CaTeNA Final Workshop

CATENA
CLIMATIC AND TECTONIC NATURAL HAZARDS IN CENTRAL ASIA

High Asia Refined analysis (HAR) for Identifying Climatic Triggers of Landslides in Central Asia

KLIMATOLOGIE
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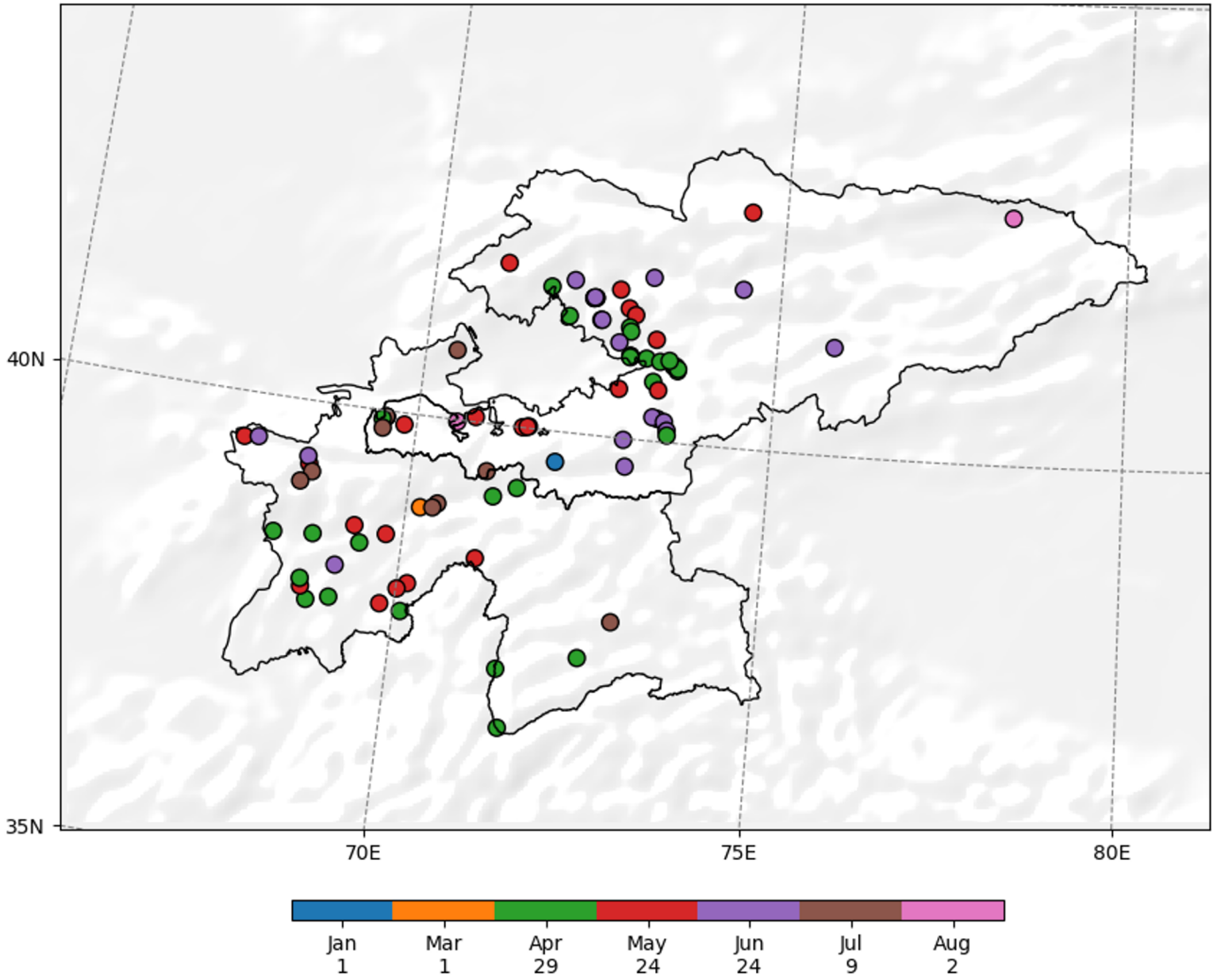
Landslide Hazards in Central Asia

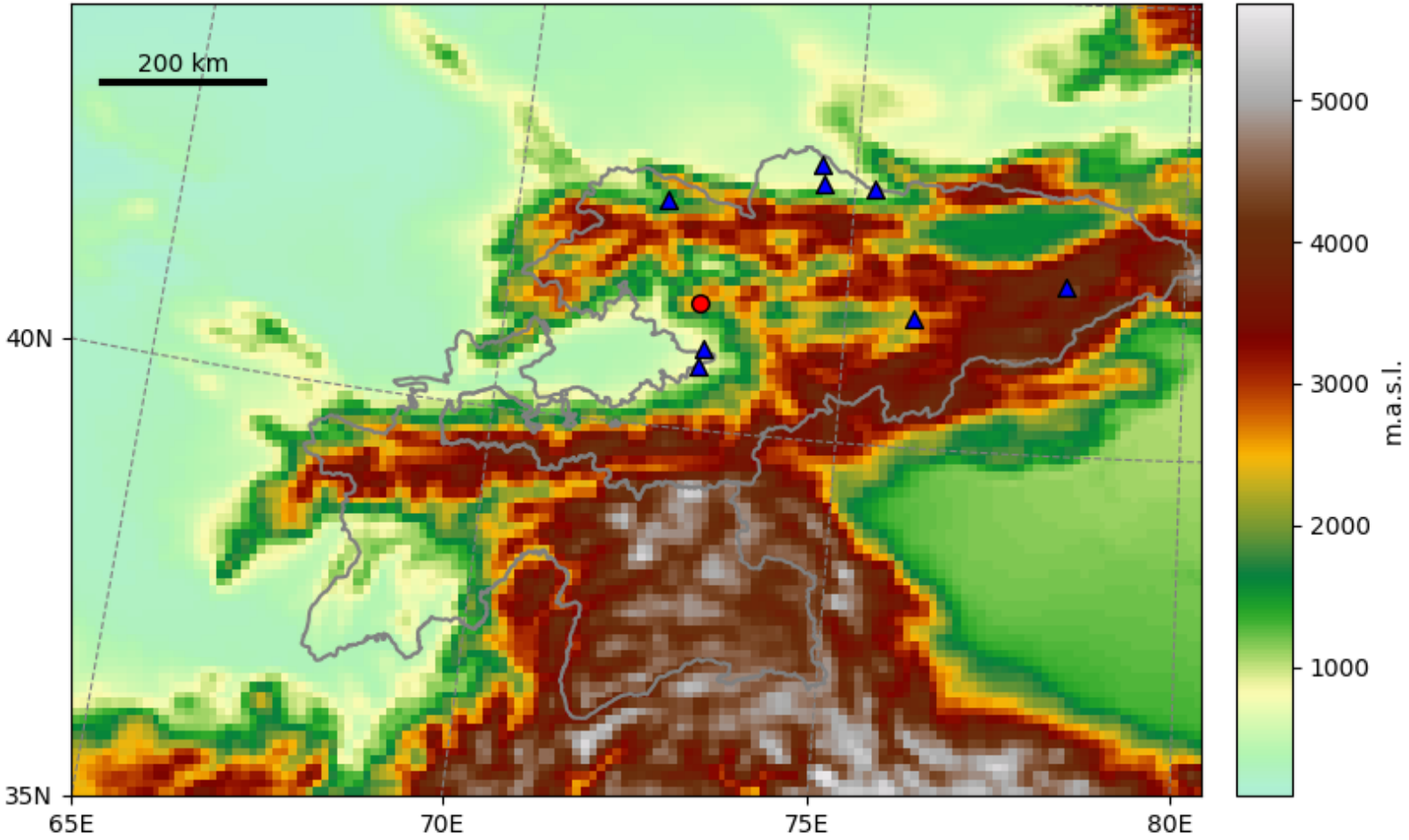


Rainfall triggered landslides in Kyrgyzstan and Tajikistan in 2007-2017.

