# On the Duration of Nonseasonal Temperature Oscillations[1]

GUNNAR I. RODEN

*Scripps Institution of Oceanography, La Jolla, Calif.*

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ABSTRACT

The duration of nonseasonal sea and air temperature oscillations above and below arbitrarily fixed levels is investigated. There is close agreement between the observed mean durations and those expected from theory for a Gaussian random variable. Mean durations of sea temperature anomalies from long term monthly means above and below the 0C level vary between 3 and 5 months, those of air temperature between 2.5 and 3 months. There is almost no dependence upon latitude. The probability distributions are log-normal for durations not exceeding 2 or 3 times the mean duration. The largest observed durations above and below the 0C level are between 1 and 2 years while those above the +1.5C or below the −1.5C levels are between 1 and 2 months.

## 1. Introduction

The duration of nonseasonal temperature oscillations above and below arbitrarily fixed levels is of importance to both meteorologists and oceanographers, particularly those interested in the interaction between the sea and the atmosphere. Yet, until recently, a rational approach to the problem was made difficult by the lack of a suitably developed theory for obtaining numerical estimates. The break-through came first in communications research. Towards the end of World War II, Rice (1944, 1945) presented an approximate theory for obtaining the distribution of intervals between successive zeros of a stationary, random and Gaussian time series. Subsequent investigators have applied this theory to problems ranging from ocean waves (Longuet-Higgins, 1957a; Ehrenfeld *et al.*, 1958), to irregularities in the ionosphere (Longuet-Higgins, 1957b). Not all the problems of finding the statistical distribution of intervals between successive zeros of a random function have been solved however, and it is of interest to know whether an analysis of the duration of sea and air temperature oscillations can shed some additional light on the problem.

In the following we shall regard the temperature oscillations as belonging to a stationary, random, Gaussian and ergodic process. This implies that oscillations are adequately described by the second order correlation functions and their derivatives and that, by analyzing a finite record length, we are indeed justified to draw conclusions as to the general nature of the temperature fluctuations.

[1] Contribution from the Scripps Institution of Oceanography, University of California San Diego.

## 2. Data

The following investigation is based on sea and air temperature records kept by the U. S. Coast and Geodetic Survey (1956, 1962) and the U. S. Weather Bureau (1949–1963), respectively. Sea temperature records for Balboa, Panama Canal Zone, for 1909–1963 were kindly furnished by the Panama Canal Company (unpublished). The locations of the tide gage and meteorological stations are shown in Fig. 1. Monthly mean sea temperatures are obtained from daily observations around 0800. Monthly mean air temperatures represent half the sum of the daily minimum and maximum readings. The accuracy of the monthly means is estimated to be about 0.1C. In all cases the linear trend was removed from the records before proceeding with the analysis.

## 3. The mean duration of nonseasonal temperature oscillations

Let $\theta(t)$ be a stationary random variable with zero mean and let $\theta'(t)$ and $\theta''(t)$ denote the first and second derivatives of $\theta(t)$. Then, provided the temperature and its derivatives possess a jointly normal distribution, the mean duration of the temperature above an arbitrarily fixed level $I$ (or below $-I$) is given by Rice (1945, 1958), and Longuet-Higgins (1958, 1962a) as:

$$\overline{DUR}(\theta)=\pi\left(\frac{\varphi_0}{\varphi_0'}\right)^{\frac{1}{2}}\cdot\exp(I^2/2\varphi_0)\cdot(1-P(I/\varphi_0^{\frac{1}{2}})) \quad (1)$$

where $\overline{DUR}$ refers to the mean duration, and $\varphi_0$ and $\varphi_0'$ are the variances of $\theta(t)$ and $\theta'(t)$, respectively. The function $P(x)$ refers to the probability integral:

$$P(x)=\frac{2}{(2\pi)^{\frac{1}{2}}}\int_0^x e^{-t^2/2}dt. \quad (2)$$

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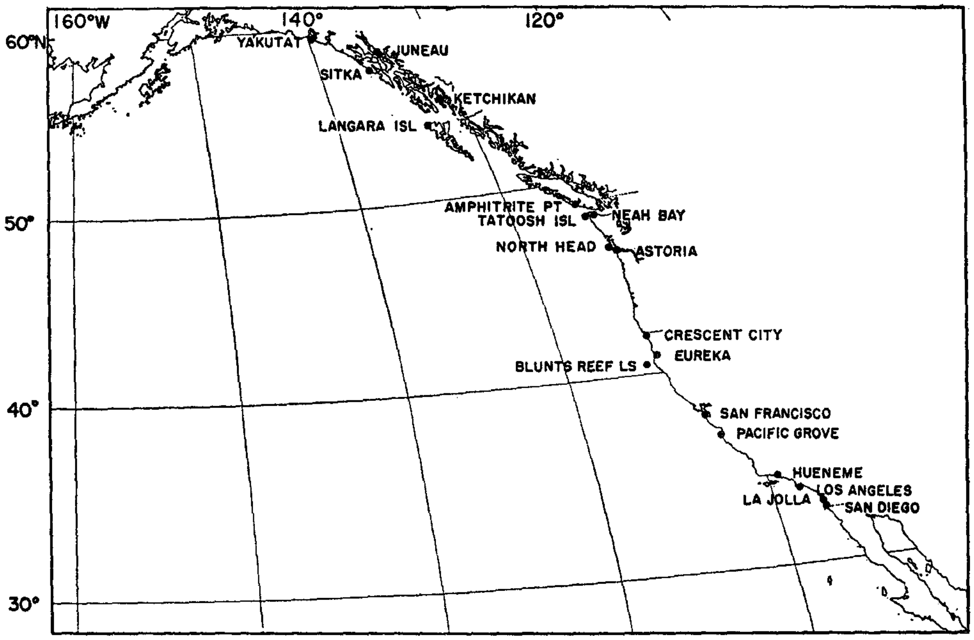


FIG. 1. Locations of the tide gage and meteorological stations employed.

