Doppler Radar Wind Profiles

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ABSTRACT

Doppler weather radars can be employed to determine wind profiles at a high temporal resolution. Several algorithms and quality ensuring procedures for the extraction of wind profiles from radar volume data have been published. A comparison and verification of the extracted wind profiles has been performed at KNMI. The verification results indicate that weather radars can provide high-quality wind profiles.

Keywords: Doppler Weather Radar, Radiosonde, NWP, Wind profiles, Verification

1. INTRODUCTION

Weather radars are well known for their ability to detect precipitation at a high spatial and temporal resolution. Precipitation data deduced from reflectivity measurements by weather radars are extensively used for monitoring of (severe) weather and are increasingly used for hydrological applications. The majority of the operational weather radars in Europe is capable of performing Doppler measurements. Using the Doppler technique, the environmental wind can be extracted from the motion of the precipitation. The wavelength of weather radars is optimized for detection of precipitation and is typically 5 or 10 cm. In clear air, therefore, no return signal and thus no wind information is expected, but often (weak) signal is received from the boundary layer, moisture gradients, or large cloud particles. KNMI operates two C-band Doppler weather radars from Gematronik which are amongst others used for obtaining wind profiles.

A Doppler radar only measures the component of the velocity vector in the line of sight, the so-called radial velocity. Radial velocity data is not straightforward to interpret, some further processing is required before it can be presented to users or assimilated into numerical weather prediction (NWP) models. Under the assumption of a linear wind field within the analyzed volume, profiles of the wind speed and direction, vertical velocity, and divergence can be extracted from radial velocity data. Several algorithms for the extraction of wind profiles have been developed, most notably Velocity Azimuth Display (VAD)[1, 2] and Volume Velocity Processing (VVP).[3]

The potential of Doppler radar wind profiles for application in nowcasting, aviation meteorology, and assimilation in NWP models has been assessed at KNMI. Radar wind profiles at De Bilt have been verified against data from the collocated radiosonde site. The verification results are presented in this article indicate that the quality of wind profiles is generally good. Care has to be taken, however, to avoid loss of quality due to ground clutter and variability of the fall speed of the precipitation. Bird migration can lead to (unexpected) major errors.

2. WIND PROFILING

A Doppler radar uses electromagnetic waves to investigate atmospheric properties: the amplitude of waves is used to estimate the reflectivity and the phase of the waves is used to estimate the radial velocity. The radial velocity of scattering particles is determined from the observed phase jumps between successive transmitted pulses. Doppler radars are recording volume data, i.e., reflectivity, velocity, and spectral width information as a function of range, azimuth, and elevation. The radar geometry used to obtain wind profiles is shown schematically in Figure 1. The radial, tangential, and vertical velocity components have been indicated in this figure.

Wind profiles can be obtained from single-site radial velocity data under the assumption of a linear wind model. In this model, the wind field in the vicinity of the radar is approximated by:

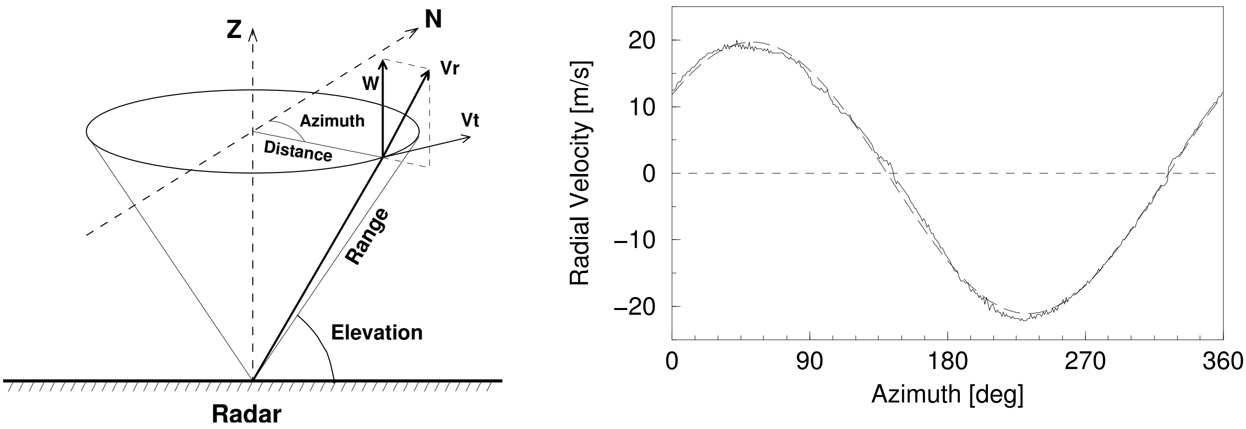

Figure 1. Schematic overview of the radar geometry used to measure Doppler wind profiles is given in left part of the figure. An example of a VAD extracted from radial velocity data is shown together with a fitted sine on the right.

