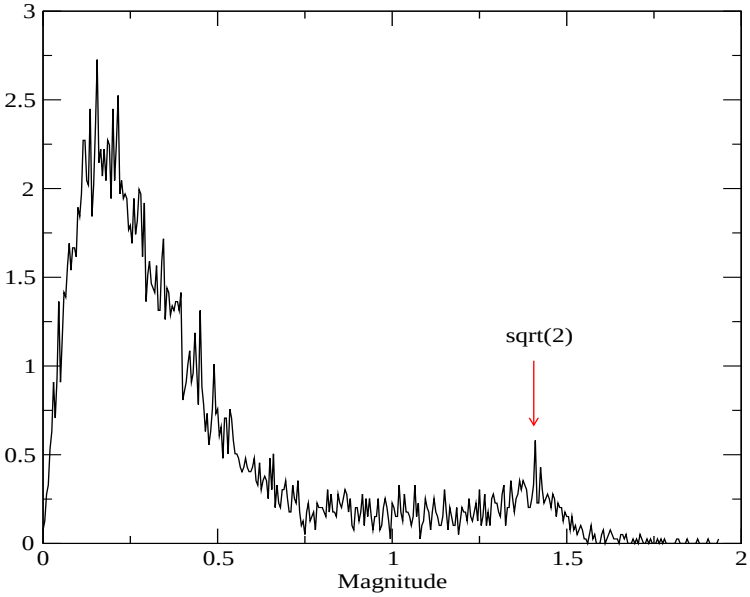
(u, v) = optical flow vector field = unknown.

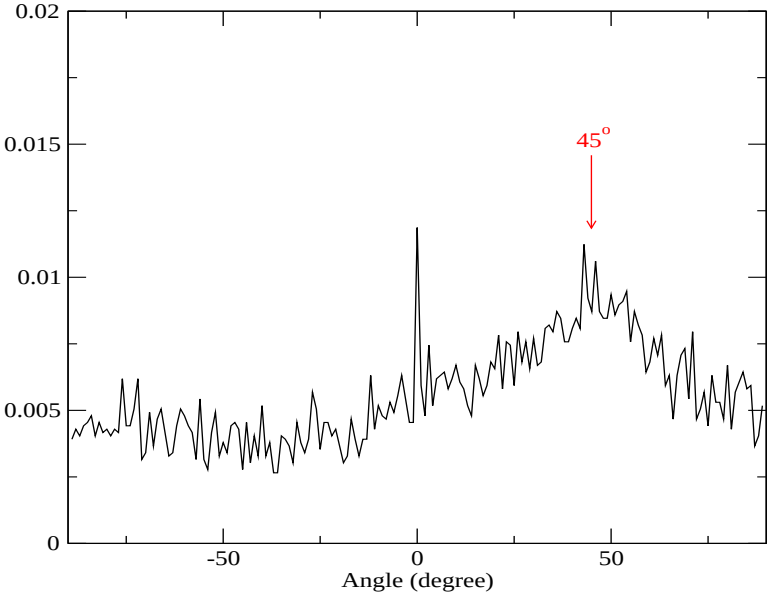
- An image pair $\rightarrow$ derivatives.
- 1 eqn, 2 parameters
- Least sq.: n eqns, 2 params (n=#pixels in window)
- A window pair $\rightarrow$ 1 vector
- An image pair $\rightarrow$ vector field


