POTENTIAL OF SAR INTERFEROMETRY IN ASSESSMENT AND PREDICTION OF NATURAL HAZARDS

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Abstract

Synthetic Aperture Radar (SAR) imaging techniques provide an excellent intrinsic geometric precision of a few metres. However, this precision may be improved by three orders of magnitude when special conditions allow the use of the radar wavelength (some millimetres) as a ranging tool, a technique called SAR interferometry The method is very accurate for small movement detection, as C N.E.S. demonstrated by the mapping of the displacement field of the Landers, California 28 June 1992 earthquake. SAR interferometry may also be used to create digital elevation models and is potentially applicable to domains such as tectonic faulting, landslides, or volcano monitoring.

1. Introduction to SAR interferometry

SAR heritage

SAR interferometry techniques are applied to radar images. They were introduced 20 years ago (Graham, 1974) and demonstrated with spaceborne data at JPL (Zebker and Goldstein, 1986). Thus, SAR interferometry benefits from all the advantages of the radar sensors:

- Radars are active sensors and the wavelengths of the centimetric range they use are not blurred by the earth atmosphere. Thus, SAR interferometry is capable of operational observations.
- The resolution in SAR images is achieved by sampling the echoes of the radar signal after reflection on the ground. The resolution is therefore independent of the distance from the radar to the ground targets High resolution is achievable by increasing the sampling frequency. For instance, ERS-1 resolution is about 8 m in range (20 m on the ground).
- The pixels of the SAR image are sorted with respect to time when the echoes come back to the radar The distance to the ground for each pixel is given by the location of the pixel in the SAR image. Only the position and speed of the satellite, but not its attitude, are required to locate a pixel on the ground.

SAR interferometry concept

The radar sends and records a coherent signal, thus, each pixel in a SAR image is made up of a radiometric value and a phase value. The radiometry is representative of the ground reflectivity at the wavelength of observation. A conventional SAR image displays only the radiometry. The phase is a feature of the electromagnetic microwave, which is usually expressed as an angle which rotates according to the round trip travel time of the radar signal: the phase rotates 360 degrees each time increasing by one wavelength (5.6 centimetres for ERS-1).

In each pixel, the phase depends on the distance from the radar to the pixel centre and on the ground targets' distribution within the pixel The latter contribution is unknown and varies randomly from one pixel to the other (the image formed by the phases is therefore never shown). However, the contribution of the ground target distribution is deterministic, it will be the same in a second SAR image acquired later in similar geometrical conditions Thus, the phase difference of the two SAR images eliminates the contributions of the ground target distribution and leads to pure geometrical information: the phase difference is proportional to the difference of the distances from the radar to the ground

If a second SAR image were acquired with the satellite exactly repeating the first track, then the phase difference would directly record any displacements of the ground as the distance from the satellite to the ground changed. The actual tracks are in fact never the same. Thus, the two SAR images have to be registered and the orbital and topographic contributions have to be removed from the phase differences to allow the displacement measurements.

Alternatively, the topographic contribution might be highlighted by removing only the orbital contributions in the phase difference: this allows the computation of digital elevation models (DEMs).

Interferometric products

The "interferometric products" processed at C.N.E.S from two SAR images are made of three images, either in SAR geometry or geo-coded:

Figure 1. Ground displacement fringes associated with the Landers earthquake

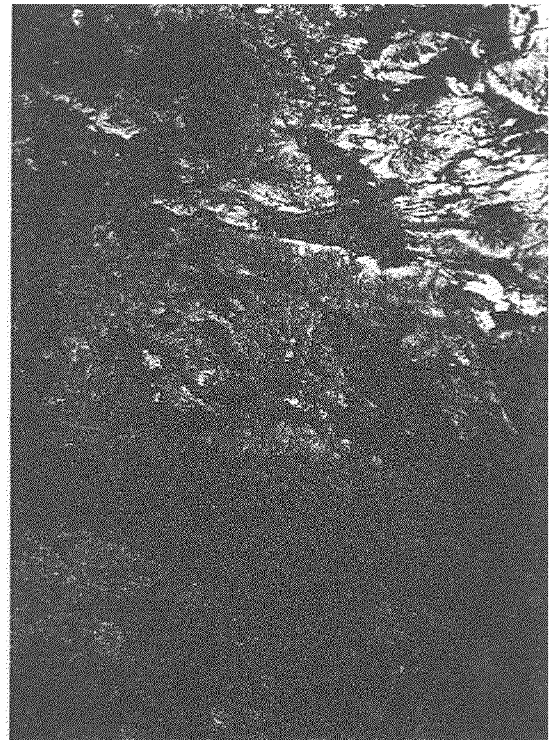

Figure 2 Coherence image corresponding to figure 1

- a conventional radiometry image, which helps locating points of interest
- a phase difference image with either only the orbital contribution removed (to show the topographic contribution) or with both orbital and topographic contributions removed (to show ground displacements, see Figure 1)
- a coherence image which gives the confidence level of each pixel in the phase difference image (see Figure 2) The coherence image also shows where the ground surface changed during the time between the two data acquisitions

The C.N E S. interferometric products are distributed by Spot Image.

Interferometric precision
The phase measurements have typically an accuracy of about 10 to 20 degrees with ERS-1 data. Thus, the ground displacements are measured with an accuracy of 1/20 to 1/40 of 2 8 centimetres, the half wavelength of ERS-1 Therefore, one can hope to detect ground displacements with amplitude of 0.7 to 1 4 millimetres Only the component toward the satellite is measured.

The topographic contribution depends roughly on the distance between the two orbital tracks It varies from nothing if the two tracks are the same to the total loss of coherence if the distance is too large. We usually characterise the topographic contribution with the altitude which leads to a phase variation of 360 degrees, called the altitude of ambiguity. One can then hope to measure the topography with an accuracy of about 1/20 to 1/40 of this "altitude of ambiguity". The altitude of ambiguity is infinite if the distance between the two tracks is zero and decreases while this distance increases

2. SAR interferometry applied to natural hazards

SAR interferometry is a remote sensing technique which offers new measurement possibilities for assessing and monitoring natural hazards

Earthquakes
One of the most spectacular applications of interferometry is the ground displacement mapping of an earthquake (Massonnet et al., 1993) Figure 1 shows the geo-coded interferogram obtained with ERS-1 SAR images acquired before (24 April 1992) and after (7 August 1992) the Landers, California event (28 June 1992). Figure 2 shows the coherence map associated with the interferogram 'The resolution of those images is the same as the digital elevation model used to remove the orbital and topographic effects 1/1200 degrees or about 90 metres. The main fault appears on the coherence image as a dark banana shaped region. In the interferogram, this area