# Estimation of depth profile of radiocesium in soil based on characteristics of gamma-ray spectra obtained by airborne radiation monitoring

*Kotaro Ochi[1], Miyuki sasaki[1], Mutsushi Ishida[2], Tomohiko Sato[3], Shoichiro Hamamoto[4], Taku Nishimura[4], Yukihisa Sanada[1]

1. Fukushima Environmental Safety Center, Sector of Fukushima Research and Development, Japan Atomic Energy Agency, 2. NESI Corporation, 3. National Livestock Breeding Center , 4. Deptartment of Biological and Environmental Engineering, Graduate School of Agricultural and Life Sciences, University of Tokyo

A large amount of radiocesium ($^{134}$Cs and $^{137}$Cs) were released into the atmosphere as a result of 2011 Fukushima Daiichi Nuclear Power Plant (FDNPP) accident. To estimate the impact of the accident to the environment, dose rate around FDNPP have been measured by Ministry of Education, Culture, Sports, Science and Technology of Japan. However six years passed since then, dose rate nearby FDNPP have been high in spite of decontamination work. The result means that it is necessary to propose of effective decontamination method as soon as possible. Information of depth profile of radiocesium in soil is important for effective decontamination method. In many cases, general measurement method of depth profile of radiocesium is troublesome due to collection and measurement of soil samples. In our previous studies, we have developed the radiation measurement techniques using unmanned aerial vehicle such as helicopter and unmanned multi rotor helicopter for rapid measurement of dose rate distribution over wide areas. In this paper, we attempt to establish the estimation method of depth profile of radiocesium in soil based on characteristics of gamma-ray spectra obtained by airborne radiation monitoring. This method expects to be useful for effective selection of area that is needed to decontaminate with high priority.
The extended farm land of National Livestock Breeding Center in Fukushima Prefecture was selected for verifying this method. This farm is located on approximately 100km south west of FDNPP in Nishigo-village. Dose rate in the farm was measured with three $LaBr_3$:Ce scintillators (3.8cmΦ×3.8cmH) using unmanned helicopter, R MAX G1 (YAMAHA Co., Ltd) at 6-10, Jun. 2016. The Spectra of $LaBr_3$:Ce scintillators showed the best resolution of the three systems, able to clearly distinguish the 605keV energy peaks of $^{134}$Cs from the 662keV energy peak of $^{137}$Cs. However, background of spectra of $LaBr_3$ were highly affected by self-contamination of the nuclides such as daughter nuclide of $^{227}$Ac and $^{138}$La in the detecter. Self-localization of the helicopter was controlled by flight programs based on differential GPS (Gloval position system). When used for monitoring, the flight altitude(altitude above grand level) of the helicopter was 20-30m and its velocity was approximately 8.0m/s. The distance from one measurement line to the other was 20-30m. The $\gamma$-ray spectra were measured per 1s continuously with position data. In addition, ratio of peak-compton (RPC) was defined by the ROI (region of interest) ratio of scattered area (50-450keV) and photo peak area (450-760keV) on $\gamma$-ray spectrum for evaluating of influence with the depth profile of radiocesium in soil. The deeper radiocesium exist in soils, the more $\gamma$-ray was scattered by soil particles compared with direct $\gamma$-ray. Thus, value of RPC changes by depth profile of the radiocesium in the soil.
Soils were sampled by liner soil sampler (0-30cm) and root auger (30-60cm) for measurement of depth profile of radiocesium. Quantitative analyses of radiocesium in the samples in the containers were conducted at the Institute for University of Tokyo using NaI(Tl) scintillators. In addition, the parameters (Depth: $D_{20\text{-}90}$) about depth profile of radiocesium were calculated for evaluating of influence with scattered $\gamma$-ray. For examples, $D_{90}$ at that the soil contains 90% of the inventory of radiocesium. It is estimated that the higher value of the parameters, the deeper radiocesium exist in soils.

 

Result of aerial monitoring indicated that relationship between RPC and $D_{90}$ has good correlation. It is suggested that feature on gamma-ray spectra of $LaBr_3$:Ce scintillators were affected by depth profile of radiocesium. Thus, it supported the hypothesis that the deeper radiocesium exist in soils, the more $\gamma$-ray was scattered by soil particles compared with direct $\gamma$-ray. Furthermore, result of quantitative analyses suggested that the depth profile of radiocesium in the farm were irregular. The irregular profiles of radiocesium in soil were result in the decontamination called reversal tillage. It was expected that the depth profile of radiocesium will show an exponential distribution with depth in many cases. However, the maximum concentration progressively moved from the surface layer to deeper ground layers when the decontamination was performed. In summary, it is hoped that this method will help in rapidly selecting of area that is needed decontamination with high priority by focusing on the feature on gamma-ray spectra.
This research was supported by grants from the Project of the NARO Bio-oriented Technology Research Advancement Institution (the special scheme project on regional developing strategy).

