SAND2003-4114
Unlimited Release
Printed November 2003

Global Climate Change and International Security

Thomas H. Karas
Advanced Concepts Group
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185-0839

Abstract

This report originates in a workshop held at Sandia National Laboratories, bringing together a variety of external experts with Sandia personnel to discuss "The Implications of Global Climate Change for International Security." Whatever the future of the current global warming trend, paleoclimatic history shows that climate change happens, sometimes abruptly. These changes can severely impact human water supplies, agriculture, migration patterns, infrastructure, financial flows, disease prevalence, and economic activity. Those impacts, in turn, can lead to national or international security problems stemming from aggravation of internal conflicts, increased poverty and inequality, exacerbation of existing international conflicts, diversion of national and international resources from international security programs (military or non-military), contribution to global economic decline or collapse, or international realignments based on climate change mitigation policies. After reviewing these potential problems, the report concludes with a brief listing of some research, technology, and policy measures that might mitigate them.

Acknowledgments

This report was made possible by the contributions of the participants, rapporteurs, and facilitators in the Sandia workshop on “The Implications of Global Climate Change for International Security.” They are listed in Appendices I and II of the report.

Contents

Foreword

On September 25 and 26, 2003, the Sandia National Laboratories (SNL) Advanced Concepts Group, working with the SNL Energy, Information, and Infrastructure Surety Division convened a workshop to explore "The Implications of Global Climate Change for International Security." Visiting Sandia were a dozen experts in international environmental policy, environmental security, and international security (see Appendix I). Joining this group were 16-20 Sandia technical and managerial staff with relevant interests, knowledge, and responsibilities (see Appendix II).

Both in plenary sessions and in breakout groups of about 10, the workshop participants were asked to discuss the following topics:

- possible physical and environmental effects of long-term as well as abrupt climate changes;
- consequences for human societies of such effects;
- pathways by which these consequences may lead to threats to national and international security; and
- scenarios which could illustrate (not exhaustively describe) how a few such pathways might lead to a regional conflict, a crisis for U.S. national security policy, and a change in the global international system.

Because the focus of the workshop was international security, the emphasis was on the downside of climate change effects—the potential risks to security. Thus, the reader will find the tone of this report to be somewhat pessimistic, since it does not address the processes and capabilities that might conceivably help social groups and nations, without much planning or preparation, cope with change effects.

Finally, although this workshop was primarily an exercise in problem exploration, the participants also discussed some of the policy implications of the pathways and scenarios they had identified.

This report is based primarily on the proceedings of the workshop, but it is not a transcript or a direct summary of the day and a half of discussions. Rather, it attempts to compile the ideas and information that emerged from the workshop into a more coherent and readable document than a verbatim record would have been. Note, therefore, that while the workshop participants were the source of the report's substance, the author alone is responsible for its flaws.

Executive Summary

The theme of the workshop reported here was the implications of climate change for *international* security. Therefore our focus is on the potential connections between climate change consequences and the ability of nation-states (individually or in groups) to secure themselves from harm caused by other nation-states. The argument here is not that climate change consequences are going to be either necessary or sufficient causes for international security problems. It is possible, though, that they might tip already precarious situations.

The Earth's climate is warming, albeit with major uncertainties about how much, how fast, and by what causes. Climate changes may occur gradually or abruptly, and in surprising ways (one projected sequence of events has northern Europe becoming much colder as a result of the Earth's climate getting warmer.)

Climatic change can result in a range of effects on the world environment: a higher frequency of extreme weather events, such as hurricanes, more rain, less rain (drought), floods, large changes in land and sea ecologies, sea-level rise. These effects, in turn, singly or in combination, can severely impact human water supplies, agriculture, migration patterns, infrastructure, financial flows, disease prevalence, and economic activity.

Both the first-order environmental effects of climate change and the societal consequences they lead to may exhibit non-linear behavior—the things that happen will not necessarily follow projected trends, but may be fairly sudden state changes that follow the crossing of thresholds or tipping points. The surprises that happen may not be predictable, but it is predictable that surprises will happen.

Gradual change is easier to adapt to than sudden change. But, in either case, different societies will have different social and economic resources for adaptation. Poorer classes of society within nations, and poorer nations in the international community, have less reserve capacity upon which to draw. In several of the less wealthy regions of the world, climate change consequences might come in addition to already stressing conditions: rapid population growth, strained agricultural resources, inadequate freshwater supplies, poor health services.

There are several ways to hypothesize that societal impacts (relating to water, agriculture, infrastructure, health, finance, economics) of climate change effects could result in international security problems (or benefits):

- aggravation of internal conflicts,
- increased poverty and inequality,
- aggravation of existing international conflicts,

- diversion of national and international resources from international security programs (military or non-military),
- contribution to global economic decline or collapse,
- international realignments based on climate change mitigation policies, or
- reduction of oil dependence (benefit).

Near the end of the workshop, suggestions for research and policy directions were briefly discussed. First, it would be helpful to decision makers if research on climate change, climate change effects, and human consequences of those effects could reduce the current uncertainties about how much of what might happen when. An effort that melded the expertise of physical, social, and computational scientists might make progress in that direction. Second, a better understanding of the phenomena might lead to technology developments for better adaptation. Third, national and international policies might better anticipate future needs for response and adaptation. For example, international development assistance might take into account the need to deal with climate change effects; international public health efforts could be strengthened to deal with climate change effect disease problems; or national or international capabilities could be developed to provide rapid infrastructure restoration assistance in the wake of environmental disasters.

Because current uncertainties make it so hard to specify appropriate investment levels in anticipatory measures, special emphasis might be given to “no regrets” measures that promise substantial benefits regardless of the specific course of climate trends.

Three Scenarios

The following scenarios are stories about how the effects climate change–related phenomena could interact with other social, political, economic, and environmental trends to threaten the security of nations. The stories center on real-world countries, regions, and international institutions, but they are not predictions of what will happen in the real world. Such predictions, most especially 20-50 years in the future, are not possible. It would not be surprising, though, if the world of the future sees events *somewhat like* those in the scenarios. The scenarios are meant to illustrate how complex, interrelated sets of variables (of which climate change-related consequences would only be one subset) could combine to pose major challenges to future national and international policy makers.[1]

South Asia in 2020

It is 2020 and the climate has not been kind to Pakistan. The annual monsoon rains have become sparse, and when rain does come, it is out of synchronization with the traditional crop planting season. Deforestation has led to soil erosion and silting of dams. In the Indus Delta, the drought has nearly completed the ongoing degradation of the mangrove forests, while fishing areas have been both polluted and over-harvested. With a growing population, the country is no longer self-sufficient in food production.

Lakes supplying water to Karachi are shrinking, while the city is swelling with angry young men no longer able to make a living back on the farm. They are ripe for recruitment from groups promising radical change.

Some radical change has already occurred in Islamabad, since radical Islamists now control the intelligence and military services. But even those organizations are regionally and ideologically divided. The "central" government controls only parts of the country. The south and north are increasingly at odds. A group in the north has increased infiltration of Kashmir and Indian counterattacks into Pakistan are growing more frequent. Regional warlords now control much of the west, frequently colluding with Afghan warlords in the drug trade.

The government will not admit it, but two nuclear weapons have disappeared from the Pakistani arsenal, and no one can or will say who has them.

Rise of China in 2030

It is 2030, and the U.S. has suffered a series of climate-related setbacks. Prolonged drought in Mexico has produced millions of "eco-refugees," many of whom are illegally joining friends and relatives in the U.S., hoping to find work. But unlike in

[1] The scenarios here are based on ideas generated by the workshop working groups, but not identical to those presented in the workshop. In particular, some of the groups produced alternate outcomes based on more optimistic, and perhaps no less realistic, assumptions than the ones made here. The thrust of this report is to call attention to potential threats and the possible utility of trying to anticipate them—not to problems that will take care of themselves.

the past, even low-paid, unskilled work is hard to find in a U.S. that has suffered several years of recession. The Federal budget is in crisis, with Social Security and Medicare payments to the "baby boom" generation taking more than 14 percent of GDP. Recovery of the economy has been hampered by three simultaneous epidemics of re-emerging infectious diseases. Nor have the high energy prices helped (on-again-off-again Iraqi-Saudi Arabian clashes have reduced Persian Gulf oil exports). The sudden cooling of northern Europe has greatly weakened that area economically and led to destabilizing shifts of population. U.S.-European relations are greatly strained, in part because of the belief held by many Europeans that the U.S. renunciation of the Kyoto-Bonn accord on reducing Greenhouse Gases (GHG) has caused their predicament.

In the Far East, the situation is different. A booming China has been absorbing foreign direct investment that used to go to the U.S., while the Chinese domestic marketplace has been able to take up the slack left by the shrinkage of U.S. exports to the U.S. Chinese mastery of electronics technology has allowed it to carry out its own "revolution in military affairs," with impressive intelligence, communications, computing, and precision delivery capabilities.

Recent climatic changes have not deprived China of agriculturally productive land but they have shifted the regions of productivity, leading to major migration and the need for realignment of infrastructure. This activity has, in turn, increased Chinese energy demands beyond those previously forecast. With the instabilities of the Middle East, China has been placing increasing emphasis on guaranteeing its oil supplies with exclusive contractual relationships with sellers and on developing the military capabilities to protect the lines of oil transport.

