JNCC Sentinel-1 Backscatter Data Provision Service

SAR processing Methodology

DEFENCE AND SPACE

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Contents

- SAR Processing Overview
- Script features and positional parameters
- Processing script orchestration
- Data volume 1 frame vs 2 frames
- Theoretical background about SAR backscatter coefficient and radiometry normalisation
- Example of generated outputs: comparison among RTC and FTC products
- Horizontal accuracy assessment (overlay with OS Open Roads and Rivers, aerial imagery)

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- Radiometry: Gamma0-VV products comparison over 4 different cover types
- Analysis and Technical challenges overcome/anticipated
- SNAP configuration folder and auxiliary data

SAR Processing Overview

Satellite: Sentinel-1 A/B Revisit Time: 6 days (InSAR configuration)

INPUT product: S1_GRD_HR VV-VH (Sentinel-1 Interferometric Wide Swath Mode Ground Range Detected High Resolution Level-1 Product)

OUTPUT (SAR derived observables generated by the processing)

- 1) Terrain corrected absolute backscattering coefficient Sigma0 and Gamma0 linear scale (suffix: TC)
- 2) Terrain corrected and Radiometrically Normalised Kellndorfer (with Local incidence angle projected on the slant range plane) backscattering coefficient Sigma0 and Gamma0 linear scale and after speckle removal in linear and db scale (**suffix: RTC**)
- 3) Terrain corrected and Radiometrically Normalised Small method backscattering coefficient Gamma0 linear scale and after speckle removal in linear and db scale (**suffix: FTC**)

Script language: Bash LINUX calling functions libraries, embedding the SAR defined processing chains, and configuration file. Use of POSITIONAL parameters to allow few processing combination

Script features

- Selection of polarisation (VV or VH or VV and VH);
- Reading directly Sentinel-1 (A/B) data in ZIP;
- Option to apply a multi-looking process;
- Option for assembly (up to 3 slices)
- Option for Precise Orbit Ephemerides correction (RESORB, POEORB); in case not available use one in the product
- Option for selection of image interpolation method during Terrain Correction;
- Option for DEM selection: SRTM 3 sec or External DEM (APGB 5m);
- Radiometric Normalisation. Both the local incidence angle correction or local illuminated area correction (terrain flattening based [RD-2]) can be implemented to compensate the topography and normalise the local variation of the scattering;
- Option for selecting different Output Coordinate Reference Systems (British National Grid, Irish Grid TM75 EPSG 29902, UTM-WGS84);

- Option for the Speckle filtering (Refined Lee, GammaMap)
- Output format: GeoTIFF-BigTIFF format;
- Logging

Positional parameters to be provided to the script for options selection

 $1 \rightarrow$ type of products to be processed: =1 GRD ; =2 SLC ## inserted to allow modularity for future SLC processing

 $2 \rightarrow$ number of slices to be processed (up to 3 adjacent slices):

 $3 \rightarrow$ polarisation to be processed: =1 (VV&VH); =2 (VV); =3 (VH)

 $4 \rightarrow$ Dem used in the processing: =1 (APGB); =2 (SRTM)

 $5 \rightarrow$ Precise orbits: =1 (RESORB if not found use the one in the product); =2 (POEORB)

 $6 \rightarrow$ Multilooking factor: =1 (Az=1 & Rg=1); =2 (Az=2 & Rg=2) etc:

 $7 \rightarrow$ Image interpolation method during terrain correction: =1 (nearest neighbour) =2 (bilinear) =3 (BICUBIC_INTERPOLATION)

 $\$8 \rightarrow DEM$ Resampling method during terrain correction: =1 (bilinear) =2 (e.g.: Bicubic INTERPOLATION)

 $9 \rightarrow CRS$ for Terrain Corrected outputs: =1 (OSGB 1936 - EPSG:27700); =2 (EPSG:29902); =3 (UTM WGS 84)

