ERS1 - SAR INTERFEROMETRY; POTENTIAL AND LIMITS FOR MINING SUBSIDENCE DETECTION

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ABSTRACT

In the Mulhouse potassic mining district (E France), the mining working involves ground subsidence phenomenons . This subsidence is increasing during 12 to 15 months after the caving processes, with a maximum vertical speed of 10 mm/day. Subsidence areas (0.5 km^2 maximum) are dissymetrical, with an active slope moving in the same direction as the mining. Movements in the active areas are followed by the mining Society. Three interferograms SAR ERS1 images of Mulhouse area have been provided by the French Centre National d'Etudes Spatiales (C.N.E.S). The topographic effects have not been geometrically corrected, because the smoothed relief of the studied area. On the third interferogram, subsidence effects have been identified. Nevertheless the active slopes (100m wide, or two pixels) are not visible, and the subsidence rate is too rapid with respect to the resolution of the interferogram (interval; 35 days). Interferograms with an interval of one or three days would be necessary for a real survey of the subsidence.

1. INTRODUCTION

ERS1 - SAR interferometry has been used for ground deformation analysis at various times, e.g. deformation linked to an earthquake (Landers, California) (Massonnet & al, 1993 and 1994, Zebker & al, 1994, Peltzer & al.1994); post-eruption deflation of a volcanoe (Mt Etna) (Massonnet et al, 1995); landslide (S France) (Fruneau & Achache, 1996). Below, we test potential and limits of this method for mining subsidence studying.

In France various areas are affected by mining subsidence; coal fields (Carnec, 1996), evaporitic accumulations, iron ore deposits. For this work we have selected the Mulhouse Potassic Basin (E France) where active mining subsidence is well documented.

2. POTASSIC BASIN OF MULHOUSE GEOLOGICAL FRAMEWORK AND SUBSIDENCE PROCESSES

The Rhinegraben is filled by a thick saliferous succession from Oligocene age. The potassic basin of Mulhouse (200 km^2) is located to the S of the graben. Two sylvinite levels are worked at a depth increasing from 400m (N) to 1100m (S). The levels thickness is included between 1m and 5m. The operating Company (Mines de Potasse d'Alsace) extracts 10MT to 13MT/year of ore. The mining method is a complete holing followed by caving. The latter involves the collapse of the immediatly overlying strata, followed by a slow creep of the whole evaporitic succession. Upwards the ground is subsiding, and hollows (0.5 km^2 maximum) expand.

(1) The gap equals closely the volume of extracted ore.

(2) The hollows are dissymmetrical with a 20mm/m slope in front of the working face.

(3) The slope is moving forward progressively at the rate of the underground working advancing.

(4) The subsidences increases with a 10mm/day maximum vertical speed during the active phase (12 to 15 months) and becomes stable after 36 months.

One may notice various disorders concerning buildings, roads, railway tracks etc.... Therefore, the mining Company takes safety provisions before the beginning of new works, and, during the mining working, the subsidence is followed by successive levellings along control lines.

3. SAR IMAGES ACQUISITION AND PROCESSING

The C.N.E.S has provided us three interferometric pairs. The images have been acquired between September 1992 and October 1993, during the phase C of ERS1 descending orbits. For each pair we have collected an amplitude image (fig. 1, a), a coherence image (Zebker &Villasenor, 1992)(fig. 1, b), and an image of phase differences(fig. 1, c). For the latter, the distance effects have been eliminated, but not the topographic effects according to the smoothed topography of the studied area, located within an alluvial plain. The phases difference is algebraic (8 bits coding) and the interval (0/255) corresponds to a complete phase rotation (360°).

D F 1_2 = DP 1_2 = ((2 / l) * (O2 - O1)* 256) +128 + (D F 2 -D F 1)reflexion*256/360 + GC

