MODUS: A multi-sensor approach to unravel natural and anthropogenic controls on landslides dynamics in the tropics

A. Dille[1,2], O. Dewitte[1], N. d'Oreye[3,4], D. Derauw[3,5,6], J-P. Malet[7], M. Kervyn[2], F. Kervyn[1]

[1] Royal Museum for Central Africa, Belgium
[2] Vrije Universiteit Brussel, Belgium
[3] European Centre for Geodynamic and Seismology, Luxembourg
[4] National Museum for Natural History, Luxembourg
[5] Universidad Nacional de Rio Negro - CONICET, Argentina
[6] Centre Spatial de Liège, Belgium
[7] École et Observatoire des Sciences de la Terre, Institut de Physique du Globe de Strasbourg, France

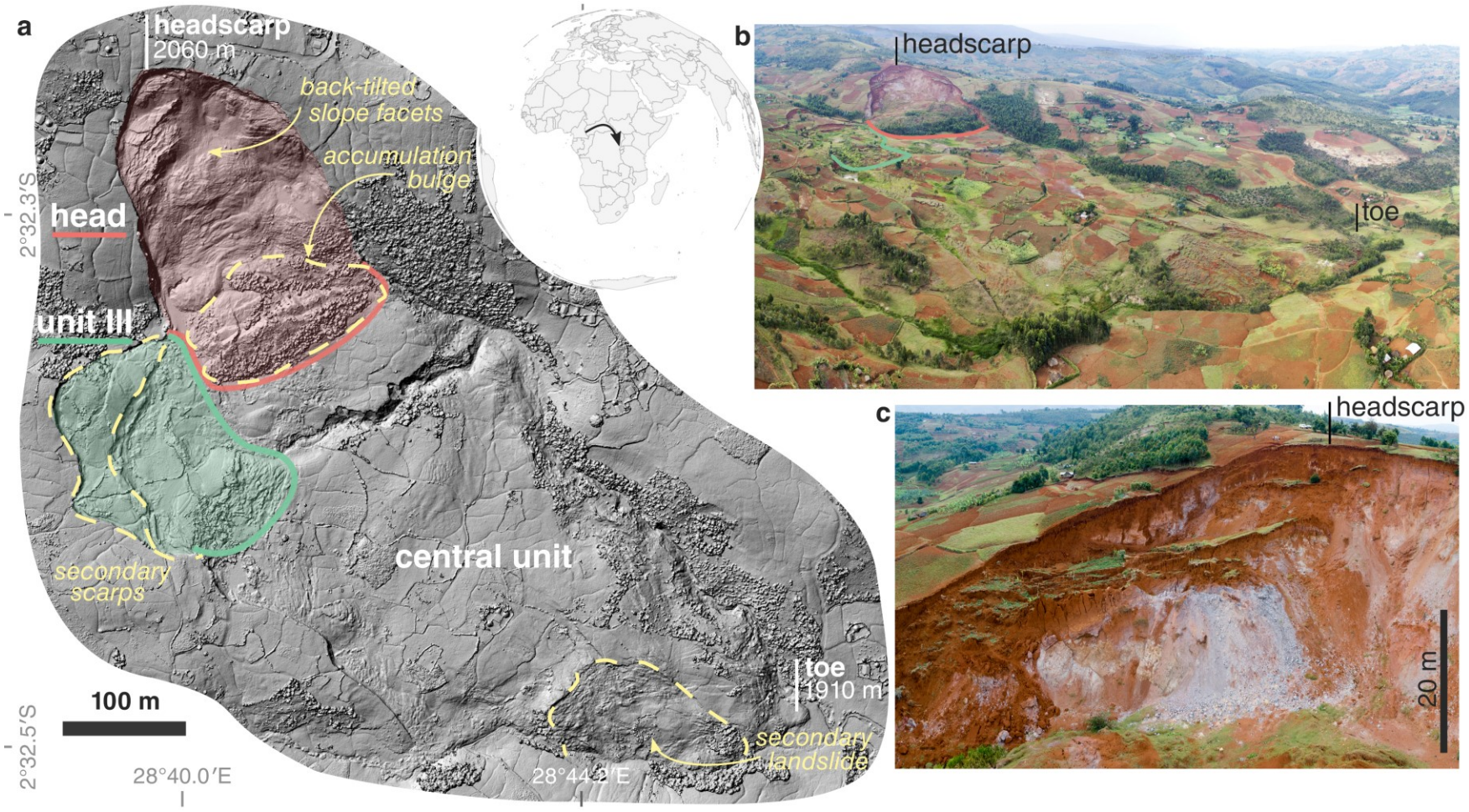
Belgian Science Policy Office
belspo


AFRICA
museum

Controls on landslide dynamic – rural landslide

Monitoring difficult because:

- **m/yr velocity**, transient **surges**
- highly **variable deformation** in space and time
- rapid **surface changes**
- **in situ monitoring difficult** to implement and maintain
- persistent **cloud cover**



Controls on landslide dynamic – image correlation, SAR amplitude and time series inversion

