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# Co-Ordinated Meteor Wind Observations from Sheffield during the January 1976 Winter Anomaly

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**Abstract.** Ground based upper atmospheric wind measurements in the 80–110 km region were made at Sheffield on three specific occasions during the El Arenosillo winter anomaly campaign in January, 1976. The radio meteor method employed in this study is described in some detail. Preliminary results indicate that appreciable wave activity was present throughout the duration of the campaign. There is little evidence, though, from the structure of the prevailing winds for significant NS air motions which are currently thought to be responsible for the transport of nitric oxide and other minor constituents from the auroral zone toward mid latitudes during a winter anomaly. Such transport may, however, have been effected by large scale wave motions, with periods of the order of 20 days, whose presence is suggested by the Sheffield data.

**Key words:** Wind velocity measurement – Wind profiles – Diurnal variations – Periodic variations – Atmospheric circulation – Meridional flow – Ionospheric disturbances.

## Introduction

Past investigations of upper atmospheric winds by the radio meteor method have shown that the dominant wind systems have a distinctly periodic character. Apart from the well known diurnal and semidiurnal tidal oscillations variations with periods in excess of one day are quite common (Muller, 1972; Muller and Kingsley, 1974). While at lower altitutdes the wind is essentially zonal appreciable meridional components are observed at meteor heights and it has been argued that the meridional flow may be responsible for the transport of nitric oxide (NO) and other minor constitutents from the auroral zone to temperate latitudes. NO and other constituents may thus travel considerable distances during their lifetime bringing about the photochemical and electron

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density changes associated with a winter anomaly. The so called prevailing wind (often no more than an unresolved component of a long period wind oscillation) may also be considered as a means for NS atmospheric transport. It is therefore of paramount importance to examine both the prevailing and periodic wind components over a wide geographic area at such times when the nature of other atmospheric parameters, for example D-region absorption, indicate the development of a winter anomaly.

Such efforts were made in a co-ordinated experiment during the El Arenosillo winter anomaly campaign, January, 1976, involving three meteor wind stations, at Sheffield (U.K.), Garchy (France) and Bologna (Italy), respectively. Although the techniques employed at these stations differ slightly amongst themselves data of identical quality, with similar spatial and temporal resolution, have been obtained over sufficiently long periods of time to allow a good description of neutral winds over a NS baseline of nearly 1000 km. The meteor wind measurements were supplemented by ionospheric drift measurements from Nancy and St. Cassien thus increasing the amount of information available on the general atmospheric circulation in the upper mesosphere and the lower thermosphere.

The present report describes the measurements conducted during three specific periods at Sheffield in January, 1976. Reference is made, in particular, to the presence of meridional wind components as a possible means of transport for minor atmospheric constituents. It is clear that the Sheffield results will become more meaningful when viewed synoptically with those obtained elsewhere. A co-ordinated study of the winter anomaly results is already in progress and will be reported on during the next Cospar meeting at Tel Aviv in June, 1977.

## Technique

Measurements of neutral air motions in the region 80–110 km can now be carried out at Sheffield on a routine basis with the use of a 36 MHz coherent pulse Doppler radar. The transmitter has a peak power of 200 kW and is operated in short pulse (25 μs) mode alternately on two Yagi-Udah aerial arrays directed NW and SW, respectively. Echoes from meteor trains are received by two interferometers, one facing NW, the other SW, and a phase comparison between the transmitted and received signals allows the radial velocity of a meteor train to be measured with an accuracy of $\pm 2$ m $s^{-1}$. The phase information on the echo wave available from the two interferometers forms the basis, together with the echo range from the pulse delay, for the computation of echo heights in the two preferred directions with a resolution of $\pm 2$ km. It is thus easy to calculate the horizontal wind flow for each echo from the measured radial velocity and by recording echoes sequentially a meaningful vertical wind profile may be established within about 15–20 min. An example of wind data obtained in such a fashion during the January, 1976 winter anomaly campaign is shown in Figure 1. It is seen that individual wind components can be resolved without appreciable data gaps between 80 and 120 km altitude. The apparent

