

RESIST



BELGIAN FEDERAL PUBLIC
PLANNING SERVICE
SCIENCE POLICY



Remote Sensing and In Situ Detection and Tracking of Geohazards:

4 years of landslides and volcanoes studies in the Kivu Basin

Royal Museum for Central Africa: F. Kervyn, O. Dewitte, E. Monsieurs, B. Smets, D. Delvaux, A. Dille

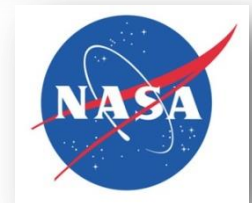
National Museum of Natural History: N. d'Oreye, G. Celli

European Center of Geodynamic & Seismology: A. Oth, J. Barrière

Centre Spatial de Liège: D. Derauw, L. Libert

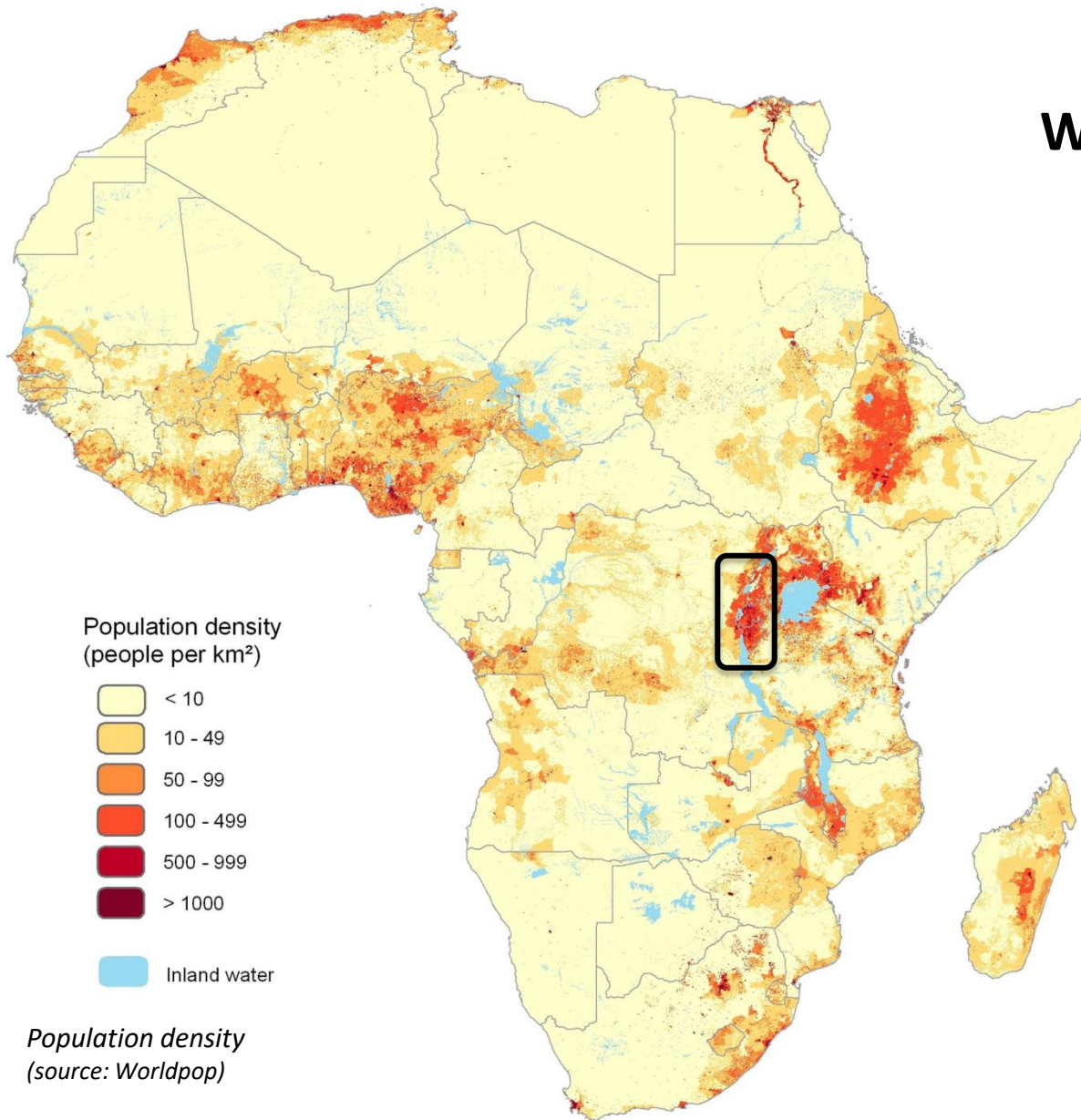
Belgium Institute of Space Aeronomy: N. Theys, H. Brenot

NASA: D. Kirschbaum



Why to study risks?

Why in the Kivu Basin?



- **Densely populated**
- **Convergence of major geohazards**
- **Poorly addressed**
- **Precarious humanitarian situation**



Scope

Capitalization on previous results

- Characterize the parameters that could / should be considered as significant in terms of volcanic and landslide (LS) activity in the Kivu rift area
- Understanding source mechanisms driving volcanic eruptions and landslides in the region

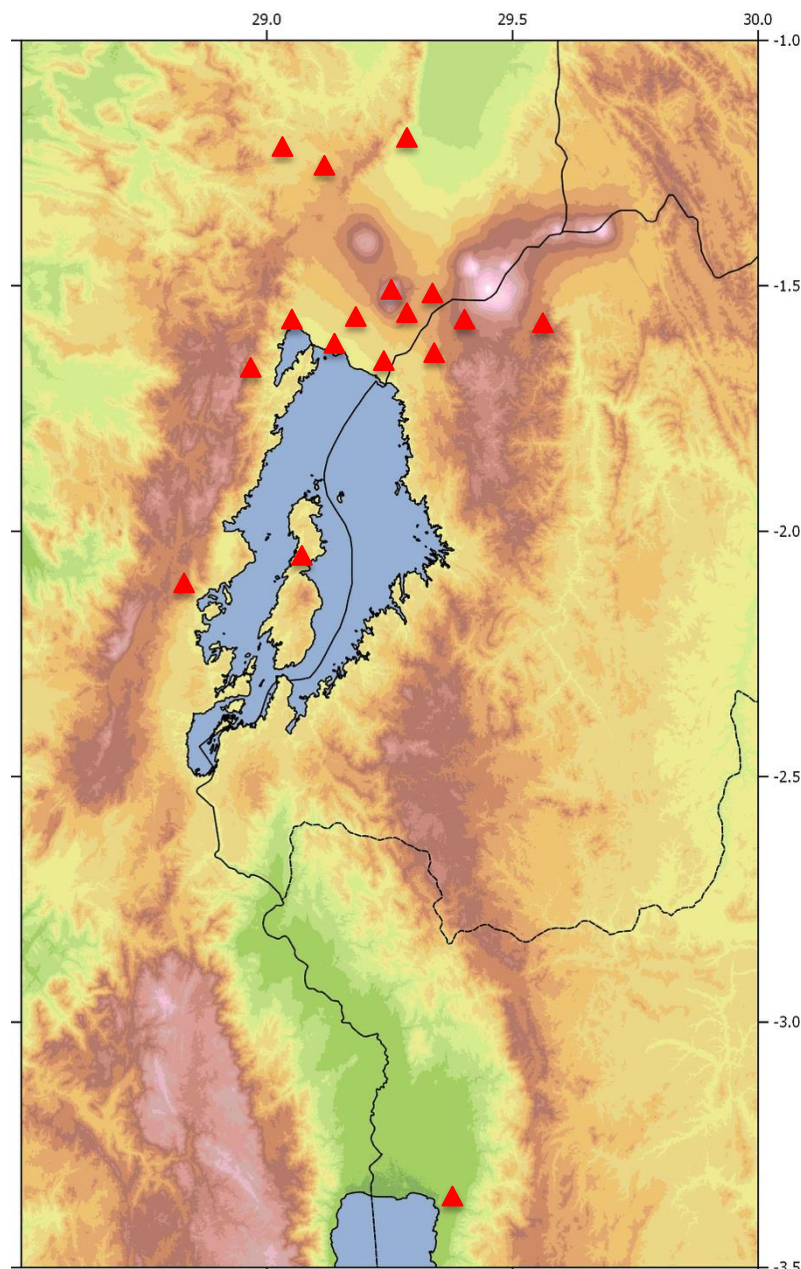
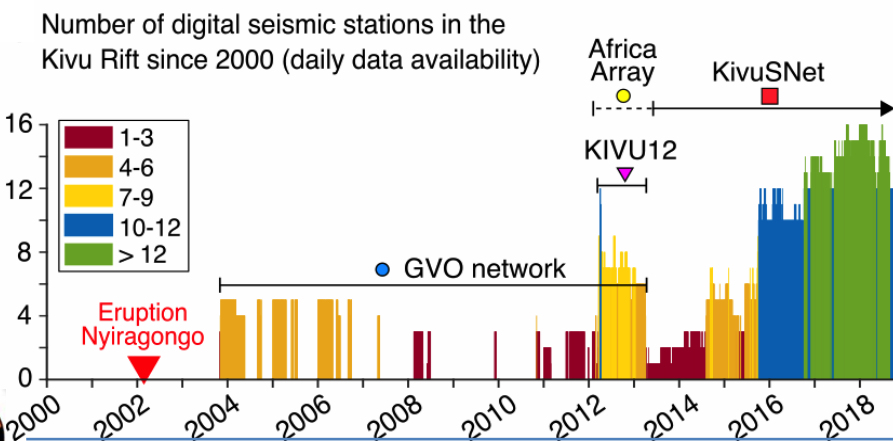
Main RESIST outputs

