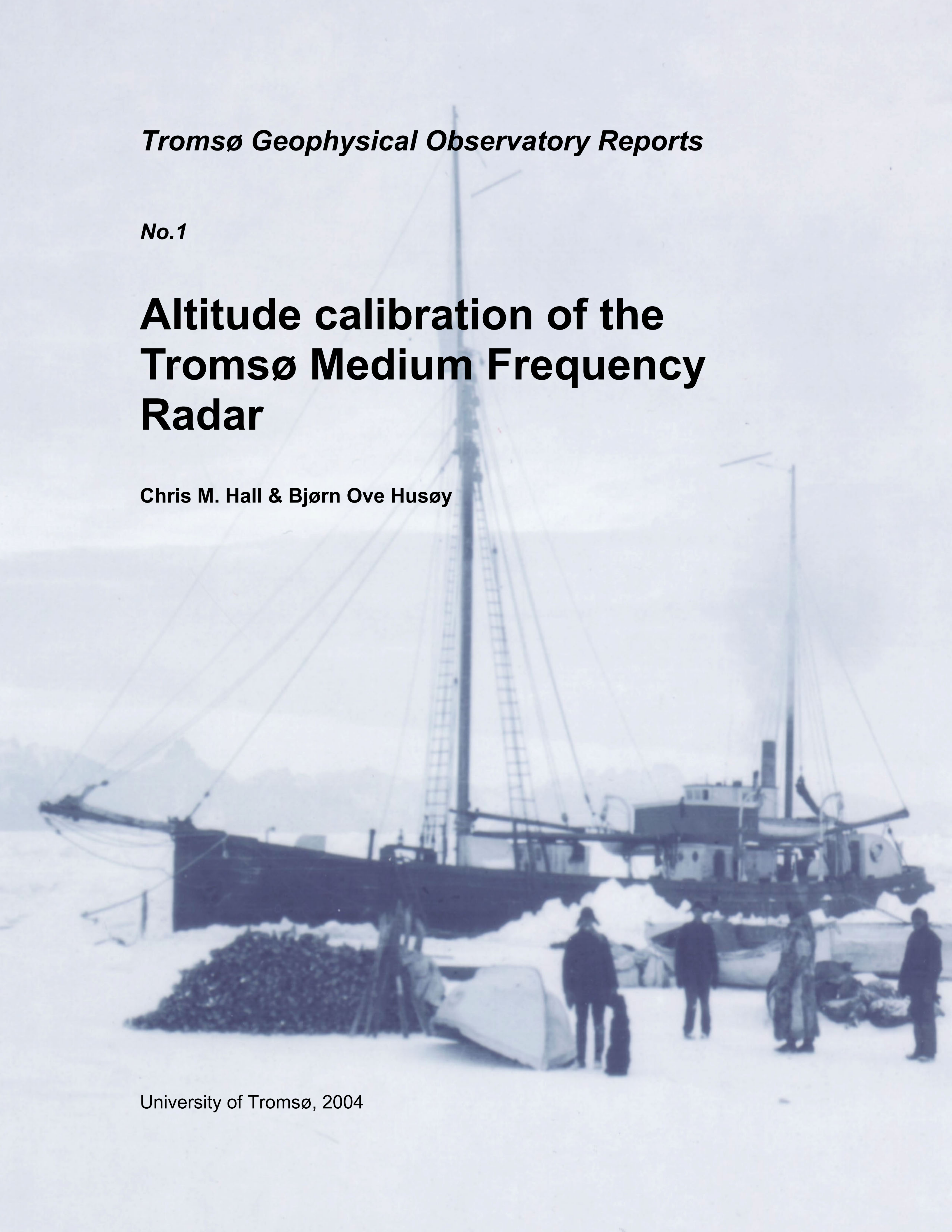

Tromsø Geophysical Observatory Reports

No.1

Altitude calibration of the Tromsø Medium Frequency Radar

Chris M. Hall & Bjørn Ove Husøy

University of Tromsø, 2004

Cover photo: “Conrad Holmboe”, Greenland, 1923. In 1922, the precursor of Tromsø Geophysical Observatory, The Geophysical Institute, acquired a 96’ steamer to service field stations in the arctic. The boat became trapped in the ice on the eastern seaboard of Greenland in 1923 while unsuccessfully attempting to relieve the personnel there, and, irrevocably damaged by the ice, she limped to Iceland and was scrapped.

Foreword

This publication is the inaugural report in the series *Tromsø Geophysical Observatory Reports*. The series is intended as a medium for publishing documents that are not suited to publication in refereed journals, but that Tromsø Geophysical Observatory wishes to make accessible for a wide readership. The topics of the reports will be within the disciplines of Tromsø Geophysical Observatory: geomagnetism and upper atmosphere physics. The language will primarily be English.

