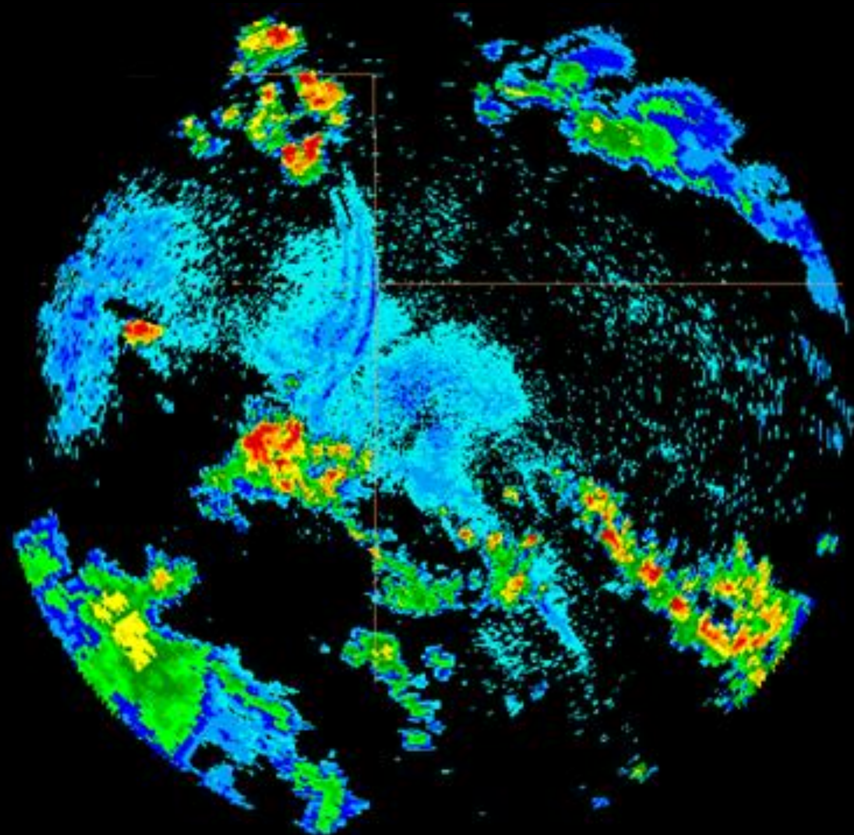
Estimation of high spatial resolution precipitation fields using merged rain gauge - radar data.

Antonio Manuel Moreno Ródenas



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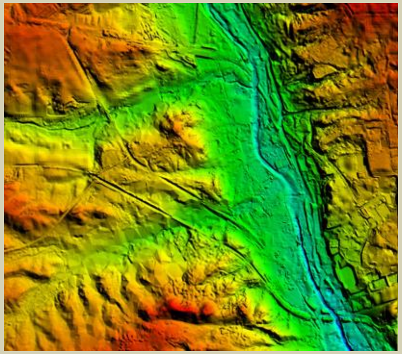
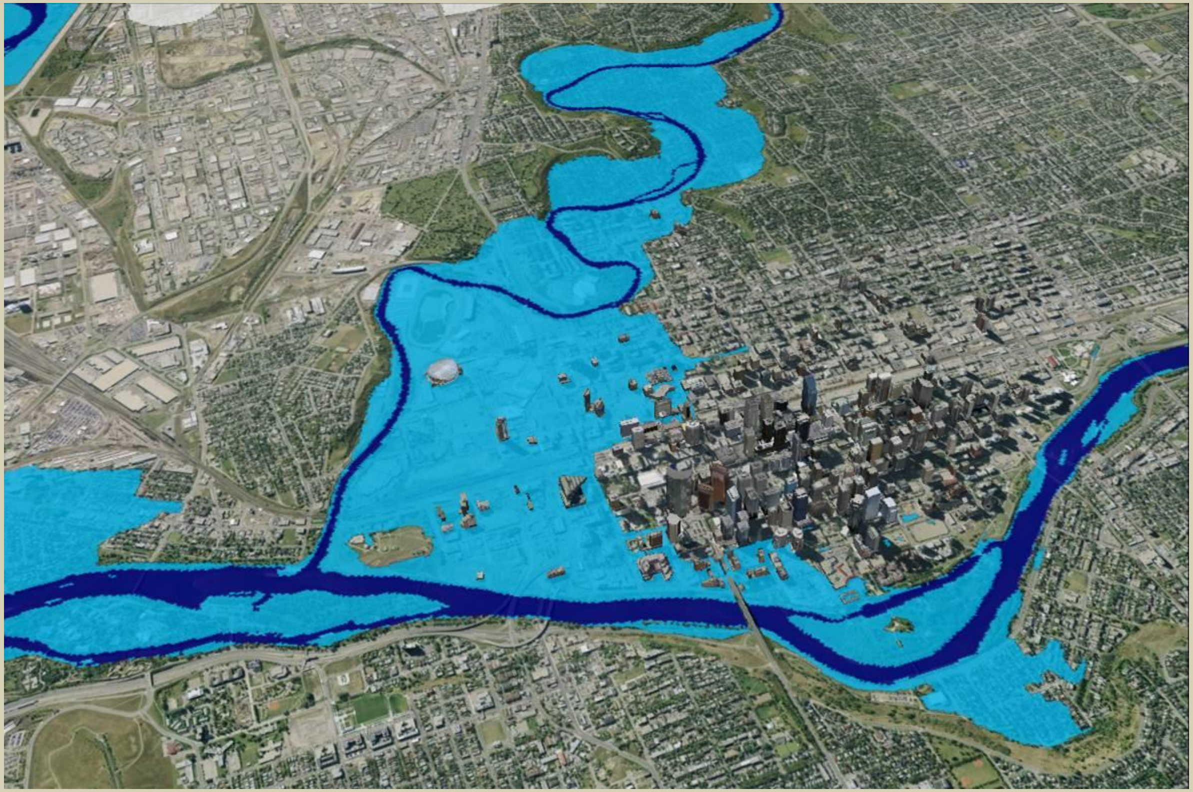
1- Introduction

Distributed rainfall-runoff modelling.

