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Advancing Integrated Water Vapor Estimation: Introducing an Enhanced Regional Prediction Model Utilizing Improved Least Squares Support Vector Machine for the Upper Rhine Graben Region

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Integrated Water Vapor (IWV) stands as a pivotal parameter in contemporary environmental research, offering crucial insights into atmospheric dynamics. Due to the inherent challenges in direct measurement, IWV necessitates estimation through various methods. Current approaches, including Global Navigation Satellite System (GNSS), radiosondes, radiometers, and satellite remote sensing, have inherent limitations, resulting in a scarcity of high spatial resolution data. While GNSS technology, radiosondes, and radiometers provide precision, they are confined to specific locations, imposing spatial coverage constraints. On the other hand, satellite remote sensing offers expansive, high spatial resolution IWV data, yet its accuracy is hindered under cloudy conditions and limited by satellite ground tracks.

This study addresses these challenges by introducing a regional IWV prediction model based on Machine Learning. Leveraging IWV data from diverse GNSS stations within a specified region, the study establishes a regional IWV prediction model utilizing an adaptive least squares support vector machine (ALSSVM). This predictive model enables accurate IWV estimation at any designated location within the region, incorporating inputs such as latitude, longitude, height, and temperature. Significantly, the model attains remarkable predictive accuracy, with an overall average root mean square error (RMSE) of 2 millimeters.

The model's performance exhibits variability across different seasons and terrains, illustrating its adaptability to diverse environmental conditions. The study further evaluates the reliability of the conventional ERA5 IWV calculation method in the specified region by comparing it against the predicted results from the proposed IWV prediction model. In conclusion, the developed model is applied to conduct a climate analysis, demonstrating its practical utility in environmental research for the transnational Upper Rhine Graben region.

Keywords:

Global Navigation Satellite System (GNSS), Integrated Water Vapor (IWV), least squares support vector machine (LSSVM), Climate Analysis