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CLIMATE CHANGE

---------------------OVERVIEW---------------

Global Climate Change

The possibility of anthropogenic (human-caused) climate change has been recognized since at least 1896, when the Swedish Nobel Prize–winning physicist Svante Arrhenius speculated that burning fossil fuels such as coal and oil might increase atmospheric carbon dioxide, affecting both climate and terrestrial biological systems. Arrhenius estimated that a doubling of atmospheric carbon dioxide would increase the mean surface temperature of Earth by about 4 to 6 degrees Celsius, a figure that is very close to those produced by contemporary climate models. In 1963 a Conservation Foundation meeting warned of “potentially dangerous atmospheric increases of carbon dioxide” (Conservation Foundation 1963, pp. 19–20) and a 1979 report from the American National Academy of Sciences stated that a “wait-and-see policy may mean waiting until it is too late” (National Academy of Sciences 1979) to avoid significant climate changes. In 1988 Senator Tim Wirth of Colorado introduced a bill calling for a 20 percent reduction in carbon dioxide emissions by 2000 from 1990 levels. Although the bill failed, it had fifteen cosponsors, both Republicans and Democrats. In 1992 virtually all the countries in the world signed the Framework Convention on Climate Change (FCCC), in which they pledged to “prevent dangerous anthropogenic interference with the climate system.”

THE ISSUE

Climate change is a difficult, complex, and challenging problem for several reasons. One reason is that Earth responds on different time scales than do political systems. Once carbon dioxide is emitted, it remains in the atmosphere for centuries, and other greenhouse gases (GHGs) can remain in the atmosphere for millennia. Because GHGs have such long residency times in the atmosphere, their effects on climate extend far into the future. Even if all GHG emissions ceased immediately, there would be at least another 0.7 degree

Celsius of warming in addition to the 0.8 degree Celsius of warming that already has occurred.

Emissions will not cease immediately. Globally, emissions are increasing, as are atmospheric concentrations of carbon dioxide. In the mid-eighteenth century there were 280 parts per million (ppm) of carbon dioxide in the atmosphere, while at the start of the twenty-first century the number was more than 383 ppm. Only the most optimistic people talk about stabilizing the atmospheric concentration of carbon dioxide at 450 ppm. If it were possible to do that, there would be about a 50 percent chance of limiting the warming to about 2 degrees Celsius, the figure that has become the benchmark for “dangerous anthropogenic interference with the climate system.” Any rapid warming, including the one that already has been experienced, causes harm to people and nature, but once the threshold of 2 degrees Celsius is crossed, the harms become universal, widespread, and acute, and the risks of catastrophic climate change grow exponentially.

Climate change will affect everyone, but the people who will suffer most are those who have done the least to

***Drought in Tanzania**, 2004. Children walk past a carcass in the Malambo district of Ngorongoro, one of Africa's most popular tourist destinations. The region is also home to the Maasai, a traditionally pastoral tribe whose livelihood is heavily affected by drought. Some theorists contend that it is the poor countries of the south that suffer the most from global climate change.* TOM STODDART/GETTY IMAGES.

bring it about. Poor countries will suffer more from climate change than will rich countries, just as they suffer more from climate variability and extreme events. Honduras suffers more from hurricanes than does Costa Rica, Ethiopia suffers more from drought than does the United States, and no country is affected more by floods than Bangladesh. In 1998, 68 percent of the land mass of that country was flooded, affecting about 30 million people, and that was only one of seven major floods that occurred over a twenty-five-year period. A rise in the sea level of 1 meter, which is plausible under many climate-change scenarios, could inundate 11.5 percent of the land in Bangladesh and 12 to 15 percent of the arable land in Egypt. Among the 300 million people who live fewer than 5 meters above sea level, 80 percent are in developing countries. A Ugandan president, Yoweri Museveni, is reported to have called climate change “an act of aggression by the rich against the poor” (Clark 2007).

When seen in this way, it seems clear that climate change is a dramatic challenge to the moral consciousness of humankind. It not only challenges people to act in a morally responsible way but it also challenges the very idea of moral responsibility.

A PARADIGMATIC MORAL PROBLEM

The paradigm of the moral problem discussed in this section is a case in which an individual acting intentionally harms another individual. Both the individuals and the harm are identifiable, and the individuals and the harm are closely related in time and space.

> Example 1: Jack intentionally steals Jill's bicycle— An individual, acting intentionally, has harmed another individual. The individuals and the harm are clearly identifiable, and they are closely related in time and space. If the case is varied on any of these dimensions, it still may be seen as posing a moral problem, but its claim to be a paradigm moral problem will be weaker. Consider some other examples, each of which varies the paradigm on a single dimension.
>
> Example 2: Jack is part of an unacquainted group of strangers, each of whom, acting independently, takes one part of Jill's bike, resulting in its disappearance.
>
> Example 3: Jack takes one part from each of a large number of bikes, one of which belongs to Jill.
>
> Example 4: Jack and Jill live on different continents, and the loss of Jill's bike is the consequence of a causal chain that begins with Jack ordering a used bike at a shop.
>
> Example 5: Jack lives many centuries before Jill and consumes materials that are essential to bike manufacturing; as a result, it will not be possible for Jill to have a bicycle.

Although it may seem that moral considerations are at stake in each of these cases, that is less clear than is the case in Example 1, the paradigm case. The view that morality is involved is weaker still, perhaps disappearing altogether, if one varies the case on all of these dimensions simultaneously.

> Example 6: Acting independently, Jack and a large number of unacquainted people set in motion a chain of events that prevents a large number of future people who will live in another part of the world from ever having bikes

For some people the perception persists that this case poses a moral problem. This is the case because the core of what constitutes a moral problem remains. Some people have acted in a way that harms other people. However, most of what typically accompanies this core has disappeared. In this case it is difficult to identify the agents, the victims, or the causal nexus between them; thus, it is difficult to deploy the usual moral concepts and assign responsibility and blame.

These thought experiments help explain why many people do not see climate change as an urgent moral problem. Structurally, the moral problem of climate change is similar in many important respects to Example 6. A diffuse group of people are setting in motion forces that will harm a diffuse group of future people. Indeed, if anything, the harms caused by climate change will be much greater than the loss of the opportunity to have a bicycle. Still, people tend not to see this as a moral problem because it is not accompanied by the features that are characteristic of a moral problem. Climate change is not a matter of a clearly identifiable individual acting intentionally in a way that inflicts an identifiable harm on another identifiable individual who is closely related in time and space. If people are to see climate change as confronting them with a clear case of moral responsibility, they will have to revise or reform these concepts.

REAL-WORLD CASE

One response would be to say that climate change is not primarily a matter of individual moral responsibility but a question of political justice among states. Indeed, it might be thought that this is truer to the sentiment that Museveni expressed. Moreover, data can be mobilized that seem to show that this view is correct. When one looks at per capita or even total GHG emissions by country, the rich nations of the North dominate. However, when one looks at the actual and expected damages from climate change, it is the poor nations of the South that do and will suffer the most.

When we look at some countries in particular, the case seems even stronger. A rise in the sea level of 1 meter will flood one-third of the coastline of Bangladesh, creating another 20 million environmental refugees. In addition, saline water will move deeper inland, fouling water supplies and crops and harming livestock. This will occur as cyclones and other natural disasters become more frequent and perhaps more intense. Bangladesh will suffer in all these ways, yet its carbon dioxide emissions per capita are one-twentieth of the global average. A typical American emits 80 times as much GHG as does a typical Bangladeshi. However, although Americans will suffer from climate change, Bangladeshis will suffer vastly more. In light of this it seems natural to say that, although most of the emitting is done by the rich countries of the North, most of the climate-change-related dying is done in the poor countries of the South.

However, when one looks at the data in more detail, complications emerge. First, per capita emissions do not march in lockstep with gross domestic product. The nation of Trinidad and Tobago emits more per capita than the United States, and Malaysia emits more per capita than France. Moreover, the atmosphere does not care where GHGs originate. A molecule of carbon dioxide emitted from the exhaust pipe of a sport-utility vehicle (SUV) in Kenya is indistinguishable from one emitted from the exhaust pipe of an SUV in the United States. A coal-fired electrical generating plant in South Africa affects climate as much as one in Germany.

From this perspective, climate change, rather than being caused by rich countries, is caused by rich people wherever they live. The richest 500 million people emit half the fossil carbon worldwide, and not all of them live in North America, Europe, Australasia, or Japan. Indeed, there are more high emitters in China than there are in New Zealand and probably more than in Australia. Because the United States has greater economic inequality, more extreme poverty, and fewer government services than do some poor countries (e.g., Cuba), more people will suffer from climate change in the United States than in some developing countries.

Once again it can be seen that climate change poses questions of global justice but strays from the paradigm. Greenhouse gas emissions are not like weapons of mass destruction launched by one country against another. The nation-state perspective is one important way of looking at climate change because nation-states are casually efficacious, but they are not the primary bearer or beneficiary of moral responsibilities. Climate change challenges not only people's sense of justice but their concepts of justice as well.

Climate change divides the future from the past as well as the rich from the poor. Those who will suffer most from climate change are those who will live at the end of the twenty-first century and beyond, and they largely will be the descendants of those who currently are living in poverty on the periphery of the developed world. What is required to “prevent dangerous anthropogenic interference with the climate system” is for people who are rich by global standards to restrict their emissions radically to benefit future generations of poor people.

This creates a problem of motivation. Burning fossil fuels primarily benefits those who burn them, while the damages are suffered largely by those who come afterward. The climate change that contemporary people are experiencing was caused largely by their parents and grandparents. The much greater level of emissions today will affect contemporary people's children and grandchildren. Because restricting emissions primarily benefits those who come later, it can be asked how it is in the interests of contemporary people to do so, especially if it is assumed, as most economists do, that their descendants will be richer than they are. From this perspective, asking people to sacrifice for future people is like asking the poor to sacrifice for the rich.

In addition to the divisions that climate change creates in the human community, it divides humans from nature. The biggest losers from climate change will be the plants and animals that are now barely surviving. At the beginning of the twenty-first century 700 mountain gorillas were clinging to life in two small areas of misty, densely vegetated forest in Uganda and Rwanda. What will happen to them when their reserves dry out and warm up as a result of climate change? Orangutan habitat is being destroyed in Indonesia to plant palm oil for biofuels as part of the attempt to mitigate climate change. Scientists predict that one-quarter of all species face extinction by the middle of the twenty-first century because of climate change. Things could be even worse if people do not act immediately to address the problem.

RESPONSES TO CLIMATE CHANGE

Three types of responses to climate change have been identified: mitigation, adaptation, and geoengineering. Mitigation involves reducing emissions and stabilizing GHG concentrations more than would be implied by a business-as-usual scenario. Adaptation involves positive adjustments in biological or cultural systems in response to actual or expected changes in climate. Geoengineerng involves the intentional large-scale manipulation of the climate system.

The consensus view is that if there is to be a reasonable chance of averting the most extreme risks of climate change, global emissions will have to peak in 2025 and decline by 50 percent by 2050 and the global economy must be virtually decarbonized by the end of the twenty-first century. Thus, cheap energy–high consumption lifestyles cannot be sustained in Europe and North America or replicated by developing countries without causing a climate cataclysm. People will have to find another way to live, and poor countries will have to find another model to guide their development.

Although environmentalists emphasize the low-hanging fruit and science enthusiasts put their faith in technological breakthroughs, the transition to a carbon-free energy system will entail real costs. If China and India cannot burn their vast stores of cheap coal, their development path will be more difficult and costly. If Brazil cannot exploit the Amazon in the way Americans exploited the U.S. West, they will forgo the use of one of their most valuable resources. Even a “Manhattan Project” that produced hydrogen cars and biodegradable products would shift resources from one part of the economy to another, displacing workers who have contributed no more to the problem than those who would benefit from the new economy. Although conservation often is presented as cost-free, it means something different to a poor person in a drafty house who relies on an old polluting car than it does to an investment banker who superinsulates his or her house and installs solar collectors on the roof.

