Data processing

SAR Specific Data Formats & SAR Data Processing

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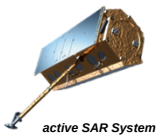
Requirements

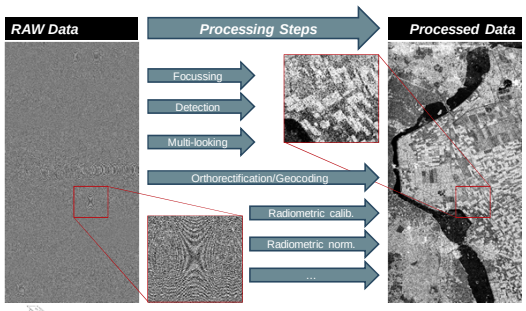
- You know the basic concept of complex SAR data
- You know and understand the Radar Equation
- You know and understand the SAR Geometry

Educational objective

- To understand what is received by the sensor
- To get introduced to different SAR products and their properties
- To learn how SAR Products are generated



Educational objective

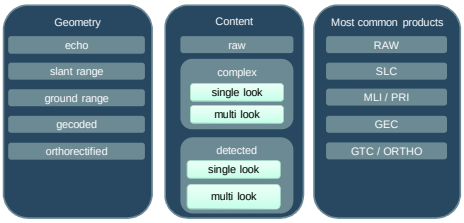


Outline

1. What is received by the sensor?
2. **SAR processing:** Focusing, Detection, Multi-looking, Geocoding, Radiometric Correction, Geometric Correction
3. **SAR-specific data formats:** SLC, MLI, PRI, ORTHO
4. Metadata
    1. Example XML
    2. Example Envi hdr
    3. Example GAMMA par file

SAR-specific data formats

- Data formats are classified according to their Geometry and the data content:



What is received by the Sensor?

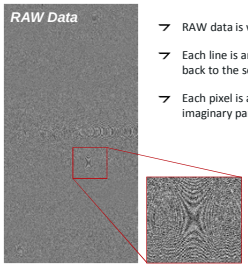
- SAR systems can acquire data in different ways, such as:

  (a) Single or dual channel (e.g. HH or HH/HV)
  (b) Interferometric (single path or repeat path)
  (c) Polarimetric (HH,HV,VV,VH)
  (d) Combination of (b) and (c)

- Different acquisition modes require different processing techniques:

  (a) **Processing of SAR data (limited to intensity processing)**
  (b) Interferometric Processing (includes intensity and interferometric phase processing)
  (c) Polarimetric Processing (includes intensity and polarimetric phase processing)
  (d) Polarimetric-Interferometric Processing (includes intensity, interferometric and polarimetric phase processing)

What is received by the Sensor?

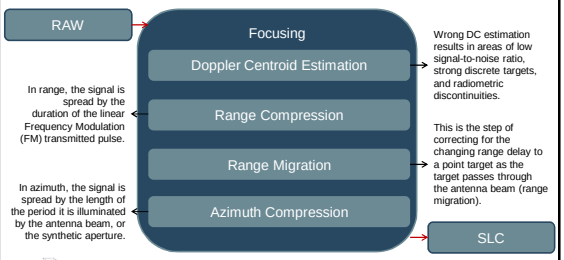


- RAW data is what has been received by the sensor
- Each line is an echo of the radar signal, that has been scattered back to the sensor by targets along the along track position
- Each pixel is a complex value (that consists of a real part and an imaginary part)

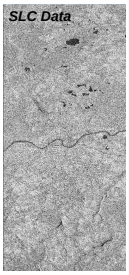
Fig. 1: This is Flevoland, a part of the Netherlands from ERS-1.

SAR processing

In the raw data, the signal energy from a point target is spread in range and azimuth, and the purpose of SAR focussing is to collect this dispersed energy into a single pixel in the output image (Single Look Complex, or SLC image).