Demand of a high quality and resolution precipitation fields





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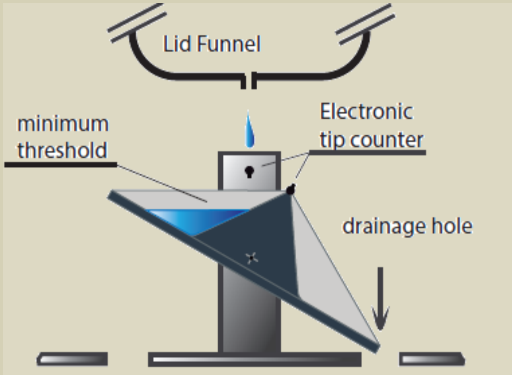
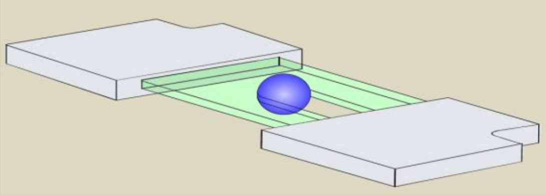
1- Introduction

Rain gauge / Disdrometer





Ground based weather Radar

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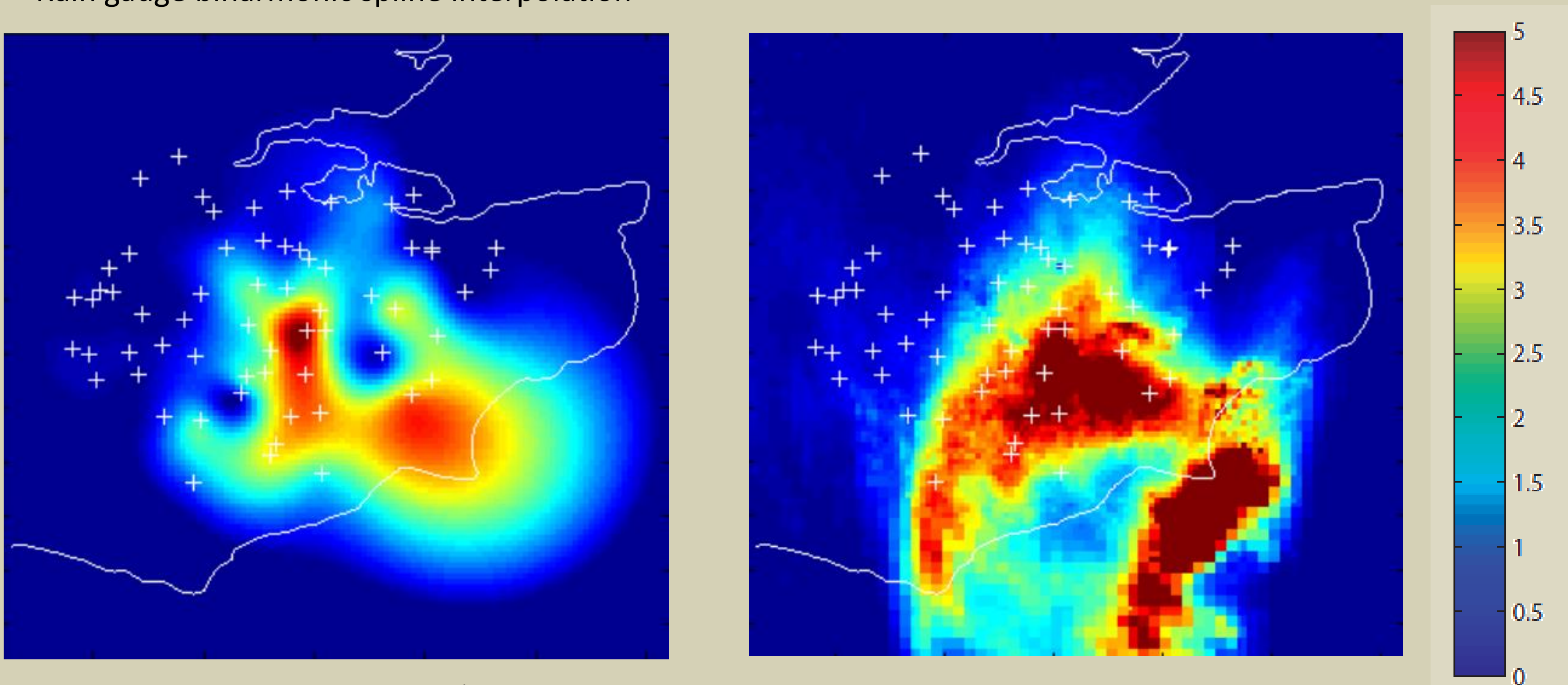
1- Introduction

Rain gauge biharmonic spline interpolation

Quantitative radar estimation



Precipitation fields for Kent area in 20th of July, 2007 (mm/h)

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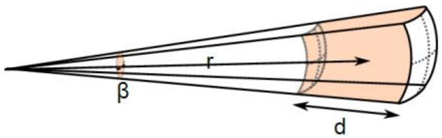
1- Introduction

Radar equation : $P_r = \frac{P_e G^2 \lambda^2 \sigma_T}{(4\pi)^3 R^4}$

Rayleigh backscattering $\sigma_i = \frac{\pi^5}{\lambda^4} |K|^2 D_i^6 \quad |K| = \left| \frac{\epsilon - 1}{\epsilon + 2} \right|$

