Near Earth Space Activities: A Turkish Initiative – "IHY 2"

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The Near Earth Space activities have been relatively new and few in Turkey. However, in the Space Age, it is inevitable that the national and international activities must be considered as competitive and complementary to each other. In this paper, by taking the advantage of 50 years anniversary of International Geophysical Year (IGY) relevant historical background in Turkey is given and some initiatives are introduced.

1. Introduction

Quoting from Siscoe [1]: "To be able to talk about the network of space-vulnerable, technological entities upon which humankind is becoming increasingly dependent, I suggest referring to it as the cyberelectrosphere. The cyberelectrosphere is defined as the global totality of all space-vulnerable, electrically enabled technological systems".

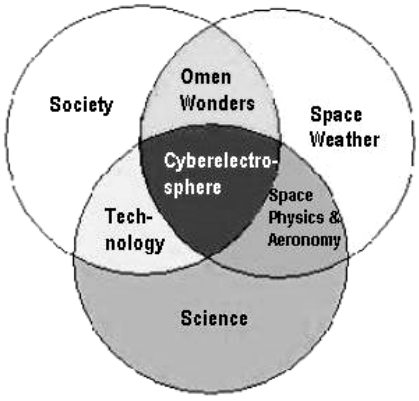

Fig.1. A triquetra illustrating how the intersection of society, science and space weather gives rise to the cyberelectrosphere (Siscoe, 2000 [1]).

Fig.1 attempts to show how the cyberelectrosphere emerges from an interaction between three subjects: society, science and space weather. Before science, the overlap of society and Space Weather in the form of low-latitude auroras that accompany space storms gave rise to omens and wonders. The overlap of space weather and science has given rise to the fields of space physics and aeronomy. The overlap of science and society has engendered modern technological society, those components of which that are vulnerable to space weather disturbances form the cyberelectrosphere at the center of the triquetra.

We, as a small group in Turkey, have demonstrated that the data driven approach such as neural network (NN) based models are very promising both in modeling the processes of the cyberelectrosphere which affects the ionospheric parameters and in filling the data gaps of missing data. In this paper, a short introduction will be made to some of the relevant work. In particular the results of the Middle East Technical University (METU) Neural Network (METU-NN) Model will be addressed. The METU-NN is the title of a data driven generic model which makes reliable forecasting, nowcasting of a Space Weather parameter of interest.

2. The Increasing role of radio in telecommunications

2.1. Internationals

The radio spectrum is the natural resource used, but not consumed, in radiocommunications and ranges from very low frequencies (3-30 KHz) to optical frequencies (300-3000 THz) [2]. As quoted from Radicella (2005) [2], radio spectrum utilization and management involves technical factors together with economic, political and sociological aspects that make necessary the establishment of international agreements and national regulations.

The Radiocommunication Sector of the International Telecommunication Union (ITU-R) is the body in charge of ensuring the rational, equitable, efficient and economical use of radio spectrum by all radiocommunication services.

Founded in 1865, it became a specialized agency of the United Nations in 1947, the International Telecommunication Union (ITU) provides an international forum for discussion in which its 189 Member States and some 690 Sector Members and associates can collaborate for the improvement and rational use of telecommunications worldwide.

The mission of the ITU-R lies within the broader framework of the purposes of the ITU, as defined in Article 1 of the ITU Constitution and is, in particular, to "maintain and extend international cooperation among all the Member States of the Union for the improvement and rational use of telecommunications of all kinds" [3].

It represents one of the major growth industries with a value of approximately 17 US $ billion per year and a subscribers annual increase of 45%.

By the beginning of the 21st century the Commission of the European Communities (CEC) had envisaged that 50% of the total teletraffic to be radio based and an ambitious research program was started under the Research and Advanced Communications for Europe (RACE) program to study the creation of a third generation mobile system [3].

By the beginning of the 21st century Personal Communications Mobile Satellite Systems, for example, like MOTOROLA IRIDIUM, INMARSAT PROJECT 21 and TRW ODYSSEY have been planned to be operational for global scale communications and on them R-T-D have been continuing.

Reasons for a Renewed Interest in High-Frequency Radio Applications to Telecommunication Systems as summarized by Radicella (2005) can be stated as [2]:

- The availability of enhanced digital signal and data processing chips and systems that permit the development of high performance communication systems, far better than former HF systems.
- The need for low cost systems for non heavy traffic telecommunication links in the absence of reliable alternative network systems, like in developing countries.
- The need for reliable backup systems for emergency uses, like telecommunication requirements after natural disasters.
- The need for multimedia transmission networks to enhance the probability of successful reception of military or national security information.

