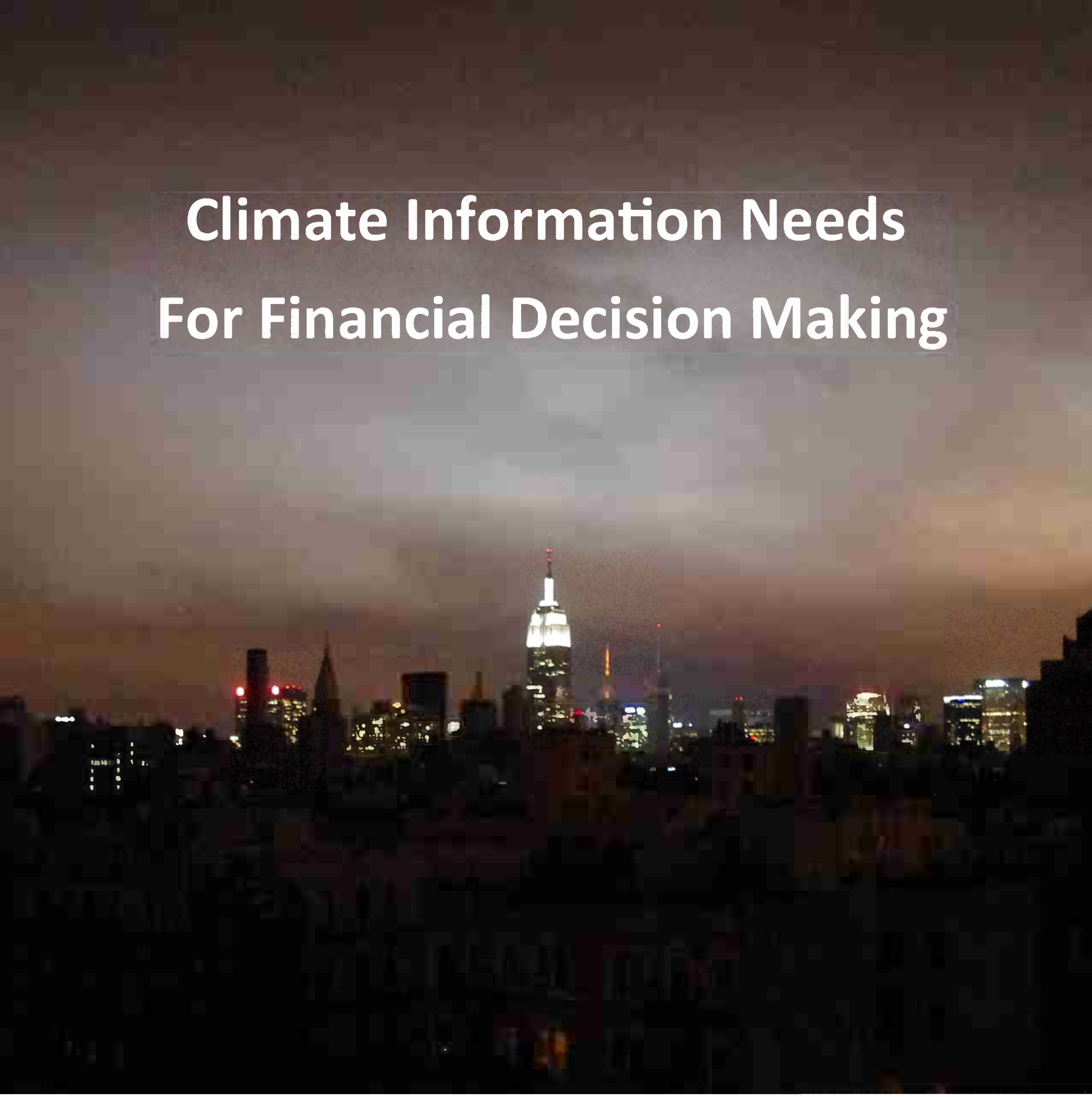
Climate Information Needs For Financial Decision Making



American Meteorological Society
Policy Program Study
November 2013

Policy Program Study

Climate Information Needs for Financial Decision Making

American Meteorological Society Policy Program

The American Meteorological Society's Policy Program is supported in part through a public—private partnership, which brings together corporate patrons and underwriters, and Federal agencies. Sponsoring agencies include the Department of Energy, the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the National Science Foundation (NSF). Corporate partners include Ball Aerospace & Technologies and Lockheed Martin.

The findings, opinions, conclusions, and recommendations expressed in this report do not necessarily reflect the views of AMS, its supporters and sponsors, or the workshop speakers, participants, and organizers.

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Acknowledgements: The workshop on which this study is based was organized by the American Meteorological Society (AMS), in partnership with the University Corporation for Atmospheric Research (UCAR). Special thanks to Gary Geeraert of the Department of Energy, Tom Bogdan and Scott Rayder of UCAR, and John Weyant of Stanford University for help planning and leading the event. Thanks to Rebecca Ranich, Bob Vallario, Frank Nutter, David Titley, Bill Hooke, and Robert Lempert for helping to develop topics, organize, and lead the workshop. Thanks also to the workshop's speakers and participants who created a vibrant discussion during the event and who provided the substantive insights for this study. This study was supported, in part, by grants from the Department of Energy (grant #DE-SC0008480), the National Oceanic and Atmospheric Administration (grant #NA09NWS4670020), and the National Aeronautics and Space Administration (grant #NNX13AM26G).

Foreword

The American Meteorological Society's Policy Program promotes understanding and use of science and services relating to weather, water, and climate. Our goal is to help the nation, and the world, avoid risks and realize opportunities associated with the earth system.

We focus on three primary approaches to accomplish this goal:

- We develop capacity within the scientific community for effective and constructive engagement with the broader society.
- We inform the broader society directly about established scientific understanding and the latest high-impact research results.
- We expand the knowledge base needed to use scientific understanding for societal advancement, particularly through our studies, research, and analysis.

The study presented here helps advance societal decision making by examining the implications of climate variability and change on near-term financial investments. We explore four key topics: 1) the conditions and criteria that influence returns on investment of major financial decisions, 2) the climate sensitivity of financial decisions, 3) climate information needs of financial decision makers, and 4) potential new mechanisms to promote collaboration between scientists and financial decision makers.

Better understanding of these four topics will help scientists provide the most useful information and enable financial decision makers to use scientific information most effectively. As a result, this study will enable leaders in business and government to make well-informed choices that help maximize long-term economic success and social well-being in the United States.

Paul Higgins
Director, AMS Policy Program

Key Findings and Recommendations

Weather events create and exacerbate risks to financial investments by causing 1) direct physical impacts on the investments themselves, 2) degradation of critical supporting infrastructure, 3) changes in the availability of key resources, 4) changes to workforce availability or capacity, 5) changes in the customer base, 6) supply chain disruptions, 7) legal liability, 8) shifts in the regulatory environment, 9) reductions in credit ratings, and 10) additional impacts that alter competitiveness (e.g., shifts in consumer preferences).

