Ionospheric Data Analysis of Demeter Sattelite Using Neural Network: Application to IAP Instrument

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Abstract. In this paper, we use the artificial neural network for prediction of ionospheric perturbations by the analysis of the Instrument Plasma Analyzer (IAP) data using the Multilayer Perceptron (MLP) neural network. Data that are used as an input and output for the training of the MLP machine are: the Helium, Electron and Ions densities, Ions temperature, Ions speed and direction. The MLP machine is composed with an input layer, an output layer and a hidden layer. Application to the Demeter satellite data of orbit 27447-1 shows that the MLP neural network machine can give good results for plasma disturbances and can be used for prediction of seismo-ionospheric perturbations.

Keywords: IAP, Demeter, MLP, disturbances, prediction.

1 Introduction

The artificial intelligence has becoming a very useful tool in plasma physics (Rozhansky et al, 2013; Svensson et al, 1999). In earth plasma the artificial intelligence is used for analysis of data recorded by satellite missions (Taylor et al, 2007). French DEMETER (Detection of Electro-Magnetic Emissions Transmitted from Earthquake Regions) micro-satellite mission had been especially designed to provide global scale observations in the topside ionosphere over seismically active regions (Bankov et al, 2010). In this paper, we used the Multilayer perceptron neural network for prediction of ionosphere plasma parameters recorded by the Instrument Plasma Analyze (IAP) installed on board of DEMETR mission; the goal is to predict future plasma parameters which are: Number of Hydrogen particles in the plasma (NH+), number of Helium (NHe+) and Oxygen particles (NO+), ions temperature (NI+), ions speed (VS and VZ), angles of ions arrival (VOX and VOZ).

2 Instrument Plasma Analyzer (IAP)

The IAP (Instrument Analyseur de Plasma) experiment installed on consists of two analyzers: APR (Analyseur à Potentiel Retardateur, Retarding Potential Analyzer)

M. Lee et al. (Eds.): ICONIP 2013, Part I, LNCS 8226, pp. 511–519, 2013.

performs the energy analysis of ram direction ions and ADV (Analyseur pour Direction de Vitesse, Velocity Direction Analyzer) determines the average angles of arrival of the ions. APR measurements allow determining the density, temperature and bulk energy of the ionospheric ions. IAP has 2 Survey modes of operation a medium energy resolution mode for APR providing a complete set of plasma parameters every ~ 360 ms and a high energy resolution mode with a lower temporal resolution providing a complete set of measurements every 720 ms. Density fluctuations from ADV measurements are available with a time resolution of 12.8 ms. There is also one Burst mode of operation featuring high energy and high temporal resolution with a complete set of plasma parameters every ~ 360 ms. Density fluctuations are available with a time resolution of 6.4 ms. The objective of the IAP experiment is to characterize the state of the ionospheric plasma, in order to detect perturbations that may be associated with seismic activity and to provide the plasma parameters that are needed to analyze the data from the plasma wave instruments, ICE and IMSC. As a secondary objective, near real time ionospheric data can be provided for space weather purposes.

3 The Multilayer Perceptron Neural Network

Multilayer feed-forward networks form an important class of neural networks. Typically the network consists of a set of sensory units or input nodes, that constitute the input layer, one or more hidden layers of neurons or computation nodes, and an output layer. Multi-layer Perceptron (MLP) neural networks with sufficiently many nonlinear units in a single hidden unit layer have been established as universal function approximators. For more details about the MLP, we invite readers to the papers of Ouadfeul and Aliouane (2012, 2013).

4 Data Analysis, Results and Conclusion

A multilayer neural network machine with three layers is implanted; the input layer is composed with eight neurons that correspond to the eight IAP plasma parameters, a hidden layer of seven neurons (obtained by test) and an output layer of eight neurons that correspond also to the IAP plasma parameters. Data of orbit 27447-1 that sweep L'Aquila area two days before the main chock of 09 April 2009 are used for the training of the neural network machine. The first time series of 151 (see Fig. 01) samples is used as an input, however the second 151 samples are used as an output (see Fig. 02). The implanted MLP machine is trained in a supervised learning and weights of connection are optimized. To check the efficiency of this neural machine the second time series is used as an input and an output is calculated by propagating the input via this machine, at this stage no training is needed since the weights of connection are calculated in the first stage. Obtained results are compared with the actual recorded plasma parameters (see Fig. 3), one can observe that the MLP machine is able to provide an acceptable model of parameters, however at the end of each time series the artificial neural network machine start to lose the memory, by consequence the MLP neural network has not long term memory, so we need always to update the weights of connection to give exact results. We suggest application of the whole process to data of other orbit to generalize its efficiency and generalize a rule.

