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Dependence of Drag Coefficient on the Directional Spreading of Ocean Waves

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Drag coefficient C_d is one of the most important properties used in modelling the air-sea interactions. Most of the dependences employ the sea drag as a function of wind speed U_{10}. Coupling between the atmospheric boundary layer and the ocean surface is usually parameterised in terms of the drag coefficient C_d

$$\tau = \rho_a u_*^2 = \rho_a C_{10} U_{10}^2 \tag{1}$$

where τ is the wind stress at the ocean surface, ρ_a is the air density, U_{10} is the wind speed measured at standard 10m height and u_* is the friction velocity. Routinely, C_{10} is parameterized as a function of mean wind speed U_{10}, but the scatter of experimental data around such parametric dependences is very significant and has not improved noticeably over some 30 years. This scatter imposes a serious limitation on predictions that make use of sea-surface-drag parameterisations.

Babanin and Makin (2008) suggested that, apart from the wind speed, C_{10} depends on a number of other physical properties and phenomena, whose effect on the sea drag should be investigated and incorporated in the final parameterisation in order to reduce the scatter. These properties include, among possible others, the directional spreading of the surface waves. The aim of the present study is to investigate the drag coefficient as a function of such angular spreading.

This will be first done by means of numerical modelling with WBLM (Wave Boundary Layer Model, Chalikov and Rainchik, 2010). 1-D equations derived by Chalikov and Rainchik are used here for extensive calculations of WBL structure in order to investigate dependence of the drag coefficient on wind speed for different directional wave spectra. The results will then be compared with the field measurements conducted during the Lake George experiment (Young et al., 2005, Babanin and Makin, 2008).

In the Conclusion, we should say that the wind speed is not the only a parameter which can influence the sea drag coefficient. In particular, in this paper dependence of C_{10} on directional spreading of surface waves was investigated. It is shown that this coefficient increases with higher directional widths and stronger wind forcing. Influence of the wave directional spectrum on the sea drag was analysed for the first time, and it is very essential. Comparisons show that the WBL Model and Lake George field experimental data agree, where available, and this fact supports the model and the analysis of sea-drag dependences and asymptotic behaviours.

Account for the directional spread is therefore essential to predict the sea drag accurately and to improve parameterisations of C_{10}. It is apparent that scatter of existing parameterisations cannot be reduced by increasing measurement accuracy; it needs understanding and parameterising multiple physical influences, including the wave directionality.