EMS Annual Meeting Abstracts
Vol. 18, EMS2021-155, 2021
https://doi.org/10.5194/ems2021-155
EMS Annual Meeting 2021

Internal boundary layer development over lake surface in case of very young waves

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An internal boundary layer (IBL) may develop above lakes due to surface roughness change. The water surface has significantly less resistance to wind flow compared to the aerodynamically rough land surface. As a result, the wind speed increases along the fetch in the IBL over the lake surface. Consequently, the wind shear stress, which is the main driving force of waves and currents in lakes, also varies along the fetch. Measurements were carried out for six weeks in 2018 within a Croatian-Hungarian observational campaign in Lake Balaton in order to explore the IBL characteristics and establish a simple but reliable IBL model that can reproduce wind shear stress variability over the lake. One wind measurement station was installed on land and three over the lake along the fetch of the prevailing wind direction. On the landside, the wind profile was observed by a sodar from which characteristic land surface roughness lengths were derived by logarithmic profile fitting. On the waterside, momentum fluxes were measured with eddy-covariance (EC) technique at fetches of ~0.1, ~3.5, and ~6 km. To describe the water surface roughness dynamics, waves were simultaneously recorded with an underwater acoustic surface tracking at the middle station. An analytic IBL model is fitted to the measured wind speed and stress data employing wind speed classes. In the model, the wind stress development is dynamically coupled with the wave state by a wave age dependent roughness length function which is valid for highly fetch limited conditions and very young wave ages of ~2-15. The model is able to quantitatively reproduce wind speed, wind stress, and wave state development over the lake surface based on land observation of wind speed if the land roughness length is also known. Based on our model and measurements, we found a considerable spatial variability of momentum flux due to the change of wave state and wind speed along the fetch. The variation of momentum flux also influences the evolving sensible heat flux, which was also compared to the EC measurements.