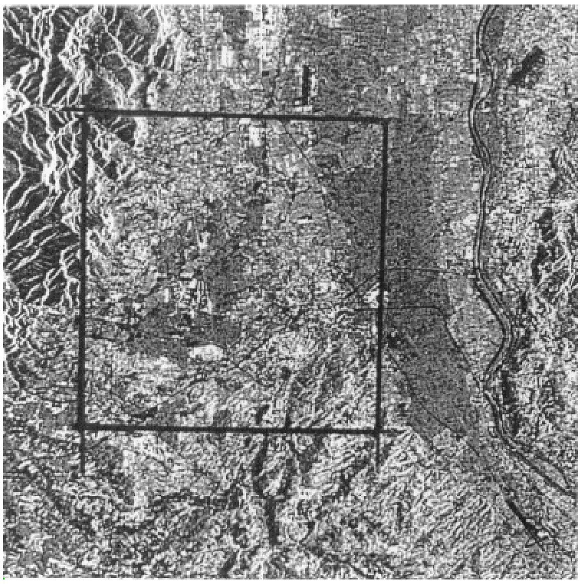
the whole modulo 256

[DP: phase difference. O; optical way (antenna/target single path). Index 1 ® Master-orbit. Index 2® Slave-orbit. GC. geometrical corrections] .

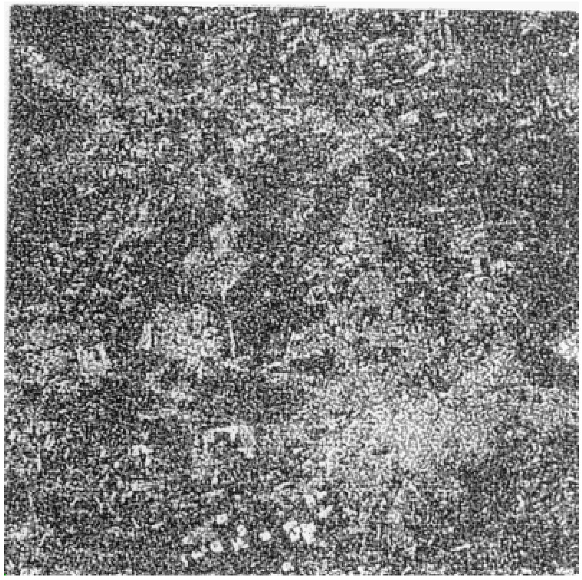
Therefore a ground subsidence involves an increasing optical way (D F > 0), and a "phase hill" signature on the images.

The first pair (interval:168 days, altitude of ambiguity: 230m) and the second pair (interval: 35 days, altitude of ambiguity: 64m) display a very important decorrelation. On the other hand, the average coherence is better on the third pair (master-orbit n°11461, date 24.09.93, slave-orbit n°11962, date 29.10.93; interval 35 days; altitude of ambiguity: 39m). Otherwise the acquisition period of the third pair is in accordance with an active phase of subsidence for various areas within the basin.

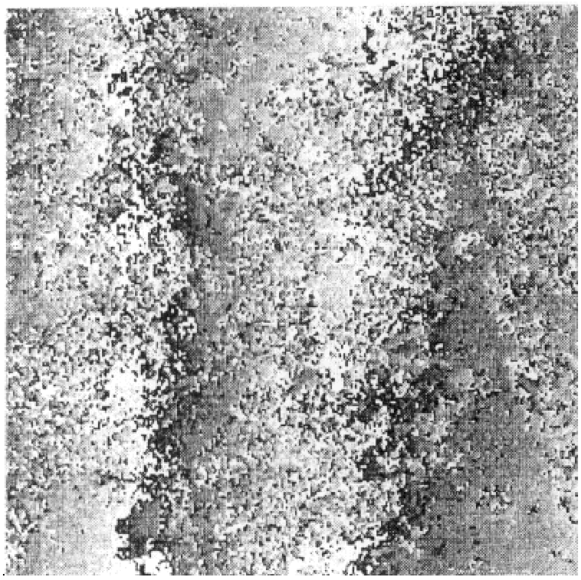
For the above-mentionned reasons, we have principally analysed the third pair. First one may notice ellipsoidal parasitic fringes centred over the Rhine River (fig. 1, c). The origin of this artefact is unknown. In order to obtain interpretable phase images of the subsidence areas, we have carried out a local "phase unrolling" over the working area (fig. 1,d).



