HARVARD UNIVERSITY

JOHN F. KENNEDY SCHOOL OF GOVERNMENT

Global Hazards and Catastrophic Risk: Assessments, Practitioners, and Decision Making in Reinsurance

Mojdeh Keykhah

Global Environment Assessment Project

Environment and Natural Resources Program

Belfer Center for Science
and International Affairs

2000-22

OCTOBER 2000

Belfer Center for Science & International Affairs

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CITATION, CONTEXT, AND PROJECT ACKNOWLEDGEMENTS

This paper may be cited as: Keykhah, Mojdeh. "Global Hazards and Catastrophic Risk: Assessments, Practitioners, and Decision Making in Reinsurance." Belfer Center for Science and International Affairs (BCSIA) Discussion Paper 2000-22, Environment and Natural Resources Program, Kennedy School of Government, Harvard University, 2000. Available at http://environment.harvard.edu/gea. No further citation is allowed without permission of the author. Comments are welcome and may be directed to the author at the Belfer Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University, 79 John F. Kennedy Street, Cambridge, MA 02138; Email mkeykhah@alumni.princeton.edu.

The Global Environmental Assessment project is a collaborative team study of global environmental assessment as a link between science and policy. The Team is based at Harvard University. The project has two principal objectives. The first is to develop a more realistic and synoptic model of the actual relationships among science, assessment, and management in social responses to global change, and to use that model to understand, critique, and improve current practice of assessment as a bridge between science and policy making. The second is to elucidate a strategy of adaptive assessment and policy for global environmental problems, along with the methods and institutions to implement such a strategy in the real world.

The Global Environmental Assessment (GEA) Project is supported by a core grant from the National Science Foundation (Award No. BCS-9521910) for the "Global Environmental Assessment Team." Supplemental support to the GEA Team is provided by the National Oceanic and Atmospheric Administration, the Department of Energy, the National Aeronautics and Space Administration, the National Science Foundation, and the National Institute for Global Environmental Change. Additional support has been provided by the Department of Energy (Award No. DE-FG02-95ER62122) for the project, "Assessment Strategies for Global Environmental Change," the National Institute for Global Environmental Change (Awards No. 901214-HAR, LWT 62-123-06518) for the project "Towards Useful Integrated Assessments," the Center for Integrated Study of the Human Dimensions of Global Change at Carnegie Mellon University (NSF Award No. SBR-9521914) for the project "The Use of Global Environmental Assessments," the Belfer Center for Science and International Affairs at Harvard University's Kennedy School of Government, the International Human Dimensions Programme on Global Environmental Change, Harvard's Weatherhead Center for International Affairs, Harvard's Environmental Information Center, the International Institute for Applied Systems Analysis, The Center for International Earth Science Information Network, the German Academic Exchange Service, the Heinrich Boll Foundation in Germany, the Heinz Family Foundation, the Heinz Center for Science, Economics and the Environment, the Massachusetts Institute of Technology's Center for Environmental Initiatives, a National Science Foundation Career Grant to Professor Daniel Schrag, the National Center for Environmental Decisionmaking Research, Yale's Department of Forestry and Environmental Studies, the University of Amsterdam's Department of Science Dynamics, the University of California at Irvine's School of Social Ecology, the University of California at Santa Cruz' Institute for Global Conflict and Cooperation, and the World Health Organization's Global Forum for Health Research. The views expressed in this paper are those of the author and do not imply endorsement by any of the supporting institutions.

Publication abstracts of the GEA Project can be found on the GEA Web Page at http://environment.harvard.edu/gea. Further information on the Global Environmental Assessment project can be obtained from the Project Associate Director, Nancy Dickson, Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University, 79 JFK Street, Cambridge, MA 02138, telephone (617) 496-9469, telefax (617) 495-8963, Email nancy_dickson@harvard.edu.

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FOREWORD

This paper was written as part of the Global Environmental Assessment Project, a collaborative, interdisciplinary effort to explore how assessment activities can better link scientific understanding with effective action on issues arising in the context of global environmental change. The Project seeks to understand the special problems, challenges and opportunities that arise in efforts to develop common scientific assessments that are relevant and credible across multiple national circumstances and political cultures. It takes a long-term perspective focused on the interactions of science, assessment and management over periods of a decade or more, rather than concentrating on specific studies or negotiating sessions. Global environmental change is viewed broadly to include not only climate and other atmospheric issues, but also transboundary movements of organisms and chemical toxins. (To learn more about the GEA Project visit the web page at http://environment.harvard.edu/gea/.)

The Project seeks to achieve progress towards three goals: deepening the critical understanding of the relationships among research, assessment and management in the global environmental arena; enhancing the communication among scholars and practitioners of global environmental assessments; and illuminating the contemporary choices facing the designers of global environmental assessments. It pursues these goals through a three-pronged strategy of competitively awarded fellowships that bring advanced doctoral and post-doctoral students to Harvard; an interdisciplinary training and research program involving faculty and fellows; and annual meetings bringing together scholars and practitioners of assessment.

The core of the Project is its Research Fellows. Fellows spend the year working with one another and project faculty as a Research Group exploring histories, processes and effects of global environmental assessment. These papers look across a range of particular assessments to examine variation and changes in what has been assessed, explore assessment as a part of a broader pattern of communication, and focus on the dynamics of assessment. The contributions these papers provide has been fundamental to the development of the GEA venture. I look forward to seeing revised versions published in appropriate journals.

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ABSTRACT

Over the last decade catastrophic natural perils have caused unprecedented losses for the insurance industry. Before 1989, the benchmark loss for insurers and reinsurers was Hurricane Betsy in 1965, with losses just under $1 billion. The Betsy baseline was supplanted by Hurricane Andrew in 1992. Causing over $19 billion in insured losses, this hurricane prompted an industry wide "cognition of catastrophe," i.e. a realization that losses could be of this magnitude and larger. After Andrew, reinsurers invested in the purchase and development of hazard assessments in order to convert the perception of chance events towards a framing of a lack of strategic knowledge, and therefore manageable through greater incorporation of scientific expertise. This paper investigates the saliency, credibility and legitimacy of two forms of catastrophe assessments for the Atlantic hurricane risk, and evaluates their effectiveness towards reinsurance decision outcomes.

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INTRODUCTION AND OUTLINE OF GEA PROJECT THEMES

In September 1992, hurricane Andrew ravaged the southern coast of Florida and states abutting the Gulf of Mexico. It inflicted not only enormous social and economic losses, prompting the Federal government to declare the hurricane's path a disaster zone, but also severely impacted the insurance sector, which had never experienced such a great catastrophic loss from a natural disaster. Those few days in September resulted in an insurance industry in shock, the losses having mounted to over $16 billion. As a comparison, the last major windstorm in the region was hurricane Betsy in 1965, with losses remaining below $1 billion at the time. The gap in the industry's perception of the probability of catastrophic loss and the reality of Andrew's destruction was an exemplary case of surprise in the insurance system.

The insurance industry responded by limiting coverage or charging much higher rates in Florida, but these measures were stymied by the Florida government. Another option was to transfer more catastrophe exposures to the reinsurance sector, but reinsurers had raised rates considerably after Andrew and had also suffered major losses. The third choice was the construction of stronger houses and reinforcement of existing ones. However, this route involved considerable industry - government coordination. Instead, the industry decided to invest in environmental assessments of natural hazards.

