GAMMA Software

Introduction:

GAMMA Software supports the entire processing chain from SAR raw data to products such as digital elevation models, displacement maps and landuse maps.

The GAMMA Software includes several Modules, each one consisting of documented, well structured code. The software is understood as a toolbox that provides a wide functionality to support the user in the setting up of his processing tasks. Programs can be run individually on the command line or they can be called from scripts that permit running processing sequences in a more automated and efficient way.

GAMMA Software Modules:

The GAMMA software is grouped into four main modules:
- Modular SAR Processor (MSP)
- Interferometry, Differential Interferometry and Geocoding (ISP/DIFF&GEO)
- Land Application Tools (LAT)
- Interferometric Point Target Analysis (IPTA)

In addition, the SAR image co-registration and geocoding functionality is also available as a separate GEO package. Furthermore, a special motion compensation package (MOCOM) and a Time Domain Back Projection processor (TDBP) are available for advanced processing of airborne data (acquired with less stable platforms).

Code:

The GAMMA software is written in ANSI-C. Many of the computationally intensive programs have been parallelized using OPENMP for multiple core processing. Standard binary distributions are available for:
- Intel/AMD processor Linux OS (Ubuntu, Debian, CentOS, Fedora, Redhat) 64-bit
- Intel/AMD processor Microsoft Windows 10 and Windows 11, 64-bit OS systems
- MacOS BigSur (11.6.1) and Monterey (12.0.1)
- Distributions for other platforms may be provided on demand.

Sensors supported:

The software was used to process data of spaceborne and airborne SAR, as well as data of the GAMMA Portable Radar Interferometer (GPRI) and the GAMMA L-band SAR, including the following spaceborne SAR:

ERS-1/2	JERS,PALSAR-1/2	Radarsat-1/2, RCM	SAOCOM
ENVISAT ASAR	SEASAT	KOMPSAT	Capella
Sentinel-1	SIR-C, UAVSAR	ICEYE	StriX
TSX, TDX, PAZ	RISAT	NovaSAR	Hisea
Cosmo-Skymed,CSG	Gaofen-3	ASNARO2	

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Architecture:

The main processing functionality is complemented by quality control and display tools. The display of the final and intermediate products as well as of the input data is supported with user-friendly display programs and programs to generate easily portable images in SUN rasterfile, BMP, and TIFF format. Data can also be exported in GeoTIFF format and as kml files.

The GAMMA Software documentation is accessible with a web-browser and consists of user guides in printable pdf format, reference manual pages for most programs in html format, installation instructions, and information on version changes, bug fixes, and upgrades.

To demonstrate specific processing sequences and to train new users, documented demonstration examples are also available. Besides the required input data, the used commands are indicated and explained. Furthermore, some intermediate results and visualizations of the final results are provided for comparison.

Under the maintenance scheme, support with the use of the software is offered. The persons answering the questions of the users are the same persons who developed the software and are using the software for their own projects.

Development:

GAMMA is dedicated to keep the software at a very advanced level. Through our R&D projects and the many contacts to highly competent SAR/InSAR/PSI specialists, we get valuable inputs to our software development activities. We regularly implement new functionality and adaptations to support new sensors and algorithms. Updates are typically provided twice a year in late June / early July and in December, and include

- Adaptations for new sensors (e.g. Radarsat Constellation Mission (RCM), ICEYE, NovaSAR, SAOCOM, Capella, StriX, Hisea)
- Adaptations to different formats (e.g. data in SICD format)
- New functionality (e.g. split-beam and split-spectrum InSAR, closure phase calculation, inpainting interpolation routines, denoising using block-matching and 3D filtering, ionosphere identification and mitigation procedures, spatially adaptive atmospheric path delay estimation, ScanSAR SLC co-registration and InSAR support)
- Improvements to existing functionality (e.g. adding an alternative interpolator, facilitating the importing of DEMs)
- Adaptations for new Operating Systems, libraries (e.g. FFTW3) etc.
- Information on the update (as specific pdf, and in the Software Documentation)

We try to remain compatible with earlier versions and older satellite data formats and limit changes to command line parameters (that may hinder automated sequences developed by users) as much as possible – and try to adequately implement and communicate necessary exceptions to this. See also the section on the recent developments at the end of this document.

Maintenance and support:

GAMMA uses its software for its own research and development activities, which also means that the software is kept up-to-date with the newest developments. Your contacts for the support are those persons who developed the software and who use it regularly for their own work!

Python wrapper:

Python programming language is getting more and more popular, with many researchers, including among Gamma Software users, increasingly using Python for processing data, analyzing results, developing their own scripts.

We now offer the possibility to integrate the Gamma Software into Python through a wrapper: the py_gamma module. It permits a smooth usage of the Gamma Software tools and data formats within Python scripts as well as within a Python Interactive Development Environment (IDE) such as Spyder or PyCharm.

