The diagnosis of a range gating problem suffered by the Aberystwyth MST radar

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1. Introduction

When the Doppler Beam Swinging MST Radar at Aberystwyth (UK) began operations in 1989, the data acquisition was handled by a PDP-11 computer. Rapid increases in available computing power meant that this task could be transferred to a desktop (Windows NT) PC in 1999. When it became necessary to upgrade the PC a few years later, the decision was made to rewrite the software (under Linux) in order to increase the flexibility with which the radar could be operated. Unfortunately the new system, which began operations on 6th February 2007, introduced a range gating error of -4 (1 μs interval) gates. This led to the wind-profile data, which are operationally assimilated by the (UK) Met Office for the purposes of numerical weather prediction, being reported at altitudes of almost 600 m lower than they should have been. Thanks to the monthly model-comparison statistics provided by the Met Office, it soon became apparent that the new system had introduced an undesirable change. Nevertheless, they did not indicate the source of the problem, which, owing to the lack of documentation for the previous acquisition system, was extremely difficult to identify. The aim of this extended abstract is to highlight the usefulness of such monitoring statistics as well as to describe the symptoms of the range gating problem.

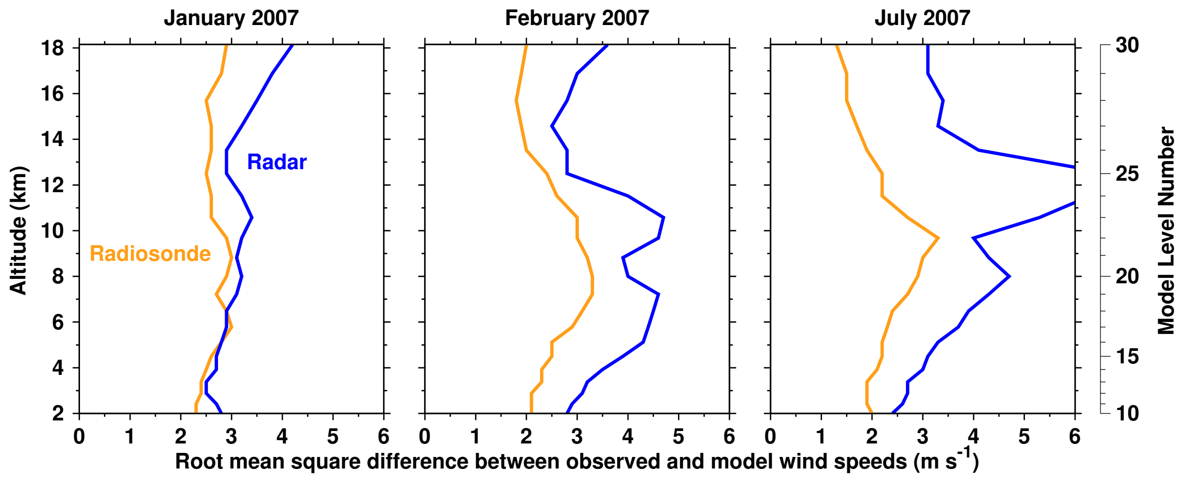

Figure 1: Met Office monthly model-comparison statistics, which are used for evaluating the accuracy of Aberystwyth MST radar wind-profile data.

2. Met Office Monthly Model-Comparison Statistics

The Met Office assimilate data from a wide variety of sources and produce a set of monthly model-comparison statistics, courtesy of Colin Parrett, for each of these. In the case of wind-profile data, the statistics include the average and the root mean square differences between the observed and model values of speed, direction, northward velocity component, and eastward velocity component. These differences should not be regarded as solely representing errors in the observed values, since the model itself is not perfect. Nevertheless, two data sources which have similar model-comparison statistics can be regarded as having similar accuracies (*Dibbern et al.*, 2003). A composite of all simultaneously-measured radiosonde wind-profiles from across the British Isles is used to generate reference model-comparison statistics for UK-based wind-profiling radars. This is a consequence of the fact that such radars are intentionally located within gaps in the radiosonde network and so no single station provides an ideal reference.