This study aims to evaluate the nature of reinsurance – expertise interactions in two assessment contexts: that of the catastrophe model and that of a joint industry – academia consortium called the Risk Prediction Initiative. It takes as its definition of assessment from the Global Environmental Assessment Project as being the "entire social process by which expert knowledge related to a policy problem is organized, evaluated, integrated and presented in documents to inform policy or decision making." (GEA 1997: 53) The Global Environmental Assessment project, through an analysis of a number of cases, identified conditions under which assessments (both as products and as communication processes) prove effective in the policy sphere. While the two cases analyzed in this paper are of practitioners in the private sector, many parallel themes are addressed.

This study begins by presenting an overview of the main findings of the GEA project with an introduction to the historical context of catastrophe assessments in reinsurance and a brief outline of the focus peril, the Atlantic hurricane risk. It then describes the two assessment cases in detail within the spatial and temporal constraints of the reinsurance practitioner's decision making routines. Finally the paper will evaluate the hazard assessments' effectiveness to decision makers in reinsurance.

The GEA project differentiates the effectiveness of environmental assessment outcomes in terms of influences listed in Table 1. This includes a change in the natural environment, an influence on the behavior or strategies of key actors, the framing of issues, agendas, or the terms of the debate, and the shaping of knowledge needs. The main reason for this diversity in effectiveness outcomes is to allow a more subtle understanding of the many factors involved in the reception of an assessment by the decision making community. This particular study continues work on the effectiveness of assessments in the private sector (Rothenburg and Levy, 1999) and also the context of practitioner – decision maker in assessments and assessments as decision support systems (Cash and Moser, 1998; Moser, Cash and Clark, 1998).

Particular assessment characteristics (both as product and as process) have been found to favor assessment effectiveness. These factors include the perceived relevance or *saliency* of an assessment among a particular decision making community, the perceived authoritativeness or *credibility* of the assessment among scientists, and the *legitimacy*, or the perceived fairness of the assessment among stakeholders of the assessment's object of study.[1] The saliency, credibility and legitimacy of an

assessment are most directly influenced by the historical context and evolution of the environmental issue, the design of the assessment, and the characteristics of the user community.

Particular historical factors affecting the saliency of an assessment include the issue attention cycle, characterizing the time dependent prominence of an issue in the public sphere (Jaeger, 1999; Downs, 1972). This cycle in large part determines the resources to be devoted to the environmental issue and promotes a particular framing of the issue. Moreover, throughout the issue attention cycle, who is communicating what to whom changes substantially, increasing the chance for multiple representations. The GEA project considers that different phases of the issue attention cycle warrant different kinds of assessments. The assessments most effective in the pre-emergence phase (characterized by an identification of the problem, its urgency, and the search for greater understanding) will be much less effective in the post – emergence phase (where policy management choices need specific input).

The design of an assessment also promotes particular levels of saliency, credibility and legitimacy. These design criteria include the structure of the science / policy interface, the procedure of participation in the assessment process, and the handling of uncertainty and dissent in the assessment report. The first refers to the nature of interactions of science and policy, implicating a wide variety of context dependent institutional and organizational arrangements (Jaeger, Farrell and VanDeveer, 1998; Jung, 1999). Taken as two extreme cases, the science / policy interface could have scientists perceived to be "co-opted" by policy makers, decreasing the technical credibility of the assessment, or as scientists preparing policy neutral reports within the cloistered institutions of academia. Most assessments are examples of the middle ground, one in which the definition of assessment as a communication process manages to capture. The facilitation of this communication has been found to be located most saliently in certain "boundary organizations."

Boundary organizations serve both policy and scientific communities and in the process negotiate the standardization and translation of knowledge for policy makers. Institutions that exhibit characteristics of boundary organizations include the Heath Effects Institute and the International Research Institute for Climate Prediction (Guston et al., 2000). What these organizations have in common is the aim to create and share scientific knowledge within *political* contexts. Such contexts involve negotiated understanding of the scales of the environmental issue, the applicability of data, and the weight of local conditions. As an integrator and translator, the boundary organization becomes a site in which trust and dialogue between policy makers and scientists can occur in a situated, yet semi-neutral forum. The boundary role of assessments span not only a particular science / policy interface, but indeed relations at multiple scales of spatial resolution (for example translating results from global climate models to local decision making needs, as evidenced in the work of Cash, 1998).

Uncertainty and dissent in an assessment are defined as the difference of expert opinion within disciplines and the interpretation of consensus. The work of the GEA project suggests that the implications of consensus or dissent for policy depend on the timing of the assessment in the issue cycle, i.e. whether 'insight-oriented' at an early stage or 'decision-oriented' with a view to affect the selection of policy measures.

Issues of participation related to saliency and trust involve the manner of assessment as communication, whether "post box" or face to face interaction. Communicating face to face was judged as improving producer – practitioner trust. However, as the case in reinsurance will show, the uncertainties and dissent in an assessment process are more likely to be displayed face to face, leading to a potential loss in scientific credibility. Participation is also directly linked to the perceived legitimacy of an assessment, whether it is produced behind closed doors, with the voices of only a few, or indeed brings in a range of judgments.

Particular characteristics of the assessment *user* community also influence saliency, credibility and legitimacy. These aspects comprise practitioner interest, capacity and openness. The GEA project found that the most effective assessments gauge and engage at an early stage the interests of the user community. The capacity to engage, however, depends on logistical and technical resources which varies among practitioners. Openness to different sources of expertise could produce conflicting evidence, thus reducing the credibility of the assessment. At the same time, openness could increase the legitimacy of an assessment by involving a number of avenues of expertise.

The case examples of the GEA project concerned mostly regional or global scale public assessments, the role of environmental models in problem solving, and the relations between science and policy. The private sector case treated in this paper takes very similar themes. These include the role of hazard models, the negotiation of boundaries between the scientific and practitioner communities, and the importance of the scale of the assessment.

Catastrophe hazard assessments focus on low probability, high consequence events, such as hurricanes, earthquakes, floods, or windstorms. These extreme events cross particular thresholds of loss for the public and private sectors. Such assessments have become increasingly salient in both public and private domains in recent years, notably after a series of natural catastrophes in the U.S. and abroad.

The two sites of assessment treated in this study comprise the catastrophe model (assessment as product) and the Risk Prediction Initiative (assessment as process). The guiding questions are:

1. How do reinsurers of catastrophe risk make use of, and debate on a daily basis, assessments provided by academic science, by private catastrophe modelers or by IPCC reports?
2. How salient and effective are these assessments within the context of competing priorities of the practitioner? Within different temporal and spatial frames?
3. How does the credibility of the assessment as product affect the assessment as process with respect to uncertainty and legitimacy?
4. How are the assessment needs and feedback of the practitioner communicated to the scientific community?

In this paper, I have tried to contextualize catastrophe reinsurance decision making within the intense pressures of the reinsurance marketplace. I have also tried to portray the temporal and spatial context of reinsurance decision priorities, to provide an indication of the avenues open for assessment as product and process. In order to understand the general context in which reinsurers require scientific expertise, the study begins with a brief outline of the role of reinsurance, the historical context of catastrophe assessments, and a description of the debates among scientists and practitioners regarding the Atlantic hurricane risk. Afterwards, a greater discussion of two assessments is provided.

