BENCHMARKS FOR CLIMATE CHANGE

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This evening I would like to explore with you some of the present geographic patterns that might be used as benchmarks for the identification of climatic change in the Upper Great Lakes region. There are some fairly momentous changes already underway. Some of these changes obviously will be accelerated or retarded by climatic change. But I think we need to be cautious about giving too much credit to climatic change or to El Niño, or to whatever else happens to be our favorite whipping boy or seems to be popular this week.

I begin with the assumption that climatic change is not going to have much direct impact on city folk. Some of them might be moderately inconvenienced, but most will simply reset their thermostats and go on about their business. Even in urban areas, I assume that many will not be greatly affected by change, and in the interest of time I will ignore it, despite its importance in a few areas. I want to focus on rural areas, which were settled predominantly by two groups. The largest native-born groups were Yankees and Yorkers, who were leapfrogging westward to the frontier. Some became farmers, to be sure, but many sought their fortunes in commerce, and they played a major role in the development of towns and cities. The other major group of early settlers came directly from Europe. Actually, the Upper Lakes States was the only large area, in the United States, where foreign-born people comprised as much as a quarter of the total population.

The construction of railroads in the 1850s, 60s and 70s enabled immigrants to travel directly from their homes to the port of embarkation in Europe, and from the port of entry in the United States directly to the frontier. For the most part the foreign-born became farmers, and often there was tension between the foreign-born on the land – the farmers, and the Yankees and the Yorkers who had businesses in small towns and cities. Neither group, however, seemed to understand that milking cows was women's work, well beneath the dignity of a man, and after a highly successful initial fling with growing wheat, they settled down to become dairy farmers.

There are well-known maps for the types of farming in the United States which identify the Upper Lakes States as a dairy farming area. But some of these maps can be grievously exaggerated – you have got to be suspicious of any map showing a distribution that changes sharply and abruptly at a state line or along an international boundary. A more realistic map is based on sales of dairy products. Two quite different but equally revealing maps can be compiled from the identical data statistics. One map shows sales per square mile, [and] emphasizes the absolute importance of Wisconsin and Minnesota as dairy states, with Michigan a very poor third. The other map, which shows sales of dairy products

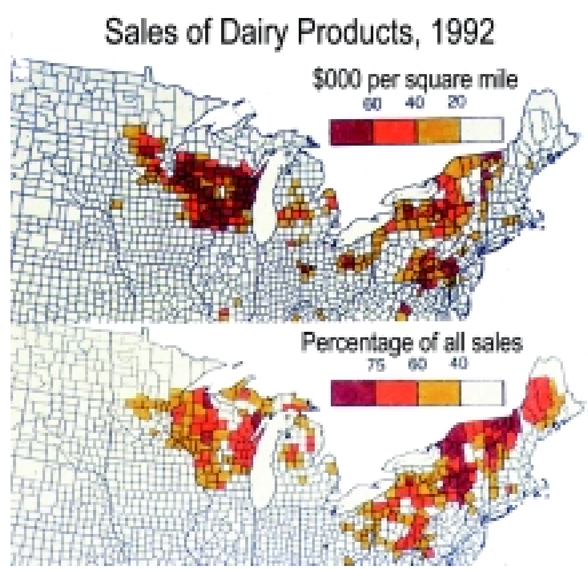


Figure 1: Sales of dairy farm products in 1992. Adapted from slide presented by Frazer Hart, May, 1998.

as a percentage of all farm sales, shows that farmers in the northeast rely far more heavily on sales of dairy products, whereas dairy farmers in the Upper Lakes States are appreciably more diversified.

Ralph Steiner is a representative Wisconsin dairy farmer. He was milking 15 cows when he started farming in 1950, and he has gradually built up his herd to 45 milking cows. Ralph has 120 acres of cultivable land. His principal crop is alfalfa, which gives him protein-rich hay that is excellent feed for his cows. He has 40 acres of corn, and he chops the entire plant for silage before the grain is ripe. Now corn is a subtropical plant, and summers in the northern part of the Upper Lakes States are too cool for the grain to ripen before the first frost. Traditional dairy farm states have barns with huge lofts for storing alfalfa hay and cylindrical silos for storing the corn crop. Better varieties and increased yields have enabled dairy farmers to fill their silos from only half as much acreage as they once needed, and some of them are willing to gamble that the rest of the corn field will ripen into grain. But they are taking a chance, that an early snow won't beat them to the punch.

Most dairy farmers have learned that it is cheaper and easier for them to buy the grain corn they need, instead of trying to grow it themselves. I think that dairy farmers in the Upper Lakes States are in for some rough sledding. They have been cocooned — they would say victimized, but I think they have been sheltered — they have been cocooned by a truly bizarre price support system. For example, a milk marketing "order" is actually an area within which all dairy farmers receive the same support price for their milk. The milk price support system is a relic of the era of the horse and buggy and the slow milk train that stopped at every crossroads.

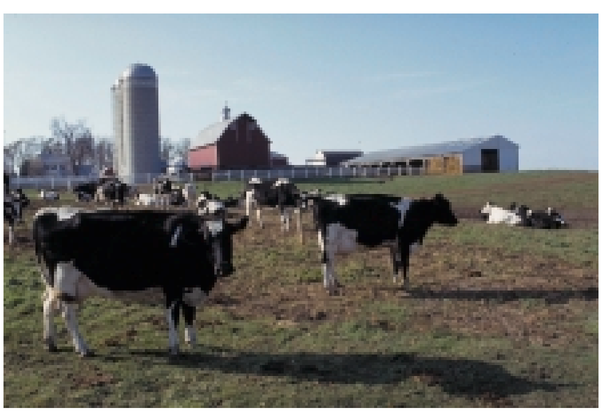


Figure 2: Dairy farm in Minnesota which contrasts sharply with the dairy farm production in California; photo by Don Breneman, Minnesota Extension Service.

Dairy farmers have a long tradition of cooperation that dates back to the days when cheesemaking left the farm house kitchen and moved into the crossroads creamery, and no other group of farmers is so well organized to insure that Congress treats them the way they want to be treated. The support price of milk increases with distance to Eau Claire, Wisconsin. And that is indeed a disadvantage for dairy farmers in the Upper Lakes States. But they have been too complacent in their political power, too conservative about adopting new technologies.

For example, the average number of cows per dairy farm in Wisconsin increased from 15 in 1949 to 50 in 1992, while California was exploding from 16 to 400. Dairy farmers around the peripheries, especially in California, have capitalized on technological innovations to develop large new dairy operations, but the Upper Lakes States have only a handful. In 1992, the United States had 564 dairy operations that were milking 1,000 cows or more. These operations accounted for less than l/2 of 1% of all our dairy farms, but they produced nearly 10% of our milk. On these large operations, the cows spend their lives in small enclosures called drylots where they are fed alfalfa hay trucked in from distant places. Three times a day they are marched to milking parlors where they are milked and given concentrated feed shipped in from all over the world. A parlor can handle 50 cows at a time – an entire average Wisconsin dairy herd in one single place – and it operates

24 hours a day. The lights have never been turned off since the day it was opened.

Urban sprawl is displacing dairy farmers in California, and they're starting to look for new areas. Joe Pires, for example, was milking 2,000 cows in Tulare, California, but he set up his kids on a large new operation near Elkton, South Dakota, just west of the Minnesota line. Joe was milking 1,400 cows, the equivalent of 28 average Minnesota dairy farms. "Why would your kids want to move from California to South Dakota?" I asked him. He thought a minute, and then he said, "They're crazy." Crazy or not — I think it is large new operations like these that are going to sound the death bell for many traditional small dairy farms in the Upper Lakes States.

Fruit production is a specialized agricultural activity along the eastern side of Lake Michigan. It capitalizes on the ameliorating effect of the lake. But I think that the days of fruit farming in Michigan also are numbered. The fruit has to be picked by hand, and finding an adequate and reliable supply of harvest labor has always been a headache for fruit producers. Some producers have taken a page from Tom Sawyer. Let the suckers pay you for the privilege of doing the work themselves by charging them to pick their own. Some producers will even sell you a tree. They tend it for you, let you know when the fruit is ripe and ready to pick, even lend you a table so you can have a picnic under your own fruit tree. Marketing is becoming a major headache. Gordon Nye has 160 acres of peach and apple orchards, and he is too small. The major grocery chains want large standard lots over the longest possible season. They would rather do business with a few large producers in California than with many small growers like Gordon. He has had to build his own roadside market. "One hour by interstate highway from the Chicago loop," he said proudly, and this is where he sells his products. The fruit farmers of southwestern Michigan already rely heavily – perhaps too heavily – on direct sales to consumers. I wonder how much longer they will be able to compete with large producers in areas with longer growing seasons. I have a hunch that many of them will be out of business long before the climate can change enough to affect them.

Figure 3: Fruit market near Traverse City, Michigan; photo by Michigan Farm Bureau.

The southwestern corner of the Upper Great Lakes region is quite a different story. Southwestern Minnesota is part of a vast field of corn and soybeans that stretches 800 miles eastward from Sioux City to Cincinnati and bulges about 200 miles north and south. In parts of Illinois and Iowa, an incredible three quarters of the land area – the total land area – is devoted to just these two crops – corn and soybeans. Farmers like Doug Magnus are concentrating on doing what their computers tell them to do. They are growing corn and soybeans that they can sell straight off the farm as cash grains. In 1983, Doug was farming 700 acres of corn and beans. He told me that was about all he could handle. This year he is farming 1,500 acres and eagerly looking for more because a 1,500 acre cash-grain farm is undersized by today's standards. Can cash-grain farming spread northward into what is now dairy country if the climate ameliorates? I doubt it for two reasons: First, the dairy areas do not have the vast level areas necessary for the efficient operation of huge modern farm machines; and secondly, extensive areas, especially in Michigan, have sandy, outwash soils of great thirstiness and low inherent fertility.

What are the agricultural prospects for the boreal forest areas in the northern parts of the Upper Great Lakes States? In Canada, where farmland is in precious short supply, they call it the pioneer fringe. They are still clearing the forests and trying to bring it into production. Unfortunately, about the only crop you can really count on in such areas is hay, and you're not going to be able to make much money growing hay. Some farmers have been able to eke out a living at the southern edge of the boreal forest, but for many of them, I suspect the principal source of farm income is the mailbox down at the end of the lane. Most attempts to

Figure 4: Isle Royale National Park, Lake Superior, Michigan. US Fisheries and Wildlife Service; photo by: Mark E. Hodgkins.

farm the boreal forest have eventually wound up in heartbreak and abandonment. Between 1934 and 1987 more than two of every three farms in the boreal forest areas of Minnesota and Wisconsin were abandoned. Even more striking is the astonishing decline in the number of farms throughout nearly all of Michigan, which is rapidly losing whatever agricultural importance it might once have had. Climatic change cannot be blamed for this loss. The cards in the environmental deck are stacked heavily against the boreal forest. Evergreen coniferous trees drop acid needles, rainwater percolating down through this litter is acidified, and leaches soluble plant nutrients from the soil. The glaciers left a terribly tangled drainage system. The problems posed by climate seem to be almost an incidental addendum to this dreary litany of environmental constraints. Climatic change is not going to change the soil, nor the topography, nor the deranged drainage system.

The primeval boreal forest was pretty spectacular before the lumber barons butchered it, to judge from the little bits and pieces that escaped. The forest that replaced it is a pretty sorry collection of weed trees. And several human lifetimes of careful management will be needed to restore the boreal forest to its primeval splendor. Forest industry companies are trying to expedite the process by developing industrial forests to produce the prodigious amounts of biomass they require. They are planting rows of coniferous seedlings on land where they had poisoned broadleaf saplings that might compete. But in the north, trees will grow only one-third as fast as in the south. Perhaps climatic change might level the playing field a bit. But one might wonder whether it is wise to encourage the growth of the pulp and paper industry which is one of our most egregious environmental polluters, spewing great clouds of toxic gases into the atmosphere and throwing great quantities of acid waste into rivers and streams.

Figure 5: Lumber camp, c.1900. Superior, Wisconsin; photo from Douglass County Historical Society.

Figure 6: Loading logs on the truck for transport to the milling plant; Superior National Forest, Minnesota; photo from USDA Forest Service.

The first lumbering operations in the boreal forest used natural waterways to reach the wooded areas, to drive the logs to the sawmills. They employed hordes of lumberjacks, who were housed in logging camps with bunk houses, cook shacks, blacksmith shops, barns for horses and oxen, and a host of smaller web buildings. But lumbering has changed. Clayton Rollins is a modern lumberman in northern Minnesota. His daddy hired 50 lumberjacks. Clayton can cut more lumber than his daddy did and only employs two workers. Clayton operates the feller-buncher. One worker drives the tractor that skids logs to the harvester; the other operates the harvester. The feller-buncher has a huge claw that grabs a tree at ground level and has a pair of powerful hydraulic shears that can cut through a 12-inch tree as easily as scissors can cut through paper. The claw grabs the tree, the shears snip it off, the machine twirls it like a baton, places it on the ground, to be skidded to the harvester, which slices it into four-foot lengths that are ready to be trucked to the mill.

After the accessible areas near the streams had been logged off, the lumbermen built railroads to get them into the more remote *interfluve* areas. The lumbering railroads had the side effect of making the boreal forest easily accessible to city folk — sufferers from hay fever, members of rod and gun clubs.

The first resorts in the boreal forest were primitive affairs where people could get back to nature. Since World War II better highways and better automobiles have spawned vast development of second homes and summer cottages. Some lakeshore areas are as extensively built up as the city streets that their residents were trying to escape. Artificial created huge new lakeshore developments. Lake Arrowhead did not even exist until the developer built a dam in 1980. He subdivided the land around it into some 2,000 more-or-less lakeshore lots and created a veritable new city. Michigan has fewer lakes and other bodies of inland water than the morainic belts of Minnesota and Wisconsin. But Michigan has even more second homes and summer cottages. The pattern in Michigan is linear rather than clustered because water related recreation in Michigan is oriented toward rivers rather than towards lakes, and many Michigan rivers have almost continuous strings of cottages.

Seasonality has been the curse of resort areas in the boreal forest. People in resort areas have had to earn their entire 12 month income in a few hectic weeks between Memorial Day and

Labor Day. But resort areas have begun to develop more year-round activity. Older folk enjoy the relative peace and quiet of the shoulder season of the fall when the noisy kids have gone back to school and the leaves are changing color. And skiing and snowmobiling attract enthusiasts in winter.

The natural history of a summer cottage is well known. It starts off as a hunting shack up in the woods, where dad and the boys can put on their red-checked flannel shirts, play poker, smoke cigars, drink whiskey, pretend that they are the reincarnation of Daniel Boone. Eventually, mom starts to get suspicious. She decides to tag along. Talk about culture shock! Finally she calms down, and says, "Well, where's the biffy?" "Gee whiz, mom, we've been using that tree out there." Next thing you know, you've got running water and electricity and a telephone. And as mom and dad start to get older, they begin to think this might not be such a bad place to retire. So they winterize the place and move into it as their new primary retirement home. It becomes their primary residence because their new second home is a trailer park beneath the palm trees in southern Florida where they winter.

Cohort survival ratios demonstrate the importance of retirement migration to the boreal forest. An age cohort is a group of people of the same age. They are ten years older when the census is taken ten years later. In some counties the number of people in the cohort age 60-64 in 1980 was greater than the number of people in the same cohort, age 50-54 in 1970. What explains this increase? It is extremely difficult to be born at any age over 50. So we may safely assume that people age 60-64 in 1980 have retired and moved to these counties. In a sense, it is the retirement belt of the Upper Lakes States.

The in-migration of retired people has helped to stabilize the economies of resort areas in the boreal forest. Retired people have created jobs in construction, in maintenance and repair. They have created new jobs for plumbers and utility workers and even garbage collectors, because rural areas in the boreal forest do not have the city services that retired people expect and demand and for which they are able to pay. Local young people, who once had to go to the cities in search of jobs when they finished school or a stint in the service can now find jobs close to home. These jobs helped to stabilize an economy in the boreal forest that is based on a complex of tourism, recreation, resorts, and retirement migration.

Figure 7: Boats at TLR Marina, Monroe, Michigan. Michigan Sea GrantExtension; photo by: Carole y. Swinehart.

I have no idea how climatic change might affect this new economy. In areas farther south, I have argued that the fruit areas in southwestern Michigan, and the dairy areas in Wisconsin, may already be under greater stress than many people seem to realize. And Michigan has almost ceased to be a farming state. I am rather more sanguine about the future of cash grain farming areas in southwestern Minnesota. But I have argued that environmental constraints will limit the expansion of cash grain farming northward. In short, I believe that momentous changes already are underway in the rural areas of the Upper Lakes States. But I defer to those of you who are assembled here to try to figure out how these areas are going to be impacted by climatic change.

WORKING TOWARDS A NATIONAL ASSESSMENT

Robert J. Corell
National Science Foundation, Arlington, VA

Dr. Robert Corell, Director of the Geosciences Division at the National Science Foundation, provided information about the purpose of the workshop from a national perspective. The following is a summary of his talk.

In 1990, the Global Change Research Act mandated the preparation of (periodic) scientific assessments of global change. In 1997, the Subcommittee on Global Change Research (USGCRP), which coordinates the U.S. Global Change Research Program (USGCRP), initiated a national, scientifically based assessment of the consequences of climate change and climate variability for the people, environment, and economy of the United States. This assessment would provide an opportunity to foster the participation of people who use global change information throughout the country and to enhance their ability to plan for and to cope with climate changes and variations. This assessment would be a core activity of the USGCRP. The USGCRP's conduct of the assessment would be overseen by the National Science and Technology Council and the Office of Science and Technology Policy. The goal of the National Assessment would be to determine the local, regional, and national implications of climate change and climate variability within the United States in the context of other existing and potential future environmental, economic, and social stresses. Of particular importance would be understanding the regional mosaic of what has been and what will be occurring as a result of global change.

Dr. Corell emphasized that the National Assessment process has been designed to create a continuing dialog among government, business and industry, labor, nonprofit organizations, the scientific research and education communities, and the public. He indicated that a multi-pronged approach will be used to generate the needed information about the implications of climate change and variability for the United States:

1. **Regional Assessments:** 20 regional assessments will focus on the issues of most importance at the regional level across the United States. Each will begin with a scoping workshop involving an average of 100 regional participants in a dialogue about perspectives and priorities related to global change for that part of the country. Each workshop will be followed by a minimum of three activities: (1) quantitative analysis of 2-3 key issues; (2) continuous engagement of regional stakeholders; and (3) publication of a report in a common format. Many regional assessments will go beyond this scope in holding additional meetings, or publishing multiple products for different audiences.

2. **Sectoral Assessments**: Sectoral assessments will focus on issues that are national in scope and related to the goods and services on which people, society, and the economies depend. The first phase of the assessment will focus on five sectors: agriculture, water, human health, forest, and coastal areas and marine resources. However, the regional assessments will provide coverage (although not necessarily national) of many additional sectors and issues.

3. **National Synthesis**: A Synthesis Report will integrate key findings from the regional and sectoral assessments and will address overarching questions related to implications over the next 25 and 100 years.

To promote consistency and coherence across the regions and sectors, a series of guideline scenarios will be prepared that estimate how the nation is expected to develop economically, demographically, and technologically over the next 25 to 100 years. A series of scenarios also will be developed that define a range of changes in climate, resource use, and ecosystem distribution so that the potential consequences of long-term climate change for the United States can be evaluated.

As the first step of the regional assessment, all of the regional workshops have been asked to address four fundamental questions:

1. What are the current environmental stresses?
2. How will projected changes in climate and climate variability exacerbate or ameliorate existing stresses, or introduce new stresses?
3. What information is needed to provide better and more certain estimates of the consequences of climate change and variability?
4. What strategies may help the region or sector cope with the anticipated consequences of changes in climate? What opportunities exist for win-win solutions and approaches?

As the USGCRP conducts the National Assessment, a number of public-private partnerships will be established with the intent of creating a collaborative network of decisionmakers, scientists, and other interested parties. Those partnerships will underlie a continuing process that will produce periodically updated, scientifically –based evaluations and summaries of current understanding.

The assessment process will be designed to be comprehensive and integrative, to couple research by scientists with specific policy-relevant needs of stakeholders, to ensure scientific excellence and credibility, to be open to broad participation, and to provide planners, managers, organizations, and the public with information they will need to cope with natural climate fluctuations and projected climate changes.

A series of summary reports will describe the consequences of climate change and variability for regions and sectors. These will be based on more detailed findings and documentation published by each regional or sectoral assessment activity. The set of summary reports will be accompanied by a synthesis report that provides an overview and integration of the regional and sectoral reports. The first series of assessment reports was completed in late 1999. These reports will point to many issues requiring elaboration as part of the continuing research and assessment process.

To support the various assessment activities, a significant USGCRP priority will be an assessment-oriented research agenda as well as a strong, broadly based research program aimed at improving fundamental understanding of the earth system. A number of agencies already have regional research and assessment programs underway, and additional activities are being planned by a broader set of USGCRP agencies.

An open and inclusive process that encourages the participation of the most qualified scientific, technical, and socioeconomic experts will ensure the credibility of the National Assessment reports. Draft assessment reports will be subject to an open and wide-reaching review process, and well-documented and reviewed alternative interpretations will be accommodated. Continuing and close involvement of stakeholders and decisionmakers will ensure relevance to policymakers. Internal and external evaluation processes will ensure that the continuing series of assessment activities and reports present a clear and fair depiction of scientific understanding and stakeholder interests and needs.

Dr. Corell noted that the value of the assessment process will depend on communicating the findings and lessons emerging from the dialog among the many and diverse stakeholders and scientific communities. The U.S. Climate Forum, held at the Department of Commerce on November 12-13, 1997, was the first major step to encourage nationwide participation in the assessment process. Assessment activities, workshop reports, and analytic findings will be communicated broadly through the media, the World Wide Web, and other channels. Reports will be made widely and inexpensively available. Outreach also will occur through programs that target both the formal (i.e., school-based) and informal (i.e., museum, park, and community-based) educational communities.

Reasons for the assessment include:

1. **To Prepare the Nation for Future Change.** To assure that the United States is prepared for future change, the United States Global Change Research Program (USGCRP) has initiated a national assessment on the potential consequences of climate variability and change for the nation. The national assessment process will analyze and evaluate what is known about the potential consequences of climate variability and change for the nation, in the context of other pressures on the public, the environment, and the nation's resources.

2. **Responsive to Congressional Needs.** The USGCRP is mandated by statute with the responsibility to undertake scientific assessments of the potential consequences of global change for the United States in the "Global Change Research Act of 1990" (P.L. 101-606), which states the federal interagency committee for global change research of the National Science and Technology Council "shall prepare and submit to the President and the Congress an assessment which:

   • integrates, evaluates, and interprets the findings of the program and discusses the scientific uncertainties associated with such findings;

   • analyzes the effects of global change on the natural environment, agriculture, energy production and use, land and water resources, transportation, human health and welfare, human social systems, and biological diversity;

   • analyzes current trends in global change, both human-inducted and natural, and projects major trends for the subsequent 25 to 100 years."

3. **Providing Input Into the Intergovernmental Panel on Climate Change.** The national assessment has been timed to provide input in the Third Assessment Report of the UNEP/WMO Intergovernmental Panel on Climate Change (IPCC), which has been working to integrate more regional detail into its analyses.

4. **Involving Stakeholders from a Broad Spectrum of Society.** The national assessment process will involve a broad spectrum of stakeholders from state, local, tribal, and federal governments; business; labor; academia; nonprofit organizations; and the general public.

5. **Linking Scientists and Stakeholders.** The assessment will link research by scientists to specific needs of the stakeholders; and will provide planners, managers, organizations, and the public with the information needed to increase resilience to climate variability and cope with climate change.

6. **Scientific Excellence Combined with Open and Participatory Approach.** The national assessment is founded on the principles of scientific excellence and openness, and will be integrative and iterative.

Dr. Corell ended his talk by describing some results from regional workshops, already held (prior to the Upper Great Lakes Workshop):

In the Southeastern United States, the El Niño-Southern Oscillation (ENSO) signal is quite pronounced. Studies of the relationship between El Niño and agricultural production in the region are helping farmers adjust to changing climate conditions, providing an example of how a better understanding of these short-term, interannual climate variations may help those who will be affected in the future by climate change.

