Cookbook

ESA SNAP – Sentinel-1 Toolbox
Differential SAR Interferometry using Sentinel-1 TOPS for Ground Displacement Measurements:
The Philippines M6.9 Earthquake (Jul 6, 2017)

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Exercise objectives

- Familiarize with open source ESA SNAP Toolbox.
- Familiarize with Copernicus Sentinel-1 SAR products.
- Training on measurement and analysis ground displacements from Sentinel-1 TOPS Level-1 SLC products
- Inspection of manual as well as batch processing options of ESA SNAP Toolbox
- End-to-end showcase for the Jul 6, 2017 Philippines M6.9 earthquake.

Useful Links

Information regarding Sentinel missions
https://sentinel.esa.int

Science Toolbox Exploitation Platform (STEP)
http://step.esa.int

Copernicus Open Access Hub (previously known as Sentinels Scientific Data Hub)
https://scihub.copernicus.eu

French Access to the Sentinel Products (PEPS)
https://peps.cnes.fr

Alaska Satellite Facility
https://www.asf.alaska.edu

Sentinel-1 Quality Control Subsystem
https://qc.sentinel1.eo.esa.int

Datasets

Copernicus Sentinel-1 IW Single Look Complex (SLC) core products acquired in TOPS mode:

Géosciences pour une Terre durable
brgm

S1A_IW_SLC__1SDV_20170701T213111_20170701T213138_017283_01CD96_67F3

S1B_IW_SLC__1SDV_20170707T213027_20170707T213054_006387_00B3A3_F81D

Data Processing Steps

Processing PART A

Data preparation by extraction of Sentinel-1 TOPS bursts over the region of interest per acquisition and sub-swath.

You do not need to run this part.

A1. **Split S1 SLC** (step applied to both scenes separately for each sub-swath)
GUI path: Radar → Sentinel-1 TOPS → S-1 TOPS Split

Input: S1A_IW_SLC__1SDV_20170701T213111_*_67F3
Output: S1A_20170701_IW1_VV_b1-3_Split
Parameters:
- Subswath: IW1
- Polarisations: VV
- Bursts: 1 to 3

Input: S1B_IW_SLC__1SDV_20170707T213027_*_ F81D
Output: S1B_20170707_IW1_VV_b2-4_Split
Processing parameters:
- Subswath: IW1
- Polarisations: VV
- Bursts: 2 to 4

Input: S1A_IW_SLC__1SDV_20170701T213111_*_67F3
Output: S1A_20170701_IW2_VV_b1-4_Split
Parameters:
- Subswath: IW2
- Polarisations: VV
- Bursts: 1 to 4

Input: S1B_IW_SLC__1SDV_20170707T213027_*_ F81D
Output: S1B_20170707_IW2_VV_b2-5_Split

Processing parameters:

Subswath: IW2

Polarisations: VV

Bursts: 2 to 5

Processing PART B

Apply Sentinel-1 TOPS SLC co-registration to estimate Enhanced Spectral Diversity (ESD) correction (range and azimuth offsets) for a sub-swath not affected by the earthquake.

You do not need to run this part.

Manual step-by-step processing

B1. **Apply Orbit File** (step applied separately to each scene)

GUI path: Radar → Apply Orbit File

Input: S1A_20170701_IW3_VV

Output: S1A_201707071_IW3_VV_Orb

Processing parameters:

Orbit State Vectors: Sentinel Precise (Auto Downlaod)

Check "Do not fail if new orbit file is not found"

Input: S1B_20170707_IW3_VV

Output: S1B_20170707_IW3_VV_Orb

Processing parameters:

Orbit State Vectors: Sentinel Precise (Auto Downlaod)

Check "Do not fail if new orbit file is not found"

B2. **Back-Geocoding**

GUI path: Radar → Coregistration → S1 TOPS Coregistration → S-1 Back Geocoding

Inputs: S1A_201700701_IW3_VV_Orb (first in order)

S1B_201700707_IW3_VV_Orb (second in order)

Output: S1A_20170701_S1B_20170707_IW3_VV_Orb_Stack

Processing parameters:

Check "Output Deramp and Demod Phase"

B3. **Enhanced Spectral Diversity**

GUI path: Radar → Coregistration → S1 TOPS Coregistration → S-1 Enhanced Spectral Diversity

Input: S1A_20170701_S1B_20170707_IW3_VV_Orb_Stack

Output: S1A_20170701_S1B_20170707_IW3_VV_Orb_Stack_ESD
Processing parameters: Defaults

