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Variations in the Spring Windfield in the Northwestern Atlantic, 1946-1985: A Progress Report

by

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Introduction

In a report presented in a theme session of the 1986 meeting of the International Council for the Exploration of the Sea (ICES), Dickson, et al. (1986) described a change in the wind field of the northeastern Atlantic Ocean and suggested some effects of the change on phytoplankton and zooplankton off the British Isles. They identified an increase in northerly wind speeds (as computed from atmospheric pressure data) in March-April in the 1970's as compared with the 1950's. They also hypothesized that changes in abundance and species composition of zooplankton standing stocks resulted from increased northerly wind speeds, because of the destabilizing effect of the wind on the upper water column, which delayed thermal stratification and reduced primary production.

The atmospheric feature they identified as the cause of the unusually strong northerlies was a positive pressure anomaly cell centered about 2,000 km south of Iceland and extending from Great Britain and the Iberian Peninsula westward to the Grand Banks of Newfoundland (Dickson, et al. 1986, Fig. 4). They believe that this feature and the northerly winds it caused were anomalous both in timing and intensity, but the principal effect was early arrival of strong winds which normally occur in May.

We were stimulated by the report by Dickson, et al. to wonder if there were corresponding changes in the windfield of the northwestern Atlantic during the same time period. The pressure anomaly cell they identified should have resulted in decreased northerly wind speeds in the northwestern Atlantic in the spring months of the 1970's compared with the 1950's.

Methods

In order to determine if there was a difference between the 1950's and 1970's windfields during spring in the vicinity of Georges Bank, we made time series plots of mean monthly wind stress components at a point on the "Northeast Peak" of the bank (42°N 66°W) for the 1946-1985 period. The wind stress values used in the plots were those computed from the atmospheric pressure field by the U.S. Navy's Fleet Numerical Oceanographic Center using a process described by Bakun (1973). Time series plots of wind stress components were similarly developed for a point off Nova Scotia (45°N 60°W), to extend the study area and to seek substantiation of any anomalies detected in the Georges Bank area. (Fig. 1 for locations)

The data base contains 40 years of derived monthly mean wind stress values routinely computed for point locations on a 3° latitude by 3° longitude grid. The values are based on recorded observations of atmospheric pressure by nearby weather stations, environmental buoys and ships at sea. Within the data set, wind stress values are recorded as meridional (north-south) and zonal (east-west) components. Plots of the 40-year time series of components for March and April are presented in Figures 2 through 5. Positive meridional values indicate northward stress; positive zonal, eastward stress.

In an effort to make certain that differences in the 1950's and 1970s wind field were not artifacts of adjustments made to the numerical model used to compute wind stress components, we constructed a time series of wind velocity observations made at the Nantucket Island Airport weather station about 320 km WSW from 42°N 66°W (Fig. 1). Even though somewhat distant, Nantucket is the closest site of regularly collected observational wind data covering the time period of interest (1948-present). Unfortunately, this time series of wind observations has not been updated in computer-compatible format since 1977, so we had to extend it from 1977 to 1985 provisionally by reading manuscript records, utilizing just a small portion of the 50,000 observations in the hand-written data.

Similarly, to validate the computed wind stess values for 45°N 60°W, we are in the process of acquiring a time series of wind observations from Sable Island (Fig. 1) which is located about 110 km to the south of 45°N 60°W.

Results

At 42°66°W the most apparent difference between the 1950's and 1970's spring wind stress conditions was seen in the meridional (north-south) components for the month of March (Fig. 2). The magnitude of the southward stresses (from northerly winds) in the 1970's (1970-1979) were considerably less than those of the 1950's (actually 1950-1962). The mean March meridional wind stress for 1970-1979 was -82.9×10^{-3} dynes/cm^2, compared with -455.8×10^{-3} dynes/cm^2 for 1950-1962 (negative = southward). The ratio of the 1970's mean to the 1950-1962 mean is 0.182. In addition, the variability of the March meridional wind stress was quite different for the two time periods. The standard deviation of the 1970-1979 values was 86.3×10^{-3} dynes/cm^2 and for 1950-1962 was 435.7×10^{-3} dynes/cm^2.

The decreased magnitudes of southward wind stresses and reduced variability of these wind stresses in March 1970-1979 are much like the conditions seen in April (Fig. 3) throughout the 40-year period (1946-1985). Apparently the unusual March conditions could be explained by the early arrival of April conditions in 1970-1979, an inference similar to that drawn by Dickson, et al. (1986) concerning March-April-May conditions of <u>increased</u> northerly winds in the northeastern Atlantic.

