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# Climate Adaptation Policy: The Role and Value of Information

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## Resources for the Future

Resources for the Future is an independent, nonpartisan think tank that, through its social science research, enables policymakers and stakeholders to make better, more informed decisions about energy, environmental, natural resource, and public health issues. Headquartered in Washington, DC, its research scope comprises programs in nations around the world.

# Climate Adaptation Policy: The Role and Value of Information

Molly K. Macauley[1]

*As defined by the Intergovernmental Panel on Climate Change, adaptation includes a set of actions to moderate harm or exploit beneficial opportunities in response to climate change. To date, little research has addressed public policy options to frame the nation's approach to adapt to a changing climate. In light of scientific evidence of extreme and unpredictable climate change, prudent policy requires consideration of what to do if markets and people fail to anticipate these changes, or are constrained in their ability to react. This issue brief is one in a series that results from the second phase of a domestic adaptation research project conducted by Resources for the Future. The briefs are primarily intended for use by decisionmakers in confronting the complex and difficult task of effectively adapting the United States to climate change impacts, but may also offer insight and value to scholars and the general public. This research was supported by a grant from the Smith-Richardson Foundation.*

## Policy Recommendations

- The U.S. federal government should redirect the nation's significant investment in climate science and data collection to include information specifically to support decisions related to climate adaptation. The following agenda will help achieve this:
  - Adopt principles about the value of information to guide data collection and analysis—not all information has value, and perfect information is often not worth the cost of acquisition.
  - Closely link the nearly 50 climate variables that science experts have identified as essential to understanding climate with priorities for practical decisionmaking to enhance ability to adapt to a changing climate.

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- Increase emphasis on the spatial scale relevant to regional, state, and local decisions.
- Exploit the current conceptualization of Earth as a system to search for climate-induced, financially relevant microcorrelations—tiny, often overlooked correlations between climate variables—over time and across different parts of the world.

- The government also should consider what information is required for early indications of climate tipping points and response to climate change if it is so abrupt, or if climate-related disasters cascade across agricultural or other systems around the world, that society is unable to adapt without significant cost, if at all.

## Introduction

Providing information to serve national interests is a longstanding role of government in supplying public goods. Census data, weather forecasts, unemployment statistics, and energy market projections are a few examples of routinely provided public information. The data leverage tremendous resources. Some of these data guide billions of dollars of federal funding to states and localities, serve as a basis for cost-of-living adjustments, and influence futures prices in stock markets around the world. Weather data support both short- and long-term planning (from hourly weather forecasts for aviation to 100-year projections of flood plain boundaries) and provide early notice of extreme events (such as hurricane warnings). Even though the data are supplied for widespread public benefit, the same data also support a host of private markets ranging from disaster insurance to specially tailored forecasts for energy, transportation, and other industries.

As part of government's role in climate adaptation policy, information will serve a similarly wide range of purposes and no doubt leverage huge financial resources. Information on changes in sea level, variability of temperatures, and the severity of drought, for instance, will be pivotal in leveraging public-sector resources in managing infrastructure (see Neumann and Price 2009). Public-health surveillance systems can incorporate information about vector-borne disease, extreme weather events, and climate-influenced changes in aeroallergens and other types of air quality (see Samet 2009). Precipitation, soil moisture, snow melt, and other indicators will signal when actions may be needed to protect terrestrial ecosystems (see Running and Mills 2009) and manage freshwater resources (see Covich 2009). Data on ocean salinity and temperature will help in understanding and predicting the effects of climate change for marine resources (see Kling and Sanchirico 2009). Climate data can assist private industry as well, including agriculture and livestock management (see Antle 2009) and insurance markets (Cooke and Kousky forthcoming; Kousky and Cooke forthcoming; Kunreuther and Michel-Kerjan 2009).

## What Information Matters Most?

Collecting these kinds of data comes at a cost. The examples above help show precisely which data and information have value for decisionmaking. The investment to date in data collection, particularly from the vantage point of space observations, is large.

Already the U.S. has invested more than $15 billion in climate-related data collection, modeling, and analysis of fundamental atmospheric, terrestrial, and oceanic processes that together make up the physical climate system. Additional expenditures—on the order of $6 billion—are required annually to operate these systems. The activities involve at least six government agencies: the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the U.S. Department of Energy, the U.S. Environmental Protection Agency, the U.S. Department of Interior, and the U.S. Department of Agriculture. All these agencies operate climate-related observing systems either in space or on the ground (to measure carbon flux, land use, and so forth). The objectives of these agencies are largely to identify the climate effects most directly related to their missions; for instance, the Department of Interior needs to know the effects on public lands; the Department of Energy needs to know the effects on fossil and renewable energy demand and supply.

