Absolute Geolocation Accuracy Re-Evaluation of WorldView-1 Basic 1B Stereo Pairs

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Outline

- Objective
- Product Description and Specifications
- Methodology
- Evaluation Results

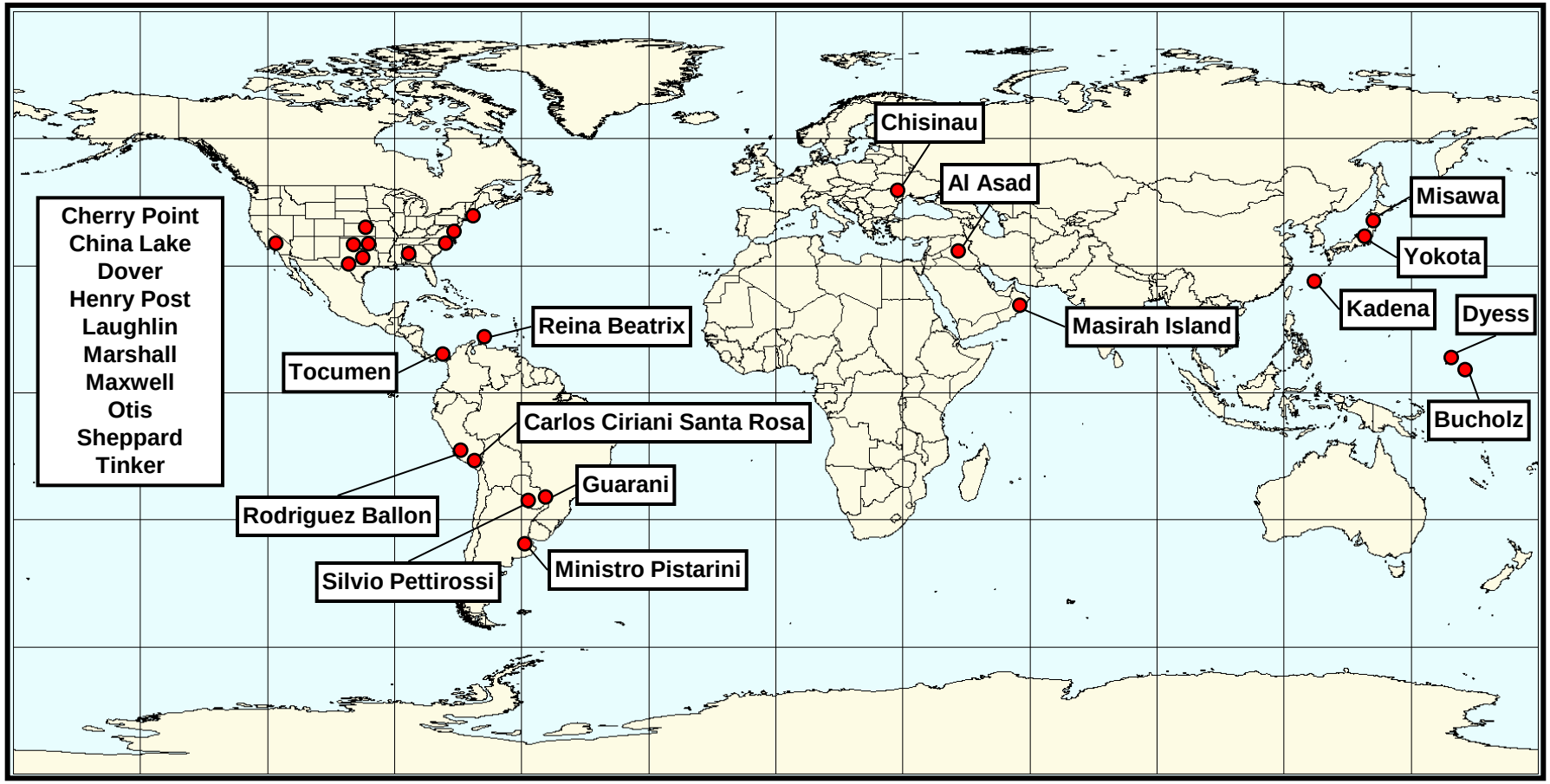
- Bonus: Monitoring Results

Objective

- To estimate the absolute horizontal and vertical geolocation accuracy of a sample of 25 panchromatic WorldView-1 Basic 1B stereo pairs collected using a scan rate of 24,000 lines per second (lps)

