THE IMPLICATIONS OF GLOBAL CLIMATIC CHANGES FOR INTERNATIONAL SECURITY

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Abstract. Global climatic changes caused by growing concentrations of atmospheric trace gases have the potential to alter international relationships, economics, behavior, and security. While there is debate about the extent to which environmental problems alone can lead to conflict, it is widely acknowledged that resource constraints can act as roots leading to economic pressures and tensions, or as triggers to conflict when other pressures and tensions exist between states. Recent widespread attention to the issue of global environmental problems, particularly climatic change, is leading to a re-examination and expansion of the traditional narrow definition of "international security". This paper discusses likely paths to international frictions and tensions and the responses that might be most appropriate to minimize the adverse consequences of climatic change for international security.

Introduction

Over the last few decades, there has been growing concern over the international implications of large-scale environmental problems. Recently, this attention has focused on the possibility of major climatic changes caused by growing atmospheric concentrations of carbon dioxide and other trace gases. Given the extent and severity of the possible climatic changes, we must begin to ask how such changes will affect international relationships, economics, behavior, and security.** There is debate about the extent to which resource constraints or environmental problems *alone* can lead to conflict, but it is widely acknowledged that resources can act as roots leading to economic pressures and tensions or as triggers to conflict when other pressures and tensions exist between states. This paper discusses the most likely paths for such effects and what responses might be appropriate to minimize the adverse consequences for international stability and tensions.

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** Threats to security can be defined to include actions that (1) threaten to drastically and quickly degrade the quality of life for the inhabitants of a state, or (2) threaten to significantly narrow the range of policy choices available to governments or non-governmental entities (Ullman, 1983). Climatic changes that lead to the deterioration of environmental quality or limit access to resources fall into both categories.

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Precise information on the regional impacts of climatic changes is unlikely to be available soon. Rather than waiting for such information, a more valuable approach would be to identify the greatest susceptibilities to existing climatic variability on the assumption that those vulnerabilities are likely candidates for further analysis. Three areas are likely to affect national and international relationships, behavior, and policy: agricultural productivity, the availability and quality of freshwater resources, and access to strategic minerals (Budyko, 1977; Roberts and Lansford, 1979; Gustafson, 1981; Wilson, 1983; Tickell, 1986). Agricultural productivity fluctuates with the weather, and the level of international trade is large. Water resources are sensitive to both floods and droughts and are limited in many regions due to natural variability or high societal demand. Certain mineral resources, including oil and gas, are found in significant amounts in regions constrained by climatic conditions and the importance of these resources to particular nations and alliances warrants attention. By looking at past climatic experience we can begin to understand the extent of future vulnerabilities.

Any analogies linking past climatic variability with international political effects are necessarily imperfect. One problem is that the links between political behavior and climatic conditions are often tenuous, given the many other relevant factors that affect such behavior. A further complication is that the magnitude and severity of future climatic changes is likely to be considerably greater than past climatic variability.

An alternative approach is to wait for more research and more detailed regional information on the environmental and economic impacts of climatic changes before taking preventative actions. This approach has two serious flaws. First, the complexity of modeling climatic behavior means that the necessary research will be slow and difficult. Unless actions begin soon to reduce the emissions of carbon dioxide and other gases, the earth will be irreversibly committed to substantial warming. Second, any international agreement to prevent major climatic changes may be complicated by a desire of certain actors (alliances, nations, sub-national groups, corporations) to capitalize on perceived regional advantages. Those actors who believe – rightly or wrongly – that they will benefit from a warmer earth will have no direct incentive to cooperate in any international agreement to prevent climatic change.

These problems are discussed below in the context of three issues that play a role in international affairs: (1) agricultural productivity and the lopsided nature of present international grain production and trade; (2) water availability and the importance of shared international freshwater resources; and (3) access to strategic northern energy minerals such as oil and gas, and the increasing difficulty of developing the remaining remote resources.

Agricultural Productivity and Trade

Threats to the basic food supplies of a country are cause for frictions and tensions between nations (Wallensteen 1986). Possible mechanisms for such threats include trade embargoes or other forms of political manipulation of access to food, environmental degradation such as loss of soil fertility, or competition among conflicting land uses. Because regional scarcity is a fundamental condition for a good to become a political tool, the disparity in food needs and food resources between the developing and the developed world has long hinted at the possibility of future conflict over access to food resources.

Food availability depends on a complex array of factors, including patterns of production, purchasing ability, and the operation of food distribution systems. The vulnerability of political behavior to the availability and quality of agricultural resources has been highlighted in recent years by internal conflicts and riots over food shortages throughout the Sahel in the 1970s, in Sudan in 1981 and 1985, in Poland in 1980, in Tunisia in 1983 and 1984, and in Morocco in 1984. These internal events often serve to increase external tensions as well (Schneider, 1983; Wallensteen, 1986).

Even today, some countries are acutely vulnerable to natural climatic variability that may cripple their own food production or substantially reduce the supply and raise the price of foodstuffs on the world market. Under conditions of changing climate and growing population, this situation may grow more precarious.

The situation for large grain producers is equally uncertain. As temperatures increase, agricultural production could expand into northern regions of the United States, the Soviet Union, China, and Canada if soil conditions, water availability, and other factors permit. But output in regions that are now productive, such as the Central Plains of the United States, the Ukraine, and Kazakhstan, could be reduced by higher temperatures and changes in water availability.

