Reviewer comments

Author comments

Major points

● I believe early on in the manuscript, it should be mentioned that the analysis is focussing on PlanetScope SuperDove data. Then the authors can potentially consider reducing the information presented on the earlier generation of PS constellation (current section 3.), and condensing the information on previous efforts which have tried to work with older PS data (Section 3.2). Mentioning some of the previous approaches is valuable, but I do not think a detailed description of those is required. More comments related to this point are also provided in other comments below.

We now emphasize that our work focuses on the newer PlanetScope generation in the Introduction section (see Lines 44-45). The orthorectification error, however, also affects data acquired by the older PS instruments. We therefore provide information on all Dove generations, but we have greatly shortened the section on previous efforts (see our responses to the related comments below).

● Consider reducing the dense text on the background of the two landslides. I agree the event description is important, but describing the general characteristics of the events and then pointing the users to published papers for more in-depth details will work better here, as the current paper does not focus on the science of landslides per se.

We agree and have condensed this section.

● Section 3.1 is again pretty dense. One option could be to break into 2 separate sections. The first could be renamed as section 3.1: Expected relative geolocation accuracy, which succinctly describes the geolocation accuracy which is expected in Planet data, quoting numbers from the Planet documentation and previous studies. The second section could describe in more detail the spatial pattern of the typical relative geolocation offset, leading up with the figure 3, describing the four main types of errors. I think there are 4 main issues shown in figure 3 are:

- ○ Error due to dynamic/outdated topography in displacement maps obtained from image pairs acquired from different orbits
- ○ Error due to stereoscopic affects in the y-direction (again more for pairs collected from different orbits?)
- ○ A general global shift which can be corrected by removing the median x and y shifts over static surfaces (this could be present in image pairs collected by both the same and different orbits)

○ Striping effects in the y-direction due to sub-frame misalignment (will be present in both L1B and L3B data, and potentially for image pairs acquired from both similar and different orbits).

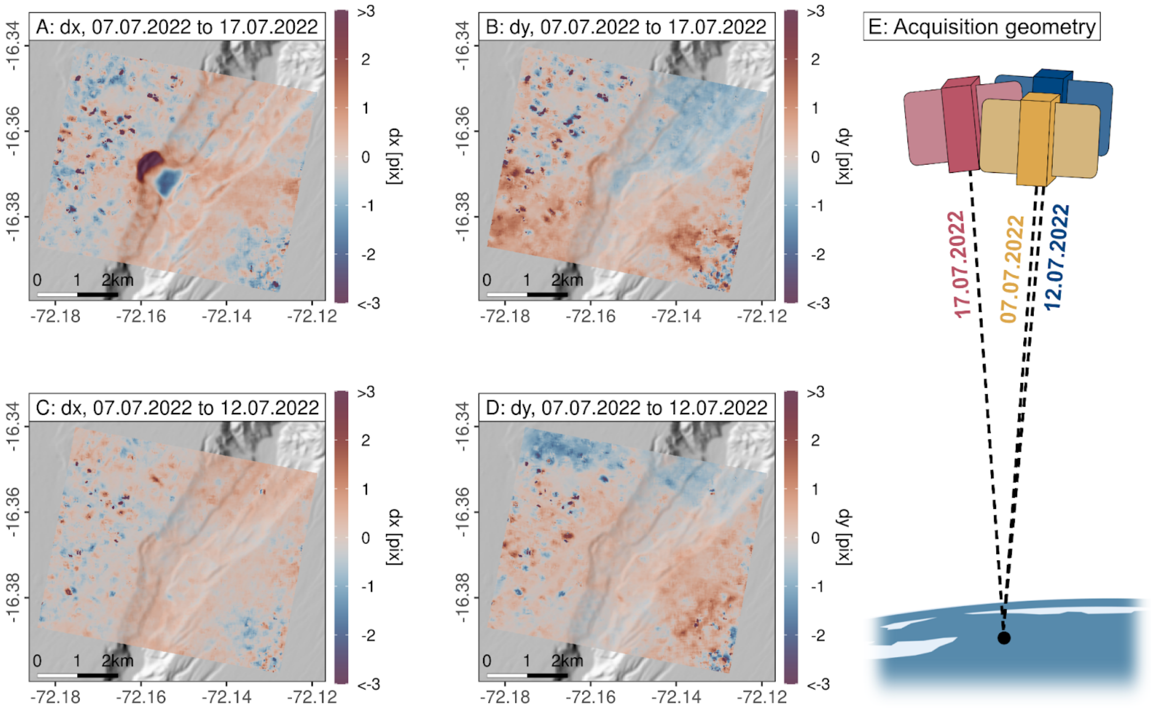
Based on the order you chose to introduce these errors, have small subsections or bullets for these 4 points in the new section. It will then be very clear to the reader that these are the four errors that the authors are going to tackle in the manuscript. Then, maintain this order when you propose corrections, describe results, and conduct discussions.