Using the wrapper:

- Binary images, point lists and data, parameter files, tab files, can be easily read, inspected, and written.
- Gamma Software program calls become Python function calls where variables can be used as function arguments, and system outputs can be stored in variables or written to log files.
- Usage within an interactive Python environment permits function name search and automatic completion.
- The documentation for each function can be easily accessed.

Matlab wrapper:

Matlab is a widely-used interactive development environment and programming language. Many researchers and engineers, including among Gamma Software users, use Matlab for processing data, analyzing results and generating figures.

We now offer the possibility to integrate the Gamma Software into Matlab through a wrapper composed of the mat_gamma and par_file classes. It permits a smooth usage of the Gamma Software within an interactive use of Matlab as well as within Matlab scripts.

Using the wrapper:

- Binary images, point lists and data, parameter files, tab files, can be easily read, inspected, and written.
- Gamma Software program calls become Matlab function calls where variables can be used as function arguments, and system outputs can be stored in variables or written to log files.
- Usage within an interactive Matlab environment permits function name search and automatic completion.
- The documentation for each function can be easily accessed.

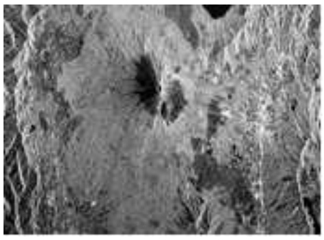
The Matlab wrapper can also be used in GNU Octave, a free software alternative mostly compatible with Matlab.

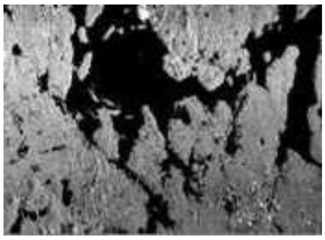
Modular SAR Processor (MSP):

The main tasks addressed with the Modular SAR Processor (MSP) are pre-processing, range compression with optional azimuth pre-filtering, autofocus, azimuth compression, and multi-look post processing.

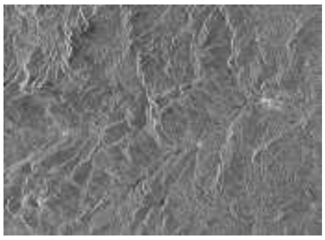
In the pre-processing step processing parameters are determined based on the raw and meta data (e.g. CEOS leader file). During range compression, data may be decimated in azimuth by pre-filtering for quick-look image processing. The azimuth processor uses the range-Doppler algorithm with optional secondary range migration as required for RADARSAT-1 data. The user can select the output geometry of the images to be either deskewed or non-deskewed. Autofocus algorithms are used to refine the along-track platform velocity estimate. The processed images are radiometrically normalized for the antenna pattern, along track gain variations of the radar, length of the azimuth and range reference functions, and slant range. Absolute calibration constants were determined for many of the available sensors/modes using either active transponders or by cross-validation with Agency processed calibrated data. It has been demonstrated that the Gamma processor is phase preserving from interferometric processing. Multi-look images are produced by time-domain averaging of the single look complex image samples. Processing related parameters and data characteristics are saved as text files that can be displayed using commercial plotting packages. The use of precision orbits (“Delft”, PRC, DORIS) is supported. ASAR Alternative Polarization (AP) raw data processing is supported. For PALSAR-1 processing of fine beam single polarization (FBS), fine beam dual polarization (FBD) as well as fully polarimetric data coming from either JAXA (for scientific users) or ERSDAC (for commercial users) is supported. Furthermore, PALSAR-1 ScanSAR raw data processing is supported. For COSMO-SkyMed RAW data processing of all stripmap modes is supported. Raw data processing of Sentinel-1 data is not supported.

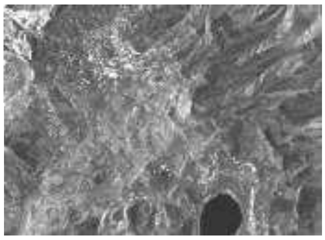
As separate packages an advanced motion compensation package (MOCOM) and a Time Domain Back Projection processor (TDBP) are also available for processing of airborne data (acquired with less stable platforms).

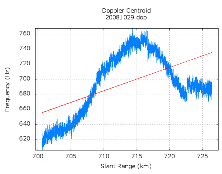

JERS-1 over Mount Fuji, processed including RFI filtering. Raw data courtesy of NASDA, Japan.

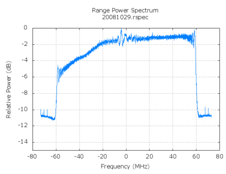

RADARSAT-1 fine mode processed with secondary range compression. MSP supports processing of all RADARSAT-1 strip map modes. Raw data courtesy of RSI, Canada.