At 45°N 60°W the differences in March meridional wind stress between the 1970's and the 1950's (Fig. 4) follow a pattern quite similar to that seen at 42°N 66°W. The mean value for 1970-1979 was 1.7×10^{-3} dynes/cm^2 and that for 1950-1962 was -426.0×10^{-3} dynes/cm^2. The standard deviation of values for 1970-1979 was 152.3×10^{-3} dynes/cm^2 and for 1950-1962 was 414.8×10^{-3} dynes/cm^2.

Once again, the unusual meridional wind stress conditions in March 1970-1979 look much like April conditions throughout the 40-year period (Fig. 5), leading to the same inference that the unusual March windstresses were caused by the early arrival of April conditions.

An alternative explanation for the decrease in meridional wind stress seen in the 1970's could possibly be changes in wind direction rather than speed. If that were the case, however, the plots of March <u>zonal</u> (east-west) stresses would show a corresponding anomaly pattern for 1970-1979. Inspection of the zonal plots (Figs. 2 and 4) shows that there is no commensurate anomaly pattern in the 1970's, so the differences in meridional wind stress appear to be definitely due to unusual wind speeds and not changes in direction.

Plots of the Nantucket Island wind velocity data resolved into mean monthly meridional components (Fig. 6) show a pattern of differences between March conditions in the 1950's and 1970's strongly similar to the pattern shown in the computed meridional wind stresses for 42°N 66°W. Since wind stress is proportional to the square of wind speed,[1] a plot of the squares of March meridional wind speeds should be more appropriate for comparison with wind stress values. The squared March meridional wind speed values for 1950-1962 and 1970-1979 for Nantucket Island (Fig. 7) do quite closely reflect the differences already revealed by the March meridional wind stress data for 42°N 66°W. The ratio of the 1970's mean wind speed square to the 1950-1962 mean is 0.183, essentially identical to the ratio of the computed wind stress means (0.182).

To test the significance of the differences revealed in the March windfield of the 1950-1962 and 1970-1979 periods, we submitted the wind stress data and the wind speed square data to t-test analyses. Using the test designed for groups of unequal size ($n_1 = 13$, $n_2 = 10$) and variance, we obtained the following statistics:

for wind stress data at 42°N 66°W $t = -3.01$ and $P < 0.01$

for wind speed square data at Nantucket Island $t = -2.69$, $P < .02$.

These results support the hypothesis that the two groups of observations, the March time series for 1950-1962 and 1970-1979, come from separate populations. We interpreted the results to mean that we can be 98% certain that the two time periods were under the influence of distinctly different atmospheric conditions.

Conclusions

1. Both the computed wind stress data and the observational wind velocity data analyzed thus far clearly show a significant difference in the northwest Atlantic in the spring (March) meridional winds. The difference portrayed in the data was a reduction in northerly wind (southward wind stress) magnitudes and variability in 1970-1979 compared with 1950-1962. This difference is opposite to that found for the same general time period in the northeastern Atlantic by Dickson, et al. (1986). This might be

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[1] Wind stress = $\vec{\tau} = \rho a\ Cd\ |\vec{v}|\vec{v}$, where ρa = air density, Cd = surface drag coefficient, $|\vec{v}|$ = scalar value of wind velocity, $\vec{v}$ = vector wind velocity.

expected when the size and location of the atmospheric anomaly feature causing the differences are considered.

2. The possibility of the observed differences being artifacts of adjustments made to the numerical model used to compute wind stress from the atmospheric pressure field was removed by the good agreement between Nantucket Island Airport wind observations and the computed wind stress data at 42°N 66°W. A similar test is planned for 45°N 60°W if we can obtain a suitable time series of Sable Island wind observations.

3. The anomalous March windfield conditions in 1970-1979 could be interpreted as early arrival of typical April conditions. Dickson, et al. (1986) presented a similar interpretation of the anomalous conditions they described in the northeast Atlantic.

4. The biological significance of the early arrival of April wind conditions in 1970-1979 in the northwestern Atlantic has not been investigated yet. Early stratification of the upper water column certainly would have an effect on primary and secondary production, but the nature of the effect is unresolved at this time. We are looking for a time series of biological data for the 1946-1985 period to use in correlative analyses with the windfield data.

