"Climate Variability and Climate Change in the United States Midwest: Mitigating and Managing Impacts and Risks"

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1. Introduction

I would like to thank Chairman Markey and Ranking Member Sensenbrenner and all of the Members of the Select Committee for this opportunity to appear before you and address the energy and environmental challenges facing our nation climate variability and climate change in the our nation's Midwest region and how we can mitigate and manage both the impacts and the risks. I would also like to thank Congressman Emanuel Cleaver, who is my representative, for his service on this important Select Committee and his guidance locally.

The United States Midwest is one of the most agriculturally productive areas in the world and supports a wide range of agro-businesses and industrial-manufacturing complexes that are economically vital to the United States. The region encompasses the headwaters and upper basin of the Mississippi River and most of the lengths of the Missouri and Ohio rivers, all critical water sources for agriculture, municipal water supply and hydro-electric power generation. This economically vital agricultural and manufacturing region is susceptible to substantial inter-annual and interdecadal variations in summer climate. Frequent severe droughts and devastating floods are features of the extreme warm season climate anomalies that affect much of the Central U. S. The drought of 1988 and flood of 1993 resulted in an estimated $52 billion in farm losses and property damage in the Midwest (Lott, 1993). The last two summers (2007 and 2008) have been especially devastating for large swaths of the Midwest due to back-to-back floods that destroyed thousands of acres of prime farmland in several states and submerged whole communities. The losses sustained from just these last two flood events undoubtedly run into tens of billions of dollars.

The financial impact of the current flood is exacerbated by the fact that many property owners in the worst-hit areas lack flood insurance because they live in areas deemed "500 year flood plains" where mortgage banks do not require flood insurance. Furthermore, it has been reported that many communities in Wisconsin, Iowa and Missouri either dropped out of or have never participated in the federally-sponsored flood insurance program for the same reason. This makes residents of those communities ineligible for federal aid under the existing rules of the National Flood Insurance Program (NFIP). Against this backdrop, the decision of the Chairman of the House Select Committee on Energy Independence and Global Warning, Honorable Edward J. Markey, to hold this hearing on "Global Warming Effects on Extreme Weather" is both timely and highly commendable. My testimony will begin with an overview of the evidence that supports the view that we are indeed in a regime of enhanced climate variability and the changes that we can expect in the future. I will discuss the implications of these current and future changes on the Midwest using a framework that integrates notions of risk and vulnerability and offer some thoughts on strategies for mitigating and managing those risks.

2. Our Changing Climate System

The material included in this section is primarily a summary of relevant sections of the recently released synthesis report of the Committee on Environment and Natural Resources of the National Science and Technology Council titled "Scientific Assessment of the Effects of Global Change on the US."

2.1. Evidence of a Changing Climate Regime: Temperature Trends

Numerous lines of evidence robustly lead to the conclusion that the climate system is warming. The Intergovernmental Panel on Climate Change (IPCC) in its 4th Assessment Report stated "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." Analyses of quality-controlled data from thousands of worldwide observation sites show that global mean surface temperatures have risen over the last 100 years by 0.74 ± 0.18 °C with the rate of warming over the last 50 years almost double for the past 100 years (Trenberth et al., 2007). Globally the warmest combined land and ocean years in the instrumental surface temperatures on record (since the mid-19th century) have mainly occurred in the past 12 years. Out of the 8 warmest years on record, 7 have occurred since 2001, and the 10 warmest years have all occurred since 1995. Additionally, widespread changes in extreme temperatures have been observed in the last 50 years around the world, and these changes in temperature extremes are consistent with the general warming (Solomon et al., 2007). Cold days, cold nights, and frost have generally become less frequent, globally while hot days, hot nights, and heat waves have become more frequent (IPCC, 2007d). A widespread reduction in the number of frost days in mid-latitude regions, an increase in the number of warm extremes, and a decline in the number of daily cold extremes are observed in 70 to 75% of the land regions where data is available. New analyses also shows that since 1950, heat waves have increased in duration (Solomon et al., 2007).

