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New methods of phase unwrapping in SAR interferometry

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Abstract

Digital Elevation Models can be computed from ERS interferometric products. The phase unwrapping step is the main problem of the process. We present a robust-to-noise phase-unwrapping algorithm based on a global analysis of the interferogram. Then, we focus on a technique that eases the phase unwrapping process by using simultaneously several interferograms. Finally, an example of DEM computed thanks to this method is presented.

Keywords: Phase unwrapping, Least square optimisation, Digital Elevation Model

Introduction

Digital Elevation Models can be computed from ERS interferometric products. The phase unwrapping step is the main problem. We present a robust-to-noise phase-unwrapping algorithm based on a global analysis of the interferogram. Then, we focus on a technique that eases the phase unwrapping process by using simultaneously several interferograms. Finally, an example of DEM computed thanks to this method is presented.

Phase unwrapping

Usually, the phase is unwrapped by computing the actual phase jumps (cf. Goldstein & al 1988, Prati & al 1990). We have developped a method that computes a mathematical model of the unwrapped phase. This model can be used to retrieve the actual phase jumps on the interferogram.

We assume that the unwrapped phase is a continuous function of range and azimut. We then compute a piecewise linear model of the phase that fits the interferogram (cf. Tarayre and Massonnet 1995).

In order to do so, we devide the interferogram into elementary squares and we adjust a linear model on each elementary square using a dichotomic search by minimizing the length of the fringes of the difference image between the elementary interferogram and the elementary model. Once we know each elementary model, we adjust the elementary models one another so that the global model is continuous. This adjustment is done using a least square minimization (Cf. Ancey & al 1994, Guiglia and Romero 1994, Tarayre 1996) on the phase of the summits of the elementary squares.

It can be shown that the phase is unwrapped as soon as the difference image between the interferogram and the model (called residue image) does not display any fringes (Cf. Tarayre and Massonnet 1995). The unwrapped phase is then retrieved by adding the residue image to the computed model.

Compared to the Guiglia method, Guiglia and Romero 1994, this method has the advantage to reduce considerably the number of points over which the least square minimization is computed. The algorithm can be applied to images with different numbers of looks according to the fringe density. The model is then extended or reduced to the desired resolution.

Figure 1 shows an example of such a phase unwrapping over Mount Etna.

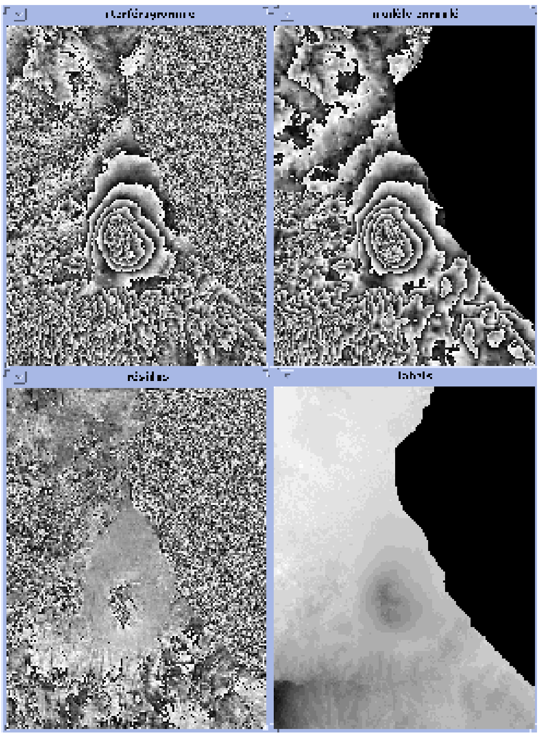

*Figure 1: The first image is the interferogram that has to be unwrapped. The second one is the model (it is represented with a 2*pi ambiguity so that it can be compared with the actual interferogram). The third image is the difference between the model and*

the interferogram. We can see that the noisy fringes above the volcanoe have been removed. Some fringes due to overlay below the volcanoe remain. The last image is the integer image corresponding to the unwrapped phase.

Multi-interferogram phase-unwrapping

The former phase unwrapping algorithm works quite well on noisy data. It can solve some overlay problems but it does not work on data with a lot of fringe discontinuities. Fringe discontinuities occur very often on low ambiguity altitude interferograms. Unfortunately, in order to obtain a Digital Elevation Model with a good precision one has to unwrapp such interferograms. To unwrap these interferograms we use a multi-interferogram scheme.

D. Massonnet has shown that it is possible to create a pseudo interferogram of higher ambiguity altitude using a linear combination of two interferograms with integer coefficients (Cf. Massonnet and Vadon 1996). This "pseudo-interferogram" is noisier to unwrapp. We create such an interferogram, we unwrap it with the former algorithm (this algorithm is robust to noise so it is well fitted to such a phase unwrapping). Then, the unwrapped interferogram is used to simplify one of the two low ambiguity altitude interferograms which is unwrapped. This method is suitable to tandem data

Figure 2 shows an example of such a multi-interferogram scheme. Two interferograms of 60 and 80 m ambiguity altitude are available. The difference of the two interferograms gives a pseudo interferogram of 123 m ambiguity altitude. This interferogram is unwrapped and used to simplify the 80 m ambiguity altitude interferogram which is unwrapped and used to unwrap the 60 m interferogram.

