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Editorial

AI for Marine, Ocean and Climate Change Monitoring

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1. Introduction

In the ever-evolving landscape of marine, oceanic, and climate change monitoring, the intersection of cutting-edge artificial intelligence (AI), machine learning (ML), and data analytics has emerged as a pivotal catalyst for transformative advancements. Within this article compilation, we embark on a journey through a diverse array of innovative AI-driven applications, each meticulously crafted to address the critical challenges inherent in understanding and managing our world's aquatic realms and climate dynamics. This exploration delves into the current status quo of marine and climate monitoring, the evolutionary processes driving us forward, and the mechanisms that underpin these advancements.

The selection of articles underscores the pivotal role of AI-driven solutions in tackling environmental challenges. These encompass a spectrum of tasks, from predicting sea-surface temperature (SST) to detecting Sargassum aggregations and addressing water eutrophication. AI's impact extends across these applications, with a significant role in unraveling the intricacies of cloud behavior—a vital component in addressing climate uncertainties. Moreover, AI offers predictive capabilities with regard to chlorophyll-a distribution and enhances our understanding of oceanic light models and thermal variations beneath the ocean's surface. These advancements are of utmost importance for understanding the biogeochemical cycle, the evolving dynamics of our oceans, and their implications for climate change at both regional and global scales. Additionally, AI and data analytics are being leveraged to enhance the precision of near-surface humidity data, effectively addressing critical climate research needs. Lastly, ML algorithms are being proposed to correct errors in satellite-derived sea-surface salinity data, promising increased accuracy and deeper insights into ocean salinity patterns. These technologies enable us to gain a more comprehensive understanding and effectively manage our natural resources.

These featured applications collectively serve as a testament to the profound significance of AI, ML, and data analytics in advancing our comprehension and stewardship of marine, oceanic, and climate dynamics. They emphasize the transformative potential of AI in reshaping our approach to environmental monitoring and bolster strategies for conservation. This represents a significant stride toward implementing more efficient solutions that can account for the intricate complexities inherent in data products and the climate system, addressing both present and forthcoming challenges associated with climate change.

2. Articles

A total of eleven papers are featured in this Special Issue. Refer to Table 1 for a concise overview of the article titles, authors, and keywords.

These research papers delve into various subjects and investigate efforts that harness the potential of artificial intelligence to enhance our understanding of marine and oceanic environments while tackling the complex challenges posed by climate change. These papers can be categorized into several core themes as previously outlined:

AI-Enhanced Sea-Surface Temperature Prediction: Researchers have been working on innovative AI/ML techniques to improve SST predictions, which have significant implications for various fields, including climate research, ecological preservation, and economic progress. These advancements include the use of graph memory neural networks (GMNNs) to encode irregular SST data effectively [1] and long-term and short-term memory neural networks (LSTMs) for SST prediction [2].

Table 1. Overview of the papers featured in the Special Issue entitled "AI for Marine, Ocean, and Climate Change Monitoring" in *Remote Sensing*.

Title	Authors	Keywords
A Graph Memory Neural Network for Sea Surface Temperature Prediction	Shuchen Liang Anming Zhao Mengjiao Qin Linshu Hu Sensen Wu Zhenhong Du Renyi Liu	sea surface temperature spatiotemporal prediction deep learning graph neural network
Prediction of Sea Surface Temperature in the East China Sea Based on LSTM Neural Network	Xiaoyan Jia Qiyan Ji Lei Han Yu Liu Guoqing Han Xiayan Lin	long short-term memory (LSTM) sea surface temperature (SST) East China Sea
Detection of Sargassum from Sentinel Satellite Sensors Using Deep Learning Approach	Marine Laval Abdelbadie Belmouhcine Luc Courtrai Jacques Descloitres Adán Salazar-Garibay Léa Schamberger Audrey Minghelli Thierry Thibaut René Dorville Camille Mazoyer Pascal Zongo Cristèle Chevalier	ocean color Sargassum MODIS MSI OLCI Sentinel-2 Sentinel-3 convolutional neural network deep learning
End-to-End Neural Interpolation of Satellite-Derived Sea Surface Suspended Sediment Concentrations	Jean-Marie Vient Ronan Fablet Frédéric Jourdin Christophe Delacourt	Interpolation data-driven model neural networks variational data assimilation missing data suspended particulate matter observing system experiment Bay of Biscay
AICCA: AI-Driven Cloud Classification Atlas	Takuya Kurihana Elisabeth Moyer Ian T. Foster	cloud classification MODIS artificial intelligence deep learning machine learning
Applying Deep Learning in the Prediction of Chlorophyll-a in the East China Sea	Haobin Cen Jiahan Jiang Guoqing Han Xiayan Lin Yu Liu Xiaoyan Jia Qiyan Ji Bo Li	LSTM chlorophyll-a East China Sea

