fOF2 prediction in Rome observatory

L. Perrone(1), M. Pietrella (1), B. Zolesi (1) and A. Malagnini(1)

(1) Istituto Nazionale di Geofisica e Vulcanologia-Via di Vigna Murata 605-Rome Italy
E-mail: perrone@ingv.it

Abstract

A prediction procedure of the hourly values of the critical frequency of the F2 ionospheric layer, foF2, based on the local geomagnetic index *ak*, is presented. The geomagnetic index utilised is the time-weighted accumulation magnetic index $ak(\tau)$ based on recent past history of the index *ak*. It is utilised an empirical relationship between the *log(NmF2(t)/ NmF2M)*, where *NmF2(t)* is the hourly maximum electron density at the F2 peak layer and *NmF2M* is its 'quiet' value, and the time weighted magnetic index. The prediction of foF2 is calculated during periods of severe magnetic activity in the current solar cycle 23 in Rome observatory.

1. Model Description

To forecast the ionospheric response to geomagnetic storms, geomagnetic indices has been introduced taking into account their past history [1 – 4].

In this work the $ak(\tau)$ index is utlised. It is derived with a time weighted series accumulation from the geomagnetic local index *ak* [5], calculated at L'Aquila geomagnetic observatory (42°23' N, 13°19'E). An improved linear correlation was found between transformed data obtained from hourly and monthly median values of foF2 and $ak(\tau)$ with $\tau = 0.8$. The transformed data of foF2 that gives the best result is, log*(NmF2(t)/NmF2M(t))*, where *NmF2(t)* is the hourly value of the maximum electron density at the F2 peak and the suffix M indicates the monthly median value of ionospheric parameter [4, 6].

The relationship here utilised is :

$$\log[NmF2(t)/NmF2M(t)] = a + b \cdot ak(0.8) \qquad (1)$$

but instead to use the monthly median to represent the 'quiet' ionosphere an average is calculated. It is obtained considering, for a selected hour, foF2 values with $ak(\tau) \leq 7$ in the thirty days preceding the day for which we want to have the 'quiet' value. This average is called 'daily' mean.

2. Data Analysis

The data utilised are the foF2 hourly values measured in Rome (41.9N; 12.5 E) observatory. Geomagnetic storms with a maximum of the geomagnetic planetary index ap ≥ 132, classified as strong events, are selected between 1996 to 2001.

A geomagnetic storm is always followed by a negative ionospheric storm when $ak(\tau) \geq 50$ (second level). (Tab. 1-Fig.1)

Table 1.The $ak(\tau)$ maxima of the selected geomagnetic storms are divided in intervals that are called $ak(\tau)$ levels.

LEVEL 1	$32 \leq ak(\tau) < 50$
LEVEL 2	$50 \leq ak(\tau) < 70$
LEVEL 3	$70 \leq ak(\tau) < 90$
LEVEL 4	$90 \leq ak(\tau) < 110$
LEVEL 5	$110 \leq ak(\tau) < 130$

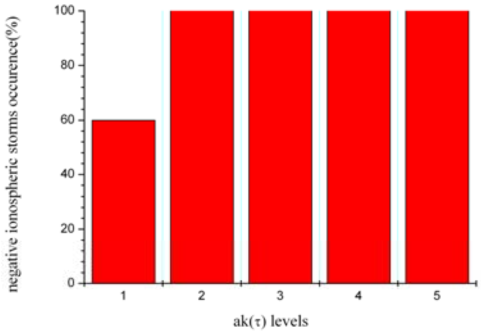

Figure 1. The occurrence of negative ionospheric storms, calculated considering the number of negative ionospheric storms respect to the number of geomagnetic storms, at different *ak(τ)* levels (Table 1).