There should also be a clear distinction between which correction corrects for what error. So maybe we the corrections are introduced, their section headers could contain information about which of the four errors is being corrected?

Along the same lines, it would be useful to plot the image acquisition geometry skyplot in the third column for each of the two pairs in Figure 3 (as in figure 8), so that it helps us in bringing out the effect of acquisition geometry on some of these errors?

Thank you for these suggestions. We have followed this and now list and explain the 4 spatial patterns of error observed in the disparity maps (orthorectification error, stereoscopic effects, ramp errors and global shift, stripes) in section 3.1. We have also reorganized our method section accordingly and now have separate subsections that describe how to mitigate what error.

We really liked the suggestion of adding a skyplot and did so, not for Figure 4, because not all co-registration errors are related to large view-angle differences, but to Figure 6 (now 5) showing the orthorectification error for an image pair acquired from a different and common perspective (we believe the reviewer meant Figures 4 and 6 instead of Figures 4 and 8). Our new Figure 5 is shown below:



● Current section 4.2 is very long, and the order in which information is presented can be improved. You already talked about how outdated DEM affects displacement mapping in the current section 3.1, ideally the your conceptual figure and text belong there, and not in the methods.

We agree that a joint description of concepts and methods is not ideal. We have integrated the description of the orthorectification error and conceptional figures in section 3.1 (see our reply to major point 3).

● Similarly, the authors talk about the discussion of using data from a .json file or the scene metadata.xml. All of this is important to consider, but it disrupts the scientific/methodological flow of the paper. Maybe some of this could be transferred from the manuscript to the github repository readme or something?

We have moved this information to the documentation in the accompanying github repository.

● DEM generation section have no mention of how accurate the output DEM is? I understand the authors want an update topography, but if the topography is biased by 10 m (or 20 m), will it still be helpful? This is important to consider for flatter sites where the height uncertainty will be high due to the smaller convergence angles of the Planet images.

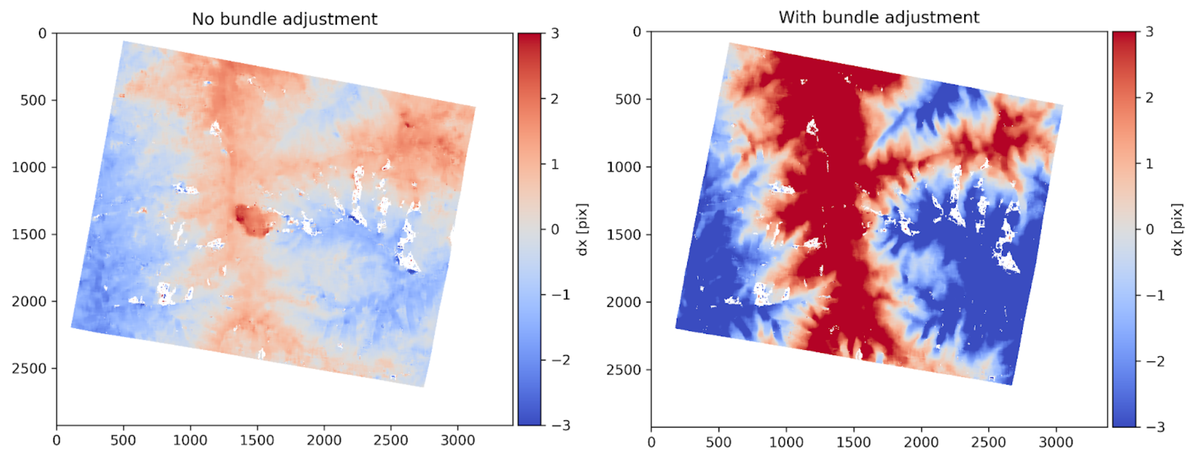
We have carried out an additional analysis to address this question. We imposed an artificial (known) elevation bias onto a DEM and compared the effect on disparity maps derived from an orthoprojected L1B pair acquired from different perspectives. We find that a vertical DEM bias of 1 m results in an orthorectification error of on average 0.056 pixel or 0.168 m in the cross-track (dx) component, while the along-track disparities (dy) appear unaffected. If a 20 m bias in the topography is still useful depends on the analyzed scenario. If you can tolerate ~3.36 m uncertainty in velocity estimates because the magnitude of displacement largely exceeds that value, it will not be a problem. However, measurements of slow slides with annual velocities of only a few meters will suffer much more from a larger DEM bias.

