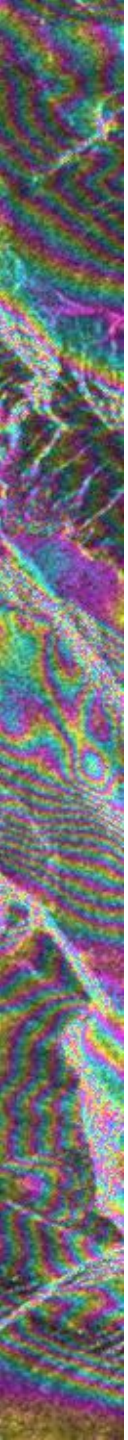

GAMMA REMOTE SENSING

GAMMA Remote Sensing

GAMMA Software

Gamma Remote Sensing AG

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(version: 2018-03-13)

Scope of presentation

- Introduce the audience to GAMMA Remote Sensing

- Introduce the audience to the type of image products created by GAMMA and possible to be generated by users of the GAMMA Software

- Give a first outlook on the GAMMA Software (modules, structure)

Overview

- Introduction to GAMMA Remote Sensing
- Structure of GAMMA software for SAR and InSAR processing

Who is GAMMA Remote Sensing?

- GAMMA Remote Sensing AG is a Swiss corporation founded in 1995 and headquartered in Gümligen, Bern.

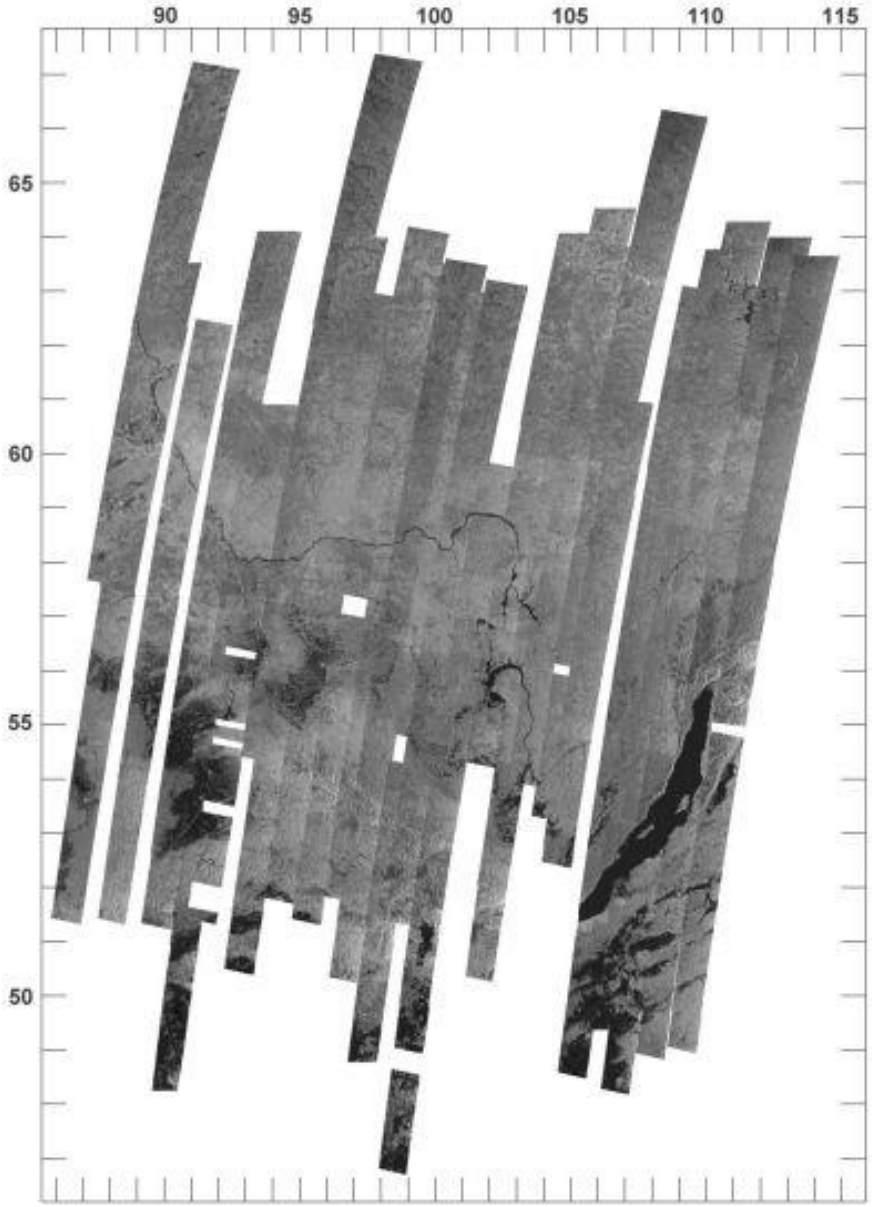
- Principal competences are in the area of application of microwaves to Earth remote sensing specifically in the areas of SAR, and interferometric SAR. Activities include research and development, software, data products, services to customers and hardware.

- The Gamma research staff have extensive experience in the areas of SAR, SAR interferometry, differential interferometry, geocoding, mosaicking of images and the development of new products for Earth Observation.

Consulting	Provision of consulting and educational services in the application of Earth observation data
Projects	Active partners in research projects involving the European Space Agency, EU and other partners.
Software	Marketing worldwide own modular Software including SAR processing, InSAR processing, differential interferometry, geocoding, display and land application tools.
Production	Operational production of various standard image products including the SpotImage Coherence Product, digital elevation models, subsidence maps, landslide maps and land use maps.
Hardware	Microwave hardware design and development. GAMMA has developed and implemented a portable terrestrial radar interferometer.
Research	Internal and external research with competent partners assure us to retain the highest level of technical and scientific expertise.