TABLE 1. Observed mean durations (months) of nonseasonal sea surface temperature oscillations (anomalies from long term monthly means).

| | Above deg C | | | | | | | Below deg C | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | −1.5 | −1.0 | −0.5 | 0 | 0.5 | 1.0 | 1.5 | −1.5 | −1.0 | −0.5 | 0 | 0.5 | 1.0 | 1.5 |
| Panama, C. Z. | | | | | | | | | | | | | | |
| Balboa | 33.9 | 20.0 | 7.3 | 3.0 | 1.7 | 1.3 | 1.2 | 1.3 | 1.5 | 1.6 | 3.0 | 6.9 | 16.9 | 34.0 |
| California | | | | | | | | | | | | | | |
| La Jolla | 26.9 | 10.3 | 5.2 | 3.1 | 2.6 | 2.4 | 2.2 | 1.4 | 1.7 | 2.6 | 3.3 | 6.6 | 13.7 | 29.1 |
| Los Angeles | 18.9 | 10.2 | 4.9 | 3.4 | 2.6 | 2.2 | 1.8 | 1.5 | 1.8 | 2.3 | 3.8 | 6.1 | 12.8 | 20.5 |
| Hueneme | 15.6 | 9.3 | 4.2 | 3.4 | 2.8 | 2.3 | 1.9 | 1.4 | 1.9 | 2.2 | 4.0 | 6.4 | 11.6 | 17.6 |
| Pacific Grove | 48.5 | 11.7 | 5.3 | 3.5 | 2.4 | 1.9 | 1.5 | 1.1 | 1.5 | 2.4 | 3.9 | 7.4 | 11.7 | 25.0 |
| San Francisco | 40.0 | 12.9 | 6.2 | 3.3 | 2.5 | 1.8 | 1.3 | 1.1 | 1.6 | 2.3 | 3.5 | 7.6 | 11.5 | 24.6 |
| Blunts Reef LS | 36.8 | 10.6 | 4.4 | 3.0 | 2.1 | 1.5 | 1.3 | 1.2 | 1.4 | 2.3 | 3.4 | 5.5 | 10.0 | 24.0 |
| Crescent City | 13.3 | 8.1 | 6.2 | 3.3 | 2.1 | 1.5 | 1.3 | 1.1 | 2.1 | 2.8 | 2.9 | 4.2 | 8.7 | 22.6 |
| Oregon | | | | | | | | | | | | | | |
| Astoria | 17.0 | 9.6 | 5.2 | 3.0 | 2.3 | 2.0 | 1.8 | 1.3 | 1.5 | 2.1 | 3.1 | 6.3 | 11.4 | 19.9 |
| Washington | | | | | | | | | | | | | | |
| Neah Bay | 22.6 | 10.5 | 6.1 | 3.1 | 2.3 | 2.0 | 1.7 | 1.4 | 2.0 | 2.7 | 3.1 | 5.9 | 10.0 | 20.7 |
| British Columbia | | | | | | | | | | | | | | |
| Amphitrite Point | 36.4 | 11.0 | 6.8 | 3.7 | 3.0 | 2.2 | 1.4 | 1.3 | 1.6 | 3.0 | 4.5 | 7.6 | 13.4 | 36.2 |
| Langara Island | 51.8 | 11.0 | 6.7 | 4.3 | 2.8 | 1.8 | 1.3 | 1.0 | 1.3 | 2.3 | 4.5 | 7.8 | 15.8 | 42.7 |
| Alaska | | | | | | | | | | | | | | |
| Ketchikan | 43.6 | 12.5 | 6.2 | 3.9 | 2.3 | 1.5 | 1.0 | 1.1 | 1.5 | 2.1 | 3.9 | 7.0 | 19.0 | 53.6 |
| Sitka | 33.1 | 18.0 | 9.6 | 4.7 | 2.7 | 1.8 | 1.0 | 1.1 | 2.0 | 3.0 | 4.5 | 7.3 | 15.4 | 59.3 |
| Juneau | 26.8 | 11.7 | 5.8 | 3.4 | 2.2 | 1.5 | 1.0 | 1.2 | 1.5 | 2.1 | 3.4 | 5.7 | 12.4 | 27.0 |
| Yakutat | 22.6 | 15.4 | 6.0 | 3.3 | 2.9 | 1.9 | 1.5 | 1.4 | 2.2 | 2.5 | 3.6 | 6.8 | 11.3 | 20.5 |

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Similarly, the mean duration of the temperature gradient $\theta'$ above an arbitrarily selected level $J$ (or below $-J$) is given by the above mentioned authors as:

$$\overline{DUR}(\theta')=\pi\left(\frac{\varphi_0'}{\varphi_0''}\right)^{\frac{1}{2}}\cdot\exp(J^2/2\varphi_0')\cdot(1-P(J/\varphi_0'^{\frac{1}{2}})), \quad (3)$$

where $\varphi_0''$ is the variance of $\theta''(t)$ and the other symbols retain their previous meaning.

