White Paper

SAR Orthorectification and Mosaicking

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This data set was provided by Defence Research and Development Canada (DRDC) as part of the Defence Initiative Research (DIR) project. The data set contains 9 high resolution, fine quad RADARSAT-2 SAR aqcuisitions in both ascending (4) and descending modes (5) collected between February 9 – October 31, 2009. Each SAR data set is approximately 1.6 Mb. In size. The range of incident angles varies from 32.40 degrees (beam mode FQ 13) to 41.58 degrees (beam mode FQ21).

The SAR data sets cover the Straits of Gibraltar and the surrounding area. The elevation ranges from sea level to over 1500 m. The scene contains the strategic port of Gibraltar as well as agricultural, urban,and forested areas.

The data in this mosaic covers a wide range of sea states and wind speeds which accounts for the variation of the backscattering from the water. The final output mosaic contains five layers which represent total power followed by calibrated σ0 intensities for all combinations of horizontal and vertical polarizations (i.e. HH, HV, VH and VV) respectively. The input sample spacing is approximately 7.5 meters in slant range. The final orthorectified mosiac output is mapped to the UTM 30 S D000 (NAD 83) projection with 10 meter spacing.

All processing described in this document was completed in June 2013 using PCI Geomatics Geomatica/GXL 2013 software as well as pre-release versions of Geomatica/GXL 2014.

The quality of the final ortho mosaic created by the PCI GXL software using the shuttle radar terrain mission (SRTM) data as the digital terrain model (DTM) is excellent. At the full 10 m. resolution all seamlines are virtually perfect (1 pixel or less displacement).

Note: This data set cannot be redistributed or resold.

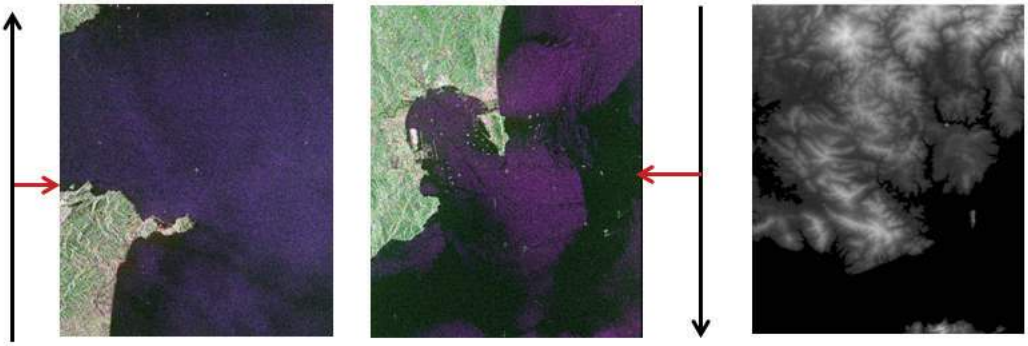
Data Sets

Input Data Sets

The input data set consists of 9 high resolution, single look, fully polarimetric data sets (Fine Quad). All data sets are projected in slant range with approximately 5 m. sample size. The radar look direction is always to the right relative to the satellite velocity. Four data sets were acquired in ascending mode (with acquisition time 18:23 GMT) and five in descending mode (acquisition time 06:22 GMT). The range of incident angles varies from 32.40 degrees (FQ13) to 41.58 degrees (FQ21).

The digital elevation model is a subset of the SRTM data with 90 meter postings (3 arc seconds).

The left and middle images below show the direction of the satellite velocity (in black) and the look direction of the radar (in red). The backscattering intnesity from HH, HV and VV is mapped to red, green, and blue respectively. The image on the right is a subset of the DEM used in this paper. The elevations are linearly scaled from lowest elevation (black) to highest elevation (white).



Ascending Pass | Descending Pass | Digital Elevation Model (DEM)

Input Data set size is 4.95 Gb for the Polarimetric SAR data and 286 Kb for the DEM subset.

The full list of input data sets used for calibrated full quad mosiac of Gibraltar is given below.

