NL-SAR Toolbox Manual

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NL-SAR Toolbox provides a collection of tools for the estimation of multi-modal SAR images with non-local filters. Beyond estimation, NL-SAR Toolbox provides a suite of tools to manipulate SAR images. There are 6 ways to interact with NL-SAR:

- through 5 interfaces:
  - in command line
  - with Matlab
  - with Python
  - with IDL
  - as a dynamic library (*e.g.* to use it from a C program).
- and through 1 plugin:
  - for PolSARpro (experimental).

Another plugin for OTB should appear soon.

So far, the command line version is the most stable one while others can crash, for instance, if you do not provide the good inputs in arguments. Feel free to fix such bugs or contribute to NL-SAR Toolbox as you wish under the term of the license (see Section 1).

NL-SAR Toolbox has been compiled and tested successfully on GNU/Linux (Ubuntu 12.04 Precise Pangolin & Linux Mint 13 Maya) and Max OS X (10.7.5 Lion).

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1 License

This software is a computer program whose purpose is to provide a suite of tools to manipulate SAR images.

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2 Installation

In the following, we are assuming that you are using `bash`. In this case, make sure that the configuration file `.bashrc` is sourced when opening a new shell instance. This is the default behavior, but not everytime (for instance on Mac OS X). In this case type once:

```
> echo 'source $HOME/.bashrc' >> $HOME/.bash_profile
```

If you are using another shell (like `csh` or `zsh`) replace in the followings `.bashrc` with the corresponding configuration file and adjust the commands accordingly.

2.1 Dependencies

First check the following dependencies:

software	feature	status
gcc	to compile the project	required
fftw3f	to enable non-local filtering with fft implementation and car filters	required
gcc version > 4.2	to enable parallelization with OpenMP	optional
lapack	to enable non-local filtering with covariance matrices higher than 3 x 3	optional
idl	to enable IDL interface	optional
matlab	to enable Matlab interface	optional
python	to enable Python interface	optional
numpy	to enable Python interface	optional
pdflatex	to create the documentation	optional

The above pieces of software have to be present in your environment variable `PATH` (for binaries) or `LD_LIBRARY_PATH` (for libraries) otherwise their associated feature will be disabled. For instance, if you want to enable the MATLAB interface, typing in your shell:

```
> which matlab
```

should give you the path where MATLAB is installed (e.g., `/Applications/MATLAB_R2013a.app/bin/matlab`). If it is not the case, type something like:

```
> echo 'export PATH=/Applications/MATLAB_R2013a.app/bin/:$PATH' >> $HOME/.bashrc
> source $HOME/.bashrc
```

Or, if you are using aliases, you can instead do the following:

```
> echo 'export PATH=$(dirname `echo ${BASH_ALIASES[matlab]}`):$PATH' >> $HOME/.bashrc
> source $HOME/.bashrc
```

Once you have checked your dependencies, you can compile and install NL-SAR in two ways: as a super user or as a non super user.

2.2 Installation for super users

First configure and compile NL-SAR by typing in a shell prompt:

```
> ./configure
> make
> sudo make install
```

This will install NL-SAR's command line interface and dynamic library interface in `/usr/`, NL-SAR's Matlab interface in Matlab's subdirectory `toolbox/nlsar/`, NL-SAR's Python interface in Python's site-packages directory and NL-SAR's IDL interface in IDL's subdirectory `external/lib/nlsar/`.

2.3 Installation for non super users

First configure and compile NL-SAR by typing in a shell prompt:

```
> ./configure --prefix=<NLSAR_PATH> --prefix-matlab=<MATLAB_PATH>
              --prefix-python=<PYTHON_PATH> --prefix-idl=<IDL_PATH>
> make
> make install
```

This will install NL-SAR's command line interface and dynamic library interface in `<NLSAR_PATH>`, NL-SAR's Matlab interface in `<MATLAB_PATH>/toolbox/nlsar/`, NL-SAR's Python module in `<PYTHON_PATH>` and NL-SAR's IDL interface in `<IDL_PATH>/lib/nlsar/`.

