

Trends in natural hazards research funding by the National Science Foundation

Geoscience Research Programs' Adaptations to Natural Disruptive Events (GRANDE)

Leila Gonzales and Christopher Keane
American Geosciences Institute

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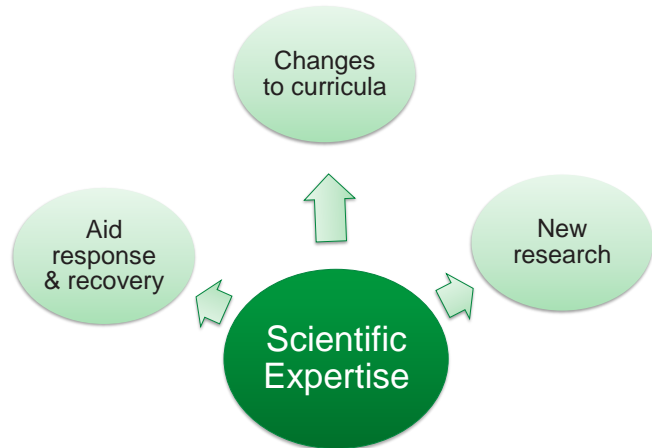
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Project Overview

Geoscience departments have the expertise for understanding the causes, impacts and risk of natural hazard events.

How do they leverage these events as opportunities for learning and research, and to aid response & recovery efforts?



Geoscience is the intellectual discipline that understands the causes, impacts, and risks of natural hazard events, and also has the opportunity to lead the way in adaptation and mitigation, leveraging the experiences from the recovery and rebuilding phases of these events for enhanced educational and research opportunities. This project examines the extent of natural hazard impacts on the geoscience community, with a specific focus on geoscience academic programs, and the response to those impacts. We specifically are interested in academic programs because they lead the way in new research and educational experiences related to natural processes as well as in developing the future professionals that can predict, mitigate, and prevent these societal impacts.

Project Goals



The GRANDE project is focused on identifying the scope of impacts of natural hazard events on the geoscience community in the United States between 2000 and 2019. The project has four major goals that are divided by work packages:

- Quantitatively assess how declared disasters impacted geoscience education, research, and departmental operations
- Identify specific operational and pedagogical outcomes that evolved from disruptive event-impacted departments
- Determine how the geoscience community has leverage natural disruptions broadly beyond those departments directly impacted by the events for education, research, or operational resilience
- Capture the attitudes and forward perspectives of students and early-career geoscientists about their expectations of impacts on the geosciences by climate change and associated disruptive events

Assessing impacts on geoscience education

Map departments
to federally
declared disasters

Examine
published
literature

Assess
research &
curricula
production

Identify faculty
size and
specialty
changes

Evaluate
federal
funding
opportunities

- Analyze trends in NSF funding from 2000 to 2019 to identify changes in number of awards and funding levels related to specific events and/or natural hazard types.



This analysis is part of Work Package 1 where we are assessing impacts on geoscience education, specifically Task 1.5 (*Examine federal funding databases for historical occurrence and scope of funding opportunities in response to notable events*).

For context, in Work Package 1, Task 1.1 we mapped the safety warning system notifications to the geocoded locations of geoscience departments and established that all U.S. geoscience departments have experienced potentially disruptive events over the project time frame, with the number of hazard-related notifications per department ranging from about 300 to over 12,000. As such, we expected to see some signal of response to some of these events in the literature and curricular materials. However, our analysis of the Journal of Geoscience Education literature indicated that hazard-related articles comprised 4.6% of all publications from 2000-2019, and our analysis of SERC curriculum resources showed that 20% of the resources related to hazards. The broader picture that is emerging from this study suggests that either impacts from natural hazard events are generally not long or severe enough to cause lasting changes or risk resilience is generally high among geoscientists thus eliciting a dampened response to hazard events.

Since funding of research drives to a certain extent the production of peer-reviewed literature and development of curricular materials, and since we are seeing a low

production of hazard-related literature and curricular materials, we examined trends in NSF funding to see if there were identifiable patterns in the funding of hazard-related research.

Questions to investigate

*How much has NSF
invested in natural hazards
research?*

*Which directorates have
invested the most in
natural hazards research?*

*What trends are there
relative to types of
natural hazard awards over
the 2000-2019 period?*

*Are there trends in types
of research by type of
natural hazard?*



Questions we wanted to understand included:

- Given the increasing frequency of hazards, do we see an increase over the 2000-2019 period in funding for hazard-related research?
- Are there trends in funding by directorate? For example, does GEO fund some types of hazard-related research, while other directorates fund different types of hazard-related research? For example, a focus on community resilience vs. facility and instrumentation awards for earthquake research, vs. specific hazard types (i.e. floods, tsunamis, hurricanes, etc.)?
- Which types of hazards are receiving funding? Do hurricanes or earthquakes receive more funding than other types of hazards? Are there inflection points in funding where we see responses to large natural disaster events, such as we did for the Sumatra earthquake and tsunami?

And the question linking back to the prior results of this work package is, “Do we see a disconnect between the production of literature and curricular materials and funding for hazard-related research?” For example, do we see a large amount of funding for research, but a low amount of production of literature and curricular resources, or are the trends in both similar?

