4.4C MEASUREMENT OF THE HORIZONTAL VELOCITY OF WIND PERTURBATIONS IN THE MIDDLE ATMOSPHERE BY SPACED MF RADAR SYSTEMS

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ABSTRACT

Two remote receiving sites have been set up at a distance of $\sim$ 40 km from the main MF radar system. This allows measurement of upper atmosphere winds from 60-120 km (3 km resolution) at the corners of an approximately equilateral triangle of side $\sim$ 20 km. Some preliminary data are compared through cross correlation and cross spectral analysis in an attempt to determine the horizontal velocity of wind perturbations and/or the horizontal wavelength and phase velocity of gravity waves.

INTRODUCTION

The three sites are illustrated in Figure 1. Figure 2 describes the equipment at each of the remote receiving sites. The remote data are similar to those of the main site (e.g., GREGORY et al., 1982) except for a higher noise level due to smaller receiving antennas (single dipoles) and the proximity of overhead power lines. Examples of data from the three sites are shown in Figure 3 (the scale vectors indicate 50 m/s). The important limitations of the system are the transmitter antenna beam width (nominally $\sim$ 150 km at a height of 100 km, but the effective area depends on the scattering process), the time resolution of the wind measurement (5 min, at present) and the site spacing. The latter two parameters mean that periods < 10 min and wavelengths $\lesssim$ 50 km are folded back to higher values, although the wide Tx beamwidth will probably reduce the effect of wavelength folding.

Two possibilities which must be considered are that (1) the perturbations are all travelling in the same direction with the same speed, in which case cross correlations between wind vectors at the three sites are sufficient to determine velocity, and (2) the perturbations are caused by independent gravity waves with different speeds and directions; here cross spectral analysis is required to separate out the different waves.

In case (1), the maximum measurable speed is determined by the minimum measurable time delay. For reasonable accuracy, given well-behaved cross correlations, the lowest delay should be greater than half a lag from zero lag (2.5 min). This puts an upper limit of $\sim$ 120 m/s on speed. In case (2), the absolute phase differences between sites must all be less than 90° so that the direction of travel may be deduced (although this is still not a unique solution). This puts a lower limit on the wavelength of $\sim$ 100 km. In addition, there must be some way of confirming the presence of the "same wave" at all sites, otherwise the phase differences will be spurious.

FIRST RESULTS

Figures 4 and 5 show cross correlation and spectral analyses for the one day available, over the height range $\sim$ 100-112 km. The data have been detrended for the correlation analysis. The autocorrelation phase shows a dominant period of $\sim$ 1 hr. The cross correlation does not show single clear peaks, however it appears that the P-D and D-W peaks are at positive lag (+5 to +10 min) and the W-P peak is at negative lag ($\sim$-5 min).
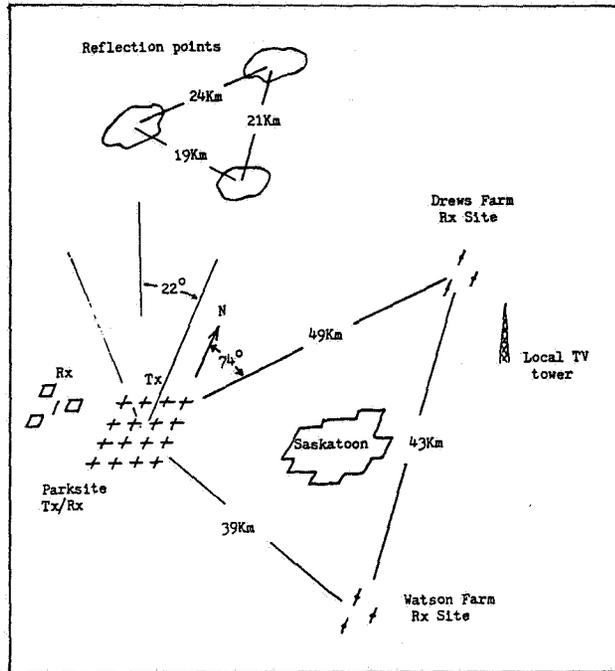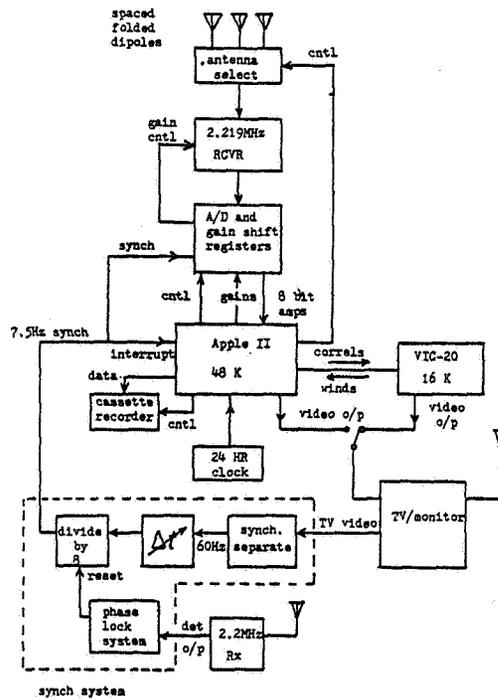
Figure 1. Geometry of spaced radio sites.

