Initial Geophysical characterization of crustal deformation following the May 2021 Nyiragongo eruption and GPS network design for continued study

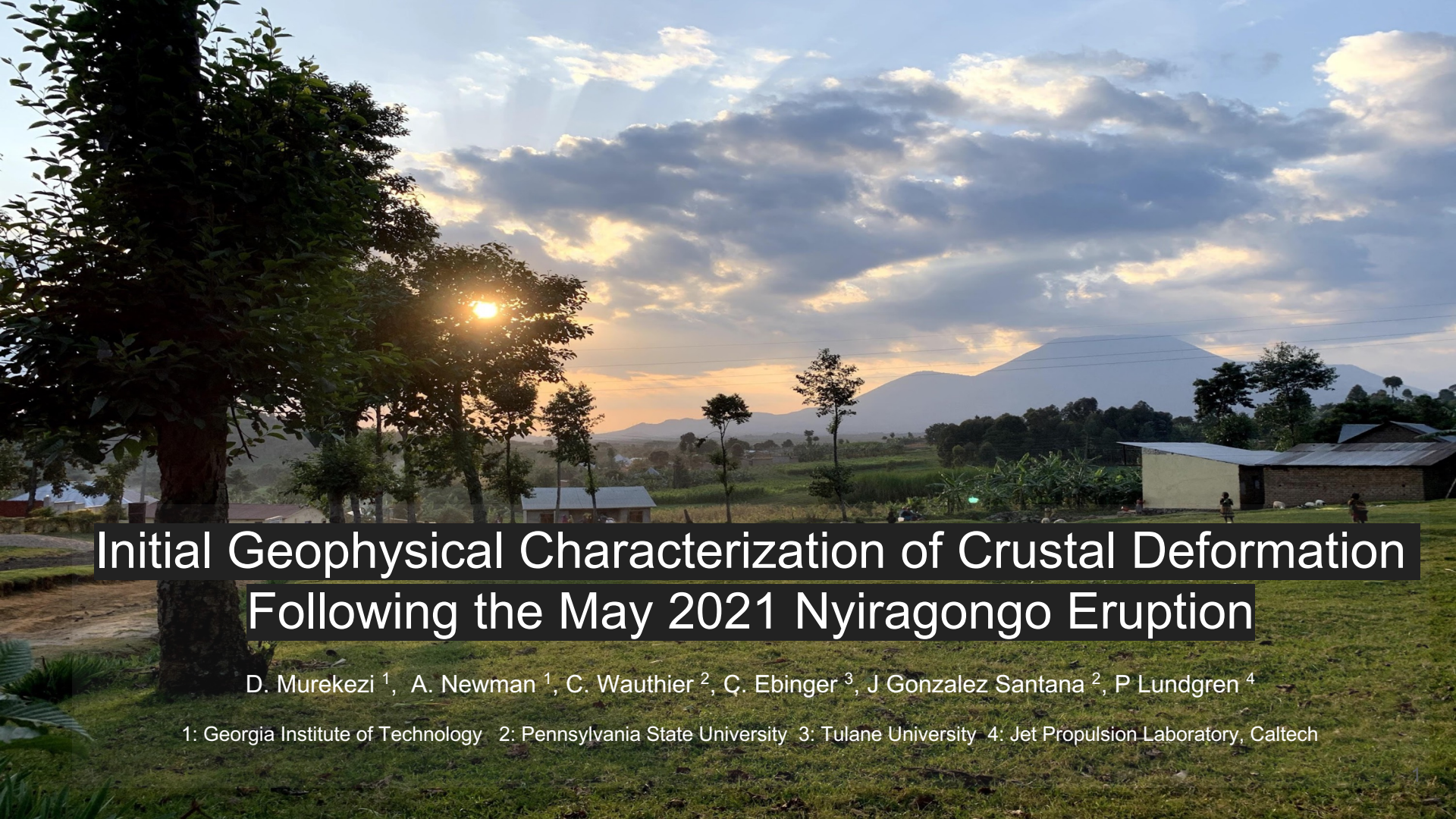
Derrick Murekezi[1], Andrew Newman[1], Christelle Wauthier[2], Cynthia Ebinger[3], Judit Gonzalez Santana[2], and Paul Lundgren[4]

[1]Georgia Tech
[2]The Pennsylvania State University
[3]Tulane University of Louisiana
[4]Jet Propulsion Laboratory, California Institute of Technology

