

# AUTOMATIC INSAR SYSTEMATIC PROCESSING AND WEB BASED TOOL FOR EFFICIENT DATA MINING: APPLICATION TO VOLCANO MONITORING IN AFRICA

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## ABSTRACT

For the need of volcano monitoring in Africa, all possible ENVISAT ASAR data is systematically programmed and ordered for a given set of Modes, Tracks and Swaths. This data is processed using a (semi-)automated procedure based on the DORIS InSAR open source software (TU Delft), Mathematica<sup>®</sup> routines and shell scripts running on Mac OS X environment. This mass processing produces thousands of phase interferograms, coherence maps, amplitude images and deformation maps (in cm). The results are available as Sun-Rasters in radar geometry or as geocoded images in conventional GIS format (ENVI<sup>®</sup> or GMT grid).

A web-based tool was developed for visualizing the rapidly increasing number of conventional differential SAR Interferograms (InSAR) and related products.

More than a simple visualization tool, it also helps to easily discriminate artifacts from deformations, to detect seasonal variations or continuous slow phenomena, or to detect timing errors or frame shifts.

Eventually potentially interesting interferograms, identified thanks to this bulk procedure are re-processed using manually fine-tuned parameters.

## 1. INTRODUCTION

A possible way (at least partly) to overcome the vegetation-induced decorrelation within differential SAR interferograms is to increase the number of SAR acquisitions. This will in principle increase the chances of producing interferograms with favorable small temporal and spatial baselines.

This method has been applied successfully since 2005 at the National Museum of Natural History in Luxembourg for studying and monitoring a.o. some active African volcanoes in Cameroon, Democratic Republic of Congo, Cape Verde and Tanzania [1].

The drawback of this method is of course the number of interferograms (and associated maps) that will obviously increase roughly as  $(n-n^2)/2$ , where "n" is the number of available SAR scenes in a given Mode, Track and Swath.

A web-based tool has hence been developed for helping with both monitoring and data mining.

More than being a tool for quickly and efficiently looking through the thousands of InSAR products, it also helps to easily discriminate artifacts from

deformations, to detect seasonal variations or continuous slow phenomena, and to detect timing errors or frame shifts. The web tool is also password-protected allowing an easy and secure way to share the information through the Internet.

## 2. THE SEMI-AUTOMATED INSAR PROCESSING

All possible ENVISAT ASAR data is systematically programmed and ordered for a given set of Modes, Tracks and Swaths over some tectonically active targets. When an e-mail issued by ESA announces the availability of a new scene, an automated script downloads and archives the corresponding files. Since the data is only made available for 10 days on the ESA FTP server such a script avoids losing the data in case of the operator being absent.

For each target (i.e. each volcanic or tectonic area in the present case) a set of optimized parameters is pre-defined for automated processing: crop size, multilook factor, Digital Elevation Model (DEM), maximum spatial baseline, file naming and locator, etc...

Based on these parameters, a single command line will either allow for computing a single interferogram or all the possible combinations of a given scene, with each compatible scene in the database. The command line calls more scripts, duplicates and modifies input cards, modifies, renames or copies input and output files, following the needs to execute the different Doris steps up to the production of geocoded relevant InSAR products and maps.

To avoid crashing computers, freezing the bulk process within an infinite loop and filling hard disk with error logs, scripts are equipped with watchdog functions that would abort a failed process. It would then rename the corresponding directory according to the reason of the failure and step to the next InSAR pair to process. Large computations can then be safely launched unmonitored.

Instead of triggering the automated bulk processing by the notification mail issued by ESA, the launch procedure is kept manual in order 1) to avoid too many simultaneous launches on a given computer and 2) for the operator to choose between a few options such as:

- The type of precise orbit(s) to use. Since the DEOS precise orbits are not produced anymore on a regular

