THE USE OF THE ORTHO-IMAGES IN GEOENVIRONMENTAL APPLICATIONS: THE ORTHO-IKONOS 2 IMAGE OF NISYROS ISLAND (GREECE)

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ABSTRACT

The corrected satellite images can be used as navigational tools for various environmental studies. At the present study, the ORTHO-IKONOS 2 Image of Nisyros Island (Greece) with 1-meter resolution, was produced after the ortho-rectification of the Panchromatic Sharpening Image IKONOS 2 of Nisyros Island, referred to the Hellenic Geodetic Reference System 1987 (HGRS'87). The ORTHO-IKONOS 2 Image of Nisyros Island will serve as a basic feature for a multi-disciplinary study relating to Early Warning and Emergency Planning of Nisyros Volcano.

1. INTRODUCTION

The islands of Nisyros, Yali, Kos, Santorini, Milos, Poros, Aegina and the Methana Peninsula constitute the Hellenic Volcanic Island Arc (HVA). The eastern sector of the HVA, including the islands of Kos, Yali and Nisyros, seems to be geodynamically very active since it comprises the largest volumes of volcanic products and is at present a region of high tectonic unrest.

Active volcanoes represent several natural hazards for populated regions. These hazards often occur as combinations of earthquakes, gas-explosions and hydrothermal eruptions, volcanic eruptions, landslides, mudflows, tsunamis etc. Because of the above aspects, the research project GEOWARN financed by the European Union (IST 12310) has been established. The objectives of this scientific study are to conduct an integrated informative, volcanological, geophysical and geochemical project to assess volcanic and seismic hazards related to the most active part of the Eastern Mediterranean by the help of a GIS database, as well as by an integrated geo-spatial multimedia system of the region. Eight institutions collaborate in this project and a large amount of heterogeneous information has to be produced and treated like graphical and numerical geo-spatial data, visualisations, derived satellite images, real-time monitoring of ground movements (DGPS and Differential Interferometry), seismic activity, changes in fumarolic gases and high hydrothermal waters (see 1st and 2nd Annual Report, www.geowarn.org).

One of the basic features of the GEOWARN project was the creation of an updated topographic map of Nisyros Island at 1:10,000 scale. A satellite geo-referenced image of a high resolution is a useful tool for high accuracy ortho-photo mapping.

At the present study, the ORTHO-IKONOS 2 Image of Nisyros Island with 1-meter resolution, was produced after the ortho-rectification of the Panchromatic Sharpening Image IKONOS 2 of Nisyros Island, referred to the Hellenic Geodetic Reference System 1987 (HGRS'87). This corrected image will serve as a basic feature for the multi-disciplinary study relating to Early Warning and Emergency Planning of Nisyros Volcano.

KEYWORDS: Ortho-photo, Ortho-photo-maps, Ortho-rectification, Digital Elevation Model (DEM), Differential GPS.

2. THE IKONOS DATA

The IKONOS 2 satellite (launched in September 1999) by Space Imaging Inc. is the world's first commercial satellite, offering high-resolution imagery. The IKONOS sensor suite is capable of generating 1-m panchromatic and 4-m multi-band

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images with off-nadir viewing up to 60° in any azimuth for a better revisit rate and stereo capabilities. IKONOS 2 satellite orbits the Earth once every 98 minutes at an altitude of approximately 680 kilometers. It constitutes a sun-synchronous orbit, and therefore the satellite will pass over a given longitude at about the same local time every day. This procedure allows relatively constant shadow angles on subsequent image collections, helping to determine object's height and radiometric qualities of the image scene. In addition, by collecting 11-bit data it generates images with a high dynamic range of 2,048 grey levels, and yields a wealth of contrast information and shadow detail.

Nisyros is mainly a rural area constituting a circular volcanic island. The ground morphology begins from the sea-level and forms a caldera rim at an altitude of about 200-300 m, while the overall relief varies between sea-level and about 700 m.