References

Dickson, R. R., P. M. Kelly, J. M. Colebrook, W. S. Wooster and D. H. Cushing. 1986. North winds and production in the eastern North Atlantic. ICES CM 1986/C:37, Hydrography Committee Ref: Biological Oceanography Committee. Theme Session Q. 13 pp. 16 fig.

Bakun, Andrew. 1973. Coastal upwelling indices, West Coast of North America, 1946-1971. NOAA Tech. Report NMFS SSRF-671.

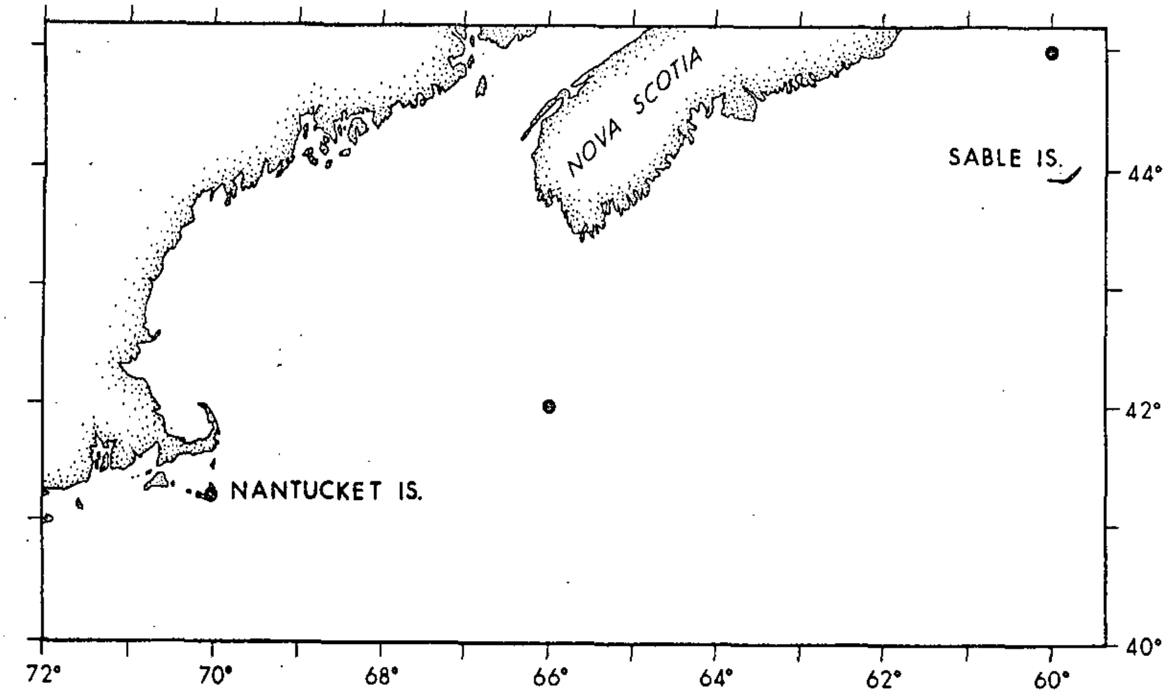

Figure 1. Location of data collection or analysis points.