COSMO-SkyMed SAR amplitude images

- 4.5 years
- 370 images
- 2 m resolution
- 1 image every 4 days

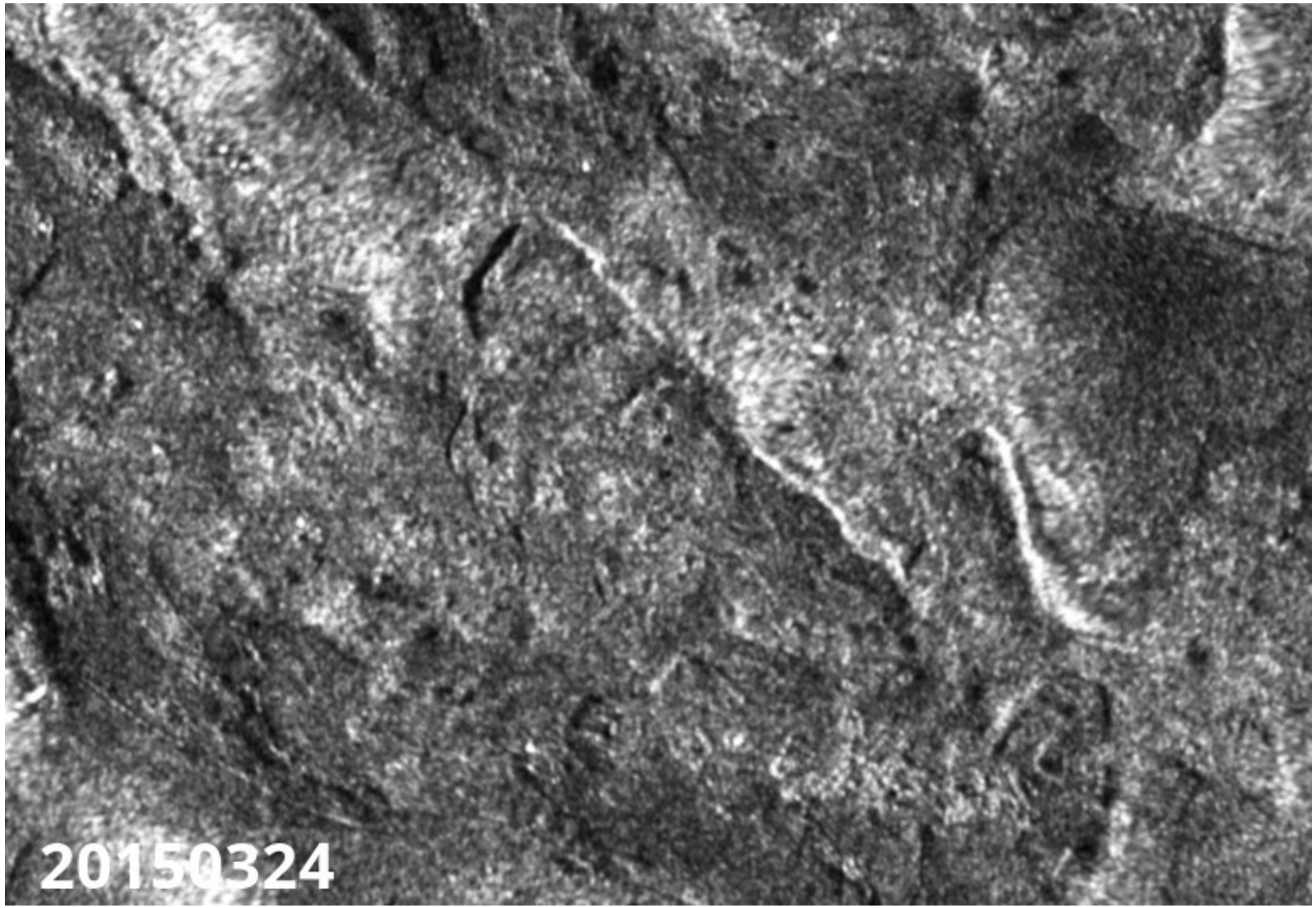
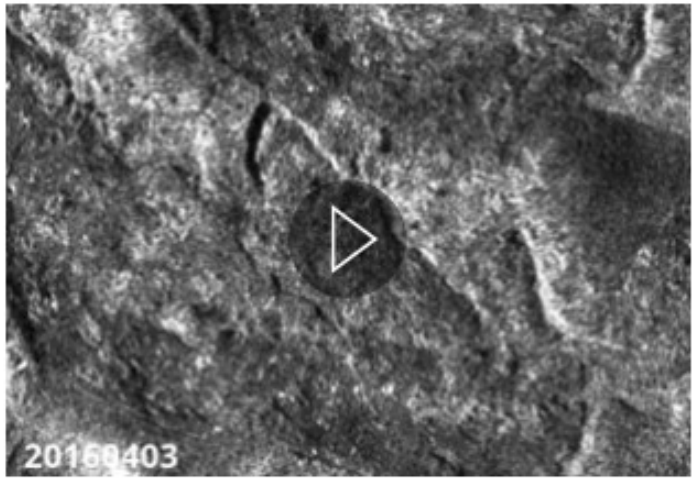
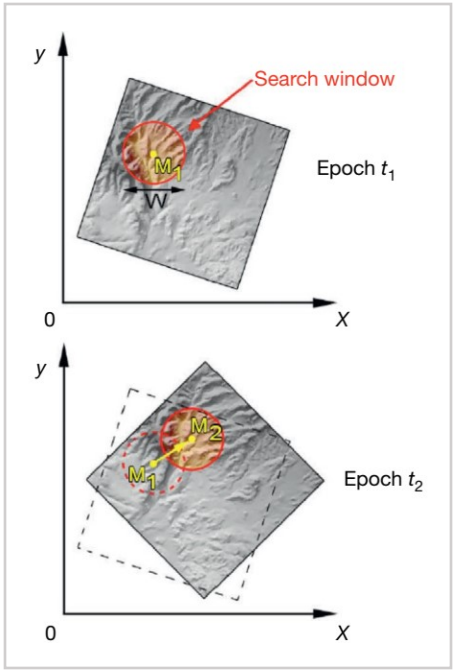


image correlation and time series inversion applied on radar amplitude images

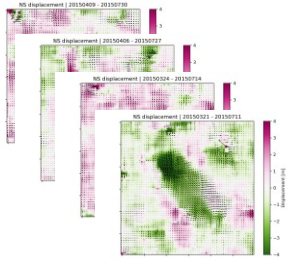
Controls on landslide dynamic – image correlation, SAR amplitude and time series inversion



