Rain Gain

Investing in Opportunities

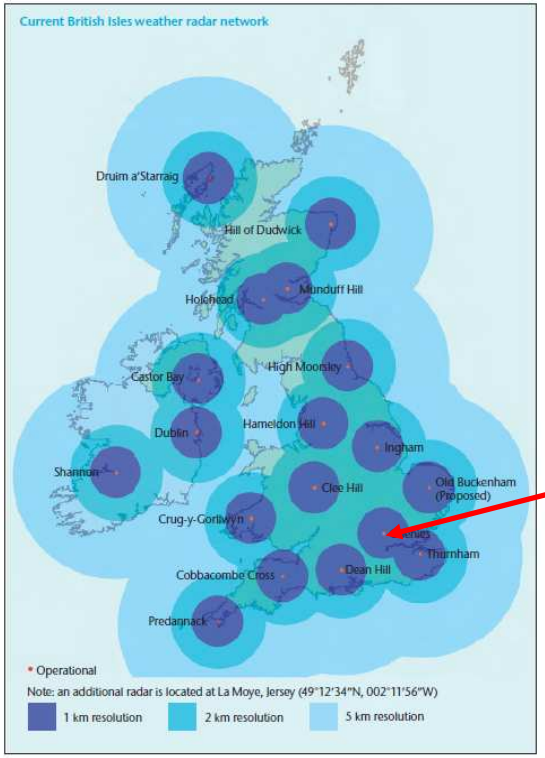
This project has received European Regional Development Funding through INTERREG IV B.

INTERREG IVB

London Project Meeting

15-17 April 2013

Field Trip : Met Office
C-Band radar of Chenies



Met Office

Picture:
Auguste Gires

Overview

Stairs inside the tower

Control unit

Pump to inject air in the wave guide to keep it dry

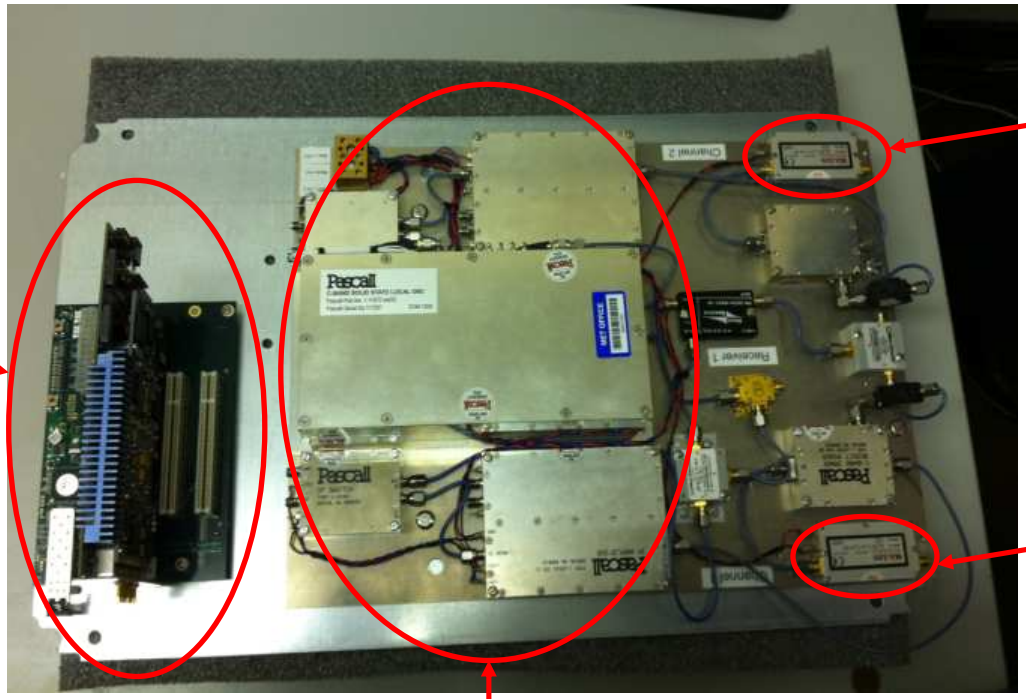
(Notes:
- already 1 dB of attenuation with the current length)
- Météo-France cabins are just underneath the radar which is much better but much more expensive. Except for this radar Met-Off does not have concrete tower but only “Echafaudage”)

Standard PC running Cyclops that manage the radar and processing the signal

Pre-processed raw data (maps of Z_H, Z_V, K_{dp}… sent to Exeter

7 days of data are stored on site

Receiver



Vertical signal amplifier

Analog to digital signal

Horizontal signal amplifier

Installed behind the antenna

(for dual pol. transmitting the data down the cabin could affect its quality)