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Abstract. Although the Tromsø Medium Frequency Radar situated at Ramfjordmoen, Norway (69°N, 19°E) has been operating for over a quarter of a century, no definitive altitude calibration has ever been documented using independent measurements of the same atmosphere. Here we perform calibrations using the recently installed (November 2003) Nippon/Norway Tromsø Meteor Radar by identifying wind features in the same volume. We also perform an independent check using oscilloscope measurements supplemented by an acoustic delay line.

Introduction

The Tromsø Medium Frequency Radar (MFR), also referred to as the Partial Reflection Experiment (PRE), has been described in detail by *Hall* [2001]. The radar was originally owned by the University of Tromsø alone, but in recent years, following acquisition of new components, has become a joint venture together with the University of Saskatchewan (Canada) and Nagoya University (Japan). Operations started in 1975 with the system primarily observing echo power from ordinarily and extraordinarily polarized transmissions, giving information concerning layering of the middle atmosphere and from which electron density could be deduced. During this time altitude calibration was performed by observing both first and second order echoes [*Harbitz*, 1977]. At the end of 1986 the system was modified to continually measure winds using the spaced antenna method [*Meek*, 1980], and, in doing so, rendered the calibration by *Harbitz* [1977] obsolete. Further receiver / data-acquisition improvements were made in 1993, 1996 and 1997. In this latter mode, the system delivered (and still does) winds every 5 minutes (usually) between 40 and 140 km altitude at 32 range-gates of 3 km separation. Due to group delay of the radio wave in the ionosphere, the altitudes calculated from the range-gate timings of the receivers must be considered virtual; this aspect is outside the scope of this report and has been addressed by *Namboothiri et al*. [1993] and *Hall* [1998]. Below 90 km altitude, however, the group delay effects are generally considered negligible and to compare results with those of other instruments [e.g. *Nozawa et al*., 2002; *Hall et al*., 2003] it is important to know the true altitudes of the range-gates. In this report, we employ two quite different methods to this end: (i) comparison of wind measurements using the co-located Nippon/Norway Tromsø Meteor Radar (NTMR) and (ii) signal timings determined by oscilloscope. NTMR is, to all intents of purposes for this study, identical to the Nippon/Norway Svalbard Meteor Radar, the specifications of which may be found in *Hall et al*. [2002].

Wind comparison method

The time and height resolutions and fields of view of the MFR and NTMR differ somewhat. These are summarized in Table 1.

Table 1. Salient parameters of Tromsø MFR and NTMR

	MFR	NTMR
Height resolution	3 km	1 km
Time resolution	5 min	30 min
Field of view	17°	~140°

Note: the effective field of view of NTMR depends on the meteor echo distribution; the time resolution of NTMR is chosen from the meteor count rate

Since the MFR field of view is wholly within that of NTMR, and assuming homogeneity of the wind field (intrinsic in derivation of vector winds using meteor radar) we deem that winds from the two systems are directly comparable (Figure 1). Direct comparison of wind features and magnitudes will be the subject of a separate study.

Data from the beginning of 2004 and until end of April are used here. First, each of a zonal and a meridional wind profile is obtained from the NTMR dataset along with the timestamp for the beginning of the 30 minute period. Then up to six 5-minute average profiles are located in the MFR data set corresponding to the NTMR averaging period and are averaged together. Thus 30-minute averages of NTMR and corresponding MFR zonal and meridional winds are assembled. The altitudes of the meteor radar derived winds are assumed to be correct.

