

EGU22-7859

<https://doi.org/10.5194/egusphere-egu22-7859>

EGU General Assembly 2022

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Predictive performance of deep-learning-enhanced remote-sensing data for ecological variables of tidal flats over time

Logambal Madhuanand¹, Katja Phillippart^{1,2}, Wiebe Nijland¹, Jiong Wang^{1,3}, Steven M. De Jong¹, Allert I. Bijleveld², and Elisabeth A. Addink¹

¹Utrecht University, Department of Physical Geography, PO Box 80.115, 3508 TC Utrecht, the Netherlands

(l.madhuanand@uu.nl)

²NIOZ Royal Netherlands Institute for Sea Research, Department of Coastal Systems, and Utrecht University, PO Box 59, 1790 AB Den Burg, Texel, the Netherlands

³University of Twente, Geo-Information Science and Earth Observation (ITC), 7514 AE Enschede, The Netherlands

Tidal flat systems with a diverse benthic community (e.g., bivalves, polychaetes and crustaceans) is important in the food chain for migratory birds and fish. The geographical distribution of macrozoobenthos depends on physical factors, among which sediment characteristics are key aspects. Although high-resolution and high-frequency mapping of benthic indices (i.e., sediment composition and benthic fauna) of these coastal systems are essential to coastal management plans, it is challenging to gather such information on tidal flats through in-situ measurements. The Synoptic Intertidal Benthic Survey (SIBES) database provides this field information for a 500m grid annual for the Dutch Wadden Sea, but continuous coverage and seasonal dynamics are still lacking. Remote sensing may be the only feasible monitoring method to fill in this gap, but it is hampered by the lack of spectral contrast and variation in this environment. In this study, we used a deep-learning model to enhance the information extraction from remote-sensing images for the prediction of environmental and ecological variables of the tidal flats of the Dutch Wadden Sea. A Variational Auto Encoder (VAE) deep-learning model was trained with Sentinel-2 satellite images with four bands (blue, green, red and near-infrared) over three years (2018, 2019 and 2020) of the tidal flats of the Dutch Wadden Sea. The model was trained to derive important characteristics of the tidal flats as image features by reproducing the input image. These features contain representative information from the four input bands, like spatial texture and band ratios, to complement the low-contrast spectral signatures. The VAE features, the spectral bands and the field-collected samples together were used to train a random forest model to predict the sediment characteristics: median grain size and silt content, and macrozoobenthic biomass and species richness. The prediction was done on the tidal flats of Pinkegat and Zoutkamperlaag of the Dutch Wadden sea. The encoded features consistently increased the accuracy of the predictive model. Compared to a model trained with just the spectral bands, the use of encoded features improved the prediction (coefficient of determination, R^2) by 10-15% points for 2018, 2019 and 2020. Our approach improves the available techniques for mapping and monitoring of sediment and macrozoobenthic properties of tidal flat systems and thereby contribute towards their sustainable management.

