FQM:
a new displacement-based forecast quality measure

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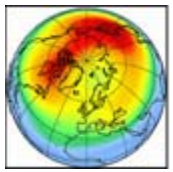
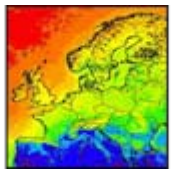
Reference:
Keil, C. and G. C. Craig, 2007: A Displacement-based Error Measure applied in a Regional Ensemble Forecasting System, *Mon. Wea. Rev.,* 135, 3248-3259.

DLR **Institut für Physik der Atmosphäre**





What kind of data does the method use?

- gridded as well as point data
- data is mapped with IDL onto same domain

- Displacement-based method has been applied so far on
  - satellite imagery (e.g. infrared Meteosat-8 (SEVIRI))
  - radar reflectivities
  - daily rainfall accumulations
  - ...

Forecast Quality Measure

- FQM is based on a
  - displacement error (of observed and forecast imagery) and an
  - amplitude error (of observed an morphed forecast imagery)

- Underlying principle: complete miss = 100% amplitude error

- 2 free parameters: max. search radius,
  threshold value

Forecast Quality Measure

$$FQM = \frac{1}{A}\sum_{A}\left(c_1 \cdot DIS + c_2 \cdot RMSE\right)$$

$$c_1 = DIS_{\max}^{-1}; c_2 = \overline{\Psi}_{obs}^{-1}$$

If forecast and observed features can be matched, the magnitude of the displacement vector (DIS) characterises forecast quality (averaged over morphed forecast feature), whereas when matching features cannot be found within the search distance, the local RMSE between both fields ($\psi_{i,j}$) is used. The FQM of a perfect forecast equals zero.

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Method: Pyramidal Matching Algorithm (Mannstein et al., 2002)

1. Project observed and simulated images to same grid

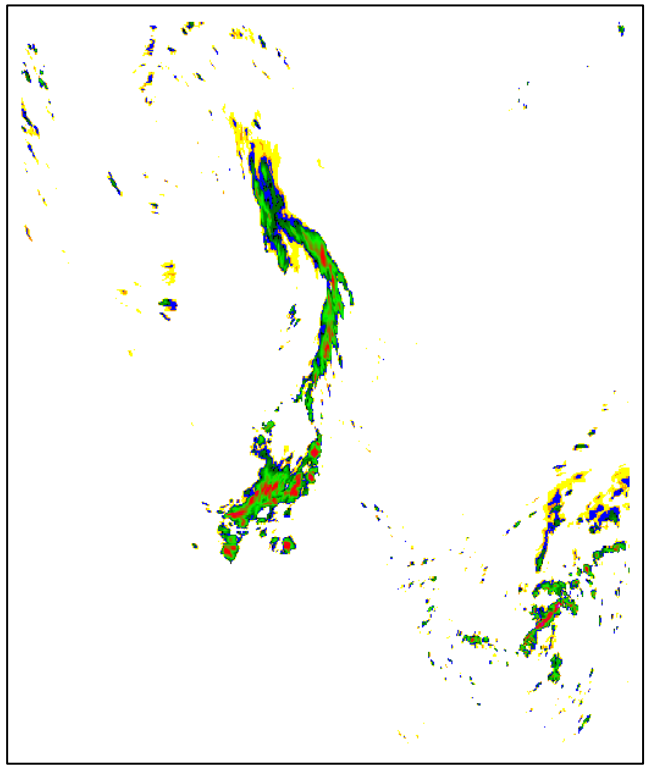
2. Coarse-grain both images by averaging of 2^F pixels onto one pixel element

3. Compute a displacement vector field that minimizes the squared difference within the range of +/- 2 pixel elements

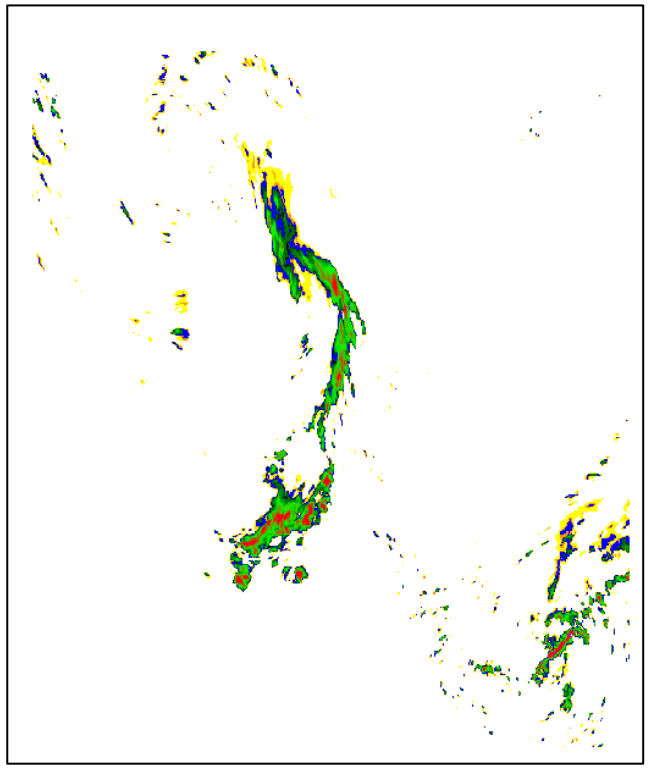
4. Repeat step 2 at successively finer scales