$$U(x, y, z) = u_0 + x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y} + (z - z_0)\frac{\partial u}{\partial z} \quad (1)$$

$$V(x, y, z) = v_0 + x\frac{\partial v}{\partial x} + y\frac{\partial v}{\partial y} + (z - z_0)\frac{\partial v}{\partial z} \quad (2)$$

$$W(x, y, z) = w_0 + (z - z_0)\frac{\partial w}{\partial z} \quad (3)$$

The derivatives of the vertical velocity W in x- and y-directions can be neglected with respect to the derivatives of U and V in z-direction.[3] In addition to the movement due to the wind, the hydrometeors have a fall velocity ($W_f < 0$). Using a constant wind field and fall velocity, the radial velocity can be calculated as a function of azimuth (ϕ) and elevation (θ):

$$V_{radial} = (w_0 + W_f)\sin\theta + u_0\cos\theta\sin\phi + v_0\cos\theta\cos\phi \quad (4)$$

$$(5)$$

When Doppler radar data is displayed at constant range and elevation (θ), the radial velocity as a function of azimuth (ϕ) will have the form of a sine, see Figure 1. The wind speed and direction can be determined from the amplitude and the phase of the sine, respectively. This technique is called Velocity-Azimuth Display (VAD).[1, 2] Instead of processing a single VAD, one can also process all available velocity volume data within a certain height layer at once. The parameters of the linear wind field can then be extracted using a multi-dimensional and multi-parameter linear fit. This so-called Volume Velocity Processing technique (VVP) has been introduced by Waldteufel and Corbin.[3]

3. VERIFICATION OF WIND PROFILES

The quality of radial velocity data and thus of wind profiles can be heavily affected by variability of the precipitation fall velocity, interfering ground clutter, and migrating birds. The quality of the Doppler radar wind profiles from De Bilt has been investigated by verification against profiles from the collocated radiosonde station. For this, wind profiles have been collected over a period of about 7 months. The average length of the difference vector between the collocated (in time and height) radar and radiosonde wind vectors has been calculated. This has been done for different threshold values on the standard deviation of the radial velocity fit. In figure 2 the average length of the difference vector has been plotted against the number of collocated wind vectors. This figure

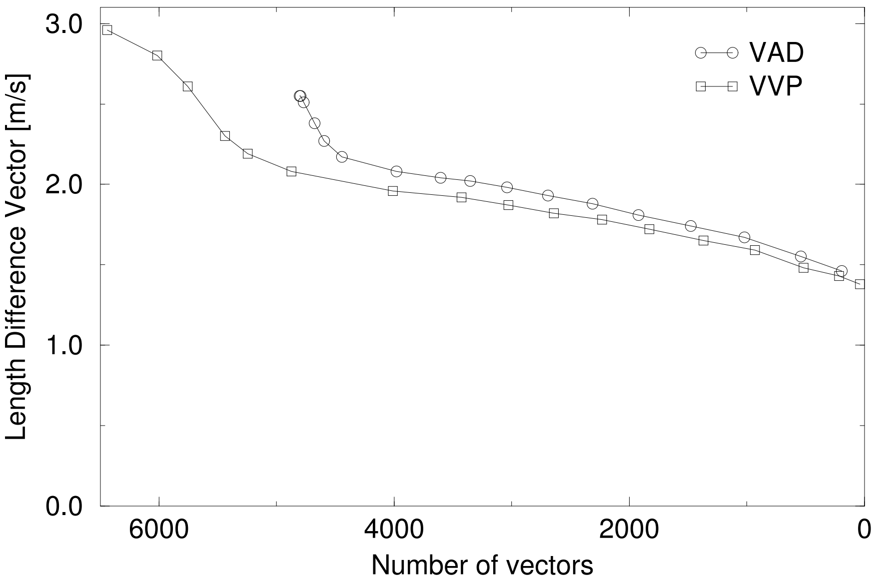

Figure 2. This figure shows the average length of the difference vector and number of collocated wind vectors when the threshold on the radial velocity standard deviation is varied. Curves for wind profiles from the VAD and the VVP technique are shown.

shows the effect of the standard deviation threshold on both the quality and the availability of the Doppler radar wind vectors. It is evident from this figure that the combination of quality and availability is more favorable for wind profiles produced using the VVP technique. In the WMO handbook of observations, an average difference vector length of 1.5 m/s is suggested for perfectly collocated, in time and space, wind vector observations. It is clear that for comparisons between radar and radiosonde the collocation is far from perfect, so an observed average length of the difference vector of roughly 2 m/s is acceptable. In addition, it compares favorably to the average length of about 3 m/s found in verification of Swedish VAD winds against radiosonde data.[4]

4. CONCLUSIONS

In many meteorological circumstances, a Doppler weather radar can provide wind profiles at a high temporal resolution. A long-term verification of the radar wind profiles at De Bilt against data from the collocated radiosonde site has been performed. The verification results indicate that the quality of the wind profiles enables further application in nowcasting and modeling.

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