BBA

Bundle Block Adjust

Positional Accuracy Improvements for Satellite Imagery at Extreme Scale

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Introduction

Motivation and methodology

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Motivation

- Reduce shear in large area ortho-mosaics
- Produce single blocks for entire nations or regions
- Improved absolute accuracy over large contiguous regions of imagery
- Improved spatial precision for vector overlay or feature extraction
- Hands-free full automation of bundle adjustment

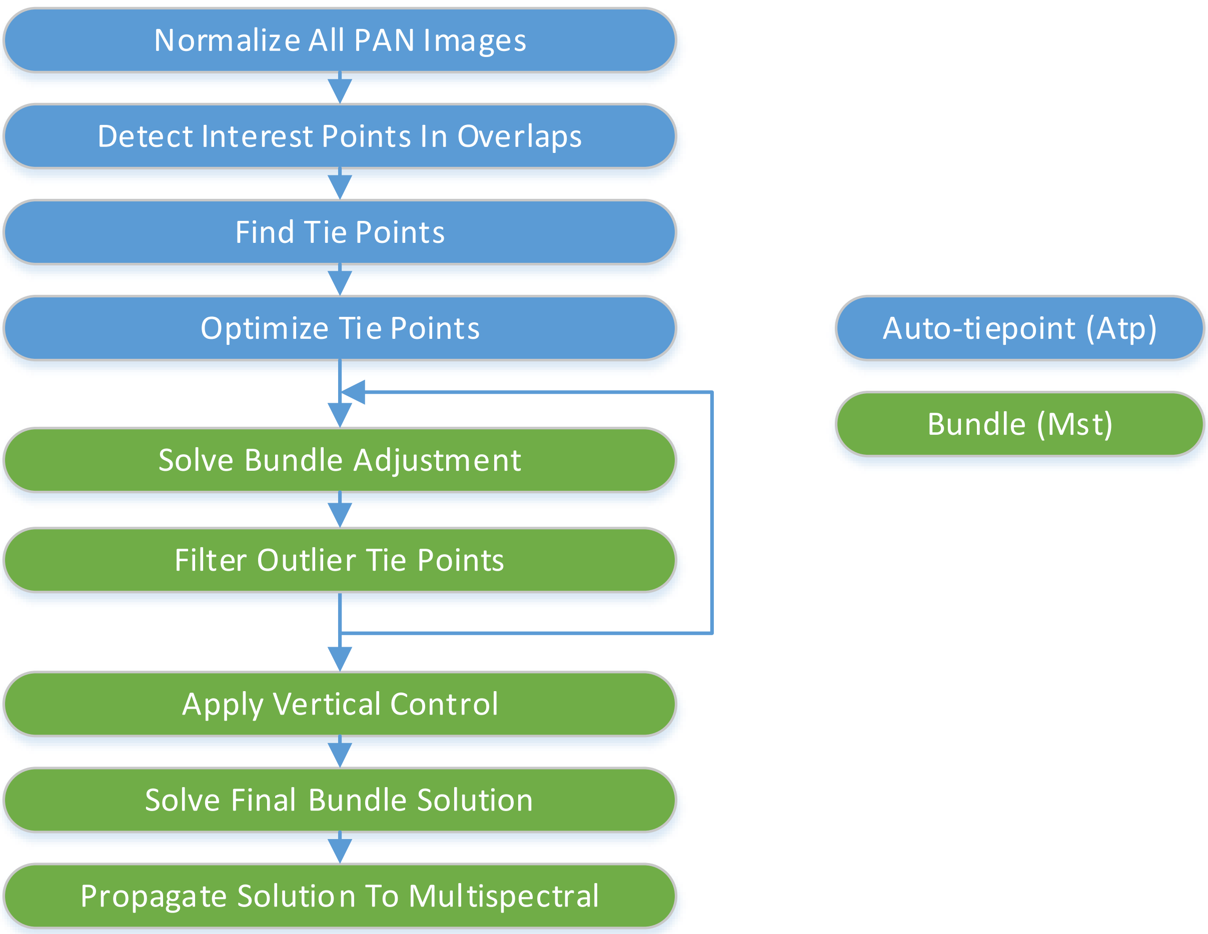
Bundle Block Adjust – BBA

Flexible Large Area Mosaic Engine - FLAME

BBA methodology

- Use pointing information from multiple images
  - Attitude and ephemeris
- Generate tie-points with Atp (Auto-tie-point)
  - find interest points using machine vision
  - cluster into tie-points in image overlaps
  - correlate points in images
  - score points and select the best
- Find an optimal solution to pointing information
  - least-squares solver
  - minimize position residuals
  - rigorous camera model
  - iterative solution to remove blunders