Methodology



Download NSF awards and funding announcements (2000-2019)



Given a pre-defined list of natural hazards, use an AI Large Language Model (mixtral-8x7b) to classify awards and funding announcements as either related to one or more natural hazards or as "not a natural hazard"



Use mixtral8x-7b to identify the type of research for each award.



Use mixtral8x-7b to identify if awards relate to specific natural hazard events.



Manually identify award funding mechanisms such as SGER, EAGER, RAPID.



Manually identify facility/instrumentation and meeting/workshop/travel awards.



We downloaded 239,260 NSF awards and 3,023 funding opportunities that were active between 2000 and 2019 to assess trends in funding for hazards research.

Award data was downloaded from the Download Awards section of the NSF Awards website (<https://www.nsf.gov/awardsearch/download.jsp>).

Funding announcements (i.e., Dear Colleague Letters, Program Summaries (Announcements / Descriptions) and Program Solicitations) were downloaded from the funding search section of the NSF website.

We used the mixtral-8x-7b Large Language Model (LLM) to determine if the awards and solicitations were related to natural hazards and to identify if they were focused on specific named natural disasters. We also used the LLM to classify the awards by research focus.

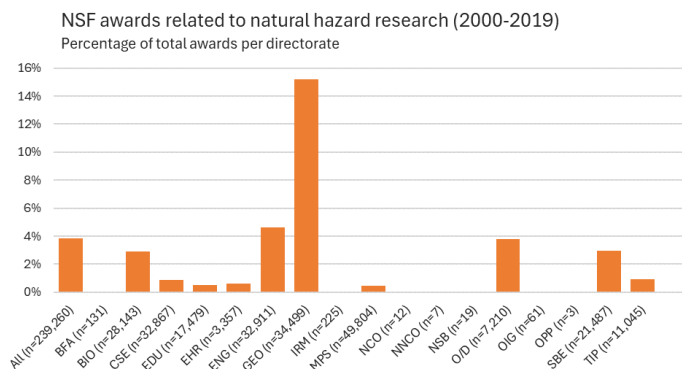
We manually identified awards that were part of specific funding mechanisms, such as SGER, EAGER, RAPID, and manually identified facility / instrumentation and meeting / workshop / travel types of awards so that we could split these from research-specific grants.

Overview of natural hazard research funding

Natural hazard-related awards comprised 3.9% of all NSF awards between 2000-2019.

GEO awarded the largest share of awards (5,239) which was 15.2% of all GEO awards.

ENG awarded the next largest share of awards (1,521) which was 4.6% of all ENG awards.



Of all awards granted during the 2000-2019 period, 3.9% were related to natural hazard research. The GEO directorate awarded the largest share of awards followed by the ENG directorate.

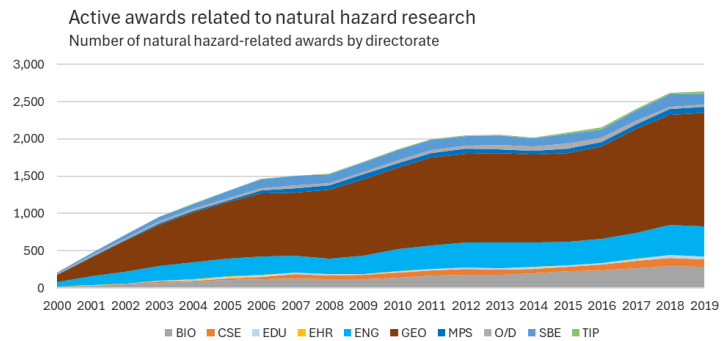
Trends in active natural hazard research funding

Active awards

For a given year, an award is considered active if the year falls between the award's start and end dates.

GEO is driving the increase in natural hazard-related research at NSF.

Increases also seen in BIO, CSE, EDU, ENG, MPS, SBE, TIP



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Since awards are multi-year projects, we also looked at the total number of active awards over the 2000-2019 period. For a given year, an award is considered active if the given year falls between the award's start and end dates.

By the numbers, GEO is driving the increase in natural hazard related research, with 95 active awards in 2000 to 1,522 active awards in 2019.

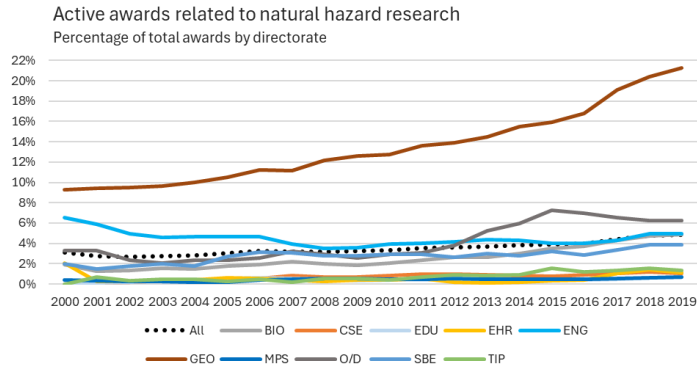
Active natural hazard award proportions

Considering natural hazard awards as a percentage of total awards by directorate:

A steady increase in natural hazard-related awards from GEO, especially since 2003.