Basic signal processing units

“Raw” data

Wave guide

(size proportional to wave length)

Transmitter

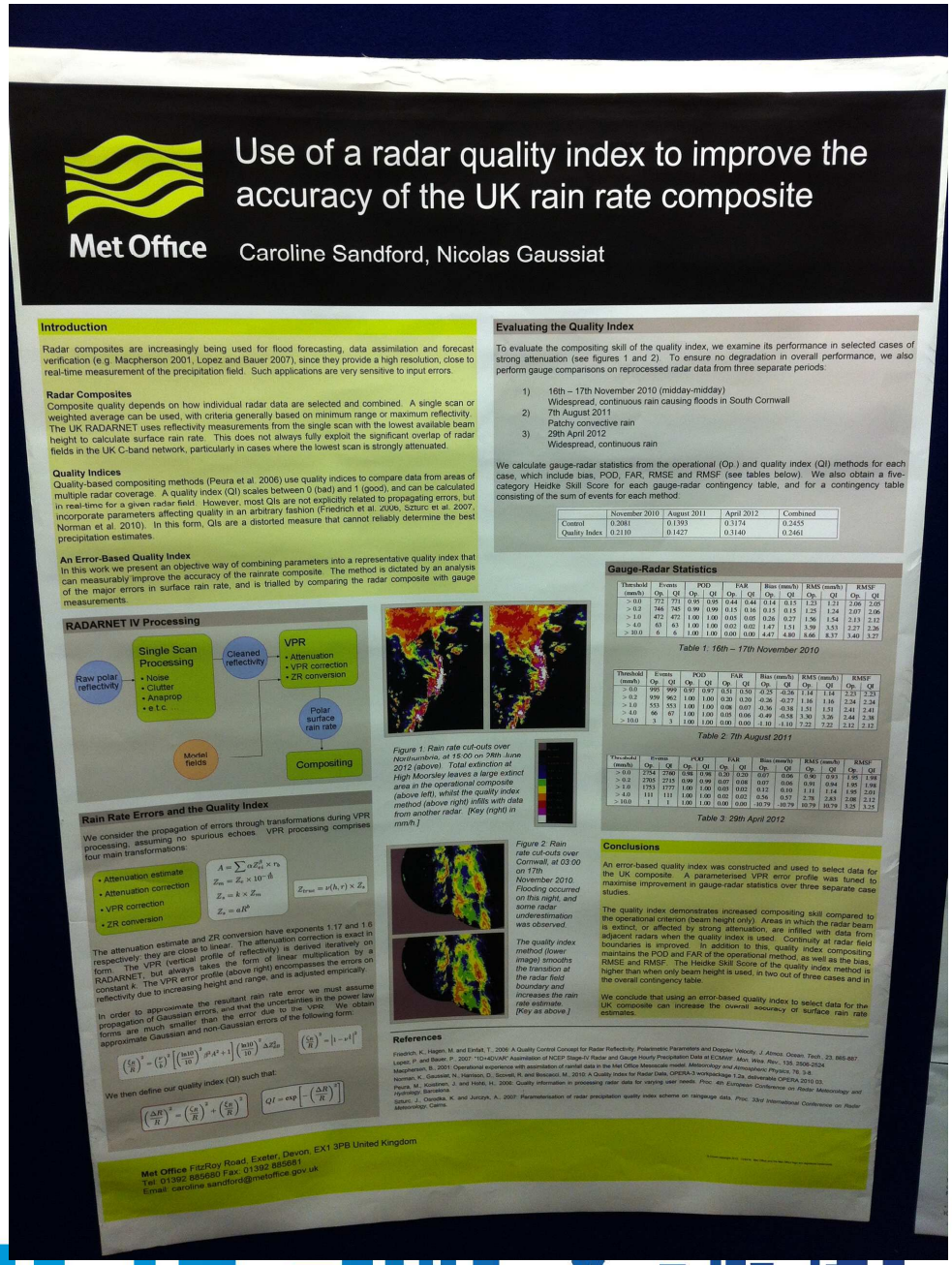
Met. Office currently upgrading its C-band radar to dual pol.

