MUF(3000) nowcasting as operation space weather product

ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

D. Sabbagh, C. Scotto, P. Bagiacchi

Istituto Nazionale di Geofisica e Vulcanologia, via di Vigna Murata 605, 00143 Rome, Italy

e-mail address: dario.sabbagh@ingv.it

Pan-European Consortium for Aviation Space weather User Services (PECASUS) is one of the three global Space Weather Centers for aviation space weather user services designed by the International Civil Aviation Organization (ICAO).
The MUF(3000) nowcasting is one of the operational space weather products inserted in PECASUS. A mapping procedure is then applied to the European stations providing MUF(3000) nowcasting over the whole area. This procedure consists in upgrading the IRI-CCIR model using available real-time measurements and the Ordinary Kriging method for spatial interpolation.

Mapping method

The value of the variable z for a given time is spatially interpolated using the Ordinary Kriging method, being:

$$z(\boldsymbol{x}_i) = \frac{\mathrm{MUF(3000)}_{[\mathrm{meas}]}(\boldsymbol{x}_i) - \mathrm{MUF(3000)}_{[\mathrm{med}]}(\boldsymbol{x}_i)}{\mathrm{MUF(3000)}_{[\mathrm{me}]}(\boldsymbol{x}_i)},$$

where $\mathrm{MUF(3000)}_{[\mathrm{med}]}$ is the value obtained by the IRI-CCIR model, and $\boldsymbol{x}_i$ are the geographic coordinates of the *i-th* ionospheric station where measurements are available (see **Table 1**).

The interpolation is performed in the region A of longitude 12°W-45°E and latitude 32°N-72°N, over a grid with spatial resolution 0.5°x0.5°.

Then, upgraded MUF(3000) maps are produced over the interpolation grid as:

$$\mathrm{MUF(3000)}(\boldsymbol{x}) = \big(1 + z(\boldsymbol{x})\big) \cdot \mathrm{MUF(3000)}_{[\mathrm{med}]}(\boldsymbol{x}), \qquad \boldsymbol{x} \in \text{grid in } A.$$

Table 1

Station	Longitude (°E)	Latitude (°N)
Chilton	-00.6	51.5
Gibilmanna	14.0	37.9
Juliusruh	13.4	54.6
Moscow	37.3	55.5
Rome	12.5	41.8
Warsaw	21.1	52.2
Athens	24.0	38.0
Pruhonice	14.6	50.0
Dourbes	04.6	50.1
Tortosa	00.5	40.8

Case studies analysis

The following four storm periods during solar cycle 24 have been analyzed: **March 2012 (Case Study 1)**, **March 2015 (Case Study 2)**, **May 2015 (Case Study 3)**, and **September 2017 (Case Study 4)**.

MUF(3000) hourly values have been used to test the method, comparing measurements and predictions at the **test stations** of **San Vito (17.8°E, 40.6°N)** and **Fairford (-01.5°E, 51.7°N)** (see figures in this panel). The results have been compared also on the basis of the RMSE values obtained between predicted and measured MUF(3000) values at the test stations (see **Table 2**).

