DLR's Airborne SAR System

F-SAR PRODUCT DESCRIPTION

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Revision Control

Version	Rev.	Date	Pages	Changes	Status
2	3	2013-06-15	all	First version released	Draft
2	4	2013-08-01	19	Description of Mosaic Products	Draft
2	5	2014-12-01	all	Circular SAR products	Draft
2	6	2015-06-09	all	CSAR and HoloSAR products	Draft
2	7	2015-10-19	8,13, 29-30	Pauli basis quicklooks; Specific change detection product components Specific ice sounding product files	Draft
2	8	2016-06-02	all	Various changes to improve consistency, added a short explanation relating to binary data formats used, updated the mosaic product description.	Draft
2	9	2016-10-18	5,8,14,16,32	Added appendix concerning radiometric calibration. Updated INF product definition. Updated GTC-LUT component definition to include polynomial coefficient matrices for "3D Geocoding"	Draft
2	10	2016-11-25	27-29	Product components for HoloSAR mode updated	Draft
3	0	2016-11-25	all	Included up-to-date examples of parameter structures, added GTC-LUT figure, changed heading indent	Draft
3	0	2017-08-16	31	Added remark regarding geocoded change detection results.	Draft
3	0	2018-03-01	17	Corrected the units of the vertical wavenumber (kz).	Draft
3	1	2019-07-12	34	Added description of the range-compressed-raw product	Draft
3	2	2019-11-28	7,31-38	Added description of the auxiliary data, in particular antenna and calibration related information.	Draft
3	2	2020-03-19	9,10	Added GPS week second row to real and reference tracks	Draft

3	3	2024-08-27	5-6, 8-15	Added description of file naming convention. Added description of GeoTiff/NetCDF4 formats. Extended GTC product with geo2sr LUTs.	Draft

CONTENTS

1 Introduction

1.1 Purpose

This document presents the structure of F-SAR data products. The structure is also reflected in the archive DIMS (Data Ingestion and Management System) of the German Remote Sensing Data Ceter, where F-SAR data are stored.

1.2 Structure of the Document

Section 2 lists the available F-SAR products and describes the overall product structure.

Section 3 lists the individual file content for each product's subdirectory.

1.3 Binary data formats

F-SAR data products are stored in two alternative binary formats. The first format primarily uses files in the DLR-internal RAT format along with ENVI header files to make the binary data readable in various other software packages. The second format is based around Cloud-Optimized GeoTiff (COG) files with some data held in NetCDF4 files. In both cases, the directory structure and the file naming convention is identical.

1.3.1 F-SAR Products in RAT Format

The first format primarily uses the RAT format, which is described in detail in Appendix 2: Rat Format. A source package of Python 3 code for reading RAT files, including the meta-data in the file header, and parsing the XML documents used to store parameters is available online: F-SAR Data Formats (dlr.de).

In addition, most RAT files are accompanied by .hdr files, which allow the data to be opened in ENVI. The widely used GDAL software library also supports the ENVI format, such that these data can also be opened using free alternatives such as QGis. All of these programs then support export to various other file formats, such as GeoTiff.

For geocoded data (primarily in the GTC product), the hdr file also specifies the parameters of the geographic grid used.

1.3.2 F-SAR Products in COG Format

F-SAR Products in the GeoTiff format save all binary data as Cloud-Optimized GeoTiff (COG) files except for the track information, which is stored in NetCDF4 files. While geocoded products are associated with a valid geographic reference system, slant range data (RGI and INF products) are not.

2 File and Directory Structure

2.1 Directory Structure

Processed campaign data is typically stored in a multi-level directory structure.

Pattern: <CAMPAIGN> / FL<flight> / PS<pass> / T<processing try>

- CAMPAIGN: two digits indicating the year of data acquisition followed by a six character campaign designation
- flight: two digits indicating flight number within the campaign
- pass: two digits indicating pass within flight
- processing try: identifier used for the processing version (the same data may be re-processed with different processing parameters or external inputs)

2.2 Product Structure

The processing try directory (or the pass directory in the case of RAW products) contains one or more products. The internal folder structure of these products is as follows:

RGI: Products in radar geometry (slant range)

RGI-SR	(Slant range data)
RGI-TRACK	(Sensor position and attitude angles)
RGI-RDP	(Processing parameters)
RGI-QL	(Quicklooks)
RGI-AUX	(internal use only)

GTC: Geocoded products

GTC-IMG	(Geocoded radar data)
GTC-DEM	(DSM generated from interferometric processing)
GTC-LUT	(Lookup tables for geocoding)
GTC-RDP	(Processing parameters)
GTC-QL	(Quicklooks)
GTC-AUX	(internal use only)

INF: Interferometric products

INF-SR	(Slant range data)
INF-TRACK	(Sensor positions)
INF-RDP	(Processing parameters)
INF-QL	(Quicklooks)
INF-AUX	(internal use only)

Mosaic products

GTC-IMG	(Geocoded radar data)
GTC-RDP	(Processing parameters)
GTC-QL	(Quicklooks)

2.3 Filename Convention (RGI/GTC/INF)

F-SAR filenames used to store processed data generally have a consistent naming convention.

