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MARINE PHYSICS: INTERNAL-SURFACE  
WAVE INTERACTION AND MICROSTRUCTURE  
MEASUREMENT PROGRAM

Charles S. Cox, et al

Scripps Institution of Oceanography

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This semi-annual report reflects the technical status of internal/surface wave interaction and microstructure projects conducted within the Advanced Ocean Engineering Laboratory at the Scripps Institution of Oceanography. These projects are: (1) Thermal Microstructure - to examine in detail the structure and dynamics of temperature and salinity and (2) Atmospheric Boundary Layer - to provide an understanding of the interaction between atmospheric boundary effects and surface waves.		

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ADVANCED OCEAN ENGINEERING LABORATORY

TECHNICAL PROGRESS REPORT

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Part I  
Microprocesses

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Part I  
Microprocesses

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## I. Project Summary

This report summarizes the work undertaken between 1 July 1973 and 1 January 1974, and should be considered as a supplement to the previous report.

## II. Technical Report

The principal effort for this period has been the development of computer programs for the processing of high density data acquired at sea and preparation for a cruise to the central North Pacific in February-March 1974.

A program which deconvolves the raw digital data record from the two temperature gradient channels and the conductivity channel has been debugged and is now in service. This permits combining the low and high frequency temperature (or conductivity) information from two separate data channels into one record of temperature vs. depth. The dynamic range achievable with this technique is greater than  $10^5$ , thus permitting a single record to contain virtually all of the significant information on the vertical profile. The resultant data is being analyzed to determine the patch sizes of regions of intense microstructure and their relation to large-scale irregularities.

During the period 21 February - 20 March 1974, vertical profiles will be made at 28°N, 155°W in the central North Pacific, making the third set of data from this location. The other measurements, made in September-October 1971, and June 1973, will be compared with this set in an attempt to determine seasonal variations in levels of microstructure activity in the upper two kilometers and to relate these to changes in the heat content of the water column.

Part II  
Midwater Thermal Structure

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under the guidance of Drs. Munk and Snodgrass

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## I. Project Summary

This report supplements previous reports on development and use of a freely floating instrumented capsule. A summary of work undertaken July 1, 1973 through December 31, 1973 is given. Future plans are indicated.

## II. Technical Report

A. Our major effort during this period has been on the analysis of data gathered in June, 1973. At that time we participated in a joint OWEX experiment with other investigators in an area 300 miles S.W. of San Diego. We obtained three thermal microstructure records, each of one day duration, and one internal wave record of 6 days length.

1. Analysis of the internal wave data is essentially completed and will be reported during the early part of 1974. Figure 1 gives a preliminary look at two internal wave spectra each estimated from half of the six day internal wave record. The observed spectra decrease as  $\omega^{-2}$  up to the local bulk Väisälä frequency and drop off sharply at higher frequencies.

Detailed thermal structure profiles typically reveal thermal inversions. In the present experiment we obtain such profiles repeatedly while advecting with the mean water motion. By removing the internal wave oscillations from the records, it is possible to more clearly observe changes in the thermal structure. Figure 2 is a preliminary sketch of a five hour segment of a structure record referenced somewhat imperfectly to the 4.665°C isotherm. It shows a thermal inversion pattern suggestive of a Kelvin-Helmholtz shear instability. Four inversions of this type, each lasting several hours, were identified in a three day segment of the data.

2. Several inversions of similar scale appear in the records of drops which included instrumentation for measuring thermal microstructure. The microstructure "signatures" of these inversions will be used to help understand their physics. Kelvin-Helmholtz shear instability, already mentioned, or interfingering of statically stable water masses with salinity compensated temperature inversions are two possibilities. The analysis of all of the June data is expected to be completed by mid 1974.

B. A two-axis self-contained electromagnetic current meter designed and prepared by Jack Olson of NUC was included in the midwater float instrumentation in initial sea trials in November.

