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Global Statistics of "Mountain" and "Alpine" Research

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Using the Web of Science®, a bibliometric analysis of the worldwide research activities associated with mountains—or the alpine part of mountains—is presented, according to country, institution, and subject.

Half of the human population depends on mountains in one way or another, and mountains cover (depending on the definition) between 12 and 26% of the ice-free terrestrial area. About 20% of the human population lives in mountains or their immediate forelands. One third of all protected areas are in mountains, and they supply water to nearly one half of the world population (Körner and Ohsawa 2005). Which are the countries that are contributing most to scientific research in mountains? Which are the leading institutions? How much are various fields of science contributing to the international scientific mountain literature?

Bibliometric data

This analysis is based on scientific publications (articles, proceedings, and reviews) in peer-reviewed journals that are listed in the ISI Web of Science (Science Citation Index Expanded, 1900 until October 18, 2008; 95% of all hits date after 1980, 1% of hits are older than 1970) and that use either the word "mountain" (including all variants of it, such as mountainous) or the term "alpine" in either the title, the abstract, or keywords (instances in the main text are not included). In other words, it is the authors' definition of what they considered a mountain or what they rated as alpine that determined the sum of articles obtained for this assessment. In its strict biogeographic meaning, the term "alpine" refers to the vegetation-covered land area above the climatic tree line (ie at elevations where trees cannot grow [Körner 2003]). The public uses the term in a much wider sense. In the scientific literature a wider meaning is also often applied, but the term certainly refers to "high mountain terrain" worldwide, not just in the Alps. It became customary in some disciplines to replace "alpine" by "Andean" or "Afro-alpine" in the respective regions. In this bibliometric survey, most of such cases may be covered by the term "mountain," but certainly not exhaustively. With the two terms "mountain-" and "alpine" most of the relevant literature should be covered. With the term "mountain-" many more fields of science are included than with "alpine" (eg medicine and engineering) so that a ranking by scientific fields became rather obscure and was thus restricted to "alpine." "Elevation" and "altitude" are terms so widely used (eg in aeronautics) that using them in a search would make it nearly impossible to identify mountain- or alpine-specific works among the results (Table 1).

Country and institution affiliation is provided by ISI for each individual author in all works including multiauthor papers. Hence, a single paper may reflect contributions from different countries, which, in fact, makes the country statistics more robust. We assume that any remaining uncertainty is random, not affecting the results. Institutions are commonly universities or defined (by one address) research laboratories. Multilocus institutions such as the University of Colorado system, or the Chinese Academy of Sciences complex, or Centre National de la Recherche Scientifique (CNRS) in France do not match this criterion and thus do not permit a fair comparison of institutions; hence, these unspecific institutions are not ranked. The potential bias introduced by the size of universities

TABLE 1 Total number of hits for ISI-listed publications using various keywords. Note that the use of these keywords is partly redundant because a publication may use one, several or all of these keywords. An asterisk indicates truncated search terms. Most articles were published during the past 30 years (see footnote). The number of documents using these keywords in the general literature was obtained by searching the web with Google™.

Terms	Number of ISI publications	Google™ hits (million documents)
"alpine"	**14,226**[a)]	**58**
"mountain*"	**55,304**[b)]	**258**
"Andean"	4251[c)]	3
"altitud*"	35,404	34
"elevation*"	93,792	43

[a)] 1978–2008 only: 13,714, ie 96% of all articles.
[b)] 1978–2008 only: 52,136, ie 94% of all articles.
[c)] 1978–2008 only: 4159, ie 98% of all articles.

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TABLE 2 Total number of ISI-listed scientific publications found under the keyword "alpine," per country (100% = 14,226).

Rank	Country	Number of publications	%
1	United States	2899	20
2	Switzerland	2125	15
3	France	1536	11
4	Italy	1410	10
5	Germany[a)]	1381	10
6	Austria	1210	9
7	Canada	877	6
8	England	736	5
9	New Zealand	614	4
10	Australia	527	4
11	Norway	448	3
12	People's Republic of China	441	3
13	Spain	430	3
14	Sweden	351	2
15	Japan	327	2
16	The Netherlands	313	2
17	Russia	244	2
18	Czech Republic[b)]	181	1.3
19	Scotland	170	1.2
20	India	152	1.1
21	Slovakia[b)]	152	1.1
22	Denmark	145	1.0
23	Belgium	127	0.9
24	Poland	127	0.9
25	Finland	111	0.8

[a)] Including the former German Democratic Republic (GDR).

