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Acclimations

Newsletter of the U. S. National Assessment of Climate Variability and Change

Science in the Service of Society: The Value of the Assessment Process

By Rosina Bierbaum, Office of Science and Technology Policy

Eighteen years ago, I came to Washington knowing only that there were three branches of government and happier working in a lab than reading a newspaper. But my experiences since have convinced me that the time of science remaining in its ivory tower is gone. Science is at the center of so many of the major crises affecting the planet today -- ozone depletion, desertification, deforestation, species loss, degradation of landscapes, fisheries decline, coastal pollution, and climate change. For better or worse, science is used or misused in policy and decision-making every day. Policymakers are not stymied by uncertainty; they must make decisions based on whatever information is available. They do not require ascientist's ideal 95% certainty to begin moving in directions they think make sense to avoid adverse consequences. Policymakers recognize that adecision "not to act" is as much a decision as one "to act". Scientists have a responsibility to help them make these "best guesses", and theprocess of assessment is among the most valuable tools at our disposal.

To overcome the local, regional, and global environmental challenges currently facing society, we need to shift away from the historic singleissue/single agency/single discipline approaches that dominated much of the last three decades. Further, we must become more proactive. Ratherthan reacting to problems after they occur, we must anticipate and avoid the worst consequences before they occur. These challenges cannot beconfronted in isolation; there are numerous interlinkages between them. The process of science-based assessment plays an important role in developing an integrated view of environmental challenges as well as their solutions. Assessment is truly one of the building blocks of sustainable development.

The evolution of environmental issues over the past 40 years has benefited greatly from assessment. Starting about 1960, both internationally and nationally, there was an increasing realization that human activities were altering the environment in unacceptable ways - we had unbreathable air and undrinkable water. The 1970s brought action. The UN Conference on the Human Environment was held in Stockholm, the UN Environment Programme was created and the London Dumping Convention was adopted. Domestically, EPA, NOAA, and the CEQ were established. The Clean Air and Clean Water Acts were passed. But even with this flurry of activity, issues were generally treated singly, without connections. And,in general, at local, sometimes regional, scales.

In the 1980's and the 1990's the perspective noticeably broadened. Scientific assessment activities played an important role in defining global-scale problems, the linkages between them, and the options for confronting them. The Montreal Protocol on Substances that Deplete the Ozone Layer was signed, and then strengthened, largely on the basis of ozone depletion assessments supported by the World Meteorological Organization and the UNEP. The Intergovernmental Panel on Climate Change (IPCC) was formed in response to increasing concerns about global climate change, and its landmark assessment reports are critical to the ongoing climate change negotiations. Increasing scientific understanding of environmental change and its consequences played an important role in bring about the 1992 Earth Summit in Rio de Janeiro, which saw the initiation of broad international agreements on biodiversity and climate change.

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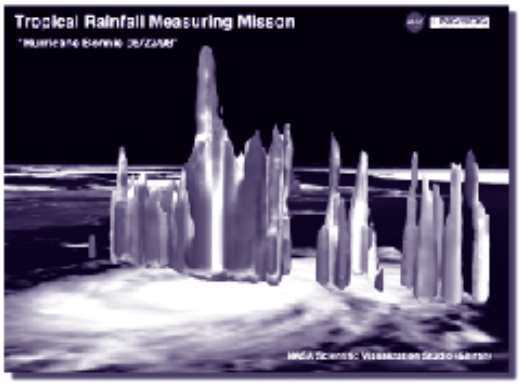
NASA Applies Space Technology to Answer Earth Science Questions

By Louis Whitsett, NASA Headquarters

Although NASA is most closely identified with human space flight and space science, Earth science has been a key element of its mission since the agency was created in 1958. Thus, NASA's involvement in the National Assessment should not come as a surprise. From the unique perspective of space, NASAresearchers are gaining a better understanding of how our air, land, water, and life interact as an integrated system to influence climate and the environment. This knowledge has led to quantum leaps in our ability to monitor and predict hurricanes, severe storms, and other environmental phenomena, and to analyze long-term global climate change.



"This image is of Hurricane Bonnie showing a (cumulonimbus) storm cloud, towering like a sky scraper, 59,000 feet (18 kilometers) into the sky from the eyewall. These images were obtained on Saturday, Aug. 22, 1998, by the world's first spaceborne rain radar aboard the Tropical Rainfall Measuring Mission (TRMM), a joint U.S.-Japanese mission. By comparison, the highest mountain in the world, Mt. Everest, is 29,000 feet (9 kilometers) and the average commercial jet flies at barely one-half the height of the Bonnie's cloud tops. Many scientists believe that towering cloud structures, such as the one observed by TRMM, are probably a precursor to hurricane intensification. NASA/Goddard Scientific Visualization Studio (Shirah/Morales)."

Advances in Earth science data and technology enabled NASA, the National Oceanic and Atmospheric Administration (NOAA), and other federal agencies to predict the 1997-1998 El Niño event almost a year in advance. This gave local officials, emergency management agencies, and residents in the affected communities critical lead time to prepare for the floods and droughts and other severe weather that El Niño typically brings. As we move through 1999, we are seeing a cold water mass called La Niña being offset by the strong warm water remnants of El Niño. The same remote sensing satellites and instruments that were successfully used along with sea-surface measurements to predict the recent El Niño will be employed to track the La Niña.