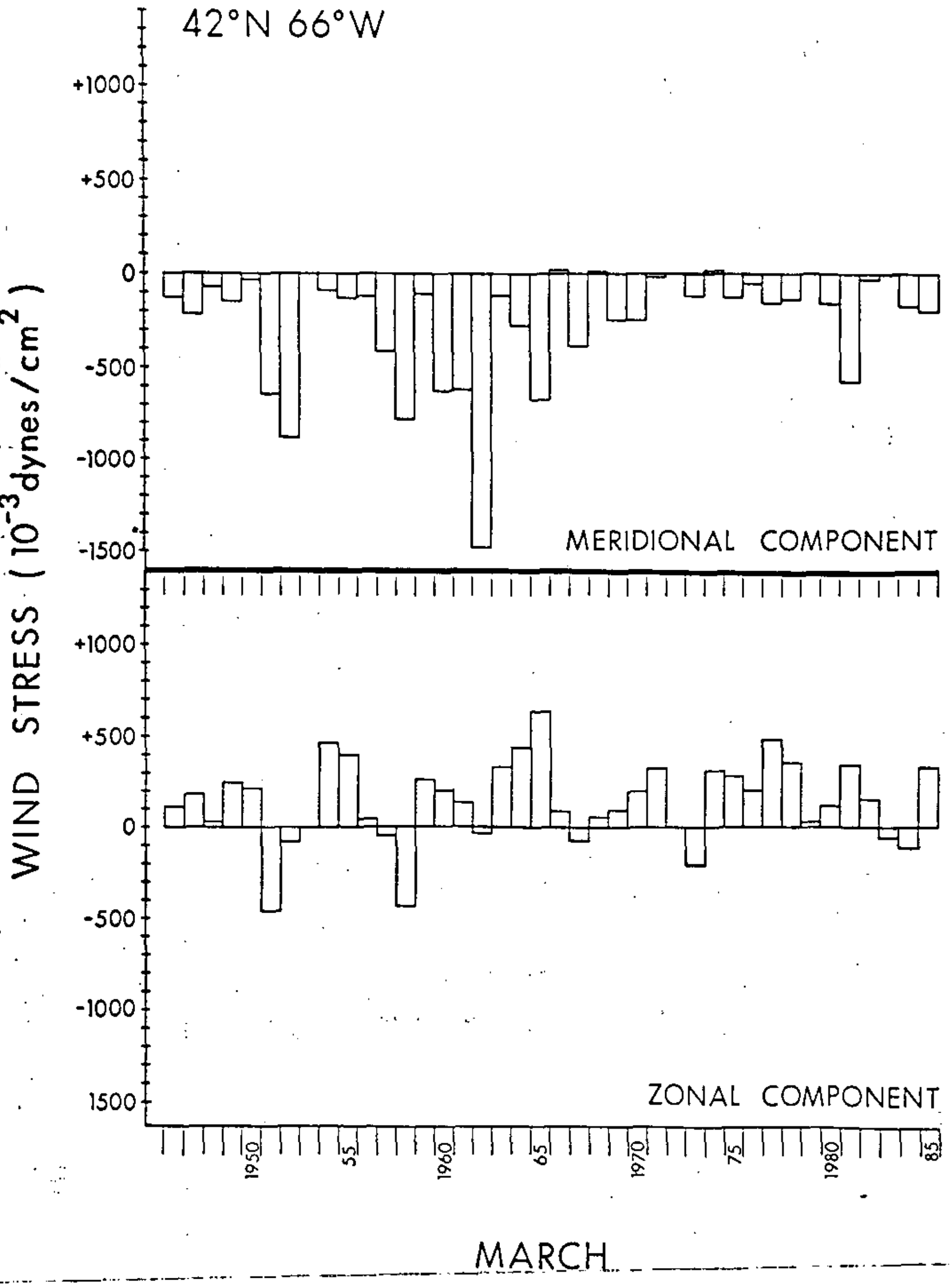

Figure 2. March mean monthly wind stress components (x 10^{-3} dynes/cm^2) computed from atmospheric pressure data for 42°N 66°W. Positive values northward and eastward.