Meanwhile, there has been a slight decline in the percentage of natural hazards awards from ENG.

The percentage of O/D natural hazard awards increased after 2011.



We examined the percentage of active awards by directorate that were related to natural hazards research. There has been a steady increase in the percentage of active awards related to natural hazards research in GEO, from 9% in 2000 to 21% in 2019.

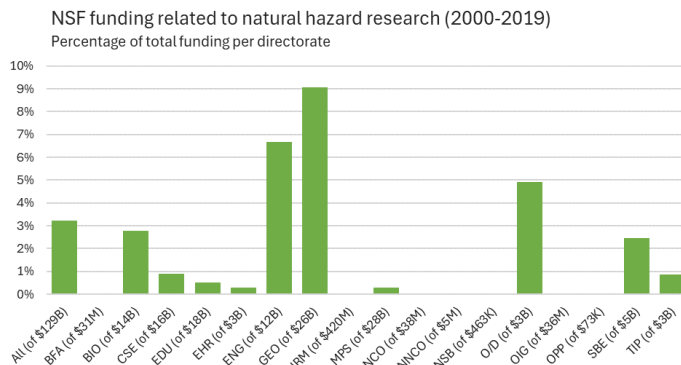
In the ENG directorate, there's been a slight decline from 7% to 5% of active awards that were related to natural hazards research over the same period.

Funding amounts by directorate

Between 2000 and 2019, NSF invested just over \$4 billion in natural hazards research, which was 3.2% of all research funding over the period.

\$2.3 billion was invested by the GEO directorate, which equated to 9.1% of its total funding.

\$797 million was invested by the ENG directorate, which equated to 6.7% of its total funding.



When we look at total funding for awards related to natural hazards research, we see that NSF funded just over \$4 billion for awards related to natural hazards, which was 3.2% of all research funding over 2000-2019.

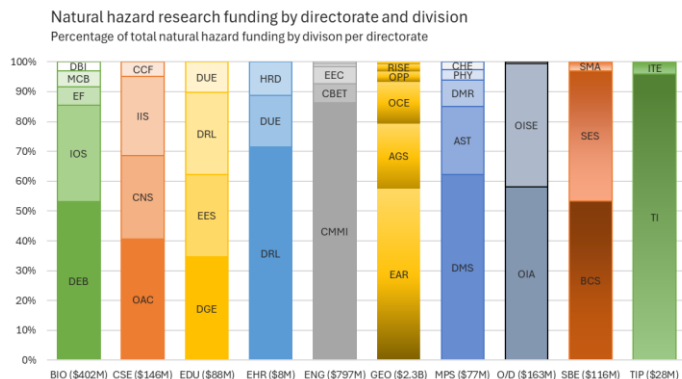
Just over half of that funding (\$2.3B) was from the GEO directorate and \$797M was invested by ENG. For GEO, this was 9.1% of it's total funding for the period, and for ENG, 6.7% of its total funding.

Funding amounts by division

61% of NSF natural hazard research funding was from

- GEO-EAR (32%)
- ENG-CMMI (17%)
- GEO-AGS (12%)

The proportion of natural hazard research funding by division within each directorate varies considerably.



Not labelled in chart due to space limitations and small percentages:
ENG: ECCS, EFMA | GEO: GEO, DPP | O/D: EPS



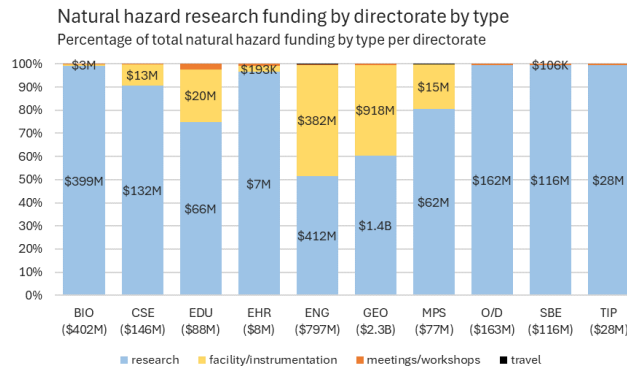
By directorate and division, most of the natural hazard related research funding came from GEO-EAR (32%), ENG-CMMI (17%) and GEO-AGS (12%). Within each directorate the proportions of natural hazard research funding varied greatly, with some directorates having funding spread relatively equally across divisions, like EDU and CSE, to others which had natural hazard research funding coming from a few divisions, such as TIP, ENG, EHR, and BIO.

Funding amounts type of award

Most natural hazard funding per directorate was for research awards.

