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SURVEYING A GLACIAL DISPERSAL TRAIN WITH AN UNMANNED AERIAL VEHICLE (UAV): A CASE STUDY AT THE ALLAN LAKE CARBONATITE

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Introduction

Research related to the use of small Unmanned Aerial Vehicles (sUAV) for geoscientific applications has grown in recent years. Their capacity to quickly survey an area, unobstructed, and with a high level of detail is promising and their use for the production of small-scale ortho-imagery and digital elevation models has been well documented (Canadian Council on Geomatics, 2016, for a review). Applications with specialized sensors are less common and case studies are needed to quantify the operational space they could occupy and to identify their limitations. For example, gamma-ray spectrometry (Figure 1) can provide chemical information about surface materials that would be distinctive but complementary to visible spectrum imagery. Gamma ray spectrometers are however heavier than optical sensors and pose more constraints for integration in a sUAV.

A small gamma-ray detector system suitable for sUAVs was designed by Natural Resources Canada (Sinclair et al, 2016) (Figure 3). Its application to surficial mapping was trialled at a known glacial dispersal train south of the Allan Lake carbonatite in Algonquin Park (Figure 2). Glacial erosion produced a 5 km long dispersal train of distinctive till covering 10 km², characterized by an anomalous concentration of Thorium. Preliminary results obtained with the gamma-ray spectrometer are briefly presented but the emphasis in this presentation is on an assessment of sUAVs operational conditions and limitations in this type of applications.

