

A multi-sensor satellite method to spatial and temporal detection of landslides and flash floods in cloud-covered tropical environments: the western branch of the East African Rift

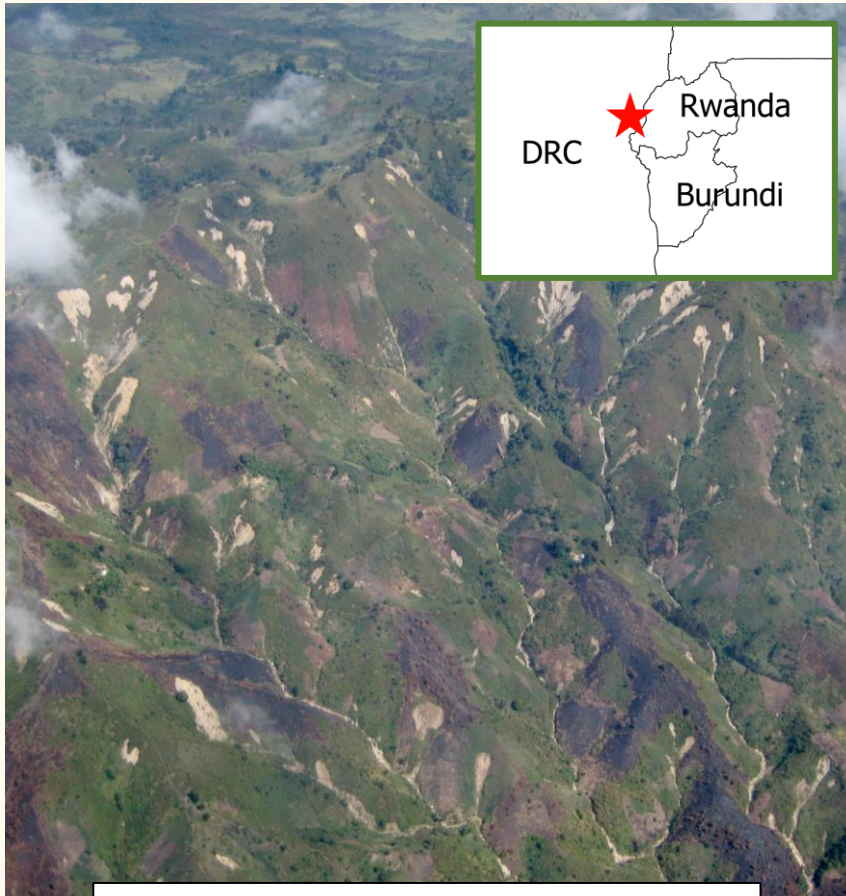
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Geomorphic hazards

Landslides



DRC – Kalehe

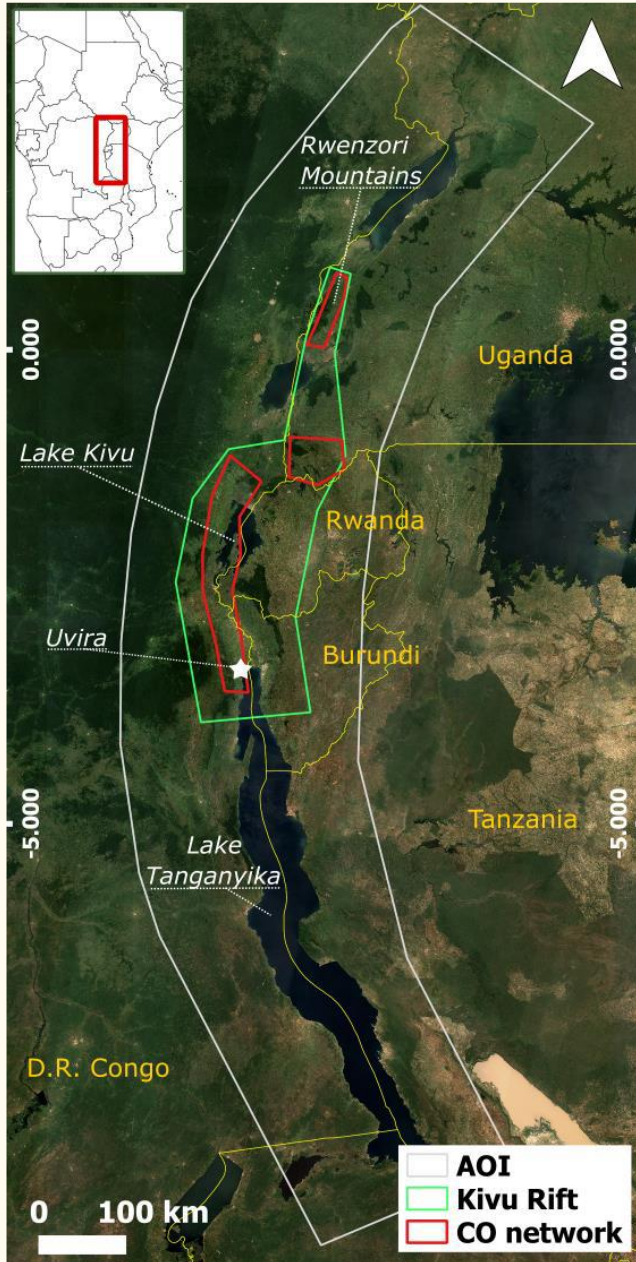
Flash floods



DRC – Uvira

Landslides and flash floods often result from a combination of complex interacting physical (rainfall) and anthropogenic processes across multiple spatial and temporal scales. In many instances, landslides and flash floods occur very quickly, sometimes in a matter of a few hours. Landslides and flash floods frequently co-occur and interact, leading to more severe impacts