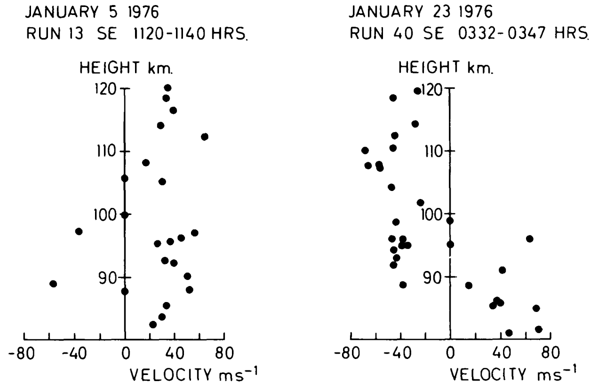

**Fig. 1.** The variation of meteor wind velocities from Sheffield as a function of height for 2 individual periods of observation, selected at random, during the El Arenosillo winter anomaly campaign. The time indicates the length of recording required to establish a meaningful vertical wind profile

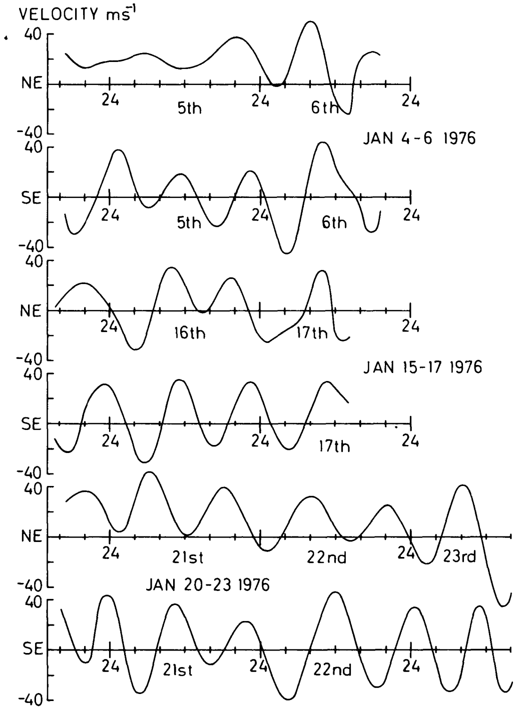

**Fig. 2.** Average NE and SE meteor wind components from Sheffield for a mean height of 97 km in the form of best fitting polynomials to the raw data

scatter in the data is currently interpreted in terms of the limited height resolution of about 2 km while it is known from rocket vapour trail experiments that wind shears of about 50 m s$^{-1}$ quite commonly occur over a height of about 1 km. It is worth pointing out that the number of available meteor echoes varies appreciably in the course of a day. At times near the maximum (about 06.00 local time) the hourly rate may be 50 times that near the minimum (about 18.00 local time) with a consequent data loss in the hours of the afternoon, affecting in particular the top and bottom of the meteor region because of the uneven echo number distribution in the vertical. The data profiles shown in Figure 1 relate to times of average meteor activity when a quasi-instantaneous wind profile may be obtained without difficulty. A lower meteor rate would necessitate longer recordings, of up to 1 h, in order to cover smoothly the whole vertical extent of the meteor region. Unfortunately, the wind structure tends to vary apppreciably from hour to hour such that recordings have to be limited to a maximum length of about 20 min. It is therefore customary to accept the data loss at certain heights and average within finite height intervals. The present results have thus been grouped into 3 main intervals such that continuous data time series are made available for three average heights. This appears adequate for the description of large scale wind features required in this study.

These time series are harmonically analysed in order to determine tidal components and, when of sufficient length are subjected to spectral analysis involving best fitting polynomial curves to the raw data.

The data at Sheffield are at present displayed on a 24 channel U.V. chart recorder. Information is extracted from the charts manually prior to computer processing which causes considerable delay in the production of the final results. It was therefore impracticable to record continuously during the whole campaign; instead the Sheffield radar was operated on three occasions for limited periods (between 2 and 3 days) while intensive observations were taking place at other stations involved in the winter anomaly campaign.

## Results

Recordings of meteor winds from Sheffield took place during the following intervals in January, 1976: (i) from 17.00 on the 4th to 20.00 on the 6th, (ii) from 15.00 on the 15th to 15.00 on the 17th, and (iii) from 17.00 on the 20th to 17.00 on the 23rd. All times quoted in this report are universal time (G.M.T.). The difference between U.T. and local mean time may be neglected for the present purposes since it is only 6 min.

