PolSARtools

Release 0.1 (alpha)

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PolSAR tools is a QGIS plugin, which generates derived SAR parameters (vegetation indices, polarimetric decomposition parameters) from input polarimetric matrix (C3, T3, C2, T2).

General Information

This plugin generates derived SAR parameters (viz. vegetation indices, polarimetric decomposition parameters) from input polarimetric matrix (C3, T3, C2, T2). The input data needs to be in PolSARpro/ENVI format (*.bin and *.hdr). It requires numpy, matplotlib python libraries pre-installed.

1.1 Installation

Note PolSAR tools requires QGIS version >=3.0.

- **The easiest way (requires internet connection) :**
  - Open QGIS -> Plugins -> Manage and Install Plugins... –> select `All` tab -> search for `PolSAR tools` –> select and install plugin
- **Alternative way (offline installation) :**
  - Go to releases of PolSAR tools -> select desired version -> download the `.zip` file.
  - Open QGIS -> Plugins -> Manage and Install Plugins... –> `install from ZIP` tab –> select the downloaded zip –> install plugin (ignore warnings, if any).

1.2 Up and running

After successful installation, find the plugin by opening **QGIS** –> Plugins –> `PolSAR tools` –> Process. As shown in the following figure.

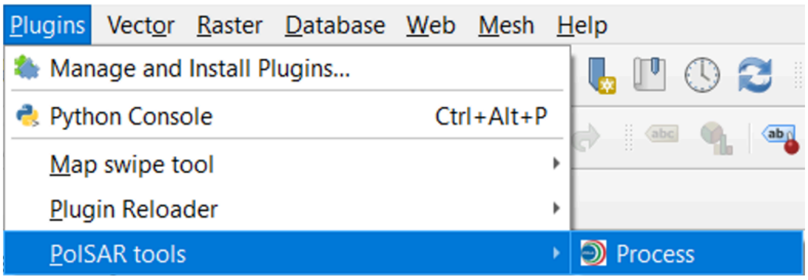

Figure 1.1. Opening the plugin

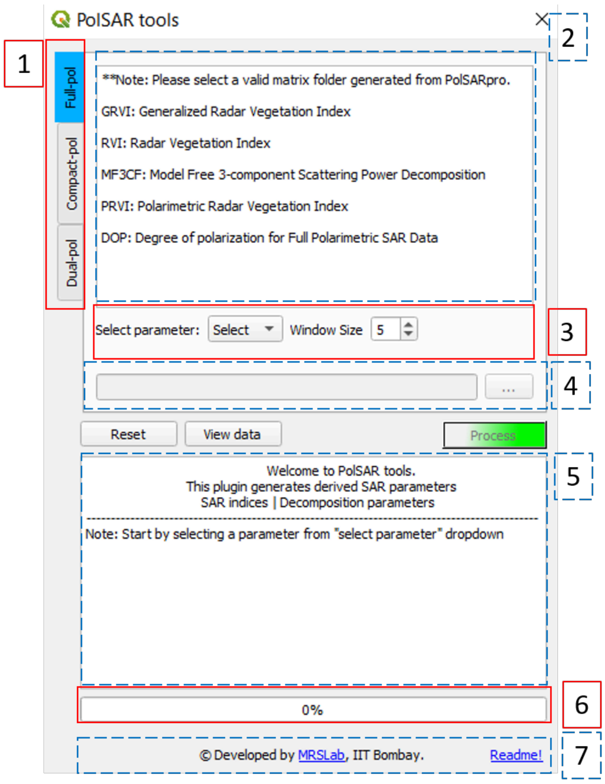

Figure 1.2. GUI-Main window layout

Layout:

1. Data type tabs: Functions are arranged according to the data dype (full-, compact- and dual-pol).
2. Function detials viewer: Contains list of functions for respective data tab.
3. Derived arameter selection, required input variables and constraints.
4. Input data folder
5. Logger: displays the log of procesing parameters
6. progressbar: displays the progress of current task.
7. Credits and quick help.

Additional `reset` button to clear the envirinment, `view data` button to import the data into **QGIS** environment and `Process` button to start processing after selecting valid input data variables.