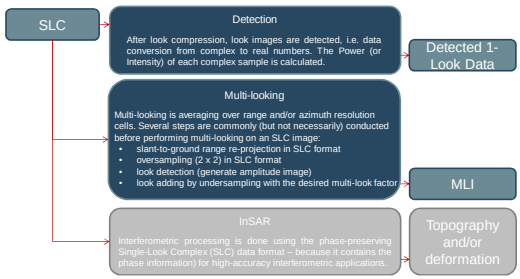
SAR-specific data formats



- Single Look Complex (SLC) is the basic single look product of the focused radar signal
- It contains the highest azimuth spatial resolution, but maximum speckle
- Each pixel is a complex number (with a real and an imaginary part)
- SLC images look extremely elongated because of rectangular resolution cell on the ground (range resolution is not constant)
- SLC data remain in slant range coordinates, they are commonly not projected onto any reference surface
- SLCs are intended for use in SAR quality assessment, calibration, and applications requiring the phase

*TSX data are delivered as **Single Look Slant Range Complex (SSC)** products, which are equivalent to the common SLC products available from other SAR satellites, like ERS-1/2, ENVISAT ASAR, RADARSAT-1 and X-SAR/SIR-C.*

SAR processing

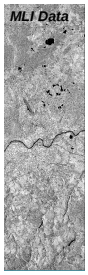


SAR processing

Multi-looking
Goal: Speckle reduction and obtaining approximately squared pixels (in ground range resolution).
Recommendation: In order to avoid over- or under-sampling effects in the geocoded image, it is recommended to generate a multi-looked image corresponding to approximately the same spatial resolution foreseen for the geocoded image product.

How to select an appropriate number of looks?	An Example (ERS-1/2 SAR data):
The number of looks is a function of: • pixel spacing in azimuth • pixel spacing in slant range • look angle at scene center ground range resolution = pixel spacing range / sin(look angle)	≈ 3.99 m ≈ 7.90 m ≈ 23° ground resolution = 7.90 / sin(23°) = 20.21m -> resulting pixel spacing azimuth: 3.99 x 5 = 19.95m -> recommended pixel size of geocoded image 20 m

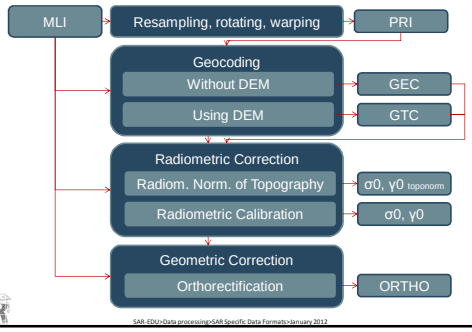
SAR-specific data formats



MLI – Multi-look Intensity

- Produced with commonly between 2 and 6 looks
- Multi-looking is done to find a good trade off between spatial resolution and radiometric variation due to speckle
- Multi-looking is an incoherent procedure
- Each pixel is a real (digital) number that represents the average amplitude of the signal within the pixel
- Commonly in ground range (e.g. TerraSAR-X ***MGD - Multi-Look Ground Range Detected Format***)
- Reference surface for ground-projection used to produce MLI (no full geocoding though!), but range resolution is constant

SAR processing



SAR-specific data formats

PRI – Precision Image

- Produced by resampling MLI images into square pixels, rotating to account for the view direction of the instrument and warping by some predefined operation so that the projected image pixels are properly georeferenced onto some geographical coordinate system
- Not geocoded yet
- Still topographic distortion

SAR processing

- **Georeferencing vs. Georectification vs. Geocoding**
- http://imageryspeaks.com/2012/01/24/georeferencing-vs-georectification-vs-geocoding/

SAR processing

Geocoding (Orthorectification)

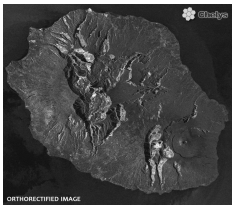
- Geocoding of SAR data refers to a transformation from the slant-range/azimuth geometry to map projection geometry, and can be ellipsoid corrected (Geocoded Ellipsoid Corrected, GEC) or terrain corrected (Geocoded Terrain Corrected, GTC).
- While the generation of GEC products does not require a digital elevation model (DEM), this is necessary for the generation of GTC products.
- The three main steps required in geocoding are
  - (i) the initial determination of the geometric transformation
  - (ii) the refinement of the geometric transformation
  - (iii) the resampling of image data sets from one coordinate system to the other

http://members.chello.nl/~r.sugardiman/html/GEO_users_guide.html
http://www.eorc.jaxa.jp/ALOS/conf/Proc_PIsymp2007/contents/proceedings/Kyoto_and_Carbon/KC07.pdf

SAR-specific data formats

ORTHO

- high precision terrain corrected geocoded image product
- ORTHO product is represented in map geometry.



