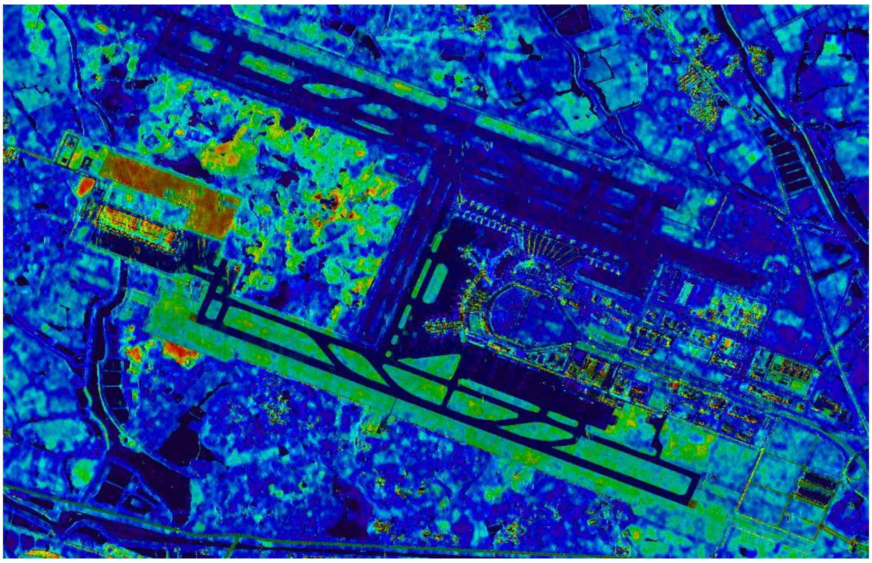
# SHPS-InSAR Toolbox 1.0
# Manual



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# 1. Introduction

The SHPS-InSAR is a MATLAB-dependent open-source toolbox and made only for research purposes. It can be downloaded from:

http://mijiang.org.cn/index.php/software/

The SHPS-InSAR is designed to refine the elements (interferometric phase, intensity/amplitude and coherence) of covariance matrix for InSAR stack using statistically homogeneous pixel selection (SHPS) algorithm. It is a variant of previous FaSHPS (Fast SHPS) method developed in Prof. Xiaoli Ding's group at The Hong Kong Polytechnic University (*Jiang et al., 2015*). The new development has taken place at Hohai University. The SHPS-InSAR will provide a fundamental observable for InSAR based geoscience applications, such as deformation monitoring or land cover mapping. It is also a basic of multi-temporal InSAR technique for distributed scatterers. I refer the reader to the survey of *Jiang et al., 2014; 2015; 2017a; 2017b* for details.

There are two pre-processing steps before the use of this toolbox. One is SAR data co-registration. This can be achieved by means of open-source (e.g., SNAP, DORIS, ROI_PAC) or commercial software (GAMMA). The other is to form differential interferograms after topography phase removal. Note that the SHPS-InSAR starts from single look images and therefore multi-looked data are not supported currently.

The toolbox has been tested for MATLAB version 2011b, 2015b, 2017a respectively, under both windows and Linux platforms. Typing help followed by the name of the script provides a brief description of the usage. All MATLAB commands and their parameters to be input are in blue throughout this manual.