- Deployment of ground based networks (GNSS, seismic)
 - ➔ Drastic changes in the understanding of Nyiragongo / Nyamulagira volcanoes
- InSAR methodological development (tools and techniques)
- The combination of ground- and spaceborne techniques has lead to new understanding
- Before RESIST: no andslide reported. After RESIST, more than 7000 mapped and 200 characterized (time and type)
- The link with rainfalls is better understood
- New InSAR techniques applied and combined with close range sensing
 - ➔ Landslide processes at studied sites are better constrained

KivuSNet :

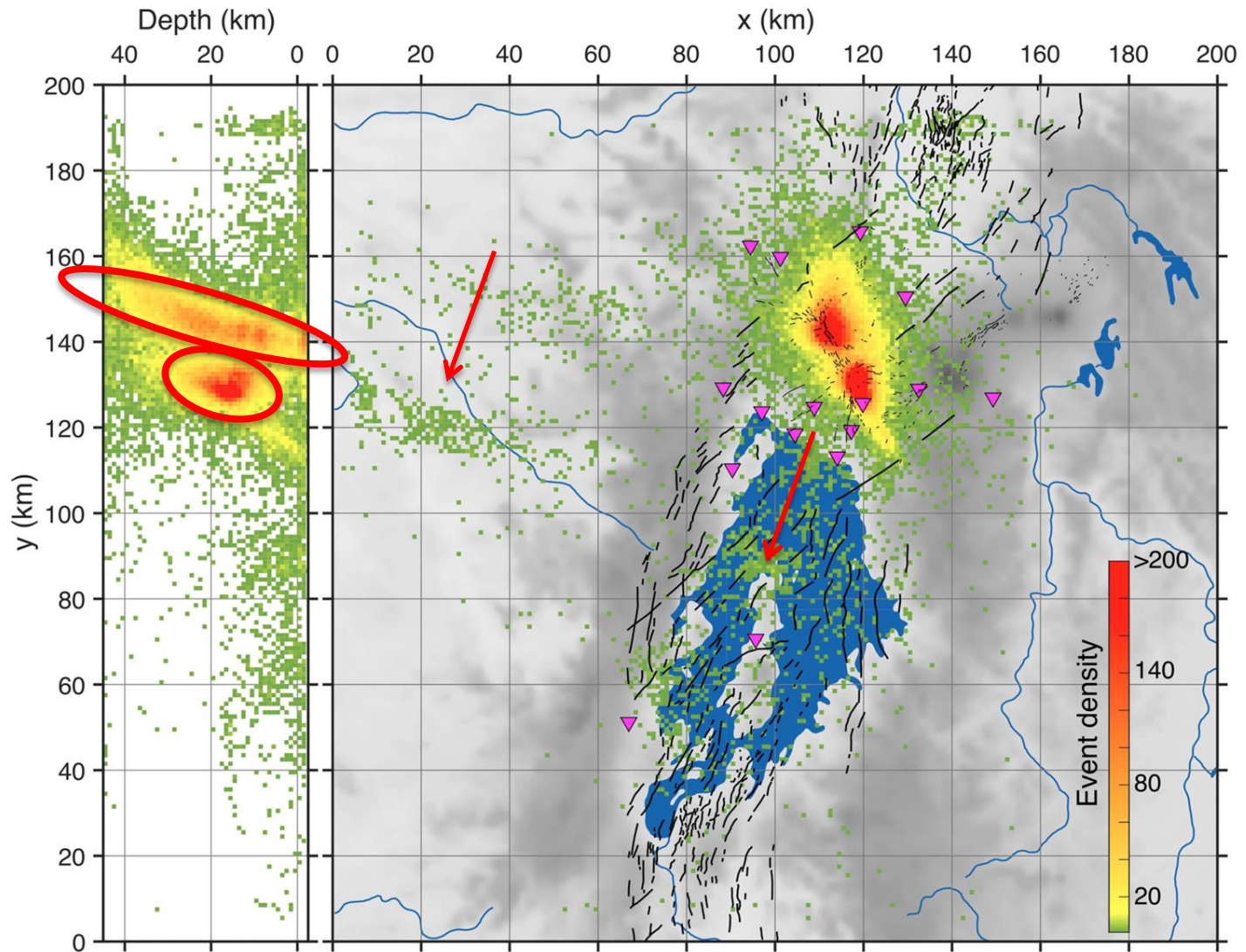
The First Dense Broadband Seismic Network for the Kivu Rift Region and Virunga volcanic Province (Oth et al., 2017)

- ➔ Instrumentation: **broadband seismometers and GNSS** + collocated infrasound
- ➔ Limited choices for secure station sites : currently 16 stations
- ➔ Overall good data quality
- ➔ Data sharing agreement with/btw local partners (DRC + Rwanda)



KivuSNet :

2015 - 2018: 46.107 events recorded



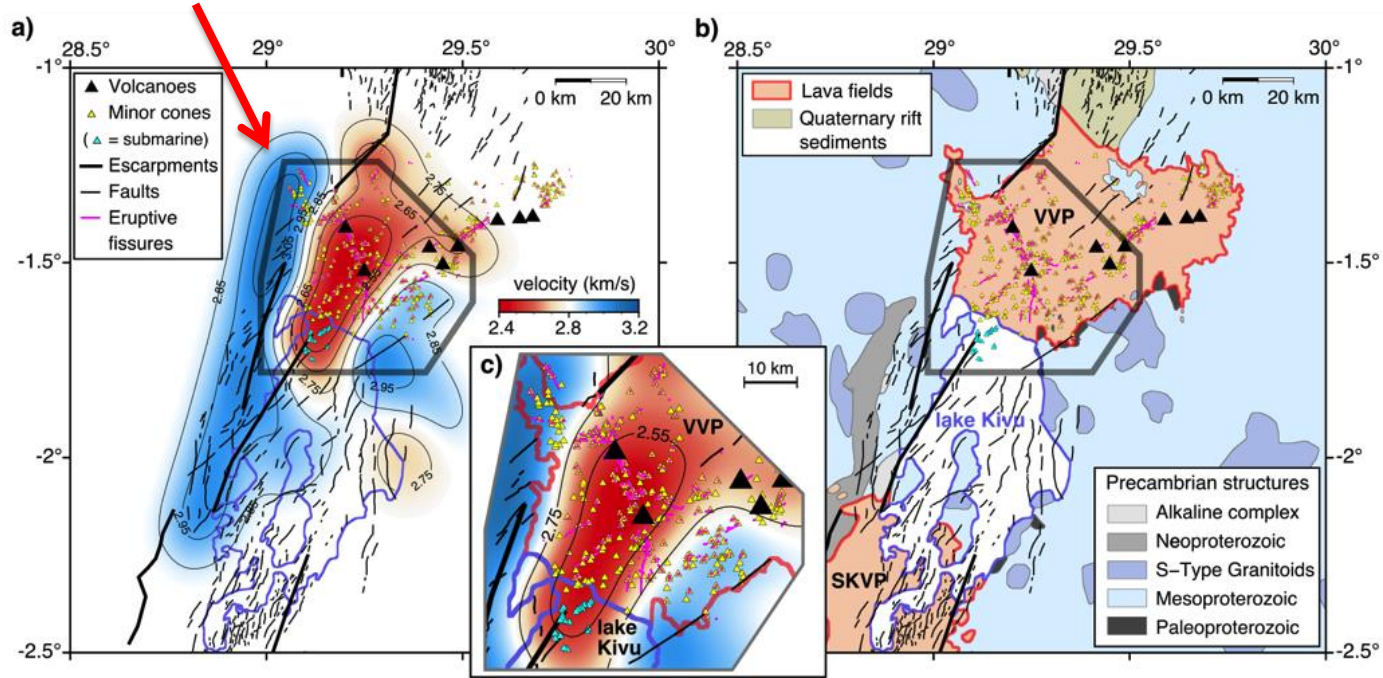
Seismic network

2D Tomographic image of the seismic wave velocity
→ the « CT scan » of the Virunga

→ Use of all available data since 2012 and continuous seismic signals generated by wave motion in the lake Kivu (lake microseisms)

→ 2D image of seismic velocity variations from the surface to 10-15 km depth

→ New insights into geological complexity: Low velocity anomaly from north of lake Kivu to active volcanoes