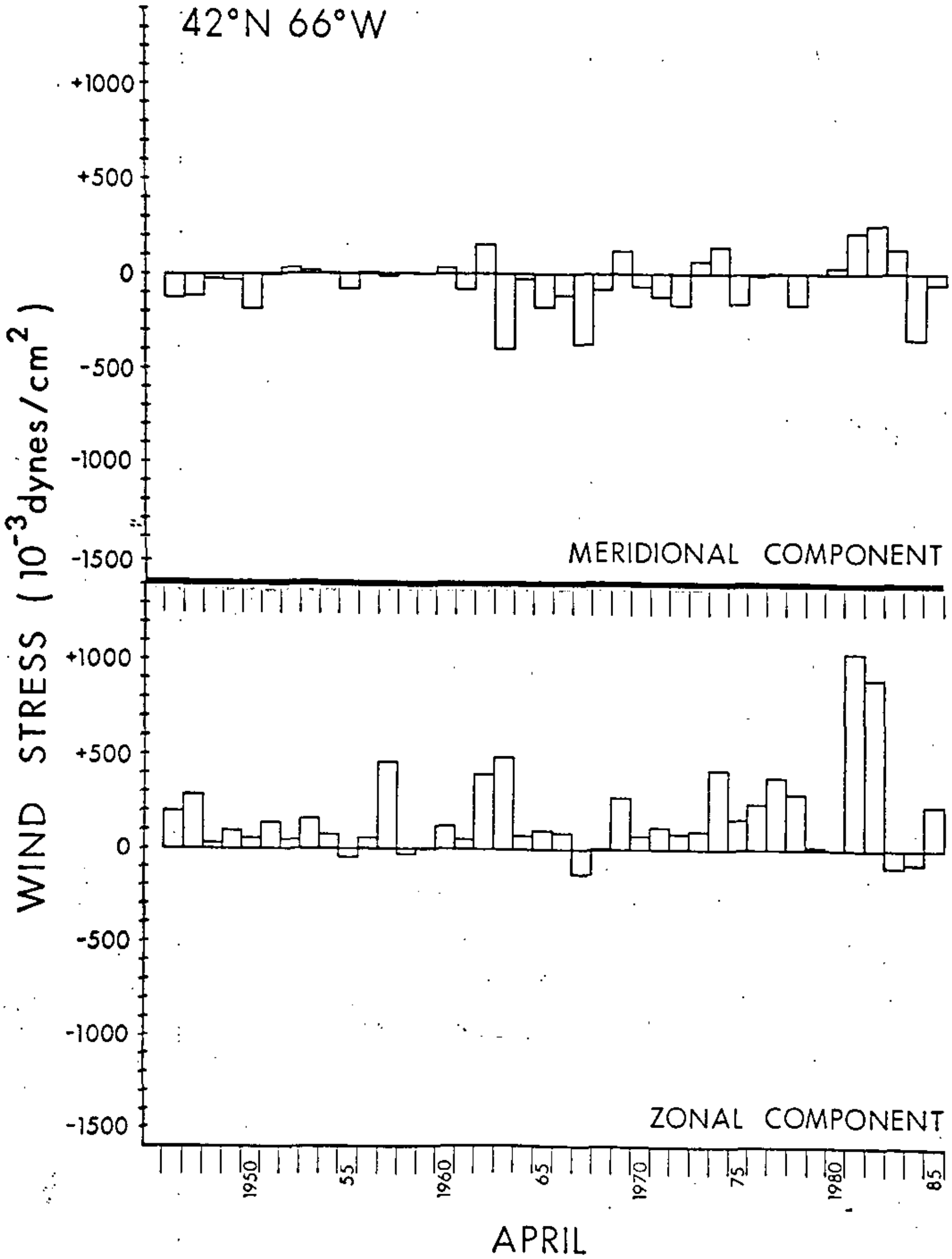

Figure 3. April mean monthly wind stress components (x 10^{-3} dynes/cm^2) computed from atmospheric pressure data for 42°N 66°W. Positive values northward and eastward.