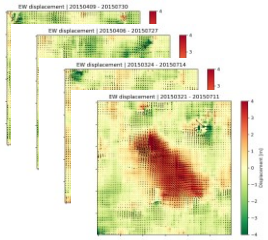
SAR Ascending



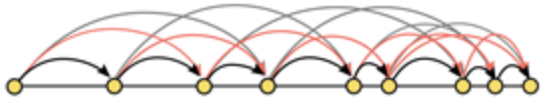
north-south offset maps



east-west offset maps

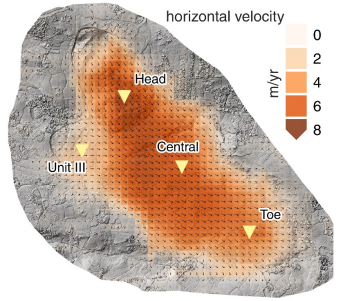


A. Image correlation

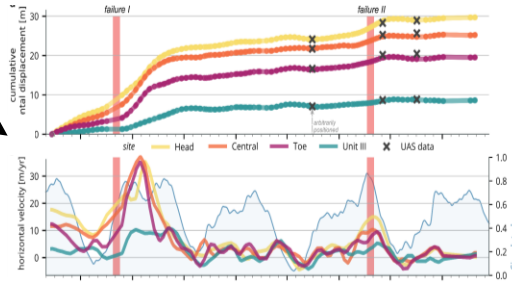


B. Integration and inversion of offset maps into time series

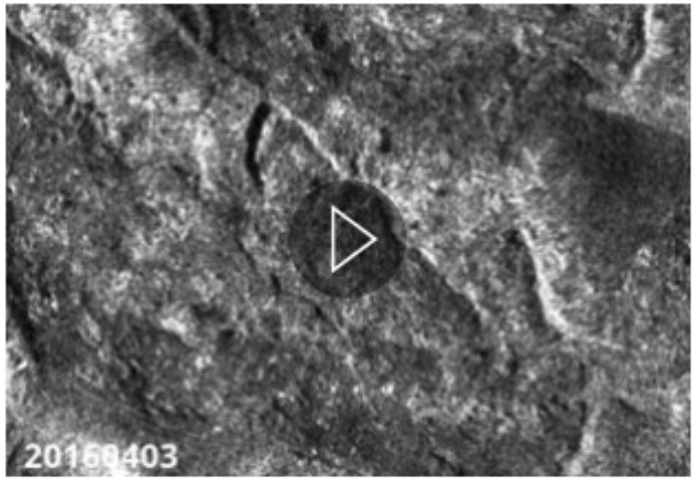
deformation field



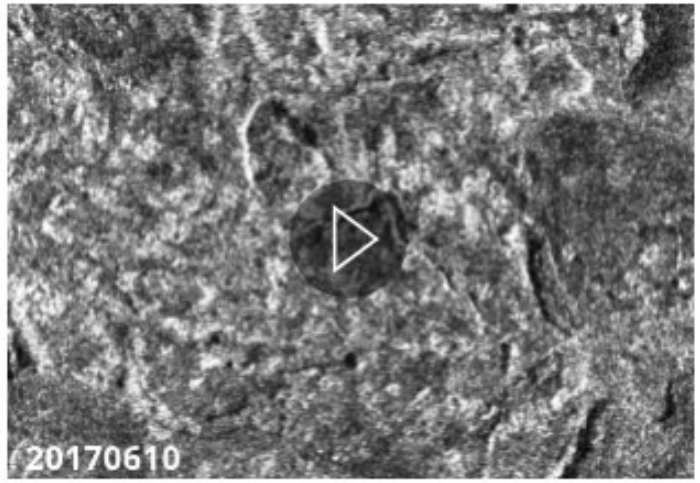
deformation time-series



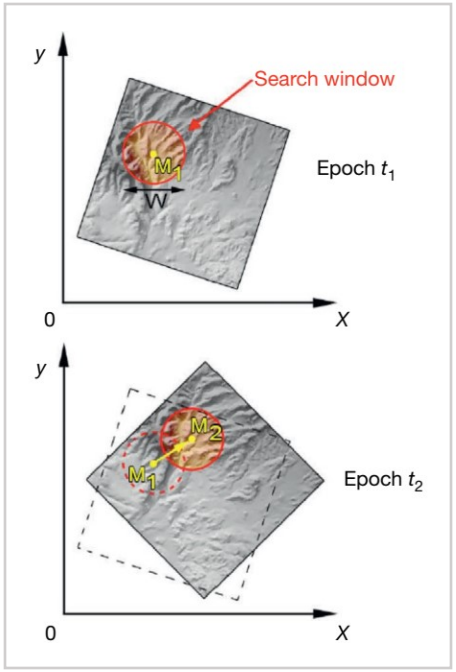
Controls on landslide dynamic – image correlation, SAR amplitude and time series inversion



