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Projected time series of glacier area and volume evolution from 2020-2100 in Karnali River Basin

Background

Glaciers are a reliable fresh water resource particularly during dry spell in the Himalayan region. However, ongoing global warming has caused rapid shrinkage of Himalayan glaciers with a high chance of their near-complete disappearance by the end of the 21st century (Kraaijenbrink et al., 2017) with great implications on future fresh water resources availability. Here we assessed the evolution of glacier area and volume till the end of 21st century in the Karnali River basin (KRB), Western Nepal using dynamic glacier model- Open Global Glacier Model (OGGM) (Maussian et al., 2018). Pronounced increasing warming trends in the Himalayan region as predicted by different general circulation models (GCMs) are central to significant wastage of glacier's mass contributing to massive reduction in total glaciated area.

The aim of this modelling study is to show the response of glaciers of KRB to global climate change and how their mass and volume evolve over time under four different representative concentration pathways (RCPs) and ten different GCMs.

Data and method

An ensemble of ten GCMs under four climate emission scenarios (RCPs) was used to study the future warming in the KRB. Further, modular open source modelling framework OGGM was utilized to simulate reference and future area and volume of the glaciers (~ 1550 in number) of KRB. OGGM is a dynamic glacier model that deploys an explicit ice dynamic module to account changes in glacier geometry as a response to changes in atmospheric temperature and precipitation. A well calibrated extended version of temperature index model calculates the mass-balance of the glaciers using user defined monthly time series of temperature and precipitation for present condition (using observed or satellite/ reanalysis climate datasets) and future condition (using GCM anomalies computed with delta method). To run OGGM for KRB, a gridded observations (CRU) for the reference climatology was used and the GCM anomalies were computed from a preselected reference period as explained in OGGM tutorials (docs.oggm.org).

