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# Preliminary hydrometeorological data analysis of the Kabul River basin, Afghanistan

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# Preliminary hydrometeorological data analysis of the Kabul River basin, Afghanistan

**Authors**

Tika Ram Gurung, Anushilan Acharya,
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# Contents

# Executive summary

One of the main objectives of the Strengthening Water Resources Management in Afghanistan (SWaRMA) project is to build cryosphere monitoring capacities in Afghanistan with an overall objective of creating the base for a sustainable, long-term cryosphere monitoring programme. Evaluating the available data on hydrometeorological variables in catchments where snow and glaciers exist is an integral part of such a monitoring programme.

This study has conducted a basic investigation of hydrometeorological data to observe the climatological and hydrological regimes in the Kabul River basin (KRB). It identifies the temporal and spatial gaps in the available data pertaining to precipitation, temperature, relative humidity, and river discharge in the KRB. We analyse this data from 19 hydrological stations and 17 meteorological stations in the KRB since 2002 and 2008, respectively.

The distance of the nearest meteorological station from one of the previously identified potential benchmark glaciers (the Pir Yakh glacier) is as much as 93 kilometres. Eight potential benchmark glaciers were identified, relying on remote sensing analysis done jointly with SWaRMA partners based on the recommendations of the World Glacier Monitoring Service (WGMS).

The data gaps vary across stations for each variable, ranging from 0% to 85% through the observation period. Among the eight sub-basins of the Kabul River basin studied, Upper Panjshir basin has the least temporal data gaps compared to other stations.

Alingar, Upper Panjshir, and Kunar sub-basins are covered by glaciers, but the hydrometeorological data of only Upper Panjshir and Kunar sub-basins were available. Thus, our basic analysis of the available data focused on those two glaciated catchments. The relationship between temperature and humidity shows a stronger negative correlation in the Upper Panjshir than the Kunar sub-basin and it is attributed to the slope of the sites. There is more diurnal temperature variability during spring and autumn than in the other seasons. The frequency and intensity of precipitation vary a lot from station to station in both glaciated catchments. The hydrographs of three stations, one each from two glacierized catchments and one from the main outlet of the Kabul River basin, show the different peak flows and rising limbs. This might be due to the lag time of snow and glacier melt in the upper catchments.

The available hydrological and meteorological data set is very crucial for understanding the climatic conditions of the KRB. But these stations and the available data from them are not enough to capture the spatial and temporal variability and altitudinal gradients of climate–glacier interactions in such a large basin. In addition, these stations are located far from the glaciers, and at lower altitudes than the glaciers. All the stations are situated below an elevation of 2,300 metres above sea level (masl ) whereas the basin's elevation ranges from 387 masl to 7,603 masl. Thus, there is an urgent need to set up high-altitude meteorological stations near the potential benchmark glaciers in different climatic zones in order to establish a comprehensive, long-term glacier monitoring programme in the KRB. This would help to understand the interactions between local climate and glaciers and to determine the controlling factors underlying glacier and snow cover changes in the region. Adequate resources should be allocated to maintain the current stations and install new stations in the future to ensure the sustainability of long-term glacier monitoring in Afghanistan.

KEY MESSAGES

Glacier monitoring helps one understand important aspects of the current climate change context because glacier melt and other changes to a glacier are considered among the best indicators of climate change. Such studies also aid the calibration and validation of downscaled climate models, which ultimately improves our understanding of hydrological processes, snow/glacier melt, and water resources in the region.

SECTION I

# Introduction

In this report, we assess the hydrometeorological data available for the Kabul River basin and identify temporal and spatial data gaps.

The Strengthening Water Resources Management in Afghanistan (SWaRMA) project aims at co-creating learning opportunities to strengthen water resources management with the goal of assessing water resources at various levels, and aiding cryosphere and flood monitoring at the community level in Afghanistan. It is a two-year project supported by the governments of Australia and Afghanistan, and implemented by the International Centre for Integrated Mountain Development (ICIMOD), Kathmandu and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Canberra. Cryosphere monitoring is one of the seven thematic working areas of SWaRMA and focuses on establishing a sustainable and long-term cryosphere monitoring programme in Afghanistan. As part of such a monitoring programme, in the high mountains, assessing the meteorological variables and water drainage in the vicinity of snow and glaciers is a prerequisite condition (Shea et al. 2015).

Contributions to river run-off from glacier melt, snowmelt, and rainfall varies within the region, and are driven by the terrain's characteristics and atmospheric circulation above it (Lutz, Immerzeel, Shrestha, & Bierkens 2014). Glacier monitoring helps one understand important aspects of the current climate change context because glacier melt and other changes to a glacier are considered among the best indicators of climate change. Such studies also aid the calibration and validation of downscaled climate models, which ultimately improves our understanding of hydrological processes, snow/glacier melt, and water resources in the region.

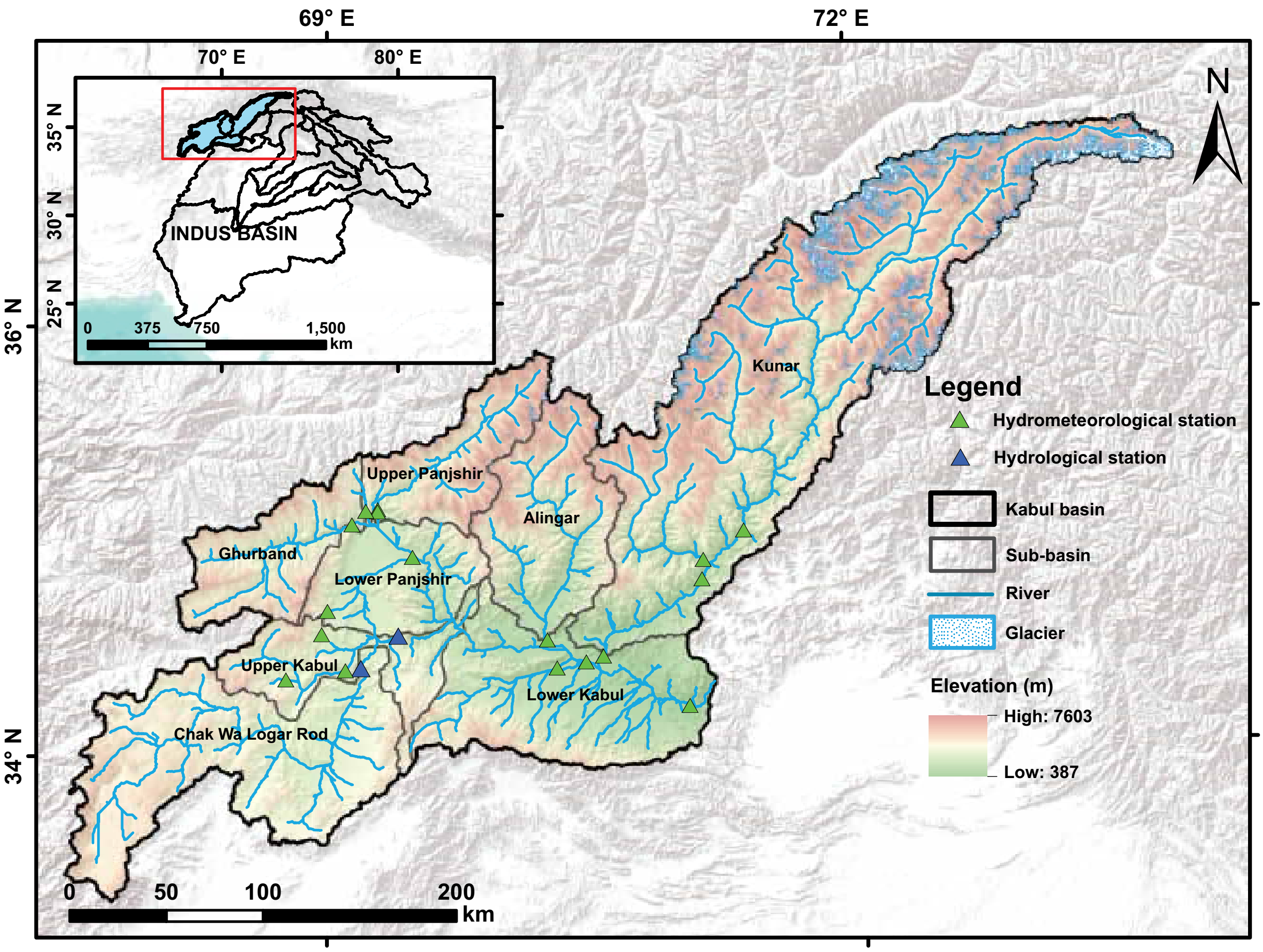
However, it is a challenge to collect long-term, high quality hydrometeorological data in high-altitude mountain regions. This is why any data that is available from near a glaciated region needs to be assessed for glacier change analyses and the planning of a suitable hydrometeorological monitoring network. In this report, we have assessed the hydrometeorological data available for the Kabul River basin (KRB) and identified temporal and spatial data gaps. In addition, a basic analysis of the available hydrometeorological data has been carried out for the KRB.

## 1.1 Study area

The Kabul River basin lies in the upper part of the Indus basin, and extends from 330 N to 370 N and 670 E to 740 E (Figure 1). It has eight major sub-basins, which were chosen for the present hydrometeorological study. The total drainage area of the KRB is 69,713 square kilometres ($km^2$) and its elevation ranges from 387 metres (m) to 7,603 m based on the Shuttle Radar Topography Mission Digital Elevation Model (SRTM DEM). Among the eight sub-basins in the KRB, the Kunar sub-basin is at the highest elevation and Lower Kabul sub-basin at the lowest. There are only three glaciated sub-basins – Alingar, Kunar, and Upper Panjshir.

The KRB experiences a semi-arid and continental type of climate, with major fluctuations in daytime and night-time temperatures. The maximum air temperature occurs during June–August and the minimum temperature during November–February (Sidiqi, Shrestha, & Ninsawat 2018). Seasonally, most of the precipitation falls in the winter season but April is the wettest month. Very little precipitation is observed in summer, with June–September being the driest months.

**FIGURE 1** LOCATION OF HYDROMETEOROLOGICAL AND HYDROLOGICAL STATIONS IN THE KABUL RIVER BASIN



KEY MESSAGES

Data from 17 hydrometeo-rological stations in the Kabul River basin were examined. In addition, data from two operational hydrological stations (without meteorological stations) are also analysed.

SECTION II

# Information from the hydrometeo-rological stations

The meteorological stations continuously measure temperature, precipitation, and relative humidity in the basin.

This report examines the available data from 17 hydrometeorological stations in the KRB (Figure 1). In addition, data from two operational hydrological stations (without meteorological stations) are also analysed. The names of all these 19 stations, with their geographical location, are presented in Table 1. The meteorological stations continuously measure temperature, precipitation, and relative humidity in the KRB. The technical specifications of each parameter are presented in Table 2. The first meteorological station was established in 2008 and the latest started in 2012. The hydrological stations were started in 2002 (Table 4).

