FRINGE 2023

Satellite Remote Sensing for Landslide analysis

A Multi-sensor And Multi-variable Satellite Observation Approach For Investigating The Reactivation and Failure Of An Old Landslide In North Central Iran Following Reservoir Impoundment

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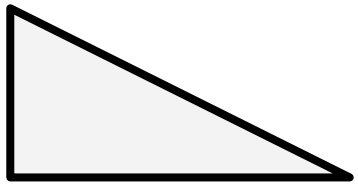
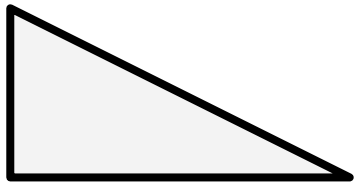
External forces → Slope → Landslide



Triggerers

Kinematics

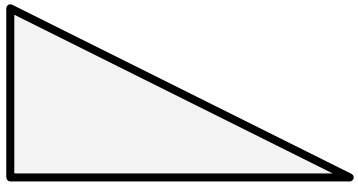
External forces → Slope → Landslide



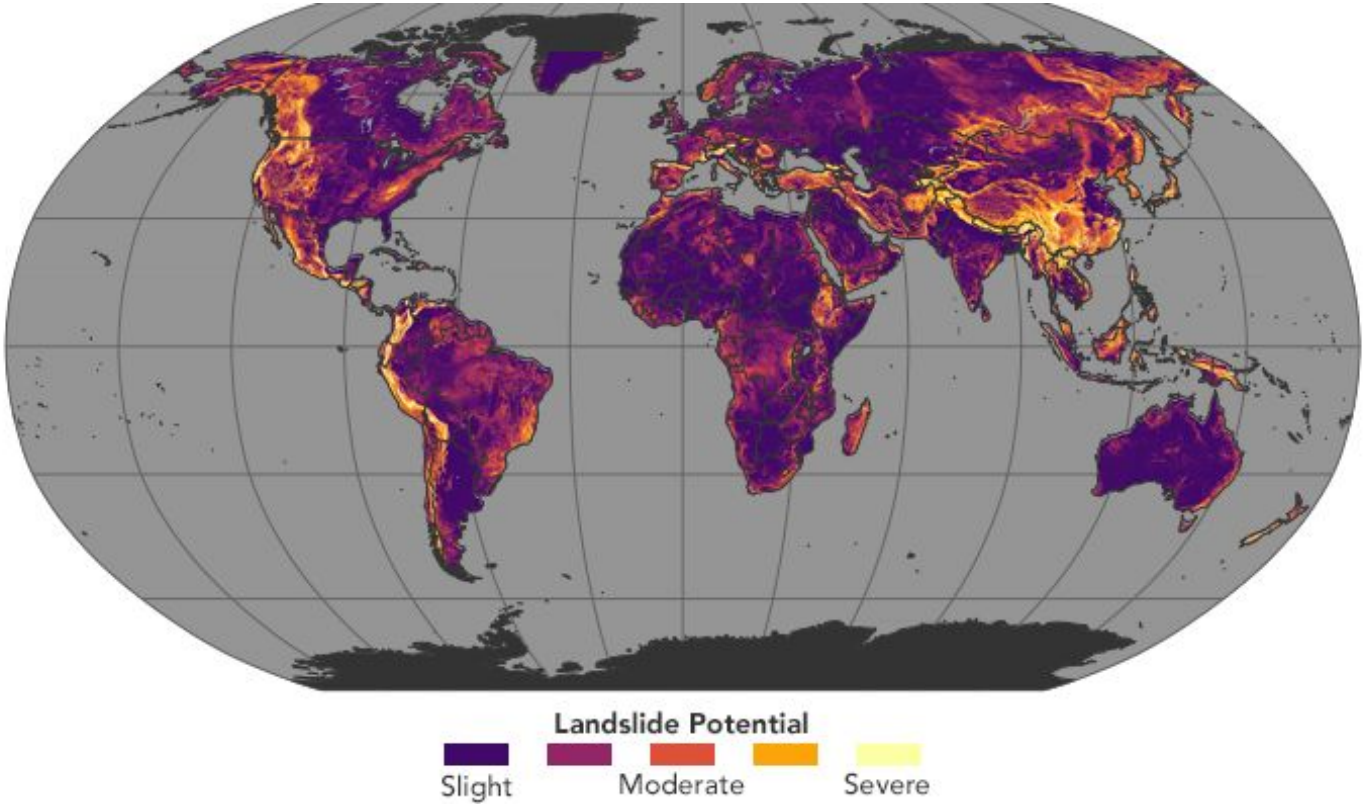
DATA

Triggerers **Kinematics**

External forces → **Slope** → **Landslide**



Stanley, T. & Kirschbaum, D. (2017)



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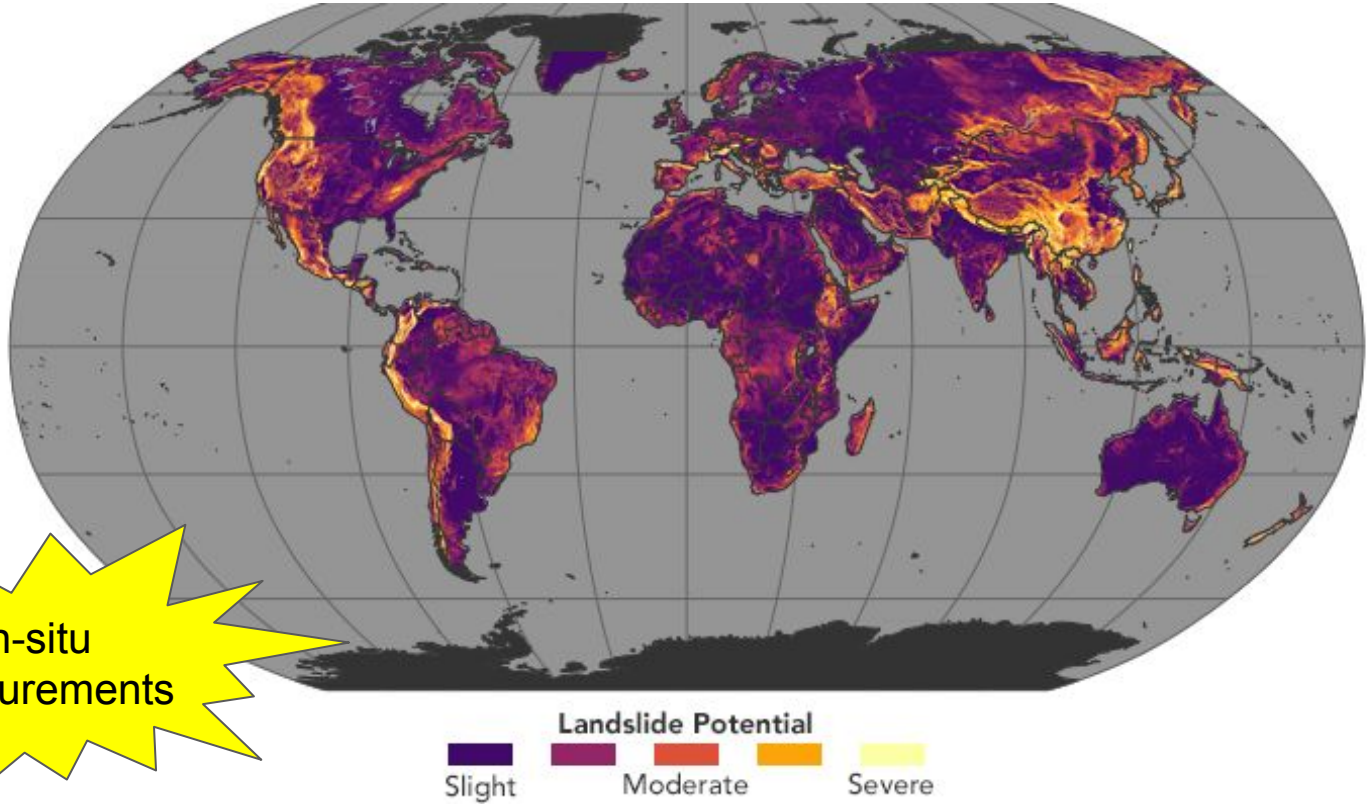
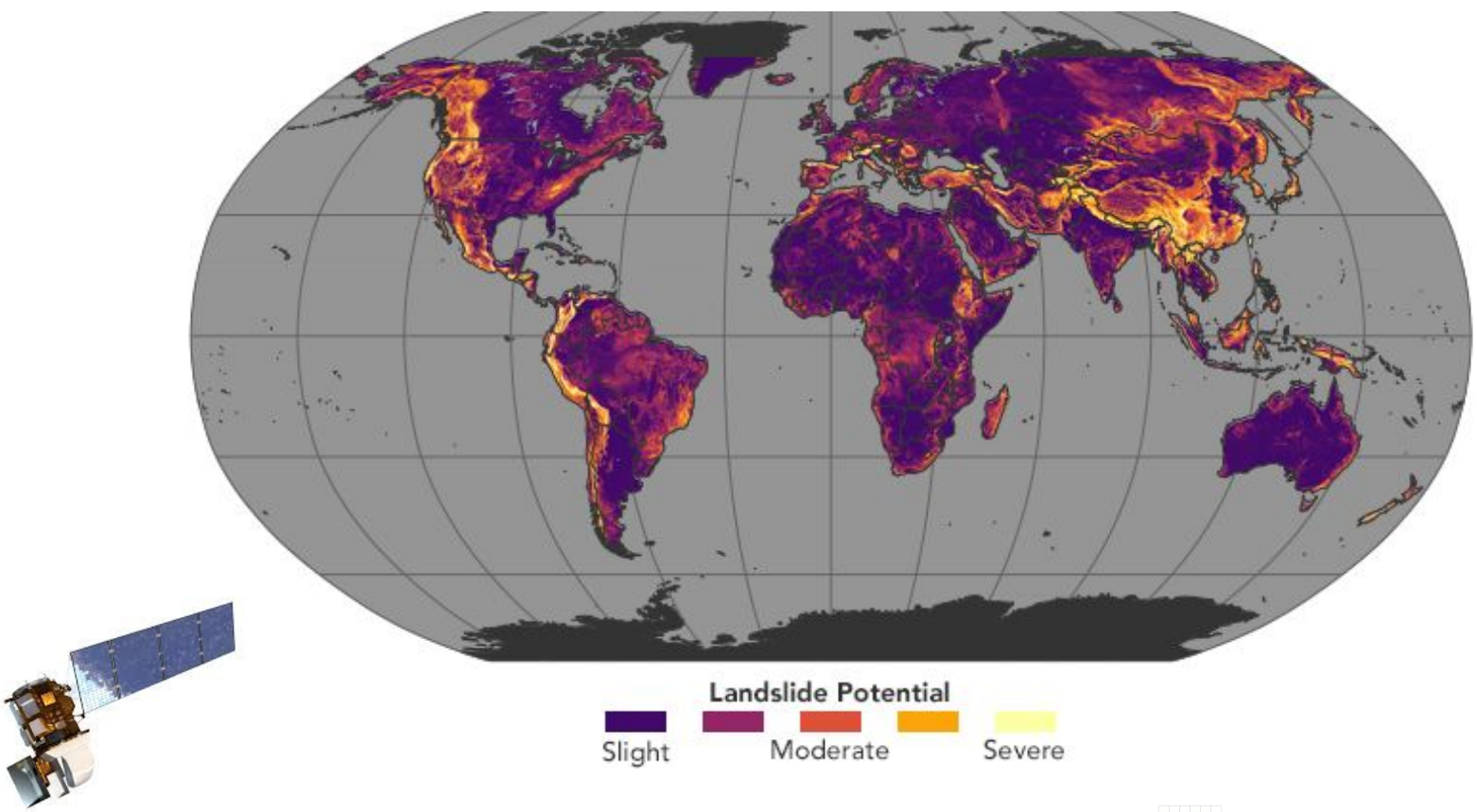
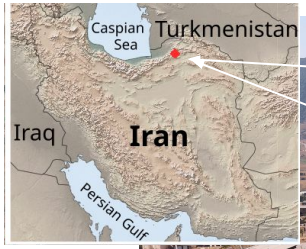