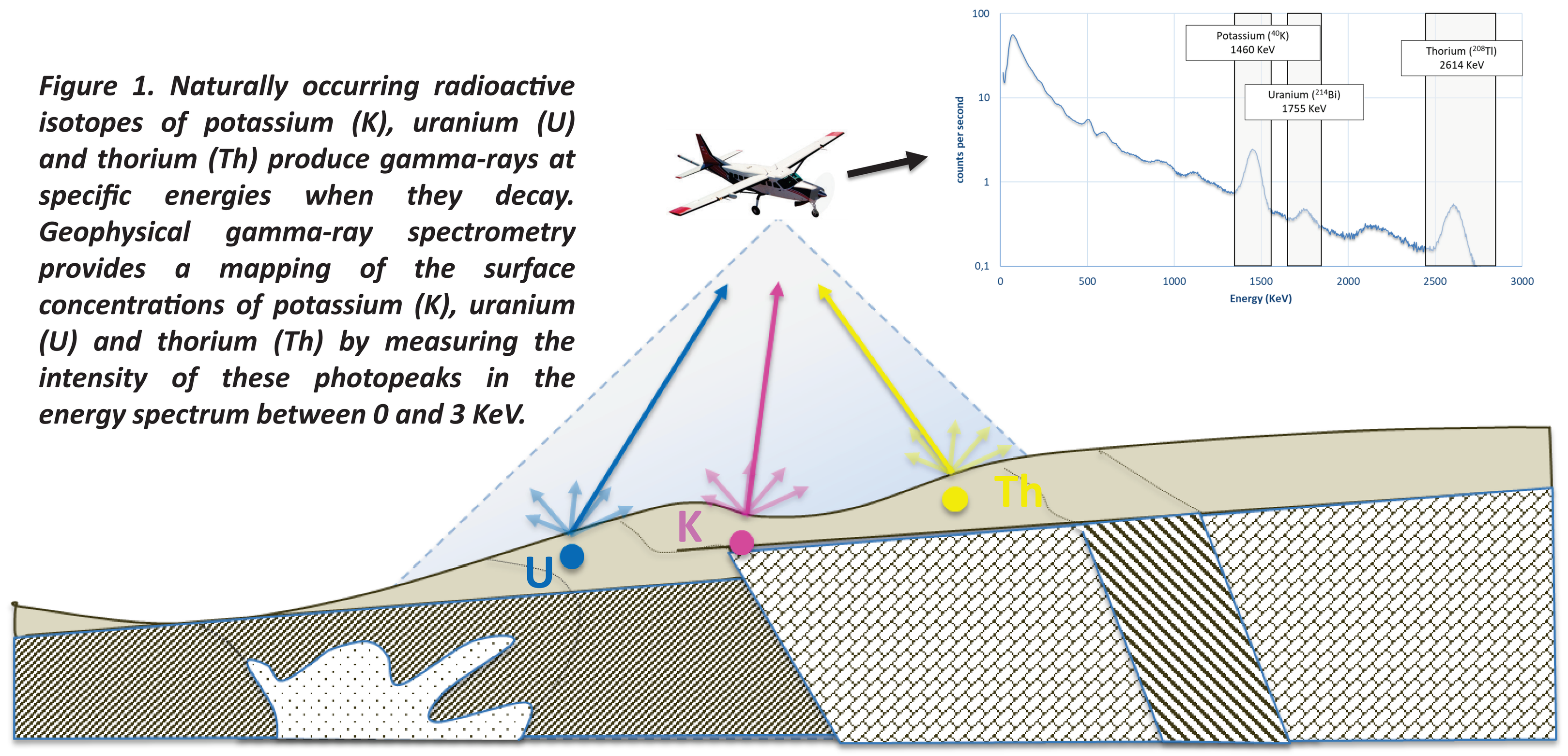

Figure 1. Naturally occurring radioactive isotopes of potassium (K), uranium (U) and thorium (Th) produce gamma-rays at specific energies when they decay. Geophysical gamma-ray spectrometry provides a mapping of the surface concentrations of potassium (K), uranium (U) and thorium (Th) by measuring the intensity of these photopeaks in the energy spectrum between 0 and 3 KeV.

Field Deployment Planning

sUAVs are defined by Transport Canada as UAVs weighing less than 25 kg. For this class of UAVs (as of 2017, in Canada), regulations exists to fly UAVs under 'exemptions' without the need to apply for a Special Flight Operations Certificate (SFOC) if a series of conditions are met (Transport Canada, 2016). For this case study, a rotary-wing UAV, the Responder (Figure 3), manufactured by ING Robotics Aviation in Ottawa, was used.

Under current regulations, the UAV must 1) be maintained in visual line-of-sight (VLOS) by the pilot-in-command, 2) in a constant command-and-control (C&C) radio link from the ground control station (GCS) and 3) within 0.5 nautical miles (926m) from the GCS.