Managing these risks most effectively will depend on scientific advances and increases in the capacity of financial decision makers to use the scientific knowledge that results.

Financial decision making would benefit, in particular, from improved projections of precipitation (amount, timing, and intensity) and extreme events (e.g., hurricanes, tornados, heat waves, droughts, floods, and other severe storms). Furthermore, increasing the spatial and temporal resolution of climate projections (including for temperature) would provide decision makers with information at the scale most relevant to their financial projects. Finally, improved integrated assessment (i.e., exploration of the physical, natural, and social dimensions) is necessary for understanding the potential societal consequences of climate variability and change and how those societal consequences could impact financial decisions.

Barriers to using climate information must also be overcome. One persistent challenge results from the difficulty in communicating scientific information to user communities. Here we propose three predefined levels of certainty for communicating about weather and climate risks: 1) possible (i.e., unknown likelihood or less than 50% chance of occurrence), 2) probable (greater than 50% chance of occurrence), and 3) effectively certain (at least 95% chance of occurrence).

Critically, a great deal of information relevant to financial analysis is already available and could be used if characterized more clearly and compellingly. For example, it is *effectively certain* that 1) increasing greenhouse gas concentrations will warm the climate, 2) changes in climate will change weather patterns, 3) a warmer climate will cause increases in temperature extremes, 4) a warmer climate will cause an increase in average sea level, 5) an increase in sea level will cause an increase in storm surge height, and 6) a warmer climate will cause more intense precipitation at some locations. It is also probable that warming will cause 1) increases in the intensity of some extreme events (e.g., tropical cyclones), 2) more intense flooding at some locations, 3) shifts in the distributions and characteristics of biological systems, and 4) increases in the intensity and/or duration of drought. Finally, it is possible that human-induced warming will cause major and widespread 1) changes to existing weather patterns, 2) impacts to physical systems (e.g., coastal boundaries, snow pack, and water resources), 3) impacts to biological resources and the goods and services they provide (e.g., crop pollination; purification of water, soil, and air; pest control; nutrient cycling; and flood and drought prevention), 4) impacts on social institutions (e.g., agriculture, transportation, public health, etc.), and 5) disruptions to key planetary-scale life-support services.

Furthermore, there is great need for an information repository and portal that provides ready access to information relating to financial decision making—a one-stop shop for raw scientific data, analysis and syntheses products, risk assessments, potential response options, case studies, and best practices.

Finally, new mechanisms to promote collaboration between the scientific community and financial decision makers are needed. Effective partnerships and strong relationships would enable the scientific community to understand financial decision makers' needs and promote understanding of the potential (and limits) of scientific understanding. The coproduction of knowledge—active collaboration of the research and user communities in the research process—also has potential to enhance the creation, communication, and use of scientific information.

Key recommendations of this study:

1) Identify climate-related risks and opportunities for financial decision making.
2) Create a framework to translate scientific information in clear and actionable terms for financial decision makers.
3) Analyze existing climate assessments and translate projected impacts into possible, probable, and effectively certain impacts.
4) Improve climate projections with respect to precipitation (timing, amount, and intensity), extreme events, and tails of probability distributions (i.e., low-probability but high-consequence events).
5) Increase spatial resolution of climate projections in order to provide climate information at the scale most relevant to financial investments.

6) Improve projections of the societal consequences of climate impacts through integrated assessments of physical, natural, and social sciences.

7) Create a user-friendly information repository and portal that provides easy access to information relevant to financial decision making.

8) Create and maintain opportunities to bring together financial decision makers, scientists, and service providers.

To achieve these goals, a sustained effort to advance the national discussion will be needed. The American Meteorological Society's Policy Program intends a series of follow-on activities to continue the collaboration between the financial decision-making and scientific communities established by this study and to help put the recommendations developed here into practice. Our follow-on activities already underway include additional studies on the vulnerability and resilience of critical infrastructure to weather events and the integrated assessment and management of climate change risks to society (recommendation 6). In addition, we are developing a follow-on proposal that would convene a working group of leaders to translate existing scientific information into clear and actionable terms for financial decision makers (recommendations 3) and to design the information repository and portal (recommendation 7). Together, these ongoing and future activities constitute a considerable next step in bringing together financial decision makers, scientists, and service providers (recommendation 8).

Introduction

The United States invests roughly $1.5 trillion U.S. dollars (USD) in capital assets each year across the public and private sectors (Orszag 2008; United States Census Bureau 2013). These investments include projects in transportation (e.g., airports, roadways, and bridges), water resource management (e.g., dams, water treatment facilities, and distribution infrastructure), defense (i.e., military installations), health care (e.g., hospitals), energy production and use (i.e., associated with extraction, production, and transmission), manufacturing (e.g., factories and other buildings), and agriculture.

In an increasingly competitive global environment, nations that invest most effectively with respect to weather and climate risks will have an important competitive advantage.

The value of these investments to businesses and the broader society will depend on how effectively the resulting projects achieve their objectives over lifetimes that routinely stretch to 50 or 100 years. Over such long time scales, financial decision makers must account for a wide range of risks, including direct physical impacts to the projects themselves and potential indirect impacts that could alter the potential return on these investments.

Furthermore, many of these investments, particularly those related to infrastructure, are designed and deployed to specific sites and are highly sensitive to climatic conditions at those sites. As a result, near-term financial decisions have long-term implications for the United States' social and economic well-being that depend, in part, on climate variability and change.

For the United States to maximize its economic well-being and to maintain its status as an economic power, these capital investments must be made wisely and effectively. In an increasingly competitive global environment, nations that invest most effectively with respect to weather and climate risks will have an important competitive advantage.

This study examines the role of climate science in financial analysis. We seek 1) to help provide financial analysts, the public, the media, and leaders in the business and financial communities with access to the best available knowledge and understanding relating to climate variability and change, 2) to identify key climate information needs to improve financial analysis, and 3) to develop and strengthen collaborations involving climate researchers and financial decision makers.

Maximizing returns on financial investments depends on accurately understanding and effectively accounting for weather and climate risks.

Our analysis examines several classes of financial decisions, ranging from the construction of major infrastructures to the use of financial instruments for spreading and ameliorating risk to investment projects. As part of this effort, we looked at cases where existing climate projection information was used in the financial analysis and cases where climate projection information was excluded from the decision process. This helps reveal the usefulness of climate information to financial analysis, the barriers to using climate information in financial analysis, and research needs to reduce these barriers and to improve the analytic capability of financial decision makers with respect to weather and climate risks.

Climate Risks for Financial Decisions

Financial investments face a range of risks due to existing weather patterns and climate variability and climate change (Table 1). Maximizing returns on financial investments depends on accurately understanding and effectively accounting for these weather and climate risks.

