Investing in Opportunities
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A wind drift correction for radar rainfall products

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1. Introduction

Quantitative precipitation estimation (QPE) by meteorological radar is affected by many uncertainties that cause radar-derived values to deviate from surface measurements. Errors in rainfall estimates arising from such factors as attenuation, beam blockage and range effects have been the subject of many studies, and a variety of schemes exist to mitigate them (Villarini and Krajewski, 2010). Such studies, however, neglect the horizontal motion of hydrometeors below the radar measurement volume, which can result in the misplacement of precipitation at the surface. This effect is known as "wind drift".

The RainGain project aims to increase cities' resilience to extreme rainfall events by improving flood forecasting over small urban catchments. For this application, a 100m-gridded radar rainfall product is desired. At this resolution the effects of wind drift can be severe (Collier, 1999), with significant downstream impacts for hydrological modelling. This work describes the design, coding and evaluation of a real-time wind drift correction on the UK radar post-processing system (Radarnet) for use in production of a high-resolution test composite for RainGain.

2. Theory

There are two possible approaches to correcting for wind drift in radar data. The prognostic approach involves tracing the path of a falling hydrometeor from the surface upwards until it intersects the lowest radar scan. The fall time for this path is calculated, and the measurement from the appropriate time is placed at the surface (Lauri et al. 2012). The diagnostic approach is to correct for instantaneous fall streak profile (FSPR): the parabolic arc visible in RHI scans in sheared wind fields (Mittermaier et al. 2004). The diagnostic correction requires only the latest wind and reflectivity data, and is thus better suited to the Radarnet architecture.

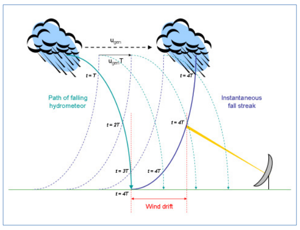

Figure 1: Schematic of wind drift as observed by radar in a wind field with constant vertical shear.

The new algorithm is an extension of that proposed by Mittermaier et al. (2004) to adjust fall streak profiles above the melting layer. The displacement due to wind drift (as marked in figure 1) is simply the integral of horizontal wind speed over increments of time. Assuming an analytical form for wind speed, and replacing time with an integral over height, displacement is fully described by:

$$\Delta x = \int_{h_b}^{0} \frac{u(h) - u_{gen}}{w(h)} \mathrm{d}h$$

Before FSPR correction, all radar PPIs in a single volume are synchronised to the composite validity time:

$$\Delta x_{synch} = u(h_b) \times (t_{comp} - t_{scan})$$

3. Implementation

The wind drift correction is applied to quality-controlled PPIs from the UK C-band radar network. A bulk advection scheme is used to calculate displacements on a pixelwise basis using the equations above.

3.1 Approximations

To calculate FSPR requires certain assumptions. In this work it is assumed that the wind profile has constant vertical shear, so that wind speed is a linear function of height. Particle fall speed is assumed to be 1m/s in the snow layer, rising linearly to 5m/s in rain through a melting layer extending 700m below freezing level (Lauri et al., 2012). The wind speed at generating level is calculated from the linear wind profile using an estimate of generating height at 2.8km above freezing level (Mittermaier et al. 2004).

3.2 Ancillary data

The additional data required for the wind drift correction are obtained from radar volume metadata (scan times, elevations and grid properties) and from UKV forecast model fields (wet bulb freezing level and 3D-gridded horizontal winds). Pixelwise wind profiles are calculated between model levels at heights of 1km and 5km.

3.3 Sensitivity

The effect of the constant shear profile assumption on wind drift displacements was simulated for beam heights of up to 1.2km, by comparing displacements calculated from the 1-5km shear to those obtained from full 63-level model profiles. The average accrued error was found to be of order 300-500m in the rain layer, rising to greater than 1km for snow measurements.

4. Evaluation

Given the theoretical precision of the wind drift correction at order 500m the algorithm was initially tested at 1km and 5km resolution, rather than being applied immediately at the 100m scale. Gauge-radar comparison statistics were obtained for single-site Cartesian radar products on grids extending to a maximum range of 55km (representative of the intended RainGain test domain). These statistics are for a selection of cases across December 2013 and January 2014, and are calculated with respect to five hourly accumulation thresholds.

In figure 2 are plotted statistics for corrected (blue) and uncorrected (red) data. The wind drift correction improves POD at most rain rates, with changes being most noticable between 1mm and 4mm hourly accumulations. However, a small increase in false alarm rate means that the equitable Heidke skill score – used as a measure of overall accuracy – is not significantly changed. By quantitative measures the wind drift correction performs well, decreasing both the bias and RMSE of radar measurements in all intensity bands.

The difference in performance on 1km and 5km grids is generally small. However, two points on these graphs are noteworthy. In the one case, POD is not so improved for 1km products at high intensities. In the other there is an increase in false alarm rate for moderate rain rate events, again at 1km resolution. Both these observations suggest the wind drift correction has less skill at 1km resolution, and could indicate an actual uncertainty in displacement calculations of order 1km or greater.

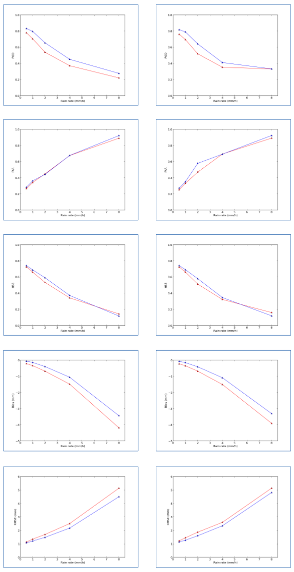

Figure 2: Gauge-radar comparison statistics for 5km (left) and 1km (right) resolution single-site products.

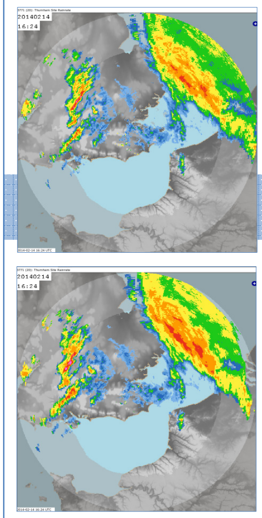

Figure 3 (left): Examples of drifted (below) and undrifted (above) single-site rain rates from Thurnham radar.

5. Conclusions

The results presented here suggest that the wind drift correction has skill for low to moderate rain rate events on kilometre-scale grids. Quantitative statistics are improved at 1km resolution for all rain rates, and increased POD is achieved in low to moderate intensity bands.

The data available for high intensity events (>8mm/h) within 55km of the nearest radar is minimal – fewer than 20 such events were recorded over the trail period. Further work is currently in progress to obtain and analyse enough high rain rate data to produce statistically reliable outcomes. Trials are also running on 100m gridded products from three radars in the UK network: Chenies, Thurnham, and the Wardon Hill research radar.

References

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