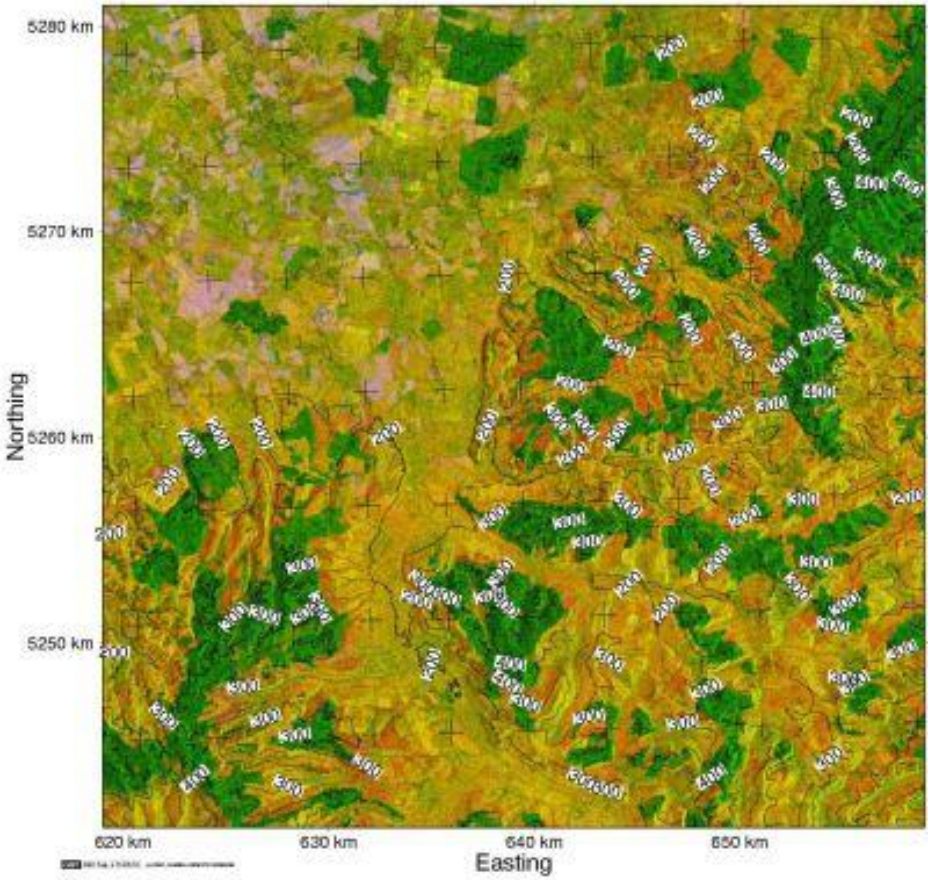
GAMMA‘s products and services: data processing

FILTERING *- Multitemporally filtered JERS backscatter image of the northern Tokyo area. Spacing is 20m. Data copyright NASDA, processing GAMMA*

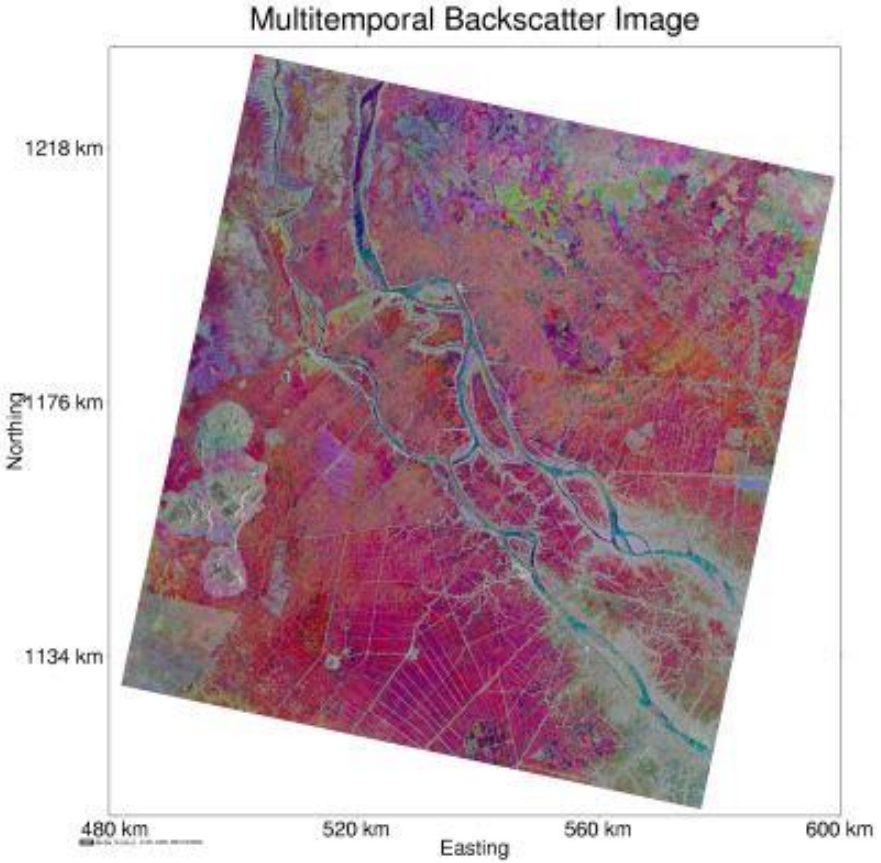


MOSAICING *- JERS SAR backscatter mosaic of Siberia (EQA projection, 50m pixel spacing), generated by mosaicing about 600 JERS scenes. (JERS Data Copyright NASDA, Processing by GAMMA)*

