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A Critical Look at Machine Learning Algorithms in River/Stream Water Temperature Modeling

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As climate change continues to impact stream systems worldwide, water temperature is an increasingly important indicator of distribution patterns and mortality rates among fish, amphibians, and macroinvertebrates. Technological advances tracing back to the 1960s have improved our ability to measure stream water temperature (SWT) at varying spatial and temporal resolutions, for the fundamental goal of better understanding stream function and ensuring ecosystem health. Despite significant advances, there continue to be a large number of stream reaches, stream segments and entire catchments that are difficult to access for a myriad of reasons, including but not limited to physical limitations. Moreover, there are noted access issues, financial constraints, and temporal and spatial inconsistencies or failures within situ instrumentation.

Over the last few decades and in response to these limitations, statistical methods and physically-based computer models have been steadily employed to examine SWT dynamics and controls. Most recently, the use of artificial intelligence, specifically machine learning (M.L.) algorithms, has garnered significant attention and utility in hydrologic sciences, specifically as a novel tool to learn yet-to-be-discovered patterns from complex data and attempt to fill data streams and knowledge gaps. Our review of publications focusing on stream water temperature modeling and prediction identified a similar number (~26) of publications utilizing M.L. in the previous four years (2020-2023), as were published in the previous 19 years, (2000-2019).

The objective of this work is three-fold: first, to provide a concise review of the utilization of M.L. algorithms in stream water temperature modeling and prediction. Second, to review M.L. performance evaluation metrics as it pertains to SWT modeling and prediction and identify the commonly-used metrics as well as suggest guidelines for easier comparison of M.L. performance across SWT studies. Finally, we examine where progress has been made in our understanding of the physical system from the use of M.L. in SWT modeling and prediction, and identify where progress is still needed to advance our understanding of spatial and temporal patterns of stream water temperature.