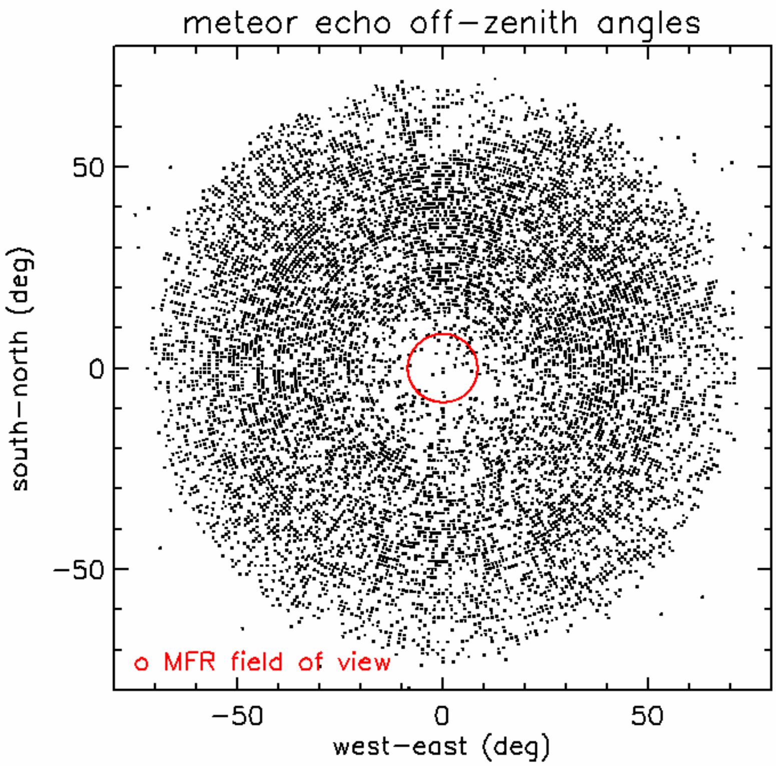

Figure 1. Zenith angle distribution of NTMR echoes (a total of over 10000) for the 4th April 2004, almost all occurring between 70 and100 km altitude. The effective field of view of NTMR is therefore ±70°. The MFR 17° field of view (i.e. half-power full width antenna aperture) is shown by the red circle,

The centre of the first MFR range-gate has been very roughly calculated to be 40 km, based on group velocity in the atmosphere and known parameters in transmitter, receiver and earlier raw data recording system [*Chris Meek*, private communication]. However this must be taken to be nominal and various "true" altitudes have been proposed varying from 40 to 49 km based on detection of a balloon with the very similar Saskatoon MFR (1996, +6 km correction; 1998, and following a transmitter change, +9 km) and comparison with wind features seen by radars in nearby Kiruna (68°N, 21°E) and Andenes (69°N, 16°E). As our starting point, we shall therefore take the MFR range-gates to be at altitudes {40 km, 43 km, 46 km, …}. At each timestep for which we have data from both radars, we have performed cross-correlations of both the zonal and meridional components. In performing these cross-correlations we have used both 3km lags (corresponding to the gate spacings of the MFR) and 1 km lags with oversampled MFR profiles (obtained by 2nd order interpolation to a 1 km resolution).