This apparent effort by China to dominate essential resources, coupled with a general rise of international assertiveness, has made Japan and Unified Korea increasingly wary. For some time, they have been doubting the willingness and ability of the U.S. to help them stand up to Chinese pressures. Japan is close to a decision to build its own nuclear deterrent arsenal. China has warned them that this would lead to the most serious repercussions.

The U.S. President has asked the National Security Council what the U.S. should do now.

Global Public Health and Trade Crisis in 2025

It is February of 2025 and South America is nearing the end of its second summer of extraordinary heat waves. Brazil and Argentina have been hit hard by a mysterious new disease epidemic that has sickened thousands and killed hundreds. At first (since no cause can be determined, but whole families are contracting the disease), human-to-human transmission is suspected. Later, as cattle get sick, "mad-cow disease"-like prions are suspected. Finally, however, it appears that human and animal grain supplies have been contaminated with the hitherto unknown pathogen. The unusually hot and moist grain transport and storage conditions may or may not have something to do with the

food contamination. The epidemic spreads to Japan and China, now major importers of South American foodstuffs.

To make matters worse, U.S. intelligence has picked up conversations among terrorists groups proposing to intentionally spread the grain disease to U.S. and European farmlands.

With no reliable test for the mystery contamination, widespread fear causes severe constriction in international trade in foodstuffs. Existing stocks of food and feed grains are destroyed. International travel becomes more difficult, first because of fears of human transmission of the disease, then because of security measures intended to prevent terrorist smuggling of the infection. The eight southern provinces of China, already with food production lowered by drought, are threatened with famine. Appearance of the grain disease in India leads to suspicions of Pakistani sabotage, heightening recently renewed tensions between the two countries. In many poorer countries, a decline in nutrition weakens the population against not only the mystery disease, but other diseases as well.

The international community has organizations that are supposed to keep this kind of food and disease crisis from getting out of hand, but they have proved unable to keep up. The World Health Organization lacked the resources to maintain the kind of global health surveillance that might have detected and pinpointed the cause of the disease earlier. The Global Information and Early Warning System of the Food and Agricultural Organization does not detect that the disease is food-related in time to prevent the food trade crisis. Exporter complaints are made to the World Trade Organization that the blocking of food imports is not justified by the known facts about how much grain is contaminated. Importing nations, however, say that even retaliatory embargoes will not deter them from protecting their populations from the risk. Globally, an economic turndown begins as food prices rise, debt servicing falls behind, and trade shrinks.

Climate Change: Gradual or Abrupt?[2]

The particular scenarios above are unlikely to occur just as described. But, in the long run, the earth's climate changes. As discussed in the next subsection, there are major uncertainties about when, how, and why climate change will happen in the future. But the potential exists for considerable impacts of climate change on human economies and societies. Moreover, given the complexity of the systems involved, the impacts might easily turn out to be non-linear—to occur suddenly as unpredictable "tipping points" are reached. These impacts, in turn, could have important implications for the security of individual nations, regions, and the international system as a whole. Although climate change impacts seem unlikely to be the primary causes of international conflicts, they do appear to have much potential for amplifying a variety of international security problems.

The Intergovernmental Panel on Climate Change (IPCC) has conducted simulations that predict "…a globally-averaged surface temperature increase by the end

[2] Most of this section originally appeared in Thomas H. Karas, *Energy and National Security* (Albuquerque, NM: Sandia National Laboratories, SAND2003-328, September 2003), pp. 21-22.

of the century of 1.4 to 5.8°C (2.5 to 10.4°F) relative to 1990."[3] According to a committee of the National Research Council, the scientific community generally thinks that warming observed in the last 50 years is likely to have been due, at least in part, to the human-caused increase in levels of GHG, particularly carbon dioxide, in the atmosphere, although "…uncertainty remains because of (1) the level of natural variability inherent in the climate system on time scales of decades to centuries, (2) the questionable ability of models to accurately simulate natural variability on those long time scales, and (3) the degree of confidence that can be placed on reconstructions of global mean temperature over the past millennium based on proxy evidence."[4]

The models used by the IPCC suggested a gradual warming over the course of the next century. Moreover, since even the most intensive efforts to curb GHG emissions will not be able to stabilize atmospheric concentrations for some time, some additional warming is inevitable if those concentrations are indeed the major cause.

The paleoclimatic record, however, shows that, in the past, dramatic climate changes have occurred very abruptly (over years, not just over decades), as well.[5] (See **Box 1**.)Obviously these changes did not result from human-generated GHG. Therefore, it is quite possible they may occur again, whatever the future effect of the gases turns out to be. However, there is some concern that the warming induced by GHG might accelerate other processes and thereby increase the likelihood of more abrupt changes.

Box 1: Abrupt Climate Change

Recent scientific evidence shows that major and widespread climate changes have occurred with startling speed. For example, roughly half the north Atlantic warming since the last ice age was achieved in only a decade, and it was accompanied by significant climatic changes across most of the globe. Similar events, including local warmings as large as 16°C, occurred repeatedly during the slide into and climb out of the last ice age. Human civilizations arose after those extreme, global ice-age climate jumps. Severe droughts and other regional climate events during the current warm period have shown similar tendencies of abrupt onset and great persistence, often with adverse effects on societies.

Abrupt climate changes were especially common when the climate system was being forced to change most rapidly. Thus, greenhouse warming and other human alterations of the earth system may increase the possibility of large, abrupt, and unwelcome regional or global climatic events. The abrupt changes of the past are not fully explained yet, and climate models typically underestimate the size, speed, and extent of those changes. Hence, future abrupt changes cannot be predicted with confidence, and climate surprises are to be expected.

Source: Committee on Abrupt Climate Change, National Research Council, *Abrupt Climate Change: Inevitable Surprises* (Washington: National Academy Press, 2001). http://books.nap.edu/books/0309075742/html/.

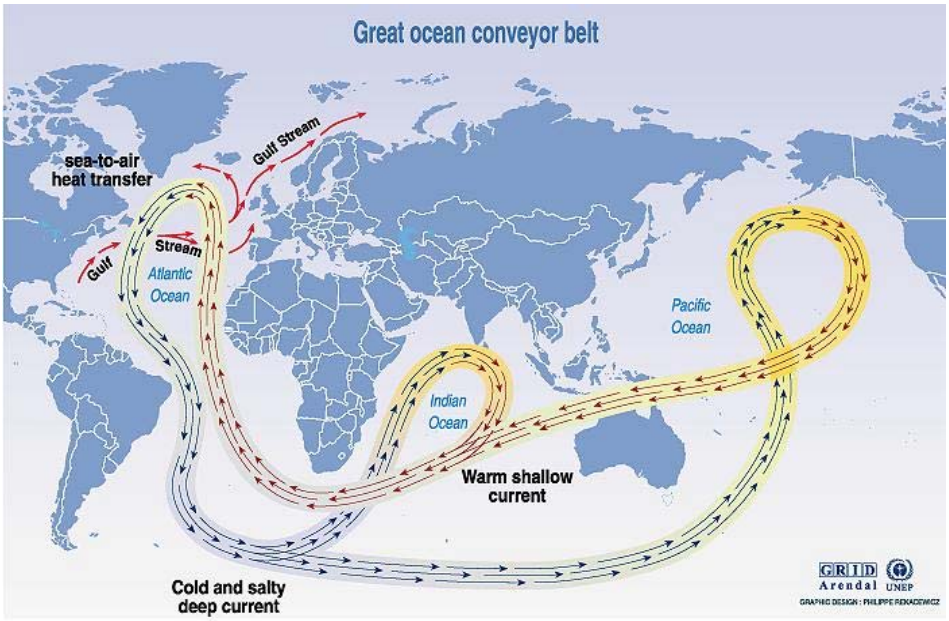
[3] Committee on the Science of Climate Change, National Research Council, "Summary," *Climate Change Science: An Analysis of Some Key Questions* (Washington: National Academy Press, 2001.

[4] Committee on the Science of Climate Change, National Research Council, "Summary," *Climate Change Science: An Analysis of Some Key Questions* (Washington: National Academy Press, 2001.

[5] Committee on Abrupt Climate Change, National Research Council, *Abrupt Climate Change: Inevitable Surprises* (Washington: National Academy Press, 2001). http://books.nap.edu/books/0309075742/html/. See also Spencer Weart, "The Discovery of Rapid Climate Change," *Physics Today,* August 2003, http://www.physicstoday.org/vol-56/iss-8/p30.html.