# 2. User Guide

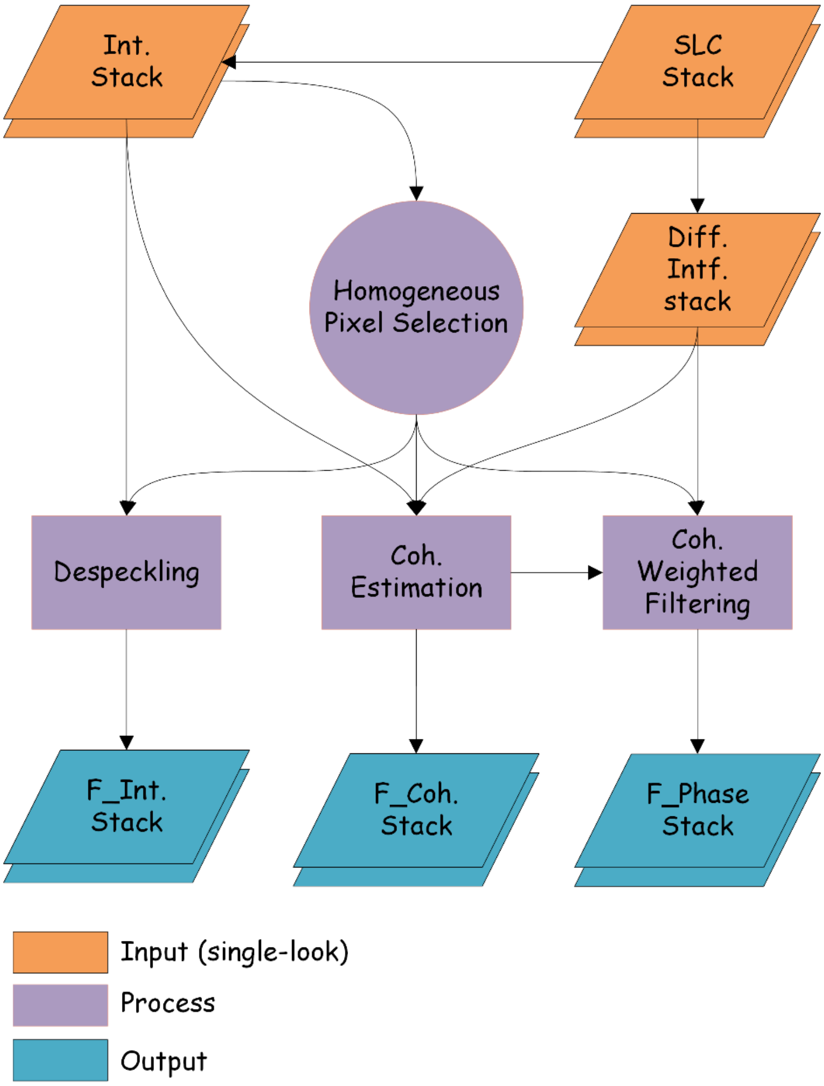


**Fig. 1.** Flowchart of SHPS-InSAR toolbox

## *2.1 Image Read*

Fig.1 presents the full procedure of data processing. The intensity and selected interferometric pair can also be calculated manually by $|S_i|^2$ and $S_i \cdot S_j^* \cdot exp(-1i \cdot ph\_topo)$ respectively, where *Ph_topo* represents topography phase component which needs to be estimated by external DEM and SAR geometry.

Once intensity stack and specified differential interferograms have been prepared in individual folder, one can input binary files to MATLAB workspace using the script ImgRead, which is a batch process version of previous script freadbk in TU-Delft InSAR toolbox after revision.

```
>> Data=ImgRead(imgpath,suffixname,nline,bkformat,machinefmt)
```

See Table 1 for details of the input parameters. The images generated by different software may have different data type and/or order. Format description for real Intensity images should be bkformat='float32' in general. It should be bkformat='cpxfloat32' for complex differential interferograms. Order for reading bytes in the file will be changed at different software. It is set to be machinefmt='b' for Big-endian ordering for GAMMA and machinefmt='n' to remain your system byte ordering for DORIS.

**Table 1** Input parameters and corresponding contents for ImgRead

| Parameter | Content |
|---|---|
| imgpath | The directory name including path |
| suffixname | The suffix name of the file to be read in the directory, e.g., GAMMA processed intensity images with suffix mli |
| nline | The height (or line) of each binary file |
| bkformat | The data type of binary file |
| machinefmt | Order for reading bytes in the file |

## *2.2 Homogeneous Pixel Selection*

Under the assumption that similar surface targets sharing the similar backscattering properties, only statistically homogeneous pixels are collected for each reference pixel (*Jiang et al., 2015; Jiang et al., 2017b;*

*Parizzi and Brcic, 2011*). The significant advantage of the algorithm is to reduce any noise induced in InSAR covariance matrix and simultaneously preserving spatial resolution of SAR imagery. The values of selected pixels can be regarded as the sample from the same population in statistic and used for subsequent parameter estimation.

