IMAGINE OrthoRadar™

Accuracy Evaluation

The Earth to Business Company

IMAGINE OrthoRadar Product Description

IMAGINE OrthoRadar is part of the IMAGINE Radar Mapping Suite and performs precision geocoding and orthorectification of SAR images, using SAR sensor models, satellite orbit models and digital elevation models (DEMs). The resulting ortho images are highly accurate and free from the significant distortions inherent in radar imagery. Fully integrated into the ERDAS IMAGINE® environment, IMAGINE OrthoRadar easily handles GCPs, DEMs and map projections. After orthocorrection, the radar images can be used to map ground features. Because radar imagery penetrates cloud cover, perennially cloud covered areas may be mapped using orthocorrected radar images.

Introduction

This document details testing and accuracy evaluation performed using the IMAGINE OrthoRadar™ module. You may find the conclusions helpful in processing your own work.

Test Data

Accuracy testing of the IMAGINE OrthoRadar module has been completed using two USA sites: Death Valley, California, and Denver, Colorado. For both areas, United States Geological Survey (USGS) quad maps at 1:24,000 were used to extract ground control points (GCPs), and USGS 30 m digital elevation models (DEMs) were used for orthocorrection. For each data set, 1 GCP was taken on each of alternating quad sheets yielding 25 well-spaced GCPs. For each test area, USGS 30 m DEM mosaics were prepared, and quads for which 30 m DEMs were not in hand were populated using 90 m DEMs.

Additionally, a single-look complex (SLC) image of Mt. Vesuvius from ESA has been used. GCPs were measured for 15 selected points using 1:50,000 topo maps.

Results are reported as root mean square (RMS) error and average error. The RMS value reflects the range of error (error bar) and the precision of the orthoimage. The average reflects any overall bias in the results and the accuracy of the orthoimage. In theory, a small RMS error and a 0 bias is the desired result.

Relative Accuracy - RADARSAT-1

To evaluate relative accuracy, two overlapping images are orthocorrected and both are read into a Viewer. The Swipe tool is used to locate features, such as roads, that are clearly seen in both images. The cursor is then used to measure the offset between the two images.

Two RADARSAT-1 stereopairs (S1 and S6) are imported and orthocorrected with no GCPs provided. Five measurements of range and azimuth misregistration between the two images are taken. The average error values are:

Table 1: Average Error Values without GCP

Range 5.3 (14 m) pixels	74 m
Azimuth 2.8 pixels	9 m

One of the stereopairs is then orthocorrected with a single GCP. Misregistration between the two images is again measured:

Table 2: Average Error Values with GCP

Range 3 (12 m) pixels	36 m
Azimuth 3 (12 m) pixels	36 m

This result suggests that, when planning to mosaic images, use of a common GCP significantly improves coregistration.

Absolute Accuracy RADARSAT-1

Denver Test Area

One Denver image is orthocorrected using a varying number of GCPs. The location of 24 GCPs taken from the topographic maps is determined on the resultant orthoimage. As this radar image contains a lot of human-made features such as roads, dams, parking lots, etc., GCPs are located quite precisely on both the map and the image. For each image, the 24 latitude and longitude values are used to calculate RMS and Average error in both range (longitude) and azimuth (latitude). The output image has 14 m pixels.

Table 3: Denver Test Area—Orthocorrected with/without GCPs

Number of GCPs in model	None	1	10	24
Range RMS Error	+39 m	+55 m	+47 m	+47.0 m
Range Average Error	-29 m	+49 m	+42 m	+36.0 m
Azimuth RMS Error	+46 m	+30 m	+30 m	+28.0 m
Azimuth Average Error	-35 m	+8 m	-1 m	-0.6 m

In orthocorrecting, the inaccuracies of an X, Y error are compounded because the wrong Z value is selected from the DEM. This concern would be trivial in flat areas, but of major importance in areas of extreme slope.

To isolate the orbit model error from the resultant DEM-induced error, each GCP was measured on an input image geocoded using an elevation input value corresponding to that GCP's elevation. For the 24 GCPs, this required 24 separate geocodings.

Table 4: Denver Test Area—Geocoded with GCPs

Number of GCPs in Model	10
Range RMS Error	+20 m
Range Average Error	-1 m
Azimuth RMS Error	+31 m
Azimuth Average Error	-7 m

From this, we can conclude that the SAR orbit model is accurate to within three (14 m) pixels.

Death Valley Test Area

A RADARSAT-1 image is orthocorrected using a varying number of GCPs. The latitude and longitude of 25 GCPs is measured on the resultant orthoimage. As this radar image contains few man-made features, location of GCPs is less precise than with the Denver image. For each image, the 25 latitude and longitude values are used to calculate RMS and Average error in both range (longitude) and azimuth (latitude). The output image has 14 m pixels.

Table 5: Death Valley Test Area—Orthocorrected with GCPs

Number of GCPs in Model	None	20
Range RMS Error	+152 m	+122 m
Range Average Error	+110 m	+70 m
Azimuth RMS Error	+78 m +	72 m
Azimuth Average Error	+15 m	+12 m

The error here is considerably larger than for the Denver test area. We can ascribe this to two factors: (1) slopes within the scene are extreme, and thus X,Y errors can translate into large Z errors; and (2) many GCPs are difficult to locate precisely on the before and/or after images. To mitigate the effect of these problems, we calculated the RMS and average error using only the most accurate of the 25 GCPs.

