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Bibliometric Analysis of Global Research Progress on Coastal Flooding 1995–2016

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Abstract: Global research progress on coastal flooding was studied using a bibliometric evaluation of publications listed in the Web of Science extended scientific citation index. There was substantial growth in coastal flooding research output, with increasing publications, a higher collaboration index, and more references during the 1995–2016 period. The USA has taken a dominant position in coastal flooding research, with the US Geological Survey leading the publications ranking. Research collaborations at institutional scales have become more important than those at global scales. International collaborative publications consistently drew more citations than those from a single country. Furthermore, coastal flooding research included combinations of multi-disciplinary categories, including 'Geology' and 'Environmental Sciences & Ecology'. The most important coastal flooding research sites were wetlands and estuaries. While numerical modeling and 3S (Remote sensing, RS; Geography information systems, GIS; Global positioning systems, GPS) technology were the most commonly used methods for studying coastal flooding, Lidar gained in popularity. The vulnerability and adaptation of coastal environments, their resilience after flooding, and ecosystem services function showed increases in interest.

Keywords: coastal flood; scientific outputs; bibliometric analysis; research trends; Web of Science

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1 Introduction

Coastal floods cause great losses to society and economy, and are widespread concerns for coastal communities (Garner et al., 2017; Lin and Shullman, 2017). Coastal floods are becoming more common due to the adverse effects of climate change on the hydrological cycle (Zahmatkesh and Karamouz, 2017). Climate change induced sea level rise, inland flows, and coastal storm trends increase the exposure and vulnerability of coastal areas (Herrera-Pantoja and Hiscock, 2015; Muis et al., 2015). Relative sea level will continue to rise in the coming centuries, although the rate of increase is uncertain (Levermann et al., 2013; Horton et al., 2014). The Intergovernmental Panel on Climate Change's Fifth Assessment Report (AR5) projected a 'likely' (> 66% probability) global-mean sea-level rise (SLR) of 52–98 cm by 2100 relative to 1986–2005 in a high emissions future (Representative Concentration Pathway (RCP) 8.5 Scenario (Riahi et al., 2011)). This increase in sea level will be disastrous for coastal countries (Wong and Keller, 2017; Wadey et al., 2017). If climate change and sea level rise cannot be reversed, mitigating losses caused by coastal flooding needs to be addressed. Therefore, a more comprehensive understanding of the causes of the coastal flooding, development paths, preventive measures, and disaster

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relief measures are required.

It is difficult to summarize a large number of documents using traditional statistical methods (Belter and Seidel, 2013). However, bibliometric analyses have been widely used in many science and engineering disciplines and can be considered a common research tool for explaining science-based production and research trends for a given topic (Keiser and Utzinger, 2005; Xie et al., 2008). Bibliometric research is based on library science methodology and information and uses a series of quantitative and visual procedures to summarize the patterns and dynamics of publications (Pritchar, 1969). Furthermore, new bivariate approaches have been introduced to study the structural and dynamic aspects of changing scientific knowledge or scientific research based on expanding traditional bibliometric analyses of the number and citation of articles (Cobo et al., 2011). The interrelationship between research disciplines, mode of cooperation between countries and institutions, and popular topics in a particular discipline can all be obtained through network analysis (Morel et al., 2009). This article will provide a global overview of the current research on coastal floods based on ISI (the Institute of Scientific Information) Web of Science information for the period 1995–2016.

2 Data and Methods

The key phrase 'coastal flood' was searched among documents published between 1986 and 2016 from the Scientific Citation Index (SCI) databases of the Web of Science (Thomson Reuters, http://apps.webofknowledge.com), which is maintained by the Institute of Scientific Information (ISI). The search results indicated 5470 publications related to coastal floods. Downloaded records included: Authors (AU), Document Title (TI), Language (LA), Document Type (DT), Author Keywords (DE), Key-words plus (ID), Author Address (C1), Reference count (NR), Times Cited (TC), Year Published (PY), Page count (PG), Subject category (SC), and Journal name (JN). Among the total, 11 document types were found: 'Peer-reviewed research articles', 'Reviews', 'New items', 'Proceedings papers', 'Editorial materials', 'Letters', 'Book chapters', 'Corrections', 'Book reviews', 'Reprints', and 'Notes'. The document type with the most number of publications was 'Peer-reviewed research articles' (4790), which accounted for 87.6% of total publications.

Articles published in England, Scotland, Northern Ireland, and Wales were classified as British (UK) publications, while articles published in Hong Kong were included in Chinese publications. Cooperation between countries or institutions was defined as 'single country publication' when all authors had affiliations in the same country and 'international collaborative publication' in the case of author affiliations from multiple countries (Fu et al., 2013). Similarly, the 'single institution publication' was defined as all authors from the same institution, and 'inter-institutionally collaborative publication' was defined as having authors from different institutions (Liu et al., 2011).

Total publications, total citations, h-index, single country (institution) publications, and citations, and international (inter-institutional) collaborative publications and citations were used to measure the 20 most productive countries (institutions) in coastal flooding research. The number of times a publication was cited as a reference by other publications is the number of citations, where a higher number of citations is a measure of better quality (Kelly et al., 2012). The h-index is often used to measure the research importance of a country/institution. Assuming there are a total of N publications in a country/agency, of which m publications have at least h citations per publication, the number of citations to other publications (N-m) is less than h for each (Hirsch, 2005). A coastal flood research network map of the 20 most productive countries (institutional) was generated based on the author affiliations through a process of co-occurrence analysis using Bibexcel and Pajek software (Xu and Boeing, 2013).