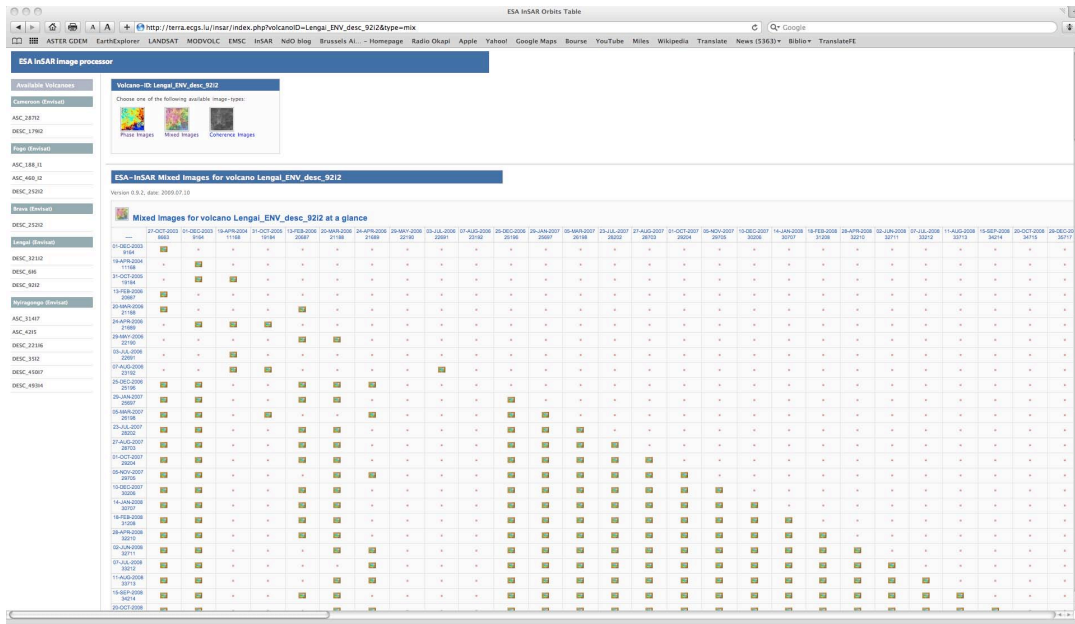


Figure 1: Web tool for InSAR product visualization. The operator selects a target (i.e. a volcano) in the column to the left and a Mode/Track/Swath. Three kinds of product to display are offered in the small upper window: the coherence maps, the phase interferograms, or the phase wrapped on the amplitude. The table displays all the interferometric pairs computed in the database.

basis, one can choose to use either Preliminary or Verified precise orbits provided by ESA. These are available respectively about 3 days and 1 Month after the SAR acquisition. A Mathematica routine interpolates, resamples and transforms them in the appropriate format. The corresponding information is then inserted in the results file and the Doris processing

is carried out. Other Mathematica programs are available to remove manually possible orbital residual lefts in the interferograms.

- Modify the default list of masters or slaves scenes to combine with the given image.

