

The Geometric Accuracy Evaluation Results of RPC (Ver.1.0)

1. Purpose

This document describes the geometric accuracy evaluation results of RPC (Ver.1.0) produced by the ALOS-PRISM RPC generating software of JAXA-EORC/RESTEC. In the RPC processing, the physical sensor model of PRISM calibrated at JAXA-EORC/RESTEC is applied and it is expected that the geometric accuracy of RPC follows the sensor model calibration and validation results.

2. Method

- 1) Generate the RPC data files ($f_1 \sim f_4 : c_1 \sim c_{20}, X_0 \sim P_0, X_s \sim P_s$) with the ALOS-PRISM RPC generating software. Both of “RPC for full image” and “RPC for each image” are generated.
- 2) Calculate image addresses of column (P) and row (L) which corresponds to reference GCPs (X, Y, Z) with generated RPC data as follows;

$$X_n = \frac{X - X_o}{X_s}, \quad Y_n = \frac{Y - Y_o}{Y_s}, \quad Z_n = \frac{Z - Z_o}{Z_s}$$

$$f(X_n, Y_n, Z_n) = c_1 + c_2 Y_n + c_3 X_n + c_4 Z_n + c_5 X_n Y_n + c_6 Y_n Z_n + c_7 Z_n X_n$$

$$+ c_8 Y_n^2 + c_9 X_n^2 + c_{10} Z_n^2 + c_{11} X_n Y_n Z_n + c_{12} Y_n^3 + c_{13} X_n^2 Y_n + c_{14} Z_n^2 Y_n$$

$$+ c_{15} Y_n^2 X_n + c_{16} X_n^3 + c_{17} Z_n^2 X_n + c_{18} Y_n^2 Z_n + c_{19} X_n^2 Z_n + c_{20} Z_n^3$$

$$L_n = \frac{f_1(X_n, Y_n, Z_n)}{f_2(X_n, Y_n, Z_n)}, \quad P_n = \frac{f_3(X_n, Y_n, Z_n)}{f_4(X_n, Y_n, Z_n)}$$

$$L = L_s L_n + L_0, \quad P = P_s P_n + P_0$$

- 3) The differences between calculated image addresses of column (P) and row (L) and mensuration image addresses of column (P_m) and row (L_m) are calculated as the errors of column (ΔP) and row (ΔL) of reference GCPs.

$$\Delta L = L - L_m, \quad \Delta P = P - P_m$$

3. Data

- 1) PRISM Standard Product L1B1

11/12/11 triplet data sets of forward/nadir/backward images respectively which were observed from Apl.28, 2006 through Jan.14, 2007 are used for the evaluation. Those data sets are sampled from the calibration data sets of JAXA-EORC/RESTEC geometric Cal/Val activities. The attitude data options are all On-Site-Precision.

2) Geometric models

The CCD alignment data (interior orientation parameters) is version 1 (Aug.30, 2006 release) which has already applied to the JAXA-EOC Standard Product processing. The PRISM sensor alignment (exterior orientation parameters) is CVST#6 (Mar, 2007) version which was calibrated by JAXA-EORC/RESTEC. Though the PRISM sensor alignment of JAXA-EORC/RESTEC corresponds to the Pointing Alignment Parameters of JAXA-EOC Standard Product processing, those two data are quite different and independently calibrated respectively. No orientation processing with GCPs is performed.

3) GCP

Reference GCPs and its mensuration results are provided by JAXA-EORC/RESTEC Cal/Val activities.

4. Results

The number of GCPs and errors stats (Bias, SD = Standard Deviation, RMS) for “RPC for each image” and “RPC for full image” of forward, nadir, and backward images are described at Table 1~6 as RPC geometric accuracies evaluation results. The units of errors are converted to meters from pixels by using the default pixel spacing of 2.5m.

Table 1 The evaluation results of “RPC for each image” - forward

Scene			ΔP			ΔL		
Date	Site	GCP	Bias[m]	SD[m]	RMS[m]	Bias[m]	SD[m]	RMS[m]
2006/04/28	Himeji	37	5.922	1.572	6.127	9.588	1.530	9.709
2006/04/28	Tokushima	28	6.271	1.244	6.394	10.026	1.745	10.177
2006/04/30	Saitama-U	166	-8.306	1.795	8.498	-8.610	1.910	8.819
2006/04/30	Saitama-L	230	-7.737	1.308	7.846	-8.169	1.435	8.294
2006/06/20	Okazaki	42	1.817	2.074	2.757	-5.827	1.540	6.027
2006/06/21	Thun	73	-1.437	1.798	2.302	-3.413	1.496	3.727
2006/07/29	Himeji	15	4.187	1.251	4.370	2.045	1.342	2.446
2006/07/29	Tokushima	28	3.798	1.095	3.953	3.953	1.622	4.273
2006/09/25	Kyoto	24	-2.216	2.166	3.099	0.672	1.664	1.795
2006/11/08	Kyushu	86	3.063	2.013	3.665	1.952	2.109	2.874
2007/01/14	Tsukuba	129	2.903	1.628	3.328	-4.222	1.993	4.669
RMS			4.892	1.669	5.169	6.185	1.687	6.411

