# Operational monitoring of radioelectric exposure in an urban environment

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**Abstract** Polemics about base stations of cellular telephones have become a recurrent source of conflict among telecommunication companies, city authorities and citizens. Following early work performed within the framework of a doctoral thesis, the french research projet ANR Samper (2008-2011) has set up, for the first time, a network of monitoring stations in an urban environment, whose measurements are processed continuously by geostatistical methods, in order to inform daily the inhabitants on the hourly variations of radioelectric exposure in their surroundings. More precisely, the system uses a kriging of the exposure measurements including as external drift the output of a physical model of the propagation of the radioelectric signal emitted at different frequencies by the base stations. We present the implementation of the ANR Samper pre-operational monitoring system set up during several months in a section of the city of Grenoble.

## 1 Introduction

The population in cities is anxious about environmental exposure, in particular to air pollution, but also, more recently, to exposure to the electromagnetic field generated by mobile phone base station antennas.

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For the purpose of informing better the population about radioelectric exposure in their neighborhood, a real-time operational system was designed by the partners of the SAMPER research project (CSTB, MINES ParisTech, Orange Labs, Satimo) and it was run successfully during several months in 2011. This system couples by geostatistical means the data from monitoring stations with the output from a physical model. A website, which is still available in the form of a demonstrator, presents the results to the general public.

This short paper begins by a brief description of the electromagnetic propagation software. Then it presents the area of study in Grenoble and the setup of the monitoring stations. Finally it explains the geostatistical treatment of the data and shows how results are displayed on the SAMPER website.

## 2 The ICARE-EM electromagnetic propagation software

The ICARE-EM software [1] has been developped by CSTB for computing the electromagnetic exposure to mobile phone base stations using ray tracing. The geometric input mostly stems from a GIS with 1m resolution and represents so called 2.5D data (i.e. buildings are 2D lines with corresponding heights). Hence 2D algorithms can be used to solve the corresponding 3D problem without quality loss (see [2] for details). The reference height for the outdoor exposure evaluation being 1.5m, a corresponding simulation with ICARE-EM is shown on Figure 1.

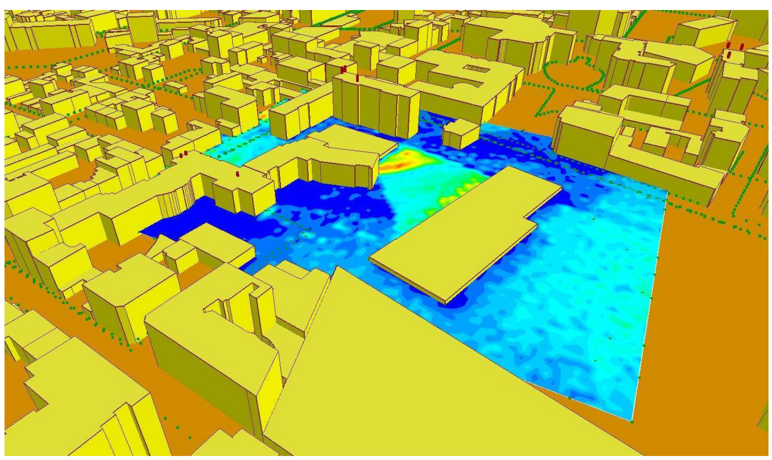

**Fig. 1** An example of ICARE-EM simulation at 1.5m height.

## 3 Area of study in the city of Grenoble

The study area is a 2 km$^2$ section of the city of Grenoble, south of the train station, which has been chosen for its urbanistic variety: 6-8 storey buildings, family houses and parcs. In and around the area about a dozen mobile phone base stations are available. The study area (delimited by a blue line) and the locations of antennas (arrows) in the vicinity are shown on the left of Figure 2.

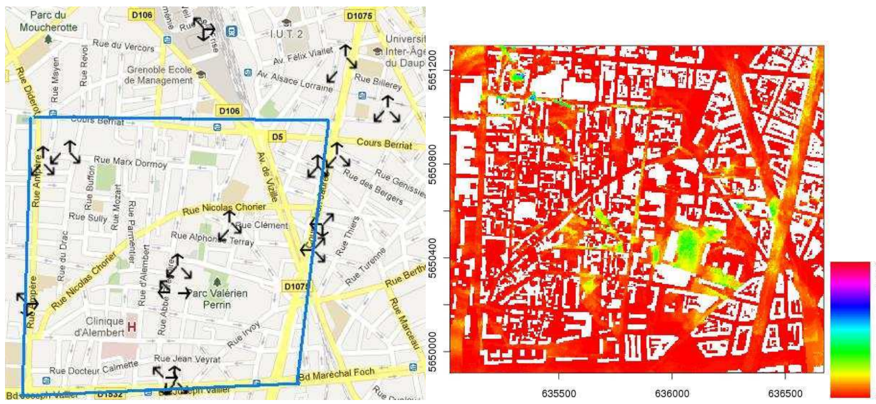


**Fig. 2** Left: study area (framed in blue) in the city of Grenoble with the position of neighboring base station antennas (arrows). Right: ICARE-EM physical model output for the study area (color scale units are in V/m).

