# Natural hazards evolution in a context of climate evolution and infrastructure development: the Kali Gandaki valley case, West-Central Nepal.

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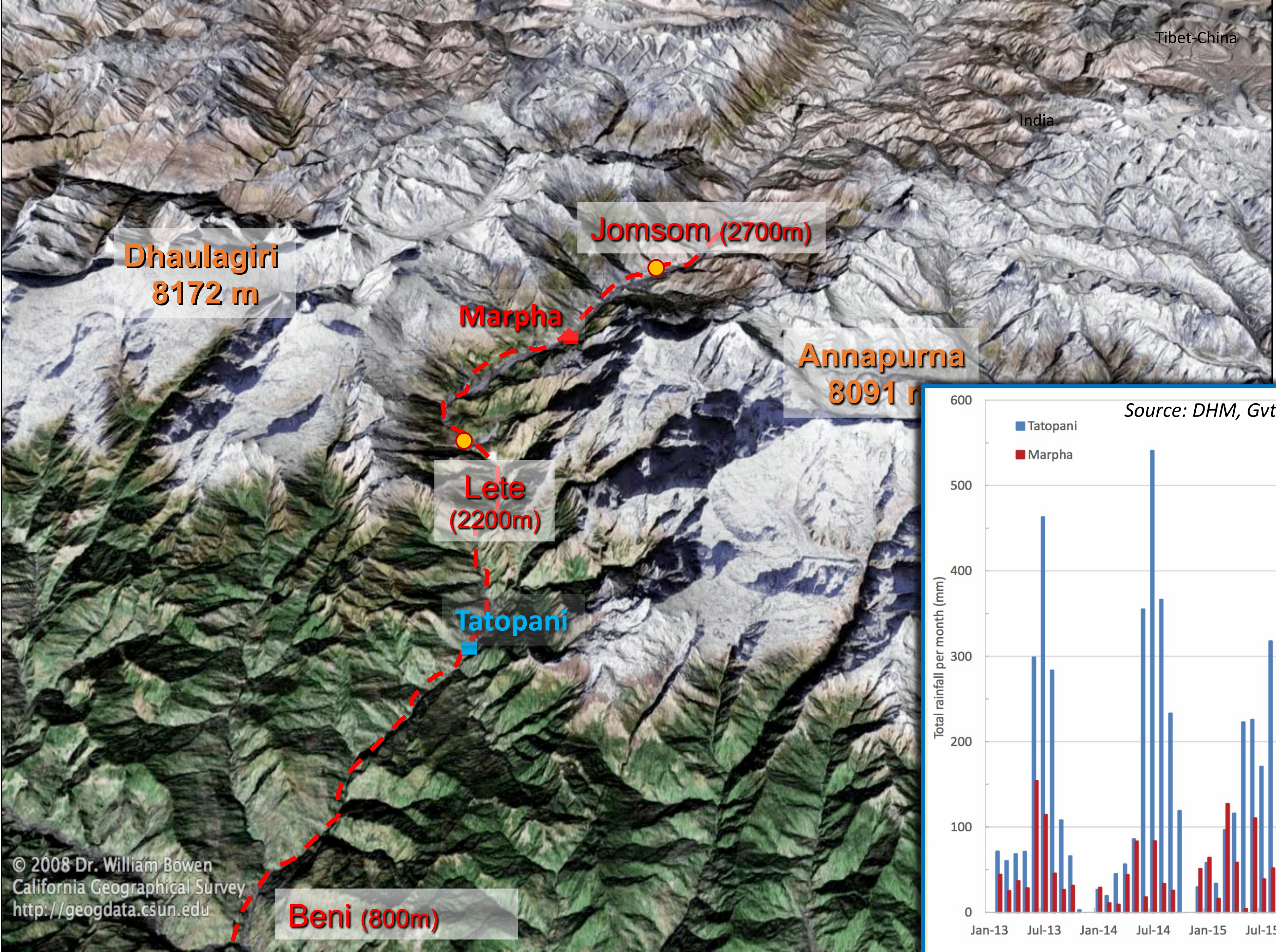
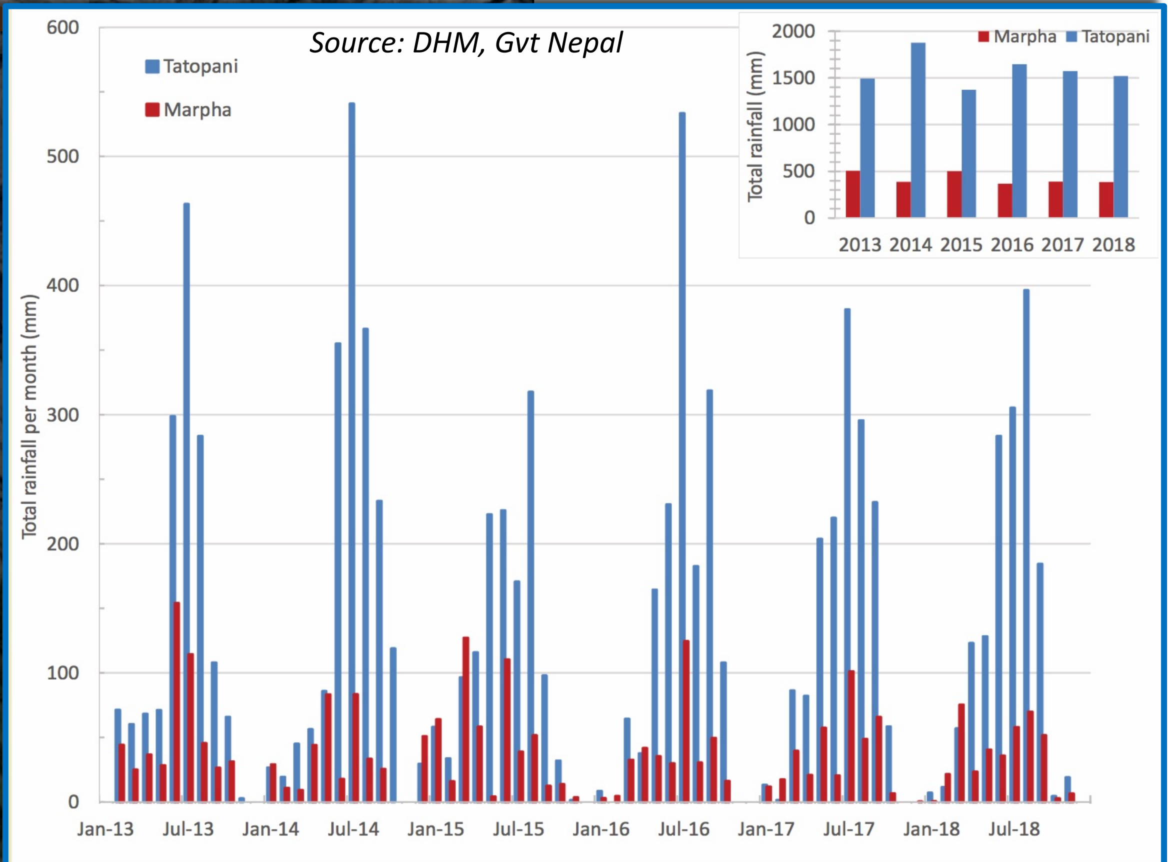
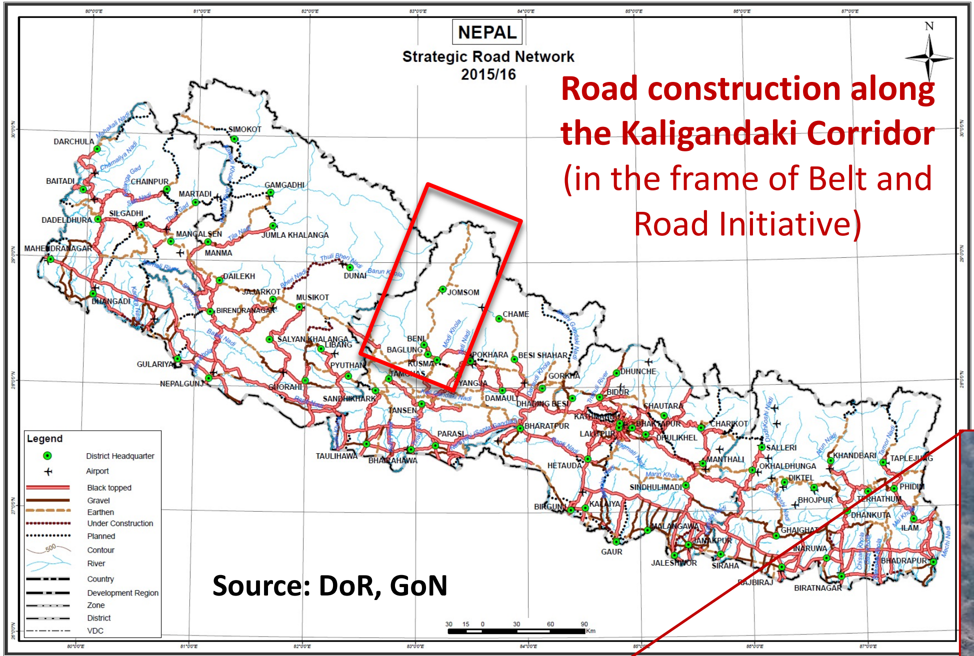
# The Kali Gandaki: deepest valley on Earth (6,000m height difference)

