Geomorphic Flux From Himalayan Flashflood Equates to >1000 yrs Average Erosion Rate

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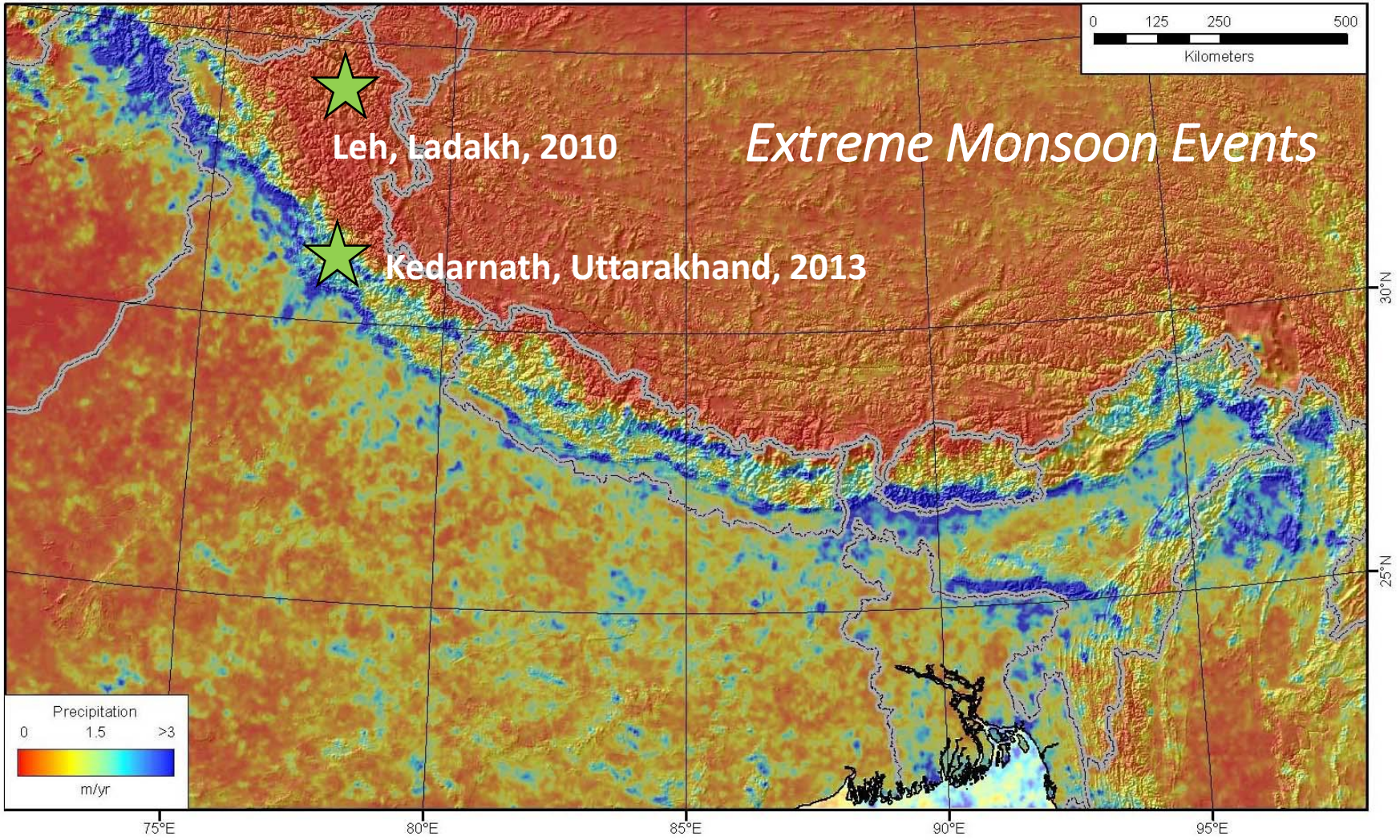
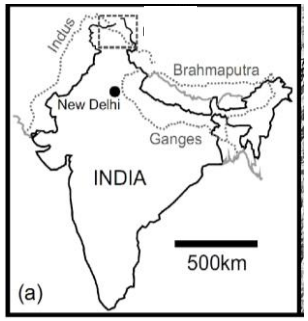
How can we use geomorphic data to understand the distribution and relative magnitude of these events?

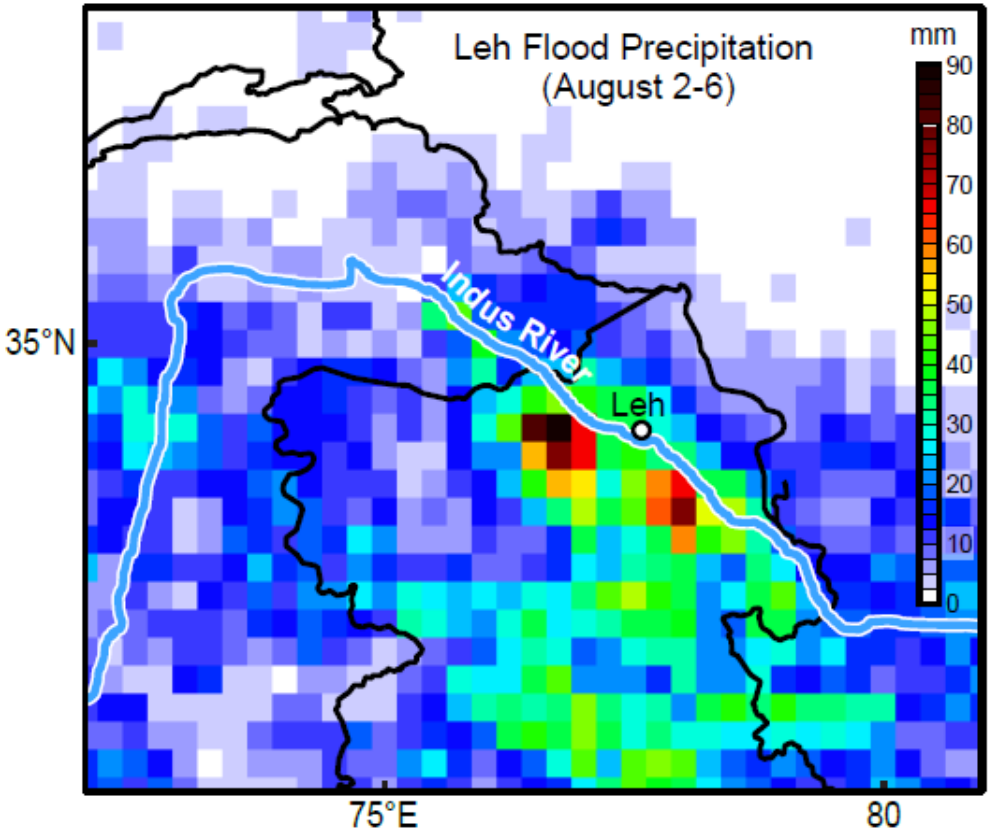


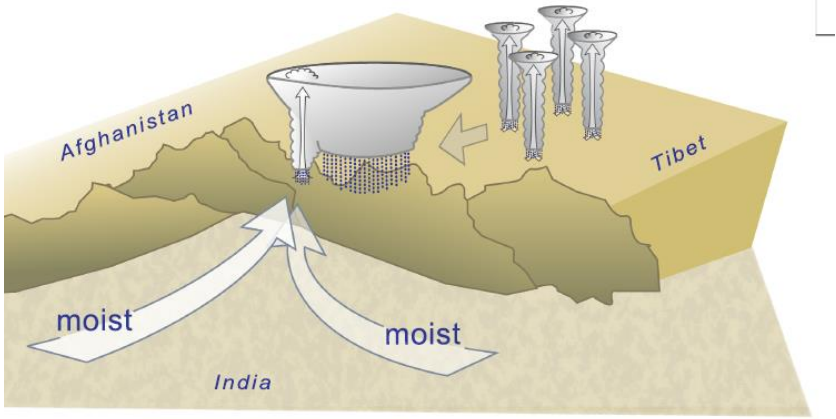
Bookhagen and Burbank, 2006, Geophys. Res Letts.

On Aug 6th 2010 a ‘cloudburst’ devastated the region – single rain gauge missed main impact

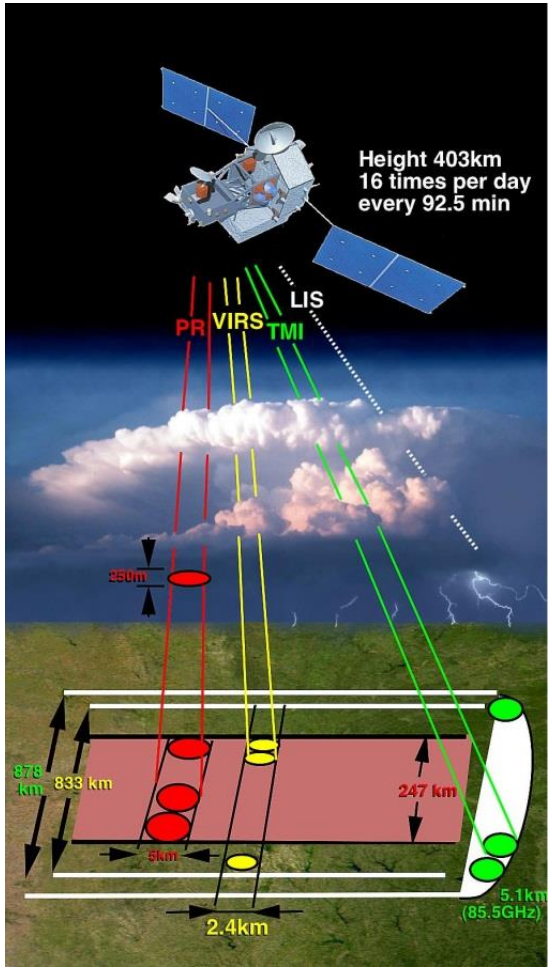


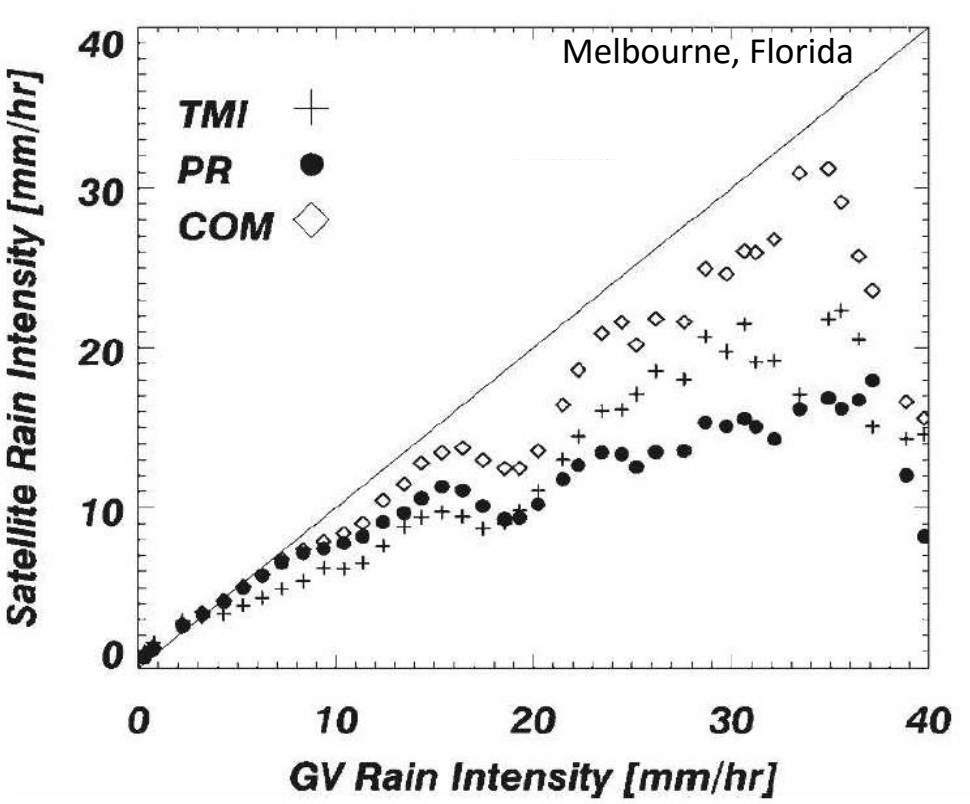
Event reconstructed using TRMM and modelled as a Mesoscale Convective System