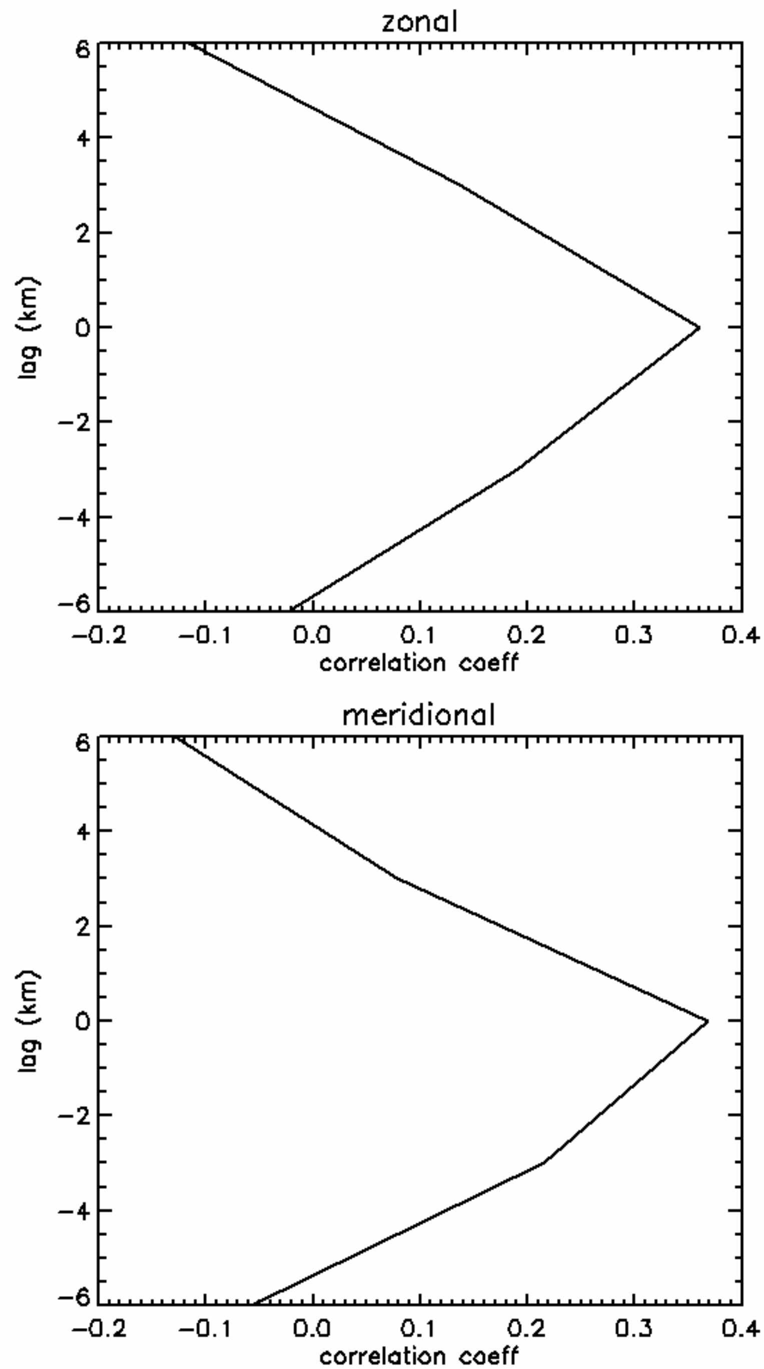

Figure 2. Results of averaging the cross-correlations of the MFR zonal (top) and meridional (bottom) wind profiles with corresponding NTMR profiles and at 3 km lag spacing.

