The MasTerEngine

The MasTer toolbox InSAR processor

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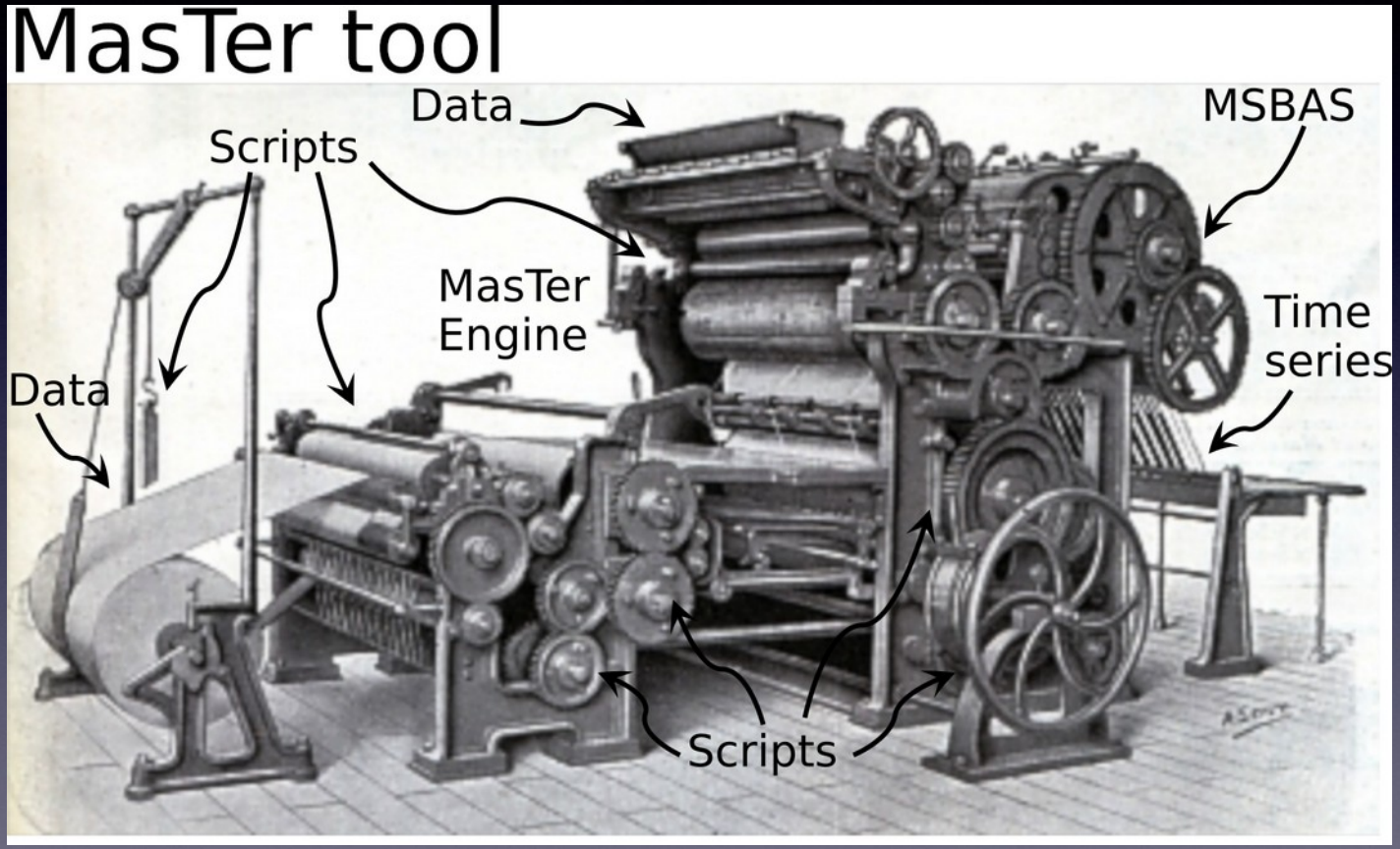
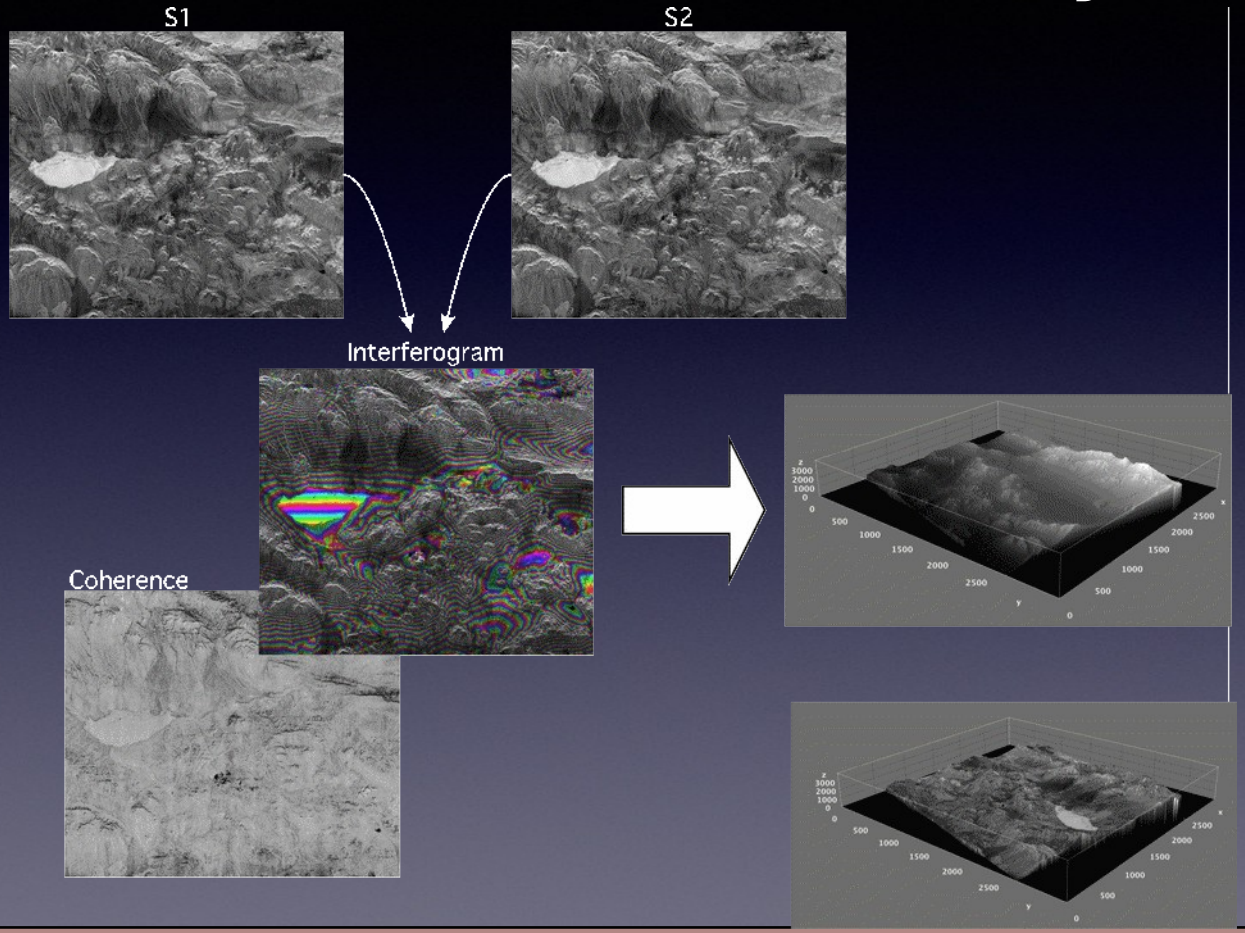
The MasTer toolbox



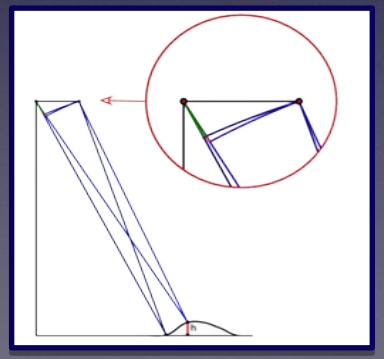
SAR Interferometry

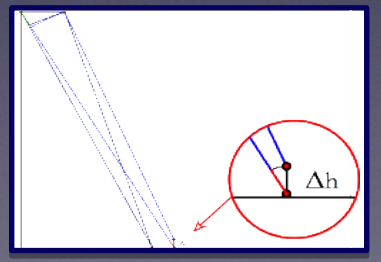


SAR interferometry

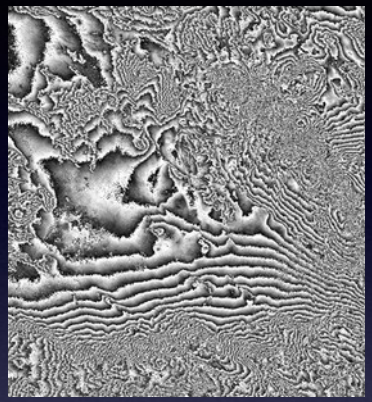
- The interferometric phase contains
  - ☞ The orbital phase
  - ☞ The topographic phase
  - ☞ The atmospheric component
  - ☞ The displacement phase
  - ☞ Noise

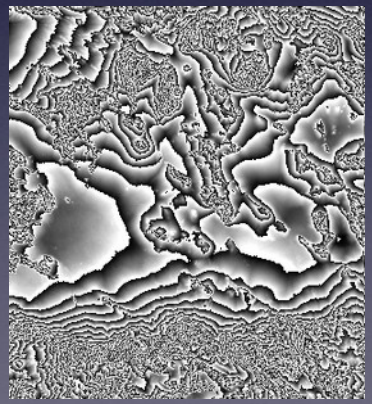
$$\Delta\varphi = \underbrace{\Delta\varphi_{orb} + \Delta\varphi_{topo}}_{geometric} + \underbrace{\Delta\varphi_{atm} + \Delta\varphi_{mov}}_{optical\ path\ variations} + \ldots + \underbrace{\epsilon\Delta\varphi}_{noise}$$