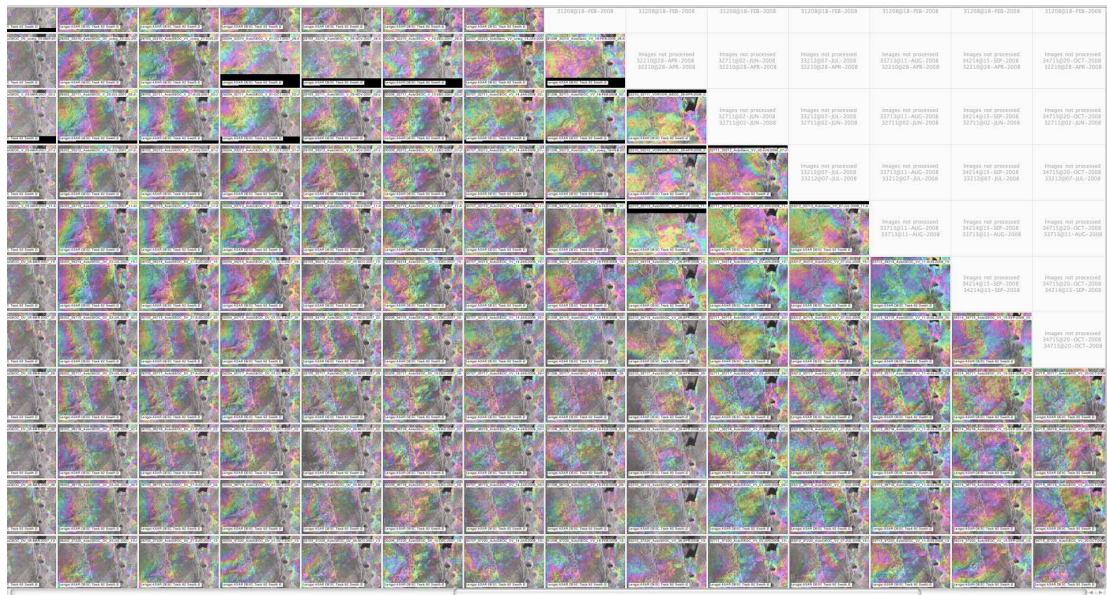


Figure 2: Extract of the table provided by the visualization web tool for InSAR products. The table shows here phase interferograms wrapped on the amplitude images (Tanzania: Lengai Descending Track 92 Swath i2). Clicking on one of the low-resolution products displays it in a new window at higher resolution.

- Choosing to unwrap the final residual phase. Given the time required for unwrapping large scenes with large decorrelated patches (as for the highly vegetated areas under equatorial latitudes) it is usually not advised to

run that option by default. For interferograms that would require it, another single command line script can be launched afterward.

