An investigation of fault and structural boundary in the northern part of the Ibaraki Prefecture by Airborne Gravity Gradient survey

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Specifying the positions and lengths of faults existing around the Atomic Power Plants should be made based on the scientific foundations. It is very important to investigate the positions and lengths of faults existing in the borders of land and sea for assuring safety, since many of the Atomic Plants are built close to the shore.
Airborne Gravity Gradient (AGG) survey with simultaneous measurements of the laser scanner data was conducted to investigate the fault structure in the northern part of the Ibaraki Prefecture, Japan, with special reference to the existence of faults assumed to extend thorough land from sea. The survey was flown in February 2016 at an altitude of 150m above terrain along north-south survey lines and east-west tie lines, spaced 250m and 2,500m apart, respectively. A differential GPS system was employed for flight path recovery.
The observed gravity gradient data were processed and vertical and horizontal derivation gravity maps were created. The characteristics of the distribution of vertical and horizontal derivation gravity anomalies were summarized as follows: (1) A border of the between high and low vertical derivation gravity anomalies is clearly distributed in the central northern part of the study area extending toward the sea. Considering geological studies (Geological survey of Japan, 1957; JAPC, 2015), the distribution of this border of the between high and low vertical derivation gravity anomalies is consistent with that of the Komagi fault and F12 fault with dipping to the southeast direction. There is anomaly found continuously from land through sea, it is suggested that Komagi fault and F12 fault are the series of faults. (2) A steep negative vertical derivation gravity anomaly, which is intercalated by positive vertical derivation gravity anomalies, is situated in the central part of the study area from land through sea. Comparing with the geological maps (Kubo et al., 2007; Yoshioka et al., 2001), this negative vertical derivation gravity anomaly may be implied the existence of fault and structural boundary, which is located at the border of the Hitachi metamorphic rock and the Abukuma metamorphic rock.
In this AGG survey, we succeeded to find the fault and the structural boundary in the borders of land and sea lying continuously, which has been previously considered to exist separately in land and sea.

Keywords: Airbornrne Gravity Gradient survey, gravity gradient, fault, structural boundary, coastal region

Fault dip estimation based on gravity gradient tensor on a profile

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It is widely accepted that the area of a disaster occurrence is generally wider on the hanging wall side than on the foot wall side of a fault and that the fault dip affects the size of the disaster area. Therefore, fault dip is an important fault parameter and has played an important role in numerical simulations for the development of hazard maps. To determine or estimate the fault dip, morphological, geological, and geophysical surveys such as excavation, seismic reflection survey, gravity survey, and other research means have been employed worldwide and have yielded extensive knowledge on fault dip and shapes.

In recent years, gravity gradiometry surveys have been widely conducted to obtain detailed subsurface structure data. This type of survey collects the gravity gradient tensor defined by the second derivatives of the gravity potential. Compared with the gravity anomaly, its response to subsurface structures is more sensitive. Various analysis techniques using gravity gradient tensors such as inversion and the semi-automatic interpretation method have been employed and discussed. Among these methodologies, a technique for estimating the fault dip by using the gradient tensor has been developed. Although the technique has yielded excellent results, gravity gradiometry surveys have been conducted in only a few areas in Japan. Hence, analyses conducted in areas in which gravity gradiometry surveys have not been conducted require use of the tensor estimated from existing gravity anomaly data.

In this study, techniques for estimating the gravity gradient tensor from gravity anomalies are shown for a profile that is frequently employed in active fault research. Moreover, these methods are employed for estimating the fault dip by using eigenvectors of the observed or calculated gravity gradient tensor on the profile. As a result, the dip of the maximum eigenvector is shown to closely follow that of a normal fault, and the dip of the minimum eigenvector closely follows the dip of the reverse fault. As an application to field data, the dip of the Kurehayama Fault located in Toyama, Japan, was estimated. A fault dip of about 42° was obtained as the dip of the minimum eigenvector of the gravity gradient tensor because the fault is a reverse fault. This dip is in agreement with conventional geological information. Although the calculated gravity gradient tensor was employed here for estimating the fault dip, the technique shown in this study is applicable to the observed data for each profile directly obtained through gravity gradiometry surveys by helicopter.

