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Emerging Space Weather Markets and some Case Studies:

Neural Network Modeling in Forecasting the Near Earth Space Parameters

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1. Introduction

Space Weather (SpW) is a new subject which has not yet become widely understood or appreciated.

SpW processes can include changes in the IMF, CME from the sun and disturbances in the Earth's magnetic field.

The effects can range from damage to satellites to disruption of power grids on Earth.

Any SpW service must be able to give reliable predictions of the Sun’s activity and its impact on the space environment and human activities.

Mathematical modeling of highly non-linear and time varying processes is difficult or impossible.

Data driven modeling methods are used in parallel with mathematical modeling

Demonstrated by the authors and others that the data driven NN modeling is very promising

(Tulunay, Y., 2004 and references there in).

NN systems are **motivated** by **imitating** human learning processes.

Whereas, the fuzzy systems are **motivated** by **imitating** human **reasoning** processes.

NN have been used extensively in modeling **real problems** with **nonlinear characteristics**.

The main advantages of using **NN**s 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 NN is essentially **independent** of the **number of neurons** in the network (Özkök, 2005; Tulunay, E., 1991).

Basic structure and properties of neural networks

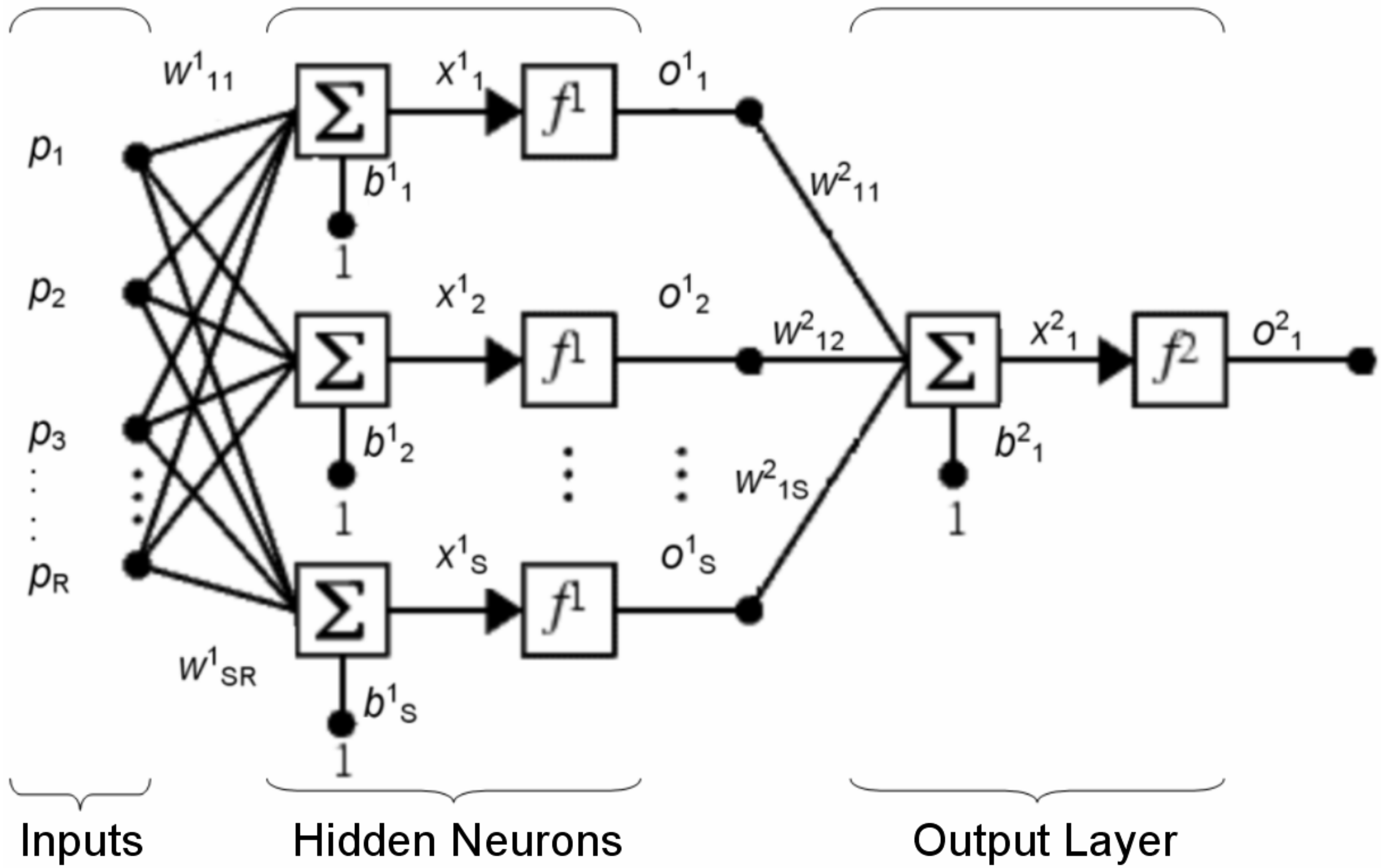

Fig. 1.1. Architecture of the METU-NN model