In-situ measurements

Stanley, T. & Kirschbaum, D. (2017)



March-April 2019 intense record rainfall over almost the whole Iran;
Flash floods and **thousands of slope failures** causing fatalities and damages;
Landslide collapse in Hoseynabad-e Kalpush village (north-east Iran);
Hundreds of houses damaged or destroyed.



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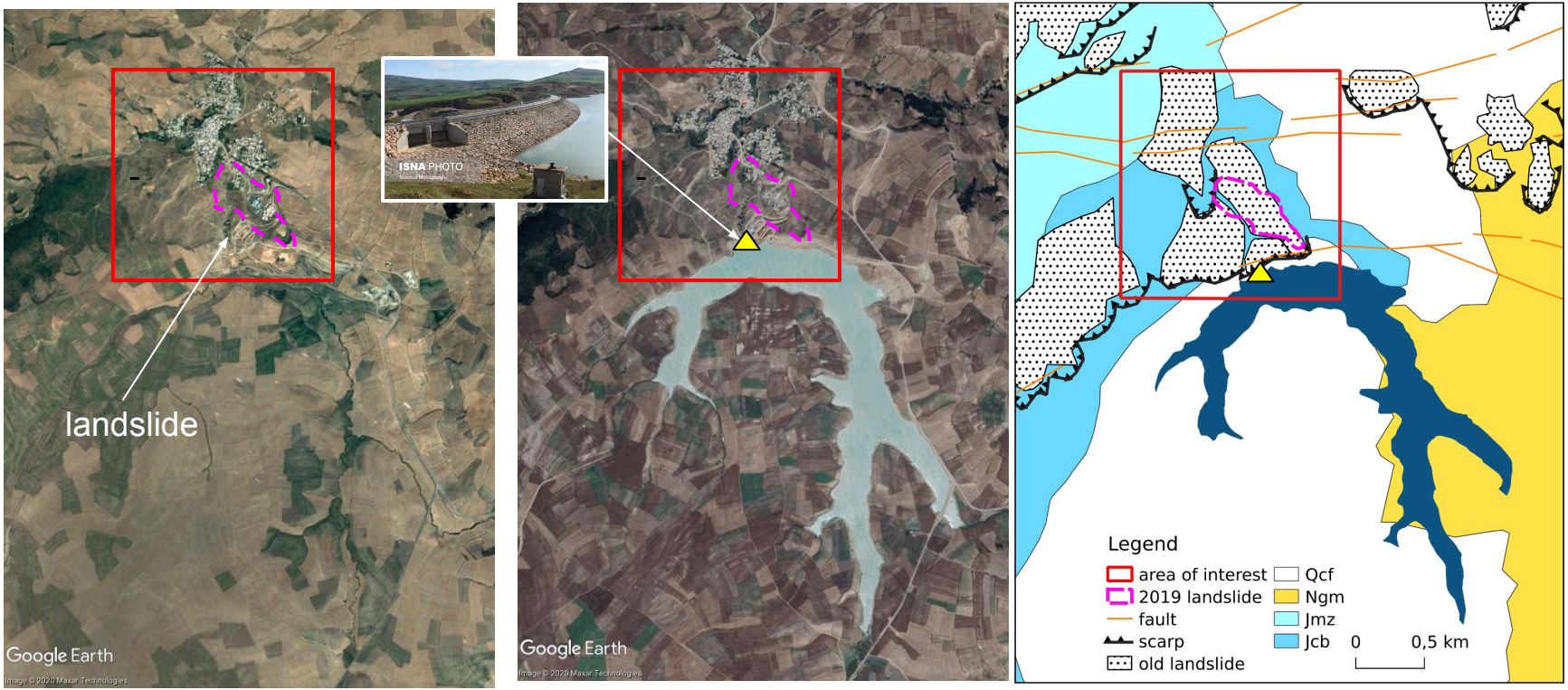

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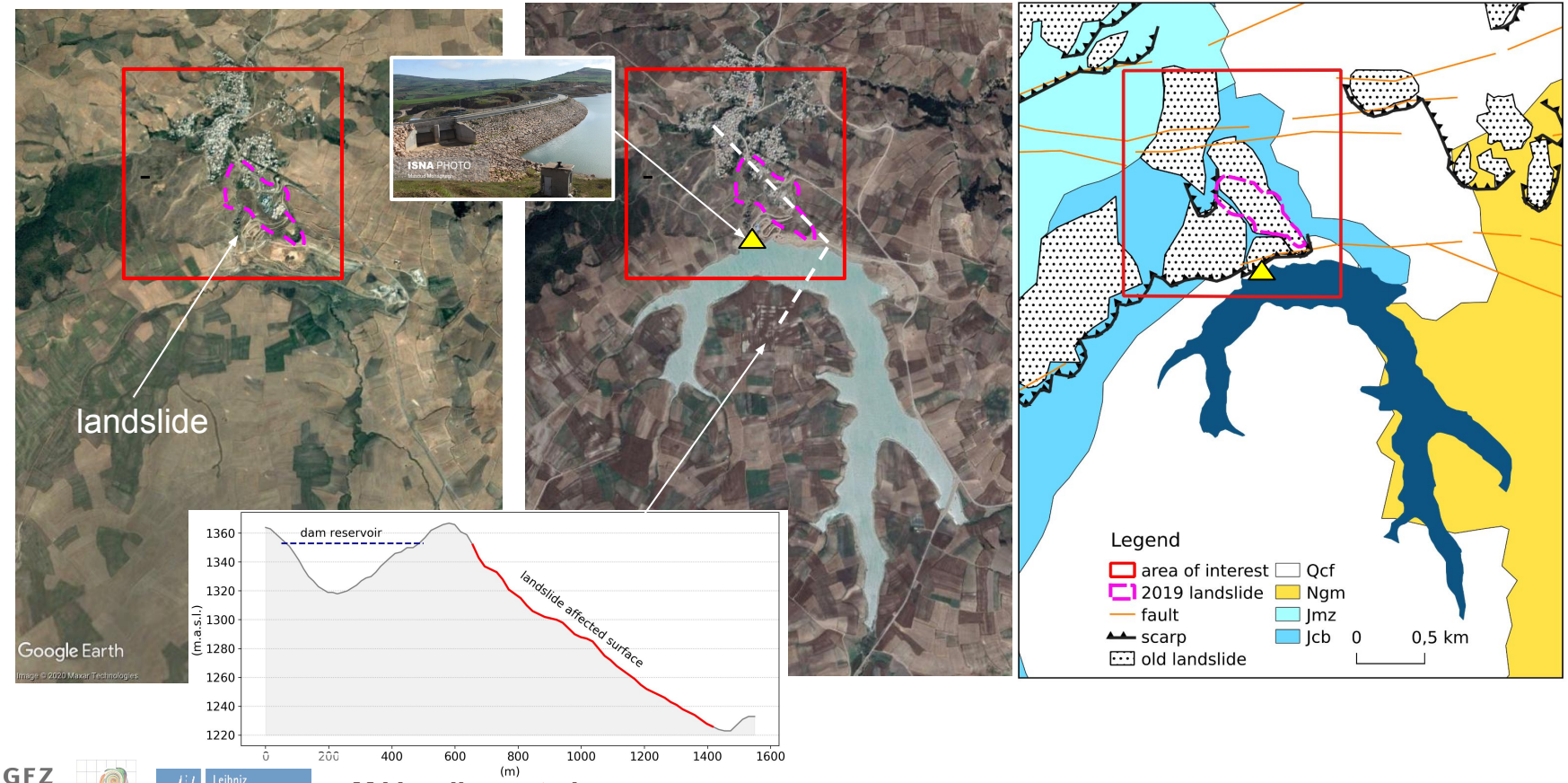

