Airborne γ-Ray Survey System Developed at LNL

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INTRODUCTION

Measurements of the ground concentrations of potassium, uranium and thorium by γ-ray spectrometry are a well-established technique [1]. At the same time, the request of radioactivity studies is constantly increasing due to more stringent regulations and after the new prospective introduction of nuclear energy in european countries.

Whereas the the in situ measurements [2, 3] are requested for samples certification or monitoring of spot area, the airborne gamma spectrometry (AGS) method is highly appropriate for large scale environmental survey. These studies are important both in the case of monitoring the natural ground radioactivity and in the case of potentially contaminated ground areas and they are used in several countries since early 1990s [4–6].

The AGS method has been found to be a powerful technique with respect to in-situ measurements since it can reduce the time consumption and monitor large areas. This of course put a constraint on the spatial resolution of the method, which averages the signal over the area covered by the time slice (typically of the order of 0.3 km^2).

A new AGS system has been developed at the LNL and it has been successfully used and tested during a more than 2 hours flight on the Elba Island. All details of the system will be discussed in the next section with a the measured concentration results.

THE EXPERIMENTAL SETUP

The detection system is composed by four sodium iodide detectors (dimensions 10 cm × 10 cm × 40 cm for a total of 4 *l* volume each). The signals are processed by a N1728B Caen circuit, which acquires the four signals in list mode (event by event). A 10 cm × 10 cm × 40 cm NAI(Tl) detector is placed in top of the other four and works as monitor of the radon gas in air [7]. This way the radon detector is partially shielded from the ground radiation. The radon monitor is powered by an Ortec module (DiGiBase) which produces one amplitude spectra every 20 seconds.

The elevation over ground is deduced by measuring the atmospheric pressure and temperature and using the Digital Elevation Model of the Tuscan Region and the Laplace formula. The GPS information, together with temperature and pressure, are saved every two seconds. All the acquisition is controlled by the PC which also provides the flight information to the pilot (in terms of direction and altitude), allowing to follow the scheduled flight plan.

The power supply needed by the system is provided by four 12 V batteries. The battery pack surrounds the radon monitor improving the shielding factor.

Fig. 1. The AGRS system mounted on the vehicle.

The system is mounted on a ultra light vehicle, called autogiro (figure 1) which is a convenient compromise between transportable weight and flight costs. The vehicle flights at about 100 m of altitude and at 100 km/h of speed.

The flight path is chosen following geological prescriptions and constrained by the morphological structure of the ground terrain. Since the 77 formations are disposed mainly from north to south (see figure 2), we decided to flight from east to west in order to cross perpendicularly, as much as possible, the formations borders. The unique region not fully covered by the airborne survey was the top of Monte Capanne, because to the weather conditions occurring the day of flight.

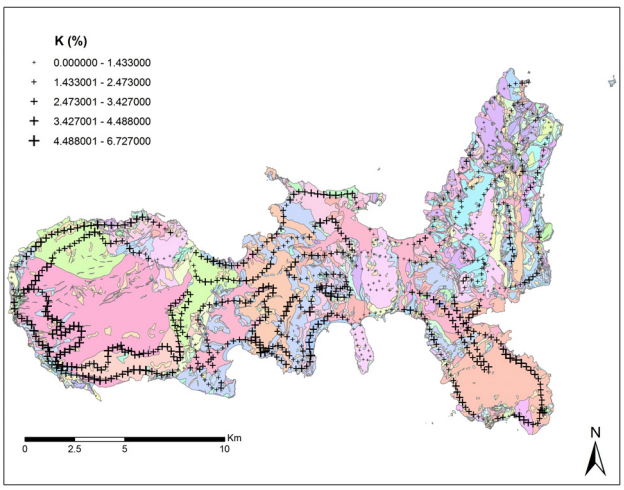

Fig. 2. Geological map of Elba Island (derived from the new Geological Map of Tuscany region realized at 1:10,000 scale by CGT, 2011). The measurements of potassium concentration are reported (crosses). For the complete official legend of the whole geological formations see 159.213.57.103/geoweb/10k/legenda10ktoscana.pdf. The coordinate system is UTM WGS84 Zone 32 North.

AIRBORNE MEASUREMENTS AND DATA ANALYSIS

The four signals from the main detectors are calibrated and reconstructed separately in spectra at fixed time intervals. This initial energy calibration is measured, at the beginning and at the end of the flight, by measuring with a γ-ray source. A more accurate one is performed during the offline analysis. Finally, the single spectra are summed and analyzed by the Non Negative Least Square (NNLS) approach of the Full Spectrum Analysis (FSA) method as described by Caciolli et al. [8]. The detector efficiency calibration is made by following the procedure already described and tested [3, 8]. The transformation of the measured concentrations to the ground values is performed by means of several corrections. The final values will be labelled with the X Y coordinates of the vertical projection of the airborne system in the middle of the flight segment, and the value is considered assigned to the full area surveyed. The two main corrections are: the vehicle height and topography and the radon in air. These correction has been applied by following the prescriptions of the IAEA [9].

By performing this analysis, we have measured the concentration of potassium and uranium and thorium. As example the measurements of potassium concentration is shown in figure 2. The data measured by the AGS system are affected by a almost 10% statistics uncertainty and a 10% up to 30% systematics (depending on the measured element). These results are the main input for the collocated cokriging interpolation which implements the geological informations in order to determine the abundances of K, eU, and eTh [10].

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