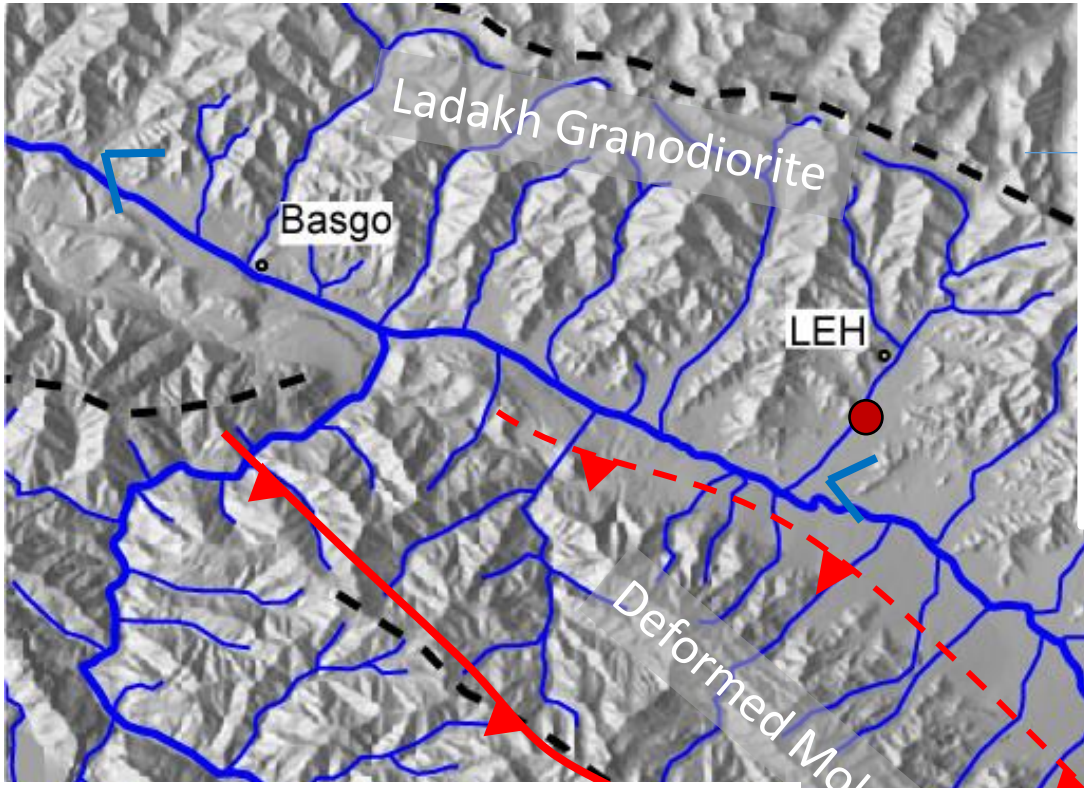
Rasmussen and Houze (2012)

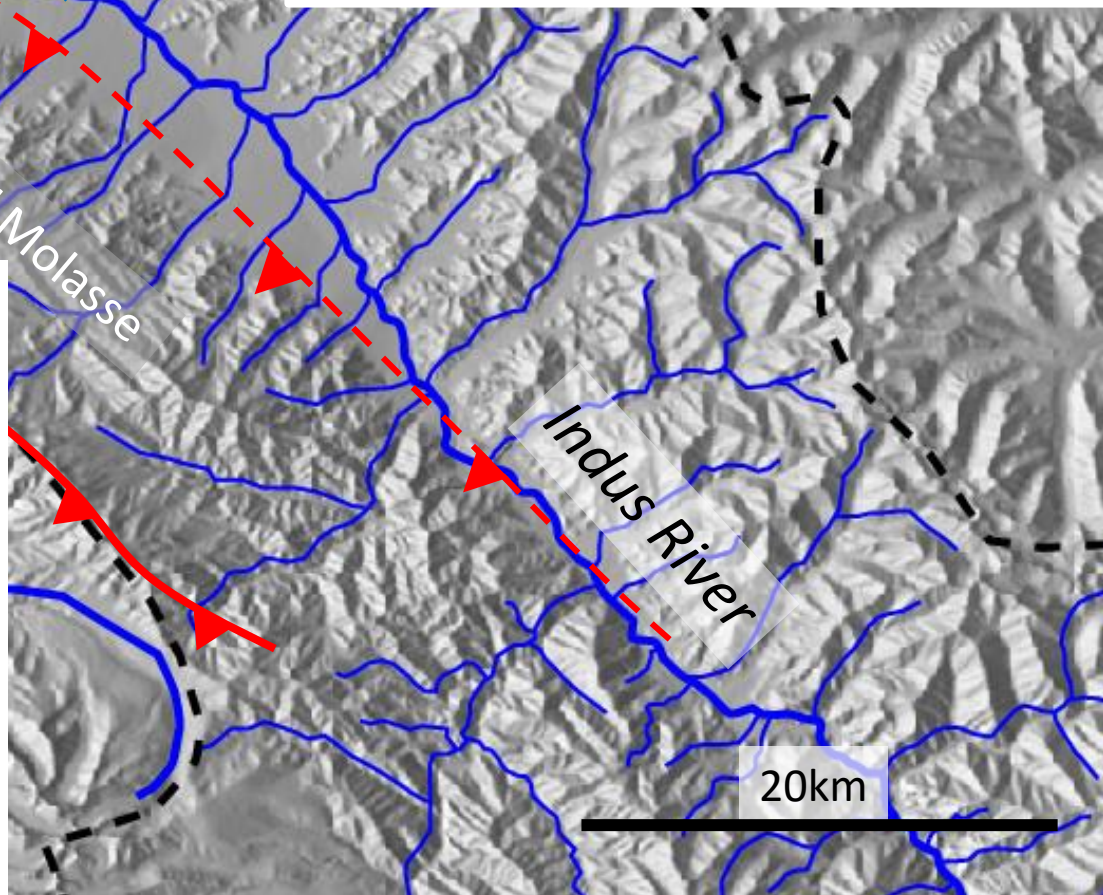


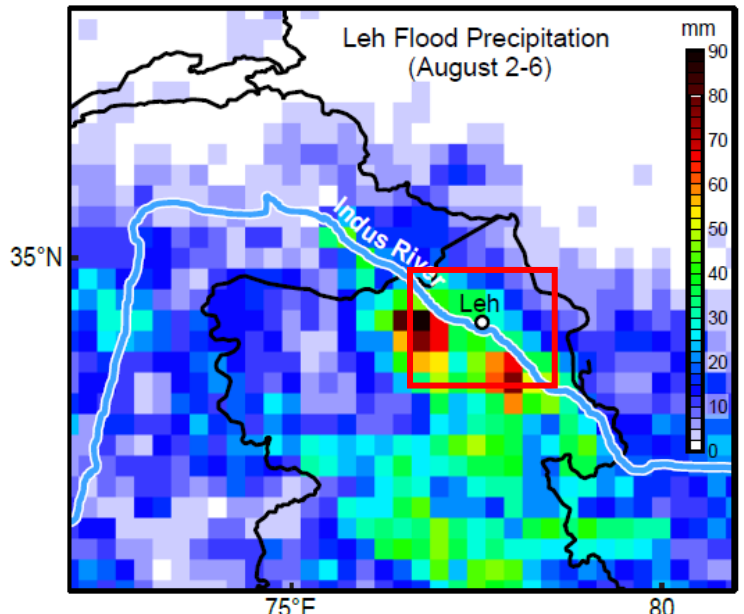


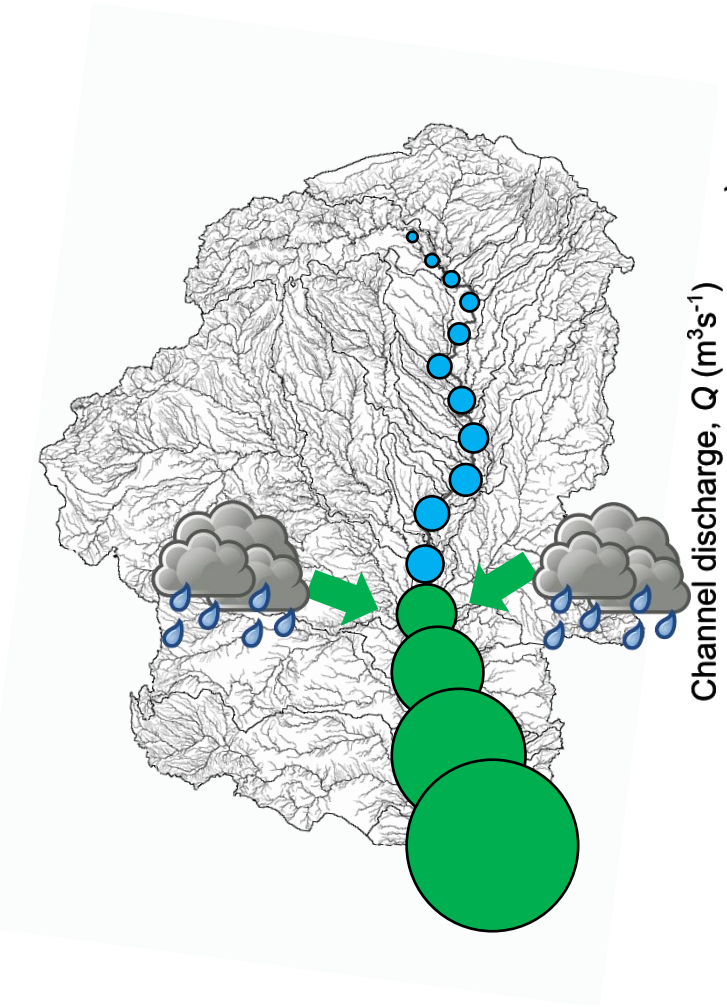
So true scale of storm events and hence their relative magnitude difficult to assess from meteorology data

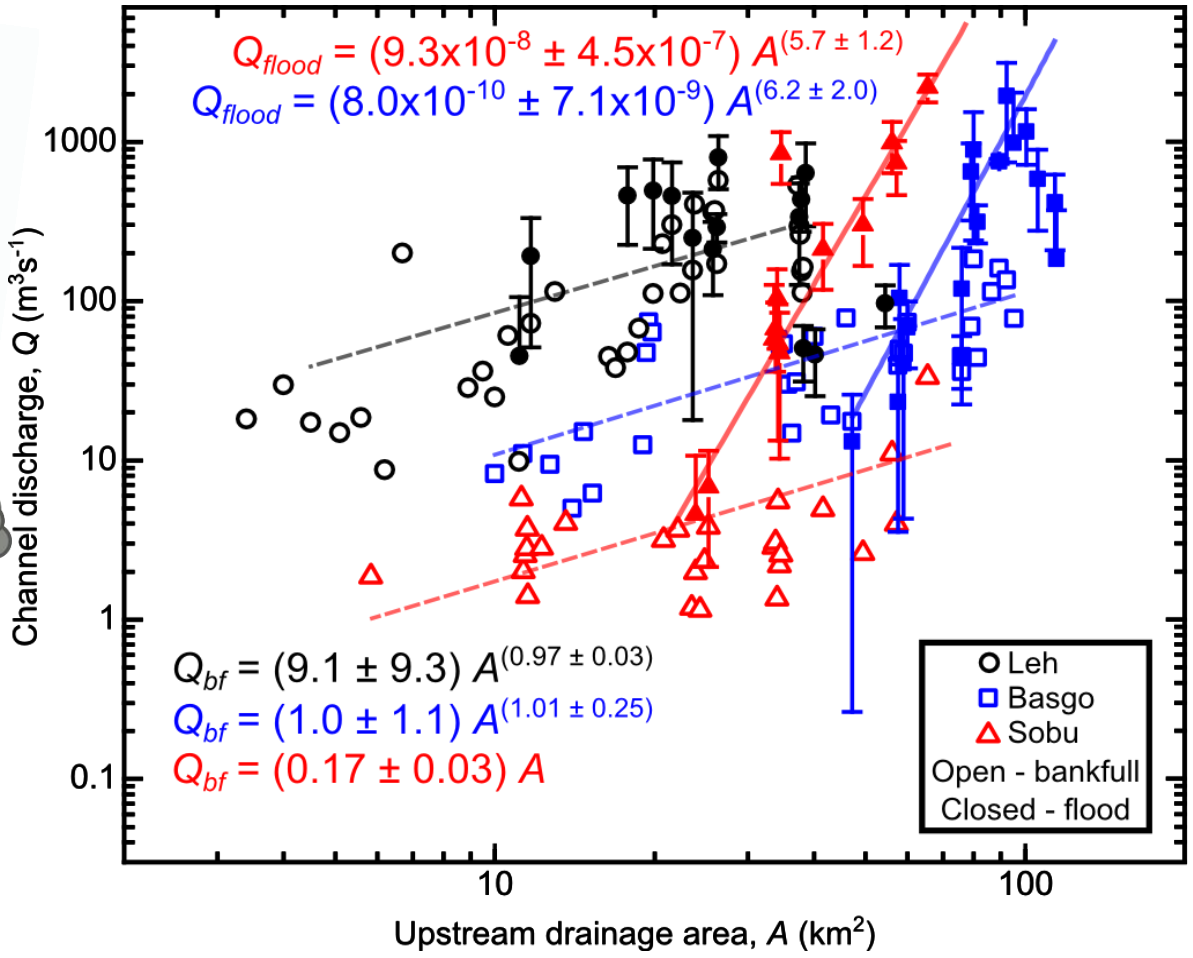
Wolff and Fisher, 2008, Am. Met. Soc.