Automated Bundle Adjust Operational Steps



- Normalized (rectified) imagery only used for machine vision object detection
- Tie-points are defined in 1B imagery
- Community Sensor Model (CSM) provides rigorous model forward and back projections
- Automated iterative deblundering and tie point filtering (Danish Method)
- (optional) Vertical control to the DEM applied after solution convergence

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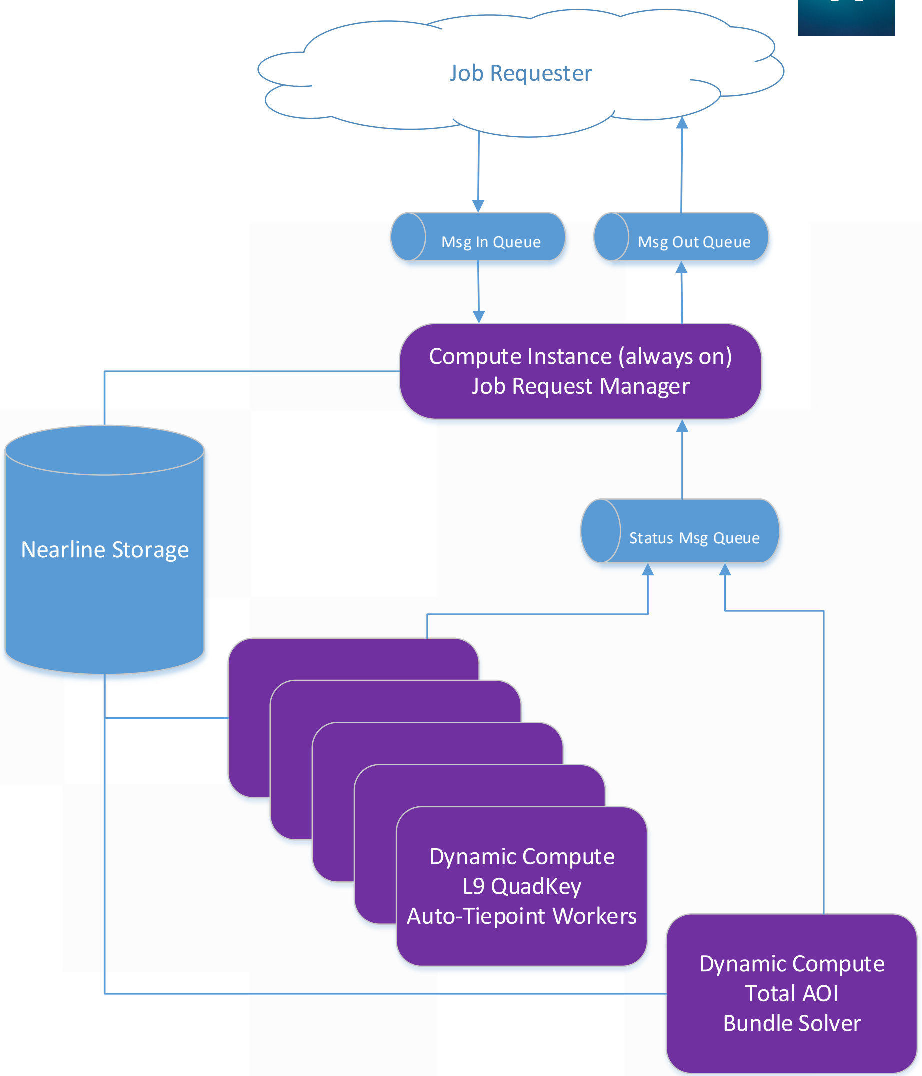
Scaling in the Cloud

Terabytes of imagery, hundreds of thousands of tie points, in large unified blocks