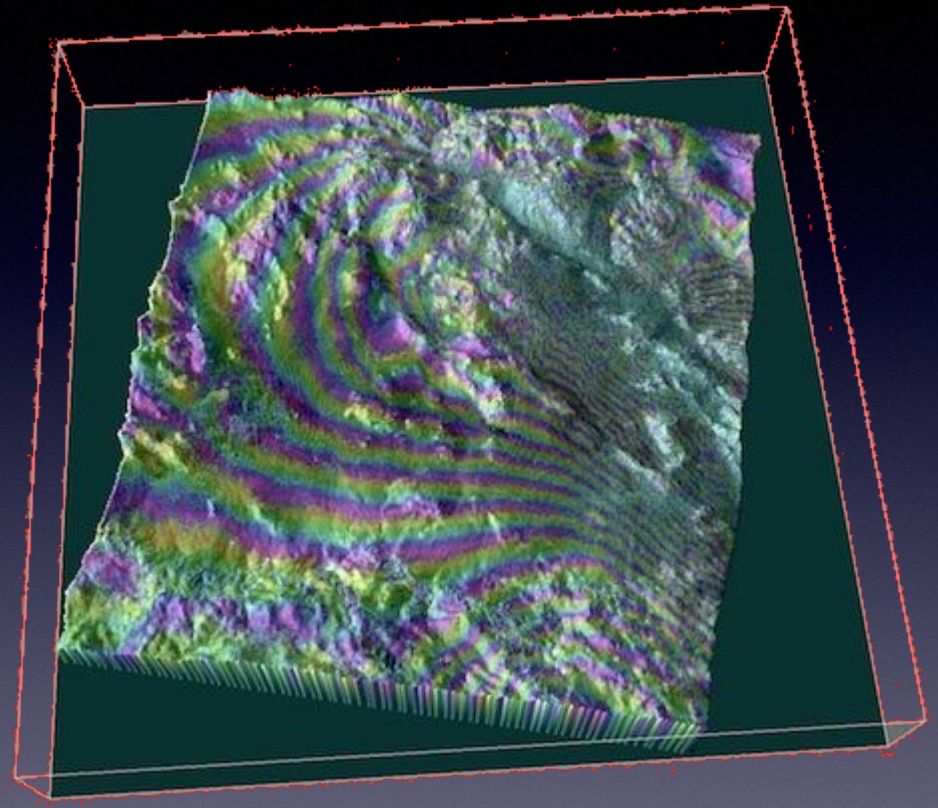




SAR differential interferometry

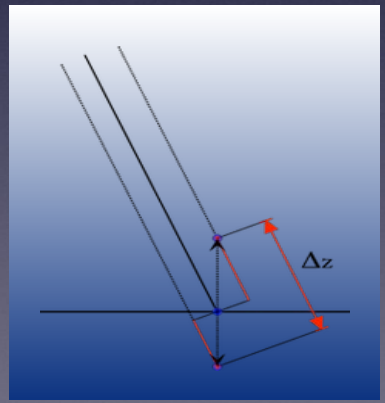




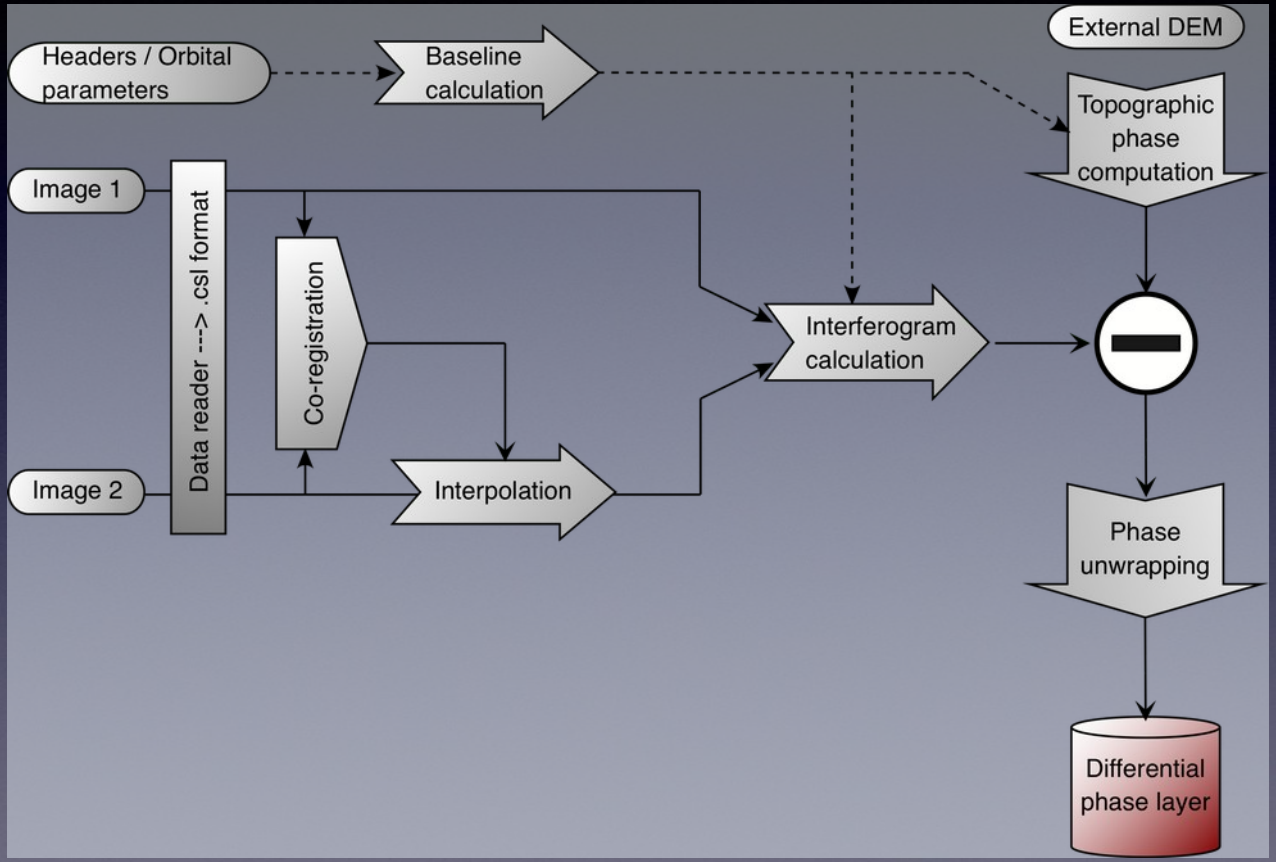


Landers earthquake - 1992

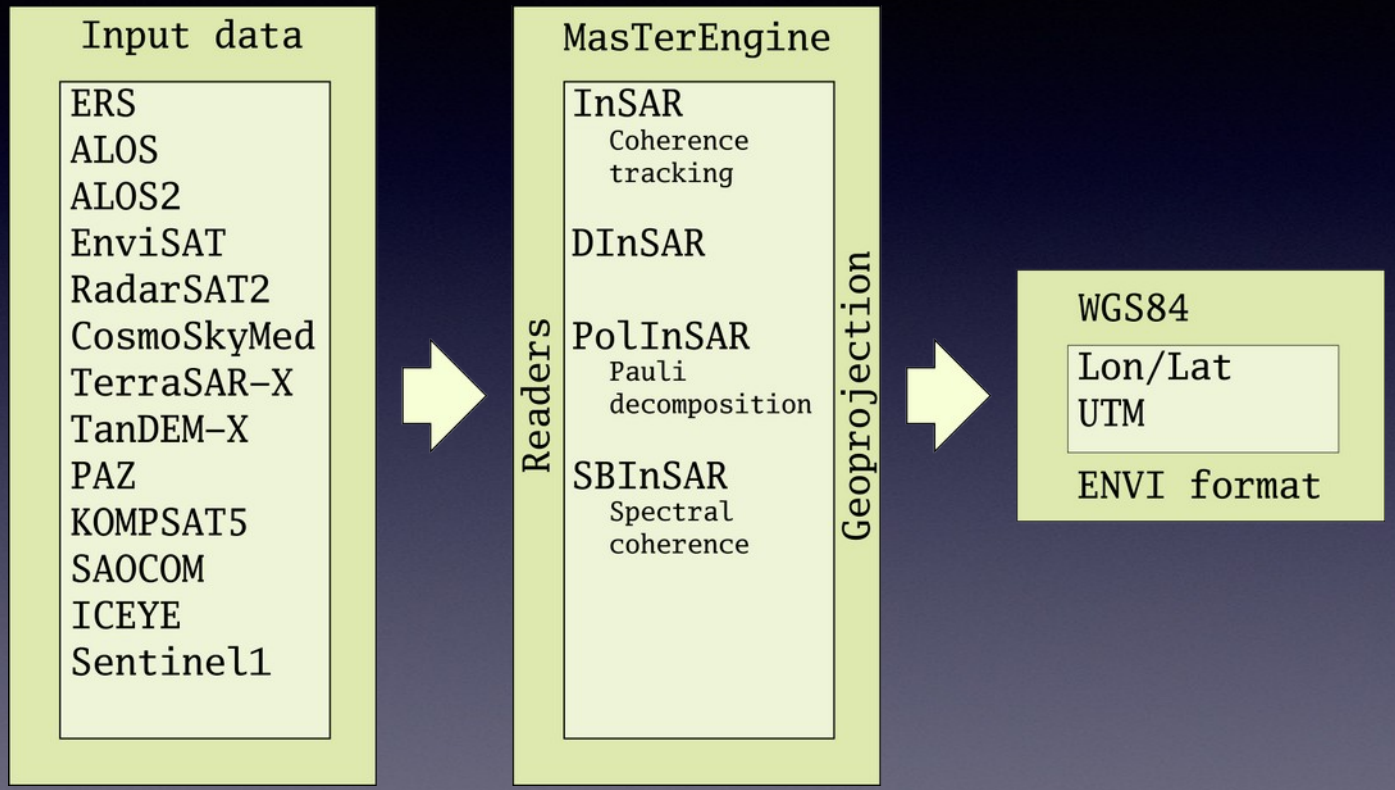
© "Robert A. Eplett/CAL EMA"
California Governor's Office of Emergency Services



DInSAR processing flow chart



The MasTerEngine



MasTerEngine

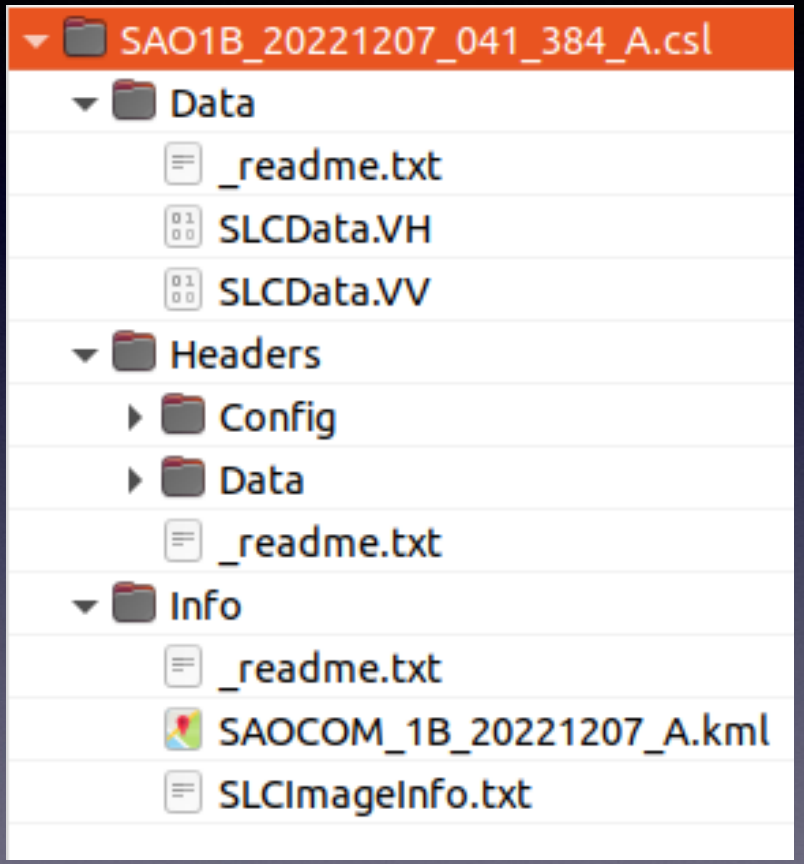
- Command line processor integrally written in C
- Use text parameters files as interfaces
  - ☞ Parameters files are formed with “key –values” pairs structures.
  - ☞ Parameter comes first and is followed by the key in the forme of a C comment /* *the key* */
- If launched with parameter -h, most of the command displays a short help.
- If launched from the working directory most of the command finds the required parameter file.

Data readers

- Bulk reading implementation for EnviSAT, CosmoSkymed, TerraSAR-X, SAOCOM, ICEYE and Sentinel.
- TSX: mono-static, bi-static and pursuit mode reading are considered.
- Sentinel 1: a .kml file delimiting area of interest by a polygon can be given in input to force reading only bursts of interest and automatically stitch frames if required

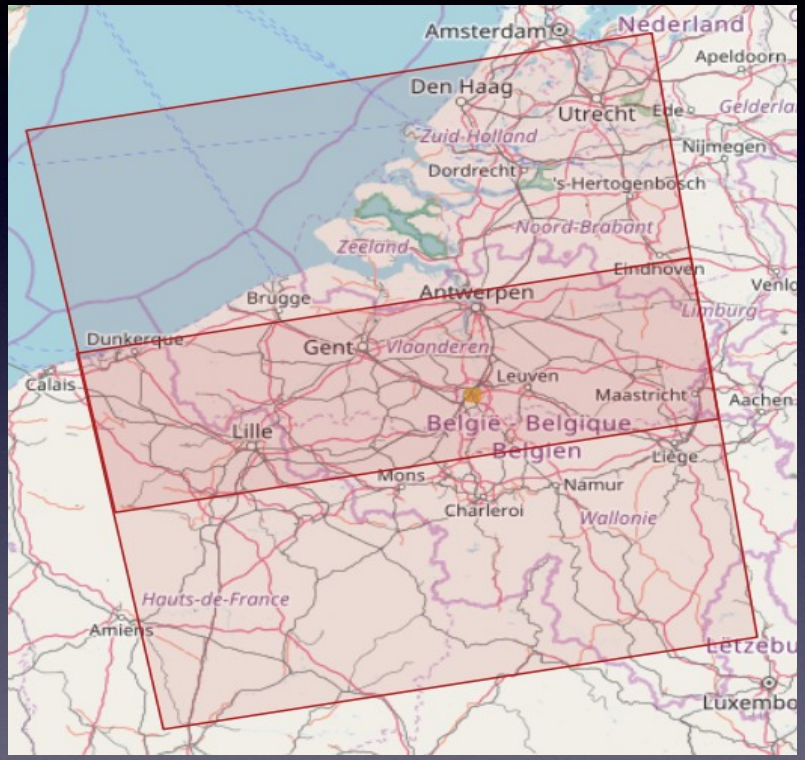
.csl data format

- Command line:
  - ERSDataReader
  - EnviSATDataReader
  - ALOSDataReader
  - RSATDataReader
  - CSKDataReader
  - TSXDataReader
  - SAOCOMDataReader
  - ICEYEDataReader
  - S1DataReader



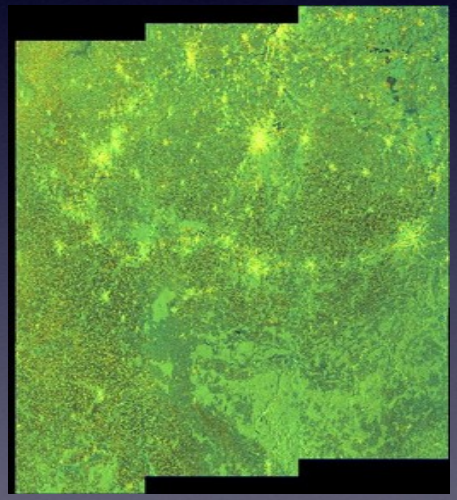
Automatic S1 burst selection

- Example for Brussels
  - ☞ S1 A/B Interferometric pair of 31 of August and 6 of September 2017
  - ☞ Remark: Frequent shift between S1A and S1B