Ladakh Granodiorite
Basgo
LEH
Deformed Molasse

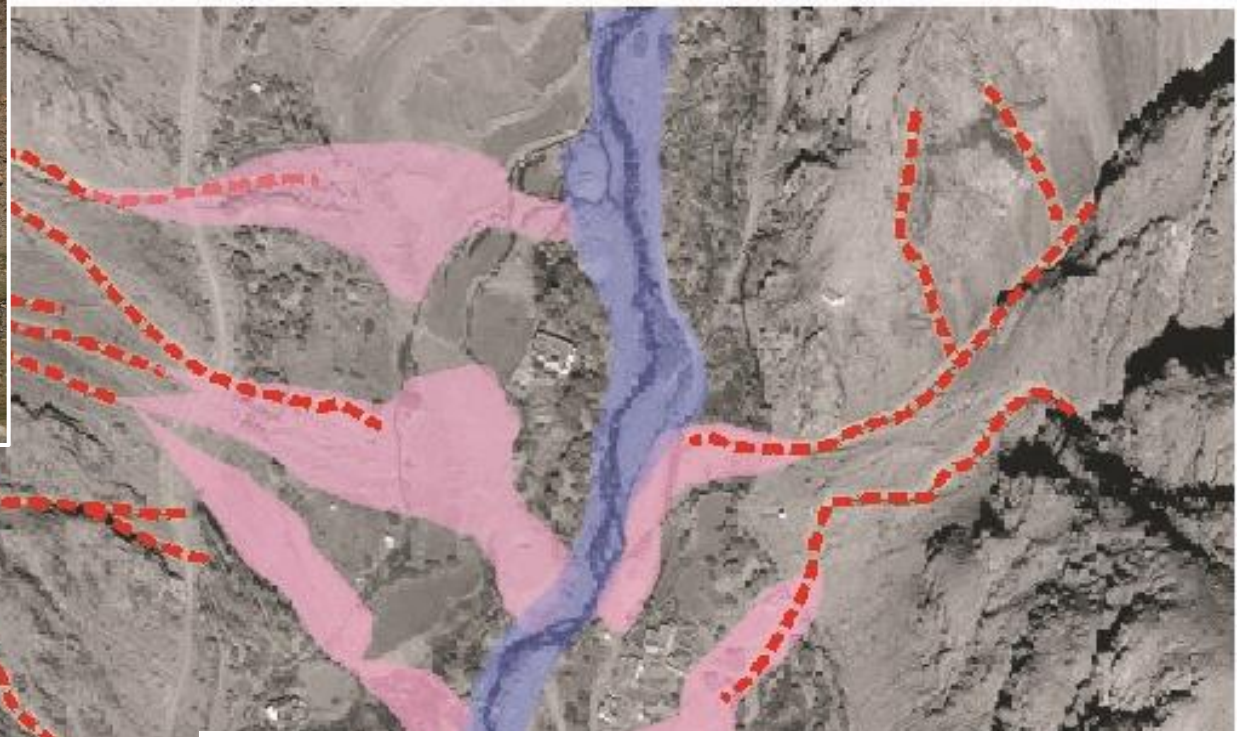

Indus River
20km

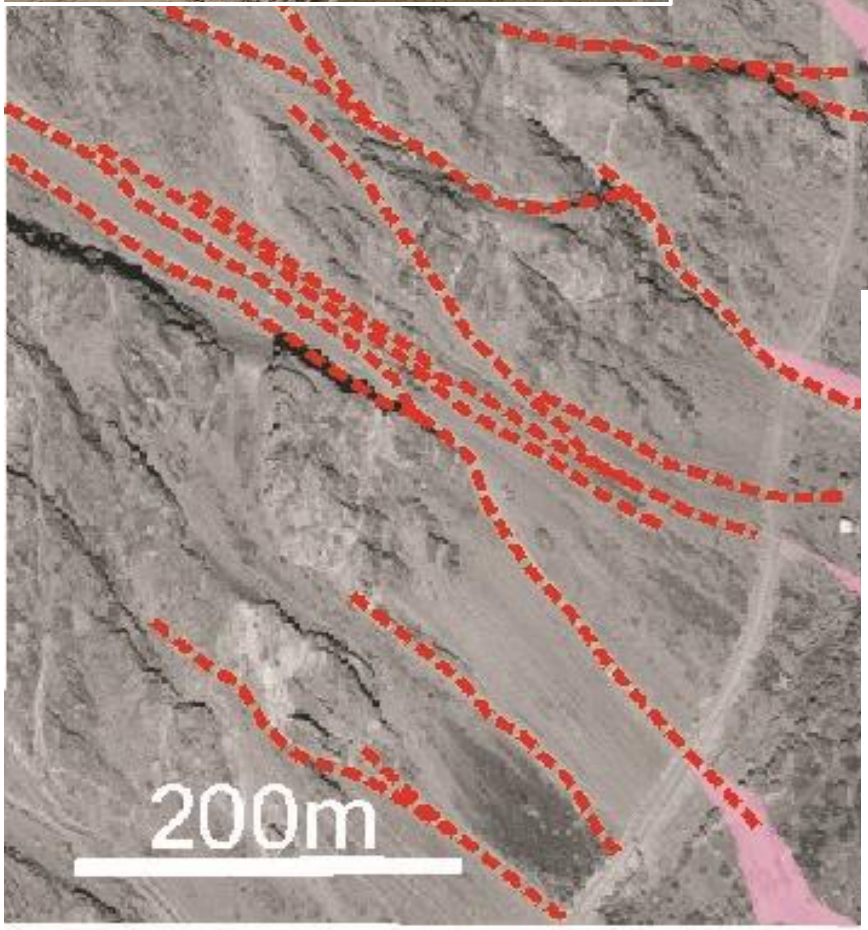

Leh Flood Precipitation
(August 2-6)
mm
90
80
70
60
50
40
30
20
10
0
Indus River
Leh
35°N
75°E
80