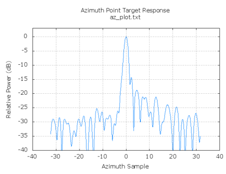

PALSAR-1 FBD mode, processed over Christchurch New Zealand, with RFI filtering. SAR raw data courtesy of NASDA, Japan.

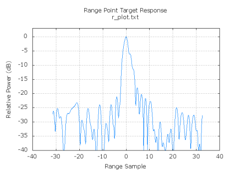

ERS-2 *zero-gyro mode* data with a high Doppler Centroid of about 3000 Hz, estimated from the raw data. Raw data courtesy of ESA.


Cosmo-Skymed high-resolution X-band data over Italy. SAR raw data courtesy of ASI, Italy


DC range dependence


Range power spectrum


Point target respond in azimuth direction


Point target respond in range direction

InSAR, DInSAR, Tracking and Geocoding (ISP/DIFF&GEO):

The Gamma Interferometric SAR Processor (ISP) together with the Differential Interferometry and Geocoding (DIFF&GEO), encompass a full range of algorithms required for generation of interferograms, differential interferograms, split-beam and split-spectrum interferograms, offset maps, and related products as height, displacement and coherence maps. Furthermore, radiometric calibration, co-registration and geocoding of SLC and GRD type products is supported, including terrain corrected sigma0 and gamma normalization.

Some functionality high-lights:

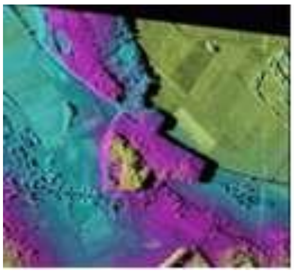
- Orbit and baseline-based phase models
- Mono- and bistatic (TDX) phase models
- Supporting 2-, 3-, and 4-pass DINSAR
- Slope adaptive common band filtering
- Adaptive filtering of interferograms
- Minimum cost flow phase unwrapping
- Region growing branch-cut unwrapping
- Estimation and compensation of atmospheric path delay
- Co-registration considering terrain effects
- Co-registration refinement using matching
- S1 IWS co-registration refinement using spectral diversity method
- S1 IWS burst selection support
- Advanced offset tracking methods
- RCM ScanSAR Interferometry
- Doppler parameter estimation from SLC
- Split-beam and split-spectrum InSAR
- Transformation SAR to map geometry
- Transformation map to SAR geometry
- Data based refinement of geocoding
- Determination of true pixel area
- Terrain corrected $\sigma°$ and γ normalization
- ERS/ENVISAT cross-InSAR
- Tandem-X DEM generation
- PALSAR FBS/FBD InSAR
- PALSAR-2 ScanSAR InSAR
- S1 TOPS mode InSAR
- TSX-ScanSAR InSAR
- Cross-mode InSAR
- Ionosphere effects mitigation
- Closure phase estimation
- Burst overlap investigations
- SLC deskew

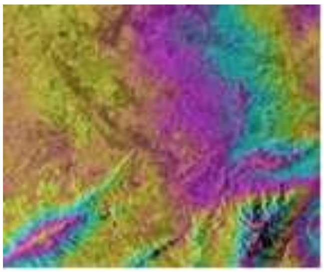
In the following further information is provided for some important applications.

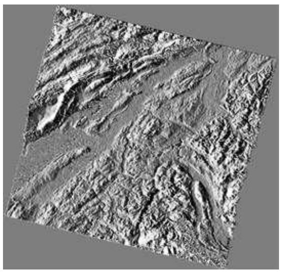
Interferometric height map generation

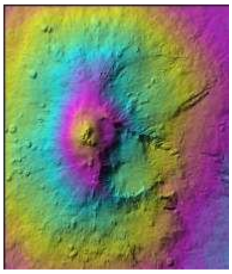
The GAMMA Software supports the generation of a height map based on a pair of interferometric SAR acquisitions. The pair can be either a “single pass” pair acquired by Tandem-X or a suited airborne system) or it can be a repeat-pass pair acquired by one of the available space-borne SAR. Using a single-pass system is strongly preferred because of temporal decorrelation, atmospheric path delay effects, and deformation phase corrupting the result in the case of a repeat pass pair. Besides the availability of a dedicated mission (Tandem-X) other elements also improved over the years. In the past the precision of the available orbit state vectors was much lower than at present, consequently the estimation of a baseline based on the interferometric data and control points was an important element. Nowadays, this step is much facilitated thanks to the available high precision orbit state vectors. Furthermore, we typically start the processing now from a pre-existing DEM (such as the SRTM) which facilitates steps as the geocoding and phase unwrapping, and permits estimating the phase to height sensitivity with high accuracy. In the past, usually a baseline-based phase model was used. Currently, we typically use the 2-pass differential interferometry approach with a phase model based directly on the orbit data.

Tandem-X DEM generation is supported for both mono-static and bi-static acquisitions.