Other countries have invested additional amounts in their own science-observing networks. Counting just the space systems—since these represent most of the expenditure so far—the entire international effort of the United States and some other 30 countries now includes 78 spacecraft carrying 125 instruments (see inventory of the efforts in World Meteorological Organization 2008b, Annex 3). The cost of these efforts is not readily available, but assuming an average cost of about $500 million per system, some $39 billion of observing infrastructure is in place. As noted, additional ground and ocean systems collect data that complement and provide "ground truthing" for the satellites.

The international efforts are organized under the Global Climate Observing System (GCOS), sponsored by the World Meteorological Organization, the United Nations Environment Programme, the International Council for Science, and the Intergovernmental Oceanographic Commission. The representatives of GCOS also work with other international efforts, including the Intergovernmental Panel on Climate Change (IPCC) and the World Climate Research Program.

Box 1 lists the data that GCOS scientists have identified as necessary to understand climate. The list includes more than 40 different physical parameters, called essential climate variables (ECVs), requiring satellites, aircraft, ocean buoys, ground monitors, and all of the hardware, software, and human talent needed to use the data. At present, not all the data are being collected. One of GCOS' challenges is encouraging member nations to help invest and fill gaps in the global system.

**Box 1. Essential Climate Variables**

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|---|
| **Atmosphere**<br><br>Surface: Air temperature, precipitation, air pressure, sea-level pressure, surface radiation budget, wind speed and direction, water vapor, evaporation and evapotranspiration<br><br>Upper Air: Earth radiation budget, upper-air temperature, wind speed and direction, water vapor, cloud properties<br><br>Composition: Carbon dioxide, methane, ozone, other long-lived greenhouse gases, aerosol properties |
| **Oceans**<br><br>Surface: Sea-surface temperature, sea-surface salinity, sea level, sea state, sea ice, current, ocean color, carbon dioxide partial pressure, ocean-surface wind and wind stress, surface air temperature/humidity, precipitation, evaporation, freshwater flux from rivers and ice melt, carbon dioxide flux across air/sea interface, geothermal heat flux on the ocean bottom<br><br>Sub-surface: Temperature, salinity, current, nutrients, carbon, ocean tracers, phytoplankton |
| **Terrestrial**<br><br>Snow cover area, glaciers and ice caps, permafrost and seasonally adjusted frozen ground, albedo, land cover, fraction of absorbed photosynthetically active radiation, leaf-area index, biomass, fire disturbance, lake level and surface temperature, soil moisture |
| *Source*: World Meteorological Organization 2006 |

## What Information Is Relevant to Climate Adaptation?

The data collection and analysis effort represented by the ECVs has focused on understanding the science of climate. As a result, and as people have started to ask for data to inform real-world decisions about adapting to climate, the ECVs have come under some constructive criticism. The concern is the age-old problem of making sure that data we collect serves both science and applied problems.

In the United States, this problem is beginning to get attention. The U.S. Government Accountability Office (2009) has begun to consider what information state and local agencies require. The Department of Commerce is proposing a National Climate Service within NOAA,[2] but it is not clear whether the new service would represent only NOAA or the data that other agencies will require as well. Even so, desirable as it may be, interagency coordination has always been difficult. For instance, years ago, analysts suggested and some in Congress unsuccessfully proposed creating a department of environmental statistics, recognizing that data about the environment cut across many government departments (see Banzhaf 2004; Portney 2003).

Unlike environmental data specific to the United States, climate as a global phenomena calls not only for organizing federal government, but making sure it connects well with ongoing efforts around the world. The problem is no easier in the case of organizing internationally. In a workshop convened after publication of the latest IPCC climate assessment report, policy experts were asked to identify the relevance of the ECVs to the kinds of decisions that countries are likely to face in adapting to climate change (World Meteorological Organization 2008a). The workshop attendees agreed that gaps exist between the data GCOS focuses on for climate science and the information required for decisions about adaptation. They agreed on the desirability of more tightly linking the priorities of science with the data people require for decisions.