If $I=0$ and $J=0$, equations (1) and (3) take the simple form:

$$\overline{DUR}(\theta)=\pi\left(\frac{\varphi_0}{\varphi_0'}\right)^{\frac{1}{2}}, \quad (4)$$

and

$$\overline{DUR}(\theta')=\pi\left(\frac{\varphi_0'}{\varphi_0''}\right)^{\frac{1}{2}}. \quad (5)$$

If $I\gg-\varphi_0^{\frac{1}{2}}$ and $J\ll-(\varphi_0')^{\frac{1}{2}}$

$$\overline{DUR}(\theta)\rightarrow 2\pi(\varphi_0/\varphi_0')^{\frac{1}{2}}\exp(I^2/2\varphi_0);$$
$$\overline{DUR}(\theta')\rightarrow 2\pi(\varphi_0'/\varphi_0'')^{\frac{1}{2}}\exp(J^2/2\varphi_0'). \quad (6)$$

If $I\gg\varphi_0^{\frac{1}{2}}$ and $J\gg(\varphi_0')^{\frac{1}{2}}$

$$\overline{DUR}(\theta)\rightarrow\frac{\varphi_0}{I}(2\pi/\varphi_0')^{\frac{1}{2}};$$
$$\overline{DUR}(\theta')\rightarrow\frac{\varphi_0'}{J}(2\pi/\varphi_0'')^{\frac{1}{2}}. \quad (7)$$

The latter asymptotic expression follows from

$$1-P(x)\rightarrow\frac{2}{(2\pi)^{\frac{1}{2}}}\frac{e^{-x^2/2}}{x}\quad\text{for } x\gg 1. \quad (8)$$

The physical interpretation of the asymptotic expressions (6) and (7) is as follows: if the fixed levels $I$ or $J$ are placed sufficiently low, most of the values of the random variable $\theta$ or $\theta'$ will lie above these levels, and the mean duration becomes very large (infinite in the limit); on the other hand, if the fixed levels $I$ or $J$ are placed sufficiently high, most values of $\theta$ snd $\theta'$ will lie below these levels and the mean duration above will become very short (zero in the limit).

It is of interest to note that equations (1) to (8) are completely determined by the autocorrelations (variances) of the random variable, and its derivatives.

As a rather trivial but useful example, assume that the temperature $\theta$ varies from its annual mean value as

$$\theta(t)=\theta_0(t)\cos(2\pi t/T+\epsilon), \quad (9)$$

where $\theta_0(t)$ is the amplitude, varying slowly with time (and having as its rms value $\bar{\theta}_0$), $T$ is the period (here taken as 12 months), $t$ is time, and $\epsilon$ is a phase lag. What is the mean duration of the temperature above its annual mean value, and what is that of the positive temperature gradient? Knowing that the autocorrelations of temperature and its derivatives at lag zero, are, respectively:

$$\varphi_0=\bar{\theta}_0^2/2;\quad \varphi_0'=\left(\frac{2\pi}{T}\right)^2\varphi_0;\quad \varphi_0''=\left(\frac{2\pi}{T}\right)^4\varphi_0;$$

we find easily that $\overline{DUR}(\theta)=6$ months, and $\overline{DUR}(\theta')=6$ months, as it should be.

To estimate the mean duration of nonseasonal temperature oscillations, such as that of temperature anomalies from long term monthly means, is more difficult. Here, the answer cannot be anticipated as in the above example, but must instead be derived from the actual observations. As the theory applies only to stationary functions, it is important to eliminate any inherent trends from the records by the method of least squares or any other suitable means, before proceeding with the analysis. In the subsequent computations the temperature gradients were obtained from the finite-difference approximations

$$\theta'(t)=\theta_{t+1}-\theta_t;\quad \theta''(t)=\theta_{t+2}-2\theta_{t+1}+\theta_t, \quad (10)$$

and the variances were computed from the autocorrelations of $\theta(t)$, $\theta'(t)$ and $\theta''(t)$:

$$\varphi(\tau)=\langle\theta(t)\theta(t+\tau)\rangle;\quad \varphi'(\tau)=\langle\theta'(t)\theta'(t+\tau)\rangle;$$
$$\varphi''(\tau)=\langle\theta''(t)\theta''(t+\tau)\rangle \quad (11)$$

at $\tau=0$. The brackets $\langle\ \rangle$ refer to the mean over the entire record length.

*a. Mean durations of nonseasonal sea surface temperature oscillations.* The observed mean durations above and below a few selected levels are shown in Table 1 for several stations along the west coast of North America. The mean duration of the nonseasonal oscillations (henceforth referred to briefly as anomalies) above and below the 0C level varies generally between 3.0 and 4.5 months. There is surprisingly little change with latitude, indicating that the processes affecting the duration occur on a large scale. It is also seen that large anomalies, on the average do not last long. The mean duration of anomalies above +1C and below −1C is, for example, only of the order of 2 months.

The fact that the durations come out in months is not an accident; it is largely due to having used monthly means as the basic data. Had hourly means been used, the answer would have been in hours. For yearly means, the durations would have been in years. This is the effect of smoothing upon the persistence (Munk, 1960). We are here interested in time scales in the order of months or, more precisely, in the month-to-month duration of monthly means.