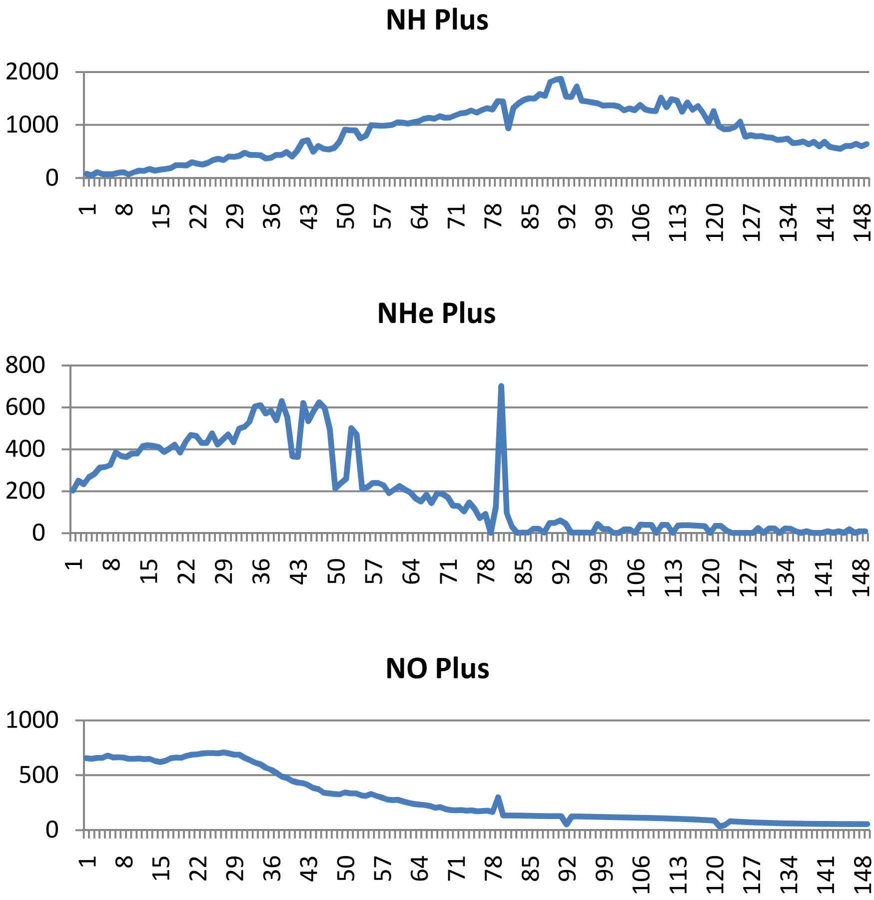

Fig. 1. First 151 samples of IAP instrument parameters of DEMETER satellite used for the MLP training

