COPING WITH CLIMATE CHANGE

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This talk is about adaptation to climate change. It argues that adaptation is an important strategy for protecting human health, ecosystems, and economic activity as the climate changes. Adaptation is an essential component of any portfolio of actions that comprise U.S. climate change policy.

Several key questions are addressed. First, why should policymakers consider adaptation as one component of a comprehensive response to climate change? Second, how much adaptation is enough? Third, what factors must decision makers consider as they design adaptive strategies to ensure that they are effective?

The paper concludes with a cautionary note that adaptation is not a panacea. It should not be the only strategy considered for the reduction of risks posed by climate change. Adaptation comes at a cost and society has limited resources to devote to this activity. Also, there are uncertainties associated with the effectiveness of any adaptive response. Any portfolio of climate change policies should consist of a mix of both adaptation and mitigation strategies.

Why Adaptation?

The climate system is dynamic. The climate has changed, is changing, and will continue to change in the future. The ongoing changes in climate pose risks to human health, ecosystems, and economic activity. They also present opportunities. The ultimate objective of climate policy should be to reduce the risks and exploit the opportunities. Adaptation is one mechanism for meeting this objective.

Some of the observed changes in climate are natural and some are human induced. We cannot yet say how much of an influence humans are having on the climate system, but we know that humans are making a difference. For this reason, the international community signed the Framework Convention on Climate Change in 1992. Article 2 of the Convention states that the ultimate objective of the Convention is:

> "...to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a timeframe sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

The Framework Convention only focuses on the mitigation of greenhouse gas emissions which will yield benefits in the future. However, the ongoing changes in climate already are having real impacts on ecosystems and society. If the ultimate goal of climate policy is to protect human health, ecosystem health, and economic activity, then adaptation must also be considered as a policy response. In contrast to mitigation, adaptive responses can yield immediate benefits in the form of reduced risks and new opportunities. Also, since emissions of greenhouse gases affect the climate system with a lag, past emissions from human activities have already committed us to some future warming. Some human-induced climate change will

occur, providing a further motivation to adapt now in anticipation of future changes.

How Much Adaptation is Enough?

Adaptation is an insurance policy. Only finite amounts of insurance can be bought, since it has a cost associated with it. How much is bought depends on the resources available to society, competing priorities, and the level of risk that is deemed acceptable.

The concept of "adaptation as insurance" is a useful one. When people contemplate spending resources on investments to deal with uncertain future climate outcomes, they sometimes ask, "What if we guess wrong?" But uncertainty is at the heart of risk and insurance. A person buys car insurance even though it is uncertain whether she will have a car accident. In fact, most people hope to avoid any accidents. I will venture to say that when a person "guesses wrong" by buying car insurance, but does not have an accident, she is not upset that an accident did not occur. She understands the value of having purchased the insurance, and continues to do so in the future.

Only society can decide how much adaptation is enough. The timing and magnitude of the investment in adaptation depends on how much risk society is willing to accept.

It is interesting to note that the Framework Convention does not attempt to define a level of acceptable risk. Although the Framework Convention refers to the concept of "dangerous anthropogenic interference," it is not explicitly defined. This omission is intentional. Science can identify the mechanisms by which changes in atmospheric concentrations of greenhouse gases may lead to climate change, and identify the risks and opportunities associated with changes in climate. But science cannot make the value-laden judgement of what level of risk is acceptable to society. That decision must be left to policymakers.

Things to Consider When Designing Adaptation Strategies

There are a number of factors that decision makers should consider as they design and implement adaptation strategies:

(1) ***Adaptation must target both the positive and negative consequences of climate change.*** Adaptation refers to more than risk reduction. It also refers to the exploitation of opportunities. If the ultimate goal of climate policy is to improve public health, ecosystem health, and social well being (including economic growth), then decision makers must invest scarce resources to exploit the opportunities as well as to reduce the risks. Most regions will be faced with a mix of risks and opportunities.