NASA participates with the National Assessment community in a major commitment to answer fundamental questions about the Earth and in using that information to address everyday problems. As one part of it's assessment efforts, NASA has sponsored scoping workshops in the following regions to investigate issues of climate change and variability:
Northern Great Plains - Held in November 1997 at the University of North Dakota, the focus of this workshop was on regional issues of agriculture and ranching.

Southeast - This scoping workshop, held in June 1997 at Vanderbilt University in Nashville, Tennessee, examined the climate change impacts affecting a nine-state region. The discussion had particular emphasis on regional agriculture, coastal resources, and extreme climate events.

Rio Grande/Southwest - In March 1998, issues facing the communities living along the U.S.-Mexico were addressed in a workshop held in El Paso, Texas.

Native Peoples and Native Homelands - This October 1998 workshop, held in Albuquerque, New Mexico, was designed by Native Peoples to examine the impacts of climate change and extreme weather variability on Native Peoples and their

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I believe that one of the key aspects of successfully confronting major environmental challenges in this day and age is the design and implementation of an assessment process that is iterative and provides usable information to decision makers along the way, even while refining near- and long-term research agendas. One of the things that we have learned is that global, regional and local problems are interlinked. For example, the processes and impacts of global change have significant regional texture and require regional-scale analysis and response. The process of assessment must apply equally well to national, regional and even local scales as it does to global ones.

Part of my preparation for a recent talk was reviewing the work and accomplishments of the interagency Committee on Environment and Natural Resources. As I looked over its first 5 years of existence, cross-cutting assessment activities stood out as some of the most notable successes. On issues ranging from harmful algal blooms to endocrine disrupters to environmental monitoring, we have managed to focus the best scientific expertise of the government--with input from the academic sector--on issues of immediate importance to national and regional decision makers. We have demonstrated that assessment techniques are useful tools to guide wise management and preservation of our natural resources.

Of all the assessments to date, the National Assessment of Climate Change is clearly the most ambitious that we have yet attempted. We are going beyond a purely scientific assessment by actively engaging the public and private sector decisionmakers in defining vulnerabilities and possible adaptation options. The time scales of the changes and the solutions range from decades to a century or more. Coping, adapting, mitigating -- all will be needed if climate change develops as most scientists believe. But, the appropriate mix is an open question requiring

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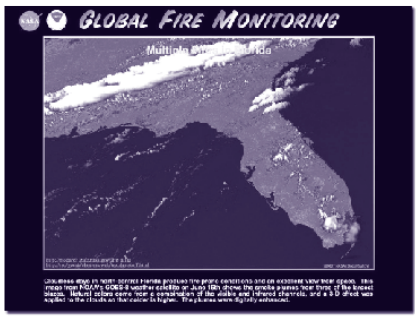
homelands. Attended by many community Elders, Native scientists and scholars, and community members, the Albuquerque workshop featured a unique integration of traditional scientific and environment analysis with the Native



Peoples' spiritual traditions and long community histories of change, adaptation, and survival in specific regions.

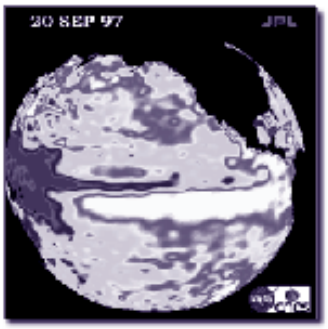
NASA looks forward to seeing the results of this first phase of the National Assessment. All of the NASA-sponsored assessments are underway and should be completed by early 2000. Each of them is striving to build on the information, resources, and partnerships developed in the regional workshops held in their areas. For instance, the Northern Great Plains assessment will draw from the November 1997 regional scoping workshop and the Native Peoples / Native Homelands assessment will integrate information from the Native Peoples / Native Homelands workshop held in October 1998.

NASA also hopes that the National Assessment will benefit from the agency's recent establishment of five Regional Earth Science Applications Centers (RESACs). Much like the regional assessments, these RESACs are aimed at targeting issues of regional concern to provide useful knowledge and guidance to policy makers and stakeholders. Because the RESACs and the National Assessment have many common goals, the RESACs will be a valuable resource for the region and sector teams. In fact, two of the RESACs will directly contribute to the assessment: the Upper Plains States RESAC will conduct the Northern Great Plains regional assessment, and the California / Southwest RESAC will support the Southwest regional assessment sponsored by the Department of the Interior.

While much of NASA's assessment work directly supports the National Assessment, the agency also funds many other projects and activities that are assessment-related. Current estimates are that NASA spends a total of between $20 and $30 million on assessment-related projects.

These projects, some of which are co-sponsored with other agencies, include the Atmospheric Model of Aviation Program, the Atmospheric Effects of Aviation Program, the Atmospheric Model Intercomparison Project, and the Upper Atmosphere Research Program. Together, these projects promise to produce dramatic advances in our knowledge of climate change and its impacts.