Input Data

Directory	File(s)	Comment
\SAR Data	RS2_OK4132_PK54172_DK52199_ FQ21_20090209_182329_HH_VV_HV_VH_SLC RS2_OK4132_PK54173_DK52200_ FQ21_20090209_182332_HH_VV_HV_VH_SLC RS2_OK5164_PK67339_DK65390_ FQ19_20090427_062241_HH_VV_HV_VH_SLC RS2_OK5164_PK67340_DK65391_ FQ19_20090427_062243_HH_VV_HV_VH_SLC RS2_OK7296_PK87931_DK85632_ FQ13_20090911_062655_HH_VV_HV_VH_SLC RS2_OK7296_PK97273_DK95830_ FQ21_20091031_182343_HH_VV_HV_VH_SLC RS2_OK4132_PK54176_DK52203_ FQ21_20090214_062238_HH_VV_HV_VH_SLC RS2_OK4132_PK54177_DK52204_ FQ21_20090214_062241_HH_VV_HV_VH_SLC RS2_OK5164_PK67338_DK65389_ FQ19_20090422_182335_HH_VV_HV_VH_SLC	Original Vendor Data Sets. Fine quad, single look, complex valued SAR data in slant range projection with approximately 5 m. spacing.
\DEM	Gibraltar_DEM_90m.pix	Gibraltar_DEM_90m.pix

The following directories contain reference products for QA purposes and are not required for processing.

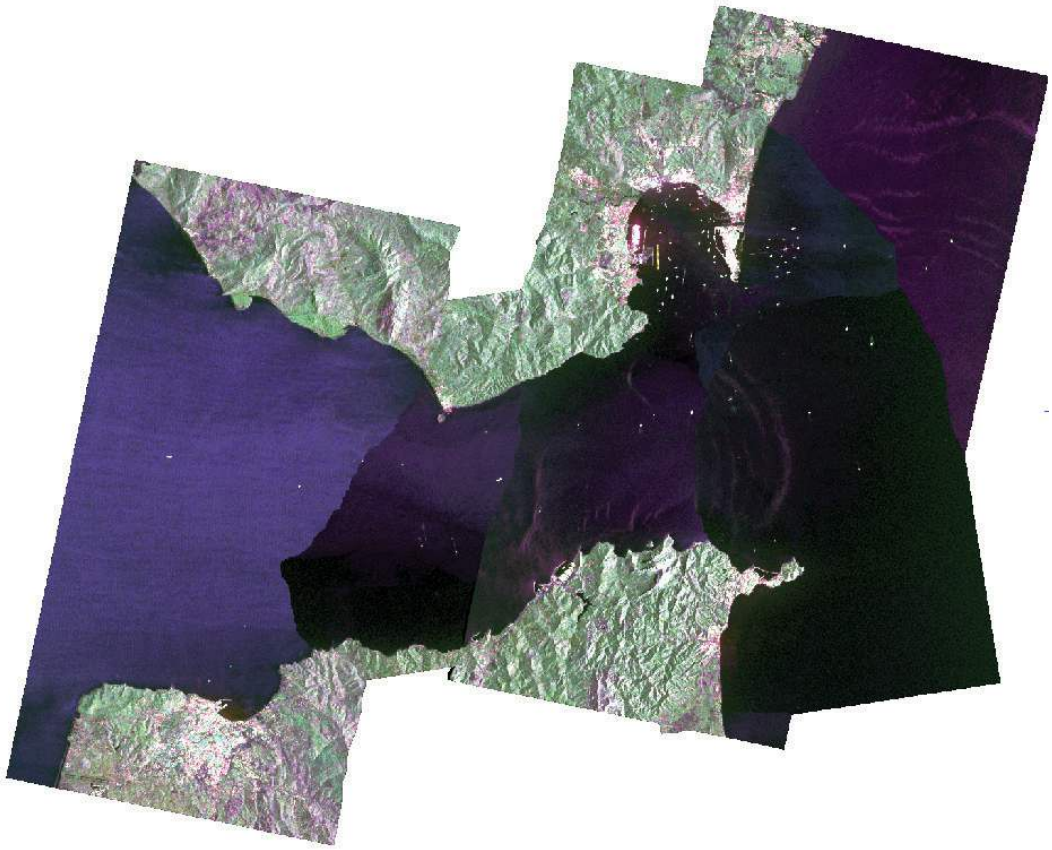
Output Data Sets

All of the output files are written as PCIDSK files. The output files contain both image layers and ancillary data required for processing and analysis. The ancillary meta-data includes sensor calibration and geocoding information.