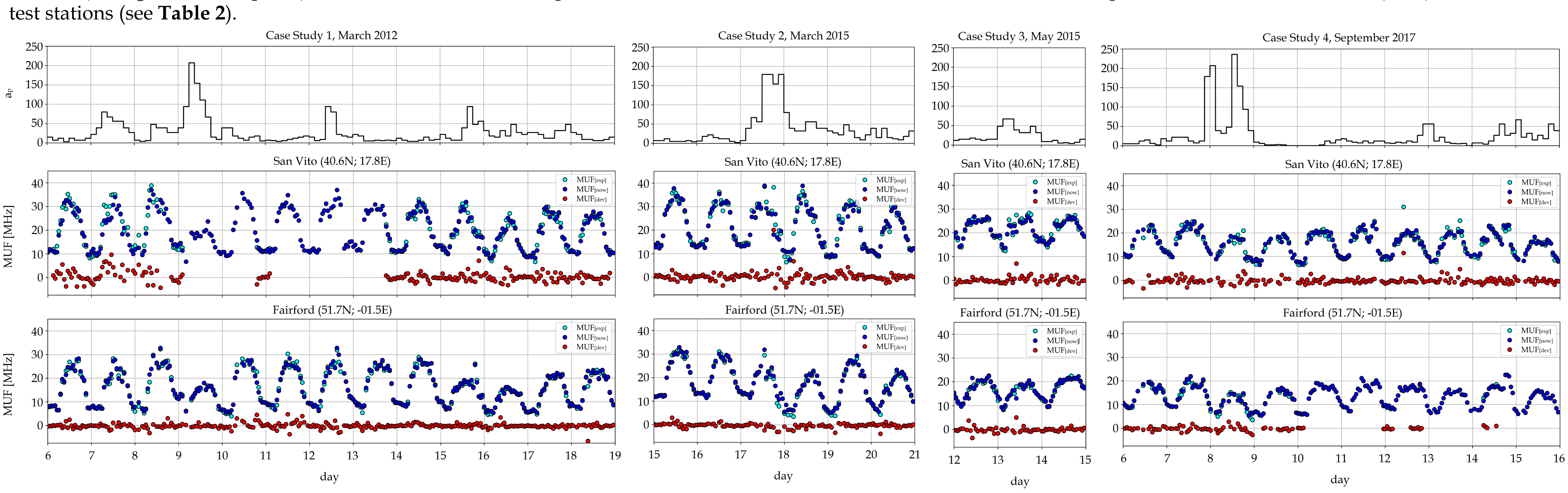
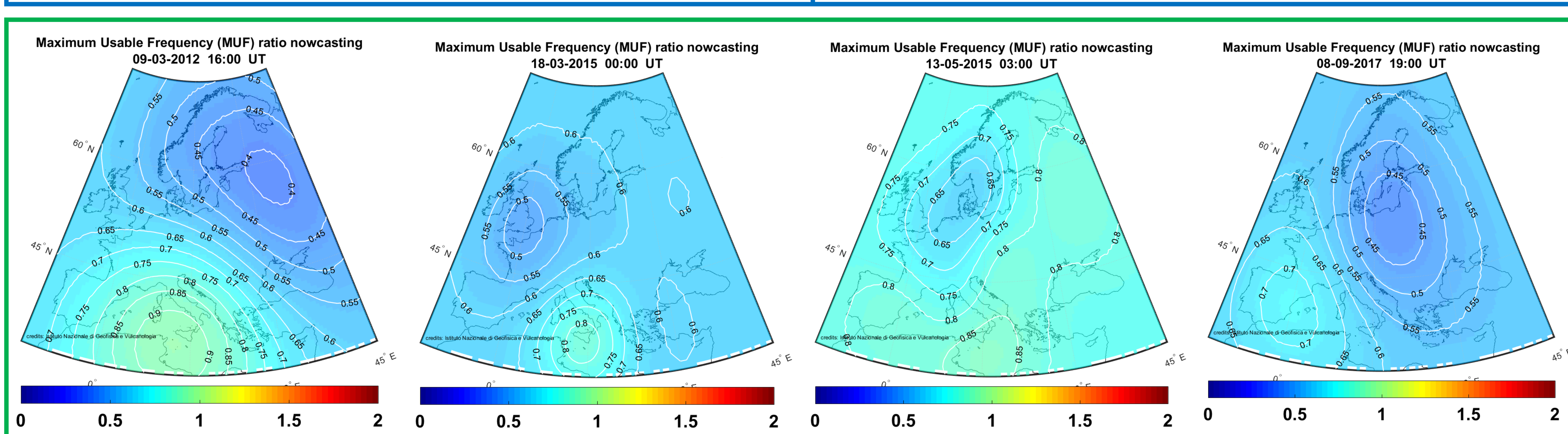


Table 2	San Vito		Fairford	
	RMSE (MHz)	n	**RMSE** (MHz)	n
Case Study 1	2.15	184	1.08	291
Case Study 2	2.27	138	0.98	127
Case Study 3	1.36	63	1.13	62
Case Study 4	1.44	188	0.85	86
Total	1.90	573	1.03	566

Results and Conclusions

- Storm periods represent the conditions of greater interest for Space Weather applications, and those more critical in terms of accuracy of models to reproduce ionospheric features.
- On the basis of the results reported in **Table 2**, the MUF(3000) accuracy achieved by this method during storm periods can be assessed as quite good, being the corresponding RMSE values at the test stations often less than 2 MHz, when computed over a whole storm period.
- RMSE values obtained at Fairford station result generally lower than those at San Vito, because of its proximity to the Chilton station, where measurements are assimilated.



- Examples of maps of the ratio MUF(3000)/ $\mathrm{MUF(3000)}_{[\mathrm{med}]}$ obtained during the four storm periods analyzed.
- When MUF ratio values get down below 0.7, advisories on degraded radiocommunication conditions in the corresponding area are issued.

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The Rome and Gibilmanna data are provided by Istituto Nazionale di Geofisica e Vulcanologia (http://www. eswua.ingv.it/).