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Large-Scale Air-Sea Interactions at Ocean Weather Station V, 1951-71

DAVID M. HUSBY and GUNTER R. SECKEL

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44 pp

CONTENTS

Figures

Tables

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ABSTRACT

The meteorological observations at OWS-V (Ocean Weather Station V, lat. 34°N, long. 164°E) were used to compute large-scale air-sea heat exchange processes and wind stresses for each month from September 1951 to March 1971. The monthly values are tabulated as anomalies from the 1955 to 1971 means. The quality of the data record and the accuracy of the derived heat exchange components are discussed.

The air-sea interaction climatology at OWS-V, which lies in the net annual heat loss area of the western North Pacific, is described. At this station the average monthly heat exchange across the sea surface is estimated to range from a gain during July of 307 cal cm^{-2} day^{-1} to a loss during December of 388 cal cm^{-2} day^{-1} with an annual loss of 32 cal cm^{-2} day^{-1}. The principal process causing monthly and seasonal variations in the net heat exchange across the sea surface, besides the radiation from sun and sky, is the heat used for evaporation. The average monthly heat lost through evaporation is estimated to range from 86 cal cm^{-2} day^{-1} during July to 374 cal cm^{-2} day^{-1} during December with an annual average of 234 cal cm^{-2} day^{-1}. Anomalous evaporation rates are caused by anomalous "vapor pressure differences" (saturation vapor pressure at the sea-surface temperature minus the vapor pressure of air) and/or anomalous wind speeds.

INTRODUCTION

Air-sea interactions in the western North Pacific Ocean play an important role in conditioning the waters that eventually reach the eastern North Pacific with its rich living resources. In mid-latitudes the ocean loses heat across the sea surface in fall and winter and gains heat in spring and summer, thus producing seasonal changes in surface temperature as well as affecting the vertical density structure.

The heat exchange across the sea surface is not uniform over the ocean as illustrated in Figure 1, reproduced from Wyrtki (1965). In a large region extending eastward from Japan to the central Pacific, the ocean loses more heat than it gains annually. In the mid-latitude eastern portion of the North Pacific, a small annual net heat gain across the sea surface indicates that most of the heat gained during spring and summer is lost during fall and winter. The excess heat lost in the west is that which was stored in the ocean at lower latitudes. The distribution of heat exchange across the sea surface indicates that the reduction of heat content in the northeastward flowing Kuroshio Current occurs primarily off Japan. When the water reaches the central Pacific heat loss on an annual average basis ceases so that the heat content of the water will not change as it continues to drift eastward. One can also postulate on the basis of the distribution of heat exchange across the sea surface, that anomalies in heat content produced or found in the western Pacific would persist after the water reaches the central Pacific and drifts eastward. Favorite and McLain (1973) have described such an event. Anomalous sea-surface temperatures were found in the western North Pacific that moved eastward across the ocean in a coherent fashion in 2 to 3 yr. This discussion illustrates that for an understanding and the prediction of interseason and interyear changes in water properties reaching the eastern North Pacific, monitoring of air-sea interaction processes, and determining their effect on the water structure, must begin in the upstream area on the western side of the ocean.

Ocean Weather Station V (OWS-V) lies within, albeit near the periphery, of the net annual heat loss region of the North Pacific (Fig. 1). The station was operated by the U.S. Coast Guard at lat. 31°N, long. 164°E from 29 September 1951 to 12 March 1955 and then at lat. 34°N, long. 164°E until its discontinuance in January 1972. Surface meteorological observations were made throughout this time. Beginning in 1965 oceanographic station data were also collected. The meteorological and oceanographic data will permit a number of investigations leading toward the objective of predicting the surface properties of the water flowing toward the eastern Pacific.

Because such predictions will be based primarily on surface marine meteorological observations obtained from merchant vessels, air-sea interactions computed from OWS-V data will provide a reliable reference. Air-sea interactions computed from OWS-V data will also permit studies of their effect on the water structure for the years when oceanographic station data are available. Finally, these studies will permit extrapolation of results to the net annual heat loss area where only merchant vessel meteorological data are available regularly.

The initial phase of this work, namely bringing the meteorological data of OWS-V into useable form, is reported here.

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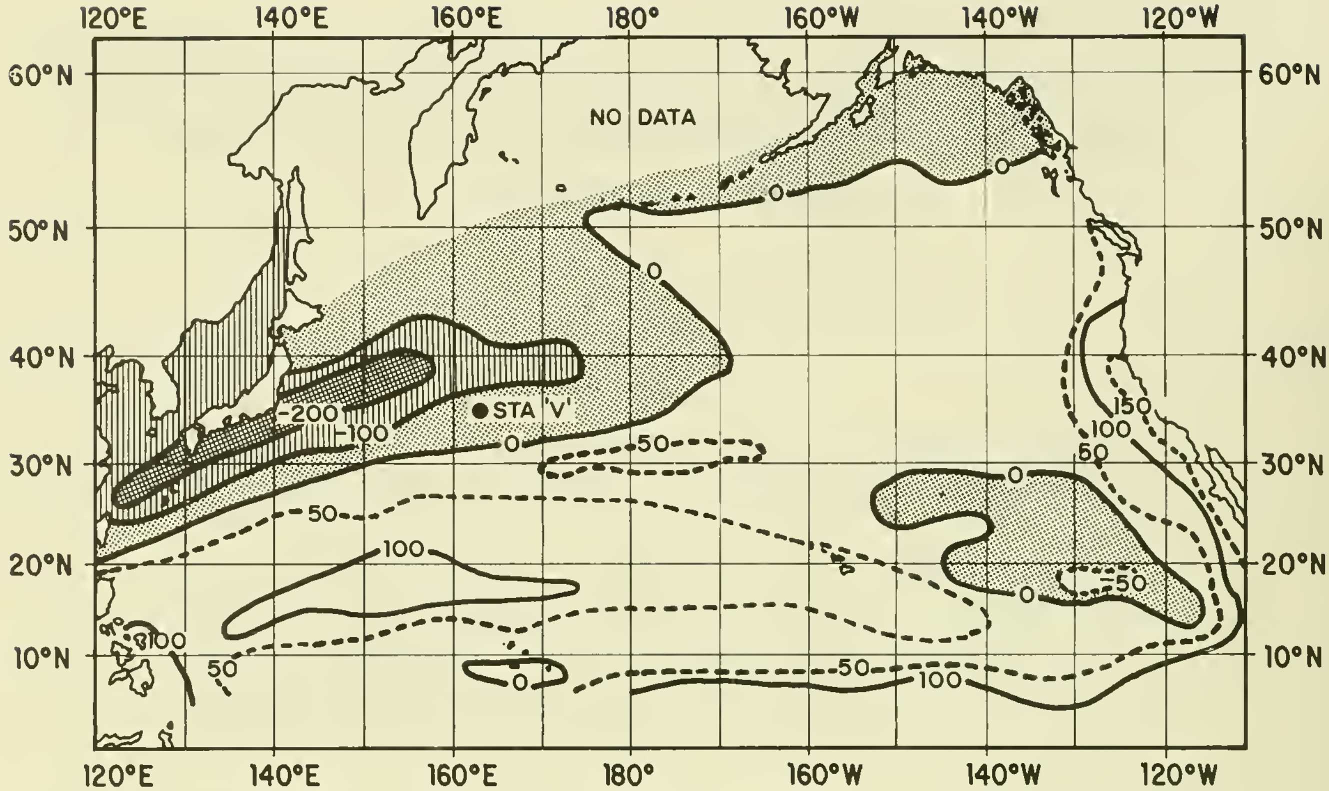

Figure 1.—Average annual amount of heat received (+) or lost (−) by the oorth Pacific Ocean across the sea surface io cm^{-2} day^{-1}, adapted from Wyrtki (1965).

In Appendix I the mean meteorological properties affecting air-sea interactions are tabulated for each month, September 1951 to March 1971. The properties include the sea-surface temperature, air temperature, difference between air and sea temperatures, vapor pressure of the air, difference between vapor pressure of the air and the saturation vapor pressure at the sea-surface temperature, wind speed, square of the wind speed, north-south and east-west components of resultant wind velocity, total cloud amount, and sea-level atmospheric pressure.

In Appendix II air-sea interaction processes computed from monthly mean meteorological properties under the assumption of neutral stability are tabulated for each month, September 1951 to March 1971. The tabulations include the net heat exchange across the sea surface, radiation from sun and sky, the effective back radiation, the conduction of sensible heat, the heat used evaporation, and the north-south and east-west components of wind stress.

In Appendix III air-sea interaction processes are again tabulated for each month, April 1955 to March 1971. These calculations include the effects of changes in atmospheric stability and daily mean meteorological properties were used. The tabulations include the net heat exchange across the sea surface, the heat used for evaporation, the conduction of sensible heat, and the north-south and east-west components of wind stress. The manner in which the meteorological data were processed and the air-sea interaction processes calculated is described in the following sections.

EMPIRICAL FORMULAE

The net heat exchange across the sea surface, Q(N), is the sum of the radiation from sun and sky, Q(S), the effective back radiation (net long-wave radiation), Q(B), the heat used for evaporation, Q(E), and the conduction of sensible heat, Q(C):

$$Q(N) = Q(S) - Q(B) - Q(E) - Q(C) \qquad (1)$$

The manner in which these terms are calculated depends upon the time scale of interest. Here we are interested in large-scale air-sea interactions with time scales of seasons and years. Our unit of time is the month.

Semiempirical formulae have been derived for the computation of air-sea interaction processes on a monthly scale. A review of these formulae has been given by Laevastu (1960), Malkus (1962), Tabata (1964a), Roll (1965), and others. The formulae used to compute the values presented in this report are listed below. Similar formulae were used by Johnson, Flittner, and Cline (1965), Wyrtki (1966), and Seckel (1970).

The heat exchange processes are expressed in units of cal cm^{-2} day^{-1}, and the wind stress at the sea surface τ_0, is given in units of dynes cm^{-2}:

$$Q(S) = Q_0\,(1 - R)\,[a\,(1 - 0.66C^3) + b\,(1 - 0.716C + 0.00252\,a)] \qquad (2)$$

$$Q(B) = 1.14 \times 10^{-7}\,(273.16 + T_w)^4 \times (0.39 - 0.05\,e_a^{1/2})(1 - 0.6C^2) \qquad (3)$$

$$Q(E) = 3{,}767\ C_D\ (0.98\ e_w - e_a)\ W \quad (4)$$

$$Q(C) = 2{,}488\ C_D\ (T_w - T_a)\ W \quad (5)$$

$$\tau_0 = \rho\ C_D\ W^2. \quad (6)$$

where a and b are the proportions of the month when clouds of cumulus and stratus type, respectively, are predominant, a + b = 1;

C, the cloudiness in tenths of sky covered;

e_a, the vapor pressure of the air in millibars computed by using the formulae of Murray (1967);

e_w, the saturation vapor pressure over pure water at the seawater temperature, in millibars;

T_a, the temperature of the air in degrees Celsius;

T_w, the temperature of the water in degrees Celsius;

W, the wind speed in meters per second;

Q_0, radiation from sun and cloudless sky in calories per square centimeter per day;

R, reflectivity of the sea surface;

α, noon altitude of the sun in degrees; and

C_D, the nondimensional drag coefficient.

Heat Exchange Computations

Q(S), radiation from sun and sky.—The direct and diffuse radiation from a cloudless sky, Q'_0, was obtained from the Smithsonian Meteorological Table (Smithsonian Institution 1949) using an atmospheric transmission coefficient of 0.7. These values were then corrected to correspond to the atmospheric transmission that gave the radiation values observed at Ocean Weather Station "P" (OWS-P) (Tabata 1964a) with the formula $Q_0 = 33.2 + 1.011\ Q'_0$. The cloudless sky radiation was then corrected for cloud cover and reflection from the sea surface, to give Q(S), the radiation passing into the water.

Uncertainty in the computed radiation from sun and sky, Q(S), is caused primarily by the cloud cover correction. The difficulties are caused by the variability of cloudiness as well as the primitive nature of observation from ships at sea. Observations at sea include an estimate of the total cloud cover regardless of type. Thus the presence of cirroform clouds with a high transmittance cause an underestimate of the calculated radiation using total cloudiness. Quinn and Burt (1968) found this to be a problem in the tropical Pacific where cumulus and cirroform clouds predominate.

Using a large number of observations from OWS-P, Tabata (1964b) derived a formula that gave the transmittance as a linear function of cloudiness and mid-month noon altitude of the sun. This formula gives Q(S) within 5% of the observed radiation when mean monthly cloud values are used. OWS-P lies at lat. 50°N where stratus type clouds predominate. In low latitudes cumulus types of clouds predominate (U.S. Weather Bureau 1938). Seckel and Beaudry (1973) showed that the cloud correction formula with a transmittance as a function of the cube of the cloudiness (Laevastu 1960) gave radiation values agreeing beter with Wake Island observations than values obtained with other correction formulae. They suggested the use of the two formulae, one for cumulus type clouds and the other for stratus type clouds. In the calculation of this report the two correction formulae were used in proportion to the occurrence during a month of cumulus and stratus type clouds.

To obtain the radiation entering the water, the incident radiation reaching a unit surface of ocean must be reduced by the amount reflected. The reflection was calculated from the formula given by Andersen (1952):

$$R = a\alpha^{b}, \quad (7)$$

where α is the mid-month solar altitude and a and b are empirical constants adapted from Tabata (1964a). For a cloud cover of 0.5 or less, a = 0.33 and b = -0.42. For a cloud cover of more than 0.5, a = 0.21 and b = -0.29.

Q(B), the effective back radiation.—The effective back radiation, Q(B), consists of the long-wave radiation from the sea surface, which is proportional to the 4th power of the absolute sea-surface temperature, minus the downward long-wave radiation from the sky. The latter depends on the water vapor content of the atmosphere as well as the type, density, and height of clouds. Because of the variability in time and space of these properties, the downward long-wave radiation is difficult to determine. A number of empirical formulae exist for the computation of Q(B), most of which were derived for overland conditions. Uncertainties are primarily introduced by the cloud factor in the empirical equations (Kraus 1972) that is given both as a linear and quadratic function of cloudiness. Because of its common application for the computation of large-scale air-sea interactions, we have used Equation (3), the modified Brunt equation (Brunt 1932) with the empirical constants of Budyko (1956).

Q(E), heat used for evaporation.—The turbulent flux of water vapor between the ocean and atmosphere, besides Q(S), is the most important process affecting Q(N). It has been estimated (Jacobs 1951) that of the total solar energy absorbed at the sea surface during the course of a year, approximately 50% is used for the evaporation of seawater that becomes available to the atmosphere in the form of energy latent in water vapor.

Absolute magnitudes of the rate of evaporation at the sea surface are still in doubt. The trouble lies, in part, with the uncertainties of the transfer coefficients—C_E, C_H, and C_D—used to calculate the turbulent fluxes of water vapor, heat, and momentum. Results of experiments over a Kansas plain (Businger et al. 1971) indicate that for neutral conditions the drag coefficient, C_D, is not equal to the sensible heat transfer coefficient, C_H. Other results (Paulson, Leavitt, and Fleagle 1972) from the Barbados Oceanographic and Meteorological Experiment (BOMEX) indicate that C_H and C_E, the evaporation coefficient, are equal but differ from C_D, the drag coefficient. Additionally, the transfer coefficients are dependent on the atmospheric stability and the ocean-wave spectrum. Deardorff (1968) derived stability corrections for the transfer coefficients at neutral stability as a function f the bulk Richardson's number. Davidson (1974) and DeLeonibus (1971) have both shown the separate influences of stability and ocean-wave spectrum on C_D.

The magnitude of the transfer coefficients and their dependence on stability and the ocean-wave spectrum is still under investigation. For this reason and despite the results quoted above, we follow Malkus (1962) in using a constant C_D in the computation of each of the turbulent fluxes (Equations (4), (5), (6)). The value used in this paper, $C_D = 0.0013$ referred to the 10-m level, has been suggested

Table 1.—Monthly mean sea-surface temperature (T) and standard deviation (σ) of the means at OWS-V (A) and in a 2° quadrangle centered at lat 31°N, long. 164°E (B) for the year 1954.

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
A	$\bar{T}$	18.6	17.5	19.1	18.7	20.6	23.7	26.6	26.5	26.6	25.5	24.2	21.8
	σ	0.44	0.69	1.08	0.69	1.94	0.51	0.90	0.60	0.41	0.37	0.53	0.50
B	$\bar{T}$	19.1	17.7	18.5	18.6	20.9	21.7	26.0	27.3	26.6	25.3	23.7	21.6
	σ	0.92	1.64	1.01	1.00	1.46	2.76	1.98	1.11	1.29	1.48	1.72	1.75

by Kraus (1972) and falls within the range of determinations made during the last 10 yr.

On a provisional basis we have also calculated the turbulent transfer processes that reflect changes in stability by using Deardorff's correction for the transfer coefficients at neutral stability (Appendix III). We feel that the use of corrections for the ocean-wave spectrum in the routine calculation of turbulent transfer processes from marine surface data would be premature.

Q(C), transfer of sensible heat.—Estimates of the turbulent flux of sensible heat between the sea and the atmosphere suffer from the same deficiencies as the water vapor flux. The sensible heat flux is proportional to the sea-air temperature difference and the wind speed. This process is of relatively small magnitude in comparison with the other air-sea interaction processes.

Wind Stress

Again, the turbulent flux of momentum across the sea surface is subject to uncertainties discussed above. In addition, because the magnitude of the stress is proportional to the square of the wind speed the climatological mean approach used in the calculation of the water vapor flux and the sensible heat flux should not be used in the calculation of the momentum flux. In this paper, the resultant stress components are the mean values of the stress components computed from individual wind observations using

$$\tau_x = \rho\ C_D\ w_x\ W \qquad (8)$$

$$\tau_y = \rho\ C_D\ w_y\ W \qquad (9)$$

w_x and w_y are the components of the wind in the zonal and meridional directions and W is the magnitude of the wind speed. For the density of air we used $\rho = 0.00123$ g cm^{-3}.

PROCESSING OF DATA

Before the summarization of meteorological properties for the computation of air-sea interaction processes, several deficiencies in the three-hourly observations at OWS-V had to be corrected. The most troublesome deficiencies are gaps in the data record and errors in the sea-surface temperature. A shift in location of OWS-V in 1955 introduces another deficiency in that comparisons of air-sea interaction processes after 1955 with those before 1955 are difficult. Procedures to overcome these deficiencies are described below.