Forecast
100
0
0
100

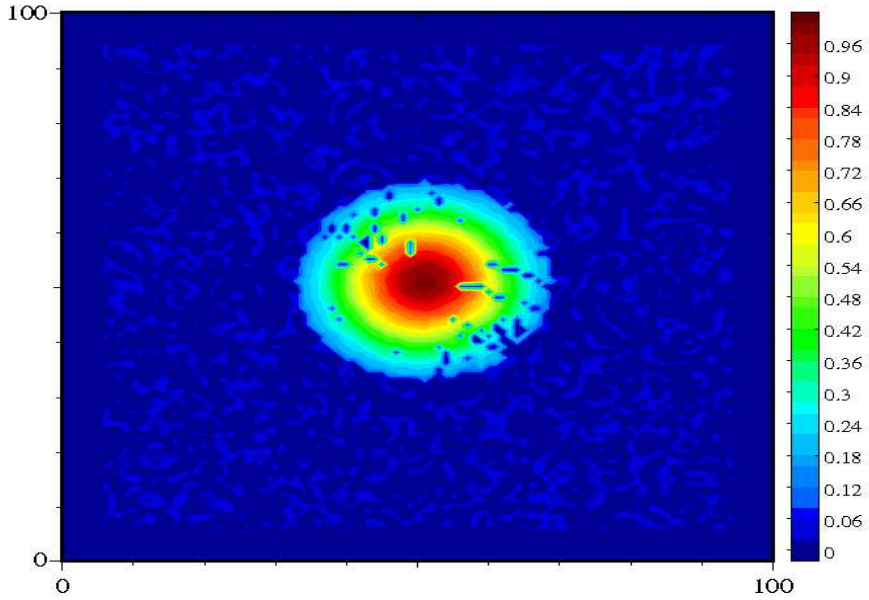

Observed
100
0
0
100


80
70
60
50
40
30
20
20
30
40
50
60
70
80

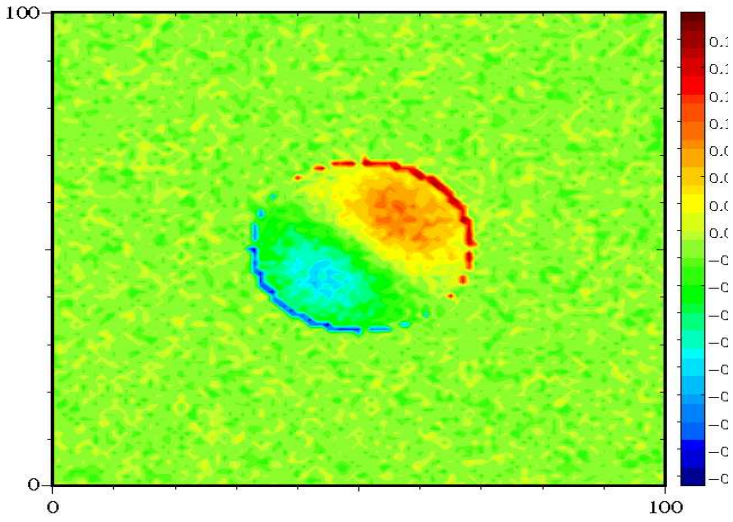

3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
sqrt(2)
Magnitude


0.02
0.015
0.01
0.005
0
-50
0
50
45°
Angle (degree)