In winter the number of negative ionospheric storms is minor respect to the other seasons. Considering the *ak(τ)* levels in winter the maxima of *ak(τ)*arrive at third level (*ak(τ) ≤ 90*).(Fig.2)

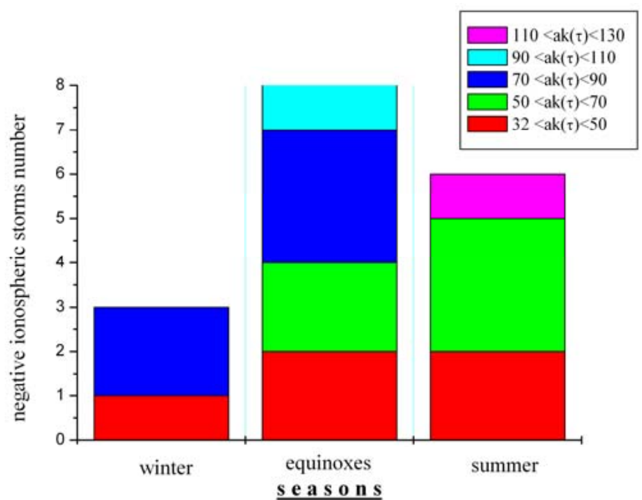

Figure 2. Number of negative ionospheric storms divided for seasons and for different *ak(τ)* levels (Table 1).
Winter:01-02-11-12
Equinoxes: 03-04-09-10
Summer: 05-06-07-08

Examples of foF2 forecasted with the relationship between the foF2 transformed data and *ak(τ)* are presented. To forecast the foF2 in some severe events occurred in the year 2001, there are selected geomagnetic storms between 1996-2000. Different predictions of foF2 are obtained utilising:

- all geomagnetic storms selected (*ak(τ)* ≥ 32)
- the geomagnetic storms with a maximum of *ak(τ)* ≥ 50

For the period 30 March – 2 April 2001, the forecasting model is better than the 'daily' mean except for the 31 March between 17 UT-23 UT. The behaviour of foF2 forecasted with the two methods is similar.(Fig.3)

For the period 10 – 14 April 2001, when foF2 decrease it can be seen that the foF2 forecasted is better than 'daily' mean. (Fig.4)

For the period 4 – 8 November 2001, the forecasting model when there is the negative ionospheric storm is better than the 'daily' mean.(Fig.5)

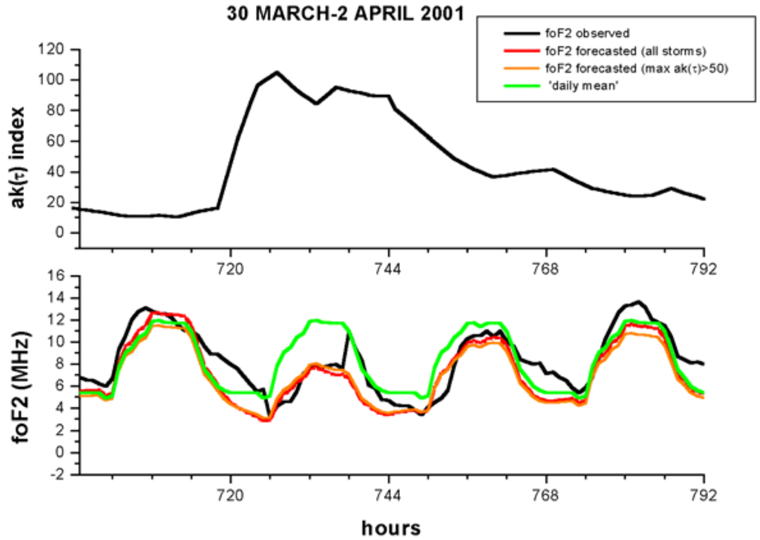

Figure 3. The time behaviour of foF2 observed, of foF2 forecasted and of the 'daily' mean for 31 March- 2 April 2001.

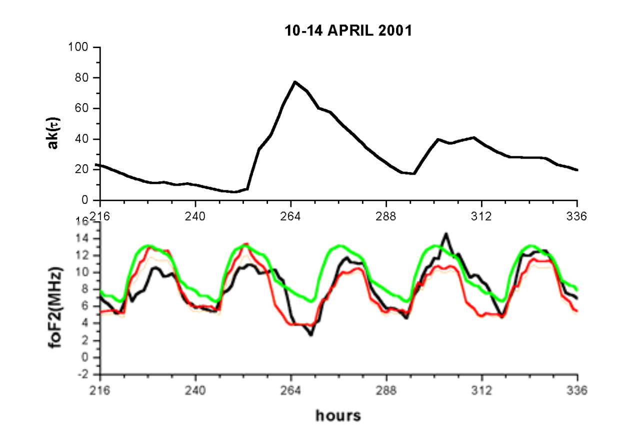

Figure 4. The time behaviour of foF2 observed, of foF2 forecasted and of the 'daily' mean for 31 March- 2 April 2001.

