NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY

Know the Earth... Show the Way... Understand the World

Geolocation Accuracy Re-Evaluations of GeoEye-1 and QuickBird-2

Paul C. Bresnahan

Contractor, NGA Image Quality and Utility Program

2012 JACIE Workshop

18 April 2012

Approved for Public Release 12-182

Methodology

- Photogrammetric software provides NIQU/CCAP capability to use physical sensor or geometry models with imagery
- Turn photogrammetric software on its head
  - “Direct Geopositioning” assessment
  - Instead of resecting or triangulating images to ground control points (GCPs), we fix image support data and allow copy of GCPs to move to the image or stereo pair
  - “Copy of GCPs” are Check Points (CPs)
- End product accuracy assessments
  - No correction for off-nadir angle

Approved for Public Release 12-182

Definitions of Statistics

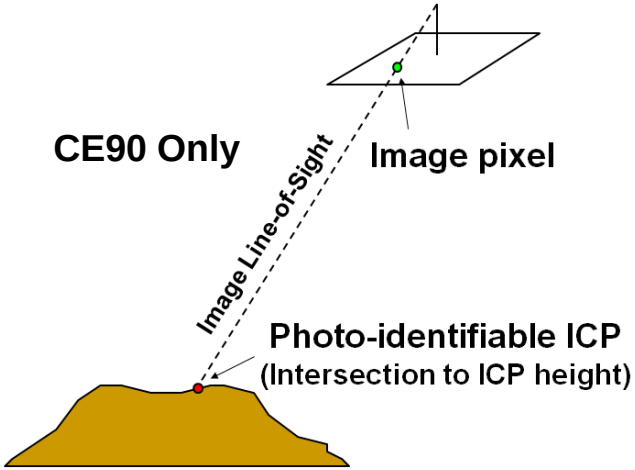
- Sample Circular Error 90% (CE90)
  - In horizontal plane
  - Radial error distance centered at zero within which 90% of the data points fall
- Sample Linear Error 90% (LE90)
  - In vertical dimension
  - Absolute value error distance from zero within which 90% of the vertical data points fall

Approved for Public Release 12-182

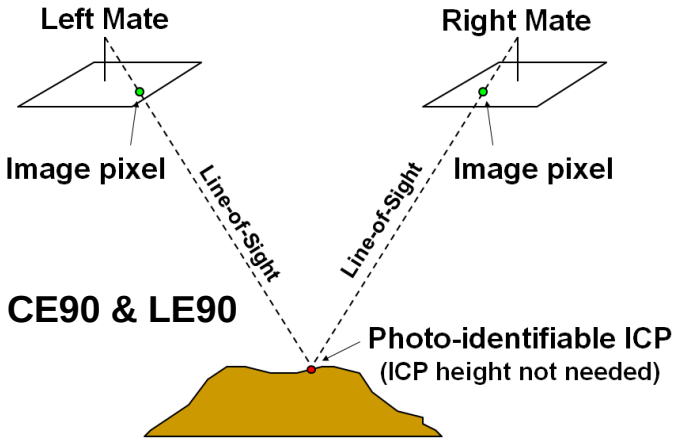
Methodology

- General Approach:
  - Mono CE90: Mono intersection of mono image or more-nadir stereo mate to checkpoint (CP) height
  - Stereo CE90 and LE90: Stereo intersection
- Images not allowed to adjust during evaluation
- Goal of evaluation is to estimate sample CE90 and LE90 error statistics for population of stereo pairs, not individual stereo pair

Monoscopic Intersection



Stereo Intersection



Approved for Public Release 12-182

GeoEye-1 Basic Product Evaluation

GeoEye Statements	Mono CE90**	Stereo CE90	Stereo LE90
GeoEye-1 Specifications (m)*	5	4	6

* Direct geopositioning (no ground control points)
** Excluding terrain effects, and with >60° elevation angle.

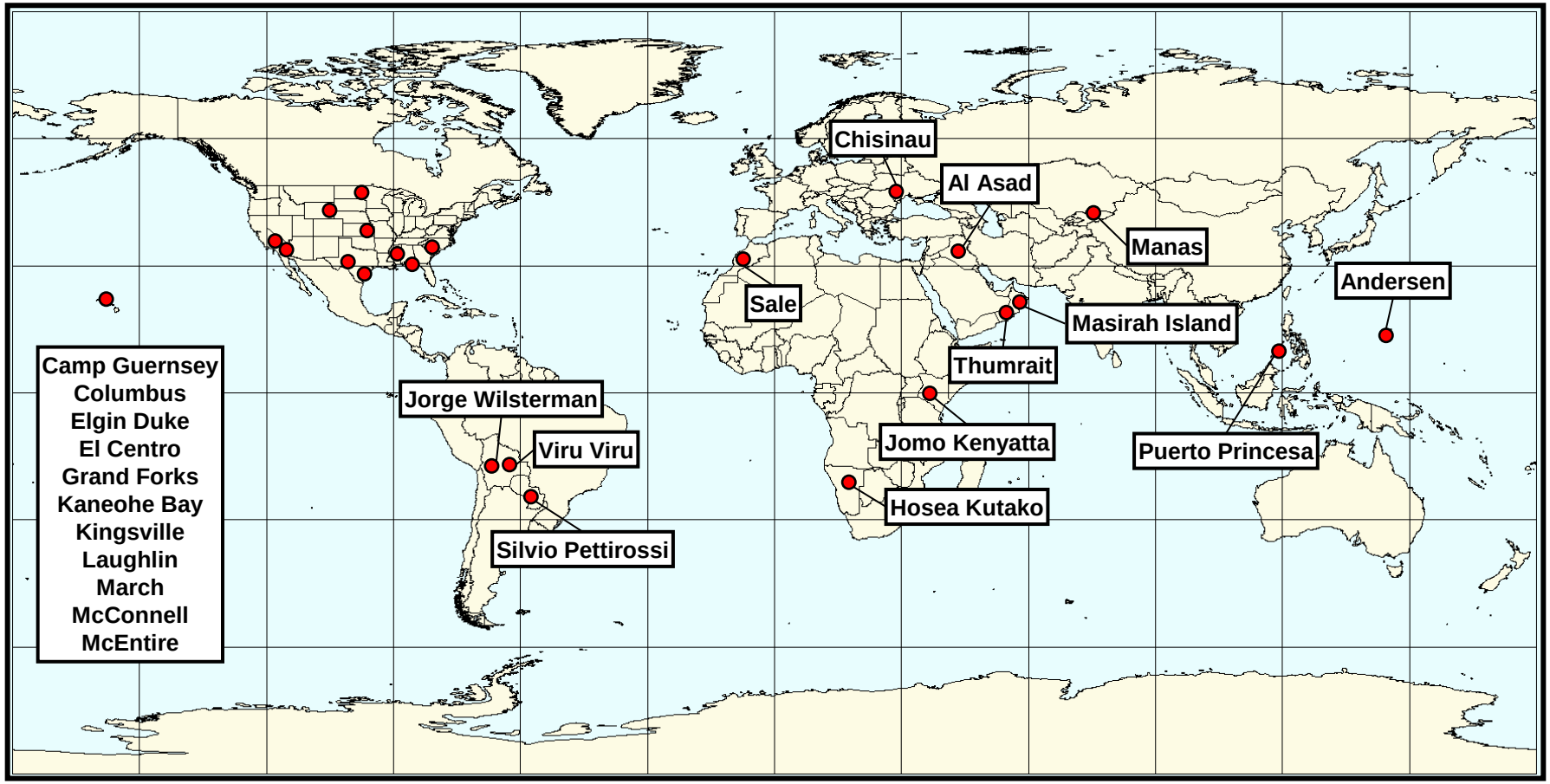
Source: http://www.geoeye.com/CorpSite/assets/docs/brochures/GeoEye-1_Fact_Sheet.pdf, accessed 8 February 2012.

