Impact of retreat of Gangotri glacier on the flow of Ganga River*

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Recently, there have been news items and discussions suggesting that the Gangotri glacier is melting at a rapid rate and it is likely that it will disappear in the next 20–30 years. Fears are being expressed that its disappearance will lead to a dry Ganga, which will not only jeopardize the life of more than 50 crore people, but also seriously hurt the religious sentiments of many more. This note presents a broad analysis of the flow contribution of major tributaries to the flow of the Ganga as well as the likely impact of the Gangotri glacier melt on the quantity of flow in this river at various locations.

Streams in headwaters area of Ganga Basin

Although the headwaters region of the Ganga in the Himalayas is dotted by a number of mighty tributaries, the Bhagirathi River that rises from the Gangotri glacier at Gomukh at an elevation of 7756 m, is traditionally considered to be the source of the Ganga. The other main stream that originates in the Ganga Basin in Uttarakhand is the Alaknanda. Flowing downhill, Bhagirathi and Alaknanda meet at Devprayag to form the Ganga River. An index map showing major tributaries of the Ganga and important towns is given in Figure 1.

The Bhagirathi is joined by the Bhilangana River on its way to Devprayag. Near the junction of these rivers at Tehri, a dam has been constructed. The river flow at the Tehri dam site generally varies from 30 to 2000 cumec. The Alaknanda rises from the glaciers Satopanth and Bhagirath Kharak (elevation about 3800 m) near the famous Badrinath shrine. The Alaknanda Basin (area 11,800 km^2) is formed by the Alaknanda River and its tributaries – Saraswati, Dhauliganga, Garunganga, Patalganga, Birehiganga, Nandakini, Pindar and Mandakini. The annual rainfall in the Alaknanda Basin ranges from 1000 to 1600 mm, and nearly 75% of the rainfall occurs during the monsoon months[1].

The maximum and minimum discharge of the Ganga River at Devprayag during 1990–91 was 4061 and 125 cumec respectively[1]. During this period, the maximum and minimum contribution of the Alaknanda to the total discharge was 3000 and 85 cumec respectively. Thus, the flow of Alaknanda at Devprayag is nearly twice that of the Bhagirathi.

Major tributaries of the Ganga and their flow contribution

A line diagram showing the major tributaries of the Ganga and their average annual flows is given[2,3] in Figure 2. Note that the south bank tributaries (left-hand side of Figure 2) contribute much less than the northern tributaries. Important features of selected tributaries of the Ganga are given in Table 1.

The average flow of the Ganga near Haridwar during the monsoon season (July–September) ranges between 2000 and 3000 cumec and the lean flow is about 100 cumec. During the lean season, the discharge at Narora is about 321 cumec[4]. Further down at Kanpur, it is 1679 cumec. At Allahabad, the lean season flow recorded is 1870 cumec; it is 4120 cumec at Varanasi and at Patna it is 5700 cumec.

Recession of glaciers in Ganga Basin

The Himalayan glaciers form the largest body of ice outside the polar caps. There are nearly 10,000 glaciers in the Indian Himalayas. After Siachen (73 km long), Gangotri is the next largest of the Himalayan glaciers.

The Gangotri system is a cluster of glaciers comprising the main Gangotri glacier (length: 30.2 km; width: 0.20–2.35 km; area: 86.32 km^2) as the trunk part of the system. The other major glaciers of the system are: Raktvarn (55.30 km^2), Chaturangi (67.70 km^2), Kirti (33.14 km^2), Swachand (16.71 km^2), Ghanohim (12.97 km^2), and a few others (13 km^2). Depth of the glacier is about 200 m and the elevation varies from 4000 to 7000 m. Satopanth and Bhagirath Kharak glaciers in the Upper Alaknanda Basin originate from the peaks of the Chaukhamba and Badrinath range. These glaciers are 13 and 18 km long with snouts at an altitude of 3800 m.

Views have been expressed that if the present rate of recession continues, the Gangotri glacier may disappear by the year 2035. There are fears that the Ganga could become a seasonal river in the near future as a consequence of climate change. Now the question arises: Will global warming result in the drying up of

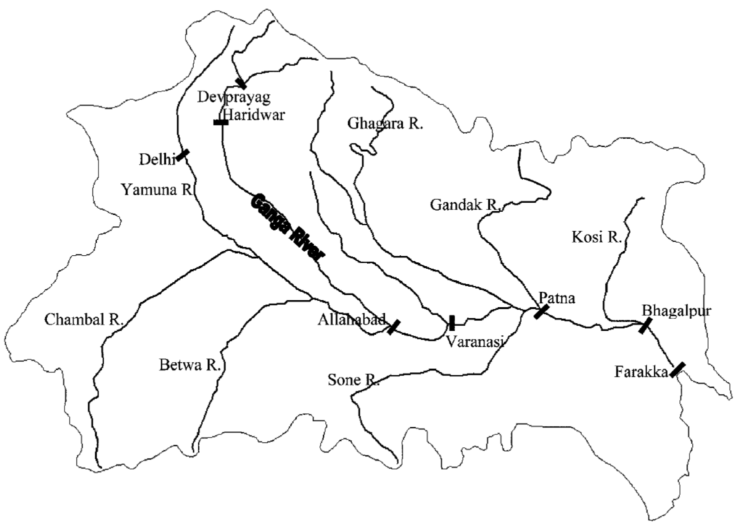

Figure 1. Index map showing major tributaries of Ganga River.

*Views and opinions expressed here are of the author and may not necessarily reflect those of the organization to which he belongs.

