Communicating Geological Hazards: Educating, Training and Assisting Geoscientists in Communication Skills

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Abstract Communication is important in all aspects of the geosciences but is more prominent in the area of geological hazards, as the main audience for scientific information often lacks a geoscience background; and because the implications of not communicating results effectively can be very serious. Geoscientists working in the hazards area face particular challenges in communicating the concepts of risk, probability and uncertainty. Barriers to effective communication of geoscience include the complex language used by geoscientists, restriction of dissemination of results to traditional scientific media, identification of the target audience, inability to tailor products to a variety of audiences, and lack of institutional support for communication efforts. Geoscientists who work in the area of natural hazards need training in risk communication, media relations, and communicating to non-technical audiences. Institutions need to support the efforts of geoscientists in communicating their results through providing communications training; ensuring access to communications professionals; rewarding efforts to engage the public; and devoting sufficient staff and budget to the effort of disseminating results. Geoscientists themselves have to make efforts to change attitudes towards social science, and to become involved in decision making at a community level.

Keywords Geohazards communication

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Introduction

> "The world desperately needs to know what scientists are learning from their research endeavors. We can't stop hurricanes or tsunamis or other extremes of nature. But if we weave into the policy-making process the right mix of knowledge – integrating disciplines like environmental sciences, engineering, and health and social sciences – we can help save lives and reduce damage to property."
> Lubchenco (2005)

One of the major themes of the International Year of Planet Earth is "Hazards – minimizing risk, maximizing awareness." In the prospectus outlining the theme, four main research questions are posed (Earth Sciences for Society Foundation 2004). This paper attempts to provide a partial answer to the fourth question posed – "What are the barriers, for each geohazard, that prevent governments (and other entities) from using risk and vulnerability information to create policies and plans to reduce both?"

The need for research on geohazards and other natural disasters was highlighted by an International Council of Scientific Unions (ICSU) scoping report in 2005 that indicated, despite scientific advances in understanding causes and mitigating effects, the frequency of such events was increasing steadily. Natural disasters were reported to be at approximately 100/decade from 1900 to 1940, 650/decade in the 1960s and 2000/decade in the 1980s; it reached almost 2800/decade in the 1990s. Property damage is doubling about every seven years over the past 40 years (ICSU 2005). These data are shown in Fig. 3 of Ch. 1 of this volume.

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The ICSU Scoping Report recognized that a serious disconnection existed between science and action. It states:

> "We have found ample evidence to suggest that policy-makers may at times act in ignorance or disregard of the relevant scientific information and thereby significantly exacerbate damage resulting from natural hazards. Examples include: removal of mangrove swamps from vulnerable coastlines; failure to take account of foreseeable volcanic or seismic risks; land use practices that augment risks from floods, landslides or wildfires; failure to make best use of satellite data and to support networked early warning systems; failure to invest in prevention; and financial incentives that encourage short-term, localised benefits at the expense of longer-term requirements." (ICSU 2005).

It is argued here that one of the main barriers to appropriate use of geoscience information in planning and policy is that of scientific communication. Further, a major reason for problems in communication is that many geoscientists lack the skills to communicate effectively with those who need to use their knowledge and expertise.

Scientists should increase their involvement and activity so as to influence both policy and public response, yet, as it will be argued below, geoscientists working in the area of geohazards frequently lack the tools to do this effectively. The need to improve skills in this area is critical; the results of research in geosciences have direct implications for the health, safety and well-being of much of the earth's population. Scientific research can be well-funded, carried out well, and show clear direction to future policy. If it is not communicated to those who create policy, or those affected by the results, it might just as well not have been done at all.

The importance and relevance of communication in hazards research has been widely recognized in the past. The United States Geological Survey Professional Paper "Nature to be Commanded: Earth Science Maps Applied to Land and Water Management" (Robinson and Spieker 1978) was a pioneering effort in communicating the importance of earth sciences, interpreting conventional geological maps in terms that were readily understood by planners. More recently, the British Geological Survey has published a guide to geoscientists (Forster and Freeborough 2006). They emphasize targeting communication at specific audiences, identifying three main groups; professionals, informed members of the public, and potential or actual victims of a hazard. Perhaps the most important conclusion of this report relates to empowerment:-

> "It is essential that any publication that tells people that they have, or may have, a problem should include guidance on how they may, themselves, take action to: determine if they have such a problem, avoid such a problem or minimise the effect of the problem. Telling them to contact a professional for advice is not sufficient. . ." (Forster and Freeborough 2006).

In 2008, the Geological Society of London published a collection of papers entitled "Communicating Environmental Geoscience" with an emphasis on geological hazards (Liverman et al. 2008). This is the first volume dedicated to this topic, and reviews much previous work in the field.

Despite these attempts to assist geoscientists in communicating hazard research, it is clear that there is much to be done in this area, and with the increasing importance of geohazards on a global level, it is likely this topic will continue to be relevant in the future.