The future holds tremendous promise for Earth science at NASA. Over the next five years, some thirty new Earth science satellites are scheduled for launch. Two of the largest and most important spacecraft will launch this year: Earth Observing System (EOS) AM-1 and Landsat 7. These launches will inaugurate a series of EOS missions designed to continue our systematic measurement of fundamental aspects of global change. And new technologies are being developed to allow us to take Earth observations better, cheaper, and faster. For instance, in 1999, the Earth Orbiter-1 satellite, due to launch late this year, will demonstrate an advanced land imaging system with a hyperspectral and multispectral capability. At the same time, through data buys and other activities, NASA is working to stimulate the fledgling remote sensing satellite industry as it develops data and products that will make a growing and lasting contribution to Earth science research and assessment work.



These satellites and other future missions are expected to generate a torrent of data for assessment research and analysis and other fields of Earth science, including operational and commercial applications. It is an exciting time in the world of climate change assessment and NASAis privileged to be a part of it.

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both scientific and societal assessment. So, we face a truly daunting task, and the difficulties are becoming clearer as we proceed. We must try to evaluate the impacts of slowly changing parameters as well as anticipate changes in extremes and the potential for "surprises" or nonlinearities. Interaction with other environmental stresses must also be examined; if possible, options that address multiple problems are preferable. We must build partnerships with all stakeholders and continually assess what we know, don't know, need to know, can know -- and how best to manage wisely while we learn more.

The way I see it, we have both a responsibility and an opportunity. Despite the difficulty of our task, we really have no choice but to attempt it. After all, decisions relevant to climate change adaptation are being made now, and some future atmospheric concentrations are being precluded, even with imperfect knowledge of their consequences. As Peter Drucker said, long range planning is not about future decisions; it is about the future of present decisions.

With this first assessment of the potential impacts of climate variability and change on the United States, we are trying to ensure a benign future environment for our children and grandchildren. We hope they will look back and conclude that we made wise decisions today.

Climate Change in Wetland Areas Part I:
Potential Impacts and Interactions

By Jon Kusler, New York Association of State Wetland Managers, and Virginia Burkett, National Wetlands Research Center, USGS

Climate change associated with increased carbon dioxide and other greenhouse gases poses significant threats to many of the world's coastal, estuarine and non-tidal wetland ecosystems. Tundra, prairie wetlands, bogs, swamps and other wetlands also play an important global role in reducing the amount and rate of increase in atmospheric carbon dioxide. As a result, destruction of wetland areas can result in a positive biotic feedback to global warming through the release of large amounts of stored carbon to the atmosphere. To date, there has been limited discussion in the US and internationally concerning the impacts of climate change and variability upon wetland ecosystems, or the role that wetlands may play in carbon sequestration.

Potential Impacts

Wetlands exist in the transition zone between aquatic and terrestrial environments, and can be dramatically affected by slight alterations in hydrology. Predictions summarized by the Intergovernmental Panel on Climate Change (IPCC, 1998) indicate a warmer climate over North America for the next century accompanied by changes in precipitation patterns. Such changes would strongly affect wetland ecological functions through changes in hydrology, biogeochemistry, and biomass accumulation.

Sea-level rise is regarded as one of the more certain consequences of global climate change. During the past 100 years sea level has risen at an average rate of about 1-2 mm per year (or 4 to 8 inches per century). The projected two- to five-fold acceleration of global average sea-level rise during the next 100 years will inundate low-lying coastal wetland habitats that cannot move inland or accrete sediment vertically at a rate that equals or exceeds sea-level rise.

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The USGCRP Presents its FY 2000 Budget Request and Program Plan

By Rick Piltz, USGCRP

Since its establishment a decade ago, the U.S. Global Change Research Program (USGCRP) has supported a comprehensive program of scientific research on the multiple issues presented by climatic and other changes in the Earth system. USGCRP-supported research has produced substantial increases in knowledge, predictive understanding, and documented evidence of global environmental change, including major scientific advances in the understanding of stratospheric ozone depletion, the El Niño-Southern Oscillation phenomenon, global climate change, tropical deforestation, and other issues. These interlinked problems of global environmental change present long-term challenges at the local and regional scales as well.

The President's Budget for FY 2000 includes $1.8 billion for the USGCRP, a 6 percent increase above the FY 1999 level. Of the total USGCRP budget, 54 percent supports Space-Based Observation Programs while 46 percent supports Scientific Research. The $829 million request for Scientific Research is an 11 percent increase above the FY 1999 level. Enactment of this USGCRP-related funding in participating Federal agencies is subject to a complex series of steps in the Congressional appropriations process, which is now underway in its early stages for FY 2000.

In its FY 2000 program implementation plan and budget, the USGCRP is organized as a series of closely linked Program Elements. These include:

- Understanding the Earth's Climate System
- Biology and Biogeochemistry of Ecosystems
- Composition and Chemistry of the Atmosphere
- Paleoenvironment and Paleoclimate
- Human Dimensions of Global Change
- The Global Water Cycle
- Carbon Cycle Science

The USGCRP is establishing a Carbon Cycle Science Initiative with significant new investments proposed in the FY 2000 budget. This effort will provide critical scientific information on the fate of carbon dioxide in the environment, the sources and sinks of carbon dioxide on continental and regional scales, and how sinks might change naturally over time or be enhanced by agricultural or forestry practices.

Assessments and their related research play an integrative role across the USGCRP programmatic areas, and are increasingly seen as an important vehicle for disseminating information to public policy and decision-making communities. In addition to the ongoing National Assessment, the USGCRP facilitates U.S. scientific participation in international assessments such as those of the Intergovernmental Panel on Climate Change (IPCC), and coordinates the U.S. Government's scientific and technical review of IPCC reports.