Recommendation 1: Identify climate-related risks and opportunities for financial decision making

In broad terms, the risks to financial investments from climate variability and change include the potential for 1) direct physical impacts on the investments themselves; 2) degradation of critical infrastructure; 3) changes in the availability of key resources (i.e., quality or quantity); 4) changes to workforce availability, continuity, or performance; 5) changes to the customer base; 6) supply chain disruptions; 7) legal liability; 8) changes to the regulatory environment; 9) reduction in credit rating; and 10) additional factors that can alter competitiveness (e.g., consumer preferences). Through these ten factors, climate variability and change can either exacerbate existing risks or cause new sources of risk to emerge, as described in greater detail below.

Table 1. Risk of climate change to financial decisions. Includes potential direct and indirect impacts from the perspective of a financial decision maker.

Risk to Investment	Examples
Direct physical impacts	Storm frequency Storm intensity Sea level rise Changes in weather patterns Melting permafrost
Resource availability	Water quality Water quantity Biological goods and services (pollination, flood and drought protection, air/water purification, etc.)
Workforce	Inability to maintain continuity Increase in worker absence Inability to hire needed workforce
Customer base	Loss of customers due to migration, loss of purchasing power, shifting preferences, or inability to meet demand
Supply chain	Disruption in the availability of critical components
Credit rating	Decreased market valuation, or credit availability
Legal liability	Litigation, legal expenses, reduced valuation
Regulatory framework	Increased costs, premature retirement of capital equipment, loss of competitiveness
Infrastructure	Damage to roads, bridges, buildings, transportation, and services
Competiveness	Shifts in consumer preferences

Weather and climate events cause direct physical impacts on financial investments. For example, the Munich Reinsurance Company estimates there were over 900 natural catastrophes in 2012 that caused losses of $170 billion USD worldwide (Fig. 1) (Geo Risks Research 2013). Roughly 65% of the financial losses occurred in the United States with Superstorm Sandy alone, causing $50 billion USD in losses. Many, though not all, of these events were weather related. Potential changes in extreme weather events associated with climate variability and change create additional risks for financial investments.

Similarly, sea level rise can exacerbate existing physical risks from extreme events or create potential risks to emerge in previously unaffected areas. For example, sea level rise is expected to cause increases in storm surge height, coastal erosion, more extensive coastal inundation, changes in surface or ground water quality and quantity, and impacts on coastal habitat and infrastructure (Solomon et al. 2007; Field et al. 2012).

Even small changes in weather can impact operations in critical economic sectors. For example, a difference in temperature of a few degrees influences the demand for electric power and natural gas, while modest changes in wind speed or cloudiness can substantially alter the output of wind and solar generation (American Meteorological Society 2012). Agriculture and transportation are also highly sensitive to routine

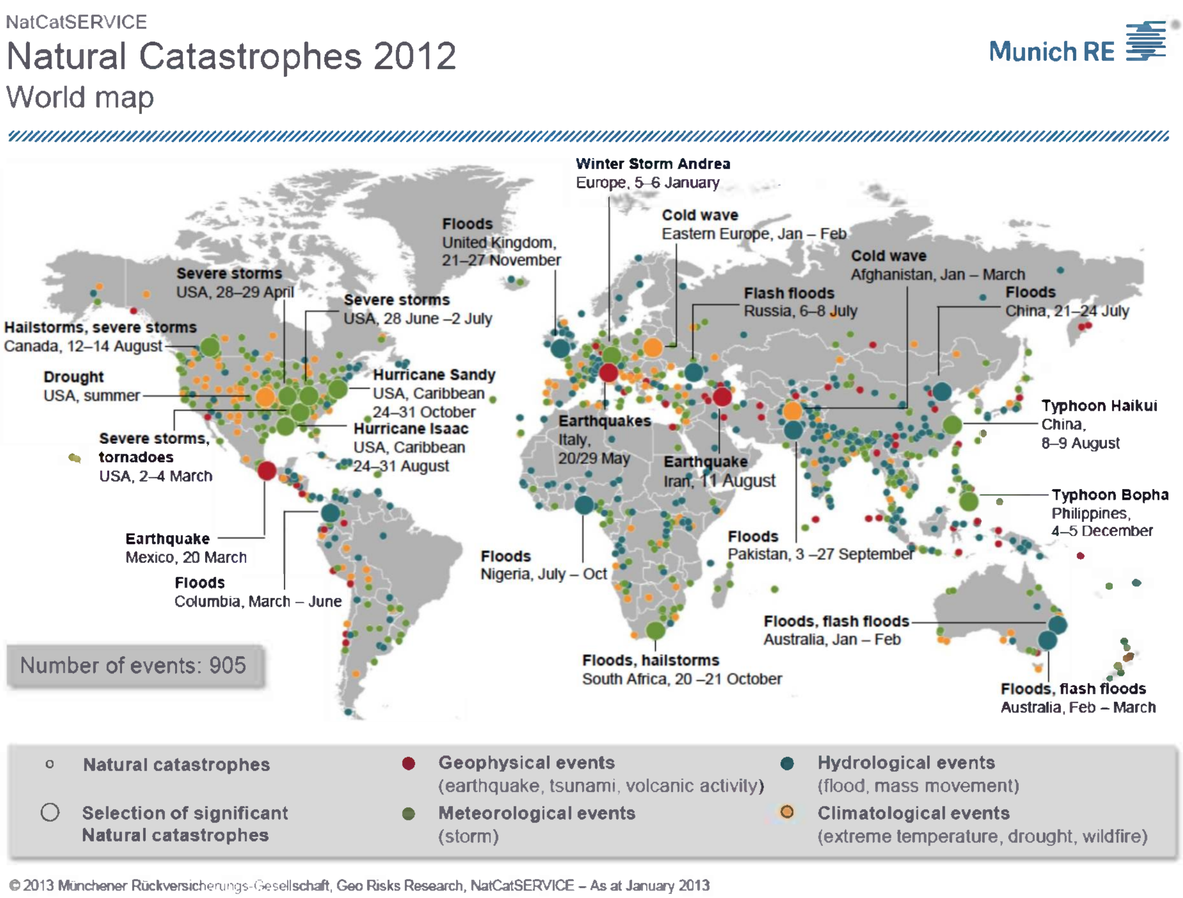

Figure 1. Natural catastrophes in 2012. Munich Reinsurance Company concludes that there were 905 events throughout the world that caused significant financial losses last year, including more than $50 billion USD in the United States owing to Hurricane Sandy alone. (The statistics/analyses provided here are the property of Munich Reinsurance Company.)

weather events. Climate variability and change have the potential to alter weather patterns and exacerbate extreme events in ways that can alter decisions when either actual or projected returns on investment are reduced.