November 23, 2022

Abstract

A combination of magmatic and tectonic processes occur on the western branch of the East African Rift System (EARS) driven by active volcanoes adjacent to active rift faults. Mt. Nyiragongo and Mt. Nyamuragira have the most recent eruptive histories of the 8 volcanoes in the Virunga Volcanic Zone (VVZ) located in a region between Rwanda, Uganda and Democratic Republic of Congo (DRC). On May 22nd 2021, Mt.Nyiragongo erupted the first major eruption following its 2002 eruption. This eruption didn't have the common precursory seismic activity expected before an eruption as was observed in the 2002 eruption seismic record. Rather, there were numerous post-eruption earthquake events with the largest of those events being a magnitude ML 5.1. Around the region of the earthquake swarm, there was observable ground deformation in the city of Goma and Rubavu where surface fissures destroyed houses and split roads apart. This deformation appears to be related to a N-S striking dike intrusion from the volcano trending south towards and under Lake Kivu, according to observed seismicity. In collaboration with the Government of Rwanda, following the May Mt. Nyiragongo eruption, we established a network of 6 seismometers (2 Meridian Compact PH and 4 Trillium Compact PH) operating at 100 sps and two complimentary raspberry Shake and Booms (SBS) around Lake Kivu. This study will focus on characterizing deformation associated with the eruption and the subsequent seismic swarm. Here we present model results based on deformation during the May 2021 eruption as recorded through ALOS InSAR scenes to understand slip concentration during the dike intrusion. Using GTDef, a set of algorithms developed in MATLAB that can incorporate a wide range of geodetic data types to model deformation observed on the Earth's surface, we model the slip distribution in this region based on the current hypothesis that the observed seismicity was a result of a dike intrusion defined by the southward propagation of the seismic swarm from Mt. Nyiragongo. Given an approximate source, we determine a preferred GNSS/GPS network design based on resolution-cost of additional stations at given locations and discuss first order characterization of the observed deformation.

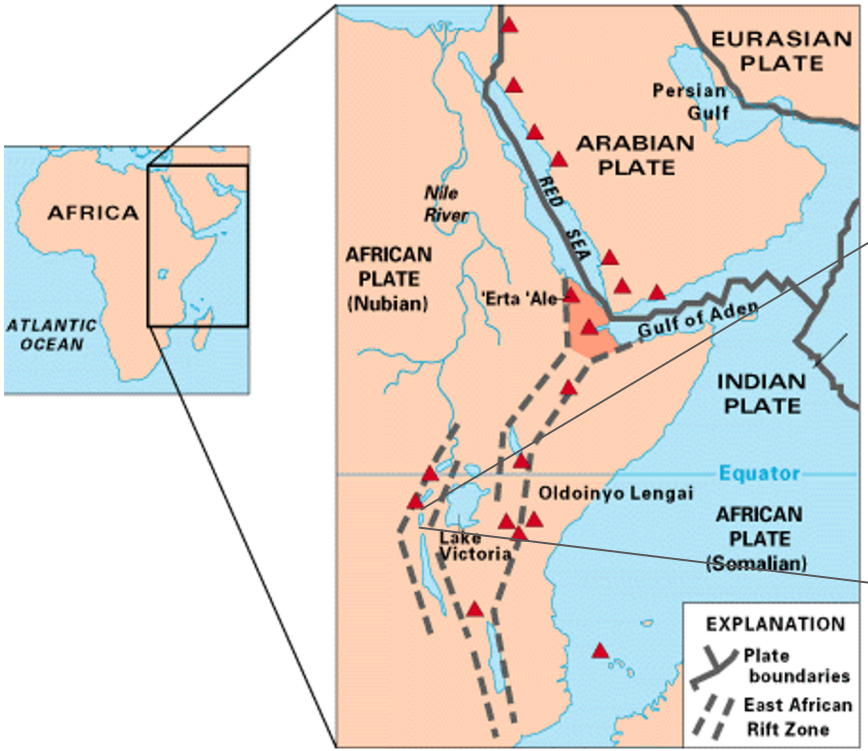


Initial Geophysical Characterization of Crustal Deformation Following the May 2021 Nyiragongo Eruption