Considerations such as these bring up questions of justice. How should people distribute the ever-shrinking rights to emit greenhouse gases? What principles should

Farmers Planting Seaweed in Bali, Indonesia, 2007*. Indonesia is particularly vulnerable to the impact of climate change, as global warming threatens to raise sea levels and flood coastal farming areas, threatening food security. Moreover, a rise in sea level would put thousands of farmers in the country at risk of losing their livelihood.* SONNY TUMBELAKA/AFP/GETTY IMAGES.

govern that distribution? Should the “luxury” emissions of the rich be treated comparably to the “subsistence” emissions of the poor? How should subnational inequality be treated in comparison to international inequality?

Many analysts endorse “contraction and convergence,” an approach that calls for contracting emissions immediately and eventually converging on equal per capita emissions for everyone in the world. How could the proposed 50 percent reduction in emissions be achieved by 2050? Former French President Jacques Chirac hinted at the possibility of a global carbon tax, and others have speculated about a global emissions trading scheme that would connect the European Union system with the emerging North American carbon markets. There are a great many technical difficulties with both approaches, and some people object to the idea of buying, selling, or taxing carbon, seeing it as a way for rich people to buy their way out of their moral obligations. How does China, where the use of coal is increasing faster than gross domestic product and is now the world's largest emitter but still relatively low in terms of per capita emissions, get integrated into this type of system?

Whether or not the nations of the world succeed in mitigating their emissions, it is clear that adaptation will play a major role in the greenhouse world. Although it is not noticed by many people, adaptation raises many of the same questions of justice as mitigation. Unless catastrophic climate change occurs, rich countries largely will be able to adapt to climate change. They will build seawalls to protect their coastal areas, compensate farmers and foresters who lose their livelihoods, and invest more in developing and maintaining water resources. However, poor countries do not have the resources to adapt. For example, it has been estimated that Bangladesh needs $4 billion to begin to adapt to climate change by building embankments, cyclone shelters, roads, and other infrastructure. However, in 2007 Bangladesh's total national budget was less than $10 billion.

Will the developed countries and rich people who are the major causes of climate change be willing to finance adaptation for poor people and poor countries? They may have self-interested reasons to do so. Climate change will cause environmental refugees and political instability in a world that is already uncertain, but nations and individuals do not always act on the basis of rational self-interest. In many countries, such as the United States, there has been a systematic backing away from providing public goods such as libraries, parks, and schools. Financing adaptation projects in faraway places would have even less appeal.

Because so little is being done to mitigate or adapt to climate change, geoengineering is gaining prominence. Moreover, the idea that in the end science will save people from themselves is a popular one, at least among Americans. Different approaches to geoengineering have been mooted—reflecting solar radiation with space mirrors, seeding the atmosphere with sulfate aerosols, fertilizing the oceans with iron, removing carbon from the atmosphere—but in general the science is relatively undeveloped.

The most important moral and political question about geoengineering concerns how the decision to implement a program will be made and by whom. It would seem that any decision to change global climate should be made with the participation of all the people of the world, as expressed through legitimate political institutions. But what are those legitimate political institutions? Do they exist? What decision rules should they follow? By and large, those who think of geoengineering as a promising approach to climate change have ignored these questions.

POLITICAL CHALLENGES

Climate change challenges the political system in addition to the problems that it poses to people's moral consciousness. Are European and North American democracies able to act on the time scale required to address climate change? Would liberal values have to be sacrificed? Would citizens have to change their values?

Reflecting on these questions leads to further questions about what development means and what kinds of lives are worth living. U.S. President George H. W. Bush is reported to have said in the run-up to the Rio Earth Summit of 1992 that "the American way of life is not up for negotiation." That categorical statement begs the question of whether the American way of life should have been up for negotiation. Is the American way of life superior to all other ways of life? Is it the only one worth living, even for Americans? There is little evidence in favor of affirmative answers to these questions. Surveys suggest that Scandinavians are happier than Americans and that, once basic needs are met, economic status is associated only very loosely with happiness.

From Plato to the present time reflection on the nature of the good life has been at the heart of philosophical inquiry. Some, such as John Stuart Mill, have argued that economic growth, the reigning ideal of progress and development, can be antithetical to the quality of life. Such ideas sound strange in a world in which the front page of the newspaper has been taken over by the business section, as if this week's economic indicators were the most important information. Whether up for negotiation or not, the American way of life will change, as will the ways of life of other nations, and it is important to think about what comes next and how to manage the transition.

Climate change is occurring, and serious impacts are being experienced, especially in polar regions and small island nations. Unless emissions are reduced significantly, the impacts will be severe and possibly catastrophic. People will have to adapt, and those already living on the margin have little capacity to do so. Can contemporary political systems respond to this challenge? In the second and third decades of the twenty-first century the answer will begin to emerge as GHG concentrations in the atmosphere continue to increase.

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----ACADEMIC JOURNAL ARTICLES----

Infectious diseases subdue Serengeti lions: infectious diseases stalk wildlife in the

Serengeti, and climate change may be an accessory.

BioScience 59.1 Jan 1, 2009. p8(6).It must be the wind, this almost-keening that rises and falls every minute or two. But guards outside the door tell a different story. Here at a lodge in Tanzania's Serengeti National Park, one watchman after another lines a curving brick walkway leading to rooms.

Not far from a guest door, a simba, as he's called in Swahili, roars. Near the lion beyond the lodge lights and under a grove of umbrella-shaped acacia trees--recline several lionesses. Perhaps the lionesses, premier nocturnal hunters of the savanna, await their prey. Zebras, among their favored meals, frequent the grasslands surrounding the lodge. The roars continue but sound no nearer. For tonight, peaceful coexistence of lions and people reigns, at least in this part of the 14,500-square-kilometer Serengeti National Park.

Multiple diseases threaten Serengeti lions

Lions face serious threats to their future, some head-on, others lurking in the grasses, unseen until it's almost too late. From growing numbers of people living along the Serengeti perimeter to the effects of infectious diseases and climate change, the king of beasts (Panthera leo) leads an uneasy life, according to Craig Packer, a biologist at the University of Minnesota who has studied the Serengeti's lions for three decades. Sometimes, he says, lions face a double whammy.

For example, lions are subject to simultaneous outbreaks of canine distemper virus (CDV) and babesiosis. CDV, a disease that results in encephalitis and pneumonia, is transmitted by domestic dogs; babesiosis is carried by a tick-borne blood parasite called Babesia. In 1994 and 2001, two "perfect storms" of extreme drought followed by heavy seasonal rains set up the right conditions for CDV and babesiosis outbreaks to converge.

When the drought was over and rains fell, Babesia-carrying ticks flourished. They infested Cape buffalo that were by then starved for food; the herbivores couldn't find enough vegetation during the drought. When the babesiosis-infected buffalo died, lions fed on their carcasses, leading to babesiosis in lions already exposed to CDV. "CDV or babesiosis alone aren't threats to lions," Packer says. "It's the combination of CDV with a high level of exposure to Babesia that killed the lions in 1994 and 2001. Although the intense babesiosis is ultimately what did it, these cofactors were completely synchronized by drought."

In 1994, one-third of the Serengeti lion population--more than 1000 lions--died. In 2001, the much smaller nearby Ngorongoro Crater population, around 100 lions, suffered a similar high percentage of losses. "Should drought occur in the future at the same time as lions are exposed to masses of Babesia-carrying ticks--and there is a synchronous CDV epidemic--lions will once again suffer very high mortality," says Packer.

If extreme weather events become more frequent as a result of global climate change, says veterinary pathologist Linda Munson of the University of California, Davis, "disease may become a major threat to animal populations that have been historically stable."

Diseases once thought to have limited impacts, such as babesiosis, should be watched closely, she says. Environmental conditions may tip the scales and result in significantly greater impacts, even in wide open places like the Serengeti.

Africa's endless plain: The lion's domain

The Serengeti is Africa's largest savanna ecosystem. Savannas--tropical and subtropical grasslands with scattered bushes and trees--are one of the largest biomes on Earth, making up more than 20 percent of the planet's land surface. Most savanna is located in Africa, with a smaller amount in South America, India, and Australia. Savannas are found near the equator where it's warm but relatively dry, and are subject to seasonal drought.

"The very name Serengeti conjures up a vast vision of open spaces and phenomenal abundance, of vast herds free to wander immense plains that stretch on forever," wrote Packer and Stephen Polasky, also of the University of Minnesota, in Serengeti III: Human Impacts on Ecosystem Dynamics. "[But] the Serengeti, despite its apparently endless bounty, is an ecological island in a rising sea of humanity.... Our grandchildren may only know Serengeti as a faintly exotic word, like Atlantis or Eden."

Safari-goers in Tanzania hope to see Serengeti wildlife while it's still there. Ironically, human population growth around the edge of the park--a staging area for Serengeti safaris--poses a threat to wildlife through habitat encroachment and spread of infectious diseases. Tanzanians as well as tourists are drawn to the Serengeti perimeter. Job scarcity elsewhere leads residents to national parks to find new ways of making a living.

Safari groups make their way into the park in Land Rover after Land Rover, hoping for a glimpse--first and foremost--of the ruler of the Serengeti, the lion. At the appropriately named Simba Kopjes (pronounced "copies"), outcrops of gneiss and granite that form large rock piles, a trio of lionesses nicknamed the three sisters rests in the midday warmth. Their bodies are so close together they appear as one. One lioness lazily lifts her head to look askance at idling vehicles crammed with gawking tourists. Since people aren't allowed out of Land Rovers in the Serengeti, the lioness knows the disturbance won't go beyond impolite staring.

From the vantage point of open-country kopjes, lions often locate carcasses to scavenge. Embankments along rivers and streams are also important hunting locales; these vegetation-lined areas provide lions with cover to stalk prey. When zebras and other animals are plentiful, lions spend 20 hours out of every 24 conserving energy, becoming active in late afternoon. They hunt mainly at night, but if an easy meal presents itself, lions will hunt by day. "Lions select areas where prey is easier to catch, rather than where prey densities are highest," says Packer. "'Catchability' counts."

Lions in the Serengeti have been continuously monitored by researchers for more than 30 years. Packer and colleagues primarily study lions living in the southeastern corner of the park. Two habitats are found in the 2000-square-kilometer area: acacia woodland and open-grass plains. Lions on the plains are fewer and have lower prey availability than their woodlands counterparts, says Packer. Shaded woodlands are home to many of the animals lions hunt.

"At any given time," Packer says, "field assistants are keeping track of some 250 lions in 15 to 20 prides." To survive, lions need a water source and a steady supply of prey, so researchers have an idea where they might be found. Monitoring involves locating as many lions as possible. "Prides of lions are territorial," says Packer, "so we know approximately where to look, but ranges can be as large as 400 kilometers." The team focuses its efforts on known "hot spots" within each territory, including water holes, riverbanks, and kopjes.

A female from each pride wears a radio collar. When the research team locates a lion, the first step is to identify all the other lions present. Lions are born with a pattern of whisker spots that never changes; these spots mark each one in a population. After the animals are identified, the scientists record information about the lions' condition: whether they are pregnant, seem ill, make a kill or are feeding on a carcass, or are mating. The lions' location is recorded on a GPS (global positioning system) unit.

Documenting "interaction events" among carnivores in the Serengeti is among the most important research conducted there. For lions, as well as hyenas and jackals, disease transmission can occur within social units like prides, but also between species during territorial defense, long-distance movements, or kleptoparasitism (stealing kills). "Lions, hyenas, and jackals are often observed at the same kill at the same time," says Packer. "Disease can spread during squabbles, or just by sharing the same food resource."

Long history of infectious diseases marks the Serengeti

For more than a century, says Packer, infectious diseases have shaped the Serengeti. "The direct and indirect effects of rinderpest, for example, have drawn the modern dimensions of this ecosystem." Rinderpest was introduced to Africa in the 1880s; it devastated the cattle herds of Tanzania's native Maasai pastoralists. The disease swept over the region like an uncontrolled brushfire, killing 90 percent of the cattle. According to some estimates, as much as 95 percent of East Africa's buffalo and wildebeest also died.

Rinderpest appeared and reappeared in skips and jumps between the late 1800s and the 1940s. By 1955, no outbreaks had been detected in wild species. But it was the calm before the storm: rinderpest reappeared in 1957, causing heavy mortality. The last year rinderpest was detected in Serengeti wildebeest was 1962; in buffalo, 1963. With the development of a vaccine against the disease, 30 rinderpest-free years followed. Then in 1997 signs suggestive of rinderpest were again found in the pastoral cattle that migrate in search of grassland and water during droughts. Immediate vaccination against the disease began throughout Tanzania.