1.3 Available functionalities

1. **Full-pol**
   - Model free 3-Component decomposition for full-pol data (MF3CF)
   - Radar Vegetation Index (RVI)
   - Generalized volume Radar Vegetation Index (GRVI)
   - Polarimetric Radar Vegetation Index (PRVI)
   - Degree of Polarization (DOP)
2. **Compact-pol**
   - Model free 3-Component decomposition for compact-pol data (MF3CC)
   - Improved S-Omega decomposition for compact-pol data (iS-Omega)
   - Compact-pol Radar Vegetation Index (CpRVI)
   - Degree of Polarization (DOP)
3. **Dual-pol**
   - Dual-pol Radar Vegetation Index (DpRVI)
   - Radar Vegetation Index (RVI)
   - Degree of Polarization (DOP)
   - Polarimetric Radar Vegetation Index (PRVI)

1.4 Example usage

Note All the following processing steps should be done in sequential manner. Sample data for all the polarization modes is provided in [sample_data](/sample_data/) folder.

STEP 1: Open the plugin as explained in Section 1.2 section.

STEP 2: Select the polarimetric data type (Full/compact/dual).

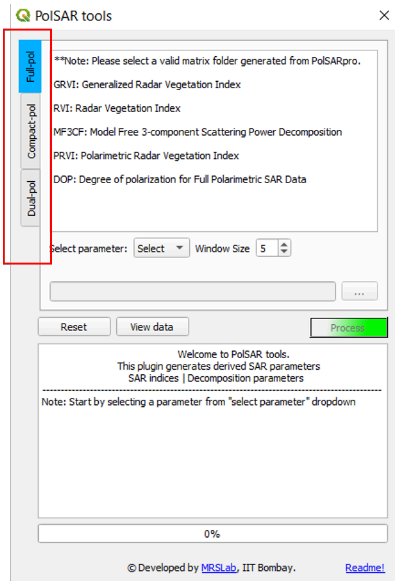

Figure 1.3. Selecting the polarimetric mode

STEP 3: Select the parameter/descriptor from the dropdown menu.

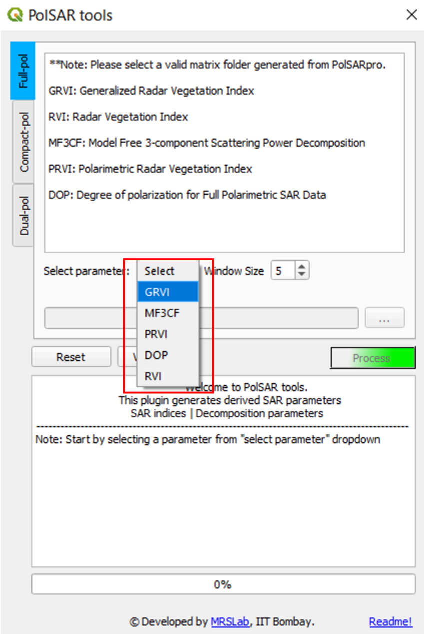

Figure 1.4. Selecting the polarimetric descriptor

STEP 4: Provide the required input variables.

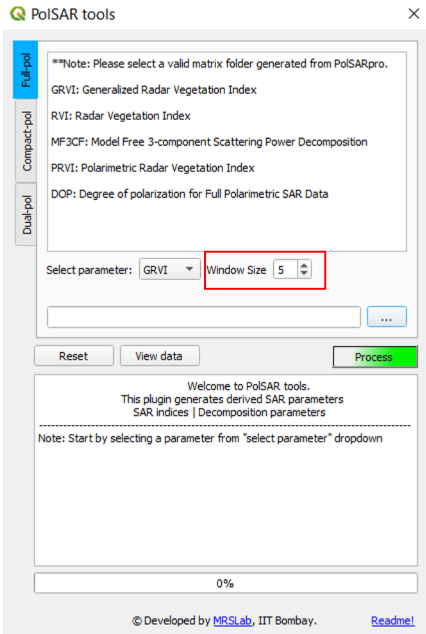

Figure 1.5. Selecting the input variables

STEP 5: Select the input matrix folder.