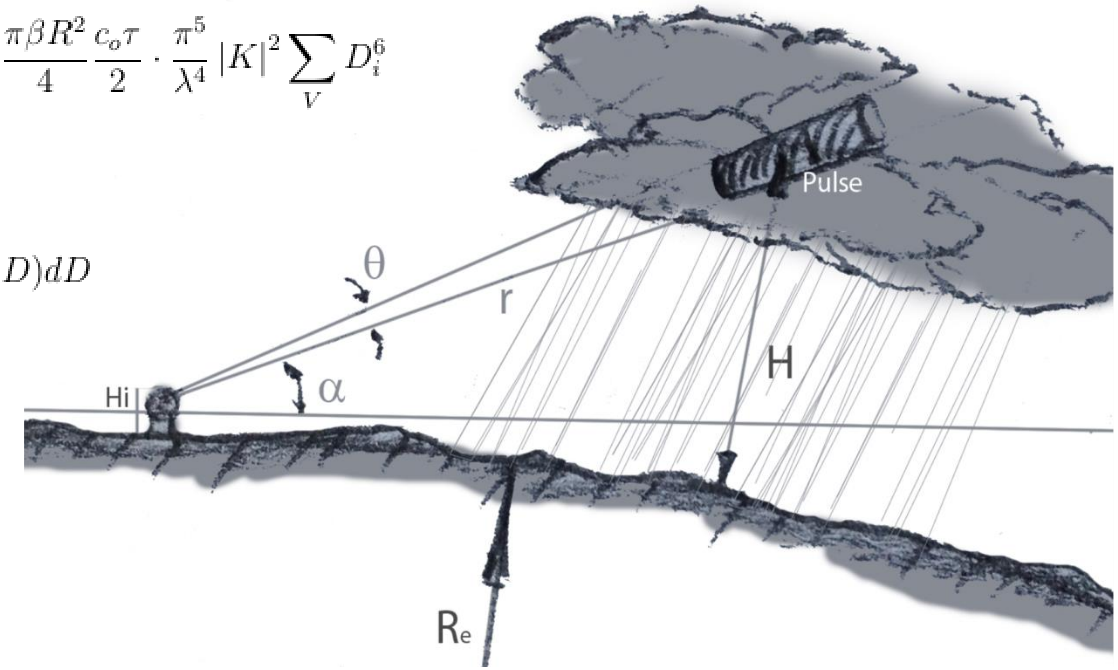


$$P_r = \frac{P_e G^2 \lambda^2}{(4\pi)^3 R^4} \cdot \frac{\pi \beta R^2}{4} \frac{c_o \tau}{2} \cdot \frac{\pi^5}{\lambda^4} |K|^2 \sum_V D_i^6$$

$$Z = \frac{\lambda^4}{\pi^5 |K|^2} \int_{D_{inf}}^{D_{max}} \sigma(D) N(D) dD \approx \int D^6 N(D) dD$$

$$R \approx \int D^{3.67} N(D) dD \qquad Z = aR^b$$

$$Z = 200R^{1.6}$$



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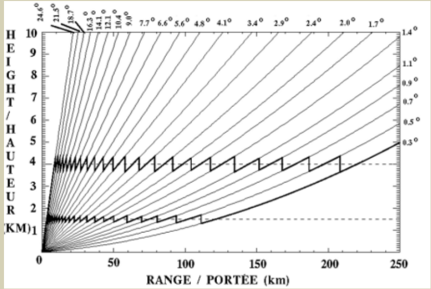
Radar Error sources