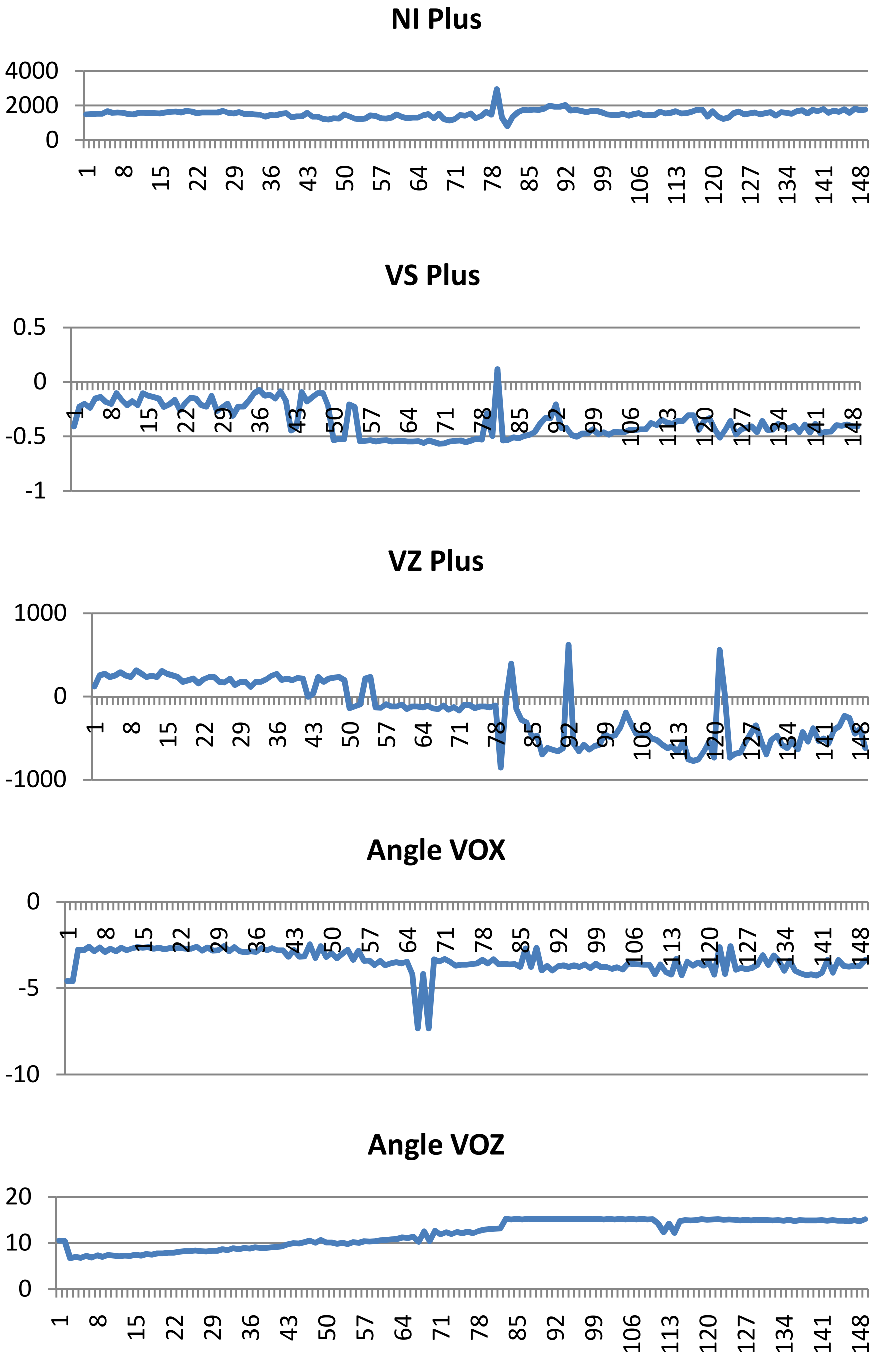

Fig. 1. (*Continued.*)