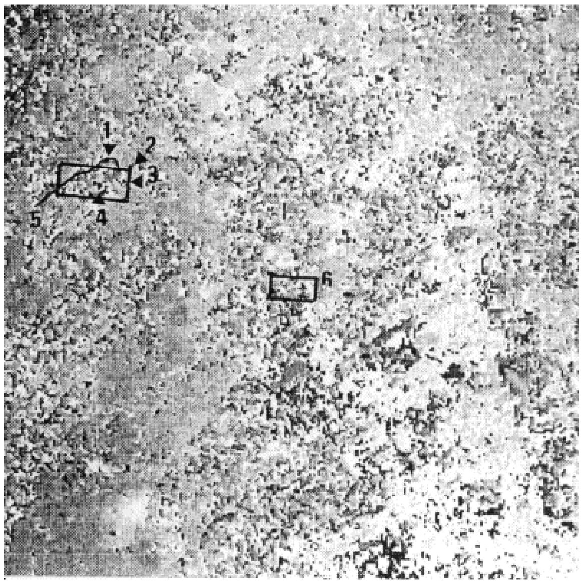
a



b



c



d

Fig. 1. SAR ERS1 Images of the Mulhouse area (master-orbit n°11461, date 24.09.93, slave-orbit n°11962, date 29.10.93; interval 35 days)

a. Amplitude Image (with localisation of b). b. Coherence Image (see also fig. 2). c. Phase difference Image. d. "local unrolling " Image (1 to 3. N Bollwiller; 3 bands of alternatively dark and light pixels according to "mini-fringes". 4. S Bollwiller. Dark band of pixels, according to the active slope bordering the S of the subsidence area. 5. Bollwiller subsidence area border. 6. Pulversheim. "phase hill ")

4. RESULTS

With the help of a geographic information system (data provided by the mining company M.D.P.A), we have located with precision the subsidence areas on the various images. During the interferometric acquisition, the subsidence is important in two selected areas; Bollwiller (maximum 205mm/35 days) and Pulversheim (maximum 80mm/35 days).

4.1. Bollwiller area

On the coherence image, one may notice a "dark spot"" within Bollwiller area (signature of a coherence loss due to the subsidence?) (fig. 2).

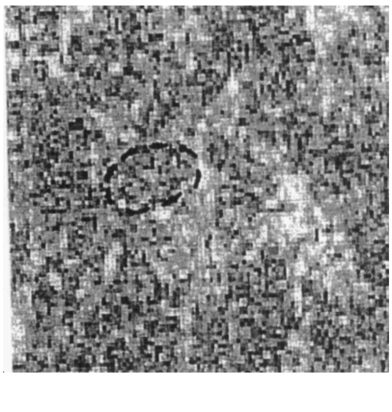


Fig. 2. "Dark spot" (circled) within Bollwiller area

(extracted of fig. 2b)

A dark spot also occurs on the "phase unrolling" image (fig. 1, d).

- this spot coincides with the subsidence area position during the interferometric acquisition.

- on the other hand, to the N of the spot, one notices an area where the pixels are unvarying; according to the M.D.P.A. data, this area is under stabilisation (subsidence less than 5 mm/35 days).

A detailed analysis of the dark spot displays

- Northwards 3 alternately dark and light pixel alignments; maybe corresponding to "mini-fringes" generated by a vertical motion of 9mm. This latter is in accordance to M.D.P.A. data for this area.

- Southwards a dark alignment corresponding to the active slope, with a complete phase fading.

4.2. Pulversheim area

In this area, one may notice a "phase hill" (light pixels zone surrounded by dark pixels). The latter (D F > 0) is the signature of a ground subsidence, but the information is only qualitative.

5. CONCLUSIONS

5.1 Size of phenomenons

Within the potassic basin, the subsidence areas are lying on 0.5 km^2 maximum (300 pixels) and the active slopes are 2 pixels wide. Consequently,

- One may detect subsidence areas by the interferometric method

- But they are too narrow for a reliable subsidence measurement.

In the studied case, for the time, the SAR interferometry is not competitive in comparison with classical levellings; nevertheless, this method provides a global vision of the subsidence areas.

5.2.Speed of phenomens

In the studied case, the subsidence speed is important (Bollwiller, 5mm/day, Pulversheim, 2.3 mm/day). 3 days or 1day/intervals (ERS1-ERS2 "tandem" phase°) would be necessary for a better understanding of ground motion. From 35 days-interferograms, the analysis must be limited to high coherence urbanized areas.

5.3. Prospects

Our work opens new prospects in use of SAR-interferometry for the detection and the analysis of the subsidence. Nevertheless it is necessary to fit the interferometric interval according to the subsidence rate previously measured on the field. For 35 days acquisitions; the interferometry is only valid for desertic or urbanized areas, where the coherence remains high during a long time.

Acknowledgements. We thank J Breniaux and Y. Lourdel (MDPA) for their informations about subsidence data and C.N.E.S. for his financial supporting.

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