JP1.8 IMPACT OF USING DOPPLER RADAR RADIAL WIND DATA IN A WINTER CYCLONE PERIOD

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1. INTRODUCTION

High-resolution observing networks are required to fulfill the needs of the present-day mesoscale numerical weather prediction (NWP) models. In many countries, e.g. Finland and Sweden, the radar network has an excellent geographical coverage and Doppler radars provide radial wind observations with good temporal and spatial resolution.

In this paper a two week winter period is studied to assess the impact of Doppler radar radial wind observations on model analyses and forecasts. The period is characterized by deep cyclones passing over the Baltic sea area. HIRLAM (High Resolution Limited Area Model) model with 9 km horizontal resolution is used in the experiment. Results from earlier assimilation experiment (Lindskog et al., 2004) with 22 km grid size indicate that using Doppler radar winds have positive impact on wind and temperature forecasts in the low and middle troposphere.

The paper is organized as follows. Section 2 considers how the radar radial wind data is handled in HIRLAM model. Section 3 discusses the experiment configuration and the results from the assimilation experiment. A short summary is presented in section 4.

2. HANDLING RADAR RADIAL WIND DATA IN HIRLAM 3D-VAR

2.1 Preprocessing of Doppler radar radial wind observations

The HIRLAM model is run operationally at Finnish Meteorological Institute with 9 and 22 km horizontal resolutions, whereas the horizontal resolution of the Doppler radar radial wind data is approximately one kilometer. Preprossessing of the radar wind observations reduces representativeness error when comparing the observations with the coarser resolution model.

Radar radial wind data is input to the HIRLAM model as so-called superobservations (hereafter SO). A SO is a generalized observation created through horizontal averaging of raw radial wind measurements in polar space. SO generation averages out random errors from the high resolution radial wind observations quite effectively. More details about the SO generation can be found in Lindskog et al. (2004).

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2.2 The HIRLAM 3D-Var

The analysis method used in HIRLAM reference system (Unden et al., 2002) is 3-dimensional variational assimilation (3D-Var). A detailed description of the HIRLAM 3D-Var can be found from Gustafsson et al. (2001) and Lindskog et al. (2001).

HIRLAM 3D-Var includes an observation operator for Doppler radar radial winds (Salonen et al., 2003). The observation operator transforms the model background state to the observed quantity, including bending and broadening of the radar beam.

2.3 Quality control for the radar radial winds

Radar wind SOs must fulfill defined quality criteria before they are accepted to the assimilation. With proper quality criteria erroneous radar observations can be effectively eliminated.

The first step in the series of the quality checks is the screening process. In screening a SO is accepted if the following criteria are fulfilled:

1. The SO is generated from at least five raw observations.
2. The variance of the raw observations forming an SO is no more than 10 m^2/s^2.
3. The elevation angle of the observation is no more than 10°.

The first criterion discards SOs which are generated from too few, perhaps isolated raw observations. These SOs can be observations from non-meteorological targets like buildings, birds or ground clutter. With this criterion almost all strongly deviating observations can be eliminated. The second criterion ensures that the raw observations used in the SO generation are in a reasonable coherence with each other. The last criterion is set because the formulation of the observation operator does not take into account the vertical velocity component in the radial wind measurements. With low elevation angles the vertical velocity component in the radial wind vector is small and can be neglected.

In addition to the screening process a background quality control (BgQC) and variational quality control (VarQC; Lorenc and Hammon, 1988; Andersson and Järvinen, 1999) are applied to the observations. In the BgQC each observation is tested against the model background. Observations differing more than a predefined limit from their model counterparts are rejected. The VarQC accounts for the gross errors in the observations. This is needed because the 3D-Var formulation assumes that the observation error distribution is Gaussian.