You will need to update your environment paths variables. Make sure you are placed in the NL-SAR's directory and type the followings:

```
> echo 'export PATH=<NLSAR_PATH>/bin:$PATH' >> $HOME/.bashrc
> echo' export LD_LIBRARY_PATH=<NLSAR_PATH>/lib:$LD_LIBRARY_PATH' >> $HOME/.bashrc
> source $HOME/.bashrc
```

2.4 Installation of the PolSARpro plugin

To also install the PolSARpro plugin, you just have to adds the following option `--prefix-polsarpro=<POLSARPRO_PATH>` to the configure script where `<POLSARPRO_PATH>` is the directory where PolSARpro is installed. For instance, if you are installing the NL-SAR Toolbox as super-user, do the following

```
> ./configure --prefix-polsarpro=<POLSARPRO_PATH>
> make
> sudo make install
```

So far, the plugin is only available for PolSARpro version 4.2.0.

2.5 Update Matlab environment

If you are using Matlab and you have specified a different prefix during configuration, you will need to update the Matlab environment as follows:

```
> echo 'export MATLABPATH=<MATLAB_PATH>/toolbox/nlsar/:$MATLABPATH' >> $HOME/.bashrc
> source $HOME/.bashrc
```

2.6 Update Python environment

If you are using Python and you have specified a different prefix during configuration, you will need to update the Python environment as follows:

```
> echo 'export PYTHONPATH=<PYTHON_PATH>:$PYTHONPATH' >> $HOME/.bashrc
> source $HOME/.bashrc
```

2.7 Update IDL environment

If you are using IDL and you have specified a different prefix during configuration, you will need to update the IDL environment as follows:

```
> echo "PREF_SET, 'IDL_PATH', '<PREFIX_IDL>/lib/nlsar/:<IDL_DEFAULT>', /COMMIT" | idl
> echo "PREF_SET, 'IDL_DLM_PATH', '<IDL_PATH>/dlm/:<IDL_DLM_DEFAULT>', /COMMIT" | idl
> source $HOME/.bashrc
```

3 Prerequisites

- From command line: works out of the box
- From Matlab: works out of the box
- From Python: add the following before doing anything

  ```
  import nlsartoolbox as nlsartb
  ```

- From IDL: works out of the box
- From C: add the following before everything

  ```
  #include <nlsartoolbox.h>
  ```

  Link to NL-SAR Toolbox with the option `-lnlsartoolbox`

The PolSARpro plugin should work out of the box.

4 Images formats

Supported formats:

- RAT formats,
- PolSARpro formats,
- XIMA formats.

Note that NL-SAR deals only with images of intensity or of covariance matrices. Other inputs will not produce what you want. If you have amplitude or complex images, use the program `sarjoin` which build an intensity image or an image of covariance matrices from amplitude or complex images (see Section 5.4).

Files can be encoded in little or big endian. The defaults behavior of NL-SAR is to interpret binary data according to your own architecture. You can specify NL-SAR that the data uses the other endianness by adding '[SWAP]' at the end of the file name (see Section 5.5)
Obviously, the PolSARpro plugin deals only with PolSARpro formats.

4.1 RAT formats

- NL-SAR can read RAT files of version 1 and 2, but it writes only RAT files in version 1.
- A RAT file is assumed to be an image of complex covariance matrices. A RAT file containing vectorial data will produce an error message. Only the arrays of the following types are implemented so far:
  - float (`var` = 4)
  - float complex (`var` = 6)
  - double complex (`var` = 9)

  Rat files with other types will produce an error message. Fell free to contact me to extend to other modalities.

4.2 PolSARpro format

- NL-SAR can read Sinclar, Coherency and Complex matrices, but it writes only Coherency and Complex matrices. Fell free to contact me to extend to other modalities.
- A PolSARPRo data is a directory containing binary files (with extensions `.bin`) and a `config.txt` file, You can find more details about this format there: `http://earth.eo.esa.int/polsarpro/Manuals/PolSARpro_DataFormat.pdf`
- Note that NL-SAR can deal with a specific mode (`PolarType: pp0`) for reading 1-dimensional data.

4.3 XIMA format

- An XIMA data is a binary file without header which comes with a file with same name and extension .dim. You can find more details about this format there: `http://perso.telecom-paristech.fr/~nicolas/XIMA/index.html`.
- NL-SAR can read all XIMA formats (NB: all formats haven't been tested, contact me if you have any troubles) but write only in cxf (complex float) from a 1-dimensional SAR image.

