4B.5 EXPLORING NEW SYNERGIES BETWEEN RADAR DATA AND MESOSCALE MODEL FORECASTS

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1 INTRODUCTION

The Nimrod automated precipitation nowcasting system of the UK Met Office is an example of synergy between radar and mesoscale model forecasts, where the combination of the two is superior to the individual components (Golding, 1998). For example, the model freezing level forecasts are used in the vertical profile of reflectivity (VPR) correction scheme. The current correction scheme used by the UK Met Office (Kitchen *et al.*, 1994) uses a standard vertical profile where the bright band depth is 700 m, with the peak 350 m below the top which is defined as the height of T_w = 0°C, obtained from the model. Mittermaier and Illingworth (2003) discuss the results of a 1-year validation of the use of the Unified Model(UM) freezing level forecasts against 94 GHz vertically-pointing cloud radar data and found that the rms error in the forecast heights is 147 m for forecasts in the t+0h to t+5h range, hence justifying the use of the UM output in the VPR correction scheme. For the UK VPR correction scheme it has been shown that errors need to be within 200 m to make an effective correction.

Jones and Macpherson (1997) have shown that the assimilation of radar-derived surface rain rates into the UM via a latent heat nudging scheme is beneficial, so it is envisaged that the more direct assimilation of, say, ice water content (IWC) derived from radar measurements in the ice could be too. Conversely, given the good performance of the UM temperature forecasts there is potential for using other model output fields such as IWC and model winds for improving the VPR and therefore surface radar rainfall estimates.

In this paper some results on the use of model winds to correct for wind drift of falling ice and snow above the freezing level. Fall streaks result in a displacement of the radar rainfall field as compared to ground measurements and this can lead to potentially disastrous errors in area rainfall distribution, especially at the urban catchment scale. Fall streaks also contribute to the large variability of VPRs in the ice, so that it has been suggested that radar-rainfall estimates from measurements in the ice are "futile" (Fabry *et al.*, 1992). For the study high-resolution radar data from the 10-cm RCRU radar at Chilbolton, southern England (51.14° N and 1.44° W) were used. The radar has a beamwidth of 0.28° and a range resolution of 300 m.

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2 HOW GOOD ARE THE MODEL WINDS?

Verification of model winds from the 1994 version of the UM mesoscale version yielded errors of 2-3 m.s^{-1} below 8 km for forecasts up to t+10h for one of the radiosonde sites in southern England (Turton *et al.*, 1994). Importantly, Turton *et al.* state that model-derived wind profiles are preferable to stale measured radiosonde profiles when the staleness is more than 3 hours. Furthermore there are only a few radiosonde ascent sites with ascents every 6 to 12 hours, whereas the model provides wind profiles at every grid point location on an hourly time step.

For the current work, single-column model wind profiles from the 2000 version of the UM (12 km horizontal grid spacing) for the Chilbolton grid reference were compared to vertical profiles of wind derived from the horizontal component of the radial Doppler wind. Fig. 1 shows such a comparison for one (range-height-indicator) RHI scan with the along-RHI component of the hourly model wind forecast. Forecasts are in the t+0h to t+5h range. Despite the discrepancies in vertical and temporal resolution between the radar and model data, the comparison is remarkably good. The plane-perpendicular profile is also shown for reference. When deriving horizontal displacements from RHI data the plane-perpendicular winds ought to be, ideally, near zero, or at the very least, small compared to the plane-parallel motion.

The comparison can be taken one step further and several scans within the same hour can be evaluated, and also the hourly forecasts on other days. Figure 2 shows

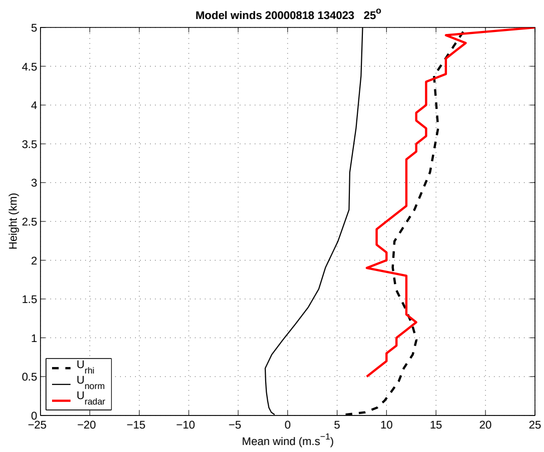

Figure 1: Wind profiles derived from the horizontal component of RHI Doppler winds and the hourly model forecast (collocated dashed and solid lines). The plane-perpendicular model wind profile (nearer 0) is also shown.

the comparison of the mean layer winds for 34 scans, spanning events between August and November 2000, and representing 10 hourly forecasts. The top of the layer is defined to be the model level closest to 4 km, the bottom being the model level closest to the freezing level. The mean layer wind calculated from Fig. 1 is but one of the data points on this graph. This suggests a good correspondence between model and radar-measured winds for a spectrum of weather systems.

