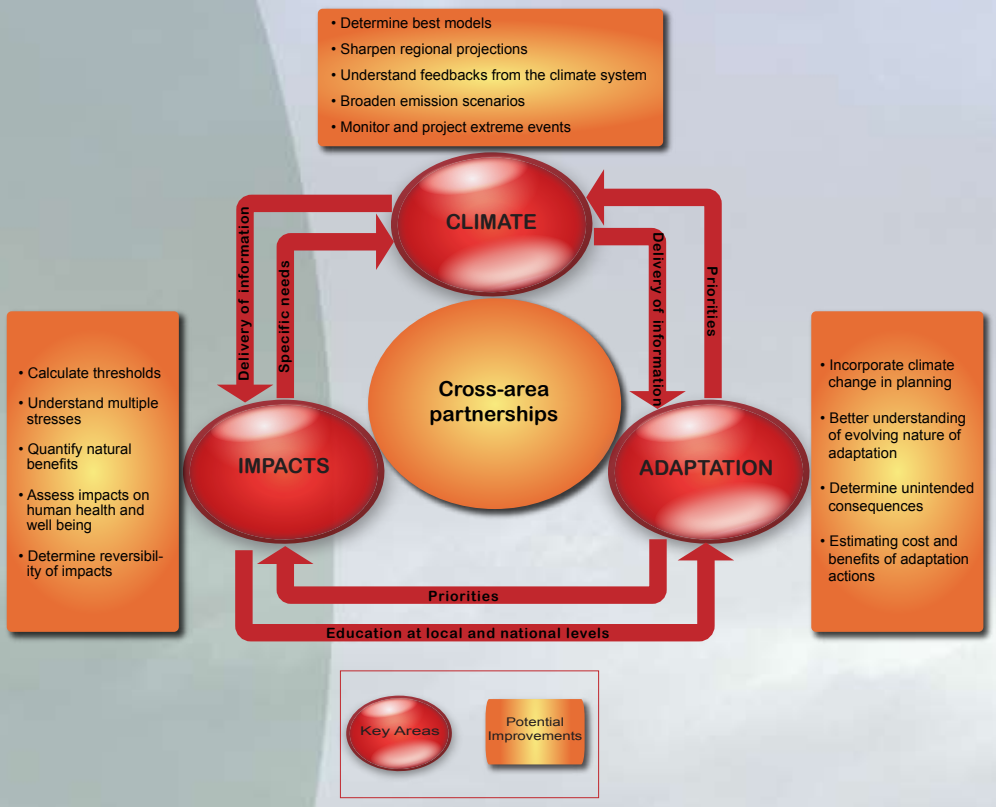
Pathways to Improved Decision Making

The focus of this report has been spread across the three interrelated areas of climate, impacts and adaptation illustrated in the figure below. Scientists and decision-makers must effectively work together to address the challenges and opportunities of our changing climate. Scientists must be able to accurately describe changing conditions in ways that are both scientifically meaningful and also relevant to decision makers, understand impacts, identify information needs, and develop strategies to help decision makers plan for adaptation to a changing climate and to reduce negative climate effects. This effort will help to effectively address problems of today, and improve our knowledge and planning for the future. It will help determine how we need to invest in research, evaluations, information services, and climate education. In the process of putting the report together, questions arose that highlighted shortcomings and limitations that should be addressed in each area. The following are the key questions along with answers that point toward pathways to improved decision making.



CLIMATE:
Analysis of past, current and future climate, the causes of climate change and the factors that can amplify or minimize it.

Assuring continued capability for documenting climate system evolution

Essential climate variables are not being adequately monitored. How can we do a better job of detecting changes in essential climate variables.

We must improve the observing systems that are necessary for providing high quality and comprehensive essential climate variables, both from surface-based observations and from satellites, so that we can accurately document the evolution of the global climate system. Without solid observation information it is very difficult to attribute known changes to any particular cause (e.g., by natural changes or by human-induced changes). Although significant investments are being made, there are substantial concerns about our ability to adhere to the United Nations' Framework Convention on Climate Change Global Climate Monitoring Principles to allow for unequivocal documentation of climate evolution. In addition this would require measuring changes in all the essential climate variables identified by the Climate Change Science Program strategic plan.

Determine best models

There are now well over a dozen climate models. What models are best for what purposes? Can more reliance be placed on some models?

All climate models are not created equal. Each has a variety of strengths and weaknesses. In this report we used all available models because there is currently no reliable way to identify which models are the best for North America. If the best models for U.S. projections were known so only the best were used, the projections in future evaluations would be sharpened. With standards and relevant observation information, the different models can be appropriately compared.

Improve regional projections

Climate change information particularly important for local and regional decision making. How can we provide local-scale climate change information to decision makers?