## Sharp contrasts in total rainfall (monsoon vs. rain shadow)



# The Middle Kali Gandaki valley and its tributaries: Which factors control geomorphic evolution?



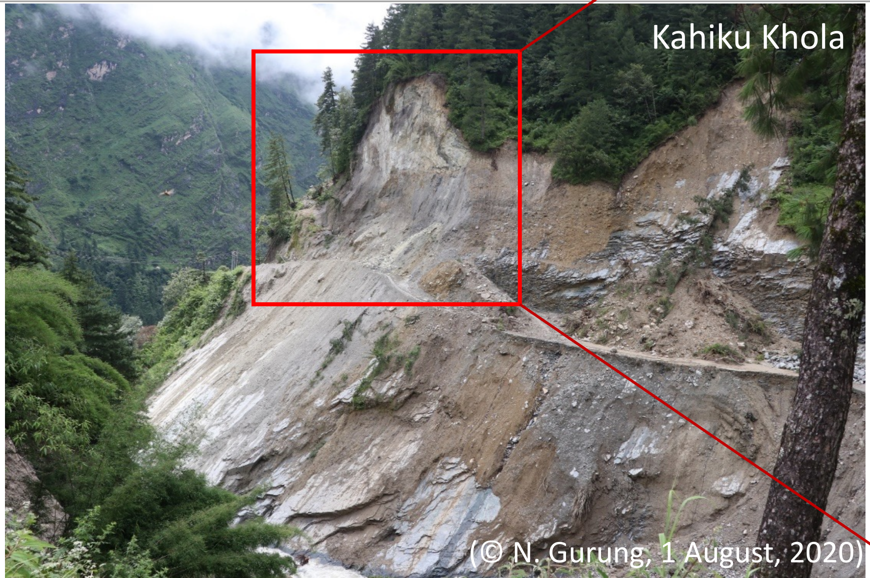

**Road construction along the Kaligandaki Corridor** (in the frame of Belt and Road Initiative)

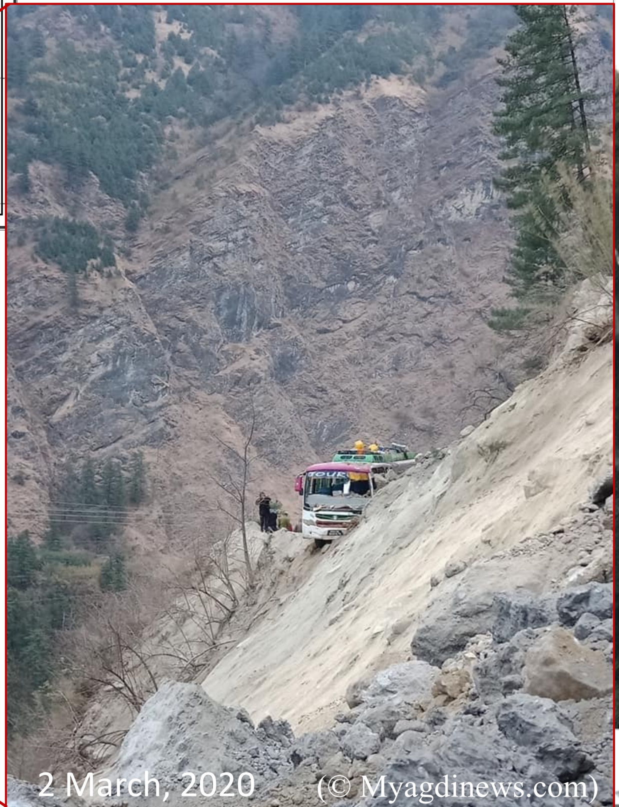
**Natural control factors:**

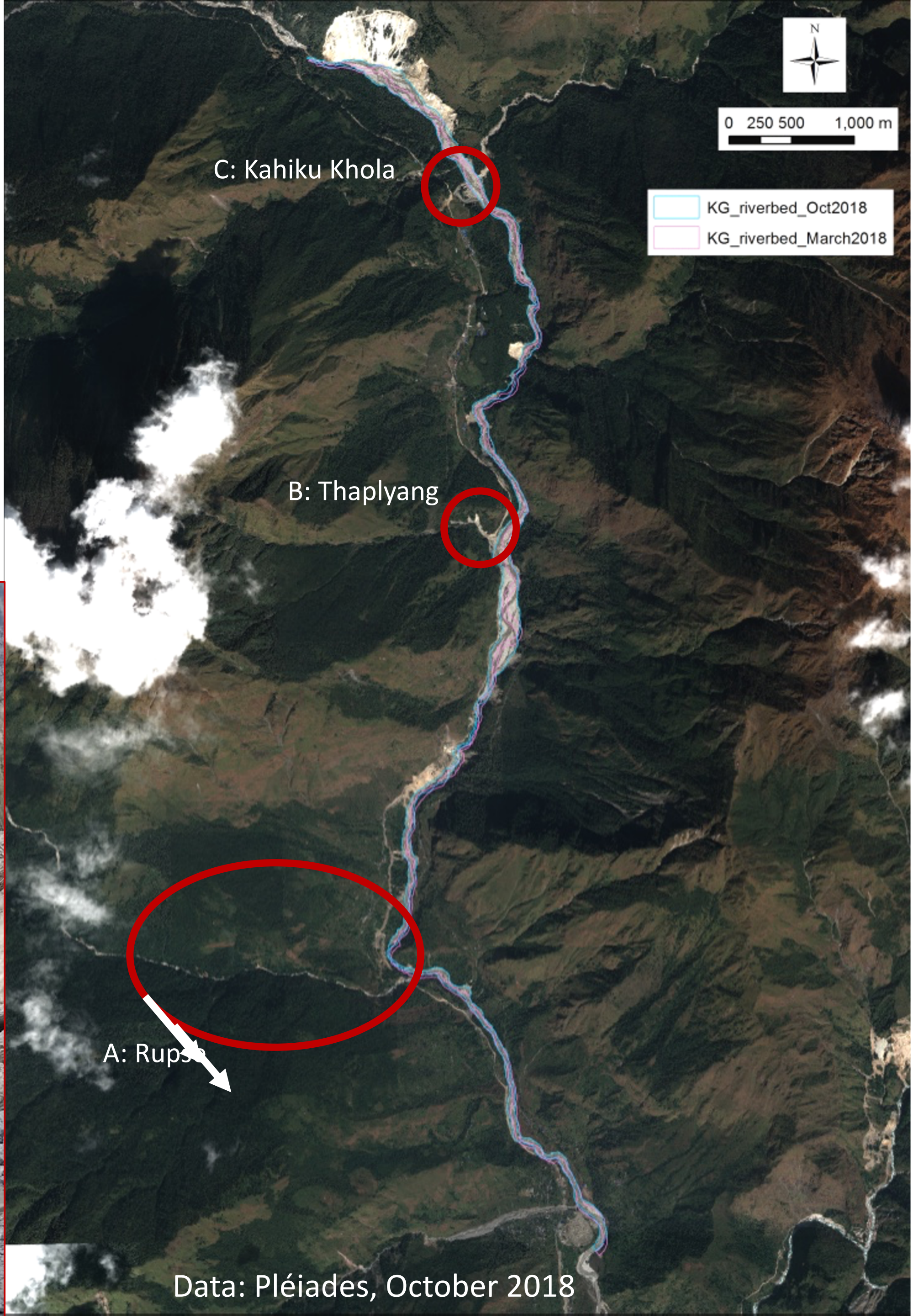
**(1) Rainfall in upper tributary catchments**