Airborne DOSAR height map over area near Solothurn (Switzerland): SAR processing, and InSAR using *MSP* and *ISP*. Data courtesy of Dornier and RSL Univ. Zürich.


SIR-C, Amazon (Columbia): InSAR height map (L-Band, vv polarization) over a tropical forest site. InSAR processing with *GAMMA ISP*. SIR-C SLC data courtesy of JPL/NASA.


ERS-1/2 Tandem, Bern (Switzerland): Shaded relief. Processing with *GAMMA MSP*, *ISP*, and *DIFF&GEO*. ERS raw data courtesy of ESA.

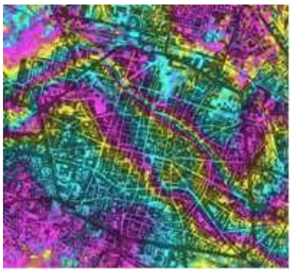

TerraSAR Tandem based height map over Mt. Etna, Italy, using. a DINSAR approach with the SRTM 3" DEM as reference. TDX SLC data courtesy of DLR.

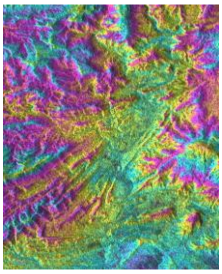
Displacement mapping using DInSAR

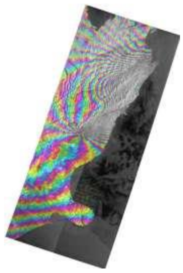
The ISP/DIFF&GEO is designed to be very flexible with respect to separating topographic and displacement effects. In 2-pass differential interferometry a DEM available from another source, e.g. the SRTM DEM; is used to simulate the topographic phase that is then subtracted from the interferogram. Other approaches, which are independent of a DEM, are 3 and 4-pass differential interferometry. In this case an interferogram, preferably one without differential effects, is used as reference to subtract the topographic phase effects. An option to determine optimum phase scaling parameters based on the best fit of the reference interferogram to the interferogram with the differential effects is included.

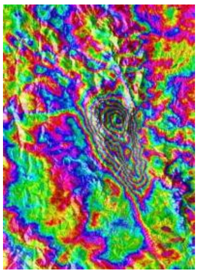
The differential interferometric phase relates to the line-of-sight (LOS) component of the ground displacement. There are programs to determine the LOS direction and assuming that the displacement is in a predefined direction (e.g. in the vertical direction, or along the surface gradient) permits estimating the displacement in that direction. Furthermore, programs to determine displacement vectors based on multiple observations, e.g. using acquisitions in ascending and descending orbits are included. There are also tools included to support the estimation and mitigation of atmospheric path delays and residual orbital phase trends. The advanced filtering and unwrapping tools are another relevant element.

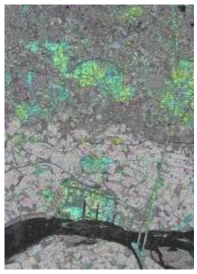
For Sentinel-1 IWS TOPS mode data co-registration and DINSAR are fully supported. For the co-registration of Sentinel-1 IWS data refinements can be determined using matching and using a spectral diversity method that considers double difference interferograms for the burst overlap areas. For PALSAR-2 DINSAR using ScanSAR data is also supported. Furthermore, ERS – ENVISAT cross-interferometry is supported.


Subsidence map over Bologna from ERS-1 DINSAR Color scale is 1cm/year per color cycle. ERS raw data courtesy of ESA.


TerraSAR-X ScanSAR DINSAR over Pakistan. Data courtesy of DLR.

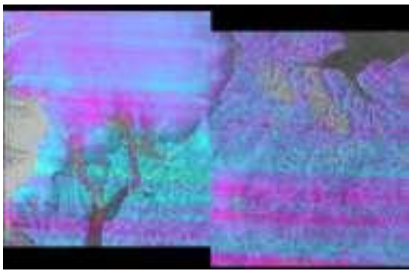

PALSAR-2 ScanSAR DINSAR over 2016 NZ Earthquake Data courtesy of JAXA.

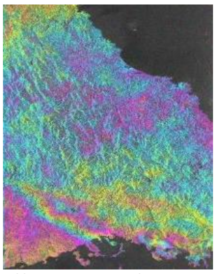

Co-seismic S1A-S1B DINSAR for Italy Earthquake 2016. S1 data courtesy ESA.

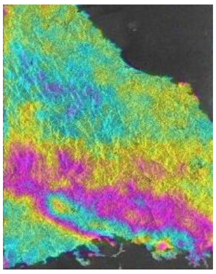

Radarsat-2 DINSAR using multi-resolution data. SLC data courtesy MDA, Canada.

