4.7 DATA ASSIMILATION AND PROBLEMS IN THE QUALITY CONTROL OF DOPPLER WINDS

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1. INTRODUCTION

The European network of Doppler radars has recently been rapidly expanding, providing a huge amount of wind observations. In this paper we will discuss the use of these winds in European-wide mesoscale models. First we will point out that the focus must be on mesoscale phenomena. We then show, by applying an artificial small-scale wind field, that VAD (Vertical Azimuth Display), Browning and Wexler (1968) winds are suitable for use in assimilation systems. The conclusions will be based on speculations, and need testing in real conditions. Finally we will discuss who should take care of the observation errors in the radar winds. The discussion is illustrated with a real case of numerical forecasts.

2. THE USEFULNESS OF RADAR WINDS

The conventional observational network over Europe is dense. In northern latitudes, especially in the case of longer waves, the winds are adjusted to the mass field. It follows that radar winds do not normally add much to the mesoscale analysis. There is one clear exception. In rapidly-developing mesoscale phenomena these wind observations may be very useful because the geostrophic adjustment is weaker. Moreover, from the point of view of duty forecasters, in such cases good numerical products are important. The focus must therefore be on mesoscale phenomena. This holds for the use of data as well as for the testing and verification of their impact.

3. DIFFERENT APPROACHES

The amount of data is extensive. This will cause dissemination problems. Radar observations include both the vertical speed of the air and that of the hydrometeors. These are not well forecast by models and there are therefore no applicable background fields. Taking these problems into account, there are three main approaches.

1. The bulk data approach. Because radars are so expensive and produce useful data continuously, it is reasonable to make use of all availaböe data. The quantities are more important than the quality, because a large amount of data will have a positive impact on the forecasts. In following this judgement, in order to avoid negative consequencies, it is on the modelling side necessary to assume the error variances of the data to be large. Hence there will be a massive data flow with neglible impact on the forecasts.
2. Make use of the lowest angles only. The vertical component will vanish and so the related problem is avoided. Because the wind can vary much locally, it is necessary to apply some kind of averaging on the data.
3. Apply filtering to the data in order to remove the vertical component, to remove the random-like subgrid variations and to compress the data. In this paper we will study this approach by applying Fourier-filtering.

4. METHOD

The aim is to compare the radial winds observed and the corresponding grid parameters. This is done in simulation experiments with different mesoscale wind fields. The exact formulae are not given here; in the following only the principle is explained.

We construct artificial wind fields. To simulate a mesoscale case, the vertical component in those fields is set to be strong. On the horizontal scale, only wavelengths from 1 km to 100 kms are included. From these fields we compute the radial winds observed by the radar. To represent the corresponding wind fields in the grid, waves shorter than 20 kms are fully removed, those between 20 and 40 kms are partially removed while the longest waves are retained. This kind of filtering simulates smoothing in a grid with an increment of about 10 kms.

A set of radar observations of a constant radius and elevation angle is selected. A mean of the radial winds is then computed by weighting them with $\sin(\phi)$ and $\cos(\phi)$, where ϕ is the radar beam azimuth angle lying between 0 and 2π. Hence two filtered values are thus obtained as an output.

In the grid, the wind components are interpolated to the radar site. The parameters corresponding to

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the previous filtered radar winds are then computed. Hence we have two filtered wind components from the radar and two corresponding values from the grid. The main difference between the radar and grid terms arises from the smoothing applied in the grid. Finally, the winds from radar and grid are compared in order to discover how well they fit.

In radar theory, such filtered winds are called VAD winds (Vertical Azimuth Display, Browning and Wexler, 1968). These winds are understood to represent the horizontal wind components. This assumption is not fully true and will generate some inaccuracies. In the present computations this will be taken into account.

The interpolation made in the grid is, in turn, seen in the modelling approach as an application of the so-called observation operator. This concept is a central one in the variational analysis. Accordingly, one can say that we are comparing VAD observations with the corresponding wind parameters as computed from the grid data in the variational analysis.

5. RESULTS

There is a certain optimal radar radius, in average terms, for which the grid wind parameters fit best with the filtered radar winds. For larger radii, the filtering is too strong and the corresponding wind components become too smoothed. For smaller radii, the filtered terms are not smooth enough and contain too much local variation not present in the grid values.

