TERRA SAR-X VALUE ADDED IMAGE PRODUCTS

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ABSTRACT:

The space mission TerraSAR-X is the first German space project implemented under a Public Private Partnership (PPP). Cooperation partners are the German Aerospace Centre (DLR) and EADS Astrium GmbH. Within this construct, DLR will be responsible for the scientific use of the TerraSAR-X data, whereas commercial marketing will be undertaken exclusively by Infoterra GmbH, a wholly-owned EADS Astrium subsidiary.
In a co-operation between Infoterra GmbH and Joanneum Research, Value Added products and processors have been developed for TerraSAR-X data. These products are mainly oriented at the area of interest or are mapping products which represent a higher level of image processing in terms of radiometric correction and orthorectification, mosaics, subsets and merges. In this paper, these products are described. Further, an insight into the automated and semi-automated production chain is provided.

1 INTRODUCTION

Commercial users of remote sensing data require detailed data adapted to their individual requirements, available quickly and reliably, independent of daylight and weather conditions. The design and performance of TerraSAR-X will precisely meet these requirements.

The Synthetic Aperture Radar (SAR) instrument of the spacecraft supplies detailed high-resolution radar imagery, day and night, under all weather conditions. The acquired data is the basis for a wide variety of products and services, such as sophisticated client-specific image interpretation, topographic maps up to a scale of 1:10,000, geo-spatial databases and terrain analysis used for a wide scope of applications. Other application sectors include environmental planning, land cover mapping, natural resource exploration, regional and urban development, crisis response and relief, insurance and risk assessment, as well as applications in border control, security, intelligence and defence.

Based upon TerraSAR-X data, a variety of different image products are offered to the customers. The TS-X image products are differentiated into two major product groups:

- **Basic Image Products** (or L1B Products), which are distributed by Infoterra GmbH for the commercial clients and by DLR for the scientific users.

- **Value Added Products** (VA Products) which are further distinguished in Enhanced Image Products and Geo-Information Products.

  TS-X Value Added products and processors were defined and developed in a co-operation between Infoterra GmbH and Joanneum Research. The products are distributed by Infoterra GmbH only.

2 TERRA SAR-X BASIC IMAGE PRODUCTS

Basic Image Products are **satellite path oriented** data sets. They correspond to the CEOS Level 1b quality. The SAR raw data are processed to basic image products by the TerraSAR-X Multi Mode SAR Processor (TMSP), which has been developed by DLR. For each individual order, the customer can specify processing options, which determine

- the geometric and radiometric resolution,

- the geometric projection, and

- the auxiliary information and annotation.

All TerraSAR-X Basic Image Products are processed and delivered in radar brightness β_0, compatible to the detected ground range products from ERS-1 and 2, ENVISAT/ASAR and RADARSAT. In contrast to ENVISAT and ERS, the complex slant range products are delivered in radar brightness as well.

With respect to the geometric projection and data representation of the data, the TS-X Basic Image Products are differentiated into four product types as follows:

- **Single Look Slant Range Complex (SSC),** with amplitude and phase information in slant range geometry;

- **Multilook Ground Range Detected (MGD),** is corrected from slant range to ground range projection;

- **Geocoded Ellipsoid Corrected (GEC),** corrected to Universal Transversal Mercator (UTM) and Uniform Polar Stereographic (UPS) projection using the WGS84 ellipsoid with an average terrain height;

- **Enhanced Ellipsoid Corrected (EEC),** corrected to UTM or UPS projection with a digital elevation model (DEM), e.g. the SRTM elevation models, which are available with a mesh width of 1 and 3 arcseconds, respectively.

These products can be delivered as either a radiometrically or a spatially enhanced product. The spatial extent corresponds to the area accessible by the TerraSAR-X standard scene. For further information on the TS-X Imaging Modes and the Basic Image Products see [1].

3 TERRA SAR-X VALUE ADDED PRODUCTS

The TS-X Value Added Products are mainly **oriented at the area of interest (defined by the customer) or are map products** which represent a higher level of image processing. These products are called **Enhanced Image (EI) Products** and will be available immediately after the satellite's commissioning phase. **Geo-Information (GI) Products**, which are based on more sophisticated processing and / or analysis methods for e.g. subsidence or change detection mapping will follow.

