WCRP Climate Research Forum
Climate research priorities for the next decade

# Disasters in the Himalayas

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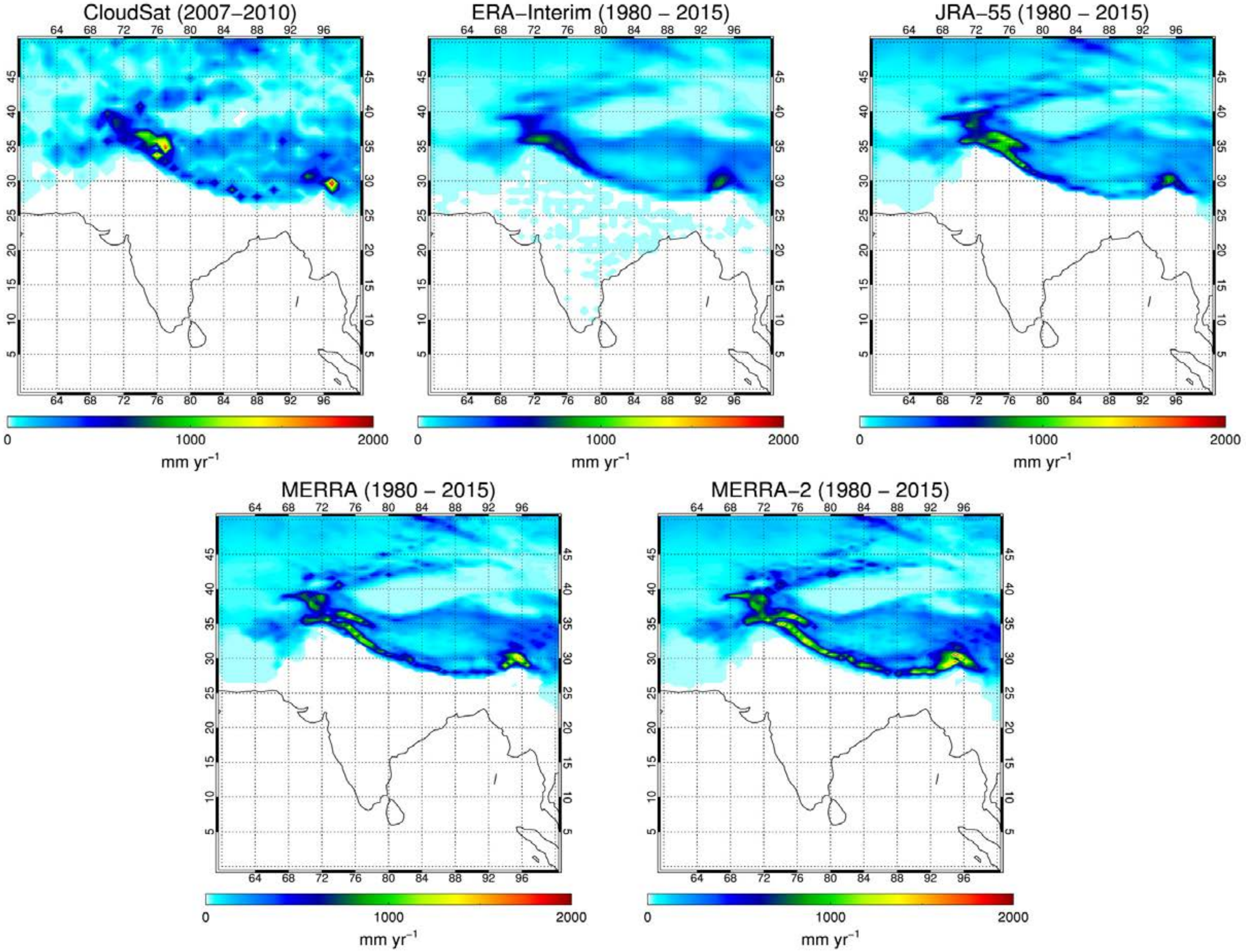
# Mountainous Hazards

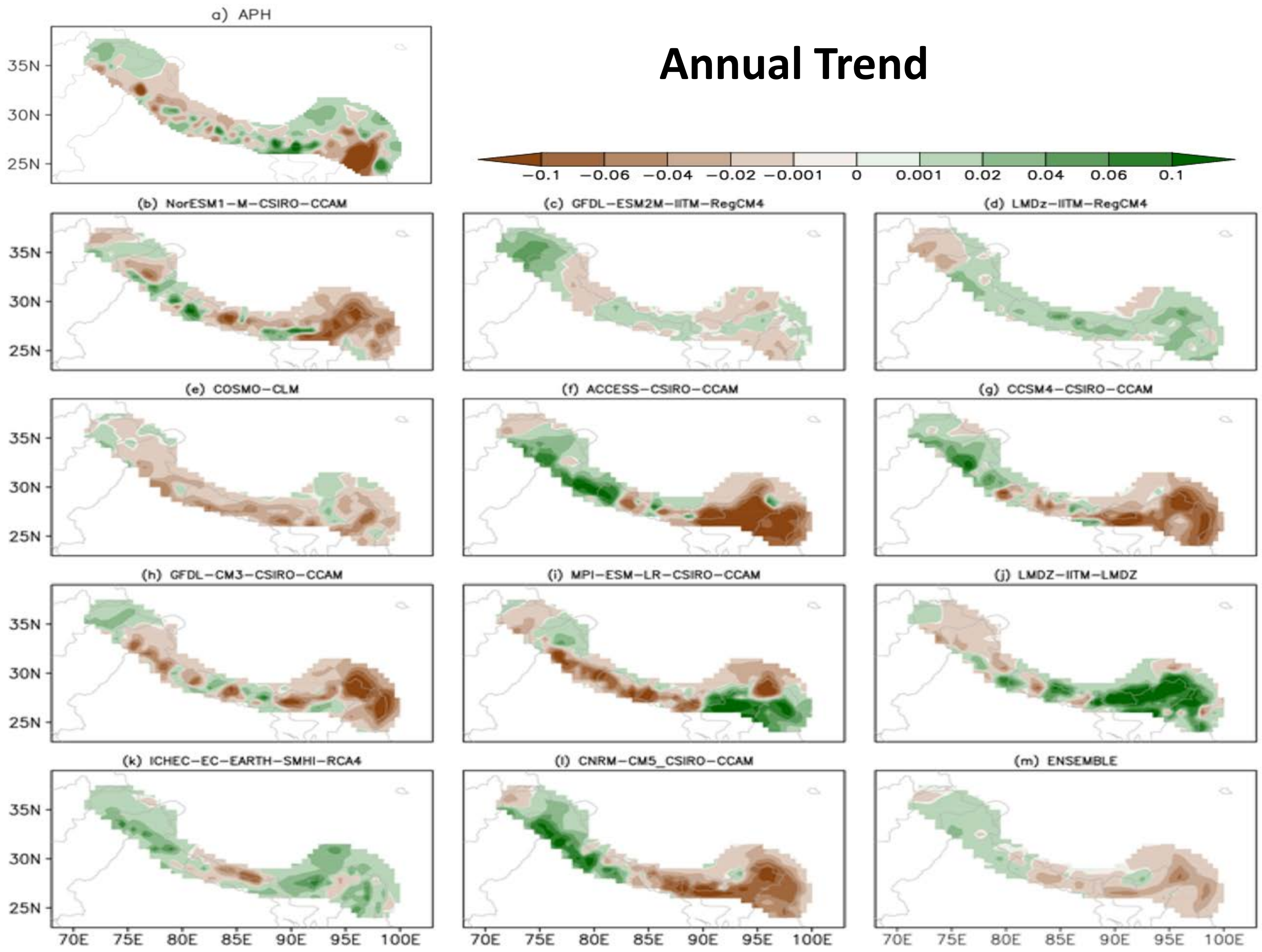
- Cloudbursts, landslides, mountain flash floods, avalanche, GLOF/LLOF, Forest fires, EQs……NEED OF MONITORING

- Energy driven systems: energy is released from shorter to longer time scale
- Complex integrated physical processes are intertwined for dynamical failure of these events
    - Cloudburst: are convectively triggered + Orographically locked systems
    - Landslides: dynamically slope failures + loose soil characterization + failure of anchorages
    - due to soil moisture saturation
    - Extreme precipitation leading to doubling of flash floods in the western mountainous rivers + adding more
    - Water discharges, in particular during spring melts
    - Urban flooding: floodplain settlements/habitation
    - GLOF: recession of glacier snout + melting leading to debris embankment forming locked water body
    - Forest fires: increased temp leading to drying of foliage: more forest count even as early as post winter

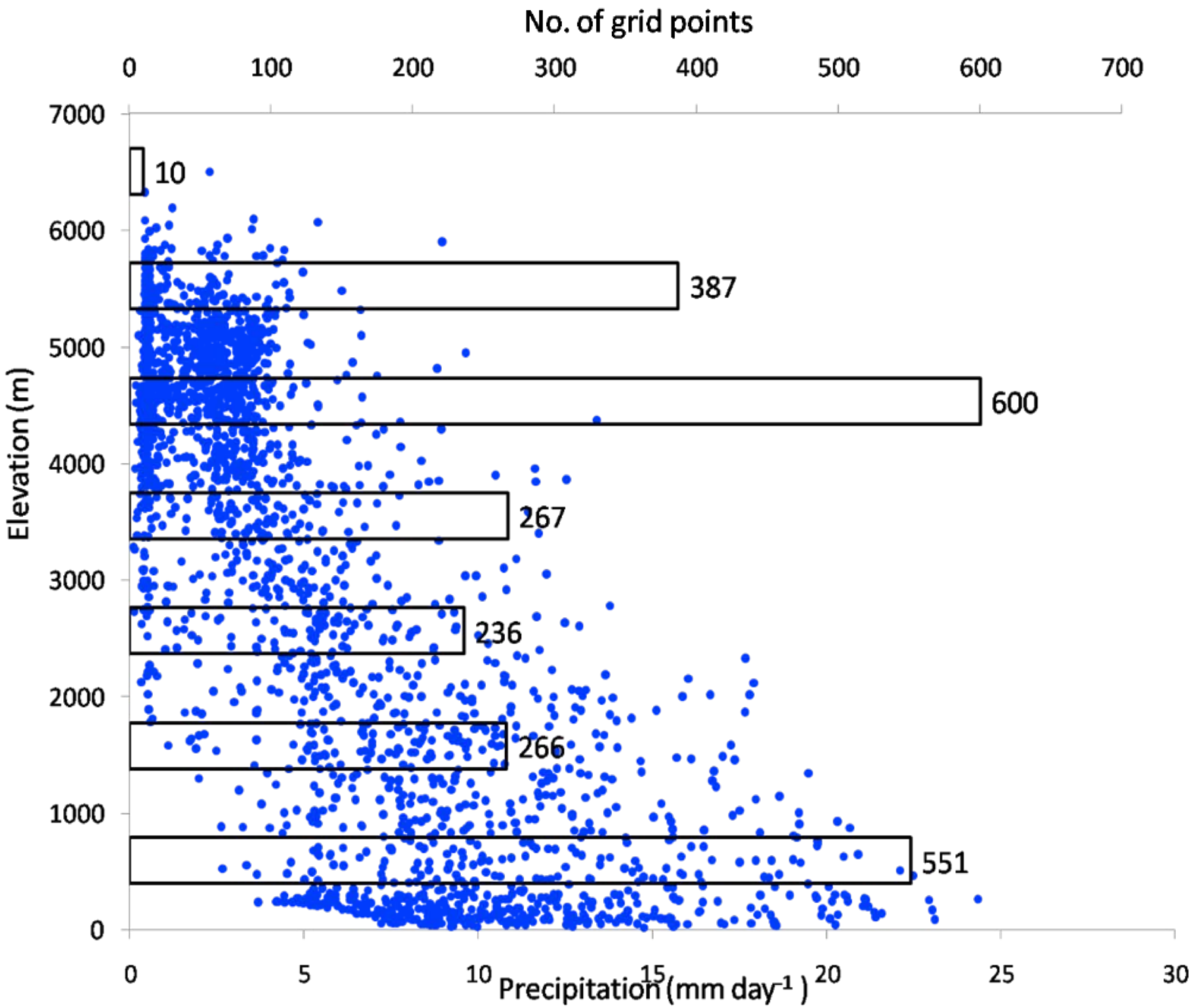



How much it snowfalls in the Himalayas (Daloz et al. 2019)