We have described this analysis and findings in the newly added sections 4.7 (Assessment of orthorectification error magnitude in response to DEM changes) and 5.3 (Magnitude of orthorectification errors).

● When using the optimized, co-incident DEM for orthorectification with the bundle-adjusted L1B image pair, did this not result in removal or at least some reduction of the stereoscopic error? Have the authors evaluated this? Ideally, this should have helped.

Yes, we have tested bundle adjustment but observed no enhancement in the quality of the disparity maps. In many cases, it degraded the co-registration accuracy even further.

Here is an example of an L1B image pair (2021-05-16 and 2023-05-11) mapprojected with and without bundle-adjust-prefix. The larger topographic effects after the bundle adjustment are visible by the larger color gradient.



Consequently, we decided to use the original RPCs from Planet without any bundle adjustment to carry out the map projection. This decision aligns with a discussion in the Ames Google Group, where bundle adjustment also did not resolve systematic errors: https://groups.google.com/g/ames-stereo-pipeline-support/c/MTVVV00Qf0I/m/fXTig3rzAgAJ

● The polynomial fit correction will require a good chunk of non-moving, static terrain distributed throughout the scene, which is important for users to consider on where this method is applied. Suppose a landslide is being studied in a glaciated area. In that case, this will likely be more difficult to apply as the glaciers will move, reducing the amount of static area that can be used for the presented sophisticated global ramp correction.

That is true and we have noted that in the discussion lines 482-483 . We have added that glaciated areas pose a particular challenge.

Lines 483-484: Similarly, terrains with widespread movement, e.g. glaciated zones, present challenges for ramp correction.

● How much of this polynomial fit step is required for L3B data from very similar perspectives?

We do not find a clear link between the difference in satellite perspective and the need for fitting a polynomial. For example, the image pair displaying a ramp error in updated Figure 3 C only has a view angle difference of 0.4°. Instead, we assume that this issue is more related to how well the camera position was constrained and how many tier points were found, which can vary from scene to scene.

● We should discuss how we are hampered by using just L3B data from common perspectives. What are we gaining from orthorectifying the L1B data from different perspectives using contemporaneous DEMs (i.e., how many new observations are added).

We have added a new section to the discussion about the advantages and limitations of the L1B and L3B approaches (section 6.3) and a new supplementary Figure (S13) showing the availability of suitable PlanetScope scenes (cloud-free, full AOI coverage) and their true view angle.

Line by Line comments

● The abstract is written very well, great work!

Thank you!

● Page 2 Line 43-44: This is a bit contradictory to your next sentence where you say that you then “carefully” select pairs from the same view directions, so how do you mitigate topographic errors arising from different view directions? Maybe clearly using bullets to describe the objectives of the study somewhere early on in the manuscript will help? You are doing a lot of cool stuff, and that should get the main space, which is getting lost in the current presentation. Something like:

○ Evaluate the different type of geolocation errors in different versions of PS-SD data (L1B, L3B, Basemaps)

○ Facilitate the use of images acquired from different perspectives in ground displacement tracking over dynamic terrain using an updated DEM derived from co-incident Planet imagery

○ Propose a workflow to carefully select L3B data for accurate ground displacement mapping?

○ Propose corrections on final displacement maps using polynomial fits to further reduce geolocation errors?

