High Latitude Drone Ecology Network – Multispectral Flight Protocol and Guidance Document

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The following protocol is the outcome of two years of multispectral drone work in the Canadian Arctic. Two three-months field seasons provided opportunities to learn through trial and error. Should you have any feedback, suggestions, questions or comments please let us know.

The information below is distilled from a blog post / short communication manuscript currently in preparation. Once published, these will be shared on the HiLDEN mailing list. If this protocol has influenced your method of data collection it would be great if you could cite the above publications in resulting manuscripts.

Content

Time of Day

All flights should be conducted between 3 hours before and after solar noon, and at most within 6 hours before and after solar noon.

You might want to harden this rule depending on the latitude of your field side / time of year, also consider mountains and other obstacles that might influence the illumination of your field site. The NOAA solar position calendar and other similar resources are useful tools to calculate solar position at your field site.

Shadows are the main reason for this, the lower the solar angle the more prominent shadows become in your images. More shadows mean a lower proportion of the surface is illuminated resulting in inaccurate estimates of surface reflectance and its derived data products, like NDVI. This becomes less of a problem on overcast days with diffuse illumination. The spectral composition of the sunlight also changes with solar elevation. This can be compensated to some degree with radiometric calibration, but extremes should be avoided.

Radiometric calibration

Radiometric calibration is the most important step of this protocol. Clouds, haze, time of day and solar position influence the spectral composition of sunlight, it is therefore key that a standard of known reflectance is used to calibrate the relative measurements of the multispectral sensor. Otherwise, comparisons between flights, sites and satellite imagery are not possible.

Pre- and post-flight calibration

Radiometric calibration is best carried out by taking calibration imagery of a known standard panel directly before or after the flight. The resulting imagery is then later used in the photogrammetry software (e.g. Pix4D) to calibrate the reflectance maps.

Only one of the two sets of calibration imagery (pre/post) will be used for radiometric calibration, but you might find that light conditions change during long flights (e.g. clouds moving in) and that conditions at the end of the flight are more representative of the majority of the flight.

We recommend using a traceable Spectralon target (or standard of similar quality) of approx. 15 x 15 cm (6” x 6”). For vegetation surveys a standard with a reflectance value of 70% would be ideal, but 40-70% should be sufficient. If you are planning to survey snow covered surfaces a pure white standard > 90% reflectance might be required.

If you are using a Parrot Sequoia sensor, please be aware that the calibration reflectance panels that can be purchased with the unit can degrade with field use, something we experienced during the 2016 season. There is little long-term information available about how these targets will perform under field conditions over the long term. With that caveat, they remain a good 'budget' option, though they are perhaps best suited for commercial work. Spectralon targets are a tested industry standard and will be more durable to the elements, but are much more expensive. These can be bought through the manufacturer Labsphere in the US or retailers world-wide.

Pre-/post-flight calibration images should be taken so that a large number of pixels are covered by the target and so that the target ID is clearly visible in the image. Ensure that the target is level on the ground and free of shadows. If your calibration photo captures many pixels of the calibration panel, a larger statistical sample can be used by the photogrammetry software to calibrate the orthomosaic reflectance maps. In this instance, a larger sample is a better sample.

As a rule of thumb with the Parrot Sequoia sensor: Hold the drone just below hip height over the target with your back to the sun, take a step aside while holding the drone in positon to avoid casting a shadow over the target.

Ensure that the target in the calibration imagery is not overexposed (i.e. saturated in the upper end of the digital numbers), as radiometric calibration will otherwise not be possible. If you are using a Sequoia Sensor, use the ‘Radiometric Calibration’ feature of the WiFi interface to obtain a bracket of calibration imagery with different exposure levels. Placing the calibration target on a high reflectance surface (such as a landing pad) may also help reduce the chance of incorrect exposures.

Finally, if you’re using a filter or lens protector during the flight, ensure that calibration imagery is taken with the filter/protector in place. Likewise, remove any filters/protectors before taking the calibration imagery if they are not used in flight.

In-flight reflectance targets

In-flight reflectance targets serve two purposes: a) as surfaces with known/calibrated reflectance they allow for quality control in the outputs of photogrammetry software (such as the reflectance and NDVI maps produced by Pix4D), and b) they are a back-up if for some reason the pre-/post-flight calibration imagery fails (e.g. deterioration of standard over time, overexposure of imagery and unintended shadows covering the target).