Table 1. *Cont.*

Title	Authors	Keywords
Vertically Resolved Global Ocean Light Models Using Machine Learning	Pannimpullath Remanan Renosh Jie Zhang Raphaëlle Sauzède Hervé Claustre	BGC-Argo ED380 ED412 ED490 global ocean light models neural network PAR
Spatiotemporal Prediction of Monthly Sea Subsurface Temperature Fields Using a 3D U-Net-Based Model	Nengli Sun Zeming Zhou Qian Li Xuan Zhou	sea temperature prediction reconstructed sea subsurface temperature data 3D U-Net
Deep Learning to Near-Surface Humidity Retrieval from Multi-Sensor Remote Sensing Data over the China Seas	Rongwang Zhang Weihao Guo Xin Wang	near-surface humidity remote sensing deep learning China Seas
An Algorithm to Bias-Correct and Transform Arctic SMAP-Derived Skin Salinities into Bulk Surface Salinities	David Trossman Eric Bayler	Salinity SMAP skin-effect bias air-sea Arctic ocean machine-learning
Super-Resolving Ocean Dynamics from Space with Computer Vision Algorithms	Bruno Buongiorno Nardelli Davide Cavaliere Elodie Charles Daniele Ciani	earth observations ocean dynamics satellite altimetry sea surface temperature artificial intelligence machine learning deep learning neural networks

Satellite-Based AI Monitoring for Environmental Challenges: Satellite-based monitoring is crucial for addressing environmental challenges such as Sargassum aggregations and suspended sediment dynamics. Novel deep learning models have been developed to detect Sargassum aggregations with higher accuracy compared to traditional index-based techniques [3]. Additionally, end-to-end deep learning schemes like 4DVarNet have been employed to improve the interpolation of sea-surface sediment concentration fields from satellite data [4].

Advancements in Cloud Classification and Climate Uncertainty Reduction Using AI: Understanding cloud behavior and reducing uncertainties in climate projections is vital. Researchers have introduced novel AI-driven techniques for cloud classification based on convolutional autoencoders [5]. These techniques aim to reduce the dimensionality of satellite cloud observations and provide valuable insights into cloud patterns, helping to address climate uncertainties.

AI-Driven Ocean Chlorophyll-a Concentration Modeling for Eutrophication Mitigation: Predicting ocean chlorophyll-a concentrations is critical for mitigating issues like water eutrophication. AI methods, particularly neural networks, have been utilized to predict chlorophyll-a distribution in marine environments, with a focus on the East China Sea [6].

ML Advances Oceanic Light Models for Comprehensive Global Biogeochemical Insights: Authors developed SOCA-light, a machine learning model, predicting oceanic light profiles globally using BGC-Argo data. The study highlights the model's accuracy, addresses data gaps, and suggests versatile applications for improving biogeochemical databases [7].

Harnessing AI for Subsurface Ocean Temperature and Oceanic Impact: Researchers have explored the prediction of subsurface ocean temperature (SSbT), an essential indicator of the ocean's thermal state. A 3D U-Net model has been employed to predict SSbT, enhancing our understanding of ocean temperature variations [8].

Data Analytics for Near-Surface Humidity Monitoring and Climate Implications: Near-surface humidity monitoring is crucial for climate research. AI-driven approaches like Ensemble Mean of Target deep neural networks (EMTnets) have been introduced to improve the accuracy of near-surface humidity data [9]. These methods have implications for understanding the impact of global warming on humidity levels.

Machine Learning for Sea-Surface Salinity Correction in Subpolar and Arctic Oceans: The correction of errors in satellite-derived sea-surface salinity (SSS) data, particularly in subpolar and Arctic Oceans, has been addressed using ML algorithms [10]. These corrections aim to improve the accuracy of salinity measurements and enhance our understanding of ocean salinity patterns.

Surface Ocean Dynamics and Climate Regulation with Advanced Data Analysis: Researchers have introduced innovative neural network architectures to improve the reconstruction of absolute dynamic topography from satellite altimeter data [11]. These advancements offer insights into surface ocean dynamics and their role in climate regulation.

3. Conclusions

In this collective reprint, multiple studies and models are presented, each addressing different aspects of marine, ocean, and climate data analysis and prediction. These investigations utilize a range of methodologies, including deep learning, neural networks, and data assimilation, with the aim of enhancing our understanding of various phenomena such as sea-surface temperature, Sargassum detection, cloud classification, chlorophyll-a concentration, subsurface ocean temperature, skin salinity, and ocean dynamic topography. Overall, these studies demonstrate the potential of AI/ML and deep learning techniques to enhance the accuracy and efficiency of data analysis, while also acknowledging the imperative for continued research and advancements in areas such as model input data, interpretation, and the refinement of more sophisticated network architectures. These papers contribute significantly to advancing our comprehension and the effective management of crucial environmental factors that impact our planet.

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