B4. **Overview and extract estimated ESD offset values**
GUI path: View → Tool Windows → Radar → InSAR Stack → Stack Information (tab)
Estimated ESD offsets:
ESD Range Shift: -0.03125
ESD Azimuth Shift: 9.865635074675083 E-4

Automatic processing using Graph Builder

B5. **Build and Apply TOPS Co-registration Processing Chain**
GUI path: Tools → Graph Builder
Input: S1A_20170701_IW3_VV (Read)
Input: S1A_20170707_IW3_VV (Read)
Output: S1A_20170701_S1B_20170707_IW3_VV_Orb_Stack_ESD (Write)
Processing parameters:

- Add operators by order as defined in manual step-by-step processing
- Specify processing parameters accordingly
- Do NOT create intermediate products
- Save processing graph (*.xml file)
- Run processing graph

B6. **Overview and extract estimated ESD offset values**
GUI path: View → Tool Windows → Radar → InSAR Stack → Stack Information (tab)
Estimated ESD offsets:
ESD Range Shift: -0.03125
ESD Azimuth Shift: 9.865635074675083 E-4

Processing PART C

Interferometric processing of selected Sentinel-1 TOPS sub-swaths combining geometric co-registration approach and ESD refinement using pre-estimated offset values.

C1. **Build InSAR Processing Chain**

GUI path: Tools → Graph Builder

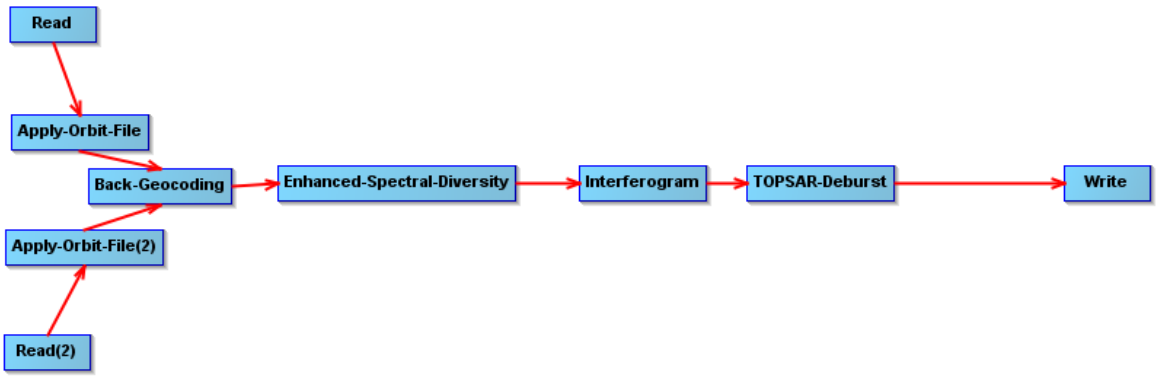
Input S1A_20170701_IW1_b1-3_VV (Read)

Input: S1B_20170707_IW1_b2-4_VV (Read)

Output: S1A_20170701_S1B_20170707_IW1_VV_Orb_Stack_ESD_Ifg_Deb (Write)

Processing parameters:

- Add and connect operators by order as shown in the figure below
- Apply Orbit File operator:
  Orbit State Vectors > Sentinel Precise (Auto Downlaod) & Check "Do not fail if new orbit file is not found"
- Back Geocoding operator:
  Check "Output Deramp and Demod Phase"
- Enhanced Spectral Diversity operator:
  Select "Use user supplied shifts" and input manually pre-estimated range and azimuth offsets
- Interferogram operator:
  Coherence Range Window Size: 20
  Coherence Range Window Size: 5
- Save processing graph (*.xml file)



C2. **Applying TOPS Co-registration Processing Chain (Sub-Swath IW1)**

GUI path: Tools → Graph Builder

Input: S1A_20170701_IW1_b1-3_VV (Read)

Input: S1B_20170707_IW1_b2-4_VV (Read)

Output: S1A_20170701_S1B_20170707_IW1_VV_Orb_Stack_ESD_Ifg_Deb (Write)

Processing parameters:

- Load pre-defined processing graph (*.xml file)
- Define output file name accordingly
- Run processing graph

C3. **Applying TOPS Co-registration Processing Chain (Sub-Swath IW2)**

GUI path: Tools → Graph Builder

Input: S1A_20170701_IW2_b1-4_VV (Read)

Input: S1B_20170707_IW2_b2-5_VV (Read)

Output: S1A_20170701_S1B_20170707_IW2_VV_Orb_Stack_ESD_Ifg_Deb (Write)