Data in the RGI and GTC products adopt the following naming convention:

<prefix>_<campaign><flight><pass>_<band>[<antenna>][<polarization>]_t<processing try>.<extension>

Example 1: slc_23gabonx0706_Phh_tP01.tif

- prefix: slc (content description, in this case Single Look Complex SAR imagery)
- campaign: 23gabonx (leading digits indicate the year in which the data were acquired)
- flight: 07 (two digits indicating flight number)
- pass: 06 (two digits indicating pass within flight)
- band: P (frequency band)
- antenna: n/a (empty for the primary antenna in each frequency band; otherwise two digits indicating transmit and receive antenna number for single-pass interferometric acquisitions)
- polarization: hh (lexicographic polarization; empty for data that applies to all channels of the frequency band)
- processing try: P01 (the same data may be re-processed with different try names with different parameters or external inputs).
- Extension: tif (for COG data or .rat + .hdr for RAT/ENVI data)

Example 2: incidence_23gabonx0706_P_tP01.tif

- prefix: incidence (local incidence angle)
- polarization: n/a (applies to all channels of the frequency band)

Example 3: amp_23icelnd0604_X22vv_t01X.rat

- prefix: amp (backscatter amplitude)
- antenna: 22 (transmit and receive on the second X-Band antenna)

Interferometric data is generally stored in the slave pass. The filenames use an extended convention that includes the name of the master acquisition.

<prefix>_<insar pair>_<band>[<insar antenna>][<polarization>]_t<processing try>.<extension>

where

<insar pair> = <master campaign><master flight><master pass>_<slave campaign><slave flight><slave pass>

and

<insar antenna> = <master transmit/receive antenna><slave transmit/receive antenna>

Example 1: slc_coreg_23gabonx0702_23gabonx0706_Phh_tP01.tif

- prefix: slc_coreg (co-registered slave SLC)
- master: 23gabonx0702 (pass 2 of flight 7)
- slave: 23gabonx0706 (pass 6 of flight 7)

Example 2: coh_23icelnd0604_23icelnd0604_X1122vv_t01X.rat

- prefix: coh (interferometric coherence)
- master and slave: 23icelnd0604 (single-pass interferometry)
- insar antenna: 1122 (master transmit and receive on antenna 1, slave transmit and receive on antenna 2)

3 Contents of Individual Product Components

3.1 RGI Product

RGI-SR

amp_*[.rat +.hdr | .tif]	amplitude slant range SAR data, Gamma-0 corrected using the local incidence angle (see Appendix 1: Radiometric Calibration)
incidence_*[.rat +.hdr | .tif]	local incidence angle map
mask_*[.rat +.hdr | .tif]	mask indicating valid samples in the slant-range imagery
slc_*[.rat +.hdr | .tif]	single-look complex slant range SAR data, Beta-0 corrected (see Appendix 1: Radiometric Calibration)
pol_full_*.png	full resolution PolSAR colour composite in lexicographic basis (optional)

Channel	Polarisation
Red	VV
Green	HV/VH
Blue	HH

pauli_full_*.png full resolution PolSAR colour composite in Pauli basis (optional)

Channel	Polarisation
Red	HH - VV
Green	HV/VH
Blue	HH + VV

slantdem_*.tif DEM in slant range geometry with heights in local coordinates (COG format only).

RGI-TRACK

Track information is saved at the full resolution. The length of the tracks may therefore be greater than the dimensions of the SLC in azimuth depending on the azimuth presuming carried out during processing (see processing parameter *pre_az* in **RGI-RDP** below).

Track information in RAT format

attit_*.rat aircraft attitude sampled equidistant in time

Row	Description	Units
0	Time	[GPS week seconds]
1	Pitch	[radians]
2	Roll	[radians]
3	Heading	[radians]

attit_resa_*.rat aircraft attitude resampled equidistant in space (see **attit**)

fixpoint_*.rat coordinate of origin of local and SAR coordinate systems

Element	Description	Units
0	Longitude	[degrees]
1	Latitude	[degrees]
2	Height over WGS84	[m]

reftr_loc_ *.rat reference track in local coordinates, resampled equidistant in time

