

# Availability and Affordability of Insurance Under Climate Change: *A Growing Challenge for the U.S.*

*Evan Mills, Ph.D.  
Richard J. Roth, Jr.  
Eugene Lecomte*



December, 2005



Commissioned by



**Ceres**

**Availability and Affordability of Insurance  
Under Climate Change  
*A Growing Challenge for the U.S.***

Evan Mills, Ph.D. • Richard J. Roth, Jr. • Eugene Lecomte

*Commissioned by*



**Ceres**

**This White Paper was commissioned by Ceres**, a national coalition of investors, environmental groups, and other public interest organizations working with companies to address sustainability challenges such as climate change. Ceres also directs the Investor Network on Climate Risk, a group of 50 institutional investors from the U.S. and Europe managing nearly \$3 trillion of assets. This update of the original report released September 7, 2005 contains expanded analysis, source material and discussion of lessons learned from Hurricane Katrina. Helpful comments were provided by Tim Wagner (Nebraska Insurance Director), Nettie Hoge (California Insurance Commission), Paul Epstein (Harvard Medical School), Richard Roth, Sr., (Actuary), Nancy Skinner (environmental policy analyst), Andrew Dlugolecki (insurance and climate expert), David Unnewehr (American Insurance Association), and Andrew Logan (Insurance Program Director, Ceres). The opinions expressed herein are those of the authors.

**[www.ceres.org](http://www.ceres.org)**

### **About the Authors**

**Dr. Evan Mills** is a scientist with the U.S. Department of Energy's Lawrence Berkeley National Laboratory, where, for the past 10 years, he has led a research initiative on insurance loss prevention. He served as co-leader of the 2001 Intergovernmental Panel on Climate Change (IPCC) analysis of the potential impacts of global climate change on the financial services sector. He has published 50 articles and reports on the subject, including a recent article in the journal *Science*.

**Richard Roth, Jr.** specializes in the financial examination of insurance companies, reinsurance, workers compensation, automobile insurance, and insurance against natural hazards. He was Chief Property and Casualty Actuary for the Department of Insurance, State of California, for 20 years, and Assistant Commissioner from 1984 to 1990. He is now associated with Bickerstaff, Whatley, Ryan & Burkhalter, a leading actuarial consulting firm in the United States and internationally. He served as Chairman of the Casualty Actuarial (Technical) Task Force at the NAIC, and was active on the two catastrophe insurance committees addressing catastrophe insurance issues for all types of insured natural disasters. Mr. Roth served twice on the Board of Directors of the Casualty Actuarial Society, and has been one of the delegates representing the Society to the International Actuarial Association. He has testified on natural disaster and earthquake insurance before the California Legislature numerous times, and three times on earthquake insurance issues before the United States Congress.

**Eugene Lecomte** is President Emeritus of the Institute for Business and Home Safety. A veteran of more than fifty years in the insurance business, Mr. Lecomte has served as President and CEO of the Insurance Institute for Property Loss Reduction, the National Committee on Property Insurance, and the Property Insurance Plans Service Office. He also served as President of the Massachusetts Automobile and Workers Compensation Rating Bureaus, and Executive Director of The Earthquake Project.

*Sponsored by grants from the Energy Foundation, The Pew Charitable Trusts, the Rockefeller Brothers Fund, and the United Nations Foundation/Better World Fund. The opinions expressed in this report are those of the authors and do not necessarily reflect the views of the sponsors.*

---

## TABLE OF CONTENTS

Foreword .....	1
I. Key Findings .....	2
II. Overview .....	5
III. The Erosion of Insurability .....	12
IV. Governments and Individuals as “Insurers of Last Resort” .....	13
V. Insurance Challenges Across the U.S. ....	16
VI. Pressure on Insurance Affordability and Availability Under Climate Change .....	30
VII. The Way Forward—Proactive Measures .....	32
Postscript—In the Wake of Hurricane Katrina .....	37



---

## Foreword

Hurricane Katrina is a poignant reminder of the threat that extreme weather events pose to U.S. insurers, government and consumers. It is the clearest signal yet that insurers face a new era of risk from rising weather-related losses and that new strategies and approaches are needed, especially as climate change impacts become more pronounced.

This white paper was prepared immediately prior to Hurricane Katrina by a three-person collaboration that included a scientist, an insurance actuary and former regulator, and an insurance veteran of 50 years. The paper explores the insurability of risks from extreme weather events and climate change, and ways in which insurance affordability and availability could be adversely impacted in the U.S. in the coming years. It includes examples where affordability and availability of insurance are already at risk from rising weather-related losses and how future financial exposure for insurers, governments, businesses and consumers could worsen if current climate and business trends continue.

In the hurricane's aftermath, the authors updated this report with a "Katrina Postscript," outlining the enormous financial losses for insurers and the likely fallout for consumers, businesses and governments. Estimated insured losses are already ranging as high as \$60 billion, double the record losses from last year's spate of hurricanes combined. Rating agencies are putting large insurers such as Allstate and State Farm on notice for possible ratings downgrades. Significant premium increases, tightening terms and market withdrawals are sure to come next, echoing what happened in Florida following last year's storms. (In fact, Allstate has already announced it will be scaling back its homeowner's insurance in the Gulf region due to "unacceptable" losses from Hurricane Katrina.) The bottom line: Katrina will be a real-world "stress test" of how well the insurance industry, its customers, and governments can withstand catastrophic losses.

One positive development in the wake of Katrina is that more insurance companies, investors and regulators are taking notice of this emerging problem. Insurance giant AIG is now saying publicly that climate change poses real risks to insurers and that actions are needed. A growing number of institutional investors, many of them members of the Investor Network on Climate Risk, are asking insurance companies to evaluate their financial risks from climate change. Even before Katrina, the National Association of Insurance Commissioners (NAIC) was planning to discuss climate change at its next membership meeting. That discussion will now take place in early December in Chicago since NAIC's fall meeting in New Orleans was cancelled.

The challenge now is taking concrete action. Despite U.S. catastrophic losses growing 10 times faster than premiums since 1971, insurers and regulators have done little so far to address the growing risks from weather-related losses and climate change. This report includes specific recommendations for addressing this growing insurance challenge and we hope they will receive serious consideration in the coming months from insurers, regulators and government officials.

Mindy S. Lubber  
President of Ceres  
Director of Investor Network on Climate Risk

---

*Hurricane Katrina will be a real-world "stress test" of how well the insurance industry, its customers, and governments can withstand catastrophic losses.*

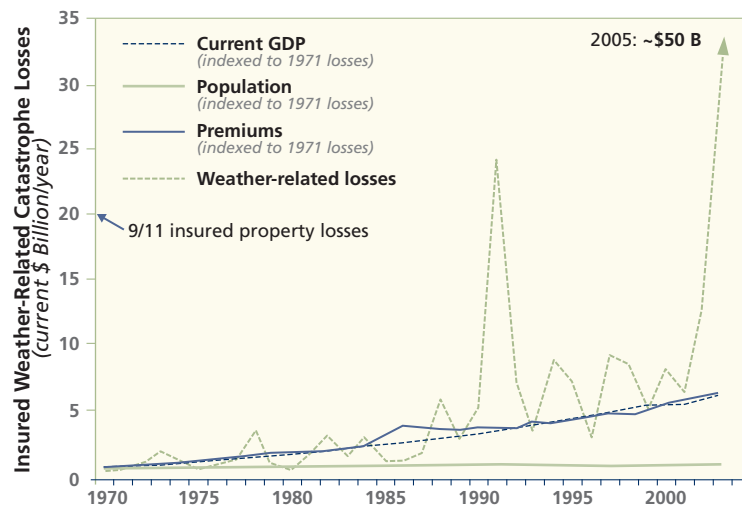
---



## I. Key Findings

History has shown that insurers and their customers can be adversely affected by weather extremes. Catastrophic weather-related insurance losses in the U.S. are rising significantly faster than premiums, population, or economic growth, and many smaller events are not even included in official totals (Figure 1). Even before Hurricane Katrina, rising losses were already being felt in parts of the country, and if trends persist, the impacts of climate change in the United States—which scientists believe is being caused primarily by human activities—will inevitably result in more insurance claims and increased costs. These higher losses, in turn, will lead to higher premiums and deductibles, lowered limits, and broader coverage restrictions. The convergence of climate change with demographic and socioeconomic trends, such as the tendency for people to move to high-risk areas, will further compound the impacts. Relevant weather- and climate-related factors include floods, windstorms, thunderstorms, hailstorms, ice storms, wildfires, droughts, heatwaves, lightning strikes, subsidence damages, coastal erosion, and a spectrum of health implications such as a rise in mold and pollen. Most insurance lines are climate-sensitive, although certainly to varying degrees.

**Insured U.S. weather-related losses are growing 10-times faster than premiums and the overall economy, and even faster when compared with population.**



**Figure 1. Insured U.S. weather-related losses are growing 10-times faster than premiums and the overall economy, and even faster when compared with population: 1971–2004.**

The losses shown above include only the two or three dozen events per year that are tabulated, omitting thousands of small events each year not considered catastrophic. Non-weather-related losses have risen much more slowly than weather-related losses. In the figure, GDP, population and premiums are indexed to 1971 loss levels to facilitate comparison. Premiums include weather-sensitive segments and exclude workers compensation, automobile liability, medical malpractice, accident-health, surety, and other miscellaneous losses. Loss cost, premium, and GDP data reflect values in year incurred; relative changes are the same if inflation-corrected. Sources: Loss data from ISO/PCS and Munich Re NatCatService, Premiums from AM Best Aggregates & Averages; and the Insurance Information Institute

Climate stresses will also place more political and financial burden on reluctant federal and local governments as they assume broader exposures and are pressured to serve as insurers of last resort. The most recent example is renewed calls in the wake of Hurricane Katrina for the federal government to establish a national catastrophic insurance fund, which is essentially a reinsurance backstop to safeguard private insurers and their customers.<sup>1</sup> Governments also are compelled to address events for which there is no insurance at all, while paying for disaster preparedness and recovery operations. A recent example of this: federal and local governments are incurring substantial liability and expenses due to landslides in southern California, with losses averaging \$100 million per year.<sup>2,\*</sup> Business and consumers will be

\* There have been occasional and minimally-subscribed private insurance offerings for landslides in California, priced several times higher than comprehensive homeowners insurance (and must be purchased on top of that insurance), with exclusions for neighborhoods that have experienced landslides in the past.

---

burdened because cash-strapped governments generally cap paid losses and shift greater portions of risk back to consumers. Risk sharing by consumers is certainly appropriate, to a degree, insofar as it encourages responsible behavior and loss prevention. Given the critical role that insurance plays in the U.S. and global economy, reduced access to affordable insurance would have profound impacts on both consumers and businesses, whether from reduced access to basic mortgage financing or loss of business-interruption insurance for offshore oil rigs.

Some of these far-reaching scenarios are already unfolding. In Florida, the wave of hurricanes in 2004 prompted substantial rate increases, despite which seven private insurers stopped writing homeowners policies in the state or withdrew from the market altogether. The effects of Hurricane Katrina—likely to become the costliest natural disaster in world history—will be even more significant than last year’s four hurricanes combined.

In Massachusetts, the state’s FAIR Plan\* recently requested a substantial (up to 25 percent in some parts of the state) rate increase to cover **future** natural disaster losses. This is unprecedented; price increases have until now been predicated strictly on historical loss experience.<sup>3</sup> Meanwhile, government-provided crop and flood insurance programs are experiencing rising losses, wildfire events are causing two times more damage compared to a few decades ago, and coastal erosion insurance is entirely unavailable. The latter issue is an especially acute concern because climate change is expected to cause a twin combination of sea level rise and stronger storm surges, a direct physical threat to many coastal properties in the U.S.

Yet, despite its role in these emerging challenges, climate change has received relatively little attention to date in the United States from government, insurers, and regulators. Although we are witnessing a precipitous rise in weather-related losses in the U.S., and numerous projections that climate change will magnify those losses in the years ahead, only a small fraction of potentially impacted U.S. insurance companies have seriously examined the business implications, and fewer still work closely with climate scientists or present their analyses publicly. Nor has the U.S. government assessed its own financial exposure from weather-related disasters (e.g., as crop and flood insurer, provider of disaster recovery, or owner of at-risk infrastructure). Remarkably, the world experiences a “9/11” each year in weather-related catastrophes, yet the issue receives only a tiny fraction of the attention as does the problem of terrorism. In Nebraska, hailstorm losses alone are more costly on a per-capita basis than New York’s losses from 9/11.<sup>4</sup>

Widespread data gaps and limited computer modeling capabilities hamper the industry’s ability to respond. Insurers and their regulators as yet have no comprehensive capacity to assess the cumulative weather-related risks from both catastrophic events and the growing number of small-scale events, which represent 60 percent of insured weather-related losses globally.

It is incumbent on insurers, regulators, policymakers and other stakeholders to develop a better grasp of the physical and business risks from the climate change issue. A recent study<sup>5</sup> found that SEC disclosure of climate change related risks among publicly-traded insurance companies in the U.S. is very poor. Climate risk reporting remains comparatively low in this sector, with only four of the largest 27 property and casualty insurers reporting (15 percent). The five insurers reporting on climate change risks in their 2004 annual SEC filings were Allianz, Aspen Insurance, Chubb, Cincinnati Financial Corporation, and Millea. Allstate did so in 2003 but did not in 2004.

---

*Government-provided crop and flood insurance programs are experiencing rising losses, wildfire events are causing two times more damage compared to a few decades ago, and coastal erosion insurance is entirely unavailable.*

---

---

\* Fair Access to Insurance Requirements (FAIR) and Windstorm Plans, are generally mandated by the state and administered by the insurers. Most insurers are required to be members of these so-called “Residual Market Mechanisms,” which aim to make insurance available to those who have been unable to gain it through the voluntary market, and involve various combinations of public (State) financing and allocation of premiums and liabilities to all insurers in a given market. Today, they serve about 1.5 million policyholders and represent \$345 billion in exposure. For a good primer, see Insurance Information Institute, <http://www2.iii.org/media/hottopics/insurance/residual/>



---

Armed with improved intelligence, the private sector would be able to better address potential market failures and thus reduce economic fallout on insurers of last resort (local, regional, and national governments). Tackling this challenge will require unprecedented cooperation and collaboration among various stakeholders (insurers, their regulators, governments, scientists, and insurance customers). Each group can bring valuable insight and talent to assessing the risks and implementing appropriate loss-prevention measures. There is a precedent for such cooperation. Devastating earthquakes in California prompted a far-reaching, positive collaboration in the 1980s among state and federal regulators, engineering firms, earthquake scientists, and other parties to better manage earthquake exposure and its potential impacts on the industry. These efforts improved the technical ability of state insurance regulators to supervise earthquake insurance companies, with the proviso that considerable affordability and availability problems remained.

We recommend the following actions by these key players:

---

**Tackling this challenge will require unprecedented cooperation and collaboration among various stakeholders (insurers, their regulators, governments, scientists, and insurance customers).**

---

### Insurers

- Strive to improve loss data collection and enhance the actuarial analysis.
- Analyze the negative and positive implications of climate change on their business, investments, and customers, and share the results with shareholders.
- Vigilantly and vigorously promote and support advanced building codes, the “fortified building” concept, and tools to mitigate potential losses.
- Engage in weather/climate research and promote the use of scientific methods for enhanced climate modeling.
- Create an industry-driven activity improving on the climate change insurance working group that was briefly active in the mid-1990s.\*
- Lead by example in reducing their corporate climate footprint.
- Encourage policy action and technical measures to achieve greenhouse-gas emissions reductions, especially where there are direct collateral benefits for the insurance core business.

### Insurance Regulators

- Review the “standards of insurability”<sup>6</sup> to identify new challenges, domestically and abroad.
- Incorporate climate risks in solvency and consumer-impact analysis.
- Encourage insurers to collect and analyze more comprehensive data on weather-related losses.
- Elevate the practice for catastrophe modeling.
- Assess exposures of insurer investments and adequacy of capital and surplus to weather extremes.
- Explore the feasibility of developing a weather exposure (large and small events) questionnaire.
- Identify and remedy undue barriers to constructive insurer activities.

### Governments

- Foster and participate in public-private partnerships for risk spreading.
- Reduce disaster losses through improved planning and post-event response.

---

\* Members included The Alliance of American Insurers, American Insurance Association, The Insurance Institute for Property Loss Reduction, National Association of Independent Insurers, National Association of Mutual Insurance Companies, Reinsurance Association of America, and State Farm Insurance Companies. A letter from this group to then Vice President Gore is reproduced as Appendix F in Mills *et al.* (2001). This group existed for only a brief period and did not have any lasting impact.

- Comprehensively assess the government’s overall financial exposure to changing patterns of weather disasters.
- Expand basic research on climate change and loss modeling, and issue climate change hazard maps.
- Take policy action to reduce greenhouse gas emissions.

### Consumers

- Minimize disaster losses through the use of recognized pre-loss mitigation practices.
- Curb emissions that cause climate change, primarily by making cost-effective energy efficiency improvements and increasing the use of carbon-free energy sources.

Markets expect insurers and their regulators to be more than fair-weather friends with regard to climate change. A key next step is to develop a better understanding of the exposures and the potential physical and market consequences for the industry and its vast customer base. The task is surely daunting, but not nearly as much as coping with the impacts of a business-as-usual scenario.

*In Florida, 15 to 20 percent of the losses from the 2004 hurricanes were borne by consumers.*

## II. Overview

At various points in history, insurers have encountered changes in their market environment that have precipitated structural shifts in their industry and the broader societal handling of risk.

The great dust bowl of the 1930s challenged crop insurers, urban riots of the 1960s challenged property insurers, and today terrorism simultaneously challenges multiple insurance lines, ranging from workers compensation to business interruption to political risk. The Great Midwest Flood of 1993, Hurricane Andrew in 1992, and the Northridge Earthquake of 1994 brought natural disasters to the fore and led to fundamental problems of affordability, exclusions, and insurability. Each event, in its own way, brought home the fact that the past is no longer a predictor of the future. These historic events all have a common element of surprise: they were not believed possible or existing science was ignored. Most recently, the Department of Homeland Security stated that the scale of Hurricane Katrina was beyond anything the department could have anticipated<sup>7</sup> yet there was significant prior understanding of New Orleans’ vulnerability.<sup>8</sup> These events resulted in establishment of public-private programs, and many proactive responses such as improved catastrophe modeling and a host of loss-prevention activities. They also led to greater (and not always welcome) retention of risk by consumers and businesses (e.g., by shifting from fixed to percentage deductibles\*). The effect of such changes is substantial. In Florida, 15 to 20 percent of the losses from the 2004 hurricanes were borne by consumers.<sup>9</sup>

First recognized by insurers in 1973,<sup>10</sup> climate change is expected to increase the damages from natural disasters, according to the latest International Panel on Climate Change (IPCC) Assessment. The problem centers on a build-up of “greenhouse” gases like carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons caused by fossil fuel burning, industrial activity, certain agricultural practices, and deforestation. A key result is an increase in land and sea temperatures with numerous consequences for human settlements. Atmospheric levels of the most critical greenhouse gas, carbon dioxide, are projected to double from their pre-industrial levels within the first half of this century.<sup>11</sup>

Global climate change will present further challenges to many insurance lines. A recent report by the Association of British Insurers (in collaboration with two of the “big-three” U.S. CAT modelers, AIR Worldwide and RMS), stated that rising carbon dioxide emissions could increase average annual losses from the three major types of storms that affect insurers—U.S.

