Understanding Near-Surface and In-cloud Turbulent Fluxes in the Coastal Stratocumulus-topped Boundary Layers

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LONG-TERM GOAL

The long-term goal is to understand the spatial and temporal variation of the surface fluxes in relation to the variability of the sea state and the stratocumulus-topped boundary layers.

OBJECTIVES

The objective of this project is to quantify the spatial and temporal variability of the turbulent fluxes in the Monterey Bay area. The analysis from this study provides the surface forcing to our collaborators (AOSN investigators) and enable us to understand these variabilities in relation to the sea states and the stratocumulus-topped marine atmospheric boundary layers (MABL) properties. The results will also be used to evaluate COAMPS for simulating the stratocumulus-topped MABL (STBL). Our work in FY03 was focused on the production of calibrated and time-synchronized high-rate wind turbulence, temperature, and specific humidity data and processed surface fluxes of momentum, sensible heat, and latent heat fluxes from the raw aircraft measurements of the Autonomous Oceanographic Sampling Network (AOSN-II) Experiment co-sponsored by the Monterey Bay Aquarium Research Institute (MBARI) and ONR. We also had a first indication of the spatial and temporal variability of the surface turbulent fluxes over Monterey Bay.

APPROACH

The raw measurements from the CIRPAS Twin Otter on the radome differential pressure, static pressure, and aircraft attitude angles, and aircraft motion needs to be combined and calibrated to generate high-rate wind turbulence data. This dataset is used to compute accurate turbulence and average quantities. The variability of the surface turbulence fluxes and variances will be linked with the large-scale temporal and spatial variability of the atmospheric and oceanic fields (mesoscale structure, flow patterns, stratocumulus, upwelling). The dataset will also be used to evaluate and improve the turbulence parameterizations of COAMPS mesoscale model for better simulation of the STBL.

Prof. Qing Wang is responsible for the overall project. Dr. John Kalogiros, an external research associate from National Observatory of Athens, Greece, is working on the data reduction. In situ observations were made by the Twin Otter research aircraft operated by the Center for Interdisciplinary Remote Piloted Aircraft Studies (CIRPAS) at the Naval Postgraduate School (NPS) during the AOSN-II experiment.

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WORK COMPLETED

1. We synchronized and processed (quality control and noise removal) the raw radome differential pressure data and the aircraft attitude angle measurements in order to retrieve the high-rate wind turbulence. We made the necessary calibration using observations from the maneuver legs designed for this purpose.

2. We calculated turbulence fluxes and variances from level legs near the surface and constructed preliminary surface maps of the fluxes, variances and average quantities for each flight.

3. This project started later in the fiscal year. Our present work is based on the dataset provided so far from AOSN aircraft measurement team. The large amount of flight data from the intensive AOSN field project this summer will be made available to us soon so that we can process and analysis the dataset more efficiently in FY04.

RESULTS

Calibration of wind estimate from raw aircraft data: On the CIRPAS Twin Otter a radome pressure system is used to measure the wind components through raw pressure measurements on the nose of the aircraft. The local wind field is significantly distorted by the aircraft body and wings and has to be corrected in order to correspond to the free air stream wind. The corrections that have to be made involve mainly corrections for the static pressure defect, the shape of the radome, and the upwash induced at the airplane nose by the aerodynamic shape of the wings. We used special aircraft maneuvers (speed run, pitch, yaw and reverse heading maneuvers) performed above the MABL in nearly non-turbulent air with small vertical wind velocity and steady horizontal wind in order to estimate these corrections. The final calibration of the attack and sideslip angles is shown in Figure 1.