A dramatic—if low-probability—possibility for abrupt change would be the shutting down of the ocean "conveyor belt" (see Figure 1) that brings warm South Atlantic water to northwestern Europe. The paradoxical result might be that a global warming trend could lead to severe cooling—possibly a return of glacial ice—in northern Europe. [6]

Figure 1: The Great Ocean Conveyor Belt



Source: Broecker, 1991, in Climate change 1995, Impacts, adaptations and mitigation of climate change: scientific-technical analyses, contribution of working group 2 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

The global conveyor belt thermohaline circulation is driven primarily by the formation and sinking of deep water (from around 1500m to the Antarctic bottom water overlying the bottom of the ocean) in the Norwegian Sea. This circulation is thought to be responsible for the large flow of upper ocean water from the tropical Pacific to the Indian Ocean through the Indonesian Archipelogo (*sic)*. The two counteracting forcings operating in the North Atlantic control the conveyor belt circulation: (1) the thermal forcing (high-latitude cooling and the low-latitude heating) which drives a polar southward flow; and (2) haline forcing (net high-latitude freshwater gain and low-latitude evaporation) which moves in the opposite direction. In today's Atlantic the thermal forcing dominates, hence, the flow of upper current from south to north.

When the strength of the haline forcing increases due to excess precipitation, runoff, or ice melt the conveyor belt will weaken or even shut down. The variability in the strength of the conveyor belt will lead to climate change in Europe and it could also influence in other areas of the global ocean. The North Atlantic atmosphere-ocean-cryosphere system appears to have natural cycles of many timescales in switching the conveyor belt. Periodic movement of excessive ice from the Arctic into the Greenland Sea appears to be responsible for the interdecadal variability of the conveyor belt. There is no evidence yet that the influx of interdecadal switching extends beyond the North Atlantic Ocean.

Source: "Vital Climate Graphics," United Nations Environment Program/ GRID Arendal at http://www.grida.no/climate/vital/index.htm

[6] Peter U. Clark, Nicklas G. Pisias, Thomas F. Stocker, and Andrew J. Weaver, "The role of the thermohaline circulation in abrupt climate change**,"** *Nature* 415, 863 - 869 (21 February 2002) at

http://www.nature.com/cgi-taf/DynaPage.taf?file=/nature/journal/v415/n6874/full/415863a_r.html .

First Order Effects of Climate Change

Scientists have identified numerous potential environmental consequences if the current trend in global warming continues or intensifies;[7] these are summarized in **Table 1**. Additional studies have tried to assess how climate change might affect several regions of the world.[8] As with the modeling and prediction of future global temperature levels, estimates of when, how, and where these effects of climate change might take place are highly uncertain. Making the problem of prediction even more difficult, many of the effects listed here may well have significant feedback loops both with each other and with the long-term global warming process. Finally, although long-term trends can be extrapolated with at least some confidence, abrupt local events or global changes resulting from some set of variables reaching an unforeseen "tipping point" are sure to be surprises.

Table 1: First-Order Effects of Climate Change

System Affected	Description
Weather and hydrology	Increased or more intense storms, floods, droughts More rain, less snowpack and glaciation Higher daytime temperatures; heat waves Increased evaporation from lakes, reservoirs Higher nighttime temperatures Regional cooling (if ocean conveyor disrupted)
Ecology	Deforestation, northern extension of forests, increased forest fires Greater vegetation growth due to increased CO2 (but possibly fewer nutrients) Regional changes in animal species Changes in plant and pest life-cycles Northward movement of tropical disease vectors Enhanced disease infectivity
Oceans and Coasts	Decreases in some fish stocks Loss coral reefs, wetlands Sea-level rise: coastal submersion, coastal erosion, saltwater contamination of fresh water Increase of toxic marine species Deglaciation and ice-pack melting
Other	Release of additional greenhouse gases from earth surface: CO2, Methane (Not related to warming: increased ozone depletion)

[7] See Working Group II of the Intergovernmental Panel on Climate Change, *Climate Change 2001: Impacts, Adaptation, and Vulnerability—Summary for Policymakers*, http://www.ipcc.ch/pub/wg2SPMfinal.pdf.

[8] See Working Group II of the Intergovernmental Panel on Climate Change, *Climate Change 2001: Impacts, Adaptation, and Vulnerability*, full report at http://www.grida.no/climate/ipcc_tar/wg2/index.htm.

.

Societal Impacts of Climate Change

The direct effects of climate change summarized above could pose a variety of challenges to interrelated systems on which human societies depend—fresh water supplies, agriculture, other economic activity, settlements and infrastructure, and healthy individuals. **Box 2** describes many of these potential impacts, but categorizes them by the climate change effect rather than the impact. In this section, we review the impacts by system affected rather than by cause. We focus mainly on negative consequences, because we are moving toward identifying potential threats to national and international security. Positive consequences are possible for some nations in some cases. These could also affect the security situations of nations, regions, or the international system as a whole.

Another point to note here is that the subsections below of the various societal systems (e.g. water, agriculture) arbitrarily separates them for discussion, but that they are in many ways tightly coupled and affect one another profoundly. Moreover, the climate change effects may worsen trends that would already exist even if climate were to remain relatively constant. Some of these connections and possible feedback loops are sketched out at various points in this section. Note also that just as the physical phenomena described thus far may have non-linear effects, human systems may also change in abrupt, unpredictable ways.

Water

According to the IPCC working group on climate change impacts, about 5 billion people may live in water-stressed regions by 2025, and climate change effects could further reduce streamflow and groundwater recharge in many of these regions.[9] Changes in water temperature can also affect water quality—the types and levels of pollutants carried. The supply of clean water for some urban areas may be affected. Water for agricultural irrigation may become scarcer. Competition within or between nations for water resources may be heightened. In other areas, increased precipitation could lead to flooding problems.

The ultimate impact of water scarcities (or of flood damage) on a nation will depend greatly on the available political and technical arrangements for water management. As with other potential climate-change impacts, the poorer, less developed countries seem at greatest risk.

[9] See footnote 7 reference, p. 9.

Box 2: Human Impacts of Climate Change Phenomena

Projected Changes during the 21st Century in Extreme Climate Phenomena and their Likelihood[a]	Representative Examples of Projected Impacts[b] *(all high confidence of occurrence in some areas[c])*
Simple Extremes	
Higher maximum temperatures; more hot days and heat waves[d] over nearly all land areas (*very likely*[a])	• Increased incidence of death and serious illness in older age groups and urban poor [4.7] • Increased heat stress in livestock and wildlife [4.2 and 4.3] • Shift in tourist destinations [Table TS-4 and 5.8] • Increased risk of damage to a number of crops [4.2] • Increased electric cooling demand and reduced energy supply reliability [Table TS-4 and 4.5]
Higher (increasing) minimum temperatures; fewer cold days, frost days, and cold waves[d] over nearly all land areas (*very likely*[a])	• Decreased cold-related human morbidity and mortality [4.7] • Decreased risk of damage to a number of crops, and increased risk to others [4.2] • Extended range and activity of some pest and disease vectors [4.2 and 4.3] • Reduced heating energy demand [4.5]
More intense precipitation events (*very likely*[a] over many areas)	• Increased flood, landslide, avalanche, and mudslide damage [4.5] • Increased soil erosion [5.2.4] • Increased flood runoff could increase recharge of some floodplain aquifers [4.1] • Increased pressure on government and private flood insurance systems and disaster relief [Table TS-4 and 4.6]
Complex Extremes	
Increased summer drying over most mid-latitude continental interiors and associated risk of drought (*likely*[a])	• Decreased crop yields [4.2] • Increased damage to building foundations caused by ground shrinkage [Table TS-4] • Decreased water resource quantity and quality [4.1 and 4.5] • Increased risk of forest fire [5.4.2]
Increase in tropical cyclone peak wind intensities, mean and peak precipitation intensities (*likely*[a] over some areas)[e]	• Increased risks to human life, risk of infectious disease epidemics, and many other risks [4.7] • Increased coastal erosion and damage to coastal buildings and infrastructure [4.5 and 7.2.4] • Increased damage to coastal ecosystems such as coral reefs and mangroves [4.4]
Intensified droughts and floods associated with El Niño events in many different regions (*likely*[a]) (see also under droughts and intense precipitation events)	• Decreased agricultural and rangeland productivity in drought- and flood-prone regions [4.3] • Decreased hydro-power potential in drought-prone regions [5.1.1 and Figure TS-7]
Increased Asian summer monsoon precipitation variability (*likely*[a])	• Increased flood and drought magnitude and damages in temperate and tropical Asia [5.2.4]
Increased intensity of mid-latitude storms (little agreement between current models)[d]	• Increased risks to human life and health [4.7] • Increased property and infrastructure losses [Table TS-4] • Increased damage to coastal ecosystems [4.4]

[a] Likelihood refers to judgmental estimates of confidence used by TAR WGI: *very likely* (90-99% chance); *likely* (66-90% chance). Unless otherwise stated, information on climate phenomena is taken from the Summary for Policymakers, TAR WGI.
[b] These impacts can be lessened by appropriate response measures.
[c] High confidence refers to probabilities between 67 and 95% as described in Footnote 6.
[d] Information from TAR WGI, Technical Summary, Section F.5.
[e] Changes in regional distribution of tropical cyclones are possible but have not been established.

Source: "Summary for Policymakers," Climate Change 2001: Impacts, Adaptation, and Vulnerability, A Report of Working Group II of the Intergovernmental Panel on Climate Change (IPPC: 1981), at http://www.grida.no/climate/ipcc_tar/wg2/pdf/wg2TARspm.pdf.