Approved for Public Release 12-182

GeoEye-1

25 Basic Stereo Pairs over 24 Test Sites

From Terminal Aeronautical Global Navigation Satellite System (GNSS) Geodetic Survey (TAGGS) Program

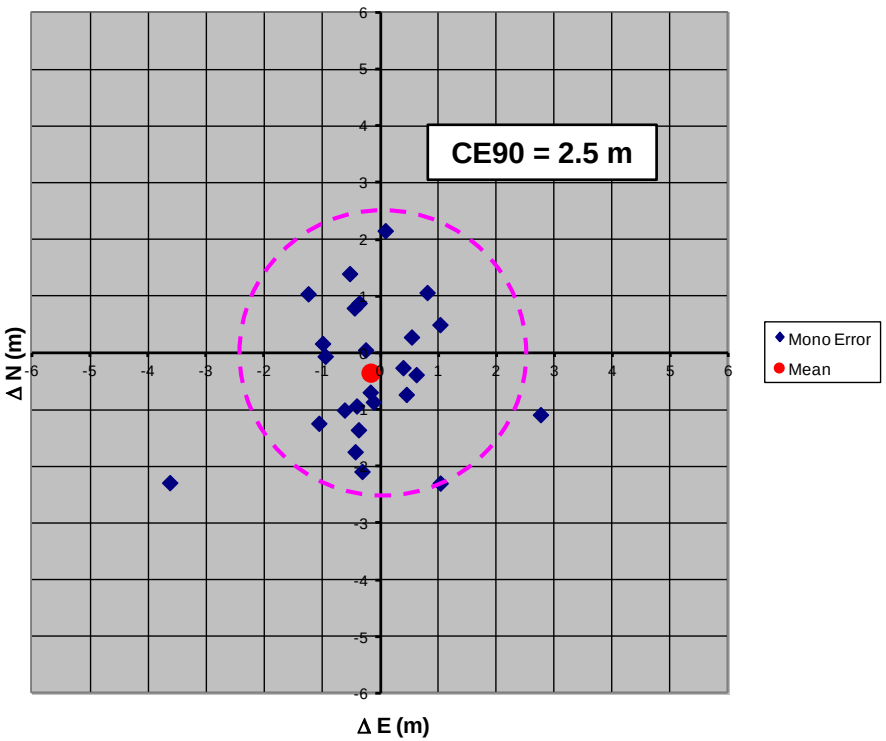


Stereo Pairs collected from December 2010 to February 2011 and processed from January to February 2011.

Approved for Public Release 12-182

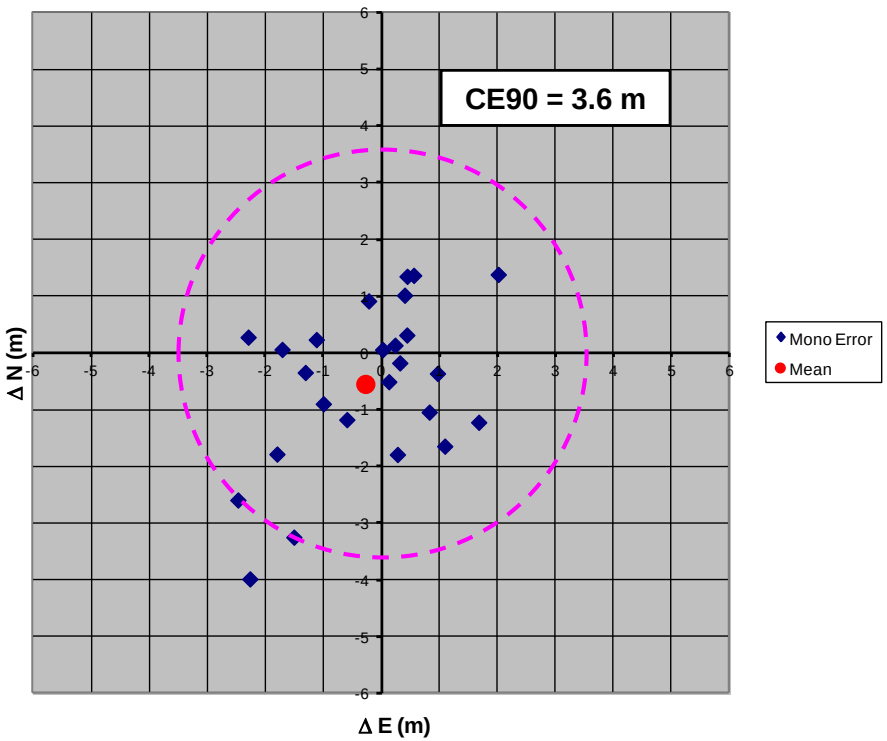
GeoEye-1
Sample Mono CE90

Mono Horizontal Errors (More Near-Nadir Basic Mates)



Elevation Angles: 57° - 84°
Mean Elevation Angle: 71°
>92.8% confidence that True CE90 < 4.3 m

Mono Horizontal Errors (More Off-Nadir Basic Mates)

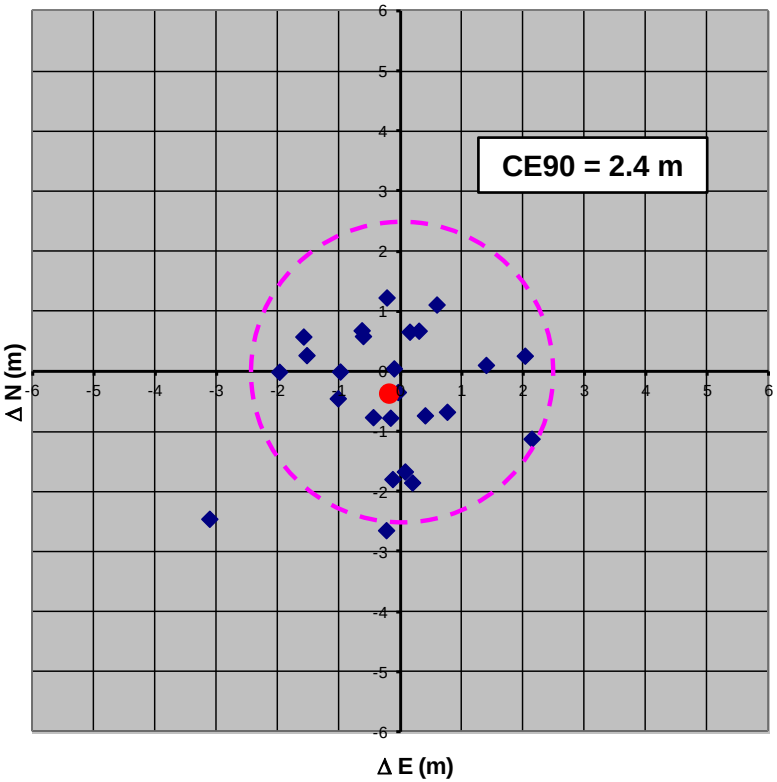


Elevation Angles: 57° - 72°
Mean Elevation Angle: 62°
>92.8% confidence that True CE90 < 4.6 m

Approved for Public Release 12-182

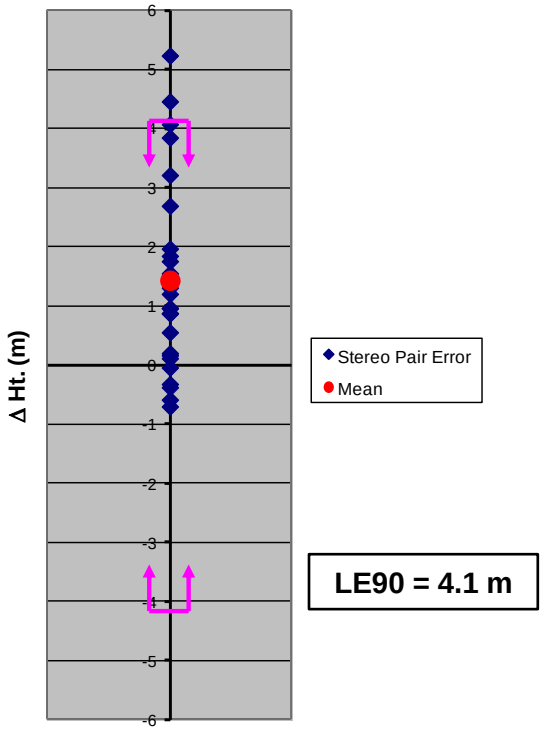
GeoEye-1
Sample Stereo CE90 / LE90

Stereo Pair Horizontal Errors (Basic)