5. Displacement vector for every pixel results from the sum over all scales

Pyramidal Image Matching: (2) coarse grain images F=4



observation



forecast

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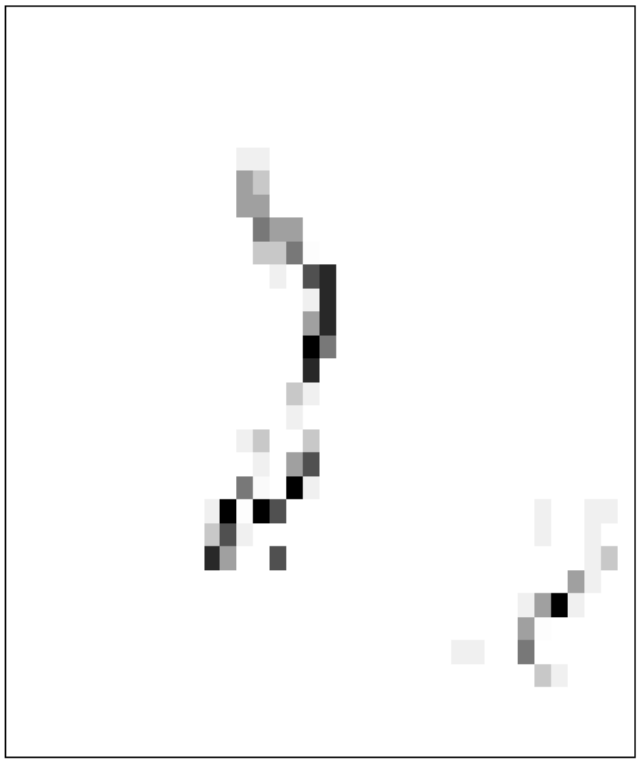
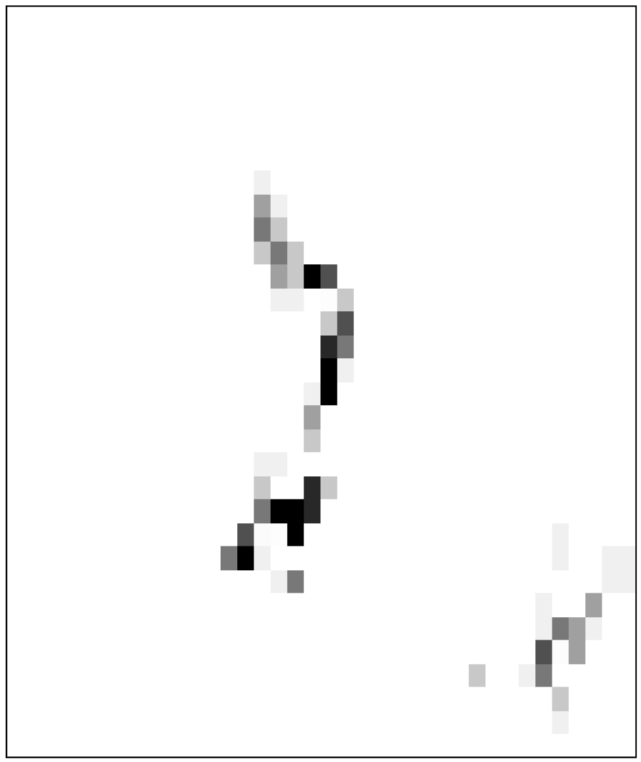
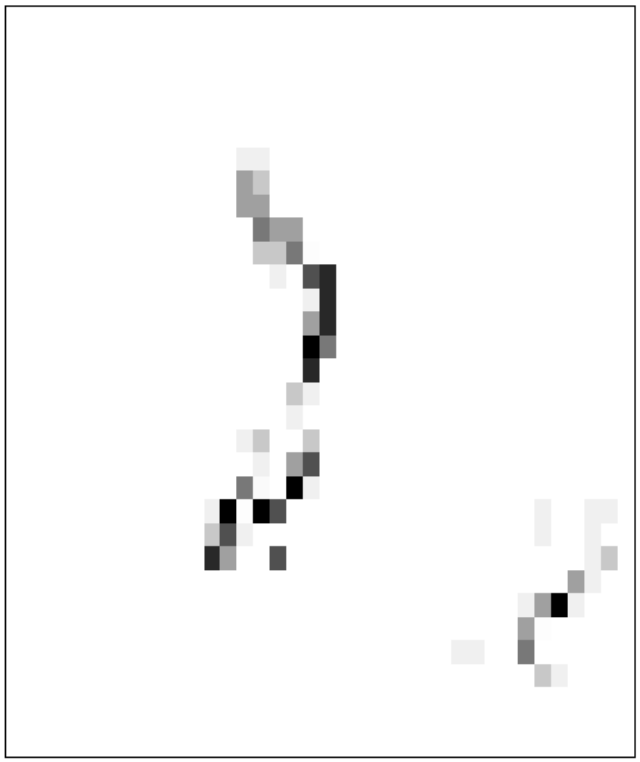