**(2) Kali Gandaki River high flow:** cf. Mapping of the active river bed in March and October 2018

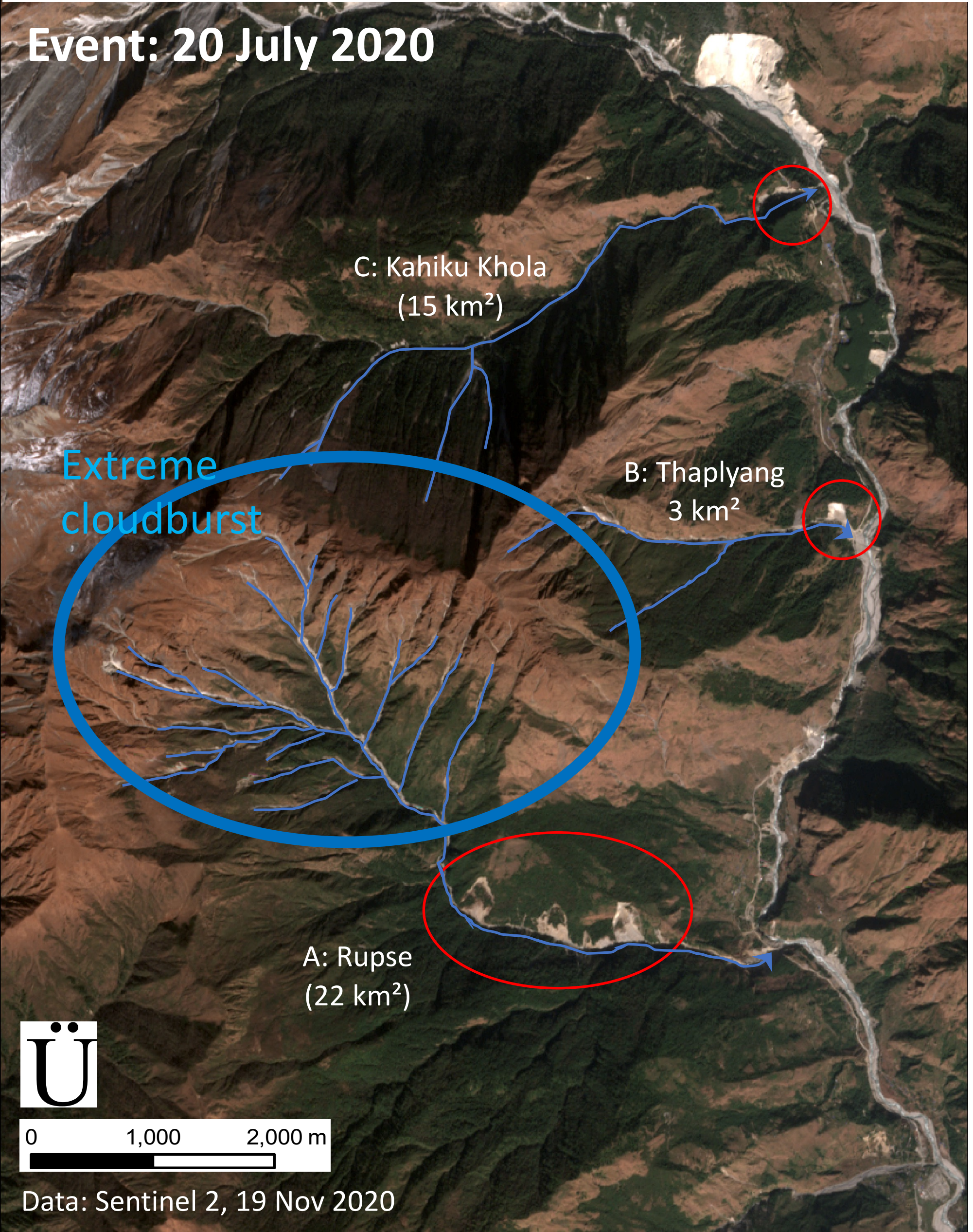
*(Bell et al., 2021, Geomorphology)*



# The Middle Kali Gandaki valley and its tributaries: Which factors control geomorphic evolution?



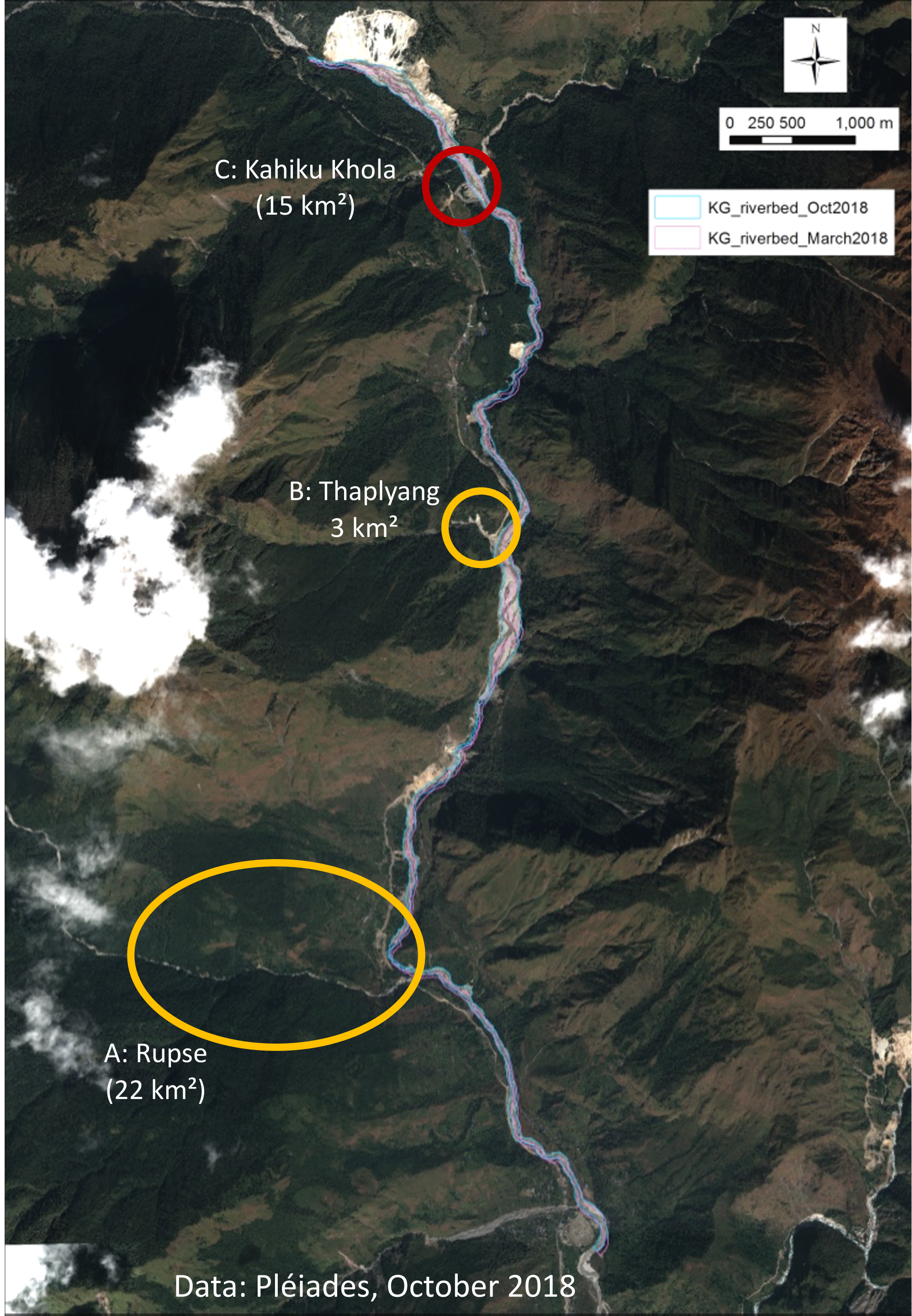

## 3 studied catchments

**Focus on 2 of them:**

- **A) Rupse khola** ($22\ km^2$), famous for its **waterfalls** downstream (banded gneiss of pelitic to araneous origin)
- **B) Thaplyang khola** ($3\ km^2$), **contact between bedrock** (calc-silicate gneiss and marbles) and an **old landslide mass (**South of Ghasa), destabilized since 2014 (road construction)

**Direct impacts on the KG:**

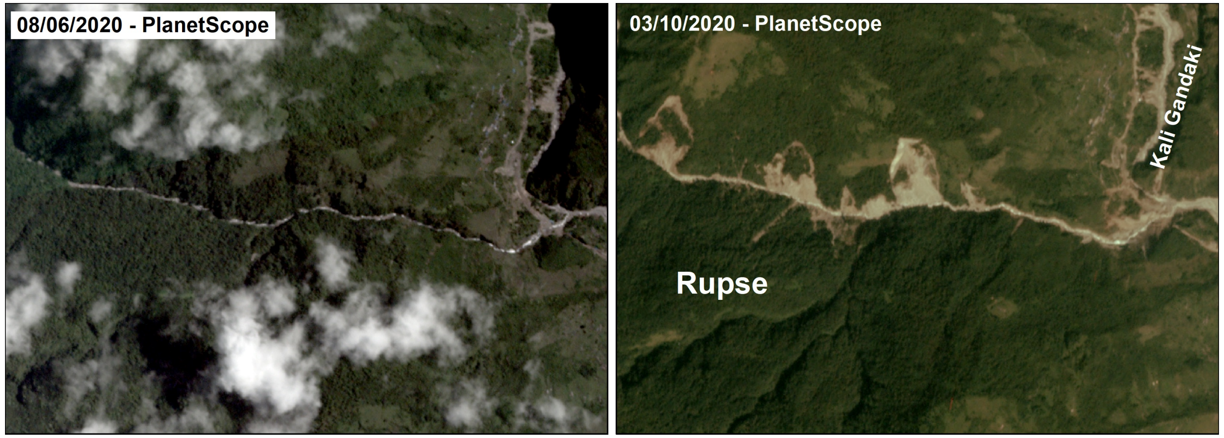
(1) Loose material provided and
(2) acceleration of the cascading process and transfer to the KG



# Methods and data collection

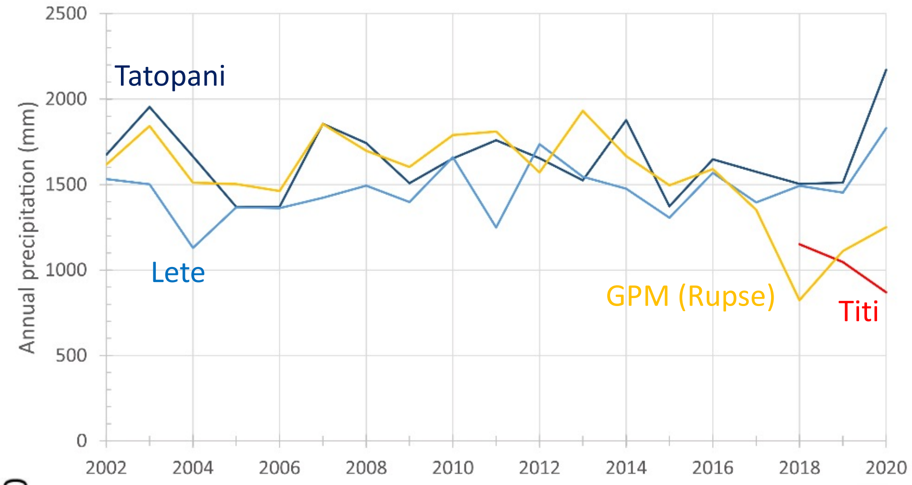
1) Satellite image interpretation (PlanetScope, Sentinel 2)
2) Diachronic field photos
3) Precipitation analysis (local stations, Global Precipitation Measurement (GPM))
4) Seismic monitoring
5) SAR analysis: Landslide timing detection

1)




2)


3)