### III. Future Plans

- A. Modifications to the midwater float and portable laboratory are underway in preparation for a nominal 30 day internal wave measurement to be conducted mid-June to mid-July.
- B. Improvements in the electromagnetic current meter based on results of the November sea trials are being made and a second unit is being built for shear measurements in conjunction with microstructure and internal wave measurements.
- C. Coordination and planning with Mike Gregg has begun in preparation for joint microstructure and internal wave measurements in the fall.

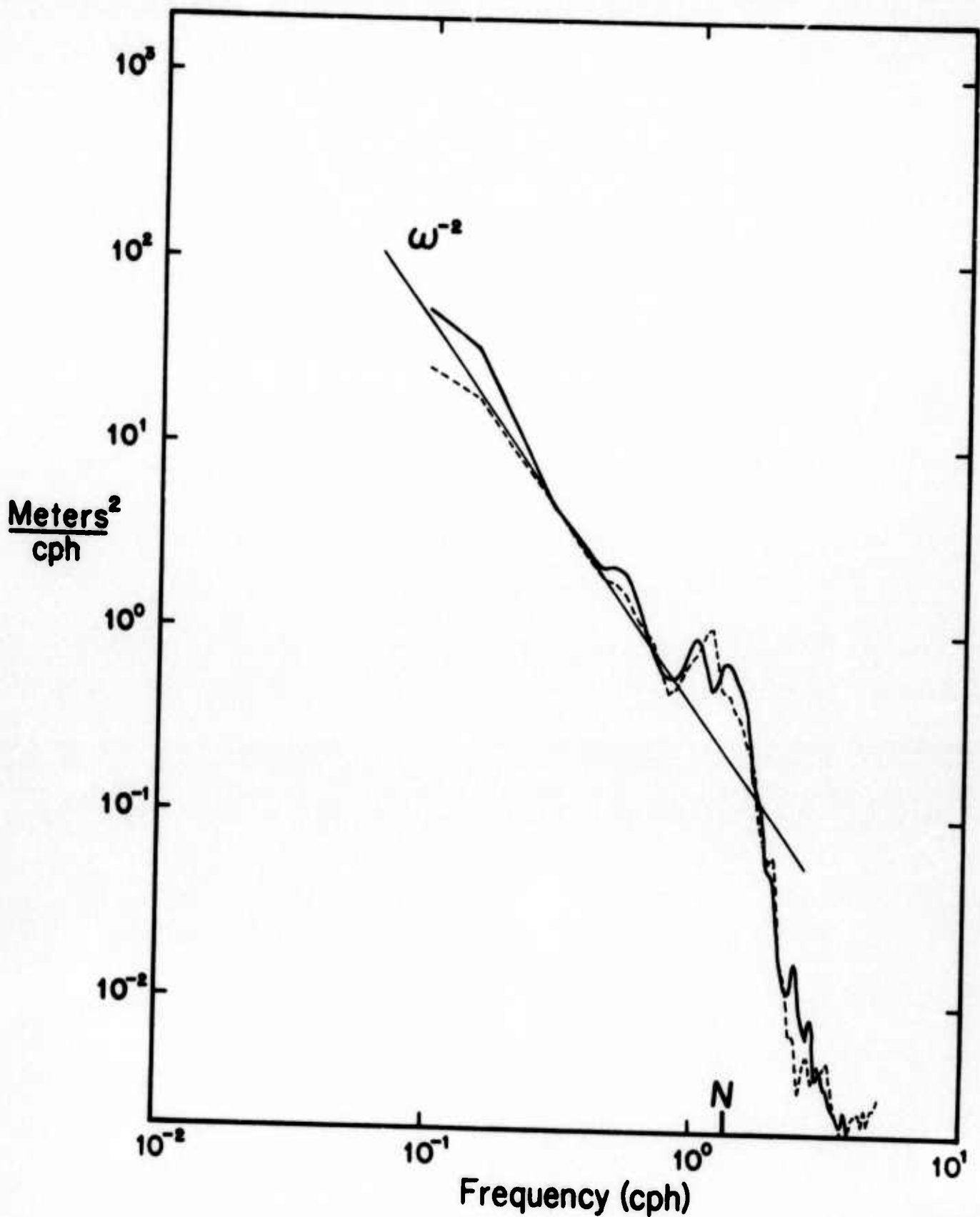


Figure 1. The solid curve is the spectrum estimated from the first three days of the six day isotherm depth series. The dashed curve is the estimate from the second three days. A straight line of slope  $\omega^{-2}$  is given for reference. N denotes the local Brunt-Väisälä frequency.

