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Mapping water quality in complex estuarine and coastal waters using deep learning models and high-resolution satellite imagery

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Abstract: Large-scale spatiotemporal water quality assessments are made possible with the advent of remote sensing imagery. Reliable remote water quality parameter estimations require sufficient in-situ measurements of surface water's Inherent Optical Properties (IOPs). These include absorption and back-scattering coefficients of optically active dissolved and particulate matter that must match with corresponding remotely sensed Reflectance (R_{rs}). In most cases, there is a severe lack of overlapping matchups needed for effective calibration and validation of Total Suspended Sediment (TSS) and Dissolved Organic Carbon (DOC). These parameters are critical to understanding water quality degradation dynamics and developing sustainable water management practices. In addition, coastal regions are the most complex, with the interplay of land, river and ocean currents affecting the flow of largely turbid discharge. The optically complex discharge results in a non-linear mapping of the reflectance spectrum to the water quality parameters, further compounded by the anthropogenic contribution of sediment concentrations, natural events such as heavy rainfall, and their combination. Thus, we must quantify the non-linear relationship between R_{rs} and water quality parameters in different climate domains.

In this study, we have numerically determined R_{rs} using radiative transfer modelling based on observed IOP measurements across the Hawkesbury, Hunter, and Clarence estuarine and coastal waters in New South Wales, Australia, during March and July 2022. We consider a 10% error in observed TSS/DOC measurements and simulate an ensemble of $R_{rs} - a_p/a_{cdom}/b_{bp}$ – TSS/DOC dataset for each of the 56 stations where the field survey was conducted. The resulting dataset of ~4 million records provides a sample space big enough for developing Deep Learning - Neural Network (DL – NN) based architectures on a cloud-based Open Data Cube (ODC) environment. Deep Multi-Layer Perceptron (DMLP) NN and Convolution NN (CNN) were tested, with DMLP exhibiting lower inherent errors of 3% compared to 4.5% of CNNs. The DMLP NN was then spectrally convolved with available atmospheric-corrected Landsat-8 multi-spectral (443, 483, 561 and 655nm) imagery over the said basins for 2022 and compared with the regional spectral library-based i-SAM (Cherukuru et al., 2021; Sanwlani et al., 2022) derived TSS and DOC maps. This work compares existing regional models and explores the potential of DL NN in mapping TSS and DOC in complex coastal waters. The DMLP model exhibits improved computational efficiency and can be employed to map the sediment loads due to flood events across these river basins.

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