USE OF A RADAR QUALITY INDEX TO IMPROVE THE ACCURACY OF THE UK RAIN RATE COMPOSITE

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Abstract

Significant overlap in the UK radar network means that the best data for rain rate estimation can be overlooked. The algorithm used to produce the UK rain rate composite chooses data from the radar with the lowest beam height, with no further considerations on data quality. In attenuating conditions this approach can cause detection failures in the composite, even when more distant radars have detected rain; the overlap in the network is not fully exploited.

We assess the benefits of using additional information in selecting the best data for the composite. By analysing the propagation of errors through rain rate calculations, we derive a quality index directly related to rain rate error. We analyse the compositing skill of this quality index using gauge-radar statistics, and compare this to the skill of the operational criterion, with a focus on attenuated cases.

The error-based quality index reduces gauge-radar RMSE in highly attenuating cases without damage to other statistics. No statistical degradation was observed over the monthly trial.

1 Introduction

Radar composites are increasingly being used in forecasting and modelling applications (Macpherson 2001, Lopez and Bauer 2007), and have been shown to increase nowcasting skill (Lin et al. 2005). The quality of these composites depends on how individual radar data are selected and combined. The UK centralised processing system (RADARNET) calculates rain rate based on reflectivity observations with the lowest available beam height. This can be inappropriate, for example in strongly attenuated cases.

Quality-based compositing methods use normalised (0-1) quality indices to compare and select data from areas of multiple radar coverage (Peura et al. 2006). However, these indices are not explicitly related to error, but combine parameters affecting quality in an arbitrary way (Friedrich et al. 2006, Szturc et al. 2007, Norman et al. 2010).

We aim here to find an objective way of combining parameters into a representative quality index that can measureably improve the accuracy of the composite. The method of combination is dictated by an analysis of the major components of surface rainrate error, and is evaluated against rain-gauge data.

2 Error-Based Quality Index

We derive a general form for the error on a processed variable, assuming that propagated Gaussian errors remain Gaussian. Since the power laws used here are close to linear, few inaccuracies arise from this assumption. If we define a processed variable $y = f(x)$, with true value $y_{true} = F(x_{true})$, errors in y are a sum of uncertainty in the functional form f and the propagated uncertainty in x. An expansion returns:

$$\Delta y^2 = |f(x) - F(x)|^2 + |F(x) - F(x + \zeta_x)|^2 + \left(\frac{dF}{df}\right)^2 \left(\frac{df}{dx}\right)^2 \xi_x^2 \tag{1}$$

where ξ_x and ζ_x are the Gaussian and non-Gaussian components of error on x.

Rainrate Error

To obtain a form for error in rain rate R, we consider the function:

$$R = R(Z_s(Z_m(Z_e, A(Z_e)))) \tag{2}$$

where Z_s is projected surface reflectivity, Z_m measured reflectivity at altitude, Z_e actual reflectivity and A estimated attenuation. We describe this as a series of transformations: estimated dB attenuation $A(Z_e)$, attenuation correction $Z_m(Z_e, A)$, VPR correction $Z_s(Z_m)$ and ZR conversion $R(Z_s)$: the main processes (after filtering) that occur in RADARNET. We approximate these transformations as:

$$A = \sum_i \alpha Z_{ei}^{\beta} \times r_b \ , \quad Z_m = Z_e \times 10^{-\frac{A}{10}}$$
$$Z_s = k \times Z_m \ , \quad Z_s = aR^b$$

where k is independent of Z_m.

We also require a function describing the error in our VPR correction. If the true surface reflectivity corresponding to Z_s is Z_{true}, we define:

$$Z_{true} = \nu(h,r) \times Z_s$$

We approximate this error as a linearly increasing function of height and range:

$$\nu(h,r) = \left(\frac{h+h_0}{h_0}\right)\left(\frac{r+r_0}{r_0}\right) \tag{3}$$

where h_0 are r_0 are constants to be determined.

Applying equation 1 to each of these in turn, and assuming that errors in functional form (other than VPR) are negligible, we obtain Gaussian and non-Gaussian components of proportional rain rate error as follows:

$$\left(\frac{\Delta R}{R}\right)^2 = \left(\frac{\zeta_R}{R}\right)^2 + \left(\frac{\xi_R}{R}\right)^2 \tag{4}$$

$$\left(\frac{\zeta_R}{R}\right)^2 = \left|1-\nu^{\frac{1}{b}}\right|^2 \tag{5}$$

$$\left(\frac{\xi_R}{R}\right)^2 = \left(\frac{\nu}{b}\right)^2 \left[\left(\frac{\ln 10}{10}\right)^2 \beta^2 A^2 + 1\right] \left(\frac{\ln 10}{10}\right)^2 \Delta Z_{dB}^2 \tag{6}$$

where ΔZ_{dB}^2 is random reflectivity error as defined in Hogan (1998).

Quality Index

We define our quality index QI:

$$QI = \exp\left[-\left(\frac{\Delta R}{R}\right)^2\right] \tag{7}$$

Whilst there are alternatives (e.g. Fornasiero et al. (2006)), an exponential form scales automatically between 0 and 1. This ensures that it is always possible to discriminate between two points of different quality, and leaves no additional constants to be tuned.

3 Trialling with UK Radar Data

Compositing in RADARNET is done on a single scan basis. A lowest usable scan (lus) map and corresponding surface rainrate is generated for each radar, after which different radar lus's are compared, and the lowest available data at each point selected for the composite. To test the quality index as a compositing criterion, a single-site lus quality index was generated for each rainrate estimate, and the highest quality data was used in the composite.

Evaluation Criteria

The maximum quality composite was tested against the operational composite using the gauge comparison tools available on RADARNET. A 24 hour tuning period was chosen to adjust the constants in $\nu(h,r)$ for maximum improvement in gauge-radar statistics. The comparison was then extended over a month to ensure no degradation over the longer term. Of the available statistics, we focused on reducing RMSE and RMSF without degrading POD, FAR or bias.

Results

We tuned the quality index over 7th August 2011: a day of widespread convective rain. We achieved reductions of order 1% in RMSE and RMSF at all rain rates, compared to the operational composite, with greater improvements at higher rain rates where attenuation becomes significant. Statistics for the month of August 2011 showed no degradation in POD, FAR or bias. Individual case studies showed improvement in continuity at some radar field boundaries previously affected by strong attenuation.

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