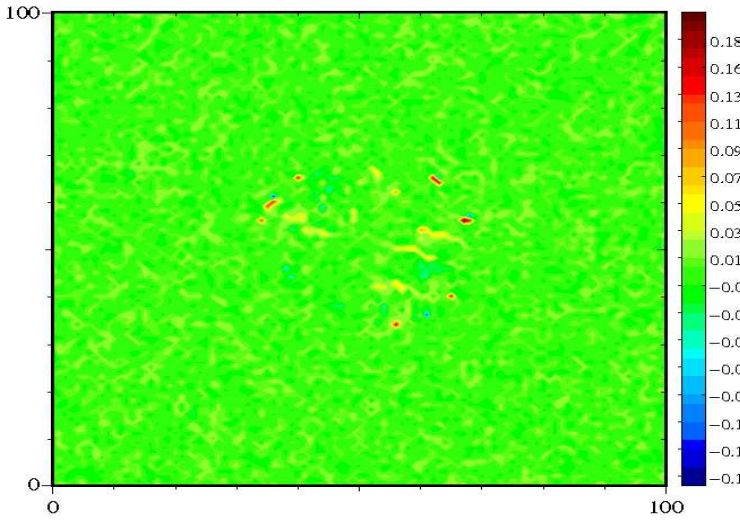
Prediction

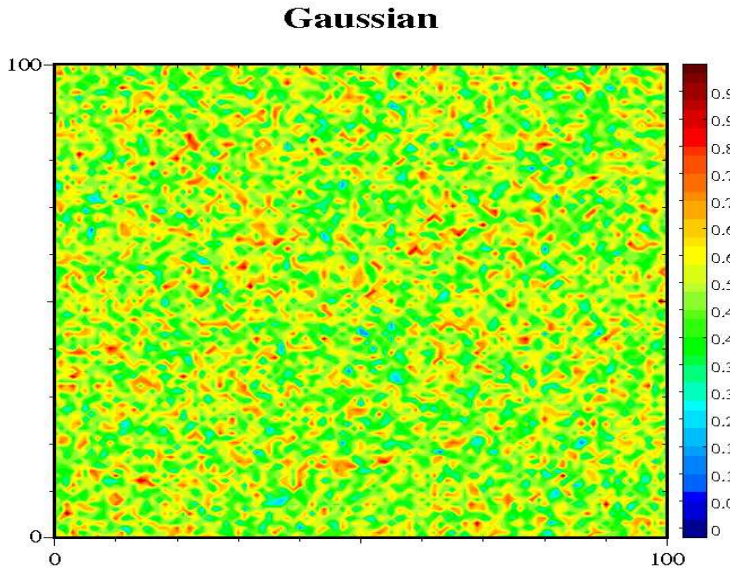


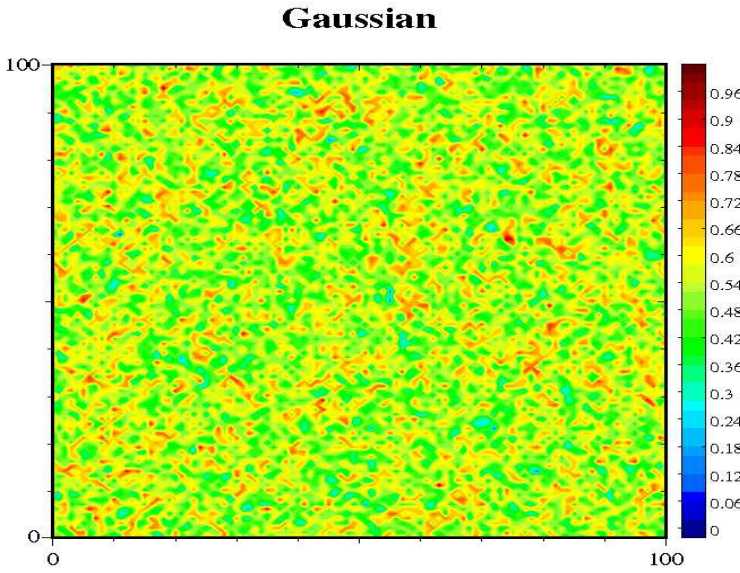
observed−forecast

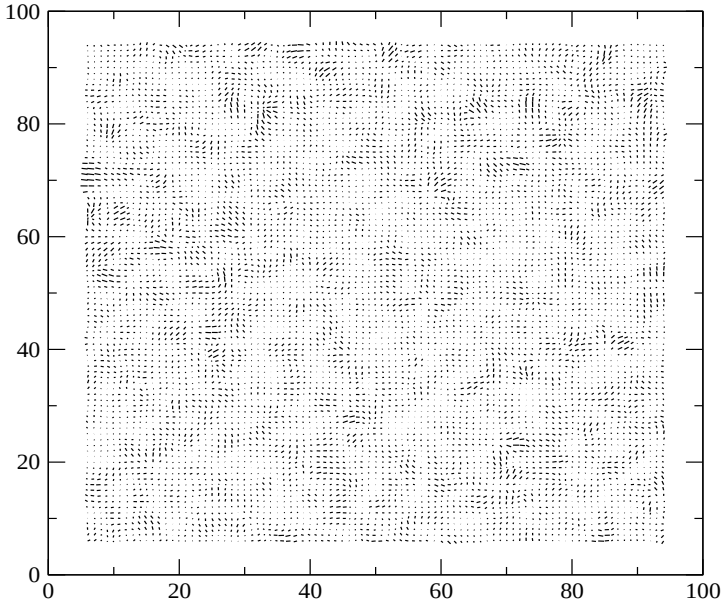


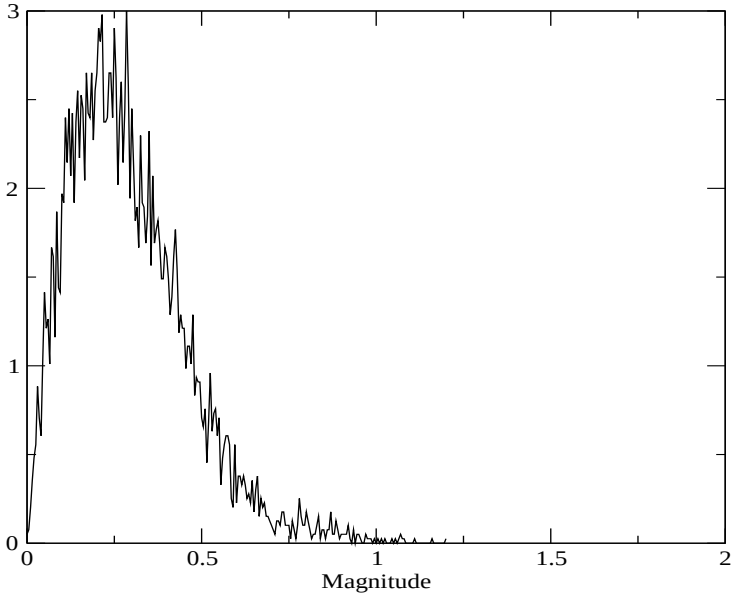