The Value Added Products are based on TerraSAR-X Basic Image Products and can be generated from new acquisitions, catalogue orders, or a combination of both. Due to a higher processing level, the products provide more processing options than the Basic Image Products and additional auxiliary information. With these products, the customer is not limited to satellite specific images and image strips but can order a full geometrically and radiometrically adjusted coverage of the selected region of interest. Further, it is possible to generate VA Products from existing VA Products, e.g. a Mosaic based on high level orthorectified images.

In the following section, the different Enhanced Image Products are described, followed by the main processing options.

3.1 Enhanced Image Products

3.1.1 ORI^{SAR} - Orthorectified image

The Orthorectified Image product is a highly accurate geocoded image including terrain correction. All terrain distortions inherent in satellite imagery, particularly in areas with a high relief, are expected to be removed. Due to the major influence of the Digital Elevation Model (DEM) on the pixel location accuracy of an orthorectified image, only high precision DEMs are used for ORI^{SAR} production. The result shows an increased pixel location accuracy in comparison to an EEC product.

The high precision DEMs used for ORI^{SAR} production can either be provided by the customer or be purchased from Infoterra GmbH. The ORI^{SAR} product is represented in map geometry. The standard map projections are UTM or UPS with WGS84 ellipsoid.

To achieve and validate high output quality for the various TS-X processing modes and resolution ranges, the following processing options can be utilized:

- optimization and validation of the underlying sensor models being used for ortho-rectification;

- automated GCP acquisition based on matching of control point chips, which are already available in a GCP chip data base;

- interactive GCP (Ground Control Points) acquisition using reference maps in order to increase the pixel location accuracy if necessary;

- dedicated quality assessment of the ORI^{SAR} output product.

The ORI^{SAR} is available with the radiometric representation in radar brightness β_0 like the Basic Image Products by default; further, an additional radiometric calibration (σ_0) or radiometric normalisation (γ_0) can be ordered (description of the radiometric corrections see RaN^{SAR}).

This product is expected to provide a higher level of geometric correction in comparison to Basic Image Products due to higher quality DEMs being used and sensor model optimization procedures being applied. It can be interpreted very quickly and is ideal for combination with other sources of information.

3.1.2 RaN^{SAR} - Radiometrically corrected image

The Basic Image Products GEC and EEC are delivered as radar brightness (β_0). The customer can order an additional radiometric calibration or radiometric normalisation of these products. The resulting product is called RaN^{SAR} (radiometrically corrected or normalized GEC or EEC image).

Both corrections compensate topography-induced effects such as local pixel scattering area and local incidence angle. Radiometric calibration and normalization will lead to a calculation of the sigma naught (σ_0) or gamma naught (γ_0) coefficient, respectively, depending on the customer's selection. Like the Basic Image Products GEC and EEC, the RaN^{SAR} is represented in map geometry. The standard map projections are UTM or UPS with WGS84 ellipsoid.

Radiometric correction may be preferred if the images are to be used for classifications which do not take angular dependencies of the SAR data into account. Further, it is also important in order to minimize the differences in the radiometry of the various images if several images of the same area or neighbouring areas are to be composed.

3.1.3 MC^{SAR} - Mosaic

To cover a geographical area larger than a standard scene, neighbouring geocoded or orthorectified images are seamlessly combined into one image. Possible input products are ORI^{SAR}, EEC or GEC, depending on the customer's localization accuracy requirements.

For mosaicing, various processing options can be utilized, some being optional, others mandatory:

- geometric quality check and optional geometric data adaptation in case of an insufficient geometric consistency. This can be done by means of low order polynomial transformation as well as matching-based image co-registration;

- radiometric quality check and optional adaptation of the input image data. Therefore, selected (critical) areas, e.g. large water bodies, can be excluded;

- automatic detection of specific mosaicing boundaries (cutlines), e.g. along natural edges or line structures like tree lines, streets or field borders. These cutlines are used to generate the mosaicing source mask, which provides information on the source input pixel to become the respective output pixel in the mosaic;

- use of source mask in mosaic production in order to avoid the visibility of cutting edges in the final image product. This will create a seamless mosaic without breaks or visible cutlines;

- dedicated quality assessment of the MC^{SAR} output product.