In-flight targets should have even reflectance values within the bands of your sensor and match roughly the reflectance of the surface of interest. For vegetation surveys we recommend 40-60% reflectance. Additional targets of higher and lower reflectance may be employed to cover a larger range of reflectance values, but this might not be practical in all situations.

In-flight targets should be at minimum 5 x 5 the Ground Sampling Distance (GSD) (25 Pixels), but 10 x 10 GSD (100 Pixels) is desirable, if not more. Again, the larger the statistical sample of pixels the better the quality control. For reasons of practicality (transport and weight) large target sizes for high altitude flights might not be achievable.

The material of the in-flight target should be as durable and Lambertian (even reflectance independent on angle of view) properties as possible. Spectralon would be ideal, but is likely not a cost-effective as an in-flight target. In our experience, it is more difficult to keep in-flight targets away from environmental influences such as water splashes, dirt and dust. Instead of Spectralon we therefore suggest selecting from the following options. They are ordered by most desireable reflectance properties, but we realize you will need to make your decision based on intended uses, budget, and time for preparation and availability.

- Calibrated felt targets produced by the finish company MosaicMill , 44% reflectance for vegetation surveys; standard size 50 cm x 50 cm, approx. 350€ per piece, custom sizes also available.
- Grey-cards made out of ‘Kodak card’ cardboard type material, obtainable from photography suppliers. Often only available in smaller sizes around paper A4 or letter format, unsuitable for large GSD. Tend to come in approx. 18% reflectance (grey) and 80% (white). Warning: Spectral properties may vary strongly across the spectrum - test in lab before use!
- Sail-cloth and canvas sheets may be alternatives, particularly for large GSD of known even spectral reflectance. Ensure the material is 100% opaque and test reflectance and lambertian properties in lab!

For uncalibrated targets, we highly recommend measuring reflectance properties before going out into the field the first time. However, in the end a bad in-flight target is better than no target. Also see ‘Care and Quality Control’ Section below.

Finally, we suggest that at least two in-flight targets should be employed; one at either extreme of the flight paths. For larger sites (> 1 ha) more target might be desirable, but only if practically feasible. Position the targets so that the aircraft passes directly over it.

Care and Quality Control of Reflectance Standards and Targets

Handle reflectance standards and in-flight targets with as much care as possible! Avoid touching the surface, exposure to rain, dirt and water splashes particularly of the Spectralon pre-/post flight calibration targets). Prolonged exposure to sun may also have a negative impact on the surface. Return the targets to a protective container as soon as possible after use.

All targets should be calibrated before and after each field season, then cleaned according to manufacturer's recommendations and re-measured ahead of the next field season. We suggest determining the absolute reflectance of the targets using a spectroradiometer in a dark room. In the past, we carried out five contact measurements per target, one in the centre and four towards each corner (but not in the very corner), average reflectance values can then be calculated for the target and band averages determined.

Ground Control Points

In addition to following the general ground control point (GCP) recommendations of the HiLDEN a few particular considerations apply to GCPs used with multispectral sensors. GSDs for the multispectral sensors are large compared to high resolution RGB sensors and the monochromatic nature of single band imagery can therefore make identifying GCPs difficult.

We recommend the use of large GCPs (8 x 8 to 10 x 10 GSD, absolute minimum 5 x 5 GSD) with a checkboard pattern, in our experience these work best (Figure 1). The checkboard pattern works well, as the squares show up as clearly defined surfaces in the monochromatic imagery. Before heading out into the field with new GCPs, ensure that they show up well in all bands. Not all whites are white and not all blacks are black in the near-infrared (NIR). Furthermore, make sure that surface reflectance properties do not vary strongly with orientation to the sun and solar angle. A good way of testing the suitability of new GCPs is taking images with the multispectral sensor on the ground and then conducting tests flights. We have made life difficult for ourselves by not testing GCPs in the past, assuming that surfaces that show up well in the visible spectrum would