The agreement between the observed and calculated

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mean durations is shown in Fig. 2. The dots refer to the observation, while the curves were obtained from the theoretical relationship expressed by equation (1). Note that the theoretical relationship is the same for the mean durations above and below fixed levels, which is a consequence of the assumption that the temperature and its derivatives possess a jointly normal distribution (Rice, 1945). The agreement between theory and observation is usually good. Deviations do, however, occur at the far ends of the curves shown here. They may indicate departures from the Gaussian assumption upon which the theory rests. The decrease of the mean duration with increase of the magnitude of the temperature anomaly is rather rapid. Thus, at San Francisco, the mean duration above −1C is of the order of 13 months, while that above +1C is only 1.8 months.

*b. Mean duration of nonseasonal sea temperature gradient oscillations.* The gradients here referred to are those

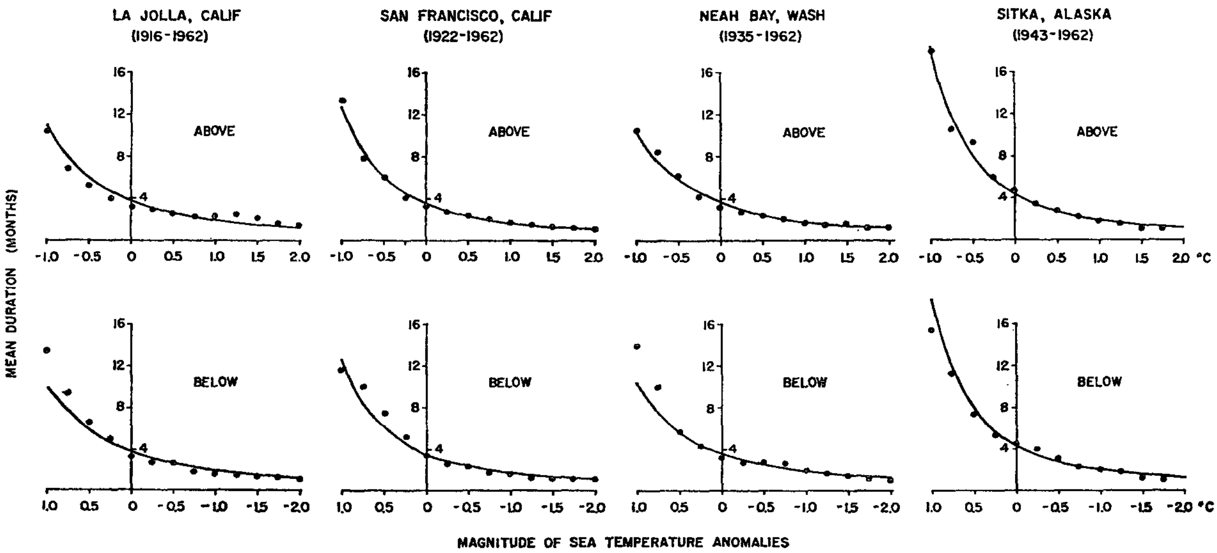


Fig. 2. Agreement between observed and calculated mean durations of sea temperature anomalies. Dots indicated observed values, and curves were calculated from equation (1).

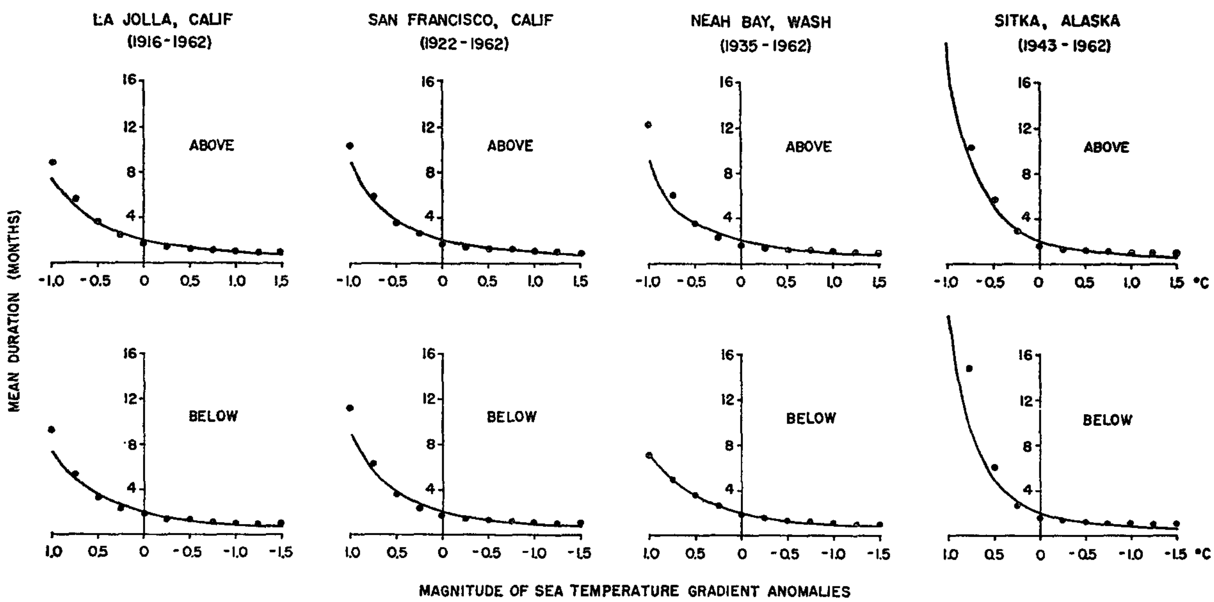


Fig. 3. Agreement between observed and calculated mean durations of sea temperature gradient anomalies. Dots indicate observed values, and curves were calculated from equation (3).

