TerraSAR-X high resolution SAR data: Ground motion and mapping applications for infrastructure, oil & gas and public health domain

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Abstract

The successful launch of TerraSAR-X has made available high resolution SAR images with new image characteristics. The objective of this paper is to present the experience of ALTAMIRA INFORMATION regarding the impact of these new data in commercial applications. Case studies will illustrate the findings.

1 Introduction

For ground motion applications, the following satellite characteristics and its benefits on radar application are evaluated:

- *Wavelength*: Compared to the C-band of Envisat and Radarsat, TerraSAR-X operates with wavelength X.
- *Increased resolution*: For ground motion movement this characteristic is of special interest for already built infrastructure monitoring.
- *Rapidity of acquisition*: Another characteristic that is discussed is the rapid image acquisition.
- *Reflectivity of Artificial Corner Reflectors (ACRs)*: Artificial Corner Reflectors are aluminium made trihedrons, that can be installed in the area of interest to guarantee the presence of a radar measurement point. It is analysed how the ACR reflectivity changes with the TerraSAR-X satellite and how ACR design might change in order to be optimised for C band.

Ground motion is illustrated with an oil & gas area case study.

In addition digital elevation models are evaluated with TerraSAR-X characteristics. The very high resolution of TerraSAR-X (1 m) combined with the 11 days cycle is optimal for the creation of digital elevation models on arid or poorly vegetated areas. A case study illustrates the findings.

Finally the contribution of TerraSAR-X data to public health domain is presented with an example of epidemiologic mapping product. The example is a project lead by the French National Space Agency (CNES) and executed by ALTAMIRA INFORMATION.

2 Ground motion applications

2.1 SPN algorithm

The Stable Point Network is an advanced differential interferometric processing technique developed at ALTAMIRA INFORMATION. It is the result of three years of research projects inside the DInSAR data analysis field for CNES (French Space Agency) and ESA (European Space Agency). The SPN tool was the first advanced interferometric processor capable to merge the new ASAR DATA with the historical ERS1/2 [1]. The SPN software relies on the DIAPASON interferometric chain for all the SAR data handling, co-registration work and interferogram generation. The DIAPASON processing software has become, since its creation in 1992, one of the most important differential interferometric tools. More than 50 companies and research laboratories around the world use it.

The Stable Point Network procedure generates three main products for a subsequent set of radar images. The mean subsidence rate, which can be derived using only 6 images. A DEM error map, produced at any resolution. Finally, the extraction of subsidence profiles, that requires from 15 to 30 images, depending on the velocity of displacement versus the intervals between image acquisitions. In any case, an increase in number of images improves the quality of the estimate.

The basis of the technique is the separation of the different artefacts from all the input data. Step by step, the dataset is processed taking into account the physic behaviour of the characterized effects versus the radar signal reflection and the acquisition geometry. Finally, the atmospheric artefacts can be estimated and removed from all the interferometric pairs as low wavelength effects. A high frequency analysis of the data is then carried out in order to extract the profiles of absolute displacement for any point selected by the user. If a DEM of the area is available, the software is also able to give the exact UTM coordinates of the analyzed points with the precision given by the DEM used and the estimated final point height (achieving a final geocoding precision of about 2 meters).

One important point of the chain is its flexibility: the software can work at any resolution and with extracted pieces of images. Moreover there is no maximum image size that constrains memory requirements, although large images increment considerably the execution time. The most critical step in CPU load, related with the image size is the subsidence rate derivation and the DEM error estimation, since this is done pixel by pixel at the end of the process.

2.2 Artificial Corner Reflectors results

In the areas where there are not natural reflectors, a network of artificial Corner Reflectors can be installed. These aluminium made trihedrons have very high reflectivity to the radar signal. This allows to analyse in detail the movement over an interesting area.

The comparison between movement computed using Envisat images and TerraSAR-X images over a Corner Reflectors network is here presented. The study area is an oil and gas extraction field. In Figure 1, the deformation obtained with TerraSAR-X (on the left) an Envisat (on the right) is compared. Although the design of the Corner Reflectors network was done specifically for Envisat satellite, the results obtained with TerraSAR-X are very similar to the Envisat ones, see also deformation plot in Figure 1.