2.2. Nationals

Some Near Earth Space (NES) activities in Turkey since 1970 which are relevant to ionospheric radiowave propagation are:

- By using the Ariel 3 and Ariel 4 satellite electron density, VLF data the morphology of the upper atmosphere at about 550 km was widely investigated.
- The Mid-Latitude Electron Density Trough was shown to be the ionospheric projection of the magnetospheric plasmapause by using Ariel 3, Ariel 4, OGO 4, ISEE 1, KYOKKO satellite data. Some modeling work of the Trough was performed in parallel.
- The possible influence of the Interplanetary Magnetic Field (IMF) Bz polarity reversals on ionospheric f_oF2 data in relation to quantification of the ionospheric variability was investigated.
- The total electron content (TEC) over Ankara longitudes was computed by using the ATS 6 satellite Faraday rotation signals.
- A High Frequency (HF) Fading Experiment was conducted between United Kingdom and Turkey.
- As part of the COST 238: PRIME (Prediction and Retrospective Ionospheric Modeling over Europe) Action, a Polish-made KOS Vertical Ionosonde was deployed at the Kandilli Observatory of the Boğaziçi University.
- Within the COST 251: IITS Action data driven modeling approach was introduced and neural network based models were constructed for forecasting f_oF2 one to twenty-four hours in advance for single stations and one hour in advance for multi stations. Neural network based models were also constructed to forecast f_oF2 one hour in advance during IMF Bz polarity reversals and to model the effect of Mid-Latitude Ionospheric Trough on f_oF2 values.
- An HF propagation experiment in Ankara and Elaziğ was conducted during the last Total Solar Eclipse of the 20th century, 11 August 1999.
- The European Science Foundation (ESF) Network on Earth Weather and Space Weather was one of the other European Union (EU) activities in the Near Earth Space discipline that Turkish scientists took part. It is expected that there will be a second phase of the activity.
- Solar, geomagnetic field, seismic and geophysical observations have been conducted at the Kandilli Observatory of the Boğaziçi University.
- An HF channel characterization project supported by the Turkish State Planning Organization is being conducted at the Middle East Technical University in Ankara. As a part of this activity, an HF transmission experiment will be conducted by setting up an International Telecommunication Union's Compliant HF Field Strength Monitoring Terminal. The work will be carried out in collaboration with ITU, Commission R. The same station will be set up at the Firat University in Elaziğ, Turkey.
- A NATO Research and Technology Organization (NATO-RTO) project on the Surface Boundary Layer Refractive Index Measurements in Greece, Turkey and United Kingdom Relevant to Optical and Microwave Frequencies in Aerospace Operations.
- At the Department of Meteorology and the Department of Physics of a few Turkish universities, some work on the Earth's magnetosheath, magnetotail, solar wind-magnetosphere-ionosphere coupling, magnetohydrodynamics, plasma physics research related to Space Physics have been conducted.
- There are a few electrical and electronics engineering departments where theoretical electromagnetics and propagation research have been conducted.

3. Case studies

3.1. Neural network modeling in forecasting the near Earth space parameters: forecasting of the solar radio fluxes [4]

Neural networks and fuzzy systems are motivated by imitating human reasoning processes. Neural networks have been extensively used in modeling real problems with nonlinear characteristics. The main advantages of using NNs are their flexibility and ability to model nonlinear relationships. Unlike other classical large scale dynamic systems, the uniform rate of convergence toward a steady state of neural networks is essentially independent of the number of neurons in the network [5, 6]. Some typical results were presented as illustration of modeling the Near Earth Space processes by employing the Neural Network. Considering the rapid growth around the world in wireless communications at GHz

frequencies in the last decade and continuing to date calls for studies of solar noise levels at such frequencies [7], we decided to use the data provided by the Trieste Observatory of solar fluxes measured at 2.695 GHz to train the METU Neuro-Fuzzy-Network (METU-NFN) and use it to forecast the values of these solar fluxes in specific time-intervals. Fig. 2 shows the results given by METU-NFN model in forecasting the Solar X-Ray bursts.

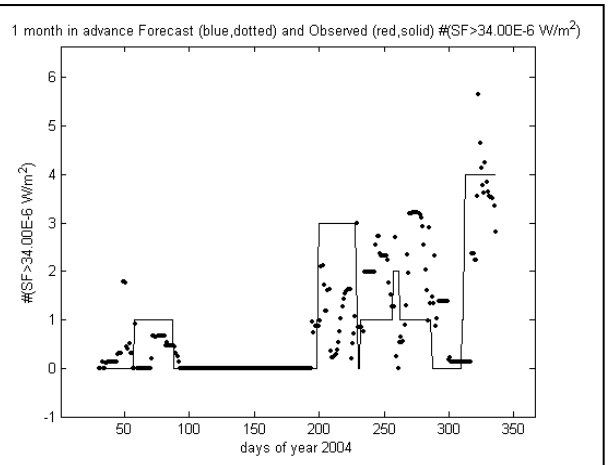

Fig. 2. Large Solar X-ray burst Forecast.