Western branch of the East African Rift

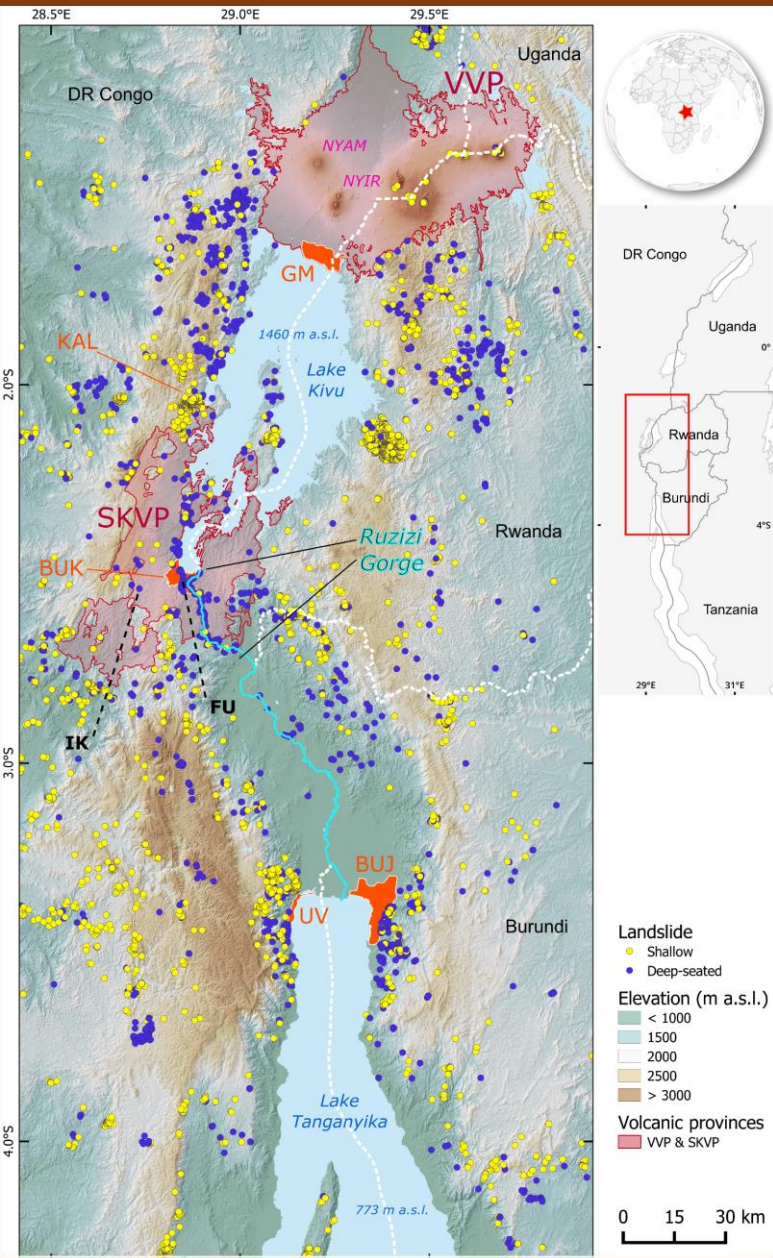


The research is carried out in the Western branch of the East African Rift, a tropical region, which is characterized by:

- Very high density of geomorphic hazards
- Strong north-south climate gradient (variability of the ITCZ)
- Hot spot of environmental change
- High population densities and uncontrolled urbanization (increased exposure)
- Uncontrolled deforestation
- Data scarcity
- Citizen-observer networks for validation and additional information ([Rwenzori Mountains](#), [Kigezi](#), [Kivu](#))

Figure: Western branch of the East African Rift. (white) location of the study area, (green) location of the Kivu Rift region where multiple landslide inventories are available. (red) The location of the citizen observer networks.