The theme of an publication is usually well-reflected by the title and keywords. Although titles are sometimes obscure and some titles lack keywords, keywords provide a general understanding of popular research topics and trends by indicating the context of the articles (Li et al., 2009). The most commonly used 226 keywords were selected, using PC-ORD 4.20 software hierarchical cluster analysis to determine categorize the development periods for coastal flooding research (McCune and Mefford, 1999).

According to the co-words network, the 50 most commonly used keywords were selected to explore research hotspots.

3 Results and Discussion

3.1 Publication output

The number of peer-reviewed research articles and all publications increased from 63 in 1995 to 528 in 2016 and from 78 in 1995 to 579 in 2016, respectively. Approximately 12.4% of all publications on coastal flooding were nonresearch articles, which is in agreement with the percentage of nonresearch articles in related disciplines (8%–15%) (Qian et al., 2015).

The characteristics of publications output in 1995–2016 show that the collaboration index refers to the average number of authors per publication, which increased from 2.6 to 4.7, indicating more frequent cooperation in coastal flooding research. In 2016, the average number of references increased to 58.7, indicating an expanding accumulation of knowledge about coastal flooding. In summary, coastal flooding research has strengthened cooperation, accumulated knowledge, and made progress.

3.2 Country, institution, and collaborations

The quantity of coastal flooding research published in different time periods shows the importance and research progress in various countries studying coastal flooding. Cluster analysis was conducted for the 127 countries with the largest volume of published papers, and the research on coastal flooding was divided into three stages of development: 1995–1997, 1998–2010, and 2011–2016. The 20 countries with the most articles in each stage were selected to create the network diagram (Fig. 1). The first phase involved four major regions: Europe, the Americas, Asia, and Oceania. Except for the United States, the remaining countries

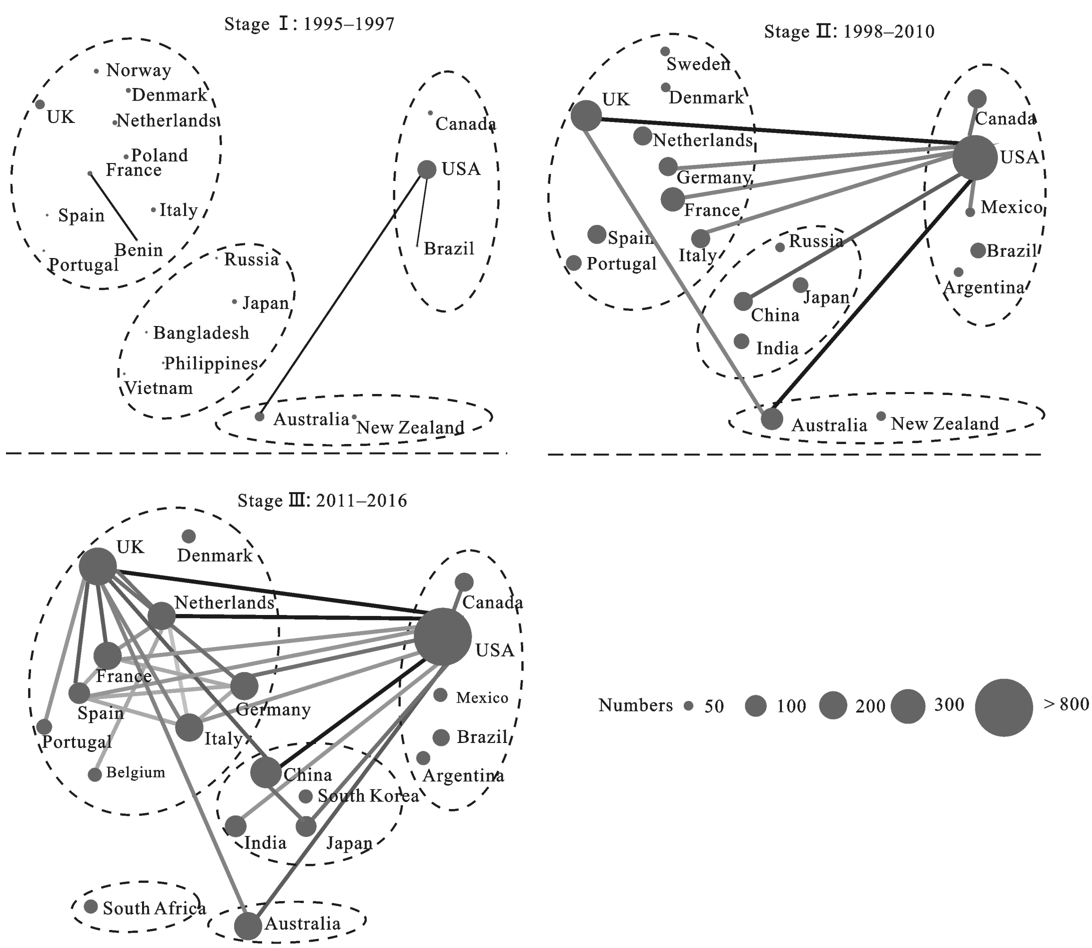

Fig. 1 Network of the 20 most productive countries in terms of number of publications related to coastal flooding across the three development stages

issued less than 50 papers; the cooperation between the United States and Australia was the most frequent, but there was little cooperation among other countries. The second phase also involved four major regions, although there was a significant increase in the number of documents issued by all countries and international cooperation was more frequent. Phase 3 involved five major regions, the initial four plus the African region; during this phase, the number of papers published rose and national cooperation was more frequent. Generally, the number of publications and international cooperation are on the rise, although there are changes in the top 20 countries that create the highest volume of papers in different phases.