Doing it in-house, i.e. a group of engineers developed the new design and they are simply buying the raw material:

→ Much less expensive

→ Keeping a high level of expertise

(Météo-France chose to let Selex do everything)



Use of a radar quality index to improve the accuracy of the UK rain rate composite

Met Office

Caroline Sandford, Nicolas Gaussiat

Introduction

Radar composites are increasingly being used for flood forecasting, data assimilation and forecast verification (e.g. Macpherson 2001, Lopez and Bauer 2007), since they provide a high resolution, close to real-time measurement of the precipitation field. Such applications are very sensitive to input errors.

Radar Composites

Composite quality depends on how individual radar data are selected and combined. A single scan or weighted average can be used, with criteria generally based on minimum range or maximum reflectivity. The UK RADARNET uses reflectivity measurements from the single scan with the lowest available beam height to calculate surface rain rate. This does not always fully exploit the significant overlap of radar fields in the UK C-band network, particularly in cases where the lowest scan is strongly attenuated.

Quality Indices

Quality-based compositing methods (Peura et al. 2006) use quality indices to compare data from areas of multiple radar coverage. A quality index (QI) scales between 0 (bad) and 1 (good), and can be calculated in real-time for a given radar field. However, most QIs are not explicitly related to propagating errors, but incorporate parameters affecting quality in an arbitrary fashion (Friedrich et al. 2006, Szturc et al. 2007, Norman et al. 2010). In this form, QIs are a distorted measure that cannot reliably determine the best precipitation estimates.

An Error-Based Quality Index

In this work we present an objective way of combining parameters into a representative quality index that can measurably improve the accuracy of the rainrate composite. The method is dictated by an analysis of the major errors in surface rain rate, and is trialled by comparing the radar composite with gauge measurements.

RADARNET IV Processing

Rain Rate Errors and the Quality Index

We consider the propagation of errors through transformations during VPR processing, assuming no spurious echoes. VPR processing comprises four main transformations:

- Attenuation estimate
- Attenuation correction
- VPR correction
- ZR conversion

$$A = \sum \alpha Z_m^{\beta} \times r_b$$
$$Z_m = Z_c \times 10^{-\frac{A}{10}}$$
$$Z_s = k \times Z_m$$
$$Z_s = aR^b$$
$$Z_{Error} = \nu(h,r) \times Z_s$$

The attenuation estimate and ZR conversion have exponents 1.17 and 1.6 respectively: they are close to linear. The attenuation correction is exact in form. The VPR (vertical profile of reflectivity) is derived iteratively on RADARNET, but always takes the form of linear multiplication by a constant k. The VPR error profile (above right) encompasses the errors on reflectivity due to increasing height and range, and is adjusted empirically.

In order to approximate the resultant rain rate error we must assume propagation of Gaussian errors, and that the uncertainties in the power law forms are much smaller than the error due to the VPR. We obtain approximate Gaussian and non-Gaussian errors of the following form.

$$\left(\frac{\Delta R}{R}\right)^2 = \left(\frac{\Delta c}{c}\right)^2 + \left(\frac{\ln 10}{10}\right)^2 \beta^2 A^2 + 1 \left(\frac{\ln 10}{10}\right)^2 \Delta Z_m^2 \qquad \left(\frac{\Delta R}{R}\right)^2 = \left|1 - \nu\right|^2$$

We then define our quality index (QI) such that:

$$\left(\frac{\Delta R}{R}\right)^2 = \left(\frac{\Delta c}{c}\right)^2 + \left(\frac{\Delta b}{b}\right)^2 \qquad QI = \exp\left[-\left(\frac{\Delta R}{R}\right)^2\right]$$

Figure 1: Rain rate cut-outs over Northumbria, at 15:00 on 29th June 2012 (above). Total extinction at High Moorsley leaves a large extinct area in the operational composite (above left), whilst the quality index method (above right) infills with data from another radar. [Key (right) in mm/h.]

Figure 2: Rain rate cut-outs over Cornwall, at 03:00 on 17th November 2010. Flooding occurred on this night, and some radar underestimation was observed.

The quality index method (lower image) smooths the transition at the radar field boundary and increases the rain rate estimate. [Key as above.]