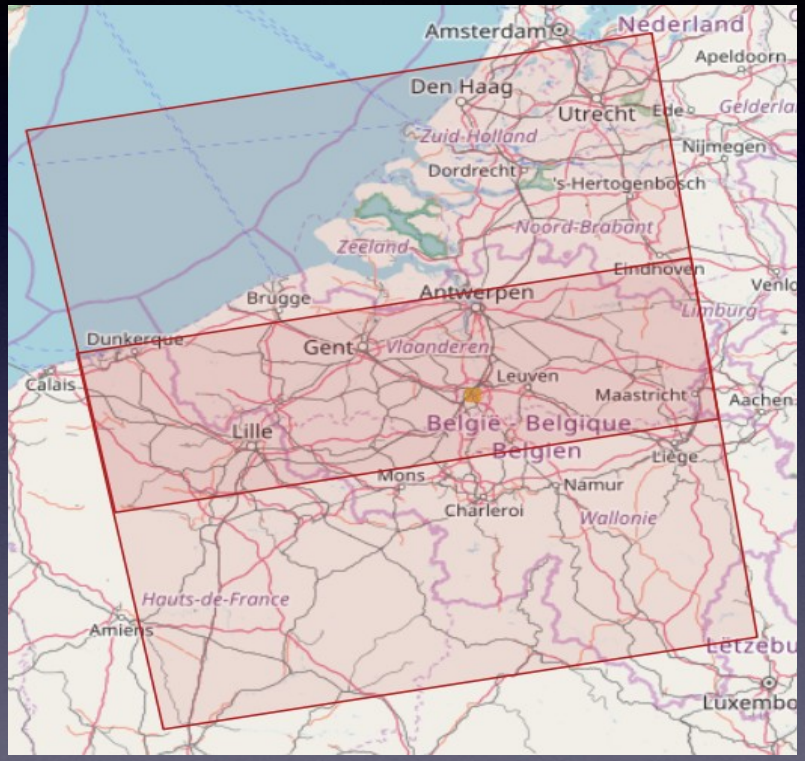


Automatic S1 burst selection

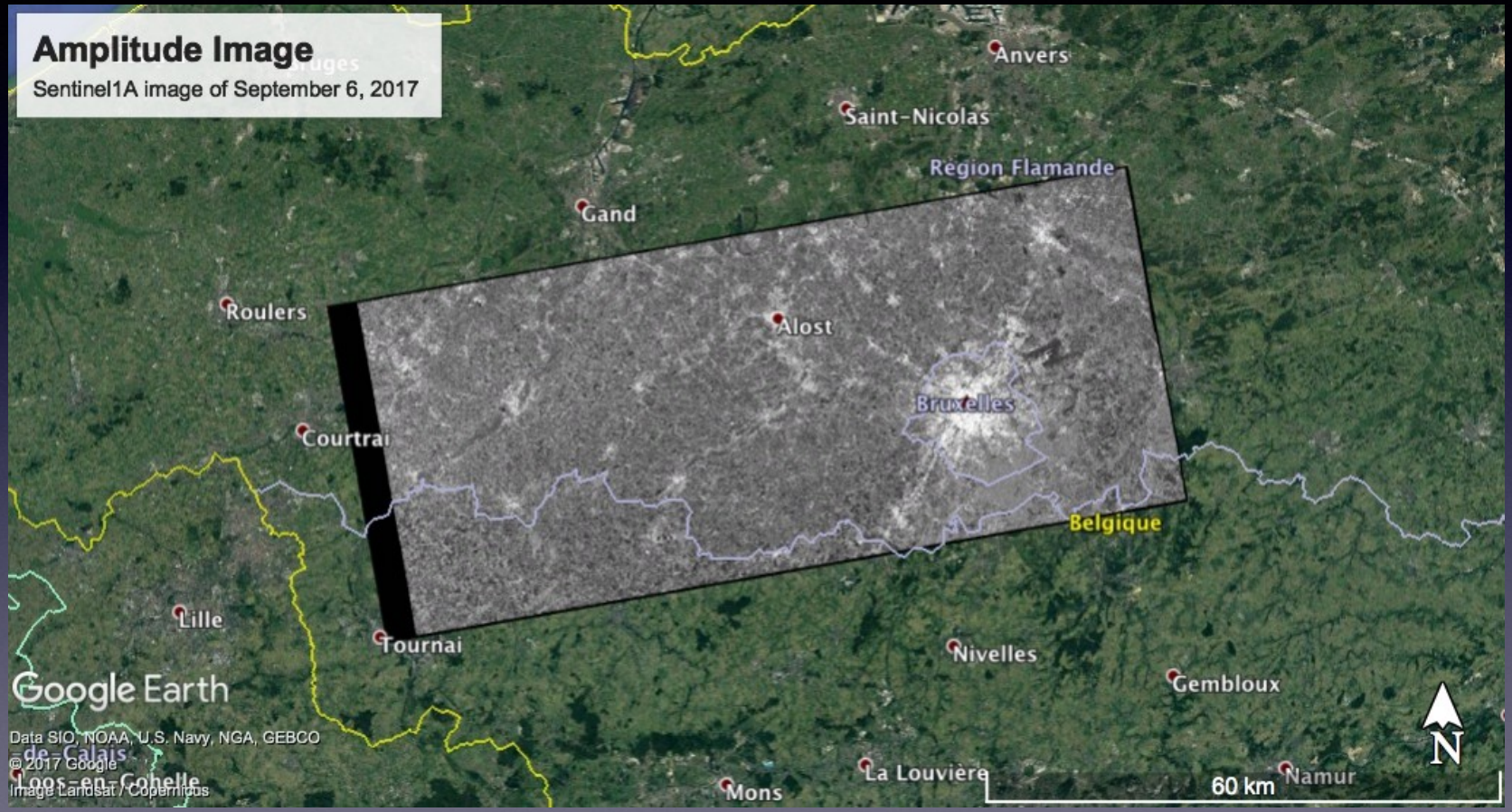
S1A



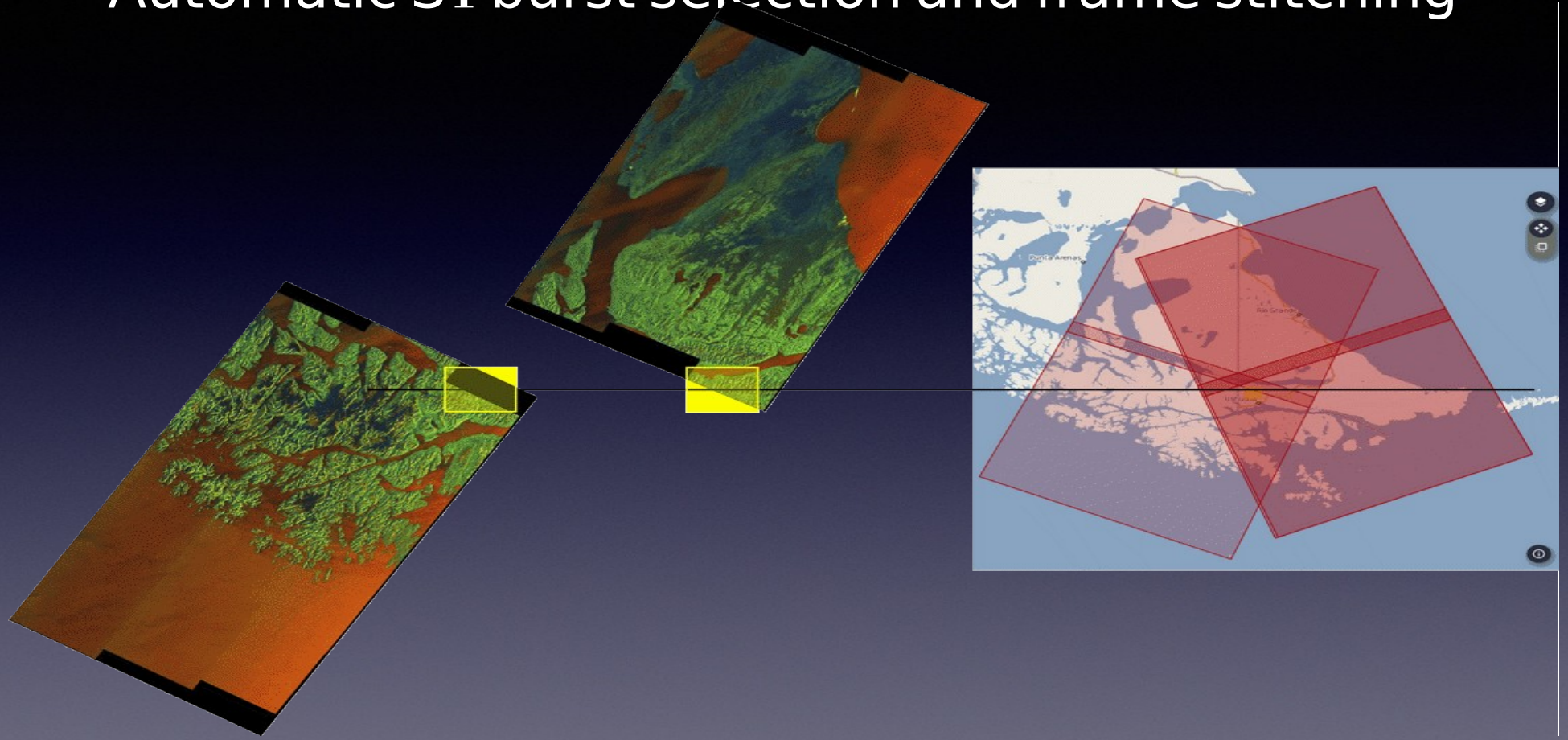
S1B



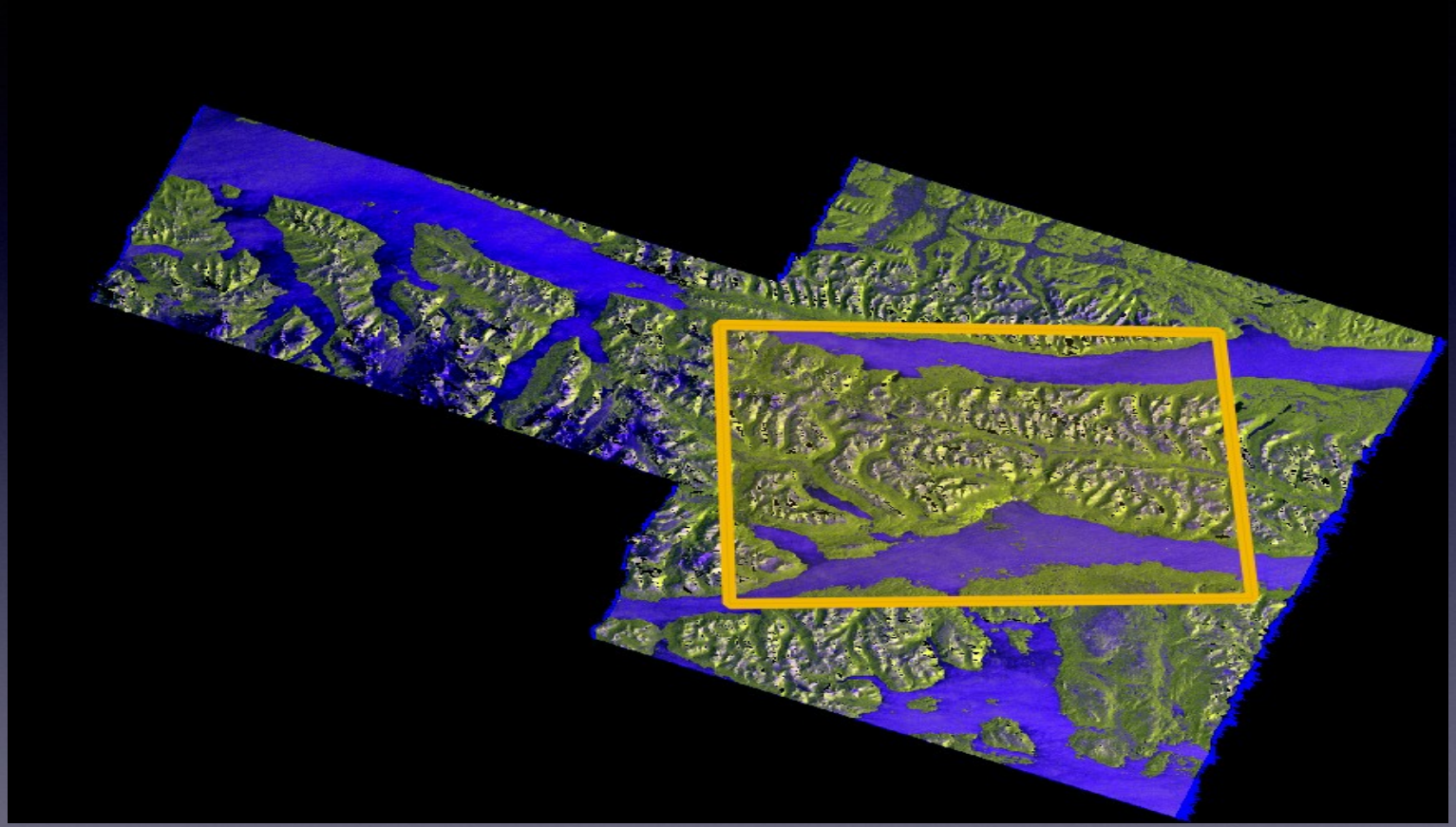
Automatic S1 burst selection



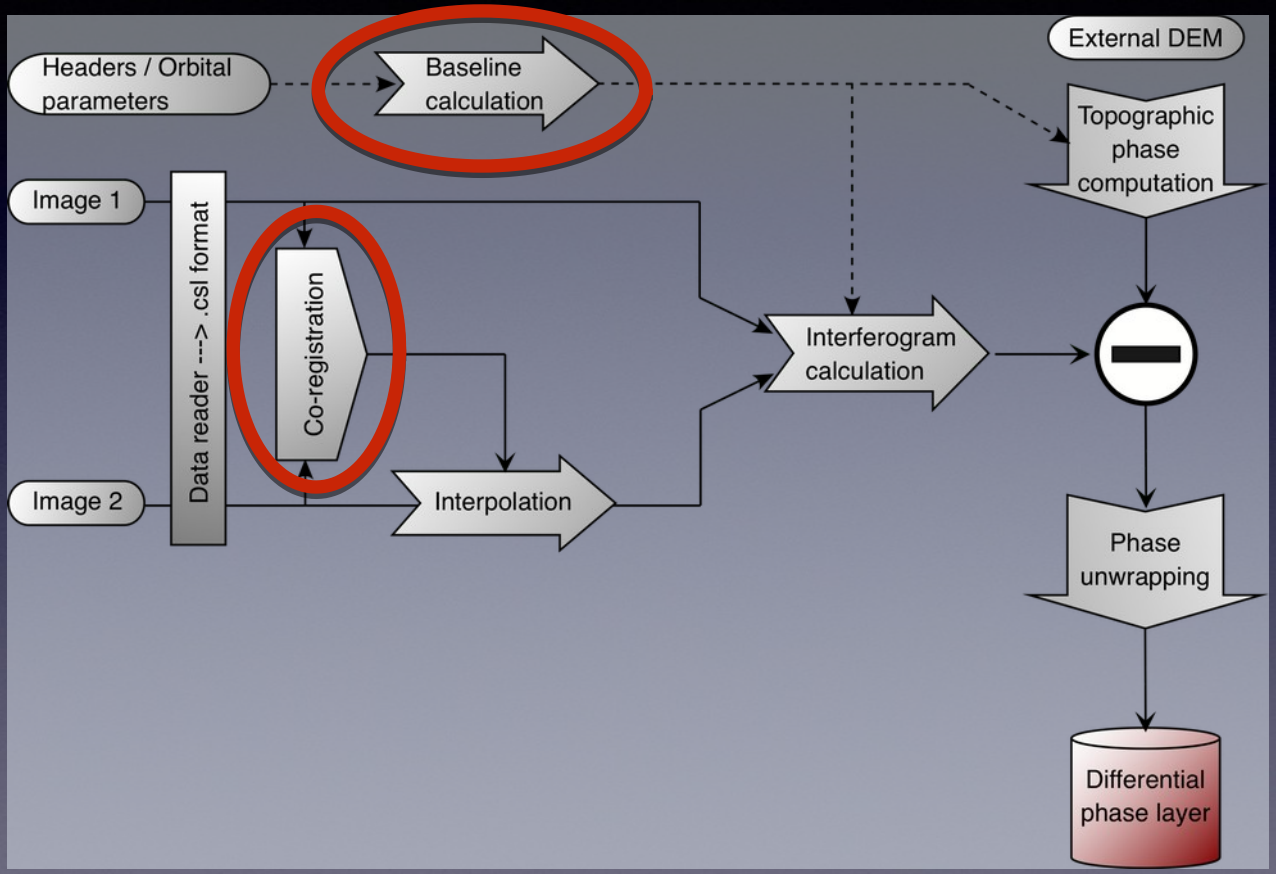
Automatic S1 burst selection and frame stitching



Automatic S1 burst selection and frame stitching



MasTerEngine specificities

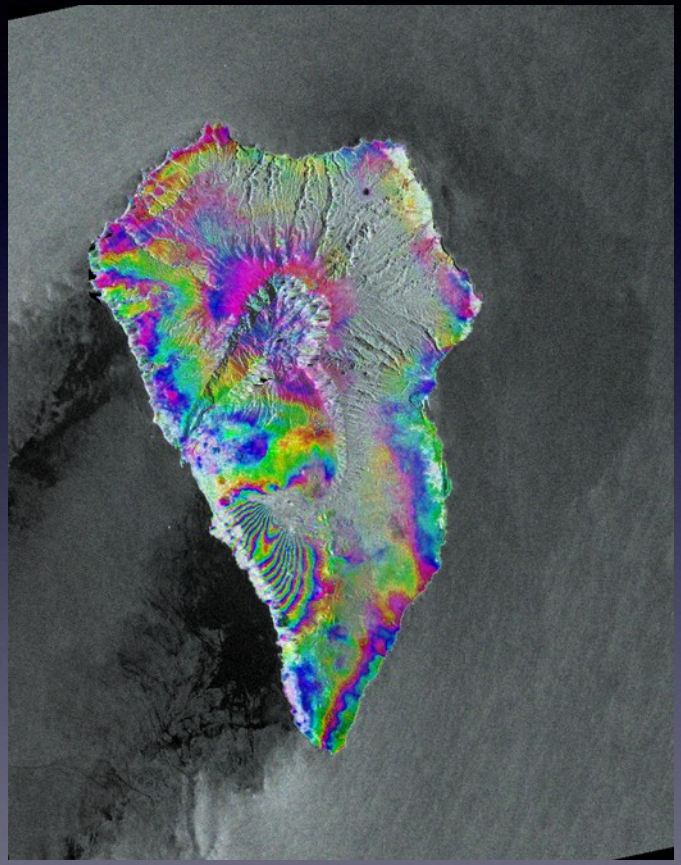


Precise orbit management

- InSAR suite:
  - ☞ Precise orbit management for EnviSAT and Sentinel
  - ☞ Precise calculation of both baseline and co-registration transform based on orbitography.
  - ✓ EnviSAT: Precise orbits lead to quasi immediate co-registration
  - ✓ Sentinel: Precise orbits lead to perfect burst co-registration.
    - ▸ No need of Extended Spectral Diversity (ESD) ultra fine co-registration.

Sentinel 1 precise orbit management example

- Automatic DinSAR processing of La Palma earthquake



External DEM management

- Command line: slantRangeDEM
  - ☞ Use an external DEM provided in ENVI format or as assambled SRTM tiles.
  - ☞ Associate this DEM with the considered master image
  - ☞ Project this external DEM into the slant range geometry of the master image.
  - ✓ Reference slant range DEM is saved within master image strucutre.