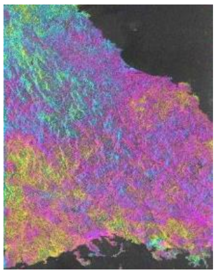
Split-Beam Interferometry (SBI), Split-Spectrum Interferometry (SSI)

SBI and SSI are supported. For both techniques an interferometric SLC pair is band-pass filtered to generate two sub-look images, for SBI these are azimuth sub-looks, for SSI, range sub-looks. In the SSI case the spectral filtering is done before the co-registration as required for the estimation and mitigation of the ionospheric path delay. In the case of the SBI the phase corresponds to meter scale azimuth displacements and ionospheric effects.


Devon Ice Cap, S1 SBI 20150117_20150129 indicating ionospheric effects

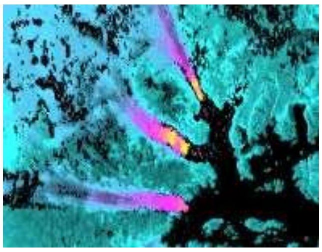

Differential interferogram

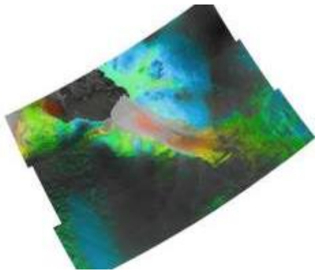

Ionospheric phase estimate


Ionosphere-corrected differential interferogram

Displacement mapping using offset tracking

The ISP/DIFF&GEO also includes advanced offset tracking tools, starting from either SLC or detected data. Offset maps can be determined using intensity cross-correlation or coherence optimization maps. Besides the offsets the estimation quality is determined. Oversampling of the input data prior to the offset estimation is supported to minimize offset bias. To support the estimation of large offsets an initial offset map can optionally be used to guide the further offset estimation. The estimated offsets can also be used to conduct a spatially adaptive co-registration, e.g. to optimize the interferogram coherence over fast moving ice sheets. Furthermore, the post-processing of the offset maps (geocoding, identification and removal of outliers, spatial filtering and interpolation, visualization) is supported.


S1 range offset map over glaciers in Greenland.


S1 IWS offset tracking result over Pine Island glacier Antarctica.

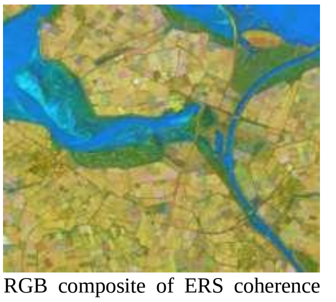
Offset tracking using S1 IWS data acquired in TOPS mode is fully supported. The ISP also supports the identification of ionospheric effects in single SLC, done by determining offsets between azimuth sub-look images.

Radiometric calibration, co-registration and geocoding

For most of the available space-borne SAR sensors and products the ISP functionality supports the absolute radiometric calibration. One important component of the DIFF&GEO is a complete set of programs for precision geocoding. Terrain and ellipsoid corrected geocoding from range-Doppler to map coordinates and vise versa are included. Well suited interpolation algorithms are applied for the resampling step. To minimize effects due to inaccurate orbit information the geocoding includes a fine registration step. To automate this step a SAR image is simulated based on the DEM and used to determine geocoding refinement using cross correlation analyses. The geocoding of images in ground-range geometry is also supported. The DIFF&GEO also supports the determination of the "true pixel area" based on an existing DEM, as used in terrain radiometric calibration, and other image parameters as the local incidence angle and a layover/shadow map. The DIFF&GEO also supports SLC co-registration considering terrain topography effects.

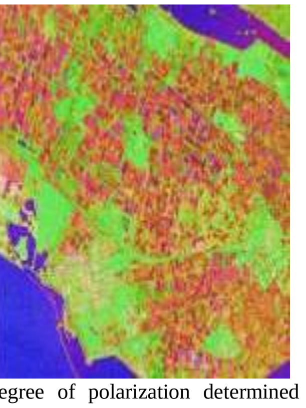
Land Application Tools (LAT):

The land application tools support filtering, parameter extraction, polarimetry, simple classification schemes, mosaicking, and additional data display tools.



RGB composite of ERS coherence (red), average backscatter (green), and backscatter temporal variability (blue) over the Netherlands.

Filtering tools include spatial filters (moving average, median, Frost, Lee, Enhanced Lee, Gamma Map, BM3D, multi-temporal structural filter) as well as multi-temporal filtering tools (based on Quegan et al 2001). Data of specified polygon regions and lines can be extracted and investigated (mean values, standard deviations, histograms). Adaptive coherence, texture, and effective number of looks estimation programs as well as programs to conduct simple calculations with image data are included. Single or multiple classes can be classified based on one or several registered input data sets using a hierarchic thresholding scheme. Mosaicking of multiple data sets in map geometry is supported. Tools to generate RGB and HIS composites and tools to exchange the image intensity of one image with that of another image are included.