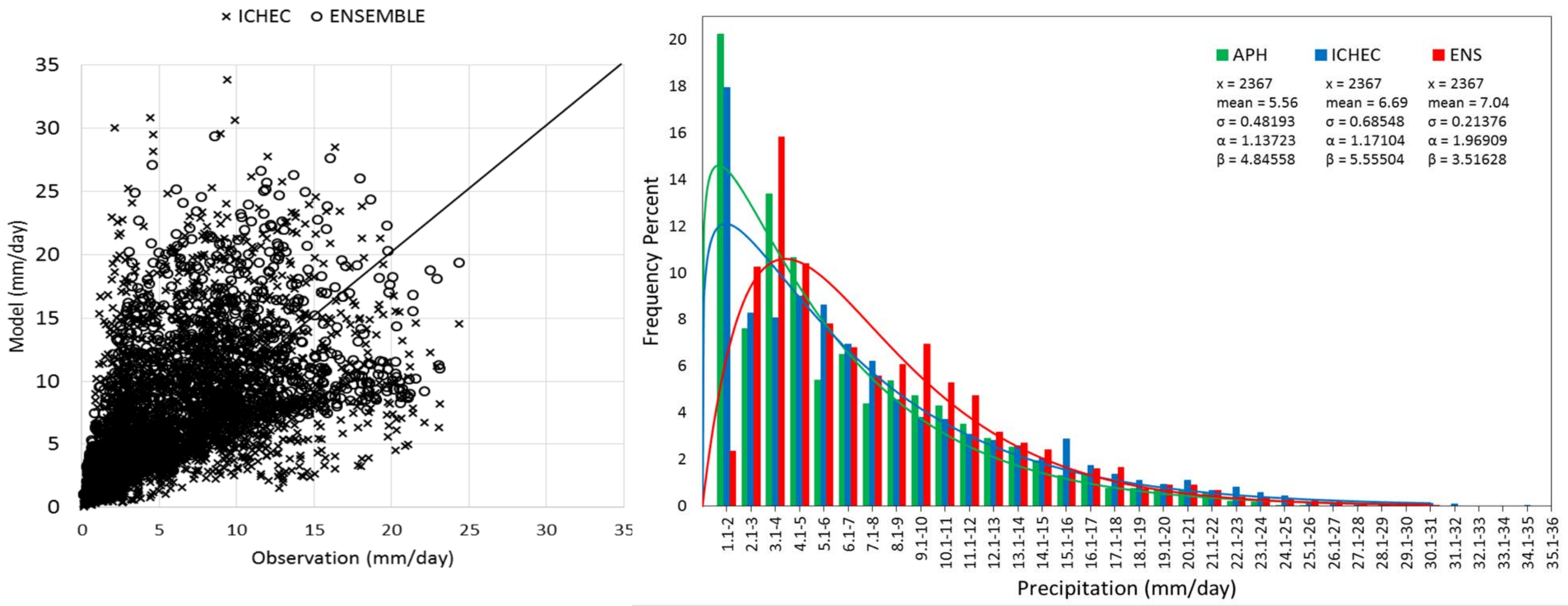
# Annual Trend



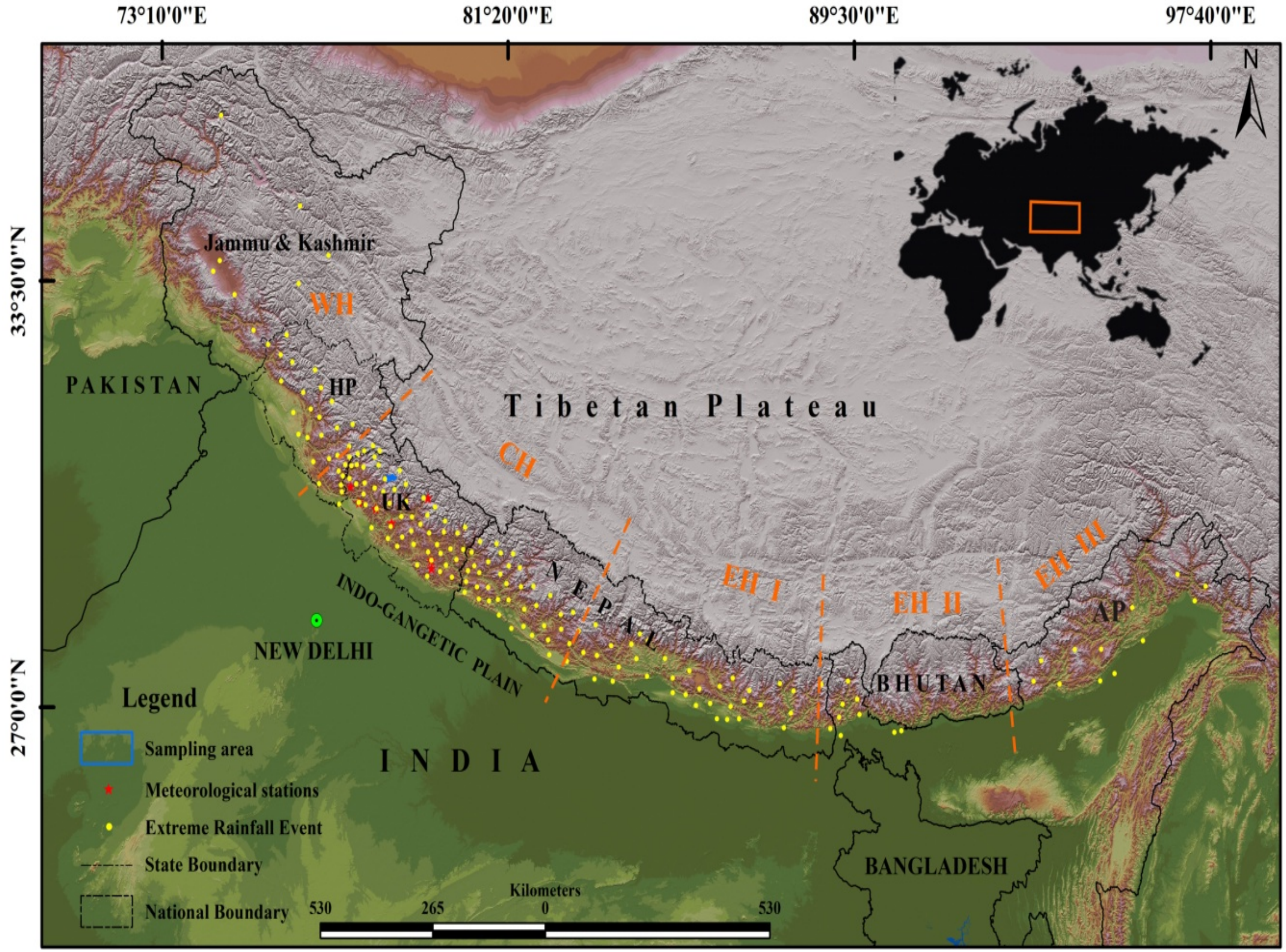

JJAS precipitation trend (mm/day/year). (Ghimire et al. (2018)




Variation in the observed precipitation (mm/day) with elevation

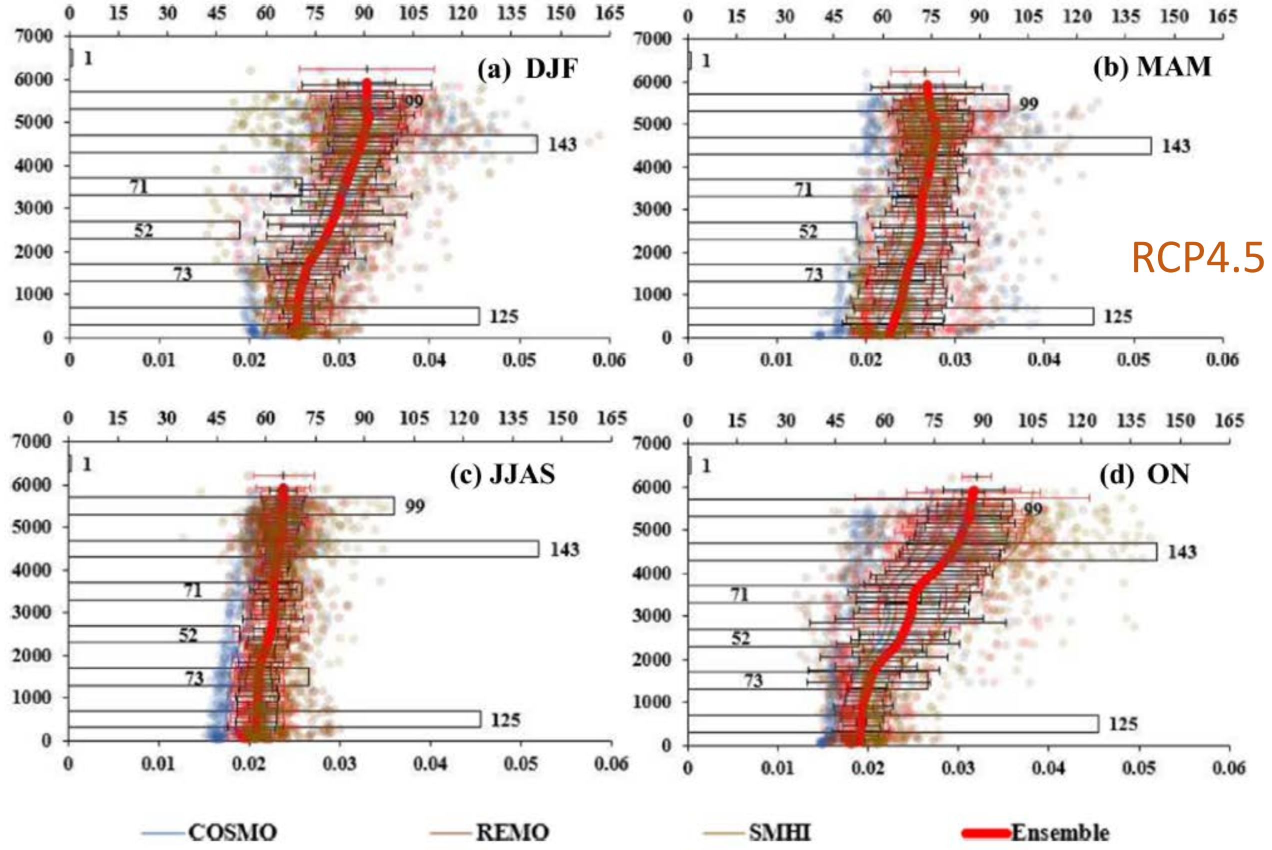



Scatter plot showing the scatter spread of the precipitation (mm/day) of the ICHEC and ensemble with reference to the observation probability distribution function showing percentage of precipitation data falling within a particular range (in bar) and normal distribution (in line).



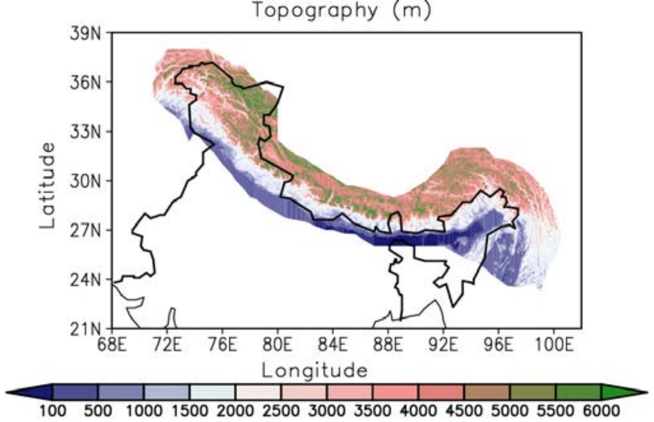

**Extreme rainfall events (EREs) in the Himalaya.** To explore facets of land-climate interactions in the Himalaya, it has been classified into three distinct regions: Western Himalaya (WH), Central Himalaya (CH) and Eastern Himalaya (EH; with sub-regions: EH I, EH II and EH III) (Table S2. The increasing trend in EREs in recent decades is most prominent in the valleys of the central Himalaya (CH). Yellow dots indicate geographical location of EREs since the 1800s (Table S1). Blue box denotes the sampling area for tree-ring cores and other geo-chronological proxies. Red dots indicate surface meteorological observatories.

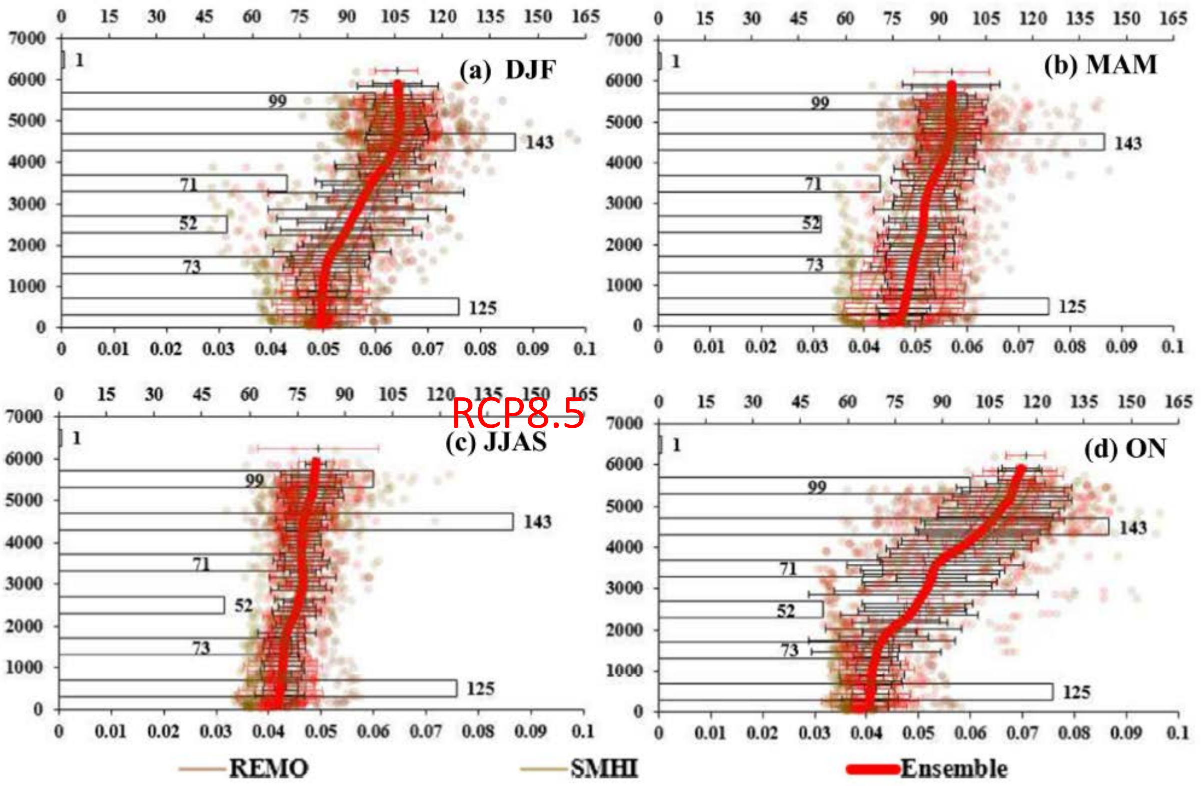
Singh et al. (2021)




RCP4.5

- Elevation dependent warming
- Differential response under different seasons (post monsoon/ winter)
- Mechanisms of warming different for seasons/ regions ??

