Repeated aeromagnetic survey of Noboribetsu volcano

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We have been developing a novel airborne survey technology by using an unmanned helicopter owned by the Hokkaido Regional Development Bureau under the framework of an industry-government-academy project. As a part of this project, we performed the third aeromagnetic survey at Noboribetsu volcano in 2019, following the past campaigns in 2016 and 2017. The unmanned helicopter was quite advantageous from the viewpoint of detecting temporal changes, since the UAV, being aided by GPS navigation, can autonomously repeat flying a designated path with a high accuracy. Magnetic field changes associated with volcanic activity have been frequently reported in previous studies. A recent research has summarized that many of such changes occur even in inter-eruptive periods with a timescale of several months to years (Hashimoto et al., 2019). At Noboribetsu volcano, we first detected a localized but seemingly significant magnetic field changes in our successive surveys.

In the course of the data processing, we, at first, removed the geomagnetic disturbance of extra-terrestrial origins by taking a simple difference between the field data of each airborne survey and the ground reference station. Then, we obtained the temporal changes between 2016-2017 and 2017-2019 by taking the field difference at the selected pairs of measurement points within 5 meters from the relevant two campaigns. Actually, maximum displacement between the closest pair was considered to be roughly 10 m, since the magnetic sensor was towed on a 4.5 m cable to avoid the magnetic noise from the helicopter body, while the positioning data was obtained by the GPS receiver on the airframe. On the other hand, the magnetic field gradient in the air was fairly small at generally less than 1 nT/m. Therefore, we considered an error range for the temporal changes in our magnetic survey was +/-10 nT.

In contrast to the comparison between 2016 and 2017 surveys, where no significant temporal change was found, we detected a remarkable dipolar pattern (A in Fig.1) around the peak of Mt. Hiyoriyama in the middle of the difference map between 2017 and 2019. In addition, a broad depression (B in Fig.1) was found in the southwestern part of Jigokudani geothermal field. The origin of the latter, corresponding to the steep escarpment at the southern edge of the geothermal field, was questionable, since it was monopolar and also corresponded to the strong negative anomaly in the original field map of 2017. Meanwhile, the former showed a clear dipolar pattern suggesting re-magnetization, although its peak-to-peak amplitude was close to the confidence limit. We applied the 3D inversion of Utsugi (2019) to the 2017 magnetic anomaly to obtain a subsurface magnetization structure. As the result, magnetization was imaged to be relatively low in the shallow part beneath the area from Mt. Hiyoriyama to Lake Oyunuma, implying a high temperature and/or hydrothermal alteration. Furthermore, the 3D inversion for the differential map between 2017 and 2019 suggested a very localized re-magnetization just beneath Mt. Hiyoriyama, where some weak fumaroles were always seen at the top. We suspected that the re-magnetization since 2017 was a signature of shallow cooling associated with a temporarily depleted background thermal activity of this area. Our study has demonstrated practical feasibility and effectiveness of the repeated aeromagnetic survey using the unmanned helicopter as a monitoring tool even under an access regulation when the Volcanic Alert Level is raised.

Keywords: aeromagnetic survey, unmanned helicopter, Noboribetsu volcano