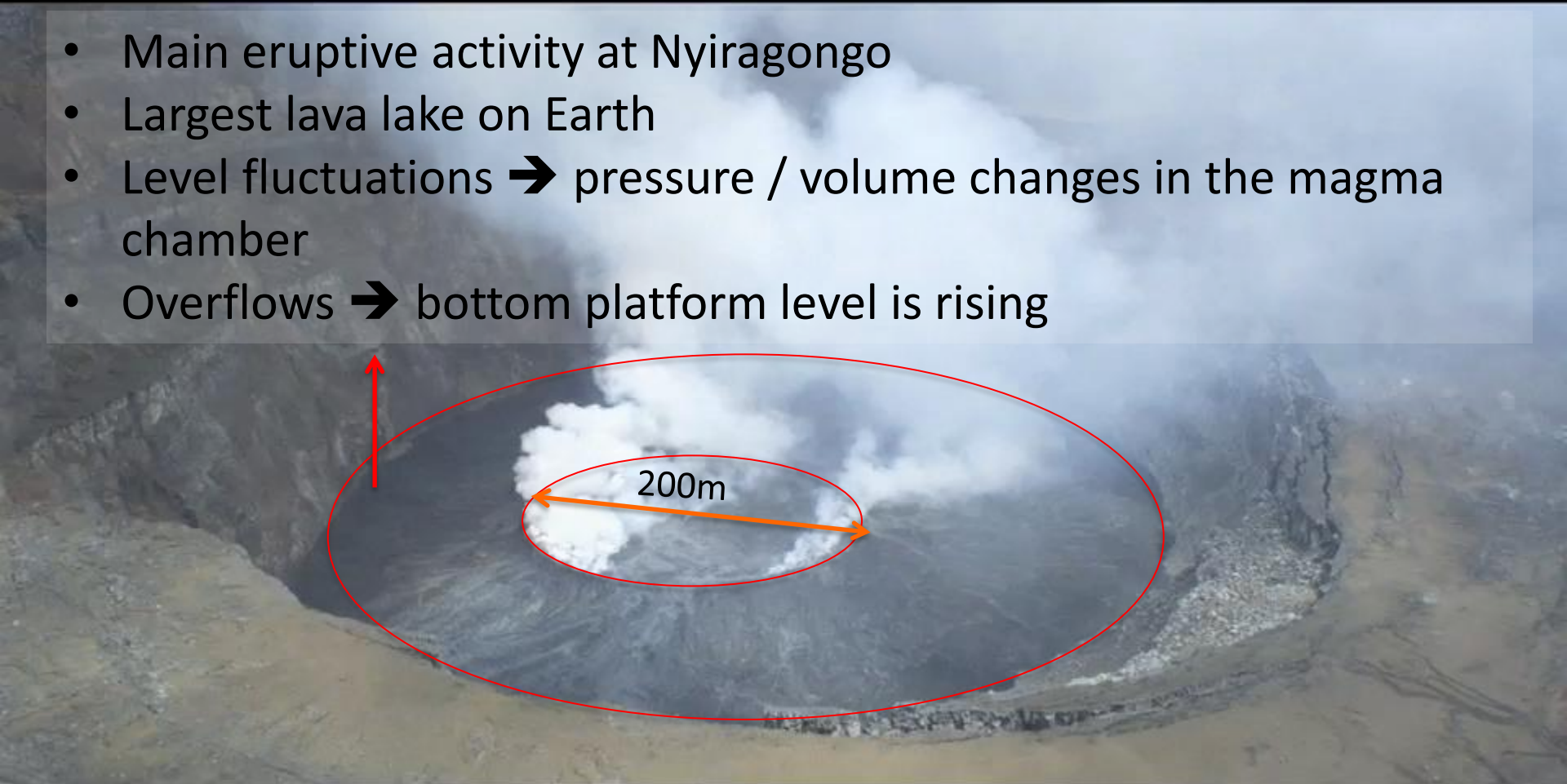


after Barrière et al. (in prep.)

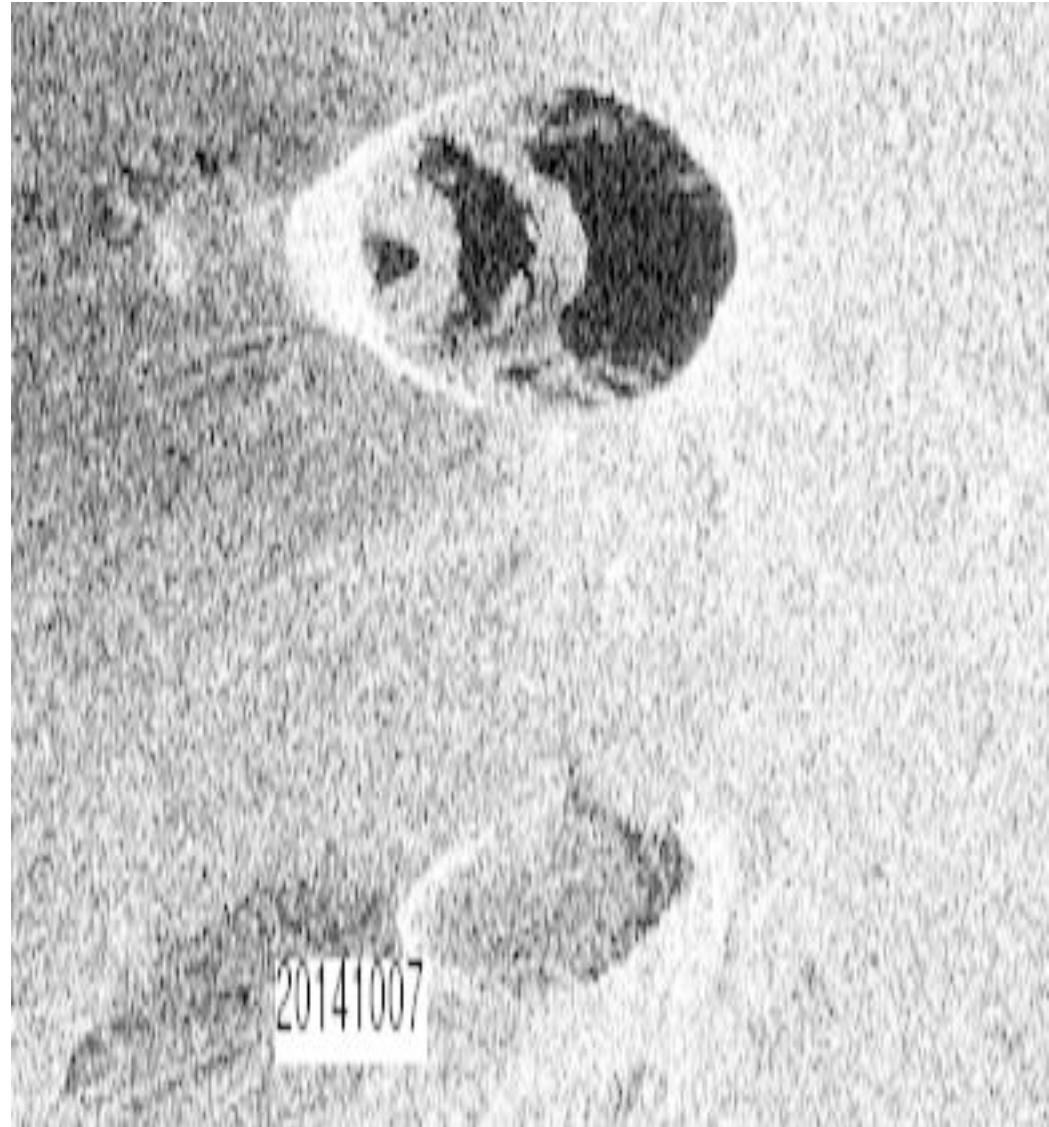
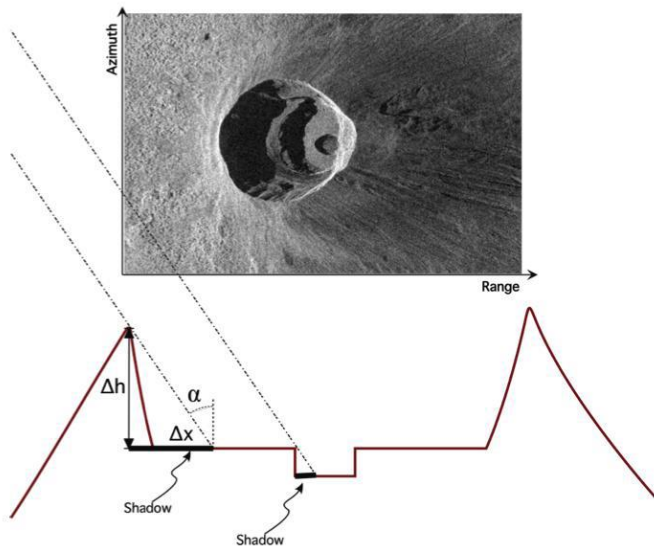


Studying lava lake dynamic

- Main eruptive activity at Nyiragongo
- Largest lava lake on Earth
- Level fluctuations → pressure / volume changes in the magma chamber
- Overflows → bottom platform level is rising



Studying lava lake dynamic



SAR amplitude images :

- Casted shadow
- Monitoring lava lake evolution
- Monitoring platforms elevation

