SAR Analysis of Building Collapse by means of the Permanent Scatterers Technique

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Abstract

As already shown in previous papers, detection of stable areas make it possible to use DInSAR techniques to get local measurements on a pixel-by-pixel basis. Reliable deformation measurements can then be obtained on a subset of image pixels, called Permanent Scatterers (PS). These points can be used as a "natural GPS network" to monitor terrain motion in the direction of the line of sight (LOS), analyzing the phase history of each one. In urban areas most of the PS correspond to single buildings whose deformation can be measured every 35 days with an accuracy better than one millimeter. Results obtained ERS SAR images are presented for 3 test sites: Camaiore (40 images), Milano (62 images) and Paris (64 images). Time series analysis of collapsed buildings in Camaiore are illustrated which show interesting precursory motions. Time series analysis of two metallic buildings in Milano and Paris are then used to validate the technique and to estimate its accuracy.

1 Introduction

The PS technique, developed at POLIMI, [4][2][3] can be used to get reliable deformation measurements of single buildings. Basically, a multi-interferogram framework allows one to separate the different signals that contribute to the interferometric phase on a pixel-by-pixel basis: topography, atmospheric phase screen (APS) and motion. In this paper three urban sites are analyzed by means of ERS SAR data. First the case of Camaiore (Italy) is taken into consideration. Here a building collapse due to karstic erosion of the terrain is analyzed. Then the case of the Cite' des Sciences et de l'Industrie in Paris (France) is shown. Here the dilation of a metallic building is correlated to the temperature series to validate and estimate the accuracy of the technique. Finally the case of two buildings in Milano (Italy) are analyzed to show again the effect of the temperature and the identification of step-wise motions.

2 The case of Camaiore

The test area is a small town located close to the Tyrrhenian coast in Italy. This area is affected by clay erosion and subsequent cavities formation. In October 1995 such a phenomenon generated the collapse of a few buildings close to center of Camaiore. 40 ERS SAR images gathered over the town of Camaiore (with a maximum relative temporal baseline of more than 6 years and a maximum relative normal baseline of more than 2000 m) were co-registered on a unique master. The local DEM was estimated starting from 4 Tandem pairs using the wavelet technique described in [1]. It is shown in figure 1. After DEM compensation the PS's located in Camaiore were identified. Most of them show a very stable behavior in time as shown in figure 2. Only the three PSs in that area corresponding to the buildings that collapsed have a different behavior as shown in figure 3 (from 1992 to October 1995 just before the building collapse) and in figure 4 (from 1992 to 1999). Eight samples just before the collapse show clear precursors. After the collapse the time series becomes almost random showing the disappearance of the PS.

3 The case of Paris

The big metallic structure visible behind the dome of the Cite des Sciences et de l'Industrie (Parc de la Villette in Paris -France) in figure 5 is affected by dilation due to the variation of the external temperature. Moreover one corner of this building is a PS and its motion has been monitored by means of the Permanent Scatterers technique. In figure 6 the PS motion measurement carried out on 64 ERS SAR images is linearly scaled and superimposed to the temperatures measured in Paris during the same days of the SAR takes. The correlation between the two curves is greater than 0.92 thus indicating that

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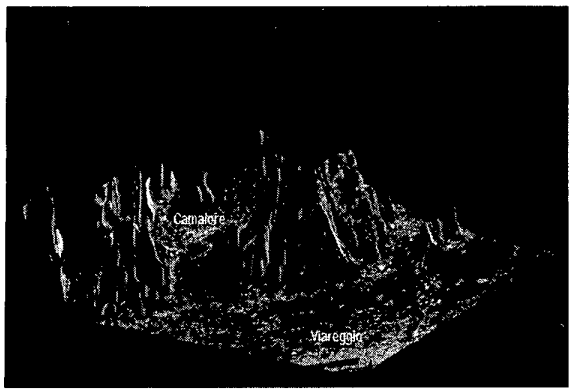

Figure 1: Digital Elevation Model of the area of Camaiore in Tuscany (Italy). The town of Viareggio and Camaiore are shown on the image. The DEM has been generated from 4 Tandem ERS pairs.

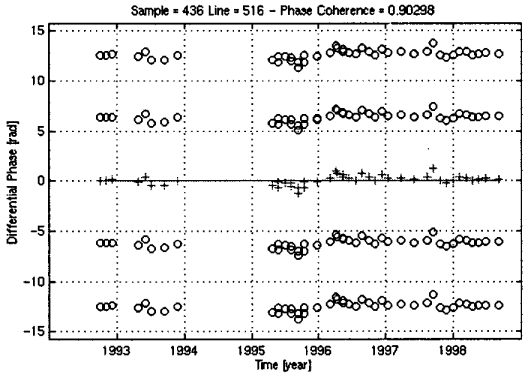

Figure 2: Time series of a stable PS in Camaiore. Different tracks show the typical 2π phase ambiguity.

the accuracy of the measurements is at least one millimeter.

4 The case of Milano

As in the case of Paris, also in Milano one PS that corresponds to a metallic structure, and thus affected by strong thermal dilation, has been identified from 62 ERS SAR images. The good correlation between the PS measurements and the record of temperatures can be appreciated by comparing figures 7 and 8. A further example of the capability of the PS technique to identify small non-linear building deformation is shown in figure 9. Here a building close to the town center shows a one centimeter step in its LOS position around July 1998. In situ investigations will be carried out in order to understand the physical reason of this behavior.