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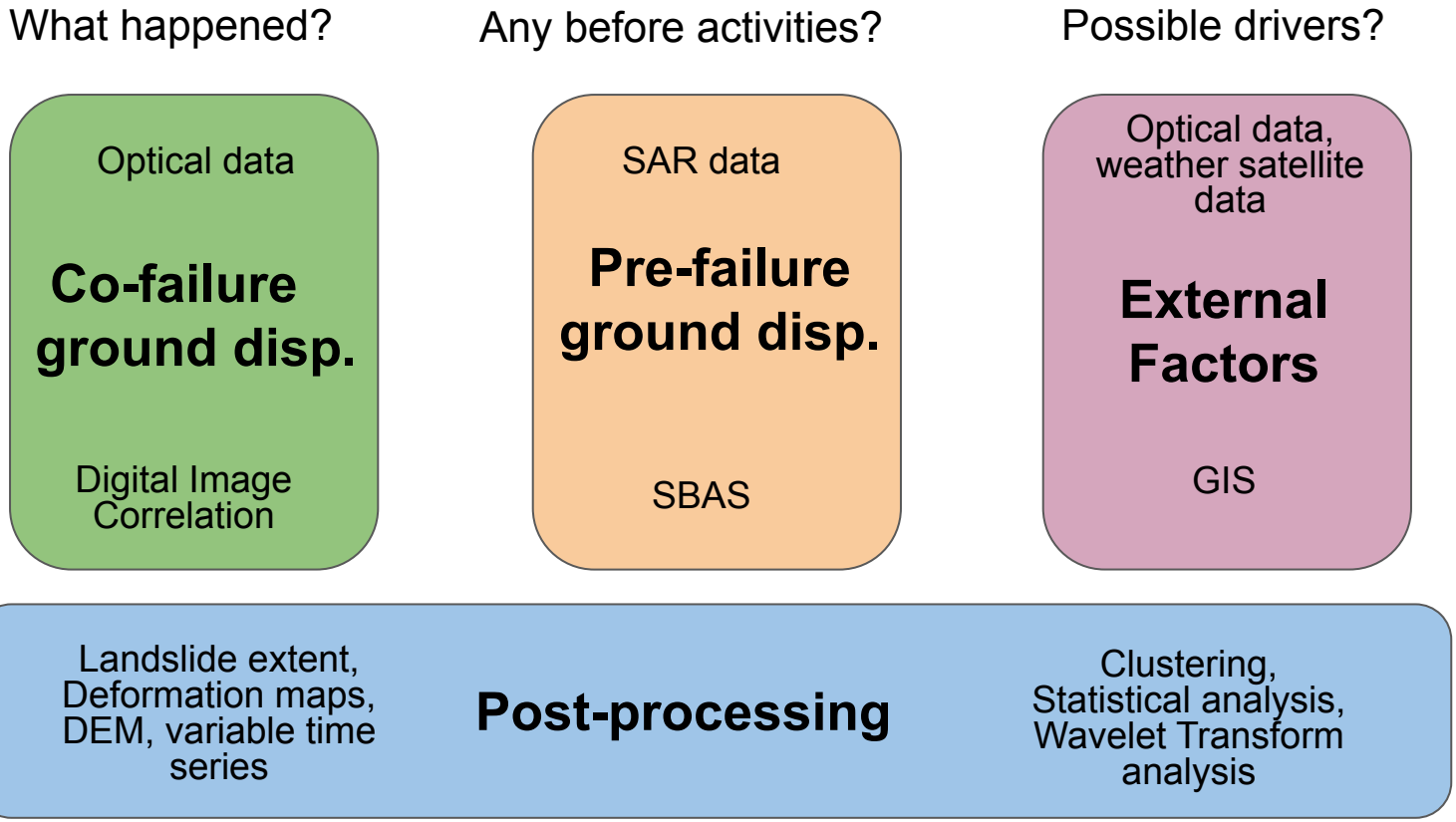
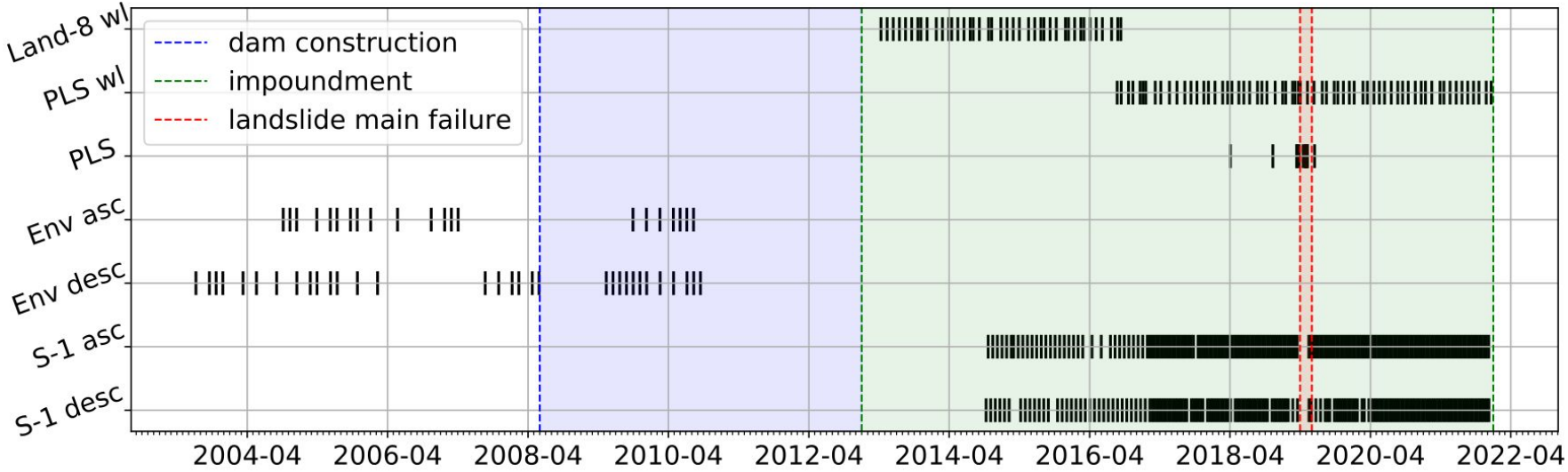

What happened?
Any before activities?
Possible drivers?
Optical data
Co-failure ground disp.
Digital Image Correlation
SAR data
Pre-failure ground disp.
SBAS
Optical data, weather satellite data
External Factors
GIS
Landslide extent, Deformation maps, DEM, variable time series
Post-processing
Clustering, Statistical analysis, Wavelet Transform analysis