Table 6: Death Valley Test Area with Accurate GCPs

Number of Accurate GCPs	15	8
Range RMS Error 7	5 m	47 m
Range Average Error	47 m	+35 m
Azimuth RMS Error	41 m	34 m
Azimuth Average Error	-3 m	+8 m

As expected, these results are approaching those for the Denver test area (RMS of 47 m and 28 m).

Nicaragua Test Area

Two RADARSAT-1 scenes, an S1-S7 stereopair (incidence angles of 24 and 48 degrees, respectively), were geocoded with and without a GCP. Six clearly defined points in the image with corresponding GPS-derived GCPs were used to calculate the error.

Table 7: Nicaragua Test Area—Degree/GCP Relationship

Incidence Angle	22 Degrees		47 Degrees	
Number of GCPs in Model	**None**	**1**	**None**	**1**
Range RMS Error	+130 m	+47 m	+184 m	+43 m
Range Average Error	+115 m	+2 m	+172 m	-4 m
Azimuth RMS Error	+222 m	+209 m	+44 m	+79 m
Azimuth Average Error	+66 m	-26 m	-204 m	-53 m

The two images geocoded without GCPs were compared using the **Swipe Tool**. The offset between the two was measured. This misregistration was 151 m in range and 157 m in azimuth.

The two images geocoded with one GCP were compared using the **Swipe Tool**. The offset between the two was measured. This misregistration was within one pixel (9.2 m) in both range and azimuth.

In geocoding, the accuracy of the resulting latitude and longitude is determined in part by the mean input elevation. The magnitude of the error is also determined in part by the incidence angle. This potential error was quantified by geocoding both Nicaragua scenes at several elevations and comparing to the same scene geocoded at sea level. The images were geocoded at 0 m, 100 m and 200 m above sea level, and the resultant induced error in position was measured.

Table 8: Nicaragua Test Area—Incidence Angle/Degrees Results

Incidence Angle	22 Degrees	47 Degrees
Range Elevation-induced Offset	2.4 m per meter elevation	0.94 m per meter elevation
Azimuth Elevation-induced Offset	0.53 m per meter elevation	0.15 m per meter elevation

Absolute Accuracy ESA, ERS-1, ERS-2

Death Valley Test Area

An ESA image is orthocorrected using zero or one GCP. The latitude and longitude of 12 GCPs is determined in the resultant orthoimage (all of these GCPs were in the RADARSAT-1 test). Some GCPs from the RADARSAT-1 test are not covered by the ESA image or are not well-imaged by the ESA image.) The 12 latitude and longitude values are measured and used to calculate RMS and Average error in both range and azimuth.

Table 9: Death Valley Test Area—Orthocorrected with/without GCP

Number of GCPs in Model	None	1
Range RMS Error	+227 m	+170 m
Range Average Error	+181 m	+151 m
Azimuth RMS Error	+84 m	+51 m
Azimuth Average Error	-51 m	-46 m

While the use of a GCP does result in some improvement, the overall resolution of this image prevents precise location of the GCPs.

Mt. Vesuvius Test Area

This ESA image does not have a corresponding DEM available, and thus the following results are for geocoding only. The elevations of the selected GCPs are derived from the available topographic maps and are used in the following analysis. Error analysis is based on the best 13 GCPs. The output image has 5 m pixels.

Table 10: Mt. Vesuvius Test Area—Geocoded with/without GCPs

Number of GCPs in Model	None	1	1	15
Range RMS	+63 m	+22 m	+30 m	+31 m
Range Average	-59 m -	3 m	+29 m	-21 m
Azimuth RMS	+140 m	+25 m	-26 m	+27 m
Azimuth Average	+138 m	+5 m	0 m	+9 m

This ESA image clearly benefits from the use of ground control to refine the orbit model. As with RADARSAT-1, a single GCP seems sufficient.

In geocoding, the accuracy of the resulting latitude and longitude is determined in part by the mean input elevation.

The potential error was quantified by using six piers, assumed at sea level, in the ESA Mt. Vesuvius image. The image was geocoded at 0 m, 50 m, 100 m and 200 m above sea level, and the resultant induced error in position was measured. From these measurements, it is found that each meter of error in elevation results in 2 m in range error and 0.45 m error in azimuth (23 degree incidence angle).

Table 11: Mt. Vesuvius Test Area—Incidence Angle/Degrees Results

Incidence Angle	23 Degrees
Range Elevation-induced Offset	2.00 m per meter elevation
Azimuth Elevation-induced Offset	0.45 m per meter elevation

Conclusions

The tests performed using IMAGINE OrthoRadar probably represent the accuracies that are routinely achievable given the feature resolution of the (5-10 m pixel) radar imagery, availability of Level II DEMs, handheld GPS limitations, and the availability of topographic maps better than 1:24,000. All things considered, given one accurate GCP, the accuracy and precision in both range and azimuth is around 30 m. Accuracy can be improved if a bias can be quantified and removed.