Funding for facility and instrumentation awards was largest for

- ENG (48%)
- GEO (39%)
- EDU (23%)
- MPS (19%)



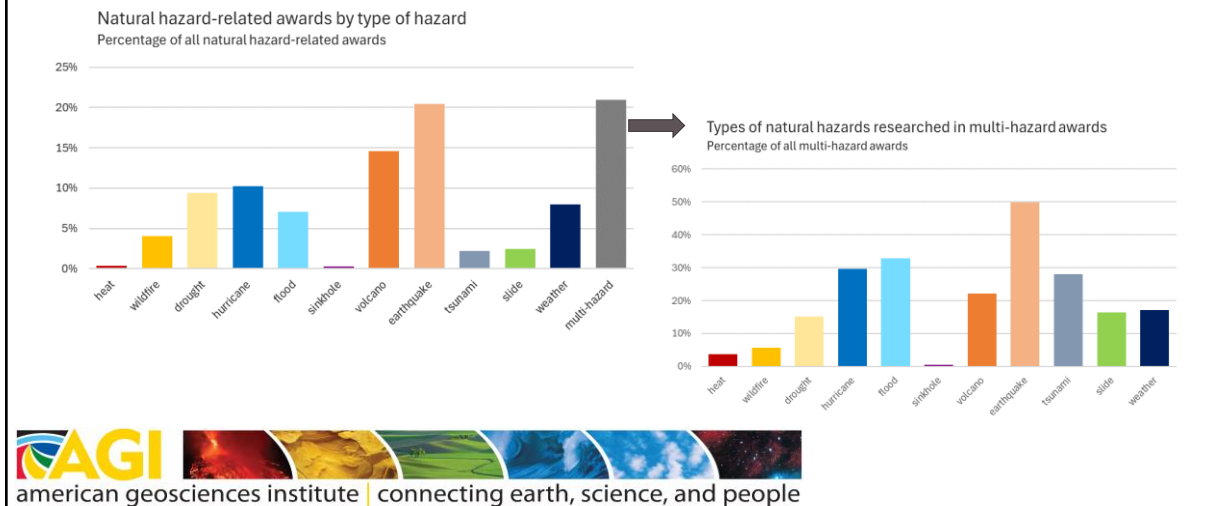
Values shown for research and facility/instrumentation funding



We analyzed the types of awards being funded by research, facility and instrumentation, meeting/workshops, and travel to better understand how much funding was for research vs. other types of awards.

Next to research awards, funding for facility and instrumentation award was the next largest type of award granted by NSF directorates. Facility and instrumentation awards comprised nearly half of ENG funding and over a third of GEO funding.

Types of research being conducted



This slide shows the percentage of natural hazard-related awards by the type of natural hazard being studied. In the case of multiple hazards, awards were classified into the multi-hazard category in the chart on the left. The chart on the right shows the percentage of multi-hazard awards by type of hazard. Note that in the chart on the right, the hazard categories can sum to over 100% since there are multiple hazards being reported.

Hazards commonly mentioned together in multi-hazard awards:

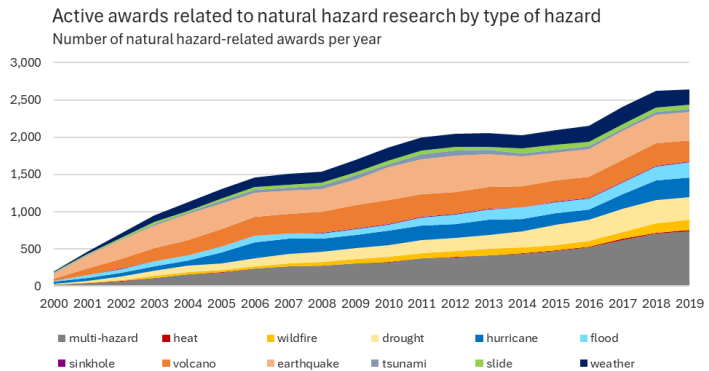
- Earthquakes and tsunamis (n=293)
- Earthquakes and volcanoes (n=277)
- Hurricanes and floods (n=173)
- Drought and flood (n=135)
- Earthquakes and landslides (n=89)
- Earthquakes, tsunamis, and volcanoes (n=59)
- Hurricanes and tornadoes (n=45)
- Floods and landslides (n=37)

Active natural hazard award proportions

Active awards

For a given year, an award is considered active if the year falls between the award's start and end dates.

Overall increase in natural hazards research, with a shift in focus on awards investigating multiple natural hazards.



We examined the number of active awards related to natural hazard research by type of hazard. What we can see is the steady increase in the number of multi-hazard awards over time.

Active natural hazard award proportions

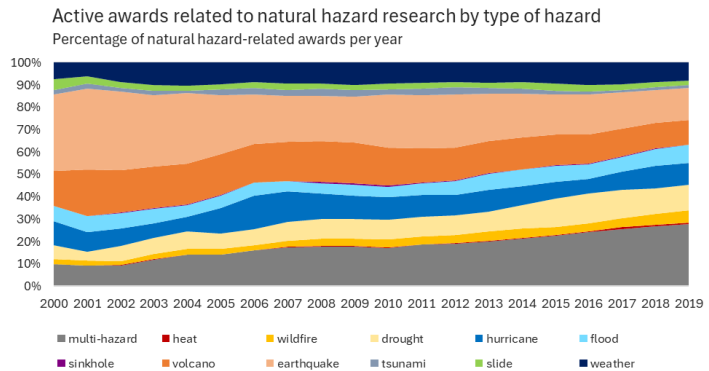
By 2019, multi-hazard awards comprised 28% of all active awards, up from 10% in 2000.