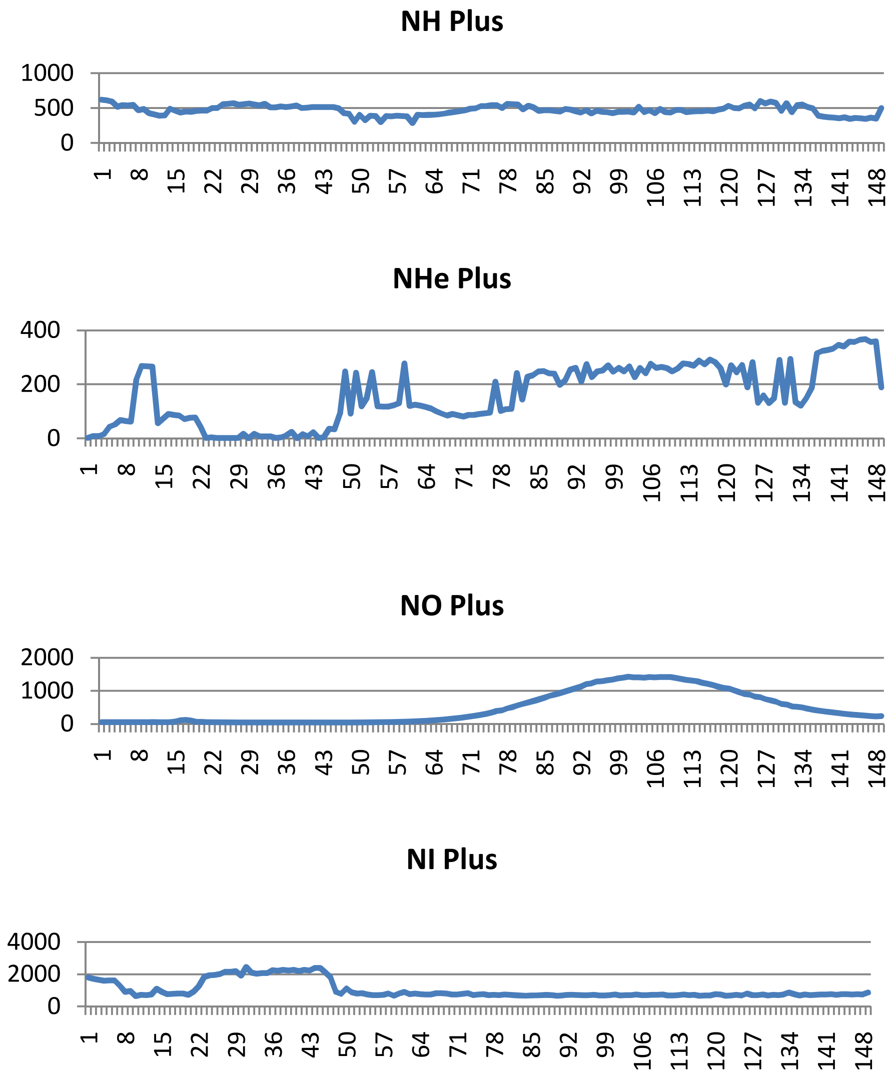

Fig. 2. Second 151 samples of IAP instrument used as an output for the MLP training