Analysis of the net effect (both regionally and globally) of climatic changes on food production is complicated by the difficulties of estimating the effect of changes in yields on world agricultural markets. Short-term reductions in yields alone are not necessarily bad for overall long-term productivity and food availability. Confounding factors include the size of stocks, subsequent investments in other regions, planting patterns, international prices, and the character of trading agreements. Thus changes in the comparative advantage of the different actors can play a greater role than absolute changes in agricultural productivity.

A Case Study: Agricultural Productivity and International Grain Trade

International tensions and conflict may be provoked by changes in the productivity of major grain importers, by the demand for grain on the international market, and by the ability of present grain suppliers to continue to generate surpluses. For example, periodic crop failures can turn into a distinct political danger. In the Soviet Union, climatic constraints play an important role in limiting agricultural productivity, where one of the problems is water availability. Uncertain rainfall is the greatest single climatic hindrance to Soviet agriculture and sixty percent of the

Soviet grain-growing area suffers some loss from inadequate moisture on the average in three or four years out of ten (Gustafson, 1981).

The direct effect of Soviet grain productivity problems is to force them to purchase grain in international markets to make up deficiencies. Figure 1 shows Soviet imports of cereals as a percentage of total world cereal trade. In recent years the Soviets have been the largest single cereal importer, accounting for 20 percent of total grain purchases. According to Gustafson (1981),

> The need to turn to international markets for grain became a regular humiliation and a drain of scarce foreign currency. In the eyes of Soviet leaders, problems with agricultural productivity threatened domestic stability, national security, and economic growth.

One of the political risks of international trade in grain is the threat of a grain embargo. In 1980, the United States imposed such an embargo on the Soviet Union in response to the Soviet intervention in Afghanistan. Because of this experience with U.S. unreliability as a grain supplier, the Soviets have made efforts to reduce their dependence on U.S. grain by spreading their purchases among the other main grain suppliers.

The principal effect of the grain embargo was to give the Soviet leadership a sharp reminder of the risks of depending on world markets for such a critical commodity. The willingness of the Soviets to continue to purchase foreign grain results from their ability as a major grain purchaser to find favorable terms from a mix of suppliers, from their ability to continue to generate foreign currency through the

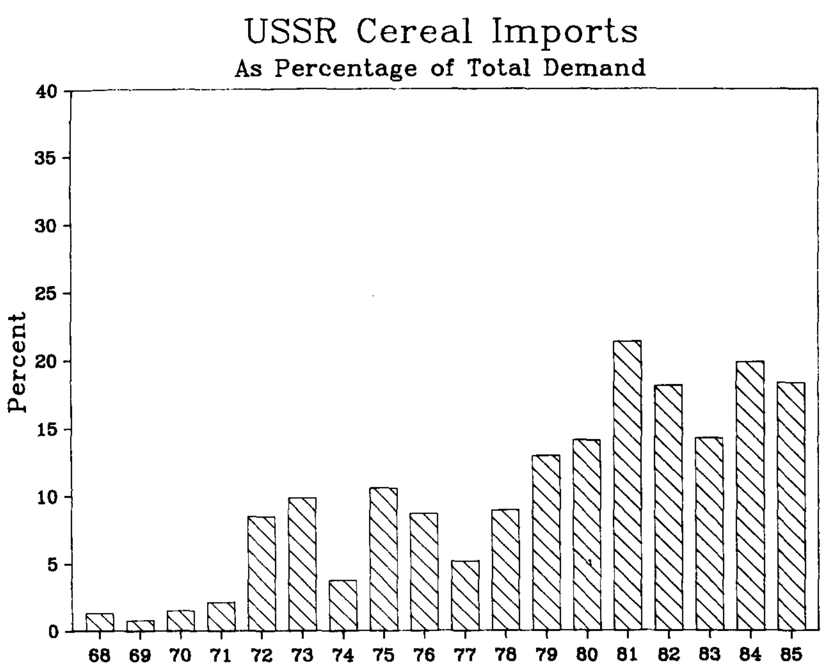

Fig. 1. Imports of cereal crops by the Soviet Union as a percentage of total world trade in cereal (1968 to 1985). The Soviet Union is the single largest importer of cereal grains (FAO, 1985).

