Future Streamflow Projection for Langtang River Basin

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Submitted by

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Abstract

Glaciers significantly influence streamflow in catchments and serve as key indicators of climate change. The IPCC's Sixth Assessment Report predicts continued glacier mass loss for decades, impacting water availability and runoff patterns, especially in the Hindu-Kush Himalayan region. This study uses the Cold Region Hydrological Model (CRHM) to simulate future streamflow in the Langtang Basin, where 53.5% of the area is glacier-covered. Therefore, future streamflow is estimated for the Langtang River Basin using CMIP6 data depicting different climatological situations and glacier cover changes. Training provided to undergraduate meteorology students on climate data analysis, enabling them to use reanalysis datasets (MEERA-2, WFDEI, ERA5) and the WECS-Gen Tool for precipitation data. This research provides insights into hydrological shifts and future water availability, benefiting downstream communities and sectors like hydropower and agriculture.

1. Introduction

Glaciers are natural reservoirs that have a massive contribution to stream flow in a catchment. Storage and release of water from glaciers depend on various climatological factors hence glaciers are one of the most visible indicators of climate change. Rapid changes in climatic conditions have shifted the accumulation and melting patterns of snow field areas and glaciers. As per the IPCC's sixth assessment report, there is high confidence that glaciers will lose mass for at least several decades even if the global temperature is stabilized and also shows that in the Hindu-Kush Himalayan region, glaciers are declining and are projected to decline further by the mid-21st century which would cause changes in the downstream runoff patterns and unknown consequences on water availability. Therefore, it is important to understand the future simulations and conditions that will highly affect the basins' melting and streamflow patterns for different climatic scenarios.

With mountain glacierized headwaters undergoing a transient shift in their hydrological and glaciological systems due to rapid climate change, it is important to understand the hydrological processes operating in the basin. Therefore for Langtang with 53.5% of the area covered with glaciers, we have used a physically based model, the Cold Region Hydrological Model (CRHM) to incorporate snow and ice processes and estimate the future streamflow for various climatic conditions which is crucial for downstream communities and in countries like Nepal for hydropower generation and agricultural activities.

Few Objectives are:

a. Future streamflow projections in different climatic conditions
b. Possible scenarios during the period of deglaciation
c. Capacitate undergraduate students on climate data analysis

3. Study Area

The Catchment extends from a longitude of 85°31'E to 85°48'E and a latitude of 28°08'N to 28°24'N. The elevation ranges from 3800 m.a.s.l. up to 7234 m.a.s.l. at Langtang Lirung peak. The catchment has an average altitude of 5169 m.a.s.l. and a mean slope of 26.7°.

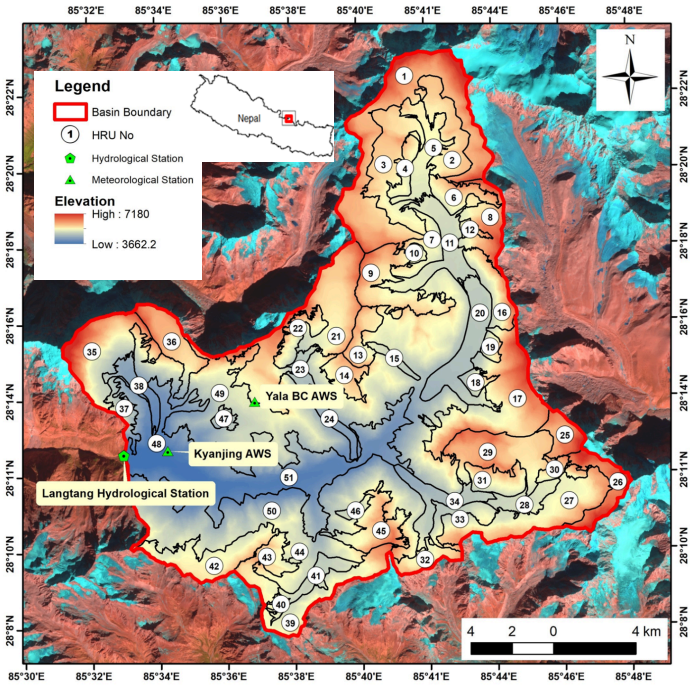


Figure 1: Elevation map

As per the HRU generated and from Fig 1 land use land cover classification from the total area of 354.15 sq. km. is as follows