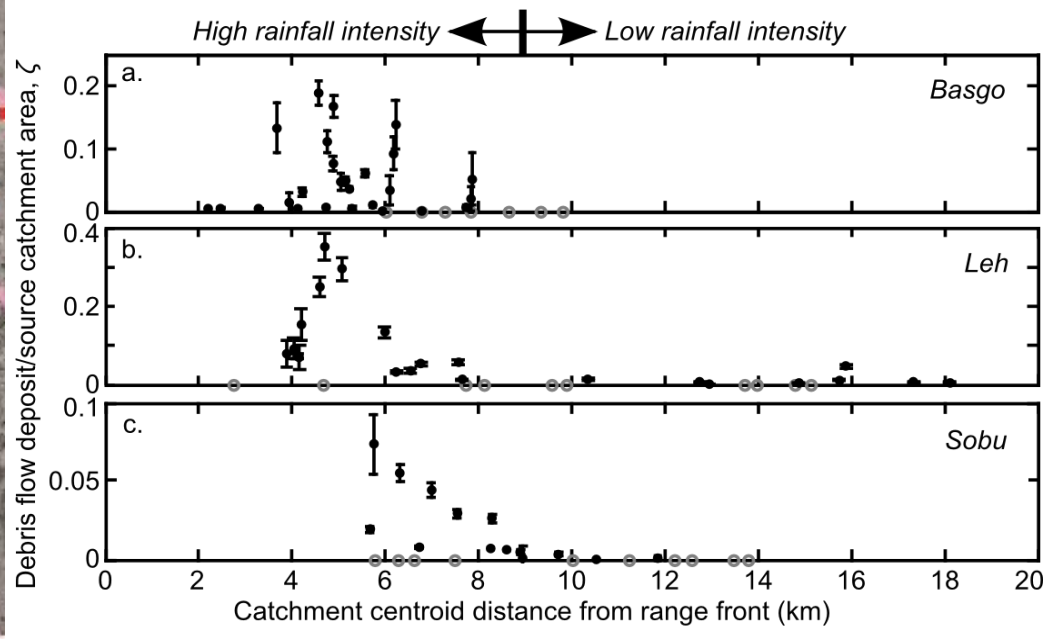




Hobley et al., 2012, Geology

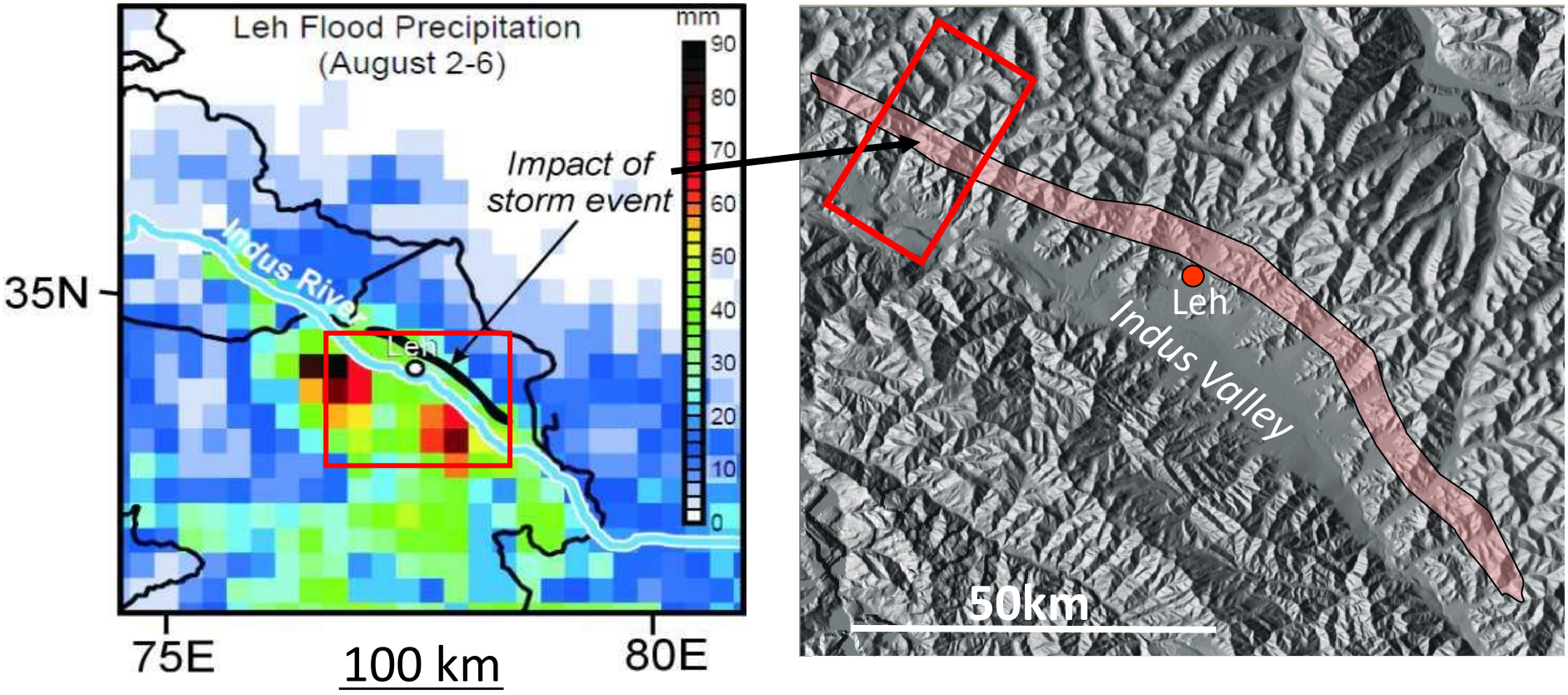




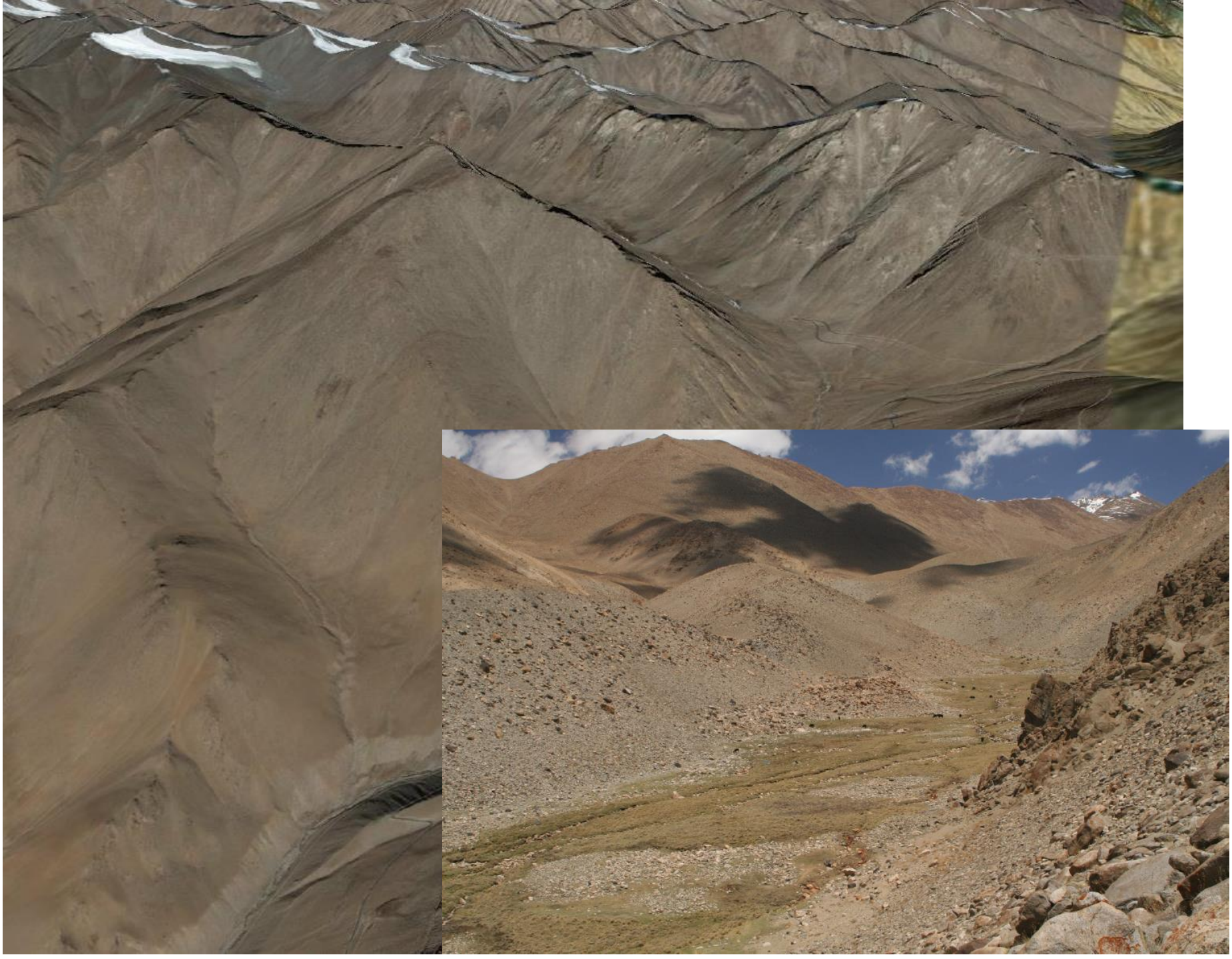


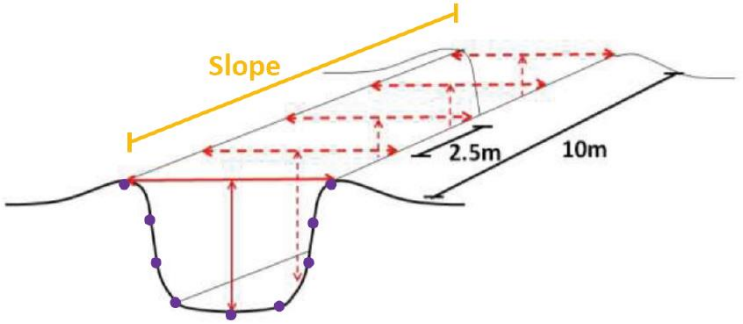
Hobley et al., 2012, Geology

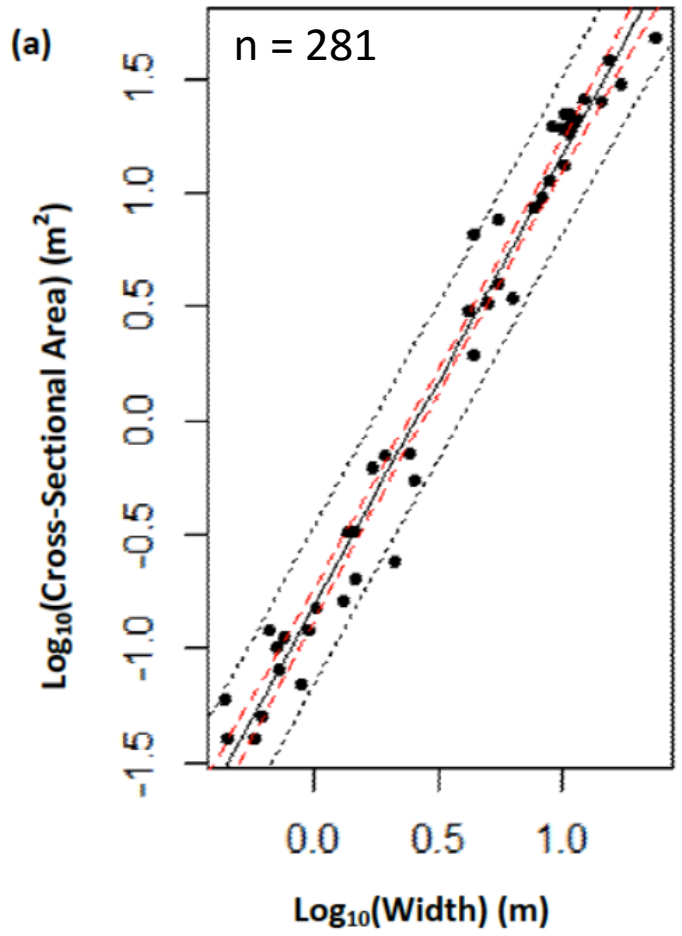
Geomorphic data relocates highest impact storm to northeast of Indus River

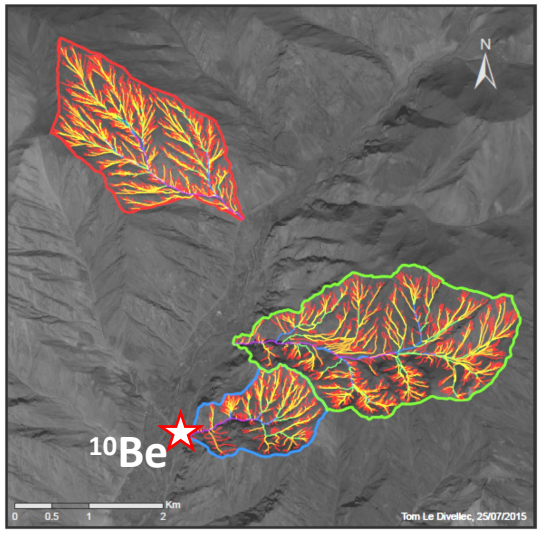


But how significant was this event?



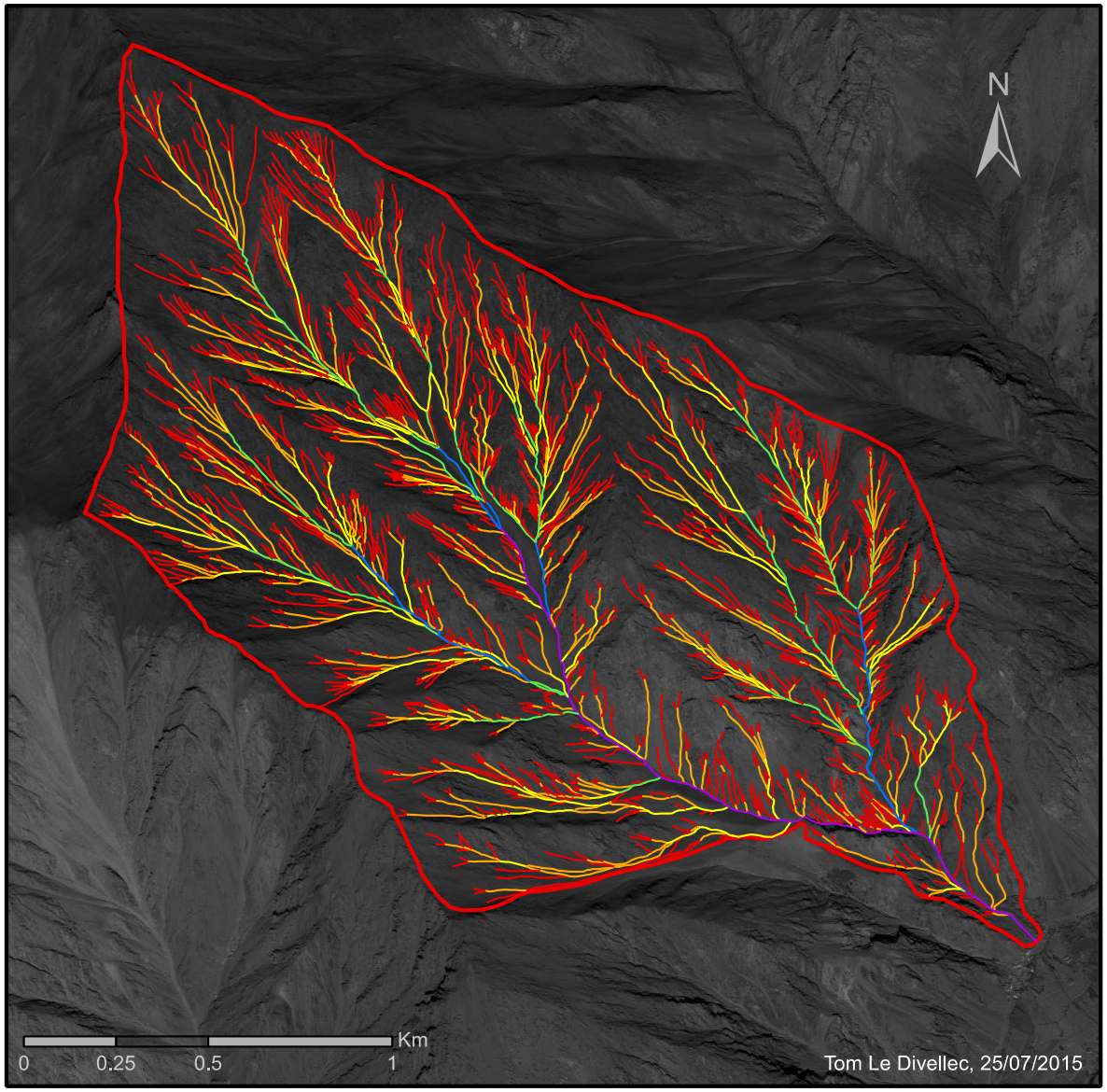

Slope
2.5m
10m


(a)
n = 281
Log10(Cross-Sectional Area) (m2)
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
0.0
0.5
1.0
Log10(Width) (m)