## Spatial distribution of stations: Distance from potential benchmark glaciers

Of the eight sub-basins covered in this study, only three – Alingar, Upper Panjshir and Kunar – have some partial glacier coverage. However, there is no hydro-meteorological data available from Alingar sub-basin, whereas Upper Panjshir and Kunar have three hydrometeorological stations each. As this report focuses on hydrometeorological data relevant for cryosphere monitoring in the KRB, a detailed hydrometeorological data analysis is carried out for these two sub-basins. In addition, mean hourly air temperature, precipitation, and daily river discharge data of the other stations will also be discussed.

Figure 2 shows the distances of stations in the KRB from the nearest potential benchmark glaciers identified jointly with SWaRMA partners based on WGMS recommendations and international practices. Potential benchmark glaciers (Table 3) and possible

| **TABLE 1** | **LOCATION OF THE HYDROLOGICAL AND HYDROMETEOROLOGICAL STATIONS IN THE KABUL RIVER BASIN** |
|---|---|

| Station | Station type | Latitude (DD) | Longitude (DD) | Elevation (masl) | Sub-basin |
|---|---|---|---|---|---|
| Tang-i-Ghara | Hydrological | 34.569881 | 69.402169 | 1,775 | Upper Kabul |
| Sang-i-Nawestha | | 34.418189 | 69.191131 | 1,813 | Chak Wa Logar Rod |
| Dakah | Hydrometeorological | 34.230706 | 71.03855 | 419 | Lower Kabul |
| Pul-i-Behesod | | 34.442347 | 70.459831 | 555 | Lower Kabul |
| Pul-i-Kama | | 34.468706 | 70.557031 | 558 | Lower Kabul |
| Pul-i-Qarghayi | | 34.546978 | 70.242489 | 643 | Lower Kabul |
| Sultanpor | | 34.415669 | 70.295842 | 686 | Lower Kabul |
| Nawabad | | 34.819692 | 71.120319 | 796 | Kunar |
| Changhasarai | | 34.909269 | 71.128836 | 847 | Kunar |
| Asmar | | 35.0426 | 71.3613 | 950 | Kunar |
| Pul-i-Shokhi | | 34.936167 | 69.484394 | 1,374 | Lower Panjshir |
| Bagh-i-Omomi | | 35.148797 | 69.287542 | 1,587 | Upper Panjshir |
| Pul-i-Ashawa | | 35.0888 | 69.141886 | 1,624 | Ghurband |
| Tang-i-Gulbahar | | 35.159328 | 69.288683 | 1,625 | Upper Panjshir |
| Bagh-i-Lala | | 35.151761 | 69.220511 | 1,698 | Upper Panjshir |
| Tang-i-Sayedan | | 34.408975 | 69.104411 | 1,870 | Upper Kabul |
| Shakardara | | 34.685486 | 69.003619 | 2,168 | Lower Panjshir |
| Qala-i-Malek | | 34.577458 | 68.970103 | 2,211 | Upper Kabul |
| Pul-i-Surkh | | 34.366842 | 68.769653 | 2,216 | Upper Kabul |

Note: DD = decimal degrees; masl = metres above sea level

| **TABLE 2** | **TECHNICAL SPECIFICATIONS OF THE PRECIPITATION, TEMPERATURE, AND RELATIVE HUMIDITY SENSORS IN THE HYDROMETEOROLOGICAL STATIONS** |
|---|---|

| Sensor | Technical specification |
|---|---|
| Precipitation | Both the rainfall and snowfall measurement gauges were simple, consisting of a weighing bucket system equipped with an antifreeze reservoir and overflow device<br>**Material:** UV resistant plastic or corrosion resistant metal (aluminum, stainless steel); shock and vibration resistant<br>**Collecting funnel area:** 314 $cm^2$<br>**Capacity:** minimum 600 mm (water equivalent), with deep vertical walls to allow for the accumulation of snow<br>**Accuracy:** ± 0.2 mm; 2% of intensity (over a period of 15 minutes); expected resolution 0.2 mm<br>**Weighing principle:** drift-free sensor; influence of wind eliminated by appropriate software algorithm |
| Temperature | Resistance type (PT100) or thermostat for temperature with radiation shield<br>**Range:** -40°C to +60°C<br>**Accuracy:** ± 0.3°C or better<br>**Resolution:** 0.1°C |
| Relative humidity | Capacitive hygrometer<br>**Range:** 5%–100% R. H.<br>**Accuracy:** ± 3% R. H.<br>**Resolution:** 0.5% |

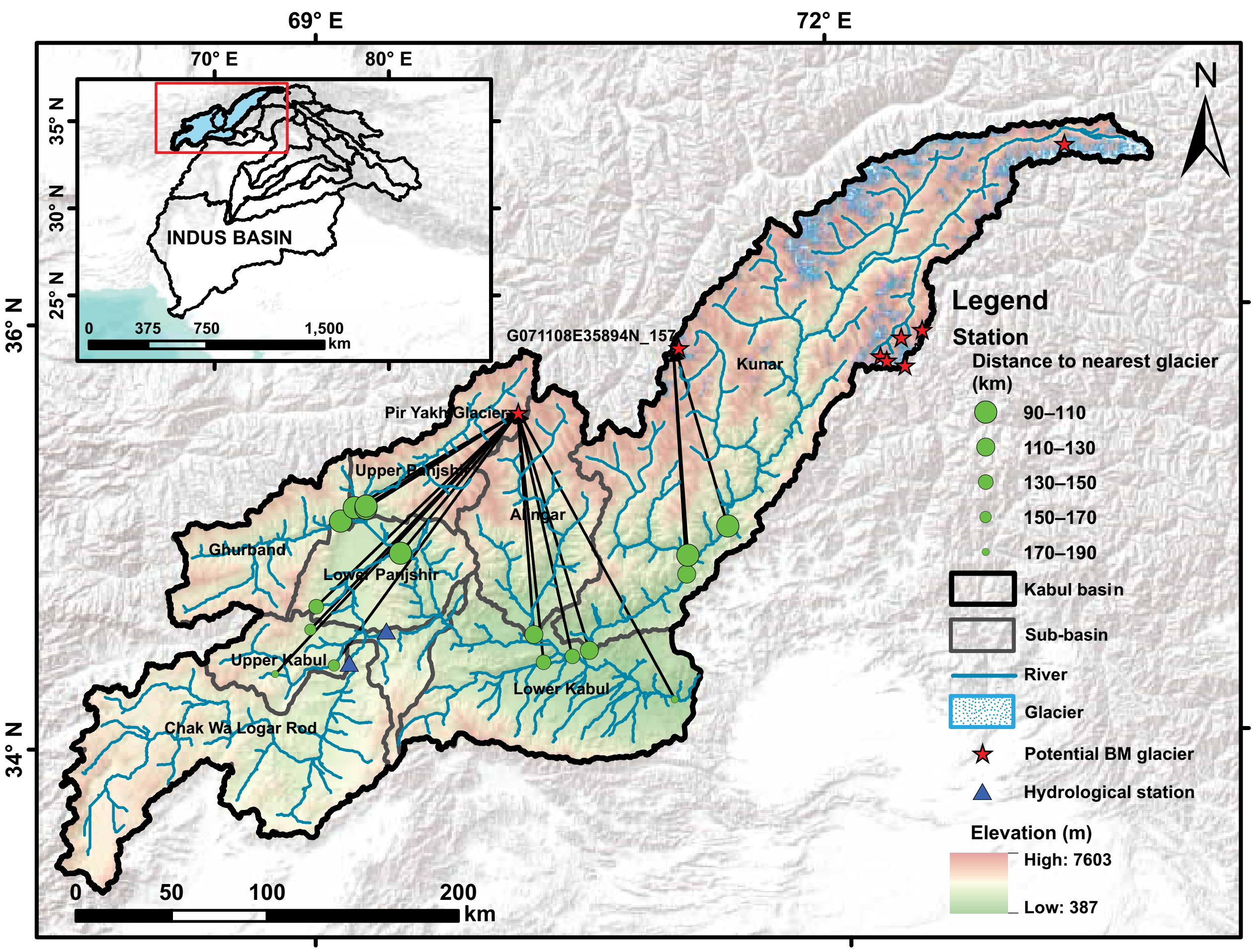
research sites were identified on the basis of their elevation range, area, historical data availability, and accessibility (Kaser et al 2003) as listed in Table 3. Two glaciers – G070170E35597N_52 (locally referred to as Pir Yakh, meaning 'old ice' in Persian) in the Upper Panjshir basin and GLIMS ID G07113E35885N_157 in the Kunar sub-basin (Bajracharya et al. 2015) – are the nearest to most of the meteorological stations in the KRB.

Tang-i-Gulbahar station is the nearest, at 93 km, whereas Pul-i-Surkh station lies at the farthest distance (186 km), from the Pir Yakh glacier.

**TABLE 3** LIST OF POTENTIAL BENCHMARK GLACIERS IN THE KRB

| S.N | Global Land Ice Measurements | Latitude | Longitude | Minimum elevation (masl) | Maximum elevation (masl) | Area (km²) |
|---|---|---|---|---|---|---|
| 1 | G072405E35772N_162 | 35.772 | 72.405 | 4200 | 4989 | 2.559 |
| 2 | G072266E35822N_459 | 35.822 | 72.266 | 4596 | 5151 | 2.4 |
| 3 | G07113E35885N_157 | 35.885 | 71.113 | 4723 | 5890 | 7.99 |
| 4 | G072390E35910N_438 | 35.91 | 72.39 | 4647 | 5390 | 2.686 |
| 5 | G072511E35938N_476 | 35.938 | 72.511 | 4455 | 5205 | 5.029 |
| 6 | G072304E35803N_575 | 35.803 | 72.304 | 4595 | 5508 | 4.333 |
| 7 | G073387E36790N_110 | 36.79 | 73.387 | 4358 | 4939 | 3.363 |
| 8 | G070170E35597N_52 | 35.597 | 70.17 | 4424 | 4924 | 1.04 |

**FIGURE 2** DISTANCE FROM METEOROLOGICAL STATIONS TO THE NEAREST POTENTIAL BENCHMARK GLACIERS

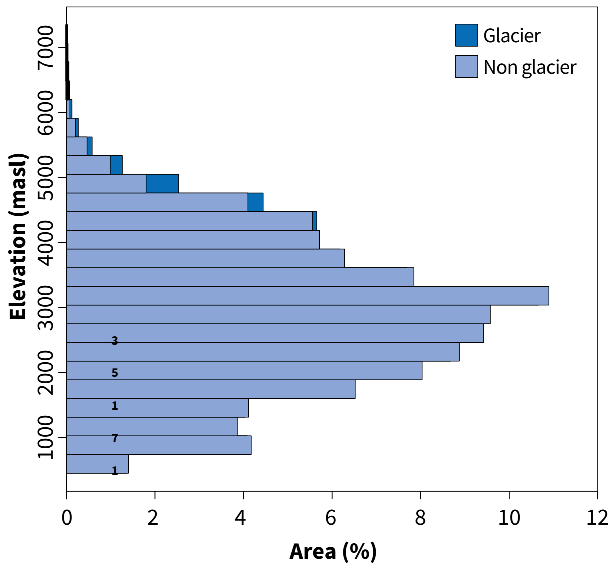


## Hypsometry

Only about 3% of the total drainage area of the KRB is glaciated. The glaciated region is located above an altitude of 3,000 masl. However, most of the glaciers lie between 4,800–5,300 masl (Figure 3).

