Machine learning techniques for Space Weather: Ionospheric conditions forecasting

Namour jorge H. (1, 2), Molina María Graciela (1, 2, 3), Cesaroni Claudio (5), Migoya Orué Yenca (6), Spogli Lucca (5), Radicella Sandro(6), Cabrera Miguel A. (1, 4)

gmolina@herrera.unt.edu.ar

1. Tucumán Space Weather Center (TSWC), Facultad de Ciencias Exactas y Tecnología, Universidad Nacional de Tucumán (FACET-UNT), Tucumán, Argentina.
2. Laboratorio de Computación Científica (LabCC), Departamento de Ciencias de la Computación, FACET-UNT, Tucumán, Argentina.
3. Consejo Nacional de Investigaciones científicas, CONICET, Argentina
4. Laboratorio de Telecomunicaciones, Departamento de Electricidad, Electrónica y Computación. FACET-UNT
5. Istituto Nazionale di Geofisica e Vulcanologia (INGV). Upper Atmosphere and Radiopropagation group, Roma, Italy.
6. The Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste, Italy.

Abstract

Being able to predict the ionosphere conditions of the ionosphere is still challenging, in particular, due to the impact of the space weather events. Recently, the scientific community have been implementing data-driven models such as machine learning (ML) based models with considerably good results. ML techniques are suitable for ionospheric forecasting due to the combination of a) the attainability of more mature algorithms (with proven good performance in many research fields), b) computing infrastructure, and c) the big amount of ionospheric data available (at global and regional level).

In this work, we apply ML algorithms to nowcast and forecast ionospheric conditions using different input data in each case. We present preliminary results for a global TEC forecasting model and a regional f0F2 forecasting model, both using deep learning techniques. TEC has been chosen for global forecasting due to its global coverage since GNSS systems allow to obtain TEC from a large number of receivers within the globe. On the other hand, f0F2 is one of the main ionospheric parameters obtained from ionosonde and it has been used for regional nowcasting.

In particular, we implemented a deep learning-based model using Long Short-Term Memory (LSTM) neural network in both cases. For the global TEC forecast, we used (Global Ionospheric Maps (GIM) as input and Kp index as one of the external forcings. This model is able to forecast one day ahead. For the global TEC forecasting, we also implemented Gated Recurrent Unit (GRU) and Convolutional Neural Networks (CNN) algorithms.

The input for the regional ionospheric nowcasting (3 hs ahead) is the critical frequency of the F2 layer (f0F2) for a low latitude station in Tucumán, Argentina (lat: 26.9 S, lon: 294.6 E). We also compare the results with the ingested version of the NeQuick model.

We show the main results and discuss stages of data curation, data resolution management, unbalance data treatment, feature engineering issues, grey box modelling, generalization issues, model into operation (R2O) and further steps.

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