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Shipboard Measurements of Surface Flux and Near Surface Profiles and Surface Flux Parameterization

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Award # N0001412WX20006

LONG-TERM GOAL

The long-term goal of this project is to understand the effects of surface waves on the structure of the marine atmospheric surface layer and surface flux parameterizations under a broad range of wind-wave conditions.

OBJECTIVES

This project is part of the High Resolution Wave-Air-Sea Interaction research initiative (HiRes). The objectives of this project are to characterize low-level atmospheric wind and thermodynamic profiles and variations, to understand oceanic and atmospheric large scale forcing that affects boundary layer properties and the role of measured wave field in modifying atmospheric surface fluxes.

APPROACH

Our work within this project consists of three parts: measurements, the subsequent data analyses, and mesoscale model evaluation/improvements. The ship-based (Sproul R/V) measurement efforts include high-rate sampling of the turbulent field for direct covariance flux measurements, continuous sampling of the low-level wind profiles by the ship-based acoustic Sodar, rawinsonde measurements of the troposphere, a suite of mean variables for quantifying the low-level thermodynamic and dynamic fields, downward radiation, and sea surface temperature measurements. The data analyses focus on the low-level surface layer properties and surface flux parameterization involving sea state parameters. In the current report we compare turbulence measurements from SPROUL R/V and FLIP R/P in the time periods when these two measurement platforms were within a short distance to each other.

Qing Wang is responsible for the overall project. Mr. Richard J. Lind worked on instrument preparation, calibration, and data sampling. Dr. John Kalogiros, an external research associate from National Observatory of Athens, Greece, worked on the data analyses.

WORK COMPLETED

Our work in FY12 focused on final refinement of results for publication. For this purpose, we added in the analyses of the turbulent measurements from R/P FLIP, which was moored in a stationary position offshore Bodega Bay, CA. This addition of the FLIP data serves two purposes: one is to help evaluate

our measurements in the vicinity but with more significant ship motion; the other is to examine the spatial variability of turbulence field in the HiRes region. Specific work done includes:

1. Computed mean values and turbulent variances and fluxes from FLIP sonic data (u,v,w,T) at two levels (14 and 20 m above sea level) that are close to altitude of the R/V SPROUL sensors.
2. Performed a quality control of the above FLIP data in order to detect problems in data acquisition and processing.
3. We compared mean values and fluxes from FLIP and SPROUL when they were within a distance of less than 10 km.
4. We computed drag coefficients from FLIP data and compared them against COARE bulk estimates.

RESULTS

FLIP sonic mean and turbulent fluxes estimation: The available data from FLIP (Courtesy of Tihomir Hristov) were from sonic anemometer measurements at two levels (14 and 20 m) above sea level between 13 and 19 June, 2010. Each sonic measured 3-dimensional wind components and air temperature (T). The sampling of the available datasets was 5 Hz. The wind components were corrected for FLIP motion due to sea waves. The averaging time period for estimation of mean values and turbulent fluxes was selected to be 10 minutes and the time series of the computed values were interpolated to the same time periods with the corresponding SPROUL results.