Degree of polarization determined from stokes parameters calculated based on a RSAT2 HH,HV SLC pair

Many of the filtering and classification tools of the LAT are also very helpful for InSAR, DINSAR, and PSI, e.g. in the post-processing (mask low quality results, condition offset maps) or to improve certain processing steps (increase S1 co-registration efficiency, correction of phase unwrapping errors).

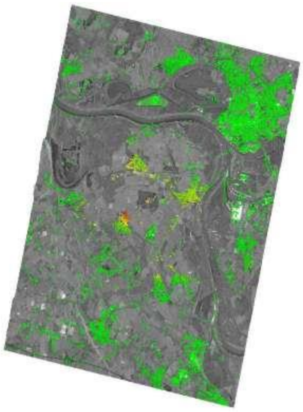
Geocoding Module (GEO):

The SAR data calibration, geocoding and image co-registration functionality is also available in the stand-alone GEO module. This module is of interest for people requiring advanced SAR data calibration, geocoding and image co-registration functionality but without interest in interferometric analysis. Terrain and ellipsoid corrected geocoding from range-Doppler to map coordinates and vise versa are supported. Well suited interpolation algorithms are applied for the resampling step. Due to inaccurate orbit information the geocoding requires a fine registration step. In order to automate this step a SAR image is simulated (based on the DEM) and used to automatically determine the fine registration using cross correlation analyses. The geocoding of images in ground-range geometry and image co-registration in SAR or in map geometry are also supported.

The functionality of the GEO is fully covered by the ISP/DIFF&GEO.

Interferometric Point Target Analysis (IPTA):

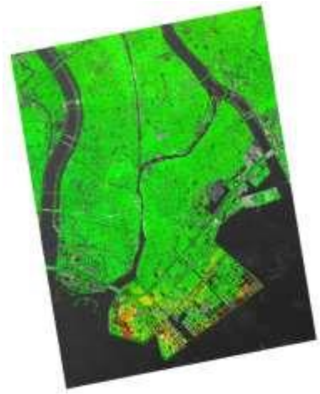
The Interferometric Point Target Analysis (IPTA) supports advanced time series analysis techniques, including Persistent Scatterer Interferometry (PSI) and Small Baseline Subset interferometry (SBAS). The IPTA is not a software supporting one or a few predefined processes, but it is a “toolbox” that supports a wide variety of approaches: using single or multi-reference stacks, using single or multi-look interferometric phases, using point or distributed scatterer phases, unwrapping the phase in the spatial or temporal domain, and storing the data in vector data format or in 2D raster format.



ERS PSI example over Borth, Germany. The average deformation rate is shown using a color scale between -7.5cm/year (red) and +7.5cm/year (blue).

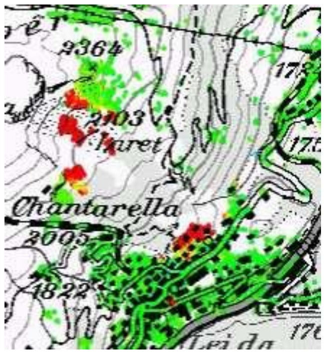
The IPTA Module is fully compatible with the other GAMMA software modules. Programs for conversion between the vector data used in the IPTA and the normal 2D raster formats used are included and the identical phase models are used. For a convenient use of the IPTA access to the GAMMA ISP and DIFF&GEO modules is required.

In the IPTA the user has the possibility to store the data in a vector data format, the so-called point data stacks, which permits to dramatically increase the processing efficiency and reduce the disk and memory requirements. Another important element are programs for a systematic use of the temporal dimension of the data.



PALSAR-1 PSI example over Chiba, Japan. The average deformation rate is shown using a color scale between -2.5cm/year (red) and +2.5cm/year (blue).

A typical IPTA processing sequence starts by co-registering multiple repeat-pass SLCs. Then, an often-used PSI approach is to pre-select early on in the process, based on a spectral coherence measure and the temporal variability of the backscatter, point target candidates. In the continuation the analysis is only done for these candidates. The physical models describing the dependence of the interferometric phase on system and target parameters are exactly the same as used in conventional interferometry. An iteration concept is used for the optimization of the phase unwrapping and information retrieval from the multi-temporal set. Parameters that are improved include the topographic height of the scatterers, the deformation, the atmospheric path delay, and the radar baselines. Different phase terms can be discriminated based on its differing spatial, temporal, and baseline dependencies. The atmospheric phase delay, for example, is relatively smooth in the spatial dimension, but uncorrelated in the temporal dimension. The topographic phase shows a linear dependence on the perpendicular baseline component and the deformation can in many cases be assumed to be relatively smooth (or low-pass) in the spatial and temporal dimensions.



Cosmo-Skymed PSI example over St. Moritz, Switzerland The average deformation rate is shown using a color scale between -1.0cm/year (red) and +1.0cm/year (blue).