Two algorithms, corresponding to parametric and non-parametric versions, have been developed in SHPS-InSAR. The script SHP_SelPoint with parameter EstAgr='HTCI' is designed for zero mean complex (circular) Gaussian distribution. When the assumption breaks down (due to temporal variations), EstAgr='BWS' deploys Baumgartner – weiB - Schindler (BWS) test statistic for general problem. Generally, HTCI is more powerful than BWS test at middle to small sample size due to smaller Type II error. The parameters used are listed in Table 2.

```
>> [SHP]=SHP_SelPoint(mlistack,CalWin,Alpha,EstAgr)
```

**Table 2** Input/output parameters and contents for SHP_SelPoint

| **Parameter** | **Content** |
|---|---|
| mlistack | The single-look intensity stack |
| CalWin | The fixed window size |
| Alpha | The significance level (default =0.05 ) |
| EstAgr | The algorithm to select homogeneous pixels (Default = 'HTCI') |
| SHP (output) | A struct including the record of homogeneous pixels, the brother number for each reference pixel and a copy of CalWin |

CalWin should be odd number with size [row col]. The larger size implies more homogeneous pixels may be selected at the cost of the possibility of the offence on local stationarity. A proper size should be empirically determined according to SAR resolution.

> **Tip:** As an alternative, the script GLRT_SelPoint selects homogeneous pixel using parametric generalized likelihood ratio test. One interesting can validate the accuracy of different methods using the script simshp (*Jiang et al., 2017b*), in which the mean power and std have been calculated. The script SHP_FootPrint is designed to show the selected brother pixels of the reference pixel from different methods.

## *2.3 Coherence Estimation*

After homogeneous pixel selection, the script AdpCohEst can be used to estimate (spatial) coherence magnitude between arbitrary pairs. The details of input/output parameters have been listed in Table 3.

```
>>[Coh,CpxCoh,BtCoh]=AdpCohEst(mlistack,mlilist,infstack,inflist,SHP,Btflag,Acc)
```

**Table 3** Input/output parameters and contents for AdpCohEst

| Parameter | Content |
|---|---|
| mlistack | The single-look intensity stack |
| mlilist | The intensity list named by <yyyymmdd> , prepared in ImgRead |
| infstack | The single-look interferograms |
| inflist | The interferogram list named by <yyyymmdd_yyyymmdd>, prepared in ImgRead |
| SHP | Output of SHP_SelPoint |
| Btflag | Bootstrapping flag to mitigate the bias of coherence magnitude (Default = false) |
| Acc | Accelerate the program (Default = true) |
| Coh (output) | Estimated coherence magnitude |
| CpxCoh(output) | Estimated complex coherence |
| BtCoh(output) | Estimated coherence magnitude after bootstrapping bias mitigation |

Coherence is a measure of the similarity between two SAR echoes and widely used for quality control in InSAR data processing. There are three error sources declining the estimate accuracy: the non-stationarity of signals over areas with rich textures (compensated by SHP_SelPoint), the phase gradient and the biased estimator (*Jiang et al., 2014*). Although the use of topography phase compensates the interferometric fringe pattern, the phase gradient is still inevitable for areas with stronger deformation. Therefore, the most accurate method is to employ fringe rate estimation algorithm to remove redundant fringes before coherence estimation. It is worth noting that the influences of long-wavelength variations such as atmospheric artifact on coherence estimation can be ignored as phase screen in an estimate window is regarded as a constant.

Finally, SHPS-InSAR provides three methods to mitigate the bias of estimator: bootstrapping, bias mitigation with second kind statistic and regular moment. The recommend of the use of estimators has been given in Table 4.

