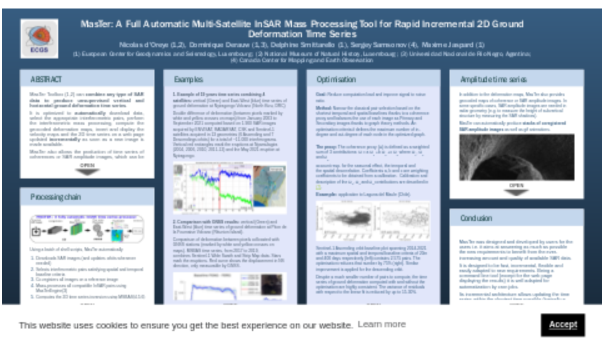
MasTer: A Full Automatic Multi-Satellite InSAR Mass Processing Tool for Rapid Incremental 2D Ground Deformation Time Series


MasTer: A Full Automatic Multi-Satellite InSAR Mass Processing Tool for Rapid Incremental 2D Ground Deformation Time Series
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ABSTRACT
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ABSTRACT

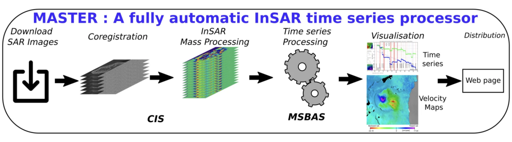
MasTer Toolbox (1,2) can **combine any type of SAR data to produce unsupervised vertical and horizontal ground deformation time series**.

It is optimized to **automatically** download data, select the appropriate interferometric pairs, perform the interferometric mass processing, compute the geocoded deformation maps, invert and display the velocity maps and the 2D time series on a web page updated **incrementally** as soon as a new image is made available.

MasTer also allows the production of time series of coherences or SAR amplitude images, which can be used e.g. for land use monitoring or geomorphological changes detection.

To MasTer the art of InSAR mass processing.

PROCESSING CHAIN

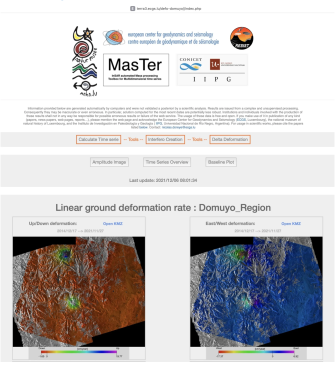


Using a batch of shell scripts, MasTer automatically

1. Downloads SAR images (and updates orbits whenever needed)
2. Selects interferometric pairs satisfying spatial and temporal baseline criteria
3. Co-registers all images on a reference image
4. Mass-processes all compatible InSAR pairs using MasTerEngine(3)
5. Computes the 2D time series inversion using MSBAS(4,5,6)
6. Update results on web page.

See example:

(click to be directed to demo web page)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european center for geodynamics and seismology
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MasTer
InSAR automated Mass processing Toolbox for Multidimensional time series
CONICET
I I P G
RESIST
Calculate Time serie
-- Tools --
Interfero Creation
Delta Deformation
Amplitude Image
Time Series Overview
Baseline Plot
Open KMZ

Last update: 2021/12/06 08:01:34

Linear ground deformation rate : Domuyo_Region

Up/Down deformation: 2014/12/17 --> 2021/11/27

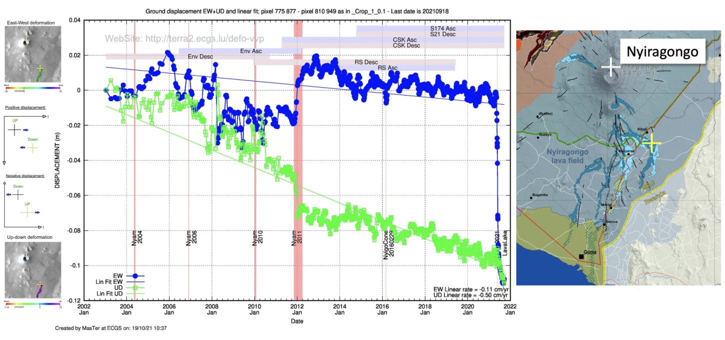
East/West deformation: 2014/12/17 --> 2021/11/27

These processes are optimized (e.g. parallel computing; sharing intermediate results whenever possible...), incremental (updating the MSBAS inversion only needs computing the last deformation maps) and self-evaluating (unsatisfying intermediate results are automatically recalculated with updated parameters or discarded if unsuccessful).

