Estimating winds using radar returns from insects

Anthony Illingworth[1], Susan Rennie[1]

[1]*Department of Meteorology, University of Reading, Earley Gate, PO Box 243, Reading, RG6 6BB, United Kingdom, a.j.illingworth@reading.ac.uk*

ABSTRACT

Radar winds are a useful source of observations which can be used to improve weather forecasts. Currently two types of radar winds are assimilated into the operational forecast models. Wind profilers are able to provide winds up to a few km in height every 15 minutes or so in nearly all weathers but only above the radar. Rain radars can provide winds out to a considerable horizontal distance from the radar, but only where there is precipitation. During the summer insects are relatively common and can be detected in the lowest km by the operational radar network and have the potential to provide winds in the boundary layer out to 20 or 30km from the radar. Such evolving surface winds could provide a valuable data source on developing convective airflows before the precipitation forms, and if successfully assimilated into a high resolution rapid update forecast model could improve the short term forecasts of convective storm development.

The development of an operational system to sense the insect winds is not trivial. Firstly, the current radars are designed to sense precipitation and tend to reject the insect returns. Secondly, the insect returns are quite weak and close to the radar sensitivity and can often be confused with echoes from the ground. Thirdly, the insects themselves may be actively flying and so the velocities are not representative of the air flow. This talk will discuss the challenges in identifying and extracting insect returns, the frequency of occurrence of such returns, and an assessment of the uncertainty and bias of the velocity measurements and how they might be assimilated into operational models.

1. INTRODUCTION

New sources of atmospheric observations are valuable for assimilation in high resolution numerical weather prediction models. Doppler radars offer high spatial and temporal resolution velocity observations. Presently, Doppler radar wind observations using precipitation echoes are assimilated into the UK Met Office forecasting models in the form of VADs (Velocity Azimuth Display). However, the direct assimilation of radial wind vectors is being implemented and tested in 2009.

Doppler radar returns from insects are another potential source of wind observations. Insect returns appear during fine weather in summer, when insects rise to altitudes of typically 1–2 km above sea level to utilise the wind for long distance migration [1][2]. The principle advantage of using insect returns is that they are present when it is not raining, hence the observations may be used to improve the forecast prior to the mencement of precipitation. In the case of convective storm development, this could provide considerable impact to the forecast in terms of correctly predicting the location of potentially flooding showers.

There are several challenges to be dealt with in utilising this potential observation source. Insects are capable of independent flight; it is therefore necessary to focus on daytime data when the smallest insects predominate [2], which fly slowly and are more likely to be carried passively. Insect echoes are much weaker than those of precipitation; weather radars are not designed to detect insects and the insect echoes are close to the radar detection limit. Ground clutter is problematic around many of the UK radars due to their location in hilly areas; the ground returns a signal stronger than that of insects and renders some areas of the scan unusable. Differentiating between clutter and insects is one of the greatest challenges.

In order to assimilate wind observations from insects, it is necessary to account for the bias in the observed velocity. This may arise from the independent insect flight, and contributions from ground clutter and other echoes such as from birds. For data assimilation it is necessary to have an estimate of the uncertainty of the observation in order to weight it appropriately, and so moderate its impact.

Here we present examples of the velocity observations obtainable from insects, indicate the uncertainty in the VAD-calculated velocity, and show the bias indicated by comparison with model backgrounds. This provides an indicator of the range and quality of insect-derived wind velocities.

2. METHOD

2.1 Instruments

The UK has four C-band Doppler radars in the weather radar network. They are located as shown in Figure 1, in the southern half of England. These operate with scans at 5 elevations between 1° and 9° every 5 minutes. In 2007, data were collected during summer from Chenies and another, dual-polarised radar, which was not in use after this time. From 2008, data were collected from the four radars, Chenies, Clee Hill, Cobbacombe and Dean Hill.

© Proceedings of the 8th International Symposium on Tropospheric Profiling, ISBN 978-90-6960-233-2
Delft, The Netherlands, October 2009. Editors, A. Apituley, H.W.J. Russchenberg, W.A.A. Monna

