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BACKGROUND NOTE

ASSESSING EXTREME CLIMATE HAZARDS AND OPTIONS FOR RISK MITIGATION AND ADAPTATION IN THE DEVELOPING WORLD

by

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EXECUTIVE SUMMARY

Risk assessment is the crucial first step in any risk management or adaptation strategy. While there are additional challenges in generating such assessments for developing countries, these should not be considered barriers to making the provision of appropriate information a priority. Key factors in delivering risk information should be to ensure that the underlying risk model is fit-for-purpose and that the information and outputs can be communicated effectively

to users. Relevant and appropriate risk modelling, and associated hazard and risk outputs, should be considered as baseline elements in risk management for the developing world.

Key Messages:

The value of risk information

- **Risk assessment, the provision of risk information, is the first crucial step in any risk management strategy and a precondition for effective disaster risk reduction (DRR) and risk transfer measures**, such as spatial planning and the provision of insurance.

Data and model requirements

- **To be effective, risk information must be appropriate to the user and fit-for-purpose**. Some key considerations are: (1) the ability for the user to access and understand what is being presented; and (2) that the information be appropriate to inform a particular class of decision (e.g. a relevant spatial resolution). **Inappropriate risk information can lead to poor decisions.**
- **Hazard maps are the simplest and often most powerful form of risk information.** Hazard maps capture the characteristics of the climate peril itself. For example, a flood hazard map might show the extent of the 1 in 100 year return period flood plain. This information is a crucial component of the initial hazard identification and can be helpful in informing many resiliency measures, such as evacuation planning. **Risk maps and data capture the likelihood and impact of a peril and are important for informing risk reduction and risk transfer**. For example, a flood risk map might show the average property loss ($) expected in a given year.
- Hazard and risk information are generated using models. The design of models can vary significantly, from the very simple to the highly detailed. Crucially, the technical specification of the model should be appropriate to the application; **in general, the more comprehensive the risk model, the more accurate it can hope to be in the representation of the hazard or risk.**
    - The required level of sophistication of the risk model is elevated if public safety is involved or financial stakes are high (e.g. flood defences protecting a low-lying city), or if a greater level of detail is needed, e.g. for hazards with strong spatial gradients, such as flood, where the hazard varies strongly with elevation.
    - More sophisticated ‘physically-based’ catastrophe models are required where spatially-correlated risk information is needed, e.g. for insurance and index-based risk transfer mechanisms. These types of models have not been traditionally used by the DRR community but can have significant benefits for many types of decisions, as they also enable higher spatial resolution, the inclusion of more extreme events and a probabilistic approach.

- In many circumstances simpler and more transparent approaches can be valuable. Simpler models may be appropriate where risks are low, show low degrees of spatial variation and/or when dealing with less costly risk reduction measures (e.g. evacuation planning).

- **Data availability is poorer in developing countries, but this should not be considered a barrier to the provision of appropriate hazard and risk information**. Data scarcity is not only found in hazard information, but also the economic, statistical, demographic and insurance data needed to inform understanding of the exposure and vulnerability**. While approaches are available to overcome data scarcity, they often entail an uncertainty trade-off.**
    - The more detailed and complete the historical records, the better the representation of risk that can be developed. Where high quality historical data are not available, work-arounds are possible, for example using regional climatological information, appropriate analogues and catchment characteristics to infer extreme river flows for flood hazard modelling.

- **Data availability in developing countries should be improved by strengthening local scientific and technical institution capabilities to monitor hazards and collect and record data.** Activities should first focus on collecting relevant hazard information (e.g. river flow and peak gusts) and recording disaster occurrence, characteristics and impacts. The application of international reporting standards to national data collection can help to ensure consistency**.**

- **In developing hazard and risk information it is important to acknowledge the inherent uncertainties associated with imperfect underlying data and to communicate these uncertainties to those who will base risk management decisions on model outputs.**

- Ensuring hazard and risk mapping is sustained long-term requires supporting local institutions and agencies, in particular, covering meteorology and hydrology.

Climate change and risk modelling

- **Strategies for disaster risk reduction (DRR) and climate change adaptation should be coordinated**; any long-term climate sensitive decision must take into account the expected evolution of climate risks over the lifetime of the decision to ensure that measures remain cost-effective and to prevent mal-adaptation. **It is also crucial to anchor climate change adaptation planning in an understanding of today's risks.**

- **Climate change elevates the need for hazard and risk modelling to explore the potential for extreme events that may not have historic precedents.** It means that historical experience may become less relevant as a guide to current and future hazard levels and that risk managers may need to consider the potential for events more catastrophic than seen previously at a location.

- While there are challenges in understanding future risks, approaches are available that can provide information useful to policymakers, albeit with inevitable uncertainties. These uncertainties must be communicated and incorporated into decision-making.

Applying Risk Information

- **The concept of risk identification and assessment still needs to be given a much higher priority in mainstream development planning, particularly in the least developed countries. In the age of the internet, access to information about hazard and risk, related to where someone lives and works, could be considered a fundamental right.** To promote the values of hazard and risk mapping and establish best practice it is important to share measurable examples of successes and information on approaches and limitations.
- In many countries, the application of risk information is limited by low risk-awareness, missing institutional capability and a lack of technical expertise. **The provision of risk information must go hand-in-hand with strengthening public institutional capabilities to distribute that information and activate responses**. Risk education is vital: simple hazard maps and risk information have the greatest benefits where distributed to all levels of the society, empowering government, businesses and individuals to take actions to reduce risks.
- **The international risk community can play an important role in raising risk awareness through expanding and distributing basic-level hazard mapping to provide global, consistent risk information.** Such initiatives do exist for seismic hazards, but not yet for hydro-meteorological hazards, despite the fact that these cause the largest number of annual fatalities.
- **The provision of risk information can facilitate, but not drive, effective risk management. Risk information can not be acted upon without effective governance or where disaster risk management is not made a priority.**

I. INTRODUCTION

Over the past few decades, weather-related disasters have accounted for 70% of all 'great' natural catastrophes (Munich Re, 2007). Between 1900 and 2004, hydrometeorological hazards were estimated to have caused economic losses of $866bn USD and 18 million fatalities (Dilley, 2006). Damages and lives lost from natural disasters have risen steeply over the past few decades and these trends are expected to continue as result of population growth, urbanisation and climate change.

Reducing the risk from climate extremes is recognised as a key facilitator of sustained economic development. Between 1985 and 1999, developing countries lost 13.4% of their combined GDP to natural disasters, versus 2.5% in industrialised countries (Hoeppe and Gurenko 2006). The disparity in fatalities is even greater; with almost 20 times as many deaths from natural disasters in the developing world. The lives lost and capital investments destroyed when a disaster strikes can sometimes set back development by several years, diverting funds away from human and economic development and into relief and reconstruction (Kreimer and Arnold 2000). For example, Tropical Cyclone Sidr in Bangladesh in 2007 led to over 3000 fatalities, damaged more than 10,000 schools and destroyed 1.8 million acres of cropland[1].

