The Science of Extreme Events: Research, Monitoring, and Mitigation of Coastal Natural Hazards

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In a Nutshell:

We recommend that a thematic hub or part of a regional hub be dedicated to the science of extreme natural hazard events that impact coastal communities. Understanding hazards is fundamental to forecasting and preparedness. The hub would include support for multidisciplinary scientific research geared towards a better understanding of the generation mechanisms, recurrence frequency and severity of the impacts of extreme hazard events on the coastal population. Important aspects of the hub include instrumentation for continuous observation, a rapid response capability, close coordination with related agencies, and hazard mitigation and outreach to stakeholders and impacted communities.

Motivation

Many coastal communities are not fully aware of the level of exposure they have to some of these extreme natural hazard events due to the lack of scientific and quantitative assessments of the local threat. This lack of understanding typically results in these communities being ill-prepared to cope with the consequences of such an event and has the potential to cause unnecessary loss of life and property. Identification of credible worst-case scenarios for these communities is an essential element in the assessment of their exposure level and is a fundamental building block to create resilient communities.

Science and Instrumentation

Hazard assessment studies should be informed by state-of-the-art science and updated on a regular basis as we deepen our understanding of the processes threatening these communities, and as new, more accurate and higher resolution data become available. The collection of high-quality and high-resolution geodetic, seismic, sea-level, and geological data sets becomes, therefore, critical to this end. Scientific Research should also be assisted by support for instrumentation and creation of monitoring networks necessary not only to collect data on which research can be based, but to enable the creation and enhancement of forecast and early warning systems that are essential to safeguarding life and property in threatened communities.

Future data networks may include crowd-sourced data, ‘human sensor networks’ (people reporting observations), and low cost but high density networks (inexpensive pressure gauges designed for scuba diving can be used as low-cost but plentiful tide gauges, for example). The dense lower resolution networks would be used to complement but not necessarily replace the sparse higher resolution networks.

Recent examples of the need for additional research into the occurrence of extreme events are the 2004 Sumatra and the 2011 Japan earthquakes and tsunamis. In both these events existing scientific assessment failed to properly quantify the severity of the events that could affect these communities. After the occurrence of these events, hazard assessment studies along subduction zones with similar characteristics in other parts of the world have been re-examined to include lessons learned from these two events, and extreme worst-case scenarios along the Cascadia subduction margin continue to be updated on a regular basis.

Rapid Response

A critical element of a CoPe Hub focused on the Science of Extreme Events is a Rapid Response capability for post-event documentation and data collection. Learning from catastrophic events requires advance planning and funding. The Extreme Events Hub needs to prepare in advance logistically and in terms of tools to collect natural science and social science data during catastrophic events, especially very rare ones (e.g., major earthquake, tsunami).

Examples of rapid post-event data collection include (1) run up levels from tsunamis, providing inundation information critical for future planning and model validation; (2) aftershocks from major earthquakes, showing seismic sequence progression and illuminating active faults; (3) geologic surveys of landslides, capturing the physical conditions that may have led to the instability; and (4) collecting social science data, leading to recognition of cultural barriers to emergency response and effective emergency communication. The November 2016 Kaikoura earthquake in coastal New Zealand demonstrates a rapid and effective post-event data collection strategy. The M 7.8 earthquake caused landslides (Dellow et al., 2017), tsunami wave run-up (Power et al., 2017), coastal ground uplift (Clark et al., 2017), multiple complex ground ruptures along onshore faults (Hamling et al., 2017), offshore fault scarps that broke the seafloor (Bai et al., 2017), offshore turbidity currents offshore the South Island (Mountjoy et al., 2018), and slow slip events in the North Island (Wallace et al., 2017). The rapid post-event studies also examined the economic and societal impacts of the earthquake (Hatton et al., 2017; Stevenson et al., 2017), effects on engineering structures (Bradley et al., 2017). Integrated, multidisciplinary rapid response efforts provide an effective means to learn about the coupled resilience of the built and natural environment.

Implementing a rapid response capability includes developing the logistics and technology to move equipment from elsewhere to the region that experienced the extreme event. Technology could be developed for scientific ‘time capsules’ to wake up and collect data when the event happens. Rapid response teams would be trained, equipped, and prepared to collect valuable, rare, and ephemeral data to advance basic science and to inform recovery, preparations, and adaptation in aftermath. Rapid response data on episodic events, coupled with long-term baseline data also provide a critical perspective on how coastal systems change over time.