GAMMA‘s products and services: thematic mapping

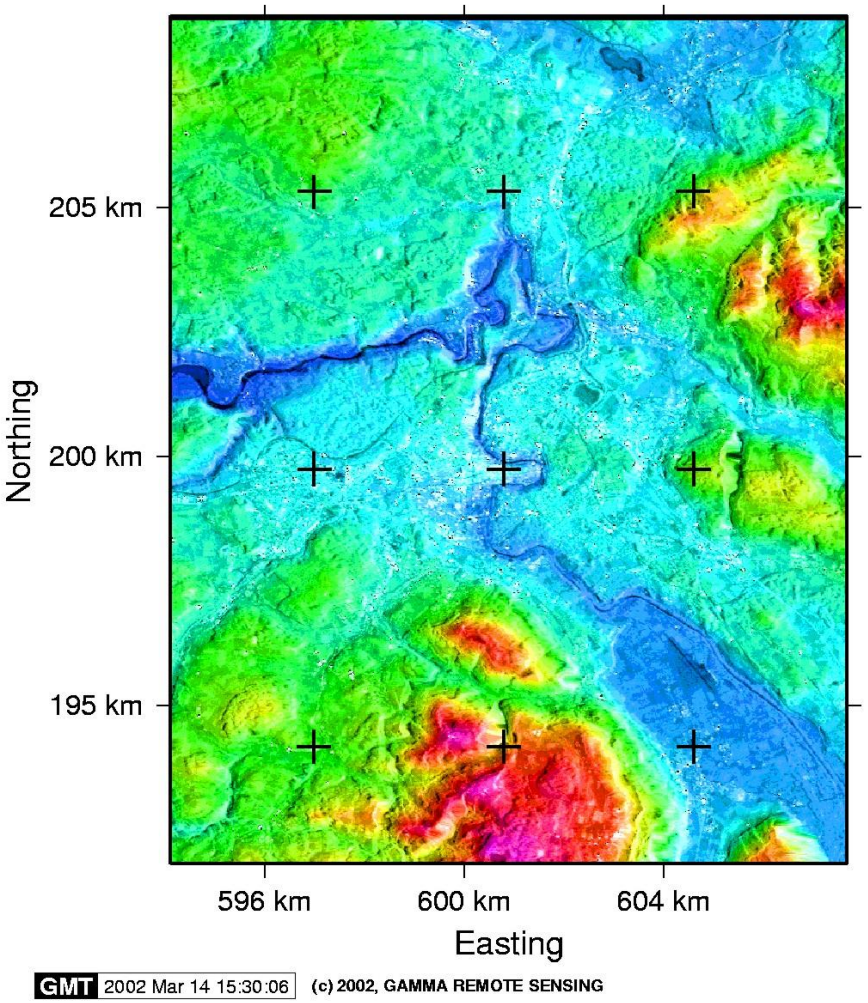


COHERENCE PRODUCT *- ERS-1/2 Tandem coherence product "ortho" (red: coherence, green: average backscattering, blue: backscatter ratio, UTM Zone 34, WGS-84, 20m pixel spacing).*

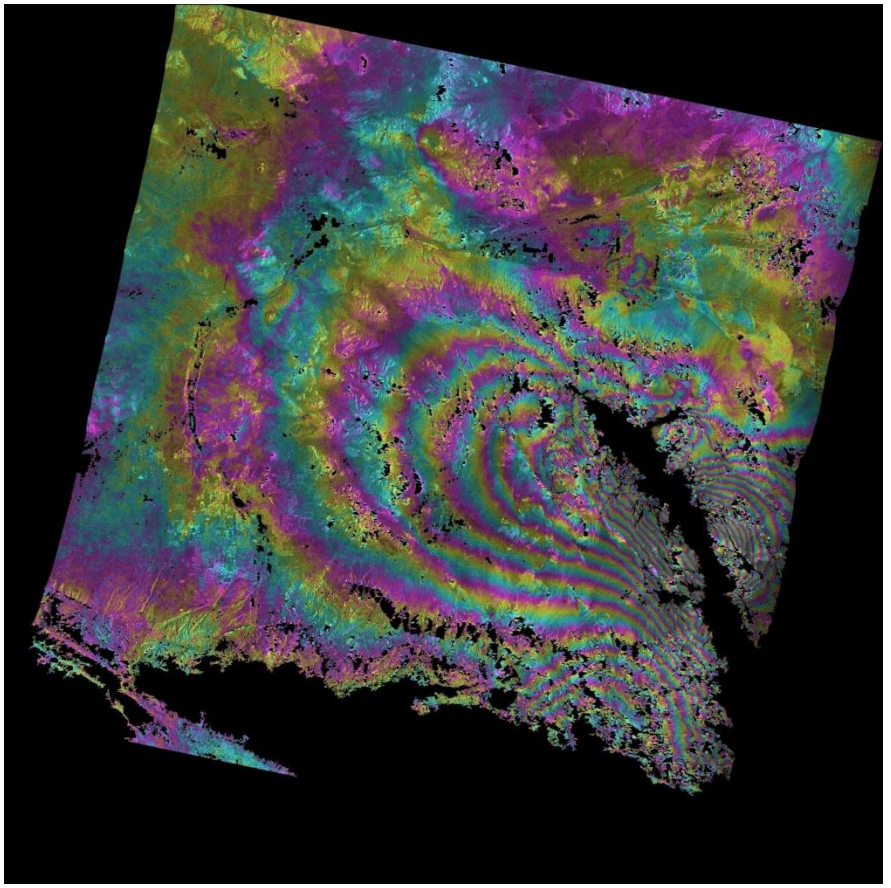


MULTITEMPORAL *- Multitemporal ERS SAR image of the Mekong area in UTM z48 projection (red 24-May-1996, green: 6-Sept-1996, blue: 20-Dec-1996). Villages along the Mekong river appear in bright color; the large flooded areas appear in red and cyan color.*

