Geometric Assessment of PlanetScope Imagery

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Introduction

NASA's Commercial Smallsat Data Acquisition (CSDA) Program was established to identify, evaluate, and acquire data from commercial sources that support NASA's Earth science research and application goals. These data augment and/or compliment the suite of Earth observations acquired by NASA and other U.S. government agencies and those by international partners and agencies.

Image data from commercial satellite companies, PlanetScope (PS) from Planet, WorldView (WV) from MAXAR, and BlackSky (BkS) are available for U.S. Government Federal civil agencies and National Science Foundation funded researchers. As the capabilities of commercial satellite vendors grow, NASA's Earth Sciences Division will continuously monitor the development of these companies.

Here we evaluate PS, BkS, and WV for effective footprint size. PS is also evaluated for geolocation accuracy, temporal stability, and Band-to-Band Registration.

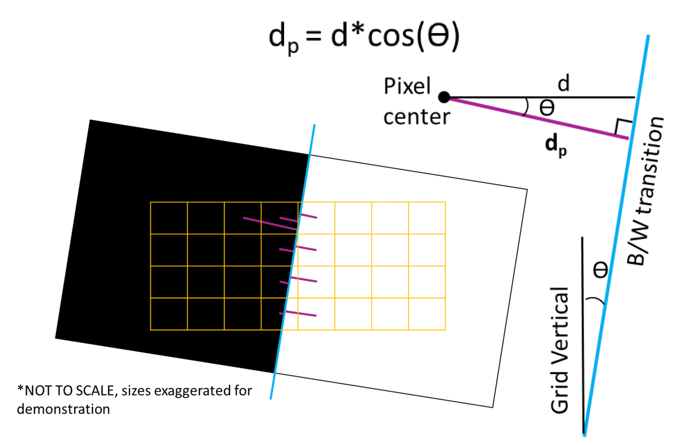
Information about these vendors, user licenses, and data is available on the Commercial Datasets web page [1]. As additional commercial small satellite datasets are evaluated and acquired, those datasets will also be made available.

Objectives

- Calculate and compare image footprint size for PS, BkS, and WV.
- Calculate relative geolocation offsets for SuperDove series images.
- Evaluate SuperDove's Band-to-Band registration (BBR) for all 8 bands.
- Evaluate temporal stability of SuperDove geolocation accuracy.

Methods

Footprint Size



Θ = Angle between transition and image grid's vertical

Step 1. Define a line as the transition from black to white (blue line in diagram to the right)

Step 2. Calculate perpendicular distance from pixel center to blue line (purple lines in diagram, d_p),

Step 3. Fit a polynomial to the transformed data to make Edge Spread Function (ESF).

Step 4. Calculate derivative of ESF to find Line Spread Function (LSF). Resolution metric, full width at half maximum (FWHM), is calculated here.

Step 5. Fourier transform the LSF to find Modulation Transfer Function (MTF). Calculate resolution metrics MTF at Nyquist and Ground Resolved Distance (GRD, where MTF(1/(2GRD)) = 0.5) here. These results are not shown on this poster.

Geolocation Accuracy

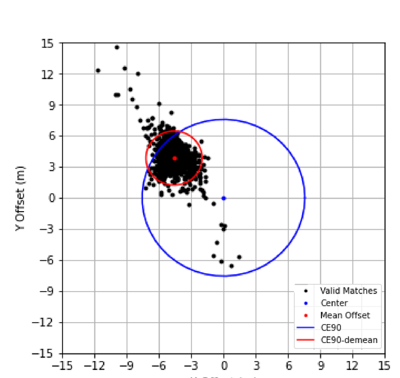
Step 1. Split reference WV and PS image into subset image chips (350 x 350 m) and resample to a common resolution.

Step 2. Impose offsets on matching chip pairs to find best Pearson Cross Correlation (PCC) value.

Step 3. Calculate a metric for quality of image match[2].

Step 4. Filter out poor quality chip matches from final assessment by approximating a gaussian fit to the data and filtering based on the derivative[3].