As shown in Table 1, the USA had the highest number of citations, h-index, single country publications (1372) and internationally collaborative publications (562). The second highest number of publications on coastal flooding was from the UK (677), followed by Australia (416) and China (391). Single country publications from the four most productive countries, 2177, accounted for 62.5% of the 3483 single country publications, with more single country than international collaborative publications. The USA published 1372 single country publications, accounting for the highest proportion of single country publications (70.9%), while Belgium published 70 internationally collaborative publications, the highest proportion at 71.4%.

The USA is at the center of an international cooperation network among the 20 most productive countries (Fig. 2a) and it was the primary collaborator with five other highly productive countries (UK, Australia, China, France, and Germany). Among the collaboration network of the 20 most productive institutions, a core group of institutions was identified (Fig. 2b). The US Geological Survey occupied a central place in the collaborative network, and institutions were more inclined to cooperate with each other in the USA. Other countries also showed a preference for domestic cooperation, such as Delft University of Technology with Deltares in the Netherlands and the University of Southampton with the National Oceanographic Centre in the UK.

Table 1 The 15 most productive countries in coastal flood research

Country	All				Single country				International collaboration			
	TP	TC	TC/TP	h-index	SP	TC	TC/SP	SP/TP (%)	CP	TC	TC/CP	CP/TP (%)
USA	1934	48144	24.9	93	1372	33895	24.7	70.9	562	14249	25.4	29.1
UK	677	15347	22.7	61	337	7056	20.9	49.8	340	8291	24.4	50.2
Australia	416	8778	21.1	49	269	5118	19.0	64.7	147	3660	24.9	35.3
China	391	5667	14.5	37	199	2231	11.2	50.9	192	3436	17.9	49.1
France	370	7817	21.1	45	186	3314	17.8	50.3	184	4503	24.5	49.7
Germany	317	5113	16.1	34	110	1164	10.6	34.7	207	3949	19.1	65.3
Italy	266	7307	27.5	42	140	2348	16.8	52.6	126	4959	39.4	47.4
Netherlands	265	6759	25.5	48	114	2641	23.2	43.0	151	4118	27.3	57.0
Spain	252	5778	22.9	35	113	2780	24.6	44.8	139	2998	21.6	55.2
Canada	238	4953	20.8	40	116	2331	20.1	48.7	122	2622	21.5	51.3
India	158	1871	11.8	21	105	1149	10.9	66.5	53	722	13.6	33.5
Brazil	157	1895	12.1	24	100	882	8.8	63.7	57	1013	17.8	36.3
Japan	152	3071	20.2	28	66	707	10.7	43.4	86	2364	27.5	56.6
Portugal	136	1758	12.9	25	72	706	9.8	52.9	64	1052	16.4	47.1
Mexico	90	779	8.7	16	44	143	3.3	48.9	46	636	13.8	51.1
New Zealand	74	1568	21.2	21	28	453	16.2	37.8	46	1115	24.2	62.2
Belgium	70	1484	21.2	19	20	295	14.8	28.6	50	1189	23.8	71.4
Denmark	70	1689	24.1	22	22	405	18.4	31.4	48	1284	26.8	68.6
Argentina	68	755	11.1	**15**	41	516	12.6	60.3	27	239	8.9	39.7
Russia	59	458	7.8	12	29	89	3.1	49.2	30	369	12.3	50.8

Notes: TP = Total publications, TC = Total citations, SP = single country publications, CP = International collaboration publications

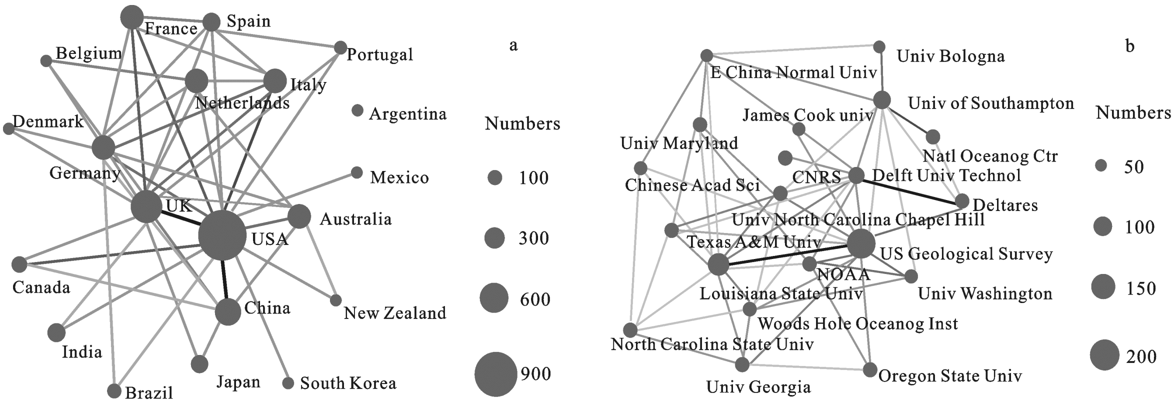

Fig. 2 The collaboration networks of the 20 most productive countries (a) and institutions (b)