GAMMA‘s products and services: DEM, earthquake mapping

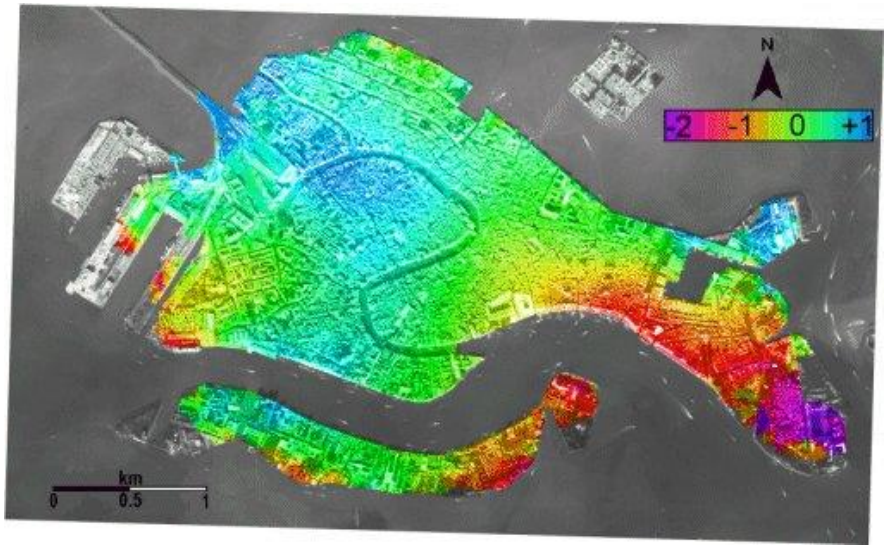


Digital Elevation Model *- Berne, Switzerland, terrain heights derived from ERS SAR interferometry (color scale ~ 500m height difference).*

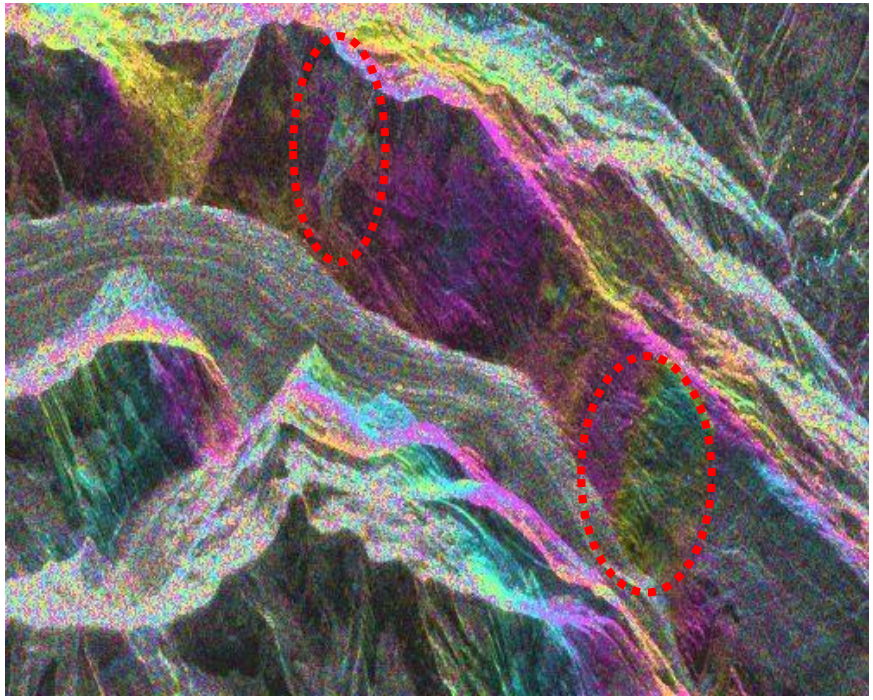


EARTHQUAKE MONITORING *- Crustal Deformation of the Landers, California Earthquake, 1992, measured with ERS-1/2 SAR interferometry. Each fringe represents 2.8 cm motion along the LOS (line of sight).*

GAMMA‘s products and services: surface deformation mapping



SUBSIDENCE MAPPING *- Land subsidence rate of Venice, Italy, between 1992 and 1996 in mm/year from ERS SAR interferometry. (ERS Data Copyright ESA 1998, Processing by GAMMA)*



LANDSLIDE SURVEYING *- Landslides in the Swiss Alps detected with ERS SAR interferometry. For the areas marked by the circles a movement of 5 cm in 105 days has been estimated*

Overview

- Introduction to GAMMA Remote Sensing

- Structure of GAMMA software for SAR and InSAR processing

What is the GAMMA Software?

- It is a commercial package for SAR processing, interferometric SAR processing, geocoding, generation of value-added products and interferometric analysis of point targets
- The software is modular
- Modular implementation means that each module deals with a specific part of the processing (SAR processing, InSAR processing, geocoding, classification etc.)
- The software is not “clicky” ….
- …. It consists of commands to be given at the command line
- Several commands can be arranged in a script that runs automatically a processing sequence

What is the GAMMA Software?

- Each image is accompanied by a text file with the main processing parameters
- Processing parameter files format *keyword: value*
- Data quality assurance is provided as text reports and specific programs
- Sensors supported: all spaceborne missions and some airborne (upon request)
- The modular software was written in ANSI-C language guaranteeing a high portability and efficient processing
- User-friendly display tools and full documentation in PDF format / HTML language complement the software

Processing v. GAMMA software modules

- From raw data to Single Look Complex (SLC) and Multi-look Intensity (MLI) images

} Modular SAR Processor (MSP)

- From 2 SLCs to an interferogram (coherence and interferometric phase)

} Interferometric SAR Processor (ISP)

- From interferometric phase to differential interferometric phase
- Image geocoding

} Differential SAR Interferometry and Geocoding (DIFF&GEO)

- Post-processing (=filtering) and value-adding processes (=classification)

} Land Application Tools (LAT)

- Display of images and reduction to smaller size (bmp, ras)

} Display tools (DISP)

- Advanced techniques

} Interferometric Point Target Analysis (IPTA)

Getting started with the GAMMA software

- The GAMMA Software consists of executables that are started on the command line by the user.
- The user types in the name of the specific program and uses command line arguments as required (data files, metadata files, parameter values, external files).
- Each program performs a specific step of a processing sequence. Programs can be arranged into scripts.
- The data files produced by the GAMMA Software are mostly raster files of data in float or short format. Related metadata are stored in text files.
- The design philosophy has been to achieve accurate processing of the data, while still permitting processing of the data on a workstation computer in a reasonable amount of time.

