VAD EXPERIMENTS USING THE INM WEATHER RADAR NETWORK

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Abstract

The text describes the work carried out at INM to monitor and test the impact of assimilation of the Velocity Azimuth Display (VAD) wind data from the INM weather radar network by the HIRLAM 3Dvar system. The preliminary tests have shown no impact over Spain but slightly positive over France. Some diagnostics of the assimilation performance have confirmed the features observed during the monitoring of these data against the present INM operational 6 hours forecasts and analysis based on Statistical Interpolation. They have also provided information about the error distribution of VAD data and its quality in respect to radiosonde wind observations.

Introduction

Last quarter of 2002 the INM started to monitor Velocity Azimuth Display (VAD) wind profiles from its weather radar network through comparison with the HIRLAM operational analysis. The work was initiated by Juliana Mol (Instituto Nacional de Meteorologia de Brasil) during her stay at the INM in the autumn 2002. This manuscript describes how her work has continued.

As first step, the monitoring has been extended to comparisons with operational HIRLAM H+6 forecasts, as it is summarised later in the text. Some preliminary VAD data assimilation experiments with the HIRLAM 3Dvar system (Gustafsson et al., 2001, Lindskog et al., 2001) have been conducted afterwards following previous work in HIRLAM with Swedish radar data by Lindskog et al. (2002) and are presented in the next section. Apart of the HIRLAM forecasts verification against surface and radiosonde observations, some other diagnostics on the assimilation performance have been obtained for all radars and some radiosonde data from Spanish stations close to radar sites and are described in the following section. The text finalizes with a summary of the work carried out, the main results obtained and the forthcoming actions that seem needed to improve the VAD data assimilation.

INM Weather radar network

The INM weather radar network started to be deployed in 1986, when the first radar was installed in northern Spain (Valladolid). However, it was not until some years ago that all radars had Doppler capability.

The current INM radar network consists of fourteen C-Band radars (5620MHz), one of them located in Canary Islands, and the rest in the Iberian Peninsula. In this work we have only used data from the thirteen radars in continental Spain. The radars sites are shown in Figure 1.

In Doppler mode, the INM radars have 1km resolution and a maximum range of 120km. Each radar performs every ten minutes a sequence of scans with twenty increasing elevation angles. Raw radar winds are preprocessed to generate VAD wind profiles every thirty minutes, through an algorithm that follows Browning and Wexler (1968) formulation.

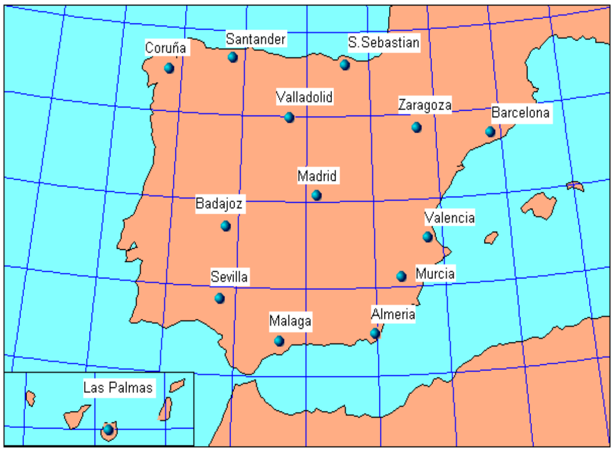

Figure 1. Location of INM weather radars in Spain

Four radiosonde stations in Spain are located very close to radars of Madrid, Coruña, Zaragoza and Murcia. The distance between radar and radiosonde stations is of the order of 25-30Km.

Monitoring of VAD wind profiles

Comparative studies between VAD wind profiles at each radar with 0.2x0.2x31 resolution INM operational H+6 forecasts and analysis have been made. INM operational upper air analysis is still based on the HIRLAM Statistical Interpolation scheme (Undén et al., 2002) . This monitoring of VAD data has allowed to observe that departures of these data from analysis and H+6 forecasts present a near gaussian distribution, although histograms seem to indicate that there are differences in data quality between different radars. In particular, some radars reveal the existence of biases in VAD data, that are more pronounced at night. A common feature that appears in most radars is a diurnal variation of analysis and H+6 forecast minus VAD standard deviation, and that there is the same distance of analysis and H+6 wind forecast to VAD data.

