GLOFs in the WOS: bibliometrics, geographies and global trends of research of glacial lake outburst floods (Web of Science, 1979-2016)

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Abstract. Research of glacial lake outburst floods (GLOFs) - specific low frequency, high magnitude floods originating in glacial lakes, including jokulhlaups - is well justified in the context of glacier ice loss and glacial lake evolution in glacierised areas all over the world. Increasing GLOF research activities, which are documented by the increasing number of published research items, have been observed in the past few decades; however, a comprehensive insight into the GLOF research

10   community, its global bibliometrics, geographies and trends in research is missing. To fill this gap, a set of 892 GLOF research items published in the Web of Science database covering the period 1979-2016 was analysed. General bibliometric characteristics, citations and references were analysed, revealing a certain change in the publishing paradigm over time. Furthermore, the global geographies of research on GLOFs were studied, focusing on: (i) where GLOFs are studied; (ii) who studies GLOFs; (iii) the export of research on GLOFs; and (iv) international collaboration. The observed trends are discussed

15   and placed in a broader context.

1 Introduction

Glacial lake outburst flood (GLOF) is a term used to describe a sudden release of (part of) water retained in a glacial lake, irrespective of the cause (trigger), mechanism (dam failure or dam overtopping) or glacial lake sub-type involved (e.g., Evans and Clague, 1994; Richardson and Reynolds, 2000). The Islandic term *jokulhlaup* is also frequently used to refer to GLOFs

20   originating in ice-dammed lakes and often (but not necessarily) induced by volcanic activity (Björnsson and Pálsson, 2008). In Spanish speaking countries, the term *aluvión* is often used to described flow-type processes of various origins, including GLOFs (Lliboutry et al., 1977). The occurrence of GLOFs is commonly tied to periods of glacier ice loss (Clague and Evans, 2000) and GLOFs are considered among the most significant geomorphological as well as the most hazardous consequences of retreating glaciers (Clague et al., 2012). Facing ongoing and even accelerating climate change and the associated glacier

25   retreat (Huss et al., 2017), research of past as well as potential future GLOFs represents a highly actual topic (O'Connor and Clague, 2015). A complex understanding of GLOFs and their related processes has significant implications for various fields such as risk management and disaster risk reduction (e.g., Hewitt, 2013), hydropower plant design (e.g., Schwanghart et al., 2016), or geomorphology and sediment yield (e.g., Korup and Tweed, 2007).

According to the Web of Science (WOS) Core Collection database (see 2.1), the term *glacial outburst flood* was firstly used by Jackson (1979), the term *glacial lake outburst flood* was firstly used by Clarke and Mathews (1981) and the acronym *GLOF* was firstly used by Grabs and Hanisch (1993). The history of research on GLOFs is, however, much older, going back to the 19th century in some regions, e.g., the European Alps (e.g., Richter, 1892), Iceland (e.g. Hákonarson, 1860) and the first half of the 20th century in others, e.g., Caucasus (Gerassimow, 1909), the Peruvian Andes (e.g., Broggi, 1942) or the North American Cordillera (e.g., Fryxell and Horberg, 1943).

Numerous studies exist that focus on a scientometric / bibliometric analysis of various research fields and their geographies (e.g., Small and Garfield, 1985), including those in geomorphology (e.g., Dorn, 2002), river research (e.g., Vugteveen et al., 2014), and natural hazard science (e.g., Chiu and Ho, 2007; Liu et al., 2012; Wu et al., 2015). While the amount of research of GLOFs has gradually increased over the past few decades (see Emmer et al., 2016), detailed insight into the GLOF research community, its global bibliometrics and geographies of research is missing. Therefore, the main objective of this study is to map GLOF research and the research community by analysing GLOF research items published in the WOS Core Collection database from the point of view of: (i) general bibliometric and scientometric characteristics (temporal analysis, journals, document types, citations and references); (ii) geographies (where GLOFs are studied and by whom). This study is expected to provide a comprehensive global overview primarily targeting the GLOF research community, but also a broader audience such as GLOF risk management practitioners and policymakers (see e.g., Carey et al., 2012).

2 Data and methods

2.1 Set of analysed items

Focussing on research results published in highly credible scientific journals and proceedings, the search was performed on items published in journals/proceedings indexed in the Clarivate Analytics Web of Science (WOS) Core Collection database (www.webofknowledge.com). This database covers items published as far back as 1900 in 13,000+ journals, contains 100+ million published items and 1.3 billion cited reference connections (Clarivate Analytics, 2017). Numerous books (e.g., Carey, 2010; Haeberli and Whiteman, 2015), book chapters (e.g. Iturrizaga, 2011) and papers not indexed in the WOS Core Collection databases as well as various scientific reports of national authorities (e.g., O'Connor et al., 2001; UGRH 2015) and so called grey literature (e.g., Horstmann, 2004) are not taken into consideration in this study.

The proper definition of the search formula is a key presumption for successfully searching for a comprehensive set of items. After several iterations, sighting shots and cross-checks with the control set of 30 papers focusing on diverse aspects of research of GLOFs, a basic searching formula was defined as follows:

TOPIC: (glaci* AND outburst* AND flood* OR jokulhlaup*)

This formula was defined to cover the terminological variability observed in this field over time and lake types, and simultaneously omit undesirable results such as items focusing on outburst floods from landslide-dammed lakes. The WOS database was analysed between September and October 2017, when all of the major journals regularly publishing GLOF research items have already released their 2016 issues to WOS database. Each item contained in the WOS Core Collection

5   database is described by a number of qualitative and quantitative characteristics, some of which are further analysed in this study (Tab. 1; see Section 3), reflecting the objectives. A total of 892 items were found and used for the building and analysis of the database (see 2.2).

2.2 Data processing, database building and analysis

The basic analysis was performed in the WOS environment, using the WOS Results Analysis tool. This tool allows the analysis

10   of the entire set of 892 items, including an overview of: (i) authors; (ii) institutions; (iii) source titles; (iv) WOS categories; (v) research areas; (vi) document types (see 3.1). Journals publishing GLOF research items (see 3.1.1) were further analysed using the WOS Journal Citation Reports tool and citations and references (see 3.1.2) were analysed using the WOS Citation Report tool. The set of 892 analysed GLOF research items (see 2.1) was exported from the WOS platform, and subsequently processed and analysed in a Microsoft Excel environment. Some of the data needed to be repaired (e.g., the institutions of all of the

15   authors involved in each research item are not available for 21 (2.4%) research items written by more than one author. In which case, the country of the affiliation of the reprint author was used).

In addition to the characteristics assigned from the WOS database, each item was manually described by certain other characteristics, based on the search in the titles, abstracts (available for 843 out of the 892 items; 94.5%), and keywords (available for 517 out of the 892 items; 58.0%), using the content analysis method (e.g., Hsieh and Shannon, 2005). These

20   include geographical characteristics, characteristics of authors (teams) contributing to individual research items and mono-/inter-nationality of the research teams. These characteristics are analysed in Section 3.2, focusing on: (i) geographical focus of GLOF research (see 3.2.1); (ii) geographies of the researchers involved (see 3.2.2); (iii) the "export" of research of GLOFs (see 3.2.3); and (iv) international collaboration (see 3.2.4).

3 Results

25   ### 3.1 General characteristics of published items

3.1.1 Bibliometric characteristics

A total of 892 GLOF research items were published in the WOS Core Collection database as of the end of 2016. At least one GLOF research item was published each year since 1979 with the exception of 1983 and 1987 (see Fig. 1). At least 10 GLOF research items were published every single year since 1993, at least 20 items since 2002 and at least 50 items since 2012. A

record number of papers was published in 2015 (n = 81; 9.1%). Nearly 500 items (n = 498; 55.8%) have been published since 2008 (during the past 8 years out of the 38-year long period of the analysis).