An advantage of using point-like targets is that they don't show the geometric decorrelation observed for distributed targets, permitting to interpret interferometric phases even for pairs with baselines above the critical baseline. Consequently, more interferometric pairs can be included in the analysis, improving the accuracy and temporal coverage achieved. This is particularly interesting for sensors with rather long spatial baselines (ERS, ENVISAST, Radarsat-1, PALSAR-1). Alternatively, using distributed targets, multi-look phases and multi-reference stacks with short temporal and spatial baselines are ways to optimize the processing for cases with very fast movements, non-uniform movements, non-urban areas, and for relatively small data stacks.

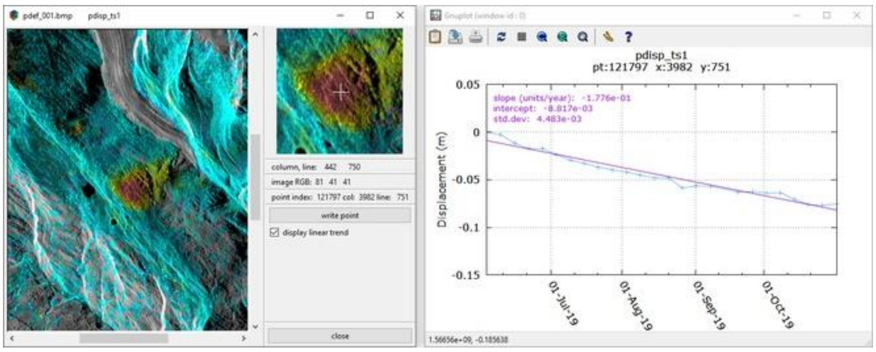
Phase unwrapping can be done in the spatial domain (using a minimum cost-flow algorithm) or in the temporal domain (applied in combination with the regression analysis). The IPTA includes functionality for estimating the atmospheric path delay (with a topography dependent component and a more local "turbulent component") based on the InSAR data. Furthermore, functionality to estimate and mitigate thermal dilation effects phases (observed particularly for high buildings) is included.

The main results derived with the IPTA are topographic heights, average deformation rates, deformation histories, and relative atmospheric path delays and related quality information. Results can be exported as text files, binary files or KML.

Time series analysis of Sentinel-1 IWS (TOPS mode) data is fully supported in the IPTA. Also supported is time series analysis of TerraSAR-X ScanSAR data.

PALSAR-2 stacks are also getting large enough to be of interest for time series analysis (supported in IPTA).

The IPTA module also supports PSI and SBAS type processing of data acquired with the GAMMA Portable Radar Interferometer (GPRI).



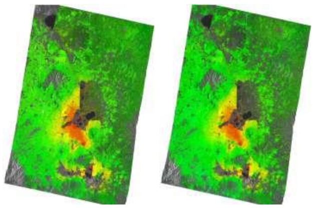
Visualization of deformation measured in a high alpine area (Moosfluh landslide near the Aletsch glacier in the Swiss alps) using a stack of 25 S1 IWS acquisitions. Point selection on the average deformation rate image (left) and plot of the deformation time-series for a single point (right).

residual phase (at start)

estimated thermal expansion phase

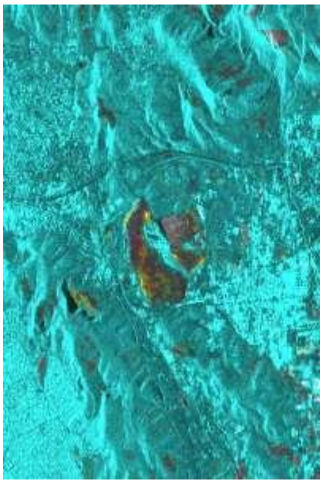
residual phase after subtraction of estimated thermal expansion phase

TSX example for mitigation of thermal expansion phase term: One color cycle corresponds to two phase cycles.



SBAS PSI

Average deformation rate derived with a stack of 12 S1 IWS data takes over Mexico City using SBAS (left) and PSI (right).



Sentinel-1A IPTA demo result over site near Athens that includes small areas with fast, potentially non-uniform, motion (average deformation rate is shown).

3. Varia:

Further information:

Additional information. e.g. on dates and contents of GAMMA Software training courses, is available at http://www.gamma-rs.ch.

To obtain a price list or a specific offer please contact: wegmuller@gamma-rs.ch

References:

There exist a number of technical reports, conference and journal papers that document a specific element or functionality of the GAMMA Software. A list of these documents with links to download the individual pdf files is available at:
https://www.gamma-rs.ch/uploads/media/GAMMA_Software_references.pdf.

Furthermore, upgrade information that is provided to the users with the 6 monthly an upgrades, is also provided as pdf for download at :
https://www.gamma-rs.ch/uploads/media/GAMMA_Software_upgrade_information.pdf.

Demo examples:

Users of the GAMMA Software get access to a list of demo examples. In a demo example a specific processing sequence is explained (e.g. S1 IWS data co-registration), input data, a README text file describing the processing and indicating the individual commands to use, and some intermediate and final results (for comparison with the results generated when going through the demo example) are provided.