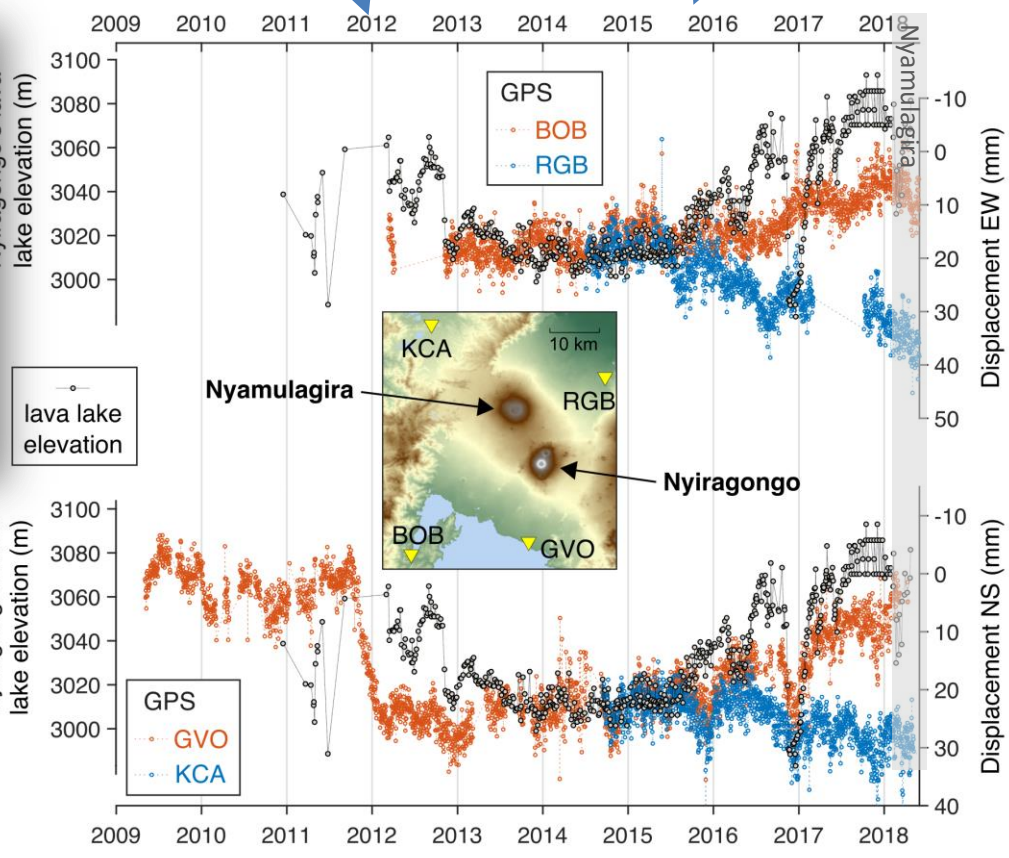
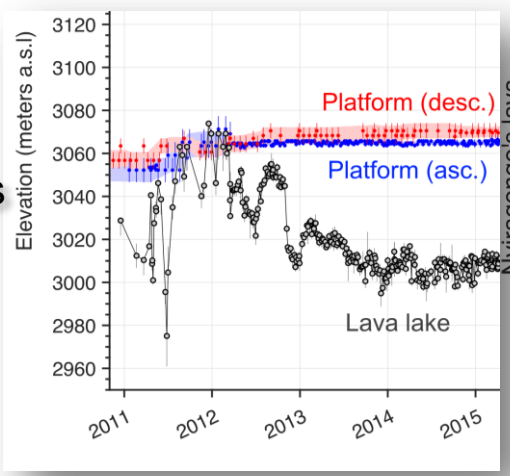
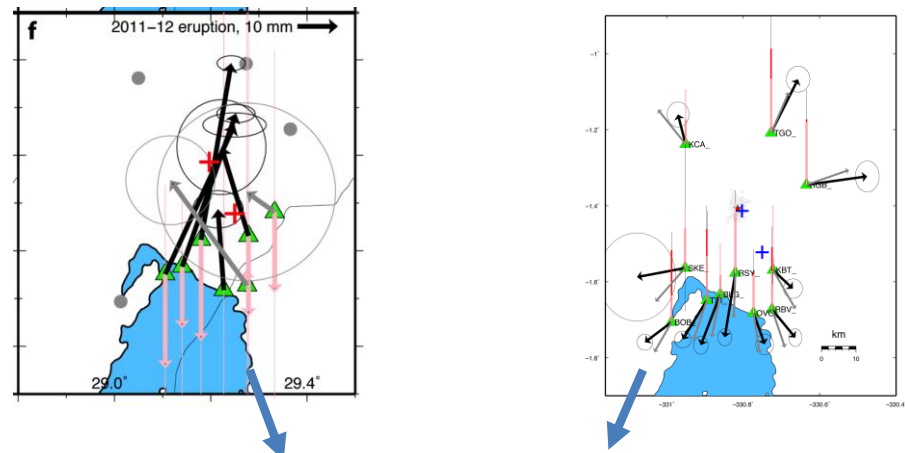
Comparison of RS / ground based GNSS lava lake level measurements :

- 2012 eruption at Nyamulagira : co-eruptive deflation. Best model from GNSS = deep source at Nyamulagira, i.e. drainage of deep reservoir.

- After 2012 eruption, lava lake level drops below P3 in Nyiragongo

- Lava lake level remains at low level until mid 2015

- At the same time, start to observe signal with GNSS (>< 2012). Best model = deep source at Nyamulagira, i.e. magma recharge of deep reservoir.



First evidence of interaction between Nyiragongo and Nyamulagira magmatic system !!

Measurements of volcanic SO₂ emissions



Objectives: SO₂ flux measurements

1. Spaceborne:

OMI (from 10.2004)

TROPOMI (from 11.2017)

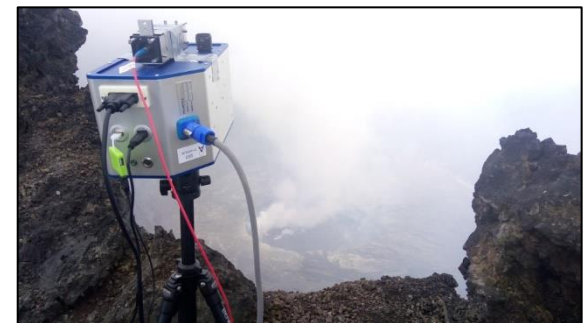
→ good spatial coverage, study of **daily to multi-annual changes** in SO₂ emissions



2. Ground-based :

UV camera and scanning spectrometers

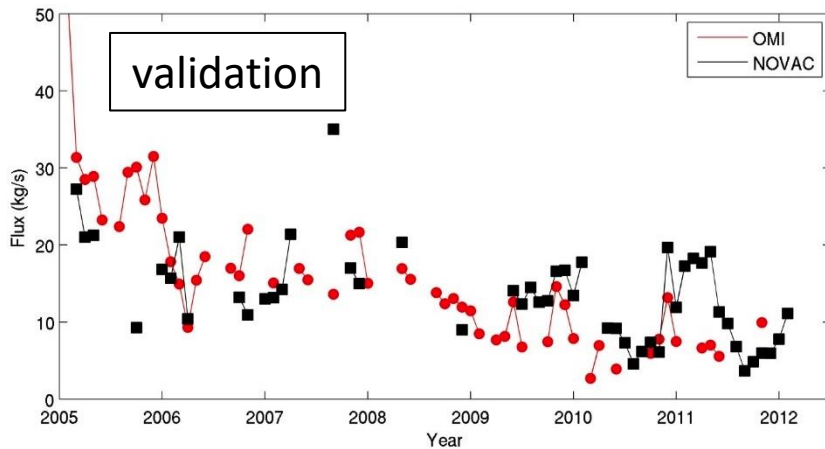
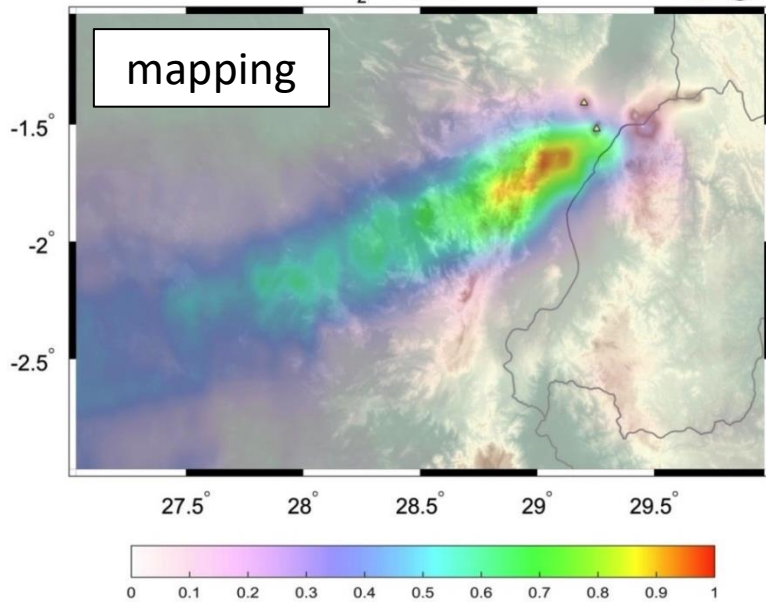
→ observations close to the source, study of **fast changes (minutes)** in SO₂ emissions