Enhanced risk management could have potentially huge and immediate benefits in developing countries. Risk management is aimed at reducing vulnerability through a combination of *risk reduction* (the adoption of measures to reduce the impacts of extremes when they occur, including emergency planning, hard defences and spatial planning, as well as measures to increase societal resilience, such as a strong and diversified economy and public health systems) and *risk transfer* (the spreading or diversification of risk, through insurance and alternative risk transfer[2], to lessen the impact on the individual). The benefits of ex-ante risk management have been shown to far outweigh those of ex-post response; for example, between 1960 and 2000, China spent $3.15 billion USD on flood control, averting estimated losses of $12 billion USD[3].

Risk assessment, the development of risk information, is the first crucial step in any risk management strategy and is a pre-condition for effective risk reduction and risk transfer. The identification, assessment and monitoring of disaster risk was identified as one of the five priorities for action of the Hyogo Framework; a set of principals adopted by 168 states in 2005 with the aim of substantially reducing disaster losses by 2015 (UN/ISDR 2007). Through understanding risks, decision-makers are empowered to take action. With risk information, decision-makers can weigh up the benefits of risk reduction measures, as well as the design of risk transfer initiatives to manage residual risks. Across much of the developed world, risk information is widely available, enabling sound risk management decisions at all levels of society. This information can range from online hazard maps[4] to the insurance catastrophe risk (cat) models built by companies like RMS. In developing countries, particularly the least developed countries (LDCs), this information is less available, reducing capacity for effective risk management.

[1] The Asian Disaster Reduction Centre (2007), http://www.adrc.or.jp/

[2] For example, micro-insurance schemes for individuals or national risk pools, such as the Caribbean Catastrophe Risk Insurance Facility (www.ccrif.org).

[3] Cited in Stern (2006)

[4] For example, the flood hazard maps available online from the UK Environment Agency: http://www.environment-agency.gov.uk/homeandleisure/floods/31656.aspx

In this paper, we consider what forms of risk information are most useful to decision-makers in developing countries and use our experience in building risk models for the developed world to explore how we can overcome the data availability challenges in the developing world to provide appropriate risk tools and information to inform both disaster risk reduction (DRR) and climate change adaptation decisions[5].

II. BUILDING APPROPRIATE AND RELEVANT RISK INFORMATION

The risk associated with any peril is defined as the product of its probability and impact. To assess any risk, such as windstorm, flood or drought risk, it is helpful to divide it into three components (Figure 1): firstly, the *hazard*, which describes the damaging agents, such as strong winds or floods and their associated probabilities; secondly, the *exposure*, which describes the assets and people expected to be situated in the path of the potential hazards (also known as the "elements at risk"); and thirdly, the *vulnerability*, which captures how susceptible assets are to damage and loss of monetary value or the potential for injury and death.

Figure 1: The core components of risk information

Detailed, quantitatively-based risk assessment is particularly important for weather extremes as their probability and impact can vary strongly by location (for example, Figure 2 shows the aggregations of different types of risks across the USA) and the potential for the rarer, but catastrophic events, like Hurricane Katrina, can often be underestimated. For decision-makers, risk information provides an essential analytical basis for many types of decisions, including land-use planning, the engineering of buildings and infrastructure, insurance, emergency response planning and water supply management. Modelling is an essential tool in risk assessment, as it requires analysing large quantities of geographical, climate and socioeconomic information. The design of risk information and the underlying model can vary significantly, from the very simple to the highly detailed. Accordingly, the level of resource investment required can also vary significantly.

[5] Note that the risk information discussed here aims to identify and quantify the probability and impact of events in any given year for the purposes of ex-ante risk management. This is quite different from weather forecasting or early warning systems, which are focussed on tracking and predicting the occurrence of specific events, for example, a hurricane striking the cost of Honduras, a short time before it occurs.

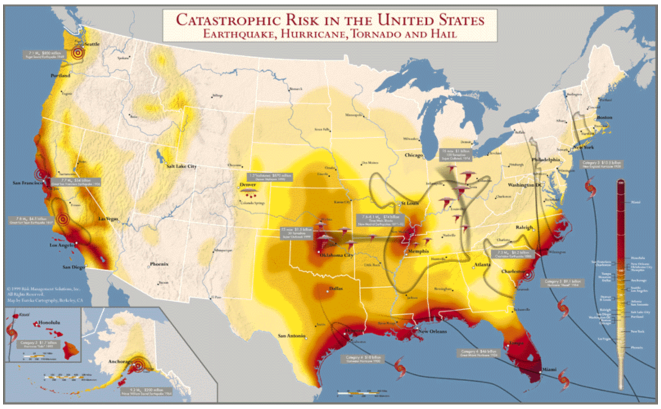

Figure 2: The RMS Catastrophe Risk Map of the United States, showing the average annual loss, the risk thermometer for major cities and the footprints and historical losses of major disasters, including earthquakes, hurricanes, tornadoes and hail[6].

Crucially, to be effective, risk information must be appropriate to the user and fit-for-purpose. Inappropriate information can lead to poor decisions. For example, if the information is deemed to be too complex it may not be used, or if a tropical cyclone model does not include secondary perils, like storm surge, it may actually lead to a decision that increases risk (e.g. as by evacuating people into a building with high storm surge risk). In determining the appropriate design of risk information, one must weigh up: (i) the ability of the user to access and understand what is being presented; and (ii) the information required to inform a particular class of risk management decision. The weighing up process must consider the trade-offs between improved risk information (and the associated costs) and the monetary and humanitarian benefits of the outputs through enhanced decision-making. For example, designing a multi-billion dollar flood management plan will warrant high quality risk information. In the following two subsections, we consider each of these points.

a. Designing Risk Data Outputs and Access

For risk information to be used effectively, it must be presented and delivered in a way that is appropriate to the needs and understanding of the different stakeholders.

- **Hazard maps are the simplest and often most powerful form of risk information, capturing the spatial distribution of the climate peril itself.** For example, a flood hazard map might show the extent of the 1 in 100 year return-period flood plain. Such information is crucial for land-use planning (e.g. ensuring critical infrastructure is located off of the flood plains) and evacuation planning. Hazard maps are particularly useful in communicating the extent and severity of potential events beyond human experience, i.e. with return periods similar to or greater than a human lifetime. It is important that the hazard is defined in sufficient detail to capture those elements relevant to the decision being made. For example, for flood management within a city, it is crucial to understand the potential depth of a flood at

[6] Further information can be found at: ***http://www.rms.com/publications/Cat_Risk_Maps.asp***

each location and how fast flooding could occur, to predict which parts of the city are likely to be most affected and which transport routes could be blocked.

- **Risk maps allow the user to identify the locations and properties of greatest risk of damage.** Risk maps and data capture both the likelihood and impact of the peril (e.g. Figure 2). This enables a decision-maker to understand expected levels of damage or potential lives loss. Such information enables governments, communities and individuals to weigh up the benefits of different risk mitigation options and plan risk management strategies. Figure 2 demonstrates one approach for presenting mapped risk data, showing the average annual loss (AAL) expected for key perils. The AAL is an important quantity used by the insurance industry in risk pricing. Other approaches are reviewed in Coburn et al. 1994.
- A useful way of presenting risk data for both public policymaking and insurance applications is the exceedence probability (EP) curve. This shows the likelihood of impacts of different magnitudes (Figure 3), allowing the user to understand whether the risk is driven by large or small events.

