ON THE DYNAMICS OF THE MOLECULAR TEMPERATURE
BOUNDARY LAYER ABOVE THE SEA

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Abstract. Results of measurements carried out in the Caspian Sea in 1975 and 1976 have been used to study the thickness of the molecular temperature boundary layer and the difference of temperature in this layer as functions of hydrometeorological parameters. This thickness of the molecular temperature boundary layer was found to be dependent on both the friction velocity and wave phase. The same is also true for the temperature difference. On the other hand, it was not possible to observe a definite dependence upon the roughness of the surface of the sea and the stability.

1. Introduction

Existing in the atmospheric boundary layer and, more specifically, directly above the underlying surface is a layer in which processes of molecular conduction and diffusion assume considerable importance because of an increase in friction (Re ~ 1). This layer divides naturally into the so-called molecular boundary layer characterized by purely molecular processes having a thickness of about 1 mm and a buffer layer with molecular and turbulent processes and a thickness of almost 1 cm. The importance of the molecular boundary layer lies in the fact that a direct determination of fluxes depends on molecular conduction and diffusion processes and knowledge of the dynamics of this layer allows one to obtain information about the mechanism of air–sea interactions.

Heretofore, problems of measuring this extremely thin layer in nature, especially above the wavy sea, permitted one to measure the molecular temperature boundary layer only. Such measurements (see Hinzpeter and Lobemeyer, 1969; Clauss et al., 1970; Hupfer et al., 1974; and Foken and Kuznecov, 1977) invariably show, in the immediate vicinity of the water surface, an extremely high temperature gradient up to about 1000 K m⁻¹. Within the limits of experimental error, this gradient is linear and shows no signs of possible turbulence (see Figure 1). In addition, there can be observed, at the upper limit, an immediate and sharp transition to a layer with substantially lower gradients and with turbulence which increases as height increases. These results allow one to make the following conclusions:

— In the air layer nearest the water surface, heat exchange between the sea and atmosphere is by molecular conduction. Turbulent processes, if any, can be neglected.

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At the upper limit of this layer, turbulent exchange processes may be seen to occur suddenly.

These facts allow one to assume that a molecular temperature boundary layer is present above the sea. Absolutely analogous conditions have also been found by Chundžua and Andreev (1973, 1974) in the molecular temperature boundary layer on the water surface.

According to Foken (1978b), a comparison of nondimensionally plotted temperature profiles with laboratory measurements carried out by Žukauskas and Šlančiauskas (1973) showed no deviations in the region of the molecular boundary layer and the lower portion of the buffer layer. This has been the case not only above water, but even above fine-grained sand (Foken, 1978a).

During laboratory measurements it was possible to observe visually that three-dimensional flow is present in the 'laminar' flow boundary layer (Kline et al., 1967; Corino and Brodkey, 1969; Kim et al., 1971, in addition to other authors). Variations in wall pressure tend to produce lower-velocity regions which become mixed in the