In the Central Great Plains, the agricultural sector faces a number of challenges. Farmers and ranchers must cope with extreme weather events—floods, droughts, blizzards, hail storms, tornadoes, and others—that might become more severe and frequent in the future. They also are working to reduce runoff of crop and animal wastes into water supplies and to slow the loss of soil to erosion.

But theirs' is not a message of despair. Already they are developing and implementing sustainable land practices, both because these practices increase their incomes and because they protect the environment. One example of such a win-win solution occurs when ranchers supplement their incomes by converting animal wastes into marketable biomass fuels, which simultaneously reduces the amount of the greenhouse gas methane released into the atmosphere. Likewise, by increasing the carbon content of the soils and thus pulling carbon dioxide from the atmosphere, farmers are adding to the resilience of their fields to drought, whether natural or enhanced by climate change.

In the Southwest, communities in arid and semi-arid environments are especially sensitive to impacts on water resources. They depend on access to adequate supplies for their people and their agriculture, but are at risk to the extremes of flood and drought cycles. Most water in the Southwest comes from melting snow in the Rocky Mountains or underground aquifers. As population in the region increases, overuse is depleting the aquifers and climate change is expected to affect the amount of water from snowmelt. At the same time, rising temperatures over land could intensify the strong convective storms that can occur in the Southwest. Understanding how all of these factors interrelate would provide the information needed by regional decisionmakers to consider options and develop plans for meeting societal needs.

In the Pacific Northwest, the Columbia River is the lifeblood of the region. Variations in climate already require management of competing water demands along the river system in order to protect fisheries while providing water for irrigation, hydroelectric power, and communities. Changes in the seasonal timing and amount of precipitation are expected to affect the timing of peak runoff and river discharge, creating a potential mismatch between water supplies and user needs. Understanding these changes would provide opportunities for the various sectors to adjust by improving irrigation efficiency, changing crops, and developing alternative energy sources.

The New England region is downwind from emissions from industrial, utility, and transportation sources in the rest of the United States and parts of Canada, the quality of life there is threatened by poor air quality. If CO_2 emissions were reduced, then the region would see benefits far beyond the prevention of climate change. Emission reductions would help abate the region's air pollution and acid rain, while improving visibility during summer months. Improving the gas mileage of automobiles, via new hybrid technologies and other innovative approaches, as well as conversion of Midwestern power production facilities to alternative energy sources, would result in lower levels of nitrogen oxides, sulfur dioxide, organic compounds, and tropospheric ozone affecting the region. Human health would benefit immediately from emission reductions; the health of the region's ecosystems also could benefit, and healthier forests would take up more CO_2 from the atmosphere.

Alaska has warmed about 5 °F over the past 30 years and this warming is already having a significant influence. Warmer days could bring more personal comfort and longer farming seasons, but they would also affect fisheries and cause a thawing of the permafrost layer. This thawing is particularly significant because it would result in damage to buildings, roads, railroads, and other infrastructure, while also causing slumping in forests that leads to their transformation into wetlands. Drier summers have reduced forest health, leading to an increase in forest fires and in insect infestation. Alaska is faced with developing the means to cope with what may prove to be the most pronounced climate change in the United States.

In the Mid-Atlantic region, climate change could have profound effects on human health, ecosystems, and outdoor recreation because of the region's unique combination of geography, aging infrastructure, economic structure, population density, and mixed land use. One of the prime issues for the Chesapeake Bay is sea-level rise. Past rises have eroded coasts, threatened homes, narrowed recreational beaches, and eroded wetlands and bay beaches that are important habitats for birds and fish. Information is needed to evaluate new construction or rebuilding within areas of high risk from natural hazards (e.g., zones prone to flooding, coastal storms, or tidal surges), and to determine the best means of protecting ecosystems and infrastructure. One of the most important elements of a response strategy would be the communication of climate change projections to improve land-use and drought planning efforts and strategies for managing water across regional or local districts.

In the Northern Great Plains, the April 1997 flood of the Red River washed out homes and businesses that had been in Grand Forks, North Dakota, and East Grand Forks, Minnesota, for generations. The disaster was expected to occur, at least on the average, only once every 500 years. The Mayors at the time, Pat Owens of Grand Forks and Lynn Stauss of East Grand Forks, faced a new uncertainty as they began to rebuild their cities. Will floods of this magnitude occur more frequently in the future? If so, what level of protection must be provided? Can dikes or diversion channels be built to withstand even greater floods? No one is quite certain how severe or how frequent future floods—or their opposites, droughts—will be. But the climate change that is already underway is likely to change the pattern of storms and spring melts in this region. The historical pattern of seasonal river flows might change as well.

For Mayors Owens and Stauss, climate change is a current issue. Displaced people and businesses need decisions now on how close to the river they can build and what level of protection will need to be provided. These decisions will affect future generations as well. To protect lives, property, and livelihoods for residents both today and tomorrow, the two mayors need the best possible information about future climates.

GLOBAL CLIMATE CHANGE AND ITS EFFECTS

Michael MacCracken
U.S. Global Change Research Program, Washington, DC

My task is to try to set the stage with respect to the size of the climate issue – what we know, what we don't know, what we sort of understand. Definite uncertainties exist. We don't know as much as we wish we did, and right now the question is how should we address the issue.

Emissions from Human Activities are Changing Atmospheric Composition

Presently, we are causing the CO_2 concentration to rise and it is clearly a result of human activities. The concentration of CO_2 was about 280 parts per million (ppm), or 0.028%, before the start of the Industrial Revolution; it is now over 360 ppm. The rising CO_2 concentration is caused by emissions are of two types. Since the start of the Industrial Revolution, there have been substantial emissions due to cutting down forests for the purpose of expanding agriculture (Figure 1). The biospheric emissions from deforestation are currently roughly one billion metric tons of carbon per year. In comparison fossil fuel emissions total about 6 billion metric tons of carbon per year. To put that into perspective, there are six billion people on the planet, so emissions total one metric ton of carbon per person per year, all being added to the atmosphere.

Figure 1: Deforestation worldwide adds 1 to 2 billion metric tons of carbon to the atmosphere each year. CLIMATE CHANGE, State of Knowledge, October, 1997; photo by ©P. Grabhorn.

The atmosphere has an annual cycle where the CO_2 concentration tends to be high in the winter and low in the summer. Each year, the greening of the planet to create leaves, grass, etc., pulls CO_2 out of the atmosphere during the summer and returns CO_2 to the atmosphere in the fall and winter. If you multiply the seasonal change in CO_2 concentration of 7 to 8 (ppm) change each year by the volume of the Northern Hemisphere, you find out how much carbon is going into the hemispheric greening each year and how much is coming back out. It turns out to be about 7 or 8 billion metric tons of carbon per year which is roughly the same amount that is being put into the atmosphere each year as a result of human activities. In other words, human activities put as much CO_2 into the atmosphere each year as it takes to green the Northern Hemisphere each year. That is a lot of carbon.

As I said, the emissions of CO_2 per person are about one ton of carbon per year on a global average, but there is a dramatic variation across the globe. The United States is responsible for about 5 tons per person. Europe and much of the rest of the developed world adds about 3 tons per person each year, while citizens in most of the developing world add only a few tenths of a ton of carbon per person each year. These are dramatic differences.

It is important to realize in this debate that carbon emissions per person is a way of looking at this issue in terms of capita the relative equity around the world. Another way to look is at total emissions per country; using this measure the United States puts out the most and China's amount is growing at the fastest rate. We need to recognize that, while there are many different ways of portraying carbon emissions in the political arena, there is strong agreement that it is a human-induced effect.

We are also adding other components to the atmosphere. The second most important greenhouse gas that is being added by human activities is methane. Its concentration has been going up significantly. During preindustrial times its concentration was 700 parts per billion (ppb) or so, and it is now over 1700 ppb. In addition, we have been adding chlorofluorocarbons and nitrous oxides. To complicate things even further, we are also adding sulfur dioxide to the atmosphere, which creates aerosols, producing that whitish haze that we have in industrial areas. Quite clearly, human activities are changing the composition of the atmosphere. We are driving the climate system. The changes in these concentrations are affecting the climate, enhancing the natural greenhouse effect.

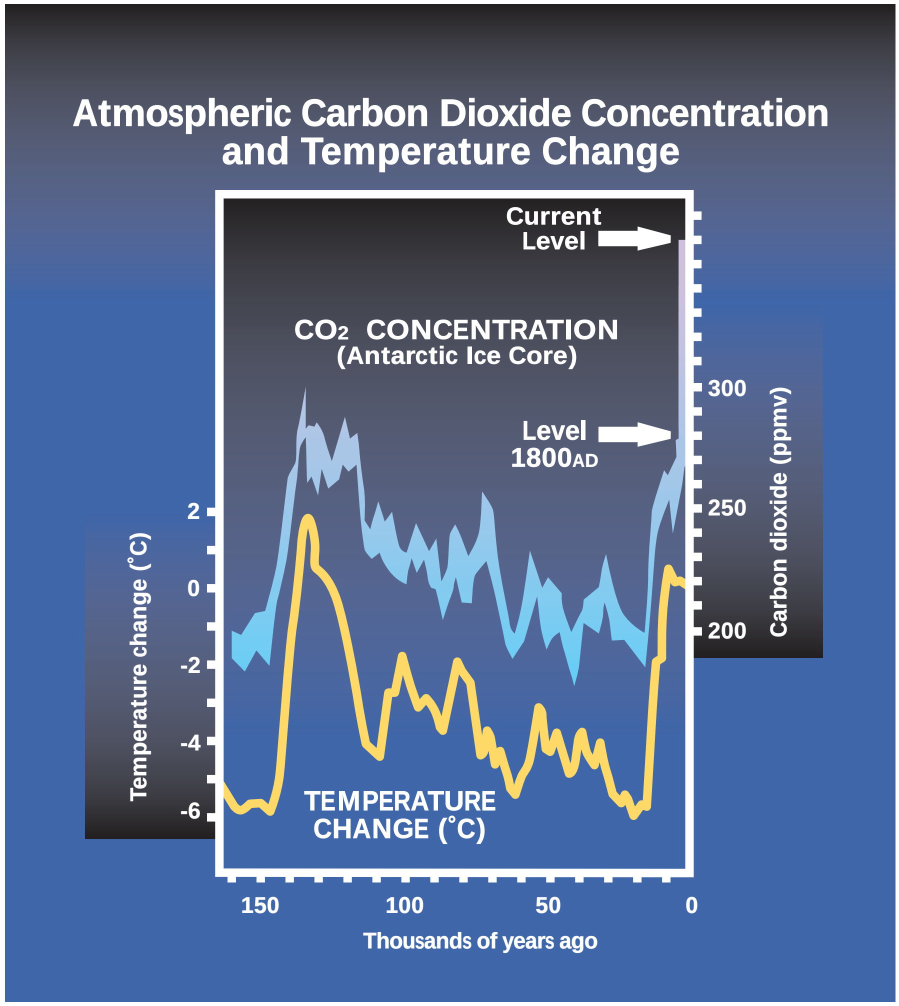


Figure 2: Atmospheric carbon dioxide concentration and temperature change. Source: Vostok ice core data from Barnola et al., 1987; current data from the Carbon Dioxide Information Analysis Center, 1997, Oak Ridge, TN.

Changing Atmospheric Composition will Enhance the Natural Greenhouse Effect

We know that the composition of the atmosphere determines how much heat (or infrared) energy is absorbed by the atmosphere and reradiated back to the surface. It is nice to think, especially on this sunny day, that solar radiation keeps us warm and provides the energy for the planet. While this is true, the surface actually receives twice as much heat energy radiated from the atmosphere as from solar radiation. Thus, solar energy absorbed at the surface is radiated away as heat energy, but then recycled by the atmosphere back to warm the surface.

We know that this is a real effect. One way we know this is by looking at what the climate might be if we were to have no atmosphere at all – like the moon. There is a very different climate on the moon. We also know this if we look at the climates of the planets. Observations indicate that Venus is very hot. The surface temperature is 700-800 ºF. You might think that it is hot because it's closer to the Sun. This is only partly true. It turns out that because Venus is very cloudy, it absorbs less solar energy per square meter than the Earth. It is very hot, it turns out, mainly, because of the very strong greenhouse effect, not just because it is closer to the Sun.

We also know that CO_2 and the climate are related because we can look back into the Earth's history. This graph (Figure 2) reconstructs conditions about 160,000 years into the past based on records of ice cores from the Antarctic. The blue curve is the concentration of CO_2 that is measured in tiny air bubbles that are trapped in the ice. Starting at zero (the present), there is a preindustrial concentration 280 part per million. Going back about 20,000 years, the CO_2 concentration during the peak of the last glacial (or "ice age") was about 200 parts per million, and this low level extends back for about 100,000 years. Going back 120,000 years or so, to the previous interglacial, the CO_2 concentration was about 300 parts per million. Scientists have since continued the record back about 400,000 years. Now the association is not perfect, but it is reasonably clear from the geologic evidence that the timing of glacial cycles is probably driven by changes in the Earth's orbit. Yet, if you consider just changes in the Earth's orbit as the driving force in a climate model, it will not produce an ice age. In order to get the conditions for an ice age, a major feedback mechanism like changes in CO_2 is needed. The evidence shows that carbon dioxide and methane are causing an important amplifying effect, with their greenhouse enhancement contributing to glacial cycling.

Enhancing the National Greenhouse Effect is Causing Changes in the Climate

Given the activities that have been changing the CO_2 concentration for a couple hundred years, are these changes affecting the temperature of the Earth? This is a record of the surface temperature (Figure 3) of the Earth's surface taken from numerous stations and ships representing land and ocean regions. The evidence shows that the average temperature of the earth is climbing gradually. It has risen about 0.6 of a degree Celsius or so over the last hundred years. The increase is not completely smooth and scientists are working to understand why. But the temperature of the Earth is clearly going up.

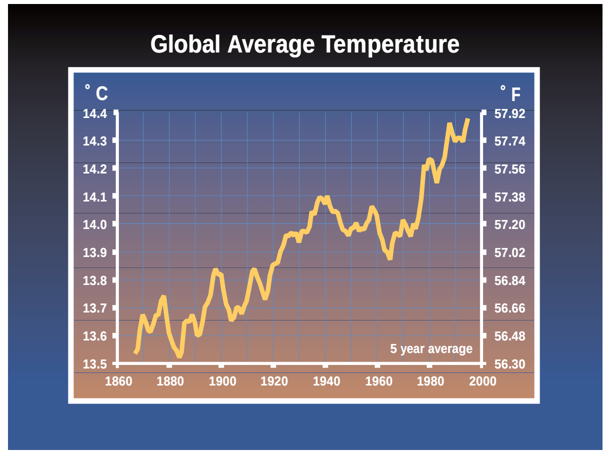


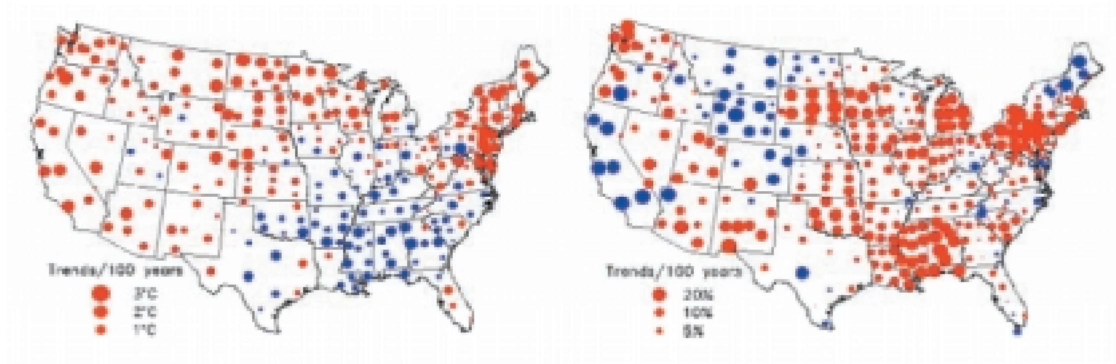
Figure 3: The global average temperature has risen by about 1º F over the last century. Source: Data from Hansen et al., 1995, Goodard Institute for Space Studies.

Other kinds of changes are also occurring. Figure 4 provides a record of where the temperature is going up in the U.S. over the last 100 years. It is warming almost everywhere. The size of the dot is an indication of the size of the trend. In some places it is warming more than others. To understand why there are changes in different regions, we must understand the regional details of climate change and that can be difficult. For example, in the North Atlantic, temperatures can be affected dramatically by what is happening to the ocean currents. Over the industrialized regions of the U.S. and to some extent over parts of Europe, the presence of sulfur aerosols may be diminishing the warming influence by somewhat masking the effect of the greenhouse gases.

There are also changes in precipitation occurring the over the U.S.– it is gradually getting wetter. That is expected from the warming of the world, which will intensify the hydrologic cycle. Again the pattern over the U.S. is not completely uniform. As was commented by the speaker last night,

Temperature and Precipitation Trends, 1900 to Present

Temperature **Precipitation**



Red circles reflect warming
Blue circles reflect cooling

Red circles reflect increasing precipitation
Blue circles reflect decreasing precipitation

Figure 4: U.S. temperature and precipitation on trends over the last 100 years. Source: Karl et al. (1996).

we do need to look critically at the data, particularly when we see systematic differences across state boundaries. Some state boundaries correspond with natural features like the Sierra Mountains, for example, along the California border. But that is not always the case and we do have to be careful. Overall, however, we are seeing a general increase in the amount of precipitation, and there is additional evidence that this increase in precipitation comes primarily in the form of heavy storms (as opposed to more frequent, light rains).

So, in answer to the question "Is the world really changing?" I think it is. The near-surface temperatures are rising and the ocean surface temperatures are rising; temperatures measured in boreholes in the Arctic are showing warming; mountain glaciers are melting; and sea levels are rising from thermal expansion and from additional water from melting glaciers. There are a host of things that are happening, including the movement of some species to new locations. There are numerous indications that changes are occurring. The difficult question is to understand why that is the case.

One of the things that the Intergovernmental Panel on Climate Change (IPCC) reported on was research to what extent these changes are due to human activities. First of all, the rate of warming that has occurred recently is dramatically different than for most periods in the past. There have been a few periods in geological history where similar dramatic changes have been recorded, but there were also other simultaneous events in the natural world, that most likely contributed to the dramatic warming. Now, in the absence of these natural factors changing in these unusual ways, we are nonetheless seeing a rapid rise in temperature. Basically, the temperature is unusually warm compared to the other period in the past. We are seeing that the lower atmosphere has warmed over the past several decades, while the upper atmosphere has cooled. This type of change is an indication that greenhouse gases are causing the change rather than other factors. If the change were due to an increase in solar radiation, both the upper and lower atmosphere would be warming. That is not happening. Because greenhouse gases remain in the atmosphere for decades to centuries, whereas aerosols remain for only a couple of weeks, the greenhouse warming influence will dominate over the long term. And so there is a range of factors that led the IPCC to conclude that, while we can't prove it definitively (i.e., we can't prove it beyond all doubt with very high statistical certainty), the balance of evidence suggests that there is a discernible human influence on the global climate.

The IPCC tried to estimate the magnitude of these changes. They used simplified climate models that include the effects of rising concentrations of greenhouse gases, the cooling influence of sulfate aerosols, and the natural variations that we think have occurred in the solar radiation, which probably caused a fair amount of the variability in earlier times. Comparing the model results with observations, the IPCC concluded that humans are indeed influencing the global climate.

The agreement however, is not perfect. One of the factors not yet included in these models are major volcanic eruptions. There was a series during the first decade of this century that likely tended to make that period a little bit cooler. There were also some major volcanic eruptions during the 20th that were not taken into account, such as Pinatubo eruption in 1991 (Figure 5). One interesting point is that, if these lower dips that occurred in the 19th century (e.g.,1883) were due to the

Figure 5: Aerial view of Mount Pinatuba after the cataclysmic June 15, 1991 erruption. Source: USGS/ Cascades Volcano Observatory, photo by E.W. Wolf.

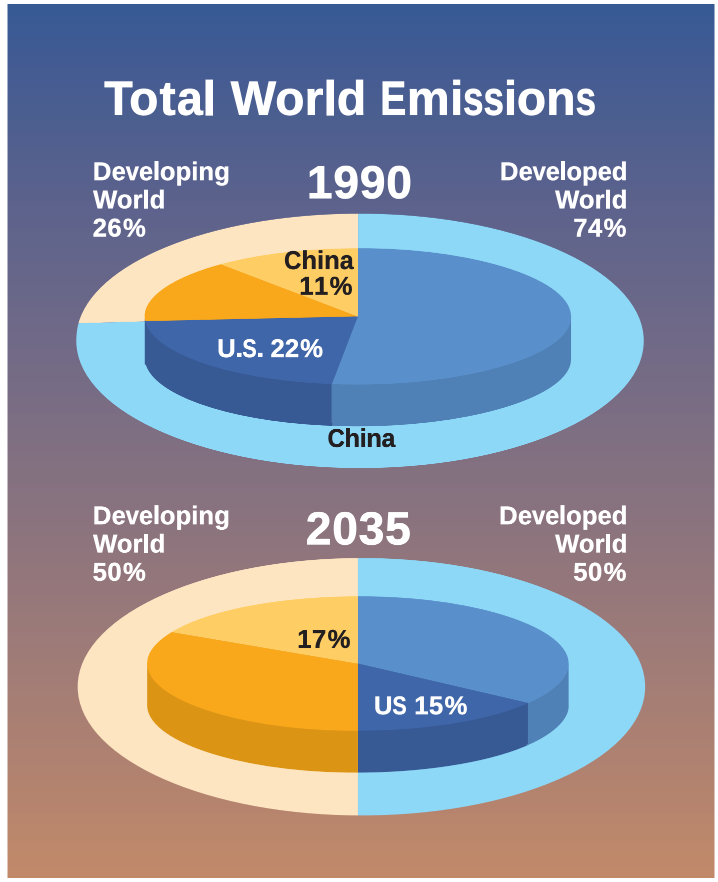


Figure 6: Total World Emissions, 1995 and 2035. Sources: Carbon Dioxide Information Analysis Center, 1997, Oak Ridge, TN; Edmonds, 1997, Batelle Laboratories, using IPCC IS92A emission scenario.

effects of major volcanic eruptions, and we think they were, the cooling after the Pinatubo eruption (which was comparable in size to the 19th century eruptions) did not take temperatures down anywhere near to what they were after the 19th century eruptions. This is one more indication that there is a warming trend that seems to be strongly influenced by human activities.

Future Emissions will Accelerate Global Warming

If we have a reasonable understanding that there has been a human effect on the recent climate, what is going to happen in the future? Human activities are currently causing the emission of 6 billion tons of carbon from fossil fuel combustion, with most of that coming from the developed nations of the world (Figure 6). In the future, there is likely to be some growth in the developed country emissions and very large growth in developing country emissions. The IPCC estimated 20 billion tons of carbon per year in the year 2100. By that time there may be 10 billion people in the world, yielding a global average total of two tons of carbon per person per year. Compared to what we have right now, which is one ton per person per year, that will represent significant growth in per capita use, but use will still be much less than in the U.S. today. There are some people who have looked at the IPCC estimate for the central trend and think they are actually underestimating what could occur because the people of the world will want to use much more energy, and carbon emissions would be even higher in the future. Alternatively, if new energy technologies are widely introduced, emissions could be less.

So what will rising emissions mean for the future? Over the past 200 years we have gone from a natural CO_2 concentration of 200-300 ppm to a level of 360-370 ppm (Figure 7). By the year 2100, if we have these kinds of emissions, which is not at all implausible, the CO_2 concentration will rise to 700 parts per million, which was last experienced on the Earth, about 40 or 50 million years ago. This would be a very dramatic change.

Because projecting changes in emissions and concentrations are uncertain, the IPPC projects relatively broad range of possible future concentrations. The lower case scenario shown in Figure 7 goes up to about 500 ppm in 2100, and this is based on the assumption that there will only be 6 or 7 billion people in the world in the year 2100. Most people think the population is going to be a lot higher than that, and IPCC also has scenarios going to higher levels.

