# Geomagnetic Indices Forecasting and Ionospheric Nowcasting Tools

## Work Package 200
## INT (Ionosphere Nowcasting Tool)

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## Summary

- Objectives
- Preliminary considerations
- SIRMUP: Real time Simplified Ionospheric regional model updating
- First concluding remarks on the method
- User requirements for INT tools
- Work Package 200 break down

## Objectives

The proposed wp has three objectives:

- to develop a software tool for the real-time mapping of the ionosphere over Europe;
- to certify its performance during geomagnetically quiet and disturbed time periods;
- to ensure its reliability in a way that it will be a useful tool for large number of users concerned with terrestrial and Earth space telecommunication systems.

## Preliminary considerations

Long term prediction of ionospheric mapping is a problem considered since the fifties years.

Global models as the well known and mainly used CCIR/ITU/IRI method and the most recent regional models, developed during the European actions COST238 and COST 251, provide fair performances needed by the RF planners .

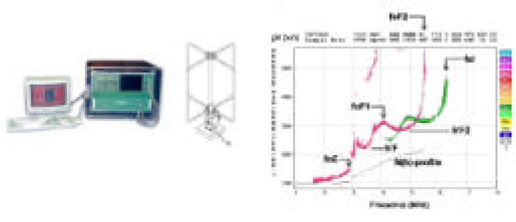
## Preliminary considerations

Short term forecasting and specially now casting of the principal ionospheric parameters, useful for space weather purposes, it is not only a problem of physical or mathematical model but it is a question of experimental measurements and logistic organization.

Global and regional now casting models need infact real time measurements that in the case of the ionospheric parameters it is also a complex problem of measurement and automatic interpretation.

## Preliminary considerations

Only special equipments located in few ionospheric observatories are able to provide automatic scaled data .



An example ionogram by Digisonde sounder

## Preliminary considerations

Consequently a space weather service that use a network of ionospheric vertical sounding stations, spread on the globe, on the continent or even on a small region, must consider all of these problems that are not only scientiphic or technical but mainly logistic , economic and politic.

Of course these problems increase their importance with the number of the reference points of observations as well the performance of every mapping method applied .

A new ionospheric regional mapping model for the real time nowcasting of the principal ionospheric parameters is in progress and testing by

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# SIRMUP Real-time Simplified Ionospheric Regional Model updating

## Aim

Ionospheric models of the standard VI ionospheric characteristics oversimplify a number of the ionospheric phenomena of real significance for radio communications applications.

We propose a real-time updating method of SIRM with autoscaled ionospheric parameters observed by four European DPS ionosondes in order to have a realistic mapping of the ionosphere over Europe in real-time, especially during storm periods.

# SIRM: Brief Review

SIRM is based on the Fourier coefficients coming from the analysis of the monthly median values of the ionospheric characteristics measured at the stations of the Eastern regions and European, collected under the COST251 project.

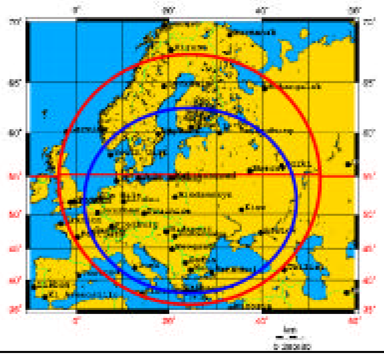
For every different month there are 12 couples of Fourier coefficients An and Yn showing linear dependence on solar activity and on geographic latitude:

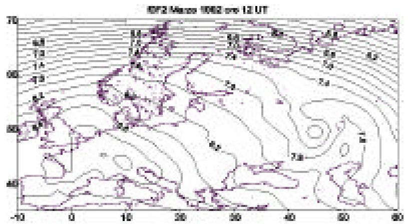
$$An = (a^1_n f + a^2_n)R12 + a^3_n f + a^4_n$$

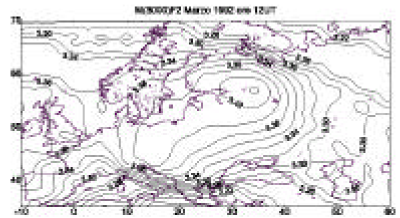
$$Yn = (b^1_n f + b^2_n)R12 + b^3_n f + b^4_n$$

$a^j_n$ and $b^j_n$ are calculated using a linear regression analysis versus the latitude.

An improved version of the SIRM model was developed and tested on the European area by the COST 251 action. Numerical coefficients were calculated by using a set of 15 ionospheric stations in Europe , part of the COST251 data base.