Source: Global Landslide Catalog, NASA; Global fatal landslide database, Sheffield University

Available Weather Stations

- Landslide event on 2011-05-11
- Weather stations from GSOD

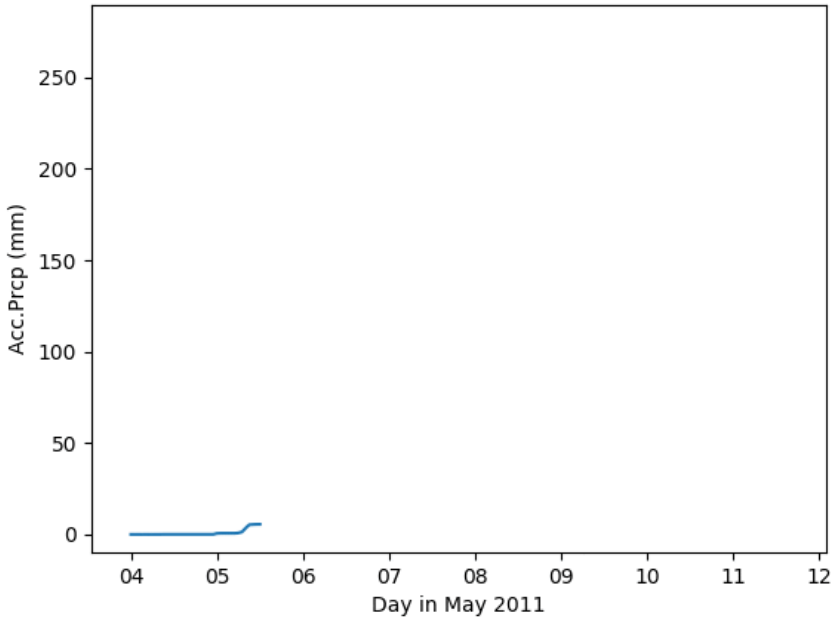


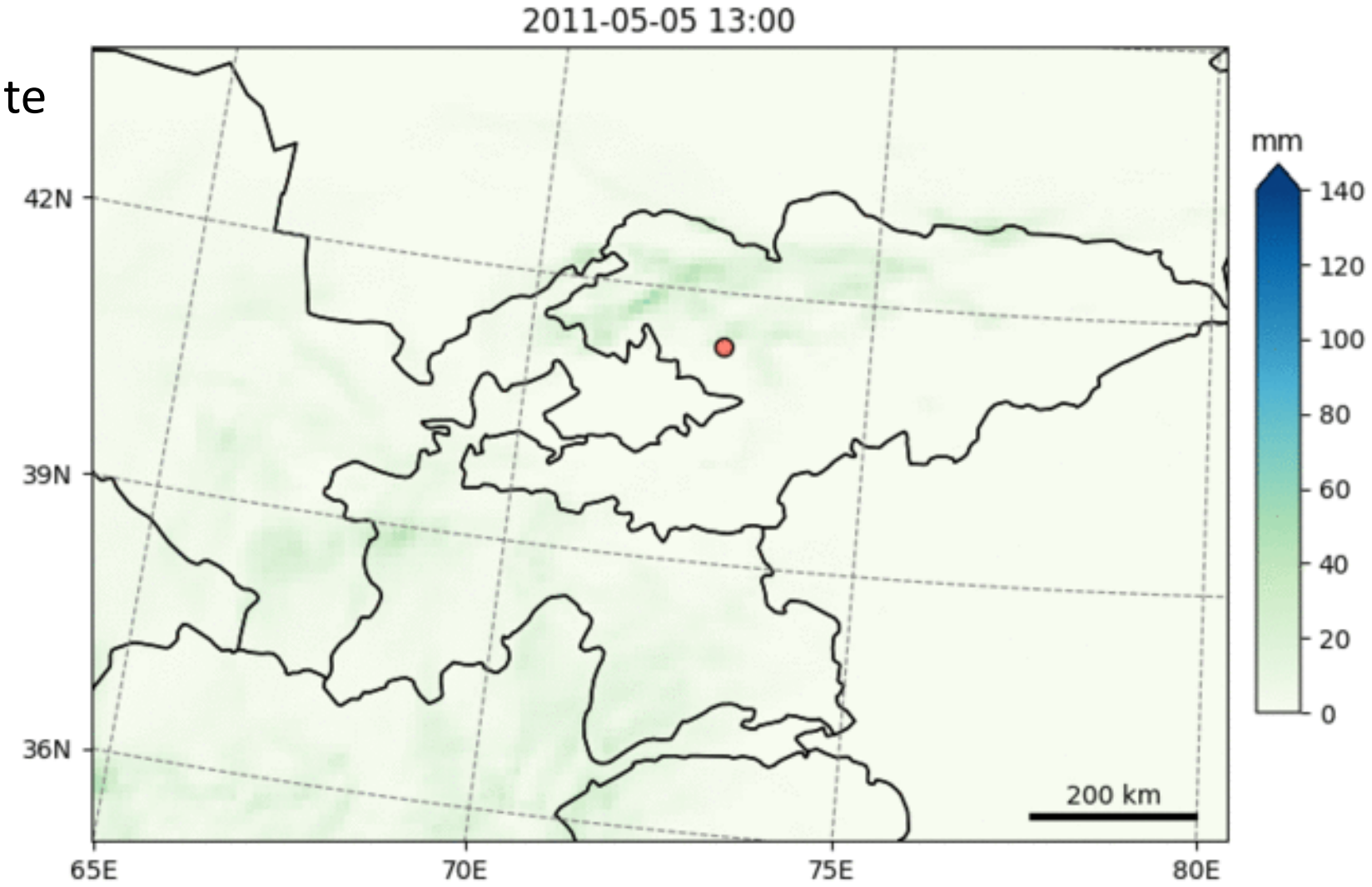
Source: Global Landslide Catalog, NASA;
Global Surface Summary of the Day, NOAA

A Feasibility Study

Accumulated precipitation

(generated by a regional climate model in 10 km resolution)



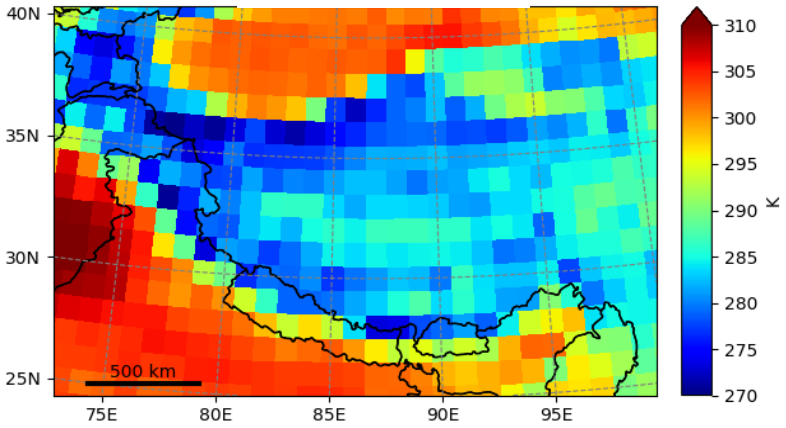


Dynamical Downscaling

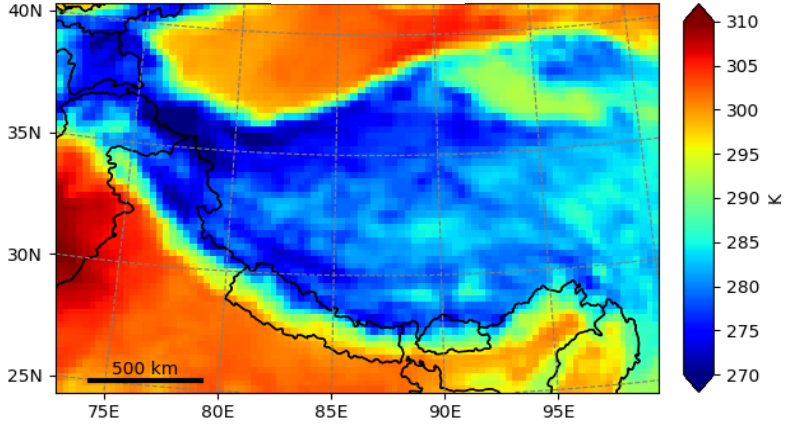
What? -> a method in **regional climate modelling** to obtain climate data with **high spatial and temporal resolution**

How? -> using global data as initial and boundary conditions to drive a Regional Climate Model (RCM)