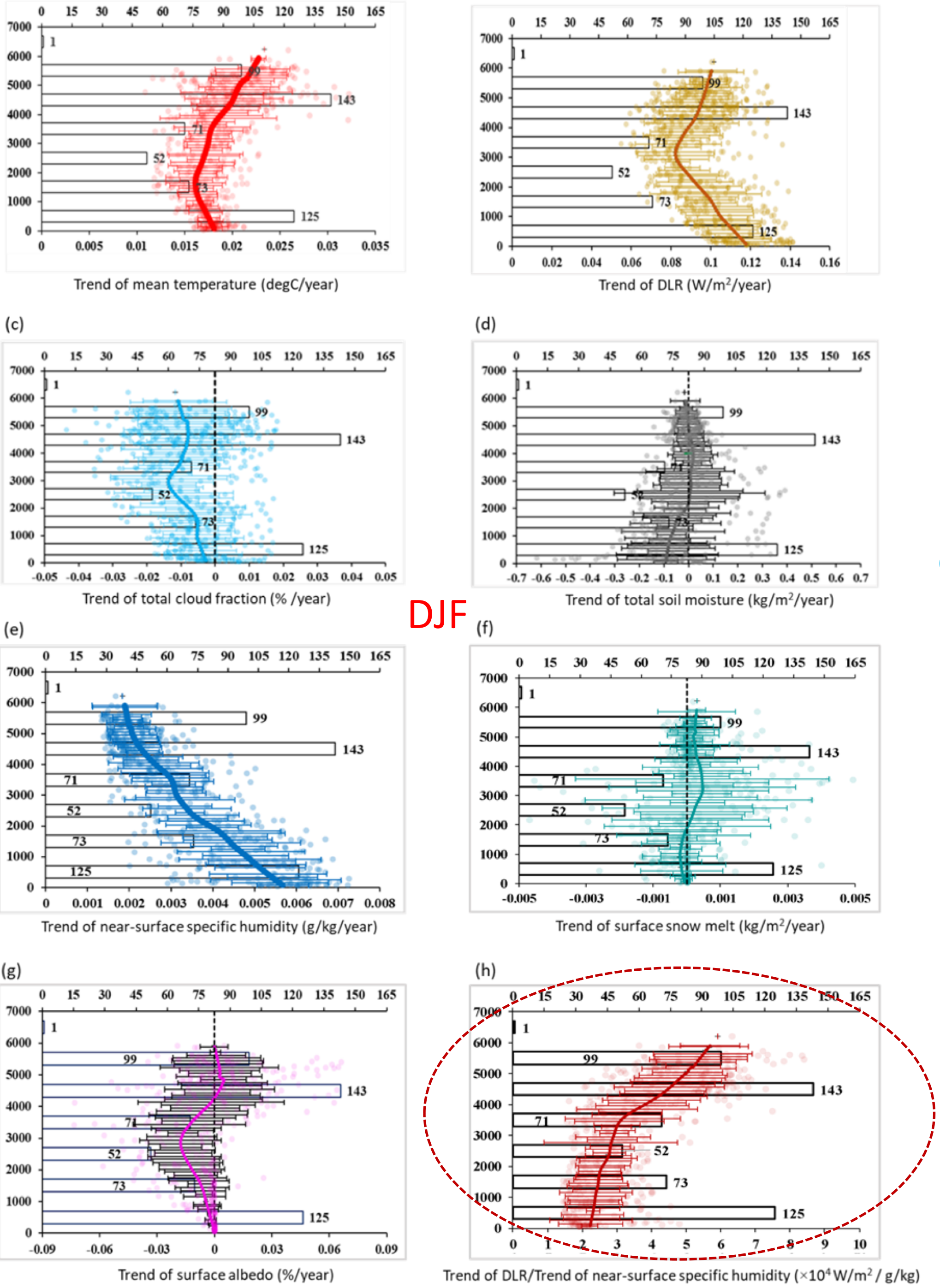



RCP8.5

Trends of the mean near surface air temperature (°C) for the period (1970-2099) including present (1970-2005) and future climate (2006-2100) under RCP4.5 scenarios at every grid point over the **Himalayan region** plotted against elevation. The scatter plot of trends from individual model experiments with ensembles (thick red line) under CORDEX-SA framework for (a) DJF, (b) MAM, (c) JJAS and (d) ON seasons have been shown as background dots; the curves in same color as their corresponding dots represent the mean in 100 m classes of altitude smoothed by LOWESS method (Clevland, 1979). The **error bar** in red shows the **spatial variability** within each 100m class while that in **black shows the intermodal variability** within the same class. The rectangular bars with numbers indicate the number of grid points falling within each 1000m altitude range.

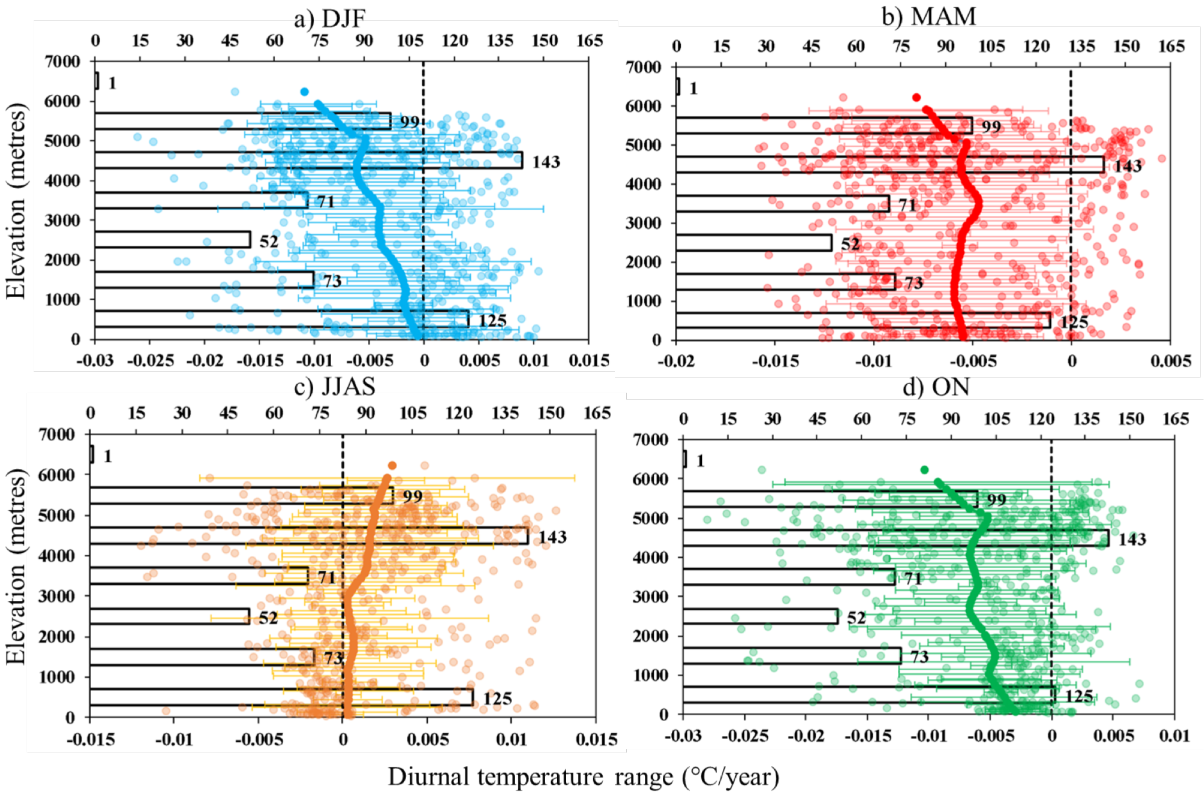
(Dimri et al. 2019)




1970-2100
RCP26

MPI-ESM-LR_REMO

Under CORDEX-South Asia experiments



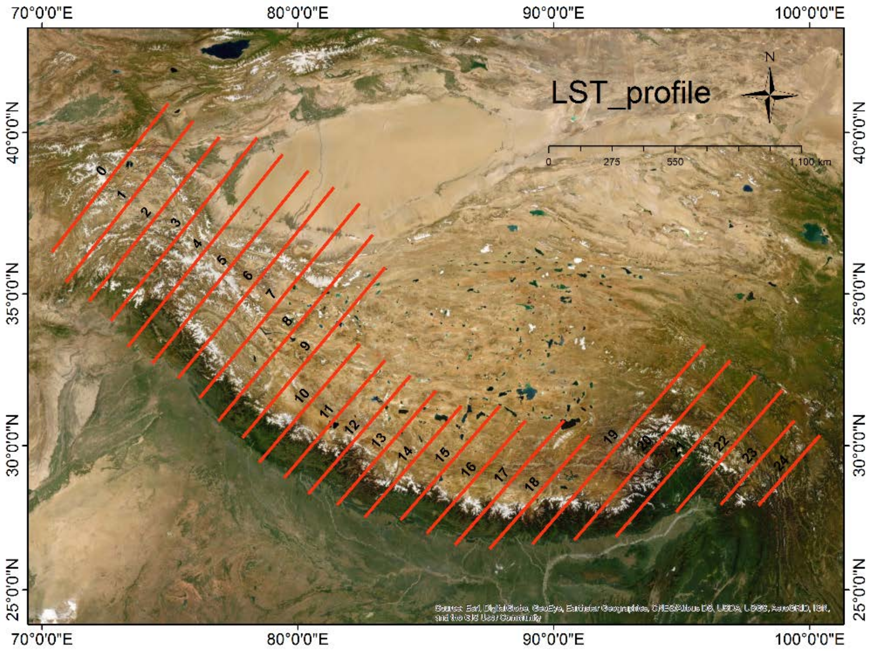

- Higher elevation: greater rate of warming during winter / post monsoon
- Downwelling longwave radiation (DLR) feedback
- Dominating trend of DLR @higher elevation as compared to specific humidity.
- Dependence of DLR on specific humidity with a threshold of 2.5 g kg−1 (Rangwala et al. 2009; Ruckstuhl et al. 2007; Naud et al. 2012).
- **Multi-model + scenario uncertainty in the mechanisms ??**

**(Dimri et al. 2021 (submitted))**

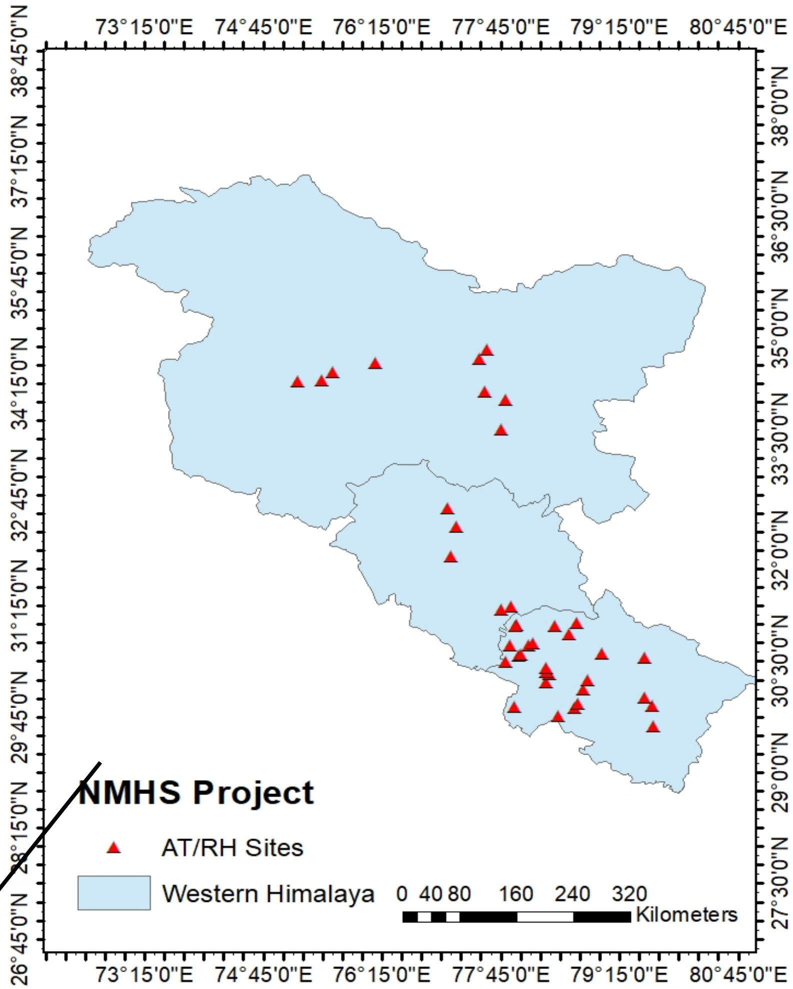
# Dynamics

## Topo-climatic regime Mapping & Characterization

**MODIS LST and TRMM Modified (Bookhagen & Burabank, 2010)**

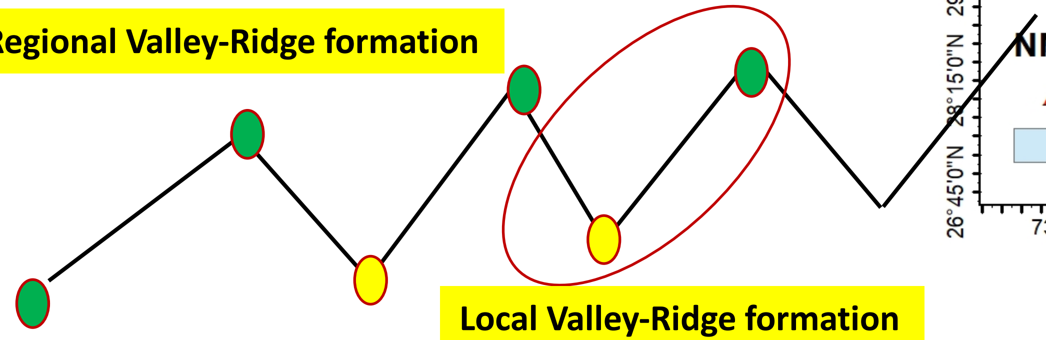



**Field Data of AT & RH)**




**Stand alone ; Vally-Ridge pairs**

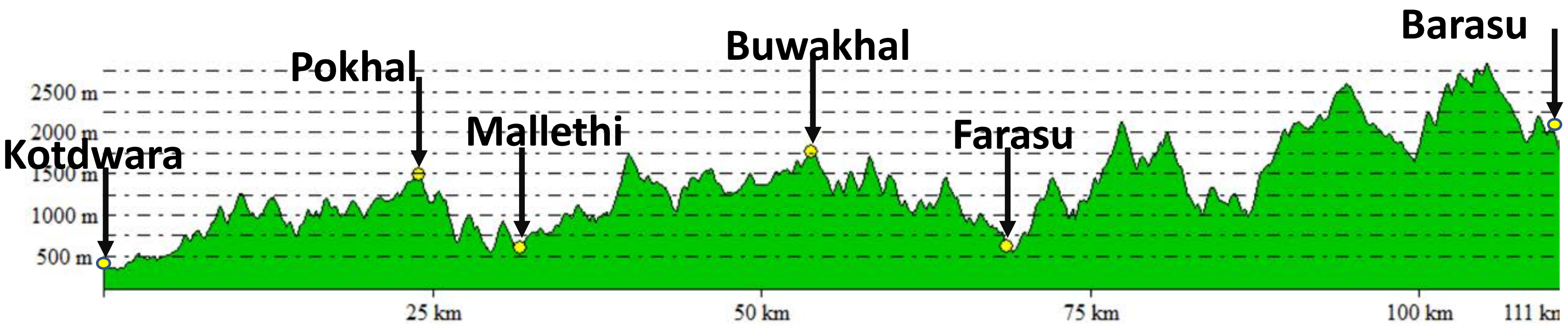
**Regional Valley-Ridge formation**



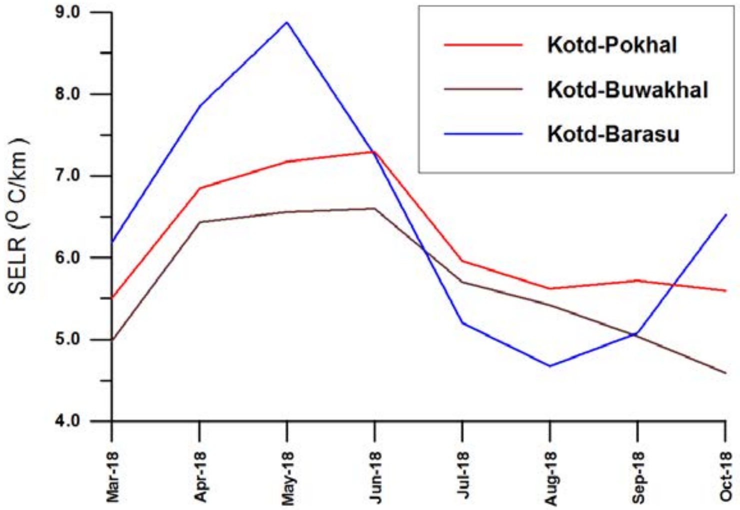
**Local Valley-Ridge formation**

**(Thayyen and Dimri, 2018)**

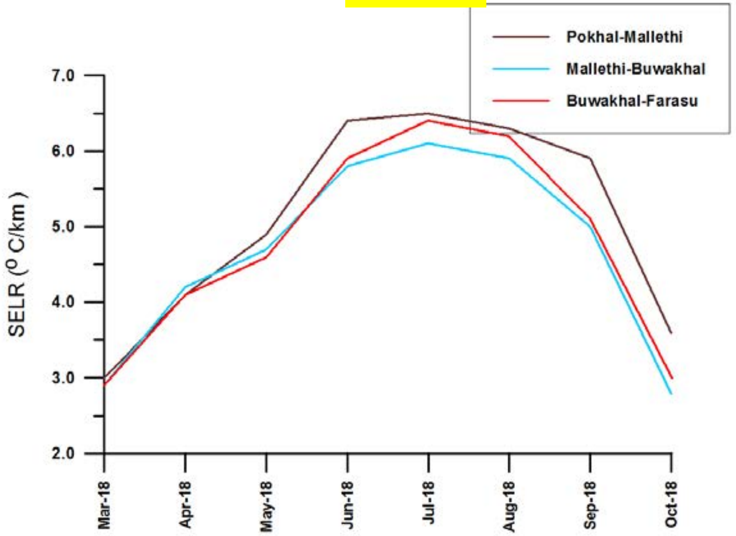
# Distinct local & Regional slope processes