Agency Cooperation

Cooperation, coordination, and sharing between federal, academic, and local agencies is needed for both research and response activities of the Extreme Events Hub. Different agencies have different missions and typically target their research and post-event response to the goals of their own mission. An example of needed coordination is in tsunami science. The USGS has responsibilities for earthquakes, NOAA for tsunamis, even though earthquakes are the cause of most tsunamis. Within NSF, funding for earthquake research and funding for tsunami research fall between directorates (EAR and OCE) despite the relation between these events. CoPe Hubs could facilitate increased coordination between these agencies with the goal of enhancing fundamental science, hazard warnings, and information transfer.

A CoPe Extreme Events Hub should also manage and coordinate cross-agency data collection efforts. Examples might include the leveraging of USGS seismic networks, geodetic networks from EarthScope/UNAVCO, tide gauge and DART data from NOAA. Offshore data collection and warning networks (e.g., cabled seismic and pressure gauge networks, seafloor geodesy) are still under development and will require ongoing coordination. Crowd-sourced data collection is another potential opportunity for hub coordination. For example, ship navigation (heading) and height (GNSS) data can capture tsunami waves. While a single low-resolution measurement of ship height is of little use, a crowd-sourced data set of data from dozens or even hundreds of ships enables researchers or automated algorithms to detect and characterize tsunami signals. Another example of the utility of crowd-sourced data is the use of social media chatter and imagery that provides real-time information on local conditions during an unfolding disaster.

Hazard Mitigation and Outreach

CoPe Hubs should serve as coordination centers and facilitators for addressing critical coastal problems and for responding to natural hazards. CoPe outreach and education specialists will serve as liaisons with regional stakeholders (e.g., public officials, civic leaders, community elders, business owners, and local residents). This approach will be most effective through a system of regional, place-based HUBs that draw expertise and knowledge from local communities and cultures. Regional cooperation, communication, and training are essential for cross-fertilization of ideas and developing appropriate methodologies for responding to complex natural hazards and their impacts on local communities.

We recommend that CoPe Hubs facilitate the implementation of hazard mitigation measures in local communities. CoPe specialists will interact with local stakeholders to identify community needs, and to build a unique understanding of local regulations, norms, and customs for addressing coastal hazards. These specialists will develop locally appropriate mechanisms for sharing science knowledge about the potential impacts and risks of hazardous events. This may include training workshops, community town hall meetings, informational signage, printed brochures and maps, and digital media resources. In addition to sharing knowledge, the CoPe Hubs will work alongside local specialists and public officials to develop plans for disaster preparedness, response, recovery, and mitigation efforts in individual coastal communities. This would involve the installation of hazard monitoring systems (e.g., tide and stream gauges, automated weather stations, doppler radar, tsunami and storm surge buoys, GPS instruments, ground motion sensors, tilt meters, etc.), as well as locally appropriate hazard warning technology (e.g., sirens, television and radio announcements, reverse 911 calls, smart-phone messaging, etc.). An additional critical aspect of this work would be to identify local experts and resources that can be deployed in support of rapid response efforts following a disaster.

We recommend that CoPe Hubs also engage in outreach and education to communicate coastal science, enhance public awareness, and foster the development of local expertise. Outreach efforts could be coordinated through a regional visitor center with exhibits, teaching spaces, and a venue for public lectures, performances, and movies. This center would also have an internet and social media presence to enhance its education and outreach programs. A successful model of this approach to public outreach and education has been developed by East Coast LAB based in Napier, New Zealand (http://www.eastcoastlab.org.nz/). As an additional component, these outreach centers would also coordinate with K-12 public school districts, community colleges, and regional universities to develop effective educational programs and curricula for teaching about coastal issues and hazards. These tiered, place-based, culturally appropriate educational efforts would serve as a pipeline for training a new generation of local coastal experts. Hands-on education and training would include high-impact practices such as learning communities, experiential learning, internships, and undergraduate research (e.g., Kuh, 2008). We recommend that CoPe Hubs develop regionally-focused Research Experience for Undergraduates (REU) and Research Experiences for Teachers (RET) programs led by hub-affiliated principal investigators.