Evaluating the Quality Index

To evaluate the compositing skill of the quality index, we examine its performance in selected cases of strong attenuation (see figures 1 and 2). To ensure no degradation in overall performance, we also perform gauge comparisons on reprocessed radar data from three separate periods:

1) 16th – 17th November 2010 (midday-midday)
   Widespread, continuous rain causing floods in South Cornwall
2) 7th August 2011
   Patchy convective rain
3) 29th April 2012
   Widespread, continuous rain

We calculate gauge-radar statistics from the operational (Op.) and quality index (QI) methods for each case, which include bias, POD, FAR, RMSE and RMSF (see tables below). We also obtain a five-category Heidke Skill Score for each gauge-radar contingency table, and for a contingency table consisting of the sum of events for each method:

	November 2010	August 2011	April 2012	Combined
Control	0.2081	0.1393	0.3174	0.2455
Quality Index	0.2110	0.1427	0.3140	0.2461

Gauge-Radar Statistics

Threshold (mm/h)	Events Op.	Events QI	POD Op.	POD QI	FAR Op.	FAR QI	Bias (mm/h) Op.	Bias (mm/h) QI	RMS (mm/h) Op.	RMS (mm/h) QI	RMSF Op.	RMSF QI
> 0.0	772	771	0.95	0.95	0.44	0.44	0.14	0.15	1.23	1.23	2.06	2.05
> 0.2	746	745	0.99	0.99	0.15	0.16	0.15	0.15	1.25	1.24	2.07	2.06
> 1.0	472	472	1.00	1.00	0.03	0.03	0.26	0.27	1.56	1.54	2.13	2.12
> 4.0	63	63	1.00	1.00	0.02	0.02	1.47	1.51	3.59	3.53	2.27	2.26
> 10.0	6	6	1.00	1.00	0.00	0.00	4.47	4.80	8.66	8.37	3.40	3.27

Table 1: 16th – 17th November 2010

Threshold (mm/h)	Events Op.	Events QI	POD Op.	POD QI	FAR Op.	FAR QI	Bias (mm/h) Op.	Bias (mm/h) QI	RMS (mm/h) Op.	RMS (mm/h) QI	RMSF Op.	RMSF QI
> 0.0	995	999	0.97	0.97	0.51	0.50	-0.25	-0.26	1.14	1.14	2.23	2.23
> 0.2	959	962	1.00	1.00	0.20	0.20	-0.26	-0.27	1.16	1.16	2.24	2.24
> 1.0	553	553	1.00	1.00	0.08	0.07	-0.36	-0.38	1.51	1.51	2.41	2.41
> 4.0	66	67	1.00	1.00	0.05	0.06	-0.49	-0.58	3.30	3.26	2.44	2.38
> 10.0	3	3	1.00	1.00	0.00	0.00	-1.10	-1.10	7.22	7.22	2.12	2.12

Table 2: 7th August 2011

Threshold (mm/h)	Events Op.	Events QI	POD Op.	POD QI	FAR Op.	FAR QI	Bias (mm/h) Op.	Bias (mm/h) QI	RMS (mm/h) Op.	RMS (mm/h) QI	RMSF Op.	RMSF QI
> 0.0	2754	2760	0.98	0.98	0.20	0.20	0.07	0.06	0.90	0.93	1.95	1.94
> 0.2	2705	2715	0.99	0.99	0.07	0.08	0.07	0.06	0.91	0.94	1.95	1.94
> 1.0	1753	1777	1.00	1.00	0.03	0.02	0.12	0.10	1.11	1.14	1.95	2.01
> 4.0	111	111	1.00	1.00	0.02	0.02	0.56	0.57	2.78	2.83	2.08	2.12
> 10.0	1	1	1.00	1.00	0.00	0.00	-10.79	-10.79	10.79	10.79	3.25	3.25

Table 3: 29th April 2012

Conclusions

An error-based quality index was constructed and used to select data for the UK composite. A parameterised VPR error profile was tuned to maximise improvement in gauge-radar statistics over three separate case studies.

The quality index demonstrates increased compositing skill compared to the operational criterion (beam height only). Areas in which the radar beam is extinct, or affected by strong attenuation, are infilled with data from adjacent radars when the quality index is used. Continuity at radar field boundaries is improved. In addition to this, quality index compositing maintains the POD and FAR of the operational method, as well as the bias, RMSE and RMSF. The Heidke Skill Score of the quality index method is higher than when only beam height is used, in two out of three cases and in the overall contingency table.

We conclude that using an error-based quality index to select data for the UK composite can increase the overall accuracy of surface rain rate estimates.

References

Friedrich, K., Hagen, M. and Einfalt, T., 2006: A Quality Control Concept for Radar Reflectivity, Polarimetric Parameters and Doppler Velocity. *J. Atmos. Ocean. Tech.*, 23, 865-887.

Lopez, P. and Bauer, P., 2007: "1D+4DVAR" Assimilation of NCEP Stage-IV Radar and Gauge Hourly Precipitation Data at ECMWF. *Mon. Wea. Rev.*, 135, 2506-2524.