Other increases:

Drought, wildfire

Declines:

Earthquakes, volcanoes, slides



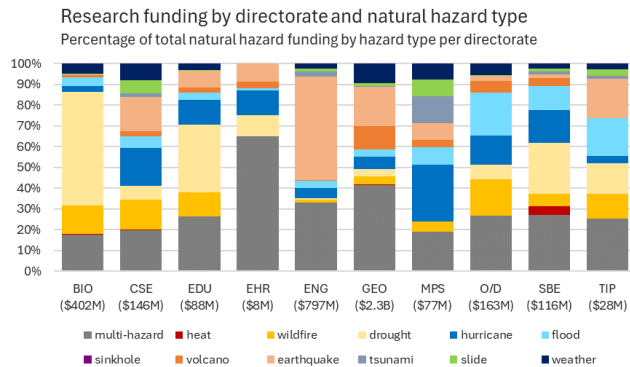
Proportionally, we see that multi-hazard awards increased from 10% of all active natural hazard related awards in 2000 to 28% in 2019. Over the same period, we see minor increases in drought awards (6% in 2000 to 11% in 2019) and wildfire awards (2% in 2000 to 5% in 2019) and declines in earthquake awards (34% in 2000 to 14% in 2019), volcanoes (16% in 2000 to 11% in 2019), and slides (5% in 2000 to 2% in 2019). Given that hazards commonly mentioned together in multi-hazard awards include earthquakes, volcanoes and landslides, it may be that we are seeing a shifting to a wider focus looking at linked events, such as earthquakes and volcanoes, or slides as a result of earthquake or volcanic activity.

Funding amounts type of award

Funding focus varies by directorate.

Multi-hazard funding was 18% or more of directorate funding.

GEO: 42% to multi-hazard
 ENG: 50% to earthquakes
 33% to multi-hazard
 BIO: 55% to drought
 EDU: 33% to drought
 EHR: 65% to multi-hazard



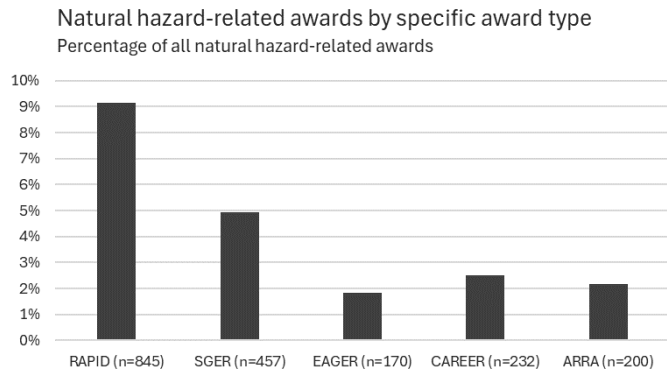
Funding for natural hazard research varies by directorate in terms of types of hazards. For example, over half of BIO's funding for natural hazard research focused on drought, while half of ENG's natural hazard funding focused on earthquakes, and nearly 2/3 of EHR's funding of natural hazard research focused on multi-hazard awards. For GEO, 42% of natural hazard funding was awarded to multi-hazard awards, 19% for earthquake awards, 11% for volcanic activity awards, and 10% for weather hazard research.

Funding mechanisms

RAPID awards comprised just over 9% of all natural hazard-related awards.

SGER awards comprised 5% of all natural hazard-related awards.

EAGER, CAREER, and ARRA each comprised < 5%.



We looked at the RAPID, EAGER, SGER, CAREER, and ARRA award types to see if there were patterns in response of these mechanisms to the different types of hazards. We were especially interested in the RAPID, EAGER, and SGER grants because they often indicate a quick response to a specific event. We also included the ARRA grants because they were very different in terms of scope, etc. and we wanted to see how much of the overall funding for natural hazard research was from that one-time infusion of resources vs other mechanisms. We also wanted to see how the funding from the ARRA mechanism differed from other mechanisms – for example, was funding more evenly distributed across hazard types than we see in other funding mechanisms or more focused on natural hazard events occurring around 2008-2009?

Definitions:

SGER (1989-2010): Small Grant for Exploratory Research (SGER) proposals are for small-scale, exploratory, high-risk research in the fields of science, engineering, and education normally supported by the NSF. The SGER is one mechanism NSF will use to support fundamental science and engineering projects whose results may enable our country to better mitigate, prepare for, respond to, and recover from catastrophic events. SGER proposals may be submitted to individual programs. Research suitable for SGERs is characterized as: preliminary work on untested and novel ideas; ventures into emerging and potentially transformative research ideas; application of new

expertise or new approaches to "established" research topics; having a severe urgency with regard to availability of, or access to data, facilities or specialized equipment, including quick-response research on natural or anthropogenic disasters and similar unanticipated events; or efforts of similar character likely to catalyze rapid and innovative advances. As the SGER mechanism phased out, EAGER and RAPID were initiated and were in a sense follow-ons to the SGER mechanism.