The full list of data sets generated to create the orthorectified mosaic is listed on the following page.

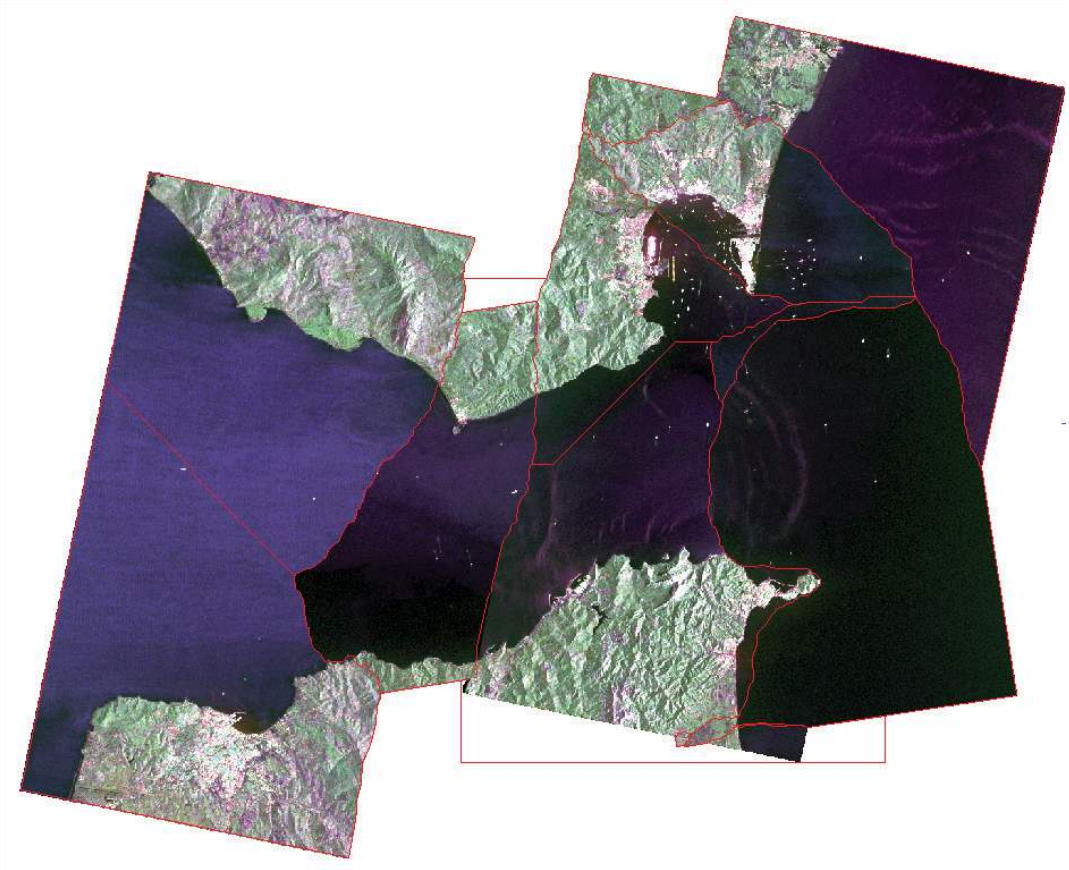
Directory	File(s)	Comment
\Ingest	\rawpix (original file name + “RAW_SAR.pix”)	Raw data in PCIDSK format produced from vendor data set.
\Ingest	\Filtered5x5 (original file name + “RAW_SAR.pix”)	Adaptive Lee Filtered (5x5) data in PCIDSK format.
\polarimetric	\raw (original file name + “PP_SAR.pix”)	PCIDSK files containing five polarimetric parameters. Selected parameters include total power, and calibrated intensities of HH,HV,VH and VV.
\ortho		Orhtorectified polarimetric parameters
\mosaic_prep	\(original file name + “ORTHO_SAR.pix”)	Contains calculated cut lines and mosaic overviews
\mosaic_prep		Preview of cutlines
\mosaic	\cutlines (original file name + “ORTHO_SAR_CUT.pix”)	Topology of cutlines
	\misc\mosaic_prep_cutline_preview.pix	List of data sets used
	\misc\mosaic_prep_topology.pix	Preview of Final
	\misc\mosiac_prep_image_status.tx)	Output mosaic.
	\misc (original file name + “cutline_preview.pix”)	
	\gibraltar_1_1.pix	

