Amazon Web Services are flexible, but they require users to be capable of developing applications using basic content libraries. This flexibility comes at the cost of needing to have a steep learning curve. By contrast, Google Earth Engine provides immediate access to functions and data, reducing the barrier to entry.

Set against the benefits of cloud computing, there are some issues that need to be considered in its use. These include the recognition that the distribution of available technology is rarely even, and that many areas still have challenges meeting the needs of basic electricity let alone the high-speed Internet connectivity required for accessing, sharing and processing large quantities of data. For this reason, it is often necessary for software developers to factor in the ability to function offline along with the capacity for downloading the required data sets, so models can be run locally. Access to electricity is a particular concern in an active disaster scenario, so the capacity to work offline is essential. Some models can take multiple days to run, and if power is cut or technology fails during that period, the model must be re-run, which costs valuable time and computing resources.

Large amounts of data (from traditional in situ sources as well as satellite sensors) are now being exchanged rapidly and across the globe by researchers and practitioners in many different fields. The growing interdependence among traditional scientific disciplines leads to the practice that data collected in one discipline is likely to be used in other disciplines. This leads to the greater need of sharing of data for the advancement of science.[218]

One of the main benefits from the large amount of data that has been created from EO sensors and many other sources has been developments in automated knowledge discovery. The ease of access to computational processing power, as well as better access to data, has led to the development of machine learning techniques. As identified by GFDRR, with any new and emerging technologies, there are many ambiguous and overlapping terminologies such as artificial intelligence, machine learning, big data and deep learning.[219] For this purpose, it is accepted that the terms are interchangeable.

Risk management is no exception to the use of machine learning, and there are new applications and uses continually being developed. Many of the uses of machine learning within disaster risk management focus on the improvement of the different components of risk modelling, such as exposure, vulnerability, hazard and risk.

Machine learning is moving beyond hard-coded algorithms to algorithms that continually learn and update themselves. This is facilitated by the development of methods where a machine may be instructed to seek information within large quantities of apparently unstructured data.[220] Although recent developments are delivering very powerful machine learning algorithms, it is important to remember that a model is only as good as the data used within it.

4.2

Conclusions

It is clear from recent developments that open data and analysis, shared and interoperable software, computing power and other technology, are the technical enablers of improved data science, risk assessment and risk modelling. For their success, they also rely on the willingness of people to work with other disciplines, across cultural, language and political boundaries, and to create the right regulatory environment for new and urgent work to proceed.

218 (Kunisawa 2006)
219 (GFDRR 2018b)
220 (UN-GGIM 2015)

Chapter 5: Challenges to change

Overwhelmingly, the shift to the Sendai Framework has ushered in a period of methodologically complicated but ultimately accurate thinking and working about reducing risk. Examples of extraordinary advances in technological ability, openness, integration and mutual support inspire hope for the future. However, significant challenges remain.

There are still mainstream journals and newspapers that publish articles about natural disasters (a term long-abandoned by the risk community – with emphasis on the tagline “disasters are not natural”). There are still those who would prefer to think of risk as a function only of hazard, with very limited perspectives on exposure and vulnerability. There are those who would prefer to see familiar risk metrics like PML attributed to each country, and are not bothered at how limited a picture of risk that presents.

There are still serious challenges related to how to calculate, characterize or depict certain kinds of data. The most obvious is the challenge with presenting probability of non-probabilistic hazards –many of which have already been outlined in this GAR – or of characterizing the vulnerability of people or assets to different hazards.

There are still challenges related to prioritization of risk reduction in the grand scheme of public investment and development planning. There are challenges related to the politicization of certain kinds of risk and risk-reducing actions, and there are challenges related to the resources required to face risk in a meaningful way.

5.1

Mindset challenges

There is growing interest to show the links among hazards, particularly hazards affected by climate change and their threat to human security through impacts on economies and livelihoods. However, the connection is complex. While water scarcity and food insecurity have been shown to play roles in displacement and unstable livelihood conditions, little is known about the strength of those relationships. Researchers are still grappling with how to ascertain specific drivers in ways that inform deliberate action.

The highly varied and complex nature of hazards dictates the need for continuous efforts by experts and authorities to reduce the risks of disaster that can affect human health, infrastructure and environmental resources. Ageing infrastructure and weak institutional and infrastructural capacities pose a challenge to risk management in many regions of the world. Industrial safety is not always high on political agendas, and human error comes into play when companies and authorities become complacent. Multidisciplinary cooperation across authorities is key to strengthening industrial safety governance with prevention at the forefront. Some countries, including large industrialized ones, are yet to establish dedicated disaster prevention and preparedness programmes and protocols. In the case of industrial safety, the number of Parties to the Industrial Accidents Convention has risen to 41 and the National Implementation Reports show progress over time. Past accidents have highlighted that transboundary cooperation on accident prevention and transboundary water pollution require greater attention.