Communication of Science

> "In our society (that is, advanced western society) we have lost even the pretence of a common culture. Persons educated with the greatest intensity we know can no longer communicate with each other on the plane of their major intellectual concern. This is serious for our creative, intellectual and, above all, our normal life. It is leading us to interpret the past wrongly, to misjudge the present, and to deny our hopes of the future. It is making it difficult or impossible for us to take good action." Snow (1959)

The influential essay "The Two Cultures" quoted above discussed the growing gulf between the sciences and humanities (Snow 1959). Since Snow wrote, increasing specialization means that major communication difficulties exist within the sciences, and even within disciplines. We now have not one scientific culture, but many, each struggling to comprehend research outside of its own area of specialization.

The issues associated with communication by scientists and the effectiveness of such communication are widely recognized – perhaps most prominently in the area of health and medicine. There is an entire area of research that deals with the communication of science, and in particular the communication of risk. There are journals devoted to the subject (Science Communication, Journal of Science Communication), courses and degrees/diplomas, and many organizations employ communications professionals to deal with these issues. There is thus a considerable literature that can be applied to the specific problems of communication associated with geological hazards. This literature, however, is published mostly in social science journals, and a geoscientist is unlikely to be exposed to it through education or training.

General barriers identified in the communication of science range from the language used in science, the lack of institutional support for communication efforts, disincentives within the scientific culture, the challenges of communicating complex concepts, and the lack of media training amongst scientists. These are discussed later in this paper.

Geoscience and Geohazards Communication

> "Both empirical research and seasoned observation support the golden rule of public education for hazards: all the sophisticated materials and behavior modification techniques do not have the force of one "good" disaster to change both what people think, their behavior, and even public policy, at least in the short-term." Mileti et al. (2004)

Within the geological sciences, the issue of communication is perhaps most prominent in geological hazard research, where the concepts of risk and probability need to be explained, where uncertainty is prominent, and where the implications of research can have direct impact on the health and safety of the public. Communication, of course, is important in all aspects of geoscience but the nature of the audience for geohazard research is different to that in other areas. For example, in the field of resource exploration and development, particularly in the areas of minerals and oil and gas, the communication of geoscience faces different challenges than in the area of hazards. The challenges of communicating complex concepts certainly still exist, and the communication of risk and uncertainty is important. However, the audience has an obligation to be educated in the area of geoscience, as they are choosing to make economic decisions based on the scientific results presented. The implications of poor communication may be unwise investment, or lack of funding for worthwhile projects. Most importantly however, the audience generally chooses to undertake whatever risk might be incurred in understanding and acting on the results of research. In the area of natural hazards, however, the audience who need to understand the implications of scientific research often are forced to do so by geographical circumstance – their home, or livelihood happens to be located in a hazardous place. In some cases, those potentially affected by geological hazards may not be aware that any hazard exists. These audiences are very different from most in the geosciences, and particular methods and techniques of communication are required. A failure to adequately communicate risk in geohazards can directly result in immediate deaths, and thus intense critical scrutiny of the communication process. In addition the target audience is far less clear – should communication be directed at planners, policy makers, or the people potentially impacted by a disaster? All three are important audiences with different needs and background knowledge.

Uncertainty and risk are terms frequently used in geohazards research. They have strict definitions and means of determining their magnitude when used in a scientific context. The same words have a different meaning when used by a policy maker or politician. Faced with uncertainty, a policy maker wants more information or study in an attempt to remove uncertainty, or may discount advice.

The focus on risk and probability matches that in the field of medical research, where it is vital that informed decisions on health and well-being be made based on scientific research. Given the similar challenges it is important to note that geosciences and other historical sciences differ markedly from the experimental sciences (Cleland 2001). Researchers in the medical field define risk and probability based on controlled experiments. The nature of the earth sciences means that often such experiments are impossible to devise. When, for instance, the probability of an earthquake striking a given area is estimated, the basic method is to review knowledge of past occurrences. The record of past events is incomplete, and fragmentary. In a controlled experiment, error bounds can be reduced by increasing the number of trials or the sample size. This is not possible when looking at the variation through time of natural processes. Thus the level of uncertainty in conclusions may be greater, and hard to reduce with further research. This increases the difficulty in communicating such results outside of the scientific community.

Geoscientists tend to have different perceptions and understanding of time than those not trained in that area, and this can give rise to additional problems in communication. A process that is considered frequent by a geoscientist might well be thought to be so rare as to not merit consideration by a politician or planner. Hazards such as earthquakes or tsunamis may have recurrence intervals of centuries but the magnitude of their impacts means that it is critical that they are taken into account in planning and policy development.

The Role of the Geoscientist

> "I feel strongly that I should not go into research unless it promises results that would advance the aims of the people affected and unless I am prepared to take all practicable steps to help translate the results into action." (White 1972).

What role should geoscientists take in the communication of geological hazards? Given that there is a body of social science research dealing specifically with societal and cultural response to hazards, and a further body dealing with scientific communication, should geoscientists restrict themselves to geoscience and leave the communication of results to others?

Futerra Sustainability Communications (2005) outlined their view of the role of the scientist and professional communicators as follows:

> "Egg-head scientists are important messengers: they have authority, and reassure people that someone understands the complicated issue of climate change. But we need common-sense and likeable intermediaries as well, to translate the opaque pronouncements of scientists into practical and obvious advice."

Futerra reinforced stereotypical views of scientists as well as perhaps imagining themselves in the role of "common sense and likeable intermediaries." There is no reason, however, that scientists cannot translate their own research into practical and obvious advice, and also perhaps be viewed as likeable rather than egg-headed!