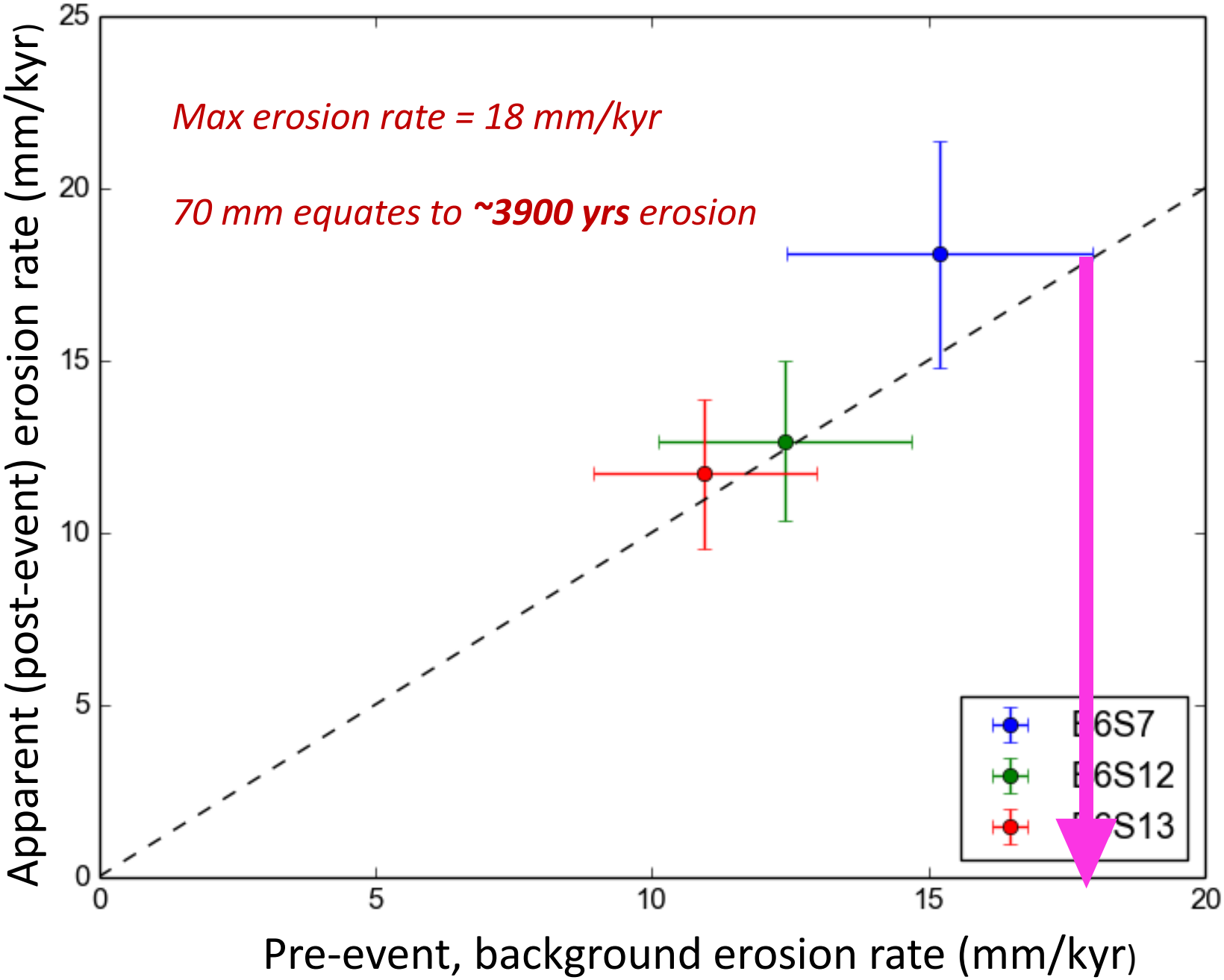


x11 ^{10}Be samples in valley

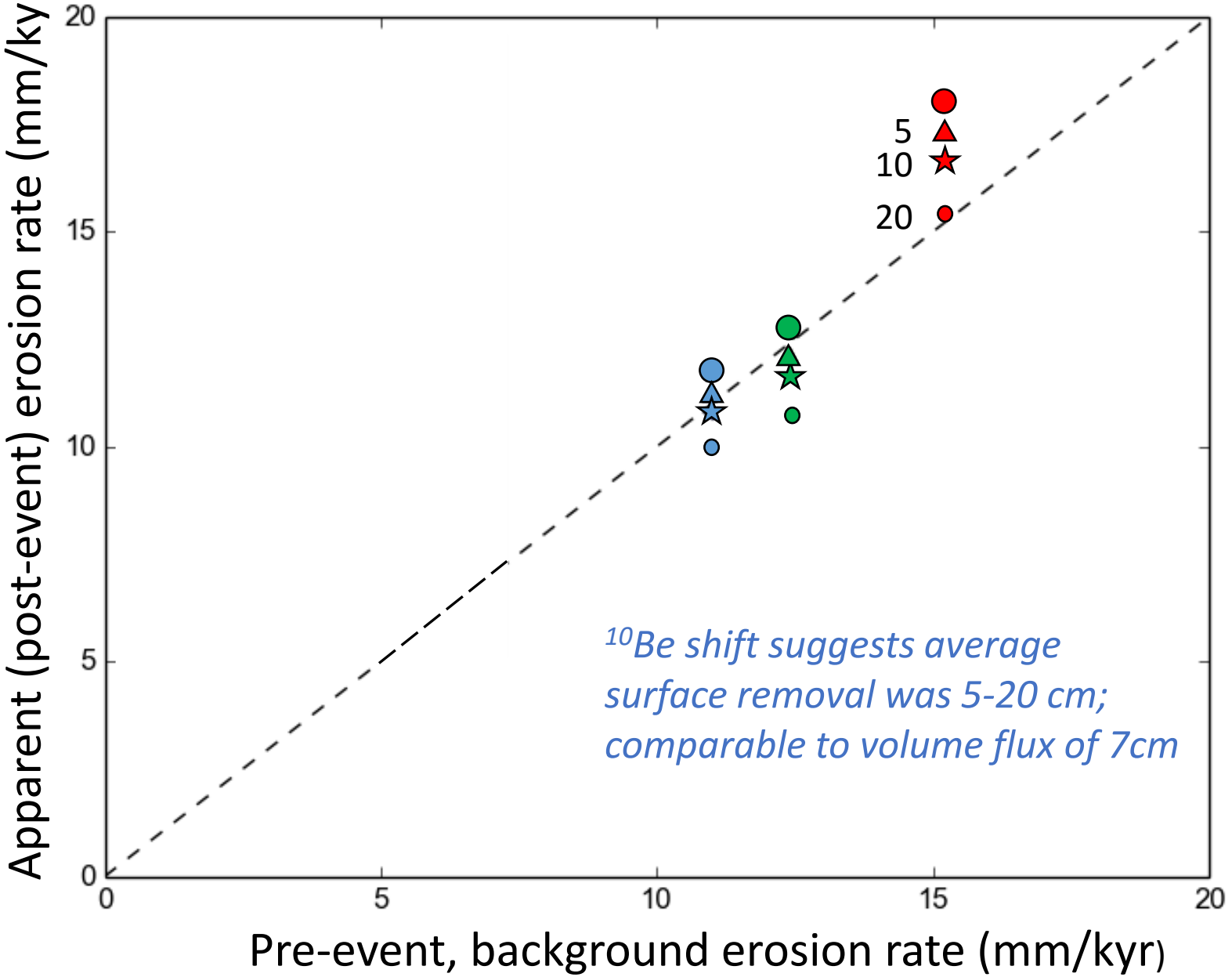
Cross-sectional areas times total length for each order flow yield a volume flux incorporating corrections for pre-event flow gulleys and levees equates to ***~70 mm of surface removal.***

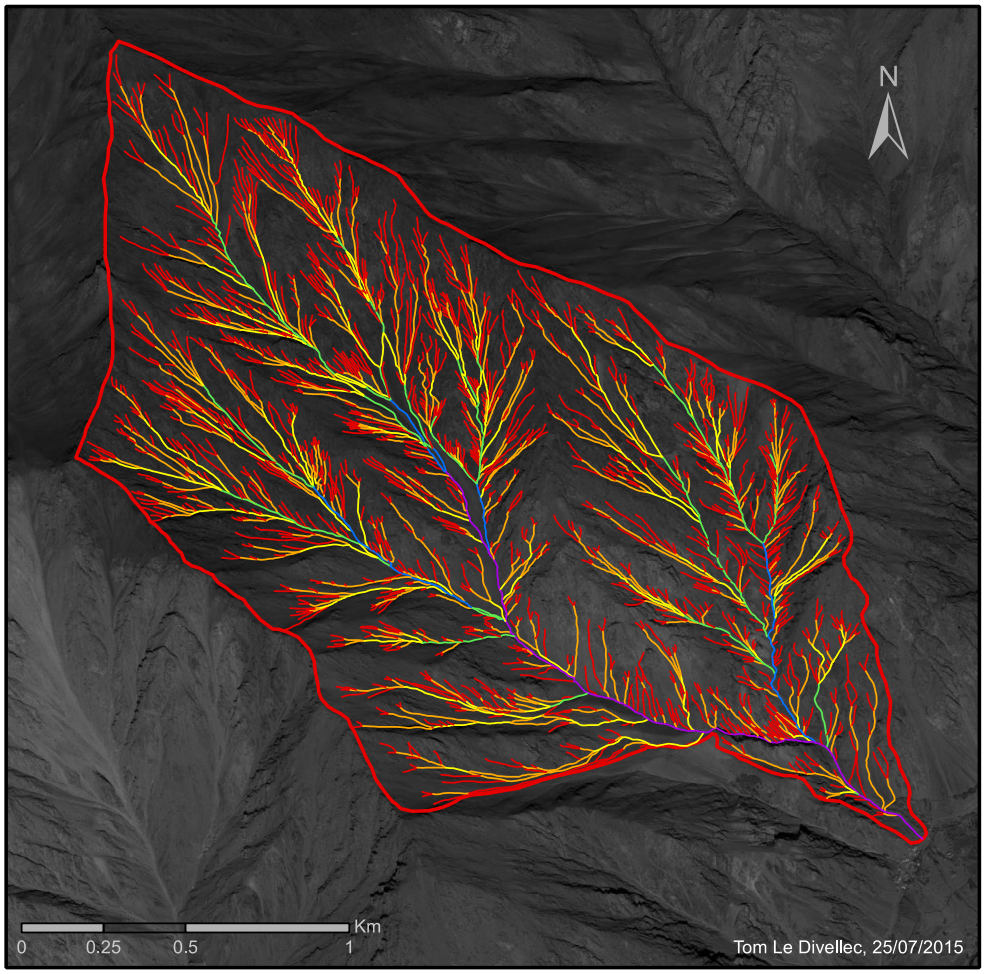


Detrital ^{10}Be derived erosion rates



What is the depth of surface stripping required to correct apparent concentrations?



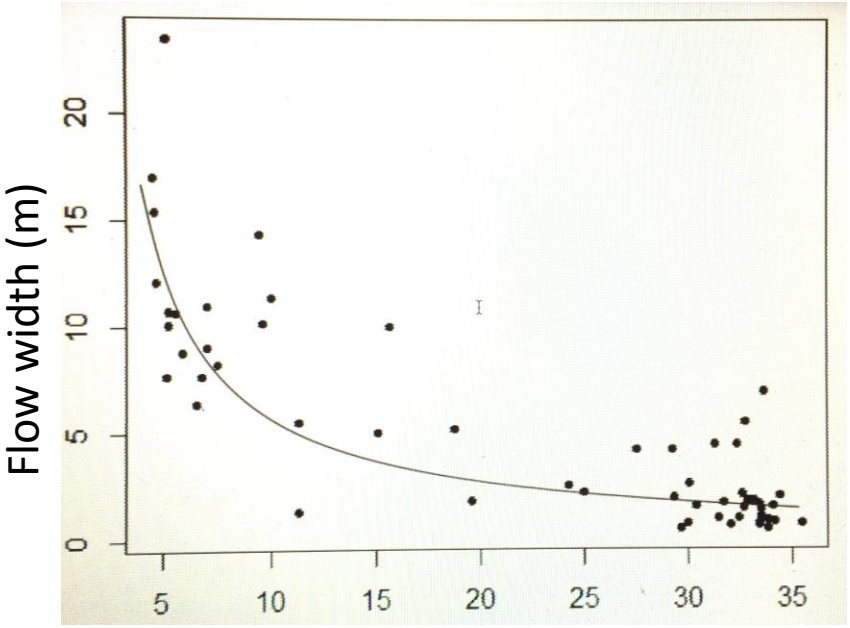


Channel Order

Catchment 1

1 2 3 4 5 6

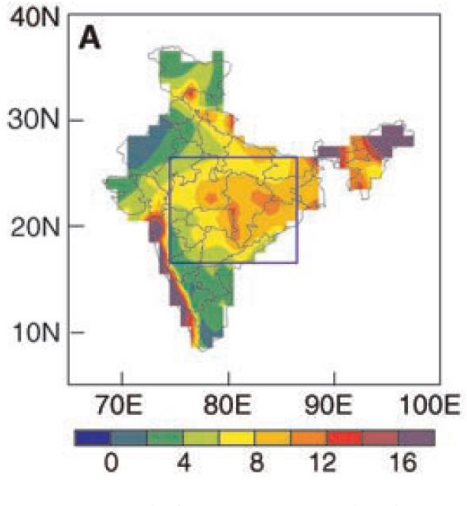
>80% of debris channels by length have average depth of <16 cm (i.e. 1st and 2nd order channels) generated on highest slopes