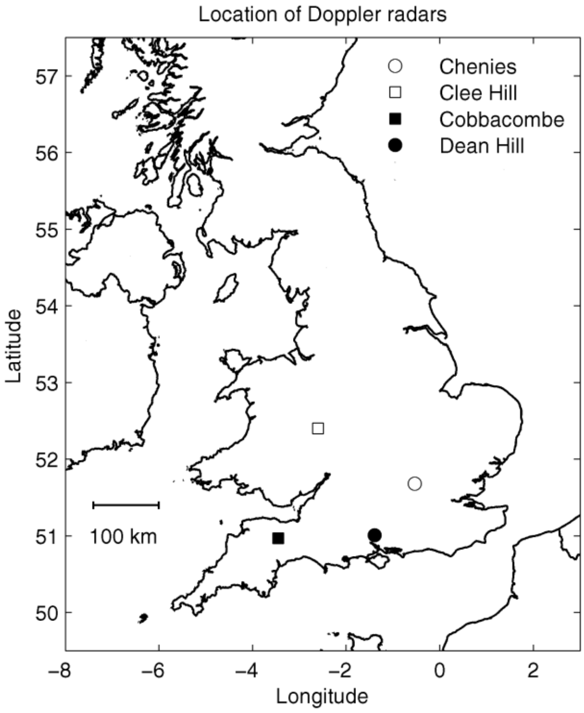

Figure 1. *Location of the four Doppler radars in the UK.*

2.2 Data Collection and Processing

The quantity of data collected is weather dependent. Insects are only present when it is dry, and the temperature is sufficiently high. The peak months are June to August, with fewer insects present outside this period. The airborne insect population varied greatly from day to day and between radars. The range to which insects were detected varied between radars, which may have been due to spatial variability in the insect density and also the amount of clutter obscuring insects at each radar site. Figure 2 shows an example of a scan from Clee Hill. The insects are only visible in regions between the ground clutter and close to the radar. The insect reflectivity is low, ~10 dBz, and clutter dominates the scan

Clutter removal constituted the greatest issue in extracting velocity observations. Methods, such as probability of detection or a clutter index [3], are ineffective with insect echoes. The former fails because insect are present at low levels almost continuously. The second only detects clutter with a very consistent signal, so weak clutter signals remain. Close to the radar, the most effective method was found to be based on the standard deviation of velocity over time. This could be used to determine what areas commonly contained clutter, and so separate clutter from insects. However, this method, like all methods, is not 100% effective; there are always situations where clutter remains, or where too much insect signal is lost.

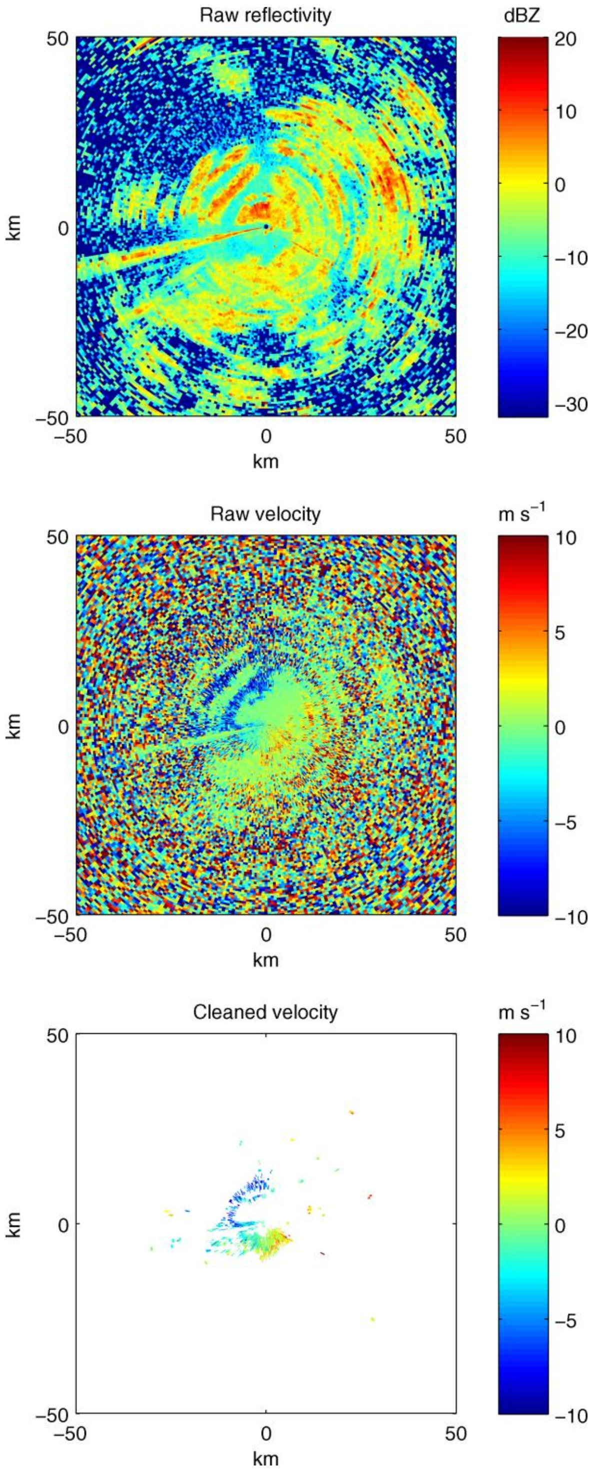

Figure 2. *Example of a Clee Hill 1° elevation scan with insects. Top panel reflectivity, middle panel velocity, and bottom panel cleaned velocity.*

3. RESULTS

The radar observations must be modified to a format suitable for assimilation, such as a VAD wind profile or a thinned or superobbed radial wind vector. VADs use the average of the radial wind field to estimate the wind speed at the radar location, by least-squares fit of a sinusoid to the data [4][5]. From this the uncertainty in the **u** and **v** velocity components can be estimated.