It is argued here that there is an obligation for geoscientists to "take all practical steps to translate their results into action" (White 1972) and that one of those steps is to take responsibility for communicating their results to those who need to be aware of them. There are good reasons to dispense with intermediaries and deliver the message directly.

Geoscientists spend their careers studying geological hazards. They have formal training through their education, and gain experience progressively – they have expertise in the processes, frequency, magnitude, and nature of the natural processes causing disasters. They thus have unique insight and understanding of geological hazards. Geoscientists therefore are best able to evaluate the significance of their results. They understand the limitations and uncertainty attached to their conclusions. In addition they are more likely to be considered trusted and reliable sources of information than politicians or government employees. Surveys in the United Kingdom show that scientists enjoy a high level of trust by the public, particularly if they work at a university (Corrado and Duthie 2006). Information conveyed directly by scientists carries more weight with the public than when it is interpreted by media or governing bodies.

If the results of research are communicated to those who need to know them by an intermediary – whether it is the media, a professional scientific communicator, or a policy maker, there is a potential for misunderstanding. Just as geoscientists may not have the background and training to communicate effectively, it is almost certain that any intermediary will lack the scientific background to comprehend the full implications of the research.

Geoscientists may not wish to be trained in communication, or might feel that they are not suited to that role. However it is inevitable that a geoscientist who works in the field of hazards will be put in a position where they have to communicate their work to non-scientists, and there may not be access to a communications professional to assist in an emergency situation. Not every geoscientist is suited, or able to interact with the media if a disaster occurs, but if that scientist is considered the expert on that type of hazard or is conducting research in that area, it is inevitable that they will be "discovered" by media – 30 s with an internet search engine will likely yield their name. It is thus important that even the most reluctant geoscientist has some understanding of communication issues.

If it is accepted that geoscientists should take a major role in communicating their results, then it is important that those scientists understand the barriers that are faced, and the means to overcome them. They need to have the skills and knowledge to make such communication effective.

Barriers to Communication

Language and Style

> "Vague and insignificant forms of speech, and abuse of language, have so long passed for mysteries of science; and hard and misapplied words, with little or no meaning, have, by prescription, such a right to be mistaken for deep learning and height of speculation, that it will not be easy to persuade either those who speak or those who hear them that they are but the covers of ignorance, and hindrance of true knowledge" (Locke 1690).

The standard means of communicating scientific results is through peer-reviewed articles in scientific journals. Such articles are directed at a select audience of fellow scientists who are familiar with the subject area. Explanation of scientific research demands a method of writing that allows the scientific method to be laid out clearly, and the logical steps taken presented in a standard sequence. This does not always make for easy reading, but is essential in order to demonstrate to the reader the assumptions made, the methods followed, and the logical train of thought required in the scientific method.

Scientific writing involves a number of stylistic conventions that do not improve readability, including the use of the third person, passive construction, and extensive use of acronyms. Each branch of science has developed a huge vocabulary of technical terms that are poorly understood outside of that specialized area. Scientific research involves the investigation of concepts and objects that lack common words to describe them, and so these technical terms are needed – yet to the reader from outside of the area of specialization these are seen as jargon. Some technical terms are hard to avoid but frequently scientific writing makes no attempt to explain concepts using simple language, even if this might be possible with some effort. When writing for a non-scientific audience, many scientists find it hard to understand what terms are not easily comprehended, as for them, with the terms in everyday use, they do not seem to be obscure, or difficult to understand. This problem is by no means restricted to the geosciences, and for instance can make important social science research inaccessible to the geoscientist.

The degree of specialization in scientific research, however, has made much scientific writing not just incomprehensible to non-scientists, but also to scientists themselves. Glanz (1997) discussed efforts within the physics community to develop guidelines for improving the clarity of writing, where the problem has become so serious that one physicist is quoted as suggesting that recent colloquia in his own department were so hard to understand that he was reluctant to encourage students to attend in case they would be "turned off from physics."

Hartz and Chappell (1998) presented the results of a survey of 1,400 scientists and journalists; 62% of journalists agreed with the statement that "most scientists are so intellectual and immersed in their own jargon that they can't communicate with journalists or the public." The extent to which this problem is acknowledged amongst scientists is shown by the fact 50% of scientists agreed with them.

Medium and Audience

Nearly all scientific research is published in the serial literature, presented at academic conferences, or described in technical reports. Scientific journals are rarely read by anyone other than scientists, and with the proliferation of specialized publications, it is unlikely that most journal papers are seen by anyone other than other specialists in that particular field of science. In order for geoscience to play an appropriate role in the efforts to deal with the problems posed by natural hazards, geoscientists must be able to adapt their communication skills to a variety of other means of communication – through the popular media, public awareness, public or community based consultation, and briefing of politicians and policy makers. The means and style of communication need to be adapted to the audience targeted. This audience will vary considerably depending on the type of hazard, and the nature of the research.