>92.8% confidence that True CE90 < 4.0 m

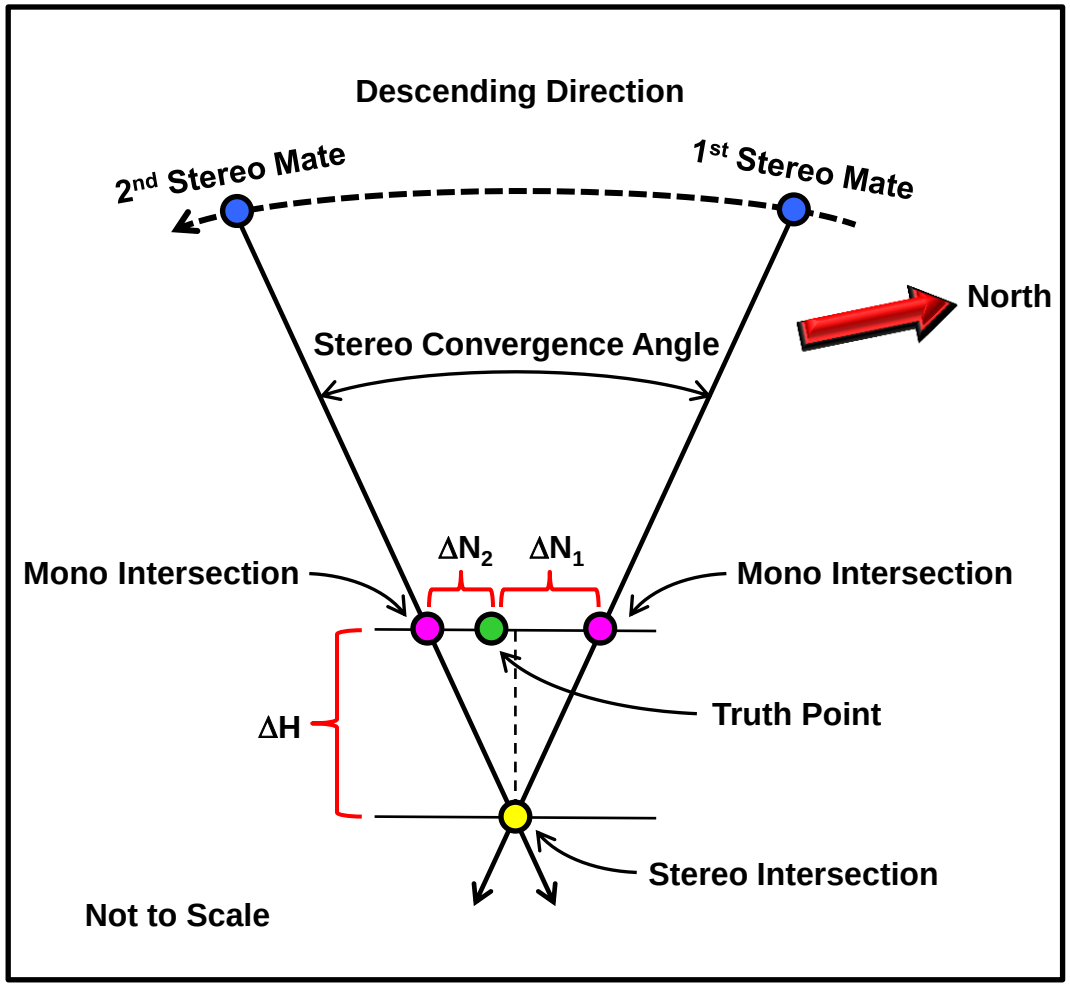
Stereo Pair Vertical Errors (Basic)



Stereo Convergence Angles: 30°- 40°
>92.8% confidence that True LE90 < 5.3 m

Approved for Public Release 12-182

GeoEye-1
Predicted Stereo Height Errors



$$\Delta H \approx \frac{\left(\frac{\Delta N_2 - \Delta N_1}{2}\right)}{\tan\left(\frac{C}{2}\right)}$$

where

$\Delta H = \text{Stereo Height Error}$

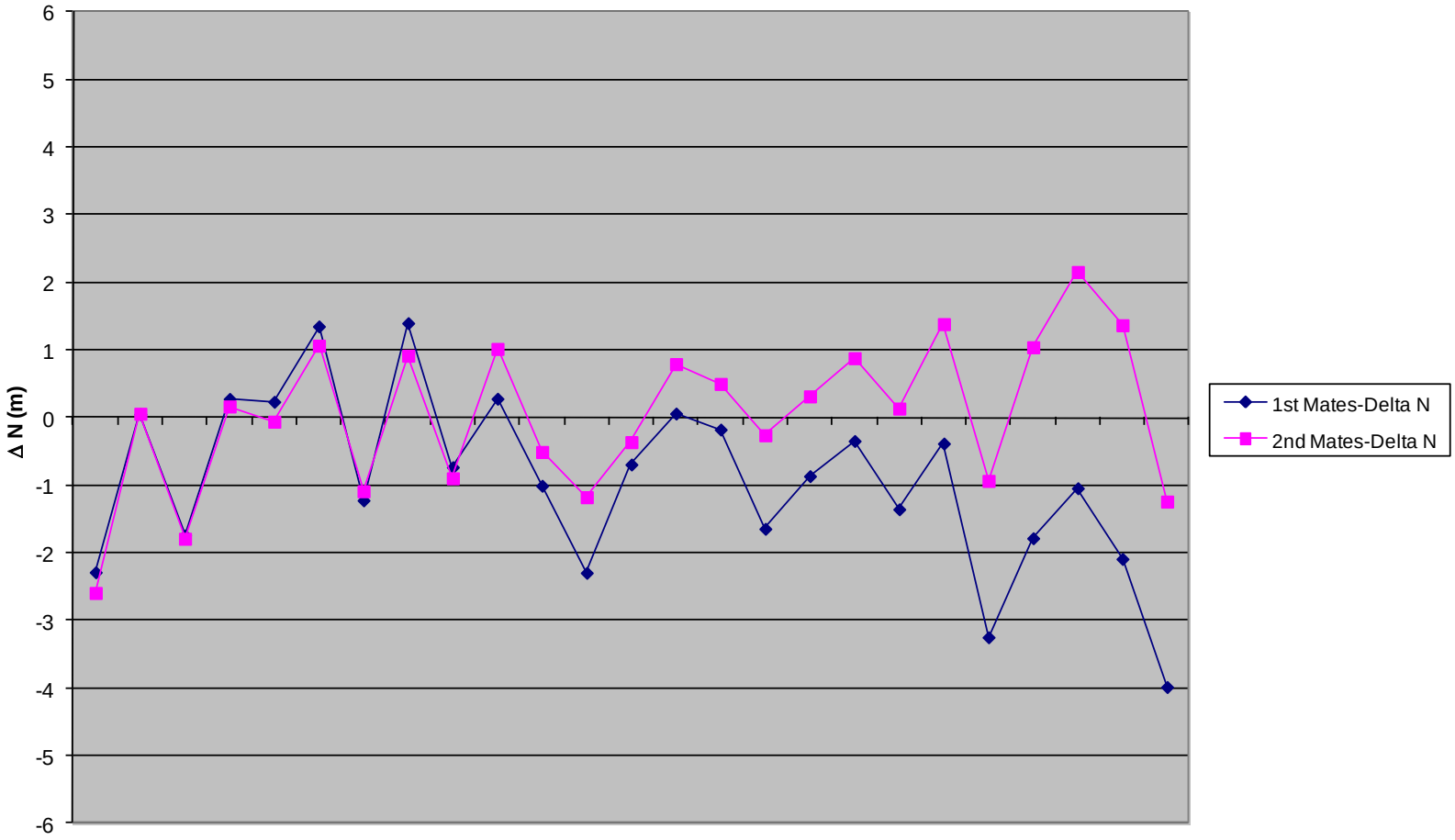
$\Delta N_1, \Delta N_2 = \text{Mono Northing Errors}$

