# Major Growth in Some Business-Related Uses of Climate Information

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## ABSTRACT

Uses of climate information have grown considerably in the past 15 years as a wide variety of weather-sensitive businesses sought to deal effectively with their financial losses and manage risks associated with various weather and climate conditions. Availability of both long-term quality climate data and new technologies has facilitated development of climate-related products by private-sector atmospheric scientists and decision makers. Weather derivatives, now widely used in the energy sector, allow companies to select a financially critical seasonal weather threshold, and, for a price paid to a provider, to obtain financial reparation if this threshold is exceeded. Another new product primarily used by the insurance industry is weather-risk models, which define the potential risks of severe-weather losses across a region where few historical insured loss data exist. Firms develop weather-risk models based on historical storm information combined with a target region's societal, economic, and physical conditions. Examples of the derivatives and weather-risk models and their uses are presented. Atmospheric scientists who want to participate in the development and use of these new risk-management products will need to broaden their educational experience and develop knowledge and skills in fields such as finance, geography, economics, statistics, and information technology.

## 1. Introduction

Sizable corporate financial losses due to climate extremes and numerous major storms during the 1990s prompted increased usage of climate information for added financial protection. Rapidly emerging uses of climate information have allowed users to assess their local and regional risks from weather and climate conditions, including extremes.

Many reasons drive the demands for climate information. The severe drought of 1988 followed by a series of major catastrophic storms in the 1990s caused major regional and national losses, creating awareness of the need to better consider the impacts of climate conditions on business and industry (Changnon and Changnon 1999). Other factors that have affected usage are the growing competition in various business sectors, partially a result of evolving global markets, and the issue of global climate change (Nutter 1999). For example, the U.S. utility industry, which was deregulated in the late 1980s, experienced enhanced competitiveness that prompted many firms to seek climate expertise and information (Changnon et al. 1995).

Advances in atmospheric sciences have also enhanced the use of climate information. Climate data now date back more than 100 years and thus are sufficient for more meaningful statistical and physical assessments of various conditions. Progress has been aided by the wide use of computers and inexpensive Internet systems, allowing rapid and frequent access to climate data banks and information. The growth of regional climate centers that provide massive amounts of quickly updated climate data helped to enhance the activities of private-sector users (Changnon and Kunkel 1999). Further, the past 40 years have seen major breakthroughs in understanding atmospheric conditions, providing access to more knowledgeable climate expertise. This expertise has been utilized, either by employing climate-skilled staff in major firms or by consulting with experts in numerous private atmospheric firms (National Research

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Council 2003). Such experts can provide tailor-made products to serve the specific needs of firms, as opposed to the widely available climate information typically produced by federal and state agencies.

Sophisticated statistical modeling has been made possible by the availability of long-term historical weather data, forming the basis for more correctly assessing a variety of risks, including those due to temperature, severe storms of different types, and precipitation (rain and snow). Instead of simply reacting to untimely climate conditions or natural hazards, new climate-assessment products allow for informed planning either to lessen losses before they occur or to enhance profits. The major user sectors now include the insurance industry, utility firms, and weather-sensitive businesses, including agribusiness, transportation firms, retail businesses, and the construction industry. In defining risks, historical climate data are integrated with various weather-sensitive societal and economic measures to form decision-support tools used to make management decisions.

Over the last 40 years, the atmospheric sciences have undergone a major transformation from a largely government-driven science (research, operations, and services) to one with a sizable service-oriented private-sector presence. This big change is related to the provision of weather and climate information, driven by the many new demands for atmospheric information by business and industry (Dutton 2002). New products and assessments include weather derivatives and weather-risk models. Although these new terms refer to ''weather related'' events, such as the occurrence of a specific high temperature or a wind speed greater than 160 km $h^{-1}$ associated with a hurricane, historical climate data are the essential tool used to understand the risks associated with these weather conditions. Furthermore, businesses who supply information have chosen ''weather'' as their key word because users understand and react better to labels of weather as opposed to climate. As one reflects on these changes, one wonders whether a traditional atmospheric science–based educational background provides the knowledge and skills necessary for future atmospheric scientists to participate in the development and use of these new risk-management products (Changnon 1998; Elsner et al. 2009). This paper describes these forms of risk/profit management and illustrates their uses. In 2009, a weather-sensitive firm had four options for managing its weather risks and enhancing its profits: 1) purchasing a traditional insurance policy, 2) using historical climate and societal data to design its operations, 3) incorporating weather/climate predictions in planning and operations, or 4) using the new risk products—weather derivatives and risk models—that are the focus of this paper.