Row	Description	Units
0	Time	[GPS week seconds]
1	+ towards the east	[m]
2	+ towards the north	[m]
3	+ upwards	[m]

reftr_loc_resa_*.rat — reference track in local coordinates, resampled equidistant in space (see **reftr_loc**)

reftr_sar_*.rat — reference track in SAR coordinates, sampled equidistant in time

Row	Description	Units
0	Time	[GPS week seconds]
1	+ In flight direction	[m]
2	+ to the left	[m]
3	+ upwards	[m]

reftr_sar_resa_*.rat — reference track in SAR coordinates, resampled equidistant in space (see **reftr_sar**)

reftr_xyz_resa_*.rat — reference track in WGS84 Cartesian coordinates, resampled equidistant in space

Row	Description	Units
0	Time	[GPS week seconds]
1	X	[m]
2	Y	[m]
3	Z	[m]

track_loc_*.rat — real track in local coordinates, sampled equidistant in time (see **reftr_loc)**

track_loc_resa_*.rat — real track in local coordinates, resampled equidistant in space (see **reftr_loc_resa**)

track_sar_*.rat — real track in SAR coordinates, sampled equidistant in time (see **reftr_sar**)

track_sar_resa_*.rat — real track in SAR coordinates, resampled equidistant in space (see **reftr_sar_resa**)

track_xyz_resa_*.rat — real track in WGS84 cartesian coordinates, resampled equidistant in space (see **reftr_xyz_resa**)

Track information in NetCDF4 format

Track information in NetCDF4 format is stored in two types of files. The first file, with prefix "refgeom", holds information about the reference geometry, which is the same for all channels in a given frequency band. The second fine, with prefix "tracks", holds channel dependent information.

Unless stated otherwise, the contents of variables stored in the NetCDF4 files follow the coordinate conventions of the RAT files with the same prefix.

refgeom*.nc / fixpoint — coordinate of origin of local and SAR coordinate systems

Element	Description	Units
0	Longitude	[radians]
1	Latitude	[radians]
2	Height over WGS84	[m]

refgeom*.nc / reftr_loc — reference track in local coordinates, sampled equidistant in time

refgeom*.nc / reftr_loc_resa — reference track in local coordinates, resampled equidistant in space

refgeom*.nc / reftr_sar	reference track in SAR coordinates, sampled equidistant in time
refgeom*.nc / reftr_sar_resa	reference track in SAR coordinates, resampled equidistant in space
refgeom*.nc / reftr_xyz_resa	reference track in WGS84 Cartesian coordinates, resampled equidistant in space

tracks*.nc / attit	aircraft attitude sampled equidistant in time
tracks*.nc / attit_resa	aircraft attitude resampled equidistant in space
tracks*.nc / track_loc	real track in local coordinates, sampled equidistant in time
tracks*.nc / track_loc_resa	real track in local coordinates, resampled equidistant in space
tracks*.nc / track_sar	real track in SAR coordinates, sampled equidistant in time
tracks*.nc / track_sar_resa	real track in SAR coordinates, resampled equidistant in space
tracks*.nc / track_xyz_resa	real track in WGS84 cartesian coordinates, resampled equidistant in space

RGI-RDP

pp_*.xml	processing parameters
step.xsl	xml style file to display XML parameters in a tabular format (see the following example)

Parameter	Value	Units	Remark
Processor	STEP-trunk	string	The name of the processor
Build	4091	string	The processor build (SVN version)
Ident	OP16BF0412	string	Campaign,flight and pass of the channel
Coding	T1X1H0_R2X1H0	string	Coding of the channel transmit and receive paths
Site	Kaufbeuren	string	Site of the image acquisition
Date	23-Jun-2016 13:29:50	date	Date and time of the acquisition (DD/MM/YYYY)
time_stamp	368890190	1	F-SAR RTC time
Band	X	string	Frequency Band (S/X/L etc.)
polarisation	HH	string	Transmit and receive polarisation (H or V for each)
Campaign	16op16bf	string	Name of the campaign
Flight	04	string	Flight (sensor continuously airborne)
Pass	12	string	Pass (individual acquisition)
prockernel	EOK	string	The name of the processing kernel used for image formation (EOK,FFBP etc.)
Azbins	83160	1	The number of azimuth bins in the raw data
Rgbins	28160	1	The number of range bins in the raw data
Prf	1201.9231	Hz	Pulse repetition frequency
Cd	1.0016000e-05	s	Chirp Duration
Rd	1.6864000e-05	s	Range Delay
Rsf	1.0000000e+09	Hz	Range sampling frequency
c0	2.9971190e+08	m/s	Speed of light in air
v0	91.148202	m/s	Sensor velocity
f0	9.6000000e+09	Hz	Centre Frequency
Lambda	0.031219990	m	Wavelength
Squint	-1.5077326	deg	Processed squint angle

