# Brief communication: Improving botanical monitoring in proglacial areas with high-resolution UAV data

Review by Anonymous RC2

*We thank the reviewer for their suggestions and comments which we followed to improve the manuscript.*

Dear authors,

overall the topic is relevant and interesting as glaciers are receding faster and thus also the enlargement of the proglacial areas.

In general the abstract is very vague, it would nice to have a short information about the result.

*We modified the abstract to take into account this comment (common to all three reviewers), keeping in mind the 100-word limit:*

*"Proglacial areas are undergoing rapid ecological and land cover changes as glaciers retreat globally. Unmanned Aerial Vehicles (UAV) are particularly suited for monitoring such complex terrains but vegetation retrievals, such as vegetation cover, have rarely been evaluated against traditional botanical surveys. In this study, we compared the vegetation cover derived from UAV images at various resolutions with vegetation cover measured in situ by experts below the Aneto glacier (Pyrenees). UAV retrievals accurately captured the altitudinal gradient in vegetation cover and the spatial variability between vegetated plots. While increasing image resolution reduced biases, they remained significant in areas with sparse vegetation."*

As you are working in a proglacial area it would be more important to cluster the plots by years ice-free than elevation and also the whole proglacial area should be clustered by years ice-free, then it would be better to compare with the adjacent area outside.

*We agree that, ultimately, the vegetation cover gradient should be considered against the ice-free period. However, as we focus here on the vegetation cover retrieval methodology and not on the botanical interpretation of the results, we believe that it is more adapted to present the gradients against elevation. First, it prevents to explain the methods to calculate the deglaciation year, keeping the article within the length expected for a Brief Communication. Also, it makes the work slightly more generic as vegetation cover gradient with elevation are also studied out of proglacial environments.*

*An article partly using these datasets and focused on a botanic analysis is currently in the making.*

Introduction:

Line 20: a comma is missing between local topography, and soil properties

*We added the comma.*

Line 29-30: However, in situ observations of the vegetation are only possible at a few dozens of plots of typically 1 m² to 4 m² - this is not totally correct as other studies use 10 m² plots (5x2 m) and estimate cover in each 1 m² subplot - (see among others: https://doi.org/10.5772/intechopen.69479, doi:10.3390/d12050191)

*Thank you for sharing these works. In Fickert (2017), two glacier forefronts are surveyed with 8 and 9 plots of 10 m² divided in 1 m² subplots for a total of 80 m² and 90 m², which does not appear in strong contradiction with our statement of "a few dozens of plots of typically 1 m²". In Fickert (2020), four glaciers are surveyed with three 10 m² plots at between 8 and 10 locations, for a total of between 240 m² and 300 m². This is indeed larger than what we state. Thus, we replaced 4 m² by 10 m² in the text.*

Methods:

Regarding the methods it is not clear how the cover values from the UAV images were derived. You refer to Deschamps-Berger et al. 2020, but this reference is missing.

*We added details about the method:*

*"The images were then classified in a land cover map with four classes (rock, rock in the shade, vegetation, and vegetation in the shade) using a random forest classifier. The classifier was trained on about 50 polygons per image defined after visual interpretation of the images, following the workflow implemented for satellite images in Deschamps-Berger et al. (2020). This resulted in an ensemble of six sets of UAV derived land cover maps, based on the area (A1 or A4-6) and the resolution of the cover map (0.1 cm, 1 cm, 5 cm)."*

*We now added the Deschamps-Berger et al. (2020) in the reference list:*

*Deschamps-Berger, C., Gascoin, S., Berthier, E., Deems, J., Gutmann, E., Dehecq, A., Shean, D., and Dumont, M.: Snow depth mapping from stereo satellite imagery in mountainous terrain: evaluation using airborne laser-scanning data, The Cryosphere, 14, 2925–2940, https://doi.org/10.5194/tc-14-2925-2020, 2020.*

It is also not clear how control points were choosen and if they were marked in the field.

*Points were not marked in the field but identified a posteriori in the images. We modified the text:*

*"The UAV has the positioning standard error of a regular GPS (~4 m). The geolocation accuracy of the initial orthomosaics was further improved by identifying control points a posteriori in the UAV images and in contemporary aerial images at 0.5 m spatial resolution from the Instituto Geografico Nacional through georeferencing facility in QGIS (QGIS Development Team)."*

Could you also give information in the text what was the minimum cover estimated in the field.