- End product accuracy assessments
  - No correction for off-nadir angle

25 Stereo Pairs over 25 Test Sites



Collected between 21 March and 26 April 2009. All products processed on 28 May 2009.

Definitions of Statistics

- Circular Error 90% (CE90)
  - In horizontal plane
  - Radial error distance centered at zero within which 90% of the data points fall
- Linear Error 90% (LE90)
  - In vertical dimension
  - Absolute value error distance from zero within which 90% of the data points fall

DigitalGlobe WorldView-1 Basic 1B Stereo Pair Product

Processing	Geometry	Swath Width (km)	Nadir GSD (m)	Bit Depth
Basic 1B	Synthetic Pushbroom	16.4 - 17.6	0.5	11-bit

DigitalGlobe Statements	CE90 and LE90 (m)*
Specification	6.5
Typical Performance	4.0 - 5.5

* At nadir, excluding terrain effects, and with convergence angle of ~35 .

Source: http://www.digitalglobe.com/index.php/48/Products?product_id=23, accessed 25 January 2010.

CCAP Absolute Geolocation Accuracy Methodology

- General Approach: Stereo intersection
- Stereo pairs *not* allowed to adjust during evaluation

CCAP Absolute Geolocation Accuracy Methodology

1) Load stereo pair onto workstation with SOCET Set® photogrammetric software

2) Import geometry model support data accompanying imagery

- a) NITF 2.1 Commercial Data Requirements Document (NCDRD) format rigorous sensor metadata
  - Imbedded camera, ephemeris, and attitude information
  - Atmospheric refraction (ATMREF) correction turned “on”
- b) Rational polynomial coefficient (RPC) replacement geometry model metadata

CCAP Absolute Geolocation Accuracy Methodology

3) Compute ground coordinates of checkpoints from test imagery sensor model support data

- Use ground-surveyed control points as checkpoints
- Measure pixel positions (line, sample) of checkpoints
- Hold test imagery fixed (by holding sensor model support data fixed) and allow checkpoint ground coordinates to adjust to pixel measurements using triangulation tool
  - For stereo pairs, each checkpoint is allowed to freely adjust (stereo intersection)

CCAP Absolute Geolocation Accuracy Methodology

4) For each checkpoint, subtract ground-surveyed coordinates from test-imagery-derived ground coordinates

- Results in a list of "Δ Easting," "Δ Northing," and "Δ Height" values

CCAP Absolute Geolocation Accuracy Methodology

5) For each stereo pair, compute error centroid

- Compute mean "Δ Easting" and "Δ Northing" values
  - Convert into horizontal "Δ Radial" value
- Compute mean "Δ Height" value
  - Convert into "absolute-value Δ Height" value

- Additional statistics:
  - Number of checkpoints
  - Maximums & minimums of Δ Easting, Δ Northing, and Δ Height values
  - Standard deviations of Δ Easting, Δ Northing, and Δ Height values

- Each stereo pair represented by single data point for CE90 and LE90 estimation

CCAP Absolute Geolocation Accuracy Methodology

Each stereo pair represented by single data point for CE90 and LE90 estimation because…

- …test sites have varying number of checkpoints
- …absolute checkpoint errors for metric, narrow field-of-view sensors tend to be similar in magnitude and direction throughout an image
- …goal of evaluation is to estimate CE90 and LE90 error statistics for population of stereo pairs, not individual stereo pair