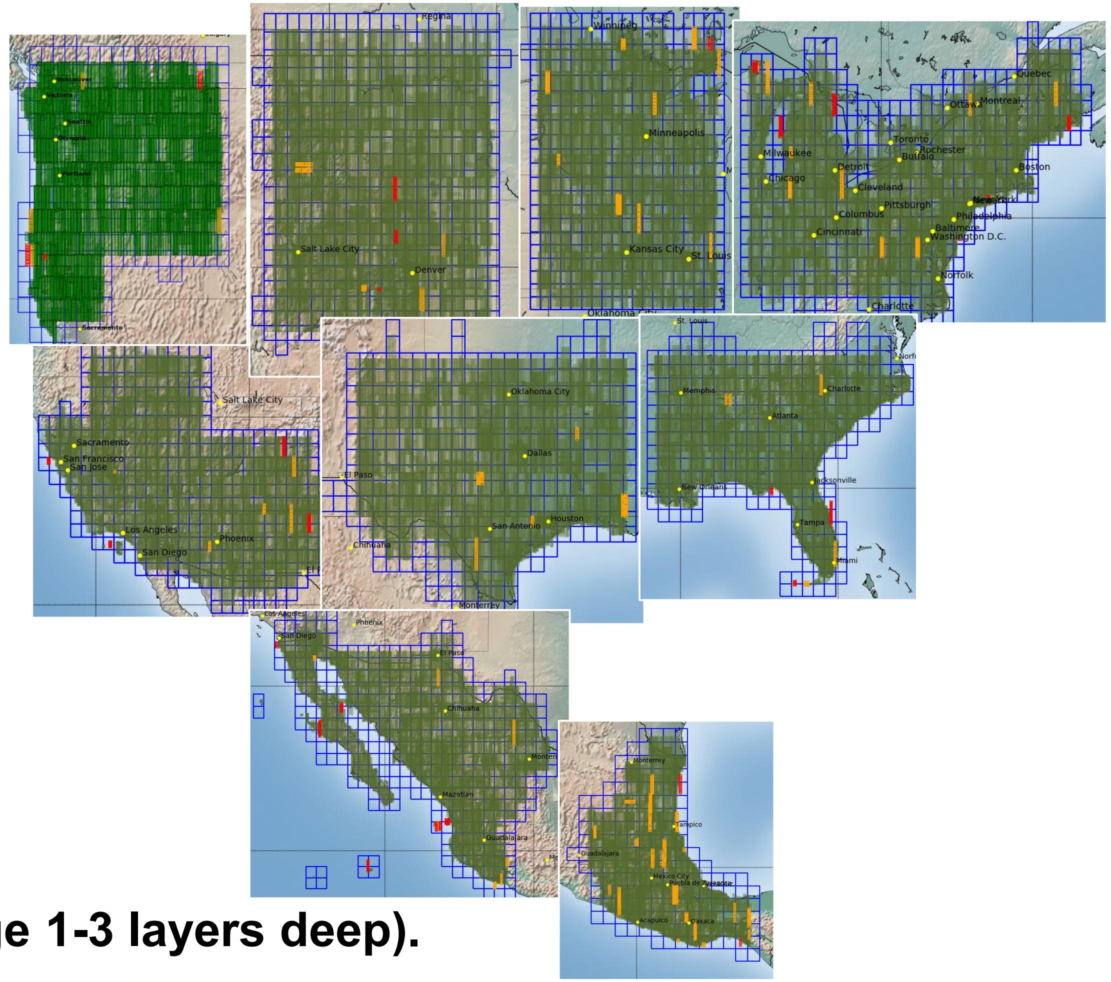
BBA Cloud Compute Solution

- A lightweight instance monitors job requests
- The AOI is determined to a first approximation
- Tie-point generation is partitioned by quadkeys
  - approx. 1 compute instance per 1 degree geocell
- Images are copied from the nearline object storage (i.e. AWS S3)
- Tie-point instances terminate once done
  - Store intermediate results in nearline storage
- Bundle instance is spun up when all tie-point data is available
- Final adjustment metadata and quality analysis is stored and the bundle instance is terminated