CATASTROPHES AND INSURANCE

Insurance serves the policy holder by providing coverage in the event of an unexpected loss. The most visible insurance products provide compensation for losses to property and life. The premium, or the price of the insurance policy, relies on an estimate of the probability distribution of the risk –a distribution of the frequency and severity of loss. In order to provide a viable service to local and regional clients, the insurer relies on loss contingencies affecting different contracts at different times. Moreover, such losses should generally be in the realm of expectation through the probability calculus.

Catastrophes represent the "tail" of the loss probability distribution, for which consequences are high, but the probability is very low. Providing coverage for this tail is problematic for the primary insurer since losses could include all policies at once, with little or no data on past events to base future expectations. Insurers hedge this uncertainty by applying for *reinsurance* to cover losses from their portfolios exceeding a certain amount – in essence they are insuring themselves against the ambiguity in the tail of the loss distribution. Without the existence of this external source of coverage to themselves, primary insurers would be loath to provide catastrophe coverage at the local level.

Reinsurers, unlike their primary insurance counterparts, provide catastrophe protection on a global scale and for various levels of loss. At the same time they face a similar problem to insurers: how to participate in the catastrophe market for which the probability of loss is difficult to assess? They hedge the possibility of a catastrophe loss by diversifying the locations in which they have catastrophe risk liabilities. A concomitant option is to purchase further reinsurance. Thus, the catastrophe reinsurance markets concern mostly the iterations of reinsurance coverage of the ambiguous probability distribution "tails" of insurance companies worldwide.

The total "exposure" or risk includes *both* the probability of a natural catastrophe striking a particular geographic region, and the number, value, and vulnerability to damage of the properties being reinsured. The first can be referred to as the cause of loss (i.e. the external stimulus) while the latter, the condition of loss. Surprisingly, for much of the latter half of the 20th century, reinsurance assessment of catastrophe risk relied on databases of the cause of loss, and neglected to monitor the changing conditions of loss. Moreover, most assessment routines involved estimation of future probabilities through an *inductive* review of past data (however sparse), framed by analogies to few particularly large events.

During the rise of catastrophe reinsurance as a global business after World War II, catastrophic insurance losses were rare, partly due to the few global centers of high value density, such as Tokyo is today. Hurricane Betsy, which damaged the Florida coast in 1965, served as one analogy to frame the catastrophic before Hurricane Andrew. Betsy did not exceed $1 billion in insured losses at the time,[2] but served to surprise the industry with its unprecedented impact (Pielke and Pielke, 1997). In the years since Hurricane Betsy, the settlement along the Florida coastline has rapidly developed. High rise office buildings and condominiums tower over a multitude of commercial and homeowner units. From these conditions of loss, it is evident that the 1965 baseline simply does not provide the proper analogy to the exposure catastrophe reinsurers are currently facing.

THE "COGNITION OF CATASTROPHE"[3]

The heightened awareness by the insurance industry towards catastrophes began in 1986 when the All-Industry Research Advisory Council (AIRAC), a group sponsored by the U.S. property/casualty insurance industry, published an assessment of the adverse effects of two $7 billion hurricanes on the U.S. insurance industry (AIRAC, 1986). The study suggested that while the first $7 billion event would damage the financial capacity of insurers and reinsurers, the subsequent $7 billion loss would engender major market dislocations.[4] The AIRAC assessment thus provided a measure of the possible impacts due to two catastrophic storms. The assessment did not prove very effective among reinsurance decision makers, mostly due to the lack of saliency of natural catastrophes among reinsurance losses.

In the year after the AIRAC assessment had been published windstorm "87J" hit the southern coast of Britain (an estimated once in 300 year event, resulting in $4.4 billion in insured losses), followed by Hurricane Hugo in 1989 in the Caribbean ($5.6 billion), a set of winter gales in Europe in 1990 ($5.9

billion), and Typhoon Mireille in Japan in 1991($6.9 billion). While these were serious loss events, they did not induce a frame shift in routines of thinking about catastrophes as such. However, the loss trend was considered by some reinsurers as tokens of global climate change (Freedman, 1997). Global warming was at the time linked by several global environmental assessments, such as that of the Intergovernmental Panel on Climate Change (IPCC) to increased storminess and extreme events (Dlugolecki, 1996). The quotes below illustrate this early perception by reinsurers of hazards as becoming "increasingly unpredictable" thereby exposing this private sector coverage provider to an unwelcome level of vulnerability.

The General Manager of Swiss Re, H.R. Kaufman, cautioned in November 1990,

> "There is a significant body of scientific evidence indicating that last year's record of insurance losses from natural catastrophes was not a random occurrence. Instead it may be the result of climatic changes that will enormously expand the liability of the property-casualty industry." (Gordes, 1993)

Lloyd's of London Deputy Chairman, Dick Hazell contributed this statement at about the same time,

> "...there is no reason to expect the recent state of disasters was just bad luck or statistical oddity. The long term impact of global warming on the world's weather patterns and the incidence of disasters due to man-made constructions or industry pollution may both ensure that a significant number of large-scale catastrophes occur somewhere around the world each year." (Gordes, 1993)

The clarion call to a new threshold of catastrophe sounded with Hurricane Andrew in 1992. While not quite a category 5 hurricane, its geographic track through southern Florida and the Gulf states precipitated over $19 billion in insured losses, in a year that witnessed over $24 billion in total insured catastrophe losses. Several insurance and reinsurance companies collapsed, precipitating a market plunge in available capital to cover future risks. One study surmised that *if* Hurricane Andrew had traveled only 50 miles further north into metropolitan Miami, insured losses would have mounted to over $50 billion, sufficient to pierce the solvency of the industry as a whole (Doherty, 1997; Changnon et al., 1997).

Two years after Andrew, California fell victim to the Northridge earthquake, producing $14.1 billion in insured losses. One could only imagine Andrew and Northridge occurring in the same year to realize the extent of liability the insurance and reinsurance sector was potentially facing.[5] The new "cognition of catastrophe" (Meszaros, 1997) by insurers moved the boundary posts of disaster for underwriters; it was a far cry from two $7 billion windstorms given in the AIRAC assessment just a decade earlier. One result of these financial shocks was to expose the Achilles' heel of reinsurance expectation routines based solely on past loss levels, disregarding changes in the conditions of loss.

Table 2 details the largest insured loss events from natural perils (Swiss Re, 2000); all have occurred within the last fifteen years. As is shown in the table, windstorms have produced catastrophe events of greatest impact, with the level of loss highly dependent on the geographies affected in the conditions of loss and the degree of private insurance protection involved (as opposed to state protection).[6]

The industry responded to this unexpected string of losses by turning to scientific expertise. They sought to tame the perceived aleatory uncertainty, or chance, of these events into a loss trend that could be estimated. In other words, they invested in converting aleatory uncertainty into epistemic uncertainty, or gaps in the state of hazard knowledge.

The paper will discuss this search for greater incorporation of scientific expertise with particular emphasis on the Atlantic hurricane risk. A select overview of some of the scientific and reinsurance discussions concerning this awesome peril is provided below.

