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CLIMATIC CONSTRAINTS AND HUMAN ACTIVITIES:

Introduction and Overview

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PREFACE

The Task Force meeting on the Nature of Climate and Society Research, 4-6 February 1980, was the third major event in climate studies at the International Institute for Applied Systems Analysis. In February of 1978, a meeting was held on "Carbon Dioxide, Climate and Society" to bring together experts from around the world to assess the state of knowledge on the prospects of climate change taking place as a result of increasing injections of carbon dioxide into the atmosphere and in particular to review work undertaken on this subject under the IIASA Energy Systems Program. The results of this conference, including both contributed papers and recommendations about prudent energy strategies and further needed research, were edited by Dr. Jill Williams and published in the IIASA Proceedings Series. In April of 1978, IIASA hosted the conjoint sessions of the International Workshop on Climate Issues organized by the Climate Research Board of the US National Academy of Sciences and the preparatory meeting for the World Climate Conference organized primarily by the World Meteorological Organization (WMO) of the United Nations. A report on the Workshop entitled "International Perspectives on the Study of Climate and Society" was prepared by the Climate Research Board, while the proceedings of the World Climate Conference, which was held in Geneva in February 1979, are available from the WMO. It is in the tradition of this interest in climatic issues at IIASA that the Task Force was convened and tried to advance our knowledge of the relationship of climate to specific aspects of physical and social systems. This paper is the introduction and overview for the proceedings of the Task Force meeting.

SUMMARY

The volume of proceedings entitled "Climatic Constraints and Human Activities" contains a summary essay and seven invited papers from the Task Force meeting on the Nature of Climate Society Research convened in February 1980 at the International Institute for Applied Systems Analysis in Laxenburg, Austria. This, the introductory essay, examines the differences in research methods on questions of short-term climate variability and longer-term climatic change, identifies some important avenues for research, and briefly surveys the papers. Ausubel and Meyer-Abich take broad looks at climate and public policy. Ausubel offers arguments from an economic point of view as to why the atmosphere is increasingly associated with developments, like climatic change, which are threatening to human activity. The paper by Meyer-Abich surveys from a political point of view the reasons that regulation of activities which could control or prevent climatic change is unlikely to take place, and why adaptation is the most likely path to be followed, especially given the current weakness of the interdisciplinary analysis of the problem of climatic change. The paper by Biswas narrows the focus and illuminates the uncertainty associated with one specific but very prominent area, the relationship between climate and crops, which one might easily assume otherwise to be a more secure area of knowledge. Three case study approaches follow, two emphasizing a geographical perspective and one a social group. Warrick's historical study of the possible "lessening" of drought impacts in the Great Plains of the United States emphasizes the need for a clear setting out of the hypotheses to be tested in research on the relationship of climate and society and the need for improvements of the modeling of the overall system. Spitz develops a model of a food producing class which is also self-provisioning, that is, where food has a dual nature as both a basic need and as merchandise to be traded, and explores the significance of drought to such a group, with

particular reference to Eastern India. Czelnai's paper on the Great Plain of the Danube Basin offers interesting insights into the extent into which natural systems have already been transformed by man and proposes ways in which sensitivity and vulnerability to climatic factors may be defined and explored. Finally, Sergin proposes a method of estimating plausible patterns of climatic change based on the similarity between seasonal changes and climatic changes of physical fields on longer time scales.

INTRODUCTION AND OVERVIEW

Jesse Ausubel and Asit K. Biswas

THE PROBLEM

Climate, defined as either the expected or the observed statistical character of weather over some specified period, varies on all time scales. Indeed, climate is perhaps the most variable aspect of our natural environment. Climatic variability thus introduces an important stochastic element into those human activities, such as agriculture and water resource management, that it influences. The extreme climatic events that are inevitable consequences of this variability pose particularly great risks to the successful functioning of these activities. Moreover, there is reason to believe that human activities themselves may lead to long-term climatic changes, with attendant changes in the statistical characteristics of climate and the return periods for defined risks.

Study of climate and its interactions with society is motivated by two general concerns. First, in complex, increasingly strained, interlinked, and rapidly evolving economic systems, climatic variability poses significant and changing risks. The return periods for extreme climatic events such as droughts are long relative to the current developmental time scale of society. Thus, the disastrous Sahelian drought of 1968-1973 pressed upon a far different society than did the earlier droughts of the century, and old relief plans and measures were largely inappropriate. Analysis is therefore desirable to understand the sensitivities and risks in economic and developmental policies that may lie unnoticed until after some climatic shock or disaster has revealed them in a most undesirable way. Second, it has become evident that human activities may lead to global climatic changes. A particular concern is the injection of carbon dioxide into the atmosphere as a consequence of fossil fuel combustion. While other aspects of the global carbon cycle are also extremely important from the point of view of potential climatic change, it is this link of climate to energy policy that probably accounts for the largest share of interest in climate in industrialized countries.