## 2. New products for weather/climate risk management

Financial pressures resulting from enormous weather-caused losses during the 1990s in the United States, coupled with deregulation of the utility industry and growing global economic competition affecting agribusinesses and other industries, led many firms to seek climate products that could be used to explain the frequency, or risk, associated with various weather conditions. For example, in 1992 the Chicago Board of Trade began offering ''catastrophe insured futures,'' an option different from reinsurance (i.e., a type of insurance policy purchased through the reinsurance industry by insurance companies to protect against major losses). Since then, the capital market has been used as a source of coverage for weather risks. This coverage, which is used to transfer insurance-type risk to the capital markets, is known as a catastrophe, or ''cat,'' bond and is an alternative to the use of reinsurance (Changnon et al. 1997).

### a. *Weather derivatives*

Weather derivatives emerged in the mid-1990s. Derivatives basically rely on long-term historical climate data to determine the likelihood of different weather outcomes. Then, for a price, certain companies provide financial coverage for a firm at risk of major losses if a certain set of weather conditions occur. Weather derivatives, also labeled ''climate contracts,'' involve two parties. One pays the other a defined sum if a specified climate or weather variable reaches (or does not reach) a certain threshold. The amount of payment usually depends on how much the variable exceeds (or falls below) the set threshold. This weather-risk-management product initially was provided by a few companies such as Enron, Aquila Energy, and Koch Energy Trading. Electric and gas utilities have been the primary customers for derivatives, and thus many policies covered various temperature-related outcomes.

In 1999, the Chicago Mercantile Exchange (CME) began offering derivatives, reflecting this rapidly growing market, and the CME has used various companies to provide the liquidity necessary for these futures options (Grannan 1999). By 2006, the CME provided derivatives for firms in 29 cities that included coverage for monthly and seasonal temperatures, precipitation, and snowfall. In January of 2006, the CME handled 108 000 weather-related contracts (Chicago Mercantile Exchange 2006). In the spring of 2007, the CME holdings began offering weekly futures and options for temperatures in 12 U.S. cities, anticipating that utility companies and energy traders would be the primary users. This shift to weekly conditions is expected to allow for multiple options to fit a variety of risk-management strategies, especially as one considers how quickly the temperature at a location can fluctuate from one anomaly to the other.

Growing usage of derivatives helped to form a ‘‘weather market’’ for companies seeking to define and/or hedge their weather-risk exposure to stabilize their incomes. Weather-risk-management products are referred to as either weather derivatives or weather insurance. In both cases, the buyer pays the provider a fee and receives protection. However, the products differ from routine insurance, which requires proof and measurement of losses, whereas derivatives are a simple ‘‘yes’’ or ‘‘no’’ for an established threshold based on historical climate data. Producers and users in the derivative industry must make several key decisions that can benefit from use of diverse climatological and statistical expertise. For example, assessing risk of a utility’s losses resulting from a high summer (or low winter) temperature threshold requires careful statistical analysis of past conditions (i.e., similar to actuarial tables developed and used by insurers). Losses could be large if the average summer temperature exceeded 30°C, but just how this average value actually occurs can vary and affect costs differently. For example, a summer could be a 3-month period with temperatures constantly ranging from 2° to 3°C above the average or could be 10 straight days with values above 38°C and near-average temperatures during the rest of the summer. Such differences can create the same summer average value, but their in-season differences greatly alter use of air conditioning and associated costs of power to meet demands (i.e., power load has a nonlinear relationship with ambient air temperature). Thus, historical temperature fluctuations within a given season also must be identified and considered by the ‘‘weather risk’’ company providing the derivatives. In some cases, the user specifies the financial-loss amount feared from a given weather condition and contracts with a risk-management firm, which assesses the relevant climate data and determines the fee to charge for the coverage. The fee payment is made before the expected event, and if the bad weather event occurs, the weather-risk firm pays the amount in the contract.

