

# **GENERALIZED DRAG LAW BASED ON RASEX AND FLIP DATA**

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## **LONG TERM GOALS**

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

## **OBJECTIVES**

The primary objective is to isolate the influences of wave age and/or 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 which can lead to large deviations from existing similarity theory. The second main objective is to replace the wave age with more specific wave properties. The final objective is to provide the data sets to other groups including LES modeling groups.

## **APPROACH**

The 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 method and eddy correlation 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 is being extended to a much larger RASEX data set outside the intensive period which includes a large sample of offshore internal boundary layer cases. The analysis is also being applied to the FLIP data set.

## **WORK COMPLETED**

We have expanded the RASEX data set to include all of the data outside the intensive period which is being quality controlled at the writing of this report. We have completed a study of the influence of internal boundary layer depth on the thermal roughness length and the transfer coefficient for heat in the coastal zone (Mahrt et al, 1997). The manuscript on the dependence of the drag coefficient on fetch and wave state was revised and just published (Vickers and Mahrt, 1997). We have made limited progress on the analysis of the LongEZ aircraft data from the FLIP experiment. We have begun a study of the internal boundary layer structure for different flow classes based on wind speed, stability and fetch.

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## RESULTS

For the coastal zone data collected during RASEX, the thermal roughness length was computed from the observed heat flux, skin temperature and traditional Monin-Obukhov stability functions. The thermal roughness length shows no clear relation to the momentum roughness length or roughness Reynolds number in contrast to previous formulations of the thermal roughness length. The momentum roughness length is strongly influenced by wave state while the thermal roughness length shows only a weak dependence on wave state except with wave breaking. The thermal roughness length and transfer coefficient decrease to small values in thin internal boundary layers which occur with short fetches over the water (Figures 1-2). The present data indicates that the internal boundary layer effect is more significant for unstable conditions compared to stable conditions. Suppression of large efficient transporting eddies by the low boundary layer top is one of several plausible explanations of the reduced heat flux. In addition, the heat flux at the 10 m observation level may be significantly less than the surface value for thin internal boundary layers. A larger more complete data set is required to better estimate the internal boundary-layer depth and separate the roles of internal boundary-layer depth, stability and wave state.

A new formulation of the thermal roughness based on the internal boundary layer depth scale is calibrated to the RASEX data. The corresponding transfer coefficient then depends on both the Obukhov length through the stability functions and internal boundary layer depth through the thermal roughness length. This approach was chosen instead of generalizing the Monin-Obukhov stability function to include the internal boundary layer depth since the latter approach combines two independent physical effects into one function and is more demanding in terms of data requirements. The relationship between the thermal roughness length and the internal boundary layer depth breaks down in the very stable case where the boundary layer is characterized by an upside down structure with the generation of turbulence occurring mainly detached from the surface.

As an alternative approach, the transfer coefficient is also formulated directly in terms of stability without requiring use of the roughness lengths. This formulation of the transfer coefficient includes the factor of two reduction in thin internal boundary layers. Although the moisture flux measurements appeared to be not as reliable, the transfer coefficient for moisture exhibited the same dependence on the internal boundary layer depth as that for heat except occurs with larger scatter.

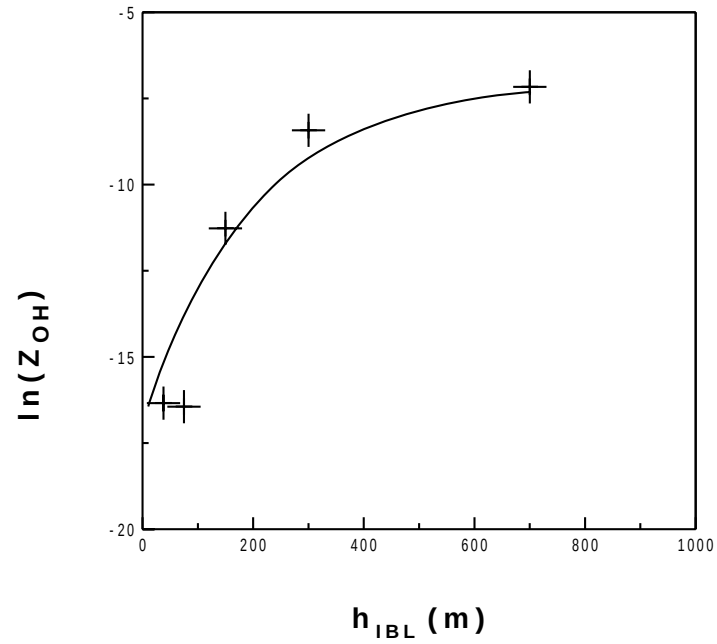


Figure 1. Dependence of the thermal roughness length on the internal boundary layer depth scale. The solid line is the model calibrated to this data.

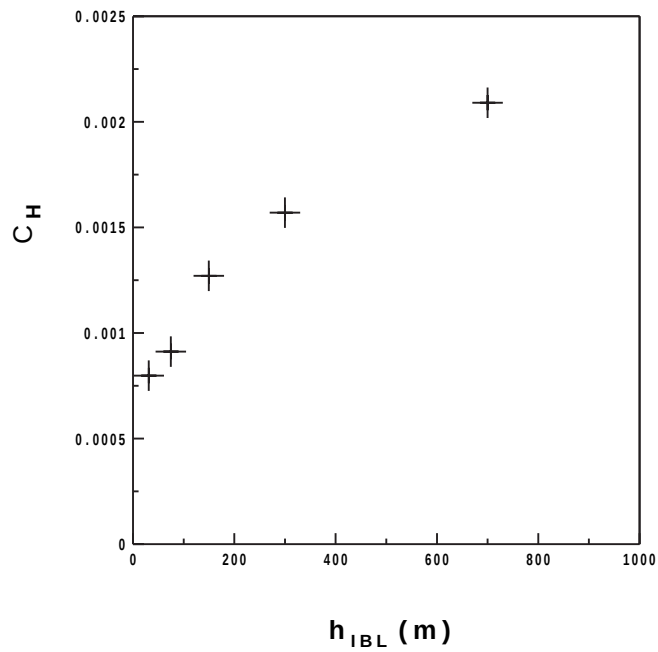


Figure 2. Dependence of the transfer coefficient for heat on the internal boundary-layer depth scale.

## **IMPACT**

The study of heat transfer in offshore flow (Mahrt et al., 1997) provides new formulations for the thermal roughness length and transfer coefficient for the coastal zone. These formulations include the important influence of the depth of the internal boundary layer on the heat transfer. While substantial errors are still expected and more data under a variety of conditions is needed, these formulations are a significant improvement upon existing formulations.

## **TRANSITIONS**

The formulas have been provided to James Doyle at the Navy Research Laboratory for inclusion in an experimental version of the regional model.

## **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 a pilot field program at Duck, North Carolina in November of 1997. This program will concentrate on spatial variations in the coastal zone using the LongEZ aircraft.

## **REFERENCES**

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