Data Gaps

Large data gaps in the time series were not common. However, there was a 13-day gap from 2 to 14 May 1970 when no observations were taken. All properties except sea-surface temperature were measured from 16 March 1952 to 31 March 1953. For this period, monthly mean sea-surface temperatures from merchant vessel observations (National Climatic Center, Tape Data Family 11) in a 2° quadrangle centered at lat. 31°N, long. 164°E were substituted and used in the heat exchange computations. Agreement between OWS-V and merchant vessel monthly mean surface temperatures is good (Table 1).

The sea-surface temperature data were also missing from 1 May 1963 to 21 June 1963, and daily bucket temperatures collected aboard the Ocean Station Vessel for the National Marine Fisheries Service (Yong 1971) were substituted.

Wet bulb temperatures for the entire month of December 1955 were missing. This data gap was filled by computing the saturation vapor pressure of the air from merchant vessel dew-point temperatures interpolated to the position of OWS-V. The saturation vapor pressure was computed by the ideal gas law formula for moist air (Longley 1970).

Erroneous Data

Erroneous sea-surface temperature values were detected during the initial pass through the data by computing a 16-point running mean. Those values which differed by more than 5°C from the running mean were rejected. A second quality control check was performed on the daily mean sea-surface temperatures for each year by using harmonic analysis as a curve-fitting technique (Seckel and Yong 1970). Fourier analysis was carried out to the 13th harmonic with a fundamental period of 365 days. Daily values that deviated more than 1°C from the expected value were rejected. Three separate 21-day periods in 1954—13 June to 8 July, 17 October to 5 November, and 28 November to 17 December—were found to contain sea-surface temperatures which were consistently about 3°C lower than surrounding data points. It was found that the same vessel was on station during these periods and we assumed that an erroneously calibrated thermometer was used on this ship with an error of 3.3°C. The erroneous temperatures were corrected by adding 3.3°C (Fig. 2).

Position Change

A change in location of OWS-V from lat. 31°N, long. 164°E to lat. 34°N, long. 164°E occurred in March 1955. Although the locations are separated by only three degrees of latitude, spatial differences of meteorological properties are of the same magnitude as the interyear differences that are of interest to us. An attempt was made to correct the pre-1955 data to the new latitude by comparing merchant

Figure 2.—Mean daily sea-surface temperature (°C) at Ocean Weather Station V during 1954. Values indicated by heavy dots and lines were derived by adding 3.3°C to original daily values.

vessel data from 2° quadrangles surrounding the two locations of OWS-V. The attempt failed, however, because inadequate sampling frequency by month produced large variability in the comparison of properties from the two areas. However, in the computation of anomalies for the cooling and heating portions of the annual cycle which will be discussed in a later section, corrections were made for the position change. The corrections used were the differences of meteorological properties based on the 20-yr means (1949-68) for each month between the two locations.

Data Summarization

All acceptable three-hourly observations of the surface meteorological properties were used to calculate a daily mean value, excepting the total cloud amount.

The daily mean of the total cloud amount was determined from those observations taken during daylight or twilight hours. Also, the predominant low cloud type was determined for each day to be either 1) cumulus (code numbers 1-4 in the U.S. Weather Bureau ship code) or 2) stratus (code numbers 5-9). The low cloud type which was observed most frequently during the day, or in case of an equal number of both types, that observed closest to local noon, designated the type for the day to be used in the cloud correction.

Monthly mean values listed in Appendix I are the arithmetic means of the daily values. These values were used to calculate the processes listed in Appendix II except that the monthly wind stress components are mean values of the daily stress components. Mean daily meteorological properties were used to obtain the results listed in Appendix III.

All properties and processes which were computed using corrections or substitutions from merchant vessel surface marine observations are annotated by an asterisk (*) in Appendices I, II, and III.

ACCURACY OF HEAT EXCHANGE COMPUTATIONS

Accuracy of the air-sea interaction values derived from marine surface meteorological properties depends both on the correctness of the empirical formulae and the quality of the data used. Surface meteorological data from ocean weather ships are generally of the best quality obtainable at sea. This is true also for the three-hourly observations at OWS-V except for the data inadequacies previously discussed. We also mentioned the uncertainties connected with the empirical formulae.

Estimates of the radiation from sun and sky, Q(S), have been uncertain because marine cloud observations are of a subjective nature. Better measurements of cloudiness such as the amount of opaque clouds or the percent of possible sunshine are not reported, and information about the thickness of the cloud layers is generally not observable from ships. There have also been a variety of empirical expressions to correct the clear sky radiation ranging from linear to cubic functions of the cloudiness. When some of these expressions, having been derived in mid-latitudes and over land, are used over the tropical Pacific, erroneous radiation estimates may result as reported by Quinn and Burt (1968).

As far as historical marine surface observations are concerned, little can be done about the subjective nature of the cloud observations. However, uncertainty in the radiation estimate due to the second cause has been reduced by the inclusion of Laevastu's (1960) and Tabata's (1964b) cloud correction formulae in Equation (2). Tabata's formula is based on extensive OWS-P observations. Laevastu's formula is based on less extensive observations made on the U.S.S. *Rehoboth.* Tabata states that when monthly mean cloudiness is used, about 70% of the estimated values fall within 5% of the observed values. Laevastu estimates, when leaving out days with a cloudiness of more than eight tenths of sky covered, that his radiation values are within 5% of measured values during about 42% of the days and within 10% of the measured values during 51% of the days when measurements were made. We estimate that our radiation values in Appendix II are better than the underestimates reported by Quinn and Burt (1968) and possibly lie within 10% of the true values.

Next in importance in the net heat exchange across the sea surface, Q(N), is the heat used for evaporation, Q(E). We have discussed the uncertainties in the drag coefficient under neutral conditions. Values of the neutral drag coefficient referred to the 10-m level in recent field experiments range from 0.0010 to 0.0016. Variations in stability and wave spectra, and the assumption that the transfer coefficients of heat, water vapor, and momentum are equal, increase the uncertainty in the magnitudes of the derived turbulent exchange processes.

Verification of the derived evaporation rate and determination of its accuracy cannot be made at this time because direct measurements have not been possible. However, gross water vapor budget estimates such as those by Riehl et al. (1951) and measurement of vertical eddy fluxes during BOMEX (Holland 1972) indicate that the derived evaporation is of the correct order of magnitude.

Third in importance is the effective back radiation, Q(B). Budyko (1974) states that formulae for Q(B) have been checked by many observations obtained during the International Geophysical Year at actinometric stations in the USSR. He states that Berliand's formula (our Equation (3)) is well corroborated for observations made at average and high humidities. However, verifications at sea are few. Measurements of Q(B) during the Trade Wind Zone Oceanography investigation reported by Charnell (1967) ranged from 58 to 173 cal cm^{-2} day^{-1}. The mean monthly Q(B) computed by Seckel (1970) for the months and area of those observations fell within the above range. Charnell's (1967) observations indicate that the upward long-wave radiation followed the Stefan-Boltzmann law with an average emissivity of 0.99 and with values ranging from 0.96 to 1.1. The downward sky radiation, dependent on the water vapor content of the atmosphere as well as the type, amount, density, and height of clouds, is more difficult to verify without extensive observations. For example, 10 24-h observations made off the Oregon coast (Reed and Halpern 1975) gave average Q(B) values only 50% of that calculated with Equation (3).

The primary cause for the differences between the observed and calculated values is the cloud correction factor. The coefficient in the cloud factor was determined for the average type and height of cloudiness occurring in a given latitude band (presumably over the USSR). The example given above illustrates that empirical formulae derived for average conditions do not necessarily hold for a short duration such as 10 days or a month or for a specific location within the latitude band.

Although the accuracy of the Q(B) calculated for OWS-V cannot be given, interseason and interannual comparisons of Q(N) are not expected to be significantly affected. The average Q(B) calculated for OWS-V (Appendix II) shows an annual range of 39 cal cm^{-2} day^{-1} compared to ranges of 288 and 595 cal cm^{-2} day^{-1} for the calculated Q(E) and Q(N), respectively.

The conduction of sensible heat, Q(C), is subject to the same limitations as the Q(E) but is of relatively small magnitude. Errors in Q(N) due to uncertainties in Q(C) are expected to be smaller than those contributed by the other heat exchange processes.

Again, the wind stress on the sea surface is subject to the same limitations as the turbulent transfers of water vapor and sensible heat. Thus, we are unable to determine the accuracy of any of the turbulent transfer processes.

Q(N) is the difference of large numbers. The relative error in Q(N) is therefore potentially much larger than that for the individual exchange processes. For example, if Q(S) is in error by 10% during July when Q(S) averages 473 cal cm^{-2} day^{-1}, then Q(N), with an average value of 278 cal cm^{-2} day^{-1}, will be in error by about 17%.

The values of the exchange processes listed in Appendix II must therefore be regarded as indices whose absolute magnitude is in doubt. Nevertheless, these indices are useful in climatic scale applications when interseason and interannual comparisons are to be made.

DISCUSSION

In this section we will take the results of Appendix II at face value and draw attention to the air-sea interaction processes that are of climatic significance at OWS-V and in the net annual heat loss area of the north Pacific Ocean.

First, consider the relative magnitudes of the heat exchange processes at OWS-V in terms of their modification of Q(S), using the 1956-70 average values (Fig. 3). The figure shows that Q(E) is the most important process by which heat is lost from the sea surface. Of the heat lost annually, Q(E) contributes 63%, Q(B) 26%, and Q(C) 11%.

Figure 3 also shows that the annual cycle is divided into a warming portion lasting from April through September and a cooling portion lasting from October through March. There is a net annual heat loss of 32 cal cm^{-2} day^{-1} at OWS-V which agrees with Wyrtki's (1965, fig. 1) chart value.

Monthly values of Q(N) and Q(E)

Monthly values for Q(N) and Q(E) and their anomalies are shown in Figures 4 to 6. Values prior to April 1955 were not corrected to reflect the change in location of OWS-V. Anomalies are calculated from the April 1955 to March 1971 monthly mean values of Q(N) and Q(E). Note that, particularly during the heat loss portion of the annual cycle, the pattern of the Q(N) and Q(E) curves are similar. This similarity is pronounced during the fall 1967 to winter 1968. The high net heat loss in November 1967 followed by low heat loss in December 1967 and then high heat loss in February 1968 was primarily caused by the heat used for evaporation. Similarities in the Q(N) and Q(E) anomaly patterns are also apparent.

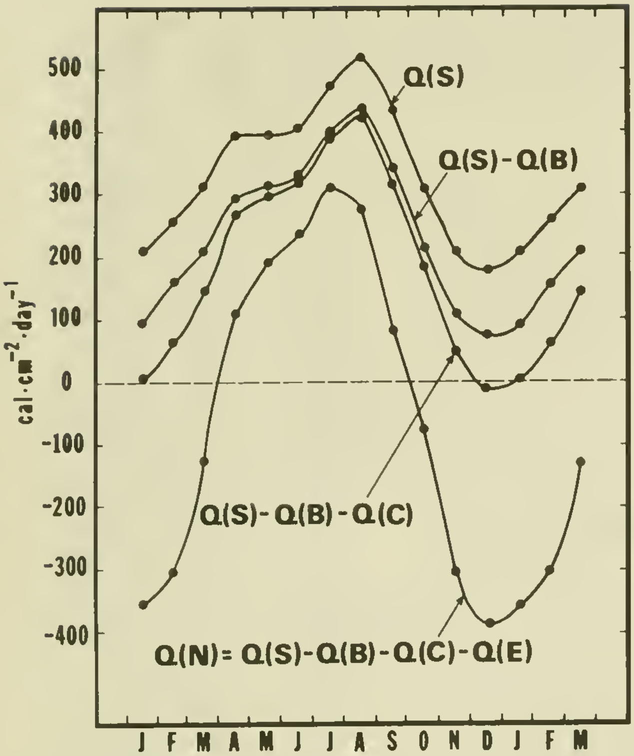

Figure 3.—Relative magnitude of the 1956-70 mean monthly components of heat exchange across the sea surface at Ocean Weather Station V (OWS-V) in cal cm^{-2} day^{-1}. Q(S)—radiation from sun and sky, Q(B)—effective back radiation, Q(C)—conduction of sensible heat, Q(E)—heat used for evaporation, and Q(N)—net heat exchange across the sea surface.

Seasonal Anomalies of Q(N) and Q(E)

Large-scale climatic anomalies are illustrated in the bar diagrams, Figures 7 and 8, in which Q(N) and Q(E) anomalies of the 6-mo averages for the warming and cooling portions of the annual cycle are shown. In these figures adjustments for the change in location of the weather ship were made. Differences in the 20-yr monthly mean (1949-68) meteorological properties between merchant vessel data collected in 2° quadrangles centered at lat. 34°N, long. 164°E and lat. 31°N, long. 164°E (Table 2) were added to the monthly mean meteorological properties from September 1951 through March 1955. The adjusted mean properties were then used to calculate the adjusted heat exchange processes and their 6-mo anomalies.

The figures show that the anomalies in most years persist for more than 6 mo. Often, an anomaly during the cooling 6 mo is followed or preceded by an anomaly of the same sign during the warming 6 mo. Pronounced cold (negative) anomalies occurred during the fall and winter of 1956-57, 1959-60, and 1967-68. A pronounced warm (positive) anomaly during the cooling portion of the annual cycle occured in 1968-69 while lesser warm anomalies occurred in 1958-59, 1962-63, and 1965-66. During the cooling 6 mo the seasonal anomalies in Q(N) reflect those of Q(E) (Fig. 8).

Q(E) as a Function of (e_w - e_a) and W

Because of the important role played by the evaporative process in the heat and water (salt) budgets of both the ocean and atmosphere, we will examine the dependence of evaporation on the wind speed, W, and the vapor pressure difference, (e_w - e_a). An "evaporation diagram" helps to illustrate this dependence (Fig. 9). In this diagram the wind speed is plotted along the abscissa and the vapor pressure difference, Δe, along the ordinate, Contours indicate Q(E) based on the bulk exchange formula with a C_D of 0.0013. The climatic mean value of W and Δe is plotted for each month and designated by Roman numerals, solid lines connecting the plotted points. This diagram allows one to determine whether a change in the evaporation rate is caused by a change in the wind speed and/or the vapor pressure difference. The "evaporative climate" of a location can be characterized by this diagram and, again one can determine whether an anomaly is caused by an anomalous wind speed and/or an anomalous vapor pressure difference. Qualitative interpretations based on this diagram are independent of the coefficient used in the bulk exchange formula.

The lowest evaporation rate at OWS-V occurs during June and July (Fig. 9) and then increases until September due to an increase in Δe with little change in W. During the next 2 mo the evaporation rate increases primarily because of the increase in the wind speed. From November through February the evaporation rate is at its maximum and changes little; the decrease in Δe is compensated for by an increase in W. After February both Δe and W decrease until the minimum evaporation rate is reached in June. The seasonal rise in evaporation is initially caused by the rise in Δe and then continues rising because of the increase in W. The seasonal decline in evaporation is caused by a simultaneous decline in both Δe and W.

Table 2.—Differences between monthly mean meteorological properties (1949-68) in 2° quadrangles centered at 1) lat. 34°N, long. 164°E and 2) lat. 31°N, long. 164°E. Values are mean (1) - mean (2). A = Sea-surface temperature, °C; B = Air temperature, °C; C = Wind speed, m sec^{-1}; D = Vapor pressure of the air, millibars; and E = Total cloud cover, tenths.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
A	-2.0	-1.3	-1.6	-1.9	-2.5	-2.6	-2.3	-1.0	-1.2	-1.1	-1.6	-1.6
B	-2.8	-2.7	-2.9	-2.3	-2.8	-2.4	-1.9	-1.1	-1.4	-1.4	-2.2	-2.2
C	0.5	1.8	1.8	0.8	1.5	0.6	0.5	0.2	1.0	0.5	1.0	1.2
D	-2.1	-2.8	-2.6	-1.7	-3.5	-3.4	-2.2	-1.5	-1.5	-2.1	-2.6	-2.2
E	0.1	0.1	0	0.1	0.1	0.1	0.1	0.1	0	0.1	0.1	0.1

MONTH	VALUE	ANOMALY
195101	NO DATA	
195102	NO DATA	
195103	NO DATA	
195104	NO DATA	
195105	NO DATA	
195106	NO DATA	
195107	NO DATA	
195108	NO DATA	
195109	112.00	0.00
195110	23.00	0.00
195111	-279.00	0.00
195112	-285.00	0.00
195201	-144.00	0.00
195202	-46.00	0.00
195203	48.00	0.00
195204	247.00	0.00
195205	316.00	0.00
195206	182.00	0.00
195207	404.00	0.00
195208	250.00	0.00
195209	270.00	0.00
195210	-26.00	0.00
195211	-218.00	0.00
195212	-202.00	0.00
195301	-360.00	0.00
195302	-165.00	0.00
195303	127.00	0.00
195304	89.00	0.00
195305	163.00	0.00
195306	322.00	0.00
195307	335.00	0.00
195308	301.00	0.00
195309	72.00	0.00
195310	21.00	0.00
195311	-186.00	0.00
195312	-290.00	0.00
195401	-224.00	0.00
195402	-149.00	0.00
195403	43.00	0.00
195404	102,00	0.00
195405	306.00	0.00
195406	264.00	0.00
195407	252.00	0.00
195408	310.00	0.00
195409	142.00	0.00
195410	90.00	0.00
195411	-364.00	0.00
195412	-352.00	0.00
195501	-255.00	0.00
195502	-210.00	0.00
195503	37.00	0.00
195504	41.00	-73.20
195505	187.00	3.07
195506	193.00	-41.20
195507	335.00	28.87
195508	394.00	124.60
195509	220.00	145.80
195510	-26.00	47.40
195511	-522.00	-231.67
195512	-511.00	-130.93
195601	-292.00	76.60
195602	-222.00	88.07
195603	-9.00	120.53
195604	162.00	47.80
195605	210.00	26.07
195606	205.00	-29.20
195607	295.00	-11.13
195608	299.00	29.60
195609	-52.00	-126.20
195610	-49.00	24.40
195611	-269.00	21.33
195612	-634.00	-253.93
195701	-579.00	-210.40
195702	-332.00	-21.93
195703	-209.00	-79.47
195704	71.00	-43.20
195705	70.00	-113.93
195706	147.00	-87.20
195707	234.00	-72.13
195708	353.00	83.60
195709	37.00	-37.20
195710	-144.00	-70.60
195711	-228.00	62.33
195712	-352.00	28,07

