

Georeferencing Ortho-Ready Images for Rational Polynomial Orthorectification

Ortho-ready images from satellite platforms such as QuickBird, IKONOS, WorldView, and Pleiades are provided with nominal (approximate) georeference computed from the satellite's orbital position and imaging geometry. The accuracy of this nominal georeferencing can vary greatly from image to image.

Although you can orthorectify a nominally-georeferenced ortho-ready image in the Image Resampling process in TNTmips using the rational polynomial coefficients (RPCs) supplied with the image and a digital elevation model (DEM), you can produce a more accurate result by first re-georeferencing the image using well-distributed 3D ground control points. The Resampling process uses the control points to adjust the RPC model to provide better registration between the image and the DEM, ensuring that the appropriate elevation value is used for each image cell during rectification. As few as four to six accurate control points may significantly improve the fit of the RPC model. Rectification using the improved georeference control produces an orthoimage with better internal geometry and less residual spatial distortion. For an example of the impact of improved georeferencing, see the Technical Guide entitled *Orthorectification Results for QuickBird*.

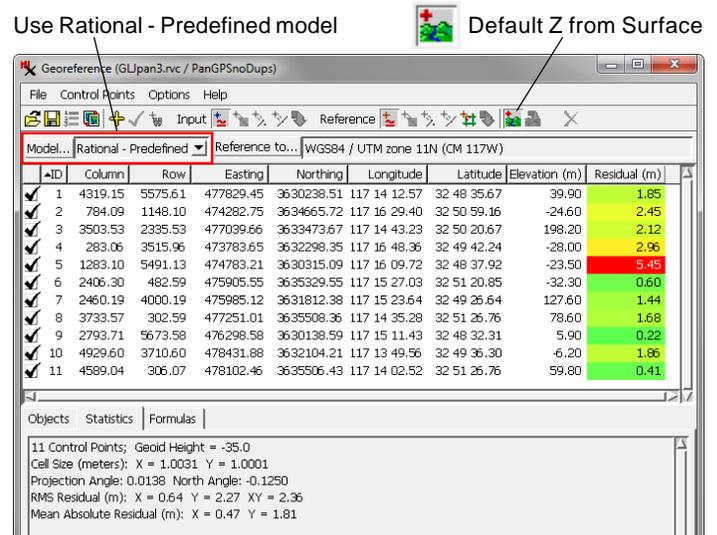
Using the Rational - Predefined Model

When you regeoreference an ortho-ready image, choose the Rational - Predefined option from the Model menu in the Georeference window. Your controls points are used to adjust the rational polynomial model, improving its accuracy in comparison to the nominal georeferencing supplied with the image. Residual errors shown for each control point are computed by first projecting all locations through the RPC model to remove terrain-related displacements. The residuals therefore reflect the fit of each point to the adjusted RPC model.

When you choose the Rational - Predefined model, you are prompted to choose the RPC model file for the image and a DEM that covers the image area. You are also prompted to enter a geoid height. This value adjusts the elevations in the DEM (usually referenced to the geoid) to elevations referenced to the WGS84 ellipsoid as required in the RPC model. You can use one of several on-line geoid height calculators to find the geoid height for the image area:

- <http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm96/intpt.html>
- <http://sps.unavco.org/geoid/>
- http://www.ngs.noaa.gov/cgi-bin/GEOID_STUFF/geoid03_prompt1.pr

You can add control points to an ortho-ready image from a GPS survey or from reference orthoimages or maps. All control points require an elevation value in order to produce an accurate adjustment of the RPC model. For GPS points, you can manually enter the elevation recorded by the GPS. For control points placed from reference data, you can turn on the Default Z from Surface icon button (see illustration above) to



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have the elevation automatically assigned from the DEM for each new point you add. Be sure to delete control points inherited from the original nominal georeferencing.

When you open a nominally-georeference ortho-ready image in the Georeference process, control points are generated at the image corners to represent this georeference information. **After you place some accurate control points, you should delete these less accurate original control points, as they will otherwise adversely influence the resulting RPC model.**

When you georeference an image using the Rational - Predefined model, the rational polynomial coefficients are stored in the saved georeference subobject. The auxiliary file that contained the original RPCs is then no longer needed.

Using Test Points

If you have a sufficient number of accurate control points, you can reserve some of them as test points by making them inactive and letting only the remaining points provide the georeference control. The individual residuals for these test points and their overall RMS errors then provide an independent test of the accuracy of your georeference control and an indication of the accuracy of the later RPC orthorectification.

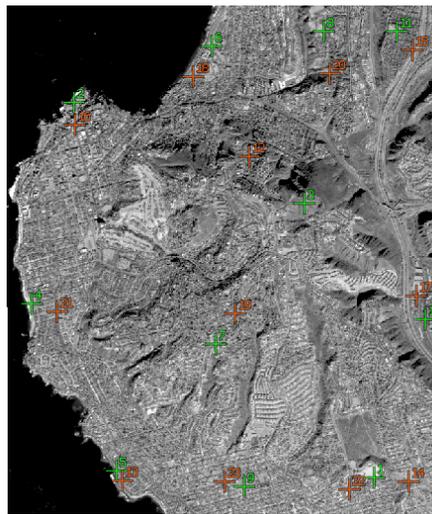
The example on the next page illustrates this procedure. The test image is an IKONOS panchromatic scene of La Jolla, California with 1-meter cell size. One copy of this image was

(continued)

regeoreferenced using well-distributed ground control points obtained in a GPS survey, and another was regeoreferenced using control points manually placed from a scanned 1:24,000 scale topographic map. Elevation control was provided by a elevation raster with 1-meter cell size created in the Surface Modeling process in TNTmips from 5-foot topographic contours of the area.