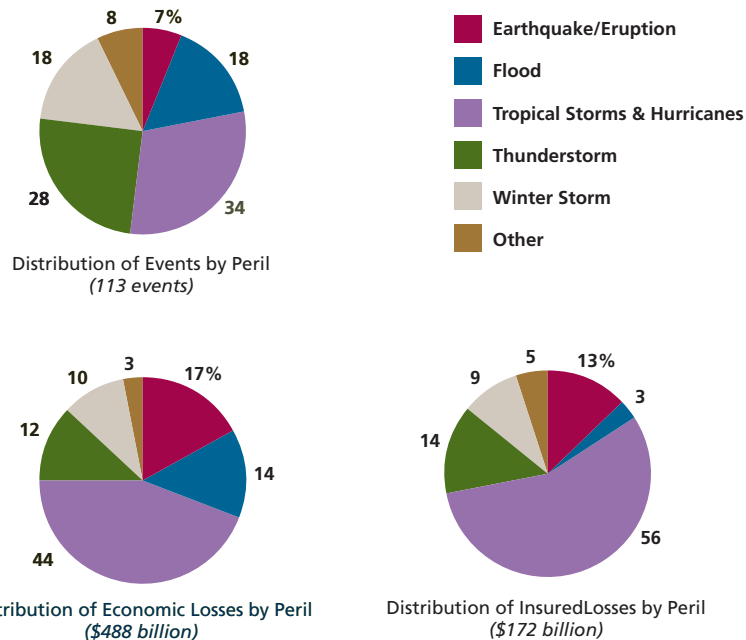
\* Such deductibles exist in 18 states, including Connecticut, Delaware, Florida, Georgia, Hawaii, Louisiana, Maine, Maryland, Massachusetts, Mississippi, New Jersey, New York, North Carolina, Rhode Island, South Carolina, Texas, Virginia) and Washington, D.C. See: [http://www.iii.org/media/hottopics/additional/katrina\\_faqs/](http://www.iii.org/media/hottopics/additional/katrina_faqs/)

**The largest homeowners insurer in Massachusetts will not renew 14,000 policies on Cape Cod and nearby islands because of projected increases in storm losses.**

hurricanes, Japanese typhoons and European windstorms—by \$27 billion a year, a two-thirds increase, by the 2080s.<sup>12</sup> The report cited recent scientific evidence suggesting that rising greenhouse gas levels and rising temperatures will boost the energy of the earth’s weather, resulting in stronger storms. The report stated that U.S. hurricanes could exhibit wind speed increases of up to six percent, enough to upgrade a category-4 hurricane to a category-5. Losses from more rare and extreme U.S. hurricanes under climate change could increase by \$41 to \$62 billion above present-day losses of \$60–\$85 billion (for 100- and 250-year events, respectively), representing a 70 to 75 percent increase. This is equivalent to an additional two to three Hurricane Andrews in a single season (2004 prices and exposures). Losses under a low-emissions scenario were only one-fifth those of a high-emissions scenario.

Current day concerns include events ranging from large scale and abrupt hurricanes to diffuse and gradual impacts such as coastal erosion or moisture damage in buildings. In both cases, insurance systems have encountered difficulty in responding, often needing to raise prices and in some cases exclude risks. While more captivating, large catastrophic events cause less damage in an average year than the aggregated impacts of relatively small events (a 40/60 ratio globally). While these smaller events may be less consequential for the largest insurers, they can have significant adverse effects on state and regional insurers.

In some cases, the consequences range from availability and affordability problems for consumers to not-always-welcome expectations on governments to pick up the tab. As a case in point, although awarded significant premium increases in the wake of major hurricane losses in 2004, seven private insurers in Florida have decided to stop writing new homeowners policies or even exit the market. The largest homeowners insurer in Massachusetts will not renew 14,000 policies on Cape Cod and nearby islands because of projected increases in storm losses.<sup>13</sup> A similar situation is underway in Texas, where escalating mold and water-damage losses in recent years have prompted dozens of insurers to pull out of the market. These types of developments give rise to state mandated systems to maintain an insurance “safety net” for consumers.



**Figure 2. Weather-related events cause vast majority of catastrophic losses, 1950–2004.** Represent 93% of Catastrophe Events, 83% of Total Economic Costs, and 87% of Insured Losses. Includes only events with \$1 billion or more in insured losses. Note that only 113 events are included. Source: American Re 2005.

---

In particular, the advent of insurance FAIR Plans shows rising risk and inadequacy of traditional insurance loss-spreading approaches. As a case in point, the Massachusetts Property Insurance Underwriting Association (or Massachusetts FAIR Plan—homeowner and commercial lines) has become the largest residential insurer in the Commonwealth, with ~\$200 million in premiums. To manage growing risks of weather-related events in some parts of the country, mandatory percentage deductibles of up to 5 percent of insured values have recently replaced traditional fixed-dollar deductibles. Similarly, a new state-run company is Florida's second largest provider of homeowners' insurance. Government-provided insurance systems (flood and crop) are seeing rising exposures and losses as well.<sup>14</sup> Although rates may be set higher than market averages, FAIR Plan premiums are often inadequate to cover losses, resulting in assessments against the individual insurer members. These rates are not necessarily actuarially based, but are set by the regulatory authorities. FAIR, Wind, and Beach Plans are increasingly purchasing reinsurance.

Weather-related losses and associated liabilities are material risks for insurers in three ways: through their core business, the weather-sensitivity of their investments, and via indirect economic impacts of extreme weather and consequent effects on consumer purchasing of goods and services, including insurance. The Insurance Information Institute has shown that U.S. insurers' financial performance is more sensitive to energy price shocks and general economic slumps (both of which can be precipitated or compounded by extreme weather events) than the economy as a whole.<sup>15</sup> Insurers are also vulnerable to the causes of climate change, e.g. increased flood risk due to deforestation, and deterioration of respiratory health due to local air pollution resulting from fossil-fuel combustion as well as greater production of pollen (precursors to respiratory diseases such as asthma) in a CO<sub>2</sub>-rich atmosphere.

Globally, the number of weather-related events, the variability of total losses, and the economic impacts and demographic drivers are all on the rise.<sup>16</sup> Insured and total property losses (\$45 billion and \$107 billion in 2004, respectively) are rising faster than premiums, population, or economic growth both globally and in the U.S. (Figure 1). Globally, inflation-adjusted economic losses from catastrophic events rose by 8-fold between the 1960s and 1990s and insured losses by 17-fold.\* The insured share of total economic losses from weather related catastrophes is also rising, from a negligible fraction in the 1950s to 25 percent in the past decade. The ratio is even higher in the U.S., with about 50 percent of total disaster losses insured in the 1990s.<sup>17</sup>

Inflation-corrected weather-related insurance losses in the U.S. property-casualty sector have risen from about \$1 billion per year in the 1970s to \$15 billion per year in the past decade, with a record high in 2004 that included \$30 billion in hurricane losses alone. By August 2005, another new record had been set. Weather-related economic (insured plus uninsured) losses from the subset of events with over \$1 billion in insured losses totaled \$486 billion over this same period. Of the total losses, \$172 billion were insured (inflation-corrected to 2004 dollars) (Figure 2). The annual average rate of loss rose from \$3 billion per year in the decade 1950-1959 to \$30 billion per year in the most recent decade (Figure 3). Averaged over the past 55 years, weather-related events have been responsible for 93 percent of all catastrophe events, 83 percent of the economic damages of natural disasters, and 87 percent of the insured losses. Important for insurance, the variability and hence unpredictability of losses has increased as well.

While often asked, it is a bit of a red herring to pose the question as to whether it is demographic/socioeconomic trends or climate change that underlie the clear and significant upturn in insured losses from extreme weather events. The observed upward trend in losses is consistent with what would be expected under climate change and with demographic factors. We believe that both factors are at work, with undesirable compounding effects (Box 1). Efforts to understand the relative roles of the two factors are important, and yet are very incomplete at present.

---

*Globally, inflation-adjusted economic losses from catastrophic events rose by 8-fold between the 1960s and 1990s and insured losses by 17-fold.*

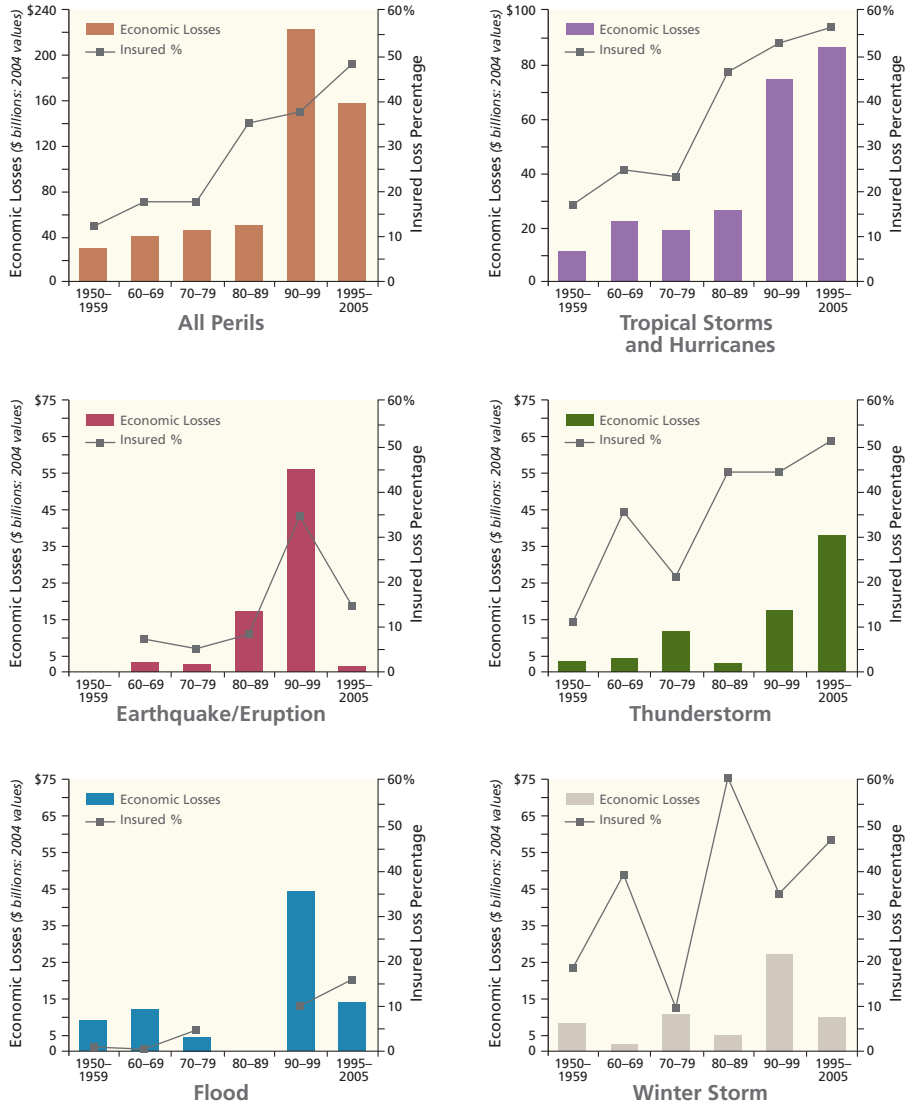
---

---

\* Natural hazard statistics and losses from Munich Re, NatCatSERVICE.

The full extent of weather-related insurance losses is not known, and only 40 percent of known losses arise from headline-catching disasters. While natural disasters are seen as the primary cause for 8.2 percent of insurer insolvencies in the U.S., an unspecified additional number—such as a subset of those due to mismanagement and reinsurer failure—involve catastrophes as a contributing factor.<sup>18</sup> Unpaid claims from insolvent insurers are typically recouped from other insurers in the market via Guaranty Fund mechanisms.

*Insured and total property losses are rising faster than premiums, population, or economic growth both globally and in the U.S.*

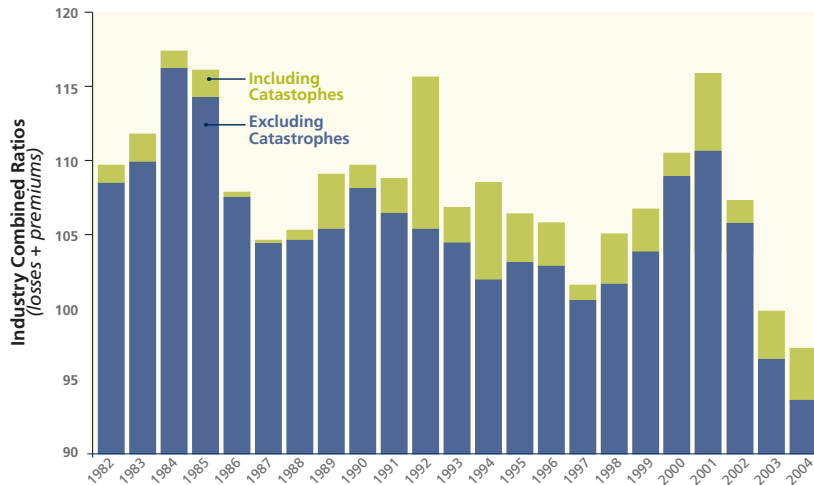


**Figure 3. Rising U.S. Economic and insured losses from natural disasters.** Includes only events with \$1 billion or more in insured losses. Source: American Re (2005).

Weather catastrophe losses have a visible adverse effect on U.S. insurers' combined ratios (profitability) (Figure 4). This class of losses has not only risen significantly more quickly than premiums, but has become more unpredictable. As insurers from the U.S. and other industrialized countries race to develop footholds in the rapidly growing emerging markets (e.g. India and China) they also assume weather-related risks there.<sup>19</sup> A statistical review by Swiss Re found that foreign insurers' growth in emerging markets averaged more than



20 percent per year during the nineties.<sup>†</sup> During the late 1990s, the U.S. was leading the way,<sup>‡</sup> with its primary insurers collecting approximately \$40 billion in premiums for policies placed overseas, with an average annual growth rate of 10 percent between 1990 and 1998.<sup>20</sup> Some reinsurers provide backstop coverage to government-provided insurance in developing countries, e.g. flooding in Bangladesh.<sup>21</sup> The developing world is a new geographical locus of vulnerability for insurers. With current premium growth rates triple of that in industrialized countries, premium volumes from the developing world will represent half of the global total in the next few decades. Developing countries' lack of disaster-resistant infrastructure, high dependence on agriculture, and other factors render these markets vastly more vulnerable to climate change. This will curtail the expansion of weather-sensitive insurance markets.



*The developing world is a new geographical locus of vulnerability for insurers. With current premium growth rates triple of that in industrialized countries, premium volumes from the developing world will represent half of the global total in the next few decades.*

**Figure 4. Natural catastrophes are a major challenge to overall insurance industry profitability in the U.S.** The role of catastrophe losses in U.S. property/casualty insurance sector profitability: 1989–2004. A measure of industry financial performance, the “combined ratio” is the ratio of losses plus expenses to premiums. Thus, an underwriting profit occurs when the ratio is less than 100. Including all weather-related events would increase the relative contribution of weather to the combined ratio, probably considerably. The combined ratio does not include investment income, which can compensate for underwriting losses when market conditions are good. Source: AM Best

Individual insurers from four continents have organized under the United Nations Financial Services Initiative, expressing concern about climate change, including firms from Australia, Austria, Canada, France, Germany, Italy, Japan, Netherlands, New Zealand, Norway, Russia, South Korea, Spain, Sweden, Switzerland, Thailand, and the United Kingdom. Some U.S.-domiciled insurers and other industry players have also expressed concern, while in a brief paper prepared in 1999 the American Insurance Association viewed it as a relatively minor issue.<sup>22</sup> With the exception of the AIA, no U.S. primary insurance trade associations have taken public positions or made recommendations. In the mid-1990s, however, U.S. insurance

\* Foreign insurers participate either by establishing local offices or purchasing an interest in local insurers. Examples of the latter include Liberty Mutual’s acquisition of the Venezuelan insurer Seguros Caracas; ING’s 49 percent acquisition of Sul America, Brazil’s second-largest carrier; MetLife’s \$962 million acquisition of Mexico’s largest life insurer; Aseguradora Hidalgo SA, and Citigroup’s stake in Mexican life insurer Seguros Banamex Aegon and Mexican pension-management company Afore Banamex Aegon (Ceniceros 2003; Pilla 2002).

† Notably: Aetna, AIG, CGU, Chubb, Cigna, Metropolitan Life, New York Life, and Prudential (Swiss Re 2000).

‡ At the time, AIA estimated that about 20 percent of U.S. insurance P/C premiums were associated with types of insurance with “significant” exposure to weather—related loss, 2 percent with “moderate” exposure, 66 percent with “minor” exposure, 9 percent with “minor to no” exposure, and 4 percent with “no” exposure. The large “minor” category is primarily auto insurance, which may have more vulnerability than assumed by AIA (see Figure 13). The paper did not evaluate other measures of vulnerability, such as profitability, solvency, or exposures according to other metrics; e.g., total insured property values for which the at-risk insurers are responsible. Effects of higher prices or reduced availability on consumers were also not evaluated.

leaders and several trade associations\* issued a letter to Vice President Gore in which they recognized that climate change was an issue for their industry and pledged to explore it more fully.<sup>23</sup> However, this group was ephemeral, no subsequent communiqué was issued, and it appears that few U.S. insurers or regulators subsequently considered the ramifications of climate change in depth. This may be changing, as exemplified by The National Association of Insurance Commissioners' new initiative in this area.

As many U.S. corporate leaders have said in other arenas, "you can't manage what you don't measure." This adage certainly holds true in the case of preparedness for extreme weather events. While the collection of weather-related loss data is better today than in the past, there are huge gaps.<sup>†</sup> In particular, the insurance industry's Property Claims Services (PCS) database is not all-inclusive in terms of types of losses, and excludes from the definition of "catastrophe" an unknown number of "small" events (i.e., those with under \$25 million in insured losses).<sup>‡</sup> Among the types of events often excluded: power outages in the United States alone are estimated to result in a cost of \$80 billion per year<sup>24</sup> and lightning strikes cause billions of dollars of losses each year.<sup>25</sup> In the case of wildfires, the PCS database contains 16 catastrophic wildfires spanning the past three decades, whereas there have been many tens of thousands of smaller fires. The result can be that entire classes of events expected to worsen under climate change (e.g., lightning or subsidence) are virtually invisible in the data. With PCS's acquisition by ISO, their data is no longer in the public domain, which is unfortunate for policy analysts.

Lacking a comprehensive grasp of the historic trends, it is difficult to prepare for the future. Similarly, catastrophe models only address a subset of the types of insurance losses expected under climate change. In addition to being able to estimate catastrophe losses in the future, it is also important to know the effect of changes in inclement weather on motor vehicle accidents and lightning strikes, the melting of permafrost on insured infrastructure, or the effects of increased pollen on respiratory health costs. The combined effect of this lack of modeling and analysis means that even if insurers are interested in the issue, they cannot be expected to fully measure and manage their risk.

**While the collection of weather-related loss data is better today than in the past, there are huge gaps... Entire classes of events expected to worsen under climate change are virtually invisible in the data.**

## Box 1. The Attribution Puzzle<sup>26</sup>

Socioeconomic and demographic trends clearly play important—and likely dominant—roles in the observed upward loss trends.<sup>27</sup> As recognized by insurers and others, migration of populations to coastal and flood-prone areas, increasing reliance on vulnerable electric power grids, and rising material wealth are among the many drivers. However, changes in the incidence and impacts of extreme weather events and sea-level rise can also be observed, and it is logical to expect economic impacts to result from the physical drivers.<sup>28, 29, 30, 31</sup> Steady increases in demographic drivers also do not explain why the variability in losses has been increasing.

An astute article in the *Wall Street Journal* following the losses of Hurricane Katrina pointed out that this "natural disaster" was indeed quite unnatural, resulting from a combination of manmade factors including rampant development in at-risk areas, maladaptation through the use of inadequate levies, human destruction of wetlands that protect against storm surges, and climate change.<sup>32</sup>

\* The signatories included The Alliance of American Insurers, American Insurance Association, Insurance Institute for Property Loss Reduction, National Association of Independent Insurers, National Association of Mutual Insurance Companies, Reinsurance Association of America, and State Farm Insurance Companies. This letter is reproduced as Appendix F in Mills et al. (2001).