This year's USGCRP annual report, Our Changing Planet: The FY2000 U.S. Global Change Research Program, describes the program, highlights key research accomplishments in 1998, outlines a perspective for global change research in the decade ahead, presents an implementation plan for the program in FY 2000 with a discussion of each of the Program Elements, and provides a detailed view of the FY 2000 USGCRP budget. To obtain a free copy of the report, contact the Global Change Research Information Office at 914-365-8930, or e-mail help@gcrio.org. The report will also be available on the web sites http://www.usgcrp.gov/ and http://www.gcrio.org/.

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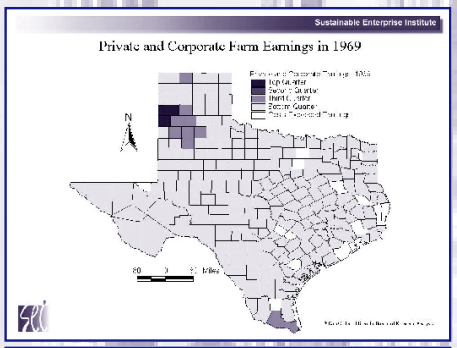
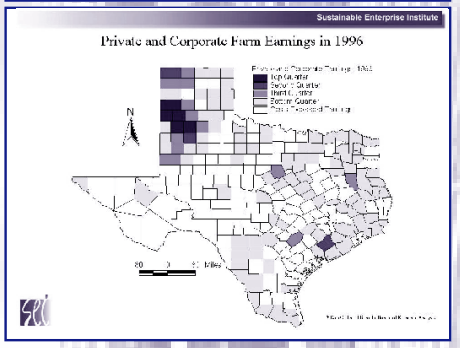
The Southern Plains and Rio Grande Basin

By Robert Harriss, Texas A&M University

Weather hazards and climate surprises constantly torment the Southern Great Plains and Rio Grande Basin region. Our initial assessment activities will elucidate some of the complex ways in which weather and climate factors interact with macroeconomic and social changes ongoing in the region, and will illustrate the danger of framing climate impact issues in a purely national context when we live in an interdependent world. It is the interaction of local and regional weather extremes with socioeconomic, environmental, and political forces at national and international scales that poses the greatest challenge for climate impact assessment in the Southern Great Plains and Rio Grande regions. Ongoing studies of the vulnerability of agribusiness systems to weather and climate extremes and an analysis of the impacts of Hurricane Mitch on immigration illustrate the value of a regional approach to impact assessment for the design of efficient and effective policies for coping with future climate variability and change.





This figure shows the impacts of El Nino in the US Cornbelt. Although the El Nino signal in the US Cornbelt is less pronounced than our other study regions, the spatial extent of La Nina on agriculture in the US Cornbelt is distinguishable using coarse-scale satellite imagery. The coarse scale satellite imagery is 8-km resolution Advance Very High Resolution Radiometer, provided by the NASA/GIMMS group. In general, corn yields during El Nino years are higher than average while yields during La Nina are lower than average. Decreased corn yields during La Nina years are more severe than the increased yields during El Nino years (Phillips et al., 1996). Growing season NDVI anomalies and yield anomalies for the time period in question are significantly correlated with an r-coefficient of .394 (significant at the .01 level using a 2-tailed test). This type of analysis is underway for all agricultural regions included within the project. Identifying areas sensitive to El Nino disruptions is just one step in the end-to-end analysis conceived of within the project. The spatial mapping of El Nino sensitive agricultural areas will enhance socio-economic analyses of El Nino impacts.

Food System Vulnerability to Drought

The nature of threats to food supplies posed by weather and climate variability has changed dramatically since the devastating droughts of the 1930s and 1950s. The damage to production agriculture by these historic droughts had destructive economic, social, and environmental impacts on the entire landscape of the Southern Great Plains and Rio Grande regions. By the 1990s, when severe drought plagued the region, the serious impacts were typically at the farm and rural county scale with minimal consequences for the regional macroeconomy. The impact of severe drought on agriculture has transitioned from being a "high profile" economic issue to an issue with relatively "low visibility" due to structural and functional changes in agribusiness. Our preliminary findings and hypotheses are:

1. Modernization and consolidation of agribusiness have increased food security during periods of weather and climate extremes.

Texas is the dominant economic player in the agricultural economy of the Southern Great Plains region, with agricultural product sales of $13.8 billion in 1997. Texas also leads the nation in receipts for livestock and livestock products and in farm real estate value. Trends in Texas agribusiness include: modernization and consolidation of production agriculture; growth in the wholesale and retail trade of food products; and the diminished value of farm products as a percentage of the total economy as the regional economy has become more diverse. Government farm policies and technology have been the driving forces that most influenced these trends.