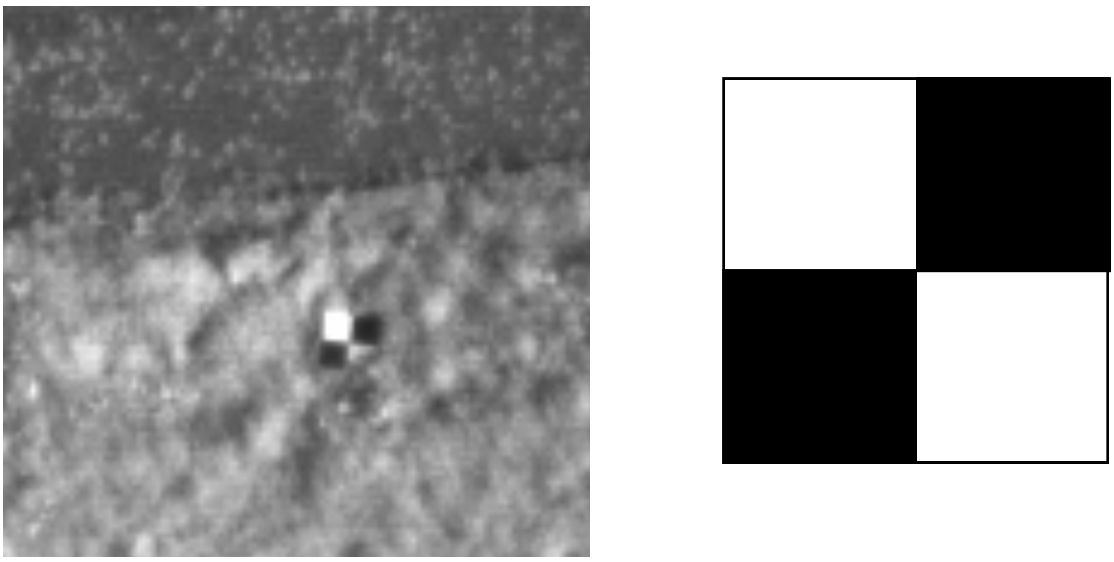

Figure 1 Sequoia NIR image of 60 cm x 60 cm GCP on grass. The GCP is made from self-adhesive tiles obtained in a local hardware store. Ground sampling distance: approx. 7.4 cm/pixel. Image curtsey to Tom Wade and Charlie Moriarty, The University of Edinburgh.

show up well in the NIR as well.

Flight Pattern

Flight plan and pattern will vary depending on the site. However, if a lawn mower flight pattern of parallel flight lines is used we recommend introducing some flight lines diagonally or across the pattern. See Figure 2 for a suggested flight plan. This will likely improve the outputs of the photogrammetry process, particularly if vegetation surfaces are mapped that are not very varied in their nature. We will send out a more detailed post on flight planning early next week.

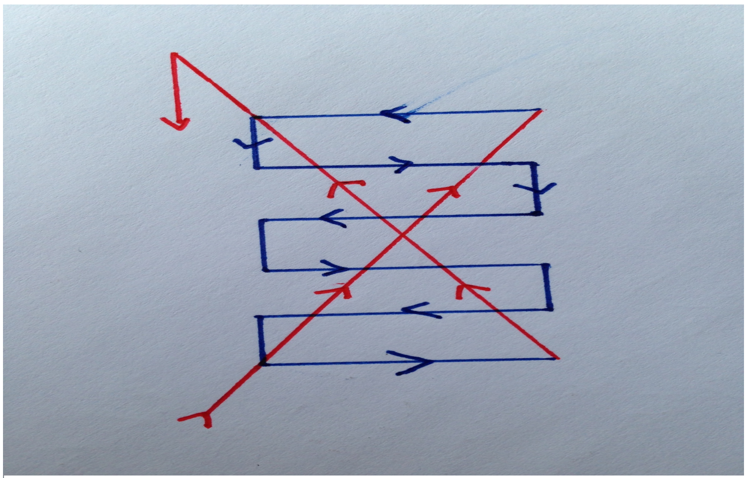

Figure 2 Lawn-mover flight patter (blue) with diagonal flight lines after take-off and before landing.

Weather Conditions and MetaData

In addition to usual flight data, it is worthwhile to log weather conditions, as well as the standards and targets used. For weather, wind and sky conditions are particularly useful for multispectral data collection, as they influence surface behaviour and solar irradiation. For sky conditions we suggest a scale from 0-9 (Table 1).

In addition temperature and information about vegetation surface wetness/dew should be recorded.

Please also see HILDEN multispectral flight log spread-sheet attached (may be filled in on paper or digital on a tablet).

Table 1 Sky Codes - adapted from NERC Field spectroscopy Facility's Log Sheets

0	Clear sky
1	Haze
2	Thin cirrus – sun not obscured
3	Thin cirrus – sun obscured
4	Scattered cumulus – sun not obscured
5	Cumulus over most of sky – sun not obscured
6	Cumulus – sun obscured
7	Complete cumulus cover
8	Stratus – sun obscured
9	Drizzle