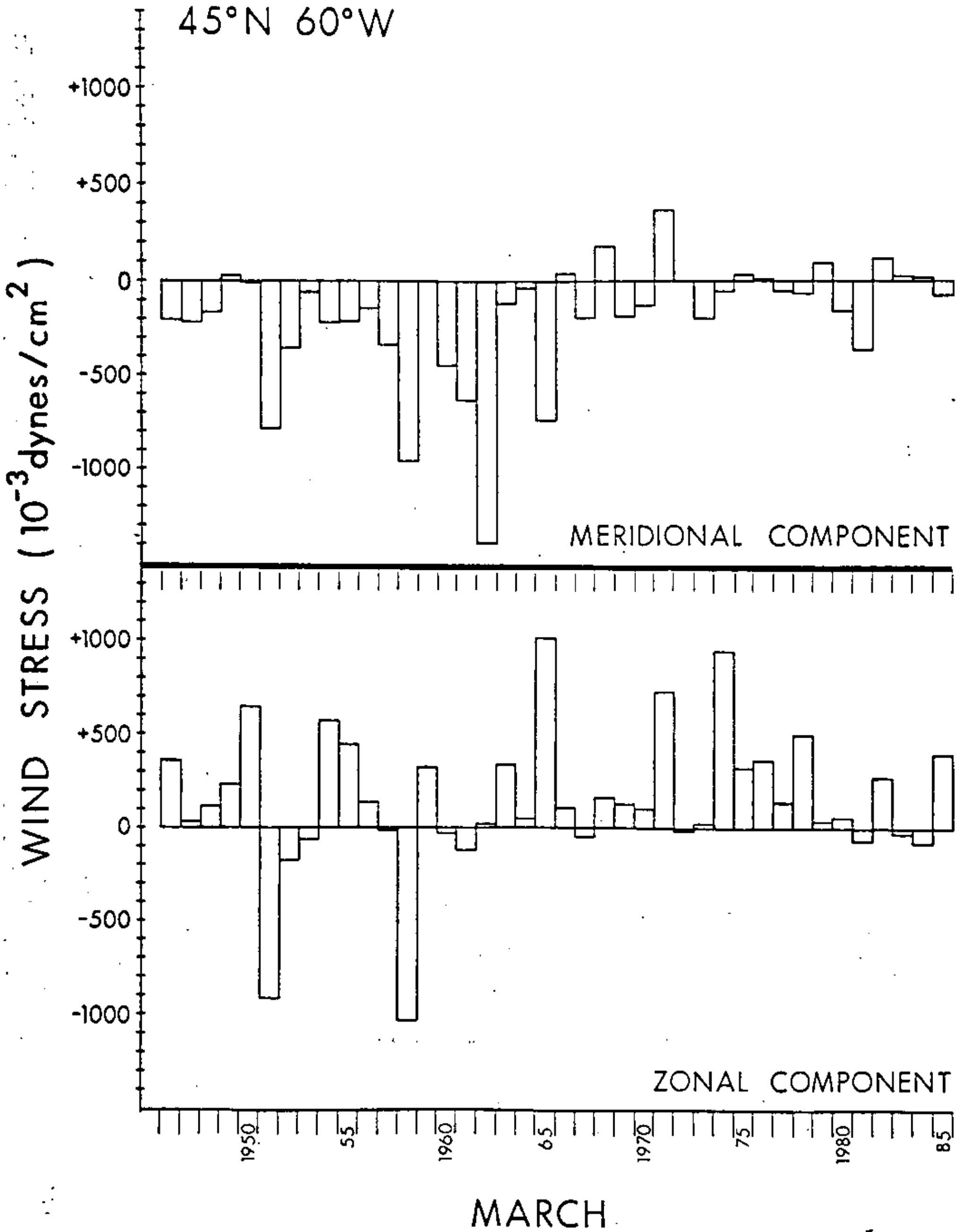

Figure 4. March mean monthly wind stress components (x 10^{-3} dynes/cm^2) computed from atmospheric pressure data for 45°N 60°W. Positive values northward and eastward.