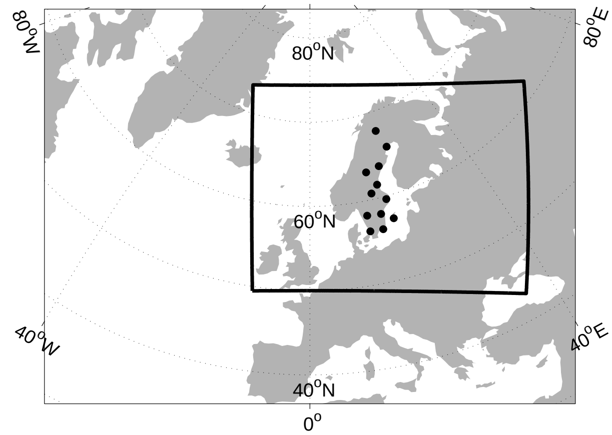

Figure 1: The model domain used in the experiments. The utilized radar sites are indicated with black dots.

3. ASSIMILATION EXPERIMENTS

3.1 Experiment configuration

A two week (1 –14 December 1999) parallel assimilation and forecast experiment has been performed to study the impact of using Doppler radar radial winds on HIRLAM model analyses and forecasts. The experiments are carried out with HIRLAM version 6.3.6 with semi-Lagrangian time integration. The North European model domain used in the experiments is shown in Fig. 1. The model has 40 levels, 406 $\times$ 306 grid points at each level and 0.08° (9 km) horizontal resolution. Analyses are made every six hours. After each analysis an incremental digital filter initialization is applied, followed by 24 h forecast. European Centre for Medium-Range Weather Forecasts (ECMWF) 4D-Var analyses are used as the lateral boundary conditions.

The conventional observations are retrieved from the ECMWF archive and the radar data from the BALTEX Radar Data Centre (`www.smhi.se/brdc`). The locations of the Swedish radars used in the study are shown in Fig. 1.

The parallel data assimilation experiments are:

1. **CTR** (control assimilation): only conventional observations are used.
2. **RAD** (radar radial wind SO assimilation): conventional observations and SOs from the Swedish radar network are used.

3.2 Quality of radar radial wind observations

Radiosonde observations are the most important observation type used in NWP models. From the mesoscale NWP viewpoint the weakness of the radiosonde observation network is it's sparse coverage both in space and time. Thus, complementary observation networks are important.

Figure 2 shows the number of SOs available at each assimilation cycle during the experiment period (panel a), and the number of SOs which have passed the screening process (panel b). In general, about 5 – 10 % of the available SOs pass the screening and at the most ca 1200 SOs are used in the assimilation. As a comparison, typically at 00 and 12 UTC cycles around 60 – 70 radiosonde observations are available at the experiment domain, whereas on 06 and 18 UTC cycles only around 10 radiosonde stations make observations. The availability of radar observations depends on the prevailing weather situation.

Figure 3 displays innovation (observation minus model background) and residual (observation minus analysis) statistics for radar radial SOs, radiosonde wind observations and aircraft wind observations (airep). The quality of SOs is good below 7 km altitude, whereas higher than 7 km both bias and rms increase notably. Note that most of the SOs above 7 km altitude originate from measurement ranges 80 km or more where the radar beam is already quite wide. The number of SOs at high altitudes is small compared to lower altitudes because in many cases the radar beam is above the cloud top. This is typical especially at winter when the clouds are more shallow. Compared to airep observations, the quality of SOs is better below 2 km altitude. The rms difference is systematically about 2 m/s higher for SOs than for radiosonde or airep wind observations (above 2 km altitude). This indicates that the SOs contain more