The known history of CDV in the Serengeti also extends back several decades. CDV infected African wild dogs in 1968 and black-backed jackals and bat-eared foxes in 1978. Then on 3 February 1994, a group of tourists hovering in a hot-air balloon over the central Serengeti noticed a male lion in distress along the banks of the Seronera River. The lion wasn't able to stand, and soon died. By May of 1994, more than a third of 250 study lions had died or disappeared; many of the rest had symptoms similar to those of the Seronera River lion. In August, the unknown disease spread to the western part of the Serengeti. It entered Kenya's Maasai Mara wildlife reserve in October. By year's end, the total lion population in the Serengeti ecosystem, which reaches across Tanzania into Kenya, had dropped from 3000 to 2000.

Scientists suspected that the disease--identified from blood and tissue samples as CDV--was coming from domestic dogs in villages around the Serengeti perimeter. Tanzanians keep dogs as security guards, to watch over domestic livestock, and to serve as family companions. Blood samples from the dogs indeed showed the presence of CDV.

"Canine distemper is spread mostly by sneezing," says Packer. "But since lions seldom venture into towns, it was unlikely that the virus had traveled directly to lions from domestic dogs. It was more plausible that the lions had caught the virus from other carnivores--hyenas, jackals, or leopards." Hyenas and jackals are scavengers that frequent villages, and leopards eat domestic dogs. Lions would come into contact with these infected species at kills.

"The pathogen responsible for CDV belongs to the morbilliviruses," Packer says. The viruses are easy to catch and can kill up to 80 percent of their victims. An outbreak of CDV in 1993 led to the deaths of thousands of domestic dogs near the Serengeti. With more than 30,000 domestic dogs living within 10 miles of the Serengeti National Park boundary, and millions more dogs throughout the rest of Tanzania, containing CDV has been a daunting task.

Enter Project Life Lion. Sponsored by the World Society for the Protection of Animals in Boston, scientists affiliated with Project Life Lion, such as Packer, Sarah Cleaveland of the University of Edinburgh, and others, started a program in the late 1990s to vaccinate dogs in villages surrounding the Serengeti against CDV. Through an intensive effort, tens of thousands of domestic dogs have been vaccinated.

CDV and babesiosis aren't the only diseases Serengeti lions contract. They're also at risk of feline herpesvirus, feline immunodeficiency virus (FIV), feline calicivirus, feline parvovirus, and feline coronavirus. Of these, feline herpesvirus and FIV are prevalent and very likely endemic in the lions. Lions and other cats are susceptible to FIV, a virus similar to HIV in humans. FIV attacks a feline's immune system and may be transmitted from one cat to another, usually through bite wounds.

FIV is very common in Serengeti lions. More than 90 percent have tested positive for the disease. The virus is also rampant in Ngorongoro Crater, where it is found in 93 percent of lions. But FIV seems to have no effect on the lions. "If FIV had compromised the immune systems of lions as it does those of domestic cats," says Packer, "there would be higher death rates from other diseases, and/or more rapid progression of disease, when lions are infected with both FIV and another disease." However, he says, the data don't show higher death or disease rates in FIV-positive lions compared with FIV-negative lions.

The best explanation, he says, lies in evolutionary adaptation. FIV could have been in the environment for thousands of years. Some lions may have a genetic trait that allows them to survive FIV infection. "These lions would have had a survival and reproductive advantage," Packer says, "leading to the spread of the trait through natural selection."

If FIV and lions coevolved, rendering the virus benign in these carnivores, they may have something to teach us about HIV in people. Studies of FIV in lions, says Packer, will help researchers in their quest to develop an HIV vaccine for humans.

Diseases continue to plague Serengeti National Park

Among the latest threats faced by Serengeti lions, along with other African animals--including humans--is rabies. The disease is caused by a virus and is transmitted through the bite or scratch of an infected animal. The first description of rabies is in the Babylon Codex, written in 23 BC. The disease thrived from ancient times until the end of the 19th century, when in 1885, Louis Pasteur developed a postexposure rabies vaccine for humans.

More than 120 years later, the disease still plagues humans, especially in developing countries in Africa, Southeast Asia, and Latin America. According to the World Health Organization, more than three billion people in 85 countries and territories worldwide are at risk of rabies. Some 10 million people receive postexposure rabies vaccines each year. Around the world, one person dies of rabies every 10 minutes, and of the total killed each day, 100 are children. Almost 25,000 people in Africa die from rabies each year.

Rabies also devastates wildlife populations. In the 1990s, rabies drove African wild dogs to local extinction in Tanzania and Kenya. In these very social dogs, when one individual becomes infected with rabies, its entire pack is likely to die. The disease also killed half the adult female bat-eared foxes, and some 20 percent of the adult male foxes, in the central Serengeti. Concerns were raised that the Serengeti's wild carnivore species might act as a reservoir for rabies.

Domestic dogs, however, once again turned out to be the culprit, report Cleaveland, Tiziana Lembo, and Magai Kaare, of the Tanzania Wildlife Research Institute, and other scientists. Domestic dogs alone are perpetuating rabies, says Cleaveland, who is also director of the Afya Serengeti Project (Afya Serengeti means "health for Serengeti" in Swahili). The effort is an outgrowth of Project Life Lion.

"We're again working with Tanzanians living near the Serengeti to ensure widespread vaccination of domestic dogs, this time against rabies," Cleaveland says. "Vaccinating the dogs should also eliminate the virus in transient hosts [people, livestock, wildlife], breaking the cycle." Domestic dogs that have been vaccinated are marked with a plastic collar to signify their protection from rabies. From 2003 through 2008, between 30,000 and 50,000 dogs were vaccinated against rabies each year.

By its second year, the Afya Serengeti Project had reduced the number of people needing hospital care for bites from rabid dogs by 82 percent. The results have been phenomenal, say Tanzanian health workers. Thanks to the project's efforts, the World Health Organization has selected Tanzania as the site for a trial national rabies control program.

The challenge now, say scientists, is to sustain vaccination coverage and extend it to all villages near the Serengeti. "Control of domestic dog rabies in the Serengeti will eliminate rabies in all other species, including humans, livestock, and wildlife," says Cleaveland. She and others found that wild species such as lions are not independently able to maintain rabies cycles, allowing rabies control measures to be targeted solely at domestic dog populations. "The finding has considerable applications for designing disease control programs," says Packer, "and minimizing extinction threats to wild camivores."

It has worked already for the African wild dog. Several packs of African wild dogs again roam the Serengeti. The Serengeti ecosystem is the wild dogs' best hope of long-term survival; thousands of square kilometers of protected area allow the wide-ranging wild dogs to avoid conflict with livestock farmers. "It's important to look at an ecosystem in its entirety," says Cleaveland. "Humans and wildlife are both part of the ecosystem. Protecting wildlife health has benefits for humans. The same holds true for protecting human health and wildlife."

Changing climate looms over the Serengeti's future

The lion's mane, that iconic symbol of the Serengeti, ultimately may indicate large-scale trouble on the horizon. If lion manes become light-colored rather than dark, and short instead of long, global warming may have moved into the Serengeti with a vengeance. Packer and scientist Peyton West determined that male lions have lighter, shorter manes in hotter seasons, years, and habitats. "Heat appears to be the dominant ecological factor shaping the lion's mane," Packer says.

Long-term forecasts predict an increase of 1.3 to 4.6 degrees Celsius in the Serengeti region by 2080. As a result, lions with dark, luxurious manes may fade into Serengeti history.

"Marcel Proust once said that the most extraordinary journey would be to see the same familiar places through the eyes of another person," writes Packer in his award-winning book, Into Africa. "But what if we could see ourselves through the eyes of another species?" With global warming on the horizon, and infectious diseases following closely behind, what lions may be revealing is our own future.

Author's note: Magai Kaare was recently killed in a car accident in Tanzania. His presence and contributions will be missed by all in the Afya Serengeti Project.

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Europe, get ready to feel the heat.

New Scientist 201.2693 Jan 31, 2009. p14(1).

A CENTURY from now, Spain and Italy will be enduring baking, parched summers while residents of central and north-west Europe will be experiencing what we now think of as Mediterranean warmth.

Reindert Haarsma and his team from the Royal Netherlands Meteorological Institute in De Bilt used existing computer models to study changes in weather patterns resulting from the expected global warming. These indicated that summer temperatures in southern Europe would rise by 2 to 3 [degrees]C compared with today's, and that lack of rain would dry up the soils. The hot, dry air above these and soils would then rise and expand, creating a low-pressure zone over the region. Winds circulating anti-clockwise around this zone would feed continental air to more northerly areas, raising temperatures there too (Geophysical Research Letters, DOI: 10.1029/2008GL036617).

Source Citation: "Europe, get ready to feel the heat.(Brief article)." New Scientist 201.2693 (Jan 31, 2009): 14(1). Global Reference on the Environment, Energy, and Natural Resources.

----------------CASE STUDIES----------------

On the impact of recent climate change on seasonal floods--a case study from a river basin in southern Quebec.

Canadian Water Resources Journal 33.1 Mar 22, 2008. p55(18).

Abstract: A study of the trends of climatic and hydrologic variables between 1960 and 2004 was completed for the Massawippi River basin in southern Quebec. Analysis of these trends was used to evaluate possible changes in the spring flood hazard in the basin. This basin is flood-prone, especially during the spring months, portions of the basin having been inundated 95 times during the 20th century. Trends were initially analyzed using plots of cumulative percentage departure from the mean, taken from the raw data. Statistical analyses of the data trends were conducted using the Mann-Kendall non-parametric test. The graphical and statistical results indicate trends toward increasing winter and spring temperatures and a change in precipitation type from snow to rain. Decreases in winter snow accumulations are particularly evident. Graphical analyses show some trend toward decreasing maximum and total river discharges, but the trends are not statistically significant. There is no clear evidence that changes in the climatic variables are causing significant changes in

river or flood behaviour. Thus, there is no evidence that changing climatic conditions are creating a greater threat from flooding.

Resume : Une etude sur les tendances des variables climatiques et hydrologiques entre 1960 et 2004 a ete effectuee pour le bassin de la riviere Massawippi, dans le sud du Quebec. L'analyse de ces tendances a ete utilisee pour evaluer les changements possibles dans les risques d'inondation printaniere dans ce bassin. Vulnerable aux inondations, en particulier pendant la periode printaniere, le bassin a ete en partie inonde a 95 reprises au cours du 20e siecle. Les tendances ont ete analysees dans un premier temps au moyen du pourcentage cumulatif d'ecart par rapport aux courbes moyennes, etabli d'apres les donnees brutes. Les analyses statistiques des tendances des donnees ont ete effectuees a l'aide du test non parametrique de Mann-Kendall. Les resultats graphiques et statistiques indiquent une tendance a la hausse des temperatures printanieres et hivernales et une modification du type des precipitations, qui passent de la neige a la pluie. La diminution des accumulations de neige en hiver est particulierement evidente. D'apres les analyses graphiques, on note que les debits (maximal et total) de la riviere ont tendance a diminuer, mais ces tendances ne sont pas statistiquement significatives. Rien ne demontre nettement que les changements des variables climatiques causent des changements significatifs dans le comportement de la riviere ou des crues. Rien ne prouve donc que le changement des conditions climatiques fasse augmenter la menace d'inondation.

Introduction

Climate change, or global warming, has become of immediate concern to scientists, policy makers and the general public. The evidence for increased global warming, resulting in major changes to the Earth's geomorphic, biologic and hydrologic sub-systems, is becoming stronger as research in this field expands. A recent IPCC report (IPCC, 2007) states that warming of the global climate system is unequivocal, resulting in increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level. It also states that long-term changes in precipitation amounts and increases in the frequency of heavy precipitation at the continental, regional and ocean basin scales have been observed (IPCC, 2007).