The data in this mosaic covers a wide range of sea states and wind speeds which accounts for the variation of the backscattering from the water. The final output mosaic contains five layers which represent total power followed by calibrated σ0 intensities for all combinations of horizontal and vertical polarizations (i.e. HH, HV, VH and VV) respectively. The final orthorectified mosiac output is mapped to the UTM 30 S D000 (NAD 83) projection with 10 meter spacing. The final mosiac output is shown below.



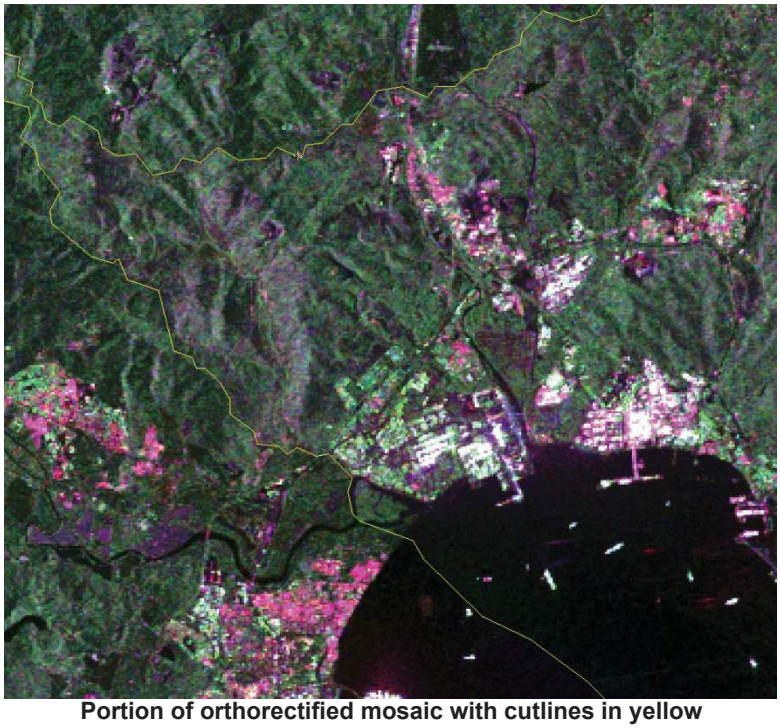
Overview of Full Quad Mosaic of Gibraltar at 10 m. spacing.

An overview of the output mosaic with the automatically generated cutlines is shown below. Although changes in the backscattering of water are very apparent, the calibrated backscattering from the land is seamlees and requires no color balancing.



Overview of Gibraltar mosiac showing automatically computed cut lines

The following images show a subsection of the final mosiac. The upper image shows the automatically generated cutlines in yellow. The lower image is a small portion of the final product.



Portion of orthorectified mosaic with cutlines in yellow

Portion of final othorectified mosaic without cutlines

Processing Description

Overview of Processing Steps

SAR Ingest

Automatic ingest of all four polarizations (HH, HV, VH,VV). The data is written as complex values in PCIDSK format. The data is calibrated to ground range backscattering using the sigma calibration option. As part of the ingest, a second directory is produced containing adaptive LEE filtered (5x5) data to reduce the effects of speckle.