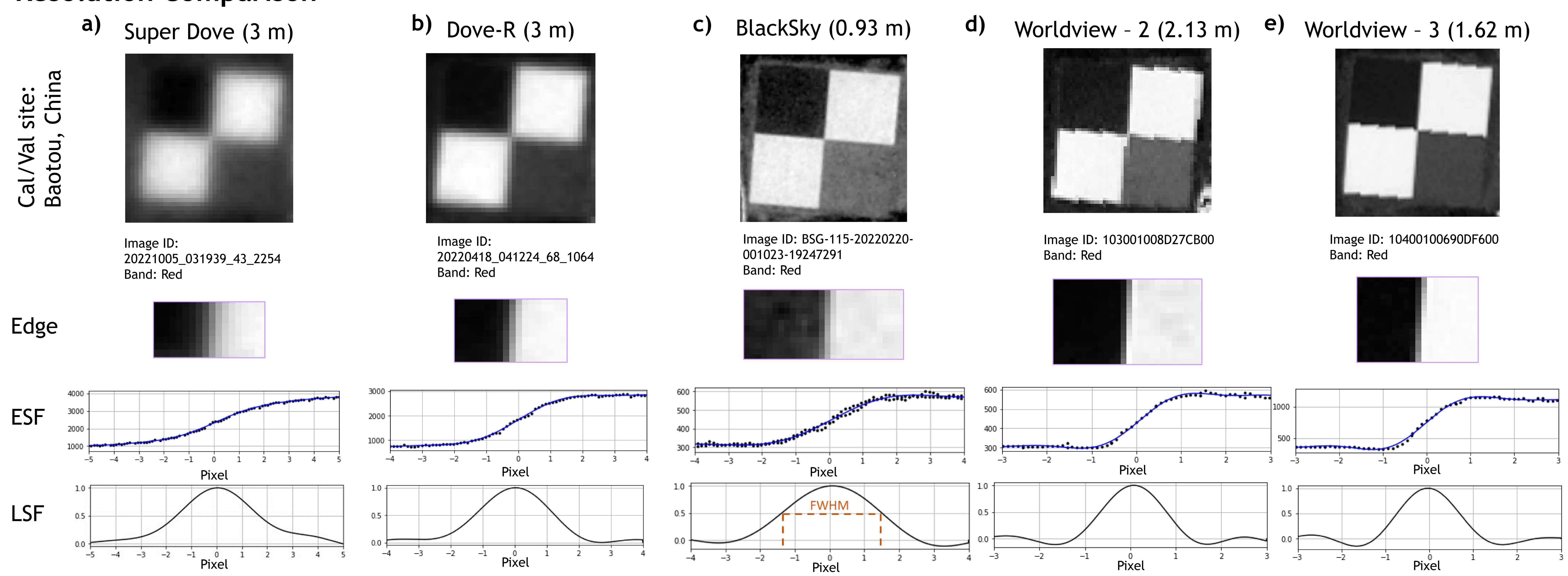
CE90-demean



CE90-demean: CE90 but with the offset bias of the reference image removed. It is similar to a precision measurement of the target image.

Left: Demonstration of CE90 (blue, 7.57 m) vs CE90-demean (red, 2.61 m) for SuperDove over Copiapó, Chile.