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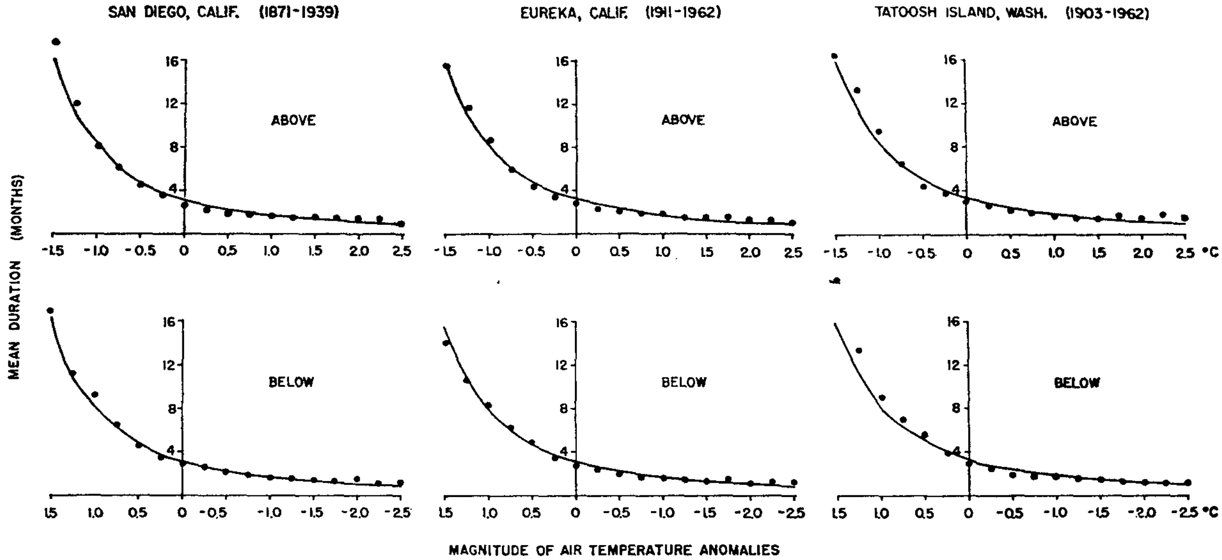


FIG. 4. Agreement between observed and calculated mean durations of air temperature anomalies. Dots indicated observed values, and curves were calculated from equation (1).

TABLE 2. Observed mean durations (months) of nonseasonal air temperature oscillations (anomalies from long term monthly means).

| Station | Above deg C | | | | | | | Below deg C | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | −1.5 | −1.0 | −0.5 | 0 | 0.5 | 1.0 | 1.5 | −1.5 | −1.0 | −0.5 | 0 | 0.5 | 1.0 | 1.5 |
| California | | | | | | | | | | | | | | |
| San Diego | 17.7 | 8.0 | 4.5 | 2.8 | 2.0 | 1.7 | 1.6 | 1.4 | 1.7 | 2.1 | 2.8 | 4.6 | 9.2 | 16.9 |
| San Francisco | 12.8 | 6.8 | 4.2 | 2.7 | 2.0 | 1.5 | 1.4 | 1.2 | 1.6 | 2.1 | 2.6 | 4.0 | 7.7 | 15.6 |
| Eureka | 15.5 | 8.5 | 4.3 | 2.8 | 2.1 | 1.8 | 1.5 | 1.4 | 1.6 | 2.0 | 2.9 | 4.9 | 8.3 | 14.1 |
| Washington | | | | | | | | | | | | | | |
| North Head | 12.0 | 8.1 | 4.1 | 2.8 | 2.4 | 1.8 | 1.7 | 1.4 | 1.7 | 1.9 | 2.8 | 4.8 | 8.1 | 13.3 |
| Tatoosh Island | 16.3 | 9.4 | 4.3 | 3.0 | 2.2 | 1.7 | 1.7 | 1.3 | 1.7 | 1.9 | 3.0 | 5.6 | 9.0 | 20.8 |

of time (C $\text{month}^{-1}$). The agreement between theory and observation is shown in Fig. 3. The curves were obtained from equation (3). As in the previous case, the observations conform rather closely to the theoretical relationship. The mean duration of gradient anomalies above and below 0C $\text{mo}^{-1}$ varies from 1.5 to 2.0 months. Anomalies above $+1$C $\text{mo}^{-1}$ and below $-1$C $\text{mo}^{-1}$ last only one month on the average. The physical interpretation is that large positive and negative anomalies of the temperature gradient last merely a short time.

*c. Mean duration of nonseasonal air temperature oscillations.* The observed mean durations above and below selected levels are summarized in Table 2 for coastal first order meteorological stations in California and Washington.[2] The mean durations of air temperature anomalies above and below the 0C level vary between 2.6 and 3.0 months. There is almost no dependence upon latitude, which seems to indicate that physical processes affecting the duration occur on a large scale.

The relation between the observed mean durations and those calculated from (1) are shown in Fig. 4. The agreement between theory and observation is good, as in the previous cases. The duration of large anomalies, such as those above $+2$C and below $-2$C is one month, on the average. On the whole, the mean durations of air temperature anomalies seem to be of the same order of magnitude, or slightly less, as those of the sea surface temperature in the vicinity of the meteorological station.