EXAMPLES

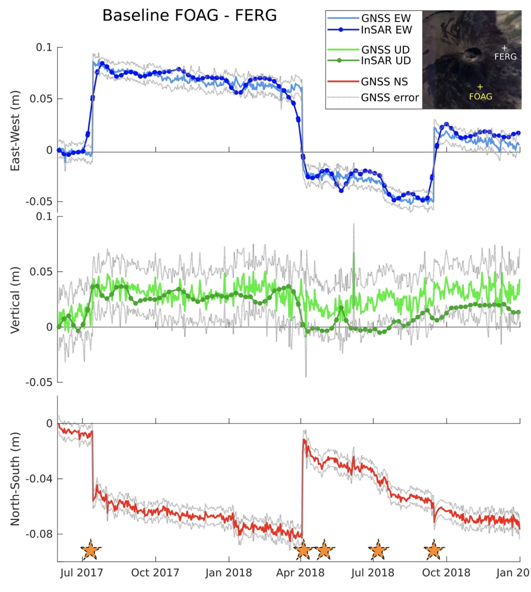
1. Example of 19 years time series combining 4 satellites: vertical (Green) and East-West (blue) time series of ground deformation at Nyiragongo Volcano (North Kivu, DRC)

Double difference of deformation (between pixels marked by white and yellow crosses on maps) from January 2003 to September 2021 computed based on 1.900 SAR images acquired by ENVISAT, RADARSAT, CSK and Sentinel-1 satellites acquired in 13 geometries (6 Ascending and 7 Descendings orbits) for a total of ~11.000 interferograms. Vertical red rectangles mark the eruptions at Nyamulagira (2004, 2006, 2010, 2011-12) and the May 2021 eruption at Nyiragongo.



2. Comparison with GNSS results: vertical (Green) and East-West (blue) time series of ground deformation at Piton de la Fournaise Volcano (Réunion Island).

Comparison of deformation between pixels collocated with GNSS stations (marked by white and yellow crosses on maps). MSBAS time series, from 2017 to 2019, combines Sentinel-1 Wide Swath and Strip Map data. Stars mark the eruptions. Red curve shows the displacement in NS direction, only measurable by GNSS.



OPTIMISATION

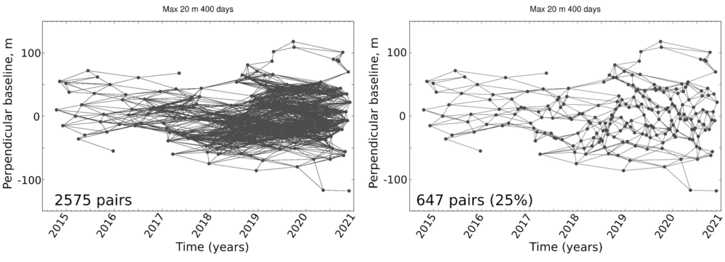
Goal: Reduce computation load and improve signal to noise ratio.

Methods: Optimization can be performed by
- using a **coherence proxy** (i.e. narrowing the classical pair selection based on the shortest temporal and spatial baselines thanks to a coherence proxy and balances the use of each image as Primary and Secondary images thanks to graph theory methods. An optimisation criteria k defines the maximum number of in-degree and out-degree of each node in the optimized graph, and/or
- applying a **coherence restriction threshold** (i.e. discarding each interferogram with a mean coherence computed on a reference region less than a given threshold).

The proxy: The coherence proxy (ω) is defined as a weighted sum of 3 contributions: $\omega = a\,\omega_1 + b\,\omega_2 + c\,\omega_3$ where ω_1, ω_2 and ω_3

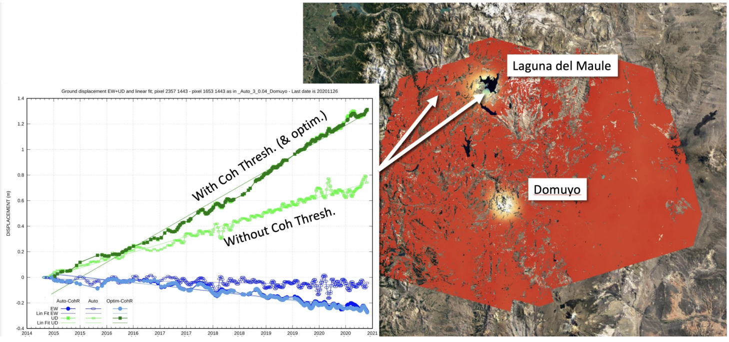
account resp. for the seasonal effect, the temporal and the spatial decorrelation. Coefficients a, b and c are weighting coefficients to be obtained from a calibration. Calibration and description of the ω_1, ω_2 and ω_3 contributions are described in (7).