## 4 INSITE Box measurement stations

For the SAMPER project seven monitoring stations of the type INSITE Box (by Satimo) have been set up at public buildings in collaboration with the City of Grenoble.

These stations work autonomously with a measurement cycle of 24 hours: measurements are taken during 22 hours every 2 seconds (only for the 3 frequency bands of GSM, DCS and UMTS in this project) with a sensitivity of 5 mV/m and they then are tranferred during 2 hours to an FTP site via a modem.

In order to have a global mobile phone exposure indicator, the three channels were combined to provide a single exposure level in $V/m$ (equivalent to the GSM 900 MHz exposure) using the formula:

$$Leq_{900} = \sqrt{(E_{GSM})^2 + \left(E_{DCS} \cdot \frac{41}{58}\right)^2 + \left(E_{UMTS} \cdot \frac{41}{61}\right)^2}$$

As an example, the values of $Leq_{900}$ at the seven monitoring stations are displayed on Figure 3 for the period 1 to 17 march 2011.

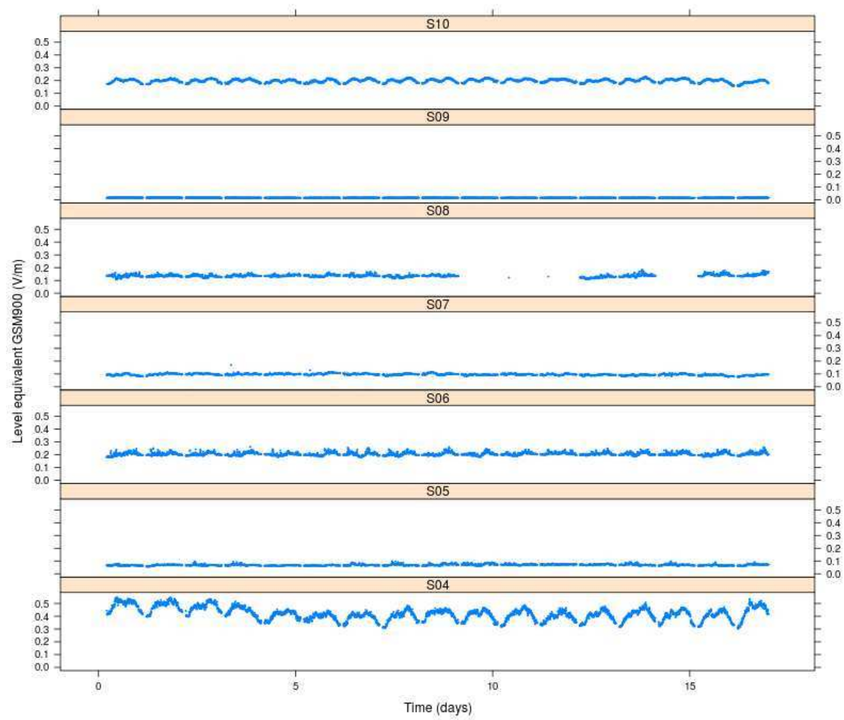


**Fig. 3** $Leq_{900}$ at the seven monitoring stations for the period 1 to 17 march.

## 5 Geostatistical interpolation

The transmitters (base station antennas) produce an electromagnetic field which propagates in the city by reflecting and diffracting on the various obstacles, i.e. the relief and the buildings. The physical model, operating by ray tracing, generates a map of the intensity of the electric field, which we might call the *electrical footprint* of the transmitters. Due to incomplete knowlege about the emission characteristics of the transmitters and also because of the variations in emission power linked to traffic, it is not likely that the simulated values coincide with the intensities measured by the stations.

Furthermore, as the data show spatial and temporal structure it seems of advantage to use a geostatistical technique to perform a statistical interpolation which combines both the station measurements and the physical model output. We use a kriging with external drift, as employed in previous applications for urban radioelectric exposure mapping [3] or for outdoor noise exposure mapping [4]. The novelty in the present case is that instead of using a purely spatial kriging neighborhood, a space-time neighborhood is considered.

A spatial variogram has been computed from field measurements with a handheld monitor (EME Spy 120 by Satimo), which is shown on the left of Figure 4. Its structure suggested the same ranges as the variogram model obtained for the ICARE-EM output (not shown). The time variogram using the measurements from the monitoring stations is shown on the right of Figure 4. For external drift kriging the reference model on Figure 4 was recalibrated on the basis of the variance of the residuals in the space-time window around a given space-time estimation point.

