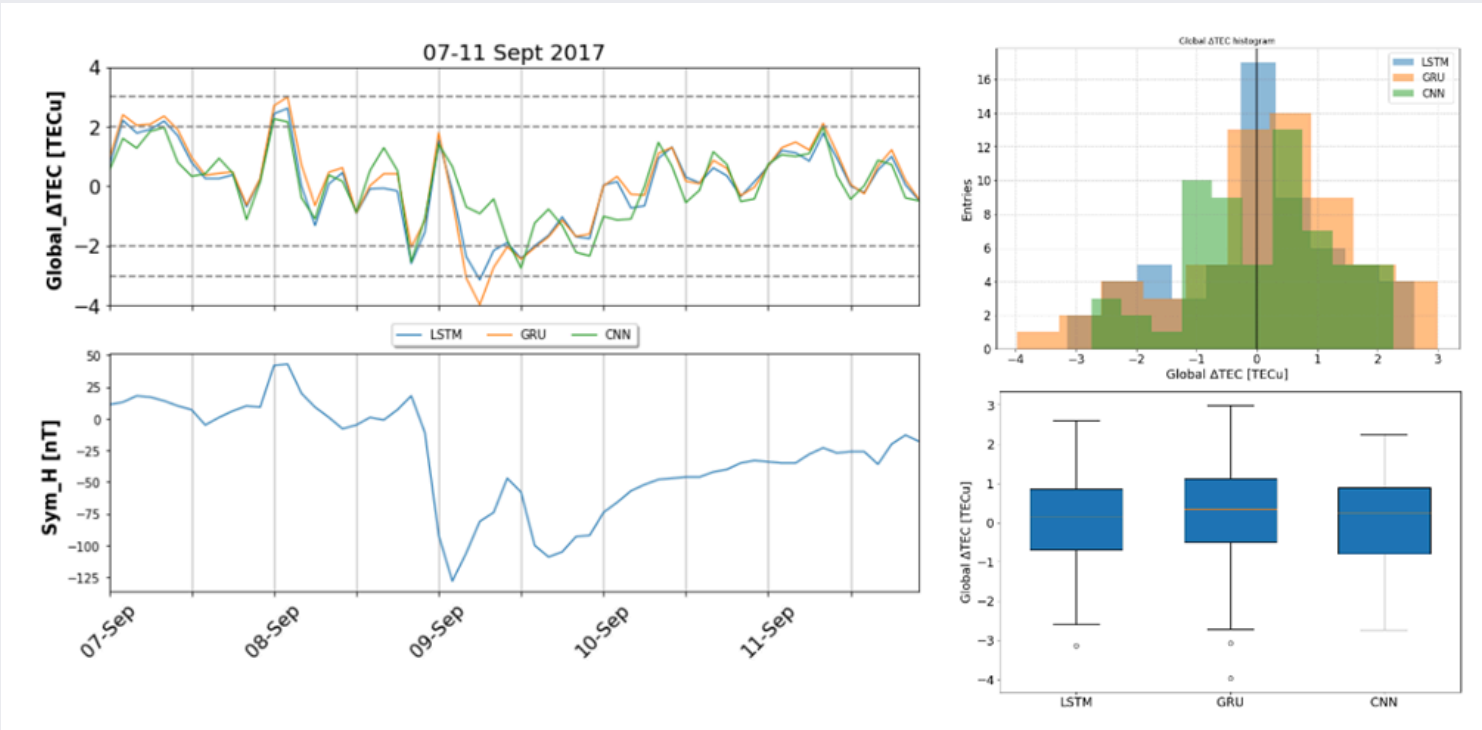
PITHIA-NRF TNA Success story: **AI4TEC** (Machine learning techniques applied to ionospheric and space weather research)

The AI4TEC project was initiated with the objective of delving into ionospheric forecasting by leveraging state-of-the-art Machine Learning (ML) algorithms. The primary focus was on enhancing the existing model operational at the INGV node, which provides global forecasting of Total Electron Content (TEC) 24 hours in advance. This research endeavor was made possible through the support provided by the TNA program of the PITHIA-NRF project.

This support facilitated collaborative and fruitful discussions among team members, including scientists from INGV and Universidad Nacional de Tucuman, enabling the exploration of innovative ML techniques for operational space weather forecasting. It also paved the way for future advancements, such as the integration of enriched datasets comprising TEC time series derived from additional Global Navigation Satellite System receivers distributed globally.

The experience gained through this project was instrumental in comprehending the challenges related to data constraints, leading to the identification of optimal datasets and parameters suitable for diverse ionospheric scales. Through rigorous analysis, the intricate interconnections between solar activity, solar wind parameters, geomagnetic indexes, and various ionospheric parameters were thoroughly explored. This comprehensive analysis laid the groundwork for meticulous feature selection and hyperparameter tuning, enabling the implementation of ML models in real-time scenarios and for operational purposes.

The collective efforts of the team yielded significant advancements, resulting in the development of improved TEC models at a global scale, forecasting 24 hours in advance. The long-term objective is to make operational these new models, providing access to them through the TSWC portal (spaceweather.facet.unt.edu.ar) and the eSWua portal (eswua.ingv.it). Additionally, the findings and methodologies employed in this research have been submitted for publication in the Special Issue "Recent Advances in Space Geophysics including COLAGE" in the prestigious Journal of Atmospheric and Solar-Terrestrial Physics (JASTP).



Time series of the mean TEC error for each investigated Deep Learning technique: Long-Short Term Memory, Gated Recurrent Unit, Convolutional Neural Network (upper left) during the case study of the September 2017 geomagnetic storm; related SymH geomagnetic disturbance index (bottom left); histogram of the mean TEC error for each technique (upper right); related whisker plots (bottom right).

References:

- *Maria Graciela Molina, Jorge Habib Namour, Claudio Cesaroni, et al. Global TEC forecasting based on deep learning techniques: a comparative study and perspectives for a Space Weather operational service. ESS Open Archive. May 05, 2023, DOI: 10.22541/essoar.168332189.94249853/v1*

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