SAR Ascending

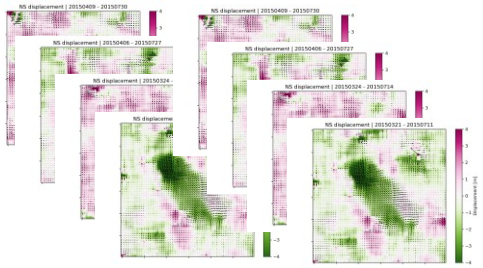


SAR Descending

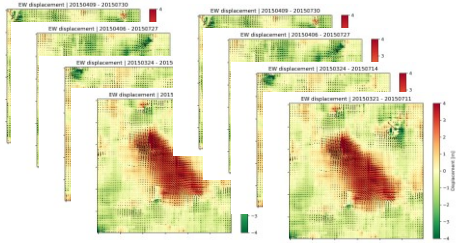


A. Image correlation

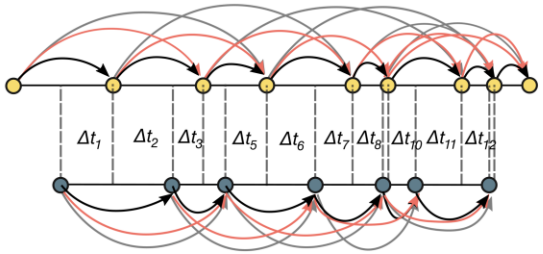
north-south offset maps



east-west offset maps

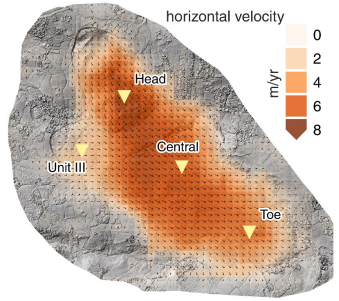


combine datasets to increase temporal sampling and SNR

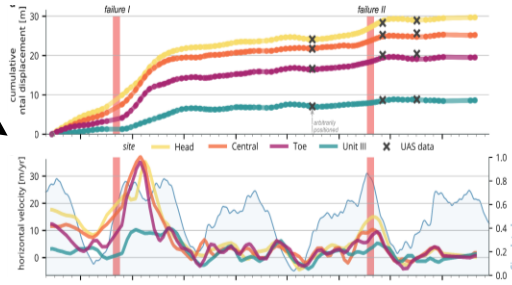


B. Integration and inversion of offset maps into time series

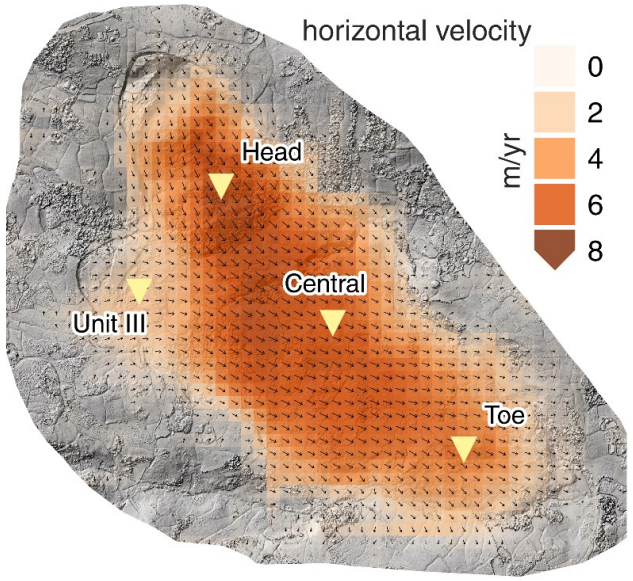
deformation field

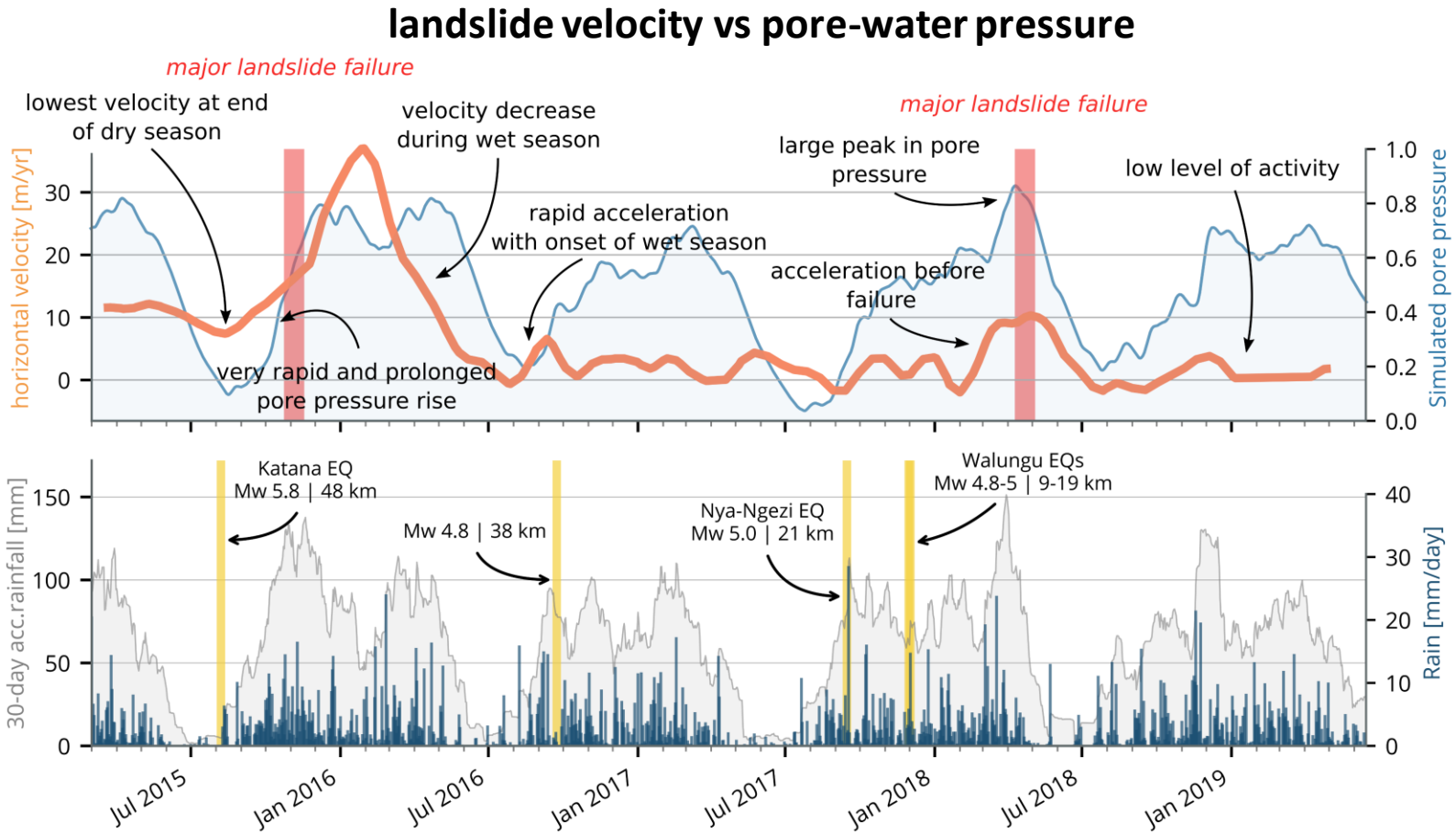


deformation time-series



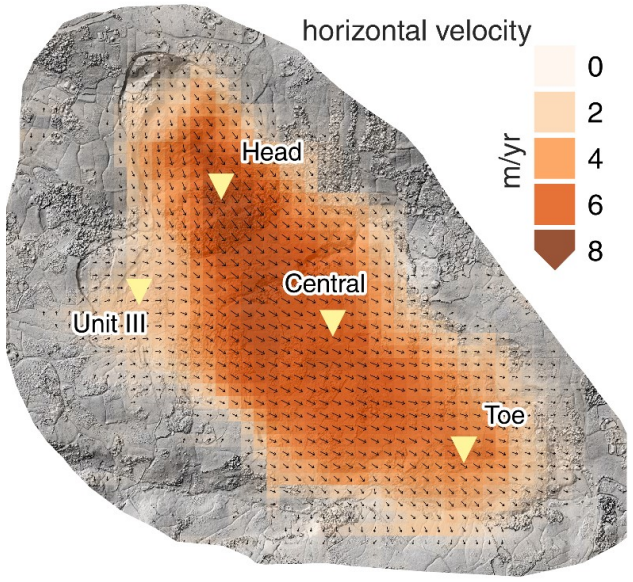
Controls on landslide dynamic – rural landslide