Scanning altitude



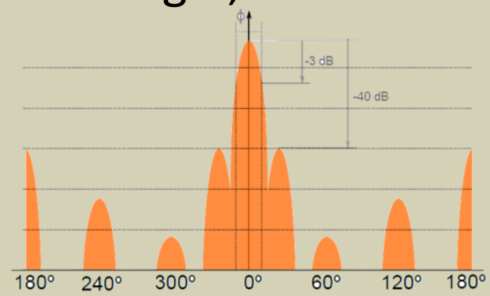
Ground clutter & Blockages

Jamming, active interference

Raindrop size distribution

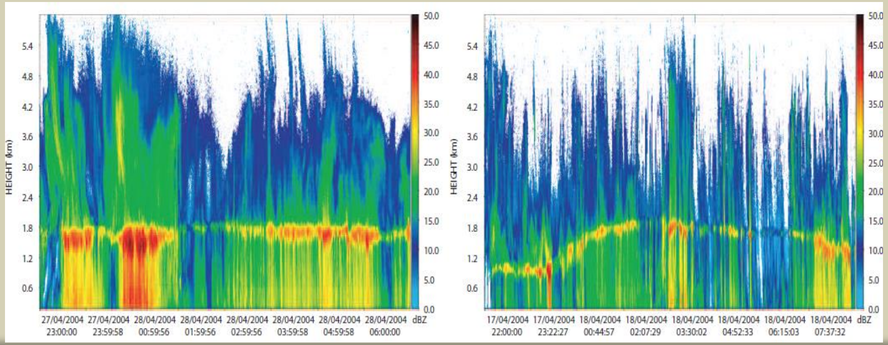
Attenuation

Echo origin, directionality



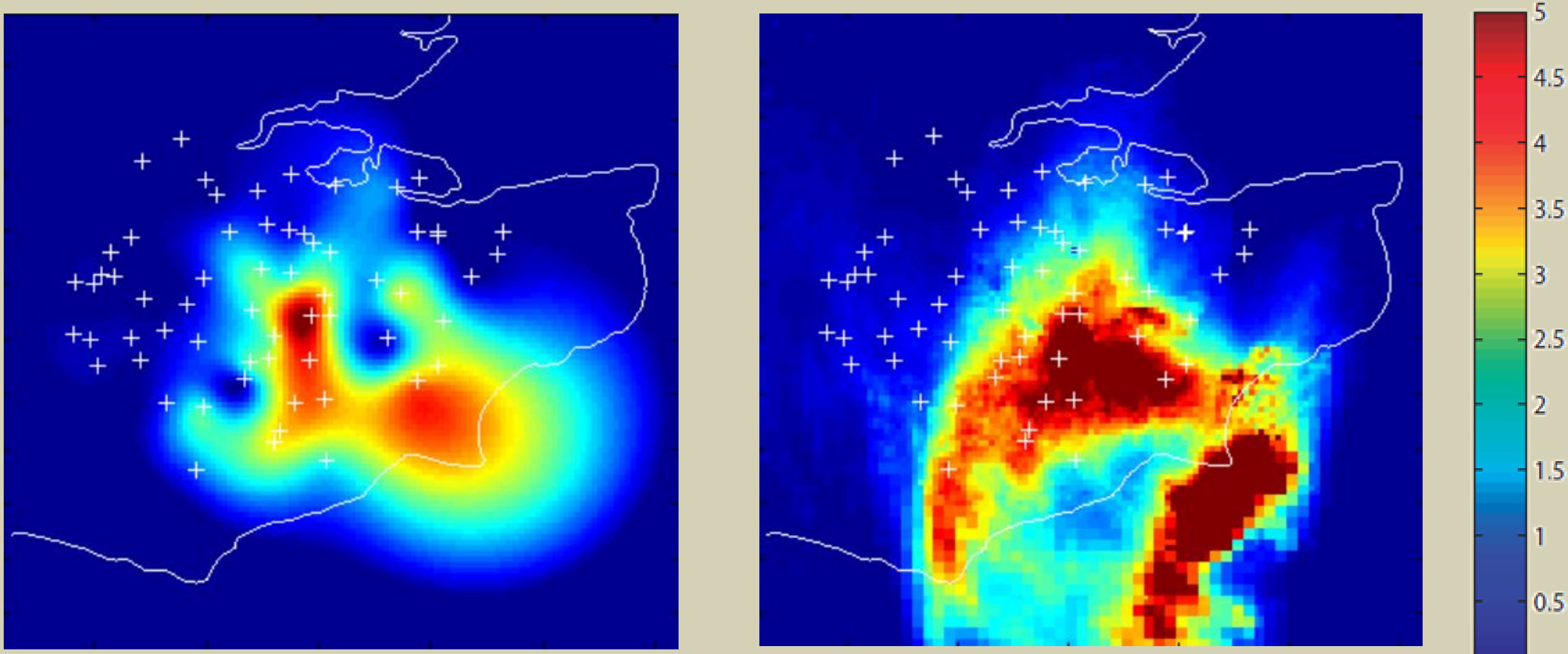
Anomalous propagation

Bright Band phenomena



Rain gauge biharmonic spline interpolation

Quantitative radar estimation



Precipitation fields for Kent area in 20th of July, 2007 (mm/h)

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Evaluation of:

-Conditional merging (Ehret y Pegram 2002). With 3 interpolation strategies:

1.-CM LI, Elastic frame fitting with linear triangulation.

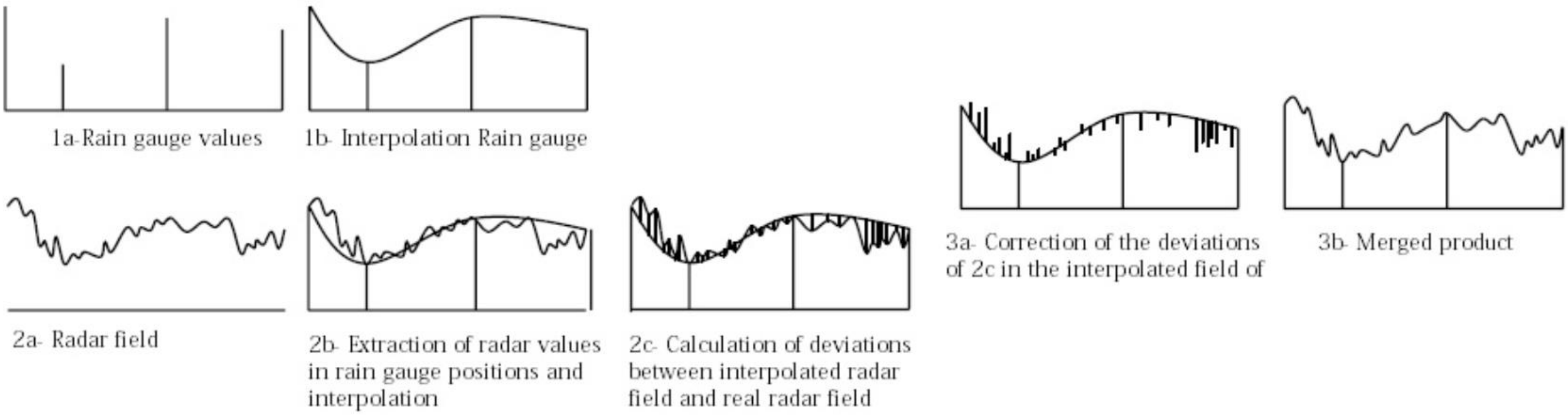
2.-CM V4, Biharmonic Spline interpolation.

3.-KRE, Kriging with radar error, Ordinary kriging method.

- 4.- KED, multivariate Geostatistic method, Kriging with external drift

2- Methods

Conditional merging workflow (Ehret and Pegram 2002).



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2- Methods

3 interpolation strategies:

1.-CMLI, Linear triangulation and elastic surface fitting.

2.-CMV4, Biarmonic spline interpolation.

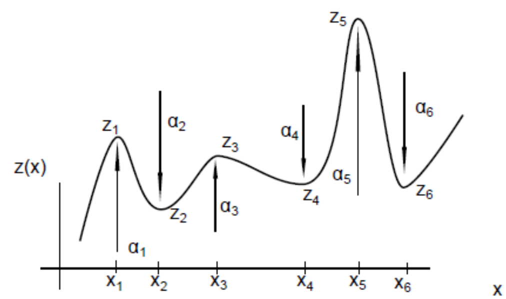
$$\nabla^4 z(x) = \sum_{j=1}^{N} \alpha_j \delta(x - x_j)$$

$$z(x_i) = z_i$$

$$\phi(x) = |x|\, 2(ln\,|x| - 1)$$

$$z(x) = \sum_{j=1}^{N} \alpha_j\, |x - x_j|\, 2(ln\,|x - x_j| - 1)$$

$$z_i = \sum_{j=1}^{N} \alpha_j \phi(x_i - x_j)$$



3.-KRE, Kriging with radar error

Kriging problem: *Best linear unbiased estimator*

Rainfall is considered an stochastic variable.

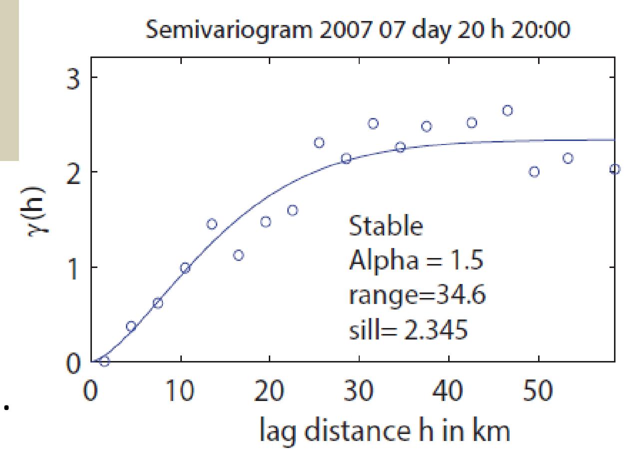
Spatial characterization of rainfall measurements (rain gauges) R(xi)
Semivariogram representation, "stable" structure.

$$\gamma(\mathbf{h}) = \frac{1}{2 \cdot N(\mathbf{h})} \cdot \sum_{i=1}^{N(\mathbf{h})} (R(x_i) - R(x_i + \mathbf{h}))^2$$

$$\gamma_\alpha(\mathbf{h}) = b \cdot (1 - e^{-\frac{|\mathbf{h}|^\alpha}{a}})$$

α =1.5

a and b parameters to estimate, reflecting sill and range of the semivariogram.