The elevation of the meteorological stations from where we got the data ranges from 419 masl (Dakah) to 2,216 masl (Pul-i-Surkh). Figure 3 shows the number of meteorological stations at different elevation bands. Most of the existing meteorological stations (82%) are located below 2,000 masl whereas the surface area of the basin below 2,000 masl constitutes only 27% of its total area.

**FIGURE 3** **HYPSOMETRY OF THE KABUL RIVER BASIN SHOWING THE GLACIATED AND NON-GLACIATED AREAS, AND THE NUMBER OF METEOROLOGICAL STATIONS AT DIFFERENT ELEVATION BANDS**



KEY MESSAGES

The discharge data is only available at time intervals of 4 or 8 hours at different stations. The are data gaps across stations for each variable, ranging from 0% to 85% through the observation period.

SECTION III

# Data availability

Data pertaining to air temperature, precipitation, and relative humidity is available at 15-minute intervals from 17 stations.

Data pertaining to air temperature, precipitation, and relative humidity is available at 15-minute intervals from the 17 stations. The discharge data is only available at time intervals of 4 or 8 hours at different stations. Issues with maintenance mean that there are temporal data gaps in almost all the stations. Detailed information on the time series and data gaps is presented in Table 4.

The Pul-i-Shokhi hydrological station was the first station to be established in the KRB, in March 2002. Pul-i-Ashawa was the first meteorological station to be established, in May 2008, and has a data gap of 16% for all meteorological variables. Tang-i-Sayedan is the latest one established, in December 2012, and has at least a 30% data gap in all meteorological variables. Overall, Shakardara, Tang-i-Sayedan, Pul-i-Surkh, Asmar, Qala-i-Malek, and Sultanpor stations are missing more than 30% meteorological or hydrological data, whereas Bagh-i-Lala and Pul-i-Qarghayi stations have less than a 10% data gap for all the variables.

## Glaciated sub-basins

There are three glaciated sub-basins in the KRB. They are Alingar, Upper Panjshir and Kunar. Data from six meteorological stations are available from two sub-basins, Panjshir and Kunar, three stations in each. There is no data available from the Alingar glaciated sub-basin. Detailed information on Kunar and Upper Panjshir sub-basins are discussed below:

### Kunar

The total area of the Kunar sub-basin is 25,917 $km^2$. It is the most densely glaciated sub-basin of the KRB, with a glacier area of 1,574 $km^2$. There are three hydrometeorological stations in the sub-basin – Nawabad, Changhasarai, and Asmar. The mean

**TABLE 4** TEMPORAL HYDROMETEOROLOGICAL DATA AVAILABILITY AND GAPS

| Station | Discharge | | Relative humidity | | Temperature | | Precipitation | | Missing data (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Starting date | End date | Starting date | End date | Starting date | End date | Starting date | End date | Dis | RH | Tem | Ppt |
| Pul-i-Shokhi | 21/03/2002 | 19/01/2017 | 02/12/2009 | 31/12/2013 | 02/12/2012 | 31/12/2016 | 06/12/2012 | 31/12/2016 | 0 | 5 | 5 | 11 |
| Tang-i-Ghara | 21/03/2005 | 19/02/2018 | – | – | – | – | – | – | 11 | – | – | – |
| Sang-i-Nawestha | 22/11/2005 | 19/01/2017 | – | – | – | – | – | – | 17 | – | – | – |
| Pul-i-Qarghayi | 21/03/2007 | 21/05/2018 | 24/07/2008 | 31/12/2016 | 24/07/2008 | 31/12/2016 | 25/07/2008 | 31/12/2016 | 8 | 1 | 1 | 5 |
| Nawabad | 21/03/2007 | 20/04/2015 | 02/09/2008 | 24/08/2015 | 01/09/2008 | 24/08/2015 | 09/09/2008 | 24/08/2015 | 5 | 16 | 17 | 16 |
| Changhasarai | 21/03/2007 | 21/06/2017 | 24/09/2008 | 31/12/2016 | 25/09/2008 | 31/12/2016 | 25/09/2008 | 31/12/2016 | 2 | 11 | 17 | 18 |
| Sultanpor | 21/03/2007 | 20/03/2017 | 05/11/2008 | 31/12/2016 | 05/11/2008 | 31/12/2016 | 30/03/2012 | 11/08/2015 | 31 | 26 | 26 | 5 |
| Dakah | 21/03/2007 | 20/11/2016 | 07/11/2009 | 19/12/2016 | 08/11/2009 | 19/12/2016 | 07/11/2009 | 19/12/2016 | 1 | 2 | 3 | 19 |
| Tang-i-Sayedan | 23/06/2007 | 20/03/2015 | 10/12/2012 | 29/06/2015 | 09/12/2012 | 28/06/2015 | 09/12/2012 | 06/28/2015 | 32 | 30 | 30 | 31 |
| Pul-i-Kama | 09/07/2007 | 11/01/2015 | 23/08/2008 | 23/08/2015 | 22/08/2008 | 22/08/2015 | 24/08/2008 | 23/08/2015 | 11 | 4 | 5 | 6 |
| Tang-i-Gulbahar | 23/08/2007 | 20/03/2015 | 09/05/2008 | 24/08/2015 | 09/05/2008 | 24/08/2015 | 05/08/2013 | 24/08/2015 | 3 | 15 | 16 | 2 |
| Asmar | 20/03/2008 | 20/12/2016 | 16/10/2008 | 24/12/2016 | 16/10/2008 | 24/12/2016 | 19/10/2008 | 24/12/2016 | 4 | 42 | 7 | 27 |
| Pul-i-Ashawa | 21/05/2008 | 20/03/2017 | 08/05/2008 | 31/12/2016 | 08/05/2008 | 31/12/2016 | 08/05/2008 | 31/12/2016 | 11 | 16 | 16 | 21 |
| Bagh-i-Omomi | 22/05/2008 | 20/03/2017 | 25/09/2008 | 31/12/2016 | 25/09/2008 | 31/12/2016 | 25/09/2008 | 31/12/2016 | 2 | 16 | 11 | 0 |
| Qala-i-Malek | 23/05/2008 | 20/03/2018 | 20/05/2008 | 01/04/2018 | 20/05/2008 | 01/04/2018 | 20/05/2008 | 01/04/2018 | 38 | 19 | 19 | 9 |
| Bagh-i-Lala | 22/10/2008 | 20/03/2017 | 08/12/2008 | 30/09/2016 | 09/12/2008 | 29/09/2016 | 08/12/2008 | 30/09/2016 | 9 | 0 | 1 | 0 |
| Pul-i-Behesod | 18/03/2009 | 19/01/2017 | 19/03/2009 | 24/10/2016 | 19/03/2009 | 24/10/2016 | 19/03/2009 | 24/10/2016 | 12 | 27 | 12 | 8 |
| Shakardara | 22/05/2009 | 20/03/2018 | 26/05/2009 | 02/04/2018 | 27/05/2009 | 02/04/2018 | 26/05/2009 | 02/04/2018 | 10 | 5 | 8 | 85 |
| Pul-i-Surkh | 24/01/2010 | 21/04/2018 | 21/04/2009 | 3003//2018 | 21/04/2009 | 30/03/2018 | 21/04/2009 | 27/11/2017 | 28 | 22 | 22 | 40 |

Note: Dis = Discharge; RH = Relative humidity; Tem = Air temperature; Ppt = Precipitation

hourly air temperature and precipitation recorded at each station are displayed in Figure 4, and the daily river discharge in Figure 5. All three stations have a less than 5% data gap regarding discharge, and a more than 10% gap regarding precipitation and temperature, except the temperature data of the Asmar station (7%).

### Upper Panjshir

The total area of the Upper Panjshir sub-basin is 4,266 km$^2$, of which 14.63 km$^2$ is covered with glaciers. It shares a boundary with the Alingar, Lower Panjshir, and Ghurband sub-basins. There are three hydrometeorological stations in this sub-basin – Tang-i-Gulbahar, Bagh-i-Lala, and Bagh-i-Omomi. The mean hourly air temperature and precipitation data from these stations are shown in Figure 6, and daily river discharge data in Figure 7. Among these stations, the precipitation data of the Bagh-i-Omomi and Bagh-i-Lala stations, and the river discharge data of Bagh-i-Lala display no data gaps, whereas the relative humidity data from Bagh-i-Omomi and the temperature data from Tang-i-Gulbahar have the largest gaps of 16% each.

## Non-glaciated sub-basins

There are five non-glaciated sub-basins in the KRB. They are Lower Kabul, Upper Kabul, Chak Wa Logar Rod, Lower Panjshir, and Ghurband. Information from all these non-glaciated sub-basins are discussed below:

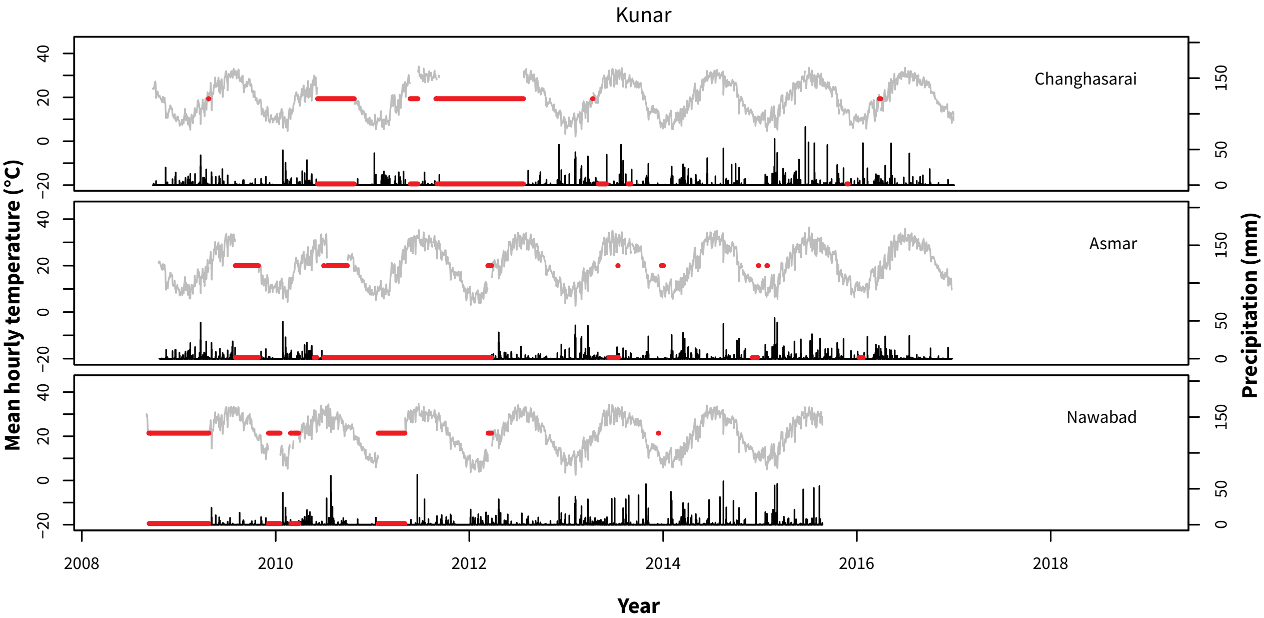
### Lower Kabul

The area of the Lower Kabul sub-basin is 9,050 km$^2$. It is surrounded by the Kunar, Alingar, Lower Panjshir, and Upper Kabul sub-basins. There are five hydrometeorological stations in this sub-basin – Pul-i-Qarghayi, Pul-i-Kama, Sultanpor, Pul-i-Behesod, and Dakah. The available mean hourly air temperature and precipitation data of each of these stations are displayed in Figure 8. Pul-i-Qarghayi has the smallest hydrometeorological data gap overall whereas Pul-i-Behesod has the largest data gap. In the case of daily river discharge data, Dakah has the smallest data gap at 1% whereas Sultanpor station has a 31% gap (Figure 9). Similarly, in the case of relative humidity, precipitation and temperature, Pul-i-Qarghayi has the least data gap.

## Upper Kabul

The Upper Kabul sub-basin is spread over 4,032 km$^2$ and surrounded by the Lower Kabul, Lower Panjshir, Ghurband, and Chak Wa Logar Rod sub-basins. It has three hydrometeorological stations and one purely hydrological station, Tang-i-Ghara. The mean hourly

**FIGURE 4** SUMMARY OF MEAN HOURLY TEMPERATURE (GREY) AND PRECIPITATION (BLACK) ALONG WITH DATA GAPS (RED DOTS) FOR ALL STATIONS IN THE KUNAR SUB-BASIN




Note: Due to issues related to maintenance, data from the Nawabad station is available only till 2015.

**FIGURE 5** DAILY RIVER DISCHARGE (GREY) ALONG WITH DATA GAPS (RED DOTS) FOR ALL STATIONS IN THE KUNAR SUB-BASIN

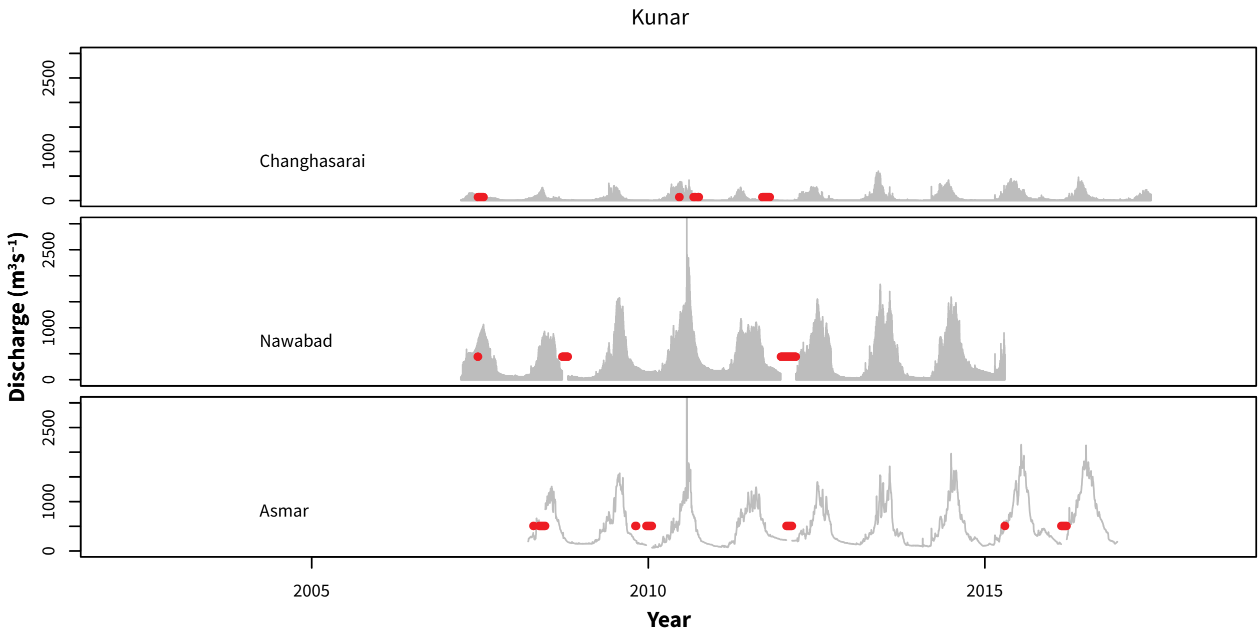


**FIGURE 6** MEAN HOURLY TEMPERATURE (GREY) AND PRECIPITATION (BLACK) ALONG WITH DATA GAPS (RED DOTS) FOR ALL STATIONS IN THE UPPER PANJSHIR SUB-BASIN

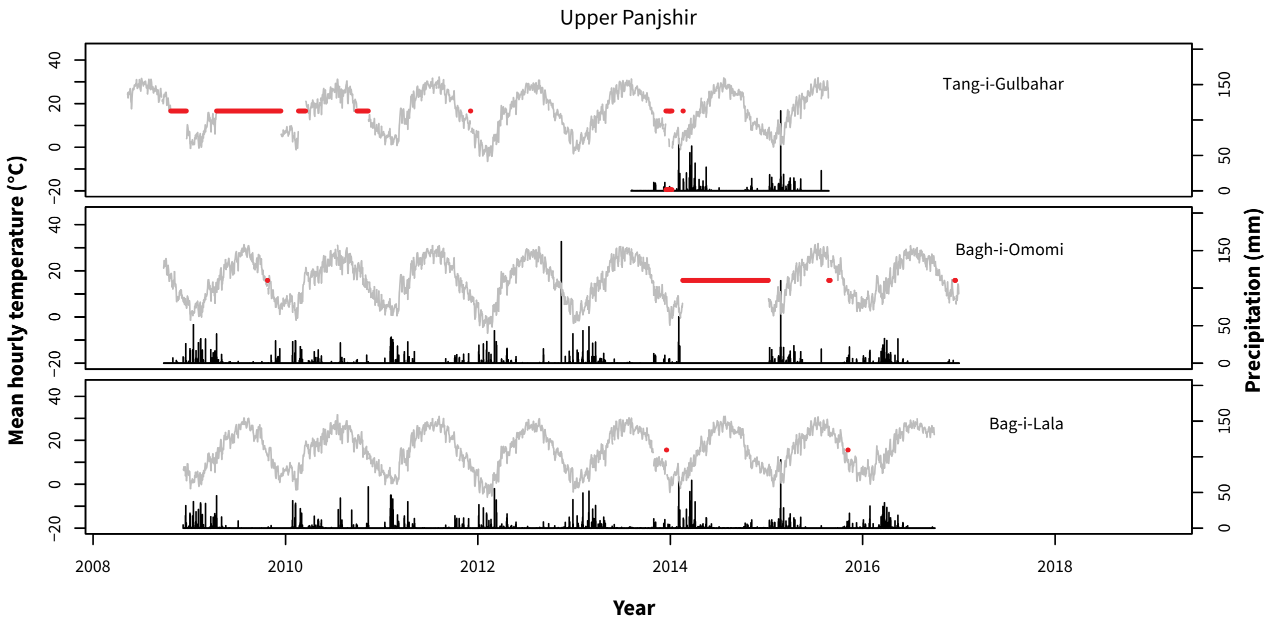
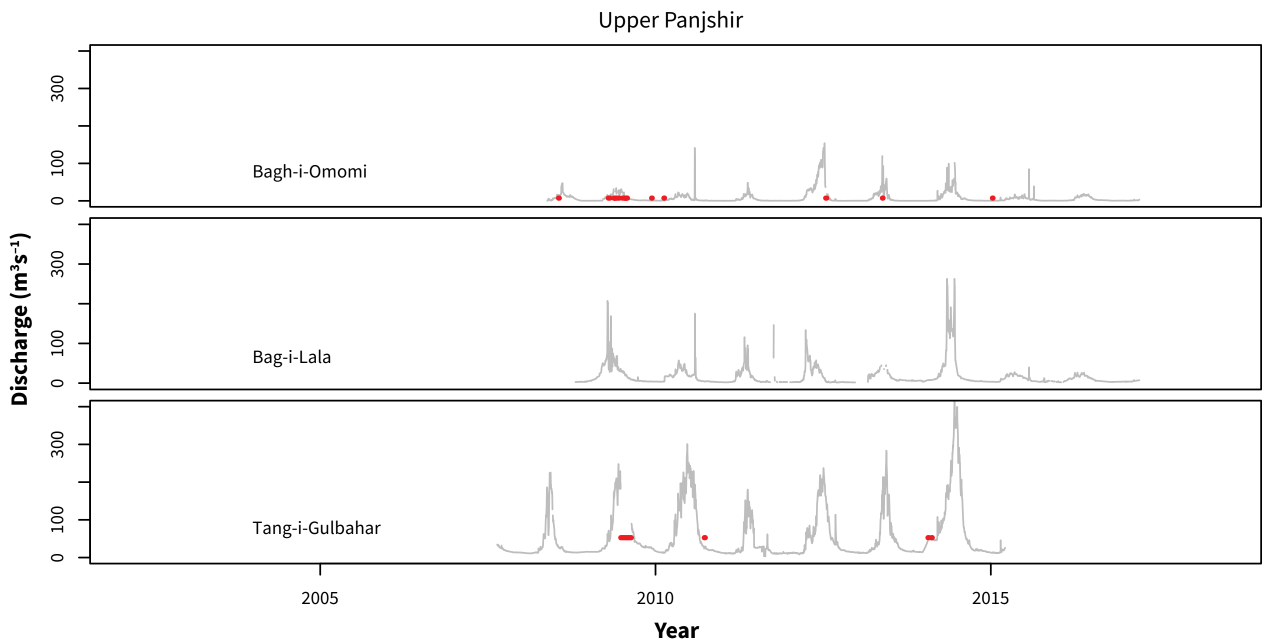



**FIGURE 7** DAILY RIVER DISCHARGE DATA (BLACK) ALONG WITH DATA GAPS (RED DOTS) FOR ALL STATIONS IN THE UPPER PANJSHIR SUB-BASIN




Note: Due to issues related to maintenance, data from the Tang-i-Gulbahar station is available only till 2015