CCAP Absolute Geolocation Accuracy Methodology

6) Estimate CE90 and LE90

- CCAP uses non-parametric estimator ("Percentile Method")
- Sort "Δ Radial" or "absolute-value Δ Height" values in ascending order
- Cut-off at 90th percentile
  - For n data points, 0.9*n + 0.5 defines position in ordered list
  - Linearly interpolate from ordered list as required

- Additional statistics:
  - Number of stereo pairs
  - Maximums and minimums of centroid values
  - Standard deviations of centroid values

90th Percentile Estimator for Ordered Statistics

Given n ordered data points $x_{(1)}, x_{(2)}, \ldots, x_{(n)}$,

where $x_{(i)} = \Delta r_{(i)}$ for CE90 and $x_{(i)} = abs(\Delta h_{(i)})$ for LE90.

Then,

$$CE90 \text{ or } LE90 = (1 - f) * x_{(i)} + f * x_{(i+1)}$$

where

$i =$ integer part of $0.9 * n + 0.5$, and

$f =$ fractional part of $0.9 * n + 0.5$.

WorldView-1 Basic 1B 24k lps Re-Evaluation Results

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WorldView-1 Basic 1B (24k lps)

Stereo Horizontal Accuracy

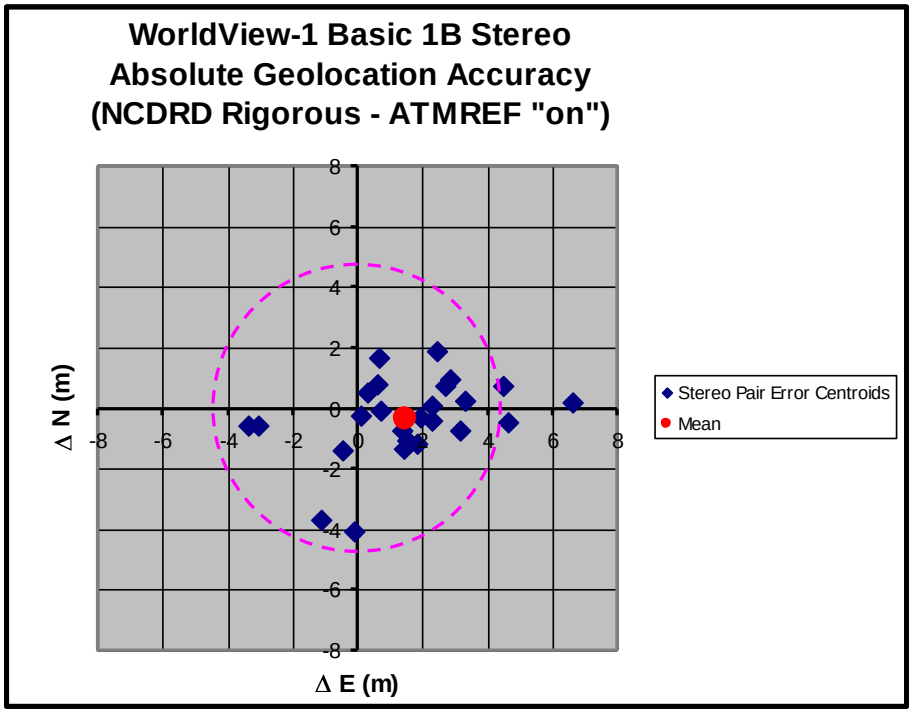
Test Site	CPs	Stereo Pair	Mean Δ E (m)	Mean Δ N (m)	Δ r (m)
Argentina, Ministro Pistarini	11	AR_MP_2009_04_17_615030_615040	-3.1	-0.6	3.1
Aruba, Reina Beatrix	5	AA_RB_2009_04_17_617010_617020	1.9	-0.3	1.9
Iraq, Al Asad	12	IZ_AA_2009_03_21_618040_618050	2.3	0.1	2.3
Japan, Kadena	13	JA_KD_2009_04_18_597030_597040	1.4	-1.3	1.9
Japan, Misawa	11	JA_MS_2009_03_21_619030_619040	0.1	-0.2	0.3
Japan, Yokota	12	JA_YK_2009_03_21_614040_614050	0.7	1.7	1.8
Marshall Islands, Bucholz	17	RM_BH_2009_04_21_616040_616050	1.4	-0.7	1.6
Marshall Islands, Dyess	13	RM_DY_2009_04_21_611050_614010	1.5	-1.1	1.9
Moldova, Chisinau	23	MD_CH_2009_04_17_613010_613020	0.6	0.8	1.0
Oman, Masirah Island	31	MU_MI_2009_04_19_597050_598010	1.8	-1.2	2.2
Panama, Tocumen	11	PM_TO_2009_04_03_618020_618030	2.3	-0.4	2.4
Paraguay, Guarani	16	PA_GU_2009_04_17_612020_612030	-3.4	-0.6	3.4
Paraguay, Silvio Pettirossi	15	PA_SP_2009_03_22_614020_614030	-0.5	-1.4	1.4
Peru, Coronel FAP Carlos Ciriani Santa Rosa	20	PE_CR_2009_04_01_611030_611040	-0.1	-4.1	4.1
Peru, Rodriquez Ballon	25	PE_RB_2009_04_05_613030_613040	-1.1	-3.7	3.8
US, Cherry Point	17	US_CP_2009_03_21_620040_620050	6.6	0.2	6.7
US, China Lake	17	US_CL_2009_03_22_623010_623020	0.7	-0.1	0.7
US, Dover	10	US_DO_2009_03_21_597010_597020	4.5	0.7	4.5
US, Henry Post	10	US_HP_2009_04_20_617050_618010	2.9	1.0	3.0
US, Laughlin	12	US_LA_2009_04_20_616020_616030	2.7	0.8	2.8
US, Marshall	14	US_ML_2009_03_21_611010_611020	4.6	-0.5	4.7
US, Maxwell	11	US_MX_2009_04_26_617030_617040	3.1	-0.7	3.2
US, Otis	20	US_OT_2009_04_12_620020_620030	2.4	1.9	3.1
US, Sheppard	9	US_SP_2009_04_20_619010_619020	3.3	0.2	3.3
US, Tinker	11	US_TK_2009_04_16_621010_621020	0.3	0.5	0.6