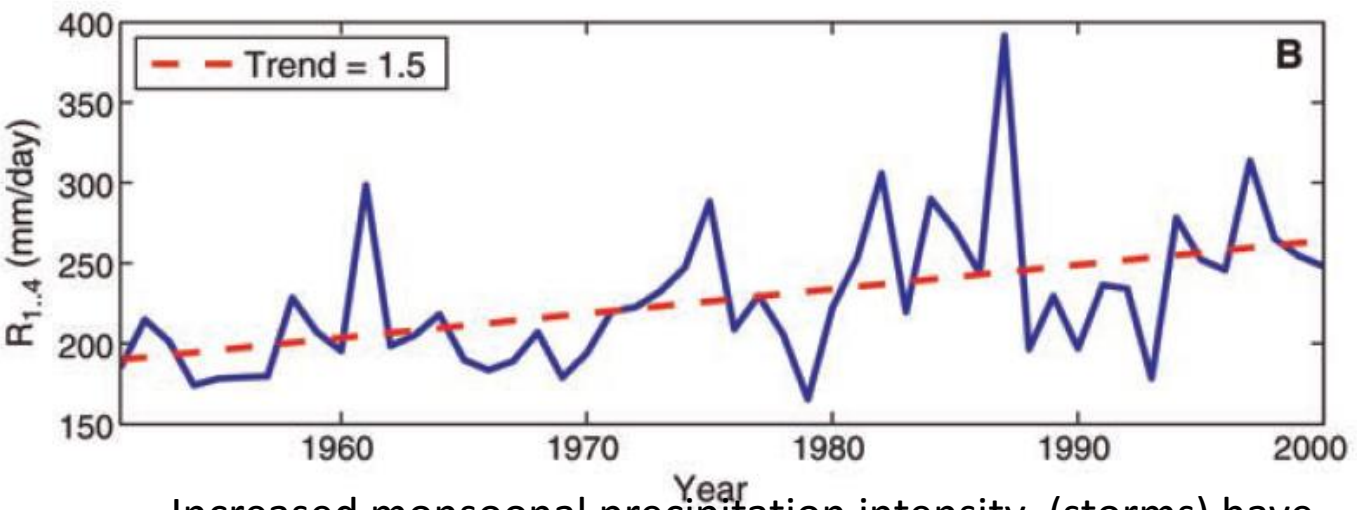
Conclusions

- *Geomorphic data required to resolve short-lived convective storms*
- *Ladakh 2010 mobilised a surface flux that represents > 3000 yrs of background erosion*
- *Majority of flux sourced from numerous shallow debris flow gulleys on steep slopes*

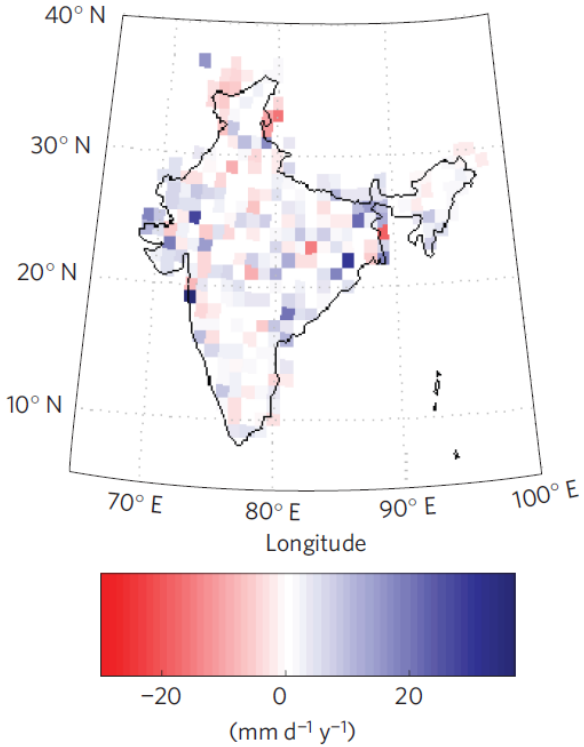
Rain Gauge data across India, but poor in Himalaya



Trend of 100-year return levels

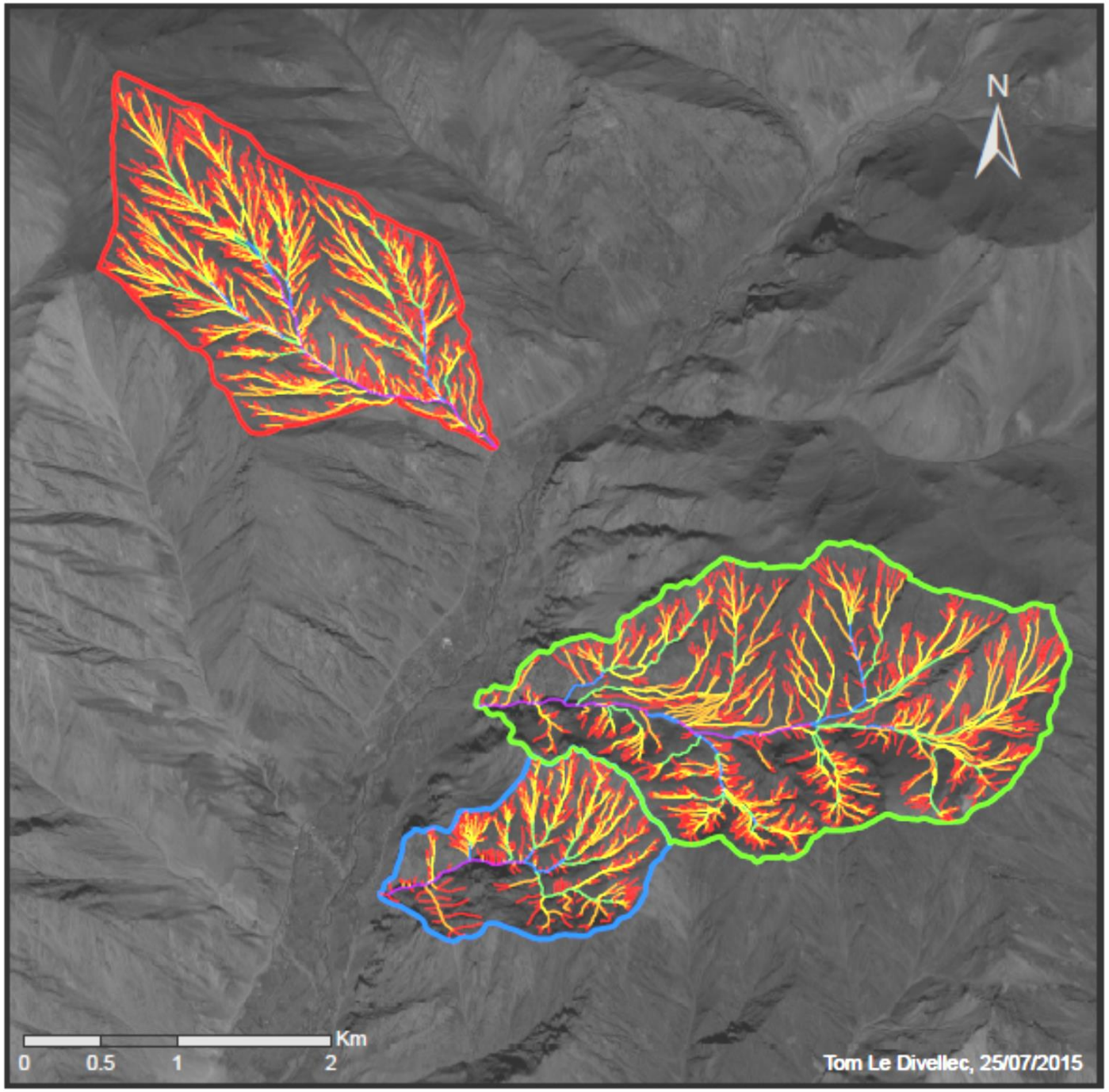


Increased monsoonal precipitation intensity (storms) have been increasing – rain gauge data (eg. Goswami et al., 2006, Science)



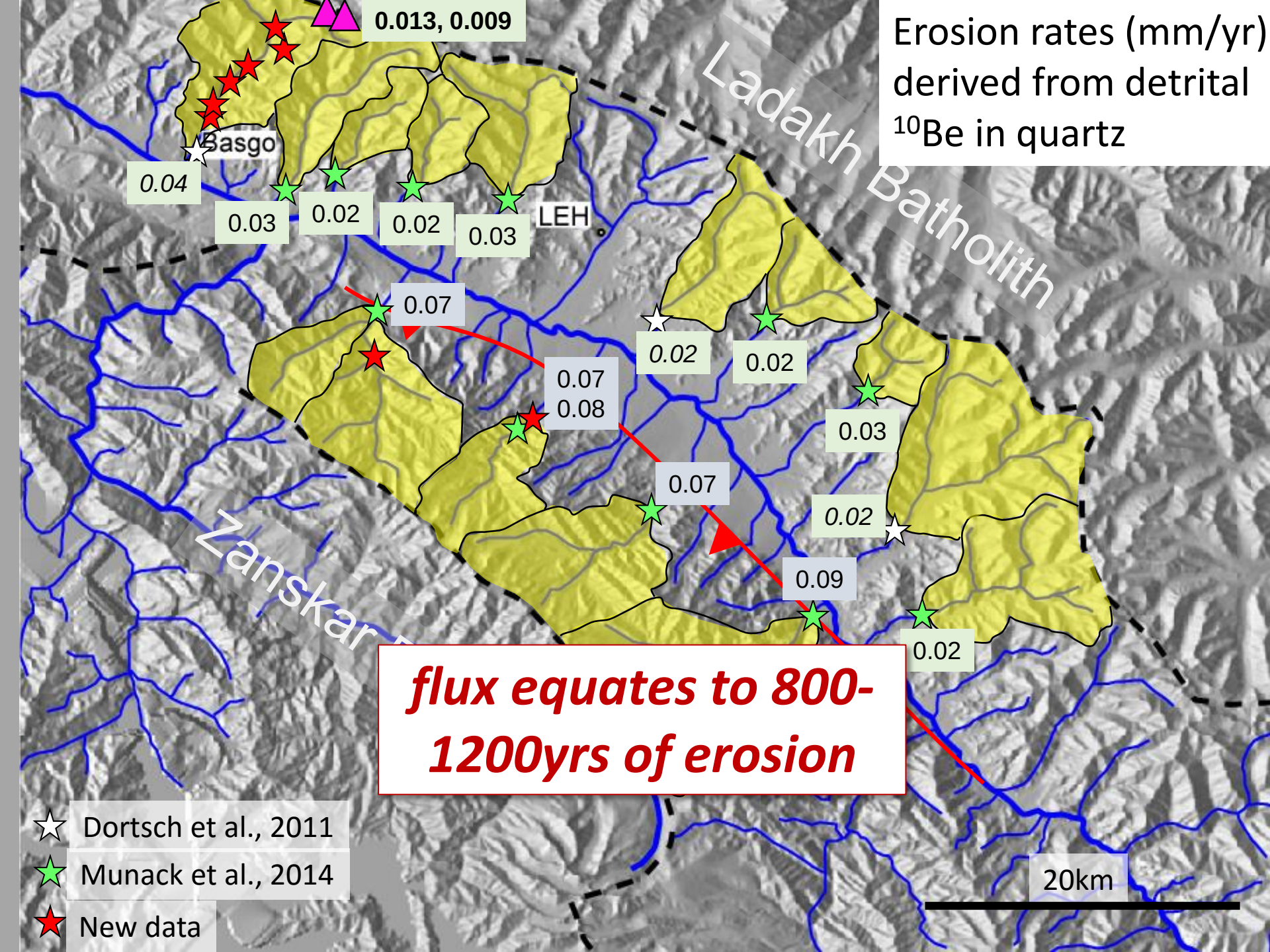
<u>*No clear evidence*</u> of a trend in intense rainfall events since 1951 – Ghosh et al., 2014 Nature Cl. Change

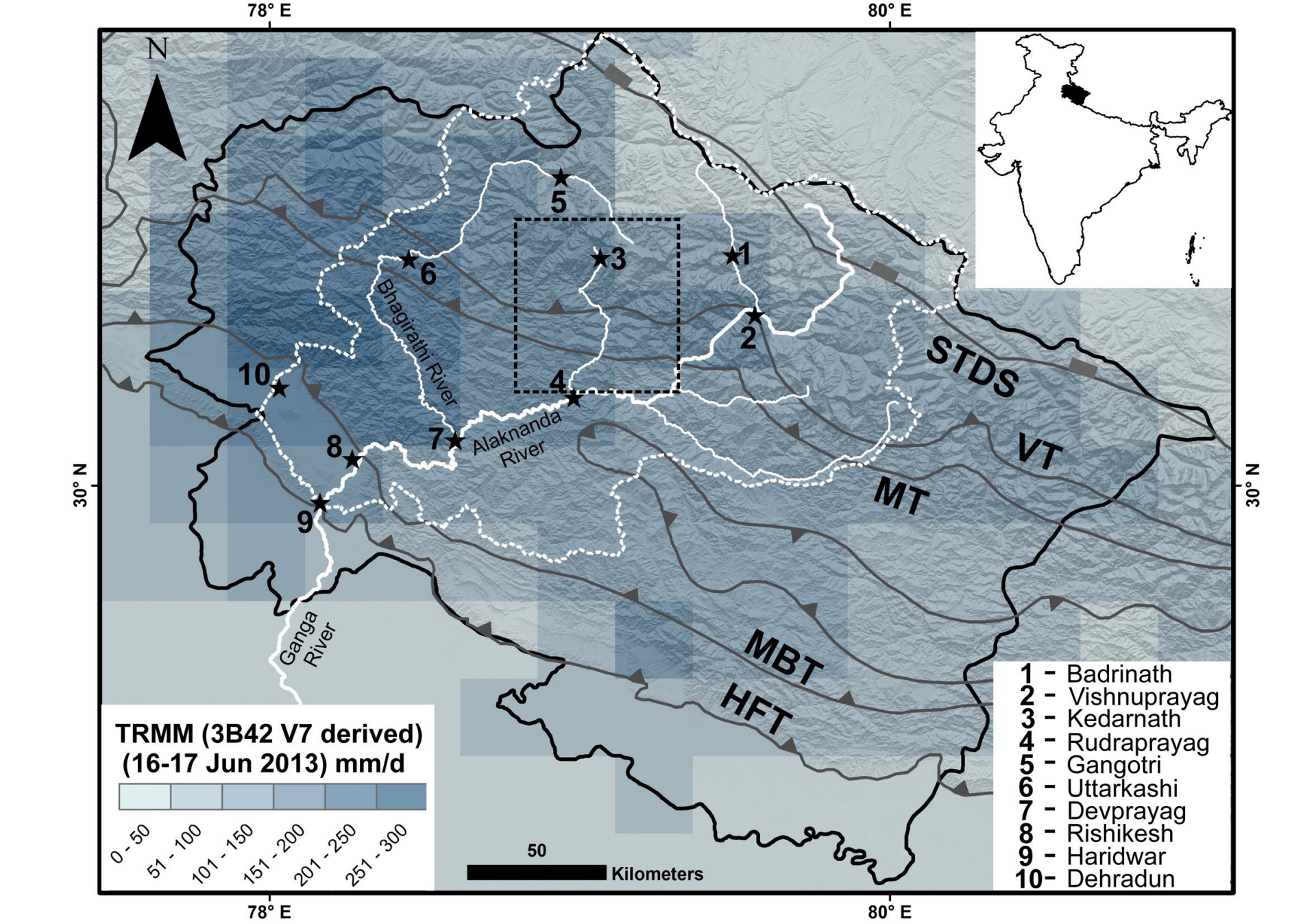
Map out debris Flows at different orders