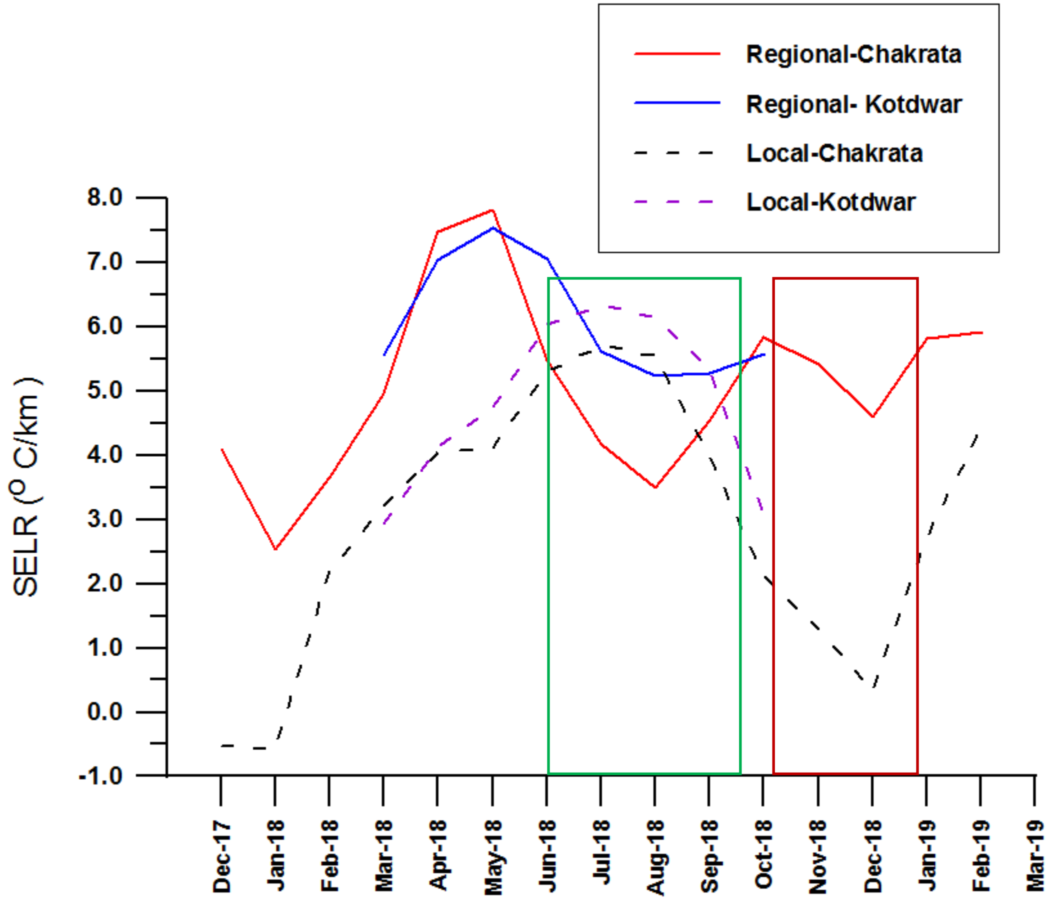

**Regional**




**Local**

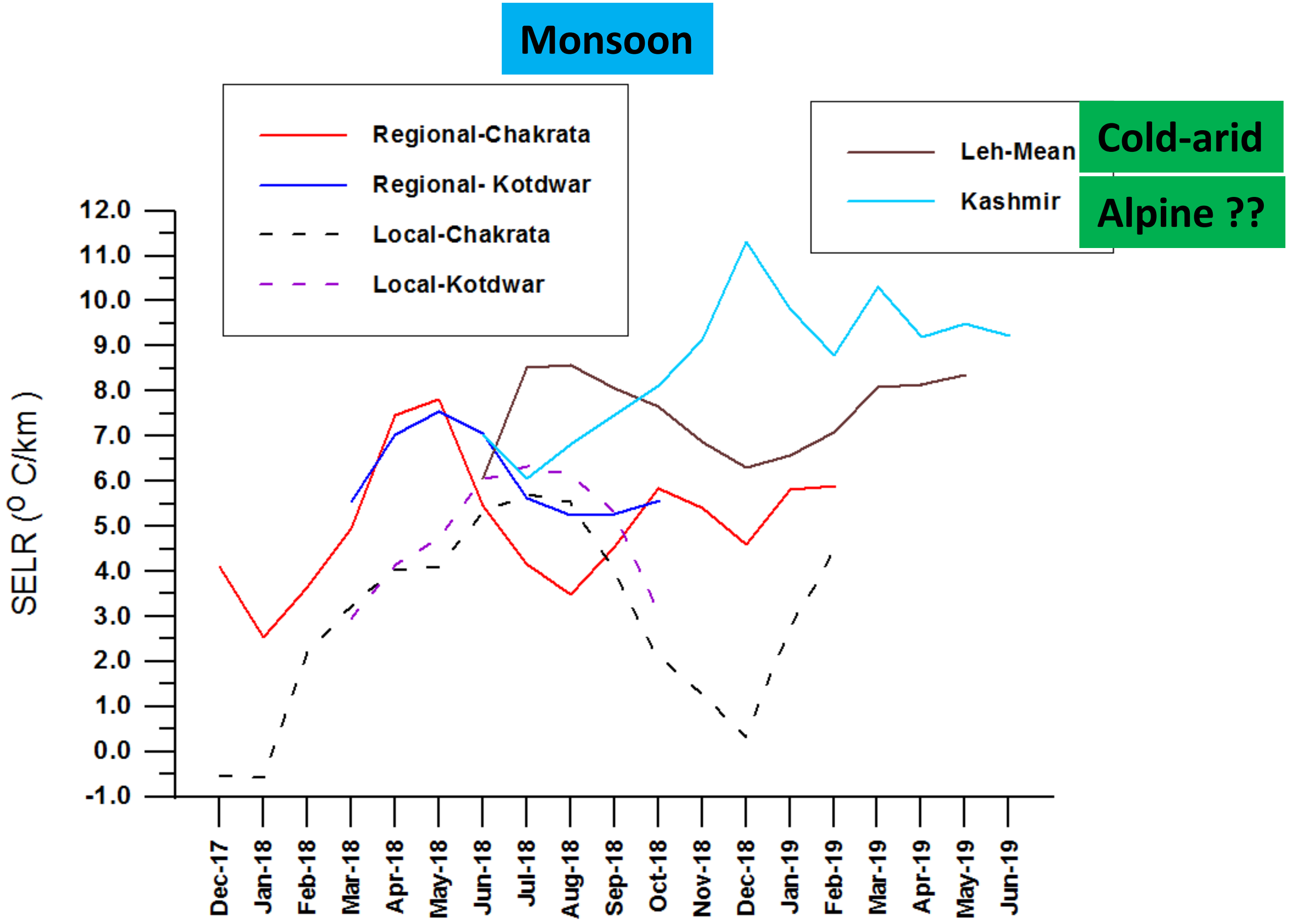


# Varying Regional and local response of SELR : Monsoon regime



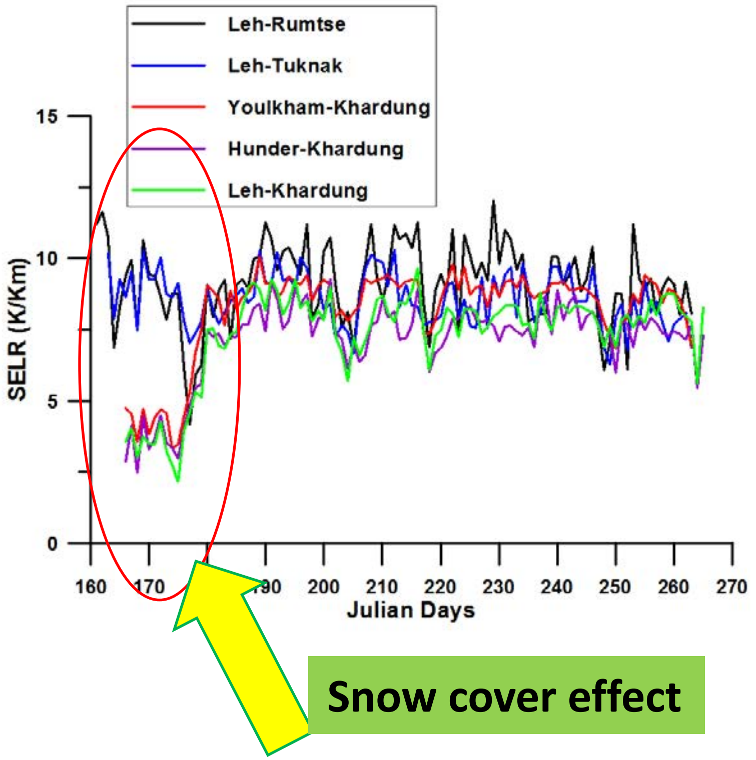

- Monsoon lowering is absent for local valley – ridge pairs
- Lower winter SELR of local valley –ridge pairs

# Summary : SELR of Western Himalayan Hydrologic Regimes

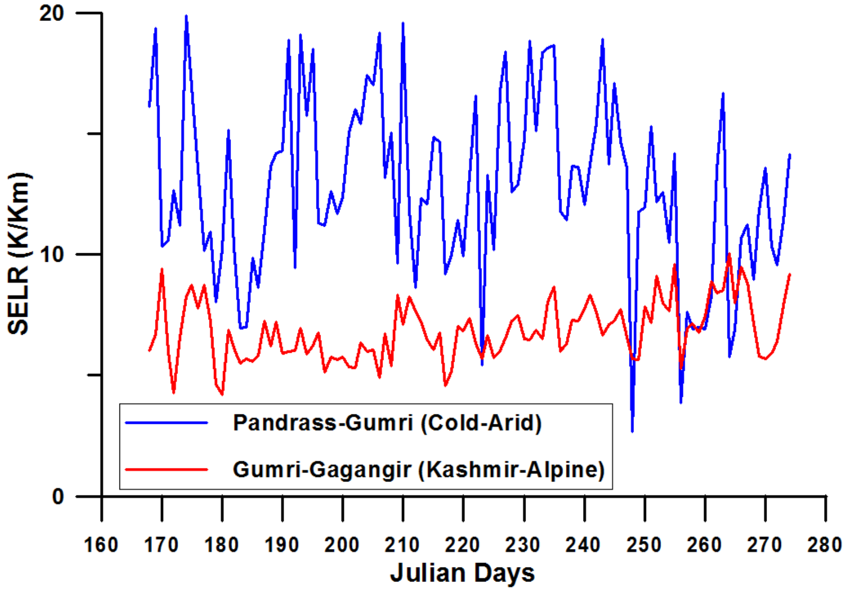


# Higher SELR of Leh-Nubra & Drass-Kashmir- Summer period

Cold-Arid region (Leh-Nubra region)

