



On Sept. 3, 2010, when NASA's Terra spacecraft captured this image over the Indus River in Pakistan, severe flooding was still causing a major humanitarian crisis in Pakistan. The city of Hyderabad is near the middle of the image.

Investing in Information

TO RESPOND TO A CHANGING CLIMATE

Molly K. Macauley

In the 1970s, a severe drought hit the Soviet Union and significantly reduced its grain harvest. As the USSR began quietly purchasing large amounts of world grain inventories, global food prices soared. Learning from the so-called "Great Grain Robbery of 1972," the U.S. Department of Agriculture began increasing its surveillance of global agricultural conditions, regularly forecasting expected crop yields and worldwide agricultural productivity. Today, the forecasts rely on a variety of satellite data, ranging from weather to land-use observations, in combination with official reports from foreign governments, overseas post reports, and other data to provide early warning and critical analyses of major world crop events.

This is just one example of how publicly provided information on global conditions is used to leverage huge financial resources. As the world adapts to a changing climate, the quantity and quality of our information will play a critical role in determining

the effectiveness of public and private responses:

» Information on changes in sea level, variability of temperatures, and the severity of droughts, for instance, will be pivotal in leveraging public-sector resources and managing infrastructure.

» Public-health surveillance systems can incorporate information about vector-borne diseases, extreme weather events, and climate-influenced changes in aeroallergens and other measures of air quality.

» Precipitation, soil moisture, snowmelt, and other indicators will signal when actions may be needed to protect terrestrial ecosystems and manage freshwater resources.

» Data on ocean salinity and temperature will help in understanding and predicting the effects of climate change on marine resources.

» Climate data can assist private industry as well, including agriculture and livestock management and insurance markets.

are required annually to operate these systems. The activities involve at least six government agencies: the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, 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).

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. The cost of these efforts is not readily available, but assuming an average cost of about \$500 million per system, some \$39 billion of observation

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

Already, the United States 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—

infrastructure is in place. And, as noted, additional ground and ocean systems collect data that complement and provide “ground truthing” for the satellites.

Valuing Information

Acquiring and developing information is not free—and government expenditures on information collection must compete with other pressing demands for government services. Understanding this, in what terms should we consider how much public effort to devote to the collection and dissemination of climate-related information?



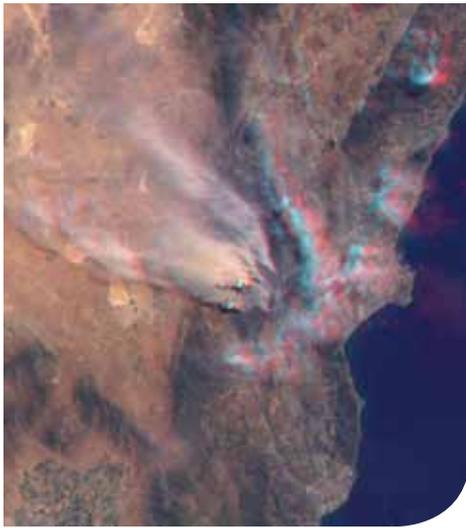
The simple economic answer, of course, is that the benefits of the information should exceed the opportunity costs of acquiring it. But there are wrinkles to this story. Four principles come into play when deciding whether investing in information delivers sufficient bang for the buck.

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 adequate—even if imperfect—information, engineers build bridges with structural tolerances, for instance, and building codes protect other infrastructure from the chance of some extreme events. Comparing the cost of uncertainty with the cost of information

acquisition thus sheds some light on how certain is certain enough.

And, in many cases, the “value of information” can be extremely large. For example, research by Jim Neumann and Daniel Hudgens (see Further Reading) finds that the infrastructure required to protect coastal California from one-half meter of sea level rise in 2100 is about \$1 billion cheaper than if the sea rises a full meter. Narrowing our uncertainty about the amount of rise would allow for a much more efficient allocation of public and private dollars. 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.



Smoke from the Station Fire in La Cañada Flintridge blankets Southern California.

Information is less useful if no action can be taken in response.

For instance, flooding and loss during monsoon seasons is a way of life in low-lying developing countries. In many places, however, people can take few precautionary actions in response to flood forecasts. 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 change building practices along low-lying coastal areas or the size of premiums charged for flood insurance—that will influence how people adapt in response to information.)

Information may have value if an action deliberately is not taken.

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 previous case—incapacity or weak incentives 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 assessments 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 to not take action.

An increase in information may not reduce uncertainty but may still be worth acquiring.

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. It simply means we knew less than we thought we did.

Abrupt Climate Change

In an extreme case, if climate was changing so abruptly that adaptation proved 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. 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. Examples include precipitous 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.

A separate concern is cascade-event catastrophes. The simultaneous failure of a large number of integrated systems, such as linked agricultural networks, 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*, Richard Posner worries that insufficient resources are devoted to evaluating the costs and benefits of extreme events, including climate tipping points. Bill Travis (see Further Reading) proposes a severe climate early warning system. He points out that such a system would operate on a time scale akin to early warning systems for earthquake hazard, drought, and famine, 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 scientific research 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 decisionmaking in a more targeted manner. Adaptation is in many cases a local and regional challenge. The United States needs 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 study Earth systems can tell us about global-scale phenomena that affect states and localities.

Principles about the value of information should be adopted to guide data collection and analysis. Not all information has value, nor does the benefit of perfect information necessarily exceed its costs. Filters need to be established to sort through the large amounts of data now being collected by global climate observing networks and some of these efforts may need to be redirected 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 U.S. 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.

FURTHER READING

- Neumann, James E., and Daniel E. Hudgens. 2006. Coastal Impacts. Chapter 13 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.
- Posner, Richard A. 2006. *Catastrophe: Risk and Response*. New York: Oxford University Press.
- Travis, William R. 2009. *Toward a Severe Climate Change Early Warning System*. Unpublished draft. Boulder, CO: University of Chicago at Boulder.