THE IMPORTANCE OF REMOTE SENSING IN THE MONITORING OF VOLCANIC ACTIVITY IN THE GOMA REGION (DR OF CONGO): EXPERIENCE FROM THE GORISK PROJECT.

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1. INTRODUCTION

The region of Goma (North-Kivu, DR Congo) lies under the threat of the Nyiragongo and Nyamulagira volcanoes that are amongst the most active in Africa. The Nyiragongo eruption that occurred in January 2002 produced spectacular lava flows that destroyed 15% of the city of Goma. Although the amount of casualties was limited, hundred thousands of inhabitants were forced to evacuate in difficult conditions, which added more pressure in a highly politically sensitive area.

This paper presents the advances of the ongoing "GORISK" project (2007-2009), a multidisciplinary initiative oriented towards the implementation of ground-based and spaceborne tools for volcano monitoring, risk assessment and study of the impacts on health and environment of Nyiragongo and Nyamulagira volcanic plumes. The GORISK main activities are the monitoring of ground deformations and of geochemical parameters from water and gases, the study of possible correlation between the prevalence of targeted diseases and volcanic plume, the updating of the map of Goma and the implementation of a GIS platform integrating all the results for planning purposes. GORISK involves scientific teams from Belgium, Luxembourg, and Italy, and local DRC end users.
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2. GROUND DEFORMATION MONITORING

Ground deformations monitoring is based on both spaceborne (InSAR) and ground based techniques with a network of 5 telemetred tiltemeters and 7 permanent geodetic GPS stations (loaned by NMNH). These tools complete efficiently the existing seismic network maintained by the Goma Volcanological Observatory (GVO).
The efficiency of InSAR in detecting ground deformations in densely vegetated volcanic environment has been evidenced by previous works [1]. The systematic InSAR monitoring of the Goma region is performed using ENVISAT ASAR data acquired in a routine mode (~ one acquisition per week). The hundreds of satellite radar images (including ERS archives) have been processed and more than 850 interferograms have been computed out of that 10-years long databank with the open source DORIS software [2]. As a result, ground deformations associated to the most recent eruptions of the Nyiragongo (2002) and Nyamulagira (2002 and 2006) were successfully detected and studied into details [3, 4].
The continuous-in-time ground-based networks are complimentary to continuous-in-space InSAR data. However, though we were able to demonstrate their reliability and robustness, ground-based measurements are suffering from interruptions and maintenance problems linked to the difficult local, economical and political context. Although spaceborne techniques cannot replace ground-based observations for early warning, the use of remote sensing turns out to be the more sustainable way to study ground deformations that can be associated with volcanic activity.

3. GEOCHEMISTRY AND HEALTH

Monitoring water quality and gas emanations from the sub-surface involves a network of 3 continuous Radon and CO_2 measurements stations and the sampling and analyses of both water and gas samples. Special attention has also been paid to the mapping and the sampling of *mazuku*, abundant in the area of Nyiragongo and Nyamulagira volcanoes. The *mazuku* correspond to depressions where carbon dioxide, being heavier than air, accumulates by gravity in high – often lethal – concentrations [5]. On the other hand, epidemiological data are studied to assess the possible impact on health of the volcanic activity and especially the influence of the permanent SO_2 plume emanating from the Nyiragongo and the episodic plume of Nyamulagira. To achieve this objective, GORISK takes benefit from the ongoing EU-FP6 project NOVAC [6] and US-NSF project ViSOR [7] that are focused respectively on ground-based and spaceborne monitoring of the volcanic gas plume. VISOR provides SO_2 dispersion maps created from OMI satellite sensor, whereas NOVAC uses DOAS systems for SO_2 concentration measurements from the ground. Health data are provided by the Belgian NGO CEMUBAC and are gathered in health centers scattered all over the province in both plume prone and free areas. The SO_2 dispersion maps are put together with epidemiological indicators of water or air related diseases in order to attest for a possible relationship between volcanic activity and human health. Nevertheless, this correlation is not always clear and the preliminary results are evidencing that other parameters such as sanitary conditions, urban pollution, meteorological data and access to health centers need to be taken into consideration. The implementation of the analysis capacity is realized through the integration of all the collected data into a GIS platform. Data are stored into a common database that needs to be exploited by the local end users.

4. UPDATE OF THE GOMA URBAN AREA MAP

Until recently, the map for the urban area of Goma did virtually not exist. There is an archive map created in colonial time when Goma was still a very small locality but it strongly contrasts with the size of the actual ~500.000 inhabitants Goma city. A new map was created locally by an NGO project [8] based on an IKONOS image dated from 2005. But since then important demographic movements related to unstable political situation and to the war were responsible for rapid urban growth. The order for a new IKONOS image acquisition was placed at the beginning of the project but remained unsuccessful for more than a year because of the permanent cloud or atmospheric mask coverage. Alternative ways are under consideration including ground differential GPS tracking.

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