D. Murekezi [1], A. Newman [1], C. Wauthier [2], C. Ebinger [3], J Gonzalez Santana [2], P Lundgren [4]

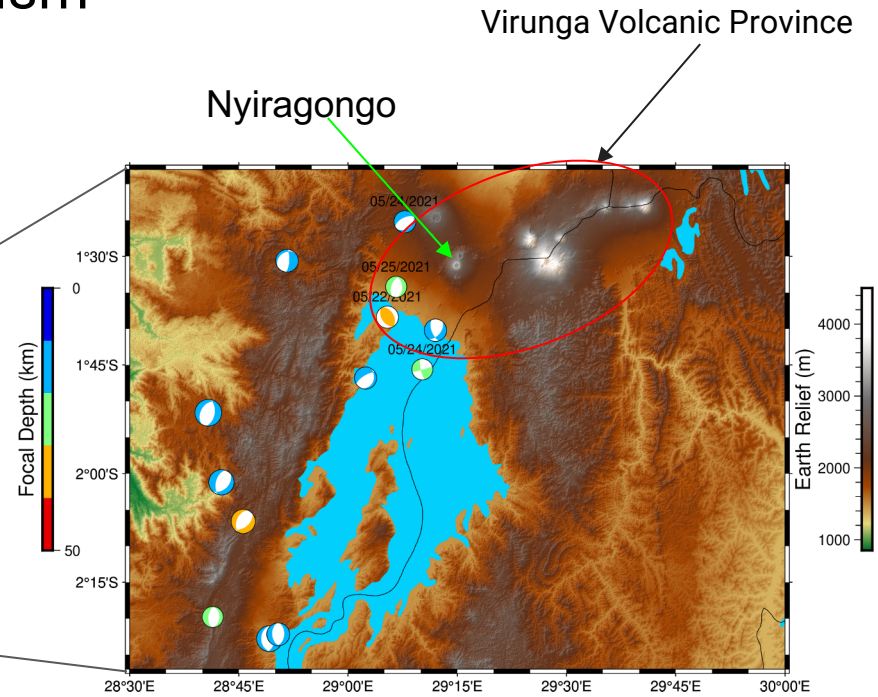
1: Georgia Institute of Technology 2: Pennsylvania State University 3: Tulane University 4: Jet Propulsion Laboratory, Caltech

