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Sentinel-1 GRD preprocessing workflow

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Abstract: The Copernicus Programme became the world largest space data provider, providing complete, free and open access to satellite data, mainly acquired by Sentinel satellites. Sentinel-1 Synthetic Aperture Radar (SAR) data have improved spatial resolution and high revisit frequency, that makes them useful for a wide range of applications. While few research applications need Sentinel-1 Ground Range Detected (GRD) data with few corrections applied, the wider part of the users needs products with a standard set of corrections applied. In order to facilitate the exploitation of Sentinel-1 GRD products, there is the need to standardise procedures to preprocess SAR data to a higher processing level. A standard generic workflow to preprocess Copernicus Sentinel-1 GRD data is here presented. The workflow aims to apply a series of standard corrections, and precisely to apply precise orbit of acquisition, remove thermal and image border noise, perform radiometric calibration, apply range doppler and terrain correction. Additionally, the workflow allows to spatially snap Sentinel-1 GRD products to Sentinel-2 MSI data grids, in order to promote the use of satellite virtual constellations by means of data fusion techniques. The presented workflow allows to produce a set of preprocessed Sentinel-1 GRD data, offering a benchmark for the development of new products and operational downstreaming services based on consistent Copernicus Sentinel-1 GRD datasets, with the aim of providing reliable information of interest to a wide range of communities.

Keywords: Sentinel-1; Synthetic Aperture Radar; Ground Range Detected; GRD; preprocessing; radiometric calibration; terrain correction

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1. Introduction

The establishment of the Copernicus Programme by the European Commission created a new paradigm in the availability and accessibility of data information, offering services based on satellite Earth Observation and in situ data under 6 thematic Copernicus services. The Copernicus Programme became the world largest space data provider, providing complete, free and open access to satellite data, mainly acquired by Sentinel satellites. Main advantages offered by Sentinel data are the improved spatial resolution and high revisit frequency, that makes them useful for a wide range of applications.

The Sentinel-1 mission is a constellation of two polar-orbiting satellites (Sentinel-1A and Sentinel-1B), which operate day and night sensing with a C-band synthetic aperture radar instrument operating at a centre frequency of 5.405 GHz, that allows to acquire imagery regardless of the weather and illumination conditions. Sentinel-1 satellites constellation acquires SAR data in single or dual polarization with a revisit time of 6 days. Sentinel-1 Level 1 data are distributed by the Copernicus Open Access Hub under two product types: Ground Range Detected (GRD) and Single Look Complex (SLC).

Sentinel-1 level-1 GRD products consist of focused SAR data that has been detected, multi-looked and projected to ground range using an Earth ellipsoid model. The ellipsoid projection of the GRD products is corrected using the terrain height, specified in the product general annotation, that varies in azimuth but is constant in range. After performing a multi-looking separately for each burst, a ground range detected image is generated merging all bursts in all sub-swaths. The Sentinel-1 GRD scene is composed of square pixels with reduced speckle, due to the multi-look processing, representing only the detected amplitude (the phase information is discarded).

2. Workflow

A standard generic workflow to preprocess Copernicus Sentinel-1 GRD data is here presented. The workflow was created in order to be used within the Sentinel application platform (SNAP), a common architecture for all Sentinel satellite toolboxes. The processing graph in 'xml' format allows to process Sentinel-1 GRD using the command line graph processing framework, that allows for batch processing of large datasets.

The preprocessing workflow consists of 7 processing steps, designed to best reduce error propagation in subsequent processes, described hereafter in separate subsections. The code to perform the preprocessing workflow is available on the GitHub repository at link: https://github.com/ffilipponi/Sentinel-1_GRD_preprocessing.

2.1 Apply orbit file

Orbit state vectors, contained within the metadata information of SAR products, are generally not accurate. Satellites precise orbit are determined after few days and are available days-to-weeks after the generation of the product. The operator to apply precise orbit available in SNAP allows to automatically download and update the orbit state vectors for each SAR scene in its product metadata, providing accurate satellite position and velocity information.