† The retiring president of Sorema made this point strongly in his retirement speech, entitled "Reflections On The Future—Climate Change And Its Impacts On The Insurance Industry".

‡ Also excluded from the ISO database are losses to utilities, agriculture, aircraft, ocean marine (including oil drilling platforms) and property insured under the federal flood insurance program. See [http://www.iso.com/press\\_releases/2005/10\\_04\\_05.html](http://www.iso.com/press_releases/2005/10_04_05.html).

Global weather-related losses in recent years have been trending upward much faster than population, GDP, or insurance premiums, and faster than non-weather-related events.<sup>33</sup> The same can be seen in the case of the U.S. (Figure 1). Specific event types have increased far more quickly than the averages. For example, damages from U.S. storms grew 60-fold to U.S.\$6 billion/year between the 1950s and the 1990s.<sup>34</sup> Some assert that rising losses are due strictly to increased vulnerability. However, the attribution studies cited in support of these assertions have material limitations. They often review only a subset of impacts from a single hazard over narrow geographical areas. There is particularly scant treatment of important non-catastrophic processes such as soil subsidence, vehicle accidents, lightning, permafrost melt, the effect of mold and airborne aeroallergens on human health, coral reef decline, or crop diseases.

According to the latest Intergovernmental Panel on Climate Change (IPCC) assessment, climate change has played a role in rising costs of natural disasters.<sup>35</sup> More data in support of this observation have been published since IPCC's report was issued in 2001. As an illustration of the linkages, the distribution and frequency of lightning strikes is expected to be changing under climate change<sup>36</sup> and insurers indeed observe a notable increase in losses during periods of elevated temperatures.

Many human activities mask losses that would otherwise manifest. These include improved building codes, early warning systems, flood control, crop irrigation, electric load-shedding to avoid blackouts during heatwaves, disaster preparedness and response, and land-use planning. Insurer exclusions or withdrawal from risky areas, higher deductibles, and lower limits, also produce a dampening effect on observed insured costs. As examples, inadequate building code enforcement was attributed to almost 70 percent of the costs from Hurricane Alicia and most of the homes damaged by the 2004 hurricanes were built before the code updates inspired by Hurricane Andrew.\* Untangling these offsetting factors is a necessary part of any comprehensive attribution analysis and has not been dealt with satisfactorily in the literature. As leading researchers in this area observed in a discussion of flood risks:

*One can easily hypothesize that increasing population and urbanization in the United States has led to a commensurate increase in population at risk. Yet, one can also hypothesize that the various societal responses may have more than compensated for population growth and in fact fewer people are today at risk.”<sup>37</sup>*

It is important not to be lulled into complacency by factors that may only temporarily mask a rise in losses, or to become complacent as a result of selective reporting of data by climate contrarians. Adaptation to climate change will have certain limits.

In any event, the consequences of future climate change will be amplified by economic development and the tendency of populations to move into harm's way. For example, as of 2004 there was almost \$7 trillion of insured property value (16 percent of total insured values) along U.S. Gulf and Atlantic coastlines, about half of which is in the Gulf.<sup>38</sup> Some cursory studies have assessed insurers' exposures to climate change based on premiums, rather than insured values.<sup>39</sup>

Regardless of the relative weights of anthropogenic climate change and increased exposure (quantification is premature), projected future climate changes are vastly more significant than observed changes to date. Rising uncertainty would complicate the fundamental actuarial and pricing processes that underlie well-functioning insurance markets. Moreover, even where there is doubt about the current “fingerprint” of climate change, the business of insurance involves anticipating future losses and taking steps to mitigate them before they rise to unmanageable proportions.

\* See <http://www.iii.org/media/hottopics/insurance/xxx/>

---

*According to the latest Intergovernmental Panel on Climate Change (IPCC) assessment, climate change has played a role in rising costs of natural disasters.*

---

---

### III. The Erosion of Insurability

Not all risks are commercially insurable. A variety of definitions of insurability are found in the literature that differ in detail but share the common theme of accepting or rejecting risks based on the nature of each risk and the adequacy of available information. The insurability of natural disasters and extreme weather events may be affected by increases in frequency, severity, or unpredictability.

In essence, private insurers require that a series of conditions be met before they will offer insurance for a given peril/hazard or enter a given market. These conditions—sometimes referred to as “Standards of Insurability”—are intended to assure insurers’ financial survival in case of catastrophic losses. Risks must be estimable and manageable yet random and sufficiently broadly spread among the population of those with insurance. Prices must be set via actuarial processes, be affordable to consumers, and fraud and complacency must be controllable. This process involves technical and subjective judgments, and history shows that insurers will relax the standards when investment profits are high. However, a worrisome situation arises when the “perfect storm” of large catastrophic losses coincides with a downturn in financial markets (whether or not there is a causal connection between the two events).<sup>40</sup>

Perhaps counter-intuitively, as societies develop they become more vulnerable to certain extreme weather impacts. For example, where once hurricanes did little damage until making landfall, it has been clearly evidenced of late that massive losses can occur to offshore oil production facilities. Very preliminary estimates place Hurricane Katrina’s damages to offshore oil infrastructure at more than three-times that of Hurricane Ivan (\$2.5 billion) the year before.<sup>41</sup> Intensifying reliance on electricity, and expansion of the electric power grid is another source of vulnerability. Losses from Hurricane Rita are expected to be even higher.

Climate change presents various challenges to insurability. These include:

#### Technical Risks

- Shortening times between loss events, such as an increased frequency of urban heatwaves
- Changing absolute and relative variability of losses
- Changing structure of types of events (e.g. different weighting of the impacts from various perils)
- Shifting spatial distribution of events
- Damages that increase exponentially or nonlinearly with weather intensity, and cascade in terms of numbers of insurance lines impacted\*.<sup>42</sup>
- Widespread geographical simultaneity of losses (e.g. from tidal surges arising from a broad die-off of protective coral reefs or disease outbreaks on multiple continents)
- Increased difficulty in anticipating “hot spots” (geographic and demographic) for particular hazards†
- More single events with multiple, correlated consequences as evidenced by the handicapping of pumping capacity due to forced evacuation of pumping-station personnel and loss of electrical power following Hurricane Katrina and the flooding in New Orleans.<sup>43</sup> Undesirable correlations were also well evidenced in the pan-European

---

\* For example, wind damages rise with the cube of the wind speed and can cause abrupt loss increases when gradual changes cross thresholds, e.g., when the point is reached that roofs disconnect from walls or when hailstone diameters/weights reach the level that they break automobile windshields.

† Associated Press. 2005. “First-ever Seattle Heat Warning Issued.” [http://news.yahoo.com/news?tmpl=story&cid=533&e=6&u=/ap/20050528/ap\\_on\\_re\\_us/hot\\_seattle](http://news.yahoo.com/news?tmpl=story&cid=533&e=6&u=/ap/20050528/ap_on_re_us/hot_seattle)

---

*The insurability of natural disasters and extreme weather events may be affected by increases in frequency, severity, or unpredictability.*

---

---

heat catastrophe of 2003—where temperatures were six standard deviations from the norm.<sup>44</sup> Immediate or delayed impacts included extensive human morbidity and mortality, wildfire, massive crop losses, and the curtailment of electric power plants due to the temperature or lack of cooling water

- More hybrid events with multiple consequences (e.g. El Niño-related rain, ice storms, floods, mudslides, droughts, and wildfires)

### Market-based Risks

- Historically-based premiums that lag behind actual losses
- Correlations between losses on the asset and liability sides of an insurer's balance sheet
- Failing to foresee and keep up with changing customer needs (e.g., new forms of risk management) arising from the consequences of climate change
- Unanticipated changes in patterns of claims, and associated difficulty in adjusting pricing and reserve practices to maintain profitability\*
- Responses of insurance regulators<sup>45</sup>
- Reputation risks falling on insurers who do not, in the eyes of consumers, do enough to prevent losses arising from climate change
- Stresses unrelated to weather but conspiring with climate change impacts to amplify the net adverse impact on insurers' core business. These include draw-downs of capital and surplus due to earthquakes or terrorist attacks and increased competition from self-insurance or other alternative methods of risk-spreading.

The public must understand that insurers have no obligation to serve, and can only be expected to do so when the standards of insurability are met. This can create market failures. Among the conclusions of a report commissioned to explore the relative roles of public and private insurance:<sup>46</sup>

*“Since the passage of the War Risk Insurance Act of 1914, Congress has developed one overriding principle to determine under what conditions the federal government should provide federal disaster insurance. ... Federal disaster insurance programs are permitted to correct a market failure in the private insurance sector. A market failure has been defined to exist when the private insurance industry is unable to provide primary insurance coverage at reasonable rates and/or does not have the capacity to provide reinsurance.”*

## IV. Governments and Individuals as “Insurers of Last Resort”

Governments assume a considerable share of the exposures to the costs of weather-related events. Requests for all forms of disaster relief (including those for the agriculture sector) and corresponding declarations doubled between the mid-1980s and mid-1990s (Figure 5-6), and total federal disaster-related payments amounted to \$119 billion between 1993 and 1997 (\$1993).<sup>47</sup> Federal aid for Hurricane Katrina alone is anticipated to top \$200 billion.

---

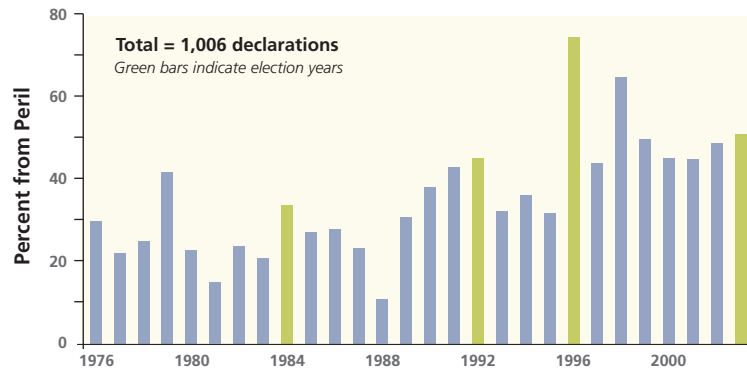
*Governments assume a considerable share of the exposures to the costs of weather-related events.*

---

---

\* Exposures are still often expressed in terms of probable maximum losses for single events rather than for entire insurance seasons. The limitations of this approach were evident in the 2004 U.S. hurricane season, with its \$60 billion of economic losses (half of which were insured). However, it should be noted that lessons learned from Hurricane Andrew helped insurers to manage these losses better than would otherwise have been the case.





**Figure 5. The annual number of major U.S. disaster declarations doubled between 1976 and 2003.** Source: Federal Emergency Management Agency (FEMA).

The costs of natural disasters to government have increased steadily in recent decades. Inflation-corrected federal relief payments for weather disasters grew 6-fold from the late 1960s to the early 1990s.<sup>48</sup> Of particular note, between the 1940s and the 1990s, flood damages (insured and uninsured)—a major government-paid risk—grew 6-fold to \$6 billion per year (inflation corrected to \$1997).<sup>49</sup>

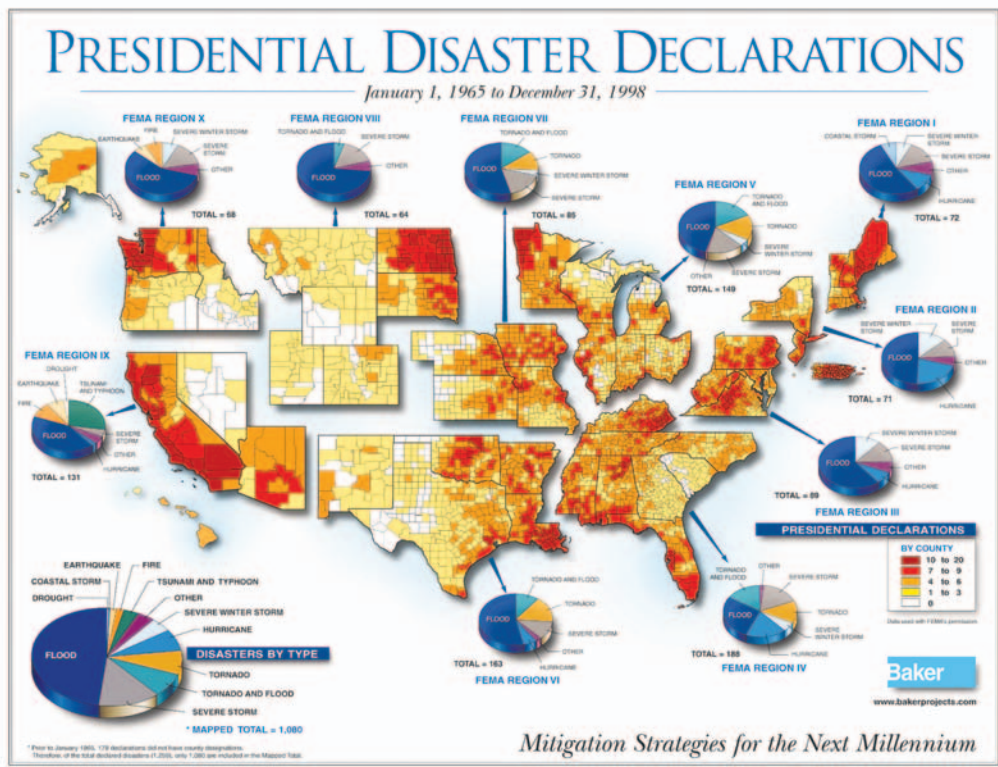
Surprisingly, the U.S. government’s full exposure to extreme weather events has never been assessed. It ranges from formal insurance programs (flood and multi-peril crop), to other forms of assistance such as disaster recovery and construction of flood defenses. As of mid-2004, the National Flood Insurance Program alone provided \$723 billion in coverage for 4.5 million policyholders, up from about \$50 billion in 1978. The program pays out over \$1 billion in some years.\*

The public sector has had mixed success in its role as a partner in understanding and managing weather-related risks. With the movement of FEMA into the Department of Homeland Security, observers have expressed concern that the shift of national focus to “manmade” disasters, as well as new layers of administration could inhibit FEMA’s effectiveness.<sup>50</sup> Compounding the problem, more and more disaster preparedness and recovery has been pushed to the cash-strapped states.

Where voluntary private insurance is not available, state governments can mandate the creation of insurance pools to be operated by private insurers. One of the better known is Citizens Property Insurance Company in Florida. All insurers seeking to operate in Florida must fund the operation and claims paid by Citizens, which is closely supervised and governed by a state-appointed board and required to provide insurance to all customers. Citizens currently covers 745,000 homeowners and businesses in the state. Their plan of operation provides for the assessment of insurance consumers and member insurers, which resulted most recently in a 7 percent assessment to assist in offsetting the aforementioned hurricane losses.<sup>51</sup> A similar system is operational in Louisiana.

\* See <http://www.fema.gov/nfip/10110409.shtm>

**We find that a wide range of insurance lines would be affected by climate change... We project that insurance buyers will be expected to pay higher prices and deductibles, with lower limits on losses payable in many cases and that governments will be asked to assume an increasing share of exposures.**



*The U.S. Government Accountability Office (GAO) recently warned that insurers may increasingly look to government to share the economic risks of natural disasters. Yet, government is increasingly a reluctant partner.*

**Figure 6. Impacts from natural disasters on the government sector are also diverse and growing**

Governments typically play a leadership role in relevant research. While the United States government is a major sponsor of climate change research, the deficiency of economic impacts analysis and adequate models means that the results are rarely directly usable by the private sector. In contrast, this linkage is made relatively well in the case of earthquake research and modeling.

Governments cannot be expected to handle losses on their own. As an illustration of the importance of insurance, \$40 billion of the total \$66 billion cost of rebuilding New York after 9/11 flowed through the insurance sector,<sup>52</sup> with most of the balance assumed by the federal government.

The U.S. Government Accountability Office (GAO) recently warned that insurers may increasingly look to government to share the economic risks of natural disasters.<sup>53, 54</sup> Yet, government is increasingly a reluctant partner. With the country's shift of emphasis from natural disasters to terrorism, FEMA's role in disaster preparedness is being phased out.<sup>55</sup> In the end, the costs of climate change will increasingly fall on consumers and businesses. Important socioeconomic implications will arise depending on the extent to which the cost is spread through insurance, reinsurance, government taxation, or borne directly through formal or informal self insurance.\* While insurance rate increases must be approved by insurance regulators, they, in many instances, lack the technical capacity to discharge this responsibility. For example, most state insurance regulatory offices don't have staff actuaries.

\* There are a variety of alternative risk transfer approaches, which today are roughly equal in size to the traditional U.S. commercial insurance market. These include informal self insurance, Captives, Risk Retention Groups, Weather Derivatives, Catastrophe Bonds and other capital market schemes. Some entities that self-insure purchase commercial reinsurance for catastrophe losses.

---

## V. Insurance Challenges Across the U.S.

In the remainder of this paper we examine the implications of climate change for the insurability of extreme weather-related events (large- as well as small-scale), and the consequences for insurance affordability and availability. We offer separate discussions of the following insurance lines:

- Property (structures, industrial, auto, inland marine, aircraft)
- Crop
- Health/Life
- Business Interruption
- Liability

---

*We project that insurance buyers will be expected to pay higher prices and deductibles, with lower limits on losses payable in many cases and that governments will be asked to assume an increasing share of exposure.*

---

We find that a wide range of insurance lines would be affected by climate change. We project that insurance buyers will be expected to pay higher prices and deductibles, with lower limits on losses payable in many cases and that governments will be asked to assume an increasing share of exposures (Table 1). These conclusions are based on trends already underway in various U.S. business/insurance sectors and the projected impacts as these trends play out further, assuming middle-of-the-road climate change projections and current response strategies on the part of the insurance industry (i.e., responses similar to those seen in the face of past disasters). It is important to note that not all prospective impacts are negative. Several beneficial outcomes are noted in Table 1, although on balance the impacts are highly undesirable.

Key variables include how insurance regulators and governments respond to changing conditions (allowed rate increases, changes in terms, etc.). In some areas, the dual regulatory authority of federal and state governments converge, and can create potential points of conflict. While insurance regulation occurs primarily at the state level, disaster management is overseen at the federal level. For example, the federal flood and crop insurance programs and now terrorism backstop reinsurance are handled from Washington. The difficulty in establishing and now continuing the Terrorism Reinsurance Act evidences how difficult it can be to find a balance acceptable to insurers and governments alike.

### Implications for various insurance lines

There is no ideal way to segment the various hazards, perils, and lines of insurance. Most consequences of climate change affect more than one line of insurance. For example, extreme heat episodes have caused simultaneous insurance losses ranging from loss of life, to wildfire-driven property loss, to crop damages, to electric power plant shutdowns, to associated business interruptions. In turn, wildfire losses touch many lines (Box 2). Similarly, a given customer class experiences many hazards, e.g., the energy sector experiences service disruptions from lightning strikes on the power grid, outages from lightning strikes or wildfires, and property damages from hurricanes that damage underwater pipelines (Box 3). These types of linkages are reflected in Table 1. Here, we organize the discussion in terms of major insurance lines. The treatment is indicative rather than comprehensive.

