InSARViz: an open source interactive visualization tool for InSAR

InSARViz: un logiciel libre pour la visualisation interactive de données InSAR

Margaux Mouchené, Renaud Blanch, Erwan Pathier et Franck Thollard

1 Scientific context

Satellite SAR interferometry (InSAR [3]) is a well-established technique in Earth Observation that is able to monitor ground displacement with a high precision (up to mm/year), combining high spatial resolution (up to a few m) and large coverage capabilities (up to continental scale) with a temporal resolution from a few days to a few weeks. It is used to study a wide range of phenomena (e.g. earthquakes, landslides, permafrost, volcanoes, glaciers dynamics, subsidence, building and infrastructure deformation, etc.)

In this project we are mainly interested in the tectonic loading of faults the leads to earthquakes. Actually, the loading of faults is done through slow tectonic plates motion (few cm/year to mm/year). Estimating this load and its variability is critical to understand the mechanics that lead to earthquake, hence evaluate the seismic hazard [1]. To be relevant, the measure has to be done on large spatial areas (*e.g.* six time the surface of France) with a resolution of around one hundred meters.

1.1 Existing tools

For several reasons (data availability, non-intuitive radar image geometry, complexity of the processing, etc.), InSAR has long remained a niche technology and few free open-source tools have been dedicated to it compared to the widely-used multi-purposes optical imagery. Most tools are focused on data processing (e.g. ROI_PAC, DORIS, GMTSAR, StaMPS, ISCE, NSBAS, OTB, SNAP, LICSBAS, GDM-SAR), but very few are tailored to the specific visualization needs of the different InSAR products (interferograms, network of interferograms, datacube of InSAR time-series). Similarly, generic remote-sensing or GIS software like QGIS are also limited when used with InSAR data. Some visualization tools with dedicated InSAR functionality like the pioneer MDX software[1] were designed to visualize a single radar image or interferogram, but not large datasets. The ESA SNAP toolbox also offers nice additional features to switch from radar to ground geometry.

1.2 New needs

However, new spatial missions, like the Sentinel-1 mission of the European program COPERNICUS [2] with a systematic background acquisition strategy and an open data policy, provide unprecedented access to massive SAR data sets. Figure 1 presents how a given area is imaged at different timestamps (top) and the density of acquisition (bottom). Images can be downloaded freely either at ESA or at any mirror like the french spatial agency (CNES). For a given area, one can get a set of images of this area taken at different date.

After a rather complex processing (done in our case by the NSBAS processing chain, which is used for instance in the on-demand service GDM-SAR) those new datasets allow to generate a network of thousands of interferograms over a same area, from which time-serie analysis results in spatio-temporal data cube: a layer of this data cube is a 2D map that contains the displacement of each pixel of an image relative to the same pixel in the reference date image. A typical data cube size is $4000\times6000\times200$, where 4000×6000 are the spatial dimensions (pixels) and 200 is a typical number of images taken since the beginning of the mission (2014). The aforementioned tools are not suited to manage such large and multifaceted datasets. In particular, fluid and interactive data visualization of large, multidimensional datasets is non-trivial. If data cube visualization is a more generic problem and an active research topic in EO and beyond, some specifics of InSAR (radar geometry, wrapped phase, relative measurement in space and in time, multiple types of products useful for interpretation…) call for a new, dedicated visualization tool.

- *Margaux Mouchené, Erwan Pathier et Franck Thollard: Univ. Grenoble Alpes, Univ. Savoie Mont Blanc, CNRS, IRD, Univ. Gustave Eiffel, ISTerre, F-38000 Grenoble, France.*
- *Margaux Mouchené et Renaud Blanch: Univ. Grenoble Alpes, CNRS, Grenoble INP, LIG, F-38000 Grenoble, France.*
E-mails: prenom.nom@univ-grenoble-alpes.fr