THE ATLANTIC HURRICANE RISK

Hurricanes and windstorms are among the greatest loss generating hazards to the insurance industry. While it may seem that the losses are due to an increase in the frequency of hurricanes, the high loss levels are more reflective of the increased societal vulnerability to catastrophes.[7] Settlements along the eastern seabord of the United States in particular, have greatly expanded over the last 25 years, with concomitant pressures on land, resources, and technological infrastructure (Mileti, 1997; Burton, Kates and White, 1993; Pielke and Pielke, 1997).

While a more specific discussion of Atlantic hurricane generation and propagation is beyond the scope of this paper, it would be relevant to note a few factors favoring hurricane activity. Many hurricanes that reach the east coast originate as storms in the tropical waters near northwestern Africa. For a hurricane to form, it must evolve through particular stages generating strength and transportability through temperature, moisture and pressure gradients. Favorable conditions include sea surface temperatures above 80 degrees Fahrenheit, low values of vertical wind shear, low air pressure, and relatively moist layers near the mid-troposphere.

Some of these factors in hurricane generation are found to alternate in the Atlantic Ocean with the onset of a climate phenomenon termed the El Niño. The El Niño refers to a reversal of the heat convection current of the Pacific Ocean and has been found to be associated with global precipitation and temperature anomalies worldwide, called teleconnections (Glantz, 1996; Philander, 1998). During an El Niño year, the conditions leading to Atlantic hurricanes are *suppressed.* At the same time, such factors are *enhanced* for hurricane development in the South Pacific. It is mainly for this reason that El Niño and climate studies in general could very well have impact on reinsurance losses worldwide. Therefore, in non- El Niño years, termed La Niña, hurricanes are less likely to develop in the Atlantic during the hurricane season, which is roughly from June through October. El Niño is often accompanied by an alteration in sea level pressure across the Pacific Ocean, called the Southern Oscillation. Taken together, the joint phenomenon is often called the El Niño - Southern Oscillation, or ENSO.

In order to derive a greater sense of El Niño's contribution to weather anomalies, earth scientists have been investigating historical clues of El Niño occurring millennia ago in paleoclimate indicators, such as coral reefs. While El Niño years have generally witnessed *subdued* hurricane activity in the Atlantic, it is worth noting that the worst insured loss to date, Hurricane Andrew, occurred during an El Niño year (Trueb, 1998). It is worth noting that it is landfalling hurricanes, such as Andrew, that are of greatest importance to insurers and reinsurers, not simply the total number of hurricanes that are formed in a particular year.

Andrew also testifies to the importance of the geographic track of a peril in determining total insured losses. Despite great advances in hurricane research over the past 20 years including greater understanding of the meteorology affecting hurricanes, measurement of hurricane characteristics in situ, and the development of hurricane forecasts, it is generally difficult to provide a geographic specific track over land (Pielke and Pielke, 1997). Indeed, some mathematicians and physicists argue that it is fundamentally impossible, due to the chaotic behavior of the peril (Casti, 1997; Woo, 1999). On the other hand, there have been numerous studies describing past decadal clustering of hurricanes impacting a

particular landmass, such as Florida. Hurricane forecaster and Colorado State University meteorologist Bill Gray argues that based on historical trends over the 20th century the Atlantic basin may be "due" for another clustering of hurricane activity following a lull in the 1970s and 1980s (Gray, personal communication, 1999; Gray et al., 1998). However, can the past provide a suitable projection onto the future? Climate modelers do not think so.

During the 1990s, General Circulation Models, or GCMs, have projected an almost inevitable rise in the number of storms and extreme events due to climate change (Dlugolecki, 1996). Among meteorologists and hurricane forecasters on the other hand, there remains skepticism of the proposed link between Atlantic hurricane activity and climate change (Gray, personal communication; Henderson-Sellers et al., 1998). Historical climate research thus also serves to improve characterization of current climate conditions as climate *change* or climate *variability*. This distinction is also important to the insurance industry. For example, French reinsurer SCOR Re noted in August 1996 (SCOR, 1996: 8)

> "In 1992 the IPCC issued a report, in which it was said that there would be more storms because of global climate change. However, in the most recent report in 1995 there was little agreement on possible changes in storminess."

An excerpt from the actual report indicated that uncertainties in tropical cyclone framed the scenarios:

> "the state of the art [tropical cyclone simulations in greenhouse conditions] remains poor because (i) tropical cyclones cannot be adequately simulated in present GCMs; (ii) some aspects of ENSO are not well simulated in GCMs; (iii) other large-scale changes in the atmospheric general circulation which could affect tropical cyclones cannot yet be discounted; and (iv) natural variability of tropical storms is very large, so small trends are likely to be lost in the noise...in conclusion, it is not possible to say whether the frequency, area of occurrence, time of occurrence, mean intensity or maximum intensity of tropical cyclones will change." (Watson et al., 1996; p. 334)

SCOR Re noted (1996: 9)

> "The message as far as climate change goes is that natural climate variability is large compared to human effects. For the next few decades, at least, natural variability as opposed to global climate change is likely to have a much larger impact on insurance business."

It may be useful to note at this point that while greater understanding of hurricane formation and propagation is the vision of many in the scientific community, from the reinsurance practitioner's perspective, a few generalized features may be sufficient. Reinsurance judgment routines center on questions not of activity per se, but of loss. For example, are El Niño years *correlated* with lower windstorm *losses*? If Andrew is any guide, the answer is ambiguous due to the heavy dependence of loss on geographic track. Research from catastrophe broker Guy Carpenter suggests that (Major, 1999)

> "...while the ENSO cycle has a definite correlation with the rate of hurricane formation in the Atlantic , there is little apparent correlation between ENSO and the occurrence of hurricanes making landfall on the US coast. The effect of ENSO on insurance losses is also uncertain."

In the meantime, hurricane forecasts and results from climate simulations have been overshadowed in the reinsurance practitioner's context by the advent of the catastrophe model.

THE RISE OF THE CATASTROPHE MODEL

Catastrophe models as assessment tools for underwriting decision making have rapidly proliferated over the past fifteen years. Part of this growth is due to demand wrought by the insurance sector's "cognition of catastrophe" after the watershed losses of Hurricane Andrew (Meszaros, 1997). Another factor in the models' commercial success is due to the advances in computing power to combine and visually display the results from thousands of simulations. The catastrophe model integrates mini-assessments of the probability of the peril in a particular geographic region, the vulnerability of the properties concerned (materials, construction, environmental conditions) to the peril (of different intensities and durations), the insured values in the insurer's or reinsurer's portfolio and the terms of the insurance or reinsurance policy (such as deductibles, reinstatements, exclusions, etc., that affect the liability of the reinsurer). The product thus combines hazard, vulnerability, and insurance variables. As they handle a number of mini-assessments of environmental and societal factors, they are comparable to integrated assessments in global environmental change research (Jaeger, 1998; Rotmans, 1998).