observation

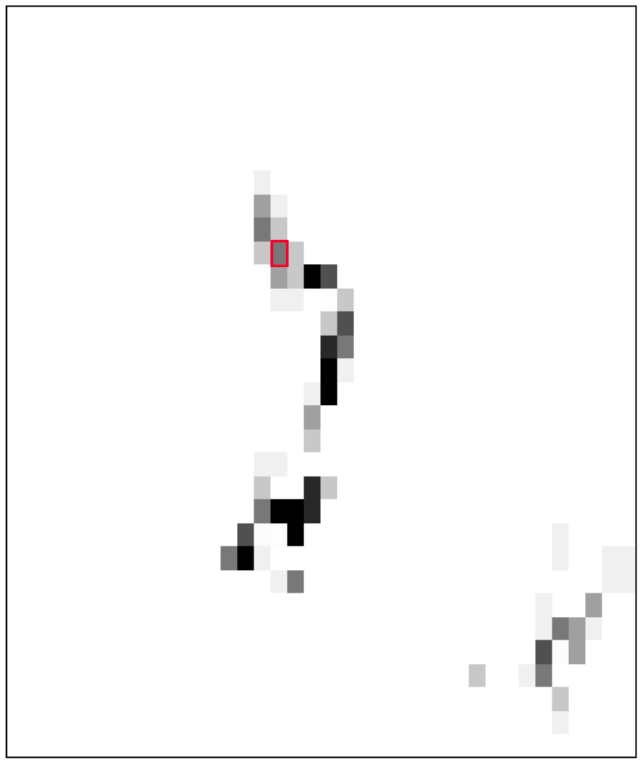


forecast

Pyramidal Image Matching: (3) displacement vector field



observation



forecast

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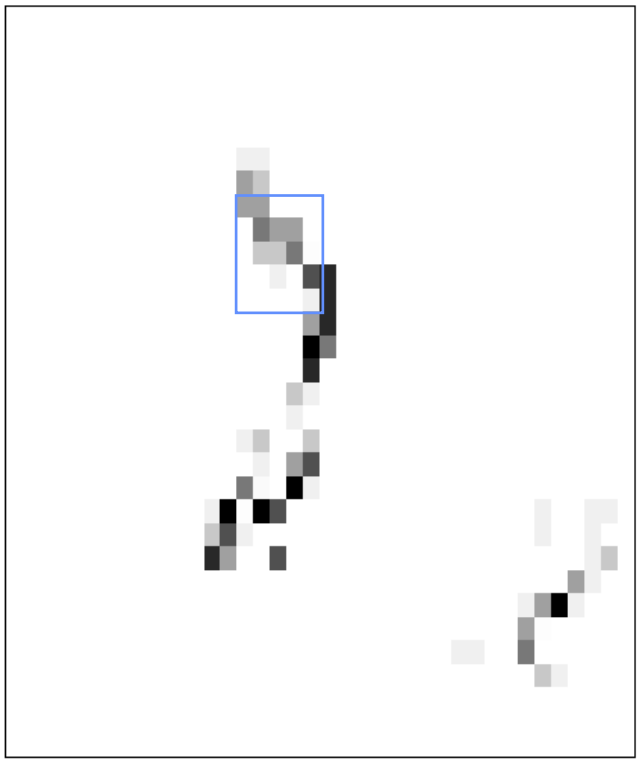
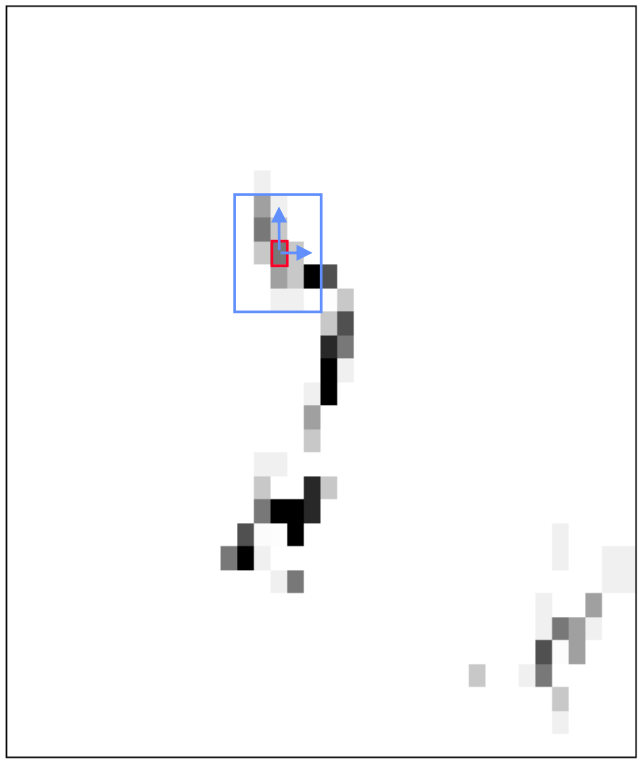


observation



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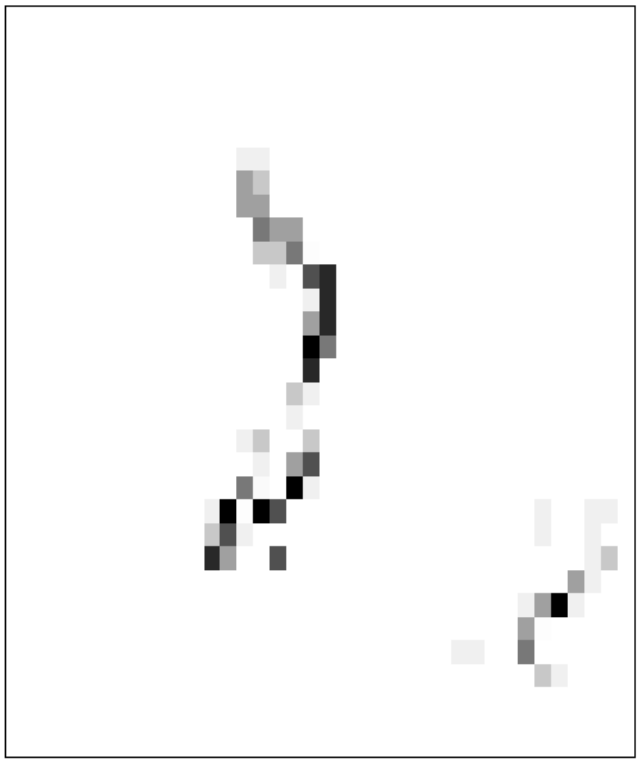