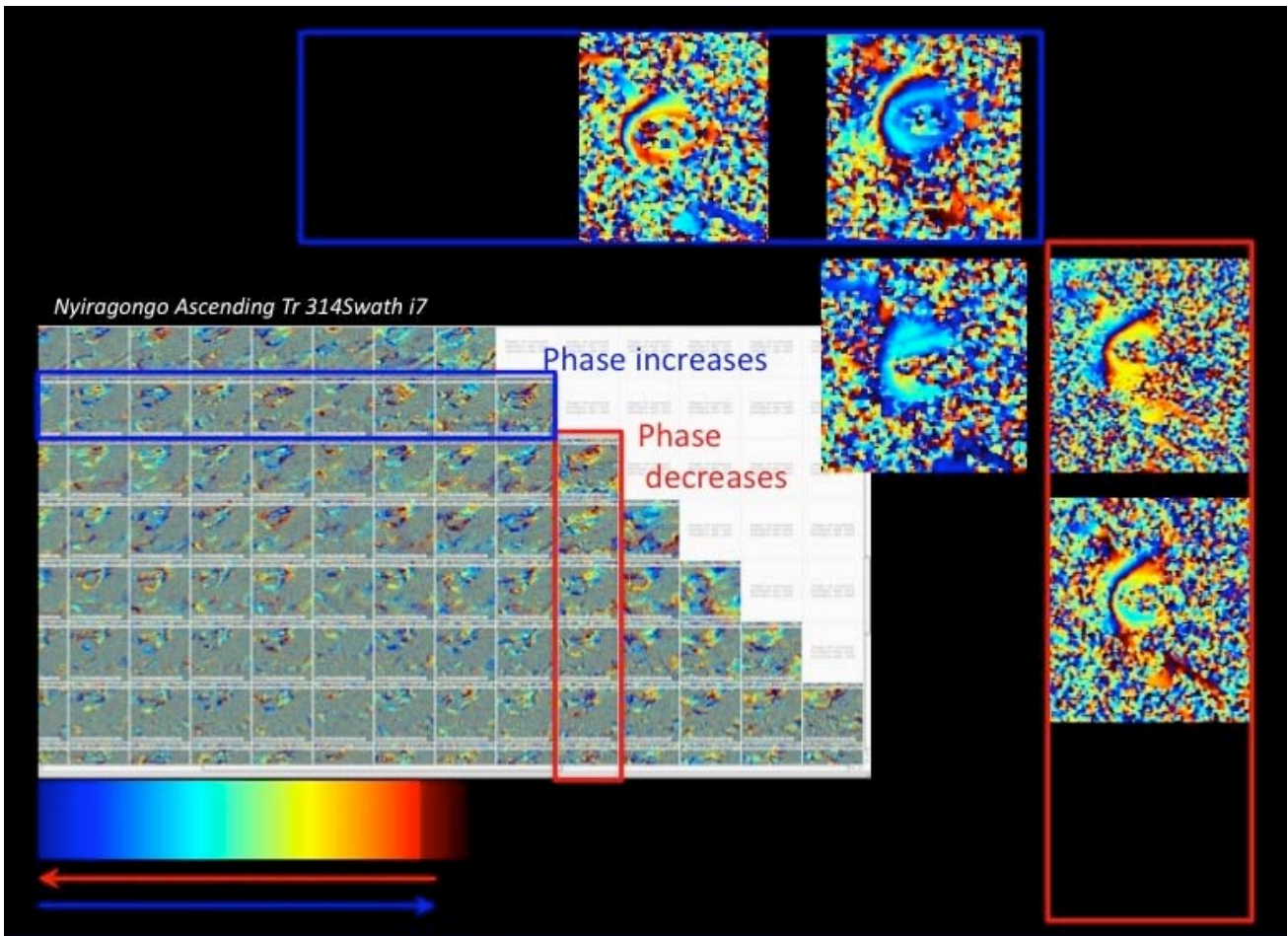


Figure 3: Table on white background: extract of web tool showing phase interferograms of the Nyiragongo area, DR Congo (Nyiragongo Ascending Track 314 Swath i7). Interferograms framed in Blue and Red show an atmospheric artifact affecting the Nyiragongo volcano (too small to be seen in the table – see enlargements to the right instead). The sign of phase delay observed on the crater area is reverted when the affected image is used as a Slave (line framed in Blue; phase increases) or a Master (column framed in red; phase decreases).

The two interferograms shown in the upper blue frame are enlargements of only the Nyiragongo crater area. These are extracted from the two interferograms at the right of the blue-framed interferograms in the table. Similarly the two interferograms shown in the red frame to the right of the figure are similar zooms extracted from the two interferograms at the top of the red-framed interferograms in the table. The amplitude of the signal (about 1,5 color cycle in the present case) is about the same on every affected interferogram (see blue and red frames) whatever the altitude of ambiguity is. This rules out possible DEM related errors. The unframed zoom is the enlargement of the same crater area, taken from the interferogram just below the contact point between the blue and red frames in the table. None of the independent interferograms spanning the affected image show similar signal (see unframed interferograms).

### 3. THE WEB-BASED VISUALIZATION TOOL

Yet another group of automated scripts will collect the results of all the pairs processed for a given Mode, Track and Swath. The Sun-Raster figures in radar geometry are converted to JPG and renamed with relevant information such as the volcano name, the

Master and Slave orbit numbers and their dates, the perpendicular and temporal baselines and the altitude of ambiguity.

Filtered phase interferograms, filtered phase interferograms wrapped on the amplitude and coherence maps are stored in distinct directories either at low

resolution (for web thumbnails icons) or medium resolution (for visualization). The automated conversion and down-sampling is made using shell scripts and open source software (ImageMagick, <http://www.imagemagick.org/>).

A cron job checks every 30 minutes if new figures are available and transfers them from the mass storage hard disks up to the Web server (hosted on a Mac OS X Server) using an open source synchronization tool (rsync, <http://samba.anu.edu.au/rsync/>).

An InSAR XHTML table is then created making use of CSS (Cascading Style Sheet) features for the design of

the Web pages.

When logged in using the appropriate password, the first page allows the user to choose a target (i.e. a volcano) and a Mode/Track/Swath in the column to the left, then the type of product to display (coherence, phase or phase wrapped on the amplitude) in a new dialog box. A first triangular table pops up (Fig. 1) filled with small yellow-green icons. These icons refer to computed interferograms.