Two major consequences of modernization of agribusiness are especially important. First, large-scale production agriculture has the resources to incorporate technological and financial coping strategies in order to combat the impacts of climate variability. Texas provides an example of consolidation of agricultural production systems. From 1969 to 1996, there was a 43% decline in the number of counties with profitable farming activity. The number of counties accounting for 75% of total farm earnings has also declined from 78 in 1969 to 30 in 1996. This spatial consolidation of the most profitable production agriculture systems into larger, vertically integrated farms tends to decrease vulnerability of the overall agricultural enterprise to weather and climate variability. These large, well-financed farms are more likely to adopt new technologies and methods for coping with weather extremes and changing markets. Second, food procurement in the wholesale and retail sectors of agribusiness is national and international in scope. The mobility of agricultural products continues to increase with improved techniques for preservation and transportation, food supplies rarely depend solely on local production. An interesting issue for future study is profit and loss dynamics in different sectors of agribusiness in response to weather and climate extremes. Under certain conditions the wholesale and retail sectors may actually benefit from local and regional crop failures.

2. The changing ownership patterns of farms and ranches may increase threats of weather and climate extremes to small landholders.

Small farm and ranch operators are in trouble nationwide. Historically, Federal farm programs have been structurally biased toward benefiting the largest farms, and sustainability indicators are typically negative for rural counties, with a significant fraction of income derived from small farms and ranches. The consequence of these trends is that agricultural impacts of weather and climate variability are becoming more often a local socioeconomic issue and are less frequently recognized as a regional or national economic crisis. It seems likely that the continued evolution of modern agribusiness will enhance food security while exacerbating rural poverty and vulnerability to climate variability.

Hurricane Mitch: Transboundary Impacts of a Climate Disaster

Hurricane Mitch devastated a large area of Central America in October 1998. The enormous human toll and economic destruction of this hurricane set off a wave of migration that continues to impact the Lower Rio Grande region of the U.S. today. For example, the 6,000 Central American illegal immigrants captured and detained along the Texas-Mexico border during the November to January period following Hurricane Mitch were almost double the number from the same period a year before. Of those captured or detained, more than half were from Honduras, the country that sustained the most damage.

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Defining Key Issues for Assessing Potential Climate Change in the Metropolitan East Coast Region

By Cynthia Rosenzweig, NASA, Goddard Institute for Space Studies, and William D. Solecki, Montclair State University

Several key issues reflecting specific societal conditions and constraints have been defined regarding the impacts of potential climate change of the Metropolitan East Coast (MEC) region. These issues include institutional constraints, equity, and global-to-local interactions.

The MEC region covers the greater New York City metropolitan area, which includes parts of three states (Connecticut, New Jersey and New York). The region is comprised of 31 counties in which nearly 1,600 cities, towns, and villages are located in an area of nearly 13,000 square miles. At the heart of the MEC region lies New York City, which currently has a population of about 7.3 million, while the total regional population is 19.6 million. The population is extremely diverse ethnically, racially, and economically - and is projected to be more so in the near future. By the year 2020, a majority of the region's residents will be of African, Asian, or Hispanic origin.

The population puts tremendous demand on regional land and water resources. Approximately 30% of the land area has been fully converted to urban uses, and the rate of conversion has accelerated although the rate of population growth has slowed. Regional water use is typically 1500 million gallons per day. Threats to the quality and quantity of the regional water supply are of increasing concern amongst regional decision-makers. The region's development has been intimately connected to the sea, with close to 1500 miles of coastline. This condition has had tremendous impact on infrastructure development; for example, four of the five New York City boroughs are located on islands. They are connected with each other and to the mainland by approximately 2200 bridges and tunnels carrying rails and roads. The MEC maintains a versatile, high-volume transportation system by air, roads, and rails (above and below ground), and on the water. These and other essential lifelines are often used to capacity. The economic heartbeat of the region is controlled by the largest financial trading market of the world, with a volume of several trillion dollars annually in stocks alone. The MEC general economy is mostly based on service industries, which depend on modern, sophisticated means of communication and transportation.

Given these conditions, the MEC research group has identified the following overarching issues that will play a critical role in the assessment:

Institutional Constraints - The MEC region's institutional framework for land use and development is governed by an incredibly complex web of community, municipal, regional, and statewide formal and informal processes involving the public, nonprofit, and private sectors - and entwined with often overarching considerations such as environmental protection, health, and safety. Many of these do not typically take into account consequences of extreme events such as severe flooding, weather conditions, and ecological changes potentially associated with global climate change. While many of these existing programs have the potential capacity to link to one another to generate global warming solutions, the linking process will be complex and demand new institutional flexibility and adaptation. For example, it is expected that broad scale institutional shifts will be demanded of institutions responsible for regional water supplies.

Equity Issues - Social equity in the MEC region is a major concern. Increased economic disadvantages have caused greater inequity in the region in recent decades. This trend is expected to continue into the future. The potential impacts of climate change are expected to further these problems. It is widely recognized that neither climate variability and change nor the impacts of that change will be uniformly distributed. Some areas in the MEC region will experience greater changes in climate than will others. Meanwhile, some populations in the region will be more or less able to respond to these changes. For example, lower-income residents will be more adversely impacted by increased heat waves because of limited access to air-conditioning. The MEC population diversity also might become a particular problem in periods of stress, such as could be introduced by future climate variability. If climate variability introduces disproportionate hardships (or even disproportionate changes) on some parts of the metropolitan area, it is expected there would be serious political problems and public rejection of policies put forward to deal with the change. Another potential source of problems is related to perceptions of inequity. This could be as critical as actual inequities in the experience of impacts. If specific socioeconomic, residential, or ethnic groups within the metropolitan area perceive that they are experiencing hardships that others do not experience, they will question, ignore, or possibly oppose the remedies proposed to deal with the problem. In short, both considerations of equity and perceptions of equity are central to successful public policy responses to climate variability.