 $(10) \rightarrow \text{determines the type of applied speckle filter: 1 (=Refined Lee); 2 (=GammaMap))}$

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Processing script orchestration

JNCC_S1_GRD_configfile_v.1.0.sh



removal in linear and db scale (suffix: FTC)

Processing Log file

Configuration file

INPUTS directories

export MAIN_DIR="./JNCC/MAIN" ##== MAIN DIRECTORY with DEM, Input dataset and Outputs export BASKET_INDIR="\${MAIN_DIR}/Basket" ##== directory containing S1_GRDH.zip products to be processed ##### export EXTDEMFILE="\${MAIN_DIR}/EXT_DEM/APGB_Qgis.tif" ##== External APGB DEM export EXTDEMNOVAL="-32768.0" ## External DEM No data value ##### OUTPUT directories export MAIN_OUTDIR="\${MAIN_DIR}/OUTPUT" ##== MAIN OUTPUT DIRECTORY where products output folders will be created ##### After Processing export PROZIP_DIR="\${MAIN_DIR}/ZIP_PROCESSED" ##== directory where S1.zip data are moved after processing ##### SW and processing xml chains directories export GRAPHSDIR="./JNCC/script/xml" ##== DIRECTORY with snap xml graphs for the processing export SNAP_HOME="/opt/snap/bin" ##== SNAP (version 5) directory export SCRIPT_DIR=".JNCC/script"

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STATIC Variable for Log files

Processing Parameters

UTM map projection parameters
export UTMPROJ="UTM Zone 31" ### e.g. "UTM Zone 30", "UTM Zone 22, South"
export centralmeridian="-3.0" ### e.g. "-3", "-51"
export false_northing="0.0" ### e.g. "0.0"

Single Slice Processing

SLICE-1 image: creation of variables needed for the processing, output folder \${SLICE_1_OUTDIR} and logfile \${SLICE_1_LOG}

For each TR POL (=VV, VH): Processing in SAR GROUND RANGE geometry

Border removal (select TR polarisation), Thermal Noise Removal, Absolute Calibration (sigma0, gamma0, beta0), Precise Orbit

GEOCODING of Absolute (ellipsoid) Sigma0 and Gamma0

TR Absolute Sigma0 and Gamma0 Multilooked (if applied) and Terrain Corrected with SRTM3sec

TR Absolute Sigma0 and Gamma0 Multilooked (if applied) and Terrain Corrected with APGB

GEOCODING and radiometric normalisation with Kellndorfer approach

TR (if applied) Multilooked, Terrain corrected an Radiometric normalised Sigma0 and Gamma0 (Kellndorfer approach with projected SR local incidence angle) with SRTM3sec

TR (if applied) Multilooked, Terrain corrected an Radiometric normalised Sigma0 and Gamma0 (Kellndorfer approach with projected SR local incidence angle) with APGB DEM

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GEOCODING and radiometric normalisation with Small approach

TR (if applied) Multilooked, Terrain corrected an flattened Gamma0 (SMALL method) with APGB DEM

VV polarisation – single frame full resolution (10m)

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🔯 Desktop	💽 S1A_12Jun2016_062939_063004_VV_Gamma0_APGB_OSGB1936_FTC_SpkRL.tif		2.5 GB TIFF image
🔜 File System	💽 S1A_12Jun2016_062939_063004_VV_Gamma0_APGB_OSGB1936_FTC_SpkRL_dB.tif		2.5 GB TIFF image
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📒 Trash	👿 S1A_12Jun2016_062939_063004_VV_Gamma0_APGB_OSGB1936_RTC_SpkRL_dB.tif		2.5 GB TIFF image
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MAIN	S1A_12Jun2016_062939_063004_VV_Sigma0_APGB_OSGB1936_TC.tif		2.5 GB TIFF image

JNCC_S1_GRD_MAIN_v1.0.sh 1 1 2 1 1 1 2 1 1 1

Bilinear Interpolation for external DEM Bilinear Interpolation for the image resampling