3.2. The trough based neural network model of the foF2 values [8]

The electron density trough is an interesting phenomenon in characterizing the behavior of the Ionosphere, in particular during the disturbed conditions. Tulunay [8] demonstrated that the neural net-based modeling is promising to forecast the ionospheric critical frequency, f_0F2 values one hour in advance for the cases when the probability of influence of trough is high. The results of the forecast are shown in Fig. 3.

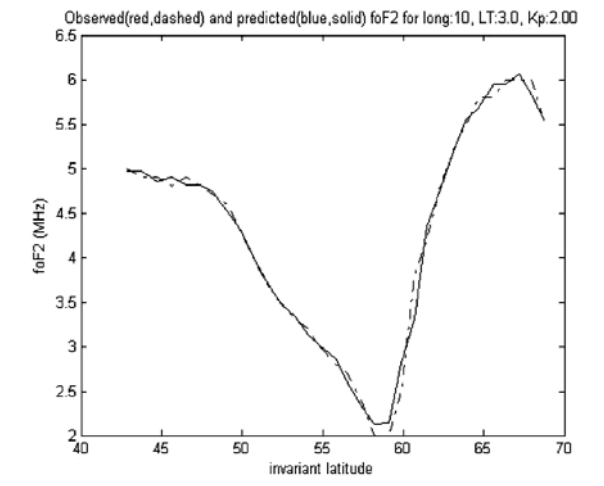

Fig.3. The predicted foF2 position and shape of the mid-latitude trough, from data and as modelled by the METU-NN model. METU-NN predicted foF2 values against invariant latitude, with longitude 10^0E, local time 03:00, Kp = 2.

3.3. Forecasting TEC Maps by using Neural Networks [9]

The METU-NN model was used in order to understand more about the complex response of the magnetosphere and ionosphere during extreme solar events, e.g. the series of space weather events in April 2002. Complying with the call of Kozyra in 2004 for a Special Publication on the Tracing the Sun-Earth Connection April 2002 Events, the results of the METU-NN model are presented in Fig.4. The figure shows the forecast values of the Total Electron Content (TEC) up to 24 hours in advance during the April 2002 Events.

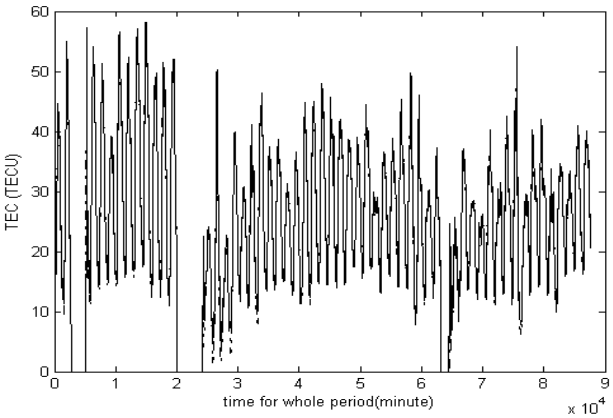

Fig.4. The observed GPS TEC results (dotted), 1 hour ahead forecast (solid) TEC values for the whole time of validation period: April-May 2002 for Hailsham.

3.4. Effects of IMF Bz reversals on the ionospheric critical frequencies (f_0F2) between 1975 and 1986 [10]

The possible effects of the interplanetary magnetic field (IMF) on the F-layer critical frequency was investigated by using the superposed epoch (SPE) method. Depending on the ionosonde selection, the contribution of geomagnetic conjugacy was also studied during the 21st Solar Cycle. Fig. 5 shows the result of the SPE analysis.

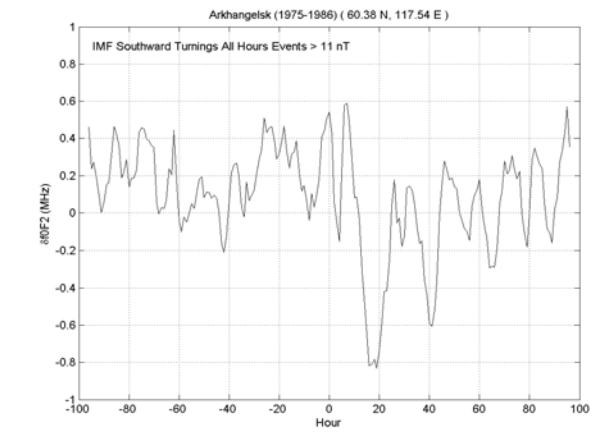

Fig.5. Critical frequency superposed epoch result of Arkhangelsk ionosonde station.