1. MDX, provided by the Jet Propulsion Lab, <https://software.nasa.gov/software/NPO-35238-1>.

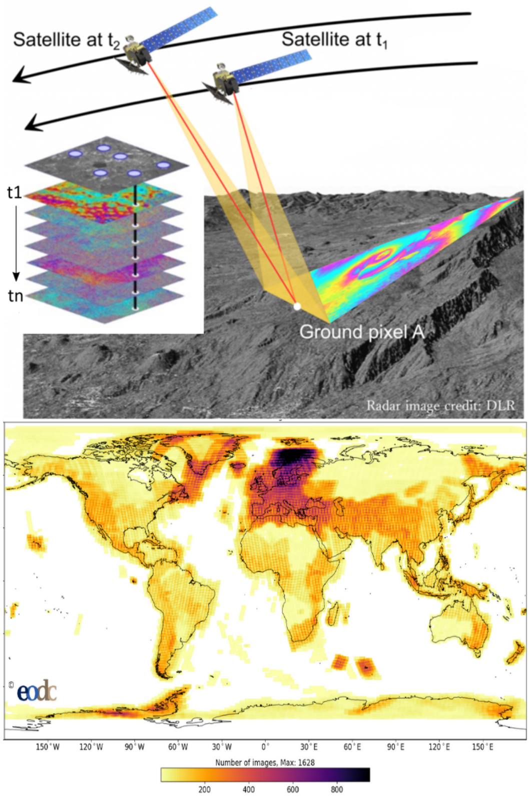

Fig. 1. InSar Presentation: **top**: the satellites imaging the same place at different times, hence allowing to build a stack of radar interferograms which are differentiation of the phase of radar images. **bottom**. Density of image acquisition. Revisiting time goes up to 2 days in Europe.

2 The InSARViz project

We started the InSARViz project with a survey of expert users in the French InSAR community covering different application domains (earthquake, volcano, landslides), and we identified a strong need for an application that allows to navigate interactively in spatio-temporal data cubes. Figure 2 illustrates two use cases for the software.

Some of the requirements for the tool are generic (e.g. open source, handling of big dataset, flexibility with respect to the input formats, smooth and user-driven navigation along the cube dimensions) and other more specific (relative comparison between points at different location, selection of a set of pixels and the simultaneous vizualisation of their behavior in both time and space, visualization of the data in radar and ground geometries…)

To meet those needs we designed the InSARViz application with the following characteristics:

- A standalone application that takes advantage of the hardware (i.e., GPU, SSD hard drive, capability to run on cluster as a standalone application). We choose the Python language for its well-known advantages (interpreted language, readable, large community) and we use QT for the graphical user interface and OpenGL for the hardware graphical acceleration.
- Using the GDAL library to load the data. This will allow to handle all the input formats that are managed by GDAL (e.g. GeoTIFF). Moreover, we designed a plug-in strategy that allows users to easily manage their own custom data formats.
- We take advantage of Python/QT/OpenGL stack that ensures efficient user interaction with the data. For example, the temporal displacement profile of a point is drawn on the fly while the mouse is hovering over the corresponding pixel. The "on the fly" feature allows the user to identify points of interest. The user can then enter another mode in which they can select a set of points. The application will then draw the temporal profiles of the selected points, allowing a comparison of their behavior in time. This feature can be used when studying earthquakes as users can select points across a fault, allowing to have a general view of the behavior of the phenomenon at different places and times.
- Multiple windows design allows the user to visualize at the same time data in radar geometry and in standard map projection, and also to localize a zoomed-in area on the global map. A layer management system is provided to quickly access files and their metadata.
- Visualization tools commonly use aggregation methods (like smoothing, averaging, clustering) to drastically accelerate image display, but they thus induce observation and interpretation biases that are detrimental to the user. To avoid those bias, the tool focuses on keeping true to the original data and allowing the user to customize the rendering manually (colorscale, outliers selection, level-of-detail).

In our road map, we also plan to develop new functionalities to visualize interactively a network of interferograms and to detect trends in the data (e.g. seasonal, linear, etc.).

InSARViz is available at https://deformvis.gricad-pages.univ-grenoble-alpes.fr/insarviz/.

