Geophysical Research Abstracts, Vol. 8, 08836, 2006
SRef-ID: 1607-7962/gra/EGU06-A-08836

Effects of the surface waves on air-sea interactions of the sea spray

M.J. Francius and A.M.J. van Eijk

TNO Defense, Security and Safety, P.O. Box 96864, 2509 JG The Hague, The Netherlands.
Contact email: marc.francius@tno.nl

Aerosols are important to a large number of processes in the marine boundary layer. On a micro-meteorological scale, they influence the heat and moisture budgets near the sea surface. Since the ocean acts both as a source and a sink for aerosols, the sea spray droplets may transfer water vapour and heat (as well as pollutants and bacteria) through the air-sea interface. While aloft, sea-salt particles shrink by evaporation or grow by condensation through interaction with the humidity field. Hence, they may affect the fluxes of water vapour and heat, which may have an impact on larger scale meteorological processes and climatology.

The French-Dutch SeaCluse model is developed to study the non-linear interactions between the marine aerosol and the scalar fields of temperature and water vapour in the marine surface layer. The SeaCluse code simulates many aspects of the dynamics of sea spray droplets in the turbulent airflow over a wavy surface [1], the thermodynamic transformations of the spray droplets and the influence of the droplets on heat and water vapour fluxes in the lower marine atmosphere. The principal originalities of the model consist of explicitly taking into account the presence of the waves and of the simultaneous resolution of both dynamical and thermodynamic processes. The SeaCluse model computes along the vertical the budgets of droplet concentration, water vapour concentration and sensible heat, including turbulence and the dynamic and thermodynamic air-droplet interactions. The main output of the model consists of vertical profiles of aerosol concentration, humidity and temperature, as well as water vapour and heat fluxes. Since evaporating droplets of 30-50 microns radius have a favourable ratio of evaporation rate and residence time in the atmosphere, the SeaCluse model focuses primarily on this size range.

The first simulations with the SeaCluse model have demonstrated several interesting aspects of the behaviour of the sea spray droplets in the marine surface layer. The relatively large droplets of some tens of microns are dispersed more effectively than expected, and the vertical domain had to be extended beyond the surface layer to allow the droplets to disperse freely [2, 3]. Recent simulations reveal that the dynamic and thermodynamic processes of marine spray droplets are very sensitive to the choice of the model of turbulent airflow above the waves [4, 5]. Indeed both the mean wind field and the turbulence are modulated by the surface waves which affects, in turn, not only the mean macroscopic motion of the droplets but also their turbulent dispersion in the lower part of the atmospheric boundary layer, the constant stress layer. The original SeaCluse windfield is based on a modification of the Monin-Obukhov similarity theory to account for the presence of a wavy surface. A semi-analytic model based on the linearization of the Reynolds-averaged Navier-Stokes (RANS) equations is also available to account for the effects of the wave boundary layer on the droplet trajectories close to the sea surface. Although this model correctly reproduces the general characteristics of the wave boundary layer over a wide range of wind-wave conditions, it introduces some severe assumptions on the vertical structure of the wave-induced motions in order to make the problem tractable. Therefore it seems unlikely that the results of this model can reliably be extended to characterize the turbulent airflow over steep and almost breaking waves. Further the sea surface is oversimplified in a linear sinusoidal wave field. This has also prompted an effort to improve the description of the coupling between the wind and the surface waves.

In this study, we introduce a new model providing a numerical solution of the Reynolds-averaged Navier-Stokes equations over a wavy surface, together with turbulence closure schemes of the eddy-viscosity type (1st order). The effect of this new description of the turbulent airflow over waves on the dynamical behaviour of the sea spray particles will be discussed. In particular, a (jet) droplet transfer function will be established, which relates the number of droplets produced at the wave surface to the number of droplets at a height aloft, e.g., 10 meters. This transfer function is required for the assessment of the aerosol source function by the top-down method, which relates measurements at some height above the waves to the amount of droplets produced at the surface.

[1] Mestayer, P. G., A.M.J. Van Eijk, G. DeLeeuw and B. Tranchant (1996). Numerical simulation of the synamics of sea spray over the waves, J. Geophys. Res., 101, 20,771-20,797.

[2] Van Eijk, A. M. J., B.J.S. Tranchant and P.G. Mestayer (2001). SeaCluse: numerical simulation of evaporating sea spray droplets, J. Geophys. Res., 102, 2573-2588.

[3] Navarro, L (2003). Modelisation de la couche de surface atmospherique marine et des processus dynamiques et thermodynamiques des aerosols. Ph.D thesis. Universite de Nantes.

[4] Meirink, J.F (2002). The role of wind waves and sea spray in air-sea interaction. Ph.D thesis. Delft Technical University.

[5] Makin, V. K. (1998). Air-sea exchange of heat in the presence of wind waves and spray. J. Geophys. Res. 103, 1137-1152.