PROCEEDINGS OF THE TWENTY-SEVENTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

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KECK GEOLOGY CONSORTIUM
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Faculty: *AL WERNER*, Mt. Holyoke College, *STEVE ROOF,* Hampshire College, *MIKE RETELLE*, Bates College
Students: *JOHANNA EIDMANN*, Williams College, *DANA REUTER*, Mt. Holyoke College, *NATASHA SIMPSON*, Pomona (Pitzer) College, *JOSHUA SOLOMON*, Colgate University

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Keck Geology Consortium: Projects 2013-2014
Short Contributions— Climate Change, Svalbard, Norway Project

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Faculty: AL WERNER, Mount Holyoke College
MIKE RETELLE, Bates College
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NATASHA D. SIMPSON, Pitzer College
Research Advisor: Robert Gaines

INTRODUCTION

Active Karst systems are rare in the Arctic due to wide spread permafrost. This study looks at patterns of lake level fluctuations of karst lake, Kongressvatnet, as well as similarly timed events in the nearby glacial lake, Linnévatnet. Karst systems are rarely active in these high latitudes; this is due to a variety of factors that contribute to the typical Arctic climate including: low temperatures, low precipitation, frozen water, and low vegetation (Salvigsen and Elgersma, 1985). Continuous permafrost decreases the potential for subsurface drainage and water flow, and underground karst will not form in this situation (Brook and Ford, 1978). However, there are places in Svalbard that demonstrate karst morphology in discontinuous permafrost areas (Holm et al. 2011).

Abrupt lake level changes have been documented in Kongressvatnet (Kongress) as well as the nearby glacial lake, Linnévatnet (Linné). Correlations between the two may indicate movement from Kongress through a larger ground-water system. In 2003, Humlum reported that 60% of Svalbard was glaciated and the other 40%, approximately 25,000 km, was permafrost and periglacial environment. Research on these high Arctic systems has been limited, but recently, a few studies have been conducted with limited success attempting to understand how these true karst systems drain water. This study may be a preliminary start towards a better understanding this active system and possible fluctuation mechanisms.

Site Area

Kongressvatnet is a karst lake set at 95 m elevation to the south east of Lake Linné (Figure 1). The lake is small, 0.55 km^2, and remains ice covered for 9-10 months of the year. It is part of a larger karst system that extends north to the ocean, with a watershed composed of carbonates and gypsum (Salvigsen and Elgersma, 1985). Kongress is fed by multiple melt water streams that originate from snow melt in the catchment. It has one primary drainage outlet to the east above present lake level, but there is evidence of free flowing higher-conductivity Kongress water discharging to the west, into the Linné Valley.

The perimeters of both Linné and Kongress show multiple higher shorelines, evidence of recent lake level changes. Water level data loggers were deployed in Kongress in 2006 and have since recorded nearly continuous level fluctuations. Some of these fluctuation events coincide with changes in the much larger lake Linné. This project compiles the available water level and environmental data in an attempt to identify patterns, abnormalities, and possible correlations between the lake level fluctuations of these two adjacent lakes. It also makes suggestions for further research on this karst system and drainage mechanisms.

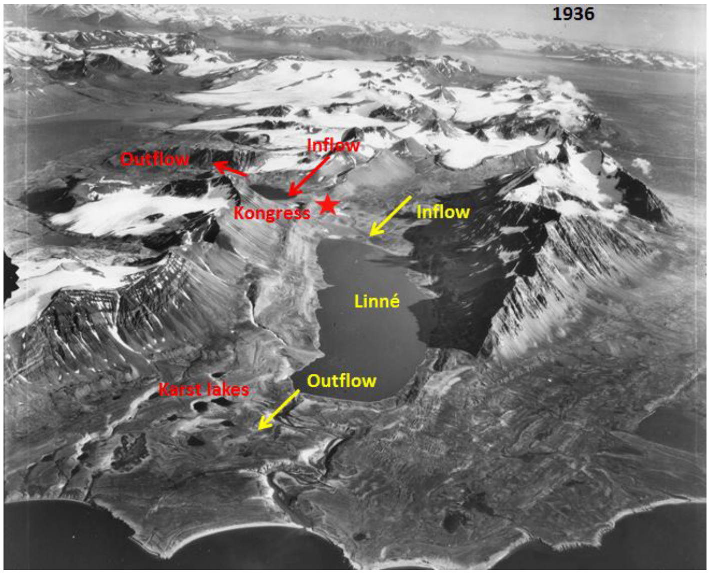

Figure 1. Adapted historical photo, from 1936, of the site area looking south. Kongress is at 95 meter elevation and Linné at 4 meter elevation. Karst system runs north/south and small lakes are seen on the north end. Starred location represents locality of Kongress spring flowing up on Linné side at low elevation

