Fringe 96
Atmospheric artifacts on interferograms

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Abstract

The use of spaceborne RADAR interferometry has considerably increased since the ERS-1 launch. In this paper we verify the atmospheric refraction hypothesis. We show that the presence of large height variations and a difference of refractive profiles between the two imagings create interferometric artifacts that have to be dealt with in the Digital Elevation Model generation process. Moreover, water content horizontal gradients, clear air turbulences and ionospheric phenomena also create local artifacts on interferograms. We conclude that one needs more than one interferogram to solve this problem.

Keywords: Interferometry, Atmospheric artifacts, Troposphere, Ionosphere, Refractive index.

Introduction

The use of spaceborne RADAR interferometry has considerably increased since the ERS-1 launch. In this paper we verify the atmospheric refraction hypothesis. First we explain the model used. Then we show that a large height variation inside a scene combined with a change of refractive index profiles between the two imagings creates interferometric artifacts that have to be dealt with in the Digital Elevation Model generation process. Finally we study the effects of an heterogeneous atmosphere on interferograms.

1-Modelisation
1.1-Ray theory model

We model the path delay due to a refractive atmosphere using Snell's law (cf. Tarayre and Massonnet 1996). The path delay depends on the refractive index profile of the atmosphere and on the angle of incidence of the ray . This refractive index profile depends essentially on altitude but it depends, to a lesser extent, on the climatic and meteorological conditions of the atmosphere. Therefore, the differential atmospheric phase shift depends on the difference of the refractive index profiles between the two imagings as well as on the incident angle of the ray.

1.2-Refractive index

The atmosphere can be devided into two layers which have different refractive index properties. In the ionosphere (above 90 km), the refractive index depends on the electronic content. The electronic density of the ionosphere depends on the altitude, latitude, solar time and solar activity. It can change temporally, between the two imagings, and spatially inside a scene (cf. CCIR 1986). In the troposphere, the refractive index depends on the temperature, pressure and water content. These quantities depend on the climatic and meteorological conditions of the atmosphere at the time of the imaging. These conditions can change from one imaging to the other and inside a scene. We have to study two different kinds of artifacts. The artifacts due to a difference of the refractive atmosphere between the two imagings and the artifacts due to spatial heterogeneities inside a scene.

2-Artifacts due to an homogeneous atmosphere

We have seen that the atmospheric path delay depends on the incident angle of the ray. In fact it produces a fringe pattern between near range and far range. This fringe pattern is similar to a fringe pattern due to an orbital error and it is removed when correcting the orbits. It has been shown in Tarayre and Massonnet 1994 and in Tarayre 1996 that the residual error due to the interpretation of an atmospheric error as an orbital error is neglectible in most usual cases. Furthermore, misplacing the satellites leads to an ambiguity altitude error. This error is also neglectible.

Another error exists in mounteneous areas. Most of the refraction occurs near the ground in the layer limit. If the altitude of the ground changes inside the scene the "amount of refraction" crossed by the ray changes. Therefore, when there is a change of the refractive index profile between the two imagings, the path delay varies with relief. In Figure 1, we show such a phenomenon. The first image is a SIRC differential interferogram of mount Etna processed with the CNES software. The volcanoe is revealed by contour lines. Two concentric fringes appear near the summit. The second image is a simulation of the refractive index error computed thanks to the real refractive index profiles obtained by sounding balloons. The third image is the residual error after removal of the atmospheric artifact. One can see that the two fringes have disappeared but a larger fringe has appeared. The use of radio-sonde data is not sufficient in this case to remove completely the atmospheric artifact.