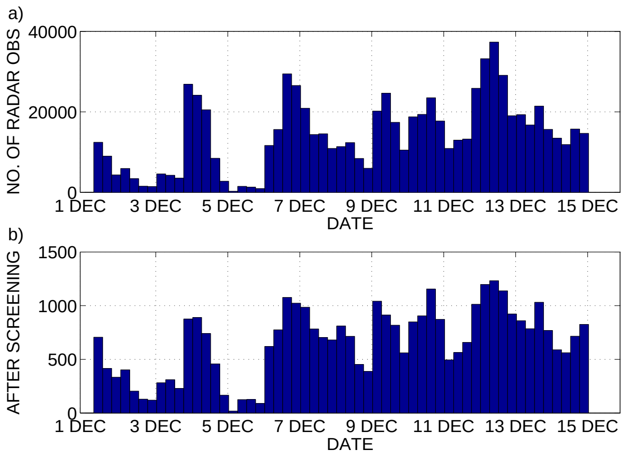

Figure 2: a) The number of SOs which are available at each assimilation cycle and b) the number of SOs after screening process.

small scale features not resolved by the model and thus appearing as random errors.

In general the quality of the SOs is good, and it may be expected that the use of radar wind information will improve the analysis of the atmospheric state in mesoscale NWP models.

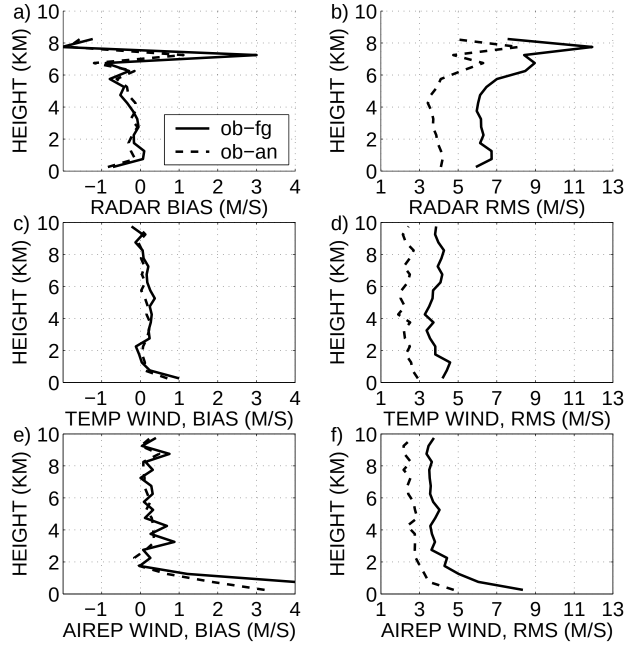

Figure 3: Bias and rms of innovation (solid line) and residual (dashed line) shown as a function of height for SOs (a, b) and wind speed from radiosonde (c, d) and airep observations (e, f).

3.3 *Verification against observations*

The impact of using SOs in analyses and subsequent forecasts is evaluated by verifying the results against radiosonde observations listed by European Working Group on Limited Area Modelling (EWGLAM). The verification is done against observations which would pass the BgQC at the verifying time. The verification is done for 850, 700 and 500 hPa wind, temperature and geopotential height fields. The model data used in the verification are analyses and 6, 12, 18, and 24 h forecasts.

Figure 4 displays the bias and rms for 850 hPa wind and temperature forecasts for CTR and RAD. In general the differences in these aggregate verification scores are small and the impact of SOs is fairly neutral. At other levels the behaviour of the verification scores is very similar to the 850 hPa level.

The bias and rms scores have quite large day-to-day variability. The day-to-day variability reveals more easily the differences between the CTR and RAD forecast performances than the aggregate values calculated over the whole 14 day experiment period. For example, the 18 and 24 h wind forecats at 850 hPa level perform better than the CTR especially between 3 – 5 and 10 – 14 De-

