

## **Surface Flux Formulations in the Coastal Zone**

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<http://moppet.oce.orst.edu/rasex/rasex.html>

### **LONG-TERM GOAL**

Derive a new drag law and roughness length relationship for the coastal zone.

### **OBJECTIVES**

Our primary objective is to isolate the influences of wave age and fetch on the drag coefficient and surface roughness length. This includes examination of the influence of internal boundary layer development on heat and momentum fluxes in the coastal zone, that can lead to large deviations from existing similarity theory. The second main objective is to augment the wave age with more specific wave properties. The final objective is to provide the data sets to other modeling groups.

### **APPROACH**

Our initial objectives were realized by first quality-controlling the RASEX data and intercomparing fluxes between different levels. Different estimates of the "observed" roughness length using the profile and eddy correlation methods were compared. Using the observed values of the drag coefficient and roughness height, different existing relationships were tested and new formulations for the transfer coefficients for heat and momentum were developed. The analysis has been extended to a much larger RASEX data set outside the intensive period, which includes a large sample of offshore internal boundary layer cases.

### **WORK COMPLETED**

During the past year, the analysis of RASEX data emphasized offshore flow and formation of internal boundary layers using both the land mast and offshore masts. The turbulence energy budget was constructed for all of the tower levels. Case studies were constructed for periods with significant temperature advection from land. A number of simulations with a TKE model were performed for offshore flow of warm air over cold water when Larry Mahrt visited James Doyle at NRL in September. The work concentrated on modification of the model to study offshore flow. The work will recommence in late fall.

# Report Documentation Page

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## RESULTS

For the RASEX data, weakly convective internal boundary layers in flow of cooler air over warmer water are generally capped by a thick layer of downward buoyancy flux in the near coastal zone. Here, the vertically integrated buoyancy flux is small or even negative and the vertically-integrated turbulence is driven by shear-generation. Near the surface, the mixing and stress are less than predicted by existing similarity theory due to suppression of convective eddies by the boundary-layer top.

With advection of warm air over cooler water in the near coastal zone, the vertical structure may be quite different than that expected from traditional conceptual models of the internal boundary layer, even though the flow is only modestly stable ( $z/L < 0.5$ ). These cases occur most frequently in the afternoon with advection of warm air from the heated land surface. In some cases, the turbulence energy and stress increase with height, reaching an elevated maximum, and the transport of turbulence energy is downward toward the surface. We refer to these cases as “upside-down boundary layers”. This upside-down structure is observed in the near coastal zone with travel times less than 10 minutes (fetches generally less than 5 km).

What generates the upside-down structure? Firstly, the shear-generation term tends to increase with height in contrast to the usual boundary layer where it decreases rapidly with height. The elevated shear-generation is due to acceleration of flow which is only weakly coupled to the sea surface. Secondly, the turbulence advected horizontally from land in offshore flow is thought to decay more slowly at higher levels where the turbulence length scale is larger and travel time is shorter (stronger wind speed). The dissipation rate divided by the turbulence energy decreases with height for both stable and unstable cases indicating that dissipation is more effective near the surface. The latter expectations are based on numerical simulations briefly discussed below.

The above results are summarized in the first two panels of Figure 1.