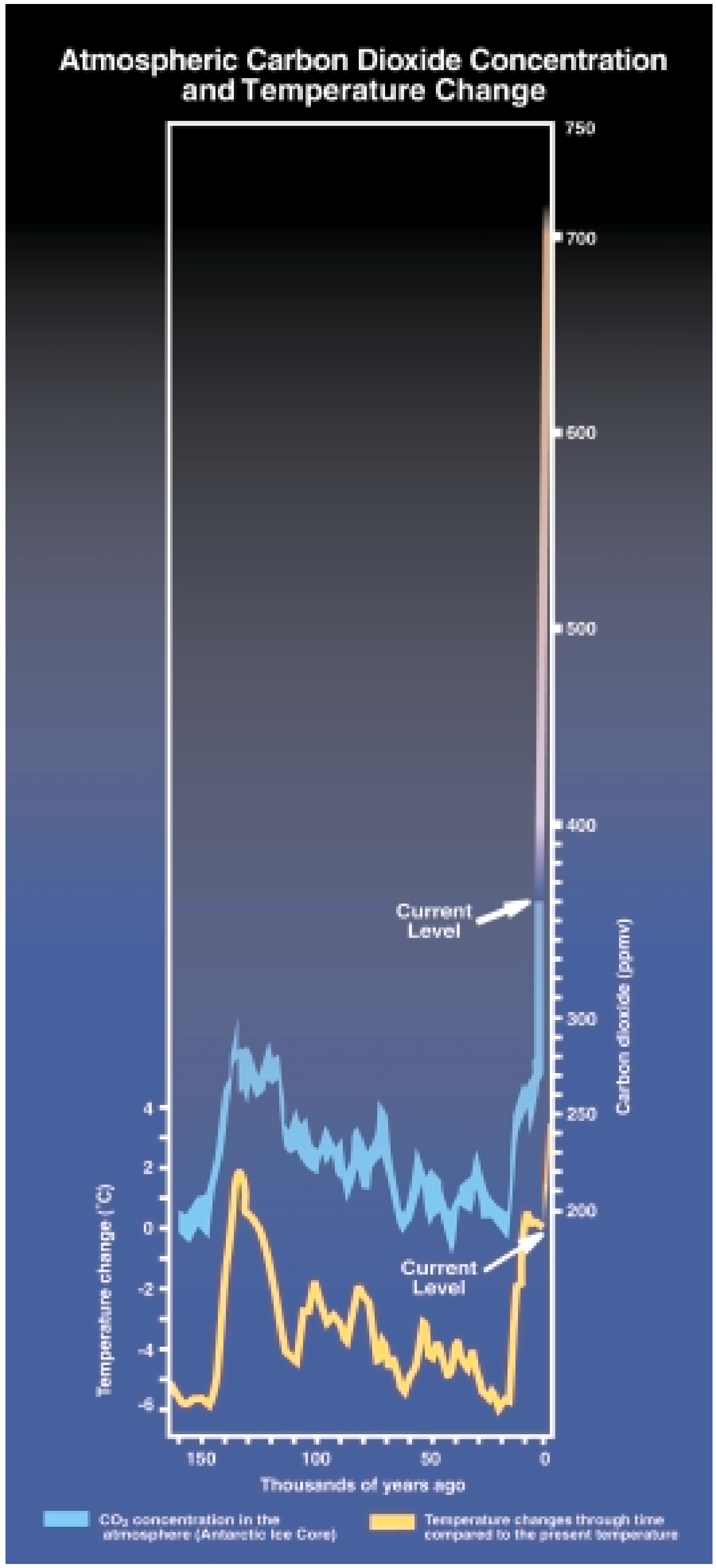


Figure 7: Atmospheric carbon dioxide concentration and temperature changes as projected to year 2100. Sources: Vostok ice core data from Barnola et al., 1987; current data from Carbon Dioxide Information Analysis Center, 1997, Oak Ridge, TN; Edmonds, 1995, IPCC emission scenario.

The climate is also going to change. If modelers assume the same response to changes in atmospheric composition as has occurred in the past, then there would be a temperature increase of about 1 to 3 1/2 degrees Centigrade. While this range seems quite broad, half of the range is due to uncertainty about how the climate will respond and the range of estimates in the climate simulation. The other half of the range is due to uncertainties in the socioeconomic assumptions – how the world will develop and what kind of energy we will use. Thus, although it sounds like a big range, it is important to understand that there are mainly two main contributors to the range.

Other changes that could occur include a potential over many centuries for intensified rates of loss of polar ice sheets in Greenland and the West Antarctic. There is a lot of ice tied up in those ice sheets – and a lot of sea level equivalent (loss of one of these ice sheets over several centuries would result in 15 feet of sea level rise). So, there are a lot of potential changes that could happen to the climate. We are getting better at modeling gradual changes, but there is also the possibility of unpredictable, sudden changes.

Consequences will Result from the Changing Climate

Most research over the past 20 to 30 years has been focused on *if climate is changing* and *is it due to human activities?* The IPCC findings are also giving a clear indication that climate is going to be changing much more in the future. Although we don't know the details, the climate will be changing. Now, the issue for some has become "So what! Who cares if it changes?" Here in Ann Arbor, in the winter you might like the temperature to be a few degree warming. On the other hand, if you are a farmer in Nebraska, a few degree warming in the summer may not be helpful at all. And so the questions have become, "What are the types of impacts that could occur?" I am going to give a brief overview of the kinds of impacts that could occur.

It is important to recognize that when you look at the impacts of fossil fuels, that they are not only the cause of these changes, but provide a tremendous benefit to society that sustains our standard of living. Thus, if we are going to justify making changes with respect to fossil fuel use, we ought to be comparing the impacts of fossil fuel cutbacks with the major types of impacts that might occur.

One category of the effects of changes in temperature, precipitation and sea level rise, are human health. It is important to look at potential impacts as well as potential coping mechanisms. For example, warmer conditions in cities that exacerbate thermal stress may be offset with air conditioning of living quarters. There may be situations where disease vectors for infectious diseases are not killed off by the frost in the winter. For instance, some were concerned that the earlier spring that has occurred this year because of the El Niño will allow some of these vectors to become active earlier in the year. There are also health-related issues about air quality that should be given attention.

A second category of potential major consequences is agriculture. Agriculture in some regions may well benefit because CO_2 is a plant nutrient. If plants have enough water, sunlight and nutrients, increasing the CO_2 concentration can actually produce agricultural benefits. In particular, the technologically advanced countries may be able to get a significant benefit from the fertilization and the increased water use efficiency that occurs. The situation is more problematic in some of the developing nations because they have much less flexibility to move crops around because they rely more on traditional kinds of one-crop economies. Another potential issue are the consequences of impacts on species and the destruction of natural habitat.

There are shifts in various species and ecosystems that are expected with a change in climate. Forests tend to be very tightly attuned to the climate, so the

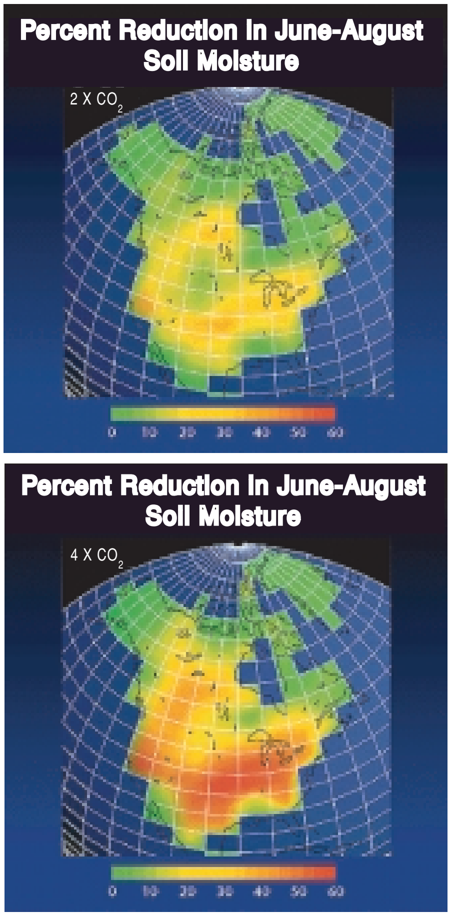


Figure 8: Percent reduction in June-August soil moisture, 2 X CO_2 and 4 X CO_2. *Source: Manabe & Stouffer, 1994, NOAA GeophysicalFluid Dynamic Laboratory, Princeton, NJ.*

forest composition will change in various ways – different species moving in different ways. Wildlife tends to be dependent on the particular timings of various ecosystem activities, and so there could, for example, be significant disruption to migrating species. Ecosystems tend not to move as a whole. Different parts have different sensitivities and they each move at different rates. They are likely to get torn apart, and the question is "What will happen with respect to how ecosystems move?"

Water resources are absolutely critical for society and the distribution of storms and rainfall are very important to determining water resources. This graph (Figure 8) is from a model calculation trying to give an *indication* of what may happen to soil moisture in various regions in the U.S. The Figure shows consequences for two times CO_2 at the left and four times CO_2 on the right. All of these colors are showing significant percentage drops and reduction of soil moisture in the summertime. The farmers will need to cope with a range of effects as a result of reduced soil moisture — to do this, farmers may change planting times, rotate their crops, or they may have to start to irrigate (assuming that there are water resources and aquifers available). Changes in soil moisture may also provide the opportunity to try novel crops, although farmers would also need different management strategies to cope with an increased incidence of pests, weeds and disease.

Impacts on coastal regions are likely to be very important. Sea level is estimated to go up by about a foot to maybe as much as three feet over the next hundred years. This range depends, to a large extent, on what happens to the polar ice sheets. The expectation is that polar ice sheets will build up some snow for a while and keep the sea level rate from rising too fast. Eventually, we would expect to get sufficient warming for melting to begin. The main lingering uncertainty in scientist's minds is that we can't fully account for the sea level rise that occurred in the last hundred years without there having been some melting of the polar ice sheets. So, with limited knowledge about the magnitude of the projected sea level changes, it is difficult to project what sea level rise will mean for particular regions around the country and around the world.

For many regions of the country, a sea level rise is going to be particularly problematic. The coast in the mid-Atlantic region around Washington, D.C. is a particularly interesting area for some of us. There are many locations where businesses and residents are within three feet of sea level – there is a lot of coastal property that is right at sea level. A couple of years ago the Chesapeake Bay had major damage due to hurricane and storm surges. Local officials looked at historical records of sea levels and concluded that sea levels are rising about a foot per century with about half of that due to global warming and about half due to the land sinking. They were very concerned. They had a conference and invited some Dutch engineers over to talk about it. The Dutch engineers turned out to be flabbergasted that the states of Maryland and Virginia didn't have a plan for building a levee across (the) Chesapeake Bay to protect them!

The Challenge of Slowing Global Warming

Given all these potentially important impacts, an important question to ask is how hard it is to do something about it? The nations of the world did agree at the Rio Summit and set the objective of trying to stabilize the climate so these kinds of impacts would not occur. This is rather an ambitious goal – to stabilize the greenhouse gas *concentrations*, not *emissions*, thereby to prevent dangerous anthropogenic interference on the climate. They set the qualification that needs to be done rapidly enough to slow down climate change and not disrupt ecosystems. However, we want to make sure that emissions are not cut so fast that food production is disrupted. We also want to do it in such a way that the cutback does not threaten sustainable economic development. This is quite a list of conditions – trying to figure out a pathway is quite a challenge.

To get a sense of what it takes to stabilize the climate system, we can estimate the reductions in emissions that are needed. If we want to stabilize the greenhouse gas concentration at today's level, we would have to reduce emissions to about two billion tons of carbon per year over the next century. That is one third of our present level, even though the population is increasing. That would be extremely difficult to do. If we want to stabilize at twice the preindustrial concentration, (about 550 ppm), we would need to limit the average emission rate for the next century to about eight billion tons of carbon. And remember what I said – the IPCC predicted that carbon emissions are projected to go from a level of 6 up to about 20 billion tons of carbon per year over the next century, or an average of maybe 12 or 13 billion tons per carbon a year for the next century, or an average of maybe 12 or 13 billion tons per carbon a year for the next century. To get the 8 billion tons of carbon per year in order to stabilize concentrations at two times preindustrial levels, we would need a 30-40% cutback globally below the projections.

Cutting the emissions too rapidly would endanger the global economy, whereas cutting emissions too slowly risks environmental damage and risks disrupting the climate. One approach might be to focus on technological options of improved efficiency and low-cost energy strategies. That requires risking some money now to invest in those kinds of strategies. What the nations are proposing to do is to take a series of steps to try and move forward. The nations of the world tentatively agreed last December to the Kyoto Agreement as a first step. I want to point out that, to achieve stabilization, this can be viewed as really only a first step. The negotiators proposed to reduce greenhouse gas emissions by 2010 from the developed countries, reaching to 5-8% below their 1990 levels. Even if this is implemented economic growth around the world will cause the concentrations and emissions to both continue to go up.

Even though this is only a beginning and it is one that has not been accepted by everyone, countries are starting to move in that direction. While there may be shortcomings in the agreement, if the world does not take some sort of first step, the question becomes at what point we do take a first step? The alternative is that the concentrations will continue upward.

The real issue is whether we can sustain ourselves through the next couple of generations, and then through the next century? The most important thing to understand for this workshop is that there is really no way that cutbacks in emissions are going to stop climate change in the near future. We are going to have to figure out how to cope with climate change – plan in advance to minimize the adverse impacts and to take advantage of any opportunities presented. What this workshop is about is looking at the changes that are projected, understanding our vulnerability, and trying to figure out if there are some win-win approaches for all of us, so we can minimize the adverse impacts that occur.

CLIMATE CHANGE IN THE GREAT LAKES REGION: PAST, PRESENT, AND FUTURE

Derek Winstanley
Illinois State Water Survey, Champagne, Illinois

Dr. Derek Winstanley, Chief of the Illinois State Water Survey, provided valuable information about the regional texture of past climate, climate change, and climate variability in the Upper Great Lakes region. He presented information, which illustrated that while global temperatures may have risen in the last 100 years by 0.5 °C, not all regions have exhibited the same trend, and that the trend, even in regions where temperatures have increased, is certainly more complicated than a simple monotonical increase. For example, Figure 1 shows that in the Upper Great Lakes region, the mean annual temperature for the region does not exhibit any long term (e.g., multi-decadal) trends over the last 100 years[1]. In fact, what are more apparent than net changes over the last 100 years are the trends that last a decade or so, as well as the interannual variability.

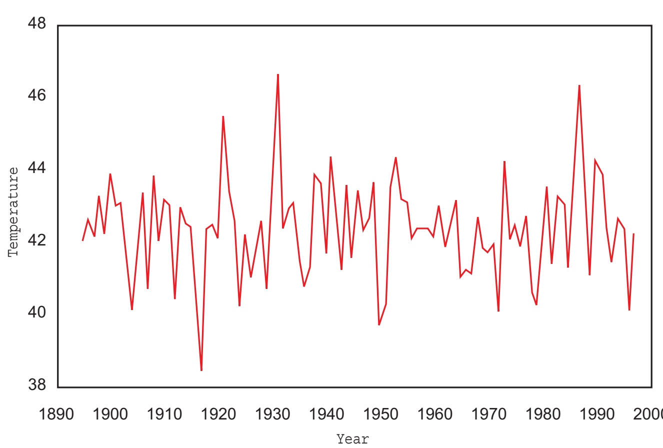


Figure 1: Annual mean temperature (ºF) for Minnesota, Wisconsin, and Michigan.

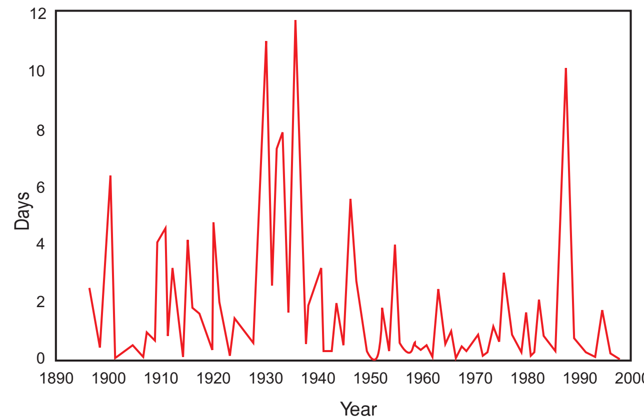


Figure 2: Number of days per year above 95°F for Minnesota, Wisconsin, and Michigan.

Temperature extremes across the region also have not shown a distinct trend over the last 100 years. Figure 2 shows that regarding heat waves, there have been only two years since 1950 where there have been more than four days with temperatures above 95 °F, while there have been ten such years between 1900 and 1950.

The high incidence of hot days is consistent with the distribution of three-day heat waves during the last century. Eleven of the fifteen greatest heat waves occurred between 1931 and

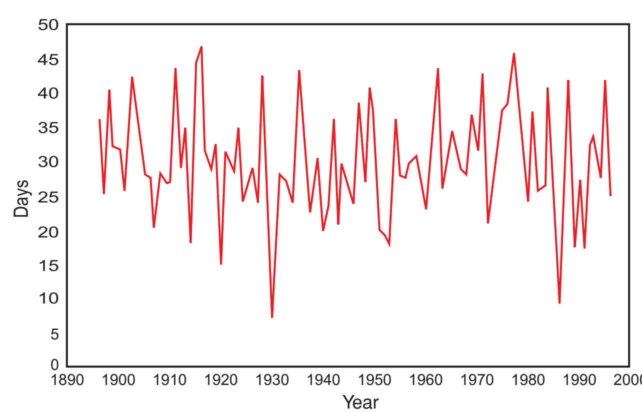


Figure 3: Number of days per year below 0°F for Minnesota, Wisconsin, and Michigan.

[1] *If only stations with filtered records (e.g., adjusted for station displacements, etc.) are included then the regional trend exhibited a 1-2º F increase.*

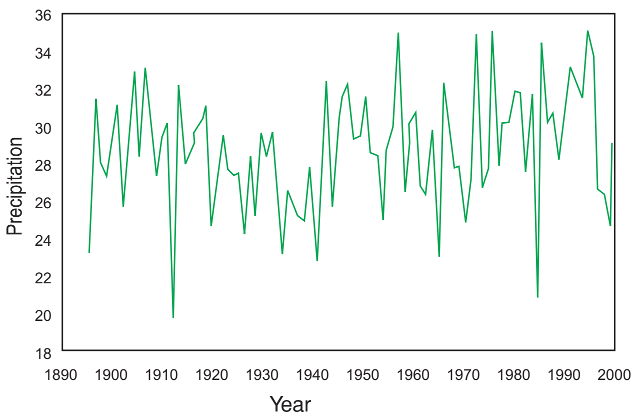


Figure 4: Average annual precipitation for Minnesota, Wisconsin, and Michigan.

1948. The great heat wave during the summer of 1995 ranks only 12th (out of 15) in terms of intensity.

Cold waves also have not shown any consistent trend over the last 100 years. The number of days per year where temperatures dropped below 0 °F decreased between 1910 and 1930 but increased between 1930 and 1980 (cf. Figure 3). First fall freeze dates, which are important from an agricultural standpoint, also have not changed - although last spring freeze dates have come earlier by about ten days since 1960.

Dr. Winstanley noted that precipitation (change) in the region is a much different story than temperature. Figures 4 and 5 show that while winter and spring precipitation for the region show no long-term trend, summer and fall precipitation does. Specifically, summer precipitation shows a decline from 1900 to the 1930s, an increase from the 1930s to the mid 1950s, a decrease from the mid 1950s to the mid 1960s, and then a gradual increase from the mid 1960s to the present. Fall precipitation shows more or less steady precipitation from 1900 to 1940, and then a slow increase from 1940 to the present. Figure 6 shows that the number of extreme precipitation events (as defined by events > 3.0 inches) has cycled over a period of about 40 years. Figure 7 shows that snowfall has

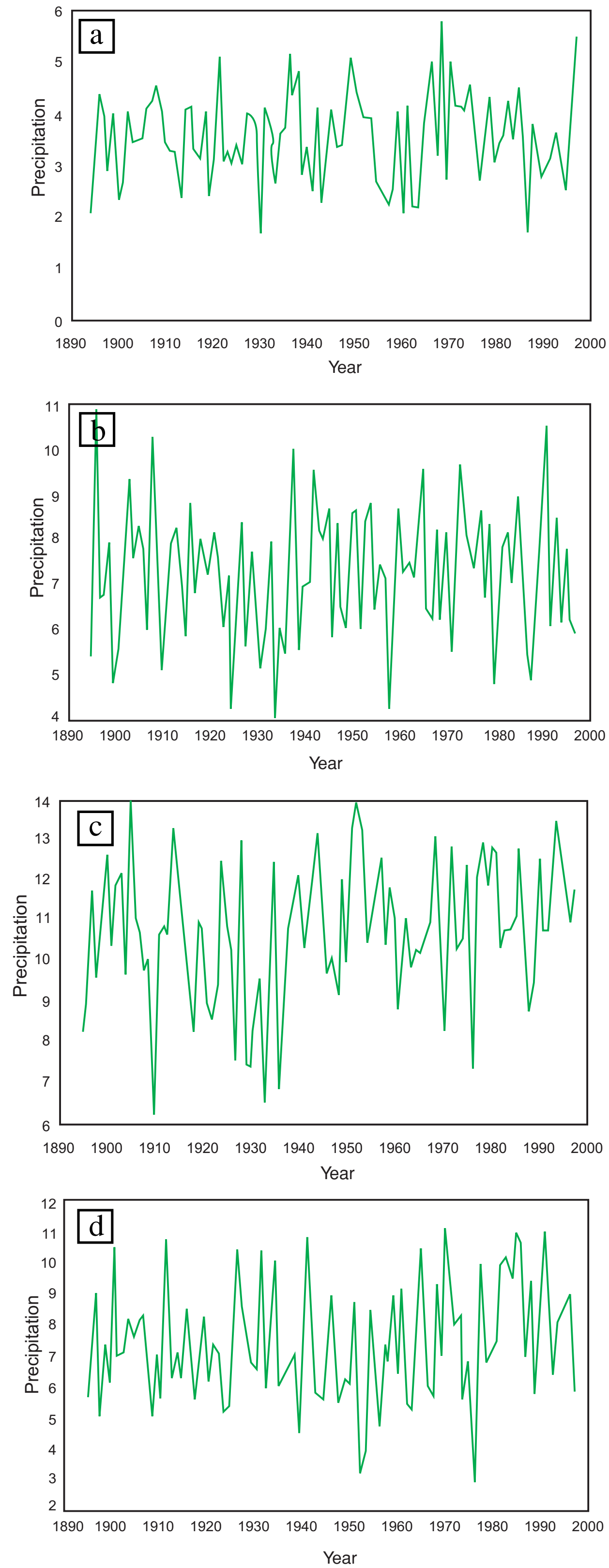


Figure 5: Average seasonal precipitation for Minnesota, Wisconsin, and Michigan. a) Winter, b) Spring, c) Summer, and d) Fall.

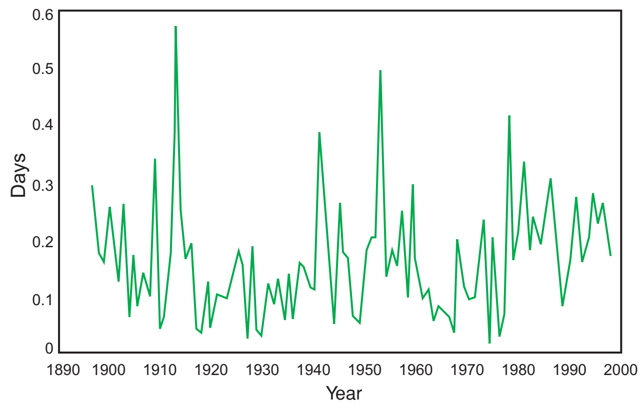


Figure 6: Number of days with precipitation greater than 3 inches for Michigan, Minnesota and Wisconsin.

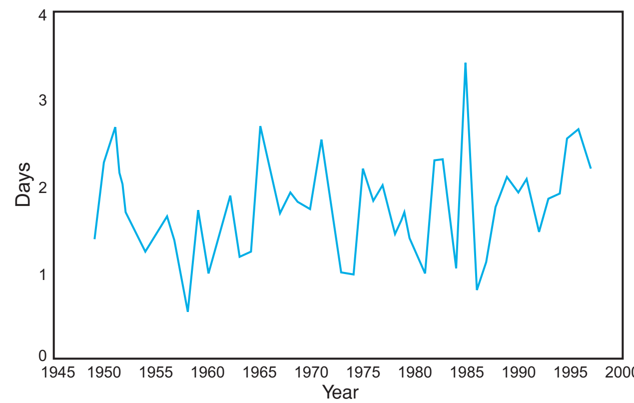


Figure 8: Number of days with snowfall greater than 5 inches for Michigan, Minnesota and Wisconsin.

increased since 1950, while Figure 8 shows that the number of heavy snowfall days (as defined by events > 5 inches) has cycled over a 30 year period.