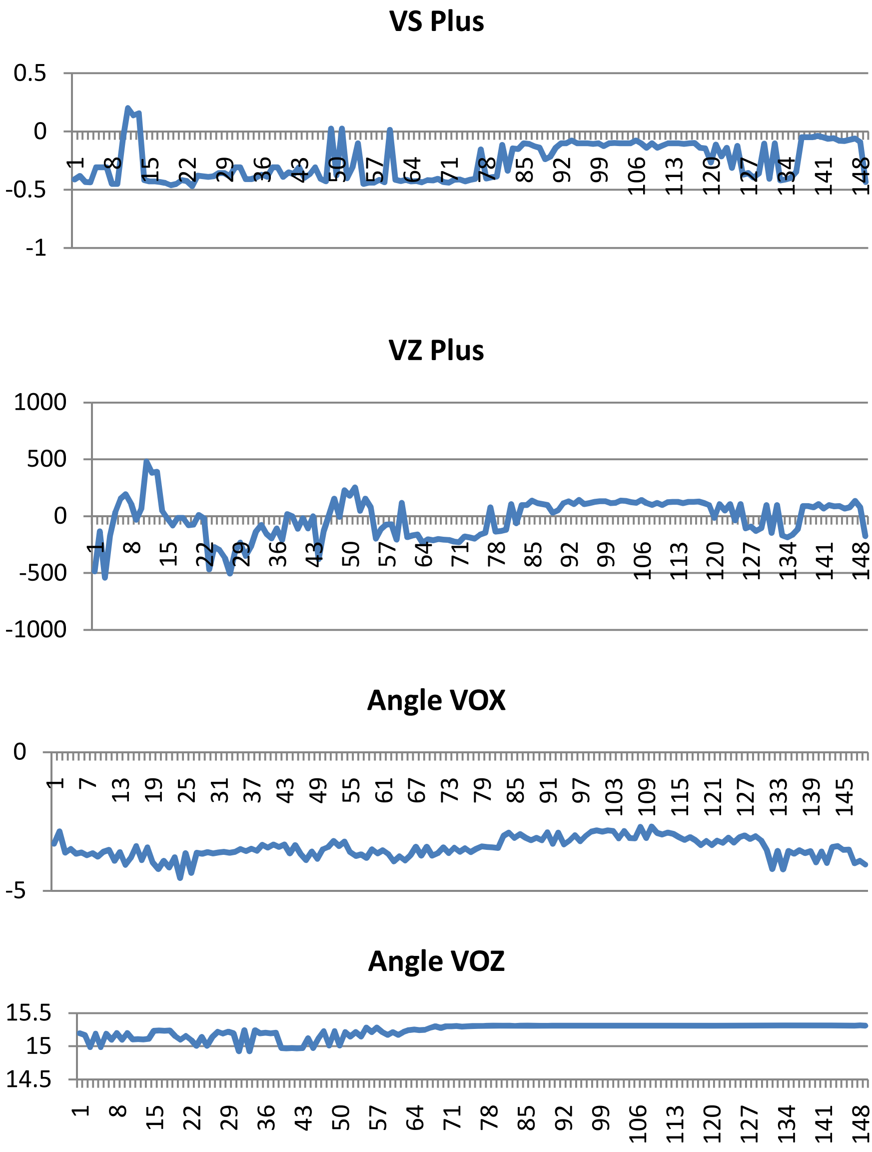

Fig. 2. (*Continued.*)

