Spatial distribution and (of) controlling factors of the debris flow hazard across High Mountain Asia

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GeoHyd Lunch Seminar

25/8/2023


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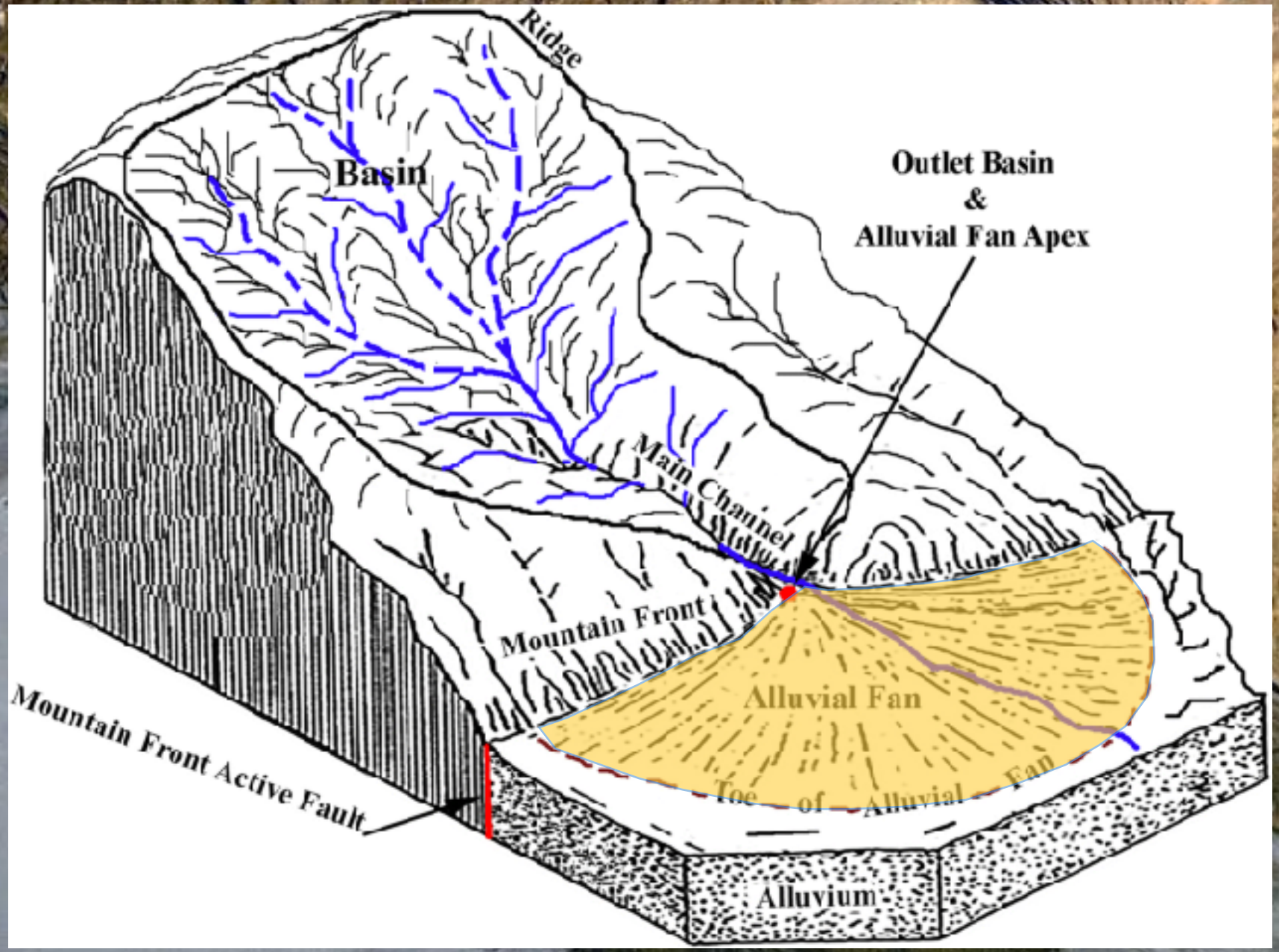
Death Valley
Photo: Marli Bryant Miller


Ridge
Basin
Outlet Basin
&
Alluvial Fan Apex
Main Channel
Mountain Front
Alluvial Fan
Toe of Alluvial Fan
Mountain Front Active Fault
Alluvium

- Most types of natural hazards are projected **to change in frequency, magnitude and areas** affected as the cryosphere continues to decline *(high confidence)*.
- Glacier retreat and permafrost thaw are projected to **decrease the stability of mountain slopes** <…> *(high confidence)*. Resulting landslides and floods, and cascading events, will also **emerge where there is no record of previous events** *(high confidence)*.
- As documented for sites in the European Alps and Scandinavia < … >, rock glaciers replenished debris flow starting zones at their fronts, so that the intensified material supply associated with **accelerated movement contributed to increased debris flow activity** *(higher frequency, larger magnitudes)* or slope destabilisation.
- At lower elevations < … > climate driven changes such as a **reduction in number of freezing days** are projected to lead to a reduction in debris flows.

- IPCC SROCC, 2019

Christoff Andermann
@ChrisAndermann

Lete Kali Gandaki hydrology station hit by Mustang landslide dam lake outburst flood #LLOF this morning. Maybe it is still recording 🤔 ? I am operating this station since 2012 @GFZ_Potsdam

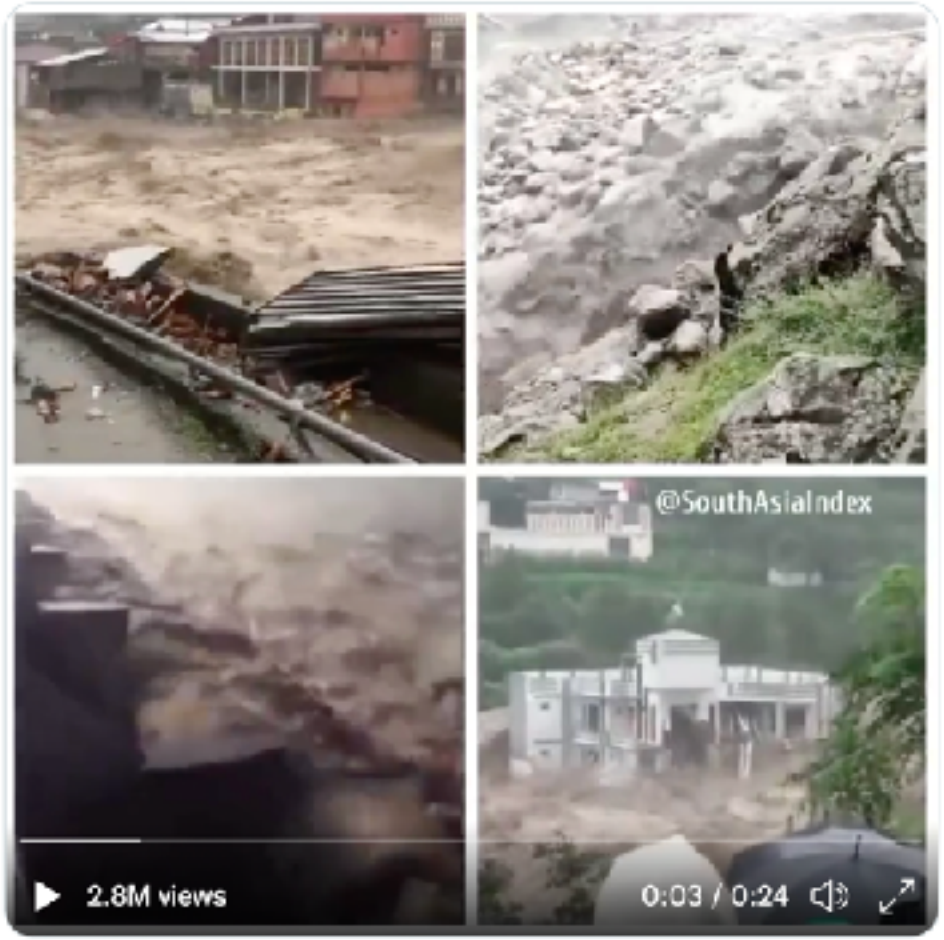
7:33 AM · Aug 14, 2023 · **62.4K** Views

Colin McCarthy @US_Stormwatch · Aug 30

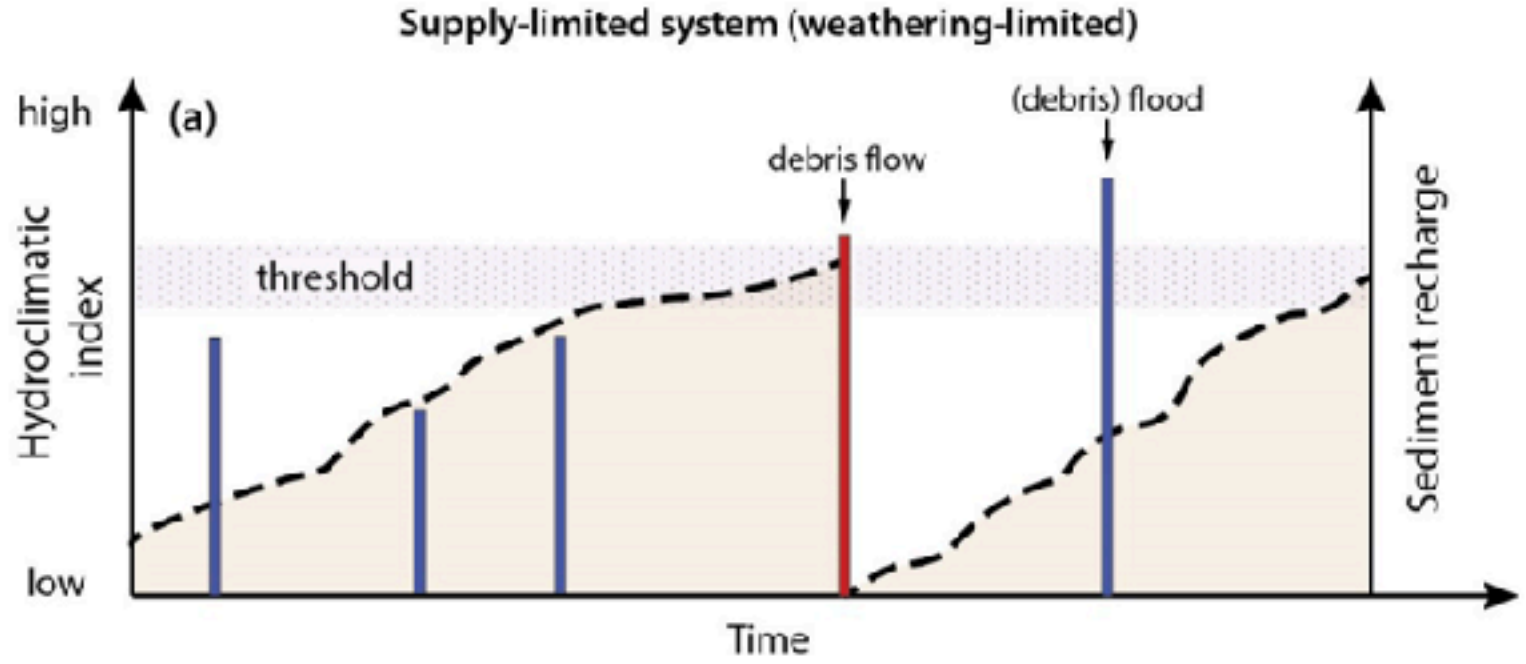
Hard to comprehend the scale of the **flood** disaster in Pakistan, the 5th most populated nation in the world.