Take, for example, the geoscientist asked to assist in dealing with an imminent volcanic eruption – this is a crisis situation, with immediate actions required. They may have to provide advice to emergency responders in terms of evacuation, assessment of the probability and magnitude of the eruption to policy makers, be asked to brief politicians, and to meet with communities threatened. Each audience requires different information, and presented in a manner that is accessible to them (Barclay et al. 2008). A completely different approach might be warranted when attempting to communicate the impact of a low-frequency, high magnitude event such as tsunamis or earthquakes that might not be perceived as imminent. Here the emphasis may be public awareness, or communicating to planners. Thus with no imminent crisis, techniques and target audiences may be quite different. The most stressful situation is when a geoscientist is called in after a disaster, where media interest is intense. Media will be seeking to assign responsibility, emergency responders will be seeking guidance, and inevitably there will be political pressure.

Thus geoscientists must be able to tailor their communications to the situation and audience they are aimed at. The language used will vary according to audience, as will the medium of communication. Geoscientists must be prepared to provide results in a variety of formats – an internal report, a public awareness poster, a media interview/sound-bite, a brochure or pamphlet, or a verbal briefing.

Preparation of an appropriate product is only part of the task of communication. It is vital that the issue of dissemination be dealt with. An excellent product is useless unless it gets into the hands of the audience it is designed for.

Culture

A major factor in discouraging scientists from developing communication skills lies in the scientific and institutional culture within which they work. Efforts to engage the broader community can be viewed with suspicion by peers, and are not always well-regarded by granting agencies or employers.

A prime obstacle to engaging the public or media cited by those interviewed by Hartz and Chappell (1998) is a loss of status amongst their peers. There is a perception amongst scientists that scientists with a high media profile are no longer doing worthwhile research themselves, and thus turn to public engagement as being in some way less demanding. A United Kingdom survey found that 20% of scientists agreed with the statement that scientists who engaged the public were less well regarded by their peers. In qualitative interviews several scientists expressed the opinion that public engagement would be detrimental to their careers (Royal Society 2006).

Schneider (1990) recounted personal experiences of negative reactions from colleagues after seeing media coverage of his statements. Media coverage resulted in detailed explanations being reduced to brief quotes, often omitting important additional information. This undermined the accuracy of the statement, and damaged the researcher's credibility with colleagues. Schneider concluded from his early experiences that scientists have two choices – either to avoid media interaction completely or to spend enough time on it to ensure that some coverage at least was accurate, and comprehensive.

Engagement with the public or the media is rarely recognized in the academic world, where grants, tenure and promotions are linked with research published in the serial literature. In the demanding environment of modern universities, geoscientists may be reluctant to devote the significant amount of time required without incentive or reward. A major reason for not engaging the non-scientific community is the need to spend more time on research (64% of respondents, Royal Society 2006). Attempts to directly influence or advise policy are generally not encouraged, particularly in the physical sciences.

The ability to interact with media may be severely limited by the institution and political environment in which the scientist works. In some countries and organizations any communication to media or public is strictly controlled, and access to policymakers or politicians limited by bureaucratic or institutional structures. The challenges of communication are even greater in these circumstances.

The role of scientists employed within government agencies is in part to provide advice to policy-makers and politicians. Their involvement is generally limited to internal advice, and direct contact with media or the public only undertaken when directed to do so by the government agency. Few government employees are at liberty to discuss hazard issues with the media.

Uncertainty

> We conclude that advances and changes must be made in the way science is conducted and uncertainty communicated. Scientists must become more effective and compelling communicators of both what is and isn't known (Kinzig et al. 2003)

Uncertainty is an integral part of science, and forms the basis of much scientific discussion. Scientists attempt to address the assumptions made, the possible errors in experiment and make uncertainty explicit. Science advances in part by debate – when there is a consensus of agreement on most areas of a subject, research will focus on those areas that are less well understood. In this type of research, results can be amenable to more than one interpretation, and it is only by testing hypotheses that science advances. The media, policy makers or the public may find this hard to understand and in extreme cases scientific uncertainty can be portrayed as scientists in dispute over conclusions. This type of uncertainty may be used as a reason not to act on the results of research when it recommends a course of action that is contrary to political direction, or might result in the expenditure of large sums of money. Bernknopf et al. (2006) found that "the uncertainty regarding the interpretation of the science inputs can influence the development and implementation of natural hazard management policies."

Many non-scientists expect certainty when presenting the results of scientific research. A poll conducted in the United Kingdom (MORI/Science Media Centre 2002) showed that 71% of those polled "looked to scientists to give an 'agreed view' about science issues"; 61% expected science "to provide 100% guarantees about the safety of medicines". Scientists are unable to provide such certainty in the presentation of results.

Risk and Probability

> "Public reaction to risk sometimes seem bizarre, at least when compared with scientific estimates.... the suggestion that a hazard poses an annual risk of death of "one chance in x" may cause near-panic or virtual indifference." (Department of Health 1997).

It is particularly important when dealing with hazards to be able to quantify the probability of a disaster occurring. This information is a critical component of a broader risk assessment. Most geoscientists working in hazards are able to present probabilities of occurrence, but communication of those probabilities can be fraught with difficulty. Other scientists, whatever the field, usually are comfortable with probabilities, as are those involved in risk assessment. However there is often a need to communicate to those without scientific or mathematical training – the public, politicians and policy makers. Hartz and Chappell (1998) documented that 63% of journalists and 82% of scientists surveyed agreed that "most members of the news media do not understand probability and statistics well enough to explain the results of scientific research."