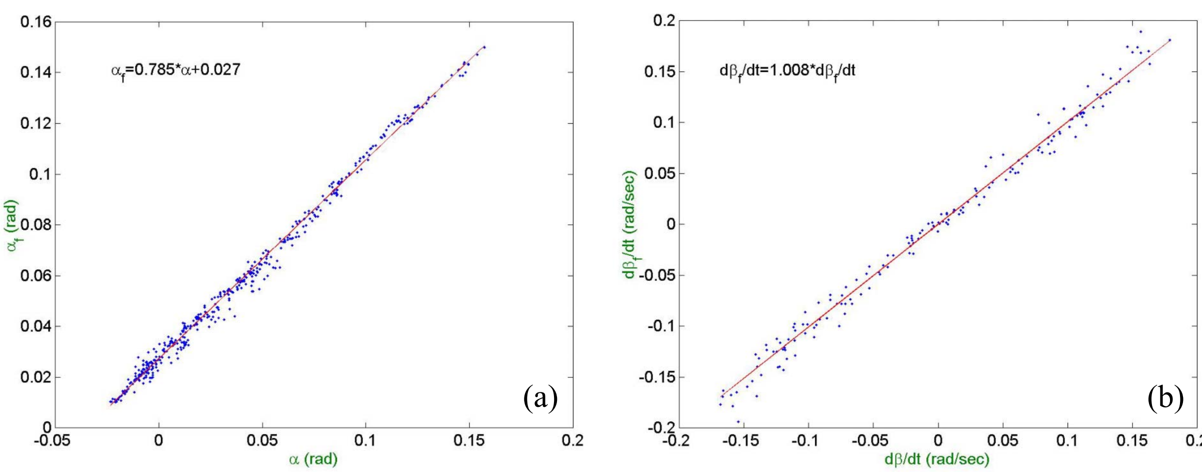

Figure 1. Calibration of attack (a) and sideslip (b) radome angles against free air streamestimations. The straight lines are best fit lines corresponding to the given equations.

We used a time differential method to compute the slope correction for the sideslip angle. The offset term of the linear correction was estimated from reverse heading data. The slope constant of the attack angle calibration is significantly less than unit due to the above mentioned upwash effect and it's value is critical in the correct estimation of the vertical wind velocity.

Surface mapping of turbulence quantities: Horizontal cross-section plots of the near surface (50-100 m above sea surface) fields of turbulence and average quantities reveal the spatial variabilities in the Monterey Bay region. As an initial attempt to locate significant mesoscale features and understanding of the temporal and spatial variability of various physical parameters, horizontal contour plots of flight level wind, temperature, turbulence variances and fluxes are generated for every Twin fights. Examples of these horizontal distributions from August 15, 2003 are shown in Figures 2, 3 and 4 for the mean fields and in Figure 5 and 6 for the turbulent statistics.

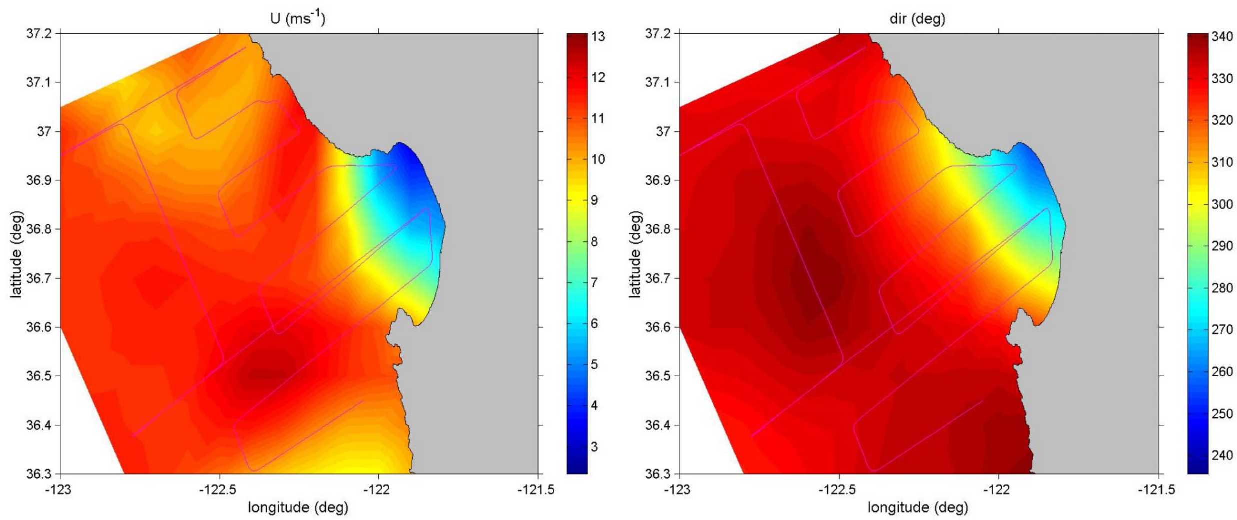

Figure 2. Near surface wind speed (U) and direction (dir) on 15th August 2003 over Monterey Bay. The flight legs used are also shown.