A **neuron** is an **information-processing unit** consisting of connecting **links**, **adder** and **activation function** or **non-linearities**.

The **adder** sums **bias** and **input signals weighted** in the neuron’s connecting links.

Activation function limits the extreme amplitudes of the output of the neuron (Haykin, 1999).

2.1. Case Study

Due to the rapid growth around the world in wireless communications at GHz frequencies, studies of solar noise levels at such freq. have become popular.

(Lanzerotti, 2002)

GOES SXR flux data of 2003 and 2004 are used to **train the METU-NN** to **forecast** the number of occurence of **large X-ray bursts (events)** in specific time-intervals, Tulunay et al. (2005).

Input Data

- Max. of SXR flux / month **(2003 & 2004)**
- Smallest of maxima is **$5.35*10^{-6}$ w/m^2**.
- SF > **$5.35*10^{-6}$ w/m^2** considered
- Upper deciles of data : **$34*10^{-6}$ w/m^2.**

Table 2.1. METU-NN Inputs

i	Number of SF values	• SF > 34.*10^{-6} w/m^2 • 34.*10^{-6} w/m^2 > SF > 5.35*10^{-6} w/m^2 • SF < 5.35*10^{-6} w/m^2
ii	First Diff. of (i)	• SF > 34.*10^{-6} w/m^2 • 34.*10^{-6} w/m^2 > SF > 5.35*10^{-6} w/m^2 • SF < 5.35*10^{-6} w/m^2
iii	Second Diff. of (i)	• SF > 34.*10^{-6} w/m^2 • 34.*10^{-6} w/m^2 > SF > 5.35*10^{-6} w/m^2 • SF < 5.35*10^{-6} w/m^2
iv	Day of SF	• In Julian day numbers
v	‘Day’ in trig. funcs.	• (Sin (2*pi*(day) / 365)) • (-Cos (2*pi*(day) / 365))

Table 2.2. Selected periods for Training and Operation of METU-NN

Training	1 April 2003	30 January 2004
Operation	31 January 2004	1 December 2004

Output

- Forecast of the number of occurence of **large X-ray bursts (events)** one month in advance.