Remote Sensing Data

Envisat, Sentinel-1, Landsat-8, PlanetScope, *CHIRPS precipitation dataset

*Climate Hazards Group InfraRed Precipitation with Station data



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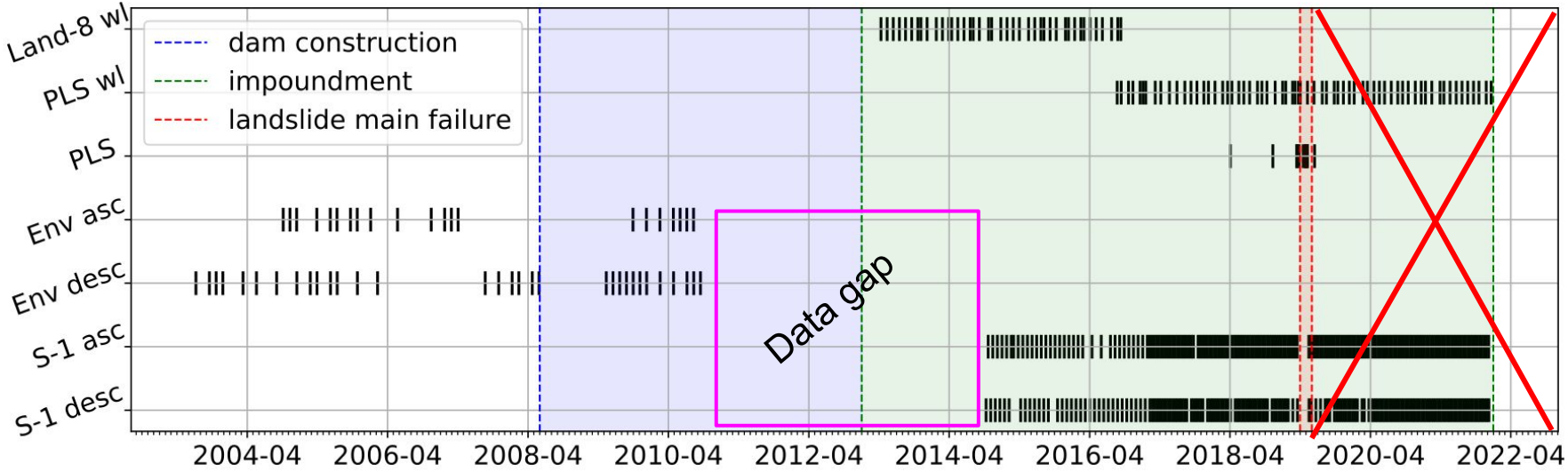
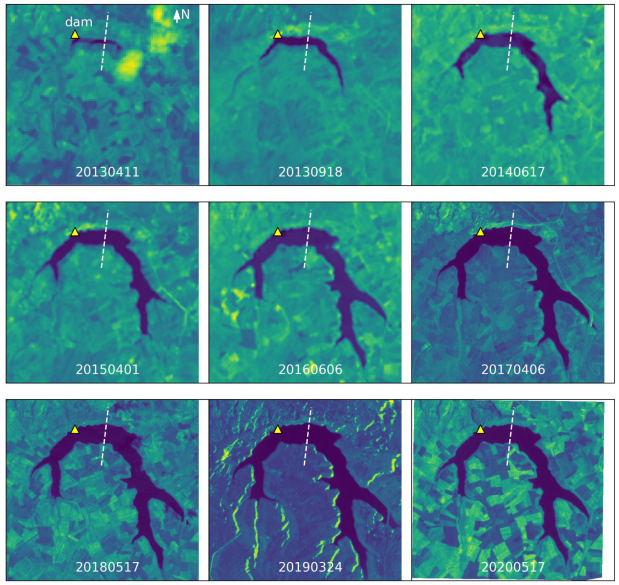
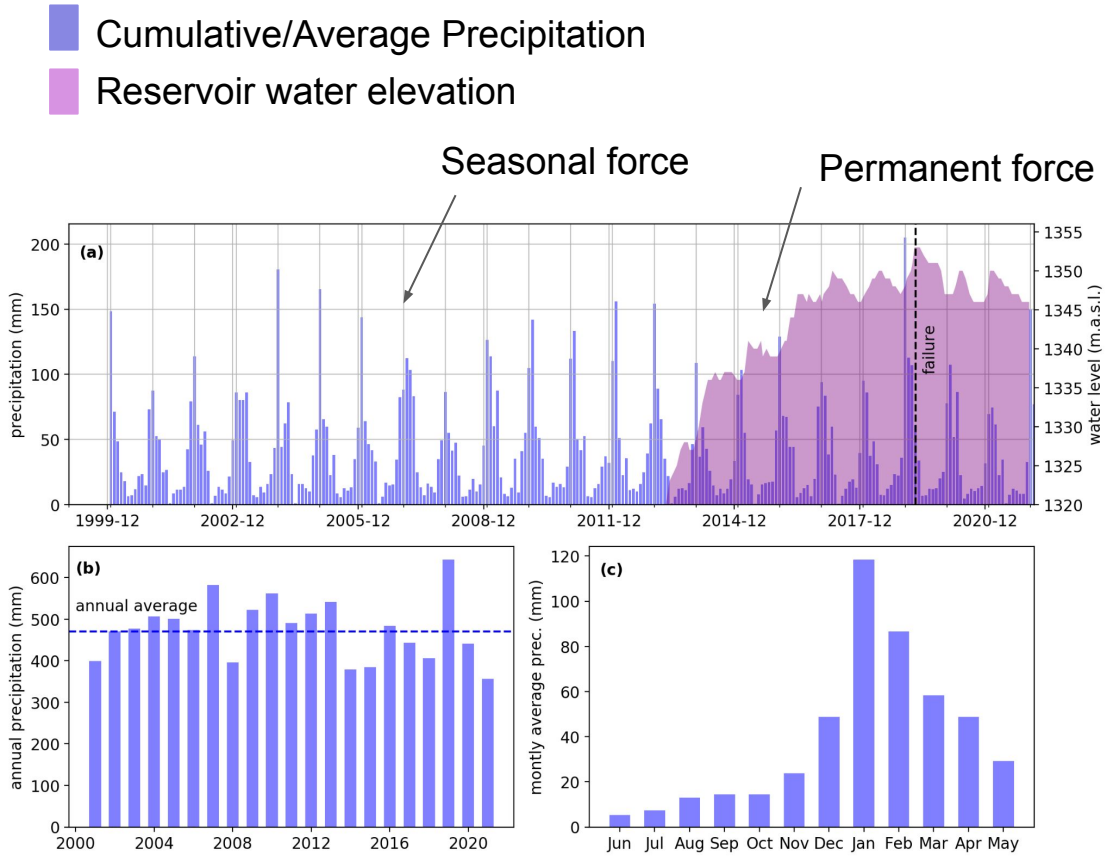


External Factors

Reservoir water elevation extraction from time series of Landsat-8 and PlanetScope images combined with SRTM





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Co-failure ground displacement

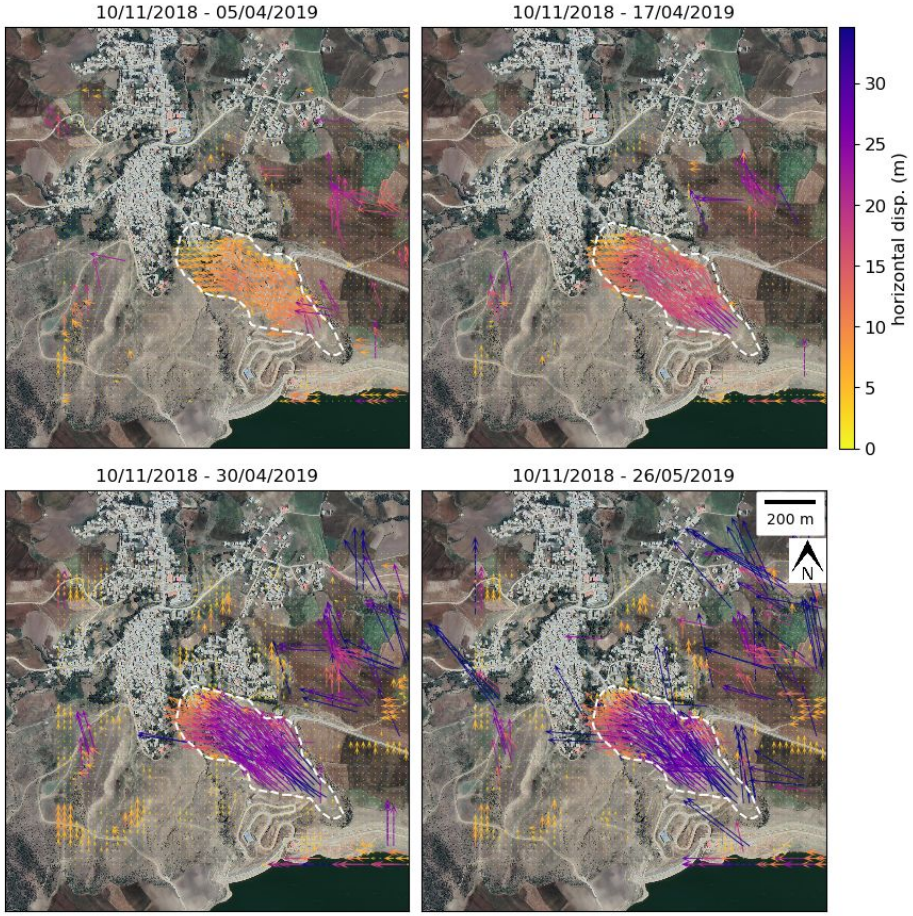
PlanetScope (3m resolution) time series 11.2018-06.2019

Deep-seated landslide failure;

Rupture scarp on the top and deposited mass on the bottom;