Projected Changes during the 21st Century in Extreme Climate Phenomena	IPCC Assessment of Change Likelihood <sup>A</sup>	Representative Examples of Projected Impacts <sup>B</sup> (all high confidence of occurrence in some areas <sup>C</sup> )	Peril or Hazard	Insurance-sector Impacts (“+” = increased losses “-” = reduced losses)							Insurance Customer Impacts										
				Property (structures; industrial)	Property (autos/marine/aircraft)	Liability: Business Interruption	Crop	Health	Life	Public Insurance	Pricing	Exclusions	Availability								
Higher maximum temperatures; more hot days and heat waves <sup>D</sup> over nearly all land areas	Very Likely	Increased hospitalizations over broad demographic range; incidence of death and serious illness in older age groups and urban poor Increased heat stress in livestock and wildlife Increased risk of damage to a number of crops Increased soil subsidence Decreased ice in northern maritime shipping lanes Increased roadway accidents (slower reaction time) Increased electric cooling demand and reduced energy supply reliability Decreased cold-related human morbidity and mortality	Heatwave					+													
			Heatwave				+														
			Heatwave				+														
			Subsidence			+															
			Float ice			-															
			Road conditions			+															
			Power Outage					+													
			Coldwave																		
			Heatwave																		
			Infestation and disease vectors																		
Higher (increasing) minimum temperatures; fewer cold days, frost days, and cold waves over nearly all land areas	Very Likely	Extended range, reproduction, and activity of some pest (e.g. pine beetle) and disease vectors Increased avalanche risk Increased permafrost melt Increased incidence of lightning Increased flood, landslide, avalanche, and mudslide damage Increased soil erosion Increased flood runoff could increase recharge of some floodplain aquifers Increased roadway accidents (driving conditions, visibility)	Avalanche	+																	
			Subsidence	+																	
			Lightning	+																	
			Flood, landslide, avalanche, mudslide	+																	
			Rain	+																	
			Flood																		
			Road conditions																		
			Drought																		
			Subsidence																		
			Drought																		
Increased summer drying over most mid-latitude continental interiors and associated risk of drought	Likely	Decreased crop yields Increased damage to building foundations caused by ground shrinkage Decreased water resource quantity and quality Increased risk of wildfire Increased risks of property damage, business interruption, loss of human life, infectious disease epidemics. Increased coastal erosion and damage to coastal buildings and infrastructure Increased damage to coastal ecosystems such as coral reefs and mangroves	Wildfire	+																	
			Wind, disease																		
			Tidal surge	+																	
			Tidal surge	+																	
			Drought																		
			Drought																		
			Storm																		
			Storm																		
			Storm																		
			Storm																		
Increase in tropical cyclone peak wind intensities, mean and peak precipitation intensities <sup>E</sup>	Likely	Decreased agricultural and rangeland productivity in drought- and flood-prone regions Decreased hydro-power potential in drought-prone regions Increased risks to human life and health Increased property and infrastructure losses Increased damage to coastal ecosystems, including loss of mangroves and coastal wetlands	Drought																		
			Drought																		
			Storm																		
			Storm																		
			Storm																		
			Storm																		
			Storm																		
			Storm																		
			Storm																		
			Storm																		
Intensified droughts and floods associated with El Niño events in many different regions	Likely	Decreased agricultural and rangeland productivity in drought- and flood-prone regions Decreased hydro-power potential in drought-prone regions Increased risks to human life and health Increased property and infrastructure losses Increased damage to coastal ecosystems, including loss of mangroves and coastal wetlands	Drought																		
			Drought																		
			Storm																		
			Storm																		
			Storm																		
			Storm																		
			Storm																		
			Storm																		
			Storm																		
			Storm																		
Increased intensity of mid-latitude storms <sup>F</sup>	Little agreement between current models as of 2001. <sup>F</sup>	Increased risks to human life and health Increased property and infrastructure losses Increased damage to coastal ecosystems, including loss of mangroves and coastal wetlands	Storm																		
			Storm																		
			Storm																		
			Storm																		
			Storm																		
			Storm																		
			Storm																		
			Storm																		
			Storm																		
			Storm																		

A. Likelihood refers to judgmental estimates of confidence used by Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report (TAR), Working Group I: very likely (90–99% chance); likely (66–90% chance). Unless otherwise stated, information on climate phenomena is taken from the IPCC Summary for Policymakers, TAR WG1.

B. These impacts can be lessened by appropriate response measures.

C. Based on information from chapters in the IPCC Third Assessment Report; high confidence refers to probabilities between 67 and 95% as described in Footnote 6 of TAR WGII, Summary for Policymakers.

D. Information from TAR WG1, Technical Summary, Section F5.

E. Changes in regional distribution of tropical cyclones are possible but have not been established.

F. Subsequent research (Knutson/Trenberth/MITTAB) has shown increased likelihood of hurricane damages.

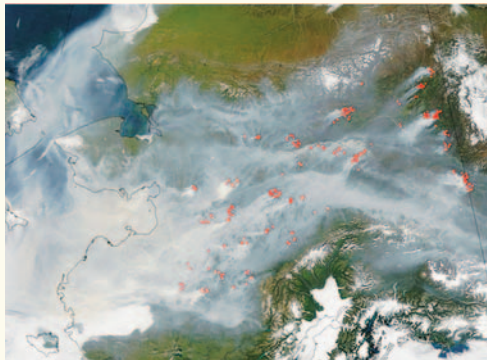
**Table 1. Examples of impacts resulting from projected changes in extreme climate events, and associated insurance implications. (Adapted from IPCC/Vellinga et al., 2001)**

## Box 2. Wildfire

The Oakland/Berkeley Tunnel Fire of 1991 demonstrated the enormous damage potential of even a single fire in the wildland-urban interface. The third costliest fire in U.S. history, it resulted in \$2 billion in insured losses (at 1997 prices), including the destruction of 3,400 buildings and 2,000 cars.<sup>56</sup> This compares with the losses resulting from a major hurricane. Added to this were extensive losses of urban infrastructure (e.g., telecommunication, water, and transportation systems); the costs of which are borne largely by local government. The insured losses from this single fire were twice the cumulative losses experienced nationwide during the previous thirty years. The Swiss Reinsurance company cited global climate change as a possible factor influencing the extent of damages caused by this and future wildfires.<sup>57</sup>

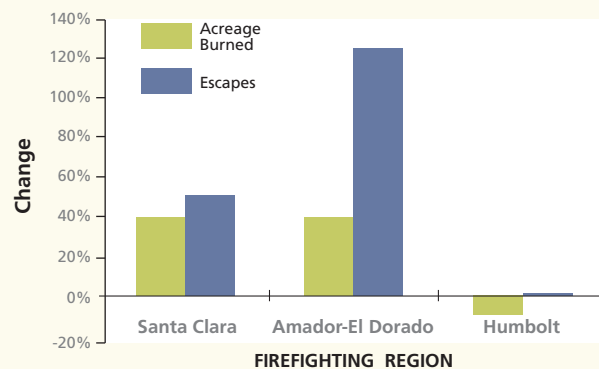
**Under climate change, wildfire damages increase considerably in parts of California.**

Wildfire impacts are not limited to property loss. Fires this summer in Montana caused a 90 percent increase in hospital admissions for respiratory problems and 57 percent for cardiac problems.<sup>58</sup> Pervasive fires in Alaska are shown in the photo below. In areas where a high probability of wildfire loss is present, if insurance is not available through primary insurers it can often be purchased if legislatively mandated insurance pools, known as FAIR Plans, are present. An inspection is required and generally a surcharge applies.<sup>59</sup>



**By mid-August 2005, 584 fires had burned more than 3 million acres in Alaska,** at which time weather conditions were causing the smoke to linger across the interior, with consequent unhealthy air quality warnings for much of the state. Air quality warnings had been issued for about 90 percent of the interior, with conditions ranging from “very unhealthy” to “hazardous” in many locations, including Fairbanks. This image was captured by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA’s Terra satellite.

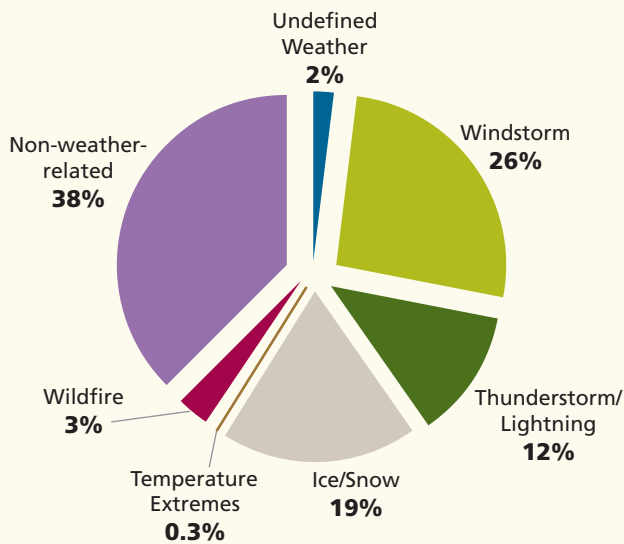
**Under climate change, wildfire damages increase considerably in parts of California.** The chart shows percentage change in wildfire outcomes under a doubling of CO<sub>2</sub> from pre-industrial levels. For example, in the Amador-El Dorado region (Sierra Nevada Foothills), the acreage burned (grey shading) by contained wildfires increases by about 40%, while the number of catastrophic escaped fires (black shading) increases by 120%. Some sub-regions exhibit up to a four-fold increase in damages. Results were calculated by coupling climate models with California Department of Forestry wildfire models, assuming full deployment of existing suppression resources. (Source: Torn et al. 1998).





### Box 3. Energy Sector Impacts

Increasingly extensive and interconnected energy systems enhance the quality of life, but also increase society's vulnerability to natural hazards.<sup>60</sup> Energy systems are exposed to large losses such as ruptured oil and electricity transmission systems and power plants due to permafrost melt throughout the northern latitudes. A particularly diverse set of risks exist in the electricity sector. The current U.S. baseline cost of electrical outages is \$80 billion per year.<sup>61</sup> Under climate change, it is likely that businesses will seek increasing business-interruption coverage for such events. In addition, increasingly frequent drought conditions could result in power curtailments that cause further business interruptions in regions heavily dependent on hydroelectric power. Drought plus unacceptably higher cooling water temperatures forced curtailments or closures of nuclear and other thermal plants in France, Germany, Romania, and Croatia and price spikes in additional areas during the heat catastrophe of 2003. At the other end of the spectrum, the 1998 North American Ice Storm—likely linked to El Niño events, in turn expected to become more common under climate change—caused extensive power outages.



**Causes of electric grid disruptions: 51.7 Million customers affected (North America 1982–2002).** The vast majority of outages (80-90%) occur in the electric distribution network, for which data by cause is not available. Source: North American Electric Reliability Council.

Weather disasters can damage other types of energy infrastructure. Massive oil sector losses were caused by Hurricane Ivan in 2004 (approximately \$2.5 billion, well in excess of the year's entire premium revenue for the sector)\* (Miller 2004). Premiums for vulnerable oil infrastructure were projected to double after this event, and consumers faced higher prices due to the 500,000-barrel per day supply shortfall.<sup>62</sup> Electric utilities were also hard hit, with one utility's costs reaching \$252 million.<sup>63</sup> The losses from Hurricanes Katrina and Rita are only now beginning to emerge, with 111 oil platforms completely lost and 52 extensively damaged. Concern has already been raised over potential elimination of insurance coverage for offshore oil infrastructure and associated business interruptions.<sup>64</sup>

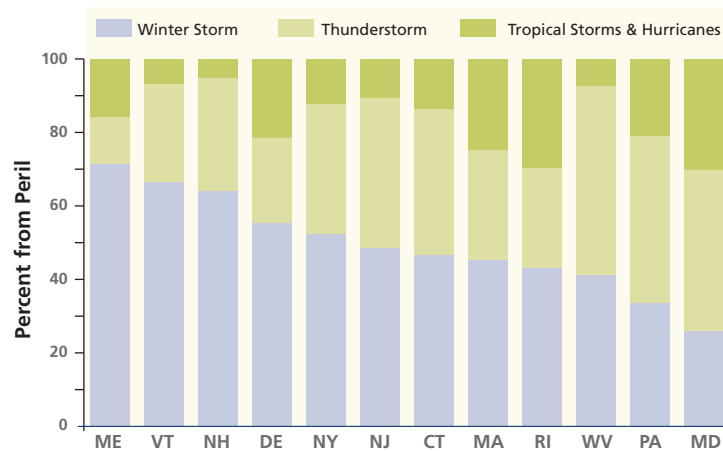
\* The Hurricane destroyed seven oil platforms, damaged six others as well as five drilling statements, and extensive pipelines were buried by underwater mudslides in the Mississippi Delta.

*The losses from Hurricanes Katrina and Rita are only now beginning to emerge, with 111 oil platforms completely lost and 52 extensively damaged.*

#### Property Insurance

Weather-sensitive segments of the property insurance market include homeowners, commercial lines, inland marine, as well as motor vehicles. Averages can be deceiving: the types of losses vary significantly from state to state (Figure 7) and from year to year.

**A new study from MIT reviewed 50 years of data and found that over that time both the duration and wind speed of hurricanes has increased 50 percent.**



**Figure 7. Percentage contribution of winter storms, thunderstorms, and tropical cyclones to total weather-related losses in the Northeastern U.S.: 1980–2004.**  
Source: American Re (2005).

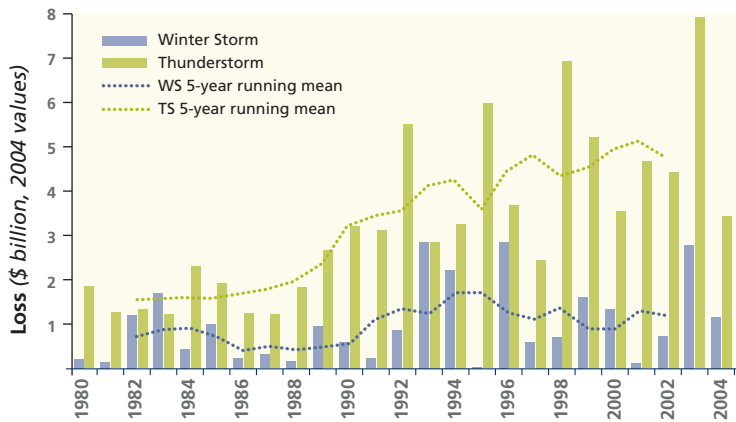
**Tropical Storms & Hurricanes:** Windstorms are a major concern, and the largest single contributor to weather-related insurance losses in the U.S. In a real-world example, Allstate stopped writing commercial insurance policies in Florida and decided not to renew 95,000 residential homeowner policies (about 15 percent of its portfolio there), because of the four hurricanes that slammed Florida in 2004.<sup>65</sup> Losses from tropical storms and hurricanes are not limited to property damages. For example, \$0.5 billion of insured crop losses resulted from hurricanes in 2004.<sup>66</sup>

The effects of climate change on hurricanes are extremely difficult to assess. Recent literature has pointed to more of a linkage than previously believed.<sup>67, 68</sup> A new study from MIT reviewed 50 years of data and found that over that time both the duration and wind speed of hurricanes has increased 50 percent.<sup>69</sup> It also identified a “high correlation” between this increase in intensity and the rise of surface water temperatures.

The insurance industry and others have made material progress toward improving society’s resilience to hurricanes. Efforts included fortified building codes (and code compliance), the development of catastrophe modeling, and consumer education. Yet, vulnerabilities remain and the Insurance Information Institute notes “serious obstacles to reducing CAT losses.”<sup>70</sup> These include unwillingness to significantly alter land use planning, political/lobbying efforts of special interests to defeat restrictions, homeowner opposition to added housing costs for disaster resilience, and subsidies (flood insurance, rate suppression), coupled with demographic trends (housing starts, population, rising replacement values).

**Thunderstorms:** The cumulative annual insured losses from U.S. thunderstorms have averaged \$3 billion per year since 1980 (\$2004), equating to those from a large hurricane in most years. One confounding factor in tracking thunderstorm losses is that some events are associated with hurricanes, and counted in that category. Thunderstorm losses have shown a significant increase over the past 25 years, even after correcting for inflation (Figure 8). The worst year in recent history (2003) saw nearly \$8 billion in insured thunderstorm losses. Hail is an important consequence of thunderstorms. The costliest hailstorm\* in Colorado history was \$625 million (\$1990).<sup>71</sup>

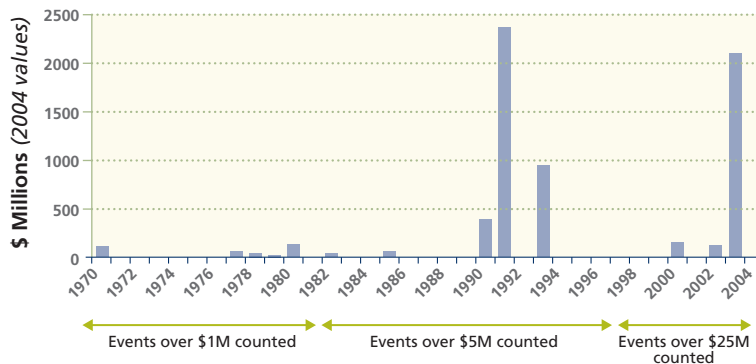
\* U.S. property insurers pay out an average of \$1.5 billion each year for hail-related claims, largely across the central U.S. (III 2000a).



**Figure 8. Thunderstorms on the rise: 1980–2004.** Annual insured losses due to thunderstorm and winter storm events. The five-year running mean is also shown. Source: American Re (2005)

**Winter storms:** Winter storms are a significant contributor to weather-related losses in New England, the Pacific Northwest and the Rocky Mountain states, accounting for about 18 percent of insured catastrophe losses nationally, and ranging up to 60 percent in Maine, New Hampshire and Vermont.\* They present a variety of hazards, including wind, tornado, snow, sleet, ice, hail, freezing rain, sub-freezing temperatures, and lightning, varying from storm to storm and region to region. Damages are similarly diverse, including frozen pipes and consequent water damage, ice-damming and roof damages, and increased vehicle accidents. Winter storms in the United States often fall below the threshold of being cataloged among official loss statistics, yet cumulatively yield more than \$1 billion each year in insured losses.† For example, only one winter storm event in 2004 met Munich Re’s criteria to be classified as a significant event, incurring economic losses in excess of \$1 billion. The most costly winter storm in recent history was a \$2.3 billion (\$2004) event in 1993.

*Winter storms in the United States often fall below the threshold of being cataloged among official loss statistics, yet cumulatively yield more than \$1 billion each year in insured losses.*



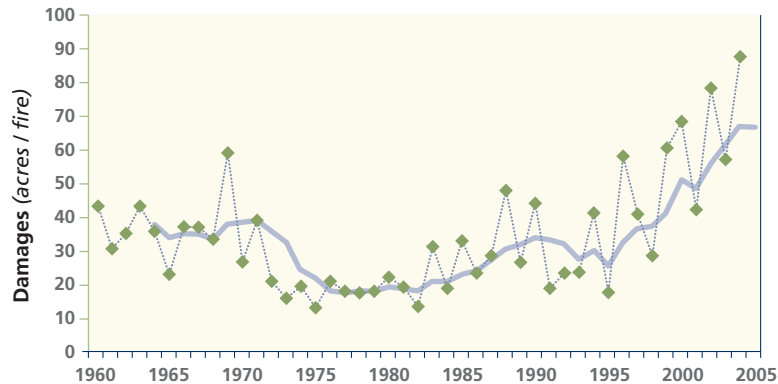
**Figure 9. Rising U.S. catastrophic insurance losses,** despite fewer fires included in the sample. Source: Insurance Information Institute. Effective January 1, 1997, Property Claim Services (PCS) defines catastrophes as events that cause more than \$25 million of insured property damage and that affect a significant number of insurance customers and insurers. From 1982 to 1996, PCS used a \$5 million threshold in defining catastrophes. Before 1982, PCS used a \$1 million threshold.

\* The Ice Storm of 1998 produced the largest loss in Canadian history, and combined Canadian and US stood in excess of \$1.2 billion US.

† These events can be defined as any extra-tropical cyclone that incurs a majority of the insured losses associated with it through the effects of frozen precipitation, high winds associated with the storm’s circulation, and/or excessively low temperatures from one or more preceding or subsequent high-pressure systems

**Wildfire:** Wildfire is another major weather-related hazard, and one that will be exacerbated by the combination of climate change, population growth, and migration to and development in at-risk woodland-recreational areas. Wildfires have over the years plagued areas of the United States from New Hampshire and Vermont, to Colorado, to California. From 1985 through 1994, U.S. wildfires claimed more than 9,000 homes<sup>72</sup> at an average insured cost nearly ten-fold greater than during the three decades prior to 1985. According to the Insurance Information Institute, the total U.S. losses from catastrophic wildfires (a small subset of the total defined in terms of events tabulated by the Property Claims Services) was \$6.5 billion (\$2004) between 1970 and 2004, corresponding to an average insured loss of just over \$400 million per fire (Figure 9), with damages rising from about 40 acres per fire in the 1970s to 80 acres per fire in recent years (Figure 10).