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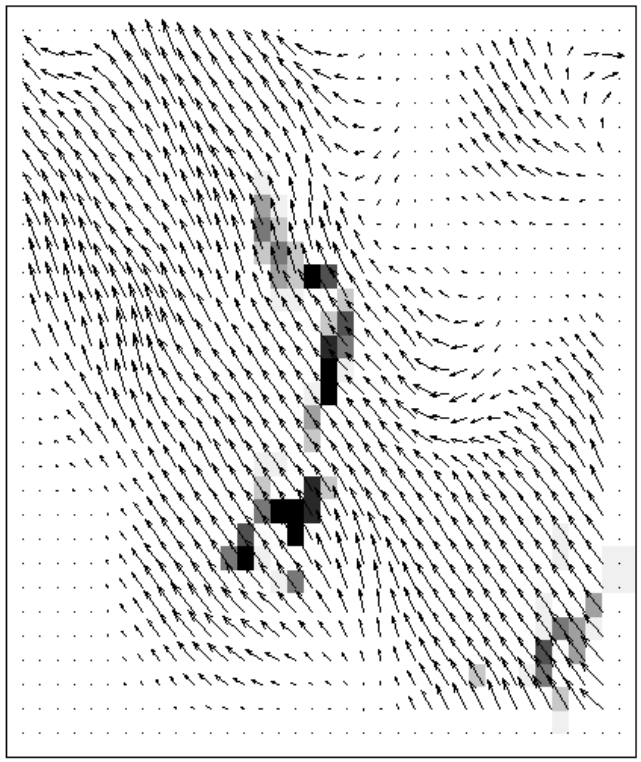
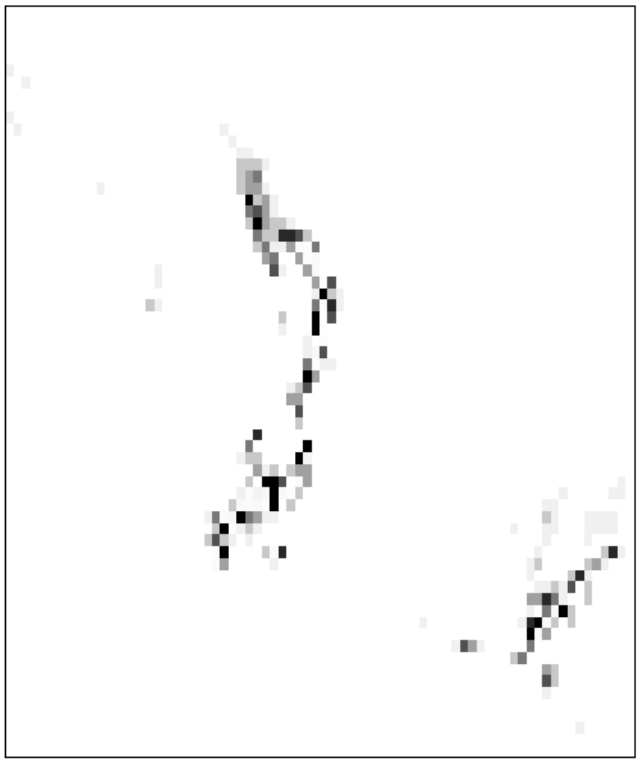


forecast

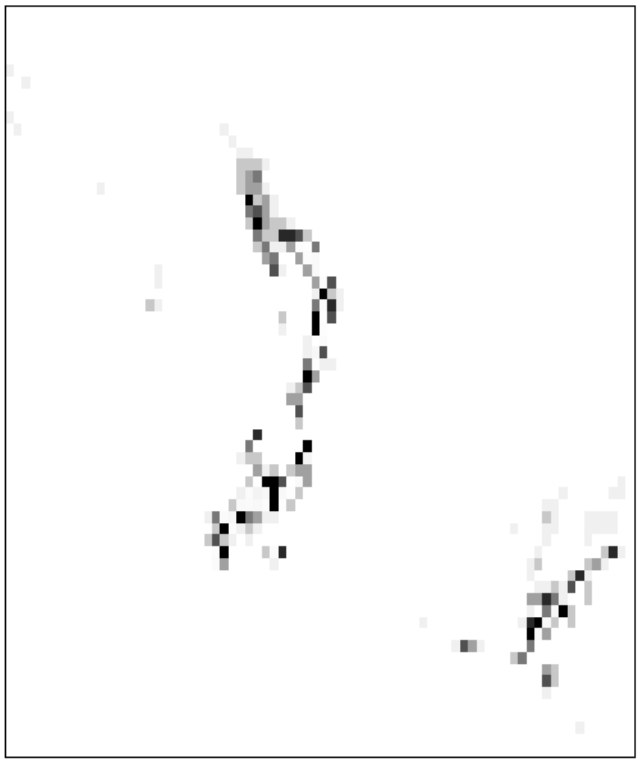
Pyramidal Image Matching: (4) finer scales