The recommendation of the OECD Council on the governance of critical risks, adopted by Ministers in May 2014, recommends that "Members establish and promote a comprehensive, all-hazards and transboundary approach to country risk governance to serve as the foundation for enhancing national resilience and responsiveness."[221] Every disaster has had an enormous impact on enhancing awareness and safety. Lessons learned have been carefully identified and are incorporated in the regimes worldwide. However, it is important to keep in mind the overarching conclusion of the root causes of the disasters as being cultural and institutional.[222] The follow-up of INSAG emphasizes that "to achieve high levels of safety in all circumstances and against all challenges, the nuclear safety system in its entirety must be robust."[223] But if catastrophic failure is the most reliable driver of change, it is clearly not a sufficiently proactive mindset.

Building a comprehensive, all-hazards and transboundary approach to risk governance is not an easy endeavour. There is an increased awareness of the importance of establishing such an approach, with Japan being one of the leading examples. At the international level, this GAR represents a milestone in the efforts to develop global overview of risk trends and risk management. Finally, the NEA report represents a major milestone for the nuclear sector in contributing to the all-hazards mindset.[224]

The Sendai Framework is a first step to fostering increased awareness of all risk and multi-stakeholder collaboration to better manage risk. Integration of anthropogenic risks in the GAR and the GRAF will bring international attention to this topic and will change public perspectives on reducing these kinds of risks.

5.2

Political challenges

The rapid rate of urbanization happening worldwide poses a wide range of challenges for governments, industry and other stakeholders in preventing and managing the risks and impacts associated with hazardous industrial facilities. Socioeconomic pressures to develop land for housing or other uses in hazard-prone areas is increasing. Some major incidents such as that at the port of Tianjin in China (2015) are a reminder that the effects can often be rendered more severe due to the absence of appropriate safety measures. It is a delicate challenge to balance the needs and demands of society and make best use of available tools to address risks.

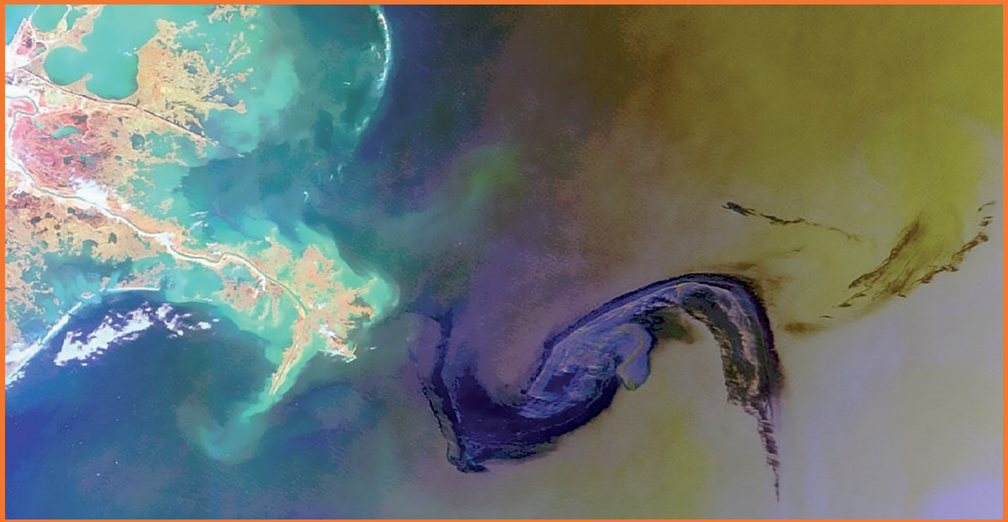
The reduction of risk rarely features high on national political agendas. On the one hand, the risk of complacency in countries with a seemingly high level of safety standards may hamper the priority of this policy area. On the other hand, a predominant focus on economic development in other countries contributes to the lack of political visibility given to hazard or risk prevention and preparedness policies. The Sendai Framework presents an opportunity in this respect – to raise the profile of all risk reduction and convince policymakers of the need to continue and step up investments in prevention – rather than bearing the cost of inaction.