Example: application to Laguna del Maule (Chile).



Sentinel-1 Ascending orbit baseline plot spanning 2014-2021 with a maximum spatial and temporal baseline criteria of 20m and 400 days respectively (left) contains 2.575 pairs. The optimisation using the coherence proxy reduces that number by 75% (right). Similar improvement is applied for the descending orbit.

Despite a much smaller number of pairs to compute, the time series of ground deformation computed with and without the optimisation are highly consistent. The variance of residuals with respect to the linear fit is reduced by up to 15-30%.



Note that in the specific case of the Laguna del Maule region, a coherence restriction threshold must also be applied to cope with the decorrelation induced by the seasonal snow cover. The coherence proxy alone keeps at least 2*k* pairs using each image (*k* times as Primary and *k* as Secondary) even if low weights are attributed to these pairs.

As already detected by Derauw et al. (1) and illustrated by the plot above, neglecting the coherence threshold leads to underestimated amplitude by up to 48%. Empty green and blue symbols show resp. the vertical and EW displacement between two pixels identified by the white arrows without optimisation. Vivid green and blue curves show the results obtained with only the coherence threshold optimization, while pale curves show the results from both optimizations.

AMPLITUDE TIME SERIES

In addition to the deformation maps, MasTer also provides geocoded maps of coherence or SAR amplitude images. In some specific cases, SAR amplitude images are needed in radar geometry (e.g. to measure the height of subvertical structure by measuring the SAR shadows).

MasTer can automatically produce **stacks of coregistered SAR amplitude images** as well as gif animations.

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1638798875/agu-fm2021/F1-4F-0F-F2-2F-5A-C6-4D-7C-88-AB-0E-A4-38-42-02/Video/_movie_CSK_Virunga_Asc_Nyigo2_FAST_Crop_Nyigo_a1jjyo.mp4

The video above shows the evolution of the crater of Nyiragongo volcano, which hosted a lava lake until its recent eruption in May 2021. Video is composed of 526 CSK scenes acquired in Ascending mode from April 2011 to September 2021.

Using the SAsha method, by measuring the shadows cast by the rim, Barrière et al. (see contribution in present meeting here) successfully measured the rises and falls of the lava lake and the changes in elevation of the crater bottom due to the successive overflows of the lava lake (8,9).

CONCLUSION

MasTer was designed and developed by users for the users i.e. it aims at answering as much as possible the new requirements to benefit from the ever-increasing amount and quality of available SAR data.

It is designed to be fast, incremental, flexible and easily adapted to new requirements. Being a command line tool (except for the web page displaying the results) it is well adapted for automatization by cron jobs.

Its incremental architecture allows updating the time series within the shortest time possible (typically a few hours) as soon as a new SAR image is provided. Several steps are self-evaluating to ensure robust and reliable processing.

MasTer is routinely applied for several type of monitoring. It remains under constant improvement.

Software and manual are available on request to authors (ndo@ecgs.lu).

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ABSTRACT

The increasing amount of Synthetic Aperture Radar (SAR) satellites orbiting the Earth, their increasing time and space resolution, the variety of wavelengths, polarizations and looking geometries, the shortening of data availability latency and the lengthening of archive databases offer unprecedented opportunities for Earth observation and hazard monitoring. The downside is that it brings new challenges for processing that huge amount of data and for making the results quickly analyzable.

To fully benefit from these advances in SAR, it requires efficient data processing infrastructure (optimized for processing speed, storage usage and security), efficient data visualization, and standardization of the final products for easy ingestion by conventional analysis tools.

We present here the InSAR Mass processing Toolbox for Multidimensional time series (MasTer), which can combine any type of SAR data to produce unsupervised vertical and horizontal ground deformation time series. MasTer is optimized to automatically download SAR data, select the appropriate interferometric pairs, perform the interferometric mass processing, compute the geocoded deformation maps, invert and display the velocity maps and the 2D time series on a web page updated incrementally as soon as a new image is made available.

The incremental architecture allows updating the time series within the shortest time possible (typically a few hours) as soon as a new SAR image is provided. Several steps are self-evaluating to ensure robust and reliable processing.

Moreover, recent methodological improvement consists in the computation of a coherence proxy to guide the pair selection optimization balancing the use of each image as primary and secondary image during the differential interferometric (DInSAR) processing. Such a pair selection increases both the processing efficiency and the signal-to-noise ratio of the time series.

MasTer also allows the production of time series of coherences or SAR amplitude images, which can be used e.g. for land use monitoring or geomorphological changes detection.

The capabilities and performances of MasTer will be illustrated with several examples. Software and manual are available upon request from the authors.

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