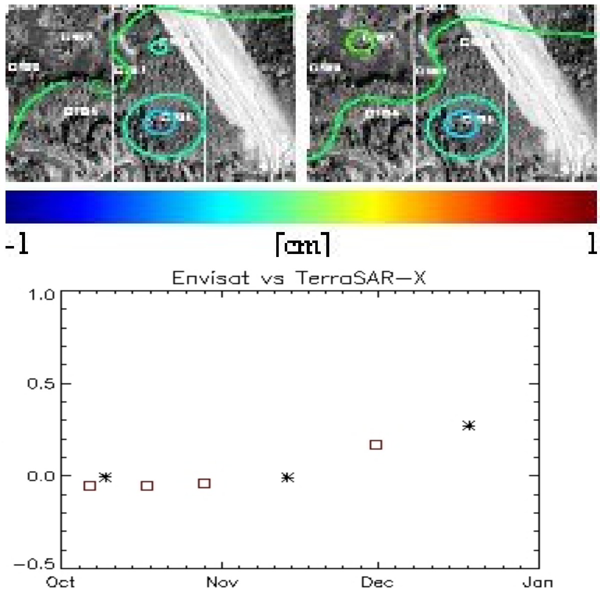

Figure 1 Comparison between ENVISAT and TerraSAR-X results (squares/TerraSAR-X, asterisks /ENVISAT)

Working with TerraSAR-X images and artificial Corner Reflectors represents two main advantages versus other satellite images: better temporal density (TerraSAR-X repetition cycle is 11 days) and better spatial density (the higher resolution of TerraSAR-X allows to increase the density of Corner Reflectors).

3 Digital Elevation Models

An important applicability of TerraSAR-X satellite is the generation of spatial high-resolution DEMs using spotlight or stripmap data. The availability of interferometric pairs with temporal gaps of 11 or 22 days makes possible to generate precise topographic maps of non-vegetated areas, where interferometric coherence is temporally preserved.

An example of DEM generation using InSAR techniques is shown in Figure 2. The lower topographic map corresponds to the TerraSAR-X result, where a pixel size of 4 x 4 meters has been obtained. On the other hand, the upper map corresponds to the Shuttle Radar Topography Mission (SRTM), with a spatial resolution of 90 x 90 meters. Obviously, as shown in Figure 2, topographic details are more clear in the TerraSAR-X DEM than in the SRTM case.

The height quality of the topographic map has been tested using a set of 30 control points, obtaining a difference standard deviation of 7 meters. These results show the high quality of TerraSAR-X topographic products, taking into account both spatial resolution and height precision.

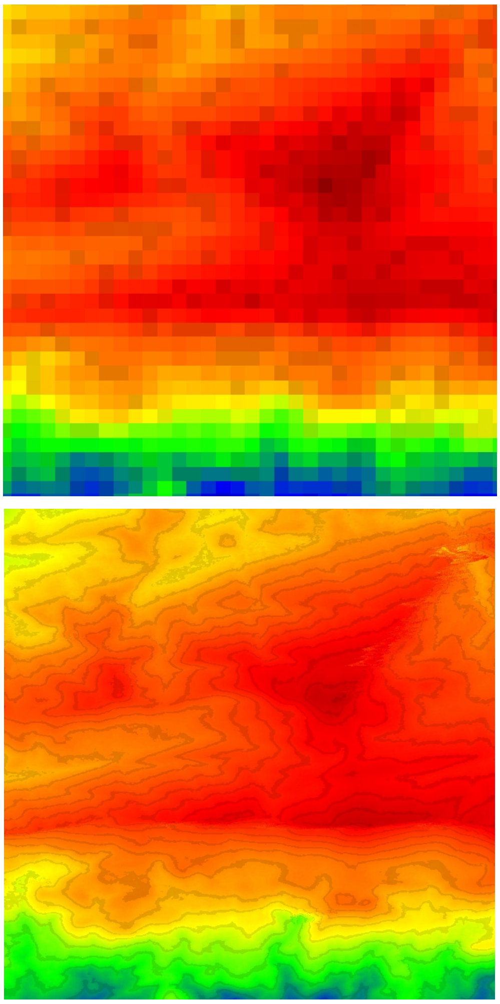

Figure 2 Comparison between SRTM (up) and TerraSAR-X (down) DEMs. Height ranges between 400 and 900 meters.