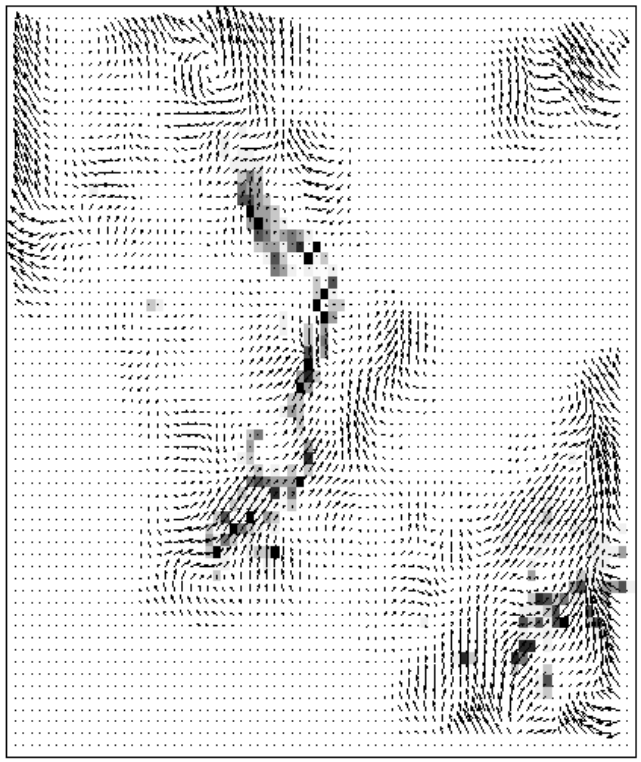
observation

forecast

Pyramidal Image Matching: (4) finer scales

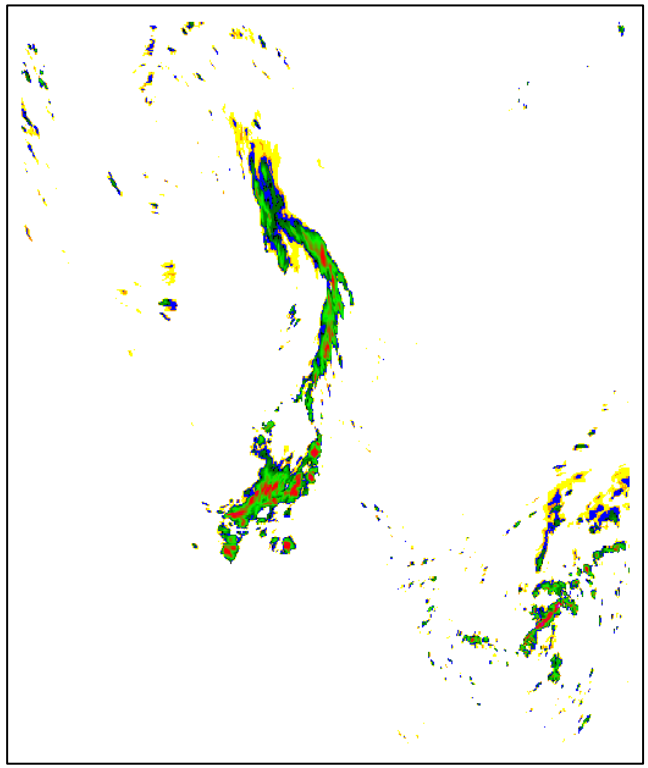


observation

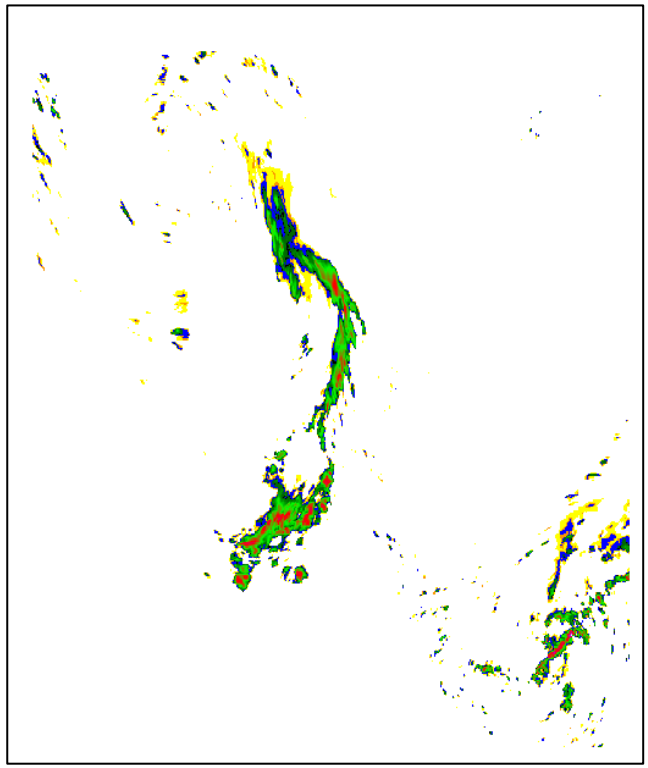


forecast

Pyramidal Image Matching: (5) sum over all scales



observation



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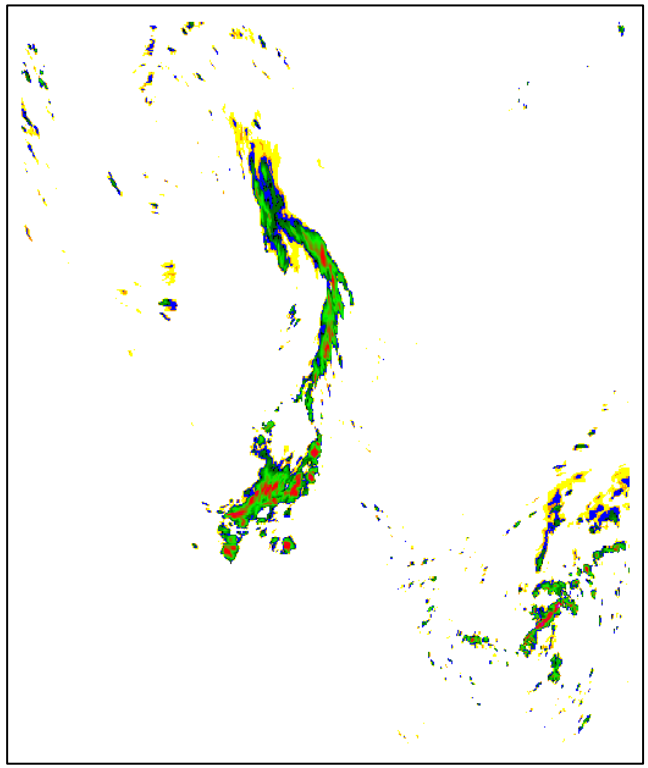
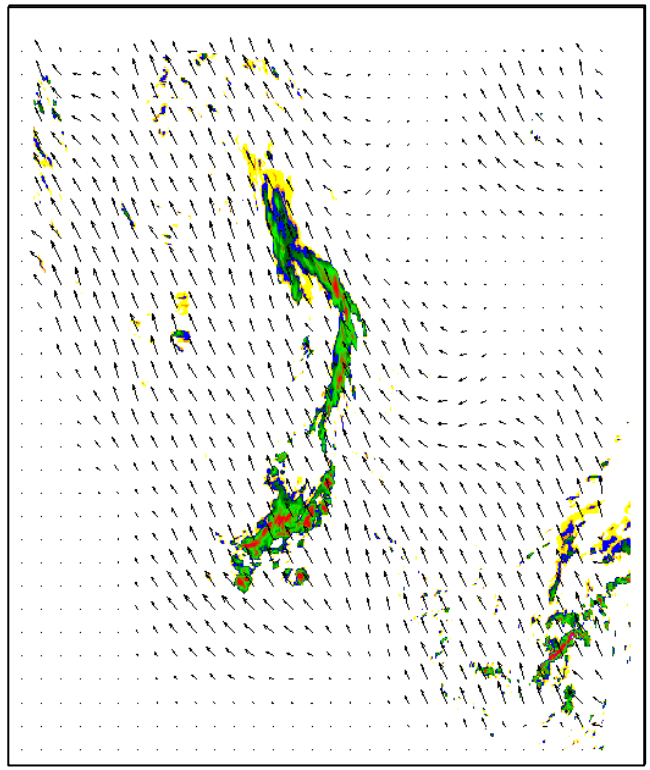