observation−prediction

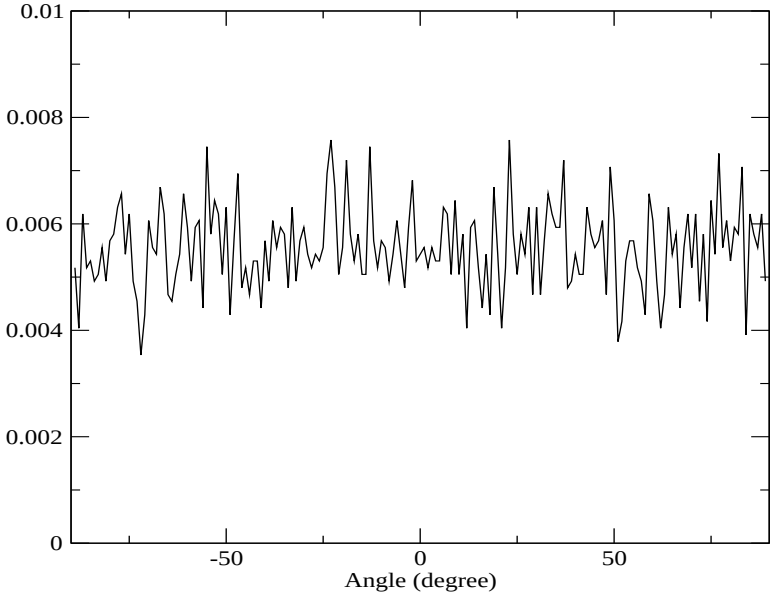


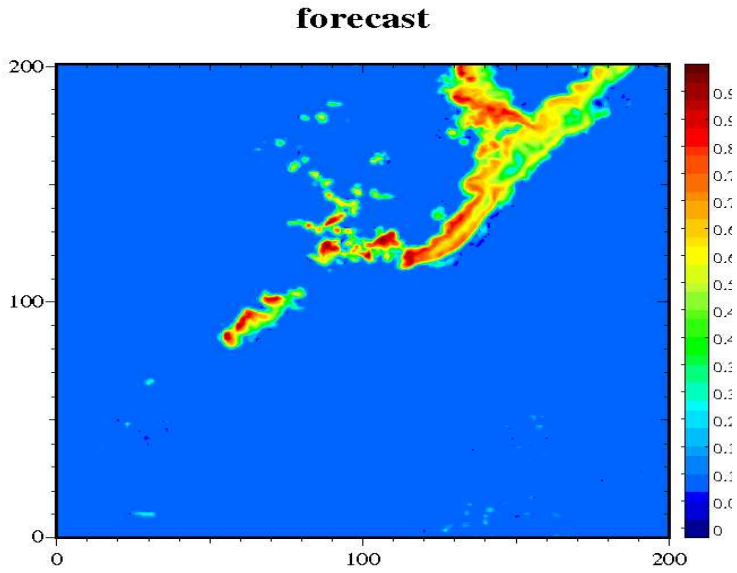

Gaussian
100
0
0
100

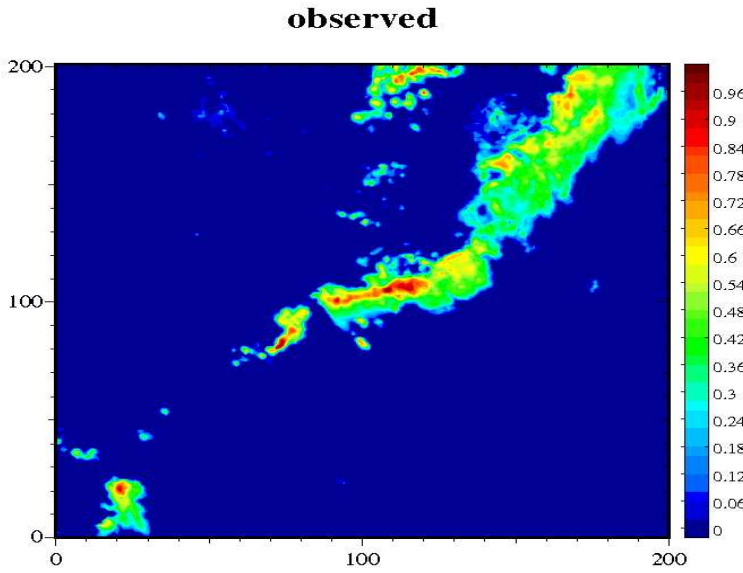

Gaussian
100
0
0
100

