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13. ABSTRACT (Maximum 200 words)

The goal of this research is to gain a better understanding of the processes affecting the near-surface flow in marine surface layer. The first objective is to improve our understanding of flux profile relationships over the ocean using our mean and flux measurements and the TKE budget equation. This has involved an investigation of the applicability of similarity theory to over-ocean measurement in order to determine these functions and their proportionality factors. The result of this investigation have shown that the turbulence statistics are similar to those computed over land as long as one is well above the wave boundary layer (WBL). The second objective is to gain a better understanding of the role that stress/wave interaction plays in these processes. The measurement of these profiles in both shallow water and open-ocean settings is allowing us to develop dimensionless functions that are valid anywhere in the constant flux layer. The results of this research that the behavior of the turbulence in the WBL is strongly affected by the wave induced flow. The height of the WBL can be a substantial portion of the surface layer depending on the wave state.

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Spectral Characteristics of the Marine Surface Layer
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Progress Report - June 15, 1995

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Research Goals:

The goal of this research is to gain a better understanding of the spectral characteristics of the marine surface layer. The research would focus on the importance of directional turbulent processes, especially those involved in stress-wave interactions. The long range goal of this research is to:

1. Develop new and revise old theoretical descriptions of turbulence, such that they are universally applicable to both over land and over sea boundary layers.

2. Improve the parameterizations and methodologies used to estimate the desired geophysical variables to more accurately describe the physical processes unique to the marine boundary layers.

3. Collect a high quality, high resolution data base to provide validation of the numerical model modifications necessary to include these processes in coupled ocean-atmosphere models.

Objectives:

An in depth study of the universality of traditional dimensionless profile functions over the ocean is the main interests of the PI in this program. Therefore, the primary objective of this research is to determine these functions over the ocean where a difference with land-derived functions is possible due to presence of waves. It is expected that these experiments will also determine the value of various "constants" (e.g., the von Karman and Charnock constants) commonly used in turbulence studies.

Another objective of this research is to examine the effect of the wave field on the various terms in the Turbulent Kinetic Energy (TKE) budget equation. With the instrumentation made available during the Risø Air-Sea Experiment (RASEX) and Marine Boundary Layers (MBL) Main Experiment, we would be able to investigate all the terms in the TKE budget. When coupled with simultaneous measurements of the wave field, we will be able to investigate how stress-wave interaction affects the transfer of momentum into the ocean.

Approach:

These studies are being conducted in two field programs. Both programs are being set up to measure turbulence flux profiles over the sea, where we expect to find a number of differences between land and sea-based measurements because of its fluid surface. The first is taking place in a highly instrumented shallow water site off the coast of Denmark. The emphasis of this program would be placed on investigating the coupling between the wave field and coherent structures (on both large and small scales) responsible for the momentum flux.

This work will be accomplished through the use of traditional and more recently developed data analysis techniques. This data is being acquired with sonic anemometers-thermometers, fast response hygrometers, and a new fast response pressure sensor. Instrumentation at the interface and under the surface will provide directional wave spectra, surface slope, and the current vector. The pressure sensors will allow us to directly study the role of the pressure transport term in the turbulent kinetic energy equation. Additionally, the combination of the surface slope and pressure sensor measurements are expected to greatly facilitate studies involving wave growth and that component of the momentum flux associated with form drag.

The second program involves an open ocean field experiment using aircraft and research vessels whose area of operations will be centered around the R/P FLIP. The emphasis of this program would be on improving our understanding of flux profile relationships over the open ocean. The ship-based measurements will supplement the oceanic and atmospheric measurements on FLIP, and will be used to examine how horizontal variability in both the oceanic and atmospheric boundary layers affect their vertical structure.

Tasks Completed:

The Risø Air-Sea Experiment (RASEX) spring phase was successfully conducted in April of 1994. During this experiment investigators from WHOI, NOAA/ETL, and Risø deployed numerous levels of fast and slow response instrumentation on a 48-m tower situated 2-Km off the coast of Lolland, Denmark. This instrumentation included six sonic anemometers/thermometers, four fast response static pressure sensors, two infrared hygrometers, and mean sensors to compute the wind and temperature profiles. Additional instrumentation to characterize the sea surface and wave-state included a wave-wire array, 2-D current meter, acoustic transducer (for wave height statistics), and an IR thermometer (for sea surface temperature). The data from this instrumentation was logged for approximately four weeks at sampling frequencies ranging from 1 Hz for the mean sensors to 10-20 Hz for the turbulence probes under mainly near-neutral to stable conditions.