Global-to-Local Interactions - The MEC region is one of the most important financial and business centers in the world. As such, local decisions and transactions that take place in the region every day have important implications for locations throughout the world. In turn, any significant disruption to the communication and transportation systems could have dire economic consequences, not only locally, but nationally and even world-wide because of the globally connected financial markets and their diverse and almost immediate impacts. From this vantage point alone, Metropolitan New York is an "Essential Facility" that is critical for the continued functioning of the national and global economy. An assessment of potential climate change impacts must take into the possibility that unusual weather events in the MEC region could disrupt these activities. For example, extreme events such as a hurricane could shut down the MEC regional communication and transportation infrastructure for an extended period, which would have impacts in distant locations for an equal and likely greater period.

The MEC assessment will focus attention on these critical issues, which reflect the extreme extent to which human systems are dominant with respect to other physical and biological systems in the region. The results of this assessment will provide insights that may be of value to other large population centers

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Arise in mean global temperature of 1-3.5° C over the next century, combined with reduced, stable, or even slightly increased total precipitation, would seriously impact some freshwater wetlands. Montane and alpine wetlands with temperature-sensitive plant and animal species may be particularly affected because they have little, if any, potential for migration. Increasing air and water temperatures are already resulting in permafrost degradation, declining water levels in boreal peatlands, and drying of wetlands at lower latitudes. Relatively small changes in precipitation, evaporation, or transpiration which alter surface or ground water level by only a few centimeters will be enough to reduce many wetlands in size, convert some wetlands to dry land or shift one wetland type to another. Changes in maximum and minimum temperature (not simply mean temperature) and in precipitation patterns (not simply total precipitation) may also have significant impacts. For example, reduced precipitation in the winter and spring may affect critical bird migration or nesting, although mean precipitation and water level remain constant.

Existing stresses and man made alterations make wetlands more susceptible to changes in climate than most deep-water and upland habitats. Many wetlands in the lower 48 states have been drained and impounded for agricultural development; levees have been constructed around them to prevent flooding, and rivers that provide essential water and nutrients have been channelized, dammed, and diked. Approximately one half of the wetlands that existed in the lower 48 states at the time of European settlement have been converted to other uses. Due to fragmentation, wetland plants and animals cannot naturally "migrate" to other locations over time in response to temperature and water level changes. Many coastal or estuarine wetlands will be unable to migrate inland in response to sea-level rise, due to dikes, levees, fills, or other development.

Impacts of climate change will vary depending upon the types, magnitudes, and rate of changes in temperature, precipitation, and other factors. Each plant species (there are more than 6,000 listed wetland plants alone) may respond somewhat differently, although certain general responses may be expected. For example, increased CO2 will increase growth rates and biomass accumulation in most plants, but differential responses among species can influence plant competition and community structure. Conversely, a combination of increased temperature and reduced precipitation in some areas of the nation may result in decreased runoff and lowered groundwater levels, causing the drying of some wetlands and a change in wetland types for some others.

In summary, wetland types likely to be substantially impacted by climate change include:

- **Coastal and estuarine wetlands -** Coastal and estuarine wetland habitats may be destroyed if sea-level rise exceeds the rate of vertical sediment accretion and inland migration is not possible. Submerged aquatic vegetation, coastal marshes, baldcypress swamps, coastal bottomland hardwood forests, and other wetland types may all be affected by salt water intrusion.
- **Permafrost wetlands -** Vast expanses of tundra, marshes, and wet meadows underlain by permafrost may be dramatically altered by changes in hydrology associated with increased temperature. Awarming of 5° C would melt virtually all of the subarctic permafrost in Alaska, which would affect more wetland acreage than is presently found in all other states combined. Massive wetland systems of the Yukon-Kuskokwim delta in western Alaska are vulnerable to both permafrost degradation and sea-level rise.Peatlands - Bogs, fens, and other largely organic wet lands at lower latitudes are highly vulnerable to subtle changes in ground water level, which plays a crucial role in the accumulation and decay of organic matter.
- **Alpine wetlands near the tops of mountains -** Even small amounts of warming may destroy "relic" plant and animal species in alpine wetlands because there will be little opportunity to migrate to other locations.
- **Prairie pothole wetlands -** Reductions in wetland size and the disappearance of some wetlands can be expected with increases in temperatures and / or reduced precipitation in the prairie pothole region. Recent work suggests that the predicted increase in temperatures in the Northern Great Plains over the next 50 years will result in more frequent droughts and declines in the numbers of both prairie wetlands and ducks.
- **Other "drier end" depressional, slope, flats, river and lake fringe wetlands -**

Drying, decrease in wetland size, and con version to uplands can be expected for most freshwater wetlands where precipitation decreases or remains steady while temperatures are increased because these wetlands are very sensitive to subtle changes in precipitation and groundwater level.

On the other hand, some riverine, lake fringe, and other wetlands in regions of the nation with increased rainfall will increase in size, and vegetation biomass may increase in wetlands overall due to rising CO2 levels. This could happen in the southeast and the northeast, where precipitation is likely to continue to increase. Wetland expansion is not likely, however, where shorelines have been "hardened" by bulkheads or where drainage is improved to prevent flooding. There may be exceptions where water levels fall as well, such as the Great Lakes where lowering of water levels may expose wide flats or benches which will be colonized by wetland vegetation.