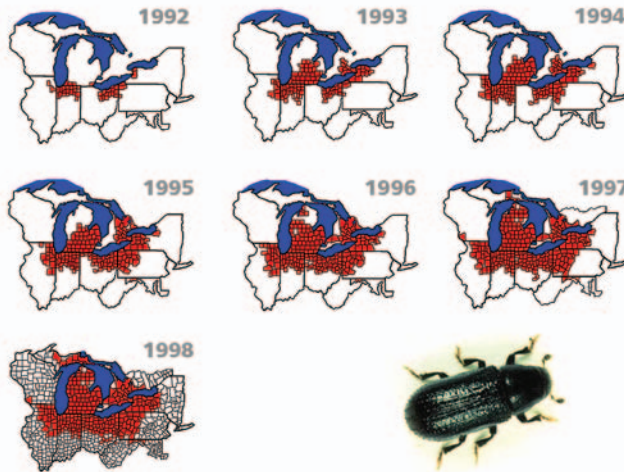
*From 1985 through 1994, U.S. wildfires claimed more than 9,000 homes at an average insured cost nearly ten-fold greater than during the three prior decades.*



**Figure 10. U.S. wildfire intensity has doubled since 1960.**

Source: National Interagency Fire Center

Wildfires can be costly disasters for property owners, governments (federal, state and municipal), and insurers. Two fires in California in 2003 caused combined insured losses of \$2.1 billion,<sup>73</sup> comparable to those from the Oakland Hills fire of 1991. According to the U.S. Department of Agriculture, nearly every state has experienced wildland/urban interface fire losses.<sup>74</sup>



**Figure 11. Temperature-Induced Spreading Pine Beetle Causes Elevated Wildfire Risk.**

The Pine Shoot beetle, an exotic species, is now found in twelve northern states: Illinois, Indiana, Maine, Maryland, Michigan, New Hampshire, New York, Ohio, Pennsylvania, Vermont, West Virginia and Wisconsin [<http://ledis.ifas.ufl.edu/IN596>]. Beetle reproduction rates and geographical range increase with temperature.

## Box 4. Examples of Lightning-Related Costs in the United States

### Fires

- Half of wildfires in Western US (approximately 10,000 each year); \$100 million in BLM suppression costs
- Over 3,000 structural and vehicle fires/year, at a cost of \$35 million (1994–1999 average)
- Approximately 18% of lumberyard fires; 30% of church fires (Ohio)

### Energy Sector

- About 30% of all power outages, with total costs ~\$1 billion per year (1997)
- About 80% of accidents involving petroleum product storage tanks events to privately-owned plants between 1985 and 2000. Between 1990 and 2000, 346 incidents to 81 nuclear sites in US

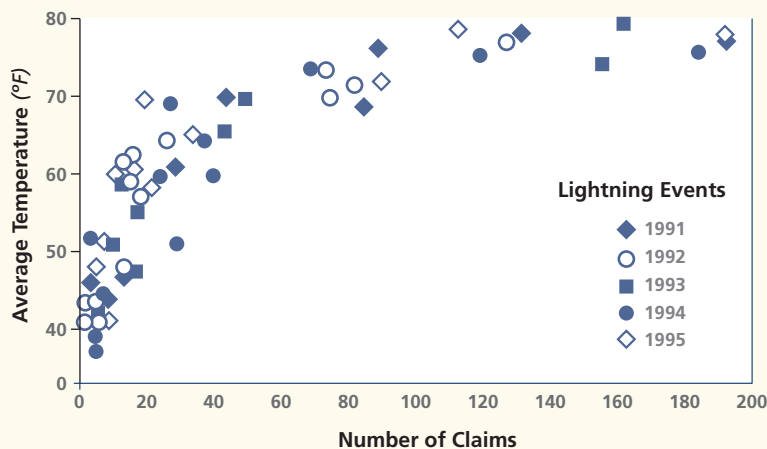
### Other Types of Damages

- Worst Losses: \$50 million warehouse (1997); \$70 million Naval Air Rocket Test Station (1926)
- Over 50% of military aircraft weather-related in-flight mishaps
- Average \$2 billion annually in airline operating costs and delays (1998)
- 101,000 desktop computer losses (\$125 million) in the year 1997
- Extensive traffic signal outages

### Insurance Losses

- Approximately 5% of all insurance claims, exceeding \$1 billion/year (as of 1989)
- Saint Paul Insurance Co: \$340 million/year, ~4% of total losses (1992–1996 average)
- State Farm Insurance Co: 307,000 claims/year, with \$332 million paid claims
- Factory Mutual Insurance Companies: 3–4% of all claims paid

Source: www.lightningsafety.com



### U.S. Lightning-Related Insurance Company Claims Rise with Temperature: 1990–1995.

(Mills 2005) Each symbol represents a lightning event in the continental U.S. Source: Hartford Steam Boiler and Inspection and Insurance Co. claims data (2000).

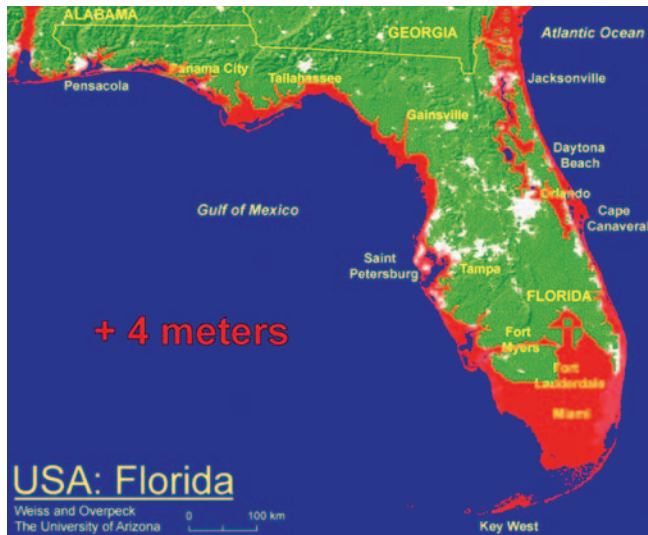
Weather-related drivers of wildfire include temperatures, humidity, wind, fuel-moisture content, and fuel types. Drought weakens trees and in many cases conspires with higher temperatures to foster super-infestations of forest pests (Figure 11), such as pine and spruce

*Lightning is responsible for \$332 million per year in claims paid by State Farm alone.*

beetles (which cause nearly 50-times the economic damage of wildfires<sup>75</sup>), with significantly elevated wildfire risk. Outbreaks in parts of Alaska—causally correlated with unusually high temperatures—have killed 90 percent of the spruce<sup>76</sup>. Lightning, also a weather-related phenomenon, is a major source of wildfire ignitions (Box 4). As forests and shrubs are the primary terrestrial carbon sink, the fires and losses add substantially to the atmospheric accumulation of carbon dioxide. An analysis that included only the effects of temperature and wind, projected that wildfire damages in some parts of California would quadruple—even with today’s full suppression resources brought to bear—under climate change.

**Coastal Erosion:** Coastal erosion is a hazard that is not insured by the public or private sectors in the U.S. However, the federal flood program will pay, indirectly, when there has been insured flood damage from a storm.<sup>78</sup> Under climate change, government-insured flood losses will increase due to the combination of sea-level rise and increased storm surges, and potentially stronger storms (Figure 12). This will be a future problem for both the National Flood Insurance Program and the increasing number of coastal property owners.<sup>77</sup>

*An analysis that included only the effects of temperature and wind, projected that wildfire damages in some parts of California would quadruple—even with today’s full suppression resources brought to bear—under climate change.*



**Figure 12. Coastal inundation arising from increases in sea level.** Includes only the effect of the thermal expansion of warming ocean waters. Excludes sea-level changes due to melting continental ice sheets.

**Flood and Other Causes of Water-Related Damage:** One of the more well substantiated forms of observed climate change is the rise in precipitation, compounded by poor land-use planning and other activities that result in development in at-risk areas. In what is termed “cat-following-cat” events, flooding is also a consequence of hurricanes, and is predicted to be responsible for an unprecedented \$15 to \$25 billion in insured losses\* for the flooding triggered by Hurricane Katrina.<sup>79</sup> There is a popular misconception that flood is not an insured risk. This is largely true for homeowners and small businesses in the United States (via the National Flood Insurance Program), but direct insurance or reinsurance for flood are often used in commercial lines. Moreover, vehicle losses due to flood are typically covered under the comprehensive portion of the standard auto policy. Business interruption insurance will apply to closures due to floods when there is commercial flood insurance. NFIP does not cover business interruptions.

Other causes of water-related damage have created a widely recognized crisis in several property insurance markets today,<sup>†</sup> linked to a number of weather-related factors, each of which is expected to become more severe under climate change. In an average year, small-

\* This exceeds, by a factor of two, the total 1980-2004 inflation-corrected value of floods in the Munich Re database of U.S. flood events.

† Hotspots include California, Nevada, Colorado, Texas, the Carolinas, Florida, and New York.



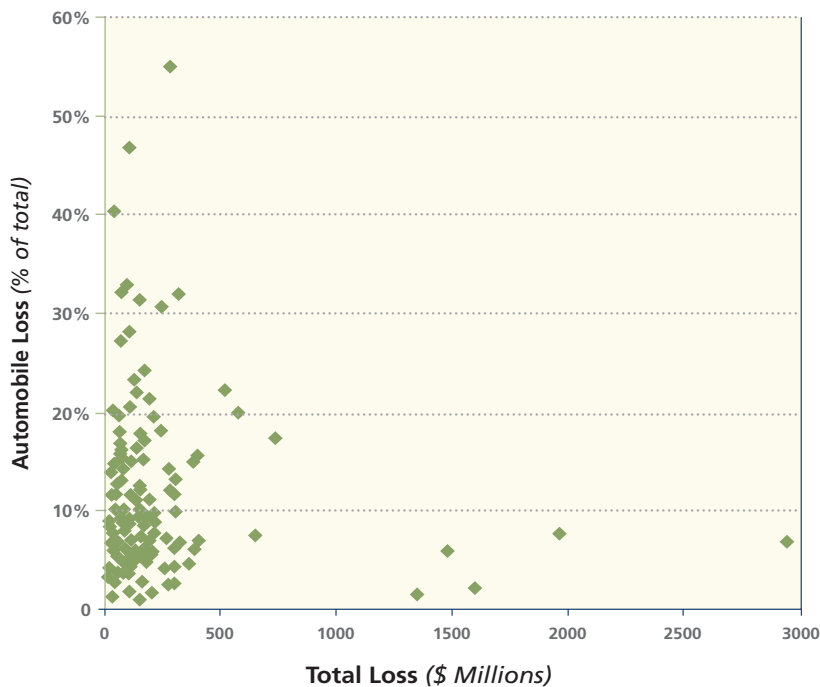
scale weather-related events are collectively as, or more, significant than major catastrophes. This is reflected by a growing number of lawsuits that target builders, contractors, developers, sub-contractors, material suppliers, product manufacturers, and architects & engineers. The subject of these suits often center on construction defects claims arising from:

- Subsidence, collapse, cracks in walls & foundations.
- Leaking roofs, windows, doors, and foundations.
- Dry rot of wood or other building materials, pest infestations.
- Mold, code violations, improper specification of building materials.

In addition to the abrupt impacts of floods are the “longer-tail” water damages in waterlogged structures, agricultural settings, and environmentally related post-flood pollution liabilities (as was illustrated following the flood that accompanied Hurricane Katrina).

**Personal automobile insurance and coverage for other types of transport systems, including aviation:** This sector is more weather sensitive than some realize. Windstorms, hail, flooding and earthquakes give rise to a surprisingly high number of automobile claims under the physical damage coverage, as PCS reports. This is due to direct damage (hail or flood) or flying objects (windstorm and earthquake). An average of 10 percent and up to 55 percent of the insured losses from catastrophes recorded by PCS were due to automobile damages (Figure 13). Vehicle accidents also increase during various forms of adverse weather, ranging from rainy conditions to heatwaves. The key point here is that under either property or liability coverage, unexpected types of claims from natural events already do occur and can be expected to occur in the future. Aviation losses are also significant, particularly from hailstorms.

*An average of 10 percent and up to 55 percent of the insured losses from catastrophes recorded by PCS were due to automobile damages.*



**Figure 13. Correlation of U.S. catastrophe and auto losses (1/1996–9/2000).** Automobile losses can exceed 50% of total catastrophe losses. In the U.S., 16% of automobile accidents are attributed to adverse weather conditions as are one-third of the accidents in Canada. Autos also sustain insurance losses during natural disasters, amounting to \$3.4 billion and 1.7 million claims between 1/1996 and 9/2000 (PCS 2000) and averaging 10% of total disaster related property losses, with much greater losses for some events, particularly hailstorm. The largest single auto loss was \$171 million. Individual events have seen as much as 55% of total losses attributed to autos. These data systematically underestimate total losses because PCS records include only those events with total losses of \$25M or more. Source: ISO/Property Claims Services.

---

## Crop Insurance

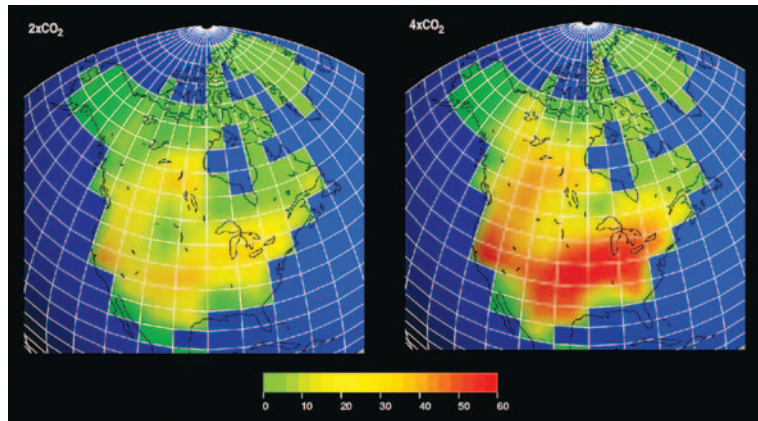
Agriculture is well-recognized as a climate- and weather-sensitive sector. Hazards include drought, excessive rain, flood, hail, heatwaves, windstorm, wildfire, insect infestation, and plant diseases. Drought is one of the most pervasive hazards, as illustrated by the \$8.3 billion total economic losses in the U.S. in 2002.<sup>80</sup> Climate change is projected to cause extensive drying in most of the United States (Figure 14), with adverse effects on crops. Climate change impacts also include more vigorous weed growth (as a result of the well-known “fertilization” effect of increased CO<sub>2</sub> concentrations in the atmosphere). Heatwaves in Europe in 2003 caused \$12 billion in crop losses, which could be a harbinger of things to come in the U.S. As shown in Figure 15, insured U.S. crop-hail losses climbed steadily from \$40 million in 1948 to nearly \$400 million in the early-to mid 1990s.<sup>81</sup>

---

**Governments assume crop risks because private insurance firms find them too unpredictable and undiversified to insure at prices that the market will bear.**

---

While some models predict increased crop yields under climate change due to more precipitation, this has been shown to be a flawed analysis. This arises from an assumption that increases in rainfall will be uniform, rather than the more realistic outcome of being concentrated in torrential downpours, which creates soil moisture saturation that is very damaging to crops. The 1993 U.S. Midwest floods resulted in losses of \$6-8 billion, although most was due to excess soil moisture from rain as opposed to direct crop loss.<sup>82</sup> U.S. corn losses due to increased torrential rains under climate change are expected to double to \$3 billion/year over the next three decades.<sup>83</sup>



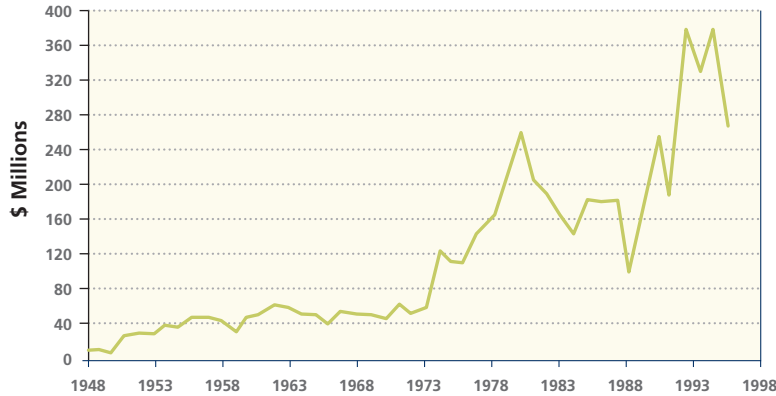
**Figure 14. Potential effect of global warming on soil moisture in North America: percent reduction in June–August soil moisture content.** Drying of 20 to 40% is seen in much of the continental U.S. under a doubling of CO<sub>2</sub>, and up to 60% in many areas under 4x CO<sub>2</sub>. Drying underlies consequences for agriculture (moisture, pests, and diseases), forests, water supply, property (via subsidence), respiratory health (via airborne particulates), etc. Source: NOAA/GFDL.

Governments assume crop risks because private insurance firms find them too unpredictable and undiversified to insure at prices that the market will bear. The Great Drought and ensuing “dust bowl” of the 1930s triggered the establishment of a “multi-peril” federal crop insurance program\* in the U.S. to cover other hazards, including drought. Private insurers retained the crop-hail segment of the market (which also includes fire), and in 1980 were asked to administer the public program and share some of the risk with the federal government as well. By 2004, over 220 million acres of cropland were insured. The program provides \$47 billion in coverage across 1.3 million policies in all 50 states, covering 350 distinct commodities.<sup>84</sup> The program is expanding into livestock (currently available in 19 states, and covers milk production in 12 states<sup>85</sup>), rangeland, and pasture. The federal government pays a portion of the premium for multi-peril and revenue-loss insurance (to cover administrative and claims-handling costs) and reinsures a portion of the losses. The government pays the entire premium for catastrophic losses. The government serves as “insurer of last resort” if private insurers fail to pay their intended share of claims. Those with insurance retain the costs associated with deductibles and caps on coverage.

---

\* The Federal Crop Insurance Act of 1938.

Until “loopholes” were closed around 1985, only about a third of farmers purchased multi-peril crop insurance, the remainder relying on (free) disaster relief and emergency loans, which averaged \$1.5 billion/year between 1988 and 1994.



**Crop insurance losses have grown 10-fold in recent decades.**

**Figure 15. Annual losses under U.S. crop-hail insurance in the United States: 1948–1995.**

Source: Changnon (1997)

Private crop-hail insurance represents a market of about \$500 million/year in premiums and is generally profitable nationally, but losses in certain regions already significantly exceed premiums (e.g. in 2003 payouts exceeded payments by a factor of 2.4:1 in West Virginia and 1.4:1 in Kentucky).<sup>86</sup> Public multi-peril (or “all-risk”) crop insurance represented a market of about \$3 billion in premiums in 2003, with a payout/premium ratio of 1.24:1 (i.e., premiums not covering payouts). Since payouts are generally yield-related, farmers needn’t experience a complete or catastrophic loss to make a claim. Those crops that are not covered by crop insurance are covered under the federal Noninsured Crop Disaster Assistance Program.

Crop insurers have recognized the risks posed by climate change.<sup>87</sup> Crop insurance systems are already under stress. Crop insurance losses have grown 10-fold in recent decades, and in some years the government’s crop and flood insurance programs have been unprofitable<sup>88, 89</sup> Any increase in the frequency of loss events will further tax insurance systems by drawing down capital and surplus at a rate differentially faster than they can be replenished, and increasing the need for subsidies.

