# A Machine Learning Framework for Short-term Prediction of Sea Level Anomalies and Surface Currents

The accurate modeling of ocean surface currents is pivotal for a wide range of applications, including oil spill monitoring, search and rescue operations, and maritime navigation. Dynamical models often face challenges in comprehensively representing the complex and nonlinear dynamics of ocean currents because of the use of empirical formulation in some aspects. These limitations can lead to inaccuracies in current predictions, necessitating the exploration of alternative approaches. Incorporating Artificial Intelligence (AI) and data-driven Machine Learning (ML) techniques offers promising opportunities to enhance the performance of surface current predictions. AI and ML can effectively manage and interpret vast datasets, capturing intricate patterns and relationships. In this study, we introduce an innovative strategy for forecasting Sea Level Anomaly (SLA) and computing surface currents specifically in the North Indian Ocean. Our approach integrates the k-Nearest Neighbours (kNN) machine learning regression method with the Variational Mode Decomposition (VMD) technique to develop hybrid models at each grid point in the North Indian Ocean spaced ~ 25 km apart. Using intrinsic mode functions of the previous five days derived from daily AVISO SLA as the predictor, this model is designed to forecast SLA seven days in advance, achieving unprecedented accuracy compared to existing numerical models for the period 2019-2020. The gridded SLA predictions from our hybrid model are then utilized to compute geostrophic currents. These geostrophic currents are combined with Ekman currents, which are derived from the 7-day forecasted winds provided by the National Centre for Medium Range Weather Forecasting (NCMRWF), to generate the total gridded forecasted surface current field for the North Indian Ocean. The root-mean-squared errors in SLA predictions from our KNN-VMD model at each grid point turn out to be within the precision of the AVISO SLA measurements except at few isolated locations. The eddy characteristics in the North Indian Ocean is also superior compared to other assimilated dynamical models. We also conducted a thorough validation of surface currents from our kNN-VMD model against the widely used OSCAR (Ocean Surface Current Analyses Real-time) currents and surface currents from buoys. The results demonstrate that forecasted surface currents from our model exhibit the lowest errors and the highest correlation with observed data, outperforming other dynamical models that assimilate SLA among other observations. This study promises an operational forecast system for SLA and surface currents with a lead time of 7 days.

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