Climate is a classic multidisciplinary problem. Its study ranges from mathematical and physical sciences, through biological and ecological investigation, to economic and political issues. It is at one extreme a subject for basic geophysical field research and computer modeling and at the other an applied question of immediate importance to policy makers concerned with disaster relief, agricultural policy, and so forth. During recent years, attention from both the scientific and policy-making communities has been given to climate, and recommendations about programs of research and action have been made.

COOPERATION AMONG ORGANIZATIONS

The World Climate Conference (Geneva, February 1979), to which IIASA actively contributed, called for further study of the climate system and of the relationship of climate and human activities. A World Climate Program has been approved by the World Meteorological Organization (WMO) and should serve as the coordinator of the activities of several international organizations, both governmental and nongovernmental. With respect to the study of the dynamics of climate, it is expected that an activity growing out of the Global Atmospheric Research Program (GARP) of WMO and the International Council of Scientific Unions (ICSU) will be most significant. With respect to supporting study of the impacts of climate on human activities, the United Nations Environment Programme (UNEP) is expected to play a leading role. The Scientific Committee on Problems of the Environment (SCOPE) of ICSU has also shown interest in this area and is planning future activities. A number of other international organizations have also expressed interest in climate, as have numerous academic and scientific institutes in countries of IIASA's National Member Organizations (NMOs). In February 1980 IIASA's Resources and Environment Area held a Task Force Meeting on the Nature of Climate and Society Research. The meeting provided an opportunity for IIASA to coordinate its activities with the various interested groups and to identify important research topics in the area of climate and human activities in general and for IIASA in particular.

In response to comments from individual scientists and the NMOs, emphasis of climate activity at IIASA has moved from the study of global climate models and the establishment of links with major modeling institutions to an emphasis on applied questions relating climate to human activities. These questions include anlysis of human activity which may influence the climate and the impact of short-term climatic variation and long-term climatic change on the environment and human activity. The Task Force Meeting and the associated planning process also raised the question of the scale of climate activity within IIASA. At one time climate was being considered as the basis of a possible "Program," a quite large effort. However, internal and external groups concurred that climate is not a suitable subject for a major IIASA program. The more modest idea of developing a core activity dealing with climate within IIASA's Resources and Environment Area and of using climate as a "cross-cutting theme" was preferred. Given its multidisciplinary character, climate might be an intelligent "user" of other IIASA research. But what types of problems and time scales should be emphasized?

VARIABILITY OR CHANGE?

In looking at research on the relationship of climate and human activities, one of the first distinctions which can be made is on the basis of time scale. For purposes of studying the impact of climate on human activity we may think of "climatic variability" as being essentially descriptive of short-term phenomena, that is the internal variability associated with any given reference period of time. The great variability of climate often misleads people into thinking that a real "change" of climate is in progress. However, by change we refer to a lasting impulsive change or consistent trend in the central tendency of climate. Studying the effects of variability about a central tendency is, in important respects, different from studying the effects of a long-term change in central tendency.

To clarify the distinction, research on climatic variability refers primarily to seasonal or annual variation, which manifests itself as periods of drought, unusually cold winters and short summers, or other consequential deviations from estimates of average values of important climatic elements. The structure of work in this field tends to be to model agricultural systems, water resource systems, or regional economies, and study the effects of some climatic impulse or shock. There is considerable possibility for historical or empirical work here. Findings on the role of variability are of interest to those who work on problems of nutrition, price fluctuations, balance of trade, disaster relief, and civil defence and to meteorological and hydrological services engaged in monitoring and forecasting. Some existing geophysical and econometric models might be adapted for policy purposes. While research on the problems associated with variability tends to focus primarily on short-term responses, critical situations, such as those arising with drought, also offer excellent opportunities to learn about underlying long-term structural features of social systems.

If a climatic change should occur on a time scale relevant to applied research, for example, an increase of the global mean temperature of between 2 ^{o}C and 5 ^{o}C over the next 40 to 100 years, it is likely to be the result of human activity. Thus, in looking at climatic change and human activities, we are interested in evaluating both potential sources of the change, and the consequences of the change.

Having identified possible causes of climatic change, such as carbon dioxide, oxides of nitrogen, and chlorofluoromethanes, one can look at three strategies of response: prevention (stopping emissions), compensation (allowing the emission and then trying to reduce climatic change in some other way, for example, planting fast-growing trees to absorb increasing atmospheric CO_2), and adaption to an accepted climatic change, as predicted by numerical models of the climate system or described by historic analogues.