Processing parameters:

- Add operators by order as defined in manual step-by-step processing
- Do NOT create intermediate products
- Save processing graph (*.xml file)
- Run processing graph

Processing PART D

Merge interferometric results from different sub-swaths and proceed with Differential SAR Interferometry (DInSAR) processing

D1. **Merge Sub-Swaths** (same acquisition date)

GUI path: Radar → Sentinel-1 TOPS → S1 TOPS Merge

Input: S1A_20170701_S1B_20170707_IW1_VV_Orb_Stack_ESD_Ifg_Deb

Input: S1A_20170701_S1B_20170707_IW2_VV_Orb_Stack_ESD_Ifg_Deb

Output: S1A_20170701_S1B_20170707_IW12_VV_Orb_Stack_ESD_Ifg_Deb_mrg

Processing parameters:

Default parameters

D2. **Removal of topographic phase**

GUI path: Radar → Interferometric → Products → Topographic Phase Removal

Input: S1A_20170701_S1B_20170707_IW12_VV_Orb_Stack_ESD_Ifg_Deb_mrg

Output:

S1A_20170701_S1B_20170707_IW12_VV_Orb_Stack_ESD_Ifg_Deb_mrg_DInSAR

Processing parameters:

Select option “Output topographic phase band”

D3. **Multi-looking**

GUI path: Radar → Multilooking

Input: *_IW12_VV_Orb_Stack_ESD_Ifg_Deb_mrg_DInSAR

Output: *_IW12_VV_Orb_Stack_ESD_Ifg_Deb_mrg_DInSAR_ML204

Processing parameters:

Number of Range Looks: 20

Number of Azimuth Looks: 4

D4. **Phase Filtering**

GUI path: Radar → Interferometric → Filtering → Goldstein Phase Filtering

Input: *_IW12_VV_Orb_Stack_ESD_Ifg_Deb_mrg_DInSAR_ML204

Output: *_IW12_VV_Orb_Stack_ESD_Ifg_Deb_mrg_DInSAR_ML204_flt

Processing parameters:

Adaptive Filter Exponent in (0,1]: 0.8

FFT Size: 64

D5. **Spatial Subset**

GUI path: Raster → Subset

Input: *_IW12_VV_Orb_Stack_ESD_Ifg_Deb_mrg_DInSAR_ML204_flt

Output: *_IW12_VV_Orb_Stack_ESD_Ifg_Deb_mrg_DInSAR_ML204_flt_sub

Processing parameters:

Geo Coordinates Menu:

North latitude bound: 11.22

West longitude bound: 125.11

South latitude bound: 10.98

East longitude bound: 124.285

D6. **Geocoding**

GUI path: Radar → Geocoding → Terrain Correction → Range-Doppler Terrain Correction

Input: *_IW12_VV_Orb_Stack_ESD_Ifg_Deb_mrg_DInSAR_ML204_flt_sub

Output: *_IW12_VV_Orb_Stack_ESD_Ifg_Deb_mrg_DInSAR_ML204_flt_sub_TC80

Processing parameters:

Select option “Output Complex Data”

Pixel Spacing (m): 80

Map Projection: WGS84(DD)

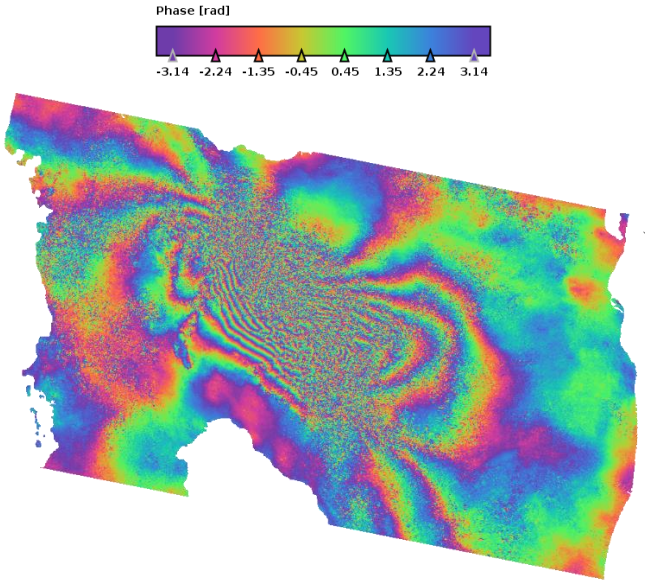
D7. **Re-calculate Interferometric Phase (wrapped)**