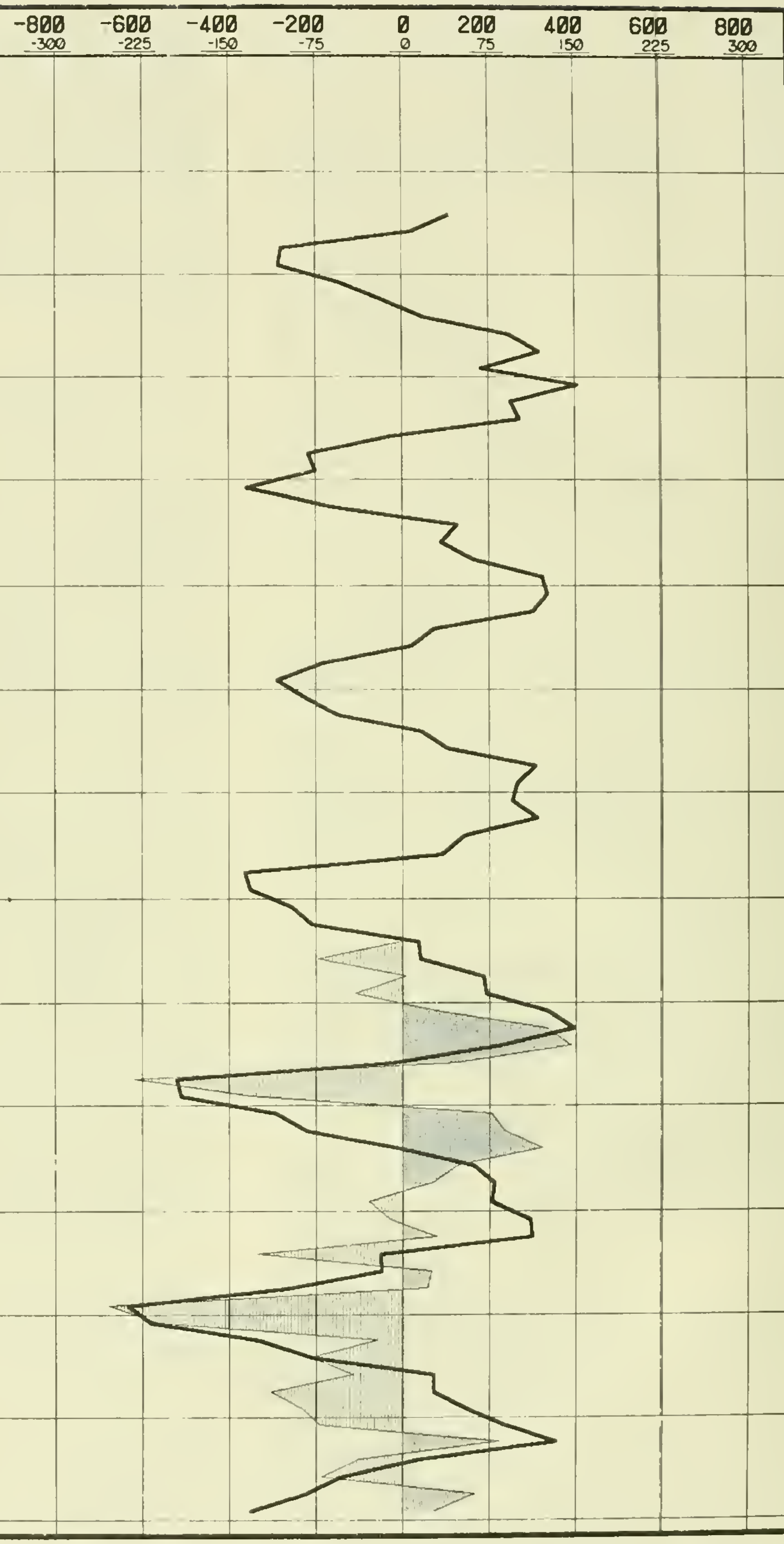

Figure 4a.—Monthly net heat exchange at Ocean Weather Station V (OWS-V), September 1951-December 1957, (solid line) and anomalies of monthly value from monthly mean, April 1955-March 1971, (shaded area). Upper row of numerals refer to scale of monthly values and lower row to scale of anomalies, units are cal cm^{-2} day^{-1}. Change in latitude of OWS-V occurred in March 1955.

MONTH	VALUE	ANOMALY
195101	NO DATA	
195102	NO DATA	
195103	NO DATA	
195104	NO DATA	
195105	NO DATA	
195106	NO DATA	
195107	NO DATA	
195108	NO DATA	
195109	-273.00	0.00
195110	-211.00	0.00
195111	-351.00	0.00
195112	-344.00	0.00
195201	-245.00	0.00
195202	-199.00	0.00
195203	-175.00	0.00
195204	-100.00	0.00
195205	-91.00	0.00
195206	-174.00	0.00
195207	-106.00	0.00
195208	-155.00	0.00
195209	-131.00	0.00
195210	-296.00	0.00
195211	-318.00	0.00
195212	-293.00	0.00
195301	-415.00	0.00
195302	-287.00	0.00
195303	-116.00	0.00
195304	-176.00	0.00
195305	-177.00	0.00
195306	-70.00	0.00
195307	-106.00	0.00
195308	-158.00	0.00
195309	-313.00	0.00
195310	-218.00	0.00
195311	-298.00	0.00
195312	-308.00	0.00
195401	-294.00	0.00
195402	-289.00	0.00
195403	-193.00	0.00
195404	-190.00	0.00
195405	-59.00	0.00
195406	-138.00	0.00
195407	-191.00	0.00
195408	-166.00	0.00
195409	-228.00	0.00
195410	-199.00	0.00
195411	-444.00	0.00
195412	-382.00	0.00
195501	-312.00	0.00
195502	-315.00	0.00
195503	-178.00	0.00
195504	-181.00	-27.07
195505	-94.00	17.07
195506	-123.00	-37.93
195507	-138.00	-55.07
195508	-96.00	57.13
195509	-184.00	51.00
195510	-245.00	17.07
195511	-498.00	-155.33
195512	-462.00	-93.07
195601	-304.00	63.67
195602	-299.00	63.27
195603	-188.00	83.47
195604	-103.00	50.93
195605	-120.00	-8.93
195606	-133.00	-47.93
195607	-121.00	-38.07
195608	-132.00	21.13
195609	-329.00	-94.00
195610	-254.00	8.07
195611	-331.00	11.67
195612	-551.00	-182.07
195701	-497.00	-129.33
195702	-370.00	-7.73
195703	-327.00	-55.53
195704	-147.00	6.93
195705	-200.00	-88.93
195706	-125.00	-39.93
195707	-89.00	-6.07
195708	-98.00	55.13
195709	-319.00	-84.00
195710	-309.00	-46.93
195711	-308.00	34.67
195712	-361.00	7.93

Figure 4b.—Monthly heat used for evaporation at Ocean Weather Station V(OWS-V), September 1951-December 1957, (solid line) and anomalies of monthly value from monthly mean, April 1955-March 1971, (shaded area). Upper row of numerals refer to scale of monthly values and lower row to scale of anomalies, units are cal cm^{-2} day^{-1}. Change in latitude of OWS-V occurred in March 1955.

MONTH	VALUE	ANOMALY
195801	-405.00	-36.40
195802	-537.00	-226.93
195803	-75.00	54.53
195804	142.00	27.80
195805	215.00	31.07
195806	292.00	57.80
195807	391.00	84.87
195808	338.00	68.60
195809	198.00	123.80
195810	150.00	223.40
195811	-170.00	120.33
195812	-449.00	-68.93
195901	-233.00	135.60
195902	-185.00	125.07
195903	-352.00	-222.47
195904	67.00	-47.20
195905	182.00	-1.93
195906	216.00	-18.20
195907	304.00	-2.13
195908	251.00	-18.40
195909	120.00	45.80
195910	-204.00	-130.60
195911	-278.00	12.33
195912	-417.00	-36.93
196001	-461.00	-92.40
196002	-325.00	-14.93
196003	-215.00	-85.47
196004	100.00	-14.20
196005	145.00	-38.93
196006	261.00	26.80
196007	470.00	163.87
196008	255.00	-14.40
196009	178.00	103.80
196010	-91.00	-17.60
196011	-353.00	-62.67
196012	-216.00	164.07
196101	-322.00	46.60
196102	-305.00	5.07
196103	-200.00	-70.47
196104	122.00	7.80
196105	233.00	49.07
196106	327.00	92.80
196107	403.00	96.87
196108	295.00	25.60
196109	59.00	-15.20
196110	-172.00	-98.60
196111	-260.00	30.33
196112	-416.00	-35.93
196201	-309.00	59.60
196202	-293.00	17.07
196203	-36.00	93.53
196204	186.00	71.80
196205	218.00	34.07
196206	331.00	96.80
196207	268.00	-38.13
196208	189.00	-80.40
196209	114.00	39.80
196210	91.00	164.40
196211	-132.00	158.33
196212	-423.00	-42.93
196301	-431.00	-62.40
196302	-375.00	-64.93
196303	-93.00	36.53
196304	291.00	176.80
196305	288.00	104.07
196306	173.00	-61.20
196307	403.00	96.87
196308	335.00	65.60
196309	117.00	42.80
196310	-127.00	-53.60
196311	-363.00	-72.67
196312	-351.00	29.07
196401	-447.00	-78.40
196402	-296.00	14.07
196403	-61.00	68.53
196404	214.00	99.80
196405	116.00	-67.93
196406	211.00	-23.20
196407	233.00	-73.13
196408	223.00	-46.40
196409	-61.00	-135.20
196410	-122.00	-48.60
196411	-260.00	30.33
196412	-460.00	-79.93

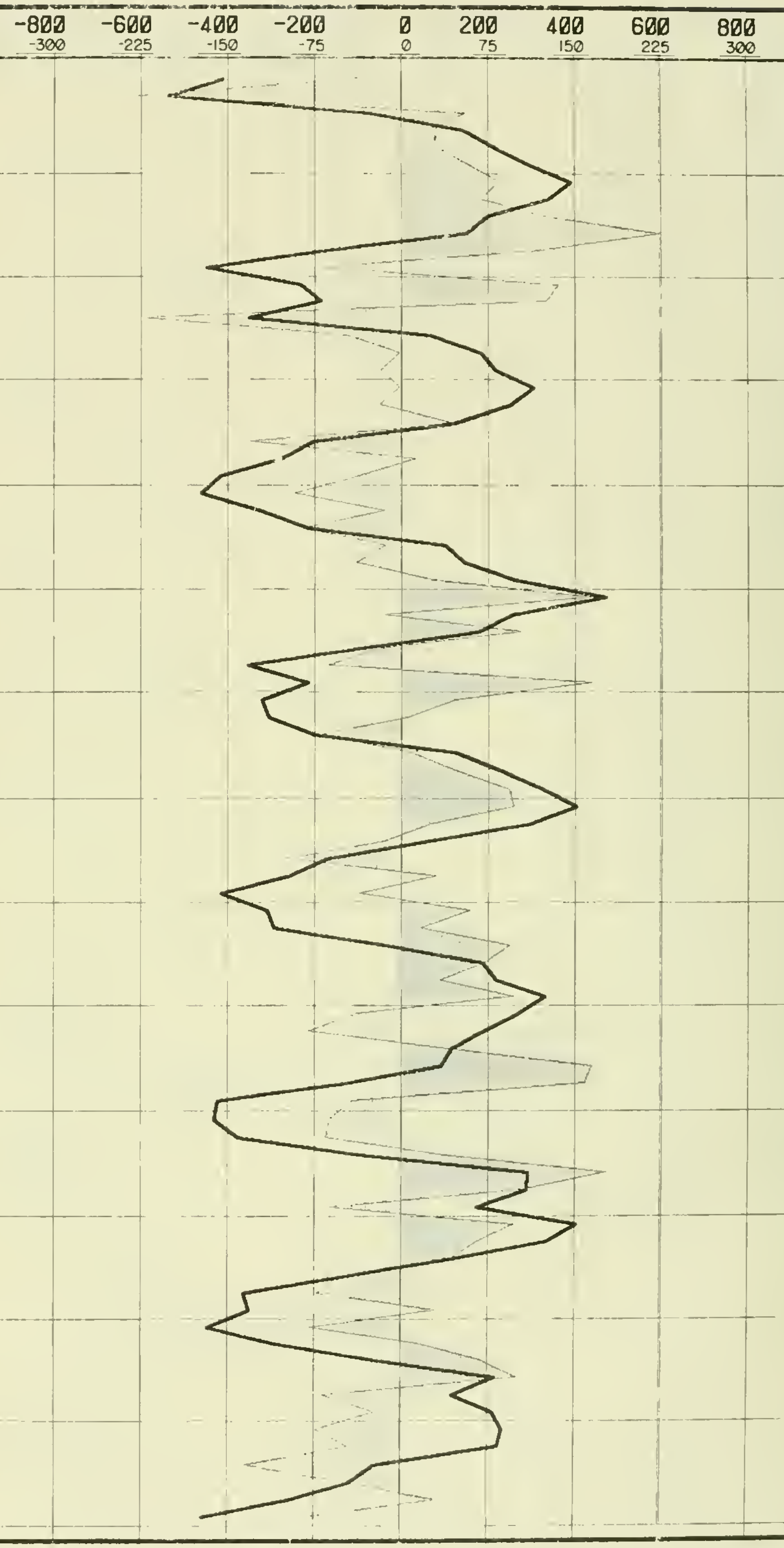

Figure 5a.—Monthly net heat exchange at Ocean Weather Station V (OWS-V), January 1958-December 1964, (solid line) and anomalies of monthly value from monthly mean, April 1955-March 1971, (shaded area). Upper row of numerals refer to scale of monthly values and lower row to scale of anomalies, units are cal cm^{-2} day^{-1}.

MONTH	VALUE	ANOMALY
195801	-397.00	-29.33
195802	-543.00	-180.73
195803	-202.00	69.47
195804	-122.00	31.93
195805	-70.00	41.07
195806	-58.00	27.07
195807	-80.00	2.93
195808	-109.00	44.13
195809	-139.00	96.00
195810	-106.00	156.07
195811	-249.00	93.67
195812	-423.00	-54.07
195901	-265.00	102.67
195902	-250.00	112.27
195903	-435.00	-163.53
195904	-195.00	-41.07
195905	-109.00	2.07
195906	-92.00	-6.93
195907	-72.00	10.93
195908	-112.00	41.13
195909	-212.00	23.00
195910	-331.00	-68.93
195911	-301.00	41.67
195912	-384.00	-15.07
196001	-430.00	-62.33
196002	-369.00	-6.73
196003	-332.00	-60.53
196004	-156.00	-2.07
196005	-148.00	-36.93
196006	-63.00	22.07
196007	-13.00	69.93
196008	-171.00	-17.87
196009	-177.00	58.00
196010	-289.00	-26.93
196011	-407.00	-64.33
196012	-238.00	130.93
196101	-308.00	59.67
196102	-347.00	15.27
196103	-338.00	-66.53
196104	-153.00	.93
196105	-93.00	18.07
196106	-41.00	44.07
196107	-84.00	-1.07
196108	-151.00	2.13
196109	-283.00	-48.00
196110	-368.00	-105.93
196111	-320.00	22.67
196112	-384.00	-15.07
196201	-320.00	47.67
196202	-365.00	-2.73
196203	-197.00	74.47
196204	-129.00	24.93
196205	-94.00	17.07
196206	-70.00	15.07
196207	-104.00	-21.07
196208	-189.00	-35.87
196209	-224.00	11.00
196210	-146.00	116.07
196211	-202.00	140.67
196212	-382.00	-13.07
196301	-453.00	-85.33
196302	-433.00	-70.73
196303	-274.00	-2.53
196304	-100.00	53.93
196305	-98.00	13.07
196306	-130.00	-44.93
196307	-40.00	42.93
196308	-142.00	11.13
196309	-203.00	32.00
196310	-299.00	-36.93
196311	-389.00	-46.33
196312	-365.00	3.93
196401	-419.00	-51.33
196402	-335.00	27.27
196403	-236.00	35.47
196404	-95.00	58.93
196405	-158.00	-46.93
196406	-118.00	-32.93
196407	-102.00	-19.07
196408	-223.00	-69.87
196409	-189.00	46.00
196410	-303.00	-40.93
196411	-310.00	32.67
196412	-425.00	-56.07

Figure 5b.—Moothly heat used for evaporation at Ocean Weather Station V (OWS-V), January 1958-December 1964, (solid line) and anomalies of monthly value from monthly mean, April 1955-March 1971, (shaded area). Upper row of numerals refer to scale of monthly values and lower row to scale of anomalies, units are cal cm⁻² day⁻¹.