This difficulty is prominent in risk and hazard mapping, where geoscientists assign probability to the occurrence of hazardous events. Hazard zones are often defined on the basis of probability of recurrence. The one in one hundred year (1%) flood zone is in common usage, yet this means of communication often results in misconceptions. Rather than the correct interpretation of a 0.01 probability of a flood occurring in any given year, many people believe that this designation means that the area will flood periodically with 100 years between floods (Ogle 2004; Bella and Tobin 2007). Communication of risk is further complicated by the fact it generally incorporates two types of uncertainty; that associated with the randomness of natural phenomena (aleatory), and the other associated with lack of knowledge (epistemic). These need to be interpreted quite differently but it is not easy to communicate the difference. Mileti et al. (2004) pointed out that scientists expend much effort in defining and refining the probabilities of future hazardous events occurring, but the public interest can be expressed much more simply – will the event occur or not, and if it does will it affect me?

Interdisciplinary and Multidisciplinary Approaches

> "If we are to build up our resilience and effectively reduce the devastating effects of natural hazards, geoscientists must coordinate their efforts with engineers, emergency management professionals, policy makers, builders, investors, insurers, news media, educators, relief organizations, and the public, as well as other scientists." Geological Society of America (2005)

The field of natural hazards allows for a wide range of approaches, and many journals, conferences and workshops describe themselves as "interdisciplinary." There are however serious communication barriers between researchers working in natural hazards that compromise the ability to operate in a true interdisciplinary manner.

The following are extracts from abstracts to papers published in the last four years in a leading natural hazards journal. Each paper is a worthwhile contribution to the body of knowledge, contains results that perhaps can be used broadly by other natural hazards researchers, but are written to communicate with fellow specialists in their area of research, whether it be process sedimentology, risk analysis or political science. It should be noted that these papers were selected at random purely to illustrate the type of language used in the various sub-disciplines of natural hazards research – there is no criticism intended or implied.

> "In order to evaluate critical condition of bed sediment entrainment, a length scale which measures an effective bed shear stress is introduced. The effective bed shear stress is defined as total shear stress minus yield stress on the bed surface. The results show that critical entrainment conditions can be evaluated well in terms of Shields curve using the effective bed shear stress instead of a usual bed shear stress."
>
> "The predictive power of logistic regression, support vector machines and bootstrap-aggregated classification trees (bagging, double-bagging) is compared using misclassification error rates on independent test data sets. Based on a resampling approach that takes into account spatial auto-correlation, error rates for predicting "present" and "future" landslides are estimated within and outside the training area."
>
> "In order to capture the complexity that arises when incorporating the varieties of interests as well as impacts protection measures have on the environment, the economy and society, transparent and multidisciplinary decision support techniques are needed. This paper looks at how Cost Benefit Analysis (CBA), a tool already applied to decisions concerning protective measures, and Multi Criteria Analysis (MCA), even though new to the field as such but already successfully practiced in other environmental areas, perform according to the abovementioned criteria."

How many researchers can honestly say that they are comfortable with the language and concepts briefly expressed in all or any of these abstracts? These papers are not badly written, but are designed to communicate with a very select audience. This likely is what the authors intended, but the style chosen may mean that comparatively few people can understand the results put forward, and their implications.

In effect, this means that many research efforts in natural hazards described as interdisciplinary are in fact multidisciplinary. A multidiscliplinary approach means that a problem is addressed independently by specialists from a variety of fields. An interdisciplinary approach means that such diverse research is integrated to address a problem that a single discipline alone cannot (Schneider 1997).

Thus, an interdisciplinary approach must not mean simply that researchers from a variety of backgrounds are working on the subject. It requires co-operation and mutual understanding between the various researchers – and this in turn means that specialists must be able to communicate effectively to those outside of their area of specialization.

Geoscientists need to be able to adapt their communication methods and skills in order to operate effectively in an interdisciplinary environment. A geoscientist who is able to communicate effectively with specialists in other disciplines can ensure that their expertise is used appropriately in interdisciplinary approaches. Geoscientists also need to educate themselves in the methods and language used in other areas of natural hazards research. By doing so, they give themselves the opportunity to integrate research in a true interdisciplinary manner and to address problems that geoscience alone cannot.

Discussion

Lessons from Climate Change

Much can be learned from the interaction of science, communication, policy and politics in the area of climate change. The issue of global climate change moved from the pages of scientific journals to the front pages of newspapers in the last twenty years. Fundamentally this change has been due to the successful communication of scientific research, although the process has been anything but easy. The means of change itself has become the subject of considerable research (see Moser and Dilling 2007). Understanding how science eventually influenced public policy and perceptions in this highly visible example may provide valuable insights into methods that may apply to geohazards. The climate change debate has been highly political, because of the major economic impact of taking mitigative measures, and the perceived impacts on influential special interest groups. This has led to the politicizing of science, with intense debate between lobby groups as to the accuracy of scientific conclusions, and funding of groups that set out to undermine the authority of climate scientists by questioning motivations and research agendas. For many years the public were presented with a "balanced" view of the debate by media who gave equal weight to climate change sceptics, when in fact the scientific community was close to unanimous in ascribing global warming to emissions resulting from industrial development. Boykoff (2008) suggested that the challenges of communicating climate change science in the midst of a heated debate acted to discourage many scientists from engaging the media. This unwillingness was often based on experience of having research misinterpreted, selectively used, or quoted to advance policy or political objectives. Boykoff goes on to state "the 'battlefield' of communicating and understanding environmental geoscience is not well-served by scientists reluctant to acknowledge and act on what is an integral piece of one's contemporary responsibility: interacting with mass media."