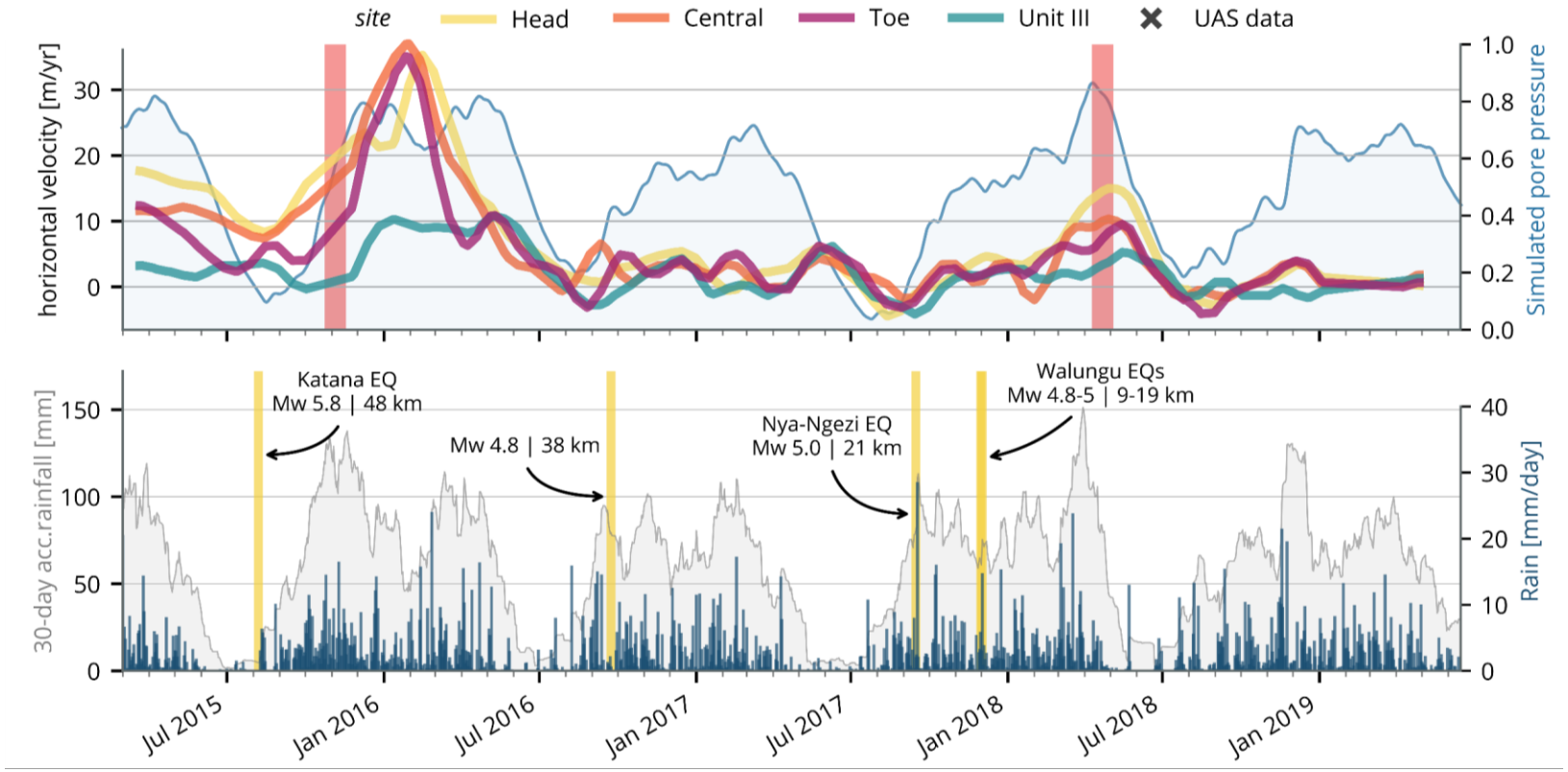


- closely **tied relationship** between **rainfalls and landslide motion**

Controls on landslide dynamic – rural landslide



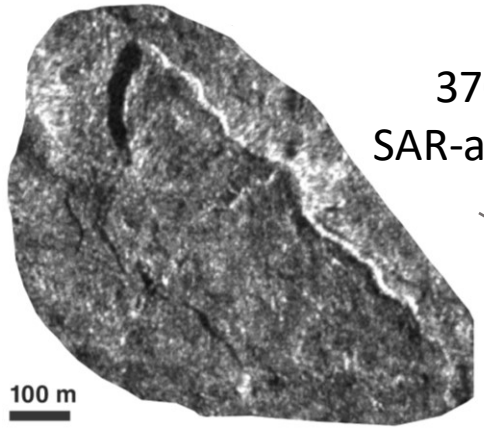
landslide velocity vs pore-water pressure



- closely **tied relationship** between **rainfalls and landslide motion**
- velocity changes **not synchronous across the landslide**
- **stress propagation/transfer**