Weather events can also reduce returns on investment decisions by damaging critical infrastructure on which those investments depend. For example, asset owners depend on public infrastructure (e.g., roads, bridges, transportation hubs, water treatment facilities, and other government services) and private service providers (e.g., for energy, telephone, cable, health care, and food) for their businesses to operate. Even when an asset proves resilient to a weather event, operations may be curtailed if the supporting infrastructure upon which those operations depend becomes unusable or unavailable. Climate variability and change create additional risks to the infrastructure on which the success of investment decisions depend.

Even small changes in weather can impact operations in critical economic sectors.

Weather events can also alter resource availability. For example, the timing and amount of precipitation and snow melt can alter water quantity and quality. Drought and elevated cooling-water temperatures can interfere with electricity generation by limiting the operation of conventional fossil fuel and nuclear power stations (American Meteorological Society 2012). When water supplies are insufficient, or water temperatures are too high, power plants' cooling needs may go unmet and be forced to shut down. These shutdowns reduce investment returns for the power plants themselves and create broader risks to financial investments through potential electricity blackouts or price spikes.

Furthermore, ecological goods and services provided by biological systems constitute key resources for numerous economic sectors, often in ways overlooked by asset owners because they are provided at such a large scale and outside market transactions (i.e., free of charge). For example, biological systems help control pests, provide pollinators for crops, assist with flood and drought control, help purify air and water, and assist with the cycling of nutrients (Corvalan et al. 2005). Widespread changes in biological systems and the goods and services they provide are anticipated in response to climate variability and change (Schneider et al. 2007).

Weather events and climate risks can also impact the workforce needed for financial investments to succeed. Even when investments themselves are unharmed, impacts from weather events can disrupt business and government operations if employees are victims and unable to report to work. In extreme cases, workers sometimes need to relocate and employers can struggle to attract workers to the locations where they are needed.

Climate variability and change can either exacerbate existing risks or cause new sources of risk to emerge.

Similarly, weather events can impact the customer base on which businesses depend. For example, population migration and dispersion away from the Gulf Coast in response to the 2005 hurricane season depleted the demand for products and services produced by local and regional businesses. Even in cases when a population remains in place, decreases in wealth or employment associated with a natural hazard can reduce demand for goods and services and thereby alter returns on investments.

Weather events and other natural hazards create risks to financial investments through potential supply chain disruptions. This is an increasingly significant risk with the expansion of globalization. For example, heavy rains in 2011 caused major flooding in Thailand, which disrupted hard drive manufacturing in the country. This created a temporary shortage of hard drives worldwide, which caused slowdowns and delays for a wide range of technology companies.

Investments that contribute to climate change (e.g., by emitting greenhouse gases) or that exacerbate the societal consequences of a weather event could face legal liability. This may include the potential for civil lawsuits (i.e. for financial damages) or legal actions that curtail operations and thereby reduce potential returns on investments.

Policy responses to climate variability and change could create risks for asset owners by altering the regulatory framework under which they operate. For example, changes to building codes, restrictions on operations through zoning, the need for additional investments in control technologies, or greenhouse gas pricing that causes an asset owner to incur additional expenses or curtail operations could all impact returns on investment decisions.

Because weather events and climate risks can alter the value of investments, they also have the potential to impact credit ratings. Notably, low-probability but high-consequence natural disasters (sometimes called "black swan" events) are often not fully accounted for in assessments of a project's potential return on investment. Therefore, improved recognition of, and accounting for, climate variability and change could alter assessments of a company's risk exposure.

Finally, returns on investments within the private sector depend on business competitiveness. Lower relative risk exposure to weather events and climate variability and change increases competitiveness directly (e.g., by minimizing costs and maximizing production) and indirectly through potential shifts in consumer preferences (e.g., by rewarding a company's perceived stability and longevity or its commitment to social responsibility).

We propose three predefined levels of certainty for communicating about future climate impacts: 1) ***possible****, 2)* ***probable****, and 3)* ***effectively certain****.*

Climate Information Needs

To be most valuable, climate information must be actionable and communicated effectively to the user communities that need it. After multiple decades of intensive research, a great deal is known about the climate system and the risks and opportunities to society posed by weather events and climate variability and change. However, much of what is known and understood has proven difficult to communicate effectively to user communities, including financial decision makers.

This sets up a two-fold challenge for climate information: 1) to communicate effectively what is already known and understood in terms that the user community (financial decision makers, in this case) can incorporate, and 2) to reveal new scientific insights that are particularly relevant to that user community.

Recommendation 2: Create a framework to translate scientific information in clear and actionable terms for financial decision makers

Intergovernmental Panel on Climate Change (IPCC) reports describe the likelihood of climate impacts using ten categories of increasing probability from "exceptionally unlikely" through "virtually certain" (Solomon et al. 2007). This broad range of likelihood categories is effective at increasing understanding among climate experts for whom the relatively fine distinctions are useful and the categories clearly defined. However, the number of categories and the nonintuitive definitions of each category likely constitute barriers to communication with outside users and lay audiences. Here we propose three predefined levels of certainty for communicating about future climate impacts: 1) possible, 2) probable, and 3) effectively certain.

Possible impacts are those for which the likelihood is assessed to be less than coin-flip odds (less that 50% chance) or for which the likelihood is unknown. Probable designates impacts that are assessed to be more likely to occur than not (i.e., greater than 50% chance of occurrence). Effectively certain impacts are those for which the chance of occurrence is assessed to be at least 95% (i.e., in 19 out of 20 cases an outcome that is effectively certain would be expected to occur).

Recommendation 3: Analyze existing climate assessments and translate projected impacts into possible, probable, and effectively certain impacts

Critically, a great deal of information is already available to allow scientists to characterize potential risks to financial investments using these three categories (Table 2). For example, it is effectively certain that 1) increasing greenhouse gas concentrations will warm the climate, 2) changes in climate will change weather patterns, 3) a warmer climate will cause increases in temperature extremes, 4) a warmer climate will cause an increase in average sea level, 5) an increase in sea level will cause an increase in storm surge height, 6) a warmer climate will cause more intense precipitation at some locations, and 7) a warmer climate will cause the degradation of permafrost (America's Climate Choices 2010; Solomon et al. 2007; Parry et al. 2007; Field et al. 2012).

Furthermore, it is probable that warming will cause 1) increases in the intensity of some severe events (e.g., tropical cyclones), 2) more intense flooding at some locations, 3) shifts in the distributions and characteristics of biological systems, and 4) the intensity and/or duration of drought to increase (America's Climate Choices 2010; Solomon et al. 2007; Parry et al. 2007; Field et al. 2012).

Near-term financial decisions have long-term implications for the United States' social and economic well-being that depend, in part, on climate variability and change.

Finally, it is possible that human-caused warming will cause 1) major and widespread changes to existing weather patterns, 2) major and widespread impacts to physical systems (e.g., coastal boundaries, permafrost, and snow pack), 3) major and widespread impacts to biological systems and the goods and services they provide (e.g., crop pollination, purification of water, soil and air, pest control, nutrient cycling, and flood and drought prevention), 4) major and widespread impacts on social institutions (e.g., agriculture, water resource management, transportation infrastructure, and public health), and 5) disruptions to key planetary-scale life-support services (Hansen et al. 2012; Rockström et al. 2009; Schneider et al. 2007).