METHODS

Data were compiled from 2007-2013 seasons for both lakes and Longyearbyen weather data was downloaded to use for meteorological interpretations with lake level fluctuations. Lake level logger data and air temperature data provided evidence for weather-driven and weather-uncorrelated rises and drainages. Automated camera photographs provided evidence for flooding events that occurred during the light season, approximately early April to mid-October. The two main correlated fluctuations that were analyzed in this comparison were the ones that occurred during the spring seasons and did not appear to be directly caused by precipitation events or temperature change.

RESULTS

Annual Lake Behavior for Kongress

The annual environmental conditions in the area follow a general pattern. The air temperature begins to fall below freezing around late September to early October and remains below freezing until late May to early June (Figure 2). The increasing air temperature initiates snow melt in the water shed and a gradual lake level rise of about two meters which occurs

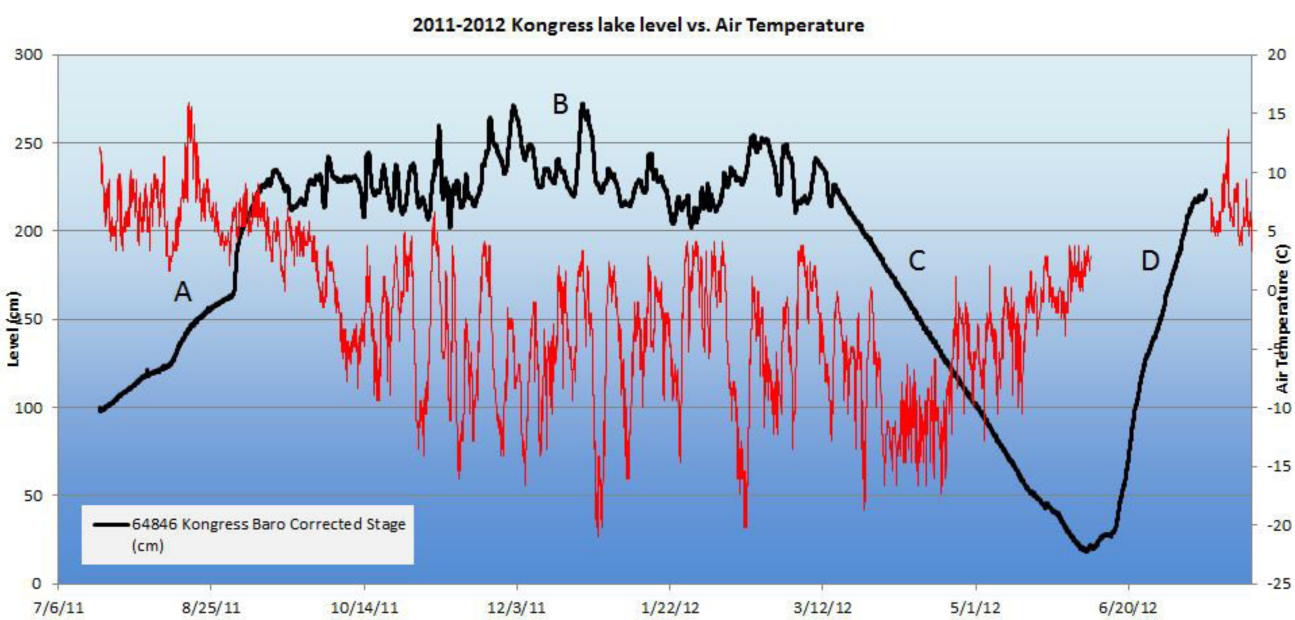

Figure 2. Barometrically corrected Kongressvatnet lake level readings for the 2011-2012 field season depicting the general fluctuation trends throughout a year. A. Patterns begins with an approximately two meter rise from early June through mid-September B. Winter months show a steady high with multiple small magnitude fluctuations C. Starting in mid-March a two meter drop begins until mid-June D) Kongress begins to fill once again

from early June to mid-September. This is the lake 'high' and the level at which it freezes at during the winter. During the winter months there are numerous fluctuations, the largest being approximately 50 cm. Around mid-March Kongress begins a gradual draining of approximately 1.25-2 meters until the spring temperatures return and the level begins its gradual rise again. There is also a consistent loss of water to the springs in Linné valley.