An example of GAMMA programs

Programs for Interferometric Processing

base_est_fft	Estimation of baseline from fringe rate
base_init	Initial baseline estimation
base_ls	Least squares baseline estimation using ground control points
base_orbit	Interferometric baseline estimation from orbit data
base_perp	estimate perpendicular and parallel components of baseline from baseline parameterfile
cc_wave	coherence estimation from interferogram and intensity images
gcp_phase	Extract unwrapped phases at GCPs
gcp_ras	Ground control point selection tool based user SUN raster or BMP format image
hgt_map	Height and ground range calculation from unwrapped interferogram and baseline information
init_offset	Initial estimation of registration offset between SLC pair (for fcomplex, and scomplex (short integer complex) formatted SLC data)
init_offset_orbit	Initial estimation of registration offset between SLC pair from orbit data
interf_SLC	Interferogram generation, including image registration, common band filtering of range and azimuth spectrum, and multi-looking (for fcomplex, and scomplex (short integer complex) formatted SLC data)
multi_cpx	Averaging and extraction of sub images from complex floating point data sets. May also be used to magnify an image or sub-image by integer factors in range and azimuth.
multi_real	Averaging and extraction of sub-images for real-valued data sets. May also be used to magnify an image or sub-image by integer factors in range and azimuth.
multi_look	Generation of multi-look intensity image from SLC image (for fcomplex, and scomplex (short integer complex) formatted SLC data)
multi_look_MLI	Multi-look averaging of real-valued multi-look intensity image (MLI) images
multi_SLC_WSS	calculate multi-look intensity image (MLI) from a ASAR Wide-Swath SLC
offset_add	Add range and azimuth offset polynomial coefficients (of *.off files).
offset_fit	Registration offset polynomials calculation from offsets file generated by offset_pwr, offset_pwr_tracking, offset_SLC, or offset_SLC_tracking
offset_pwr	Registration offset estimation for SLC images using intensity cross-correlation optimization method (for fcomplex, and scomplex (short integer complex) formatted SLC data).
offset_pwr_tracking	Estimate range and azimuth offset fields for SLC images using intensity tracking.
offset_SLC	Registration offset estimation for SLC images using coherence optimization method (for fcomplex, and scomplex (short integer complex) formatted SLC data).
offset_SLC_tracking	Estimate range and azimuth offset fields for SLC images using coherence tracking.
offset_tracking	Convert range and azimuth offsets files to displacement map.
ph_slope_base	Removal of the "flat earth" interferometric phase trend from an interferogram. The phase trend is generated using a spherical earth and a baseline model.

How does a GAMMA program look like?

SLC_intf

ANSI-C program: SLC_intf.c

NAME

SLC_intf Multi-look complex interferogram generation from registered SLC in fcomplex format.

SYNOPSIS

```
SLC_intf <SLC-1> <SLC-2R> <SLC-1.par> <SLC-2R.par> <OFF_par> <interf> <rlks> <azlks> [loff] [nlines] [sps_flg] [azf_flg]
```

<SLC-1>	(input) SLC-1, reference geometry (fcomplex)
<SLC-2R>	(input) SLC-2, coregistered to SLC-1 (fcomplex)
<SLC1_par>	(input) SLC parameter file of SLC-1
<SLC2R_par>	(input) SLC parameter file of SLC-2R
<OFF_par>	(input/output) ISP offset/processing parameter file
<interf>	(output) multi-look complex interferogram (with range phase)
<rlks>	number of range looks for multi-looking
<azlks>	number of azimuth looks for multi-looking
[loff]	offset to starting line relative to SLC-1 for interferogram (default=0)
[nlines]	number of SLC lines to process (default = to end of file)
[sps_flg]	range spectral shift flag: 1: apply spectral shift filter (default) 0: do not apply spectral shift filter
[azf_flg]	azimuth common band filter flag: 1: apply azimuth common band filter (default) 0: do not apply azimuth common band filter

EXAMPLE

```
SLC_intf 1352.slc 1610.rslc 1352.slc.par 1610.rslc.par 1352_1610.off 1352_1610.int 1 5 0 1 1
```

Structure

1) Input files

2) Output files

3) Necessary values/files <..>

4) Optional values/files [..]