Keywords: Fukushima Daiichi Nuclear Power Plant accident, radiocesium, airborne radiation monitoring, depth profile, decontamination

 

# Airborne Geophysical Survey for the Evaluation of Geothermal Potential in Japan

*Takuji MORI[1], Ryosuke Murakami[1], Takuya Ishimaru[1], Masayoshi Kameyama[1], Yoshiharu Kida[1]

1. Japan Oil, Gas and Metals National Corporation

Airborne survey is one of the most effective methods which can investigate subsurface structures in areas where are difficult to access and/or exploration activities are restricted by surface conditions. Most of geothermal areas in Japan are located in mountainous regions. Furthermore, about 80% of geothermal resources are situated within areas designated as a national park, where geothermal development activities causing big impacts on environment are limited. In recent years, regulations on geothermal development in the natural parks are gradually relaxed because accelerating renewable energy is required to mitigate global warming. However, geothermal development movements by private companies are not active in those areas due to huge risk of subsurface uncertainty caused by lack of geological information. Therefore, since 2013, according to a government policy, Japan Oil, Gas and Metals National Corporation (JOGMEC) has been conducting airborne geophysical surveys to provide regional basic information for evaluation of geothermal potential, which leads to promote the geothermal development.
Airborne Gravity Gradiometry (AGG) method and time domain electromagnetic and magnetic method using a helicopter (HELITEM) are applied in the surveys. AGG survey is suitable for delineating geological structures in detail. HELITEM survey has an advantage over frequency domain electromagnetic survey as it has deeper penetration. A helicopter can fly at lower altitude with lower velocity than a fixed wing, which provides higher resolution and higher signal intensity data. Adopting the helicopter is beneficial especially for topography with steep slopes such as the mountain regions in Japan.
We are studying analysis methodologies for the acquired geophysical data. For example, we tried a variety of filtering to extract structural features such as lineaments from AGG data. Ground truth surveys with outcrop sampling are also conducted to ascertain the analysis results of the airborne geophysical surveys. We have completed the airborne geophysical surveys in more than 10 areas in Japan, so far. In this presentation, we will introduce results and our experience from the surveys recently acquired.
The authors acknowledge local municipalities and related organizations for their understanding and cooperation with us to conduct the airborne survey.

Keywords: airborne geophysical survey, geothermal resources, gravity survey, electromagnetic survey

 

# CONTRIBUTION OF THE INTERPRETATION OF AERO-GEOPHYSICAL DATA IN THE INCREASE OF GEOLOGICAL AND STRUCTURAL KNOWLEDGE, IN THE PROVINCE OF CABO DELGADO, MOZAMBIQUE.

*Carlos Castigo Macuacua[1]

1. Hokkaido University

Macuácua, Carlos.[1]
[1]Faculty of Engineering, Hokkaido University, Japan; ccmacuacua@gmail.com

**Abstract:**
The evolution of geosciences, with the appearance of new techniques of data collection and analysis, and the implementation of new technologies in its various fields of action have led to the development of more realistic geological maps, thus contributing to the growing discovery of new mineral deposits.
In 1970, the first aero-geophysical surveys were carried out by Italian company CGG with a view to boosting geological research work and contributing to the increase of geological knowledge at the country level. But it was in 2004/5 that the geophysics in Mozambique witnessed a major evolution, with the performance of aero-geophysical surveys by FUGRO, of high resolution, with flight lines spacing of 300 m, flight height of 100 m, and comprises data from Total magnetic field and gamma-spatter.
The integration of the high-density aero-geophysical data interpretation as a tool to support the geological mapping allowed an easy discrimination of the geological complexes, structural and kinematic interpretation and identification of intrusive bodies. The examples presented here refer to the province of Cabo Delgado, an area with potential for research of several mineral resources, but which has few publications of geological mapping works.
In this region, the aero-geophysical surveys conducted by FUGRO in 2004/5 were of fundamental importance in assisting the geological mapping for the project to compile the Geological Map of Mozambique, carried out by Norconsult in the periods of 2002 to 2007, and financed by several national and foreign institutions.
In addition, some dissertation work was carried out in the Province of Cabo de Delgado, being (Danta, 2009) the most relevant on processing and interpretation of aero-geophysical data, in the province of Cabo Delgado.
As an example, the interpretation of radiometric data of high resolution added to field observations revealed the existence of folded and mylonitic contact between the geological complexes of Xixano and Marrupa, in the province of Cabo de Delgado.
In addition, Nipepe Klippe is a geological structure whose discovery was made possible by combining ternary images of radioelements (K, Th, U) resulting from high-density aero-geophysical data and field observations. The image of the first vertical derivative superimposed on the satellite image revealed the existence of dikes inside the complex of Marrupa.
This information, based on the data processing related to high-density aero-geophysical surveys and field observations, contributed significantly to the increase of geological and structural knowledge for the improvement of the geological map of the province of Cabo Delgado.