Balloon winds tend to describe local temporal variations, i.e., they are closer to radar winds computed at small radii. It follows that radar winds at the optimal radius are more suitable for grid applications than balloon winds. In the present simulation with artificial small-scale wind fields, the difference between the grid and radar winds at the optimal radar radius, given in terms of standard deviation, was only 30 % of that at small radar radii (or, approximately, 30 % of that between grid and balloon winds).

The results can be improved by applying more complicated observation operators in the grid and by taking combinations of radar winds at different radii. In all cases, it is necessary to select the radar radii correctly to get the best results. In the present mesoscale wind fields, the vertical component is assumed to vary horizontally. It then adds a residual term to the VAD winds. This term is poorly described in the models. Therefore, in the present computations, the main error source is the vertical component. The main advantage of using the optimal radar radius comes from the filtering that most efficiently simulates the grid smoothing.

The optimal radius is about 0.7 times the grid interval.

It follows that VVP winds (), Waldteufel and Corbin (1979), cannot be recommended because in them the radii applied are decided and fixed by the organization responsible for operating the radar.

6. WHO SHOULD MONITOR THE OBSERVATION ERRORS?

In variational analysis, all of the data sources are used efficiently, including the background field. It is then easy in the quality control scheme to remove erroneous radar observations. It is natural therefore to expect that the modelling system should monitor the observation errors. Potential error sources are listed in the following:

1. Echoes from birds or actively-moving insects.
2. Ground echoes and channelling of the radar beam.
3. External electric equipments disturbing the radar signals; other radars, such as those on ships.
4. Folding errors.
5. VAD terms computed inaccurately from non-complete data circles.
6. Surprises.

In the assimilation system, to detect an error, the observation will be compared with other data. A clear difference indicates that the observation is suspicious and should be rejected. In this case observations showing rapid, new, unexpected development tend to be rejected, too, because in such cases the differences tend to be large. In other words, we lose the potentially high value of the radar wind observations. These will only be used to support, and perhaps slightly change, the analysis based on other data sources. Hence, full use of the radar observations can only be made if the high quality of the radar observations can be guaranteed and practically all observations can be accepted. The responsibility for this automatically falls to the radar operator.

7. AN ILLUSTRATIVE "SURPRISE" CASE

The Finnish Meteorological Institute carries out operational data assimilation and short-range numerical weather prediction using the Hirlam (High Resolution Limited Area Model) system. Radar winds are not employed. However, in a pre-operational data assimilation experiment of the system, the radar wind profiles were accidentally treated as wind soundings and allowed to influence the analysis accordingly. The data control was applied as in the case of pilot winds, i.e., only very exceptional observations were removed.

The resulting systematic difference between the analysis and the first guess is shown in Fig. 1. There were a total of six Doppler radars producing VVP winds. A clear centre, with a slight shift eastwards from the radar along the prevailing mean flow is seen. This indicates a systematic error in the wind observations of the Utajärvi radar. It is satisfying that the other radars are not detectable in the mean analysis increment.

It has been difficult to find the origin of the error. It seems to be due to a programming error which nullified sometimes the winds within some layers. The error was thus large but random.

It is concluded that the quality control scaheme was obviously not able to stop the erroneous Utajärvi data from entering the analysis. This would have required stricter quality control. On the other hand, there are often large gradients in the wind speed, and hence relatively large departures from the background field should be tolerated in the wind components in order not to exclude correct observations. This would seem to put a very high quality requirement on the wind observations offered to the system.

8. CONCLUSIONS

In principle, VAD winds are very suitable for present data assimilation systems. They compress the data needed for the data dissemination. They can be used for any grid increment by selecting the appropriate radar radius. VVP winds are not recommended because in producing these the radar radii are selected by the radar operator.

Efficient use of radar winds places very strict quality requirements on the wind observations offered to the data assimilation system. If this cannot be met then the radar data should be downgraded to the class of less useful bulk data applied in a routine manner.

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9. REFERENCES

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Fig. 1. Mean analysis increment of wind speed in October 1998 in m/s at about 860 hPa. The differences at the Utajärvi radar indicate systematic errors in the VVP winds.