The left panel of Figure 1 shows the root mean square differences between the observed and model wind speeds for January 2007, i.e. for the month before the new data acquisition system began operations. As is typical, the profiles are closely matched for the radar and for the composite radiosonde data, indicating that the radar data are of good quality. The slight increase in the radar values compared to the radiosonde values at the higher model levels is attributed to the decreasing availability of useful radar returns with increasing altitude in the lower stratosphere. By contrast to the case for January 2007, the radar values are significantly larger than the radiosonde values at all model levels for February 2007 (middle panel). This gave an unambiguous indication that the new data acquisition system has introduced an undesirable change.

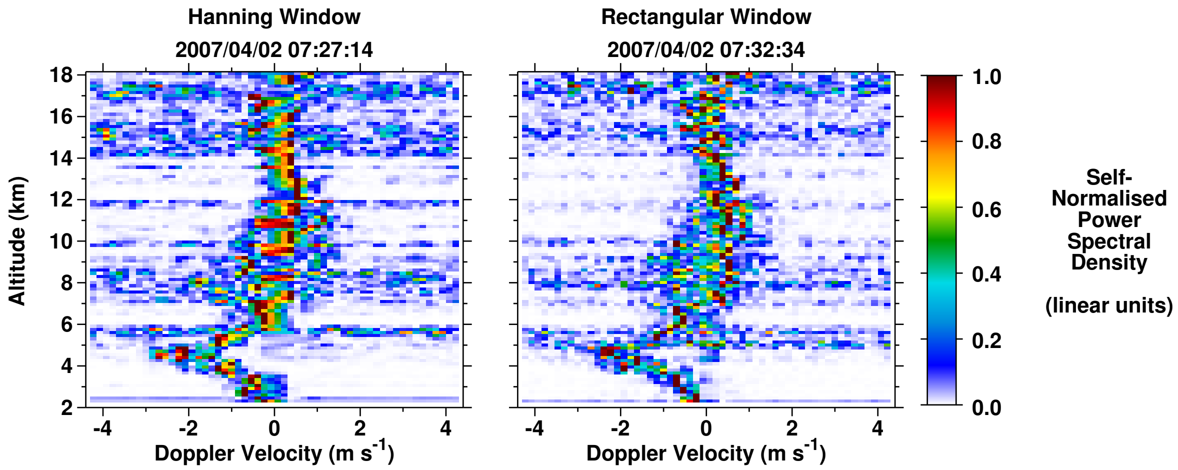

Figure 2: The central halves of two Vertical beam Doppler spectra for observations made just over 5 minutes apart.

The only obvious change between the old and new systems was the choice of data weighting window used in deriving the Doppler spectra (e.g. *Hooper*, 1999). The old system allowed only a Rectangular window to be used. This requires correction of the power spectral density (PSD) for only the central velocity bin (with a value linearly interpolated between the PSDs for the adjacent velocity bins) in order to remove the the effects of dc biases in the raw data. A Hanning window was initially used with the new system. This requires correction of the PSDs for the central three velocity bins. As can be seen from Figure 2, use of the Hanning window leads to a more-obvious correction-artefact for signal components which are characterised by near-zero Doppler velocities compared with use of the Rectangular window. It was speculated that this might lead to greater variability in the Vertical beam radial velocities and that this in turn led to a reduction in the accuracy of the horizontal wind components. However, there was no improvement in the model-comparison statistics following a switch to use of the Rectangular window in April 2007.

The jet stream was located much further south during July 2007 than is typical for summer months. Consequently peak upper-tropospheric wind speeds in excess of 50 m s^{-1} were relatively-common above Aberystwyth (the tropopause altitude was predominantly in the range 8 - 11 km). Since wind speeds tend to decrease much more rapidly as a function of altitude above the jet peak than below it, the effects of the range gating error are particularly noticeable in the former region. This explains the exceptionally large differences between the radar and radiosonde model-comparison statistics at altitudes of around 12 km in the right panel of Figure 1.

