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17 November 2021 - Wednesday	
09:15-09:45	Opening
09:45-10:15	Land Management (Chair: Prof. Dr. Chryssy POTSIOU – FIG Honorary President) **Spatio-Temporal analysis of climate change in India: A theoretical perspective** Rajaram Patil, Moushumi Datta **Investigation of assembly centers in the disaster areas in Merkez District of Uşak Province in Turkey** Fatma Yüksel, Fatih Taktak **Developing 3D real estate tax visualization / management system with GIS based procedural modelling approa ch** Sevket Bediroglu
10:15-10:30	Break
10:30-12:00	Remote Sensing & Photogrammetry - 1 (Chair: Dr. Artur GIL - University of the Azores, Portugal)
	Analysis of forest degradation by using GIS and remote sensing: A case study of Chandoli National Park Kolhapur in Maharashtra State Rajaram Patil, Govardhan Ubale **Mapping of flood areas using Sentinel-1 Synthetic Aperture Radar (SAR) images with Google Earth Engine cloud platform – A case study of Chamoli district, Uttarakhand- India** Mohammed Faizan, Gobinath Palanisamy **Using Sentinel-1 GRD Sar Data for volcanic eruptions monitoring: The Case-Study of Fogo Volcano (Cabo Verde) in 2014/2015** Rafaela Tiengo, José Pacheco, Jéssica Uchôa, Artur Gil **Determination of vineyards with support vector machine and deep learning-based image classification** Özlem Akar, Ekrem Saralıoğlu, Oğuz Güngör, Halim Ferit Bayata **Assessing the interrelationship between LST, NDVI, NDBI and land cover change in Amuwo-Odofin, Lagos Nigeria** Alfred Sunday Alademomi, Chukwuma John Okolie, Daramola Olagoke, Samuel Akinnusi, Elias Adediran, Hamed Olanrewaju, Abiodun Olawale Alabi, Tosin Salami, Joseph Odumosu **Detecting changes in Mangrove Forests along the Bintang Bolong Estuary, Gambia using Google Earth Engine, Sentinel-2 Imagery and random forest classification** Lisah Ligono, Chukwuma Okolie **Remote sensing approach for aerosol optical thickness (AOT) monitoring in relation to the road network in Lagos Metropolis, Nigeria** Chukwuma Okolie, Emmanuel Ayodele, Erom Mbu-Ogar, Samuel Akinnusi, Olagoke Daramola, Abdulwaheed Tella, Rose Alani, Alfred Alademomi
12:00-13:00	Lunch Break
13:00-14:15	Surveying & Geodesy (Chair: Assoc. Prof. Dr. Lyubka PASHOVA - National Institute of Geophysics, Geodesy and Geography – Bulgarian Academy of Sciences, Bulgaria)
	Vertical accuracy assessment of Dems around Jabal Al-Shayeb Area, Egypt Ali Shebl, Mohamed Atalla, Árpád Csámer **The current state of use of satellite-based positioning systems in Turkey** Nuri Erdem, Abdulsamet Demirel **Estimation of tidal constituents from sea level registrations in BAB "St. Kliment Ohridski", Livingston Island** Lyubka Pashova, Borislav Alexandrov **Accuracy assessment of positioning based on single and Multi-GNSS** Lukman Abdulmumin, Yusuf Ramalan, Haruna Ibrahim, Abubakar Adamu Musa **Monitoring bathymetric changes of Commodore Channel, Lagos Nigeria** Babatunde Anibaba, Peter Nwilo, Chukwuma Okolie, Michael Orji, Olagoke Daramola **Accuracy assessment of established control within University of Lagos, Nigeria** Abiodun Alabi, Alfred Alademomi, Tosin Salami, Adedayo Okutubo, Wale Oyedokun **Establishment of a geodetic network for the deformation monitoring of the Third Mainland Bridge** Samuel Akintoye, Hamed Olanrewaju, Hannah Abioye, Chukwuma Okolie, Samuel Akinnusi, Adegbite Usman
14:15-14:30	Break
14:30-16:00	Geographic Information Systems 1
	Suitability analysis of solid waste dumpsites in Igabi Lga, Kaduna State – Nigeria Kaka Atta, MUHAMMAD NURA Idris, Yabo Stephen, Lukman Olawunmi Giwa **Comparative analysis of pedestrian stride length methods** Nimet Karagöz, Fatih Gülgen **Monitoring and prediction of land cover change in Anambra River Basin using cellular automata and markov chain technique** Peter Nwilo, Nna-Njar Gertrude Njar, Utibe Bassey Inyang, Chukwuma John Okolie, Olagoke Emmanuel Daramola, Michael Joseph Orji, Hamed Olabode Olanrewaju, Samuel Akinbola Akinnusi, Andy Osagie Egogo-Stanley **Geospatial intelligence (Geoint) with Geographic Information Systems (GIS)** Halil İbrahim Onyil **Age and gender differences in perceptions and health impacts of noise in an academic environment** Alfred Alademomi, Johanson Onyegbula, Rahmat Adepo, Chukwuma Okolie, Abiodun Alabi, Babatunde Ojegbile, Olagoke Daramola, Nehemiah Alozie, Samuel Akinnusi, Taiwo Adewale **FAHP And GIS based land use suitability analysis for agriculture in Aksaray City, Turkey** Süleyman Sefa Bilgilioğlu