Table 1 illustrates some concerns that attendees expressed. The table shows that only a subset of the 40-some variables of scientific interest has relevance to climate adaptation in major sectors. The first column groups the ECVs from Box 1 into a few broad categories. The remaining entries in the table indicate which variables are deemed useful for climate adaptation in managing activities and resources including agriculture, public health, infrastructure, marine and freshwater resources, terrestrial ecosystems, and possible abrupt climate change. In addition to the specific variables of interest, an additional longstanding concern has been that the spatial and temporal scales of many variables remain too gross for many decisions. For example, knowing that hurricane formation in the Pacific Ocean is likely to be more frequent and severe than it has been in the past is less useful than knowing how many hurricanes are likely to make landfall, where, and when.

[2] See http://www.noaa.gov/climate.html (accessed March 10, 2010).

**Table 1. High-Priority Climate Data to Assist in Adaptation**

| | Agriculture | Public health | Infrastructure | Marine resources | Terrestrial ecosystems | Freshwater resources | Abrupt climate change |
|---|---|---|---|---|---|---|---|
| Precipitation (frequency, intensity, quantity, and type) | √ | √ | √ | √ | √ | √ | |
| Sea-level rise | | | √ | √ | | √ | |
| Surface and upper-air temperatures | √ | √ | √ | | √ | √ | |
| Ocean color (chlorophyll concentration and carbon particulates) | | | | √ | | | |
| Aerosols (depth and other properties) | | √ | | | | | |
| Water vapor (a "natural" greenhouse gas linked to cloud formation and precipitation) | | | | | | | |
| Land cover types and changes (high-resolution data) | √ | | | | √ | √ | |
| Soil moisture | √ | | | | √ | √ | |
| Glacier ice melt | √ | | | | √ | √ | |
| Ice sheet elevation changes | | | √ | | | | √ |
| Methane release | | | | | | | √ |
| Atlantic Meridional Overturning Circulation | | | | | | | √ |

*Sources*: Based on information in World Meteorological Organization 2006, 2008; National Research Council 2002a; U.S. Climate Change Science Program 2008.

These criticisms do not imply that improving understanding of fundamental climate science is unimportant for practical decisionmaking. An example is the value of understanding microcorrelations, which are tiny correlations between variables that easily can be overlooked (Kousky and Cooke forthcoming). The strong correlation between Atlantic tropical cyclones and atmospheric dust from the Saharan air layer is an example for which precipitation and aerosols, two of the climate variables, need to be understood together. Critics of data collection tend to view the variable of precipitation but not the variable of aerosols as important, for instance, less fully appreciating scientists' concept of the collection of all variables to represent Earth as system. Balancing information for climate science and decisions, then, necessarily calls for more interaction between scientists and decisionmakers across federal agencies; among federal, state, and local agencies; and between the United States and other countries. Such is the complexity of climate as a global public good with very local effects.

## What Information Has Value?

In light of these concerns, how can government best fulfill its role in providing information relevant for climate adaptation? A long line of decision-theoretic research on the value of information offers some general principles.[3] Their application could prove useful as federal agencies shape their roles and formulate budgets for providing relevant information for adaptation, both domestically and in representing U.S. interests in the scheme of global data-collection efforts. The principles from previous research include the following:

- Because information is not costless, perfect information may not be worth its cost of acquisition.
- Information is less useful if no action can be taken in response.
- Information may have value if an action deliberately is not taken.
- An increase in information may not reduce uncertainty but may still be worth acquiring.

Because acquiring information is not costless, one principle is that perfect information may not be worth its cost of acquisition. In fact, people typically make decisions with less-than-perfect information—that is, with at least some uncertainty, balancing the chance of a mistake against the cost of more information. With good enough imperfect information, engineers build bridges with structural tolerances, for instance, and building codes protect other infrastructure from the chance of some types of extremes. Comparing the cost of uncertainty with the cost of information acquisition thus sheds some light on how certain is certain enough. To illustrate, Box 2 describes the difference of nearly a magnitude in the cost of coastal protection in California for a rise in sea level of 50 centimeters compared with 1 meter. Comparing the likelihood of each outcome with the cost of information acquisition and protection can help to describe how certain the information needs to be in a standard value-of-information framework. Economically framed questions such as this will help inform public investment in information.

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[3] Macauley 2006 summarizes much of this research and offers perspective on these principles in the context of Earth science data.

**Box 2. The Value of Information for Coastal Protection**

"In a study of the impacts of sea-level rise (SLR) in California, the annualized capital and annual maintenance costs for coastal protection in the year 2100 to respond to a 50 cm SLR were estimated at roughly $200 million (year 2000$)—the comparable figure for a 1 m SLR was more than $1.5 billion.

