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Jökulhlaup Observed at Greenland Ice Sheet

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On 31 August 2007, about 35 kilometers upstream from the town of Kangerlussuaq, in western Greenland, a roughly 0.5-square-kilometer permanently ice-dammed lake on the northern flank of the Russell Glacier—an outlet glacier of the Greenland Ice Sheet—suddenly broke free and drained into the Watson River (Figure 1). A 25-meter drop in the lake water level resulted over an approximately 17-hour period (Figure 3a). A glacial outburst such as this is known by the Icelandic term jökulhlaup, derived from the words jökull (glacier) and hlaup (meaning sprint or burst) [*Robert*, 2005].

Before 2007, the last known jökulhlaup from this glacier was in July 1987; jökulhlaups at this location occur once every 8–10 years on average. The 2007 jökulhlaup occurred after the most intensive melt season—with the biggest melting area and melt index (defined as the melting area times the number of melting days)—on the Greenland Ice Sheet since the first satellite observations in 1979 [*Tedesco*, 2007]. The ice dam broke after 4 days with a temperature range of 4.0°–17.0°C, averaging 9.5°C, resulting in glacier ablation, and with a rainfall total of 33 millimeters (Figure 2a).

At the Watson River's drainage basin outlet at Kangerlussuaq, six discharge measurements were conducted during low flow in June 2007 as a part of a recently started research program: Stage and discharge were lower than 14.5 meters and 150 cubic meters per second, respectively. River stage was measured every 20 minutes during the runoff season from June to September, and it was recorded with a pressure transducer placed approximately 75 meters upstream from where two bridges cross the river at well-defined, stable cross sections on bedrock. These discharge measurements were used to develop a stage-discharge relationship ($R^2 = 0.91$) and to convert the stage measurements into a river discharge time series. The relationship had an accuracy of 5–10% during low flows; peak flow estimates were less accurate because all of the discharge measurements for developing the stage-discharge association were made during low flows.

The 2007 summer stage hydrograph shows that the rising limb of the short-lived jökulhlaup began at 3:00 A.M. local time (UT – 2 hours) on 31 August, and the stage peaked approximately 11 hours later at 2:00 P.M. The direct contribution of the jökulhlaup to the enhanced runoff appears to have ended at 8:00 P.M. on 31 August. At its peak, the river stage was 4.25 meters above the average August water level (Figure 2a).

On the basis of the stage-discharge relationship, the maximum Watson River discharge during the jökulhlaup is calculated to have been approximately 540 cubic meters per second, and the total runoff during the event is estimated to have been 28.8 million cubic meters (Figure 2b). Outflow from the ice-dammed lake is estimated to have been 11.3 million cubic meters; the additional 17.5 million cubic meters is due to frictional melting of ice as the flood traveled in contact with the glacier, together with an input from base flow.

Most jökulhlaups in western Greenland are undetected and occur far from populated centers with at-risk infrastructure. As in this case, though, jökulhlaup events can sometimes pose a serious risk to nearby communities [*Roberts*, 2005]. If the stage had crested even 1 meter higher during peak time on 31 August, the water line may have washed out bridges and cut off the water supply to Kangerlussuaq (Figure 3b). Furthermore, the two bridges that span Watson River also may have failed during the peak event. If the jökulhlaup had occurred during mid-July or mid-August, when the ice melt contribution from the Greenland Ice Sheet was very high, the river stage would have been substantially higher and most likely would have resulted in considerable infrastructure damage.

In a warmer climate, there may be an increase in the frequency and impacts of these jökulhlaups [*Evans and Clague*, 1994]—due to increasing future air temperature, increasing melting, and increasing runoff—but a decrease in their magnitude due to changes in glacier/ice sheet dynamic processes.

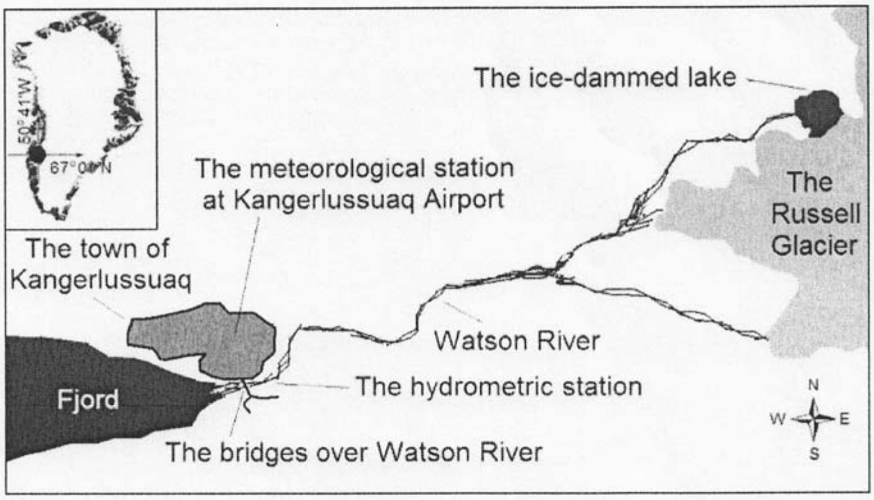

Fig. 1. Kangerlussuaq area, western Greenland (black dot in inset map), including the location of the ice-dammed lake and the hydrometric station at the drainage basin outlet. The figure is out of scale. The lake is approximately 35 kilometers upstream from the station.