5 Interfaces and their basic commands

This section describes the different basic commands/functions that are available to manipulate SAR images in different languages: command line, Matlab, Python, IDL or in C.

5.1 Reading information

- From command line:

```
> sarinfo file.rat
dimensions:
    M = 512
    N = 256
    D = 3
```

- From Matlab:

```
> [M, N, D] = sarinfo('file.rat')
M =
     512
N =
     256
D =
       3
```

- From Python:

```
In [1]: M, N, D = nlsartb.sarinfo('file.rat')

In [2]: M, N, D
Out[2]: (512, 256, 3)
```

- From IDL:

```
> PRINT, sarinfo('file.rat')
          512         256           3
```

- From C:

```
sardata* sarimage;

// anything

if (!(sarimage = sardata_alloc()))
    // treat error
if (!(sarimage = sarread_header("file.rat", sarimage)))
    // treat error
printf("M=%d N=%d D=%d\n", sarimage->M, sarimage->N, sarimage->D);

// anything

sardata_free(sarimage);
```

5.2 Reading data

The following commands import a SAR image from disk to memory

- From Matlab:

```
> sarimage = sarread('file.rat');
```

Look at the matrix dimensions:

```
> size(sarimage)
ans =
     3      3    256    512
```

- From Python:

```
In [1]: sarimage = nlsartb.sarread('file.rat')
```

  Look at the matrix dimensions:

```
In [2]: shape(sarimage)
Out[2]: (512, 256, 3, 3)
```

- From IDL:

```
> sarimage = sarread('file.rat')
```

  Look at the matrix dimensions:

```
> PRINT, size(sarimage, /DIMENSIONS)
       3           3         256         512
```

- From C:

```
sardata* sarimage;

// anything

if (!(sarimage = sardata_alloc()))
    // treat error
if (!(sarimage = sarread("file.rat", sarimage)))
    // treat error

// anything

sardata_free(sarimage);
```

Note that a command line version would be meaningless.

5.3 Writing data

The following commands export a SAR image from memory to disk.

- From Matlab:

```
> sarwrite(sarimage, 'newfile.rat');
```

- From Python:

```
In [1]: nlsartb.sarwrite(sarimage, 'newfile.rat')
Out[1]: True
```

- From IDL:

```
> sarwrite, sarimage, 'newfile.rat'
```

- From C:

```
sardata*    sarimage;

// anything

if (!(sarwrite(sarimage, "newfile.rat")))
    // treat error
```

```
// anything

sardata_free(sarimage);
```

Note that a command line version would be meaningless.

5.4 Join

The following commands creates an intensity image or a covariance matrix from a list of amplitude images or a single look complex images:

- From command line:

```
> sarjoin file1 [file2 ... fileN] newfile
```

Note that it is the only command of NL-SAR which deals with amplitude or single look complex data as input. If you provide only one file in input, this function basically compute the intensity image from the amplitude or complex image.

5.5 Conversion

The following example convert a RAT file to PolSARpro format:

- From command line

```
> sarconvert file.rat newfile
```

- From Matlab:

```
> sarimage = sarread('file.rat');
> sarwrite(sarimage, 'newfile');
```

- From Python:

```
In [1]: sarimage = nlsartb.sarread('file.rat')

In [2]: nlsartb.sarwrite(sarimage, 'newfile')
Out[2]: True
```

- From IDL:

```
> sarimage = sarread('file.rat')
> sarwrite, sarimage, 'newfile'
```

- From C:

```
sardata*    sarimage;

// anything

if (!(sarimage = sardata_alloc()))
    // treat error
if (!(sarimage = sarread("file.rat", sarimage)))
    // treat error
if (!(sarwrite(sarimage, "newfile")))
    // treat error

// anything

sardata_free(sarimage);
```

The following example convert a PolSARpro format to the same PolSARpro format except it switches the endianness of the output:

- From command line

```
> sarconvert file newfile[SWAP]
```

- Same principle from other interfaces.