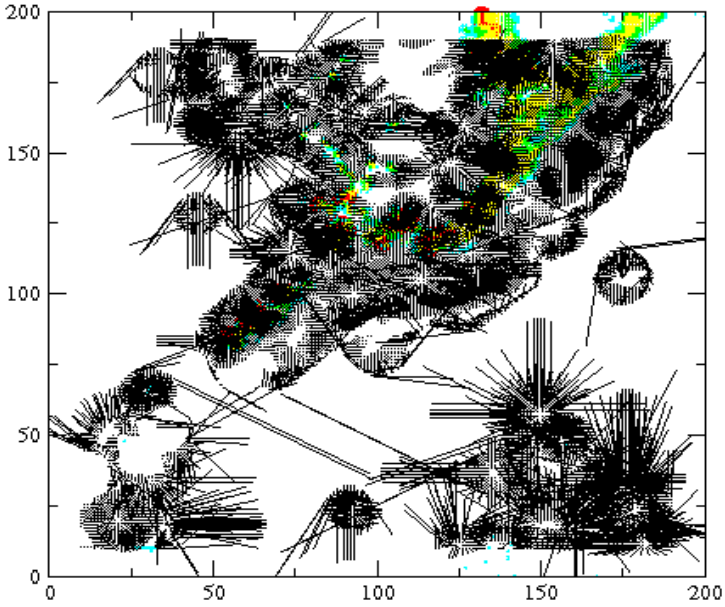

100
80
60
40
20
0
0
20
40
60
80
100

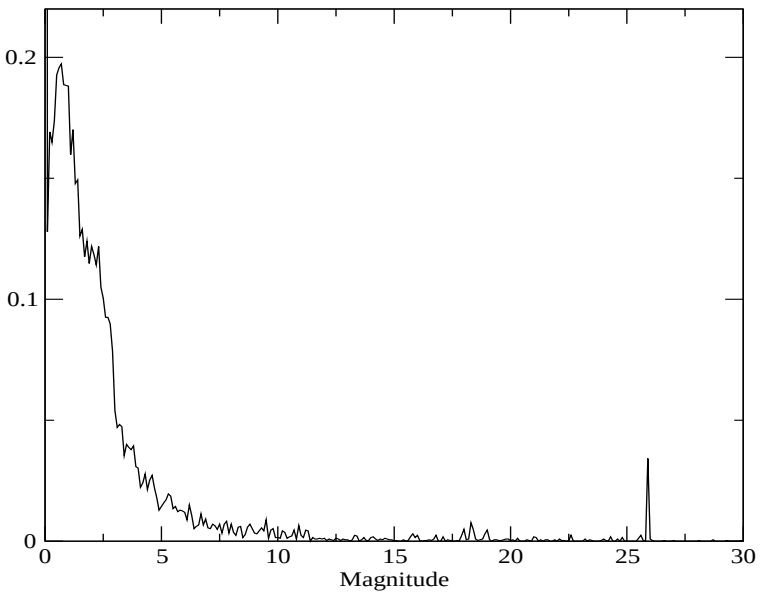

3
2
1
0
0
0.5
1
1.5
2
Magnitude

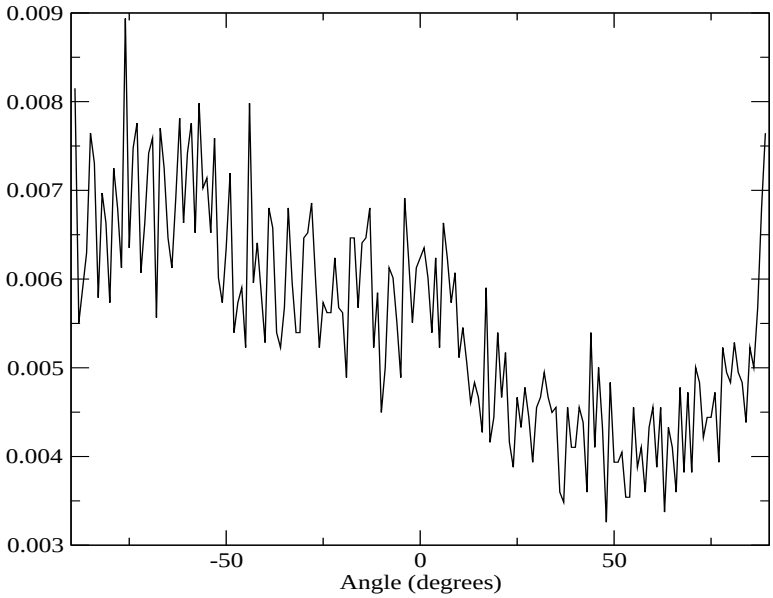

0.01
0.008
0.006
0.004
0.002
0
-50
0
50
Angle (degree)