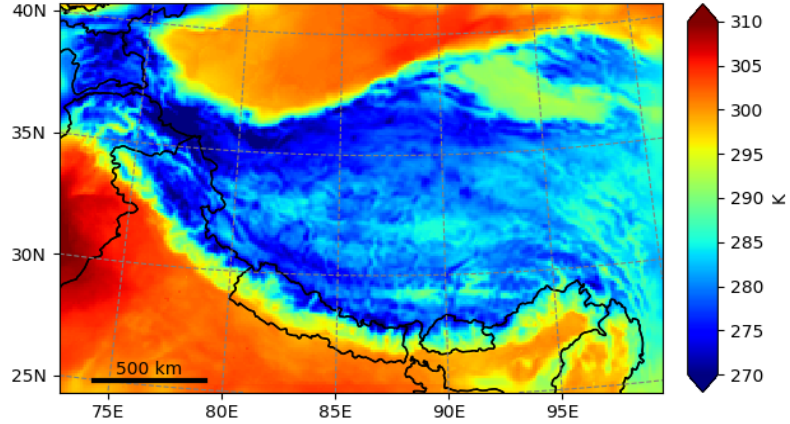
~110 km



30 km



10 km



Pros -> based on physical principles

Cons -> computation-intensive and time-consuming

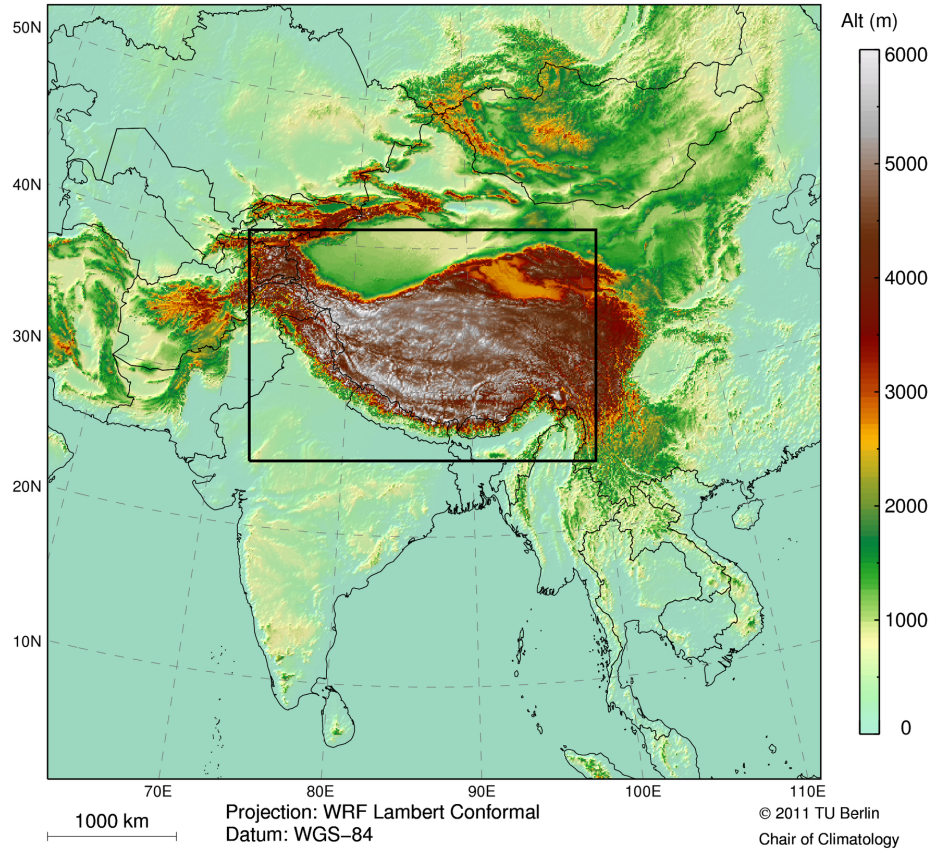
High Asia Refined Analysis (HAR)

- An atmospheric dataset generated by dynamical downscaling
- Spatial resolution: 30 km, 10 km
- Temporal coverage: October 2000 – October 2014
- Comprehensively analyzed and validated (e.g. Prichard et al., 2019; Li et al., 2020)
- Widely applied in many research fields, such as snow and energy balance modelling, hydrological modelling, etc.

But:

-> 10 km domain does not cover the whole Kyrgyzstan and Tajikistan

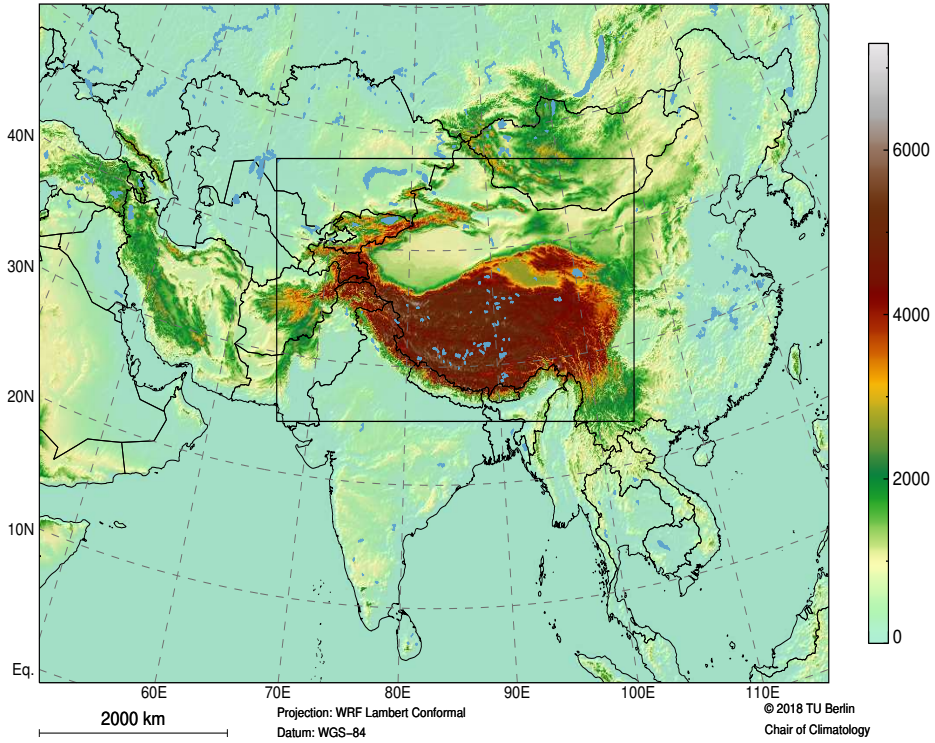
-> temporal coverage is too short for long-term and climatological studies



Maussion et al. (2011, 2014)

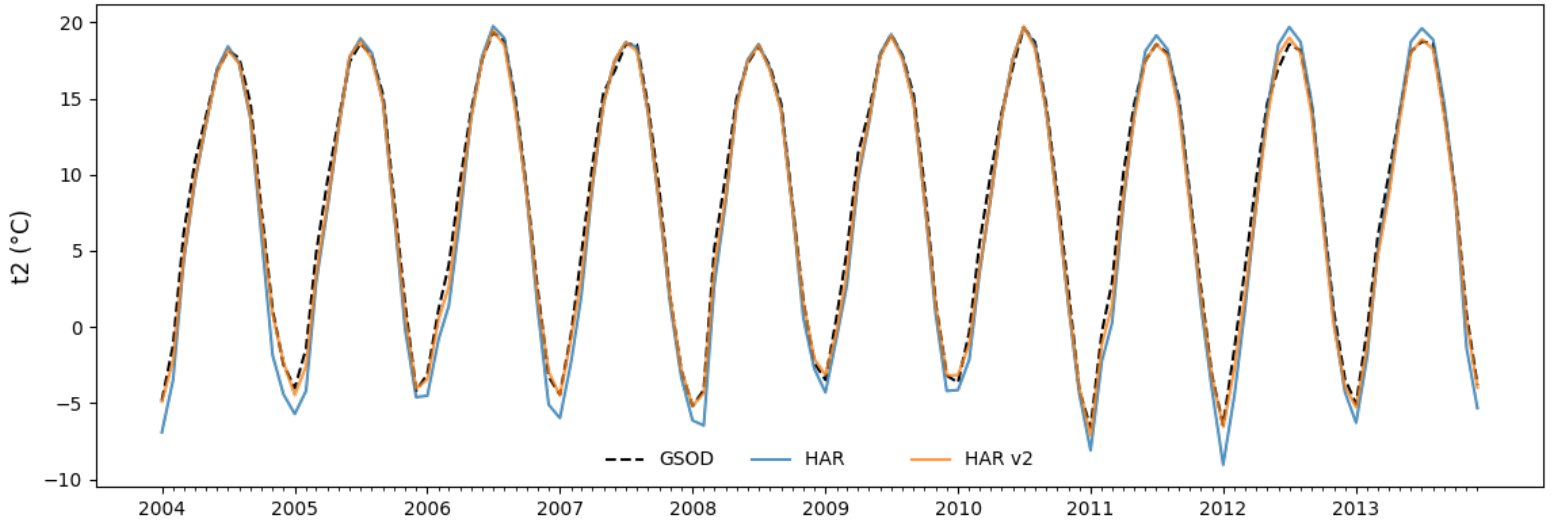
High Asia Refined Analysis Version 2 (HAR v2)