In order to provide an output of the probability of losses exceeding a certain level, catastrophe modelers use two different approaches, one mainly deterministic, and the other, probabilistic (Kozlowski and Mathewson, 1997). In the first method, historical data on a particular peril such as hurricanes, serve as a baseline for trends in a region. *Deterministic* modeling then uses this data to simulate a number of specific (past) events. The technique in *probabilistic* modeling, on the other hand, is to run many hypothetical events covering a range of possible outcomes. These two methods allow the modeler to assess the probabilities and severity of loss (i.e. loss likelihood) and a distribution of exceedence probability - the chance that a loss will exceed a certain level. While the output is technologically sophisticated and visually stunning, catastrophe models contain a number of assumptions and some may argue, omissions, both at the level of global climate variables and local conditions.

For example, acquiring relevant data for the models can be extremely difficult, notably if past weather conditions have not been well recorded, the reliability and quality of data is questionable, or data are scattered. Moreover, climate data can be, as one catastrophe modeler exclaimed "fiendishly expensive" (Beatty, 1998). In Europe, such information usually comes at a cost, while in the United States, much of it is available publicly through government agencies, although this is also changing. When data are not directly available, deductive inferences are sometimes made using contingent data. For example, one catastrophe modeling firm digitized six-hourly pressure maps from the UK Met Office to derive windspeeds at high altitudes. On the other hand, cynical modelers advise the adage "rubbish in, rubbish out" as applicable to catastrophe modeling as any other modeling enterprise (Beatty, 1998). The IPCC report itself mentions the problem of inhomogeneities in historical data for catastrophe modeling purposes (Dluglolecki et al., 1996). Such limitations in data should be recognized, as they influence the applicability of the model's theoretical components.

Indeed, underestimating the uncertainties involved is a grave mistake, counsel two catastrophe modelers from Risk Management Solutions (Boissonnade and Collignon, 1999). They take the example of their tropical cyclone model, and the four hurricane forecasts that were used as its basis.[8] The RMS modelers remark on the spotty success records of the forecasters themselves and that the accuracy of US landfalling hurricanes is "inconsistent." On the other hand, improvements to the resolution of the models could require "an exponential increase in the amount of data, processing power and money required to build the model." (Beatty, 1998) Other sources of uncertainty include assumptions from the "raw" data

provided in technical estimates of material behavior under stress – to be included in the vulnerability component of the model. For example, the steel frame structures during the Northridge earthquake did not withstand the level of disturbance as had been assumed they would..

Complicating the uncertainties involved in catastrophe models are their proprietary status: they have been termed "black boxes" since their source codes, data, assumptions, and uncertainties are generally kept out of the practitioner's eye. A major foundation for their credibility lies in their assumed ability to predict loss values in particular regions due to different perils.[9] The attractiveness of these models is their capacity to translate scientific data to the temporal and spatial decision frame of the practitioner, including the context of the reinsurer's own portfolio. In order to evaluate the effectiveness of this kind of assessment as product a brief description of the temporal and spatial contexts of reinsurance decision making is provided below.

THE CONTEXT OF THE REINSURANCE PRACTITIONER

Reinsurers operate within specific *temporal* frameworks that are common throughout the industry and serve to coordinate key market activities. One important reference is the renewal season for the annual catastrophe reinsurance contract. North American reinsurance contracts, for example, are reviewed and renegotiated each January.[10] Therefore, in order to have relevance to decision making in reinsurance, environmental assessments must arrive to the reinsurer in advance of the renewal season. The periods are characterized by intense contract negotiations between underwriters and brokers, who mediate risk information from clients.

Spatially, reinsurers seek to diversify accumulation of catastrophe risk, in order to not be too greatly exposed to loss from a particular region. Reinsurers can thus choose to accept risks from particular geographic zones characterized by their exposure to California earthquake or Florida windstorm and at the same time choose risks in less disaster prone locations around the world, such as Continental Europe. However, the recent destructive storms Lothar and Martin in France and Germany illustrate the perpetual possibility of surprise as to the next major loss for reinsurers. Therefore, a spatial distribution of risks, while limiting potential loss, does not prevent catastrophic liabilities from reaching the reinsurer.

In this study, the main focus concerned catastrophe reinsurers and selected American reinsurance companies. The methodology involved a literature review of academic texts, trade publications, and five phases of field work involving semi structured interviews offering a diversity of perspectives. The participants included reinsurance underwriters, brokers, rating agency specialists, hurricane forecasters, hazards researchers, catastrophe modelers, government climate forecasters (El Niño, and hurricanes), and trade journalists. As the catastrophe market is one of the most competitive in reinsurance, it was naturally not possible to interview for particular reinsurance strategies. Rather, the approach of this study was of a more generalized nature: how do reinsurers approach catastrophe assessments of the Atlantic hurricane peril and towards what ends?

THE BERMUDAN CONTEXT

After Hurricane Andrew precipitated the collapse of a number of insurance and reinsurance companies, 8 specialized catastrophe reinsurance companies established themselves on Bermuda. They situated themselves on this Atlantic island which has developed a thriving financial services infrastructure, made more attractive by its tax status. These companies, funded by mostly American and British capital providers, formed an international reinsurance hub committed to catastrophe reinsurance. One of the distinguishing characteristics of these small firms was their open search for and incorporation of hazard

assessments. Within a few years these new companies claimed a quarter of the global catastrophe reinsurance market, abetted by the drain in international reinsurance capital after Hurricane Andrew. Demand for catastrophe reinsurance outweighed supply, permitting a large profit base and good returns for shareholders. However, as London and other reinsurance centers began to recover from Andrew, and as new market entrants increased the available capital to underwrite catastrophe risks, rates began to decline, and profitability was more difficult to achieve. By 1999 most of the original eight have either merged, shut down, or diversified to include other lines of reinsurance.

As an analogy to the issue attention cycle in policy, the saliency of hazard assessments reached a peak in the years following Hurricane Andrew. At the same time, catastrophe modeling companies were prepared with an assessment product that communicated directly to the perceived needs of the reinsurance community, particularly the Bermudans. The models as carriers of extended databases of loss were already an improvement, in addition to their exposure monitoring capabilities. As simulators of future catastrophic events, the models also provided substantial scientific expertise that until that time was very unevenly divided among the reinsurance community as a whole (mostly depending on internal technical capacity).

At first, the models' "black box" proprietary aspects were not considered as heavily as their compatibility with the "numbers" they could provide reinsurers. Indeed, in some early cases the models were taken as "truth machines," capable, with the input of teams of scientists in the catastrophe modeling firms, to provide robust probabilities to counter the uncertainty of the future. Such reaction to the assessment as model was not dissimilar to the systems modeling promises of the early 1970s (Kwa 1987). However, unlike climate models, which have long lead times, catastrophe models can be verified comparatively quickly, for example with the Northridge earthquake, the winter storms in Canada, Hurricane Floyd, Winter Storm Lothar, and Hurricane Hugo. Thus, a learning process took place, not unlike the evolution of expectations of "predictability" among policy makers of global circulation models during the early 1990s (Henderson-Sellers et al. 1998, Shackley and Wynne 1996; Shackley, 1997).

Such experiences, mostly involving verification of the model against catastrophe events, promoted greater internal capacity among reinsurers to become more reflective model users. The three main model providers have different approaches, and loss estimates belonging to certain key catastrophe events (such as a Miami hurricane or a San Francisco earthquake) began to assume an "anchoring quality" in characterizing the quality of a particular model. There is a parallel process of distinguishing among Global Circulation Models by policy makers through models' estimates of future temperature rise (van der Sluijs et al., 1998). The credibility of the catastrophe models, while moving through a learning cycle of expectations of the science, did not diminish the models' placement in the reinsurance tool box. As one reinsurance underwriter remarked, "What else do we have?" (personal communication, 2000). In fact, some expressed a modest optimism that as catastrophes continued to occur, the models could only become better calibrated. In addition to purchasing third party models, the Bermudan reinsurers have also created models in house to in part to test against the black boxes.