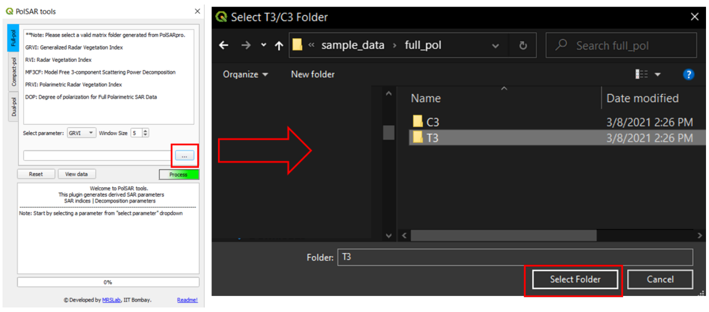

Figure 1.6. Selecting the input folder

STEP 6: Wait for the logger to prompt `` `->> Ready to process.` `` –> click process

Note Do not click process button more than once while it is processing. It may crash the QGIS and the plugin. It is possible that the plugin may show not responding for larger datasets but please wait for the process to complete.

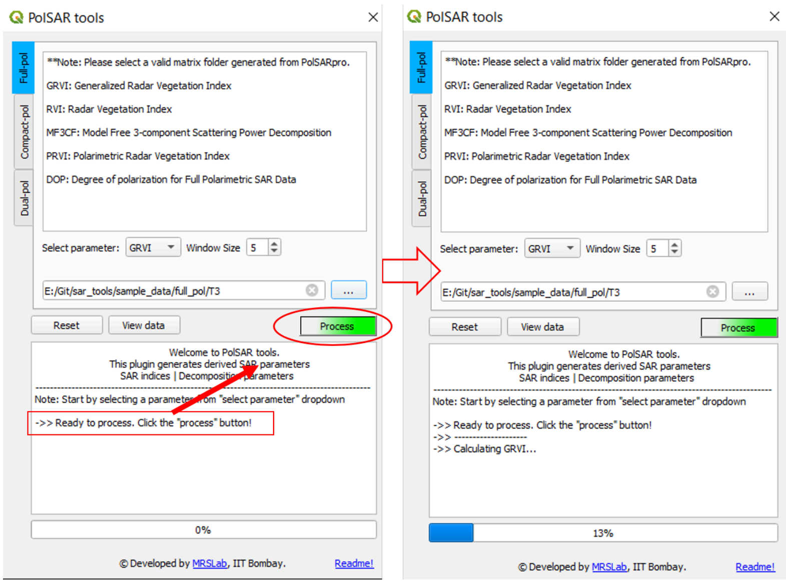

Figure 1.7. Processing the data for selected descriptor

STEP 7 (optional): Click view data to import the data into QGIS for vizualisation of the generated descriptors.