Polarimetric Parameters

A number of polarimetric parameters are computed from the filtered complex valued PCIDSK data. The user has the option to select from 65 parameters. For the mosaic, the total power (which will be used to generate the mosaic cutlines) as well as the four calibrated intensities are selected. The selected scaling type for the output is “linear”.

Orthorectification SAR

The calibrated polarimetric parameter data sets are othorectified. The required shift for the orthorectification is derived using the known radar viewing geometry, ground control points (GCPs) extracted from the meta data, and interpolated elevations derived from the DEM. The digital elevation model (DEM) is a subset of the shuttle (SRTM) data set with 90 m. spacing. Once the rquired shift has been calculated, a cubic resampler is used to generate the interpolated output value. The selected output projection for the output is is UTM 30 S D000 with a 10 m. spacing. The UTM projection was selected because it preserves the 1:1 relationship in the X and Y directions.

Mosaic Preparation

The orthorectified data sets are used as input for the final mosaic. This step automatically defines the cutlines to be used in the final product. Since the input data is calibrated, no color balancing is applied. The cutline method is based upon the minimum difference between the calibrated values. The data set closest to the middle is used as the starting point.

Mosaic Generation

The final mosaic is genrerated from the previously calculated cutlines. A blend width of 3 pixels using the cubic convolution resampler is used. The output is written to a single file. No additional editing is required.

Processing Methodology

This dataset was provided by Defence Research and Development Canada (DRDC) as part of the Defence Initiaive Research (DIR) program.

All processing in this report is generated by a stand alone Dell Studio XPS with an i7 960@ 3.2Ghz CPU, 12GB RAM, 1.0 TB 7200 rpm SATA HDD.

The processing software was GXL 2013 and Geomatica GXL 2013 QA bundle releases along with pre-release capability of GXL 2014.

The 5 GXL tasks required to generate the full orthorectified mosiac (at 10 m spacing) were executed in less than 30 minutes. To fill in the portions of the mosiac which woul normally be in shadow, the mosaic is contructed from both ascending and descending passes. The data set was acquired over a 8 month period from February 2009 to October 2009. The final mosaic was examined visually and the fit and colour balancing for the terrain areas appears to be excellent. However; the cut lines in the water are apparent due to significant changes in backscattering caused by changes in environmental conditions (e.g. wind speed and direction) between acquisitions.

Processing Steps

The GXL parameters selected for the creation of the SAR mosiac are described in the following sections. The highlighted parameters are described in more etail at the end of each section.

Data Ingest SAR

Scene Source:	<path>\SAR Data
Output Folder:	<path>\Ingest
Overwrite Results	Checked
Calibrate:	Checked
Calibration Type:	Sigma
Apply Filter	Checked
Filter Type	Adaptive Lee
Filter Size	5

Scene Source: **\SAR Data**

The \SAR Data directory contains the 9 vendor supplied full quad SAR data sets. The single look complex (SLC) data sets cover the Straits of Gibraltar and were acquired between February and October 2009. There are 4 ascending and 5 descending passes. The nominal slant range resolution is 7.5 m. with a 5 m. spacing.

Output Folder: **\Ingest**
Overwrite Results **Checked**

This is the directory which will contain the reformatted (to PCIDSK) data sets. Ther required ancillary data is extracted as part of the ingest. Any regenerated files will be overwritten.

Calibrate: **Checked**
Calibration Type: **Sigma**

The sigma calibration option is selected. This option provides calibrated output in ground range (rather than slant range).

Apply Filter **Checked**
Filter Type **Adaptive Lee**
Filter Size **5 Pixels**

To reduce the effects of speckle, a spatial filter is applied. The selected filter type is Adaptive Lee. This filter has the advantage of perserving edges while still filtering homogeneous areas (such as water) strongly. A moderate sized filter (5x5) is applied.