Other issues that constantly change and affect threshold levels in derivatives include a region’s demographics, population shifts, altered property values, and new technologies. For a utility company, costs of a 30°C summer in 1980 would be different from one in 2008 because of more homes and businesses (greater demand) and shifts in air conditioning use and technologies. These societal issues affect how a utility selects a threshold for derivative coverage and how a firm providing derivative coverage determines its fee scale. The issues also reveal a need to consider and integrate a variety of conditions.

### *b. Weather-risk models*

In the early 1990s, major financial losses in the United States resulted from several major weather hazards, including Hurricane Andrew in 1992 (Changnon and Changnon 1999) and the great Midwestern floods of 1993 (Changnon 1996). Sizable property losses from several catastrophic storms during the 1990s had severe impacts on the insurance industry (Changnon et al. 1997). Insurance firms sought explanations for these large, unexpected losses, including the possibility of global climate change due to enhanced levels of greenhouse gases (Lecomte 1994; Changnon et al. 1999). As a result, some insurance companies developed expertise for estimating weather-related risks. The risk in a particular region is a function of weather conditions, the environment, and societal vulnerability, including ongoing demographic shifts, changes in insurance coverage, and increasing population and wealth (Changnon 2003). Because these variables are not static, firms must continually update information and incorporate changes into scenarios they develop.

A key problem for many insurance firms that relied on traditional insurance coverage is that the property–casualty insurance industry had not kept records in past years about weather losses and their coverage across the United States. In contrast, in 1949 the crop–hail insurance industry formed an association with a central data bank that collected records of each loss and its coverage, establishing a loss/cost ratio, from all 45 firms in the business to address crop-related losses, not property losses (Roth 1996). Because the property insurance industry had never set up a comparable national data bank, there were no nationwide records of property losses or their coverage for any past year or for any weather hazard. Although the National Oceanic and Atmospheric Administration’s *Storm Data* publication could be used to identify the location and date of many severe-weather occurrences, the assessment of storm-related property damages was inconsistent across time and space (Changnon and Changnon 1999; Gall et al. 2009). Thus, there were no county-scale property loss data that are necessary to assess risk at specific locations, which is essential to establish adequate insurance rates (Roth 1996).

The lack of nationwide historical records of individual losses and coverage meant that property insurance firms faced major risk-assessment problems during the 1990s. For example, without access to historical data collected over time on hail losses to property in Colorado, or tornado losses in western Oklahoma, or hurricane losses in each county in the Carolinas, the property insurance industry could not use traditional means to define their risk and to set rates correctly. The question raised by insurers was, If quality historical storm loss data do not exist for a given place, can they be created?

The answer from atmospheric scientists was yes. A new product provided by another sector of the developing weather market involved modeling based on various historical climate datasets and published information to estimate the weather risk to local and regional properties in a given area. This new business sector developed mainly to address insurance-related concerns over potential losses in a region from severe-weather extremes such as hurricanes. The new industry used weather-risk modeling to create quantitative measures of various storm hazards as they relate to property damage at a point or an area in any part of the United States. For example, a typical modeling firm has staffing expertise in engineering, computer technology, geography, weather, finance, and insurance. Such firms collect all available historical data and information and create risk models for various locations.

Risk modeling for insurers seeks to create risk patterns replicating historical storm loss data for regions where they were not collected. For example, the transfer of a major flood pattern that hit Alabama to another target area (of interest to an insurance firm) to assess risk there in a meaningful way requires a variety of skills. The demographics of the target region must be well defined and the environment must be carefully measured, including defining the flood potential and the area's structural laws and building-construction patterns.