Macpherson, B., 2001: Operational experience with assimilation of rainfall data in the Met Office Mesoscale model. *Meteorology and Atmospheric Physics*, 76, 3-8.

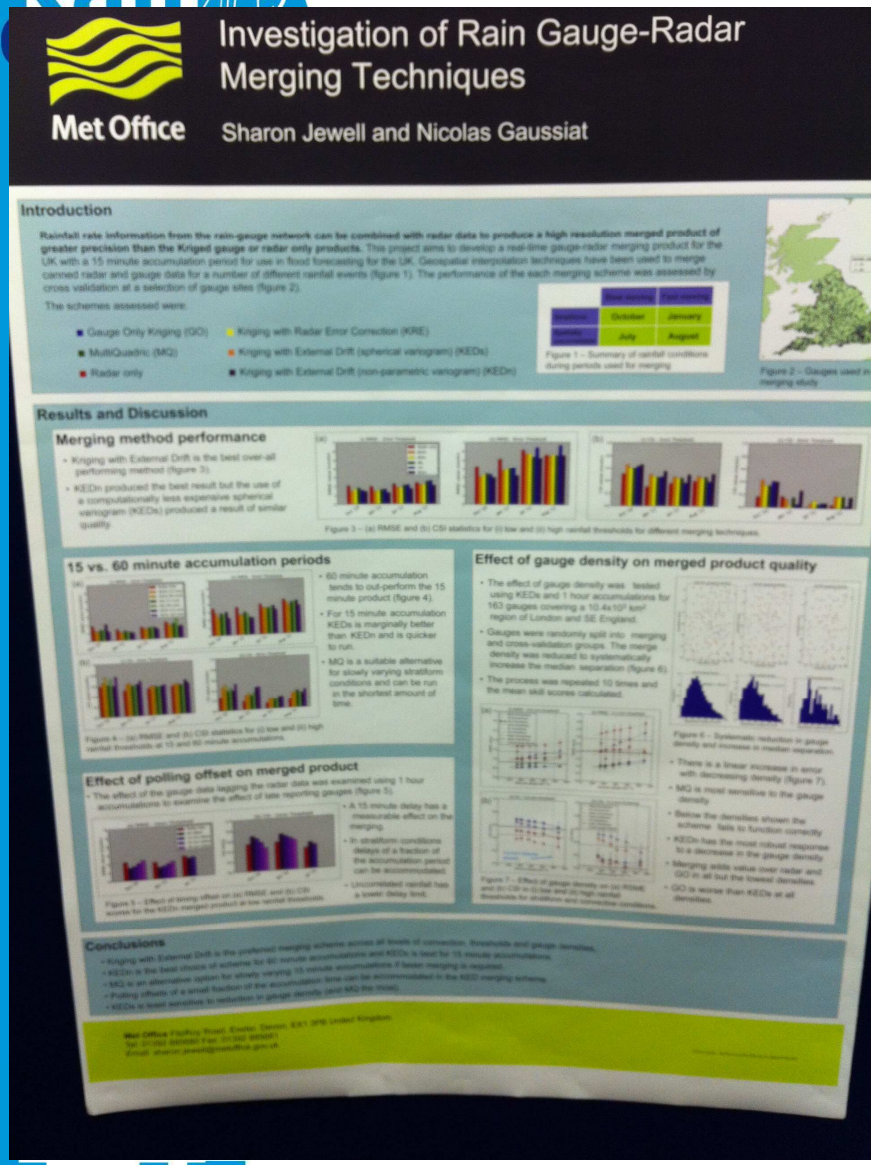
Norman, K., Gaussiat, N., Harrison, D., Scovell, R. and Beecroft, M., 2010: A Quality Index for Radar Data. OPERA-3 workpackage 1.2a, deliverable OPERA 2010 03.

Peura, M., Koistinen, J. and Hohti, H., 2006: Quality information in processing radar data for varying user needs. *Proc. 4th European Conference on Radar Meteorology and Hydrology*, Barcelona.

Szturc, J., Ośrodka, K. and Jurczyk, A., 2007: Parameterisation of radar precipitation quality index scheme on raingauge data. *Proc. 33rd International Conference on Radar Meteorology*, Cairns.

Met Office FitzRoy Road, Exeter, Devon, EX1 3PB United Kingdom
Tel: 01392 885680 Fax: 01392 885681
Email: caroline.sandford@metoffice.gov.uk

Météo-France is developing the same kind of stuff.



Jacqueline Sugier (head of radar signal processing at Met. Off.) believes that merging will still be needed with rain gauges even with dual pol because radars are still measuring in altitude and not on the ground)