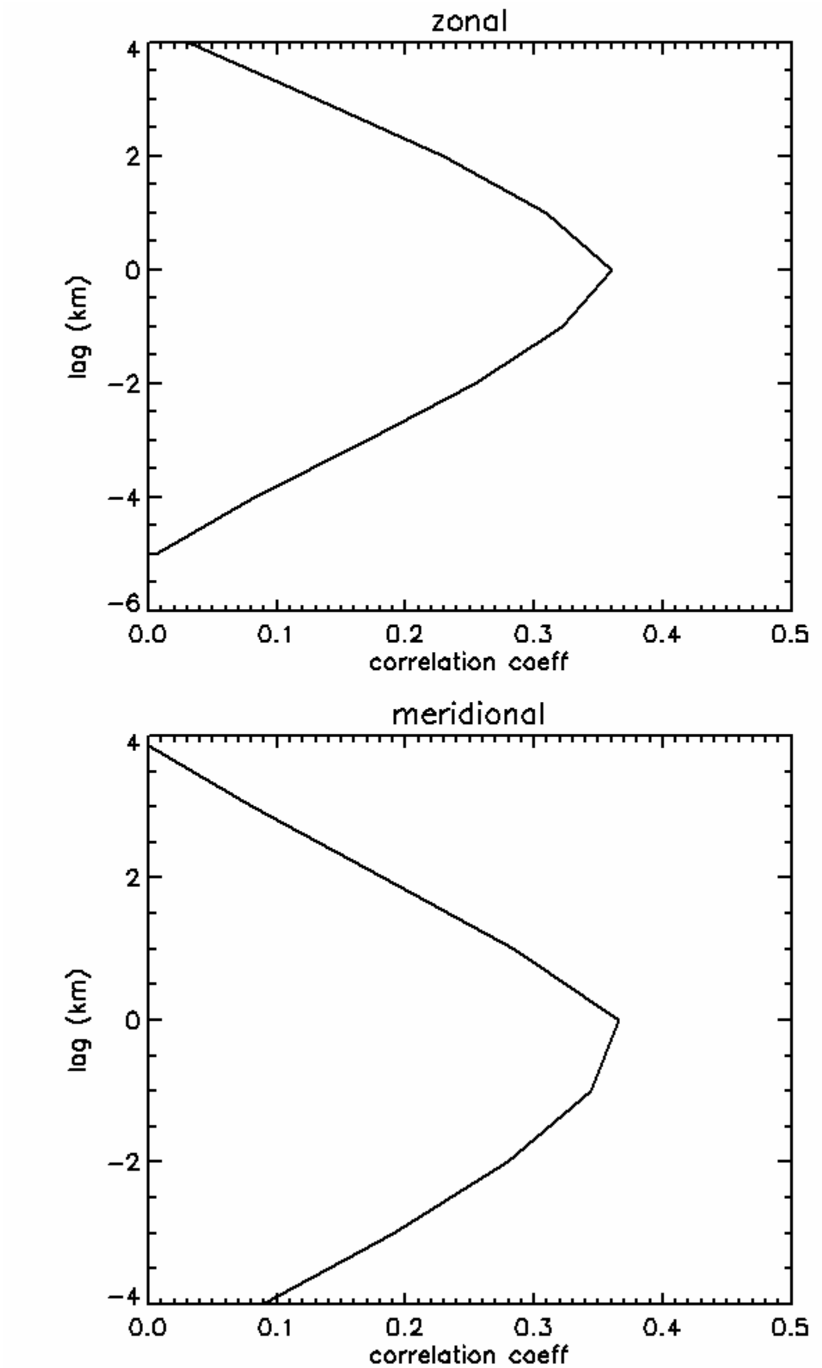

Figure 3. As for Figure 2 but with 1 km lag spacing

Thereafter the means of each of the zonal and meridional correlation functions (2026 in all) were found for both 3 km (Figure 2) and 1 km (Figure 3) lags. While the absolute values of the correlation coefficients are only around 0.3, the drop off at all lags apart from zero suggests very strongly that the nominal 40 km MFR gate is indeed at 40 km altitude. From Figure 1, we can furthermore attempt to explain the low correlation coefficients. At the meteor echo heights the field of view of NTMR spans some 200 km and therefore the wind amplitudes obtained are spatial averages over scale sizes comparable with gravity wave horizontal wavelengths. The MFR half-power beam intersects a volume only around 26 km diameter at 90 km and so gravity wave activity will add a variability to the wind amplitudes measured that is smoothed out by NTMR.

We may now construct daily plots of zonal and meridional amplitude as functions of height and time for each radar. By grace of the prominent semidiurnal tide we are able to test the hypothesis that the MFR range-gates are at {40 km, 43 km, 46 km, …}. Two such examples are shown here, in Figure 4 (9^{th} January 2004) and Figure 5 (20^{th} March 2004). These dates have been selected to illustrate approximate winter solstice and vernal equinox conditions, to have reasonably good MFR coverage, but otherwise no particular criteria. It is possible to examine heights of the same features, in particular both the minima (deepest blue) and direction changes (transitions from blue to green), as seen by each radar.

Inspection of Figures 4 and 5 and also other similar plots for other dates (not shown here) validate our choice of altitudes for the MFR range-gates. Such dates were selected for well-defined tidal phase signatures; in fact 9^{th} January 2004 (Figure 4) is somewhat atypical, the maximum signal normally occurring at 85 km as is the case for 20^{th} March (Figure 5).