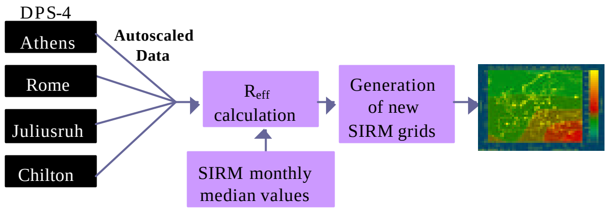






# SIRMUP real-time updating method

The SIRMUP updating method is based on the idea that real time values of foF2 at one location can be determined from the SIRM model by using an effective sunspot number, $R_{eff}$, instead of the R12 index.




## Effective sunspot number $R_{eff}$

$R_{eff}$ is chosen to give the best fit between model calculation and actual measurements.

The sunspot number giving the minimum mean square error is called the effective sunspot number, $R_{eff}$. The mean square error is calculated as follows:

$$\Delta = \frac{1}{n}\sum_{i=1}^{n}\left(foF2_{obsi} - foF2_{cali}\right)^2 ,$$

where n is the number of stations,

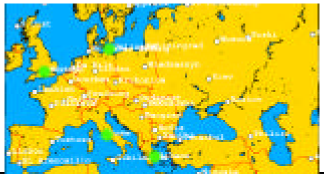
$foF2_{obsi}$ is the observed foF2 at station i

$foF2_{cali}$ is the calculated foF2 at station i

$foF2_{cali}$ is calculated for different sunspot numbers to determine the minimum mean square error and thus $R_{eff}$.

## Reference stations

The stations having the capability in providing regularly real-time observations were used as reference stations to determine $R_{eff}$.



| Reference stations | Geographic Latitude | Geographic Longitude |
|---|---|---|
| Athens | 38.1 | 23.9 |
| Rome | 41.8 | 12.5 |
| Chilton | 51.6 | 358.7 |
| Juliusruh | 54.6 | 13.4 |

## Relative errors

•Moscow, San Vito, Sofia, Ebro: Test stations chosen to test the reliability of the model. For each test station, foF2 was calculated by the SIRM model, using first the observed sunspot number R12, and then the calculated $R_{eff}$. The relative errors between the observed and the calculated foF2 values were determined using the following equations:

$$e1 = \frac{\left|foF2_{obs} - foF2_{SIRM}\right|}{foF2_{obs}}$$

$$e2 = \frac{\left|foF2_{obs} - foF2_{SIRMUP}\right|}{foF2_{obs}}$$

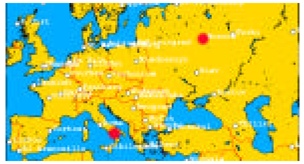
•where $foF2_{obs}$ is the observed foF2 at the test station, $foF2_{SIRM}$ is the SIRM calculated foF2 at the test station using the observed R12 sunspot number, and $foF2_{SIRMUP}$ is the SIRM calculated foF2 at the test station using Reff.

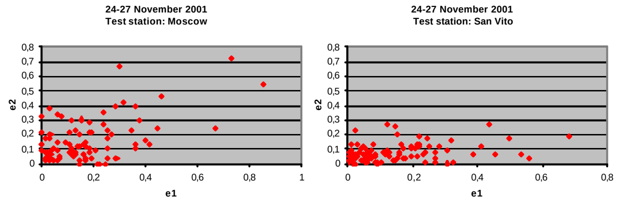
•**The method of real-time updating is successful when e2<e1.**

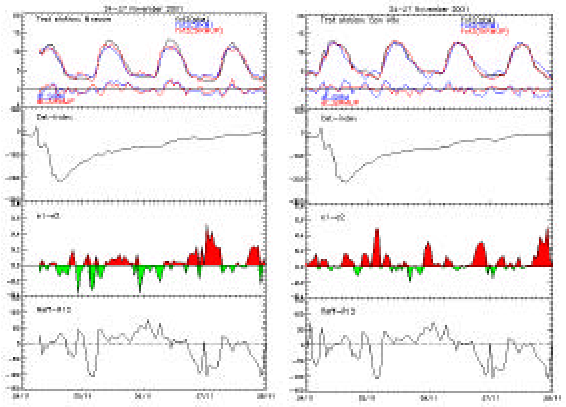
# Simulation Results

| Time Period | Geomagnetic Activity | Test stations |
|---|---|---|
| 24-27 November 2001 | Storm Period | Moscow (55.5°N, 37.3°E)<br>San Vito (40.6°N, 17.8°E) |
| | | |
| 6-10 December 2001 | Quiet Period | Ebro (40.5°N, 0.5°E)<br>San Vito (40.6°N, 17.8°E) |

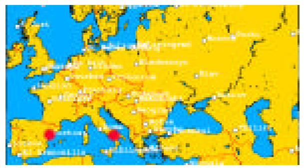
# Relative errors: November 2001 storm event