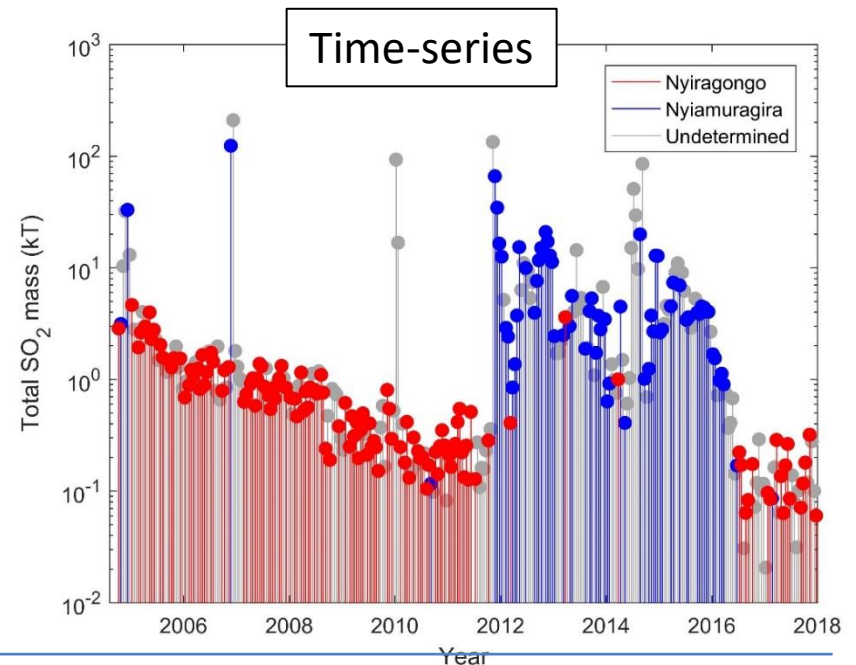
Satellite observations



OMI SO₂ VC [DU] Feb 2006

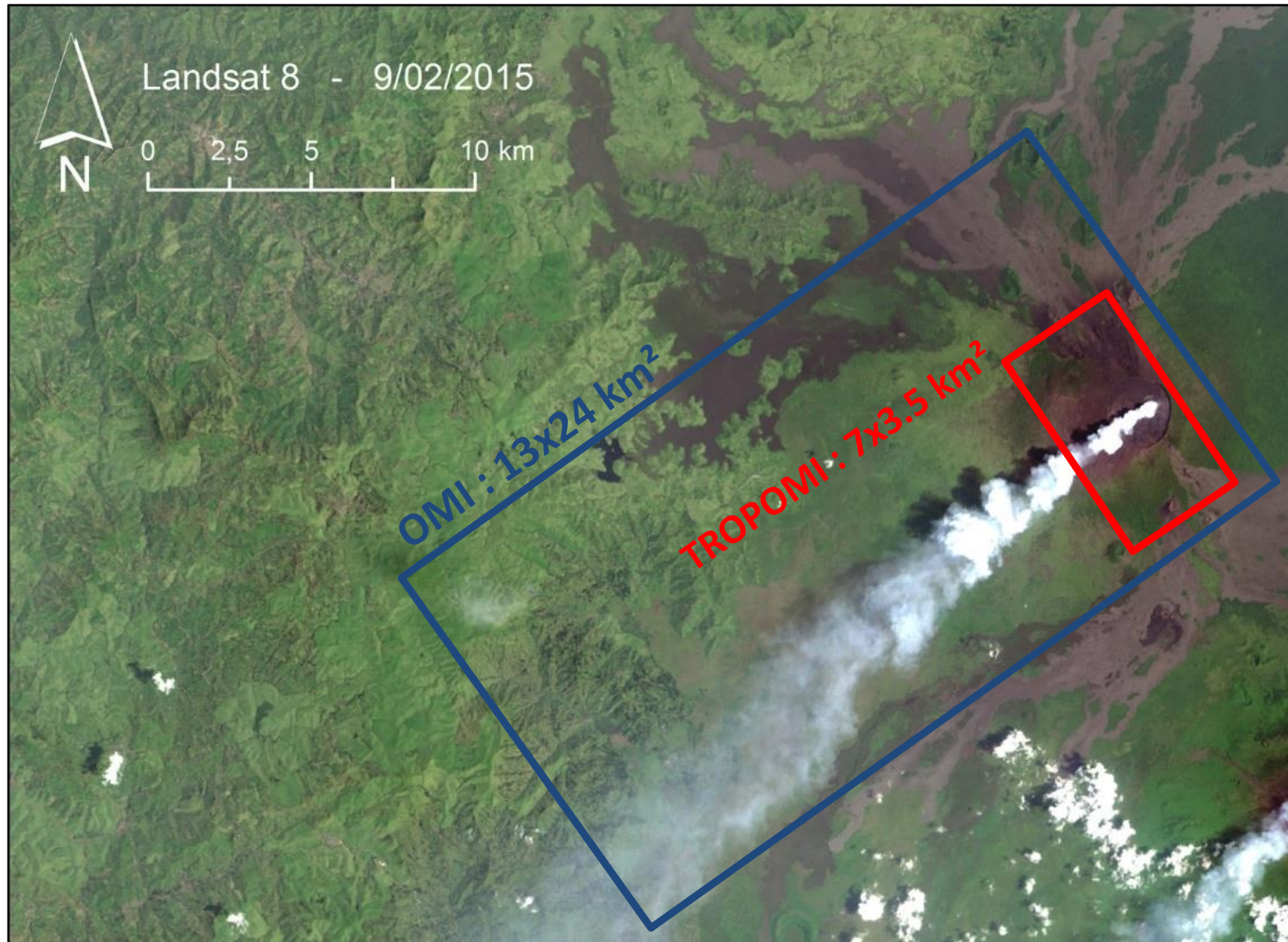


- OMI SO₂ mass time series (14 years) has been generated and consolidated through intercomparison with ground-based data (NOVAC) and seismic data (WP6).
- Development of a technique to discriminate the sources from SO₂ mapping (oversampling).



New TROPOMI satellite: game changer!