$C = \text{Stereo Convergence Angle}$

Approved for Public Release 12-182

GeoEye-1

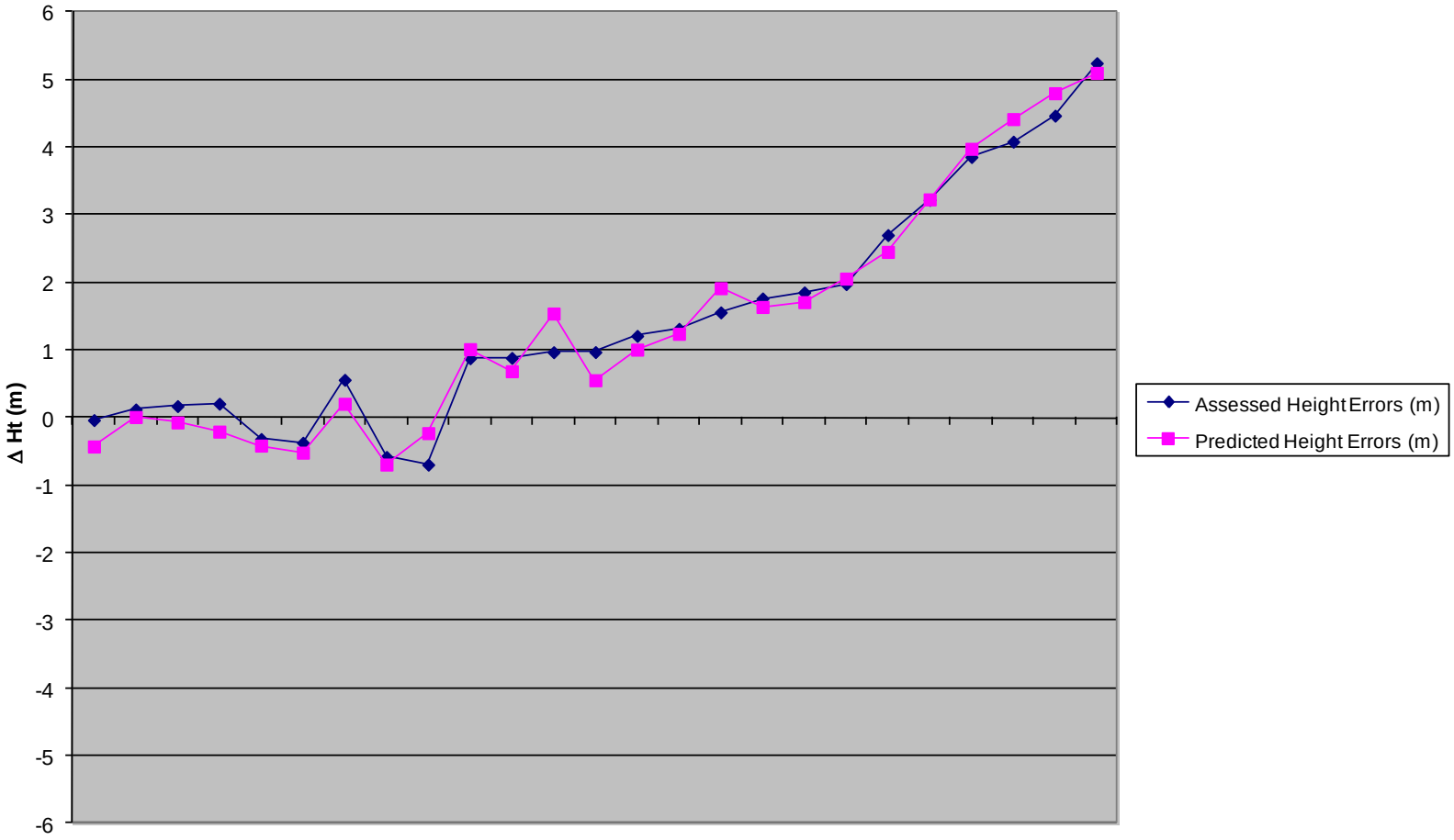
Stereo Mates Northing Errors; Sorted by Abs. Ht. Error



Approved for Public Release 12-182

GeoEye-1

Predicted vs. Assessed Ht. Errors; Sorted by Abs. Ht. Error



Approved for Public Release 12-182

QuickBird-2 Basic 1B Product Evaluations

DigitalGlobe Statement	Mono CE90**
QuickBird-2 Specification (m)*	23

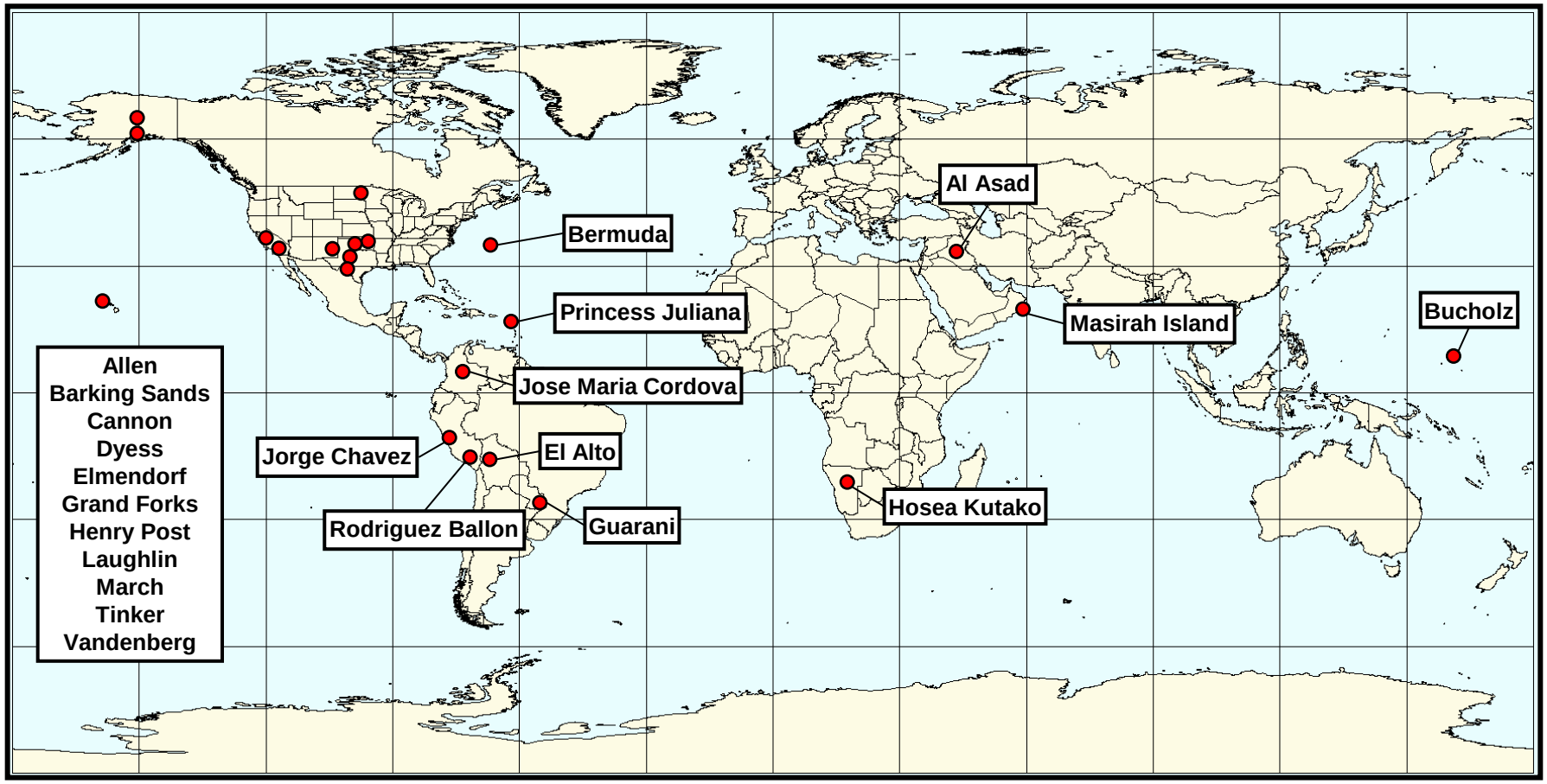
* Direct geopositioning (no ground control points)
** Excluding terrain effects, and at nadir.