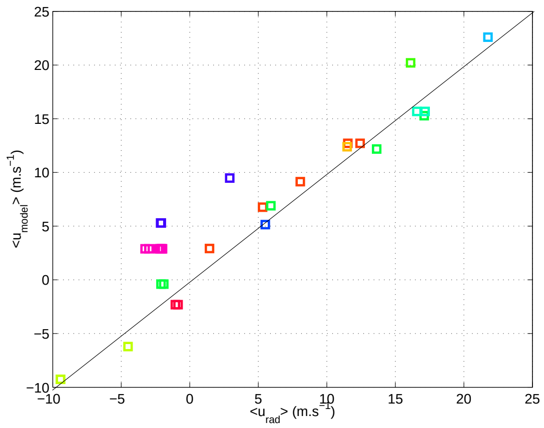

Figure 2: Comparison of mean layer-winds derived from the model in the azimuth direction and Doppler winds for 34 scans, representing 10 different model hours.

3 CALCULATING FALL STREAK PATHS

Consider the schematic representing fall streak geometry in Fig. 3.

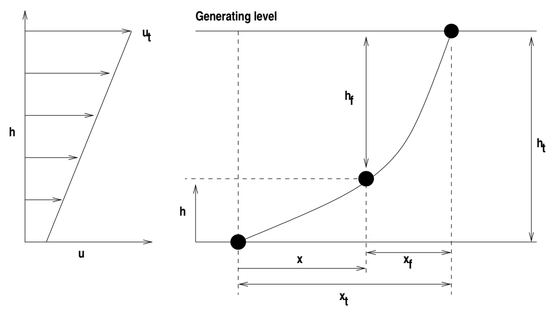

Figure 3: Fall streak geometry showing the assumed constant shear and linear wind profile. The height of the generating level is denoted as h_t. At any given height, h, the distance x can be calculated from the parabolic trajectory.

The vertical shear of the horizontal wind (in the RHI direction), S, is calculated for the layer between two reference heights, the freezing level (h = 0) and a generating height, h_t. A linear wind profile between these two heights is assumed, giving a constant shear. For RHI calculations a unidirectional shear profile is required, so that motion through the RHI plane is minimal or negligible. Given a constant fall speed, w, the displacement, x at any given height can then be calculated using Eq. 1.

$$x = \frac{S}{w}\left(h\,h_t - \frac{h^2}{2}\right) \qquad (1)$$

The displacement scales with w and depends on the generating level height h_t. A constant fall speed of 1 m.s^{-1} was found to be appropriate. The single model-column wind profile (a 12 by 12 km grid box area) was considered to be representative of the radar domain. Shown in Fig. 4 is an RHI for 18 August 2000 at 13:40 UT at 25° azimuth. A strong bright band with fall streaks is evident. Fall streak geometries and displacements based on the height that precipitation has fallen from its generating region are superimposed as white dashed lines. Displacements of between 10–15 km were calculated for layer depths of 2.5–3 km with a layer shear of 5×10^{-3} s^{-1}. The shape and displacements are captured by the calculations, suggesting that the constant fall speed, shear and single-column assumptions are sufficient.

The two fall streaks were produced using two different generating level heights, 500 m apart. The magnitude of the calculated displacements is dependent on the generating level height which for the RHI data is *a priori* information. In an operational context this will not be known and some proxy for it will need to be used. Initial investigations have shown that the height of the -15°C wet-bulb temperature may be a good indicator of the generating level height.

4 APPLICATION IN THE PLAN VIEW

Most operational radars collect data in volume mode, as a sequence of plan-position-indicators (PPI), one of the purposes being the calculation of radar-rainfall estimates. Although studying the vertical plane using RHIs is instructive and a proof of concept, the method must be applicable in plan-view. Eq. 1 can also be used to describe motions in both x- and y-directions. The displacements are range-dependent because the magnitude depends on the height of the beam above the freezing level, which increases with distance from the radar. To keep the idea of the layer between the generating and freezing levels, corrections are only applied for heights falling within the layer interval.