GLOF research has been published under 256 diverse *source titles* (journals and proceedings) indexed in WOS, of which 26 journals / proceedings have published 10+ GLOF research items each (515 items in total; 57.7%) and 10 journals / proceedings have published 20+ items each (297 items in total; 33.3%). The Journal of Glaciology (n = 48; 5.4%), Quaternary Science Reviews (n = 46; 5.2%) and Geomorphology (n = 39; 4.4%) have published 30+ items, in total 133 (14.9%). Twenty of the most popular journals / proceedings have published a total of 449 (50.3%) items. Twenty-two out of the 26 journals that published 10+ items each have a Q1 or Q2 ranking in at least one WOS category. Four of these journals have IF > 4, 11 have IF > 3 and 20 have IF > 2. Eight research items (0.9%) have been published in top ranked journals (Nature, Science).

The analysed GLOF research items have been publish in journals indexed in 48 diverse *WOS categories*. The vast majority of published items (n = 558; 62.6%) have been published in journals indexed in the *WOS category* "geoscience multidisciplinary", followed by "geography physical" (n = 338; 37.9%), "water resources" (n = 149; 16.7%) and "geology" (n = 117; 13.1%). Research of GLOFs is represented in 34 diverse research areas. The most frequently represented *research area* is "geology" (n = 666; 74.7%), followed by "physical geography" (n = 338; 37.9%), "water resources" (n = 149; 16.7%) and "environmental science ecology" (n = 100; 11.2%). In terms of *document types*, the vast majority of the GLOFs items published in WOS are classified as articles (n = 731; 82.0%), while 149 are classified as proceedings papers (16.7%) and 50 are classified as reviews (5.6%). A few items are also classified as letters, editorial materials or notes.

3.1.2 Citations and references

The 892 published GLOF research items have attracted a total of 18,570 citations (as of the end of 2016) and around 13,000 citations without self-citations. The number of citations has gradually increased during the analysed period, from tens of citations per year in the 1980s, hundreds of citations per year in the late 1990s and 2000s, thousands of citations per year in the 2010s, to up to 2,514 citations in 2016, which basically reflects the increasing number of GLOF research items published (see 3.1). Each item has an average of 51.63 records in the list of references, rarely exceeding 100 references.

Each GLOF research item has obtained an average of 20.82 citations (14.57 without self-citations). The most cited paper (Hemming, 2004) has obtained 581 citations (as of the end of 2016) and the 108 most cited papers (12.1% of all) have obtained more than 50% of all citations. Approximately one quarter (n = 228; 25.6%) of all items have two or less citations, of which 107 were published in 2014 or earlier. The H-index of GLOF research items is 62 (October 2017). In terms of citations obtained by individual items per year, 7 items obtained 15+ citations / year, 21 items obtained 10+ citations / year, and 77 items obtained 5+ citations / year during the analysed period. Each item obtained an average of 2.11 citations (1.48 excluding self-citations) per publication–year (8,798 publication-years in total). The ratio of citations in a given year divided by the cumulative number of items published until a given year has gradually increased from 0.28 in the early 1990s to 2.90 in 2015.

3.2 Geographies of GLOFs, GLOF research and researchers

3.2.1 Where are GLOFs studied?

The occurrence of GLOFs is closely tied to the retreating glaciers and is, therefore, geographically clustered. Based on the previous GLOF inventories and overviews (Carrivick and Tweed, 2016; Emmer et al., 2016), eleven non-overlapping hotspots of GLOFs occurrence are distinguished around the globe (see Tab. 2), of which three are located in Asia (HKH, CAS, KRK), in Europe (ALP, ICL, SCA) and North America (ALA, GRL, NAC) and two are located in South America (CAN, PAN). ICL, NAC and HKH are the most prominent GLOF research hotspots with 180, 144 and 142 research items, respectively. The documented numbers of GLOFs are, however, highly disproportionate (see 4.2). GLOFs have been studied on all of the continents including Africa (e.g. Girard et al., 2012), Australia (e.g., Goodsell et al., 2005) and Antarctica (e.g., Margerison et al., 2005), and extreme outburst floods are also thought to shape the landscape of Mars (e.g., Lapotre et al., 2016).

Three types of studies are distinguished among the GLOF research items in terms of geographical focus: (i) regionally-focused items; (ii) multi-regionally-focused items; and (iii) items with no regional focus (e.g., theoretical or model studies). It was determined that almost three quarters of all GLOF research items (n = 651; 73.0%) have their geographical focus in 11 of the pre-defined hotspots of GLOFs occurrence, of which 32 items (3.6%) are characterised as multi-regionally-focused (e.g., Worni et al., 2012; Haeberli et al., 2016). However, the actual number of research items with a certain geographical focus is slightly higher (> 80%), considering items that are geographically focused on regions outside the eleven hotspots of GLOF occurrence, such as Altai / Siberia (21 items, e.g., Margold et al., 2011), Svalbard (5 items; e.g., Schoner and Schoner, 1997), Caucasus (4 items; e.g., Petrakov et al., 2012), Antarctica (21 items, e.g. Margerison et al., 2005) or items focused on Mars (23 items; e.g., Rodriguez et al., 2015). In terms of individual countries, the most prominent country of GLOF research is Iceland (180 research items).

From the point of view of geographical focus on individual lakes, 37 items are focused on repeated Late Pleistocene outbursts from the proglacial Lake Missoula, likely being the most researched glacial lake outburst flood (e.g., Benito and O'Connor, 2003), followed by the 8.2 ka outburst flood from Lake Agassiz, which is mentioned in 28 research items (e.g., Clarke et al., 2004). Various aspects of jokulhlaups on the Katla volcano, Iceland, are elaborated in 27 research items (e.g., Duller et al., 2014). The most famous glacial lakes in GLOF hazard / risk studies nowadays - Imja Tsho, Tsho Rolpa (both Nepal Himalayas) and Palcacocha (Peruvian Andes) have received the attention of 17, 9, and 7 research items, respectively (e.g., Rounce et al., 2016; Klimeš et al., 2016).

3.2.2 Who studies GLOFs?

In total, 1,885 authors from more than 750 institutions in 45 countries have contributed to the 892 analysed GLOF research items. Considering the number of items published by each author, it emerges that a research item on GLOF is written on average by 3.49 authors, indicating generally small teams executing GLOF research. Almost one sixth of the 892 research items (n = 146; 16.4%) have been written by individuals, while 746 items (83.6%) by research teams (two or more co-authors).

The share of research items written by individuals, however, is dramatically decreasing over time. While 32.8% of all research items published before 2000 were written by individuals, 20.9% were written in 2000-2004, 17.2% in 2005-2009, 6.0% in 2010-2014 and 7.1% in 2015-2016, revealing a certain change in the publication paradigm (see also 4.1). Slightly more than two thirds of GLOF research items (n = 632; 70.9%) have been published by mononational research teams/individuals, while 260 research items (29.1%) have been published by groups of authors from two or more countries (international research teams; see 3.2.4). Researchers from up to six countries have been involved in one individual GLOF research item (e.g., Benn et al., 2012). The share of GLOF research items written by international research teams is gradually increasing over time from 26.4% in 2000-2004, 30.2% in 2005-2009, 35.6% in 2010-2014 to 36.8% in 2015-2016. However, significant differences exist between individual countries (see also Section 3.2.4).

More than 750 *institutions* have been involved in research of GLOFs, of which 17 institutions have published 20+ GLOF research items (369 items in total; 41.4%). Nine of these 17 institutions are located in Europe (United Kingdom, Iceland, Switzerland and France), seven in North America, and the remaining one in Asia. Overall geographical distribution of GLOF research items by the countries of the authors' institutions suggests a strong dominance of authors from Europe and North America: 497 items (55.7% of all) were (co-)authored by researchers from Europe; 344 items (38.6% of all) were (co-)authored by researchers from North America (USA + Canada); 179 items (20.1% of all) were (co-)authored by researchers from Asia (including Russia); 29 items (3.3% of all) were (co-)authored by researchers from Latin America; 25 items (2.8% of all) were (co-)authored by researchers from Australia (Australia + NZ); and 7 items (0.8% of all) were (co-)authored by researchers from Africa.