**Table 4** The application of bias mitigated coherence estimators

| Estimator | Burden | Resolution preservation | Script | application |
|---|---|---|---|---|
| Bootstrapping | high | Full | AdpCohEst | Deformation monitoring |
| Second kind statistic | low | Some loss with smoothness | BiasCorr/ BiasCorrAcc | Classification/ Change detection |
| Regular moment | low | Some loss with smoothness | BiasCorr/ BiasCorrAcc | Classification/ Change detection |

When use bootstrapping, set Btflag=true in AdpCohEst. The other two estimators can be deployed by the script BiasCorr.

```
>> BiasCorrcoh = BiasCorr(CpxCoh,SHP,EstAgr)
```

See Table 5 for details of the input parameters.

**Table 5** Input parameters and corresponding contents for BiasCorr

| Parameter | Content |
| --- | --- |
| CpxCoh | Complex coherence, output of AdpCohEst |
| SHP | Output of SHP_SelPoint |
| EstAgr | The algorithm to mitigate bias (Default='sec') |

The SHPS-InSAR also provides an accelerative version BiasCorrAcc with the same parameter input.

Conventional boxcar coherence estimation with Gaussian kernel can be achieved without input of SHP file.

**Tip:** Throughout this manual, the option Acc=true denotes improving the computational efficiency at the cost of memory exhaust. In default status, bstep = 1000*1000 pixels are processed synchronously each time. One can revise the value at each script by evaluating the free memory.
When bootstrapping method has been used, two additional parameters have been fixed in AdpCohEst. Bootstrapping replication B=200 is a compromise between the efficiency and accuracy. Larger B represents more robust results. coh_thre =.5 implies that the bias of the observations less than .5 has been mitigated as larger values have very weak bias. The bootstrapping estimate can be validated using the script simcoh.

## *2.4 Phase Filtering*

Interferometric phase is vital for deformation monitoring and should be filtered to reduce random noise before phase unwrapping. Script IntfFilt removes noise using coherence magnitude as a weight and homogenous pixels for each reference pixel. Because the filter is designed in 2D field, spatial averaging with a great number of sample may lead to a faker over full noise region or contaminate the properties for point-wise targets, the script sets two parameters to preserve original phase for filtered interferogram. Cohthre=.25 is used to mask fast decorrelation area and BroNumthre=5 is used to preserve the point-wise targets. One can revise the threshold in the script.

```
>> Ph = IntfFilt(intfstack,coh,SHP,FiltWin,Acc)
```

The description of the input parameters is listed in Table 6.

**Table 6** Input parameters and corresponding contents for IntfFilt

| Parameter | Content |
|---|---|
| intfstack | The single-look interferograms |
| coh | Coherence magnitude, output of AdpCohEst and/or BiasCorr |
| SHP | Output of SHP_SelPoint |
| FiltWin | Filtering window in which SHPs are collected to average |
| Acc | Accelerate the program (Default = true) |

FiltWin should be empirically selected. It should be no more than CalWin. When square window size is set, IntfFilt uses the circular window to filter the interferogram. Conventional boxcar filtering would be implemented without input of SHP.

## *2.5 Despeckling*

The intensity stack can be filtered by script DeSpeckling to remove the speckle noise. The filtered SAR image can preserve the resolution and maximize noise reduction. See Table 7 for details about the input parameters.

```
>> Mliimg = DeSpeckling(mlistack,SHP,Acc)
```

**Table 7** Input parameters and corresponding contents for DeSpeckling

| Parameter | Content |
|---|---|
| mlistack | The single-look intensity stack |
| SHP | Output of SHP_SelPoint |
| Acc | Accelerate the program (Default = true) |

When SHP is missing, DeSpeckling employs conventional boxcar filter with Gaussian kernel to reduce the speckle.

# 3. Example

In this example I illustrate how to generate more accurate covariance matrix from 25 SLC data stack. The results can be further processed using current software after format transformation.