As a result, a critical element of efficient adaptation is an accurate estimate of future SLR—at minimum, infrastructure planners need a reliable estimate of SLR during the expected useful life of the coastal defense project."

*Source:* Neumann and Hudgens 2006.

Another principle from value-of-information research is that information is not particularly useful if no action can be taken in light of the information. For instance, flooding and loss of life during the monsoon season is a way of life in low-lying developing countries. In many places, however, people can take few precautionary actions in response to the flood forecast. This principle suggests that even data that are spatially and temporally well scaled for a community may serve little use in some situations. (This example also suggests that the value of information is necessarily linked with other actions, such as incentives to build along low-lying coastal areas or premia charged for flood insurance, that will influence how people adapt in response to information.)

A related principle is that information is useful when it informs a deliberate decision *not* to take action. The U.S. agricultural sector, for example, could face an export market in which farmers in another country may decide not to irrigate—even when severe drought is forecast—unless the expected world price for the crop in the longer run is large enough to recoup irrigation costs. Much like the case of incapacity to take action in response to information, deliberately deciding not to take action depends on a host of circumstances additional to the information itself. For this reason, researchers applying value-of-information assessment have pointed out that care needs to be taken if the metric is the action of a person using the information. Failure to observe an action may mask the decision not to take action.

Both principles just described—lack of capacity to take action, and deliberate decision to take no action even if one could—have implications for the value of information. For instance, they mean that to assess the benefits and costs of climate data, the agencies supplying the data will require substantial understanding about the full nature of these decisions. Data collection agencies—NASA and NOAA—will need to work closely with on-the-ground practitioners who will use the data in making decisions about adaptation. Regrettably, some studies point out that agencies do not always build or use this bridge. (For example, the National Research Council (2002b; 2003; 2007, chapter 5) points out that the agencies typically do not consult the people who will use the data in which the agencies invest.) This point also exemplifies an important link between federal, state, and local government roles in adapting to climate change. Many actions to adapt to climate change will not be a federal responsibility. They will be subnational, taken by state and local officials or the private sector (for instance, farmers or private insurers). But some federal role to inform these actions follows from the "global public good" nature of climate science and the international network of observing systems, justifying at least in part the federal provision of climate data.

One more general principle is that an increase in information may not reduce uncertainty. Examples abound in the case of information collected as part of scientific research, where additional data can lead to more questions rather than answers, or medical testing, where additional results may fail to confirm prior diagnoses. An outcome of more uncertainty ex post—that is, after information collection—does not mean that the information lacks value.

Finally, it is important to return again to balancing data for climate science and climate policy. As noted earlier in the mention of microcorrelations among climatic phenomena, the complexity of these interactions is a reminder of how problematic it can be to want measures of extreme precipitation without appreciating the interrelationships among sea-surface temperature, surface winds, and other variables that combine to influence precipitation. Even these interrelationships can have benefit in a value-of-information context. Box 3 gives an example. It describes the potentially large undercapitalization of global insurers if they neglect microcorrelations that may underlie the complex interactions of Earth's climate.

## Information about Abrupt Climate Change

In an extreme case, if climate was changing so abruptly that adaptation was ineffective, what information might government provide in an early-warning system? Abrupt climate change is defined as a large-scale change in the climate system that takes place over a few decades or less, persists (or is anticipated to persist) for at least two decades, and causes substantial disruption in human and natural systems (National Research Council 2002a; see also discussion in U.S. Climate Change Science Program 2008). Scientists use the paleoclimate record and other information to infer possible causes of rapid, large-scale change to which society may be unable to adapt. A report from the U.S. Climate Change Science Program (2008, 1) lists these as rapid changes in ice sheets leading to a rise in sea level, widespread and sustained changes in the hydrological cycle, abrupt change of the Atlantic meridional overturning circulation, and rapid release into the atmosphere of methane trapped in permafrost and on continental shelves.

**Box 3. Climate as Global System: A Role for Government to inform Microcorrelations**

The complex interactions among the atmosphere, oceans, ice at the poles, and land use make up the global climate system and undoubtedly will result in instances of small correlations around the world. Microcorrelations are very tiny correlations between variables that can be easily overlooked. If an insurance company thinks they are aggregating policies whose losses are independent, when in actuality they have a small, positive correlation, they could lose much of the diversification benefits they seek. While it is clear that policies geographically close to each other will have correlated losses, the climate system can sometimes correlate losses in disparate parts of the globe. A good example is El Niño, which causes changes in weather patterns around the world.