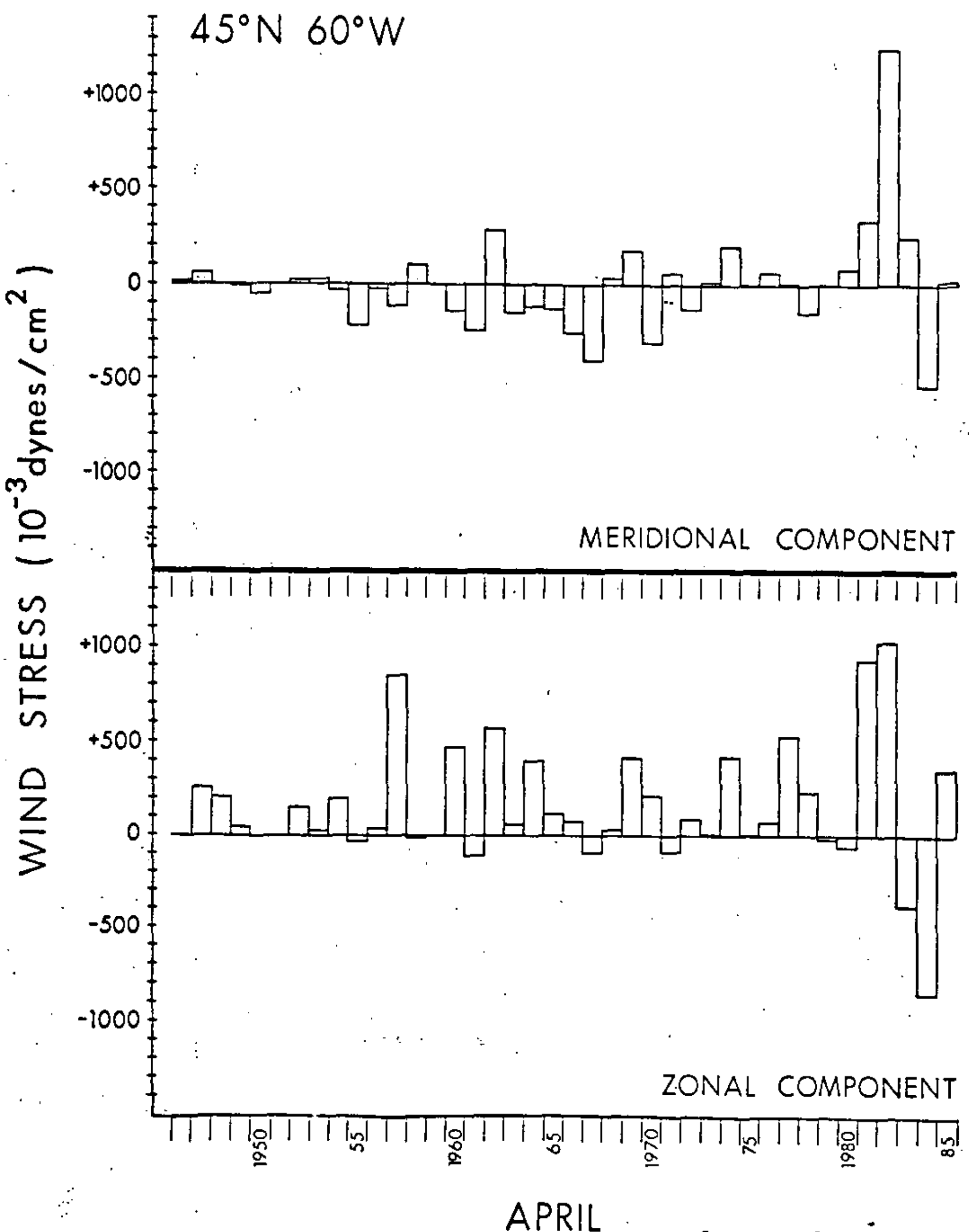

Figure 5. April mean monthly wind stress components (x 10^{-3} dynes/cm^2) computed from atmospheric pressure data for 45°N 60°W. Positive values northward and eastward.