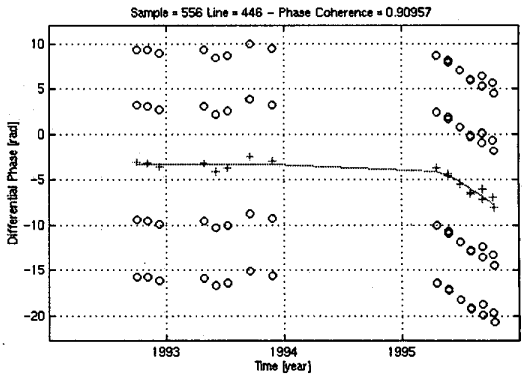

Figure 3: Time series of a PS corresponding to a collapsed building in October 1995. The time series stops just before the building collapse and clearly shows precursors.

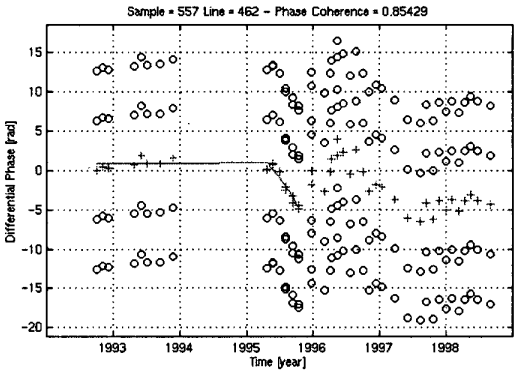

Figure 4: Complete time series of a PS corresponding to a collapsed building in October 1995. The time series becomes almost random after the collapse showing the disappearance of the PS.

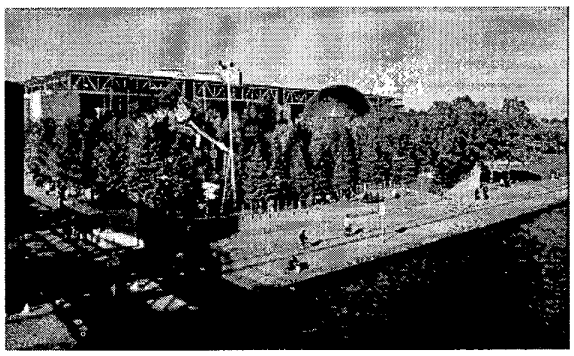

Figure 5: Picture showing the Cite des Sciences et de l'Industrie in Paris. The dome and the metallic structure affected by thermal dilation are clearly visible.

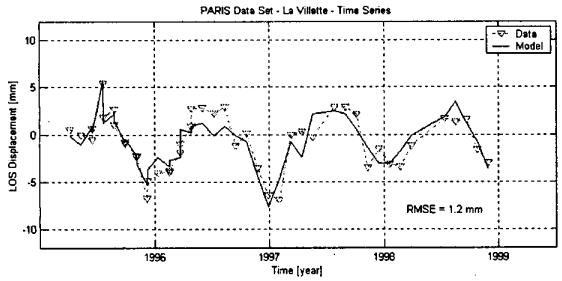

Figure 6: PS motion measurement carried out on 64 ERS SAR images (triangles). Temperatures measured in Paris during the same days of the SAR takes (solid line).

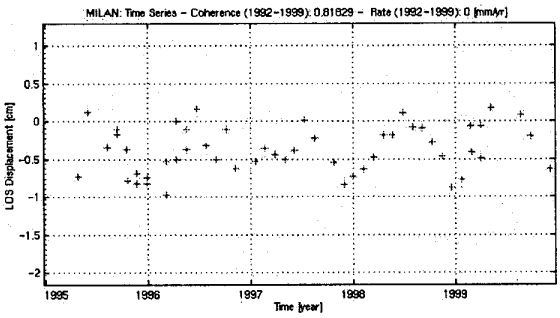

Figure 7: Measurement of the thermal dilation of a metallic structure in Milano by means of the PS technique.

5 Conclusions

We have shown that in urban areas Permanent Scatterers exist that allow to extract millimetric measurements of buildings displacement. The accuracy of the technique has been validated by cross-correlating the thermal dilation of metallic structures and record of temperatures. The use of all the images of the ERS data set (with no care of the well known perpendicular baseline and spatial coherence limitations in SAR interferometry) allows to get the highest possible temporal sampling. Thus, it has been shown that the PS technique allows to measure non-linear motions of buildings providing an useful indication to civil protection to prevent building collapses.

6 Acknowledgments

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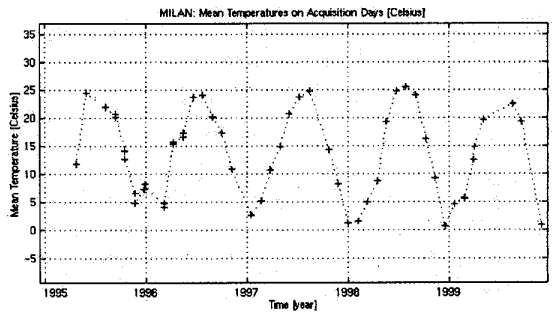

Figure 8: Record of temperatures in Milano during the same days of the ERS SAR takes.

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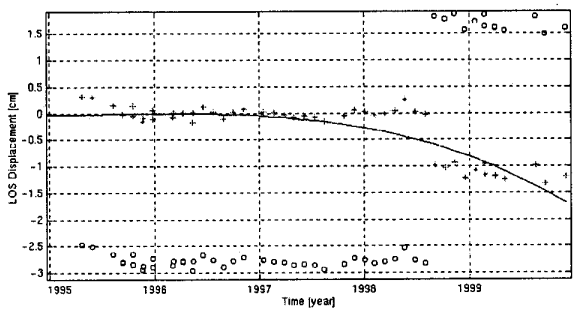

Figure 9: Non-linear building deformation in Milano (+). The solid line is a fourth order data interpolation used by the current software version.