Polarimetric Parameters

Input Scenes:	**<path>\Ingest\filtered5x5**
Output Folder	**<path>\polarimetric**
Output File Type	PCIDSK (pix)
Oputput File Options	TILED256
Overwrite Result	**Checked**
Filter When Necessary	Not selected
Filter Type	Not applicable
Filter Size	Not applicable
Number of Looks	Not applicable
Total Power	**Selected**
HH Intensity	**Selected**
HV Intensity	**Selected**
VH Intensity	**Selected**
VV Intensity	**Selected**
Intensity Ratios	Not Selected
Scaling Type	**Linear**
Touzi Discriminators	Not Selected
Touzi decompositions	Not Selected
Angular Units	Not applicable
Generate Polarimetric Discriminators	Not Selected
Orientation Step Size	Not applicable
Ellipticity Step Size	Not applicable
Freeman Durdan	Not Selected
Entrpy, Alpha, Beta, Anisotropy	Not Selected
Orthorectify	Not Selected
DEM Source	Not applicable
DEM Units	Not applicable
DEM Background Elevation	Not applicable
Map Units	Not applicable
Pixel Output Size	Not applicable
Resampling Type	Not applicable

Input Scenes:	**\Ingest\Filtered5x5**

The calibrated and filtered data written in PCIDSK format during the ingest step is used as input

Output Folder	**\Polarimetric**
Oputput File Options	**TILED256**

The selected polarimetric parameters are generated for each input data set and written to the specified directory. The user has the option to select any subet from theavailalble options. The tiled option results in increased processing speed.

Filter	**Not selected**
Filter Type	**Not Selected**
Filter Size	**Not Selected**
Number of Looks	**Not applicable**

No further filtering is applied. Note: Filtering has already been applied during the ingest phase.

Intensities:	**Total Power**	**Selected**
	HH Intensity	**Selected**
	HV Intensity	**Selected**
	VH Intensity	**Selected**
	VV Intensity	**Selected**
	Intensity Ratios	**Not Selected**
	Scaling Type	**Linear**

The total power and calibrated intensities written as linear values are the selected parameters for the mosiac output. The ratios of the intensities are not used.

Phase Differences	**Not Selected**
Angular Units	**Not applicable**

No phase information is required for the mosaic.

Touzi Discriminators	**Not Selected**
Touzi Decompositions	**Not Selected**
Angular Units	**Not Applicable**

The Touzi discriminators and decompositions are not selected for the mosaic

Generate Polarimetric Discriminators	**Not Selected**
Orientation Step Size	**Not Applicable**
Elliticity Step Size	**Not Applicable**

No polarimetric discriminators are required for the mosaic.

Freeman Durdan	**Not Selected**
Entropy, Alpha, Beta, Anisotropy	**Not Selected**

No power decompositions are required for the mosaic.

Orthorectify	**Not Selected**
DEM Source	**Not Applicable**
DEM Background Elevaton	**Not Applicable**
Map Units	**Not Applicable**
Pixel Output Size	**Not Applicable**
Resampling Type	**Not Applicable**

The mosiac requires all of the output to be reampled to a common grid. This will be accomplished in the next step during the Orthorectify SAR option.

Orthorectify SAR

Input Scenes:	**<path>\ortho**
Output XML File	**<path>\mosaic_prep**
No Data Value	
Overwrite Results	**Checked**
Sorting Method	**Nearest to Centre**
Start Image	
Normalization Method	
Normalization Method Extra Options	
Color Balancing Method	
Color Balancing Extra Options	
Local Color Balance Mask Layer	
Local Color Balance Mask Segment	
Global Color Balance Mask File	
Global Color Balance Mask Layer	
Global Color Mask Segement	
Cutline Method	**Minimum Difference**
Cutline Method Extra Options	
Auto Constrain	
Thiessen Factor	
Local Cutline Avoidance Mask Layer	
Local Cutline Avoidance Mask Seg	
Global Cutline Avoidance Mask File	
Global Cutline Avoidance Mask Layer	
Global Cutline Avoidance Mask Seg	

Input Scenes	**\Ortho**

The orthorectifed polarimetric paramters are used as input.

Output XML File	**\mosaic_prep.xml**

This is the directory that is created to contain all the cutline and preview information for the final mosaic.

No Data Value	**Not Applicable**
Sorting Method	**Nearest to Centre**
Start Image	**Not Applicable**

Build the mosaic from the center toward the edges.