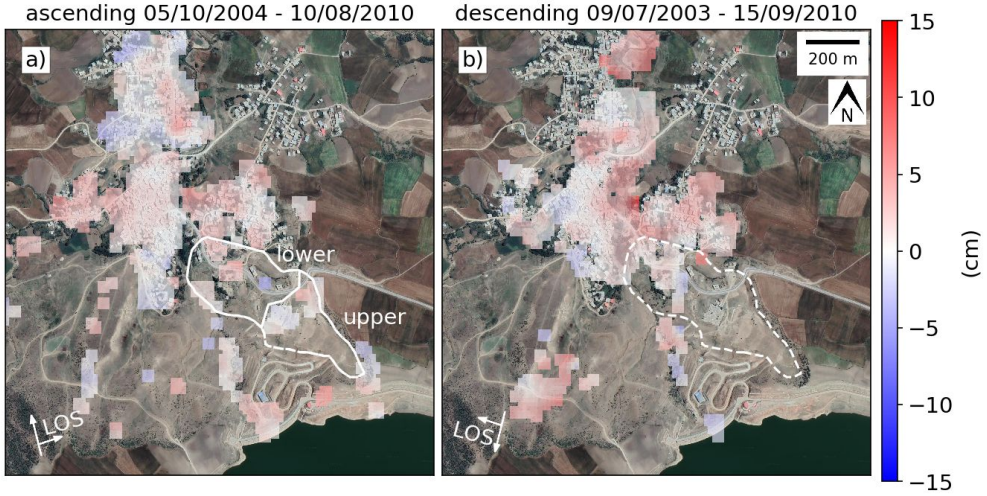
Horizontal offset higher than 40m on the upper part;

Up to 8 m on the lower part.

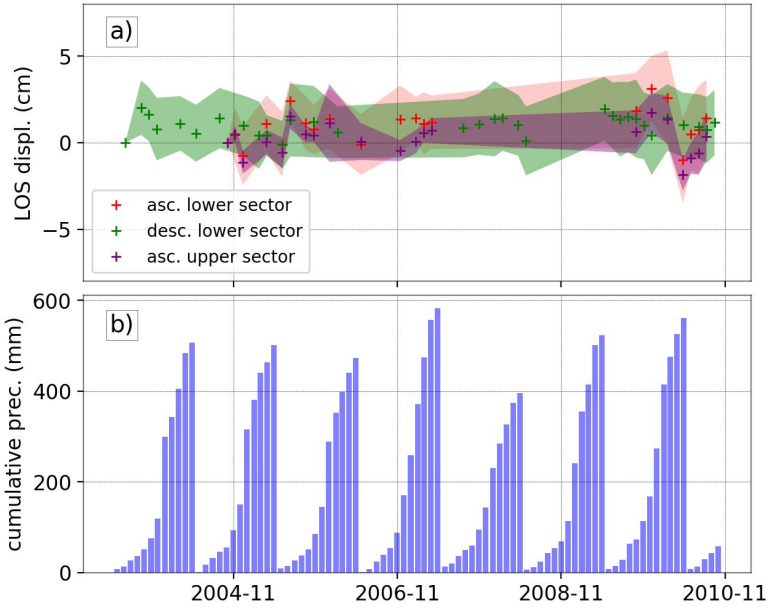


Pre-failure ground displacement

Envisat dataset Sept. 2003 - Sept.2010



LOS ground displacement



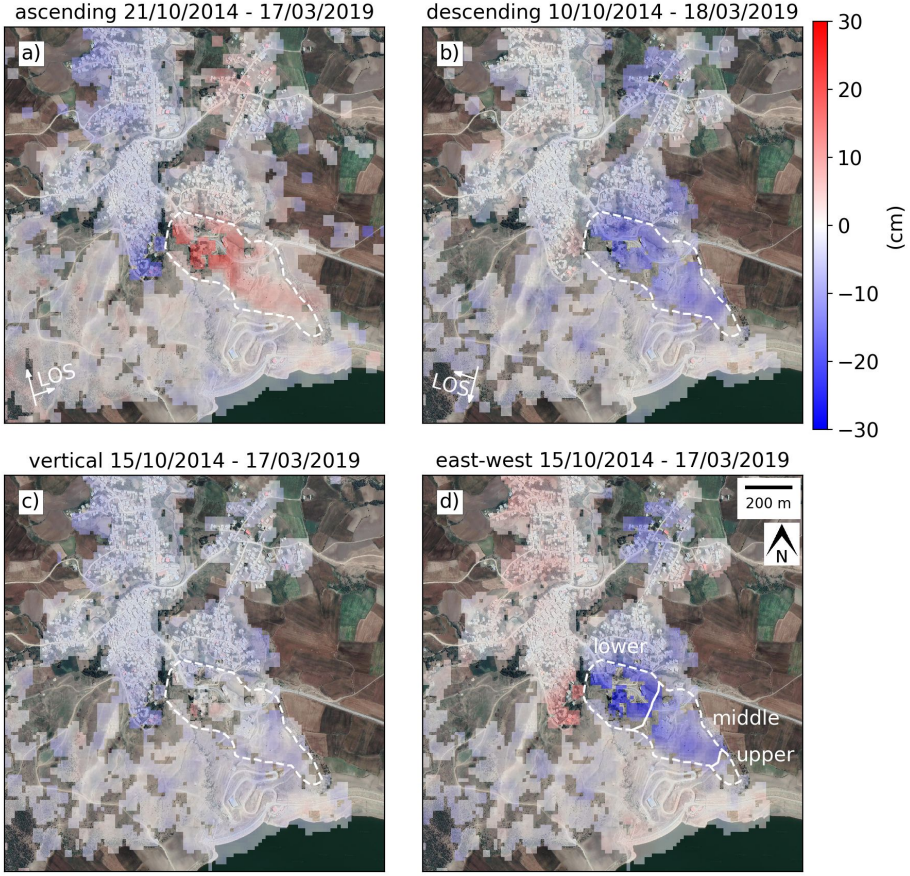
Pre-failure ground displacement

Sentinel-1 dataset 10.2014-03.2019

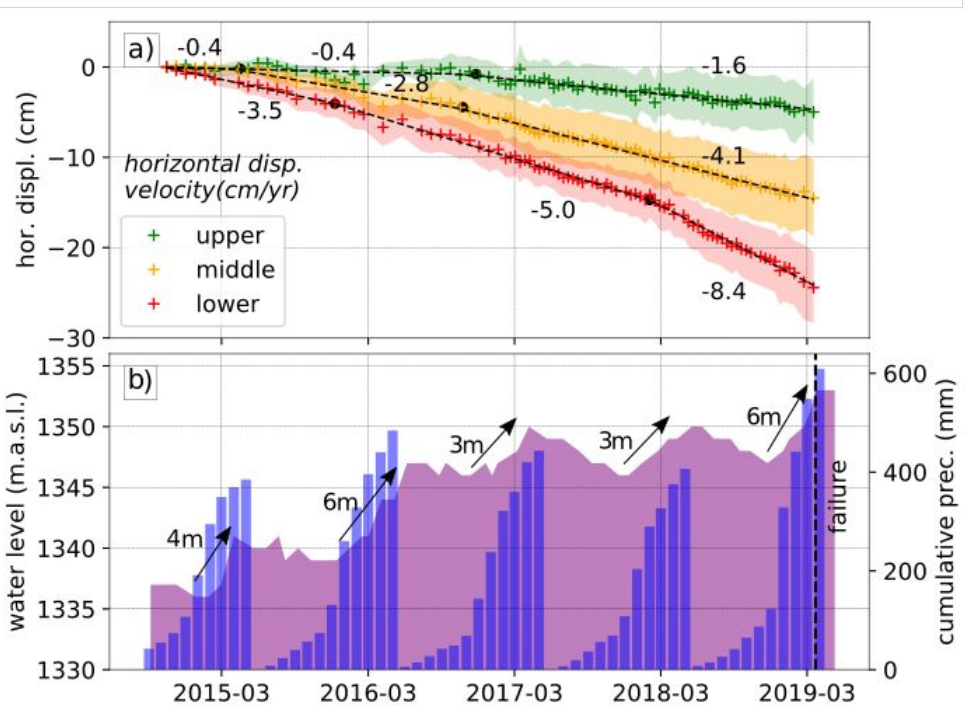
Predominant horizontal east-west oriented component;

Up to 30 cm of horizontal shift in 4 and a half years;

Few cm of vertical downward motion.

