DETECTION OF THE SUBSIDENCE AFFECTING A SHOPPING CENTER IN MARSEILLES (France) USING SAR INTERFEROMETRY

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ABSTRACT

Help of satellite radar interferometry for urban subsidence observation has been demonstrated for several years now. This monitoring tool is able to provide an assessment of the ground motion with a millimetric accuracy and a large spatial coverage.

We present here a result of this technique applied to the monitoring of a small area : the «Grand Littoral» shopping centre complex and cinema multiplex in Marseilles, France. This construction work was one of the most important construction site of this last few years in France. Inaugurated in October, 1997, the multiplex had to close 6 of its 15 cinemas five months later because of collapsing risks due to important ground movements. It has been totally closed in July, 1999. The multiplex building demolition is currently under way. Finally, this "flop" represents a cost of 30 millions euros.

14 ERS images acquired between 1992 and 2000 had been processed in order to produce a set of 105 differential interferograms. We performed a recursive correction of orbital and topographic fringes using a FFT computation and a Digital Elevation Model provided by the French National Institute (IGN). The analysis of the interferograms series has allowed to detect unambiguously a signature of few pixels corresponding to the ground movement. From this study, we observed a ground deformation during 1997 to 1998, an overall stability during late 1998 to 1999 and again a deformation during late 1999 to 2000. This study shows that, in specific cases, traditional InSAR is able to provide valuable information on very localised ground deformation. It also shows the interest of a comprehensive study of the full ERS archive of this site in order to assess the stability of the ground before, when no ground-based measurements were available, during, and after the construction works.

1 INTRODUCTION

The "Grand Littoral" shopping centre complex and cinema multiplex of Marseilles was one of the most important construction work of this last years in France. It has been built on a former quarry, which provided materials for the neighbouring tilery. The construction work began in 1995, and the site had been inaugurated in 1997. In 1998, evidences of ground movements leaded to the closing of 6 cinemas out of the 15. The cinema multiplex had to entirely close in July, 1999. The demolition works began then, and the building is now totally pulled down. This affair was one of the most expensive for the insurers in France, the total cost representing more than 30 millions Euro. 14 ERS images acquired between 1992 and 2000 were at our disposal. The aim of this study is to check the feasibility of a monitoring of this phenomenon with SAR interferometry.

2 DATA PROCESSING

As already mentioned above, the data stack was consisting in 14 ERS-1&2 images, acquired between 1992 and 2000. The table of the Fig. 1 describes these images. We use the Gamma software for the interferograms computation [1].

After having co-registered each image upon a reference chosen in order to minimise the baseline distribution, all the interferograms with baselines smaller than +/-300 meters had been computed. The orbital fringes had been removed thanks to precise orbits from the Delft university [2] and a FFT computation of the phase ramp had been performed to refine the baselines. Orbital fringes computed from these baselines had been removed. A Digital Elevation Model from the French institute for cartography (IGN) had been used to remove the topographic fringes.

The 105 interferograms had been visually checked and selected. Only 17 interferograms had been used for the final interpretation (see Fig. 2.). A mean deformation map had been computed with a least square adjustment of the temporal series [3-4]. For purpose of visualisation, the interferograms had been filtered with a Goldstein filter and geocoded [5].

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Date	Orbit	Satellite	Baseline$_\perp$
1992/07/15	5220	ERS-1	0
1992/08/19	5721	ERS-1	85
1992/09/23	6222	ERS-1	165
1993/06/30	10230	ERS-1	-151
1995/05/19	20093	ERS-1	-22
1996/01/19	23600	ERS-1	-124
1997/01/04	8937	ERS-2	130
1997/08/01	31616	ERS-1	-25
1998/01/24	14448	ERS-2	-70
1998/08/22	17454	ERS-2	-243
1998/12/05	18957	ERS-2	-158
1999/10/16	23466	ERS-2	18
1999/11/20	23967	ERS-2	-172
2000/01/28	44642	ERS-1	36
2000/06/17	26973	ERS-2	28
2000/09/30	28476	ERS-2	-31

Fig. 1. Characteristics of the data set

3 DETECTION OF THE MOVEMENT

The visual analysis of the set of interferograms upon the "Grand Littoral" zone reveals the presence of a particular signature. This signature appears on several independent interferograms (see Fig. 3.), which ensures that this signal is not a tropospheric artefact. There is no correlation between the baseline and the magnitude of the signal, which ensures that the signal is neither a topographic artefact due to a DEM error. These different fringe patterns should hence be due to ground movement or movement of the buildings.

4 TEMPORAL MONITORING

The following figure represents the set of interferograms that had been used for the interpretation and the archive subset used in this study.