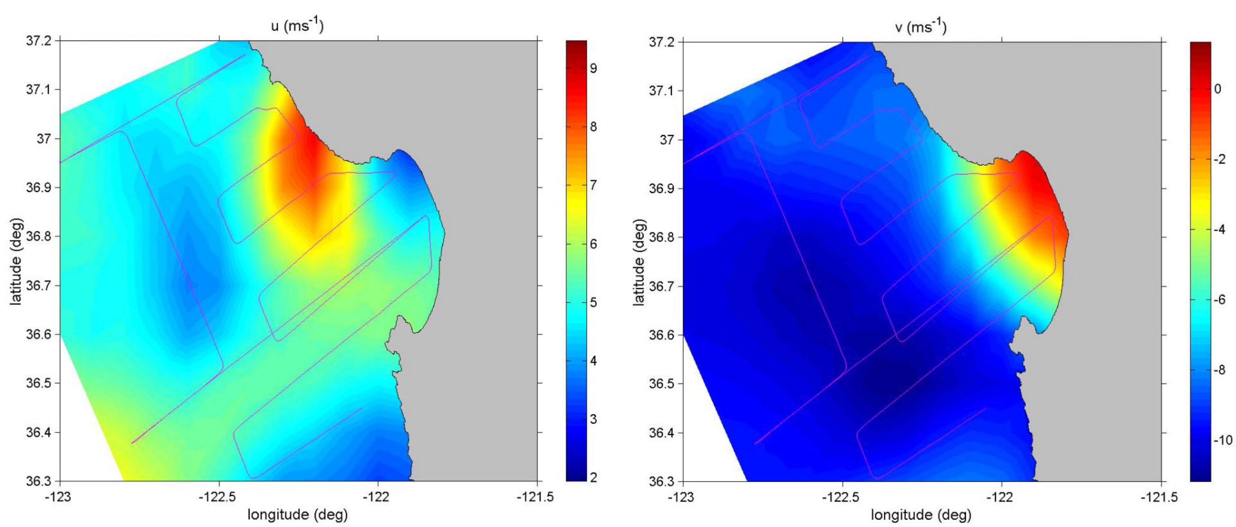

Figure 3. As in Figure 2, except for wind speed east (u) and north (v) components.

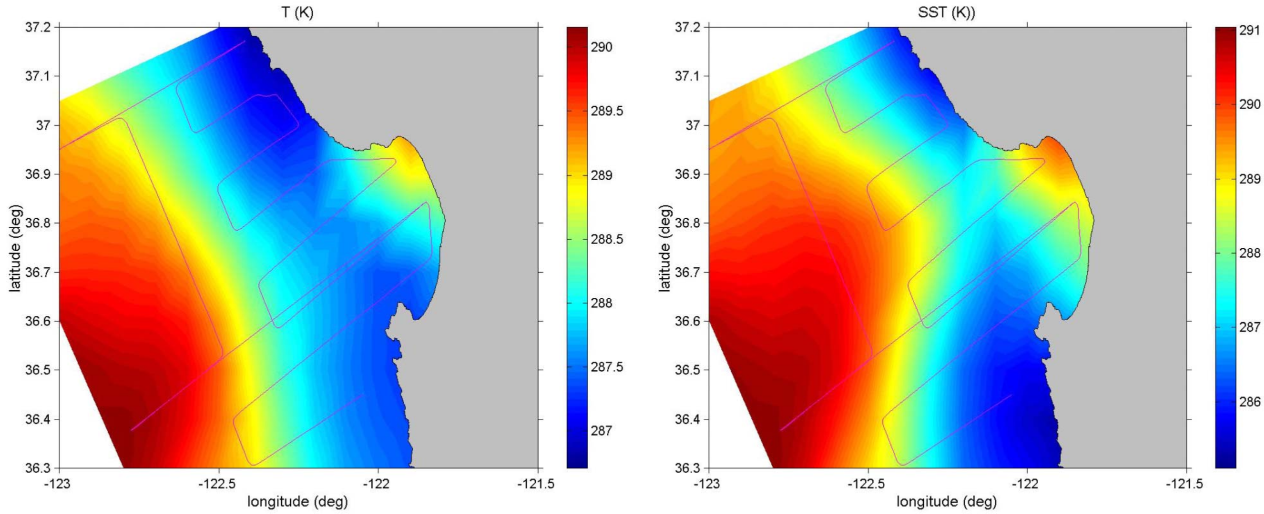

Figure 4. As in Figure 2, except for air temperature (T) and sea surface temperature (SST).