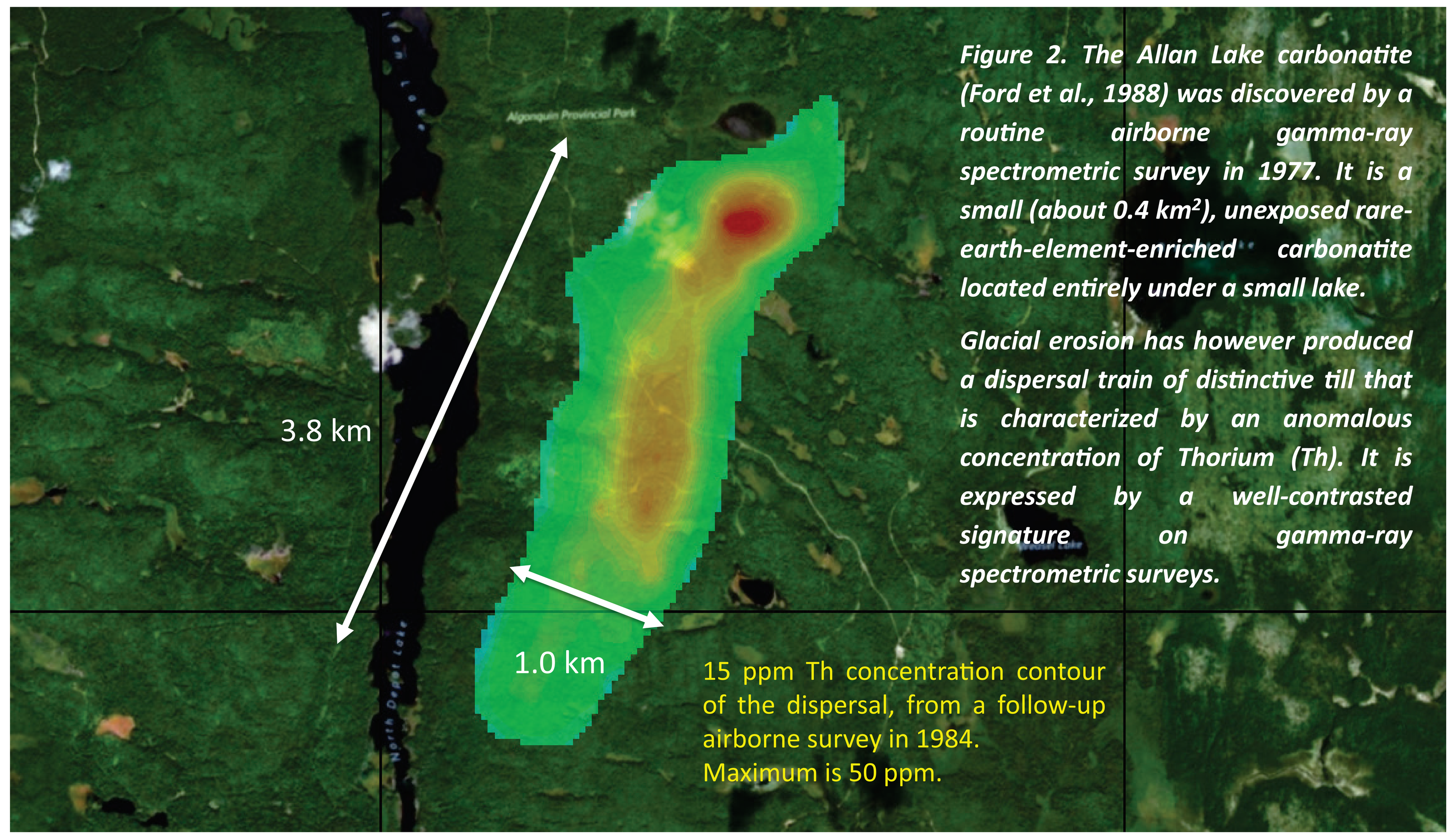

Figure 2. The Allan Lake carbonatite (Ford et al., 1988) was discovered by a routine airborne gamma-ray spectrometric survey in 1977. It is a small (about 0.4 km²), unexposed rare-earth-element-enriched carbonatite located entirely under a small lake.

Glacial erosion has however produced a dispersal train of distinctive till that is characterized by an anomalous concentration of Thorium (Th). It is expressed by a well-contrasted signature on gamma-ray spectrometric surveys.