The geographic accuracy for a geocoded or orthorectified radar image is determined in large part by two things. One is the accuracy of the ephemeris data supplied with your image. Judging by the Denver test area results, it is possible for the RADARSAT-1 ephemeris to be so accurate as to require no GCPs, and get an accuracy of 37 m (2.6 pixels). However, in the Nicaragua test area, geocoding without a GCP resulted in a total error of 268 m (28 pixels).

The second factor is the accuracy of the GCPs. With the Nicaragua test set, use of a single GCP decreased the total measured error from 268 m to 77 m. Even more important, this reduced the misregistration between the two geocoded images from 218 m to 14 m. This is important if several images are to be mosaicked.

The accuracy of an orthoimage is greatly affected by the latitude and longitude matchup between the geocoding of the input image and the DEM. The level of this importance is determined by the local relief. An estimate of this match can be derived by draping the radar orthoimage over a shaded relief of the DEM and/or swiping the orthoimage over the DEM. If a mismatch can be quantified (commonly 1-2 pixels in X and Y), it should be removed from the DEM using Set Drop Point and the radar image reorthorectified.

Due to the large range, lesser azimuth and shift induced by incorrect elevation input when geocoding, attention should be paid to the importance of this parameter. Unless you are working on a coastal plain, the default value of 0 is not acceptable. At the minimum, a best estimate of the mean scene elevation should be used. For certain scenes (e.g., Denver, CO), it may be advantageous to geocode subsets at different mean elevations.

As indicated in discussing the Death Valley data sets, locating GCPs in a radar image is not easy in areas lacking human-made features. This is due in part to a difficulty in understanding how a visible (to the eye) feature is imaged by radar and by the obfuscating effect of speckle in the radar image. Use of no GCP could be preferable to use of an inaccurate one. This depends upon the accuracies of the ephemeris of the particular image and the GCPs in question.

Processing time, of course, depends upon your system. A Sun Sparc 12 required 1 1/2 hours to geocode a full RADARSAT-1 scene (8000 × 9200). On a PC (Dell Dimensions XPS D266), a full RADARSAT-1 scene took 1 3/4 hours to geocode. Orthorectification requires 3 to 5 times longer depending on how well your system handles file input and output (I/O) requirements.

It is possible that the resultant geocoded/orthorectified image has a bias (average error) nearly as large as the RMS error (error bar length). It is also possible to have a 0 bias. This can be determined if several accurate GCPs are available. If a large bias can be quantified, it should be removed using the Viewer function Raster | Set Drop Point.

Note that the SPOT orthoimage requires GCPs to achieve acceptable accuracy while the radar model does not. This suggests that, for applications such as oil slick monitoring where GCPs are not obtainable, the radar ephemeris combined with the IMAGINE OrthoRadar module can provide very acceptable results.

For coregistering data sets (e.g., SPOT XS with RADARSAT-1), the optimal approach would be to orthorectify each separately and then either: (1) Set Drop Point on both to a common GCP, or (2) Set Drop Point on one to a common tie point. This same approach should be used prior to mosaicking multiple images from a single sensor or a mix of images, for example, RADARSAT-1 and ESA.

Given no ground control, the optimal approach would be to use a radar orthoimage as the base layer and rectify other (SPOT, Landsat) imagery to it using a (2nd order) polynomial. This is because the radar ephemeris data seems to be more accurate than the ephemeris data of the optical sensors.

Given one very accurate GCP, well-defined in the imagery, the optimal approach would be to first use the GCP to refine the orbit. After orthorectification, this same GCP could be used with Set Drop Point to remove the (unquantified) bias.

If the available imagery is Single Look Complex (SLC), consider your project usage before import. Unless the intended application requires complex format (e.g., interferometric processing), you should probably import as a detected image. This produces a smaller data file and an image with better visual appearance. It is easier to recognize features. To locate the GCPs in the image, the Viewer functions Rotate, Flip and Stretch should be used to multilook and orient the image so that it best corresponds to the map.

About ERDAS

ERDAS – The Earth to Business Company – helps organizations harness the information of the changing earth for greater advantage.

ERDAS creates geospatial business systems that transform our earth's data into business information, enabling individuals, businesses and public agencies to quickly access, manage, process and share that information from anywhere.

Using secure geospatial information, ERDAS solutions improve employee, customer and partner visibility to information, enabling them to respond faster and collaborate better. It also means better decision-making, increased productivity and new revenue streams.

ERDAS is a part of the Hexagon Group, Sweden. For more information about ERDAS or its products and services, please call +1 770 776 3400, toll free +1 866 534 2286, or visit www.erdas.com.

ERDAS. Inc.
Worldwide Headquarters
5051 Peachtree Corners Circle
Norcross, GA 30092-2500 USA
Phone: +1 770 776 3400
Toll Free: +1 877 GO ERDAS (463 7327)
Phone: + 770 776 3400
Fax: +1 770 776 3500
E-mail: info@erdas.com
Website: www.erdas.com