Research in geological hazards has the potential to become highly political, as decisions are made that have profound economic and social impacts, and ultimately may result in the loss or saving of lives. Where lives have been lost, research then will be viewed in an environment where politicians and policy makers may be trying to avoid responsibility, others will be seeking scapegoats, and scientists may be caught in the middle, with their communication skills being tested in the most demanding of circumstances.

An issue that is highly relevant both in climate change and hazards research is how to portray uncertainty. This issue became prominent in communication of climate change, where uncertainty in research seized upon by some as a means of discounting research findings, and in some cases was re-framed to cast doubt on scientific competence (Williams 2000; Zehr 2000; Boykoff 2008).

Perhaps the most powerful tool used by climate scientists was the establishment of the Intergovernmental Panel on Climate Change, where an international group of credible scientists was created to inform policy and management decisions. There is little doubt that the series of IPCC reports have been highly effective in this objective.

The IPCC reports use a methodology developed and outlined by Moss and Schneider (2000) to address the communication of uncertainty. Moss and Schneider emphasize the importance of quantifying uncertainty wherever possible and provide useful guidelines as to appropriate language to describe different levels of uncertainty in a standardized manner. They point out that "there is strong experimental evidence that the same uncertainty words often have very different meanings for different people in different circumstances". Thus they suggest that "very high confidence" should be associated with a probability of 0.95–1.00, "high confidence" with 0.67–0.95 and so on. Such methods might well be applied to communication of geological hazards.

Climate change science also showcased the role of the professional or expert communicator interpreting the results of science into an accessible or popular format. Former US vice-president Al Gore's presentation series and later film "An Inconvenient Truth" did much to raise the profile of climate science. Any scientist, however, can learn from the methods used by Gore to interpret the science of climate change. His medium of choice – the computer-generated presentation – is the standard method used by nearly all scientists at academic conferences. However, the use of spectacular images, careful use of analogy, and most importantly personalizing the message by using individual experience showed how to engage a wide audience – "a paragon of clear science communication" (Minkel and Stix 2006). The approach Gore took to address the issue of climate change also offers lessons. Rather than rely on the media to interpret his message, he chose to deliver his presentation directly to as many people as he could – firstly through the presentation itself, and training of numerous other presenters, and later through the documentary film. The exclusion of the "media filter" was deliberate, and based on years of experience as a politician.

Education and Awareness

Many geoscience degrees include some training in communications. These, however, are designed to educate students in using the traditional means of scientific communication – how to write an abstract, the basics of writing a scientific paper or report, how to prepare a poster for a conference, or preparation of computer presentations. Education for geoscientists needs to address the broader aspects of communication. A brief review of M.Sc. programmes in geohazards shows courses with an emphasis on technical content, with communication issues absent from the curriculum. A similar review of the more general topic of natural hazards suggests that communication issues are rarely taught.

In training geoscientists specializing in geohazards, education should cover dealing with the media, writing for public and policy makers, and some exposure to the social science literature in natural hazards. One innovative example is the Master's International programme in "Mitigation of natural geological hazards" at Michigan Tech University in the United States. This degree includes international research through the Peace Corps programme, and courses in inter-cultural hazard communication.

There is a similar dearth of training at the professional level. In Canada, where most provinces require geoscientists to be professionally registered, the standard curriculum defining the basic education for a geoscientist does not include any component of communication with the public, and professional development opportunities are similarly sparse. This needs to be remedied.

Communicating with the Media

> "By always bearing in mind two crucial facts – that the news media are not going to change the way they work to please scientists, and that they should be approached as a branch of the entertainment industry – all subsequent decisions and behaviours on the part of scientists and their companies/institutions will be more likely to be blessed with success." Neild 2008

Communicating with the media is difficult and there is no substitute for formal training and practice. The relationship between science and media was explored by Hartz and Chappell (1998), and their report identifies numerous concerns that scientists have when dealing with journalists. A common concern of scientists dealing with the media is that findings will be portrayed in an inaccurate or misleading manner. Only 11% of scientists surveyed by Hartz and Chappell (1998) had great confidence in the press, and similar responses were interpreted as showing that scientists in general were not comfortable with media coverage of scientific research. This is perhaps due to the fact that 73% of those surveyed in a Royal Society survey in the UK had no training whatsoever in engaging with the public or media (Royal Society 2006).