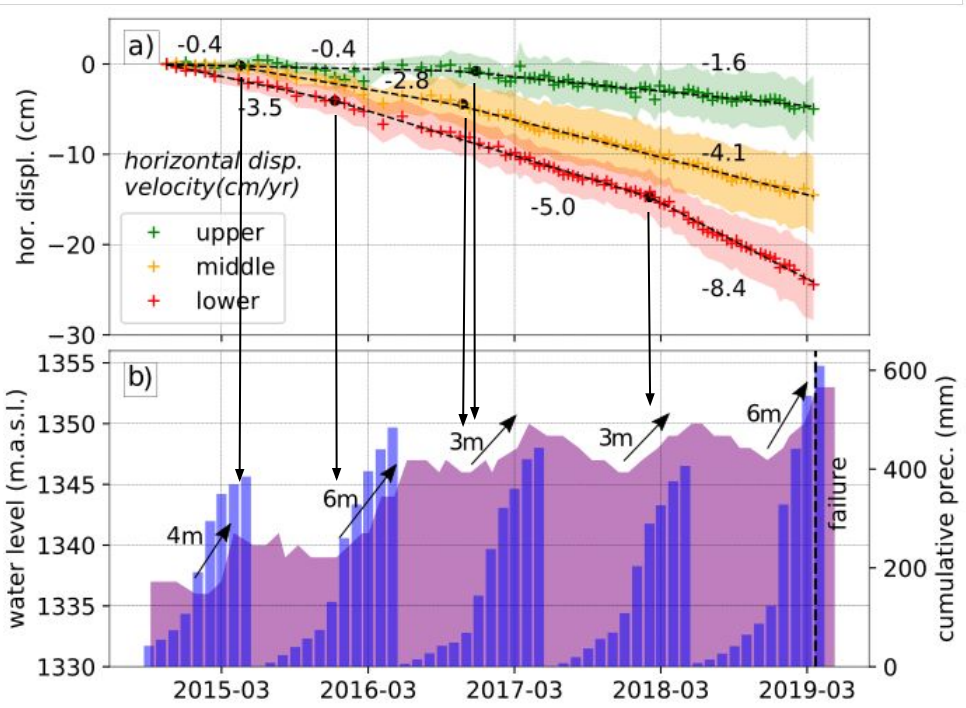


Horizontal component



Nearly linear trends increasing with time;

Horizontal component



Nearly linear trends increasing with time;

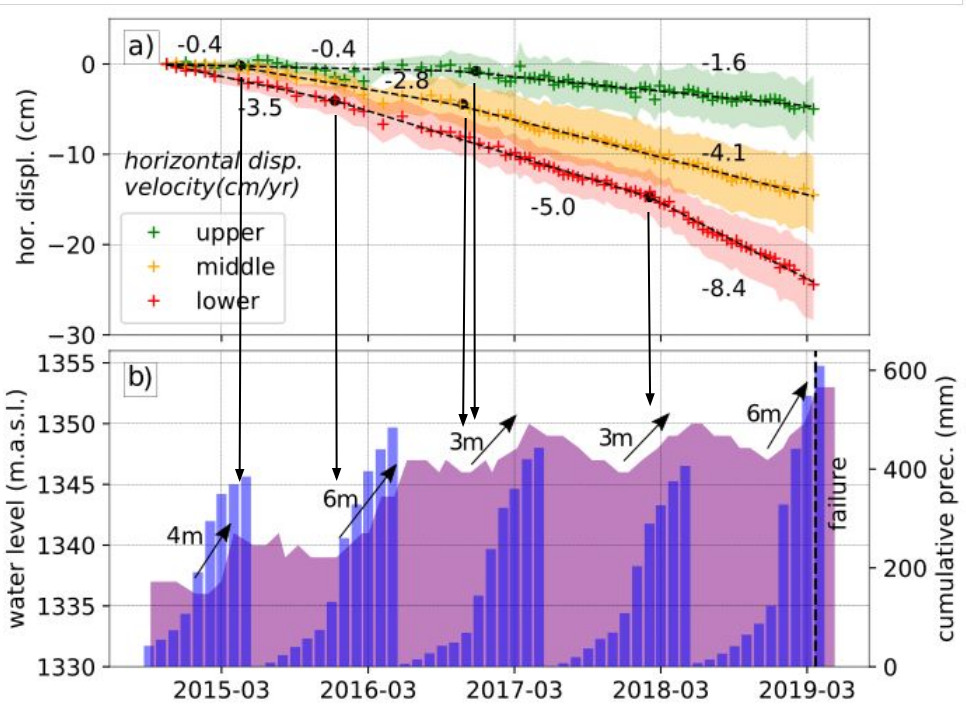
The lower part was already moving at the end of 2014 (the water level was **18 m**);

The middle part started to move around May 2015 (the water level was **22 m**);

The upper part started to move around January 2017 (the water level was **28 m**);

Retrogressive mechanism of destabilization;

Horizontal component



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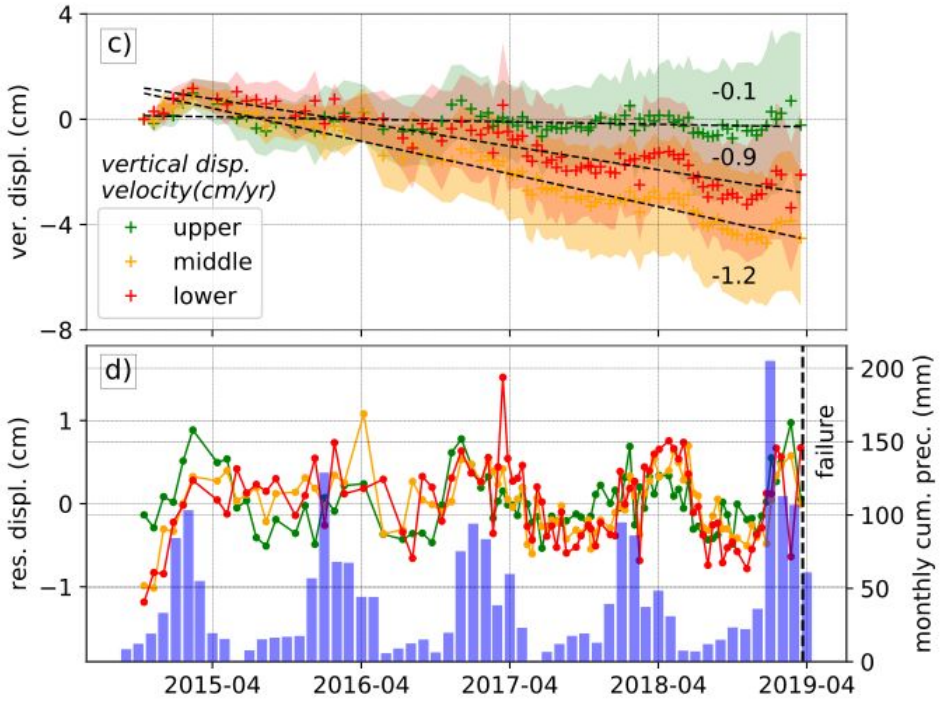
The upper part started to move around January 2017 (the water level was **28 m**).

Retrogressive mechanism of destabilization;

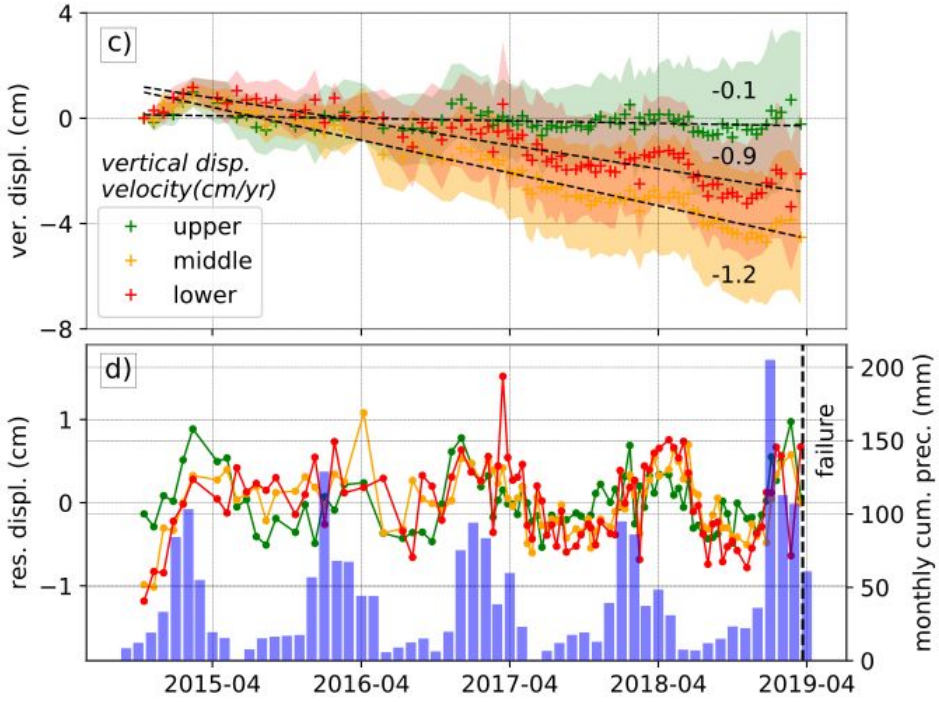
Constantly acting external force (not a seasonal one) due to the water impoundment.