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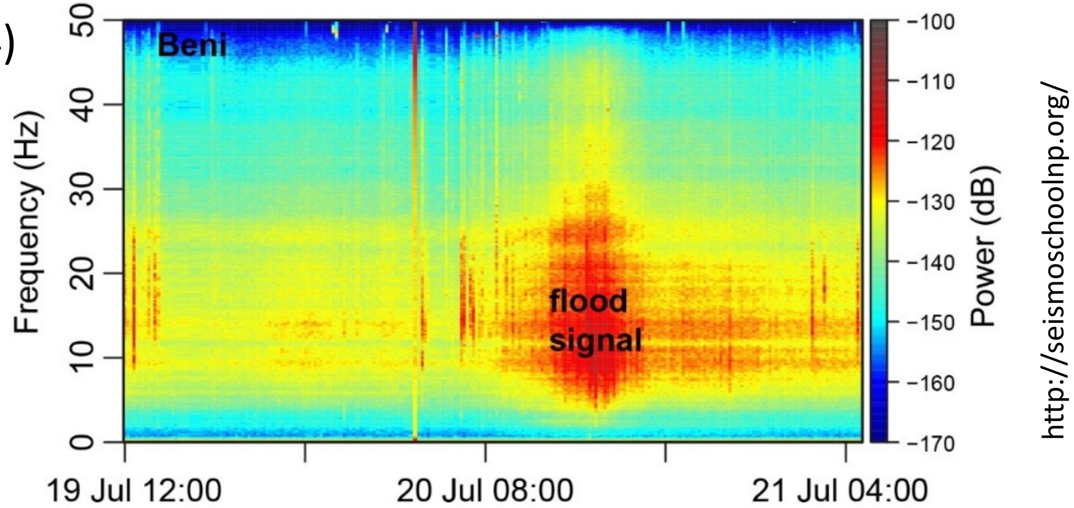
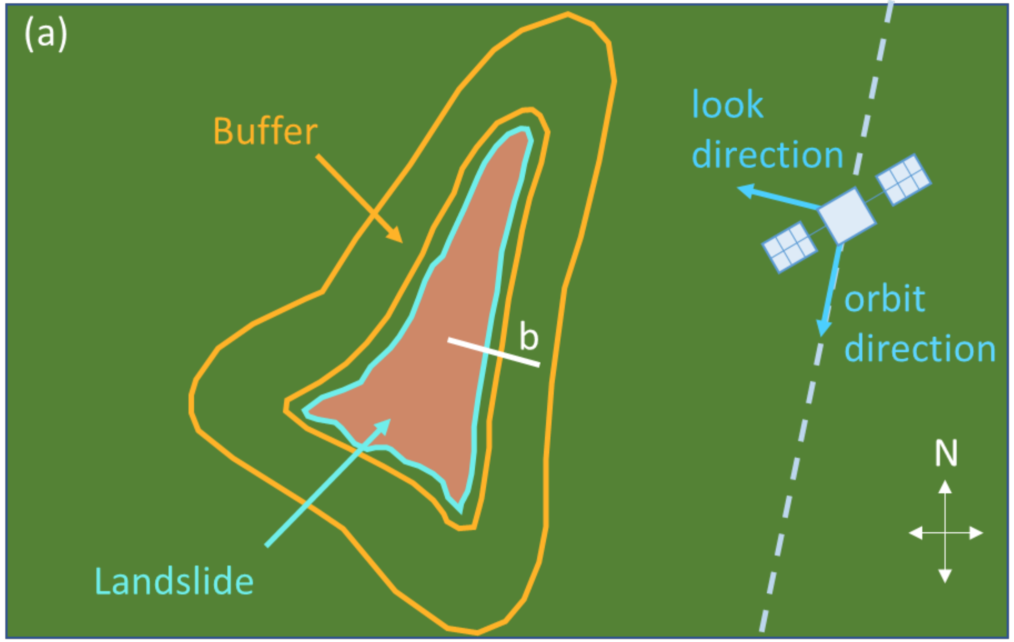
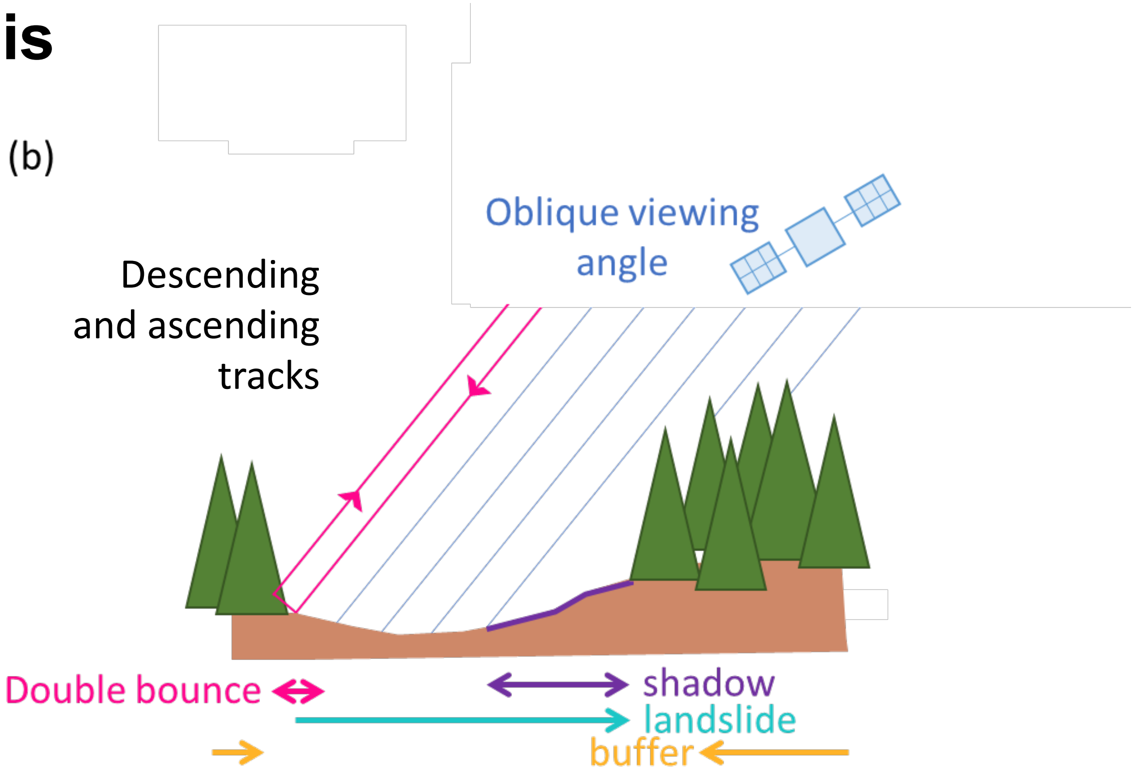


# Methods and data collection: 5) SAR analysis

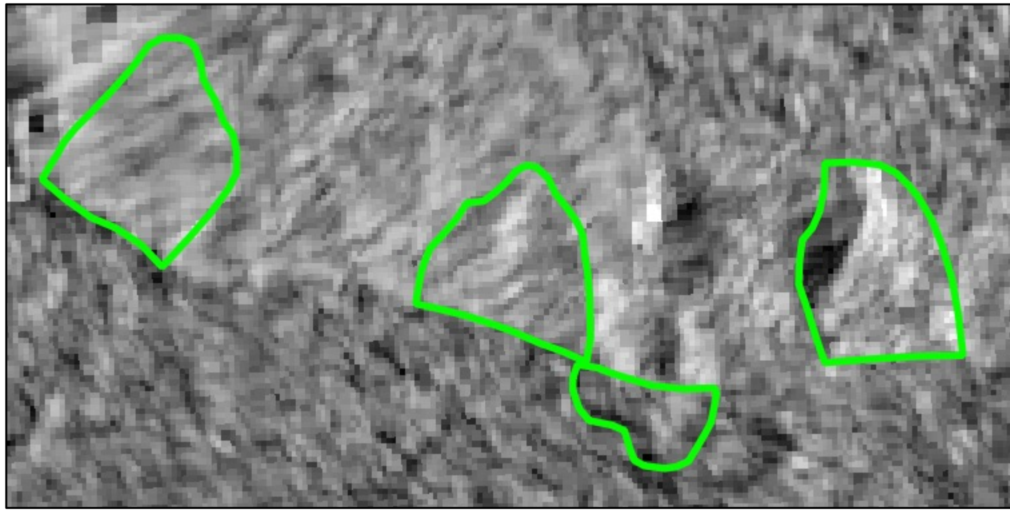



**SAR Methods of landslide timing detection**:

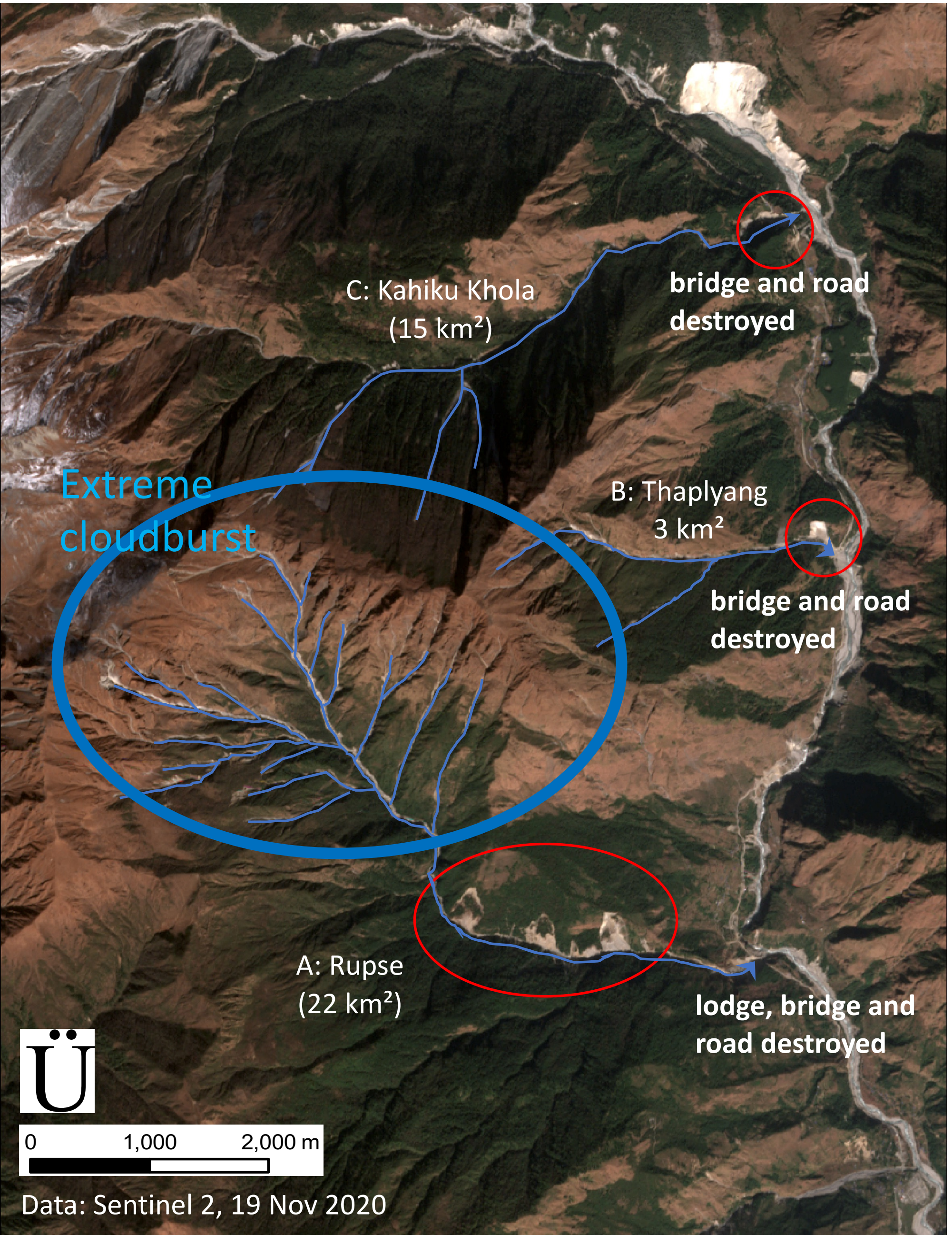
1. Step increase or decrease in the difference in median amplitude between the landslide and a “background” zone defined by a buffer around the landslide polygon
2. Step increase in variability between pixels within the landslide polygons (assessed using standard deviation)
3. Emergence of geometric shadows cast within landslide polygons
4. Emergence of bright spots cast within landslide polygons