Mitigation Options

There are no practical options for protecting wetlands as a whole from increased temperature, changes in precipitation, or rapidly rising sea level - although a variety of

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NCAR Conducts Climate Model Evaluation

By Ruth Doherty and Linda O. Mearns, National Center for Atmospheric Research

Two NCAR scientists have conducted a qualitative assessment of the accuracy of climate simulations by comparing observations over North America with results from two state-of the-art coupled atmosphere and ocean general circulation models. Although differences between models and observations can arise for many reasons relating to both model and data limitations, documenting and understanding differences from observations is important in designing impact studies.

The model simulations being evaluated are from the Canadian Climate Centre (CGCM1) and the British Hadley Centre (HADCM2). Seasonal-mean averages of key surface and atmospheric variables in their baseline simulations were examined to determine how their simulated climates compare to the observational data sets of Legates and Wilmott (henceforth L&W) and reanalyses of past weather observations by a team from NOAA's National Center for Environmental Prediction (NCEP) and NCAR. While one must be cautious about drawing firm conclusions due to possible limitations in available data sets, comparison of historical control simulations against the L&W surface temperature climatology revealed that both model simulations have a warm bias over much of Canada and the north-central U.S. in autumn and winter and a cold bias in the West in all seasons (possibly due in part to differences in the average height of mountains in the model and the average altitude of observation stations).
The models also show a warm bias in the Great Plains in summer and autumn. Both model simulations also displayed a wet bias over the Rocky Mountains, and a wet bias in the Northeast and Canada in the spring and summer months when compared to the L&W precipitation climatology. These biases are generally greater in the CGCM1 simulations than in the HADCM2 simulations.

Surface pressure patterns were also compared between the two model simulations and the NCEP/NCAR reanalyses. Both models simulated the Aleutian and Icelandic storm-generating low-pressure systems in winter to be a bit too intense. In general, the HADCM2 simulations underestimated and the CGCMI simulations overestimated the strength of the major high-pressure systems off the Atlantic and Pacific coasts of North America. Geopotential height patterns (i.e., the heights of pressure layers that steer the winds) were more closely represented in the CGCM1 simulations; however, the tropospheric temperatures simulated by both models were colder than observations.

Simulations made by both models to project future temperature and precipitation patterns were also examined, focusing on changes from present conditions for three ten-year time slices centered on 2030, 2060, and 2090. Because biases in model simulations of the present may also be present in the simulations of future conditions (e.g., for differences caused by not fully representing mountain heights), at least some aspects of projected changes in climate may not be seriously affected by the biases in the baseline simulations. However, this may not always be the case and therefore, care must be taken in interpreting and applying any model results. In the simulations examined, the CGCM1 simulations displayed more intense and extensive warming than the HADCM2 simulations. However, projected precipitation changes (mainly positive) in these future periods were somewhat similar in both models, especially of an increase in precipitation in the Western coastal US in winter. However, the CGCM1 model simulated more regions of decrease, particularly in the southeastern US. Because models are only starting to be able to represent regional patterns of the climate, it should not be surprising that differences exist between these models; that they exist points to the need for considering the results of several models as impact studies are being done.

The results of these analyses are being made available to scientists involved in the National Assessment to assist in their interpretation of the results of these model simulations of climate variability and change.

For more information, contact:
Linda O. Mearns, Environmental and Societal Impacts Group, NCAR P.O. Box 3000; Boulder, CO 80307; phone: (303) 497-8124; e-mail: lindam@ucar.edu A detailed report of these analyses can be found on the web at http://www.dir.ucar.edu/esig/doherty/

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It is worth noting that Honduras is one of the poorest of the countries in Central America. This rapid escalation of immigration pressure exacerbates existing environmental, economic, and social vulnerabilities to weather and climate extremes that are among the most serious anywhere in the U.S. The wealth and stability of the U.S. is always a magnet for people struggling to survive in Mexico, Central America, and the Caribbean. However, the impact of a Central American hurricane has quickly turned a law enforcement management issue into an international border, humanitarian, and sustainability crisis.

Our case study has documented a variety of crisis management issues that are relevant to coping with future international disasters occurring near U.S. borders. Because of such interactions, the U.S. National Assessment Program will need to look beyond U.S. borders to identify and characterize what may be the most significant threats to the America from future climate variability and change.

Regional Mini-Workshops on Coping with Climate Extremes in Urban Environments

The urban environment is not only the place where most Americans live, but also may be the most likely origin of future climate impact surprises. In the Southern Great Plains and Rio Grande regions, rapid urbanization is occurring in a relatively benign climate. Our preliminary studies signal increased threats ahead in the areas of urban flooding, energy supply, air quality, and public health. These risks are growing at an especially fast rate along the Texas-Mexico border due to unsustainable urban and community development practices. Poverty, poor land-use practices, and social isolation are major contributing factors to increased vulnerability in cities and towns throughout the region.

