How Could Lake-Effect Snow Storms Evolve in a Warming Future Climate?

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When cold, dry air travels over a relatively warmer lake, lake-effect snow (LES) develops due to an increase in moisture flux from the lake to the atmosphere, which in turn promotes cloud formation and subsequent precipitation. A destructive LES storm struck the Buffalo region in New York, from November 17-20, 2022. Buffalo, located at the eastern end of Lake Erie and subject to winter winds that sweep across the lake, was inundated with nearly 7 feet of snow, prompting the declaration of federal emergencies by multiple counties. The LES storm highlighted the need for at-risk communities to enhance their preparedness for comparable future incidents. Using a cloud-resolving 4 km scale, we investigated how such an LES storm might manifest in a warmer future climate by employing the Pseudo-Global Warming (PGW) method and a two-way coupled lake-atmosphere regional climate modeling system. The modeling system comprises a two-way coupled Weather Research and Forecasting (WRF) model and a Finite Volume Community Ocean Model (FVCOM)-based three-dimensional lake model. Under the PGW methodology, the future atmospheric forcing necessary for our regional climate modeling system was derived from a reanalysis climate dataset by incorporating projected atmospheric changes from a variety of CMIP6 earth system models. Furthermore, we integrated the warming signals in the lakes by utilizing the projected lake conditions obtained from a regional climate modeling system that was previously established and also incorporated an FVCOM-based lake model. According to our findings, the total storm precipitation for such an event by the end of this century could increase by 14% under a high-emission scenario, with an increase in rainfall at the expense of snowfall. Under the present-day climate conditions, snowfall was the primary type of precipitation experienced during the event. However, in a warmer future climate, the distribution of precipitation might be nearly equal between snowfall and rainfall. By conducting two additional simulations in which either the lake or atmosphere is warmed individually using the projected future conditions, we found that the warmer lakes primarily contributed to the increase in storm precipitation through increased evaporation, while the warmer atmosphere primarily influenced the form of storm precipitation during such an LES storm in the future.