The MC^{SAR} is represented in map geometry. The standard map projections are UTM or UPS with WGS84 ellipsoid. The product provides seamless image information over a large area. It is quickly interpretable and combinable with other sources of information. Thus, it can be used for map sheet generation.

3.1.4 OI^{SAR} - Oriented Image

The Oriented Image is a subset of an orthorectified or geocoded image scene, mosaic or ascending / descending merge. The subset region is defined by the customer through an area of interest polygon or corner coordinates of the desired region. The product can either be characterized by the user defined area of interest or by a map sheet orientation according to relevant mapping standards or customer defined extensions. The product

is represented in map geometry, with the standard map projections UTM or UPS with WGS84 ellipsoid.

The OI^{SAR} can be combined with other sources of information, so it can directly be used e.g. for map sheet generation. The customer receives an image that covers the specified area of interest rather than satellite-typical image strips that may only cover the area in fractions.

3.1.5 ADM^{SAR} - Ascending/Descending Merge

Typical characteristics of SAR images acquired over rugged terrain are the radar layover, foreshortening and shadow effects, which are not useful in an ortho-rectified product A reduction of these effects can be achieved by a combination of ortho-rectified SAR images which have been acquired from ascending and descending right looking orbits. Respective merging options are included in the VA processing suite, resulting in a so-called ADM^{SAR} product.

During ascending/descending merge, an ascending and a descending ortho image are combined in order to replace no-information areas – like layover and shadow areas – by information available in the respective other image. Furthermore, also for the information areas an "optimized" output pixel can be generated, based on decision and merge criteria, which consider e.g. the local incidence angle or pixel resolution relationship.

The scope of delivery includes the individual source images for the respective ascending and descending orbits in ortho-rectified geometric quality. Thus, EEC, ORI^{SAR} or MC^{SAR} generated from these products can be used as input to the ADM^{SAR} generation. The Source Image Mask (SOU) will present the origin of each pixel in the product. The ADM^{SAR} is represented in map geometry. The standard map projections are UTM or UPS with WGS84 ellipsoid.

The ADM^{SAR} is of particular interest for areas with steep mountain terrain, where shadow and layover can significantly disturb the analysis.

3.2 Envisaged Geo-Information Products

The following Geo-Information Products are currently planned and will be developed during the commissioning phase.

3.2.1 OM^{SAR} – OrthoMap

The OrthoMap consists of an orthorectified image with accurate image geometry within a map frame annotated by a legend. It is generated from Oriented Images (OI^{SAR}) which in turn have been produced from orthorectified images (EEC, ORI^{SAR} or MC^{SAR} products). The layout ranges from simple map frames to highly integrated cartographic products according to relevant mapping standards or customer specifications

3.2.2 CDM^{SAR} – Change Detection Map

CDM^{SAR} focuses on long-term monitoring of urban areas and settlements e.g. to detect surface sealing and urban sprawl. Such information can be used e.g. for urban monitoring and urban planning applications or map updates.

3.2.3 SUB^{SAR} – Subsidence Map

The subsidence map provides information on long-term surface displacement in urban areas and settlements. Such vertical surface displacement may be caused e.g. by tectonics, subsurface mining, or earthquakes, and the resulting maps can be used for risk diagnostics.

3.3 Processing options for Value Added Products

3.3.1 Radiometric correction

The TS-X Basic Image Products are delivered in radar brightness (β_0) by default. However, it is possible to order a radiometric correction for the GEC and EEC products – called RaN^{SAR}. For the ORI^{SAR} is also possible to generate radiometric corrected images. If one of these products is selected as input to ADM^{SAR} or OI^{SAR}, the respective output can also have a radiometric correction. The standard MC^{SAR} is delivered in radar brightness (β_0). It is possible to choose between two types of radiometric correction:

- **Radiometric calibration:** resulting in sigma naught (σ_0). The correction factor $\sin\alpha$ is applied to average pixel intensity determined from beta naught.