For a better understanding of the importance of microcorrelations, Kousky and Cooke (2009) offer an example based on a study of flood claims in U.S. counties. Suppose an insurance company sells a one-year catastrophic flood insurance policy paying $10,000 in damages should a flood occur. Assume the probability of this event is 0.001 per year. The "actuarial fair price" for this policy would be $10 (probability times loss). Assume the firm's risk-management regime stipulates that cash reserves must be capable of covering claims with a 99.9 percent probability. In this case, the company must keep $10,000 in reserve to guard against insolvency, since this is the loss that would occur with probability 1-.999. Now, suppose the company pools this policy with 10,000 other independent policies with identical probabilities and losses. To cover the .001 loss probability of these 10,000 policies, the company must hold $197,666. Although the income from premiums went up by a factor of 10,000, the required cash reserves went up only by a factor of 20. This is the diversification value of bundling policies. If, however, these 10,000 policies had on average a correlation equal to that found for flood claims across all U.S. counties (0.041), the company would need to hold $2,079,887. Neglecting the microcorrelation would lead the company to be undercapitalized by a factor of 10.

*Special thanks to Carolyn Kousky for providing this example.*

Another concern is cascade-event catastrophes. Kousky, Rostapshova, Toman and Zeckhauser (2009) illustrate these with the example of weakened agricultural systems around much of the globe after several years of historically unusual drought. The simultaneous failure of a large number of these systems could constitute another type of abrupt climate change with limited time for response.

The value of information to improve understanding of these types of changes in climate depends in part on the ability to take action in advance of and in response to the information. In his book *Catastrophe*, Posner (2004) worries that insufficient resources are devoted to evaluating the costs and benefits of extreme events, including climate tipping points. Pindyck and Wang (2009) use a general equilibrium model to estimate the tax on consumption that society would be willing to accept to reduce the probability or impact of an extreme event such as abrupt climate change. Some fraction of this willingness to pay represents the value of information to plan for or alleviate the event (perhaps by geoengineering a deliberate change in climate). Travis (2009) proposes a severe climate early–warning system. He points out that such a system would operate on a time scale akin to earthquake hazard, drought, and famine early–warning systems, which are based on long-term probability, and the Torino asteroid threat scale, which is based on the probability of impact and the potential ensuing effects over periods of years to decades. He argues for improvements in information, specifically in the form of enhanced monitoring and more science to better anticipate an abrupt change.

## Concluding Thoughts

These observations point to the usefulness of redirecting the nation's significant investment in climate science and data collection to include information specifically to support decisions. A step in this direction is to assign an agency or interagency group the task of more closely linking the GCOS climate variables to priorities for decisionmaking to enhance our ability to adapt to a changing climate. Another step is to increase emphasis on the spatial scale of regional, state, and local decisions and give priority to the information they require. At the same time, climate science has advanced to conceptualize Earth as one system. This integrated approach can be exploited to search for climate-induced, financially relevant microcorrelations over time and different parts of the world. These microcorrelations are particularly important to insurers, whose role figures prominently in managing large risks. We need a more systematic plan than the current piecemeal approach among agencies for balancing information to serve two ends: what people in states and localities need to know, and what scientists who think of the Earth as a system can tell us about global-scale phenomena that affect states and localities.

A related recommendation is to adopt principles about the value of information to guide data collection and analysis. Not all information has value, nor does the benefit of perfect information necessarily exceed its costs. Some filters need to be established to sort through the large amounts of data now being collected by global climate observing networks and possibly redirect these efforts, if necessary, to provide the kind of information necessary for adaptation.

Finally, the specter of tipping points raises additional questions about the provision of information if, despite best efforts, society is unable to adapt to abrupt changes in climate. What information is required to monitor the approach of possible extreme changes in climate? How early is early enough for action to be taken? At present, no agency has the responsibility to ask and answer questions such as these, despite their relevance to long-term thinking about both adaptation and our recourse if our best efforts to adapt fall short.

## References


Antle, John. 2009. *Agriculture and the Food System: Adaptation to Climate Change*. Washington, DC: Resources for the Future.

Banzhaf, Spencer H. 2004. Establishing a Bureau of Environmental Statistics. *Issues in Science and Technology* Winter: 26–30.

Cooke, Roger, and Carolyn Kousky. Forthcoming. Climate Dependencies and Risk Management: Microcorrelations and Tail Dependence. Issue brief. Washington, DC: Resources for the Future.

Covich, Alan P. 2009. *Emerging Climate Change Impacts on Freshwater Resources: A Perspective on Transformed Watersheds*. Washington, DC: Resources for the Future.