MONTH	VALUE	ANOMALY
196501	-331.00	37.60
196502	-249.00	61.07
196503	-162.00	-32.47
196504	29.00	-85.20
196505	250.00	66.07
196506	321.00	86.80
196507	296.00	-10.13
196508	206.00	-63.40
196509	33.00	-41.20
196510	-197.00	-123.60
196511	-303.00	-12.67
196512	-290.00	90.07
196601	-320.00	48.60
196602	-224.00	86.07
196603	-109.00	20.53
196604	-66.00	-180.20
196605	279.00	95.07
196606	213.00	-21.20
196607	291.00	-15.13
196608	290.00	20.60
196609	169.00	94.80
196610	-104.00	-30.60
196611	-353.00	-62.67
196612	-453.00	-72.93
196701	-416.00	-47.40
196702	-341.00	-30.93
196703	-136.00	-6.47
196704	72.00	-42.20
196705	185.00	1.07
196706	312.00	77.80
196707	312.00	5.87
196708	272.00	2.60
196709	125.00	50.80
196710	-154.00	-80.60
196711	-560.00	-269.67
196712	-188.00	192.07
196801	-458.00	-89.40
196802	-587.00	-276.93
196803	-45.00	84.53
196804	57.00	-57.20
196805	135.00	-48.93
196806	190.00	-44.20
196807	323.00	16.87
196808	184.00	-85.40
196809	-77.00	-151.20
196810	55.00	128.40
196811	-292.00	-1.67
196812	-337.00	43.07
196901	-180.00	188.60
196902	-94.00	216.07
196903	-99.00	30.53
196904	155.00	40.80
196905	251.00	67.07
196906	53.00	-181.20
196907	299.00	-7.13
196908	225.00	-44.40
196909	60.00	-14.20
196910	-91.00	-17.60
196911	-184.00	106.33
196912	-379.00	1.07
197001	-345.00	23.60
197002	-286.00	24.07
197003	-142.00	-12.47
197004	111.00	-3.20
197005	-18.00	-201.93
197006	261.00	26.80
197007	70.00	-236.13
197008	326.00	56.60
197009	93.00	18.80
197010	58.00	131.40
197011	-350.00	-59.67
197012	-336.00	44.07
197101	-278.00	90.60
197102	-393.00	-82.93
197103	-130.00	-.47
197104	NO DATA	
197105	NO DATA	
197106	NO DATA	
197107	NO DATA	
197108	NO DATA	
197109	NO DATA	
197110	NO DATA	
197111	NO DATA	
197112	NO DATA	

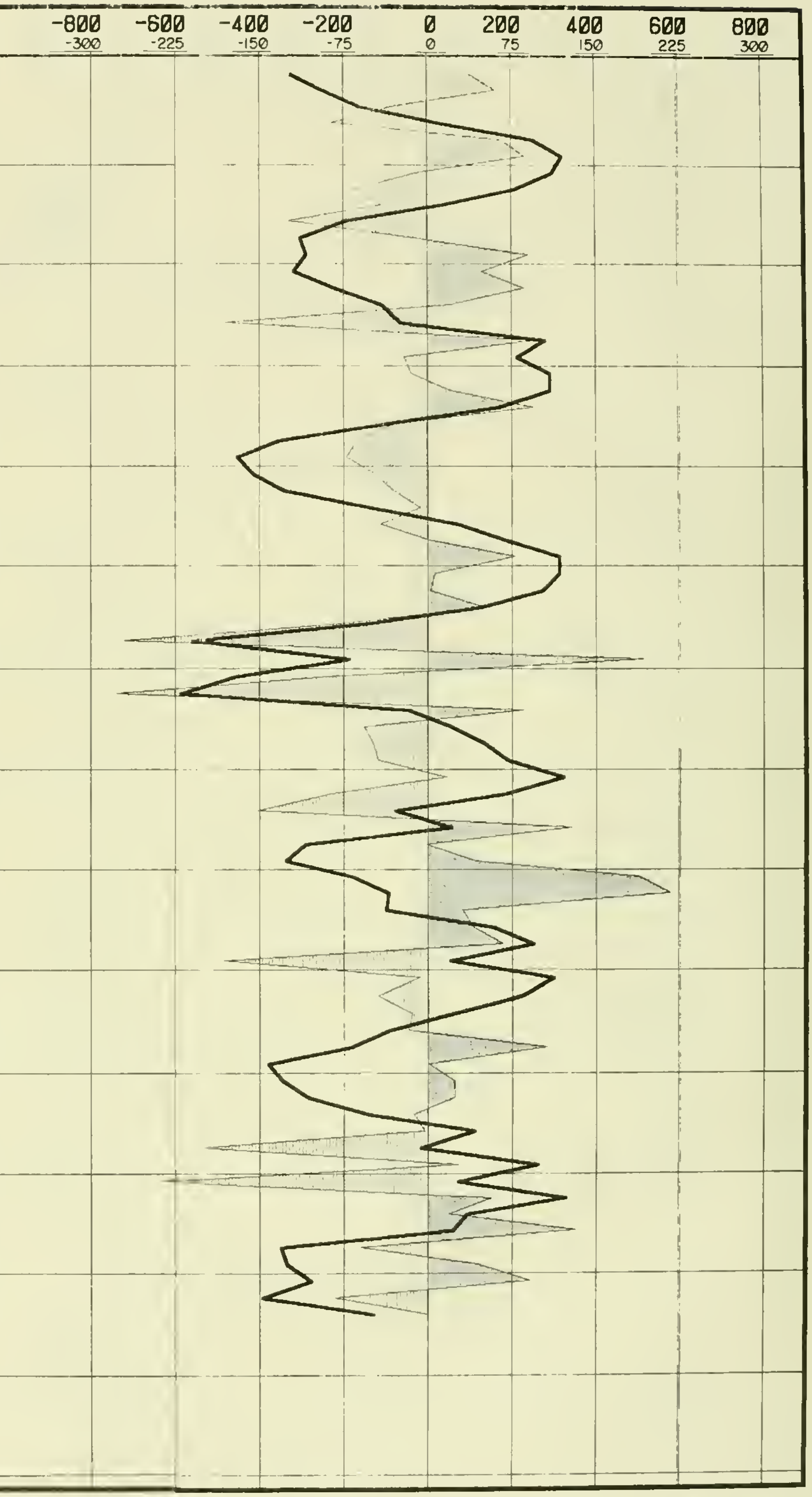

Figure 6a.—Monthly net heat exchange at Ocean Weather Station V (OWS-V), January 1965-March 1971, (solid line) and anomalies of monthly value from monthly mean, April 1955-March 1971, (shaded area). Upper row of numerals refer to scale of monthly values and lower row to scale of anomalies, units are cal cm^{-2} day^{-1}.

MONTH	VALUE	ANOMALY
196501	-337.00	30.67
196502	-319.00	43.27
196503	-301.00	-29.53
196504	-196.00	-42.07
196505	-80.00	31.07
196506	-56.00	29.07
196507	-56.00	26.93
196508	-135.00	18.13
196509	-287.00	-52.00
196510	-282.00	-19.93
196511	-369.00	-26.33
196512	-304.00	64.93
196601	-349.00	18.67
196602	-281.00	81.27
196603	-244.00	27.47
196604	-255.00	-101.07
196605	-80.00	31.07
196606	-118.00	-32.93
196607	-117.00	-34.07
196608	-151.00	2.13
196609	-194.00	41.00
196610	-289.00	-26.93
196611	-393.00	-50.33
196612	-426.00	-57.07
196701	-407.00	-39.33
196702	-392.00	-29.73
196703	-285.00	-13.53
196704	-187.00	-33.07
196705	-112.00	-.93
196706	-55.00	30.07
196707	-141.00	-58.07
196708	-167.00	-13.87
196709	-230.00	5.00
196710	-326.00	-63.93
196711	-552.00	-209.33
196712	-227.00	141.93
196801	-446.00	-78.33
196802	-563.00	-200.73
196803	-189.00	82.47
196804	-172.00	-18.07
196805	-159.00	-47.93
196806	-108.00	-22.93
196807	-85.00	-2.07
196808	-178.00	-24.87
196809	-314.00	-79.00
196810	-154.00	108.07
196811	-367.00	-24.33
196812	-358.00	10.93
196901	-228.00	139.67
196902	-207.00	155.27
196903	-243.00	28.47
196904	-119.00	34.93
196905	-68.00	43.07
196906	-53.00	32.07
196907	-108.00	-25.07
196908	-181.00	-27.87
196909	-216.00	19.00
196910	-236.00	26.07
196911	-246.00	96.67
196912	-370.00	-1.07
197001	-355.00	12.67
197002	-361.00	1.27
197003	-281.00	-9.53
197004	-180.00	-26.07
197005	-77.00	34.07
197006	-56.00	29.07
197007	-32.00	50.93
197008	-158.00	-4.87
197009	-209.00	26.00
197010	-239.00	23.07
197011	-396.00	-53.33
197012	-336.00	32.93
197101	-299.00	68.67
197102	-409.00	-46.73
197103	-284.00	-12.53
197104	NO DATA	
197105	NO DATA	
197106	NO DATA	
197107	NO DATA	
197108	NO DATA	
197109	NO DATA	
197110	NO DATA	
197111	NO DATA	
197112	NO DATA	

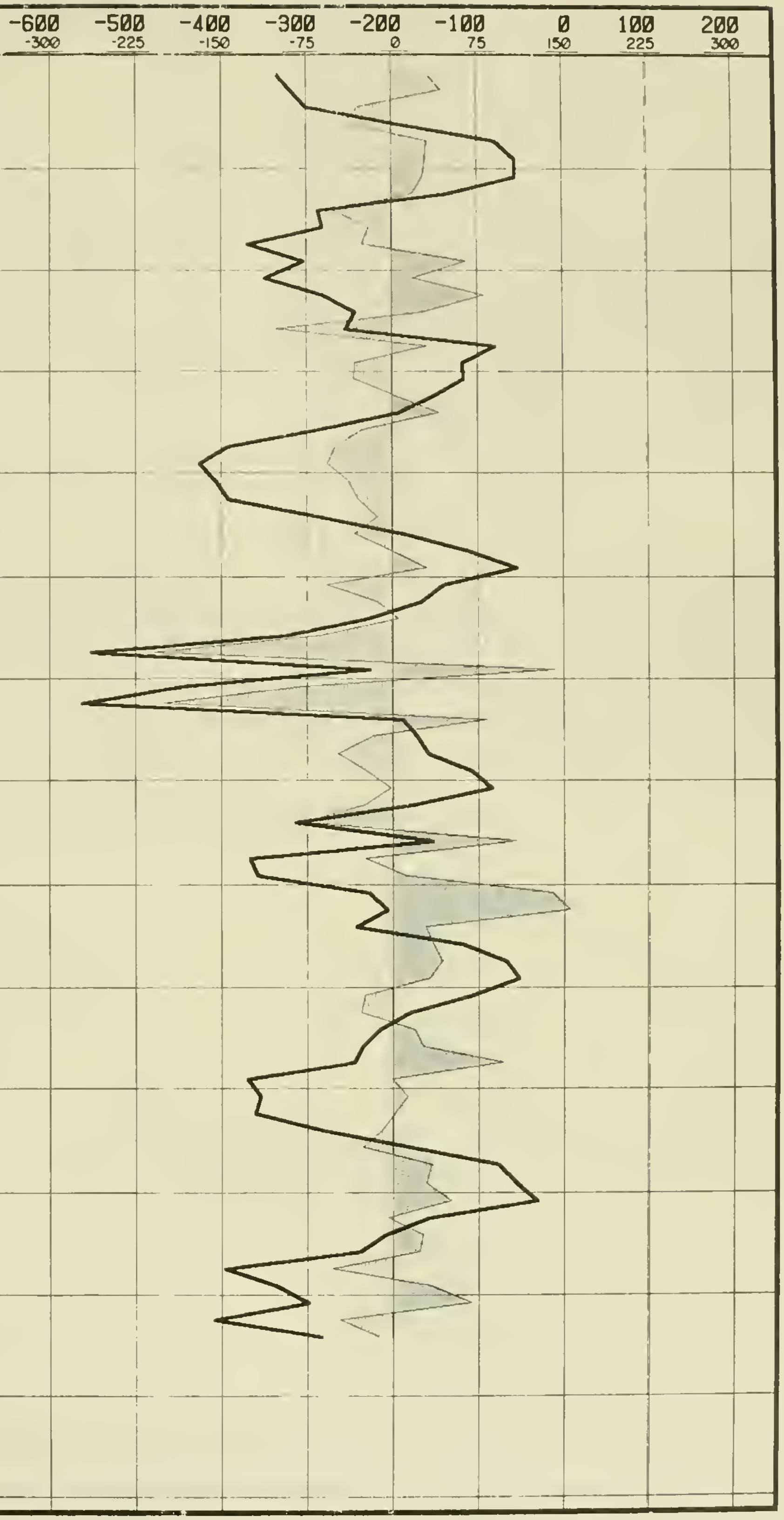

Figure 6b.—Monthly heat used for evaporation at Ocean Weather Station V (OWS-V), January 1965-March 1971, (solid line) and anomalies of monthly value from monthly mean, April 1955-March 1971, (shaded area). Upper row of numerals refer to scale of monthly values and lower row to scale of anomalies, units are cal cm^{-2} day^{-1}.

Figure 7.—Seasonal anomalies of net heat exchange at Ocean Weather Station V (OWS-V), October 1951-March 1971, for 6-mo cooling (solid bar) and 6-mo warming (dashed bar) portions of the annual cycle. Anomalies are relative to the 1952-70 mean values. Values prior to April 1955 were adjusted for the change in latitude of OWS-V.

Figure 8.—Seasonal anomalies of heat used for evaporation at Ocean Weather Station V (OWS-V), October 1951-March 1971, for 6-mo cooling (solid bar) and 6-mo warming (dashed bar) portions of the annual cycle. Anomalies are relative to the 1952-70 mean values. Values prior to April 1955 were adjusted for the change in latitude of OWS-V.

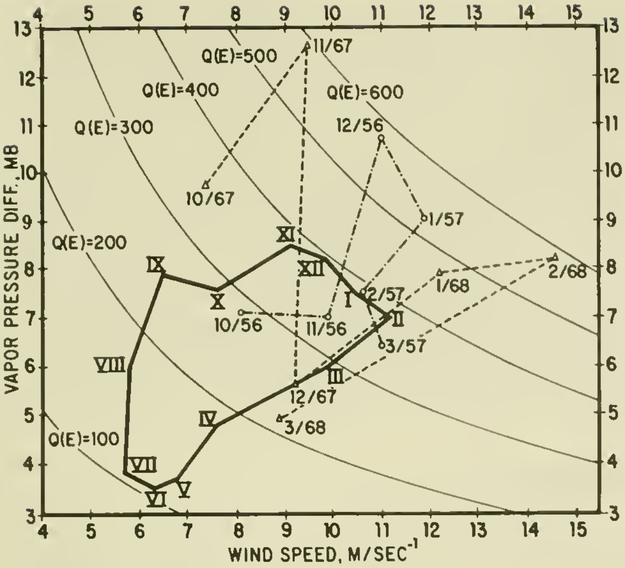

Figure 9.—Evaporation diagram for the 1956-70 mean values of the vapor pressure difference, $\Delta e = e_w - e_a$, and wind speed, W, with monthly values for the fall and winter of 1956-57 and 1967-68. Δe is in mb and W in m sec^{-1}. Months are indicated by Roman numerals. The curvilinear isopleths give the evaporation rate in contour intervals of 100 cal cm^{-2} day^{-1}.

An anomalously high evaporation rate was experienced at OWS-V during the fall of 1956 and winter of 1957. For these months values of Δe and W are plotted in Figure 9. It is evident that although the wind speed for December 1956 and January 1957 were more than 1 m sec^{-1} higher than normal, the principal contribution to the anomalously high evaporation was an anomalously high Δe. Other anomalously high evaporation months were November 1967 and February 1968. During November 1967 the wind speed was near normal, but Δe was 4.1 mb above normal (Fig. 9). During February 1968, although Δe was above normal, the most significant factor in the high evaporation was the anomalously high (3.5 m sec^{-1} above normal) wind speed.

These examples reveal that either Δe or W can be the principal cause for an anomalous evaporation rate at OWS-V. However, a comparison of the seasonal anomalies of wind speed at OWS-V (Fig. 10) with the seasonal anomalies of the evaporative heat loss (Fig. 8) indicates that anomalous evaporation rates are usually associated with anomalous wind speeds.

Effect of Stability on Q(E)

Although it is premature to apply refinements that are still under investigation in the routine computations of air-sea interaction processes, it is interesting to determine the probable effects of atmospheric stability on the computation of Q(E). Deardorff (1968) defined the bulk Richardson number as a practical, dimensionless measure of atmospheric stability. He derived empirical expressions as functions of the bulk Richardson number to correct the

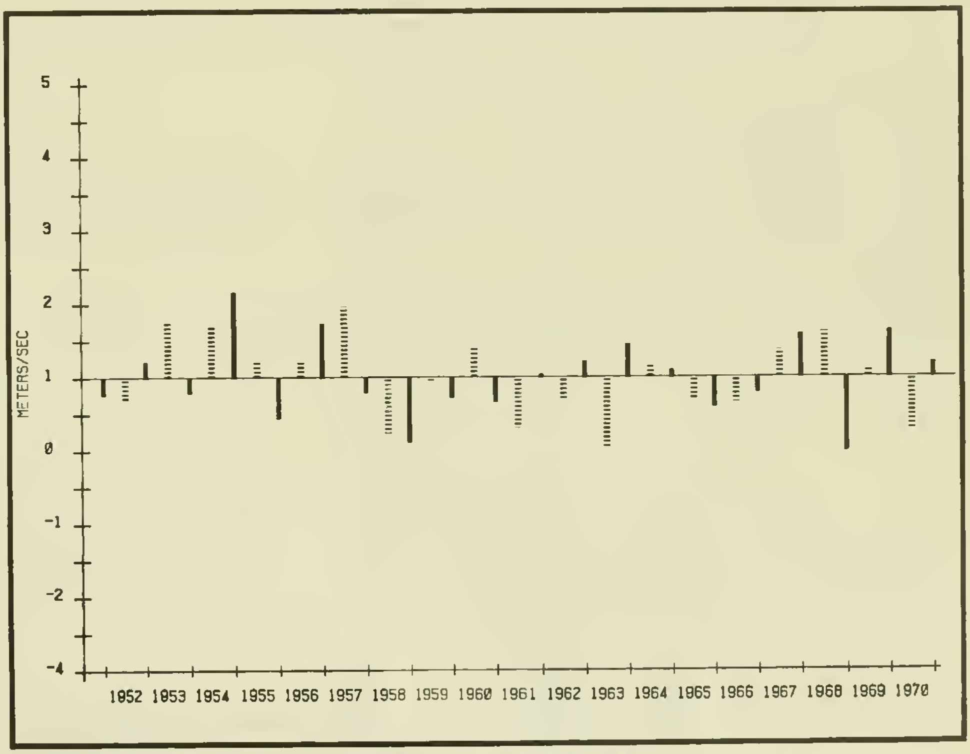

Figure 10.—Seasonal anomalies of wind speed at Ocean Weather Station V (OWS-V), October 1951-March 1971, for 6-mo cooling (solid bar) and 6-mo warming (dashed bar) portions of the annual cycle. Anomalies are relative to the 1952-70 mean values. Values prior to April 1955 were adjusted for the change in latitude of OWS-V.

neutral stability turbulent transfer coefficients for the effect of atmospheric stability. Turbulent exchange processes at OWS-V were calculated using Deardorff's method with a neutral condition C_D of 0.0013 referenced to the 10-m level of observations (Appendix III). C_H and C_E were assumed equal to C_D for neutral conditions. Neutral conditions were assumed when the absolute value of the air-sea temperature difference was less than 1°C. The 1956-70 monthly mean $Q(E)_S$ values calculated by this method are listed in Table 3 along with $Q(E)_N$ values calculated with a constant C_D of 0.0013 and mean daily meteorological properties.

It is seen in Table 3 that the relative differences between the two methods are smallest during July and August. Although, on average, the relative difference between $Q(E)_N$ and $Q(E)_S$ ranges from 6 to 15%, for individual months the difference may be as large as 30%. The use of Deardorff's formulae shows that the effect of atmospheric stability on the turbulent transfer processes at OWS-V can be significant. The stability effect is not necessarily as large over other portions of the ocean as at OWS-V. For example, at OWS-N in the eastern North Pacific, the effect was less than 5% (Dorman, Paulson, and Quinn 1974).

Heat Exchange Processes Computed from Daily vs. Monthly Mean Meteorological Properties

Heat exchange processes over the oceans have generally been computed from monthly estimates of meteorological properties because in most areas daily values are not available. For the sake of comparability and because OWS-V is to serve as a reference station for the computation of heat exchange processes from merchant vessel data, we have used monthly mean meteorological properties.