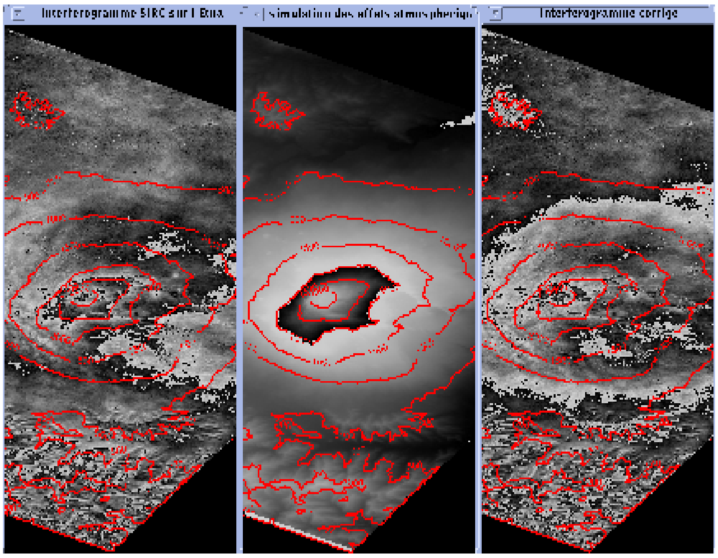

Figure 1: Atmospheric artifact on mount Etna SIRC interferogram. The first image represents a differential interferogram over mount Etna. The relief has been removed. The second image is the simulated artifact and the third image is the difference between the real and simulated artifacts.

3-Artifacts due to an heterogeneous atmosphere

Atmospheric heterogeneities can also produce artifacts.

Ionospheric irregularities can be important. The irregularities of the F-layer (around 300 km high) can reach 1.5 fringes in C band.

In the troposphere, the refractive index varies essentially with water content. Under stable conditions, the wator pressure changes slowly horizontally. It has been observed smooth changes of the order of 0.3 fringes on ERS interferograms. Under unstable conditions, the refractive index can change more quickly (cf. Panofsky and Dutton 1984) leading to artifacts up to 2 or 3 fringes. Artifacts due to growing cumulus have been observed on the Landers site (Cf Figure 2). Artifacts due to a vertical wind shear have also been observed (Cf Figure 3) Tarayre and Massonnet 1996.

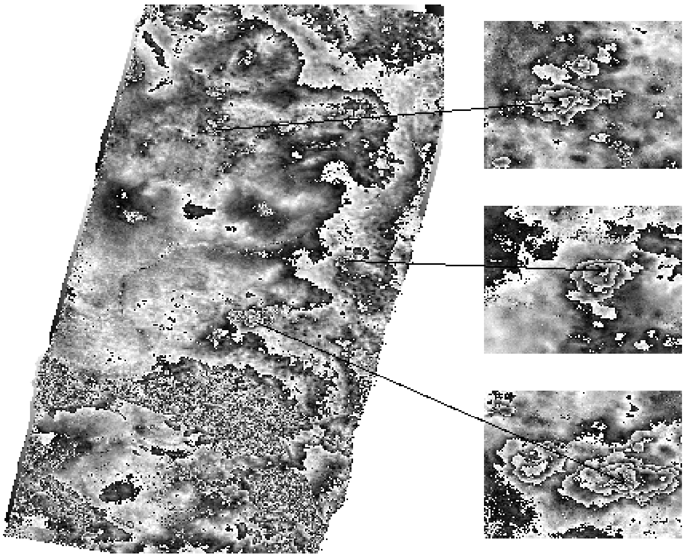

Figure 2: Fringe pattern due to growing cumulus on the Landers site.

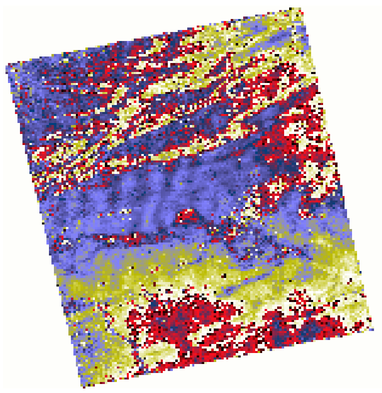

Figure 3: Baltimore interferogram. Fringes due to the relief are seen in the top and bottom of the image. The wave pattern that appears in blue is due to a vertical wind shear.

Conclusion

We have shown that the presence of large height variations and a difference of refractive profiles between the two imagings create interferometric artifacts that can reach one fringe. This phenomenon has to be dealt with when processing data to construct Digital Elevation Models. Moreover, water content horizontal gradients, clear air turbulences and ionospheric phenomena also create local artifacts on interferograms. It seems that these artifacts appear on most interferograms but that their orders of magnitude vary drastically according to the meteorological situation. In order to remove these artifacts on Digital Elevation Models, one needs more than one interferogram to process data.

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