Heading	91.164020	deg	Sensor heading
Antdir	1	1	Antenna pointing direction (-1/1 for left/right)
h0	3047.7072	m	Sensor altitude
terrain	779.59671	m	Average terrain height
cbw	7.6000000e+08	Hz	Chirp bandwidth
abw	233.54506	Hz	Processed azimuth bandwidth
res_az	0.50000000	m	Processed azimuth resolution
res_rg	0.25261143	m	Processed range resolution
res_az_ml	0.50000000	m	Multi-looked azimuth resolution
res_rg_ml	0.50000000	m	Multi-looked range resolution
looks_az	1	1	Number of looks in azimuth after multi-looking
looks_rg	1	1	Number of looks in range after multi-looking
ps_az	0.30334121	m	Pixel spacing in azimuth
ps_rg	0.14985595	m	Pixel spacing in range
sub_az	1	1	Sub-sampling in azimuth
sub_rg	1	1	Sub-sampling in range
sub_az_ml	2	1	Sub-sampling in azimuth after multi-looking
sub_rg_ml	1	1	Sub-sampling in range after multi-looking
pre_az	4	1	Presumming in azimuth
alpha	[0.540000,0.540000]	1	Vector of hanning alpha parameters for spectral weighting in [azimuth,range]
alpha_ml	[0.540000,0.540000]	1	Vector of hanning alpha parameters for spectral weighting in [azimuth,range] in multi-looking
R	Pointer	m	Vector of one-way range distances for the columns of the slant range image
rref	3618.0471	m	Reference range for processing (ECS only)
nrx	46080	1	Number of pixels in azimuth for the processed image
nry	14560	1	Number of pixels in range for the processed image
nrx_part	[15233,61312]	1	The [start,end] of the scene in azimuth (if only part of the scene was processed)
nrx_part_to	[15165,61244]	samples	Part of date processed, with respect to the non-resampled track
nry_part	[5456,20015]	1	The [start,end] of the scene in range (if only part of the scene was processed)
nry_pad	24576	1	The number of pixels in range, padded for processing speed
rb_first	0	1	The column index of the first valid range bin
rb_last	14559	1	The column index of the last valid range bin
calib_type	0	1	The type of calibration carried out (-1: none, 0: beta0 (ECS), 1: beta0, 2: sigma0, 3: gamma0, 4: gamma0 w/o DEM slope)
rfi_thresh	0.0000000	1	Threshold for RFI filtering (0 deactivates filtering)
topo_moco	2	1	The type of topography compensation during processing (0: none, 1: ECS moco, 2: ECS with SATA)
highsquint	0	1	Flag to indicate that this data has has exceptionally high squint: Enables high-fidelity MoCo
ang_range	[15.000000,90.000000]	deg	Range of valid off-nadir angles in the processed image: [min angle, max angle] in degrees.

Structure **geo_poly**

The bounding polygon of the valid pixels in the processed image. Given in pixels and Longitude/Latitude/Height. Geographic coordinates are with respect to the WGS84 ellipsoid.

Parameter	Value	Units	Remark
Pixels	[0.0000000,167.00000, 14559.000,311.00000, 14559.000,11208.000, 0.0000000,11352.000]	pixels	Pixel coordinates of the valid samples in the processed image: [x1,y1,...,x4,y4].
Lonlat	[10.593800,47.873338,795.46507, 10.592819,47.846476,793.71590, 10.636977,47.846148,738.46193,	Geographic coordinates	The geographic coordinates corresponding to the points in 'pixels': [lon1,lat1,heigh1,...,lon4,lat4,height4]

	10.639179,47.874019,727.46173]			where 'lon' and 'lat' denote 'longitude' and 'latitude', respectively.
sounder_mode	0	1	1 indicates that this data set was acquired in nadir-looking geometry	

RGI-QL

amp_full_*.png	high resolution amplitude slant range image (optional)
amp_pres_*.png	presummed amplitude slant range quicklooks
attitude_*.png	plots of the sensor attitudes
pol_pres_*.png	presummed PolSAR colour composite in lexicographic basis (see **pol_full** in **RGI-SR**)
pauli_pres_*.png	presummed PolSAR colour composite in Pauli basis (see **pauli_full** in **RGI-SR**)
track_*.png	plots of the real and reference tracks in black and red, respectively