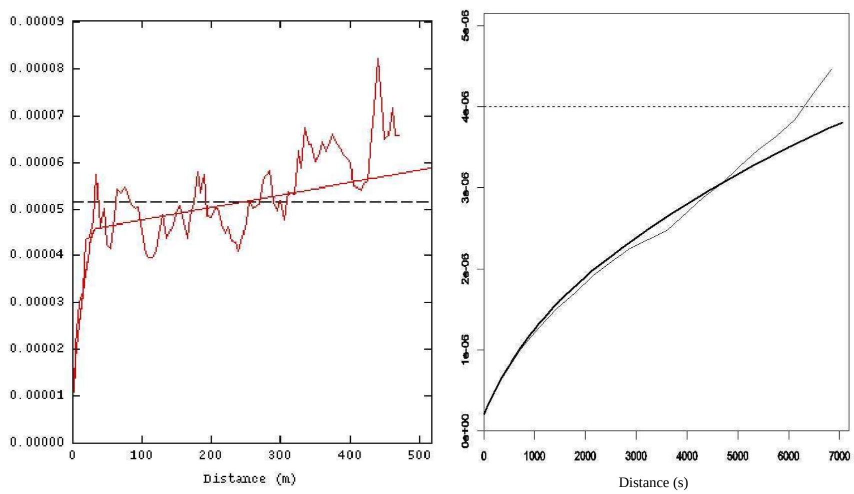


**Fig. 4** Left: spatial variogram from field measurements. Right: time variogram computed on monitoring station data (2 hours).

The external drift kriging for a given hour is performed using a space-time neighborhood with all available data within a time window $\pm$30mn, knowing that the time data is averaged on a support of 6mn. A corresponding map for Friday 4 april 2011 at 8pm is displayed on the right of Figure 5.

The SAMPER demonstration site (http://samper.ensmp.fr) provides a facility for displaying for a given hour, day or month the corresponding exposure map of the study area. A screenshot of the website is shown on Figure 6. The time series of measured data can also be displayed for the selected period for any monitoring station, on the right of the kriged map. Furthermore, it is possible to display estimated values at a few “test points” (the green dots on the map displaying kriging results).

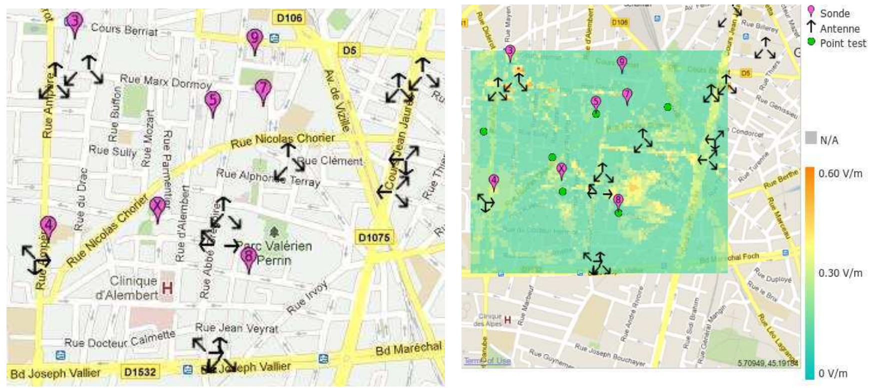


**Fig. 5** Left: study area with base station antennas (arrows) and the seven INSITE Box monitoring stations (colour dots). Right: study area with superimposed map obtained by geostatistical interpolation which combines the ICARE-EM electric footprint with space-time data from the INSITE Box stations.

The SAMPER website was designed for operational monitoring: during the demonstration period, every day in the early morning hours, the data was transferred by each monitoring station to the FTP site and processed in real-time for immediate display of the results of the preceding day.

## 6 Conclusion

We have presented an operational monitoring system to inform the citizen about the outdoor radioelectric exposure in an urban environment. This system, the first of its kind, has been implemented and run in real-time in a section of the city of Grenoble during several months in 2011. The next step would be to put into service such a system in conjunction with existing air pollution and noise exposure web services for better information of the population about the real amount of environmental exposure in their vicinity.