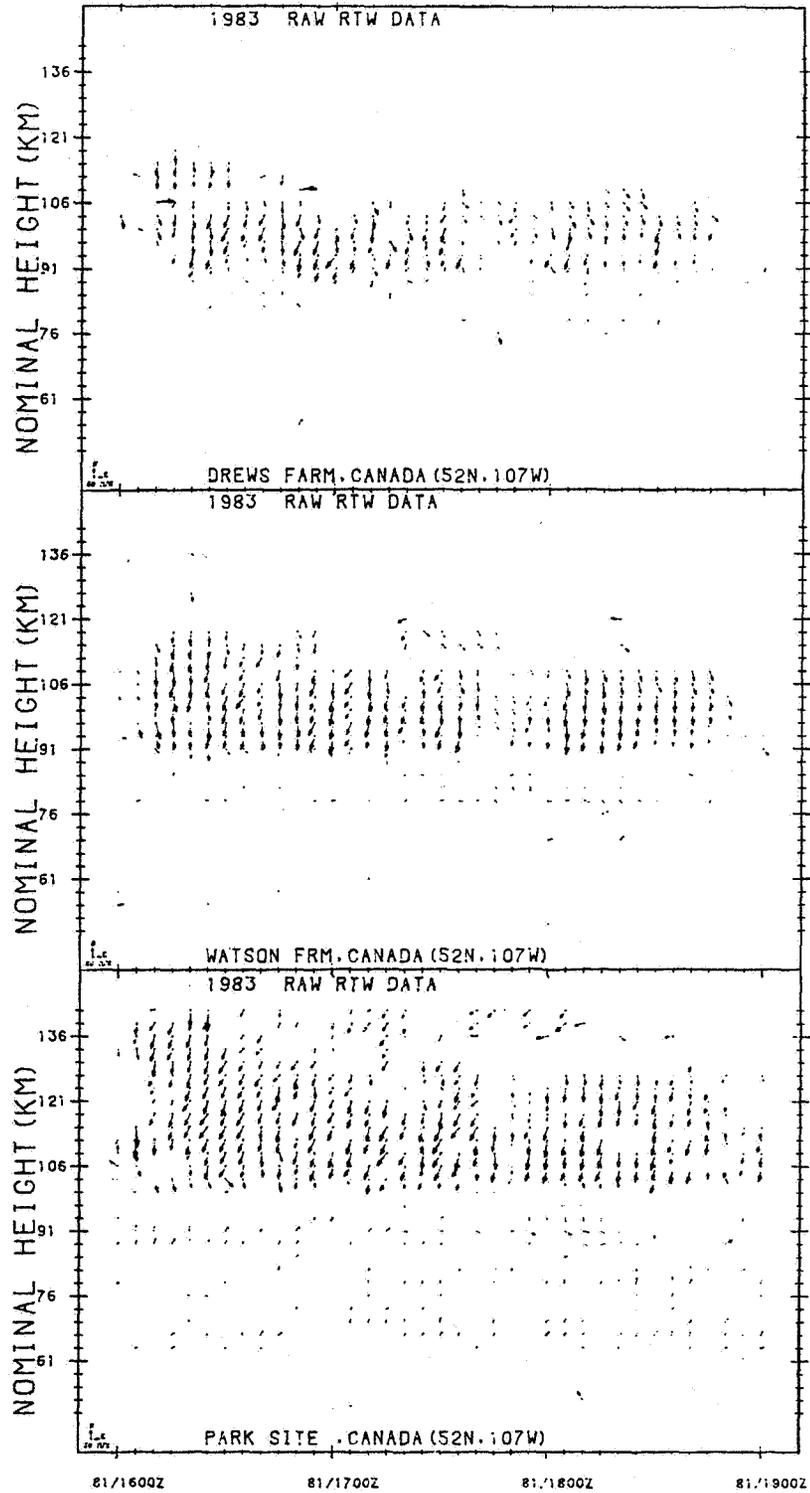Figure 2. Block diagram of remote receiving/analysis/
recording system.