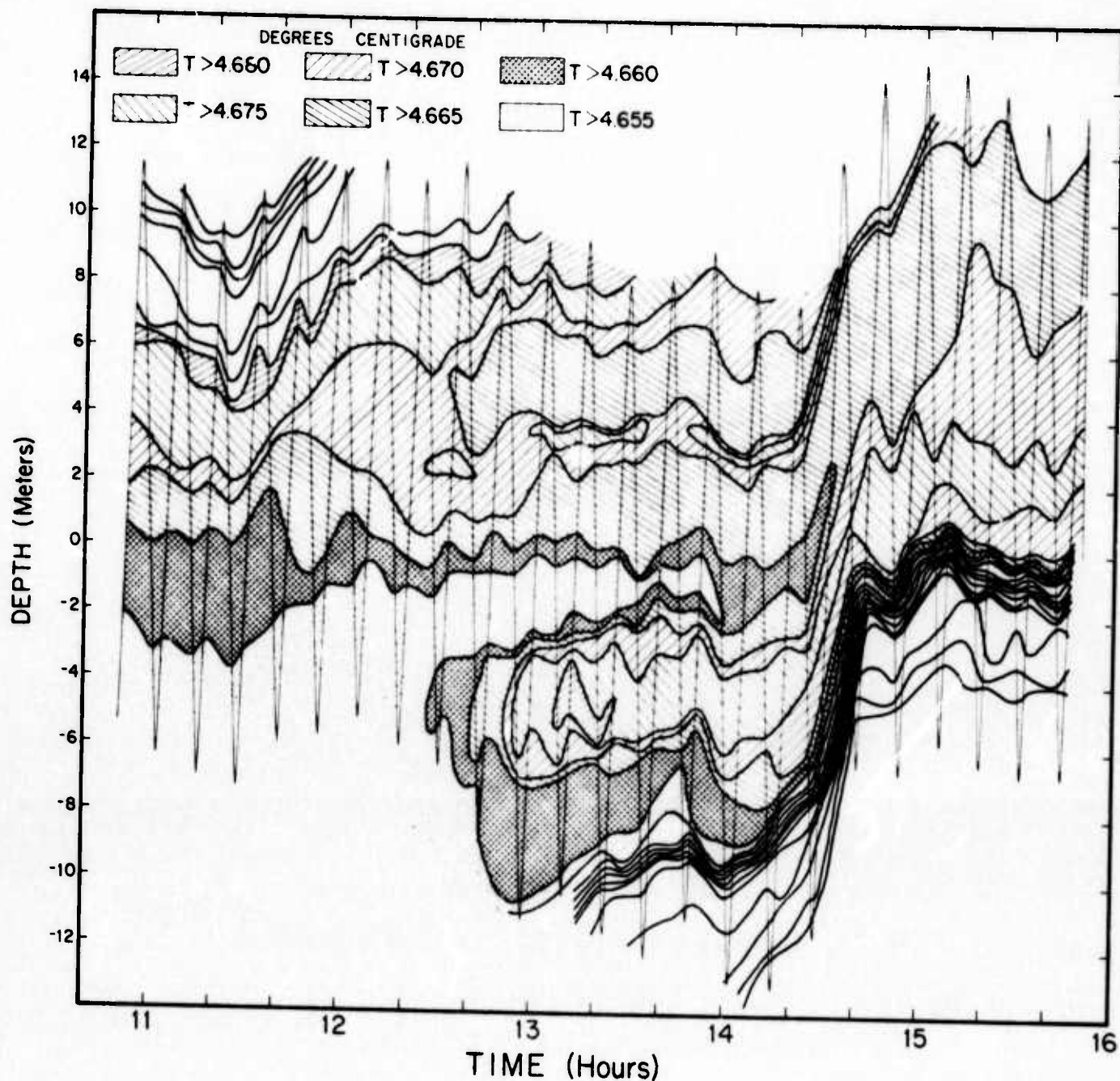


Figure 2. This figure shows a five hour segment of the thermal structure motion relative to an isotherm. The ordinate is distance relative to that isotherm. The heavy curves are contours of isotherms spaced every .005°C, and the various shaded areas are areas where the temperature lies within particular .005°C bands, as indicated by the legend. The lighter sawtooth curve is the path in time taken by the temperature sensor.