Space Imaging Europe S.A. provided an uncorrected IKONOS scene of PAN/MSI type (acquisition date April 8, 2000), presented 10% cloud coverage at a minor area of the western part of the island. The scene dimensions were 9504 pixels and 9696 lines and the scene ID is po_6804_rgb_0000000.tif. The upper left geographic coordinate of the image is E 27.11°, N 36.63°, while its lower right geographic coordinate is E 27.21°, N 36.54°. The product was delivered in GEO-format issued at UTM projection, WGS'84 datum and with a nominal accuracy (90% confidence in circular error) of 50 m on the ground.
(http://www.spaceimaging.com/carterra/geo/prodinfo/geotech.htm).

3. DATA AND PARAMETERS FOR THE ORTHORECTIFICATION

A Digital Elevation Model (cell size: 2 m) as well as a number of selected ground control points (GCPs) offering high accuracy, were used for the ortho-rectification of the IKONOS 2 Image. The GCPs were measured by Differential GPS (DGPS) measurements using dual frequency geodetic receivers.

3.1 Ground Control Point Determination

A number of 38 ground control points (GCP's) were collected, performing DGPS measurements during 2001, under normal weather conditions over Nisyros. Two dual-frequency geodetic GPS receivers were used (WILD SR 299). The coordinates of the GCP's were calculated from ties on the permanent GPS stations of the Nisyros GPS network (Lagios 2000). The Nisyros GPS network refers to a pillar at the NE part of Kos Island, about 33km to the NE of Nisyros. That pillar belongs to the Hellenic 1st order geodetic network, EGSA'87, the Hellenic projection system applying the GRS'80 ellipsoid. That pillar (No 182) has coordinates (in EGSA'87) X=792708.63m, Y=4087832.75m and Height=32.320m.

The processing and adjustment of the GPS observations were made using the SKI Pro software of Leica, which was adequate as an analysis tool due to (i) the small distances of the measured base-lines (Dixon 1991) and (ii) the very high rate and long recording time (Lagios et al. 1998; Lagios 2000; Ganas et al. 2001). Then for all GCPs, the following information was collected: Point ID, image position (Pixel, Line), elevation, and ground position (X, Y). It was found that the error estimation of the horizontal coordinates was between 1-3mm, while 2-5mm in the vertical direction. The GCPs were identified on the ground using a laptop computer in situ. The points were measured in the UTM–rectified Panchromatic Sharpening Image IKONOS 2 of Nisyros Island, based on their coordinates by the use of ERDAS software, ver. 8.4. The image was imported to the ERDAS software and pre-processing techniques were applied to enhance the aesthetics; specifically the image's histogram was elaborated and a new look-up table was generated. The position of GPS measurements is indicated on the IKONOS 2 Image (Fig. 1).

3.2 The High Resolution DEM of Nisyros Island

The use of a DEM is important for any environmental study of a region, because:

- It represents a modern digital topographic map in three- dimensions and serves as a base for thematic applications (geology - tectonic - orthorectified satellite images etc.)

- It serves as a base for production of a great variety of maps (3-D maps, slope – aspect maps etc.)