Today, global climate models are only able to make projections for large regions. There are not enough computer resources to provide information at the local level and, even if adequate computer resources existed, the models are not designed to take into account local-scale physical processes. Yet it is local information that is needed for communities to make informed decisions on how best to adapt to their local changing climate. This report adjusts projected large-scale information in order to make finer scale analyses. Another method is to use a regional model that uses the large-scale model projections as input. The downside to both of these methods is that some regionally important phenomena are not adequately taken into account. Hurricanes and El Niños, for example, are particularly difficult for large-scale global models to reproduce accurately. Decreasing the scale on which global climate models are run and incorporating appropriate smaller-scale physical processes in the models would require, among other things, faster computers, but would provide better local information to decision makers.

Understand how the climate system responds to change

Earth system feedbacks to global climate change are not generally modeled. What potentially important effects are they ignoring?

Scenarios for future emissions of greenhouse gases are used for climate models in this report. Yet there are many possible responses from the earth system that are not well quantified and therefore not taken into account in model projections. For example, studies show that substantial amount of the carbon safely stored for thousands of years in permafrost will likely be released as methane when the permafrost thaws. As methane is a greenhouse gas, more methane would cause additional warming. Also, melting ice and soot deposited on ice reduce surface reflection, which means that more energy is absorbed, thus increasing surface warming. Oceans absorb one third of global carbon emissions, but this effect is dependent upon changes in ocean temperature and circulation. Wildfires are responding to climate change. When a fire burns it releases gases and particles into the atmosphere and also changes how much sunlight is reflected off the surface, all of which also impacts climate. These responses are not yet fully understood but must taken into account in order to make more accurate climate projections.

Expand emission scenarios

Global carbon emissions now exceed the highest IPCC emission scenarios of future change. What can be done to better inform policy?

Recent global carbon dioxide emissions have actually been higher than the emissions that were projected for this time by the highest emission scenario used in this report. A wider range of scenarios is needed in order to take into account all plausible futures. For example, the scenarios we used do not adequately take into account the effect of rising crude oil costs into consideration of future emissions nor do they include changes in land cover associated with producing biofuels. Will higher fuel costs lead to a quicker adaptation of solar and wind power? Also, current emission scenarios do not adequately take into account potential agreements to limit greenhouse gas emissions. Without emission scenarios that include these possible futures and others, models can not adequately project future climate change. [1, 2]

Monitor and project extreme events

Extreme events have tremendous impacts, yet many kinds of events are not being accurately observed and adequately projected. How can this be addressed?

At the present time, we do not know the trends in tornadoes, severe local thunderstorms, or the frequency of hail because there have been so many changes in the observing methods used to detect and document them. Furthermore, climate models can not sufficiently reproduce all of the processes of the atmosphere that contribute to local severe weather. Therefore, this report does not discuss how local severe weather events, such as the number or intensity of tornadoes, are likely to change in the future. Hurricanes are another type of extreme event that is very important to the United States. Observations are better for hurricanes than for local severe events, but more information is still needed to fully understand how the number and intensity of hurricanes has changed over the years. Developing climate models that can make projections for areas five miles or less will improve understanding for both hurricanes and local severe weather, and allow scientists to evaluate the conditions that are favorable for these extreme events.

IMPACTS:
Identification of the past, present, and future impacts of climate change on society as well as managed and natural systems.

Calculate thresholds

Crossing certain thresholds can lead to dramatic effects. Are there other thresholds we should be watching for?
There are many different thresholds, but even where they are known, their potential impacts are not fully understood. For example, as carbon dioxide in the atmosphere increases, carbon dioxide in the ocean increases as well, making the ocean more acidic. There is evidence that, as the ocean becomes more acidic, it is harder for marine organisms to take calcium out of seawater to produce corals and shells. There is a threshold beyond which coral reefs can not survive but we are not sure yet when that point will be reached. The impacts from climate change will likely occur in bursts as thresholds are crossed. These bursts will occur in response both to biological changes and physical changes, such as melting ice. In general, more research is needed to quantify the impacts of crossing particular thresholds.

Understand multiple stresses

Multiple stresses are common in society and the environment. And so we need to be prepared to deal with multiple stresses. Is climate change likely to produce other complex stresses that we should know about?
Climate change is occurring in the context of other changes including changes in the chemistry of the atmosphere and precipitation, and changes in land cover and land use. We need to better understand how these stresses interact with climate change to affect ecological and social systems. Research in this area should include multi-factor experiments and simulation modeling.