InSAR initialisation

- Command line: initInSAR

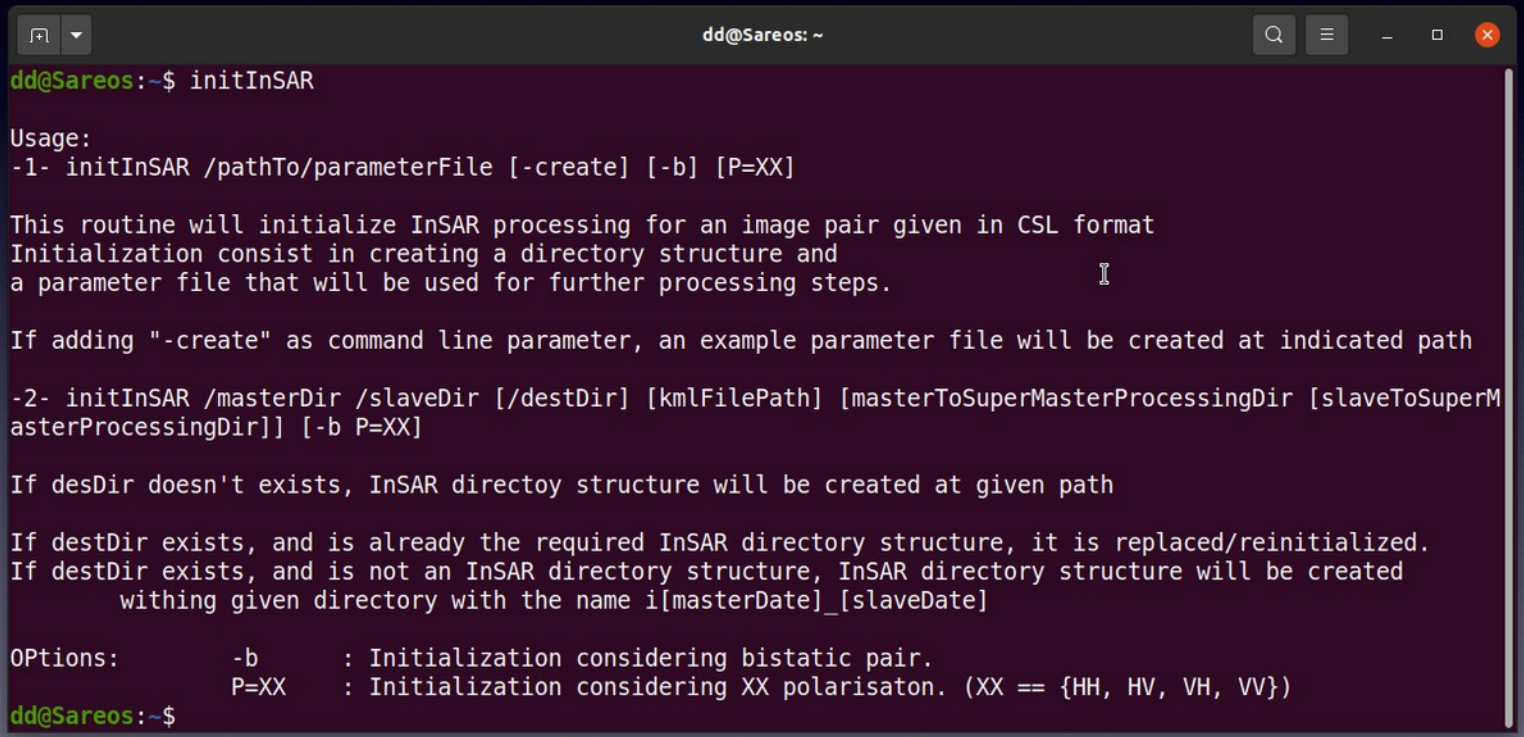
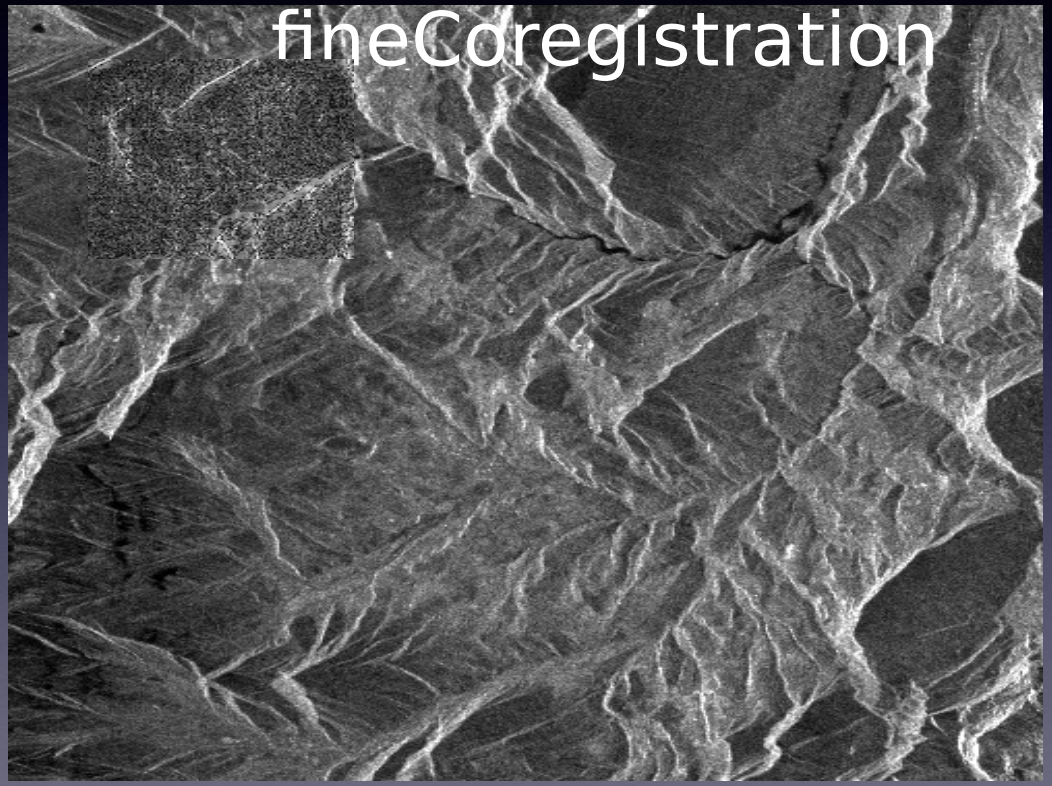
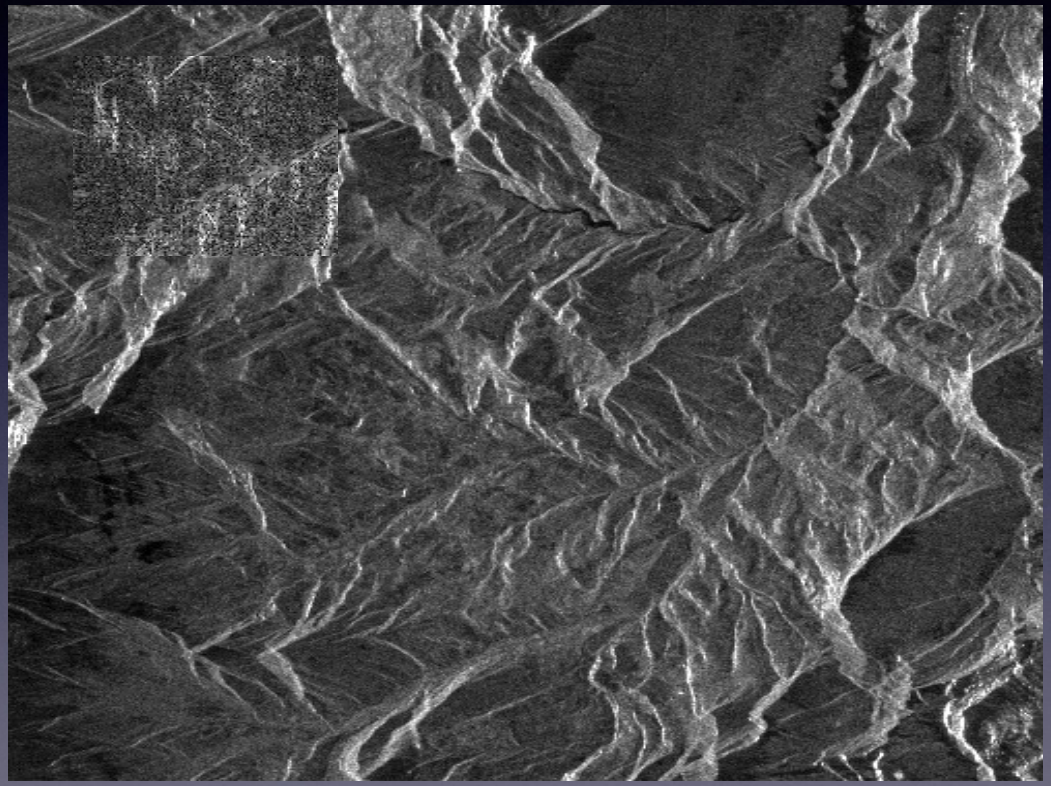


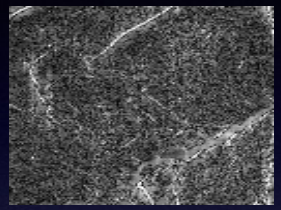
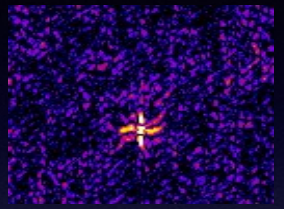
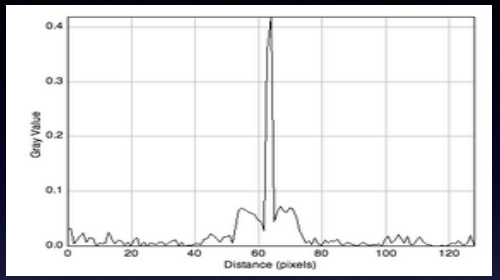
Image coregistration

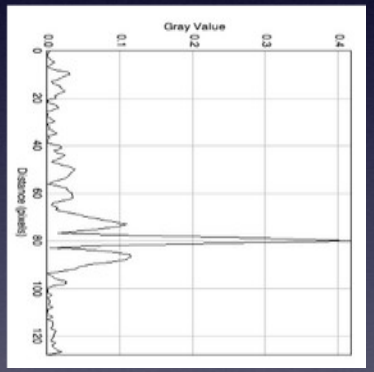
- Command line: coarseCoregistration / fineCoregistration





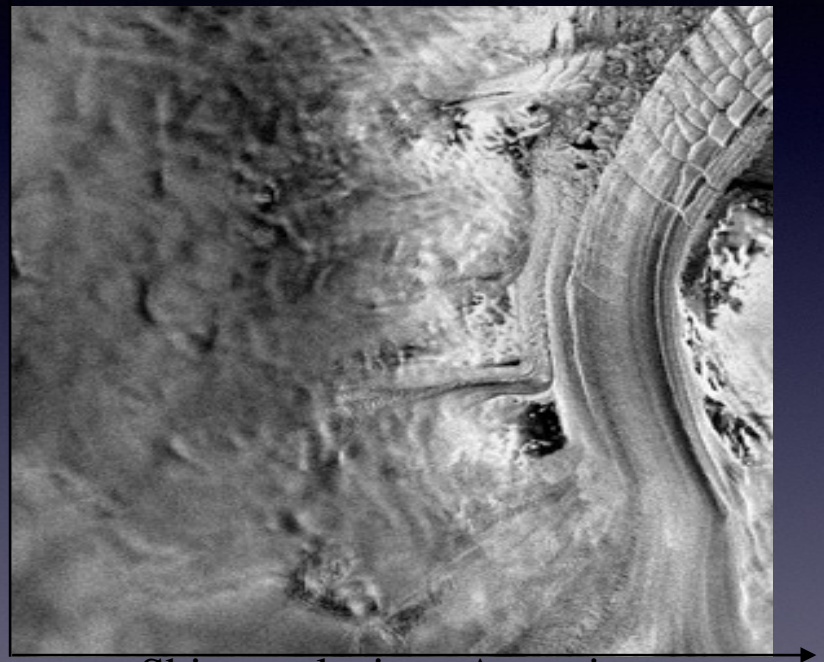
Images co-registration

- 



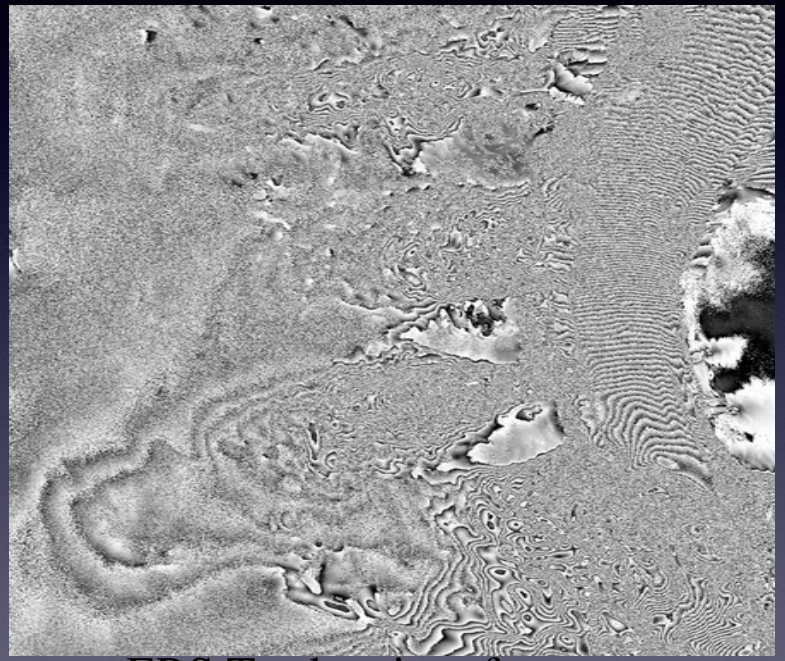


- Local co-registration results may be used to track locally the shift leading to the best coherence

Coherence tracking



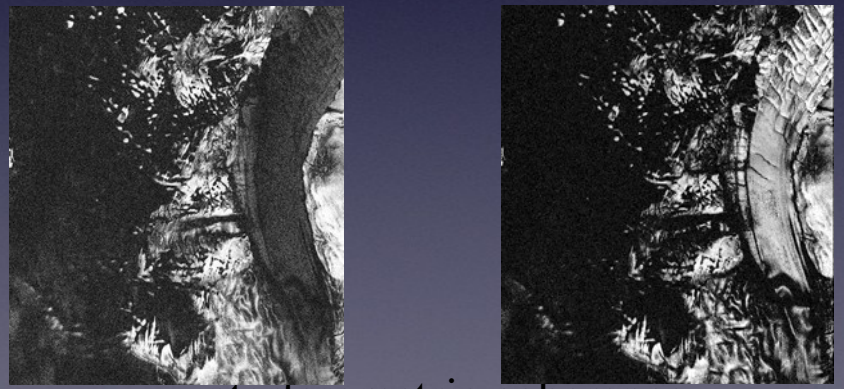
Shirase glacier - Antartica
June 2, 1996



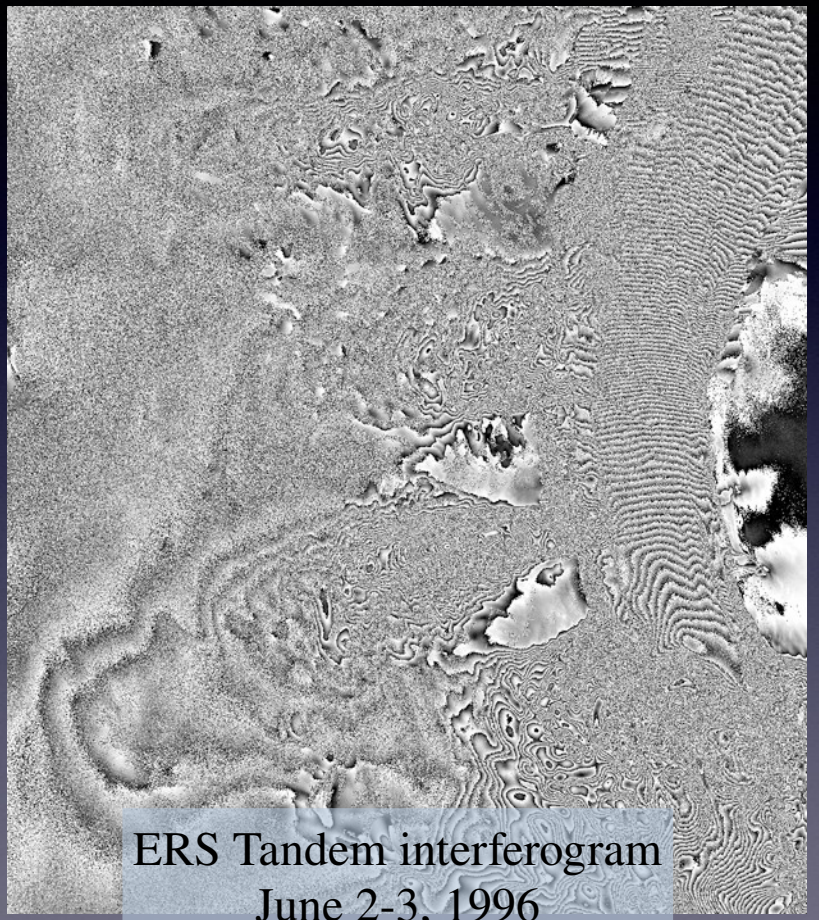
ERS Tandem interferogram
June 2-3, 1996

Coherence tracking

- Differential interferometry allows measuring the line of sight displacement component.
  - ☞ The azimutal component of the displacement may be estimated using coherence tracking