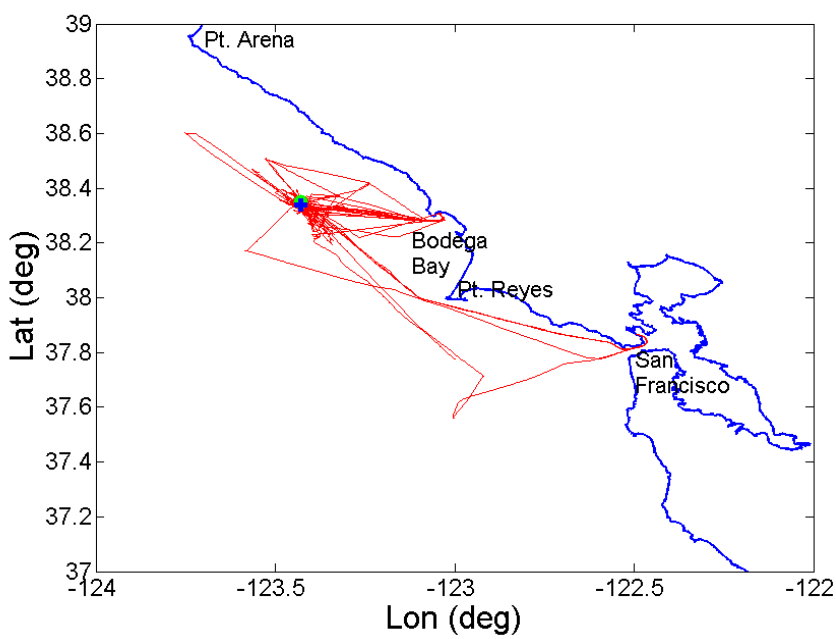

Figure 1. SPROUL track (red line) during the experiment with FLIP (blue cross) and NPS buoy (green circle) positions indicated.

FLIP was moored at 38.3377° latitude and -123.4282° longitude (about 26 km off the California coast), while SPROUL was performing trips during the period from 1 to 30 June, 2010 in the broad area around FLIP as shown in Fig. 1. Wave data were obtained from the waverider Datawell buoy of NPS moored at 38.3483° latitude and -123.4281° longitude (about 1.5 km from FLIP), which were analyzed as described in the report of last year. For the comparison between FLIP and SPROUL data (bow mast data at 12 m above sea level) the time periods selected were the ones when the distance between FLIP and SPROUL was less than 10 km. These were mainly the days of 13 and 17 June, 2010.

Quality Assessment of available FLIP sonic data: This part of the work indentified two issues with the FLIP data we have for the SPROUL measurement intercomparison. One is the large tilt of the sonic at 14 m altitude, the other is the substantial noise in the high-rate measurements. The tilt problem resulted in unrealistically large momentum fluxes because of the correlation between the vertical and horizontal velocity components. Attempts were made by estimating the tilt angles from the linear correlation between 10 minutes averages of w and u or v and assuming a zero daily average w. The sonic Cartesian system was then rotated with these tilt angles and new u, v and w values were estimated. This correction removed most of the high flux values in FLIP data, although corrections from the raw data may give better results. The high noise is associated with the droplets accumulating on the sonics' transducers (Tihomir Hristov, personal communication) and is thus uncorrectable. At this point, we are trying to get data from Dr. Tihomir Hristov from a level that may be less affected by droplets to better serve for the purpose of SPROULD/FLIP comparison.

Comparison of mean values and fluxes from FLIP and SPROUL: A direct comparison of the temporal variations from FLIP and SPROUL are shown in Figs. 2 and 3. These results are from the time periods when the distance between FLIP and SPROUL was less than 10 km. For the 13th of June both levels of FLIP measurements of wind speed agree with each other and with the SPROUL data. A small underestimation in SPROUL wind speed maybe due to the fact that SPROUL level (12 m) is below FLIP levels and probably in the surface-wave boundary layer. The agreement in wind direction is also quite good and during the rapid change of wind direction as wind speed decreased after 1500 UTC time. Air temperature from FLIP at 14 m follows well SPROUL measurements but with a bias of about 2 K. Air temperature from FLIP at 20 m shows periods of large discrepancy from 14 m level and SPROUL data. On the 17th of June the agreement in wind direction from all data is within 5 degrees, FLIP at 20 m wind speed agrees with SPROUL but FLIP 14 m wind speed shows large deviation and spikes. This is in agreement with the problems identified in data quality assessment that the FLIP sonic data from 14 m level is likely more problematic than other levels.