- 25 stereo pairs
- NCDRD support data
- ATMREF correction “on”

Mean (m)	1.5	-0.4	2.6
Standard Deviation (m)	2.2	1.4	1.5
Maximum (m)	6.6	1.9	6.7
Minimum (m)	-3.4	-4.1	0.3

WorldView-1 Basic 1B (24k lps)

Stereo Horizontal Accuracy (n=25)



Test Site	Sorted Δ r (m)	Test Stereo Pair
Japan, Misawa	0.3	JA_MS_2009_03_21_619030_619040
US, Tinker	0.6	VQ_TK_2009_04_16_621010_621020
US, China Lake	0.7	US_CL_2009_03_22_623010_623020
Moldova, Chisinau	1.0	MD_CH_2009_04_17_613010_613020
Paraguay, Silvio Pettirossi	1.4	PA_SP_2009_03_22_614020_614030
Marshall Islands, Bucholz	1.6	RM_BH_2009_04_21_616040_616050
Japan, Yokota	1.8	JA_YK_2009_03_21_614040_614050
Marshall Islands, Dyess	1.9	RM_DY_2009_04_21_611050_614010
Aruba, Reina Beatrix	1.9	AA_RB_2009_04_17_617010_617020
Japan, Kadena	1.9	JA_KD_2009_04_18_597030_597040
Oman, Masirah Island	2.2	MU_MI_2009_04_19_597050_598010
Iraq, Al Asad	2.3	IZ_AA_2009_03_21_618040_618050
Panama, Tocumen	2.4	PM_TO_2009_04_03_618020_618030
US, Laughlin	2.8	US_LA_2009_04_20_616020_616030
US, Henry Post	3.0	US_HP_2009_04_20_617050_618010
US, Otis	3.1	US_OT_2009_04_12_620020_620030
Argentina, Ministro Pistarini	3.1	AR_MP_2009_04_17_615030_615040
US, Maxwell	3.2	US_MX_2009_04_26_617030_617040
US, Sheppard	3.3	US_SP_2009_04_20_619010_619020
Paraguay, Guarani	3.4	PA_GU_2009_04_17_612020_612030
Peru, Rodriquez Ballon	3.8	PE_RB_2009_04_05_613030_613040
Peru, Coronel FAP Carlos Ciriani Santa Rosa	4.1	PE_CR_2009_04_01_611030_611040
US, Dover	4.5	US_DO_2009_03_21_597010_597020
US, Marshall	4.7	US_ML_2009_03_21_611010_611020
US, Cherry Point	6.7	US_CP_2009_03_21_620040_620050