The impacts of climate change on hydrologic systems in Canada, at national and regional levels, have been documented by numerous authors. Ashmore and Church (2001) completed a national survey of the climate-induced hydrological changes on river dynamics, wherein the climate-streamflow connection was analyzed using historical data and case studies of the effects on flow regime changes. Data were plotted as raw data series. Long-term trends in the raw data were identified using cumulative percentage departure from the mean plots. In general, they found precipitation trends relate closely to streamflow, especially mean annual flow and, to a lesser degree, maximum annual flow. Relationships between temperature trends and streamflow were much more difficult to identify. Reduced snow accumulation due to higher winter temperatures could reduce the magnitude of spring nival floods; other effects of regional temperature are less obvious (Ashmore and Church, 2001). Burn and Hag Elnur (2002) also completed a national survey of hydrologic trends. For the southern Quebec section of the Great Lakes/St. Lawrence region they found evidence for increasing annual maximum flows, but no trend for spring or autumn flows. These results were in contrast to the overall situation they found in Canada. In general, annual maximum flows seem to be decreasing in the south and increasing in the north, and spring flows increasing due to an earlier onset of the spring snowmelt (Burn and Hag Elnur, 2002).

Regional studies looking at the relationships between climate and streamflow in Canada have focused on relatively large-scale watersheds. Burn et al. (2004a) found increases in winter flows and some increase in spring flows in two watersheds in the Mackenzie River basin, using the Mann-Kendall non-parametric statistical test. Their results on the Laird River and Athabasca River basins showed some similarities in the trends observed in hydrological variables. Both basins showed trends to increasing spring flow and an earlier onset of the spring freshet, but decreases in the annual maximum flow (Burn et al., 2004a). The changes in spring streamflow could have consequences for spring flood activity. Burn et al. (2004b) found that stations with significant hydrological trends had related changes in temperature, particularly winter and spring temperatures. McBean and Motiee (2006) used simple linear regression analysis and the MannKendall test to demonstrate significant increases in precipitation and streamflows in the Great Lakes region; temperature trends were not found to be significant. They suggest increases in precipitation could have dramatic impacts on water quantity, noting that a major impact would be changes in the frequency and magnitude of extreme hydrologic events (McBean and Motiee, 2006). Very few studies have been made on the relationships between climatic variables and streamflow in relatively small watersheds in Canada. Roy et al. (2001) use results from the Canadian GCM (CGCM1) and a coupled hydrology-hydraulics model to investigate the impact of climate change on flooding in the Chateauguay River basin (2500 km2) in southern Quebec. Their results predict large increases in total annual streamflows and maximum discharges for the basin. Maximum discharges are predicted to increase by up to 250%, drastically increasing the flood hazard (Roy et al., 2001).

Two basin-scale studies from neighbouring regions of the United States of America are relevant to the present study. Hartley and Dingman (1993), in a study of New England river basins, demonstrate the sensitivity of snowmelt to surface air temperature during the winter/spring period. Their investigations in 13 river basins show that higher temperatures result in lower snowfall amounts causing a more uniform distribution of seasonal streamflows. However, maximum, or peak, flows are related to total precipitation and are not significantly related to temperature (Hartley and Dingman, 1993). Dudley and Hodgkins

(2005) present a survey of 20th century streamflow trends in coastal river basins in Maine. Summer (June to October), fall/ early winter (September to January) and winter/spring (January to May) streamflow trends are correlated positively to meteorological variables, specifically surface air temperature and precipitation. Evidence was found for earlier spring maximum streamflows due to higher precipitation in late fall/early winter, and higher mean temperatures. However, little evidence for trends in the magnitude of total runoff volume was discovered (Dudley and Hodgkins, 2005).

The focus of the present case study is an analysis of climatic and hydrologic trends in the Massawippi River basin in southern Quebec from 1960 to 2004. Historical trends in precipitation and temperature will be studied in an effort to detect any possible impacts changes in the climatic variables may be having on the hydrologic trends and, thus, on spring flooding. An increase in the frequency of spring flood events in the Massawippi River basin during the last part of the 20th century suggested by print media reports, and noted by Jones (2002), cannot be directly assessed by the methods used in this study. However, changes in streamflow are analyzed and used as an indicator of possible changes in flood occurrence. Possible changes in the occurrence of both flash and regional spring flood events as a result of climate change will be examined in this context. Annual flows will be analyzed in less detail.

Other drivers of hydrological change, such as changes in land use or management, increased urbanization or changes in stream regulation, are not considered to be of great importance in the study area. Land use in the area is of three principal types: agriculture, Christmas tree farming and recreation. Jones (1999) concluded there was little change in these land uses during the period 1964 to 1994. There are no major urban centres within the study area. No changes in stream regulation occurred during the last half of the 20th century.

Methods

Trends in climatic and hydrologic variables can be presented and analyzed using various methods, both graphical and statistical. Graphical plots of the cumulative percentage departure from the mean are used as the primary method of detecting trends in the data series here. The cumulative departures from each data series mean were calculated from temperature, precipitation and streamflow data sets and then graphed using the method initially presented by Karanka (1986), and subsequently successfully employed by numerous authors, most recently Ashmore and Church (2001) and Egginton (2005). In this method the cumulative departures from the mean are the sum of each annual value minus the mean of the entire series divided by the mean, multiplied by 100 to give a percentage. Detailed information on the method can be obtained in Karanka (1986) or Egginton (2005). Using this method, a graphical representation of trends in a series is presented. A section of the plot with a negative slope represents a period of below-normal conditions; a section with a positive slope represents a period of above-normal conditions (Karanka, 1986). This method has been used successfully by other authors to show trends in climatic and hydrologic data series. Assel (1980) used cumulative departures from mean to assess freezing degree-days in the Great Lakes region. Ashmore and Church (2001) used cumulative percentage departure from the mean plots to display hydrological trends in a number of Canadian watersheds. Gadgil et al. (2002) used percentage departure from the mean plots to identify monsoonal rainfall variations in India. Egginton (2005) used cumulative percentage departures from the mean to identify trends in climate variability and their relationship to slope stability in British Columbia.

The statistical analysis of hydrologic and climatic trends has been performed using a variety of tests. Cunderlik and Burn (2004) provide a summary of the recent literature on analyzing hydrological variables. McBean and Rovers (1998) outline a number of parametric and non-parametric methods used for the detection of trends in climatic and hydrologic data, while Kundzewizc and Robson (2004) review trend analysis methodologies in general. McBean and Motiee (2006) use a combination of the parametric "Simple Linear Regression Model" and the non-parametric Mann-Kendall test. The linear regression analysis is used in order to provide a primary indication about the existence of trends in precipitation, temperature and streamflow data series; the Mann-Kendall test detects trends that are monotonic but perhaps not linear (McBean and Motiee, 2006). A number of other authors have used the Mann-Kendall test to conduct trend analysis in streamflows and climatic variables in large regions (Burn et al., 2004a; Cheng et al., 2004; Cunderlik and Burn, 2004; Yue et al., 2003). Simple linear regression analysis is used less often because of its dependence on normality in the data series; climatic and hydrologic time series have an inherent variability and often exhibit non-normal distributions (Burn, 1994). Another non-parametric test that may be used to detect trends in time series data is the Mann-Whitney-Pettitt method (Pettitt, 1979). Cheng et al. (2004) used the Mann-Whitney-Pettitt and the Mann-Kendall non-parametric methods to assess trends in rainfall data in Taiwan. They found the tests yield consistent results for rainfall characteristics in similar geographic regions (Cheng et al., 2004).

In this study trends in the data are presented as raw data series plots together with the cumulative percentage departure from the mean plots. The cumulative percentage departure from the mean plots provide a primary indication about the presence of trends in the time series data. They are presented as the principal evidence of trends in the time series under consideration. Since the main focus of this study is the relationship between climate trends and spring flood events, climatic variables considered most influential in producing spring floods were chosen for graphical examination.

Spring floods occur in the study area as two main types: regional floods and flash floods (Jones, 2002). Regional floods are usually seasonal, often occurring when winter or spring rains along with melting snow provide the river basin with too much water too quickly. A large rainfall onto a deep snowpack creates ideal conditions for this type of flood, especially during the late winter and early spring seasons. The frozen ground present at this time of year increases runoff by blocking infiltration. Long-term flooding of urban and rural areas is the end result. Regional floods occur predominantly during April in the Massawippi basin (Jones, 1999) and are influenced strongly by total winter (previous December, January, February) snowfall, April maximum one-day rainfall events and the snowcover depth at the end of March (Jones, 2004). Thus, these three precipitation-related variables were chosen for graphical analysis. The general relationship between temperature and snowmelt described by Hartley and Dingman (1993) is made specific by Karl et al. (1993) who found a strong indirect interrelationship between maximum surface temperature and snowcover depth in regions they considered sensitive to snowcover variations. In southern Quebec the seasonal temperature sensitive snowcover time period is April and May (Karl et al., 1993). April is prime regional flood month in the Massawippi basin, thus winter and spring maximum temperatures are selected for graphical analysis.

Flash floods are rapidly occurring events, often hitting within minutes or hours with no warning. They cause immediate rises in stream water levels and high water velocities. Flash flood events occur due to intense, short-lived rainstorms. The presence of a deep snowcover will contribute additional water to the event but is not necessary for flooding to occur. The size of April peak rainfall events and the end of March snowcover depth are considered important influences on spring flash floods in the Massawippi basin.

Five hydrological variables were chosen for graphical analysis: annual total discharge, annual maximum daily discharge, spring total discharge, April maximum daily discharge and winter total discharge. These variables are considered most appropriate for portraying possible climate-induced changes in the basin hydrology that may impact spring flood behaviour.

Data are also analyzed statistically using the Mann-Kendall non-parametric test. This test is applied to further verify the outcomes of the graphical analysis for the climatic and hydrological variables. Additional climatic and hydrological variables considered of secondary importance to spring flooding are also analyzed using the Mann-Kendall test. These include climatic data for winter and spring minimum temperatures, total spring rainfall, total annual precipitation, and the winter and spring solid/total (S/ T) precipitation ratios, and hydrologic data for summer and autumn streamflows. These additional analyses will provide a more general sense of the interaction between the changing climatic and hydrological conditions.

The Mann-Kendall test has been described in detail by many authors (Burn and Hag Elnur, 2002; Burn et al., 2004a; Cunderlik and Burn, 2004; McBean and Motiee, 2006). A brief description of the test results will be provided here. The Kendall S-statistic is computed from the raw data series, where large positive values of S' indicate increasing trends and negative values indicate decreasing trends. For the 10% significance level used in this study, a probability value of less than 5% or greater than 95% (100--5) would indicate a significant result. The probability value can be used to determine whether or not the trend is statistically significant, and is derived from the Z values. The Beta value indicates the magnitude of the slope, an indication of the degree of change associated with the variable. The version of the test used in this study has been extensively tested and provides correct results (Burn, 2005).

Study Area and Data Analysis

The study area includes all terrain drained by the Massawippi River and its tributaries (Figure 1). The basin has a total area of 1670 km2, a quasi-circular shape and the terrain is one of rolling hills with an overall slope to the north. Principal tributaries include the Coaticook, Moes, Ascot, Tomifobia and Niger Rivers. A total of over 2000 km of stream channels exist within the Massawippi Basin, however most of these channels are relatively short, less than 4 km in length. The only extensive water body that interrupts stream channel flow in the basin is Lake Massawippi. Smaller water bodies, including Lakes Lyster and Averill, and Norton and Little Averill Ponds are located at the periphery of the basin, acting as water collection areas for streams. All streams follow the regional slope running in a generally south-north direction, eventually coming together as the Massawippi River, which discharges its volume into the St. Francis River at Sherbrooke.

A detailed study of flood events in the Massawippi River basin from 1964 to 1994 found 23 flood events in 19 of the 31 years (Jones, 1999). Historical and hydrological analyses of floods during the 20th century found that 95 flood events occurred in 66 of the 100 years, mainly during March and April (Jones, 2002). Extension of this analysis of the historical records into the years 2000 to 2004 shows one additional flood event in March 2003; no April flood events occurred. Two of the largest and most damaging floods on record occurred in April 1982 and April 1994. Jones (2004) showed that the 1982 event was of the flash flood type, occurring extremely quickly and caused almost completely by an unusually intense rainstorm; the 1994 event, in contrast, exhibited the more usual characteristics of a regional flood with a slow buildup to peak, caused by a combination of rainfall and snowmelt. The flash flood event of 1982 was by far the most damaging flood in the history of the Massawippi River Basin (Jones, 2004).