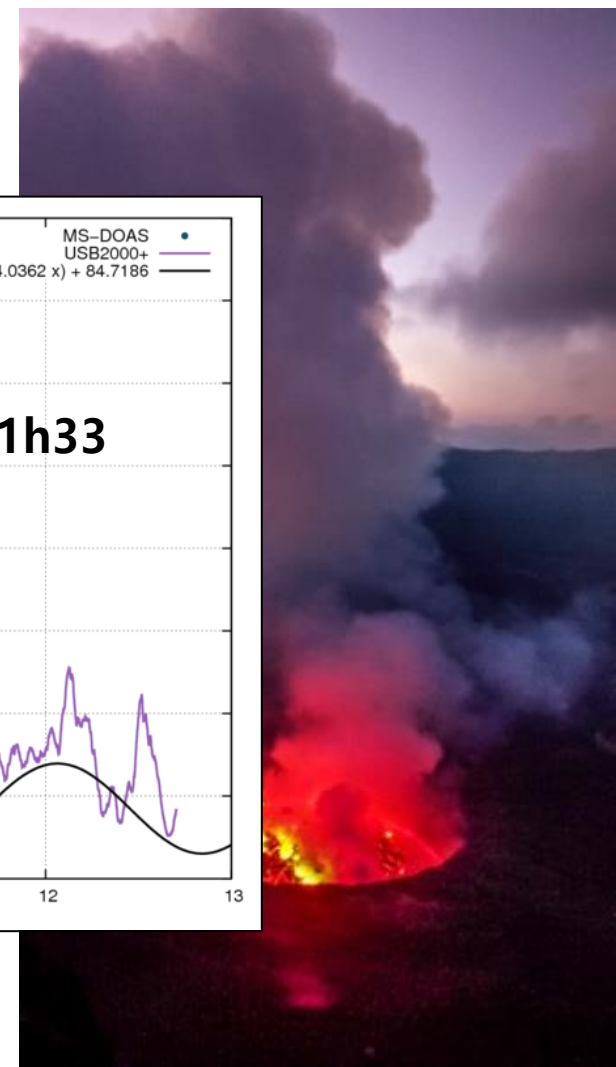
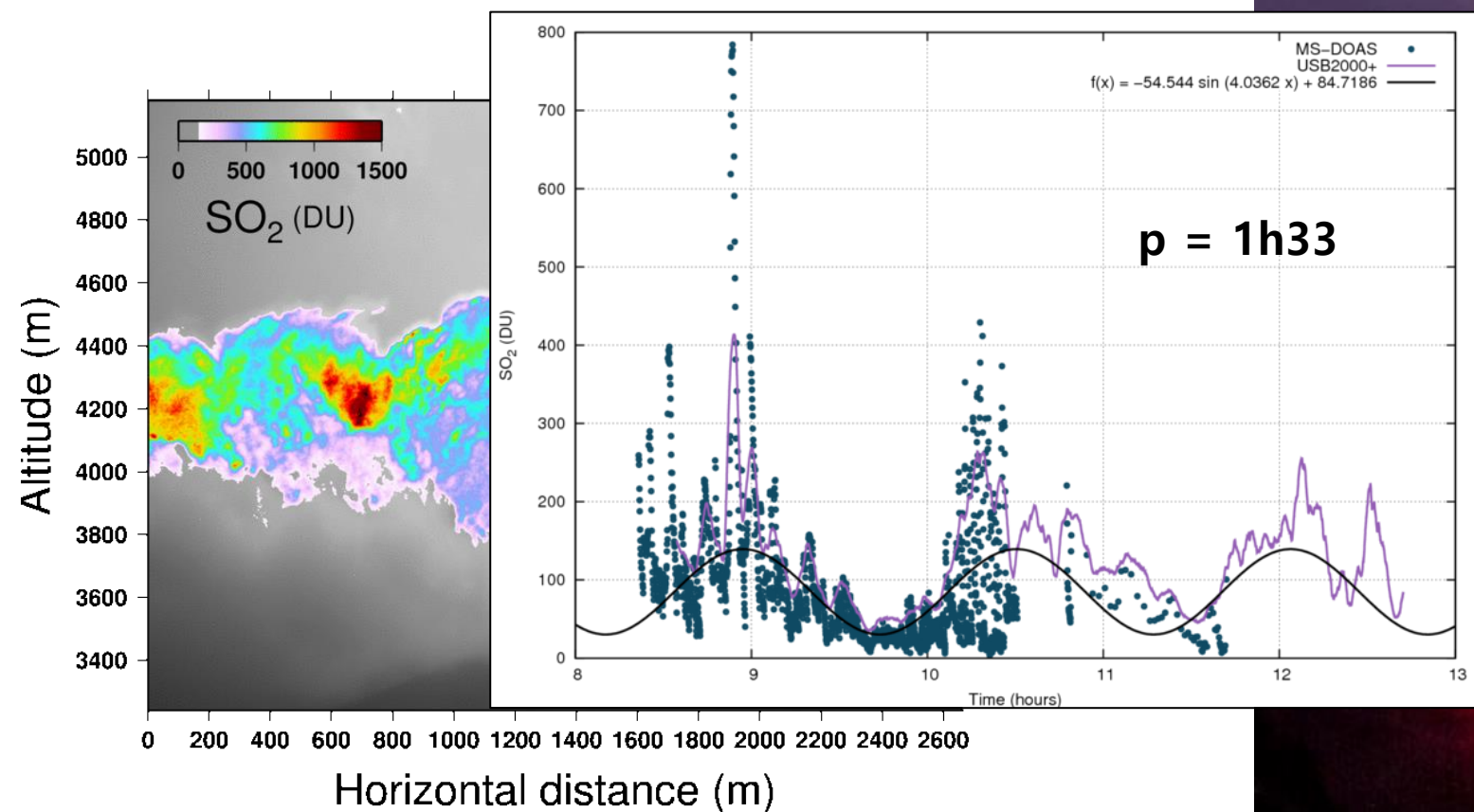
Better spatial resolution => Improved detection limit, better source discrimination (work in progress)



Ground-based measurements



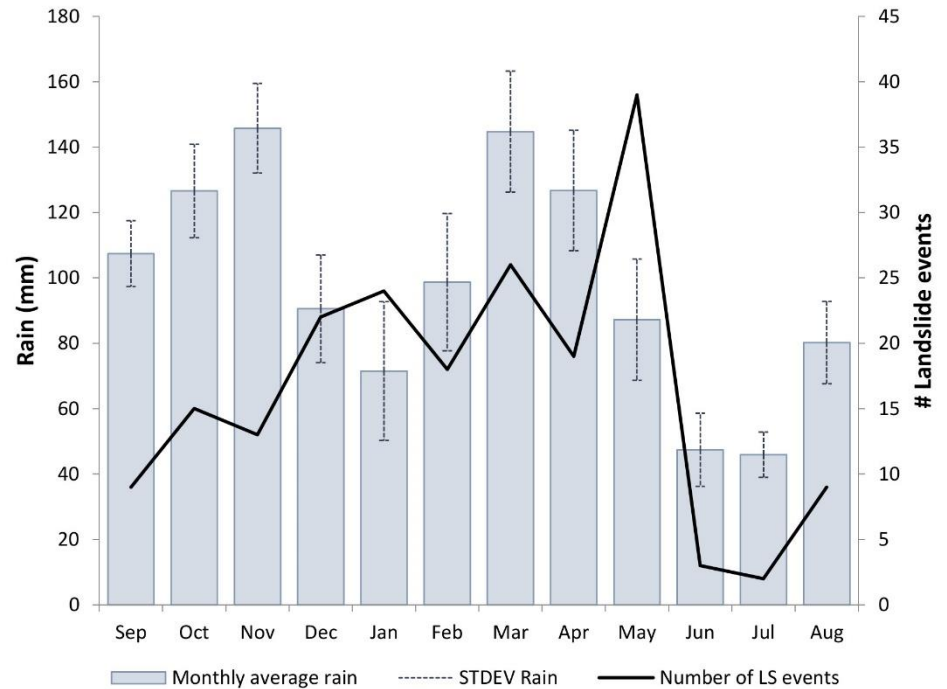
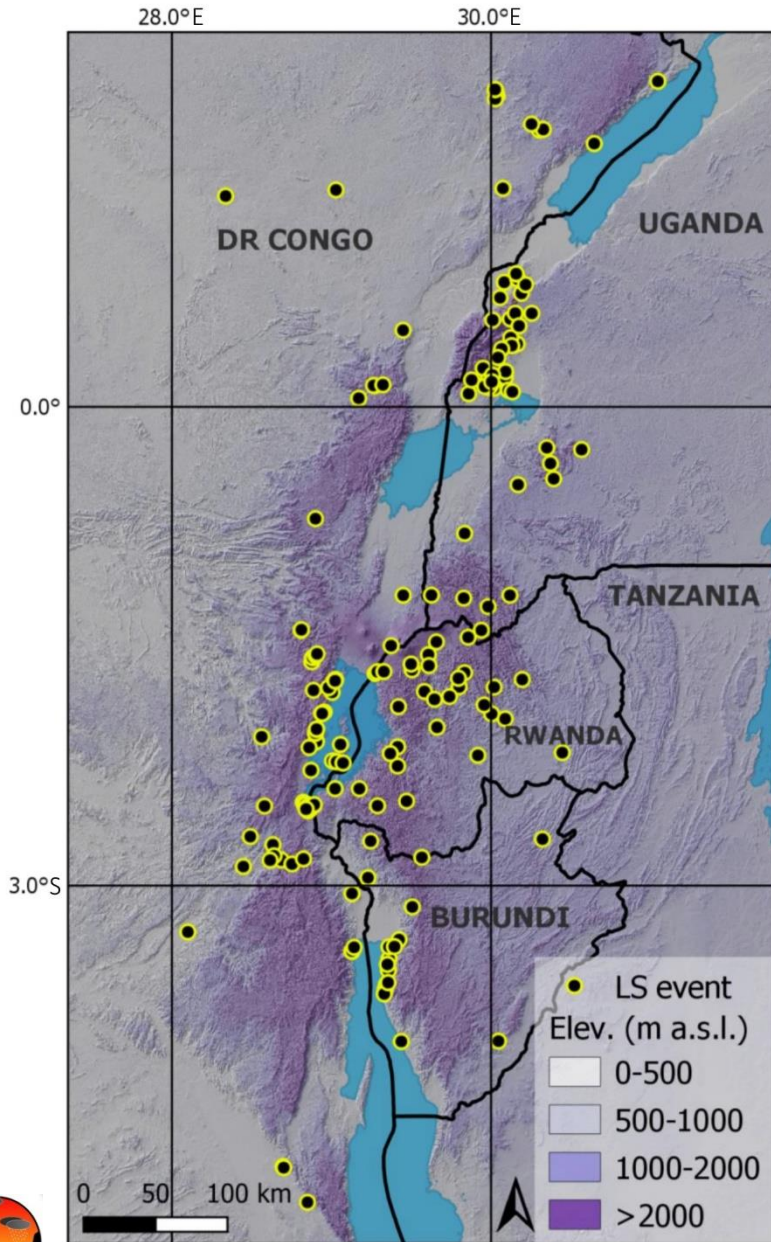
- Study of Nyiragongo lava lake SO₂ emissions at **high temporal resolution**, evidence of cyclicality.
- **Complementary instrumentation**, UV imagery and spectrometers