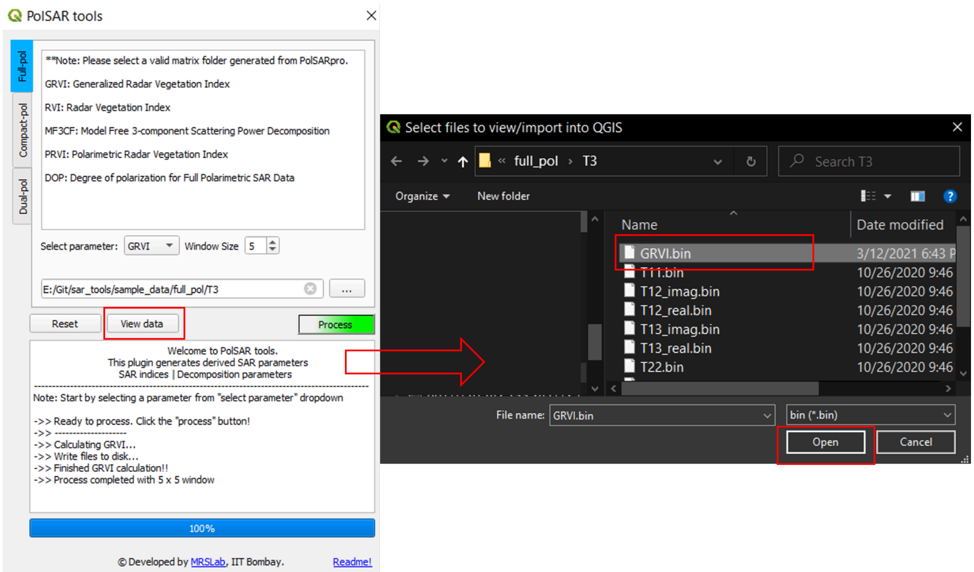

Figure 1.8. Importing the data into QGIS for visualization

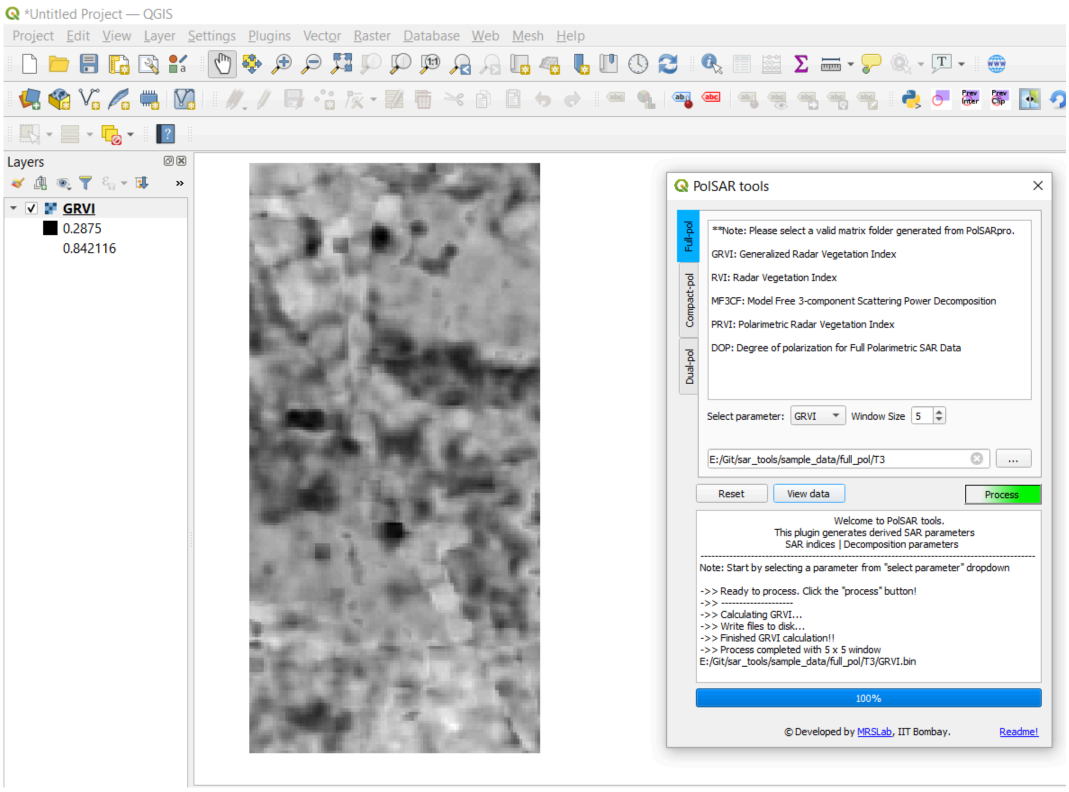

Figure 1.9. Imported data in QGIS

1.5 Functions description

Description and the details of all the core functions of this plugin are available here: (Functions description)

1.6 Contributions

1. Contribute to the software

   Contribution guidelines for this project

2. Report issues or problems with the software

   Please raise your issues here : https://github.com/Narayana-Rao/PolSAR-tools/issues

3. Seek support

   Please write to us: bnarayanarao@iitb.ac.in

Functions Description

2.1 Full-pol functions

Full-pol functionalities require the SAR data in the form of covariance (C3) or coherency matrix (T3). A typical file structures of T3 and C3 matrices are as follows:

C3 matrix files		**T3 matrix files**	
C11.bin	C11.hdr	T11.bin	T11.hdr
C12_real.bin	C12_real.hdr	T12_real.bin	T12_real.hdr
C12_imag.bin	C12_imag.hdr	T12_imag.bin	T12_imag.hdr
C13_real.bin	C13_real.hdr	T13_real.bin	T13_real.hdr
C13_imag.bin	C13_imag.hdr	T13_imag.bin	T13_imag.hdr
C22.bin	C22.hdr	T22.bin	T22.hdr
C23_real.bin	C23_real.hdr	T23_real.bin	T23_real.hdr
C23_imag.bin	C23_imag.hdr	T23_imag.bin	T23_imag.hdr
C33.bin	C33.hdr	T33.bin	T33.hdr