Table 2. Possible, probable, and effectively certain climate impacts from greenhouse gas emissions to financial decision making, where "possible" connotes either unknown probability or less than 50% likelihood, "probable" connotes greater than 50% likelihood, and "effectively certain" connotes greater than 95% likelihood.

Probability of Impacts	**Impact**
Effectively certain	Increasing greenhouse gas concentrations will warm climate. Changes in climate will alter weather patterns. A warmer climate will • increase temperature extremes, • cause more intense precipitation at some locations, • degrade permafrost, • increase average sea level, and • increase storm surge height.
Probable	Increased intensity of some extreme events (e.g., tropical cyclones). More intense flooding at some locations. Shifts in the distributions and characteristics of biological systems. Increased intensity and/or duration of drought.
Possible	Major and widespread • changes to existing weather patterns, • impacts on physical systems (e.g., coastal boundaries, permafrost, snow pack), • impacts to biological systems and the goods and services they provide, • impacts on social institutions (e.g., agriculture, water resource management, transportation, public health), and • disruptions to key planetary life-support services.

The use of possible, probable, or effectively certain can also make explicit potential tradeoffs between the highly detailed description of a particular impact and its likelihood of occurrence. For example, it is possible that sea level will rise by several meters over the current century, probable that sea level will rise between 28 and 98 cm (roughly 1–3 ft) over the next century, and effectively certain that sea level will rise as a result of climate warming and that this will exacerbate storm surges and coastal inundation. As the specificity (and urgency) of a particular impact increases, the likelihood of its occurrence often decreases or becomes more difficult to characterize. The three categories allow the consideration of a range of potential consequences by explicitly trading off specificity with likelihood of occurrence. This provides the user communities with greater capacity to assess for themselves the implications of potential impacts (and likelihoods) on decision making.

Investments will be most successful, and will advance the interests of society most effectively, if they are grounded in the best available knowledge & understanding.

This discussion and the characterizations provided in Table 2 are not intended to be comprehensive given the vast existing body of information on potential climate impacts. Rather, Table 2 is intended to illustrate the potential of using a more streamlined description of probabilities to characterize risks in terms that are more actionable and more easily communicated to financial decision makers or other user communities. More comprehensive translation of existing scientific research will require additional efforts.

Toward this end, the Policy Program is developing a follow-on study proposal that would seek, in part, to translate existing climate impact assessments such as those from the IPCC and the National Climate Assessment (NCA) into more accessible information for financial decision makers using the possible, probable, and effectively certain framework. The easily accessible risk classifications that result would complement the more sophisticated quantification approaches that already exist and thereby increase the information resources available to users. The effort would bring together scientists and financial decision makers in order to establish a working group focused on characterizing a broad range of potential climate change impacts into the possible, probable, and effectively certain language.

Recommendation 4: Provide greater information on precipitation (timing, amount, and intensity), extreme events (particularly hurricanes, tornados, heat waves, droughts, floods, and other severe storms), and the tails of probability distributions (i.e., low-probability but high-consequence events)

Financial investments are often most sensitive to extreme weather events and variations in precipitation. At the same time, the projection of future precipitation patterns and extreme events remains among the most uncertain aspects of climate variability and change. Therefore, improvements in the projection of precipitation patterns and extreme events (e.g., storm frequency, storm intensity, and storm track) would be particularly beneficial to financial decision making.

Recommendation 5: Increase spatial detail of climate projections in order to provide climate information at the scale most relevant to financial investments

Increases in spatial and temporal resolution of climate projections (and increased confidence in those higher resolution projections) would also provide more detailed climate information at the locations where financial investments occur. This would make it easier to incorporate climate information into financial decision making and help identify potentially beneficial risk management options for financial investments.

Recommendation 6: Improve projections of the societal consequences of climate events through enhanced integrated assessment

The societal consequences of climate variability and change will depend on three contributing factors: 1) the nature of the event itself (e.g., intensity, speed of onset, and duration); 2) the sensitivity of key systems, resources, and institutions to the weather event (i.e., Table 1); and 3) the potential to find substitutes for those systems, resources, and institutions in case of disruptions (Higgins and Steinbuck submitted). Improved understanding of each contributing factor and how they may interact would provide critical insights on the potential consequences of climate variability and change and potential management strategies to alleviate risk.

In support of this recommendation, the AMS Policy Program has developed, and is continuing to refine, a new conceptual tool for climate change risk assessment (Higgins and Steinbuck submitted). The conceptual tool is intended for any interested individual (expert or nonexpert) and enables the exploration of a broad range of potential societal consequences of climate change. The goal is to increase public understanding of climate risks, support risk management decision making, and facilitate communication of climate risks across disciplinary boundaries, particularly among physical, natural, and social scientists.

Mechanisms to Create, Communicate, & Use Climate Information

For information creation, communication, and use to be most effective, new mechanisms for promoting collaboration between the scientific community and financial decision makers are likely necessary. We identify two overarching goals for such collaborations: 1) that they enhance the capacity of financial decision making to incorporate knowledge and understanding (i.e., that existing knowledge is available and easily incorporated into financial analysis and decision making), and 2) that they enable new advances in scientific understanding in those areas most useful to financial decision making.

For each goal, effective partnerships and strong relationships must be built to enable the scientific community to understand the user community's needs and the user community to understand the scientific potential (and limits) of future advances.

Recommendation 7: Create a user-friendly information repository and portal that provides easy access to information relevant to financial decision making

As a key first step, there is great need for a centralized portal that provides ready access to information relating to financial decision making. A one-stop shop for such information might include raw scientific data along with analysis and syntheses products that provide information in a range of formats for a range of users. The repository could also provide assessments relating to risks and opportunities, response options and their advantages and disadvantages, case studies, and best practices, when available and appropriate.

Such a repository could be created and maintained by an individual government agency, a collection of agencies [e.g., the United States Global Change Research Program (USGCRP)], a national laboratory, the academic community, scientific societies [e.g., AMS, the American Geophysical Union (AGU), or the American Association for the

Advancement of Science (AAAS)], other nongovernmental organizations, or a collaboration among these.

In support of this recommendation, the AMS Policy Program will develop a follow-on proposal to convene a small working group of key leaders to analyze and design a one-stop information repository and portal. The working group would be scoped with characterizing implementation options for the portal; assessment of advantages and disadvantages of the different potential implementation strategies; identifying remaining needs for analysis that, if met, could improve the effectiveness of the portal; and the development of an implementation strategy to bring the portal into existence.