observation



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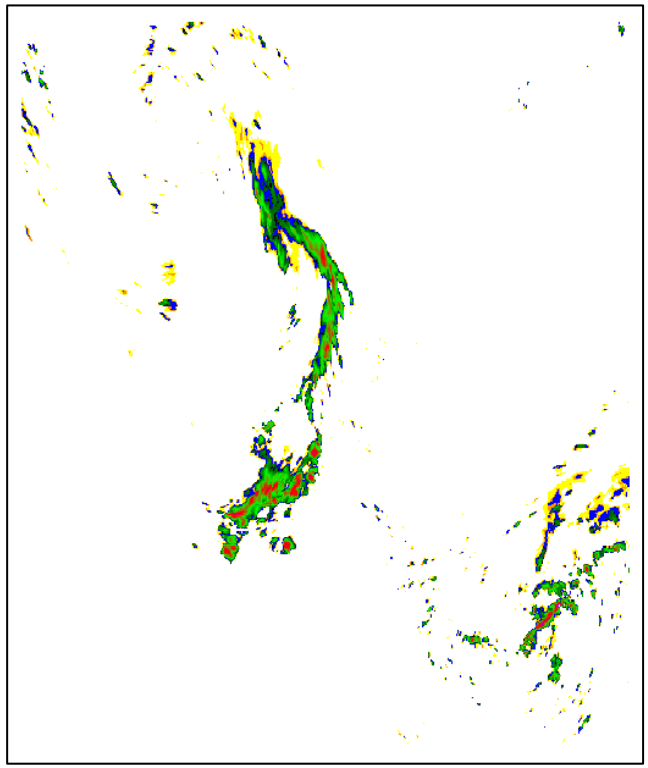

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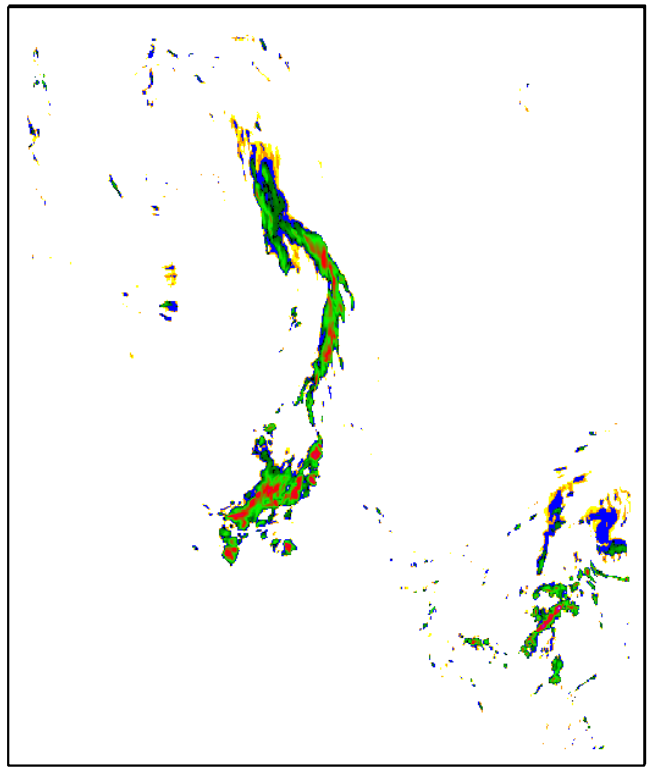

forecast

FQM = displacement error + ...