- Strategy: dynamical downscaling
- Forcing Data: ERA5 reanalysis
- RCM: Weather Research & Forecasting model (WRF) V4.1
- Spatial resolution : 10 km
- Currently, simulation for years 2004 -2018 is available

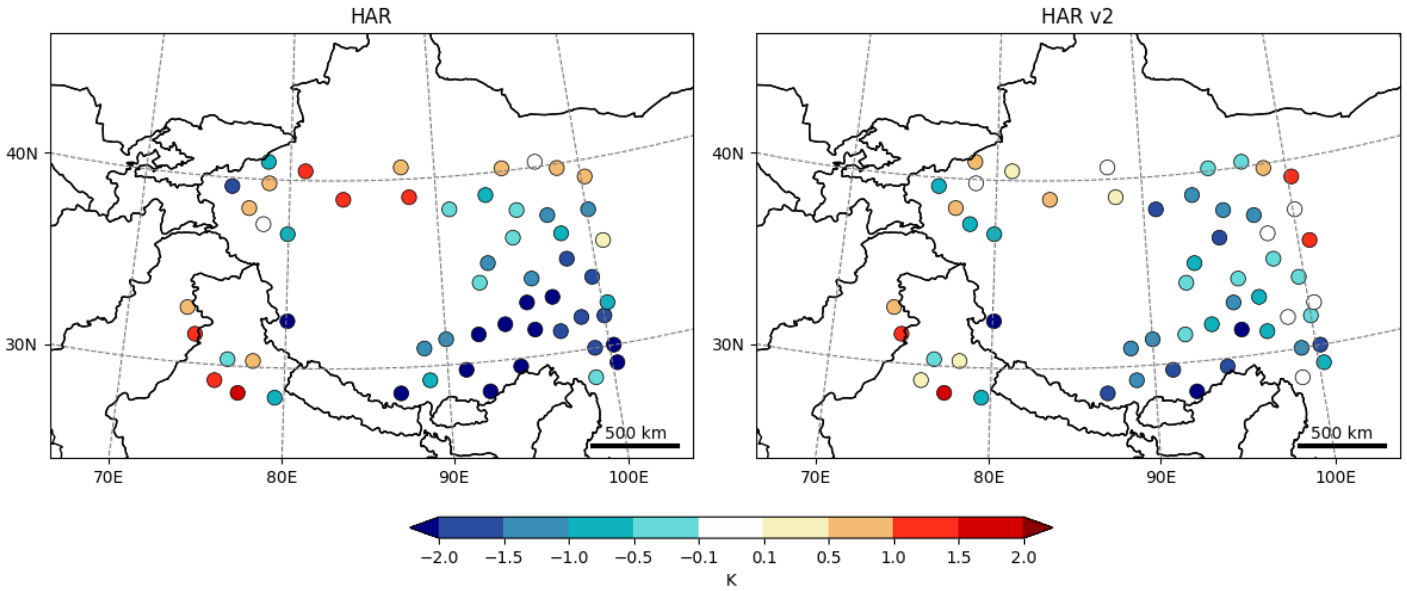


Wang, X., Tolksdorf, V., Otto, M., & Scherer, D. (2020) WRF-based Dynamical Downscaling of ERA5 Reanalysis Data for High Mountain Asia: Towards a New Version of the High Asia Refined Analysis. *International Journal of Climatology*.

Validation
Air temperature at 2 m

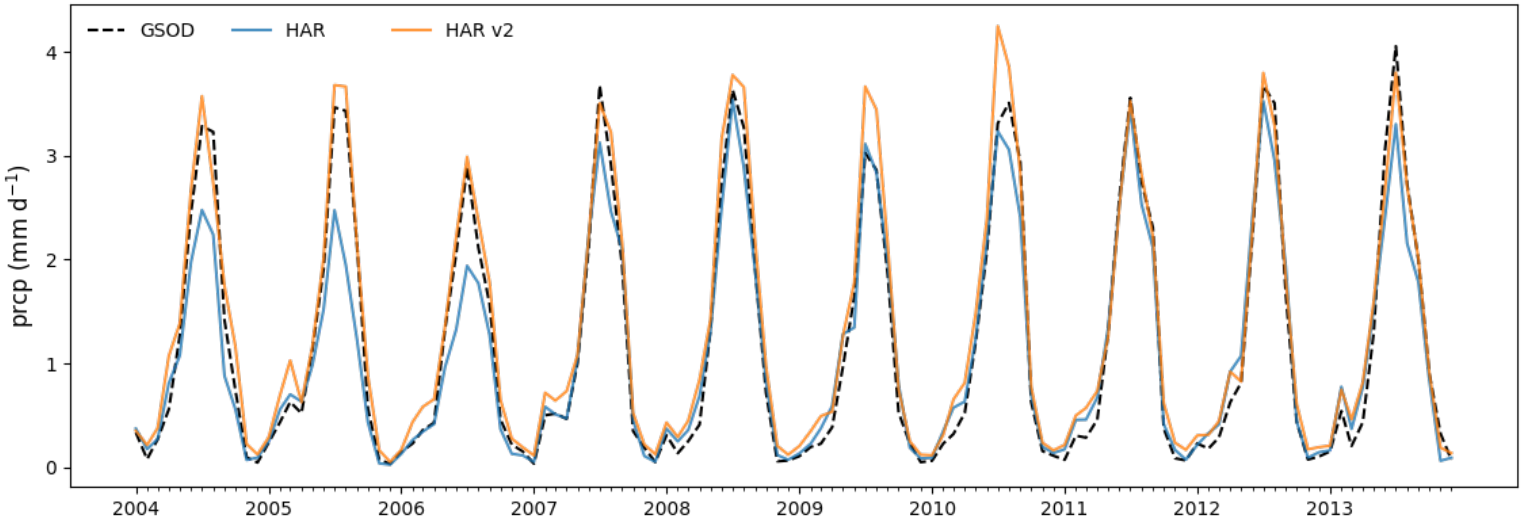


Monthly time series of air temperature at 2 m (°C) from GSOD, HAR and HAR v2.