Keywords: Fault dip, eigenvector, gravity gradient tensor

Development of a three dimensional information extraction method from an airborne sensor (ARTS-SE) multiple-view images

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To increase the opportunity for the airborne observations, we have developed our 2.5nd-generation airborne imaging system, the Airborne Radiative Transfer Spectral Scanner for a single-engine aircraft (ARTS-SE) for volcano observations in June of 2015. The platform for ARTS-SE is a widely used single-engine Cessna 208 aircraft. ARTS-SE consists of a modified system of our former push-broom imaging spectrometer (ARTS) and a newly developed camera system; Structure and Thermal Information Capture (STIC). This system consists of four cameras. These cameras are the two visible cameras and the two thermal infrared cameras. The STIC specifications were planned to provide images data set for Structure from Motion (SfM) technique for operational volcanic observations to assess volcanic activity. We present first results of data analyses for visible and infrared image from STIC image (Hakoneyama (Owakudani) acquired on 5 December 2015) using commercial photogrammetric image processing software packages. We demonstrate how STIC images can be used to detect a three dimensional information of volcanic geothermal field.

Keywords: airborne sensor, SfM, volcano, infrared remote sensing

Basic study for application of inverse radiation problem to airborne radiation measurement

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Since accident of the Fukushima Daiichi Nuclear Power Station (FDNPS), some unmanned vehicle was applied for radiation measurement around the FDNPS. Japan Atomic Energy Agency (JAEA) is developing a radiation measurement method using a small multi-rotor helicopter (micro UAV) for measurement of radiation in the environment. The micro UAV is expected to be useful due to measuring the radiation distribution at small areas (such as personal residence area) easily. In the conventional method, there are some premises to convert from count rate to dose rate at 1 m above the ground (agl.). 1) The dose rate at 1 m agl. is constant, 2) topography is a plane (plane source model) and 3) relationship of altitude and count rate are exponential correlation. Therefore, it is difficult that dose rate by airborne radiation measurement is precisely measured at the mountains and uneven place of dose rate by the conventional method. In addition, the influence of the radiation from a structure and tree on the ground is not ignored at the low altitude less than 50 m that micro UAV can fly stably. In this study, the successive approximation method which is used in the medical radiation such as Positron Emission Tomography (PET) is attempted to apply to environmental radiation measurement.
Our micro UAV was based on the commercial drone system produced by 3D Robotix Co., Ltd. (Calofornia, USA). The radiation detector was selected the GAGG scintillation detector (2cm ×2cm ×2cm) which is manufactured by Furukawa Co., Ltd. (Tokyo, Japan). The gamma-ray spectrum data was collected every three seconds with the position data by Groval Positioning System (GPS). A DSM (Digital surface model) data was acquired from photographs by the microUAV. For comparison, a radiation distribution on the ground was obtained using a survey meter with GPS (NESI Co., Ltd. Ibaraki, Japan).
The algorithm of the successive approximation method was assumed the measured value at the detector is expressed as the sum of the product of attenuation coefficient and ground point. The measured value(Yi) at the detector(i) is expressed by equation [1].
$Yi = \Sigma[j=1 \rightarrow B] \ \lambda j \ Cij$ [1]
where B is number of ground calculation point, Cij is attenuation coefficient and λj is calculation value at ground point(j) respectively. The attenuation coefficient (Cij) applied the air attenuation coefficient and the angle correction factor of the detector. Distance and angle attenuation coefficient were used of total energy photons count to the distance of Cs-137(662keV) point source was calculated by montecalro simulation (PHITS: Particle and Heavy Ion Transport code System by JAEA).
The airborne monitoring by micro UAV conducted in two areas (approximately 1 km^2) at Fukushima prefecture. A flat area and a forest area were selected. The count rate data is obtained by flying 10m or 50m agl. and 10m line spacing. These data was applied by the algorithm of the successive approximation method. These results was compared by conversion results of conventional method at same place. NMSE (Normalised Mean Square Error) which is compared with the airborne data and the ground data was defined for evaluation of accuracy of the algorithm of the successive approximation method.
In flat area, NMSE of the conventional method is 0.105 and NMSE of the successive approximation method is 0.034. Successive approximation method was close to the ground value compared with the conventional method. On the other hands, NMSE of the conventional method is 0.302 and NMSE of the successive approximation method is 0.214 in the forest area. The difference of attenuation factor by radiation energy and radiation attenuation of tree is not taken into account in the current algorithm. This method can expected detailed map by doing optimizing the algorithm and accumulate measurement

