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SPECTRAL ANALYSIS OF A SEA-SURFACE TEMPERATURE AND ATMOSPHERIC PRESSURE RECORD OFF SOUTHERN CALIFORNIA

BY

GUNNAR I. RODEN

ABSTRACT

Sea-surface temperature and atmospheric pressure records during the past 40 years indicate that an inverse relation exists between the temperature at La Jolla, California, and the pressure difference at Lat. 30N, Long. 110–130W. A spectral analysis of these records is made and the energy density, autocorrelation, coherence and phase relations are investigated.

Introduction. During the last 40 years, records have been made of the temperature of the sea surface at the end of Scripps Pier, La Jolla, California. These records, if plotted against time, show seasonal as well as nonseasonal variations. These nonseasonal variations are not understood at the present time, though in many cases it has been possible to relate them to large scale changes in the atmospheric circulation (Roden and Reid, ms.). In order to eliminate seasonal variations of temperature and wind, anomalies are used in the present investigation. The term “anomaly,” here defined as the monthly mean minus the mean monthly mean, has been applied to all points of the record. The wind anomaly is expressed in the form of a pressure difference anomaly, taken between Long. 110W to 130W at Lat. 30N (U. S. Weather Bureau, 1917–1956). The variation of the pressure difference and temperature anomalies with time is shown in Fig. 1. A positive pressure difference anomaly means an increased geostrophic wind from the north. It is seen that anomalies of considerable magnitude exist and that there appears to be an inverse relation between the pressure difference and temperature. The latter is consistent with the idea that north wind gives upwelling and advection of cold water. Some of the anomalies seem to be persistent over a long time. It is the purpose of this paper to subject these records to spectral analysis and to investigate whether the impressions gained visually are substantiated.

Spectral Analysis. The method used is that developed by Tukey (1949) and further described by Munk, Snodgrass and Tucker (ms.); it involves the auto- and cross-correlations, from which the energy

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Figure 1. (top) Pressure difference anomaly at Lat. 30N between Long. 110W-130W; (bottom) Temperature anomaly, LaJolla Pier.
densities, coherence and phase relationships can be obtained. A definition of these quantities is given in the last mentioned paper and no recourse into the theory will therefore be attempted here. In the present case the analysis of the anomaly records was carried out by a Remington 1103 digital computer at the Convair plant in San Diego, California, for \( n = 480 \) (number of serial values) and \( m = 62 \) (number of spectral lines). The results are shown in Figs. 2 and 3. The energy spectrum of the pressure difference anomaly (Fig. 2a) shows that most of the energy is contained in the low frequency part of the spectrum, \( \text{viz.}, \) between zero and 1.6 cycles per year. The total energy amounts to 4.62\((\text{mb})^2\). The peak at about one cycle per year is quite pronounced; however, it is an artificial feature due to the incomplete elimination of the annual term and therefore it is of no significance. The high frequency part of the spectrum contains relatively little energy.

**Figure 2.** a, Energy spectrum of pressure difference anomaly; b, Energy spectrum of temperature anomaly; c, Coherence between pressure difference and temperature anomaly; d, Phase lead of pressure difference anomaly over temperature anomaly.
Figure 3. a, Autocorrelation of pressure anomaly; b, Autocorrelation of temperature anomaly.
and its features are probably insignificant. The energy spectrum of
the temperature anomaly (Fig. 2b) is similar to the pressure difference
anomaly in that the largest part of the energy is contained in the low
frequency part of the spectrum. The total energy is 0.87 (°C)². The
coherence between the pressure difference and temperature anomalies is
shown in Fig. 2c. The 95% confidence limit (for discussion, consult
Munk, Snodgrass and Tucker, ms.) lies at 0.51 (dashed line). From
this it is seen that the coherence is significant for low frequencies only.
Prominent peaks occur at approximately 1.5, 2.3 and 2.8 cycles per
year, but their meaning is not readily understood. The phase (Fig. 2d)
represents the phase lead of the pressure difference anomaly over the
temperature anomaly. The outstanding feature is the 180 degree
phase difference, indicating that an inverse relation exists between
both. This confirms the visual impression shown in Fig. 1. The in-
verse relationship is particularly pronounced for frequencies between 0
and 1.7, and again between 2.6 and 3.4 cycles per year. The auto-
correlation of the pressure and temperature anomalies is shown in Figs.
3a and 3b, respectively. The 95% confidence limits lie at r = ±0.1.
The interesting feature is that the autocorrelation of the pressure
anomaly remains positive for more than 62 months and that the func-
tion decreases very little with time after the sharp drop during the first
month. The autocorrelation of the temperature anomaly reaches the
95% confidence limit after six months. The slight increase of function
with time at the end of the record is probably insignificant.

Summing up the spectral analysis of the records has yielded the fol-
lowing results: a) there exists an inverse relation between the anomalies
of temperature at La Jolla Pier and the pressure difference (i.e., the
northerly wind component) at Lat. 30N, Long. 110–130W; b) the
coherence between pressure difference and temperature anomalies is
better for low frequencies (long periods) than for high frequencies
(short periods); c) the pressure difference anomalies are persistent over a
longer time than are the temperature anomalies.

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REFERENCES

MUNK, W. H., F. E. SNOGDGRASS AND M. J. TUCKER
Spectra of low frequency ocean waves. (Unpublished manuscript).

RODEN, G. I., AND J. L. REID, JR.
On a relation between atmospheric pressure and sea surface temperatures in the
North Pacific Ocean. (Unpublished manuscript).
Tukey, G. W.


U. S. Weather Bureau

1917–1956. Monthly mean sea level pressure for the northern hemisphere. Published monthly by the Extended Forecasting Section of the U. S. Weather Bureau, Washington, D. C.