Thanks for pointing this out. We have followed your advice and have replaced the former description of our contributions with the following bullet points to present them more clearly:

1. Examine the different sources of errors compromising co-registration accuracy between PlanetScope scenes, particularly those captured by the latest PSB.SD instruments.
2. Present a workflow to mitigate the orthorectification error through a careful selection of correlation pairs based on common satellite perspective (jointly determined by the satellite's look direction, view angle, and motion direction) for orthorectified L3B data.
3. Enable the use of images acquired from different perspectives through manual orthorectification of unrectified L1B data based on an updated DEM derived from co-incident Planet imagery.
4. Propose corrections of the displacement maps through fitting polynomials to further reduce co-registration errors.

● Line 60 to 65: This could again be shortened, as the information can be presented better in the hopefully condensed study area section.

We have removed the last two sentences of the introduction and included this information in the description of the test sites.

● Line 137-140: Maybe the line describing what RPC are and that they are used by Cubesat constellations can be skipped? RPCs are in widespread use now and are used by almost all satellite vendors who provide unrectified data.

We have removed the line about the RPC use by Cubesat constellation and RPC bias compensation to shorten the paragraph but would like to retain the short description of RPCs for readers who are not familiar with the concept.

● Rename Section 3.2: Again given the focus of the paper on PS2-SD data, do we need this section to be so lengthy? An alternative could be to describe in a sentence each all previous studies with old data (or maybe make a table of that with the sensors considered, the correction type, the number of images and science applications) and then let the readers figure it out. The authors can then mention that none of these approaches have been able to correct errors in PS2-SD sensor, which is the main focus of the study.

We have greatly shortened Section 3.2, summarized the previous approaches and stressed that in our work, we focus on the newer PSB.SD instruments.

● Line 234: Instead of going into all of this detail on how the data can be delivered, this could be simplified by saying we use green band due to xyz reasons, which corresponds to band x in PS2-SD data. We are not using products from older sensors, so why mention this granular detail about them?

True. We have modified the line accordingly.

● Line 477: What is meant by corrected L3B data? Has the polynomial fit been applied to the L3B data here?

Yes, with corrected L3B we refer to the processing steps where the polynomial fit has been applied. In response to the feedback from Reviewer 1, we have completely rewritten this section and made sure to explicitly state which data at which processing state we refer to.

● Section 5.3: In this section, I am a bit confused on what pairs were used to conduct this analysis. In Figure 14, was the L3B and L1B data selected for a pair acquired from a different perspective, or the similar perspective?

Previous Figure 14 showed histograms estimated from a pair taken from different perspectives. However, in response to the feedback from Reviewer 1, we have replaced that Figure by a scatter plot showing the IQR across stable terrain for all image pairs before and after the application of the polynomial fit.

● Section 6.2.1 is important, thanks for conducting the analysis and sharing your findings!

We are glad to hear that you found this analysis useful.

● Line 530 to 533: could you show through a figure by what is meant by the misalignment in single vs multiple subframes? This is not clear to me in the current form.

An example of what the misalignment of single vs. multiple subframes looks like is given in Figure 3B and 3C in the original manuscript. Misalignment of multiple subframes results in a regular striping pattern (Figure 3B). In contrast, in Figure 3C we observe that only the lowermost part of the disparity map is offset. The latter scenario can be approximated by a second or third order polynomial, but multiple stripes cannot. We agree, however, that this statement may be confusing and because it is a rather rare case, we have removed the sentence about the compensation of single frame misalignment from the manuscript and also chose different examples for Figure 3.

● Line 537: What is the marginal lower accuracy (e.g., 1 m, 2 m, 3 m?) which the users should be comfortable with?

That depends on how many sub-frames were misaligned in an image and how well the transitions were smoothed. From our experience, we see that the magnitude of the striping effect is typically at or below 1 pixel (3 m). Considering the spread of disparities estimated across stable terrain as a quality indicator, Figures 13 and 15 in the revised manuscript show that the IQR of the dy component is only about 0.25 pixel (0.75 m) larger than that of the dx component. On this basis, we define the "marginal lower accuracy" as < 1 pixel in the revised manuscript.

● Line 587 to 589: Thanks for conducting this analysis and sharing your results!

Thank you!