Weather-related events have already been observed to upset the financial stability of crop insurers. As a result of drought and bad fiscal management, the largest private participant (American Growers Insurance Company) became insolvent in 2002\* after having operated successfully for 56 years. This event evidenced the weather sensitivity of the sector and risks to insurers and prompted considerable concern by the government. The U.S. Government Accountability Office issued a report finding that the federal agency designated to oversee the financial health of the crop insurance program needed to implement better methods to monitor and communicate with participating insurers and their regulators.<sup>90</sup> The transition cost the taxpayers \$40 million. Nationally, the drought caused an increase in losses of approximately 33 percent (\$1 billion) to the federal crop program. This story evidences the challenges. In 2002, \$139 was paid in claims for every \$100 collected in premiums.<sup>91</sup>

\* Technically, the Nebraska Department of Insurance took control of the company in an effort to address the fiscal problems.

---

## Health/Life Insurance

The life/health segment represents a large share of U.S. insurance premium volumes. Climate change is expected to adversely impact the prevalence of vector-borne diseases, heat stress, water quality, aeroallergens (such as pollens\* and mold), and the health of natural systems that can cause economic and insured losses for humans (e.g., forest beetle infestations leading to timber loss and wildfire).<sup>92</sup> Natural disasters also have material impacts on mental health; the World Health Organization has estimated that up to 2.5 million people will experience moderate to severe psychological distress following the great Tsunami of 2004, with 25,000 to 50,000 experiencing persistent problems.<sup>93</sup> An in-depth treatment of health issues is provided in the “Climate Change Futures” study, conducted by the Harvard Medical School’s Center for Health and the Global Environment and sponsored by Swiss Re and the UN Development Programme.<sup>94</sup>

---

***More airborne allergens, rising temperatures, greater humidity, more wildfires, and more dust and particulate pollution may considerably exacerbate upper respiratory disease and cardiovascular disease.***

---

The combination of more airborne allergens, rising temperatures, greater humidity, more wildfires,<sup>†</sup> and more dust and particulate pollution may considerably exacerbate upper respiratory disease (rhinitis [hay fever], conjunctivitis, sinusitis) and cardiovascular disease (e.g., due to reduced oxygen and increased carbon monoxide during fires). Cases of asthma, already causing greater impacts than Alzheimer’s disease, would sharply increase. The baseline cost of asthma was \$13 billion per year in U.S. alone as of the mid-1990s (half of which are direct healthcare costs). If a 30 percent increase took place in the U.S., the incremental cost of \$4 billion per year would be on a par with that of a very large hurricane each year.

Large natural catastrophes have resulted in major loss of life, even in well-insured regions such as Western Europe (the heatwave of 2003 killed up to 35,000 people above the norm). Aside from individual events, life insurance losses are not likely to increase significantly in the U.S. However, losses would rise from current levels and could be quite significant in emerging markets (where U.S. insurers increasingly seek to do business).

## Business Interruption Insurance

Losses due to the disruption of business operations typically range from 20 to 40 percent of claims resulting from hurricanes. Other weather-related triggers for business-interruption claims include lightning, flood, and wildfire. Visibility problems during wildfires in Malaysia this summer forced the closing of the country’s largest port and many businesses.<sup>95</sup> Business interruption policies often have a “time deductible”, i.e., only losses incurred after a fixed period (e.g. 3 days) following the loss event will be covered. There are various forms of business interruption insurance, e.g. “contingent” versions that cover indirect impacts such as supply disruptions due to events far from the insured’s business.

## Liability Insurance

Liability claims due to climate change are probably the least well understood class of exposures. They take several forms. During natural catastrophes, it is generally unusual for a claim to arise under liability insurance, since there must be a negligent act that causes damage to another’s property. It could happen when a landslide damages a neighbor’s property, or by not being attentive to poor road conditions in driving, as mentioned. Government entities are often sued after landslides. Contractors’ liability and mold problems have been liability issues in California, but legal developments and policy changes will make these claims more difficult in the future.

Claims are already significant from property damages due to mold and moisture (product liability, professional liability). This has become a crisis for homeowners insurers in some

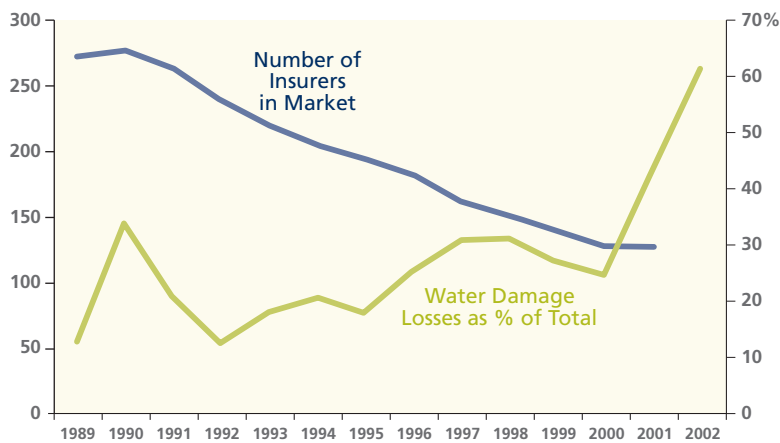
---

\* Pollen has been observed to increase by 60 percent with a doubling of pre-industrial atmospheric CO<sub>2</sub> concentrations.

† In Western Montana, hospital admissions for heart and lung ailments increased significantly at the height of the 2004 wildfire season. Admissions for respiratory disease in Ravalli County increased by 90 percent and those for heart problems by 57 percent.

regions, as evidenced by claims of \$3 billion nationally, and anticipated to become an issue in commercial lines in the future.<sup>96, 97</sup> While this has been aggravated by excessive litigation and media exaggeration, there was also an underlying fact of increased moisture-related losses (up more than four-fold in Texas the past several years compared to the prior decade, representing 60 percent of homeowners' claims value) and changes in construction practice that fostered mold production.\* Data from the Insurance Information Institute† indicate that:

- \$850 million in paid claims in 2001; \$35,000/claim
- Water-related claims are 60 percent of the total in Texas, 30 percent in California
- All but 19 states had mold exclusions as of 2002
- Cost \$444/household (premium increase) in Texas<sup>98</sup>
- The issue is “migrating” to commercial lines (property, liability, workers compensation, commercial liability, and business interruption)
- Insurers say that mold—a climate- and weather-related hazard—will threaten affordability, and is a major factor in insurers leaving the Texas market (Figure 16)



**Insurers say that mold—a climate- and weather-related hazard—will threaten affordability, and is a major factor in insurers leaving the Texas market.**

**Figure 16. Texas insurers leave market as water-damage claims rise.** Sources: Texas Department of Insurance; Texas Coalition for Affordable Insurance Solutions from A.M. Best data via Insurance Information Institute (Hartwig 2003).

In an entirely different form of liability claims, corporate liabilities may eventually arise from claims against large emitters of greenhouse gases.<sup>99</sup> This is being played out first in the U.S., as is evidenced by Attorneys General from NY, CA, CT, ME, NJ, RI, VT suing electric utilities to force three percent annual reduction of GHG emissions over 10 years. State Treasurers from CA, CT, ME, NM, NY, OR, and VT have called for disclosure of financial risks of global warming in securities filings.

Directors and Officers (D&O) liability has already been identified as an arena in which climate change impacts may be brought back to insurers. In the post-Enron, post-WorldCom marketplace, there is considerable concern about the ability of corporate leadership to proactively manage risks and anticipate business threats. Swiss Re is concerned that D&O policyholders understand the climate change risks that may influence the financial performance or even solvency of their companies, and has called for disclosures on corporate practices.

\* A popular misconception is that energy efficiency is the cause of the mold/moisture problem. While bad application of energy efficiency features can cause such problems, the root cause is bad construction practice (efficient or otherwise).

† Information posted here <http://www.iii.org/media/hottopics/insurance/mold2/>, and in presentations on the site by Robert Hartwig.

---

## VI. Pressure on Insurance Affordability and Availability Under Climate Change

Extreme weather events have already precipitated contraction of insurance coverage in some markets, and the process can be expected to continue if losses increase in the future. Impacts vary, of course, depending on the specific circumstances, and can be relatively minor (gradual price increases) or more significant. While not a weather-related event, the Northridge Earthquake of 1994 provides a sobering example of how trend changes in natural disasters can lead to serious questions of insurability and undesirable outcomes for consumers (Box 5).

### Box 5. The Retreat of Catastrophe Insurance: The Case of Earthquake\*

---

*Directors and Officers (D&O) liability has already been identified as an arena in which climate-change impacts may be brought back to insurers.*

---

- Northridge Earthquake of Jan 17th 1994 gave \$15Bn market loss equivalent to 28 years of annual premiums
- Insurers demanded immediate increase in residential rates and Insurance Commissioner refused
- Insurers threatened to leave the state—fear for a collapse in the mortgage and housing market
- State set up the California Earthquake Administration as alternative provider of earthquake coverage (with policies managed by insurers)
- Under pressure from reinsurers and to reduce overall risk load CEA imposed 15 percent deductibles
- CEA policies are 2x as expensive and only give half the coverage of policies prior to 1994
- Earthquake insurance penetration dropped from 30 percent in 1993 to 10 percent today

\* Excerpted from presentation by Robert Muir-Woods, Chief Research Officer, Risk Management Solutions, June 29, 2005 “The Future of the Insurance Industry under Climate Change.”

While regulation is a key factor in the evolution of these changes, it must also be kept in mind that various forms of insurance (e.g., surplus lines and “county municipals”) have limited, if any, regulation.\* It is worth noting that insurance also comes under the purview of non-insurance regulatory bodies, e.g., the SEC for corporate governance and independent rating agencies, such as Standard & Poor’s and A.M. Best & Co., and some industry observers say that the time may be coming where these groups have more influence than traditional insurance regulators.<sup>100</sup>

Based on the preceding insurance-line assessments, we offer the following U.S. outlook for the types of issues discussed in this paper, particularly the ways in which trends in extreme weather events are eroding insurability.

- **Flood**—currently a mix of public/private insurance and risk sharing. Under climate change, we expect insurability problems to extend from the present personal and small-commercial lines into larger commercial lines. To highlight this issue, one need only look to the enormous flood losses of Hurricane Katrina.
- **Windstorm**—a largely insured risk at present. We are already seeing considerable insurability problems and associated changes in terms and pricing, non-renewals, market withdrawal, etc. This could increase dramatically under climate change, resulting in further shifting of losses to governments and consumers.

---

\* Most domestic reinsurers are fully licensed and regulated insurers. Foreign reinsurers must maintain deposits in the United States in order for the primary insurer to take credit for the reinsurance on its balance sheet.



- **Agriculture and livestock**—currently a public/private insurance partnership. Climate change will stress this sector considerably, with potential for impacts due to drought, flood, pests, or other events on a scale with the Great Dust Bowl of the 1930s. The public crop program could become insolvent, although it would likely continue to provide coverage for political and socioeconomic (public policy) reasons.
- **Wildfire**—currently largely privately insured. We anticipate an evolution similar to that seen from the earthquake hazard, i.e., more retention of risk by purchasers of insurance and more involvement by state governments, while insurers raise deductibles and reduce limits of liability and scope of coverage.
- **Mold and moisture damage**—largely commercially insured until the crisis emerged a few years ago. Now, many states have exclusions. A Federal Mold Pool has been proposed as House Bill 5040 and has been endorsed by some stakeholders,<sup>101</sup> which would shift this risk to the government sector.
- **Earth movement and coastal erosion**—primarily insured by government, if at all. Permafrost melt, subsidence of dry soils, and sinkholes will become more prevalent, as will mudslides and property losses from coastal erosion. As an example, sinkhole losses have been rising in Florida, with rate increases of 35 percent in loss-prone areas and calls for new insurance pools to help handle the risk.<sup>102</sup> Government programs covering storm-surge-driven losses on eroded property could be overwhelmed with losses under climate change, with the result of more retention by property owners.
- **Health impacts**—currently largely privately insured. Aside from the emergence of new diseases, we do not anticipate an insurability crisis under climate change. Certain forms of losses could increase sharply, however, particularly concerning respiratory disease. Impacts will manifest in the form of elevated health insurance prices. The U.S. government has assumed a steadily increasing share of health insurance costs, up from about 25 percent in 1965 to almost 50 percent today.<sup>103</sup>

The aggregate effect of the preceding observations is towards rising insurability problems resulting in structural changes that alter the current risk-spreading formula in the United States and the market share for insurers. This is exemplified by the growth in so-called “surplus lines” insurers (currently collecting \$33 billion in the U.S. in 2005, up 65 percent since 2002)<sup>104</sup> that are largely outside the regulatory framework for pricing. It is not unusual for surplus lines providers to fill the vacuums created as conventional insurers leave particularly risky markets (e.g., in response to mold-related withdrawals from the Texas market or post-hurricane withdrawals in the U.S. Gulf states). While surplus insurers help address insurance availability problems, the combination of higher prices, absence of solvency regulation, and non-admittance to risk-spreading pools renders consumers availing themselves of surplus insurance more vulnerable.

Another example of the shifting of costs to consumers has been evidenced (according to the Insurance Information Institute) in hail-prone parts of Texas, Kansas, Kentucky, and other mid-western states where, in addition to tightening deductibles, some companies are providing coverage for roofs on a depreciated (actual cash value), rather than a replacement-cost basis.

Governments already play a role in preparing for or recovering from virtually each class of climate-related loss we have examined, and will be called upon to do more. As losses from climate change increase, consumers and businesses will be required to assume a larger proportion of a growing absolute level of losses, both via deductibles that precede paid loss as well as via costs that exceed coverage limits [essentially as “self (re)insurers”], either directly or as taxpayers who pay for government assistance in the aftermath of extreme weather events. As seen with the existing flood program, governments set relatively low limits on losses (\$250,000 for personal lines and \$500,000 for commercial lines), and exclude coverage for temporary living expenses or business interruptions.

Insurers can be largely insulated from the impacts, as long as regulators award an adequate combination of rate increases and permission to change terms and market participation.

---

*As losses from climate change increase, consumers and businesses will be required to assume a larger proportion of a growing absolute level of losses, both via deductibles that precede paid loss as well as via costs that exceed coverage limits*

---

---

However, this could translate into some slowing of growth in commercial insurance premium volumes, but also lower claims.

## VII. The Way Forward—Proactive Measures

There exist a host of responses that are desirable for the business community and consumers alike. They require, however, successfully overcoming and integrating responses to a combination of technical and policy related hurdles. Thus, there must be a willingness to seek solutions and to build the structure for policy implementation, as well as good actuarial analysis and catastrophe modeling.

Success will depend on emphasizing science rather than rhetoric (at either end of the political and ideological spectrum), and fostering understanding rather than polarization. Such polarization can have a counterproductive effect on sound analysis and risk management. Proof of climate change claims and counter-claims by “vigorous assertion” and research based on preconceived outcomes, make for dramatic news headlines but fail to genuinely address the nonpolitical and hopefully multi-partisan desire to safeguard homeowners and businesses from the fallout of natural disasters.

We offer some specific recommendations below, indicating logical leadership roles from various key players: Insurers, insurance regulators,\* state and federal governments, and insurance consumers. In practice, solutions require collaboration and risk-sharing among these stakeholder groups. Following are some thoughts on the roles these groups can play while working in unison. Public-private partnerships are clearly essential. Insurers and governments have devised and must continue to craft innovative means for spreading financial risk while fostering loss-prevention practices.<sup>105, 106</sup> Care must, of course, be taken that new activities are consistent with the anti-trust requirements of the Sherman Act.

### Insurers

- **Strive to improve loss data collection and actuarial analysis.** Better (more thorough) data collection and analysis of observed trends are essential (coupled with attribution analysis—what is the role of climate change versus socioeconomic/demographic drivers?)
- **Analyze the negative and positive implications of climate change on their business, investments, and customers, and share the results with shareholders.** It would be prudent for insurers to comprehensively examine the full range of potential effects of climate change on their businesses, including property/casualty lines, life/health lines, and their investment portfolios. Such analyses should include effects of changes in frequency, type, and intensity of extreme as well as small-scale events on insurability and surplus, and shifts in market share to or from alternative risk transfer mechanisms such as self insurance, catastrophe bonds, or weather derivatives. The U.S. Government Accountability Office has expressed concern about the relative risks of some of these alternatives compared to traditional insurance.<sup>107</sup> Responding to climate change will also present opportunities for insurers and their shareholders, as noted by AIG, Allianz (owner of Fireman’s Fund and PIMCO),<sup>108</sup> and other insurers.
- **Vigilantly and vigorously promote and support advanced building codes, the “fortified building” concept, and tools to mitigate potential losses.** For example, when indoor air quality issues first arose, insurers, fearing catastrophic and unmanageable losses, excluded coverage.<sup>109</sup> As the years passed, insurers have learned more about building science and ways to pre-empt problems through better building design and operation, with the result that the situation has begun to shift from “problem” to “opportunity”.<sup>110</sup> It takes courage to constantly and universally promote strong building codes and land use control measures. As evidenced by the modest scale of beneficial activities such as those of the Institute for Business and Home Safety, the insurance industry considerably under-invests in risk management and loss prevention.

---

\* The McCarron-Ferguson Act of 1945 placed the regulation of the insurance industry under the states

---

*Proof of climate change claims and counter-claims by “vigorous assertion” and research based on preconceived outcomes, make for dramatic news headlines but fail to genuinely address the nonpolitical and hopefully multi-partisan desire to safeguard homeowners and businesses from the fallout of natural disasters.*

---

- **Engage in weather/climate research and promote the use of scientific methods for enhanced climate modeling.** While insurers should not be expected to conduct basic research, their deep understanding of risk assessment and management, coupled with their traditions of data collection, represent potent ways in which they could augment existing climate science. One of the potential outcomes—better modeling— could significantly improve the quality and applicability of data and risk analyses, facilitating availability of insurance in regions where the current lack of information is an obstacle to market development (Box 6). One potential area might be flood risk, which has often been viewed as uninsurable. This would constitute a major sea-change in the perspective of insurers regarding this particular hazard (Swiss Re 2002). CAT modelers recognize the need for this.<sup>111</sup> A very positive precedent for this type of work has been set in the case of earthquake insurance.

### **Box 6. Coupled Climate and CAT Models for Better Strategic Intelligence**

Disjointed modeling traditions hamper insurers' ability to assess weather-related risks and regulators' ability to safeguard both insurers and consumers. Insurers' weather-related loss models focus primarily on single catastrophic events (to the exclusion of a broader array of small-scale events that have larger aggregate impacts), are predicated on extrapolating historical trends to normatively defined areas of exposure, and largely neglect life/health impacts. The models are typically applied to hypothetical disaster scenarios at the individual insurer level, rather than to probabilistic regional or national scenarios based on expected trends. They are also based on isolated events (e.g., single hurricanes), rather than aggregate seasonal effects across a range of perils. One of the "big-3" modeling firms noted that Hurricane Katrina revealed a number of shortcomings in existing models, shortcomings that yield systematic underestimation of exposures.<sup>112</sup> Not all relevant events are covered by insurance models (particularly the non-catastrophic events, e.g., permafrost melt, that yield large claims in the aggregate), and existing models and storm-rating scales are incomplete, e.g., covering the wind effects of hurricanes but not the ensuing water-related losses.<sup>113</sup>

In contrast, the climate change community's models are future-focused and yield longer-term results not easily applied to business decision-making or particularly abrupt climate change impacts.<sup>114</sup> Winterstorms are an important category of relatively small-scale event that is not well captured in current catastrophe modeling tools.