Methodology

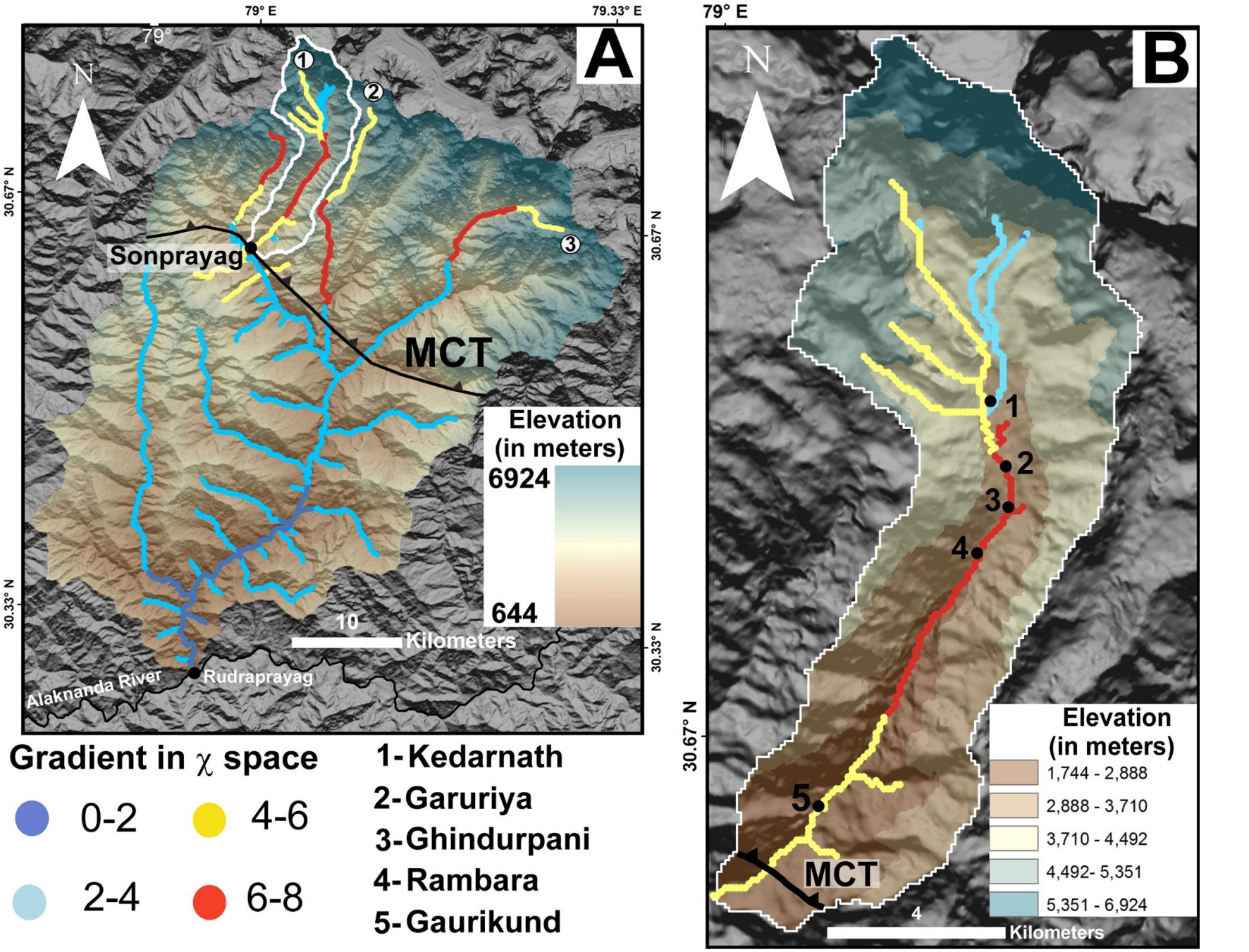
1) Map debris flows and establish a stream ordering
2) Width/depth scaling relationship established for 281 sites covering full range
3) Find average cross-sectional area for each stream order by plotting cumulative frequency of streams order and of channel cross-sectional area and assigning the same proportionate division from the channel orders to the cross-sectional areas. Also cross-checked that assigned area/orders are correct based known location of measurements.
4) Obtain slope corrected lengths from remote imager for each order and multiply by average cross-sectional area.


Erosion rates (mm/yr) derived from detrital ^{10}Be in quartz
Ladakh Batholith
Zanskar
Basgo
LEH
0.013, 0.009
0.04
0.03
0.02
0.02
0.03
0.07
0.07
0.08
0.02
0.02
0.03
0.07
0.02
0.09
0.02
flux equates to 800-1200yrs of erosion
Dortsch et al., 2011
Munack et al., 2014
New data
20km

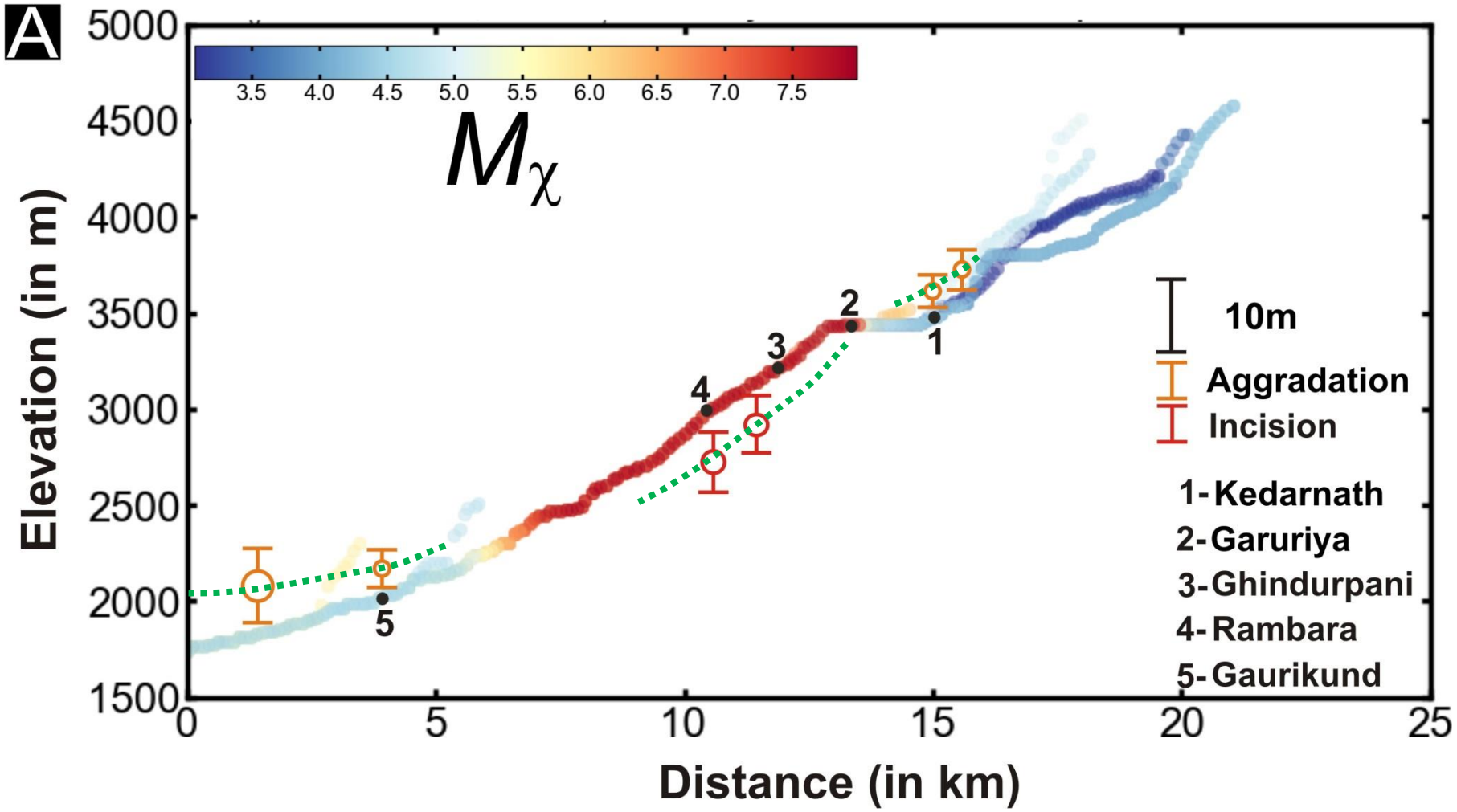


Kedarnath, Uttarakhand, 2013

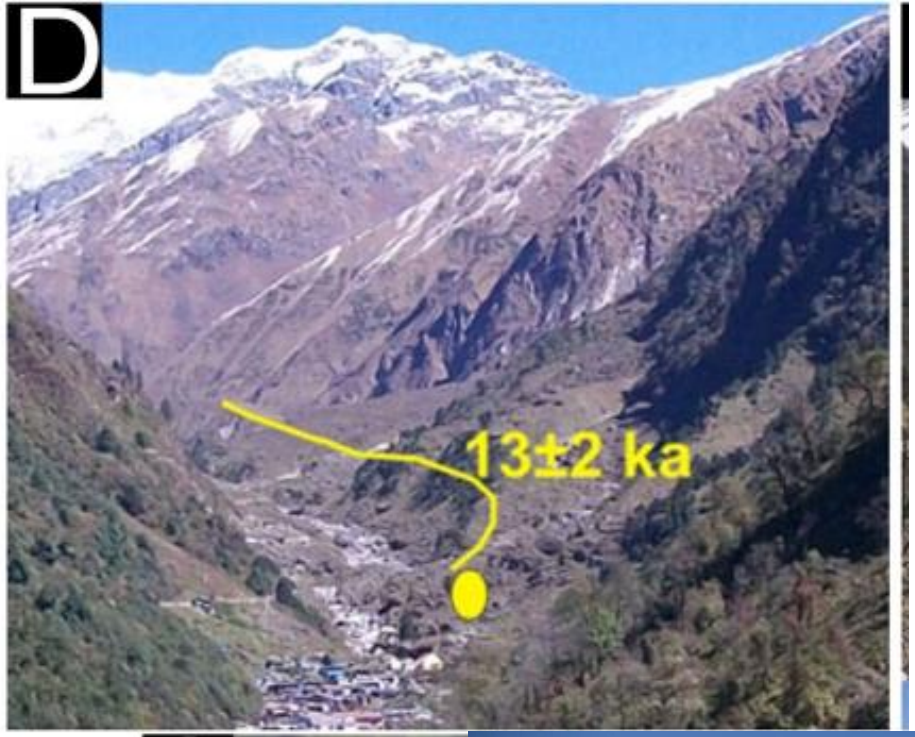
Devrani et al., 2015, Geophys. Res. Letts