Recommendation 8: Create and maintain opportunities to bring together financial decision makers, scientists, and service providers

In addition, there remains a need for a working community of users and producers of climate information. Existing resources include both the AMS Policy Program and AMS's Commission on the Weather and Climate Enterprise (CWCE), which bring together the academic, government, and private sectors through public–private partnerships. Similarly, the University Corporation for Atmospheric Research (UCAR) constitutes a major partnership between government agencies and the academic community. Government agencies also promote collaboration among the public, private, and academic sectors through initiatives such as the National Oceanic and Atmospheric Administration (NOAA)'s Regional Integrated Sciences and Assessments Program (RISAS) and Cooperative Institutes, the U.S. Department of Agriculture (USDA)'s Cooperative Extension System Offices, and the U.S. Department of Energy (DOE)'s national labs.

Efforts to promote the coproduction of knowledge (i.e., the joint participation of the scientific and user communities in the research process) are particularly noteworthy. Coproduction enables the continuous collaboration between producers and users of information starting from the initial scoping of the research project through data collection and analysis (i.e., knowledge generation), communication and dissemination of information, and uptake and use of information by the user community. Collaboration between the research and user communities throughout this process can enhance the creation, communication, and use of climate information.

There are also potential downsides to coproduction approaches that must be managed. For example, coproduction approaches require time and resources to create and maintain. This can drain limiting funds and personnel and requires individuals to develop new skills and expertise. Time spent establishing new connections and communicating with new communities may come at the expense of collaborations with one's own community. Similarly, developing new skills can either enhance or detract from those activities one is already most equipped to advance.

A key challenge to creating a coproduction process is in setting up a process that brings together compatible information providers with users in need of information. Six criteria can help coproduction efforts be most likely to succeed: 1) goals must be defined and align with both the producer and user communities, 2) responsibilities must be clearly specified (e.g., for leadership and particular contributions), 3) collaboration must occur throughout the process, 4) adequate resources and capacity must be available, 5) all participants must see clear benefits of contributing, and 6) whenever possible, individual contributions should be able to stand alone.

The AMS Policy Programs' ongoing and follow-on activities will continue to bring together leaders from the scientific community and financial decision makers. The working groups and follow-on studies described above constitute a key next step in developing and maintaining collaborations between scientists and financial decision makers.

Conclusions

Financial decision makers face complex challenges and opportunities relating to their near-term investment choices. Most notably, they must determine how to ensure that their long-term investments will persist and thrive over multiple decades. These investments will be most successful, and will advance the interests of society most effectively, if they are grounded in the best available knowledge and understanding.

Too often the insights gained within the scientific community are not applied effectively throughout the broader society. Scientists sometimes struggle to convey their knowledge beyond the scientific community and decision makers too often overlook the scientific insights that could improve outcomes. Therefore, society needs new and stronger mechanisms to promote collaboration among experts, policy makers, members of the media, and the public.

It is our intention that the discussions initiated through this study will lead to stronger and more collaborative relationships between the climate science and finance communities, particularly where financial analytical barriers can be measurably reduced based on increased performance capabilities of climate models and prediction systems.

The American Meteorological Society's Policy Program intends to conduct a series of follow-on activities to continue the collaboration between the financial decision-making and scientific communities established by this study and to help put the recommendations contained in this report into practice. Our follow-on activities already underway include additional studies on the vulnerability and resilience of critical infrastructure to weather events and the integrated assessment and management of climate change risks to society (recommendation 6). In addition, we are developing a follow-on proposal to this study that would convene a working group of leaders to translate existing scientific information into clear and actionable terms for financial decision makers (recommendations 3) and to design the information repository and portal (recommendation 7). The working group will identify options for the creation and implementation of the portal; assess advantages and disadvantages of the different implementation options; identify remaining needs for information that, if met, could improve the effectiveness of the portal; and offer an implementation strategy to bring the portal into existence. Together, these activities constitute a considerable next step in bringing together financial decision makers, scientists, and service providers (recommendation 8).

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Appendix I: Speaker Synopses

Rebecca Ranich, Director, Federal Energy and Resource Management, Deloitte Consulting LLP

Ranich offered a strategy for leveraging climate information to manage risks stemming from extreme weather disruptions. The first step, she said, is to identify vulnerabilities like the level of dependence on infrastructure or location of supply chains. Climate information on floods or drought is therefore central to defining the scope of the resulting uncertainty. Next, the impact of extreme weather must be quantified in terms of cost. For example, supply chain losses over the last two years jumped 465 percent between 2009 and 2011 due to extreme weather. Finally, cost–benefit analysis and the consequences of inaction must be weighed in formulating an action plan for gauging the impact of extreme weather in financial decision making.

Ranich also stressed the importance of utilizing climate data in risk management to create value, not merely protect it. That is one reason risk management now resides at the C level of many corporations. A key challenge for these emerging “chief risk officers” is the reality, according to a 2012 Deloitte survey, that “people are unaware of what they need to do concerning risk.”

Growing uncertainty stemming from extreme weather events creates risks in the form of higher costs, but it also creates opportunities. For example, investment in infrastructure offers a “breakthrough opportunity” to limit the effects of extreme weather while spurring economic development, Ranich argued.

Precisely how to bridge the staggering spending gaps for investment in water, power, and other infrastructure remains a fundamental issue. But Ranich argued that leveraging climate data to build more resilient cities is one way to attract investment.

Kyle Beatty, Senior Vice President, Business Solutions, Atmospheric and Environmental Research

Beatty described the Atmospheric and Environmental Research (AER) Emerging Risk Research Program designed to identify new and known weather risks. These risks are evolving in unexpected ways with unknown consequences. The AER initiative seeks to bring to the table stakeholders from the insurance industry as well as other financial decision makers.

With a growing number of power outages caused by extreme weather events, the group initially focused on blackout risks associated with extreme weather and aging grid infrastructure. The result was a set of probabilistic risk assessment tools designed for use as a framework for estimating the direct costs of blackouts to businesses.

Among the relevant climate datasets were historical satellite imagery showing changes in the landscape over time and, for example, the relationship of trees to power lines. Another focus was landscape changes that produced greater heating and, with it, increasing storm frequency. The exercise was designed to assess whether those changes resulted in a greater storm frequency and intensity and, if so, how does that affect risk?

Beatty concluded that "decision-integrated use of weather content" and the quantification of emerging risks offer financial decision makers an opportunity. For example, property insurers with more information about weather risks might begin offering insurance coverage for more emerging risks if there are sufficient data and analytics to confidently quantify the risk of financial loss, Beatty commented.

Sharon Hays, Vice President for Science and Engineering Activities, Computer Sciences Corp.

Computer Sciences Corp. (CSC) approaches climate modeling and financial decision making from the perspective of "big data." Very large datasets are needed to make these decisions. Hays, a former Office of Science and Technology Policy (OSTP) official, said the growing emphasis on big data is about turning the roughly 15 petabytes of U.S. government climate data into "actionable information." The value of this data can be unlocked through careful analysis, then the datasets can be synced with private sectors requirements for making billion-dollar decisions in areas ranging from commodity trading and purchasing to infrastructure and manufacturing investments.

