

Temporal variation of glacial lakes since 1976 in the Great Himalayas revealed by satellite imageries

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The supra-glacial lakes are abundantly formed on the glacier tongues of debris-covered valley glaciers especially in the eastern Great Himalayas, which may be as a result of global warming. The lakes have frequently burst and hazardous floods have happened, since the lakes are dammed by an unstable moraine formed in the Little Ice Age (Yamada 1998). The flood is called Glacier Lake Outburst Flood (GLOF). The GLOF is a new face of the natural disaster newly arising in the Himalayas in the later half of 20th century and has been a serious problem for the socio-economical development of Himalayan countries such as Nepal, India, Bhutan and China.

Is the lake still newly born? How much are the lakes expanding? By using Landsat MSS and ETM imageries, respectively taken in 1976 and 2000/2001/2002, temporal variation of the lakes during 24 to 26 years are investigated in the northern and southern slopes of the Great Himalayas spreading over the longitude between 85°15' and 91°00' E. To examine the regional characteristics in the temporal variation of the lakes, the northern and southern slopes are divided into three sub-regions by River Arun running from Tibet to Nepal and River Kangpu from Tibet to Sikkim. Thus the covered area are divided into six sub-regions, which are called North-West (NW), North-Center (NC) and North-East (NE), which sub-regions belong Tibet, and South-West (SW, belonging eastern Nepal), South-Center (SC, eastern Nepal to western Sikkim) and South-East (SE, eastern Sikkim and Bhutan). The moraine-dammed glacier lakes more than 0.01 km²

in area are extracted from the imageries due to the limitation of the special resolution.

The numbers and area of the glacier lakes in each sub-region in 1976 and 2000s are shown in **Table 1**. Those of new lakes formed after 1976 are also shown in the Table. It is characterized that the total glacier area in the northern slope (Tibetan side) is larger than that in the southern slope, while the total number in the northern slope is less than that in southern slope, because the size of valley glaciers in the northern slope is remarkably larger than that in the southern slope. The number of present glacier lakes is totally 539 with the area of 122.46 km², which includes the count of new lakes formed after 1976. Total expansion area of the lakes amounts to be 37.47 km², including the total area of 10.25 km² for 35 lakes newly formed. Especially, the lakes in Bhutan (sub-region SE) have developed more than two times in the area, while 1.35 times on an average in the other sub-regions. As a result of examining the reasons of lake expansion in terms of global warming and the inclination of topography, where glaciers are situated, no clear relation is found in the global warming, but in the topography: The gentler an inclination of topography is, the more the glacial lakes develop.

Reference

Yamada T 1998. *Glacier lake and its outburst flood in the Nepal Himalaya*. Data Center for Glacier Research, Japanese Society of Snow and ice. Monograph No. 1. 96p

Table 1: Number and area of the glacier lakes in 1976 and 2000s, and also those of new lakes formed after 1976, in each sub-region.

Sub-region	1976		2000s		formed after 1976	
	Number	Area (km ²)	Number	Area (km ²)	Number of New Lake	Area of New Lake (km ²)
NW	54	24.62	61	33.02	7	0.22
NC	70	15.29	90	20.76	20	1.86
NE	56	17.70	72	22.46	16	0.93
SW	89	11.47	121	17.83	32	1.15
SC	59	6.15	78	8.43	19	1.07
SE	82	9.76	117	19.96	35	5.02
Total	410	84.99	539	122.46	129	10.25