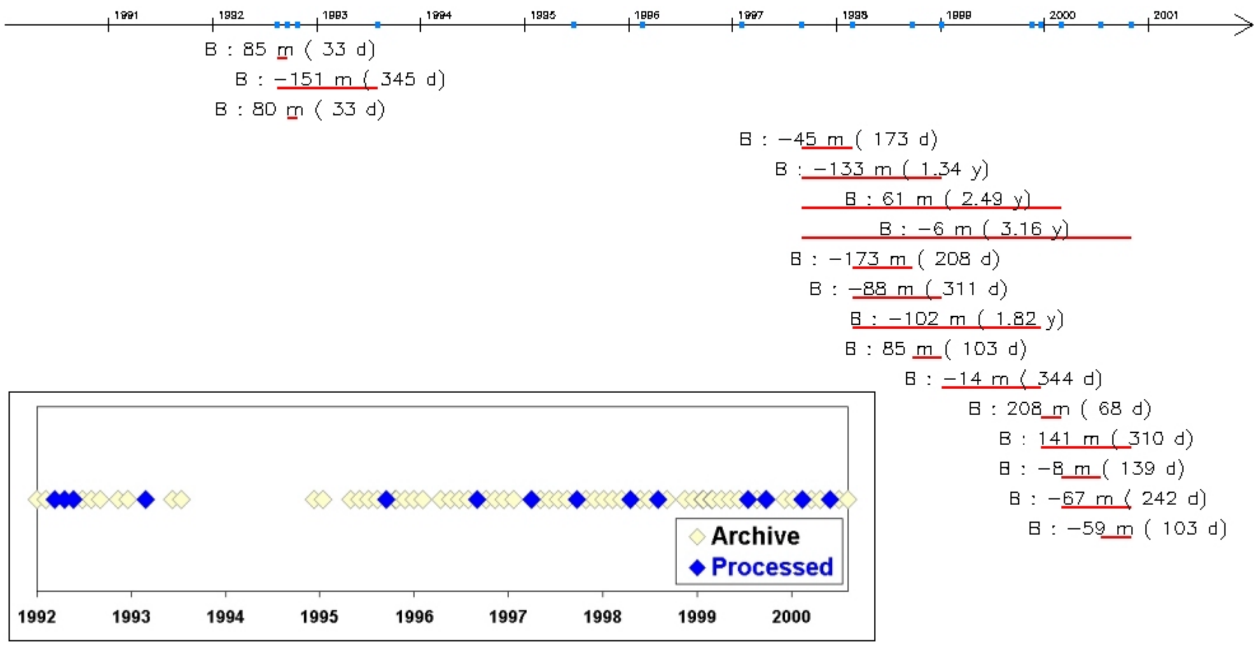

Fig. 2. Characteristics of the selected interferograms – presentation of the data set compared to the ERS1&2 archive

Of course, the temporal sampling given by 14 images irregularly acquired within this 8-year time span is too weak to allow a correct monitoring. However, by selecting within this data set a connected subset covering the whole period, it is possible to have very rough idea of the history of the movement. The following figure presents the result of this approach.

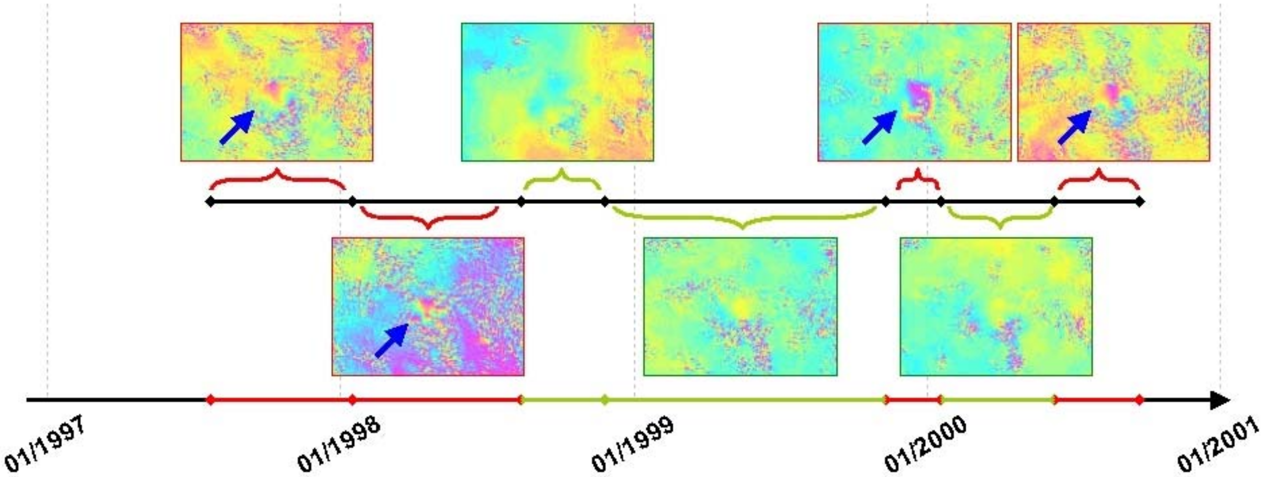

Fig. 3. Temporal monitoring of the phenomenon – red : evidence of movement – green : apparent stability

Finally, an image of the mean displacement rate (converted in vertical ground movement) had been computed, for the 1997-2000 period. This allows to have an integrated view of the phenomenon. The following figure presents this result.