SAR processing

Radiometric adjustment

- Further radiometric corrections, compensating for effects of local pixel scattering area and local incidence angle on the local backscatter, can be carried out. Two different kinds of radiometric corrections; **radiometric calibration** and **normalization**:
  - Radiometric calibration: standardized backscatter "units"
  - Radiometric (topographic) normalisation: corrects for topographic effects

SAR-specific data formats

Satellite/ Mode	RAW	SLC	MLI	PRI	GEO	ORTHO
TerraSAR-X		SSC		MGD	GEC	EEC
JERS-1	JERS_1_RAW level 0	JERS_1_SLC level 1				
ALOS PALSAR	FBS, FBD, PLR level 1.0	FBS, FBD, PLR level 1.1		FBS, FBD, PLR level 1.5		
ENVISAT ASAR		ASA_APS_1P		ASA_APP_1P		
COSMO-SkyMed		SCS (Single Look Complex slant range)	DGM (Multi-look ground range)		GEC (Geocoded Ellipsoid Corrected)	GTC (Geocoded and Terrain Corrected using a DEM)
RADARSAT-1		SLC level 1		SGF level 1		
RADARSAT-2						

For the current radar satellites the generic radar products are very similar in their characteristics, but have different names and acronyms.

Metadata

- Metadata include all important image and image acquisition parameter
- Metadata are stored in text format, e.g. xml format
- SAR image files always come with a metadata file
- Some examples of important information contained in a metadata file:
  - sensor (e.g. TerraSAR-X, PALSAR HH, …)
  - acquisition date
  - range samples
  - azimuth lines
  - range looks
  - azimuth looks
  - image format (e.g. FCOMPLEX)
  - image geometry (e.g. slant range, …)
  - range pixel spacing
  - azimuth pixel spacing
  - radar frequency
  - doppler polynominal
  - …

Metadata

What is XML?

- XML stands for EXtensible Markup Language, it is a simple, very flexible text format derived from SGML (ISO 8879)
- XML is a markup language much like HTML, but
  - XML was designed to transport and store data, with focus on what data is
  - HTML was designed to display data, with focus on how data looks
- XML tags are not predefined. You must define your own tags (The tags used in HTML are predefined. HTML documents can only use tags defined in the HTML standard (like <p>, <h1>, etc.))
- XML is designed to be self-descriptive
- XML does not DO anything. It is just information wrapped in tags

Metadata

- A part of a typical XML File is shown below:

```
<level1Product xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation="SUPPORT/level1Product.xsd">
  <generalHeader fileName="TSX1_SAR__SSC_____SL_D_SRA_20080723T141508_20080723T141510.xml" fileVersion="1.0" status="PRELIMINARY">
    <itemName>
      Level 1B Product
    </itemName>
    <mission>
      TSX-1
    </mission>
    <source>
      GS
    </source>
    <destination>
      User
    </destination>
    <generationSystem version="4.6">
      TMSP
    </generationSystem>
    <generationTime>
      2012-01-17T08:20:57.000000
    </generationTime>
    <referenceDocument>
      TX-GS-DD-3302 Basic Product Specification 1.5
    </referenceDocument>
          .
          .
          .
```


Metadata

- A typical GAMMA parameter file is shown below (ERS1.slc.par):

title:	orbit 33322
sensor:	ERS1
date:	1995 10 22
start_time:	37330.443200 s
center_time:	37334.988800 s
end_time:	37339.53300 s
azimuth_line_time:	5.9527733e-04 s
line_header_size:	12
range_samples:	2500
azimuth_lines:	13273
range_looks:	1
azimuth_looks:	1
image_format:	SCOMPLEX
image_geometry:	SLANT_RANGE
range_scale_factor:	1.0000000
azimuth_scale_factor:	1.0000000
center_latitude:	47.8100 degrees
center_longitude:	6.8970 degrees
heading:	185.0770 degrees
range_pixel_spacing:	7.9969008 m
azimuth_pixel_spacing:	3.971000 m
near_range_slc:	8.5171741e+05 m
center_range_slc:	8.6585854Se+05 m
far_range_slc:	8.7331982e+05 m
first_slant_range_polynomial:	0.0000E0 0.0000E0 0.0000e+00 0.0000e+00 0.0000e+00 0.0000e+00 s m-1 m^-1 m^-2 m^-3
center_slant_range_polynomial:	0.0000E0 0.0000E0 0.0000e+00 0.0000e+00 0.0000e+00 0.0000e+00 s m-1 m^-1 m^-2 m^-3
last_slant_range_polynomial:	0.0000E0 0.0000E0 0.0000e+00 0.0000e+00 0.0000e+00 0.0000e+00 s m-1 m^-1 m^-2 m^-3
incidence_angle:	24.8820 degrees
azimuth_deskew:	ON