displacement error

FQM = displacement error + amplitude error

displacement error

amplitude error

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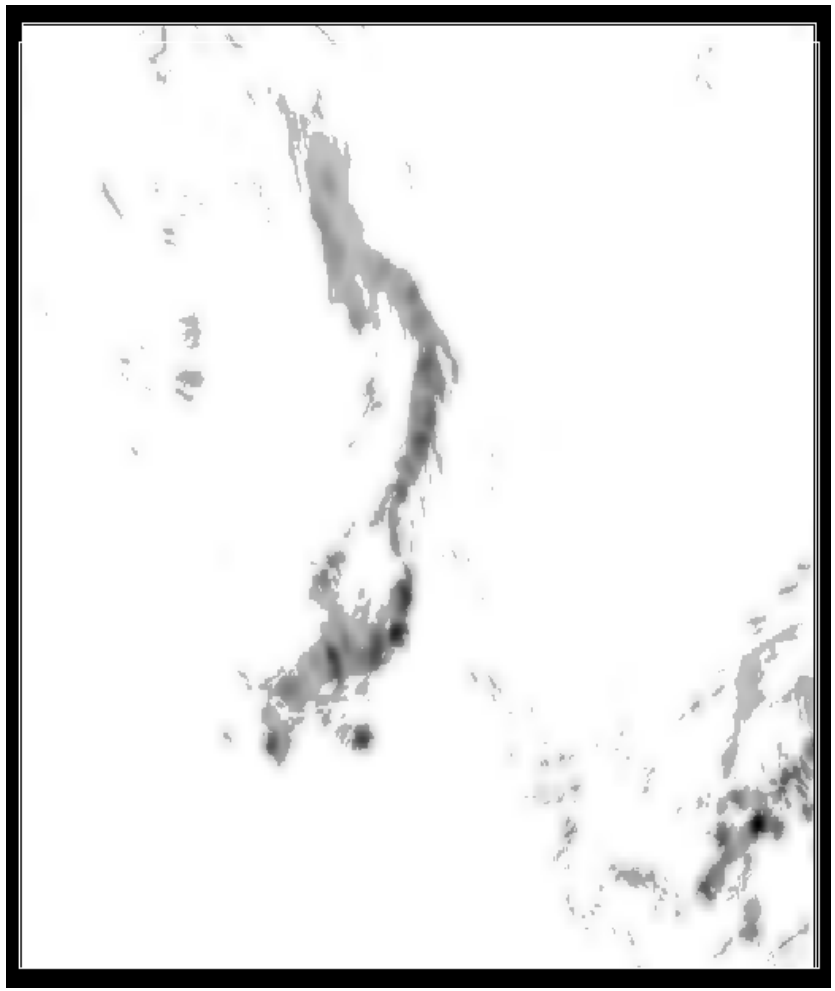


FQM

FQM on fake perturbed cases

Results:

max displacement: $DIS_{\max} = 256km$

precip threshold: $\psi_{thr} = 1mm$

exp	bias	thr	eqth	far	fqm	dis	gp dis	rmse	rank
fake 001	1.01	0.45	0.42	0.38	0.0149	0.092	13274	0.0247	1
fake 002	1.01	0.32	0.29	0.52	0.0173	0.184	13356	0.0243	2
fake 003	1.02	0.20	0.17	0.67	0.0216	0.362	13323	0.0228	3
fake 004	1.04	0.11	0.08	0.79	0.0306	0.711	12507	0.0234	6
fake 005	1.20	0.06	0.03	0.87	0.0476	0.548	7976	0.0767	7
fake 006	0.87	0.21	0.18	0.68	0.0300	0.325	11204	0.0446	5
fake 007	1.74	0.14	0.11	0.67	0.0221	0.374	9828	0.0286	4

FQM on fake geometric cases

Results:

max displacement: $DIS_{\max} = 256km$

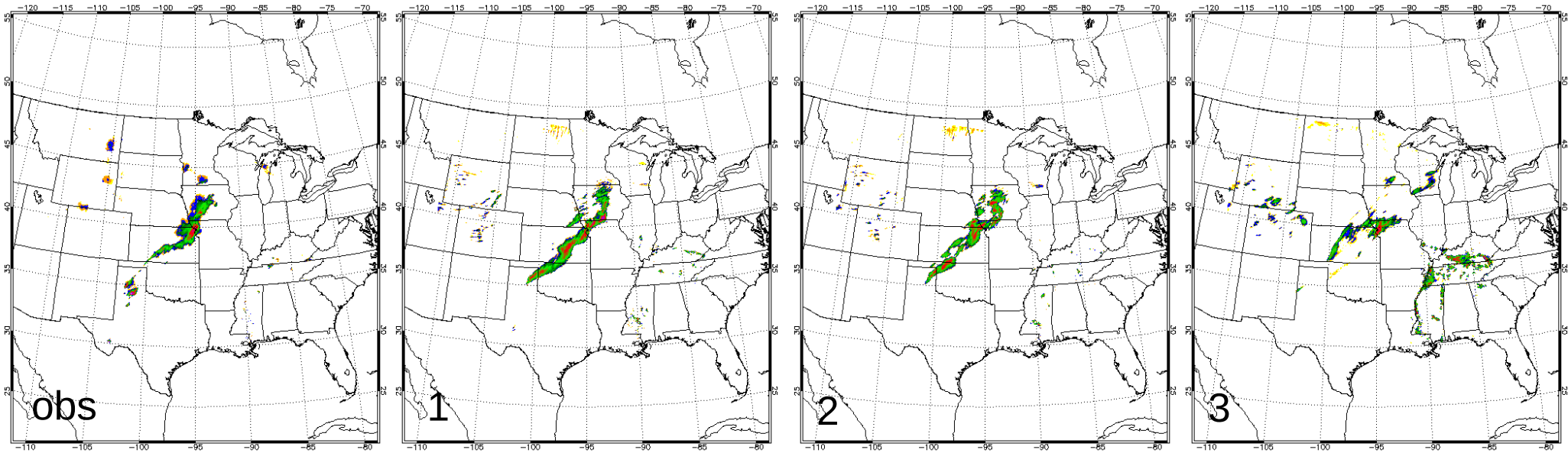
precip threshold: $\psi_{thr} = 1mm$

exp	bias	thr	eqth	far	fqm	dis	gp dis	rmse	rank
geom 001	1.00	0.00	-0.02	1.00	0.0140	0.774	7943	0.0019	1
geom 002	1.00	0.00	-0.02	1.00	0.0198	0.575	710	0.0379	3
geom 003	0.25	0.00	-0.03	1.00	0.0303	0.723	7664	0.0371	4
geom 004	1.00	0.00	-0.02	1.00	0.0184	0.648	4453	0.0245	2
geom 005	0.12	0.11	0.08	0.89	0.0602	0.591	22604	0.0638	5