*We added this information in 2.3: "The minimum, median and maximum cover observed were 31%, 43% and 67% at A1 and 2%, 9% and 31% at A4-6."*

What would have been helpful for getting cover values and classify pixels in the UAV images as vegetation, would have been the calculation of vegetation indices like the NDVI but derived from RGB images - there are a lot of such indices available.

*We agree that this is a potential improvement of the method that we added in discussion:*

*"More complex vegetation cover retrievals using convolutional neural networks or adding bands derived from topographic information do not seem to guarantee better results (Niederheiser et al., 2021; Zangerl et al., 2022). However, it might be beneficial to include RGB-derived indices or to acquire near-infrared images to derive the NDVI values, as it is an index specific to vegetation (Bayle et al., 2021; Niederheiser et al., 2021)."*

Results:

the points available for comparison differ between methods and results

*After careful reading of the article, we could not find the mentioned mismatch. We suppose that the confusion might come from the total number of plots surveyed in situ (6 times 10 = 60 in 2.3) and propose to add in 2.4:*

*"Due to on-site modifications of the sampling strategy to adapt to the field, all the in situ plots were not within the the UAV acquisitions, resulting in 14, 12 and 38 points available for comparison for the UAV resolution of 0.1 cm, 1 cm and 5 cm respectively."*

Fig. 3: it is not clearly showing the differences between in-situ measurements and cover derived from UAV image classification, this would be important because you want to evaluate the UAV cover by using in situ data

*We modified the figure (a) to highlight the differences between in situ and UAV measurements by making more visible the median and min-max markers. We also reduced the visibility of the boxplot where both datasets were not available, preventing comparison:*