Nearly 1400 dead, 1 million houses damaged or destroyed, and 50,000,000 people displaced.

1/3 of the country is underwater.



✅ Enough water
❌ Enough sediments



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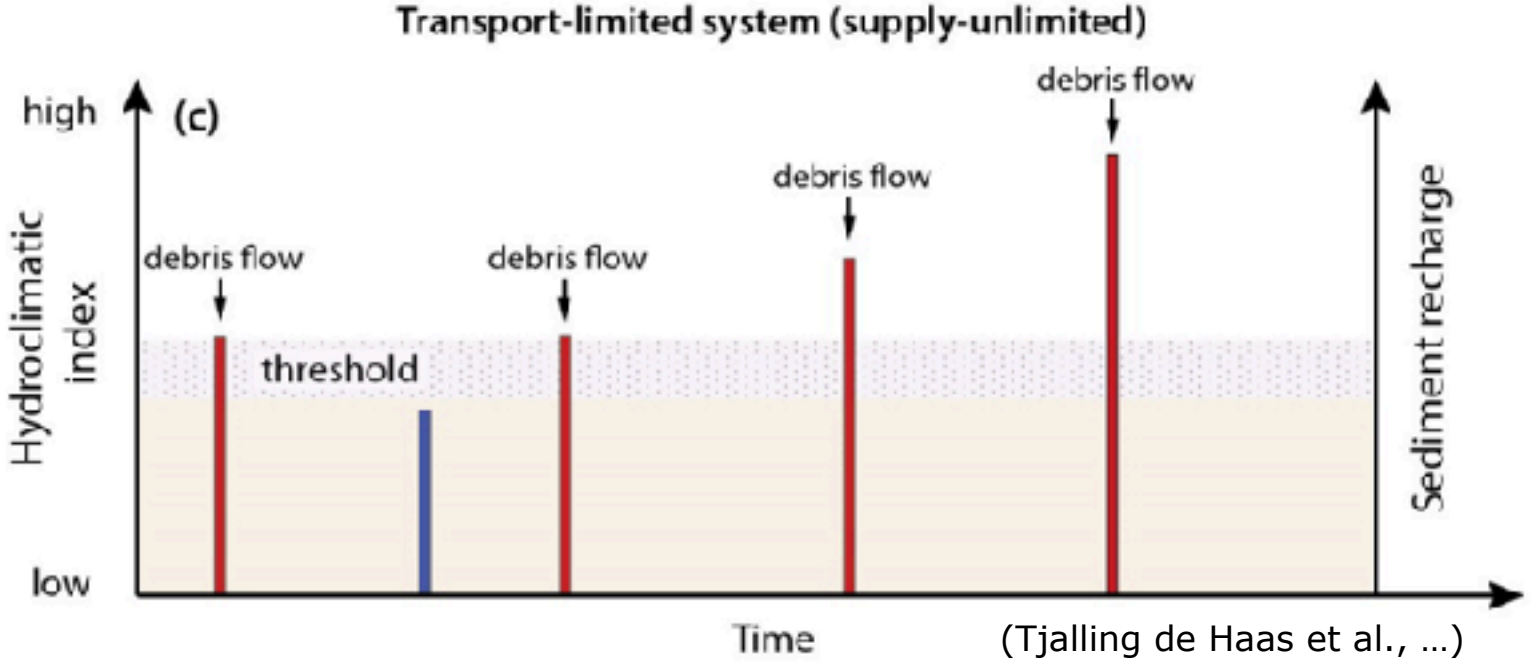

(Tjalling de Haas et al., …)


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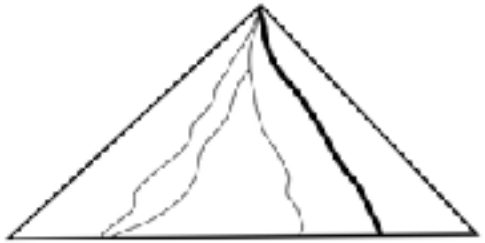
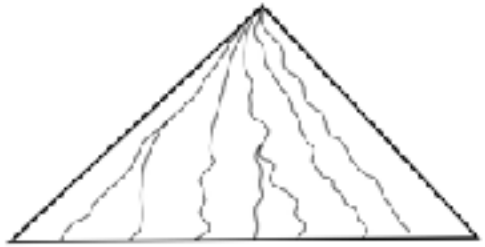
00:00:22:10