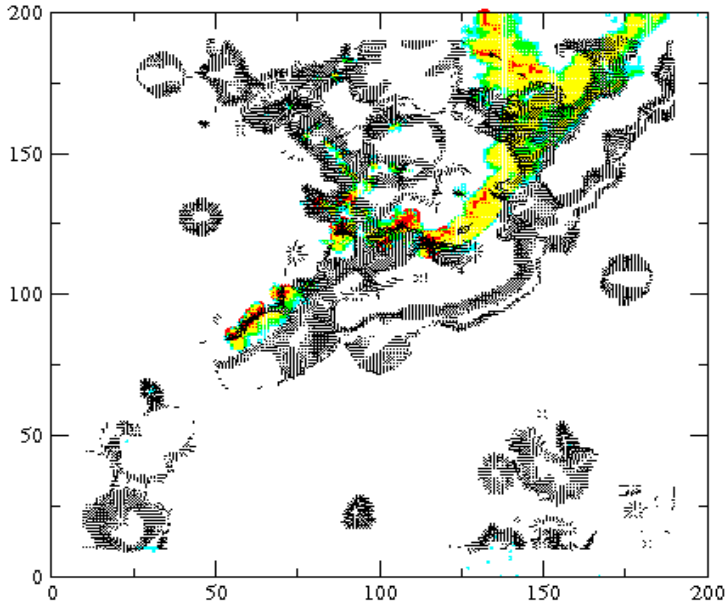

forecast
200
100
0
0
100
200

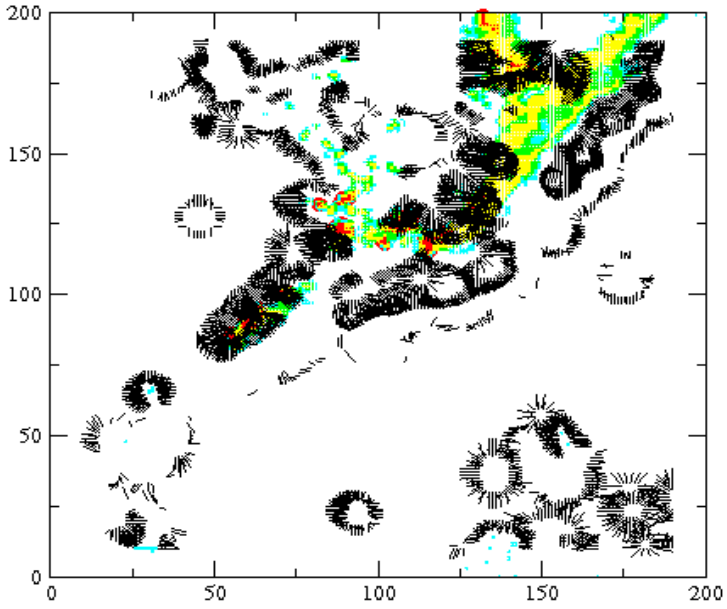

observed
200
100
0
0
100
200
0.96
0.9
0.84
0.78
0.72
0.66
0.6
0.54
0.48
0.42
0.36
0.3
0.24
0.18
0.12
0.06
0