In Table 4, the 1956-70 monthly values of the heat exchange processes computed from the mean daily and mean monthly meteorological properties and using a constant C_D are listed. Evidently the differences are small and well within the uncertainties of the determinations discussed earlier. Seckel (1970) used a variable C_D to calculate the evaporation rate over the central Pacific Ocean. Comparisons showed that the evaporation rate near OWS-N was an average of 28% higher when computed from daily properties than when monthly properties were used.

Wind Stress

The wind stress climatology for OWS-V is presented in Figure 11. From April through November the resultant stress is small in magnitude and variable in direction. Components less than 0.28 dynes cm^{-2} were not plotted. From December through March the resultant stress is predominantly directed eastward with the largest magnitudes occurring during January and February, when the stress may exceed 2.0 dynes cm^{-2}. The meridional components during February through March show no prevailing direction and, in addition, the magnitude tends to be small in comparison to the zonal component. Winter

Table. 3.—1956-1970 mean monthly heat used for evaporation computed with neutral stability coefficient, $Q(E)_N$, corrected for stability, $Q(E)_S$, in units of cal cm^{-2} day^{-1}. Range of relative differences for individual months indicated by Δ%.

	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
$Q(E)_N$	362	362	270	152	103	89	77	144	225	266	346	373
$Q(E)_S$	403	398	296	175	116	99	82	153	250	293	392	415
ΔQ(E)	41	36	26	23	13	10	5	9	25	27	46	42
% change	11.3	9.9	9.6	15.1	12.6	11.2	6.5	6.3	11.1	10.2	13.3	11.3
Δ%	7-17	7-16	4-21	9-30	6-18	4-16	0-16	1-16	2-22	4-15	1-17	7-17

Table 4.—Mean monthly heat exchange processes at Ocean Weather Station V, 1956-70, computed with mean monthly meteorological properties (M) versus those computed with mean daily properties (D). Units are cal cm^{-2} day^{-1}.

	Q(S)[1]		Q(B)[2]		Q(E)[3]		Q(C)[4]		Q(N)[5]	
	M	D	M	D	M	D	M	D	M	D
Jan.	203	205	114	112	363	362	87	88	-362	-358
Feb.	259	255	113	111	365	362	96	94	-315	-314
Mar.	311	311	104	103	272	270	64	64	-129	-127
Apr.	393	386	99	102	155	152	28	27	109	101
May	394	410	84	88	110	103	15	14	184	202
June	402	420	75	82	87	89	8	7	231	239
July	473	469	76	78	86	77	2	-1	307	313
Aug.	518	486	85	82	149	144	6	5	277	252
Sept.	432	419	97	93	231	225	20	19	83	79
Oct.	310	303	96	93	261	266	30	32	-77	-89
Nov.	207	205	100	97	352	346	60	60	-304	-302
Dec.	178	176	107	105	374	373	84	86	-388	-390

[1] Radiation from sun and sky.
[2] Effective back radiation.
[3] Heat used for evaporation.
[4] Conduction of sensible heat.
[5] Net heat exchange across the sea surface.

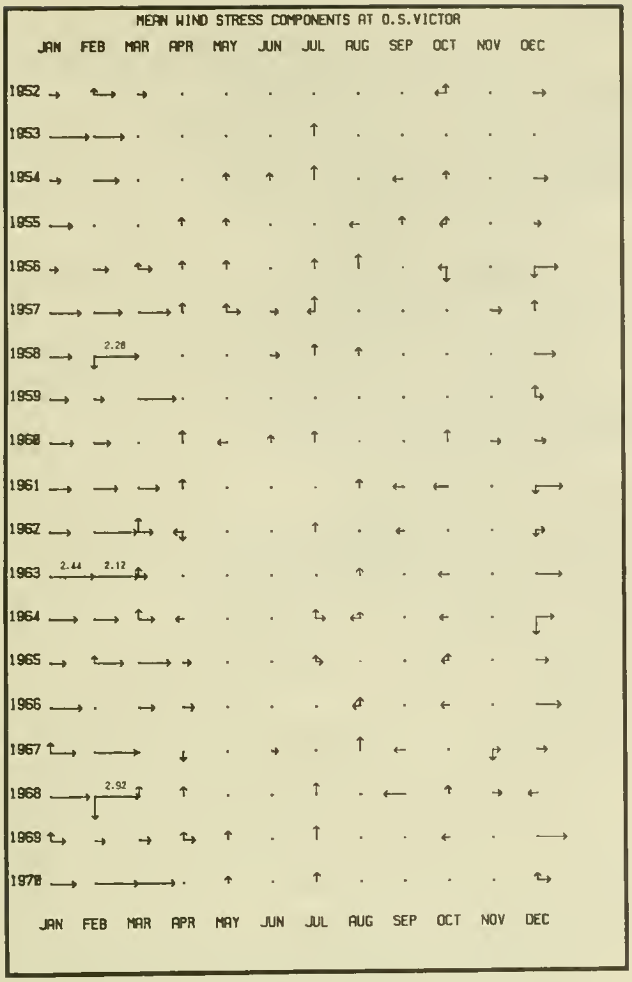

Figure 11.—Monthly components of resultant wind stress at Ocean Weather Station V (OWS-V), 1952-70. Magnitudes of less than 0.28 dyne cm^{-2} were not plotted. Distances between points are equivalent to 2 dynes cm^{-2}. The magnitude of stress components larger than 2 dynes cm^{-2} are labelled.

months with anomalously high or low stress tend to be months with anomalously high or low evaporation rates, for example, February 1958, January and February 1963, and February 1968. This association does not necessarily apply generally because an anomalously high mean wind speed used in the evaporation formula can occur during a month with a low resultant wind stress. For example, the month of November has, on the average, a wind speed approximately as high as during December and March (Appendix I) and, yet, the resultant stress for November is much lower than that during December and March (Fig. 11).

CONCLUSION

Figure 1 shows that the highest net annual heat loss at lat. 34°N lies more than 1,500 km to the west of OWS-V (Ocean Weather Station V). It is therefore possible that the air-sea interaction climatology at OWS-V will differ from that of the high heat loss area to the west. During fall and winter the Asian high- and Aleutian low-pressure systems pump cold, dry continental air over the warm waters of the western Pacific causing high evaporative and sensible heat losses. The seasonal variation in the net heat exchange across the sea surface in the high heat loss area, therefore, is associated with the monsoon circulation of the Asian continent.

According to climatic sea-level pressure charts, during fall and winter, OWS-V lies in the westerly wind sytem associated with the Aleutian low and the subtropical high pressures. In agreement with the pressure charts, the wind stress during these seasons is predominantly zonal (Fig. 11). Evidence of the monsoon type of circulation is absent in that small meridional components of the stress directed northward or southward occur irregularly.

Despite the differences in the wind regimes between OWS-V and near the Asian continent, the importance of the evaporative heat loss during fall and winter relative to the other heat exchange processes is expected to be similar. From November through March the sea-surface temperature at OWS-V is 2°C or more warmer than the air temperature and the average wind speed is more than 9 m sec^{-1}. High evaporation rates during fall and winter are therefore expected and are the principal contribution to the net annual heat loss at OWS-V (Fig. 3).

Evaporation is also a major contributor to the seasonal variation in the net heat exchange across the sea surface with an annual range of 288 cal cm^{-2} day^{-1} compared to the annual range in radiation from sun and sky of 340 cal cm^{-2} day^{-1}. To the west, the evaporation becomes the dominant process causing the seasonal variation in the net heat exchange. Near Japan an annual range in the heat used for evaporation of more than 500 cal cm^{-2} day^{-1} is indicated by Wyrtki (1966).

The evaporation diagram, Figure 9, shows the relative contributions of the vapor pressure difference and the wind speed to the changes in the evaporative heat loss at OWS-V. These factors are not entirely independent, since both depend on the circulation associated with the atmospheric pressure distribution. For example, anomalously high evaporation rates occurred during February of 1958 and 1968. These months also had anomalously high wind speeds, vapor pressure differences, and air-sea temperature differences, and Figure 11 shows that there was a southward component in the resultant wind stresses. Mean sea-level pressure charts[2]/ for these months indicate an eastward displacement of the Aleutian Low resulting in northwesterly winds in the vicinity of OWS-V. Thus, OWS-V, near the periphery of the net annual heat loss area, can experience a wind and air-sea interaction regime that is commonly found to the west.

The uncertainties in the computation of the air-sea interaction processes had little bearing on the foregoing discussion. Interseason and interannual variations would be evident regardless of the magnitude of the coefficients or whether stability corrections are used. The processes listed in Appendix II are therefore indices for quantitative comparisons. Results obtained when the stability corrections of Deardorff (1968) were used in the computations of the turbulent exchange processes (Appendix III) indicate that interseason and interyear differences based on

[2]Northern Hemisphere charts of mean sea-level atmospheric pressure, Long-Range Prediction Group, NOAA, National Meteorological Center.

Appendix II are underestimates. The stability correction can also increase differences in the turbulent exchange processes between areas such as between OWS-V and OWS-N.

The use of air-sea interaction processes in the application of oceanography to fisheries and climatic problems will increase in the future. Although the results of this report are useful for climatic comparisons, further research in marine boundary layer processes is needed to place confidence limits on the derived air-sea interaction processes. With the broadening application of air-sea interaction research there is also a need for a consensus among scientists on the empirical formulae and methods of computation to be used.

LITERATURE CITED

ANDERSON, E. R.
1952. Energy budget studies. Water loss investigations: Volume 1, Lake Hefner studies. U.S. Navy Electron. Lab., Tech. Rep. 327, p. 71-112.

BRUNT, D.
1932. Notes on radiation in the atmosphere. Meteorol. Soc. Lond. 58:389-420.

BUDYKO, M. I.
1956. The heat balance of the earth's surface (Teplovoĭ balans zemnoĭ poverkhnosti). Gidrometeorologicheskoe izdatel'stvo, Leningrad, 255 p. (Transl., 1958, 259 p.; Off. Tech. Serv., U.S. Dep. Commer., Wash., D.C., PB 131692.)
1974. Climate and life. Academic Press, N.Y., 508 p.

BUSINGER, J. A., J. C. WYNGAARD, Y. IZUMI, and E. F. BRADLEY.
1971. Flux-profile relationships in the atmospheric surface layer. J. Atmos. Sci. 28:181-189.

CHARNELL, R. L.
1967. Long-wave radiation near the Hawaiian Islands. J. Geophys. Res. 72:489-495.

DAVIDSON, K. L.
1974. Observational results on the influence of stability and wind-wave coupling on momentum transfer and turbulent fluctuations over ocean waves. Boundary-Layer Meteorol. 6:305-331.

DEARDORFF, J. W.
1968. Dependence of air-sea transfer coefficients on bulk stability. J. Geophys. Res. 73:2549-2557.

DeLEONIBUS, P. S.
1971. Momentum flux and wave spectra observations from an ocean tower. J. Geophys. Res. 76:6506-6527.

DORMAN, C. E., C. A. PAULSON, and W. H. QUINN.
1974. An analysis of 20 years of meteorological and oceanographic data from Ocean Station N. J. Phys. Oceanogr. 4:645-653.

FAVORITE, F., and D. R. McLAIN.
1973. Coherence in transpacific movements of positive and negative anomalies of sea surface temperature, 1953-60. Nature (Lond.) 244:139-143.

HOLLAND, J. Z.
1972. Comparative evaluation of some BOMEX measurements of sea surface evaporation, energy flux and stress. J. Phys. Oceanogr. 2:476-486.

JACOBS, W. C.
1951. Large-scale aspects of energy transformation over the oceans. *In* T. F. Malone (editor), Compendium of meteorology, p. 1057-1070. Am. Meterol. Soc., Boston.

JOHNSON, J. H., G. A. FLITTNER, and M. W. CLINE.
1965. Automatic data processing program for marine synoptic radio weather reports. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 503, 74 p.

KRAUS, E. B.
1972. Atmosphere-ocean interaction. Oxford Univ. Press, Lond., 275 p.

LAEVASTU, T.
1960. Factors affecting the temperature of the surface layer of the sea. Commentat. Physico-Math. Soc. Sci. Fenn. 25:1-136.

LONGLEY, R. W.
1970. Elements of meteorology. John Wiley & Sons, Inc., N.Y., 317 p.

MALKUS, J. S.
1962. Large-scale interactions. *In* M. N. Hill (editor), The sea, 1:88-294. Interscience Publ., N.Y.

MURRAY, F. W.
1967. On the computation of saturation vapor pressure. J. Appl. Meteorol. 6:203-204.

PAULSON, C. A., E. LEAVITT, and R. G. FLEAGLE.
1972. Air-sea transfer of momentum, heat and water determined from profile measurements during BOMEX. J. Phys. Oceanogr. 2:487-497.

QUINN, W. H., and W. V. BURT.
1968. Incoming solar radiation over the tropical Pacific. Nature (Lond.) 217:149-150.

REED, R. K., and D. HALPERN.
1975. Insolation and net long-wave radiation off the Oregon coast. J. Geophys. Res. 80:839-844.

RIEHL, H., T. C. YEH, J. S. MALKUS, and N. E. LaSEUR.
1951. The north-east trade of the Pacific Ocean. Q. J. Meteorol. Soc. 77:598-626.

ROLL, H. U.
1965. Physics of the marine atmosphere. Academic Press, N.Y., 426 p.

SECKEL, G. R.
1970. The Trade Wind Zone Oceanography Pilot Study Part VIII: Sea-level meteorological properties and heat exchange processes July 1963 to June 1965. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 612, 129 p.

SECKEL, G. R., and F. H. BEAUDRY.
1973. The radiation from sun and sky over the North Pacific Ocean. (Abstract 0-33) EOS, Trans. Am. Geophys. Union 54:1114.

SECKEL, G. R., and M. Y. Y. YONG.
1970. Harmonic functions for sea-surface temperatures and salinities, Koko Head, Oahu, 1956-69, and sea-surface temperatures, Christmas Island, 1954-69. Fish. Bull., U.S. 69:181-214.

SMITHSONIAN INSTITUTION.
1949. Smithsonian meteorological tables. 6th rev. ed. prepared by Robert J. List. Smithson. Misc. Collect. 114, 527 p. (Publ. 4014).

TABATA, S.
1964a. A study of the main physical factors governing the oceanographic conditions of station P in the northeast Pacific Ocean. Doctor. Sci. Thesis, Univ. Tokyo, 264 p.
1964b. Insolation in relation to cloud amount and sun's altitude. *In* K. Yoshida (editor), Studies on oceanography, p. 202-210. Univ. Tokyo Press, Tokyo.

U.S. WEATHER BUREAU.
1938. Atlas of climatic charts of the oceans. Prepared under the supervision of W. F. McDonald. U.S. Weather Bureau No. 1247, 65 p.

WYRTKI, K.
1965. The average annual heat balance of the North Pacific Ocean and its relation to ocean circulation. J. Geophys. Res. 70:4547-4559.
1966. Seasonal variation of heat exchange and surface temperature in the North Pacific. Univ. Hawaii Inst. Geophys., HIG-66-3, Honolulu, Hawaii, 8 p.

YONG, M. Y. Y.
1971. Sea-surface temperatures and salinities collected between 1957 and 1969 at nine Pacific monitoring stations. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Natl. Mar. Fish. Serv., Data Rep. 69, 35 p. on 1 microfiche. [Available National Technical Information Service, 5285 Port Royal Road, Springfield, VA. 22151, as COM-72-10099.]

APPENDIX I

Monthly mean meteorological properties at Ocean Weather Station V (OWS-V) and monthly anomalies (from long-term mean), September 1951 to March 1971. Those values above the solid line pertain to the period when OWS-V was situated at lat. 31°N, long. 164°E; those below the line to the location at lat. 34°N, long. 164°E.

The properties tabulated are as follows:

Sea-surface temperature
Air temperature
Air-sea temperature difference
Vapor pressure of the air
Vapor pressure difference between air and at sea surface
Wind speed
Square of the wind speed
North-south component of resultant wind velocity
East-west component of resultant wind velocity
Total cloud amount
Sea-level atmospheric pressure.

The long-term monthly means and standard deviations of the means listed at the top of each page were computed for the period April 1955 to March 1971 only. The individual monthly mean values are the algebraic sum of the long-term monthly mean and the monthly anomaly.

The asterisk (*) preceding a monthly anomaly value denotes a correction of the original data or substitution for missing observations.