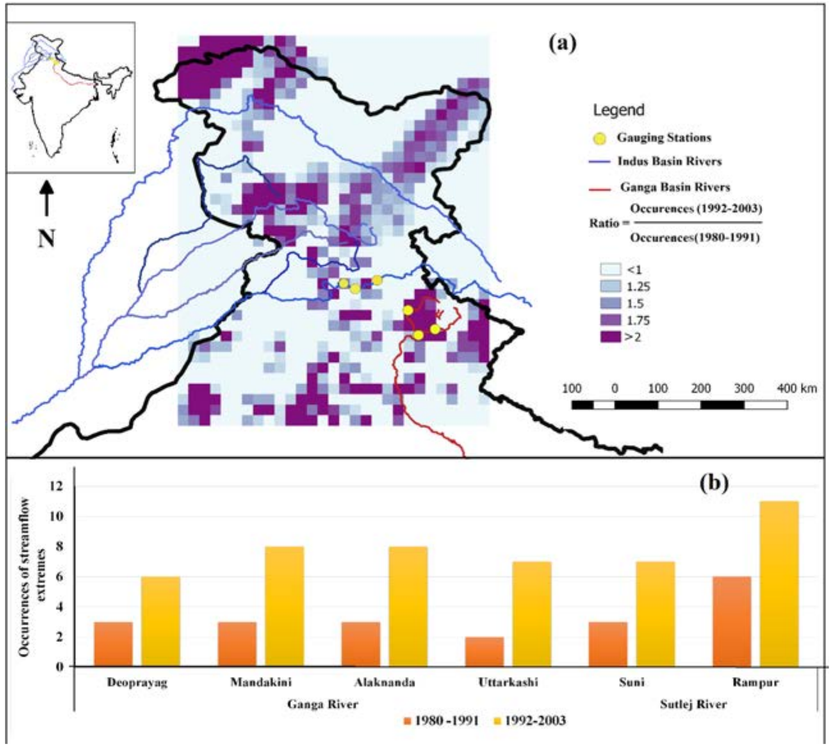



Drass Vs Kashmir

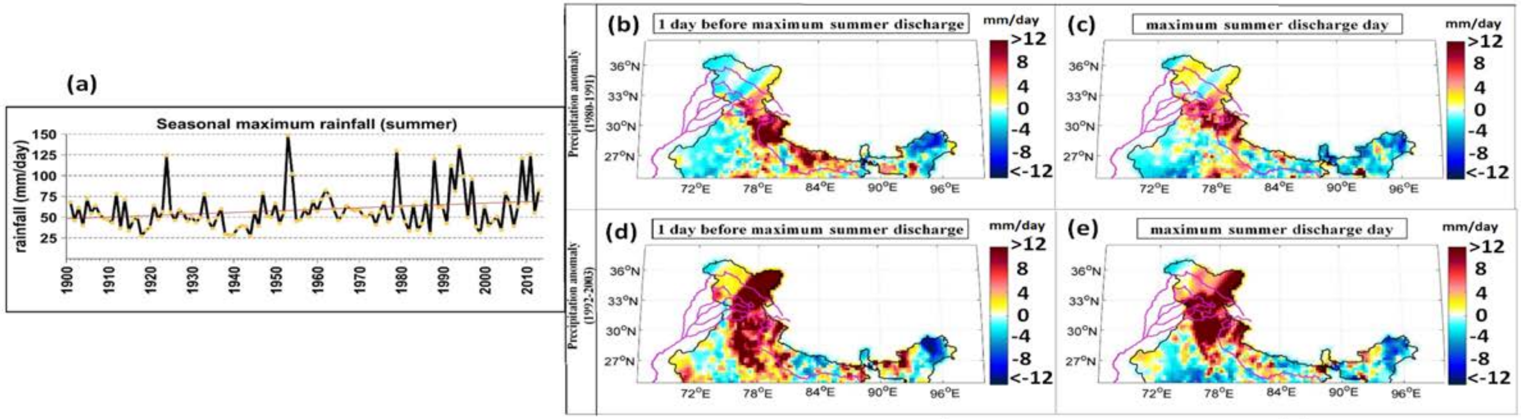


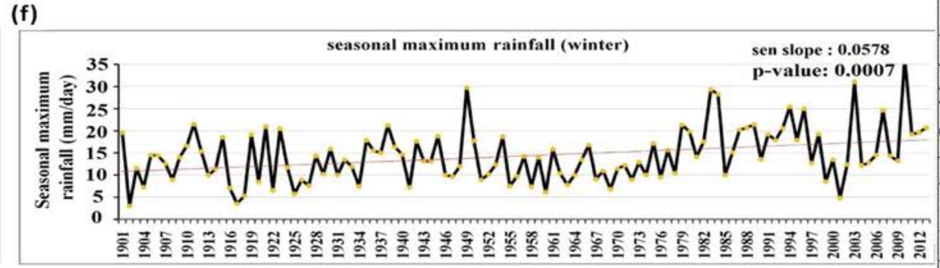
# Floods

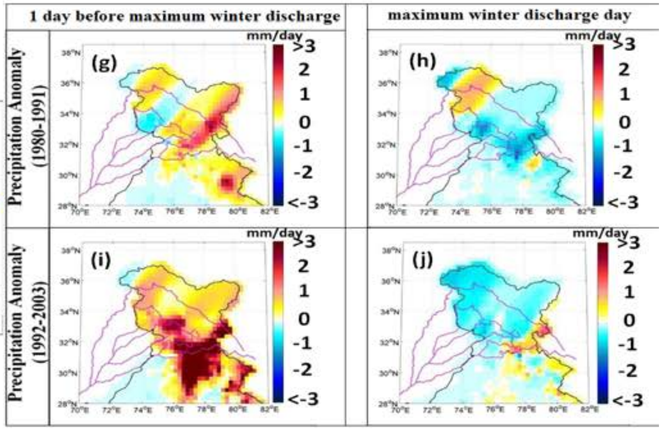
Occurrences of Extreme Flow: Doubled




Increase in Rainfall Extremes during both Summer and Winter

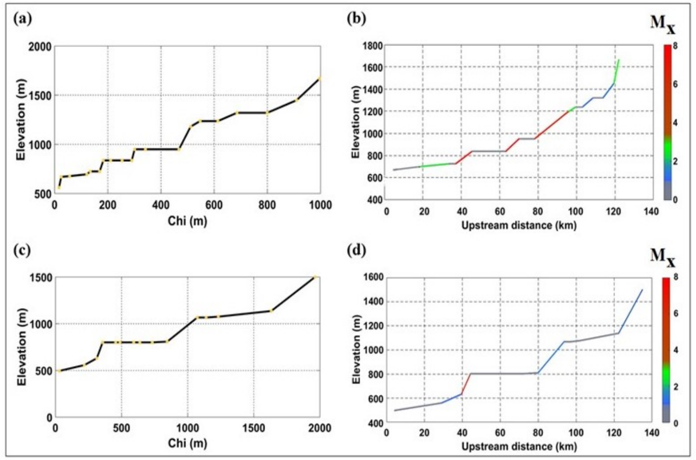



Role of Geomorphology: Chi Index

Sudden sharp changes in Chi Index results flash flood




Increased Extreme Flow in Western Himalayan River Basin (Ghosh et al. 2020)

(a)

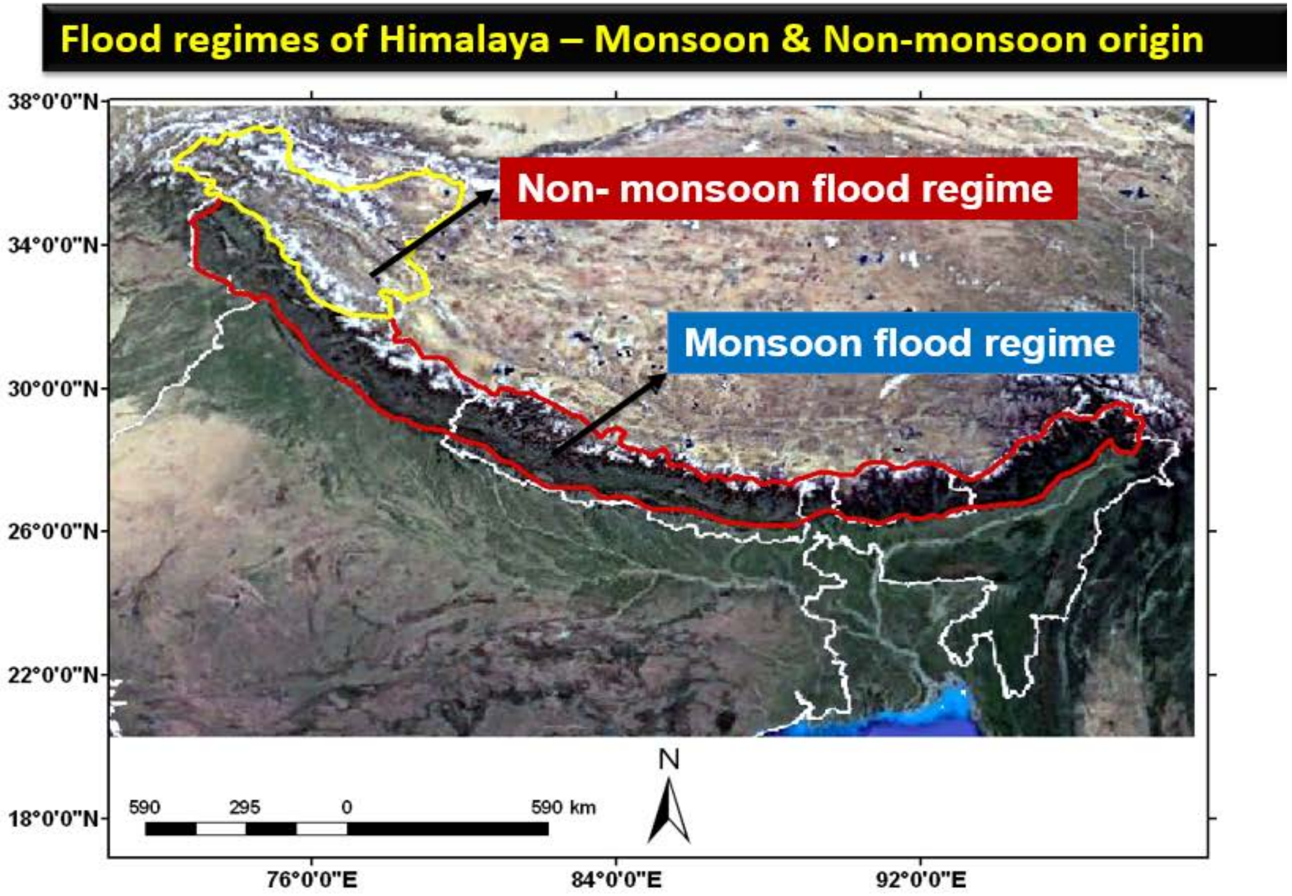
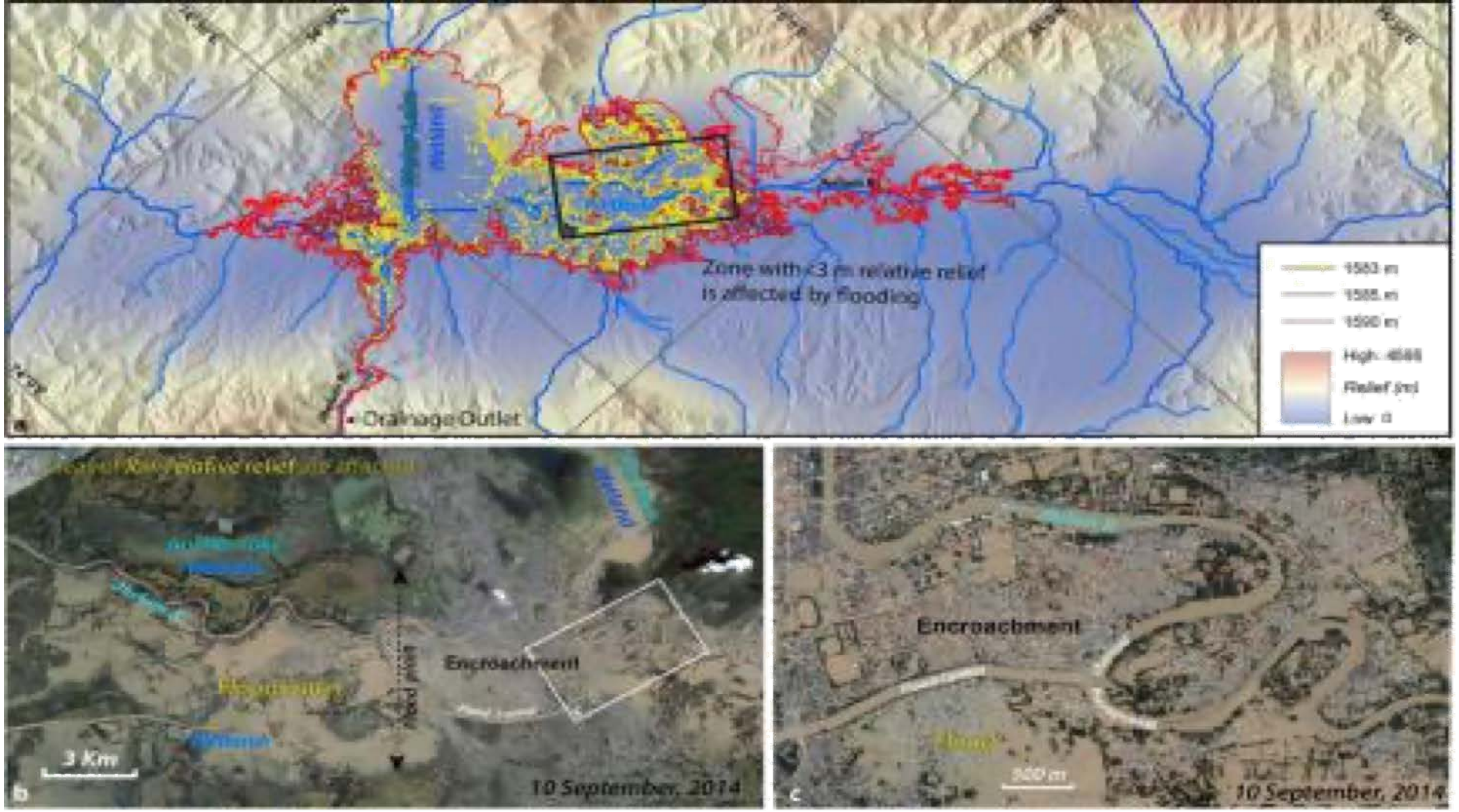
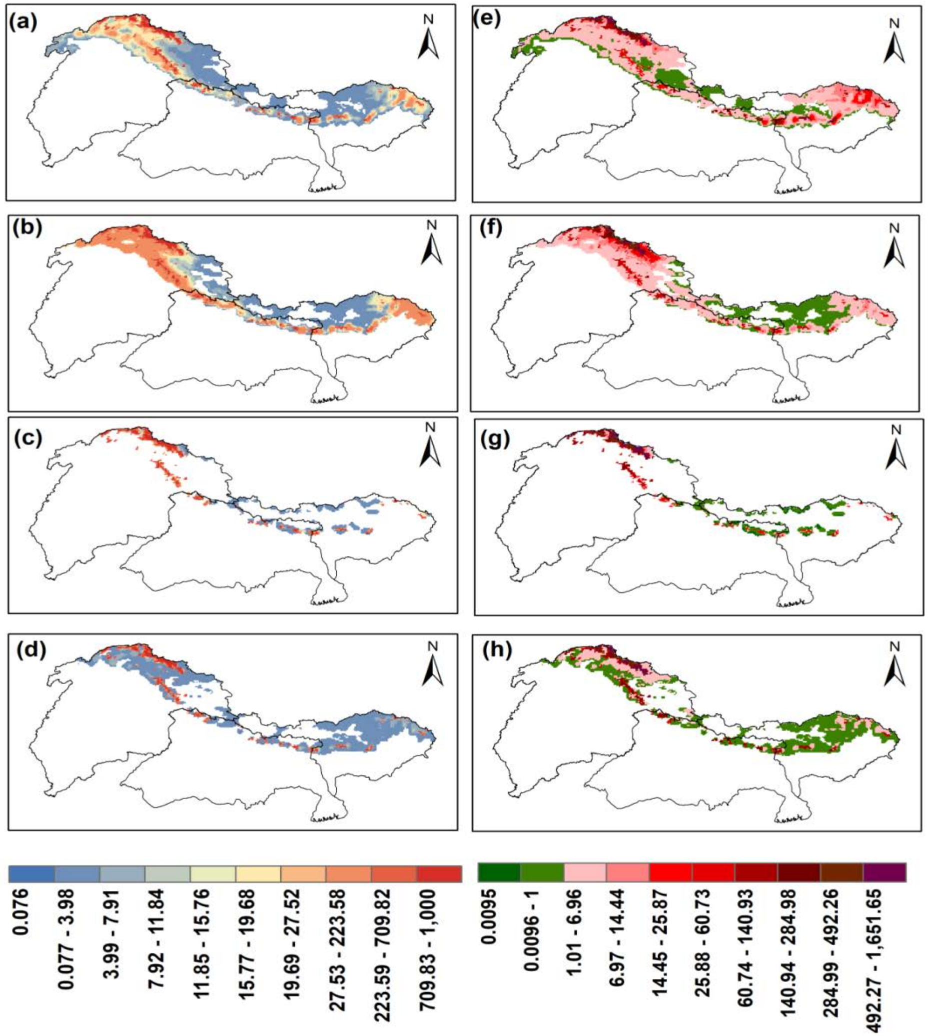




Fig. (a) Recent flood events in Himalayan rivers. Numbers correspond to events in Table 1. (b) Glacio-hydrological regime of the Himalayas, trans-Himalayan region.