[b)] Older works from "Czechoslovakia" were allocated 50:50 to these new countries.

was not accounted for. As the results will show, all this hardly affected the outcome, because all leading universities in the concerned fields are among the smaller guild, by international standards, and thus, large universities are found at low ranks, despite their size. In the following analysis, results obtained with the search term "mountain-" and "alpine" are treated separately.

Results of bibliometric analysis

Of all 14,226 publications that matched the search term "alpine," 56% were authored or coauthored by researchers situated in either the United States (20%), Switzerland (15%), France (11%), or Italy (10%) (Table 2). On a proportional basis (ie per number of inhabitants [Table 3]), Switzerland is leading, with 282 published works per one million inhabitants, followed by New Zealand (151), Austria (145), and Norway (94), with the nations coleading in absolute terms falling back to only 24 publications per million in France and Italy and 10 in the United States. The absolute numbers of publications found under "mountain-" are dominated by engineering, mining, and medicine and show that the United States hold a 40% overall share (Table 4). The per capita ranking of "mountain-" publications is similar to the result for "alpine-" (Table 5), with Switzerland, New Zealand, Norway, Scotland, Canada, and Austria ranking as the top six. The results of this bibliometric analysis most likely reflect the combined effects of scientific dedication to mountain or alpine research and the overall culture of publishing scientific research in the various countries.

In terms of numbers of publications per institution, a rating is rather difficult, given the very different sizes and broad geographical distribution of institutions, and meaningful data appeared to result from the search term "alpine" only (Table 6). If size differences among institutions are not taken into consideration, the 5 leading institutions worldwide are the Swiss Federal Institute of Technology (ETH) with 457 publications, the University of Bern (Switzerland) with 366 publications, the University of Innsbruck (Austria) with 354 publications, the University of Colorado in Boulder with 330 publications, and the University of Basel (Switzerland) with 239 publications. It is quite obvious that this ranking also reflects the number of working groups at each of these universities (number of principal

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TABLE 3 Number of "alpine" publications per million inhabitants per country.

Rank	Country	Inhabitants (in millions)	Publications per million inhabitants
1	Switzerland	7.5	282
2	New Zealand	4.1	151
3	Austria	8.3	145
4	Norway	4.8	94
5	Sweden	9.0	39
6	Scotland	5.1	33
7	Slovakia[b]	5.4	28
8	Canada	33.0	27
9	Denmark	5.5	26
10	Australia	21.4	25
11	France	64.5	24
12	Italy	59.6	24
13	Finland	5.3	21
14	The Netherlands	16.6	19
15	Germany[a)]	82.2	17
16	Czech Republic[b)]	10.4	15
17	England	50.4	15
18	Belgium	10.6	12
19	United States	304.5	10
20	Spain	46.1	9
21	Poland	38.1	3
22	Japan	127.3	3
23	Russia	142.4	2
24	People's Republic of China	1314.0	0.3
25	India	1148.0	0.1

[a)] Including the former German Democratic Republic (GDR).

[b)] Older works from "Czechoslovakia" were allocated 50:50 to these new countries.

investigators [PIs]). For instance, the number of PIs working in related fields is >50 at the top-ranked ETH Zürich, while it is <5 at the University of Basel, which ranks fifth.

The journals that contribute most to the body of alpine-related publications are *Arctic, Antarctic and Alpine Research* (348 or 2.4%), *Tectonophysics* (2.4%), *Eclogae Geologicae Helvetiae* (1.3%), *Oecologia* (1.1%), *Schweizerische Mineralogische und Petrographische Mitteilungen* (1%), and *Ecology* (0.9%). Most journals in the range that follows (0.6–0.8%) are related to geology. *Mountain Research and Development* (this journal) contributed 0.5% of all articles despite its young age (ranking 33rd of 334 journals with >10 hits). Of all articles matching the search term "mountain," *Geological Society of America Bulletin* ranks at the top with 823 hits (1.5%), followed by *Geology* (1.1%), *Journal of Geophysical Research* (1%), *Forest Ecology and Management* (0.9%), and *Mountain Research and Development* (0.9%), with the bulk of the top 40 journals ranked under "mountain" covering the field of Geosciences in the widest sense.