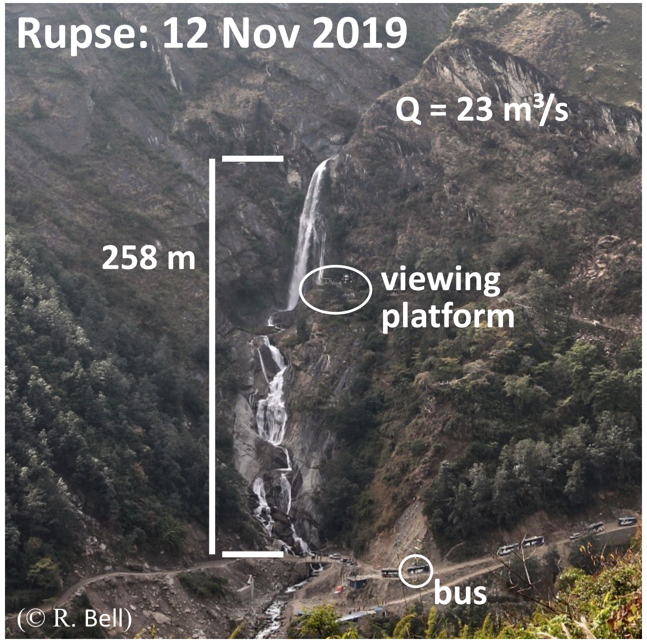
*(for details, see Burrows et al., in review - NHESS discussions)*



# Preliminary results: RUPSE

## Event: 20 July 2020, 4-6pm (min. 30-40 yrs event)

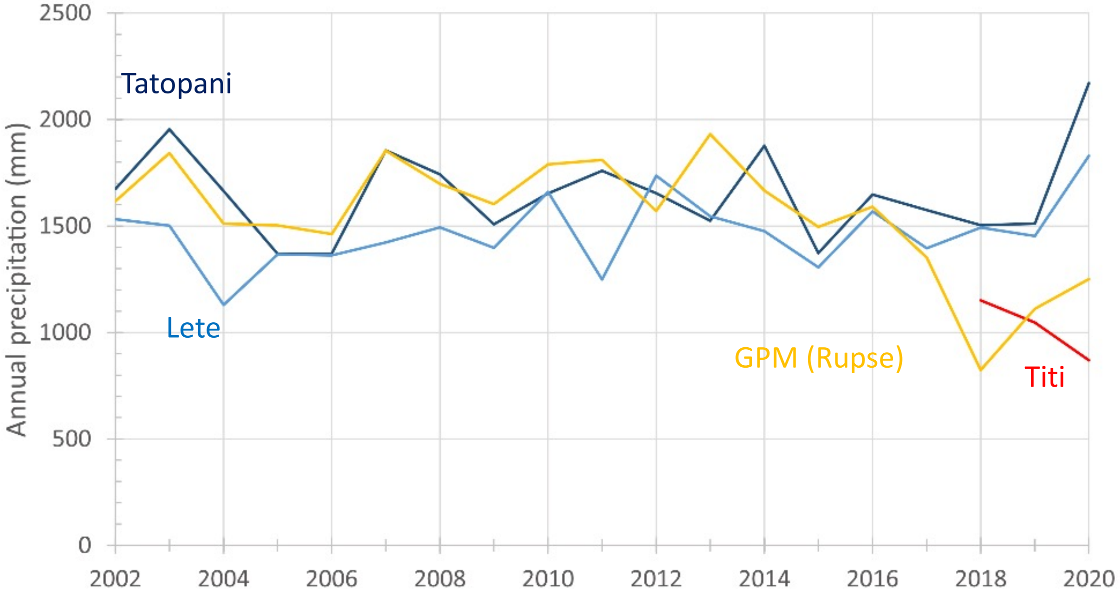




Extreme cloudburst localized based on erosional traces

Event not captured in local station and GPM data

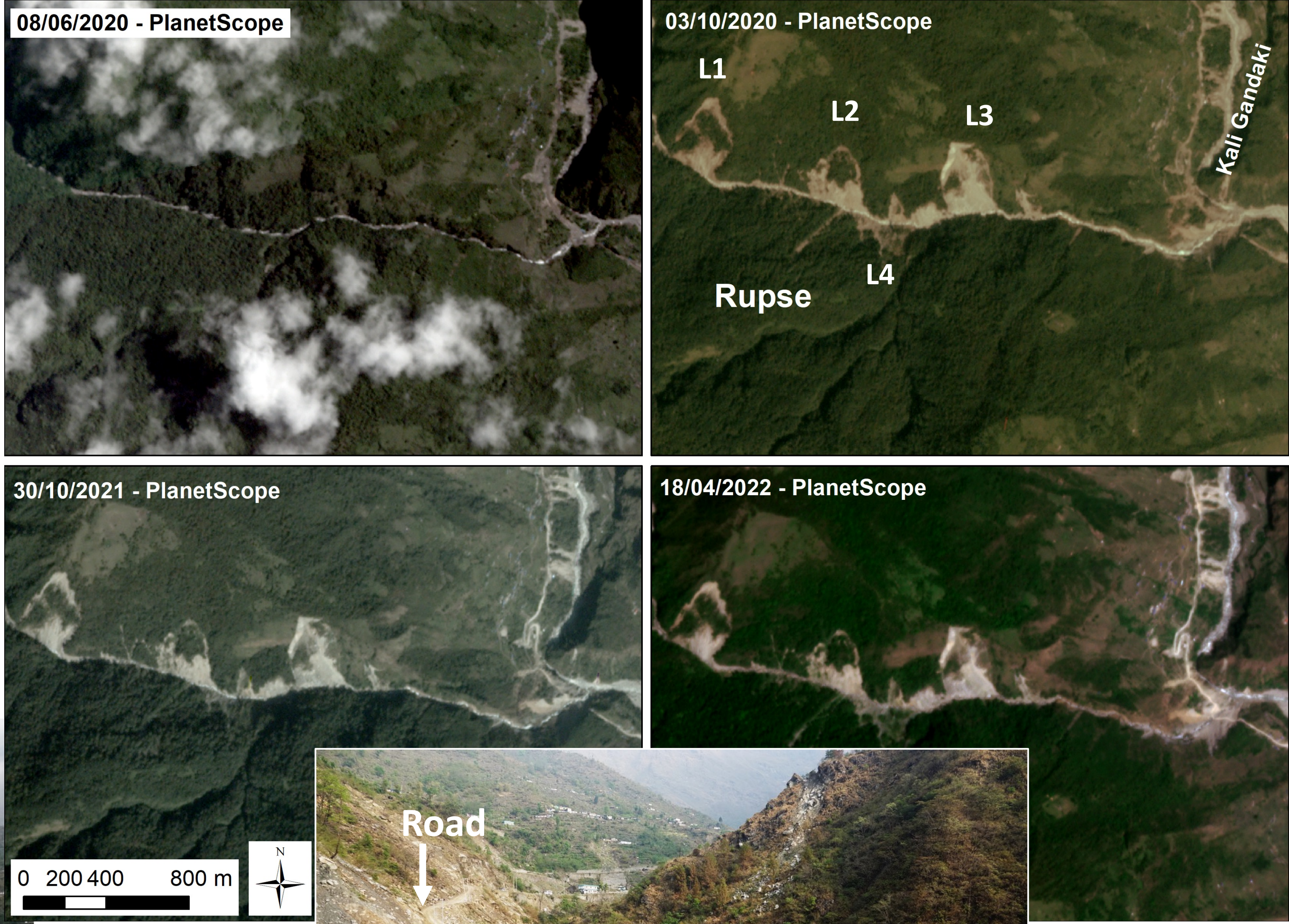


# Preliminary results: RUPSE

**Landslide volume estimations:**
L1: 2 million $m^3$
L2: 1.6 million $m^3$
L3: 2.1 million $m^3$
L4: 0.3 million $m^3$

**PlanetScope images**: apparently no landslide movement since late monsoon 2020 => stability?

**Re-opening and cleaning of the road:**
**=> continuous lower hillslope instability**
**=> loose sediment transfer to the KG**