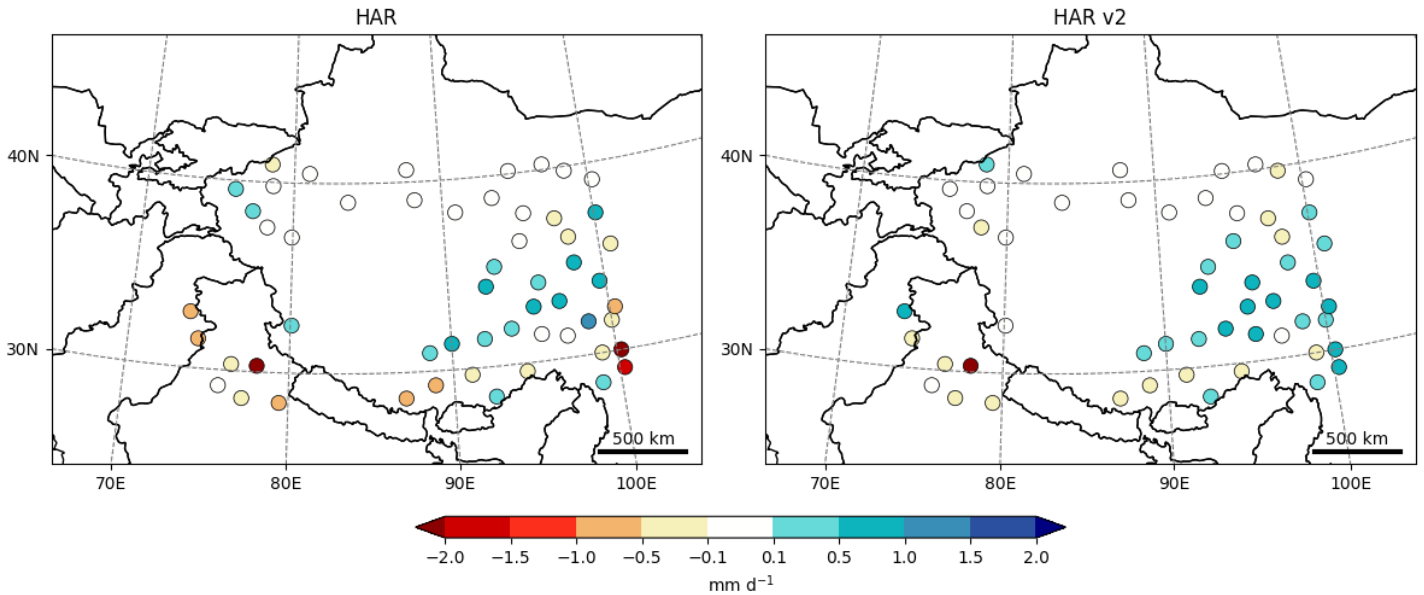


Mean bias (K) of monthly air temperature at 2 m from 2004-2013 for HAR (left) and HAR v2 (right) at GSOD stations.

Validation
Precipitation



Monthly time series of precipitation (mm d^{-1}) from GSOD, HAR and HAR v2.



Mean bias (mm d^{-1}) of monthly precipitation from 2004-2013 for HAR (left) and HAR v2 (right) at GSOD stations.

How to Download?

- HAR v2 website:

  www.klima.tu-berlin.de/HARv2
- The output of the model is post-processed into *product-files: o*ne single file per variable and per year at various temporal resolutions
- File naming convention:

HAR v2_spatial resolution_temporal resolution_variable type_variable name_year.nc

d10km

h (hourly, model output)
d (daily means)
m (monthly means)
y (yearly means)
static (time invariable fields)

2d (surface)
3d_eta (model eta levels)
3d_pressure (pressure levels)
3d_soil (soil levels)

Landslide Catalogue

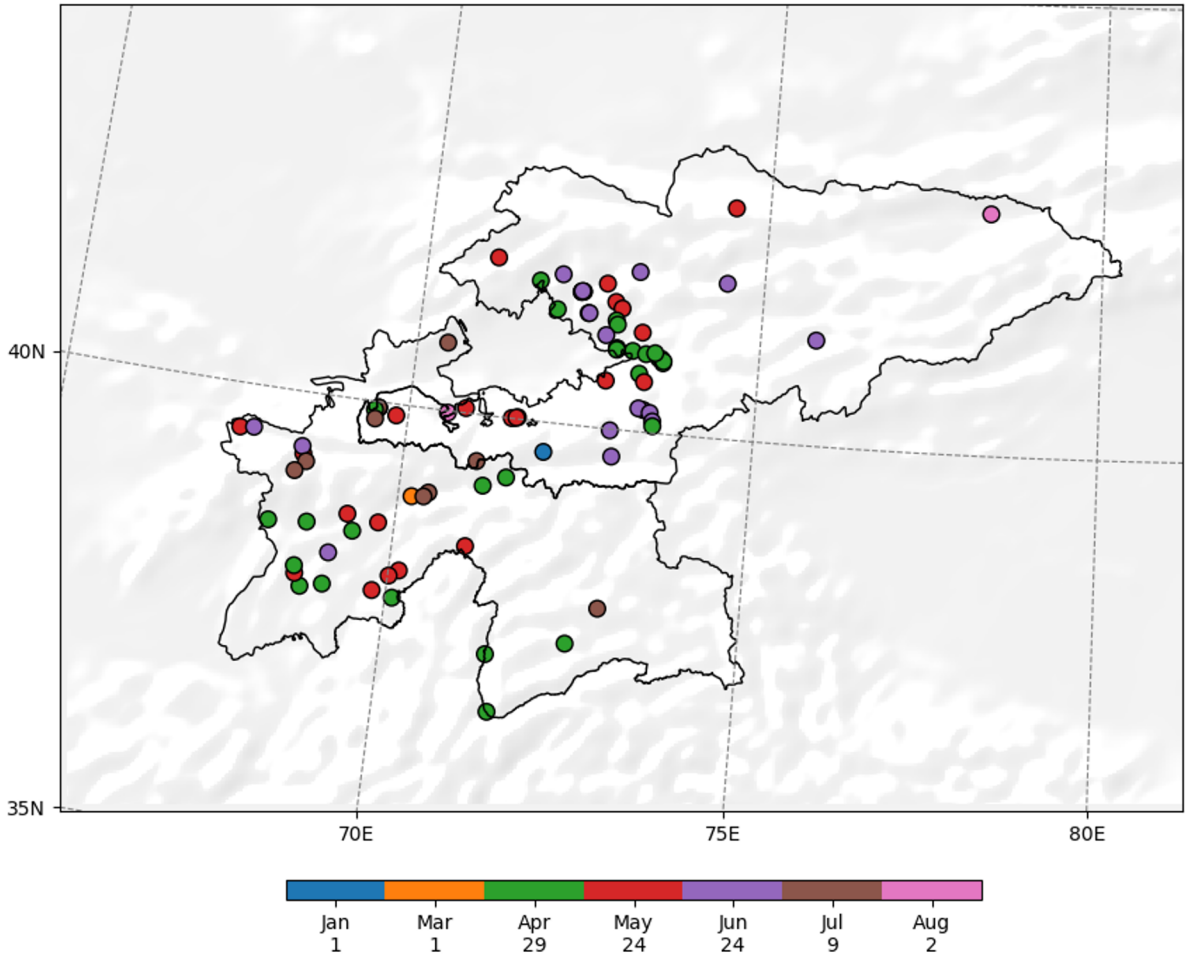
- Combine two data sets:

  - Global landslide catalogue from NASA (2007-2017)