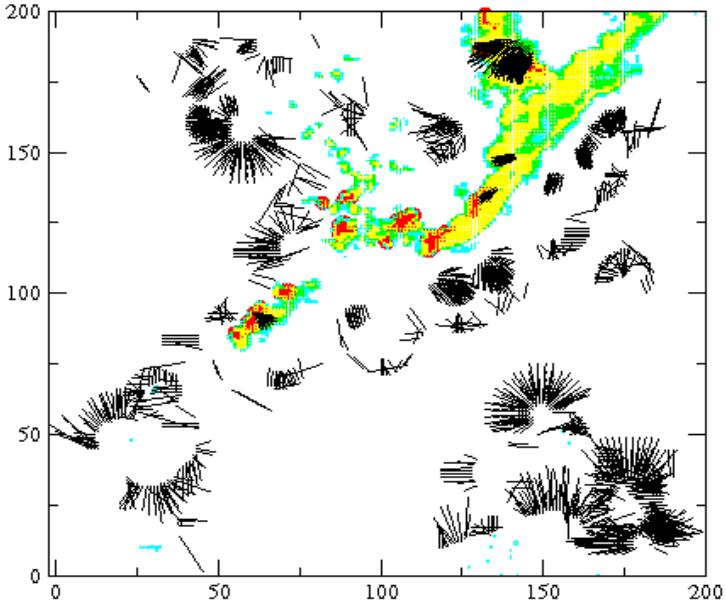

200
150
100
50
0
0
50
100
150
200

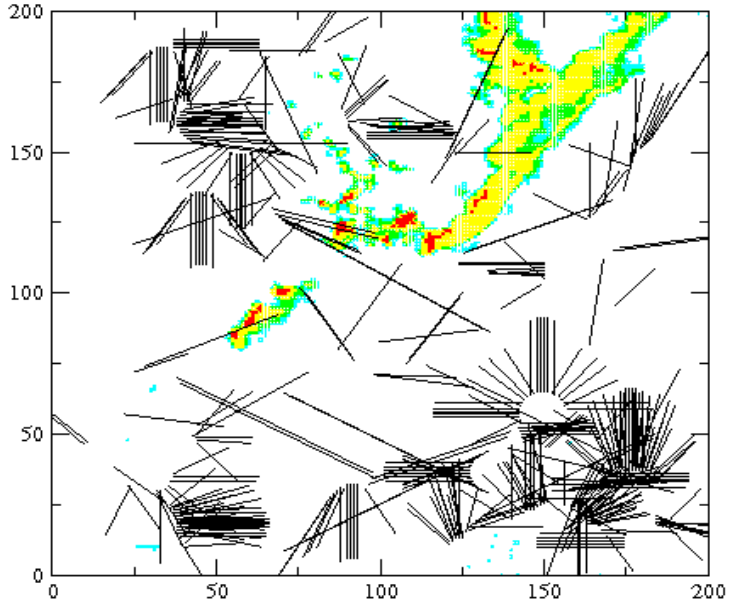

0.2
0.1
0
0
5
10
15
20
25
30
Magnitude


0.009
0.008
0.007
0.006
0.005
0.004
0.003
-50
0
50
Angle (degrees)