The lack of media training means that scientists are unaware of the way in which journalists work, and what they are looking for. It is important that geoscientists involved with the media understand how journalists operate, and where their interest and concerns lie. They should not be viewed as a convenient means of informing the public. Expectations that they will be happy to translate and interpret research findings in an accurate and unbiased manner are frequently not met. Journalists are interested in selling stories and thus will focus on what they consider to be of interest to their readers. They will focus on drama, conflict, and human interest. Journalists may also attempt to present a balanced view of any scientific controversy – even if the consensus scientific view strongly favours one side (Boykoff and Boykoff 2004). Scientists, on the other hand, look for media coverage to educate the public about their work (over 40% cited this as an important reason for engagement with the media in the Royal Society Survey), yet misunderstand the nature of media coverage. Neild (2008) outlines common misconceptions of the way the media operates.

If a geoscientist has an understanding of how journalists operate, they can prepare themselves to better communicate their expertise. Developing a working relationship with journalists who specialize in science issues can greatly assist in public awareness of hazards but the most demanding situations are when a disaster has occurred, or when one appears imminent. Geoscientists must be well prepared to deal with the media, as there will be a wish to gain authoritative information from a trusted expert in the field. Following the advice of Mileti et al. (2004), the message conveyed must be clear, free of technical language, supported by additional more detailed information, and consistent. Conflicting interpretations, or confusing statements can give rise to frustration, or misinterpretation. Journalists may portray such conflicting messages, or expressions of uncertainty, as conflict within the scientific community. Packaging information specifically for the media can be effective – journalists often work under pressure of deadlines, so well-prepared and written background information will often appear in final coverage.

It is important that geoscientists talking to the media very clearly separate scientific findings from opinion. Schneider (2002) suggested that scientists should be able to answer the questions "What might happen?"; "How do you know?"; and "What are the odds?" based on research, but if asked "What should we do?" clearly state that the answer is an opinion, or value judgment, and needs to be considered as such. If representing a government organization, scientists are generally restricted to scientific findings only and cannot venture opinion, speculation or comment on policy.

Communicating with the Public

> "In the centre of the mainstream or standard (neoclassical) economic model of decision-making resides the anonymous rational man who performs omniscient probability calculations with unlimited cognitive resources, and maximizes expected utility in the face of scarce resources." Wang (2001)

Phrases such as public engagement, public awareness, and public education are often used yet there must be an understanding that the public is not a uniform group that can be treated as a single entity. The "public" consists of individuals who require different information according to their own personal needs and interests. The public can be a whole community or country, where the objective of communication is to raise the awareness of hazards. It can be a targeted group that needs to be warned about impending disasters, or it can be an unfortunate group of individuals who have been directly affected by a disaster. The "public" may have a completely different culture than that of the scientific researcher (see for example Pettersen et al. 2008 for case studies of adaption of communication methods based on understanding of traditional culture).

The field of science communications has undergone change in recent years. The traditional model governing public communication of science was that of "information deficit" (Burgess et al. 1998). This, in simple terms, suggested that the public would take appropriate action if only they were provided with the right information by scientists. Success of the communication process was measured by what were considered appropriate changes of behaviour by the public when provided with scientific results – there is implicitly an expectation of a rational response by the public to this new information. It has become clear, however, that simply providing information will not result in changes in behaviour (Owens 2000). This top-down model is based on the assumption that scientists are trusted, and that they, and policy makers know what is best for the "public." In its least effective form the public is only consulted in order to legitimize a predetermined course of action.

Owens (2000) states "There could hardly be a clearer demonstration of the flaws in the information deficit model than the persistent refusal of the public to have their allegedly irrational conceptions of risk 'corrected' by providing them with more information." The alternative to this model is termed by Owens the "civic" model of communication. The principle here is of dialogue, where scientists and public work together to first define the problems that exist, and to propose solutions. This requires an acceptance that expertise may be found outside of scientific research – through local or traditional knowledge for instance. It requires scientists to participate at a community level, and to not only provide information but to listen to concerns and information brought forth by others. The idea behind this type of engagement is to provide the public (in the case of hazards generally the people directly affected by a potential or actual disaster) with the information they need to take action. That information may well differ from that which the scientist believes should be taken into consideration. Owens discusses the challenges raised by this type of public engagement and questions how effective this can be in practice (notably pointing out that erecting a number of new processes for public consultation may not change the effectiveness of public engagement). If it is accepted that the civic, or deliberative model of public engagement is more effective, it requires fundamental changes in the way that scientists deal with the public. On a practical level, it is useful for the geoscientist to be aware that the information deficit model of communication has been shown to be ineffective, and that experimenting with other means of public engagement is needed.

The work of Handmer (2000) provides further insight into the challenges of communicating hazard information to the public. He analysed the particular case of flood warnings, attempting to identify reasons why warnings had proved ineffective in several major floods in the 1990s. He firstly pointed out that "failure" of flood warnings is based on inability to meet unreasonable expectations. Other areas of hazard communication might be equally ineffective, but where warnings need to be communicated effectively under intense pressure in brief time-spans, any problems are seized upon by the media. He goes on to discuss the importance of tailoring the warning to the audience at risk and highlights the importance of shared meaning. "To have any chance of 'success' warnings need to have meaning which is shared between those who draw them up and those for whom they are meant to inform. They must also appear relevant to the individual decision-maker." (Handmer 2000).

Handmer emphasizes the importance of consultation in developing warnings, suggesting the process should be more akin to negotiation, but indicates that the populations at risk are often diverse, and one warning system is unlikely to be effective in all cases.