Similar to the global trend, U.S. temperatures also warmed during the 20th and into the 21st century. The U.S. average annual temperature is now approximately 0.6 °C warmer than at the start of the 20th century, according to NOAA (2008a), with an increased rate of warming over the past 30 years. There is some disagreement about which year was the warmest on record due differences in data sets, processing and analyses (NASA found 1934 while NOAA data shows 1998). The year 2007 was the 10th warmest year for the contiguous United States since national records began in 1895, according to preliminary data from the NOAA National Climatic Data Center (NOAA, 2008a). Additionally, the past 9 years have all been among the 25 warmest years on record for the contiguous United States, a streak that is unprecedented in the historical record, and the last nine 5-year periods were the warmest 5-year periods in the last 113 years of national records, illustrating the anomalous warmth of the last decade.

Regional data for North America confirms that warming has occurred throughout most of the United States. The U.S. Historical Climate Network of NOAA's National Climatic Data Center found that for all but 3 of the 11 climate regions, the average temperature increased more than 0.6 °C between 1901 and 2005 (NOAA, 2007b). Furthermore, North American regional studies consistently show patterns of changes in temperature extremes consistent with a general warming (Trenberth et al., 2007), including intense warming of the lowest daily minimum temperatures over western and central North America (Robeson, 2004 in Trenberth et al., 2007). The U.S. Climate Change Science Program (CCSP) Synthesis and Assessment Report 3.3 (SAP 3.3.), Weather and Climate Extremes in a Changing Climate (Karl et. al., 2008) concluded that in the United States there has been a shift towards a warmer climate with an increase in extreme high temperatures and a reduction in extreme low temperatures:

> • Since the record hot year of 1998, 6 of the last 10 years (1998–2007) have had annual average temperatures that fall in the hottest 10% of all years on record for the United States. The number of heat waves (extended periods of extremely hot weather) also has been increasing since 1950. However, the heat waves of the 1930s remain the most severe in the U.S. historical record.
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> • There have been fewer unusually cold days in the United States during the last few decades and the last 10 years have had fewer severe cold waves than any other 10-year period in the historical record, which dates back to 1895. There has been a decrease in frost days and a lengthening of the frost-free season over the past century. For the United States as a whole, the average length of the frost-free season over the 1895 to 2000 period has increased by almost two weeks.

2.2. Evidence of a Changing Climate Regime: Precipitation Trends

As surface temperatures rise, the evaporation of water vapor increases from oceans and other moist surfaces. Increased evaporation is leading to higher concentrations of water vapor in the atmosphere. Increased atmospheric water vapor tends to produce weather systems that lead to increased precipitation in some areas. At the same time, increased evaporation and evapotranspiration from warming can lead to increased land surface drying and, therefore, increased potential incidence and severity of droughts in other areas. Unlike temperature, precipitation is highly variable spatially and temporally which makes the task of establishing robust long-term trend difficult in some regions, especially the data sparse areas of the world. Nonetheless, the conclusion from the IPCC report is that long-term trends from 1900 to 2005 have shown significant increases in precipitation over many large regions (e.g., North and South America) and drying in others (e.g., the Sahel). Additionally, more intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics.

Over the contiguous United States, annual precipitation totals have increased at an average rate of 6% per century from 1901 to 2005, according to an analysis of data from the NOAA National Climatic Data Center's U.S. Historical Climate Network (Version 1; NOAA, n.d.). There has been significant variability in U.S. regional precipitation patterns over time and space. Despite the overall national trend towards wetter conditions, severe droughts have affected several parts of the U.S. in the last two decades, including the 1988 drought that affected the Midwest, the long running drought in the southwestern United States from 1999 through 2007, and more recently the severe drought experienced in the southeastern United States (NWS CPC, 2008).

The IPCC (Solomon et al., 2007) reports that it is *likely* that there have been increases in the number of heavy precipitation events within many land regions, even in those regions where there has been a reduction in total precipitation amount; this is consistent with a warming climate and observed increases in the amount of water vapor in the atmosphere, which have been significant. Increases have also been reported for rarer (1 in 50 year return period) precipitation events, but only a few regions have sufficient data to reliably assess such trends (Trenberth et al., 2007). Observations over the contiguous United States show statistically significant increases in heavy precipitation (the heaviest 5%) and very heavy precipitation (the heaviest 1%) of 14% and 20%, respectively, primarily during the last three decades of the 20th century (Kunkel et al., 2003 in Trenberth et al., 2007 and Groisman et al., 2004 in Trenberth et al., 2007). This increase is most apparent over the eastern parts of the country. Some evidence suggests that the relative increase in precipitation extremes is larger than the increase in mean precipitation (Trenberth et al., 2007). CCSP SAP 3.3 (Karl et al., 2008) concluded that very heavy precipitation (the heaviest 1%) in the continental United States increased by 20% over the past century, while total precipitation increased by 7%. Additionally, the monsoon season is beginning about 10 days later than usual in Mexico and in general, for the summer monsoon in southwestern North America, there are fewer rain events, but the events are more intense (Karl et al., 2008).