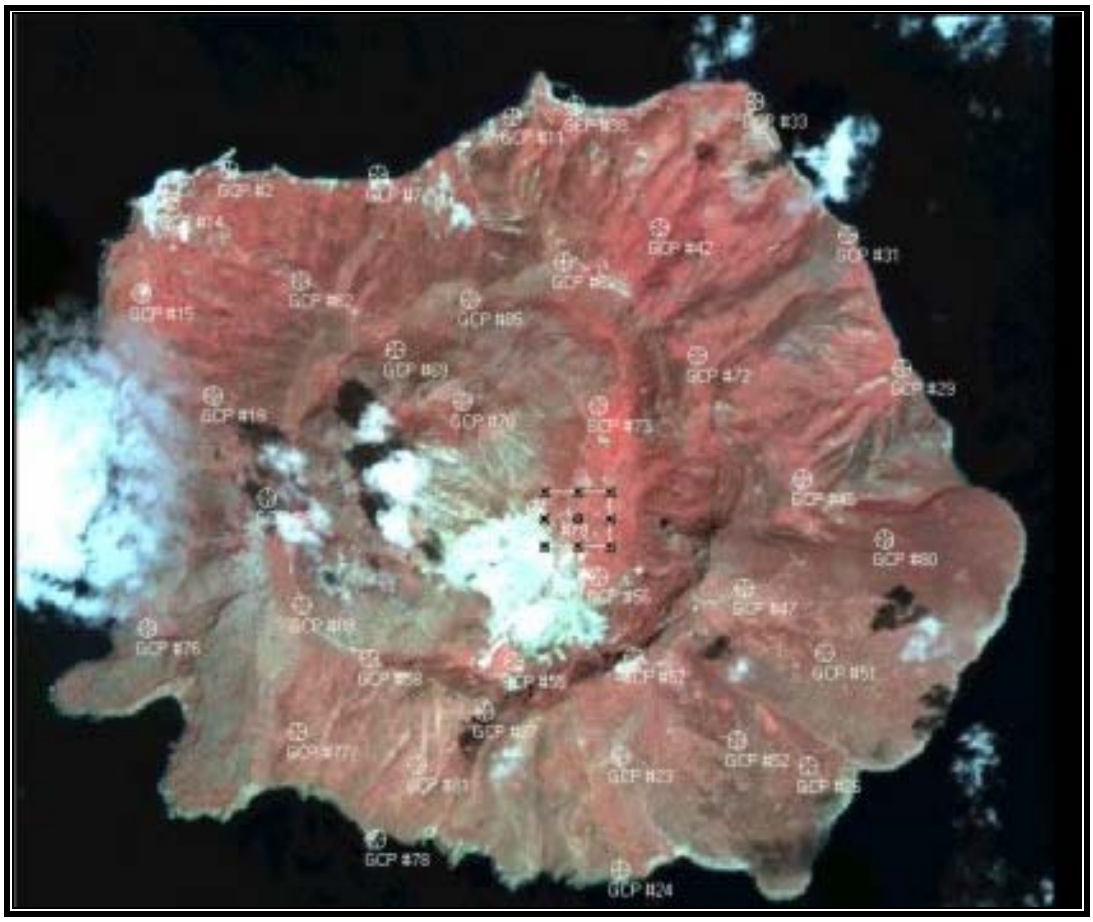

Figure 1. The IKONOS 2 Image of Nisyros Island with selected Ground Control Points for the Ortho-rectification.

The applied methodology for obtaining a DEM, depends on numerous parameters, like the type of the data (contours, points, drainage network, etc), the quality and the density of the data relating to the morphology of the study area, as well as the use of the DEM. The result depends on the parameters of the algorithm, the cell size, the scale, etc. (Vassilopoulou, 1999; Vassilopoulou, 2001; Vassilopoulou & Hurni, 2001).

A high resolution DEM had to be produced. The basic input data were contours with a good density, as well as elevation points and drainage network. The Topogrid Algorithm of Arc/Info 8.02 was thus used for the creation of the DEM. The Topogrid Algorithm of Arc/Info 8.2 generates a hydrologically corrected grid of elevation from point, line, and polygon coverages. It is based upon the ANUDEM program developed by Hutchinson (1988, 1989).

The high resolution DEM in the Hellenic Geodetic Reference System (Vassilopoulou & Hurni, 2001) has the characteristics presented in Table 1:

TABLE 1
Characteristics of the high resolution DEM of Nisyros Island

Cell size = 2 m
Number of rows = 4118
Number of columns = 4575
Xmin, Ymin : 778864.500, 4049554.750
Xmax, Ymax: 788014.500, 4057790.750
Type of the data : floating points

3.3. The Ortho-Ikonos 2 Image of Nisyros Island

The Panchromatic Sharpening IKONOS 2 Image of Nisyros Island was ortho-rectified using the polynomial mapping functions of Kratky of 14^{th} degree with 14 terms. As input the GCPs coordinates in HGRS'87 and the pixel coordinates in the original IKONOS Image (not the ERDAS transformed), were used. Orthos were generated separately for each channel of IKONOS 2 Image, using the high resolution DEM. Finally the ortho-IKONOS 2 Image with resolution 1 m was produced (Fig. 2), (Vassilopoulou et al., 2001). This corrected image has the characteristics shown in Table 2:

TABLE 2
Characteristics of Ortho-IKONOS 2 Image

Resolution = 1 m
Datum: Hellenic Geodetic Reference System 1987 (HGRS'87)
Projection: Transverse Mercator
Spheroid: GRS'80
X,Y of UL corner : 779172.875000, 4057305.500000
X,Y of LR corner : 787528.875000, 4050127.500000
Number of rows = 8357
Number of columns = 7179

The estimated RMS is about 1.5m and 1m in X and Y directions, respectively. The result is satisfied considering that the original IKONOS image was generated from 1m resolution PAN Image and three MS Images of 4m resolution. Additionally, the unknown sharpening algorithm introduces certain geometric and radiometric errors. Thus, the result is better than expected.

