Spatial Variations of the Wave, Stress and Wind Fields in the Shoaling Zone

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LONG-TERM GOAL

Our long term goals are to improve parameterization of surface fluxes in the coastal zone in the presence of wave growth, shoaling, and internal boundary layer development. These goals include improving the present form of similarity theory used by models to predict surface fluxes and stress over water surfaces and documenting development of internal boundary layers in the coastal zone that are currently not modelled correctly, particularly in cases of flow of warm air over colder water.

OBJECTIVES

Our objectives are to provide quality controlled data sets which include spatial variation of surface fluxes, stress and wave characteristics and provide vertical structure of the wind and thermodynamic variables in the coastal zone. The objectives also include both evaluation of present formulations for surface fluxes at the air-sea interface and evaluation of model simulations of internal boundary layer development.

APPROACH

The first approach has been implementation of an extensive literature survey on existing studies of air-sea interaction in the coastal zone and internal boundary layer development. The second approach is implementation of three field programs, one completed in fall of 1997 and two to be completed in 1999. The spring 1999 field program is designed to study the internal boundary layer in offshore flow, particularly in stable conditions. The third approach is data analysis and evaluation of existing boundary layer and surface flux formulations. The fourth approach is model comparisons with other groups.

WORK COMPLETED

The 1997 Shoaling Experiment is described in Sun et al. (1999). The NOAA LongEZ examined both the horizontal and vertical structure of offshore flow near Duck, North Carolina. The data was processed and quality controlled at Oregon State University by Dean Vickers under the guidance of Jielun Sun (NCAR). Flights were aligned and the data were composited. Aircraft soundings required special corrections for superficial oscillations in wind speed, most apparent with slant soundings.

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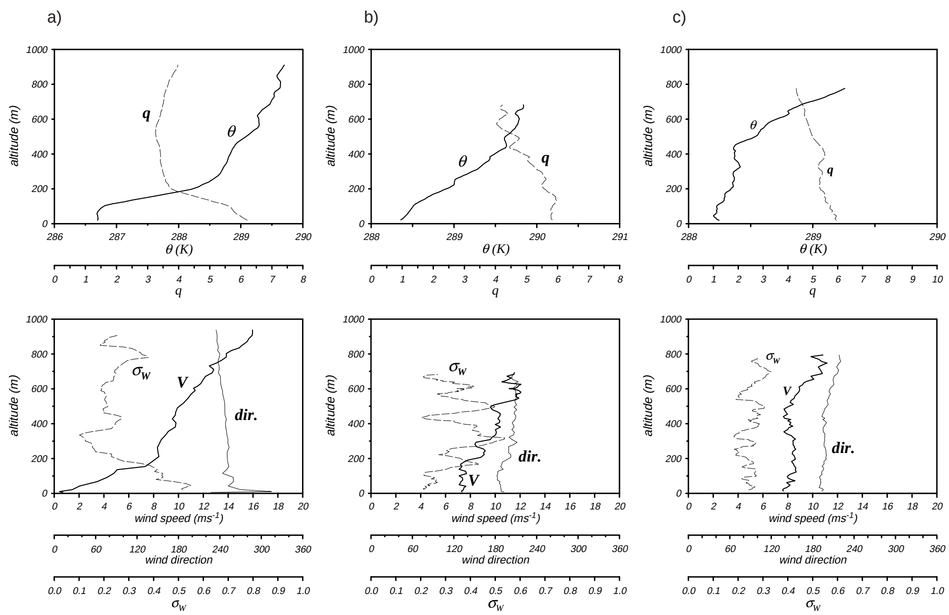
RESULTS

The literature has focused primarily on offshore flow corresponding to strong temperature advection. However on a day-to-day basis, offshore flow experiences a more modest land-sea temperature contrast. The 1997 Shoaling data indicate that with development of an internal boundary layer, residual turbulence above the internal boundary layer decays, leading to distinctly different depths of the old boundary layer and the new internal boundary layer. On the other hand, this data also indicates the existence of an "adjusting boundary layer", where a well-defined internal boundary layer does not develop. In general the momentum was less well-mixed than potential temperature or moisture. The latter two variables along with turbulence intensity were used to identify the vertical structure of the boundary layer.



Vertical soundings of potential temperature and specific humidity (upper panels) and wind speed and direction and the standard deviation of vertical velocity (lower panels) for three different soundings taken with fetches of approximately (a) 30 km, (b) 40 km and (c) 60 km during the morning of 3 November 1997. The effects of short term nonstationarity and spatial variation can not be separated in these soundings.

In some cases with offshore flow of warmer air over cooler water, the elevated turbulence above the apparent new boundary layer was as strong as the boundary-layer turbulence. The elevated turbulence could be due to elevated shear-generation and/or residual turbulence advected from the deeper boundary layer over land. The latter might be enhanced by acceleration of the flow formerly in the land boundary layer which is now detached from the thin stable marine boundary layer and the surface stress. These possibilities are under investigation. In some cases, the elevated turbulence is stronger than the surface based turbulence and it becomes difficult to define the boundary-layer depth. Figure 1 shows cases where a shallow marine mixed layer forms (panel a), the mixed layer collapses and the turbulence is actually stronger at higher levels (panel b) and a quasi-mixed layer is established in the lowest 500 m but the turbulence above the mixed layer is as strong as in the mixed layer (panel c). In the later case, the definition of the boundary layer is somewhat ambiguous.

Collectively considering all of the cases, one can imagine development of a stable internal boundary layer which thickens in the downstream direction, with the major allowance that the turbulence may be greater above the internal boundary layer. However, there is a further complication. Consultation of other aircraft soundings suggests that the vertical structure varies substantially even in the same region at similar times. Apparently, the vertical structure of the boundary layer is not stabilized. The turbulence evolves through a transitory stage where the turbulence increases over a layer of roughly 500-m thickness, substantially reducing the stratification in this layer. This stage is followed by weaker turbulence and re-stratification. For want of a better term, we use the term "adjusting boundary layers" to label the entire scenario.

IMPACT/APPLICATION

The results from the November 1997 Shoaling Experiment suggest that numerical models require substantial improvement before they can approximate offshore flows, particularly in the case of stable flows due to warm air advection over cooler water. The results of this field work also suggest modifying the spring experiment plan to include more repeated aircraft soundings at the same location and include flights inland to better understand the total mesoscale circulation system which influences the coastal zone.

RELATED PROJECTS

Analysis of offshore tower eddy correlation data is being carried out under grant N00014-98-0282 from the Office of Naval Research. This data allows analysis of detailed vertical structure in the lowest 40 m whereas the above work concentrates on horizontal structure in the coastal zone.

PUBLICATIONS

Mahrt, L., Dean Vickers, J. Sun, Timothy Crawford, Chris Vogel and Ed Dumas, 1999: Coastal Zone Boundary Layers. 13th Symposium on Boundary Layers and Turbulence. American Meteorological Soc. Dallas.

J. Sun, L. Mahrt, Dean Vickers, John Wong, Tim Crawford, Chris Vogel and E. Dumas, 1999: Air-sea interaction in the coastal shoaling zone. 13th Symposium on Boundary Layers and Turbulence. American Meteorological Soc. Dallas.