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Wind variability and sheltering effects on measurements and modeling of air-water exchange for a small lake

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Lakes with a surface area of less than 10 km^2 account for over 50% of the global cumulative lake surface water area, and make up more than 99% of the total number of global lakes, ponds, and wetlands. Within the boreal regions as well as some temperate and tropical areas, a significant proportion of land cover is characterized by lakes or wetlands, which can have a dramatic effect on land-atmosphere fluxes as well as the local and regional energy budget. Many of these small water bodies are surrounded by complex terrain and forest, which cause the wind blowing over a small lake or wetland to be highly variable. Wind mixing of the lake surface layer affects thermal stratification, surface temperature and air-water gas transfer, e.g. O_2, CO_2, and CH_4. As the wind blows from the land to the lake, wake turbulence behind trees and other shoreline obstacles leads to a recirculation zone and enhanced turbulence. This wake flow results in the delay of the development of wind shear stress on the lake surface, and the fetch required for surface shear stress to fully develop may be $\sim$O(1 km). Interpretation of wind measurements made on the lake is hampered by the unknown effect of wake turbulence.

We present field measurements designed to quantify wind variability over a sheltered lake. The wind data and water column temperature profiles are used to evaluate a new method to quantify wind sheltering of lakes that takes into account lake size, shape and the surrounding landscape features. The model is validated against field data for 36 Minnesota lakes. Effects of non-uniform sheltering and lake shape are also demonstrated. The effects of wind sheltering must be included in lake models to determine the effect of wind-derived energy inputs on lake stratification, surface gas transfer, lake water quality, and fish habitat. These effects are also important for correctly modeling momentum, heat, moisture and trace gas flux to the atmosphere.