(2) Adaptation comes at a cost. The scarce resources that society uses to adapt to a changing climate must be diverted from other productive activities. The additional resources that will be needed to protect the elderly and very young from heat stress during more frequent heat waves in a future climate could be used for alternative purposes. Society has limited resources to devote to adaptation, and decision makers should ensure that the expected net benefits (*i.e.,* the benefits minus the costs) are positive. Also, the effects of climate change must be considered in the context of other stresses. Resources that are used to adapt to climate change could be used to reduce other stresses on human health, ecosystems, and economic systems.

Society either can delay investing in adaptation and react to changes in climate as they occur (*reactionary adaptation*), or it can anticipate future change and invest in adaptation now (*anticipatory adaptation*). In either case, there is a

cost associated with adaptation. It is a question of when the costs are incurred and what they buy. The decision of whether to adapt now or later should be based on a comparison of the present value of expected net benefits associated with acting sooner versus later.

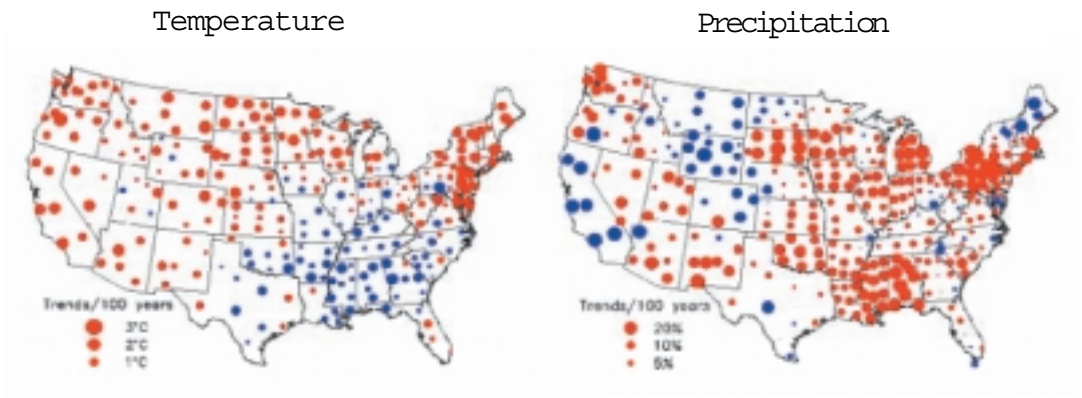
(3) Climate change will have distributional effects across people and places. Figure 1 depicts the changes in average temperature and precipitation that have occurred across the United States during the last one hundred years. There is a regional texture to the changes. The changes that occurred in the Great Lakes region are different than those in the Southeast. In some parts of the country, temperature and precipitation increased, and in other locations they decreased. The regional differences must be considered as one designs adaptive responses since the resulting impacts will be site specific. Strategies that may be effective in California may not be effective in Michigan.

Also, different groups of individuals will have different levels of vulnerability to climate change, because of different physical characteristics (*e.g.,* age, infirmities), and differences in socioeconomic status (*e.g.,* income). The design of adaptive strategies should be tailored to the vulnerable demographic groups. For example, the elderly and very young are most vulnerable to heat stress, and adaptive responses have to be targeted to their needs.

(4) It is important to characterize the mechanisms by which impacts may occur. It is not enough to identify the potential consequences that climate change may have for a particular physical or human system. The mechanisms by which the impacts may occur must be understood to ensure the effectiveness of adaptation.

Consider, for example, how farmers might adapt to the expected increase in rainfall that will accompany a warmer world. If they anticipate that the precipitation will occur as light, steady rainfall events, then they might shift to alternative types of crops that do better in wetter weather. However, if they anticipate that the intensity of rainfall will consistently increase over time, they may choose different planting and tilling practices. In fact, a close examination of the historic data reveals that there has been a noticeable change in the character of precipitation events

Temperature and Precipitation Trends, 1900 to Present



Red circles reflect warming
Blue circles reflect cooling

Red circles reflect increasing precipitation
Blue circles reflect decreasing precipitation

Figure 1: Temperature and precipitation trends in the US. Source: Karl et al. (1996).

The graph in Figure 2 (from the National Climatic Data Center) shows that the percentage of area across the United States that has experienced extreme precipitation events – defined as greater than or equal to two inches per day – has increased. This change in character is an important consideration for farmers as they adapt to a changing climate.