The relief map of the Kashmir valley overlaid with the contours of 1583, 1585 and 1590 masl, which depict bulk of the valley axis inundated during flooding with ~3 m relief from base level of ~1583 m, (b) The google image of Kashmir flood on 10th September 2014 showing inundation of low lying areas within 1585 m contour and the region is undergoing rapid infrastructural growth encroaching the floodplain, (c) The meandering Jhelum river clearly depict a mature stage of river, which is encroached by residential growth including the flood canal. (Ray et al. 2019)

# MEAN SWE AND MEAN Ratio of SWE to Precipitation



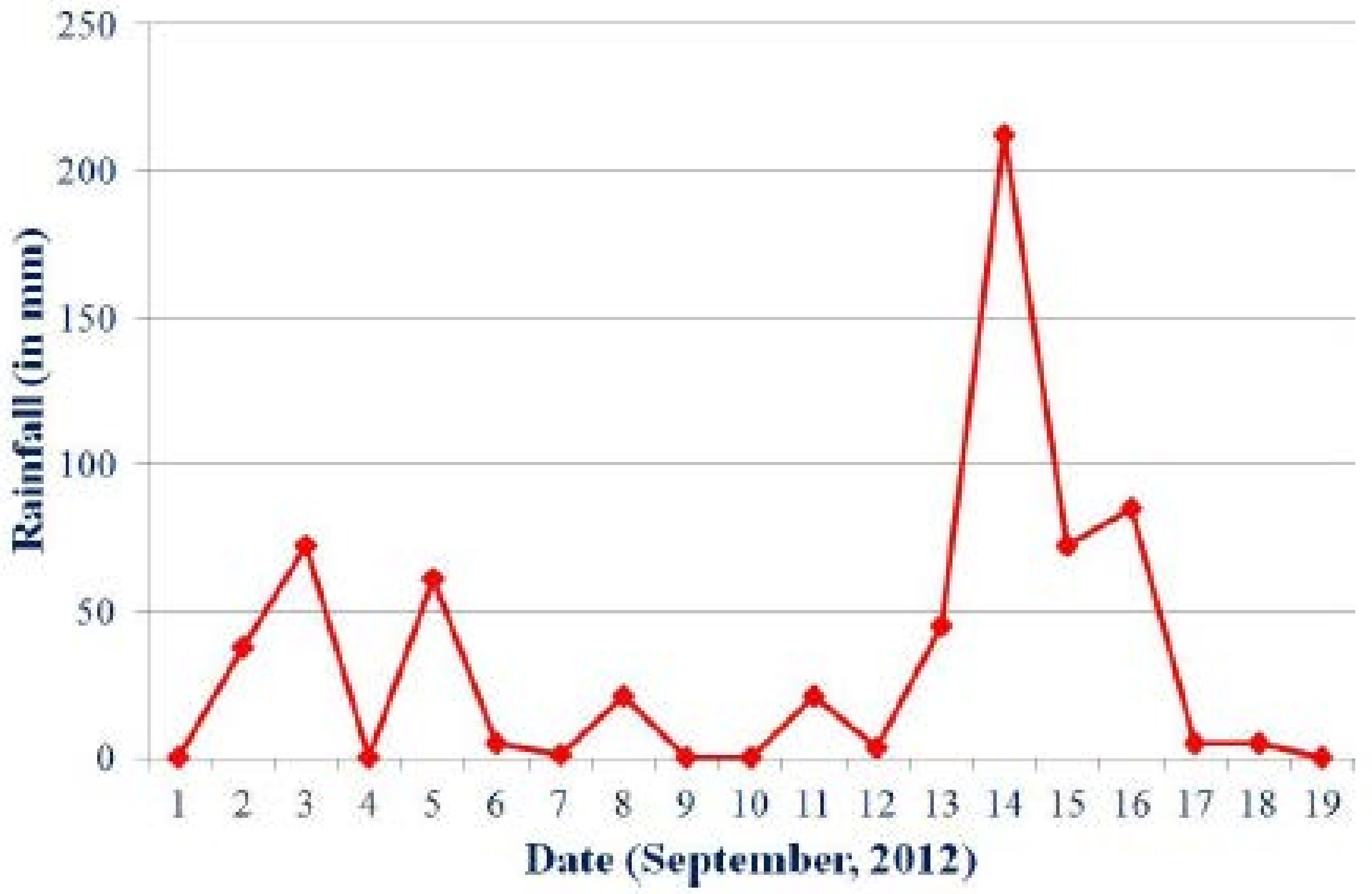

Left panel describe Mean Snow water equivalent(in cm) during(a)winter (b)pre-monsoon (c)monsoon and (d)post-monsoon. Right panel describe Mean of SWE to the mean of precipitation (in cm) storage during (e)winter (f)pre-monsoon (g)monsoon and (h)post-monsoon

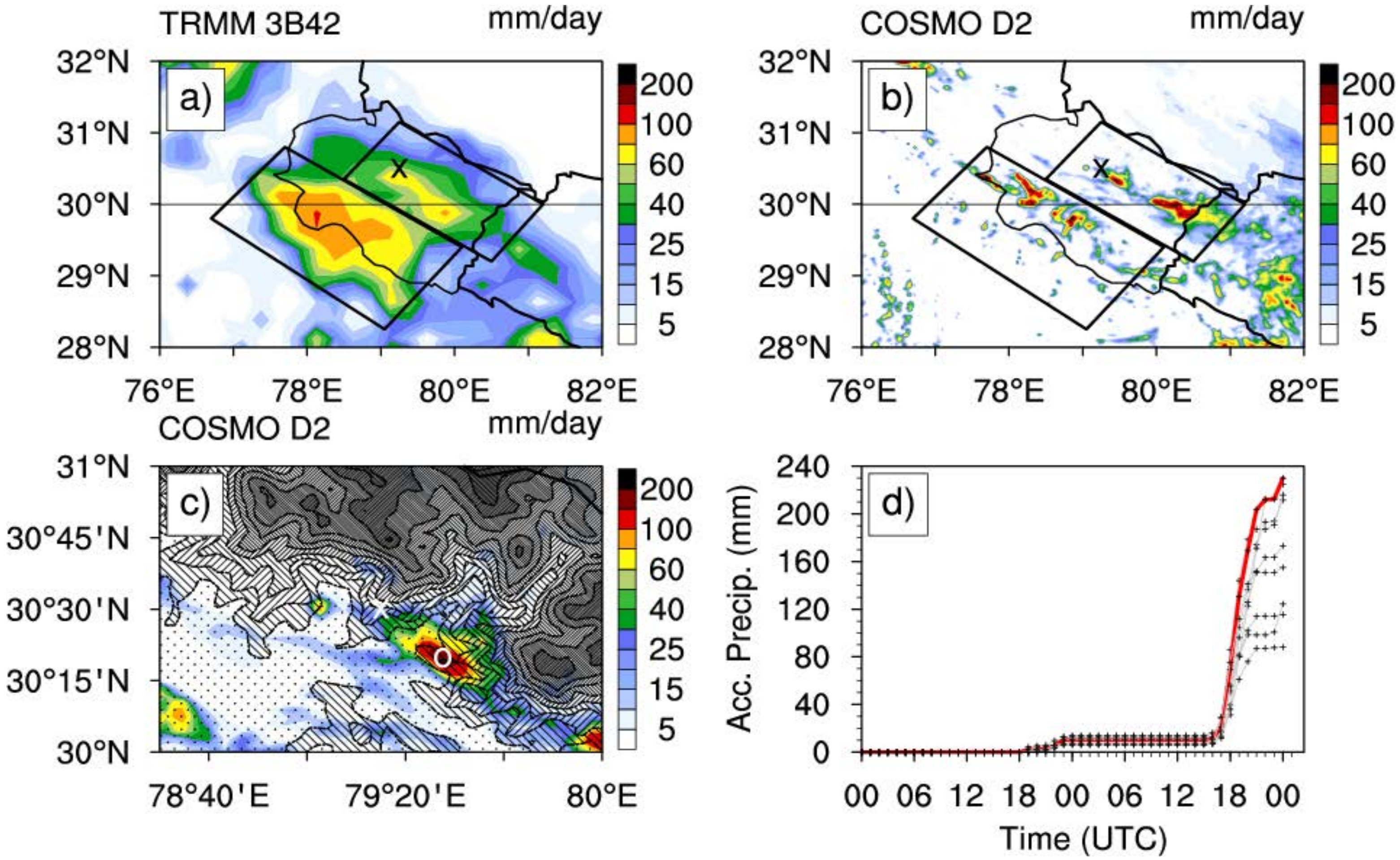
- Study of glacier mass change is often carried out on individual glaciers and hardly provide tangible input to the linkages between the glacier change and downstream hydrology (Thayyen and Gergan, 2010).
- Value more than 1 indicate SWE is more than that of precipitation.
- Ratio of SWE to precipitation is used as evidence to support effect of climate change.
- Maximum area is dominating from the value greater than 1 flashing that SWE is that area is maximum at that upper Himalaya.
- Decrease in water availability in rivers over medium to long term might be a response of shrinking of glaciers due to rise in temperatures (Bolch et al., 2012).
- Snow precipitation is shifting towards wet precipitation due to increasing temperatures.

(in preparation)

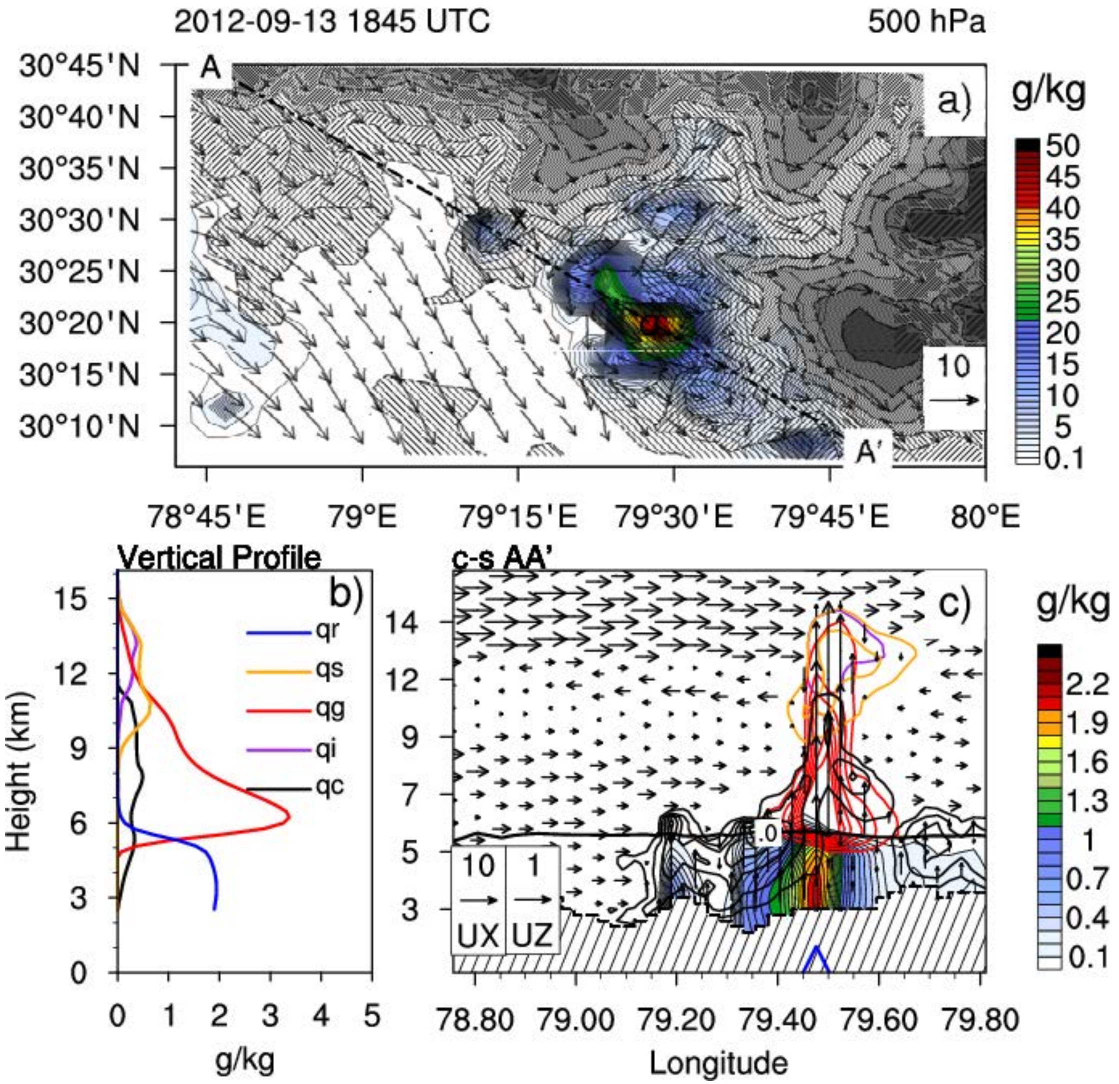
# Cloudbursts

- **13-14 Sep 2012 at Ukhimath in Central Himalayas: Storm diagnostics**





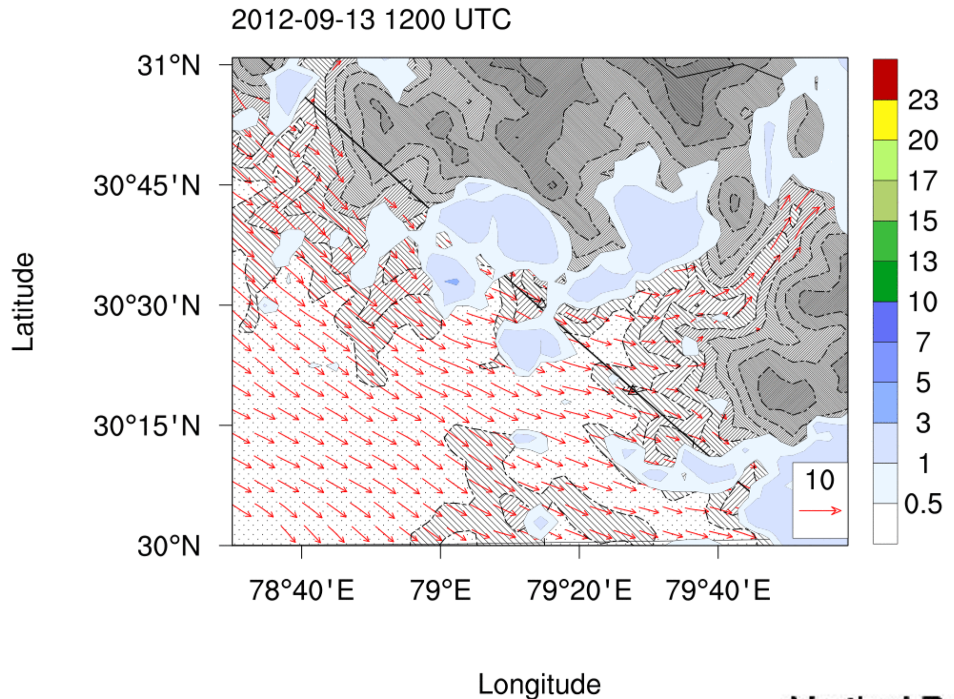

**a)** Daily accumulated precipitation on 13 Sept. 2012 from TRMM 3B42 data **b)** Daily accumulated precipitation on 13 September 2012 simulated using COSMO (D2 domain). The two bands of precipitation are outlined, along with the borders of Uttarkhand state. **c)** Zoomed modeled accumulated precipitation with the local topography at the resolution of D2 domain (2.8km) The topography contour interval is 500m from 2000 to 6000 m elevation. **d)** Time-series of accumulated precipitation at location marked "o" and the surrounding grid cells, starting from 12 Sep. 2012. The precipitation accumulation for spatial plot is from 0000 UTC to 2330 UTC. (Shrestha et ai. 2017)