Table 2 The evaluation results of “RPC for full image” - forward

Scene			ΔP			ΔL		
Date	Site	GCP	Bias[m]	SD[m]	RMS[m]	Bias[m]	SD[m]	RMS[m]
2006/04/28	Himeji	37	5.750	2.558	6.293	9.687	2.089	9.910
2006/04/28	Tokushima	28	6.203	2.617	6.733	10.211	2.292	10.465
2006/04/30	Saitama-U	166	-8.197	2.681	8.624	-8.780	2.917	9.251
2006/04/30	Saitama-L	230	-7.559	2.441	7.943	-8.579	2.613	8.968
2006/06/20	Okazaki	42	1.719	1.779	2.474	-6.200	2.125	6.554
2006/06/21	Thun	73	-1.381	1.613	2.123	-3.815	1.968	4.292
2006/07/29	Himeji	15	4.108	2.017	4.577	2.856	2.134	3.565
2006/07/29	Tokushima	28	3.802	2.322	4.455	4.070	2.330	4.690
2006/09/25	Kyoto	24	-2.581	2.048	3.295	0.485	2.256	2.308
2006/11/08	Kyushu	86	2.794	2.846	3.988	1.918	3.214	3.743
2007/01/14	Tsukuba	129	2.888	1.616	3.309	-4.671	2.530	5.312
RMS			4.814	2.270	5.322	6.412	2.434	6.858

Table 3 The evaluation results of “RPC for each image” - nadir

Scene			ΔP			ΔL		
Date	Site	GCP	Bias[m]	SD[m]	RMS[m]	Bias[m]	SD[m]	RMS[m]
2006/04/28	Himeji	37	3.886	1.831	4.295	1.576	1.416	2.119
2006/04/28	Tokushima	28	4.307	1.094	4.443	2.398	1.572	2.868
2006/04/30	Saitama-U	166	-4.971	1.722	5.261	-5.092	1.759	5.387
2006/04/30	Saitama-L	230	-4.709	1.512	4.946	-4.360	1.388	4.575
2006/06/20	Okazaki	42	2.866	2.039	3.517	5.286	1.307	5.446
2006/06/21	Thun	73	0.556	1.901	1.981	7.115	1.784	7.335
2006/07/14	Saitama	209	2.208	2.100	3.047	5.524	1.720	5.785
2006/07/29	Himeji	15	1.758	1.283	2.176	3.287	1.706	3.703
2006/07/29	Tokushima	28	2.778	1.356	3.091	5.061	1.872	5.396
2006/09/25	Kyoto	24	-2.276	2.056	3.067	2.201	1.762	2.819
2006/11/08	Kyushu	86	1.213	2.264	2.568	-0.301	2.217	2.237
2007/01/14	Tsukuba	129	-3.967	1.789	4.352	-5.905	1.677	6.139
RMS			3.255	1.780	3.710	4.458	1.698	4.770

Table 4 The evaluation results of “RPC for full image” - nadir

Scene			ΔP			ΔL		
Date	Site	GCP	Bias[m]	SD[m]	RMS[m]	Bias[m]	SD[m]	RMS[m]
2006/04/28	Himeji	37	3.999	1.806	4.388	1.768	1.510	2.325
2006/04/28	Tokushima	28	4.400	1.191	4.559	2.445	1.841	3.060
2006/04/30	Saitama-U	166	-4.885	1.741	5.186	-4.992	1.753	5.290
2006/04/30	Saitama-L	230	-4.649	1.518	4.890	-4.346	1.448	4.581
2006/06/20	Okazaki	42	2.834	1.667	3.288	5.107	1.727	5.391
2006/06/21	Thun	73	0.568	1.631	1.727	7.006	2.152	7.329
2006/07/14	Saitama	209	3.188	1.969	3.747	5.918	2.648	6.484
2006/07/29	Himeji	15	2.008	1.360	2.425	3.550	1.918	4.035
2006/07/29	Tokushima	28	2.872	1.412	3.201	5.111	1.919	5.459
2006/09/25	Kyoto	24	-2.892	1.728	3.369	1.855	2.146	2.836
2006/11/08	Kyushu	86	1.309	2.372	2.709	-0.167	2.237	2.244
2007/01/14	Tsukuba	129	-3.778	1.754	4.165	-5.865	1.714	6.111
RMS			3.366	1.704	3.773	4.469	1.944	4.874