(5) Climate change will have indirect effects, as well as direct effects. As decision makers prioritize possible investments in adaptation, they must make sure to consider the indirect effects of climate change. For example, climate change will have both direct and indirect effects on human health. The direct effects include the mortality and morbidity effects of weather extremes like heat waves. The indirect effects include outcomes that may be mediated through ecological changes that are caused by climate change, like the spread of infectious diseases. Depending on the geographic location under consideration and the characteristics of the vulnerable populations, the indirect effects may be as important, or more important, than the direct effects.

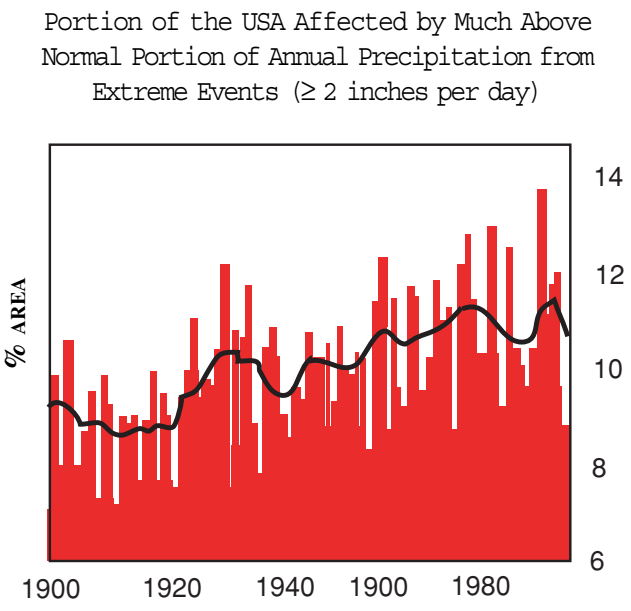


Figure 2: The change in the area of the US affected by increases in the proportional of total annual precipitation derived from extreme daily precipitation events (great than or equal to 2 inches per day).

(6) There are uncertainties associated with the effectiveness of any adaptive response. Policy makers should not assume that adaptation will be completely effective, as evidenced by the effectiveness of adaptive responses under current climatic conditions. People die of heat stress every year, even though society has the know-how and resources to prevent these deaths. If society is unable to prevent these deaths today, why should we assume that it will be any more effective preventing them tomorrow?

(7) Adaptation can have adverse impacts in addition to their intended effects. Beware of maladaptation. An adaptive response may have unintended secondary consequences that outweigh the benefits of undertaking the strategy. For example, pesticides that are used to eradicate mosquitoes that may carry infectious diseases (*e.g.*, dengue fever) may have their own adverse impacts on human health. These offsetting effects must be considered before the eradication program is implemented.

(8) Policies intended to adapt to future climate can increase the resiliency of systems to current climatic conditions. These are often termed "no regrets" strategies. For example, the elimination of federal flood insurance for new construction in flood plains will reduce the possibility of property damage under current climate, and increase the resiliency of infrastructure to more frequent floods in the future. Strategies like this have the attraction of yielding immediate benefits to society, as well as potential future benefits. They also may be less expensive than adaptive responses that would have to be undertaken in the future. And they might keep future options open.

The design and implementation of an effective adaptation strategy is not an easy undertaking. Policymakers should not be cavalier about the

ease with which adaptation can be achieved, nor the expected effectiveness of any policies they implement.

The Consequences of Inaction

Figure 3 depicts the array of consequences that climate change may have if society doesn't adapt. Some of these effects are well understood, such as the implications of climate change for heat stress and deaths. In other cases, we have only begun to identify and understand the sensitivity of systems to weather and climate, and do not have any idea of what will be the effects of a changing climate.

The purpose of this section is to provide three examples of expected impacts to illustrate the types of considerations decision makers must make as they design adaptive responses.

Human Health

The potential consequences of climate change for human health are receiving increased attention as they are becoming better understood. Figure 4 illustrates an array of health effects that may be influenced by a changing climate through a variety of pathways. The effects that are influenced through more direct pathways include death due to heat stress, and the impacts of extreme weather events like floods and storms. Health impacts that occur through more indirect pathways include those mediated through changes in ecosystems, such as vector-borne and water-borne infectious diseases.