**FIGURE 8** SUMMARY OF MEAN HOURLY TEMPERATURE (GREY) AND PRECIPITATION (BLACK) ALONG WITH DATA GAPS (RED DOTS) FOR ALL STATIONS IN THE LOWER KABUL SUB-BASIN

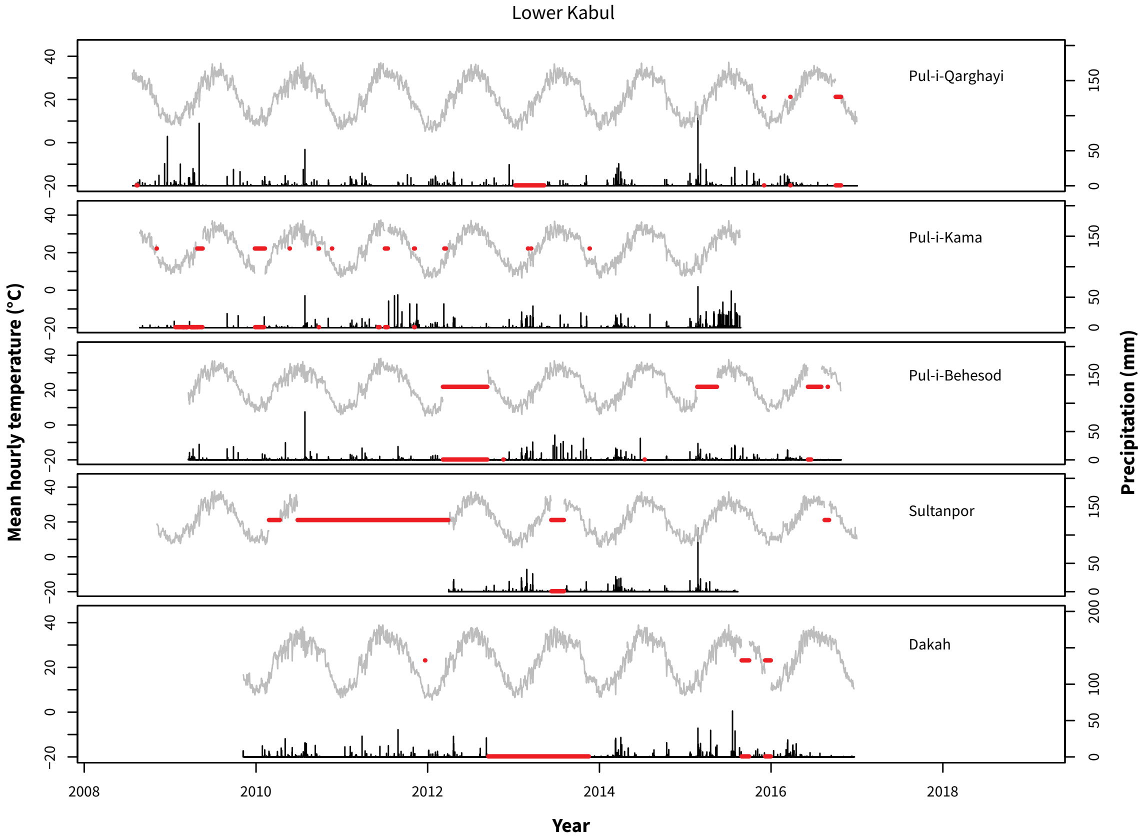
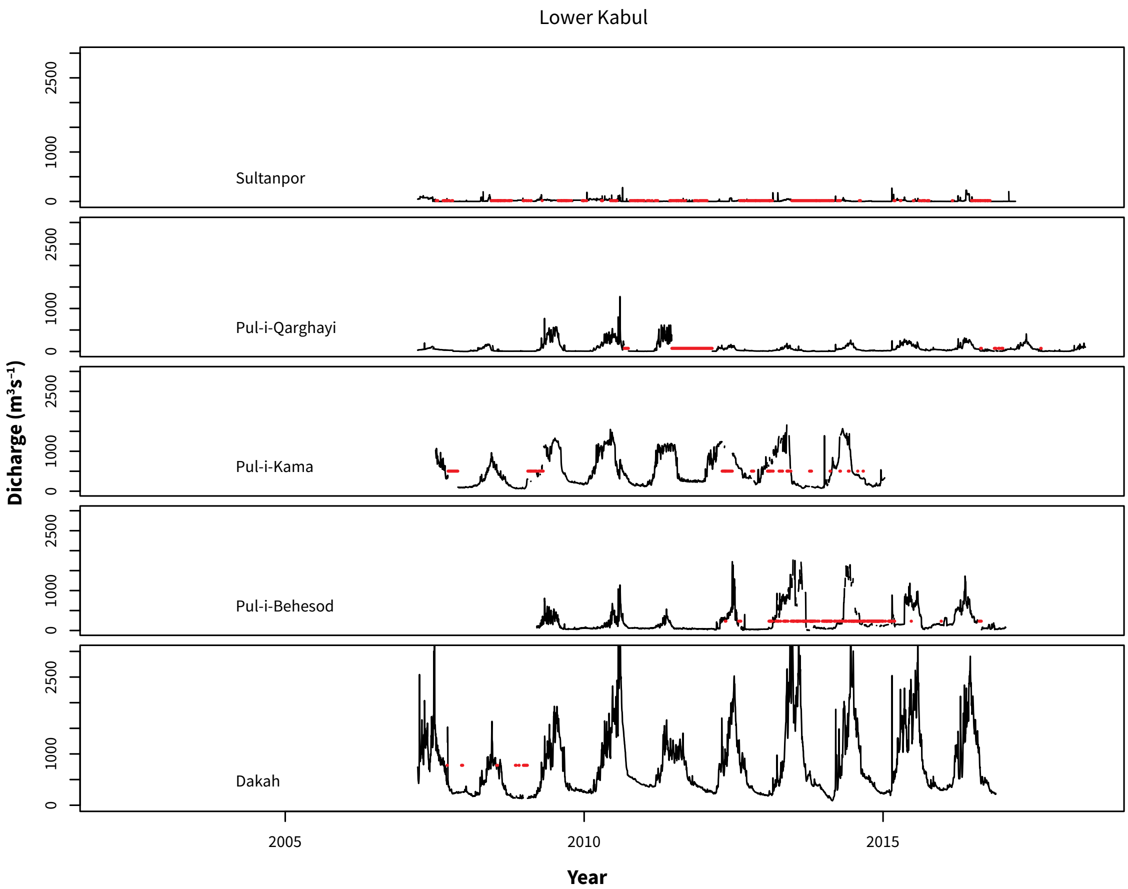



**FIGURE 9** DAILY RIVER DISCHARGE DATA (BLACK) ALONG WITH DATA GAPS (RED DOTS) FOR ALL STATIONS IN THE LOWER KABUL SUB-BASIN



air temperature and precipitation data of each station in the Upper Kabul sub-basin is displayed in Figure 10 and the daily river discharge data in Figure 11. There is, on average, a more than 20% data gap in all the data sets of the Upper Kabul sub-basin.

### Chak Wa Loger Rod

There is only one hydrological station in Chak Wa Loger Rod, Sang-i-Nawestha. It was established in 2005, and has a data gap of 17%. Its daily river discharge data for about a decade together with its data gaps are displayed in Figure 11 (bottom section).

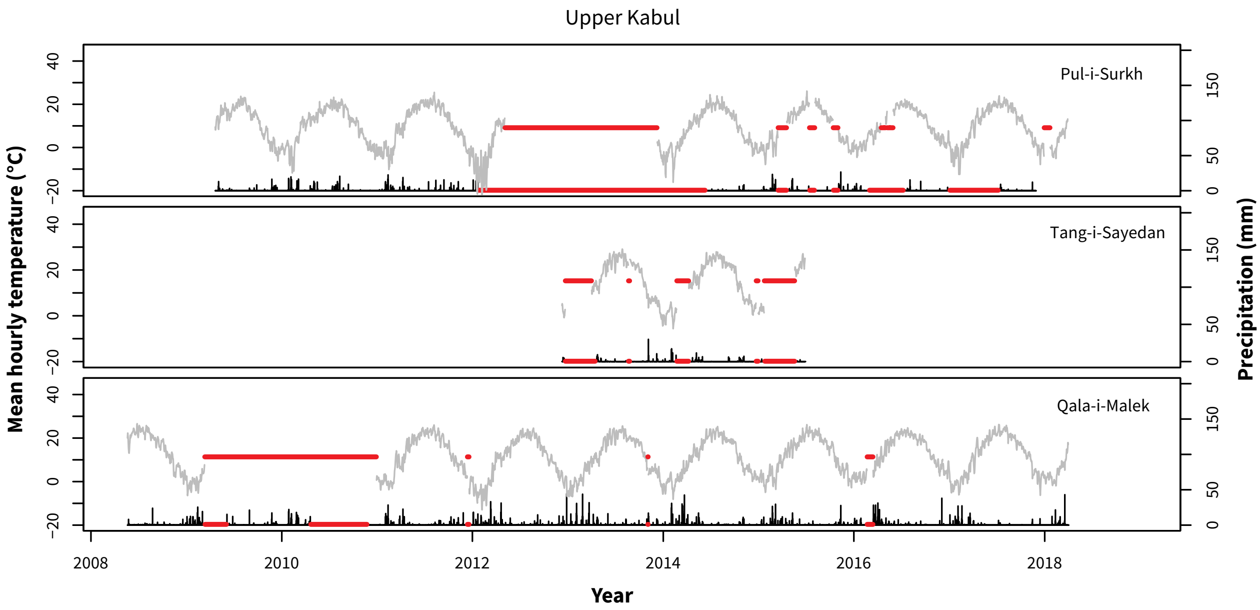
### Lower Panjshir

Lower Panjshir is located in the centre of the KRB and is surrounded by Upper Kabul, Ghurband, Upper Panjshir, and Alingar sub-basins. The sub-basin has two hydrometeorological stations, Shakardara and Pul-i-Shoki. The available data is presented in Figures 12 and 13. In the Shakardara station, temperature and discharge data have a gap of less than 10% whereas the precipitation data has a huge gap of 85%. This is the highest data gap in compare to all the existing precipitation data in the KRB. The next highest data gap is 40% in Pul-i-Surkh station, and most of the data gap of precipitation are not more than 20%.

### Ghurband

The area of the Ghurband sub-basin is 4,334 km$^2$ and it shares its boundary with Upper Panjshir, Lower Panjshir, and Upper Kabul sub-basins. There is data available from only one station in this sub-basin – Pul-i-Ashawa (Figure 12, bottom section). Pul-i-Ashawa is the oldest meteorological station among all those discussed in this study. The mean hourly air temperature, precipitation, and daily river discharge data of the Pul-i-Ashawa station are displayed in the bottom sections of Figures 12 and 13. The Pul-i-Ashawa data series has gaps of 16%, 16%, 21%, and 11% with regard to air temperature, relative humidity, precipitation, and river discharge respectively.