RGI-AUX (for internal use only)

ant1d_*.sav	1D antenna diagrams in elevation and azimuth
ant2d_*.sav	2D antenna pattern (elevation and azimuth) for central frequency
ant3d_*.sav + .png	3D antenna pattern (squint,off-nadir,frequency)
ant3d_pha_cent* .png	3D antenna phase center
offnadir_*[.rat +.hdr | .tif]	Off-Nadir angle for each pixel of the SLC [radians]
pol_nesz_*.rat + .png	2D image of estimated NESZ values (presummed)
pol_nesz_vec_*.rat	1D vector of NESZ values as a function of off-nadir angle
pol_profile_*.png	HH/HV/VH/VV intensities as a function of range and co-/cross-pol phase differences
replica_*.rat +.png	Chirp replica
replica_*.rat + .png	Quicklook of the chirp replica
slantdem_*.rat	DEM in slant range geometry
tc_vector_*.rat	vector to transform from beam-center to zero Doppler geometry
tiepoint_eval*.png	Tiepoint evaluation plots
tiepoints_*.sav	Tiepoint coordinates, orientation, image positions and evaluated performance
*.log	log-files of the processing
*.pbs	pbs-files of the processing

3.2 GTC Product

For geocoded data in the RAT + ENVI hdr format, the layout of binary geocoded data on disk follows the GeoTiff convention. When binary geocoded data or lookup tables are read directly from disk (i.e. without using proper GIS software/libraries), it is therefore important to note that:

- The *last* row of data corresponds to the *minimum* northing coordinate and the northing increases towards the first row.
- The *first* column corresponds to the *minimum* easting coordinate and easting increases towards the last column.

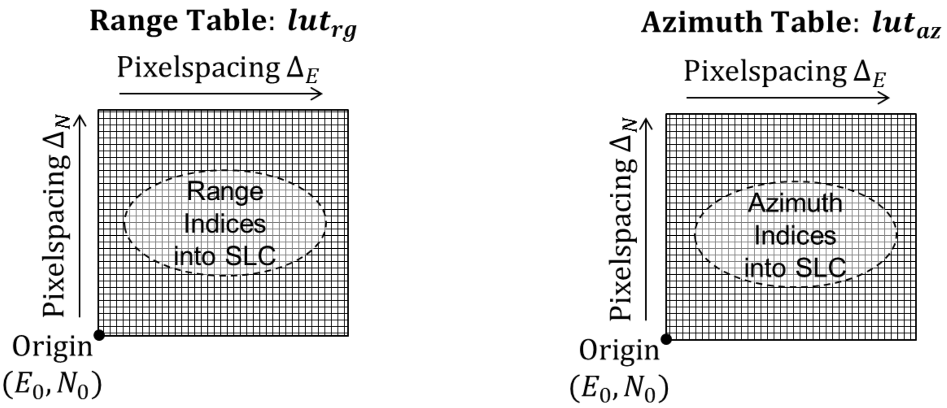
GTC-IMG

ampgeo_*[.rat +.hdr | .tif]	geocoded amplitudes
maskgeo_*[.rat +.hdr | .tif]	geocoded binary valid sample mask
incidencegeo_*[.rat +.hdr | .tif]	geocoded local incidence angle
mlookgeo_*[.rat +.hdr | .tif]	geocoded multilooked amplitude (optional)
mlookgeo_*.png	high resolution geocoded multi-look image (optional)

GTC-DEM

demgeo_*[.rat +.hdr | .tif]	geocoded DSM from InSAR processing ([m] over the WGS84 Ellipsoid)
hemgeo_*[.rat +.hdr | .tif]	geocoded height error map ([m], height standard deviation)

GTC-LUT



UTM Coordinate $(E, N) \rightarrow$ Slant range (rg, az):

$$rg = lut_{rg}\left[\frac{E-E_0}{\Delta_E}, \frac{N-N_0}{\Delta_N}\right]$$

$$az = lut_{az}\left[\frac{E-E_0}{\Delta_E}, \frac{N-N_0}{\Delta_N}\right]$$

sr2geo_az_*[.rat +.hdr | .tif]	geocoded azimuth index into the SLC, denoted lut_{az} in the example above (UTM grid, see ENVI .hdr file for projection parameters)
sr2geo_rg_*[.rat +.hdr | .tif]	geocoded range index into the SLC, denoted lut_{rg} in the example above (UTM grid, see ENVI .hdr file for projection parameters)
sr2latlon_az_*.rat +.hdr	geocoded azimuth index into the SLC (Lat/Lon grid, see ENVI .hdr file for projection parameters)
sr2latlon_rg_*.rat +.hdr	geocoded range index into the SLC (Lat/Lon grid, see ENVI .hdr file for projection parameters)
geo2sr_east_*[.rat +.hdr | .tif]	"inverse" LUT with the easting pixel index for each sample of the slant-range grid. Used for mapping raster data from the UTM grid to slant-range.

geo2sr_north_*[.rat +.hdr | .tif] "inverse" LUT with the northing pixel index for each sample of the slant-range grid. Used for mapping raster data from the UTM grid to slant-range.
geo2sr_curvature_*[.rat +.hdr | .tif]
Curvature correction to be applied when converting ellipsoidal height (WGS84) to a height in the Cartesian local coordinate system (e.g. used by slantdem).