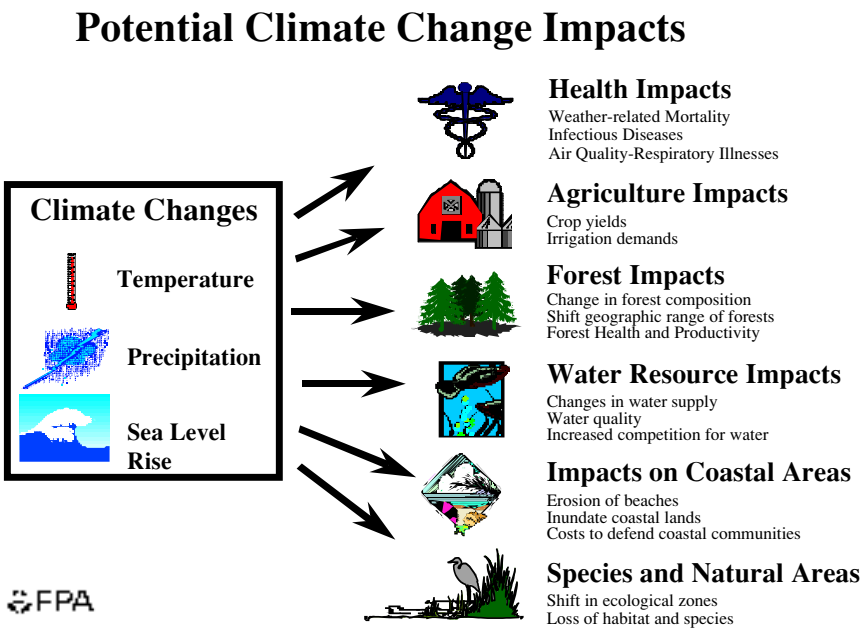


Figure 3: Potential climate change impacts; Source: US Enviornmental Protection Agency.

Indirect health effects also include those associated with changes in air quality and the quality of drinking water.

The direct effects of heat stress can be used to illustrate some of the factors that must be considered when designing an adaptive response. Climate change is expected to increase the frequency of summertime heat waves, and increase the risk of death due to heat stress. But a possible benefit might be a decline in the number of extremely cold days in wintertime, with an accompanying reduction in the number of wintertime deaths. (The potential magnitude of this positive wintertime effect is not well understood.)

Figure 4 depicts results of a study done by Kalkstein and Green to project potential increases in deaths due to heat stress in the years 2020 and 2050. The results for one scenario of future climate change, as well as data on actual recorded deaths in 1993, are shown.

It is known from the medical literature that the elderly, the very young, and people suffering with various illnesses tend to be the most vulnerable to heat stress. But Figure 5 also suggests that the impacts of climate change on human mortality are city-specific. There is a regional texture to the effects of heat stress. This may be due to a number of factors, such as differences in infrastructure, the extent to which people have physiologically adapted to extreme heat, air conditioning use, and the number of elderly and very young living in each city. The conclusion is that remedial actions must be city specific and targeted to specific populations within each city.