Spring 2008 Flooding Event

Analysis was done on two events during the spring of 2008 and 2011. In 2008 during Kongress spring draining, in an 8 day span from May 31 to June 8, Linné rose 28 cm while Kongress dropped 11 cm. This flooding of Linné caused the ice dam to break and lake level to drop back down (Figure 3). Air temperature remained around and below zero degrees centigrade. Conductivity in Linné showed an introduction of fresh highly conductive water likely from Kongress. Automated camera images displayed a flooding on the top of ice covered Linné starting the week before the level loggers picked up the rise. Linnédalen weather data showed a total of only 5.52 mm of rainfall on June 2, with no other significant precipitation events the week before or during.

Spring 2011 Flooding Event

This event follows a similar pattern to 2008. From May 1 to May 8, Linné rose 30 cm while Kongress dropped 13.3 cm. Following this, the Linné ice dam broke which corresponds with the rapid level drop (Figure 4). Air temperature remained around zero degrees centigrade. Similar to 2008, automated camera images displayed a flooding on the top of ice covered Linné starting the week before the level loggers picked up the rise. Linnédalen weather data showed a total of 26.2 mm of rainfall during this week long event. This larger amount of rain fall combined with the volume lost from Kongress is still small

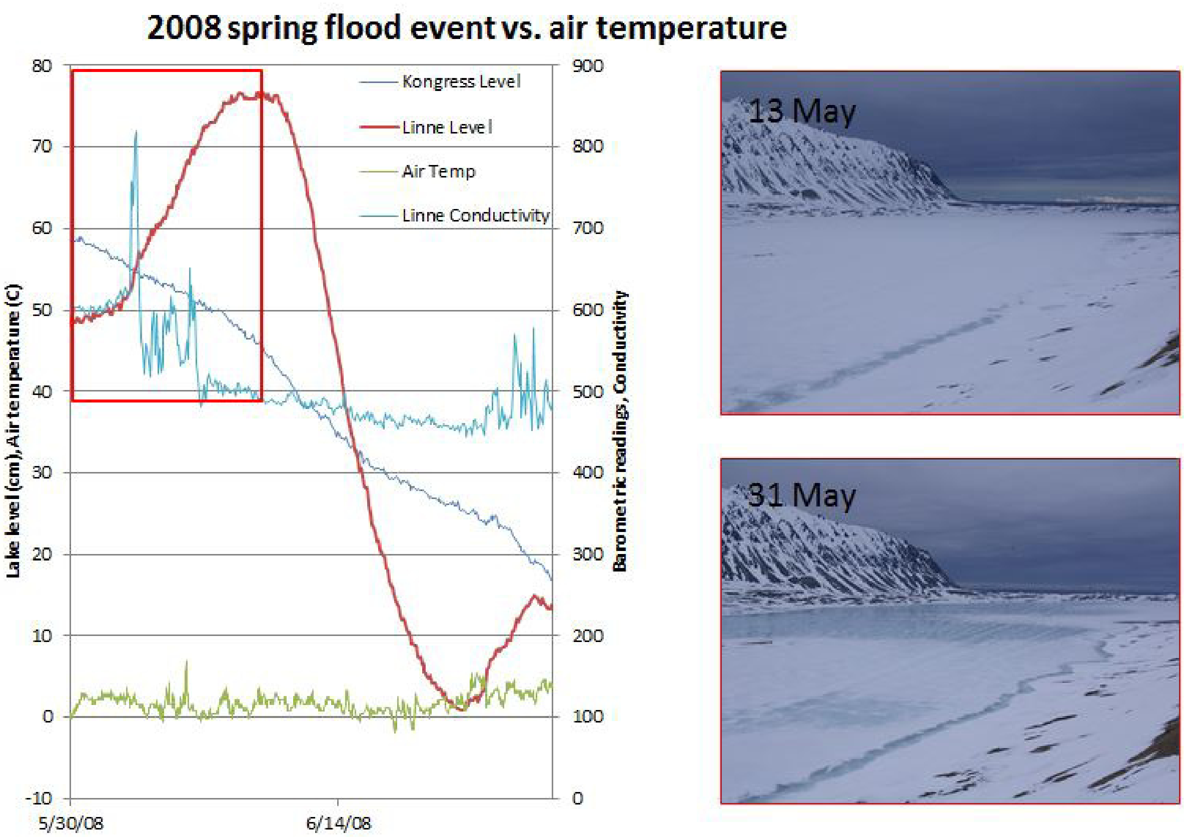

Figure 3. The spring 2008 lake level fluctuations compared to both air temperature and Linné conductivity. The red box highlights the correlated event. From May 31 to June 8, Linné rose 28 centimeters and Kongress dropped 11 cm. Air temperature is stable around 0° C and weather data show little to no rain fall before or during the event. Conductivity spikes at the beginning of this flooding event which signifies the introduction of high conductivity water into Linné, likely originating from Kongress. Automated camera photos from one week before show a flooding on top of the ice which then freezes again.