Estimated Stereo CE90 = 4.5 m

WorldView-1 Basic 1B (24k lps)

Stereo Vertical Accuracy

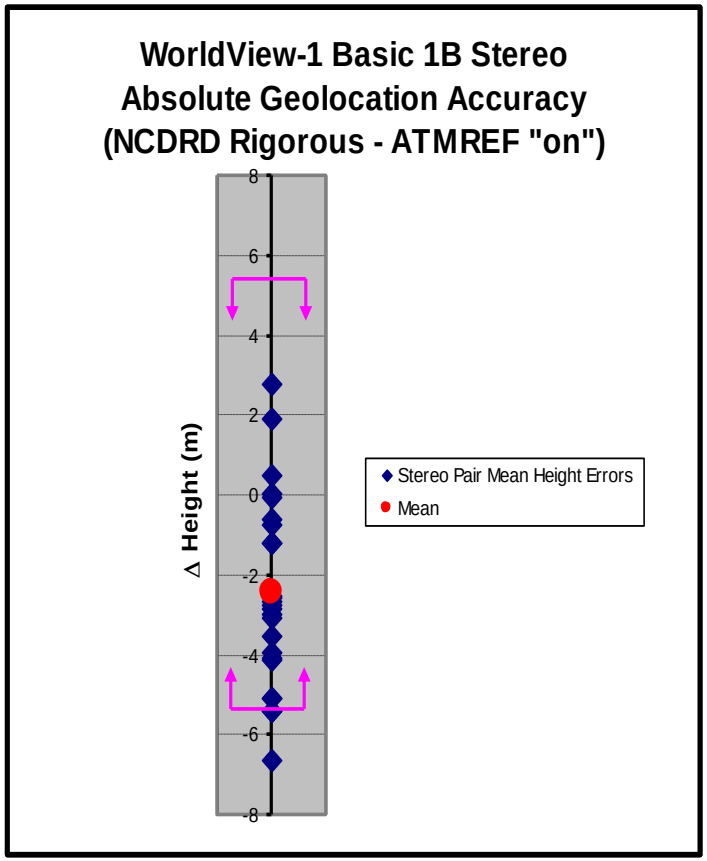
Test Site	CPs	Stereo Pair	Mean Δ Height (m)	Abs. Mean Δ Height (m)
Argentina, Ministro Pistarini	11	AR_MP_2009_04_17_615030_615040	-0.6	0.6
Aruba, Reina Beatrix	5	AA_RB_2009_04_17_617010_617020	-2.7	2.7
Iraq, Al Asad	12	IZ_AA_2009_03_21_618040_618050	-1.2	1.2
Japan, Kadena	13	JA_KD_2009_04_18_597030_597040	1.9	1.9
Japan, Misawa	11	JA_MS_2009_03_21_619030_619040	-5.1	5.1
Japan, Yokota	12	JA_YK_2009_03_21_614040_614050	-2.6	2.6
Marshall Islands, Bucholz	17	RM_BH_2009_04_21_616040_616050	0.0	0.0
Marshall Islands, Dyess	13	RM_DY_2009_04_21_611050_614010	-3.0	3.0
Moldova, Chisinau	23	MD_CH_2009_04_17_613010_613020	-6.6	6.6
Oman, Masirah Island	31	MU_MI_2009_04_19_597050_598010	-3.5	3.5
Panama, Tocumen	11	PM_TO_2009_04_03_618020_618030	-5.1	5.1
Paraguay, Guarani	16	PA_GU_2009_04_17_612020_612030	-2.7	2.7
Paraguay, Silvio Pettirossi	15	PA_SP_2009_03_22_614020_614030	-0.1	0.1
Peru, Coronel FAP Carlos Ciriani Santa Rosa	20	PE_CR_2009_04_01_611030_611040	-0.7	0.7
Peru, Rodriquez Ballon	25	PE_RB_2009_04_05_613030_613040	-2.5	2.5
US, Cherry Point	17	US_CP_2009_03_21_620040_620050	-5.4	5.4
US, China Lake	17	US_CL_2009_03_22_623010_623020	-3.1	3.1
US, Dover	10	US_DO_2009_03_21_597010_597020	-3.9	3.9
US, Henry Post	10	US_HP_2009_04_20_617050_618010	-4.1	4.1
US, Laughlin	12	US_LA_2009_04_20_616020_616030	-2.9	2.9
US, Marshall	14	US_ML_2009_03_21_611010_611020	0.5	0.5
US, Maxwell	11	US_MX_2009_04_26_617030_617040	2.8	2.8
US, Otis	20	US_OT_2009_04_12_620020_620030	-4.1	4.1
US, Sheppard	9	US_SP_2009_04_20_619010_619020	-1.2	1.2
US, Tinker	11	US_TK_2009_04_16_621010_621020	-5.4	5.4