18 November 2021 - Thursday	
09:00-10:30	Remote Sensing & Photogrammetry 2 **SFM photogrammetry for land use change analysis in a Sub-Urban area of Nigeria** Chima Iheaturu, Chukwuma Okolie, Solomon Musa, Emmanuel Ayodele, Andy Egogo-Stanley **Monitoring the change of coastline with remote sensing and GIS: A case study from Izmit and Gemlik Gulfs, Turkey** Tümay Arda, Melis Uzar **Analysis of Land-Use/Land-Cover dynamics in Ibadan Metropolis, Oyo State, Nigeria** Aliyu Zailani Abubakar, Swafiyudeen Bawa, Yahaya Abbas Aliyu, Tarwase Tosin Youngu, Usman Sa'i Ibrahim, Ayo Olalekan Fatoyinbo **Fully automated drought analysis from the products of the moderate resolution imaging spectroradiometer (MODIS)** Ali Levent Yagci **Development of a user-friendly program: "Real-Time Image Properties Display"** James Olaleye, Abiodun Alabi, Alfred Alademomi, Damilola Olatayo, Tosin Salami **Determination of Karina Lagoon surface area water temperature changes using remote sensing methods** Elif Akyel, Özşen Çorumluoğlu **Using remote sensing to monitor aerosol optical thickness (AOT) and its relationship with land cover in Lagos Metropolis, Nigeria** Emmanuel Ayodele, Chukwuma Okolie, Samuel Akinnusi, Erom Mbu-Ogar, Olagoke Daramola, Abdulwaheed Tella, Rose Alani, Alfred Alademomi
10:30-10:45	Break
10:45-12:00	Geographic Information Systems 2
	Mapping federal government dams in Nigeria Sola Oluwayemi, Adedayo Olayiwola **Monitoring the spatial distribution of CO2 within the University of Lagos Main Campus** Alfred Alademomi, Musa Animashaun, Oluwatimileyin Abolaji, Chukwuma Okolie, Babatunde Ojegbile, Olagoke Daramola, Nehemiah Alozie **Spatial relationship between NDVI, EVI, SAVI and land cover changes in the Lake Chad area from 1987 to 2017** Peter Nwilo, Chukwuma Okolie, Abdulkareem Umar, Samuel Akinnusi, Babatunde Ojegbile, Hamed Olanrewaju **Assessment of noise levels and associated health impacts in an academic environment** Alfred Alademomi, Johanson Onyegbula, Rahmat Adepo, Chukwuma Okolie, Babatunde Ojegbile, Abiodun Alabi, Olagoke Daramola, Nehemiah Alozie, Andy Egogo-Stanley, Inioluwa Ayantayo **Application of GIS and analytical hierarchy process for flood vulnerability assessment in Adamawa Catchment, Nigeria** Ayila Adzandeh, Dupe Olayinka-Dosunmu, Isa Hamid-Mosaku, Chukwuma Okolie, Peter Nwilo, Caleb Ogbeta **Locational analysis of infrastructural facilities in selected oil and non–oil producing areas of Akwa İbom State** Mbom-Abasi Inyang, Alabi Soneye, Chukwuma Okolie, Shakirudeen Odunuga, Johanson Onyegbula, Samuel Akinnusi, Hamed Olanrewaju
12:00-13:00	Lunch Break
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	Comparative analysis of forest change by type of Natural Park using clear cuts method Eun Ha Park, Ji Young Kim, Jin Won Kim, Byeong-Hyeok Yu **Shallow-water bathymetry using Landsat 8 imagery – Example of Ibafon Creek** Chukwuma Okolie, Emmanuel Ayodele, Oluwatobi Raji, Waliyah Adedokun, Olagoke Daramola, Samuel Akinnusi, Hamed Olanrewaju **Vegetation mapping from vegetation indices using a UAV-based sensor** Emmanuel Ayodele, Chukwuma Okolie, Imole Okediji **Evaluation of Landsat and MODIS imagery fusion for high-resolution evapotranspiration mapping over large agricultural area** Ayoub Moradi **Accuracy assessment and conflation of DEMs over Kaduna State, Nigeria** Swafiyudeen Bawa, Moses Mefe, Ebenezer ayobami Akomolafe, Monye Joseph Chukwuweta, Lukman Abdulmumin, Abubakar Adamu Musa **Applications of remote sensing in solving Myriads of Geological Problems: A review** Ogbonna Okpuru, Maruf Orewole, Sunday Olotu **3D modeling of underwater objects using photogrammetric techniques and software comparison** Seda Nur Gamze Hamal, Ali Ulvi **Documentation of cultural heritage by photogrammetric methods: a case study of Aba's Monumental Tomb** Engin Kanun, Aydın Alptekin, Murat Yakar