Regional scale problem



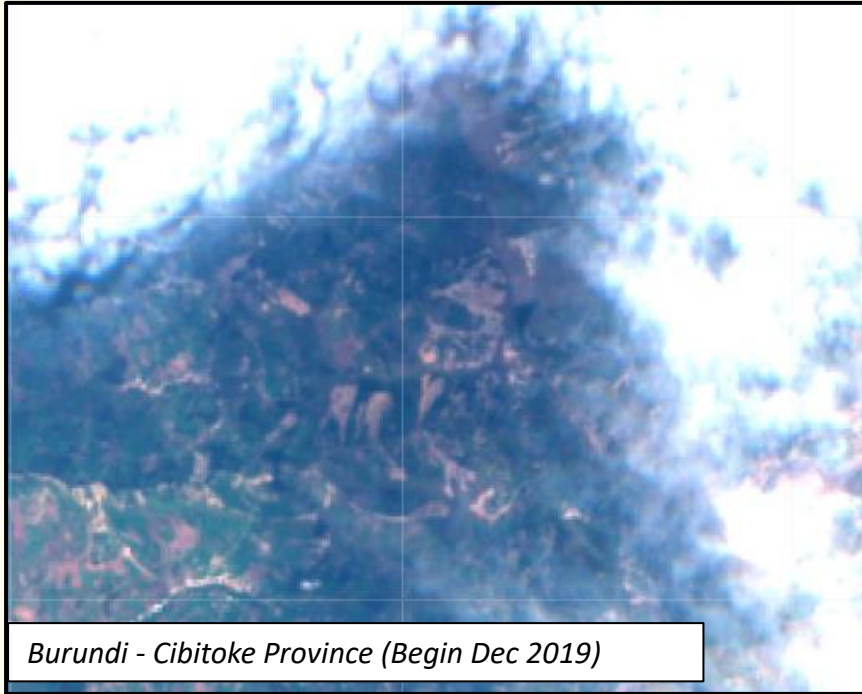
Existing landslide inventory from previous work in the study area.

It is important to investigate multiple events at the regional scale to be able to derive trends in landslide and flash flood occurrences

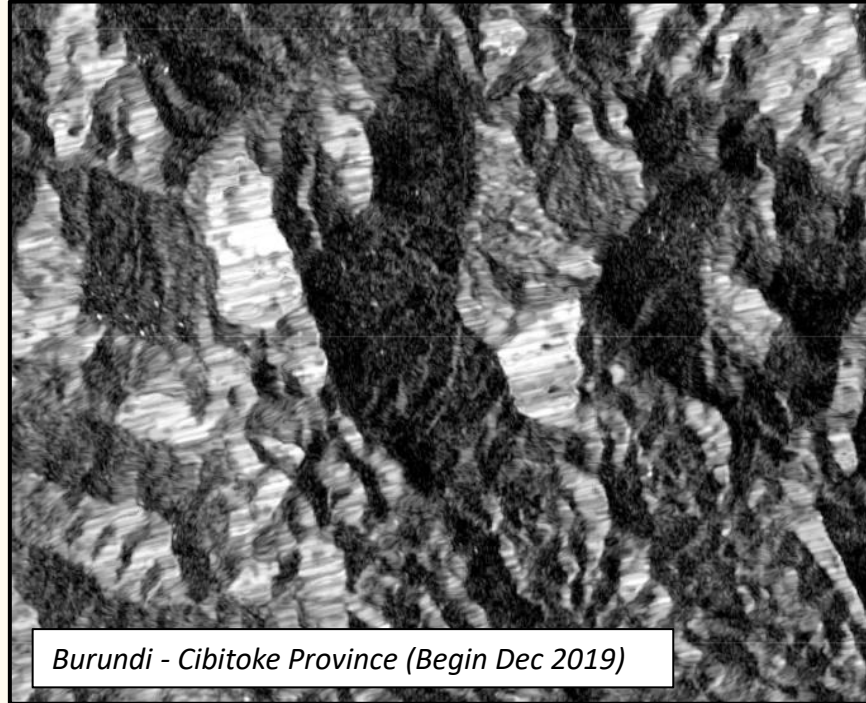
- This will help investigating strength of drivers, such as landscape, preconditioning climate and triggering climate drivers
- This will help investigate human impact (land use and land cover change) and can help society in understanding geomorphic hazards considering current societal concerns (urban growth, deforestation).

Remote sensing

Optical (Sentinel 2)



SAR (Sentinel 1)



Why Copernicus Sentinel?

1. Global coverage
2. Freely available
3. High repeat time (6-12 days)
4. High resolution (10 - 15 m)

Sentinel-1: Used for deriving landslide and flash flood timing

Sentinel-2: Used for deriving landslide and flash flood location (using an existing random forest classification ([IMCLASS](#)))

Remote sensing presents an ideal tool for landslide and flash flood inventorying in a data-scarce, large area. Specifically in the tropics, where optical data is persistently affected by cloud cover. Here, the **objective** is to develop a remote sensing methodology that aims to identify accurately in space and time the landslide and flash flood events in the western branch of the East African Rift using a multi-temporal change analysis approach combining optical and SAR amplitude and phase coherence data

SAR time series - Methods

The method is currently in development and continuously updated. Here we present the first part of this research on deriving landslide and flash flood timing using SAR imagery. We use both amplitude and coherence imagery and create time series at the landslide and flash flood level to visualize potential change.