In order to facilitate a general comparison of the data with those obtained elsewhere average winds have been computed for the whole of the meteor region by using all the measurements, regardless of altitude. These correspond to an average altitude of about 97 km, an altitude where the distribution of echo numbers shows a pronounced peak for the Sheffield radar system. Polynomial curves have been fitted to the raw data, using a least square method, and these are shown, for the NE and SE components, respectively, in Fig. 2. All curves indicate a pronounced semidiurnal variation which may be attributed to the effects of the solar tide. Diurnal variations, though not conspicuous in the curves, are resolved by harmonic analysis. Individual trends in the data are well marked and are now understood to be the effect of unresolved oscillations whose periods exceed the lengths of the data series. By averaging all velocities over each period of observation the so called prevailing wind is obtained. Notations in this report conform to the ionospheric convention such that a positive NE amplitude represents a wind blowing toward the NE.

**Table 1.** The semidiurnal tide during January, 1976

| Date | Altitude (km) | NE | | SE | | U | | V | |
|---|---|---|---|---|---|---|---|---|---|
| | | Phase (degrees) | Amp ($m\ s^{-1}$) | Phase (degrees) | Amp ($m\ s^{-1}$) | Phase (degrees) | Amp ($m\ s^{-1}$) | Phase (degrees) | Amp ($m\ s^{-1}$) |
| 4–6 | 76–90 | 165 | 22 | 273 | 20 | 215 | 18 | 131 | 24 |
| 4–6 | 91–104 | 133 | 18 | 225 | 41 | 201 | 31 | 68 | 32 |
| 4–6 | 105–118 | 139 | 27 | 216 | 34 | 183 | 34 | 79 | 27 |
| 15–17 | Av. 97 | 270 | 25 | 333 | 28 | 304 | 32 | 205 | 19 |
| 20–23 | 76–90 | 255 | 23 | 354 | 26 | 308 | 22 | 213 | 26 |
| 20–23 | 91–104 | 220 | 29 | 307 | 33 | 267 | 32 | 170 | 31 |
| 20–23 | 105–118 | 200 | 23 | 279 | 31 | 247 | 29 | 139 | 24 |
| 20–23 | Av. 97 | 226 | 24 | 305 | 26 | 267 | 28 | 173 | 24 |

**Table 2.** The diurnal tide during January, 1976

| Date | Altitude (km) | SE | | NE | | U | | V | |
|---|---|---|---|---|---|---|---|---|---|
| | | Phase (degrees) | Amp ($m\ s^{-1}$) | Phase (degrees) | Amp ($m\ s^{-1}$) | Phase (degrees) | Amp ($m\ s^{-1}$) | Phase (degrees) | Amp ($m\ s^{-1}$) |
| 4–6 | 76–90 | 262 | 7 | 167 | 14 | 194 | 11 | 321 | 12 |
| 4–6 | 91–104 | 196 | 6 | 124 | 9 | 153 | 9 | 265 | 7 |
| 4–6 | 105–118 | 284 | 17 | 91 | 4 | 288 | 9 | 281 | 15 |
| 15–17 | Av. 97 | 228 | 7 | 249 | 4 | 235 | 8 | 204 | 3 |
| 20–23 | 76–90 | 252 | 9 | 209 | 7 | 234 | 11 | 299 | 5 |
| 20–23 | 91–104 | 38 | 7 | 247 | 6 | 236 | 3 | 52 | 9 |
| 20–23 | 105–118 | 141 | 7 | 287 | 11 | 250 | 5 | 120 | 12 |
| 20–23 | Av. 97 | 87 | 7 | 215 | 6 | 273 | 4 | 156 | 7 |

The data for January 4–6 and 20–23 were recorded while extensive rocket experiments were under way at El Arenosillo. Because of the importance of these particular periods we have conducted data analysis for 3 individual height regions in order to examine the vertical propagation, or their absence, of the periodic wind components. For the middle period, January 15–17, only average wind parameters for a mean height of 97 km have been investigated.

The results of harmonic analysis of the data series for the various periods of observation have been condensed in 3 tables. Table 1 contains information on the semidiurnal tidal oscillation which is the most pronounced at all altitudes. The data show that the tidal wind may be represented by an elliptically rotating vector with an amplitude of about 20–30 m $s^{-1}$ with the phase of maximum velocity toward N near 06.00 local time. Phase variations in the vertical are