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Using Sentinel-1 GRD SAR data for volcanic eruptions monitoring: the case-study of Fogo Volcano (Cabo Verde) in 2014/2015

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ABSTRACT

The last eruption in the Fogo Volcano, which began in November 2014, was the first eruptive event captured by the Sentinel-1 (S1) mission. The present work sought to complement previous research and explore the potential of utilizing data from the Synthetic Aperture Radar (SAR) S1 mission to better monitor active volcanic areas. S1 Ground Range Detected (GRD) data was used to analyze the changes that occurred in the area before, during, and after the eruptive event and was able to identify the progress of the lava flow and measure the affected area (3.89 km^2 in total). Using the GRD data on Google Earth Engine (GEE) platform demonstrated high potential in terms of response time to monitor and assess eruptive scenarios in near-real-time, which is fundamental to mitigate risks and to better support crisis management.

1. Introduction

The archipelago of Cabo Verde is located between latitudes 14º and 18º North and longitudes 22º and 26º West. Situated in the Atlantic, 1300 km from the Canary Islands, its territory has 10 islands and 13 islets and Fogo Island was the site of the last eruption (Fig. 1). Fogo Volcano is the most active volcano in this archipelago, with about 26 eruptions in the last 500 years.

After almost 20 years since the last eruption occurred in 1995, a new eruptive event with strombolian characteristics began in November 2014 and lasted approximately 78 days.

Fogo Island has an extensive eruptive history being the only island of the Archipelago of Cape Verde to have volcanic activity. The Fogo Volcano has a caldera with approximately 8 km in diameter that was formed from two collapses that occurred in the central part of the volcano and Pico do Fogo was formed in the sequence of collapses on the eastern flank of the island (Brum da Silveira et al., 1997).

