Tracking Jet Stream Winds from Ground Level Pressure Signals[1]

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ABSTRACT

A major portion of atmospheric pressure fluctuations in the 30–90 min period range was observed to move across a small array of microbarographs with speeds and directions that correlate with jet stream winds. Measured speeds (10–50 m $\sec^{-1}$) and periods, with plane wave assumptions, yield wavelengths of the order of 100 km. The pressure fluctuations were observed, however, to decorrelate in much less than one wavelength, implying that they are not *free* waves, but more likely are disturbances dragged along by the tropopause winds.

1. Introduction

It has long been known that the jet stream may be a major source of energy input to the atmosphere in the mesoscale range; that is, at wavelengths of the order of 100 km and periods of tens of minutes (Pinus *et al.*, 1967). Some investigators of atmospheric phenomena (J. Young, personal communication; Claerbout, 1967) have gone so far as to state that a large portion of ground level pressure fluctuations is associated with the jet stream. Results obtained as part of our study of low-frequency atmospheric pressure background noise (Herron *et al.*, 1969) fully confirm this point of view. In this paper, we report in detail the good correlation that can persist for weeks between the direction of jet stream winds and the direction of low-frequency pressure disturbances crossing a microbarograph array. A companion paper (Tolstoy and Herron, 1969) presents a theoretical mechanism accounting for the observed correlation.

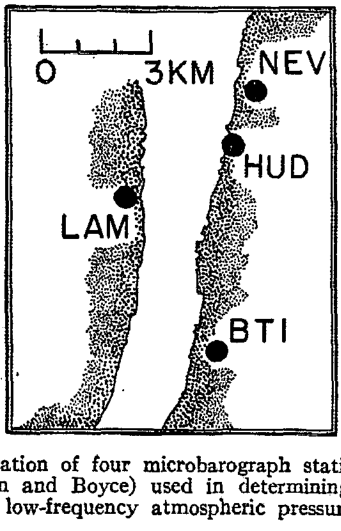

FIG. 1. Location of four microbarograph stations (Lamont, Nevis, Hudson and Boyce) used in determining direction of movement of low-frequency atmospheric pressure background fluctuations.

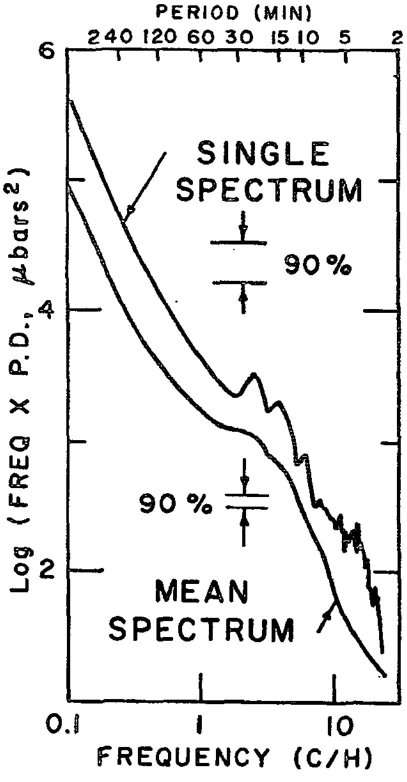

FIG. 2. Single atmospheric pressure power spectrum (24-hr sample of data, 3 August 1967) and mean of 27 single spectra (from August 1967) for Hudson Laboratories station. The power density values were multiplied by the corresponding frequency in order to flatten the spectra. The 90% confidence limits are shown for the single and mean spectra.

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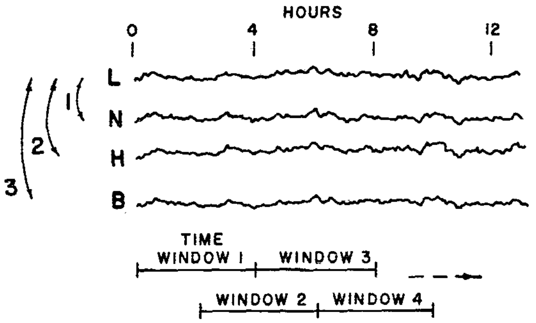

Fig. 3. Sample of atmospheric pressure background fluctuations caused by jet stream winds. Within each "time window" cross-spectral analyses were performed between the Lamont data channel (L) and each of the other channels.

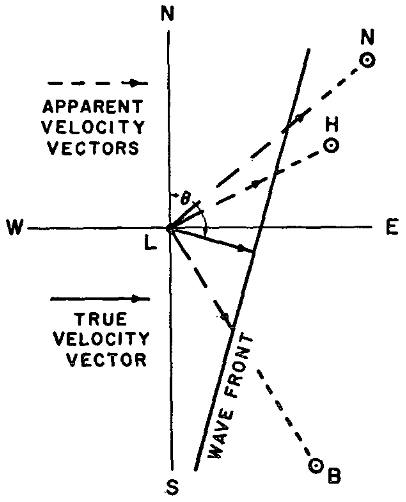

Fig. 4. Least-squares fit of straight-line wavefront through tips of apparent phase velocity vectors resulting from cross-spectral phase measurements. Magnitude and direction of true velocity vector is given by computer.