Demonstration on 13 May 2005 case

$$DIS_{\max} = 256km$$

$$\psi_{thr} = 1mm$$

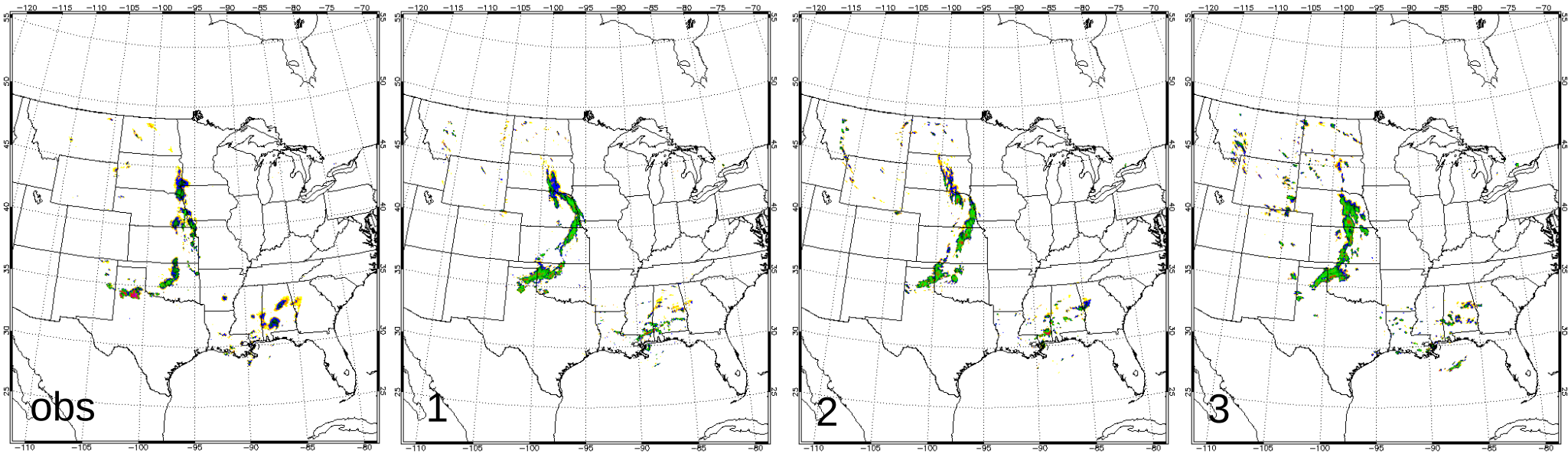


exp	bias	thr	eqth	far	fqm	dis	gp dis	rmse	rank
wrf2caps	0.91	0.19	0.17	0.69	0.0334	0.424	6711	0.0547	2=
wrf4ncar	1.05	0.26	0.24	0.58	0.0315	0.298	7555	0.0535	1
wrf4ncep	0.69	0.13	0.10	0.81	0.0335	0.362	8852	0.0533	2=

Demonstration on 1 June 2005 case

$$DIS_{\max} = 256km$$

$$\psi_{thr} = 1mm$$



exp	bias	thr	eqth	far	fqm	dis	gp dis	rmse	rank
wrf2caps	1.09	0.13	0.10	0.76	0.0465	0.426	10094	0.0748	2
wrf4ncar	1.19	0.13	0.10	0.74	0.0435	0.316	9692	0.0741	1
wrf4ncep	0.99	0.08	0.05	0.85	0.0485	0.317	8791	0.0852	3

FQM for all sp2005 cases

Results:

max displacement: $DIS_{\max} = 256km$

precip threshold: $\psi_{thr} = 1mm$

exp	bias	thr	ets	far	fqm	dis	gp dis	rmse
426	0.69	0.08	0.05	0.88	0.0196	0.399	6276	0.0287
	0.70	0.08	0.06	0.87	0.0210	0.446	7238	0.0283
513	0.91	0.19	0.17	0.69	0.0334	0.424	6711	0.0547
	1.05	0.26	0.24	0.58	0.0315	0.298	7555	0.0535
	0.69	0.13	0.10	0.81	0.0335	0.362	8852	0.0533
514	0.86	0.16	0.13	0.74	0.0336	0.268	7085	0.0591
	0.95	0.16	0.13	0.74	0.0344	0.271	6308	0.0615
	0.79	0.10	0.07	0.83	0.0391	0.323	5533	0.0707
518	1.05	0.15	0.14	0.74	0.0107	0.363	2709	0.0172
	1.01	0.12	0.11	0.79	0.0115	0.346	2011	0.0201
	0.71	0.10	0.08	0.85	0.0108	0.277	2580	0.0186

exp	bias	thr	ets	far	fqm	dis	gp dis	rmse
519	0.58	0.09	0.08	0.87	0.0105	0.396	3209	0.0156
	0.60	0.09	0.08	0.87	0.0109	0.410	2485	0.0174
	0.66	0.13	0.12	0.81	0.0089	0.270	3378	0.0139
525	1.46	0.06	0.05	0.86	0.0243	0.451	4315	0.0403
	1.34	0.06	0.05	0.87	0.0262	0.488	3659	0.0449
	0.94	0.07	0.05	0.88	0.0259	0.440	4018	0.0442
603	0.98	0.10	0.09	0.81	0.0183	0.392	3916	0.0300
	1.18	0.09	0.07	0.82	0.0198	0.479	4218	0.0311
	0.83	0.11	0.10	0.81	0.0171	0.283	4826	0.0284
604	0.78	0.08	0.05	0.87	0.0255	0.397	5081	0.0425
	0.94	0.08	0.06	0.85	0.0233	0.397	5190	0.0379
	0.50	0.08	0.05	0.89	0.0293	0.370	7156	0.0473

Summary

- FQM consists of two equally weighted components
  - displacement error (of observed and forecast imagery) and an
  - amplitude error (of observed an morphed forecast imagery)

- Underlying principle: complete miss = 100% amplitude error

- 2 free parameters: max. search radius (*i.e.* size of pixel elements), threshold value

- Displacement vector field is determined with an area based image matcher using classical optical flow technique