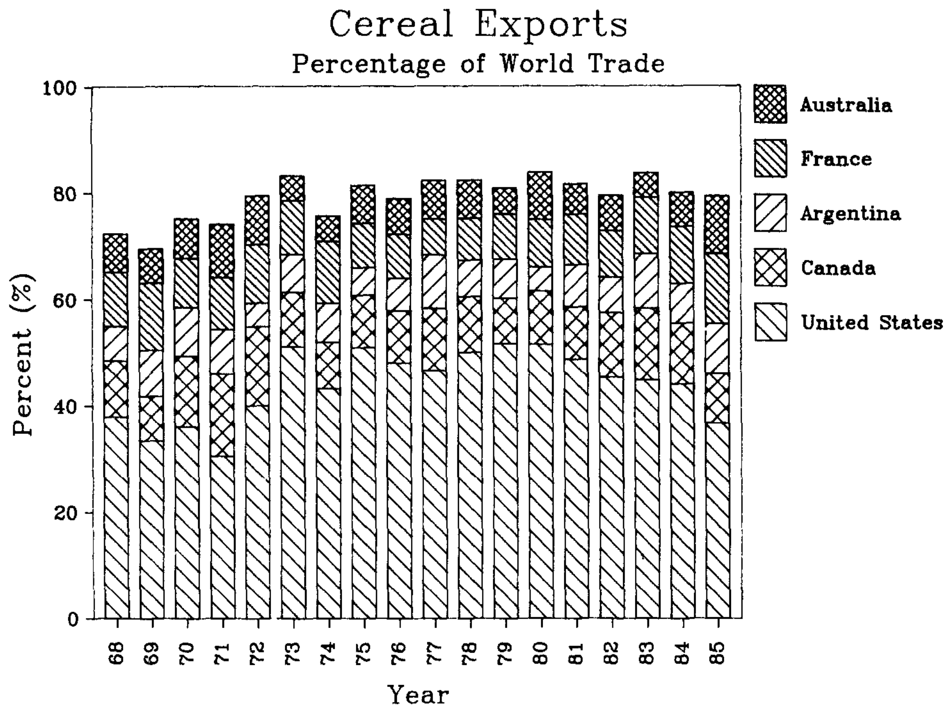

Fig. 2. Exports of cereal crops by the principal exporters as a percentage of world cereal trade (1968 to 1985). Together, the United States, Australia, France, Argentina, and Canada export around 80% of all cereal crops (FAO, 1985).

sale of other natural resources (notably fossil fuels, gold, and certain minerals), and from their belief that as their agricultural industry becomes more efficient, their reliance on foreign grain sources will decrease. In fact, the vulnerabilities arising from international trade in grain cut both ways. In recent years, drought in Russia and Kazakhstan has been one of the major uncertainties for Western grain markets, and sudden and massive purchases by the Soviet Union have played havoc with world prices.

Given this type of climatic vulnerability and the importance of a limited number of countries in the international grain markets (see Figure 2), further attention to increasing the reliability of agricultural production and reducing climatic constraints is warranted. Some specific recommendations include developing a more robust food-distribution system, particularly in food-importing regions, developing strains of grain that are climatically resistant to temperature extremes and moisture shortages, planting crops with different physiological characteristics in a single region to minimize the risk of a localized adverse event, or the parallel idea of dispersing a single crop type over several areas to decrease impacts from the same adverse event, and larger available food reserves to buffer climatically-induced changes in production.

Water and Security

International political frictions and tensions have arisen over the control of, access to, or the quality of freshwater resources (Naff and Matson, 1984; Falkenmark, 1986; Gleick, 1988). Even in the absence of climatic changes, pressures on existing water resources are growing due to increases in population, industrial water demand, and development in semi-arid and arid regions. Where water resources are shared, as in international river basins or bodies of water bordering more than one country, the possibility of friction and conflicting demands exists. The nature of such frictions varies from region to region – from disputes over water quality in humid regions to competition for scarce resources in arid and semi-arid regions.

Nearly 50 countries on four continents (shown in Table I) have more than three-quarters of their total land area falling within international river basins, while globally 47% of all land area falls within international river basins. Over 200 river basins are multinational, including 57 in Africa and 48 in Europe (see Table II). The extent of this interdependence can be seen in Table III, which lists thirteen different major rivers with five or more nations forming part of the watershed. Examples from the different continents include the Danube, whose basin lies within 12 different nations; the Nile, which runs through nine; the Amazon, which runs through seven; the Mekong, which runs through six; and the Ganges-Brahmaputra, which runs through five (United Nations, 1978).

TABLE I: Number of countries with >75% of total area falling within international river basins

Africa	23
North and Central America	0
South America	6
Asia	8
Europe	13

Source: United Nations (1978).

TABLE II: International river basins

	International river basins	% of area in international basin
Africa	57	60
North and Central America	34	40
South America	36	60
Asia	40	65
Europe	48	50
Total	215	47

Source: United Nations (1978).

TABLE III: Rivers with five or more nations forming part of the basin

	#	Area (km^2)
Danube	12	817,000
Niger	10	2,200,000
Nile	9	3,030,700
Zaire	9	3,720,000
Rhine	8	168,757
Zambezi	8	1,419,960
Amazon	7	5,870,000
Mekong	6	786,000
Lake Chad	6	1,910,000
Volta	6	379,000
Ganges-Brahmaputra	5	1,600,400
Elbe	5	144,500
La Plata	5	3,200,000

Source: United Nations (1978).

Regions with a history of international tensions or competition over water resources include the Jordan and Euphrates Rivers in the Middle East, the Nile, Zambezi, and Niger Rivers in Africa, the Ganges in Asia, and the Colorado and Rio Grande Rivers in North America. As water demands increase, the probability of conflict over remaining water resources will also increase. Problems may be indicated by low per-capita water availability, which suggests high population, few overall water resources, and a sensitivity to water quality. Table IV provides a partial list of those countries that are both dominated by international river basins and that have limited per-capita water availability. If better data can be made available, such indicators can be used to identify regions that may be susceptible to future water conflicts (Gleick, 1989).