3 Acknowledgments

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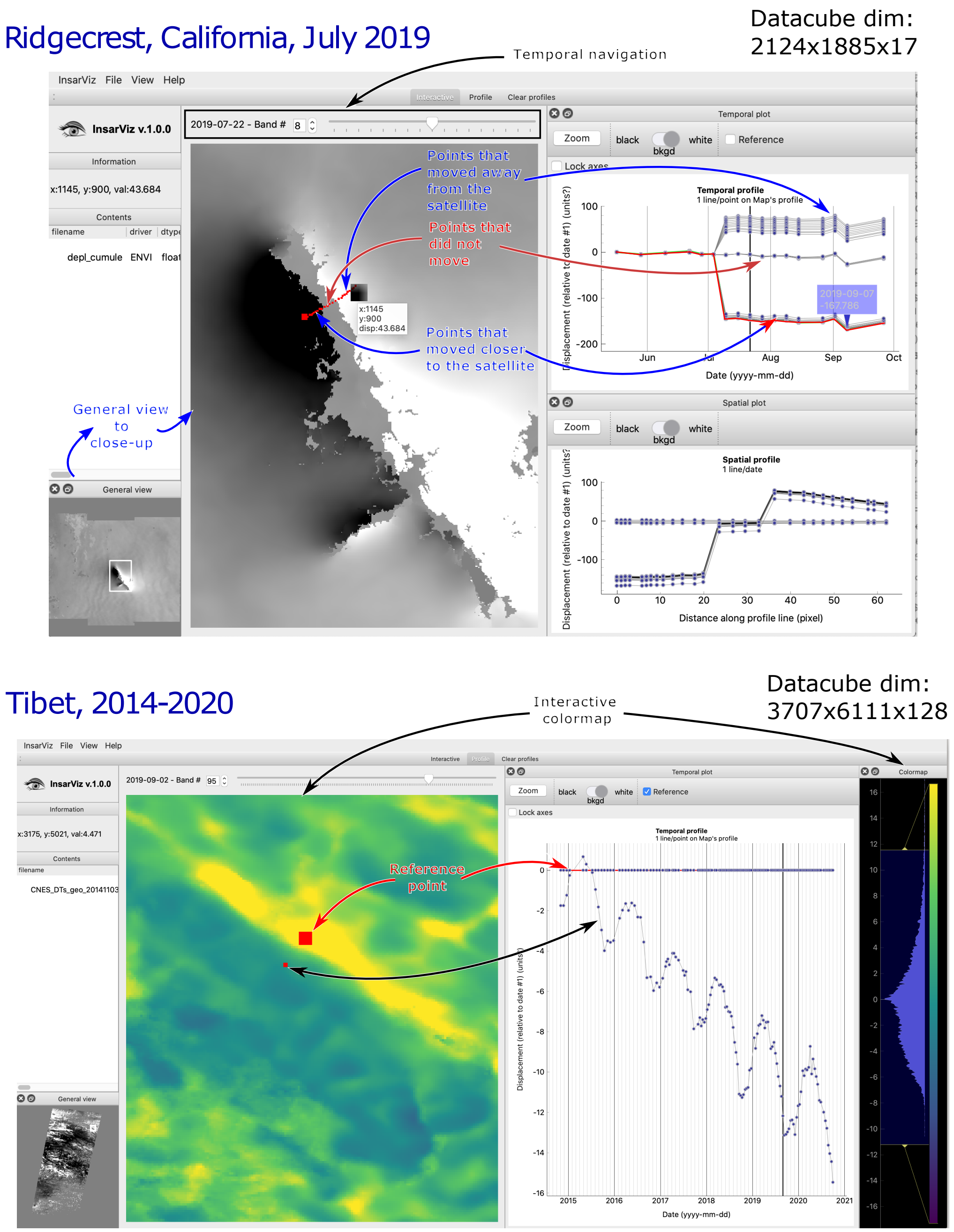

Fig. 2. InSARViz: case studies – (top) Ridgecrest, California, July 2019; (bottom) Tibet, 2014-2020.

References

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