The climate- and catastrophe-modeling communities operate largely in isolation. The Reinsurance Association of America has noted the opportunity and imperative for integrated assessments of climate change impacts, stating to its constituents "it is incumbent upon us to assimilate our knowledge of the natural sciences with the actuarial sciences—in our own self interest and in the public interest".<sup>115</sup> An effort to bridge the gap, in the case of windstorms under climate change, yielded striking results.<sup>116</sup> While conducted by the Association of British Insurers, the CAT modeling was performed by one of the leading U.S. firms (AIR Worldwide, a subsidiary of the Insurance Services Office, ISO). U.S.-based RMS also contributed to the study. Predicted losses, technical prices (risk premiums), and capital requirements under a low-emissions scenario were one-fifth to one-eighth those under a high-emissions case. The value of improved data and modeling is central, as evidenced by a potential shift in the industry (thanks in part to better models) toward accepting flood risks in areas where they previously had been viewed as uninsurable.<sup>117</sup>

Several insurance trade organizations, plus State Farm, endorsed this idea in a letter to then Vice President Gore in 1995,<sup>118</sup> yet little headway has been made in this direction in the ensuing years.

*Disjointed modeling traditions hamper insurers' ability to assess weather-related risks and regulators' ability to safeguard both insurers and consumers.*

---

*After New Orleans, it's becoming clearer that we are experiencing more frequent and more powerful weather events that pose huge challenges for the insurance industry... This is both a coastal issue and a heartland issue. We're seeing all kinds of extreme weather in the Great Plains, including drought, tornadoes, brushfires and severe hailstorms.*

Tim Wagner, Director  
Nebraska Department  
of Insurance

---

- **Create an industry-driven activity improving on the climate change insurance working group that was briefly active in the mid-1990s.\*** There would be real benefit of new dialogue among trade associations, their member companies, and unaffiliated insurers. The original group existed for only a brief period and did not have any lasting impact.
- **Lead by example in reducing their corporate climate footprint.** While not among the major emitters of greenhouse-gas emissions, insurers nonetheless own and operate enormous numbers of buildings in which energy efficiency opportunities abound. Hartford Steam Boiler's headquarters was among the very first buildings to receive the Energy Star label for energy performance.
- **Encourage policy action and technical measures to achieve greenhouse-gas emissions reductions, especially where there are direct collateral benefits for the insurance core business.**<sup>119</sup> For example, FM Global has promoted energy efficient "torchiere" light fixtures because of their fire-safety benefits, as an alternative to the energy guzzling halogen models dominating the market.<sup>120</sup> An aggressive energy efficiency campaign in California avoided 50 to 150 hours of rolling blackouts during the summer of 2001.<sup>121</sup> Most energy efficiency strategies also provide peak demand reductions, which are beneficial in the event of power shortages e.g., during extreme temperature events. The American Insurance Association has endorsed various forms of emissions reduction strategies (as well as land-use planning), observing that some have the "win-win" benefit of reduced insurance hazards (Box 7). They also, rightfully, point out that care should be taken to ensure that climate change mitigation strategies do not have inadvertent adverse consequences on the insurance core business.

### **Box 7. Energy Efficiency Strategies Endorsed by the American Insurance Association\***

- **Speed Limits Have Both Safety and Environmental Benefits:** Experience during the 1970s and 1980s with national speed limits of 55 mph has conclusively shown that lower speeds not only save energy and reduce greenhouse gas emissions, but also lower deaths and injuries on the highways. The abandonment of a national speed limit and a return to 65, 70, or higher mile per hour speed limits in most states was an unfortunate societal development affecting highway safety, energy usage, and greenhouse gas emissions.
- **Energy savings and loss control:** Working with several property-casualty insurers, the U.S. Department of Energy's Lawrence Berkeley National Laboratory has identified areas where energy efficiency improvements also reduce fire, explosion, or winter storm hazards. Insurers can support improvements in energy efficiency as long as they do not create new, unanticipated risks to human safety and property, particularly when energy efficiency strategies measurably improve safety and loss control.
- **Public Transportation and Other Non-Driving Alternatives:** Property-casualty insurers are generally supportive of increased investments and improvements in public transportation, and other initiatives that encourage less driving including "smart growth" strategies, HOV lanes, and pedestrian and bicycle access. These strategies reduce energy usage and promote cleaner air. For auto insurance and highway safety, they reduce congestion in urban areas and stress on drivers that leads to increased accident rates. Public transportation also helps to enhance and preserve mobility options for young and very elderly drivers that tend to have higher accident rates.
- **Telecommuting:** Increased telecommuting takes drivers off the road during the highest morning and afternoon rush hours in the most congested urban areas where accident rates and insurance costs are the highest. Telecommuting also reduces energy consumption and emissions.

\* Quoted from the American Insurance Association documents.<sup>122, 123</sup>

---

\* The original members are listed in the Key Findings section.

---

## Insurance Regulators<sup>124</sup>

- **Review the “standards of insurability” to identify new challenges, domestically and abroad.** Given the changing conditions, it would be prudent for regulators to revisit the standards of insurability and examine the various climate-related hazards (on a line-by-line basis) in this context. The potential for insurer-initiated risk management should be evaluated for risks that are deemed currently or potentially uninsurable. As U.S. insurers do more business overseas, the risks there must be assessed as well. Calling for disclosures of climate risks is one approach. In an indication of the willingness for insurers to disclose their risks and activities, Aetna, Allstate, AIG, Prudential, and St. Paul Travelers have voluntarily participated in the Carbon Disclosure Project.\*
- **Incorporate climate risks in solvency and consumer-impact analysis.** In anticipation of a continued rise in losses (which are rising faster than premiums), regulators will need to redouble their efforts to ensure solvency and to encourage best practices among insurers and self insurers. This will, in turn, minimize adverse consumer impacts. An important example was the All-Industry Research Advisory Council’s report in 1986, which surprised the insurance community by quantifying the considerable effect of multiple mega-catastrophes on insurer solvency.<sup>125</sup> It is remarkable that this work has not been replicated or updated over the intervening 20 years. Another area that merits analysis is the degree to which insurer investments may unexpectedly decline in value if they have not been thoroughly vetted for climate risk issues.
- **Encourage insurers to collect and analyze more comprehensive data on weather-related losses.** The existing floor of \$25 million per loss erodes the value of the PCS data.<sup>†</sup> Relaxing this limit within PCS, or creating a new data-gathering body would be of value. Currently there is scant information on the role of weather events in vehicle accidents, power outages, and, especially, health-related losses. While catastrophe losses are relatively well documented, few comprehensive statistics exist for equally important “small-scale” events such as lightning strikes and soil subsidence. Basic insurance loss data should be more readily available in the public domain.
- **Elevate the practice of catastrophe modeling.** In order to assess exposures of insurers and their customers, CAT models (or other tools) should integrate the processes of climate change. The models should be subject to peer review. The Florida Commission on Hurricane Loss Projection Methodology may be a good model for replication and expansion to other perils.<sup>‡</sup> Existing CAT models, however, only cover a subset of insurance-relevant climate change impacts. These voids should be filled with new modeling methods.
- **Assess exposures of insurer investments and adequacy of capital and surplus to weather extremes.** Extreme weather events affect the financial markets, real estate, and other assets in which insurer capital and surplus are invested. Insurers held over \$3 trillion in stocks and bonds alone, as of the year 2001,<sup>126</sup> representing almost 9 percent of the total market, held primarily by life-insurers.<sup>127</sup> Analyses of the potential for erosion of capital and surplus or liquidity problems should include shifts in weather impacts. Insurers themselves must make this assessment, the result of which will be confidential and held by the insurer but accessible to regulators. While a \$300+ billion insurer surplus is often cited as an adequate war chest for disasters, only a fraction of it is available for losses arising from extreme weather events, to any particular insurer, or to a specific category of loss.
- **Explore the feasibility of developing a weather exposure (large and small events) questionnaire.** Doing so for climate change would be more complicated, and certainly would have to be implemented at the level of specific perils (e.g., hurricanes). This could

---

*Reinsurers who provide a backstop on large losses are engaged on the climate issue, but much more work needs to be done by the primary insurers who consumers rely on when catastrophes hit.*

Joel Ario, Oregon Insurance Administrator  
Vice President, National Association of Insurance Commissioners

---

---

\* Their statements on the issue can be found at: <http://www.cdproject.net/>

† According to the Insurance Information Institute, when the floor was raised from \$5M in 1996 to \$25M in 1997, the number of catastrophes fell from 41 in 1996 to 25 in 1997, mostly due to this reclassification. See <http://www.iii.org/media/hottopics/insurance/xxx/>

‡ See <http://www.sbafla.com/methodology/>



---

be modeled partially after the California Insurance Department's annual Earthquake Questionnaire.

- **Identify and remedy undue barriers to constructive insurer activities.** Among the possible barriers to further insurer engagement in the climate change responses are the inability to recover climate research costs through rates and ways in which antitrust laws might impede the gathering and analysis of useful claims data. A thorough review of issues should be conducted.

### Governments

- **Foster and participate in public-private partnerships for risk spreading.** If executed properly, potent synergisms can help maintain insurability where coverage could otherwise be withdrawn. Various levels of government (from local to international) can contribute here.
- **Reduce disaster losses through planning and post-event response.** Hurricane Katrina highlights the need for pre-event loss assessment, in-depth planning, and a higher level of preparedness.
- **Maintain (or even restore) insurability by improving resilience to disaster losses.** The American Insurance Association offered six recommendations to the OECD for mitigating catastrophe risk.<sup>128</sup> These included early warning systems, better land-use planning, improved building codes and catastrophe-resistant reconstruction, improved coordination and planning of national and international relief efforts, assistance in catastrophe contingency planning, and support for pre- and post-event mitigation and response. Local governments often have lead responsibility for the above-mentioned activities.
- **Comprehensively assess the government's overall financial exposure to changing patterns of weather disasters.** Governments are vulnerable to impacts on flood and crop insurance, outlays for emergency disaster relief, and as significant owners of weather-sensitive infrastructure.
- **Expand basic research on climate change and loss modeling, and issue climate change hazard maps.** By analogy, the hazard maps for earthquakes indicate risks of liquefaction and landslides. In the case of climate change, such maps could show the relevant projected impacts, by peril. Policymakers must reckon with the fact that budget constraints impede the implementation and updating of hazard maps.
- **Take policy action to reduce greenhouse gas emissions.** Governments are already engaged in efforts to reduce greenhouse gas emissions, and, in light of the potential impact to insurance customers, these efforts should be redoubled.

### Consumers

- **Minimize disaster losses through the use of recognized pre-loss mitigation practices.** Consumers (whether in households or the business sector) must ultimately understand and weigh the risks they face, adopt loss-prevention measures, and make informed insurance purchasing decisions.
- **Curb emissions that cause climate change, primarily by making cost-effective energy efficiency improvements and increasing the use of carbon-free energy sources.** Ultimately, it is insurance consumers (whether homeowners, renters, businesses, or industries) that consume energy and contribute to other causes of climate change. Whether heating and cooling in homes, lighting in office buildings, fuel-economy in vehicles, or industrial processes, a myriad of cost-effective energy-efficiency strategies are available to reduce energy use by 50 percent and more in many cases.

---

*It has become evident that climate change will continue to challenge insurers and state insurance regulators. Inevitably, this will pose a threat to the availability of essential insurance coverages for consumers.*

The National Association of Insurance Commissioners

---



---

## Postscript—In the Wake of Hurricane Katrina

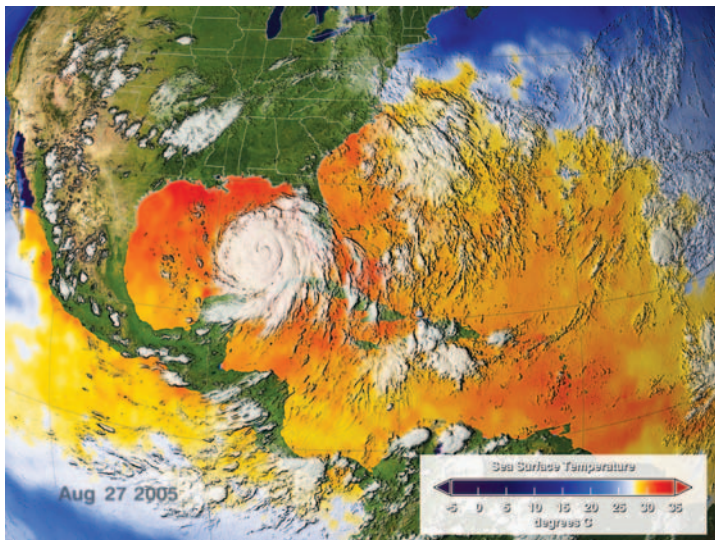
*Work on this paper began shortly before Hurricane Katrina struck New Orleans and the broader Gulf Region in late August 2005. The ripple effects of Katrina across public and private insurance highlight many of the questions of insurance availability and affordability discussed in this report.*

The Insurance Information Institute\* has stated that Hurricane Katrina is “the worst natural disaster the insurance industry has ever handled,” and according to ISO’s preliminary estimates, 1.6 million claims are expected (Figure 17). The storm’s footprint was historic, and the storm surge may have exceeded 30 feet, causing ultra-rare “500-year return period” flooding in some areas.<sup>129</sup> The full extent of the losses are not yet known, but this historic event clearly created an intricate web of impacts involving almost all lines of insurance, plus additional economic impacts affecting the broader economy. Preliminary estimates include 500,000 left homeless, more than 250,000 properties and 200,000 cars destroyed, major crop and fishery losses and disruption of agricultural exports, temporary loss of 95 percent of the region’s oil production, as well as interrupted foreign oil imports, elevated national and international energy prices to \$70/barrel, and demands for tens of billions of dollars in federal disaster relief. Widespread pollution resulted from washed-out sewage systems, landfills, industrial sites, and gasoline and oil tanks (equivalent to two-thirds of the famous Exxon-Valdez spill).

---

*The full extent of the losses are not yet known, but this historic event clearly created an intricate web of impacts involving almost all lines of insurance, plus additional economic impacts affecting the broader economy.*

---



**Figure 17. Warm ocean waters energize hurricanes.** This image depicts the three-day average of sea surface temperatures (SSTs) from August 25-27, 2005, and the growing breadth of Hurricane Katrina as it passed over the warm Gulf of Mexico. Yellow, orange and red areas are at or above 82°F, the temperature needed for hurricanes to strengthen. By late August SSTs in the Gulf were well over 90°F. Sources: NASA/GSFC/SVS

The property losses stem from multiple factors, among them, wind (including tornadoes following the hurricane), flood, fire, looting, mold, and environmental contamination. Virtually every property-casualty insurance line has been impacted, including homeowners, commercial property, personal and commercial automobile, and environmental liability. Due to disruption of supply lines and the protracted recovery, extraordinary business interruption losses are expected, compounded by the outage of 30 electric power stations serving 1.3 million customers and forced evacuations of disaster management personnel, and disruptions to five of the top twelve U.S. ports. Significant losses occurred in lines of business and asset classes not normally significant in past catastrophes; these included cargo, inland

---

\* See [http://www.iii.org/media/hottopics/additional/katrina\\_faqs/](http://www.iii.org/media/hottopics/additional/katrina_faqs/). Most of the statistical information in this section comes from Risk Management Solutions (2005).

---

marine and recreational watercraft, floating casinos, onshore energy, and automobiles. Direct economic losses are compounded by local inflation (e.g., 15 percent higher lumber prices) induced by the event. With 1,200 deaths and uncounted healthcare costs, life and health insurance will be impacted as well. Rating agencies have put large insurers such as Allstate and State Farm on notice for possible ratings downgrades.<sup>130</sup>

With estimated insured losses currently ranging up to \$60 billion—double last year’s record of \$30 billion in hurricane losses from four hurricanes in the U.S.—Katrina is a real-world “stress test” of how well the insurance system and its customers can withstand future catastrophic losses. It also focuses increased attention about the influence of climate change on hurricanes and the rising human vulnerability to such cataclysmic events. No doubt, Katrina will prompt a wave of insurance price increases, tightening terms and market withdrawals. The federal government, with 377,000 flood insurance policies in force in Louisiana alone, will have large numbers of claims through the National Flood Insurance Program (NFIP)—which provides \$52 billion of coverage in Louisiana—and broader disaster relief efforts. Amid renewed calls for a national reinsurance backstop for catastrophes, both FEMA and NFIP will likely have to obtain new funds from the U.S. Treasury to compensate for insufficient reserves. Preliminary estimates of government aid and reconstruction—\$200 billion or more—are comparable to the cost of the war in Iraq, and are double that of the Marshall Plan. Most low-income households will face the difficult circumstance of having no insurance at all.

---

***No doubt, Katrina will prompt a wave of insurance price increases, tightening terms and market withdrawals.***

---

As did Hurricane Ivan the year before, Katrina caused enormous offshore property losses to oil and gas infrastructure\* and on-shore losses to the electricity sector, with associated business interruptions. Following the storm, the local power utility Entergy quickly filed for bankruptcy protection.<sup>131</sup>

### **Effects on Insurance Prices and Availability**

As coverage is curtailed and prices increase, Katrina will have more acute impacts on insurance buyers than on insurance companies. Price increases (on top of those awarded after the active 2004 hurricane season) will extend out of the Gulf region, and, indeed, beyond the U.S. borders, reversing the downward global trend in reinsurance prices.<sup>132</sup> Florida-based homeowners insurers were awarded 15 to 20 percent premium increases to recover losses from 2004, and it is likely that similar requests will be put before the state regulators across the Gulf region given the even larger losses in 2005.

Caps on total losses payable under the government-funded National Flood Insurance Program (currently \$250,000 for residences and \$500,000 for small businesses) haven’t kept pace with inflation or rising property values. As a result, there will be increasing demand for commercial insurance layers to pick up where public relief leaves off. Those policies will be priced quite steeply. For example, in the wake of the recent mold crisis in Texas, surplus-lines insurers entering that market to fill the vacuum left by departing homeowners insurers are commanding three-fold higher premiums. The recent string of hurricane losses could lead to a similar scenario.

The energy sector is sure to be hard-hit. Already absorbing price increases of 25 percent in some areas after hurricanes in 2004, similar or greater increases in the cost of business interruption insurance and property insurance will likely follow Katrina and Rita. Of more concern, some in the industry fear the loss of insurance availability altogether in some areas.

It’s not only prices that are of concern. The losses of 2005 will no doubt extend the industry trend towards specifying percentage deductibles instead of fixed-value ones.

---

\* Reflecting the combined effects of hurricanes Katrina and Rita, as of October 7, 2005, oil production in the Gulf was down by 78 percent and natural gas by 64 percent. In addition 111 oil platforms destroyed, 52 extensively damaged, 19 adrift, and 44 pipelines damaged. About 200 oil rigs and 1,300 platforms remained evacuated. Source: U.S. Department of Energy “Gulf Coast Hurricanes Situation Report #12”.

---

“Wind deductibles” of 2 percent already exist in some markets. This would correspond to a \$10,000 deductible for a \$500,000 loss (compared to the \$500 to \$1000 fixed-level deductibles otherwise typical of homeowners policies).

For some insurers, higher premiums may not be enough to keep them in the market. Reduced availability of insurance may have greater long-term consumer impacts than price increases. This will place more pressure on governments to establish FAIR Plans and other “residual market mechanisms.”

### Growing Evidence of Climate Connections

Much more work must be done to understand the potential effect of climate change on hurricane activity, and to isolate the superimposed effects of natural cycles from human influences today and in the future. In August 2005, MIT professor Kerry Emanuel reported that the destructiveness (peak winds and duration) of tropical storms and hurricanes in the Atlantic and western North Pacific has more than doubled since the 1970s<sup>133</sup> and, in September 2005, Webster et al.<sup>134</sup> independently reported that the frequency of Category 4 and 5 hurricanes had also almost doubled in all ocean basins. These researchers independently found that the changes in storm intensity and the frequency of large storms were correlated with warming of the tropical oceans, and they projected that continued warming is likely to enhance storm intensity still further. Also in 2005, Scripps Institute of Oceanography reported that the ocean has absorbed 84 percent of the globe’s warming—effectively delaying the effect of climate change on surface air temperatures—and that the trend is unmistakably associated with human activities.<sup>135</sup> Yet, despite this growing body of evidence, current techniques for characterizing hurricanes are crude. The category-based hurricane rating system does not reflect size, storm surge, rainfall, or inland flooding associated with these storms. Hurricanes also remobilize CO<sub>2</sub> sequestered in the oceans, and inject huge volumes of vapor into the atmosphere, both of which feed the climate change process.