Agriculture

Not only could increased droughts lead to agricultural water scarcities, but higher temperatures could lead to higher crop water demand. Flooding, soil erosion, and saltwater contamination can make farming more difficult. Extreme variability between drought and intense precipitation can damage agriculture. Productivity can also be reduced by pest infestations and crop diseases.

Since higher percentages of people in less developed countries depend directly on agriculture, declines in food productivity could affect those countries most strongly. Poorer countries that rely heavily on food imports could suffer if reduced production elsewhere led to higher prices.

Settlements and infrastructure

Increased storm intensities, flooding, coastal erosion, and sea-level rise[10] can damage buildings, roads, and utility distribution systems such as electric power lines. As population concentrates in cities, the value of infrastructure at risk increases. Drought can reduce energy supplies to regions dependent on hydroelectric power. Warming may reduce demand for space heating energy in some places, but increase demand for cooling energy elsewhere.

Decreased agricultural productivity may lead to increased migration to cities, thereby adding to the pressures on urban infrastructure and services.

Finance[11]

Insurance instruments can help spread the risks from losses due to extreme weather events (life and property, business loss and delays, crops), and governments can supplement private insurance programs. However, there are also some dangers that insurers and reinsurers, including governments, may be vulnerable to abrupt increases in losses. There is also the possibility that government-subsidized insurance can give incentives to people to adapt poorly to environmental risks (e.g. floods) by underpricing the costs of doing so. On the other hand, when insurance prices accurately reflect the risks involved in locating homes and infrastructure in places vulnerable to extreme weather, they can encourage more effective adaptive behavior.

---

[10] Sea-level rise can multiple socio-economic effects well beyond the direct damage to flooded infrastructure. See See Working Group II of the Intergovernmental Panel on Climate Change, "Chapter 6: Coastal Zones and Marine Ecosystems" in *Climate Change 2001: Impacts, Adaptation, and Vulnerability* at http://www.grida.no/climate/ipcc_tar/wg2/pdf/wg2TARchap6.pdf. For global statistics on population near coasts, see R. Gommes *et. al*., "Potential Impacts of Sea-Level Rise on Populations and Agriculture," *SD Dimensions* , posted March 1998 (Sustainable Development Department, Food and Agriculture Organization, United Nations, at http://www.fao.org/sd/eidirect/EIre0045.htm.

[11] See Working Group II of the Intergovernmental Panel on Climate Change, "Chapter 8: Insurance and Other Financial Instruments," in *Climate Change 2001: Impacts, Adaptation, and Vulnerability* at http://www.grida.no/climate/ipcc_tar/wg2/pdf/wg2TARchap7.pdf. See also Innovest Strategic Value Advisors, "Climate Change & the Financial Services Industry, Module 1-Threats and Opportun;ites, " July 2002 at http://www.innovestgroup.com/pdfs/Innovest_UNEP1_10_15_02.pdf and "Module 2: A Blueprint for Action" at http://www.innovestgroup.com/pdfs/Innovest_UNEP2_10_15_02.pdf.

Lack of availability of insurance for investment projects in less developed countries could deter needed foreign investment. Today's global capital markets have various instruments for hedging and diversifying risks (e.g. syndication, options, swaps, futures contracts). But developing countries may be less able to take advantage of these. It may be, however, that new financial instruments can be developed to spread and hedge against the risks in these countries.

Richer countries like the United States may be able to cope fairly well with the financial impacts of climate change effects. However, the U.S. (and to an even greater extent Japan and Western Europe) in the next few decades will also be facing substantial population aging that will result in smaller percentages of the people working and more people dependent on Social Security, pensions, and subsidized health care. Thus, the needs of the aging will compete for government funds with domestic adaptation to climate change effects, foreign development aid and disaster assistance, and military requirements.

Health[12]

Climate change effects can have adverse consequences for human health. With warming, disease vectors such as mosquitos may move farther north and to higher altitudes. Disease transmission seasons may last longer. Extreme weather events (storms, floods), besides injuring people directly, may cause population displacement, damage food production and distribution, or reduce the availability or quality of fresh water—any of which can increase the risks that infectious diseases will spread.

Areas with limited public health services—often the case in developing countries—would be especially vulnerable.

In a 2000 National Intelligence Estimate describing the security threat from infectious diseases, the U.S. National Intelligence Council predicted that over the next ten years the threat would first worsen, then modestly improve as global socio-economic conditions improved.[13] But climate-related increases in disease prevalence, combined with the challenges of other climate change effects, might stymie that progress.[14]

Economics

Combinations of some or all of the above phenomena can seriously harm local, national, or regional economies, and perhaps the global economy. Water scarcities can reduce crop production, as well as divert worker energies to obtaining family water supplies. Decreased agricultural productivity may also lead to malnutrition or to higher

---

[12] See Working Group II of the Intergovernmental Panel on Climate Change, "Chapter 9: Human Health," in *Climate Change 2001: Impacts, Adaptation, and Vulnerability* at http://www.grida.no/climate/ipcc_tar/wg2/pdf/wg2TARchap9.pdf.

[13] U.S. National Intelligence Council, *The Global Infectious Disease Threat and Its Implications for the United States* (NIE99-17D, January 2000), at http://www.cia.gov/cia/reports/nie/report/nie99-17d.html.

[14] For more on the political and security implications of disease (relevant to the section below on security consequences of climate change effects), see Andrew T. Price-Smith, *The Health of Nations: Infectious Disease, Environmental Change, and Their Effects on National Security and Development* (Cambridge, MA: MIT Press, 2001).

food prices; it may lead to migration of farmers to ecologically marginally growing areas or to city slums. Crop losses could mean loss of agricultural export revenues needed to finance imports. Weather-caused infrastructure damage harms the businesses dependent on the infrastructure, while repairing the damage and otherwise coping with disasters diverts resources from productive use. Financially hedging against climate change effect risks may, in various settings, help or harm insurance companies; in any case it costs resources. An unhealthy workforce, whether on the farm or in the city, will be less productive.

With a globally interdependent economy, there is some risk that particular combinations of regional economic distress could lead to an international economic downturn. The chances of this happening might be increased if severe weather events (made more frequent by climate change) occurred at around the same time in different regions. Or, an abrupt, low-probability, high-consequence event such as the shutdown of the Atlantic "conveyor belt," rapidly freezing much of northern Europe, might greatly damage one of the world's major economic engines.

Finally, the very unpredictability of climate change-related impacts on human activities could have a depressing effect on international investments. Uncertainty can foster investor caution and hesitation.

GHG Emission Reduction Efforts

The belief that GHG emissions are largely responsible for global warming, and that stabilization of atmospheric GHG could mitigate that warming and its effects, could lead to major socio-economic consequences. Although the U.S. Government currently takes the position, in contrast to that of many other nations, that GHG emission reductions are not called for, this position could change again.[15] U.S. and other government laws and policies could impose a variety of regulations and incentives to reduce GHG emissions.

If atmospheric GHG were stabilized, then it is plausible that the above-outlined effects of climate change, and thus their human consequences, would be reduced—though there is still some debate over the degree or reduction possible. Those who question the value of reducing GHG emissions, however, argue that the costs would harm the economies of the nations attempting to do so. (Others argue that the costs can be less, and the benefits greater, than reduction opponents believe).

Greater use of renewable energy resources and of distributed power production technologies might result in less vulnerability to extreme weather effects, since energy infrastructure damage might be more localized.

[15] This is not an argument of the merits of the case about GHG emissions, nor a proposal that policy should change again, but merely a recognition of the possibility that the policy *could* change.

Sensitivity, Adaptability, and Vulnerability

Analysts working with the IPCC have emphasized the importance of considering sensitivity, adaptability, and vulnerability in assessing potential climate change consequences. *Sensitivity,* for our purposes, is the degree to which the environmental systems upon which humans depend will respond to changed climatic conditions. *Adaptability* is the degree to which the human systems can change to cope with the environmental changes—whether in response to or in anticipation of the changes. *Vulnerability* is the extent of damage or harm the human systems may come to, given their levels of sensitivity and adaptability.

Many societies, including the U.S. and other economically developed nations, probably have a resiliency in social and political institutions that will allow them to adapt. New technologies, especially if they can be transferred where and when they are needed, should facilitate adaptation.

Wealthy individuals and groups in general will have more adaptive capacity than poor ones.[16] As noted in the previous subsections, richer nations will have more adaptive capacity than poor ones.[17] For example, a study of the potential impacts of climate change on the U.S. concluded:

> For the nation as a whole, direct economic impacts are likely to be modest, while in some places, economic losses or gains are likely to be large. For example, while crop yields are likely to increase at the national scale over the next few decades, large increases or decreases in yields of specific crops in particular places are likely. [18]

The vulnerability of many poorer countries may be exacerbated by trends that are proceeding independently of climate change effects. Rapid population growth, for example, is stressing land use, pressing migration to cities, presenting the challenge of large numbers of unemployed youth, and increasing pollution. Several regions of the world are already short of fresh water. Health services and public health infrastructures are already wanting.