BBA – positional accuracy at scale

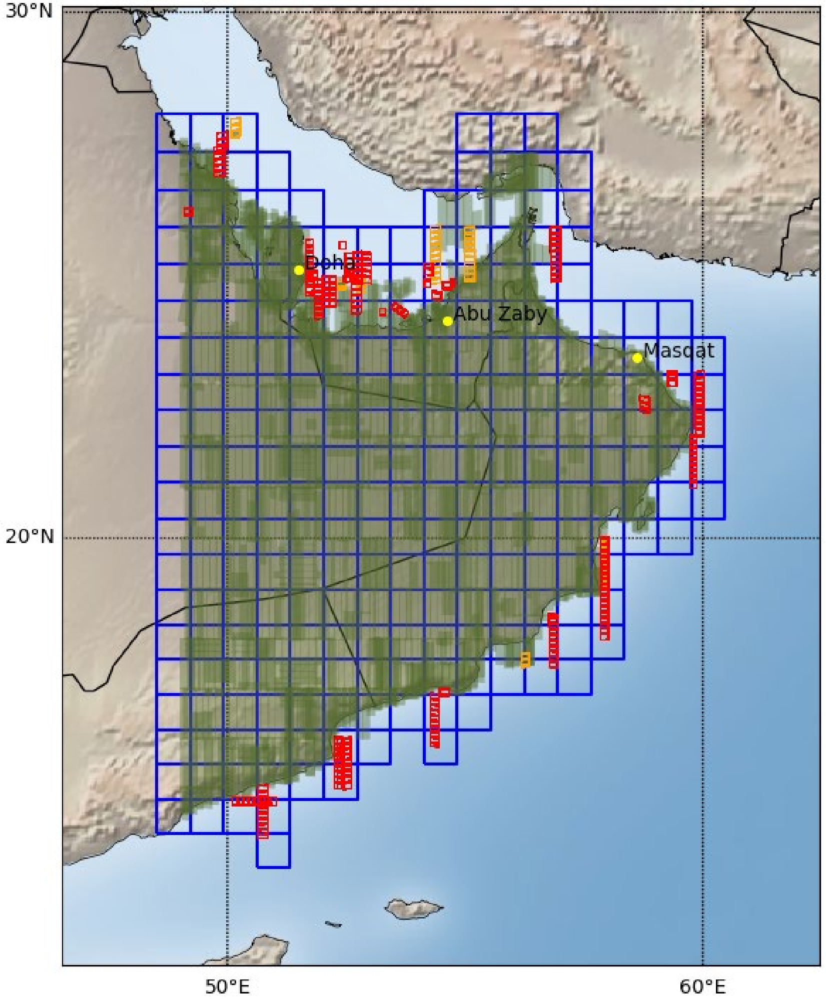
- Partition by grid and assign each partition a compute instance
- Each AWS EC2 compute instance type is based on the number of pixels in that partition (scaled for CPU, RAM, and local disk)
- Hundreds of **simultaneous instances** using machine vision to find tie-points
- Further divide each partition to run thousands of auto-tie-point tasks on each compute instance
- As soon as each partition is done, the results are saved to AWS S3 storage and the instance terminates.
- Bundle solver is also highly accelerated via parallel processing on a multi-core node



1-2 million km^2 AOIs complete in 6-10 hours (imagery average 1-3 layers deep).

Automated bundle adjustment at scales not previously possible in WorldView-class imagery.

Expert system scores quality and identifies focus areas for an operator to optionally examine in greater detail