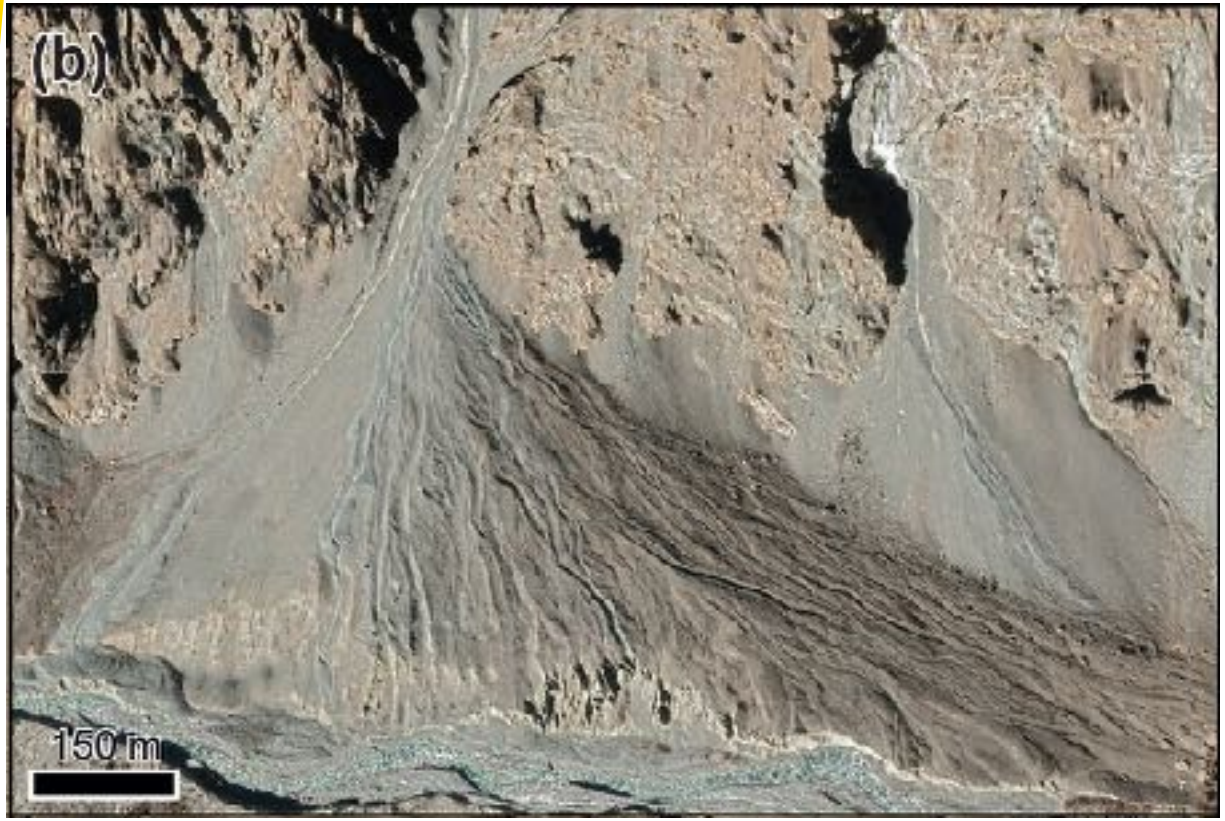
Langtang
Nepal Himalaya





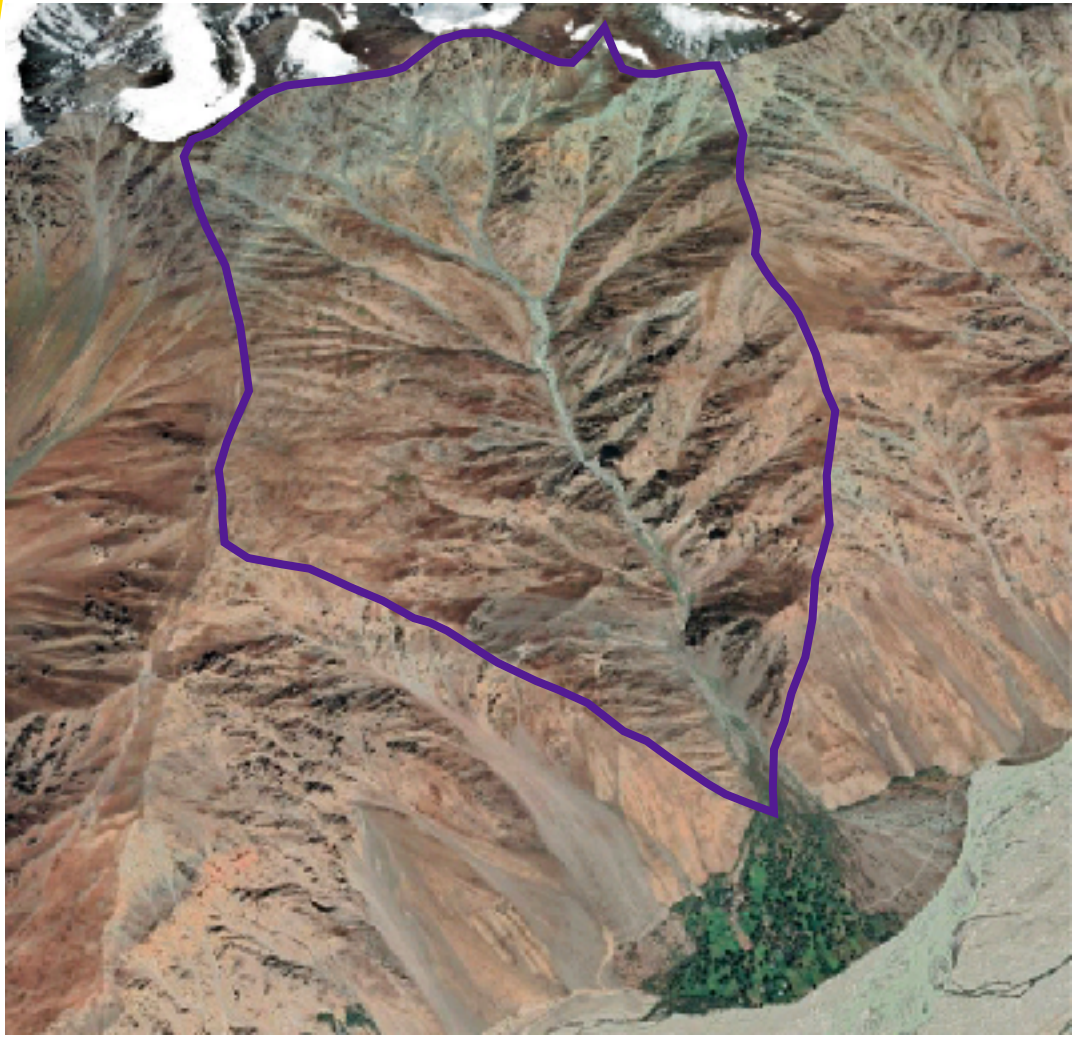
Debris flow dominated

Flood dominated



Somewhere in E Hindu Kush

Somewhere in E Himalaya

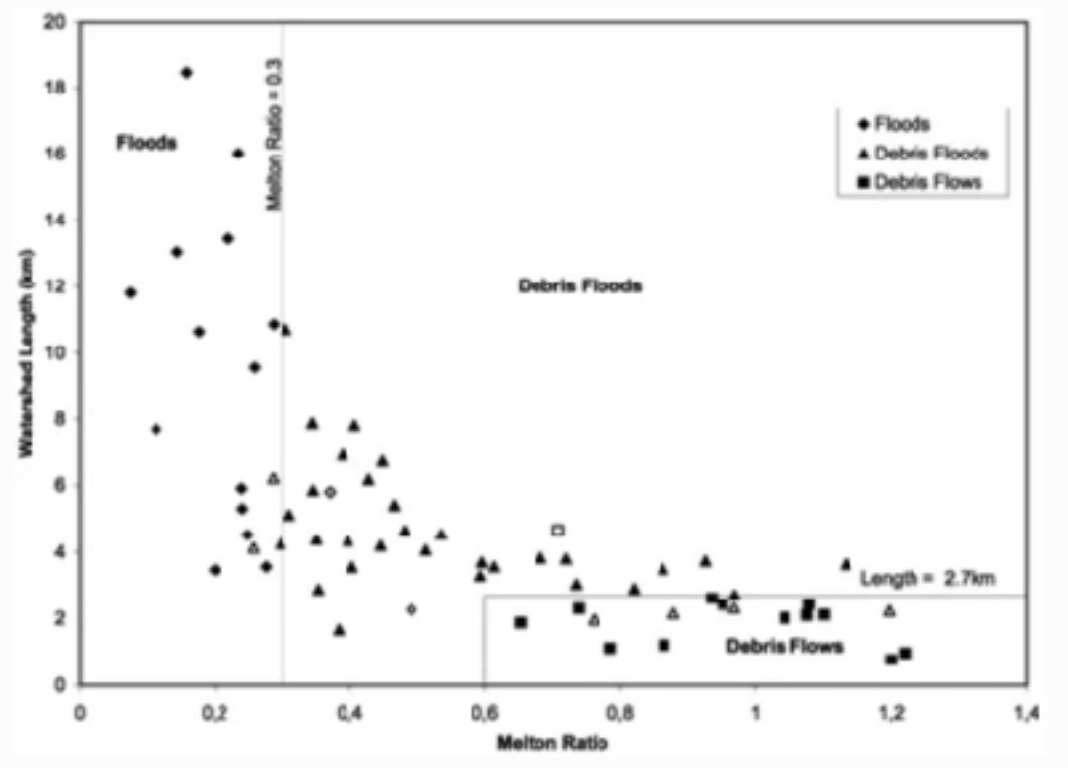


somewhere in Pamir

Image source: Google Earth

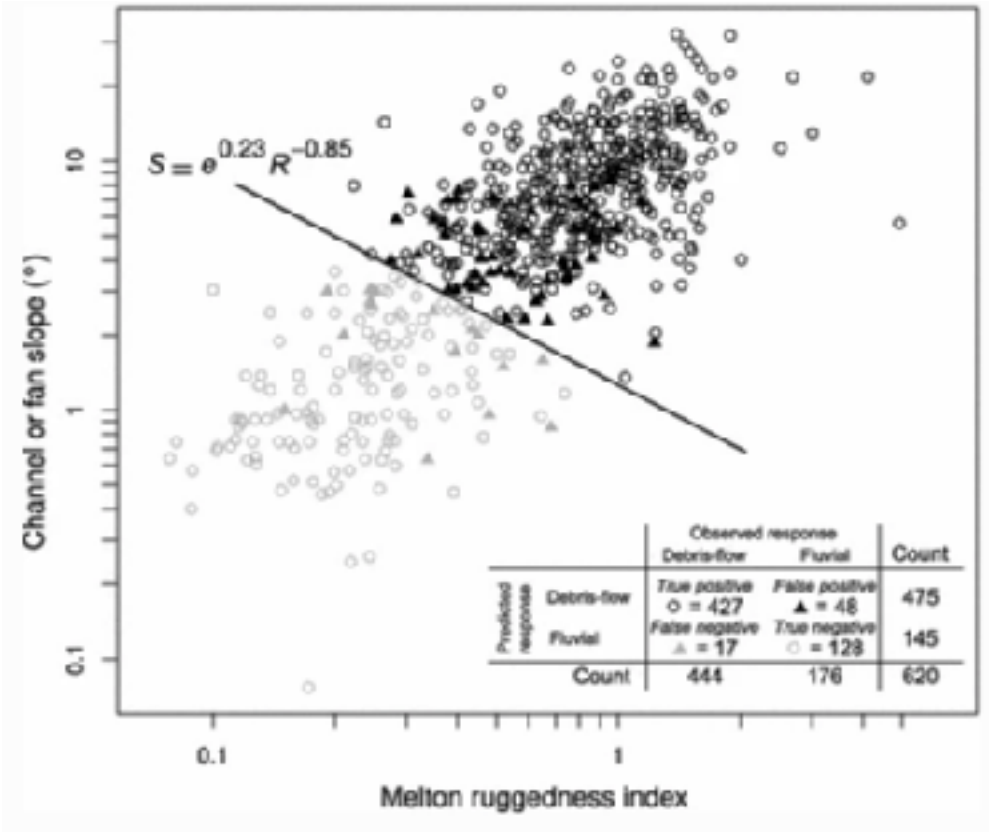
Morphometry threshold for classification

$$M = \frac{relief}{\sqrt{area}}$$



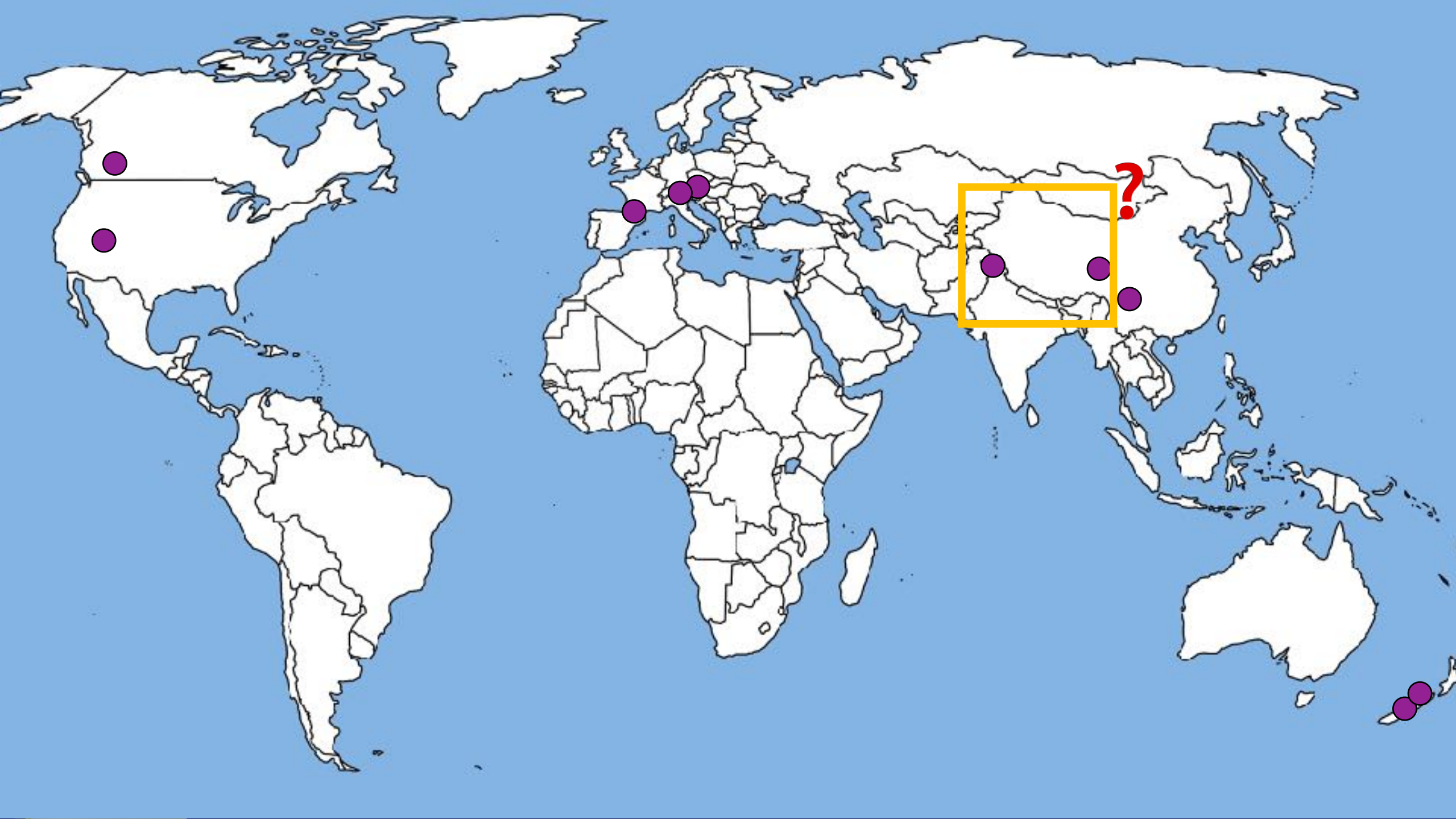
- Field based -> small scale
- Melton index and watershed length are good enough

(Wilford et al., 2004)