Of the 25 top-ranked authors (out of 24,886) in terms of number of publications in the hit-list for "alpine" (irrespective of their position in the byline of multiauthor papers), 8 are based at a Swiss institution (4 of the top 6), 8 at an American institution, 3 at a French institution, and 1 each is based in New Zealand, Austria, Norway, Chile, People's Republic of China, and Japan, in this sequence (data not shown).

In terms of scientific fields, the problem is that papers often belong to more than one subject group. Consequently, the sum of the percentages does not yield 100% if the ranking is done by specific disciplines (journal profiles). Therefore, the analysis based on 10,760 articles in the 324 journals with >10 hits for "alpine" is presented in bulk for major sectors only. The two main blocks are geosciences with 45% of all papers across subfields (geology, geochemistry, mineralogy, physical geography, hydrology, meteorology, and atmospheric sciences) and biology with 40% of the papers (plant or animal sciences and ecology, both terrestrial and aquatic). Multidisciplinary works constitute 9% of the papers, and those that cannot be allocated make up 6%. If ranked by the search term "mountain*", the hit list is dominated by geosciences in the widest sense.

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TABLE 4 Total number of ISI-listed scientific publications found under the keyword "mountain*" per country (100% = 55,304).

Rank	Country	Number of publications	%
1	United States	22,361	40.4
2	Canada	4012	7.3
3	Germany[a)]	3582	6.5
4	PR China	3147	5.7
5	France	3106	5.6
6	England	2789	5.0
7	Japan	2072	3.7
8	Switzerland	1905	3.4
9	Spain	1844	3.3
10	Australia	1840	3.3
11	Italy	1742	3.1
12	Russia	1293	2.3
13	Austria	895	1.6
14	Sweden	883	1.6
15	Poland	857	1.5
16	Scotland	784	1.4
17	New Zealand	753	1.4
18	Norway	735	1.3
19	Czech Republic[b)]	726	1.3
20	South Africa	721	1.3
21	The Netherlands	682	1.2
22	India	560	1.0
23	Taiwan	553	1.0
24	Finland	490	0.9
25	Argentina	401	0.7

[a)] Including the former German Democratic Republic (GDR).

[b)] Older works from "Czechoslovakia" were allocated 50:50 to these new countries.

Conclusions

Overall, this analysis illustrates that an overproportional fraction of mountain research is produced in a handful of rather small countries and institutions. By all criteria, Switzerland emerges as a leader in mountain research. The small population of an otherwise scientifically very active society may contribute to the high per capita ranking; however, even in absolute terms Switzerland contributes nearly as much as the United States to the scientific output in alpine research. A remarkable outcome of this analysis is the high ranking of Austria, New Zealand, Scotland, and Norway, all very small countries each producing an overproportional contribution to both "mountain" and "alpine" research per capita.

The explanation for these rankings may lie in the importance of mountains in certain countries and their culture and history, including the status of economic development. However, it does not seem that the mountain area per se is a key criterion. In Switzerland, ca. 70% of the country (whose area is only 40,000 km^2) consists of mountains. Both in terms of mountain land area (5.7 million km^2, or two-thirds of the country) and number of people living in mountains (ca. 350 million), China ranks at the top, but it is only very recently that published contributions of China to mountain research have started to increase rapidly. It seems, rather, that the major drivers of mountain and alpine research are geopolitical position, scientific tradition, and economic welfare, which explains the global patterns of scientific leadership in mountain research as reflected in this bibliometric analysis.