VADs were calculated for all days with sufficient insect returns. For the VADs produced from the data, typical uncertainties for **u** and **v** are described in Figure 3. Often the uncertainty was less than 1 m s^{-1}, although it could be as high as 3 m s^{-1}. VADs with very high uncertainties, or that were obviously erroneous, were excluded. Differences in the error for **u** and **v** probably result from the distribution of clutter, such that if the wind is parallel to **u** a better VAD fit may be achieved than if the wind is parallel to **v**, due to which parts of the sinusoid are represented and where clutter contamination might be worst.

The uncertainty in the velocity estimation from VADs is only part of the error contribution to the velocity observation. Additional biases result from clutter contamination, independent insect flight, and potential impact from other targets such as birds. Clutter contamination would typically result in a reduction of velocity, as clutter is expected to return a velocity near zero, depending on ground type [3]. Comparison of many insect VADs with model background (observation minus background) indicated a mean bias of observed speed 0–2 m s^{-1} lower than the model for the radars most affected by clutter; this bias was typically greater at low altitudes [1]. Chenies had a small positive bias, reflecting its lesser clutter.

At high altitudes the speed bias tended to be closer to zero, or positive. This could be accounted for by independent insect flight, birds, or bias introduced during processing. Larger, strongly flying insects may be more common at high altitudes because they can better maintain body heat. Using only daytime data ensures that smaller insects comprise the majority of airborne biota [2].

The vector RMS bias, that is the mean magnitude of the vector difference between the observed and model velocities, is shown in Figure 4. Close to the ground, the mean was in the order of 3 m s^{-1}. This increased with height. Note that above 1500 m (1100 m for Cobbacombe) there were less than 20 VADs contributing to the average.

From these error magnitudes it might therefore be concluded that the error appropriate to assign to an insect-derived VAD is in the order of 3–4 m s^{-1}. This figure could be reduced if processing can be improved by 1) improved clutter detection, 2) more stringent processing to produce a smoother velocity field, and 3) excluding suspect VADs. It should now be emphasised that the results presented here are from processing intended to maximise the number of VADs used in the observation-background analysis; moderately suspect VADs were permitted, to assist determining the sources of error.

Any developments to reduce clutter contamination would be beneficial in reducing the error bias. Removal of spurious values using a signal quality index may also improve results, by disqualifying untrustworthy velocity measurements. Exclusion of high-uncertainty VADs would increase confidence in the velocity estimate. Finally, exclusion of low velocity VADs, or even VADs when the model indicates calm winds, may be helpful in excluding cases when insects' independent flight could dominate.

