基於物理法則的人工智慧方法
應用於西北太平洋之海表溫度重建技術
A Physics-Informed AI Approach for Reconstructing SST from Satellite Observation over the Northwestern Pacific

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Abstract

Sea surface temperature (SST), an important indicator for studying energy exchange between the ocean and the atmosphere, plays a crucial role in regulating climate systems and weather patterns. Variations in SST across different spatial and temporal scales provide valuable insights into changes in oceanic heat distribution, air–sea interactions, and marine environmental conditions. Hence, long-term and short-term monitoring of marine environments, combined with comprehensive analysis of observational data, is essential for providing continuous and reliable SST fields. These efforts contribute to a deeper understanding of complex ocean dynamics, support sustainable marine resource management, and enhance disaster prevention.

Geophysical parameters derived from remote sensing techniques enable continuous, large-scale observations with high spatial and temporal resolution. However, satellite-based infrared remote sensing faces a major challenge due to atmospheric interference, particularly cloud contamination. The presence of clouds often leads to substantial data gaps, reducing the completeness and reliability of SST products and consequently limiting subsequent marine environmental analyses and applications.

In this study, we utilize SST datasets from Himawari-9 and propose a physics-informed machine learning (PIML) method to reconstruct daily SST fields over the entire northwestern Pacific Ocean. In particular, a Radial Basis Function which explicitly incorporates the advection-diffusion processes of environmental fluids is embedded into the network architecture to effectively learn and estimate SST from temporal and spatial perspectives. Overall, PIML method has showed excellent performance in full-domain SST reconstruction, achieving a significant improvement compared to conventional statistical methods, such as Data Interpolation Empirical Orthogonal Functions (DINEOF).

Key words: Sea surface temperature; Reconstruction; Satellite observation; Physical process; Machine learning