Companies could hedge against disruptions to their supply chains caused by extreme weather, for example, by using climate information to execute trades in relevant commodity markets. An illustration was recent droughts in the Midwest that caused huge spikes in corn futures as the drought persisted. These price spikes affected the supply chains of industries like soda makers and food processors.

Ultimately, Hays said CSC is attempting to leverage large climate datasets to provide the analytical tools needed by the agricultural and manufacturing sectors to manage their risks. As an example, the ability of farmers to leverage tools based on climate data would improve their chances of hedging risks in the commodity markets. In this way, Hays said, farmers would be better positioned to cope with variable weather patterns like droughts or floods.

CSC has concluded that there is a growing market at the intersection of big data and climate. Hays stressed that financial decision makers are now in a position to define the terms of the debate about how to utilize big data while helping to shape the policy decisions based on analysis of these datasets.

Lindene Patton, Chief Climate Product Officer, Zurich Financial Services

As extreme weather events and natural disasters increase in frequency, the insured portion of the resulting losses is declining precipitously over time, Lindene warned. Between 1992 and 2010, the percentage of damage from severe weather covered by states and the U.S. government increased as insurance coverage of property damage declined. Feds and states primarily cover infrastructure damage.

Fundamentally, Lindene explained, insurance is about restoring private assets. Hence, risky behavior like rebuilding along coasts continues because owners know they will be reimbursed when the next storm hits. "Getting people to move [away from coasts or flood plains] is a tough nut to crack," she conceded.

Meanwhile, combined federal–state disaster response is underfunded to the tune of $3 trillion USD, creating what Lindene called a "climate resilience gap." When there is not enough government funding or insurance coverage to cover losses from extreme weather, one possible outcome is expensive tort litigation.

The far less expensive alternative to litigation would be using climate data to make better financial decisions.

Lindene noted some progress toward bridging the climate resilience gap, including an actuarial climate risk index. The goal is integrating regional, composite indicators with relevant multiyear regional climate models and economic consequences. The index could serve as a tool to help make insurers—and other industries—more aware of the impact of climate change. An application might be predicting the longer-term impact of losses in a particular region, she said.

Jeffrey Marqusee, former Executive Director of the DOD-managed Strategic Environmental Research Development Program

The U.S. Department of Defense (DOD)'s 2010 Quadrennial Defense Review concludes that climate change affects DOD roles and mission, meaning the Pentagon must complete a comprehensive assessment of its far-flung infrastructure. That includes 539,000 "facilities," more than 307,000 buildings, and 500 "installations."

Marqusee said coastal installations are most vulnerable due to sea level rise associated with climate change. Bases in Alaska are of immediate concern.

Nevertheless, Marqusee noted the disconnect within DOD between the impact of climate change and weather, explaining that there is little concern in the military about the impact of climate change but "weather affects everything we do!"

In response, DOD has undertaken pilot studies to develop climate change decision-making tools for its coastal and other installations. As a result, the impact of climate change is being "baked into" DOD's master planning.

Moreover, Marqusee said DOD is well positioned to use climate information for future planning since the military is accustomed to operating under uncertain conditions. The challenge, he added, will be leveraging climate information to operate amid this uncertainty.

DOD's adaptation roadmap has four goals: 1) define a coordinating body to address climate change, 2) utilize a robust decision-making approach based on the best available science, 3) integrate climate change considerations into existing processes, and 4) partner with other federal agencies and allies to address climate change challenges.

Panel Discussion: Catastrophe Modeling Companies and Climate Change

Franklin Nutter, moderator; Peter Dailey, AIR Worldwide; Annes Haseemkunju, EQECAT Inc.; Jessica Turner, Risk Management Solutions

The climate science and financial communities speak different languages—a reality a panel of catastrophe modelers addressed in discussing risk management and growing information needs.

Asked by Nutter what aspects of climate change risk managers focus on, Dailey emphasized that managing uncertainty is the "bread and butter" of actuarial science. He added that understanding annual weather variability is critical. The climate science version of war gaming is also a useful exercise in compiling catastrophe models.

Haseemkunju added that the insurance industry needs "stable" statistics based on historical weather data. At some point along the timeline, he said "cat modelers" must draw the line between weather and climate data.

Turner stressed that catastrophic risk modeling is event driven. Especially since Hurricane Katrina in 2005, she said Risk Management Solutions (RMS) has attempted to model the average number of hurricane landfalls over the next five years, acknowledging that the Atlantic is currently experiencing heightened activity levels. Since cat modeling tends to focus on extreme events, historical weather data is lacking. For example, historical stream flow data goes back only five years in some locations.

Beyond hurricanes, cat modelers have so far found few signals about climate change that cannot be explained by natural variability. What is needed is better feedback loops between climates scientists and modelers, Turner added. Publishing climate research is one way to fill the gap, as is a forum like this workshop, which brings together different domains that do not normally talk to one another.

Panel Discussion: What Can Financial Decision Makers Expect from Climate Scientists?

John Weyant, moderator; Lawrence Buja, National Center for Atmospheric Research; Tony Janetos, Boston University; Bill Collins, Lawrence Berkeley National Laboratory

Buja postulated that the evolution of climate science has reached “Climate 3.0,” a version in which climate scientists partner with decision makers to forge usable climate science that serves society. One example would be providing usable climate science data to decision makers on a quarterly basis.

“What we are really talking about here is climate services,” Buja said. “Maybe we should start calling it that.”

As the need for data grows, the impact of climate change and variability can already be seen in industries like forestry and energy production as certain climate thresholds are crossed, said Janetos. While climate studies have documented the direct effects of climate change and variability on phenomena like fire frequency, Janetos stressed that the time scales of events like droughts also matter, be they weeks, months, or decades.

Janetos also called for a better definition of “risk” so that financial decision makers could assign values to losses that he said are currently “unpriced.”

Collins stressed the impact of the computing explosion since 1990. “Our ability to compute is growing much faster than our ability to observe,” he said, meaning that despite “fragile” support for earth observation tools, we have greater ability to study climate change with higher resolution. By 2020, climate modeling may approach resolutions of 1 km.

The challenge for climate scientists providing information to decision makers will be extending weather and climate predictions beyond weeks to years and scaling up resolution to thousands of kilometers. Collins also expressed concern that some economists may be “lowballing” the risks of climate change and that that view may prevail in the current debate about what actions decision makers should take.

Panel Discussion: Case Studies and Perspectives

Energy Operations: Jeff Williams, Director, Climate Consulting, Entergy Corp.
Coastal Engineering: Dilip Trivedi, Moffatt and Nichol Engineers
Water Infrastructure: David Behar, Climate Program Director, San Francisco Public Utilities Commission

Williams emphasized that the $1.5 billion USD in losses attributed to Hurricanes Katrina and Rita exposed the energy sector's lack of reliable information on how to manage its risks. A 2010 Gulf Coast adaptation study concluded that climate change will likely increase losses over time. It also found that for every dollar spent on "hardening" infrastructure, there was an estimated $5 USD return on that investment.