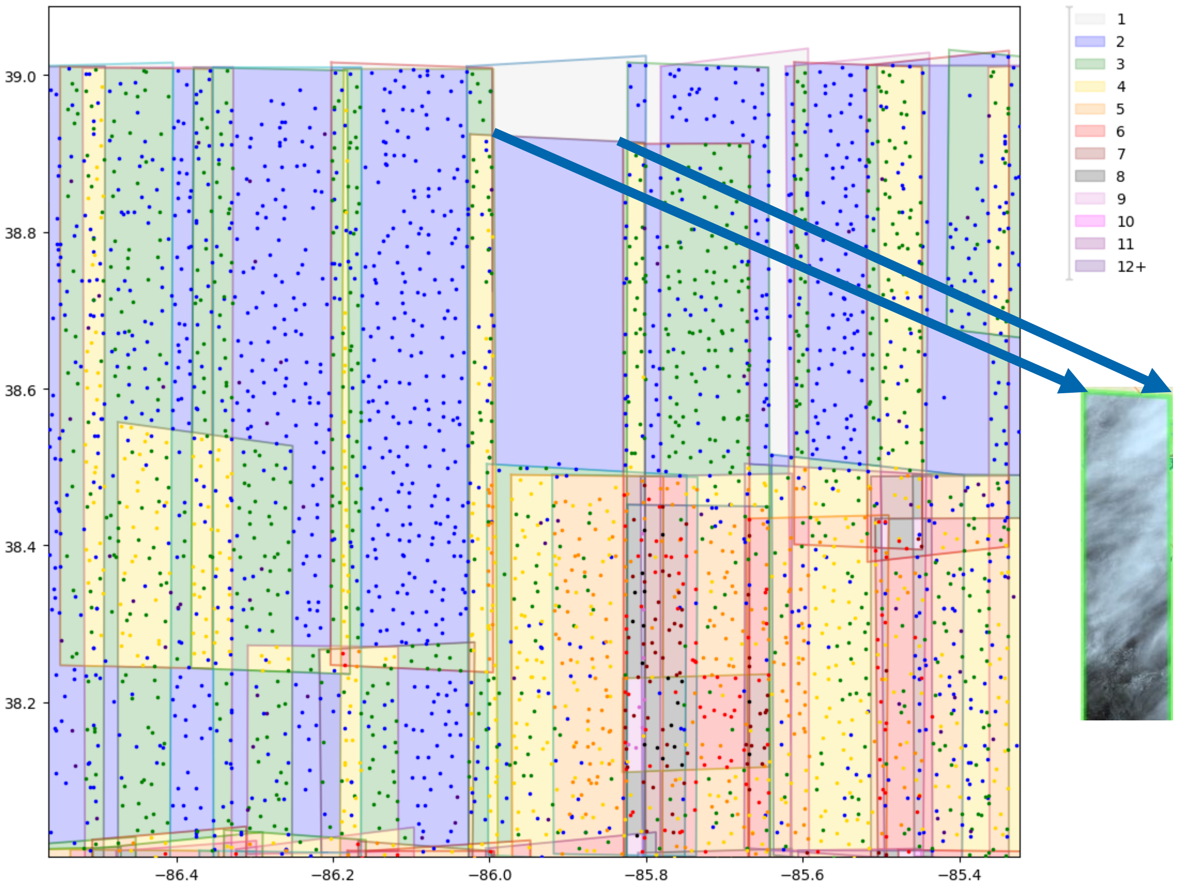
On the left:

Image strips that have large adjustments appear yellow. Those with no adjustment appear red. Using the tool on the right we can determine why various images have been flagged.

On the right:

Evaluation tool shows amount of overlap and depth of points by color coding. Problem areas can be examined in browse imagery.

In almost all situations, a lack of tie-points or depth of points is due to water, clouds, snow or shifting sands.