Although wealth may be the most important indicator of adaptive capacity, social-psychological factors could hinder adaptation in either poor or rich countries. First, if change takes place gradually enough, societies may not recognize the need for adaptive change until very late in the game. Responses they do make may favor preservation of the

---

[16] Thomas Homer –Dixon argues that powerful groups in a society may react to environmental scarcities with "resource capture":

Resource capture eoccurs when a fall in the quality and quantity of a renewable resource interacts with population growth to encourage powerful groups within a society to shift resource distribution in their favor. This shift can produce dire environmental scarcity for poorer and weaker groups in the society.

Environment, Scarcity, and Violence (Princeton, NJ: Princeton University Press, 1999), p. 73.

[17] On the other hand, it might be argued that nations with well-developed infrastructures (e.g. transportation, utilities) might also be subject to complexities and rigidities that make some adaptations difficult. The northern US/southern Canada power blackout and the problems in restoring Washington, DC area power after a hurricane—both in 2003—might be cited as examples.

[18] National Assessment Synthesis Team, *Climate Change Impacts on the United States:The Potential Consequences of Climate Variability and Change* (US Global Change Research Program,Washington DC,2000), p. 9, at http://www.gcrio.org/NationalAssessment/overpdf/1IntroA.pdf

status quo. As an example, consider the tendencies of residents of flood-prone areas to build higher dikes or to demand more publicly-supported flood insurance rather than to relocate. Second, the complexity and unpredictability of climate change effects and consequences may make anticipatory adaptation very difficult—regions, states, and localities may be very uncertain about what effects may reach them and when. Third, (quite in contrast to the first point), changes may be very abrupt and, worse, not end in a stable state. For example, cooling might quickly follow heating, flooding might quickly follow drought.

The study of impacts on the U.S. of climate change effects points out:

> Vulnerability in the US is linked to the fates of other nations, and we cannot evaluate national consequences due to climate variability and change without also considering the consequences of changes elsewhere in the world. The US is linked to other nations in many ways, and both our vulnerabilities and our potential responses will likely depend in part on impacts and responses in other nations. For example, conflicts or mass migrations resulting from resource limits, health, and environmental stresses in more vulnerable nations could possibly pose challenges for global security and US policy.[19]

International Security Consequences

The theme of the workshop reported here was the implications of climate change for *international* security. Therefore, our focus is on the potential connections between climate change consequences and the ability of nation-states (individually or in groups) to secure themselves from harm caused by other nation-states. There is an emerging school of thought that proposes that a better perspective is that of "human security" rather than just the security of nations.[20] This perspective seems especially relevant to the climate change issue, because the primary societal effects will be on people and communities. Nevertheless, our interest here is in how those effects may in turn affect the security of nations. This is a matter of focusing on one set of problems rather than another (even while recognizing that they may all be related); it is not a matter of arguing that the human security perspective is invalid.[21]

---

[19] Ibid.

[20] For example, the Program on Human Security at the Harvard Center for Basic Research in the Social Sciences argues:

> In the last two decades, the international community has begun to conclude that attempts to ensure the territorial security of nation-states through military power have failed to improve the human condition. Despite astronomical levels of military spending, deaths due to military conflict have not declined. Moreover, even when the borders of some states are secure from foreign threats, the people within those states do not necessarily have political freedom and democracy, proper health care, education, enough food, or freedom from crime. In response to these developments, the international community has gradually moved to combine economic development with military security and other basic human rights to form a new concept of human security. Unfortunately, by common assent the concept lacks both a clear definition, consistent with the aims of the international community.

Found at http://www.cbrss.harvard.edu/programs/hsecurity/hsmission.htm.

[21] Some, however, argue that talking about "environmental security" and taking a national (vs. human) security perspective on climate change "…risks making it a military rather than a foreign policy problem and a sovereignty rather than global commons problem." John Barnett, "Security and climate change," *Global Environmental Change* 13 (2003), p. 14.

There are several ways to hypothesize that societal impacts (relating to water, agriculture, infrastructure, health, finance, economics) of climate change effects could result in international security problems (or benefits):

- aggravation of internal conflicts,
- increased poverty and inequality,
- aggravation of existing international conflicts,
- diversion of national and international resources from international security programs (military or non-military),
- contribution to global economic decline or collapse,
- international realignments based on climate change mitigation policies, or
- Reduction of oil dependence (benefit).

The argument here is not that climate change consequences are going to be either necessary or sufficient causes for international security problems. It is possible, though, that they might tip already precarious situations.

Internal Conflict

Few if any would argue that the effects of climate change are likely to lead directly to rebellion, revolution, civil war, or the breakdown of states. On the other hand, it seems quite plausible that the societal consequences of climate change effects (described above) could exacerbate existing social and political tendencies to conflict. In addition, a state with limited capacity to respond to environmental stresses could find itself less able to respond to insurgent threats. Not only would its economic and military resources be spread more thinly, but its populations could come to see it as less able to perform the functions of government.

Aggravation

Climate change consequences could exacerbate political conflicts in various ways. As noted above, climate change-induced scarcities (e.g. arable land or fresh water) can lead to increased disparities in wealth and power. Where such disparities lead to movements for radical change, insurgency sometimes occurs. Migration to cities could concentrate large numbers of dissatisfied unemployed people. Severe national economic difficulties could increase support for radical change. Alternatively, scarcities in resources such as land or water may give already conflicting identity groups additional reasons to fight. Internal migration resulting from climate change affects could also stimulate identity group conflicts. [22]

[22] Examples of identity group conflicts (but ones not centering on resource scarcity) are those between Hutus and Tutsis in Rwanda or Serbs and Muslims in the Balkans.

International Repercussions

Internal conflicts can have international repercussions. First, states can fail or at least become highly dysfunctional—not leading to some new regime, but to breakdown of law and order and most other governmental functions. Armed factions, headed by local warlords, may be in more or less continuous conflict. Recent examples include Somalia and Afghanistan after the Soviet withdrawal (and, some would say, again today). A nation with a failed state can threaten international security in various ways. It may become the locus of criminal activity, such as narcotics, people smuggling, or black market trade (such as the diamond trade in Sierra Leone). It may become a magnet and harbor for terrorist groups.

Unresolved civil conflicts can also draw in external intervention. Competing foreign powers may see an opportunity to harass or gain ground on their adversaries—as happened frequently during the Cold War. Or, they may see a need to restore order so as to maintain access to strategic commodities or locations (such as oil in Saudi Arabia). Even in the absence of external competitors, failed states may seem to require the intervention of other national or international peacekeeping forces. This can place the peacekeeping forces at risk, or at least dilute the international community's pool of available peacekeepers.

Civil conflicts may be internally resolved, but in ways that end up threatening other nations. Economic distress in the 1920s and 1930s fostered the rise of aggressive militarist regimes in Germany, Japan, and Italy. Law and order of a sort was brought to post-Soviet Afghanistan by the Taliban, whose religious extremism led them to harbor like-minded international terrorists.

Poverty and Inequality

Poverty and inequality (which may be amplified by climate change consequences) do not necessarily lead to revolution or state failure. They may, however, increase the appeal of extremist groups who threaten domestic stability or who advocate international terrorism. The Madrasahs, or religious schools, of Pakistan, for example, provide education, food, shelter, and militant Islamic indoctrination to poor youth.

International Conflicts

Just as climate change consequences are unlikely by themselves to cause civil wars, they are unlikely directly to cause international wars. Yet some indirect pathways are imaginable. Mentioned above was the establishment of aggressive regimes. Climate change-related migration might aggravate existing conflicts: an external state might come

to the defense of its own ethnic kind across the border. Competition for climate-change redistributed resources—especially water—might aggravate existing conflicts.[23]

National Resource Diversion

Maintaining the U.S. role of sole global superpower is expensive—with the military budget alone approaching $450 billion. A trillion dollar deficit is projected for the next decade. Towards the end of that decade, the baby-boomer generation will start collecting Social Security and Medicare entitlements, and continue doing so for 30 years or more. Even though the U.S. may be rich enough to adapt successfully to possible climate change effects, the body politic may decide that it cannot both do that and continue to support the U.S. role of sole global superpower. Further, should worldwide climate change effects lead to international economic decline, the U.S. is unlikely to escape.

The ability of other relatively wealthy nations to contribute militarily or economically to maintaining international peace could likewise be diminished by the demands of climate change adaptation. (Moreover, most of the other wealthier nations are facing a population aging problem even greater than that of the U.S.) This decline in contributions from the wealthy could happen as less developed countries undergo even greater stress and need more international assistance than they have before. The demand for international peace restoration and peacekeeping, disaster relief, and development aid could grow even as the supply diminishes.

Global Economic Decline

A climate-change induced global economic decline would mean the interruption of income streams, default of debts, curtailment of international investments, cascading national bankruptcies, and growing individual and national poverty. How the world might emerge from all this is unpredictable, but the experience of the Great Depression of the 1930s does not offer a reassuring precedent.

International Realignments

In geopolitical terms, the end of the cold war left the U. S. as the world's dominant economic and military power. It is possible to imagine the consequences of climate change either weakening or strengthening that position. The results in either direction, however, might not necessarily be greater international peace and stability. A weakened U.S. would be less capable of playing a stabilizing role—whether in international financial markets or in potential military conflicts. For example, how the regional tensions among China, Korea, and Japan might play out without the U.S. presence is not at all clear. One possibility would be decisions by Korea, Japan, and Taiwan that they need their own nuclear weapons to deter Chinese domination.