Perhaps more striking than the recent precipitation trend for the region is the trend in lake levels (Figure 9). For example, lake levels for Lake Michigan and Lake Huron have basically decreased by 5 feet from 1890 to 1940 and have increased by 4 feet since then. The other four Great Lakes show similar trends.

Dr. Winstanley showed several correlation charts to indicate the relationship between average temperature, snow, cold days, and hot days. The chart for temperature vs. snow shown in Figure 10 suggests that a temperature increase of 3 °F would lead to a snow reduction of 20 inches, 12 fewer subzero days, and 5 more 90 °F-plus days.

While the temperature and precipitation trends over the last century across the Upper Great Lakes are not entirely consistent with global trends, they are reflective of national trends and variations. Figure 11 shows how winter temperatures on average have oscillated with a period of about 50 years for the whole U.S. The regional changes between the first 50 years and the second 50 years show warming in the western U.S. and cooling in the southeastern U.S. Dr. Winstanley presented several examples. One from the southeast (e.g.,

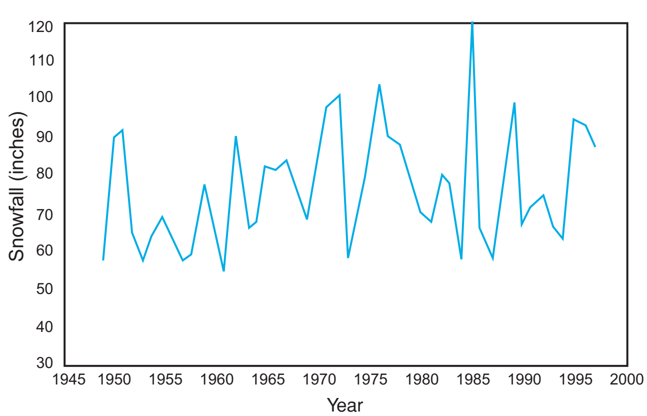


Figure 7: Total annual (January-December) snowfall (in) for Michigan, Minnesota and Wisconsin.

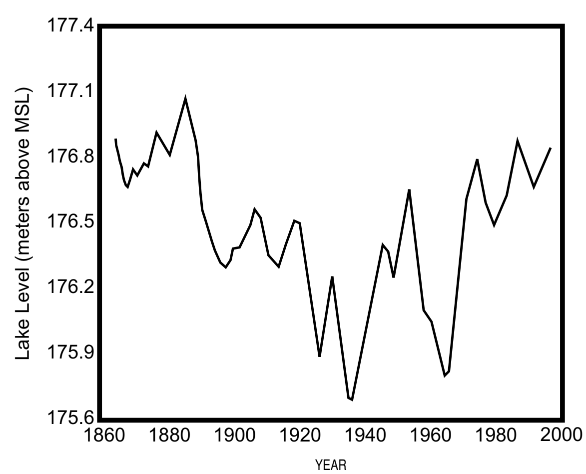


Figure 9: Historic levels on the Great Lakes.

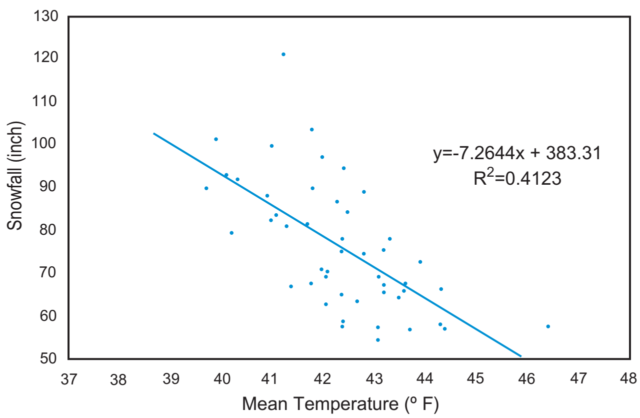


Figure 10: Mean annual temperature (ºF) vs. total annual snowfall (in) for Michigan, Minnesota and Wisconsin.

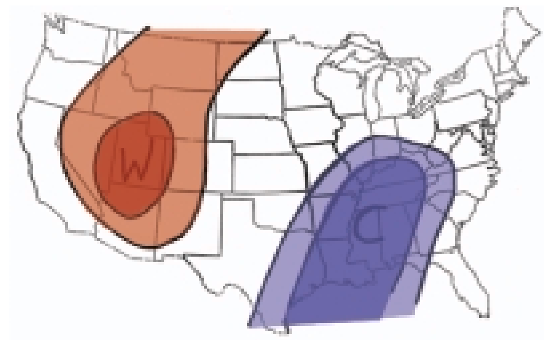


Figure. 11: Temperature trends from the period of 1900-1949 to the period 1950-1998. A "W" indicateds warming during the last ~50 years, a "C" indicates cooling over the last ~50 years.

Mississippi) showed how the cooling occurred abruptly in the late 1950s (e.g., 2 °F in about 5 years) and has since weakened slightly. Another example showed a similar trend farther north, (e.g., in Illinois) where temperature anomalies dropped from +1.5 °C to -0.5 °C from 1940 to 1980. Other places in the Northern Hemisphere have also shown temperature decreases over the last 30 years, for example, in the Arctic, as shown in Figure 14.

Dr. Winstanley noted that the regional textures and the areas of cooling shown in Figure 11 are easier to understand when one considers what else in addition to increases in carbon dioxide (CO_2) are affecting temperatures. While CO_2 increases are more or less global in extent and would suggest warming, the presence of aerosols (as part of the products that result from the burning which has increased the CO_2) in differing concentrations would suggest cooling. The short-term impacts of aerosols have been confirmed by many numerical simulations using General Circulation Models. That is, while the simulations show slight cooling trends for selected regions of the U.S. (e.g., Northeast, West Coast, Southeast) during the latter part of the 20th century, the simulations show warming everywhere across the U.S. by the beginning of the 21st century.

Dr. Winstanley concluded his talk by emphasizing five major points:

- Natural climate variability on a decadal scale is high.
- Natural climate variability on a century scale is not well known.
- No simple regional climate response to 50% increase in greenhouse gas concentrations is known.
- Future climate is likely to continue being highly variable.
- Regional response to cumulative forcing by all human activities remains highly uncertain.

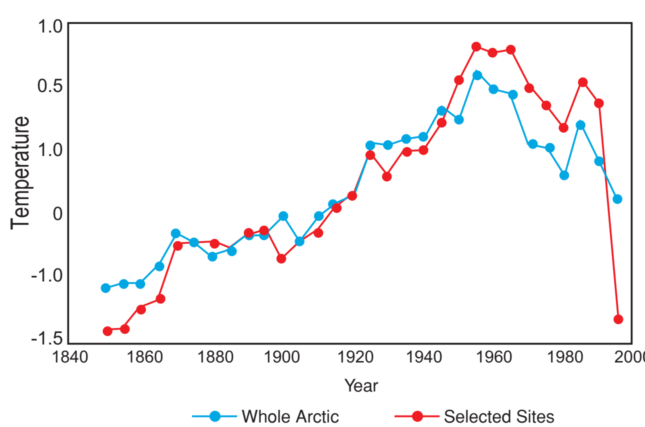


Figure 12: Temperature is this absolute or relative (of) vs. Time (1850-Present) for the arctic region.

MAKING SENSE OF CLIMATE CHANGE IMPACTS

Otto C. Doering III
Purdue University, Indiana

How To Approach The Issue

It may be better in the long-run if we back off of the arguments about whether climate change will occur. We can look at climate change on the basis of a contingency analysis – doing some looking ahead to the future just in case it occurs. We do this in our everyday lives. Few of us expect our houses to burn down, yet most of us carry fire insurance. We argue little about whether our house will actually burn down or not. We just make a contingency plan in case it does.

What sort of forward thinking or contingency planning do we need to get under way to deal with impacts? First we need to try to understand the nature of the climate change impacts that may occur and then what the drivers of this change are likely to be. If we don't have some understanding of these, then we are not likely to be successful in coping. People tend to talk about climate change impacts and about mitigation strategies. With the first they infer adaptation, with the second they infer policies to reduce carbon emissions. But, what we are actually dealing with is the potential impacts of climate change (most of it in the future) and the very real impacts today of proposed mitigation strategies imposed on us by national policy.

Both the potential future impact of climate change and the impacts of mitigation strategies are important and need to be considered in parallel. Agriculture is a sector where the impacts of climate change itself are of primary importance. Sectors such as transportation, energy, and primary metals are likely to be more affected by mitigation/regulatory driven impacts than by the actual climate change itself.

Direct Climate Change Impacts

In agriculture there are several basic concerns about climate change in the Midwest and Upper Great Lakes region. We do not appear to be dealing with a potentially uniform change. More important for agriculture is the potential change of the gradient and of the seasonal relationships. The regional models (which, by the way, we believe are not very reliable) indicate a greater degree of warming in the North as compared with the South. In addition, the models indicate that there will be more warming in the winter than in the summer. If this is true, it poses a somewhat different set of problems for plant breeders and plant protection specialists than a uniform moderate warming everywhere. Pests are much more likely to winter over in contrast to being killed by the cold winters as they are today.

Figure 1: Tarnished plant bug, Lygus lineolaris, is a serious pest of alfalfa being grown for seed. Source: U.S. Department of Agriculture (USDA), photo by Scott Bauer.

An even greater challenge for agriculture may be posed by what the climatologists term "seasonal fuzziness." With the warming, spring will come a bit earlier and fall will come a bit later, but, more important, the seasonal demarcation may not be as distinct. There may be more chance of late frosts in the spring and early frosts in the fall. This poses a special problem for agriculture in our regions given the great advantage in getting corn and soybean crops planted early to capture the maximum insolation.

Why do we worry about this, and what is the equivalent of the insurance policy that we need to be thinking about? It takes time to develop frost or pest resistant varieties and pest control practices to meet challenges like those projected here. It will be in the best interests of the agricultural research establishment to have such possibilities in the back of their minds as they develop the research agenda for the coming decades. Private firms can approach this from the standpoint of determining how much they can afford to invest in new technology. A frost resistant corn variety able to deal with the seasonal fuzziness that might occur and still allow a farmer to get his crop in early might be worth up to a quarter of a farmer's net income as compared with the cost of frost loss that would otherwise occur. The contingency thinking mentality is especially critical for public agricultural research. Much of the adaptation that will not yield a clear profit will need to be spearheaded by the public sector to prevent or reduce the chance of food shortfalls.

Mitigation Impacts

Much of the early discussion in the U.S. of mitigation focused on utilities and heavy industry. Transportation was usually left out of the equation. Transportation accounts for about a third of our energy use with industry and utilities making up roughly another third and all other uses making up the final third. In OECD countries (Organization for Economic Cooperation and Development), transportation is a third of all CO_2 emissions and road freight traffic (much less efficient than rail) has tripled in the last 25 years. My suspicion is that the politics of dealing with reducing transportation emissions is much more difficult than the politics of

Figure 2: Monroe Power Plant (fossil fuel), Lake Erie. Source: Center for Great Lakes Aquatic Sciences, April, 1986.

regulating large industries or utilities that can be portrayed as the bad guys. Thus, politicians have avoided tackling this one head-on. In the U.S. our auto transportation is so driven by our geography and historical suburban settlement patterns that this will not be easy to modify. If vehicle populations and miles driven per year continue to increase as in the past, the imposition of the Sierra Club's recommended average fuel efficiency of 34 mpg for trucks and 43 mpg for cars starting now will still leave us 20% short the target of reducing CO_2 levels to those of 1990 by the year 2010.

For the energy industry, coal, which is 43% of the electric generating capacity, actually provides 56% of the electricity and emits 88% of the CO_2. Under some of the regulations suggested, coal is dead. It's reprieve might come if the industry can perfect a technology to give efficiency levels similar to combined cycle turbines that run on natural gas. Some of the suggestions are to move to generation with natural gas. We now have a glut of natural gas, and it is clean and cheap. But, natural gas is our premium petrochemical building block for things from plastics to fertilizer to pharmaceuticals. Do we want to blow future generation's supply of this unique feedstock out the end of turbines to produce increasing amounts of electricity? To meet the 2010 objective of 1990 CO_2 emissions we will have to do more than change fuels. We will have to take a number of important steps: cut electricity load growth in half, cut heat rates 10%, shift 10% of the generation to natural gas, increase renewables share by 20% and increase transmission and distribution efficiency by 10%.

Actually Biting the Bullet

It all comes down to a willingness to take costs upon ourselves to deal with a broad public concern. As long as there is uncertainty about the event, there will be many unwilling to pay the costs of doing something. Thus, automobile drivers will not want to be forced by higher prices of gasoline to reduce fuel consumption. In March 1979 gasoline was $1.10 a gallon. In the summer of 1998 it was well below a dollar across the U.S. and the dollar is worth one third what it was in 1979. The fuel efficiency standards are the only reason we have the efficiency levels we do have in automobiles today. We are unwilling to use prices to encourage efficiency.

> "If you ask several sectors to take the easy and less expensive steps to control CO_2 emissions, it will be cheaper than asking one sector to take the full burden and climb up the increasing cost of getting decreasing amounts of CO_2 out of the system."

If we look at efforts to deal with climate change as an insurance premium or a contingency planning effort many people may be more willing to do something modest about it. The argument about whether it will happen and by how much is paralyzing. We need to be realistic about the costs. Piling all the costs on electric utilities or on heavy industry is perceived as saving the public from paying those costs – it only delays the bill a little. In addition, total costs will be lower if we get all sectors of the economy to contribute a little to the solution rather than put the full burden on one or two players. There is economic logic to this statement. For any sector to reduce CO_2 emissions, there are things that can be done initially at modest cost. To try to squeeze more and more CO_2 out of emissions costs more and more as the CO_2 producing industry proceeds up an increasing cost curve using more expensive technology.

What we might do is be as realistic as possible about the risk, treat our activities as insurance, and insist that all sectors (and countries) take at least those steps that are less expensive for them to take to slow the growth of CO_2. The environment for this will have to be one of regulatory stability so people can invest in change without fear of having the rules of the game change. Most everyone is going to have to be willing to pay something.

REGIONAL CLIMATE CHANGE AND FRESH WATER ECOLOGY[1]

John J. Magnuson
University of Wisconsin, Madison, WI

Dr. John Magnuson, Director of the Center for Limnology at the University of Wisconsin at Madison, Wisconsin talked about the potential impacts of climate change on lakes in the Great Lakes region. Below is a summary of his talk.

Dr. Magnuson first noted the importance of the ecology in the region. Besides the Great Lakes themselves, which have a surface area of 244,160 km^2 and a volume of 23 x 10^{15} liters, the region has numerous other (smaller) lakes and streams. For example, Wisconsin alone, has 12,500 lakes covering 14,000 ha, 2,000,000 ha of wetlands, and 53,000 km of streams. The region includes the Laurentian Great Lakes and a diverse collection of smaller glacial lakes, streams and wetlands located south of permanent permafrost and extending towards the southern extent of Wisconsin glaciation.

Dr. Magnuson then described briefly the paleoclimate of the region, in order to set the stage for a description of the current climate and future climate scenarios. He noted that the region was mainly drier than present, except for a brief period around 9,000 YBP (years before present). Between 12,000 and 7,000 YBP, the region was cooler by up to 7 °C. Between 7,000 and 3,000 YBP, the region was up to 3 °C warmer. Since then, the climate has been less than 2 °C cooler than present.

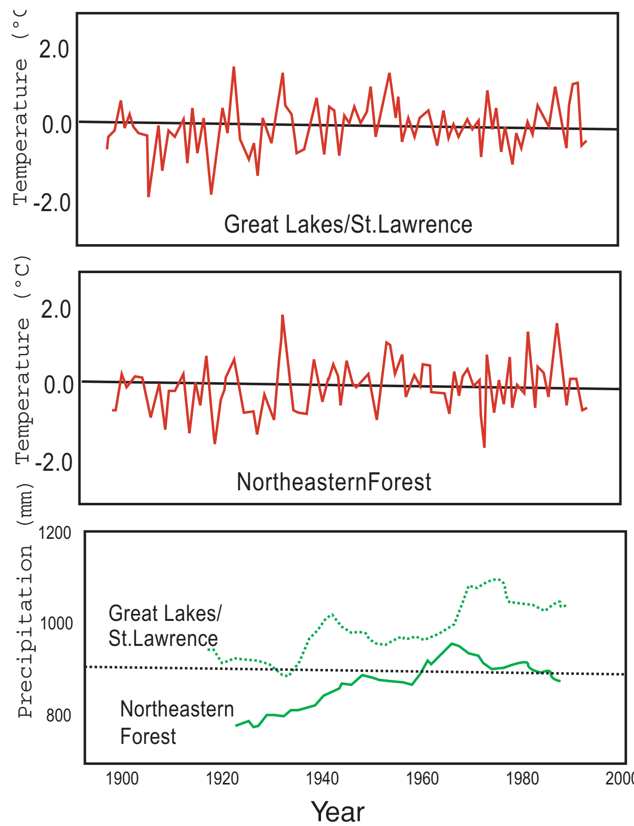


Figure 1: Departure from 1951-1980 average temperature (solid line) and linear trends (dashed lines) for (a) Great Lakes basin/ St. Lawrence lowlands, and (b) Northeastern Forest, (c) Annual precipitation (9 year running mean) amount for these two regions. Source: Magnuson et al. 1997.

Overall, the region is warmer and wetter now than it has been over most of the last 12,000 years. More recently, specifically since 1911, observed air temperatures have increased by about 0.11 ºC per decade in spring and 0.06 ºC in winter; annual precipitation has increased by about 2.1% per decade (cf.Figure 1 and 2). Additionally, ice thaw phenologies since the 1850s indicate a late winter warming of about 2.5 ºC.

Dr. Magnuson described in some detail the climate change scenarios that were used in a recent study (cf. Magnuson, et. al 1997). Four general circulation models (listed in Table 1)

[1] *Much of this summary is extracted from a recent paper, Potential Effects of Climate Changes on Aquatic Systems: Laurentian Great Lakes and Precambrian Shield Region, J.J. Magnuson, K.E. Webster, R.A. Assel, C.J. Bowser, P.J. Dillon, J.G. Eaton, H.E. Evans, E.J. Fee, R.I.Hall, L.R. Mortsch, D.W. Schindler and F.H. Quinn. Hydrological Processes, Vol.11,825-871 (1997).*

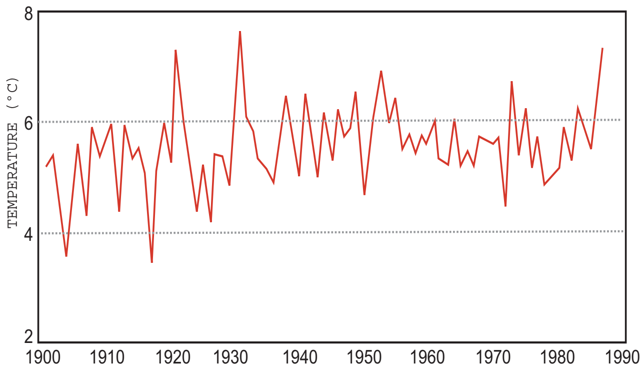


Figure 2: Annual temperatures for the Great Lakes basin (1960-1990). Source: Magnuson et al. 1997.

were examined. All showed temperature increases from 2-5 ºC (summer) to 4-8 ºC (winter). All showed precipitation changes from -20 to +10% in summer and -10 to +20% in winter (cf. Magnuson, et al 1997). Additionally, climate change scenarios were created by transposing climates from areas which represent now what the Great Lakes region climate is expected to be in the future (cf. Table 1).

Such changes in climate have altered and would further alter hydrological and other physical features of lakes. Warmer climates, i.e., 2 x CO_2 climates, are expected to lower net basin water supplies, stream flows, and water levels owing to increased evaporation in excess of precipitation. Lake levels are expected to drop 0.5-2.5 m. Reductions in lake levels would be most dramatic where increases in temperature and decreases in precipitation are greatest – in the southern half of the basin. Small inland lakes may completely disappear or at best shrink so much that salinities and nutrient and pollution concentrations increase to dangerous levels. Figure 3 shows the observed 20-year trend for inland lakes in northwestern Ontario (lake 240 basin). Note that decreasing precipitation and increasing evapotranspiration (ET) have led to dramatic decreases in basin discharge.

Additionally, a warmer climate would decrease the spatial extent of ice cover on the Great Lakes. Ice-on dates would come later in the fall or winter season and ice-on dates would come earlier in the winter or spring season. Such changes have already been observed. Ice-off dates for Lake Mendota, Wisconsin and Grand Traverse Bay, Michigan have increased by 8 and 12 days, respectively, since the late 1800s.

Table 1: Average, annual, steady-state Great Lakes basin hydrology under base (1XCO_2), transposition and 2 X CO_2 scenarios Values in italics are the percentages change form the the base case.

Scenario	Overland precipitation	Evapotranspiration (m^3/s)	Basin runoff (m^3/s)	Over lake precipitation (m^3/s)	Over lake evaporation (m^3/s)	Net basin supply (m^3/s)
1 X CO_2 (Base case)	13855	7814	6206	6554	4958	7803
Transposition scenarios:						
#1 6ºS x 10ºW	14643 +6%	10201 +31%	4674 -25%	6767 +3%	7394 +49%	4048 -48%
#2 6ºS x 0ºW	17167 +24%	11198 +43%	6154 -1%	8169 +25%	6615 +33%	7708 -1%
#3 10ºS x 11ºW	16236 +17%	11563 +48%	4877 -21%	7379 +13%	8699 +75%	3556 -54%
#4 10ºS x 5ºW	20095 +45%	13907 +78%	6308 +2%	9482 +45%	8364 +69%	7426 -5%
2 X CO_2						
CCC*	13637 -2%	7727 +22%	6090 -32%	6499 0%	5352 +32%	7237 -46%
GISS†	13871 +2%	9317 +21%	4658 -24%	6747 +4%	6821 +27%	4584 -37%
GFDLø	13725 +1%	9176 +19%	4714 -23%	6501 0%	7685 +44%	3530 -31%
OSU¶	14438 +6%	9204 +19%	5438 -11%	6903 +6%	6745 +26%	5596 -23%

* Canadian Climate Center GCM (Croley, 1993)
† Goddard Institute for Space Studies GCM (Croley, 1990)
ø Geophysical Fluid Dynamics Laboratory GCM (Croley, 1990)
¶ Oregon State University GCM (Croley, 1990)

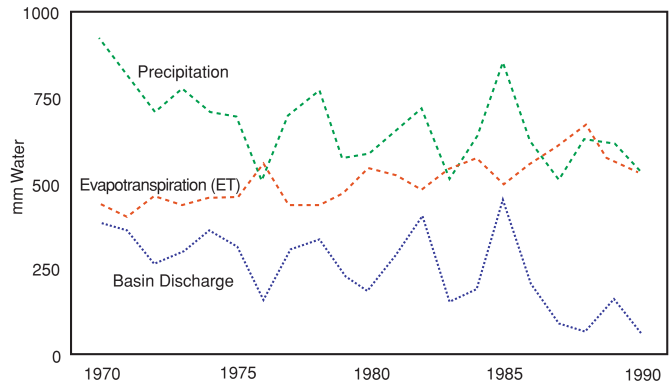


Figure 3: Hydrological changes observed for the lake 240 basin during the 20-year period of warmer and drier conditions at ELA (Experimental Lakes Area in northern Ontario). Adapted from Schindler et al., 1996a). Source: Magnuson et al. 1997.

Ice-off dates have decreased by 14 and 20 days respectively at these two sites. Small lakes, especially those to the south, would no longer freeze over every year. Simulations using output from several general circulation models show that stratified lakes are 1-7 ºC warmer for surface waters, and 6 ºC cooler to 8 ºC warmer for deep waters (cf. Figure 4). Thermocline depth would change (4 m shallower to 3.5 m deeper). A decreased thermocline depth would occur from the temperature changes alone, which would stabilize the surface layer and reduce mixing. An increased thermocline depth, however might occur owing to increases in light penetration which would occur because of the reduced input of dissolved organic carbon (DOC). Dissolved oxygen would increase below the thermocline.