5.6 Extraction

The following commands extract a subarea from position (x, y) to position $(x + width - 1, y + height - 1)$ with a decimation step:

- From command line

```
> sarextract file.rat newfile.rat x y width height step
```

- From Matlab:

```
> sarimage_new = sarimage(:, :, y + (1:step:height)), x + (1:step:width));
```

- From Python:

```
In [1]: sarimage_new = sarimage[x:x + width:step, y:y + height:step, :, :]
```

- From IDL:

```
> sarimage_new = sarimage[*, *, y:(y + height - 1):step, x:(x + width - 1):step]
```

- From C:

```
sardata*    sarimage;
sardata*    sarimage_new;
long int    xoffset, yoffset, width, height, step;

// anything

if (!(sarimage_new = sardata_alloc()))
    // treat error
if (!(sarimage_new = sardata_extract(sarimage, sarimage_new,
                                     x, y, width, height, step)))
    // treat error

// anything

sardata_free(sarimage_new);
```

5.7 RGB export

- From command line:

```
> sar2png file.rat rgbexport.png [alpha]
```

where `alpha` is an optional parameter to enhance contrast (default 3)

- From Matlab:

```
> rgbexport = sar2rgb(sarimage [, alpha]);
```

The argument `alpha` is the same as for the command line version.
Look at the matrix dimensions:

```
> size(sarimage)
ans =
     3      3    256    512
> size(rgbexport)
ans =
   512    256      3
```

The storing convention for the RGB image is reversed compared to our usual convention to ensure compatibility with the Matlab Image Toolbox.

- From Python:

```
In [1]: rgbexport = nlsartb.sar2rgb(sarimage [, alpha]);
```

The argument `alpha` is the same as for the command line version.
Look at the matrix dimensions:

```
In [2]: shape(sarimage)
Out[2]: (512, 256, 3, 3)
In [2]: shape(rgbexport)
Out[2]: (512, 256, 3)
```

- From IDL:

```
> rgbexport = sar2rgb(sarimage [, alpha])
```

The argument `alpha` is the same as for the command line version.
Look at the matrix dimensions:

```
> PRINT, SIZE(sarimage, /DIMENSIONS)
       3           3         256         512
> PRINT, SIZE(rgbexport, /DIMENSIONS)
       3         256         512
```

- From C:

```
sardata*    sarimage;
rgbdata*    rgbexport;

// anything

if (!(rgbexport = rgbdata_alloc()))
    // treat error
if (!(rgbexport = sar2rgb(sarimage, rgbexport, alpha, gamma)))
    // treat error

// anything

rgbdata_free(rgbexport);
```

5.8 Viewer

- From command line:

```
> sarshow file.rat [alpha]
```

The argument `alpha` is the same as for the RGB export.
The first time, you will probably have the following message:

```
Please set your environment variable NLSAR_VIEWER
```

You need to define an environment variable `NLSAR_VIEWER` pointing to your favorite image viewer. For instance for Linux, if you like Eye Of Gnome, type the following:

```
> echo 'export NLSAR_VIEWER="eog -n"' >> $HOME/.bashrc
> source $HOME/.bashrc
```

Or, if you prefer Konqueror

```
> echo 'export NLSAR_VIEWER=konqueror' >> $HOME/.bashrc
> source $HOME/.bashrc
```

For Mac OS X, you can use

```
> echo 'export NLSAR_VIEWER="open -W"' >> $HOME/.bashrc
> source $HOME/.bashrc
```

- From Matlab:

```
> sarshow(sarimage [, alpha]);
```

The argument `alpha` is the same as for the RGB export.

- From Python:

```
In [1]: nlsartb.sarshow(sarimage [, alpha]);
Out[1]: True
```

The argument `alpha` is the same as for the RGB export.

- From IDL:

```
> sarshow, sarimage [, alpha]
```

The argument `alpha` is the same as for the RGB export.

6 Interfaces for image filtering

6.1 Car filters

NL-SAR Toolbox implements the boxcar, diskcar and gausscar filters. Examples:

- From command line:

```
> sarboxcar file.rat newfile.rat [hW]
```

where `hW` is the half-width of the box (default 1).

- From Matlab:

```
> sarimage_new = sarboxcar(sarimage [, hW]);
```

The arguments are the same as for the command line version.

- From Python:

```
In [1]: sarimage_new = nlsartb.sarboxcar(sarimage [, hW]);
```

The arguments are the same as for the command line version.

- From IDL:

```
> sarimage_new = sarboxcar(sarimage [, hW])
```

The arguments are the same as for the command line version.