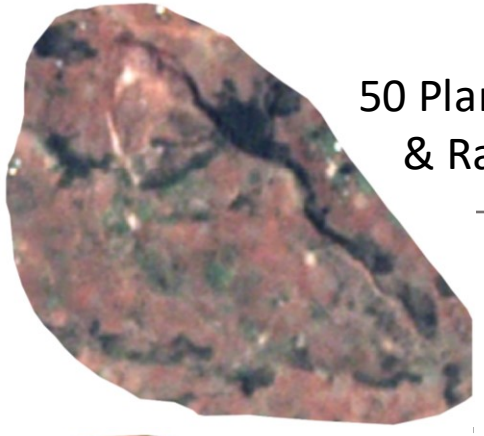
SAR-amplitude vs optical satellite

SAR-amplitude images



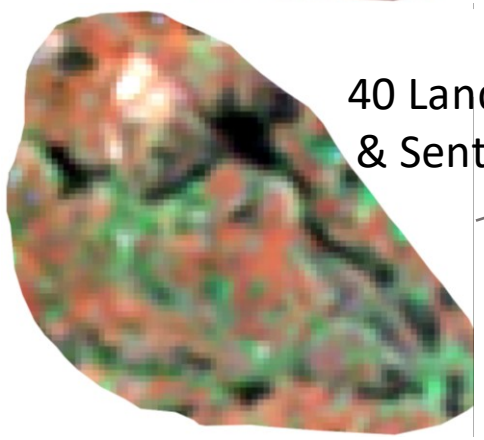
370 CSK
SAR-amplitude

High-resolution optical satellite images

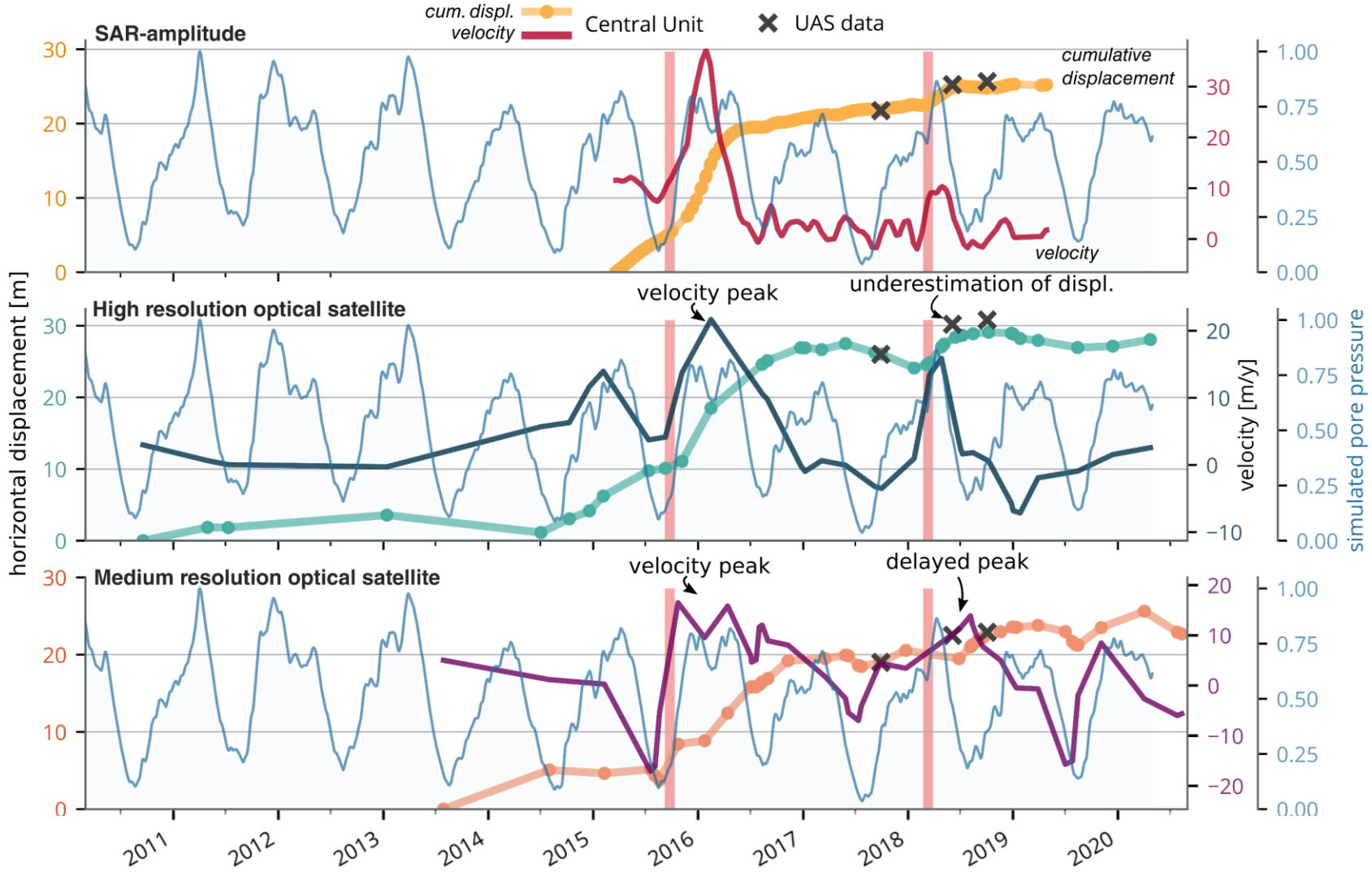


50 PlanetScope
& RapidEye

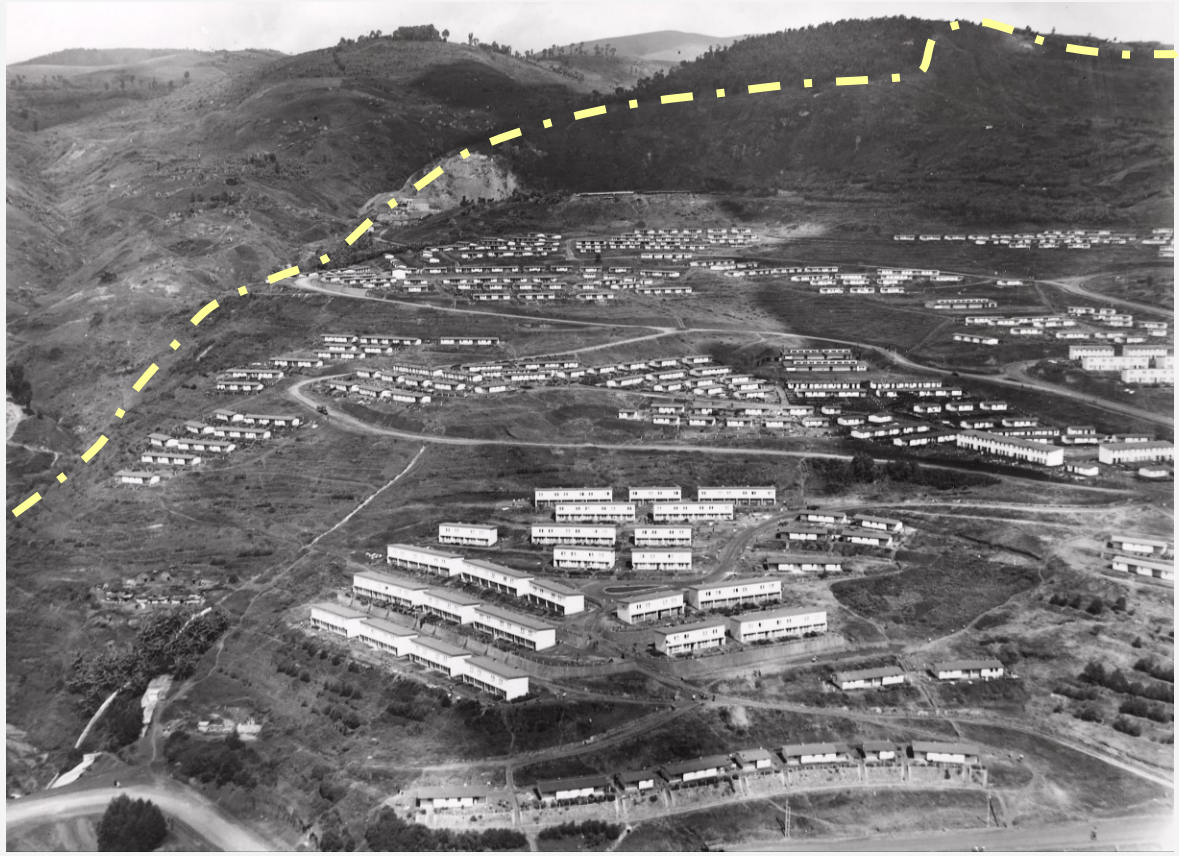
Medium-resolution optical satellite images