EAGER (2009-current): EAGER is a type of proposal used to support exploratory work in its early stages on untested, but potentially transformative, research ideas or approaches. This work may be considered especially "high risk-high payoff" in the sense that it, for example, involves radically different approaches, applies new expertise, or engages novel disciplinary or interdisciplinary perspectives.

RAPID (2009-current): RAPID is a type of proposal used when there is a severe urgency with regard to availability of or access to, data, facilities or specialized equipment, including quick-response research on natural or anthropogenic events and similar unanticipated occurrences.

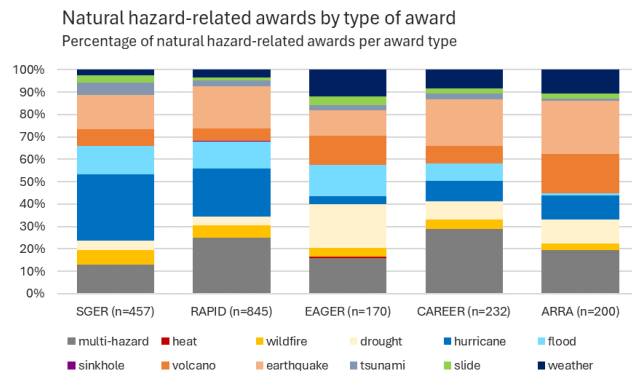
ARRA (2009): American Recovery and Reinvestment Act (Recovery Act) awards. We examined these to see if there was a large proportion of natural hazard related awards from the ARRA mechanism, given the additional \$3 billion in supplemental funding the NSF received in 2009 from the Recovery Act.

CAREER (2009-present) : The Faculty Early Career Development (CAREER) Program is a Foundation-wide activity that offers the National Science Foundation's most prestigious awards in support of early-career faculty who have the potential to serve as academic role models in research and education and to lead advances in the mission of their department or organization. Activities pursued by early-career faculty should build a firm foundation for a lifetime of leadership in integrating education and research. NSF encourages submission of CAREER proposals from early-career faculty at all CAREER-eligible organizations and especially encourages women, members of underrepresented minority groups, and persons with disabilities to apply. We included these to see what proportion of natural-hazard related research was awarded using this mechanism. This is a proxy for looking at investment in early-career faculty doing natural hazard research.

Funding mechanisms by natural hazard type

Types of natural hazards researched by funding mechanism varies.

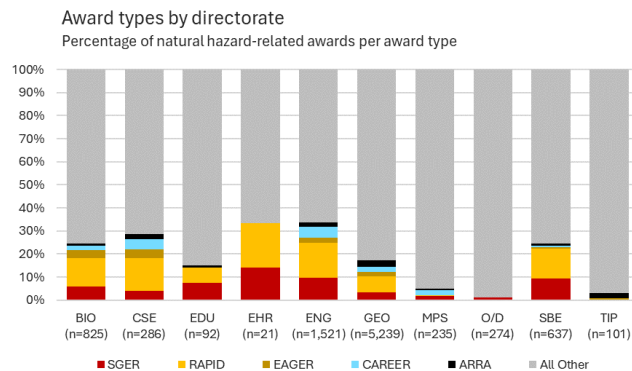
Top natural hazard types across funding mechanisms included: Multi-hazard, earthquakes, hurricanes, and drought



SGER which was a forerunner to RAPID and EAGER grants had a large proportion of funding invested in hurricane (30%), earthquake (16%), and multi-hazard (13%) research. RAPID grants followed a similar pattern in hurricane (21%), earthquake (19%), and multi-hazard (25%) research investment. EAGER grants focused more on drought (19%), multi-hazard (16%), volcanoes (13%), and earthquakes (11%). CAREER grants showed investment in primarily multi-hazard research (29%), and earthquake research (21%), while ARRA funding was primarily focused on earthquakes (24%), multi-hazards (20%), and volcanoes (18%). Floods comprised 12% - 14% of funding from SGER, RAPID and EAGER mechanisms.

Funding mechanisms by directorate

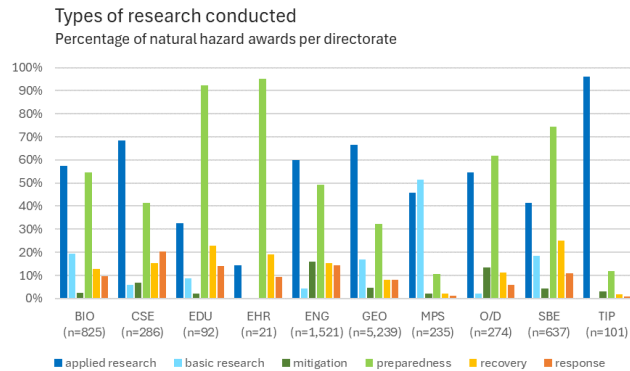
Of these mechanisms, RAPID and SGER awards were most common, comprising 1/3 or less of all natural hazard-related awards.



RAPID and SGER mechanisms were the most common types of mechanism for natural hazard research awards and the SGER awards here were more focused on rapid response to specific events than on more high-risk type of awards that are characteristic of the later EAGER mechanism.