GTC-LUT: Optional files for "3D Geocoding"

sr2geo3d_rg_o[12] *[.rat +.hdr | .tif]
polynomial coefficients for updating the range lookup table to reflect a different DEM height
sr2geo3d_az_o[12] *[.rat +.hdr | .tif]
polynomial coefficients for updating the azimuth lookup table to reflect a different DEM height
sr2geo3d_h0*[.rat +.hdr | .tif] ellipsoidal heights used to compute the original lookup tables in sr2geo*rat

These files are provided to allow users to geocode data onto arbitrary DEMs by computing corrections to the lookup tables held in the sr2geo*rat files. All of the files above contain 2D matrices defined on the same geographic grid as the lookup tables and other geocoded data.

The sr2geo3d_h0*rat file holds the input DEM heights used for geocoding. The range and azimuth lookup tables for a height offset δ_h relative to this DEM can be obtained from the coefficient matrices as follows:

$$sr2geo_{rg}^{new} = sr2geo_{rg} + \delta_h sr2geo3d_{rg}^{o1} + (\delta_h)^2 sr2geo3d_{rg}^{o2}$$

$$sr2geo_{az}^{new} = sr2geo_{az} + \delta_h sr2geo3d_{az}^{o1} + (\delta_h)^2 sr2geo3d_{az}^{o2}$$

Computing lookup tables for a given absolute ellipsoidal height h_{new} is accomplished by defining

$$\delta_h = h_{new} - sr2geo3d_{h0}$$

GTC-RDP

pp_*.xml RGI processing parameters (see **RGI-RDP**)
ppgeo_*.xml geocoding processing parameters
step.xsl xml style file to display XML parameters in a tabular format (see the following example)

Parameter	Value	Units	Remark
processor	STEP-trunk	string	The name of the processor
build	4325:4338M	string	The processor build (SVN version)
ident	AFRISR0812	string	Campaign,flight and pass of the channel
coding	T1P1H0_R5P1H0	string	Coding of the channel transmit and receive paths
site	Nkok	string	Site of the image acquisition
date	12-Feb-2016 10:35:59	date	Date and time of the acquisition (DD/MM/YYYY)
band	P	string	Frequency Band (S/X/L etc.)
polarisation	HH	string	Transmit and receive polarisation (H or V for each)
campaign	16afrisr	string	Name of the campaign
flight	08	string	Flight (sensor continuously airborne)
pass	12	string	Pass (individual acquisition)
prockernel	BACKGEOCODING	string	The processing kernel used
utm_step_east	2.0000000	m	UTM grid sampling east
utm_step_north	2.0000000	m	UTM grid sampling north
utm_file	…	string	DEM file used as input
ellipsoid	WGS84	string	The ellipsoid used for geocoding (default WGS84)

ell_major_axis	6378137.0	m	ellipsoid major axis
ell_minor_axis	6356752.3	m	ellipsoid minor axis
long0_scl	0.99960000	1	Scaling factor at central meridian
long0_step	6	deg	difference of central meridians of adjacent UTM zones
flag_datum_change_track	0	1	flag to perform datum shift for reference track
track_ax	0.0000000	m	translation in X-axis
track_ay	0.0000000	m	translation in Y-axis
track_az	0.0000000	m	translation in Z-axis
track_rx	0.0000000	rad	rotation around X-axis
track_ry	0.0000000	rad	rotation around Y-axis
track_rz	0.0000000	rad	rotation around Z-axis
track_scale	1.0000000	1	scaling factor
flag_presum	0	1	flag to perform presumming/averaging to adjust resolution to UTM grid
file2geocode	Pointer	string	Array of slant range files to be geocoded

GTC-QL

ampgeo_*.png + .kml	geocoded amplitude quicklooks (.kml for Google Earth display)
polgeo_pres_*.png + .kml	geocoded PolSAR colour composite (.kml for Google Earth display)
demgeo_*.png + .kml	quicklook of DEM from interferometric processing (optional)

3.3 INF Product

INF-SR

coh_*[.rat +.hdr | .tif]	interferometric coherence
kz_*.rat	vertical wavenumber [rad/m]
pha *[.rat +.hdr | .tif]	residual or *flattened* interferometric phase (after flat earth and DEM compensation)
pha_dem_*[.rat +.hdr | .tif]	the phase that needs to be subtracted from the master – slave interferogram to *flatten* it (i.e. to remove the flat earth and topographic phase components)
slc_coreg_*[.rat +.hdr | .tif]	slave SLC image (see **RGI-SR**), coregistered to master geometry

INF-SR: Optional files (output during InSAR DEM generation)

insardem_*[.rat +.hdr | .tif]	DEM from InSAR processing (slant-range)
pha_cal_*[.rat +.hdr | .tif]	interferometric phase after baseline calibration
pha_uw_*[.rat +.hdr | .tif]	unwrapped Phase (optional)

INF-TRACK

The contents of this component largely correspond to the RGI-TRACK component of the slave acquisition (see section 3.1 for details). In addition, the INF-TRACK component may include residual baseline errors which are estimated as part of the repeat-pass interferometric processing chain. These baseline errors are in the SAR coordinate system.