The exceptional position of Swiss mountain research is rooted in a long tradition. The first description of the elevational changes of vegetation in mountains was published by Conradus Gessner in 1555 in Zürich. The foundation of atmospheric sciences (that in mountains in particular) can be attributed to the works by Horace-Benedict de Saussure around 1800 in Geneva. The first textbook on alpine plant ecology was published by Carl Schröter in Zürich in 1906. Switzerland was not directly involved in the major political crises of the last century and thus experienced a continuous development of the scientific endeavor of mountain research over more than a century. Such dedication and commitment to mountain-related research are reflected in today's hosting of international scientific networks in Switzerland such as the World Glacier Monitoring Service (in Zürich), the Mountain Research Initiative (MRI, currently in Bern), the Global Mountain Biodiversity Assessment

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TABLE 5 Number of "mountain*" publications per million inhabitants per country.

Rank	Country	Inhabitants (in millions)	Publications per million inhabitants
1	Switzerland	7.5	253
2	New Zealand	4.1	185
3	Norway	4.8	154
4	Scotland	5.1	154
5	Canada	33.0	122
6	Austria	8.3	107
7	Sweden	9.0	98
8	Finland	5.3	92
9	Australia	21.4	86
10	United States	304.5	73
11	Czech Republic[a)]	10.4	70
12	England	50.4	55
13	France	64.5	48
14	Germany[b)]	82.2	44
15	The Netherlands	16.6	41
16	Spain	46.1	40
17	Italy	59.6	29
18	Taiwan	22.9	24
19	Poland	38.1	22
20	Japan	127.3	16
21	South Africa	47.9	15
22	Argentina	39.4	10
23	Russia	142.4	9
24	People's Republic of China	1314.0	2
25	India	1148.0	0.5

[a)] Older works from "Czechoslovakia" were allocated 50:50 to these new countries.
[b)] Including the former German Democratic Republic (GDR).

(GMBA, in Basel), and the strongly mountain-oriented Centre for Development and Environment (Bern). Outside the country, Switzerland supports a series of international agencies in the field of mountain research, conservation, and sustainable development such as the International Centre for Integrated Mountain Development (ICIMOD, Kathmandu, Nepal) and the Mountain Forum (with their central office also in Nepal), the Mountain Partnership (central office in Rome, Italy, hosted by the Food and Agriculture Organization [FAO]), and the Global Mountain Program (ILRI, in Ethiopia). A Swiss scientist, Bruno Messerli, was one of the key actors responsible for the inclusion of Chapter 13 (sustainable mountain development) in Agenda 21 at the Rio Earth Summit.

Given the critical role mountains play worldwide for the supply of major goods and benefits but also for nature conservation, it is time that more countries, the larger and/or economically strong ones in particular, take over responsibility for mountain research at home and abroad, where support for regional research capacity is needed.

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TABLE 6 ISI-listed publications for "alpine", ranked by institutions belonging to a defined location/city (100% = 14,226 articles). For institutions belonging to national networks or clusters of universities, see footnote a.

Rank	Institution[a)]	Record count	%
1	Swiss Federal Institute of Technology, Zurich	665	4.7
2	University of Bern	366	2.6
3	University of Innsbruck	354	2.5
4	University of Colorado (Boulder)	330	2.3
5	University of Basel	239	1.7
6	University of Otago	216	1.5
7	University of Zurich	209	1.5
8	University of Vienna	206	1.4
9	University of Grenoble 1	202	1.4
10	University of Milano	196	1.4
11	University of Oslo	143	1.0
12	University of Torino	131	0.9
13	University of Lausanne	127	0.9
14	University of Paris 6	123	0.9
15	Paul Scherrer Institute, Villigen	118	0.8
16	University of Padua	118	0.8
17	Australian National University, Canberra	115	0.8
18	University of Salzburg	114	0.8
19	University of Munich	111	0.8
20	University of Bergen	101	0.7
21	University of Lyon	101	0.7

[a)] National network institutions (not ranked above) contribute to the following percentages: All institutes belonging to the Chinese Academy of Sciences: 2.2%, to the CNR (National research Council, Italy): 1.8%, to the CNRS (National Center for Scientific Research, France): 1.1%, to the University of Alberta: 1.0%, to the US Geological Survey: 0.9%, to the Russian Academy of Sciences: 0.9%, to the University of Washington: 0.8%, to the CSIC (Spanish National Research Council): 0.8%, to the INRA (French National Institution for Agricultural Research): 0.7%, to Colorado State University: 0.7%, to the University of British Columbia: 0.7%.

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