2.2 Thermal noise removal

Sentinel-1 image intensity is disturbed by additive thermal noise, particularly in cross-polarization channel [1]. Thermal noise removal is in particular reducing noise effects in the inter-subswath texture, normalizing the backscatter signal within the entire Sentinel-1 scene and resulting in reduced discontinuities between sub-swaths for scenes in multi-swath acquisition modes. The thermal noise removal operator available in SNAP for Sentinel-1 data can also re-introduce the noise signal that could have been removed during the level-1 products generation, and update product annotations to allow for re-application of the correction [2]. Sentinel-1 level-1 products provide a noise look up tables (LUT), provided in linear power, for each measurement data set and is used to derive calibrated noise profiles matching the calibrated GRD data [2].

2.3 Border noise removal

While generating level-1 products, it is necessary to correct the sampling start time in order to compensate for the change of earth curvature. At the same time, the azimuth and range compression is leading to radiometric artefacts at the image borders. The border noise removal algorithm [3], available as an operator in SNAP, was designed in order to remove low intensity noise and invalid data on scene edges.

2.4 Calibration

Calibration is the procedure that converts digital pixel values to radiometrically calibrated SAR backscatter. The information required to apply the calibration equation are included within the Sentinel-1 GRD product, specifically a calibration vector included as an annotation in the product allows simple conversion of image intensity values into sigma nought values. The calibration is reversing the scaling factor applied during the level-1 product generation, and applying a constant offset and a range-dependent gain, including the absolute calibration constant.

In the proposed preprocessing workflow, LUTs to produce sigma nought values is proposed, in order to generate radiometrically calibrated SAR backscatter with respect to the nominally horizontal plane. Sigma specifies the strength of reflection in terms of the geometric cross section of a conducting sphere, and represents the radar cross section of a distributed target over that expected from an area of one square meter. The sigma nought has a significant variation with incidence angle, wavelength, and polarisation, as well as with properties of the scattering surface.