Hydrologic data are available for rivers within the Massawippi River basin beginning in 1960. All available data from discharge stations on the Ascot, Coaticook, and Massawippi Rivers were obtained from Le Centre d'expertise hydrique du Quebec. Discharge data for the Moes River were calculated from a regression equation based on flow in the neighbouring Ascot River. Temperature, precipitation and snowcover depth data for the same time period were obtained from Environment Canada for the five climatic stations within or adjacent to the Massawippi River basin: Coaticook, Lennoxville, Magog, Saint Malo and Sawyerville North. Temperature data for the Sawyerville North station are available from 1962. See Figure 1 for climatic and hydrological station locations. Raw data and cumulative percentage departure from the mean plots for the chosen climatic variables are presented in Figures 2a to 2e; graphical results for the hydrologic variables are found in Figure 2f; MannKendall results are provided in Table 1.

Analysis of the graphical results reveals a number of trends apparent in the climatic and hydrologic data. All cumulative percentage departure from the mean plots for winter maximum temperature show positive slopes in recent decades, especially since the late1970s; the plots for St. Malo and Sawyerville North exhibit the smoothest positive slopes (Figure 2a). This indicates a trend toward higher daytime temperatures during winter through the 45-year study period. A similarly positive trend is evident on three of the five cumulative percentage departure from the mean plots for spring maximum temperature: Lennoxville, St. Malo and Sawyerville North. The plot for Coaticook shows a positive slope from circa 1975 until the early1990s, then a negative slope to 2004; the plot for Magog shows no distinct overall trend (Figure 2b). Graphical evidence for higher daytime temperatures during the spring season exists, but it is less conclusive than the winter data. Taken together, the cumulative percentage departure from the mean graphical plots of maximum temperature data show an overall trend for increasing maximum temperatures in both winter and spring seasons.

In contrast, the Mann-Kendall analyses of the temperature data indicate that only two of the five stations have statistically significant trends over the 45year study period. For both winter and spring maximum temperature data, the St. Malo and Sawyerville North stations have significant trends at the chosen 10% level. In all four cases, the S' and Z values indicate positive, increasing trends for maximum temperature. The trends at the other three stations are considered insignificant by the Mann-Kendall test (Table 1).

Distinct trends also exist in the precipitation plots. The strongest trend is in the cumulative percentage departure from the mean plots for mean winter total snow (Figure 2c). Four of the five stations, Coaticook, Lennoxville, Magog and Sawyerville North, show negative slopes. St. Malo, in direct contrast, shows a positive trend in winter total snow, particularly in the period between the mid-1980s and the mid-1990s; since 1996 the plot shows a trend toward less winter snow. Over the complete 45-year study period, the St. Malo data trend is less clear than those from the other four stations. The overall trend from the other four stations is to less total snow accumulation during the winter months in the Massawippi basin area.

The Mann-Kendall statistical analysis of winter total snow indicates that the data trends from three of the five stations can be considered statistically significant

(Table 1). Lennoxville, Magog and Sawyerville North stations all have significant trends toward less total winter snow over the study period. The statistical analysis for the St. Malo station data indicate an insignificant positive trend exists. The trend at Coaticook is the weakest of the five. Both the raw data and cumulative percentage departure from the mean plots show total winter snowfall at that station decreasing through the 1970s, remaining low in the 1980s, then increasing again in the 1990s right up until 2004 (Figure 2c). Thus, the Mann-Kendall trend statistic for Coaticook records the lack of a consistent overall trend for this station.

All of the cumulative percentage departure from the mean plots for the end of March snowcover depth show quite similar trends (Figure 2d). All of the plots peak in the mid to late-1970s, then show an overall decline in the end of March snowcover depth into the 1990s. Looking at the raw data plots, the only year with a major end of March snowcover depth at all five stations since 1990 is 2001. The Mann-Kendall analyses for this variable indicate statistically significant trends exist at three of the five stations: Coaticook, Magog, Sawyerville North (Table 1). All three stations have strong negative trends, indicating significant decreases in the end of March snowcover depths. The stations at Lennoxville and St. Malo also have negative trends, but they are very weak and not statistically significant (Table 1).

Mann-Kendall statistical analyses were also performed on the solid to total precipitation ratios (S/ T ratios) for winter and spring (Table 1). The winter S/T ratio is seen to display a negative, decreasing trend at all stations, but is statistically significant only at the Lennoxville and Magog stations. A negative, decreasing trend is also apparent for the spring S/T ratios at all stations, but statistical significance is achieved only at the St. Malo station. The overall decreasing trends for both of these ratios indicate a change in the type of precipitation, from solid precipitation, mainly snow, to rain but statistical significance is lacking (Table 1).

Data plots for the third precipitation variable analyzed graphically, April maximum one-day rainfall, all show a negative slope (Figure 2e). This is indicative of a decrease in the magnitude of April one-day rainstorms over the study period. The plots clearly show this decrease in recent years, from approximately 1995 to 2004. The raw data plots for Lennoxville, Magog and St. Malo show this decreasing trend most clearly; plots of cumulative percentage departure from the mean for Lennoxville and St. Malo show the steepest negative slope to the curves during the last part of the study period. According to the Mann-Kendall analyses, only the trends at Lennoxville and St. Malo are statistically significant (Table 1). Both stations are shown to have moderately strong negative values for S' and Z, indicating decreasing trends at both stations. Mann-Kendall statistical analyses were also performed on spring total rainfall and annual total rainfall. Like April maximum one-day rainfall, spring total rainfall shows a negative trend. However, the strength of both of these rainfall trends varies. Only the St. Malo station has statistically significant trends for both variables while Magog and Sawyerville North trends have no statistical significance for these variables; the other three stations have mixed results. Trends in annual total rainfall are also inconsistent. Coaticook and St. Malo have very strong positive trends, Lennoxville has a very strong negative trend and the other two stations show no significant trend (Table 1).

Trends in water discharge through the Massawippi River basin were analyzed graphically using five variables: annual total, annual maximum daily, spring total, April maximum daily and winter total discharges. These were the variables considered to be most indicative of changes in spring flood behaviour in the basin; the annual variables were also chosen to provide comparison with previous studies of hydrologic change. The graphical plots for four of the five variables--all except winter total discharge--display discharges peaking in the mid to late-1970s, declining to the early 1990s, then staying relatively stable until 2004 (Figure 2f). Between 1960 and 2004, the total amount of water moving through the Massawippi River basin, on an annual and spring season basis, has remained almost unchanged; annual totals have decreased slightly, the spring totals more noticeably. Discharge peaks, as represented by the annual and April maximum daily discharge plots, have decreased over the period as well, with both the annual and April maximum daily discharges decreasing at about the same rate. In contrast, the winter total discharge has increased slightly, the only positive trend among the variables analyzed (Figure 2f).

The Mann-Kendall analyses for the discharge variables indicate that none of the five variables show significant trends over the 45-year study period (Table 1). All of the S' and Z values, except winter total discharge, are negative, indicating decreasing trends, but they are statistically insignificant at the 10% level. The spring total discharge probability percentage is the strongest. Winter total discharge is shown to be a positive, increasing trend, but also a statistically insignificant one. In a general way, the Mann-Kendall analyses agree with the graphical analyses, with most discharge values showing decreasing trends over time.

Discussion

The results of this local study allow an evaluation of changing climatic and spring flood-producing hydrologic conditions in a relatively small river basin. They also allow comparisons and contrasts to be made with studies made at regional and national scales. As Ashmore and Church (2001) point out, hydrologic changes influenced by climatic changes will differ geographically and will be dependent on the size of the basin in question. Climatic data from the Massawippi River basin region, through the 1960 to 2004 period, display trends toward warmer winter and spring temperatures. Graphical and statistical analyses of mean winter and spring maximum temperatures display positive, increasing trends (Figures 2a and b, Table 1). Statistical analyses of mean winter and spring minimum temperatures also display positive, increasing trends (Table 1). Overall, temperatures throughout the study period increased, although statistical significance was not achieved at all stations. This trend to increasing temperatures is in agreement with studies in other parts of Canada, at different scales. Burn et al. (2004a; b) and Cunderlik and Burn (2004) found increasing temperature trends in northwestern Canada; Lawson (2003) found a trend toward warmer winter temperatures in the prairie region of western Canada; Dibike and Coulibaly (2005) found an increasing trend in mean daily temperatures in the Saguenay River basin in northern Quebec. Temperature trends in the Massawippi basin are also similar to those found in the neighbouring New England state Maine. Dudley and Hodgkins (2005) found trends to increasing winter and spring mean temperatures.

This general increase in temperatures in the Massawippi basin is accompanied by significant changes in some of the basin's precipitation variables. Notably, mean winter total snow accumulations have a strongly negative, decreasing trend, and end of March snowcover depths also have strong negative trends. Rainfall trends are less strong. Graphical and statistical analyses for April maximum one-day rainfall and statistical analyses for spring total rainfall show generally decreasing trends for the former and increasing trends for the latter. The data trends for total annual precipitation are also mixed. Both positive and negative trends are seen in the statistical data. By comparison, McBean and Motiee (2006) found overall significant positive trends for overlake annual precipitation in the Great Lakes region between 1948 and 2000. A number of other large-scale regional studies (e.g., Karl et al., 1993; Ashmore and Church, 2001; Przybylak, 2002) have found positive trends in total annual precipitation for various Canadian regions during the last half of the 20th century. This local study provides partial support for those conclusions.

Graphical trends in selected Massawippi River basin discharges are negative, decreasing trends for all variables except winter total discharge (Figure 2f). Statistical analyses show these trends are insignificant (Table 1). Additional statistical analyses of summer and autumn total discharge trends show a lack of trend for either variable (Table 1). Based on the analysis of spring and annual maximum, and spring total discharges, no significant changes in streamflow during the spring season through the Massawippi basin have occurred during the study period. The spring and autumn results are in agreement with the national study completed by Burn and Hag Elnur (2002) which showed no significant trend for spring and autumn streamflows between 1960 and 1997 in southern Quebec. Since spring floods are directly related to streamflow, no significant changes in the flood hazard are suggested. In contrast to the results from the national study by Ashmore and Church (2001) and the local study of the Chateauguay River basin by Roy et al. (2001), no increased threat from flooding is occurring in the Massawippi River basin of southern Quebec. In an indirect manner, the late 20th century increase in flood event frequency suggested by print media reports in Jones (2002) is also not supported by the hydrologic data analyzed in this study.

Conclusions

A variety of temperature and precipitation trends during the study period for the Massawippi River basin are graphically, and for some variables statistically, apparent; only graphical trends are apparent for streamflows. Based on the evidence for trends in climatic variables, temperatures are increasing and precipitation is falling more as rain than snow in the winter and spring seasons. The decreasing trends for winter total snowfall and end of March snowcover depth, over the 45-year study period, suggest a deceasing amount of snow is available for melt and river discharge during April when floods are most probable. The accompanying decrease in April maximum one-day rainfall events suggests less water is available for both slow-building regional flood and fast-building flash flood events. Although there is graphical evidence for decreasing trends for maximum and total discharges, none of these trends are statistically significant. If future trends continue as they have during the study period, something only continued research can ascertain, the flood spring hazard in the Massawippi River basin should be reduced. At present, there is no clear evidence that changes in the climatic variables are causing significant changes in river or flood behaviour. Thus, there is no evidence that changing climatic conditions are creating a greater threat from flooding. There is also some statistical evidence to suggest total annual precipitation is increasing. However, there is no evidence for statistically significant changes in annual maximum or total river discharges. In fact the trends for these variables are negative, implying decreasing annual streamflows.

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Table 1. Mann-Kendall Test Results.