- **Radiometric normalization:** resulting in gamma naught (γ_0). The correction function $1/\cos\alpha$ is applied to sigma naught.

3.3.2 Auxiliary raster products

All TS-X Value Added Products are accompanied by auxiliary raster products, which can contain conversion, positional information and other ancillary information. Depending on the Value Added Product type, different auxiliary raster products are available.

Geocoded Incidence Angle Mask (GIM): The GIM contains information on the local incidence angle and on the location of radar shadowing and layover. This mask has the same coding and file structure as the GIM available for the EEC products [1]. The mask can be used for further processing, e.g. radiometric calibration using the incidence angle information. The GIM is available for ORI^{SAR}, RAN^{SAR}, and all other VA products derived from these products or EEC.

Incidence Angle Mask (IAM): The IAM is an alternative representation of the local incidence angle information. The values are not coded, thus the mask can be directly used for further processing such as radiometric calibration using the incidence angle information. The IAM is available for ORI^{SAR}, RAN^{SAR}, and all other VA products derived from them.

Layover and Shadow Mask (LSM): The LSM is the second part of the alternative representation of the GIM. It contains information on radar shadow and layover regions in the image. Like the IAM it can directly be combined with the image data. The LSM is available for ORI^{SAR}, RAN^{SAR}, and all other VA products derived from them.

Local Resolution Mask (RES): The RES identifies the actual ground resolution of the SAR system for each pixel resulting from the local topography and incidence angle. The RES is available for the ORI^{SAR} and products derived from it.

Source mask (SOU): The source mask gives a numeric value that allows the identification of the source input image for each output pixel. The Source Mask is optionally available for the MC^{SAR}, ADM^{SAR} and the OI^{SAR}.

Enumeration files: Enumeration files consists of the **Along Track** Enumeration file **(ALT)** and **Across Track** Enumeration file **(ACT)**. Both files provide the original location in SAR (range-azimuth) geometry for each output pixel. These files are useful for conversions from slant range to geocoded geometries (and vice-versa), e.g. for geocoding additional products co-registered with the input image. The enumeration files are only available for ORI^{SAR} if it is produced with a DEM provided by the customer.

The following table gives an overview on the availability of Auxiliary Raster Products for TS-X Value Added Products.

Product	Auxiliary files						
	GIM	IAM	LSM	SOU	RES	ALT	ACT
ORI^{SAR}	✓	✓	✓		✓	✓*	✓*
RAN^{SAR}	✓	✓	✓				
MC^{SAR}	✓*	✓*	✓*	✓	✓*		
OI^{SAR}	✓*	✓*	✓*	✓*	✓*		
ADM^{SAR}	✓*	✓*	✓*	✓	✓*		

* optional, depending on input products type (see description)

3.3.3 Projections

The standard cartographic projections for TS-X Value Added Products are Universal Transversal Mercator (UTM) and Uniform Polar Stereographic (UPS) with WGS84 ellipsoid. A transfer of the products to other projections is possible, depending on the required projection and customer order.

3.3.4 File Formats

The TS-X Value Added Products standard delivery format is GeoTiff. The annotation information is provided in xml format. COTS software (like Leica Geosystems Erdas Imagine, PCI Geomatics, etc) supports this format. However, it is also possible to order additional reformatting into e.g. ERDAS IMG, NITF, PCI PIX format.

3.3.5 Scaling

All TS-X Value Added Products are produced in 16bit. Sometimes the data may be reasonably reduced to 8bit, e.g. for visualization purposes for mapping applications, or if this scaling does not lead to significant loss of information detail. The customer can order an additional 8bit scaling of the VA Products image data; an automated or an interactive 8bit scaling option can be selected.

REFERENCES

[1]   M. Eineder and T. Fritz (coord.), "TerraSAR-X Ground Segment, SAR Basic Product Specification Document (TX-GS-DD-3302), Release 1.4, 06. October .2006

[2]   Infoterra GmbH, TSXX Value Added Product Specification (TSXX-ITD-SPE-0009, in preparation, 2007