Part III

Surface Waves and Near Surface Effects

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Part III

Surface Waves and Near Surface Effects

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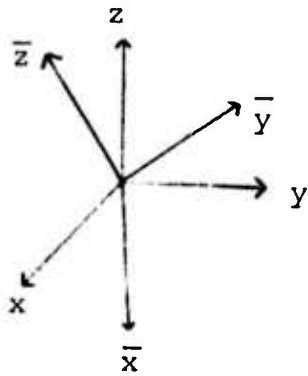
## I. Project Summary

As described in the previous Technical Report, a well instrumented open ocean experiment OWAX was successfully undertaken during the first six months of 1973. The primary goals of the research for the period from July 1, 1973 to December 31, 1973 have been 1) to derive equations to utilize the inertial platform data to correct the velocity and wave height data for FLIP's motion, 2) to undertake preliminary analysis of the atmospheric-turbulent boundary layer data, and 3) to examine atmospheric boundary layer, internal and surface wave data for possible correlations. Detailed analysis of the data is proceeding.

## II. Preliminary Results

A. Inertial Platform Correction for FLIP's Motion. Measurements of the various velocity components in the atmospheric turbulent boundary layer as well as wave height information carried out from a non-inertial platform such as FLIP must be corrected for the motion of the platform or sensors. This motion contaminates the measured data in two main respects: first the height of the sensor probes above the mean sea surface level varies with time, and thus a spurious time dependent velocity is read by the anemometers because of the presence of the non-uniform velocity profile in the atmospheric boundary layer, second the probes themselves are being swept through space with an unknown time varying velocity with respect to an inertial coordinate system and this velocity must be subtracted from the recorded data. During OWAX, FLIP's motions were accurately recorded by means of a Litton inertial platform and gyroscopes so that the anemometer data could be corrected. The following is a brief description of a correction procedure we developed and which will be applied to the data in the near-future.

The general motion of a rigid body (FLIP) can be considered as composed of the translational motion of any point in that body and of a rigid body rotation about that point. On FLIP the translational motion is obtained by integration of the accelerations read by the Litton inertial platform, and the rotation is obtained from the three angles read from the gyroscopes. Since the gyroscope axes maintain their orientation in space, this orientation is used to define the direction of the desired velocity components, with the z axis (yaw) being vertical to the mean ocean surface, and the X axis pointing approximately into the wind. Let the gyroscope coordinate system be denoted by S, and the system fixed to FLIP be denoted by  $\bar{S}$ . Then it can be shown



that any point fixed to FLIP (described as  $\bar{r}^i$ ) will have components  $r^i$  in S given by the following transformation:

$$\begin{pmatrix} r^1 \\ r^2 \\ r^3 \end{pmatrix} = \underbrace{\begin{pmatrix} \cos\theta\cos\phi & \sin\psi\cos\theta\sin\phi & \cos\psi\cos\theta\sin\phi \\ \sin\theta\cos\phi & \sin\psi\sin\theta\sin\phi & \cos\psi\sin\theta\sin\phi \\ -\sin\phi & \sin\psi\cos\phi & \cos\psi\cos\phi \end{pmatrix}}_{R_k^i(t)} \begin{pmatrix} \bar{r}^1 \\ \bar{r}^2 \\ \bar{r}^3 \end{pmatrix} \quad (1)$$

Where the angles in the rotation matrix are with respect to the gyroscope gimbaling system and are read out directly as data:

- $\theta$  = yaw (z axis)
- $\phi$  = pitch (approx. y axis)
- $\psi$  = roll (approx. x axis)

In particular the fixed values  $\bar{r}^i$  are chosen to be the vector components of the probe location with respect to the Litton inertial platform at time  $t = 0$  when  $\theta = \phi = \psi = 0$ , and these are known from the geometrical placement of the apparatus.