Source: http://www.digitalglobe.com/products#imagery&basic-satellite-imagery, accessed 8 February 2012.

Approved for Public Release 12-182

QuickBird Altitude Change Evaluation

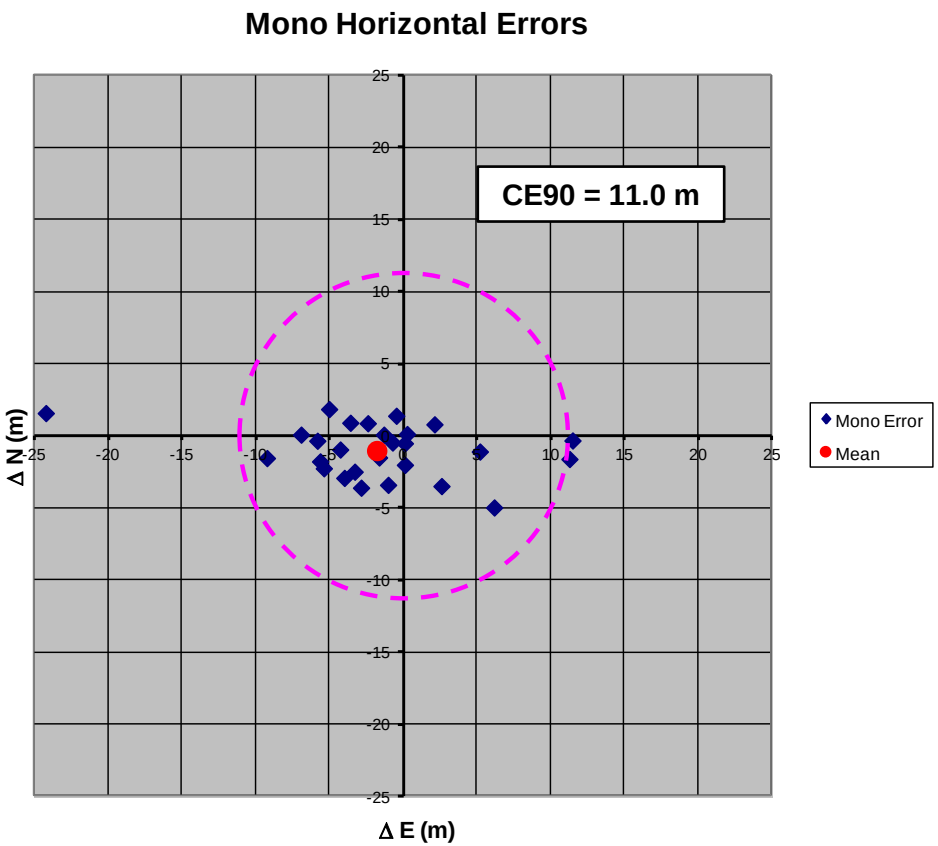
27 Basic 1B Images over 22 Test Sites



Images collected from April to June 2011 and processed from May to July 2011.

Approved for Public Release 12-182

QuickBird
Altitude Change Evaluation

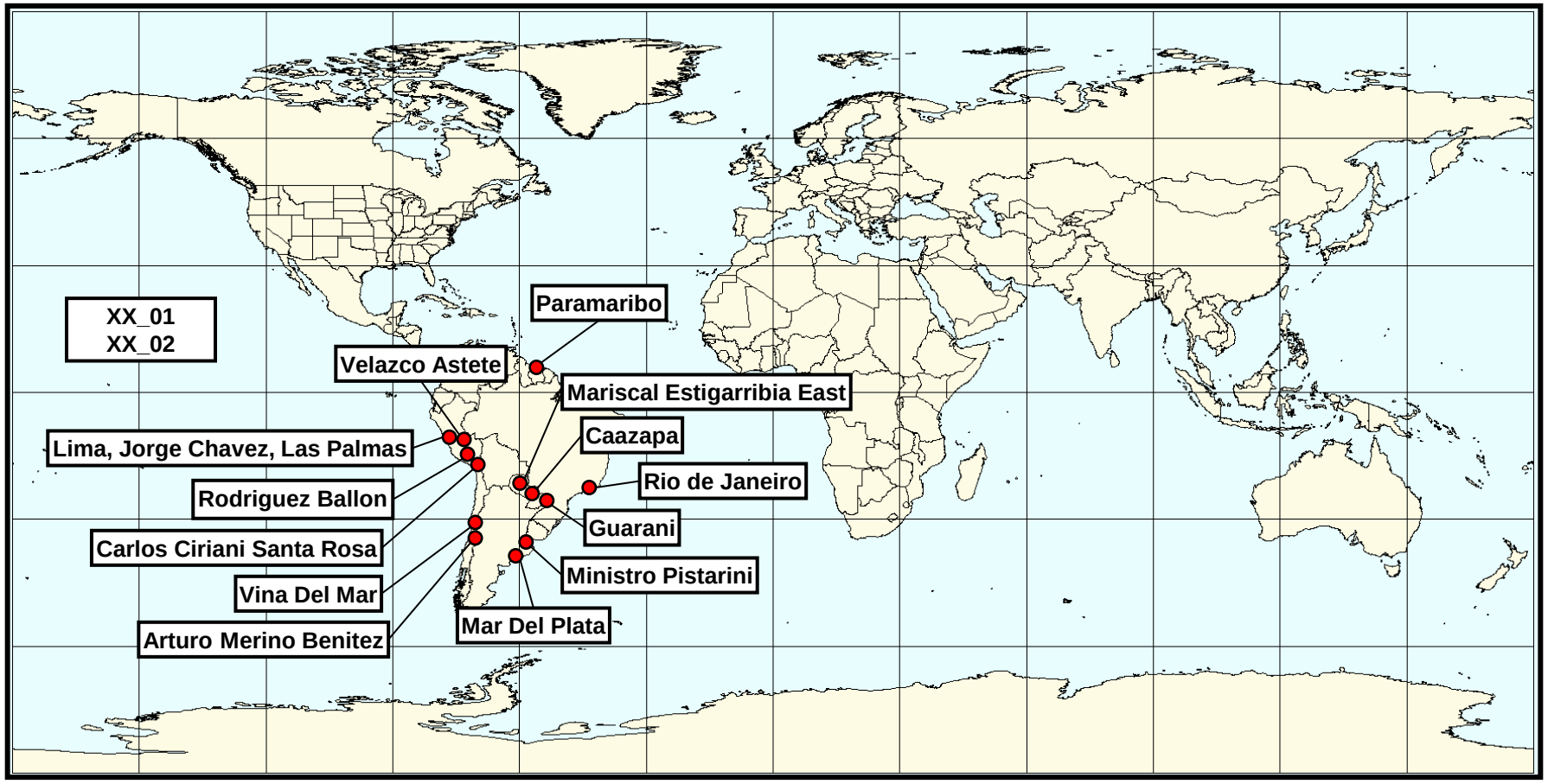


Off-Nadir Angles: 5° - 19°
Elevation Angles: 69° - 85°
>94.1% confidence that True CE90 < 24.3 m