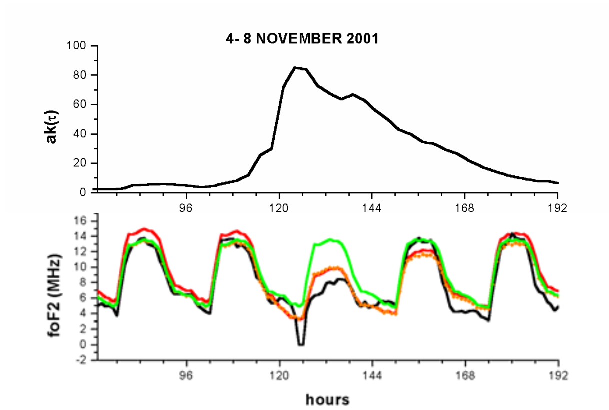

Figure 5. The time behaviour of foF2 observed, of foF2 forecasted and of the 'daily' mean for 4 - 8 November 2001.

For the days in which is observed the negative ionospheric storm, σ values between the foF2 forecasted, utilising the two methods, and the foF2 observed value are calculated (Tab.2). For comparison is inserted the σ calculated between foF2 'daily' mean and the observed value. The forecasted model give better results respect to the 'daily' mean, in particular for the 6/11.

Table 2. σ values calculated when there is a negative ionospheric storm.

DAY	*max* $ak(\tau) \geq x$	σ		DAY	*max* $ak(\tau) \geq x$	σ
31/03/2001	x=32	2.14		12/04/2001	x=32	00.97
	x=50	2.02			x=50	1.21
	'daily' mean	3.01			'daily' mean	1.58
01/04/2001	x =32	1.47		06/11/2001	x=32	1.45
	x=50	1.61			x=50	1.21
	'daily' mean	1.91			'daily' mean	4.21

3. Preliminary Results

For the cases analysed:

- A geomagnetic storm with a maximum of $ak(\tau) \geq 50$ is always followed by a negative ionospheric storm.
- The major number of negative ionospheric storms occurs for $ak(\tau) < 90$ and for equinox/summer season. In winter the maxima of geomagnetic storms arrive to $ak(\tau) < 90$.
- The forecasting model gives better results respect to the use of the 'quiet' value of foF2. The behaviour of the two fof2 forecasted, considering all the geomagnetic storms and the geomagnetic storms with a maximum of $ak(\tau) \geq 50$, are very similar.
- It is necessary to analyse others geomagnetic/ionospheric storms and probably better results can be reached forecasting foF2 for different seasons and hours.

4. References

1. G. L. Wrenn " Time-Weighted accumulations ap(t) and Kp(t)," *J. Geophys.Res*., **92**, 1987, pp. 10,125-10,129.
2. J. Wu, . and P. J. Wilkinson, " Time-weighted indices as predictors of ionospheric behaviour," *J. Atmos. Terr. Phys*, **57**, 1995, pp. 1763-1770.
3. T.J Fuller-Rowell T.J., M.V Codrescu,., E. Araujo-Pradere, and I. Kutiev, "Progress in developing a storm-time ionospheric correction model," *Adv. Space Res*., **22**, 6, 1998, pp. 821-827.
4. L. Perrone, , and G. De Franceschi, "A correlation study between time-weighted magnetic indices and the high latitude ionosphere," *Physics and Chemistry of the Earth*, **24**, 4, 1999, pp. 389-392.
5. G. K Rangarayan,." Indices of geomagnetic activity, Geomagnetism, "ed. *Jacobs Academic Press, London. ,* **3**,1989, pp. 323-384.
6. L. Perrone, M. Pietrella and B. Zolesi, "A Prediction model of foF2 over periods of severe geomagnetic activity", *Adv. Space. Res.*, **39**, 2007, pp. 674-680.