The IMF southward polarity reversals, the events of $|\Delta Bz| \geq 11$ nT, seem to reduce the f_0F2 by about 1 MHz within the 20 hours after the event.

Superposed epoch study was employed depending on the calculated diurnal variation of f_0F2 (control curve). The diurnal variation in the f_0F2 data were removed by subtracting the mean of f_0F2 for the same UT on all the magnetically quiet days (Kp<2+) within 15 days around the IMF Bz turnings events for IMF Bz effects. "IMF Bz turning events" were identified by three criteria: (1) southward polarity change; (2) $|\Delta Bz|=11$ nT; (3) preserving the polarity for 3 hours before and after polarity change. Relying on the definition, 41 events were identified. Same procedure, starting from the control curve computation continuing with the event definition, was employed for the IMF By effects. Since the IMF By controls different physical phenomena, the event definition was different from the IMF Bz event definition.

It was observed that Kp index shows rises before IMF Bz events and it takes time to decay and go back to quiet period. Moreover, the rising period was seen to be relatively short than the decaying period. Similar characteristics were observed for IMF Bz values. For an IMF Bz event, before an event, IMF Bz increases in the northward direction and suddenly reverses to southward direction. Average values of peaks were found to be at ~11 nT and ~-12 nT, giving an average change of ~23 nT. Around the specified events, -4 / + 4 days averages of f_0F2 were computed, revealing 1 MHz of decrease for f_0F2 within 20 hours after the event.

3.5. The ELF Characterization of the Earth – ionosphere cavity [11]

Fig.6 shows the diurnal variation of the Schumann Resonances obtained at the Şarköy and Gönen stations around the Sea of Marmara in Turkey in 2004. The diurnal variation of frequencies shows two power maxima at about 0800 LT and 1800 LT.

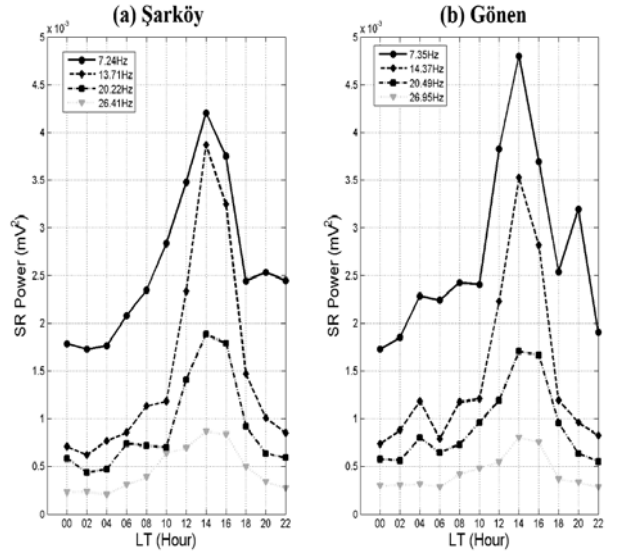

Fig.6. Diurnal variation of Schumann Resonances for stations Şarköy (a) and (b) Gönen.

3.6. Integration of METU-IFS server to COST 724 Server (BIRA) [12]

One of the main objectives of the COST 724 Action is to create the European Space Weather Web. In this connection the NN model developed in Turkey will be implemented to the server running on the Belgium Institute for Space Aeronomy. Fig.7 gives brief information about how the communications are done and computations are carried out.

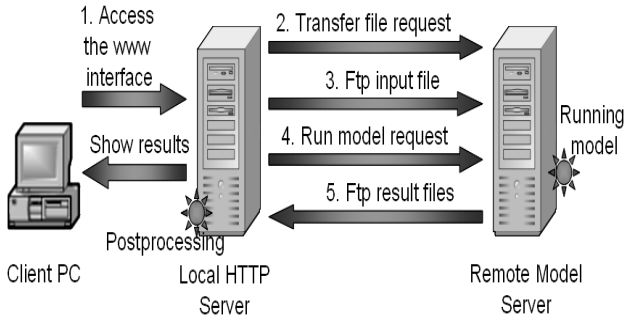

Fig.7. Structure of the model implementation.

4. Summary

Near Earth Space activities in Turkey are briefly reported. These activities may play an important role in creating stronger links with the International Heliophysical Year (IHY) related activities.

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