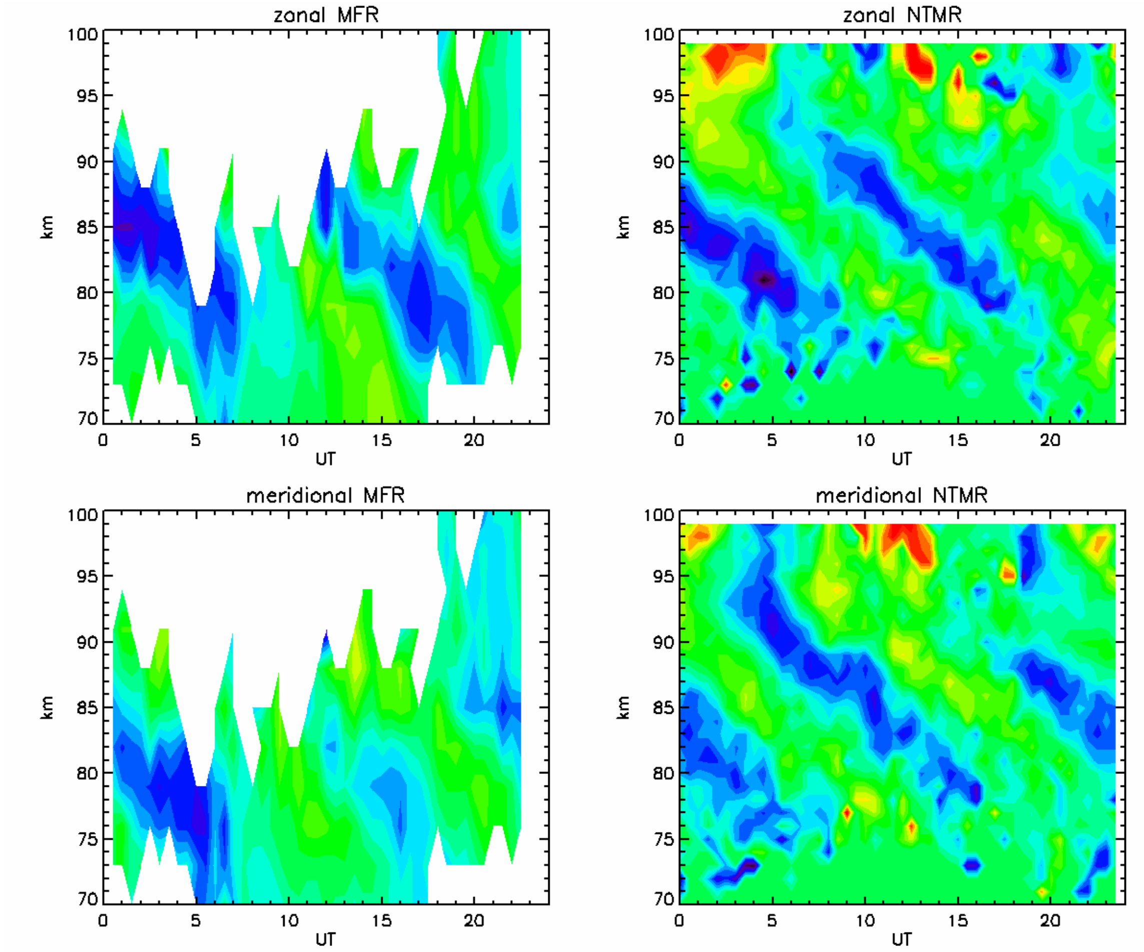

Figure 4. 9th January 2004 wind amplitudes as functions of time and height and with the altitude calibration as described in the text. Top-left: MFR zonal; top-right: NTMR zonal; bottom-left MFR meridional; bottom-right NTMR meridional. The colour coding is such that the transition from green to blue is zero, cold colours denote westward (zonal) and southward (meridional) and colour transitions occur every 10ms^{-1}.