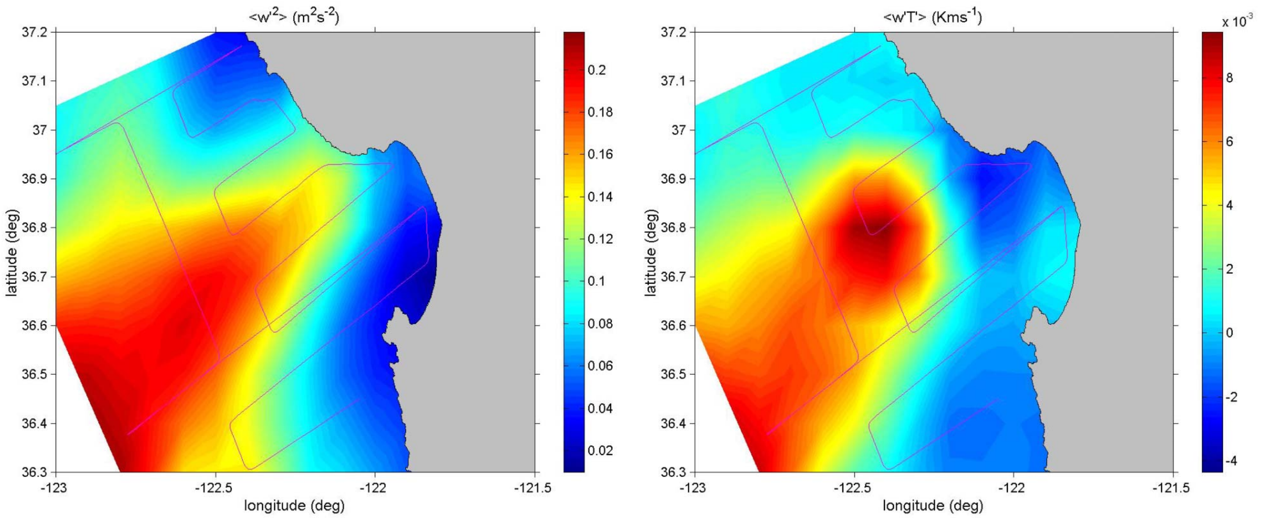

Figure 5. As in Figure 2, except for vertical wind variance (<w'2>) and heat flux (<w'T'>).

From Figures 2-6, it can be seen that the flow pattern is a northerly wind which is blocked and turned to onshore wind well in the bay. The wind components show that there is a strong east component at the northern part of the bay. As can be seen in air and sea surface temperatures there is an upwelling zone close to the shore except in the bay near St. Cruz, which is also observed from previous studies. The vertical velocity variance and heat flux show a region of strong turbulence extending from south-west to northeast at the north part of the bay. Finally, the momentum fluxes pattern seems to be linked with the wind speed components features mentioned above. From the initially processed results as shown above, it is clear that turbulent fields patterns should be important in the dynamics of the local MABL structure and in driving the ocean circulation. Further analysis to be carried out next project year is expected to improve the calibration and make further analysis on the nature of the turbulence variances and fluxes.

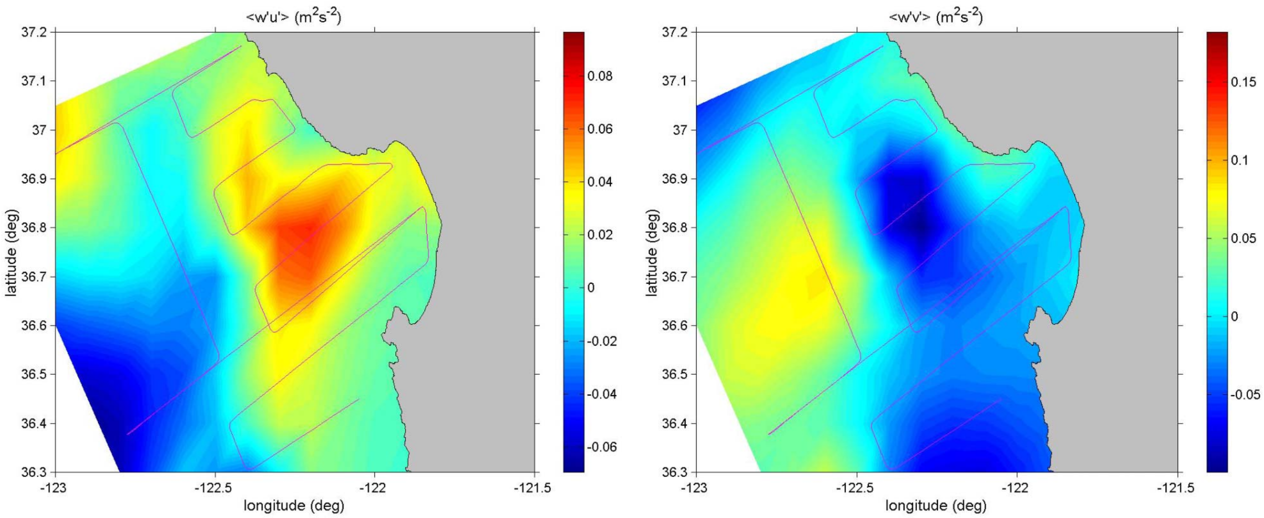

Figure 6. As in Figure 2, except for momentum fluxes <w'u'> and <w'v'> .

IMPACT/APPLICATIONS

The MABL structure in the Monterey Bay is quite complex and the surface turbulence fluxes play important roles in the the upper ocean dynamics in the area. Our study provide a more complete picture of the coastal air-sea interaction in addition to other AOSN dataset.

TRANSITIONS

The results of this project will potentially help to improve the turbulence parameterizations of COAMPS which is a critical point in STBL simulation.

RELATED PROJECTS

Related project is the AOSN-II Experiment co-sponsored by MBARI and ONR and other PI project (Award # N0001403WR20193).