While interest remained high among reinsurers for this assessment product, the degree of openness to different sources of expertise began to change. Logistical and technical infrastructures in the firms began to form around catastrophe models and their formalized input requirements. As the models gained greater market presence, conferring substantial informational benefits in a translation of the science to reinsurance decision making frames, other sources of "raw" expertise diminished in applicability. These included rough estimates of return period forecasting, the broker's file on the risk, or rough and ready assessments of hazards as available in the publication CRESTA jointly managed by Munich Re and Swiss Re. In effect, the models complement and to some extent challenge these older forms of underwriting expertise, leading to a type of "knowledge lock-in" in the specifications of the model.

This process is analogous to Sante Fe Institute economist Brian Arthur's observation of technological lock-in (1989), i.e. the tendency of economic systems to adopt technologies through historical contingency, and be shaped in what other technologies penetrate the market by these earlier versions. Taking the comparison back to the "knowledge lock-in" in catastrophe companies, the presence of the model in the firm congeals a particular entry of hazard assessment to the reinsurer, molding data requirements and evaluation methods to conform to a market wide standard. Indeed, the visibility and the sophistication of the technology soon led to its adoption by many overseas reinsurers. Keeping in mind the numerous uncertainties involved in catastrophe modeling, the standardization of catastrophe risk assessment expertise through the models promotes their transportability among different firms and in different areas of the same firm.

The models as artifacts, as standards, and as decision tools, are used as symbolic credentials in the market. Since the founding of the Bermudan reinsurers, the models have gone beyond a tool for only the most specialized in the business to a standard and indicator of prima facie expertise. As such, the purchasing of catastrophe models is a type of symbolic *knowledge leveraging*. The catastrophe modeling products may also influence expectations of predictability in the sciences and the extent to which the models displace the routine tacit knowledge of many older reinsurance underwriters, and their "feel for the risk". According to a number of studies in forecasting and resource management, success in prediction breeds further societal expectations of predictability (Holling, 1995; Sarewitz et al., 2000).

At the same time, the technical capacity of reinsurance practitioners to judge models and use them under appropriate caveats may range markedly from one firm to another (Golnaraghi, 1997). This variation is mostly due to the highly technical and knowledge intensive nature of the models, the lack of transparency of the model design to third parties, and the non scientific training of most reinsurance underwriters. It is a similar issue to that faced by climate change scientists and the *epistemic capacity* of policy communities. The policy makers employing the climate model usually do not hold expertise of the disciplines used in the model, thereby causing a gap between the modeler's tacit assumptions and understanding of the uncertainties and role of the models as verifiable, visible knowledge (Shackley and Wynne, 1996).

In a parallel to climate modeling outcomes and their roles in international negotiations, catastrophe models and the assessments provided should be viewed within the caveats of modeling endeavors generally (Casti, 1997a). The simulation by the model is a representation of reality, and is constructed on the foundations of assumptions of the science communities involved, the modeling translation, the epistemologies and methodologies brought to bear, and the contemporary understanding of the physical systems (Casti, 1997b; Morgan and Morrison, 1999). Indeed, Munich Re geophysicist Ernst Rauch cautions against taking the models as literal forecasts, stating (Dowding, 1998)

> "It is important to understand that there is a big difference between catastrophe prediction and catastrophe modeling. The term 'prediction' is very often used in a misleading way as it is impossible for anybody to predict catastrophes by means of the exact location, time and intensity of the event. 'Catastrophe modeling' allows the insurance industry, based on scientific and statistical methods, to have a technical, sound understanding of loss occurrence probabilities from a long term perspective."

One main role of the models has been to provide a "technical" price for a particular risk, in order to compare to market rates and also sometimes to justify certain corporate strategies. For example, some reinsurers may abstain from accepting risk contracts they consider underpriced, according to the model evaluation. At the same time, the pressure for premium income as evidenced in the market currently

would place great shareholder pressure on such model based approaches. The competition in catastrophe reinsurance pricing allows very limited opportunities for the model outputs to remain sticky on underwriter's pricing. Therefore, similar to political priorities vitiating recommendations based on climate models, the outputs of catastrophe models could be ineffective in the face of market pressures.

The importance of continuity, relationships, and market share strategies also play a large role in reinsurance practices. Much of the catastrophe reinsurance market relies on client commitment to long term risk sharing. In light of these contextual considerations, it may be said that the models serve a stronger role as exposure monitors and simulation enablers than as market pricers or as a handmaiden to decision outcomes. This role is consistent with much of the GEA project's findings that environmental assessments are most effective in shaping the perception of knowledge needs and the terms of the debate rather than effecting changes in policy decisions.

Catastrophe modeling firms do not offer open access to the design or sensitivity of their models. As private sector producers, the firms market the models as solutions. This confidentiality can be problematic to evaluations, affecting the credibility and legitimacy of the models. However, the models serve a variety of functions among the practitioner community as noted above. As such, the uncertainties in the models are considered along with their marketing value to reinsurance clients and the relevance to the decision environment.

While reinsurers do not participate in the assessment design of catastrophe models, they are active in its refinement. The models provide a good deal of integrated information, and practitioners have their own opinions on how the information can be more effectively presented to be more commercially useful. Tim Mardon, underwriting vice president of Bermudan reinsurer Tempest Re suggests that (Dowding, 1998)

> "all perils covered by a reinsurance treaty must be included; all assumptions need to be independently verifiable; consistency between model versions needs to be maintained (or very good reasons given why it is not); and costs need to be minimized."

This dialogue between modelers and practitioners echoes Moser and Cash (1998) in their search to understand "what produces effective information and decision systems for addressing climate change, and [how can one] integrate that understanding into management systems." Indeed, the Risk Prediction Initiative in Bermuda set itself this question in the case of tropical cyclones.

RISK PREDICTION INITIATIVE

The Risk Prediction Initiative is an industry – academic research consortium formed soon after Hurricane Andrew as part of the Bermuda Biological Station for Research. At the time of its inception, interest among reinsurers for catastrophe assessments and favourable market conditions releasing reinsurers' financial resources had both reached a crest. Thus, there existed great momentum in providing a financial infrastructure for this type of expertise – reinsurance interaction. The RPI framed their approach as the open alternative to catastrophe models.

It stated (Malmquist, 1997: 36)

> "Existing risk models use different proprietary techniques. Because these techniques are proprietary, it is impossible to determine how the assumptions they employ affect their quality. Yet models using different proprietary techniques often generate significantly different losses for the same insurance portfolio. Some consistency or public validation

> of these risk models would help model users justify, both to themselves and their clients, that the model-derived decisions they make are valid. Because it is difficult to persuade competing companies to make their models public, it may be expedient to create a public, peer-reviewed wind model. Insurers could use this model as a baseline to compare their various proprietary data sets. Equal access among insurers to a public, peer-reviewed model would improve confidence in existing models."