Fourteen out of 1,885 individual researchers (0.7% in all) have published 10+ GLOF research items each (189 items in total; 21.2%) and 90 researchers (4.8% of all) have published 5+ GLOF research items each (436 items in total; 48.9%). Researchers from the USA have contributed to 240 research items (26.9%), followed by 213 items (co)authored by researchers from UK (23.9%) and 115 research items (co)authored by researchers from Canada (12.9%; see Fig. 2). The seven most productive GLOF research countries have published 50+ GLOF research items each (678 items in total; 76.0%) and 16 different countries (England, Scotland and Wales are counted separately) have published 20+ GLOF research items each (802 items in total; 89.9%).

3.2.3 The "export" of research of GLOFs

It is obvious that a certain geographical disproportion exists between the countries where GLOFs are studied (11 hotspots of GLOF occurrence; see 3.2.1) and the top 10 GLOF research countries (see 3.2.2; see Fig. 2), which have contributed to a total of 740 (83.0%) GLOF research items. The "export" of research from the top 10 GLOF research countries to 11 hotspots of GLOF occurrence is described in this section (see Tab. 3 and Tab. 4). Considering the country of the first author only (i.e. each item is counted only once in the country of the first author even if it was written by an international research team; Tab. 3), the following patterns are observed: (i) more than three thirds (78.3%) of research items focusing on 11 hotspots of GLOF occurrence were authored by researchers from the top 10 GLOF research countries; (ii) 43.5% of imported research items were

authored by researchers from the 10 GLOF research countries; (iii) researchers from the USA and UK have performed research in all 11 hotspots of GLOFs occurrence; (iv) researchers from Iceland, China and Norway have focused almost exclusively on hotspots overlapping with their countries (ICL; CAS, HKH, KRK; and SCA, respectively); (v) the research in ALA and NAC has almost exclusively been performed by the researchers from overlapping countries (74.5% of research items focusing on ALA has been elaborated by researchers from USA and 84.7% of research items focusing on NAC has been elaborated by researchers from USA and Canada).

Considering the countries of all of the institutions contributing to individual GLOF research items (see Tab. 4), it is seen that: (i) researchers from the USA, UK and Switzerland have contributed to research in all 11 hotspots of GLOF occurrence; (ii) the most prominent GLOF research exporter is UK (154 items), followed by USA (84 items) and Switzerland (53 items); (iii) the researchers from Iceland and China focus almost exclusively on hotspots overlapping with their countries (ICL; CAS, HKH, KRK); (iv) the share of imported research from the top 10 countries is very high in GRL, KRK, CAS and HKH, while it is very low in ALP, ALA and NAC; (v) the research in hotspots located in developing countries is dominated by researchers from the USA and Japan (HKH); Germany, Switzerland and UK (CAS); Switzerland, Germany and the USA (KRK), Switzerland and the USA (CAN); and UK (PAN).

3.2.4 International cooperation

Section 3.2.2 shows that items written by international research teams represent 29.1% of all GLOF research items with a gradually increasing trend. However, there are significant differences between individual countries (see Tab. 5). The highest number of international research items was authored (first author) by researchers from the UK (56 items), followed by the researchers from the USA (38). The researchers from the USA contributed to 91 international research items (36.1% of all), followed by researchers from UK who contributed to 84 international research items (33.3% of all). The share of international items on the overall number of items published among the top 10 GLOF research countries varies from 34.8% (Canada) to 71.4% (Norway).

The vast majority of the 45 GLOF research countries (n = 42) have contributed to at least one international GLOF research item (Lebanon, Saudi Arabia and Uzbekistan have not). The intensity of international cooperation between GLOF research countries is illustrated in Fig. 3. An overall number of 468 individual bilateral research ties exist (each tie represents one joint publication between two countries; see Tab. 1). Very strong cooperation (20+ joint research items) exists between researchers from the USA and the UK (24 joint research items), and the UK and Iceland (21), and strong cooperation (10+ joint research items) exists between the USA and Canada (19), the USA and Iceland (13), Switzerland and Germany (12), and the USA and Japan (10). Certain patterns are observed regarding the cooperation between groups of countries.

4 Observed trends in GLOF research: A discussion

4.1 Is there a changing publishing paradigm?

Research of glacial lake outburst floods (GLOFs) represents a dynamic research field, reflecting the needs and challenges brought by the rapidly changing environment (e.g., Huss et al., 2017). A certain change in the publishing paradigm is observed among the published GLOF research items and documented by the analysed characteristics (see Section 3.1). Firstly, the amount of research of GLOFs had an exponentially increasing trend in the WOS database between 1979 and 2016. From the field of natural hazard science, a similar trend is observed in research on tsunamis (Chiu and Ho, 2007), a more remarkable trend is observed in research on landslides (Xu et al., 2015) and a less remarkable trend in research on earthquakes (Liu et al., 2012). This trend is similar despite the fact that the GLOF research field is an order of magnitude smaller than the other above-mentioned fields and is in concordance with the generally observed trends across the scientific disciplines (e.g., Sandstrom and Van den Besselaar, 2016). Secondly, the increasing amount of published research items within the certain research field is directly tied with the increasing amount of citations obtained by individual items within this field (e.g., geomorphology; Dorn, 2002), which is also valid also in the case of GLOF research (see 3.1.2). Thirdly, the share of GLOF research items written by individuals is observed to have dramatically declined over the few past decades (see 3.2.2). This observation is not surprising considering the general trends in research and science, and may indicate the increasing average extent and, hence, multidisciplinarity of the research teams involved (see also Skilton, 2009). Last but not least - the changing paradigm in GLOF research is also seen in the thematical content of GLOF research items. While hazards and risks, geomorphology and hydrology have traditionally dominated in GLOF research, recently other aspects such as climate justice have come to the forefront (e.g., Huggel et al., 2016).

4.2 Trends in geographies

A significant disproportion is observed between the number of documented GLOFs from specific regions and the number of GLOF research items geographically focused on a given region (see 3.2.1). While 270 GLOFs are documented from ICL (180 research items), only 47 are documented from HKH (142 research items; see Tab. 2). This disproportion can be explained as a result of: (i) differences in the causes and mechanisms of GLOFs (repeated GLOFs from ice-dammed lakes in ICL, one-off GLOFs from moraine-dammed lakes in HKH); (ii) incomplete GLOF inventories in less researched and/or less settled regions such as remote areas of HKH (see Emmer et al., 2016); (iii) the expected future increase in GLOF occurrence in HKH (Harrison et al., in review). On the other hand, the highest number of GLOFs are documented from ALP (n = 301), where only 46 studies were performed, which may be related to the late stage of glacier retreat in a post-LIA context (see also Emmer et al., 2015).