Land Use Land Cover	Area Covered (sq. km)
Pasture	35.2
Debris Covered Glacier	37.8
Bare (Area without Vegetation)	129.7
Firn Covered Glacier	151.7

Table 1: Land Cover

4. Data

The observed data is taken from two automatic weather stations at Kyanjing Station that are installed by ICIMOD (International Centre for Integrated Mountain Development), and the Department of Hydrology and Meteorology (DHM), Government of Nepal. Daily data from 2002-2009 and hourly data from 2012-2019 are taken from DHM and ICIMOD respectively for temperature, precipitation, solar radiation, relative humidity, sunshine hour, and wind speed.

For reanalysis data, we have taken WFDEI data from 1979 to 2018 which is a global land surface reanalysis data set at a 0.5°x0.5° latitude-longitude grid.

Future data has been retrieved from CMIP6 for three models NESM3_r1i1p1f1_gn EC-Earth3_r1i1p1f1_gr and MPI-ESM1-2-HR_r1i1p1f1_gn which depicts warm dry, cold wet and cold dry conditions respectively (NDRI, 2024)

5. Methods

1. Data Input

Due to the limited availability of observed data, three sets of reanalysis data; ERA5, MERRA-2, and WFDEI were bias-corrected concerning the observed data from DHM. As per the results, WFDEI data is more similar to the observed data indicating a better representation of the climatic conditions of LGRB. Therefore, bias-correct reanalysis data from WFDEI is used as meteorological forcing for the model.

Data provided:

Observation	Description	Units
T	air temperature	ºC
Rh	relative humidity	%
u	wind speed	m/s

P	precipitation, as actual data for every interval	mm/interval
Qsi	Incoming shortwave radiation	W/m2
Qli	Incoming longwave radiation	W/m2

Table 2: Input Data

2. Data Extraction and Analysis

Data (Precipitation and Temperature) were extracted from sources like ESGF and Copernicus. All the data were downloaded from ESGF and Copernicus. All the future data were extracted using the CDO package. To understand the variability and changes in the data Panoply was used. All the data retrieved was analyzed using R programming. All the retrieved data were bias-corrected considering the reanalysis dataset from WFDEI which was bias-corrected concerning the in-situ data from Kyanjing station. NDRI provided all the codes required for bias correction. Since the model, CRHM only uses hourly resolution datasets all the daily provided future resolution data was converted to hourly resolution. The historical data was used from 1998-2018 which was further corrected for the datasets of 2030-2050. For temeprature, we calculated the monthly average for 2030-2050 and the other for 1998-2018. Then monthly bias was calculated for all the temperature data from the average datasets created from historical and future data. Then the biases were fed to the dataset of 1998-2018. In the case of precipitation, monthly cumulative data was calculated for 2030-2050 and 1998-2018. Then precipitation was already given in daily timestamp hence the same was usable for the model. All the bias-corrected historical and future data were then expected to behave as future datasets.

3. Cold Region Hydrological Modelling (CRHM)

The Cold Region Hydrological Modelling (CRHM, Fig. 2) is a platform created to develop physically-based hydrological models in the cold region as well as temperate climate over small to medium-sized basins. CRHM is a module-based object that allows the user to choose possible basin spatial configuration, spatial resolution, and physical process models of varying degrees (Pomeroy et al., 2022). CRHM is an outcome of intensive study of cold regions and other hydrological processes (Pomeroy et al., 2022). CRHM-Glacier (Pradhananga and Pomeroy, 2022) will be used to simulate the runoff from the Langtang Glacier.