Handmer (2000) also warned that even where effort has been made to achieve shared meaning, warnings fail for a variety of reasons – people understand the warning but do not care about the risk; people are unable to act despite the warning for economic, social or personal reasons; or people dislike being told what to do by authority, preferring to make their own decisions. He also points out that warning systems and communication need to evolve along with the society at risk – systems designed to work with a relatively homogenous group 20 years ago now may have to deal with a variety of languages and cultural backgrounds; or with people who have little experience or knowledge of previous events, and are ill-equipped to deal with them.

Communicating with Policy Makers and Politicians

Communicating with politicians or policy makers requires different techniques to communicating with the public. In order to be truly effective, the scientist needs to understand how decisions are made, how policy is developed, and where their input can be most useful. The message the geoscientist brings forward may not be welcome, as it may result in media interest, public pressure to expend funds, or be perceived as potentially embarrassing to the government. This does not make the task of communicating geoscience any easier.

The communication issues differ depending on where the geoscientist is employed. If external to the government or policy making body, then understanding the institutional and decision making structure allows scientific advice to be tendered where it is most likely to be used (Simpson 2008). Such input may be via existing institutional structures such as standing committees, public hearings, or public enquiries. In some cases the governing body may not be seeking scientific input, and then, if the geoscientist believes that their research has implications for public policy or safety, they may wish to work with the media, non-government organizations, or groups of concerned citizens to build up public interest and political pressure.

Geoscientists working within government should understand the decision-making structure that leads to policy development. The critical factor in communicating geohazards research here is understanding the audience, and their prime concerns in reaching decisions. Politicians in democratic governments may be governed by relatively short-term considerations, as the electoral process is usually on a four to five year cycle. Thus issues that might arise in that time frame may gain more attention than hazards with a recurrence interval of decades or centuries. Decisions are sometimes made from a political or economic perspective rather than a scientific one, and the geoscientist must to be able to communicate their results with an understanding of these implications. The tendency to focus on short-term issues and therefore to dismiss long-term risks (or rare events) can be reduced where government officials have a legal requirement for "duty of care" of their constituents. In this case, the nondisclosure of available hazard and risk information carries the threat of prosecution, which tends to result in more willingness to promote an open dialogue about risks.

Some Simple Rules for Communication

This is by no means intended as a comprehensive guide to communication of geohazards but provides a starting point for those aware of a need to improve their communication skills when dealing with hazards. These draw on the discussion above but also heavily on Mileti et al. (2004), essential reading for anyone involved in communicating geohazards, as well as other sources.

- Understand the culture, background and decision making structure of your audience (whether indigenous people, or government bureaucracy).
- Work with communications professionals but be prepared to lead efforts yourself.
- Differentiate between scientific fact and opinion or value judgements.
- Prepare a variety of products in a variety of formats, tailored to different audiences.
- Dissemination of information is as important as the information itself; use a variety of media – TV, radio, newspapers, distribution of brochures.
- Ensure a consistent message.
- Avoid technical terms, use analogy, commonplace examples; strive to be as clear as possible.
- Communication of hazards is an ongoing process, not a one-off effort; be prepared to repeat information numerous times.
- Don't expect provision of information to change behaviour; become involved in the discussion at all levels and be prepared to listen and learn as well as instruct.
- The geoscientists' role is to provide information to assist people in making decisions, not to make decisions for them. If the geoscientist possesses information on what people should do before, during and after an event this needs to be conveyed clearly and effectively.

Conclusions

Despite many advances in the field of communication of science, and some admirable efforts in the communication of geohazards, much needs to be done. It is clear that geoscience research with direct implications to health, safety and economic well-being is frequently not being used by the public, policy makers and politicians. Any efforts to improve the ability of geoscientists to communicate their knowledge may help in the mitigation of geological disasters.

Several recommendations are made.

1. When educating geoscientists to work in the area of hazards, communication skills must be taught and media training should be provided. Geoscientists must be exposed to the social science approach to hazards and disasters so they understand their role in the broader context of natural hazards, and be able to take part in interdisciplinary research.
2. Institutions – whether they be government, academia or industry – need to support geoscientists in developing communication skills. This can be through in-house training, employment of media and communication specialists, or encouragement to geoscientists who wish to engage the public.
3. Research findings need to be communicated in a variety of ways – certainly through the traditional scientific paper or report, but also in formats more accessible to those potentially affected by disasters, or in a position to mitigate them through policy.
4. Geohazard project development must include both time and budget for communication and dissemination of results.
5. Alternatives must be sought to top-down communication models. Geoscientists need to be able to engage in genuine dialogue at the community level.
6. Journals that wish to be viewed as interdisciplinary need to ensure that contributions are written so as to be useful to the widest range of readers, or at least include a "plain language" summary of the findings, and their implications.

The IUGS Commission "Geosciences for Environmental Management" established a working group "Communicating Environmental Geoscience" in 2006. The working group attempts to develop and improve the tools and skills environmental geoscientists need to communicate effectively with non-specialists – politicians, policy makers, regulators, educators, and the public at large. They direct a programme of workshops, training courses, meetings, and publications. The group is building on existing efforts, but to effectively reach a world-wide community of environmental geoscientists remains challenging.

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