These physical changes would in turn affect the phytoplankton zooplankton benthos and fishes. Annual phytoplankton production may increase but many complex reactions of the phytoplankton community from altered temperatures, thermocline depths, light penetrations and nutrient inputs would be expected. Zooplankton biomass would increase, but, again, many complex interactions would be expected. Generally, the thermal habitat for warm-, cool-, and even cold-water fishes would increase in size in deep stratified lakes, but would decrease in shallow unstratisfied lakes and in streams. Less dissolved oxygen below the thermocline of lakes would further degrade stratified lakes for cold water fishes.

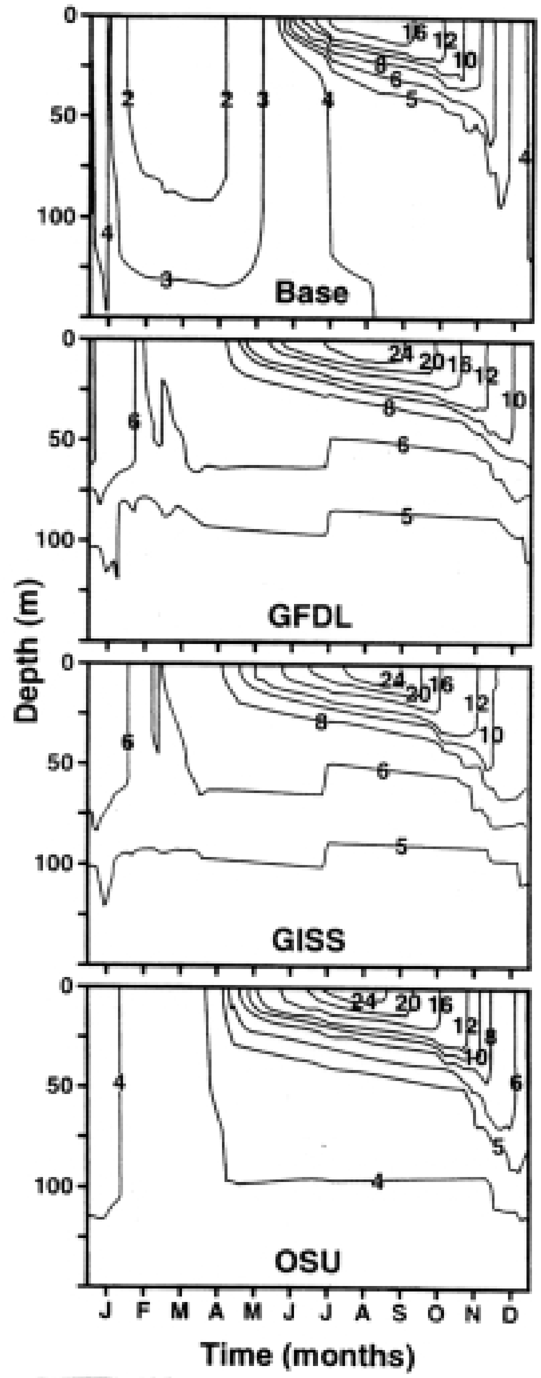


Figure 4: Simulated temperature isotherms (ºC) for Lake Michigan under base and 2 X CO_2 scenarios from three global climate models (modified from McCormick, 1990). Source: Magnuson et al. 1997.

Growth and production would increase for fishes that are now in thermal environments that are cooler than their optimum, but decrease for those that are at or above their optimum, provided they cannot move to a deeper or headwater thermal refuge. The zoogeographical boundary for fish species could move north by 500-600 km; invasions of warmer water fishes and extirpations of colder water fishes should increase. Assuming a 5 ºC temperature increase, approximately three new species would inhabit inland lakes in Ontario, nearly doubling in some cases, the varieties of fish in any given lake. The largest increase in variety would occur midway between the north and south boundaries of tertiary watersheds (cf. Figure 5). Limitations along the northern boundary would still be temperature limited, while limitations along the southern boundary would exist because there are already a large variety of species.

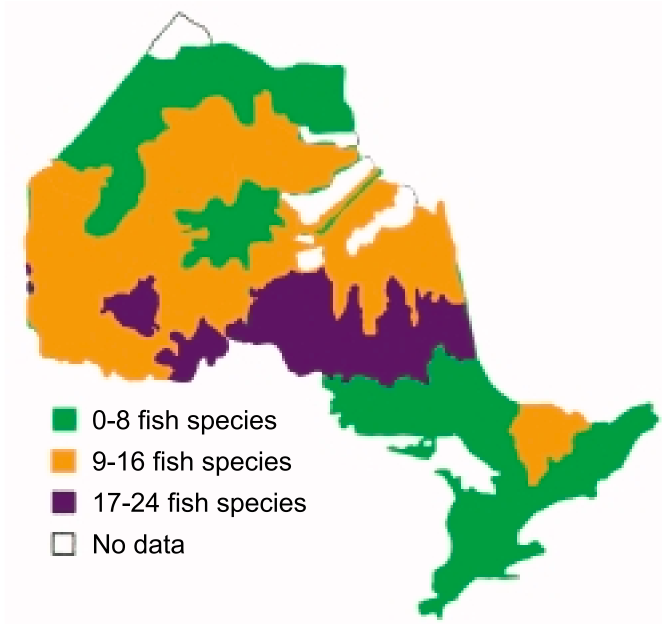


Figure 5: Tertiary watersheds in Ontario where 0-8, 9-16 and 17-24 of the 33 freshwater fish species with temperature-determined boundaries are predicted to be able to invade following climate warming of 4.5-5.5 ºC (modified from Minns and Moore, 1995). Source: Magnuson et al. 1996.

Dr. Magnuson emphasized it is important that aquatic ecosystems across the region will not necessarily exhibit coherent responses to climate changes and variability, even if they are in close proximity. Lakes,wetlands, and streams will respond differently, as will lakes of different depth or productivity. Differences in hydrology and the position in the hydrological flow system, in terrestrial vegetation and land use, in base climates and in the aquatic biota can all cause different responses. Additional complications will occur because climate change effects interact strongly with effects of other human-caused stresses such as eutrophication, acid precipitation, toxic chemicals, and the spread of exotic organisms. Additionaly, aquatic ecological systems in the region are sensitive to climate change and variation.

In closing, Dr. Magnuson highlighted some of the expected impacts related to water resources as a result of climate change. Changes in lake levels, recently observed or simulated in 2 X CO_2 scenarios, exceed those observed or simulated for sea level changes. Human responses to such large changes would be costly, particularly those related to shipping, dredging, and replacement or refurbishing of shoreline structures in the Great Lakes. Changes in ice cover also influence shipping costs. In addition, higher demand and usage of water from the Laurentian Great Lakes would probably occur following a decrease in net basin water supplies.

For shipping at simulated water levels 0.5-1.5 m lower than base levels, dredging costs would be incurred or ships would have to carry lighter loads . If lighter loads are carried, then the costs per ton transported in 2 X CO_2 scenarios will increase from 1.6 to 33% depending on the harbor (Duluth/Superior, Two Harbors, and Whitefish Bay on Lake Superior, and Toledo, Cleveland, and Buffalo on Lake Erie) and the scenario (GISS, GFDL and OSU). Cargoes would have to be reduced by 1.6-2.7% to get into the harbors without additional dredging. Dredging costs can be as high as $ 31 million per harbor not including the costs associated with shipping-related facilities. For the 101 km Illinois shoreline of Lake Michigan including Chicago, $138-312 million would be needed over a 50-year period for dredging harbors to compensate for a 1.25-2.5 m decline in lake level. The cost of sheeting, and bulkheads slips, and docks was estimated at an additional $113-203 million. Taken together, these shipping costs for the Illinois shoreline total $251-515 million over a 50-year period. Increased dredging activities would also have implications for destruction of benthic habitats and resuspension of toxics in harbor sediments.

Even with lighter loads, the same amount of goods could be shipped over a season if the ice-free season were longer (see section on ice, below). For Buffalo, an increase in the shipping season of 99 days would be sufficient to compensate for the need for lighter loads with a 1.5 m decline in water level; simulated increases in the ice-free period more than compensated for the need for lighter loads in two (GISS and OSU) of the three climate scenarios. For Lake Superior ports, a slightly shorter increase in the ice-free season would be sufficient based on all GCM scenarios. The bottom line projection for shipping costs for ports on Lakes Superior and Erie, as a consequence of reduced water levels plus the longer shipping season apparent in 2 X CO_2 scenarios, was 1-7.5% above present costs or about one half of the increases in costs from water level reductions taken alone.

Additional costs, unrelated to shipping, have been estimated for the Illinois shoreline of Lake Michigan by Changnon et al. (1989) for 2 X CO_2 scenarios. These included costs to extend water intake structures for city water supplies ($16-17 million), to relocate beach facilities ($1-2 million) and to extend and modify storm water outfalls ($2-4 million). These costs are less than those associated with shipping. Historical responses to lower water in the Chicago area include relocation and encroachment to take advantage of the new beach areas. Damage to these structures was extensive when water levels returned to higher levels.

Generation of electricity from hydroelectric facilities in the Great Lakes Basin would also be reduced in a drier and warmer climate. Presently, the capacity of the Great Lakes electric generation system is about 3.2 million kW for Ontario, 1.7 million kW for Quebec and 3.1 million kW for New York. The costs of replacing the hydroelectric power generated at Niagara and along the St. Lawrence River following a 0.6 m decline in water level in Lakes Erie and Ontario is high. Long-term annual costs of replacing this capacity with nuclear or fossil fuel plants were estimated to be in the range of U.S. $169 million in 1988 for New York and Canadian $1 billion for Ontario. The combined output from these hydropower facilities is of the same magnitude as that of the Tennessee Valley Authority.

GLOBAL WARMING IN MINNESOTA: PLAYING WITH FIRE

Michael Noble
Minnesotans for an Energy Efficient Economy
Minneapolis, Minnesota

It is a great honor to be invited to speak at this regional conference of the global change research program. I am the director and the prime organizer behind a Minnesota coalition called Minnesotans for an Energy Efficient Economy. My governing Board represents 13 groups with primary interests in energy conservation, sustainable development, neighborhood and rural environment issues and renewable energy. I brought a fistful of brochures that describe our policy and research programs in renewable energy, environmental tax reform, electric industry restructuring and more recently, a public education campaign on climate.

We do not debate whether global warming is real. Like John Browne, chief executive of British Petroleum, we recognize that the reality of global warming is backed by "effective consensus among the world's leading scientists and serious and well-informed people." We recognize that human-induced global climate change is almost certainly here now, and that its effects on our state could prove disastrous. The main uncertainty at this point is how rapidly global warming will proceed and whether we can slow it enough to allow ourselves and nature a chance to adapt.

And so, we pose two questions: What does this mean for Minnesota's environment and economy? What must we do now?

We hold the optimistic view that Minnesotans and all Americans can respond to this opportunity to invest in a cleaner, more efficient energy future. A nation capable of hurling a telescope around Jupiter is certainly equal to the challenge of reducing its dependence on fossil fuels.

Our organization's first involvement in global warming issues began in 1991, when we helped pass legislation that required our utility regulators in MN to make a best effort at estimating the societal costs of electricity generation. The public interest community and state agencies in Minnesota worked together in a contested administrative proceeding against a coalition representing the State of North Dakota, the coal industry and all Minnesota utilities. The goal was to reach an estimated economic quantification of the costs of environmental damages from electricity generation.

In a December 1996 decision described as conservative by the Minnesota Public Utilities Commission, the cost of current emissions from Minnesota alone leaves our children a debt in environmental damages of between $1 billion and $6.5 billion each year (see Environmental Costs Web Page at http://www.me3.org/projects/costs). In the end, activists realized that many of the risks of climate change were not readily quantifiable in market terms. For example, how do you value a potential for species extinction, as habitats and ecological communities are torn apart by rising temperatures or declining precipitation? What cost estimate should be applied to damage to Minnesota's own Boundary Waters Canoe Area Wilderness and Voyagers National Park that may suffer massive deaths of the spruce and conifer forests, because these biological systems are at the southernmost edge of their ecological range. Warming is expected to begin moving the boundary of these boreal forests northward, within our lifetime, and according to Daniel Botkin, a prominent forest scientist who consults with the timber industry, the changes could begin within the coming decade.

Figure 1: A view of Enron's Minnesota wind farm. Each turbine will generate enough electricity to suply 200-250 homes. They grace the rural landscape along the Buffalo Ridge north of Lake Benton, MN. Source: http://www.me3.org/, Photo: Mark Frederickson, Down River Alliance.

Our group has just begun to talk about these ecological issues, in part to communicate with a wider audience like habitat conservation groups and hunting and fishing lobbies. We've jointly sponsored events with senior or religious groups. We're taking our message into the schools.

Unlike traditional environmental groups focused on preservation and wilderness, our message is one of radical technological transformation. We believe that markets can be transformed and the old technology swept out. In a way, we are more pro-development and proinvestment than your average entrepreneur or stockbroker – we want a rapid and sustained orderly development of new efficiency and renewable technologies.

For example, we are watching with enthusiasm the development of a half billion dollar Minnesota wind industry, with almost 200 utility-scale wind turbines rising on a ridge in southwestern Minnesota as we speak. We impatiently await the Toyota Prius next year, a sedan that will get an honest 70 miles per gallon. We await their American competitors – the fuel cell cars, or hybrid cars or electric cars – that pollute a fraction as much as today's cars, or not at all.

So will global warming prompt the public demand this kind of technology overhaul in their choice of electricity sources and in their cars? Will the market direct these changes, or will policy makers set the course? Is the public even tuning in?

The director of the NASA's Goddard Institute, James Hansen said in *Newsweek* in January 1996 "the climate system is being pushed hard enough that change will become obvious to the man on the street within the decade." When I read that statement, I called Robert Watson, who was then the White House Science Policy Advisor and is now the chair of the International Panel on Climate Change. I asked Watson if he thought that Hansen's statement was reasonable. He said that Hansen is within the mainstream of climate science and that he may well be right.

I often quote this statement, not for what it says about the climate, but what it says about the potential for public opinion snapping into focus that we have a big problem on our hands. James Hansen appears to have been right: the people of Minnesota may be slowly catching on that something is already amiss with the climate. One year ago, all of America watched on the nightly news the destruction of one of the economic hubs of the State of North Dakota, the city of Grand Forks by what was called offhandedly a 500 year flood. Fargo had received about ten feet of snow that winter, breaking the all-time record of seven and a half feet, and smashing the average annual snowfall of a little more than three feet.

No single weather event is directly attributable to a warming climate, of course, but global warming means increased weather catastrophes. The increasing frequency of freakish storms is becoming apparent to the public.

Last July 1, over 3 inches of rain fell in the Twin Cities in an hour, sweeping several houses off their foundations in neighborhoods with no seeming risk of flooding. Three of the past four winters set top-ten snowfall records in Duluth, Minnesota. In July 1995, a freak windstorm swept through northern Minnesota and destroyed 6.5 million trees. The Minnesota DNR estimated the economic worth of the downed trees at a third of a billion dollars. This spring Minnesota suffered a Texas-style F4 tornado, cutting a swath of destruction a mile and a half wide and 65 miles long. The public may not understand the huge uncertainties in the connection of severe weather events and the changing climate, but they are well aware of a constant stream of new weather records. At a gut level the public is growing to understand what the pioneer Wallace Broecker of Columbia tells us: "climate is an angry beast and we are poking it with sticks."

As of last summer, our polls show that two thirds of Minnesotans thought that global warming is a serious or very serious problem. Since then, news of Kyoto has inundated the papers; the linkage to El Niño is cautiously discussed; the Twin Cities most popular weatherman became an outspoken convert; 1997 edged out 1995 as the warmest year on record. This year began with the strongest El Niño, the warmest February ever, the earliest ice-out on northern lakes, and in most people's minds, spring came a month early (it's tough to be against that, let me tell you.)

April 1998 finds global warming stories on the cover of *National Geographic*, the *Atlantic*, the *New Republic*, and *Audubon Magazine*. In *Audubon Magazine*, environmental writer Bill McKibben writes of Kyoto and the "strong sense that the tide had turned; for all their money and power, the oil companies and coal barons were now on the defensive… How long that moment lasts will depend, more than anything, on the weather… Another nasty summer, another spasm of storms, another round of reports about increased precipitation and changing seasons… those might be enough to cement this new politics into place."

In ***Playing with Fire: Global Warming in Minnesota***, we argue the idea that Minnesota is at greater risk than many other states. Recognizing large uncertainties, we talk about the work of scientists who study how global warming will affect our farms, forests, waters, and prairies. We gathered the distinguished work of Minnesota's ecologists and agricultural economists who are thinking about the issue, and try to present their work with an advocacy voice, a call to action, while still respecting the uncertainties and the tentative nature of scientific inquiry.

The climate modelers often predict greater warming at higher latitudes, and our early review of the National Oceanic and Atmospheric Administration's "best of the best" Minnesota temperature records appear to bear that out. So what could this mean for Minnesota?

A vegetation map of North America shows that in Minnesota the vast prairies of the western states meet the hardwood forests of the eastern U.S. and the mixed conifer hardwood forests of the north. In the furthest northern edge, Minnesota's wildernesses have the spruce, tamarack and cedars that typify boreal forests stretching all the way to Hudson Bay. Our state is the only place on the continent where these various ecosystems meet. This dynamic mix provides us with a remarkable natural diversity. If, as scientists are suggesting, the earth warms by 3-7 °F over the next fifty to one hundred years, and warming is in fact greater at northernmost latitudes, that diversity will be threatened.

Of greatest concern is the pace of global warming. Margaret Davis, a University of Minnesota Regents' Professor and a member of the National Academy of Sciences is here with us tonight. She has for many years researched the migration of tree species in North America, and concludes that many tree species may not be able to extend their ranges northward fast

Figure 2: North shore of Lake Superior. Source: Minnesota Extension Service, Dave Hensen, Septemer, 1992.

enough to keep up with the change in climate. According to Professor. Davis, "If the change occurs too rapidly for colonization…, population sizes may fall to critical levels, and extinction will occur." In other words, entire forests could die, unable to adapt to new conditions.

Another University of Minnesota ecologist John Tester presented a slide show to a roomful of Minnesota legislators meeting at Lake Itasca, the headwaters of the Mississippi. Only a 5 °F difference in average annual temperature between the climate enjoyed by the stately pines of Itasca State Park, and the prairie lands that stretch westward to the Rockies beginning only 40 miles away. Itasca State Park is the crown jewel of a great Minnesota State park system. Some computer models forecast warming for that region possibly much higher than 5 °F. If that happens, the forests of Itasca could disappear. Indications that northern latitudes would warm faster would put Minnesota north woods and lake country at a deeper risk than southern farmland. This is doubly unfortunate, because these resources are the most vulnerable, and represent the greatest biological diversity.

Forest ecologist Daniel Botkin has also studied the impact of global warming on the forests of the Great Lakes region. He has predicted that drier, warmer conditions will reduce soil moisture, contributing to increased plant pests and diseases and forest fires. "The dominant species [will] shift from those with commercial value to those of little commercial value," he writes.

Some scientists and economists have projected that increased carbon dioxide would fertilize trees and boost their growth, and that productivity could increase in commercial tree farms. James Teeri from the University of Michigan has studied the impact of increased CO_2 on aspen trees and has found that, in the long run, though aspens grow faster and larger, the quality of their wood is reduced, and the effects on the surrounding ecosystem are negative.

We also summarize the enormous uncertainties associated with agriculture in a changing Minnesota climate. Longer growing seasons are attractive on their face to farmers, but to temper farmer enthusiasm for a warmer climate, we cite Cynthia Rosenzweig, a research agronomist at NASA/Goddard Institute for Space Studies, and Daniel Hillel, professor emeritus of plant and soil sciences at the University of Massachusetts. They have looked extensively at yield and costs associated with increased pests and weeds and drought. Their new book ***Climate Change and the Global Harvest*** published just last month by *Oxford University Press*.

We argue that Minnesota's agriculture is too important to take a big gamble. In 1996, our agricultural exports totaled $3 billion and ranked seventh in the nation. Many of our communities depend on agriculture for economic and social survival. Our coalition has worked in Minnesota to get farmers involved in opportunities with renewable energy sources such as wind power and biomass.

Minnesota's 12,000 lakes are a gift to us from glacial retreat and a climate cool and wet enough to maintain them. Our lakes are tourist destinations and our sport fishing industry brings in

Figure 3: Great Blue Heron. Source: Don Breneman, Visualizing the Great Lakes, http://www.epa.gov/glnpo/image.

about $1 billion a year. One quarter of all Minnesotans, over a million people, are expected to be on a lake for this Saturday's fishing opener. Since way before a Minnesota Governor held up a northern pike on the cover of Time Magazine in 1973, lakes and streams have been synonymous with the good life in Minnesota.

Rising levels of greenhouse gases will create a warmer, drier climate that could severely affect our lakes and streams. If drier conditions are expected to accompany global warming, it will result in lower lake levels and river flows, warmer water and reduced water quality, and the deterioration of fish habitat in many areas. Lakes in northern Minnesota could see ice out four to five weeks earlier and ice and snow thickness reduced by 50 %, endangering ice fisherman and snowmobilers.

Again, northern lakes may be more severely harmed than southern Minnesota lakes. David Schindler, a limnologist at the University of Alberta, studied a group of lakes in Ontario just 120 miles north of the Boundary Waters Canoe Area (BWCA). The boreal freshwater ecosystems he examined are similar to those of the BWCA.

Schindler's study showed that during a 20-year period, the mean annual water temperature increased 3.6°F. Drying caused declines of over 50 percenoff and led to fires in the area. Such changes in temperature and precipitation would have devastating effects on the ecosystems of the BWCA and Voyagers National Park.

Elevated water temperatures may reduce trout habitat in 50% of northern Minnesota lakes. With warming at the upper bounds of estimates from a carbon dioxide doubling, in all likelihood, trout would disappear from southeast Minnesota streams and North Shore rivers.

Minnesota's prairies once had 7 million acres of wetlands. Today, only 20% of those acres remain. Prairie wetlands depend on reliable precipitation and consistent temperatures, both of which global warming would threaten. The mallards, pintails, and blue-winged teals that breed in wetlands would be severely affected by the higher temperatures predicted by global models.

The danger to wetlands would come from dryness as well as heat. W. Carter Johnson, professor of ecology South Dakota State University, found that if temperatures increase 3.6° to 7°F, precipitation would have to increase 10 to 25% just to maintain the current status of prairie wetlands. But that sort of precipitation increase may not happen under global warming. Some models show a loss of 50% or more in soil moisture. Johnson expects wetlands to be choked with cattails, which would reduce the habitat quality and number of ducks. Many wetlands might be lost completely.

Eville Gorham, a prestigious University of Minnesota ecologist, has also pointed out that warmer, drier conditions pose the threat of peatlands increasing their emissions of CO_2. Peatlands are waterlogged lands made of dead reed cattails, sedges, and sphagnum moss. They hold huge amounts of carbon that would be released into the atmosphere if the water tables fall as the result of higher temperatures and greater dryness. The carbon dioxide given off would exacerbate global warming.

He also points out that while peatlands naturally burn, drier conditions could produced sustained burning of peat underground for years. He likened such fires to a "Kuwait of the North." This worst-case scenario could enormously increase CO2 emissions, through a massive and uncontrolled burning of what is essentially a fossil fuel.

What Can We Do to Make a Difference? Early and Decisive Domestic Action Is the Answer.

Last year, an internal debate raged within the Clinton Administration whether we could reduce our global warming emissions without hurting the economy. Economic predictions of the impact on the U.S. economy from reductions in greenhouse gas emissions vary widely as a result of the differing assumptions built into the economic models.

Models based on worst case assumptions predict a reduction in GDP growth, while others based on best-case assumptions predict stimulated economic growth. Generally, I agree with Dan Lashof, the top climate guy at the Natural Resources Defense Council that if you torture an economic model long enough, it will confess to anything.

