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Ocean response to varying wind in models with time and depth dependent eddy viscosity

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The work examines response of the upper ocean to time-varying winds. In the Ekman paradigm the effect of wind is considered as time-varying horizontally uniform tangential wind stress applied to the ocean surface and the turbulent diffusion of momentum is described employing the Boussinesq closure hypothesis via a single scalar eddy viscosity. Here, in contrast to all other works based upon the Ekman model and its extensions, we assume the eddy viscosity to be both time and depth dependent. Under the assumptions of linear dependence of eddy viscosity on depth and arbitrary time dependence of wind we find exact general solution to the Navier-Stokes equations which describes dynamics of the Ekman boundary layer in terms of the Green's function. Three basic scenarios are examined in detail: (a) An increase of wind ending up with a plateau; (b) Switch-off of the wind; (c) Strictly sinusoidal wind. Their analysis shows that accounting for time dependence of eddy viscosity substantially changes the response, compared to the predictions of the models with constant in time viscosity. We also report a severe limitation of the Ekman type models and their all known to us generalizations employed in modelling of the oceanic surface boundary layer. The Ekman current caused by a growing wind quickly becomes unstable with respect to inviscid inflectional instability. These instabilities are fast, which suggests spikes of dramatically enhanced mixing in the corresponding parts of the water column. This picture is incompatible with the existing paradigm which assumes a smooth diffusion of momentum.