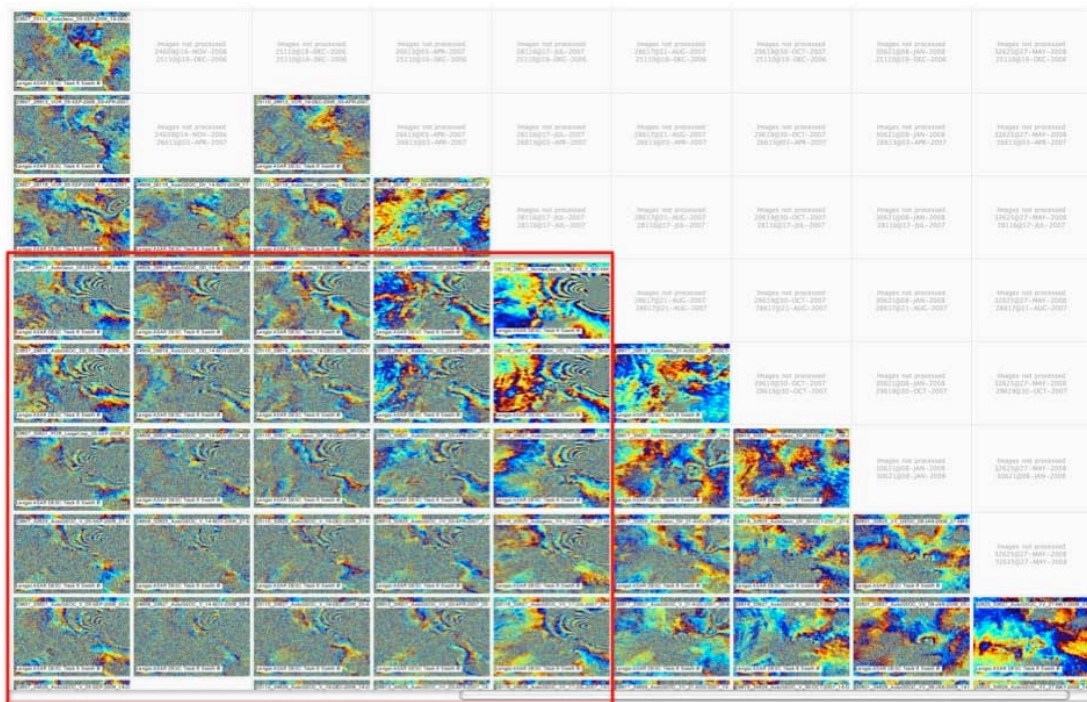


Figure 4: Extract of web tool showing phase interferograms of the Lengai volcano and Lake Natron area, Tanzania. (Lengai Ascending Track 6 Swath i6). All the interferograms spanning July 17th 2007 (framed in red) show an extensive ground deformation related to a dyking event [2]. Unlike the atmospheric artifact no phase reversal is observed in the present case.

The column and line headers are respectively the Master and Slave characteristics (date and orbit number). Empty cells mean that no interferogram could be computed for that given pair (usually because the perpendicular baseline is too large). The table allows the user to view on a single page which products are available vs. time.

When the operator moves the mouse pointer over one of these yellow cells, a low-resolution preview of the interferometric product pops up. Clicking on the icon opens a new page displaying the medium resolution product. Relevant information about interferometric parameters and processing is given in the name of both the low and medium resolution images.

A second table similar to the first one is also displayed. It shows low-resolution thumbnails instead of the

yellow icons. The table is then obviously much larger but offers a global view and the possibility to compare many products at a glance (Fig. 2).

The position of each interferometric product in the tables (based on its Master and Slave orbit numbers) is computed using the open source PHP language combined with the “jquery” java script library (<http://www.jquery.org>, mainly used to make the figures to pop up under the mouse pointer).

For the sake of transfer/display speed, the visualization is limited to medium resolution images. The full resolution Sun-Rasters or geocoded products are (so far) only accessible by ftp on request.

#### 4. APPLICATION FOR DATA MINING AND EVENTS DISCRIMINATION

The web tool is more than a simple interface to visualize a large amount of data and look through the thousands of different interferograms. It offers the possibility of quickly and easily discriminating atmospheric artifacts from deformations, to detect seasonal variations and

continuous slow phenomena, or to detect timing errors or frame shift.

For instance, when an atmospheric artifact affects an image, all and only the interferograms combining that image will display that signal (that is one line and one column in the table). Moreover, the sign of phase delay will be reverted when the affected images are used as the Master or the Slave in the interferogram.