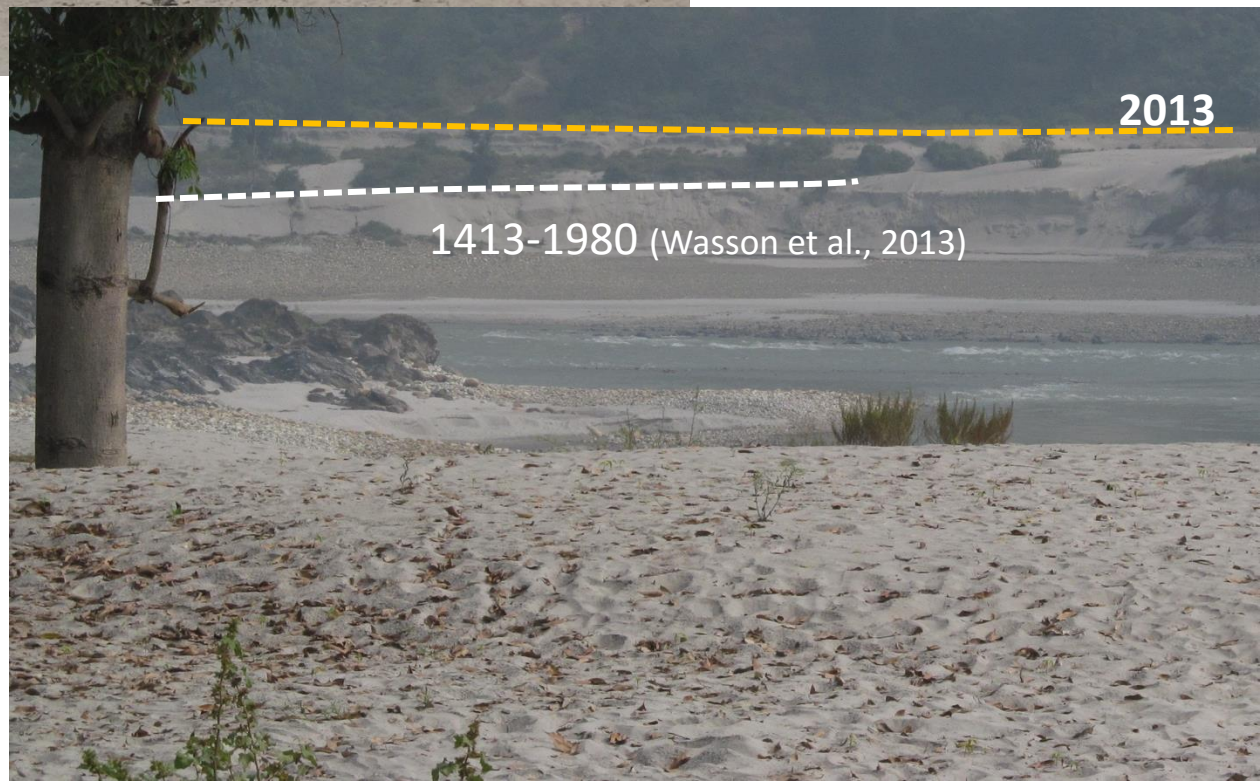
Devrani et al., 2015, Geophys. Res. Letts



Devrani et al., 2015, Geophys. Res. Letts

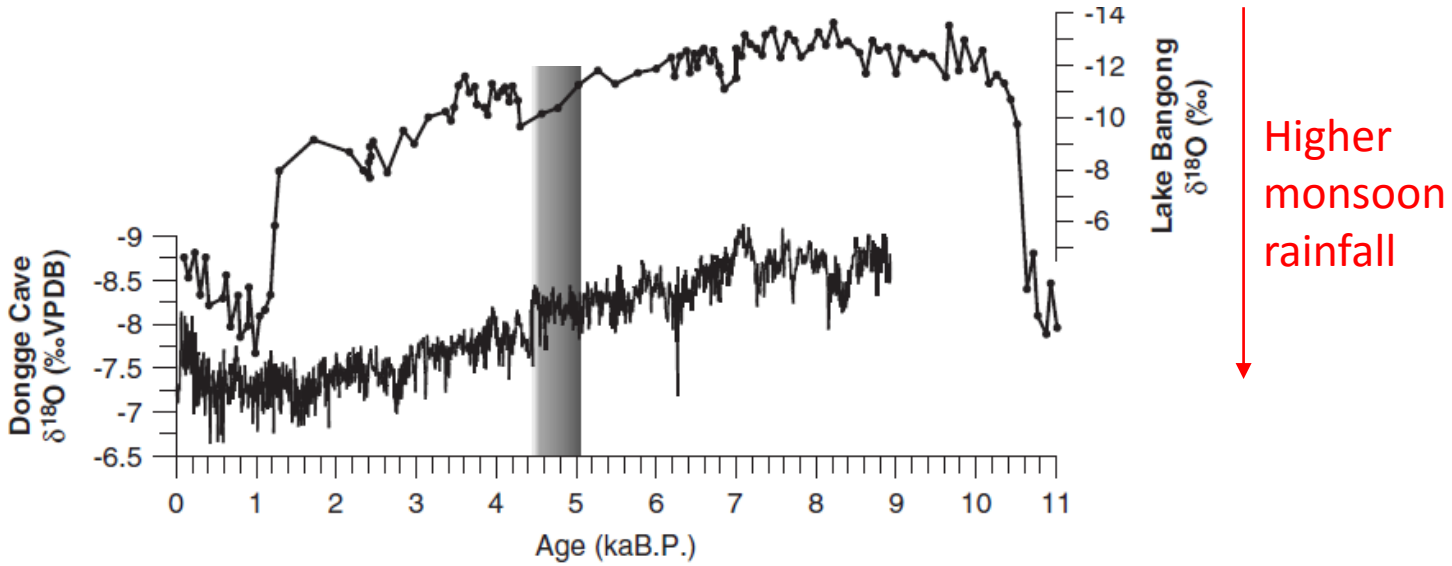


Mehta et al., 2012


2013
1413-1980 (Wasson et al., 2013)

Conclusions

- Geomorphic analysis is the only technique that yields high resolution reconstruction and relative magnitude of extreme storm events in Himalaya
- Ladakh and Uttarakhand events represent the biggest events in last 1000-10,000 yrs.
- Does this represent a change to the system?

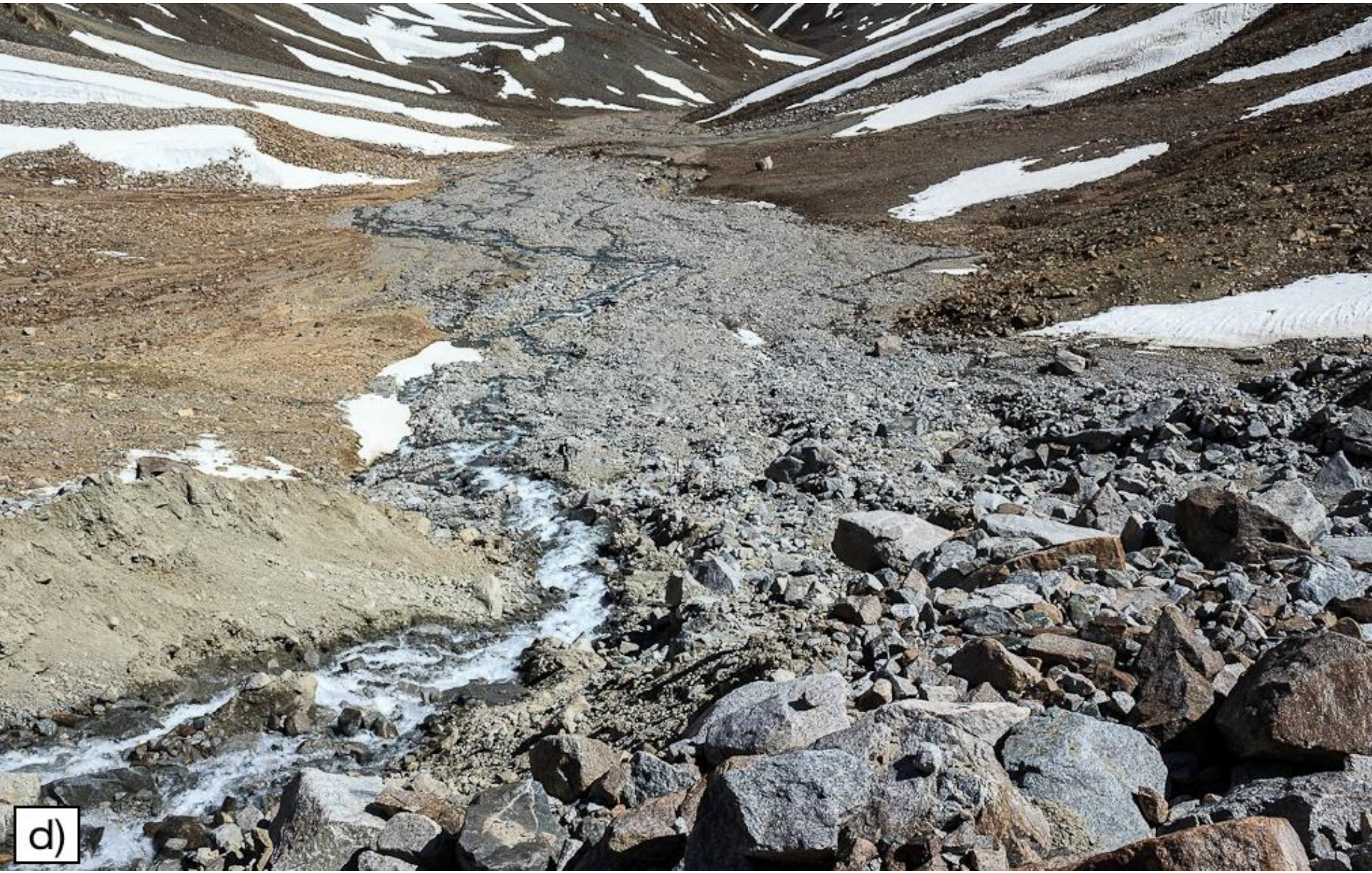


Fleitmann et al., 2007., Q. Sci Rev.

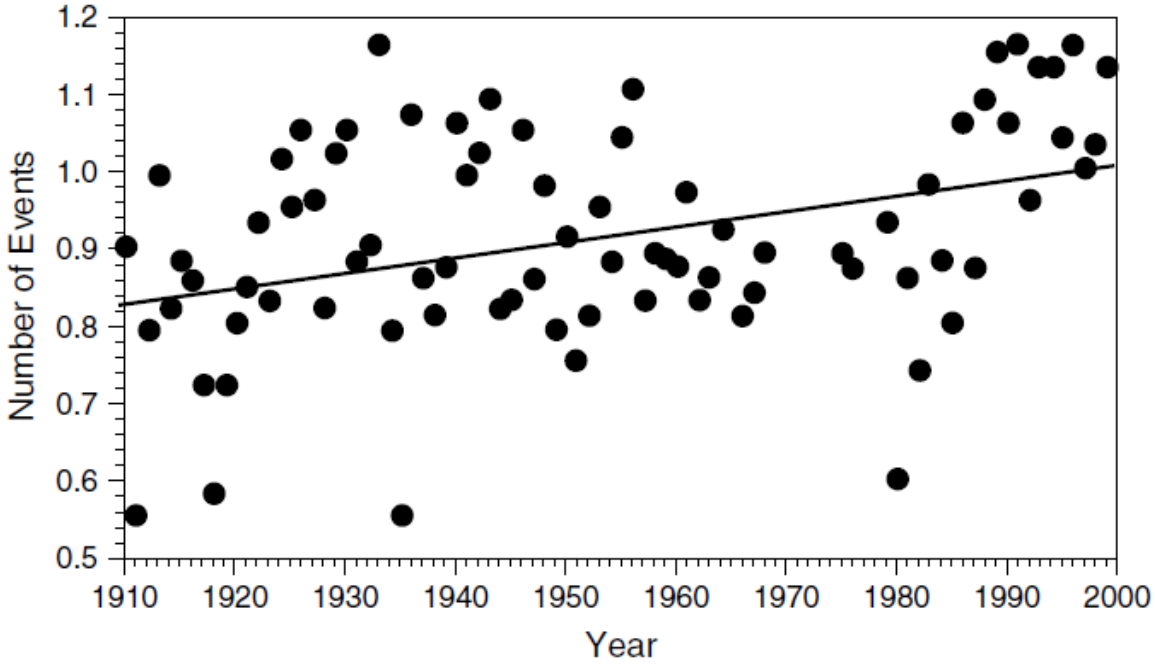
Unaffected valley above Ney (Basgo)

Debris flows from side valleys and widening and aggradation of main valley in Basgo

Measurements of debris flow size


d)

Increased numbers of precipitation events based on weather stations
(Roy and Balling, 2006, Int. Jour. Clim.)



BASGO 10Be samples:

BAS11		
BAS5		
BAS2		
B6S7	34.30627	77.33621
B6S12	34.25405	77.2935
B6S13	34.26511	77.29596
BASGO-02-BGS7	34.30627	77.33621
BASGO-04-BGS12	34.25405	77.2935
BASGO-05-BGS13	34.26511	77.29596