We are currently in the final stages of planning for two workshops concerned with how urban systems can better cope with climate extremes. A workshop in Houston, Texas, the fourth largest city in the U.S., is focused on the application of remote sensing and geographic information system technologies in reducing the impacts of extreme temperatures and precipitation. Particular attention is given to the design of specific projects that will enhance the use of vegetated landscapes for flood protection, energy management, and other coping strategies for a warmer and wetter climate scenario. This workshop will be held at the Houston Advanced Research Center, May 24-25, 1999.

Aworkshop in Laredo, Texas will be a design charette that produces a plan for an urban river floodplain restoration project that could benefit economic, education, recreation, and other stakeholder interests. This workshop is tentatively planned for May, 1999.

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Calendar

NATIONAL ASSESSMENT SPONSORED MEETINGS:

Mid-Atlantic: Meeting of Advisory Committee
University Park, Pennsylvania, May 2-3, 1999
(Contact: Ann Fisher, fisherann@psu.edu)

Teleconference on Telecommunications Technologies and Applications for Businesses
Fargo, North Dakota, May 4-6, 1999
(Contact: George Seielstad, gseielst@aero.und.edu)

Northern Great Plains: Series of Teacher Workshops
TBD, Spring 1999
(Contact: George Seielstad, gseielst@aero.und.edu)

Meeting of the National Assessment Synthesis Team
Washington, D.C., June 7-9, 1999
(Contact: Melissa Taylor, mtaylor@usgcrp.gov)

Native Peoples Workshop (tentative)
TBD, June 1999
(Contact: TBD)

Meeting of the National Assessment Synthesis Team
Woods Hole, Massachusetts, August 10-20, 1999
(Contact: Melissa Taylor, mtaylor@usgcrp.gov)

RELATED MEETINGS:

EPA Regional Conference on Global Warming: What Does It Mean for the Midwest?
Kansas City, MO, April 28, 1999
(Contact: Monica Duda, 703-247-2410)

Biodiversity and Climate Change: Conservation in the Face of Uncertainty
New York City, NY, April 30-May 1, 1999
(Contact: rapaport@amnh.org; www.research.amnh.org/biodiversity/)

The President's Council on Sustainable Development-National Summit
Detroit, MI, May 2-5, 1999
(Contact: www.sustainableamerica.org or call 1-800-334-3976)

AWRA: Potential Consequences of Climate Variability and Change to Water Resources of the United States
Atlanta, Georgia, May 10-12, 1999
(Contact: American Water Resources Association, 703-904-1225, awrahq@aol.com)

5th National Clean Cities Conference and Exposition
Louisville, Kentucky, May 23-26, 1999
(Contact: http://www.ccities.doe.gov/)

Combustion & Global Climate Change: Canada's Challenges & Solutions
Calgary, Alberta, Canada, May 26-28, 1999
(Contact: Canadian Environmental Industry Association (CEIA), 1-613-236-6222; info@ceia-acie.ca.; http://www.ceia-acie.ca/)

American Geophysical Union Spring Meeting: Special Session on Integrated Assessment of Climate Impacts
Boston, Massachusetts, May 31-June 4, 1999
(Contact: Phil Mote, philip@atmos.washington.edu)

Seventh International Conference - Air Pollution '99
San Francisco, California, July 27-29, 1999
(Contact: Liz Kerr, Wessex Institute of Technology, Phone: 44(0) 1703 293223; liz@wessex.ac.uk)

American Agricultural Economics Association, Pre-Conference Workshop: Tutorial on Climate Change and Variability
Nashville, TN, August 7, 1999
(Contact John Reilly; Phone: 617-253-8040; jreilly@mit.edu; or Otto Doering; 765-494-4226;doering@agecon.purdue.edu; http://aaea.org/meetings/m99/workshops.html)

AWRA's Annual Water Resources Conference
Seattle, WA, December 5-9, 1999
(Contact: awrahq@aol.com or 703-904-1225)

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management measures could be applied on a wetland by wetland basis to increase the resiliency of specific wetlands or to reduce or partially compensate for impacts. Many of these measures would be considered "no risk" or "low risk" and could be justified based upon non-climate threats to wetlands alone. For example, increased protection for existing wetlands and removal of stresses (e.g., water pollution) may not only reduce the sensitivity of plants and animals to small changes in temperature or precipitation, but also achieve broader wetland protection and restoration goals.

Other "no risk" measures for achieving broader objectives and reducing climate change impacts include: development setbacks for coastal and estuarine wetlands; sediment diversions for dams; linking presently fragmented wetlands and waters to provide the passageways and corridors needed for plant and animal migration; using water control structures for some wetlands to enhance particular functions and address decreased precipitation and / or increased evaporation; increasing management programs for exotic species; and implementing various wetland restoration measures.

Federal, state, and local governments should, on a regional basis, identify and target for active management those wetlands that are expected to be most susceptible to small changes in climate. Wetlands which will meet not only present but future needs (e.g., waterfowl production) under various climate change scenarios should receive high priority for protection, acquisition, and management. Wetland restoration and creation may also be used to offset some of the impacts of climate change. For example, salt marsh restoration might be implemented in tidally restricted or degraded wetlands. New peatlands might be created through impoundment in some areas. But, there will be both economic and other practical limits (e.g., limited availability of land) upon use of such methods.

Note: A follow-on article by the authors entitled "Climate Change in Wetland Areas Part II: Carbon Cycle Implications" will be published in the next issue of Acclimations.

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Newsletter of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change

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