[2] For Tatoosh Island and North Head, Wash., the entire record was used. For Eureka, Calif., the record for the homogeneous period 1911–1962 was considered. For San Francisco and San Diego, Calif., the periods before the rapid growth of the cities were selected, extending from 1871–1935, and from 1871–1939, respectively.

## 4. The probability distribution of the duration of nonseasonal temperature oscillations

The mathematical calculation of the probability distribution presents considerable difficulties. No closed form expressions are known to exist for the distribution

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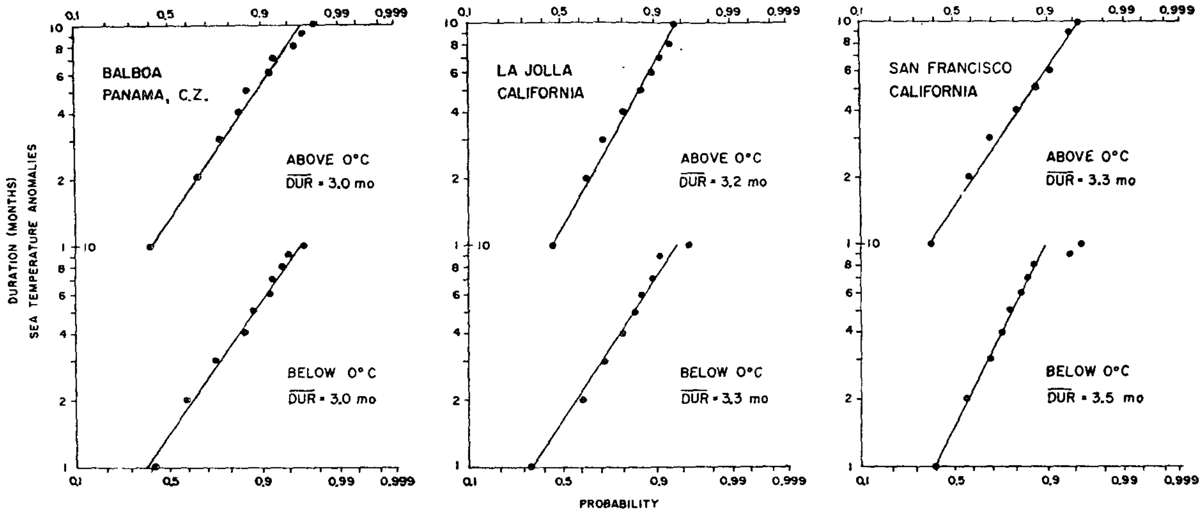


Fig. 5. Probability of the duration of nonseasonal sea temperature oscillations. Ordinate shows duration on a logarithmic scale, and abscissa indicates probability.

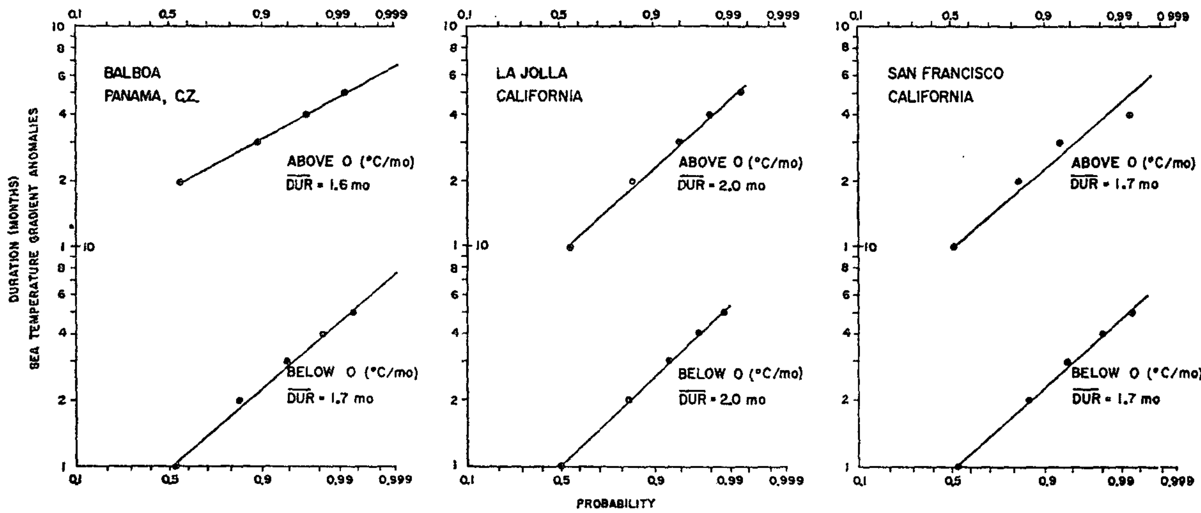


Fig. 6. Probability of the duration of the gradient of nonseasonal sea temperature oscillations. Ordinate shows duration on a logarithmic scale, and abscissa indicates probability.

of the duration. In a few cases, asymptotic forms have been derived by a method of successive approximation (Longuet-Higgins, 1958). Most of the results are valid only for stationary, Gaussian random variables having a narrow power spectrum. More recently, Longuet-Higgins (1962b) derived exact upper and lower bounds to the probability functions of random variables with prescribed power spectra, not necessarily narrow. He was able to prove rigorously, that for a Gaussian process the complete distribution function cannot be of the type of a simple negative power law, as has been claimed previously by Favreau *et al.* (1956), on the basis of incomplete data. It is, however, generally believed that for *very* large durations, the probability decreases asymptotically as a negative exponential (Kuznetsov *et al.*, 1954; Rice, 1958).

