Supplement Text S1

Agisoft Photoscan Digital Surface Model Workflow:

1. **Add photos**
    a. Manually disable/remove takeoff and landing photos
    b. Use all photos if there is minimal overlap in flight lines and few redundant photos (e.g., flight lines set up using mission planning software).
    c. If photo coverage is good, but repeat lines/photos are present, use ¼ to ½ of photos, align on low, and check coverage. Add additional photos to improve coverage if needed. Recheck alignment.

2. **Camera calibration**
    a. Check initial settings.
    b. Using "**auto**" alignment and default settings.
    c. For GoPro photos, change type to "**fisheye.**"
    d. Optional: break out different focal lengths and camera elevations into different calibration groups

3. **Alignment**
    a. Quality: "**highest**"
    b. Pair preselection "**generic**." Selecting "**disabled**" will yield more points if camera positions aren't systematic (e.g., in a line). With **disabled**, all photos are compared to one another, at the cost of additional processing time.
    c. Optional: if geotagged photos are used, select "**disabled**" to achieve better alignment (so alignment not limited by mediocre geotagged photo locations).
    d. Key point limit: **60k**, tie point limit **0** (no limit).
    e. Deselect "**adaptive model fitting**" (not sure what this does).
    f. **Optimize** cameras after initial alignment

4. **Coordinate System**
    a. Update geographic coordinate system. For Borah Peak, we used **NAD83(2011)** (EPSG::6318).
    b. Update "**Image coordinate accuracy.**" Marker accuracy is how well you can place the markers on the photos, so this depends on the image clarity and resolution. Generally, use a marker accuracy of **0.5 pixels** for GoPro and **0.3 pixels** for mirrorless (e.g., Sony a5100) cameras. If photos are really clear/sharp, **0.1 pixels** is justifiable.
    c. Tie point accuracy of **0.1-0.5 pixels**.
    d. Leave "**measurement accuracy**" as default values.

5. **Markers**

a. Import CSV – with **GPS RMS** field used as "**accuracy.**" Set "**Start import at row**" to row with first point. Double check that columns are assigned correctly (compare headers in table preview).
b. Deselect any markers outside of project area and any geotagged photos in the Reference pane.
c. Build Mesh if helpful for locating targets.
d. Place a few markers, update georeferencing.
e. Hand place as many markers as possible, while minimizing "**Error (m)**" (model error in RMSE). Avoiding placing warped/distorted/poor resolution targets if possible (in some cases, needed to add these to reduce model error).
f. Optimize cameras using parameters **f, cx, cy, k1, k2, k3, b1, b2, p1, and p2**. Uncheck markers with high errors and re-optimize to reduce model error (RMSE).

6. **Gradual Selection.** This is an important step of cleaning the sparse point cloud before building the dense cloud. Optimize using parameters in step 5f.
    a. Reconstruction uncertainty. Filter out photo pairs (tie points) that have poor geometry. With a fixed wide angle lens, good overlapping flight lines, sharp photos, etc., reconstruction uncertainty will not exceed 10. With less ideal conditions, 15 is more reasonable.
        i. Select points **>10-15**, being careful not to remove too many points (aim for ~10-50% depending on cloud size).
        ii. Delete points and optimize.
        iii. Check camera "projections" in error window. <200 projections = poor alignment and point cameras will not be used.
        iv. Repeat (a total of 2 times).

    b. Projection accuracy. Relative accuracy of tie-points at multiple scales. High quality photos/points – can go to 2; 3-6 more reasonable with image issues (artifacts, blurry, etc.). Not influenced by camera calibration.
        i. Select points **>3** (can attempt 2.5), being careful not to remove too many points (aim for ~10-50% depending on cloud size).
        ii. Delete points and optimize.
        iii. Check for projections <200.
        iv. Repeat (a total of 2 times).

    c. **Reprojection error (~2-3x).** This is how well 2D and 3D reconstructions of the tie points match, measured in pixels. Iterate, aiming for <0.3 pixels.
        i. Select points >**0.3**, or **~5–10%** of points, whichever is less. Watch for too many projections <200.
        ii. Delete points and optimize.
        iii. Repeat (at least 2-3 times), getting as close to 0.3 as possible.

7. **Dense Point Cloud**
    a. Quality: **High**
    b. Depth filtering: **Aggressive**

8. **DSM**
    a. Construct DSM in Photoscan using dense cloud as source.
    b. Export DSM as GeoTiff.