Box 5.1. Macondo, United States of America, 2010

The Macondo blowout and explosion of an offshore oil drilling well in the Gulf of Mexico caused 11 deaths and 16 critical injuries. It dumped approximately 5 million barrels of oil into the Gulf of Mexico. In its study of the Macondo accident, the Deepwater Horizon Study Group noted that it was marked by organizational failures including:

- **a.** Multiple system operator malfunctions during a critical period in operations
- **b.** Not following required or accepted operations guidelines ("casual compliance")
- **c.** Neglected maintenance
- **d.** Instrumentation that either did not work properly or whose data interpretation gave false positives
- **e.** Inappropriate assessment and management of operations risks
- **f.** Multiple operations conducted at critical times with unanticipated interactions
- **g.** Inadequate communications between members of the operations groups
- **h.** Lack of awareness of risks
- **i.** Diversion of attention at critical times
- **j.** Culture with incentives that provided increases in productivity without commensurate increases in protection
- **k.** Inappropriate cost and corner cutting
- **l.** Lack of appropriate selection and training of personnel
- **m.** Improper management of change

Figure 5.1. Envisat image of oil spilling into the Gulf of Mexico off the coast of the United States of America, on 22 April 2010; the oil spill is visible as a dark purple whirl at centre bottom



(Source: ESA 2010 and Nadeau, P H. (2015). Deepwater Horizon Study Group: Lessons learned from the . . .. 10.13140/RG.2.1.1447.3125.)

221 (OECD 2014)
222 (IAEA 2015b); (IAEA 2017a)
223 (IAEA 2017)
224 (NEA 2018b)

5.3

Technological challenges

While probabilistic models have been in development for decades, there is a lack of consolidated risk analysis methodologies and tools. Extensions to traditional industrial risk analysis are needed to consider the characteristics of anthropogenic and other non-probabilistic events. The risks are therefore not adequately considered in deterministic risk assessment. As a clear understanding of the full nature of risk is suboptimal, preparedness levels are low, even in countries generally considered well prepared for disasters.

Data availability is the bottleneck in understanding many hazards. Data is the basis for gaining knowledge on the dynamics of risk, and is crucial for risk assessment, scenario planning and risk reduction practice. Data (un) availability is driven by a variety of factors. In natural-disaster situations, chained events like NATECH disasters are often overlooked, and their importance is recognized only when the full brunt of their impact becomes visible in terms of medium- to long-term health effects, persistent water and soil pollution, and major economic losses due to clean-up and recovery. An additional reason for data unavailability is that information on technological risks is often considered confidential and is closely held by industry or as a matter of national security. In many countries, there is no register of disaster impact, and often regulators do not even know the number, activity type and location of hazardous installations in a country's territory. Also, there is a tendency among operators of hazardous installations to avoid voluntarily disclosing information about accidents or near misses in their establishments to avoid negative repercussions on their activity.[225]

Another contributing factor to the scarcity of data is the loss of stakeholder interest in the risk once media attention abates. This usually goes together with a redefinition of priorities and a subsequent drop in resources available for mitigating a specific risk. Economic pressures are a powerful factor in decision-making, especially for activities and locations where profit margins are poor or in countries suffering from other governance challenges. Economic constraints can lead to intentional or unintentional bad decision-making where, for example, productivity gains or the optimization of operational efficiency are prioritized over possible safety concerns.[226] In some cases, the failure to implement adequate risk management solutions can also be attributed to economic drivers, for example when resources are stretched, and other risks are perceived as more critical. The quality of information in loss databases is not uniform, and exhibits different levels of detail and accuracy. The level of detail is particularly heterogeneous for anthropogenic hazards.

Vulnerability remains a weak component in hazard models. As noted in previous chapters, with few exceptions, vulnerability has – until recently – been examined largely in terms of physical vulnerability only. Socioeconomic vulnerability is much more complicated, and its inclusion in models will require clearer definitions, different kinds of data and a series of delicate decisions about what can be modelled. It is also a dynamic variable depending on the scenario; for example, in epidemics, any given disease is usually identified as affecting certain groups faster and more severely than others. Validation of models is also a technical challenge. Satellites can provide a great deal of information for certain kinds of risk information, but the models need to be validated with ground-based evidence, which requires resources. Finding answers at one scale by extracting them from a much larger scale risks the validity of the conclusions if not done very carefully. The use of proxies – imperfect functions to characterize elements for which no accurate measurement is possible – is a popular way of enriching risk models, but this practice risks the credibility and defensibility of the results. Ground-truth exercises are becoming a standard requirement, as are requests for validation of climate change impact at the local level.

5.4

Resource challenges

Foreseeable disasters continue to happen in countries with generally high levels of risk awareness and advanced risk management capacities. The situation is even more challenging in the developing world where the foundational facilities, technical competencies and computing capacity are often lacking, leaving decision makers ill-prepared to understand risk on their own terms. Moreover, low-income countries often struggle to access financial support, particularly as risk reduction often falls outside the humanitarian funding stream.