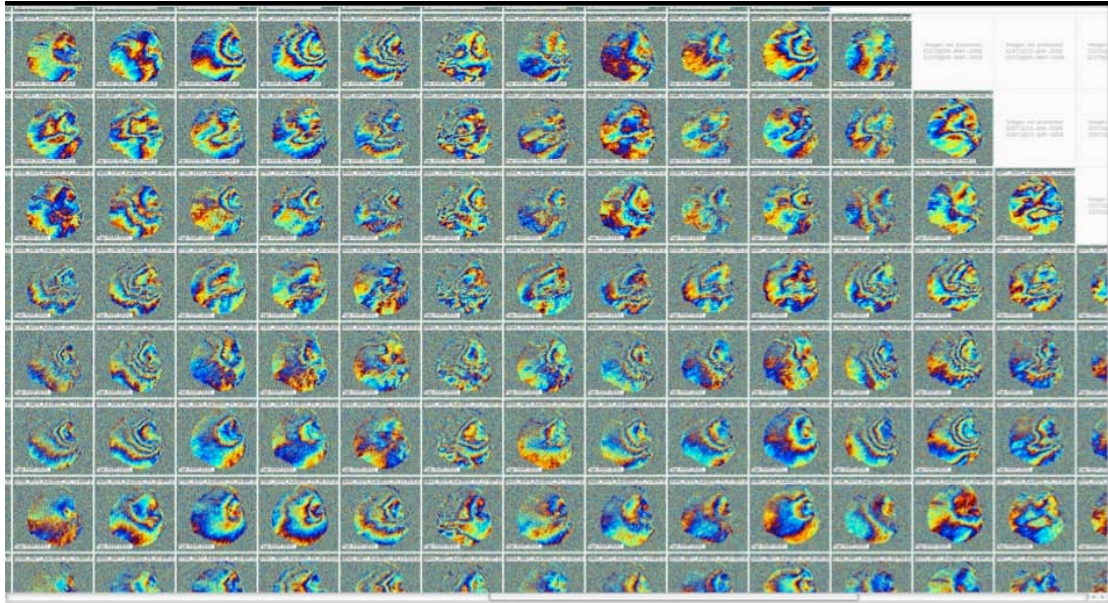


Figure 5: Extract of web tool showing phase interferograms of the Fogo volcano, Cape Verde. (Fogo Descending Track 252 Swath i2). Clear phase delays with different signs can be observed over time. Although these signals have a clear correlation with the topography, no correlation can be seen with the altitude of ambiguity, ruling out DEM errors. It was shown that these variations are attributed to variations of precipitable water vapor in the troposphere due to the Inter-Tropical Convergence Zone (ITCZ) seasonal variations [3].

Fig. 3 shows an example of an atmospheric artifact localized on the Nyiragongo volcano in DR Congo. Since the neighboring Nyamulagira volcano does not show similar features despite its proximity (15 km) and similar dimensions, and since that behavior hasn't been observed in past data, at a first glance, one could easily misinterpret that signal as an inflation/deflation of the volcano.

Such artifacts are easily discriminated from the real deformations as a deformation will affect all and only the interferograms spanning a given epoch, whatever the combination of (independent) images is. As it can be seen from the example on Fig. 4, the signal is not only visible in one column and one line of the table, but in the entire box below a given date.

Obviously the tools will easily allow the detection of slow progressing phenomena such as lava compaction. It also facilitates the detection of seasonal variations (Fig. 5).

Finally, the web tool can also help to detect timing errors or frame shifts. Every scene from a given Mode, Track and Swath is ordered with the same frame along

the orbital path. The Master scene is always cropped at the same line and pixel numbers. When a timing error or a frame shift occurs, the image will appear shifted in the interferometric products (Fig. 6).

#### 5. CONCLUSIONS

The automated bulk processing and the web interface have proven to be a simple, quick and efficient tool for the management of the large InSAR data base. It also helps to easily discriminate artifacts from deformations, to detect seasonal variations or continuous slow phenomena, or to detect timing errors or frame shift.

Thanks to the pre-defined parameters and the automated procedure, the tools are also useful for fast response in case of a crisis. Usually each new scene can be combined with the previous most recent compatible image from the database to produce the last interferogram within less than 30 minutes.

Scripts and Mathematica routines may be made available on request to the corresponding author although without the manual but containing the documentation written in the scripts. The procedure was set up and upgraded step by step during the growth of

the project(s) and tailored for our needs and hardware, based on our configurations. It is hence not portable “as it is” and could certainly be optimized.



Figure 6: Extract of web tool showing coherence maps of the Fogo volcano, Cape Verde. (Fogo Ascending Track 460 Swath i2). The scenes are always processed with the same crop counted in lines and pixels in the Master image. One can clearly see the shift of the volcanic island in the frame of the scene as underlined by the red curves.

## 6. ACKNOWLEDGEMENTS

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