



Geolocation Accuracy Re-Evaluation of Cosmo- Skymed Spotlight and Stripmap Imaging Mode Products

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Outline

- Objective
- Product Descriptions
- Methodology
- Evaluation Results



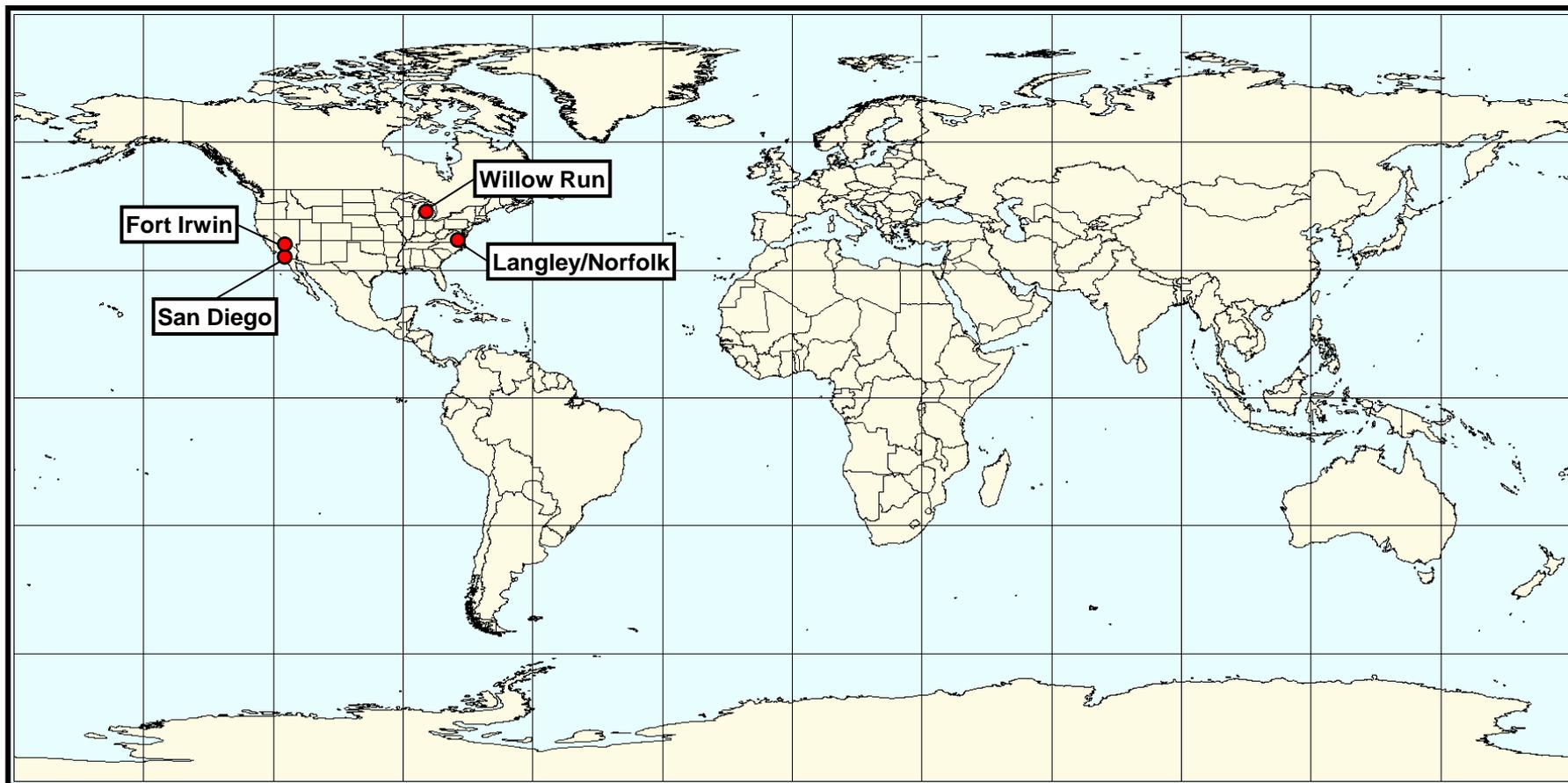
Objectives

- To estimate the absolute horizontal geolocation accuracy of a sample set of:
 - 6 Spotlight (S2) imaging mode products
 - 4 Stripmap (HIMAGE) imaging mode products



Cosmo-Skymed

10 Images over 4 Corner Reflector Test Sites



Images collected between August 2008 and April 2010 and processed between November 2010 and January 2011.