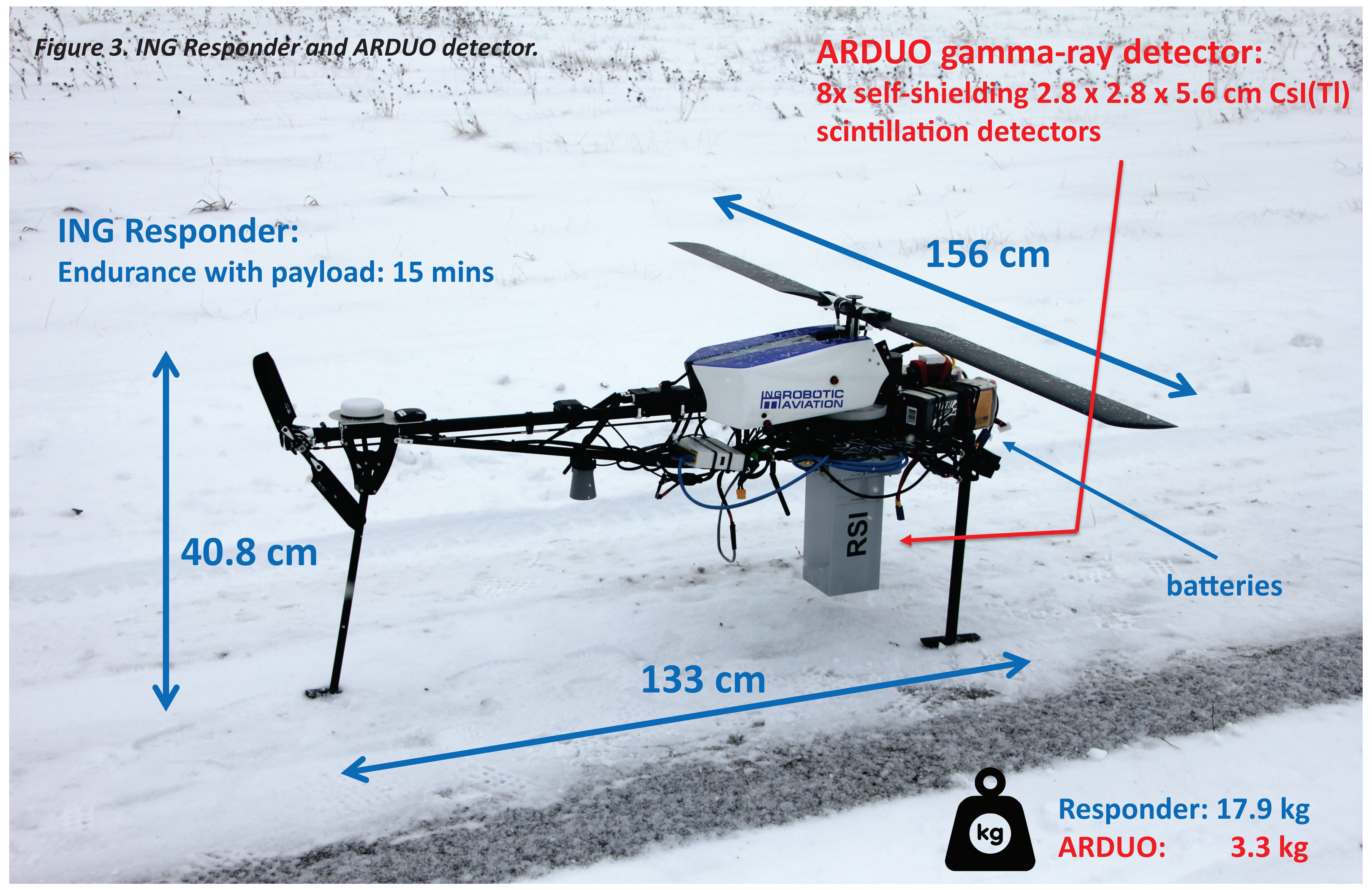

Figure 3. ING Responder and ARDUO detector.

The spatial extent and radiation signature of the Allan Lake dispersal train appeared to correspond well to the flight performance and radiation mapping capability of NRCan's radiation detection UAV. This location also provided several logistical advantages. The various logging trails and roads in the area can give direct access to and off the dispersal train, and many clearings are well located to install the UAV's Ground Control Station (GCS). The site was visited on two occasions, in October 2016 and in July 2017, prior to the UAV mobilization to assess the feasibility of deploying the UAV. Trail accesses with a 4x4 vehicle was verified and clearings seen on satellite imagery were visited to confirm their suitability for flight operations. An open, flat and large enough space (30m x 30m) with minimal vegetation was required for mobilization of the GCS and safe take-off and landing of the UAV. Ground gamma ray spectrometry measurements were also collected to evaluate the strength of the signal to be seen by the UAV detector. Due to the fairly tall canopy that was observed on site, it was decided to plan the UAV deployment for late fall, to minimize the visual obstruction caused by the deciduous trees foliage.

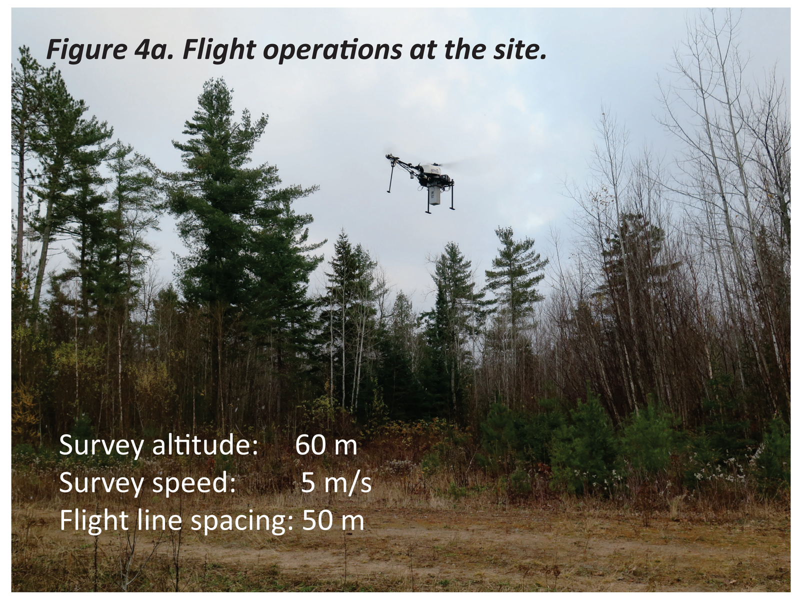

Figure 4a. Flight operations at the site.