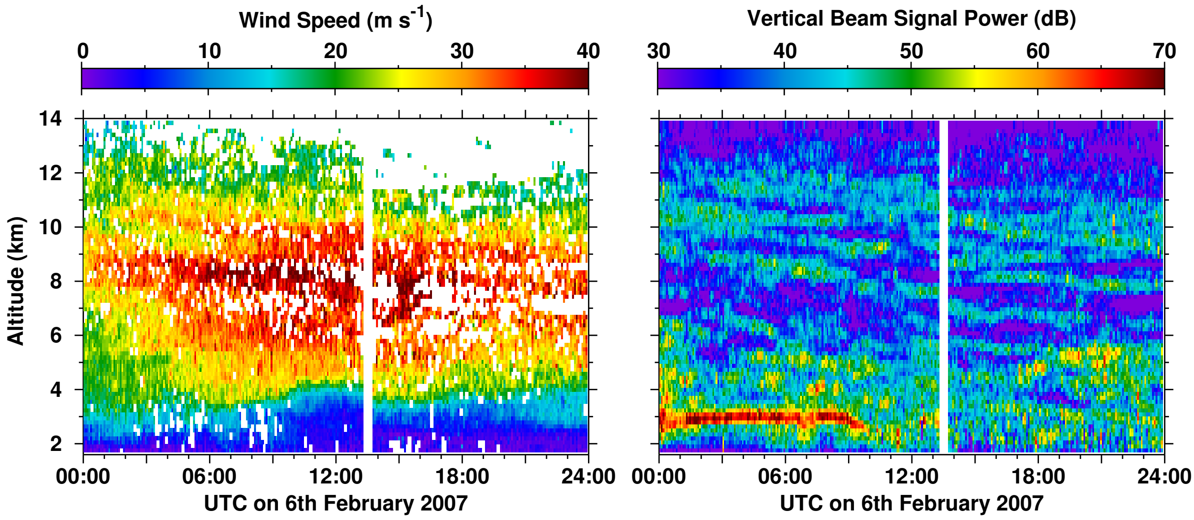

Figure 3: MST radar data for the day when the switch was made between the old and the new data acquisition systems (at around 13:30 UT). No correction has been made for the range gating error.

3. Alternative Methods For Revealing The Range Gating Error

The ability to detect a range gating error is highly-dependent upon the presence of a sharp change in a radar parameter value as a function of altitude. It is unfortunate that such a feature did not exist for the day when the switch was made between the old and new data acquisition systems. As can be seen in the left panel of Figure 3, the upper-tropospheric maximum in wind speed is broad and relatively featureless. The data acquired with the new system are shown without correction for the range gating error. They fail to unambiguously suggest that an altitude offset of -600 m has been introduced. Moreover, comparably-plausible visual fits can be obtained for any range gate correction of between 0 and 8 gates. The same is true of the Vertical beam signal power data, shown in the right panel of Figure 3.

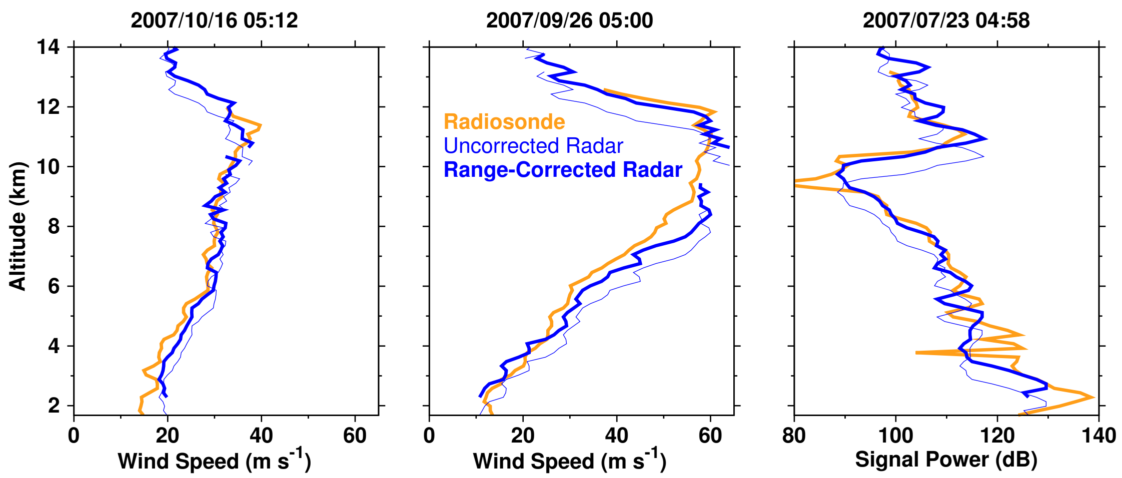

Figure 4: Comparisons between data acquired simultaneously by the MST radar and by radiosondes launched from Aberporth, which is located 45 km to the south-west of the radar site.