2. Recording and analysis of data

Herron *et al.* (1969) have described the details of an experimental system for the study of atmospheric pressure variations. Briefly, a large array of microbarographs, with dimensions of several hundred kilometers, is connected by telephone lines to a laboratory in Dobbs Ferry, N. Y. In addition, a small sub-array of four stations, with separations of several kilometers, surrounds Dobbs Ferry (Fig. 1). The signals from all stations are recorded and processed by digital computer. The digital sampling rates and frequency response of the system allow the study of pressure variations in the period range of several minutes to several hours.

The spectral properties of atmospheric pressure variations were studied by computing mean monthly power spectra based on 24-hr samples of data. Fig. 2 shows the mean of 27 single spectra at Hudson Laboratories for August 1967. Mean spectra for other months are similar in shape. Also shown in Fig. 2 is one of the individual spectra included in the mean. This spectrum contains fine structure, in the 1–10 cycles hr^{-1} range, which is typical of many of the individual spectra. The fine structure is variable from spectrum to spectrum. It was also observed that the power levels of the spectra were most variable in the 1–10 cycles hr^{-1} range. The mean spectra were computed in order to average out the fine structure and the variability in spectral level and reveal statistically stable spectral features.

The knee in the mean spectrum and the greater variability observed in the individual spectra in the

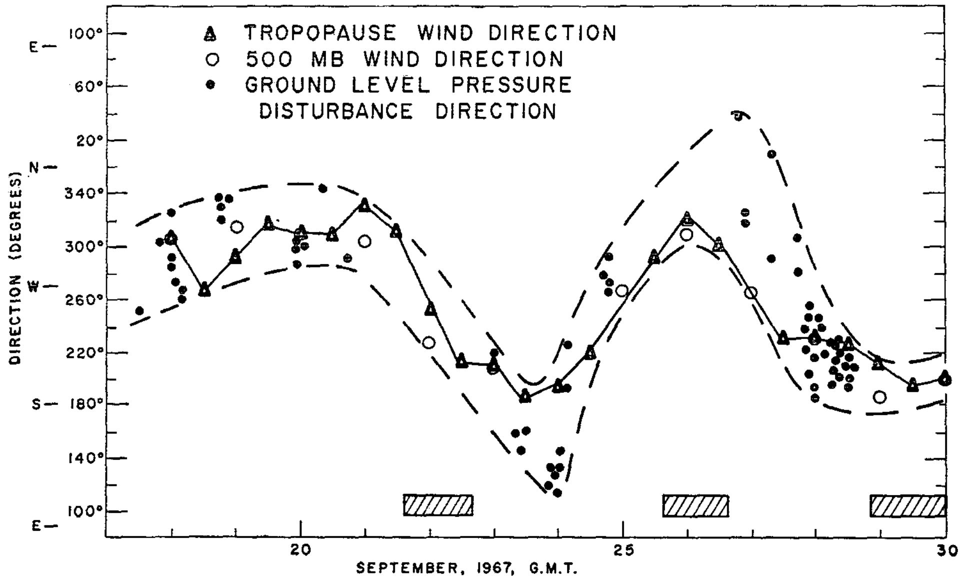

Fig. 5. Correlation of direction of movement of low-frequency pressure disturbances and direction of high altitude tropospheric winds. Cross-hatched areas indicate sections of missing pressure data.

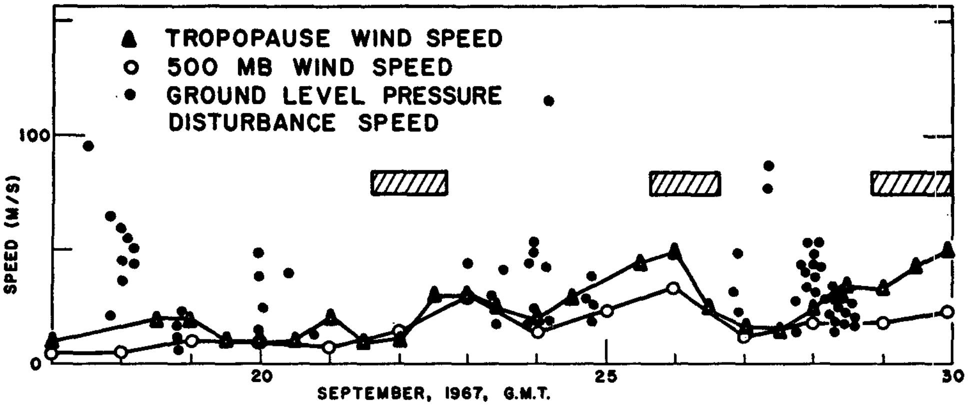

FIG. 6. Correlation of speed of low-frequency pressure disturbances and speed of high altitude tropospheric winds.

1–10 cycles hr^{-1} range indicate that there is energy input to the ground level atmosphere in this spectral range. It was further observed that the mean monthly spectral levels varied throughout the year as the core of maximum turbulent kinetic energy of the jet stream moved relative to the Dobbs Ferry area, suggesting that the jet stream winds are the major source of pressure fluctuations in the mesoscale range. The analysis to be described below confirms this hypothesis.