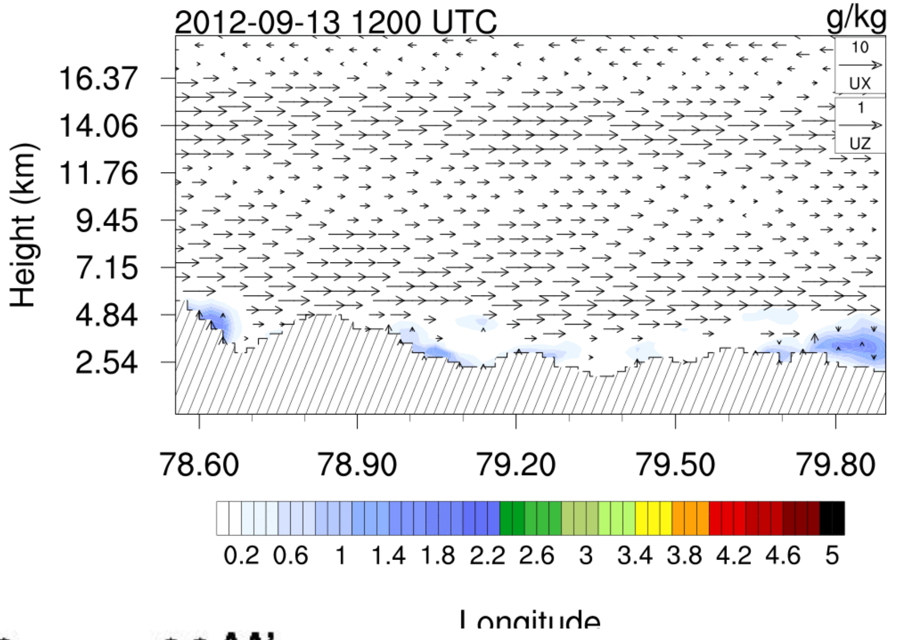



**a)** Simulated variables for D2 domain on 13 Sep 1845 UTC: Vertically integrated rainwater mixing ratio (g/kg, color shading) and wind vectors (m/s) at 500 hPa. The "x" and "o" mark represents the Ukhimath town and the location of maximum precipitation respectively. **b)** Averaged vertical profile of hydrometeors at precipitation maximum , along the c-s AA'. **c)** Cross-section AA' of hydrometeors (qr in color shading, qc, qi, qg, qs in solid line from 0.2 to 2.4 g/kg at interval of 0.4 g/kg), wind vectors and temperature (black contour, showing melting level), along the c-s AA'.

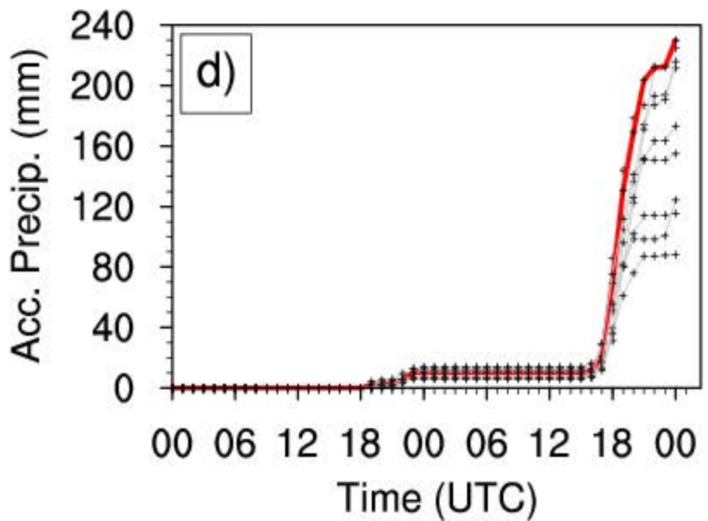
# Research Highlights

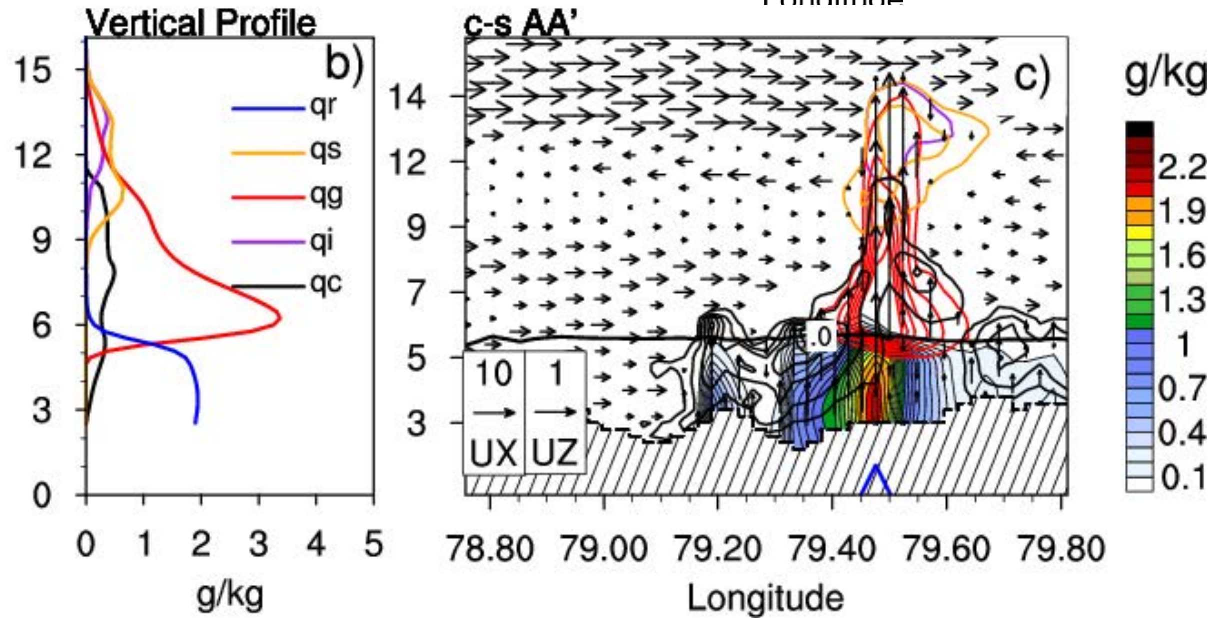
## Cloudburst in the Central Himalayas during 13-14 September 2012