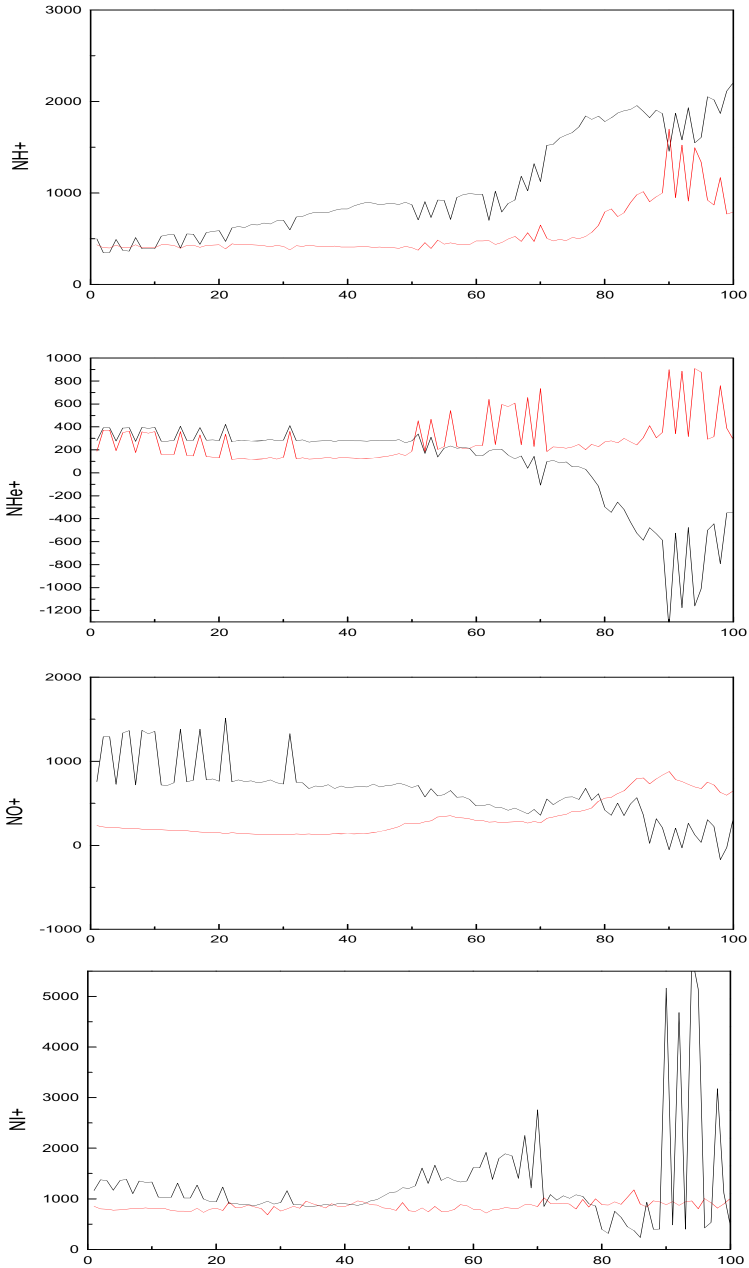

Fig. 3. Predicted IAP plasma parameters using the implanted MLP machine

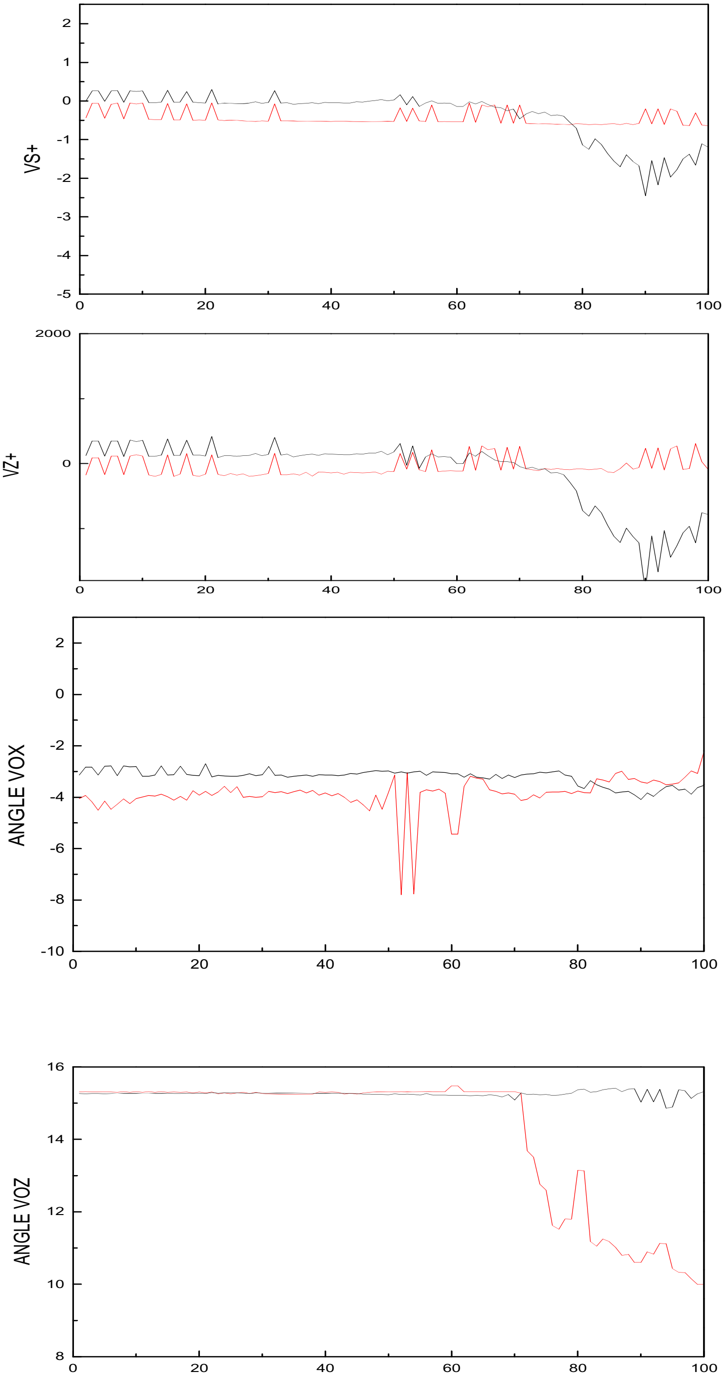

Fig.3. (*Continued.*)

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