It has also been shown that an apparent geographical disproportionateness exists between the hotspots of GLOF occurrence (see 3.2.1) and top countries performing GLOF research (see 3.2.2), leading to the geographical "export" of research (see 3.2.3) - a phenomenon not yet fully captured within the context of the GLOF research field. The research of GLOFs is traditionally dominated by researchers from Europe and North America (see 3.2.2), while researchers from other

countries - especially those overlapping with GLOF occurrence hotspots located in developing regions – have come into play more recently, frequently as members of international research teams, but also as the first authors. An example is the research of GLOFs in Kyrgyz Tien Shan, which was formerly led by foreign researchers with the participation of Kyrgyz researchers (e.g., Janský et al., 2009; Narama et al., 2010), but has been led by Kyrgyz researchers with the contribution of foreign

5   researchers more recently (Zaginaev et al., 2016), indicating a certain shift in the research paradigm and/or successful knowledge transfer (e.g., Fazey et al., 2014; Gherardini and Nucciotti, 2017). A similar shift is observed in other regions such as CAN (early GLOF works published at WOS by Vilímek et al. (2005) compared to the recent work of Colonia et al. (2017)) or HKH (Watanabe and Rothacher (1996) and the recent work of Prakash and Nagaraja (2017)). A trend in the internationalization of GLOF research teams has also been observed in the past few decades (see 3.2.4), which is in line with

10   the general trends observed (e.g., Jappe, 2007).

5 Conclusions

This study shows how research of glacial lake outburst floods (GLOFs) published in the Web of Science Core Collection database has become topical over the past few decades (analysed period 1979-2016); how the publishing culture and paradigm have changed over time and what the trends and disproportions in geographies of research on GLOFs are. A significant

15   exponential increase in the number of GLOF research items published in the WOS database is revealed, with > 50% of the research items being published since 2008. While 1,885 researchers from more than 750 institutions in 45 countries have contributed to 892 of the analysed GLOF research items, a relatively small number of 90 leading researchers (4.8% of all) have published 5+ items each and have together contributed to almost half (48.9%) of all of the GLOF research items. Furthermore, the following trends were revealed among the published items over time: (i) internationalisation (increasing share

20   of research items written by international teams); (ii) geographical disproportionateness (disparity between where GLOFs occurred and the top GLOF research countries). Eleven hotspots of GLOF occurrence and research have been identified, of which five are located in developing regions. The export of research especially to these five hotspots has been documented. It was shown that researchers from the UK, the USA, Canada, Germany and Switzerland are the most active in exporting GLOF research worldwide and also in international cooperation. The trend of larger involvement of local researchers is observed

25   among recent studies in hotspots of GLOFs located in developing countries, e.g., Central Asia or Central Andes.

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References

Aggarwal, S., Rai, S., Thakur, P. K. and Emmer, A.: Inventory and recently increasing GLOF susceptibility of glacial lakes in Sikkim, Eastern Himalaya, Geomorphology, 30(295), 39–54, doi:10.1016/j.geomorph.2017.06.014, 2017.

Benito, G. and O'Connor, J. E.: Number and size of last–glacial Missoula floods in the Columbia River valley between the Pasco Basin, Washington, and Portland, Oregon, Geological Society of America Bulletin, 115(5), 624–638, doi:10.1130/0016-7606(2003)115<0624:NASOLM>2.0.CO;2, 2003.

Björnsson, H. and Pálsson, F.: Icelandic Glaciers, Jokull, 58, 365–386, 2008.

Broggi, J.A.: Informe preliminar sobre la exploracion y estudio de las condiciones de estabilidad de las lagunas de la Cordillera Blanca, ELECTROPERU S.A, Lima (Peru), 1942.

Carey, M.: In the Shadow of Melting Glaciers: Climate Change and Andean Society, Oxford University Press, New York, 2010.

Carrivick, J. L. and Tweed, F. S.: A global assessment of the societal impacts of glacier outburst floods, Global and Planetary Change, 144, 1–16, doi:10.1016/j.gloplacha.2016.07.001, 2016.

Chiu, W. T. and Ho, Y. S.: Bibliometric analysis of tsunami research, Scientometrics, 73(1), 3–17, doi:10.1007/s11192-005-1523-1, 2007.

Clarke, G. K. C., Leverington, D. W., Teller, J. T. and Dyke, A. S.: Paleohydraulics of the last outburst flood from glacial Lake Agassiz and the 8200 BP cold event, Quaternary Science Reviews, 23(3–4), 389–407, doi:10.1016/j.quascirev.2003.06.004 , 2004.

Clague, J. J. and Evans, S. G. (2000): A review of catastrophic drainage of moraine–dammed lakes in British Columbia, Quaternary Science Reviews, 19(17–18), 1763–1783, doi:10.1016/S0277-3791(00)00090-1, 2000.

Clague, J. J. and O'Connor, J. E.: Glacier–related outburst floods, in: Snow and ice–related hazards, risks, and disasters, Haeberli, W. and Whiteman, C. (Eds.), Elsevier, Amsterdam, 487–519, 2015.

Clague, J. J., Huggel, C., Korup, O. and McGuire, B.: Climate change and hazardous processes in high mountains, Revista de la Asociación Geológica Argentina, 69(3), 328–338, 2012.

Clarivate Analytics: Web of Science fact book, Clarivate Analytics, online report, 2017.

Colonia, D., Torres, J., Haeberli, W., Schauwecker, S., Braendle, E., Giraldez, C. and Cochachin, A.: Compiling an Inventory of Glacier–Bed Overdeepenings and Potential New Lakes in De–Glaciating Areas of the Peruvian Andes: Approach, First Results, and Perspectives for Adaptation to Climate Change, Water, 9(5), 336, doi:10.3390/w9050336, 2017.

Dorn, R. I.: Analysis of geomorphology citations in the last quarter of the 20th century, Earth Surface Processes and Landforms, 27(6), 667–672, doi:10.1002/esp.345, 2002.

Duller, R. A., Warner, N. H., McGonigle, C., De Angelis, S., Russel, A. J. and Mountney, N. P.: Landscape reaction, response, and recovery following the catastrophic 1918 Katla jokulhlaup, southern Iceland, Geophysical Research Letters, 41(12), 4214–4221, doi:10.1002/2014GL060090, 2014.

Emmer, A.: Geomorphologically effective floods from moraine–dammed lakes in the Cordillera Blanca, Peru, Quaternary Science Reviews, 117, 220–234, doi: 10.1016/j.quascirev.2017.10.028, 2017.

Emmer, A., Merkl, S. and Mergili, M.: Spatio–temporal patterns of high–mountain lakes and related hazards in western Austria, Geomorphology, 246, 602–616, doi:10.1016/j.geomorph.2015.06.032, 2015.

5   Emmer, A., Vilímek, V., Huggel, C., Klimeš, J. and Schaub, Y.: Limits and challenges to compiling and developing a database of glacial lake outburst floods. Landslides, 13(6): 1579–1584, doi:10.1007/s10346-016-0686-6, 2016.

Evans, S. G. and Clague, J. J.: Recent climatic change and catastrophic processes in mountain environments, Geomorphology, 10, 107–128, doi:10.1016/0169-555X(94)90011-6, 1994.

Falátková, K.: Temporal analysis of GLOFs in high–mountain regions of Asia and assessment of their causes, AUC
10   Geographica, 51(2), 145–154, doi:10.14712/23361980.2016.12, 2017.

Fazey, I., Bunse, L., Msika, J., Pinke, M., Preedy, K., Evely, A. C., Lambert, E., Hasting, E., Morris, S. and Reed, M. S.: Evaluating knowledge exchange in interdisciplinary and multi–stakeholder research, Global Environmental Change–Human and Policy Dimensions, 25, 204–220, doi:10.1016/j.gloenvcha.2013.12.012, 2014.

Fryxell, F. M. and Horberg, L.: Alpine mudflows in Grand Teton National Park, Wyoming, Geological Society of America
15   Bulletin, 54, 457–472, 1943.

Gerassimow, A. P.: On the glacial lake outburst at the north–east slope of Mt. Elbrus (in Russian), Izvestiya Geolkoma, 28(7), 156–160, 1909.

Gherardini, A. and Nucciotti, A.: Yesterday's giants and invisible colleges of today. A study on the 'knowledge transfer' scientific domain, Scientometrics, 112(1), 255–271, doi:10.1007/s11192-017-2394-y, 2017.