results in many areas.

Keywords: Drone, micro UAV, Remote radiation measurement, Terrain correction, Successive approximation method, Fukushima Daiichi Nuclear Power Plant Accident

Improvement of analysis accuracy of radiation monitoring using unmanned helicopter

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After the Fukushima Daiichi Nuclear Power Plant accident occurred in 2011, the air dose rate was measured using an unmanned helicopter in the high radiation area around the power station. Measurement was carried out by measuring the counting rate of gamma rays with using an LaBr3 detector at an ground altitude of 100 m and a line interval of 80 m. Measured data was analyzed and converted into air dose rate at 1 m above the ground.
Since the counting rate of gamma rays decreases exponentially with altitude and proportional to 1 m height air dose rate, calibration measurement was performed to obtain altitude correction coefficient (air attenuation coefficient) and the conversion coefficient in the flat area where the change in the air dose rate was small,.
We analyzed the LaBr3 system by the gross count method after applying dead time correction of the detector. Furthermore, after subtracting the dose rate derived from the natural radionuclide, data with the different measurement date was corrected to the reference date (generally end date of measurement) using the attenuation correction formula. The analysis result was mapped by Kriging method using ArcGIS. To confirm the validity of the measurement, ground measurement was carried out by a survey meter, and a comparison was made between the air dose rate obtained from an unmanned helicopter and the measured value on the ground.
Examination result shows the change in the count rate due to the season change and the divergence on ground measurement value according to the measuring point was observed. At the beginning of the accident, the air dose rate due to contamination was high and the physical decay rate of the radioactive material was not known but there was attenuation due to weathering and decontamination and counting rate should be calculated accurately in low dose area. For this reason, we considered analysis that take account of improved analysis parameters and consider effect from radiation source influenced by topography and flight altitude.
As a result of the examination, analysis parameter was improved by analyzing the air attenuation coefficient as a function of air density and using "mass attenuation coefficient" obtained by dividing the air attenuation coefficient by the air density as a constant. We conducted inverse analysis to improve the influence from radiation source by topography and flight altitude and confirmed that it can be analyzed with higher resolution.

Keywords: gamma-ray spectrometry, Unmanned Helicopter, Mass attenuation coefficient, 3D inversion

High-resolution Aeromagnetic Survey over the Eastern Sagami Bay Area, Kanto Region, Japan