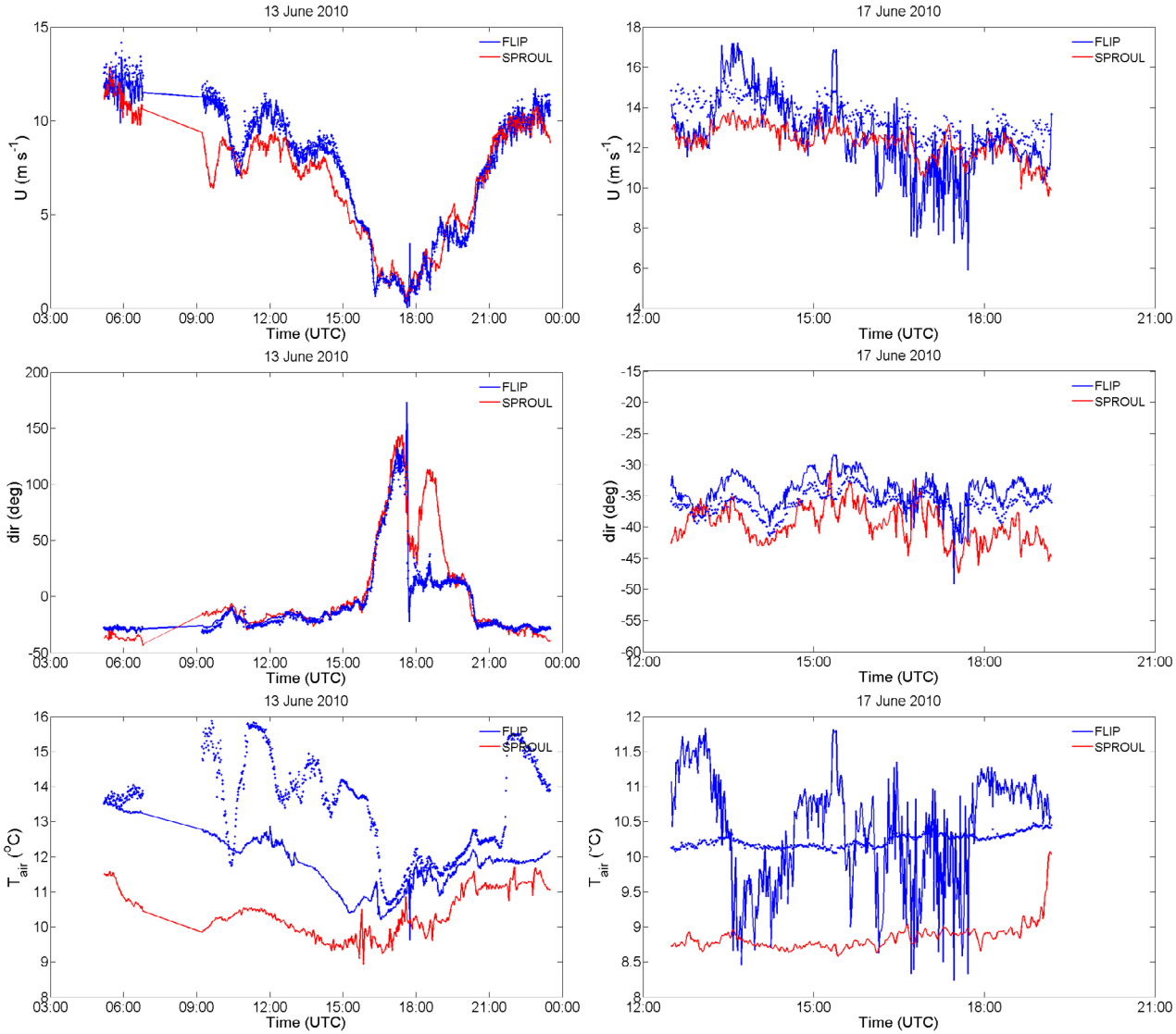

Figure 2. Time series of 10 minutes average of wind speed (U), wind direction (dir) and air temperature (T) from FLIP sonics at 14 (blue line) and 20 m (blue dots) above sea level for 13 and 17 June, 2010.

Figure 3 shows time series for FLIP and SPROUL of friction velocity and heat flux. While the FLIP 14 m level agrees well with 20 m level and with SPROUL data on the 13th of June, friction velocity is highly overestimated during a significant portion of the time periods. This probably has to do with incomplete correction of the tilt effects in high frequences, the effect of which also shows on the disagreement in heat flux from FLIP and SPROUL. The 20 m level measurements from the FLIP show similar spikes in heat flux. On the 17th of June the fluxes from FLIP 20 m agree with SPROUL data but the FLIP data from 14 m level show too high fluxes, which is in agreement with the co-spectra on that day shown in Fig. 4.