Keywords: Importance, aerogeophysic, geological mapping

 

 

# Development of frequency domain electromagnetic exploration system using unmanned aerial vehicle (UAV/drone)

*Takumi Ueda[1], Yuji Mitsuhata[1], Shin Kato[2], Akiya Kamimura[2], Kazuhiko Tanimura[3], Tomoyuki Izu[4], Daizo Ueda[5], Junichiro Fujii[5]

1. Geological Survey of Japan, AIST, 2. AIST, 3. Hitachi, Ltd., 4. ENROUTE CO., LTD. , 5. Yachiyo Engineering Co., Ltd.

In recent years, industrial activities using unmanned vehicles, especially small unmanned aerial vehicles (UAVs, drones), have become extremely common globally in various fields (environment, infrastructure, agriculture, logistics, security, etc.). There has also been rapidly growing interest in the development of the geophysical exploration method for subsurface visualization by UAV. However, the necessary technology for geophysical exploration has yet to be established compared with optical measurement from the air to acquire surface information, which has already been advanced in terms of technology. This is mainly due to size and weight of geophysical equipments, measured signal strength, data quality and difficulty of stable flight.

Traditionally, for efficient exploration of a wide area and of inaccessible areas, conventional gravity/magnetic and electromagnetic (EM) exploration using a helicopter or a fixed-wing aircraft have been developed and used. However, applicable targets have been limited because of the difficulty of operations to meet regulations such as airframe remodeling and flight altitude control, particularly in a densely inhabited district (DID), and limitations and restrictions of exploration specifications (depth and resolution of investigation).
On the other hand, the existing traditional ground survey method using manpower has faced various problems such as a reduction in exploration efficiency for surface conditions (topography, vegetation, accessibility, etc.), survey costs, and others. Therefore, as a new exploration method for filling the gap between conventional airborne and ground surveys, there are high expectations for geophysical exploration using UAVs (drones).

In addition, considering the current situation of Japan, where there have been natural disasters such as the landslide disaster caused by heavy rain in Hiroshima, the Ontake volcanic disaster in 2014, and the 2016 Kumamoto earthquake, there is an urgent need to establish not only UAV techniques to obtain information about the surface but also methods for conducting underground surveying quickly, safely, and more accurately in inaccessible areas.

Therefore, in this research, we have been working to develop a new method that uses existing portable EM survey equipment with frequency domain electromagnetic methods, suspended by drone, to obtain geo-electrical information. In this presentation, we introduce the progress and details of the development of the drone-suspended electromagnetic survey system, including results of field experiments.

Keywords: exploration geophysics, applied geophysics, electromagnetic exploration, airborne geophysics, unmanned aerial vehicle, UAV, drone

 

# Penetration depth of the GREATEM survey

*QIONG WU[1,2], Sabry Abd Allah[2], Toru Mogi[2]

1. Jilin University, 2. Hokkaido University

The grounded electrical source airborne transient electromagnetic (GREATEM) system uses a grounded electrical transmitter and an aircraft equipped with a receiver. Numerical forward modelling, using a finite-difference staggered-grid method, is performed to generate a three-dimensional (3D) resistivity structure model. A 3D electromagnetic forward-modelling scheme is modified and used to calculate the response of the study model in which a conductor is suited under ground surface at different depths. The sizes of conductor are 100 x 100 x 100 m, 200 x 200 x 200 m, 400 x 400 x 400 m. Depths of conductor are set to 50, 100, 200, 400, 600 m under ground surface. The bedrock has a resistivity of 100 Ω·m, and the resistivity of conductor is 1 Ω·m, 10 Ω·m. The vertical magnetic (Hz) field response decay curves for the different depths are compared. The results showed some differences between the Hz of different depths, so it is possible to detect that conductor in cases of different depths at flight altitude Z = 50 m. We used the relative difference (RD), defined as $|(Hz^{stand}-Hz^{case})/Hz^{stand}|$, of Hz field response for different depths to estimate responses difference quantitatively. When the size of conductor is bigger, it is easier to be detected. For low-resistivity conductor, the detection depth of GREATEM is up to 600m at flight altitude Z= 50 m.
The Ogiri geothermal area is located in southwestern Japan, a southern part of Kyushu Island. The arrangement of the geological structures is Quaternary volcanic rocks and Mesozoic metamorphic formation from the top down. Synthetic numerical models was used to construct 3D resistivity structure model of GREATEM system data in the study area. A 3D model of 3.7×4.2×2.3 $km^3$ was designed, and discredited into 52×38×41 cells using the grids coordinates that are modelled to the geothermal area. The 3D resistivity model has been based on layered earth resistivity structures. In order to estimate the penetration depth of GREATEM in a geothermal field, we set the resistive basement rock layer at various depth and investigated change of GREATEM responses. There are some differences between the Hz of different depths. The RD of Hz field response is also calculated. The results showed that, the GREATEM can detect structure of a cap rock layer and top of geothermal reservoir, and the penetration depth is up to 1600 m below the ground surface.