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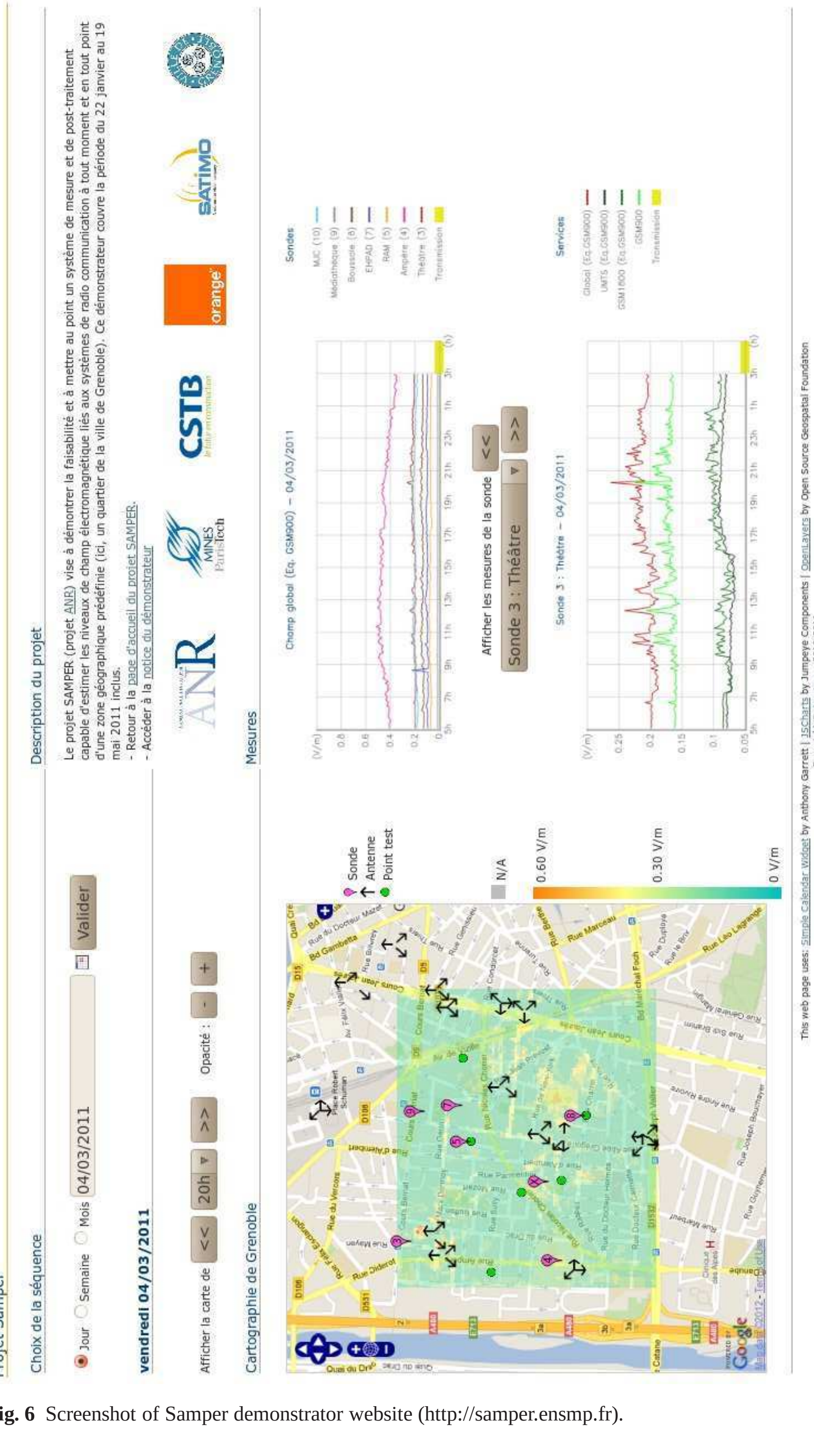


**Fig. 6** Screenshot of Samper demonstrator website (http://samper.ensmp.fr).

## References

1. E. Conil, F. Gaudaire, and J.-C. Bolomey, “Icare: a tool for far field’s prediction extended to include effects of near field’s objects,” in *IEEE International Symposium on Microwave, Antenna, Propagation and EMC Technologies for Wireless Communications: MAPE*, vol. 1, pp. 780–783, 2005.
2. N. Noé and F. Gaudaire, “Reflection on curved surfaces in a 2.5D ray-tracing method for electromagnetic waves exposure prediction in urban areas,” in *General Assembly and Scientific Symposium, XXXth URSI*, pp. 1–4, 2011.
3. Y. Ould Isselmou, H. Wackernagel, W. Tabbara, and J. Wiart, “Geostatistical estimation of electromagnetic exposure,” in *geoENV VI – Geostatistics for Environmental Applications* (A. Soares, M. Pereira, and R. Dimitrakopoulos, eds.), pp. 59–69, Springer, 2008.
4. O. Baume, B. Gauvreau, M. Bérengier, F. Junker, H. Wackernagel, and J. P. Chilès, “Geostatistical modeling of sound propagation: principles and a field application experiment,” *J Acoustical Soc America*, vol. 126, pp. 2894–2904, 2009.