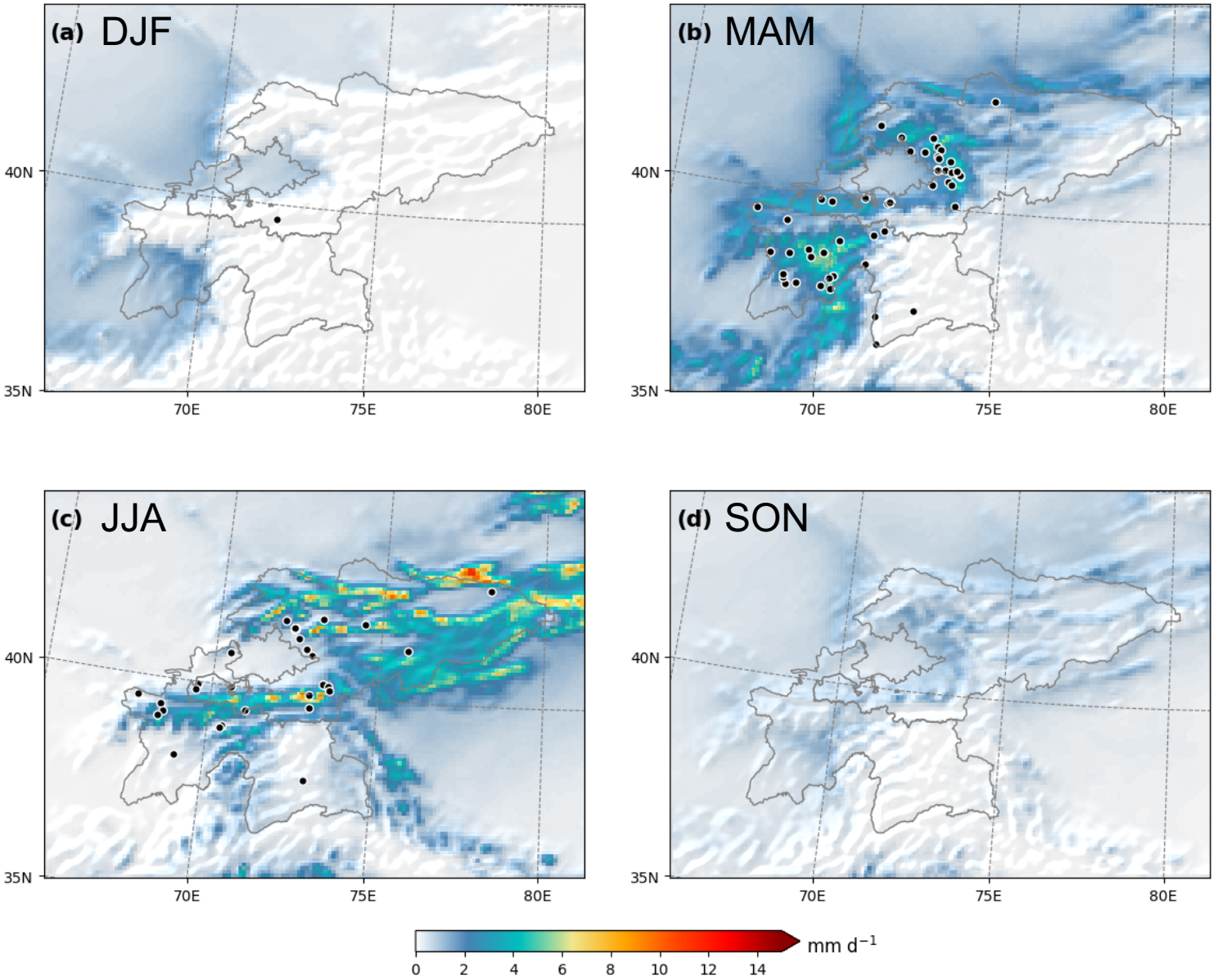
  - Global fatal landslide database from Sheffield University (2004-2017)

- Select landslide events in **Kyrgyzstan and Tajikistan**
- Select landslide events within **2007-2017**
- Select **rainfall triggered** events
- Delete duplicate entries

-> 90 events: 79 from NASA, 11 from Sheffield

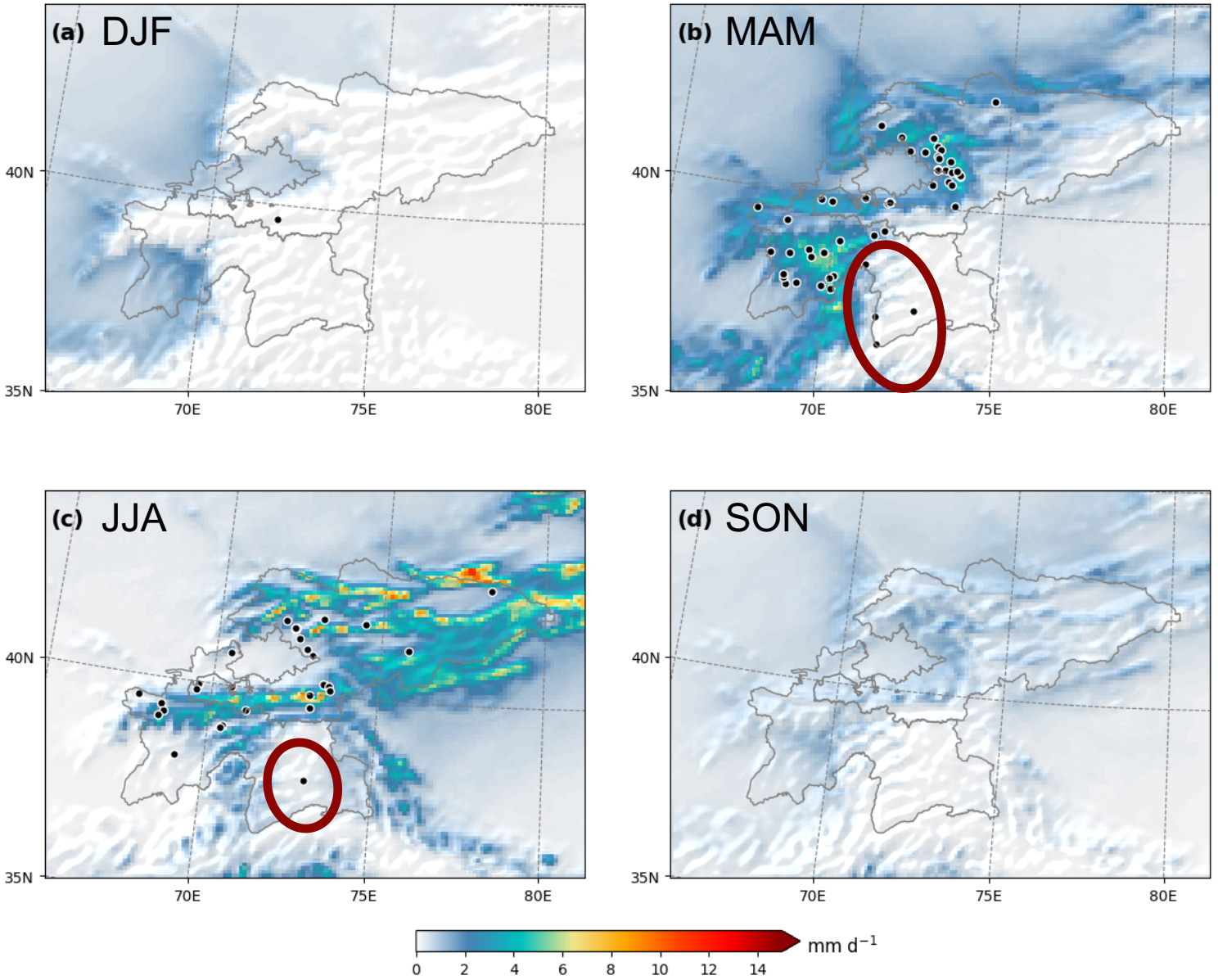


Rainfall Seasonality



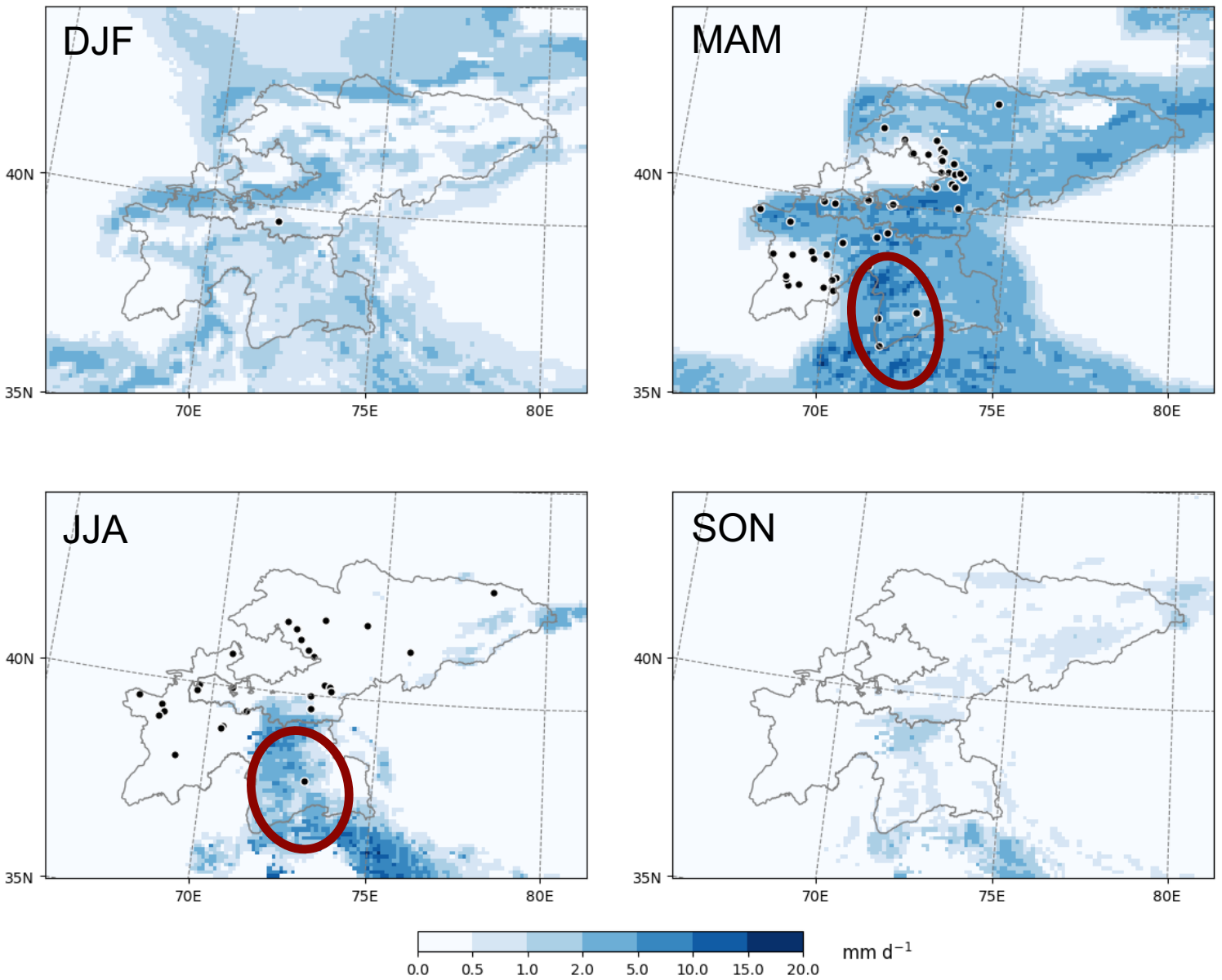
Seasonal rainfall (mm d^{-1}) in Kyrgyzstan and Tajikistan averaged over the period of 2007-2017. Black dots: landslide events.