	Period	N	S'	Z	Beta	Proba-bility
Mean Winter Maximum Temperature						
Coaticook	1960-2004	45	116	1.14	0.02	87.2%
Lennoxville	1960-2004	45	151	1.48	0.03	93.0%
Magog	1960-2004	45	43	0.42	0.01	66.3%
St. Malo	1960-2004	45	172	1.68	0.04	95.4%
Sawyerville North	1962-2004	43	240	2.51	0.06	99.4%
Mean Winter Minimum Temperature						
Coaticook	1960-2004	45	306	2.99	0.07	99.9%
Lennoxville	1960-2004	45	215	2.11	0.05	98.2%
Magog	1960-2004	45	119	1.16	0.02	87.8%
St. Malo	1960-2004	45	-65	-0.64	-0.02	26.2%
Sawyerville North	1962-2004	43	26	0.27	0.00	60.7%
Mean Spring Maximum Temperature						
Coaticook	1960-2004	45	23	0.22	0.01	58.9%

Lennoxville	1960-2004	45	101	0.99	0.02	83.9%
Magog	1960-2004	45	10	0.10	0.00	53.9%
St. Malo	1960-2004	45	325	3.18	0.07	99.9%
Sawyerville North	1962-2004	43	210	2.20	0.04	98.6%

Mean Spring Minimum Temperature

Coaticook	1960-2004	45	260	2.54	0.04	99.5%
Lennoxville	1960-2004	45	164	1.61	0.03	94.6%
Magog	1960-2004	45	138	1.35	0.02	91.1%
St. Malo	1960-2004	45	-58	-0.57	-0.01	28.5%
Sawyerville North	1962-2004	43	34	0.36	0.01	63.9%

Winter Total Snowfall

Coaticook	1960-2004	45	-49	-0.48	-0.35	31.6%
Lennoxville	1960-2004	45	-308	-3.01	-2.57	0.1%
Magog	1960-2004	45	-357	-3.49	-2.51	0.0%
St. Malo	1960-2004	45	137	1.34	1.02	91.0%
Sawyerville North	1962-2004	43	-171	-1.67	-1.25	4.7%

End of March Snowcover Depth

Coaticook	1960-2004	45	-198	-2.77	0.00	0.3%
Lennoxville	1960-2004	45	-49	-0.69	0.00	24.6%
Magog	1960-2004	45	-149	-1.80	0.00	3.6%
St. Malo	1960-2004	45	-71	-0.72	0.00	23.5%
Sawyerville North	1962-2004	43	-222	-2.46	-0.19	0.7%

Spring Total Rainfall

Coaticook	1960-2004	45	199	1.95	1.14	97.4%
Lennoxville	1960-2004	45	34	0.33	0.28	63.0%
Magog	1960-2004	45	83	0.81	0.46	79.2%
St. Malo	1960-2004	45	185	1.81	1.58	96.5%
Sawyerville North	1962-2004	43	19	0.19	0.20	57.4%

April Maximum One-Day Rainfall

Coaticook	1960-2004	45	-113	-1.11	-0.10	13.4%
Lennoxville	1960-2004	45	-189	-1.85	-0.18	3.2%
Magog	1960-2004	45	-138	-1.35	-0.13	8.9%
St. Malo	1960-2004	45	-200	-1.96	-0.23	2.5%
Sawyerville North	1962-2004	43	-109	-1.07	-0.10	14.3%

Annual Total Precipitation

Coaticook	1960-2004	45	249	2.44	3.24	99.3%
Lennoxville	1960-2004	45	-289	-2.83	-4.91	0.2%
Magog	1960-2004	45	3	0.03	0.01	51.2%
St. Malo	1960-2004	45	237	2.32	5.94	99.0%
Sawyerville North	1962-2004	43	61	0.60	0.94	72.5%

Winter S/T Ratio

Coaticook	1960-2004	45	-109	-1.07	-0.16	14.3%
Lennoxville	1960-2004	45	-243	-2.38	-0.26	0.9%
Magog	1960-2004	45	-203	-1.99	-0.34	2.4%
St. Malo	1960-2004	45	-135	-1.32	-0.16	9.3%
Sawyerville North	1962-2004	43	-129	-1.26	-0.18	10.3%

Spring S/T Ratio

Coaticook	1960-2004	45	-111	-1.09	-0.15	13.9%

Lennoxville	1960-2004	45	-77	-0.75	-0.09	22.6%
Magog	1960-2004	45	-81	-0.79	-0.10	21.4%
St. Malo	1960-2004	45	-169	-1.65	-0.27	4.9%
Sawyerville North	1962-2004	43	-45	-0.44	-0.06	33.0%

Massawippi River Discharges

Annual Maximum	1960-2004	45	-145	-1.42	-1.10	7.8%
Annual Total	1960-2004	45	-37	-0.36	-9.64	35.9%
April Maximum	1960-2004	45	-149	-1.46	-1.49	7.2%
Winter Total	1960-2004	45	121	1.18	9.39	88.2%
Spring Total	1960-2004	45	-163	-1.59	-22.3	5.5%
Summer Total	1960-2004	45	-21	-0.21	-0.96	41.9%
Autumn Total	1960-2004	45	5	0.05	0.50	52.0%

Notes:

The Probability Value (%) determines Trends significant at the 1% the Positive values of S' indicate. The average slope of thetrends, is given by Beta.

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CASE STUDY: Studying a Volcano to Understand Climate Change

In June of 1991, after 600 years of slumber, Mount Pinatubo in the Philippines exploded (Figure 15-1). A huge amount of volcanic material blasted out of the mountain, sending a cloud of air pollutants and ash to a height of 35 kilometers (22 miles). Avalanches of hot gases and ash roared down the sides of the mountain, filling valleys with volcanic deposits. It was the second-largest volcanic eruption of the 20th century. (The largest took place in Alaska in 1912.)

The eruption of Mount Pinatubo killed hundreds of people, destroyed homes and farmland, and caused hundreds of millions of dollars in damage. At the same time, it enabled scientists to test whether they understood the global climate well enough to estimate how the eruption would affect temperatures on the earth.

By the late 1980s, most of the world’s climate scientists had become concerned that human actions, especially fossil fuel use, were enhancing the world’s natural greenhouse effect and contributing to a rise in the average temperature of the atmosphere. Some stated publicly that such global warming was likely to occur and could have disastrous ecological and economic effects. Their concerns were based in part on results from computer models of the global climate. But were these models reliable?

Although their complex global climate models mimicked past and present climates well, Mount Pinatubo provided scientists with an opportunity to perform a more rigorous test of such models. Soon after the volcano erupted, James Hansen, a U.S. National Aeronautics and Space Administration (NASA) scientist, estimated that the Pinatubo explosion would probably cool the average temperature of the earth by 0.5 C° (1 F°) over a 19-month period. The earth would then begin to warm, Hansen said, and by 1995 would return to the temperatures observed before the explosion. His projections turned out to be correct.

To make his forecasts, Hansen added the estimated amount of sulfur dioxide released by the volcano's eruption to a global climate model and then used the model to forecast how the earth's temperature would change. His model passed the test with flying colors. Its success helped convince most scientists and policy makers that climate model projections—including the impact of human actions—should be taken seriously.

Hansen's model and nineteen other climate models indicate that global temperatures are likely to rise several degrees during this century—mostly because of human actions—and affect the earth's global and regional climates, economies, and human ways of life. To many scientists and a growing number of business executives, global climate change (a broad term referring to changes in any aspects of the earth's climate, including temperature, precipitation, and storm activity) represents the biggest challenge that humanity faces during this century. The primary question is: What should we do about it?

Source: *Living in the Environment*, edited by G. Tyler Miller Jr. and Scott E. Spoolman. Belmont, CA: Brooks/Cole, 2009.

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Global Climate Change

Encyclopedia of Science, Technology, and Ethics, Vol. 2. 2005.

Global climate change refers to the ways in which average planetary weather patterns alter over time. The term *global warming,* though common, is a misnomer, for under some scenarios it is possible that part of the earth could cool, even as most of the planet gets warmer. The global climate change debate offers a superb case study of the relations existing in the early twenty-first century among science, technology, politics, and questions of meaning and value.

Defining the Problem

Because of the long timescales involved, climate change is difficult to experience directly; knowledge of meteorological variation generally falls under the classification of "weather." Science and technology—in forms such as the uncovering of the basic physical principles of atmospheric science, geologic evidence such as glacial moraines and plant remains, and determinations of ancient atmospheric concentrations derived from ice cores taken from the Greenland and Antarctic ice sheets—is needed to identify even the possibility of climate change. This fact has encouraged the assumption that both the definition of and the human response to possible climate change should be fundamentally scientific and technological in nature.

Geologists have known since the mid-nineteenth century that local, regional, and global climate undergoes change through time. Indeed, adding the term *change* to climate is nearly a redundancy, because climate varies on all timescales from decades to millions of years. This makes it difficult to clearly distinguish between the concepts of *weather* (transient variations) and *climate* (the long term status of the system).

For instance, the earth experienced an ice age that peaked 18,000 years ago; but considering the larger span of the earth's history, it is still in an ice age. While the norm for humanity, geologic evidence suggests that the earth has had ice on its poles for only a very small fraction of its history.

It was the Swedish chemist Svante Arrhenius (1859–1927) who in 1896 first suggested the possibility of human-induced climate change through the burning of fossil fuels. Climate change came to general notice in the 1970s, when concern was voiced about the possibility of global *cooling* leading to a new ice age. This remains a live possibility: Evidence of ancient climates shows that in the last 800,000 years the planet has seen a series of oscillations between ice ages, of approximately 100,000 years in duration, and interglacials, of around 10,000 years in length. Earth is thus overdue for a cold spell.

The 1980s saw the rise of concern about the "greenhouse effect" caused by increasing levels of human-produced carbon dioxide and other gases that trap heat in the atmosphere. Concern exploded in the summer of 1988, which saw record warmth throughout the United States. This warming trend appears to be continuing: Nine of the ten hottest years since the beginning of record keeping in 1880 have occurred between 1990 and 2003.

Ethical, Political, and Philosophical Issues

What defines climate change as a "problem" at all? This question relates to a long-standing debate within environmental ethics on whether nature has only instrumental value for human beings or has intrinsic value outside of any considerations of its value to humans. The first (anthropocentrist) position claims that concern about the environment should be motivated by an interest in human welfare. The second (ecocentrist) position believes that animals, species, ecosystems, and even rock formations and climate patterns can have qualities that make them the objects of moral concern.

On the first view, climate change is a problem only from the perspective of human wants, needs, and obligations to one another. Rising sea level is a physical event; it is only when it floods New Orleans or the Maldives that it becomes a problem. From this point of view, climate change has become a crisis in two senses in the early 2000s. First, human populations, structures, or the ecosystems societies depend upon may be exposed to climate-induced dangers such as rising sea level, changes in temperature and/or precipitation, changes in the frequency of extreme events such as hurricanes, and changes in vegetation and the growing season. Second, if climate change is partially or wholly human-caused—that is, if it is anthropogenic in nature—then the persons, industries, or societies that have caused these problems may fairly be held accountable.

This latter question has spawned a global debate about the respective responsibilities of developed and developing nations to address climate change. The debate turns on the fact that most of the increase of greenhouse gases to date has been caused by industrial nations, especially the United States, whereas most of the future contribution of greenhouse gases to the atmosphere is likely to come from developing countries such as China. Should developed countries be required to address questions of greenhouse gas emissions first, because they caused the problem, allowing developing nations to pollute more as they develop their industries? Or is such an approach self-negating, in that any real solution to greenhouse gas emissions requires a common global effort?

On another view, however, climate change is a more than a human affair. Climate change is certainly an issue for any species driven to extinction by ecosystem change. It is here that the question of global climate change touches upon core questions within the philosophy of nature. Species come into and go out of existence constantly; does it matter whether a species' extinction is caused by natural climate variability or anthropogenic change? In the mind of some, the difference is crucial: Change (including extinction) that is natural in origin should be tolerated and adapted to, whereas human-caused change or extinction should be addressed and mitigated. Making the question even more vexed are claims that there is no "natural" left in the early twenty-first century. On this view the entire earth, including its atmosphere, has become an artifact through centuries of inhabitation, cultivation, and pollution (Allenby 1999, McKibben 1999). These aspects of the climate change debate point toward religious and metaphysical considerations concerning the status of nature rather than to more and better data and predictions. In ways similar to the current debate concerning genetic engineering, questions are increasingly being asked about whether nature represents a limit that should be acknowledged and in some sense obeyed.