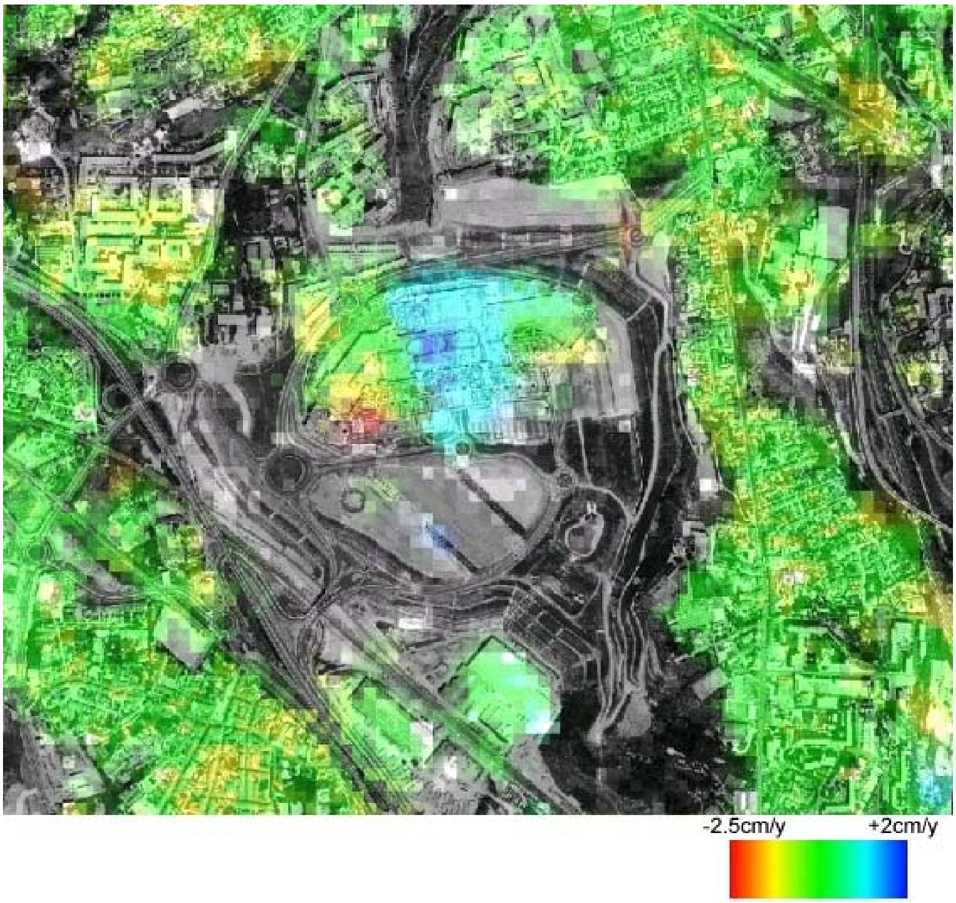

Fig. 4. Map of the mean displacement rate between 1997 and 2000 around the “Grand littoral” centre

According to this image, it appears that :

- almost the whole area covered by the shopping centre remains coherent for this period. The south-western part of the centre, where is located the cinema multiplex, shows a loss of coherence,
- two zones present a ground motion : the south-western part, which moves away from the satellite, and the middle of the centre, which moves towards the satellite.

This could be interpreted as a tip-over of the zone, but our interpretation must remain very cautious. First, this image is the linear average of all the movement that could have occurred during this period, and then, the temporal sampling of the phenomenon is too low to have a precise idea of the temporal behaviour of the zone. Finally, the shopping centre is fitted out with devices allowing the stability control of the buildings, which hampers an interpretation based only on the geomechanical characteristics of the site.

5 CONCLUSION

This study showed that, for the particular case of the "Grand littoral", SAR interferometry could be used to detect and monitor a building movement. However, this study did neither allow to precisely understand the history of the ground movement that caused the building damages nor detecting some precursors. Obtaining this kind of information would have required the exploitation of the full archive. In our case, unfortunately, information for the year 1993 could have been very precious. This study focuses once more on the potential of the ERS1&2 archive interferometric processing, which allows one to have information and measurements for the time period preceding the actual detection of the ground motion.

6 REFERENCES

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