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$$\hat{R}(x_0) = \sum_{i=1}^{n} \left(\omega_i(x_0) \cdot R(x_i)\right)$$

3.-KRE, Kriging with radar error

$$\sum_{j=1}^{n} \omega_j \gamma_{ij} + \mu = \gamma_{i0}, \quad \forall i = 1, \ldots, n$$

$$\sum_{i=1}^{n} \omega_i = 1$$

$$\begin{bmatrix} \gamma_{1,1} & \gamma_{1,2} & \cdots & \gamma_{1,n} & 1 \\ \gamma_{2,1} & \gamma_{2,2} & \cdots & \gamma_{2,n} & 1 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \gamma_{n,1} & \gamma_{n,2} & \cdots & \gamma_{n,n} & 1 \\ 1 & 1 & \cdot & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} \omega_1 \\ \omega_2 \\ \vdots \\ \omega_n \\ \mu \end{bmatrix} = \begin{bmatrix} \gamma_{1,0} \\ \gamma_{2,0} \\ \vdots \\ \gamma_{n,0} \\ 1 \end{bmatrix}$$

2- Methods

KED, Kriging with external drift. (kriging multivariate)

Direct mix between distributed radar data and punctual rain gauge measurements.

$$E[R(x)] = \sum_{k=0}^{p} \beta_k f_k(x) \quad E[R(x)] = \beta_0 + \beta_r f_{rad}(x)$$

$$\sum_{j=1}^{n} \omega_j \gamma_{ij} + \mu_0 + \mu_r \cdot Z_i = \gamma_{i0}$$

$$\sum_{i=1}^{n} \omega_i = 1 \qquad \sum_{j=1}^{n} \omega_j Z_j = Z_0$$

$$\begin{bmatrix} \gamma_{1,1} & \gamma_{1,2} & \cdots & \gamma_{1,n} & Z_1 & 1 \\ \gamma_{2,1} & \gamma_{2,2} & \cdots & \gamma_{2,n} & Z_2 & 1 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ \gamma_{n,1} & \gamma_{n,2} & \cdots & \gamma_{n,n} & Z_n & 1 \\ Z_1 & Z_2 & \cdot & Z_n & 0 & 0 \\ 1 & 1 & \cdot & 1 & 0 & 0 \end{bmatrix} \cdot \begin{bmatrix} \omega_1 \\ \omega_2 \\ \vdots \\ \omega_n \\ \mu_r \\ \mu_0 \end{bmatrix} = \begin{bmatrix} \gamma_{1,0} \\ \gamma_{2,0} \\ \vdots \\ \gamma_{n,0} \\ Z_0 \\ 1 \end{bmatrix}$$

3- Case study

-Application of the 4 algorithms to 6 storm data sets from July 2007 in Kent, England

1 - Data quality processing

2- Selection and storm classification (convective/stratiform)

4- Merging for hourly accumulation

3- Cross comparison of the data using RG as reference values

Bias, RMSE, Correlation coeff, Ratio of variances

Data:

73 Tipping bucket rain gauge
0.2 mm Volume threshold

Radar C-Band composite (NIMROD PROJECT)
1 km^2, 5min

Environment Agency

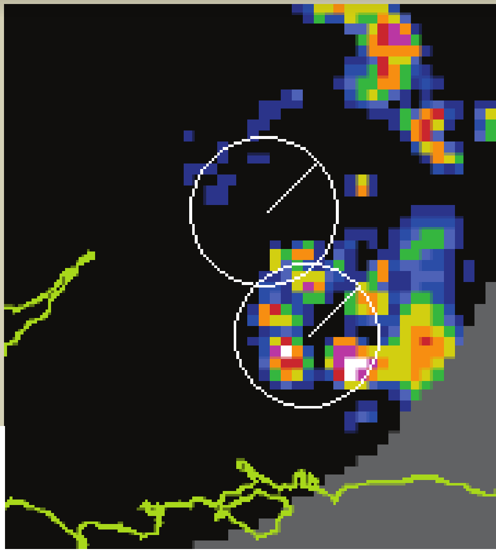
British Atmospheric Data Centre

Met Office

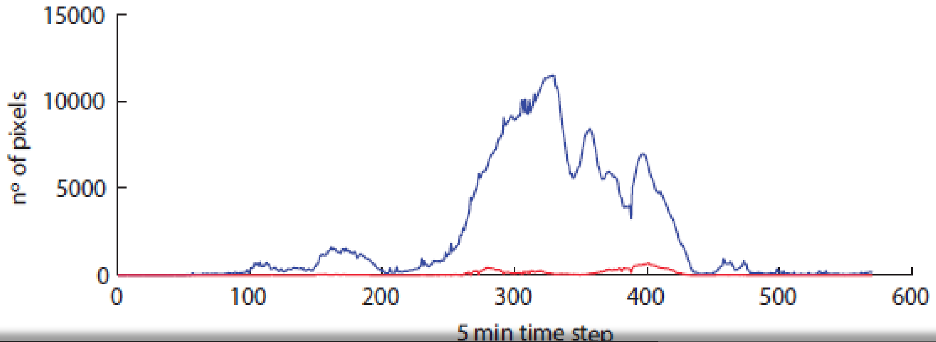
Storm classification

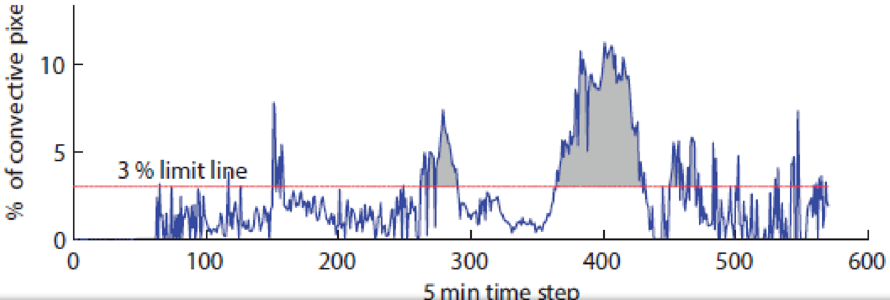
Importance of Convective-stratiform convective, DSD.
Possible interaction with the algorithms.

