Machine Learning Techniques Promote the Study of Internal Solitary Wave Dynamics in the Global Oceans

XIAOFENG LI1, XUDONG ZHANG1

1 Institute of Oceanology, Chinese Academy of Sciences, China

Internal solitary waves (ISW) are widely distributed globally and significantly affect the ocean environment and offshore activities. ISWs are characterized by large amplitude, long-wave crest, and long-propagation distance. Amplitude and propagation speed are two key dynamic parameters of ISW. Retrieval of these two parameters from satellite images with traditional methods suffers from low accuracy, time-costing, and energy-consuming problems. Machine learning techniques show strong abilities when incorporating multidimensional data and handling nonlinear problems, which can improve the accuracy and efficiency of the ISW amplitude retrieval and forecast. ISW amplitude can be accurately measured with field experiments, but the in-situ data is limited in number. Therefore, ISW lab experiments were designed following the Similarity Law in fluid mechanics, which is more easily collected and can serve as an additional data source for ISW studies. We implemented a transfer learning model to retrieve IW amplitude from satellite images to use the lab data efficiently. The model is purely data-driven, pre-trained with lab data, and re-trained with satellite/in-situ data. A short connection was incorporated into the transfer learning framework to reduce information loss. Compared with the classic KdV equation-based method, the developed model was more accurate. For ISW with an amplitude exceeding 100 m, the model can be expected to get an absolute error of 10 m. We developed an ISW propagation speed model based on a large dataset of 810 quasi-synchronous satellite images with clear ISW signatures in 13 global hotspots. The model adopts two tailored modifications to incorporate the ISW domain knowledge and solve the ISW sample distribution imbalance problems. Implementation domain knowledge (IDK) includes selecting relevant ocean factors and ISW properties based on oceanography theory and remote sensing imaging mechanisms. The second tailored modification adopts advanced model architecture (AMA) by introducing the Gaussian clustering algorithm to classify ISW samples into several groups beyond the limitation of space and time. The model-predicted ISW speed shows good accuracy, with a root mean square error/relative error rate of 0.16 (7.9) and 0.30 m/s (12.7%) on the training and test dataset. Analysis shows that IDK and AMA improve the model performance by 19.4% and 13.1%, respectively. What has been achieved in the ISW studies using machine learning techniques proves that artificial intelligence has great potential in oceanographic studies.