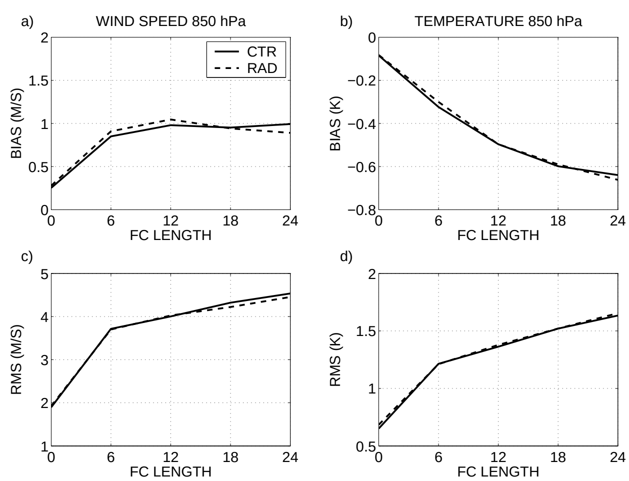

Figure 4: Bias and rms shown as a function of forecast length for 850 hPa wind speed (a, c) and temperature (b, d).

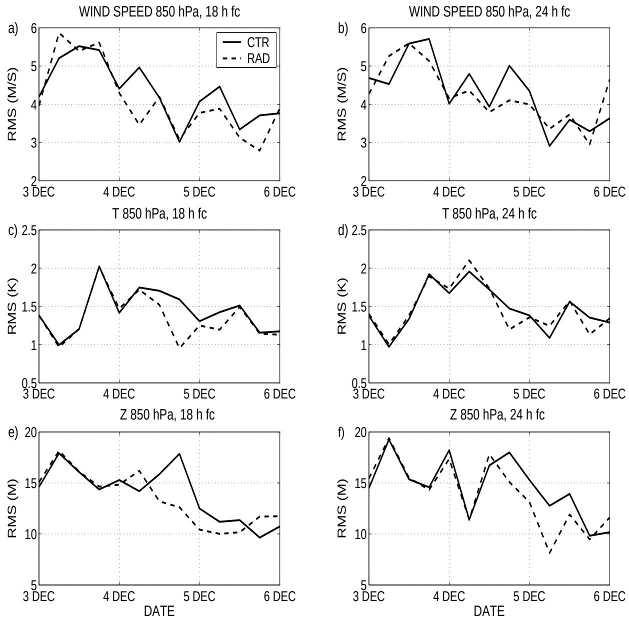

Figure 5: Daily rms shown for 18 and 24 h forecasts at 850 hPa pressure level for the period of 3 – 5 December: wind speed (a, b), temperature (c, d) and geopotential height (e, f).

cember (not shown). From Fig. 2 we see that at those time periods there have been notable amount of radar SOs available. A small improvement can be seen also in the aggregate values of Fig. 4 a and c.

During 3 – 5 December a very strong windstorm (Anatol) crossed the Northern Europe. The storm passed from the North Atlantic through northern parts of Great Britain, Denmark and the south of Sweden over to the Baltic region. The storm caused large environmental and economical losses. The center of the low-pressure decreased by more than 40 hPa in twelve hours reaching its observed minimum of 952 hPa over southern Sweden at 4th of December. The highest observed wind gusts at synoptical stations were over 50 m/s.

Figure 5 displays the day-to-day variability of the rms for 850 hPa wind, temperature and geopotential height forecasts after 18 and 24 h model integration during 3 – 5 December. The rms scores for RAD (dashed lines) are better for all verified variables than for CTR. Similar improvement can be seen also on other pressure levels.

4. SUMMARY

High resolution observing networks will become more important when the resolution of the NWP models increases. Radar networks provide information about radar radial wind and radar reflectivity with high spatial and temporal resolution. In this study, the radar radial winds are utilized in 9 km resolution HIRLAM model as spatial averages. The quality of these superobservations (SO) is found to be good.

The results obtained from the two-week data assimilation and forecast experiment are promising and similar to the results from an earlier experiment with 22 km resolution model. On average the impact of the SOs is rather neutral. In certain cases, like the winter storm during 3 – 5 December, the forecast utilizing radar wind information performs better than the control run.

ACKNOWLEDGEMENTS

The research has been funded by the Academy of Finland project “Doppler radar wind assimilation”. The participation in the 32nd AMS conference on radar meteorology is funded by Magnus Ehrnrooth’s foundation.

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