East African Rift System and Volcanism

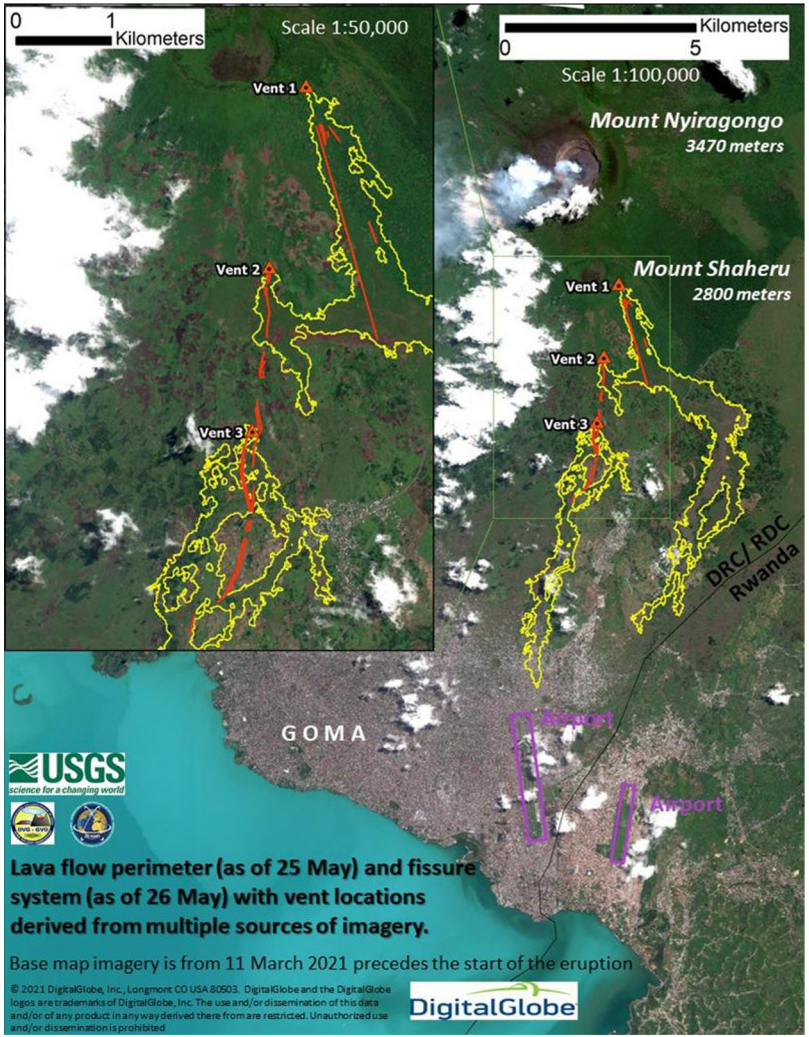


Branches of the East African Rift System

Source : USGS

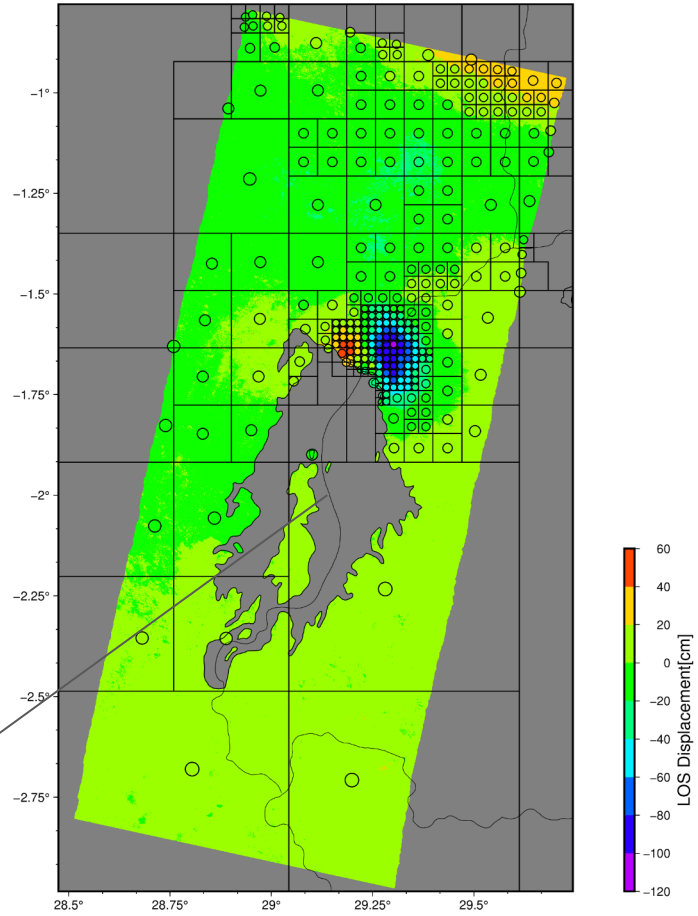


Kivu Rift System and 2002-2021 Seismicity


0 1 Kilometers
Scale 1:50,000
Vent 1
Vent 2
Vent 3
0 5 Kilometers
Scale 1:100,000
Mount Nyiragongo
3470 meters
Mount Shaheru
2800 meters
Vent 1
Vent 2
Vent 3
DRC/ RDC
Rwanda
GOMA
Airport
Airport
USGS
science for a changing world
Lava flow perimeter (as of 25 May) and fissure system (as of 26 May) with vent locations derived from multiple sources of imagery.
Base map imagery is from 11 March 2021 precedes the start of the eruption
© 2021 DigitalGlobe, Inc., Longmont CO USA 80503. DigitalGlobe and the DigitalGlobe logos are trademarks of DigitalGlobe, Inc. The use and/or dissemination of this data and/or of any product in any way derived there from are restricted. Unauthorized use and/or dissemination is prohibited
DigitalGlobe

Interferogram Subsampling

- We used a Quadtree technique to subsample the InSAR interferogram with position determined by center-of-mass of data
- We used the subsampled LOS displacement data to invert for the extent of ground opening due to the dike intrusion
- Inversion was computed using *GTDef*, a linear least squares inversion of weighted data



N-S Dike Intrusion

- Most deformation appears to be on the Rwandan side
- InSAR data shows maximum 6 m of opening in the area of most deformation
- More than 2 m of opening for over 15km length
- Opening appears more shallow (2 km) in the north than in the south (3 km)