The Scientific Effort

Concerns about global climate change have led to a massive, unprecedented, and worldwide scientific, technological, and political effort to understand the causes and consequences of climate change. The basic assumption underlying all of these efforts is that climate change science is necessary for the devising of climate change policy.

The United States leads the world in climate change research, funding more than half of all the work. Approximately half of the nearly $2 billion annual budget for the U.S. Global Change Research Program (USGCRP, The U.S. Government's Interagency Research Program On Climate Change) is devoted to satellites and other data systems. The rest supports research across a wide range of sciences such as physics, atmospheric chemistry, oceanography, and ecology. A significant part of this research is conducted through computer simulations, the best known of which are global climate models (GCMs) that run on the world's fastest computers. Products of a truly global scientific and technological effort, GCMs have produced sets of predictions concerning the possible state of the atmosphere in 2100. (There is, of course, nothing magical about the year 2100; it was picked for symmetry and because this period was thought to be within the moral horizon of most people. In fact, computer models predict that change will accelerate after this date.)

Research into the social and political aspects of climate change—broadly known as "human contributions and responses to global change"—receives around 2 percent of the USGCRP budget, or $50 million. Even then, the overwhelming majority of this investment goes toward quantitative (often economic) social science research. While questions of ethics and values have often been voiced in public debate, research into such questions has been pursued only at the margins. The overall definition of the problem of climate change thus remains deeply immersed in science: The USGCRP seeks to identify the basic facts of the matter, leaving questions of value and justice to the political realm. More to the point, the assumptions remain quite positivistic: It is assumed that ethical and political solutions will somehow be derived from advances in climate science.

After two decades of concerted research, the community of climate change scientists have reached a high degree of consensus on several basic points: The global climate is warming; this warming is largely anthropogenic in origin; and the consequences of this warming could be quite severe. In the words of the National Research Council's Committee on the Science of Climate Change, "Greenhouse gases are accumulating in Earth's atmosphere as a result of human activities … Temperatures are, in fact, rising" (NRC 2001, p. 1).

Science Meets Policy

Climate science research in the United States and other nations (principally the European Union and Japan) feeds into a global political effort to manage the problem of global climate change. The Intergovernmental Panel on Climate Change (IPCC) lies at the center of these efforts. The World Meteorological Organization and the United Nations Environment Programme founded the IPCC in 1988 "to assess scientific, technical and socio-economic information relevant for the understanding of climate change" (IPCC). The IPCC consists of:

- Working Group I, which assesses the scientific aspects of the climate system and climate change
- Working Group II, which focuses on the vulnerability of socioeconomic and natural systems to climate change, the consequences (both negative and positive) of climate change, and possible options for adapting to climate change
- Working Group III, which evaluates options for restricting greenhouse gas emissions and other ways to mitigate climate change
- The Task Force on National Greenhouse Gas Inventories, which runs the IPCC National Greenhouse Gas Inventories Programme

In addition, a series of special reports supports the working groups, the most important being the Special Report on Emissions Scenarios (SRES), which provides baseline sociological, political, and economic parameters for GCMs. Since 1990 the working groups have issued a series of joint assessment reports on a five- to six-year basis. These reports represent a remarkable synthesis of technoscientific research. Each assessment directly involves hundreds of scientists who collectively spend thousands of hours collating and synthesizing the available information on the above topics in a thick set of volumes. After a series of reviews, each volume is then boiled down to a "summary for policymakers" that attempts to extract insights most relevant to decision makers worldwide.

These IPCC reports are created to support the United Nations Framework Convention on Climate Change (UNFCCC), which seeks to devise a global political strategy. In late 1997 the UNFCCC gathered representatives from more than 160 nations in Kyoto, Japan, to negotiate binding limitations on greenhouse gases for developed nations. The resulting Kyoto Protocol called for developed nations to agree to limit their greenhouse gas emissions as compared with the levels emitted in 1990. The bulk of the political efforts to address the challenges of climate change have centered on negotiating the particular provisions of the Kyoto Protocol.

The results, however, have not been encouraging. Even if the Kyoto Protocol were to be ratified—and the Bush Administration announced its rejection of the protocol in 2001—the proposed limitations to greenhouse emissions would not come anywhere near the estimated 50 to 75 percent reduction scientists believe is necessary to stabilize atmospheric levels of carbon dioxide. What is more, the

$25 to $30 billion the United States spent on climate change research from the early 1980s to the early 2000s highlights the questionable structure of the existing global climate change debate. Across this twenty-year period, the range of uncertainty for the predicted amount of change in global mean temperatures by 2100 actually *increased,* from 1.4 to 5.4 degrees Celsius in 1980 to 1.4 to 5.8 degrees Celsius in 2001. This increase in the range of possible warming has provided cover for politicians to call for more research instead of devising plans of action.

Future of the Problem

The paradox is that at the same time that a scientific consensus has formed on the reality of climate change, the actual range of future outcomes has increased rather than shrunk. A number of factors contribute to this increase of uncertainty, including a greater appreciation of the complexity and attendant lack of understanding concerning some parts of the climate system (for instance, the behavior of clouds, and the ocean–atmosphere interface), the difficulties in matching differing types of data, and the possibility that a system as complex as world climate is fundamentally unpredictable in nature. But the core difficulty lies elsewhere: The computer simulations used to model the atmosphere for the year 2100 are themselves fundamentally dependent on future sociological and economic indicators that are essentially unknowable. This is the significance of the SRES scenarios, which provide the basic inputs and parameters for the GCMs.

The SRES scenarios consist of six different imagined future patterns of energy use, technological progress, and social, political, and economic development. These six possible development paths explore future choices concerning population, lifestyle, the degree of globalization and economic integration, the development of non-carbon-based energy sources, and the possibility of carbon sequestration—choices that are not predictable in ways analogous to physical systems. Moreover, the point is not just that future social conditions cannot be predicted, but that they are in large part a function of human choices. The future does not simply befall humanity; individually and collectively humans exercise a significant influence over what happens. Rather than treating the future as if it were beyond human control, the challenge of global climate change calls for public debate about desirable futures.

It is thus arguable that while scientific research on climate change has greatly increased the knowledge and appreciation of the problem, the focus of attention should now shift toward two other areas that complement climate science: better understanding the nature of the social, ethical, political, and political dimensions of the problem, and devising ways to increase the resilience of both natural and social systems to a global climate that is already undergoing alteration. This approach would involve a shift in attention away from precisely modeling the climate system and toward devising a "no-regrets" strategy tied to sustainable development, social justice, and the modification of desires. The problem, however, is that such a "soft" approach to global climate change runs up against 300 years of tradition in which humankind has attempted to engineer its way out of problems rather than developing personal and political means for modifying its behavior.

ROBERT FRODEMAN

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United Nations Climate Change Conference 2008

http://unfccc.int/meetings/cop_14/items/4481.php
December 1-12, 2008
Poznań, Poland
Sponsored by the United Nations Framework Convention on Climate Change (UNFCCC)

The 2008 United Nations Climate Change Conference in Poznań ended with a commitment from governments to shift into full negotiating mode next year in order to shape an ambitious and effective international response to climate change, to be agreed in Copenhagen at the end of 2009. Parties agreed that the first draft of a concrete negotiating text would be available at a UNFCCC gathering in Bonn in June of 2009.

The finishing touches were put to the Kyoto Protocol's Adaptation Fund, with Parties agreeing that the Fund would be a legal entity granting direct access to developing countries. Progress was also made on a number of important ongoing issues that are particularly important for developing countries, including: adaptation; finance; technology; reducing emissions from deforestation and forest degradation (REDD); and disaster management.

A key event at the Conference was a ministerial round table on a shared vision on long-term cooperative action on climate change.

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EU/UN/CLIMATE CHANGE: US CHANGE OF TONE CONFIRMED AT TOKYO MEETING.

(Conference news)

Europe Environment Feb 19, 2009. p243900.

Without a shadow of a doubt, the new US administration is adopting a more open and flexible attitude to climate change, as Washington's partners were able to observe at the first meeting of the year, on 12 and 13 February in Tokyo, convened to prepare the ground for the United Nations climate conference in Copenhagen in December 2009.

The representatives of 22 nations, among them the planet's leading emitters of greenhouse gases - the United States, China and the European Union - came together for an informal working session in the Japanese capital to start preparing the Copenhagen conference. Yvo de Boer, secretary-general of the Climate Convention, also attended.

"I can assure you that there is a pronounced change in tone with this new American administration," observed Artur Runge-Metzger, the European Union's climate negotiator. The Tokyo meeting, he continued, was the first contact with US climate officials since President Obama's inauguration last month, even though none of the new officials took part in the discussions. "There is a will to get involved in the climate change issue and to take action, and the best proof of that is that most of the positions of responsibility on climate policy have already been filled in the Obama administration," he added. "We are entering a new bracket and a real phase of negotiation," declared the co-chairman of the debates, Brazil's Sergio Barbosa Serra. The other co-chair for the session, Japan's Akihiko Furuya, pointed out that 2009 "is critical; we only have ten months until Copenhagen".

The next preparatory meeting under United Nations auspices will be in Bonn (Germany), from 29 March to 8 April.

AVIATION READY TO PLAY THE GAME

Four of the world's biggest airlines - Air France-KLM, British Airways, Cathay Pacific and Virgin Atlantic - as well as the airport operator BAA called, on 12 February, for the aviation sector's CO2 emissions to be taken into account in the negotiations for a new global climate agreement. The airlines, represented by the Aviation Global Deal Group (AGD), said the sector needs a "pragmatic, fair and effective" approach in the context of the international negotiations.

A CRUCIAL ROLE

"Aviation can play a crucial role in emissions reduction," observed Tony Tyler, chief executive officer of Cathay Pacific, speaking on behalf of AGD.

Aviation is not covered by the Kyoto Protocol, but the European Union has decided unilaterally to include this sector in its Emission Trading Scheme (ETS) from 2012. The AGD's position reinforces its determination to see the same thing happen at global level.

Source Citation: "EU/UN/CLIMATE CHANGE : US CHANGE OF TONE CONFIRMED AT TOKYO MEETING.(Conference news)." Europe Environment (Feb 19, 2009): 243900. Global Reference on the Environment, Energy, and Natural Resources. Gale.

-----------PRIMARY DOCUMENTS---------

THE KYOTO PROTOCOL

The Parties to this Protocol,

Being Parties to the United Nations Framework Convention on Climate Change, hereinafter referred to as "the Convention,"

In pursuit of the ultimate objective of the Convention as stated in its Article 2,

Recalling the provisions of the Convention,

Being guided by Article 3 of the Convention,

Pursuant to the Berlin Mandate adopted by decision 1/CP.1 of the Conference of the Parties to the Convention at its first session, Have agreed as follows:

Article 1 For the purposes of this Protocol, the definitions contained in Article 1 of the Convention shall apply. In addition:

1. "Conference of the Parties" means the Conference of the Parties to the Convention.
2. "Convention" means the United Nations Framework Convention on Climate Change, adopted in New York on 9 May 1992.
3. "Intergovernmental Panel on Climate Change" means the Intergovernmental Panel on Climate Change established in 1988 jointly by the World Meteorological Organization and the United Nations Environment Programme.
4. "Montreal Protocol" means the Montreal Protocol on Substances that Deplete the Ozone Layer, adopted in Montreal on 16 September 1987 and as subsequently adjusted and amended.
5. "Parties present and voting" means Parties present and casting an affirmative or negative vote.
6. "Party" means, unless the context otherwise indicates, a Party to this Protocol.
7. "Party included in Annex I" means a Party included in Annex I to the Convention, as may be amended, or a Party which has made a notification under Article 4, paragraph 2(g), of the Convention.