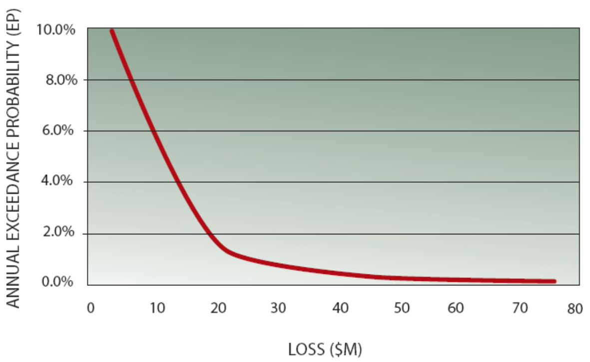

Figure 3: An illustrative exceedence probability curve. As an example, this curve shows that the probability of exceeding a $25million loss in a given year is rough 1% (a 1 in 100 year return period event).

Risk analysis tools, like Cat modelling software, have the advantage over risk maps and data of giving the user more flexibility in the analysis and communication of risk information. This means that the user can explore more specialised scenarios and produce customised outputs. For example, an insurer will use a risk model to analyse risk specific to its own portfolio. Policymakers could use risk tools to explore in detail the benefits of different risk mitigation strategies. However, it is important to consider the local capacity to run the tool and interpret the data.

b. Information Needs for Risk Management Decisions

The characteristics of risk information must be appropriate for the decision-making application. Different types of risk management decisions require distinct minimum standards of risk information and this should be reflected in the technical specification of the underlying model (illustrated in Tables 1 and 2). For example, the most complex models tend to be the Cat models used by the insurance industry, used to solve the dual problems of risk pricing and risk diversification in the same modelling platform. In general, the more complex the risk model the more comprehensive the differentiation of risk between areas. In many circumstances, however, simpler, more transparent approaches can also be appropriate and still powerful, for example, where risks are low, show low degrees of spatial variation and/or when dealing with less costly risk reduction measures, such as for emergency response planning. Simpler models may also be appropriate where safety margins are applied, such as in land-use planning, or to provide a 'first-cut' view of risk to highlight the need for further action (e.g. The World Bank's "Natural Disaster Hotspots" study, Dilley et al. 2005). For policymaking applications, there are clear advantages in basing different types of decisions on a consistent and coherent modelling methodology. In these cases, the model design must encompass all the components required to inform any of the individual decisions.

Table 1: The characteristics of risk information for different types of risk management decision; the scores (from 1 to 3 being the highest need) give a rough indication of the need for that characteristic.

Risk Modelling needs:	Insurance	Single-Location Infrastructure Design	Emergency Response Planning	Land-use Planning Policy	Resource Management Strategies (e.g. drought and water supply)	Risk Reduction Strategies (e.g. building codes, flood defences)
Presentation of Risk Information	Risk Model (3)	Hazard Data at Site (1)	Regional Hazard Map (1)	Regional Hazard Map (1)	Hazard and Risk Maps and Data (2)	Risk Maps and Data (2)
Need for multi-peril and -impact information	2 (case dependent)	2	3	3	2	3
Drive towards greater accuracy	3	2	1	2	2	2
Spatial resolution needs	3	3	1	1	1	2 (case dependent*)
Need for spatially correlated risk information	3	1	2	2	2	2 (case dependent*)
Consideration of high return period events	3	2 (dependent on criticality**)	3	2	3	2 (dependent of criticality**)
Need for probabilistic information	3	2	1	2	3 (case dependent)***	3 (case dependent)***
SCORE (/21)	**20**	**13**	**12**	**13**	**15**	**16**

*some applications will require high-resolution, spatially correlated risk information (e.g. flood defence systems) while others will not (e.g. building codes) **decisions with higher stakes will require consideration of more extreme events (e.g. LNG facilities) ***probabilistic where cost-benefit analysis is required; e.g. to assess alternative investment options.

Table 2: Description of risk information needs with examples and implications of the technical specification of the underlying model.

III. Climate Risk Modelling For the Developing World

Understanding risks from weather extremes is challenging, both due to their rarity and the complexity of the scientific processes that determine the extremes. For example, even in the developed world, detailed weather records extend back at most 50-100 years (depending on the peril). The synthetic stochastic catalogues of extreme events in RMS Cat models have been designed to overcome the inevitable shortage of experience of actual extreme events, and are used extensively by the insurance industry to manage risk across their portfolios. However, there are additional challenges to be overcome in estimating catastrophe risk in the developing world due to the lack of relevant data. While approaches are available to overcome a lack of data, this inevitability increases the uncertainty in the risk estimates. In this section, we consider how the characteristics of the risk information relate to the technical specification of the underlying model, and how we can overcome some of the data availability challenges in the developing world to deliver appropriate and relevant risk models.

a. Technical Specifications of a Risk Model

The required characteristics of the risk information directly define the necessary technical specification of the underlying model. Table 2 demonstrates this for different types of application, illustrating, for example, decisions for which high-resolution or probabilistic data is required. In designing a risk model it is important to consider how the user needs relate to the core elements; its fundamental architecture, the elements of risk represented and the treatment of spatial information. In general, the more comprehensive the risk model, the more accurate it can hope to be in the representation of the hazard or risk, and the more data and resource intensive it will be to develop.

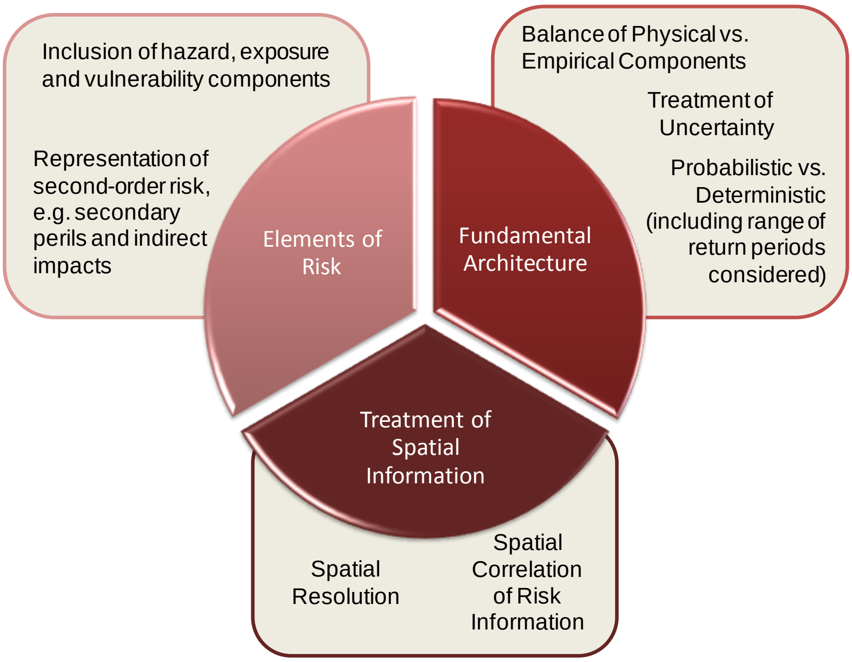

Figure 4: A schematic categorisation of the technical specifications of a generic risk model

Table 2: An illustration of the relationship between the information needs for a decision and the technical specification of the underlying risk model.