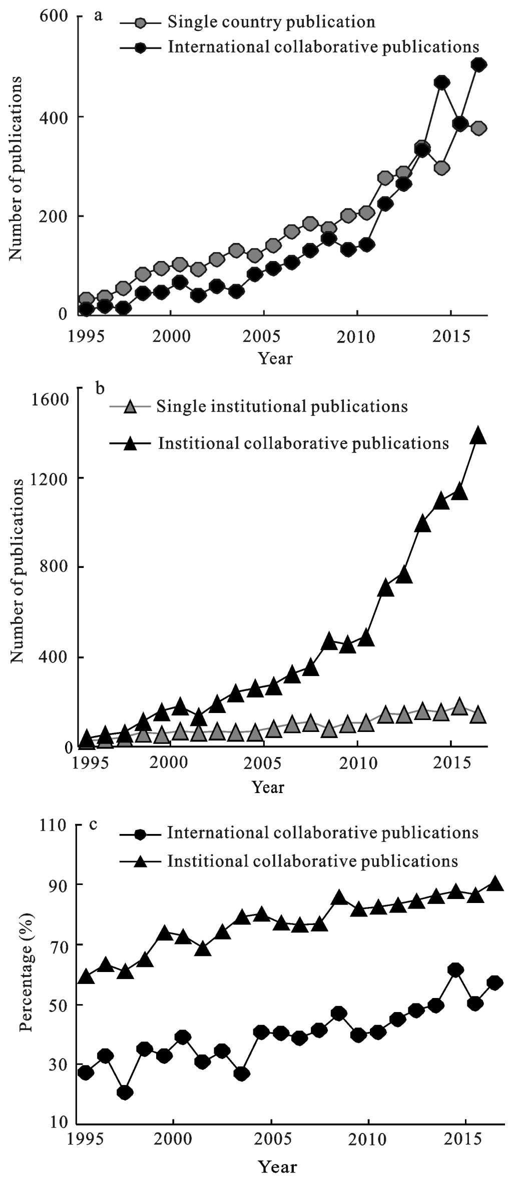

Fig. 3 The number of (a) international collaborative and single country, (b) institutional collaborative and single institution publications, and (c) total percentage of publications

Since 2014, the total number of international cooperative publications exceeded the amount issued by a single country (Fig. 3a). Statistically, a total of 4037 institutions were involved in coastal flooding research, and the top 20 institutions ranked by publication number are listed in Table 2. Among the top 20 institutions, there are 11 in the USA, two each in Sweden, the Netherlands, and China, and one each in France, Italy, and Australia. The US Geological Survey led institutional productivity with 201 publications, Louisiana State University ranked second with 159 publications, and the University of Southampton ranked the third. The institution with the most cited publications was the University of Washington, although this institution had only 42 publications. There have been more inter-institutional publications than single institution publications since 1995, and institutional collaborations have become more prevalent (Fig. 3b). The number of inter-institutional articles was much larger than international collaborations (Fig. 3c), indicating that domestic cooperation was frequent. The percentage of institutional collaborative publications was more than 50% in all 20 most productive institutions.

3.3 Science categories and interdisciplinary activities

In the SCI database, coastal flooding publications are divided into the 88 themed categories identified by the ISI; the number of occurrences of the top 20 categories account for about 95% of the total. Publications with two or more subject categories accounted for 58.6% of total publications, with 3208 publications. Coastal flooding research usually involves two or more disciplines and can be considered interdisciplinary

Table 2 The most productive institutions in coastal flood research

Institution	All				Single institution				Institutional collaboration			
	TP	TC	TC/TP	h-index	SP	TC	TC/SP	SP/TP (%)	CP	TC	TC/CP	CP/TP (%)
US Geological Survey[1], USA	201	6454	32.1	43	52	2023	38.9	25.9	149	4431	29.7	74.1
Louisiana State University, USA	159	3768	23.7	36	64	1393	21.8	40.3	95	2375	25.0	59.7
University of Southampton, UK	90	2525	28.1	25	13	206	15.8	14.4	77	2319	30.1	85.6
TU Delft[2], Netherlands	73	1908	26.1	23	7	357	51.0	9.6	66	1551	23.5	90.4
Texas A&M University, USA	67	1595	23.8	23	19	499	26.3	28.4	48	1096	22.8	71.6
NOAA[3], USA	60	1748	29.1	25	6	118	19.7	10.0	54	1630	30.2	90.0
Chinese Academy of Sciences, China	59	1135	19.2	18	7	232	33.1	11.9	52	903	17.4	88.1
CNRS[4], France	56	852	15.2	20	4	77	19.3	7.1	52	775	14.9	92.9
University of Maryland, USA	55	1741	31.7	19	16	320	20.0	29.1	39	1421	36.4	70.9
Deltares, Netherlands	54	738	13.7	13	2	42	21.0	3.7	52	696	13.4	96.3
UNC[5], USA	53	1431	27.0	21	15	423	28.2	28.3	38	1008	26.5	71.7
University of Georgia, USA	51	1315	25.8	19	17	550	32.4	33.3	34	765	22.5	66.7
University of Bologna, Italy	44	1270	28.9	18	11	227	20.6	25.0	33	1043	31.6	75.0
NC State University[6], USA	43	1473	34.3	19	14	376	26.9	32.6	29	1097	37.8	67.4
Oregon State University, USA	43	1033	24.0	21	9	288	32.0	20.9	34	745	21.9	79.1
WHOI[7], USA	43	1060	24.7	17	8	206	25.8	18.6	35	854	24.4	81.4
University of Washington, USA	42	1475	35.1	19	10	500	50.0	23.8	32	975	30.5	76.2
East China Normal University, China	41	1054	25.7	17	4	73	18.3	9.8	37	981	26.5	90.2
James Cook University, Australia	41	957	23.3	18	6	77	12.8	14.6	35	880	25.1	85.4
National Oceanographic Centre, UK	41	456	11.1	12	8	78	9.8	19.5	33	378	11.5	80.5

Notes: TP=Total publications, TC=Total citation, SP=Single institution publications, CP=Institutional collaboration publications; [1] US Geological Survey=United State Geological Survey, [2] TU Delft=Delft University of Technology, [3] NOAA=National Oceanic and Atmospheric Administration, [4] CNRS = Centre National de la Recherche Scientifique, [5] UNC= University of North Carolina, [6] NC State University= North Carolina State University, [7] WHOI =Woods Hole Oceanographic Institution

research. Based on network centrism, a core group provides a metric for the relative importance of nodes in the interdisciplinary networks of the 20 major disciplines (Fig. 4). Geology occupies a central position in an interdisciplinary network with 1882 publications (34.4% of the total) and is the most productive discipline. Followed by Environmental Sciences & Ecology (1840 publications, 33.6%), Water Resources (948 publications, 17.3%), Oceanography (896 publications, 16.4%), Marine & Freshwater Biology (783 publications, 14.3%), and Physical Geography (777 publications, 14.2%).