The interface, the RPI, serves as a pooling body: it collects the funding streams from the reinsurance companies and contracts work to various researchers at the Biological Station as well as in the United States. The focus is to improve the ability to forecast tropical cyclones, i.e. those water bound storms that could form (landfalling) hurricanes. A selection of the RPI research mission is provided in Table 3 (Malmquist, 1997).

As Table 3 notes, much of the work is directed at the refinement of the science with little if any formal translation to insurance practices. Since many scientists working on these projects come from within the culture of academia, there is a significantly different character to this interface than that of the catastrophe modeling firms. Due to the wish lists of their majority funders, the reinsurers, the scientists negotiated which scales of analysis and data sets were most relevant to pursue investigations, while the incorporation of the results in the reinsurers' daily decision routines was less discussed. Indeed, researchers at the RPI view their commitment to academic science (funded by reinsurers) in part as the production of peer reviewed articles and attendance at conferences. The reinsurers, on the other hand were less interested in the polished standard of proof of the academic article. They sought strategic expertise: i.e. results that would provide a greater standard of accuracy than already exists. The first "model" of interaction, that of production of academic science for reinsurance, went through a learning cycle in which the RPI realized that the interface itself was as much a concern as the production of the science.

The expertise – reinsurance interactions were usually concentrated in workshops held at the RPI, in which numerous academic hurricane and climate experts would be invited to present their views. Prominent hurricane scientists, such Bill Gray from Colorado State University, Jim Elsner of Florida State University, Christopher Landsea at the National Hurricane Center, and Kerry Emanuel of MIT, offered different "expert opinions" on hurricane dynamics at several RPI workshops. It was not rare for the reinsurers assembled to witness a face to face contested discussion on the science of hurricane formation or the forecasting of future Atlantic hurricane activity. Thus while there exists greater openness in participation and sources of expertise in the RPI increasing the legitimacy of the assessment, this inclusion of the multiple views within the sciences risks could decrease the credibility of the product as authoritative. In this sense, this boundary organization has provided a conduit for reinsurers to gain direct access to the pluralism that exists within a scientific field.

Since its inception in 1992, the RPI has been exhorted by its reinsurance funders towards ever greater specificity to reinsurance needs in its research products, for example from a focus on forecasting hurricane activity in general to forecasting *landfalling* hurricanes. Moreover, there has been greater pressure from reinsurers to have such expertise formed to accommodate the renewal seasons – i.e. to have such forecasts by November of the *preceding* year. It is not uncommon for funding to be moved among scientists as reinsurers request greater specificity or change the focus of their epistemic or knowledge needs – for example towards the vulnerability of different building materials to hurricane intensities.

Part of the interesting contingency with which the Risk Prediction Initiative finds itself as a boundary organization funded by the private sector is that it depends to a certain degree on the state of reinsurance

markets. In current times of great market competition, few catastrophes, and low premium income, there is greater hesitation on the part of reinsurers to maintain a financial obligation to basic scientific research with an applied component. Indeed, as one reinsurance underwriter remarked, "This is a loss driven business." Catastrophes deplete capital in the market, allowing the steep increase in prices, less competition, profits and a greater allowance for external funding Since Hurricane Andrew, rates for catastrophe reinsurance have only declined, sometimes by as much as 33% per year. Due to great competition and short time frames, the reinsurance markets hold short memories. After a few relatively mild catastrophe years, other reinsurance goals such as the level of premium income and market share begin to dominate practitioner priorities.

Indeed, reinsurance timeframes favor very swift research products that suit a very particular decision need. To a certain extent, the perfection of the research result is not as important as its access. Therefore, the level of acceptable uncertainty in academic science and reinsurance differ, with reinsurance tolerant of greater relative uncertainty, while academic research stress that propositions should be nearly perfect – i.e. as certain as possible. Dissent, such as the lack of consensus among hurricane and climate scientists, is treated as a part of this "evolving science" and therefore from the reinsurance perspective bound to have such controversies. The effectiveness of the RPI products depends on the structuring of the science – practitioner interface, and their incorporability into wind models and other products similar to those reinsurers already use.[11] Participation in the RPI can also be seen as a credibility credential for reinsurers; at the same time they participate in the same pool of knowledge as their competitors, learning all the while of the complexities involved in scientific assessments for industry.

CONCLUSIONS

In this concluding section, the main questions of the study will be revisited, with an aim to provide a few integrating thoughts on the effectiveness of hazard assessments as decision support systems for reinsurance practitioners. The main questions of the paper comprised:

1. How do reinsurers of catastrophe risk make use of, and debate on a daily basis, assessments provided by academic science, by private catastrophe modelers or by IPCC reports?
2. How salient and effective are these assessments within the context of competing priorities of the practitioner? Within different temporal and spatial frames?
3. How does the credibility of the assessment as product affect the assessment as process with respect to uncertainty and legitimacy?
4. How do reinsurers communicate their assessment needs to the scientific community?

These questions have been addressed in the paper with respect to the saliency, credibility, and legitimacy of two forms of assessments, the catastrophe model and the Risk Prediction Initiative. Both are constrained by practitioner interest, openness and capacity. Both are also influenced by the structure of the expertise – reinsurer interface, the procedures of participation in the assessment, and the handling of uncertainty and dissent. The two main differences in the two examples, the proprietary model versus the participatory strategic expertise provided by the Risk Prediction Initiative, become the levers over which to discuss effectiveness of the two assessments.

As influencing pricing decisions (i.e. change in decision making outcomes), the two assessments find their effectiveness constrained by the level of market competition. The dominance of traditional market practices influenced by relationships to brokers and clients and the loss driven mentality of reinsurers does little to promote effectiveness towards pricing decisions in the market as a whole. While the market does not act in consort on pricing, there is little that a few small or medium sized firms can influence.

However, they do influence the perception of knowledge needs, the terms of the debate, the issue frames and agendas, and in some cases, the strategies of the key players.

The effectiveness of the catastrophe model lies not so much in the opening of its assumptions. Most reinsurance companies have developed in – house models to calibrate answers to the catastrophe models they may also purchase. The catastrophe model represents very specialized scientific knowledge integrated to produce a measure of damage on one's portfolio. The underwriters take the models "with a grain of salt" but at the same time, the dissemination of the models across the industry serve to keep the salience of catastrophe risk in the minds of practitioners and credibility of scientific assessment capacity. Therefore, there is a certain recognition that the industry as a whole is operating with the same tools, the same uncertainties, and the same omissions. Indeed, the first priority of the reinsurance company is not to understand the climate or the generation of a hurricane. It is to produce end of year results that outperform the competition, and to maintain client continuity and pricing stability. The legitimacy of the assessment is thus not tied to its credibility. It is legitimate because the catastrophe model has become a standard tool, albeit not as a prediction machine.

In investigating the characteristics of the science/commerce interface, the catastrophe modeling company does resemble in certain ways a boundary organization in the mediation of science and commerce. The companies employ PhD scientists to contribute to the modeling of the natural hazard probability and the vulnerability of the properties concerned. The financial translation of these two components are represented by modules on the repair costs of the hypothetical events and finally by a loss evaluation according to the terms of liability of the reinsurance company. Integration occurs within the firm, often employing former reinsurance practitioners to further match the scientific expertise employed with the needs of industry. Thus participation is limited to those with a connection to the company. It was not possible to inquire how uncertainty and dissent was treated in the model product, but internal validation of the model and verification against past known events do provide some standards of reference.