Approved for Public Release 12-182

QuickBird Evaluation Over South America

54 Basic 1B Images over 17 South American Test Sites

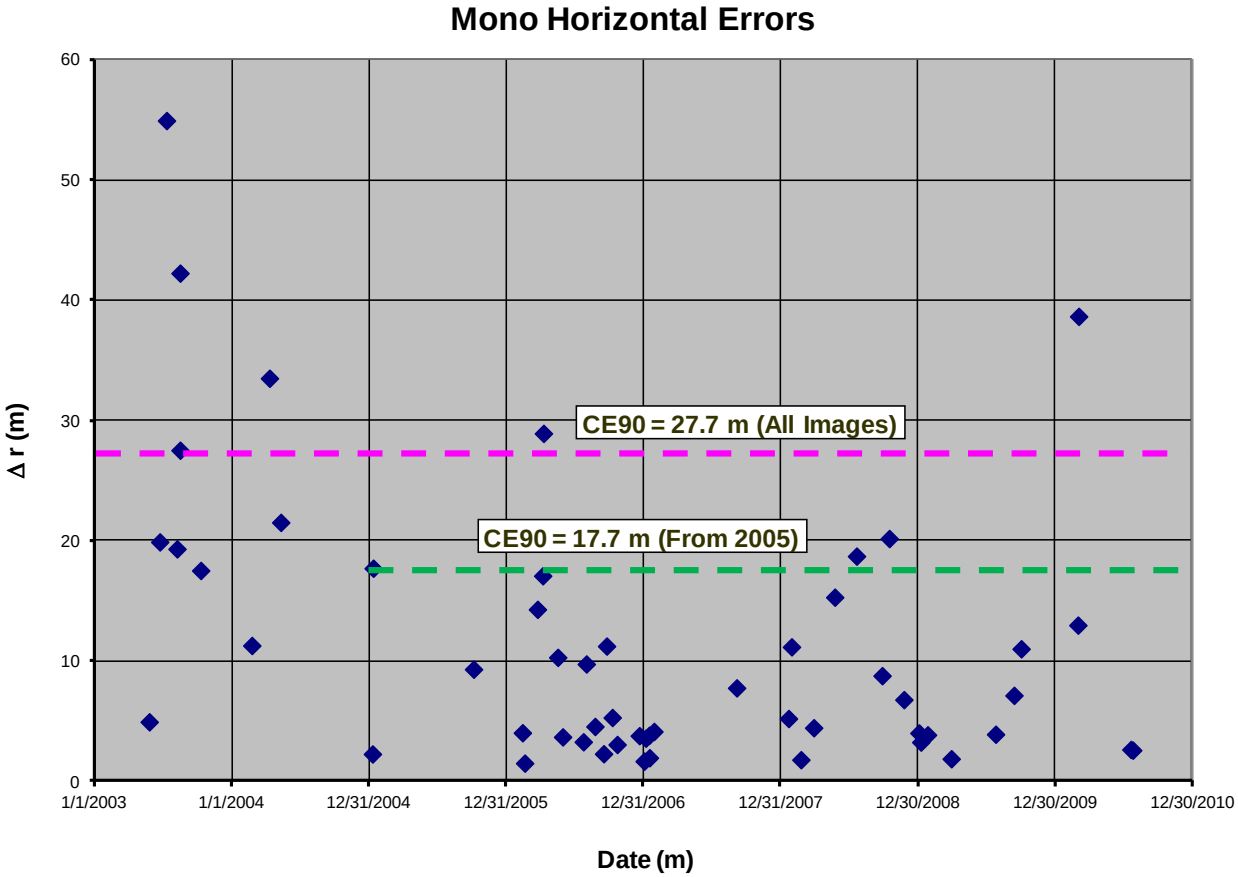


Images collected from May 2003 to June 2010. 41 images from 2005 onward.

Approved for Public Release 12-182

QuickBird

South America Evaluation



Off-Nadir Angles: 1° - 43°
Elevation Angles: 43° - 89°
>92.6% confidence that True CE90 < 29.0 m (From 2005)

Approved for Public Release 12-182

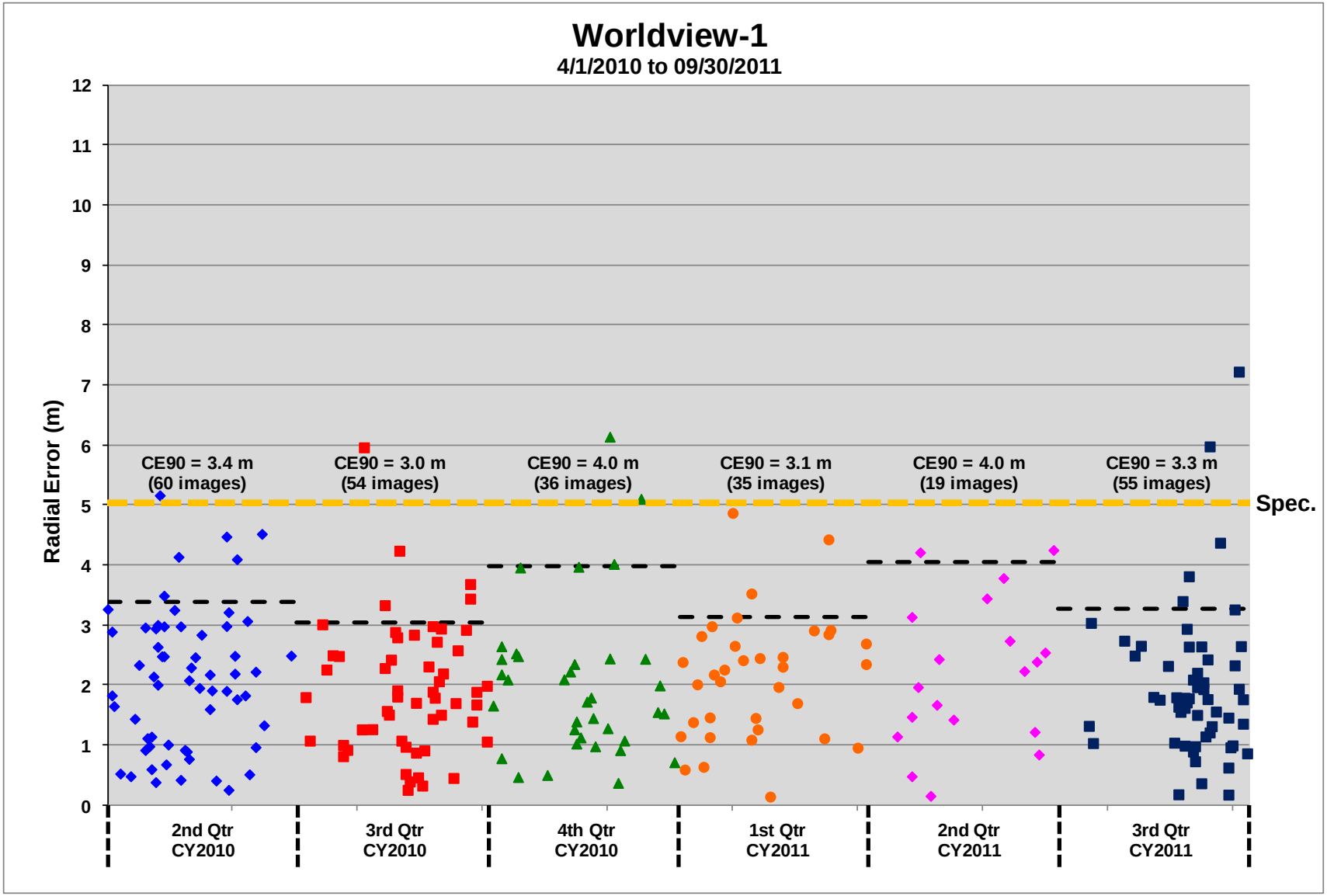
Geolocation Accuracy Monitoring Update

Vendor Specifications	GeoEye-1**	WorldView-1/2***	IKONOS**	QuickBird***
Mono CE90 (m)*	5	5	15	23