To test the horizontal accuracy of the RPC orthorectification model, 12 test georeference control points were added to each image and set as inactive (see illustration above). These test points were added manually by visual reference to aerial orthoimages with 0.5 foot cell size.

The table below shows predicted RMS error statistics for these images using the adjusted RPC model that are computed automatically by the Georeference process for the active (control) and inactive (test) points. The GPS georeference control provided a more accurate orthorectification model, and the RMS error for the test points is



ID	Column	Row	Easting	Northing	Longitude	Latitude	Elevation (m)	Residual (m)
6	2406.30	482.59	475905.55	3635329.55	117 15 27.03	32 51 20.85	-32.30	0.60
7	2460.19	4000.19	475985.12	3631812.38	117 15 23.64	32 49 26.64	127.60	1.45
8	3733.57	302.59	477251.01	3635508.36	117 14 35.28	32 51 26.76	78.60	1.68
9	2793.71	5673.58	476298.58	3630138.59	117 15 11.43	32 48 32.31	5.90	0.22
10	4929.60	3710.60	478431.88	3632104.21	117 13 49.56	32 49 36.30	-6.20	1.87
11	4589.04	306.07	478102.46	3635506.43	117 14 02.52	32 51 26.76	59.80	0.42
12	2851.52	1783.51	476374.45	3634027.55	117 15 08.87	32 50 38.61	111.56	1.01
13	1358.47	5604.39	474860.00	3630206.66	117 16 06.76	32 48 34.41	-24.48	1.54
14	4725.48	5613.52	478233.46	3630198.53	117 13 57.03	32 48 34.40	18.24	1.35
15	4779.29	523.79	478294.15	3635287.62	117 13 55.13	32 51 19.67	58.04	2.24
16	797.95	1406.89	474302.65	3634403.89	117 16 28.61	32 50 50.66	-3.86	1.46
17	4820.45	3426.88	478324.08	3632384.15	117 13 53.73	32 49 45.38	-8.36	2.28
18	2186.76	838.84	476687.49	3634973.15	117 15 35.39	32 51 09.26	-31.90	1.86
19	2689.10	3640.83	476216.72	3632169.77	117 15 14.77	32 49 38.26	136.47	1.63
20	3802.98	802.89	477313.65	3635008.79	117 14 32.83	32 51 10.54	32.99	1.67

Panchromatic IKONOS image (1-m cell size) of La Jolla, California showing GPS survey control points (green) used as georeference control for the RPC model. Test points (orange) were placed manually from reference orthoimages and made inactive so that they were excluded from the model.

within the error of the model points. The circular error (computed manually from the RMS errors) for the GPS image is close to that claimed for orthorectified IKONOS images provided by the satellite operator.

For more information, see the tutorial entitled *Orthorectification Using Rational Polynomials*.

Georeference from:	Root Mean Square (RMS) Errors (meters)			Circular Error (meters), 90% Probability (CE90)
	X	Y	XY	
Global Positioning System Survey 11 well-distributed control points	0.63 m	2.27 m	2.36 m	3.11 m
Scanned 1:24000 topographic map 22 control points	2.09 m	2.96 m	3.62 m	5.42 m

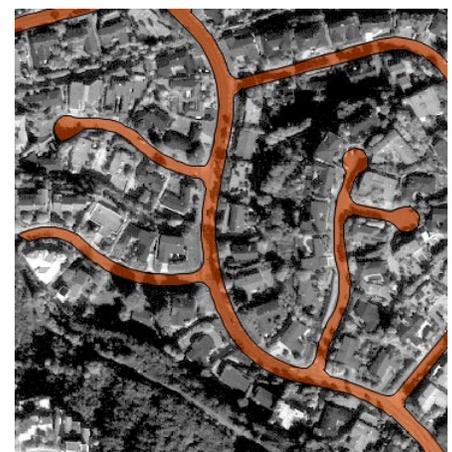
Predicted Positional Errors from Rational Polynomial Model and Detailed DEM							
For Georeference Control Points				For 12 Test Points from 0.5-foot orthophotos			
Root Mean Square (RMS) Errors (meters)			Circular Error (meters), 90% Probability (CE90)	Root Mean Square (RMS) Errors (meters)			Circular Error (meters), 90% Probability (CE90)
X	Y	XY		X	Y	XY	
0.63 m	2.27 m	2.36 m	3.11 m	1.30 m	1.06 m	1.68 m	2.53 m
2.09 m	2.96 m	3.62 m	5.42 m	2.66 m	4.92 m	5.59 m	8.13 m



Topographic contours (orange, with 10-foot contour interval) overlaid on portion of orthoimage (0.15-meter cell size), both obtained from County of San Diego. Street overlay (red fill) traced from same orthoimage for testing. Area has 200 feet (60 meters) of relief from lower right to upper left; width of area is 440 m.



Street vector overlaid on portion of IKONOS panchromatic image georeferenced with GPS points, prior to RPC orthorectification. Significant misregistration of the street overlay results from internal image distortion in the unrectified image due to local terrain relief.



Street vector overlaid on IKONOS pan image after RPC orthorectification. Rectification successfully removed terrain relief effects from the image, so there is now excellent registration with the planimetrically-correct street overlay.