EGU24-5495, updated on 11 Sep 2024
https://doi.org/10.5194/egusphere-egu24-5495
EGU General Assembly 2024

Improvements of Radiative Transfer Processes in CoLM-Lake based on applications in in-situ lake simulations

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Lakes play an important role in the context of climate change response, necessitating accurate simulation of their thermal states to address associated challenges. Despite the progress in lake modeling, the description of several processes within current models require improvement. Traditional 1-D models often neglect the extinction effect of lake ice and oversimplify the extinction coefficient of lake water with a parameterized schemes. Moreover, the radiative transfer scheme adheres to the conventional Beer law. This study aims to enhance the radiative transfer process within the CoLM-Lake (The Common Land Model – Lake scheme). Implementation steps involve integrating observed water extinction coefficients for individual lakes, introducing the ice extinction coefficient, distinguishing radiation calculations between the visible light and infrared band, and replacing the traditional Beer law with a two-stream approximation scheme. The research analyzes simulation results regarding to freeze-thaw cycles, latent heat flux, sensible heat flux, lake surface temperature, and vertical temperature profiles. Results indicate that the simulated European lake surface temperatures driven by ERA5-LAND outperforms those for American lakes by CoLM-Lake. Incorporating observed water extinction coefficients, adding ice extinction, and employing the two-stream approximation scheme results in slight changes to the freeze-thaw date, but significant variations in ice thickness. For lakes with greater depths, the simulated latent and sensible heat flux exhibit substantial improvements, with more consistency with observed data. Validation of vertical temperature profiles for Nam Co (92m) and Sparkling (18m), two representative lakes, reveals that the original CoLM-Lake scheme overestimates/underestimates the upper lake temperature of Nam Co during summer/winter, and underestimates the winter upper temperature and summer lower temperature of Lake Sparkling. However, considering ice extinction and implementing the two-stream approximation mitigates these simulation errors. The study further incorporates ice dynamic processes into CoLM-Lake, distinguishes lake ice ages, and differentiates ice between blue and white ice, with subsequent evaluation. In conclusion, adopting the proposed scheme enhances the physical processes within CoLM-Lake, resulting in improved simulation performance.