Development of the 2D classifier algorithm.
Study of the backscattered power intensity.



$$Pixel\ Convectivo\ si: \begin{cases} Z_{pixel} - \langle\langle Z_{back}\rangle\rangle > 10dB \\ Z_{pixel} > 40dB \end{cases}$$





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Storm Classification.

Storm n^o	Date (2007 07)	Time frames	n^o RG	Maximun accumulated rainfall (mm) RG	Radar at RG	Radar field	Type
1	04 09:00 - 05 00:00	16 h	62	7.6	14.1	21.2	C
2	05 12:00 - 06 01:00	14 h	62	4.6	2.9	4.57	S
3	19 21:00 - 20 14:00	18 h	62	54.8	39.8	83.3	C
4	23 10:00 - 24 01:00	16 h	62	29.6	20.9	29.4	S
5	27 16:00 - 28 04:00	13 h	62	6.8	4.1	9.7	S
6	28 18:00 - 29 09:00	16 h	62	20	8.2	23.5	S

4- Results and discussion

Storm 1 Method	Bias (mm/h)	RSME (mm/h)	Corr (-)	RVar (-)
Radar	0.05	0.88	0.48	0.53
KRE	-0.17	1.11	0.289	1.32
CMV4	-0.244	1.43	0.17	2.26
CMLI	-0.259	1.45	0.169	2.31
KED	-0.1739	0.828	0.426	0.507

Storm 3 Method	Bias (mm/h)	RSME (mm/h)	Corr (-)	RVar (-)
Radar	-0.41	2.71	0.84	0.33
KRE	-0.054	1.62	0.938	1.09
CMV4	-0.039	1.62	0.937	1.07
CMLI	-0.05	1.62	0.938	1.07
KED	-0.028	1.477	0.947	1.05

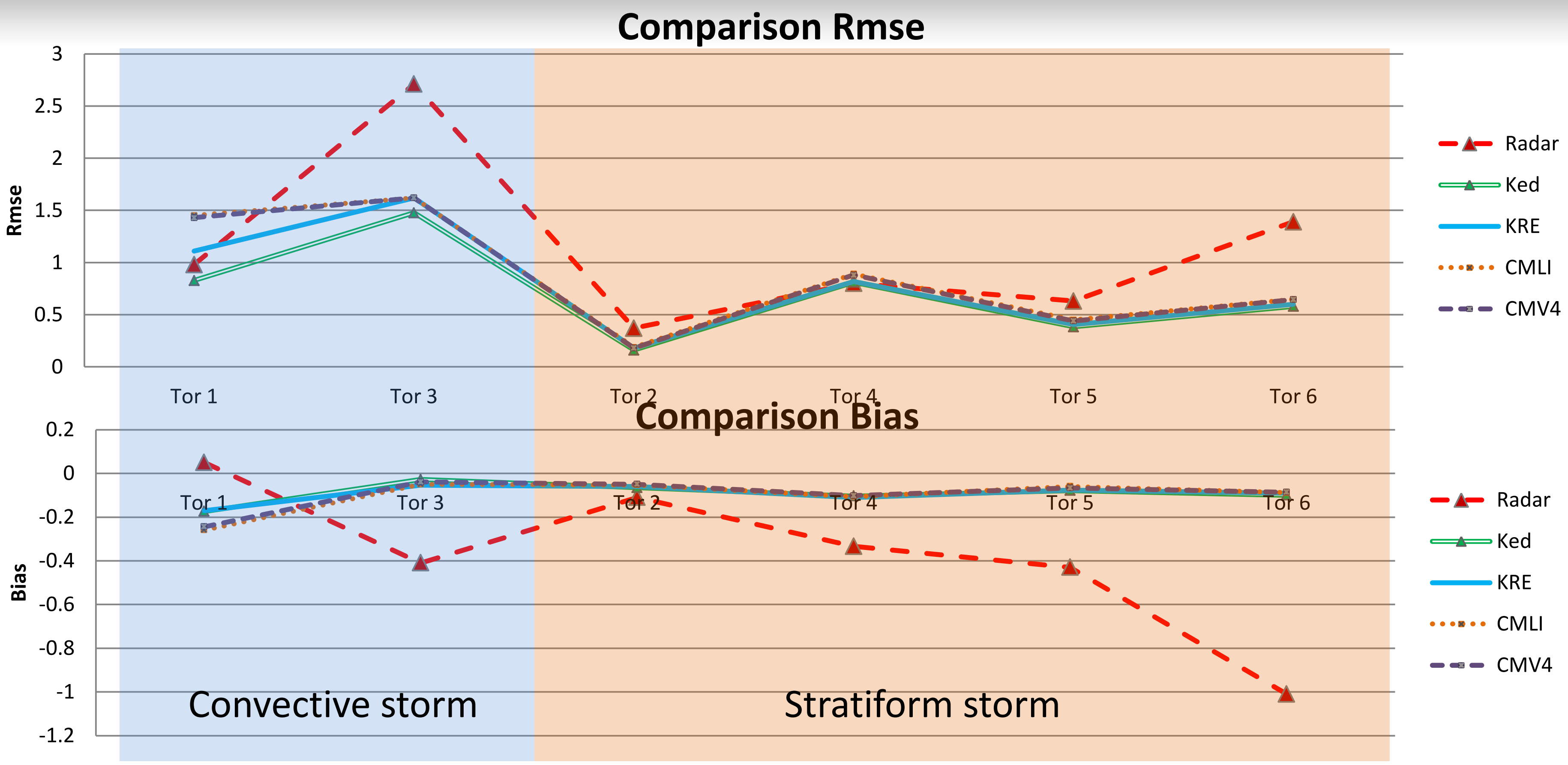
Storm 5 Method	Bias (mm/h)	RSME (mm/h)	Corr (-)	RVar (-)
Radar	-0.43	0.63	0.56	0.26
KRE	-0.076	0.404	0.734	0.82
CMV4	-0.067	0.44	0.71	1.04
CMLI	-0.06	0.449	0.701	1.05
KED	-0.0785	0.383	0.758	0.755

Storm 2 Method	Bias (mm/h)	RSME (mm/h)	Corr (-)	RVar (-)
Radar	-0.11	0.37	0.02	1.13
KRE	-0.06	0.179	0.76	1
CMV4	-0.05	0.18	0.766	1.2
CMLI	-0.052	0.1878	0.762	1.23
KED	-0.0655	0.16	0.79	0.866