**Table 3.** The "prevailing" wind during January, 1976

| Date | Altitude (km) | NE ($m s^{-1}$) | SE ($m s^{-1}$) | Total Mag. ($m s^{-1}$) | Direction E of N Degrees | U ($m s^{-1}$) | V ($m s^{-1}$) |
|---|---|---|---|---|---|---|---|
| 4–6 | 76–90 | 30 | −5 | 30 | 35 | 17 | 25 |
| 4–6 | 91–104 | 34 | −13 | 36 | 24 | 14 | 33 |
| 4–6 | 105–118 | 24 | −2 | 24 | 41 | 16 | 18 |
| 15–17 | Av. 97 | −1 | 6 | 6 | 144 | 4 | −5 |
| 20–23 | 76–90 | 13 | 6 | 14 | 70 | 13 | 5 |
| 20–23 | 91–104 | 12 | 1 | 12 | 50 | 9 | 7 |
| 20–23 | 105–118 | 8 | 2 | 8 | 59 | 7 | 4 |
| 20–23 | Av. 97 | 13 | 3 | 14 | 58 | 12 | 7 |

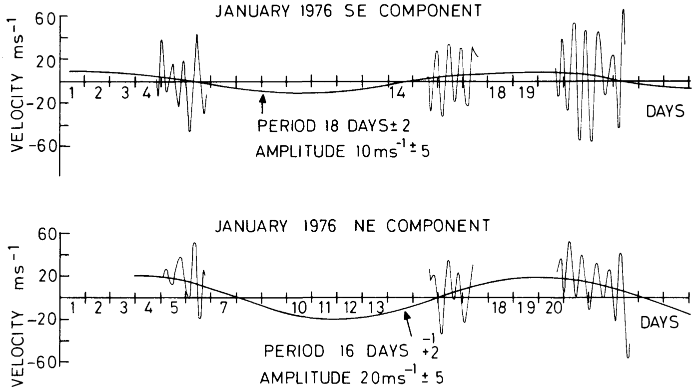

**Fig. 3.** Best fitting long periodic sinusoids to three pairs of meteor wind data sets recorded at Sheffield during the El Arenosillo winter anomaly campaign

comparatively small, the steady trend in the data indicating that we are dealing with a propagating mode of large vertical wavelength.

Table 2 shows the results relating to the diurnal tidal wind oscillation. Its amplitude is generally smaller than that of the semidiurnal oscillation and the phase appears to be variable.

The so called prevailing wind components are described by the data shown in Table 3. It is evident that from Sheffield the prevailing wind had an amplitude of about 20 $m s^{-1}$ directed almost due NE during January 4–6, falling to about 6 $m s^{-1}$ to the SE during January 15–17, and rising again to about 14 $m s^{-1}$, directed NE during January 20–23. There is little vertical structure in the prevailing wind. It is seen that NS winds exist at certain times which is of particular interest with regard to the possible transport of NO and other minor constituents.

In an attempt to resolve oscillations with periods exceeding the length of each individual meteor wind run we have fitted sinusoids to the data which match the trend that is evident in the polynomial curves shown in Figure 1. It was found that sinusoids of constant amplitudes could only be fitted when their periods had very specific values. Figure 3 illustrates the method used where it is seen that for both the SE and NE wind components sinusoids of comparable amplitude and almost identical period fit the observed wind variation. Although the method is somewhat artificial in using a sinusoid of one particular period instead of a more complex waveform the resulting oscillation is comparable with those caused by the presence of planetary waves during the winter season.

## Discussion and Conclusion

Although the measurements of winds from Sheffield during January, 1976 were intermittent it appears fair to draw attention to the general absence of pronounced NS air motions, while the winter anomaly was in progress, which could account for significant transport of minor constituents from the auroral region. The important aspect is the maintenance of such transport over sufficiently large distances during the lifetime of such constituents whose lifetime exceed the order of about one day. Although the prevailing winds were strong at times they generally blew into unfavourable directions as far as the meridional transport is concerned. Tidal oscillations, though represented by large amplitude winds, have insufficiently long time scales to effect coherent mean transport over large distances. One would therefore tend to look for the presence of long period wind oscillations of sufficient amplitude, such as associated with planetary waves, as an effective means of transport. There is some evidence that these may have existed during the January, 1976 winter anomaly as seen by the trend in the data shown in Figure 3. An amplitude of about 20 m $s^{-1}$ may be just sufficient to cause meridional displacement over the expected latitudinal range south of the auroral zone. We are conscious though, that a detailed study of planetary wave structure, apart from the need for continuous recordings over long periods, depends on the synoptic analysis of data recorded simultaneously in different locations. It is gratifying to note that such an analysis is already in progress and we are now awaiting its results with considerable interest.

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