40 Landsat 8
& Sentinel-2



Controls on landslide dynamic – urban landslide



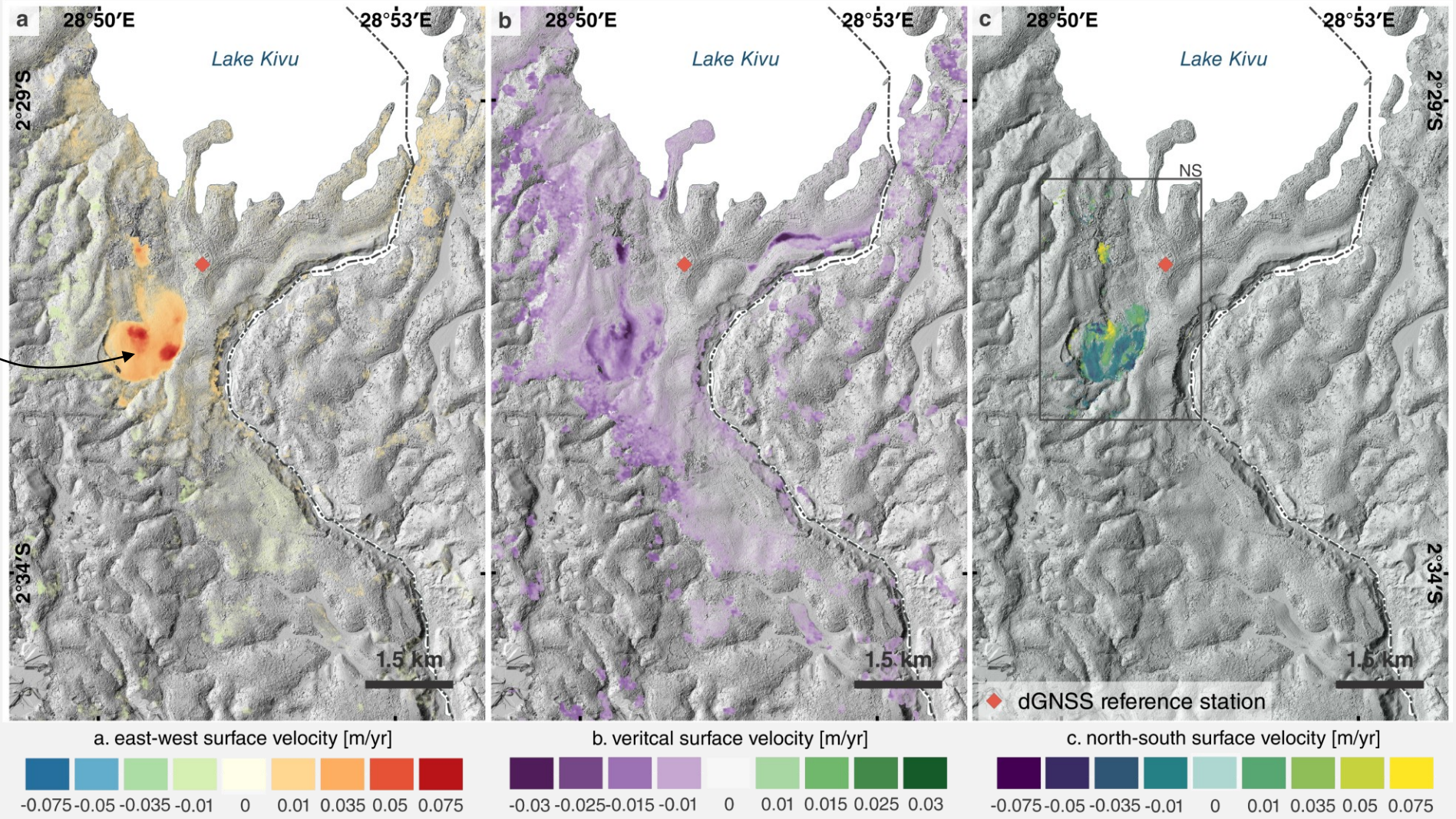
Funu landslide in 1959

Funu landslide in 2018

Controls on landslide dynamic – SAR interferometry

SAR interferometry to measure 3D surface displacements with a sub-weekly resolution over 4.5 years

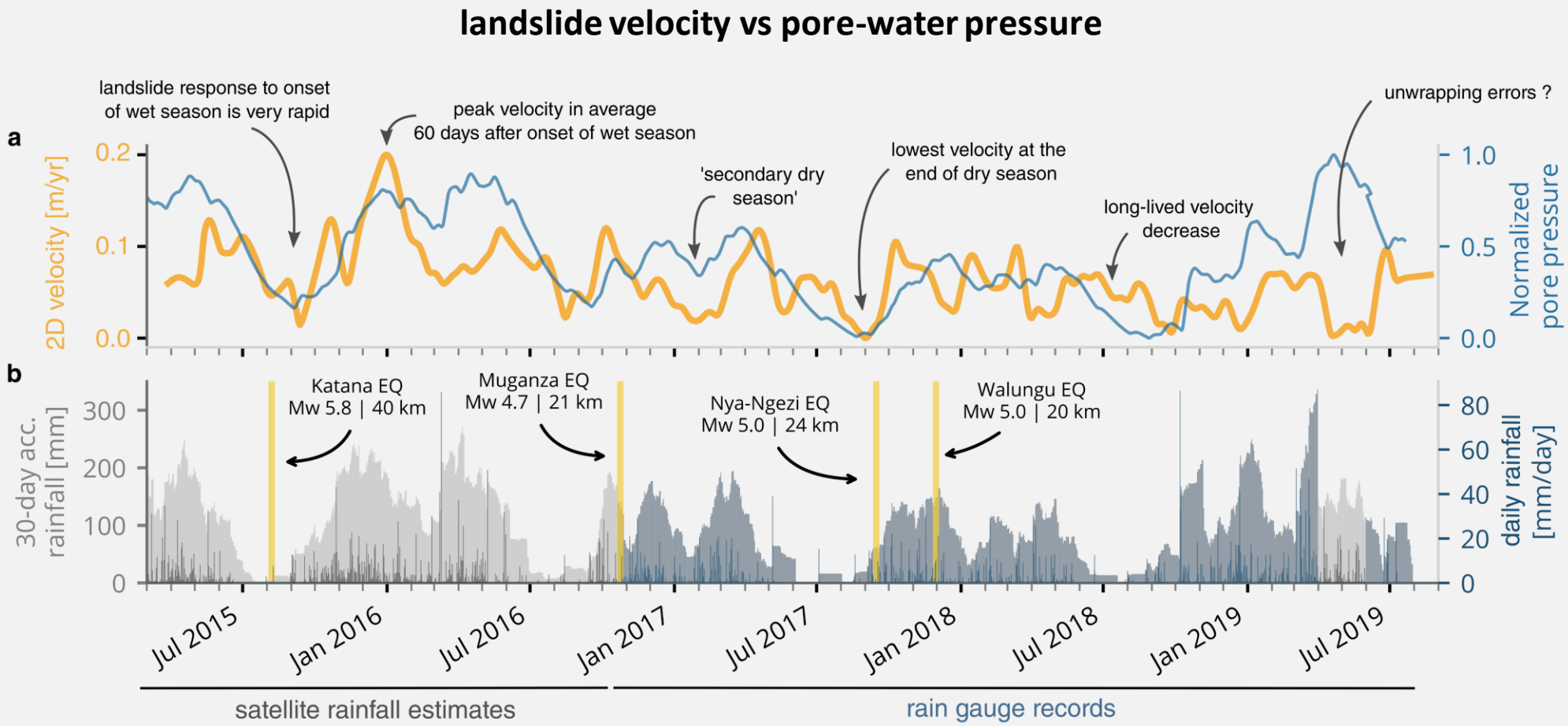
Funu landslide



Combination of COSMO-SkyMed & Sentinel-1 SAR images

- 4.5 years
- 370 CSK + 220 S1 images
- 1 image every 2 days
- 4 orbits, 3D deformation