It is not appropriate to associate any single event with climate change. Climate is the long-term average of weather, and so it is the broader trends in weather events where climate change leaves its fingerprints. While climate change may have significant impacts on hurricane damages in the future, for two reasons hurricanes are the least likely place to find a climate change fingerprint in the historical record. First, the growth in population and values at risk along coastlines have been much more rapid than any expected climate change signal, making efforts to isolate the smaller effect from the larger one problematic. Second, far too few hurricanes make landfall to allow for a statistically meaningful analysis of trends.\* Insufficient data and incomplete understanding of hurricane processes, however, are not synonymous with proof or disproof of a connection between past climate changes and past hurricane damages—it is just too soon to tell. There is more certainty, however, that climate changes will yield more severe hurricanes in the future.

---

***Researchers independently found that the changes in storm intensity and the frequency of large storms were correlated with warming of the tropical oceans.***

---

---

\* See discussion on Kerry Emanuel’s website: <http://wind.mit.edu/~emanuel/anthro2.htm>

---

## Endnotes

1. Rushing, J.T. 2005. "Nelson to Renew Call for National Catastrophic Insurance Fund," *The Florida Times-Union*, September 1.
2. Louis, A.M. 1998. "Landslide Insurance Offered But Many Ineligible to Buy Policies," *San Francisco Chronicle*, February 6, p A19.
3. Mohl, B. 2005. "Home Insurer Seeks 25% Rate Hike on Cape, Islands," *The Boston Globe*, p. C7, September 15.
4. Personal communication, Tim Wagner, Nebraska Insurance Director.
5. Chan-Fishel. 2005. "Fourth Survey of Climate Change Disclosure on SEC Filings of Automobile, Insurance, Oil & Gas, Petrochemical, and Utilities Companies," Friends of the Earth (September).
6. Originally formalized by Denenberg, H.S., 1964. *Risk and Insurance*, Englewood Cliffs, NJ: Prentice-Hall, Inc., p. 615.
7. Gosselin, P and A. Miller. 2005. "Why FEMA Was Missing in Action," *LA Times*. September 5. [http://news.yahoo.com/s/latimests/20050905/ts\\_latimes/whyfemawasmissinginaction](http://news.yahoo.com/s/latimests/20050905/ts_latimes/whyfemawasmissinginaction)
8. Travis, J. 2005. "Scientists' Fears Come True as Hurricane Floods New Orleans," *Science* 309:1656.
9. Musulin, R. and J. Rollins. 2005. "Frequency Matters." *Best's Review*, January, p. 68.
10. Munich Re, 1973. *Flood Inundation*, Munich: Munich Reinsurance Company.
11. IPCC, 2001. *Climate Change 2001*, Geneva: Intergovernmental Panel on Climate Change, United Nations and World Meteorological Organization (found at: [www.ipcc.ch](http://www.ipcc.ch)).
12. Association of British Insurers. 2005. "Financial Risks of Climate Change," London, 40pp and "Technical Annexes," 139pp.
13. Mohl, B., 2005 (op. cit)
14. Harrington, J. 2005. "Nationwide to Stop Writing in Fla.," *St. Petersburg Times*, August 12.
15. Hartwig, R. 2001. "The Economic Slump: What it Means for P/C Insurers," Presentation, Boston: Insurance Information Institute
16. Mills, E. 2005. "Insurance in a Climate of Change," *Science* 308:1040-1044. [http://eetd.lbl.gov/emills/PUBS/Insurance\\_Science.html](http://eetd.lbl.gov/emills/PUBS/Insurance_Science.html)
17. American Re. 2005. "Annual Review of North American Catastrophes 2004," American Reinsurance Company, Princeton, NJ.
18. *Bests Review*. 2004. "Insolvency Most Often Pinned to Insufficient Loss Reserves," (July I), p. 14. A value of 7% is given in 2004 Best's Insolvency Study: Property/Casualty, U.S. Insurers, 1969-2002, as cited by Sonnett (2005).
19. Mills, E. 2004. "Insurance as an Adaptation Strategy for Extreme Weather Events in Developing Countries and Economies in Transition: New Opportunities for Public-Private Partnerships," Lawrence Berkeley National Laboratory Report No. LBNL-52220. [http://eetd.lbl.gov/emills/PUBS/Insurance\\_Emerging\\_Markets.html](http://eetd.lbl.gov/emills/PUBS/Insurance_Emerging_Markets.html)
20. III. 2003. "The III Insurance Fact Book: 2002," Boston:Insurance Information Institute.
21. Personal communication, Bruce Shepherd, Lloyds of London (RJ Kiln & Co, Ltd).
22. AIA. 1999. "Property-Casualty Insurance and the Climate Change Debate: A Risk Assessment," Washington, D.C.: American Insurance Association.
23. This is reproduced as Appendix F in Mills, E., E. Lecomte, A. Pears. 2001. "U.S. Insurance Industry Perspectives on Global Climate Change," Lawrence Berkeley National Laboratory Report No. 45185. <http://eetd.lbl.gov/emills/PUBS/LBNL-45185.html>
24. LaCommare and Eto. 2004. "Understanding the Cost of Power Interruptions to U.S. Electricity Consumers," Lawrence Berkeley National Laboratory Report No 55718.
25. Mills, E. "When the Lights Go Out," *Best's Review*, Oldwick, NJ: A.M. Best Company. July. pp. 73-77.
26. Adapted and expanded from discussion in Mills (2005).
27. Changnon, S.A., R.A. Pielke Jr., D. Changnon, R.T. Sylves, and R. Pulwarty. 2000. "Human Factors Explain the Increased Losses from Weather and Climate Extremes," *Bulletin of the American Meteorological Society*, 81(3):437-442.
28. Changnon, S.A. and M. Demissie. 1996. *Climatic Change* 32(4):411-421.
29. Zhang, K., B.C. Douglas, and S.P. Leatherman. 2005. *Climatic Change*. 64:41-58.

30. Easterling, D.R., G.A. Meehl, C. Parmesan, S. Changnon, T.R. Karl, and L.O. Mearns. 2000. "Climate Extremes: Observations, Modeling, and Impacts," *Science* 289: 2068-2074.
31. Karl, T.R. and K.E. Trenberth. 2003. *Science* 302:1719-1723.
32. Begley, S. 2005. "Man-Made Mistakes Increase Devastation of 'Natural' Disasters," *Wall Street Journal*, September 2, p B1.
33. Mills, E., 2005. op. cit.
34. Easterling et al., 2000 (op. cit.)
35. Vellinga et al., 2001 (op. cit.)
36. Reeve, N. and R. Toumi. 1999. "Lighting Activity as an Indicator of Climate Change," *Q.J.R. Meteorol. Soc.* 125:893-903.
37. Kunkel, K.E., R.A. Pielke, Jr., and S. A. Changnon, 1999. "Temporal Fluctuations in Weather and Climate Extremes that Cause Economic and Human Health Impacts: A Review," *Bulletin of the American Meteorological Society*, 80(6): 1077-1098.
38. AIR Worldwide Inc. 2005. "The Coastline at Risk: Estimated Insured Value of Coastal Properties," (September 21).
39. AIA. 1999 (op. cit.)
40. Swiss Re. 2003. "Natural Catastrophes and Reinsurance," Swiss Reinsurance Company, Zurich, *Sigma* 2/2003.
41. Rigzone. 2005. "Katrina: Damage to Oil Fields Worse Than Ivan," [http://www.rigzone.com/news/article.asp?a\\_id=25005](http://www.rigzone.com/news/article.asp?a_id=25005)
42. Risk Management Solutions. 2005. "Hurricane Katrina: Profile of a Super Cat: Lessons and Implications for Catastrophe Risk Management," RMS, Newark, CA, (October), 29pp.
43. Risk Management Solutions (op. cit.)
44. Schar, C., P.L. Vidale, D. Luthi, C. Frei, C. Haberli, M.A. Liniger, and C. Appenzeller, 2004. *Nature* 427:332-335.
45. In the wake of Hurricane Andrew, regulators limited or rejected insurers' requests for price increases or permission to cancel hundreds of thousands of policies. A decade later, in response to the four deductibles charged to some Florida homeowners following an intense year of hurricanes, regulators mandated reimbursement of 36,000 homeowners, forbade insurers from canceling or non-renewing victims, and required the instatement of "single-season" deductibles for the windstorm hazard.
46. Mittler, E. 1992. "A Fiscal Responsibility Analysis of a National Earthquake Insurance Program," University of California, Los Angeles, Prepared for the Earthquake Project of the National Committee on Property Insurance (NCPI).
47. Anderson, D.R., 2000. "Catastrophe Insurance and Compensation: Remembering Basic Principles," *CPCU Journal*, Society of Chartered Property and Casualty Underwriters, 76-89.
48. Easterling, D.R., Evans, J.L., P. Ya. Groisman, T.R. Karl, K.E. Kunkel, and P. Ambenje. 2000. "Observed Variability and Trends in Extreme Climate Events, a Brief Review," *Bulletin of the American Meteorological Society* 81(3):417-425.
49. Easterling et al., 2000 (op. cit.)
50. III. 2002. "The Lessons of Hurricane Andrew: Is Florida Really Ready?" Presentation by Robert Hartwig, Ph.D., Boston: Insurance Information Institute.
51. Harrington, J. 2005. "Insurance Bills up 7% for All," *St. Petersburg Times*, August 18.
52. Hartwig, R. 2003. "Trends & Challenges in the Property Insurance Business Today," Presentation to IBHS Meeting, November 12, Orlando, Boston: Insurance Information Institute.
53. U.S. GAO. 2005. Catastrophe Risk: U.S. and European Approaches to Insure Natural "Catastrophe and Terrorism Risks," United States Government Accountability Office, February, GAO-05-199.
54. U.S. GAO, 2000. "Insurers' Ability to Pay Catastrophe Claims," US General Accounting Office, Washington, USA, report B-284252, 32 pp. <http://www.gao.gov/corresp/gg00057r.pdf>
55. Holdeman, E. 2005. "Destroying FEMA," *Washington Post*, p. A17, (August 30).
56. Insurance Services Office, 1997 (op. cit.)
57. Swiss Re. 1994. "Fire of the Future," Swiss Reinsurance Company, Zurich.
58. Bible, R. 2005. "Breathless," *Wildfire Magazine*, [http://wildfiremag.com/ar/firefighting\\_breathless/](http://wildfiremag.com/ar/firefighting_breathless/)



59. Insurance Services Office. 1997. *The Wildland/Urban Fire Hazard*, New York: ISO,
60. Sullivan, L. 2003. "Depending on Technology," *Risk Management Magazine*, October, p. 6.
61. LaCommare and Eto. 2004. "Understanding the Cost of Power Interruptions to U.S. Electricity Consumers," Lawrence Berkeley National Laboratory Report No 55718.
62. See *The Energy Daily*. 2004. "Hurricane Ivan's Final Indignity: Higher Home Heating Costs," October 12, p. 3, and *The Energy Daily*. 2004. "Progress Energy's Hurricane Bill: \$252 Million," November 3, p. 4.
63. The Energy Daily. 2004. "Progress Energy's Hurricane Bill: \$252 Million," November 3, p. 4.
64. Beales, R. 2005. "Louisiana Governor Calls for Evacuation of New Orleans," *Financial Times*, August 31.
65. Harrington, J. 2005. "Nationwide to Stop Underwriting in Fla.," *St. Petersburg Times* (August 12).
66. III. 2005. "Crop Insurance," Boston: Insurance Information Institute.
67. Knutson, T.R. and R.E. Tuleya. 2004. "Impact of CO<sub>2</sub>-Induced Warming on Simulated Hurricane Intensity and Precipitation: Sensitivity to the Choice of Climate Model and Convective Parameterization," *Journal of Climate*, Vol 17., No. 18: 3477-3495.
68. Trenberth, K. 2005. "Uncertainty in Hurricanes and Global Warming," *Science* 308: 1753-1754.
69. Emanuel, K. 2005. "Increasing Destructiveness of Tropical Cyclones over The Past 30 years," *Nature*, 436: 686-688.
70. Insurance Information Institute, 2002 (op. cit.)
71. Guy Carpenter. 2005. "Natural Hazard Review: 2004."
72. U. S. Department of Agriculture and U. S. Department of the Interior. 1995. *Federal Wildland Fire Policy*, Available at <http://www.fs.us/land/wdfirex.htm>.
73. Swiss Re. 2004. "Natural Catastrophes and Man-Made Disasters in 2003," *Sigma* 1/2004, Zurich, Switzerland.
74. U. S. Department of Agriculture and U. S. Department of Interior. 1995. (op. cit.)
75. Logan, J.A., Régnière, J., Powell, J.A. 2003. "Assessing the Impacts of Global Warming on Forest Pest Dynamics," *Front Ecol Environ* 1(3): 130-137.
76. Logan, J.A., Powell, J.A. 2001. "Ghost Forests, Global Warming, and the Mountain Pine Beetle (Coleoptera: Scolytidae)," *American Entomologist* 47(3): 160-172.
77. Fried, J.S., M.S. Torn, E. Mills. 2004. "The Impact of Climate Change on Wildfire Severity: A Regional Forecast for Northern California," *Climatic Change* 64 (1-2): 169-191.
78. Heinz Center. 2000. "Evaluation of Erosion Hazards," The Heinz Center, Washington, D.C.
79. Risk management Solutions, 2005 (op. cit.).
80. Wilhite, D. 2003. "Water 101: Understanding the Drought Hazard," National Drought Mitigation Center, University of Nebraska. Presentation.
81. Easterling, et. al. 2000 (op. cit.)
82. Rosenzweig, C., F. N. Tubiello, R. Goldberg, E. Mills, and J Bloomfield. 2002. "Increased Crop Damage in the U.S. from Excess Precipitation under Climate Change," *Global Environmental Change*, 12:197-202. LBNL-47985.
83. Rosenzweig et al. 2002. (op. cit.).
84. Davidson, R.J, Jr. and B. Doane. (no date.) "Agent & Adjustor Licensing," U.S. Department of Agriculture, Risk Management Agency (presentation).
85. Insurance Information Institute. 2005. "Crop Insurance," [http://www.iii.org/media/hottopics/insurance/crop/?table\\_sort\\_544612=5](http://www.iii.org/media/hottopics/insurance/crop/?table_sort_544612=5)
86. Insurance Information Institute, 2005 (op. cit.)
87. Gibson, S. 2004. "The Insurance Implications of Climate Change for Agriculture," Presentation, 17 March.
88. Heinz Center. 2000. *Evaluation of Erosion Hazards*, Federal Emergency Management Agency, 252 pp. <http://www.fema.gov/nwz00/erosion.htm>
89. Changnon, S.A., D. Changnon, E.R. Fosse, D.C. Hoganson, R.J. Roth Sr., and J.M. Totsch. 1997. "Effects of Recent Weather Extremes on the Insurance Industry: Major Implications for the Atmospheric Sciences," *Bulletin of the American Meteorological Society* 78(3):425-431.



90. GAO. 2004. "Crop Insurance: USDA Needs to Improve Oversight of Insurance Companies and Develop a Policy to Address Any Future Insolvencies," United States General Accounting Office, Report GAO-04-517, 55pp.
91. Insurance Information Institute, 2005 (op. cit.)
92. Epstein, P. 2005. "Climate Change and Human Health," *New England Journal of Medicine*, 353, 14:1433.
93. Miller, G. 2005. "The Tsunami's Psychological Aftermath," *Science* 309:1030.
94. Epstein, P. and E. Mills (eds). 2005. "Climate Change Futures: Health, Ecological and Economic Dimensions," Harvard Medical School. Swiss Re and UN Development Programme.
95. *USA Today*. August 11, 2005. "Malaysia Imposes Emergency as Haze Turns Air Hazardous," [http://www.usatoday.com/news/world/2005-08-11-malaysiahaze\\_x.htm?csp=36](http://www.usatoday.com/news/world/2005-08-11-malaysiahaze_x.htm?csp=36)
96. Hartwig, R. 2003. "Mold and Insurance: Is the Worst Behind Us?" Presentation to the Casualty Actuarial Society Seminar on Ratemaking, San Antonio, TX, March 27. Boston: Insurance Information Institute.
97. Hartwig, R. and C. Wilkinson. 2003. "Mold and Insurance," Insurance Issues Series, Volume 1, Number 4, Boston: Insurance Information Institute.
98. Hartwig, R. 2002. "Mold and Insurance: Truth and Consequences," Presentation. Boston: Insurance Information Institute.
99. Allen, M.R. and R. Lord. 2004. "The Blame Game: Who Will Pay for the Damaging Consequences of Climate Change?" *Nature*. 432:551-552.
100. Hartwig, R. 2002. "The Role of Governments in the Insurance Industry," Boston: Insurance Information Institute. Presentation to the Royal Institute for International Affairs, London.
101. Pahl, R.J. undated. "Mold: The \$1 Billion Challenge," American Association of Insurance Services. [http://www.aaisonline.com/articles/15rn11\\_02%20p082-085.pdf](http://www.aaisonline.com/articles/15rn11_02%20p082-085.pdf)
102. *Insurance Journal*. 2005. "Insurance Regulation Report Recommends Sinkhole Fund; Fla. Legislators Considering Options," (April 14).
103. Hartwig, R. 2002 (op. cit)
104. *Business Insurance*. 2005. "Surplus Lines Premiums and Taxes by State," September 12, p. 20.
105. Mills, E. 2004 (op. cit.)
106. Linnerooth-Bayer, J., M.J. Mace, R. Verheyen. 2003. "Insurance-related Actions and Risk Assessment in the Context of the UN FCCC," Background paper for UNFCCC workshops.
107. U.S. Government Accountability Office. 2005. "Risk Retention Groups: Common Regulatory Standards and Greater Member Protections Are Needed," GAO-05-536.
108. Dlugolecki, A.. and S. Lefeld. 2005. "Climate Change & the Financial Sector: An Agenda for Action," Allianz and WWF.
109. Chen, A. and E. Vine 1999. "It's in the Air," *Best's Review*, January, pp. 79-80.
110. Perry, C. 2005. "Mold Could Grow Profits for Insurers," *Best's Review*, p 14, May 30.
111. Presentation by Robert Muir-Woods, Chief Research Officer, Risk Management Solutions, June 29, 2005 "The Future of the Insurance Industry under Climate Change."
112. Risk Management Solutions, 2005 (op. cit.)
113. Hoffmann, M.A. 2005. "Above-average Storm Activity Predicted," *Business Insurance*, September 26, p. 31.
114. Alley, R.B., J. Marotzke, W.D. Nordhaus, J.T. Overpeck, D.M. Peteet, R.A. Pielke Jr., R.T. Pierrehumbert, P.B. Rhines, T.F. Stocker, L.D. Talley, J.M. Wallace. 2005. "Abrupt Climate Change," *Science* 299:2005-2010.
115. Nutter F.W. 1996. "Insurance and the Natural Sciences: Partners in the Public Interest," *Journal of Society of Insurance Research*, (Fall), pp. 15-19.
116. Association of British Insurers, 2005 (op. cit.).
117. I. Menzinger and C. Brauner. "Floods are insurable!" Swiss Reinsurance Company, Zurich, 2002
118. Mills, E., *et al.*, 2001 (op. cit.)
119. Mills, E. 2003. "The Insurance and Risk Management Industries: New Players in the Delivery of Energy-Efficient Products and Services," *Energy Policy* 31:1257-1272.

Investor Network on Climate Risk  
Ceres, Inc.  
99 Chauncy Street  
Boston, MA 02111  
617-247-0700  
[www.incr.com](http://www.incr.com)