Figure 4b. Location of the Ground Control Station (GCS) at one of the take-off site.

Field Operations

UAV field operations took place on November 6th-9th, 2017 (Figure 4a and 4b). Flight plans covering the dispersal, from its center axis to its transverse edge were prepared. However, test flights showed that 1) visual line of sight with the UAV couldn't be maintained through the forest canopy even with the limited foliage, and that 2), also because of the canopy, the GCS experienced intermittent loss of radio communication with the UAV, while it was flying. Flight plans were reduced to a maximum extent of about 300m to ensure that flight operations were compliant with Transport Canada's exemption conditions. Two survey flights could then be completed.

During the October 2016 and July 2017 field visits, an extensive set of measurements to characterize the dispersal were collected to support the upcoming UAV case study but also to further knowledge about this dispersal. It included over 50 in-situ gamma-ray spectrometry measurements at various location along the dispersal and in background areas. A backpack portable gamma-ray spectrometer providing continuous measurements of the gamma-ray signal was also used to connect the in-situ points, and to provide a cross profile of the dispersal. Furthermore, 14 till samples were collected for laboratory gamma-ray spectrometry analysis, from which a subset of four samples was analyzed for geochemistry and indicator minerals. These results will be presented at a latter time, with a more in depth analysis of the UAV survey results.

Results

UAV gamma-ray measurements were processed in accordance with standard guidelines (IAEA, 1991), and were corrected for background and variations in altitude above the ground. Corrected thorium surface concentration data was then gridded to present spatial variations (Figure 5) . At a survey altitude of 60m above the ground, the ARDUO detector was at the limit of its sensitivity. It resulted in a very low corrected count rate, about 2 counts per seconds, on average. Despite the weak signal-to-noise ratio, a difference in the overall magnitude of Thorium concentrations can be seen between the two flights, with FLT3, close to the central axis of the dispersal, exhibiting a higher Th concentrations than FLT4, on the outside margin.

FLT3 presents a local maximum in Th concentration that extends within the middle of the survey grid from its southern limit. It may suggest a refined location for the central maximum of the dispersal, as compared with the legacy airborne survey. But the significant statistical fluctuations do not allow to conclude unequivocally. Lower survey speed or tighter survey line spacing could increase the signal to noise ratio and contribute in a better resolution of this feature.