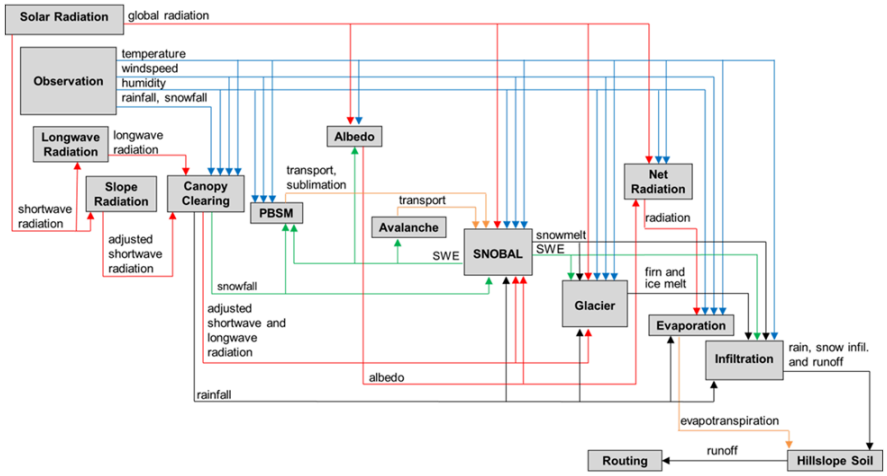
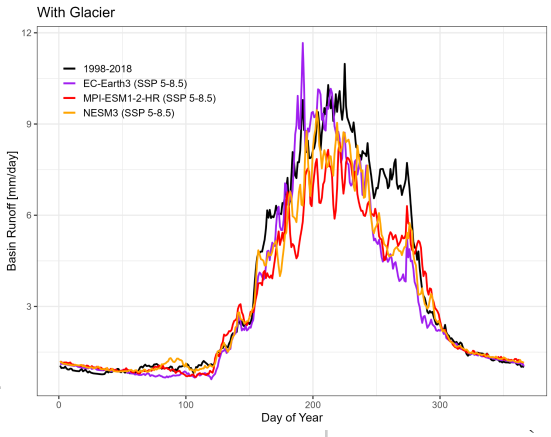


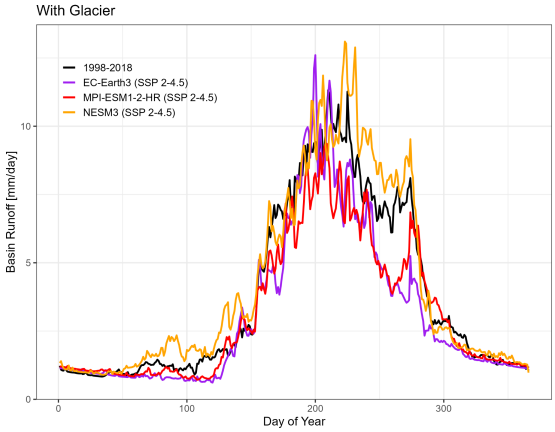
Figure 2: Modular structure of CRHM-glacier

(Pradhananga & Pomeroy, 2022)

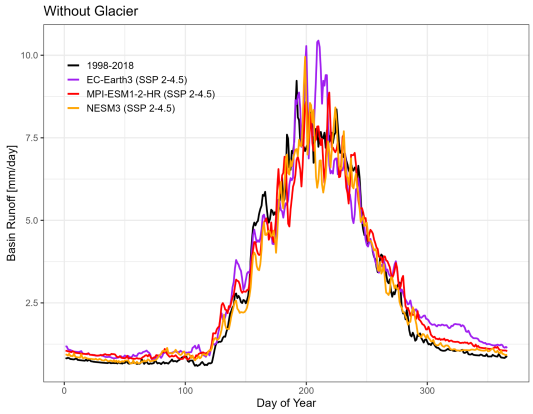
4. Result and Discussion

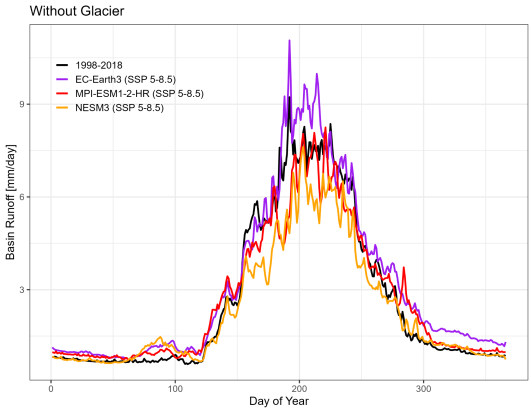
With and without glacier scenarios:





With Glacier	Wet)	Dry)	NESM3 (Warm Dry)
2 - 4.5	15.64%	16.39%	88.54%
5 - 8.5	1.44%	10.53%	7.27%





Without Glacier	EC-Earth3 (Cold Wet)	MPI-ESM1-2-HR (Cold Dry)	NESM3 (Warm Dry)
2 - 4.5	31.17%	27.20%	-8.42%
5 - 8.5	3.96%	11.67%	13.17%

5. Bio

Susa Manandhar is a dedicated Master's student at the Central Department of Hydrology and Meteorology, keen to understand the impacts of climate change on the cryosphere. With a keen interest in social interaction, inclusion, and scientific research, she explores how collaborative and inclusive approaches can drive meaningful outcomes in her field. Susa's work is driven by a passion for leveraging diverse perspectives to enhance the understanding and mitigation of climate-related challenges, aiming to contribute to sustainable and impactful solutions for the environment.

Bio of B.Sc Students

Ashok Ghimire is a final year undergraduate student at Tri-Chandra Multiple Campus, Kathmandu, Nepal majoring “Bachelors in Meteorology”. He is currently working on research titled “Assessing the Accuracy of MERRA-2 Temperature Data in High Altitude Regions: A Case Study of the Langtang Basin” as a part of his curriculum. His interest towards climatic models and hydrology has driven him to purse his degree in meteorology. Along with academics, his hobbies include playing football, cricket, badminton, & table tennis and travelling to new places. He aspires to become a leading researcher in the field of meteorology and hydrology focused on learning about climatic models and impacts of climate change on glaciers.

Aakriti Dhakal is an undergraduate student currently pursuing her bachelor’s degree in meteorology from Tri-Chandra Multiple Campus. She is now working on the research topic “PERFORMANCE EVALUATION OF ERA5 REANALYSIS DATASET FOR TEMPERATURE VARIABLE IN LANGTANG BASIN”. She has an interest in the field of science particularly in hydrology and meteorology. Apart from study, she loves listening to music and travelling. She shows interest in learning about the weather and climate-related phenomena and its impact on day to day lifestyle of the people and glaciers.

Sushant Dhital is a fourth-year student at Tri Chandra Campus, majoring in Bachelor in Meteorology. Interest in climate change and environmental problems is what led him to pursue Meteorology for his study. In addition to his learning endeavor, Sushant actively engages in spreading his scientific knowledge, bridging the gap between academia and practical application with a part-time role as a science teacher at Saipal Academy. His role as a science teacher enables him to share insights of his study with the students, fostering a broader understanding of the subject. Beyond academics and the classroom, His hobbies

include singing, traveling, and playing the guitar. He is currently involved in a research project as a part of his curriculum on the topic "Study of Temperature Trends and Variability in the Langtang Basin Using WFDEI Reanalysis Data". In the future, he aspires to become a researcher

Yagya Karki is a dedicated student pursuing a B.Sc. in Meteorology at Tri-Chandra Multiple Campus. With a passion for understanding atmospheric phenomena, Yagya is currently delving into the intricate world of meteorological research. Recently, Yagya embarked on a significant project titled **"**Future Rainfall Prediction and Analysis**,"** in collaboration with Susa Sister. Recognizing the challenge of achieving 100% accuracy in weather prediction, they are exploring the potential of weather generators to forecast future precipitation data, particularly for agricultural purposes.

6. Knowledge Dissemination

Through a targeted workshop conducted by APN, I successfully imparted essential skills in climate data analysis to four Bachelor's students majoring in Meteorology. As a result, these students are now able to handle and interpret meteorological parameters. Mr. Ashok Ghimire, Mr. Sushant Dhital, and Ms. Akriti Pokhrel are leveraging advanced reanalysis datasets—MEERA-2, WFDEI, and ERA5 respectively—to investigate temperature trends and variability in the Langtang Basin using bias-corrected data. Additionally, Mr. Yagya Karki is generating past and future precipitation data utilizing the WECS-Gen Tool for a station in Morong. This initiative has empowered the students to undertake and complete their Bachelor's project work, showcasing their newly acquired expertise and contributing valuable insights to the field of climate science.