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METU Data Driven Forecast Models: From the Window of Space Weather IAU Symposium 335

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Abstract. Space weather processes, in general, are non-linear and time-varying. In such cases 'data driven models' such as Neural Network, Fuzzy Logic and Genetic Algorithm based models were proved promising to be used in parallel with the mathematical models based on first physical principles. In particular, with the recent developments in 'big data' systems, one of the urgent issues is the development of new signal processing techniques to extract manageable, representative data out of the 'relevant big data' to be employed in 'training', 'testing' and validation phases of model construction. Since 1990, under the EU Frame Work Program Actions, we have developed such models for nowcasting, forecasting, warning and also for filling the data gaps on space weather cases including prediction of orbital spacecraft parameters. In particular, some typical, illustrative examples include the forecasting of the ionospheric critical frequencies foF2, during disturbed conditions, such as solar storms and extreme events; GPS total electon content(TEC); solar flare index during solar maximum and the construction of solar EUV flux variations. The associated input data organisation and the typical errors which have been within the acceptable operational expectations are summarised in terms of absolute values, percent and RMS. The aim of the paper is to show that the data driven approaches are promising for the forecasting of space weather.

Keywords. Near Earth Space, Space Weather, Data Driven Models, Forecast

1. Introduction

Near Earth Space (NES) Processes are highly complicated in that they are non-linear and time varying. Therefore, mathematical modelling, based on the 1st Physical Principles is usually very difficult or impossible. For such cases, we recommend the data driven modelling methods to be employed in parallel with the mathematical approach. Because non-linear systems are usually too complicated where exact analytical relationships based on first physical principles are prohibitively difficult to construct. We, a small group at the Middle East Technical University (METU), had worked on the data driven generic models of the Near Earth Space (NES) during the EU Actions of COST 238; 251; 271; 296, IHY and, ES 0803 between 1990 and 2015. The data driven models have been designed and developed. Briefly, we have demonstrated that the models based on Neural Network (NN), Fuzzy Logic (FL) and Genetic Programming (GP) have been promising both in modelling the Space Weather (SpW) effects on the ionosphere parameters and in filling the data gaps of the missing data and mitigation processes. The basic requirement for this is the availability of the representative data for the phenomena under the investigation. NN models have the capability of "learning", in other words, the capability of 'generalization'; FL models have the capability of inbedding the 'expert knowledge' into

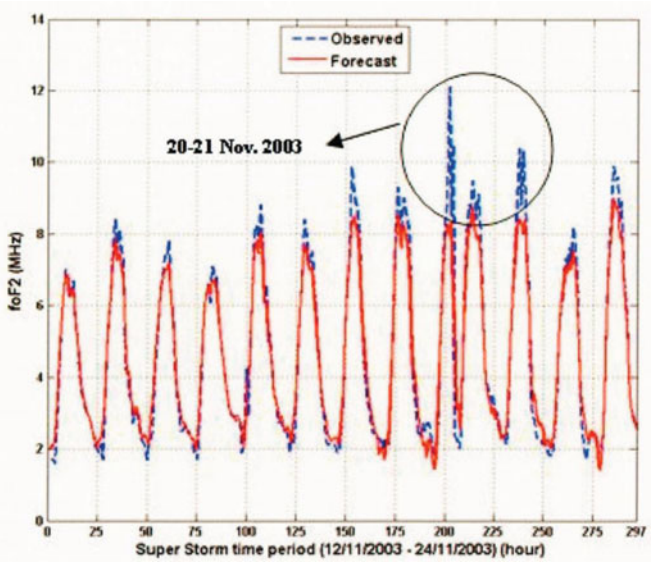

Figure 1. Superimposed are the observed and 1-h ahead forecast values of the Chilton f_oF2 versus the number of hours for the period of 12–24 Nov. 2013.

the model (see Altınay *et al.* 1997, Tulunay *et al.* 2004a, 2004b and 2005). Generalization capability of NNs are better than the generalization capability of numerical methods. At the present time, however, with the recent developments in the 'big data' systems, one of the urgent issues have been the development of new signal processing techniques to extract manageable representative data to be employed in 'training', 'testing', 'validation' phases during the process of model construction (Tulunay & Tulunay 2016). Some typical examples and results are presented in Section 2.

2. Some Typical Examples and Results

2.1. *AE NFN F_oF2 Forecast Model (COST 296)*

Figure 1 shows the forecast of the f_oF2 during a super storm of 2003 for the Chilton ionosonde critical frequencies. The sharp variations in these frequencies due to the super storm of 2003 are followed closely by the 1-h ahead forecast model.

2.2. *METU-NN GPS Total Electron Content (TEC) Forecast Model*

The 10-minute vertical TEC data evaluated from GPS data are employed in the model to forecast vertical TEC 1 hour ahead for 16–29 November 2003 which includes the space weather events. Figure 2 shows the observed and 1h ahead forecast TEC map for 20 November 2003 13:00h. Figure 2 (left) presents the observed map of TEC values over Europe and Figure 2 (right) presents the 1-h ahead forecast map of TEC values for the same area. It shows that the value distributions are considerably similar. This similarity demonstrates the satisfactory performance of METU-NN GPS TEC Forecast Map Model. Table 1 shows the performance parameters for the GPS forecast TEC values.

3. Conclusions

Data driven models have been developed and constructed to forecast the space weather events and to mitigate their associated probable effects (e.g. Earth System Science and

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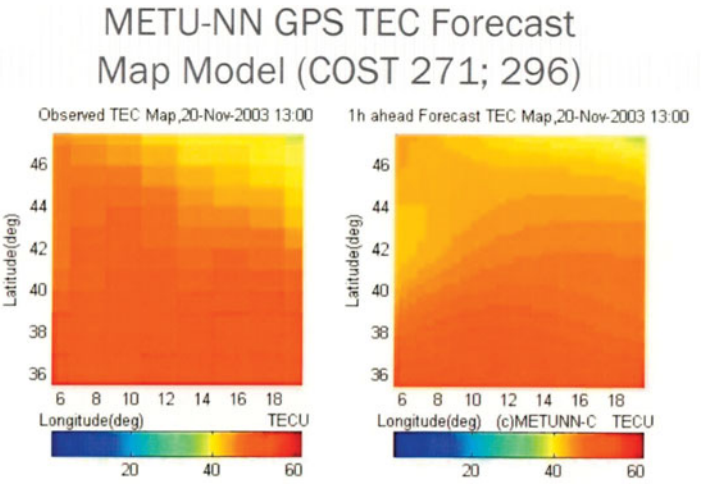

Figure 2. Map of the observed and 1-h ahead forecast TEC values over Europe for the 20 November 2003 13:00h.

Table 1. GPS TEC Forecast Performance Parameters for 16–29 November 2003

	(COST 296 8-th MCM 13–15 March 2008, WG 1 Report)	
LOCATION	Absolute error (TEC units) ($\times 10^{16}$ electron/m^2)	Cross correlation coeff. (%)
11.5°E; 38.5°N	1.58	98
13.5°E; 41.5°N	1.49	97
15.5°E; 44.5°N	1.52	97
Overall TEC Map	1.65	97

biological systems). Some typical examples are presented to give some idea concerning the performance of data driven models when used in space weather applications. In short, the data driven models are efficient not only in problem solving, but also in understanding the natures of the associated processes.

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