Interpretable Framework of Physics-guided Neural Network for Water temperature Simulation

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Abstract

With the development of large-scale rice cultivation management initiatives in East Asia, there is concern that a reduction in the number of human cultivators per unit area may lead to poor water management, which could result in decreased land productivity, owing to abnormal high- and low-temperature damage to crops. Accurate simulation of paddy field water temperature is important for studying its impact on crops and for providing timely information to aid in decision making for more efficient management under limited resources. We propose a neural-network framework that considers the heat transfer by the vegetation canopy and applies physical-theory constraints in its training. A novel tuning method is proposed to cope with the trade-off between water temperature accuracy and physical consistency during training to ensure that the calculated water temperature variations in a paddy field enjoy high accuracy and physical consistency. In the experiments, the proposed framework outperforms (with RMSE 0.78°C) both physical process models (with RMSE 1.06°C) and pure neural-network models (with RMSE 0.9°C) while maintaining high accuracy in the case of sparse datasets. Furthermore, an attention-mechanism input layer is integrated into the model to rank feature importance, providing global interpretation to the proposed framework. We also perform sensitivity analysis on the physical process and propose models to compare their different strategies of feature ranking. The results show that the two methods have different sensitivities to different types of feature patterns, but they complement each other. In summary, the proposed model is credible and stable for practical applications and has the potential to guide more efficient paddy management.

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1