VH polarisation – single frame full resolution (10m)

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MAIN	🕎 S1A_12Jun2016_062939_063004_VH_Sigma0_APGB_OSGB1936_TC.tif	2.5 GB	TIFF image

JNCC_S1_GRD_MAIN_v1.0.sh 1 1 3 1 1 1 2 1 1 1

Bilinear Interpolation for external DEM Bilinear Interpolation for the image resampling

VV polarisation – 2 assembled consecutive frames assembled full resolution (10m)

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MAIN	🕎 S1A_12Jun2016_062939_063029_VV_Sigma0_APGB_OSGB1936_TC.tif	4.8 GB	TIFF image

JNCC_S1_GRD_MAIN_v1.0.sh 1 2 2 1 1 1 2 1 1 1

Bilinear Interpolation for external DEM Bilinear Interpolation for the image resampling

VH polarisation is of same size

Backscattering Coefficient

Radar backscatter: Ellipsoid-normalisation



Ellipsoid-normalisation

Calibrated sigma nought for detected products can be derived as:

$$\sigma_{i,j}^{0} = \underbrace{\frac{DN_{i,j}^{2}}{K}}_{\beta^{0}} \sin\left(\alpha_{i,j}\right)$$

Ellipsoid

Model

Introducing Terrain-Normalisation

Name	Symbol	Normalisation Reference	Derivation
Beta Nought	$oldsymbol{eta}^{0}$	Area formed by Sample Intervals in Slant Range / Azimuth Plane	$\beta = k \cdot P_s / P_i$ $\beta^0 = \beta / A_\beta$
Sigma Nought	$\sigma_{\scriptscriptstyle E}^{\scriptscriptstyle 0}$	Ellipsoid Ground Area	$\sigma_E^0 = \beta^0 \cdot A_\beta / \underline{A}_\sigma$
Gamma Nought	${\pmb \gamma}_E^0$	Ellipsoid Ground Area projected in plane ⊥ to Look Direction	$\gamma_E^0 = \beta^0 \cdot A_\beta / \underline{A}_\gamma$
Gamma Taut	γ_T^0	Integrated <i>Terrain</i> Area projected in plane ⊥ to Look Direction	$\gamma_T^0 = \beta^0 \cdot A_\beta / A_\gamma$

David Small (RSL UZH) - QWG ESRIN 2009.10.27-28

Backscattering Coefficient

Radar backscatter: slope-normalisation by LIM (local incidence mask)



Small method for slope normalisation

Local Incidence Angle Mask (LIM)

 The most common slope-normalisation methodology found in the literature is best placed between ellipsoid- and terrain-based normalisation conventions

• Normalisation for local variation of scattering area: $\sigma_{NORLIM}^{0} = \sigma_{E}^{0} \cdot \frac{\sin\theta}{\sin\theta_{m}}$ Kellndorfer et al., TGRS, Sept. 1998.

 Fails to account for scattering area variations caused by terrain in non-neighbouring DEM samples

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Summary of Normalisation Conventions

Convention	1	2	3	4	5	
	$\boldsymbol{\beta}^{\scriptscriptstyle 0}$	$\sigma_{\scriptscriptstyle E}^{\scriptscriptstyle 0}$	${\gamma}^0_E$	$\sigma_{\scriptscriptstyle T}^{\scriptscriptstyle 0}$	${\gamma}_{\scriptscriptstyle T}^{\scriptscriptstyle 0}$	
Earth Model	None	Ellipsoid		Ter	Terrain	
Reference Area	A_{eta}	\underline{A}_{σ}	\underline{A}_{γ}	A_{σ}	A_{γ}	
Area Derivation	$\delta_r \cdot \delta_a$	$\delta_{_g}\cdot\delta_{_a}$	$oldsymbol{\delta}_p\cdot oldsymbol{\delta}_a$	$\int\limits_{DHM} \delta_g \cdot \delta_a$	$\int\limits_{DHM} \delta_p \cdot \delta_a$	
Normalisation	$\beta^{\circ} = \frac{\beta}{A_{\beta}}$	$\beta^{0} \cdot \frac{A_{\beta}}{\underline{A}_{\sigma}} = \beta^{0} \cdot \sin \theta_{e}$	$\beta^{0} \cdot \frac{A_{\beta}}{\underline{A}_{\gamma}} = \beta^{0} \cdot \tan \theta_{e}$	$eta^{o} \cdot rac{A_{eta}}{A_{\sigma}}$	$eta^{o} \cdot rac{A_{eta}}{A_{\gamma}}$	