- 25 stereo pairs
- NCDRD support data
- ATMREF correction “on”

Mean (m)	-2.4	2.9
Standard Deviation (m)	2.4	1.8
Maximum (m)	2.8	6.6
Minimum (m)	-6.6	0.0

WorldView-1 Basic 1B (24k lps)

Stereo Vertical Accuracy (n=25)



Test Site	Sorted Abs. Δ Height (m)	Test Stereo Pairs
Marshall Islands, Bucholz	0.0	RM_BH_2009_04_21_616040_616050
Paraguay, Silvio Pettirossi	0.1	PA_SP_2009_03_22_614020_614030
US, Marshall	0.5	US_ML_2009_03_21_611010_611020
Argentina, Ministro Pistarini	0.6	AR_MP_2009_04_17_615030_615040
Peru, Coronel FAP Carlos Ciriani Santa Rosa	0.7	PE_CR_2009_04_01_611030_611040
Iraq, Al Asad	1.2	IZ_AA_2009_03_21_618040_618050
US, Sheppard	1.2	US_SP_2009_04_20_619010_619020
Japan, Kadena	1.9	JA_KD_2009_04_18_597030_597040
Peru, Rodriquez Ballon	2.5	PE_RB_2009_04_05_613030_613040
Japan, Yokota	2.6	JA_YK_2009_03_21_614040_614050
Paraguay, Guarani	2.7	PA_GU_2009_04_17_612020_612030
Aruba, Reina Beatrix	2.7	AA_RB_2009_04_17_617010_617020
US, Maxwell	2.8	US_MX_2009_04_26_617030_617040
US, Laughlin	2.9	US_LA_2009_04_20_616020_616030
Marshall Islands, Dyess	3.0	RM_DY_2009_04_21_611050_614010
US, China Lake	3.1	US_CL_2009_03_22_623010_623020
Oman, Masirah Island	3.5	MU_MI_2009_04_19_597050_598010
US, Dover	3.9	US_DO_2009_03_21_597010_597020
US, Henry Post	4.1	US_HP_2009_04_20_617050_618010
US, Otis	4.1	US_OT_2009_04_12_620020_620030
Panama, Tocumen	5.1	PM_TO_2009_04_03_618020_618030
Japan, Misawa	5.1	JA_MS_2009_03_21_619030_619040
US, Tinker	5.4	VQ_TK_2009_04_16_621010_621020
US, Cherry Point	5.4	US_CP_2009_03_21_620040_620050
Moldova, Chisinau	6.6	MD_CH_2009_04_17_613010_613020