At present the list of demo examples includes:

- Basic demo examples for MSP/ISP/DIFF&GEO/LAT supporting users guide examples (gamma_demo_cd_20080627)
- MSP demo examples for PALSAR, JERS, ERS, ERS2-zero-gyro, ASAR, CS (Gamma_demo_MSP)
- IPTA demo examples (IPTA_demo_ERS_Borth, IPTA_demo_PALSAR_Chiba, IPTA_demo_S1_Athens)
- BM3D filtering of backscatter, ratio, interferogram (Gamma_demo_BM3D_filter)
- Cross-mode / cross-resolution interferometry for PALSAR2, RSAT2, S1 (PALSAR2_multi_resolution, PALSAR2_ScanSAR_Stripmap_InSAR, RSAT2_multi_resolution, S1_TOPS_Stripmap_InSAR)
- Displacement components decomposition (S1 asc/desc Iran-Iraq Earthquake)
- S1 burst number identification and selection (Gamma_demo_S1_burst_number)
- Geocoding or orbits clearly different from N-S direction (SCH_and_gc_map2)
- ScanSAR interferometry (ScanSAR_DInSAR_S1_A174)
- Closure phase calculation (Gamma_demo_closure_phase_PALSAR_Etna)
- Ionosphere identification, estimation and mitigation (ionosphere_PALSAR1_Furuya, ionosphere_PALSAR2_Tokyo, ionosphere_S1)
- Visualization and rasterfile generation using vis… programs (Gamma_demo_vis)
- S1 coregistration and DInSAR (S1_Mexico_coreg, S1_Mexico_INSAR, S1_Bari_coreg, S1A_S1B_DINSAR_ItalyEarthquake)
- S1 offset tracking and Split-beam InSAR (DevonIceCap, Greenland_tracking)
- S1 multi-temporal backscatter (S1_Magdeburg_multitemp)

- RFI filtering of S1 and PALSAR data (Gamma_demo_RFI_filtering)
- Tandem-X DEM generation (TDX_demo_Etna)
- Python wrapper demo (py_gamma_demo)
- ASNARO2 InSAR (Gamma_demo_ASNARO2_Uluru)
- DEM importing demo (Gamma_demo_DEM)
- S1 coherence estimation (Gamma_demo_S1_coherence_estimation)
- ICEYE data handling (Gamma_demo_ICEYE)
- Radarsat Constellation Mission (RCM) data handling (Gamma_demo_RCM)
- SAOCOM data handling, InSAR and polarimetry (Gamma_demo_SAOCOM)
- Spatially variable height dependent atmospheric path delay (PALSAR_Etna_atm)
- S1 differential interferometry (S1_Yibal_InSAR_demo)
- S1 IPTA demo over high Alpine area (IPTA_demo_Aletsch)
- IPTA SBAS style demo over an oil field in Oman (PALSAR1_SBAS_Yibal)
- S1 IPTA PSI style demo over an oil field in Oman (IPTA_demo_S1_Yibal_PSI)
- Radiometric calibration demo (Gamma_demo_radcal)
- Capella data handling (Gamma_demo_Capella)
- PALSAR2 ScanSAR DInSAR (Gamma_demo_PALSAR2_ScanSAR_NZ)
- PALSAR2 stripmap IPTA (Gamma_IPTA_demo_PALSAR2_Ticino)
- PALSAR2 ScanSAR IPTA (Gamma_IPTA_demo_PALSAR2_ScanSAR_Mexico)

Recent developments:

- ALOS PALSAR ScanSAR data processing and interferometry
- ICEYE, NovaSAR, ASNARO-2, RCM, SAOCOM, Capella, StriX, Hisea adaptations
- PALSAR-2, TSX, and RCM ScanSAR interferometry
- Sentinel-1 (S1A/S1B) adaptations
- Multi-baseline time-series analysis
- Enhanced offset-tracking functionality
- Split-beam and split-spectrum interferometry
- Identification and mitigation of ionospheric effects
- RSAT-2, PALSAR-2, S1 cross-mode interferometry
- Improved DEM reading and writing out geocoded results.
- Confirmation that PAZ is fully supported using the programs for TSX
- BM3D filtering
- Python wrapper
- Closure phase calculation
- Tools to investigate burst overlap areas in TOPS and ScanSAR mode data
- Spatially adaptive estimation of height dependent atmospheric path delay phase
- InSAR generation, filtering, interpolation and unwrapping in map geometry
- Update of display and raster file generation programs
- Matlab wrapper
- RFI filtering of SLC data
- Supporting spatial filtering, interpolation, unwrapping of IPTA data in map geometry
- Update of point data visualization
- Reading of data in SICD format
- SLC deskew
- Doppler parameter estimation from SLC

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