Based on its survey of available climate data, Entergy concluded that it would remain viable only if it can mitigate the effects of climate change in the Gulf and help its customers adapt to the impact of climate change. "Meaningful action takes the worst outcomes off the table," Williams said.

Trivedi provided a primer on Bay Area coastal redevelopment that takes into account sea level rise projected to range between 16 and 55 in. Design criteria in coastal areas must now factor for sea level rise (SLR) probability along with the design life of coastal projects. For example, the frequency of drainage backups that used to occur once every 30 years is increasing, and must be accounted for in new Bay Area designs.

One approach called "managed retreat" uses wider setback areas to allow for future SLR. Engineers are even considering projects like stretching a membrane across the base of the Golden Gate Bridge to reduce bay flooding at high tide, Trivedi said.

In an effort to adapt San Francisco's public infrastructure to climate change, Behar said his agency seeks to invest $335 billion USD in its drinking water infrastructure. "At the end of the day, it's about investment."

What is needed by municipal planners is "actionable science" in the form of data, analysis, and forecasts that are sufficiently predictive to support decision making, including capital investment decisions. Municipalities are clamoring for this information, Behar said, but what is currently available reflects poor quality assurance and quality control.

Enter the science community, urged Behar, who proposed a federally organized central repository for climate data with a regional structure but responsive at the local level.

Gary Geernaert, Director, Climate and Environmental Sciences Division, U.S. Department of Energy, and Vice Chairman, U.S. Global Change Research Program

Geernaert stressed the need to find new ways to leverage climate data through concrete mechanisms that rely on robust data to reduce future risks. To accomplish this, a middle ground is needed between the science and financial communities—one in which climate scientists understand the requirements of financial decision makers such as actuarials and risk managers. Only then can climate scientists deliver the information financial decision makers need.

Geernaert further urged participants at the workshop to develop an action plan for merging the common interests of the financial and climate science communities.

Climate Information Needs For Financial Decision Making, Day Two: Synthesis, Conclusions, and the Way Forward

Day Two of the workshop focused on assimilating expert presentations and workshop discussions as a means to identifying new forms of collaboration between the financial community and climate scientists.

A working group led by John Weyman of Stanford University outlined the current and future climate information needs for the financial community, with particular emphasis on the "nexus" between energy, land, water, and food production. The working group found that hydrology linkages appeared to be among the most critical needs for many industries.

There was general agreement that the metrics for defining the reliability and robustness of climate information should be provided by the financial community. Weyman's group suggested the reliability metric for weather information/predictions be based largely on terminology already used by the financial community—namely, "proven," "probable," and "possible."

Another issue identified by the working group was the ability to forecast beyond two weeks, or "farcasting," and how far into the future climate modeling by something like a proposed climate service could extend. Ten years? There was also disagreement over whether the services to be offered by a proposed climate service were ready for prime time. For example, some attendees said greater fidelity was needed for data like heating degree days. Still, few questioned the need for such data.

Another hurdle stressed during the discussion is that historical weather data is often improperly formatted to permit widespread use. Who should pay for this formatting—an industry consortium that could directly benefit from easier access or a government–industry partnership? Such issues must still be resolved, the working group concluded.

Finally, the workshop discussion turned to concrete steps for identifying mechanisms to enhance collaboration between financial decision makers and the climate science community. UCAR President Tom Bogdan, who led the second working group, said the emphasis must be precompetitive rather than proprietary.

Bogdan proposed a matrix approach that would address specific issues relevant to the financial community (e.g., regional issues like drought in the Midwest or sea level rise in the Southeast United States). The matrix would bring together users and scientists around specific impacts and would focus on generating recommendations for action.

Gary Geernaert again stressed the need for “actionable” recommendations that will forge closer connections between stakeholders. Ultimately, he added, a robust mechanism that enhances collaboration between climate scientists and stakeholders in the financial community will serve to expand the availability of climate information while improving the quality of climate science research—to the benefit of all.

Appendix III: Workshop Agenda

CLIMATE INFORMATION NEEDS FOR FINANCIAL DECISION-MAKING
June 3-4, 2013

1200 New York Avenue, NW
Washington, DC 20005

June 3, 2013

8:00 am	Continental Breakfast
8:30-8:35 am	Welcome (Keith Seitter)
8:35-8:45 am	The two-fold challenge (Gary Geernaert)
8:45-9:10 am	Climate risks associated with financial decisions (overview) - Rebecca Ranich, Deloitte Consulting LLP

Businesses & agencies using climate information in major financial decision-making (moderator: Scott Rayder)

9:15-9:45	AER (Kyle Beatty)
9:45-10:15	CSC ClimateEdge (Sharon Hays)
10:15-10:45	BREAK
10:45-11:15	Zurich Financial Services (Lindene Patton)
11:15-11:45	Department of Defense (Jeffrey Marqusee)
11:45-1:00 pm	*Lunch*

1:00-2:00 pm	**Panel/talks: catastrophe modeling companies and climate change** (lead/moderator: Franklin Nutter) - Peter Dailey, AIR Worldwide - Annes Haseemkunju, EQECAT, Inc. - Jessica Turner, RMS
2:00-3:00 pm	**Panel/talks: What can financial decision-makers expect from climate science?** (lead/moderator: John Weyant) - Lawrence Buja, National Center for Atmospheric Research - Tony Janetos, Boston University - Bill Collins, Lawrence Berkeley National Laboratory
3:00-3:30 pm	BREAK

Case Studies & Perspectives

3:30-4:45 pm	Energy Operations (Jeff Williams) Treasure Island (Dilip Trivedi) Water infrastructure (David Behar)
4:45-5:30 pm	**Group Discussion on Key Outcomes: information, communication, collaboration, federal policy and agencies, and risk management under uncertainty**
5:30 pm	Wrap up for Day 1 (Gary Geernaert)

June 4, 2013

7:30 am	Continental Breakfast
8:00-8:10 am	Day I recap and Day II goals (Gary Geernaert)

Synthesis, Conclusions, & the way Forward

8:10-9:10 am	**Outcome 1:** Climate information needs for financial decision-making. Working group lead: John Weyant.

9:10-10:10	**Outcome 2:** Mechanisms to enhance collaboration between the climate science community and financial decision-makers. Working group lead: Tom Bogdan.
10:10-11:00	**Break**
11:00-12:30	Public briefing/media event: Climate information needs for financial decision-making (moderator: Paul Higgins) - Gary Geernaert, Department of Energy, Climate & Environmental Sciences Division - Tom Bogdan, University Corporation for Atmospheric Research - John Weyant, Stanford University
12:30 pm	Adjourn