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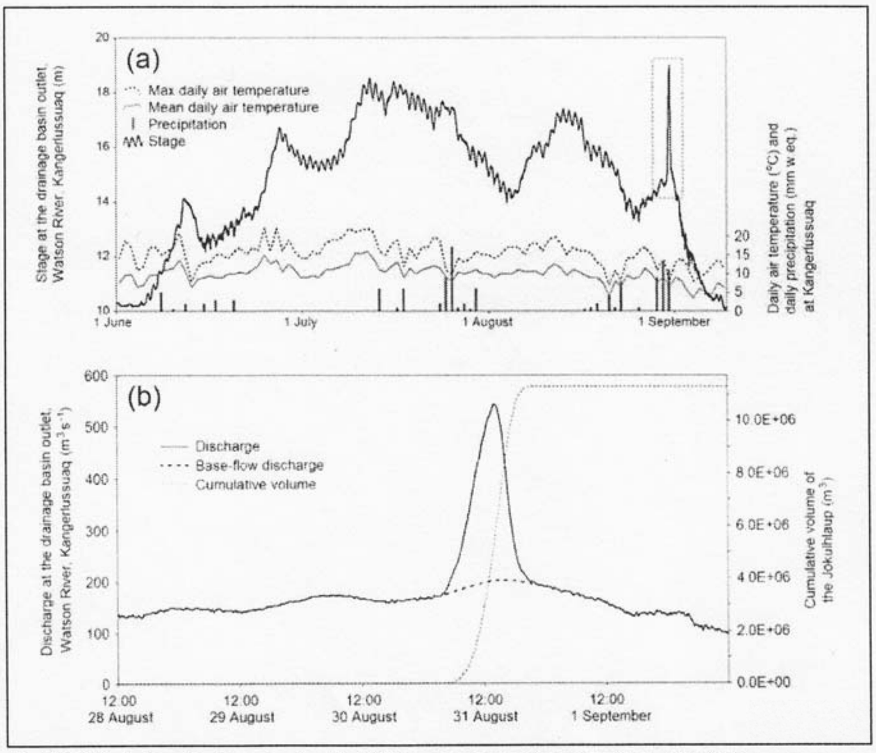

Fig. 2. (a) Variations in stage during the 2007 summer runoff season from June through early September at the drainage basin outlet at Kangerlussuaq. The dotted rectangle indicates the jökulhlaup. (b) Enlargement of the discharge variations during the short-lived jökulhlaup from the period 28 August through 1 September.

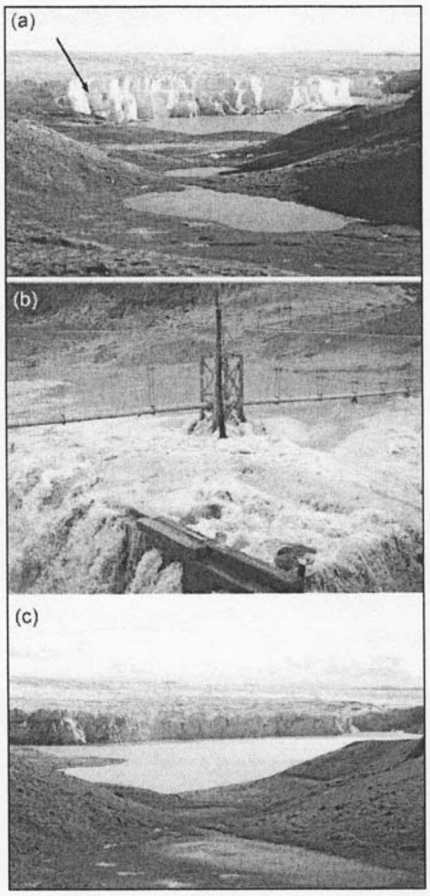

Fig. 3. (a) The ice-dammed lake on 2 September 2007 after the jökulhlaup. The arrow indicates the water level in the lake before drainage. (b) The water supply pipeline just upstream from the two bridges over the Watson River at the drainage basin outlet at Kangerlussuaq during peak time on 31 August 2007. (c) The ice-dammed lake on 10 August 2008. Photos by Mark Begnaud, VECO Polar Resources.

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