---

[23] There is little historical evidence of nations going to war directly over water, though sudden changes may outpace the ability of joint water management institutions to resolve water disputes. See Aaron T. Wolf, Shira B. Yoffe, and Mark Giordano, "International waters; identifying basins at risk," *Water Policy* (2003), pp. 29-60, at http://www.iwaponline.com/wp/00501/0029/005010029.pdf.

On the other hand, an even more lopsided distribution of power between the U.S. and the rest of the world might also carry risks. Not only non-state terrorist groups (as with Al Qaeda today), but some nations might see expansion of asymmetric warfare capabilities as the only way to protect themselves against U.S. domination. The result might be more attacks on U.S. interests at home and abroad. Traditional U.S. military capabilities may have limited effectiveness against such attacks.

Should global warming continue, and should much of the world blame that on disproportionate U.S. emissions of GHG, and on failure of the U.S. to ratify the Kyoto-Bonn accord, then the U.S. may find that the international cooperation it seeks on various fronts (from trade agreements to counter-terrorist police work) will be harder to come by.

Reduction of Oil Dependence

Controversy continues over how much global warming will occur and how much reduction of GHG emissions it would take to mitigate that. However, should the current and future heavy energy users in the world successfully switch to non-fossil fuel sources, then the global dependence on imported oil would begin to decline. This development would severely affect the economies that depend on oil exports, but ease the national security threats that come with oil supply disruptions in the importing countries[24]

Research, Technology, and Policy Discussion

It can be argued, then, that (depending on the substitute energy sources) a world weaned from oil consumption could not only be less vulnerable to energy supply disruptions, but also to the higher levels of global warming that IPCC models forecast. But several countervailing considerations apply. First, even with reduced emissions, atmospheric GHG levels may not stabilize in time to prevent substantial further warming. Second, the models do not offer clear guidance about how much emission reduction will result in how much lower global temperatures. Third, it is an open question as to whether the world's nations will in fact act to significantly reduce GHG emissions. Fourth, even lower levels of warming might trigger dramatic climate change: non-linear forces may be in play. Finally, the paleoclimatic record shows that abrupt climate changes have occurred on Earth without the presence of anthropogenic forcing. The kinds of change described above could occur whether GHG are playing a decisive role or not.

It seems prudent, therefore, to plan ahead for potential climate change consequences. There are many uncertainties—about how much climate change is likely to happen, what effects will result, where and when they will occur, and how vulnerable the affected countries and regions will be to negative social, political, and economic consequences. Because of these uncertainties, it is difficult to assess just how much investment in this planning would be reasonable. But two general guidelines seem sensible:

[24] See Karas, *Energy and National Security*, *op. cit*. footnote 2, pp. 10-15.

- First, it would be worthwhile to reduce the uncertainties about what is happening and what will happen.

- Second, there may be "no regrets" measures that not only would enhance adaptation to climate change effects and their human consequences should these occur, but also would bring benefits to human, national, and international security whether or not negative climate change effects happen.

The following suggestions do not constitute a well-developed set of proposals, but are ideas that emerged during the closing workshop discussions.

Research

Continued research on the phenomenon of climate change, its causes and effects, could help in at least two ways. First, greater certainty about the future pace of change and the human role in accelerating or decelerating it might encourage political decisions to take mitigating (GHG reduction) actions. (Alternatively, such research might prevent waste of resources on policies that could have little mitigating effect). Second, more detailed understanding of when and where climate change effects might strike could permit more anticipatory adaptive measures.

Integrated with the climate change research, social science research might better pinpoint the countries and regions most vulnerable to negative climate change consequences (i.e. most sensitive and least able to adapt). This research would seek better understanding of:

- how the various human consequences of climate change effects might interact with one another,

- what capabilities for managing change states have or lack ,

- what conditions are more likely to lead to internal conflict, and

- how bilateral or international assistance for anticipatory adaptation could then be focused on the most vulnerable (or, from a more *realpolitik* point of view, those most likely to cause international security difficulties.)

Short of precisely predicting climate change phenomena and their probable effects on human societies, it might at least be possible to get earlier warning of processes that are underway. Climate scientists and social scientists, perhaps aided by computing technologies, might generate a wide range of possible climate change-effect/human consequence pathways or scenarios. They might then identify constellations of events and data (physical and social) to be monitored continuously for indications that threatening scenarios were emerging.

Another class of research would be the development of technologies that might facilitate adaptation to climate change effects. Agriculture in particular might benefit.

One example might be techniques for growing crops with less than the usual amounts of water. Another might be ways of adapting crops and farming methods to changes in temperature and growing seasons.

Policy and Technology Deployment Measures

One policy change to anticipate human consequences of climate change would be to tailor current bilateral and multilateral development assistance to improve the capacities of poorer countries to adapt to climate change effects. For example, energy infrastructures might be designed in a distributed way that was less vulnerable to large-scale weather-related outages. Agricultural development could deploy the kinds of technologies alluded to above. Land-use planning could anticipate potential climate change effects, perhaps as predicted by improved atmospheric models.

Developing countries public health surveillance and service infrastructures are already quite weak. Globally, international public health surveillance could also stand improvement. The already significant problem of emerging and re-emerging infectious diseases makes improvement of national and international public health capabilities a "no regrets" policy.

An anticipatory policy measure for the wealthier states—the U.S. in particular—might be the creation of a standing "reconstruction expeditionary force" that would be prepared to assist stricken nations in adaptive responses to extreme weather events and abrupt environmental changes. This service would be analogous to military intervention forces, but instead deploy expertise and technology in infrastructure restoration. Although its long-term purpose might be to respond to climate-change consequences, it might also function in post-conflict situations—as, for example in Iraq. Such a capability, then, could turn out to be another "no regrets" measure.

Conclusion

The lesson from the Sandia workshop is not that the climate change phenomenon is leading inexorably to disaster for the human race. Rather, it is that there is a wide range of potential climate-related hazards to human economic and social systems. The extremity of these hazards could be larger than what we have considered to be "normal." Failure to adapt effectively o these events could imperil international peace and security.

Climate change happens. Sometimes it has happened very abruptly. Whether or not the current global warming trend can be fully attributed to human-generated greenhouse gases in the atmosphere or not, continued study of the potential physical effects of climate change and their consequences for human society is in order. This study would benefit from continued communication among both physical and social scientists in an effort to better understand the risks and the most effective strategies for adaptation and recovery.

It is also worth considering whether precautionary preparations to cope with them would be prudent. However, since the timing and locations of these hazards are so uncertain, it seems prudent to search for “no regrets” measures that would bring benefits before –or whether or not—they are needed to respond to climate change consequences.

Appendix I: Visiting Participants

Ricardo Bayon

…is a fellow with the New America Foundation, where he is examining policy implications of the interaction between the financial system and the environment, how socially responsible investment can play a role in promoting environmental objectives, transparency in the financial system and its effect on the environment, and the ways in which unrecognized and undervalued environmental goods and services subsidize the economic system. He is developing strategies to harness the creativity of capital markets to help preserve the world ecosystem. He has advised numerous international organizations, including the Inter-American Development Bank, Domini Social Investments, The National Wildlife Federation, and Rainforest Action Network. He has recently been working with The Nature Conservancy to create a new institution that will bring together insurers, bankers, financiers and environmentalists to come up with new approaches to environmental protection.

Kent Hughes Butts

…is Professor of Political Military Strategy, and the Director of the National Security Issues Branch in the Center for Strategic Leadership, U.S. Army War College. His prior positions include: Research Professor in the Strategic Studies Institute (SSI) of the Army War College, Associate Professor, Science Research Laboratory, U.S. Military Academy at West Point, and United States Defense and Army Attaché, Uganda, Tanzania, and Malawi. Dr. Butts teaches the Army War College Weapons of Mass Destruction, Environmental Security, and Strategic Planning elective courses and has conducted international conferences, workshops, or games for the Departments of Defense in Australia, Poland, Czechoslovakia, Canada, and the United States. He headed the U.S. delegation and co-chaired the NATO Environmental Security Pilot Study Meetings in Warsaw and Prague in 1997, and was a member of the U.S. delegation to the OSCE Economic Forum (Prague) and NATO Environmental Security Meetings (Vancouver) in 1999. He is author or editor of numerous national security publications, and co-author of the book, *Geopolitics of Southern Africa: South Africa as Regional Superpower*.

Jack Goldstone

…is a sociologist and the Virginia E. and John T. Hazel Professor be joining the George Mason University School of Public Policy as the; he is also a Research Fellow at the Mercatus Center. His research interests include revolutions and social movements, demography and international security and social theory. Among his many publications is the book chapter "Imminent Political Conflicts Arising from China's Population Crisis" (1999). Professor Goldstone has conducted over twenty years of prize-winning research on social conflict and social change, focusing on global patterns of comparative development. He has acted as a consultant to the World Bank, the White House and the Central Intelligence Agency. At UC Davis he directed the Center for History, Society, and Culture as well as teaching Sociology (1989-present) and International Relations (1992-2003).