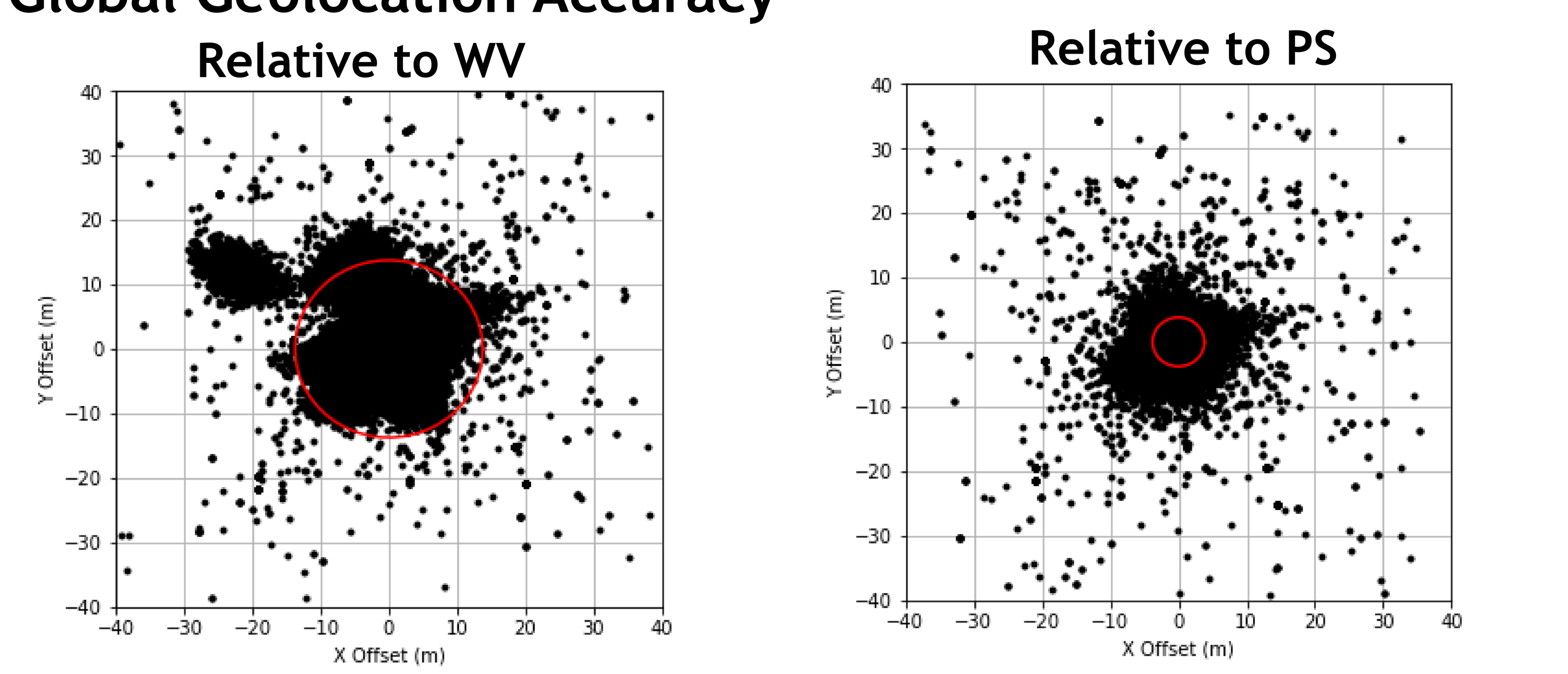
Resolution Comparison



FWHM = 3.3 pixels = 9.9 m | FWHM = 2.5 pixels = 7.5 m | FWHM = 2.7 pixels = 2.5 m | FWHM = 1.5 pixels = 3.2 m | FWHM = 1.4 pixels = 2.3 m

- Image footprint size was examined for a random sensor in each of the 5 SuperDove launches. One sensor that performs close to the average is presented here (a). Alongside that is image footprint size evaluation for (b) PS's Dove-R sensor, (c) BkS sensor Global-15 which is similar to the average BkS performance, (d) Maxar's WorldView-2 (WV2), and (e) Maxar's WorldView-3. Edge images show the edge used in ESF/LSF calculations.
- When FWHM > gridded image pixel size, over-sampling occurs. When the FWHM/pixel-size ratio > 2, aggregation may be performed to reduce data volume and to increase SNR (signal noise ratio).

Global Geolocation Accuracy



SuperDove relative geolocation accuracy was examined at 25 globally distributed cities. **Left** shows all chip offsets, with CE90 = 13.76 m in the red circle. **Right** shows CE90-demean, or internal consistency, for the same chips. The global CE90-demean is 3.80 m.