**FIGURE 10** SUMMARY OF MEAN HOURLY TEMPERATURE (GREY) AND PRECIPITATION (BLACK) ALONG WITH DATA GAPS (RED DOTS) FOR ALL STATIONS IN THE UPPER KABUL SUB-BASIN




Note: Due to issues related to maintenance, data from the Tang-i-Sayedan station is available only till 2015

**FIGURE 11** DAILY RIVER DISCHARGE (BLACK) ALONG WITH DATA GAPS (RED DOTS) FOR ALL STATIONS IN THE UPPER KABUL AND CHAK WA ROGER ROD SUB-BASINS

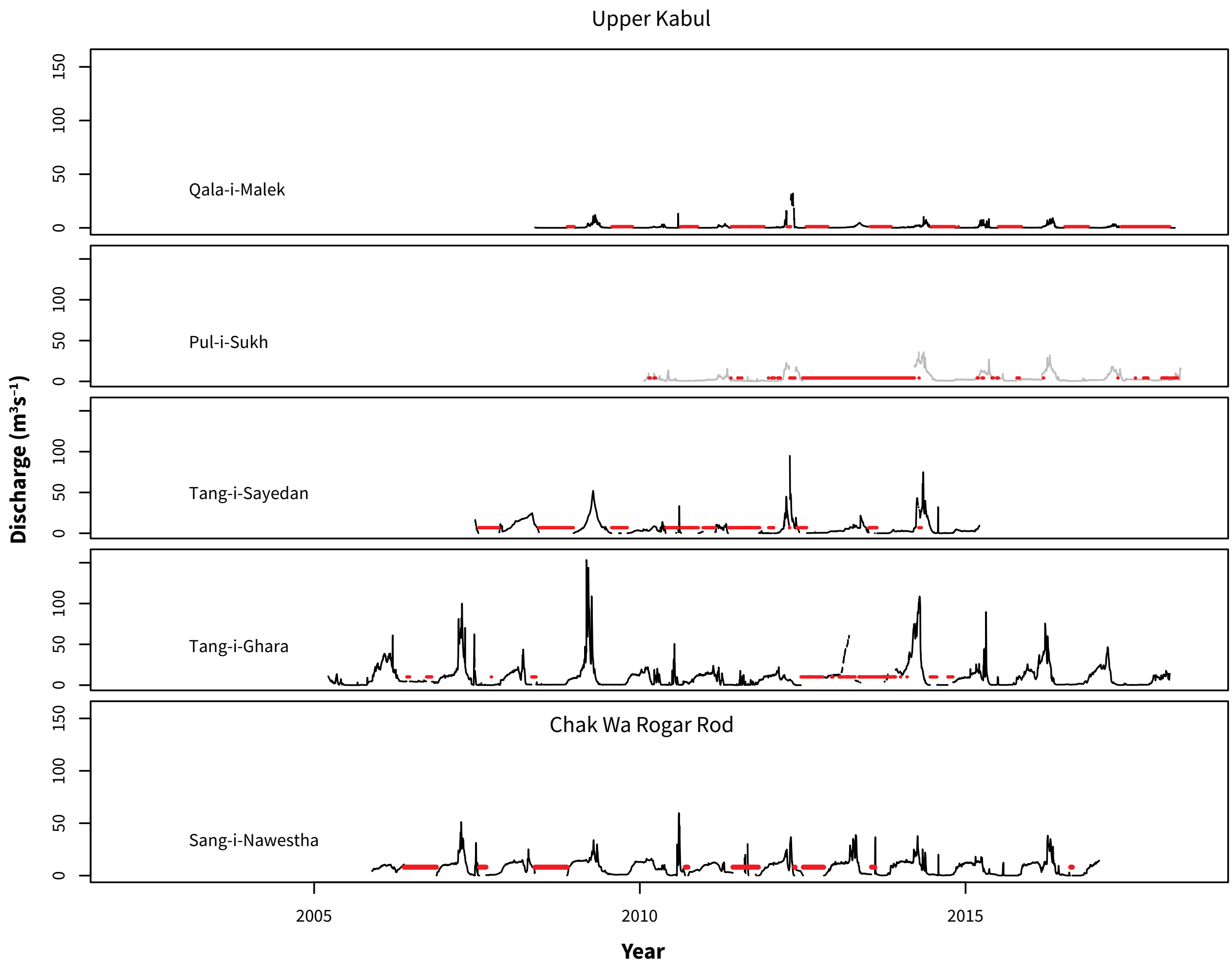



**FIGURE 12** SUMMARY OF MEAN HOURLY TEMPERATURE (GREY) AND PRECIPITATION (BLACK) ALONG WITH DATA GAPS (RED DOTS) FOR STATIONS IN THE LOWER PANJSHIR AND GHURBAND SUB-BASINS

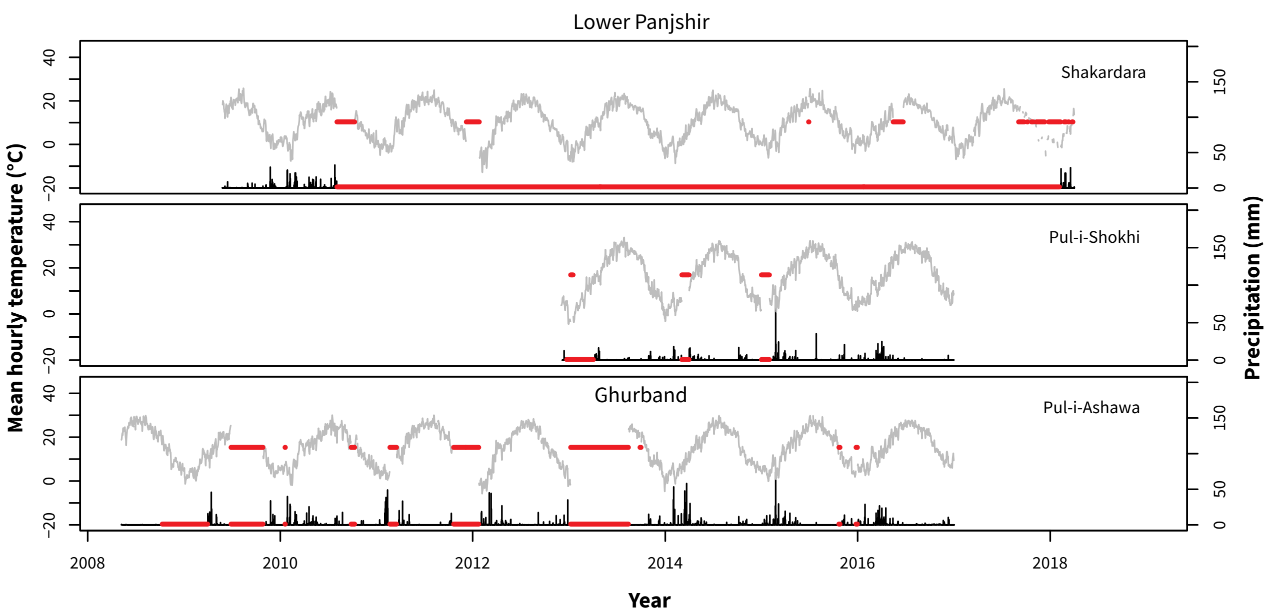
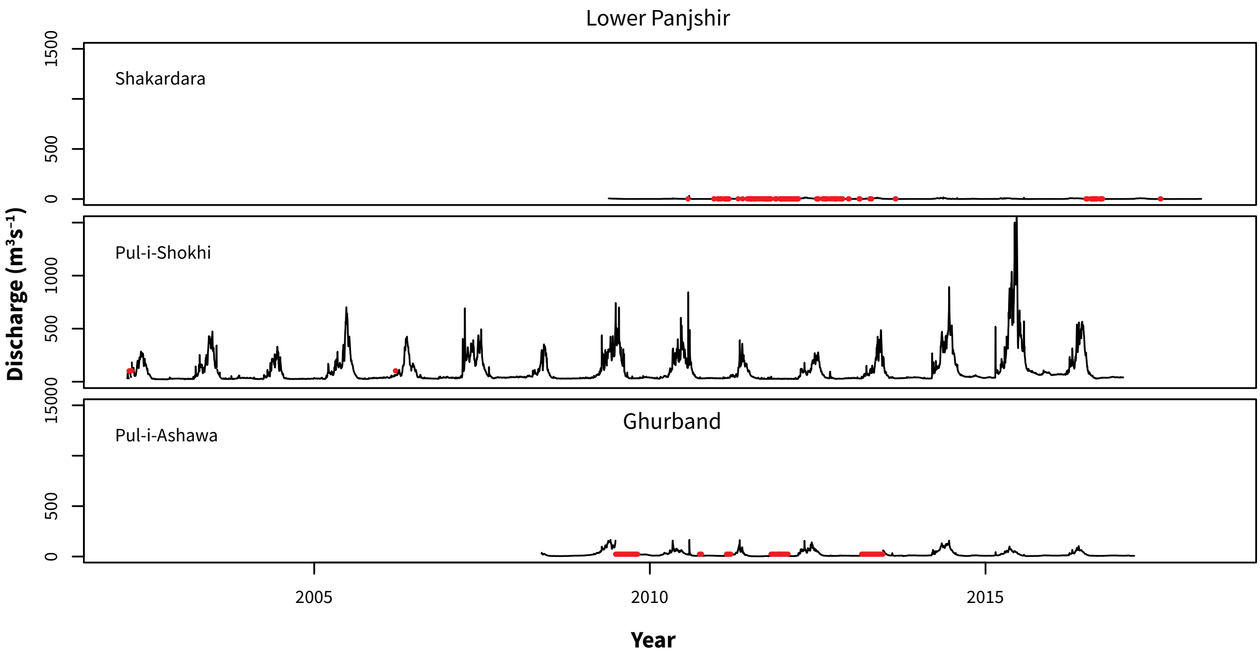


**FIGURE 13** DAILY RIVER DISCHARGE (BLACK) ALONG WITH DATA GAPS (RED DOTS) FOR STATIONS IN THE LOWER PANJSHIR AND GHURBAND SUB-BASINS



KEY MESSAGES

We inspect the relationship between air temperature and relative humidity, diurnal air temperature, and the frequency of precipitation and its intensity.