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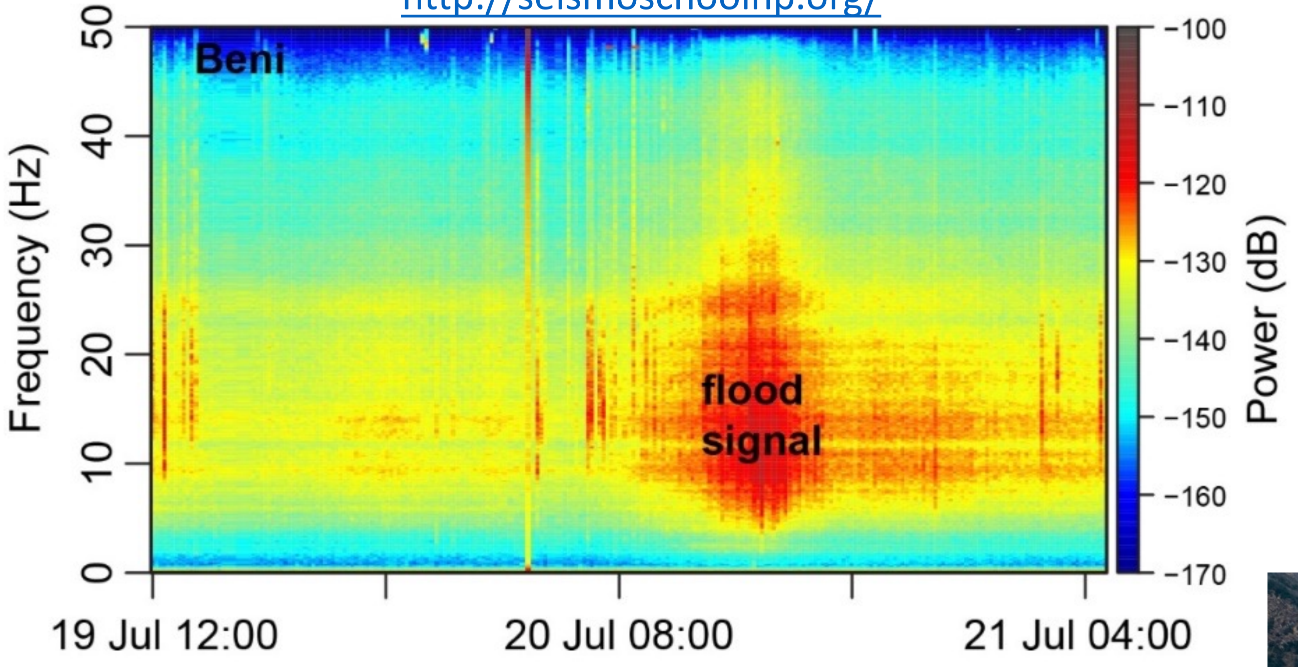
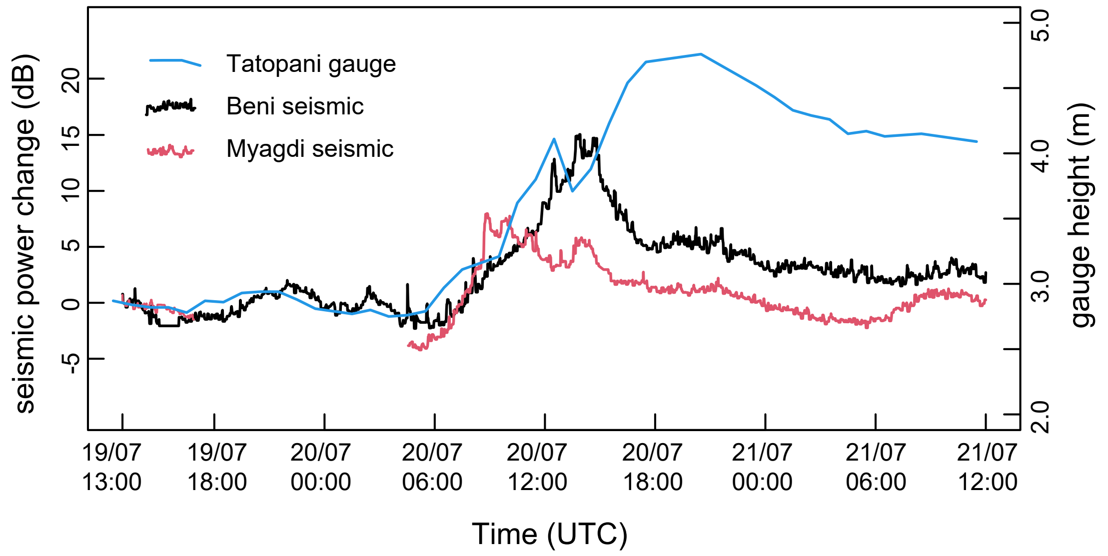
Many loose sediments at the junction KG and Rupse khola

# Preliminary results: RUPSE

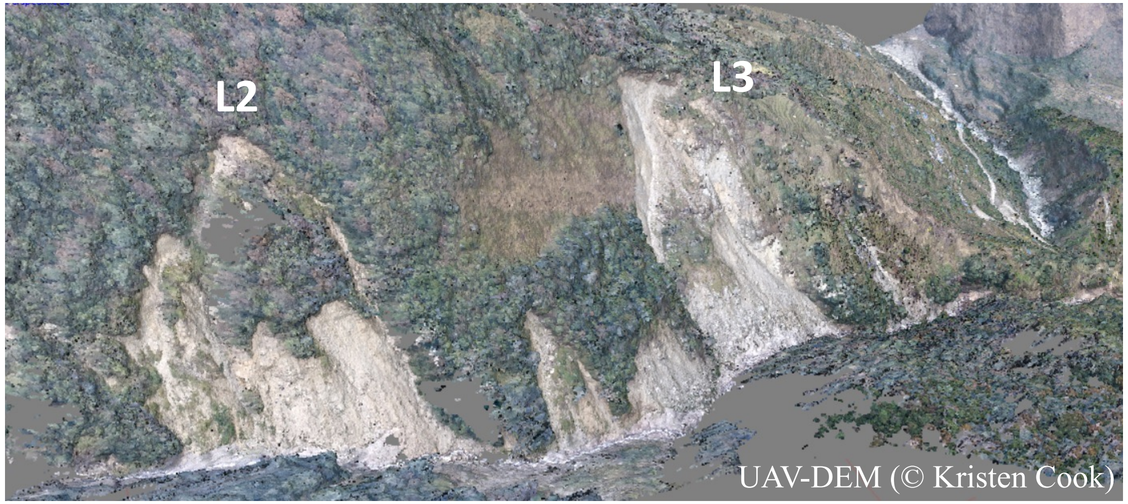
**Signal of the flood recorded at Beni seismic station**

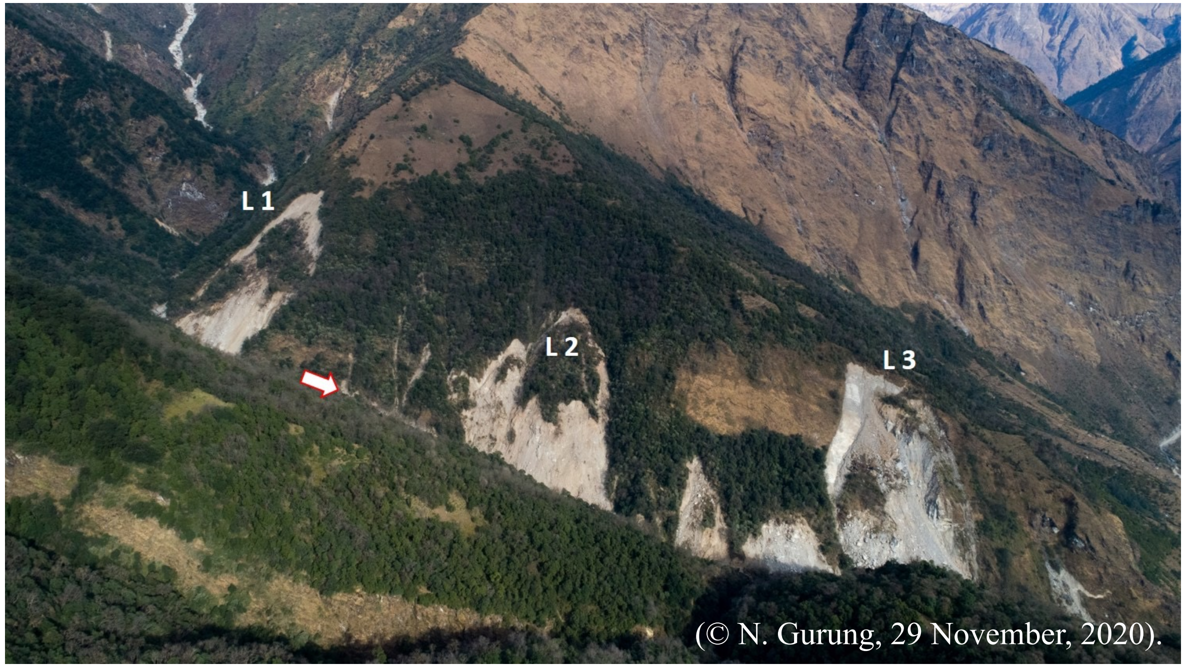
http://seismoschoolnp.org/




The landslides provided **loose material** (partially old landslide colluvium) to the Rupse khola then to the KG downstream