20   Girard, F., Ghienne, J. F. and Rubino, J. L.: Occurrence of hyperpycnal flows and hybrids event beds related to glacial outburst events in a Late Ordovician proglacoal delta (Murzuq Basin, SW Libya), Journal of Sedimentary Research, 82(9–10), 688–708, doi:10.2110/jsr.2012.61, 2012.

Girard, F., Ghienne, J. F., Du–Bernard, X. and Rubino, J. L.: Sedimentary imprints of former ice–sheet margins: Insights from an end–Ordovician archive (SW Libya), Earth–Science Reviews, 148, 259–289, doi:10.1016/j.earscirev.2015.06.006, 2015.

25   Goodsell, B., Anderson, B., Lawson, W. J. and Owens, I. F.: Outburst flooding at Franz Josef Glacier, South Westland, New Zealand, New Zealand Journal of Geology and Geophysics, 48(1), 95–104, 2005.

Grabs, W. E. and Hanisch, J.: Objectives and prevention methods for glacier lake outburst floods (GLOFs), in: Snow and glacier hydrology (proceedings of the Kathmandu Symposium, November 1992), Young, G.J. (Ed.), International Association of Hydrological Sciences (IAHS), Great Yarmouth (U.K.), 341–352, 1993.

30   Grinsted, A., Hvidberg, C. S., Campos, N. and Dahl–Jensen, D.: Periodic outburst floods from an ice–dammed lake in East Greenland, Scientific Reports, 7, 9966, doi:10.1038/s41598-017-07960-9, 2017.

Guan, M. F., Wright, N. G., Sleigh, P. A. and Carrick, J. L.: Assessment of hydro–morphodynamic modelling and geomorphological impacts of a sediment–charged jokulhlaup, at Solheimajokull, Iceland, Journal of Hydology, 530, 336–349, doi:10.1016/j.jhydrol.2015.09.062, 2015.

Haeberli, W., Buetler, M., Huggel, C., Lehmann Friedli, T., Schaub, Y. and Schleiss, A. J.: New lakes in deglaciating high–mountain regions – opportunities and risks, Climatic Change, 139(2), 201–214, doi:10.1007/s10584-016-1771-5, 2016.

Hákonarson, M.: Kötluhlaup í Jökulsá á Sólheimasandi, Íslendingur, 1, 19th July, 1860.

Harrison, S., Kargel, J., Huggel, C., Reynolds, J., Shugar, D., Betts, R., Emmer, A., Glasser, N., Haritashya, U., Klimeš, J., Reinhardt, L., Schaub, Y., Wiltshire, A., Regmi, D. and Vilímek, V.: Climate change and the global pattern of moraine–dammed glacial lake outburst floods, The Cryosphere Discuss., https://doi.org/10.5194/tc–2017–203, 2017, in review.

Hemming, S. R.: Heinrich events: Massive Late Pleistocene detritus layers of the North Atlantic and their global climate imprint, Reviews of Geophysics, 42(1), RG1005, doi:10.1029/2003RG000128, 2004.

Hewitt, K.: Environmental disasters in social context: toward a preventive and precautionary approach, Natural Hazards, 66(1), 3–14, doi:10.1007/s11069-012-0205-6, 2013.

Horstmann, B.: Glacial lake outburst floods in Nepal and Switzerland – New threats due to climate change, Germanwatch, Germany, 2004.

Huggel, C., Wallimann–Helmer, I., Stone, D. and Cramer, W.: Reconciling justice and attribution research to advance climate policy, Nature Climate Change, 6, 901–908, doi:10.1038/NCLIMATE3104, 2016.

Huss, M., Bookhagen, B., Huggel, C., Jacobsen, D., Bradley, R. S., Clague, J. J., Vuille, M., Buytaert, W., Cayan, D. R., Greenwood, G., Mark, B. G., Milner, A. M., Weingartner, R. and Winder, M.: Toward mountains without permanent snow and ice, Earths Future, 5(5), 418–435, doi:10.1002/2016EF000514, 2017.

Hsieh, H. F. and Shannon, S. E.: Three Approaches to Qualitative Content Analysis, Qualitative Health Research, 15(9), 1277–1288, doi:10.1177/1049732305276687, 2005.

Iribarren Anacona, P., Mackintosh, A. and Norton, K. P.: Hazardous processes and events from glacier and permafrost areas: lessons from the Chilean and Argentinean Andes, Earth Surface Processes and Landforms, 40, 2–21, doi:10.1002/esp.3524, 2015.

Iturrizaga, L.: Glacier Lake Outburst Floods, in: Encyclopedia of Snow, Ice and Glaciers, Singh, V. P. et al. (Eds.), Springer, U.K., 381–399, 2011.

Jackson, L. E.: Catastrophic glacial lake outburst flood (jokulhlaup) mechanism for debris flow generation at the spiral tunnels, Kicking horse River basin, British Columbia, Canadian Geotechnical Journal, 16(4), 806–813, 1979.

Janský, B., Engel, Z., Šobr, M., Beneš, V., Špaček, K. and Yerokhin, S.: The evolution of Petrov lake and moraine dam rupture risk (Tien–Shan, Kyrgyzstan), Natural Hazards, 50(1), 83–96, doi:10.1007/s11069-008-9321-8, 2009.

Jappe, A.: Explaining international collaboration in global environmental change research, Scientometrics, 71(3), 367–390, doi:10.1007/s11192-007-1676-1, 2007.

Klimeš, J., Novotný, J., Novotná, I., Jordán de Urries, B., Vilímek, V., Emmer, A., Strozzi, T., Kusák, M., Cochachin Rapre, A., Hartvich, F. and Frey, H.: Landslides in moraines as triggers of glacial lake outburst floods: example from Palcacocha Lake (Cordillera Blanca, Peru), Landslides, 13(6), 1461–1477, doi:10.1007/s10346-016-0724-4, 2016.

Korup, O.: Earth's portfolio of extreme sediment transport events, Earth–Science Reviews, 112(3–4), 115–125, doi:10.1016/j.earscirev.2012.02.006, 2012.

Korup, O. and Tweed, F.: Ice, moraine, and landslide dams in mountainous terrain, Quaternary Science Reviews, 26, 3406–3422, doi:10.1016/j.quascirev.2007.10.012, 2007.

5   Lapotre, M. G. A., Lamb, M. P. and Williams, R. M. E.: Canyon formation constraints on the discharge of catastrophic outburst floods of Earth and Mars, Journal of Geophysical Research–Planets, 121(7), 1232–1263, doi:10.1002/2016JE005061, 2016.

Liu, X. J., Zhan, F. B., Hong, S., Niu, B. B. and Liu, Y. L.: A bibliometric study of earthquake research: 1900–2010, Scientometrics, 92(3), 747–765, doi:10.1007/s11192-011-0599-z, 2012.

Lliboutry, L., Morales, B. A., Pautre, A. and Schneider, B.: Glaciological problems set by the control of dangerous lakes in
10 Cordillera Blanca, Peru. I. Historical failures of moranic dams, their causes and prevention, Journal of Glaciology, 18(79), 239–254, 1977.

Margerison, H. R., Phillips, W. M., Stuart, F. M. and Sugden, D. E.: Cosmogenic He–3 concentrations in ancient flood deposits from the Coombs Hills, northern Dry Valleys, East Antarctica: interpreting exposure ages and erosion rates, Earth and Planetary Science Letters, 230(1–2), 163–175, doi:10.1016/j.epsl.2004.11.007, 2005.

15 Margold, M., Jansson, K. N., Stroeven, A. P. and Jansen, J. D.: Glacial Lake Vitim, a 3000–km(3) outburst flood from Siberia to the Arctic Ocean, Quaternary Research, 76(3), 393–396, doi:10.1016/j.yqres.2011.06.009, 2011.

