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Medium- to long-term forecast of sea surface temperature using EEMD-STEOF-LSTM hybrid model

Rixu Hao[1,2], Yuxin Zhao[1,2], Xiong Deng[1,2], Di Zhou[3], Dequan Yang[1,2], and Xin Jiang[1,2]
[1]College of Intelligent Systems Science and Engineering, Harbin Engineering University, Harbin, China
[2]Engineering Research Center of Navigation instrument, Ministry of Education, Harbin, China
[3]China ship development and design center, Wuhan, China

Sea surface temperature (SST) is a vitally important variable of the global ocean, which can profoundly affect the climate and marine ecosystems. The field of forecasting oceanic variables has traditionally relied on numerical models, which effectively consider the discretization of the dynamical and physical oceanic equations. However, numerical models suffer from many limitations such as short timeliness, complex physical processes, and excessive calculation. Furthermore, existing machine learning has been proved to be able to capture spatial and temporal information independently without these limitations, but the previous research on multi-scale feature extraction and evolutionary forecast under spatiotemporal integration is still inadequate. To fill this gap, a multi-scale spatiotemporal forecast model is developed combining ensemble empirical mode decomposition (EEMD) and spatiotemporal empirical orthogonal function (STEOF) with long short-term memory (LSTM), which is referred to as EEMD-STEOF-LSTM. Specifically, the EEMD is applied for adaptive multi-scale analysis; the STEOF is adopted to decompose the spatiotemporal processes of different scales into terms of a sum of products of spatiotemporal basis functions along with corresponding coefficients, which captures the evolution of spatial and temporal processes simultaneously; and the LSTM is employed to achieve medium- to long-term forecast of STEOF-derived spatiotemporal coefficients. A case study of the daily average of SST in the South China Sea shows that the proposed hybrid EEMD-STEOF-LSTM model consistently outperforms the optimal climatic normal (OCN), STEOF, and STEOF-LSTM, which can accurately forecast the characteristics of oceanic eddies. Statistical analysis of the case study demonstrates that this model has great potential for practical applications in medium- to long-term forecast of oceanic variables.