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Key Points:

- Two-year eddy covariance measurements of large-lake latent, sensible heat, and CO_2 fluxes
- Western Lake Erie acted as a yearly CO_2 source but a small CO_2 sink in summers
- Western Lake Erie returns approximately 90% of annual rainfall via evaporation

Supporting Information:

- Supporting Information S1

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Diurnal to annual changes in latent, sensible heat, and CO_2 fluxes over a Laurentian Great Lake: A case study in Western Lake Erie

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Abstract To understand the carbon and energy exchange between the lake surface and the atmosphere, direct measurements of latent, sensible heat, and CO_2 fluxes were taken using the eddy covariance (EC) technique in Western Lake Erie during October 2011 to September 2013. We found that the latent heat flux (*LE*) had a marked one-peak seasonal change in both years that differed from the diurnal course and lacked a sinusoidal dynamic common in terrestrial ecosystems. Daily mean *LE* was 4.8 ± 0.1 and 4.3 ± 0.2 MJ m^{-2} d^{-1} in Year 1 and Year 2, respectively. The sensible heat flux (*H*) remained much lower than the *LE*, with a daily mean of 0.9 ± 0.1 and 1.1 ± 0.1 MJ m^{-2} d^{-1} in Year 1 and Year 2, respectively. As a result, the Bowen ratio was <1 during most of the 2 year period, with the lowest summer value at 0.14. The vapor pressure deficit explained 35% of the variation in half hourly *LE*, while the temperature difference between the water surface and air explained 65% of the variation in half hourly *H*. Western Lake Erie acted as a small carbon sink holding -19.0 ± 5.4 and -40.2 ± 13.3 g C m^{-2} in the first and second summers (May–September) but as an annual source of 77.7 ± 18.6 and 49.5 ± 17.9 g C m^{-2} yr^{-1} in Year 1 and Year 2, respectively. The CO_2 flux (F_{CO_2}) rate varied from -0.45 g C m^{-2} d^{-1} to 0.98 g C m^{-2} d^{-1}. Similar to *LE*, F_{CO_2} had noticeable diurnal changes during the months that had high chlorophyll *a* months but not during other months. A significantly negative correlation ($P < 0.05$) was found between F_{CO_2} and chlorophyll *a* on monthly fluxes. Three gap-filling methods, including marginal distribution sampling, mean diurnal variation, and monthly mean, were quantitatively assessed, yielding an uncertainty of 4%, 6%, and 10% in *LE*, *H*, and F_{CO_2}, respectively.

1. Introduction

Lakes play important roles in determining local, regional, and even global climate through complex interactions of biophysical and biogeochemical processes [*Rouse et al.*, 2005; *Cole et al.*, 2007; *Nordbo et al.*, 2011]. The Laurentian Great Lakes contain 20% of the Earth's surface freshwater and are highly influential on water and carbon budgets in the North America. As the largest inland water ecosystem, the albedo, heat capacity, roughness, surface evaporation, and greenhouse gas exchange of the Great Lakes differ greatly from those in the surrounding landscapes [*O'Donnell et al.*, 2010]. Understanding these exchanges and the environmental controls over this open water surface is therefore critical when quantifying the influences on the regional climate and weather [*Vesala et al.*, 2006; *Liu et al.*, 2009; *Polsenaere et al.*, 2013]. Yet the changes of carbon and water fluxes over the lake surfaces have not been reported, especially at broader temporal scales (monthly, seasonal, and yearly), due to the difficulties in collecting reliable observations over the open water [*Atilla et al.*, 2011; *Bennington et al.*, 2012].

Previous studies reported that inland lakes have significant impacts on local/regional water and energy cycles [*Eugster et al.*, 2003; *Long et al.*, 2007; *Liu et al.*, 2012]. Globally, lake evaporation (*E*) is an important atmospheric moisture source that returns ~60% of annual lake precipitation to the atmosphere [*Oki and Kanae*, 2006], affecting water resources, climate, and vegetation at multiple spatial-temporal scales [*Blanken et al.*, 2000; *Xiao et al.*, 2013]. Accurate information on the exchanges of energy and water between the lake surface and the atmosphere is also the most important process to include when modeling the feedback interactions between lake and climate. In addition to an obvious shortage of flux data over lake surfaces, it remains unclear whether the physical processes that govern the exchanges of water and energy during a single climatic period, or a specific location, can be extrapolated to