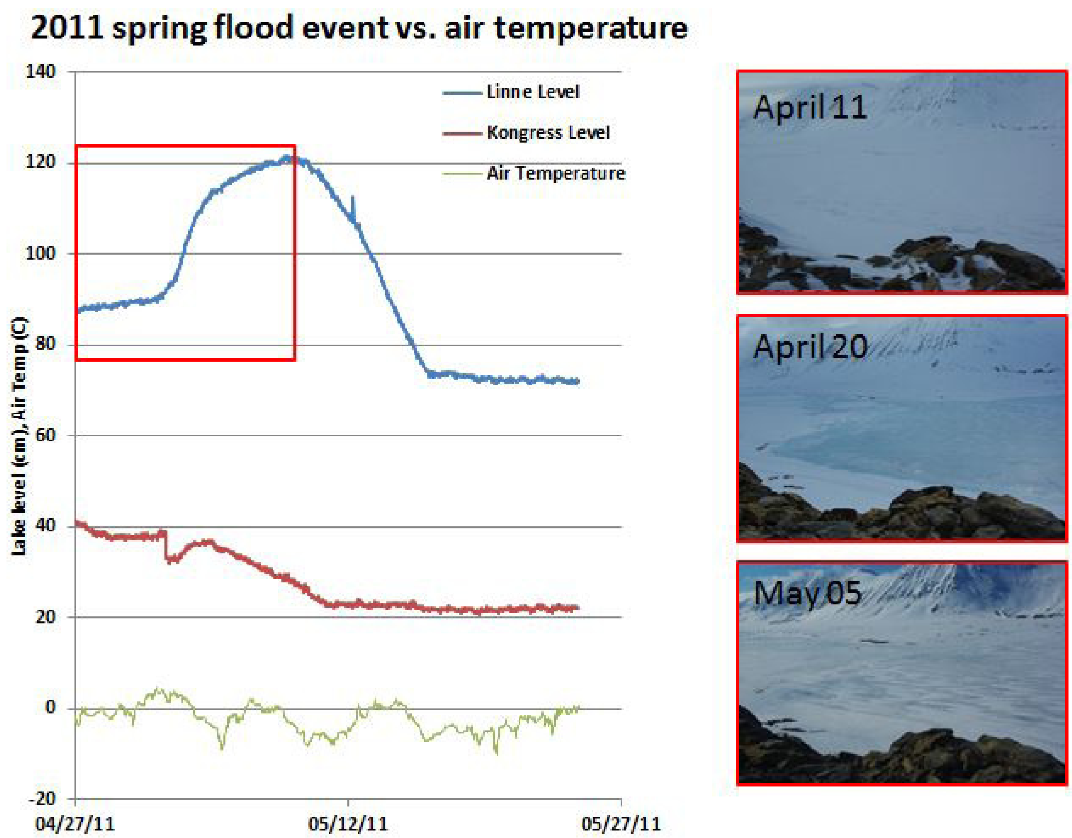

Figure 4. The spring 2011 lake level fluctuations compared to air temperature with the red box highlighting the correlated event. From May 1 to May 8, Linné has a quick rise of 30 cm while Kongress drains 13.3 cm. Air temperature remains mostly below 0°C. Photos show evidence of a flooding event on top of the lake ice beginning two weeks before the level rise appears on sensors

Table 1. Rough mass balance calculations for the 2008 and 2011 spring events. These are based off the lakes area and by assuming straight shore edges with no grading. This was an appropriate assumption because of the large difference in magnitude for volume change between the two lakes.

Event Dates	Linné level change (m)	Volume gained Linné (m^3)	Kongress level change (m)	Volume lost Kongress (m^3)	ΔVolume (m^3)
2008: May-31 – June 8	0.28 rise	1,288,000	0.11 drop	61,270	1,226,730
2011: May 1-May 8	0.3 rise	1,380,000	0.133 drop	74,081	1,305,919

compared to the volume gained in Linné. Rough mass balance calculations (Table 1) for both events show a substantial difference between the volume lost from Kongress and the volume gained in Linné. This may infer that Kongress draining is part of a larger groundwater system.