Definitions of Sample Statistics

- Circular Error 90% (CE90)
 - In horizontal plane
 - Radial error distance centered at zero within which 90% of the data points fall



Cosmo-Skymed Product Processing

| Imaging Mode | Satellites | Product Pixel Sampling (m) | Ground Resolution (m) | Scene Size (km) | Geometric Processing | Polarization |
|-------------------|-------------------------------------|----------------------------|-----------------------|-----------------|---|------------------|
| Spotlight-2 (S2) | CSK-1 (1) CSK-2 (3) CSK-3 (2) | 0.5 | ~1 | ~10 x ~10 | Level 1B Detected Ground Multi-look (DGM) | HH (3) VV (3) |
| Stripmap (HIMAGE) | CSK-1 (3) CSK-2 (1) | 2.5 | ~5 | ~40 x ~40 | Level 1B Detected Ground Multi-look (DGM) | HH (2) VV (2) |

Based on discussions with e-GEOS, expected accuracy of ~2 m CE90.



Methodology

- General Approach:
 - Mono intersection of range/Doppler arcs to checkpoint (CP) heights
- Images *not* allowed to adjust during evaluation
- Goal of evaluation is to estimate CE90 error statistics for population of images, not individual images
 - Estimated CE90 for 6 spotlight images
 - Individual image error statistics for stripmap images



Methodology

- 1) **Load image onto workstation with SOCET Set[®] photogrammetric software**

- 2) **Import physical sensor model support data accompanying imagery**
 - Including sensor information and ephemeris points



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 physical model support data fixed) and allow checkpoint horizontal ground coordinates to adjust to pixel measurements using triangulation tool



Methodology

- 4) **For each checkpoint, subtract ground-surveyed coordinates from test-imagery-derived ground coordinates**
 - Results in a list of “ Δ Easting” and “ Δ Northing” values



Methodology

5) Compute 2 types of data points for each image

a) Error Centroid

- Compute mean “Δ Easting” and “Δ Northing” values and convert into horizontal “Δ Radial” value

b) Root Mean Square Error (RMSE)

$$RMSE_E = \sqrt{\frac{\sum_{i=1}^n (\Delta E_i)^2}{n}} \quad RMSE_N = \sqrt{\frac{\sum_{i=1}^n (\Delta N_i)^2}{n}} \quad RMSE_r^{Horizontal} = \sqrt{RMSE_E^2 + RMSE_N^2}$$

n is number of ICPs

- Each image represented by one or the other of these single data points for mono Spotlight image CE90 estimation
- Additional statistics:
 - Number of checkpoints
 - Maximums & minimums of Δ Easting and Δ Northing values
 - Standard deviations of Δ Easting and Δ Northing values



Methodology

6) Estimate CE90

- CCAP uses non-parametric estimator (“Percentile Method”)
- Sort error centroid or RMSE data points 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 images
 - Maximums and minimums of data points
 - Standard deviations of data points



90th Percentile Estimator for Ordered Statistics

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

where $x_{(i)} = \Delta r_{(i)}$ or $x_{(i)} = \text{RMSE}_{r_{(i)}}$.

Then,

$$CE90 = (1 - f) * x_{(i)} + f * x_{(i+1)}$$

where

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

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



Cosmo-Skymed Evaluation Results



Cosmo-Skymed All Images Horizontal Errors (n=10)