Band-to-Band Registration

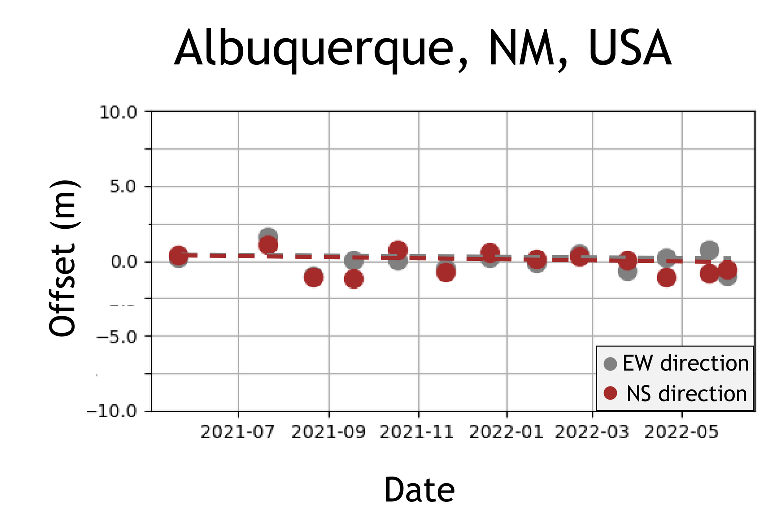
- Most bands are less than 1/3 of a pixel offset from the red band.
- Yellow is the closest to Red, with an offset of r_i = 0.39 m
- NIR is the farthest offset at mean r_i of 1.13 m.
- NIR also has the fewest valid matches of all the bands.

$$r_i = \sqrt{x_i^2 + y_i^2}$$

The east-west and north-south offsets of each valid chip match are x_i and y_i, respectively.

Band vs. Red	# of Valid Matches	Mean(r_i) (m)	CE50(r_i) (m)	CE90(r_i) (m)
Coastal Blue	79726	0.69	0.47	1.26
Blue	81598	0.52	0.34	1.01
Green I	94215	0.44	0.30	0.82
Green	109539	0.40	0.28	0.73
Yellow	125743	0.39	0.26	0.68
Red Edge	101528	0.50	0.31	0.93
NIR	41913	1.13	0.73	2.36

SuperDove Temporal Stability



Time vs. mean geolocation offsets for each PS image analyzed at a location. Gray dots show the E-W offsets, brown dots show N-S offsets. Time series was analyzed at Albuquerque, NM (12 mo.)

Summary

Footprint Size

- SuperDove's effective footprint size is FWHM = 3.3 pixels (9.9 m) in this example. Overall, average effective footprint size is FWHM = 3.23 pixels (9.7 m).
- Comparing to other CSDA satelites, Superdove's pixel size is the most oversampled, followed by BlackSky and Dove-R at 2+ pixels FWHM, while WV2 and WV3 are marginally oversampled.
- Aggregating SD images by 3 x 3 pixels would reduce data volume by 90% without data content lost.

Geolocation Accuracy

- Relative to WV data, relative geolocation accuracy varies by location. Globally, SuperDove has a CE90 of 13.76 m.
- SuperDove geolocation accuracy is internally consistent and stable over time. Globally, SuperDove has a CE90-demean of 3.80 m, much smaller than the footprint size (~10 m).

Band-to-Band Registration

- Offsets are sub-pixel for all bands when compared to Red band, and offsets are much smaller than sensor footprint size (~10 m). Mean radial offsets vary from 0.39 m – 1.13 m.

Questions? Email Alana Semple at alana.g.semple@nasa.gov

References: [1] Commercial SmallSat Data Acquisition Program: https://www.earthdata.nasa.gov/esds/csda [2] De Luccia, F. J., Houchin, S., Porter, B. C., Graybill, J., Haas, E., Johnson, P. D., Isaacson, P. J., and Reth, A. D. doi: 10.1117/12.2229059 (2016). [3] Semple, A., B. Tan, and G. Lin. (2023), "Automation of Geometric Accuracy Assessment Algorithm", JACIE 2023 Workshop.