Estimated Stereo LE90 = 5.4 m

WorldView-1 Basic 1B (24k lps)
NCDRD Rigorous vs. RPC Comparison

Test Site	Stereo Pair	Stereo Pair (RPC-NCDRD1)			
		ΔΔ E (m)	ΔΔ N (m)	r (m)	ΔΔ Height (m)
Argentina, Ministro Pistarini	AR_MP_2009_04_17_615030_615040	-0.01	0.03	0.03	0.20
Aruba, Reina Beatrix	AA_RB_2009_04_17_617010_617020	-0.70	0.15	0.71	0.01
Iraq, Al Asad	IZ_AA_2009_03_21_618040_618050	0.02	0.03	0.04	0.15
Japan, Kadena	JA_KD_2009_04_18_597030_597040	0.13	0.00	0.13	-0.05
Japan, Misawa	JA_MS_2009_03_21_619030_619040	-0.04	0.17	0.17	0.29
Japan, Yokota	JA_YK_2009_03_21_614040_614050	0.07	-0.03	0.08	-0.06
Marshall Islands, Bucholz	RM_BH_2009_04_21_616040_616050	-0.05	0.03	0.06	0.28
Marshall Islands, Dyess	RM_DY_2009_04_21_611050_614010	0.07	0.05	0.09	-0.01
Moldova, Chisinau	MD_CH_2009_04_17_613010_613020	-0.05	0.04	0.06	0.28
Oman, Masirah Island	MU_MI_2009_04_19_597050_598010	0.06	-0.01	0.06	0.03
Panama, Tocumen	PM_TO_2009_04_03_618020_618030	-0.01	0.07	0.07	0.11
Paraguay, Guarani	PA_GU_2009_04_17_612020_612030	-0.04	0.07	0.08	0.36
Paraguay, Silvio Pettirossi	PA_SP_2009_03_22_614020_614030	0.04	0.05	0.06	0.04
Peru, Coronel FAP Carlos Ciriani Santa Rosa	PE_CR_2009_04_01_611030_611040	0.05	0.05	0.07	0.46
Peru, Rodriquez Ballon	PE_RB_2009_04_05_613030_613040	0.11	0.03	0.12	0.73
US, Cherry Point	US_CP_2009_03_21_620040_620050	-0.03	-0.02	0.04	0.16
US, China Lake	US_CL_2009_03_22_623010_623020	0.04	0.02	0.04	0.08
US, Dover	US_DO_2009_03_21_597010_597020	0.10	-0.04	0.11	3.37
US, Henry Post	US_HP_2009_04_20_617050_618010	0.00	0.00	0.00	0.31
US, Laughlin	US_LA_2009_04_20_616020_616030	-0.03	-0.02	0.04	0.23
US, Marshall	US_ML_2009_03_21_611010_611020	-0.07	-0.04	0.08	0.05
US, Maxwell	US_MX_2009_04_26_617030_617040	-0.07	0.00	0.07	0.24
US, Otis	US_OT_2009_04_12_620020_620030	0.04	-0.01	0.04	0.14
US, Sheppard	US_SP_2009_04_20_619010_619020	0.07	0.01	0.07	0.42
US, Tinker	US_TK_2009_04_16_621010_621020	-0.03	-0.04	0.05	0.27