SEA SURFACE TEMPERATURE (DEGREES CELSIUS)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	17.5	16.5	16.3	16.8	18.5	20.4	24.2	25.8	25.5	24.0	21.6	19.5
STANDARD DEVIATION OF MONTHLY MEANS												
	.8	.7	.9	.7	.8	.8	1.0	.4	.7	1.0	1.0	.9
MONTHLY ANOMALIES												
1951									* -.7	* -.6	* .4	* -.5
1952*	-1.2	* -.5	*-1.1	* .1	* 1.5	* 2.1	* -.8	* .2	* -.1	* 2.1	* 1.4	* .6
1953*	-.3	* -.6	* -.3	* -.3	* .2	*-2.0	*-1.0	* .3	* .4	* .8	* .6	* .3
1954*	-.9	* -.3	* .8	* -.1	* -.4	*-2.0	* -.8	* -.4	* -.1	*-1.2	* -.1	*-1.3
1955*	-.2	* 1.7	* -.7	1.2	.8	1.1	2.1	-.4	.5	1.3	2.5	2.2
1956	1.3	.1	.0	-.4	2.1	1.0	1.1	.2	.4	.2	.7	.5
1957	.7	.3	-.0	.3	-.4	-.9	-1.3	-.7	-.2	-.6	-.6	.9
1958	.5	.5	.6	.3	-.4	.8	.8	-.0	-1.5	-1.1	.6	.9
1959	-1.1	.5	1.0	.4	.8	.1	-1.0	-.5	-1.1	-2.0	-1.1	.8
1960	1.1	.9	1.0	.7	-.2	-.8	-.8	-.1	.0	.8	.5	-.1
1961	-.2	1.0	.5	.6	.1	.7	1.1	.7	.3	.2	.6	-.2
1962	.5	.3	.3	.2	-.8	1.2	.3	.7	.1	-.2	.1	.6
1963	.5	-.0	.1	-.4	-.4	-.4	-1.4	-.1	-.4	.1	-.1	-.5
1964	.0	-1.2	-1.4	.3	.0	-.8	-.0	.4	.6	.9	-.7	-1.0
1965	-.4	-.8	-.6	-1.0	-1.3	-.7	-1.1	-.8	.9	1.2	-.5	-.2
1966	-1.3	.3	.1	.3	-.4	.4	.2	-.3	.9	.5	.0	-.0
1967	.5	-.2	.2	-1.1	-.6	-.3	.3	.3	.9	1.0	.9	-1.3
1968	-.5	-.4	-.3	.1	-.4	-.5	-.5	.2	-.3	-.5	-.8	-.6
1969	.0	.4	.5	-.0	1.1	.0	.7	-.0	-.7	-1.6	-1.9	-1.2
1970	-1.2	-1.2	-2.3	-1.3	-.0	-1.1	-.3	.4	-.3	-.2	.0	-.8
1971	-.4	-.3	.3									

AIR TEMPERATURE (DEGREES CELSIUS)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	14.9	13.8	14.3	15.6	17.8	20.0	24.0	25.4	24.5	22.8	19.6	16.8
STANDARD DEVIATION OF MONTHLY MEANS												
	.7	.9	.8	1.0	.9	.9	.7	.4	.7	1.0	.8	.9
MONTHLY ANOMALIES												
1951									*-2.6	* -.6	* -.6	* -.6
1952*	-.4	* .3	*-1.0	* .5	* .8	* .9	* -.4	* -.1	* .4	* 1.3	* 1.0	* 1.1
1953*	-.8	* -.9	* -.5	*-1.0	*-1.7	*-1.4	*-1.0	* .1	* .4	* .6	* .4	* -.1
1954*	-.8	* -.4	* -.3	*-1.0	* -.1	* -.1	* -.1	* -.5	* -.7	* .6	* .2	* .9
1955*	-.6	* .5	* -.8	1.0	1.0	.6	.5	.2	.9	1.6	.7	.1
1956	1.3	.7	1.0	.2	1.7	.5	.3	.3	-.4	-.4	.7	-1.8
1957	-1.2	-.3	-.5	.3	-1.3	-1.9	-1.6	-.8	-.5	-1.0	-.2	1.6
1958	.2	-.3	.5	.3	-.2	1.0	1.0	.2	-1.0	-.3	1.3	.2
1959	.1	.5	-.5	.2	.7	-.1	-1.2	-.5	-1.3	-2.7	-1.3	.6
1960	-.1	.3	-.0	1.0	-.7	-.5	.2	-.5	.3	1.0	.4	.8
1961	-.3	.4	-.2	1.0	.4	1.1	.9	.7	-.2	-.3	.6	-.9
1962	.1	.4	1.2	.3	-.6	1.4	.3	.2	.1	.7	1.0	.1
1963	.7	-.3	.1	-.8	-.7	-1.0	-.9	.1	-.1	-.1	-.1	.0
1964	-.2	-1.1	-1.0	.7	-.9	-.9	-.0	.3	.8	.3	-.2	-1.6
1965	-.4	-.2	-.6	-1.5	-.6	-.1	-.5	-.8	.2	1.2	-.1	.8
1966	-.6	.7	.5	-1.2	-.1	.1	-.1	.0	1.1	.3	-.3	.1
1967	.3	.5	-.5	-1.2	-.7	.2	.4	.4	1.1	.5	-1.1	.3
1968	-.5	-1.5	.5	.5	-.4	-.5	-.2	-.2	-.3	.3	-.5	.6
1969	1.3	2.2	.9	1.1	1.8	.8	.9	-.2	-.7	-1.2	-1.1	-.7
1970	-.9	-.9	-1.9	-1.7	.6	-.8	.1	.4	-.2	.0	.2	-.2
1971	.4	-1.1	.6									

AIR-SEA TEMPERATURE DIFFERENCE(DEGREES CELSIUS)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	-2.6	-2.7	-2.0	-1.2	-.7	-.4	-.2	-.4	-1.0	-1.2	-2.1	-2.7

STANDARD DEVIATION OF MONTHLY MEANS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	.8	.8	.7	.6	.5	.5	.6	.3	.4	.5	.8	1.1

MONTHLY ANOMALIES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951									*-1.9	* .1	*-1.0	* -.1
1952*	.8	* .8	* .1	* .4	* -.7	*-1.2	* .4	* -.3	* .5	* -.8	* -.4	* .5
1953*	-.5	* -.3	* -.2	* -.7	*-2.0	* .6	* -.0	* -.3	* -.1	* -.2	* -.2	* -.3
1954*	.2	* -.0	*-1.1	* -.9	* .4	* 1.9	* .7	* -.2	* -.6	* 1.8	* .3	* 2.1
1955*	-.4	*-1.1	* -.0	-.1	.2	-.5	-1.6	.6	.5	.3	-1.8	-2.1
1956	-.1	.6	.9	.6	-.5	-.5	-.9	.0	-.9	-.6	.0	-2.3
1957	-1.9	-.6	-.5	-.1	-.9	-1.0	-.2	-.1	-.4	-.4	.4	.7
1958	-.3	-.8	-.0	.0	.2	.3	.2	.2	.5	.8	.7	-.8
1959	1.1	.1	-1.5	-.2	-.1	-.2	-.2	-.1	-.2	-.7	-.2	-.2
1960	-1.2	-.6	-1.0	.3	-.5	.4	1.0	-.4	.3	.2	-.1	.9
1961	-.1	-.6	-.7	.3	.3	.3	-.1	.0	-.5	-.4	.0	-.7
1962	-.3	.2	.8	.0	.2	.2	-.0	-.5	.0	.8	.8	-.4
1963	.2	-.3	-.0	-.4	-.3	-.7	.5	.2	.3	-.2	-.0	.6
1964	-.2	.1	.5	.4	-.9	-.1	.0	-.1	.2	-.6	.5	-.6
1965	.0	.6	-.0	-.5	.7	.6	.6	.0	-.7	.0	.5	1.0
1966	.7	.4	.5	-1.5	.3	-.3	-.3	.3	.3	-.2	-.4	.2
1967	-.1	.7	-.7	-.1	-.0	.6	.0	.1	.3	-.5	-1.9	1.6
1968	-.1	-1.1	.8	.4	-.1	-.0	.3	-.4	-.0	.8	.4	1.2
1969	1.2	1.8	.4	1.2	.7	.7	.2	-.1	.1	.4	.9	.5
1970	.3	.3	.4	-.4	.6	.3	.4	.0	.2	.3	.2	.6
1971	.8	-.8	.3									

VAPOR PRESSURE OF THE AIR,(MB.)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	12.6	11.8	12.6	14.6	17.6	20.6	26.4	27.2	24.8	22.4	17.5	14.5
STANDARD DEVIATION OF MONTHLY MEANS												
	.9	1.0	1.0	1.5	1.5	1.4	1.1	1.2	1.6	1.9	1.5	1.1
MONTHLY ANOMALIES												
1951									*-7.6	*-1.0	* -.3	*-1.1
1952*	.5	* .6	* -.6	* 1.8	* 2.2	* .8	* -.4	* .3	* 2.0	* 2.5	* 1.9	* 1.2
1953*	.1	* -.9	* 1.2	* -.3	*-2.2	*-2.1	* .2	* .1	* .4	* 1.6	* 1.6	* -.0
1954*	.4	* -.6	* 1.0	*-1.4	* 1.0	* .4	* .3	* -.6	* -.5	* 2.2	* 1.1	* 2.5
1955*	.9	* .5	* -.2	1.5	2.0	1.0	.3	1.1	2.0	3.2	1.3	.5
1956	2.0	.6	1.4	1.1	2.6	.3	.6	1.7	-1.1	.9	2.1	-1.8
1957	-.7	-.2	-.4	1.0	-1.9	-1.9	-1.4	-.8	-1.3	-2.6	-.3	1.5
1958	-.2	-1.0	.7	-.2	.2	2.3	1.7	1.4	-1.3	.3	2.6	.0
1959	.5	1.2	-.7	-.2	1.3	.3	-1.5	.2	-3.0	-4.6	-.5	1.2
1960	-.4	.3	-.8	1.5	-.7	.0	1.2	-2.3	1.2	2.1	.2	1.2
1961	-.3	.6	-.1	.9	.6	1.8	1.2	1.6	-1.9	-1.1	.7	-.4
1962	.4	.7	1.9	.7	-.8	1.9	.2	-.3	.7	1.9	2.3	.7
1963	.6	-.5	.2	-.8	-.9	-1.7	-1.1	-.0	.2	-.5	-.2	-.5
1964	-.2	-.8	-.8	1.7	-1.4	-1.9	-.2	-.5	2.1	-.1	-.1	-2.1
1965	-.4	.1	-1.0	-2.0	-1.1	-.1	-.6	-1.5	-1.1	1.5	-.7	.9
1966	-1.2	.4	.6	-2.0	-.3	-1.0	-1.2	.7	1.7	-.5	-1.2	-.9
1967	-.1	.0	-1.4	-1.8	-1.1	.5	-.9	1.1	2.4	-.3	-2.7	.9
1968	-1.0	-1.7	1.0	.1	-1.4	-1.4	-.5	-1.2	-.7	1.2	-1.7	-.1
1969	1.7	2.1	.7	1.2	2.9	.6	1.0	-.8	-.7	-1.5	-1.7	-.9
1970	-1.3	-.8	-1.6	-2.7	.0	-.8	1.4	-.5	.8	.3	-.2	-.3
1971	.6	-1.2	.3									

VAPOR PRESSURE DIFFERENCE (MBS.)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	7.5	7.0	6.0	4.8	3.7	3.5	3.8	6.0	7.9	7.6	8.5	8.2

STANDARD DEVIATION OF MONTHLY MEANS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	1.0	.9	1.1	1.0	.9	.9	1.5	1.3	1.4	1.5	1.7	1.4

MONTHLY ANOMALIES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951									* 6.3	* -.1	* .9	* .4
1952	*-2.0	*-1.2	* -.7	*-1.8	* -.1	* 2.3	*-1.1	* .0	*-2.2	* 1.4	* .2	* -.4
1953	* -.5	* .1	*-1.7	* -.2	* 2.5	* -.9	*-1.9	* .5	* .4	* -.2	* -.7	* .3
1954	*-1.6	* .2	* -.1	* 1.1	*-1.5	*-3.4	*-1.7	* -.2	* .3	*-4.3	*-1.4	*-4.3
1955	*-1.3	* 1.5	* -.7	-.2	-2.3	.9	2.9	-1.9	-1.1	-.9	2.8	* 2.7
1956	-.3	-.5	-1.4	-1.5	.5	.8	1.6	-1.2	1.9	-.5	-1.5	2.5
1957	1.5	.5	.4	-.7	1.3	.5	-2.2	-.5	.7	1.5	-.6	-.3
1958	1.1	1.6	-.0	.5	-.5	-1.0	-.2	-1.4	-1.5	-2.4	-1.7	1.3
1959	-1.8	-.6	2.0	.6	-.3	-.0	.1	-1.1	1.0	1.3	-1.4	-.1
1960	1.7	.9	2.0	-.5	.5	-1.2	-2.2	2.2	-1.0	-.5	.4	-1.1
1961	-.1	.6	.3	-.2	-.1	-.6	.6	-.2	2.5	1.4	.1	.5
1962	.1	-.5	-1.6	.1	-.5	-.2	.5	1.7	-.6	-2.3	-2.3	-.0
1963	-.1	.3	-.1	.6	.4	1.1	-1.1	-.1	-.9	.7	.1	-.4
1964	.2	-.6	-.8	-1.5	1.5	.7	.3	1.2	-1.0	1.7	-.9	.7
1965	-.2	-1.1	.3	.6	-.5	-.9	-1.3	-.1	2.8	.6	.2	-1.2
1966	-.1	-.1	-.5	2.2	-.1	1.4	1.6	-1.3	.0	1.4	1.1	.7
1967	.7	-.3	1.7	.4	.4	-1.0	1.6	-.5	-.8	2.1	4.1	-2.7
1968	.4	1.2	-1.1	-.1	.9	.6	-.3	1.5	.4	-2.2	.4	-.8
1969	-1.8	-1.6	-.2	-1.3	-1.2	-.5	.2	.7	-.7	-1.3	-1.3	-.8
1970	-.2	-.6	-1.0	1.1	-.0	-.8	-2.1	1.1	-1.8	-.8	.4	-.9
1971	-1.1	.8	.1									

WIND SPEED (METERS/SEC)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	10.5	11.2	9.9	7.6	6.8	6.3	5.7	5.8	6.5	7.6	9.1	9.9
STANDARD DEVIATION OF MONTHLY MEANS												
	1.2	1.8	1.3	1.2	1.2	1.1	1.0	.9	1.0	1.1	.9	.8
MONTHLY ANOMALIES												
1951									*-1.6	* -.7	* -.0	* -.2
1952*	-.8	* .4	* .4	* -.4	* .1	* -.1	* .1	* -.2	*-1.0	* .1	* -.2	* -.8
1953*	2.0	* 1.3	* -.9	* .7	* .9	* .3	* 1.6	* -.5	* 2.0	* -.5	* .3	*-1.0
1954*	.2	* 1.2	* -.9	* -.5	* 1.4	* 1.0	* 2.4	* .2	* .0	* .5	* 2.8	* 3.6
1955*	.1	* -.3	* .5	1.4	1.6	.9	-1.6	-.1	-.4	.7	.5	-.8
1956	-1.2	-1.2	-.8	.4	-.0	.3	-.4	.7	.8	.5	.9	1.1
1957	1.4	-.5	1.2	.9	2.1	1.0	2.3	-1.6	1.5	-.1	-.3	.0
1958	-.2	2.4	-2.5	-2.3	-1.2	.9	.2	-.1	-1.7	-2.9	-.9	-.3
1959	-.2	-2.5	2.1	.7	.7	1.0	-.7	-.4	-1.2	.6	.3	.4
1960	-.5	-1.0	-1.0	1.4	1.4	1.8	-.0	-1.1	-.6	1.8	.9	-2.3
1961	-1.6	-1.3	1.0	.0	.1	-2.3	-1.3	.3	-.6	1.4	-.9	.3
1962	-1.3	.9	-.0	-.6	-.4	-.9	.3	-.2	.4	-1.2	-1.8	.2
1963	2.7	1.4	.2	-3.1	-1.4	.4	-1.1	-.3	-.0	.3	.9	.2
1964	1.3	.2	.0	-.7	.0	.5	.6	1.2	-.3	-.4	.1	.4
1965	-.5	.6	.5	.4	-.8	-.4	.6	-.6	-.6	.0	.7	-.3
1966	.2	-2.4	-.1	.4	-1.4	-.7	-.7	1.8	-1.1	-.5	-.3	.3
1967	.2	1.5	-1.9	.5	-.4	-.0	.5	1.3	.7	-.3	.4	-.7
1968	1.7	3.5	-.9	.8	1.0	-.1	.8	-.5	2.1	-1.0	-.0	.5
1969	-1.8	-2.6	-.7	.6	.5	-1.5	.9	.3	.2	.9	-1.5	1.0
1970	.0	1.1	2.5	-.8	-1.9	-.9	-.4	-.8	.8	.3	1.0	.1
1971	-.3	.0	.3									

SQUARE OF THE WIND SPEED,M2/SEC2

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	135.9	151.5	121.2	74.4	59.2	51.8	42.3	44.6	56.4	73.2	101.9	122.5

STANDARD DEVIATION OF MONTHLY MEANS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	29.6	45.0	30.9	17.0	19.0	15.3	11.8	13.5	18.8	18.2	18.0	15.7

MONTHLY ANOMALIES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951									-27.2	-22.3	-22.2	-34.3
1952	-35.3	-41.5	-34.4	-19.8	-22.2	-13.0	-6.4	-11.0	-30.8	-11.3	-26.0	-37.4
1953	44.9	-20.0	-60.1	-7.8	-12.4	-9.1	17.6	-12.1	11.6	-18.3	-20.5	-49.8
1954	-5.7	-21.4	-53.2	-24.0	-6.5	.7	21.2	-2.9	-16.7	-2.2	38.2	58.3
1955	-13.8	-48.9	-37.5	21.9	28.2	11.4	-5.9	.6	-8.6	8.3	5.3	-9.2
1956	-33.5	-24.9	-17.3	2.0	-4.4	7.6	-5.6	11.4	13.9	14.7	17.6	15.1
1957	33.0	-5.0	36.5	12.0	35.2	16.5	29.4	-20.1	34.8	-1.7	-7.4	-2.0
1958	4.1	63.7	-48.9	-33.1	-20.8	9.3	1.4	-3.1	-26.6	-40.4	-18.3	-4.5
1959	-4.5	-63.7	50.1	5.1	12.3	9.8	-9.3	-7.2	-19.9	17.3	3.7	2.7
1960	-14.1	-29.1	-27.2	25.9	25.4	32.0	-4.7	-17.7	-14.8	28.2	18.8	-43.5
1961	-37.4	-28.3	26.4	-7.1	-1.4	-28.9	-16.8	4.0	-2.4	16.7	-18.1	9.3
1962	-29.7	18.1	-6.9	-3.1	-6.3	-16.5	2.2	3.8	-.7	-24.0	-31.3	11.6
1963	59.7	32.8	2.1	-30.1	-18.6	7.4	-17.1	-6.7	-1.7	1.5	25.4	3.2
1964	28.4	-1.7	-4.6	-18.8	1.4	1.9	9.7	13.9	-10.5	-6.1	-3.8	13.1
1965	-13.5	3.9	10.0	.4	-14.7	-6.3	4.3	-10.7	-12.9	-3.2	7.9	-10.3
1966	-1.8	-60.1	-4.1	6.5	-22.8	-8.2	-5.8	28.9	-15.8	-9.3	-.9	13.6
1967	11.7	39.1	-40.6	4.2	-2.7	-3.7	4.1	17.1	8.8	-5.0	18.2	-20.1
1968	43.2	96.1	-25.4	17.2	12.5	.3	7.7	-5.1	41.7	-22.2	-4.1	8.0
1969	-42.7	-60.5	-13.7	9.6	5.3	-19.6	13.7	6.5	2.3	20.4	-31.9	16.2
1970	1.4	22.7	60.8	-12.6	-28.6	-13.2	-7.3	-15.7	12.4	4.7	18.6	-3.2
1971	-4.1	-3.2	2.9									

ZONAL COMPONENT OF WIND,(M/SEC)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	5.6	6.3	3.7	.3	.3	1.1	.1	-.5	-.7	-1.5	.6	3.5

STANDARD DEVIATION OF MONTHLY MEANS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	2.0	3.1	2.2	1.8	1.5	1.3	1.7	1.9	1.9	1.4	1.2	2.3