Following are the avaialble functions for full-pol data:

2.1.1 `RVI` (Radar Vegetation Index)

This functionality computes the Radar vegetation index for full polarimetric SAR data. The required input and the computed output are as follows:

```
input : input_T3/C3_folder, window_size
output : RVI_FP.bin
```

The formulation of RVI is as follows:

```
\text{RVI}_{fp} = \frac{4 \times \lambda_3}{\lambda_1+\lambda_2+\lambda_3}
```

where, `\lambda_1, \lambda_2` and `\lambda_3` are the eigen values of coherency matrix (T3) in descending order (`\lambda_1 > \lambda_2 > \lambda_3`). Further details can be found in [[8]](#8)

2.1.2 `GRVI` (Generalized volume based Radar Vegetation Index)

This functionality computes the generalized volume based radar vegetation index for full polarimetric SAR data. The required input and the computed output are as follows:

```
input : input_T3/C3_folder, window_size
output : GRVI.bin
```

The formulation of GRVI is as follows:

$$\text{GRVI} = \left(1 - \text{GD}_{\text{GV}}\right)\Big(\frac{p}{q}\Big)^{2\,\text{GD}_{\text{GV}}}, \quad 0\le \text{GRVI} \le 1$$

where, GD_{GV} is the geodesic distance between Kennaugh $(\mathbf{K})$ matrices of the observed and the generalized volume scattering model, p,q are minimum and maximum value of distances between $\mathbf{K}$ matrices of the observed and elementary targets respectively. A detailed explanation of GRVI is available in.

2.1.3 `MF3CF` (Model Free 3-Component decomposition for Full-pol data)

This functionality computes the model free 3 component scattering power decomposition for full polarimetric SAR data. The required input and the computed output are as follows:

```
input : input_T3/C3_folder, window_size
output: Ps_FP.bin, Pd_FP.bin, Pv_FP.bin, Theta_FP.bin
```

The formulation of the scattering powers (P_s : Surface, P_d : Double bounce, P_v : volume) is as follows:

$$P_{d}^{\text{FP}}=\frac{m_{\text{FP}}{\text{Span}}}{2}{\left(1-\sin2\theta_{\text{FP}}\right)}\\$$

where m_FP is degree of polarization, θ_FP scattering type parameter, Span is the sum of the diagonal elements os coherence matrix (T3). The derivation of these parameters in-terms of coherancey matrix (T3) elements is as shown below. Further details can be obtained from [[4]](#4)

$$m_{\text{FP}}=\sqrt{1-\frac{27|\mathbf{T3}|}{\big(\mathrm{Trace}(\mathbf{T3})\big)^3}};\qquad{}\ \text{Span}=T_{11}+T_{22}+T_{33}$$

2.1.4 `PRVI` (Polarimetric Radar Vegetation Index)

This functionality computes the polarimetric Radar vegetation index for full polarimetric SAR data. The required input and the computed output are as follows:

```
input : input_T3/C3_folder, window_size
output: PRVI_FP.bin
```

The formlation of PRVI interms of degree of polarization and cross-pol backscatter intensity can be expressed as follows:

$$\text{PRVI}_{fp}=(1-\text{DOP}_{fp})\sigma^\circ_{\text{XY}}$$

where, DOP_{fp} 3D Barakt degree of polarization and can be expressed as shown below. Further details on the PRVI can be found in [[1]](#1)

$$\text{DOP}_{fp}=\sqrt{1-\frac{27\times\text{det([T3])}}{\text{(Trace[T3])}^3}}$$

2.1.5 `DOP` (Degree of Polarization)

This functionality computes the 3D Barakat degree of polarization for full polarimetric SAR data. The required input and the computed output are as follows:

```
input : input_T3/C3_folder, window_size
output: DOP_FP.bin
```

$$\text{DOP}_{fp}=\sqrt{1-\frac{27\times\text{det([T3])}}{\text{(Trace[T3])}^3}}$$

Further details on the Barakat Degree of polarization can be found in [[10]](#10)

2.2 Compact-pol functions

Compact-pol functionalities require the SAR data in the form of 2x2 covariance matrix (C2). A typical file structures of C2 matrix is as follows:

C2 matrix files	
C11.bin	C11.hdr
C12_real.bin	C12_real.hdr
C12_imag.bin	C12_imag.hdr
C22.bin	C22.hdr

2.2.1 `CpRVI` (Compact-pol Radar Vegetation Index)

This functionality computes the compact-pol radar vegetation index for compact polarimetric SAR data. The required input and the computed output are as follows:

```
input : input_C2_folder, window_size
output: CpRVI.bin
```

The formulation of the CpRVI is as follows:

```
\text{CpRVI}=\left(1-\dfrac{3}{2}\text{GD}_{\text{ID}}\right)\Big(\frac{p}{q}\Big)^{2(\frac{3}{2
p=\text{min\{SC,OC\}},q=\text{max\{SC,OC\}}\\
\text{SC}=\frac{S_0-S_3}{2};\qquad{}\text{OC}=\frac{S_0+S_3}{2};\\
S_0=\text{C11+C22};\qquad{}S_1=\text{C11-C22};\\
S_2=\text{C12+C21};\qquad{}S_3=\pm\text{j(C12-C21)}\\
```

where, `\text{GD}_\text{ID}` is the geodesic distance between Kennaugh matrices (`\mathbf{K}`) of the observed and the ideal depolarizer, `p, q` are minimum and maximum values of `\text{SC}` and `\text{OC}` which are functions of stocks parameters (`S_0`, `S_1`, `S_2`, and `S_3`). A detailed explanation of CpRVI is available in [[6]](#6).

2.2.2 `iS-Omega` (improved S-`\Omega` decomposition)

This functionality computes the scattering powers for compact polarimetric SAR data. This is an improved decomposition technique based on Stokes vector(S) and the polarized power fraction (`\Omega`). The required input and the computed output are as follows:

```
input : input_C2_folder, window_size, tau, psi, chi
output: Ps_iSOmega.bin, Pd_iSOmega.bin,Pv_iSOmega.bin
```

The stokes paramters can be written in terms of the covariance matrx (C2) elements as follows:

```
S_0=\text{C11+C22};\qquad{}S_1=\text{C11-C22};\\
S_2=\text{C12+C21};\qquad{}S_3=\pm\text{j(C12-C21)}
```

Then, the parameters Same-sense Circular (`\text{SC}`) and Opposite-sense Circular (`\text{OC}`) can be expressed as follows:

```
\text{SC}=\frac{S_0-S_3}{2};\qquad{}\text{OC}=\frac{S_0+S_3}{2};
```

Now, based on the ratio of `\text{SC}` and `\text{OC}` the decomposition powers can be derived as given below. Further details can be found in [[7]](#7)

```
\text{SC/OC}<1;\qquad{}\qquad{}\qquad{}\qquad{}\qquad{}\qquad{}\qquad{}\text{SC/OC}>1\\P_s=\Omeg
\\P_v=S_{0}\left(1-\Omega\right)\qquad{}\qquad{}\qquad{}\qquad{}\qquad{}P_v=S_{0}\left(1-\Omega\
```

2.2.3 MF3CC (Model Free 3-Component decomposition for Compact-pol data)

This functionality computes the model free 3 component scattering power decomposition for compact polarimetric SAR data. The required input and the computed output are as follows:

```
input : input_C2_folder, window_size, tau
output: Ps_CP.bin, Pd_CP.bin, Pv_CP.bin, Theta_CP.bin
```

The formulation of the scattering powers (`P_s` : Surface, `P_d`: Double bounce, `P_v`: volume) is as follows:

```
P_{d}^{\text{CP}}=\frac{m_{\text{FP}}{S_0}}{2}{\left(1-\sin2\theta_{\text{CP}}\right)};\\P_{v}^{
```

where `m_\text{CP}` is degree of polarization; `\theta_\text{CP}` : scattering type parameter; `S_0, S_3`, are Stokes parameters. The derivation of these parameters in-terms of covariance matrix (C2) elements is as shown below. Further details can be obtained from [[4]](#4)

```
m_{\text{CP}}=\sqrt{1-\frac{4|\mathbf{C2}|}{\big(\mathrm{Trace}(\mathbf{C2})\big)^2}};\qquad{}\t
S_0=\text{C11+C22};\qquad{}\qquad{}\qquad{}\qquad{}\qquad{}S_1=\text{C11-C22};\\
S_2=\text{C12+C21};\qquad{}\qquad{}\qquad{}\qquad{}S_3=\pm\text{j(C12-C21)};\\
\text{SC}=\frac{S_0-S_3}{2};\qquad{}\qquad{}\qquad{}\qquad{}\qquad{}\text{OC}=\frac{S_0+S_3}{2};
```