Last year the group Redefining Progress in San Francisco found five prestigious economists to propose a simple statement on climate. The group succeeded in collecting 2500 additional signatories (including several Nobel Laureates) of the Economists' Statement on Climate Change. If you think it is hard to get scientists to agree on something, try economists. But more economists agreed on this statement than any other petition previously circulated. In part, it says "For the U.S. in particular, sound economic analysis shows that there are policy options that would slow climate change without harming American living standards, and these measures may improve U.S. productivity in the long run."

One example of these analyses was completed last year in May, the Energy Innovations report by five major environmental organizations. They found that with policies targeted at the electricity sector and the auto sector, emissions could be reduced 30-40% by 2010 and save the economy money. Largely, this is true because efficiency is cheaper than waste.

The Panel on Energy Research and Development of the President's Committee of Advisors on Science and Technology has pointed out that many of the improvements in energy technology that would slow global warming would have additional benefits. These include reducing dependence on imported oil, expanding U.S. technology exports, reducing air and water pollution, fostering sustainable economic development, and strengthening U.S. leadership in science and technology. In other words, even if there was no climate problem, we would be advocating for energy efficiency, clean energy, and better transit and land use.

If we move forward toward this future, we can enjoy cleaner more breathable air, fewer cases of asthma, more comfortable and economical homes, quieter and more livable neighborhoods, new markets for environmental technologies, convenient transportation, and diversified rural economies through wind energy and biomass energy. So if we are very lucky, and it turns out that the warming at the lowest end of the estimates, what have we lost by cutting emissions? The IPCC estimates that benefits such as reduced air pollution could offset between 30 and 100% of climate abatement costs.

Every time humankind has switched from an existing fuel to a newer one - from wood to coal, coal to oil, oil to natural gas - the switch has been associated with economic progress. The same is true for alternative fuels. States and nations who lead the transition to alternative energy will enjoy an economic advantage. As the world demands energy-efficient technologies and environmentally safe fuels, upper Midwest states should seize the opportunity to incubate these industries of the future. Visit our web site at http://www.me3.org/ to learn about pro-renewable and pro-efficiency policies that can be implemented with the restructuring of the electric industry, or about a national movement in the states to shift part of existing tax burdens onto pollution.

The emphasis for the United States must be on domestic action to reduce its emissions, not trading for the unused emission credits of a collapsed Russian economy. Complex equity issues arise when Senators and the President prevent the U.S. from reducing its emissions until international negotiations achieve "meaningful participation" by key developing nations. Currently the richest 10% of American annually emits 11 tons of carbon dioxide each, whereas the poor people of the world emit (on average) a tenth of a ton, even if the clearing of forests and burning of grasslands are all attributed to underdeveloped nations.

On the other side of this debate, the Energy Information Administration released a report in April predicting that, without major economic or technical changes, world emissions will surpass 1990 emissions by 80% by the year 2020. Contrast that increase with the call by the International Panel on Climate Change for a 60 to 80% reduction in emissions to stabilize the climate.

Most of the increase in emissions come from developing nations, so it is a deep and troubling problem to balance the fairness arguments of the developing nations against the climate imperative to reduce emissions by two-thirds or more. So worldwide, do not expect changes in population and technology and lifestyle to come easily. A Kyoto delegate asks why Americans expect to ride two to a car, while counting on developing nations to reduce riding the bus. Apparently he has not enjoyed watching the on-ramp at rush hour in any major American city. If the rich western nations do not lead with low- or zero-emission transportation and energy systems, who will?

Following the Kyoto agreement, my hopes soured a bit that the tide had turned, that the oil and coal interests were set back, and the world would be moving toward sensible reductions. Since then the national rhetoric has been anything but reassuring, with anti-Kyoto resolutions percolating up in legislatures in several states. When it comes time to do our part, we seek the easy road. This past month, the President announced his agenda for restructuring the electric industry, and missed the easy opportunity to make a big step toward his own emissions goals for 2010. He should have called for Congress to require that all coal-fired power plant that are exempt from the Clean Air Act Amendments be required to meet modern standards.

Often I am told that the climate problem is indeed global, and Minnesota's emissions are small by comparison. My one Midwestern state represents 2% of U.S. emissions, and since the U.S. represents 25% of the world's, Minnesota

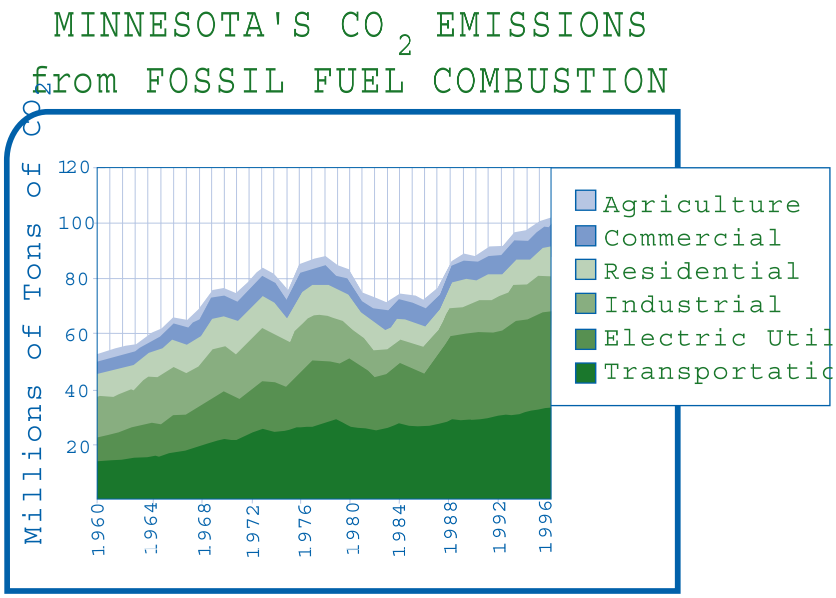


Figure 4: Minnesota's CO_2 Emissions from fossil fuel Combustion; Source: Minnesota Pollution Control Agency.

is responsible for about 1/2% of the global total. That is more than many countries, such as Iraq or Ecuador, so if countries should plan for reductions, why shouldn't states? There are six midwestern states well represented at this conference. I haven't checked emissions from each, but I expect some are a little more than Minnesota's and some a little less. Using MN as an average, these midwestern states represent more than 3% of the world's total output-maybe as much as 5% considering Michigan's and Illinois economy. If forward-looking, well-educated citizens from Wisconsin Michigan and Indiana and Minnesota won't lead, then who? If automotive and utility strongholds like Chicago and Ohio and Detroit won't lead, then who?

Our group released our report this spring at the Minnesota Science Teachers annual convention, and we have spent time talking to middle school children about the problem. When they ask me why I spend time in schools, instead of talking to adults, I give them three reasons: first, adults are too busy working, paying bills and raising children to focus on this-they should study it themselves and explain it to their parents, I tell them. Second, adults sense that things will be as they have been, and they have a hard time imagining the changing climate is upon us, and that we have an option to reduce its impact by early action. Kids, on the other hand, have great imaginations and can easily envision switching to cars and power plants that don't pollute. Lastly, I tell them that the problem will be more theirs than ours. I quote them Tom Karl, now head of the National Climatic Data Center – where by the way, you can get the "best of the best" data sets for temperature changes at various sites in your state. Tom Karl says: "If you look out your window, part of what you see in terms of weather is produced by ourselves. If you look out the window fifty years from now, we're going to be responsible for more of it." When I ask them why we called our report ***Playing with Fire***, they are silent for a minute. Then they offer that global warming is mostly caused by burning fossil fuels – and that this is a very risky time. I remind them that playing with fire can quickly get out of control in surprising and unexpected ways.

GETTING ADDITIONAL INFORMATION

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Some important questions for climate impact assessment are: How does current climate affect human and natural activities? How will climate change impact human and natural systems? What are the linkages between climate and a particular activity, or climate and an area? What are the sensitivities? What are the vulnerabilities? Are there significant thresholds? How do we adapt to the current climate – its variability and extremes and how we might adapt or respond to future climate change?

The climate change issue is exceedingly complex. There are many information needs. In our group (Adaptation and Impacts Research Group formerly Environmental Adaptation Research Group), we focus on *direct impact*s of climate change but there is also value in considering *indirect impact*s. The challenges are identifying the problems/impacts and developing solutions-adaptation. In terms of adapting and assessing our vulnerability to climate, we need to consider impacts of climate change, extreme events, and the cost of the "normal" climate (e.g., water resources management and planning is a cost of adapting to our current climate). Adaptation can become a maladaptation; one of our researchers described how crop insurance may impede adapting to climate variability in agriculture. By studying the impact of a 2 x CO_2 scenario, we identify the costs of the future climate, and how we could adapt. Since countries are having difficulties reducing their emissions and concentrations of greenhouse gases continue to increase, we should assess the impacts of 3 x and 4 x CO_2 .

In the remainder of my presentation, I will outline information needs on themes relevant to the discussion at this workshop. I will draw upon my experiences from the *Great Lakes – St. Lawrence Basin Project* and the *Canada County Study*.

Scenarios. Consider temperature and precipitation changes in the Great Lakes basin. The current climate change scenarios from GCMs (General Circulation Models) do not incorporate the aerosol influence. Some people think that global warming is not occurring in the Great Lakes area because there has been little measured temperature change (approximately 0.5 ºC). But the warming within our region in the short term may be masked due to cooling by sulfate aerosols.

We use climate change scenarios as plausible futures or "what if " conditions. We provide this information on the Great Lakes basin to give some boundaries for planning and to illustrate the seriousness of the issue. Scenarios are not predictions. But consider: "what if" temperature within this region increased 4-9 ºC in the winter? "What if" in the summer, it went up 4-6 ºC? "What if" precipitation went down by 10% or up by 20%? For the Great Lakes-St. Lawrence basin, the scenarios indicate an increase in temperature but precipitation change is variable.

Assessment Design

In the *Great Lakes-St. Lawrence Basin* (GLSLB) *Project,* we used a matrix (Figure 1) as a framework to guide the content of studies and their integration. We chose four *climate sensitive theme* areas – water use and management, ecosystem health, human health, and land use and management. The studies were also to address key *cross-cutting research topics*: climate and biophysical systems or impacts, socioeconomic impacts, adaptation, and also

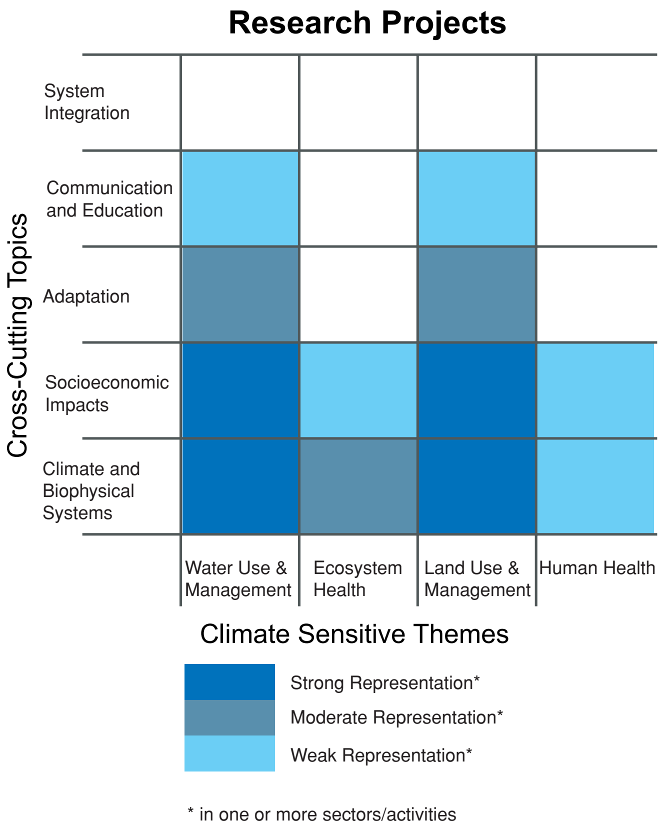


Figure 1: Great Lakes-St. Lawrence Basin Project research matrix. The cross-cutting research topics are identified by rows (e.g., System Integration, Communication & Education, Socioeconomic impacts, etc.)

communication and education. The color graph (Figure 1) shows that in some theme areas these topics were better integrated than in others. Water use and management and land use and management have a long history of being sensitive and vulnerable to climate, and the assessments are more advanced. Ecosystem health is next, and human health is an assessment area that is in its infancy (we had two studies). One key gap was that we do not have a good understanding of urban impacts of climate change. We did not address that particularly well in our Project.

What were some of the objectives of our assessment? We wanted to identify "no regrets" strategies. I guess, in a sense, it is hedging the uncertainty with respect to the scenarios for future climate. What adaptation strategies make sense now, in terms of addressing climate variability and climate change and other known environmental problems and make sense irrespective of how much the climate changes? We wanted to express the impacts in simple terms, so that we could work with decision makers and policy makers. We wanted to highlight social, economic, and political impacts, develop some vulnerability indices (we did not do that very well), and also provide some guidance on the divergence of information. For example, Great Lakes lake levels were recently at an all-time high, and our scenarios suggest water levels might drop 20 cm-2.5 m. One question that emerged frequently in our impact discussions was "what are the impacts of extreme events?" We need methods for developing scenarios to address that particular problem.

Water Resources. In the *Canada Country Study* and in the *Great Lakes – St. Lawrence Basin Project* one of the water resources issues that was considered critical was groundwater – the bottom line is we do not know very much about it. First, we do not have an inventory of how much groundwater is in the Great Lakes basin (at least, I am sure that is true for the Ontario side). Therefore, it is extremely difficult to assess the impacts. I know of one study in the Great Lakes region on ground water impacts of climate change scenarios (Grand River Basin in Ontario). There is a new study characterizing the regional ground water hydrology for southwestern Ontario to assess climate change impacts – the results will be extremely interesting.

Some of the information requirements that emerged from the 1997 Symposium on "Adapting to climate change and variability in the Great Lakes – St. Lawrence Basin" were integrating water quantity studies with water quality studies, and integrating these results into policies such as the Great Lakes Water Quality Agreement. Other questions relate to adaptation – how do we respond to climate change? How do we better conserve water? How do we value water more appropriately?

Land and Water Ecology. Ecosystem characteristics and functioning – how might they be affected by climate change? Consider climate change interacting with other air issues such as acidification. A study reported that pH levels in small lakes in the Dorset area, north of Toronto, were recovering because of reductions in sulfur dioxide and then pH remained constant – this is [likely] tied to drought effects.

Exotics and Their Effects on Native Species are an Important Issue

In the Great Lakes basin protection, remediation, and restoration of habitat is important. The case that I am familiar with is wetlands. We want to protect, remediate, and restore existing wetlands and to secure more wetlands. But what are the impacts of climate change on hydrology, water level changes, and precipitation and how will these changes affect wetlands and our success at remediation?

Boreal forests [may] decline in certain areas. Why? How? What are the impacts of droughts and fires? [These are] Extremely important [questions].

Agriculture. Mike Brklacich (who was a lead author for the Agricultural Chapter in the *Canada Country Study*) reviewed climate change and agriculture research in Canada. He found that we have done a fair amount of assessment on agro-climatic properties, (e.g., the number of freeze-free days, growing-degree days, etc.) and what climate change means to those agro-climatic properties in the Great Lakes region. We have looked at productivity changes for individual crops and land, in certain regions of Canada, such as Ontario. Also, grain crops such as corn and wheat, are better understood than specialty crops, like potatoes. Brklacich recommends studying the indirect impacts of climate change on international agriculture on Canadian agriculture e.g., Russia's production of grain potentially increasing and changing patterns of migration affecting demand for food. How does climate change affect international agricultural economics and the competitive advantage or disadvantage of a particular region? He also talks about mitigation and adaptation, preventing climate change by using cropping and tillage practices to enhance CO_2 uptake, and coping mechanisms to deal with the impacts of climate change. There is the issue of what climate change means to agricultural economics at the farm level, individual farm-level decision making, and the farmers' bottom line, and how this translates to the economy within a region, and also within a country.

Human Health. The topic of human health within our Project was addressed in a limited fashion. We looked at the incidence of heat stress and the potential for malaria in Toronto. I think human health is an extremely important theme because it can make climate change "personal." Important policy changes may be made, if it means protecting human health. Research on human health effects should explore the relationship between warmer air temperatures and potential increase in air pollution such as smog in Windsor and other areas, and trends in extreme events (e.g., storm tracks, heat waves, storms, and floods). Another area that should receive attention is [evaluating] what are the risks of infectious diseases for a particular region? For example, the risk of malaria increases for the Toronto region, because of favourable temperature conditions for certain mosquitoes. This is a potential stress on the health care system and we need to examine ways to respond to that risk. We need case studies on the health and well being of people – the physical and psychological health – in response to extreme events such as heat waves, floods, etc.

Economy & Commerce. Some of the questions that emerged from discussions in the

GLSLB Project were: What are the costs of impacts? What are the costs of adaptation? For example, in agriculture, farmers can adapt, but we need to assess the "costs" of adaptation in terms of money, technology, new research efforts as well as the best timing for adaptive measures. How do the costs of adaptation compare from one region to another? What are the costs to take advantage of opportunities? What activities might we lose because of climate change? Historical analogues, such as the 1988 drought, provide information on past extreme events, the economic impacts, and how people responded.

One study for the GLSLB Project, assessed the economic impact of two climate change scenarios. Impacts were represented by productivity changes in agriculture, forestry, fishery, hydro-electricity generation and commercial navigation (about 10% of the Ontario economy by employment) in an Input-Output Model, called LINK. The "net" impact on the Ontario economy was assessed. One scenario showed a very small positive gain, and the other showed a small negative impact on the economy. "Net" economic impact fails to represent the distributive effects; one number does not present which regions have gains, which regions will be affected, and how that will play out in the policy and the decision making for Ontario. This method has to be used carefully.

Another area that needs serious consideration is economic tools that we can use to promote adapting to impacts of climate change, such as conservation of water or energy.

Governance. There are significant governance issues in the Great Lakes – St. Lawrence Basin on water apportionment, for example. The Niagara River Treaty involves apportioning water between Canada and the US for hydroelectric generation and tourism to maintain sufficient flow over Niagara Falls. This treaty may be re-negotiated soon.

Lakes Superior and Ontario are regulated. For example, Lake Ontario is regulated to maintain water levels for navigation, recreation, hydroelectric generation and to prevent shoreline erosion. We have the potential for upstream and downstream conflicts. If you have significantly lower water levels in Lake Ontario because of climate change, studies indicate that the regulation plan fails. The issue becomes how to effectively regulate to maintain lake levels within Lake Ontario and to meet minimum flow targets for hydroelectric generating needs and levels for Port of Montreal navigation. What are the economic impacts to the Port of Montreal if flow in the St. Lawrence River decreases 20-40%?

Through the Great Lakes Water Quality Agreement, 43 areas of concern (AOCs) have been identified within the Great Lakes. These areas need remediation to enhance and bring back beneficial uses. The Remedial Action Plans (RAPs) for the 43 AOCs have not considered climate variability or potential climate change. We are assessing the impact of climate change in one RAP by studying the Bay of Quinte watershed. Lakewide Management Plans (LAMPs) are being developed for the Great Lakes – they are starting to consider climate change, which is of great interest to me.

One of the questions that came out of the 1997 symposium was "Are there any adaptations that could be harmonized on a bilateral basis … or a strategy for integrated adaptation?"

Communication. Communication has repeatedly emerged as an important need. In the early 1980s, communication and climate change were not issues – and now they are very important. We realize that we need to build stakeholder participation and public awareness, understanding, and (hopefully) action into climate impact assessment.

We need to communicate our probabilistic data more effectively. The general public and many stakeholders do not understand our science in terms of probabilities and uncertainties. People want information on what is known and what is certain about climate change. Scientists always talk about uncertainties. Barry Smit illustrated a communication problem. "We scientists talk in terms of mean climate change such as temperature …." Perhaps some of the problem in communication is that we are not using the right words to talk to our stakeholders. For instance, when talking to people in the wine industry in southern Ontario, we might refer to "the mean temperature in winter." What we really should say to them is, "your ice wine industry – the one you rely on for freezing temperatures … Actually, no other conditions in the world are quite as good for ice wines …The conditions may no longer occur because of climate change." You would have their attention because you are talking about something to which they can relate.

I think that it is encouraging to have the climate change research agenda driven in partnership with stakeholders. A successful strategy is local stakeholder forums within, for example, watersheds. One of the studies in the GLSLB Project approached farmers' groups in Quebec and held forums and outreach sessions with the farmers, to get feedback and help answer their questions on climate change impacts and adaptation.

Adaptation. Once some of the impacts have been identified – we have to think about how we are going to cope with climate change. We need to define operationally what we mean by adaptation and maladaptation. What is the process of adaptation? What do you have to do to adapt? What are the costs? A schematic (Figure 2) by Burton et al., 1993 identifies potential adaptation strategies. *Share the loss.* Use insurance. *Bear the loss.* If you build in a flood plain and it floods, you are on your own. *Modify the events. Prevent the effects.* Use structural, technological innovation, and legislative, regulatory, financial, institutional, administrative changes, market-based incentives, and changes in on-site operations. *Research.* Consider *education* and promoting *behavioral change. Avoid the impacts.* Some adaptations to consider are changing your use or your location.

Why adapt? Climate is not constant. It has a range of conditions and it creates uncertainty. So, adaptation is a way of responding to the uncertainty in our information. We have both opportunities and risks that we should consider. Think about how you might respond – do not necessarily respond –

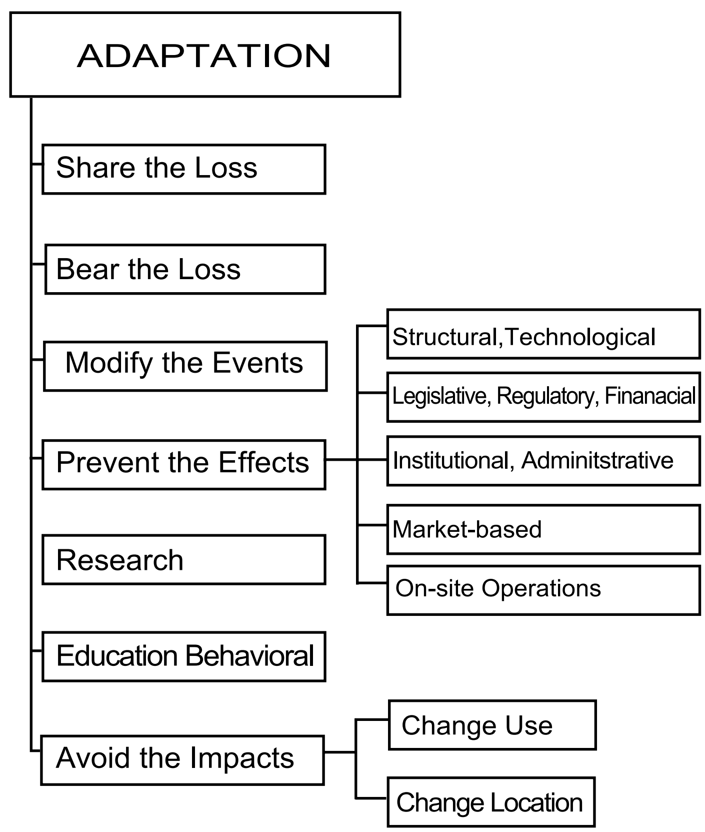


Figure 2: A conceptual framework of adaptation. Source: adapted from Burton et al., 1993.

but at least think about climate change impacts and adaptation in a proactive manner. Also, our experiences are based on past climate, and it may not be a reliable guide in the future.

Advances in Methodology. What do you need to do? Some ideas for innovation are listed in Figure 3. The current studies portion lists what we tried to accomplish in the Great Lakes-St. Lawrence Basin Project as well as other studies in Canada. Impacts in sectors need to be integrated. For example, agriculture researchers should talk to the water resources people. We are starting to make those linkages and beginning to integrate on a cross-sectoral basis.

In most cases, we have always used 2 x CO_2 equilibrium scenarios which is an artifact of the modelling exercise. We need to address current climate variability and what it means. We also need to get a better picture of 2 x CO_2 and beyond to 3 x CO_2 and 4 x CO_2. This is necessary, because people will get the impression that the changing climate is going to stop at 2 x CO_2 and it will not. The Intergovernmental Panel on Climate Change (IPCC) has identified a number of GCM scenarios that will be available to impacts researchers around the world for the next assessment (on a web site). There will be three or four model results available, which will lead to some continuity in scenario use.