Controls on landslide dynamic – urban landslide



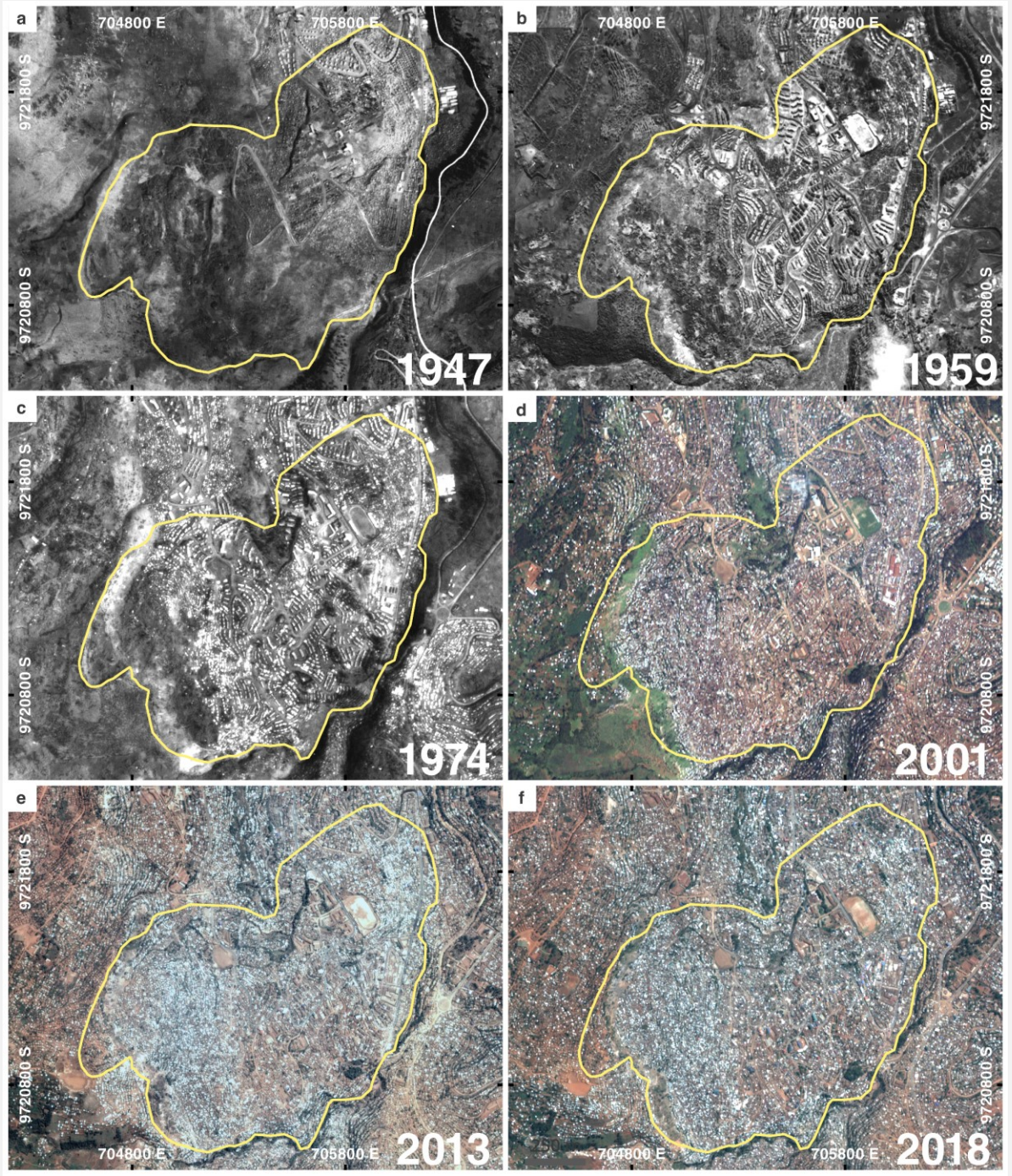
- closely tied relationship between pore pressure and landslide velocity, despite **large depth difference** and an **order magnitude difference** in velocity scale

Long-term hillslope changes

Progressive hillslope urbanisation

- only the **landslide toe was urbanised** in 1947
- **intensification of informal urbanisation** in the ’90s
- from early 2000, **80 % of the landslide is urbanised**

- acceleration of large landslide section between 1974 and 2001

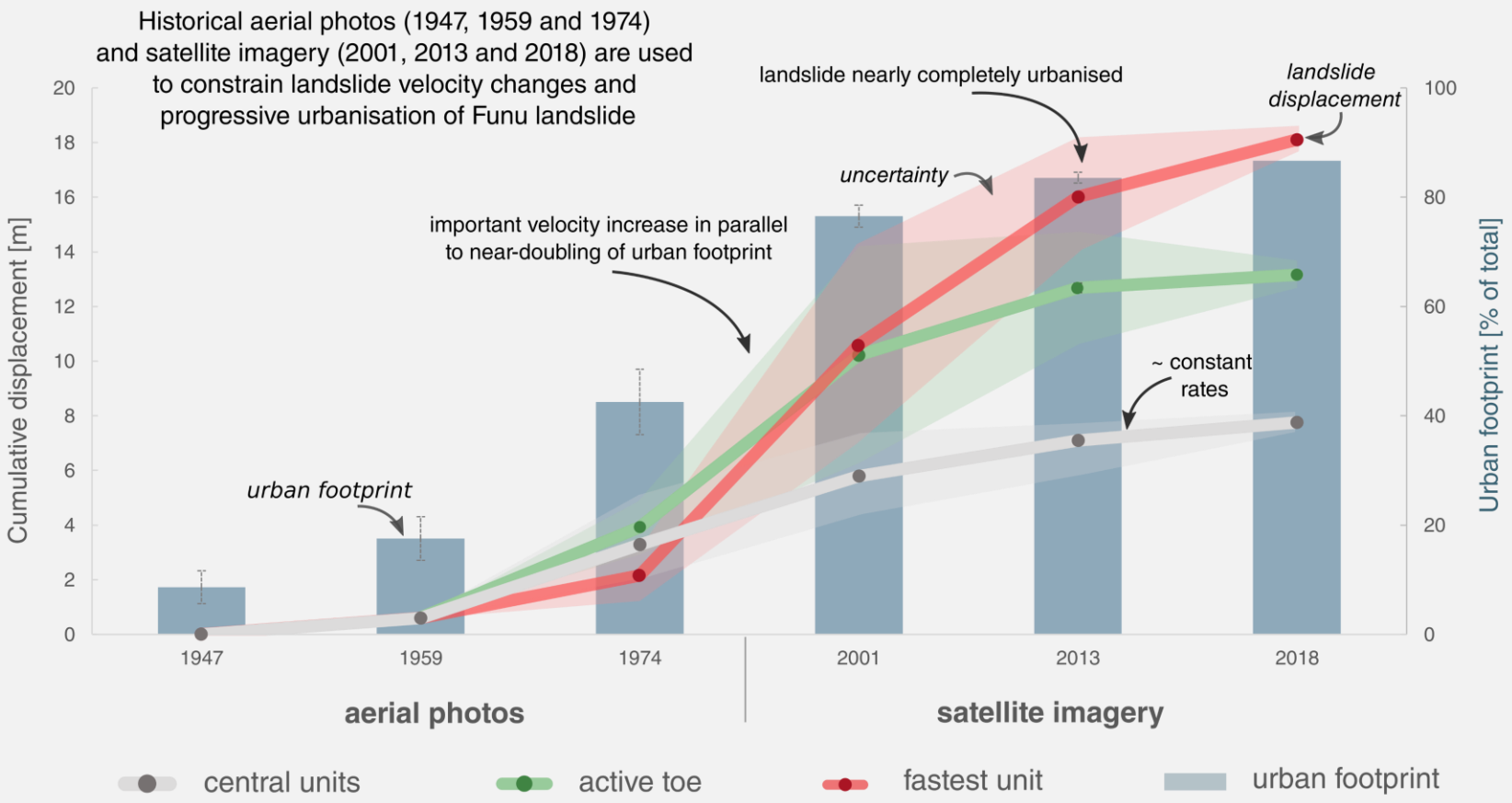


Long-term hillslope changes

Progressive hillslope urbanisation

- only the **landslide toe was urbanised** in 1947
- **intensification of informal urbanisation** in the ’90s
- from early 2000, **80 % of the landslide is urbanised**

- **acceleration of large landslide section** between 1974 and 2001



Conclusions

- Rainfall exert main control, but we need to consider **internal landslide dynamic,** as well as **environmental changes** such has urbanisation
- It has implications on our evaluation of **landslide hazards**, but also of how **humans** are interfering with **landscape evolution**
- Importance of taking advantage of **synergies** between **sensors** and **wavelengths** to ensure **optimal exploitation** of **growing archive** of repeat **satellite imagery**

Belgian Science Policy Office
belspo