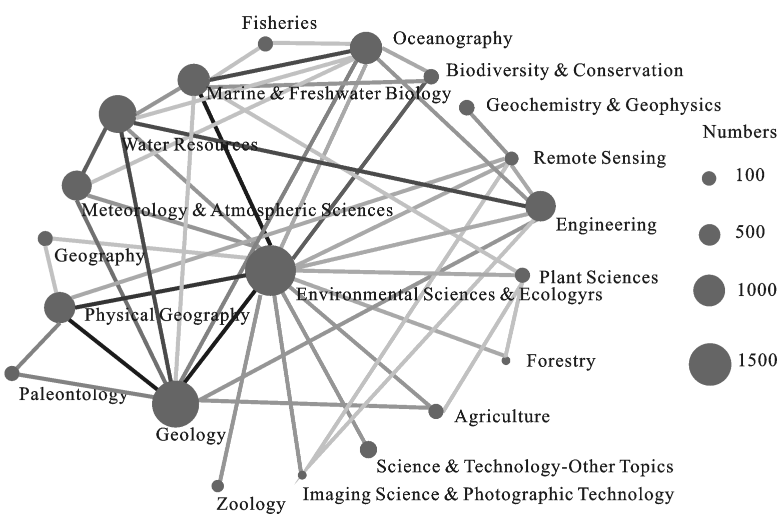

Fig. 4 The interdisciplinary network of the 20 most productive Web of Science categories

All six categories indicate growing trends, with the number of publications in 'Geology' and 'Environmental Sciences & Ecology' growing rapidly; these two categories switch between the first and second rankings (Fig. 5). Based on the category descriptions, geology encompasses the physical history of the Earth, rock compositions, and physical changes that the Earth has undergone or is undergoing, but excludes physics. This category covers sedimentology, stratigraphy, hydrogeology, ore geology, structural geology, regional geology, and petrology. These resources are somewhat narrow in scope and are not given to the interdisciplinary study of the Earth Sciences. Environmental Sciences & Ecology covers resources concerning many areas related to the interrelationships of organisms and their environments. This category also includes general ecology resources and those devoted to particular ecological systems, soil science and conservation, water resources research and engineering, and climate change.

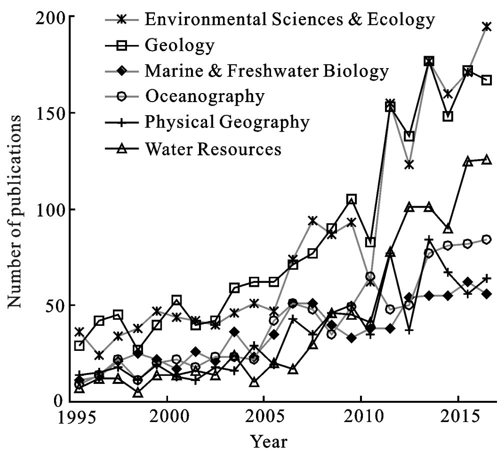

Fig. 5 The number of articles for the six most productive Web of Science categories

3.4 Research trends and hotspots

Of the total 5470 publications, 4169 publications, 76.2%, recorded keyword information. A total of 12 106 unique keywords were extracted from these 4169 publications, and there were 23 323 total occurrences of these key words. Most keywords were not frequently used, but a small number of keywords were widely repeated; the keywords and their rankings followed a power law distribution. Among the 12 106 keywords, the 226 most frequent keywords appeared 6359 times, in other words, the occurrences of the most frequent keywords (1.8% of total keywords) accounted for 27.3% of the total number of occurrences. However, 9576 keywords appeared only once, accounting for 79.1% of the total, and 11 880 keywords appeared in less than 10 articles, accounting for 98.1%. Using Hierarchical Cluster Analysis (HCA), coastal flooding studies were divided into two distinct phases based on the composition of 226 of the most frequent key words for coastal flooding research (Fig. 6): Phase I (1995–2007) and Phase II (2008–2016). Among the 226 commonly used keywords, the top 50 were extracted (0.4%); they appeared 3684 times, accounting for 15.8% of the total number of keywords occurrences. Table 3 shows the temporal evolution trend of some frequently used keywords, and the co-words network shows the correlation between keywords for coastal flooding (Fig. 7).