VAD assimilation experiments

The work has continued testing the impact of VAD data through assimilation experiments with the HIRLAM 3Dvar system. Two experiments have been run over the DMR area and with the same resolution (0.5 x 0.5 x 31), using 6.1.2 HIRLAM reference system version. The time period chosen has been 1-31 October 2002, representative of a rainy autumn in Spain. The experiments have been performed with a six hours assimilation cycle, ECMWF analysis as boundaries and H+48 maximum forecast length at each 00, 06, 12 and 18 UTC. 3Dvar analysis with statistical background constraint (Berre, 2000) has been used and only conventional observations have been assimilated. We will call REF the reference experiment, and VAD the experiment assimilating VAD data.

In respect to the usage of VAD profiles, INM VAD data have been interfaced to the OBSPROC program using the existing SCANVAD FORTRAN routine, but introduced as PILOT reports.

VAD wind profiles closest to 00, 06 12 and 18 UTC have only been used and the observation error standard deviation for VAD has been set to $\sigma_{0\ VAD} = 4m/s$ for both components. In the HIRLAM variational data assimilation system, the observation error standard deviation for radiosonde is set to $\sigma_{0\ RS} = 2.2m/s$ for both components in similar vertical levels. No data redundancy check has been applied to VAD data, but it has been observed that its vertical resolution is highly variable and, in general, its data density larger than that of radiosondes. Although the monitoring of these data has revealed the existence of biases in VAD data, they have not been corrected in this preliminary test.

Standard observation verification scores have been obtained for different subsets of stations (EWGLAM list and different geographic areas) apart of for all observations in model area for VAD and REF model forecasts. They have shown that the highest impact of assimilating VAD wind profiles from the INM weather radar network appears over France, in particular in mean sea level pressure and ten meter wind. This impact is positive for model forecasts from 12 and 18 UTC analysis, being smaller in case of those starting from 12UTC analysis, when also observed wind profiles from seven radiosonde stations in the Iberian Peninsula are assimilated by the HIRLAM 3Dvar system. A neutral impact for model forecasts of mean sea level pressure and ten meter winds starting from 00 and 06UTC analysis is observed over this area. When looking at observation verification scores over Spain and Portugal no impact of VAD assimilation is found.

Diagnostics of the assimilation performance for VAD experiment

Some diagnostics have been obtained for VAD experiment in order to check the assimilation performance. In particular we wanted to confirm if the features observed during the monitoring of VAD data against the INM operational analysis and H+6 forecasts based on Statistical Interpolation HIRLAM upper air analysis and a old HIRLAM model version were still observed in VAD experiment based on the HIRLAM 3Dvar analysis and 6.2 forecast model version.

In order to identify the model contribution to the background departures from VAD data, we have also looked at radiosonde wind innovations from stations close to radar sites in Spain (only data from levels below 600hPa). The following diagnostics have been obtained:

- The amount of VAD available data at 00, 06, 12 and 18UTC for each radar; the amount of radiosonde wind available data at 00 and 12UTC for stations close to radar sites.
- The bias of VAD and radiosonde wind innovations for each wind component for every radar at 00, 06, 12 and 18UTC, and radiosonde station at 00 and 12UTC.
- Histograms of innovations and residuals for each wind component for every radar at 00, 06, 12 18UTC, and for each close radiosonde at 00 and 12UTC.
- The number of VAD data rejected by the HIRLAM 3Dvar system quality control checks.

It has been observed that the amount of VAD data depends on the time of the day. There are less VAD data at 00 and 06UTC but still more than radiosonde data below 600hPa at 00 or 12UTC.

There is a positive bias in VAD innovations, specially at 00 and 06UTC. Its magnitude depends on the radar, and the bias in the meridional component shows to be larger than the observed in zonal wind. Radiosonde wind innovations at the four Spanish stations close to some radar locations (Coruña, Madrid, Zaragoza and Murcia) do not show the bias observed in VAD innovations at any time of the day.

Histograms of innovations have confirmed the existence of VAD data bias in some stations, but when its magnitude is small (normally at 12UTC), the background departures distribution shows to be very similar to that of the closest radiosonde wind innovations, indicating very good quality VAD data. However, quality depends very much on the radar (Madrid is representative of the worst behaviour), and on the time of the day, not only the bias but the width of the histograms. This seems to indicate that the VAD observation error presents a diurnal variation. Figures 3 and 4 show the described behaviour for the radar and the radiosonde in the surroundings of Madrid. It can be observed that both histograms of innovations for the meridional wind component are very similar at 12UTC, but at night the radar data quality is worse.