Future climatic changes can reduce or exacerbate these water-related tensions. Among the critical concerns are changes in (1) water availability from altered precipitation patterns or evaporative losses due to higher temperatures, (2) the seasonality of precipitation and runoff, (3) flooding or drought frequencies, and (4) the demand for and the supply of irrigation water for agriculture.

Two Case Studies: The Colorado River and the Nile River

Details about water allocation and use in the Colorado River and the Nile River – both international rivers – can provide insights into how water conflicts arise and what appropriate mechanisms for resolving such frictions might look like.

The Colorado River flows through some of the most arid regions of the United States and Mexico and it is vital for agriculture in both countries. As a result, the Colorado is extensively used – so extensively that Mexico would receive almost no flow were it not for an international treaty signed in 1944 that guarantees a fixed

TABLE IV: Selected countries dominated by international river basins with low per-capita water availability[1,2]

Country	Area in international river basin (%)	Per-capita water availability 10^3 m^3 yr^{-1}
Ethiopia	80	2.39
Gambia	91	4.48
Ghana	75	3.65
Sudan	81	1.31
Togo	77	3.66
Peru	78	1.93
Afghanistan	91	2.76
Iraq	83	2.00
Belgium	96	0.85
Bulgaria	79	1.97
Czechoslovakia	100	1.79
Germany (D.D.R.)	93	1.01
Hungary	100	0.56
Poland	95	1.31
Romania	98	1.59

[1] This list is incomplete because of limited data on water availability by country. As better data become available, this indicator will become more reliable as a measure of water stress in a region.
[2] Examples of countries with high per-capita water availability and few international river basins include: Cameroon (27.4×10^3 m^3 yr^{-1}), Canada (134.2×10^3 m^3 yr^{-1}), Colombia (68.9×10^3 m^3 yr^{-1}), Norway (98.8×10^3 m^3 yr^{-1}), and New Zealand (140.8×10^3 m^3 yr^{-1}).
Sources: World Resources Institute (1987), United Nations (1978).

volume of water to Mexico annually. This treaty was negotiated after nearly 50 years of contention and disagreement over the sharing of the Colorado River.

Unfortunately, the treaty provisions for allocating shortages during a drought are ambiguous and have never been tested. Also, no provisions in the treaty cover the possibility of a climatic change that could alter the long-term availability of water in the river. These ambiguities and omissions could result in a revival of U.S. – Mexican frictions if the runoff available in the Colorado were to be reduced by climatic changes (Gleick, 1988). In fact, there are some suggestions that carbon dioxide-induced climatic changes could lead to a reduction in streamflow in this region (Revelle and Waggoner, 1983; Flaschka *et al.*, 1987). A solution worth pursuing is for the two nations to resolve the ambiguities over the allocation of shortages and to reach a specific agreement about how climatic changes are to be identified and handled before such changes appear.

A similar agreement for the Nile River is complicated by the fact that the Nile's catchment and riparian drainage area is in the territory of nine nations: Egypt, Sudan, Ethiopia, Kenya, Tanzania, Zaire, Uganda, Rwanda, and Burundi. Although the principal water users are Egypt and the Sudan, the runoff is mostly generated by precipitation in Ethiopia and the other countries. Competition for the waters of the Nile first arose in the early 1900s over growing Egyptian needs. The question of allocation of the Nile flow was submitted to international mediation in 1920, and in 1929, a Nile Waters Agreement was adopted that reflected Egypt's dominant interest. Conflict over allocations resurfaced in the 1950s, a period of growing water use in Sudan and internal unrest in both countries. In 1959, after minor military skirmishing between Egypt and the Sudan, the Sudanese abrogated the 1929 Nile Agreement by unilaterally raising the height of the Sennar Dam in the Sudan. By late 1959, due to a change in the political climate, negotiations were reopened and a new "Agreement for the Full Utilization of the Nile Waters" was signed.

The agreement reached in 1959 between Egypt and the Sudan, while settling the Egypt-Sudan conflicts, ignores all other riparian users. In the future, these users are likely to play a larger role in the use of the Nile (Uganda and Zaire with Lake Mobutu, Uganda, Kenya, and Tanzania with Lake Victoria, and Lake Tana in Ethiopia) because of growing population and irrigation demands. Any climatically-induced change in water availability will further complicate the future use of the Nile, contributing to political jousting and friction.

These examples suggest that attention could usefully be focused on those regions where existing pressures over water resources are already a problem. In these cases, mechanisms for allocating shortages must be designed and agreed upon before climatic changes begin to alter the hydrologic regime. International water law, though immature in its development and application, must play a role. By codifying these allocation schemes, mechanisms can be put into place to resolve conflicts before they become acute.

Northern Mineral Resources

Access to certain strategic minerals is already constrained in some regions by climatic conditions. In particular, the ability to extract oil and natural gas in Arctic continental and offshore regions depends on expensive and vulnerable methods and materials. Yet significant resources underlie these regions and they are a vital element in national economies and world trade markets. Any change in climate that affects the ease of extracting these resources will play a role in the response of international actors to initiatives to control climatic change.