SECTION IV

# Analysis of hydro-meteorological data

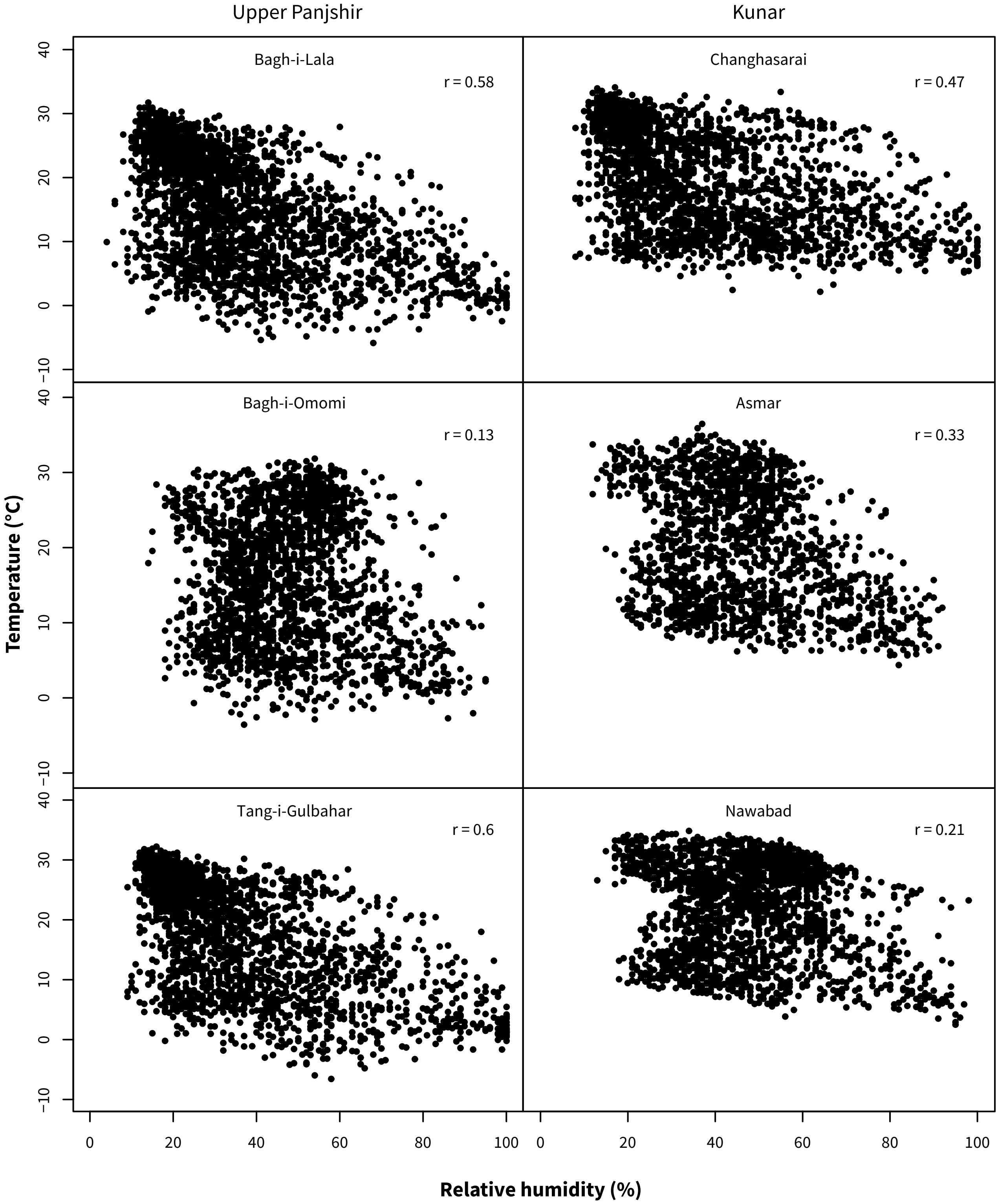
The analysis in this section is focused on the two glacierized catchments where hydrometeorological stations have been established.

This study has conducted a basic investigation of hydrometeorological data to observe the climatological and hydrological regimes in the Kabul River basin. The analysis in this section is focused on the two glacierized catchments where hydrometeorological stations have been established. The relationship between air temperature and relative humidity, diurnal air temperature, and the frequency of precipitation and its intensity are inspected. In the case of the river discharge data, one station from each glaciated catchment (Asmar and Tang-i-Gulbahar stations) and one from the Lower Kabul sub-basin (Dakah station), through which most of the river discharge of the KRB occurs, have been chosen for analysis.

## Temperature and relative humidity

Analyses of individual climatic variables and their relation to other variables from the same station as well as from other stations show the importance of data quality and also help in understanding the basin's characteristics. Investigation of the scatterplot of the relationship between temperature and relative humidity for two glaciated basins shows the two types of regimes (Figure 14). There is a strong negative correlation between temperature and relative humidity in Upper Panjshir whereas there is relatively no relation between the two in the Kunar sub-basin. In the Upper Panjshir sub-basin, temperature and relative humidity data indicate that the vapour pressure here is calmer than that in the Kunar sub-basin, while the air is cooling/warming. It might be the result of the stations being situated at lower slopes that are less exposed to wind. Similarly, in the Kunar

**FIGURE 14** RELATIONSHIP BETWEEN AIR TEMPERATURE AND RELATIVE HUMIDITY IN SIX STATIONS OF TWO GLACIERIZED SUB-BASINS, UPPER PANJSHIR AND KUNAR



sub-basin, the relationship between temperature and humidity suggests that there is limited air mixing due to the stations are being located in higher slopes . The flow of air upslope and downslope directly brings atmospheric moisture from the higher or lower elevations (Duane, Pepin, Losleben, & Hardy 2008).

## Diurnal temperature

We have analyzed the diurnal temperature data from stations in Upper Panjshir and Kunar based on the seasons. Spring is from March to May, the summer season starts in June and ends in August, autumn spans September to November, and winter from December to February. The mean diurnal cycles of temperature for each season on the basis of available data are presented in Figure 15.

The Figure 15 shows a high diurnal variability in spring and autumn. It might be attributed to the pleasant weather conditions. It is observed that summer and winter have relatively less variability, due to the fact that it is often cloudy during these seasons, resulting in frequent precipitation.

## Precipitation

Total glacier melt in the high altitudes is governed, among other factors, by the timing and magnitude of precipitation, as precipitation here is highly dependent upon air temperature. The frequency of precipitation is the highest during the late afternoon (Figure 16) whereas a minimal frequency occurs until 10 am in both the glaciated sub-basins of the KRB during all seasons. The frequency of precipitation also gradually decreases after 8 pm in these sub-basins. In both the Kunar and Upper Panjshir sub-basins, the frequency of precipitation throughout the day is lower during the summer season as compared to the autumn and winter seasons.

There is no clear pattern to the intensity of precipitation for all stations during all seasons (Figure 16). The intensity of precipitation is the highest during different seasons in different sites. For example, it is 8 mm an hour at Tang-i-Gulbahar in the summer season and, similarly, 8 mm an hour at Nawabad during the winter season. It seems that most stations receive highly intense precipitation during the morning (8–11 am) through the year, barring in

**FIGURE 15** MEAN (SOLID) AND STANDARD DEVIATION (SHADED) DIURNAL CYCLE OF AIR TEMPERATURE IN KUNAR AND UPPER PANJSHIR SUB-BASINS DURING AUTUMN, WINTER, SPRING, AND SUMMER

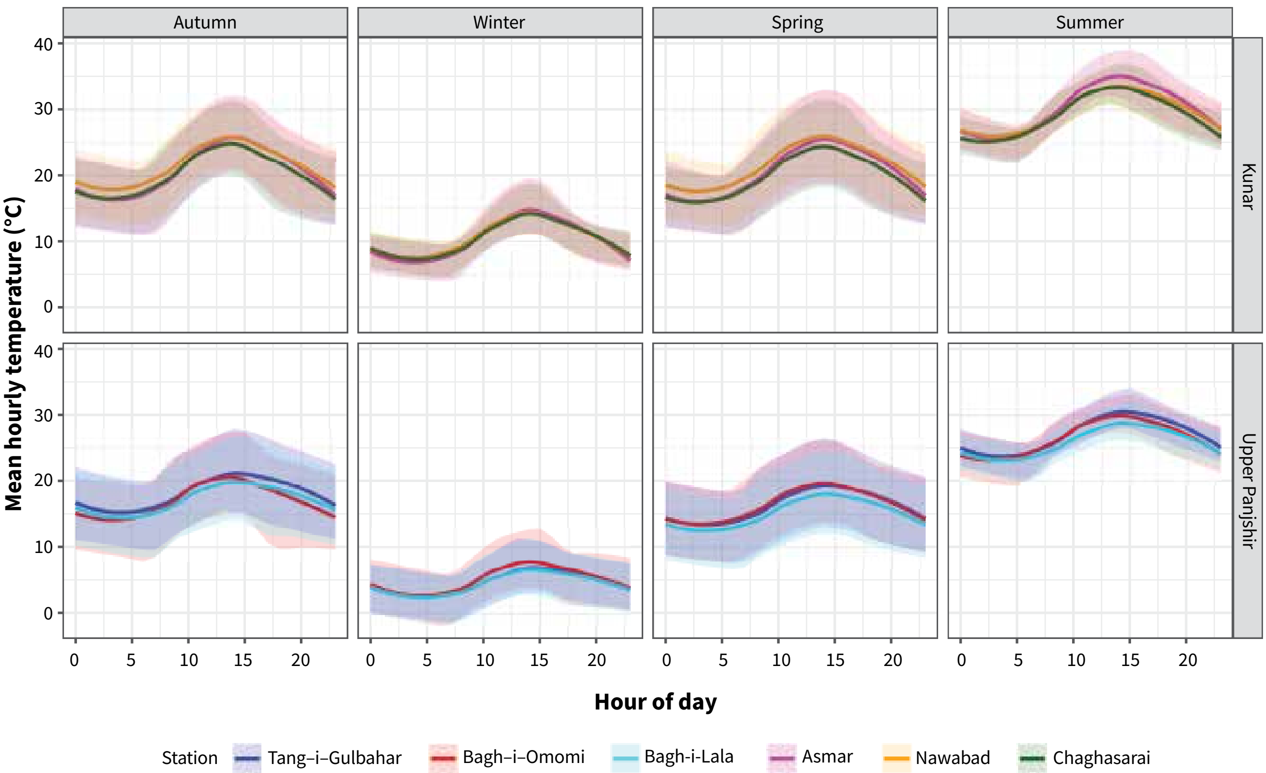
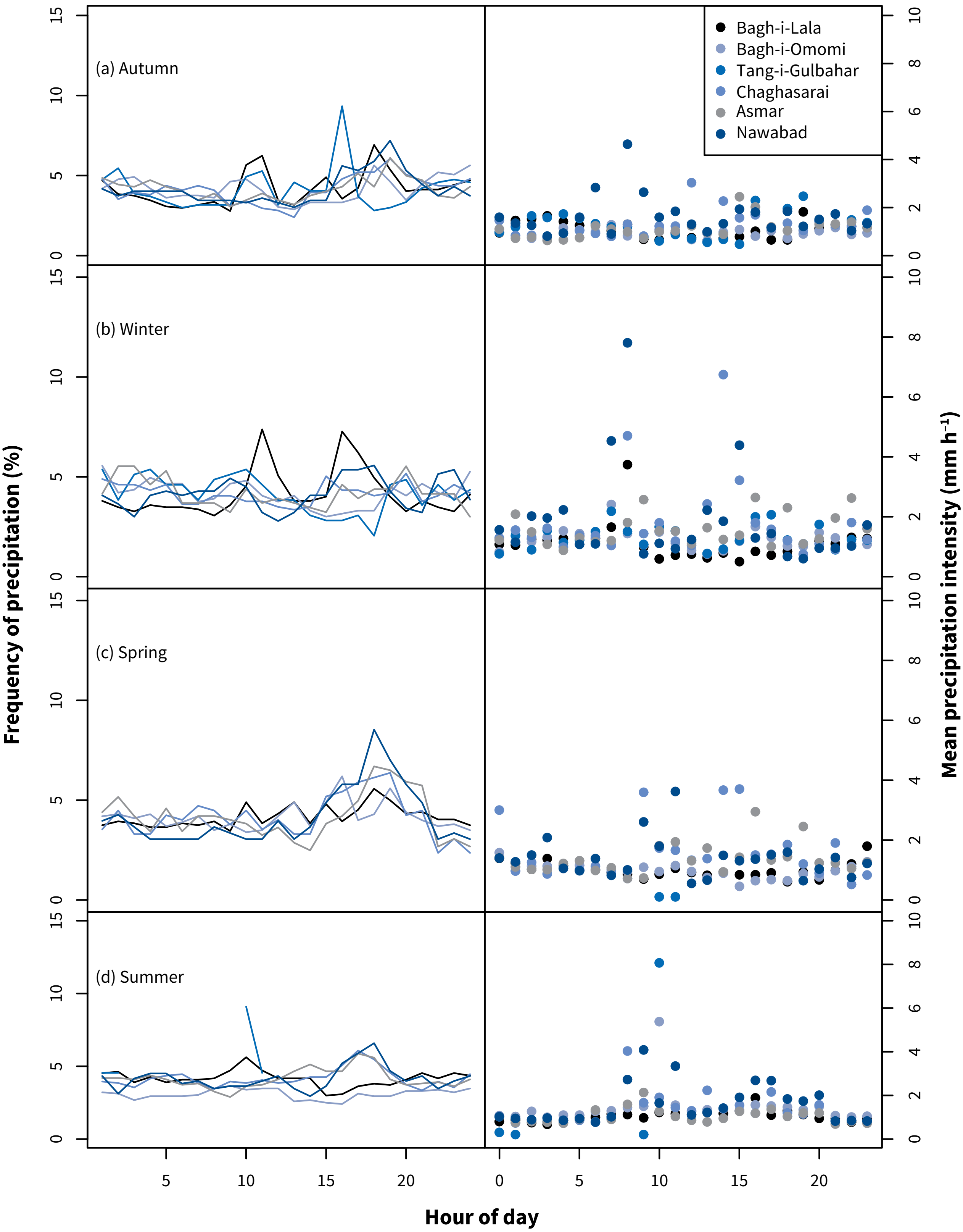