4 Epidemiology mapping

4.1 Context of the project

The context of this project is given by the paper released in the Remote Sensing of Environment, "Classification of mosquitoes ponds from high-spatial resolution remote sensing: Application to Rift Valley Fever epidemics in Senegal" [2].

"During the rainy season the abundance of mosquitoes over the Ferlo region (Senegal) is linked to dynamic, vegetation cover and turbidity of temporary and relatively small ponds. The latter create a variable environment where mosquitoes can thrive and thus contribute to diffusion and transmission of diseases such as the Rift Valley Fever. The small size and complex distribution of ponds require the use of high-spatial resolution images for adequate detection".

The objective of the project is to demonstrate the benefits of TerraSAR-X high resolution data in the identification and monitoring of ponds during the rainy season.

This presentation is a first evaluation based on acquisitions made during TerraSAR-X commissioning phase. The data was acquired in October and November, end of the rainy season. Results will alow optimizing acquisition strategy during the rainy season July-August 2008.

4.2 Data selection

For the monitoring of these areas, high-resolution radar images have been selected, specifically, spotlight TerraSAR-X data. The main advantages of these images are:

- Spatial resolution up to 1-2 meters.
- Usage of HH polarization for maximization of scattering differences between water bodies and ground.
- High quality images no matter of light conditions (day or night) and presence of clouds.

Two TerraSAR-X SpotLight images have been acquired over the area of interest with one cycle difference to allow InSAR processing.

These characteristics are important for continuous monitoring, since periodical acquisitions can be programmed with different weather conditions and all these data can be perfectly combined for generating the final products.

4.3 Algorithm description

Three main features of TerraSAR-X images have been used for water detection:

- Low reflectivity of calm water in comparison with other ground structures.
- Low InSAR coherence when combining two different images with a very short temporal baseline.
- High spatial resolution for small water bodies detection.

Evolution maps are the results of this process where ponds as small as 16m² have been detected, see Figure 3.

In the case of epidemiology, High-resolution TerraSAR-X data meet the initial objective which consisted in water bodies detection and temporal monitoring of ponds. This is the case not only for large or medium-size water bodies, but for small ponds that rapidly change their sizes within a few days. The possibility of monitoring them no matter the weather conditions (rain, clouds, day light..), demonstrates the applicability of these images for the next phase of the project which will start this summer during the rainy season.

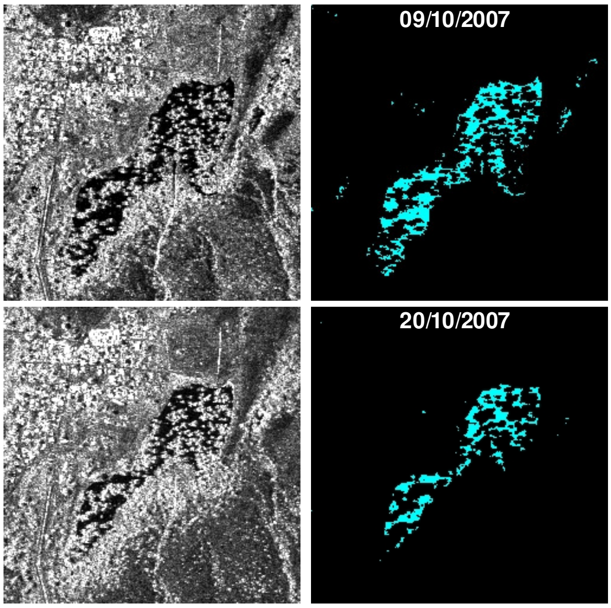

Figure 3 Temporal evolution of water bodies

References

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[2] J.P. Lacaux et al.: *Classification of ponds from high-spatial resolution remote sensing: Application to Rift Valley Fever epidemics in Senegal*. Remote Sensing of Environment (2006), doi: 10.1016/j.rse.2006.07.012.