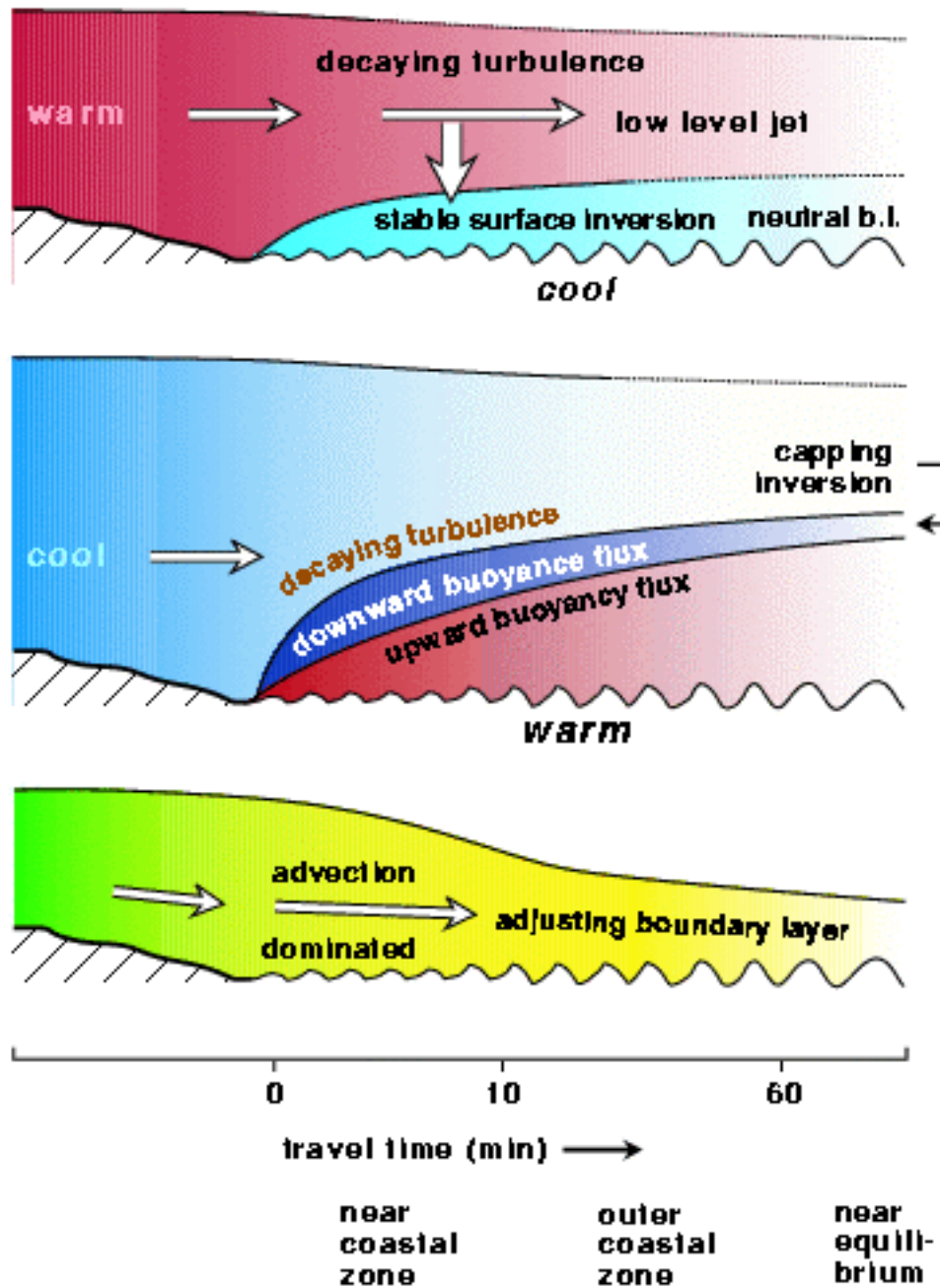


Figure 1. Hypothesized two-layer structure for offshore flow. a) Flow of warmer air over a cooler surface. The downward-pointing area indicates the possibility of downward transport of turbulence energy. b) Flow of cooler air over a warmer surface. c) Small air-sea temperature difference. The phase speed of the wind driven waves ( $C_p$ ) increases in the offshore direction. The values of offshore travel time for partitioning the near-coastal zone, outer coastal zone and near-equilibrium region are based on RASEX analyses. Transitions are gradual and travel time values probably vary dramatically between different situations.

The third case in Figure 1 must be examined in more detail with future analysis of aircraft data since the vertical scales are too large to be captured by the tower.

The numerical simulations reproduce some aspects of the above observations including elevated shear-generation of turbulence and downward transport of turbulence kinetic energy. However, the model develops pressure disturbances above the boundary layer which are of unknown origin. These disturbances exert an influence on the wind field. The cause of these disturbances and relationship to boundary conditions are being investigated. With weak offshore flow, the present vertical resolution in the model appears to be inadequate.

## **IMPACT/APPLICATION**

The above results indicate that flow of warm air over colder water will not be well described by many boundary-layer models in that the primary source of turbulence may be detached from the surface and propagate downward. Presumably TKE models have more potential for this flow situation than surface based boundary-layer models, such as used in virtually all operational models.

## **RELATED PROJECTS**

Work on an ONR grant entitled "Spatial Variations of the Wave, Stress and Wind Fields in the Shoaling Zone" (N00014-97-1-0279) will conduct an additional field program at Duck, North Carolina in November of 1999. This program will concentrate on spatial variations in the coastal zone using the LongEZ research aircraft and ground based sonic anemometers at the shore and on the pier.

## **PUBLICATIONS**

Vickers, Dean and L. Mahrt, 1999: Monin-Obukhov similarity theory in the coastal zone. To appear. *Quart. J. of the Roy. Met. Soc.*

Vickers, Dean and L. Mahrt, 1999: Monin-Obukhov similarity theory in the coastal zone. 13th Conference on Boundary Layers and Turbulence. Amer. Met. Soc. Dallas. 407-410.

Mahrt, L., Vickers, D., Edson, J., Wilczak, J., Hare, J. and J. Hojstrup, 1999: Boundary-Layer transitions in offshore flow. Submitted to *Boundary Layer Meteorology*.