Risk modeling of severe storms, for application and use by the insurance industry, involves three factors or inputs. The first is a hazard-based assessment of the space and time dimensions of hurricanes, hailstorms, tornadoes, or other storm types under consideration. The second is a regional assessment of vulnerable factors, including land use, land and property values, and susceptibility of existing property to storm damage. The third is consideration of the various types of insurance coverage in the targeted region (personal, commercial, etc.). Each factor serves as a component to be integrated into a firm's risk model for a given hazard at a specific target location.

Analytical approaches for determining the dimensions of a weather hazard for an area generally have followed two paths. One involves utilizing existing climate information about a given weather event obtained from past studies to develop a model (i.e., composite) of the weather hazard. This form of assessment of possible weather hazards is based on detailed case studies and/or measurements of a major past storm. One or more of these models are applied to any area apt to have such storms. In essence, this approach estimates the potential damage from well-documented past catastrophic events (e.g., transposing Katrina to eastern Florida).

The other approach combines climate records of several past extreme events to create the dimensions of a potential future outcome (i.e., a typical event) in the target area. For example, past records of major hurricanes have been used to create damage models (rain and wind) for path size and depth of inland penetration (Drayton 2000; Risk Management Solutions 2004). In turn, these values of intensity are applied to potential hurricane regions.

Both storm-based approaches to risk assessment have become widely used by the insurance industry and by consulting firms who develop storm-simulation models, sometimes labeled ‘‘catastrophe models’’ (Woo 2000; Grossi and Kunreuther 2004). As an example of the second approach, Jagger et al. (2001) used records of winds and structural damages related to winds for several hurricanes to create probability models of winds along U.S. hurricane-prone coasts.

Because these various types of weather-risk models are used to determine insurance rates, an important question is whether the models are reasonable and correctly assembled (Pielke et al. 1999). This becomes an issue for the insurance industry and for state insurance regulators, as well as a concern for the insured public. After Hurricane Andrew, the state of Florida established the Commission on Hurricane Loss Projection Methodology, which now certifies hurricane models that can be used to establish residential insurance rates. The state of Florida also funded development of a public hurricane loss-projection model. A recent technological development uses a geographic information system approach so that insurers of a given firm buying the product can visualize the hazard pattern and the property-at-risk pattern in any area and then determine their level of risk and rate structure (Siner 2005).

Hurricane Katrina in August 2005 most recently became the worst natural disaster in the United States, with damages estimated at $125 billion. Claims at the two largest U.S. insurance firms led to payments in excess of $10 billion. This huge storm loss revealed that the insurance industry's weather-risk models had been underestimating the risks of such supercatastrophes (Risk Management Solutions 2006). The record loss triggered new interest in risk management for very major catastrophes.

### c. *Hurricane futures*

Recent major losses from hurricanes, totaling $184 billion during 2003–08, coupled with long delays in loss settlements and payments, plus tougher economic conditions in the United States, led to another climate-based

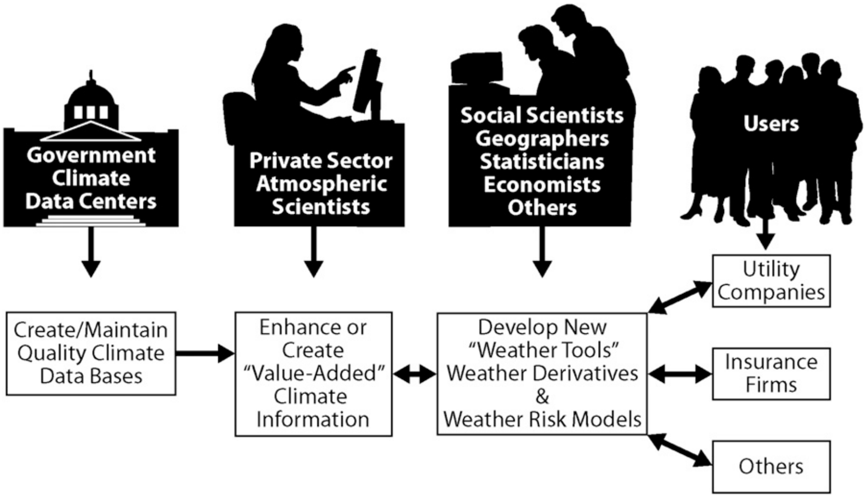

FIG. 1. Schematic showing the processes and individuals (or institutions) involved with developing business-related climate decision tools. Arrows indicate interactions between the different processes and individuals.