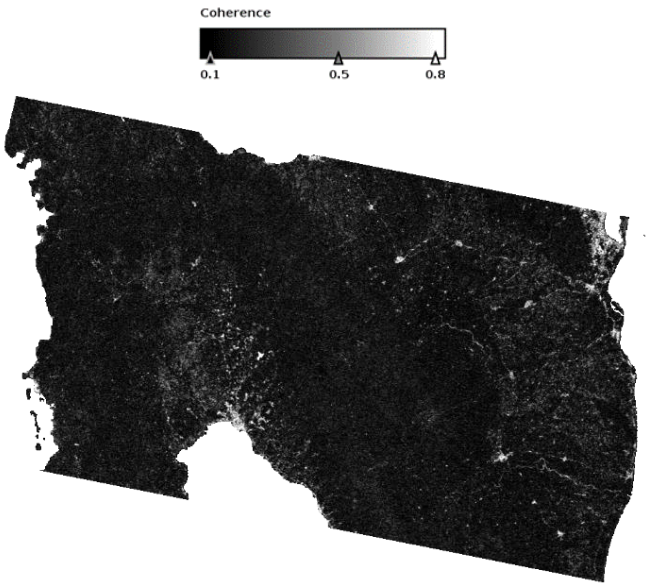
Select File: *_IW12_VV_Orb_Stack_ESD_Ifg_Deb_mrg_DInSAR_ML204_flt_sub_TC80

GUI path: Raster → Band Math

Processing parameters:

- Name: wphase
- Select option “Virtual (save expression only, don’t store data)”
- Band maths expression:
  atan2(q_ifg_VV_01Jul2017_07Jul2017,i_ifg_VV_01Jul2017_07Jul2017)





Processing PART E

Phase unwrapping and conversion to displacements.

E1. **Phase Unwrapping (Export to SNAPHU)**
GUI path: Radar → Interferometric → Unwrapping → Snaphu Export
Input: *_IW12_VV_Orb_Stack_ESD_Ifg_Deb_mrg_DInSAR_ML204_flt_sub
Output Directory: */SNAPHU_1_1
Processing parameters:

- Specify full path to "Target folder"
- Statistical-cost mode: DEFO
- Number of Tile Rows: 1
- Number of Tile Columns: 1

E2. **Execute Unwrapping via SNAPHU** (Linux OS)

- Navigate to previously specified "Target folder" in Linux Terminal
- Open configuration file (**snaphu.conf**) in "Target folder"
- Copy command to call snaphu:
  snaphu -f snaphu.conf Phase_ifg_VV_01Jul2017_07Jul2017.snaphu.img 1081
- Execute command in Terminal

Note: For Windows OS you need to download a pre-configured SNAPHU Virtual Machine (VM) @ http://sourceforge.net/projects/s1tbx/files/snaphu_vm/SAR%20Mint%2064.zip/download

E3. **Phase Unwrapping (Import from SNAPHU)**
GUI path: Radar → Interferometric → Unwrapping → Snaphu Import
Input: *_IW12_VV_Orb_Stack_ESD_Ifg_Deb_mrg_DInSAR_ML204_flt_sub (Read)
Output: *_IW12_VV_Orb_Stack_ESD_Ifg_Deb_mrg_DInSAR_ML204_flt_sub_unw
Processing parameters:

- 2-Read Unwrappined Phase:
  Navigate to file "UnwPhase_*.snaphu.hdr" in Target folder
- 3-SnaphuImport:
  Select option "Do NOT save Wrapped Interferogram in the target product"

E4. **Convert Phase to Displacement**
GUI path: Radar → Interferometric → Products → Phase to Displacement
Input: *_IW12_VV_Orb_Stack_ESD_Ifg_Deb_mrg_DInSAR_ML204_flt_sub_unw

Output:
*_IW12_VV_Orb_Stack_ESD_Ifg_Deb_mrg_DInSAR_ML204_flt_sub_unw_dsp
Processing parameters:
Default parameters

E5. **Terrain Correction Geocoding**
GUI path: Radar → Geocoding → Terrain Correction → Range-Doppler Terrain Correction
Input: *_IW12_VV_Orb_Stack_ESD_Ifg_Deb_mrg_DInSAR_ML204_flt_sub_unw_dsp
Output:
*_IW12_VV_Orb_Stack_ESD_Ifg_Deb_mrg_DInSAR_ML204_flt_sub_unw_dsp_TC80
Processing parameters:
Pixel Spacing (m): 80
Map Projection: WGS84(DD)