In the present case, the analysis is based on discrete data, rather than on continuous functions, and the power spectra of the nonseasonal temperature oscillations are wide rather than narrow (Roden, 1960, 1962). Moreover, the durations that are of interest here are neither very small nor very large. This makes a comparison with the hitherto developed theoretical approximations difficult. The following discussion is therefore based on empirical findings entirely.

*a. The probability of the duration of nonseasonal sea temperature oscillations.* The cumulative probability functions for the durations above and below the 0C level are shown in Fig. 5. The ordinate shows the duration on a logarithmic scale, and the abscissa indicates probability. The dots refer to the observations, and the straight line has been fitted to them by eye. The out-

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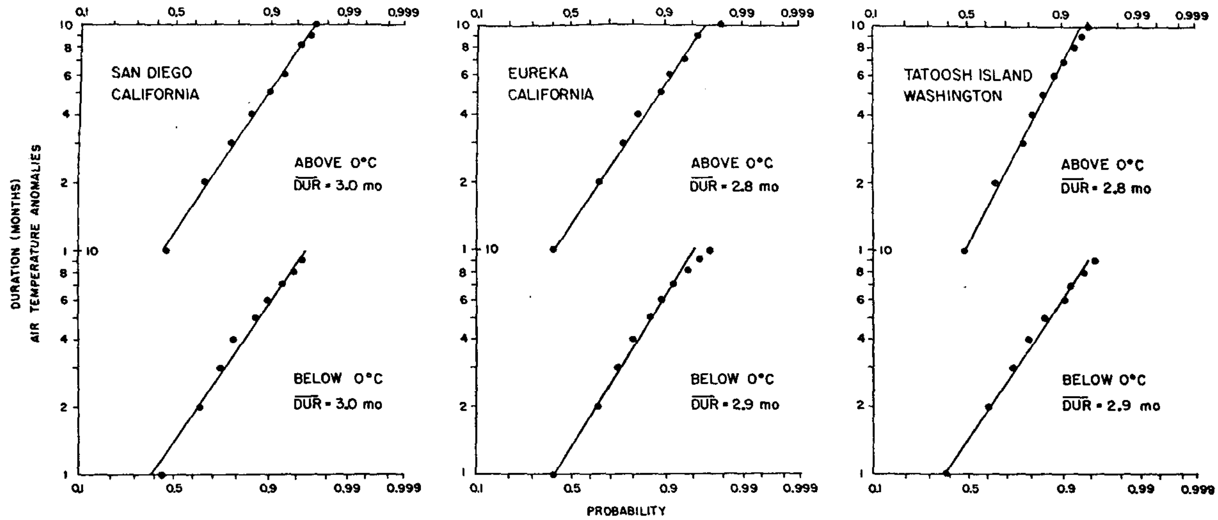


FIG. 7. Probability of the duration of nonseasonal air temperature oscillations. Ordinate shows duration on a logarithmic scale, and abscissa indicates probability.

standing feature is that for durations up to 2 or 3 times the mean duration, the cumulative probability function is approximately log-normal. This relation does not necessarily hold for durations in excess of 2 or 3 times the mean durations, as a careful inspection of the figure will indicate. To illustrate the probabilities involved, consider the duration of positive sea temperature anomalies at La Jolla, Calif.; here the probability that the anomaly will last 3 months or more is approximately 0.25, 7 months or more, 0.1, and 11 months or more, about 0.05.

*b. The probability of the duration of the gradient of nonseasonal sea temperature oscillations.* The cumulative probability functions are shown in Fig. 6. They are approximately of a log-normal type. Durations above 6 months have not been observed for the cases shown here. The probability that a gradient anomaly will last for a long time is rather small. At La Jolla, Calif., for example, the probability is only 0.02 that such an anomaly will last 4 months or more.

*c. The probability of duration of nonseasonal air temperature oscillations.* The relevant cumulative probability functions are shown in Fig. 7. They are approximately log-normal for durations not exceeding 2 or 3 times the mean duration. For the stations considered here, the following probabilities are characteristic for the duration of positive and negative air temperature anomalies (above and below the 0C level): The probability that the anomalies will last for 3 months or more is about 0.25, for 6 months or more, about 0.10, and for 9 months or more, roughly 0.04.

## 5. Extreme durations of nonseasonal temperature oscillations

The largest observed durations of sea and air temperature anomalies above and below selected levels are summarized in Tables 3 and 4, respectively. It is seen that the largest durations above and below the 0C level are of the order of 1 to 2 years. Those above the +1C level and below the −1C vary mostly between 4 and 10 months, and those above the +1.5C level and below the −1.5C level have characteristic magnitudes between 1 and 2 months. The physical implication of this is that even the extreme durations of large positive and negative sea and air temperature anomalies are short.