An ALOS PALSAR dataset (frame: 660, path: 216) with FBS/FBD model acquired over Los Angeles, South California from 20061231 to 20110226 is used. A subarea with size 501 pixels by 457 pixels over Los Alamitos Army Airfield is selected. This dataset can be downloaded freely from Alaska Satellite Facility website: https://www.asf.alaska.edu/

As scene identifier the toolbox uses the date. The data pre-processing is implemented using GAMMA software. 25 intensity images and 3 interferograms are available on the DEMO and placed in a directory called MLI and DIFF respectively.

To read images to MATLAB workspace, using:

```
>> curpath  = pwd;
>> mlipath  = [curpath,filesep,'MLI']; %directory name
>> diffpath = [curpath,filesep,'DIFF'];
>> basemapname = 'mli_ave.ras';

%data input
>> nlines = 501;
>> mlistack =ImgRead(mlipath,'mli',nlines,'float32');
>> intfstack =ImgRead(diffpath,'diff',nlines,'cpxfloat32');
```

Where a basemap with Sun Raster format is used for showing the footprint of the homogeneous pixels.

In order to select homogeneous pixel, [15 15] window size and significance level Alpha = 5% are defined.

```
%SHP selection
>> CalWin = [15 15]; %[row col]
>> Alpha=0.05;
>> [SHP]=SHP_SelPoint(mlistack.datastack,CalWin,Alpha);
```

The homogeneous pixel number can be seen in Fig. 2, showing how many brother sample for each pixel. Visually, the bareland in the middle have more sample than bottom-left areas where point-wise targets are dominant.

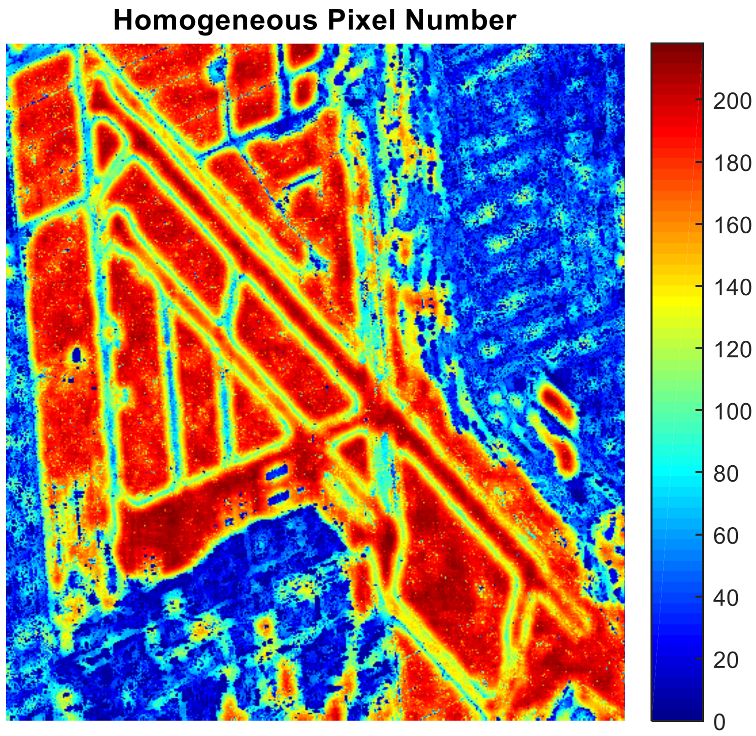


**Fig. 2.** Homogeneous pixel number for each reference pixel

To check the accuracy of selected pixel, using the command below:

```
>> Footprint =[75,169];
>> SHP_FootPrint([mlipath,filesep,basemapname],SHP,Footprint);
```

A reference point in coordinate [75 169] is used. It can be seen in Fig. 3 that the pixels having the similar texture with reference are collected, showing that this method is good at processing linear features. The user can also manually select pixel without input of the coordinate.