Vertical component



Small main linear trend;

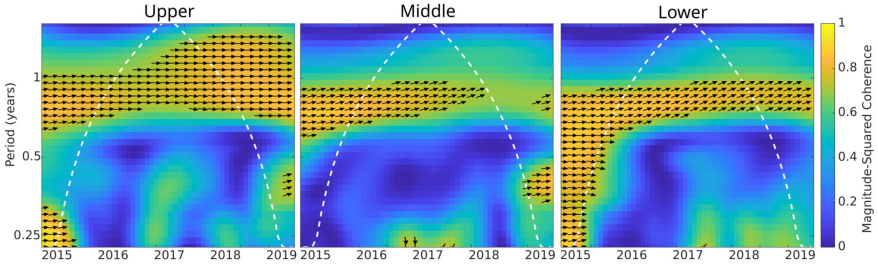
Vertical component



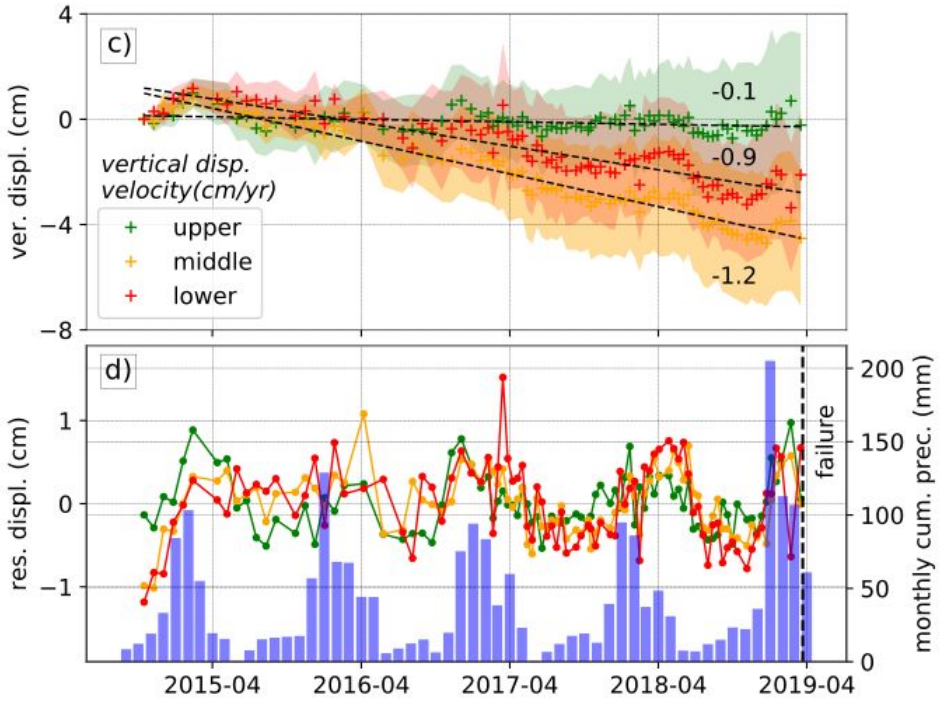
Small main linear trend;

Seasonal component that correlates yearly and in-phase with the monthly cumulative precipitation

Cross Wavelet Transform



Vertical component



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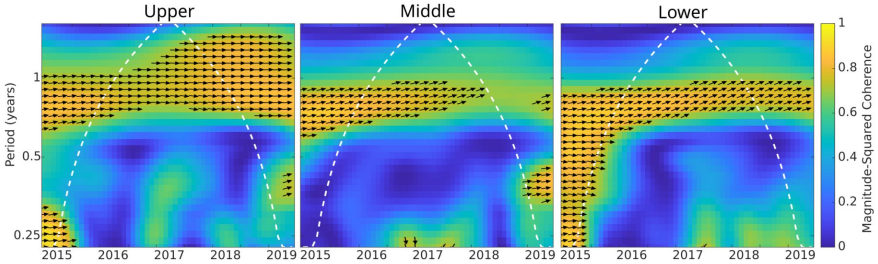
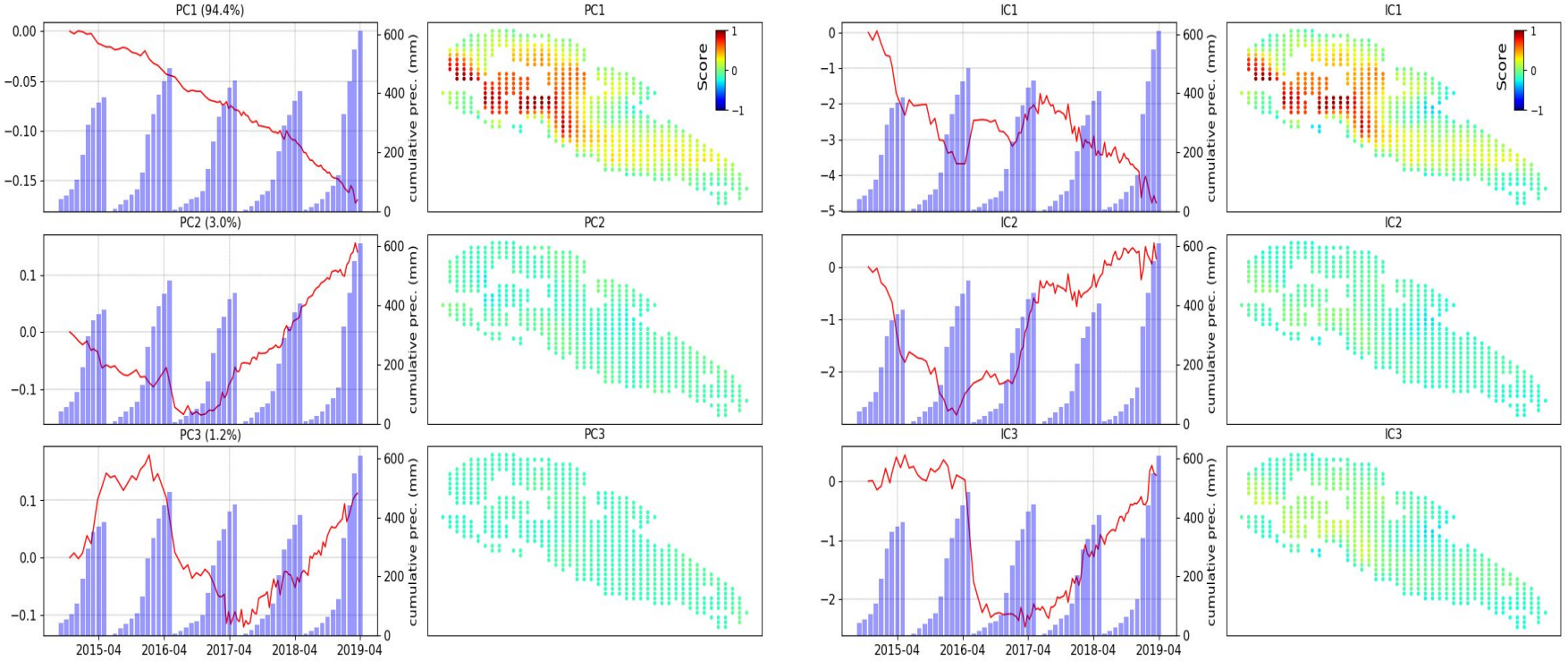
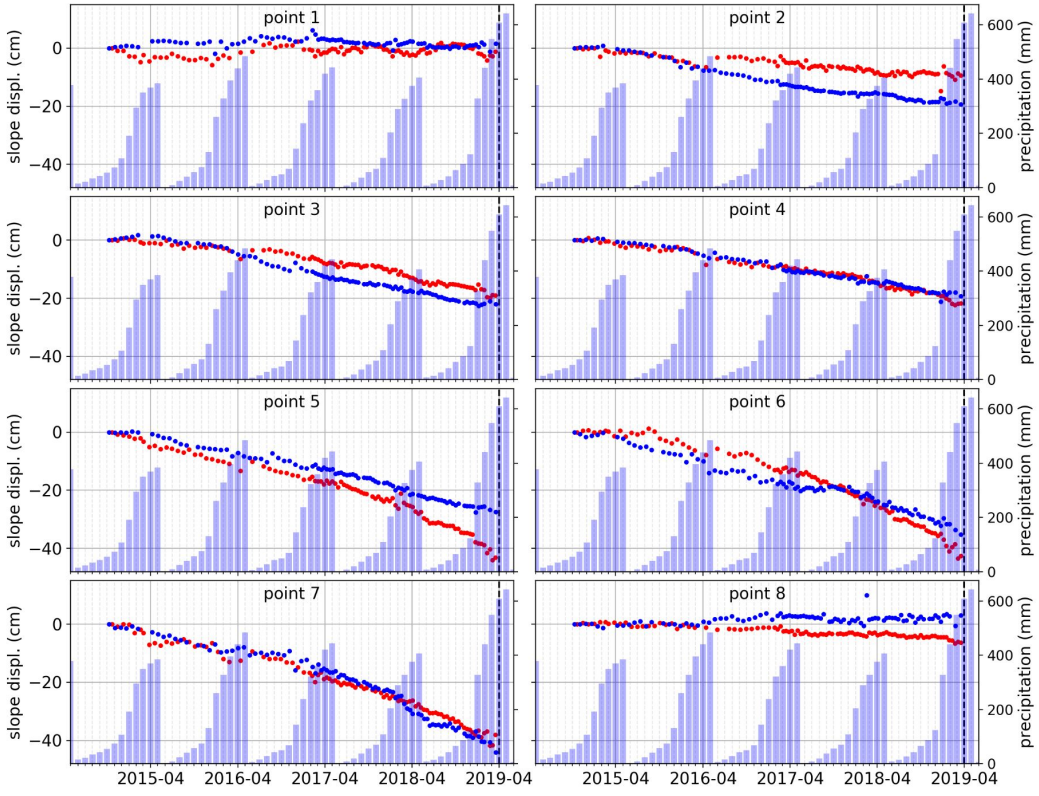


Swelling and shrinkage of the shallower soil layer due to seasonal soil moisture change.