[In past climate impact assessments, we have assumed that] Everything-else-remains-equal (EERE) – society, economy, technology – and that climate change is imposed in the future on a region, a sector, an activity that has remained the same. We need social and economic scenarios that [do not] simply acknowledge an increase in population in a region, but include an increase in a demand for water, a change in technology and perhaps chart a different development paradigm. In the past we have focused on the biophysical impacts. We still do. That is the closest link, the most obvious and the easiest link to climate – but we have to develop methods to analyze the economic, social and policy implications as well.

New Directions for Impact Assessment Methodology

Current Studies	New
Sectoral →	**Integrated**
2 X CO_2 Equilibrium →	Present climate and transient scenarios
2 X CO_2 Conditions →	Beyond 2 X CO_2 to 3x & 4x CO_2
EERE →	Socioeconomic Scenarios
Biophysical Analysis →	Economic, Social, Policy Analysis
Adaptation →	Maladaptation
Direct Impacts Only →	Indirect Impacts from Elsewhere
No Stakeholders →	Stakeholder Participation
Negative Impacts & Risks →	Benefits & Opportunities

Figure 3: New directions for climate change impact assessment methodology.

In the GLSLB Project, we initiated research on adaptation. We also have to think about maladaptation. A recent research proposal for the Prairies of Canada described adaptation to drought only in terms of technology and finding new supplies of groundwater to augment irrigation for agriculture. We need to think more broadly than that and consider institutional and behavioural changes.

In the past we have looked only at direct impacts – an impact on a region, an activity – we need to consider indirect impacts from outside our region.

We need to include stakeholders (e.g., Sierra Club). They make valid contributions on identifying research needs and communicating impacts and adaptation.

We have always focused on negative impacts and only the risks. In some instances, like a study in the Arctic for the oil industry on decreasing in ice cover and potential increase in storm surge, the stakeholder only wanted information on the negative impacts so they could respond. But I think we have to acknowledge that there may be some benefits and opportunities to climate change and position ourselves to take advantage of those conditions.

In conclusion, part of the role of our impacts work is to help decision makers, policy makers, and the public to pay attention to the climate change issue and help them plan for the future. Use this goal to help guide future research.

GLOBAL CLIMATE CHANGE: A BUSINESS MODEL APPROACH

Charles B. Kitz
Chrysler Corporation, Allen Park, Michigan

You've probably heard there are some pretty spectacular things going on outside in the world where Chrysler is allegedly going through a cooperative agreement with Mercedes-Benz. I can tell you this much — there definitely are negotiations going on. We have not concluded anything, and even if we do, we still have to get through our boards and our stockholders and all the other things we have to do, and I don't know any more about it frankly than you do, but this has been kept pretty quiet, as you might guess, at the very highest echelons of the company.

But I do want to thank you for inviting me here, and I've been invited to bring a business perspective to this workshop today. I hope that it will complement the perspectives that you've already taken from government, science and academia, and I appreciate the opportunity to present our side of how we should go up into a global climate issue. Now each of our disciplines here takes a different approach. This approach is probably similar to the one that many of you use to make decisions yourself. It includes several steps.

First, you define the issue — that is, you look at it from all sides and gather information. Secondly, you find the root cause and what brought this issue to the forefront in the first place. Thirdly, identify the time constraints — in other words, how much time do you have to make a proper decision to deal with the issue. Then develop alternative responses, and, of course, weigh these alternatives in terms of costs and benefits. And lastly, you bring it all together and recommend a course of action.

Now then I'd like to lay out the decision-making process from a business standpoint. I'd also like to apply it to the issue we're all here to discuss. When addressing serious questions like global climate, we tend to fall back on things with which we're familiar to deal with it. In the case of business, we take a process approach to decision-making, and let me show you what I mean. The first issue is defining the global climate change and what it may mean. I know that all of you are very familiar with this issue, so I won't go into a lot of detail, but let's just summarize it very quickly.

This is a chart (Figure 1) I'm sure all of you have seen in one form or another — world temperature records over the last 150,000 years. The data of course are based on ice core samples from Greenland and Antarctica. And, as you can see, there's a small correlation between the

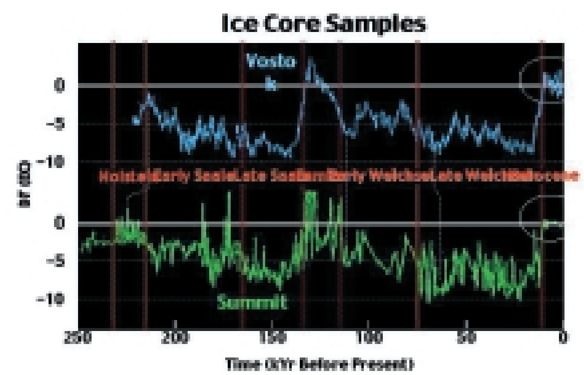
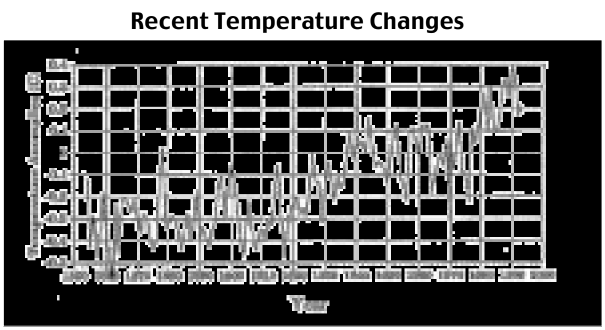


Figure 1: World temperatures over the past 150,000 years, obtained from ice core samples.

temperature estimates from the two sources, and also there have been some pretty wild swings in each period, both in warming and cooling trends. I'd also like to point out the area on the far right of the chart, which is the most recent period. It shows the temperature swings have been generally less severe the past 100 years.

And here is a more detailed look at the most recent data (Figure 2). It shows that the earth's temperature has been gradually increasing just about a half a degree Centigrade or about one degree Fahrenheit from the late 1980s to the present. And you will also note that most of this increase occurred before 1940, and then there was a relative stable trend from 1940 to 1980 and then another rising and increase in temperature beginning after that. Other reputable studies from earth's satellites and weather balloons have shown a very slight decrease in temperature over the last 20 years, but I'm not here to debate the science with you – I think that's your job – let's just agree that there is sufficient cause for concern. Because this is a very complex subject, I think we all understand that much more needs to be learned and that the science is uncertain. In business when we face uncertainty what we tend to do is keep digging for more information, time permitting, of course. So we strongly endorse more objective research to help clarify the issue and understand it better. Now before you get upset, it doesn't mean we recommend doing nothing in the meanwhile. On the contrary, we are in the business to do things and to take action. I'll talk a little bit later, about what we are doing.



Source: Trends '93: A Compendium of Data on Global Change

Figure 2: Average temperature changes across the U.S. over the last 150 years.

But first let's move on to the second step in the decision-making process — what is the root cause of global climate change? This research has shown the key is the greenhouse effect. There's no doubt there is a greenhouse effect, and thank heavens there is one because without it temperatures on earth would be about 90 ˚F colder than they are on the average [now]. But what's the root cause of the greenhouse effect? It is, of course, all greenhouse gases in the atmosphere. I'm sure you know that water vapor makes up about 97% of those gases. I can just add as a side, I'm somewhat perplexed personally why nobody pays any attention to water vapor because it is the most abundant greenhouse gas and in fact human activity contributes significantly to water vapor as well. After all, we burn fossil fuel that has water vapor as a by-product. We spray water on crops and lawns, we build reservoirs that contribute to evaporation and so on. But it's the remaining 3% of greenhouse gases I understand on which all the attention is focused. And certainly of those 3%, carbon is the one that has generated the most concern in terms of the effect on climate.

Again, here is a chart (Figure 3), you are probably familiar with, which measures the increase of CO_2 concentration in Honolulu, Hawaii. Since 1960 the concentration has increased from about 310 parts per million to more than 360. Where it gets interesting is when scientists cor-

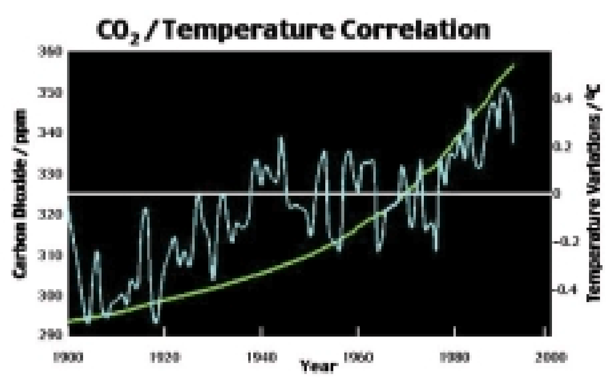


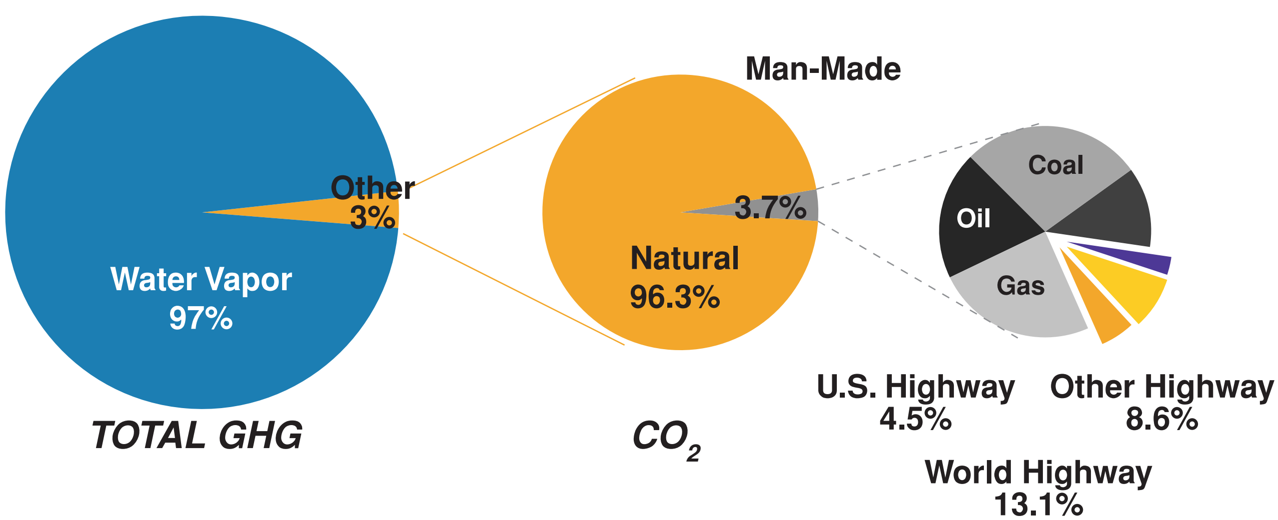
Figure 3: Trends in carbon dioxide (green curve) and surface temperature (blue curve) at Mauna Loa, Hawaii.

relate data like this with temperature data, and here's what it looks like. The rising CO_2 level does correlate broadly with the rise in global temperature levels. And to some scientists, it is more than a correlation – it is cause and effect. But by no means is that the only scientific correlation. Other scientists point to correlation between temperature and solar activity, ocean currents, aerosols, and other things. We know that all these things have an influence, but CO_2 is the one that is most talked about, and where does CO_2 come from?

Now, earlier we said that 3% of all greenhouse gases are not water vapor. The majority of that remaining 3% is comprised of CO_2, and of the CO_2, the majority comes from natural phenomena and only about 4% is man-made (Figure 4). If you multiply by 3.7%, man-made CO_2 accounts for about 0.12% of all the greenhouse gases. The argument of course is that even this small amount is enough to upset the balance of nature because CO_2 does accumulate in the atmosphere and it can be retained there for decades. And that influences the greenhouse effect. But then again, where is CO_2 coming from that is man-made?

Well, automobiles are often singled out as the major contributor to man-made CO_2, and the fact is cars and trucks are responsible for about 13% of all man-made CO_2, which we accept as our piece of the action and realize we have to do something about that. And we're working hard at that. But despite that, I want you to understand the point that even dramatic reductions in cars and trucks are not the sole bullet that's going to solve this problem alone. And even – it's interesting that even if every car and truck in the world were eliminated and not just became super fuel efficient, the total reduction in CO_2 would amount to less than one-half of 1%. In greenhouse gases altogether, if we go through the multiplication, it would be reduced by 0.0016.

So speaking as a representative of Chrysler, I'd like to make the point that autos are not the only



Eliminate all cars and trucks
- CO_2 reduction (13.1% X 3.7%) = 0.48%
- GHG reduction (13.1% X 3.7% X 3%) = 0.0016%

Figure 4: Breakdown of greenhouse gas contributions. Sources: IPCC, International Energy Agency, et. al.

• 20+ years before taking action results in approximately 0.2 ºC temperature increase over a 100 year period
– *Nature Magazine*

• "Delaying the implementation of emission controls for 10-20 years will have little effect on atmospheric concentrations"
– *US Congress Office of Technology Assessment*

or even the biggest culprit in the rise of carbon emissions worldwide. So we come back from the auto industry to the realization that while man-made CO_2 is an important contributor, other elements are also at work, and the root cause also needs more understanding. That's why we also support more research to help resolve these uncertainties. It's not an open-ended strategy, however, because despite the uncertainty, we understand that the clock is ticking and no one wants to see progress on this issue bogged down, especially if this timing becomes critical.

We know that the overall cast we have requires the U.S. to reduce greenhouse gases 7% below the 1990 baseline between 2008 and 2012, And what that means is more than a 30% reduction from what is called "business as usual" conditions. Is the timing contained in the Kyoto protocol reasonable?

In a recent article that appeared in *Nature magazine*, Research Unit in England concluded that waiting more than 20 years before taking action to limit man-made greenhouse gas emissions would result in about a 0.2 ºC temperature increase – but over a hundred year period. Now this confirmed an earlier statement by report from the U.S. Congress Office of Technical Development which said, and I quote, "delaying the implementation of emission controls for 10 to 20 years will have little effect on atmospheric concentrations." Now obviously different authorities have different interpretations of urgency, and I really don't want to get into that because I don't know what the resolution is, but they do seem to agree we can take some time to do this right without catastrophic effects. And I would add my observation that taking a bit more time to develop the right strategy is better than rushing into the wrong strategy.

But what is the right strategy? And that search begins the fourth step in our decision-making process to develop alternatives. Now in broad terms, business must develop alternatives or contingency plans to prepare for whatever outcome is possible. There are a couple of points that underline what our overriding philosophy is on global climate change. First, we believe that continuing development of advanced technologies is the best strategy. These technologies can permit sustainable development; that is, they can provide environmental benefits coincident with economic progress. And second, the timetable for these technologies cannot be artificially mandated. They will emerge as fast as market acceptance is achieved. And, believe me, the world auto-makers are aggressively engaged in a competitive race to be the first to bring advanced technologies to market because the first one that gets there is going to reap very huge rewards much like Chrysler did with our minivan. If you get to the market first, you've got a tremendous leg up on your competitors. But a critical element is to develop advanced technologies that people will want to buy and in fact can afford to buy because it's important that if nobody buys these, there will be no environmental benefit. We've seen that, for example, and what we'd like to avoid is a situation that's comparable to the current electric vehicle mandates, where automobile makers were forced to build vehicles and nobody bought them because they simply aren't acceptable yet. They have the technology problems, they have the cost problem, and until we fix those, they are not going to be bought in great numbers. So that's our overall philosophy.

Now let me take a look at some specifics in terms of facilities and in terms of our vehicles, and I'll use Chrysler examples. Regarding our production facilities, Chrysler's total energy consumption (Figure 5) from our plants breaks down – it is shown on the left of this line. We use 58% natural gas, 35% electricity, with the rest – it's pretty small – divided among the coal, coke, and oil in our facilities to produce cars. On the right-hand side you will see how much CO_2 results from this first commitment. Electricity accounts for almost two-thirds of the total, and natural gas about one-third.

Now we have no control over the CO_2 emissions that come from electric utilities, so the electricity part of this is not our piece of the action. Where we do have control is by moving away from coal and oil fired boilers and increasing the use of cleaner burning natural gas which we at Chrysler have pursued very aggressively already. But while we have made progress regarding the type of fuel we use, we now need to better control the amount of fuel that we use. That's because almost all of the fuel that we use is for heating our plants, many of which are in the northern temperate zones. Simply packing up our facilities and moving to the tropics is not an option. That would be socially and economically untenable. Besides, there are more promising alternatives we can use to save fuel that we are investigating.

Key amounts goes, for example, a great deal of our fuel used goes towards running our paint shops which require a lot of air transfer. The simple solution is to reduce the amount of air going through these shops that doesn't have to be heated, and that is what we are attempting to do with something called the powder paint process. In conjunction with GM - Ford and paint suppliers we're developing new paint material and processes that require fewer air exchanges and create fewer emissions, that contribute to ozone formation. And that's because these powder paints simply bond magnetically to the sheet metal and they don't require spraying.

Turning now to our on-road vehicle programs, most of our advanced technology developments are within the Partnership for a New Generation Vehicle or **PNGV**, as you probably are familiar with. This is a government-industry relationship, which has a target to achieve up to 80 miles per gallon in fuel economy in the mid-sized sedans. We are developing both alternative power trains and alternative materials to lead us to this goal.

Let me show you some examples of each. Here's our EPIC (see photo on next page), which stands for Electrically Powered Interurban Commuter. It's our minivan. We've already placed these in government service and more will be available this fall. And very soon we'll fit these mini-vans with advanced *electro-metal* high-drive batteries for longer range and useful life.

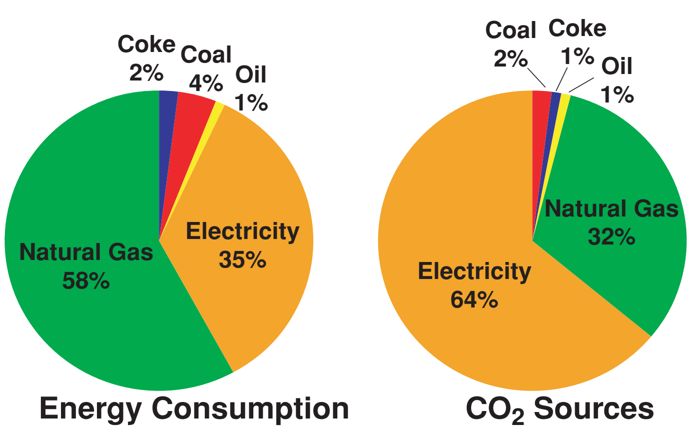


Figure 5: Chrysler energy consumption breakdown for Chrysler's production facilities. Source: Chrysler Corporation.

This is a Dodge Intrepid ESX2. It's a hybrid vehicle. We introduced this at the North American auto show in Detroit last January. This vehicle is a second-generation hybrid in development at Chrysler. It's termed a hybrid because it uses both a small diesel engine and an electric motor, whose batteries are charged on the fly by the diesel engine. It could get up to 70 miles per gallon, but with comparable room and cargo space as the Intrepid that we sell today.

In the more distant future, a ways away yet from the commercialization, is the advanced fuel cell that we are developing. It uses hydrogen extracted from gasoline to produce enough electricity to power the car. And although fuel cells can also create hydrogen from methanol — a lot of other manufacturers are pursuing methanol — Chrysler is interested in gasoline-based technology because the fuel infrastructure is already in place across the country, which makes it more attractive to people who will determine the success of any fuel cell powered vehicle — once again it's the customer. Somewhat less revolutionary powertrain developments include the Compression Ignition Direct Injection or CIDI engine with a continuously variable transmission. Developments like these and others are showing great promise of fuel efficiencies, and these will be available in the near term.

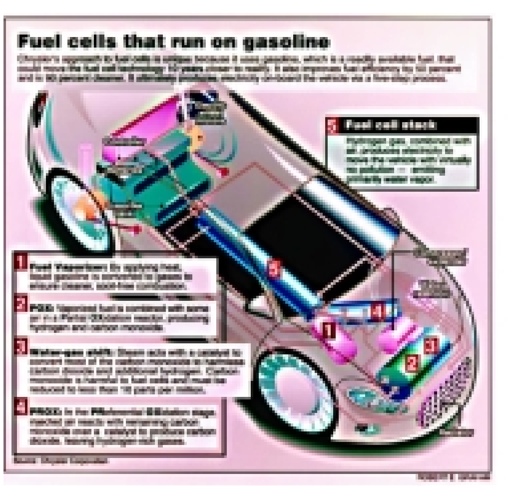


Figure 6: Schematic of Chrysler implemented technology for gasoline-powered fuel cell vehicles.

Next I'd like to show you briefly a few examples of our work in advanced development materials. As many of you know, this is our production street rod, the Plymouth Prowler (see photo below), which went on sale last year. While it is mostly known for its retro design, the Prowler is also noteworthy for its use of alternative materials and production processes. It has a frame and body of primary aluminum while magnesium composites of plastics also play important structural roles. This is a learning tested for aluminum intense vehicle with a very limited production time. We are hopeful the lessons we learn here will transfer to a large-scale production vehicle, because, after all, why wait to use better fuel economy. Our work on advanced materials for volume production cars and trucks also began but they're not right for sports cars shown on the left. With the Viper we learned that large-scale composite molding is something

we can do. We've taken that work to a much higher level with our Chrysler Composite Vehicle or CCV that is shown on the right. Interestingly, the CCVs entire body is molded out of just four parts and is joined with fasteners and adhesives. And by the way, it's molded from a plastic resin similar to what soda pop bottles are made from. All in all we are not sure which of these technologies will provide the proper mix of vehicle attributes, and the affordability to achieve market acceptance. We can build these products, but to realize environmental progress, people have to buy them. And technological breakthroughs don't happen according to a predetermined schedule, so it's impossible to predict when we would be able to sell them in quantity.

However, I can predict that it's unlikely that Chrysler or any other automaker will be able to meet a 30% reduction in CO_2 emissions by the period from 2008 to 2012 as mandated by the Kyoto protocol. Now why is that? Well, first of all, they're not in production. And it also takes years to develop And test these new revolutionary technologies. It also takes years to convert our facilities. But most important of all is the issue of how long it takes to change what's already on the road. This line shows total new versus used vehicles in use in the U.S. in 1997. As you can see, only 7% are new purchases. Chrysler contributed only 1% of that, and 93% were used cars and trucks. So what I'm suggesting is that even if the auto industry already had all these technologies – which it doesn't – and even if we converted all of our facilities to that technology today – which we haven't – it would still not be able to meet the Kyoto objective because it takes 15 to 20 years to turn over all the fleet of used vehicles making an impact on the air.

That's not to say we're not doing anything, but what we're trying to say is even if we do all this stuff, don't count on it making a big contribution to CO_2 reduction by the time period of the Kyoto protocol. And, of course, to achieve a 30% reduction in the short term, what will probably be needed are draconian measures to force reduced usage or people's vehicle miles traveled through measures such as gas rationing or advanced price increases, neither of which are very politically attractive. And of course it's likely that the economic impact of more than a 30% forced reduction under the Kyoto Treaty will go far beyond fuel prices.

Charles Rivers and Associates, a respected economic analysis firm, estimated these effects on the Great Lakes States that we're talking about

Economic Impact of Return to 1990 Greenhouse Gas Level (2010)

	Gross State Product	Jobs (000)	Avg. Income
Michigan	-0.7%	-44	-3.0%
Wisconsin	-0.7	-33	-3.1
Minnesota	-0.9	-25	-2.9
Illinois	-0.9	-59	-3.2
Indiana	-0.6	-44	-3.8
Ohio	-0.6	-60	-3.3
Region Effect	**-0.7%**	**-265**	**-3.2%**

Source: Charles River Associates (1997)

here on this stage – if carbon dioxide emissions simply had to equal 1990 levels by the year 2008 to 2012 – this was done prior to Kyoto, and of course Kyoto is now 7% below stabilization levels, so it makes it even tougher. That would mean there would be across the board declines in gross state profits as well as declines in number of jobs and therefore in income.

The bottom line of all this is that even if the U.S. and all developed countries in the world obligated to reduce CO_2 by the protocol achieved the objectives in the prescribed timetable, worldwide CO_2 would still increase 32%, and that's not my estimate – that's from the U.S. Energy Information Administration.