Information needs:	Description	Examples	Implications for Specification
Presentation of Risk Information	The balance of information about hazard, exposure and vulnerability.	• For some applications, hazard maps and data may be sufficient to inform a decision, e.g. in designing flood defences around an industrial facility. • For emergency response planning, decision-makers will be interested in the footprint of possible events versus the locations of people, economic centres and infrastructure.	This relates directly to the structure of the model. For example, a typical Cat model will include separate hazard, exposure and vulnerability components, linked together for generating loss statistics in the end financial model.
Need for multi-peril and -impact information	The inclusion of information on multiple perils (e.g. both flood and hurricane); on secondary perils (e.g. storm surge from a windstorm) and/or indirect damages	• An insurer will require information about the perils covered by the policies that it issues. • Disaster risk managers need to consider all possible perils and impacts.	Each peril will require its own hazard and risk information. Additional impact information will require the introduction of new vulnerability data.
Drive towards greater accuracy	The level of uncertainty acceptable in the estimates and the balance of that uncertainty (i.e. pessimistic versus conservative).	• Insurers have strong financial incentives towards ensuring lower uncertainty in their risk estimates. Insurance is also an example of where it might not be acceptable to add conservatism to the risk estimate, as this would unfairly favour the insurer. • Higher uncertainty may be acceptable for policy decisions where safety margins are applied (e.g. land-use planning).	Higher accuracy (lower uncertainty) in a risk model can be achieved through improving the level of detail in hazard modelling, incorporating secondary perils and more detailed exposure and vulnerability data.
Spatial resolution needs	The spatial detail of the risk information (e.g. regional versus localised information)	• For property insurance applications, high resolution is preferable to differentiate risk across their portfolio. • Higher resolution is important in areas with major concentrations of exposure and strong gradients of hazard (e.g. flooding). • High resolution will also be required for critical facilities.	Higher spatial resolution increases the data needs of the model.
Need for spatially correlated risk information	Spatially correlated risk information can tell us the probability of two or more locations being affected simultaneously by an event.	• This type of information is crucial for the insurance industry for which the principal risk management tool is portfolio diversification. • Spatial correlation is not important for decisions relevant to individual sites, for example, building codes.	Understanding the full spatial correlation of risk requires some form of physical modelling, as employed in Cat models.
Consideration of long return period events	Considering the impacts of rarer and higher impact events, i.e. return periods greater than the length of most historical records (>100 years).	• Including a greater range of extreme events in the risk assessment is important for decisions where stakes are high, for example, public safety (planning evacuation) or defending a major economic centre through flood defences.	Greater uncertainty is inevitable where the return periods of events considered passes beyond the duration of detailed historical records. There are many ways of extending the modelling beyond historical records, e.g. employing geological information; using extreme value statistical techniques (for single sites); or physical modelling approaches.
Need for probabilistic information	Probabilistic approaches attempt to represent the range of impacts from a comprehensive set of possible events and their respective likelihoods. Conversely, deterministic approaches focus on estimating the impact of a small number of individual 'representative' events.	• Probabilistic information allows the decision-maker to weigh the relative impacts and probabilities of a large range of possible disasters. It is required for risk management in insurance applications and in many risk mitigation decisions (e.g. for cost-benefit analyses of options). • Deterministic approaches can be useful for some decisions, such as evacuation planning.	Typically, a probabilistic model, like a Cat Model, will be powered by some form of stochastic hazard information to represent the full range of possible disasters in a region (as well as their characteristics and likelihood). The vulnerability component might also be probabilistic.

One of the most crucial decisions required in determining the appropriate risk modelling framework concerns whether there is a need to explore the spatial correlation of loss. This type of information is crucial to the insurance industry, as portfolio diversification is the principal form of risk management, but it is also important for broader disaster risk planning. To fully understand the likelihood and spatial extent of a hazard, we need to understand the physical processes that drive it; this necessitates some form of probabilistic, 'structural' (physical) modelling approach. Today, this characteristic is one of the key differentiators of insurance Cat Models from other types of risk models available. Probabilistic, catastrophe modelling is relatively new to the disaster risk management community. For example, assessments of DRR options have traditionally been based on the local experience of previous disasters, i.e. an empirically-derived deterministic approach. The problem with such an approach is that historical experience and observations alone can not capture the full range of possible disasters. The uncertainty inevitably becomes greater for rarer and more extreme events, for which data is always limited. This can lead to overestimation of the likelihood of a recent catastrophe or underestimation of the potential for an event that has not recently been experienced. For single-site modelling, statistical techniques can help to overcome this. For example, extreme value distributions can provide an estimate of the likelihood of a high-impact rare event from the available population of observed extremes (the uncertainty of which is determined by the quality and duration of the input data). On their own, such techniques will however not capture the full spatial variability of events.

In addition to spatially-correlated risk information, catastrophe modelling enables higher spatial resolution information, the inclusion of rarer and more extreme events and a more complete probabilistic approach. Physical, catastrophe modelling approaches do have significant advantages over more traditional approaches for many applications; though do tend to require a higher level of scientific expertise and investment. For example, in such approaches, the modelling attempts to create a full stochastic set of potential spatial events based on a re-sampling of the parameters of actual events using an understanding of the underlying physical processes[7]. **The capabilities of a physical, catastrophe modelling approach can have significant advantages for the DRR community.** Such an approach would be particularly beneficial for disaster risk management, land-use planning, resource management and risk reduction strategies, where it is necessary to understand the spatial correlation of risk between areas and the likelihood and impact of the more extreme events.

b. Data and Resource Availability

All forms of relevant data are generally poorer in developing countries, not only hazard data, but also the economic, statistical and demographic data needed to inform exposure and

[7] For more information, see http://www.rms.com/Publications/RMS%20Guide%202008.pdf

vulnerability modelling. As a benchmark, Table 3 summaries the data requirements to build sophisticated Cat models; key determinants of the data intensity of a risk model are the spatial resolution of the required risk information and the type of peril.

	Catastrophe Risk Model Data Requirements (for Hydrometeorological Hazards)
Hazard	• Long, high quality historical records of hazard occurrence with good spatial coverage and detailed observations of key characteristics (e.g. peak gusts for tropical cyclones or water depths for flooding). • Continuous, systematic and consistent records of relevant hydrometeorological data, such as river flow data and rainfall. • High-resolution hazard-relevant geospatial information, such as elevation, land-cover and the location and specification of flood/sea defences. • Physical understanding of the hazard (preferably, proven physical models calibrated to local geography and climate conditions).
Exposure	• High-resolution exposure information (e.g. exposure types and crop types by location), including damage-defining characteristics (e.g. construction type).
Vulnerability	• Detailed records of damages from past events, linked to exposure categories (e.g. insurance claims data).