PCA (horizontal component) ICA

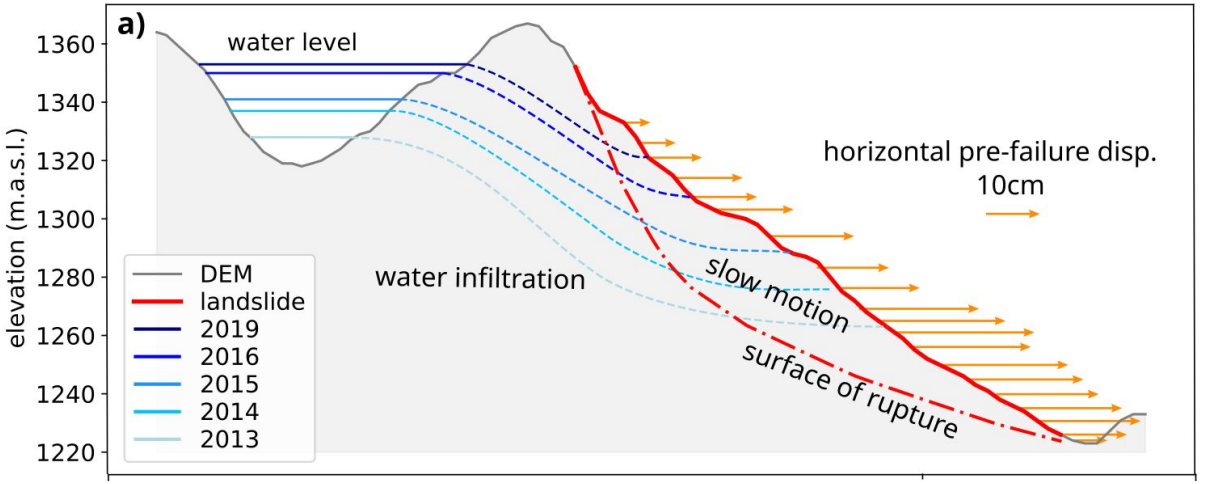


Slope displacement (ascending and descending)



From relict to a slow-moving landslide:
An relict landslide was reactivated due to water impoundment. Results shows that in this first stage, the landslide kinematics was mainly controlled by the dam water level changes.

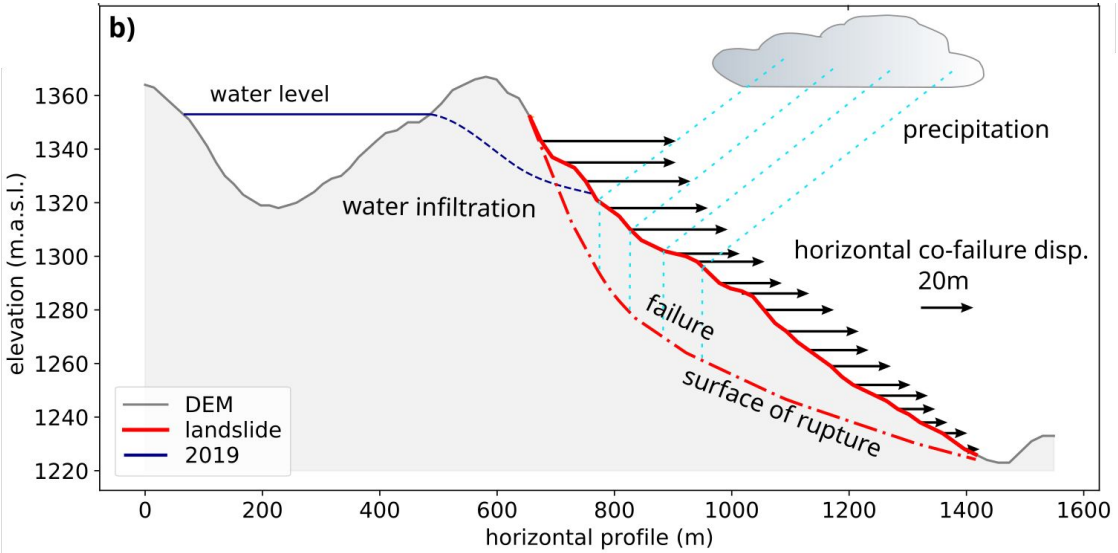
The SAR revisit time does not allow to observe any precursors in the weeks/days before the failure.



Triggers for the 2019 landslide failure

- Exceptional precipitation infiltration;
- Slope geomechanical degradation due to 4.5 years prefailure slow motion;
- Changes of the hydraulic conditions of the slope due to the water reservoir;
- Further groundwater increase due to the reservoir water level rise following the exceptional precipitation period

It is not possible to separate the effect on the landslide of the different contributions triggering the final landslide failure using remote sensing only.

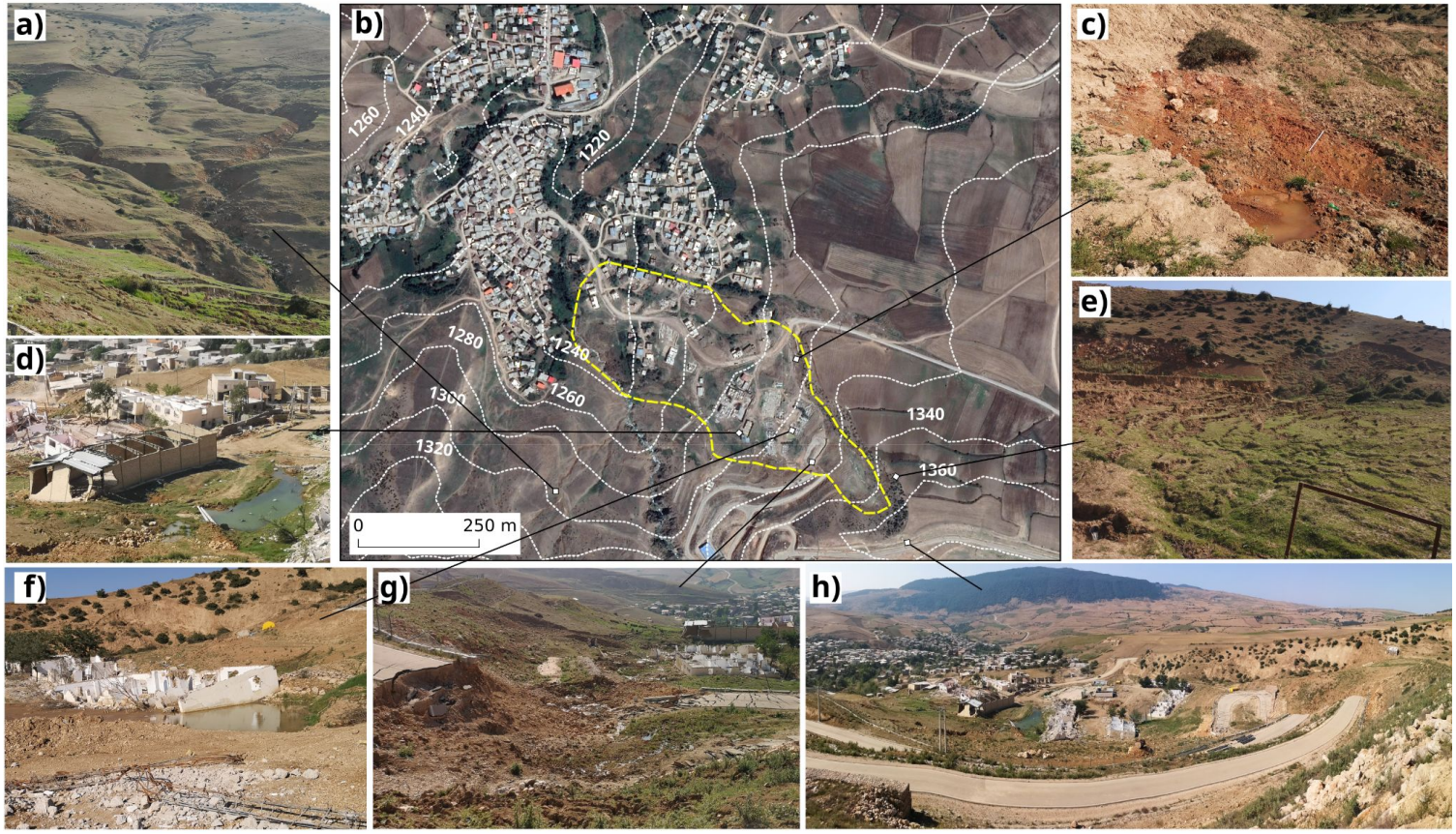


General conclusions

Rainfall and anthropogenic factors needs to be considered together in landslide interpretation;

Multi-sensor and multi-variable satellite observation approach provides better interpretation of landslides kinematics and driving forces;

Time-series extraction strategies can impact landslide interpretation.


a)
b)
c)
d)
e)
f)
g)
h)
1260
1240
1220
1280
1240
1300
1260
1320
1340
1360
0
250 m