STUDYING THE IONOSPHERE USING MACHINE LEARNING. Thomas Y. Chen[1], [1]Academy for Mathematics, Science, and Engineering (thomaschen7@acm.org)

Introduction: By drawing inferences from sets of labeled data, supervised machine learning techniques serve as an important tool for heliophysics advances in the decade ahead and beyond. Using deep learning-based computer vision tools like neural networks and other methods like random forest ensemble models and support vector machines (SVMs), scientists can gain high-level insights from large quantities of solar physical data. In the study of geomagnetic space weather and ITM physics, the ionosphere is a useful parameter to examine. The ionosphere is located in the Earth's upper atmosphere, in which solar radiation causes atoms to be ionized. This ionization creates layers of free electrons, and the impacts of events in the ionosphere is measured using Global Navigation Satellite Systems (GNSS) receivers. Recent works have striven to develop machine learning models to understand ionospheric variability in solar space weather and to predict disturbances. We contend that machine learning and artificial intelligence (AI) applied for robust discovery and investigation into the Earth's ionosphere and its interactions with aspects of the Sun is an area of research that should be highlighted in the NASA 2024 Heliophysics Decadal Survey.

Surveying Current Work: The University of California Irvine's Center for Machine Learning and Intelligent Systems presents a landmark multivariate ionosphere dataset, which has been utilized by many authors such as [2] and [3] in pure machine learning papers to demonstrate the development of various models, irrespective of their relevance to solar physics. Meanwhile, [4] and [5] present methodologies of forecasting ionospheric total electron content (TEC) over low-latitude GNSS stations. There has been significant interest in how artificial intelligence can aid in the detection of the ionospheric irregularities in GNSS-derived maps [6]. When constructing accurate nowcasting models, a key challenge that remains is the aspect of feature selection. The comparison of different approaches from linear regression to support vector regression and gradient boosting has yielded valuable results [7]. The Ionosphere AI Project on Github provides computer vision functions for the detection of features in noisy ionospheric data [8]. Exploring GPS radio signal scintillation and HF wave propagation, the intersection between computer vision applications and ionospheric events has been further examined through analysis of the main ionospheric trough (MIT) [9].

Conclusions: The heliophysics community should work with the computer science and AI research communities to develop complex machine learning models to forecast and assess the ionosphere where necessary, while taking into account considerations like algorithm interpretability, dataset bias, and the alternative benefits of using conventional statistical modeling. For example, 3-dimensional computer vision approaches such as the use of generative adversarial networks (GANs) and 3D reconstruction can potentially be further explored to study the ionosphere, solar phenomena, and space weather. For the decadal survey, a white paper initiative open to any interested co-authors in relevant communities is planned to connect scientists across disciplines.

References:

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