CLIMATE CHANGE AND WATER RESOURCES: THE CHALLENGES AHEAD

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Changes in water resource availability, water quality and the destructive potential of storms and floods will play a central role in determining how climate change will affect human well-being and the functioning of the natural systems on which we depend. The critical role of water may appear obvious given its importance for agricultural productivity, human health and the functioning of ecosystems. It is perhaps less widely understood that water also plays a key role in the functioning of the climate system. In fact, global warming and changes in the water cycle are intricately linked.

While we have an imperfect understanding of the local-scale details of the changes to come, the scientific community now has considerable confidence in projections of some of the key features and broad-scale regional patterns of future changes in the world's water resources. The evidence strongly suggests that many areas of the world that are already grappling with intense competition and growing demands for scarce water supplies may face steadily worsening water supply conditions in the future. Everywhere, climate change will introduce new obstacles into the business of water resource planning and policy development because the climatic and hydrologic patterns of the past will no longer provide a reliable guide to the future.

Perhaps the most helpful way to begin grappling with future water resource changes is to start by taking stock of what we know, what we do not know and why. This analysis will first provide a rough outline of the current state of scientific understanding of the likely impacts of climate change on the world's water resources. It will then turn to the implications of these changes—and particularly the implications of unavoidable uncertainties—for water resource planning and policy negotiations.

Scientific Understanding of Changes in Climate and the Water Cycle

The basic science of the greenhouse effect is well understood and has come to a consensus. Some of the major greenhouse gases—water vapor, carbon dioxide,

Journal of International Affairs, Spring/Summer 2008, vol. 61, no. 2.

methane and nitrous oxide—occur naturally in the atmosphere. They play a critical role in the earth's energy balance because they trap enough outgoing infrared radiation to make the surface of the earth warm enough to support life. Concerns about climate change arise from the fact that human activities are releasing large quantities of these substances—and other even more powerful manufactured greenhouse gases such as halocarbons—into the atmosphere. Because carbon dioxide and many of the halocarbons have very long atmospheric lifetimes, the increased concentrations are likely to result in an enhanced greenhouse effect in the future.

The climate system will react to such an increase in heat-trapping capacity by setting in motion processes that will adjust the earth's energy balance to a new equilibrium. These processes include the release of latent heat through increased evaporation, plant transpiration and precipitation—in other words, acceleration of the hydrologic cycle.[1] Hydrologic changes are, thus, an integral part of global climate change. In addition to accelerating evaporation, warming also increases the moisture-holding capacity of the atmosphere. Atmospheric water vapor, in turn, is a powerful greenhouse gas, so increases in the water content of the atmosphere will create a positive feedback that will tend to amplify the warming that humans have initiated by burning fossil fuels and engaging in other activities that release greenhouse gases.[2] It is estimated that the water vapor feedback may be large enough to roughly double the impact of an increase in carbon dioxide alone.

Cloud cover will also change. Clouds play a dual role—both amplifying warming by absorbing outgoing infrared radiation and producing a cooling effect by reflecting away incoming solar radiation. The net effect of cloud-cover changes will depend on the details of changes in cloud characteristics, altitude and location. It remains unclear whether cloud changes will have a positive or negative impact on global average temperatures.[3]

Other positive feedbacks include the warming effect of shrinking snow and ice cover as a darker earth's surface reflects less sunlight back to space, and the impacts of warming on natural sources and sinks of carbon dioxide and methane. Changes in the extent of wetlands and consequent methane generation and changes in the uptake and release of carbon from the oceans accompanied previous periods of warming and cooling. The expected effects of future warming include increased production of methane by tropical wetlands and a decline in the ability of the world's oceans to remove CO_2 from the atmosphere, because the solubility of CO_2 in seawater diminishes as the water warms.[4] In addition, we are generating other pollutants that play a role in the earth's energy budget. For example, tiny particles from combustion, especially sulphate aerosols, tend to produce cooling by reflecting incoming sunlight, while dust and soot deposits on snow surfaces have an opposite impact.