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Observation of wave-driven air-water turbulent momentum exchange in a large but fetch-limited shallow lake

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Wind-induced waves play a key role in air-sea momentum and heat exchange. Surface gravity waves are dynamically changing roughness elements that result in a strongly variable drag at the air-water interface. Fetch-limited shallow lakes differ significantly from open ocean circumstances since the developing wave field is mostly characterized by young and growing waves that i) are steeper and can collapse by breaking or white-capping at lower wind speeds, and ii) travel with lower phase velocity. As a consequence, momentum and heat flux estimation methods arising from open ocean observations cannot be directly applied. It is already documented that drag coefficients can differ from open ocean values significantly (e.g. in the coastal zone); however, few attempts have been made to describe air-water turbulent exchange processes in case of large, but still fetch-limited shallow lakes.
In part of the FIMO-CROHUN measurement campaign air-water turbulent flux measurements were performed in Lake Balaton (mean depth is 3.2 m, surface area 600 km^2) for a one-month-long period. Turbulent momentum and heat fluxes were measured with eddy-covariance technique at an offshore station, while waves were simultaneously recorded with underwater acoustic surface tracking. Momentum fluxes were also recorded at two further stations closer to the shore. Altogether, the three locations were lying along the prevailing wind direction to be able to characterize the internal boundary layer development over the lake surface as well.
In this study we analyze the measured wind stress and surface waves to explore the variability of drag coefficient in case of small-amplitude high-frequency waves (typical peak wave period = 1.8 s, significant wave height = 0.25 m), but in terms of a relatively wide range of observed wind speeds (0.1-17 m/s) and wave heights (0.01-0.7 m). We compare our results with relevant model formulations that attempt to estimate momentum flux using different wave state parameterizations (i.e. wave age and wave-slope modified Charnock formulations) and show that observed drag coefficients are significantly larger than those established for oceanographic conditions.