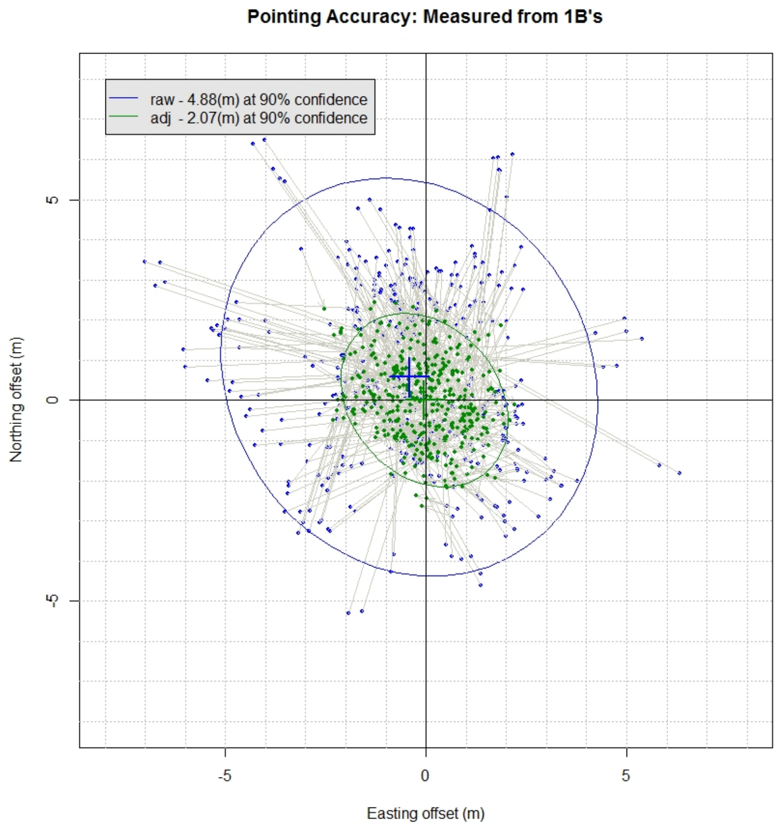


Results

1B and orthomosaic accuracy examples

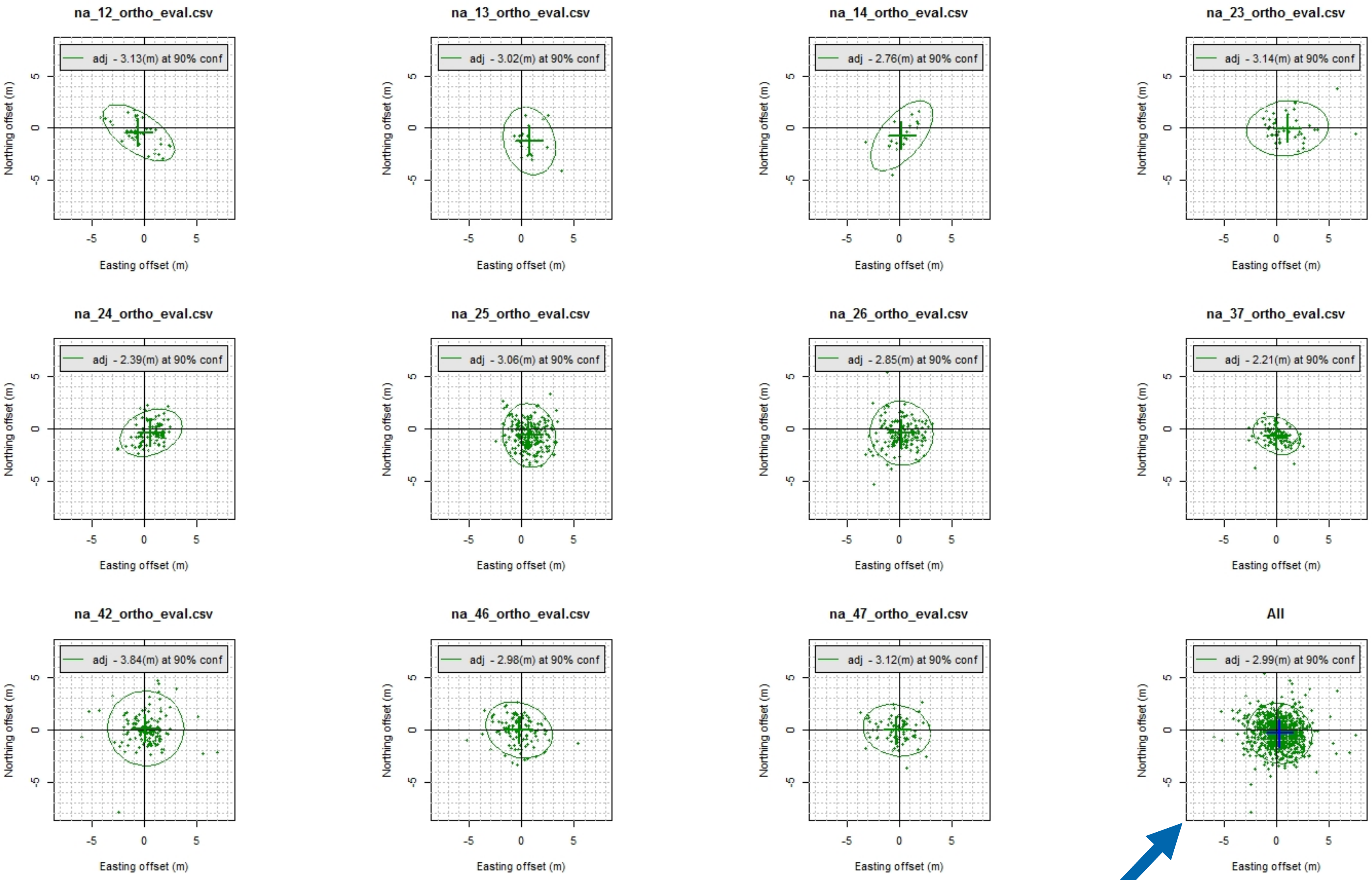
Results – 1B pointing accuracy

- 1B pointing accuracy measured before (blue) and after (green) BBA
- Manually measure pointing accuracy to well established ground control
- Run BBA on production blocks (~600 images each)
- Measure adjusted pointing accuracy from same points
- Track movement of points from before to after