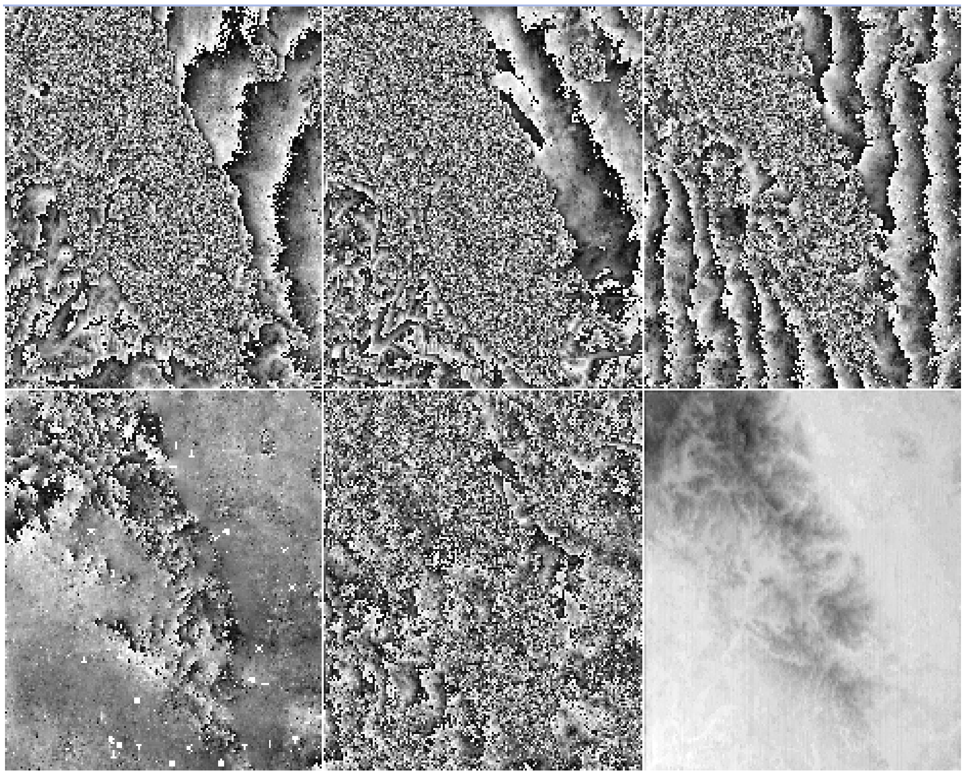

Figure 2: Top images: The first and second images represent respectively the 60 and 80 m ambiguity altitude interferograms. The third one is the pseudo interferogram which displays less small fringes and is easier to unwrapp. Bottom images: The first image is the residue image after unwapping the pseudo interferogram. The second one is the simplified 60 m interferogram. There are few noisy fringes that can be unwrapped with our algorithm. The last image is the unwrapped 60 m interferogram.

Example : Vosges site

Having two interferograms of the Vosges area (one of 60 m ambiguity altitude and the other of 80 m ambiguity altitude) we computed the output DEM. The phase unwrapping process has been explained in the last section. We corrected the orbits using 50 altitude points (i.e. points on the interferogram of known altitude). One can show that orbits are best corrected using a large number of non-precise altitude points than with few, but precise, altitude points (Cf. Tarayre 1996). We computed the two DEM and compare them two 200 ground control points collected on 1:25000 map of the area. The best results are obtained with the 80 m ambiguity altitude interferogram. The rms error is 36 m in mountaneaous area and 15 m in valleys (CF Figure3). This error is quite large but it has to be interpreted with caution since we did not have a reference DEM to compute it.

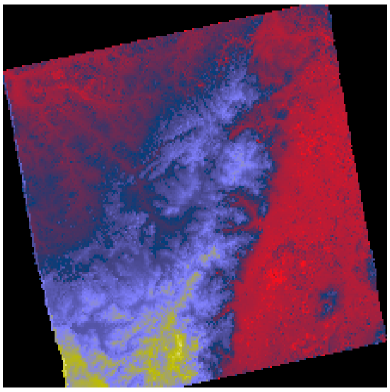

Figure 3: Vosges DEM processed with the 80 m interferogram.

In order to analyse the artefacts on the scene, we removed from the 80 m interferogram the topography estimated with the 60 m interferogram. The output image (Figure 4) should not display any variation since theoretically the topography is better estimated with a low ambiguity altitude interferogram. Figure 4 displays some phase variations. Therefore, there is an artefact on one of the two interferograms. Having only two interferograms we cannot conclude which interferogram is corrupted by artefacts. Nevertheless, the computation of the rms error between the interferometric DEM and ground control points tends to show that the 60 m interferogram was more corrupted than the 80 m interferogram.

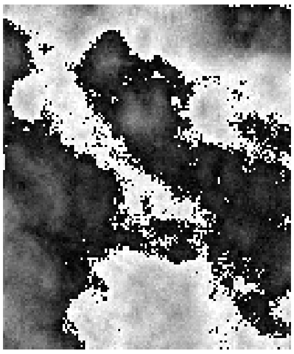

Figure 4: This image represents the artefact due to the 80 m or 60 m interferogram.

Conclusion

We have presented a robust-to-noise phase-unwrapping algorithm based on a global analysis of the interferogram. We have focused on a technique that eases the phase unwrapping process by using simultaneously several interferograms. Finally, an example of DEM computed thanks to this method has been presented.

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