Quantify natural benefits

Nature provides us with many benefits such as food, fuel and fiber as well as many services we take for granted such as the cleansing of air and water. Are there benefits that we depend upon that are in jeopardy?
More research is needed to adequately quantify vulnerable resources. There are likely to be both gradual changes in climate averages and changes in the occurrence of extreme weather and climate events such as severe storms, droughts, floods, and fires as we move from the present climate into the future climate. These changes will likely impact the natural benefits in ways we do not yet fully understand.

Assess impacts on human health and well being

Climate change is going to impact many aspects of human health and well being. Are these impacts being adequately measured and projected so we can take action before a problem gets too serious?
In some cases, yes. For example, the United States has an excellent disease reporting system that accurately monitors the spread of diseases such as the West Nile virus. In other cases the answer is no. For example, some projections of the potential areas of malaria infection in the United States failed to adequately take into account the ability to control the mosquitoes that carry malaria should an outbreak start. Presently, the spread of diseases and human illnesses caused by weather and climate are not accurately monitored and classified according to weather phenomenon. Predicting future costs of human health impacts and well-being is difficult without accurate information from the past. Most diseases are of biological origin and have climate thresholds which are difficult to predict but may affect the distribution of diseases. In addition, the combined impacts of global and local climate effects must also be considered. For instance, ozone pollution, which occurs at the local level, and heat spells, which may occur due to regional or global changes in climate, can both be harmful to human health.

Determine reversibility of impacts

Some aspects of climate change appear to be irreversible . Are the irreversible impacts being monitored adequately so that we can take precautions?
To better identify our vulnerability will require long-term information that is both location specific and species specific. For example, some plant and animal species adapted to the cold tops of mountains will be displaced by species from lower elevations as warming allows those species to move up slope. Land managers who are informed by continuous, long-term observations may be able to preserve pockets of selected environments.

ADAPTATION:
Planning decisions from individual to national levels that take climate change as well as values such as quality of life into consideration.

Incorporate climate change in planning

We didn't pay much attention to climate change in the past and our country developed just fine. Why do we need to pay so much attention to it now?

Climate variability has had profound impacts on the United States in the past. A good example is the intensive farming in the short grass prairies of the Plains states in the early 1900s. This farming came to a dramatic halt as the droughts of the Dust Bowl started in 1930, causing dark clouds of topsoil to blow eastward. By 1940, 2.5 million people had moved out of the region. This tragedy could have prevented if there was better farm land practices and a better understanding of the risk of prolonged drought in the plains. We are now faced with climate change which will impact all regions of the country. If climate change is not taken into account in almost all aspects of planning, we will miss opportunities to minimize risk or maximize benefits from climate change. It will be important for climate and planning experts to work with those who make policy decisions in order to fully incorporate climate change information into planning.

Better understanding of evolving nature of adaptation

Climate is no longer constant. It will now continuously evolve so adaptation must also be dynamic. How can this adaptation be most effective?

In the past, some reports have discussed planning for the future as if we are moving directly from Climate A to Climate B and it was the transition between the two climates that we needed to focus on. This report has tried to stress that the climate, looking back over the last few decades and looking forward to the end of the Century and beyond, will be in a continual state of transition. The climate will be constantly changing and therefore our adaptation requirements will be constantly changing. It is important to understand vulnerabilities and adaptive abilities, and to support development of best practices for adaptation. Continual communication and exchange of information among climate scientists, researchers of climate impacts, decision makers, and the public is necessary. Better communication between these groups will help communities and individuals make the best decisions to adapt to their changing climate.

Determine unintended consequences

We've seen food prices sky rocket around the world while more corn is being turned into fuel forcing corn grown for food on to more marginal land. This consequence was not widely discussed when ethanol policy was being debated. Are there other unintended consequences awaiting us?

It is possible that if we focus on one issue associated with climate change we might inadvertently create another problem. Other unintended consequences will arise as both humans and natural systems respond to climate change. Because the cause of global warming, fossil fuel use, is such a large part of the world's economy and politics, any effort to address it will be bound to have multiple effects. Furthermore, because global warming's direct effects will be impacting societies in all parts of the world, unanticipated impacts are bound to arise and may be far reaching. As illustration, drought in one country may lead to increased immigration into another. More research is needed to determine and quantify the unintended consequences in time to proactively respond to them.

Estimating costs and benefits of adaptation actions

This Unified Synthesis Product outlines a number of adaptation strategies to help society cope with climate change in the context of other stresses. Do we have adequate methods to carry out cost-benefit analyses for such adaptation strategies?

Cost-benefit analysis remains a major challenge when dealing with adaptations to climate change. A complete analysis often requires valuing market and non-market goods and services, and we do not yet know how to do this. A particularly difficult issue is determining the value of irreversible changes. These costs could be factored into a more quantitative and complete analysis of climate change by considering earth system chemistry and physics along with the structure and function of land and water ecosystems. This would enable us to more wisely choose among adaptation choices.