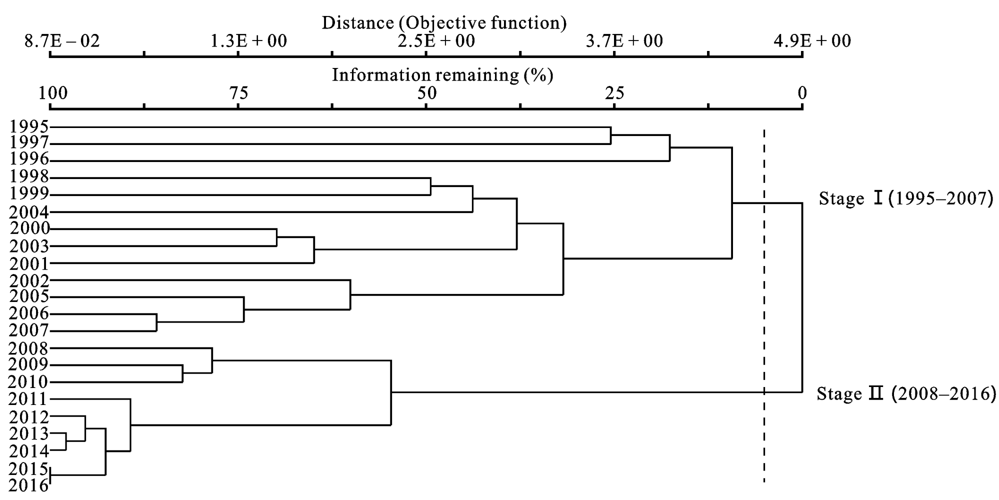

Fig. 6 Dendrogram of several periods of coastal flood research based on hierarchical cluster analysis (HCA) of the 226 most frequent keywords

Table 3 The temporal evolution of the 16 most frequently used keywords in global research on coastal flood in 1995–2016

Keywords	Whole period (1995–2016)		First phase (1995–2007)		Second phase (2008–2016)	
	Cnt	R	Cnt	R	Cnt	R
Flooding	338	1	84	1	254	1
Climate Change	298	2	49	4	249	2
Sea Level Rise	262	3	60	2	202	3
Storm Surge	189	4	34	7	155	4
Coastal Flood	133	5	23	17	110	5
Estuary	107	6	56	3	51	15
Wetlands	102	7	39	5	63	8
Numerical Modeling	92	8	29	12	63	9
Salt Marsh	88	9	36	6	52	14
Hurricanes	82	10	19	21	63	7
Vulnerability	77	12	7	88	70	6
Adaptation	71	15	10	56	61	10
Flood Risk	61	21	6	117	55	11
Lidar	38	39	1	892	37	23
Resilience	32	47	2	421	30	34
Ecosystem Services	31	49	2	572	29	36

Notes: Cnt = count of occurrences, R = rank

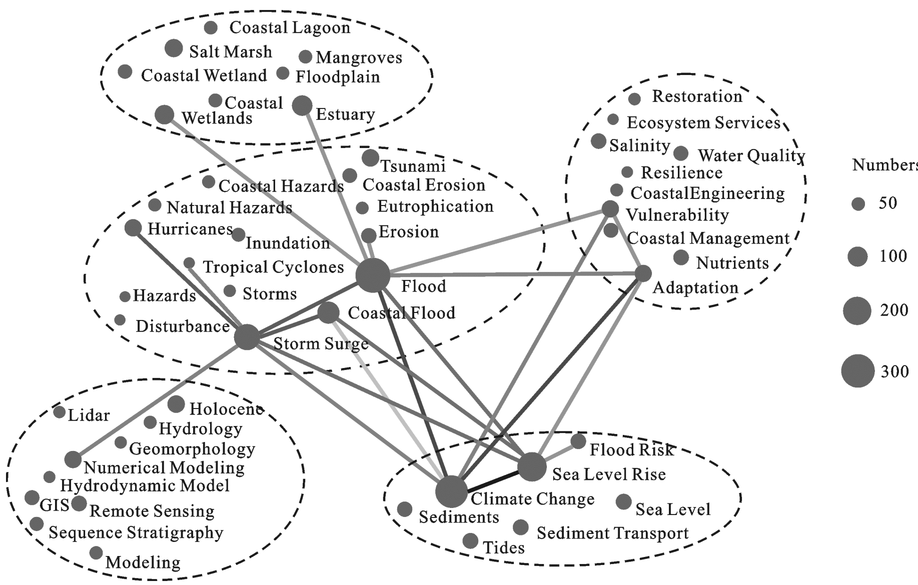

Fig. 7 The co-word network of the 50 most frequent keywords in global research on coastal flood in 1995-2016

According to the research hotspot network map (Fig. 7), coastal flooding research can be divided into five primary themes. The first theme is natural disasters, such as ‘Flood’ and ‘Storm Surge’. The keyword rankings (Table 3) shows that ‘Flood’ ranks first because ‘Coastal Flood’ was used as a search term, while most publications separate keywords such as ‘coastal’ to represent location and ‘flood’ to represent disaster type. According to the common word network, flood, coastal flood, storm surge, and other types of natural disasters are classified as a major category. Storms and hurricanes are one of the causes of coastal flooding, while disasters, such as inundation and erosion, are caused by coastal floods. Floods first erode coastlines, causing them to loosen, collapse, and retreat; flooding can destroy residential buildings and infrastructure and affect the production of agricultural fisheries.

The second theme is global change phenomena, such as 'Climate Change' and 'Sea Level Rise'. These global changes are major causes of natural disasters and have drawn increasing attention from all sectors of society. Climate change triggers natural disasters by changing climatic factors, such as precipitation, temperature, atmosphere, soil, and sea water. Among them, the ranking of flood risks closely linked to sea level rise rose from 117 publications in 1995–2007 to 11 in 2008–2010, which shows that flood risk caused by sea level rise has received attention (Wong et al., 2017).

The third theme includes 'Vulnerability', 'Adaption', and associated words, indicating interactions with human communities in coastal flooding studies, and the impact on coastal environment from floods. Coastal vulnerabilities (Silva et al., 2017), resilience, adaptation, and ecosystem services are also the focus of research, with their rankings rising from 88, 421, 56, and 572 in the first phase to 6, 34, 10, and 36, respectively. This shows that the flood disasters in the coastal zone increased in popularity. Higher vulnerabilities are associated with bigger disasters when the coastal zone has poor resilience, adaptation, and ecosystem services.