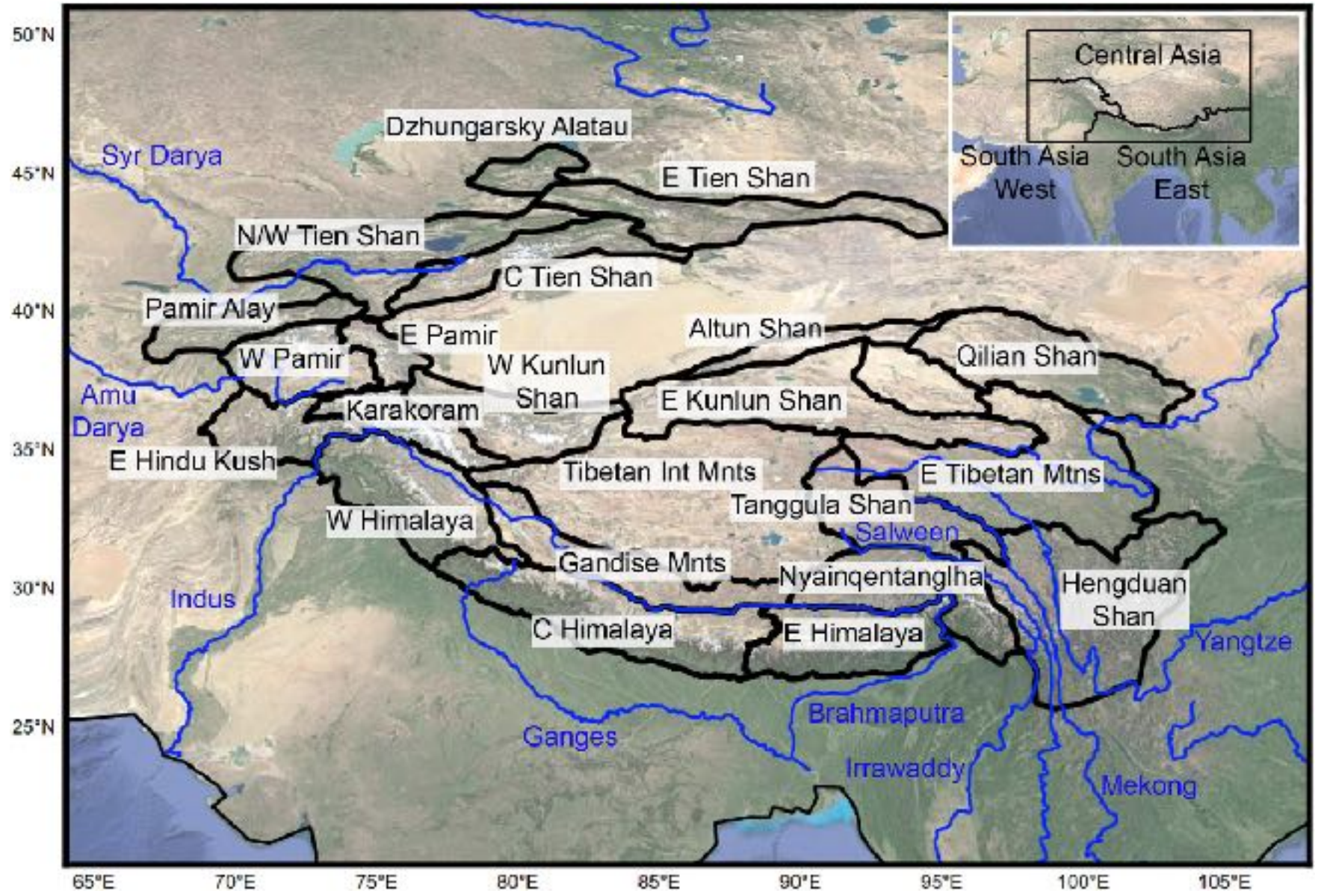


- Dataset from all over the world (review)
- Only Melton index and the fan slope as predictors

(Bertrand et al., 2013)



What is happening in HMA?



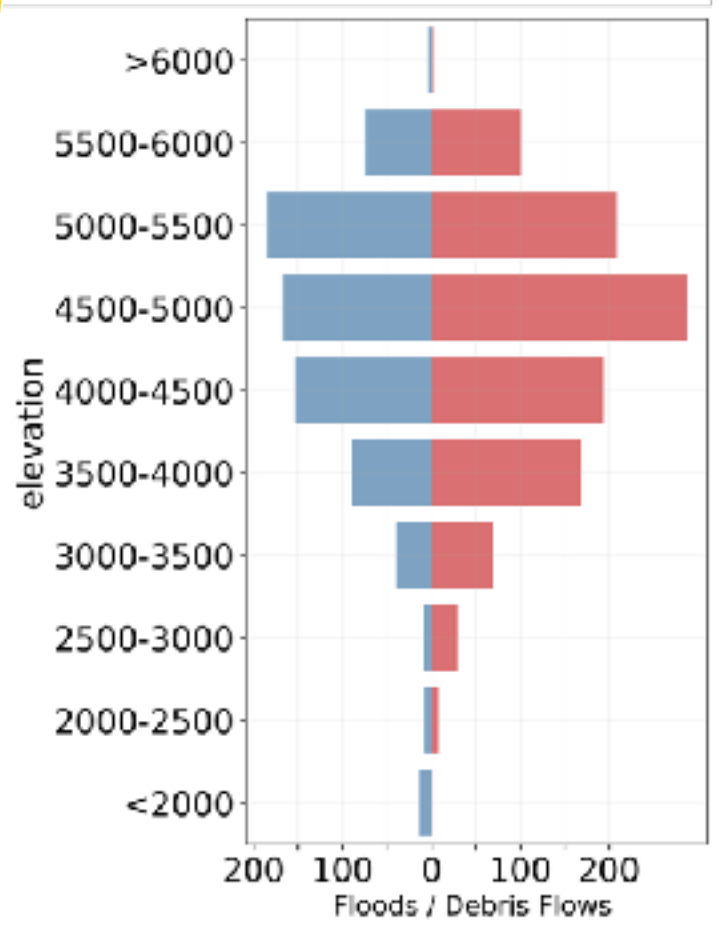
(D. Rounce et al., 2020)

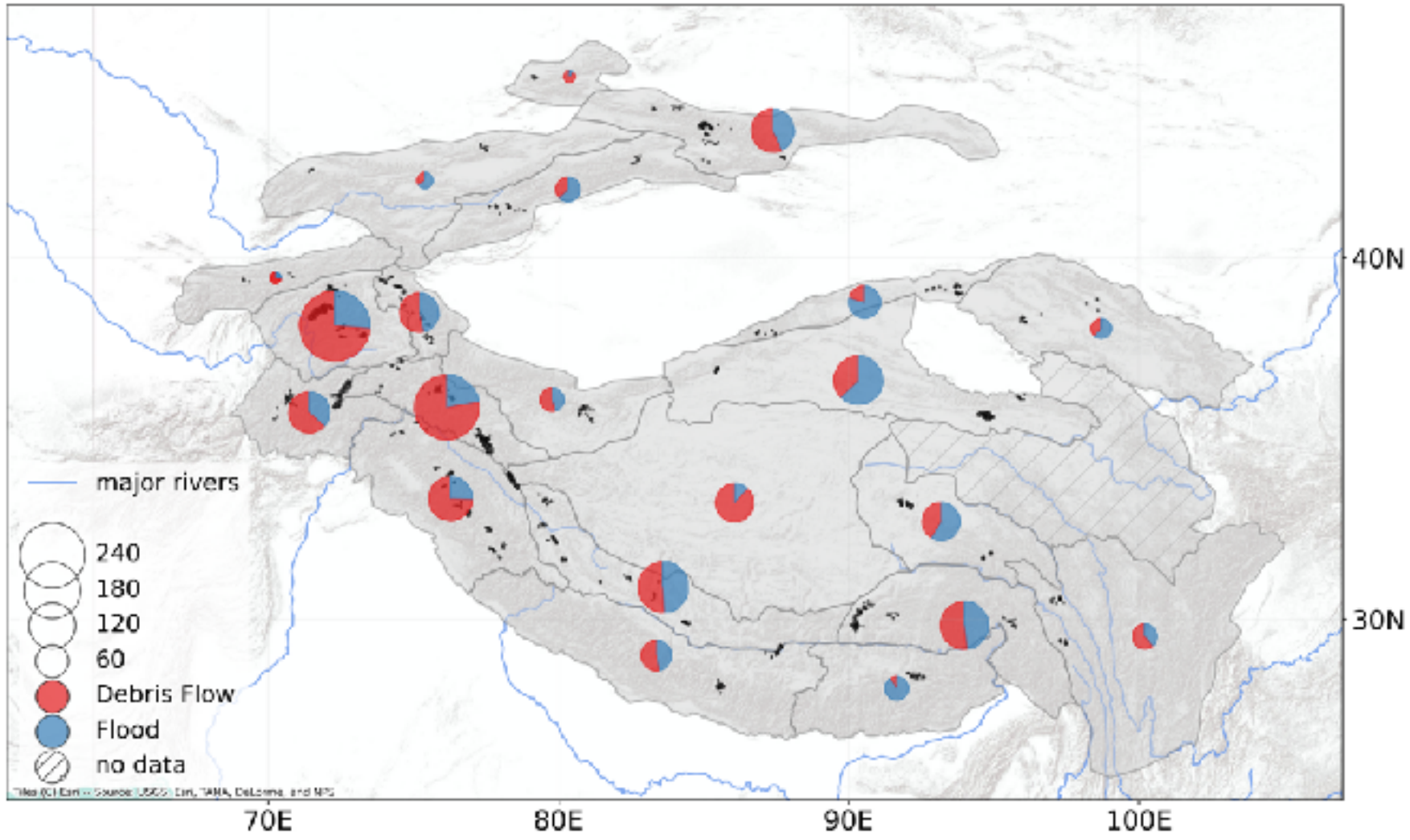
Research questions and the goals:

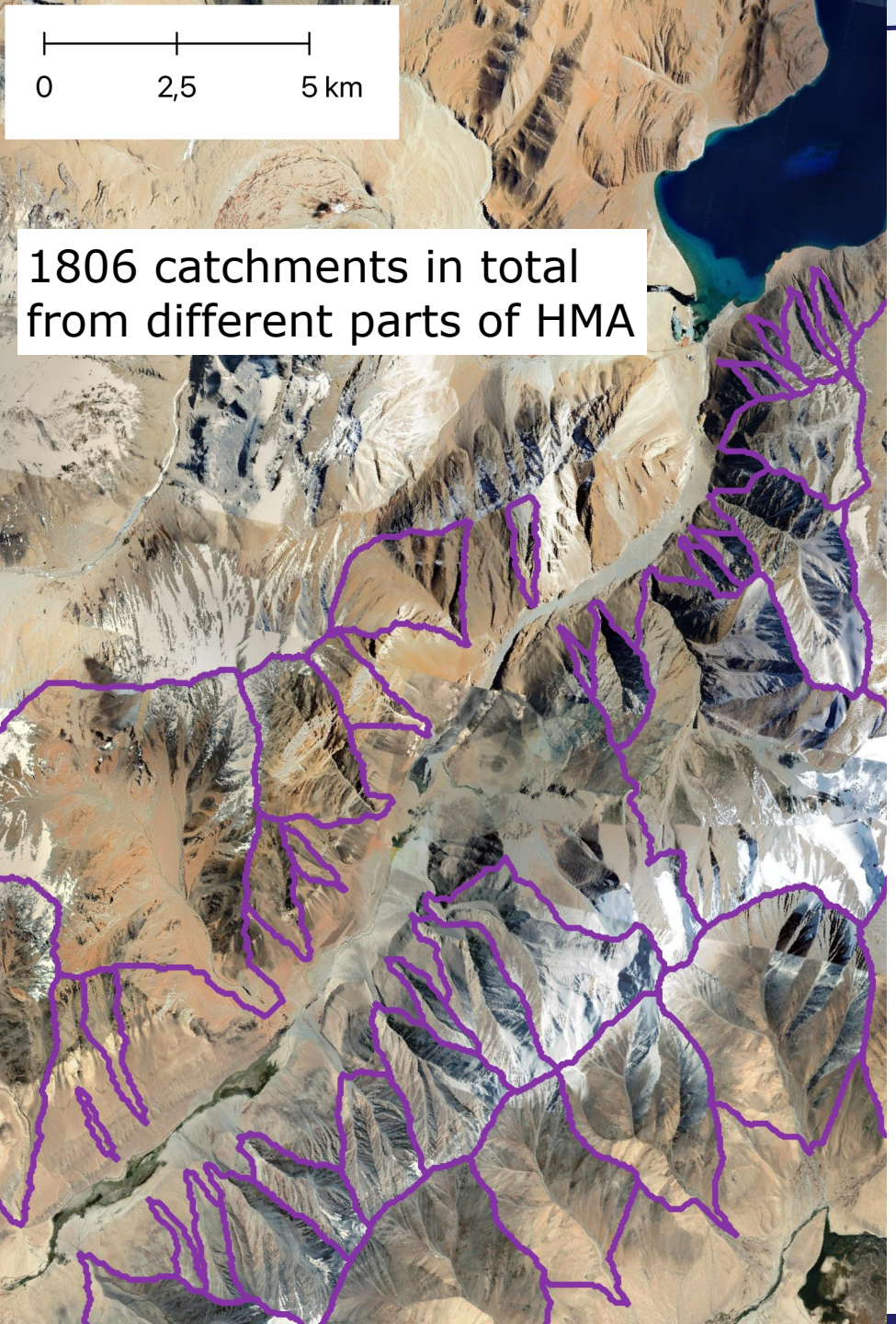
- to **use ML classifier to estimate probabilities** of debris-flow vs flood dominated system
- to **identify the parameters, that matter** for the classification
- to estimate the effect of the **climatic features** on classification
- to **find out** if there are any regional differences