Normalization Method	**None**
Normalization Method Extra Options	**Not Applicable**

Data is already calibrated and normalization is not required..

Color Balancing Method	**None**
Color Balancing Extra Options	**Not Applicable**

Data is already calibrated and color balancing is not required.

Local Color Balance Mask Layer	**None**
Local Color Balance Mask Segment	**Not Applicable**
Global Color Balance Mask File	**Not Applicable**
Global Color Balance Mask Layer	**Not Applicable**
Global Color Mask Segement	**Not Applicable**

Data is already calibrated.

Cutline Method	**Minimum Difference**
Cutline Method Extra Options	**Not Applicable**
Auto Constrain	**Not Checked**
Thiessen Factor	**Not Applicable**

The automatically generated cut lines are based upon the minimum difference between the total power of the calibrated data sets.

Local Cutline Avoidance Mask Layer	**None**
Local Cutline Avoidance Mask Seg	**Not Applicable**
Global Cutline Avoidance Mask File	**Not Applicable**
Global Cutline Avoidance Mask Layer	**Not Applicable**
Global Cutlune Avoidance Mask Seg	**Not Applicable**

No user defined masks etc. or additional editing is required.

Mosaic Generation

Input Scene File:	**<path>\mosaic_prep.xml**
Output Folder	**<path>\mosaic**
Output Background Value	
Output File Type	PCIDSK
Oputput File Options	TILED256
Overwrite Result	**Checked**
Tile Base Name	**Gibraltar**
Tile Specification	**Single Tile**
Tile Specification Extra Options	
Area of Interest	
Crop Tiles to AOI	**Checked**
Blend Width	3
Resampling Method	Cubic
Create Source Map	
Existing Tile Rule	Skip
Delete Empty Tile	None
Apply LAE	
Output Enhanced Tiles Only	**Checked**

Input Scene File **\mosiac_prep.xml**

This is the XML file specified during the mosaic preparation. The subdirectories contain the cutlines and previews of the final mosaic.

Output Folder **\Mosaic**

The specified folder will contain the final mosiac output product.

Output Background Value	**Not Applicable**
Output File Type	**PCIDSK**
Output File Options	**TILED256**
Overwrite Result	**Checked**

All (5) channels will be written to the final mosaic in PCIDSK tiled format. Any previous cutline results etc. in the output directory will be overwritten.

Tile Base Name	**Gibraltar**	
Tile Specifiaction	**Single Tile**	
Tile Specification Extra Options	**Not Applicable**	
Area Of Interest	**Blank**	**(implies all)**
Blend Width	**3 (pixels)**	
Resampling Method	**Cubic**	
Create Source Map	**Not Checked**	
Existing Tile Rule	**Skip**	
Delete Empty Tile	**None**	
Apply LAE	**Unchecked**	
Output Enhanced Tiles Only	**Checked**	

The output is a single tile covering all of the area covered by the input orthorectified files. The output could be restricted to the area defined by the area of interest file. No source maps were generated and previously generated tiles (of which there are none) are ignored.

Benchmark Information

Software: GXL 2013 (MS Windows, 64bit OS).
Hardware:
Date: June 14, 2013

Step	Processing Time	Comment
Ingest	12 m 07 s	9 full quad data sets calibrated and apadtively filtered
Polarimetric Parameter Generation	5 m 07 s	Five polarimetric parmeters generated
SAR Orthorectification	12 m 44 s	Five data layer orthorectified
Mosaic preparation	34 s	9 images (5 layers each)
Mosaic Generation	55 s	Final mosaic

About the Author

John Wessels joined PCI Geomatics in 2008 as the company's senior remote sensing scientist. He is responsible for the development and implementation of all radar related technologies and applications.

Mr. Wessels has over 30 years of international experience leading the technical development of remote sensing applications using radar and optical satellite data. He has developed applications for coastal surveillance, ship detection, environmental assessment and disaster monitoring. He is currently involved in the development of change detection techniques from polarimetric data for environmental and military applications.

Mr. Wessels received his Bachelor of Science degree in Mathematics and Computer Science from the University of Guelph in 1975.