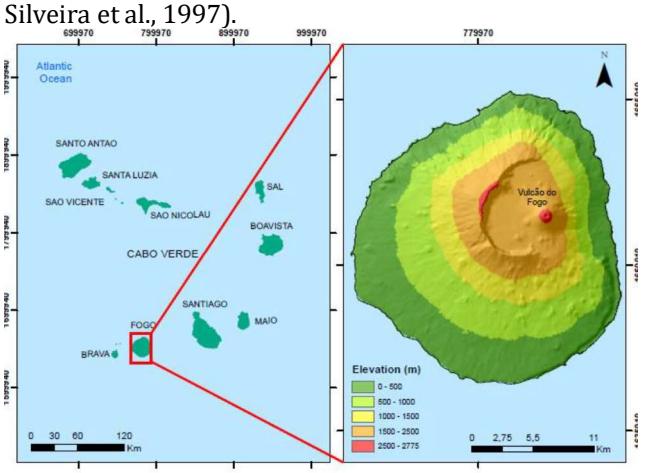

Figure 1. Map of Fogo Island, one of the ten volcanic islands of the Cabo Verde Archipelago. The Pico do Fogo (Fogo Volcano) constitutes the higher point of the island (2829m).

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Eruptive events may make it impossible to access affected areas and gather *in situ* data. Thus, the advancement of geospatial technologies proves critical in better understanding the genesis of these events remotely (Pyle et al., 2013; Jerram, 2018).

Mapping and updating the cartography of areas with active volcanism configures a fundamental task as it constitutes a tool to be used in the planning and crisis management process, as well as in the development of research, risk assessment, and crisis management (Fitz, 2008; Silva et al., 2018).

SAR data provides several advantages over other monitoring techniques due to the acquisition process of data in inaccessible and all-weather scenarios, by day or night. Besides that, S1 allows a relevant improvement for cost-effective monitoring and risk assessment of active volcanic areas. S1 pixel resolution is about 5x20 m in azimuth and range, respectively, with a revisiting cycle of 6 days. High spatial resolution SAR data is fundamental to allow the detection of unconformities in remote areas. SAR data is becoming essential in collecting relevant information about the dynamic processes by which an eruption can be generated (Fujira et al., 2017).

The GRD data from S1 mission was used in this study to identify the progress of the lava flow and measure the affected area, in order to assess its potential to monitor and assess eruptive scenarios in near-real-time, which is fundamental to mitigate risks and to better support crisis management.

2. Data and methods

This paper is focused on the application of S1 products in order to analyze eruptive scenarios. S1 GRD data was used to monitor the progression of the lava flows related to the 2014/15 eruption event through the detection of surface changes.

GRD is a S1 product that corresponds to SAR data detected, analyzed, and projected to the ground range taking into account the ellipsoidal Earth model, with separation capability in the object-target ratio of approximately 20 x 22m (ESA, 2016; ESA, 2021; Mullissa et al., 2021).

GRD consists in a product that presents the image amplitude values relative to backscattering, considering parameters such as surface roughness. These images require preprocessing to remove thermal noise. The workflow shown in Figure 2, suggested by Filipponi (2019), was applied to process this data in the SeNtinel Application Platform (SNAP) software.

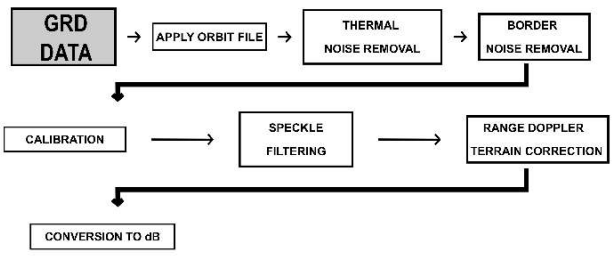

Figure 2. Workflow for removing thermal noise from S1 GRD data in SNAP software

The first stage of this procedure consists of the *Apply Orbit File* step, which corresponds to a refinement of the accuracy and the information referring to the position and speed of the satellite. Thenceforth, the *Thermal Noise Removal* step was applied in order to remove the thermal noise, thus normalizing the backscattering signal of the images. Subsequently, the *Border Noise Removal* procedure was used to compensate for the Earth's curvature levels, thus reducing the low-intensity noise contained in the images. *Calibration* step was then applied, ensuring that the image pixels were correlated with the backscattering that occurred during the information acquisition phase (ESA, 2021). Then, *Speckle Filtering* step was applied, which corresponds to the process of filtering speckles and noise. Afterward, *the* Range Doppler Terrain Correction step was undertaken to perform the geometric correction of the terrain to compensate for image distortions. The last step of this workflow consisted in converting the backscattering coefficient into decibels through a logarithmic transformation.