Narama, C., Dushonakunov, M., Kaab, A., Daiyrov, M. and Abdrakhmatov, K.: The 24 July 2008 outburst flood at the western Zyndan glacier lake and recent regional changes in glacier lakes of the Teskey Ala–Too range, Tien Shan, Kyrgyzstan, Natural Hazards and Earth System Sciences, 10(4), 647–659, 2010.

20 O'Connor, J. E., Hardison, J. H. and Costa, J. E.: Debris flows from failures of neoglacial–age moraine dams in the Three Sisters and Mount Jefferson Wilderness Areas, Oregon, U.S. Geological Survey, Reston, VA, 2001.

Prakash, C. and Nagarajan, R.: Outburst susceptibility assessment of moraine–dammed lakes in Western Himalaya using an analytic hierarchy process, Earth Surface Processes and Landforms, 42(14), 2306–2321, doi:10.1002/esp.4185, 2017.

Richardson, S. D. and Reynolds, J. M.: An overview of glacial hazards in the Himalayas, Quaternary International, 65/66, 31–
25 47, doi:10.1016/S1040-6182(99)00035-X, 2000.

Richter, E.: Urkunden über die Ausbrüche des Vernagt– und Gurglergletschers im 17. und 18. Jahrhundert, Forsuchen Dtsch. Landes Volkskd. 6, 345–440, 1892.

Rodriguez, J. A. P., Kargel, J. S., Baker, V. R., Gulick, V. C., Berman, D. C., Fairen, A. G., Linares, R., Zarroca, M., Yan, J. G., Miyamoto, H. and Glines, N.: Martian outflow channels: How did their source aquifers form, and why did they drain so
30 rapidly?, Scientific Reports, 5, 13404, doi:10.1038/srep13404, 2015.

Rounce, D. R., McKinney, D. C., Lala, J. M., Byers, A. C. and Watson, C. S.: A new remote hazard and risk assessment framework for glacial lakes in the Nepal Himalaya, Hydrology and Earth System Sciences, 20(8), 3455–3475, doi:10.5194/hess-20-3455-2016, 2016.

Round, V., Leinss, S., Huss, M., Haemming, C. and Hajnsek, I.: Surge dynamics and lake outbursts of Kyagar Glacier, Karakoram, Cryosphere, 11(2), 723–739, doi:10.5194/tc-11-723-2017, 2017.

Sandstrom, U. and Van den Besselaar, P.: Quantity and/or Quality? The Importance of Publishing Many Papers, PLOS One, 11(11), e0166149, doi:10.1371/journal.pone.0166149, 2016.

5 Schoner, W. and Schoner, M.: Effects of glacier retreat on the outbursts of Goesvatnet, southwest Spitsbergen, Svalbard, Journal of Glaciology, 43(144), 276–282, 1997.

Schwanghart, W., Worni, R., Huggel, C., Stoffel, M. and Korup, O.: Uncertainty in the Himalayan energy–water nexus: estimating regional exposure to glacial lake outburst floods, Environmental Research Letters, 11(7), 074005, doi:10.1088/1748-9326/11/7/074005, 2016.

10 Shaw, J., Stacey, C. D., Wu, Y. S. and Lintern, D. G.: Anatomy of the Kitimat fiord system, British Columbia, Geomorphology, 293(A), 108–129, doi:10.1016/j.geomorph.2017.04.043, 2017.

Small, H. and Garfield, E.: The geography of science: disciplinary and national mappings, Journal of Information Science, 11(4), 147–159, doi:10.1177/016555158501100402, 1985.

Skilton, P.F.: Does the human capital of teams of natural science authors predict citation frequency?, Scientometrics, 78(3), 15 525–542, doi: 10.1007/s11192-007-1953-z, 2009.

UGRH: Consolidado de Actividades Realizadas en el Año 2015 Por la Unidad de Glaciología y Recursos Hídricos, Autoridad Nacional del Agua (ANA), Unidad de Glaciología y Recursos Hídricos (UGRH), Huaráz, Peru, 2015.

Vilímek, V., Zapata, M. L., Klimeš, J., Patzelt, Z., Santillán, N.: Influence of glacial retreat on natural hazards of the Palcacocha Lake area, Peru, Landslides, 2, 107–115, doi:10.1007/s10346-005-0052-6, 2005.

20 Vugteveen, P., Lenders, R. and Van den Besselaar, P.: The dynamics of interdisciplinary research fields: the case of river research, Scientometrics, 100, 73–96, doi:10.1007/s11192-014-1286-7, 2014.

Watanabe, T. and Rothacher, D.: The 1994 Lugge Tsho glacial lake outburst flood, Bhutan Himalaya, Mountain Research and Development, 16(1), 77–81, doi:10.2307/3673897, 1996.

Wilcox, A. C., Wade, A. A. and Evans, E. G.: Drainage events from a glacier–dammed lake, Bear Glacier, Alaska: Remote 25 sensing and field observations, Geomorphology, 220, 41–49, doi:10.1016/j.geomorph.2014.05.025, 2014.

Worni, R., Huggel, C., Clague, J. J., Schaub, Y. and Stoffel, M.: Coupling glacial lake impact, dam breach, and flood processes: A modeling perspective, Geomorphology, 224, 161–176, doi:10.1016/j.geomorph.2014.06.031, 2014.

Wu, X. L., Chen, X. Y., Zhan, F. B. and Hong, S.: Global research trends in landslides during 1991–2014: a bibliometric analysis, Landslides, 12, 1215–1226, doi:10.1007/s10346-015-0624-z, 2015.

30 Xu, M. Z., Bogen, J., Wang, Z. Y., Bonsnes, T. E. and Gytri, S.: Pro–glacial lake sedimentation from jokulhlaups (GLOF), Blamannsisen, northern Norway, Earth Surface Processes and Landforms, 40(5), 654–665, doi:10.1002/esp.3664, 2015.

Zaginaev, V., Ballesteros–Canvas, J. A., Erokhin, S., Matov, E., Petrakov, D. and Stoffel, M.: Reconstruction of glacial lake outburst floods in northern Tien Shan: Implications for hazard assessment, Geomorphology, 269, 75–84, doi:10.1016/j.geomorph.2016.06.028, 2016.

Tab. 1: Analysed characteristics describing each GLOF item.

Characteristics	Description	Value
WOS database:		
Author(s)	A list of authors contributing to GLOF research items	1,885 authors
Author's affiliation (institution)	A list of institutions contributing to GLOF research items	764 / 787 institutions*
Author's affiliation (country)	A list of countries where the institutions are located	45 countries
Year published	Year of publication in the journal	1979**-2016
Cited references in WOS collection	Number of references cited in one item	0-280***
Cited by	Cumulative number of citations obtained by one item	0-581****
Source title	Name of the journal / proceeding that published the GLOF research item	256 different journals / proceedings
WOS categories	WOS category in which the journal / proceeding is indexed	48 WOS categories
Research area	WOS research areas	34 research areas
Document type	WOS document types	9 document types
Manually assigned characteristics (see 2.2):		
Geographical focus	Manually assigned geographical focus of the individual item, where relevant	11 hotspots of GLOF occurrence; other regions
No. of authors	Items written by individuals are distinguished from items written by two or more authors (research teams)	Items written by an individual researcher; item written by a team
Mono-/inter-nationality	Items written by author(s) from one country (mononational) are distinguished from items written by authors from more than one country (international)	Item written by an individual researcher / mononational team; item written by an international team
International research ties	Manually assigned bilateral research ties (each tie represents one joint publication between two countries)	A matrix of 468 bilateral research ties

* institutions / institutions-enhanced

** the first GLOF research item published in the WOS database (Jackson, 1979)

*** the highest number of references cited by one item (Girard et al., 2015)

5   **** the highest number of citations obtained by one item by the end of 2016 (Hemming, 2004)

Tab. 2: Hotspots of GLOF occurrence.