In general, the background noise showed nearly complete decorrelation at the station separations of the large array, but relatively high correlation over the small array of Fig. 1. This noise coherence over the small array was utilized in a "running" cross-spectral analysis computer program which moved a "time window" in overlapping steps across the set of signals from the small array (Fig. 3). Within each "time window," cross-spectral analyses were performed between various pairs of signals of the set. The time at the center of the window was assigned to each coherence and phase angle measurement resulting from the cross-spectral analyses. By this method, disturbances moving across the array could be detected by searching for time intervals of high coherence. The geometry of the array was given to the computer and when coherencies above a specified value were found, apparent phase velocity vectors between stations were computed (Fig. 4). A least-squares fit of a straight line through the tips of the vectors then gave the orientation of an assumed plane wave front. Thus, measurements were obtained of the true speeds and directions of pressure disturbances of various frequencies moving across the array.

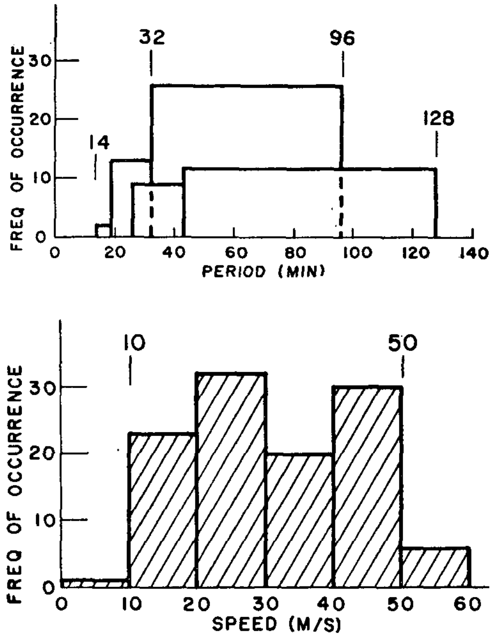

FIG. 7. Frequency of occurrences of the speeds and periods of background pressure fluctuations which correlate with jet stream winds.

3. Results

The result of applying this technique to several weeks of data in September 1967 is demonstrated in Fig. 5. The ground level pressure disturbances moved generally out of the west and although the directions scatter over about 60° of azimuth, they very clearly correlate with the synoptic period changes in direction of the tropopause winds. The directions of the jet stream over Dobbs Ferry were interpolated from U. S. Weather Bureau tropopause wind maps.

The pressure disturbance directions of Fig. 5 were obtained by using both a 4- and 8-hr "time window" and requiring a minimum coherence of 0.65 between signals for a speed-direction determination. This level of coherence gave phase measurements which usually yielded low residuals in the least-squares fit. By further rejecting those least-square determinations whose residuals exceeded a specified value, it was possible to obtain plots such as shown in Fig. 5.

For this technique and for the array geometry of Fig. 1, speed determination is generally less accurate than direction determination; consequently, there is no detailed correlation of pressure disturbance speeds with jet stream speeds (Fig. 6). However, from histograms showing the predominant speeds and periods of the disturbances (Fig. 7), it is seen that the speeds (10–50 m $\sec^{-1}$) coincide with the usual tropopause wind speeds over Dobbs Ferry. Most of the moving disturbances had periods ranging from 32–96 min.

The observed speeds and periods of the jet stream noise imply wavelengths of about 20–300 km with just over 100 km being most common. Herron *et al.* (1969) have shown, however, that the background noise decorrelates rapidly with distance. Spectral coherence values, for the periods of interest here, drop to a level of random coherence in 20–30 km, that is, in considerably less than one typical wavelength of the jet stream noise. Such behavior indicates that the moving pressure disturbances are not *free* waves in the atmosphere.

4. Concluding remarks

There are, of course, sources of disturbance in the mesoscale range other than the jet stream, such as convective activity, free gravity waves and, especially, disturbances associated with the passage of weather fronts. However, our observations indicate that jet stream winds are the major source of continuous disturbance in our geographic area.

Experience in this study has indicated that the array of Fig. 1 is far from optimum. An array of several more stations, at slightly greater separations, with a geometry to take advantage of the prevailing direction of the jet stream, might allow continuous tracking of the winds with considerable accuracy in direction and speed.

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REFERENCES

Claerbout, J. F., 1967: Electromagnetic effects of atmospheric gravity waves. Ph.D. dissertation, M.I.T.

Herron, T. J., I. Tolstoy and D. W. Kraft, 1969: Atmospheric pressure background fluctuations in the mesoscale range. *J. Geophys. Res.*, **74** (in press).

Pinus, N. Z., E. R. Reiter, G. N. Shur and N. K. Vinnichenko, 1967: Power spectra of turbulence in the free atmosphere. *Tellus*, **19**, 206–213.

Tolstoy, I., and T. J. Herron, 1969: A model for atmospheric pressure fluctuations in the mesoscale range. *J. Atmos. Sci.*, **26**, 270–273.