Histograms of the analysis residuals show that the analysis is very close to VAD data, still closer than to radiosonde wind observations. In some cases it has been observed that, although the assumed observation error value for VAD was set higher than that of radiosonde wind, $\sigma_{O\ VAD} > \sigma_{O\ RS}$, the larger amount of VAD data produces the analysis to be negatively biased when looking at radiosonde wind residuals.

Inspection of quality control checks has revealed that no VAD data were rejected during the first guess check and only a few VAD wind data were considered to have gross errors by the variational quality control.

Observation minus first guess standard deviation has been also calculated separately for radiosonde wind data from the Spanish stations considered in this study and for each of the thirteen INM radar stations. The obtained values are very similar in some cases, as e.g. Coruña radiosonde station and its closest radar. In other cases, as e.g. Madrid, the magnitude of the observation minus first guess standard deviation for VAD data is much larger than for radiosonde, specially at night.

The results obtained are supported by other comparisons of VAD data against radiosonde data carried out at INM (S. Conejo and F. Elizaga, 2003). However these studies also indicate that the quality of VAD wind pofiles during October 2002 is the worst found in one year long period analyzed in their work.

Summary

Preliminary assimilation experiments have been carried out to test the impact of VAD wind profiles assimilation from the INM weather radar network. Objective verification scores show no impact of VAD data in almost all areas. Only an improvement in mean sea level pressure and ten meter wind has been found over France for forecasts starting from 18 and 12UTC analysis.

Some diagnostics have been obtained to check the assimilation performance using VAD and radiosonde wind innovations. They have confirmed the main features found during the monitoring of VAD data against the operational H+6 and analysis archived at INM. Observation departures from first guess show near gaussian distribution. Observation error standard deviation shows a diurnal variation, and some radar present biases specially during night time.

So, in order to optimally assimilate VAD wind profiles it seems needed:

- To introduce a radar by radar bias reduction scheme dependent on the time of the day,

- To estimate the observation error standard deviation for VAD wind profiles and make it dependent on the time of the day. One possible method to determine it consists on using wind innovations of radiosonde close to radars.
- To reduce the amount of VAD data introducing some VAD data thinning in the vertical

Work in the coming months will be devoted to develop these enhacements for VAD assimilation and test its impact.

Acknowledgements

Juliana Mol (Instituto Nacional de Meteorologia de Brasil) developed the FORTRAN routines to generate the model equivalent of VAD wind profiles from the archived at INM operational analysis and started the work to monitor VAD data from the INM weather radar network.

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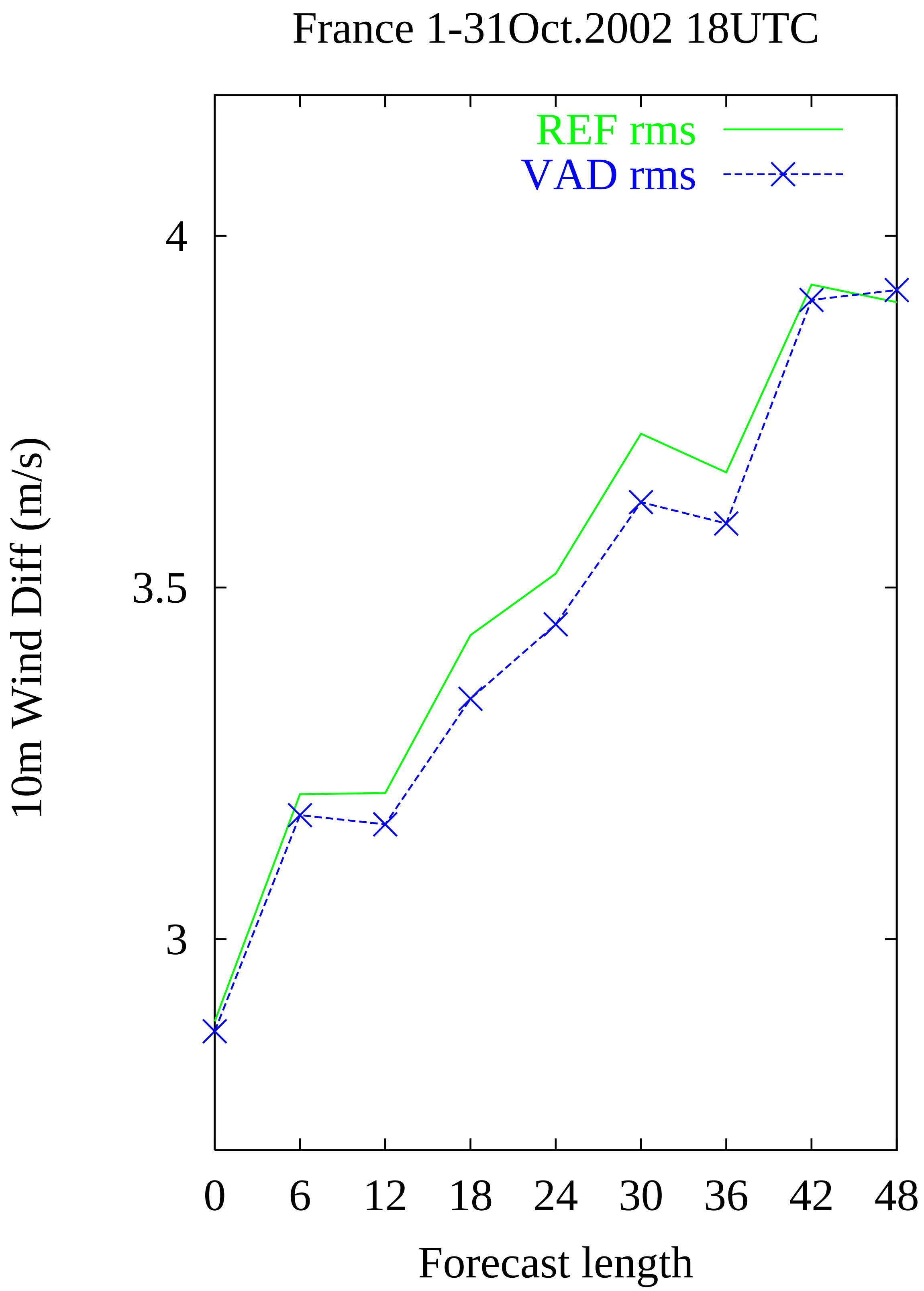

