VeRSUS

Studying and Monitoring Open-Vent Volcanoes from Space

Benoît Smets
Royal Museum for Central Africa, Belgium
What is a lava lake?

= Basin + open conduit + shallow reservoir

Model of persistent lava lakes
- Bi-directional flow of magma

Cyclic variations
- Gas piston effect
- Rising vs. sinking of magma

Sporadic and long term lava lake level changes
- Magmatic intrusions
- Flank eruptions
- Stress change
- ...

Harris (2008) - GRL
The VeRSUS Project: Objectives

1. Exploring and developing the capability of new satellites sensors to provide complementary quantitative information on the dynamics of persistent lava lakes.

2. Getting a better understanding of the source mechanisms of variations in the lava lake activity.

Satellites: Sentinel-1, -2, -3, 5P, COSMO-SkyMed, PlanetScope, Pléiades, ...
3. The VeRSUS Project: Case studies

Kīlauea (Hawaii, USA)
- LL activity: 2008-2018
- Well monitored lava lake
- LL drained in May 2018
- Best for pre-eruptive lava lake activity

Nyiragongo-Nyamulagira (D.R.Congo)
- LL activity: 2002 – Present
- Modern monitoring developed recently
- Best for studying LL persistence and LL “birth”

Photo © USGS
Photo © B. Smets
SAR Imagery – Lava lake level measurement (RESIST heritage)

SAR-shadow technique

\[
\text{depth (in m)} = \text{shadow} \times \cos (\varphi) \times \text{resolution (in m/pixels)}
\]

Courtesy of N. d'Oreye (ECGS)
SAR Imagery – Ground deformation (RESIST heritage)

InSAR and MSBAS time-series

Courtesy of N. d'Oreye (ECGS) and H. Geirsson (U. Iceland)
Photo-interpretation and mapping

Volcano: Nyamulagira
Sat.: PlanetScope

Volcano: Nyamulagira
Sat.: COSMO-SkyMed
2. Thermal Remote Sensing

Volcano: Nyiragongo
Sat.: Terra/Aqua MODIS

- P3 level (Ascending)
- Lava Lake level (Asc.)
- VRP (1-day hpfiler)
- VRP (90-day moving average)
SO$_2$ Emissions – TROPOMI: improved detection limit

**Sentinel-2 + Sentinel-5 Precursor composite image (17 June 2018)**

*Courtesy of N. Theys (BIRA)*
SO₂ Emissions – TROPOMI: improved detection limit

Sentinel-2 + OMI composite image (17 June 2018)
The VeRSUS Team

**AFRICA museum**

**B. Smets, F. Kervyn**
Optical/SAR Remote Sensing, UAV, Photogrammetry
Expertise on Virunga volcanoes

**N. Theys, H. Brenot**
UV-Visible-IR Remote Sensing
Expertise on SO$_2$/BrO gas emissions

**ECGS**

**N. d’Oreye, J. Barrière, A. Oth**
SAR Remote Sensing, Seismology, Geodesy
Expertise on Virunga volcanoes

**USGS**

**C. Kern**
UV-Visible-IR Remote Sensing
Expertise on Hawaiian volcanoes
## The VeRSUS Project: Expected outcome

<table>
<thead>
<tr>
<th>Deliverable</th>
<th>Due (Month, relative to the beginning of the operations of the project)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WP0: PROJECT COORDINATION</strong></td>
<td></td>
</tr>
<tr>
<td>D0.1 – Minutes of meeting</td>
<td>After each meeting M5, M30, M36</td>
</tr>
<tr>
<td>D0.2 – Periodic reports</td>
<td>M5, M30, M36</td>
</tr>
<tr>
<td>D0.3 – Steering committee organization</td>
<td>M15</td>
</tr>
<tr>
<td>D0.4 – Field mission plan and report</td>
<td></td>
</tr>
<tr>
<td><strong>WP1: VISIBLE-NIR AND RADAR OBSERVATIONS</strong></td>
<td></td>
</tr>
<tr>
<td>D1.1 – Updated time-series of lava lake level measurements (SAR-shadow technique)</td>
<td>M30</td>
</tr>
<tr>
<td>D1.2 – Updated InSAR MSBAS time-series on Nyiragongo, Nyamulagira and Kilauea</td>
<td>M30</td>
</tr>
<tr>
<td>D1.3 – Quantitative description of the eruptive activity using VNIR satellite imagery</td>
<td>M30</td>
</tr>
<tr>
<td>D1.4 – Ground-based measurements during a field expedition at Nyiragongo and Nyamulagira</td>
<td>M15</td>
</tr>
<tr>
<td><strong>WP2: THERMAL RADIATION</strong></td>
<td></td>
</tr>
<tr>
<td>D2.1 – Time-series of volcanic heat fluxes from various satellites</td>
<td>M30</td>
</tr>
<tr>
<td>D2.2 – Ground-based TIR camera measurements of the lava lake activity</td>
<td>M15</td>
</tr>
<tr>
<td><strong>WP3: SO₂ EMISSIONS</strong></td>
<td></td>
</tr>
<tr>
<td>D3.1 – Time-series of SO₂ fluxes from S5P TROPOMI</td>
<td>M30</td>
</tr>
<tr>
<td>D3.2 – Ground-based UV spectroscopy of volcanic plumes</td>
<td>M15</td>
</tr>
<tr>
<td><strong>WP4: INTERPRETATION OF MAGMATIC PROCESSES</strong></td>
<td></td>
</tr>
<tr>
<td>D4.1 – Improved 2D Modelling of the lava lake dynamics and the related magmatic intrusions</td>
<td>M36</td>
</tr>
<tr>
<td>D4.2 – Key aspects to use lava lake observations as a volcano monitoring tool</td>
<td>M36</td>
</tr>
</tbody>
</table>

### Expected output

- **Quantitative monitoring of lava lakes using multidisciplinary RS**
- **New insights** into lava lake dynamics
- **Key knowledge and tools** for further research and improved volcano monitoring