Data: Google Earth images 📌

Identified alluvial fans, assigned the dominant process







Morphometry

- median elevation
- relief
- area
- perimeter
- median slope
- Melton ratio
- circularity ratio
- compactness

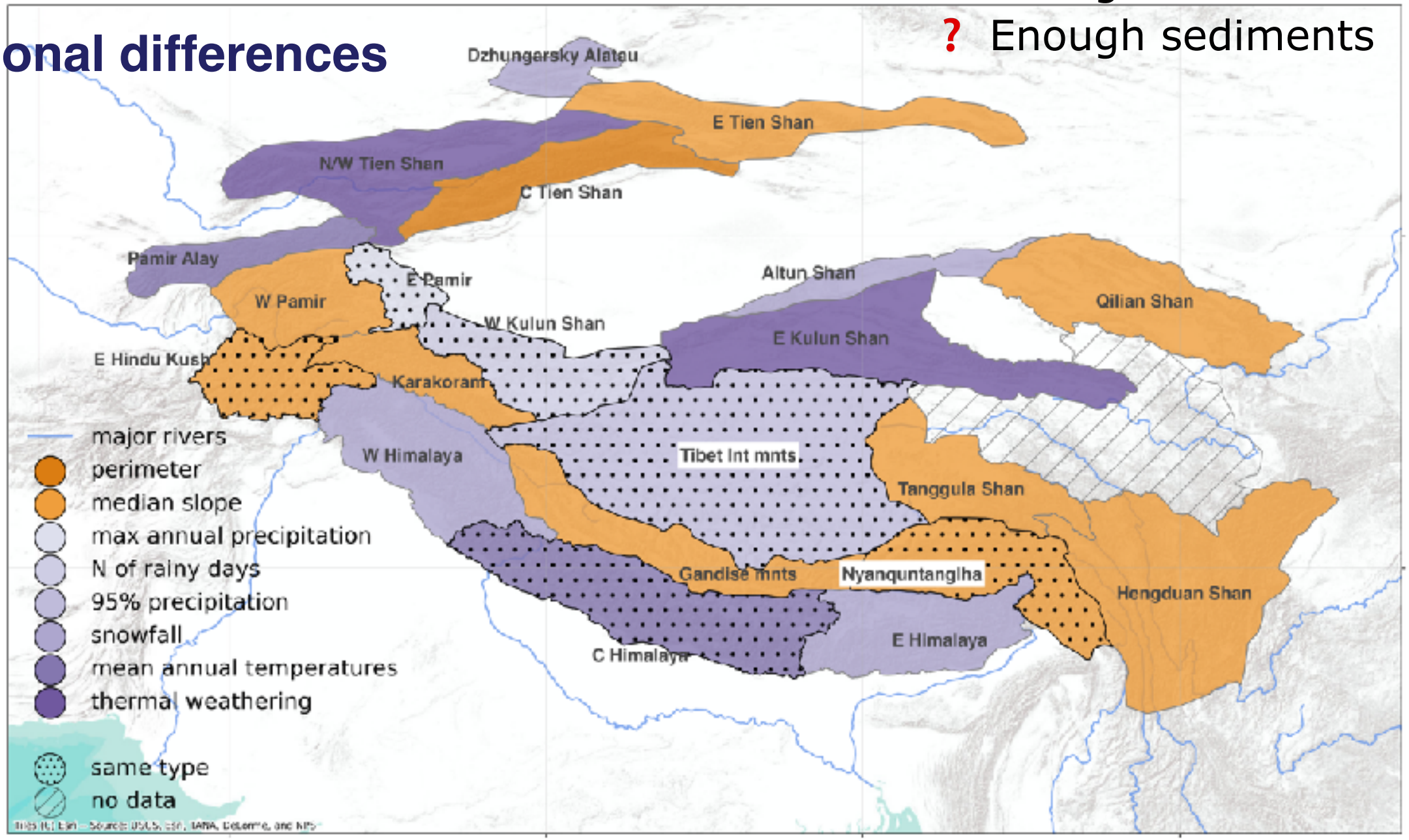
Climate

- total annual precipitation
- max annual precipitation
- N of wet days
- 95% precipitation
- snowfall
- rainfall
- mean annual temperature
- thermal weathering
- frost weathering
- vegetation cover (%)
- continuous permafrost
- glacier

Regional differences

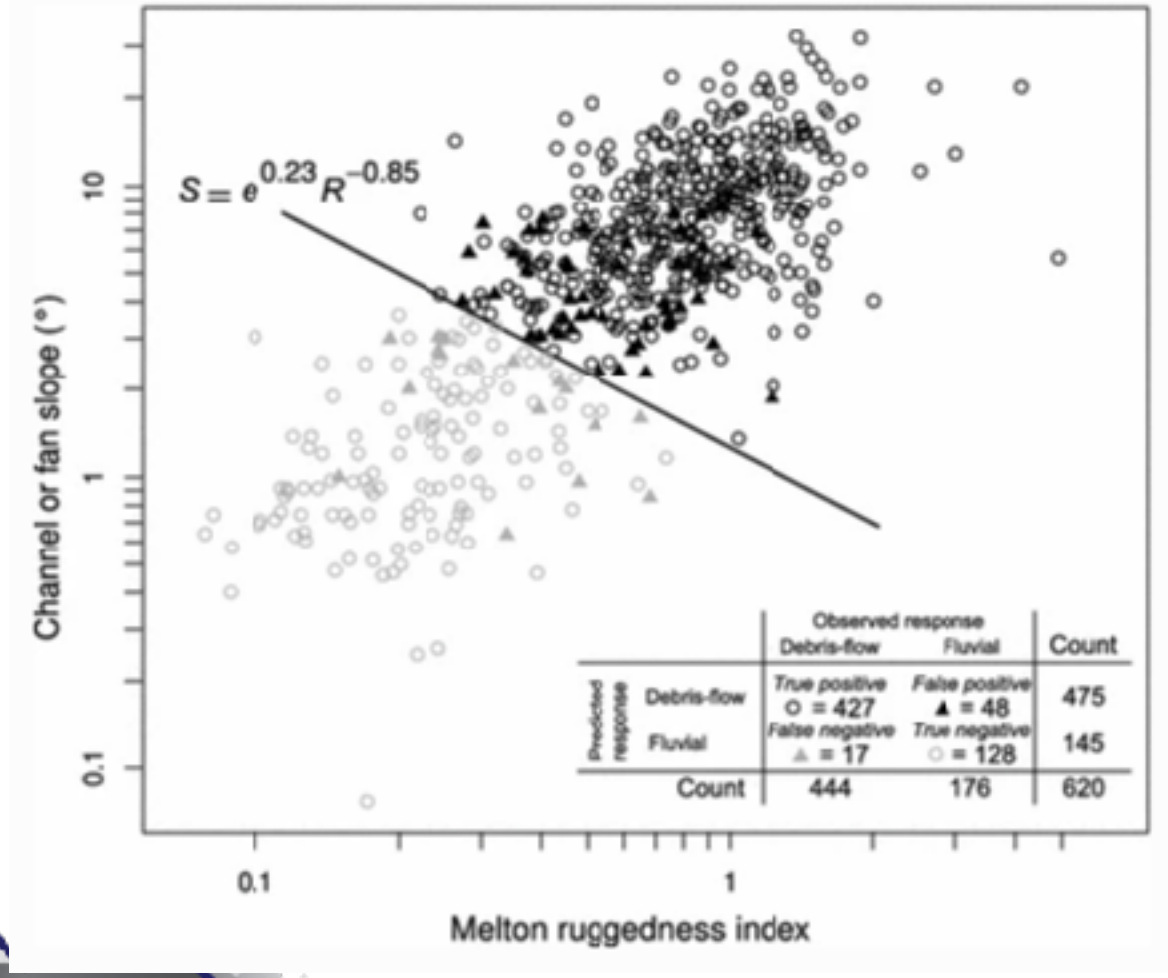
? Enough water

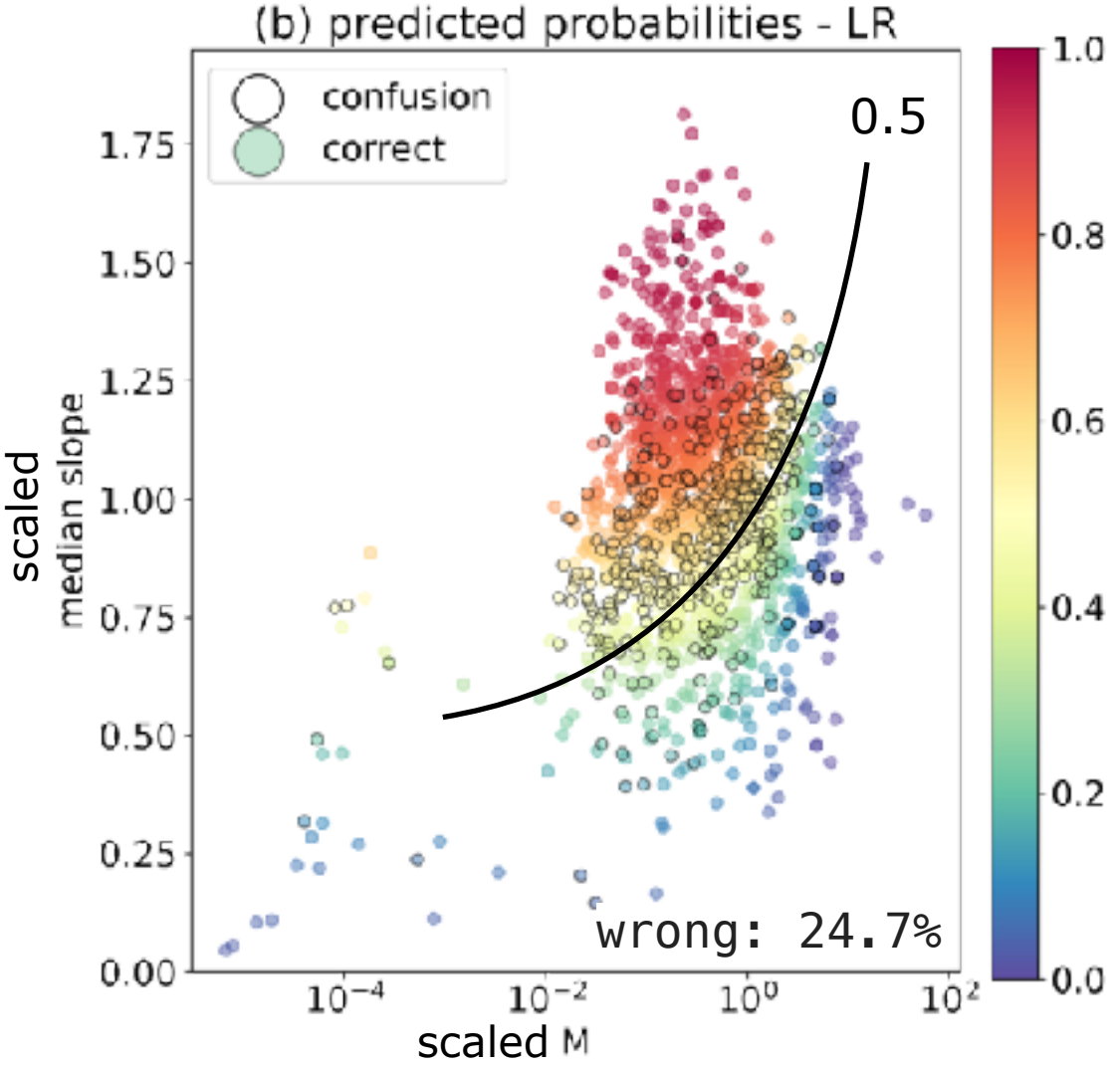
? Enough sediments



High Mountain Asia data: just 2 features

(Bertrand et al., 2013)