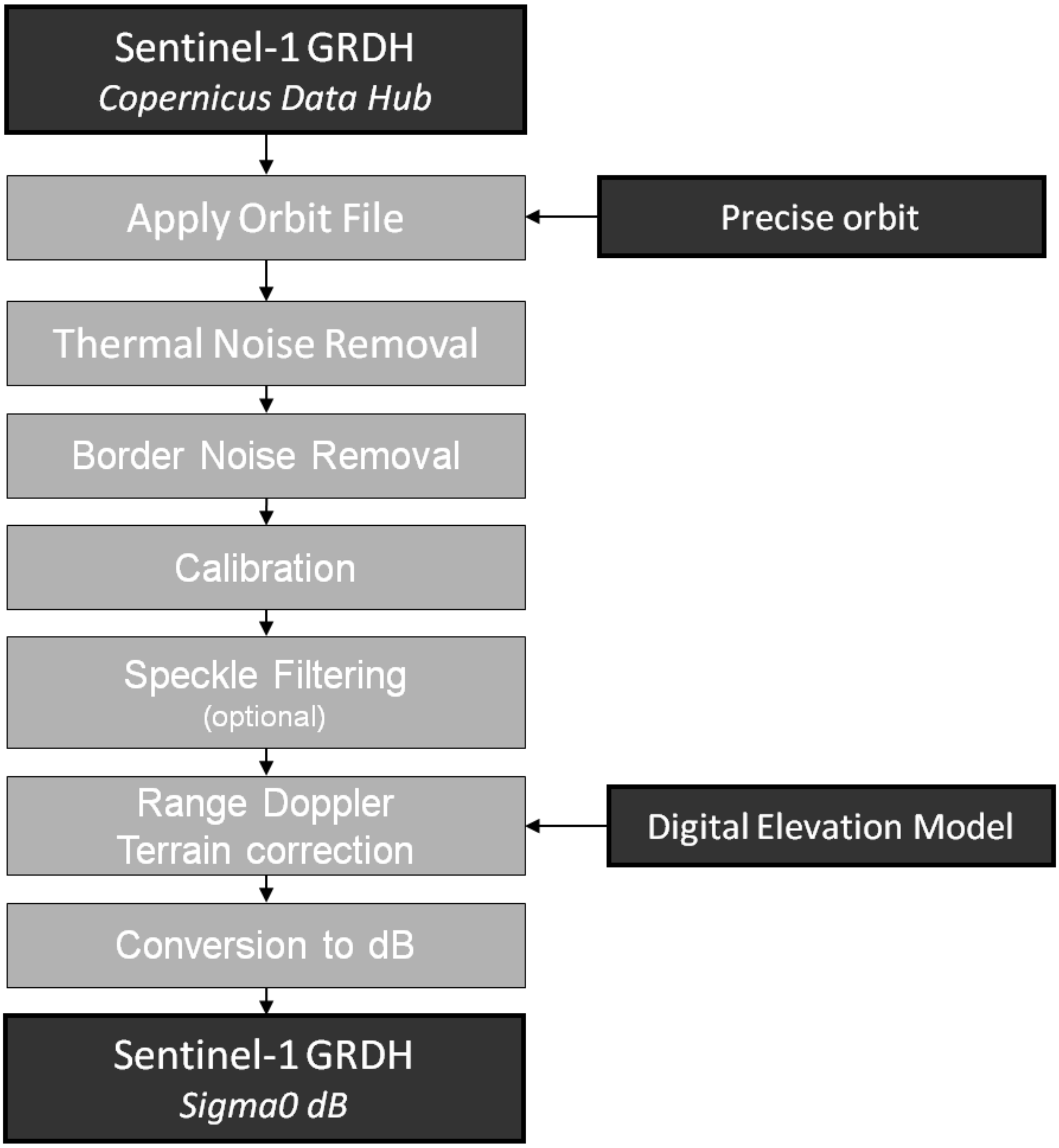

Figure 1. Sentinel-1 GRD preprocessing workflow.

2.5 Speckle filtering

Speckle, appearing in SAR images as granular noise, is due to the interference of waves reflected from many elementary scatterers [4]. Speckle filtering is a procedure to increase image quality by reducing speckle. When such procedure is done at an early processing stage of SAR data, speckle is not propagated in ongoing processes (i.e. terrain correction or conversion to dB). Speckle filtering is not advisable when there is an interest for the identification of small spatial structures or image texture, since it might remove such information. The refined Lee filter has been found to be superior, with respect to other single product speckle filters, for visual interpretation, because of its ability to preserve edges, linear features, point target and texture information [4]. More recently, multitemporal speckle filters have been developed to reduce speckle taking advantages from multiple SAR observations in time. The proposed preprocessing workflow includes a speckle filtering step, which could be skipped by selecting 'None' as filter type. Currently one of the following filter is available in SNAP single product speckle filter operator: 'Boxcar', 'Median', 'Frost', 'Gamma Map', 'Lee', 'Refined Lee', 'Lee Sigma', 'IDAN'.

2.6 Range Doppler Terrain Correction

SAR data are generally sensed with a varying viewing angle greater than 0 degrees, resulting in images with some distortion related to side looking geometry. Terrain corrections are intended to compensate for these distortions so that the geometric representation of the image will be as close as possible to the real world. Range doppler terrain correction is a correction of geometric distortions caused by topography, such as foreshortening and shadow, using a digital elevation model to correct the location of each pixel. The range doppler terrain correction operator available in SNAP implements the Range Doppler orthorectification method [5] for geocoding SAR scenes from images in radar geometry. It makes use of available orbit state vector information in the metadata, the radar timing annotations, the slant to ground range conversion parameters together with the reference digital elevation model data to derive the precise geolocation information [2]. The target Coordinate Reference System (CRS) can be selected and optionally set to match the UTM zone of the overlaying Sentinel-2 granules. The operator allows to select the image resampling method and the target pixels spacing in the target CRS. This processing step allows to spatially snap Sentinel-1 GRD products to Sentinel-2 MSI data grids, in order geolocate data to a common spatial grid and promote the use of satellite virtual constellations.

2.7 Conversion to dB

As last step of the preprocessing workflow, the unitless backscatter coefficient is converted to dB using a logarithmic transformation.

3. Conclusions

A standard generic workflow to preprocess Copernicus Sentinel-1 GRD data was presented. The workflow aims to produce a set of preprocessed Sentinel-1 GRD data, offering a benchmark for the development of new products and operational downstreaming services based on consistent Copernicus Sentinel-1 GRD data.

The workflow applies a series of standard corrections, and precisely to apply precise orbit of acquisition, remove thermal and image border noise, perform radiometric calibration, apply range doppler and terrain correction. Additionally, Sentinel-1 GRD products can be spatially coregistered to Sentinel-2 MSI data grids, in order to promote the use of satellite virtual constellations by means of data fusion techniques.

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Conflicts of Interest: The author declares no conflict of interest.

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