DISCUSSION

Although it is tempting to accept all of these level changes at face value – it is possible that at least some of the events are not real but rather are apparent lake level changes due to other conditions. In particular, it is possible that hen lake level lowers the logger could become frozen into the lake ice and the associated pressure changes could simply reflect the 'freeze-in' process. The Kongress level data from 2009-2010 showed the largest rapid fluctuations that occurred on the order or 3 m/hr. The Linné level logger did not deploy properly in the end of the July field season of 2008, so we were unable to correlate Linné level. Automated camera imaged from May 22, 2010 did document a flood event for Linné at the same time as the Kongress loggers recorded multiple large fluctuations. However, these rates of 3 m/hr are extreme for these data sets.

A technical support employee for the Onset Computer Corporation reviewed the data from the 2009-2010 field season and inputted that if sensors were encased in ice, that may damage the sensor (S. Kelly, personal communication, March 1-6, 2014). This ice encasing would not likely damage the sensor, but the calibration could be compromised. There is no way of knowing if the calibration would have been thrown off in the case of encasement, unless pressure and freezing tests were run on the logger that was in the lake in 2009 and compared it to another sensor of the same brand. The melt water influx from the watershed and minimal rain precipitation do not account the three meter rise in one hour. This may mean that the abnormal fluctuations seen in the data sets, particularly the 3m in one hour changes during 2009 are not real water level changes but instead apparent changes due to sensor malfunction. Caution should be used when including it in an overall analysis of lake level fluctuation patterns.

The majority of the lakes fluctuations roughly follow the temperature changes, precipitation events, and snow melt. A few of the larger events and level changes discussed above support the idea that this active karst system is influencing ground-water movement from Kongress to the Linné valley. During these times, Kongress appears to build up pressure throughout the winter and drain, sometimes rapidly, throughout the early spring months. There is a possibility that Kongress does not drain completely through the outlet on the eastern shore. The mass balance calculations show a discrepancy in that volume lost in Kongress is clearly not enough to account for the volume gain in Linné, suggesting that Kongress is part of a larger ground-water system.

Mechanisms for lake level change

Rises and drainages of the lake may respond to precipitation, snow melt, and ice dam breakings. However, these bigger correlated events may require a different explanation for the Kongress drainage mechanism. A siphon may drain water through the karst system, if Kongress is part of a larger ground-water system. Water could be stored until it is released into Linné which may explain the volume discrepancy in the mass balance calculations. Field (1999) describes a siphon as a flooded cave passage where water first flows up, is put under pressure, and is then released downward. Once these siphons have completely filled up the pressure is large enough to push water through the outlet that is at higher elevation. Drainage stops when water level falls below the "intake" and the siphon is broken. Although this is one possible drainage mechanism, we hesitate to make that conclusion without further research and data collection. Siphons are dependent on the pressure build up and increased drainage (Field, 1999). Elevated temperatures and increased snow melt may activate this mechanism.

RECOMMENDATIONS FOR FUTURE STUDIES

In order to understand the drainage systems and the extent to which these may influence Linné, further field seasons will need to be analyzed. Tests should be run on the sensors themselves to see how they react to pressure and freezing changes for comparisons to the data already collected. If water is being drained from Kongress through some sort of siphoning mechanism it would be interesting to determine the magnitude of water that could be stored in this karst system. The evidence of free flowing Kongress springs near the Linné input area may be used as evidence for a storage system in the carbonate host rock. It may be possible to do a ground-water storage calculation if we could determine water-budget parameters like storage volume, subsurface inflow and outflow, and an understanding of the hydraulics and water level changes much greater than is known now.

CONCLUSIONS

Correlations were made in the comparison between Linné and Kongress lake level changes. Lake level generally follows weather and snow melt trends with minor to moderate fluctuations occurring throughout the year. During the Spring in 2008 and 2011, Linné level logger data show rapid rises while Kongress drained. The conductivity spikes in Linné indicate that this is an introduction of fresh higher conductivity Kongress water. This suggests that drainage from Kongress does not all flow to the east and may be draining into Linné. These flooding events occur while air temperature is still below freezing. It is possible that rain fall and some snow melt may attribute or cause these events, a very clear correlation seems to show that Kongress is influencing the Linné level at some times. These level changes may be occurring due to a pressure build up and siphon mechanism acting in the karst system. Future research should be conducted to broaden the understanding on these rare Arctic karst systems and their drainage mechanisms.

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