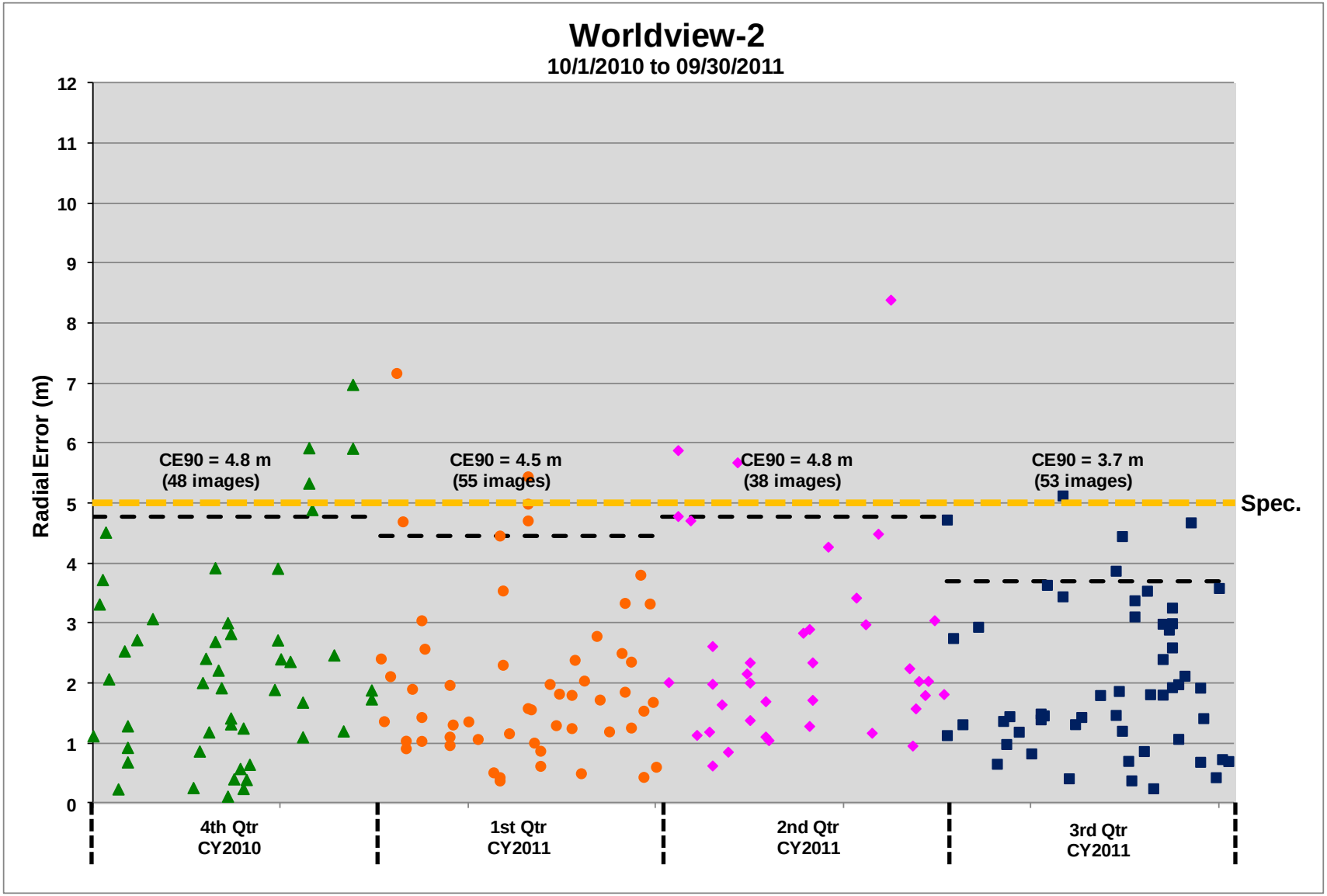
* Direct geopositioning (no ground control points)
** Excluding terrain effects, and with >60° elevation angle.
*** Excluding terrain effects, and at nadir.

Sources: http://www.digitalglobe.com/products#imagery&basic-satellite-imagery, **accessed 16 February 2012.**
http://www.geoeye.com/CorpSite/products-and-services/imagery-collection/satellite-imagery-products/product-specifications.aspx, **accessed 16 February 2012.**