Hotspot of GLOF occurrence	Hotspot acronym	No. of documented GLOFs from a given region*	No. of GLOF research items geographically focusing on a given region	Examples of recent studies
Asia:				
Central Asia (Pamir, Tien Shan)	CAS	69	37	Zaginaev et al., 2016
Hindu Kush - Himalaya (including Tibet)	HKH	47	142	Aggarwal et al., 2017
Karakoram	KRK	98	20	Round et al., 2017
Europe:				
European Alps	ALP	301	46	Emmer et al., 2015
Iceland	ICL	270	180	Guan et al., 2015
Scandinavia	SCA	121	21	Xu et al., 2015
North America:				
Alaska	ALA	80	34	Wilcox et al., 2014
Greenland	GRL	22	34	Grinsted et al., 2017
North American Cordillera	NAC	246	144	Shaw et al., 2017
South America:				
Central Andes	CAN	35	27	Emmer, 2017
Patagonian Andes	PAN	71	30	Iribarren Anacona et al., 2015

* based on Carrivick and Tweed (2016); Falátková (2017); Emmer (2017); note that the numbers of GLOF documented from less settled regions are likely to be underestimated (see also the text)

Tab. 3. Research exports from the top 10 countries to 11 hotspots of GLOF occurrence. Only the reprint address of the first author is considered in this table (each item is counted only once). The number of items from overlapping countries (OC; e.g., Switzerland and ALP; Norway and SCA) is shown in brackets.

Country	CAS	HKH	KRK	ALP	ICL	SCA	ALA	GRL	NAC	CAN	PAN	Excl. OC		Incl. OC	
TG	37	142	20	46	180	21	34	34	144	30	27	715			
USA	1	19	1	1	15	1	(26)	8	(61)	5	1	52	2.	139	1.
UK	4	13	1	5	76	4	2	12	9	4	6	136	1.	136	2.
Canada	1	2	2	2	4	0	3	2	(61)	1	0	17	6.	78	3.
Iceland	0	0	0	0	(49)	0	0	0	0	0	0	0	10.	49	4.
Germany	5	15	4	(1)	8	0	0	1	2	1	3	39	3.	40	6.
China	(6)	(16)	(3)	0	0	1	0	0	0	0	0	1	8./9.	26	8.
Switzerland	3	7	2	(19)	1	0	0	0	0	5	2	20	5.	39	5.
Japan	3	21	1	2	0	0	1	0	1	0	0	29	4.	29	7.
France	0	1	0	9	6	0	0	0	0	0	0	16	7.	16	9.
Norway	0	1	0	0	0	(7)	0	0	0	0	0	1	8./9.	8	10.
TI10	17	79	11	19	110	6	6	23	12	16	12	311		560	
TI10/1G	45.9	55.6	55.0	41.3	61.1	28.6	23.1	67.6	8.3	53.3	44.4	43.5		78.3	

TG - Total number of items geographically focused on a given region; TI10 - Total number of items authored by researchers from the top 10 GLOF research countries (excluding overlapping countries)

Tab. 4. Geographical focus of research items of the top 10 GLOF research countries (11 hotspots of GLOF occurrence). All items (co)authored by researchers from the given country are considered in this table (i.e. research items written by international research teams are counted for each country separately). The number of items from overlapping countries (OC; e.g., Switzerland and ALP; Norway and SCA) is shown in brackets.

Country	Hotspots of GLOFs occurrence (see also Tab. 2)											Total			
	CAS	HKH	KRK	ALP	ICL	SCA	ALA	GRL	NAC	CAN	PAN	Excl. OC		Incl. OC	
TG	37	142	20	46	180	21	34	34	144	30	27	715			
USA	3	27	4	1	30	1	(28)	11	(76)	6	1	84	2.	188	1.
UK	6	19	1	7	82	4	3	12	9	4	7	154	1.	154	2.
Canada	2	7	3	3	5	0	4	5	(70)	1	2	32	6.	102	3.
Iceland	0	0	0	0	(78)	0	0	0	0	0	0	0	10.	78	5.
Germany	8	17	4	(2)	10	0	0	3	3	2	4	51	4.	53	6.
China	(11)	(22)	(6)	0	1	1	0	1	0	0	0	3	9.	42	7.
Switzerland	7	15	5	(27)	3	2	2	2	4	9	4	53	3.	80	4.
Japan	3	26	1	3	0	0	1	0	2	0	0	36	5.	36	8.
France	0	2	0	(11)	9	0	0	0	0	0	1	12	8.	23	10.
Norway	3	5	0	1	3	(8)	0	3	3	0	0	18	7.	26	9.

5   TG - Total number of items geographically focusing on a given region

Tab. 5. International research items authored and co-authored by researchers from the top 10 GLOF research countries.