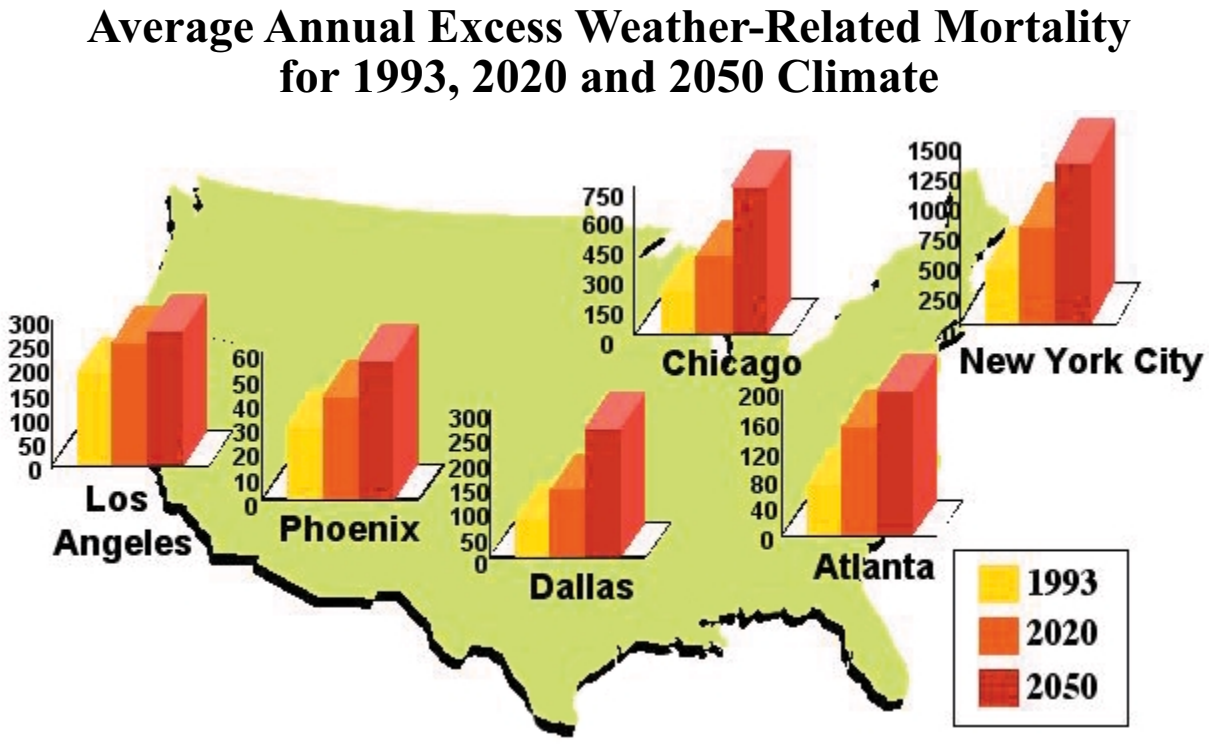


Figure 4: Average annual excess weather-related mortality for 1993, 2020 and 2050 climate based on GFDl climate change scenario. Note: Includes both summer and winter mortality. Assumes full acclimation to changed climate. Includes population growth.; *Sources: Kalkstein and Green (1997); Chestnut et al.(1995)*

Figure 4 also depicts the preventable deaths that occur each year under current climatic conditions. The people who died in 1993 from heat stress might have been saved if response strategies had been more effective. It is essential that policy makers discover the reasons for these deaths, so that more effective responses can be implemented in the future. For example, it is not enough to issue "heat wave alerts" over radio stations. In some cases (as in Chicago in 1995), the elderly may live in high crime areas and be afraid to open their windows or travel to air conditioned environments, even if they hear the alerts.

Adaptation during heat waves can be costly. It is expensive to run air conditioners, although many can afford it. However, the most vulnerable people, like the elderly, often are those least able to afford to use air conditioners. This problem can be overcome by implementing city emergency response programs. These programs might, for example, provide transportation for the elderly to air conditioned environments, or deliver water to people to avoid dehydration. These programs also come at a cost, but if they are successfully implemented, they will provide immediate benefits in the form of saved lives. They also will increase the resiliency of urban populations to future climate change.

Water Resources

Water is the "lynchpin" that integrates many regions and sectors. Water quantity and quality will be affected directly and indirectly by climate change. The development of strategies for adapting to these effects will be complex.

The cumulative effect of climate change on water supplies and water quality is complex and not easy to predict. As the climate changes, it is expected that precipitation will increase. The hydrologic cycle is expected to intensify, causing the world to become wetter. However, at any point in time, the changes in precipitation will vary by region (as seen in Figure 1). Some regions will benefit, while others may suffer. The frequency of extreme precipitation events like floods and droughts will also increase. At the same time, warming will increase evaporation, tending to lower lake levels, reduce stream flows, and dry soils. The ultimate effect on available water supplies and water quality is uncertain.