In the case of an active disaster situation, managing impact on the population and built environment while having to respond to a chained hazard event precipitated by the first event inevitably leads to competition for scarce response resources.[227] For example, after the 1999 Kocaeli earthquake in Turkey, about half of Izmit fire department's human resources were sent to fight the fire at a burning oil refinery instead of being available to support search and rescue for earthquake victims.[228] This becomes complicated because the consequences of the secondary event could include the risk of toxic releases, fires or explosions that would hamper emergency-response activities and exacerbate impact by endangering the first responders.[229]

5.5

Conclusions

An important paradigm shift has been taking place in risk communication towards integrated and participatory processes, which are often challenging to manage in practice. Risk communication cannot be viewed as an afterthought to risk assessment and decision-making. Risk information and warnings are likely to be questioned by populations who are anxious about the decisions they are being asked to make related to the risk. If people are asked to evacuate to uncomfortable shelters, they will want good reasons for this. Their criteria may not emphasize accurate scientific evidence or may they interpret it differently to risk researchers. The involvement of a wider community in risk assessment, management and mitigation would improve risk literacy, benefiting authors and readers, therefore ensuring that risk communication is more effective, and that people's questions about risk are addressed.

The following challenges require direct attention and action:

- **Awareness:** Further educational and awareness-raising campaigns are needed to help stakeholders recognize vulnerability to hazards.
- **Risk governance:** Risk governance should be approached in a holistic way. Also, private sector and government need to have the incentives and modes that facilitate sharing the responsibility and cost of risk. IRGC proposes an innovative risk governance framework and guidelines on how to address emerging risks.[230]
- **Legal infrastructure:** As experience shows that risk reduction works best if required by law, specific legislation for risk reduction should be enacted and enforced. This needs to be accompanied by guidance on how to achieve the goals set out in the legal framework to help industry be compliant and to support authorities in assessing if undertaking has met the associated safety objectives. A liability and compensation framework is also required.

225 (Krausmann, Cruz and Salzano 2017)
226 (Wood et al. 2017)
227 (Necci et al. 2018)
228 (A.M. Cruz et al. 2004)
229 (Girgin 2011)
230 (IRGC 2015)

- **Risk communication:** Communication at all levels should be improved to ensure that information on risks flows freely and effectively across all of society. Better exchange of and access to risk management resources should also be guaranteed.
- **Risk assessment:** Research should focus on the development of methodologies and tools for risk assessment and mapping. For this purpose, better loss and damage functions are needed for all hazards. Human, environmental and economic impacts should also be assessed, with the latter two often being neglected.
- **Data collection:** The easy and free sharing of relevant data on all risks, disaster events and even near misses should be promoted and facilitated to support learning from past events for prevention and mitigation. Data exchange should ideally also happen among sectors and countries.
- **Cooperation and partnerships:** Cooperation among all stakeholders, particularly at the local level, is essential for reducing risks. Public–private partnerships, and regional and international networks should be fostered that facilitate collaboration for effective risk management.

Chapter 6: Special section on drought

Among the weather-related natural hazards, drought is probably the most complex and severe due to its intrinsic nature and wide-ranging and cascading impacts. It affects agricultural production, public water supply, energy production, transportation, tourism, human health, biodiversity, natural ecosystems, etc. Droughts are recurrent; they can last from a few weeks to several years, and can affect large areas and populations. The related impacts develop slowly, are often indirect and can linger for long times after the end of the drought. While the impacts result in severe economic losses, environmental damage and human suffering, they are generally less visible than the impacts of other natural hazards (e.g. floods and storms) that cause immediate and structural damages, which are clearly linked to the hazard and quantifiable in economic terms.[231] Therefore, the drought risk is often underestimated and remains a "hidden" hazard.[232] Proactive drought risk management is still not a reality in most parts of the world.

Drought-related fatalities mainly occur in poor countries. However, in wealthy countries, people suffer from indirect effects such as heat stress or dust, leading to a variety of health impacts.[233] Examples are persistent unemployment, migration and social instability related to failures in public water supply, food insecurity and potential conflict.

Drought is likely to become more frequent and severe in the twenty-first century in many regions of the world.[234] A better understanding of the physical processes leading to drought, its propagation, the societal and environmental vulnerability to drought and its impacts are more important than ever. The key challenge is to move to the widespread adoption of proactive risk management strategies.[235] This includes the analysis of past trends and future projections of drought, as well as analysis of the societal and environmenttal exposure and vulnerability. All determine drought risk, which can be managed by developing policies and management plans that are adapted to the local context.[236]

Droughts are a recurring feature and are defined with respect to the long-term average climate of a given region. They should be distinguished from aridity, a seasonally or fully dry climate (e.g. desert) and from water scarcity, a situation where the climatologically available water resources are insufficient to satisfy long-term average water requirements. A megadrought is a very lengthy and pervasive drought, lasting much longer than normal, usually a decade or more.

---

231 (UNISDR 2011a)
232 (UNISDR 2011a)
233 (van Lanen et al. 2017); (UNESCO 2016)
234 (Spinoni et al. 2018); (IPCC 2014)
235 (Wilhite 2014); (Wilhite, Sivakumar and Pulwarty 2014)
236 (Wilhite 2014); (Global Water Partnership Central and Eastern Europe 2015)