MONTHLY ANOMALIES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951									.4	.5	-.3	-2.2
1952	-3.5	-1.0	-1.2	-1.4	-.4	1.0	-1.7	.8	-.6	-1.5	-2.4	.2
1953	2.3	.5	-5.0	-1.1	-.5	-.7	-2.3	-.6	-1.0	1.2	.5	-3.2
1954	-3.4	-.9	-5.4	-1.8	-.8	.3	-1.3	-1.4	-3.2	2.6	.4	-1.7
1955	-.6	-5.0	-4.7	-.4	.9	.5	1.5	-3.0	.5	-.0	-.4	-1.8
1956	-3.4	-2.7	-.6	.2	.6	-.8	-1.4	2.0	2.2	-1.4	.1	2.0
1957	1.0	-.2	2.7	-.7	3.5	.9	-2.4	.3	1.2	.5	2.5	-3.1
1958	-1.5	2.9	-2.8	1.6	-.5	2.4	.7	-.2	.5	-.7	-1.3	1.6
1959	-1.8	-3.2	3.6	.1	.4	.4	-.8	1.3	2.3	2.4	-1.0	-1.7
1960	-.1	-2.2	-2.4	1.2	-2.1	.6	-1.4	-.1	-.8	-.1	1.6	-.4
1961	.4	.0	1.0	-1.8	-.3	-1.4	.5	-.8	-2.5	-2.8	1.1	2.5
1962	-.5	2.8	-.0	-2.8	.0	-1.4	1.2	2.4	-1.8	1.3	.3	-.2
1963	5.4	3.6	-1.9	.0	-.5	-2.1	-1.3	.6	1.3	-.9	-.1	2.8
1964	.1	-.8	.2	-2.7	-2.3	1.2	3.5	-3.2	2.1	-.8	-1.2	.1
1965	-.6	.3	1.9	2.5	.7	-.8	2.6	.0	1.1	-.4	-1.1	-.9
1966	2.1	-5.7	.7	2.9	.7	.4	.2	-1.8	-.6	-.5	-1.4	1.9
1967	.3	2.1	-2.6	-1.8	-1.9	1.1	-1.7	.9	-2.1	2.7	.2	-.7
1968	1.7	5.4	-2.4	-1.0	-1.2	-2.1	-1.4	1.7	-4.1	1.5	1.8	-5.2
1969	-1.5	-3.9	-1.1	2.5	1.7	.7	1.8	2.5	1.1	-.0	-.4	3.8
1970	.4	2.7	4.3	.3	.1	.3	-1.5	-2.8	-.6	-.6	-.9	-.6
1971	-2.1	-1.2	-.5									

MERIDIONAL COMPONENT OF WIND,(M/SEC)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	.2	-.2	1.0	1.1	1.5	1.0	3.0	1.6	.5	.9	.1	-.3
STANDARD DEVIATION OF MONTHLY MEANS												
	1.0	1.5	1.1	1.6	1.1	.9	1.4	1.6	1.1	1.5	1.2	1.7
MONTHLY ANOMALIES												
1951									-4.3	-1.2	-.2	-.1
1952	.3	2.4	-.8	-.4	1.4	-.7	-1.9	-.8	-.3	2.2	-.2	.7
1953	.1	1.1	.4	-.3	-1.2	.3	.6	.9	-2.2	.8	.6	.3
1954	-1.1	.3	-1.0	-1.4	1.4	1.6	1.9	-.9	-1.0	1.5	.8	.1
1955	.3	.8	.8	.5	.3	-.3	-2.1	-1.2	1.8	1.1	-.6	-1.7
1956	1.1	1.9	.8	1.2	1.8	-1.2	1.0	2.7	-2.0	-2.8	2.1	-2.2
1957	-1.1	-.5	.2	1.7	.7	.1	2.0	-2.4	-.2	-1.1	-.4	2.9
1958	-1.1	-2.4	.4	.4	-.7	1.2	1.5	1.6	-.9	-.5	1.5	-.6
1959	.3	.3	-1.2	-.8	.5	.6	-1.8	-.3	-.5	-1.2	.5	2.3
1960	-.2	.5	-1.1	2.0	-.5	1.5	1.7	-2.1	.3	2.3	.6	1.2
1961	-1.1	.2	-.3	1.7	.6	.1	-2.1	1.2	-2.0	-1.6	1.0	-1.3
1962	-.4	1.4	2.4	-3.2	.2	-.2	.7	-.7	.2	2.4	1.2	-.5
1963	.1	-.5	.4	-1.3	-2.0	-1.8	-1.6	.6	.7	-.5	-.2	-.8
1964	-.4	-1.2	1.2	.2	-1.4	.2	-.1	.6	1.1	-.9	-.3	-3.3
1965	-.7	1.8	-.7	-.2	.4	.7	-.5	-.8	-.3	1.7	.3	.9
1966	-.1	1.3	-1.4	-1.0	.2	-.9	-1.1	.7	.4	-.8	-1.1	.8
1967	1.5	1.4	-1.1	-3.2	-1.0	1.0	-1.0	2.9	.3	.6	-2.5	.1
1968	-.3	-3.8	1.5	1.0	-1.5	-.5	1.6	-.5	-.7	1.9	-.9	.1
1969	2.3	1.3	-1.2	1.2	1.5	-.1	1.0	-1.4	1.0	-.1	-1.2	.3
1970	-1.1	-.1	-.2	-.3	1.2	-.5	.9	-1.0	.8	-.6	-.1	1.8
1971	1.2	-1.5	.2									

TOTAL CLOUD AMOUNT (TENTHS OF SKY COVERED)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	.7	.8	.8	.8	.8	.9	.8	.7	.6	.7	.8	.8

STANDARD DEVIATION OF MONTHLY MEANS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	.0	.0	.0	.1	.1	.1	.1	.1	.1	.1	.1	.0

MONTHLY ANOMALIES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951									* -.3	* .0	* .1	* .0
1952*	-.0	* .1	* -.0	* -.0	* -.1	* .0	* -.1	* .2	* -.1	* -.0	* .0	* -.1
1953*	.0	* .0	* -.1	* .1	* .0	* .0	* .1	* .1	* -.1	* .1	* .1	* .1
1954*	.1	* .1	* -.2	* .0	* .0	* -.0	* .1	* .0	* -.1	* -.0	* .1	* .1
1955*	.1	* .1	* -.1	.1	.1	.0	-.1	-.1	-.2	-.0	.1	-.1
1956	-.0	.0	.0	.0	-.0	-.0	-.0	.0	.1	-.1	-.1	-.1
1957	.0	.0	.0	.1	.0	.1	.1	-.0	-.1	.1	-.0	.1
1958	.0	.0	.1	.0	.1	.0	-.1	-.0	.0	-.1	.0	-.0
1959	-.0	.1	-.0	-.0	.0	.1	.0	.1	-.0	.1	.0	.1
1960	-.0	-.0	.0	.0	.0	.1	-.1	-.0	-.0	-.0	-.0	.0
1961	.1	.0	-.1	.0	-.0	-.0	-.1	-.0	-.1	-.0	-.0	-.0
1962	.0	-.0	.0	-.1	.0	-.1	.1	.1	.0	-.1	.0	.0
1963	-.1	-.1	-.1	-.4	-.2	.0	-.1	-.1	.0	.0	.1	-.0
1964	.1	.1	-.1	-.1	.0	.0	.1	-.0	.0	.0	.0	.0
1965	.0	-.0	-.0	.0	-.0	-.1	.1	.1	.0	.0	-.0	.0
1966	-.0	.1	.1	.1	-.1	.0	-.0	-.0	-.1	.0	-.0	.0
1967	.0	-.0	-.0	-.0	.0	-.0	-.1	.0	-.1	.0	-.1	-.0
1968	-.0	-.1	.1	.1	.0	.1	-.0	.1	.1	-.0	-.1	-.0
1969	-.0	.0	.0	.0	.0	-.2	.0	.0	.1	.1	-.0	-.1
1970	-.0	-.1	-.0	.0	-.0	.1	.0	-.1	.1	.1	.0	.0
1971	.0	.0	-.0									

SEA LEVEL ATM. PRESSURE (MBS.)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	1010.9	1012.0	1015.4	1020.7	1018.6	1015.1	1016.8	1015.7	1016.2	1018.5	1018.0	1014.7
STANDARD DEVIATION OF MONTHLY MEANS												
	3.5	4.6	3.2	2.3	2.2	1.5	1.6	2.0	1.9	1.2	1.9	2.9
MONTHLY ANOMALIES												
1951									.4	-.1	-2.2	2.8
1952	9.0	2.5	-1.2	1.6	.7	1.1	2.1	-1.0	-.4	.9	-.6	2.1
1953	-.3	5.8	5.1	-2.2	-1.0	.9	.4	2.1	-.2	-1.1	-.4	6.5
1954	2.1	4.6	5.0	.2	.3	.2	-2.2	1.9	2.1	-2.9	-2.7	-1.7
1955	7.4	4.3	6.1	.6	.2	-.5	.5	.7	3.1	2.1	-.1	-2.3
1956	.2	.9	5.1	.7	3.1	-1.3	-.5	-.5	-1.0	-1.7	1.2	-2.0
1957	2.5	1.5	-4.5	-1.1	-2.9	-2.2	-.7	-.1	.5	.8	.2	5.0
1958	4.7	-.2	2.7	.7	.2	.5	2.3	1.2	-1.5	1.1	1.0	.5
1959	2.6	7.1	-1.5	2.8	-3.2	-1.5	-1.9	-4.2	-3.7	-.5	.1	3.4
1960	-.3	3.1	-1.3	-.8	-1.1	.9	1.3	3.1	1.7	.9	-.9	.6
1961	.2	-5.0	-.6	2.6	2.4	1.6	-.7	.7	2.1	.5	-1.2	-7.8
1962	-2.9	-3.1	1.7	-2.4	-.1	1.5	-.9	.7	1.3	2.0	-.1	-1.5
1963	-10.4	-6.5	.5	.0	2.9	1.9	1.0	-.1	-.1	-.7	-2.0	1.4
1964	3.2	.9	-2.0	4.8	.8	-1.5	-1.6	1.4	1.3	.5	-2.4	-.3
1965	.4	-.9	-6.1	-4.3	3.0	-.2	-3.7	-1.1	1.3	-.0	4.3	1.9
1966	.3	8.1	-2.5	-2.7	-1.6	-.5	1.9	.2	-.1	-1.5	.1	-2.5
1967	1.7	1.5	3.9	1.1	-1.4	-2.0	.9	-1.9	-.4	.2	.9	1.3
1968	-3.4	-9.0	4.2	-1.2	-3.4	-.1	1.6	-.9	.1	-1.0	-.7	1.1
1969	2.6	4.1	1.9	-1.7	-.1	3.2	1.1	-2.9	-3.3	-2.2	2.7	-.7
1970	-1.1	.2	-2.6	1.0	1.1	.2	-.5	3.8	-1.2	-.4	-3.2	1.9
1971	-.4	-2.9	1.0									

APPENDIX II

Monthly estimates of heat exchange processes and wind stress at Ocean Weather Station V (OWS-V) and monthly anomalies (from long-term mean), September 1951 to March 1971. Those values above the solid line pertain to the period when OWS-V was situated at lat. 31°N, long. 164°E; those below the line to the location at lat. 34°N, long. 164°E.

The estimates tabulated are as follows:

Q(N), Net heat exchange across the sea surface
Q(S), Radiation from sun and sky
Q(B), Effective back radiation
Q(C), Conduction of sensible heat
Q(E), Heat used for evaporation
τ_x, Zonal component of resultant wind stress
τ_y, Meridional component of resultant wind stress.

The long-term monthly means and standard deviations of the means listed at the top of each page were computed for the period April 1955 to March 1971 only. The individual monthly estimates are the algebraic sum of the long-term monthly mean and the monthly anomaly.

The asterisk (*) preceding a monthly anomaly denotes the correction of original data or the substitution for missing observations.

NET HEAT EXCHANGE,Q(N),IN CAL/CM2/DAY

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	-362	-315	-129	109	184	231	307	277	83	-77	-304	-388

STANDARD DEVIATION OF MONTHLY MEANS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	100.7	121.9	85.7	83.8	80.1	75.8	90.3	62.3	90.9	102.2	114.6	109.2

MONTHLY ANOMALIES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951									* -40	* 38	* -68	* 7
1952*	175	* 72	* 46	* 99	* 47	* -99	* 95	* -91	* 174	* -7	* 5	* 107
1953*	-45	* -71	* 146	* -75	*-140	* 34	* 25	* -26	* -27	* 36	* 31	* 15
1954*	89	* -50	* 75	* -62	* 49	* 194	* 34	* -2	* 32	* 262	* -18	* 218
1955*	60	*-120	* 36	-68	3	-38	28	117	137	51	-218	*-123
1956	70	93	120	53	26	-26	-12	22	-135	28	35	-246
1957	-217	-17	-80	-38	-114	-84	-73	76	-46	-67	76	36
1958	-43	-222	54	33	31	61	84	61	115	227	134	-61
1959	129	130	-223	-42	-2	-15	-3	-26	37	-127	26	-29
1960	-99	-10	-85	-9	-39	30	163	-22	95	-14	-49	172
1961	40	10	-71	13	49	96	96	18	-24	-95	44	-28
1962	53	22	93	77	34	100	-39	-88	31	168	172	-35
1963	-69	-50	36	182	104	-58	96	58	34	-50	-59	37
1964	-85	19	68	105	-68	-20	-74	-54	-144	-45	44	-72
1965	31	66	-33	-80	66	90	-11	-71	-50	-120	1	98
1966	42	91	20	-175	95	-18	-16	13	86	-27	-49	-65
1967	-54	-26	-7	-37	1	81	5	-5	42	-77	-256	200
1968	-96	-272	84	-52	-49	-41	16	-93	-160	132	12	51
1969	182	221	30	46	67	-178	-8	-52	-23	-14	120	9
1970	17	29	-13	2	-202	30	-237	49	10	19	-46	52
1971	84	-78	-1									

INCOMING RADIATION,Q(S),IN CAL/CM2/DAY

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	203	259	311	393	394	402	473	518	432	310	207	178

STANDARD DEVIATION OF MONTHLY MEANS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	18.0	22.4	28.5	56.0	74.7	62.8	101.6	48.6	68.7	40.1	20.9	18.7

MONTHLY ANOMALIES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951									* 131	* 6	* -8	* 24
1952*	22	* -38	* 31	* 17	* 62	* -11	* 68	*-106	* 65	* 62	* 6	* 50
1953*	33	* -6	* 63	* -58	* 25	* 4	* -24	* -27	* 73	* 3	* 1	* -29
1954*	-1	* -15	* 93	* -13	* -6	* 53	* -18	* 6	* 64	* 58	* -2	* -16
1955*	-2	* -35	* 29	-50	-32	5	115	57	85	21	-31	30
1956	4	-6	-1	-19	47	34	37	-1	-20	47	21	45
1957	-3	-1	2	-59	10	-29	-75	31	66	-13	19	-13
1958	-1	11	-46	-11	-26	21	77	13	9	57	-3	13
1959	-11	-23	19	8	-8	-15	-17	-75	29	-32	-24	-22
1960	7	9	-2	-20	15	-11	74	14	31	11	21	-14
1961	-33	-6	36	1	23	41	103	17	51	40	5	9
1962	5	24	-23	58	13	86	-28	-47	18	34	-23	-20
1963	48	42	52	166	117	-4	50	56	-3	-4	-26	14
1964	-20	-22	29	40	0	16	-72	28	-201	10	-17	7
1965	0	3	6	-26	24	55	-65	-98	19	-104	15	-11
1966	15	-38	-35	-39	70	19	23	10	42	5	6	-19
1967	-7	-17	26	3	1	41	72	7	38	1	26	-2
1968	10	25	-42	-59	4	-31	11	-62	-84	0	35	0
1969	-8	-19	-23	-26	-1	-202	6	-17	-49	-54	-9	6
1970	11	34	1	35	-244	-15	-306	70	-24	-18	0	-8
1971	-17	-4	8									

HEAT OF EVAPORATION,Q(E),IN CAL/CM2/DAY

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	363	365	272	155	110	87	86	149	231	261	352	374
STANDARD DEVIATION OF MONTHLY MEANS												
	75.2	93.5	66.4	43.5	37.9	33.7	37.0	35.4	57.0	72.2	90.2	79.2
MONTHLY ANOMALIES												
1951									* 94	* -28	* 40	* 16
1952	*-121	* -58	* -20	* -67	* -4	* 71	* -26	* -2	* -94	* 51	* -1	* -45
1953	* 41	* 49	* -96	* 13	* 108	* -17	* -41	* 2	* 86	* -26	* -22	* -24
1954	* -73	* 48	* -28	* 33	* -39	*-100	* -27	* 4	* 12	*-155	* 27	*-145
1955	* -60	* 70	* -19	26	-16	36	52	-53	-47	-16	146	* 88
1956	-59	-66	-84	-52	10	46	35	-17	98	-7	-21	177
1957	134	5	55	-8	90	38	3	-51	88	48	-44	-13
1958	34	178	-70	-33	-40	-29	-6	-40	-92	-155	-103	49
1959	-93	-115	153	40	-1	5	-14	-37	-19	70	-51	10
1960	67	4	60	1	38	-24	-73	22	-54	28	55	-136
1961	-55	-18	66	-2	-17	-46	-2	2	52	107	-32	10
1962	-43	0	-75	-26	-16	-17	18	40	-7	-115	-150	8
1963	90	68	2	-55	-12	43	-46	-7	-28	38	37	-9
1964	56	-30	-36	-60	48	31	16	74	-42	42	-42	51
1965	-26	-46	29	41	-30	-31	-30	-14	56	21	17	-70
1966	-14	-84	-28	100	-30	31	31	2	-37	28	41	52
1967	44	27	13	32	2	-32	55	18	-1	65	200	-147
1968	83	198	-83	17	49	21	-1	29	83	-107	15	-16
1969	-135	-158	-29	-36	-42	-34	22	32	-15	-25	-106	-4
1970	-8	-4	9	25	-33	-31	-54	9	-22	-22	44	-38
1971	-64	44	12									

EFFECTIVE BACK-RADIATION,Q(B),IN CAL/CM2/DAY

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	114	113	104	99	84	75	76	85	97	96	100	107

STANDARD DEVIATION OF MONTHLY MEANS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	7.1	8.9	10.0	14.6	9.6	8.6	8.8	7.5	8.6	6.4	10.8	9.6