- From C:

```
sardata*    sarimage;
sardata*    sarimage_new;
int         hW;

// anything

if (!(sarimage_new = sardata_alloc()))
    // treat error
if (!(sarimage_new = sarboxcar(sarimage, sarimage_new, hW)))
    // treat error

// anything

sardata_free(sarimage_new);
```

6.2 NL-SAR filter

NL-SAR Toolbox implements the NL-SAR filter. Examples:

- From command line:

```
> sarnlsar file.rat newfile.rat L [hW hP verbose noise.rat]
```

where `L` is the equivalent number of look of the input noisy image, `hW` is the radius of the largest search window size (default 12) and `hP` the half-width of the largest patches (default 5). If `verbose` = 1, steps and progressing bars are displayed on the standard output (default 1). `noise.rat` an homogeneous image containing only noise (default iid L looks Wishart)

- From Matlab:

```
> sarimage_new = sarnlsar(sarimage, L [, verbose, hW, hP, sarnoise]);
```

The arguments are the same as for the command line version.

- From Python:

```
In [1]: sarimage_new = nlsartb.sarnlsar(sarimage, L [, verbose, hW, hP, sarnoise])
```

The arguments are the same as for the command line version.

- From IDL:

```
> sarimage_new = sarnlsar(sarimage, L [, verbose, hW, hP, sarnoise])
```

The arguments are the same as for the command line version.

- From C:

```
sardata*    sarimage;
sardata*    sarimage_new;
int         L;
int         nb_optional_args = 2;
int         verbose, hW;

// anything

if (!(sarimage_new = sardata_alloc()))
    // treat error
```

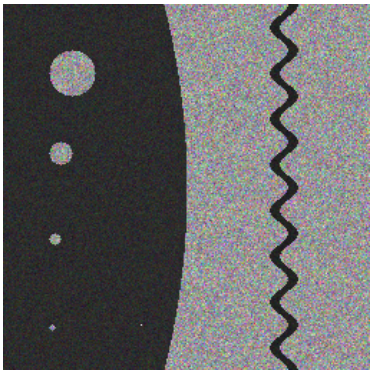
```
if (!(sarimage_new = sarnlsar(sarimage, sarimage_new, L,
                              nb_optional_args, verbose, hW)))
    // treat error

// anything

sardata_free(sarimage_new);
```

The arguments are the same as for the command line version. In this examples only two optionals arguments are given.

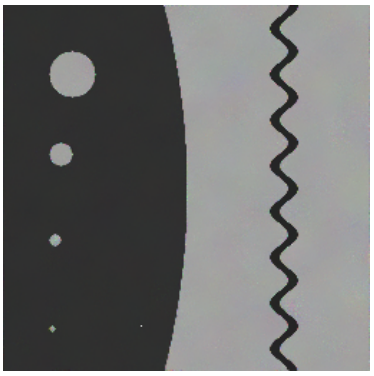
Example

- From command line:

```
# Create a simulated polsar image with 3-looks Wishart speckle
> sarmire example.rat 256 256 3 3
> sarshow example.rat
```



```
# Run the non-local estimation
> sarnlsar example.rat result.rat 3
Load image
Noise analysis
        eta2=0.33 [theoretical=0.33] corr=0.03
        => #scales=3 step=1
Compute similarity statistics
        s=1 hP= 1 mean=9.758588 std=1.576362
        s=1 hP= 5 mean=9.717225 std=0.428879
        s=2 hP= 1 mean=1.118128 std=0.216376
        s=2 hP= 5 mean=1.111482 std=0.064944
        s=3 hP= 1 mean=0.375286 std=0.107277
        s=3 hP= 5 mean=0.374484 std=0.035698
Computation (#proc=1, #windows=1)
|================================================| 100%
Save image
> sarshow result.rat
```



- From other interfaces: See provided examples in directory `examples`.

7 Plugin of the NL-SAR filter for PolSARpro

From PolSARpro, you can run the NL-SAR filter from the menus:

`Process` → `Polarimetric Speckle Filter` → `NLSAR Speckle Filter`.

Note that unlike the interfaces described in the previous function, the PolSARpro plugin does not give you (yet) the possibility to provide an homogeneous image containing only noise to the NL-SAR filter. In this case, the NL-SAR filter will assume that the speckle is described by a L looks Wishart distribution. Performances can then be affected, essentially when speckle is spatially correlated.

This plugin is experimental and as not been tested exhaustively.