Article 2

1. Each Party included in Annex I, in achieving its quantified emission limitation and reduction commitments under Article 3, in order to promote sustainable development, shall:

(a) Implement and/or further elaborate policies and measures in accordance with its national circumstances, such as:

(i) Enhancement of energy efficiency in relevant sectors of the national economy;

(ii) Protection and enhancement of sinks and reservoirs of greenhouse gases not controlled by the Montreal Protocol, taking into account its commitments under relevant international environmental agreements; promotion of sustainable forest management practices, afforestation and reforestation;

(iii) Promotion of sustainable forms of agriculture in light of climate change considerations;

(iv) Research on, and promotion, development and increased use of, new and renewable forms of energy, of carbon dioxide sequestration technologies and of advanced and innovative environmentally sound technologies;

(v) Progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse gas emitting sectors that run counter to the objective of the Convention and application of market instruments;

(vi) Encouragement of appropriate reforms in relevant sectors aimed at promoting policies and measures which limit or reduce emissions of greenhouse gases not controlled by the Montreal Protocol;

(vii) Measures to limit and/or reduce emissions of greenhouse gases not controlled by the Montreal Protocol in the transport sector;

(viii) Limitation and/or reduction of methane emissions through recovery and use in waste management, as well as in the production, transport and distribution of energy;

(b) Cooperate with other such Parties to enhance the individual and combined effectiveness of their policies and measures adopted under this Article, pursuant to Article 4, paragraph 2(e)(i), of the Convention. To this end, these Parties shall take steps to share their experience and exchange information on such policies and measures, including developing ways of improving their comparability, transparency and effectiveness. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session or as soon as practicable thereafter, consider ways to facilitate such cooperation, taking into account all relevant information.

2. The Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the International Civil Aviation Organization and the International Maritime Organization, respectively.

3. The Parties included in Annex I shall strive to implement policies and measures under this Article in such a way as to minimize adverse effects, including the adverse effects of climate change, effects on international trade, and social, environmental and economic impacts on other Parties, especially developing country Parties and in particular those identified in Article 4, paragraphs 8 and 9, of the Convention, taking into account Article 3 of the Convention. The Conference of the Parties serving as the meeting of the Parties to this Protocol may take further action, as appropriate, to promote the implementation of the provisions of this paragraph.

4. The Conference of the Parties serving as the meeting of the Parties to this Protocol, if it decides that it would be beneficial to coordinate any of the policies and measures in paragraph 1(a) above, taking into account different national circumstances and potential effects, shall consider ways and means to elaborate the coordination of such policies and measures.

Article 3

1. The Parties included in Annex I shall, individually or jointly, ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts, calculated pursuant to their quantified emission limitation and reduction commitments inscribed in Annex B and in accordance with the provisions of this Article, with a view to reducing their overall emissions of such gases by at least 5 per cent below 1990 levels in the commitment period 2008 to 2012.
2. Each Party included in Annex I shall, by 2005, have made demonstrable progress in achieving its commitments under this Protocol.
3. The net changes in greenhouse gas emissions by sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990, measured as verifiable changes in carbon stocks in each commitment period, shall be used to meet the commitments under this Article of each Party included in Annex I. The greenhouse gas emissions by sources and removals by sinks associated with those activities shall be reported in a transparent and verifiable manner and reviewed in accordance with Articles 7 and 8….

Article 25

1. This Protocol shall enter into force on the ninetieth day after the date on which not less than 55 Parties to the Convention, incorporating Parties included in Annex I which accounted in total for at least 55 per cent of the total carbon dioxide emissions for 1990 of the Parties included in Annex I, have deposited their instruments of ratification, acceptance, approval or accession.
2. For the purposes of this Article, "the total carbon dioxide emissions for 1990 of the Parties included in Annex I" means the amount communicated on or before the date of adoption of this Protocol by the Parties included in Annex I in their first national communications submitted in accordance with Article 12 of the Convention.
3. For each State or regional economic integration organization that ratifies, accepts or approves this Protocol or accedes thereto after the conditions set out in paragraph 1 above for entry into force have been fulfilled, this Protocol shall enter into force on the ninetieth day following the date of deposit of its instrument of ratification, acceptance, approval or accession.
4. For the purposes of this Article, any instrument deposited by a regional economic integration organization shall not be counted as additional to those deposited by States members of the organization.

Article 28 The original of this Protocol, of which the Arabic, Chinese, English, French, Russian and Spanish texts are equally authentic, shall be deposited with the Secretary-General of the United Nations. **DONE** at Kyoto this eleventh day of December one thousand nine hundred and ninety-seven.

IN WITNESS WHEREOF the undersigned, being duly authorized to that effect, have affixed their signatures to this Protocol on the dates indicated.

Annex A

Greenhouse gases

Carbon dioxide (CO_2)

Methane (CH_4)

Nitrous oxide (N_2O)

Hydrofluorocarbons (HFCs)

Perfluorocarbons (PFCs)

Sulphur hexafluoride (SF_6)

Sectors/source categories

Energy

Fuel combustion

Energy industries

Manufacturing industries and construction

Transport

Other sectors

Other

Fugitive emissions from fuels

Solid fuels

Oil and natural gas

Other

Industrial processes

Mineral products

Chemical industry

Metal production

Other production

Production of halocarbons and sulphur hexafluoride

Consumption of halocarbons and sulphur hexafluoride

Other

Solvent and other product use

Agriculture

Enteric fermentation

Manure management

Rice cultivation

Agricultural soils

Prescribed burning of savannas

Field burning of agricultural residues

Other

Waste

Solid waste disposal on land

Wastewater handling

Waste incineration

Other

Annex B

Party Quantified emission limitation or reduction commitment (percentage of base year or period)

Australia 108

Austria 92

Belgium 92

Bulgaria□ 92

Canada 94

Croatia□ 95

Czech Republic□ 92

Denmark 92

Estonia□ 92

European Community 92

Finland 92

France 92

Germany 92

Greece 92

Hungary□ 94

Iceland 110

Ireland 92

Italy 92

Japan 94

Latvia□ 92

Liechtenstein 92

Lithuania□ 92

Luxembourg 92

Monaco 92

Netherlands 92

New Zealand 100

Norway 101

Poland 94

Portugal 92

Romania 92

Russian Federation 100

Slovakia 92

Slovenia 92

Spain 92

Sweden 92

Switzerland 92

Ukraine 100

United Kingdom of Great Britain and Northern Ireland 92

United States of America 93

Countries that are undergoing the process of transition to a market economy.

-----------------PODCASTS--------------------

How Conclusive is Climate Change Research?

(12:00-1:00 PM)(Interview)(Broadcast transcript)(Audio file)
Day To Day Jan 28, 2009.

To listen to this broadcast, click here:

http://www.npr.org/templates/story/story.php?storyId=99952246

ALEX COHEN, host:

This is Day to Day. I'm Alex Cohen. In the midst of an economy that's failing miserably, we sometimes forget there are other problems on the horizon, ones that could potentially threaten our existence. Climate change continues to be a serious issue. It's one former Vice President Al Gore is talking about today on Capitol Hill. I spoke earlier with Stephen Schneider, who researches global warming at Stanford University, who says much has changed in recent years and in recent weeks.

Dr. STEPHEN SCHNEIDER (Climatologist, Stanford University): The biggest progress that's taken place, if I can be so politically blunt, is the change of administrations from one that was hostile to the notion that there should be government control on private industries' emissions and one which believes that it has to listen to science first and politics second, and that taking care of the global commons is an important priority alongside of the economy.

And we now are historically closer to having world agreements on starting down the road of getting climate policy than we've ever been, and that's a result, I think, of the combination of nature cooperating with theory, because we've been talking about this for a long time. I first testified to the Senate why energy and climate policy were the same to Ribicoff and Muskie in 1979. What's taken us so long?

First hearing Al Gore ever had in '81, which I also was at with the number of other colleagues, we were arguing the same thing. It took a long time because it was theoretical then. Now, it's happening, damages are occurring, people's attention is poised on fixing the problem. And at the same time, we have an administration that's actually willing to do it.

COHEN: So you mentioned there's this change in attitude in Washington. What about action? What specifically do you think President Obama needs to do now?

Mr. SCHNEIDER: Well, I think he needs to do a lot of things. We first have to realize that we've got in the pipeline climate change, and we're committed to a few more degrees of warming, kind of, no matter what we do, so we have to have an adaptation strategy. How are we going to protect coast lines against intensified hurricanes? How we're going to deal with the increased fires in the West? What are we going to do with melting glaziers?

We've got to do that regardless of climate policy. To try to control emissions, we have to deal adaptation. The second thing is we have to use our energy more efficiently. We need building codes. So what we're going to have to do is to nationalize the kind of California activities where everybody has to participate and it's not just a random lottery of states values. Then finally, we have to help the brilliant American industry to be able to invent our way out of the problem through cheaper solar machines and better grids for wind machines. And we need incentives. We'll need loan guarantees.

I mean, if we can spend almost a trillion dollars bailing out some greedy people who messed up in an under-regulated environment, how about spending a tenth that much trying to produce green jobs, and at the same time, reduce our dependence on foreign oil and help the environment.

COHEN: How do you think our current economic situation is going to affect efforts to curb global warming?

Mr. SCHNEIDER: Of course, Alex, you're right that at a time of physical stress, people do not want to spend extra money that they think people need to go out and consume and so forth. So that'll put pressure on reducing the rate at which we're controlling pollutants. But at the same time, if you want to solve the problem in the long run, you can't continue to support the rape and scrape industries, which really don't have a long-term sustainable future because of environmental side effects.

The second thing that we need to do is we need to protect the environment, and if we don't have green tech, we're going to have very serious environmental problems, even worse than we already do. And number three, there's the problem of defending the lines of supply of imported oil, and therefore, the more we can produce domestically with green tech, the better off we are.

COHEN: That term you used, rape and scrape, what do you mean by that?

Mr. SCHNEIDER: Mountaintop removal in coal areas, logging into primary forests. We used to build our economy by moving logs around in diesel trucks. That's not how we do it much any more. We build the economy by moving electrons around in the microchips of computers. We get a lot more gross domestic product for that per unit of energy than we do with the old way of doing things, like in the Victorian industrial revolution. However, there are people whose jobs depend upon doing it the old way, and they want to preserve that in perpetuity even though it's not great for the economy, and it's certainly not good for the environment.

So we'll have to find fair ways to have job retraining, to have compensation, to have tax breaks for industries that go into those areas that used to produce products which we now know are polluting. And all of that will require a vision to see this as not simply an energy problem, not simply an environmental problem, not simply a security problem, but a problem that cuts across the social needs of the society.

COHEN: As we look ahead to the future, what is the latest in terms of what we can know about how temperatures might rise because of climate change in the future?

Mr. SCHNEIDER: We don't know whether they're going to warm up another three degrees or another 10 this century. Three degrees more is not a good thing, but 10 is utterly catastrophic. That's a difference between an ice age and our current warm period happening not in 5,000 years, like nature, but in a hundred, which would be devastating. Species would go instinct. We'd have problems with food and water. So we sure don't want the high end, and none of us can rule it out, better than a 10 percent chance.

So we really need to do research and try to pin that down. Another thing that's critical is - so what is the long-term prospect for our cities and our ports? How much is the sea level going to rise? What are our coast lines going to look like? Well, that depends upon how fast Greenland and parts of the West Antarctic ice sheet melt. That's a big unknown.

COHEN: There was a piece appearing in the New York Times this week that described new research that basically found even if we curb emissions now, climate change will likely continue until at least the year 3000. Do you feel like there is any solution? Can we ever go back?

Mr. SCHNEIDER: We should not think about the fact that we're going to be pristine and back what we were like before the industrial revolution. I think we have to have a different notion. We have used the industrial revolution to get rich. We've improved our quality of life. Now, those very techniques are reducing the quality of life through environmental side effects. Let's try to prevent it from getting a lot worse.

So while we can't stop a few degrees of warming on top of where we already are, we can stop the 10 degrees. My notion is do as much as you can, as fast as you can, as fairly as you can, and as cost effectively as you can, and don' t get hung up on the numbers because three degrees is a lot better than six, and 10 degrees is dramatically worse than any other numbers.

So let's approach what we can realistically do and set up the adaptation funds to try to deal with that, which we're already stuck with because we didn't have the foresight way back when to anticipate these problems.

COHEN: Stanford University's Stephen Schneider is part of the Intergovernmental Panel on Climate Change. That group was awarded the 2007 Nobel Peace Prize along with former Vice President Al Gore.

Source Citation: "How Conclusive is Climate Change Research?(12:00-1:00 PM)(Interview)(Broadcast transcript)(Audio file)." Day To Day (Jan 28, 2009) Global Reference on the Environment, Energy, and Natural Resources. Gale.