Figure 4 compares data from radiosondes launched from Aberporth, which is 45 km to the south-west of the radar site, with MST radar data which are averaged over 1 hour starting from the time of the launch. In the absence of a well-defined peak in the wind speed profile (left panel), the fit between the radiosonde and radar data is comparably-plausible irrespective of whether or not a range gate correction (of +600 m) has been applied. However, within the sharp shear layer at the top of the jet shown in the middle panel, it is clear that the range-corrected radar data provide a much better agreement. A sharp change in Vertical beam signal power at the tropopause (right panel) is a more-common radar feature than a sharp wind shear. Consequently it offers an alternative and often-clearer method for identifying a range gating problem. The Vertical beam signal power is predicted from high-resolution radiosonde measurements of temperature, pressure and relative humidity, as described by *Hooper et al.* (2004) and references therein.

As seen above, a single radar-radiosonde comparison can be highly misleading. A statistical approach is needed in order to reach a meaningful conclusion. The left panel of Figure 5 shows how the correlation coefficient between radar and radiosonde wind speeds varies as a function of the number of range gates by which the radar data are corrected. This is based on 147 radiosondes launched from Aberporth during the period between June and December 2007. It is not clear how much significance should be attached to the fact that the peak value occurs at +5 rather than +4 range gates.

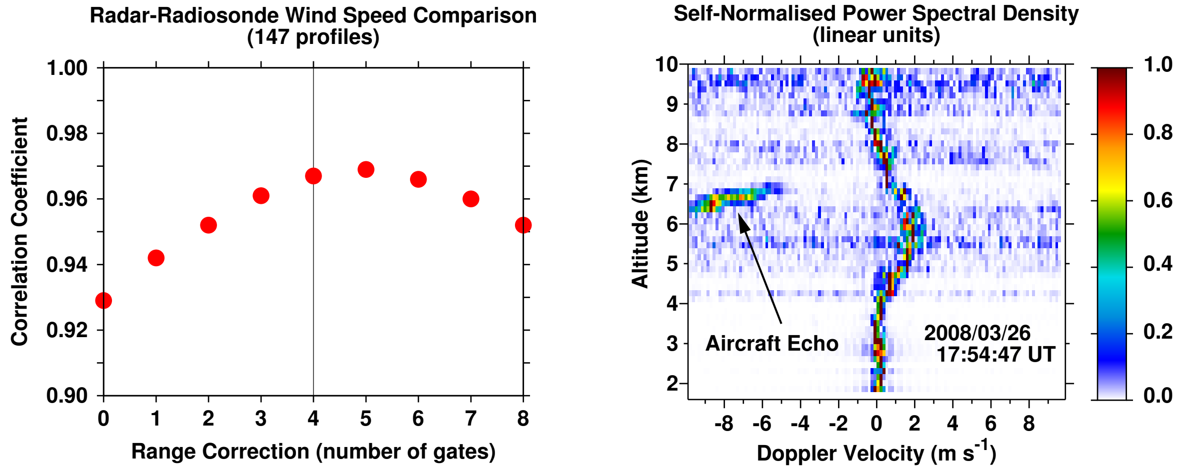

Figure 5: (left) A statistical comparison of radar and radiosonde wind speeds and (right) radar Doppler spectra showing an aircraft echo.

During March 2008, an aircraft flew level paths over the radar at known altitudes. The Doppler spectra shown in the right panel of Figure 5 were observed by a radar beam directed 6° off-vertical towards the north-east. However, given that the aircraft was known to be flying at an altitude of 3.66 km, it must be assumed that the aircraft echo, at an apparent altitude of 6.5 km, was observed through a side-lobe. In the following observation (made 23 s later at 6° off-vertical towards the south-west, but not shown), the aircraft echo is at an apparent altitude of 8.0 km, despite the fact that the aircraft remained at the same level. Clearly aircraft echoes are of no value for validating a radar's range gating.

4. Conclusions

As demonstrated here, monitoring statistics can provide an invaluable indication of degradations in data quality. Nevertheless, their significance can be difficult to interpret until the source of the problem is known. The range gating issue was finally fixed on 8th April 2008.

5. References

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