Comparisons between Canadian prairie MF radars, FPI (green and OH lines) and UARS HRDI systems

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Abstract. Detailed comparisons have been completed between the MF radars (MFR) in the Canadian prairies and three other systems: two ground-based Fabry-Perot interferometers (FPI) and the UARS high resolution Doppler imager (HRDI) system. The radars were at Sylvan Lake (52°N, 114°W), Robsart (49°N, 109°W) and the main continuing facility is at Saskatoon (52°N, 107°W). Statistical comparisons of hourly mean winds (1988–1992) for the Saskatoon MFR and FPI (557.7 nm green line) using scatter plots, wind speed-ratios, and direction-difference histograms show excellent agreement for Saskatoon. No serious biases in speeds or directions occur at the height of best agreement, 98 km. If anything, the MFR speeds appear bigger. The same applies to the Sylvan Lake MFR and Calgary FPI, where the best height is 88 km. In both cases these are close to the preferred heights for the emission layers. Differences between measurements seen on individual days are likely related to the influence of gravity waves (GW) upon the optical and radar systems, each of which have inherent spatial averaging (350, 50 km respectively), as well as the spatial difference between the nominal measurement locations. For HRDI, similar statistical comparisons are made, using single-overpass satellite winds and hourly means (to improve data quality) from MFR. Heights of best agreement, based upon direction-difference histograms, are shown; there is a tendency, beginning near 87 km, for these MFR heights to be 2 or 3 km greater than the HRDI heights. Speeds at these heights are typically larger for the satellite (MFR/HRDI = 0.7–0.8). Reasons for the differences are investigated. It is shown that the estimated errors and short-term (90 min) differences are larger for HRDI than for the MFR, indicating more noise or GW contamination. This leads to modest but significant differences in median speed-ratio (MFR/HRDI < 1). Also, comparison of the two systems is made under conditions when they agree best and when they show large disagreement. For the latter cases both systems show higher relative errors, and the HRDI vectors are frequently small. It is suggested that spatial or temporal GW wind fluctuations are the likely cause of the larger HRDI-MFR disagreement when wind speeds are small. No satisfactory explanation exists for the overall discrepancy in speeds between the MFR and HRDI.

1 Introduction

Previous comparisons between HRDI and ground-based experiments (radar, optical, rocket) have employed a variety of analysis methods; these include scatter-plots of north-south (meridional) and east-west (zonal) components of individual wind measurements, comparisons of instantaneous height-profiles (EW, NS), and comparisons of tidal and background mean winds for selected intervals (Burrage et al., 1993; Burrage et al., 1996; Khattatov et al., 1996). Briefly, the comparisons have shown slopes of the scatter plots to be generally less than 1, which has been taken to mean that HRDI values are equal or greater than those from other systems. The largest discrepancies are in the meridional component.

Since MF radars have been the dominant ground-based systems, these differences have led to careful and exhaustive examination of possible biases in the winds from such equipment (e.g. Cervera and Reid, 1995; Manson et al., 1996). Scatter plots comparing zonal or meridional winds are useful in identifying offsets and magnitude biases between systems which measure the same two independent wind components, such as HRDI and its companion experiment on UARS, WINDII. However, the MF radar analysis produces a vector wind in which the direction is expected to be unbiased, because of the azimuthal symmetry of the measurement, while the speed can be biased by several known effects, e.g. external noise. It is easier to identify such possible
biases in vector comparisons, viz. speed and direction. The use of direction also allows for the heights of best agreement to be determined between systems.

To provide balance, the same analyses will be applied to comparisons between ground-based radar and FPI optical systems, as well as to radar and HRDI.

The following two sections discuss MFR wind biases and height calibration uncertainties. Sections 4 and 5 describe results for two independent MFR-FPI comparisons, which both show that MFR speeds are a little greater than FPI values. Section 6 compares the Saskatoon MFR and HRDI simultaneous-data sets. HRDI and MF error estimates are examined, to see whether their differences could explain the apparent speed bias. Finally the HRDI and MF values are divided into two sets according to whether they agree or not to see whether any dissimilarities are evident.