Rainfall Seasonality



Seasonal rainfall (mm d^{-1}) in Kyrgyzstan and Tajikistan averaged over the period of 2007-2017. Black dots: landslide events.

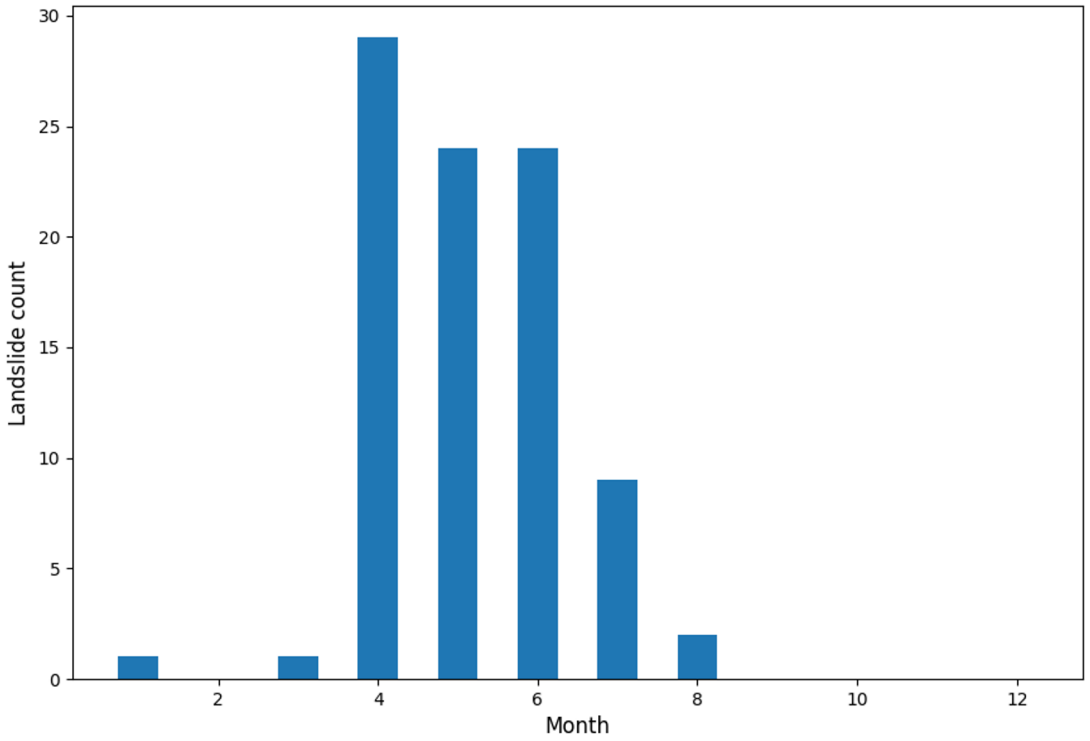
Snowmelt Seasonality



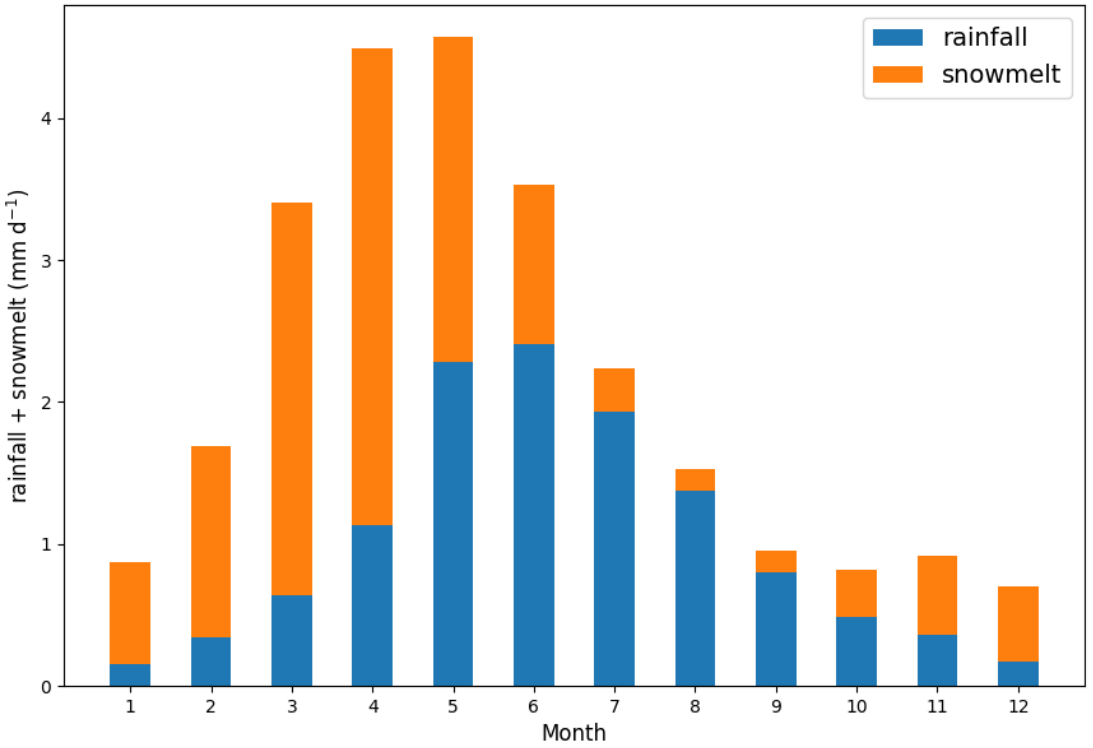
Seasonal snowmelt (mm d^{-1}) in Kyrgyzstan and Tajikistan averaged over the period of 2007-2017. Black dots: landslide events.