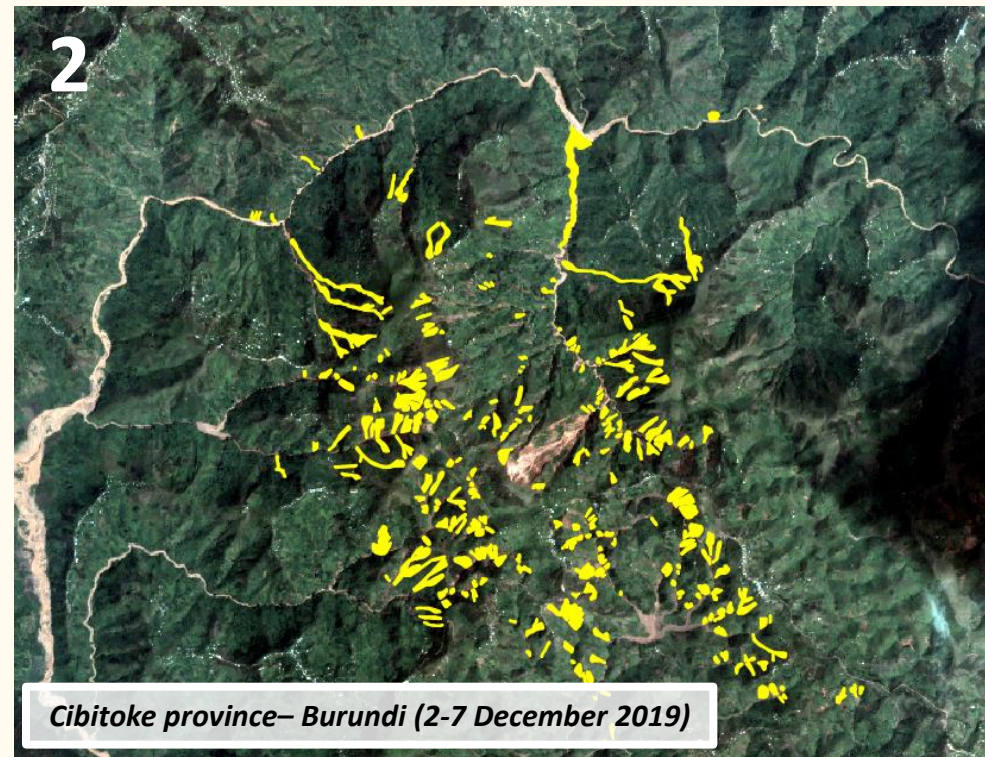
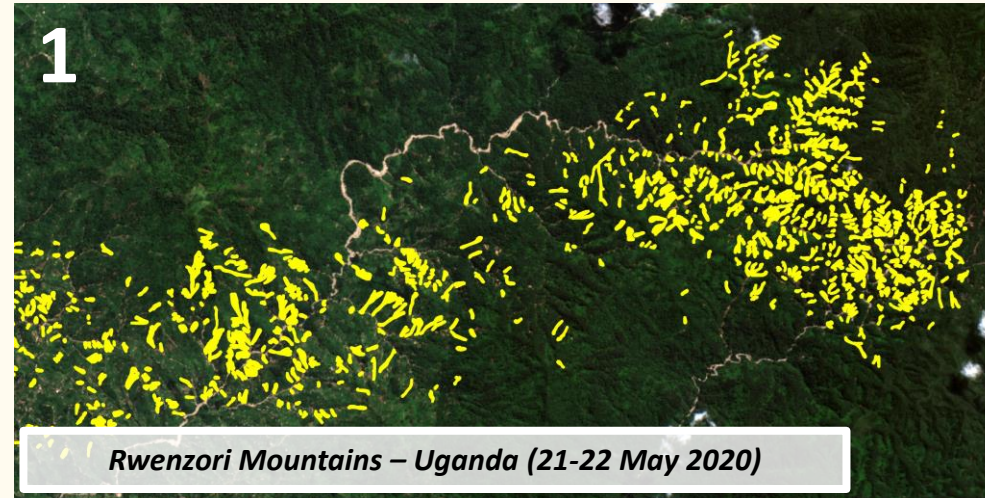
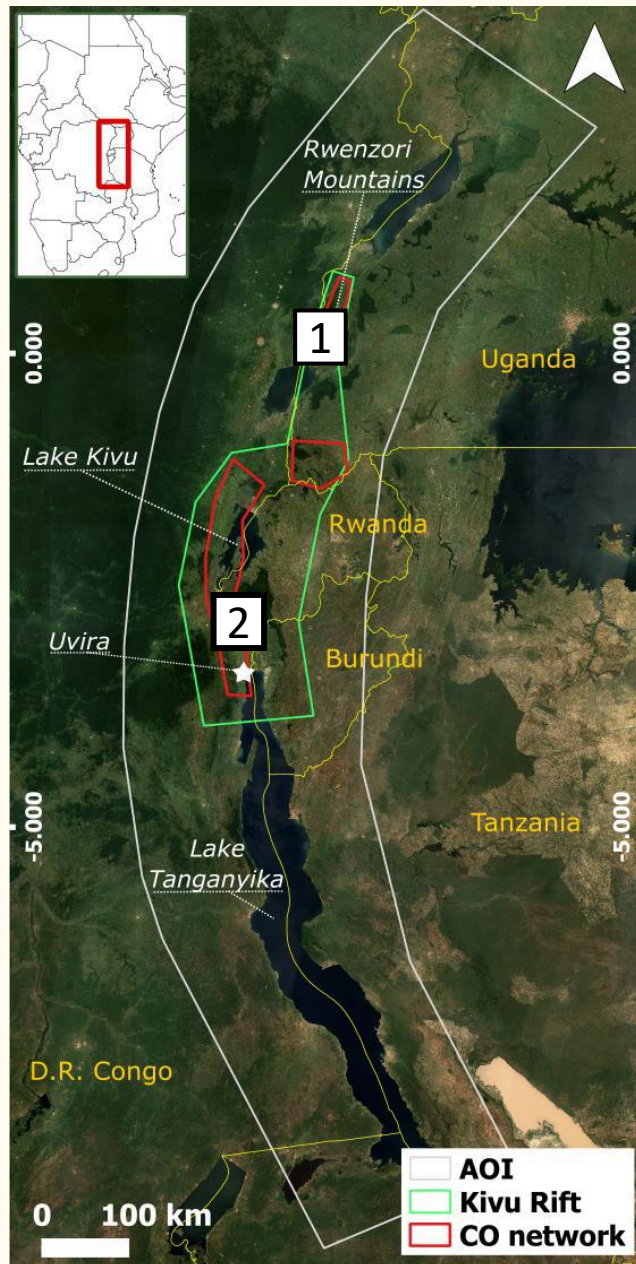
Coherence