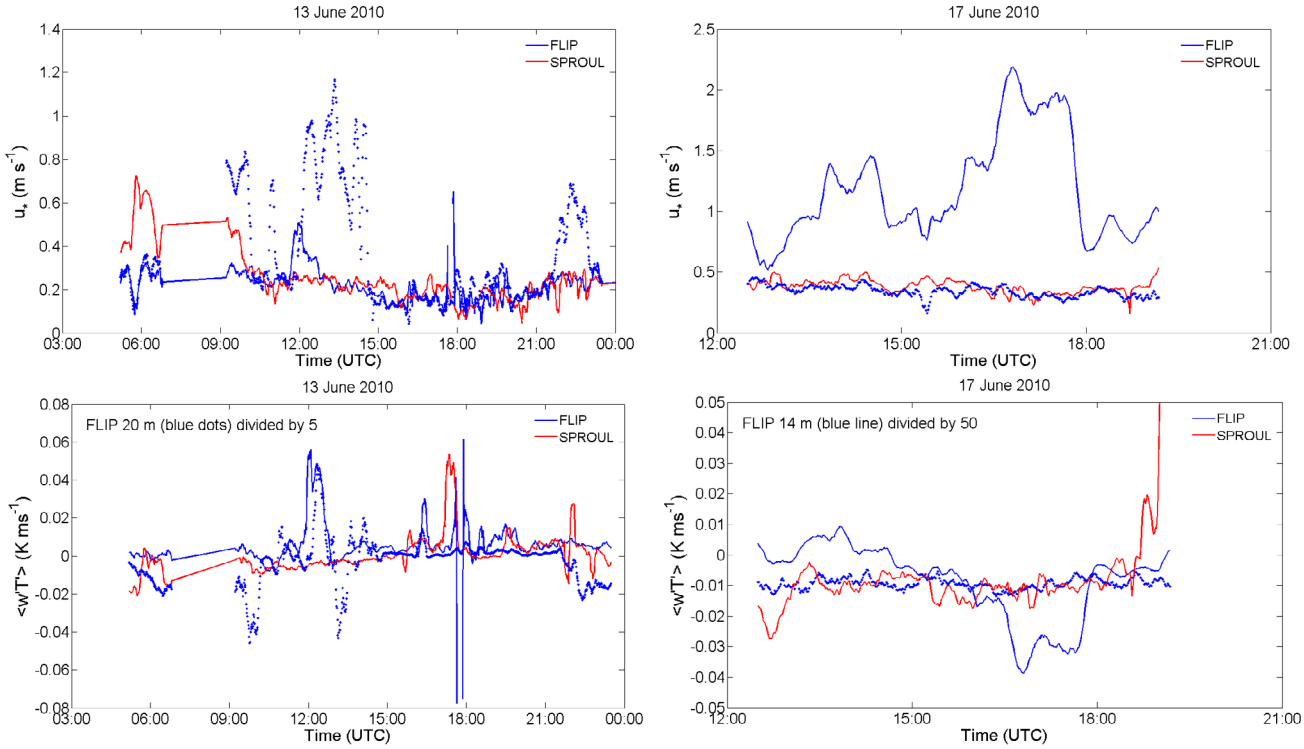

Figure 3. Time series of 10 minutes average of fiction velocity (u_*) and heat flux <w'T'> from FLIP sonics at 14 (blue line) and 20 m (blue dots) above sea level for 13 and 17 June, 2010.

Drag coefficients from FLIP data: Neutral transfer coefficients were estimated from data using the parameterizations of velocity roughness length that were described in last year's report. Surface layer flux-profile relationships were used to obtain 10-m wind in neutral stability from measurements at other levels under various stability influence. The results from COARE 3.0 bulk parameterization of turbulent fluxes with the same parameterization of velocity roughness length were also estimated. The measurements were also separated into swell and sea waves dominant cases according to the wave energy criterion mentioned above using wave data from NPS buoy near FLIP (data courtesy of Thomas Hebers).