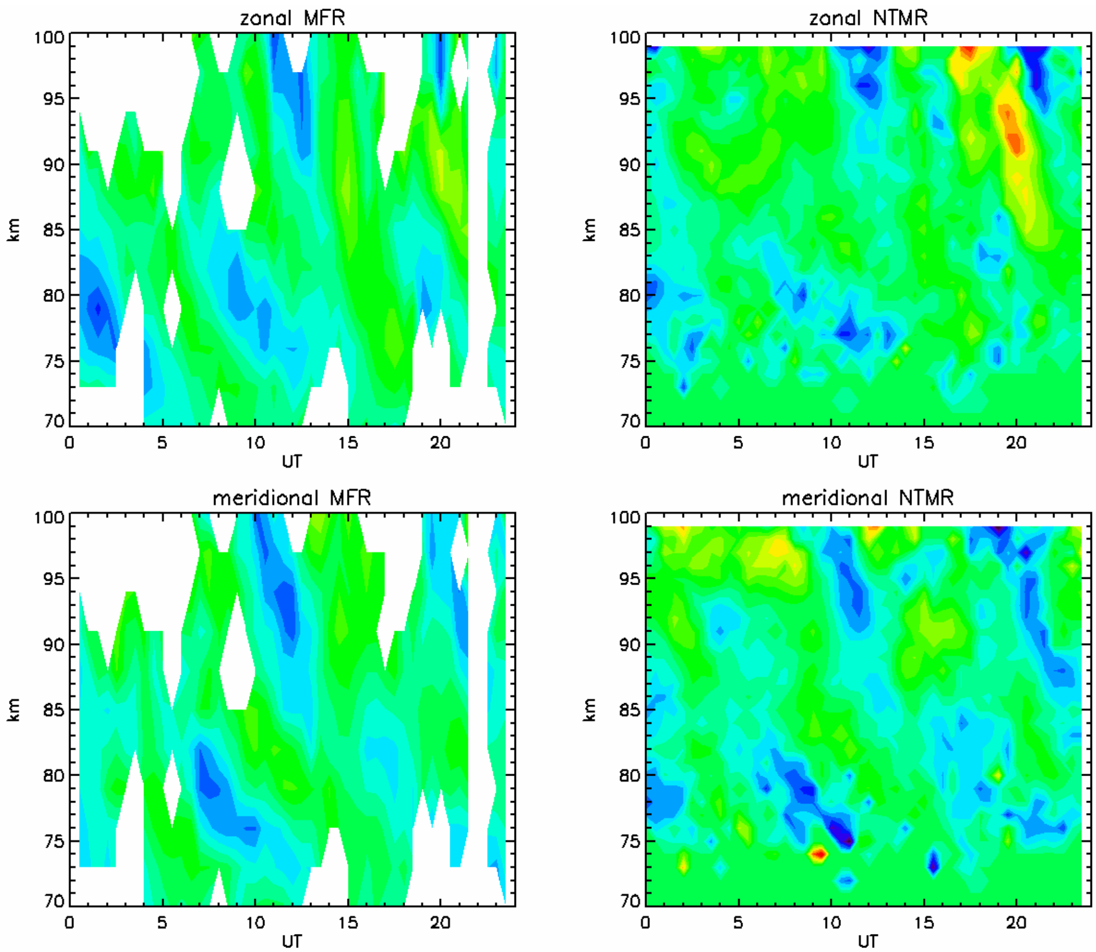

Figure 5. As for Figure 4 but for 20th March 2004

Signal timings method

Originally, it was envisaged that using an acoustic delay line of length corresponding to the round trip to some altitudes covered by the normal experimental set-up would provide a definitive calibration. A delay line was borrowed for this purpose, but its length was only 100μs and therefore not only corresponding to an altitude well below the first normal measurement gate of 40 km, but also shorter than the recovery time of the blanking used to protect the receivers from the transmitter ground-pulse. To overcome this problem, the receiver protection was disabled, suitable attenuation inserted (together with the delay line) at the receiver input and transmitter power reduced. However, running the receiver with gates starting at ground level failed to generate data at the receiver output in which the 100μs delayed pulse could be unambiguously identified, even though the delayed signal could be identified by an oscilloscope. It was decided, therefore to simply use a higher quality oscilloscope alone. Various approaches were employed to reduce ambiguity.

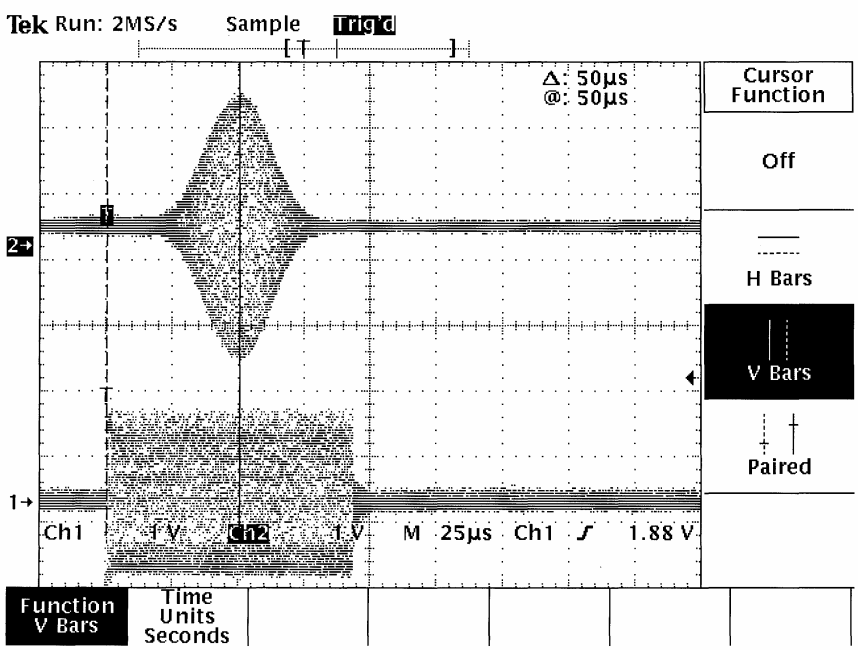

Figure 6. Oscilloscope screen showing transmitted pulse seen at receivers (upper trace) and the pulse synchronized to the receiver to trigger the transmitter (lower trace)

Without the need for reduction in transmitter power, attenuation at the receiver or removal of the receiver protection, it was possible to simply examine the delay from the start of the transmit trigger signal to the peak of the transmitted pulse. As seen from Figure 6, this was found to be 50±2μs and includes the delays in antennas including cabling.

Next, sufficient attenuation was inserted between the antenna feed and the receiver (only one channel of the possible 3 was used) and the blanking protection removed. The measurement point was then moved to the analogue output of the receiver (Figure 7).