8 Frequently asked questions (FAQ)

How can I participate to the development of NL-SAR Toolbox? Send me an email!

Why does Matlab crash with the following message "Invalid MEX-file [...]: undefined symbol: fftwf_cleanup"? Matlab might use its own precompiled version of FFTW3. NL-SAR Toolbox uses the version usually placed in the directory `/usr/lib/`. In order to use the right version, run matlab from command line as follows:

```
LD_PRELOAD=/usr/bin/libfftw3f.so:$LD_PRELOAD matlab
```

Why `mex` compilation failed with message `ld: library not found -lgomp`? Matlab might not use `gcc` to compile `C` programs. To change this behavior, do the following

```
cp <PREFIX_MATLAB>/bin/mexopts.sh $HOME/.matlab/<version>/mexopts.sh
chmod 755 $HOME/.matlab/<version>/mexopts.sh
```

where you replace `<PREFIX_MATLAB>` by the directory where MATLAB is installed and `<version>` by the version identifier (something like `R2013a`). Then edit the file `$HOME/.matlab/<version>/mexopts.sh`. Locate the lines

```
CC='<some compiler>'
```

where `<some compiler>` might be for instance "`xcrun -sdk macosx10.7 clang`" and replace them by

```
CC='gcc'
```

Then rerun compilation.

I've just installed some dependencies (for instance `libfftw3f`) but when I run `./configure` it cannot find it, why? NL-SAR Toolbox uses the command `locate` to find your dependencies. You may need to update your locate database. On Linux run

```
sudo updatedb
```

On Mac OS X run

```
sudo /usr/libexec/locate.updatedb
```

Most of your examples are based on covariance matrices. Could you give an example of using the NL-SAR filter with an image of intensity? Intensity images are particular cases of 1×1 matrices. Hence, every examples with covariance matrices can be used identically with intensity images. File with RAT or XIMA formats can be used for intensity images. A modified PolSARpro format can be used for intensity image with as specific mode `PolarType: pp0`. If you are using another specific format, an alternative is to load your file from Matlab, Python, IDL or C in a single precision floating matrix that you give as an argument to NL-SAR functions. Recall that NL-SAR Toolbox assumes that the content of a scalar image corresponds to intensity values (not the amplitude). You can use `sarjoin` (see Section 5.4) to convert amplitude images to intensity images.

I've exported an intensity image in PolSARpro format from the Next ESA SAR Toolbox (NEST), but NL-SAR Toolbox cannot read it, why? When you export an intensity image from NEST to PolSARpro format, the directory contains a file `config.txt` and `Intensity_HH.bin`. Rename `Intensity_HH.bin` to `C11.bin` and change in the file `config.txt` the field `PolarType` from `pp1` to `pp0`. NL-SAR Toolbox will then read your file successfully, otherwise contact me.

I want to produce interferograms with NL-SAR toolbox but the input and output are images of covariance matrices. What should I do? From a pair of single look complex images (SLC), you can build an image of 2×2 covariance matrix with the command `sarjoin` (see Section 5.4). Then run NL-SAR on this image. After you can retrieve the interferometric phase or coherence (normalized correlation) from the produced image. For instance, you can do the following using Matlab:

```
> insar_phase     = squeeze(angle(sarimage(1,2,:,:)));
> insar_coherence = squeeze(abs(sarimage(1,2,:,:)) ./ ...
                        sqrt(abs(sarimage(1,1,:,:)) .* abs(sarimage(2,2,:,:))));
```

If you moreover assume the same reflectivity (radar cross-section) for each pair of corresponding pixels in both images, the coherence can be refined as

```
> insar_coherence = squeeze(2 * abs(sarimage(1,2,:,:)) ./ ...
                        (abs(sarimage(1,1,:,:)) + abs(sarimage(2,2,:,:))));
```

Look at the matrix dimensions:

```
> size(sarimage)
ans =
     2     2   256   512
> size(insar_phase)
ans =
   256   512
> size(insar_coherence)
ans =
   256   512
```

9 Not documented yet

- `sarnlsar_dispatch` for distributing NL-SAR on a cluster.
- `sarcat` for concatenating files.
- `sarmire` to generate a simulated SAR image with multi-scale structure.
- `sarnoise` to generate an homogeneous SAR image with noise only.