Snowmelt Seasonality

Monthly occurrences of landslide

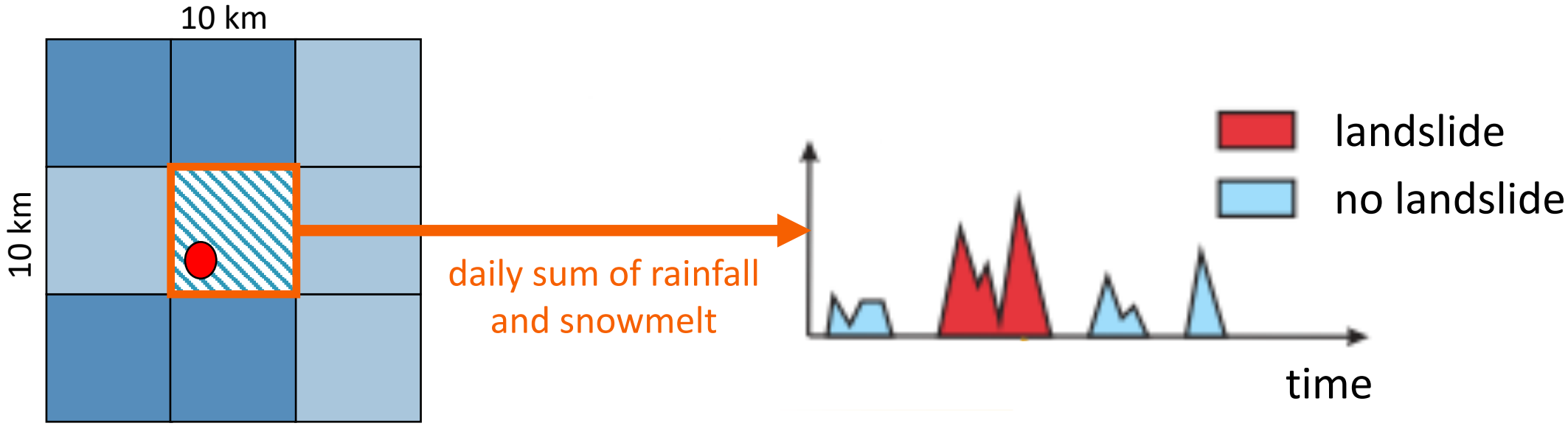


Monthly rainfall and snowmelt



Rainfall + Snowmelt Event Classification

- Select landslide events with a location accuracy ≤ 10 km -> 41 landslide events
- Extract time series of the daily sum of rainfall and snowmelt from the corresponding grid cell -> 35 time series
- For each time series, an independent event is a series of consecutive days in which more than 1 mm d^{-1} of the sum of rainfall and snowmelt is simulated



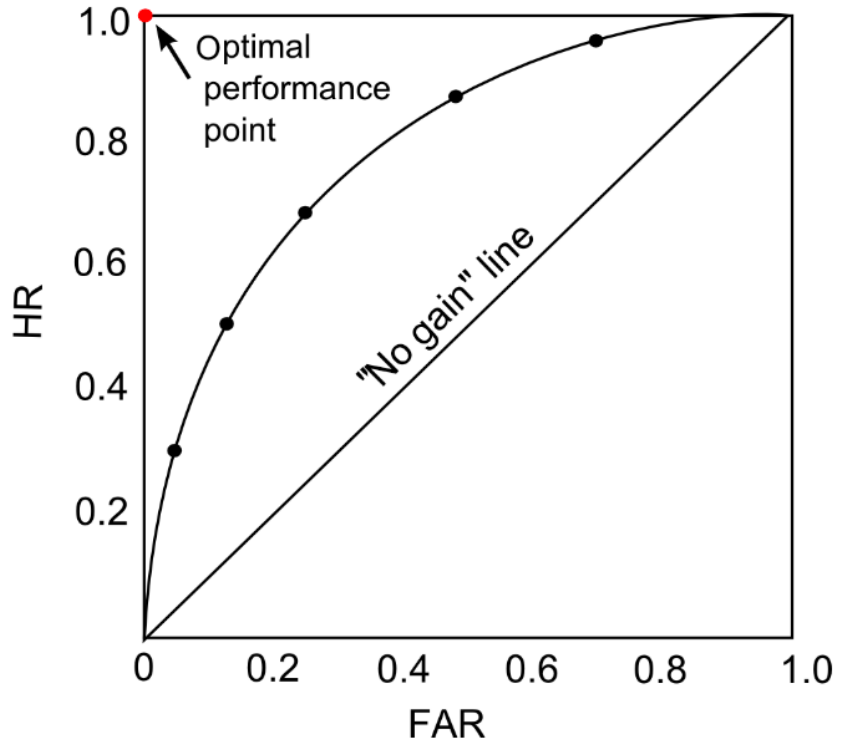
Modified after Leonarduzzi et al. (2017)

Threshold Definition

(a)

Predicted events \ Observed events	Yes	No
Yes	TP	FP
No	FN	TN

(b)



Modified after Zhuo et al. (2019)

Skill scores

- Hit rate: $\mathrm{HR} = \frac{TP}{TP+FN}$
- False alarm rate: $FAR = \frac{FP}{FP+TN}$
- Distance to the optimal performance point:

$$d = \sqrt{(HR-1)^2+(FAR-0)^2}$$

Skill Scores

	Reconstruction percentage	Mean intensity			Maximum intensity		
		Threshold (mm d^{-1})	HR	FAR	Threshold (mm d^{-1})	HR	FAR
Rainfall + Snowmelt	77.1%	5.6	0.67	0.31	8.0	0.70	0.29

Skill Scores

	Reconstruction percentage	Mean intensity			Maximum intensity		
		Threshold (mm d^{-1})	HR	FAR	Threshold (mm d^{-1})	HR	FAR
Rainfall + Snowmelt	**77.1%**	5.6	0.67	**0.31**	8.0	**0.70**	**0.29**
Rainfall	62.9%	4.8	0.68	0.40	7.9	0.64	0.30

Conclusions

- HAR v2 is a suitable dataset for investigating climatic triggers of landslides in Central Asia
- Not rainfall alone but the sum of rainfall and snowmelt is the climatic trigger of landslides in Central Asia
- This method of threshold definition can be also applied for landslide prediction, but it needs further improvement

References

Froude, M. J., & Petley, D. N. (2018). Global fatal landslide occurrence from 2004 to 2016. *Natural Hazards and Earth System Sciences*, *18*(8), 2161–2181.

Kirschbaum, D., & Stanley, T. (2018). Satellite-Based Assessment of Rainfall-Triggered Landslide Hazard for Situational Awareness. *Earth's Future*, *6*(3), 505–523.

Leonarduzzi, E., Molnar, P., & McArdell, B. W. (2017). Predictive performance of rainfall thresholds for shallow landslides in Switzerland from gridded daily data. *Water Resources Research*, *53*(8), 6612-6625.

Li, D., Yang, K., Tang, W., Li, X., Zhou, X., & Guo, D. (2020). Characterizing precipitation in high altitudes of the western Tibetan plateau with a focus on major glacier areas. *International Journal of Climatology*.

Maussion, F., Scherer, D., Finkelnburg, R., Richters, J., Yang, W., & Yao, T. (2011). WRF simulation of a precipitation event over the Tibetan Plateau, China--an assessment using remote sensing and ground observations. *Hydrology & Earth System Sciences*, *15*(6).

Maussion, F., Scherer, D., Mölg, T., Collier, E., Curio, J., & Finkelnburg, R. (2014). Precipitation seasonality and variability over the Tibetan Plateau as resolved by the High Asia Reanalysis. *Journal of Climate*, *27*(5), 1910-1927.

Pritchard, D. M., Forsythe, N., Fowler, H. J., O'Donnell, G. M., & Li, X. F. (2019). Evaluation of Upper Indus near-surface climate representation by WRF in the high Asia refined analysis. *Journal of Hydrometeorology*, *20*(3), 467-487.

Segoni, S., Piciullo, L., & Gariano, S. L. (2018). A review of the recent literature on rainfall thresholds for landslide occurrence. *Landslides*, *15*(8), 1483–1501.

Wang, X., Tolksdorf, V., Otto, M., & Scherer, D. (2020) WRF-based Dynamical Downscaling of ERA5 Reanalysis Data for High Mountain Asia: Towards a New Version of the High Asia Refined Analysis. *International Journal of Climatology*.

Xu, Z., Han, Y., & Yang, Z. (2019). Dynamical downscaling of regional climate: A review of methods and limitations. *Science China Earth Sciences*, *62*(2), 365-375

Zhuo, L., Dai, Q., Han, D., Chen, N., & Zhao, B. (2019). Assessment of simulated soil moisture from WRF Noah, Noah-MP, and CLM land surface schemes for landslide hazard application. *Hydrology and Earth System Sciences*, *23*(10), 4199-4218.