2.2.4 DOP (Degree of Polarization)

This functionality computes the degree of polarization for compact polarimetric SAR data. The required input and the computed output are as follows:

```
input : input_c2_folder, window_size, tau
output: DOP_CP.bin
```

The conventional degree of polarization in terms of stokes paramters can be written as follows:

```
\text{DOP}_{cp}=\frac{\sqrt{S^2_1+S^2_2+S^2_3}}{S_0}
```

where,

```
S_0=\text{C11+C22};\qquad{}S_1=\text{C11-C22};\\
S_2=\text{C12+C21};\qquad{}S_3=\pm\text{j(C12-C21)}
```

2.3 Dual-pol

Dual-pol functionalities require the SAR data in the form of 2x2 covariance matrix (C2). A typical file structures of C2 matrix is as follows:

C2 matrix files	
C11.bin	C11.hdr
C12_real.bin	C12_real.hdr
C12_imag.bin	C12_imag.hdr
C22.bin	C22.hdr

2.3.1 RVI (Radar Vegetation Index)

This functionality computes the radar vegetation index for dual polarimetric (HH | HV), (VV | VH) SAR data. The required input and the computed output are as follows:

```
input : input_c2_folder, window_size
```

```
output: RVI_dp.bin
```

The formulation of RVI is as follows:

$$\text{RVI}_{dp} = \frac{4 \times \sigma^\circ_{\text{XY}}}{\sigma^\circ_{\text{XX}}+\sigma^\circ_{\text{XY}}}$$

where, σ°_{XX} is co-pol backscatter intensity and σ°_{XY} is corss-pol backscatter intensity

2.3.2 DpRVI (Dual-pol Radar Vegetation Index)

This functionality computes the dual polarimetric radar vegetation index for dual polarimetric (HH | HV), (VV | VH) SAR data. The required input and the computed output are as follows:

```
input : input_C2_folder, window_size
output: DpRVI.bin
```

The formulation of DpRVI is as follows:

$$\text{DpRVI} = 1- \text{DOP}_{dp}\Big(\frac{\lambda_1}{\lambda_1+\lambda_2}\Big)$$

where,

$$\text{DOP}_{dp} = \sqrt{1-\frac{4\times \text{det ([C2])}}{\text{(Trace [C2])}^2}}$$

[C2] is co-variance matrix, and λ_1, λ_2 are the eigen values of $\langle\mathbf{[C2]}\rangle$ matrix in descending order. Further details on DpRVI can be obtained from [[5]](#5)

2.3.3 PRVI (Polarimetric Radar Vegetation Index)

This functionality computes the polarimetric radar vegetation index for dual polarimetric (HH | HV), (VV | VH) SAR data. The required input and the computed output are as follows:

```
input : input_c2_folder, window_size
output: PRVI_dp.bin
```

The formulation of PRVI is as follows:

$$\text{PRVI}_{dp}=\Big(1-\sqrt{1-\frac{4\times\text{det([C2])}}{\text{(Trace[C2])}^2}}\Big)\sigma$$

where, [C2] is co-variance matrix and σ°_{XY} is corss-pol backscatter intensity.

2.3.4 DOP (Degree of Polarization)

This functionality computes the 2D Barakat degree of polarization for dual polarimetric (HH | HV), (VV | VH) SAR data. The required input and the computed output are as follows:

```
input : input_c2_folder, window_size
output: dop_dp.bin
```

$$\text{DOP}_{dp}=\sqrt{1-\frac{4\times\text{det([C2])}}{\text{(Trace[C2])}^2}}$$

where, [C2] is co-variance matrix. Further details on the Barakat Degree of polarization can be found in [[10]](#10)

Chapter 3

References

References of the research work used in this plugin.

The current version of PolSAR tools is v0.6.3 and is licensed under the GPL-3.0 license.