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Specification and Forecast of Ionospheric Total Electron Content Using VISTA and Machine Learning

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In the current era, the ionospheric total electron content (TEC) derived from multi-frequency Global Navigation Satellite System (GNSS) receiver is arguably the most utilized dataset in the ionospheric research area, and also has essential practical importance, as it is the largest naturally occurring error source for GNSS positioning, navigation, and timing (PNT) accuracy. The potential of using the GNSS data as a backbone of the space weather observational system has been demonstrated in the last decade with the GPS system, and as we are moving into the multi-GNSS era, we are at the forefront of a new chapter by combining the traditional space science and the modern optimization and machine learning (ML) algorithms to make a leap forward in the specification and forecasting of ionosphere state and variability. We proposed a new video completion method called the VISTA (Video Imputation with SoftImpute, Temporal smoothing and Auxiliary data), which can be implemented via an optimization algorithm, to specify the global ionosphere TEC maps. The VISTA model is able to capture multi-scale ionospheric TEC structures, such as large-scale storm-enhanced density (SED) and meso-scale equatorial plasma bubbles (EPBs). After constructing the database using VISTA, we apply advanced machine learning tool to forecast the TEC maps. Performance of the new forecasting model is then compared with the forecasting model previously developed using traditional IGS maps and validated against real TEC observations.