Storm 4 Method	Bias (mm/h)	RSME (mm/h)	Corr (-)	RVar (-)
Radar	-0.334	0.8	0.86	0.48
KRE	-0.11	0.819	0.82	0.96
CMV4	-0.102	0.88	0.8	1.05
CMLI	-0.106	0.89	0.79	1.05
KED	-0.1037	0.81	0.82	0.99

Storm 6 Method	Bias (mm/h)	RSME (mm/h)	Corr (-)	RVar (-)
Radar	-1.01	1.39	0.27	0.117
KRE	-0.09	0.6	0.8	0.89
CMV4	-0.086	0.645	0.79	1.03
CMLI	-0.088	0.647	0.79	1.04
KED	-0.1	0.58	0.81	0.87

4- Results and discussion



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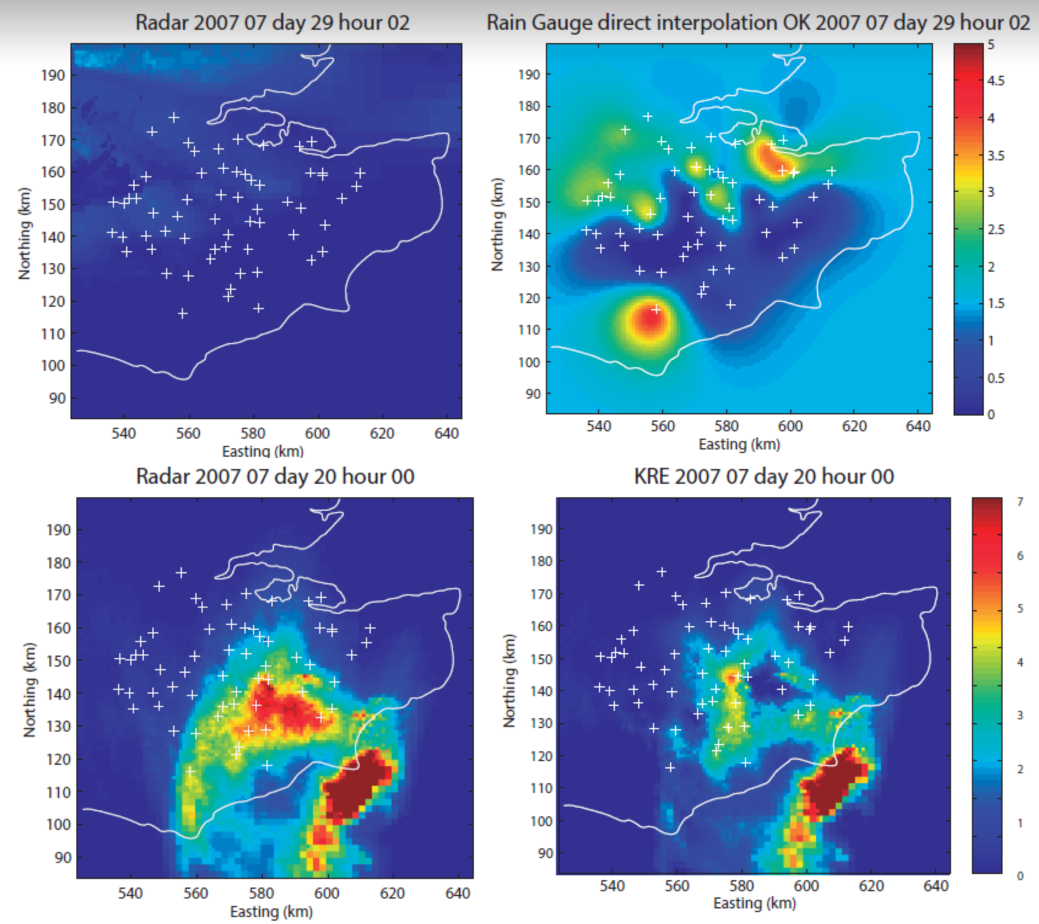
4- Results and discussion

Instabilities in the method:

- Bad initial conditioning.
- High influence of the rain gauges errors.

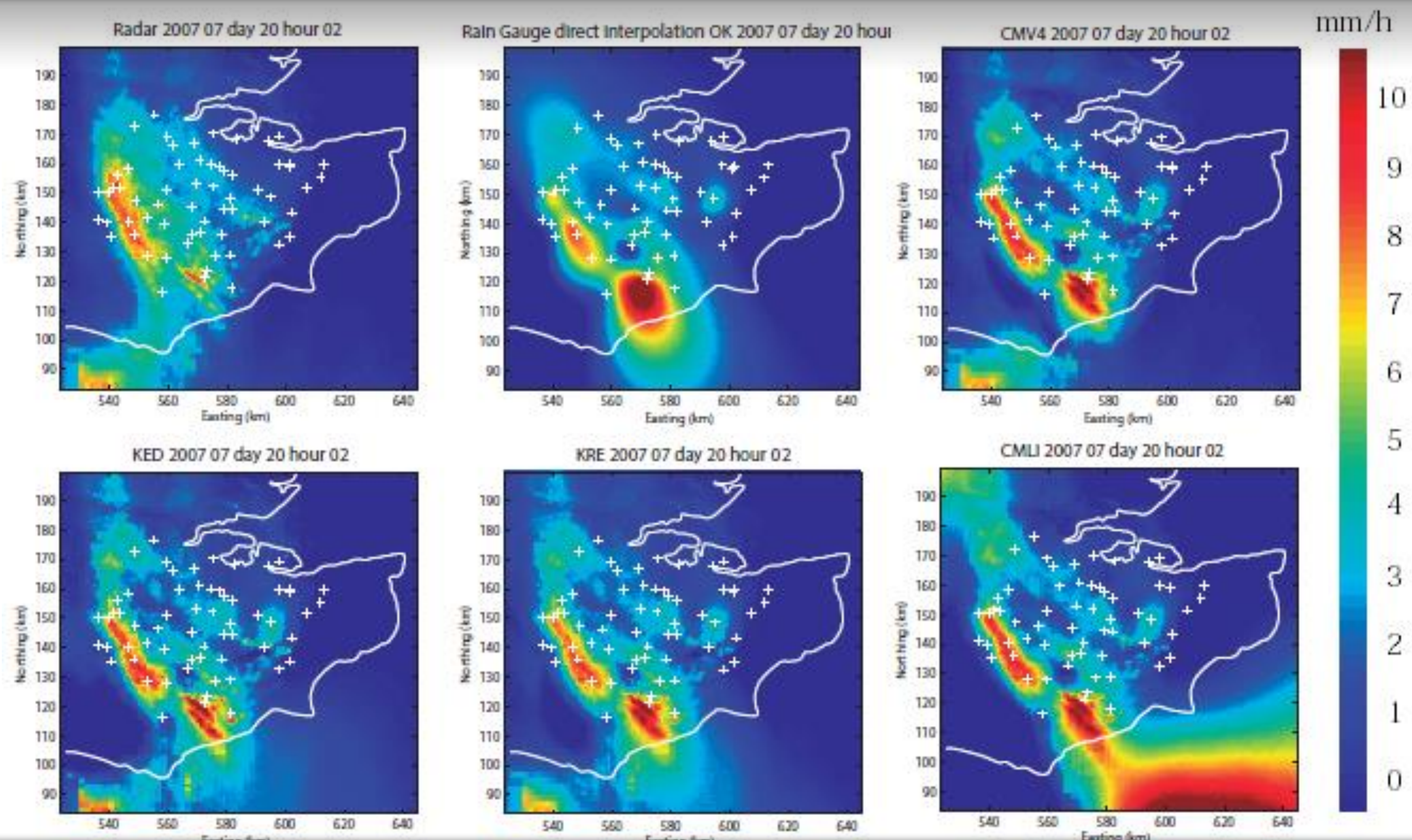
Developments proposed:

- Radar feeded filters for rain gauge errors.
- Non-parametric semivariograms.



4- Results and discussion

Estimation of high spatial resolution precipitation fields using merged rain gauge - radar data.



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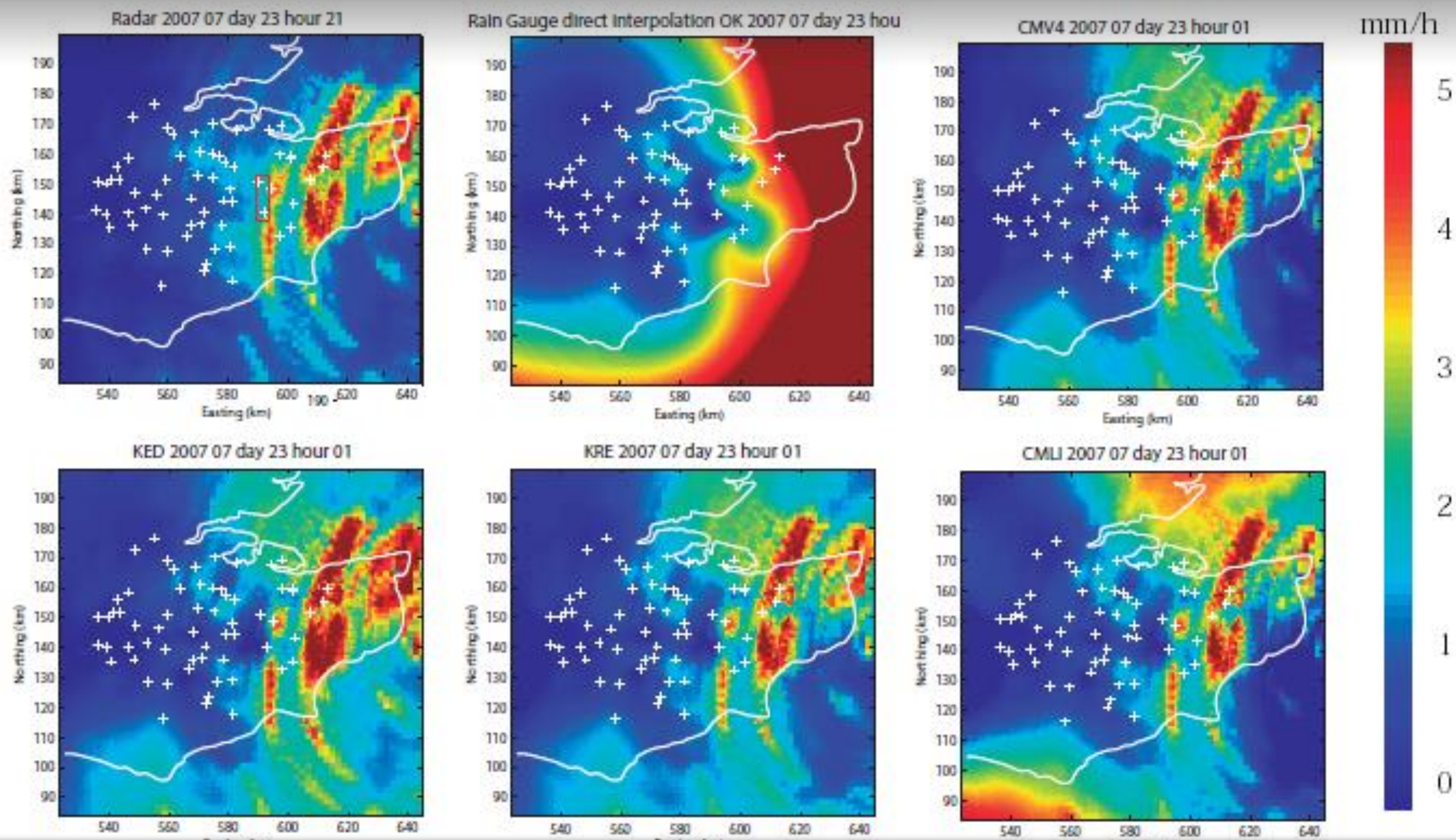
4- Results and discussion



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5- Conclusions

1- The use of quality radar estimations is essential if the target is to reproduce the spatial variability of rainfall with detail (1km^2). Application of merging techniques is still necesary since radar can present important errors.

2- It is necesary the use of high quality pluviometric information, since they are considered as true ground in this applications (nevertheless they are not error exempt).

3- CMLI and CMV4 are too often affected by merging instabilities.
They are outperform by KRE and KED. Both present a good representation of most rainfall structures. Still KED behave better under convective cases. This is possibly due

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THANKS FOR YOUR ATTENTION