The fourth theme is coastal flooding prone areas; different coastal types suffer from different levels of damage when flooding occurs, with different types of coasts, such as wetland, estuary, salt marsh, and mangroves receiving major attention. Climate change poses many challenges to estuary flooding risk, and new techniques and methods are required to achieve early warning of flooding in estuaries (Freire et al., 2016). Wetlands are considered the 'kidneys' of the Earth. However, under the threat of flooding, wetland systems are very fragile. Detailed disaster management plans should be formulated to reduce the risks of flooding (Mentzafou et al., 2017). Mangroves can ease the erosion of the coast by floods and reduce the damage that hurricanes do on land (Deb and Ferreira, 2017).

The fifth theme is based on 'Numerical Modeling', 'Remote Sensing', and other measures society is taking to mitigate damage from natural disasters. Flooding disasters involve a wide range of issues, but monitoring real-time dynamics in an important component of fully understanding disaster development. Methods include numerical modeling (Karamouz et al., 2017; Wong et al., 2017b), remote sensing, Geographic Information System (GIS), and Lidar. Among them, numerical modeling is the main research method and is commonly used to study coastal flood using 3S(Remote sensing, RS; Geography information systems, GIS; Global positioning systems, GPS) technology. However, as Lidar use has increased, Lidar's keyword ranking rose from 892 in the first phase to 23 in the second. The advantage of the radar is that it can detect long-range targets both day and night without blocking from fog, cloud, and rain. These all-weather and all-day characteristics make it useful for real-time and efficient disaster monitoring.

4 Conclusions

Global trends in coastal flooding research were evaluated using bibliometric analysis of publications, institutions, countries, science categories, and keywords. The results indicate that the scientific output regarding coastal flooding increased significantly between 1995 and 2016 in terms of publications, collaborators, and references.

Globally, the USA dominated studies of coastal flooding, with the largest number of single country and internationally collaborative publications, followed by the UK, Australia, China, and France. The US Geological Survey had the highest number of institutional publications, followed by Louisiana State University, and the University of Southampton. At the global level, institutional cooperation was more frequent than international cooperation in this disciplinary research. Furthermore, there was more cooperation among various institutions within the USA, and institutions in other countries were more inclined to cooperate with each other in their own countries. However, international collaborative publications are always cited more frequently than single country publications. Coastal flooding research usually involves two or more disciplines and can be considered interdisciplinary. Within the interdisciplinary network, the 'Geology' category occupies a central position, followed by 'Environmental Sciences & Ecology', 'Water Resources', 'Oceanography, Marine & Freshwater Biology', and 'Physical Geography'.

The key word analysis provides a better grasp of trends and hotspots in coastal flooding research. Five themes were identified in coastal flooding based on keywords: types, locations, causes, environment, and response measures. The most common disasters were floods, hurricanes, storm surges, and tsunamis. The most important research locations of coastal flooding were wetlands and estuaries. The research trends indicate that many scholars regard climate change and sea level rise as the main causes of coastal flooding. The vulnerability and adaptation of the coastal environment, its resilience after the flood, and ecosystem services function are increasingly becoming popular research topics. Numerical modeling and 3S technology are the most commonly used methods for studying coastal flooding, although monitoring by Lidar has gained more attention.

The overview of coastal flood research suggests that the following points should be addressed. 1) Research on coastal flooding must be conducted under the larger backdrop of climate change, and the link between coastal floods and climate change is worthy of further exploration. 2) Research on coastal flooding has seen more cooperation among domestic agencies, but less cooperation among countries. However, the ocean is an inseparable whole. Coastal flooding process occurs in many countries and involves various disciplines. Therefore, beyond domestic cooperation, a focus should be placed on international and interdisciplinary cooperation to better prevent and mitigate disasters. 3) The widespread use of high technology will significantly increase work efficiency. The state should strengthen scientific and technological investment and develop more efficient and convenient monitoring equipment.

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References

Belter C W, Seidel D J, 2013. A bibliometric analysis of climate engineering research. *Wiley Interdisciplinary Reviews- Climate Change* 4(5): 417–427. doi: 10.1002/wcc.229

Cobo M J, López-Herrera A G, Herrera-Viedma E et al., 2011. Science mapping software tools: review, analysis, and cooperative study among tools. *Journal of the American Society for Information Science and Technology*, 62(7): 1382–1402. doi: 10.1002/asi.21525

Deb M, Ferreira C M, 2017. Potential impacts of the Sunderban mangrove degradation on future coastal flooding in Bangladesh. *Journal of Hydro-Environment Research*, 17: 30–46. doi: 10.1016/j.jher.2016.11.005

Freire P, Tavares A O, Sá L et al., 2016. A local-scale approach to estuarine flood risk management. *Natural Hazards*, 84(3): 1705–1739. doi: 10.1007/s11069-016-2510-y

Fu H Z, Wang M H, Ho Y S, 2013. Mapping of drinking water research: a bibliometric analysis of research output during 1992–2011. *Science of the Total Environment*, 443: 757–765. doi: 10.1016/j.scitotenv.2012.11.061

Garner A J, Mann M E, Emanuel K A et al., 2017. Impact of climate change on New York City's coastal flood hazard: increasing flood heights from the preindustrial to 2300 CE. *Proceedings of the National Academy of Sciences of the United States of America*, 114(45): 11861–11866. doi: 10.1073/pnas.1703568114

Herrera-Pantoja M, Hiscock K M, 2015. Projected impacts of climate change on water availability indicators in a semi-arid region of central Mexico. *Environmental Science & Policy*, 54: 81–89. doi: 10.1016/j.envsci.2015.06.020