The total motion of the probe with respect to an inertial coordinate system can then be given in two parts:

$$v_p^j(t) = \underbrace{v_a^j(0) + \int_0^t a^j(t') dt'}_{\text{integration of inertial platform data}} + \underbrace{\left\{ \frac{d}{dt} R_k^j(t) \right\} \bar{r}^k}_{\text{derivative of gyroscope data}} \quad (2)$$

$j = 1, 2, 3$

The probe position as a function of time can be obtained by further integration:

$$x_p^j(t) = x_a^j(0) + v_a^j(0)t + \int_0^t \int_0^{t'} a^j(t'') dt'' + R_k^j(t) \bar{r}^k \quad (3)$$

The two constants of integration are not explicitly given by the experiment but may be approximately found by the following argument. If FLIP is adequately moored, one expects its time average motion to vanish. Hence by letting

$$v_p^j(t) = 0 \quad \text{and} \quad x_p^j(t) = 0,$$

one obtains the initial values  $v_a^j(0)$  and  $x_a^j(0)$ .

By the above technique the instantaneous location and velocity of the probe is known, and thereby the instantaneous velocity data can be corrected:

$$v_{\text{true}}^i(t) = v_{\text{measured}}^i(t) + v_{\text{probe}}^i(t) \quad (4)$$

It must be further noted that since the velocity data is read by sensors which change orientation with FLIP's motion, the interpretation of the velocity components needs to be corrected by the same rotation matrix that was exhibited above. Then finally:

$$v_{\text{true}}^j(t) = v_{\text{platform}}^j + v_{\text{rotation}}^j + R_k^j(t) \bar{v}_{\text{measured}}^k, \quad j = 1, 2, 3 \quad (5)$$

In light of the above discussion several errors arising from FLIP's motion need to be determined numerically by computer calculation. By use of equation (3) the vertical location of the probe is computed as a function of time. Assuming that the measurements are made in the logarithmic portion of the atmospheric boundary layer, it is possible to estimate the error in the measured signal due to the changing vertical location of the probe. The three correction terms appearing in equation (5) need to be computed and separately assessed. By cross-multiplication of equation (5) and time averaging, one may directly assess the relation between the corrected and uncorrected Reynolds stresses. By taking the Fourier transform of each term separately, one may see if the correction terms add a dominant spurious spike into the spectra of fluid turbulence. Another effect of probe motion which needs to be considered, but which one expects to be negligible, is the apparent broadening of the frequency-wavenumber relation that is customarily obtained from Taylor's hypothesis. In other words, a probe moving into the wind records higher frequency turbulence than while moving away from it. This effect is felt in scalar spectra as well as velocity spectra.

B. Atmospheric Turbulent Boundary Layer Data. Analysis of OWAX temperature and humidity data has confirmed other evidence indicating that the temperature spectrum shows a definite departure from the  $-5/3$  law inertial subrange form expected for passive scalar mixing at high Reynolds number. The humidity spectra exhibit the expected inertial subrange behavior as shown in Figure 11 of the previous report. It is interesting to note that using the same electronic equipment and techniques, measurements of temperature and humidity spectra in the atmospheric boundary layer over land were carried out this summer at a Minnesota test site in a joint experiment with the Air Force Cambridge Research Laboratories. Both temperature and humidity spectra exhibited the expected  $-5/3$  behavior over land. The reasons for this result is still under investigation and seem of fundamental importance to the physics of the marine boundary layer.

C. Internal Wave, Surface Wave and Atmospheric Boundary Layer Interactions. Some preliminary indication exists that internal waves are influencing sea surface temperature and atmospheric temperature. From some strip chart data recordings, the air temperature can be seen to decrease and the sea surface temperature increases as an internal wave event occurs. The cause and magnitude of the surface response to the internal wave event, as well as exactly what is measured by the Pinkel detector, are under study.