There also will be indirect effects on water supplies due to changes in the demand for water across regions and sectors as the climate changes. The water required for human consumption in urban areas is the same water that is needed for irrigation in agriculture, to support fish habitat, for hydropower, to sustain ecosystems, and for recreational purposes. As water becomes scarcer in some areas, and as the demand for water increases in some sectors, there will be additional stresses on available water supplies.

The unique role of water as an "integrator" across sectors makes the development of any adaptation strategy complex. There are certainly "no regrets" strategies that can increase the resiliency of water supply systems to current climate and climate change. More efficient markets for water, particularly in the western United States, will lead to a more efficient allocation of water among competing uses, reduce the possibility of water shortages under current climate, and increase the resiliency of systems to future climate change. But this type of adaptation also has costs associated with it. Establishment of more efficient markets for water may also lead to increases in the costs of water to end users as water is distributed to its highest valued uses.

The story does not end there. As established "property rights" for water are eliminated, adaptation decisions by various end users of water may be affected. For example, farmers may no longer be able to assume that irrigation

will be a viable and affordable adaptation strategy. The water may be available to them in markets, but may be too costly for them to use.

Maladaptation may also occur. Water markets may have unintended negative side effects on systems that are not represented in markets (*e.g.,* ecosystems). These systems may suffer as water is diverted to other uses, unless their needs are somehow "internalized" in water markets.

All of these factors must be considered as adaptive responses are developed. The development of strategies for ensuring adequate water supplies and water quality, even under current climatic conditions, is complex.

Agriculture

Most existing studies suggest that climate change will be beneficial to U.S. agriculture if one accounts for the effects of international trade, declines in agricultural productivity that are likely to occur in developing countries, changes in world food prices, and the ability of U.S. farmers to adapt to a changing climate. However, this conclusion is incomplete, and when reported by itself, is misleading. It fails to convey the regional distribution of agricultural impacts within the U.S. Although the U.S. as a whole might benefit, some regions may be harmed. There also will be distributional effects within any particular region. For example, farmers who plant wheat in Texas may experience increases in yields as the climate changes, but farmers who plant corn in Texas may experience declines in yields. The latter may adapt by switching the types of crops they plant.

The uncertainty about the impact of climate change on U.S. agriculture is even more complicated. We have already seen how the competition for water may make it more difficult for farmers to rely upon irrigation as their sole means of adapting to a warmer world. If climate becomes more variable as the hydrologic cycle intensifies, and the frequency and intensity of extreme precipitation events becomes more difficult to predict, farmers may have more trouble making decisions about what to plant and when to plant. This illustrates why it is important to characterize the mechanisms by which impacts may occur.

If farmers decide to adapt to warming by increasing fertilizer use, increases in intense precipitation events may lead to more runoff into streams and lakes, degrading water quality. From society's perspective, this may be viewed as maladaptation. Similarly, if a changing climate leads to the spread of pests, farmers may choose to increase their use of pesticides. But this may have unintended and undesirable effects on human health and the health of ecosystems.

The ultimate consequences of climate change for U.S. agriculture are unclear. And adaptive responses taken by farmers may have important implications for other sectors in society.

Conclusion

Adaptation is a necessary strategy for responding to climate change. In contrast to efforts to mitigate greenhouse gas emissions, adaptation can yield immediate benefits to society and the environment in which we live. Society must decide what constitutes acceptable risks to human health, ecosystems, economic activity, and social well being, and how much adaptation is desirable. It must also decide on a combination of mitigation and adaptation options.

The development of adaptive responses can be a complex undertaking. Many factors must be considered as adaptive strategies are designed and implemented. Failure to do so can lead to ineffective outcomes, maladaptation, and reductions in social well being. Decision makers should not be cavalier about how effective adaptation will be.

Many opportunities to adapt already exist. Examples include the development of improved monitoring and surveillance systems to protect public health, establishment of markets to efficiently allocate water, requirement of setbacks and rolling easements to protect coastal zones against sea level rise, development of heat-resistant crops for agriculture and seed banks to facilitate the movement of managed forests, and establishment of migration corridors for wildlife.

Effective adaptation is necessary and possible. But a lot of research about adaptation still needs to be done to ensure that policy makers and resource managers are able to make intelligent and informed decisions.

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