Table 3: Summary of data requirements for sophisticated catastrophe risk modelling for hydrometeorological hazards

Useful public hydrometeorological records are available in the developing world, but are generally shorter, less detailed and less accurate (or in many cases, just inaccessible due to distribution issues). Data on impacts from past events is also patchy and of generally lower quality. Table 4 compares the data availability in five developing countries and for the UK, based on information gathered by RMS India. For example, in the UK, up to 100 years of high quality daily river flow data for 200 stations can be downloaded online (free-of-charge for research purposes), whereas in Malawi, river flow data from 45 stations of variable quality and length is available only from governmental agencies. Data quality and availability is highly variable between countries and is not only determined by wealth. For example, Malawi and Mozambique have a similar GDP per capita, but work by RMSI has shown that the data availability in Mozambique is far poorer than Malawi due to the loss of records during the civil war. The geography of some countries, like Nepal, also makes data collection more of a challenge reducing availability. Data on the higher impact events is typically most difficult to obtain as, for example, measuring equipment can be damaged by extreme weather or alternatively, is dismantled to avoid damage.

	Local Meteorological/ Hydrological Records	Records of Damage from Past Events	Geo-Spatial and Exposure Data
UK	Daily river flow data for around 200 stations available online (over 250,000km^2). High density hourly station observations (around 200 Met Office stations plus hundreds more from cooperating institutions) and daily high-resolution gridded weather data available online. Some station data back to the mid-1800s and high density data from the 1950s.	Detailed public and private sector data for several decades (less detailed beyond), including insurance claims data and public-sector damage records. Demonstrated in RMS retrospective reports: e.g. hazard/damage report on 1953 storm surge and 1607 Bristol floods[8].	Detailed public and private sector data, including high-resolution, high quality LIDAR-based elevation data and exposure information from aerial photography (e.g. up to better than 1m resolution in some city areas). Detailed public survey data and insurance exposure data.
Malawi	Rainfall and temperature observations for 45 stations over 120,000km^2 and around a dozen daily river flow stations. Length and quality variable.	Aggregated loss information available at country level	SRTM DEM[9] (90m). Land-use, land-cover datasets. Population, agriculture and transport infrastructure data available from government agencies.
Mozambique	Rainfall and temperature observations for 56 stations over 800,000km^2 and around 45 daily river flow stations. Length and quality of data variable.	As Above	As Above
Nepal	High quality, long records; though sparse in highest altitude regions	Little financial information.	Topographic maps, land-use, land-cover datasets and soil data.
Philippines	Detailed meteorological data for four stations, with half degree gridded daily data for the Cagayan valley extending back to the 1950s. Daily river flow data for 175 gauge stations (over 300,000km^2) and cyclone track data.	Records of flood and drought damages to crops, population and infrastructure ($). Flood inundation satellite images available.	SRTM DEM (90m) plus digital maps of administrative areas, population distribution, river and other water supply networks, and transport infrastructure. Land-use maps including detailed agricultural information.
India	One degree gridded rainfall data covering all India, 1951-2002. Daily weather station data for 218 stations and daily river flow data for three river basins (over 3.3 million km^2).	Limited public and private (insurance) records of past losses. Information tends to be sparse, difficult to access and not comprehensive.	SRTM DEM (90m) and digital administrative boundary maps. Some insured exposure records are available in city areas. Detailed public survey data and land-cover maps are available.

Table 4: Examples of data availability findings for RMS India projects in developing countries, compared to UK.

To maximise the utility of data that does exist, RMS India has developed a number of ‘data cleaning’ approaches, for example, ensuring the consistency of historical observations and using statistical techniques to infer data gaps in time series where data is missing. These approaches are particularly useful in developing the technical analyses for index-based weather insurance products, where good historical weather indices are a pre-requisite for implementation. For example, in 2008, RMS India,

[8] http://www.rms.com/Publications/

[9] Digital Elevation Model (DEM) based on the NASA Shuttle Radar Topography Mission (SRTM)

working with the World Bank, provided technical assistance to the Agricultural Insurance Company of India Ltd, which involved establishing and applying standardized protocols for simulating or in-filling data using surrounding station data, satellite data, or simulation, as well as correcting inconsistencies in the historical datasets between existing and new automatic weather stations.

Overcoming the Challenges of Data Availability

Data scarcity should not be considered a barrier to the provision of appropriate hazard and risk information as 'work arounds' are possible in all cases. **These approaches generally entail an uncertainty (or accuracy) trade-off**.

Hazard Information: **Gaps in local hazard information may be in-filled using global observational datasets and regional climatological information.** For example:

- *Drought:* Droughts tend to extend over large areas, so local ground-based observations can be supplemented by global satellite-based observations (several datasets are available, most recently the NASA Soil Moisture Active-Passive Mission). For example, Barlow et al. (2006) uses a global precipitation database (based on both satellite and ground-based data) combined with records of drought occurrence from EM-DAT[10] to estimate drought hazard in Asia.
- *Tropical Cyclone:* In developing countries, wind speed observations are limited and records of the highest wind speeds are rare. A lack of local wind speed measurements can however be overcome using regional and satellite observations of cyclone intensity and track, although data on the size of a cyclone's wind field and rainfall may be more difficult to reconstruct.
- *Flooding:* Modelling river- and flash-flooding is data intensive, requiring high resolution digital elevation data, good quality local flow observations and a detailed knowledge of the hydrology of the river basin. This type of information is often difficult to obtain in developing countries. Methodologies have been developed to overcome this, for example: inferring extreme flow characteristics from other rivers with analogous catchment characteristics and climatology, and using satellite and airborne elevation mapping (e.g. the NASA Shuttle Radar Topography Mission (SRTM)) and flood extent observations (e.g. the Dartmouth Flood Observatory[11]). Flood risk models have now become relatively standardised and basic modelling software is widely available, for example, from the US Hydraulic Engineering Center[12].
- *Storm Surge:* Storm surge modelling also requires high resolution digital elevation data and preferably, detailed records of actual sea levels during storm surges. While such records are

[10] Emergency Events Database (EM-DAT): http://www.emdat.be/

[11] http://www.dartmouth.edu/~floods/

[12] http://www.hec.usace.army.mil/software/

unlikely to be available for developing countries, the availability of physically-based storm surge models means that hazard characteristics can be estimated based on the population of driving meteorological events, e.g. the tracks and wind fields of tropical cyclones (Massey et al. 2007), alongside a knowledge of local bathometry. Some low-resolution global datasets of storm surge characteristics are also now available; in a recent project, RMS and our partners utilised extreme sea level data from the DIVA coastal vulnerability tool[13] to produce a global ranking of cities most exposed to storm surge risk (Nicholls et al. 2007).

Vulnerability Information:

Vulnerability here is defined as the level of damage resulting from a given severity of hazard and is usually represented by vulnerability functions (Figure 5). In a risk model, vulnerability functions will be developed relevant to the exposure types (e.g. agricultural or residential exposures) and even appropriate to the specifics of an individual building type. For example, in RMS Cat models, vulnerability is defined based on the characteristics of the building type (e.g. building age, construction materials and number of storeys, plus 'secondary' factors such whether the house has dry flood proofing) as well as occupancy (e.g. whether the building is used for accommodation, warehousing or industrial activity). The key to mapping these functions at RMS has been a combination of engineering knowledge and insurance claims data. The higher the resolution of vulnerability functions the greater the data requirements.