Coherence maps are created using successive SAR images. Time series are created by taking the average coherence value per landslide or flash flood.

Amplitude

Amplitude time series are created by taking the average amplitude value per landslides or flash flood. Amplitude is additionally processed into spatial amplitude correlation (SAC). SAC is calculated on the landslide and flash flood level and represents the correlation from one reference image to the other images within the time series.

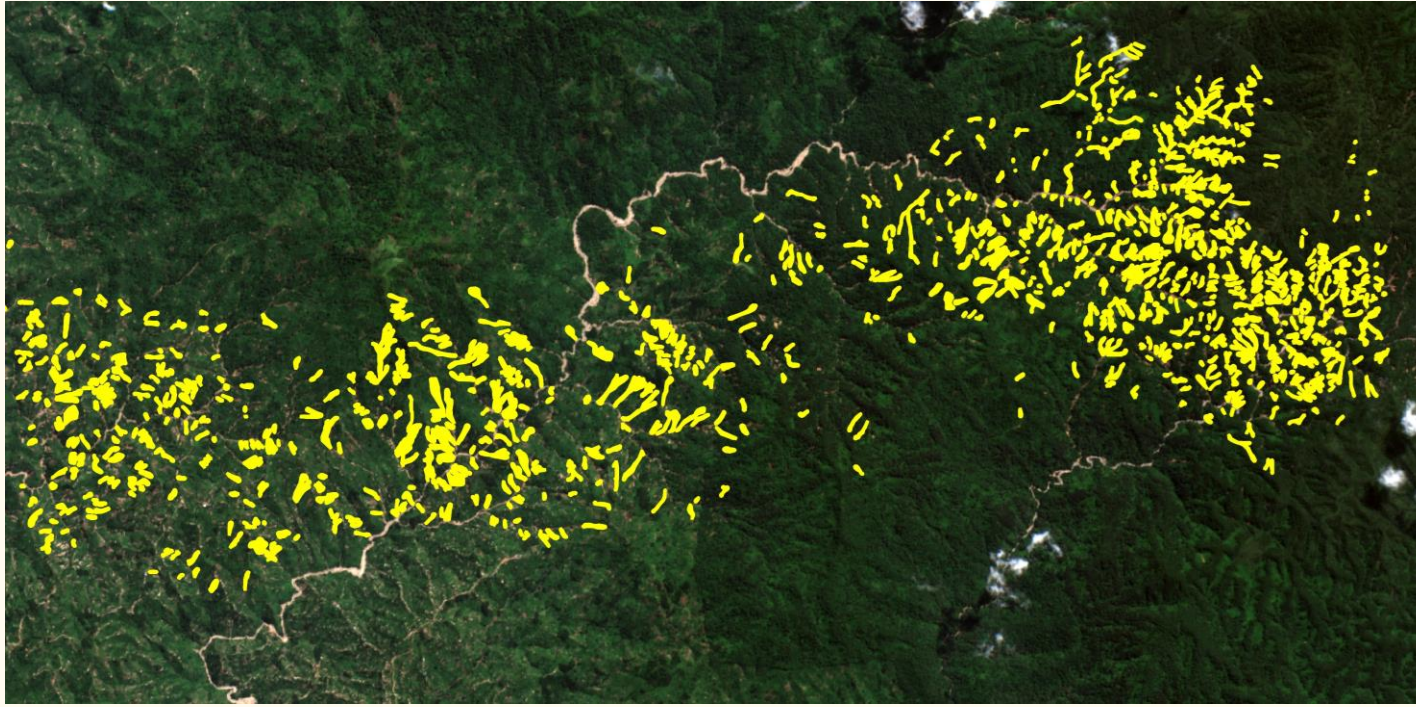
Recent events



In this presentation we focus on two specific events in different landscapes.