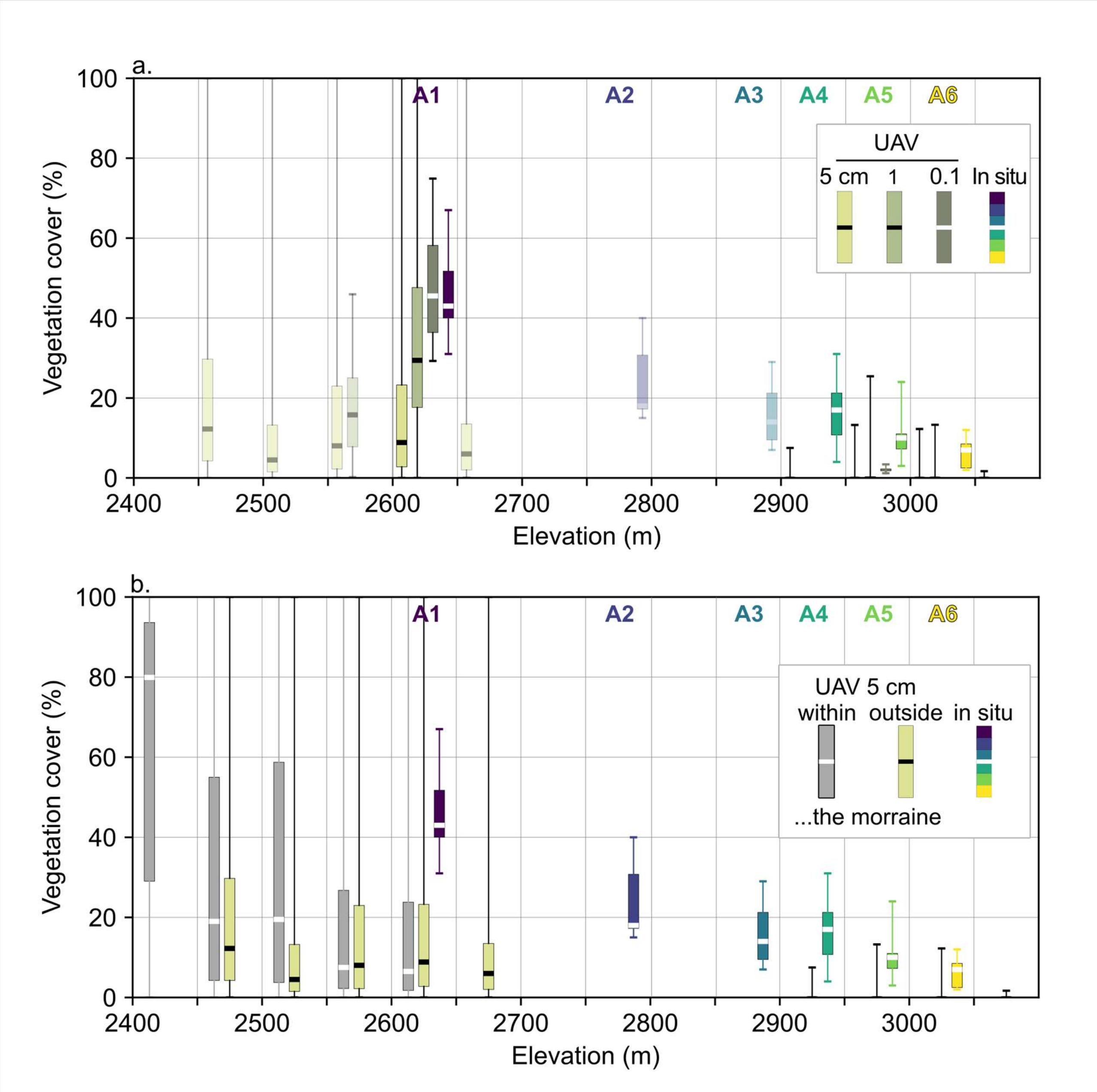


Fig. S2: Please highlight the large plants because one can identify them only when zooming in in the PDF on the computer, then it would be much clearer for the reader.

*The two large plants visible in these images are now highlighted with a white circle and the maps were slightly zoomed in.*
*Please note that we also added a new figure (Fig. S6) showing all the potential vegetated areas mentioned in discussion:*
*"For instance, 18 and 137 groups of vegetated pixels larger than a circle with a radius of, respectively, 10 cm and 5 cm were automatically extracted from the 1.3 ha covered by the 1 cm-resolution map in the high-elevation area, which is the most difficult to explore due to its relief (Fig. S6 ~~not shown~~)."*

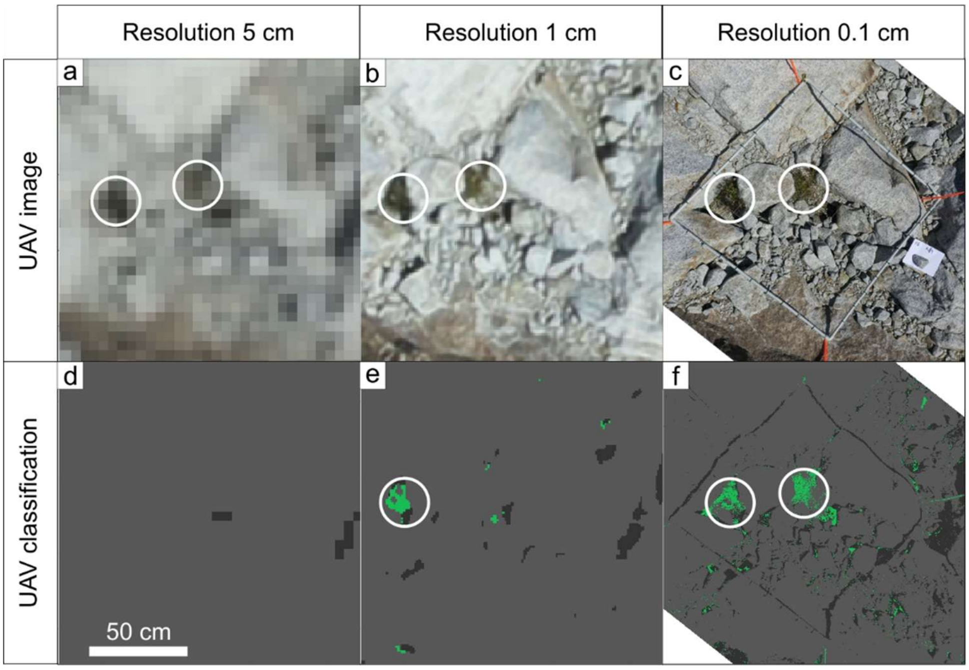


***Figure S2.*** *UAV images (a, b, c) and derived classification (d, e, f) of one of the A5 plots at the three available resolutions from left to right: 5 cm, 1 cm and 0.1 cm. Vegetation appears in green in the classification, while rock is in grey and black. Large vegetated patches are shown with white circles.*