Charles D. Kolstad

… is Professor of Environmental Economics and Policy at the University of California, Santa Barbara, where he is jointly appointed in the Bren School of Environmental Science and Management and the Department of Economics. At UCSB he leads the NSF-funded PhD program in Economics and Environmental Science. He is particularly interested in the role of information in environmental decision-making and regulation. His past work in energy markets has focused on coal and electricity markets, including the effect of air pollution regulation on these markets. With over 100 publications, he has published in a variety of journals. He is an editor of *Resource and Energy Economics*, has been an Associate Editor of the *Journal of Environmental Economics & Management (JEEM)*, and is currently on the editorial board *of Land Economics and JEEM*. In 2000, Oxford University Press published his

undergraduate text, Environmental Economics. He also co-edited the North-Holland book *Measuring the Demand for Environmental Quality*. His prior, non-academic, experience includes working at the Los Alamos National Laboratory in New Mexico and in the Peace Corps in West Africa.

Ana Rosa Moreno

… is on the staff of the U.S.-Mexico Foundation for science, where she works on issues relating to environmental health on the U.S.-Mexican border and on global climate change. She worked on the Second Assessment Report, IPCC and in the third Assessment Report, IPCC (WMO/UNEP) in the impacts, adaptation and vulnerability group. She is co-author of different UN publications on climate change and health and author of international papers on the subject. She has attended several international meetings on climate change. She is a reviewer of UNDP publications on climate change. She is a reviewer for Assessments of Impacts and Adaptations to Climate Change research proposals.

Gaurav Rajen

… is a consultant to the Cooperative Monitoring Center at Sandia National Laboratories where he has been studying regional environmental security and cooperation and nuclear nonproliferation issues in South Asia. He has worked as a consultant and a senior manager for several U.S. and international federal, state, tribal and private agencies and as a Research Associate Professor in Civil engineering at the University of New Mexico. Since 1996, he has managed a security, environmental and energy studies consulting firm with a primary focus on South Asia. He has been a member of the US Environmental Protection Agency and the US Department of Energy's national working groups that developed guidance on select environmental management issues, testified to US Congressional subcommittees on Navajo uranium mine remediation, and organized environmental security workshops in India, Nepal, Sri Lanka and the US. He has published numerous reports and papers in disarmament, engineering, and social science journals. Some of his publications include, *Cooperative Environmental Monitoring in the Coastal Regions of India and Pakistan*, and *Cooperative Remote Sensing Projects to Increase Nuclear Transparency in South Asia*.

Jack Schick

…has worked with the U.S. Department of State on international political disputes over adaptation and greenhouse gas mitigation responsibilities in the context of the Framework Convention on Climate Change and the putative Kyoto Protocol--as a member of the US delegation--roughly since 1990, when he participated in the final plenary of the IPCC on its First Assessment Report. He works quite closely on the USG Interagency Working Group on Climate Change with DOE, EPA, NOAA, Agriculture, and USAID and with the US Embassy Science Counselors.

Andrew T. Price-Smith

…is Assistant Professor of Environmental Science and Policy, and Research Fellow at the Center for Globalization at the University of South Florida – St. Petersburg. He earned his doctorate from the University of Toronto in 1999, and his post-doctoral training at CIESIN and the School of International and Public Affairs of Columbia University. He is author of *The Health of Nations :Infectious Disease, Environmental Change, and Their Effects on National Security and Developmen*t (MIT Press, 2002) and editor of *Plagues and Politics: Infectious Disease and International Policy* (Palgrave/Macmillan Press, 2001). He currently acts as consultant to the United States Institute of Peace, to Special Operations of the USDOD, and to the World Development Group of the World Bank. His research interests include the relationship among infectious disease, environmental change, international prosperity, and political stability.

Marvin S. Soroos

…is professor of political science and public administration at North Carolina State University (Raleigh, NC), where he has taught courses on global problems and policies since 1970. His publications have made a significant contribution to extending the field of policy studies to the international and global levels of

political organization. His best known book, *Beyond Sovereignty: The Challenge of Global Policy* (University of South Carolina Press, 1986) received his college's Distinguished Research Publication Award in the Social Sciences in 1987. He has also been a pioneer in the field of global environmental politics, which his been his principal teaching and research interest since the mid-1970s. With David Orr (currently of Oberlin College), he co-edited an early book in the field entitled *The Global Predicament: Ecological Perspectives on World Order* (University of North Carolina Press, 1979). His most recent book, The Endangered Atmosphere: Preserving a Global Commons (University of South Carolina Press, 1997) examines the evolution of international law pertaining to protection of the atmosphere, more specifically efforts to address the problems of atmospheric testing of nuclear weapons, acid rain, depletion of the ozone layer, and global climate change. He has been the International Studies Association's liaison to the International Human Dimensions of Global Environment Change Program (IHDP) and served on the scientific advisory committee for the Global Environmental Change and Human Security Program, which is associated with IHDP.

Jennifer Turner

…is a senior project associate in the Woodrow Wilson Center's Environmental Change and Security Project (ECSP) where she directs the project's activities on environmental issues in China. As coordinator of ECSP's China Environment Forum she holds monthly meetings in Washington, DC on a variety of energy and environmental challenges facing China. Besides meetings in Washington, DC, She has coordinated several study tour activities in China and the United States bringing together Chinese and U.S. experts on issues of environmental nongovernmental organizations, environmental journalism, water conflict resolution, and municipal financing of environmental infrastructure. In addition to coordinating the China Environment Forum, she also serves as editor of the Wilson Center's journal, the China Environment Series. She recently coauthored with Pam Baldinger the policy brief "Crouching Suspicions Hidden Potential: U.S. Environmental and Energy Cooperation with China."

David Unnewehr

...is Senior Research Manager, Policy Development and Research Department, American Insurance Association (AIA) in Washington D.C. His work focuses on research and policy impacting disaster risk assessment, mitigation, and policy, including the new terrorism risk, property-casualty insurance economics, auto and homeowners insurance, credit-based insurance scoring in underwriting, regulatory modernization, urban insurance availability, and climate change. Mr. Unnewehr authored the April 1999 American Insurance Association policy paper on climate change, "Property-Casualty Insurance and the Climate Change Debate: A Risk Assessment."

Shira Yoffe

…is a Science Officer and AAAS Diplomacy Fellow in the Office of Global Change, U.S. Department of State. Her current portfolio includes impacts and adaptation to climate change, water and climate, and Earth observations systems. She is author of numerous articles on transboundary water resources and her doctoral research explored indicators of conflict and cooperation in international river basins. She has a Ph.D. in Geography from Oregon State University and a Masters in international relations from the Fletcher School of Law and Diplomacy, Tufts University. She has also worked as a research scientist in the Emerging Technologies group, Pacific Northwest National Laboratory and as project manager of the Transboundary Freshwater Dispute Database at Oregon State University.

Appendix II: Sandia Participants

Mark Allen

Energy, Information & Infrastructure Surety Division/ Nuclear & Risk Technologies/ Risk & Reliability Analysis
Mark Allen is the manager of the Risk & Reliability Department in the Nuclear Energy Programs Center. The Department serves customers both at the NRC and DOE. Mark holds graduate degrees in economics, business and computer science.

Arnold Baker

Arnold B. Baker is the Chief Economist of Sandia National Laboratories. His current responsibilities include serving as the primary strategic planning resource for the Energy & Infrastructure Assurance Business Unit, managing the Unit's economic and public policy analysis and modeling, and serving as economic and strategic planning advisor to Sandia Corporation. In addition, he is the Past President of the United States Association for Energy Economics. He holds a BA in History and MA and Ph.D. degrees in economics from Virginia Polytechnic Institute and State University.

Dianne Barton

Information, Computation and Engineering Sciences/ Computation, Computers, Information & Mathematics/ Evolutionary Computing
Dianne Barton holds a PhD in Geochemistry and is currently working on development of multi-agent models of complex systems on massively parallel platforms. She is interested in coupling an agent based model to a global climate model to simulate how international resource consumption will respond to climate change, how trade networks and international alliances are likely to adapt, and how alterations in energy consumption and land use will feedback on climate.

David Betsill

National Security & Arms Control/ International Security Problems/ International Security Initiatives
The Center works with US and international participants to explore ways that technology can facilitate regional confidence building in such areas as arms control, nonproliferation, and environmental security. David is a hydrologist and environmental engineer with a broad interdisciplinary background and experience in environmental characterization, monitoring, and remediation. Recent regional and transboundary projects include cooperative applications of technology and confidence building measures for sustainable grazing and agriculture in the Middle East, and for water quality monitoring across transboundary rivers in Central Asia and South Asia.

Dave Borns

Energy, Information & Infrastructure Surety Division/ Geoscience & Environment Center/ Underground Storage

Mark Boslough

Information, Computation and Engineering Sciences/ Computation, Computers & Math/ Evolutionary Computing
Member of the technical staff in the Evolutionary Computing and Agent-Based Modeling Department. His background is physics and geophysics, with an emphasis on computational modeling. He was PI on a project to develop an MPI parallel version of the paleoclimate code Genesis, and was the national laboratory member of the Partnership for Modeling Earth System History (PMESH), an NSF program. "He is currently collaborating with the National Center for Atmospheric Research (NCAR) on their Spectral Element Atmospheric Model (SEAM), a dynamical core for climate General Circulation Models (GCM)."