To illustrate the method and for validation purposes the correction is applied at ranges where 0.5° data are also available below the bright band, in the rain. Figure 5 shows the uncorrected and corrected sector scans at 2.5° on 30 March 1999 at 11:37 UT together with the 0.5° sector scan PPI at 11:35 UT, all as as 1 km averages of rain rate, R. The layer shear was 2×10^{-3} s^{-1} with the bright band located at 1.8 km. The uncorrected 2.5° PPI shows no rain in the area coincident with the 0.5° rain area, whereas after the application of the fall streak correction the rain area is now in the same place. One of the main interests of the study is the scale dependence of such a correction, 2- and 5-km averages were also calculated. The ratios of the uncorrected-to-corrected pairwise residuals ($R_{0.5^o} - R_{2.5^o}$), for the different averages show a 3–7% reduction in the spread of residuals due to the application of the fall streak correction, although such

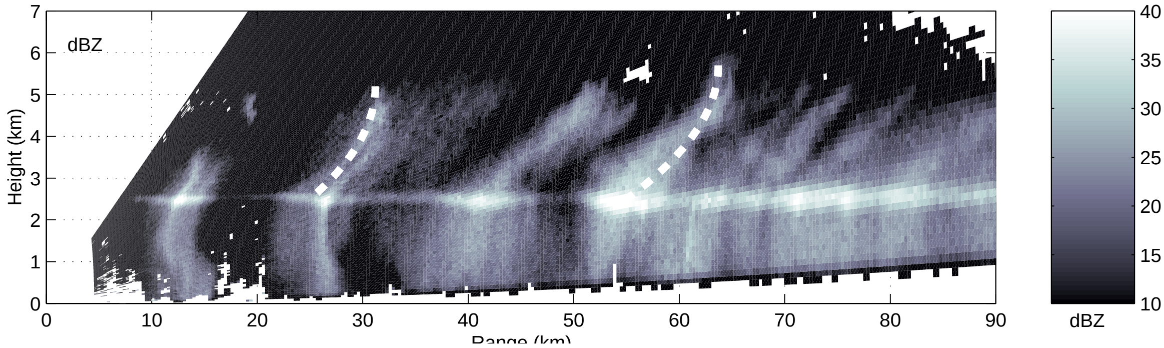

Figure 4: RHI for 20000818 at 13:40 UT at 25° showing clear fall streaks. Fall streaks calculated using Eq. 1 are superimposed.

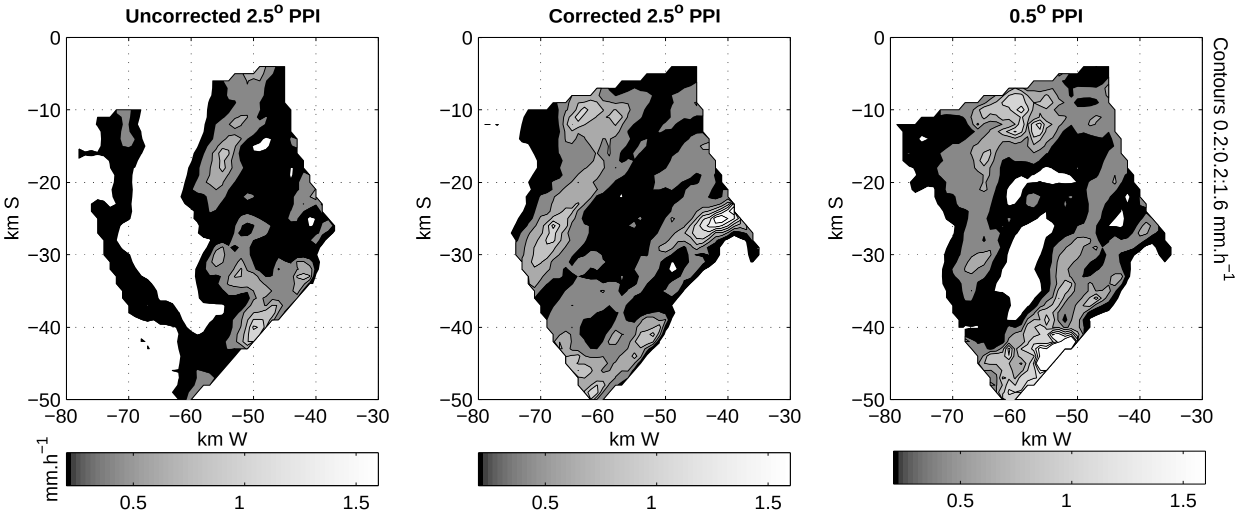

Figure 5: Uncorrected and wind-drift corrected 2.5° PPIs and the 0.5° counterpart as 1 km averages of rainfall rate.

measures are a poor indication of the improvements in the location of showers.

5 CONCLUSIONS

Observational evidence shows that wind drift can cause displacements of 10–20 km. These displacements are reproducible using UM mesoscale forecast winds, and improve the ground placement of rainfall measured by the radar aloft when compared to near-surface values. The magnitudes of the displacements show it to be a significant effect on radar-rainfall products at 1, 2 and 5 km resolution, so any correction for this effect, even with crude assumptions, should improve the surface rainfall estimate.

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