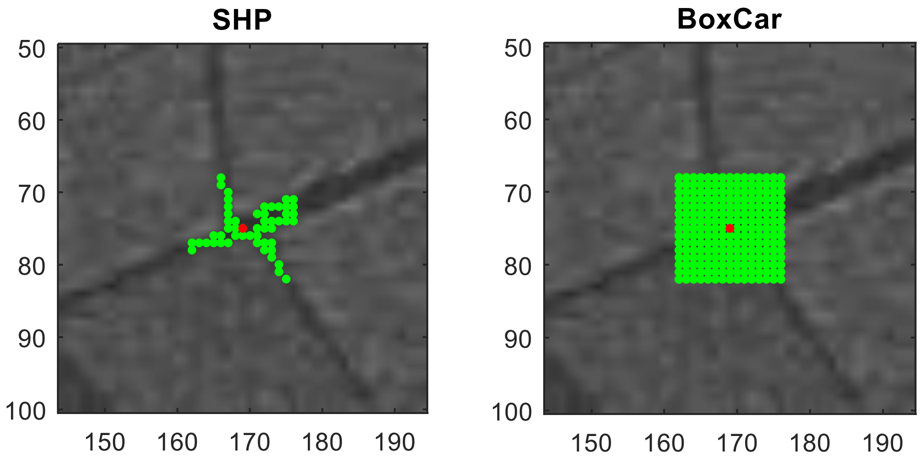


**Fig. 3.** Footprint of reference (red) and its homogeneous pixels (green)

Once all pixels are collected, we can estimate covariance matrix for each point.

```
>> [Coh,Cpxcoh,btcoh] =
AdpCohEst(mlistack.datastack,mlistack.filename,intfstack.datastack,in
tfstack.filename,SHP,false,false);
```

In this case, we didn't use bootstrapping to reduce the bias as large window has been used, implying smaller bias. However, this may increase the risk of the non-stationarity in mean in local. We try to mitigate both the bias and variance of coherence estimator using second kind statistic method. The results have been presented in Fig. 4

```
>> Biascorrcoh = BiasCorrAcc(Cpxcoh,SHP,'sec');
```

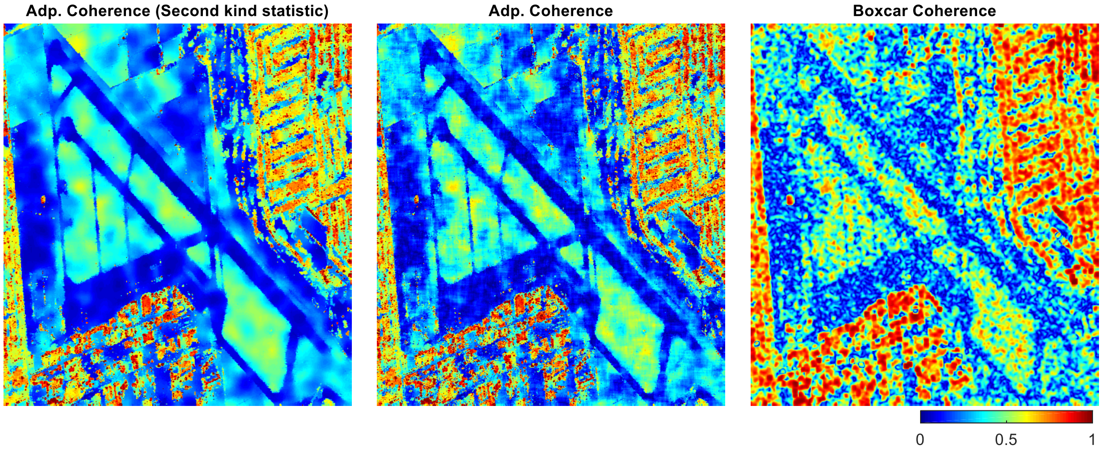


**Fig. 4.** Coherence estimation for pair 20100223_20100410

For phase filtering, we test [13 13] window size. The default value for boxcar filtering is [5 5].

```
%Phase filtering
>> Acc=true;
>> ADPPh = IntfFilt(intfstack.datastack,Coh,SHP,[13 13],Acc);
>> BOXPh = IntfFilt(intfstack.datastack);
```