The oil and gas potential of the northern Arctic regions is very large. Despite only limited exploration, Arctic proven reserves already comprise a substantial fraction of the proved reserves of the countries of the region, as shown in Table V, and the volume of 'potentially recoverable' oil is several times larger. These figures should be compared with estimated global 'proved' oil reserves of 95 billion tonnes (700 billion barrels) of oil, and gas reserves of 100 trillion cubic meters (3600 trillion cubic feet).

The technical and environmental challenges, monetary costs, and ecological and economic risks of finding and extracting Arctic energy resources are immense.

TABLE V: Arctic oil resources

	Arctic potentially recoverable[a] (10^9 bbl)	Arctic proved reserves (10^9 bbl)	Total proved reserves[c] (10^9 bbl)	Arctic proved reserves as a percent of total proved reserves
United States	17–55	7	33	21
Soviet Union	50–80	22	59	37
Canada	15	1–2	8	12–24
Norway	10–15	[b]	11	[b]

Sources: Garrett 1984, Bergesen *et al.* 1987, British Petroleum 1987.
[a] Undiscovered potential. Most U.S. estimates fall in the range of 17 to 24 billion barrels. High-side estimates for the United States are 39 to 55 billion barrels (Garrett, 1984). Gas resources could be as great as 60 trillion cubic meters (2000 trillion cubic feet). Gas estimates are highly uncertain.
[b] Accurate Norwegian Arctic oil reserves data are unavailable, but estimates range between 100 and 300 million tonnes (or 0.7 to 2 billion barrels).
[c] Estimates of world 1986 proven oil reserves total 700 billion barrels, of which 480 billion are in the Middle East.

Development of much of the new oil and gas potential in the Arctic will be substantially more expensive than the production of the already costly Prudhoe Bay and Western Siberian fields. The average cost of production in the Soviet oil industry is about $7 per barrel, while estimates of the production costs for the most expensive new fields in Western Siberia are nearly $50 per barrel (Bergesen *et al.*, 1987). The difference in capital costs of production between Saudia Arabia and the Arctic Chukchi Sea (between the U.S. and the Soviet Union) is a factor of 60.

The major environmental constraints to economic and resource development in the onshore Arctic are cold, wind conditions, snow duration and depth, permafrost, storm intensities and durations, and ice formation. Climatic problems in the offshore oil regions of the Arctic include extreme low temperatures, ice on the platforms, sea-ice extent and movement during the winter, and typhoon-like storms produced by polar low-pressure regions. In an average year in Siberia, 33% of the total loss of work time is attributed to low temperatures (Mote, 1983). For example, in the continental United States, a 3000-m oil well is drilled in a maximum of 34 days. Under Siberian conditions, such a well cannot be drilled in under 90 days, even though the Soviet Union has considerable expertise in working with permafrost and Arctic conditions. While part of the difference may be explained by differences in equipment, the greatest constraint is the climate. Even supposedly ice-resistant oil-drilling platforms are now often constrained during winters by severe ice (Bergesen *et al.*, 1987). Table VI lists the additional costs of development imposed by environmental constraints in Siberia over average mid-latitude development costs.

Higher temperatures from climatic changes could reduce some of the difficulties of extracting mineral resources in the far north, but as Table VI shows, other cli-

TABLE VI: Major environmental constraints to Siberian energy development

Condition	Additional costs of development over mid-latitude costs (%)
Cold, wind, humidity	30–115
Snow duration, blizzards, and depth	10–12
Permafrost	15–30
Icings, other[a]	15–40

Source: adapted from Mote (1983).
[a] 'Other' includes seismicity, avalanches, swampiness, water availability, and polar light levels.

matic factors also contribute to these difficulties. For example, as temperatures rise, partial melting of the permafrost layer may occur, affecting construction practices and existing physical developments. Similarly, a reduction in sea-ice extent may lead to higher precipitation in the region due to greater evaporation from a warmer, open ocean. This in turn may lead to higher snowfall and more difficult operating conditions. The possibility of a gradual buildup of northern glaciers and ice caps has even been raised (Antonov, 1978).

Given the importance of northern mineral resources, climatic constraints are unlikely to prevent future development. Even today, despite the difficulties in exploiting northern minerals, the Western Siberian oil fields produce about half of all Soviet oil (Mote, 1983), and more than 50% of all Soviet hard currency income during the 1980s has been derived from oil. The question is whether or not future climate changes will significantly increase or decrease the difficulty – and hence the expense – of that production. Current analyses of Soviet economic conditions suggest that the maintenance or increase of oil exports is a key to sustaining import levels (including grain) essential for the Soviet Union's economic plans and political priorities (Bergesen *et al.*, 1987). Similarly, the goal of reducing U.S. dependence on Middle Eastern oil (and thus theoretically increasing national security) is often claimed to hinge upon the development of Alaskan/Arctic oil reserves. The uncertainties posed by future climatic changes will complicate these problems.

Winners and Losers: The Complication of Perceptions

Avoiding political polarization on the issue of climatic change depends greatly on the perception of the participants. If some international actors believe that they will benefit from climatic changes while others suffer, such perceptions – correct or not – will drive policy actions and decisions. The views of those with the financial and technological means at their disposal to affect the outcome or mitigate the impacts of climatic changes are especially important. Arguments for international action are complicated by individual actors taking positions dependent not on the global good, but on the perceived advantage or disadvantage to them of the likely change and impact.