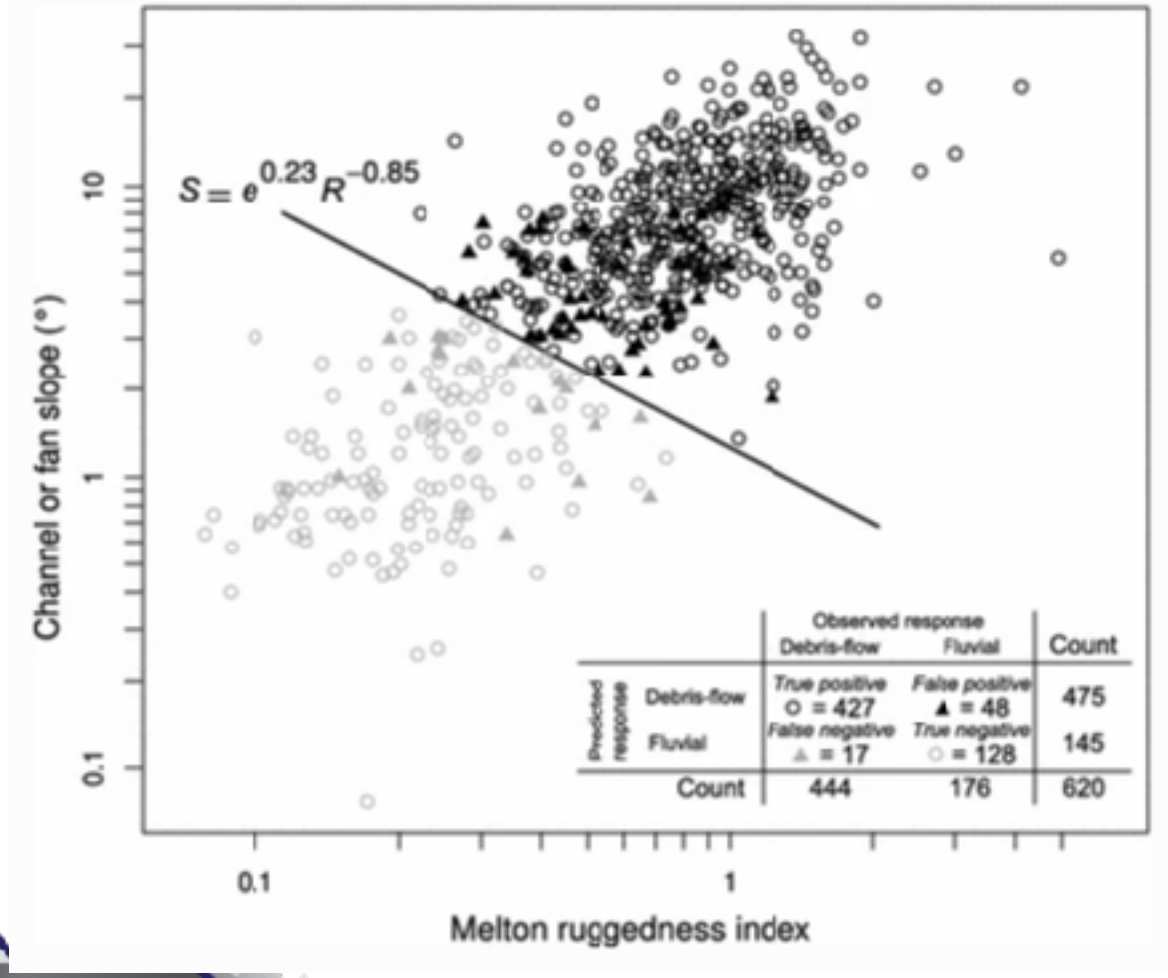


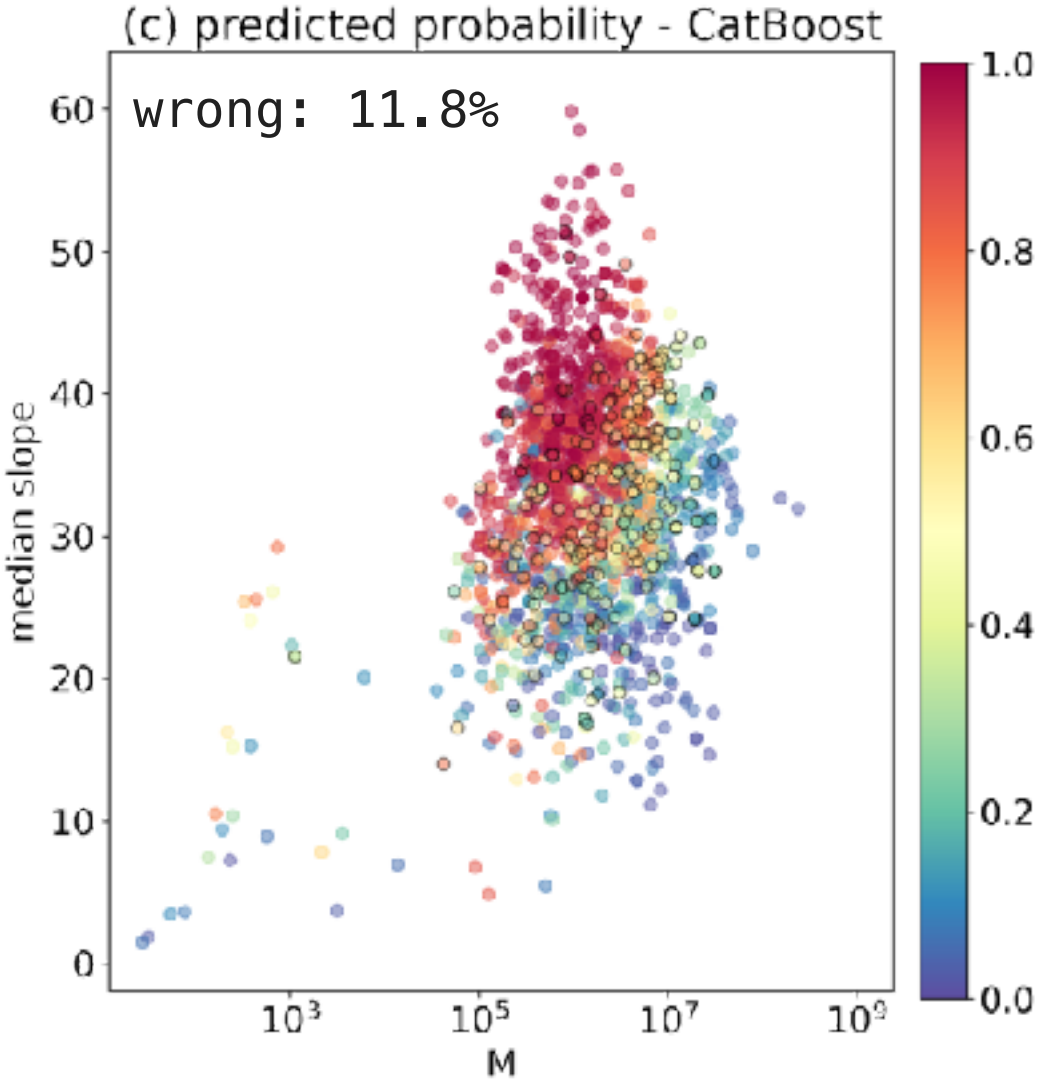


More sophisticated classification structure?

High Mountain Asia data: + climatic information

(Bertrand et al., 2013)