The trends in both temperature and precipitation in the Midwest reflect these national trends but with some regional variations. For example, the National Assessment of Climate Change Impacts on the United States conducted under the auspices of the US Global Change Research Program concluded that during the last 100 years, Midwestern temperatures have increased substantially across the region. The northern Midwest has warmed by almost 2 °C while the southern Midwest, especially along the Ohio River valley has cooled by a little less than 1 °C. Annual precipitation has increased by up to 20% in some areas with most of this increase coming from periods of heavy rainfall.

3. Future Projections: A “Bottom-Up” vulnerability Perspective

Climate models are the primary tools used by the climate science community to project future changes in the climate system, including temperature, precipitation, and sea level at global and regional scales. Confidence in changes projected by global models decreases at smaller spatial and temporal scales because many important small-scale processes, in particular clouds, cannot be represented explicitly in models, and so must be included in approximate form as they interact with largerscale features (Randall et al., 2007). On these scales, natural climate variability is relatively larger. In addition, uncertainties in local forcings and feedbacks also make it difficult to estimate the contribution of greenhouse gas increases to observed small-scale changes (IPCC, 2007d). According to the IPCC (Meehl et al., 2007):

> Confidence in models comes from their physical basis, and their skill in representing observed climate and past climate changes. Models have proven to be extremely important tools for simulating and understanding climate, and there is considerable confidence that they are able to provide credible quantitative estimates of future climate change, particularly at larger scales. Models continue to have significant limitations, such as in their representation of clouds, which lead to uncertainties in the magnitude and timing, as well as regional details, of predicted climate change. Nevertheless, over several decades of model development, they have consistently provided a robust and unambiguous picture of significant climate warming in response to increasing greenhouse gases.

From the foregoing, it is clear that existing model simulations that have been used to predict the future climate (Houghton et al., 2001 ; US National Assessment) have used models with only subsets of climate forcings and feedbacks. To apply these results to predict the future climate changes at regional or local scales and for economic activities such as Midwestern agriculture will at best only provide minimal insight. Rather than focus on the perspective driven by global model predictions that are downscaled to agricultural impacts (*a top-down approach*) a more useful perspective would be to focus on the view of the affected party (*a bottom-up approach*) by assessing key societal and environmental vulnerabilities to range stressors (Sarewitz et al., 2000; Pielke and Guenni, 2004; Steffen et al., 2004; Sarewitz and Pielke Jr., 2005, Pielke et al., 2007). The strength of this vulnerability paradigm is that it frees climate change policy studies from the requirement to focus on global mean surface temperature change as the metric to link to economic impact due to anthropogenic changes in atmospheric composition (Houghton et al., 2001) and allows a more rigorous assessment that extends far beyond global mean temperatures and include other anthropogenic climate forcings such as land-use change (e.g., Pielke Sr., 2001, Marland et al., 2003, Adegoke et al., 2003, Adegoke et al. 2007), the multiple forcings associated with aerosols (e.g., Andreae et al., 2004; Niyogi et al., 2004) as well as complex feedbacks (National Research Council, 2003).

The framework for vulnerability assessments is place-based and has a bottom-up perspective, in contrast to the GCM-focus which is a top-down approach from a global perspective. The vulnerability focus is on the resource of interest, agricultural production, water resources, health impacts etc. The challenge is to use resource specific models and observations to determine thresholds at which negative effects associated with this resource occur. Changes in the climate *represent only one threat*; the climate itself may also be significantly altered by changes in agricultural practices and of other land management, and there are multiple, nonlinear interactions between the forcings. The GCM models, even if they were skilful predictions, still only capture a portion of the threat to a specific sector, such as energy or agriculture.