Table 5 The evaluation results of “RPC for each image” - backward

Scene			ΔP			ΔL		
Date	Site	GCP	Bias[m]	SD[m]	RMS[m]	Bias[m]	SD[m]	RMS[m]
2006/04/28	Himeji	37	2.657	1.576	3.090	11.086	1.517	11.189
2006/04/28	Tokushima	28	2.707	1.171	2.950	11.945	1.216	12.007
2006/04/30	Saitama-U	166	-2.765	1.611	3.200	-11.699	1.886	11.850
2006/04/30	Saitama-L	230	-3.033	1.340	3.315	-10.252	1.673	10.388
2006/06/20	Okazaki	42	1.180	1.524	1.927	-8.560	1.936	8.777
2006/06/21	Thun	73	0.927	1.575	1.828	-2.454	3.104	3.957
2006/07/29	Himeji	15	4.024	1.673	4.358	1.183	1.738	2.102
2006/07/29	Tokushima	28	3.656	1.300	3.881	3.602	2.274	4.260
2006/09/25	Kyoto	24	-1.303	1.346	1.873	0.915	2.296	2.472
2006/11/08	Kyushu	86	-2.236	1.895	2.931	-2.443	2.109	3.227
2007/01/14	Tsukuba	129	7.345	1.594	7.516	-6.178	2.351	6.610
RMS			3.353	1.522	3.683	7.665	2.066	7.938

Table 6 The evaluation results of “RPC for full image” - backward

Scene			ΔP			ΔL		
Date	Site	GCP	Bias[m]	SD[m]	RMS[m]	Bias[m]	SD[m]	RMS[m]
2006/04/28	Himeji	37	2.582	1.568	3.021	11.362	1.645	11.481
2006/04/28	Tokushima	28	2.768	1.537	3.167	12.081	1.319	12.153
2006/04/30	Saitama-U	166	-2.646	1.723	3.157	-11.548	1.881	11.700
2006/04/30	Saitama-L	230	-2.924	1.487	3.281	-10.083	1.642	10.216
2006/06/20	Okazaki	42	1.133	1.520	1.896	-8.511	1.809	8.701
2006/06/21	Thun	73	0.976	1.636	1.905	-2.539	3.041	3.962
2006/07/29	Himeji	15	3.920	1.563	4.220	1.596	2.038	2.588
2006/07/29	Tokushima	28	3.710	1.619	4.048	3.754	2.022	4.264
2006/09/25	Kyoto	24	-1.078	1.358	1.734	0.889	2.100	2.281
2006/11/08	Kyushu	86	-2.181	1.913	2.901	-2.150	2.107	3.010
2007/01/14	Tsukuba	129	7.301	1.578	7.470	-6.023	2.232	6.423
RMS			3.309	1.597	3.674	7.671	2.029	7.935

5. Summary

The bias errors of RPC are following the fitting accuracy of PRISM alignment trend model (exterior orientation parameters) calibrated by JAXA-EORC/RESTEC. Table 7 shows the fitting residuals of PRISM alignment model of CVST#6 which was applied to RPC data. The accuracies of “RPC for full image” are worse than “RPC for each image” in forward images though there are no such trends in nadir and backward images. The nonlinearity of CCD unit alignment (interior orientation parameters) of forward CCD 6-7-8 is too large to be represented in RPC cubic polynomials. Fig.1 shows the configurations of CCD unit alignments theoretically expressed in $f=2,000\text{mm}$ pin-hole camera. There are some wrong standard deviations (e.g. Thun- ΔL). These errors are also confirmed at PRISM alignment model calibrations and are because of yaw angle errors. The detailed analysis of those errors is still ongoing. At Mar.22, 2007, the on-board STT parameter calibration was performed and the attitude data may have offset errors after the date. The evaluations and calibrations of those offset errors are not yet performed. The new RPC version will be released as soon as those evaluations and calibrations are finished.

Table 7 Fitting residuals of PRISM alignment model (CVST#6)

	No. of Scenes (P1/P2)	Linear regression residuals sigma [deg]		Linear regression residuals sigma in ground level [m]		
		Roll	Pitch	X	Y	XY(RSS)
FWD	13/11	0.000430	0.000366	5.20	5.27	7.40
NDR	17/11	0.000285	0.000349	3.44	4.21	5.44
BWD	16/10	0.000279	0.000367	3.37	5.30	6.28

P1 = Launch~2006/09/05, P2 = 2006/09/06~2007/01/14

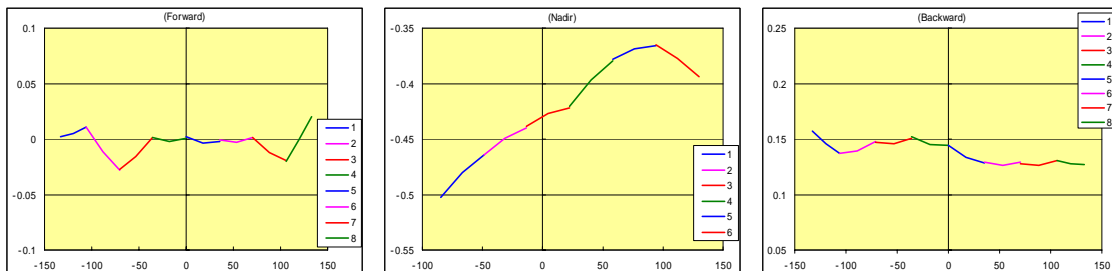


Fig.1 Configurations of CCD unit alignments

(Theoretical expression in $f=2,000\text{mm}$ pin-hole camera, provided by Dr. Hashimoto, EORC)