Marine Boundary Layer Physics

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LONG-TERM GOALS

Enhance understanding of coastal meteorology on the mesoscale scale and in the marine boundary layer (MBL) by an intensive modeling effort that is coordinated cooperatively with relevant field studies. Assess the role of mesoscale forcing in shaping the structure and dynamics of the coastal MBL. Advance understanding of the detailed turbulence mechanisms whereby heat, momentum, and moisture are exchanged between the atmosphere and underlying surface, whether it's land or water.

OBJECTIVES

The coastal MBL generally is highly inhomogeneous in space and temporally nonstationary. Turbulent fluxes vary rapidly in magnitude and may even change sign. Detailed studies are required to unravel the complex dynamics and physics of the coastal MBL. The objective here is to intensively examine turbulence within the MBL and its impact on flow dynamics with an emphasis on fundamental fluid behavior rather than parameterized physics.

APPROACH

Surface transfer at the air-sea interface and the resulting dynamic interactions between atmosphere and ocean will be examined for both realistic and idealized conditions. State-of-the-art large eddy simulation (LES) models, which directly resolve the energy-carrying eddies of a flow, will be used for studies requiring microscale detail. For meso-γ studies of the coastal MBL, the nested nonhydrostatic Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) model will be used and supplemented with field experimental data.

WORK COMPLETED

The effect of turbulent mixing upon the three-dimensional density currents that form in coastal regions, a result of the inhomogeneous forcing created by a land/sea interface, has been investigated using a LES model to explicitly resolve the turbulence. Previous studies of such phenomena have only parameterized such effects and have not resolved the 3D mixing occurring both at and behind the leading edge of the density current front. On the meso-γ scale, COAMPS and field data collected during the ONR COAST and Coastal Waves experiments (Rogers et al. 1998) have been used to investigate the MBL dynamics of supercritical flow along varying coastal orography. To isolate the nature of the flow dynamics, idealized experiments have been designed and conducted of wall-bounded supercritical flow. An additional study addresses the formation of atmospheric island wakes and the

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parameter space that controls whether the wakes are long and stationary, or instead form Karman vortices.

RESULTS

Analysis of the LES gravity current results shows that turbulence flux divergence is most important for the temperature equation. At any given location turbulent flux divergence is small relative to the momentum transport by the mean flow, but integrated over the density head the turbulent transfer is larger than the mean flow transport. For a density current the horizontal flux divergence is generally larger than the vertical flux divergence and thus cannot be neglected; in larger scale models this term is crudely parameterized and thus not well represented. Turbulent dissipation is found to be strongest at the leading edge of the frontal interface rather than in the region behind the head. Super-, sub-, and trans-critical flow responses have been demonstrated to occur in shallow, inversion-capped flow along the California coast based upon field observations and model simulations. Expansion fans and hydraulic jumps present in the observations have been successfully simulated with COAMPS. The dependence of island wakes upon upstream Froude number and MBL depth/island height ratio has been explored for adiabatic flow and is being investigated for the case of a heated island. In FY98 results were presented at the Battlespace Atmospherics Conference (San Diego), the Conference on Coastal Atmospheric and Oceanic Prediction (Phoenix), the Rossby-100 Symposium (Stockholm), and the Conference on Mountain Meteorology (Flagstaff).

IMPACT/APPLICATIONS

The littoral is considered the most important and challenging region for conducting military operations. Part of the challenge stems from the need for accurate prediction of the weather parameters (such as cloud ceiling, visibility, EM/ and E/O conditions, etc.) that impact naval forces in the littoral.
The desire from the fleet for detailed forecasts of boundary layer parameters in the littoral region is leading to mesoscale model simulations run at increasingly fine horizontal resolution (model grid spacing on the order of 1-20 km). It is at such scales where the proper treatment of boundary layer processes play an increasing role in the overall accuracy of the short-term (0-36 hour) mesoscale forecasts. It is these forecasts that will directly impact the decision making process in the Strike Warfare and general Naval operations. Fundamental understanding of boundary layer processes, particularly turbulent fluxes, is required in order to make practical advances in the treatment of such processes in NWP models.

TRANSITIONS

None

RELATED PROJECTS

Related 6.1 projects having document number N0001498WX400001 are BE033-03-4K (6.1-Meso) and BE033-02-4K (6.1-Aero). In 6.2 (N0001498WX400008) related projects are BE-35-2-18 (6.2 Meso), BE-35-2-20 (6.2-AeroNRL), and BE-35-2-44 (6.2 Param/Moist).

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