1. A landslide event containing 1068 landslides in the Rwenzori Mountains that occurred in a dense pristine forest where landslide scars are very distinct features.
2. A landslide event containing 307 landslides in the Cibitoke province of Burundi that occurred in an area containing a combination of cultivated land, and forest patches. Due to the cultivated land, landslide scars are less distinct compared to the Rwenzori Mountains event.

SAR time series - Examples



Rwenzori Mountains, Uganda 1068 landslides

Coherence: A strong increase corresponding to the event occurrence is visible

Amplitude: A decrease corresponding to the event occurrence is visible, however it is not pronounced and a similar drop is visible earlier in the time series.

Spatial amplitude correlation (SAC): A strong increase corresponding to the event occurrence is visible

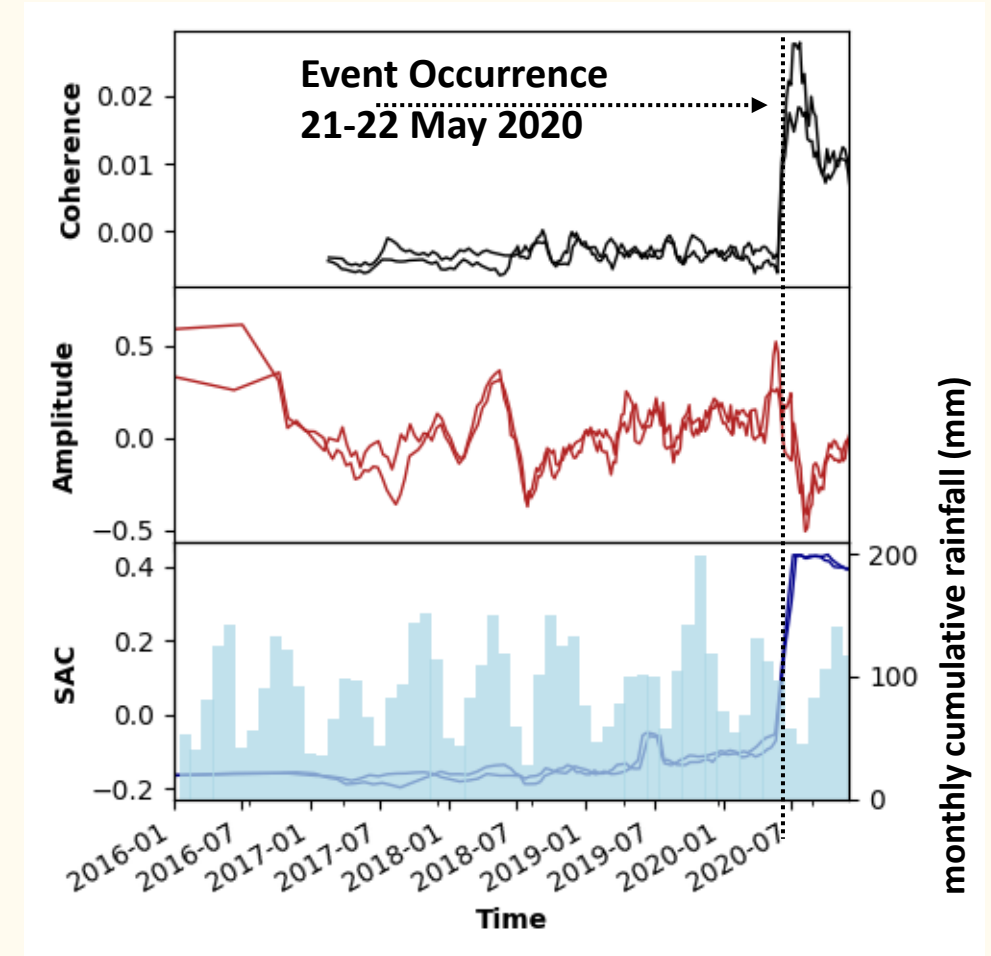
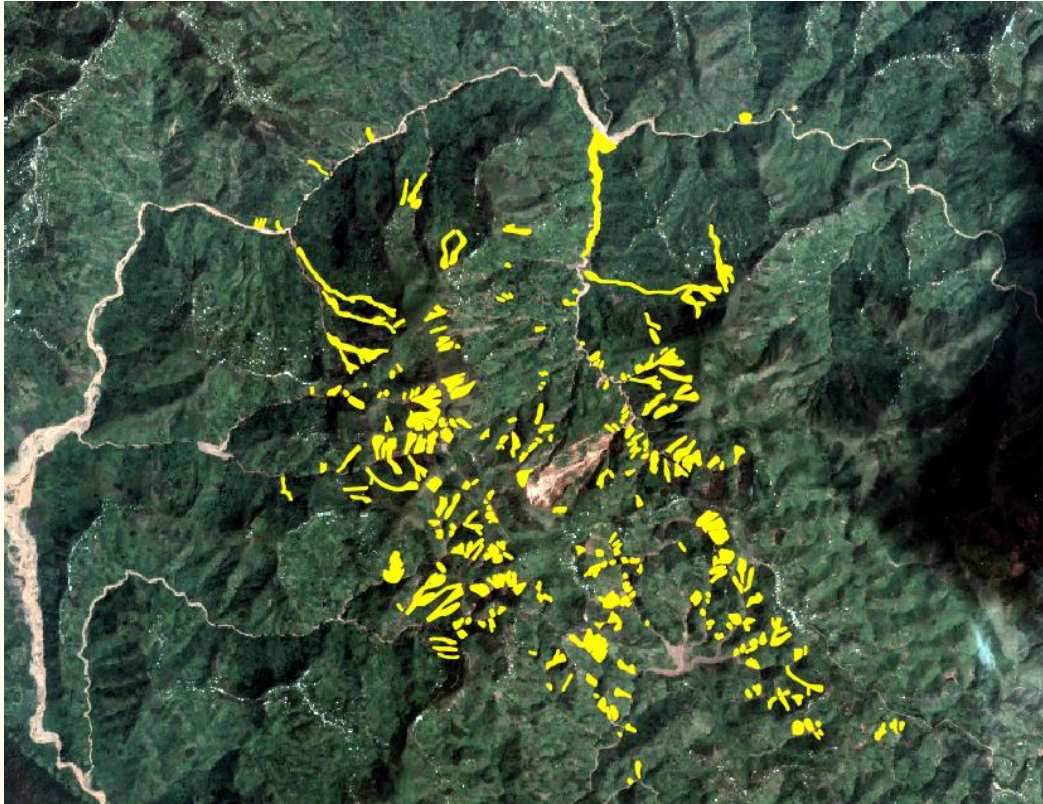