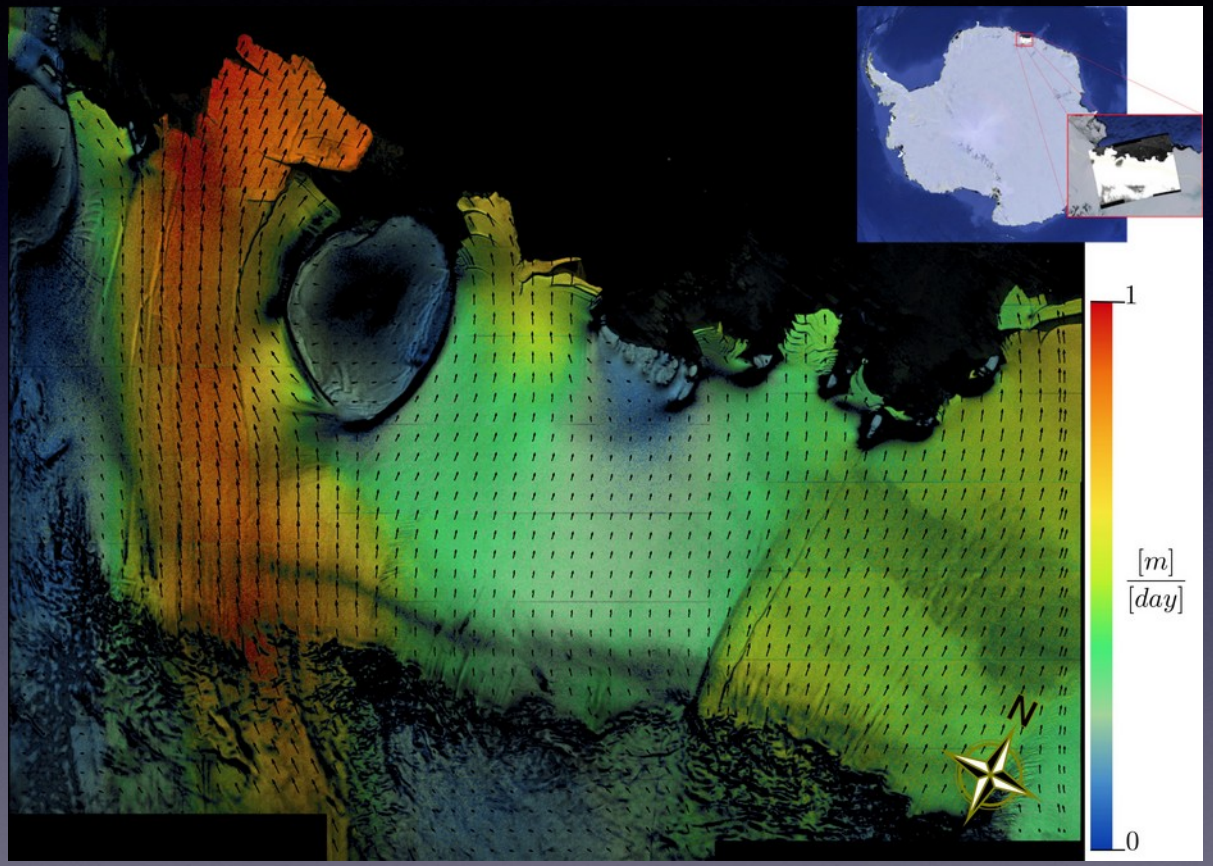


interferometric coherence
ERS Tandem June 2-3, 1996



ERS Tandem interferogram
June 2-3, 1996

Coherence tracking with S1

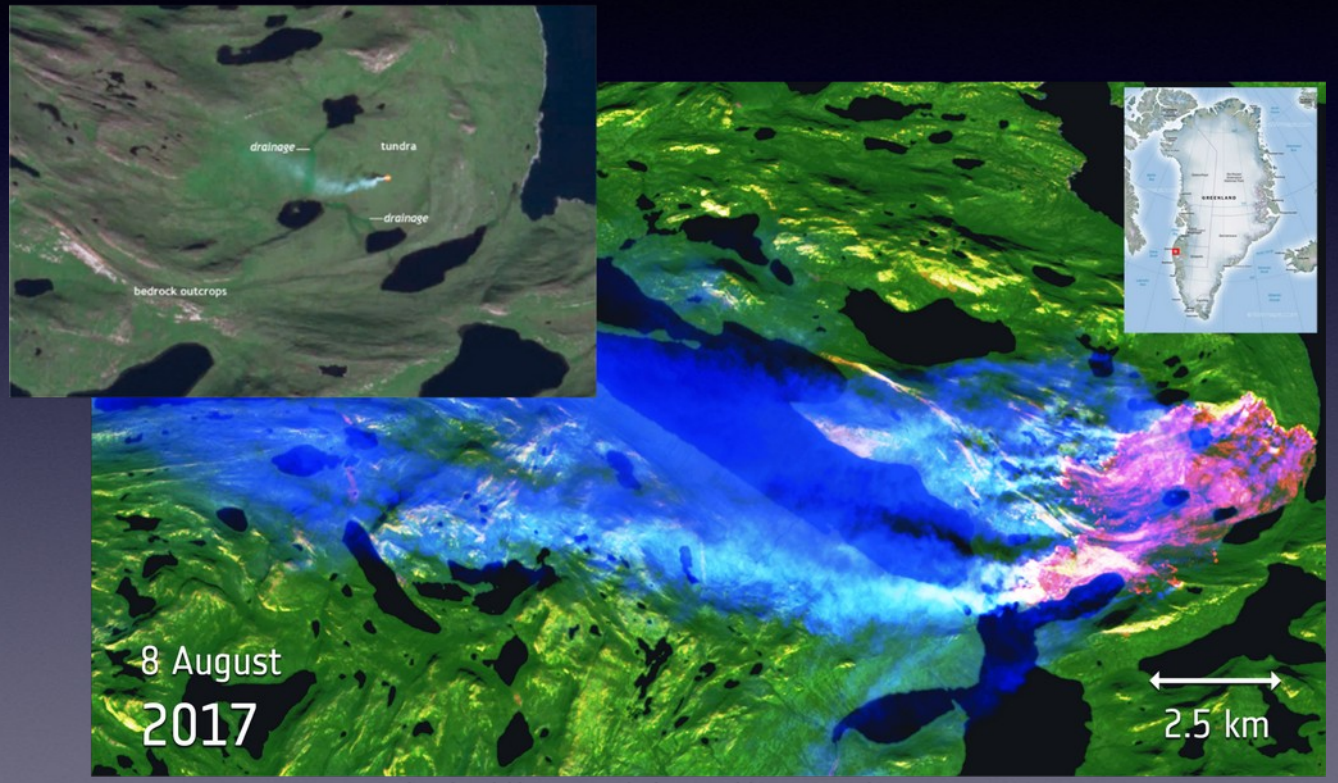


S1 Recent application: Coherence monitoring

- Greenland wildfire
  - ☞ First observed on July 31, 2017

Coherence monitoring

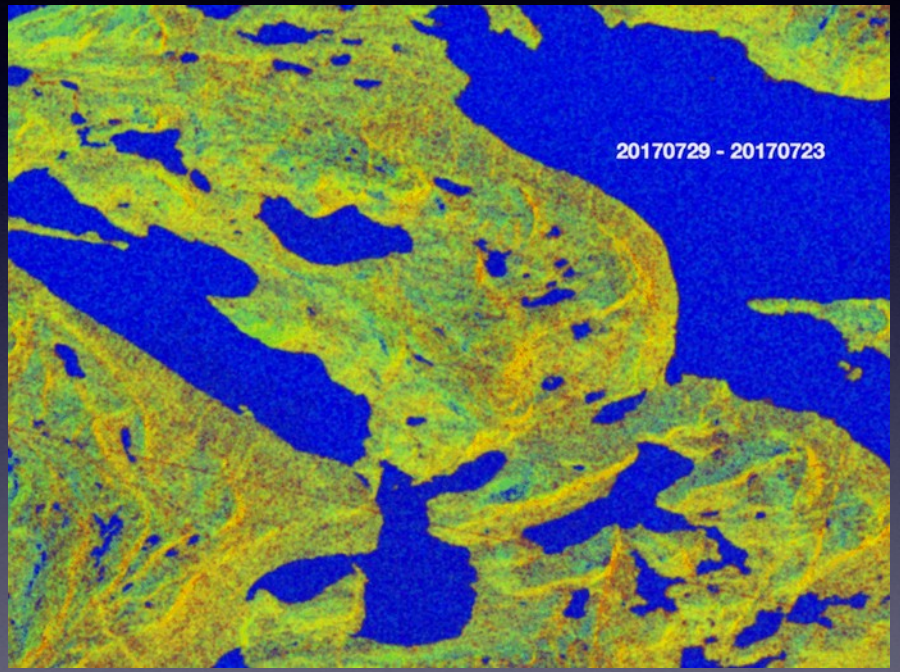
- Greenland wildfire - Sentinel2 observation



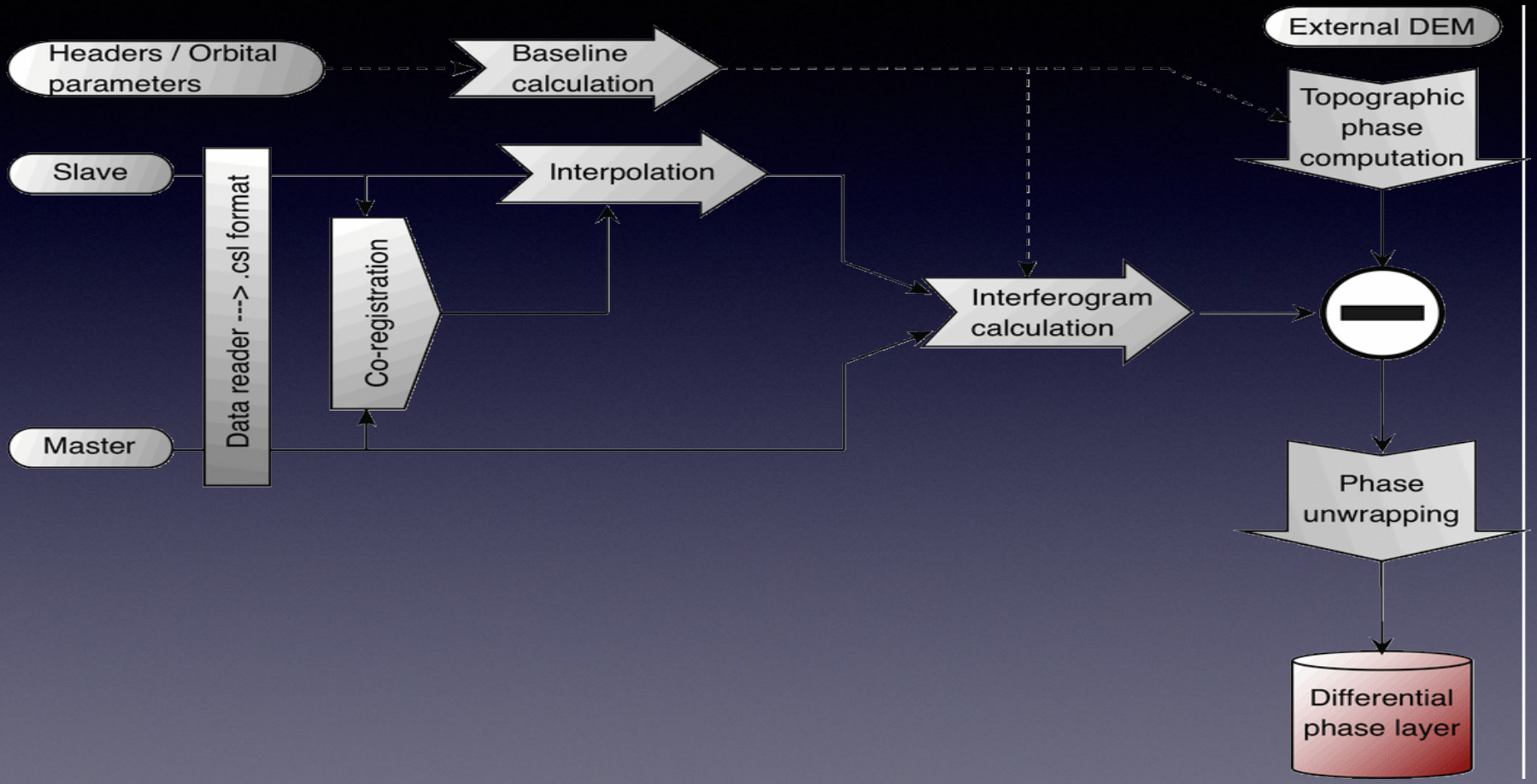
Greenland wildfire extend observed by Sentinel2 - August 8, 2017

Coherence monitoring

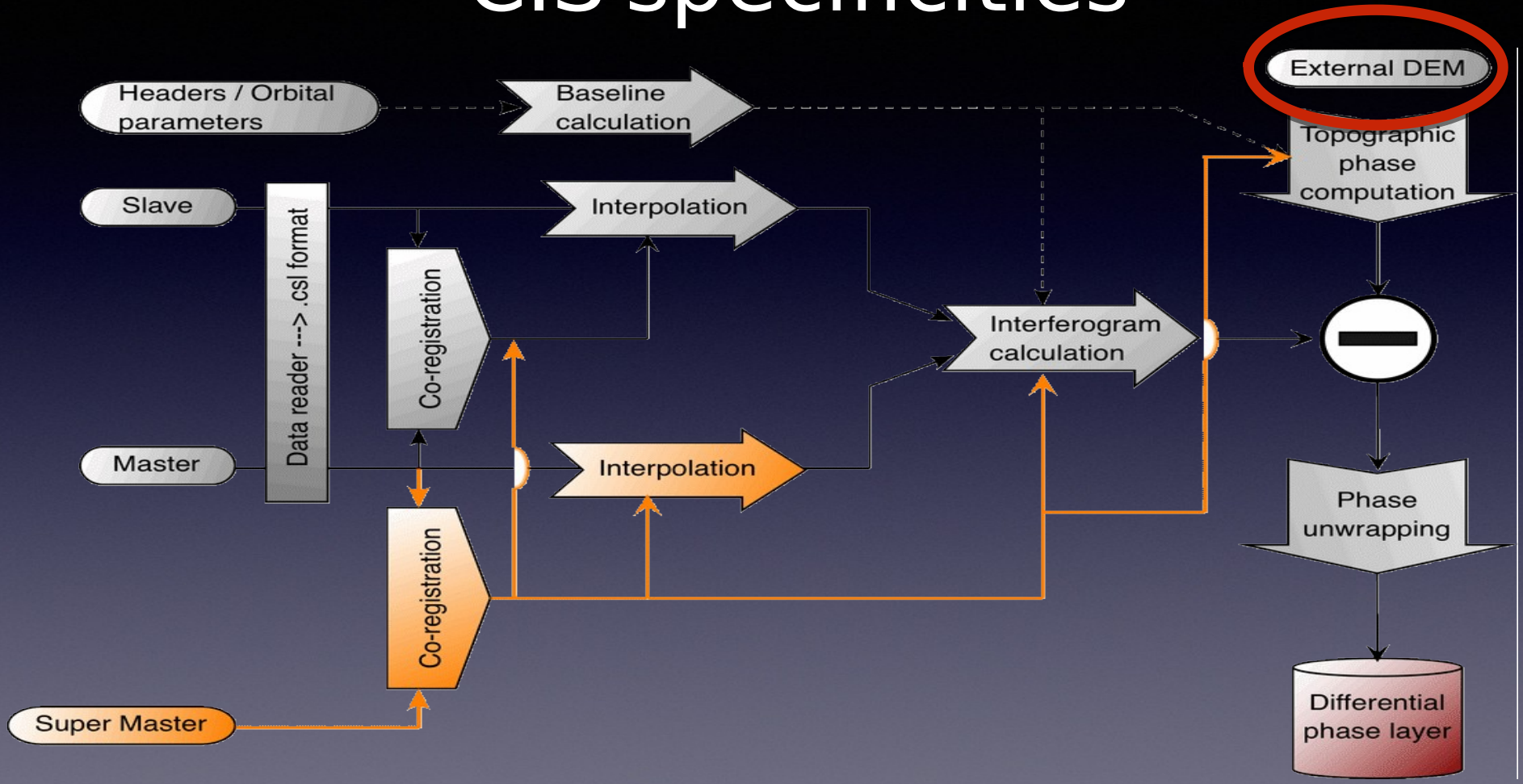
- Greenland wildfire - Sentinel1 observations
  - ☞ Fire extension monitoring using 6-days Sentinel1A - Sentinel1B coherence layers