Image and parameter file

```
Gamma Interferometric SAR Processor (ISP) - Image Parameter File

title:     Las Vegas
sensor:    ERS2
date:      1996  5 24
start_time:                66145.32350   s
center_time:               66148.00193   s
end_time:                  66150.68036   s
azimuth_line_time:    5.9527268129e-04   s
line_header_size:                 0
range_samples:                 2500
azimuth_lines:                 9000
range_looks:                      1
azimuth_looks:                    1
image_format:               SCOMPLEX
image_geometry:             SLANT_RANGE
range_scale_factor:        1.0000000
azimuth_scale_factor:      1.0000000
center_latitude:           36.3022040   degrees
center_longitude:        -115.1315850   degrees
heading:                 -168.0391970   degrees
range_pixel_spacing:        7.905919   m
azimuth_pixel_spacing:      3.988540   m
near_range_slc:           840596.7515   m
center_range_slc:         850475.1973   m
far_range_slc:            860353.6431   m
first_slant_range_polynomial:         0.00000      0.00000  0.00000e+00  0.00000e+00  0.00000e+00  0.00000e+00  s m 1 m^-1 m^-2 m^-3
center_slant_range_polynomial:        0.00000      0.00000  0.00000e+00  0.00000e+00  0.00000e+00  0.00000e+00  s m 1 m^-1 m^-2 m^-3
last_slant_range_polynomial:          0.00000      0.00000  0.00000e+00  0.00000e+00  0.00000e+00  0.00000e+00  s m 1 m^-1 m^-2 m^-3
incidence_angle:             23.3003   degrees
azimuth_deskew:           ON
azimuth_angle:               89.9701   degrees
radar_frequency:       5.3000000e+09   Hz
adc_sampling_rate:     1.8960000e+07   Hz
chirp_bandwidth:         1.55500e+07   Hz
prf:                      1679.90239   Hz
azimuth_proc_bandwidth:   1059.34645   Hz
doppler_polynomial:        256.45760 -6.27573e-04  2.03891e-09 -1.39360e-14  Hz Hz/m Hz/m^2 Hz/m^3
doppler_poly_dot:        0.00000e+00  0.00000e+00  0.00000e+00  0.00000e+00  Hz/s   Hz/s/m   Hz/s/m^2   Hz/s/m^3
doppler_poly_ddot:       0.00000e+00  0.00000e+00  0.00000e+00  0.00000e+00  Hz/s^2 Hz/s^2/m Hz/s^2/m^2 Hz/s^2/m^3
receiver_gain:              -19.0000   dB
calibration_gain:            57.2000   dB
sar_to_earth_center:             7159285.4639   m
earth_radius_below_sensor:       6370682.1402   m
earth_semi_major_axis:           6378137.0000   m
earth_semi_minor_axis:           6356752.3141   m
number_of_state_vectors:                    5
time_of_first_state_vector:       66090.00000   s
state_vector_interval:               30.00000   s
state_vector_position_1:  -1988424.5180   -5212694.9610    4485728.8660   m   m   m
state_vector_velocity_1:     -3348.2769      -3644.1109      -5703.6829   m/s m/s m/s
state_vector_position_2:  -2088125.5010   -5319249.1410    4312450.3650   m   m   m
state_vector_velocity_2:     -3297.7811      -3458.9606      -5847.2762   m/s m/s m/s
state_vector_position_3:  -2186251.1190   -5420201.1650    4134949.4540   m   m   m
state_vector_velocity_3:     -3243.2587      -3270.6670      -5985.1537   m/s m/s m/s
state_vector_position_4:  -2282681.1540   -5515459.7400    3953399.6700   m   m   m
state_vector_velocity_4:     -3184.7494      -3079.4311      -6117.1789   m/s m/s m/s
state_vector_position_5:  -2377296.6560   -5604939.6480    3767978.5510   m   m   m
```

A very important concept of the GAMMA software is that image files are accompanied by a text file, called parameter file, that includes metadata reporting all important image and image acquisition parameters

Software documentation

- For each package of the GAMMA Software the documentation consists of a User's Guide and a Reference Manual.
- The User's Guide provides a brief description of the processing possibilities offered by the package, the programs available in the package and examples of typical data processing.
- The Reference Manual is intended to help the user with specific documentation on individual programs. It also clarifies the metadata structure adopted for image data description.
- Demos including documented examples of scripts to perform typical SAR and interferometric SAR processing are also provided.
- For an overview of the functionality of an individual program and its syntax, the user can type the name of the program on the command line. More information is provided in the software documentation.

Software documentation

The documentation is in form of HTML pages and PDF documents

(to access it: *path_to_GAMMA_Software_installation*/Gamma_documentation.html)

GAMMA Software Documentation

1st December 2016 at 1:59pm

Contents

GAMMA Software Introduction

Software overview: This document provides an overview of the Gamma Software basics, requirements and functionality.

DIFF/GEO Documentation - GEO only

Differential Interferometry/Geocoding: Ellipsoid and terrain geocoding, image simulation, image co-registration, and simulation of SAR images

DISP Documentation

Display Tools and Utilities: Display radar image data and interferometric data sets, generation of raster images (Sun Raster, BMP, or TIFF) for these data, tools for creation of GeoTIFF images, generation of RGB raster images, selection of ground control points, file operations (real to complex, complex to real, arithmetic operations, byte swapping), image transformations such as copy, fill, flip, or value replacement, generation of KML files for GoogleEarth.

IPTA Documentation

Interferometric Point Target Analysis: a collection of tools to exploit the temporal and spatial characteristics of interferometric signatures collected from point targets to accurately map surface deformation histories, terrain heights, and relative atmospheric path delays. The IPTA also contains tools for time series analysis of continuous 2D interferograms.

Time-Series Analysis: for 2-D continuous and point based interferograms. Weighted Least-Squares solution for time-series deformation from sets of interferograms forming an interferometric spatial and temporal network. Tools for filtering and display of Time-Series data.

ISP Documentation

Interferometric SAR Processor: SLC image co-registration and resampling, baseline estimation, generation of interferograms and correlation maps, adaptive interferometric filtering, phase-unwrapping, and conversion of data from slant to ground range.

LAT Documentation

Land Application Tools: Classification of image products, Polarimetric tools, adaptive coherence filter, multi-temporal analysis and filtering, speckle filters, statistics, data mosaics.