	USA	UK	Canada	Iceland	Germany	China	Switzerland	Japan	France	Norway
Total number of research items (co)authored	240	213	115	85	68	65	60	38	30	28
No. of international items authored	38	56	14	17	22	10	19	13	4	1
No. of international items co-authored	53	28	26	34	17	16	23	10	9	19
No. of international items (authored + co-authored)	91	84	40	51	39	26	42	23	13	20
% share on the total number of research items written by an international team (n = 252)	36.1	33.3	15.9	20.2	15.5	10.3	16.7	9.1	5.2	7.9
% share on the total number of research items of the given country	37.9	39.3	34.8	60.0	57.4	40.0	70.0	60.5	43.3	71.4
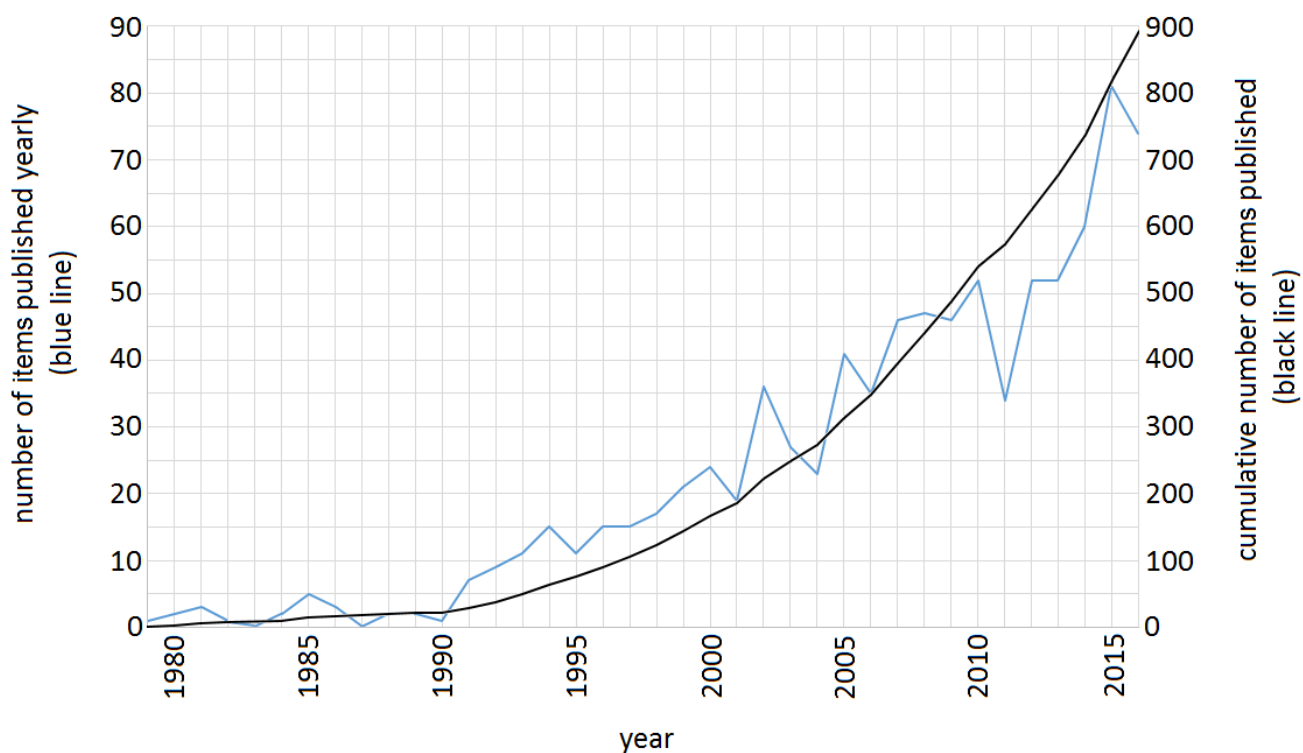
Figure 1: Yearly and cumulative number of GLOF research items published in the WOS Core Collection database (the first item was published in 1979).
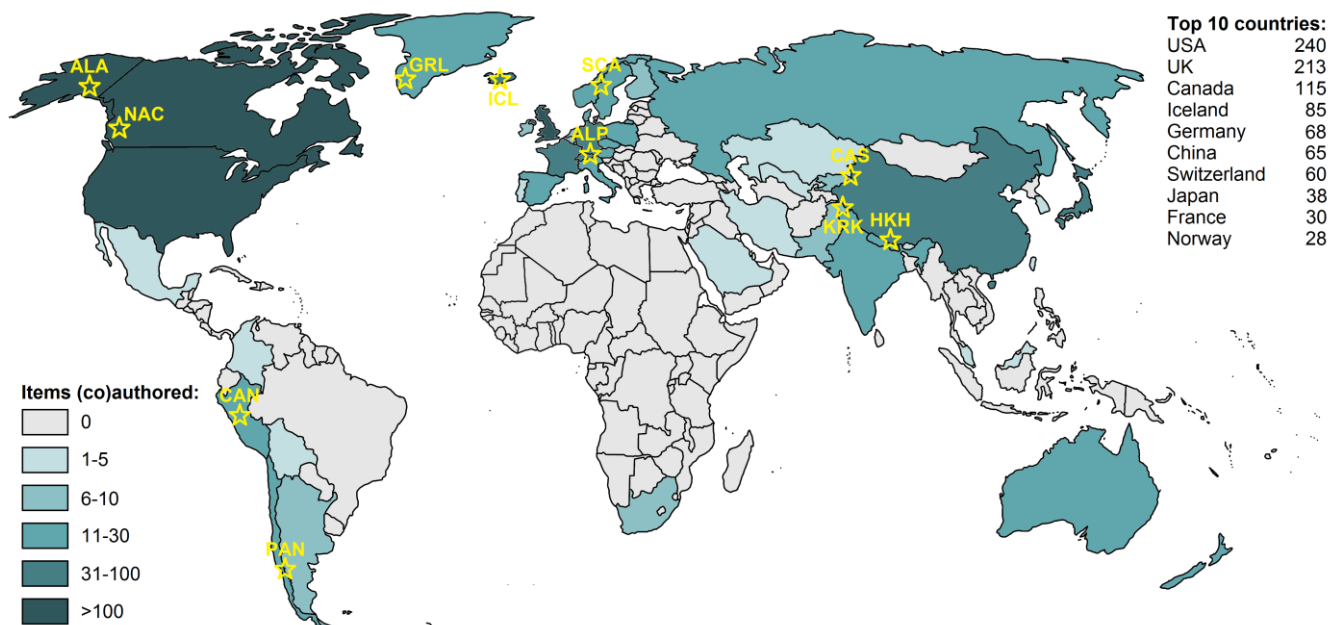
Figure 2: Hotspots of GLOF occurrence (yellow stars; see Tab. 2 for hotspot acronyms) and the geographical distribution of published GLOF research items by country.
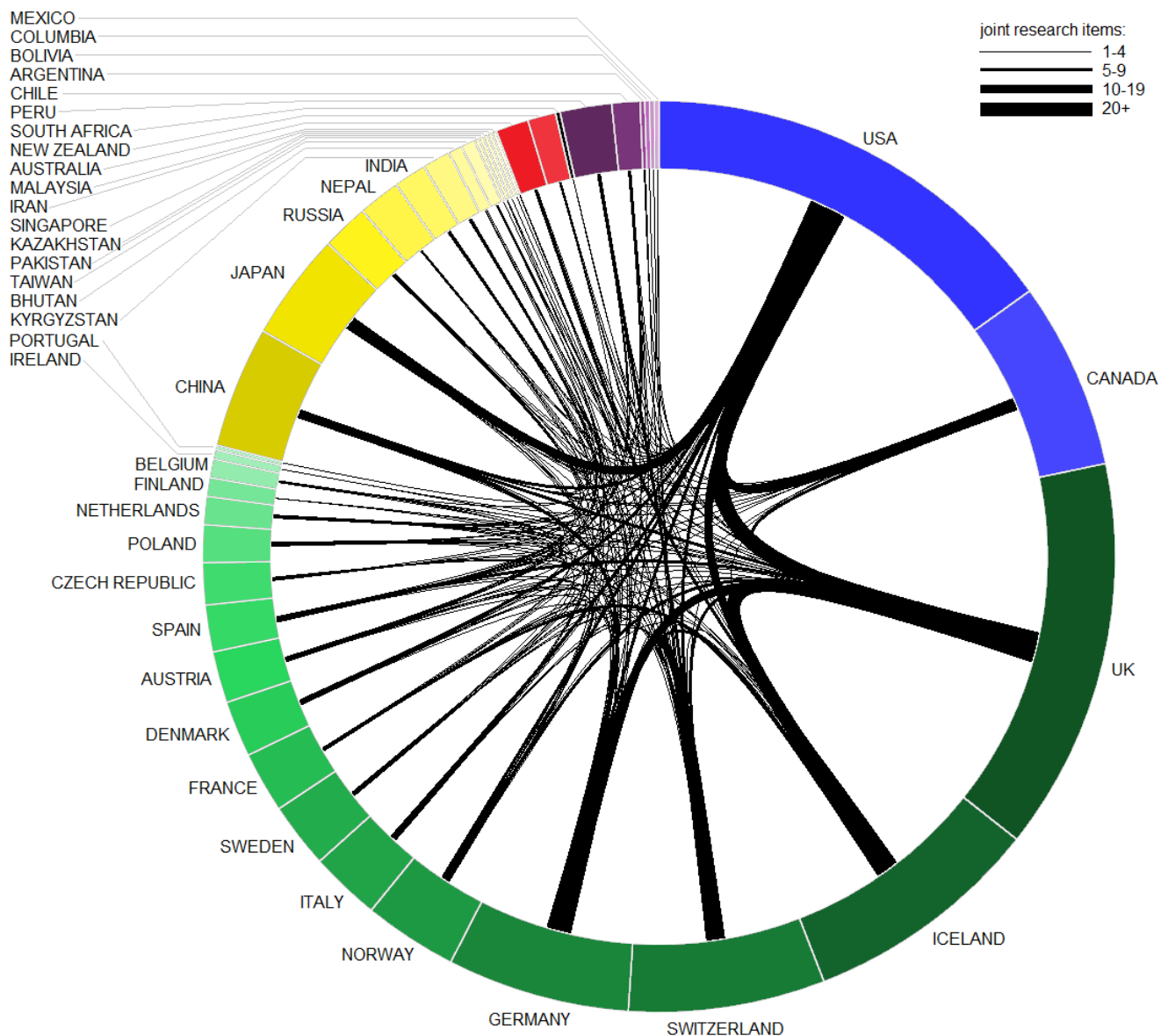
Figure 3: International cooperation between GLOF research countries. The number of international items (co)authored is proportionally indicated by the size of a sector (see also Tab. 5).