## 6. Conclusions

The following conclusions can be drawn from an analysis of the duration of nonseasonal sea and air temperature oscillation (anomalies from long term monthly means):

1) There is close agreement between the observed mean durations and those expected from theory for a stationary Gaussian random variable.
2) the mean duration of sea temperature anomalies above and below the 0C level varies between 3 and 5 months. Anomalies above +1C and below −1C last between 1.5 and 2.0 months.
3) the mean duration of anomalies of the sea temperature gradient above and below the 0C $mo^{-1}$ level varies between 1.5 and 2.0 months.
4) the mean duration of air temperature anomalies above and below the 0C level falls between 2.5 and 3.0 months. Anomalies above +1C and below −1C last between 1.5 and 2.0 months.
5) The probability distributions for the duration of sea and air temperature anomalies are log-normal for durations not exceeding 2 or 3 times the mean duration. For longer durations this relationship does not necessarily hold.

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TABLE 3. Observed extreme durations (months) of nonseasonal sea surface temperature oscillations (anomalies from long term monthly means).

| Station | Above deg C | | | | | | | Below deg C | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | −1.5 | −1.0 | −0.5 | 0 | 0.5 | 1.0 | 1.5 | −1.5 | −1.0 | −0.5 | 0 | 0.5 | 1.0 | 1.5 |
| Panama, C. Z. | | | | | | | | | | | | | | |
| Balboa | 71 | 67 | 31 | 29 | 5 | 4 | 3 | 3 | 5 | 9 | 20 | 35 | 96 | 129 |
| California | | | | | | | | | | | | | | |
| La Jolla | 104 | 51 | 22 | 17 | 16 | 11 | 6 | 4 | 6 | 14 | 19 | 31 | 60 | 158 |
| Los Angeles | 95 | 79 | 32 | 30 | 16 | 9 | 8 | 4 | 5 | 13 | 19 | 26 | 72 | 115 |
| Hueneme | 70 | 47 | 26 | 26 | 17 | 12 | 6 | 4 | 7 | 13 | 18 | 32 | 56 | 94 |
| Pacific Grove | 167 | 38 | 35 | 26 | 12 | 10 | 5 | 2 | 4 | 11 | 23 | 28 | 63 | 189 |
| San Francisco | 141 | 64 | 36 | 26 | 12 | 5 | 3 | 2 | 5 | 8 | 14 | 36 | 49 | 85 |
| Blunts Reef LS | 151 | 48 | 18 | 13 | 7 | 5 | 3 | 2 | 4 | 8 | 12 | 14 | 31 | 54 |
| Crescent City | 43 | 26 | 24 | 15 | 5 | 5 | 3 | 3 | 5 | 12 | 10 | 20 | 32 | 77 |
| Oregon | | | | | | | | | | | | | | |
| Astoria | 74 | 58 | 26 | 25 | 12 | 7 | 6 | 3 | 5 | 10 | 14 | 29 | 44 | 67 |
| Washington | | | | | | | | | | | | | | |
| Neah Bay | 86 | 37 | 31 | 12 | 10 | 7 | 4 | 3 | 5 | 8 | 16 | 28 | 35 | 60 |
| British Columbia | | | | | | | | | | | | | | |
| Amphitrite Point | 72 | 40 | 34 | 17 | 14 | 10 | 3 | 3 | 5 | 16 | 26 | 40 | 79 | 186 |
| Langara Island | 142 | 42 | 35 | 20 | 8 | 5 | 3 | 2 | 4 | 12 | 15 | 53 | 103 | 187 |
| Alaska | | | | | | | | | | | | | | |
| Ketchikan | 151 | 71 | 36 | 27 | 9 | 4 | 2 | 3 | 6 | 9 | 16 | 23 | 76 | 119 |
| Sitka | 82 | 73 | 41 | 22 | 13 | 9 | 1 | 2 | 8 | 10 | 28 | 47 | 73 | 176 |
| Juneau | 82 | 39 | 21 | 11 | 6 | 5 | 2 | 2 | 5 | 7 | 12 | 16 | 39 | 115 |
| Yakutat | 81 | 59 | 29 | 19 | 10 | 7 | 3 | 2 | 8 | 9 | 17 | 29 | 53 | 113 |

TABLE 4. Observed extreme durations (months) of nonseasonal air temperature oscillations (anomalies from long term monthly means).

| Station | Above deg C | | | | | | | Below deg C | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | −1.5 | −1.0 | −0.5 | 0 | 0.5 | 1.0 | 1.5 | −1.5 | −1.0 | −0.5 | 0 | 0.5 | 1.0 | 1.5 |
| California | | | | | | | | | | | | | | |
| San Diego | 62 | 33 | 30 | 24 | 10 | 10 | 7 | 5 | 8 | 12 | 14 | 26 | 45 | 83 |
| San Francisco | 70 | 58 | 49 | 21 | 7 | 7 | 4 | 3 | 6 | 10 | 12 | 20 | 66 | 101 |
| Eureka | 94 | 66 | 46 | 11 | 10 | 6 | 5 | 6 | 6 | 11 | 19 | 24 | 29 | 67 |
| Washington | | | | | | | | | | | | | | |
| North Head | 54 | 46 | 26 | 16 | 12 | 8 | 7 | 4 | 5 | 9 | 15 | 23 | 54 | 54 |
| Tatoosh Island | 71 | 49 | 23 | 21 | 10 | 7 | 6 | 3 | 8 | 11 | 15 | 29 | 56 | 108 |

6) the largest observed durations of sea and air temperature anomalies above and below the 0C level are of the order of 1 to 2 years, while those above the +1.5C and below the −1.5C levels are between 1 and 2 months.
7) there is close agreement between the durations of nonseasonal sea and air temperature oscillations.

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