MSP Documentation

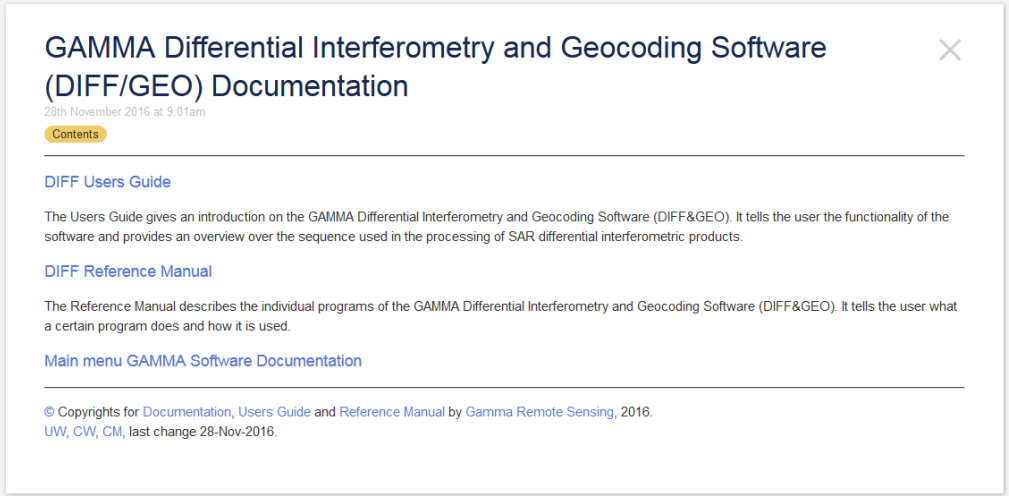
Modular SAR Processor: Generate SLC image products from raw SAR data from ERS, JERS-1, Radarsat-1, SIR-C, ENVISAT ASAR, ALOS PALSAR-1, and Cosmo-Skymed.

GAMMA Software Installation Information

The Installation Manual provides information on how to install the software. If you have the source code distribution, there is information on how to compile and link the source code.

Software documentation

Looking at User‘s Guides and Reference Manuals



GAMMA Differential Interferometry and Geocoding Software (DIFF/GEO) Documentation

28th November 2016 at 9:01am

Contents

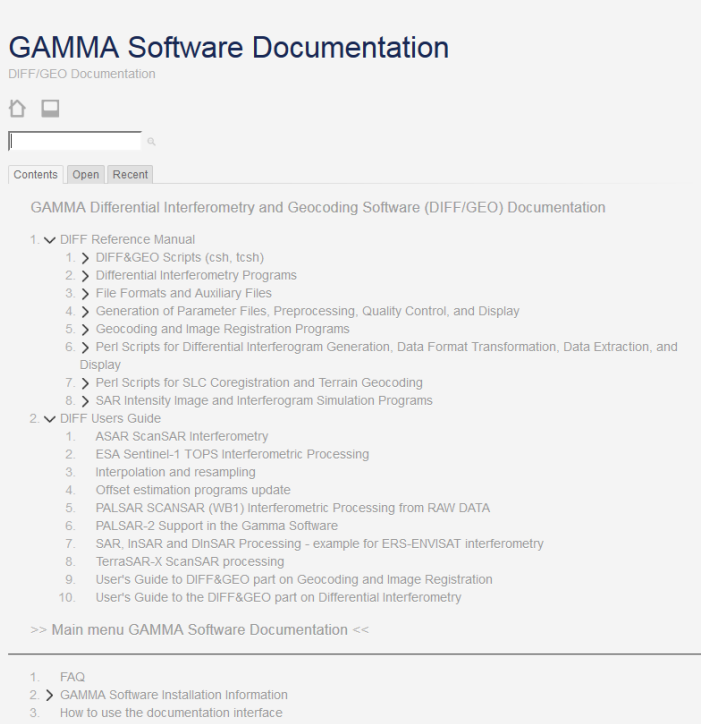
DIFF Users Guide

The Users Guide gives an introduction on the GAMMA Differential Interferometry and Geocoding Software (DIFF&GEO). It tells the user the functionality of the software and provides an overview over the sequence used in the processing of SAR differential interferometric products.

DIFF Reference Manual

The Reference Manual describes the individual programs of the GAMMA Differential Interferometry and Geocoding Software (DIFF&GEO). It tells the user what a certain program does and how it is used.

Main menu GAMMA Software Documentation



GAMMA Software Documentation

DIFF/GEO Documentation

Contents | Open | Recent

GAMMA Differential Interferometry and Geocoding Software (DIFF/GEO) Documentation

1. DIFF Reference Manual
   1. DIFF&GEO Scripts (csh, tcsh)
   2. Differential Interferometry Programs
   3. File Formats and Auxiliary Files
   4. Generation of Parameter Files, Preprocessing, Quality Control, and Display
   5. Geocoding and Image Registration Programs
   6. Perl Scripts for Differential Interferogram Generation, Data Format Transformation, Data Extraction, and Display
   7. Perl Scripts for SLC Coregistration and Terrain Geocoding
   8. SAR Intensity Image and Interferogram Simulation Programs
2. DIFF Users Guide
   1. ASAR ScanSAR Interferometry
   2. ESA Sentinel-1 TOPS Interferometric Processing
   3. Interpolation and resampling
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   5. PALSAR SCANSAR (WB1) Interferometric Processing from RAW DATA
   6. PALSAR-2 Support in the Gamma Software
   7. SAR, InSAR and DInSAR Processing - example for ERS-ENVISAT interferometry
   8. TerraSAR-X ScanSAR processing
   9. User's Guide to DIFF&GEO part on Geocoding and Image Registration
   10. User's Guide to the DIFF&GEO part on Differential Interferometry