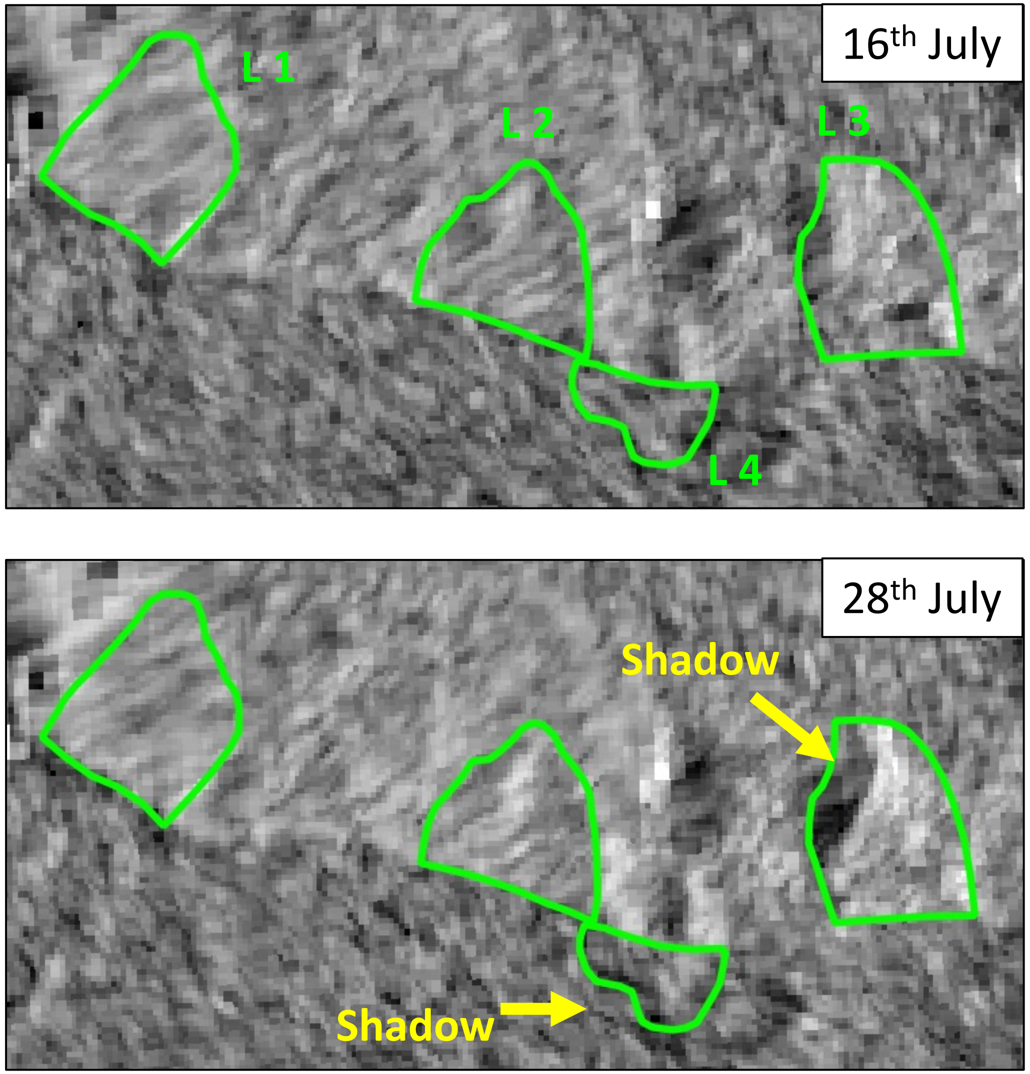



# Preliminary results: RUPSE

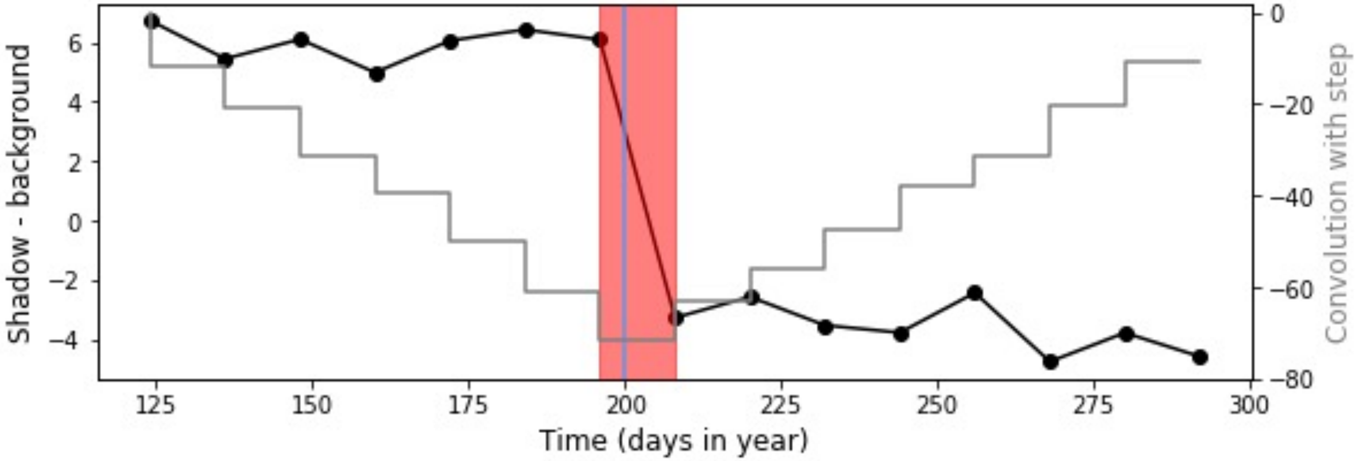
Timing of landslides:

L2: in between 7-31 July 2020
L3 and L4: in between 16-28 July 2020
L1: in between 14-17 Sept 2020

**Ascending track SAR**




**Rupse L 3**





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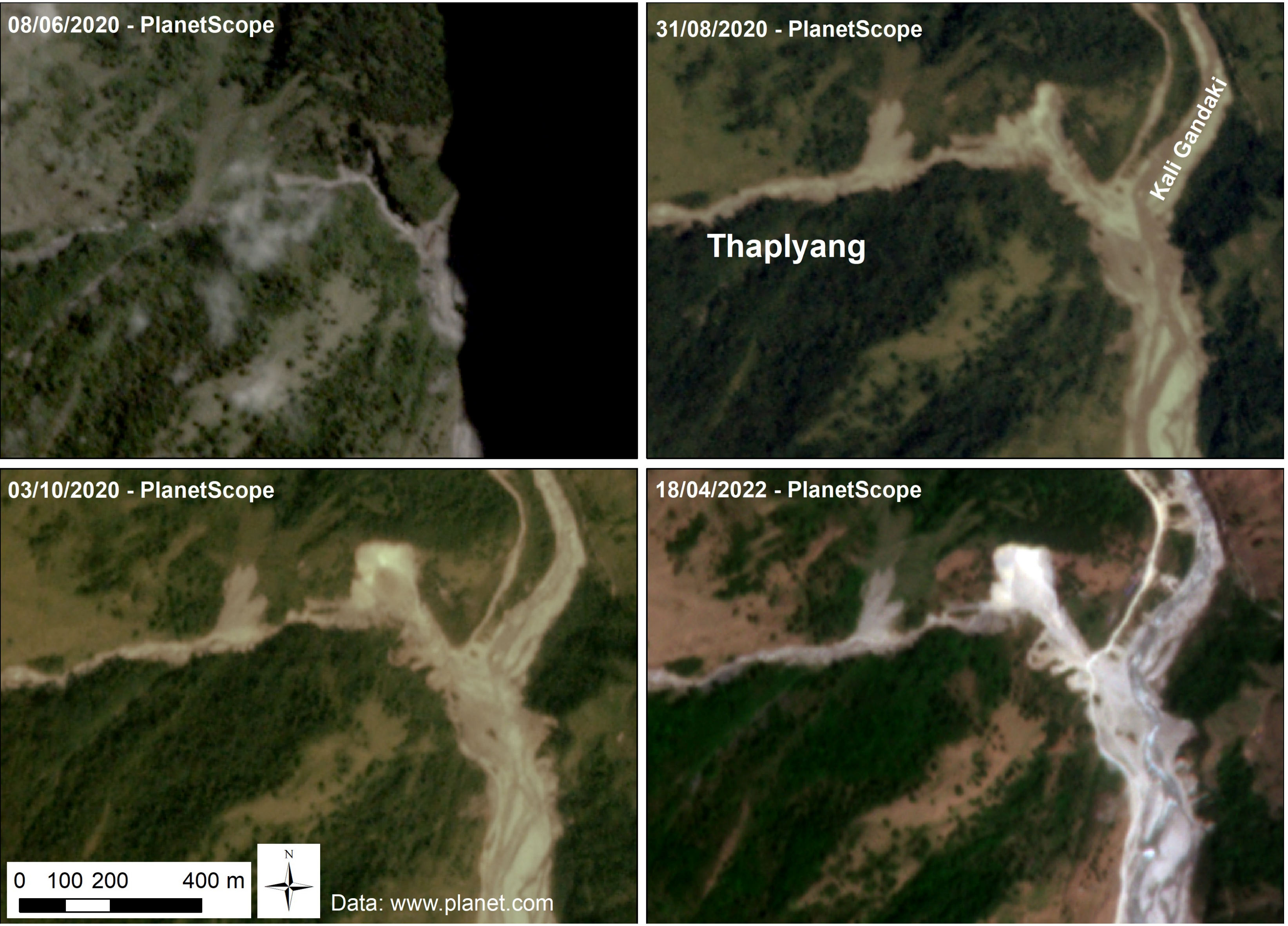
# Preliminary results: THAPLYANG

PlanetScope images showing clearly the rapid collapse of the left slope of Thaplyang khola

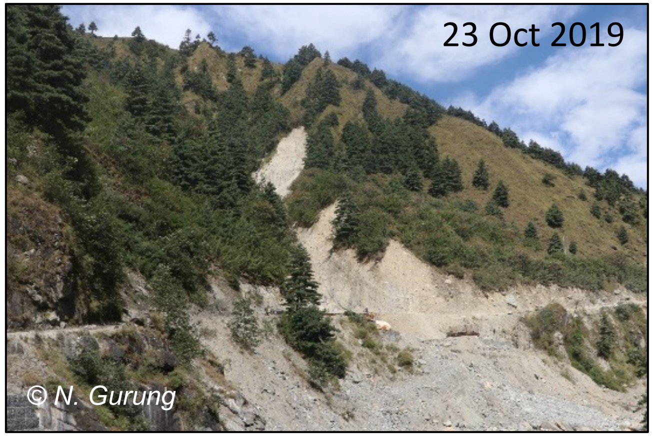




Photos by N. Gurung

Bridge at the junction Thaplyang/KG

# Preliminary results: THAPLYANG

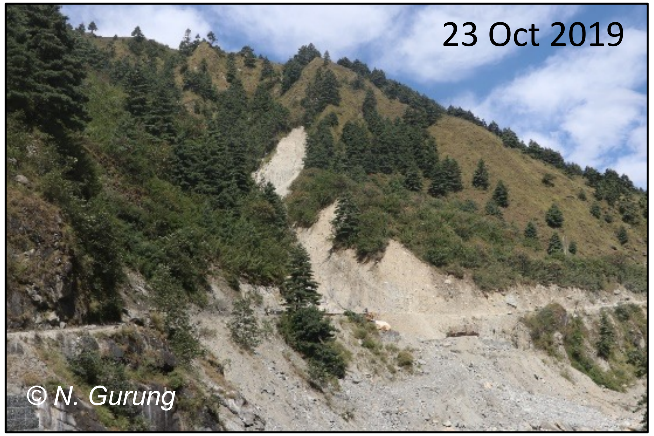





**Initial trigger: the road construction (2008), then its 2-lane upgrading**
(Oct. 2012)
*NB:* First destabilisation of the lower catchment in 2014 *(see Bell et al. 2021)*

2020
Total landslide volume: 0.5 million $m^3$

# Preliminary results: THAPLYANG



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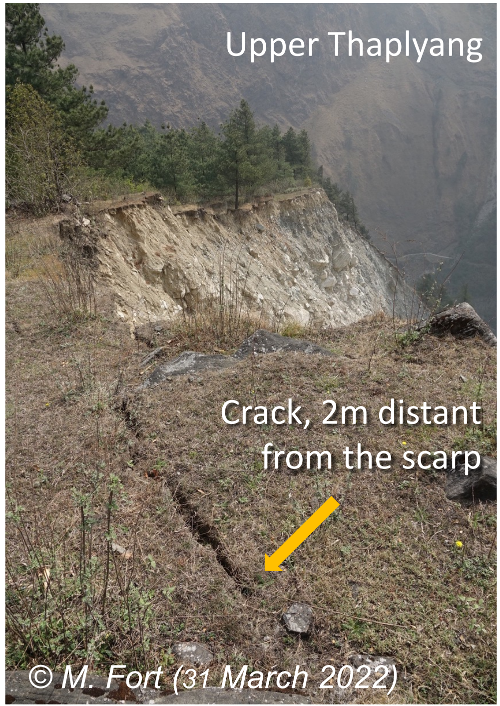
**2020**: two more successive collapses in July and Sept/Oct