The GRD data acquired by the S1 mission is described in Table 1.

Table 1. S1 data used to generate the GRD of the area affected by lava flow

Image acquisition dates	Orbit
08 November 2014	Descending
27 November 2014	Ascending
09 December 2014	Ascending
21 December 2014	Ascending
02 January 2015	Ascending
07 February 2015	Ascending

To map the lava flow of the 2014/15 eruption, the GRD data was analyzed to identify the different paths that lava flow ran through day by day.

With the GRD data processed, the raster calculation tool of Arcmap 10.4 software was used to compute an Image Differencing Change Detection (Lu et al., 2004). In this procedure, each image after the start of the event is subtracted from a pre-event image. For this purpose, the value of an image referring to the last hours of the eruption was subtracted from an image prior to the beginning of the event. Very high ("change") and very low ("no change") values were thresholded in order to obtain the change detection map. To assess the accuracy and validate each change detection procedure, the Overall Accuracy was computed with independent validation datasets with 50 change/no change sampling points (Congalton and Green, 1999).

3. Results and discussion

In order to analyze the lava flow temporal progression, S1 GRD data was used to identify the affected area along the eruptive event. The successive change detection procedures showed Overall Accuracies ranging between 0.70 and 0.90. The surface changes that occurred during the 2014/15 eruption can be visualized in Figure 3. These changes are in line with the detailed

description made by Cabral (2015) for this eruptive event.

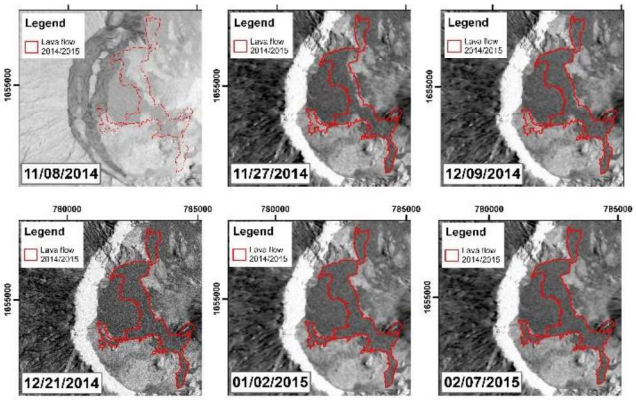

Figure 3. Level-1 GRD S1 multitemporal data used to illustrate the progression of the lava flow during the 2014/15 eruption.

In Figure 4, it is possible to note that some of the areas previously observed as affected by the 2014/15 lava flow were not identified in the change detection procedures with GRD data. It might be explained by the fact that there were no substantial roughness changes in the overlap area of 2014/15 lava flow with that of 1995 which occured at Chã das Caldeiras, as exposed by Bignami et al., (2020).

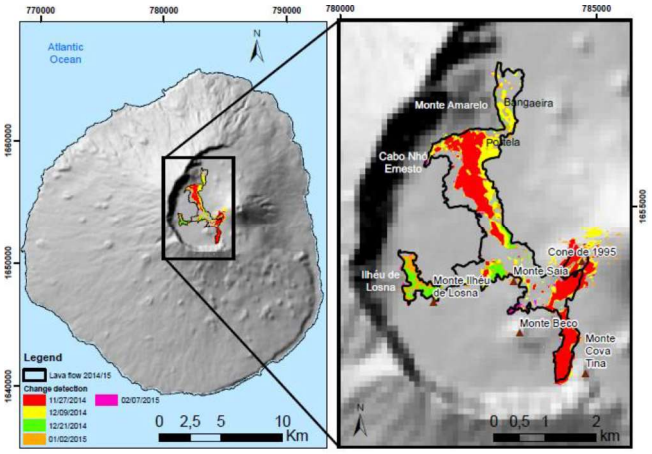

Figure 4. Changes detected with S1 GRD data throughout the 2014/15 eruptive event

The values of the total area affected by the lava flow were estimated to be approximately 3.89 km^2. The result is in relative agreement with other authors' findings when applying different techniques (Table 2).