Row	Description	Units
0	+ In flight direction	[m]
1	+ to the left	[m]
2	+ upwards	[m]

Track information in RAT format

baseline_error_*.rat	residual baseline errors estimated during interferometric processing, stored in a three dimensional array [n_iterations, track_length, axis]. The total estimated residual baseline error is given by summing over the first axis. The result is in the SAR coordinate system (see table above)

Track information in NetCDF4 format

tracks*.nc / baseline_error_<master id>

residual baseline errors estimated during interferometric processing stored in the SAR coordinate system (see table above). <master id> is of the form <campaign><flight><pass> (e.g. 23gabonx0702).

INF-RDP

pp_*.xml	processing parameters of master SLC
ppinsar_*.xml	parameters for InSAR processing
step.xsl	xml style file to display XML parameters in a tabular format (see example below)

Parameter	Value	Units	Remark
processor	STEP-trunk	string	The name of the processor
build	4325:4338M	string	The processor build (SVN version)
ident	AFRISR0812	string	Campaign,flight and pass of the channel
coding	T1P1V0_R6P1V0	string	Coding of the channel transmit and receive paths
site	Nkok	string	Site of the image acquisition
date	12-Feb-2016 10:35:59	date	Date and time of the acquisition (DD/MM/YYYY)

band	P	string	Frequency Band (S/X/L etc.)
polarisation	VV	string	Transmit and receive polarisation (H or V for each)
master_campaign	16afrisr	string	campaign name of the master pass
master_flight	01	string	flight ID of the master pass
master_pass	07	string	pass ID of the master pass
prockernel	FUSAR	string	The processing kernel used
baseline	[0.347289,62.3161,0.00000]	m	Baseline [horizontal,vertical]
topo	1	1	Take into account the slant-range-DEM in InSAR Processing
coreg	2	1	Coregistration mode. 1: geometry w/o DEM; 2: geometry with DEM; 3: geometry+offset from data
rgfilter	0	1	Perform spectral range filtering; 0: no filter; 1: band-pass; 2: range adaptive
phasetype	3	1	Type of phase computed.1: unmodified; 2: flat-earth removed; 3: DEM removed (residual)
presumming	[1,1]	1	Presumming factor in [range,azimuth] for coherence and phase
complexcoh	0	1	Derive phase from complex coherence (otherwise only presumming, no filter)
cohalgo	1	1	Type of coherence filter. 0: moving average; 1: Gauss
kz	2	1	Compute KZ; 0: do not compute; 1: with flat-earth; 2: with topography
uwalgo	0	1	Unwrapping algorithm. 0: no phase unwrapping; 1: region growing; 2: SNAPHU; 3: graph-cuts
bcalalgo	0	1	Type of baseline calibration. 0: do not calibrate; 1: with reflectors; 2: with reference DEM; 3: from data (SD)
p2halgo	0	1	Phase to height conversion. 0: no phase 2 height; 1: 2D using KZ; 2: 3D Newton
Structure **ms**			
Parameters for residual baseline error estimation			
Structure **geogrid**			
Parameters for InSAR DEM geocoding (see ppgeo in GTC-RDP)			

INF-QL

baseline_*.png	plot of the real interferometric baseline
baseline_error*.png	plot of the estimated (and corrected) residual baseline error
coh _*.png	presummed coherence quicklook
pha _*.png	quicklook of the residual phase (after subtracting flat earth and DEM)

INF-QL: Optional files (output during InSAR DEM generation)

insardem_*[.rat +.hdr | .tif]	DEM from InSAR processing (slant-range)
pha_cal_*[.rat +.hdr | .tif]	interferometric phase after baseline calibration
pha_uw_*[.rat +.hdr | .tif]	unwrapped Phase (optional)
insardem_*.png	the corrections applied to the input DEM by interferometric processing
kz_*.png	quicklook of the vertical wavenumber
pha_uw_*.png	quicklook of the unwrapped interferometric phase

INF-AUX (for internal use only)