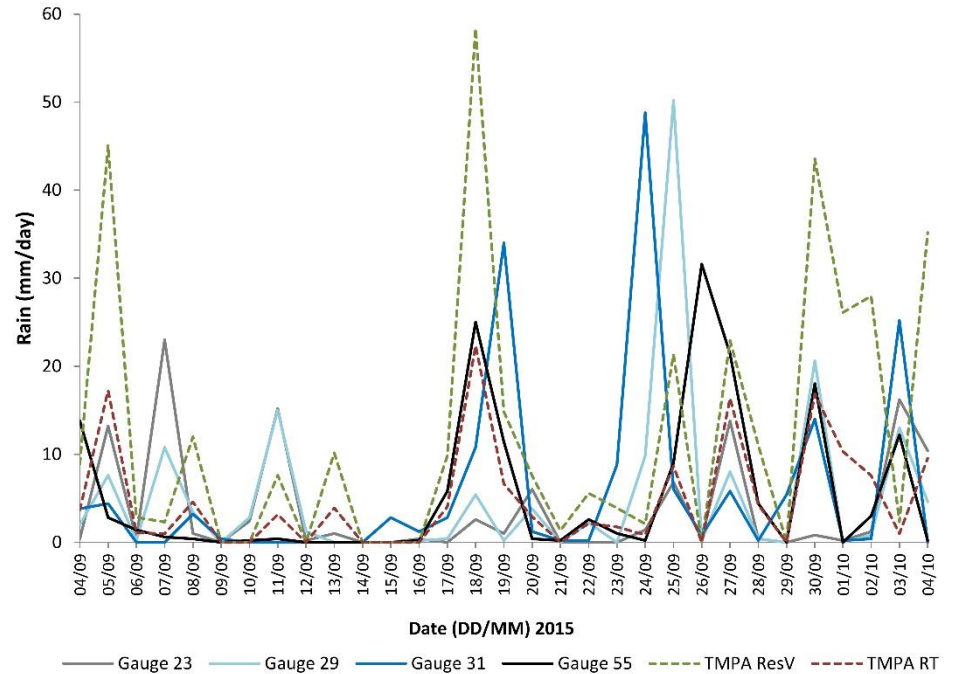
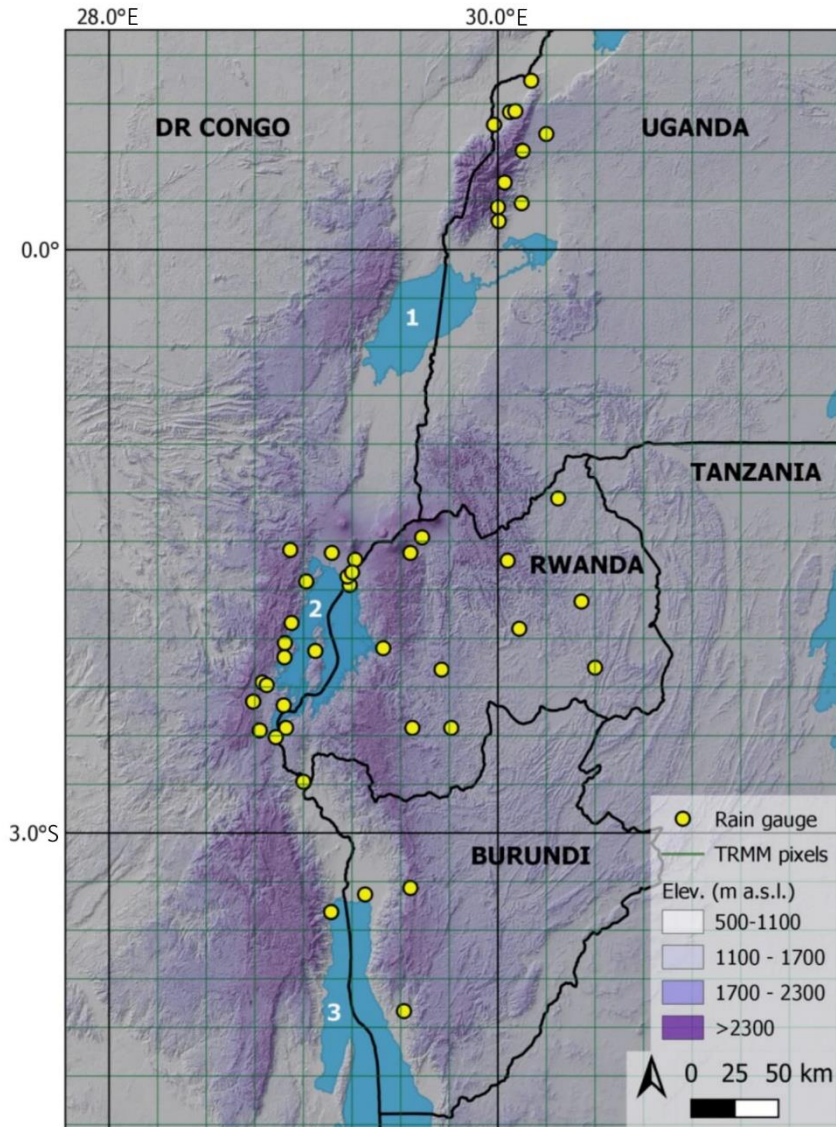
Landslide hazard assessment



Landslides in the WEAR



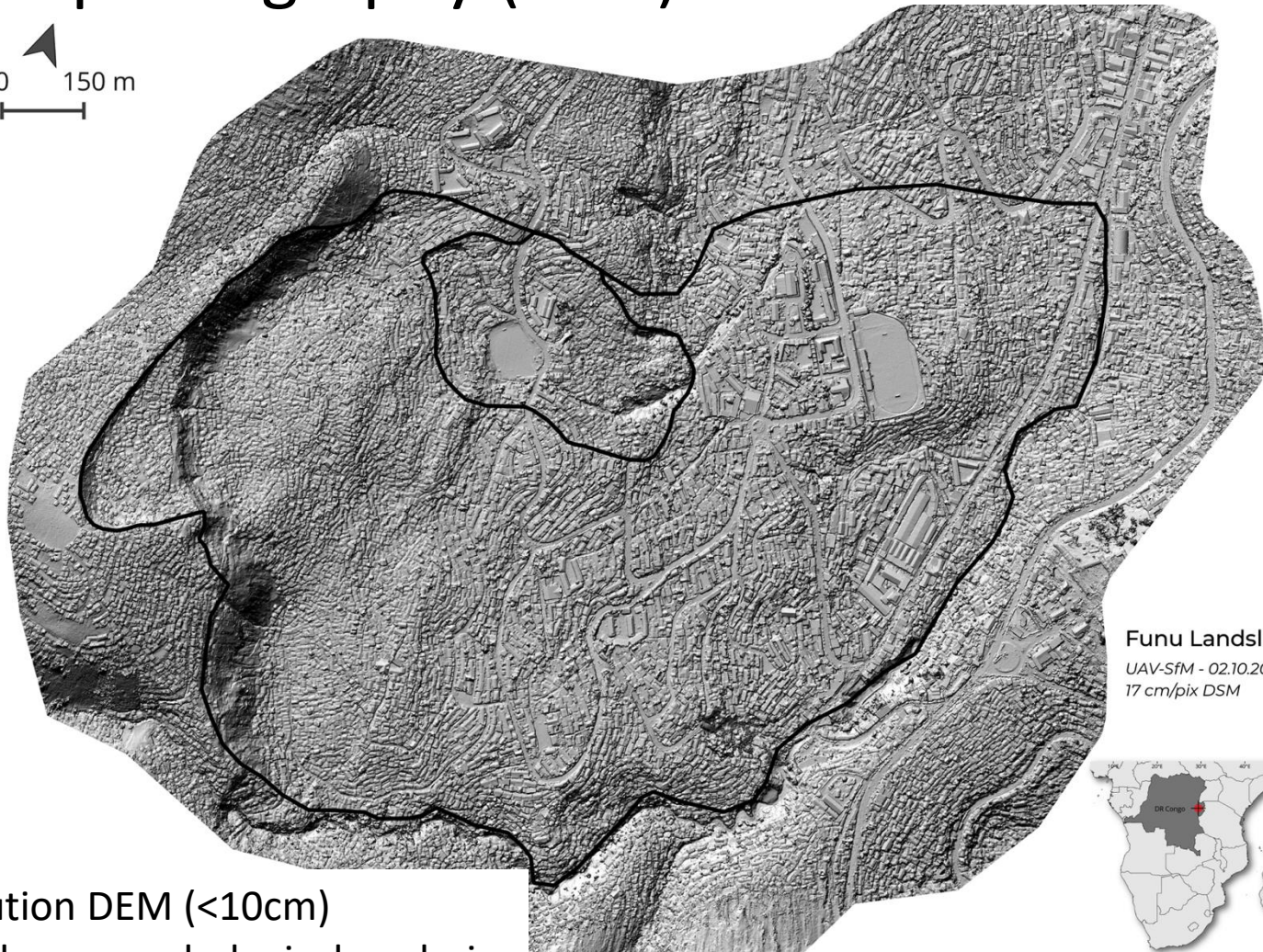
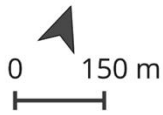
Rainfall data



Field & close range sensing observations



Aerial photography (UAV)