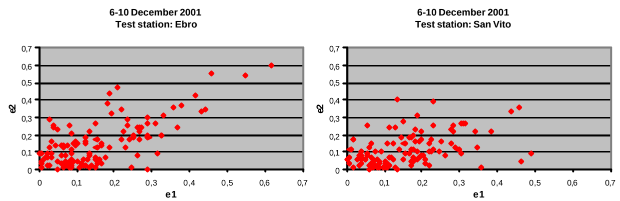


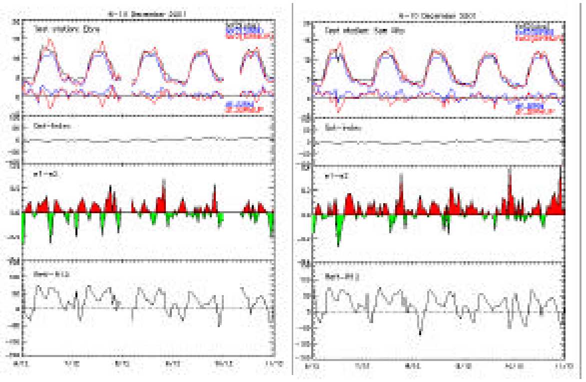


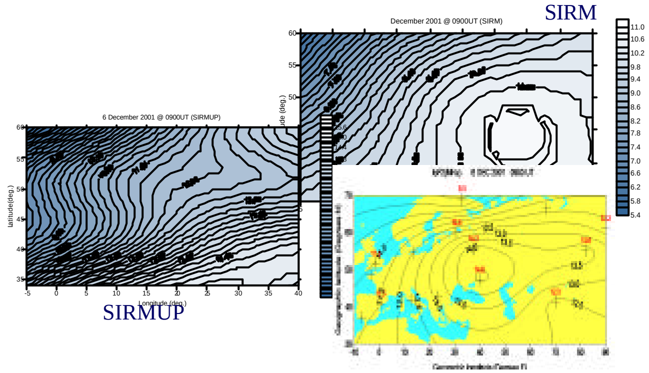
# Relative errors: 6-10 December 2001 quiet period







## First preliminary examples of a continental service




## First concluding remarks on the method

- Real-time predictions of foF2 at middle latitudes in a continental region as Europe can be improved by using real-time observations at a grid of an adequate number of reference stations spread over Europe.
- Real-time predictions are more successful at the center of the mapping area.
- Real-time predictions are still valid, but on a limited area, by using a reduced number of reference stations.
- For storm periods real-time predictions are much improved comparing to SIRM results.

## User Requirements for the INT tools

Ionospheric Nowcasting (INT) has the main objective of developing software tools able to provide the ionospheric mapping now casting of the maximum electron density (foF2) and of the trasmission factor M(3000)F2 on a region of main interest for the users as described in the GIFINT technical proposal.

## User Requirements for the INT tools

**Availability of real time maps of foF2, updated every hour, on the Italian and near Balcan region as required by the two users. The effective solar activity index is calculted by using real time scaled ionograms provided by the Ionospheric vertical station at the centre of limited the region , in this case Rome (41.9N; 12.5 E)**

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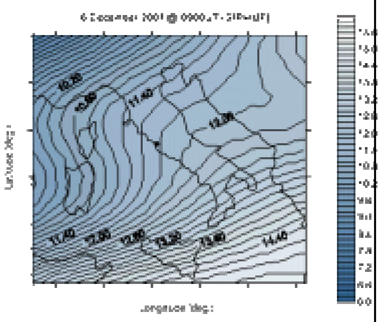

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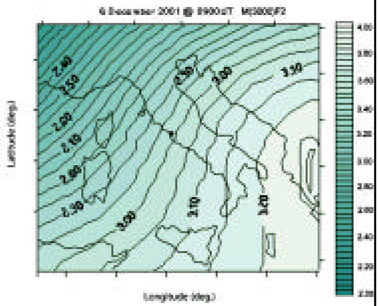

## GIFINT WP 200 Work break down

**now in progress**

1 The collection and validation of the ionospheric hourly data values of 15 ionosperic vertical ionospheric stations over the European region will be provided by RAL. These data will be processed by INGV to calculate numerical coefficients for the ionospheric characteristics foF2 and M(3000)F2 to be applied in the mapping model generation SIRM .

2 INGV (with the collaboration of NOA) and RAL will develop software tools to update the performances of the SIRM model to be able to provide the ionospheric mapping now casting of the maximum electron density (foF2) and of the trasmission factor M(3000)F2 as described in the GIFINT technical proposal.

## GIFINT WP 200 Work break down

**to be achieved**

3 INGV (with the collaboration of NOA) will test the software performance during geomagnetically quiet and disturbed conditions, determining the relative errors between the observed and calculated ionospheric parameters.

4 INGV (with the collaboration of NOA) will calculate a set of hourly ionospheric maps for any months and for different standard values of the effective solar activity index.

5 INGV (with the collaboration of NOA) and RAL will develop a prototype server demonstrator illustrating the main features and results with the generation of real time ionospheric maps for Italian and near Balcan region as required by the two Italian users.