CIS specificities



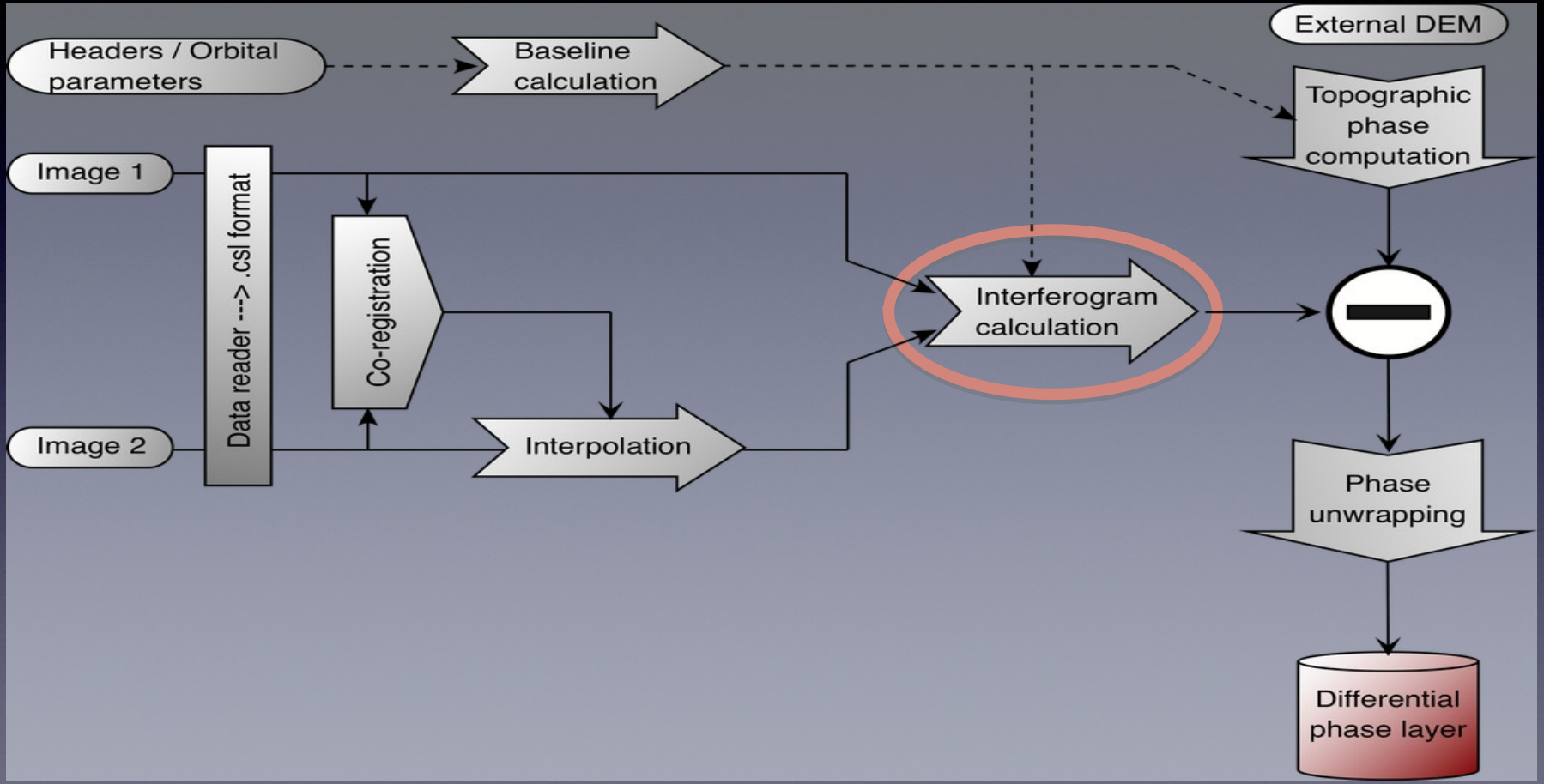
CIS specificities



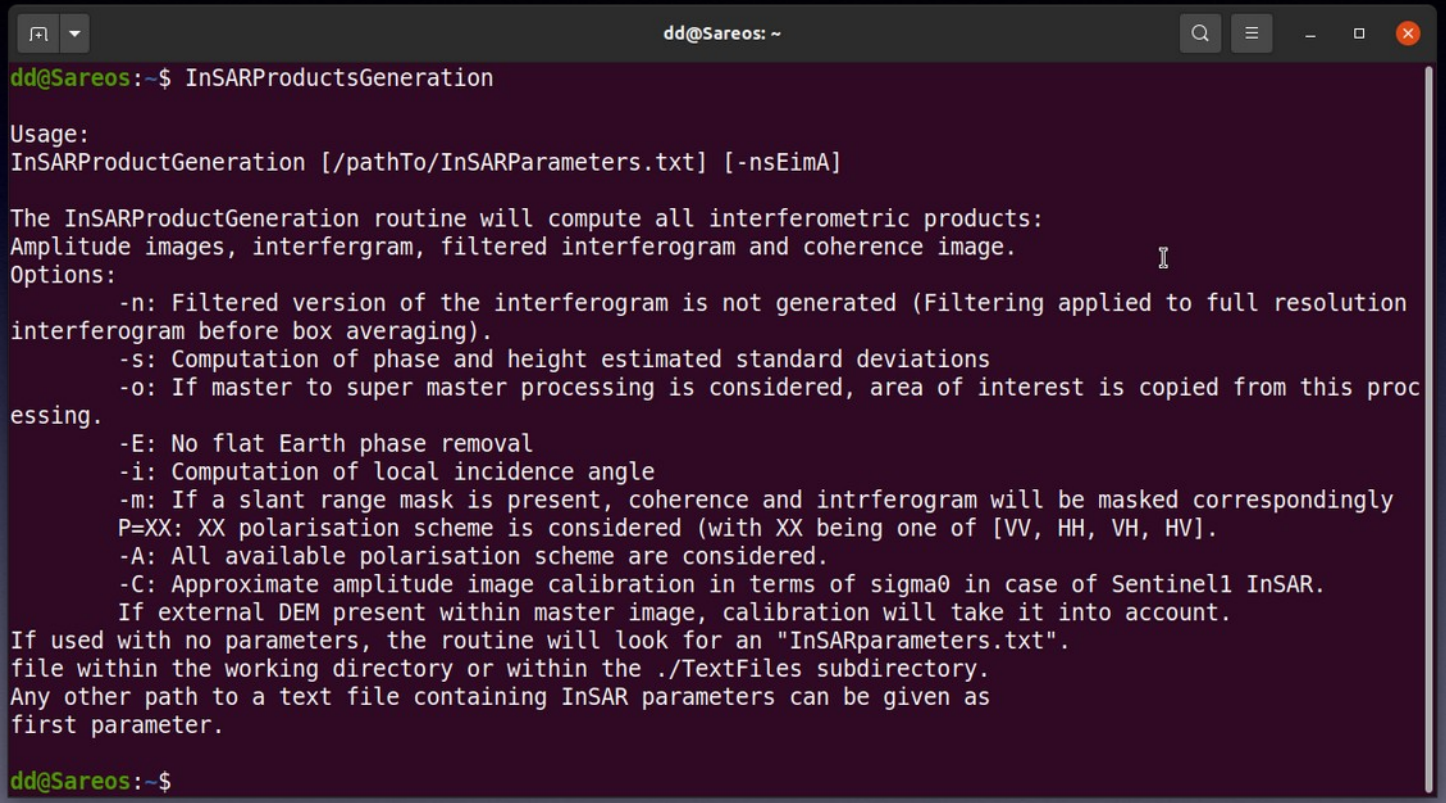
MasTerEngine specificities

- External DEM management:
  - ☞ An external DEM can be associated to the (super) master image
  - ✓ DEM provided in SRTM or ENVI format
- Mask management
  - ☞ In the same way, an mask provided in ENVI format may be provided and associated to the super master to perform all subsequent processing only on the predefined area
  - ✓ Objective: limit and speed up processing

MasTerEngine specificities



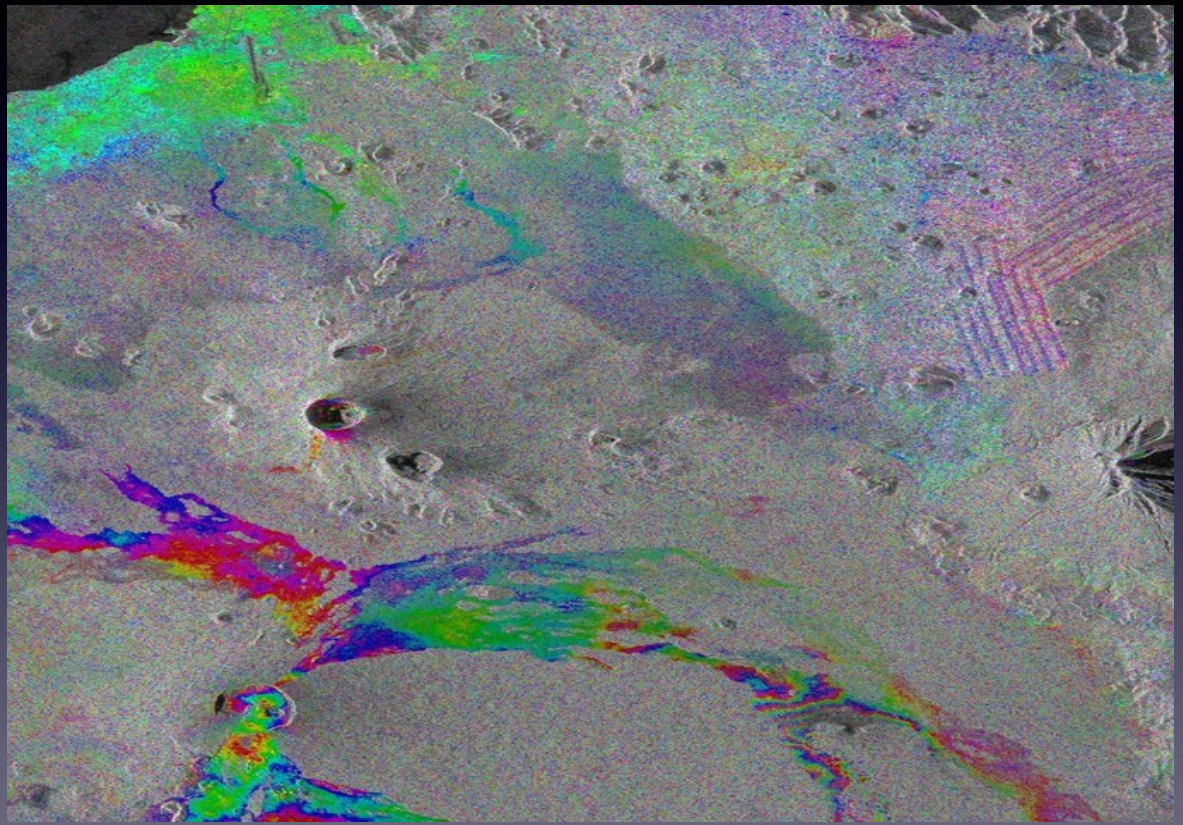
InSAR products calculation



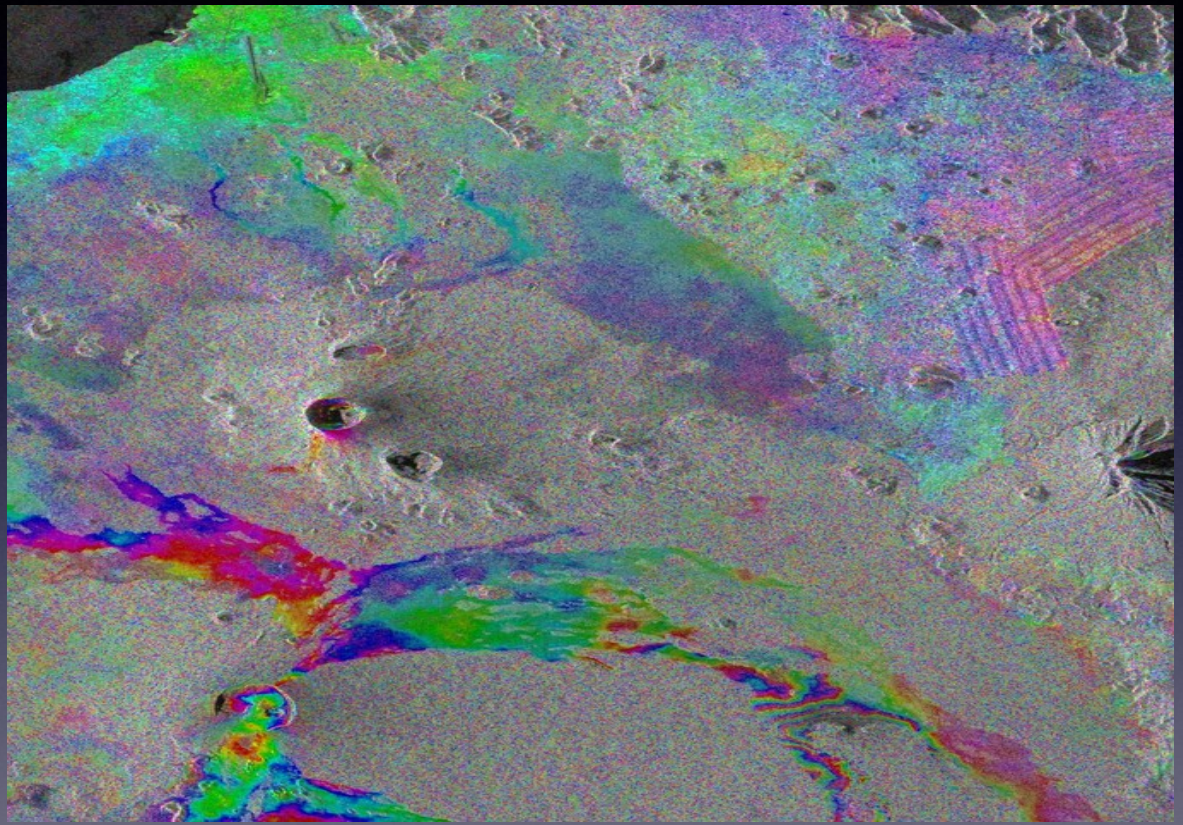
Filtering

- Command line: interferogramFiltering
- Two filters available:
  - ☞ Adaptative filtering
  - ✓ Goldstein based filtering
  - ☞ Home made:
  - ✓ Gaussian filter of the complex components of the interferogram