Preliminary results from this experiment has shown that the data collected during this phase are of very high quality. The few problems that arose during the experiment were

addressed over the summer, and improvements to the existing setup have been included in the RASEX fall phase. This phase began on 28 September and is currently collecting data under more unstable conditions. Daily checks of the data have shown that it is in even better shape than that collected during the spring. Data acquisition will continue through the end of October, and possibly into the middle of November.

In preparation for the R/P FLIP component of this experiment, the PI participated in a 10 day test cruise in August of 1994 with Dr. Carl Friehe of UC-Irvine. During the cruise, an 18-m mast was deployed at the end of one of FLIP's booms to provide wind profiles using cup anemometers. Four sonic anemometer/thermometer were also deployed during this cruise in order to examine the flux profiles and provide the necessary scaling parameters to compute the dimensionless profile functions.

The PI then participated in the MBL Main Experiment off the Monterey Coast from April 14 to May 14, 1995. During this cruise the Dr. Friehe, Mr. Scott Miller (UC-Irvine) and the PI again deployed the mast with additional instrumentation including 12 levels of cup anemometers, 4 levels of sonic anemometers/thermometers and 3 static pressure sensors. Approximately seven Gbytes of data were collected over a 12 day period. Initial analysis of this data is currently underway.

The PI was also involved in deploying instrumentation aboard the R/V Wecoma during this experiment. This involved the deployment of a Direct Covariance Flux System (DCFS) on the ship's bow mast, which included instrumentation designed to remove the ship's motion from the velocity measurements. These measurements will allow us to compute the fluxes directly using the eddy correlation method, and will provide a means to examine the horizontal variability of the momentum and heat fluxes when combined with the FLIP data. The data will also be combined with the oceanographic data taken aboard the Wecoma to study the effects of atmospheric forcing on the oceanic mixed layer.

Results:

The atmospheric measurements from the spring experiment have been combined with oceanic measurements of wave height, wave slope, and subsurface currents taken from wave-wire arrays, current meters and acoustic transducers. The combined data set is enabling us to examine many aspects of air-sea interaction through separation of the stress vector into turbulent, wave induced and viscous stress components. Well above the wave boundary layer, the stress is due primarily to atmospheric turbulence. At the surface, this momentum transfer is due to the viscous stress and wave components. This wave component is often further divided into long and short wave components. The former is often associated with form drag, while the latter is often parameterized using Charnock's relationship. Our ability to directly measure the form drag associated with waves longer than 1 meter is what makes RASEX unique. This is accomplished by correlating the static pressure fluctuations with the wave slope measurements (using the 0.5 m wave wire array) to compute the momentum flux sustained by these longer waves.

The preliminary results from the spring and fall experiments were presented at the 11th Symposium on Turbulence and Diffusion held in Charlotte, NC this spring. These results indicate that the wave component is approximately 25% of the total flux in developing sea conditions under high winds. The results also indicate that this ratio is strongly dependent on the wave age parameter, C/u_*. By combining this data with the data collected during the FLIP campaign we expect to gain significant insight into the role played by long waves in momentum transfer. For example, the measurements have allowed us look quantitatively at how the ratio of long-wave component to the total momentum flux (estimated above the wave boundary layer using the sonics) changes as a function of the angle between the mean wind vector, the stress vector, and the dominant waves.

Relationship to Other Projects:

The work involved in the MBL ARI is nicely complements the research objectives of the High Resolution ARI. The goal of this program is to be able to physically interpret remotely sensed radar images. The models created to interpret these images can then be inverted to remotely acquire geophysical parameters such as wind speed and direction. My main interest in this program is to understand how atmospheric forcing affects these images. Since the radar systems sense this forcing through the effect of the winds stress and atmospheric stability on the wave field, the knowledge gained from the MBL programs concerning stress/wave interaction will also assist us in our High Resolution research. Additionally, the work with the DCFS will eventually allow us to deploy a reliable low power system capable of measuring the fluxes directly from a discus buoy. The PI strongly believes that this system would greatly benefit the research to be conduced during the Coastal Mixing and Optics ARI.

Publications:

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Wilczak, J., A. Bedard, J. Edson, J. Hare, J. Højstrup, and L. Mahrt 1995: Pressure transport measured on a sea mast during the RASEX program, *AMS Eleventh Symposium on Turbulence and Diffusion*, Charlotte, NC, 11-14.