There is only one thing to suggest *a priori* that climatic changes away from present climatic conditions will be disadvantageous: that is the argument that world agricultural and industrial systems have evolved under climatic conditions that have been relatively constant and that society has maximized its ability to produce food, energy, and resources under these conditions.

This argument has some merit. The distribution of crop production, the design and operation of water-supply systems, and other important physical and institutional structures were designed and developed with existing climatic conditions in mind. Any deviation from those conditions will necessarily entail expensive modifications, adaptations, and reorganizations. But despite efforts to reduce our vulnerability to climatic conditions, our climatic independence is incomplete. The growing evidence that anthropogenic climatic changes will produce climatic conditions considerably more extreme than those experienced in recent history raises even greater concerns.

There are hints that certain regions of the world will benefit, at least initially, from increases in average temperatures. China and Japan could benefit from increased rice yields and multiple cropping seasons; the U.S.S.R., the northern U.S., and southern Canada could benefit from increases in the length of their growing seasons; and so on. If these predictions are accepted, *whether or not they are true*, then other incentives for international cooperation for managing CO_2 emissions must be developed.

But there are two serious problems with setting policy today using forecasts of future benefits. First, the net societal impact depends on not just regions that benefit but on those that suffer as well. Second, the uncertainties about actual regional effects are so great that policies made on the basis of early and incomplete predictions would be both highly unreliable and difficult to justify. For example, poor conditions in one area are sometimes compensated for by more favorable conditions in another. Similarly, short-term improvements may be followed by long-term productivity losses as the climatic changes become more severe. Figure 3 shows this type of impact. Pitovranov *et al.* (1987) show that transient changes in climate derived from climate model data may lead to different agricultural impacts in the short-term and the long-term in the Leningrad area. In their study, yields of winter rye are projected to increase in the short-term because of higher temperatures and unchanged summer precipitation but then drop after 2010 because of large increases in summer precipitation and decreases in soil fertility. Yield reductions may be further exacerbated by increases in surface water pollution from nitrate leaching.

The importance of perceptions depends directly upon the ability of the 'perceiver' to affect the outcome. Table VII lists those countries that are the greatest sources of carbon dioxide and other trace gases as of the late 1980s. These coun-

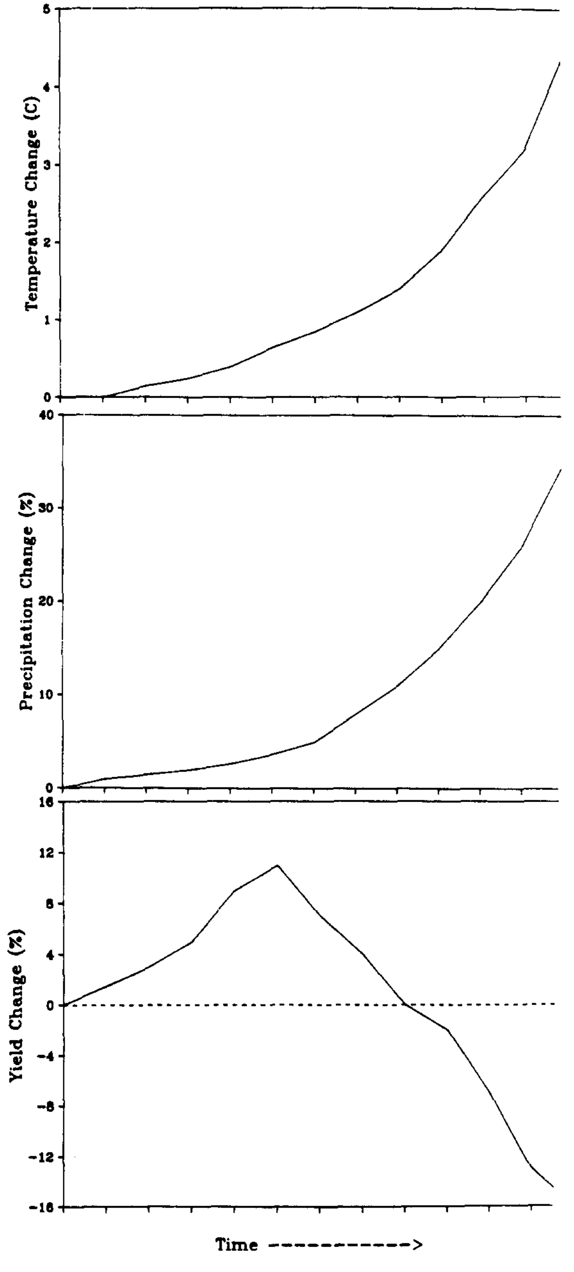

Fig. 3. Possible transient changes in agricultural yield with time. The bottom graph shows yields initially increasing as mean temperatures (top graph) and mean precipitation (middle graph) increase. Further increases in yields, however, are prevented by additional increases in temperature and precipitation, which may cause crop damage when they reach certain levels. This type of effect will complicate the analysis of climatic impacts over a long period of time.