Keywords: GREATEM, 3D resistivity structure model, penetration depth, geothermal survey

 

# Can magnetic survey estimate locations of intrusions?

*Shigeo Okuma[1], Yoshihiro Ishizuka[1], Tadashi Nakatsuka[1]

1. Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST)

The Geological Survey of Japan (GSJ), AIST conducted various magnetic surveys such as stinger-mounted helicopter-borne magnetics, helicopter-borne EM and magnetics and ground magnetics in the Usu Volcano area, Hokkaido Japan after its 2000 eruption to better understand the subsurface structure of the volcano (i.e. Okuma et al., 2010). Recently, 3D imaging method was developed (Nakatsuka and Okuma, 2014) and applied (Okuma et al., 2014) to the aeromagnetic anomalies of the volcano observed by the stinger-mounted helicopter-borne magnetics flown at an altitude of 150 m above terrain. The result revealed the subsurface distribution of basaltic somma lava but no information about magmas intruded during the recent eruptions in 1977-1978 and 2000 was obtained. This implies a difficulty to estimate locations of intrusions by a single magnetic survey and instead we proposed an alternative repeat survey (Okuma et al., 2013).

This time, we took a different approach to overcome the problem. We thoroughly reexamined the aeromagnetic anomalies observed by helicopter-borne EM and magnetics flown at an altitude of 70 m above terrain. Since the flight altitude of this survey is lower than that of the former one, a dipole of magnetic anomalies with a reverse polarity was found on the southwestern flank of the main edifice of volcano. To confirm the magnetic anomaly, we, then, conducted a ground magnetic survey along some profiles. As a result, a comparable magnetic anomaly was observed on ground. Whereas, the survey area is underlain by basaltic somma lava which shows high NRM intensities (6-10A/m) (Okuma et al., 2014). This suggests the existence of an intrusive body with a magnetization intensity lower than that of the somma lava. There are two possibilities which account for the magnetic anomaly. A hot magma of the recent eruptions might have intruded in the somma lava since some fumarolic activities were observed nearby during the ground magnetic survey. A cooled magma intruded during older eruptions is another possibility. Volcanic activities of the volcano changed from basaltic to dacitic after the formation of the main edifice. Since the NRM intensities of dacite is lower than that of soma lava (Nemoto et al., 1957), an old dacitic intrusion can account for the magnetic anomaly as well. Consequently, a repeat magnetic survey might play a role of judging if which hypothesis is more suitable by observing temporal magnetic changes.

Keywords: intrusion, magma, magnetic survey, 3D imaging, Usu Volcano, Usu 2000 Eruption

 

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

*Hideyuki Satoh[1], Yamashita Ichiro[2], Craig Annison[3], Atusi NINOMIYA[4], Akihiko Chiba[4], Shirota Atsushi[4], Aibe Sho[4]

1. Secretariat of Nuclear Regulation Authority, Nuclear Regulation Authority, 2. Fugro Japan Co., Ltd., 3. CGG Aviation (Australia) Pty Ltd., 4. Sumiko Resources Exploration & Development Co., Ltd.

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

*Shigekazu Kusumoto[1]

1. Graduate School of Science and Engineering for Research, University of Toyama

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

*Tetsuya Jitsufuchi[1]

1. NIED

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

*Miyuki Sasaki[1], Azusa Ishizaki[1], Yukihisa Sanada[1]

1. Japan Atomic Energy Agency

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 $\lambda j$ 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

*Youichi Yuuki[1], masamichi maeshima[1], Eiji Nakayama[1]

1. Oyo corporation

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

*Mitsuyoshi Iwata[1], Shigeo Okuma[1], Tadashi Nakatsuka[1], Ayumu Miyakawa[1], Sawako Kinoshita[1]

1. Geological Survey of Japan, National Institute of Advanced Industrial Science and Technology (AIST)

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

*Sabry Abd Allah[1], Toru Mogi[2]

1. Institute of siesmology and volcanology-faculty of science, HOKKAIDO UNIVERSITY, 2. Division of Sustainable resources Engineering, Faculty of Engineering, Hokkaido University

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

*Takao Koyama[1], Takayuki Kaneko[1], Takao Ohminato[1], Atsushi Watanabe[1]

1. Earthquake Research Institute, University of Tokyo

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

 