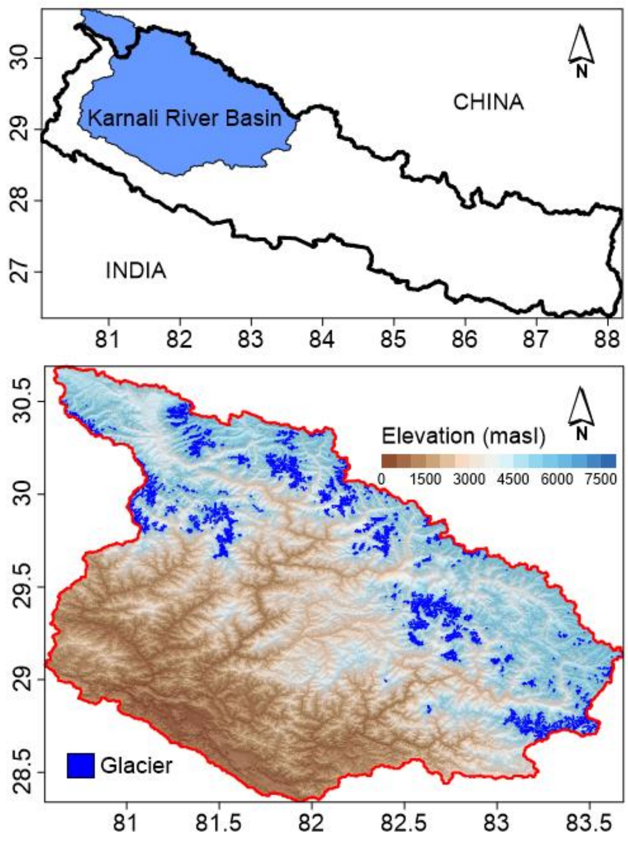

Figure 1: Study area

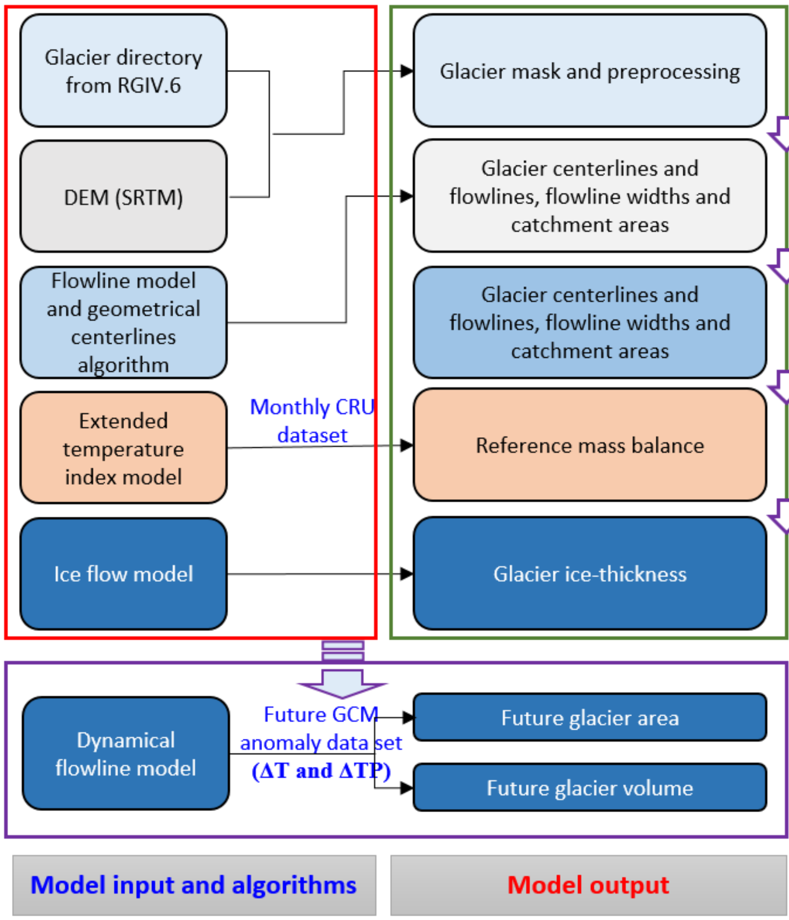

Figure 2: Flowchart illustrating different steps of workflow in OGGM

Future projection of air temperature in KRB based

Figure 3 shows the mean annual air temperature of entire KRB for historical period (1951 – 2015) and future period (2015- 2021) based on ensemble of ten GCMs of coupled model inter-comparisons (CMIP6) project for four different shared socioeconomic pathways (SSPs). Downscaled and bias-corrected using empirical quantile mapping (QRM) for maximum and minimum air temperatures data from CMIP6 projections were obtained from Mishra et al., 2020 for KRB from which we computed basin wise mean air temperatures for historical and future time periods.

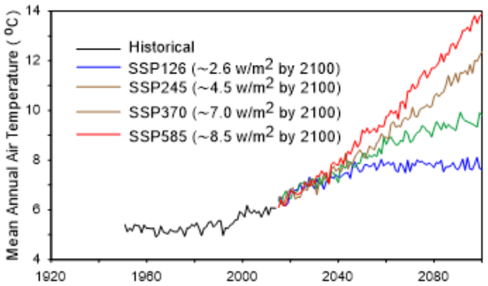

Figure 3: Mean annual air temperature of KRB from 1950-2100 computed with 10 GCM ensembles of CMIP6 projection

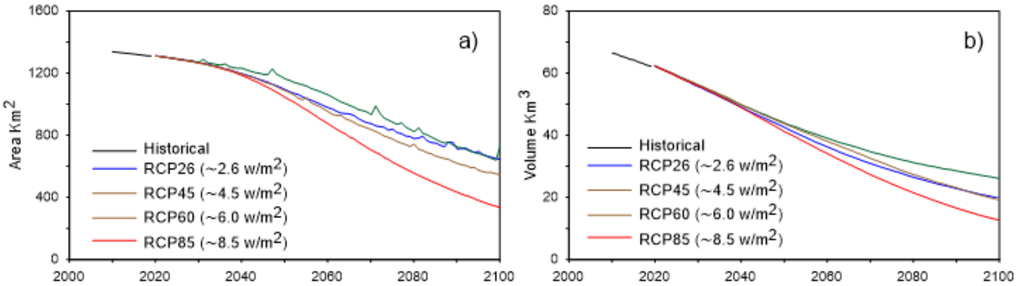

Figure 4: Projected glacier a) area and b) volume of KRB

Bias corrected projections from 10 CMIP6-GCMs project a warmer (3.12 – 5.32 °C) in the mean air temperature of basin average of KRB by the end of 21st century compared to that of the historical mean air temperature (5.36 °C) for the period 1951-2014.

A significant loss in glacier area and volume is estimated from 2020 to 2100 in KRB as shown in the Figure 4 for an ensemble of 10 GCMs under climate scenarios. The average glaciated area in KRB is estimated to decrease from 1310 km² to 643.6, 493.6, 490.5 and 323.3 km², a decrease of 50-75% and the average glacier volume from 62.24 km³ to 25.73, 19.27, 18.67, 12.3 km³, a decrease of 58-80 % for RCP26, RCP45, RCP60, and RCP85 respectively.

Scenario	Mean air temperature (°C) for one standard deviation
Historical (1951- 2014)	5.36±0.46
SSP126 (2015-2100)	3.12±0.43
SSP245 (2015-2100)	3.8±0.52
SSP370 (2015-2100)	4.6±0.57
SSP245 (2015-2100)	5.32±0.77

Time Period	2020	Decrease in glacier area and volume by the end of 2100			
		RCP26	RCP45	RCP60	RCP85
Area (km²)	1310	663.6 (50 %)	493.6 (62 %)	481.86 (63 %)	323.3 (75 %)
Volume (km³)	62.24	25.73 (58 %)	19.27 (69 %)	18.67 (79 %)	12.3 (80 %)

Remarks

The future evolution of glacier area and volume has great implications in future fresh water resources availability, poses challenges to hydropower generation, and ecosystems and contributes to increased impacts from related cryospheric hazards. In addition to the hydrologic implications the projected changes of glaciated area in KRB have broader ramifications for agriculture, forestry, water quality and resource development.

References

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Maussion, F., Butenko, A., Champollion, N., Dusch, M., Eis, J., Fourteau, K., ... and Marzeion, B., 2019. The open global glacier model (OGGM) v1. 1. Geoscientific Model Development, 12(3), 909-931.

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