INSAR_*.log	log-file of Insar-processing
INSAR_*.pbs	pbs-File of insar-processing
tiepoint_bcal_*.png	evaluation of the baseline calibration using tiepoints (e.g. corner reflectors)
tiepoint_height_*.png	tiepoint height error

3.4 Mosaic Product

Mosaic products are generated by combining several GTC products and follow the conventions of standard GTC product (see section **GTC** above) with following omissions:

- There are no lookup tables (GTC-LUT) since there is no slant range product in this case
- Only geocoded amplitudes (gamma-0 corrected) and a valid sample mask are provided

Appendix 1: Radiometric Calibration

SAR images are commonly radiometrically corrected in one of three fashions: beta-0, sigma-0 and gamma-0. Which type of correction is appropriate depends on the application at hand. The aim of this appendix is therefore to summarise how F-SAR data can be converted from one type of radiometric calibration to another.

In general, the formula for converting F-SAR imagery to dB values corresponding to any one of the three calibration types is as follows:

$$I_{dB} = 10log(\langle f|I\quad|^2\rangle)$$

where I denotes the input image, *f* denotes a scale factor and <…> denotes spatial averaging or multi-looking. The scale factor *f* depends on the input image and the desired type of radiometric calibration in the output. The following table summarises the factors used for different conversions:

Input	Product Component	Factor *f* to achieve desired output		
		Beta-0	**Sigma-0**	**Gamma-0**
slc	RGI-SR, INF-SR	1	$sin(\theta_{inc})$	$tan(\theta_{inc})$
amp	RGI-SR, GTC-IMG	$1/tan\,(\theta_{inc})$	$cos(\theta_{inc})$	1

The angle θ_{inc} in the table above refers to the local incidence angle, which is given, for each sample of the image grid, in the **incidence** files that are provided as part of the RGI-SR (see section 3.1) and GTC-IMG (see section 3.2) product components for slant range and geocoded data, respectively.

Appendix 2: Rat Format

The following table indicates the binary structure of RAT (version 2) files on disk. All floating point and complex data follow IEEE standards and are stored with little endian byte ordering.

Format description:

Group	Tagname	Length [byte]	Type	Example	Description
RAT (100 bytes)	MagicLong	4	1 x long	844382546	Magic number for recognizing RAT
	Version	4	1 x float	2.0	RAT Version number
	NDIM	4	1 x long	2	Number of dimensions of data matrix
	NCHANNEL	4	1 x long	1	Number of channels
	DIM	32	8 x long	1000,2000,0,0,0,0,0,0	Number of samples per dimension
	VAR	4	1 x long	4	IDL variable type (1- byte, 2-integer, 4 –float, 6 – complex)
	SUB	8	2 x long	5, 8	Subsampling factors
	RATTYPE	4	1x long	100	RAT type
	RESERVED	36	9 x long	9x0	<empty>
INFO (100 bytes)	INFO	100	string		Description of file content
GEO (100 bytes)	PROJECTION	2	1 x int	1	Projection Type (0=Lat/Long, 1 = UTM, 2 = Gauss-Krüger)
	PS_EAST	8	1 x double	1.0	Sampling in Easting ([deg] or [m])
	PS_NORTH	8	1 x double	1.0	Sampling in Northing ([deg] or [m])
	MIN_EAST	8	1 x double	436041.00	Minimum easting (lower left corner)
	MIN_NORTH	8	1 x double	5921365.0	Minimum northing (lower left corner)
	ZONE	2		32	Projection zone
	HEMISPHERE	2		1	Hemisphere (1 – north, 2 - south
	LONG0SCL	8	1 x double	0.99996	Scaling factor at central meridian
	MAX_AXIS_ELL	8	1 x double	6378137.0	Ellipsoid major axis
	MIN_AXIS_ELL	8	1 x double	6356752.3	Ellipsoid minor axis

	DATUM_SHIFT	100	7 x double + 64 byte		Datum Shift Parameters (3x translation, 3x Rotation, 1x Scaling) in case other than WGS-84 ellipsoid is used.
	RESERVED	18	18 x byte		<empty>
STAT (100bytes)	STAT	100	25 x long	0	Reserved for statistical values of data matrix.
DATE (100bytes)	START_TIME	19	string	2012-11-14 T18:20:06	Start time of data acquisiton
	STOP_TIME	19	string	2012-11-14 T18:21:29	Stop time of data acquisiton
	RESERVED	62	62 x byte		<empty>
RESERVED1	RESERVED	100	25 x long		<empty>
RESERVED2	RESERVED	100	25 x long		<empty>
RESERVED3	RESERVED	100	25 x long		<empty>
RESERVED4	RESERVED	100	25 x long		<empty>

Functions for reading and writing the RAT format are available for IDL and python upon request.