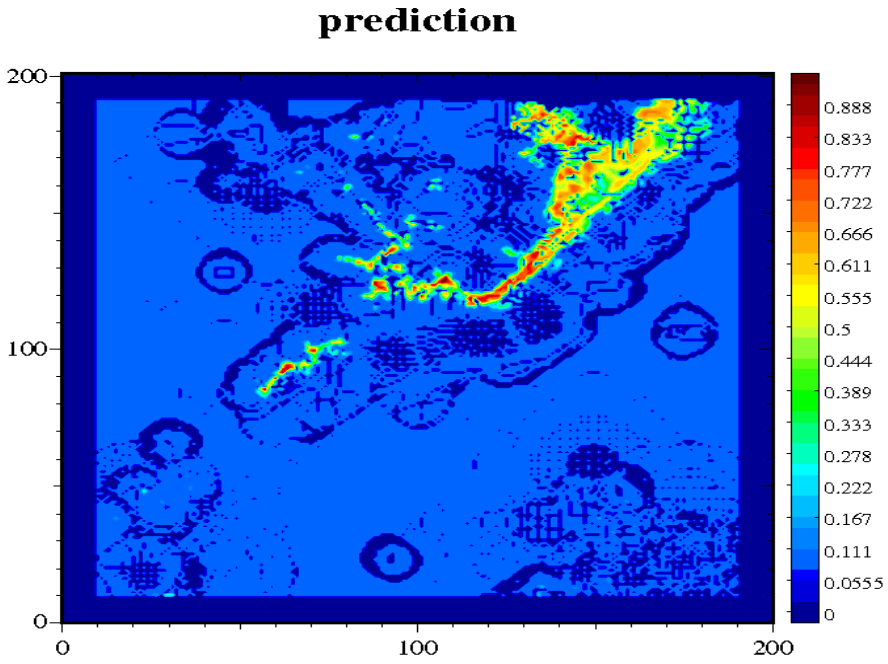

200
150
100
50
0
0
50
100
150
200

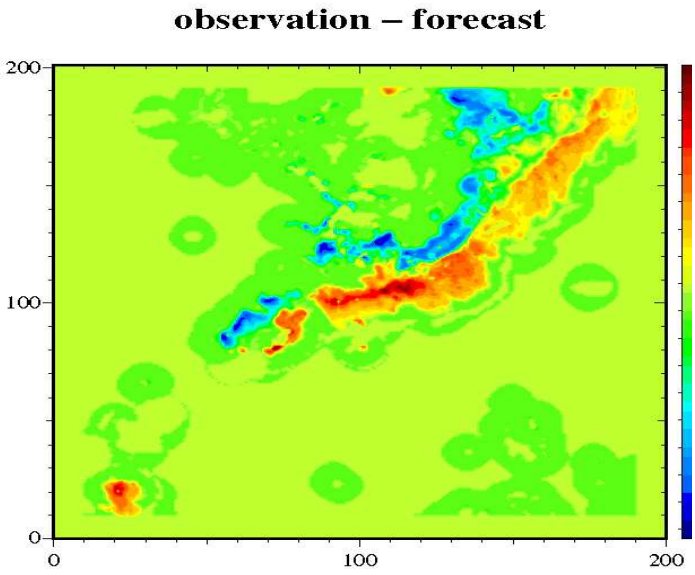

200
150
100
50
0
0
50
100
150
200

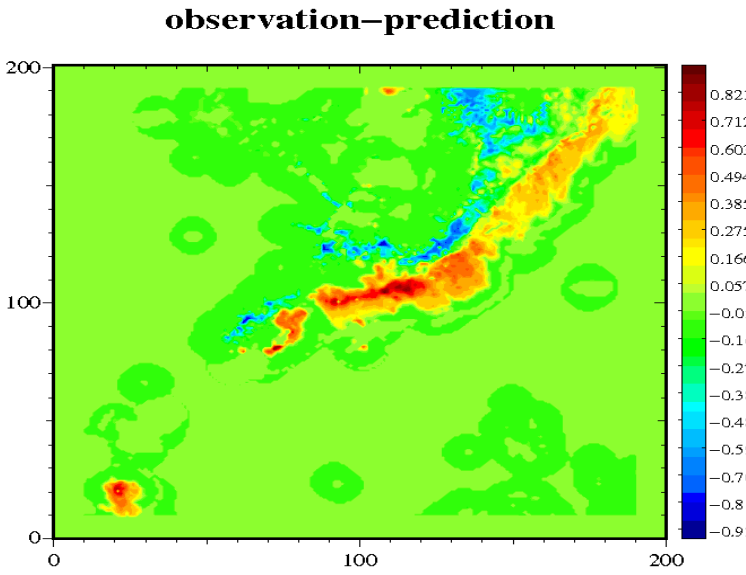

200
150
100
50
0
0
50
100
150
200


200
150
100
50
0
0
50
100
150
200

Nowcasting?


prediction
200
100
0
0
100
200
0.888
0.833
0.777
0.722
0.666
0.611
0.555
0.5
0.444
0.389
0.333
0.278
0.222
0.167
0.111
0.0555
0


observation – forecast
200
100
0
0
100
200


observation–prediction
200
100
0
0
100
200
0.821
0.712
0.603
0.494
0.385
0.275
0.166
0.0571

Future Work

- Examine other cases

- Continuous fields (e.g. SLP)

- Better diagnosis of flow field

- Lucas-Kanade vs. Horn-Schunk

- Very short-term forecast

Acknowledgement

- Werner Stuetzle, Don Percival, Albert Kim
- Valliappa Lakshmanan.

- Office of Naval Research - Verification

- Office of Naval Research - Counter IED