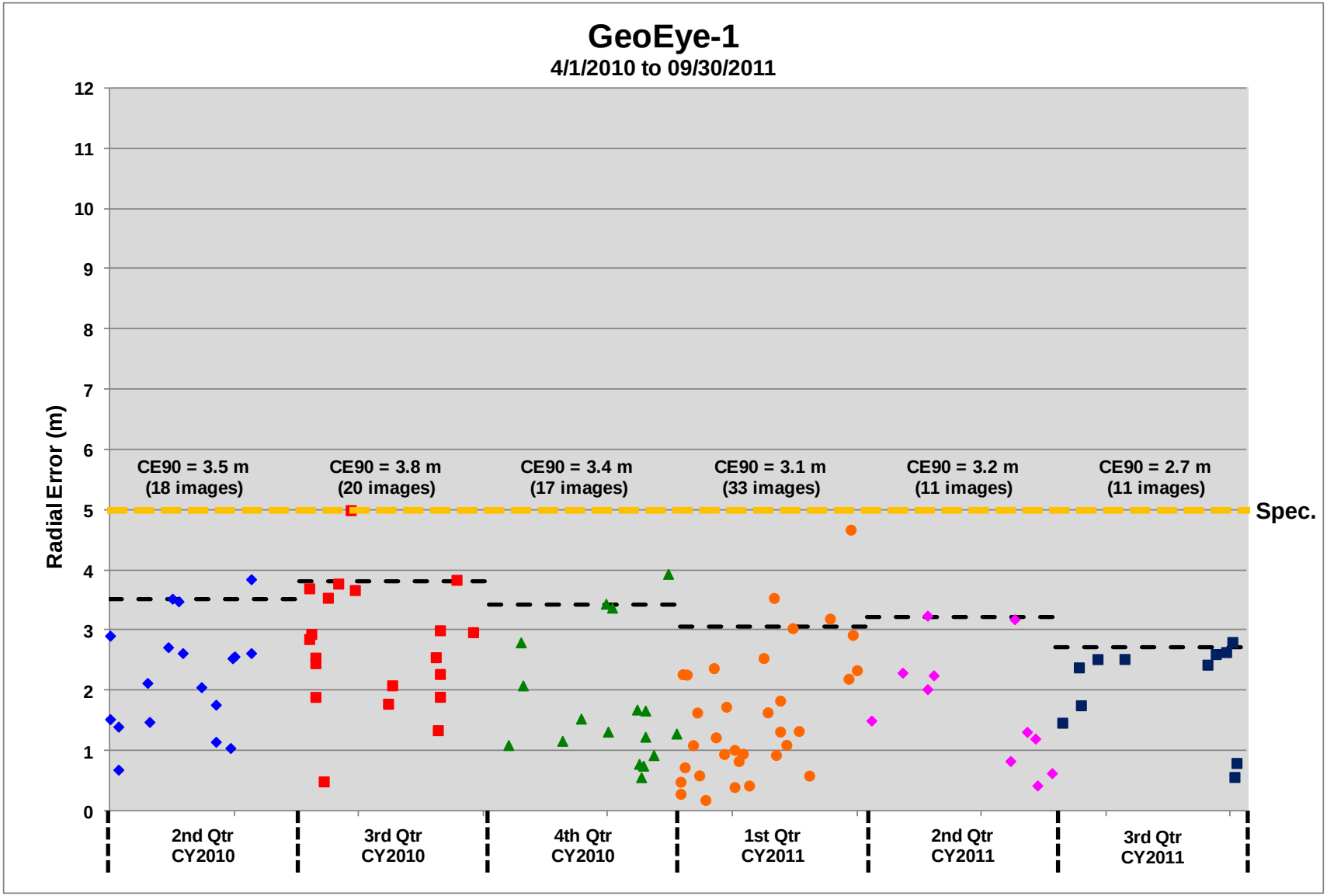
Approved for Public Release 12-182



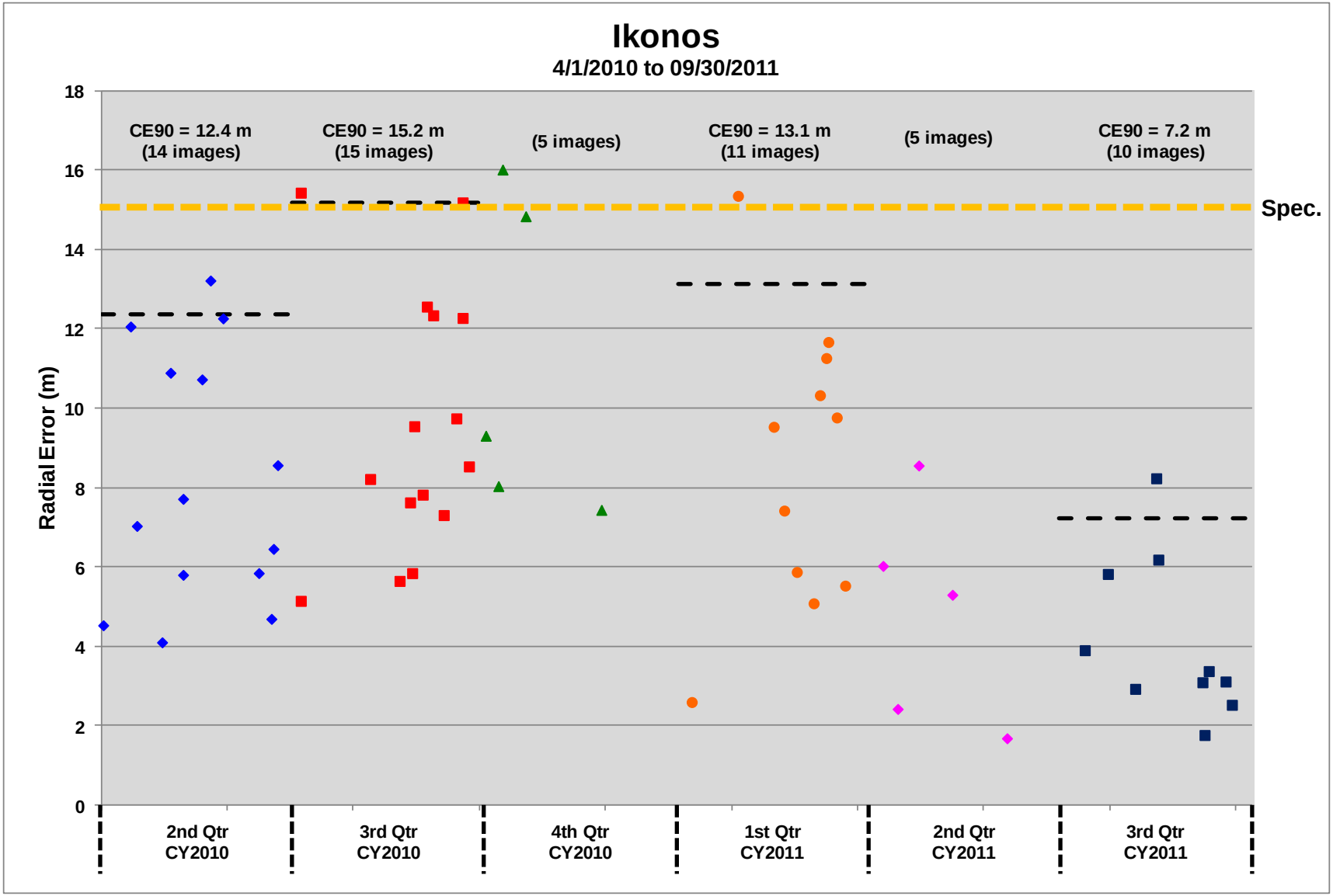
Approved for Public Release 12-182



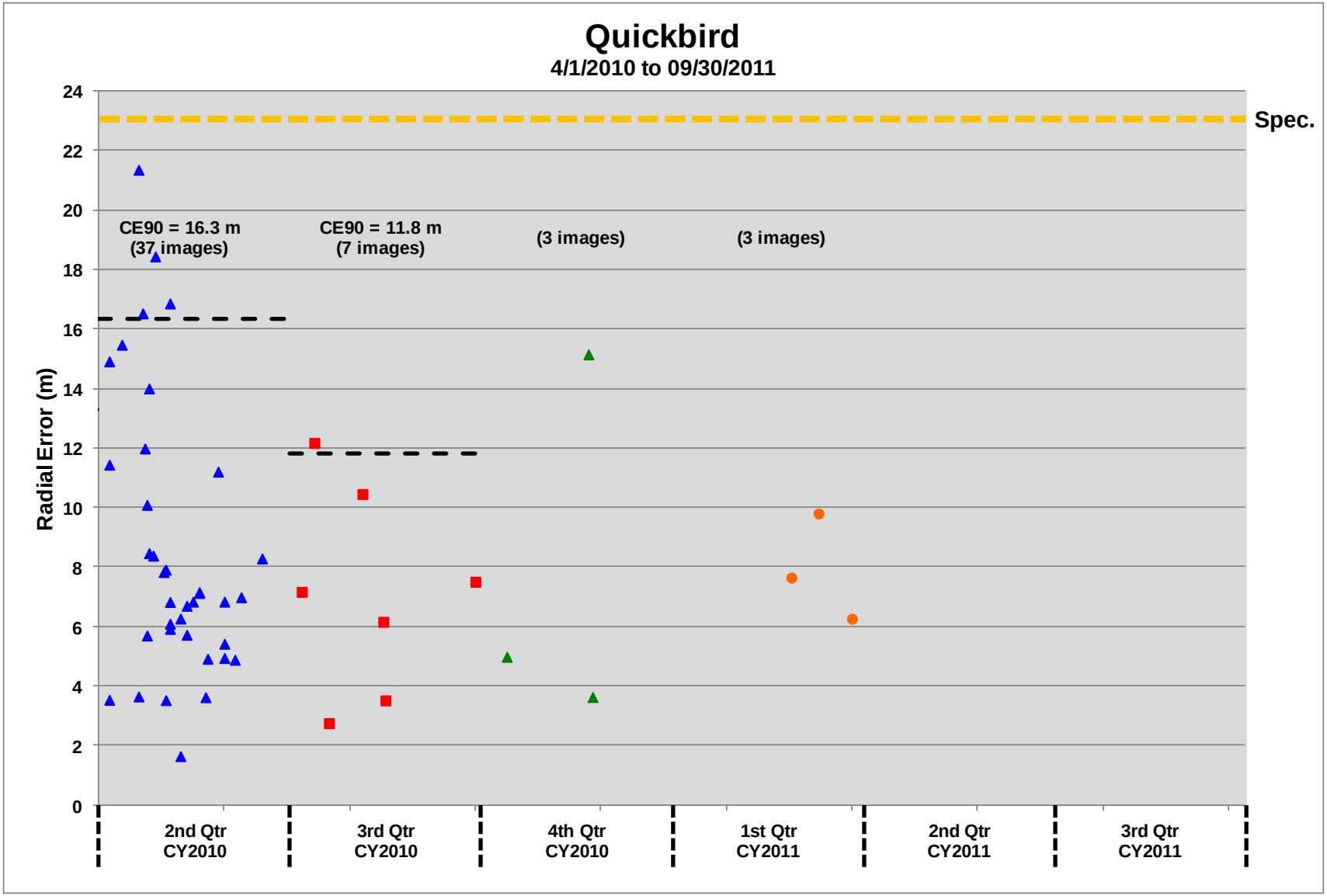
Approved for Public Release 12-182



Approved for Public Release 12-182



Approved for Public Release 12-182



Approved for Public Release 12-182

Summary

- With two minor exceptions, imagery within vendor-stated geolocation accuracy specifications
  - Early QuickBird-2 images over South America
  - CY2010 Qtr3 IKONOS: CE90 estimate slightly above specification but sample size of only 15 images and uncertainty of estimate straddles the specification line
- Minimal impact for both cases

Approved for Public Release 12-182