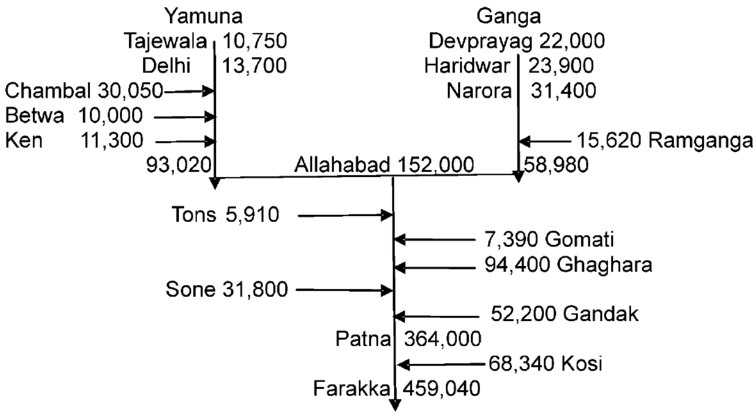

Figure 2. Ganga and its major tributaries. Numbers are average annual flows in million cubic metres.

Table 1. Important features of selected tributaries of the Ganga

Tributary	Origin	Catchment area (km^2)
Yamuna	Rises from Yamunotri Glacier near Banderpoonch peaks in the Mussourie range at an elevation of about 6387 m in Uttarkashi District	363,000
Ghaghra	Rises at an elevation of 4800 m near Manasarovar Lake	127,950
Sone	Originates at an elevation of 600 m at Sonbhadra, Maikala range of hills, Madhya Pradesh	71,260
Gandak (Kali in Nepal)	Originates near the Nepal–Tibet border at an altitude of 7620 m to the northeast of Dhaulagiri	46,300
Kosi	Rises at an altitude of 7000 m in the Himalayas	74,500

Source: Jain *et al.*[3].

Ganga River? If so, what about the survival of 500 million people who depend on its waters?

According to IPCC[5] by year 2070–99, surface temperatures in South Asia are likely to rise between 1.56°C and 5.44°C, depending upon the future growth scenario. On a geological timescale, the retreat of glaciers is not unusual. It is believed that about 4000 years ago, the snout of the Gangotri glacier was at the Gangotri temple and its retreat over this period has been just 18 km. The glacier has been retreating at different rates. In the intervening period, it also advanced a bit during the Little Ice Age in the 16th–18th century. In the late 1960s, the retreat rate of the Gangotri glacier was about 30 m/yr. Over the past few decades, the rate of recession of Gangotri glacier[6] has been between 22 and 27 m/yr.

Assuming the recession rate of Gangotri glacier to be 40 m/yr, simple computations show that a glacier of 30 km length will take about 700 years to completely melt away. After considering nonlinearities and to make a conservative estimate, the time-span could be assumed to be hundreds of years. Further, there will be years of heavy snowfall in between which will extend the life of the glaciers. Thus the prediction that the Gangotri glacier system would become extinct by 2035 is alarming. Undoubtedly, the glaciers are retreating, but not at a catastrophic rate and they are not going to disappear in the near future. Note that different glaciers in the same climatological set-up respond differently to the changing climate[6]. Hence, long-term studies on glacier mass balance and glacier dynamics are needed to understand the impact of climate change on Himalayan glaciers.

The Ganga is not totally dependent on glaciers for its water, even in the headwaters region. Most of its catchment area in India is rain-fed. Only about 7% of the basin up to Devprayag is glacier-fed. Snow and glacier melt contribute only 29% to the annual flow at Devprayag; the rest is from rainwater. At Devprayag, the average annual flow[2] is about 22,000 MCM (million cubic metres). This means that the average snow + glacier contribution at Devprayag is about 6380 MCM. Of course, the percentage of snow and glacier-fed area progressively reduces as one moves downstream, and so does the contribution. More than 70% of the flow at Haridwar is due to rainfall and the river has significant amount of baseflow downstream of Haridwar. Hence the possibility of the Ganga becoming a seasonal river downstream of Haridwar in the near future is low.

Among the tributaries of the Ganga, Yamuna River contributes about 61% of the total flow at Allahabad, and just 16% comes from Haridwar. Four mighty rivers join the Ganga in Bihar: Ghaghara, Gandak, Kosi and Sone. The contribution of these four rivers is 246,740 MCM, which is 1.62 times the flow at Allahabad. Note that the average annual flow at Patna is about 364,000 MCM, which is nearly 17 times the flow at Devprayag.

Besides Gangotri, other glaciers in the headwaters region of Alaknanda, Yamuna, Ghaghara, Kosi, etc. also contribute to the flow in the Ganga. While the Gangotri glacier has received a lot of attention, few studies have been conducted on other glaciers. Although Gangotri glacier has religious importance, hydrologically glaciers are important according to their area and melt contribution. Hence, when predicting the impact of glacier retreat on the flow of the Ganga, it would be necessary to consider the retreat (or otherwise) of all the contributing glaciers.

Note that on account of global warming and climate change, temperatures alone will not change. Other variables such as precipitation intensity and quantity, cloud cover, wind, etc. will also change and it is a complex task to predict the overall scenario with confidence. A detailed measurement and modelling study needs to be conducted to derive useful inferences.

Epilogue

No doubt Gangotri glacier is shrinking, but it is not going to disappear anytime soon. Its retreat will not have a drastic influence on the flow of Ganga River as is projected. Beyond Haridwar, the influence of the Gangotri glacier on river flow becomes progressively lesser and it is less than 4% at Allahabad. Besides Gangotri, several other glaciers contribute to the flow of the Ganga and a holistic view of the situation is needed. The current database about the properties and behaviour of Himalayan glaciers needs to be strengthened. Long-term studies on glacier dynamics and mass balance are needed to understand the behaviour of Himalayan glaciers and the impact of climate change on them.

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