>> Main menu GAMMA Software Documentation <<

1. FAQ
2. GAMMA Software Installation Information
3. How to use the documentation interface

Example of reference manual

Differential Interferometry Programs

28th March 2017 at 8:57am

DIFF Reference Manual

atm_mod	Perform linear regression of atmospheric phase with respect to height
base_add	Addition of 2 baseline files
comb_interfs	Combination of complex interferograms with optional integer phase scaling
dh_map_orb	Calculate delta height from differential interferometric phase using state vectors for baseline calculation
diff_ls_fit	Estimation of phase scaling factors using least squares fitting method
diff_ls_unw	Subtract unwrapped phase 2 from unwrapped phase 1 (with least squares fitting for phase scaling)
dispmap	Displacement map generation from unwrapped differential phase
dispmap_ENU	Solve for deformation in East, North, Up (ENU) given measurements of deformation along different vector directions
dispmap_sim	Calculate radar LOS displacement given ENU displacement and the radar look vectors for each point in the DEM geometry
dispmap_vec	Calculation of displacement vector field from displacement direction and measured component
dispmap_vec2	Calculation of displacement vector field from 2 measured components (asc./desc.)
quad_fit	Estimation of 2-D quadratic model phase function from a differential interferogram
quad_sub	Subtraction of quadratic model phase function from a differential interferogram
scale_base	Unwrapped phase scaling with scale factors determined from baseline files
sub_phase	Subtract unwrapped phase 2 from either complex or unwrapped interferogram 1
stacking	Stacking of multiple differential interferograms

GAMMA Software Documentation

DIFF/GEO Documentation

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   9. User's Guide to DIFF&GEO part on Geocoding and Image Registration
   10. User's Guide to the DIFF&GEO part on Differential Interferometry

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1. FAQ
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Example of a program in the Reference Manual

dispmap_vec

!8th March 2017 at 8:57am

Differential Interferometry Programs

Gamma DIFF&GEO: Reference Manual

dispmap_vec

ANSI-C program: dispmap_vec.c

NAME

dispmap_vec - Calculation of displacement vector field from displacement direction and measured component.

SYNOPSIS

```
dispmap_vec <DEM_par> <dispmap> <lv_theta> <lv_phi> <fv_theta> <fv_phi> <dv_norm> [dv_theta] [dv_phi] [dv_x] [dv_y] [dv_z]
```

<DEM_par>	(input) DEM/MAP parameter file
<dispmap>	(input) displacement observation (along look-vector) (float)
<lv_theta>	(input) look-vector elevation angle (float or constant value in deg.)
<lv_phi>	(input) look-vector orientation angle (float or constant value in deg.)
<fv_theta>	(input) flow-vector elevation angle (float or constant value in deg.)
<fv_phi>	(input) flow-vector orientation angle (float or constant value in deg.)
<dv_norm>	(output) norm of 3-dim displacement vector (float)
[dv_theta]	(output) elevation angle of 3-dim displacement vector (float)
[dv_phi]	(output) orientation angle of 3-dim displacement vector (float)
[dv_x]	(output) easting component of 3-dim displacement vector (float)
[dv_y]	(output) northing component of 3-dim displacement vector (float)
[dv_z]	(output) vertical component of 3-dim displacement vector (float)
[mask_angle]	cutoff angle in degrees between the look and normal vector to mask inaccurate results (default: 5)

EXAMPLE

```
dispmap_vec aoi.dem_par aoi.disp aoi.lv_theta aoi.lv_phi aoi.grad_theta aoi.grad_phi aoi.disp_norm aoi.disp_theta
aoi.disp_phi
```

Calculates the 3D displacement field based on the indicated DINSAR based line-of-sight displacement component and the indicated direction field (along height gradient). The output displacement field is expressed through the norm, the elevation angle (theta) and the orientation angle (phi).

```
dispmap_vec aoi.dem_par aoi.disp aoi.lv_theta aoi.lv_phi aoi.grad_theta aoi.grad_phi aoi.disp_norm - - aoi.disp_x aoi.disp_y
aoi.disp_z
```

Calculates the 3D displacement field based on the indicated DINSAR based line-of-sight displacement component and the indicated direction field (along height gradient). The output displacement field is expressed through the easting (x), northing (y) and vertical (z) components.

DESCRIPTION

dispmap_vec calculates the displacement vector field based on the indicated DINSAR based component and displacement direction field. The main application is in landslides and glacier motion monitoring where the assumption of motion along the gradient of the topographic height is an often used assumption. The program permits to calculate the 3D displacement vector field from the DINSAR result (which provides only the displacement component in the direction of the SAR look vector and the displacement direction field (derived e.g. using the assumption of flow along the height gradient).

The dimensions of the image files and the map projection which is the reference are defined in the DEM/map parameter file.

Differential interferometry permits to estimate the deformation component in the SAR look direction. This DINSAR based information is specified through the displacement component in the look direction and the direction angles (elevation theta and orientation phi) in the map geometry. The look vector direction angles can be determined using the program look_vector.

The motion or flow direction is indicated through the related direction angles (elevation theta and orientation phi). For the case of motion along the surface height gradient the flow direction field can be calculated based on a DEM using the program dem_gradient.

The output displacement vector is available as displacement norm, elevation and orientation angles, or as easting (x), northing (y) and vertical (up) components, stored in separate binary files (float). Notice that the displacement vector components (norm, elevation and orientation angle) will differ from the indicated flow direction field because for "negative" displacements along the indicated direction (different sign of vector).

The elevation angle is defined as the angle between the horizontal surface and the look vector with positive angles indicating sensor positions above the surface. The orientation angle is defined as the angle between the East direction and the projection of the look vector on the horizontal surface plan. The orientation angle increases towards north, with the North direction corresponding to PI/2 (and south to -PI/2). Both angles are expressed in radians.

Warning: the interferometric observation is only sensitive to motion in the SAR look vector direction. For other directions the sensitivity is reduced which leads to higher errors.

OPTIONS

Other flow direction fields (than the DEM gradient field) calculated from geophysical (or geometrical models) can be used. Nevertheless, no specific programs are currently included to calculate the related direction fields.

SEE ALSO

dispmap_vec2, look_vector, dem_gradient, typedef_ISP.h, typedef_DIFF.h .