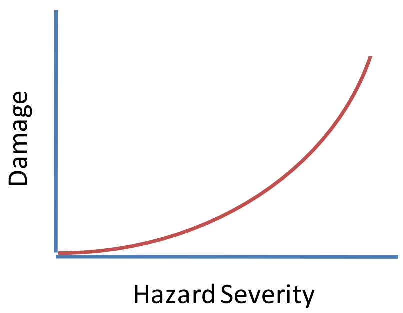

Figure 5: Illustrative vulnerability function

For the developing world, even where insurance exists, claims data is generally of poor quality and difficult to access. Public-sector loss information is also likely to be patchy and regionally aggregated at best; for example, in a recent OECD project to explore flood risk in Mumbai, the contributors were able to obtain only state-level damage figures for one past flood event. A lack of vulnerability information can be overcome in many cases by transferring vulnerability functions from similar regions and building types and calibrating them to local conditions using the available loss information. Global loss databases (e.g. the Munich Re and Swiss Re disasters databases and international disaster databases, such as EM-DAT) can help to fill in any gaps in local loss information for event reconstruction.

[13] http://diva.demis.nl/

Higher accuracy in vulnerability modelling can be achieved where on-the-ground surveys have been undertaken at local community level. The collection of such data post-disaster, supported by international reporting standards[14], was made a priority by the Hyogo Framework for Action. This represents a very positive step towards improving risk assessment in the developing world.

Exposure Information:

A lack of detailed exposure data has been the most difficult problem to overcome in developing risk models for developing countries. However, the high resolution satellite imagery data now widely available (e.g. Google Earth) has revolutionised exposure mapping and now makes it possible to develop detailed exposure maps even for the LDCs. In the developed world, exposure information is obtained from government data sets on property locations and taxation as well as insurance records and/or commercial surveying organisations. In the developing world, with a few exceptions[15], such data sets are not yet available. Today, this can be overcome through combining satellite-derived information with available local data. For example, in the Mumbai project, RMS India developed exposure maps by combining information from State census records, satellite-based land-use, land-cover maps and local fire insurance records. Global population and land-use datasets are also available, such as the Center for International Earth Science Information Network's (CEISIN's) gridded population of the world dataset at 5km resolution and the LANDSAT land-use land-cover dataset[16].

We have demonstrated that for each component of the model, approaches are available to overcome data scarcity. While these often entail an uncertainty trade-off, in general, the accuracy that can be achieved is more determined by the financial resources, scientific expertise and time available, than local data availability. For example, with larger resources, uncertainties in the exposure module could be reduced by conducting detailed on-the-ground local surveys, and vulnerability functions could be refined through engineering surveys on recent episodes of damage. Such work is time intensive; for example, in RMSI projects, data collection and cleansing can contribute up to 65% of the total effort.

Data availability in developing countries should be improved through strengthening local institutional capabilities to monitor hazards and collect and record damage data. Activities can include collecting relevant hydrological and meteorological hazard information as well as recording disaster occurrence and impacts. Data must also be accessible. Accessibility can be enhanced through

[14] There is also now a push towards national-level databases that use international standards, for example, DesInventar for Latin America and the Caribbean (www.desinventar.org).

[15] For example, there are initiatives to collect building specific exposure data for some cities in Central and South America.

[16] http://glcf.umiacs.umd.edu/data/

developing dedicated data centres, for example, the Mexico Government, set up the Centro Nacional de Prevención de Desastres, with a mandate to collect, catalogue and synthesize relevant hazard, exposure and vulnerability data and make this available for activities in support of public awareness and government policy making[17].

c. The Status of Risk Modelling Today

There has been a pronounced increase in the demand for risk information in the developing world in recent years, particularly in the transition economies, reflecting a stronger focus on DRR and climate change adaptation and the growing opportunities for risk transfer.

RMS is already beginning the process of expanding risk modelling into the developing world, in response to the now growing demand from the insurance sector. To date, this modelling is restricted to earthquake, with widespread coverage, and tropical cyclone, for key locations of interest to the insurance industry, such as India, China and the Caribbean Islands[18].

In parallel, RMS India (RMSI) has worked with international bodies to develop risk models to inform alternative risk transfer initiatives and risk reduction decision making in the public sector[19]. RMSI have pioneered the development of a hierarchical risk assessment approach; a framework of models of increasing sophistication, designed to be appropriate for different risk management needs, user information capacities and resource availability. The hierarchy extends from the simplest hazard mapping of historical event footprints, to facilitate hazard identification and resiliency planning (e.g. emergency response strategies), to a fully probabilistic risk model that can be used for informing risk reduction and risk transfer decisions (Figure 6). The consistency of the underlying approach is important, particularly for LDCs, as it means that the risk information capacity can be gradually developed over time. To implement this approach, RMSI has worked in partnership with the World Bank and others to understand the user needs and data availability and design risk information that is affordable, appropriate and useful.

[17] Chapter 2 of UN/ISDR (2007)

[18] **For further information, contact RMS European Headquarters in London: info@rms.com**.

[19] **For information on RMS India climate change activities contact Satya Priya: Satya.Priya@rmsi.com**

Figure 6: RMSI's Hierarchical Risk Modelling Approach for the Developing World.

Outside of RMS, several initiatives are taking place to build risk information for the developing world. Several public and private international organisations have actively promoted and helped sponsor hazard and risk mapping in many developing regions. For example:

- The Central American Probabilistic Risk Assessment (CAPRA), an open-source platform to facilitate the communication of risk information to inform risk management decisions[20].
- The Disaster Risk Reduction Programme of the WHO (established in 2003) has worked to coordinate global hazard mapping through its relationships with National Meteorological and Hydrological Services, focussing on strengthening local capacities and standardising approaches. For example, in collaboration with the Global Risk Identification Programme, the WMO plans to lead two major projects on flood, drought and tropical cyclone risk assessment, producing standardised hazard databases and mapping and analysis tools.
- The Munich Re and Swiss Re online disasters databases and maps, which provide vital information on the most significant natural hazards by region and data on past events. Such mapping services have been used by insurers for 'geographical underwriting' of natural-hazard risks, as well as assisting engineers and public agencies in identifying which hazards are likely to be of principal concern.

Such initiatives play an important role in raising risk awareness and empowering decision-makers in the developing world. To ensure risk assessment is sustained long-term there is a need to build local risk assessment capabilities, supported by public institutions and agencies, in particular, covering meteorology and hydrology. In parallel, the international risk assessment community can help to facilitate immediate improvements to risk management, and as well as the growth of insurance

[20] CAPRA: http://www.eird.org/capra-eng/index.html

markets and alternative risk transfer, through expanding and distributing basic-level hazard mapping to provide global, consistent risk information. Such international initiatives do exist for seismic hazards (e.g. the Global Earthquake Model[21]), but not yet for hydro-meteorological hazards, despite the fact that these cause the largest number of annual fatalities.