Types of research

Applied research and research related to natural hazard preparedness were the most common types of research conducted across directorates.



We next examined types of research being funded by directorate to understand the types of research being funded. We looked both at applied and basic research as well as research focused on response, recovery, mitigation and preparedness.

Applied research and research related to natural hazard preparedness were the most common types of research conducted in these awards.

Note that awards could be classified into multiple research types in this chart.

Research type definitions:

Mitigation: This phase includes actions taken to prevent or reduce the cause, impact, and consequences of disasters.

Preparedness: This phase includes planning, training, and educational activities for events that cannot be mitigated.

Response: The response phase occurs in the immediate aftermath of a disaster.

Recovery: During the recovery period, restoration efforts occur concurrently with regular operations and activities.

Basic research: The research is conducted to advance knowledge and theory without consideration for commercial gain or practical application.

Applied research: The research is conducted to solve a particular problem for specific situation.

Awards related to named events by natural hazard

Hurricanes, earthquakes, and volcanoes were the most common named events.

Top events named in awards:

2005 Hurricane Katrina: 175

2017 Hurricane Harvey: 133

2017 Hurricane Irma: 78

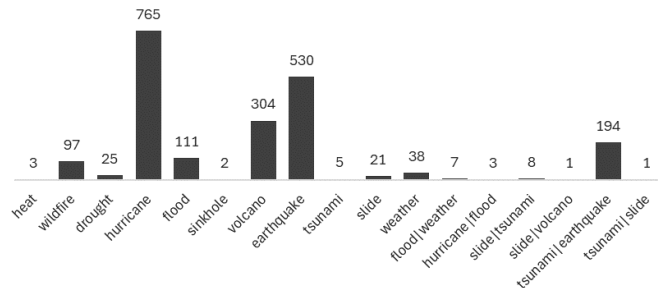
2003 Tohoku, Japan earthquake: 73

2017 Hurricane Maria: 71

2004 Indian Ocean earthquake: 64

2012 Hurricane Sandy: 58

Natural hazard-related awards by type of named event
Number of awards by natural hazard type

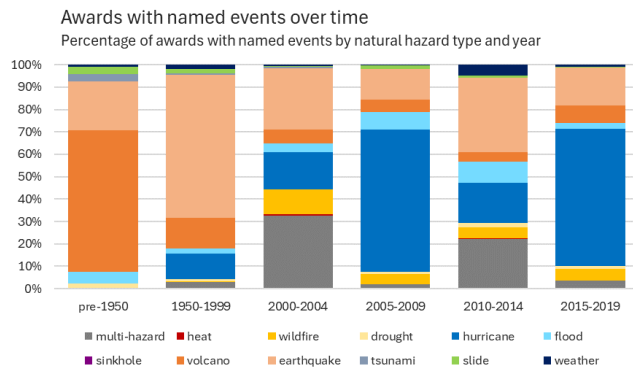


We examined the awards to see if there were notable events that were specified in the award title and/or abstract. Hurricanes, earthquakes, and volcanoes were the most commonly named events in the natural hazard-related awards. Top named events in this set of awards included Hurricanes Katrina, Harvey, Irma, Maria and Sandy, as well as the Tohoku earthquake in Japan and the 2004 Indian Ocean earthquake and tsunami.

Awards related to named events by natural hazard

Top events by year bracket

- **pre-1950:** 29 different volcanic events
- **1950-1999:** Turkey, Taiwan, and Northridge earthquakes
- **2000-2004:** Indian Ocean earthquake & tsunami, 2002 Denali earthquake
- **2005-2009:** Hurricanes Katrina and Rita
- **2010-2014:** Tohoku earthquake & tsunami; Hurricane Sandy, New Zealand earthquakes, Haiti earthquake, Chile earthquake & tsunami
- **2015-2019:** Hurricanes Harvey, Irma, Maria, Florence, Michael, and Matthew; Nepal earthquake



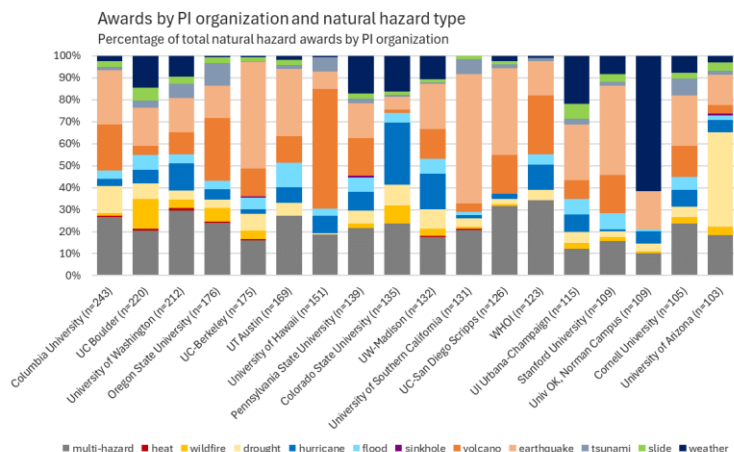
Awards with named events have changed in topical focus over time. Awards that focused on pre-1950, most commonly mentioned historic volcanic events, while those grants mentioning events from 1950-1999 were predominantly focused on the earthquakes in Turkey, Taiwan, and Northridge, California. Awards with named events that took place between 2000-2004 were primarily focused on multi-hazard events, such as the Indian Ocean earthquake and tsunami, and the 2002 Denali earthquake. Awards with named events in 2005-2009 primarily focused on Hurricanes Katrina and Rita, and those with named events in 2010-2014 were focused on the earthquakes in Japan, New Zealand, and Chile as well as Hurricane Sandy. Those with named events in 2015-2019 were focused mostly on Hurricanes Harvey, Irma, Maria, Florence, Michael, and Matthew, as well as the Nepal earthquake.