Kling, David, and James N. Sanchirico. 2009. *An Adaptation Portfolio for the United States Coastal and Marine Environment.* Washington, DC: Resources for the Future.

Kousky, Carolyn, Olga Rostapshova, Michael Toman and Richard Zeckhauser. 2009. "Responding to Threats of Climate Change Megacatastrophes," RFF Discussion paper 09-45, November.

Kousky, Carolyn, and Roger Cooke. 2009. "The Unholy Trinity: Fat Tails, Tail dependence, and Micro-correlations," RFF Discussion Paper 09-36-REV, November.

Kousky, Carolyn, and Roger Cooke. Forthcoming. Adapting to Extreme Events: Managing Fat Tails. Issue brief. Washington, DC: Resources for the Future.

Kunreuther, Howard, and Erwann Michel-Kerjan. 2009. Encouraging Adaptation to Climate Change: Long-Term Flood Insurance. Issue brief 09-13. Washington, DC: Resources for the Future.

Macauley, Molly K. 2006. The Value of Information: Measuring the Contribution of Space-Derived Earth Science Data to Resource Management. *Space Policy* 22: 274–82.

National Research Council. 2002a. *Abrupt Climate Change: Inevitable Surprises*. Washington, DC: National Academies Press.

National Research Council. 2002b. *Toward New Partnerships in Remote Sensing: Government, the Private Sector, and Earth Science Research*. Washington, DC: National Academies Press.

National Research Council. 2003. *Using Remote Sensing in State and Local Government: Information for Management and Decision Making*. Washington, DC: National Academies Press.

National Research Council. 2007. *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*. Washington, DC: National Academies Press.

Neumann, James E., and Daniel E. Hudgens. 2006. Coastal Impacts. In *The Impact of Climate Change on Regional Systems: A Comprehensive Analysis of California*, edited by Joel B. Smith and Robert Mendelsohn. Northampton, MA: Edward Elgar, chapter 13.

Neumann, James E., and Jason C. Price. 2009. *Adapting to Climate Change: The Public Policy Response—Public Infrastructure*. Washington, DC: Resources for the Future.

Pindyck, Robert, and Neng Wang. 2009. The Economic and Policy Consequences of Catastrophes. Working paper 15373. Cambridge, MA: National Bureau of Economic Research.

Portney, Paul R. 2003. Testimony of Paul R. Portney, President, Resources for the Future, before the U.S. House of Representatives Committee on Government Reform Subcommittee on Energy Policy, Natural Resources, and Regulatory Affairs. June 6. Washington, DC: Resources for the Future. http://www.rff.org/rff/Documents/RFF-CTst-03-portney.pdf *(accessed April 20, 2010).*

Posner, Richard. 2004. *Catastrophe: Risk and Response*. New York: Oxford University Press.

Running, Steven W., and L. Scott Mills. 2009. *Terrestrial Ecosystem Adaptation*. Washington, DC: Resources for the Future.

Samet, Jonathan M. 2009. *Adapting to Climate Change: Public Health*. Washington, DC: Resources for the Future.

Travis, William R. 2009. Toward a Severe Climate Change Early Warning System. Unpublished draft. Boulder, CO: University of Chicago at Boulder.

U.S. Climate Change Science Program. 2008. *Abrupt Climate Change. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research*. P.U. Clark, A.J. Weaver (coordinating lead authors), E. Brook, E.R. Cook, T.L. Delworth, and K. Steffen (chapter lead authors). Reston, VA: U.S. Geological Survey. http://www.climatescience.gov/Library/sap/sap3-4/final-report/ (accessed June 2009).

U.S. Government Accountability Office. 2009. *Climate Change: Observations on Federal Efforts to Adapt to a Changing Climate*. GAO-09-534T. Washington, DC: US Government Accountability Office.

World Meteorological Organization. 2006. *Systematic Observation Requirements for Satellite-Based Products for Climate*. GCOS-107/WMO/TD No. 1338. Geneva, Switzerland: World Meteorological Organization

World Meteorological Organization. 2008a. *Future Climate Change Research and Observations: GCOS, WCRP and IGBP Learning from the IPCC Fourth Assessment Report*. Geneva, Switzerland: World Meteorological Organization.

World Meteorological Organization. 2008b. *The Space-Based Global Observing System in 2008 (GOS-2008) Volume 1 Satellite Programme Description*. Geneva, Switzerland: World Meteorological Organization