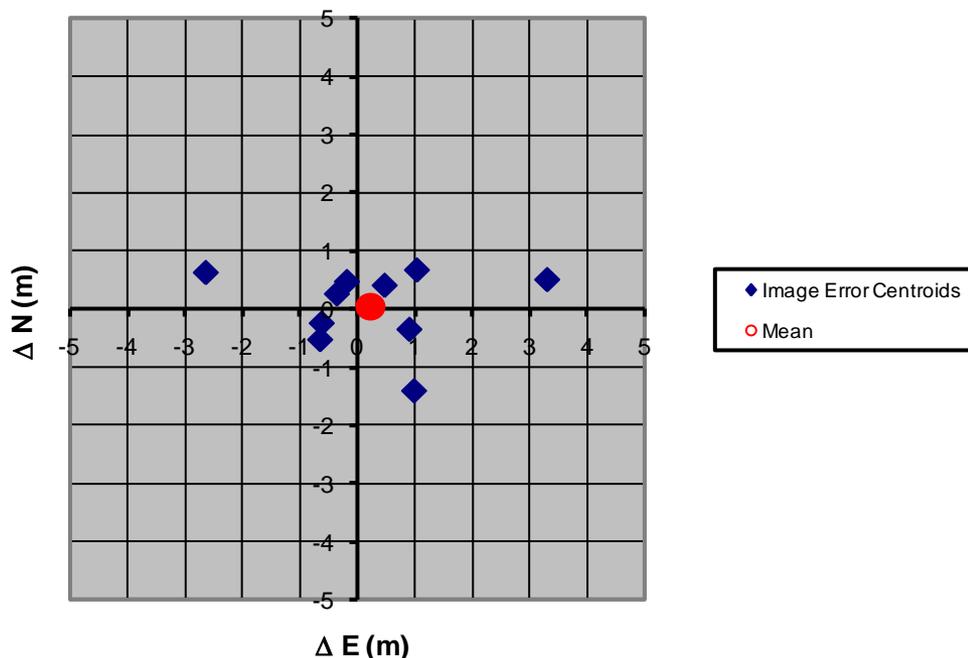
| Test Site | Collection Date | Satellite | Mode | Polarization | CPs | Δ E (m) | | | | Δ N (m) | | | | RSS Δr (m) | RMSE (m) | | | |
|-------------------------|-----------------|-----------|------|--------------|-----|----------------|---------|------|------|---------|---------|------|------|------------|----------|-----|-----|-----|
| | | | | | | Mean | Std Dev | Min | Max | Mean | Std Dev | Min | Max | | Δ E | Δ N | Δ r | |
| US, Fort Irwin | 31-Aug-2008 | CSM-1 | HI | HH | 3 | 3.3 | 0.0 | 3.3 | 3.3 | 0.5 | 0.0 | 0.5 | 0.5 | 3.3 | 3.3 | 0.5 | 3.3 | |
| US, Fort Irwin | 18-Sep-2008 | CSM-2 | S2 | HH | 3 | -0.6 | 0.0 | -0.7 | -0.6 | -0.2 | 0.0 | -0.3 | -0.2 | 0.7 | 0.6 | 0.2 | 0.7 | |
| US, Langley and Norfolk | 11-Aug-2008 | CSM-1 | S2 | HH | 2 | 1.0 | 0.0 | 1.0 | 1.0 | 0.7 | 0.1 | 0.6 | 0.7 | 1.2 | 1.0 | 0.7 | 1.2 | |
| US, Langley and Norfolk | 26-Nov-2009 | CSM-2 | S2 | VV | 7 | -0.4 | 0.3 | -0.8 | 0.2 | 0.3 | 0.4 | -0.3 | 0.9 | 0.4 | 0.5 | 0.5 | 0.7 | |
| US, Langley and Norfolk | 3-Apr-2010 | CSM-2 | S2 | VV | 2 | -0.6 | 0.1 | -0.7 | -0.6 | -0.5 | 0.0 | -0.5 | -0.5 | 0.8 | 0.6 | 0.5 | 0.8 | |
| US, Langley and Norfolk | 4-Apr-2010 | CSM-3 | S2 | VV | 2 | 0.5 | 0.0 | 0.5 | 0.5 | 0.4 | 0.0 | 0.4 | 0.4 | 0.6 | 0.5 | 0.4 | 0.6 | |
| US, Langley and Norfolk | 6-Apr-2010 | CSM-1 | HI | VV | 6 | -0.2 | 0.3 | -0.6 | 0.1 | 0.5 | 0.3 | 0.0 | 0.7 | 0.5 | 0.3 | 0.5 | 0.6 | |
| US, Langley and Norfolk | 9-Apr-2010 | CSM-2 | HI | VV | 6 | -2.6 | 0.7 | -3.3 | -1.5 | 0.6 | 0.5 | 0.0 | 1.3 | 2.7 | 2.7 | 0.8 | 2.8 | |
| US, San Diego | 3-Apr-2010 | CSM-3 | S2 | HH | 3 | 0.9 | 0.1 | 0.7 | 1.0 | -0.3 | 0.3 | -0.5 | 0.0 | 1.0 | 0.9 | 0.4 | 1.0 | |
| US, Willow Run | 23-Aug-2008 | CSM-1 | HI | HH | 11 | 1.0 | 0.3 | 0.5 | 1.4 | -1.4 | 0.5 | -2.2 | -0.3 | 1.7 | 1.0 | 1.5 | 1.8 | |
| | | | | | | Mean | 0.2 | 0.2 | 0.0 | 0.5 | 0.0 | 0.2 | -0.2 | 0.4 | 1.3 | 1.2 | 0.6 | 1.4 |
| | | | | | | Std Dev | 1.5 | 0.2 | 1.7 | 1.3 | 0.7 | 0.2 | 0.8 | 0.6 | 1.0 | 1.0 | 0.3 | 1.0 |
| | | | | | | Max | 3.3 | 0.7 | 3.3 | 3.3 | 0.7 | 0.5 | 0.6 | 1.3 | 3.3 | 3.3 | 1.5 | 3.3 |
| | | | | | | Min | -2.6 | 0.0 | -3.3 | -1.5 | -1.4 | 0.0 | -2.2 | -0.5 | 0.4 | 0.3 | 0.2 | 0.6 |