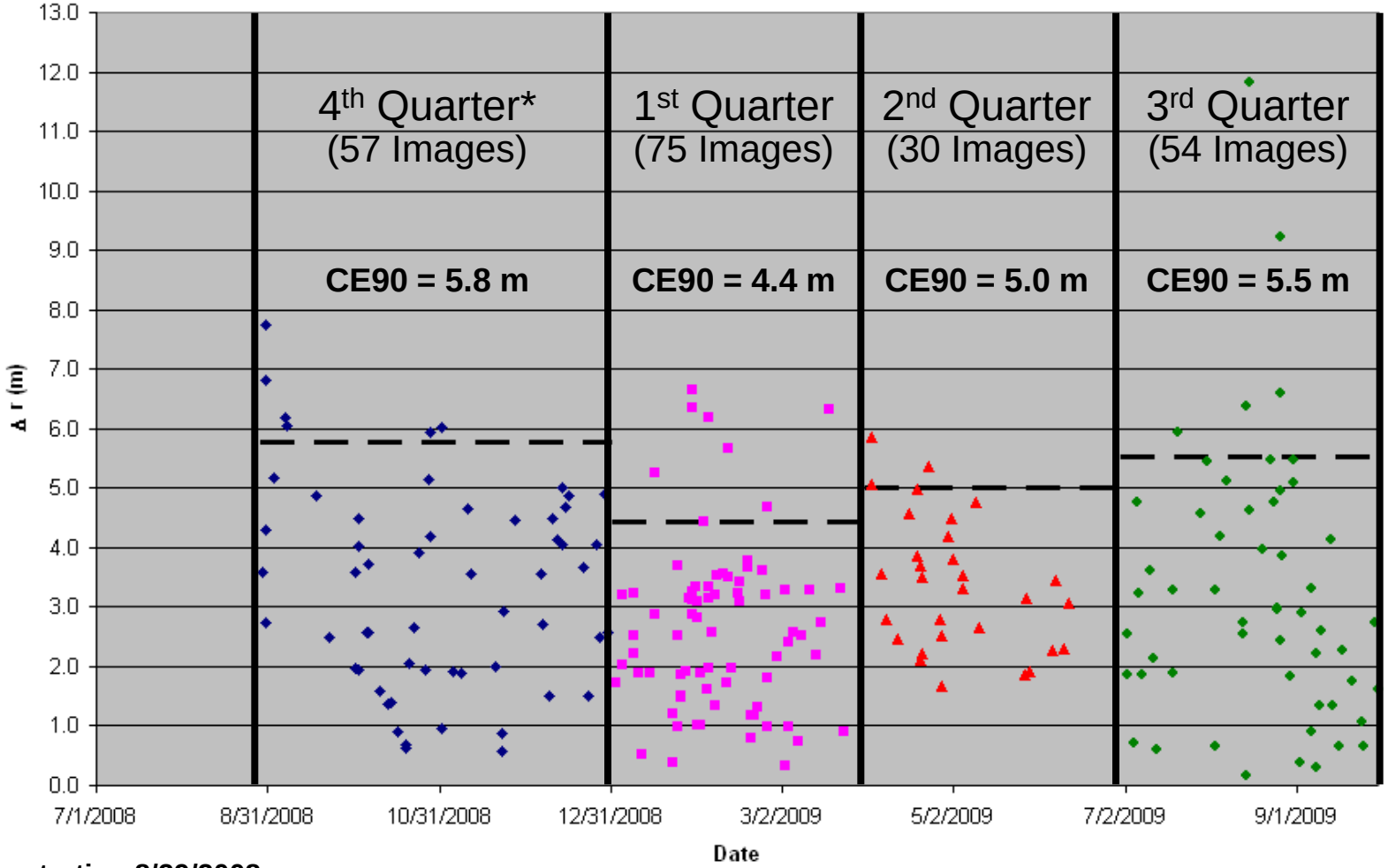
- 25 stereo pairs
- RPC - NCDRD Rigorous

Mean (m)	-0.01	0.02	0.09	0.32
Standard Deviation (m)	0.15	0.05	0.13	0.66
Maximum (m)	0.13	0.17	0.71	3.37
Minimum (m)	-0.70	-0.04	0.00	-0.06

Monitoring Results

WorldView-1 CE90 Performance

Additional Monoscopic Images



*** Actually starting 8/29/2008**

Questions?

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