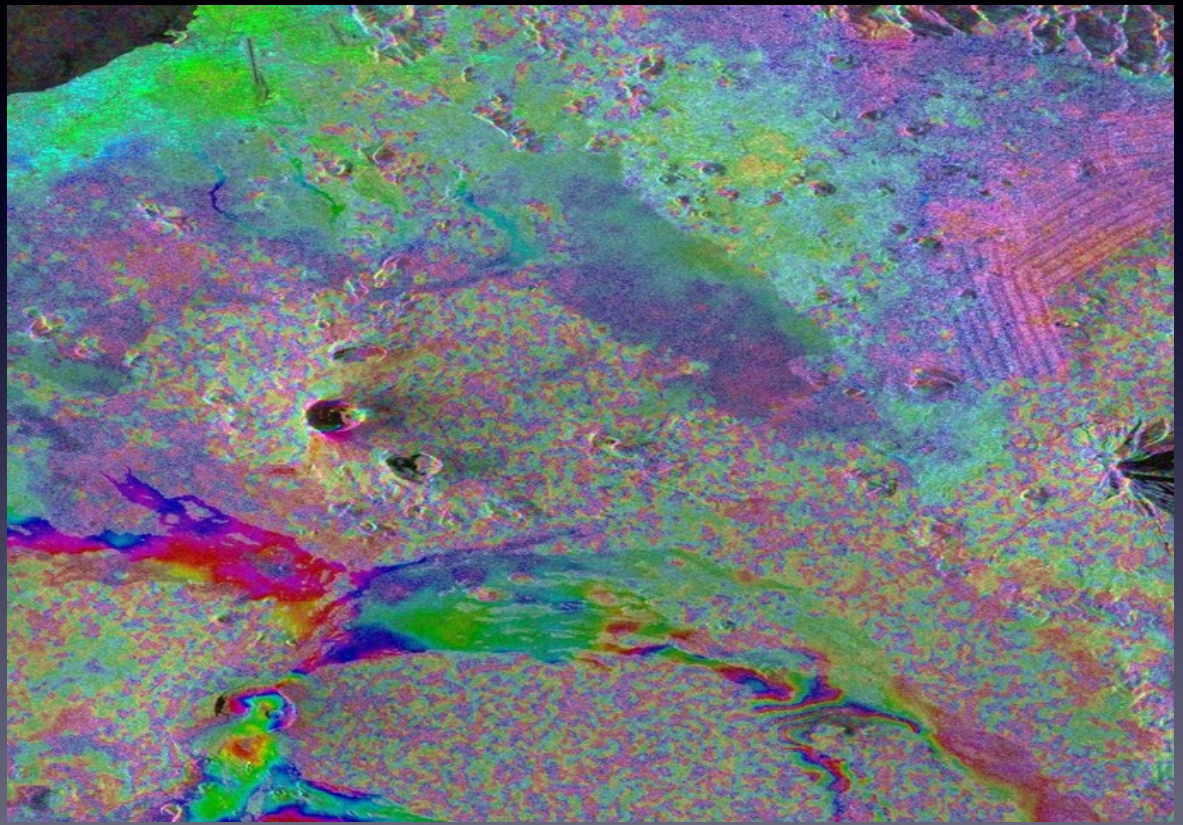
Adaptative filtering



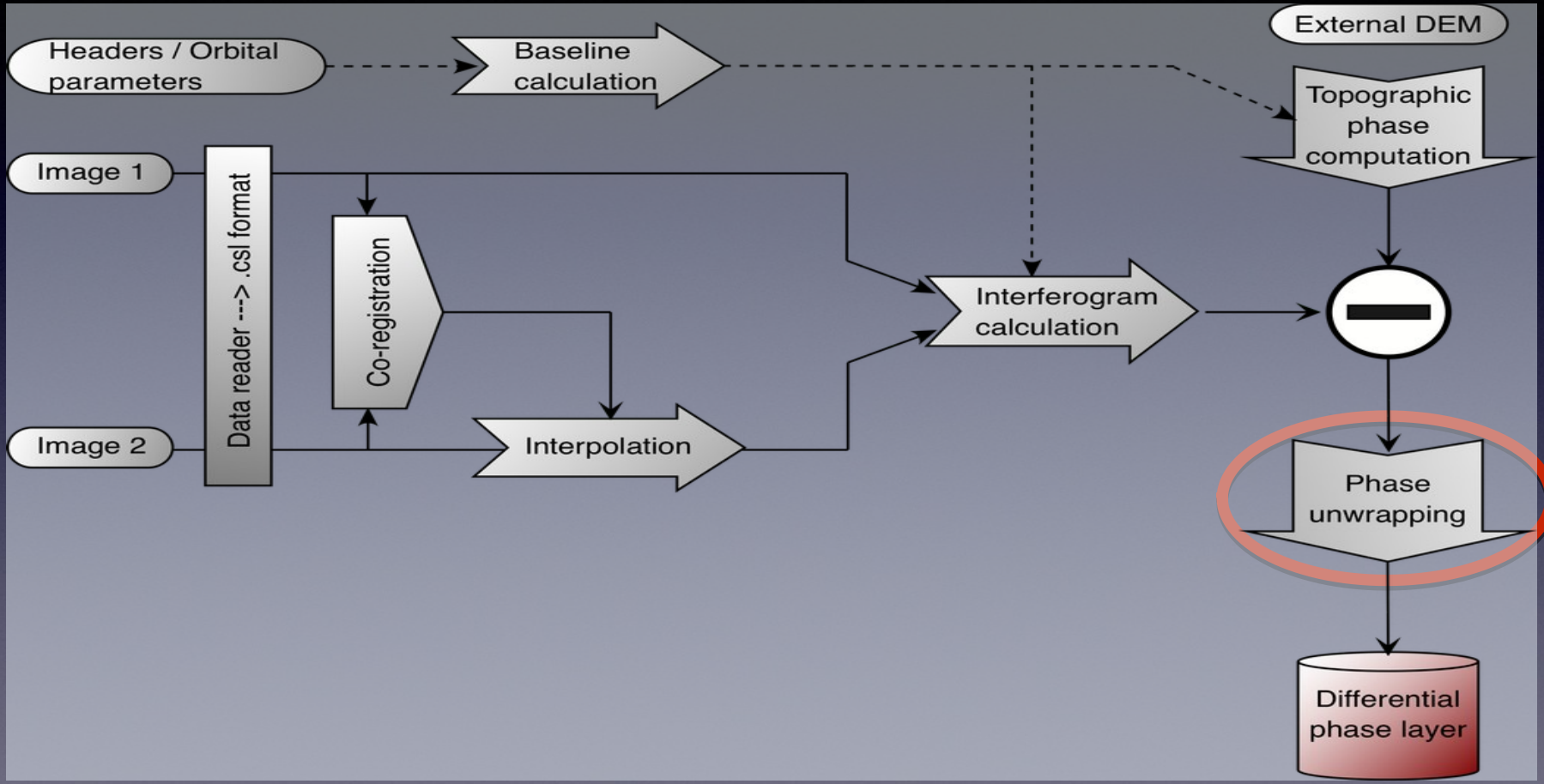
Adaptative filtering



Combined filtering...



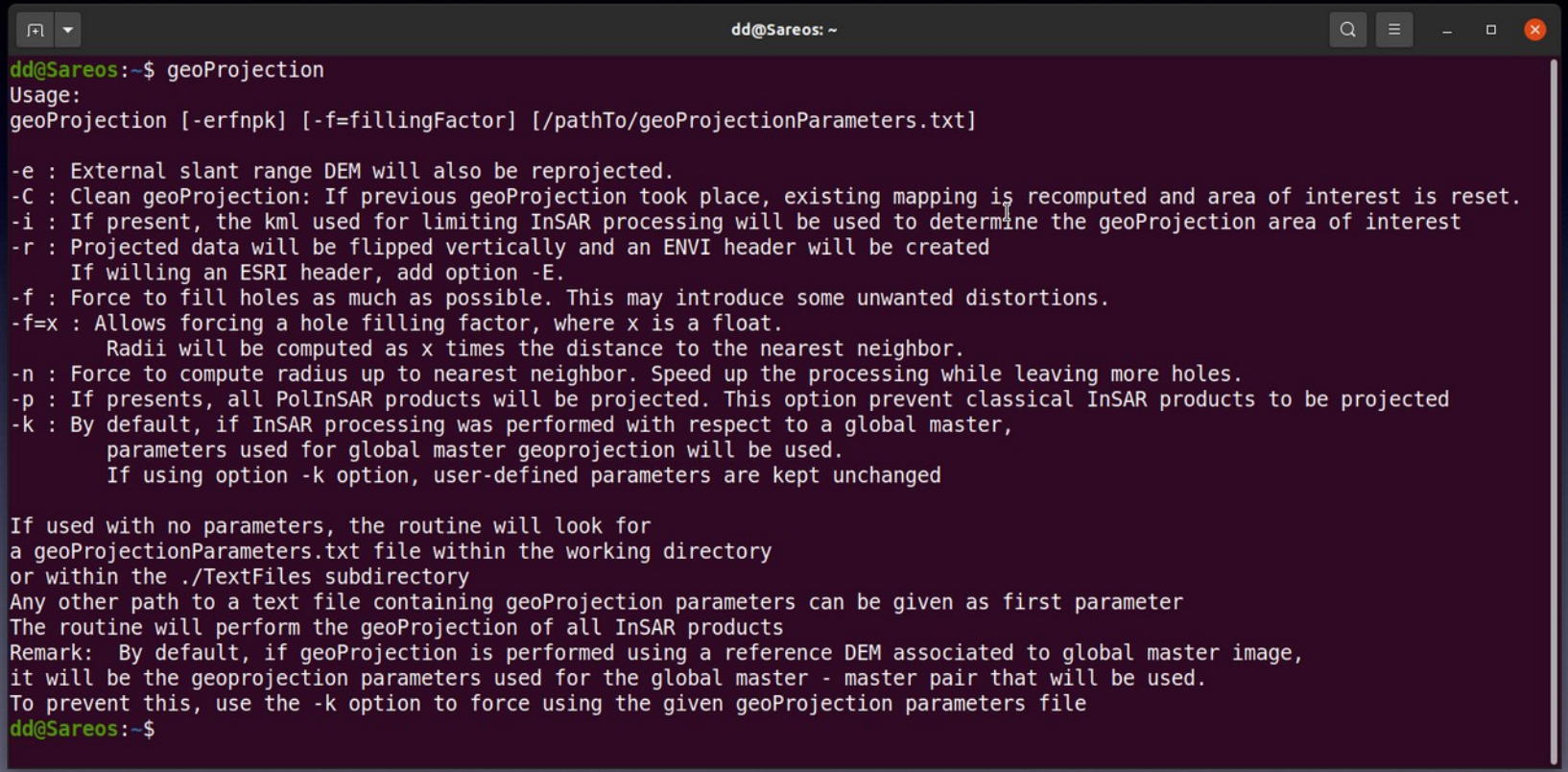
Phase unwrapping



CIS specificity: 3 phase unwrapping methods

- Command line: phaseUnwrapping
  - ☞ Coherence-driven branch cut algorithm
  - ☞ snaphu integration
  - ☞ Deterministic phase unwrapping implementation (forget it for now)

GeoProjection

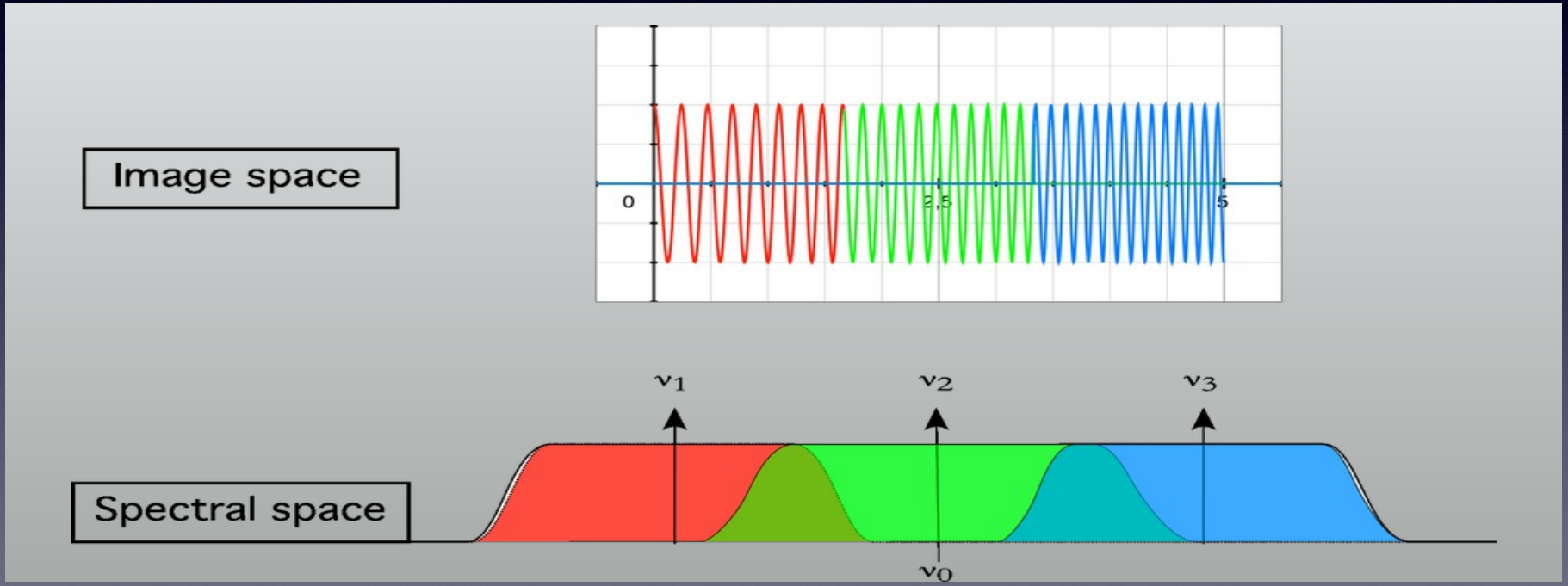


Split-band processing

- Split-band processing also known as Multi-Chromatic Analysis (MCA) consist in taking advantage of the spectral diversity offered by wide band SAR sensors to perform a spectral analysis of the observed signal.
  - ☞ Wide band can be split into sub-bands to perform spectral analysis.
- From a single acquisition, one can generate several images of lower resolution centred on slightly different carrier frequency.