**=> Impacts on the KG sediment load and transfer**



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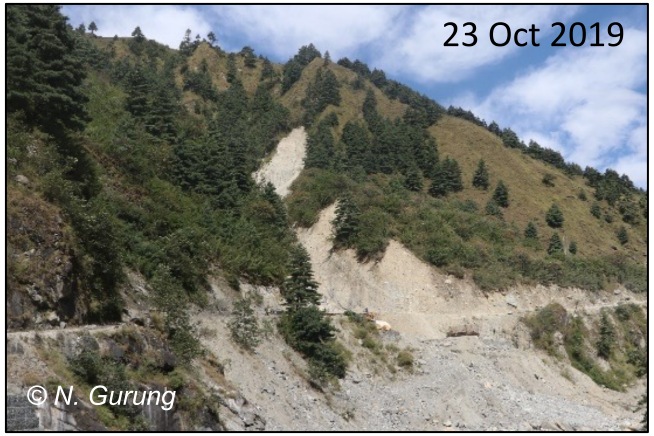



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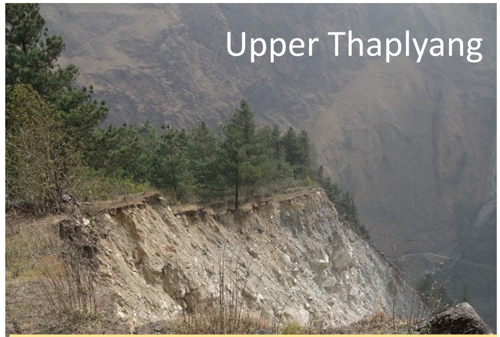




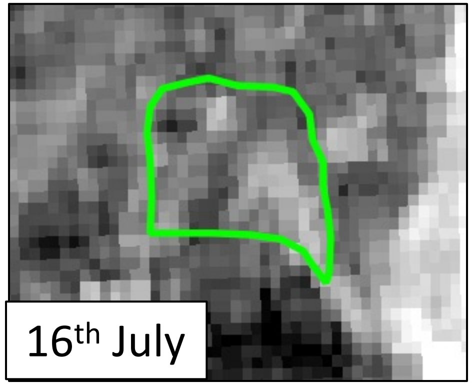

**2020**: two more successive collapses in July and Sept/Oct

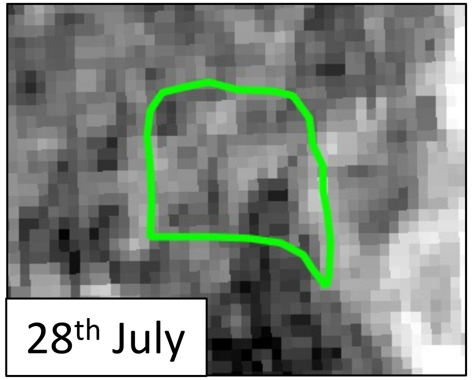
**=> Impacts on the KG sediment load and transfer**

The active area increased from: **9100 $m^2$** (March 2018) to **9600 $m^2$** (Oct. 2018) then **32300 $m^2$** (Nov 2020)

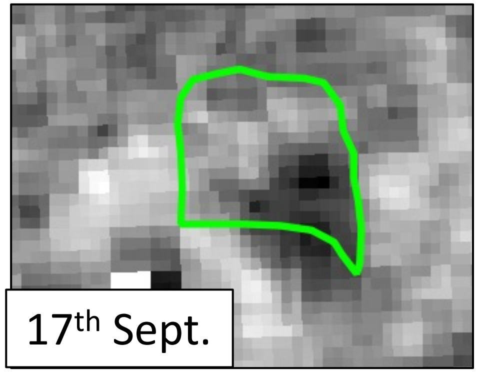
# Preliminary results: THAPLYANG

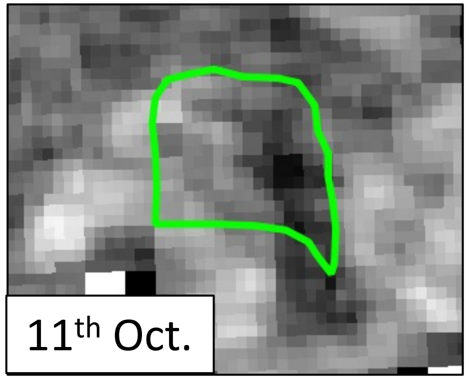
**Thap 1**, ascending track SAR



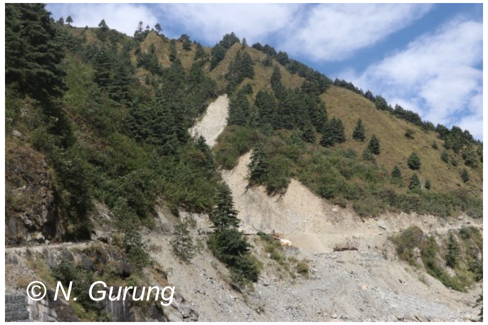




**Thap 1**, descending track SAR




23 Oct 2019




1$^{st}$ Failure

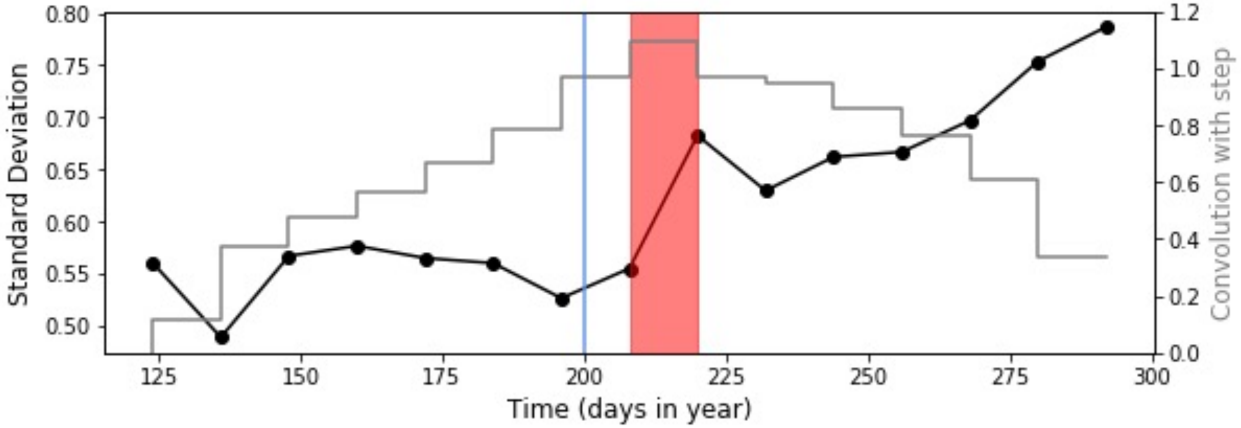
31 July 2020


**Clearly two events during monsoon, which caused:**
**-Bridge destruction**
**-Blocking of the road during several days**

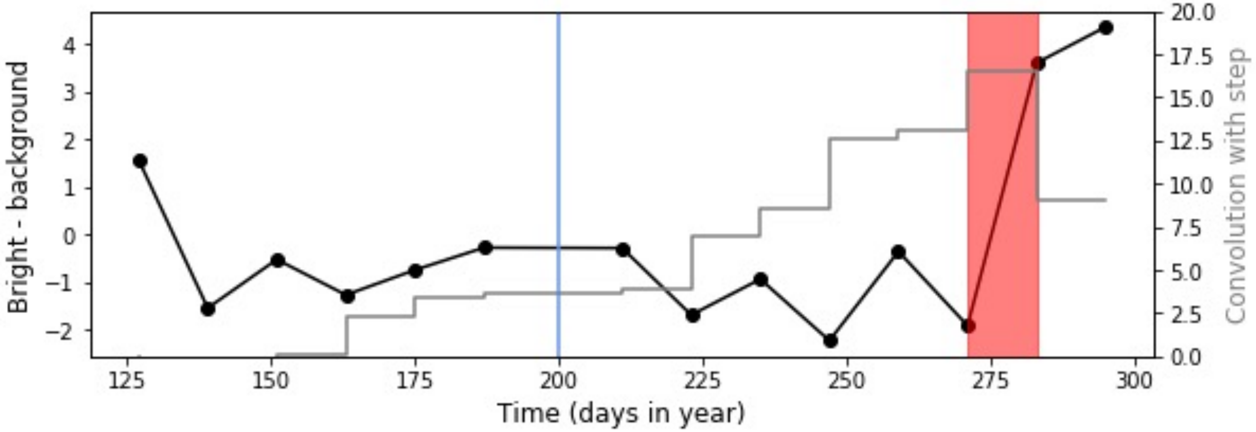
2$^{nd}$ Failure

10 Nov 2020


**Thap 1**, ascending track (28$^{th}$ July – 9$^{th}$ August)




**Thap 1**, descending track (26$^{th}$ September – 8$^{th}$ October)



# Some conclusions:

1. General **destabilization** of the gorge section of the Kali Gandaki and its old colluvium deposits (landslide material, glacial and/or fluvial alluvium and related lacustrine deposits)
⇒ reveals a former, complex paleo-topography of this deep valley.

2. Very rapid evolution, i.e. Thaplyang site, active since 2014, with a dramatic erosion increase from 9100 $m^2$ (March 2018) to 9600 $m^2$ (Oct. 2018) and 32300 $m^2$ (Nov 2020)

3. In providing loose material, it has accelerated the cascading system and transfer of sediments into the main Kali Gandaki River over 40 km (Beni), as recorded by seismic signals

4. These repeated disasters (river bank collapses, bridges and settlements destruction; traffic obstruction) affect the tourism economy and development along this major link between south China and north India.

# Way forward:

1. Complete SAR analysis for different sites

2. Better quantify the overall exported sediment volumes

3. Evaluate the impacts of this changing geomorphology on future infrastructure development and settlements (continuous mapping, local interviews, …)

4. New sections should allow a better understanding of the past quaternary evolution of the valley