Take the case of agriculture for instance, in CCCP SAP 4.3, Harfield et al. (2008) showed that agricultural systems in the U.S. are highly diverse and distributed over a variety of climates, regions, and soils. However, regardless of where they are grown, crops and livestock are affected by temperature, precipitation, carbon dioxide, and water availability. Indeed, variability in yield from year to year is mostly (and strongly) related to weather effects during the growing season (Hatfield et al., 2008). The agricultural sector within the United States is sensitive to both short term climate variability and long-term climate change. Productivity is driven by the interaction of a variety of variables including temperature, radiation, precipitation, humidity, and wind speed (Easterling et al., 2007). Vulnerability of the U.S. agricultural sector to climate change is a function of many interacting factors including pre-existing climatic and soil conditions, changes in pest competition, water availability, and the sector's capacity to cope and adapt through management practices, seed and cultivar technology, and changes in economic competition among regions. The IPCC (Easterling et al., 2007) found that the growth, development, and yield of crops are dependent upon their responses to their climatic environment (Porter and Semenov, 2005). Particular crops are suited to a particular range of conditions, thus production is reduced and damage can occur when thresholds are exceeded, even for short periods in some cases (Wheeler et al., 2000; Wollenweber et al., 2003 in Easterling et al., 2007).

The productivity of most agricultural enterprises has increased dramatically over recent decades due to cumulative effects from technology, fertilizers, innovations in seed stocks and management techniques, and changing climate influences. Given the interaction of these various factors, it is difficult to identify the specific impact from any one factor on specific yield changes. The largest changes are probably due to technological innovations (Hatfield et al., 2008). However, weather events are a major factor in annual crop yield variation. Yields of major commodity crops in the United States have increased consistently over the last century, typically at rates of 1 to 2% per year (Troyer, 2004), with significant variations across regions and between years. In the midwestern United States from 1970 to 2000, corn yield increased

58% and soybean yield increased 20%, with annual weather fluctuations resulting in year-to-year variability (Hicke and Lobell, 2004).

Research reported in Hatfield et al. (2008) found variable reductions in maize yields. One study found a 17% reduction per 1 °C increase across the United States (although this study did not include effects of water availability) (Lobell and Asner, 2003). Another study found that the response of global maize production to both temperature and rainfall over the period 1961 to 2002 was reduced 8.3% per 1°C warming (Lobell and Field, 2007). Soybean has cardinal temperatures that are somewhat lower than those of maize. Responses to increasing temperatures are regionally dependent. Yield may actually increase 2.5% with a 1.2 °C rise in the upper Midwest, but would decrease 3.5% for 1.2 °C increase in the South (Boote et al., 1996, 1997). Lobell and Field (2007) reported a 1.3% decline in soybean yield per 1 °C increase in temperature, taken from global production against global average temperature during July to August, weighted by production area. Reviewing the literature for North America, the IPCC (Field et al., 2007) found that in the Corn and Wheat Belts of the United States, yields of corn and soybeans from 1982 to 1998 were negatively affected by warm temperatures, decreasing 17% for each 1 °C of warm-temperature anomaly (Lobell and Asner, 2003).

As with their responses to temperature, crops respond differently to increasing CO_2 concentrations. The evidence for maize response to CO_2 is sparse and questionable (Hatfield et al., 2008). On its own, the expected increment of CO_2 increase over the next 30 years is anticipated to have a negligible effect (i.e., 1%) on maize production (Leakey et al., 2006). In contrast, based on the metadata summarized by Ainsworth et al. (2002), a doubling of atmospheric CO_2 concentrations is expected to yield a 38% increase in soybean yield. In the midwestern United States, an atmospheric CO_2 increase from 380 to 440 ppm is projected to increase yield by 7.4%. For wheat, a cool-season cereal, doubling atmospheric CO_2 concentrations (350 to 700 ppm) increased grain yield by about 31%, averaged over many data sets (Amthor, 2001). For rice, doubling atmospheric CO_2concentrations (330 to 660 ppm) increased grain yield by about 30% (Horie et al., 2000).