4. THE USES OF THE ORTHO-IKONOS 2 IMAGE

The ortho-IKONOS 2 Image is a useful support for the high accuracy ortho-photo- mapping. Thus, the update of the topographic map of Nisyros at 1:10,000 scale is based on this image by the use of image interpretation characteristics and proper digitization on the screen.

The ortho-IKONOS 2 Image after a post-processing including filtering and enhancement was used for the mapping of the roads. For the mapping of all the categories of buildings (i.e. house, church, ruin) and land use (i.e. forest, rock, village), the image is used without post-processing.

This corrected image can be used as a visualisation, as well as the base map for the locations of the various measurements of DGPS in the fields of applied geophysics, seismology, geothermics, geochemistry etc. It is also a useful tool regarding geology, tectonics and geomorphology, not only in the laboratory (for the interpretation and digitisation procedures), but also during field work campaigns used as a base map.

The production of an updated topographic map that will contain all the topographic data classified in categories, as well as various ortho-maps relating to the topography, geology, tectonic etc. (Fig. 3 & 4), is intended in the near future. Generally this image will serve as a navigational tool for the Early Warning and Emergency Planning of Nisyros Volcano.

5. CONCLUSIONS

The ortho-images with high resolution and specifically the ortho-IKONOS Images (1-meter resolution) can provide useful information regarding the geology and the geodynamics of a region, as well as to various geo-environmental applications to the laboratory and to the field work.

At the present study, the ortho-IKONOS 2 image serves as a basic feature for the multi-disciplinary study of Nisyros Volcano.

These corrected satellite images, apart for general visualizations, can be used in the following domains, and serve various purposes, such as:

Figure 2. The ortho-IKONOS 2 Image of Nisyros Island

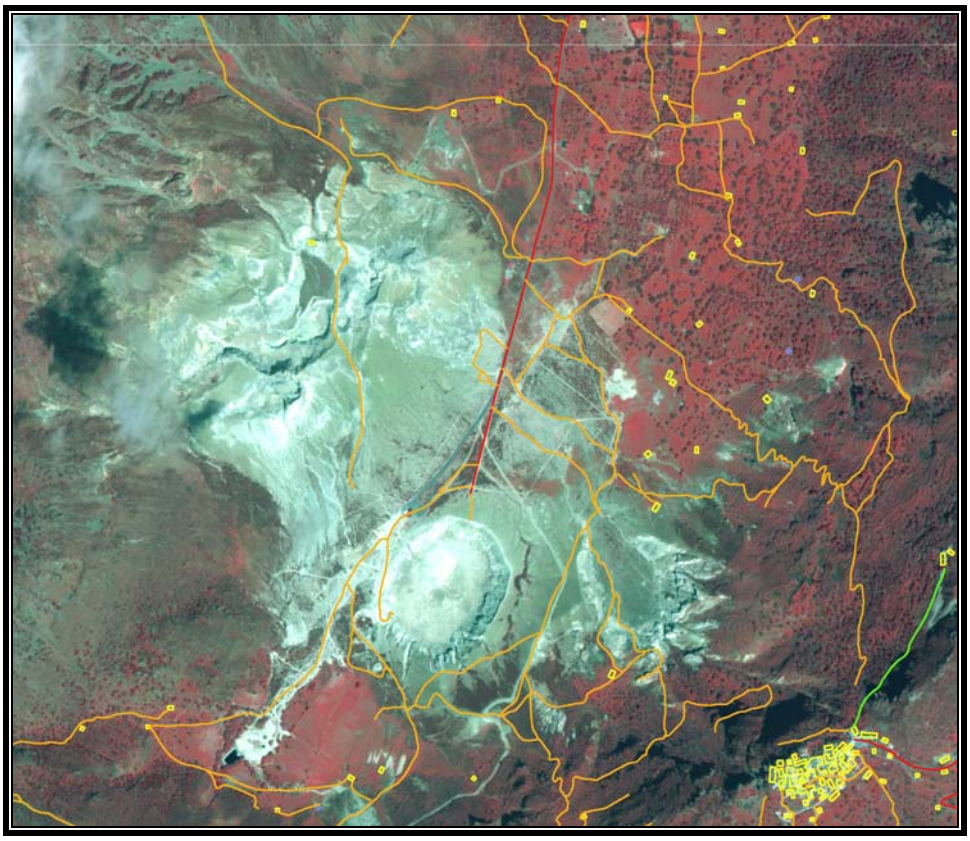

Figure 3. The ortho-IKONOS 2 satellite image overlaid by the topographic information (roads and buildings classified in categories); a useful support for the update of the topographic map.

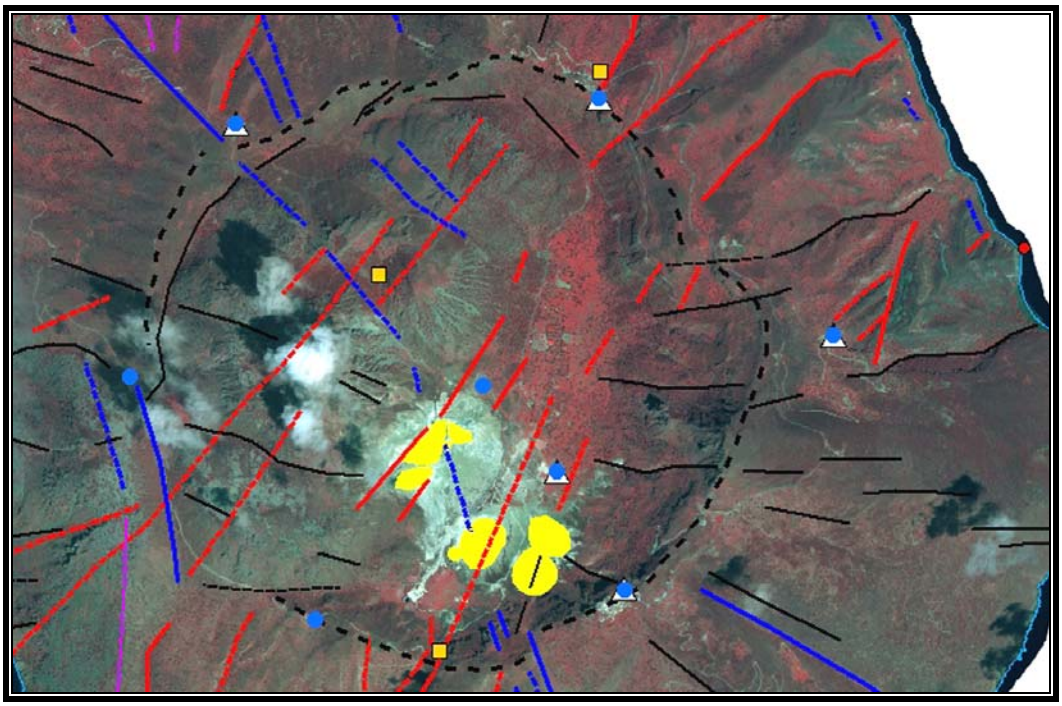

Figure 4. The ortho-IKONOS 2 satellite image overlaid by the tectonic features [i.e. faults classified in categories, the position of GPS stations (blue circles), micro-gravimetric stations (triagles), fumaroles (rectangles)].

(i) For the production of various ortho-maps relating to Topography, Land use, Tectonics, Neotectonics, Morphotectonics, Geology, Geomorphology.

(ii) As a base map for the location of the GPS measurements or stations in applied disciplines of geosciences (geophysics, seismology, geothermics, geochemistry, hydrogeology), both in the field and the laboratory.

Subsequently, these corrected images can be used as navigational tools for emergency planning, in crisis management and evaluation procedures in devastated areas due to any natural disaster (floods, forest fires, earthquake devastation, volcanic eruption), as well as useful tool for all non-accessible areas without proper maps.

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