Funu Landslide
UAV-SfM - 02.10.2017
17 cm/pix DSM

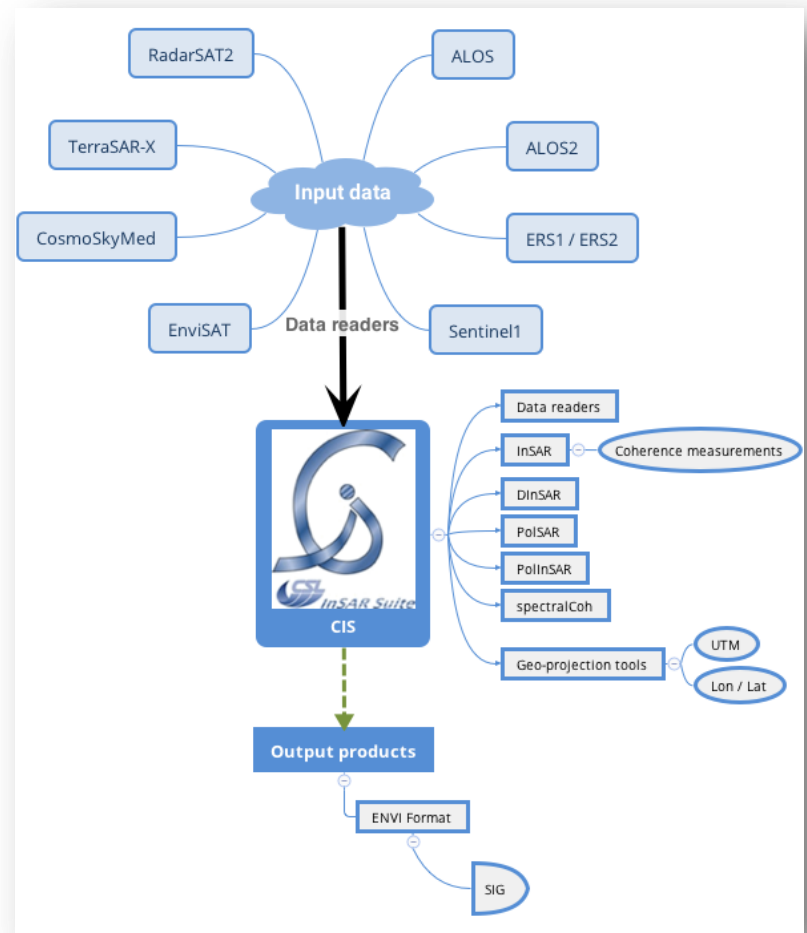


- High resolution DEM (<10cm)
- Detailed geomorphological analysis
- Time series → study of the dynamic
- Merging with precipitation data



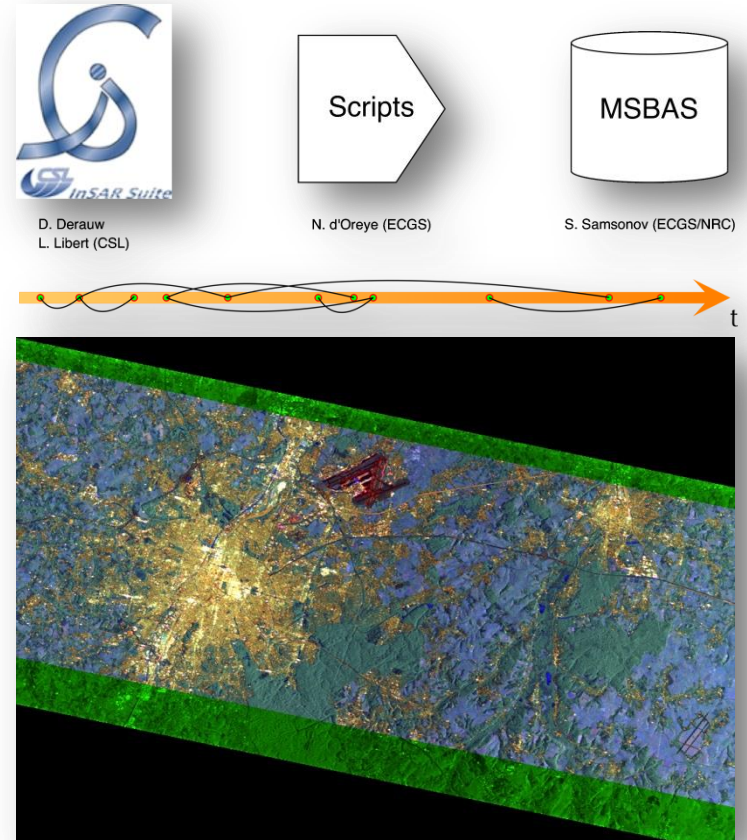
CSL InSAR Suite

- An in-house interferometric processor performing all InSAR processing steps.
- Differential InSAR, Split-Band, Polarimetry
- Multi sensors
- Specifically adapted to automatisisation
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 - Mass processing

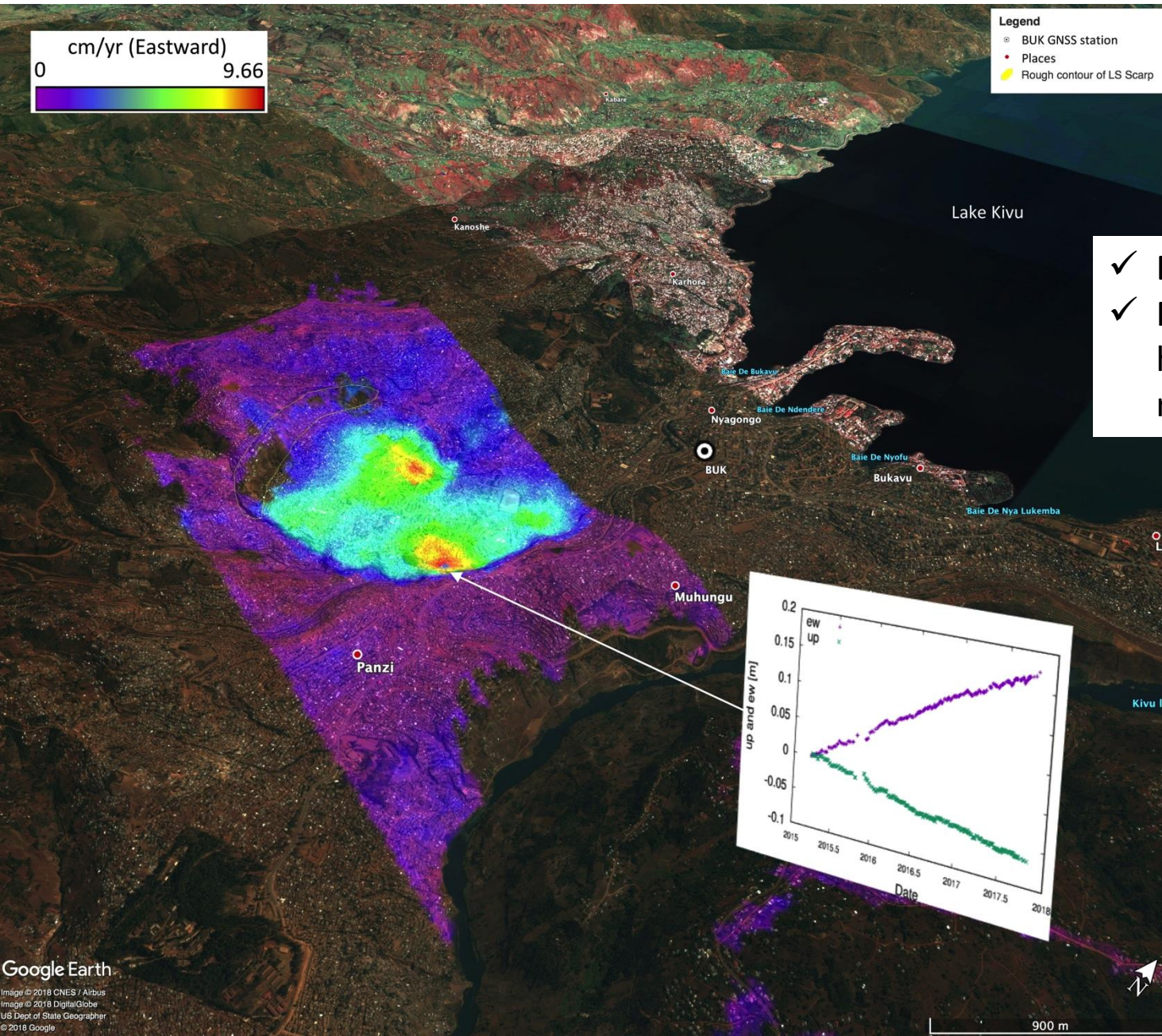


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MSBAS InSAR for ground displacements mapping



- ✓ Displacement in 2D
- ✓ Multi-sensors → higher temporal resolution

Main RESIST outputs

- Monitoring capacities have drastically improved and ready for operational setup
- Scientific community attention has been raised
 - ➔ In-situ data
 - ➔ Virunga Super Sites
 - ➔ CEOS Landslides
- At the local/regional levels strong interactions between scientists and decision makers
 - ➔ improved understanding
 - ➔ risk awareness has raised

Main RESIST outputs

- 22 peer reviewed publications (2015 – 2018)
- > 10 MSc students from the South supervised
- 2 ongoing PhD (South) + 2 initiated (South) in a new project
- 3 PhD (North)

Web sites

- www.virunga-volcanoes.org
- <http://resist.africamuseum.be>

Media

- Scientific expedition organized for BBC