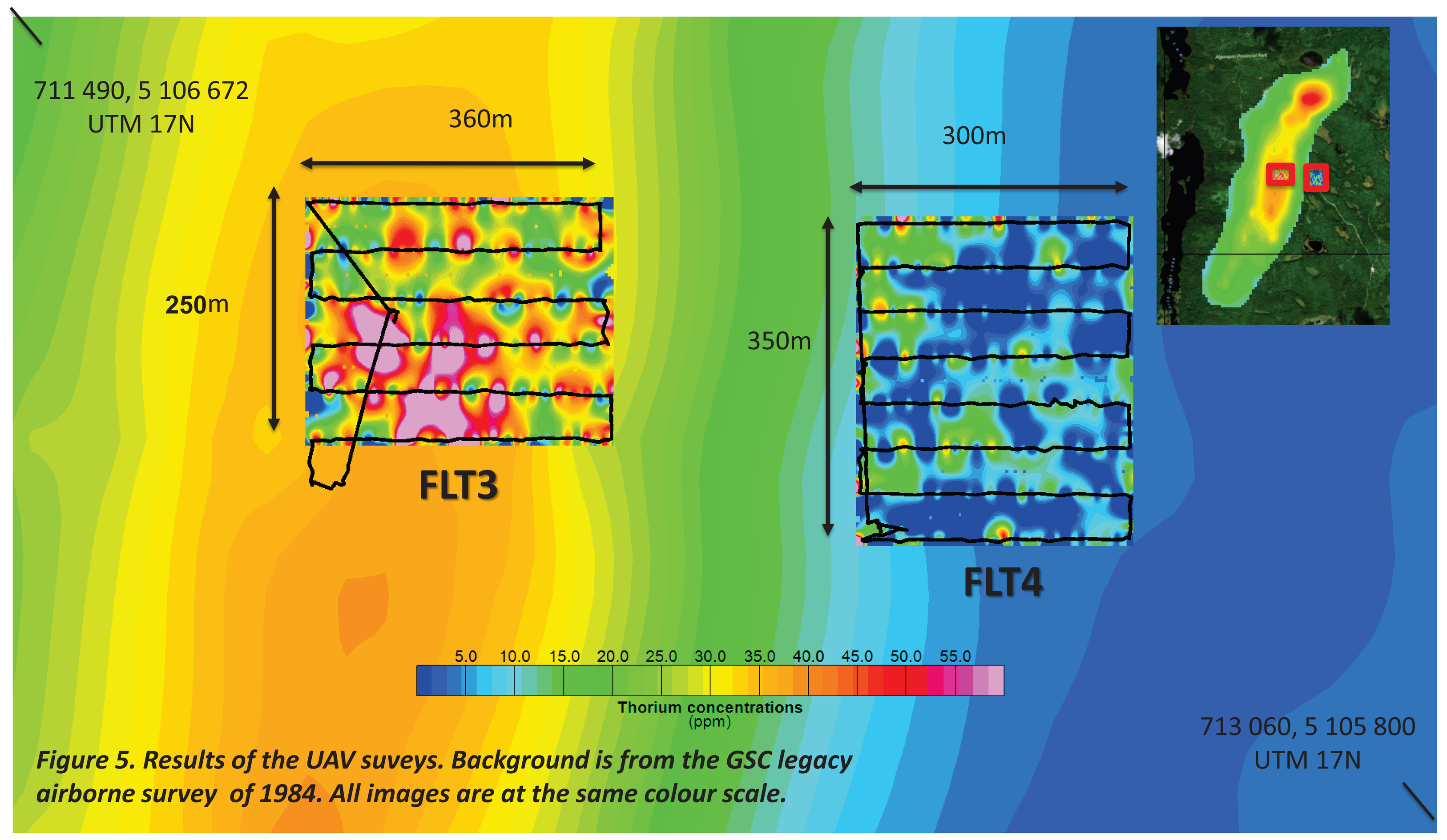

Figure 5. Results of the UAV suveys. Background is from the GSC legacy airborne survey of 1984. All images are at the same colour scale.

Conclusions

In terms of size and weight, the Responder UAV system is at the higher end of the sUAV class and its operation differ significantly from that of small 'prosumer' quadcopters. A series of observations were made during these field trials in relation to operational limitations and benefits of these larger sUAVs:

- Larger sUAVs cannot be carried by field personnel over long distances but must be brought to the survey site by a motorized vehicle. This implies that trails passable with a 4x4 or ATV vehicle are usable and can provide an access to the site.
- Their higher payload capacity can accommodate heavier sensors or accept more than one. For example, they could collect optical imagery at the same time as spectrometry data.
- Their increased size make it easier to visually track the vehicle while it is flying, helping to maintain VLOS.
- The specific UAV type used here (single-rotor) operated very well in somewhat adverse weather conditions with gusting wind and snow precipitations on occasions during the field operations.

More general observations were also made in relation to operations of sUAV:

- In a forested environment, flight plans must be limited to extents of about 300m in order to maintain VLOS and a continuous command-and-control (C&C) radio link with the UAV.
- Frequent re-positioning of the GCS is thereafter necessary to achieve good coverage of a geological target. In turn, this will have a cost in time during field operations.
- An aerial platform or a boom lift could be used to bring the GCS and the UAV operator above the top of the canopy to improve visual tracking of the vehicle. But this will also increase mobilization time, efforts and cost.
- Increasing the endurance of the sUAV may result in limited benefits in terms of range because of the constraints on survey extents due to VLOS and C&C link requirements.

As demonstrated here, and under the conditions of these trials, UAV surveys could ensure a continuous coverage of a target that would have not been achievable by a ground based survey. Moreover, this coverage is unbiased and does not depend on the ease of accessing some measurement sites as opposed to others.

Notes:

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