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AI4GNSS-R: Implementing and Interpreting AI for GNSS-R Applications in Ocean and Atmosphere

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Global Navigation Satellite System Reflectometry (GNSS-R), which exploits GNSS signals reflected off the Earth surface, is a novel remote sensing technique for monitoring surface properties such as ocean winds and soil moisture. Spaceborne GNSS-R employs cost-efficient receivers operating on Low Earth Orbit (LEO) satellites, providing abundant observations with broad coverage and improved temporal resolution. The current operational method for retrieving ocean wind speed uses the Minimum Variance Estimator (MVE) and relies on parameters derived from the Delay-Doppler Map (DDM). However, this method does not fully consider all the information available in the DDM. With the growing data volume, advanced data-driven methods are proposed to improve wind speed estimation by analyzing the full Delay-Doppler Map (DDM) and additional parameters.

The Helmholtz AI project Artificial Intelligence for GNSS Reflectometry (AI4GNSS-R), launched in 2021, aims to implement AI in processing GNSS-R measurements to improve existing product accuracy, enhance the physical understanding of GNSS-R, and explore new GNSS-R applications. As part of this initiative, a global ocean wind speed dataset was created from NASA's Cyclone GNSS (CyGNSS) mission observations. Based on an initial deep learning model, data fusion was applied to correct rain effects by incorporating external precipitation information. This model surpasses the operational MVE algorithm by 40% and outperforms the baseline model, especially at wind speeds exceeding 16 m/s. A case study of Hurricane Laura (August 2020) further demonstrated its performance under extreme weather conditions. Additionally, explainable AI (XAI) is applied to evaluate the impact of Delay-Doppler Map (DDM) pixels as well as ancillary parameters on model predictions.

The AI4GNSS-R project highlights the power of AI in advancing GNSS-R applications in oceanic and atmospheric research while demonstrating its potential to enhance physical understanding and broaden the scope of GNSS-R technology.

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