SAR Products in Map Geometry

GTC	NORLIM	RTC
σ_E^0 or γ_E^0	\mathbf{X}_T^0 or \mathbf{X}_T^0	γ_T^0
$\sigma_E^0 = \beta^0 \cdot \sin \theta_e$	$\sigma_E^0 \cdot \frac{\sin\theta}{\sin\theta_m}$	$\rho^0 A_\beta$
$\gamma_E^0 = \beta^0 \cdot \tan \theta_e$	$\gamma_E^0 \cdot \frac{\sin\theta}{\sin\theta_m}$	$p \cdot \frac{1}{A_{\gamma}}$
	Kellndorfer et al., TGRS, Sept. 1998.	

David Small (RSL UZH) - QWG ESRIN 2009.10.27-28

Terrain corrected absolute backscattering coefficient Gamma0 (TC)



Example of VV polarisation DEM: APGB CRS: OSBG

Terrain corrected and Radiometrically Normalised Kellndorfer Gamma0



Example of VV polarisation DEM: APGB CRS: OSBG

Terrain corrected and Radiometrically Normalised Small Gamma0



Example of VV polarisation DEM: APGB CRS: OSBG

Gamma0 VV FTC (dB) – Small method



Gamma0 VV RTC (dB) - Kellndorfer



Horizontal accuracy: Overlay with OS Open Roads and Rivers



Horizontal accuracy: Overlay with OS Open Roads and Rivers



Horizontal accuracy: Overlay with Aerial Imagery





Radiometry: Gamma0-VV comparison

Statistics in linear and dB scale have been computed over 4 different cover types:

- Agricultural field
- Forest
- Industrial area
- Water (lake)

The statistics have been computed from the Gamma0-VV TC, RTC, FTC, FTC speckle reduced products generated by using the APGB DEM and in two subsequent dates, 31 May 2016 and 12 June 2016:

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S1A_IW_GRDH_1SDV_20160531T062938_20160531T063003_011499_011886_34C6 S1A_IW_GRDH_1SDV_20160612T062939_20160612T063004_011674_011DFE_7BA3

Results are showed in the following slides

Statistics comparison Gamma-0 VV: agricultural field @ Penston



Statistics comparison Gamma-0 VV: Forest @ Dura Den



Statistics comparison Gamma-0 VV : Industrial Area @ Pelstream Burn



Statistics comparison Gamma-0 VV: Water lake @ Loch Coulter

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Analysis

- Impact on results by operator that use DEM: result with and without concatenation are different for Terrain corrected product (TC, RTC, FLT)
- Resampling Method used for the DEM is bilinear. However it could be changed by using its positional parameter
- FTC product does not have portions of the image where the DEM contains no data. This is due the flattening operator that masks out the part of the image where the DEM has no data.
- When a different CRS respect to the one of the DEM is used then an error in the horizontal positional accuracy is introduced.
 - → Recommendation: It is advised to preserve the CRS of the DEM as output CRS of produced output
- RTC product: in the sea area can present artefact where the DEM is absent and replaced with 0 by SNAP
 - → Recommendation DEM APGB to be extended for covering as well part of the sea to avoid possible presence of artifacts

Technical challenges overcome/anticipated

Provided APGB DEM geotiff format not accepted in SNAP → solution: opened into Qgis and saved again in geotiff with size up to 48GB.

AIRB

- size of produced outputs