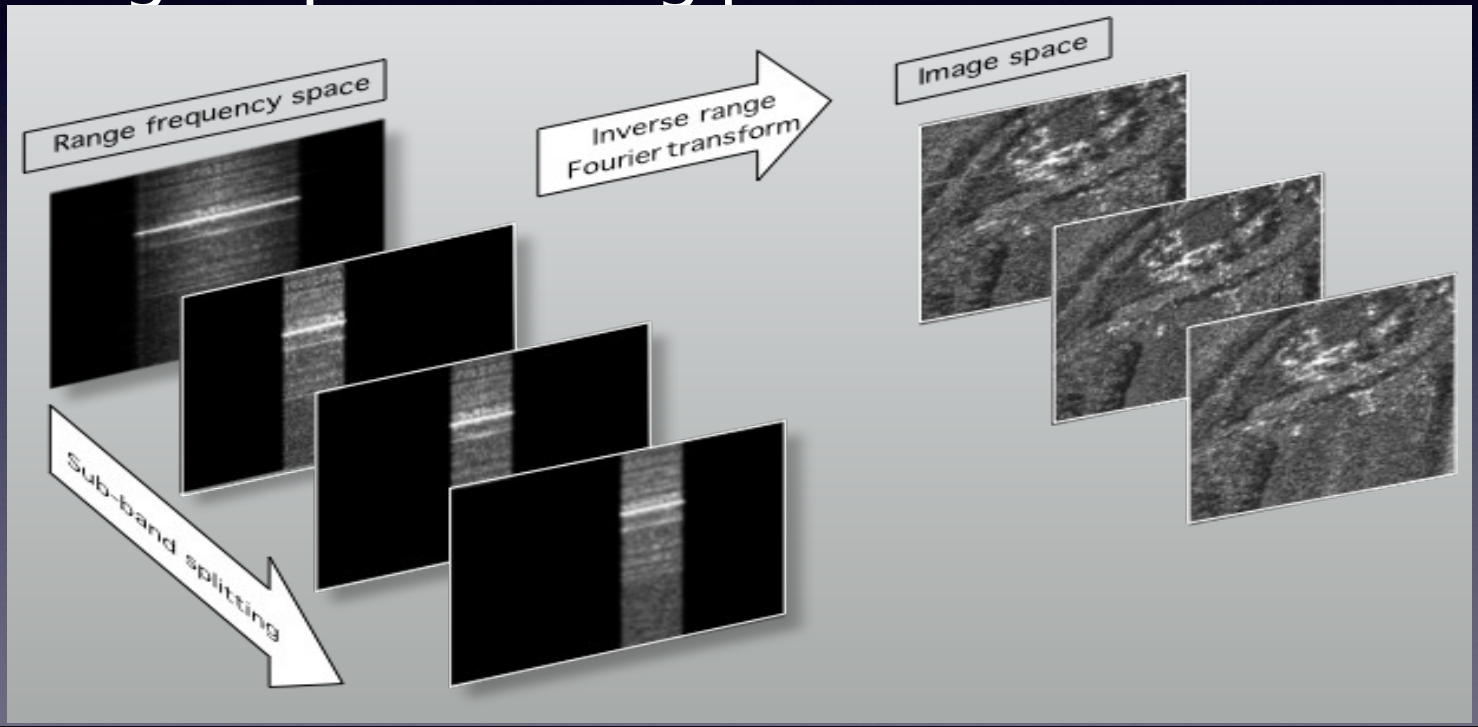
Split-band processing

- Three ways to explain split-band processing
  - ☞ Sensor point of view:



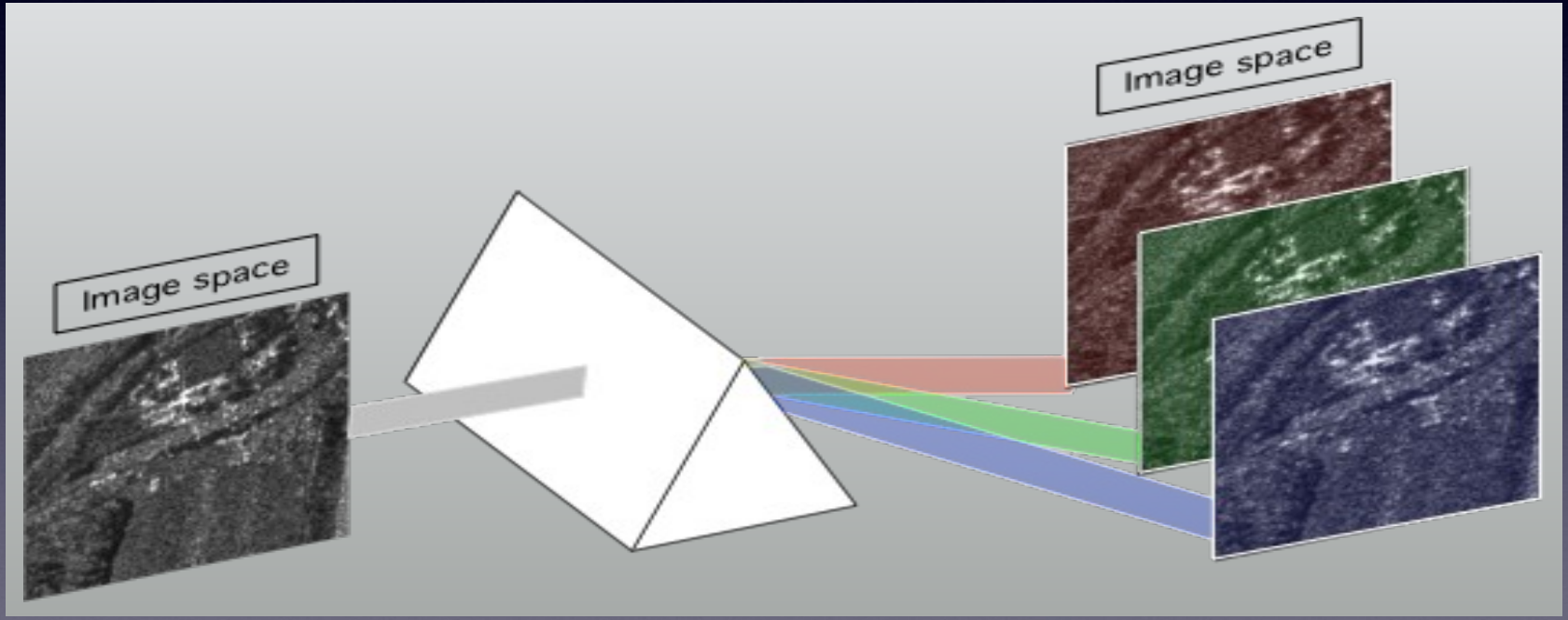
Split-band processing

- Three ways to explain split-band processing
  - ☞ Signal processing point of view:



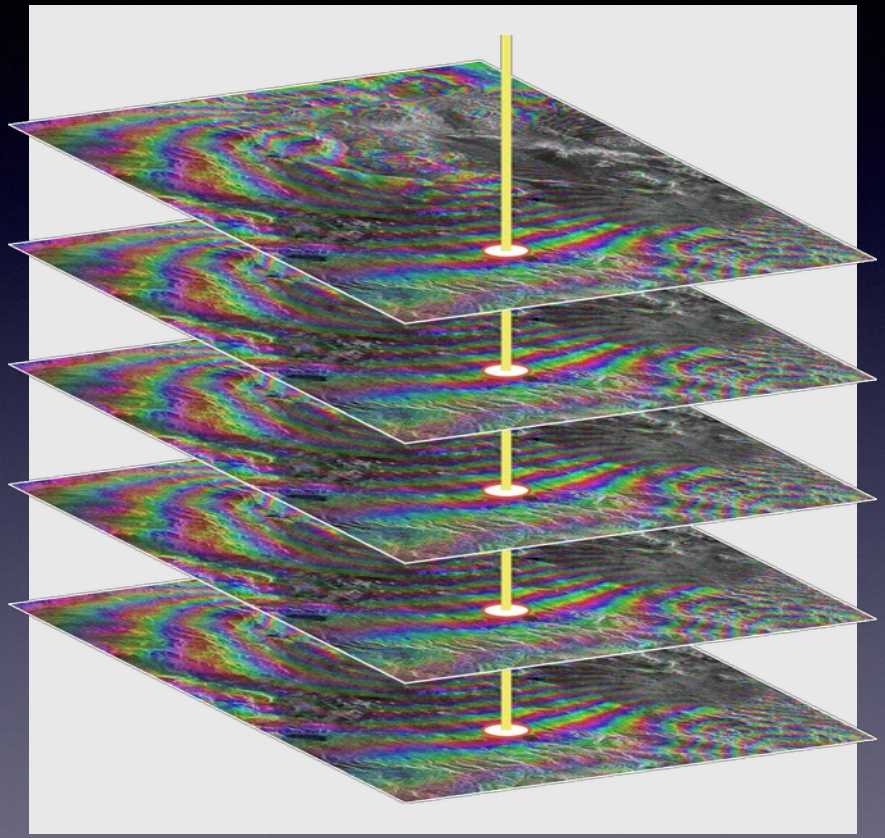
Split-band processing

- Three ways to explain split-band processing
  - ☞ Optical point of view:



Split Band InSAR (SBInSAR)

- SBInSAR is based on this spectral analysis
  - ☞ to generate several InSAR pairs of lower resolution from a single one.
  - ☞ Each sub-band interferometric pair leads to an interferogram generated with its own frequency (or wavelength).
  - ✓ Fringe rate will vary with respect to wavelength



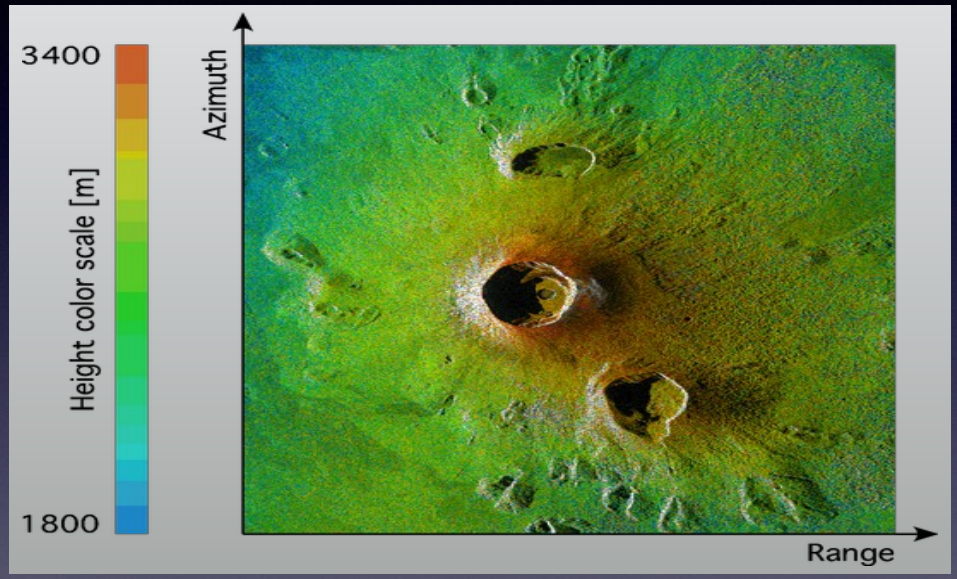
Nyiragongo example

- Nyiragongo volcano, Kivu basin, East RDC

- Command line. SBInSARProductsGeneration
- Example:
  - ☞ Lava lake monitoring
  - ☞ Data: TanDEM-X 2012-07-21

Nyiragongo example

- “Absolute” phase derived from SBInSAR processing was converted into local heights
  - ☞ Despite the relatively poor accuracy, performing a weighted average with respect to spectral coherence, height difference between crater rim and lower crater platform P3 was estimated to be of approximately 410m while the expected value is of about 390m.

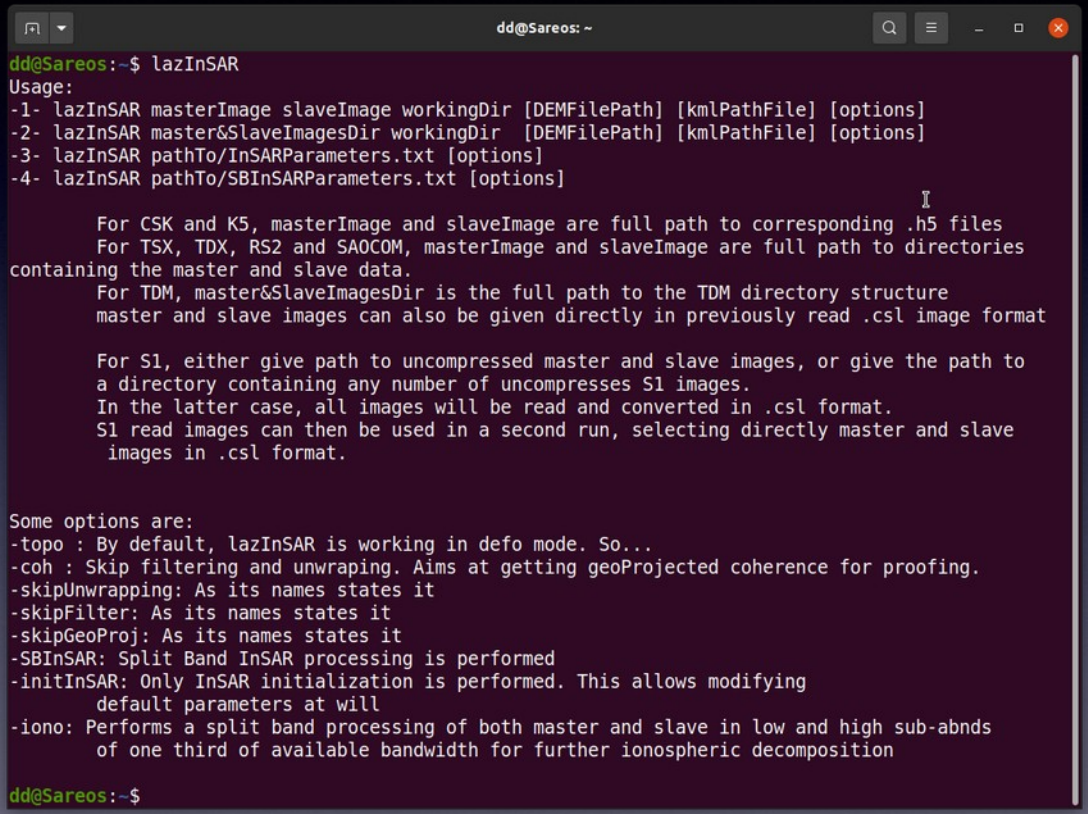


lazInSAR

lazInSAR

The InSAR software for the lazy ones

lazInSAR


dd@Sareos: ~
dd@Sareos:~$ lazInSAR
Usage:
-1- lazInSAR masterImage slaveImage workingDir [DEMFilePath] [kmlPathFile] [options]
-2- lazInSAR master&SlaveImagesDir workingDir [DEMFilePath] [kmlPathFile] [options]
-3- lazInSAR pathTo/InSARParameters.txt [options]
-4- lazInSAR pathTo/SBInSARParameters.txt [options]
For CSK and K5, masterImage and slaveImage are full path to corresponding .h5 files
For TSX, TDX, RS2 and SAOCOM, masterImage and slaveImage are full path to directories containing the master and slave data.
For TDM, master&SlaveImagesDir is the full path to the TDM directory structure
master and slave images can also be given directly in previously read .csl image format
For S1, either give path to uncompressed master and slave images, or give the path to a directory containing any number of uncompresses S1 images.
In the latter case, all images will be read and converted in .csl format.
S1 read images can then be used in a second run, selecting directly master and slave images in .csl format.
Some options are:
-topo : By default, lazInSAR is working in defo mode. So...
-coh : Skip filtering and unwraping. Aims at getting geoProjected coherence for proofing.
-skipUnwrapping: As its names states it
-skipFilter: As its names states it
-skipGeoProj: As its names states it
-SBInSAR: Split Band InSAR processing is performed
-initInSAR: Only InSAR initialization is performed. This allows modifying default parameters at will
-iono: Performs a split band processing of both master and slave in low and high sub-abnds of one third of available bandwidth for further ionospheric decomposition
dd@Sareos:~$

Conclusion

MasTerEngine is a complete InSAR Suite allowing to perform all classical processing steps.

- It has its own specificities:
  - ☞ InSAR processing referenced to a Super Master image
  - ☞ Homemade phase unwrapping in addition to snaphu
  - ☞ Homemade filtering in addition to Goldstein filter
  - ☞ Homemade geoprojection tools
  - ☞ Coherence tracking tool
  - ☞ SBInSAR tool
- MasTerEngine was adapted, modified and tuned everywhere it was possible to make it highly scriptable leading to MasTer

Mass processing Toolbox for Multidimensional time series