MONTHLY ANOMALIES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951									* 53	* 1	* -10	* 0
1952*	-1	* -23	* 5	* -2	* 4	* -6	* 7	* -17	* -2	* -2	* -9	* 9
1953*	0	* -5	* 13	* -16	* 8	* 0	* -8	* -6	* 7	* -10	* -16	* -20
1954*	-12	* -13	* 21	* 0	* -9	* 3	* -8	* 1	* 8	* -4	* -18	* -28
1955*	-15	* -21	* 7	-15	-15	-4	15	4	7	-7	-17	* 11
1956	2	-2	-5	-5	2	3	1	-6	-5	10	2	24
1957	-2	-2	0	-16	4	-7	-11	7	11	-2	1	-13
1958	-1	4	-15	-1	-10	-5	3	-3	-1	10	-11	4
1959	-3	-13	8	4	-8	-9	-2	-12	13	5	-7	-12
1960	6	5	2	-8	2	-8	3	10	-2	-4	6	-8
1961	-7	-5	10	-1	0	0	9	-2	17	11	-1	3
1962	-3	2	-14	11	1	9	-7	-6	-6	4	-14	-8
1963	16	12	11	46	24	-2	9	9	-2	2	-11	4
1964	-8	-8	11	8	0	3	-13	6	-8	1	-6	6
1965	1	4	5	0	4	8	-12	-11	3	-4	6	-6
1966	9	-12	-12	-2	15	3	5	1	2	2	5	-3
1967	-2	1	13	6	-1	3	13	-3	2	3	21	-2
1968	6	17	-15	-15	1	-10	2	-3	-13	-3	18	1
1969	-5	-9	-7	-7	-10	23	-4	1	-9	-8	8	10
1970	11	14	4	4	6	-7	-8	14	-9	-9	1	-2
1971	-7	3	4									

TRANSFER OF SENSIBLE HEAT,Q(C),IN CAL/CM2/DAY

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	87	95	54	28	15	8	2	6	20	30	60	84
STANDARD DEVIATION OF MONTHLY MEANS												
	30.9	36.2	26.9	14.7	13.2	10.8	9.3	4.5	9.7	14.3	26.3	37.5
MONTHLY ANOMALIES												
1951									* 25	* -5	* 29	* 2
1952*	-31	* -29	* 0	* -11	* 16	* 24	* -6	* 5	* -12	* 20	* 10	* -20
1953*	38	* 21	* 0	* 22	* 50	* -12	* 2	* 4	* 8	* 3	* 7	* 1
1954*	-4	* 10	* 25	* 18	* -6	* -43	* -15	* 4	* 13	* -45	* 6	* -60
1955*	14	* 36	* 5	9	-3	12	22	-10	-11	-7	57	* 55
1956	-8	-31	-32	-13	10	12	15	1	23	16	4	91
1957	83	13	27	5	31	25	8	0	14	8	-15	-22
1958	10	51	-15	-8	-6	-5	-2	-4	-12	-25	-24	22
1959	-38	-25	71	8	4	5	4	1	-1	20	7	10
1960	34	10	22	-2	15	-8	-17	5	-7	1	8	-41
1961	-10	7	31	-7	-8	-8	2	0	7	17	-7	25
1962	-1	0	-27	-2	-5	-5	2	8	1	-23	-32	16
1963	12	22	3	-5	2	14	-7	-3	-6	6	6	-17
1964	18	-3	-14	-11	21	3	1	3	-6	12	-14	23
1965	-5	-21	5	15	-15	-11	-10	-1	11	-1	-10	-32
1966	-21	-33	-15	40	-9	4	5	-5	-8	2	8	-2
1967	6	-19	7	4	0	-10	1	-2	-4	10	60	-52
1968	18	82	-28	-7	4	0	-4	6	7	-22	-11	-35
1969	-49	-73	-17	-27	-15	-12	-2	3	-1	-7	-32	-8
1970	-8	-5	1	6	-14	-6	-5	-1	-2	-6	0	-19
1971	-29	27	-7									

ZONAL WIND STRESS (DYNES/CM2)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	1.1	1.3	.7	.0	.0	.2	.0	-.1	-.1	-.2	.1	.7

STANDARD DEVIATION OF MONTHLY MEANS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	.5	.8	.5	.3	.2	.2	.2	.2	.3	.2	.2	.5

MONTHLY ANOMALIES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951									.1	.1	-.1	-.4
1952	-.7	-.4	-.4	-.1	-.0	.1	-.1	.1	-.1	-.2	-.4	-.1
1953	.7	.0	-.9	-.1	-.0	-.1	-.2	-.0	-.1	.2	.2	-.6
1954	-.6	-.2	-1.0	-.2	-.1	.0	-.2	-.2	-.3	.4	-.1	-.0
1955	-.1	-1.1	-.8	.0	.2	.1	.2	-.3	.1	-.1	-.0	-.4
1956	-.7	-.6	-.1	-.1	.1	-.1	-.1	.2	.4	-.1	-.1	.4
1957	.3	-.1	.7	-.1	.6	.2	-.3	.0	.2	.0	.4	-.5
1958	-.1	1.0	-.6	.1	-.1	.3	.1	-.0	.1	.0	-.2	.3
1959	-.3	-.8	1.0	.0	.0	.1	-.1	.2	.3	.3	-.2	-.3
1960	-.1	-.6	-.5	.2	-.4	.1	-.1	-.0	-.1	-.0	.3	-.2
1961	-.2	-.2	.2	-.2	-.0	-.1	.0	-.1	-.4	-.4	.1	.6
1962	-.2	.5	-.1	-.4	.0	-.2	.1	.3	-.2	.2	.0	-.3
1963	1.3	.8	-.3	-.0	-.1	-.3	-.1	.1	.2	-.2	-.1	.5
1964	.1	-.2	-.0	-.4	-.2	.1	.4	-.4	.3	-.1	-.1	.1
1965	-.3	-.0	.3	.3	.1	-.1	.3	.0	.2	-.0	-.2	-.1
1966	.3	-1.2	-.0	.4	.1	.1	.0	-.3	.0	-.1	-.2	.4
1967	.0	.6	-.5	-.3	-.2	.1	-.2	.1	-.4	.4	.2	-.2
1968	.5	1.6	-.5	-.2	-.3	-.2	-.2	.2	-.9	.2	.3	-1.1
1969	-.5	-.9	-.2	.5	.2	.0	.2	.3	.2	-.1	-.1	.7
1970	.0	.6	.9	.0	-.0	.0	-.2	-.2	-.0	-.0	-.1	-.1
1971	-.3	-.4	-.1									

MERIDIONAL WIND STRESS (DYNES/CM2)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	.0	-.1	.2	.2	.2	.1	.4	.2	.1	.1	.0	-.1

STANDARD DEVIATION OF MONTHLY MEANS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	.2	.4	.2	.3	.2	.1	.2	.2	.1	.3	.2	.3

MONTHLY ANOMALIES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951									-.4	-.2	-.1	.0
1952	-.0	.3	-.2	-.1	.1	-.1	-.2	-.1	-.0	.3	-.1	.1
1953	.0	.2	-.1	.0	-.2	-.0	.2	.0	-.3	.1	.0	.1
1954	-.2	.1	-.2	-.3	.1	.2	.3	-.2	-.1	.3	.2	-.1
1955	.0	.2	.0	.2	.1	-.0	-.3	-.2	.3	.2	-.0	-.2
1956	.1	.3	.1	.2	.2	-.1	.1	.4	-.2	-.7	.3	-.4
1957	-.3	-.1	.0	.3	.2	.0	.3	-.3	.0	-.0	-.0	.5
1958	-.1	-.5	.0	.0	-.1	.1	.2	.2	-.1	-.1	.3	-.1
1959	-.0	.1	-.2	-.2	.1	.1	-.2	-.1	-.1	-.1	.1	.6
1960	.0	.1	-.2	.4	-.1	.2	.1	-.3	.0	.4	.2	.2
1961	-.2	.1	-.0	.2	.1	-.0	-.3	.2	-.3	-.2	.2	-.3
1962	-.1	.3	.4	-.5	.0	-.1	.0	-.1	-.0	.3	.2	-.2
1963	.0	-.2	.2	-.2	-.4	-.3	-.2	.0	.0	-.0	-.0	-.1
1964	-.1	-.2	.3	-.1	-.1	.0	.1	.1	.1	-.2	-.1	-.8
1965	-.0	.4	-.2	-.1	.0	.1	-.1	-.1	-.0	.2	-.0	.1
1966	-.0	.3	-.3	-.1	.0	-.1	-.1	.1	.1	-.0	-.2	.2
1967	.4	.2	-.2	-.6	-.1	.1	-.1	.4	-.0	.2	-.5	-.0
1958	-.1	-1.0	.3	.3	-.2	-.0	.2	-.0	-.1	.2	-.1	-.0
1969	.4	.2	-.2	.2	.2	-.0	.2	-.2	.2	.0	-.2	.1
1970	-.2	.1	-.1	-.0	.1	-.1	.0	-.2	.0	-.1	-.0	.4
1971	.2	-.3	.1									

APPENDIX III

Monthly estimates of turbulent exchange processes at Ocean Weather Station V (lat. 34°N, long. 164°E) and monthly anomalies from long-term mean, April 1955 to March 1971.

Monthly estimates of:

Q(N), Net heat exchange across the sea surface,
Q(C), Conduction of sensible heat,
Q(E), Heat used for evaporation,
τ_x, Zonal component of resultant wind stress, and
τ_y, Meridional component of resultant wind stress

were computed from daily mean meteorological properties. Transfer coefficients, C_D, C_H, and C_E, were corrected for atmospheric stability using bulk Richardson number formulae of Deardorff (1968). $C_D = C_H = C_E = 0.0013$ for neutral stability conditions.

Individual monthly mean values are the algebraic sum of the long-term monthly mean and the monthly anomaly.

NET HEAT EXCHANGE,Q(N), IN CAL/CM2/DAY

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	-410	-365	-164	66	177	215	290	221	40	-124	-357	-443

STANDARD DEVIATION OF MONTHLY MEANS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	113.0	133.4	130.2	85.6	67.2	69.2	49.3	60.7	91.0	103.7	133.5	134.0

MONTHLY ANOMALIES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951												
1952												
1953												
1954												
1955				-47	63	-32	27	100	148	56	-246	
1956	74	90	125	69	-19	-46	-59	26	-177	-32	45	-314
1957	-258	-30	-85	-25	-129	-87	-8	55	-69	-78	63	45
1958	-77	-235	58	54	-1	8	25	57	110	209	147	-64
1959	147	122	-275	-79	-10	-49	-50	-5	7	-116	16	7
1960	-132	-30	-135	-17	-84	-10	92	-75	67	-42	-22	184
1961	44	-2	-54	35	8	65	54	29	-74	-119	72	-124
1962	48	24	109	6	47	81	-48	-112	-9	188	204	-69
1963	-60	-69	32	181	48	-119	65	58	22	-43	-52	59
1964	-90	49	71	110	-94	-37	-60	-55	47	-61	53	-109
1965	50	90	-28	-77	49	79	-27	-43	-82	-11	-43	135
1966	23	107	30	-185	79	-27	-41	23	86	-27	-43	-57
1967	-15	-22	-34	-36	1	63	-19	-6	41	-82	-314	218
1968	-116	-295	113	-15	-87	-35	3	-79	-157	169	32	84
1969	209	250	33	65	46	140	-20	-28	13	-29	141	25
1970	43	30	-17	-31	89	21	66	58	27	12	-55	78
1971	109	-93	24									

HEAT OF EVAPORATION,Q(E),IN CAL/CM2/DAY

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	433	398	295	175	116	99	82	153	250	293	392	415

STANDARD DEVIATION OF MONTHLY MEANS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	34.4	100.0	76.5	49.8	45.5	37.3	31.4	42.5	57.4	80.1	104.2	92.1

MONTHLY ANOMALIES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951												
1952												
1953												
1954												
1955				20	-64	23	21	-66	-75	-29	173	
1956	-52	-67	-93	-58	25	53	40	-26	123	29	-26	223
1957	152	14	55	-11	92	32	-40	-37	83	42	-37	-18
1958	50	189	-67	-42	-27	-13	0	-47	-102	-155	-117	52
1959	-139	-109	233	70	-13	18	11	-45	-13	67	-41	-12
1960	86	16	73	1	57	-12	-47	58	-48	40	35	-135
1961	-48	-18	59	-23	2	-49	-1	-7	81	115	-54	75
1962	-43	-3	-33	6	-32	-24	16	61	1	-144	-172	24
1963	81	67	-6	-54	5	78	-27	-16	-22	39	39	-27
1964	57	-40	-38	-66	56	35	7	77	-48	46	-46	75
1965	-38	-58	28	41	-32	-36	-21	-19	70	21	33	-96
1965	1	-93	-35	119	-31	15	30	-8	-45	26	37	48
1967	17	25	33	31	-10	-31	55	15	-8	67	243	-155
1968	88	214	-133	-1	62	3	5	43	90	-139	1	-41
1969	-156	-172	-23	-43	-36	-43	17	24	-41	-4	-118	-12
1970	-17	-11	13	13	-48	-36	-56	7	-40	-16	53	-52
1971	-33	53	2									

TRANSFER OF SENSIBLE HEAT,Q(C),IN CAL/CM2/DAY

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	100	108	71	33	16	10	-0	6	23	36	71	98
STANDARD DEVIATION OF MONTHLY MEANS												
	35.7	39.4	30.3	17.3	16.8	12.0	8.4	6.5	11.1	16.6	31.2	45.8
MONTHLY ANOMALIES												
1951												
1952												
1953												
1954												
1955				6	-25	4	4	-11	-14	-10	65	
1956	-6	-30	-32	-15	13	10	20	1	26	26	-1	110
1957	130	17	34	5	32	26	-11	4	14	7	-16	-27
1958	12	51	-15	-14	-2	-1	0	-5	-14	-22	-30	18
1959	-44	-25	35	14	1	3	9	1	-2	18	10	1
1960	44	18	25	1	23	-5	-16	11	-5	7	0	-47
1961	-9	6	13	-14	-3	-7	3	1	12	18	-13	57
1962	0	-3	-34	11	-13	-7	2	13	4	-29	-38	30
1963	7	19	1	-3	10	24	-4	-4	-5	5	6	-25
1964	19	-9	-16	-12	24	3	0	5	-7	18	-16	33
1965	-10	-26	4	14	-16	-15	-7	-1	12	-1	7	-46
1966	-15	-37	-14	46	-10	4	7	-7	-8	2	6	-2
1967	-10	-17	15	7	-3	-12	2	-2	-5	11	75	-59
1968	25	91	-34	-10	8	-4	-3	8	6	-28	-18	-41
1969	-36	-80	-13	-30	-16	-14	-1	3	-6	-3	-35	-15
1970	-13	-6	6	1	-18	-8	-7	-2	0	-6	1	-27
1971	-36	32	-14									

ZONAL WIND STRESS (DYNES/CM2)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	1.0	1.2	.7	.0	.0	.1	.0	-.0	-.1	-.2	.1	.6

STANDARD DEVIATION OF MONTHLY MEANS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	.4	.7	.4	.2	.2	.1	.2	.2	.3	.2	.2	.4

MONTHLY ANOMALIES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951												
1952												
1953												
1954												
1955				.0	.2	.0	.2	-.3	.1	-.1	-.0	
1956	-.7	-.6	-.1	-.0	.1	-.1	-.1	.2	.3	-.1	-.1	.4
1957	.3	-.1	.6	-.1	.5	.2	-.3	.0	.2	.0	.4	-.4
1958	-.1	.8	-.5	.1	-.1	.2	.1	-.0	.1	.0	-.2	.3
1959	-.3	-.7	.9	.0	.0	.1	-.1	.1	.2	.3	-.2	-.2
1960	-.0	-.5	-.4	.2	-.4	.1	-.1	-.0	-.1	-.0	.3	-.2
1961	-.1	-.2	.2	-.2	-.0	-.1	.0	-.1	-.3	-.4	.1	.5
1962	-.2	.5	-.1	-.4	.0	-.2	.1	.3	-.2	.2	.0	-.2
1963	1.1	.7	-.3	.0	-.1	-.2	-.1	.1	.1	-.1	-.1	.5
1964	.1	-.2	-.0	-.3	-.2	.1	.4	-.3	.2	-.1	-.1	.1
1965	-.2	-.0	.3	.3	.1	-.1	.2	.0	.2	-.0	-.2	-.1
1966	.3	-1.1	-.0	.4	.1	.1	.0	-.3	.0	-.1	-.2	.4
1967	.0	.5	-.5	-.3	-.2	.1	-.2	.0	-.3	.3	.2	-.2
1968	.6	1.4	-.5	-.1	-.2	-.2	-.2	.2	-.7	.2	.3	-.9
1969	-.4	-.8	-.2	.4	.2	.0	.1	.2	.2	-.1	-.1	.6
1970	.0	.5	.8	.0	-.0	.0	-.1	-.2	-.0	-.0	-.1	-.1
1971	-.3	-.3	-.1									

MERIDIONAL WIND STRESS (DYNES/CM2)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN=	.0	-.1	.2	.1	.1	.1	.3	.2	.0	.1	-.0	-.1

STANDARD DEVIATION OF MONTHLY MEANS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	.2	.3	.2	.2	.1	.1	.2	.2	.1	.2	.2	.3

MONTHLY ANOMALIES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1951												
1952												
1953												
1954												
1955				.1	.1	-.0	-.3	-.2	.3	.2	-.0	
1956	.1	.3	.1	.1	.2	-.1	.1	.4	-.2	-.6	.2	-.4
1957	-.3	-.1	.0	.2	.2	.0	.3	-.2	.0	-.0	-.0	.5
1958	-.1	-.4	.0	.0	-.1	.1	.1	.1	-.1	-.1	.2	-.1
1959	-.0	.1	-.2	-.2	.1	.1	-.2	-.1	-.1	-.1	.1	.5
1960	.0	.1	-.2	.3	-.1	.2	.1	-.2	.0	.4	.2	.2
1961	-.1	.1	-.0	.2	.0	-.0	-.2	.1	-.3	-.2	.1	-.2
1962	-.1	.2	.4	-.5	.0	-.1	.0	-.1	-.0	.2	.1	-.2
1963	.0	-.1	.2	-.1	-.3	-.2	-.2	.0	.0	-.0	-.0	-.1
1964	-.1	-.1	.2	-.0	-.1	.0	.1	.1	.1	-.2	-.0	-.7
1965	-.0	.4	-.2	-.1	.0	.1	-.1	-.1	-.0	.2	.0	.1
1966	-.0	.2	-.2	-.1	-.0	-.1	-.1	.1	.1	-.0	-.2	.2
1967	.4	.2	-.2	-.5	-.1	.1	-.1	.4	-.0	.1	-.4	-.0
1968	-.1	-.8	.2	.2	-.2	-.0	.2	-.0	-.0	.2	-.1	-.0
1969	.3	.2	-.2	.2	.2	-.0	.2	-.2	.2	.0	-.2	.1
1970	-.2	.0	-.1	-.0	.1	-.1	.0	-.1	.0	-.1	-.0	.4
1971	.2	-.2	.1									

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76
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