The first joint industry – academic workshops of the Risk Prediction Initiative were those of optimism towards the incorporation of science for reinsurers. At the same time, the initial specialization by the Bermudan reinsurers in catastrophe reinsurance boosted the salience of the Atlantic hurricane threat. Workshop participation of prominent academic scientists was outstanding, with reinsurers coming into direct contact with a range of scientific approaches to hurricanes and climate. While this participation increased the legitimacy of the assessment, the reinsurers are more concerned with how the expertise can directly improve their expectations of loss trends next year. The short term and very directed focus of reinsurers contrasts with the long term and knowledge building approach in the academic sciences. However, the public nature of the RPI improves the capacity of the reinsurers to know the range of expertise in existence, and to evaluate expertise as it is given within this range. For example, they have references points of academic knowledge, to compare and contrast in the formation of their recognition of "the science." On the other hand "the science" is broadly understood to be developing, with increased predictability as its goal.

In response to the four questions above, it is worthwhile to regard the reinsurer's approach towards expertise as a combination of familiarity with particular *people* and a *resonance* with the practitioner's frames of reference. Most if not all the reinsurers interviewed knew Bill Gray, James Elsner, and Christopher Landsea. Many have met them in person, either at workshops or conferences. Their status as the hurricane gurus is not one of expert prediction, but rather as scientists with differing "expert opinion." Thus in the RPI assessment context, the forecasters have become in a sense not simply external perspectives, but also part of the dynamics of the expectation of the assessment itself, as the "entire social process by which expert knowledge related to a policy problem is organized, integrated and presented in documents to inform policy or decision making."

The most salient entry of scientific expertise in reinsurance decision making has been the catastrophe model, which functions both as a simulator and a monitor of reinsurance exposure worldwide. While the models contain numerous uncertainties, they represent an epistemic or knowledge credential in the industry as a whole. Information provided by the IPCC assessment did not enter the decision routines of the reinsurer, more likely due to the differing temporal and spatial resolution of climate models, and the fact that such models have come under increasing skepticism by reinsurers since a change in estimates of storminess over several IPCC reports.

The saliency and effectiveness of these sources of expertise depend on their ease of translation into insurance epistemology of finance and statistics (Elsner, 1999). The practitioner does not have time to perform the necessary links – it must be presented as integrated and relevant, and at the same time present the impact on losses. The uncertainties in the assessment are compared with other domains of uncertainty to the practitioner, such as the financial markets, political and legal conditions, competition, and client continuity. The annual time frame and the rigidity of information requirements before the renewal seasons places reinsurers at a disadvantage vis à vis the financial markets, which move on the basis of continually updated information and an anonymous exchange of capital and risk. Cycles of capital capacity in the market then directly influence the ability of the reinsurance underwriter to provide decisions that can be maintained in the market, in other words, capital influences the effectiveness of these scientific assessments.

The credibility of the assessment as product could affect the credibility of the assessment as process. The catastrophe models and their ability to forecast events, or estimate losses, is a part of most catastrophe reinsurers' toolbox. If the models do not converge, or are otherwise inconsistent with respect to the input data provided by reinsurers, then the assessment as process as evidenced in the RPI is framed in terms of "a developing science."

Finally, the reinsurers use a number of communication processes to provide feedback to the assessment providers. With respect to catastrophe modeling firms, reinsurance practitioners are sometimes hired full time by the firms, promoting the exchange of integrated knowledge from the practitioner's perspective and scientific capacity. On the other hand, feedback from practitioners themselves is not as frequent or detailed as in the Risk Prediction Initiative. The Initiative, through the generation of "wish lists" from reinsurers, is able to provide a baseline for reinsurance needs on specific expertise. Another manner of communication has been conferences in which scientific societies communicate their expertise to reinsurers. Many such exchanges also happen informally in RPI sponsored events and at national insurance gatherings.

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TABLES

Table 1: Factors in Assessment Effectiveness

- change in the natural environment
- behavior of key actors
- strategies of key actors
- issue frames and agendas
- terms of the debate
- perception of knowledge needs

Table 2: 10 Most Expensive Natural Catastrophes for Insurers at 1999 prices (Sigma/Swiss Re, 2000)

Event	Region	Date	Insured Loss ($ billion)
Hurricane Andrew	USA	1992	19.060
Northridge Earthquake	USA	1994	14.122
Hurricane Mireille	Japan	1991	6.906
Winter Storm Daria	Europe	1990	5.882
Hurricane Hugo	Puerto Rico	1989	5.664
Winter Storm Lothar	Europe	1999	4.500
Autumn Storm	Europe	1987	4.415
Winter Storm Vivian	Europe	1990	4.088
Hurricane George	USA / Caribbean	1998	3.633
Typhoon Bart	Japan	1999	2.980

Table 3: Areas of research for the Risk Prediction Initiative

1. Improve basic understanding of tropical cyclones and their link to climate
2. Improve the skill of seasonal and multi-year forecasts of tropical cyclone landfall probability
3. Determine fidelity of various proxies for tropical cyclone landfall
4. Create global landfall teleconnection maps
5. Create/compile public data sets related to landfall of tropical cyclones in key cities/regions
6. Support improvement and comparison of physical models for seasonal to interannual forecasting of global tropical cyclone landfall
7. Participate in and sponsor special sessions at scientific meetings

ENDNOTES

[1] The obstacles to effective assessments as lack of compatibility of the assessment product cycle and the evolving needs of the policy process, a lack of scientific credibility, ambiguous standards of evidence and argument, and a lack of political legitimacy.

[2] According to Kamford (1995), the adjusted values of Hurricane Betsy place it at about $4.3 billion in 1994 prices.

[3] Jacqueline Meszaros (1997) "The Cognition of Catastrophe: Preliminary Examination of an Industry in Transition" Working Paper, Wharton Risk Management and Decision Processes Center, Philadelphia.

[4] The report, however, presented the loss values as given, thus not entering a discussion of current monitoring practices.

[5] Moreover, these insured loss figures are only a fraction of the total economic losses.

[6] It is notable that until last year, the Kobe earthquake ranked 9th in this listing. However, Japan relied much more on state protection in the event of earthquakes, and did not purchase much private protection (at the same time, the total economic losses for Kobe are among the highest for any catastrophe). Kobe as an insured loss event was superceded by three windstorms in 1999.

[7] The frequency of windstorms has actually decreased over this century (Smith, 1999).

[8] The forecasts were of Dr. William Gray at Colorado State University, Dr. James Elsner of Florida State University, Dr. Mark Saunders at University College London, and the NOAA-CPC/National Hurricane Center.

[9] For example one firm estimated a $53 billion loss for a class 5 hurricane moving thro ugh Miami, and $52 billion for New York class 4 hurricane (Dlugolecki, 1995).

[10] For Japanese contracts, this occurs in April, and for Australian contracts, in July.

[11] Indeed, Peter Jennings on ABC News referred to hurricane research as "an imperfect science" thus promoting a framing or indeed a hierarchy of the sciences based on predictability (Jennings, May 2000).

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