**FIGURE 16** HOURLY PRECIPITATION FREQUENCY AND INTENSITY FOR KUNAR AND UPPER PANJSHIR SUB-BASINS, DURING AUTUMN, WINTER, SPRING, AND SUMMER



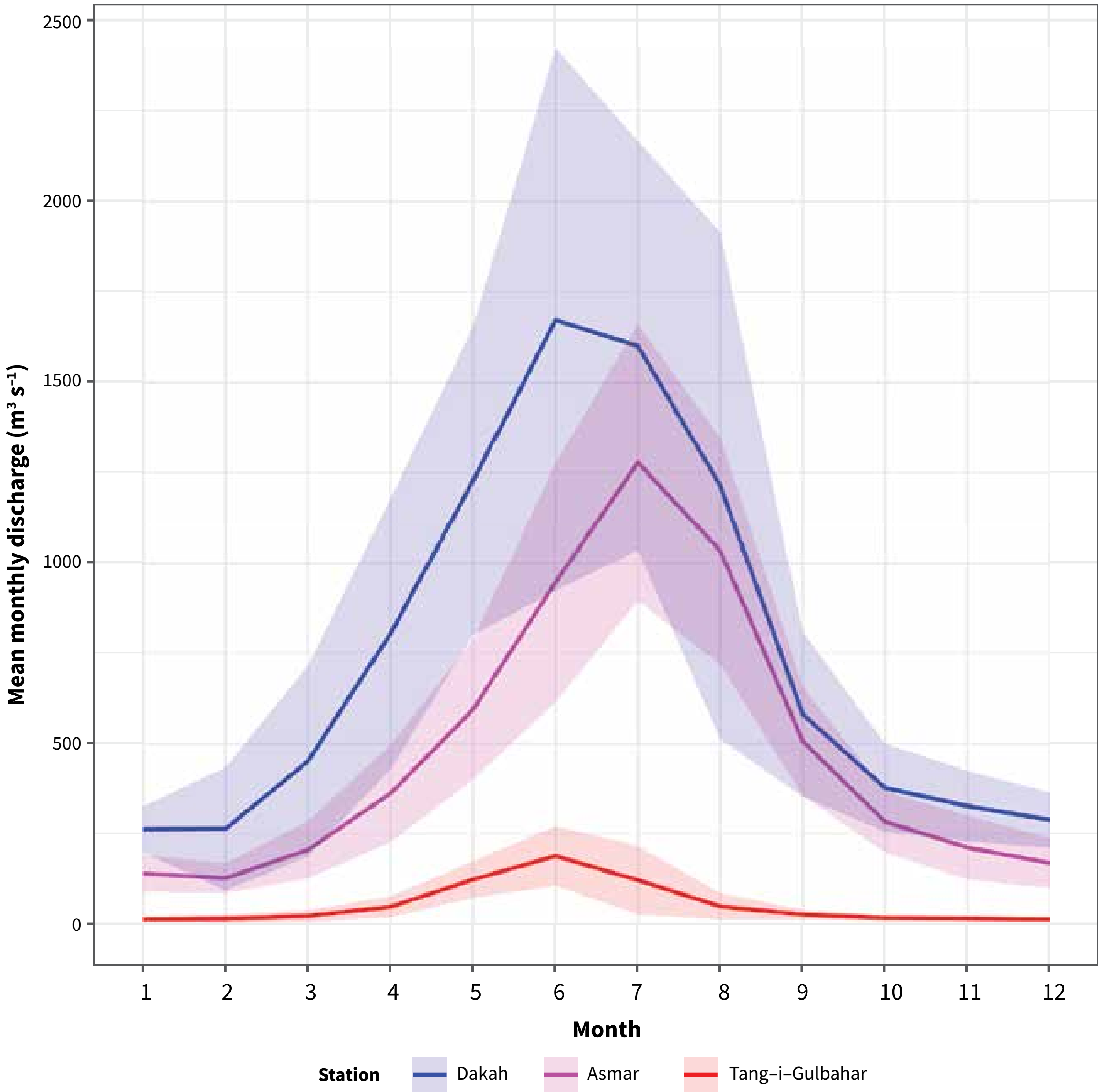

Note: Legend colours represent both frequency and intensity of precipitation winter and spring, when there is also a high intensity of precipitation in the afternoon (1–3 pm).

## Discharge

The river discharge is directly associated with the amount of water moving off the watershed into the stream channel, and coming from precipitation, snowmelt, glacier melt, stream water, and other sources. The data suggests that it is affected by the season and weather patterns, as it shows that the volume of discharge increased during rainstorms and decreased during dry periods. Here we present the hydrograph of three stations (Figure 17), two from glaciated catchments, and one from the main outlet of the KRB. In all three stations, the discharge is highly variable during the summer months. The rising limb and recession limb also show the same pattern for the two glaciated catchments.

The characteristics of the watershed (shape, size, and slope) also determine the movement of water flows with resulting changes in the hydrograph. Upper Panjshir is the smallest catchment and this is endorsed by Figure 17 (Tang-i-Gulbahar) as well, with a lower discharge compared to other basin's stations. The peak flow at Dakah (where the contributions of glacier melt are lesser than others) occurs in June whereas July is the peak flow month for Asmar station (where the glacier melt contribution is high). This could be attributed to the lag time in snow and glacier melt in the upper part of the catchment.

**FIGURE 17** MEAN MONTHLY RIVER DISCHARGE AT DAKAH, ASMAR, AND TANG-I-GULBAHAR HYDROLOGICAL STATIONS




Note: The shaded colour denotes the standard deviation of mean monthly data

KEY MESSAGES

There is an urgent need to maintain the current hydrometeorological stations and install new ones in glaciated regions, or even on one of the potential benchmark glaciers identified by this study. Ultimately, this would help to understand the interactions between local climate and glaciers, and to determine the controlling factors for glacier and snow melt and snow cover changes in the region.

SECTION V

# Conclusions and recommendations

Routine glaciological inspections and adequate resources must be ensured for sustainable and long-term glacier monitoring in Afghanistan.

Glaciers cover about 3% of the total drainage area of the Kabul River basin. Though most of the glaciers lie between elevations of 4,800–5,300 masl, the hydrometeorological stations are located below 2,300 masl , articulating the lack of glacio-hydrological information which would complement cryosphere monitoring. The nearest meteorological station from one of the potential benchmark glaciers (Pir Yakh) is 93 km away.

In terms of temporal data gaps, temporal coverage of key hydrometeorological indicators is satisfactory in most stations in the basin, except in some such as Tang-i-Sayedan, Shakardara, Pul-i-Surkh, Asmar, and Sultanpor. Regarding diurnal variability, greater diurnal temperature variability is seen in the spring and autumn than in the other seasons. The frequency and intensity of precipitation differ from station to station in the glaciated sub-basins – Upper Panjshir and Kunar – of the KRB.

The available meteorological and hydrological data is crucial for understanding the climatic conditions in the basin. However, these stations do not capture the true picture of such a large basin. In addition, these stations are located far from the glaciers and at much lower altitudes. There is an urgent need to maintain the current hydrometeorological stations and install new ones in glaciated regions, or even on one of the potential benchmark glaciers identified by this study. Routine glaciological inspections and adequate resources must be ensured for sustainable and long-term glacier monitoring in Afghanistan.

Ultimately, this would help to understand the interactions between local climate and glaciers and to determine the controlling factors for glacier and snow melt, and snow cover changes in the region.

SECTION VI

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# About ICIMOD

The International Centre for Integrated Mountain Development (ICIMOD), is a regional knowledge development and learning centre serving the eight regional member countries of the Hindu Kush Himalaya – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan – and based in Kathmandu, Nepal. Globalisation and climate change have an increasing influence on the stability of fragile mountain ecosystems and the livelihoods of mountain people. ICIMOD aims to assist mountain people to understand these changes, adapt to them, and make the most of new opportunities, while addressing upstream-downstream issues. We support regional transboundary programmes through partnership with regional partner institutions, facilitate the exchange of experience, and serve as a regional knowledge hub. We strengthen networking among regional and global centres of excellence. Overall, we are working to develop an economically and environmentally sound mountain ecosystem to improve the living standards of mountain populations and to sustain vital ecosystem services for the billions of people living downstream – now, and for the future.

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