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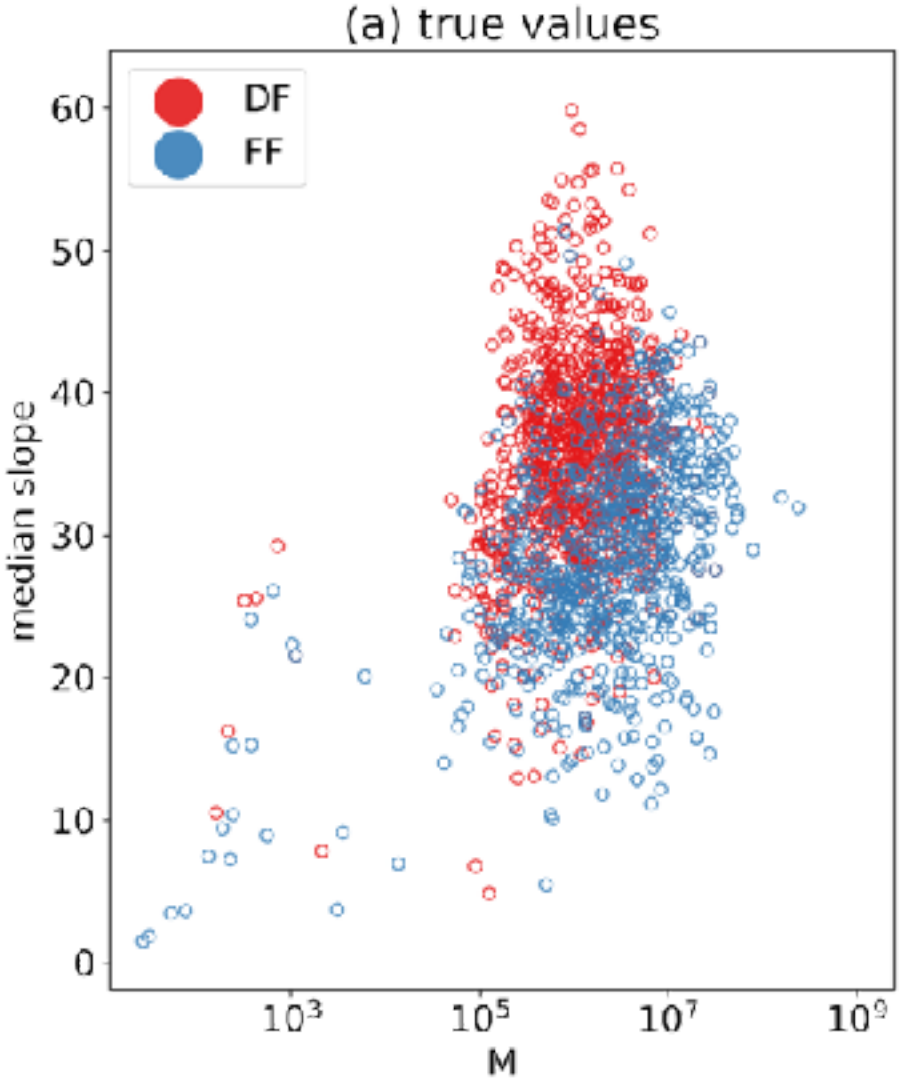
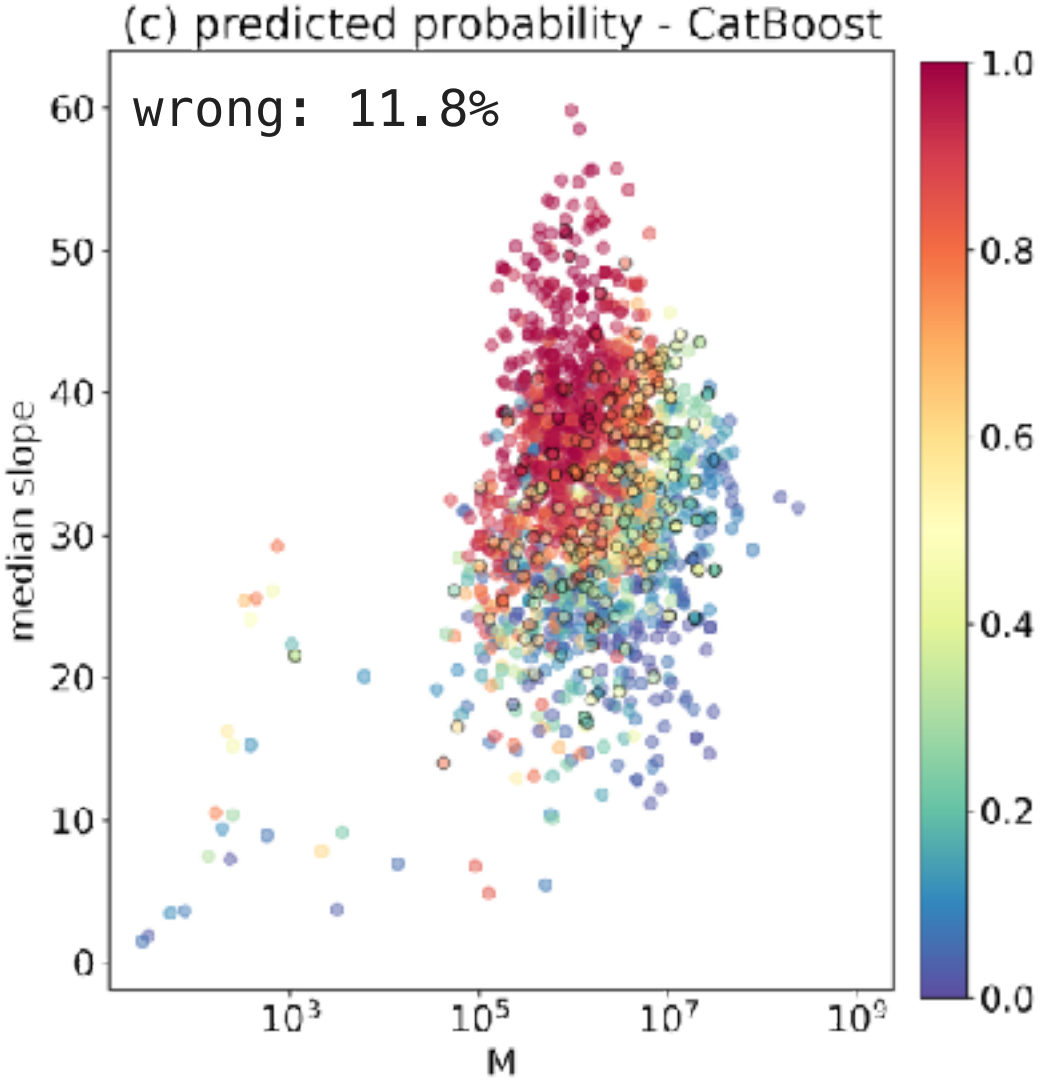
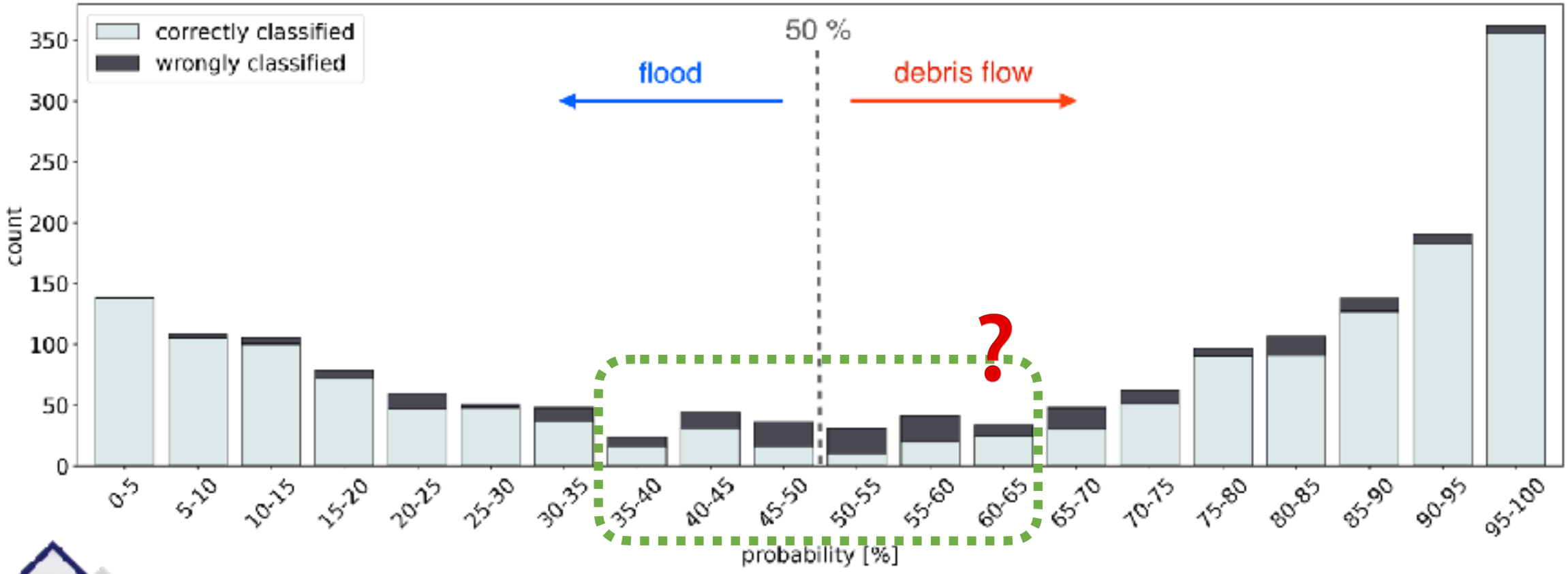
High Mountain Asia data: climatic information

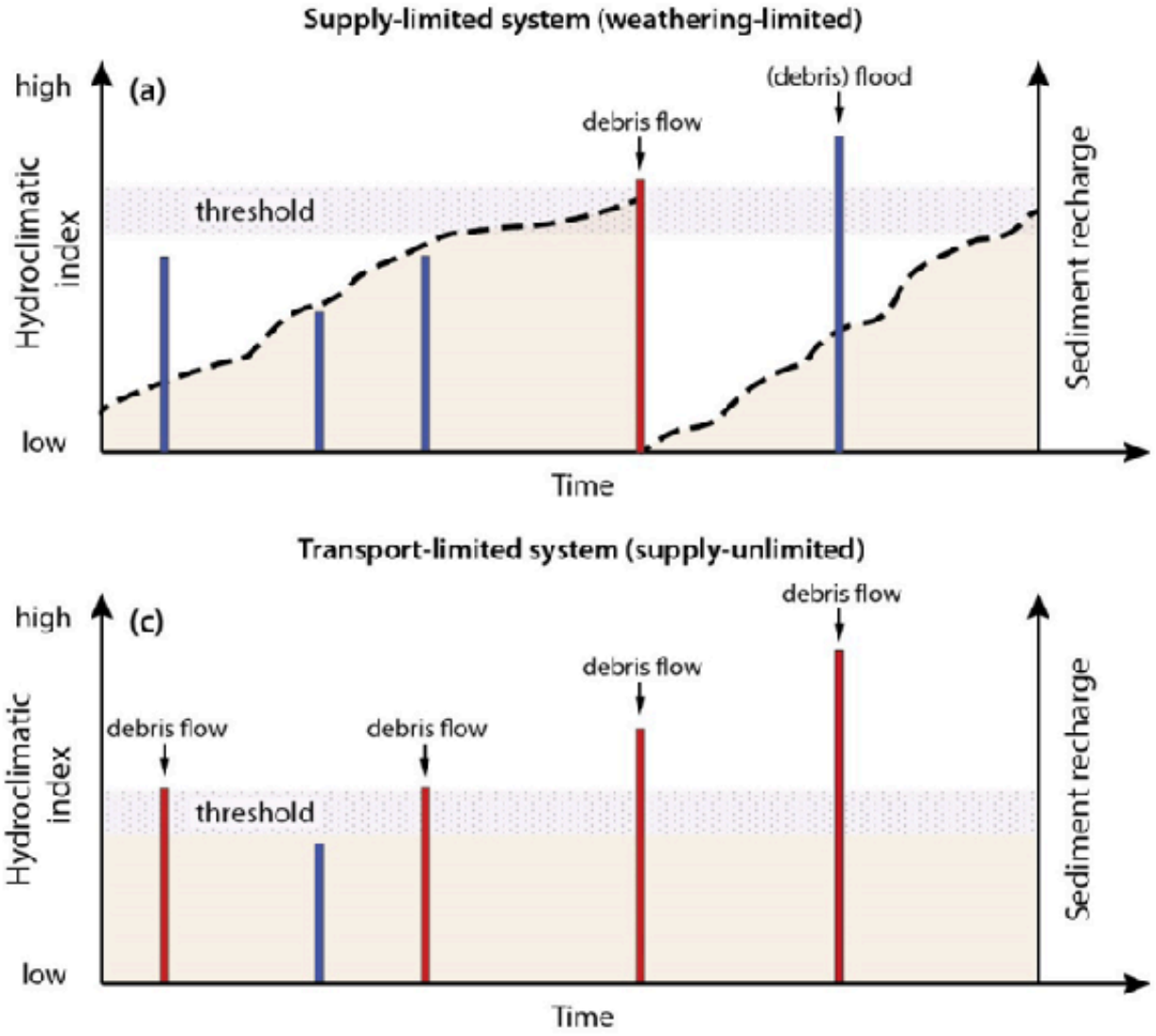




What can we learn from the classification performance?



Concluding thoughts..