Clearly, the vulnerability of North American agriculture to climatic change is multi-dimensional and is determined by interactions among pre-existing conditions, stresses stemming from climate change (e.g., changes in pest competition and water availability), and the sector's capacity to cope with multiple, interacting factors, including economic competition from other regions as well as advances in crop cultivars and farm management (Parson et al., 2003 in Field et al., 2007). Water access is the major factor limiting agriculture in southeast Arizona, but farmers in the region perceive that technologies and adaptations such as crop insurance have recently decreased vulnerability (Vasquez-Leon et al., 2002 in Field et al., 2007). Areas with marginal financial and resource endowments (e.g., the U.S. northern plains) are especially vulnerable to climate change (Antle et al., 2004 in Field et al., 2007). Unsustainable land use practices will tend to increase the vulnerability of agriculture in the U.S. Great Plains to climate change (Polsky and Easterling, 2001 in Field et al., 2007).

4. Managing and Mitigating Climate Induced Risk

Climate change contains elements of both risk and uncertainty. Risk is often defined as more short-term in nature, more measurable, and predictable. Uncertainty arises from the unknown, is often more long term, and typically is difficult to quantify. Climate change and weather-related events contain elements of both risk and uncertainty. Uncertainties in projections of global surface warming derive almost equally from uncertain emissions and incomplete knowledge about some of the forcing factors. Moreover, non-trivial challenges persist in quantifying projections because existing model simulations that have been used to predict the future climate have used models with only subsets of the climate forcings and feedbacks. Addressing these challenges requires a greater focus, as discussed in the preceding section, on assessing key societal and environmental vulnerabilities. While this paradigm is firmly established in fields such as Biology and Political Ecology, only recently have the climate community began exploring it as a basis for understanding the functioning, resilience and vulnerabilities of coupled socio-economic and biophysical systems at policy-relevant time and space scales. This vulnerability paradigm can help refine knowledge about place-based sector-specific risk and uncertainty, so decision-makers will better understand the causes and ramifications of change and improve their ability to understand the consequences of policy, strategy, and operational changes. This model can be applied, for example, to address climate risk management in the energy and agricultural sectors by posing the question: "How should Midwestern energy and agribusinesses respond to climatic uncertainties that are not likely to be relieved in the near future?" Each of these sectors faces uncertainties that are primary or derivative in nature.

Primary uncertainties are those that are a direct effect of climate change. These are industries that experience direct damage as a result of climate change or weather-related events. Examples include the insurance industry needing to payout larger amounts as a result of claims stemming from natural disasters, and agriculture, an industry which may have negative impacts upon crop yield as a result of changing climate.

Derivative uncertainty for a business stems from the political response to climatic uncertainty. The energy business is the best example. Among the issues currently being considered are: Will the political authorities respond to climate uncertainty with new regulations that require local utility companies to replace fossil fuel generation with something else? What else? What response right now best protects the interests of shareholders and serves the companies' public responsibility?

In the Greater Kansas City metro area, where I live, significant local actions are underway to address climate risk and mitigation using the "bottom-up" model that we have advocated here. Working with community leaders and more than 100 volunteers representing a broad range of stakeholders, the City of Kansas City, Missouri has developed an ambitious Climate Protection Plan that will be submitted to the Kansas City Mayor, Mark Funkhouser, and the City Council in July, 2008 for their consideration and adoption. It includes goals and actions to reduce municipal and community-wide greenhouse gas (GHG) emissions by 30% below year 2000 levels by 2020 and an aspirational goal to reduce community emissions 80% by 2050. An additional 19 metro mayors from across the metro area in Kansas and Missouri have signed the U.S. Conference of Mayors Climate Protection Agreement and will be working together to make GHG emission reductions a regional effort in the Greater Kansas City area.

The local business community has also taken an active role in climate protection. The Greater Kansas City Chamber of Commerce has created a Climate Protection Partnership Program for metro area employers (businesses, institutions, not-for-profit organizations, and government entities) to commit to assessing their carbon footprint and implementing GHG reduction measures. To date, 150 metro area employers representing more than 100,000 employees have signed on to the partnership. Additionally, Kansas City Power & Light, the largest local energy provider in the Kansas City area has committed to offsetting 6 million tons per year of GHG emissions by 2012 through additional wind energy generation projects and the aggressive implementation of energy efficiency initiatives. Cities, businesses, and citizens across the Midwest are looking to Congress for leadership and guidance to help strengthen and sustain home grown efforts to mitigate risk and reduce the vulnerability of their systems and infrastructure to the current and potential impacts of climate change.

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