2.1.Results

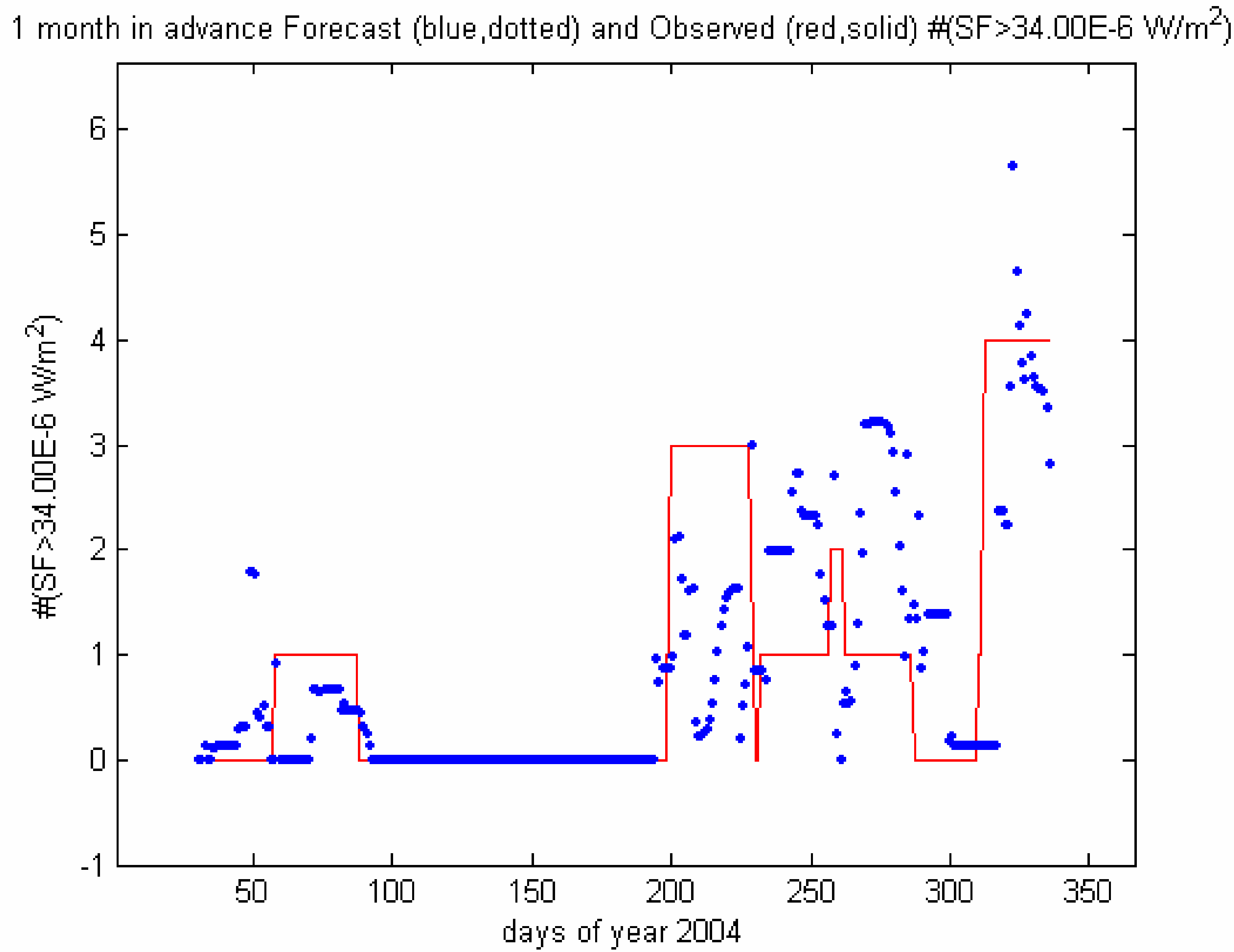

Fig. 2.1. The number of events: observed (red), and forecast (blue) one month in advance between 31 Jan. - 1 Dec. 2004