Now why is that? It's simply because all developing countries, as you know, have no obligation to the Kyoto protocol, and their emissions of greenhouse gases are increasing faster than the developed world. So the developed world could go through all the suffering and economic pain, and little environmental progress would accrue.

In summary, let me say that Chrysler shares concerns expressed by many that the global climate could affect future generations and accordingly we support actions to understand science better. We also believe that access to the most advanced technologies and voluntary implementation in the competitive marketplace are the best responses to this environmental challenge. But we do recognize that no environmental benefit will be realized unless we insure that our technology meet buyer needs and all bases contribute to a global solution. And finally in our judgment, implementation timetables are unnecessarily aggressive, and it would seem prudent to take the time to do it right.

COPING WITH CLIMATE CHANGE

Joel D. Scheraga*
U.S. Environmental Protection Agency
Washington, DC

This talk is about adaptation to climate change. It argues that adaptation is an important strategy for protecting human health, ecosystems, and economic activity as the climate changes. Adaptation is an essential component of any portfolio of actions that comprise U.S. climate change policy.

Several key questions are addressed. First, why should policymakers consider adaptation as one component of a comprehensive response to climate change? Second, how much adaptation is enough? Third, what factors must decision makers consider as they design adaptive strategies to ensure that they are effective?

The paper concludes with a cautionary note that adaptation is not a panacea. It should not be the only strategy considered for the reduction of risks posed by climate change. Adaptation comes at a cost and society has limited resources to devote to this activity. Also, there are uncertainties associated with the effectiveness of any adaptive response. Any portfolio of climate change policies should consist of a mix of both adaptation and mitigation strategies.

Why Adaptation?

The climate system is dynamic. The climate has changed, is changing, and will continue to change in the future. The ongoing changes in climate pose risks to human health, ecosystems, and economic activity. They also present opportunities. The ultimate objective of climate policy should be to reduce the risks and exploit the opportunities. Adaptation is one mechanism for meeting this objective.

Some of the observed changes in climate are natural and some are human induced. We cannot yet say how much of an influence humans are having on the climate system, but we know that humans are making a difference. For this reason, the international community signed the Framework Convention on Climate Change in 1992. Article 2 of the Convention states that the ultimate objective of the Convention is:

> "...to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

The Framework Convention only focuses on the mitigation of greenhouse gas emissions which will yield benefits in the future. However, the ongoing changes in climate already are having real impacts on ecosystems and society. If the ultimate goal of climate policy is to protect human health, ecosystem health, and economic activity, then adaptation must also be considered as a policy response. In contrast to mitigation, adaptive responses can yield immediate benefits in the form of reduced risks and new opportunities. Also, since emissions of greenhouse gases affect the climate system with a lag, past emissions from human activities have already committed us to some future warming. Some human-induced climate change will occur, providing a further motivation to adapt now in anticipation of future changes.

How Much Adaptation is Enough?

Adaptation is an insurance policy. Only finite amounts of insurance can be bought, since it has a cost associated with it. How much is bought depends on the resources available to society, competing priorities, and the level of risk that is deemed acceptable.

The concept of "adaptation as insurance" is a useful one. When people contemplate spending resources on investments to deal with uncertain future climate outcomes, they sometimes ask, "What if we guess wrong?" But uncertainty is at the heart of risk and insurance. A person buys car insurance even though it is uncertain whether she will have a car accident. In fact, most people hope to avoid any accidents. I will venture to say that when a person "guesses wrong" by buying car insurance, but does not have an accident, she is not upset that an accident did not occur. She understands the value of having purchased the insurance, and continues to do so in the future.

Only society can decide how much adaptation is enough. The timing and magnitude of the investment in adaptation depends on how much risk society is willing to accept.

It is interesting to note that the Framework Convention does not attempt to define a level of acceptable risk. Although the Framework Convention refers to the concept of "dangerous anthropogenic interference," it is not explicitly defined. This omission is intentional. Science can identify the mechanisms by which changes in atmospheric concentrations of greenhouse gases may lead to climate change, and identify the risks and opportunities associated with changes in climate. But science cannot make the value-laden judgement of what level of risk is acceptable to society. That decision must be left to policymakers.

Things to Consider When Designing Adaptation Strategies

There are a number of factors that decision makers should consider as they design and implement adaptation strategies:

(1) Adaptation must target both the positive and negative consequences of climate change. Adaptation refers to more than risk reduction. It also refers to the exploitation of opportunities. If the ultimate goal of climate policy is to improve public health, ecosystem health, and social well being (including economic growth), then decision makers must invest scarce resources to exploit the opportunities as well as to reduce the risks. Most regions will be faced with a mix of risks and opportunities.

(2) Adaptation comes at a cost. The scarce resources that society uses to adapt to a changing climate must be diverted from other productive activities. The additional resources that will be needed to protect the elderly and very young from heat stress during more frequent heat waves in a future climate could be used for alternative purposes. Society has limited resources to devote to adaptation, and decision makers should ensure that the expected net benefits (*i.e.,* the benefits minus the costs) are positive. Also, the effects of climate change must be considered in the context of other stresses. Resources that are used to adapt to climate change could be used to reduce other stresses on human health, ecosystems, and economic systems.

Society either can delay investing in adaptation and react to changes in climate as they occur (*reactionary adaptation*), or it can anticipate future change and invest in adaptation now (*anticipatory adaptation*). In either case, there is a cost associated with adaptation. It is a question of when the costs are incurred and what they buy. The decision of whether to adapt now or later should be based on a comparison of the present value of expected net benefits associated with acting sooner versus later.

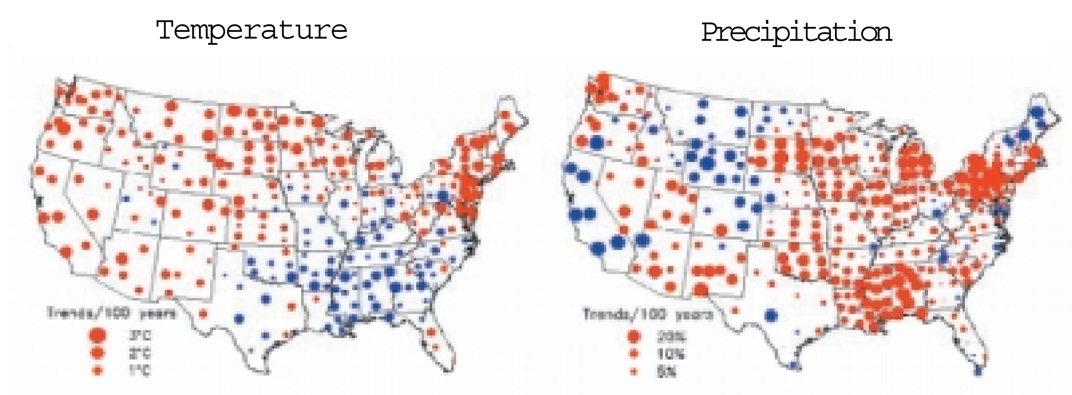
(3) Climate change will have distributional effects across people and places. Figure 1 depicts the changes in average temperature and precipitation that have occurred across the United States during the last one hundred years. There is a regional texture to the changes. The changes that occurred in the Great Lakes region are different than those in the Southeast. In some parts of the country, temperature and precipitation increased, and in other locations they decreased. The regional differences must be considered as one designs adaptive responses since the resulting impacts will be site specific. Strategies that may be effective in California may not be effective in Michigan.

Also, different groups of individuals will have different levels of vulnerability to climate change, because of different physical characteristics (*e.g.,* age, infirmities), and differences in socioeconomic status (*e.g.,* income). The design of adaptive strategies should be tailored to the vulnerable demographic groups. For example, the elderly and very young are most vulnerable to heat stress, and adaptive responses have to be targeted to their needs.

(4) It is important to characterize the mechanisms by which impacts may occur. It is not enough to identify the potential consequences that climate change may have for a particular physical or human system. The mechanisms by which the impacts may occur must be understood to ensure the effectiveness of adaptation.

Consider, for example, how farmers might adapt to the expected increase in rainfall that will accompany a warmer world. If they anticipate that the precipitation will occur as light, steady rainfall events, then they might shift to alternative types of crops that do better in wetter weather. However, if they anticipate that the intensity of rainfall will consistently increase over time, they may choose different planting and tilling practices. In fact, a close examination of the historic data reveals that there has been a noticeable change in the character of precipitation events

Temperature and Precipitation Trends, 1900 to Present



Red circles reflect warming
Blue circles reflect cooling

Red circles reflect increasing precipitation
Blue circles reflect decreasing precipitation

Figure 1: Temperature and precipitation trends in the US. Source: Karl et al. (1996).

The graph in Figure 2 (from the National Climatic Data Center) shows that the percentage of area across the United States that has experienced extreme precipitation events – defined as greater than or equal to two inches per day – has increased. This change in character is an important consideration for farmers as they adapt to a changing climate.

(5) Climate change will have indirect effects, as well as direct effects. As decision makers prioritize possible investments in adaptation, they must make sure to consider the indirect effects of climate change. For example, climate change will have both direct and indirect effects on human health. The direct effects include the mortality and morbidity effects of weather extremes like heat waves. The indirect effects include outcomes that may be mediated through ecological changes that are caused by climate change, like the spread of infectious diseases. Depending on the geographic location under consideration and the characteristics of the vulnerable populations, the indirect effects may be as important, or more important, than the direct effects.

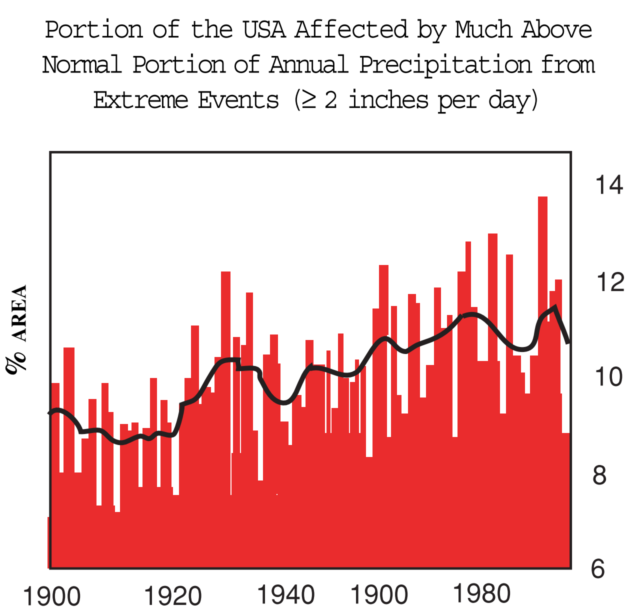


Figure 2: The change in the area of the US affected by increases in the proportional of total annual precipitation derived from extreme daily precipitation events (great than or equal to 2 inches per day).

(6) There are uncertainties associated with the effectiveness of any adaptive response. Policy makers should not assume that adaptation will be completely effective, as evidenced by the effectiveness of adaptive responses under current climatic conditions. People die of heat stress every year, even though society has the know-how and resources to prevent these deaths. If society is unable to prevent these deaths today, why should we assume that it will be any more effective preventing them tomorrow?

(7) Adaptation can have adverse impacts in addition to their intended effects. Beware of maladaptation. An adaptive response may have unintended secondary consequences that outweigh the benefits of undertaking the strategy. For example, pesticides that are used to eradicate mosquitoes that may carry infectious diseases (*e.g.,* dengue fever) may have their own adverse impacts on human health. These offsetting effects must be considered before the eradication program is implemented.

(8) Policies intended to adapt to future climate can increase the resiliency of systems to current climatic conditions. These are often termed "no regrets" strategies. For example, the elimination of federal flood insurance for new construction in flood plains will reduce the possibility of property damage under current climate, and increase the resiliency of infrastructure to more frequent floods in the future. Strategies like this have the attraction of yielding immediate benefits to society, as well as potential future benefits. They also may be less expensive than adaptive responses that would have to be undertaken in the future. And they might keep future options open.

The design and implementation of an effective adaptation strategy is not an easy undertaking. Policymakers should not be cavalier about the ease with which adaptation can be achieved, nor the expected effectiveness of any policies they implement.

The Consequences of Inaction

Figure 3 depicts the array of consequences that climate change may have if society doesn't adapt. Some of these effects are well understood, such as the implications of climate change for heat stress and deaths. In other cases, we have only begun to identify and understand the sensitivity of systems to weather and climate, and do not have any idea of what will be the effects of a changing climate.

The purpose of this section is to provide three examples of expected impacts to illustrate the types of considerations decision makers must make as they design adaptive responses.

Human Health

The potential consequences of climate change for human health are receiving increased attention as they are becoming better understood. Figure 4 illustrates an array of health effects that may be influenced by a changing climate through a variety of pathways. The effects that are influenced through more direct pathways include death due to heat stress, and the impacts of extreme weather events like floods and storms. Health impacts that occur through more indirect pathways include those mediated through changes in ecosystems, such as vector-borne and water-borne infectious diseases.

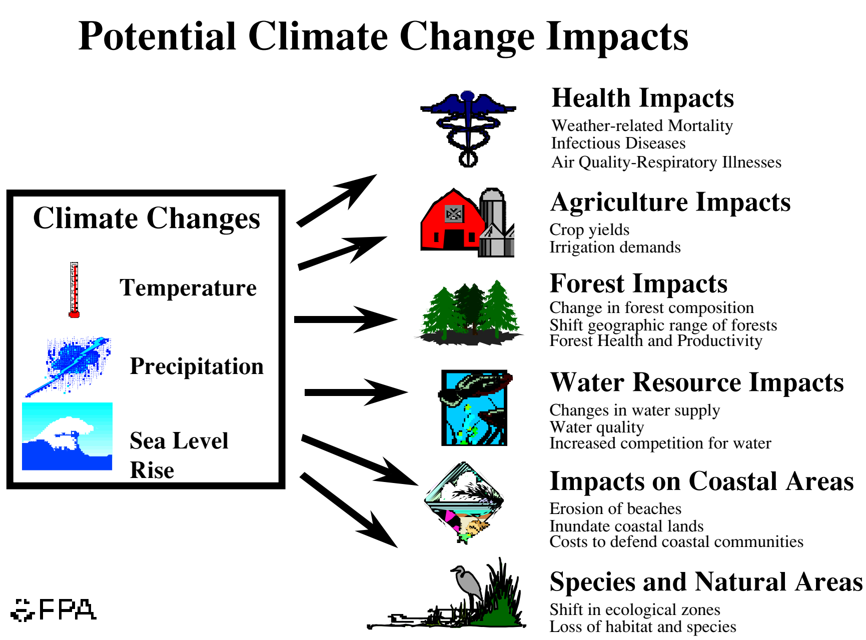


Figure 3: Potential climate change impacts; Source: US Enviornmental Protection Agency.

Indirect health effects also include those associated with changes in air quality and the quality of drinking water.

The direct effects of heat stress can be used to illustrate some of the factors that must be considered when designing an adaptive response. Climate change is expected to increase the frequency of summertime heat waves, and increase the risk of death due to heat stress. But a possible benefit might be a decline in the number of extremely cold days in wintertime, with an accompanying reduction in the number of wintertime deaths. (The potential magnitude of this positive wintertime effect is not well understood.)

Figure 4 depicts results of a study done by Kalkstein and Green to project potential increases in deaths due to heat stress in the years 2020 and 2050. The results for one scenario of future climate change, as well as data on actual recorded deaths in 1993, are shown.

It is known from the medical literature that the elderly, the very young, and people suffering with various illnesses tend to be the most vulnerable to heat stress. But Figure 5 also suggests that the impacts of climate change on human mortality are city-specific. There is a regional texture to the effects of heat stress. This may be due to a number of factors, such as differences in infrastructure, the extent to which people have physiologically adapted to extreme heat, air conditioning use, and the number of elderly and very young living in each city. The conclusion is that remedial actions must be city specific and targeted to specific populations within each city.

Average Annual Excess Weather-Related Mortality for 1993, 2020 and 2050 Climate

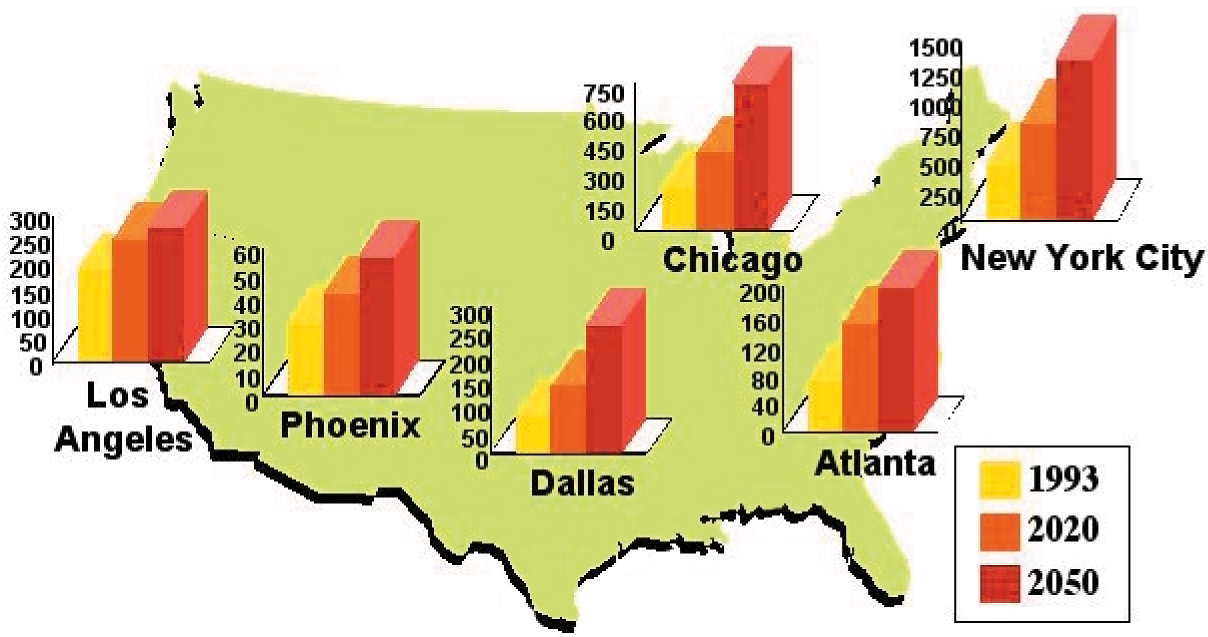


Figure 4: Average annual excess weather-related mortality for 1993, 2020 and 2050 climate based on GFDl climate change scenario. Note: Includes both summer and winter mortality. Assumes full acclimation to changed climate. Includes population growth.; *Sources: Kalkstein and Green (1997); Chestnut et al.(1995)*

Figure 4 also depicts the preventable deaths that occur each year under current climatic conditions. The people who died in 1993 from heat stress might have been saved if response strategies had been more effective. It is essential that policy makers discover the reasons for these deaths, so that more effective responses can be implemented in the future. For example, it is not enough to issue "heat wave alerts" over radio stations. In some cases (as in Chicago in 1995), the elderly may live in high crime areas and be afraid to open their windows or travel to air conditioned environments, even if they hear the alerts.

Adaptation during heat waves can be costly. It is expensive to run air conditioners, although many can afford it. However, the most vulnerable people, like the elderly, often are those least able to afford to use air conditioners. This problem can be overcome by implementing city emergency response programs. These programs might, for example, provide transportation for the elderly to air conditioned environments, or deliver water to people to avoid dehydration. These programs also come at a cost, but if they are successfully implemented, they will provide immediate benefits in the form of saved lives. They also will increase the resiliency of urban populations to future climate change.

Water Resources

Water is the "lynchpin" that integrates many regions and sectors. Water quantity and quality will be affected directly and indirectly by climate change. The development of strategies for adapting to these effects will be complex.

The cumulative effect of climate change on water supplies and water quality is complex and not easy to predict. As the climate changes, it is expected that precipitation will increase. The hydrologic cycle is expected to intensify, causing the world to become wetter. However, at any point in time, the changes in precipitation will vary by region (as seen in Figure 1). Some regions will benefit, while others may suffer. The frequency of extreme precipitation events like floods and droughts will also increase. At the same time, warming will increase evaporation, tending to lower lake levels, reduce stream flows, and dry soils. The ultimate effect on available water supplies and water quality is uncertain.

There also will be indirect effects on water supplies due to changes in the demand for water across regions and sectors as the climate changes. The water required for human consumption in urban areas is the same water that is needed for irrigation in agriculture, to support fish habitat, for hydropower, to sustain ecosystems, and for recreational purposes. As water becomes scarcer in some areas, and as the demand for water increases in some sectors, there will be additional stresses on available water supplies.

The unique role of water as an "integrator" across sectors makes the development of any adaptation strategy complex. There are certainly "no regrets" strategies that can increase the resiliency of water supply systems to current climate and climate change. More efficient markets for water, particularly in the western United States, will lead to a more efficient allocation of water among competing uses, reduce the possibility of water shortages under current climate, and increase the resiliency of systems to future climate change. But this type of adaptation also has costs associated with it. Establishment of more efficient markets for water may also lead to increases in the costs of water to end users as water is distributed to its highest valued uses.

The story does not end there. As established "property rights" for water are eliminated, adaptation decisions by various end users of water may be affected. For example, farmers may no longer be able to assume that irrigation will be a viable and affordable adaptation strategy. The water may be available to them in markets, but may be too costly for them to use.

Maladaptation may also occur. Water markets may have unintended negative side effects on systems that are not represented in markets (*e.g.*, ecosystems). These systems may suffer as water is diverted to other uses, unless their needs are somehow "internalized" in water markets.

All of these factors must be considered as adaptive responses are developed. The development of strategies for ensuring adequate water supplies and water quality, even under current climatic conditions, is complex.

Agriculture

Most existing studies suggest that climate change will be beneficial to U.S. agriculture if one accounts for the effects of international trade, declines in agricultural productivity that are likely to occur in developing countries, changes in world food prices, and the ability of U.S. farmers to adapt to a changing climate. However, this conclusion is incomplete, and when reported by itself, is misleading. It fails to convey the regional distribution of agricultural impacts within the U.S. Although the U.S. as a whole might benefit, some regions may be harmed. There also will be distributional effects within any particular region. For example, farmers who plant wheat in Texas may experience increases in yields as the climate changes, but farmers who plant corn in Texas may experience declines in yields. The latter may adapt by switching the types of crops they plant.

The uncertainty about the impact of climate change on U.S. agriculture is even more complicated. We have already seen how the competition for water may make it more difficult for farmers to rely upon irrigation as their sole means of adapting to a warmer world. If climate becomes more variable as the hydrologic cycle intensifies, and the frequency and intensity of extreme precipitation events becomes more difficult to predict, farmers may have more trouble making decisions about what to plant and when to plant. This illustrates why it is important to characterize the mechanisms by which impacts may occur.

If farmers decide to adapt to warming by increasing fertilizer use, increases in intense precipitation events may lead to more runoff into streams and lakes, degrading water quality. From society's perspective, this may be viewed as maladaptation. Similarly, if a changing climate leads to the spread of pests, farmers may choose to increase their use of pesticides. But this may have unintended and undesirable effects on human health and the health of ecosystems.

The ultimate consequences of climate change for U.S. agriculture are unclear. And adaptive responses taken by farmers may have important implications for other sectors in society.

Conclusion

Adaptation is a necessary strategy for responding to climate change. In contrast to efforts to mitigate greenhouse gas emissions, adaptation can yield immediate benefits to society and the environment in which we live. Society must decide what constitutes acceptable risks to human health, ecosystems, economic activity, and social well being, and how much adaptation is desirable. It must also decide on a combination of mitigation and adaptation options.

The development of adaptive responses can be a complex undertaking. Many factors must be considered as adaptive strategies are designed and implemented. Failure to do so can lead to ineffective outcomes, maladaptation, and reductions in social well being. Decision makers should not be cavalier about how effective adaptation will be.

Many opportunities to adapt already exist. Examples include the development of improved monitoring and surveillance systems to protect public health, establishment of markets to efficiently allocate water, requirement of setbacks and rolling easements to protect coastal zones against sea level rise, development of heat-resistant crops for agriculture and seed banks to facilitate the movement of managed forests, and establishment of migration corridors for wildlife.

Effective adaptation is necessary and possible. But a lot of research about adaptation still needs to be done to ensure that policy makers and resource managers are able to make intelligent and informed decisions.

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