3 Projects
88 GCPs
127 images
380 rays

Ortho accuracy with BBA, 11 sample blocks in CONUS



All 11 combined

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Ortho accuracy tested in samples worldwide

AOI	CE90 (m)	# of GCPs	# of strips
Australia	2.2	40	2334
Middle East	2.9	45	1406
South Africa	2.8	39	825
Brazil	3.5	78	1589
South Korea	3.0	45	508
United States	3.0	1250	495-648
Central Europe	2.7	140	1115

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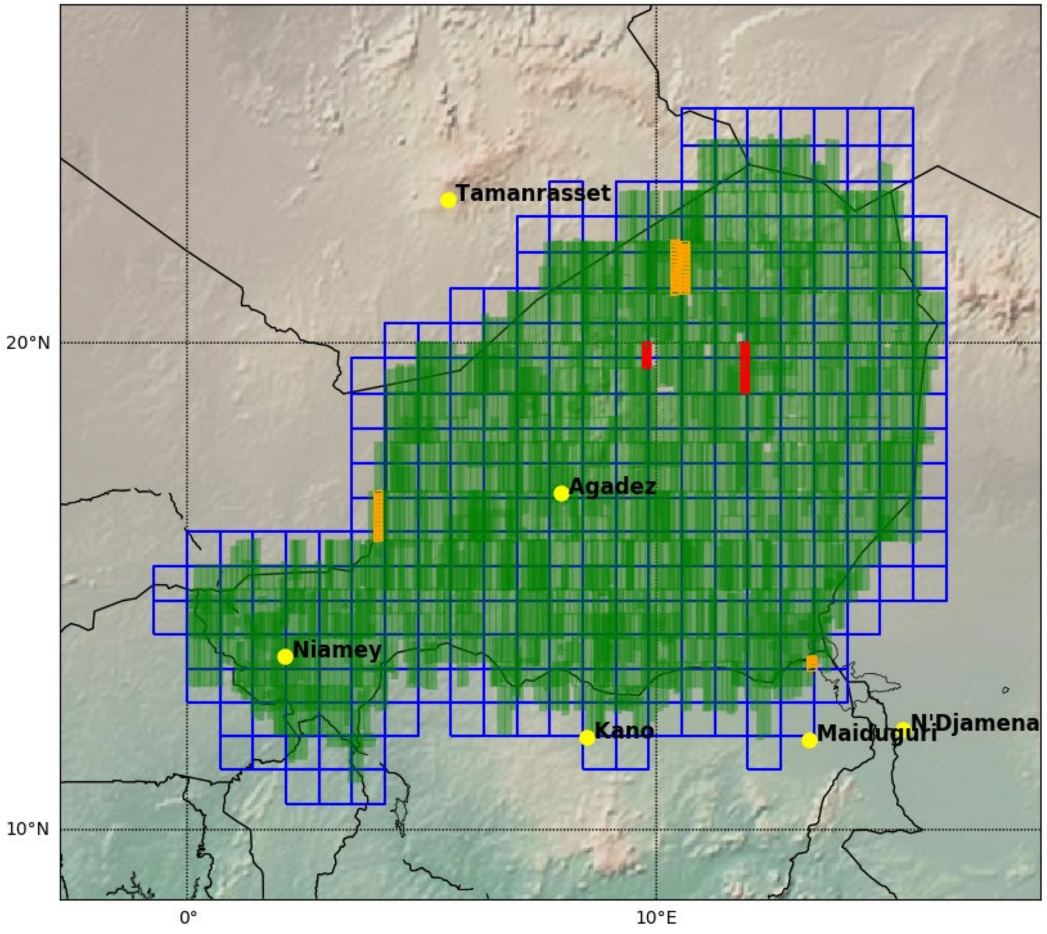
Without BBA, ~7m shear
10 m
50 ft


With BBA, ~2m shear

Summary

- Hands-free bundle adjustment
- Blocks at country scale in 30-50cm imagery
- Significantly improved shear in orthomosaics
- Absolute accuracy of 2.5-4.5m CE90 in ortho (typical)
- AWS cloud scalability allows for completion in less than a day



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