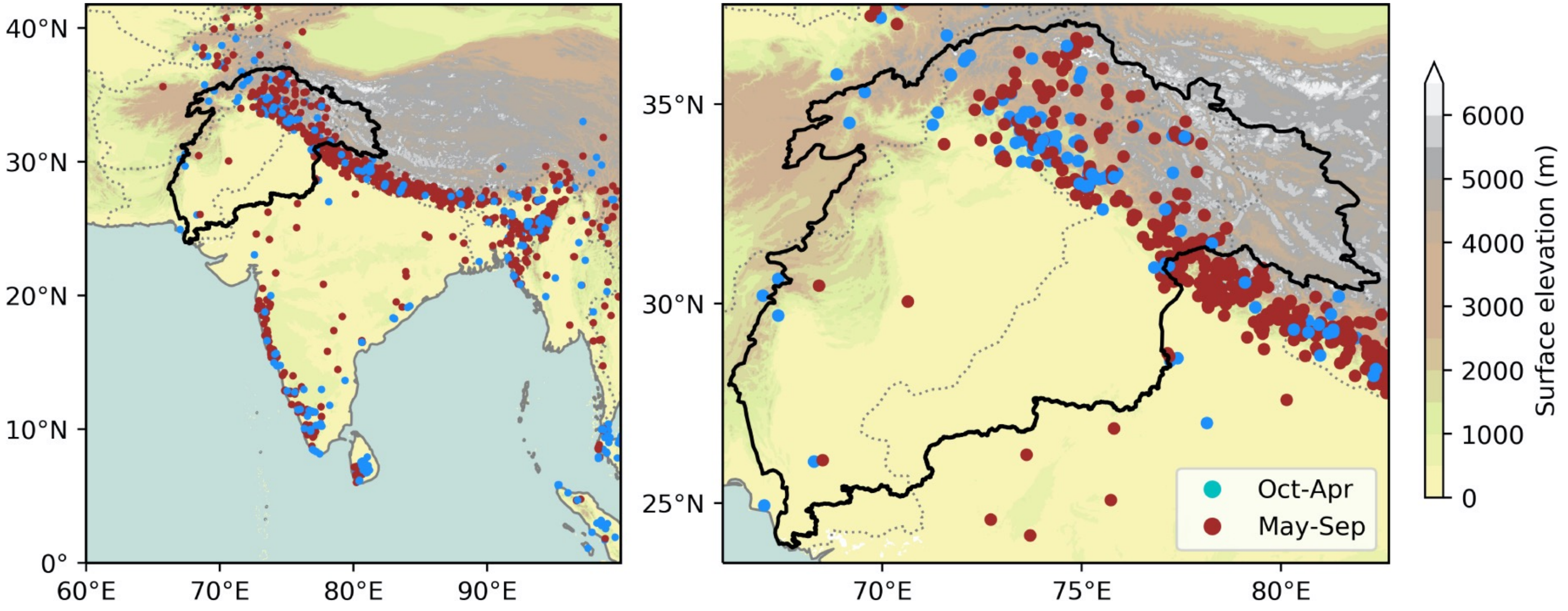




600 hPa wind vectors and sum

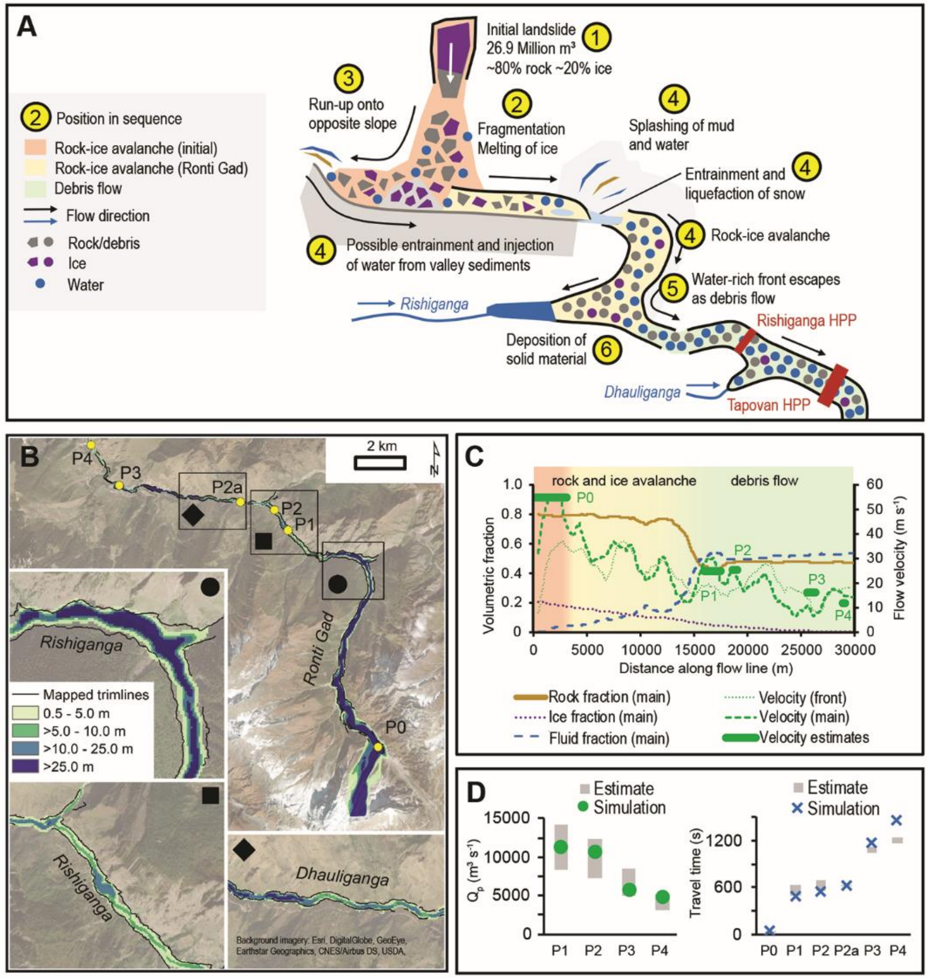


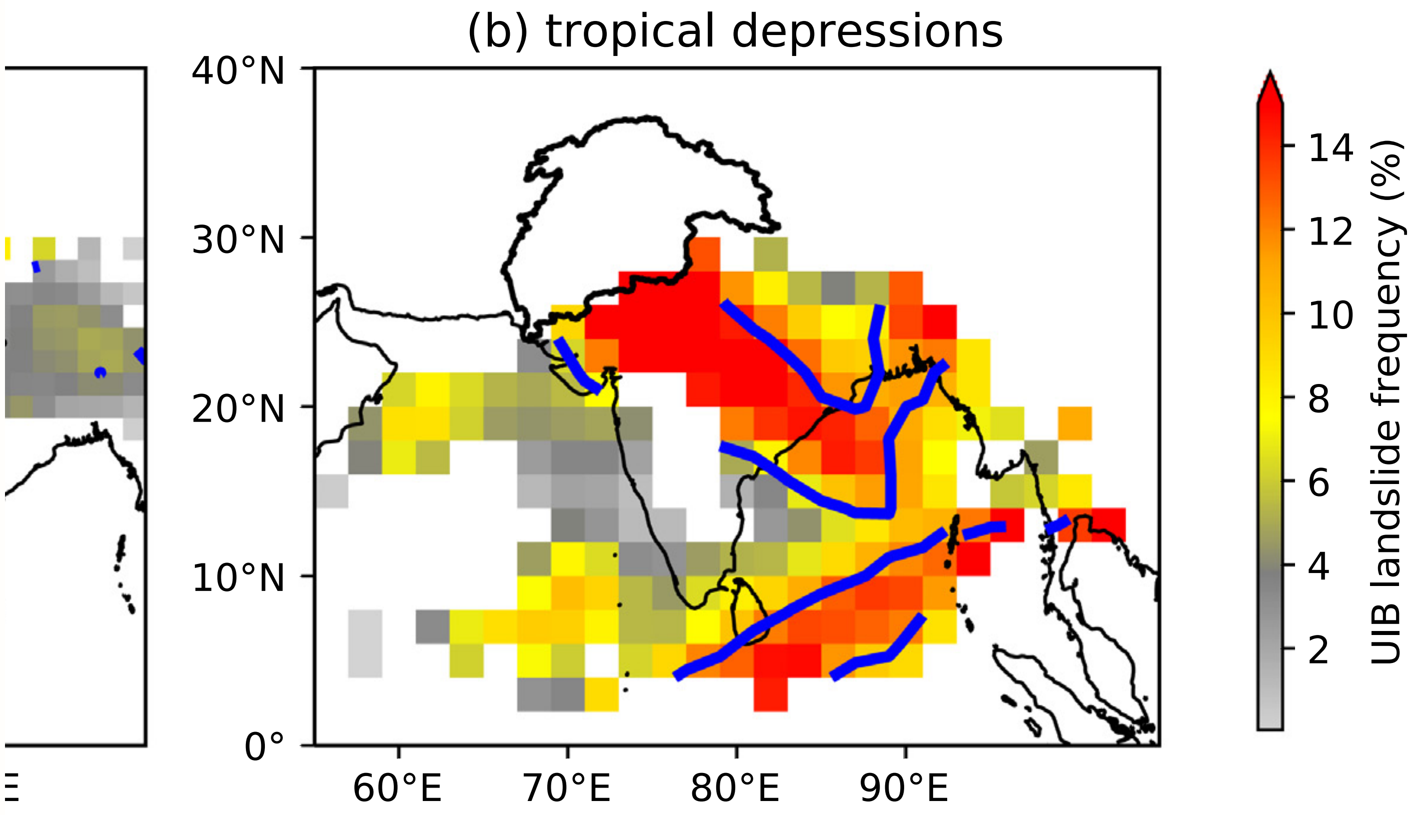



# Landslides



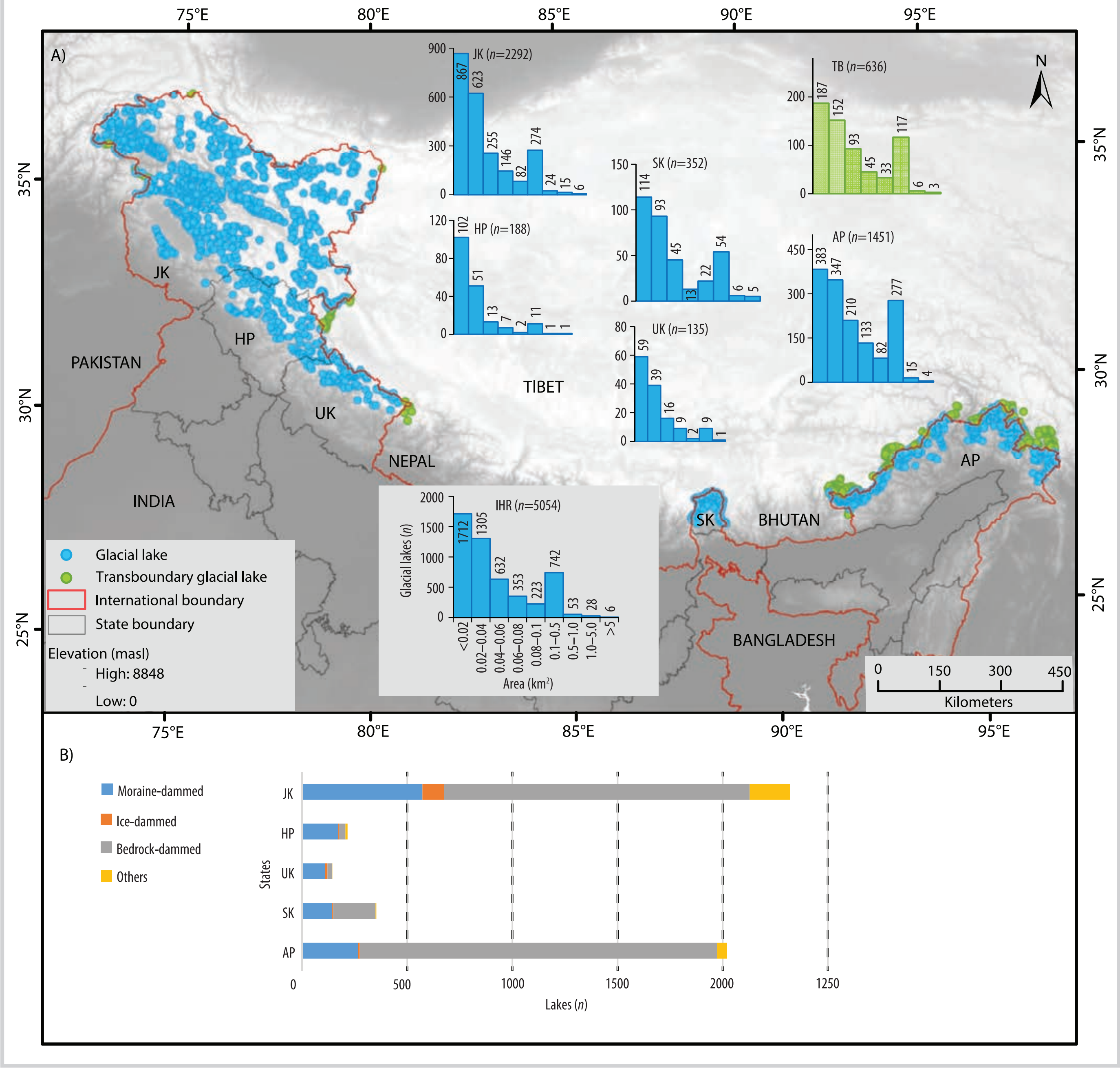

Locations of landslides in the NASA GLC, covering 2007–2015. Blue dots mark landslides occurring between October and April; brown dots mark those occurring between May and September. The thick black line marks the boundary of the Indus Basin. Left: over the Indian peninsula and surrounding area; right: over the Indus Basin (marked in black). (Hunt et al. 2021)




lide in the UIB, given presence of (a) a western disturbance in October–April or (b) a tropical depression in May–September in a given 2°×2° gridbox. The climatological values of 5% day−1 and 11% day−1 for October–April and May–September respectively are drawn with a solid blue line. Grid boxes with fewer than five systems in

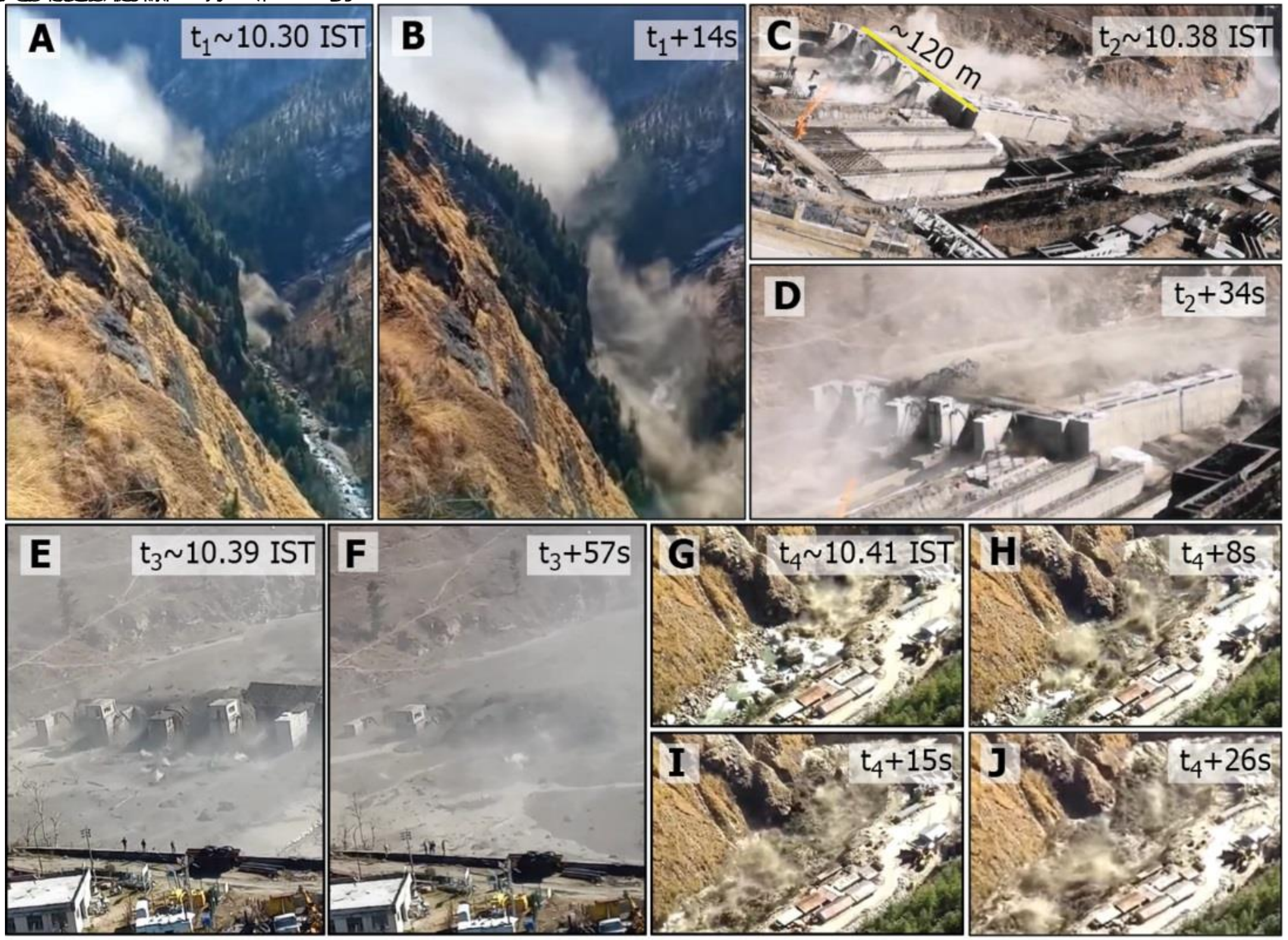
are not shown.



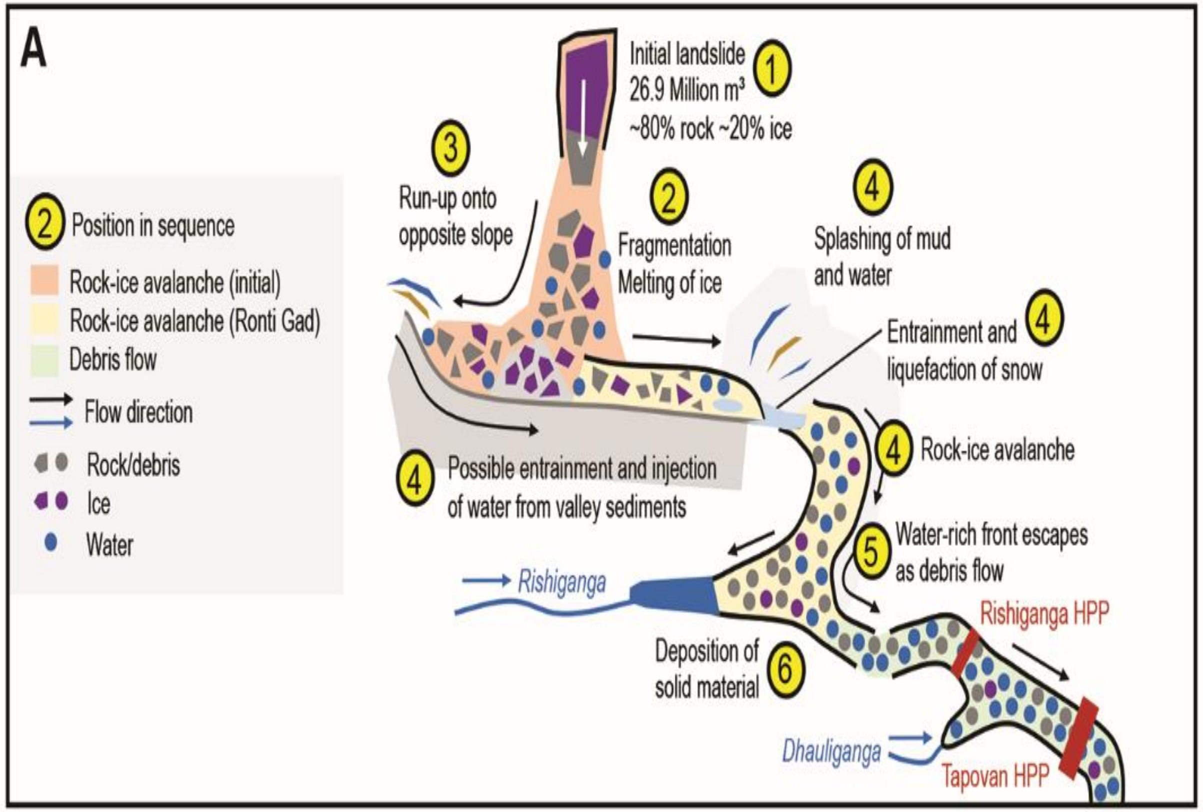

(A)Spatial distribution of glacial lakes in the IHR (n 1⁄4 4418), along with transboundary glacial lakes (n 1⁄4 636) that have potential flood trajectories draining into the IHR. (B) Glacial lake typology. Background:

(B) SRTM DEM (90 m). Red lines indicate the international border of India, whereas gray lines refer to state borders within India.

(C)(Mal et al. 2020)




Parts a-b: Electricity Market in India: Dhauliganga 4*70 MW Coffer Dam collapse in Uttarakhand Chamoli... Prayers for Uttarakhand; URL: https://www.youtube.com/watch?v=96nopxNn-Qp4&t=1s; accessed: 28th February 2021
Parts c-d: Kamlesh Maikhuri (https://www.facebook.com/100005762340793/videos/1678161685719227/ (since removed)) ; Permission: verbal permission of the author given to Kavita Upadhyay
Parts e-f: Manvar Rawat (https://www.facebook.com/100007108448247/videos/2796749477238640/) ; Permission: verbal permission of the author given to Kavita Upadhyay
Parts g-j: RW • Rishikeshwritings: Uttarakhand Flood 2021|| Rishikesh , Srinagar , Devprayag , Haridwar; URL: https://www.youtube.com/watch?v=QE0iPLq8gbY; accessed: 28th February




Sugar et al. (2021)

Cascading disasters patterns

Thanks