Hirsch J E, 2005. An index to quantify an individual's scientific research output. *Proceedings of the National Academy of Sciences of the United States of America*, 102(46): 16569–16572. doi: 10.1073/pnas.0507655102

Horton B P, Rahmstorf S, Engelhart S E et al., 2014. Expert assessment of sea-level rise by AD 2100 and AD 2300. *Quaternary Science Reviews*, 84: 1–6. doi: 10.1016/j.quascirev.2013.11.002

Karamouz M, Ahmadvand F, Zahmatkesh Z, 2017. Distributed hydrologic modeling of coastal flood inundation and damage: nonstationary approach. *Journal of Irrigation and Drainage Engineering*, 143(8). doi: 10.1061/(ASCE)IR.1943-4774.0001173

Keiser J, Utzinger J, 2005. Trends in the core literature on tropical medicine: a bibliometric analysis from 1952–2002. *Scientometrics*, 62(3): 351–365. doi: 10.1007/s11192-005-0027-3

Kelly B D, Lundon D, Glynn R et al., 2012. A bibliometric analysis of urological oncology research output over 55 years. *BJU International*, 109: 66–67.

Levermann A, Clark P U, Marzeion B et al., 2013. The multimillennial sea-level commitment of global warming. *Proceedings of the National Academy of Sciences of the United States of America*, 110(34): 13745–13750. doi: 10.1073/pnas.1219414110

Li L L, Ding G H, Feng N et al., 2009. Global stem cell research trend: bibliometric analysis as a tool for mapping of trends from 1991 to 2006. *Scientometrics*, 80(1): 39–58. doi: 10.1007/s11192-008-1939-5

Lin N, Shullman E, 2017. Dealing with hurricane surge flooding in a changing environment: part I. Risk assessment considering storm climatology change, sea level rise, and coastal development. *Stochastic Environmental Research and Risk Assessment*, 31(9): 2379–2400. doi: 10.1007/s00477-016-1377-5

Liu X J, Zhang L, Hong S, 2011. Global biodiversity research during 1900–2009: a bibliometric analysis. *Biodiversity and Conservation*, 20(4): 807–826. doi: 10.1007/s10531-010-9981-z

McCune B, Mefford M J, 1999. *Multivariate Analysis of Ecological Data*, *Version 4.20*. Gleneden Beach: MjM Software Design.

Mentzafou A, Markogianni V, Dimitriou E et al., 2017. The use of geospatial technologies in flood hazard mapping and assessment: case study from river Evros. *Pure and Applied Geophysics*, 174(2): 679–700. doi: 10.1007/s00024-016-1433-6

Morel C M, Serruya S J, Penna G O et al., 2009. Co-authorship network analysis: a powerful tool for strategic planning of research, development and capacity building programs on neglected diseases. *PLoS Neglected Tropical Diseases*, 3(8): e501. doi: 10.1371/journal.pntd.0000501

Muis S, Güneralp B, Jongman B et al., 2015. Flood risk and adaptation strategies under climate change and urban expansion: a probabilistic analysis using global data. *Science of the Total Environment*, 538: 445–457. doi: 10.1016/j.scitotenv.2015.08.068

Pritchar A, 1969. Statistical bibliography or bibliometrics. *Journal of Documentation*, 25(4): 348–349.

Qian F, He M C, Song Y H et al., 2015. A bibliometric analysis of global research progress on pharmaceutical wastewater treatment during 1994–2013. *Environmental Earth Sciences*, 73(9): 4995–5005. doi: 10.1007/s12665-015-4183-3

Riahi K, Rao S, Krey V et al., 2011. RCP 8.5—a scenario of comparatively high greenhouse gas emissions. *Climatic Change*, 109(1–2): 33–57. doi: 10.1007/s10584-011-0149-y

Silva S F, Martinho M, Capitão R et al., 2017. An index-based method for coastal-flood risk assessment in low-lying areas (Costa de Caparica, Portugal). *Ocean & Coastal Management*, 144: 90–104. doi: 10.1016/j.ocecoaman.2017.04.010

Wadey M, Brown S, Nicholls R J et al., 2017. Coastal flooding in the Maldives: an assessment of historic events and their implications. *Natural Hazards*, 89(1): 131–159. doi: 10.1007/s11069-017-2957-5

Wong T E, Bakker A M R, Keller K, 2017a. Impacts of Antarctic fast dynamics on sea-level projections and coastal flood defense. *Climatic Change*, 144(2): 347–364. doi: 10.1007/s10584-017-2039-4

Wong T E, Bakker A M R, Ruckert K et al., 2017b. Brick v0.2, A simple, accessible, and transparent model framework for climate and regional sea-level projections. *Geoscientific Model Development*, 10(7): 2741–2760. doi: 10.5194/gmd-10-2741-2017

Wong T E, Keller K, 2017. Deep uncertainty surrounding coastal flood risk projections: a case study for New Orleans. *Earth's Future*, 5(10): 1015–1026. doi: 10.1002/2017EF000607

Xie S D, Zhang J, Ho Y S, 2008. Assessment of world aerosol research trends by bibliometric analysis. *Scientometrics*, 77(1): 113–130. doi: 10.1007/s11192-007-1928-0

Xu Y Y, Boeing W J, 2013. Mapping biofuel field: a bibliometric evaluation of research output. *Renewable and Sustainable Energy Reviews*, 28: 82–91. doi: 10.1016/j.rser.2013.07.027

Zahmatkesh Z, Karamouz M, 2017. An uncertainty-based framework to quantifying climate change impacts on coastal flood vulnerability: case study of New York City. *Environmental Monitoring and Assessment*, 189(11): 567. doi: 10.1007/s10661-017-6282-y