Figure 2. Root mean square of 10m wind vector difference over France for forecasts starting from 18UTC analysis

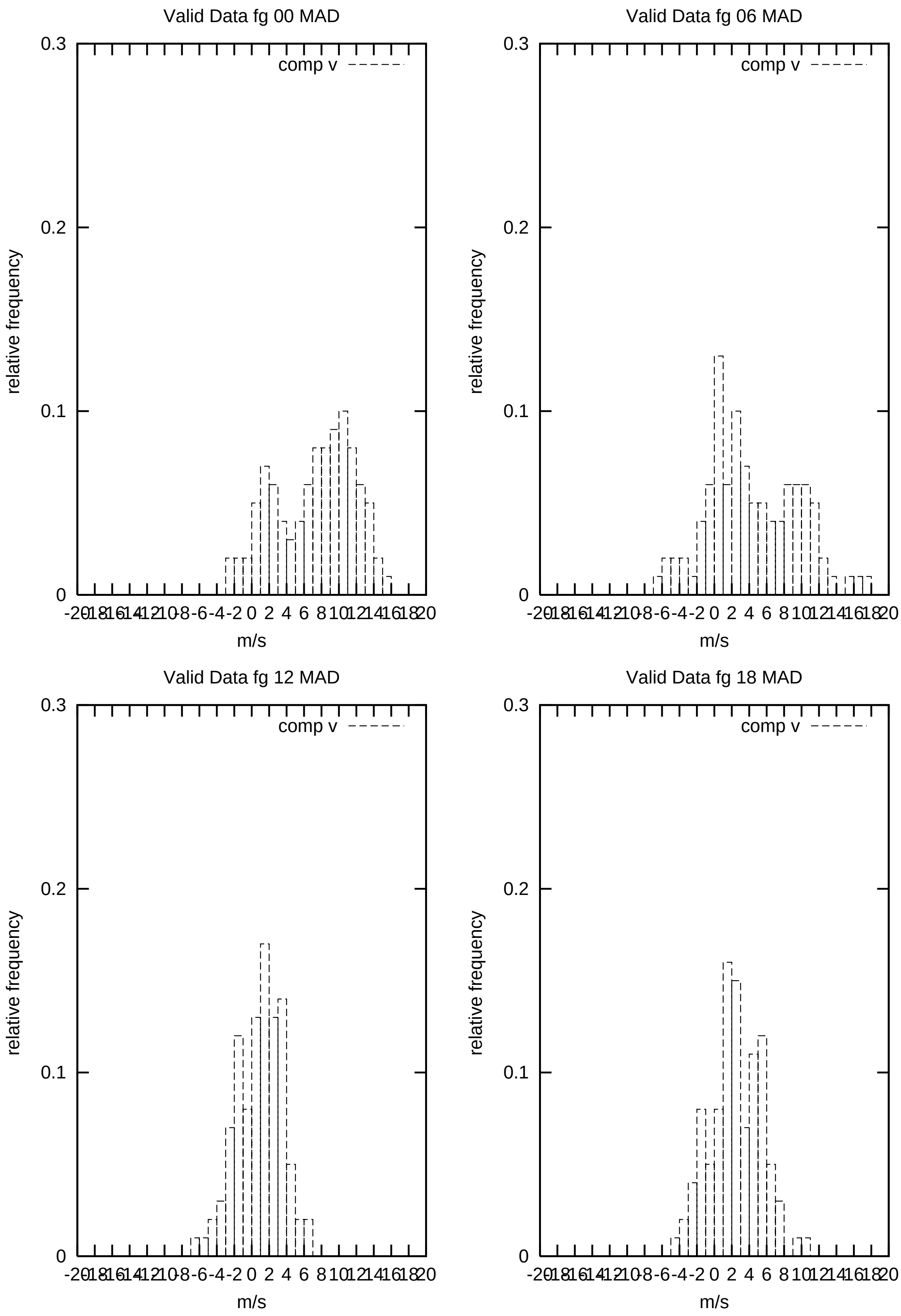

Figure 3. Histograms of innovations of