Figure 4 shows drag coefficients from FLIP at the measurement levels against neutral wind speed. The velocity roughness used is Eq. (3) given in the previous year's report:

$$z_{0u}=1200h_s(h_s/L_p)^{4.5}+0.11\nu/u_*,$$

which was found to give the best agreement between measurements and bulk estimations. The smooth flow limit is $0.11\nu/u_*$ (ν is the kinematic viscosity of air and u_* is the friction velocity). The significant wave height h_s (defined as $4E^{1/2}$, E is the wave energy by wave power integration) and the time period T_p (L_p wavelength, $C_p=L_p/T_p$ is the phase speed) of the wave spectrum peak for mature sea waves are given by: $h_s=0.0248U^2$ and $T_p=0.729U$. The ratio h_s/L_p is the wave slope or steepness. All the above parameterizations are for sea waves and do not include swell waves. Thus, in time periods when swell dominates sea waves, these parameterizations are expected to fail. Figure 4 shows that swell dominates most of the FLIP measurement period (Fig. 4).

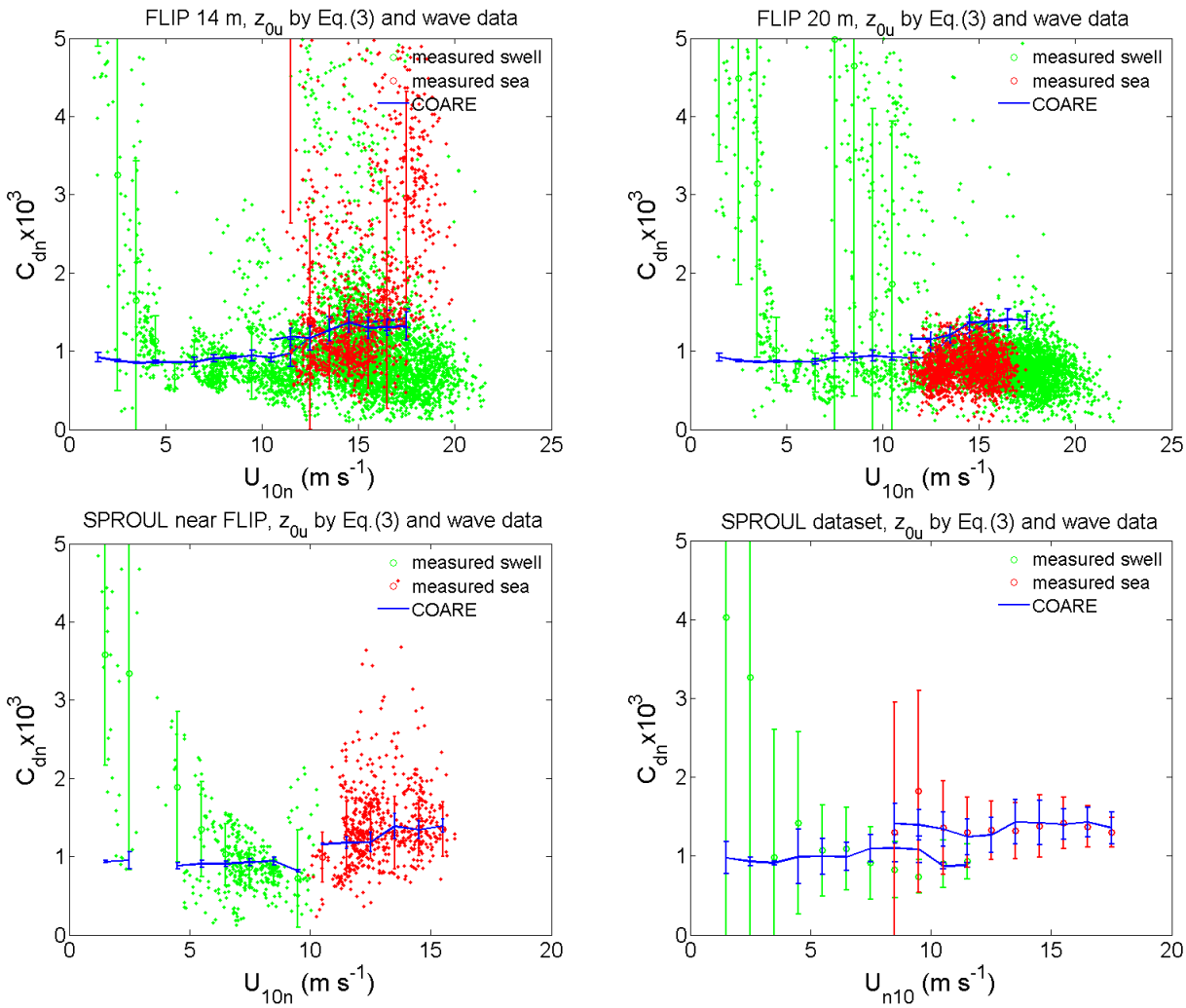

Figure 4. Neutral drag coefficient C_{dn} against neutral wind speed at 10 m above sea level U_{n10} in wind bins of 1 m s^{-1} with standard deviation (roughness length estimated from Eq. (3)). Top: results from R/P FLIP from all FLIP measurement period at 14 m (left) and 20 m (right) measurement levels; Bottom: results from R/V SPROUL near FLIP (left) and from all SPROUL measurement period.

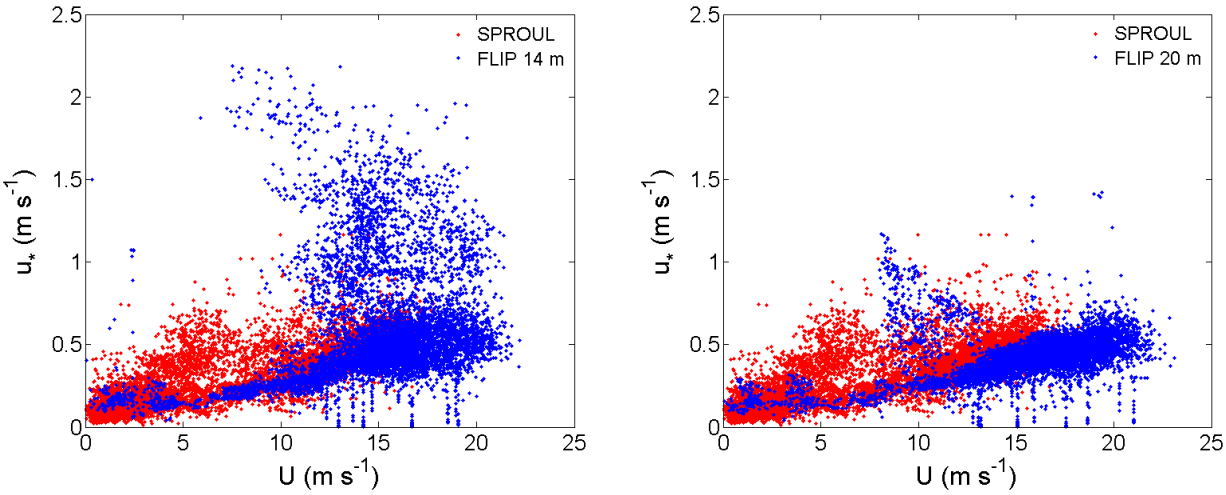

Figure 5. Friction velocity u_* against 10 minutes average wind speed from SPROUL and FLIP.

The measured drag coefficients at low wind speed show the well known rise due to swell effects, which has also been observed in SPROUL data as well as in previous field campaigns. Generally FLIP data at both levels seem to underestimate the drag coefficient and there are time periods (described in the previous sections) where the drag coefficient is highly overestimated due to measurement problems. Figure 5 shows scatter plots of friction velocity against wind speed for FLIP and SPROUL data. A near linear increase of friction velocity with wind speed is expected as observed in SPROUL data. FLIP data shows group of data points away from this linear behavior due to the measurement problems mentioned above and on average friction velocity is lower (underestimation) than SPROUL data. We will be working with the Dr. Tihomir Hristov using more FLIP data to understand the differences seen from the two platforms.

IMPACT/APPLICATIONS

The measurements described in the previous paragraphs make up a very useful dataset for the understanding of the behavior of the atmospheric boundary layer near sea surface under different wind and sea wave conditions.

TRANSITIONS

The results of the work presented in this report are a validation of SPROUL data. The analyses results of this project will potentially add in the improvement of the parameterization of turbulent fluxes near sea surface in mesoscale models and improvement of wave forecast models.

RELATED PROJECTS

Related project is the ONR High Resolution Wave Air-Sea Interaction DRI.