IV. CLIMATE CHANGE AND DISASTER RISK

Any long-term climate-sensitive decision should be resilient to trends in climate and exposure over its lifetime. Many of our disaster risk management strategies and buildings and infrastructure today have been designed with the assumption that the characteristics of climate hazards will remain constant over time. However, we now know that this assumption is not necessarily appropriate. For example, it is clear that sea levels are rising as a result of anthropogenic climate change (increasing storm surge risks) and we are beginning to see a statistically-robust (though more difficult to attribute) intensification of Atlantic tropical cyclones (IPCC 2007). The IPCC 2007 concluded that in the future, global warming will very likely lead to an increase in the global frequency of heavy precipitation and heat extremes, and likely lead to an intensification of tropical cyclones (including an increase in peak gusts and rainfall levels). This could have significant implications for the global landscape of natural catastrophe risk; for example, ABI (2005) demonstrated that even a relatively small 6% increase in hurricane wind speeds could lead to a 75% increase in average annual losses in the US. **It is crucial that both DRR and the likely effects of climate change are incorporated into development planning today to increase the resilience of society and prevent costly mal-adaptation and the 'locking-in' of future risks (e.g. from building in high hazard coastal areas). Through coordinating DRR and climate change adaptation strategies, in particular managing the exposure and vulnerability to disasters, societies can reduce their losses immediately.**

The risk information needs for climate change adaptation have many similarities to those for traditional climate risk management; the difference is the time horizon represented. This inevitably increases the uncertainty in the risk estimate. Climate change elevates the need for risk modelling as it means that historical experience alone becomes less relevant as a guide to risk and that risk managers must consider the potential for events more catastrophic than seen previously at a location. The tools for communicating risk today, and the models underlying risk information, are transferable to climate change adaptation. The difference is that the model must represent future hazard, exposure and vulnerability. For example, RMS has recently pioneered the development of 'climate-conditioned' Cat models, which produce scenarios of future risk. These models have the

[21] The Global Earthquake Model project: http://www.globalquakemodel.org/

same structure and present-day risk information as traditional cat models, but incorporate adjustments based on climate and socioeconomic projections.

By underpinning DRR and adaptation with a consistent risk assessment framework we can help to ensure a coordinated approach to policy development.

a. Modelling the Impact of Climate Change on Disaster Risk

Quantifying the effects of climate change on the characteristics of weather events is challenging, even at a regional level. Fundamentally, there are significant uncertainties in our current understanding of how climate change will affect extreme weather events, even qualitatively. While it is possible to make broad projections around trends in some global characteristics of extremes (in particular, their increasing intensity) from climate model experiments and the fundamental physics, very little can be said with any certainty about local or even regional changes. One of the main reasons for this is that the global climate models (GCMs) that produce climate projections are not yet high enough resolution to model extremes. For example, most GCMs produce output with a spatial resolution of around 125 – 400km, whereas it has been suggested that a resolution of 1km or less is required to capture the essential characteristics of intense storms (Chen et al. 2007). While it is possible to run models at higher resolution this is computationally intensive and therefore significantly reduces the length of model runs that are possible and the number of runs (vital for exploring the uncertainty in the model). Even in the Fifth Assessment Report of the IPCC, the highest resolution GCMs will be around 50km.

The uncertainty in climate change projections is inherently greater for tropical and monsoonal regions, where most the developing countries are located. For example, most climate models disagree on the sign of future precipitation changes in the tropics (IPCC 2007). This is again due to the difficulties in simulating small-scale processes, which are particularly important in tropical climatology. The availability of higher resolution climate projections is also poorer in the developing world. While a limited number of regional climate models are available (e.g. PRECIS[22]), there is a need for larger ensembles of models (as provided currently by the range of GCMs and more recent 'perturbed physics' ensembles) to allow decision-makers to explore the range of uncertainty.

Risk modelling approaches are available that incorporate GCM data to provide future hazard scenarios useful to policymakers, albeit with inevitable uncertainties. For example:

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[22] The UK Met Office-Hadley Centre PRECIS project (http://precis.metoffice.com/)

- GCM outputs are useful for informing global-scale risk identification, to provide a first-cut view of the hotspots of future risk. For example, Nicholls et al. 2007 produced a ranking of global cities most exposed to current and future storm surges, estimating future storm surge heights by combining global mean sea level rise estimates with a simple index of regional changes in future tropical and extra-tropical storm intensities (both based on GCM output).
- For more localised risk assessment, GCM data can be used to explore changes in the large-scale 'predictand' climate signals associated with local hazards. For example, in recent work, RMS has analysed projections of changes in sea surface temperatures and windshear in the Atlantic 'Main Development Region' from GCMs and explored their use as predictands for long-term Atlantic hurricane activity rates. Such approaches can be used to create 'climate-conditioned' versions of Cat Models for adaptation studies (e.g. Lloyd's of London 2008).
- There are many examples of where 'downscaling' (Box 1) is used to bridge the divide between GCMs and the data needs of more localised risk modelling. For example, RMS India has used downscaling approaches to explore the impacts of climate change on drought risk. In one study, a combination statistical-dynamical downscaling approach was used to generate future scenarios of state-level rainfall and temperature changes in India. These scenarios were used to drive an integrated drought-crop risk model, and to explore the benefits of adaptation options, such as changing crop varieties and planting times[23].

Each of these approaches makes assumptions and therefore adds uncertainty to the original GCM projections. In each case, the uncertainty in the risk outcomes must be fully explored, through running multiple scenarios and sensitivity testing the outcomes to the assumptions made. It is crucial to communicate these uncertainties to those who will base risk management decisions on the outputs.

Box 1: Downscaling Approaches for Climate Risk Assessment

Downscaling approaches aim to produce higher resolution from lower resolution GCMs. The approaches can be divided into two types:

- *Dynamical downscaling* uses higher resolution climate models (typically ~50km or below), called Regional Climate Models (RCMs), over smaller areas, to represent specific regions of interest. RCMs are typically nested within a GCM. The advantage of this approach is that the model represents the physical processes in the region and can credibly simulate a broad range of climates. The main disadvantage is that RCMs are computationally intensive; limiting the number of models runs available for comparison. The uncertainties involved are similar to a normal GCM; in particular, localised extremes, such as tropical cyclones and flooding, are still not well represented in standard RCMs.

[23] http://www.wassan.org/apdai/documents/Drought,%20Andra%20Pradesh%20Vol-I.pdf

- *Statistical downscaling* is an empirical modelling technique, which uses observed relationships between the large-scale (predictor) and small-scale (predictand) climate variables today to empirically generate small-scale climate data from low resolution GCM projections. The advantage of these techniques is that the models are inexpensive to run and several tools are widely available. The principal disadvantages are that they assume the relationships employed remain stable in a changing climate and that some techniques lack coherence across climate variables (for example, not linking rainfall and temperature).

Like GCM output, downscaled data provided an indication of future conditions but should not be treated as a definitive view of the future. Such data can be useful in decision-making provided that findings are interpreted appropriately with adequate treatment of the limitations and uncertainties involved. For a full discussion of downscaling approaches and their limitations, see Kundzewicz et al. 2007.

Incorporating trends in exposure and vulnerability in risk modelling is as important, or more so, than trends in hazard. The uncertainties in these trends are significant and can be more difficult to quantify. For example, Nicholls et al. 2007 demonstrates that trends in exposure contribute around two-thirds of the increase in the population and assets at risk from storm surge in the 2070s (assuming constant vulnerability). The uncertainties in exposure and vulnerability become increasingly dominant over time. In risk modelling, exposure trends are typically represented by scaling present-day exposure based on regional projections (e.g. using the UN population, economic growth and urbanisation projections as in Nicholls et al.). Similarly, the benefits of land-planning scenarios can be explored through manipulating the exposure data (e.g. limiting new building in flood plain areas). Other adaptation options, such as building retrofits, new crop types or flood defences can be modelled through manipulating vulnerability functions accordingly. For example, through using a simple 'climate-conditioned' RMS cat model, a recent study demonstrated that making homes more resilient and resistant to flooding (e.g. with a strengthened structure and dry flood proofing) could actually reduce their future average annual losses to below present-day levels (Figure 8).