Table 2. Total areas affected by the 2014/15 eruption, according to different authors

Area (km^2)	Reference
5,42	Cappello et al., (2016)
4,85	Richter et al., (2016)
4,97	Bignami et al., (2020)
4,8	Bagnardi et al., (2016)
4,53	Vieira et al., (2021)

The use of cloud-based platforms (e.g., GEE) allows their users to instantly access and analyze geospatial data through web interfaces (Gorelick et al., 2017). The user accesses all the cloud-hosted data without having to download the data of interest, in addition to the possibility of developing custom algorithms based on Python and JavaScript (JS) Application Programming Interfaces, which greatly reduces the computational constraint on the part of users (Navarro, 2017; Kumar & Mutanga, 2018; García et al., 2018).

A JS-based application was generated in GEE platform using a code by Google (2021) and adapted in order to compare the GRD images of S1 referring to the area affected by the lava flows resulting from the eruptive event. The data filtering parameters used in the JS script were applied to the GEE-based data collection entitled 'COPERNICUS/S1_GRD', with VV polarization corresponding to the IW mode.

The images in this application refer to the period from October 2014 to February 2015 (Fig. 5).

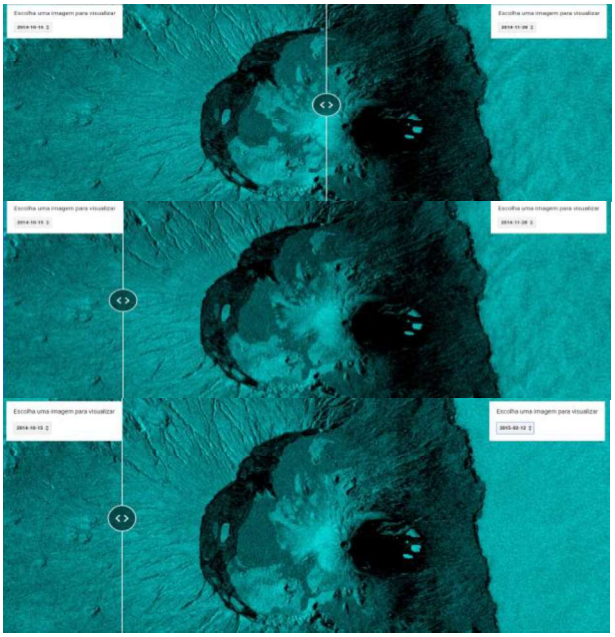

Figure 5. GEE-based application using S1 GRD data to observe the path of lava flows during the eruptive event. Above) Image from October 15th (2014) in a scenario prior to the eruption. Middle) Image from November 27th (2014) corresponding to the first hours of the eruptive event. Below) image from February 12th (2015) showing a post-eruption scenario. Application available at: <https://rafaelaptiengo.users.earthengine.app/view/fogocomparision>.

By selecting an image from before and after the eruptive event, the app is able to show the surface changes caused by the lava flow.

The use of GEE proves to be, therefore, a great asset to ensure greater speed of response, since it presents results in a matter of minutes after the script development.

4. Conclusion

Monitoring surface changes during eruptive events using S1 GRD data proved cost-effective in terms of data processing and analysis, with lower computational cost, and results consistent and coherent with those previously obtained with S1 SLC data or other types of

SAR data (including commercial high spatial resolution sensors). Therefore, this approach is pertinent and suitable for research but is especially valuable to integrate low-cost monitoring systems of active volcanic areas in near-real-time. The systematic use of GRD products can thus serve as the basis for event monitoring that confers greater agility in computation and analysis time for decision support. Furthermore, with the availability of the no-cost computing power provided by the GEE platform, and being GRD the only S1 data type currently available in the GEE catalog, this methodological approach can be considered as pertinent and cost-effective for supporting near-real-time monitoring and crisis management in active volcanic areas.

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