Chris Cameron

Energy, Information & Infrastructure Surety Division/ Energy & Transportation Security/ Energy Systems Analysis
Chris joined Sandia in 1977 after earning a PhD in Physics from Duke U. He initially worked in nuclear safeguards for the civilian nuclear power cycle, but has worked in the field of solar energy and energy systems analysis since 1981.

Stephen Conrad

Energy, Information & Infrastructure Surety Division/ Information & Infrastructure Systems/ Critical Infrastructure Surety
Stephen Conrad works as an analyst for the National Infrastructure Simulation and Analysis Center (NISAC) where he is developing high-level modeling tools for evaluating infrastructure interdependencies and system vulnerabilities. Steve has performed infrastructure interdependency assessments for California and assessments of the effects of proposed security policies on operations in selected Pacific Northwest ports. He is also working with Lucent Technologies to build detailed models of telecommunication system performance under various disruption scenarios. Prior to joining the NISAC team, Steve worked on various problems in the areas of hydrology, probabilistic performance assessments for radioactive waste disposal, and systems analysis.

Warren Cox

Energy, Information & Infrastructure Surety Division/Energy & Transportation Security Center/ Environment Monitoring & Characterization Department
His professional training is business, Hydrology, Public Health, and applied mathematics. He spent 9 years running Sandia's Environmental Restoration Project, followed by 3 years in program development, mainly advanced sensor technologies. In partnership with another Sandian, he now oversees the International Sustainable Engineering Group (6233), primarily doing technology deployment of renewable energy in the developing world, mostly Latin America. He is interested sustainable development to address the roots of terrorism, improve the human condition through technology, and improve global security.

Jeff Danneels

National Security & Arms Control/ Security Systems & Technology/ Civilians Surety Programs
Department Manager within the Security Systems and Technology Center at Sandia National Laboratories. He manages critical infrastructure security programs and is responsible for the Risk Assessment Methodology for Water Utilities, RAM-W. Shortly after the events of 9/11, he testified to Congress on two occasions. His first testimony concerned the security of the water infrastructure and in the second he outlined security research needs to better protect the water infrastructure.

Peter Davies

Energy, Information & Infrastructure Surety Division/Geoscience & Environment Center
Director of Geoscience & Environment Center; SNL Water Initiative Coordinator; member of Governor's Blue Ribbon Task Force on Water. Fields of Discipline: Geology and Applied Earth Sciences

Bob Eagan

Energy, Information & Infrastructure Surety Division
Vice President of Energy, Information & Infrastructure Surety Division with responsibilities for fossil, renewable and nuclear energy, geosciences, and nuclear power safety and repositories, information technology programs and programs responsible for the safety and security of commercial aviation and infrastructure protection. Previously he was Vice President of Science Technology and Components where he was responsible for R&D in materials, microelectronics, and manufacturing technology. He holds Ph.D. and MS degrees in Ceramic Engineering from the University of Illinois and a BS in Ceramic Engineering from Alfred University.

Scott Jones

Energy, Information & Infrastructure Surety Division/Energy and Transportation Security Center/Energy Systems Analysis
Mechanical Engineer working in the Energy Systems Analysis Department (6202). He is interested in broad-scope energy modeling and scenario analysis

Jay Keller

C*alifornia Laboratory/Combustion and Physical Sciences Center/Engine Combustion & Hydrogen*

Jennifer Nelson

Information, Computation and Engineering Sciences/Computation, Computers and Math Center/New Initiatives
Manager of the Evolutionary Computing and Agent-Based Modeling Department. This Department is pursuing the development of the next generation of climate modeling and incorporating agent -based modeling to enhance our understanding of the economic and social impacts of climate change.

Rush Robinett

Energy, Information & Infrastructure Surety Division/Energy and Transportation Security Center Energy & Transportation Security

Jerry Simmons

Science & Technology and Partnerships Division/Physical and Chemical Sciences Center/Semiconductor Materials & Device Sciences Department
Manager of the Semiconductor Material and Device Sciences Dept. Jerry is head of Sandia's Solid State Lighting program, which involves about 40 researchers, and is heavily involved in a national industrial consortium on solid state lighting for energy efficiency improvements.

Hank Westrich

Science & Technology and Partnerships Division/Laboratory Directed Research & Development

Gerry Yonas

Chief Scientist and Director, Advanced Concepts Group
Physicist with a background in technology aspects of strategic national security issues current focused on the war on terrorism.

Bernie Zak

Energy, Information & Infrastructure Surety Division/Energy and Transportation Security Center Environment Monitoring & Characterization Department
Develop and manage the DOE Atmospheric Radiation Measurement (ARM) Climate Research site on the North Slope of Alaska; interests: climate-related atmospheric and radiative transfer phenomena; use of satellite remote sensing at high latitudes.

Rapporteurs:

Connie Brooks

Energy, Information & Infrastructure Surety Division/ Energy & Transportation Security/ Solar Programs

Judy Moore

Advanced Concepts Group

Ron Pate

Advanced Concepts Group
Intersection and interdependency of technical, socio-economic, and national/global secuity issues tied to energy, water, agriculture, development, and environment. Formal training in applied physics, electrical and systems engineering, with specific expertise in energy systems, sensor systems, electromagnetics, pulsed power and directed energy, and selected aspects of systems modeling and simulation.

Facilitators:

Warren Klein

Energy, Information & Infrastructure Surety Division, Energy & Transportation Security/Business Management Systems Group
Senior Administrator in the Nuclear Weapons Strategic Management Unit, works with senior executives in the areas of strategic and operational planning. Also designs and facilitates workshops and large meetings.

Ron Stoltz

Manger of the Sandia, California government relations office.
His interest in climate change stems from a 1998 Sandia strategic planning exercise. Climate change was one of the potential “national and international challenges” that could rival nuclear proliferation as an area of concern and one that acould be addressed by a combination of technical, political, and sociological research.

Jessica Turnley

Advanced Concepts Group
A cultural anthropologist, with interests in issues at the intersection of the social and technical, including the "cross-cultural" conversations that occur between scientists, citizens, and policy makers and the inclusion of the human in engineering design. She has worked in areas including national security, economic evelopment, environmental risk analysis and management, and the development of science and engineering applications

Organizer

Tom Karas

Advanced Concepts Group

Distribution:

Ricardo Bayon
New America Foundation
8 Morning Sun Avenue
Mill Valley, CA 94941

Kent Butts
Center for Strategic Leadership
Army War College
650 Wright Avenue
Carlisle, PA 17013

Jack Goldstone
School of Public Policy
George Mason University
4400 University Drive
Fairfax, VA 22030

Charles Kolstad
Donald Bren School of Environmental Science
University of California
Santa Barbara, CA 93106

Ana Rosa Moreno
The United States-Mexico Foundation for Science
San Francisco N, 1626 Desp. 205
Mexico, D.F. Mexico
MEXICO

Andrew Price-Smith
University of South Florida
502 S. Freemont #332
Tampa, FL 33606

Jack Schick
U. S. Department of State
2201 C Street NW, Room 4330
Washington, DC 20520

Marvin Soroos
North Carolina State University
Caldwell 212, Political Science
Raleigh, NC 27695-8102

Jennifer Turner
Woodrow Wilson Center
1300 Pennsylvania Ave NW
Washington, DC 20004

David Unnewehr
American Insurance Association
1130 Connecticut Ave NW, Ste 1000
Washington, DC 20036

Shira Yoffee
U. S. Department of State
2201 C Street NW, Room 4330
Washington, DC 20520

MS0136 Warren Klein, 9720

MS0318 Diane Barton, 9216
MS0318 Jennifer Nelson, 9209
MS0318 Mark Boslough, 9216
MS0323 Hank Westrich, 1011
MS0451 Stephen Conrad, 6541
MS0601 Jerry Simmons, 1123
MS0701 Peter Davies, 6100
MS0703 Chris Cameron, 6202
MS0703 Connie Brooks, 6216
MS0703 Scott Jones, 6202
MS0706 David Borns, 6113
MS0710 Michael Hightower, 6202
MS0724 Bob Eagan, 6000
MS0741 Marjorie Tatro, 6200
MS0741 Rush Robinett, 6200
MS0748 Mark Allen, 6400
MS0749 Arnie Baker, 6010
MS0755 Bernie Zak, 6233
MS0755 Warren Cox, 6233
MS0789 Jeff Daneels, 5862
MS0839 Gerry Yonas, 16000
MS0839 Jessica Turnley, 16000
MS0839 Judy Moore, 16000
MS0839 Ron Pate, 16000
MS0839 Tom Karas, 16000
MS1373 David Betstill, 5324
MS9041 Ron Stoltz, 12122
MS9053 Jay Keller, 8300
MS9018 Central Technical Files, 8945-1
MS0899 Technical Library, 9612 (2)