Figure: Average coherence, amplitude and spatial amplitude correlation (SAC) time series for the complete event

SAR time series - Examples



Cibitoke province, Burundi
307 landslides

Coherence: A strong increase corresponding to the event occurrence is visible

Amplitude: No change corresponding to the event occurrence is visible. The signal seems highly influenced by rainfall patterns

Spatial amplitude correlation (SAC): A strong increase corresponding to the event occurrence is visible

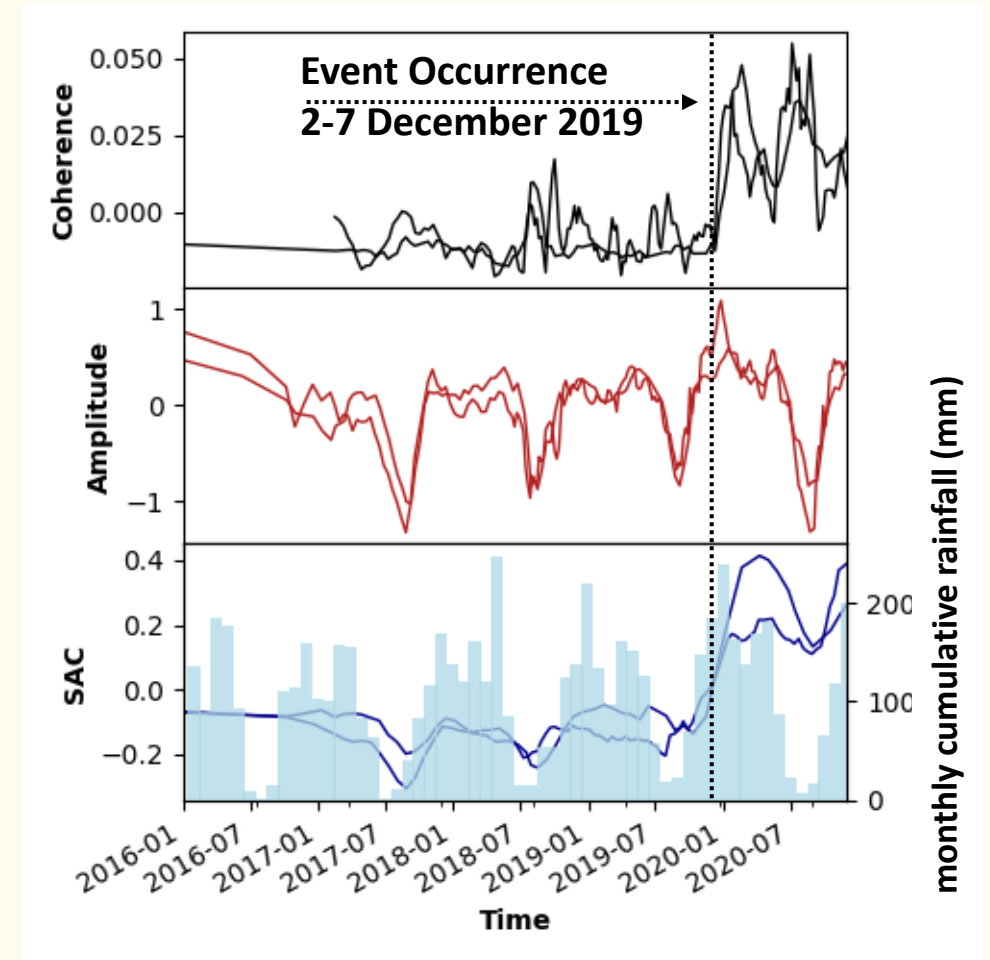


Figure: Average coherence, amplitude and spatial amplitude correlation (SAC) time series for the complete event

SAR time series – Landslide and flash flood timing

1068 landslides, Rwenzori Mountains, Uganda

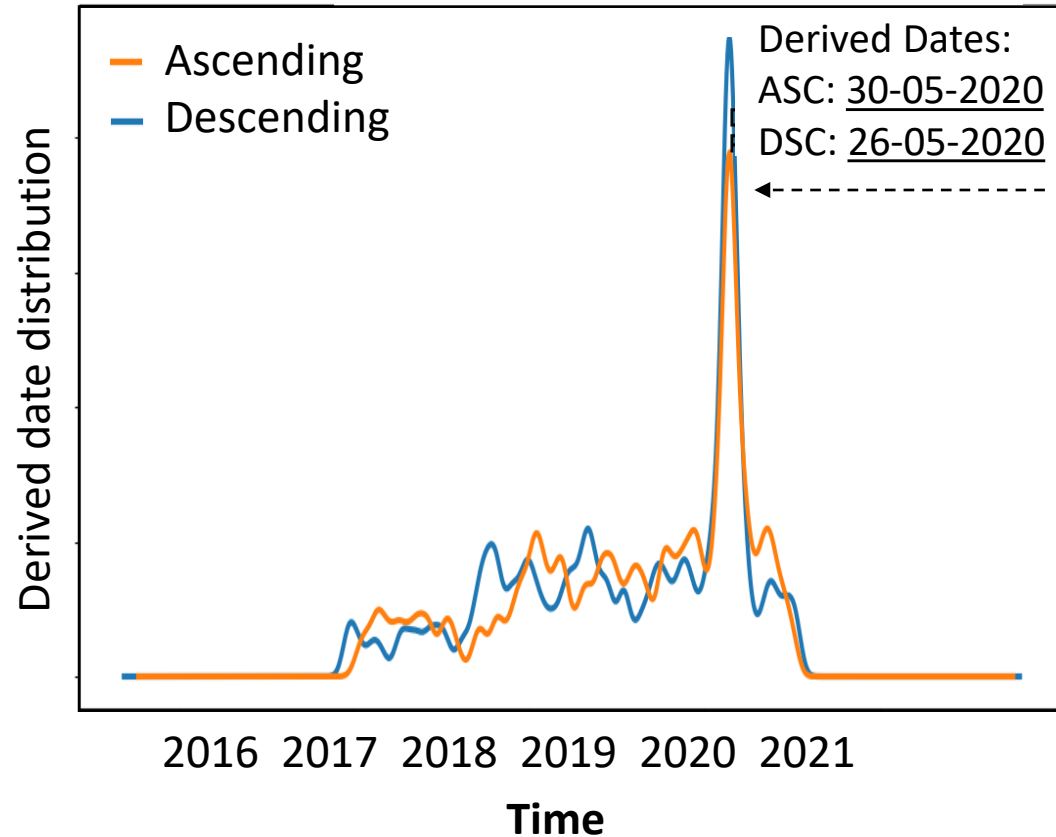


Figure: Distribution of the accumulated derived dates for the 1068 landslides in the Rwenzori Mountains event. The distribution shows a peak around the event occurrence

Event timing is derived in two steps:

- Per landslide and flash flood time series a [binary segmentation change detection](#) is applied. The most significant change within every time series is pointed out and the corresponding date is derived.
- The derived dates from every landslide and flash flood are accumulated and the date which is in the majority is assigned as the event date. The figure on the left shows the distribution of these accumulated dates for the event in the Rwenzori Mountains.

Additionally we can categorize the landslides within one event based on their properties such as area, slope, land use and aspect and apply the timing method to see if changing properties have effect on the accuracy of the derived timing. This can help to better understand time series behaviour.

Landslide and flash flood location – conclusion and future prospects

Landslide and flash flood timing

- Both coherence and spatial amplitude correlation show a pronounced change in the time series at the time of the event occurrence
- Sentinel 1 SAR imagery can effectively be applied to derive event timing

Future prospects

- Increase signal understanding by categorizing the event inventories using parameters such as area, slope, land use and aspect and analyze the ability to derive the most accurate timing.
- Apply the proposed timing method on the landslide and flash flood event inventories created with the IMCLASS classification method