TABLE VII: Percent of world production of CO_2 and chlorofluorocarbons

	CO_2[a]	CFC-11[b]	CFC-12
United States	24	23	30
Western Europe and Canada	16	49	33
Japan, Australia, and New Zealand	6	20	15
Soviet Union and other CPEs[c]	26	6	19
All others	28	2	3

[a] These figures include carbon dioxide from fossil fuel combustion and industrial fuel use, but do not include the contribution from biomass burning (Rotty, 1987a).
[b] Chlorofluorocarbon data are from Mintzer (1987).
[c] CPE: Centrally-planned economies.

tries are disproportionately able to affect the outcome given their populations and physical size.

Most previous international environmental disputes have been among developed countries – the Western European community, the United States, and Canada over acid rain; the industrialized nations over chlorofluorocarbon emissions; the United States, Canada, and the Soviet Union over Arctic haze, and so on. In part, this has been because these countries have been either the principal polluters (as Table VII suggests) or the principal victims of the pollution.

Large-scale climatic impacts alter this picture, because of the global extent of the impacts. Among the principal victims of climatic change will be those nations least able to either adapt to or mitigate the changes – developing countries dependent on international agricultural trade, with access to few mineral resources, and with little international economic clout. At the same time, the principal carbon dioxide polluters may be shifting from the major industrialized powers to developing countries with growing populations and a growing need for energy. By the mid-1980s, developing countries produced as much carbon dioxide from fossil fuel combustion as did Western Europe, and their share is growing (Rotty, 1987b).

Discussion and Need for Future Work

Future climatic changes caused by industrial activities will have widespread societal impacts. Among these impacts will be changes in the quality of, quantity of, or ease of access to freshwater and mineral and energy resources, and changes in the productivity of agriculture. These impacts, in turn, will alter human well-being, the quality of life, and the range of options and policy choices available to governments. In order to prevent these climatic impacts from causing international tensions and conflicts, they must be more thoroughly explored and strategies developed to either mitigate or prevent the worst effects.

A wide range of options is available. For world markets, such as the international trade of agriculture, many tools are already used to reduce the severity of climatic variability. These include food-storage programs, distribution systems, and famine identification and assistance plans. Each of these existing mechanisms must be strengthened. Other options can also play a role under conditions of long-term climatic change. Among the more promising are the development of climatically-resilient strains of crops, better long-term forecasting abilities, and strategies for reducing the vulnerability of mono-cropping to specific climatic events.

Where existing tensions may be exacerbated by climatic change, such as in disputes over water resources, advances are needed in both conflict resolution among states and in the development of international resource law. Such advances would be useful not only for resolving international resource controversies, but for addressing the very issue of future climatic change.

There are a variety of international "rules" used to allocate resources and arbitrate disputes among the nations of the world. But for problems concerning the atmospheric environment – a true global commons – there are very few precedents. In this case, individual nations both pollute the resource and are, in turn, affected by the environmental impacts. When the affected resources are common to more than one state – such as where rivers or lakes lie within more than one country – rules involving problems of international pollution apply. Principle 21 of the UN Declaration on the Environment, adopted in 1976, says:

> States have, in accordance with the Charter of the United Nations and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction.

Similarly, an agreement drafted by UNEP in 1977 says:

> States have a duty to cooperate in the field of the environment concerning the conservation and harmonious utilization of natural resources shared by two or more States. Accordingly, consistent with the concept of equitable utilization of shared natural resources, States should cooperate with a view to controlling, preventing, reducing and eliminating adverse environmental effects which may result from the utilization of such resources. Such cooperation shall take place on an equal footing and due account shall be taken of the sovereignty and interests of the States concerned.

International laws and agreements provide tools for cooperative efforts on international resource problems. Such tools provide the structures and mechanisms through which nation-states manage their interactions. International law is only one factor among many – including political, economic, social, scientific, and technological factors – that influence national policymaking and decisions, but it is a necessary element in natural resource issues. Unfortunately, international law presently lacks the kind of highly-developed legal institutions of national legal systems. One major problem is that international environmental law does not have an effective system of sanctions.

Emerging principles of international environmental law suggest some constraints on the ability of a nation to pursue any resource policy it chooses if those policies degrade the environment of other nations (Bilder, 1980). Nations may not in principle (although they do in practice) pollute an international river or discharge wastes into the atmosphere or oceans, if these threaten severe environmental damage to neighbors or the global community. Thus even in internal resource decisions, states should take into account the impact of these decisions on other nations' interests.

Finally, differing perceptions about the severity of global climatic changes must not be allowed to stop comprehensive international negotiations. Although there are likely to be disagreements about specific regional impacts, no region or country can expect to benefit from rapid climatic changes that would overwhelm the capacity of even wealthy countries to adapt. Many actions that would prevent or delay climatic change are appropriate in their own right, such as energy conservation, a reduction of dependence on fossil fuels, and a ban on the use of certain trace gases with long-term atmospheric effects. These cooperative strategies can reduce the rate of climatic change and give us time to both improve our understanding of climatic impacts and to reflect on appropriate international responses.

References

Antonov. V. S.: 1978, 'The Possible Impact on the Arctic Ocean from the Proposed Transfer of Water from the Northern Rivers of the U.S.S.R. to the South', *Polar Geology* **2**, 223–231.

Bergesen, H. O., Moe, A., and Ostreng, W.: 1987, *Soviet Oil and Security Interests in the Barents Sea*, Frances Pinter, Publishers, London, England, 144 pp.