product: a "hurricane future" (Carabello 2009). This new trading option was designed by CME in 2007 so as to deal more effectively with hurricane losses, and it uses climate information in a risk-modeling mode. This new product of the CME Group appeared in 2007, and CME handled 32 600 hurricane contracts traded in 2008 to those seeking financial protection against storm losses (individuals, communities, and businesses). The contract is not developed until a hurricane develops near the United States, and the entity seeking coverage must identify where the loss will occur and the loss potential based on the storm's expected size and wind speeds, which is labeled the Carvill hurricane index (CHI). If the storm occurs where the contract stated and with the selected CHI or more severe CHI, payment of loss is made 2–3 days after the storm. If the storm does not meet the CHI or the chosen location, the contract funds go to the CME and the financial firms working with CME.

## 3. Discussion

Growth of new markets for climate information is partly reflected in the formation in 1999 of the Weather Risk Management Association (WRMA). Reports by the 45 WRMA member firms in 2005 revealed that the industry had grown rapidly, with 21.7 million weather contracts for the year ending in March of 2005, which have a value of $8.3 billion and represent 50% more contracts than in the previous year (Stell 2005). The WRMA reported that the 2005 weather contracts were related to temperature (85%), rain (10%), wind (3%), and snow (2%). Product applications were for energy (72%), agriculture (9%), retail business (7%), construction (7%), and transportation (5%). Contracts for temperature-based derivatives increased in 2005, and the CME added 4.2 million contracts in the third quarter of 2005 (Chicago Mercantile Exchange 2006). One climate-information firm provides a variety of products such as weather-risk assessments (i.e., derivatives), risk modeling, and predictions for several sectors, including agriculture, energy production/sales, retail business, construction, and travel (Elsner et al. 2009). The process of developing value-added climate information, based on available climate data, for weather-sensitive decision makers requires interaction among all parties involved in the process: 1) those collecting and maintaining quality climate datasets, 2) those analyzing the risks of a specific weather event, and 3) the end user. Figure 1 identifies participants and how they interact in the processes described.

Use of weather derivatives has become well established. Setting realistic thresholds for derivatives requires careful analysis of historical climate conditions plus careful monitoring of socioeconomic changes in the area covered by a derivative-based policy. Users of information based on new modeling techniques for assessing severe-weather risk need to be aware of inherent uncertainties of estimating procedures using available climate information. Efforts to create desired but unavailable climatological measures relating to potential severe-weather conditions can be subject to question and require careful assessment. As Portman (2002) stated, "The success of weather trading depends on the reliability of the science behind it, including the proper use of and access to the latest research findings and technological developments."

Risk models of severe storms are better than having no information, but users must understand that these are time and space estimates and hedge accordingly. Otherwise, they may over- or underestimate the risk of losses from severe storms. Credibility and accuracy of these storm and catastrophe models are important issues because they involve government regulation of insurance rates and represent potentially high costs of insurance coverage for consumers. Hurricane futures, a trading contract of CME, have become widely used in recent years.

The increased need for the atmospheric science community to work with weather-risk managers suggests that broader education of undergraduate and graduate meteorology students is worth consideration. More than ever, atmospheric scientists are being asked to do more than just predict the weather. Not only must they be able to communicate effectively the physical conditions associated with weather events, they must understand the climatology of such events and how this information can fit into decision-support systems developed by weather-sensitive organizations.

A new form of climate risk that is now emerging concerns future climate change. The costly Katrina outcome raised serious questions about climate change that could lead to ever more frequent and/or more intense storms (Pielke et al. 2005). This issue not only involves consideration of a range of future climate outcomes, but also involves how government policies that affect an industry are and will be changing to address this risk (Wellington et al. 2004).

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