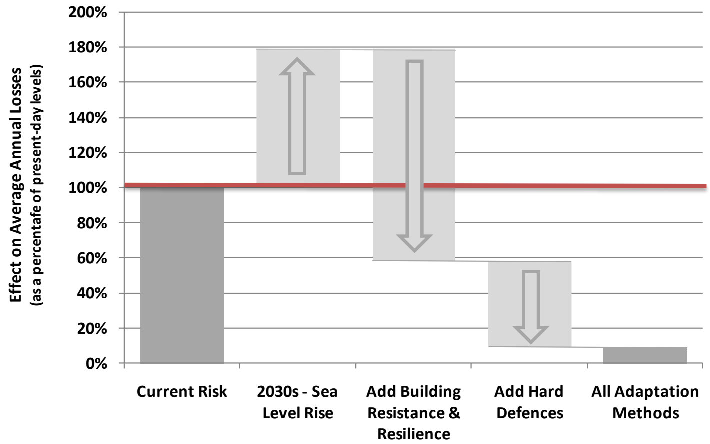

Figure 8: An example of the impacts of sea level rise on average annual losses from storm surges in high risk coastal areas in the UK and the loss reduction benefits of adaptation (building more resilient and resistant buildings and hazard defences). Figure reproduced from Lloyd's of London (2008).

Policymakers must incorporate the uncertainties in climate change risk assessments into their decision-making process. It is unlikely that the uncertainties in climate change risk assessments will be reduced significantly on the timescales that some adaptation decisions will need to be made, particularly those around buildings and public infrastructure. To overcome this, decision-makers will need to adopt approaches for making robust decisions under uncertainty; that is, managing, rather than reducing, the uncertainty. Such approaches have been used across several different disciplines and have begun to be applied to climate change adaptation. For example, Groves and Lempert (2006) apply robust decision-making approaches to long-term water resource management in California.

b. Adaptation Modelling in Practice

The majority of adaptation studies to date have tended to consider only changes in the mean climate. This is a significant omission and could lead to maladaptation. Studies have also tended to be low-resolution, aimed at demonstrating the need for adaptation and the cost-effectiveness of different options, rather than informing specific local adaptation strategies[24]. Over time there will be a growing need for climate change risk information to inform local adaptation decisions and this will require a much greater knowledge of vulnerabilities and higher-resolution hazard and exposure information. An example of such a project is ABI (2006), which uses a climate-conditioned version of the RMS UK Storm Surge model to demonstrate that sea level rise could increase losses associated with a major storm by £7.5 – 16 billion by the 2080s in the UK; this is compared to a detailed scenario of improved flood management (in line with Government strategy), which is shown could offset future losses by around 50 – 60%.

The adaptation community can learn much from disaster risk management in terms of the risk communication and the information needs for decision-making. The communication and decision-making tools for each are very similar. For example, the UK Environment Agency's Thames 2100 project (expected in 2009), which aims to inform long-term flood management in the Thames estuary, will produce a series of outputs aimed at different stakeholder groups, including high-level investments recommendations and extensive scenario-based hazard and loss maps at a number of future time intervals (exploring the uncertainties), damage statistics and multi-criteria cost-benefit analyses of a range of adaptation strategies[25]. Public awareness and risk education is also crucial to ensure the successful implementation of plans. **Sharing information on risk analysis approaches and best-practice in decision-making will be crucial to ensuring an effective response to the**

[24] See review of adaptation analyses in Agrawala et al. 2008.

[25] Tim Reeder, UK Environment Agency, personal communication

challenges posed by climate change. International organisations and companies can be important facilitators of this exchange.

V. CONCLUSIONS AND BROADER PERSPECTIVE

The take-away from this document should be that relevant and appropriate risk modelling is possible. Our conclusion is that despite data deficits in the developing world and the challenges in modelling current and future risks, it is possible to provide appropriate, affordable and useful risk information to inform decision-making. We find that, to date, the key barrier to the provision of risk information has not been the technical difficulties in building risk models, but the lack of demand and accordingly low investment. Over the coming years, the expansion of the insurance market and heightened concerns about climate change should help to provide this impetus, particularly for the transition economies. However, the development of risk information for the poorest countries will likely continue to require additional support in the near-term.

The concept of risk identification and assessment still needs to be given much higher priority in mainstream development planning. To promote the values of hazard and risk mapping it is important to highlight examples of success, where actions based on risk information have led to measurable benefits in terms of reduced casualties and economic impacts of disasters. Policymakers and risk modellers should also share information on the successes and limitations of risk assessment approaches and establish best practice.

However, while the provision of risk information can facilitate effective disaster risk management and adaptation, it can not drive it. Risk information can not be acted upon without effective governance or where disaster risk management is not made a priority. For example, in many countries, even where good risk-reducing regulations exist these are not rigorously enforced, either due to lack of investment and political support, corruption or in many cases, competing immediate concerns. For example, Jakarta has developed planning regulations to prevent building in high flood risk areas; but, the urban poor continue to build illegally along the riversides (returning when relocated) as this means they can more easily find much-needed work in the city (Caljouw et al. 2004). More than 60 people were killed in the floods in Jakarta in 2007.

The provision of risk information must also go hand-in-hand with strengthened public institutional capabilities to apply and distribute that information. In many regions a basic level of risk information is already available, but the application of this risk information is limited by awareness, investment resources, institutional capacity and technical expertise. For example, the

AGRHYMET centre in Niger[26] provides state-of-the-art seasonal forecasts for the Sahel, but confronts a lack of institutional capability and relevant distribution channels, which prevents this powerful information from being employed[27].

Risk awareness and education is also vital. Simple hazard and risk information has the greatest benefits where it is distributed to, and understood by, all levels of the society, empowering government, businesses and individuals to take actions to reduce risks. For example, the Vulnerability Atlas of India, which includes hazard maps for all the major perils, has been successful in empowering individuals to take micro-level actions to reduce their own risks, as well as enabling local authorities reduce societal risk, through for example reviewing land-use planning regulations (UN/ISDR 2007). Similarly, in Cuba and Jamaica, risk education is built into the school curriculum, making students leading actors in raising community awareness.

While it is important to develop local risk assessment capability, the international community can play an important role in raising risk awareness through expanding and distributing simple hazard maps to provide global, consistent risk information. Such investment could have double benefits; for example, 'models make markets' (Muir-Wood, 2008), the provision of risk information is likely to draw the interest of the global markets and hasten the development of risk sharing initiatives, such as micro-insurance and catastrophe insurance pools. **In this age of data availability and global communication, risk information should be considered a fundamental right.**

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[26] http://www.agrhymet.ne/eng/index.html

[27] Merylyn Hedger IDS, personal communication (for more information see UN/ISDR 2007)

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