Bilder, R. B.: 1980, 'International Law and Natural Resource Policies', in Dorner, P. and M. A. El-Shafie (eds.), *Resources and Development*, The University of Wisconsin Press, Croom Helm, London, pp. 385–421.

British Petroleum (BP): 1987, *BP Statistical Review of World Energy*, British Petroleum Company, Britannic House, Moor Lane, London, 36 pp.

Budyko, M. I.: 1977, *Climatic Changes*, American Geophysical Union Translation, Waverly Press, Inc., Baltimore, Maryland, 261 pp.

Falkenmark, M.: 1986, 'Fresh Waters as a Factor in Strategic Policy and Action', in A. H. Westing (ed.), *Global Resources and International Conflict: Environmental Factors in Strategic Policy and Action*, Oxford University Press, New York, pp. 85–113.

Flaschka, I., Stockton, C. W., and Boggess, W. R.: 1987, 'Climatic Variation and Surface Water Resources in the Great Basin', *Water Resources Bulletin* **23**. No. 1. pp. 47–57.

Garrett, J. N.: 1984, 'Conventional Hydrocarbons in the United States Arctic: An Industry Appraisal', in Westernmeyer, W. E. and K. M. Shusterich (eds.), *United States Arctic Interests: The 1980s and 1990s*, Springer-Verlag, Inc. New York, pp. 39–58.

Gleick, P. H.: 1988, 'The Effects of Future Climatic Changes on International Water Resources: The Colorado River, The United States, and Mexico', *Policy Sciences* **21**, 23–39.

Gleick, P. H.: 1989, 'Vulnerability of Water-Supply Systems', in P. Waggoner and R. R. Revelle (eds.), *Climate and Water: Climate Variability, Climate Change, and the Planning and Management of U.S. Water Resources*, American Association for the Advancement of Sciences, John Wiley & Sons. New York (in press.)

Gustafson, T.: 1981, *Reform in Soviet Politics: Lessons of Recent Policies on Land and Water*, Cambridge University Press, Cambridge, England, 218 pp.

Mintzer, I. M.: 1987, *A Matter of Degrees: The Potential for Controlling the Greenhouse Effect*, World Resources Institute, Washington, D.C., 60 pp.

Mote, V. L.: 1983, 'Environmental Constraints to the Economic Development of Siberia', in Jensen, R. G., Shabad, T. and A. W. Wright (eds.), *Soviet Natural Resources in the World Economy*, The University of Chicago Press, Chicago, pp. 15–71.

Naff, T. and Matson, R. C. (eds.): 1984, *Water in the Middle East: Conflict or Cooperation*, Westview Press, Boulder, Colorado, 236 pp.

Pitovranov, S., Iakimets, V., Kiselev, V., and Sirotenko, O.: 1987, 'The Effects of Climatic Variations on Agriculture in the SubArctic Zone of the USSR, in M.L. Parry, T. R. Carter, and N. T. Konijn (eds.), *The Impact of Climatic Variations on Agriculture. Volume 1. Assessments in Cool Temperate and Cold Regions*, Kluwer Acad. Publ., Dordrecht, The Netherlands, pp. 617–722.
Revelle, R. R. and Waggoner, P. E.: 1983, 'Effects of a Carbon Dioxide-Induced Climatic Change on Water Supplies in the Western United States', in *Changing Climate*, National Academy of Sciences National Academy Press, Washington, D.C., pp. 419–432.
Roberts, W. O. and Lansford, H.: 1979, *The Climate Mandate*, W. H. Freeman and Company, San Francisco, California, 197 pp.
Rotty, R. M.: 1987a, 'Estimates of Seasonal Variation in Fossil Fuel CO_2 Emissions', *Tellus* **39B**, 184–202.
Rotty, R. M.: 1987b, 'A Look at 1983 CO_2 Emissions from Fossil Fuel (with Preliminary Data for 1984)', *Tellus* **39B**, 203–208.
Schneider, S. H.: 1983, 'Food and Climate: Basic Issues and Some Policy Implications', in V. P. Nanda (ed.), *World Climate Change: The Role of International Law and Institutions*, Westview Press, Boulder, Colorado, pp. 46–63.
Tickell, C.: 1986, *Climatic Change and World Affairs*, Revised edition. Center for International Affairs, Harvard University, University Press of America, Lanham, Maryland, 76 pp.
Ullman, R. H.: 1983, 'Redefining Security', *International Security* **8**, 129–153.
United Nations: 1978, *Register of International Rivers*, Pergamon Press, Oxford, England, 58 pp.
Wallensteen, P.: 1986, 'Food Crops as a Factor in Strategic Policy and Action', in A. H. Westing (ed.), *Global Resources and International Conflict: Environmental Factors in Strategic Policy and Action*, Stockholm International Peace Research Institute, United Nations Environment Programme, Oxford University Press, Oxford, pp. 143–158.
Wilson, T. W. Jr.: 1983, 'Global Climate, World Politics and National Security', in Nanda, V. P. (ed.), *World Climate Change: The Role of International Law and Institutions*, Westview Press, Boulder, Colorado, pp. 71–78.
World Resources Institute: 1987, *World Resources 1986*, Basic Books, Inc., New York, 353 pp.

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