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The effect of natural surfactants on air-water momentum exchange under light wind conditions in Lake Geneva

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Randomly distributed patches of smooth or rough/rippled surfaces are readily observed on most water bodies. Smooth surface patches are called natural slicks and typically form under low wind conditions (< 6 m s^{-1}) when biogenic surfactants in the surface microlayer accumulate above a certain threshold. They may have spatial scales from tens of meters to kilometers. Slicks suppress the formation of wind-induced Gravity-Capillary Waves (GCW), leading to altered surface reflectance of light and microwaves and can also affect near-surface turbulent motions. Therefore, it is of interest to determine the effect slicks can have on the air-water exchange of momentum, heat, and gas, which can influence the biogeochemical dynamics in the near-surface layer of lakes and oceans.

We investigated the spatiotemporal variability in momentum flux caused by slicks in Lake Geneva during several field campaigns using eddy covariance instrument setups mounted on an autonomous catamaran. The measurements were combined with aerial and shore-based imagery (both RGB and thermal). In addition, surface microlayer sampling was conducted from an accompanying boat to determine whether visually-identified smooth patches were associated with higher enrichments of fluorescent dissolved organic matter, a proxy for natural surfactants. Wavelet analysis was used to explore short-time (~1 min) averaged air-water exchange variations related to the transition from smooth slicks to rough surface areas that cannot be captured by the conventional eddy covariance analysis method.

Our results suggest that under light wind conditions and in the absence of short GCW on the surface of slicks, wind stress cannot be effectively transferred to the water, leading to reduced momentum exchange inside slicks compared to the surrounding non-slick areas. This results in lateral gradients in vertical mixing that can affect air-water exchange processes and contribute to spatial variability in surface temperature and near-surface heat content.