v wind component for Madrid radar at 00, 06, 12 and 18UTC

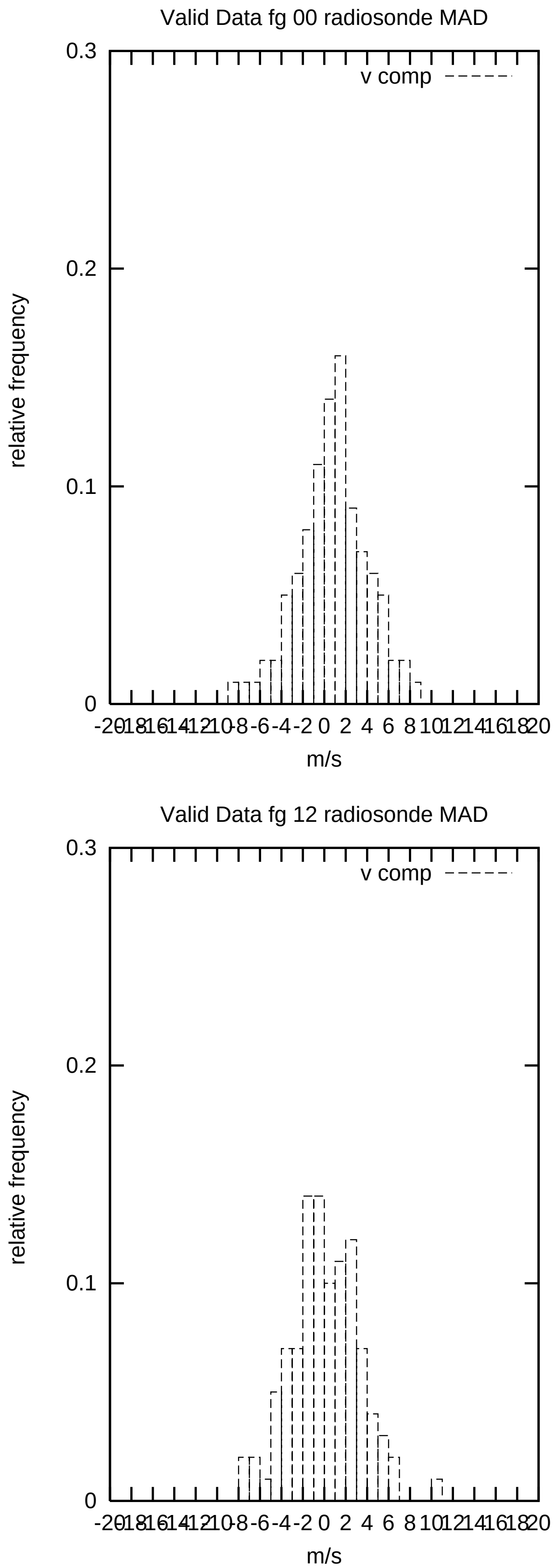

Figure 4. Histograms of innovations of v wind component for Madrid radiosonde at 00 and 12UTC