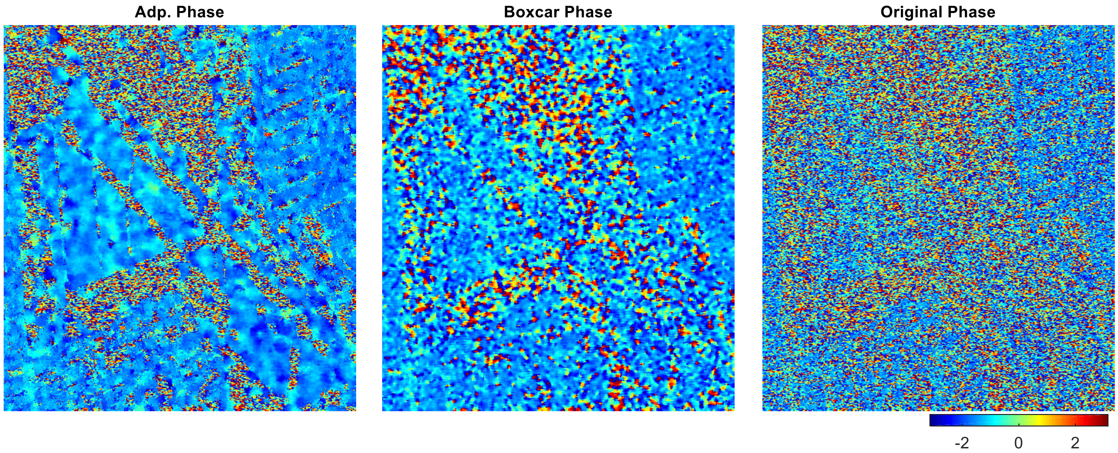


**Fig. 5.** Interferometric phase filtering for pair 20090823_20091008

Note that in Fig. 5 some regions after phase filtering in the left are still noisy, we give up areas with very low coherence to reduce the faker using coherence threshold 0.25 in this case.

Finally, the intensity image is filtered in Fig. 6, only one image has been tested in this case.

```
%Despeckling
>> ADPMli = DeSpeckling(mlistack.datastack(:,:,1),SHP,Acc);
>> BOXMli = DeSpeckling(mlistack.datastack(:,:,1));
```

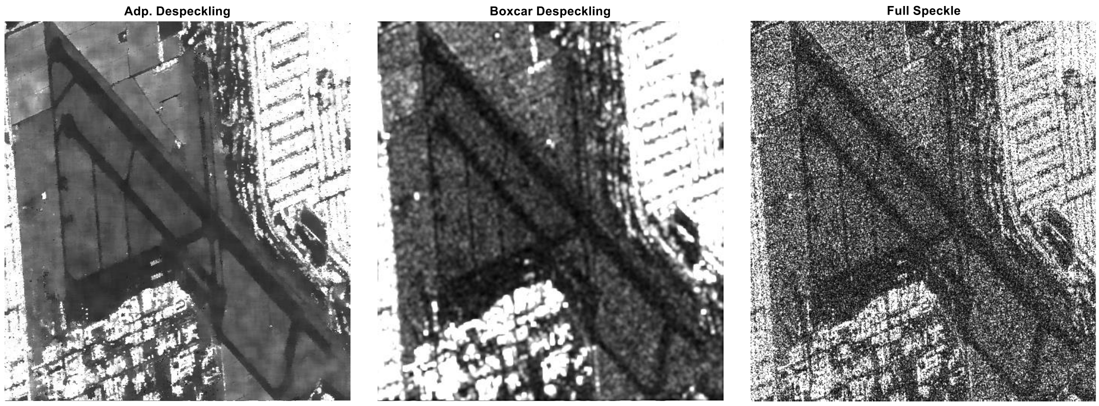


**Fig. 6.** Despeckling for SAR image 20061231

From the cases above, it can be seen that the structure and resolution can be preserved and the errors can be removed in varying degrees.

## Acknowledgement

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# 4. Bibliography

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