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The Geological Survey of Japan (GSJ), AIST has been conducting various geophysical surveys such as seismic reflection, ocean floor gravity and aeromagnetic surveys in the transition zones of the Japanese Islands to better understand the subsurface structures related to active faults and geologic basement structures for some model areas.
A high-resolution aeromagnetic survey was conducted over the eastern Sagami Bay Area, Kanto Region, Japan in November 2016. The survey was flown along E-W traverse lines and N-S tie lines spaced 250 m and 1,000 m, respectively. The flight altitudes were 150 m above sea level over offshore areas and 300 m above terrain over onshore areas, respectively. Total magnetic intensities were observed by a Cesium magnetometer at 10 Hz and flight paths were recovered by DGPS. A preliminary aeromagnetic map without height correction has been compiled. According to the map, characteristics of magnetic anomalies are summarized as follows:
(1) An ESE-WNW trending magnetic high belt, parallel to a gravity high belt (Okuma et al., 2016) extends from the northern part of the Miura Peninsula to Enoshima Island, corresponding to the Hayama Upheaval Belt.
(2) A NW-SE magnetic trend extends from the south of Enoshima Island to the Takeyama Faults in the Miura Peninsula.
(3) In the middle of the Miura Peninsula, a magnetic high is distributed over the area where ultrabasic rocks like serpentinites outcrop.
(4) In the Miura Peninsula, another magnetic high lies over the distribution area of the Early ? Middle Miocene Yabe Formation, Hayama Group in which small outcrops of basaltic rocks reside at its northern boundary. This magnetic high further extends southeastward along the Kinugasa Faults.
(5) Two dipoles of magnetic anomalies with a reverse polarity are distributed over the Kamegi Spur offshore of the western Miura Peninsula.

Keywords: aeromagnetic survey, magnetic map, Hayama Formation, Hayama Upheaval Belt, Miura Peninsula, Sagami Bay

Three-dimensional resistivity modeling of GREATEM survey data from Ontake Volcano, northwest Japan

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Ontake Volcano is located in central Japan, 200 km northwest of Tokyo and erupted on September 27, 2014. To study the structure of Ontake Volcano and discuss the process of its phreatic eruption, which can help in future eruptions mitigation, airborne electromagnetic (AEM) surveys using the grounded electrical-source airborne transient electromagnetic (GREATEM) system were conducted over Ontake Volcano. Field measurements and data analysis were done by OYO Company under the Sabo project managed by the Ministry of Land, Infrastructure, Transport and Tourism.
Processed data and 1D resistivity models were provided by this project. We performed numerical forward modeling to generate a three-dimensional (3D) resistivity structure model that fits the GREATEM data where a composite of 1D resistivity models was used as the starting model. A 3D electromagnetic forward-modeling scheme based on a staggered-grid finite-difference method was modified and used to calculate the response of the 3D resistivity model along each survey line. We verified the model by examining the fit of magnetic-transient responses between the field data and 3D forward-model computed data. The preferred 3D resistivity models show that a moderately resistive structure (30–200 m) is characteristic of most of the volcano, and were able to delineate a hydrothermal zone within the volcanic edifice. This hydrothermal zone may be caused by a previous large sector collapse.

Keywords: Airborne EM, 3D resistivity modeling, GREATEM survey, Volcanic surveys

Geomagnetic change detected by repeated aeromagnetic survey in Miyakejima, Japan

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Miyakejima is a volcanic island on the Izu-Bonin arc and the last eruption occurred in 2000 with the summit subsidence. A huge amount of gas emission as about ten thousand tons per day has continued for a few years after the eruption and is decreasing gradually. Now amount of gas emission is as small as about a couple of hundreds tons per day. Although the previous volcanic activity seems ceasing, there are LP events, volcanic tremors and a large amount of gas emission sometime in these days. Recent activity seems to gradually increase again and we need to prepare the next coming eruptive events.

We've carried out the aeromagnetic survey by using an UAV in the end of May 2014 and Nov. 2016 to detect the temporal changes of geomagnetic field. It took flights in the area inside "Hachimaki-rindo" except the crater, in which elevation is 300 m above the sea level and over. The flight height is almost kept as about 100 m above the ground and the measurement line interval is also about 100 m. Total distance of flight is about 130 km. By comparing the measurements of two surveys, they are very consistent as a whole but have some difference/changes.

The most significant change shows a characteristic pattern of which is positive in south and negative in north. It simply indicates that the magnetization occurs in volcanoes. Another explanation may be piezomagnetic effect due to increase of the pressure under the ground. Actually it is difficult to judge which mechanism is correct, but the latter mechanism looks more likely to be, according to other evidences of increase of recent volcanic activities.

Keywords: UAV, Miyakejima, geomagnetic field