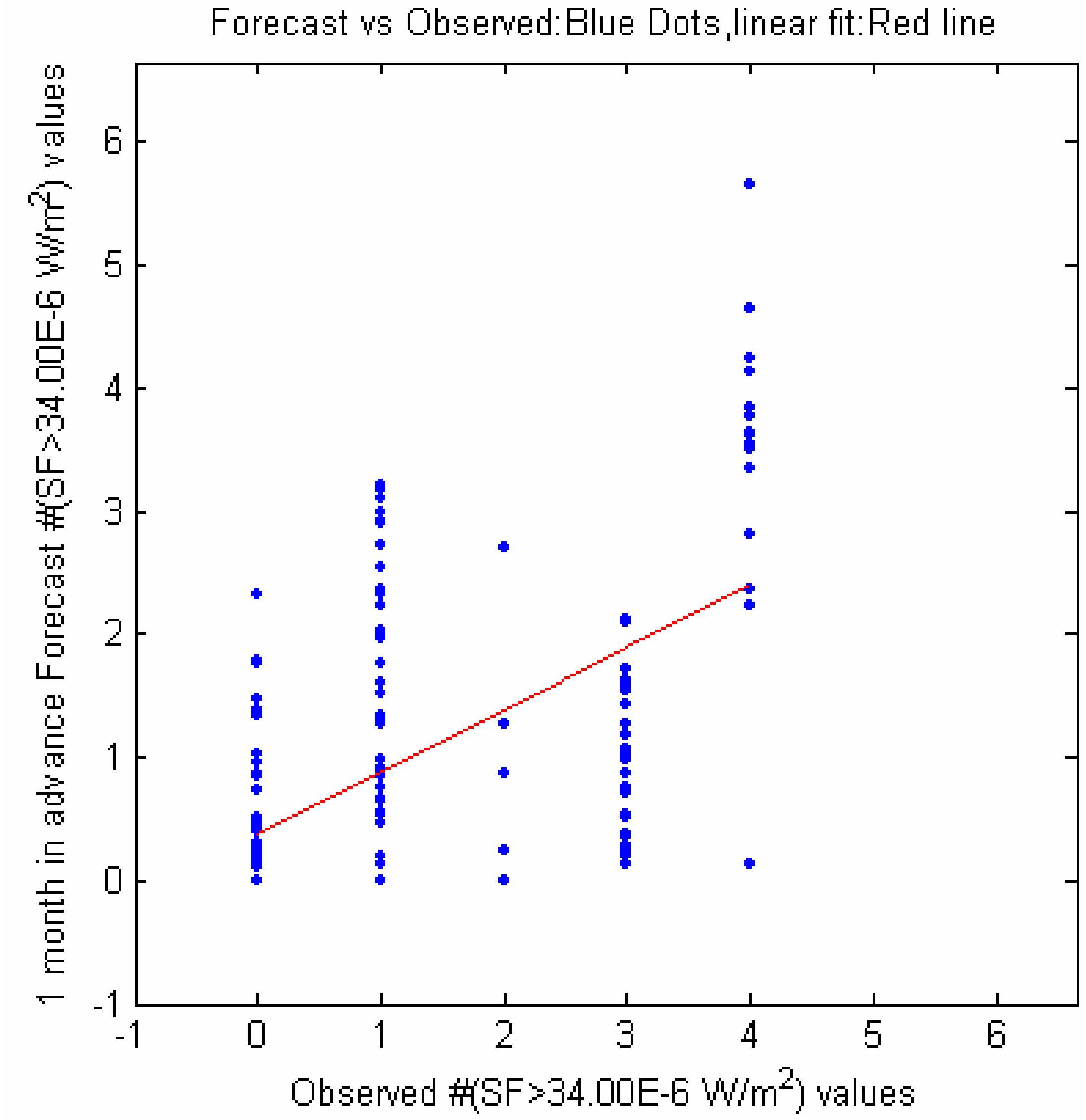

Fig. 2.2. The scatter diagram of the forecast versus observed number of events

Table 2.3. Errors on the forecast number of events

RMS error	1.13
Absolute error	0.72
Cross Correl. Coeff.	0.57

2.3.Conclusions

METU-NN model
forecasts
number of occurrence of
‘events’
in the next 30-day interval with
an absolute error of 0.72

- At a significance level of 0.05, the cross correlation coefficient between the observed and forecast number of occurrence of events is 0.57.

3.1. Case Study

(Özkök, 2005)

METU-NFN is derived by including some expert information in the METU-NN

Applicability of the neurofuzzy systems on the ionospheric forecasting studies is demonstrated.

Table 3.1. A comparison of the results with METU-NFN & METU-NN models for TEC forecasting process

	NFN 1NN*	METU-NN**
Cross correlation	0.98	0.99
MSE	3.77	3.041
RMSE	1.94	1.74
Average Absolute Error (TECU)	1.32	1.16
Average Epoch Duration (ms)	1717	3233

*NFN 1NN: NFN model drives METU NN Model.
**Neural Network Model

3.2. Conclusion

- Applicability of the neurofuzzy models on ionospheric forecasting has been shown.

- With a considerable large input-output data set the NN models produce better results.

- NFN models offer an alternative when data are not enough.
- NFN models may be used for faster t raining and short operation times at the expense of performance.

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