(Tjalling de Haas et al., …)

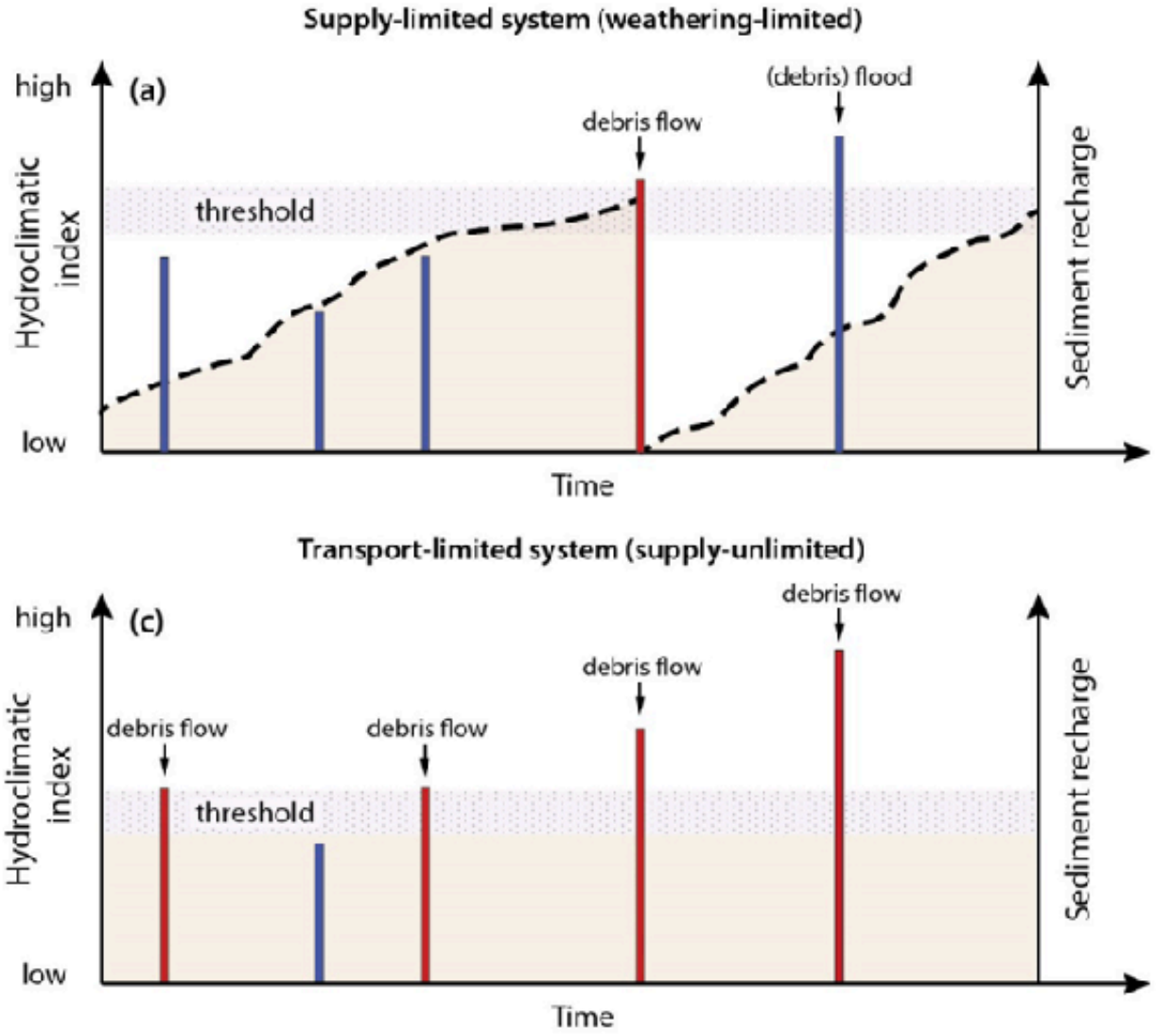
✅ water availability

✅ sediment availability

x

🔶 size and slope

Concluding thoughts..



(Tjalling de Haas et al., …)

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x

🔶 size and slope

Concluding thoughts..

✅ water
✅ sediments

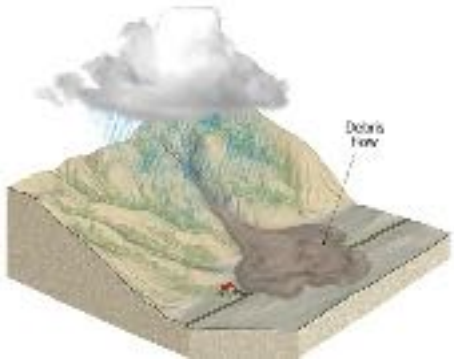
? water
? sediments

✅ water
❌ sediments

Debris flow dominated

Flood dominated

Concluding thoughts..



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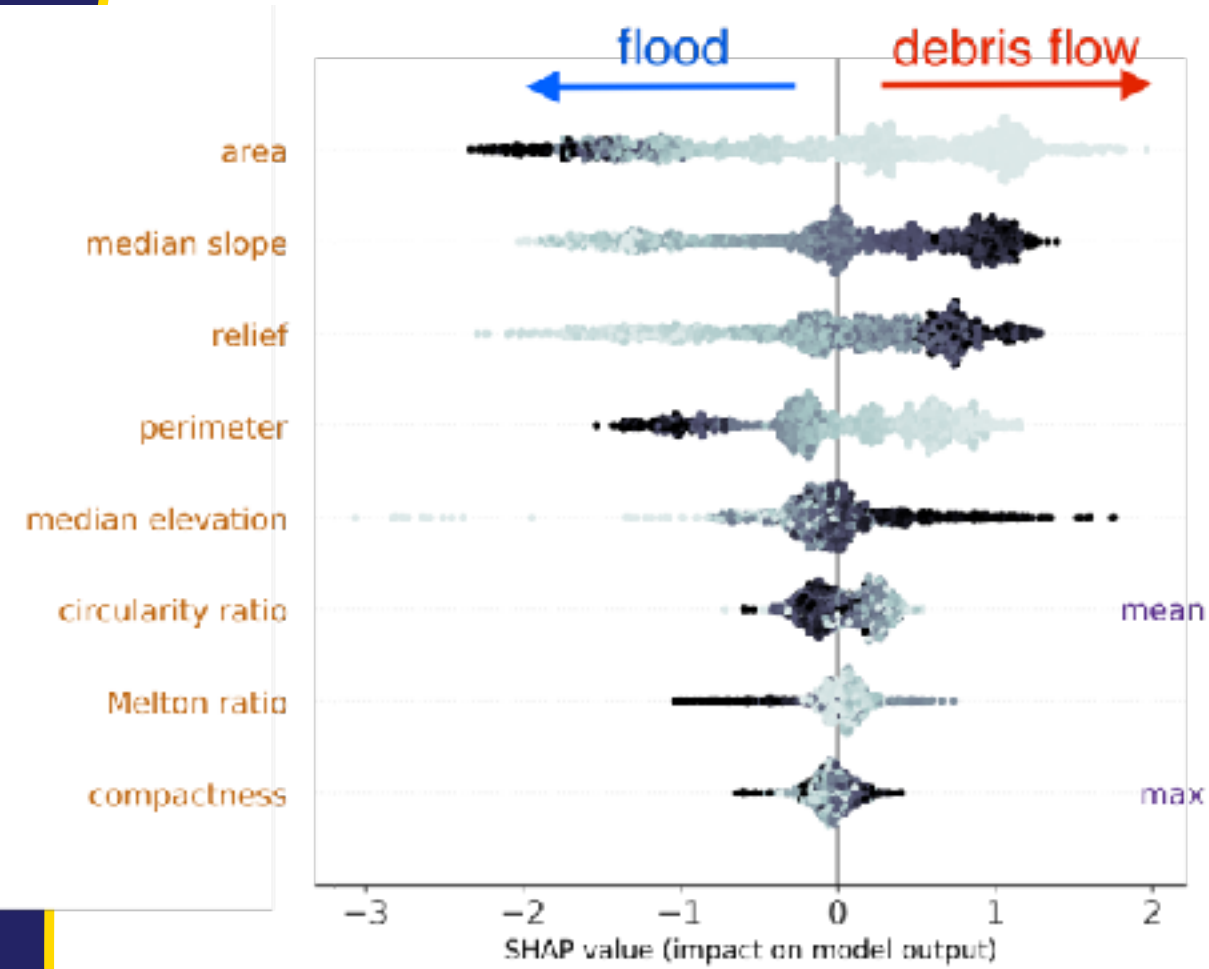
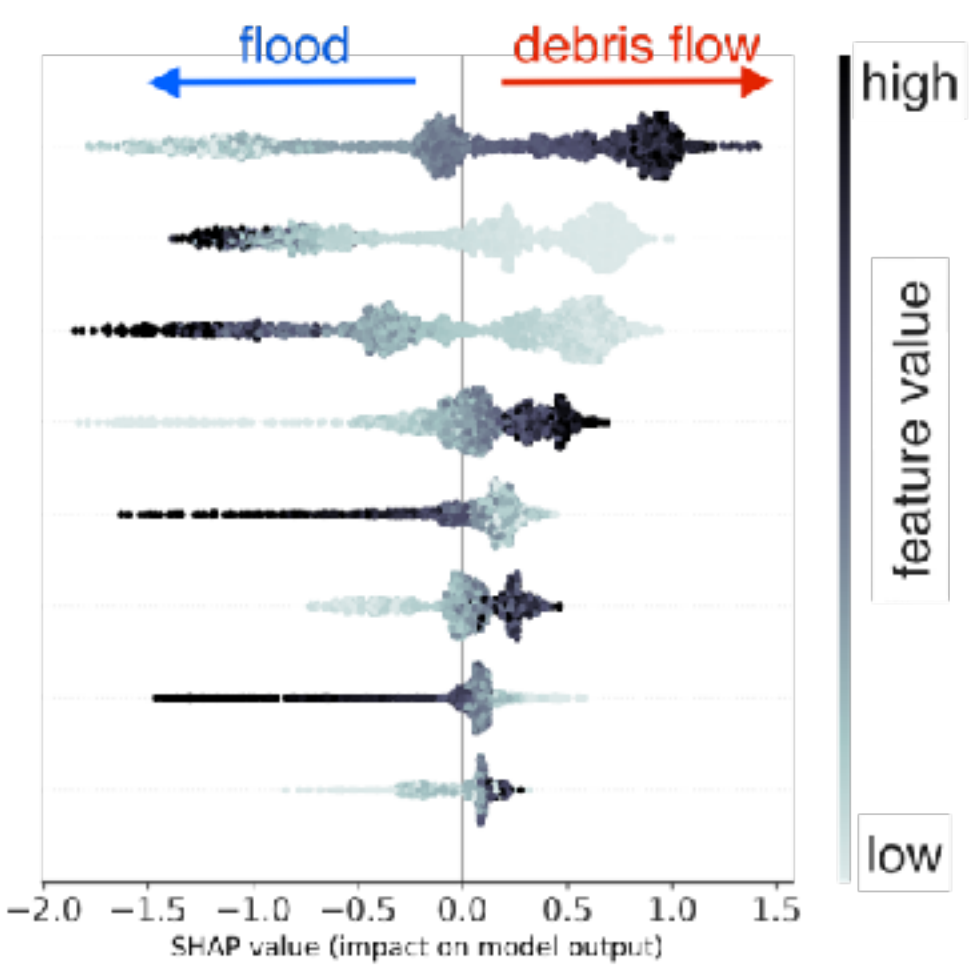

flood
debris flow
area
median slope
relief
perimeter
median elevation
circularity ratio
Melton ratio
compactness
−3
−2
−1
0
1
2
SHAP value (impact on model output)


flood
debris flow
median slope
area
perimeter
snowfall
thermal weathering
mean annual temperature
frost weathering
max annual precipitation
−2.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
SHAP value (impact on model output)
high
feature value
low