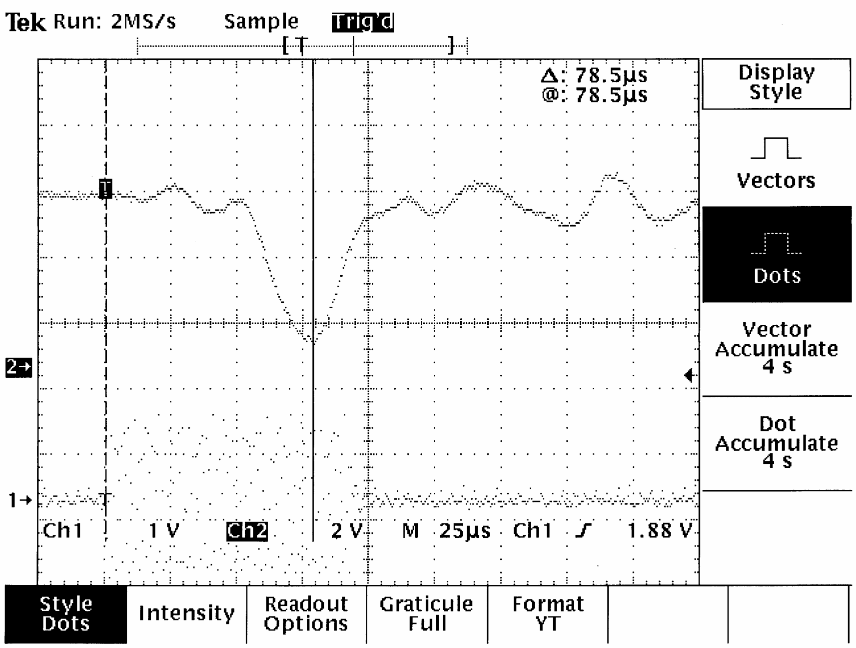

Figure 7. As for Figure 6, but received pulse measured at the receiver analog output (i.e. the demodulated signal) (inverted Gaussian in top trace).

The delay from the start of the transmit trigger signal to the peak of the transmitted pulse was found to be 78 ± 2μs and now including the delays in antennas including cabling and demodulation in the receiver. The attenuation required to define the peak in the transmitter pulse was so large as to render the 100μs delayed pulse (i.e. with the delay line) invisible. Decreasing the attenuation to make the delayed pulse visible resulted in Figure 8.

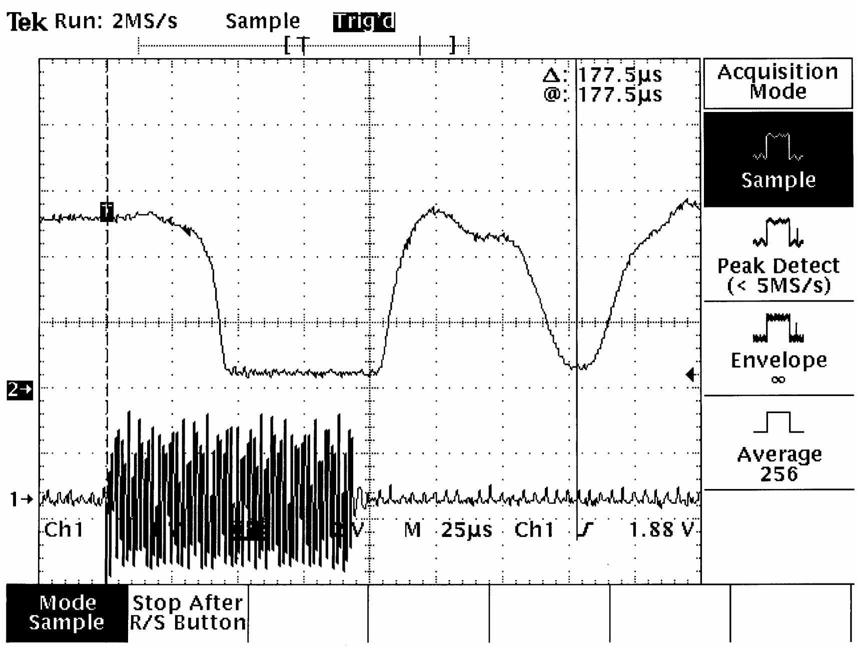

Figure 8. As for Figure 7, but showing the 100μs delayed pulse (top trace, inverted Gaussian to the right) at the cost of cropping the ground pulse.

The addition of the delay line confirms the measurement philosophy is correct by introducing a known (i.e. 100μs) timescale, and also, very importantly, confirms that the transmitted pulse did indeed travel through the antenna system and not from the transmitter synchronization and directly into the receiver through the building. From knowledge of the receiver ADC and sampling timing, the centre of the first altitude gate is timed to be at 356μs. Our measured cumulative delay in transmitter pulse, cables and receiver front-end is 78μs; a further measurement without cabling failed to discern a delay for the cables and so we add a further 4μs. Thus we estimate that the height for the first altitude gate to be $3.10^{8}\times [356 - (78 + 4)].10^{-6} / 2$ m = 41 km. Uncertainty in reading the oscilloscope, whether the ground pulse travels through the antenna cable or through the earth between transmitter and receiver units, and, in the event of the former, that the distance between transmitter and receiver antennas should be taken into account, and amount to an additional 600m which must be subtracted from the height estimate [*Chris Meek*, private communication].

Conclusion

Had the delay line been such that we were able to direct the signal from the transmitter antenna via the receiver antennas and delay and into the data output in a fashion that the signal appeared in a gate normally measured (i.e. in the mesosphere), then we would have had much confidence in this method of calibrating the gate heights. As we saw above, however, the oscilloscope method remained open to question, although by only less than 1 km. Given the well defined peaks in correlation when comparing with the NTMR results, we conclude that when running in the current normal (as of 1997 to present) mode of operation, the gates are centred on {40, 43, 46, … 133} km.

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