Largest Stripmap (HIMAGE) radial error is 3.3 meters, compared to 5 meter ground resolution.



Cosmo-Skymed All Images Horizontal Errors (n=10)

Cosmo-Skymed Spotlight and Stripmap
Absolute Geolocation Accuracy
(Physical Sensor Model Data)





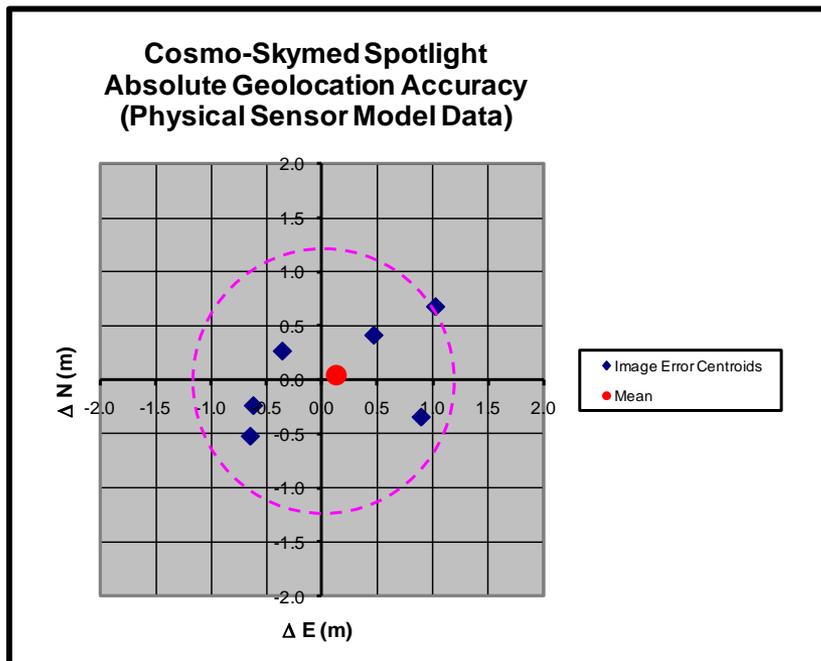
Cosmo-Skymed Spotlight Images Horizontal Accuracy (n=6)

| Test Site | Date | Sorted RSS Δr (m) |
|-----------------|-------------|---------------------------|
| Langley/Norfolk | 26-Nov-2009 | 0.4 |
| Langley/Norfolk | 4-Apr-2010 | 0.6 |
| Fort Irwin | 18-Sep-2008 | 0.7 |
| Langley/Norfolk | 3-Apr-2010 | 0.8 |
| San Diego | 3-Apr-2010 | 1.0 |
| Langley/Norfolk | 11-Aug-2008 | 1.2 |

Estimated Mono CE90 = 1.2 m

| Test Site | Date | Sorted RMSE Δr (m) |
|-----------------|-------------|----------------------------|
| Langley/Norfolk | 4-Apr-2010 | 0.6 |
| Fort Irwin | 18-Sep-2008 | 0.7 |
| Langley/Norfolk | 26-Nov-2009 | 0.7 |
| Langley/Norfolk | 3-Apr-2010 | 0.8 |
| San Diego | 3-Apr-2010 | 1.0 |
| Langley/Norfolk | 11-Aug-2008 | 1.2 |

Estimated Mono CE90 = 1.2 m





Questions?



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