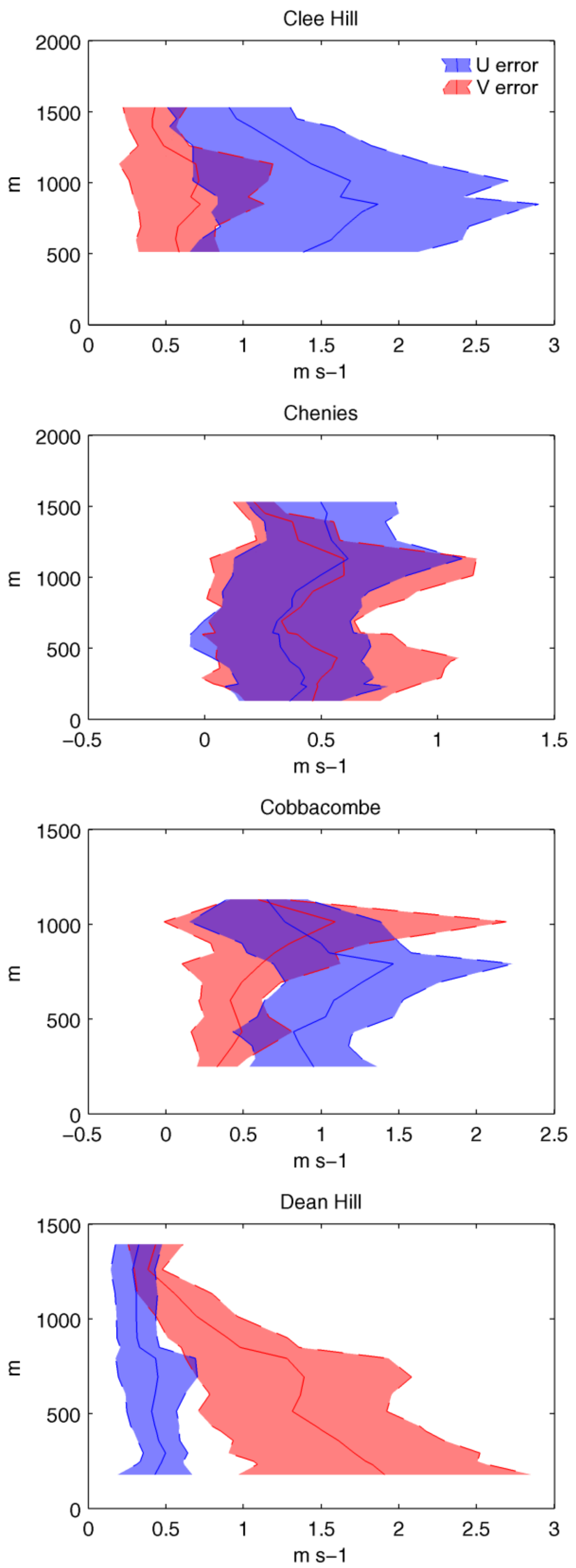

Figure 3. *Mean error of **u** and **v** from VAD calculation based on least-squares fit, with +/- one standard deviation shaded, for U (blue) and V (red).*

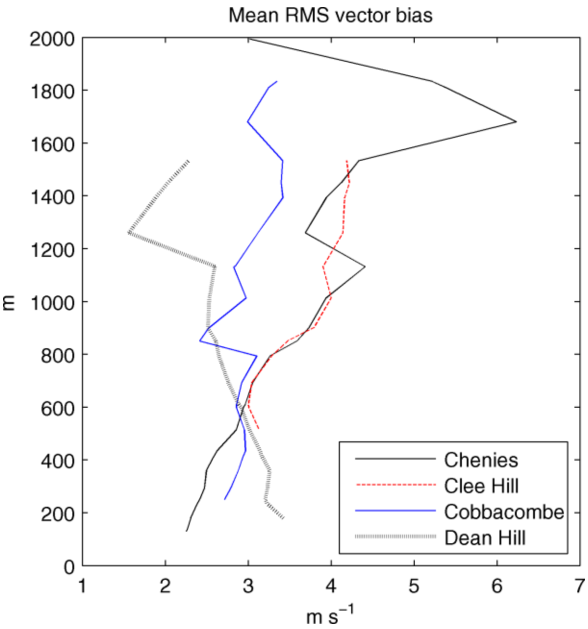

Figure 4. *Mean RMS vector difference between observation and model background.*

4. CONCLUSION

Insect returns were collected from UK Doppler radars during the summers of 2007and 2008. The insect returns have been shown sufficient to create VADs with uncertainty of 0.5 to 3 m s^{-1} in each vector component. The error in the velocity is also likely to be up to several metres per second as a consequence of potential contamination from ground clutter, birds, and independent insect flight.

REFERENCES

[1] Rennie, S., A. J. Illingworth, S. L. Dance, S. Ballard, submitted: The accuracy of velocity observations from UK Doppler radars using insects. *Meteorological Applications*.

[2] Wood, C. R., E. J. O'Connor, R. A. Hurley, D. R. Reynolds, A. J. Illingworth, 2009: Cloud-radar observations of insects in the UK convective boundary layer, *Meteorological Applications*, in press.

[3] Sugier J., J. Parent du Châtelet, P. Roquain, A. Smith, 2002: Detection and removal of clutter and anaprop in radar data using a statistical scheme based on echo fluctuation, *Proceedings of ERAD 2002 - the Second European Conference on Radar Meteorology*, pp. 17-24, Delft, Netherlands.

[4] Andersson T., 1992: A method for estimating the wind profile and vertical speed of targets from a single Doppler radar, *WMO Technical Conference on Instruments and Methods of Observation (TECO-92)*, Vienna Austria, 11-15 May 1992, Report No 49, pp. 380-384.Author1 A. B., C. Author2, 2007: Journal Article Title, *Journal Name*, **47**, pp. 25-30.

[5] Michelson D. B., T. Andersson, J. Koistinen, C. G. Collier, J. Riedl, J. Szturc, U. Gjertsen, A. Nielson, S. Overgaard., 2000: Baltex Radar Data Centre Products and their Methodologies, *SMHI Reports, Meteorology and Climatology*, RMK No 90, 76pp.