azimuth_angle:	90.0000 degrees
radar_frequency:	5.30000e+09 Hz
adc_sampling_rate:	1.89600e+07 Hz
chirp_bandwidth:	1.55500e+07 Hz
prf:	1.67990e+03 Hz
azimuth_proc_bandwidth:	7.66000e+02 Hz
doppler_polynomial:	4.50338e+02 0.00e+00 0.00e+00 0.00e+00 Hz Hz/m Hz/m^2 Hz/m^3e
receiver_gain:	23.000 dB
calibration_gain:	0.000 dB
sar_to_earth_center:	7.15708483e+06 m
earth_radius_below_sensor:	6.39657483e+06 m
earth_semi_major_axis:	6.37814400e+06 m
earth_semi_minor_axis:	6.35675590e+06 m
number_of_state_vectors:	5
time_of_first_state_vector:	37329.88600 s
state_vector_interval:	2.60000 s
state_vector_position_1:	4837791.35 950299.47 5189453.59 m m m
state_vector_velocity_1:	5570.23920 -913.9411 -5012.2472 m/s m/s m/s
state_vector_position_2:	4852857.32 947916.74 5176481.20 m m m
state_vector_velocity_2:	5558.29460 -918.7148 -5026.9038 m/s m/s m/s
state_vector_position_3:	4866887.37 945321.61 5163310.73 m m m
state_vector_velocity_3:	5542.30750 -923.4705 -5041.5237 m/s m/s m/s
state_vector_position_4:	4880480.80 943114.12 5150182.33 m m m
state_vector_velocity_4:	5528.27850 -928.2282 -5056.1068 m/s m/s m/s
state_vector_position_5:	4894857.69 940694.29 5137016.04 m m m
state_vector_velocity_5:	5514.20640 -932.9650 -5070.6524 m/s m/s m/s

Metadata

- A typical ENVI Header File is shown below:

```
ENVI
description = {
  Registration Result. Method: 1st degree Polynomial w/ nearest
neighbor [Wed Dec 20 23:59:19 1995] }
samples = 709
lines   = 946
bands   = 7
header offset = 0
file type = ENVI Standard
data type = 1
interleave = bsq
sensor type = Landsat TM
byte order = 0
map info = {UTM, 1, 1, 295380.000, 4763640.000, 30.000000,
30.000000, 13, North}
z plot range = {0.00, 255.00}
z plot titles = {Wavelength, Reflectance}
pixel size = {30.000000, 30.000000}
default stretch = 5.0% linear
band names = {
  Warp (Band 1:rs_tm.img), Warp (Band 2:rs_tm.img), Warp (Band
3:rs_tm.img), Warp (Band 4:rs_tm.img), Warp (Band 5:rs_tm.img),
Warp (Band 6:rs_tm.img), Warp (Band 7:rs_tm.img)}
wavelength = {
   0.485000,  0.560000,  0.660000,  0.830000,  1.650000, 11.400000,
2.215000}
fwhm = {
 0.070000, 0.080000, 0.060000, 0.140000, 0.200000, 2.100000,
0.270000}
```

→ *Optical sensor!*

Further reading

- Woodhouse 2006 pp. 300/301
- ftp://earth.ox.ac.uk/pub/michellp/ISP_html/ISP_users_guide.pdf
- http://www.tiger.esa.int/training/SAR_LA1_th.pdf
- http://www.exelisvis.com/portals/0/pdfs/envi/SARscape_SupportedSensors.pdf
- http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=05356148
- http://www.isprs.org/proceedings/XXXVII/congress/1_pdf/37.pdf
- http://www.w3schools.com/xml/xml_usedfor.asp
- http://www.w3c.de/Misc/XML-in-10-points.html
- http://www.trfic.msu.edu/products/profcorner_products/Intro_Microwave.pdf
- http://earth.esa.int/landtraining07/D1LA1-LeToan.pdf
- http://www.nv.et-inf.uni-siegen.de/pb2/research/sar/sar_e.htm