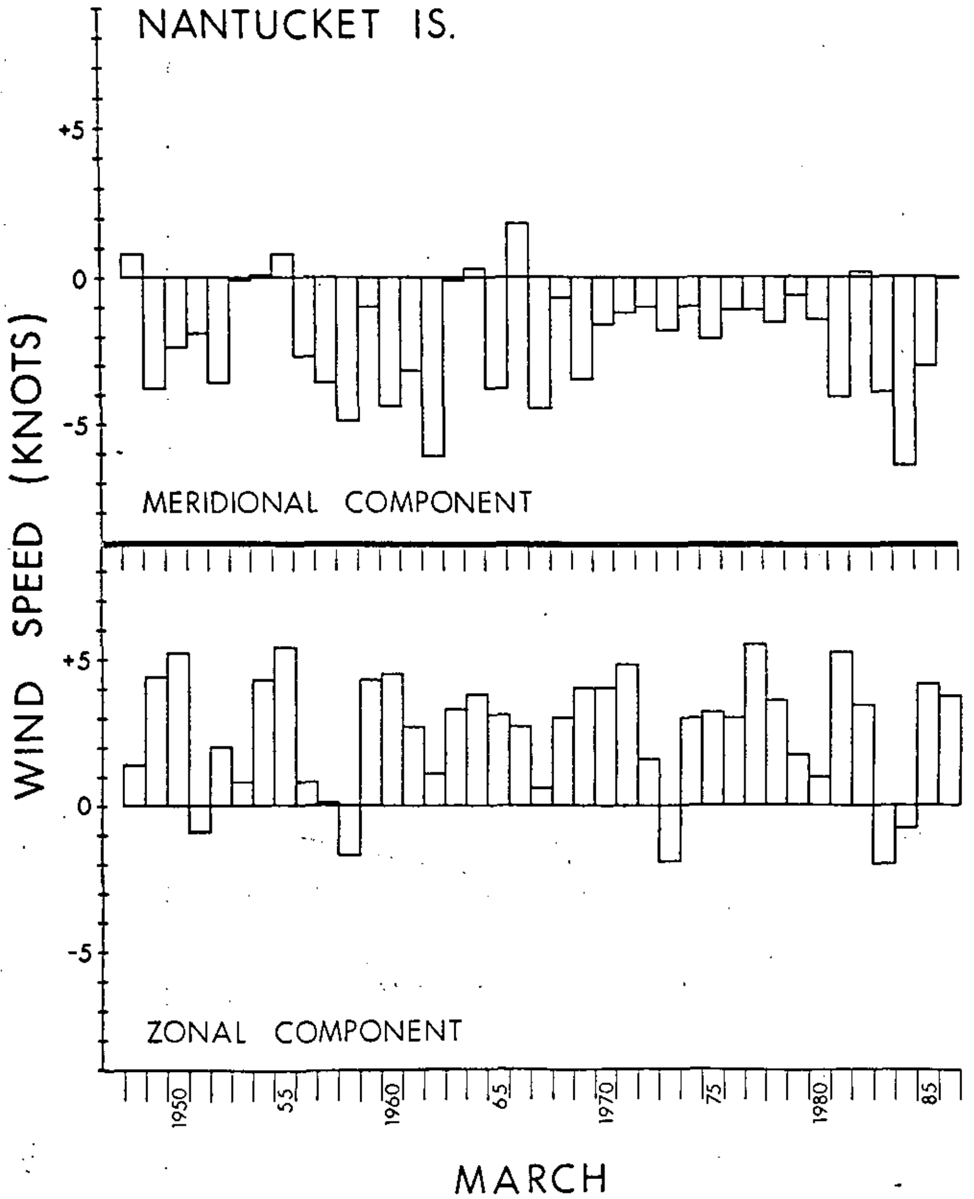

Figure 6. Average March wind velocity components (knots) observed at the Nantucket Island weather station. Positive values northward and eastward.

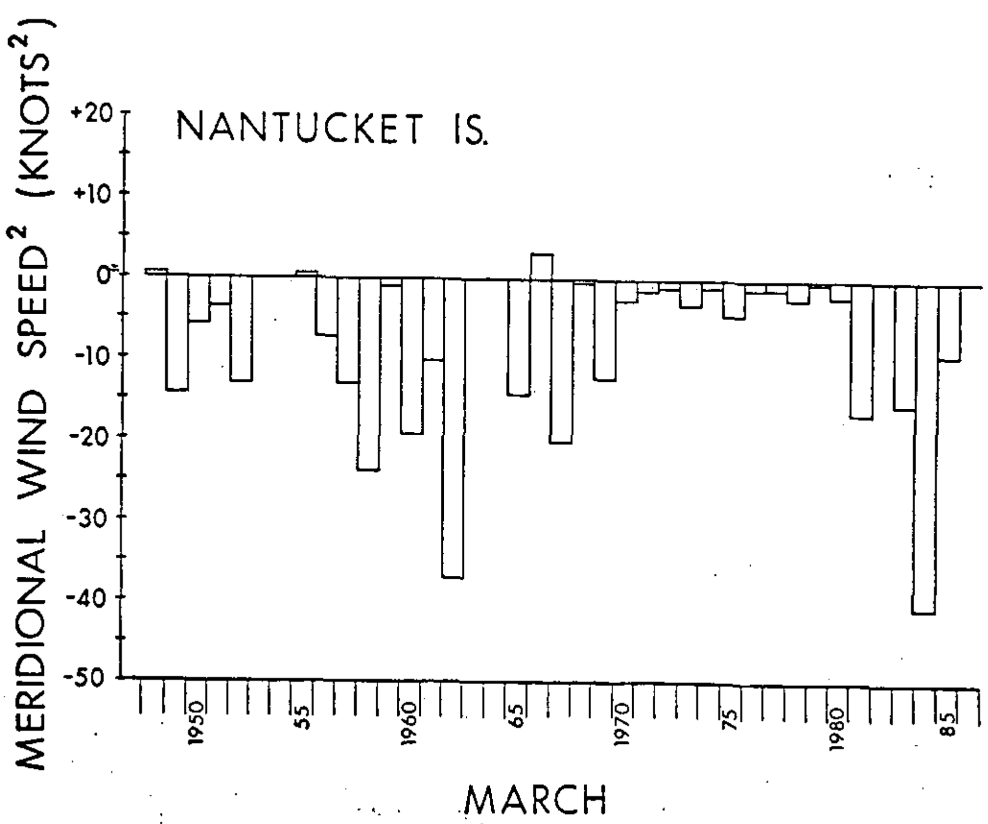

Figure 7. Square of the average March meridional wind speed (knots^2) at the Nantucket Island weather station. Positive values northward.