In the following study the term “error” is generally used to denote random error in a measurement, not a difference or a bad value.

### 2 Biases in MFR winds

Sources of potential biases in MFR measurements have been discussed by Meek (1995) among others. The most common one is external noise, which causes depression of antenna-versus-antenna cross-correlation values used by the spaced antenna analysis in wind determination (Meek, 1980). The majority of these could be corrected, but often, possibly due to fitting a Gaussian to a non-Gaussian correlation or to a very narrow auto-correlation function for the noise level determination, correlation results in correlation values > 1. These latter data would have to be discarded, even though the wind value may not have a significant bias. The effect of noise can also be accentuated by a small receiver array (triangle size effect). Correction for noise eliminates this effect (e.g. Meek, 1990). In this work, instead of correcting for noise and accepting the loss of some data, we prefer to select data which are not significantly affected by noise.

Other errors are possible, such as signal statistics not agreeing with the Gaussian correlation model (Meek, 1980) because, for example, there are too few scatterers (Holdsworth and Reid, 1995).

There is also small bias involved by taking a vector hourly mean, viz. if the wind direction is changing, the mean speed could be smaller than any individual speeds. Tests on a large set of MFR data gave median ratios of 0.92 and 0.98 for divided sets of $V < 30$ and $V > 30$ m/s respectively. However, there could be a similar effect acting on HRDI because of its spatial averaging.

The analysis model (full correlation analysis, FCA) assumes statistical stationarity over the record length (5 min). Also, if the fading data are not stationary (or have high noise level), they are more likely to be rejected in the analysis. Thus a selection based on number of values per hour is likely to select data on which the analysis performs best. Since no noise correction is done, these data will have an uncorrected noise bias. A separate statistical study, comparing original (for which the number left after noise correction was >6 of a possible 12), and corrected hourly means showed a residual bias of <10% above 80 km with a smaller bias (<5%) for 85–94 km in daytime.

It is possible that all these biases could combine, resulting in significantly lower than actual speeds, but as will be seen later, comparisons with FPI systems argue that this is not the case in practice.

### 3 Errors in MFR heights

The Saskatoon radar has a nominal resolution of 3 km (20 μs pulse). An accurate range calibration was obtained from observations of a research balloon, floating at ~36 km, which carried a global positioning system (GPS) unit. The method was to locate times when the balloon echo-strength was equal at two adjacent height gates ~60–70 km, and work out the real range from the GPS locations of the radar and balloon. The final calibration used here is a rounded version of the measurements. This could result in MFR heights which are up to ~1 km too small.

A more serious source of error is caused by retardation of the radio waves by ionization, the height is then termed *virtual* height. The resulting error is only important near the E-region total reflection echo. Namboothiri *et al.* (1993) have investigated this problem, and found that MFR heights above 94 km begin to depart significantly from real heights at noon in the summer ionosphere at our radio frequency. Away from noon, or in the winter, the departure is less serious because of reduced ionization. We avoid this problem here by selecting appropriate comparison heights depending on season and time of day.

Other lesser errors include moderate angular spread, resulting in a lower effective height (viz. the average height is less than the range). In the extreme case of total reflection from a sporadic-E (Es) layer (these are usually located above 95 km), the measurement will apply to its height even when the apparent height (the range) is greater. Also an extremely height-stable layer could result in an unknown error within the 3 km radar resolution; and an ionospheric tilt would make the measured height larger than real, again because of an oblique angle the range is greater than the height of scatter.

Most of these potential errors lead to MFR winds being appropriate to a lower height than that stated, and since wind speed tends to increase with height, would lead to lower than actual speeds being found.

The technique of sliding the FPI or HRDI, and MFR heights with respect to each other for the lowest direction-difference, which we will employ later, depends on there being a strong tidal signal (circular wind vector rotation with height) with a relatively short vertical wavelength (Manson and Meek, 1986). In this case the wind direction-difference will be very sensitive to height differences, especially at the upper heights where the tides are large.