Top PI Organizations

PI organizations receiving 100 or more natural hazard-related awards.

These organizations received 29% of all natural hazard-related awards.

Funding for these organizations totaled \$1.09 billion.



We next looked at the organizations of the primary investigators (PIs) on awards for natural hazard-related research to see how funding has been awarded across the academic enterprise. We focused on the organizations of PIs that received 100 or more natural hazard-related awards between 2000 – 2019. The chart here shows those organizations, and they received 29% of all natural-hazard related awards during the 2000-2019 period, which totaled just over \$1B.

The chart shows the types of hazard research conducted by PIs at these organizations.

NSF opportunities by natural hazard type

1% of opportunities related to natural hazards (42 of 3,023)

RAPID/EAGER/SGER

2005 Hurricane Katrina: 2

2010 Haiti earthquake: 1

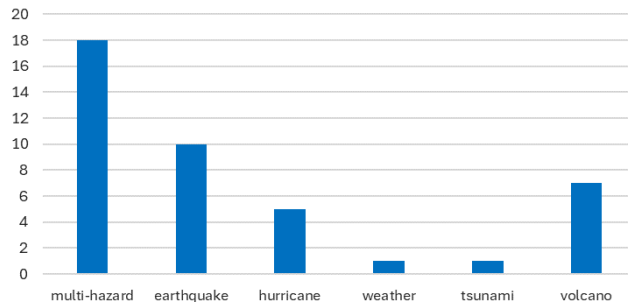
2011 Earthquakes in Japan & New Zealand: 3

2017 Hurricane Harvey: 1

2017 Hurricane Irma: 1

2018 Hurricane Season: 1

Opportunities by natural hazard type
Number of natural hazard-related opportunities



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We next examined NSF funding opportunities to understand the percentage of opportunities focused on natural hazards research. We looked at Dear Colleague Letters, Program Summaries, and Program Solicitations from the funding search section of the NSF website. Of the 3,023 opportunities listed between 2000 and 2019, only 1% were related to natural hazards. Of those 9 were related to RAPID/EAGER/SGER opportunities in response to hurricanes or earthquakes. Most opportunities were focused on multiple hazards, followed by those focused on earthquake and volcanic activity.

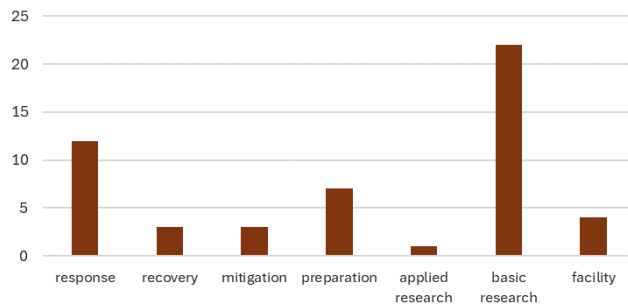
NSF opportunities by research type

Basic research opportunities were primarily for:

- EarthScope research
- NEESR research
- GEO programs:
Petrology & Geochemistry
Geophysics

Note – opportunities could be categorized into multiple research types.

Opportunities by type of research
Number of natural hazard-related opportunities



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We examined the types of research activities that the opportunities focused on. Note that the opportunities could be categorized into multiple types of research activities. Basic research activities were primarily for EarthScope, NEESR and the Petrology & Geochemistry and Geophysics GEO programs. Natural hazard response and preparation were the second and third most common types of research opportunities related to natural hazards.

NSF opportunities by directorate

Most opportunities were funded by GEO or ENG.

12 were funded by multiple directorates, with the majority related to RAPID/SGER/EAGER types of opportunities.



By directorate, most of the funding opportunities were from GEO or ENG. 12 of the 42 opportunities were funded by multiple directorates with the majority of these multi-directorate opportunities being RAPID, SGER, or EAGER funding mechanisms.

Next steps...

- Extend this analysis through 2024 to see if there are any changes in research funding and opportunities for natural hazard research.
 - Include additional funding mechanisms such as CRISES and CHIRP in the extended analysis.
- Extend analysis of literature and curriculum resources to 2024 to see if there is a change in the production of natural hazard related literature and curriculum resources.



We plan to extend our analysis to include 2020-2024 awards and funding opportunities, including additional funding mechanisms such as CHIRP and CRISES. In addition, we are planning to extend our analysis of the literature and curriculum resources to see if there is any uptick in production of natural hazard related resources and publications after 2020.