Figure 3. Sample wind vectors from the three sites. Note that Drews' and Watson's height labels are ~12 km low.
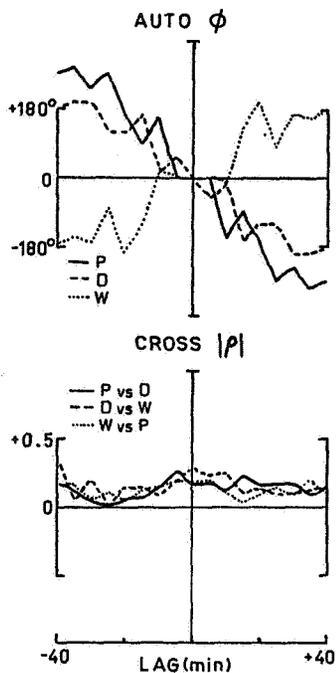
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Figure 4. Cross correlation analysis between spaced wind vectors over a 4-hr period (1982 Mar 21, 1600-1955 GMT).
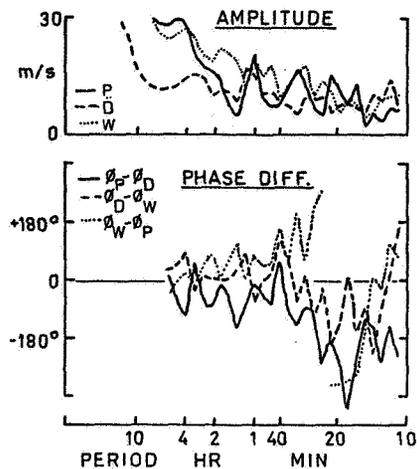

Figure 5. Cross spectral analysis between spaced wind vectors. Note that the frequency ("period") scale is linear in f^3 (not f, as is usual) and extends from 0 to the Nyquist frequency (10 min period).

The spectral analysis (Figure 5) is more illuminating. The spectra have been calculated by separate harmonic analysis (least squares) at each frequency, and the frequency scale distorted to give more resolution at the longer periods. The peak at $\sim$ 1 hr period is clear, and the slopes of the phase differences (which define time delay) are also fairly clear. They indicate delays of $\sim$ 10 min (P→D), 1 min (D→W), and 10 min (P→W) . This gives a rough velocity estimate of 30 m/s, 100° east of north. Apparently, on the average all frequency components have the same delay between sites. The phase differences show large fluctuations, however, which means that wavelength and velocity calculations for a single period would be almost random. One way around this is to select significant periods on the basis of coherence from an average cross spectrum over height or frequency. This will be done in the future when longer data sequences are available.

CONCLUSIONS

Preliminary spaced wind observations have been analysed to determine the velocity of wind perturbations. There is some indication that all frequency components have a common speed and direction. Since there is only one day of simultaneous data available at the time of writing, general conclusions are impossible.

REFERENCE

Gregory, J. B., C. E. Meek and A. H. Manson (1982), J. Atmos. Terr. Phys., 44, 649.