If there is a possibility of controlling the specific cause of possible climatic change, then research is likely to focus on prevention and compensation. For each potential source of climatic change it may be possible to a greater or lesser extent to undertake cost-benefit or risk-benefit studies. For example, one may look at the value of using the stratosphere for waste disposal versus the effects of climatic change, the value of using certain fuels versus the effects of climatic change, and so on. Such studies would desirably be embedded in a larger context of, for example, comparative risks associated with energy strategies or agricultural technologies.

However, it is not necessary to identify a specific cause in order to commence examination of the impacts of climatic change. Indeed, one line of argument is that in the course of the 1970s meteorologists and atmospheric chemists have steadily presented evidence of threats to climate. Some of these have subsequently been reevaluated as probably not dangerous, for example, stratospheric flight, but the likelihood that some pervasive, cumulative human activity will change the climate appears to be growing.

In order to gain a better understanding of the potential dimensions of such environmental change, as well as to improve methods to understand it as it is specified more clearly, one might alternatively simply postulate a drastic change (or "scenario") and explore its meaning. Whatever the cause of a long-term change, the factors and the policies and actions available for consideration will not be the same set as those for variability. Most importantly, as one is faced with thinking generations ahead, technological change becomes a dominating feature in the analysis, as well as the underlying ethical issue of human interest and responsibility in nature. More specifically, for example, questions of human migration, large-scale capital investments, and environmental preservation may change significantly as functions of the time scale being considered.

Of course, whether or not a cause is posited, much greater uncertainty will also characterize the long-range evaluation of the relationship of changing climate to, for example, agriculture or ecology, and ensuing social, economic, and political analysis will be very tentative. Existing economic models are unlikely to be useful, but certain aspects of economic theory may shed light on the problem. For example, issues of common property and intergenerational equity arise, and insights into desirable and feasible policies may be gained through consideration of factors such as these. The policy orientation of studying climatic change will differ from that of variability to the extent that the work on climatic change will be more directed toward those interested in long-term planning in society and questions of choice of energy path, environmental preservation, and so forth.

While there are methodological differences associated with the different time scales of these two categories of research, it does not make sense to investigate them entirely independently of one another. As Czelnai points out in his paper in these proceedings, the impact of a slow and gradual climatic change on society and economy will probably appear in the shape of difficulties caused by the changing recurrence time of extreme values on which important designs are based. Any assessment of long-term impacts must therefore be accompanied by study of the impacts of short-term variability. Moreover, the short-term variability is usually much larger than the rate of long-term changes, and the combined effects of short- and long-term variations may also become a new source of difficulty. Finally, decisions required for short-term problems may be in conflict with those for long-term problems, so some coordination between those dealing with the two general areas is desirable. Clearly, in the end, studies of the two kinds of problems are complementary. Indeed, studying the effects of variability may be one of the better ways of coming to understand the magnitude of the effects of a possible large-scale, longer-term change.

IMPORTANT AVENUES OF RESEARCH

On the basis of the Task Force Meeting and associated activities, a number of directions for future research were identified. These include (1) improving the climatological basis for studies of the effects of climatic variability and change, (2) specifying better from the point of view of economic geography where future injections of CO_2 may originate, (3) exploring issues involved in linking "physical" and "socioeconomic" models in a problem oriented integration, (4) developing knowledge of the relationship of climate to water and food on a sectoral basis, and (5) developing knowledge of the interactions of climate and human activities from a national or regional perspective. A brief description of each of these research areas follows.

(1) Studies of the interaction of climate and human activities must be founded on the best possible climatological basis, with respect to both climatic variability and change. A number of useful activities might be undertaken in this field by climatologists and atmospheric modelers working in consultation with agriculturalists, water resource experts, geographers, economists, and others. An initial activity might be development of a data base on plausible

patterns of climatic change through the next century and on models of climatic variability suitable for use in "impact" analyses. Preliminary scenarios of climatic change might be developed based on reviews of worldwide research and on consideration of critical scientific issues such as ocean-atmosphere coupling and role of soil and biomass in the carbon cycle. There is a growing amount of research deriving scenarios for future climate based both on numerical modeling using general circulation models and on the use of past periods as analogues for the future (see, for example, the paper by Sergin in these proceedings). As the available material grows, it will become useful to engage in comparisons of projections of climatic change and to attempt to improve the realism of these projections, particularly with respect to applicable time and space scales. With respect to studies of the role of climatic variability, certain kinds of statistical studies of climate may provide a useful framework. Again, these must be designed in such a way that the "user" disciplines will be able to apply them.

(2) Strategies of response to the CO_2 issue must be concerned with the national or regional origin of CO_2 emissions and the rate at which CO_2 may be expected to be injected by various groups into the atmosphere. The rate at which CO_2 is injected is a critical determinant of the rate of the projected climatic change. Choice of possible prevention or compensation strategies may be largely determined by who is injecting CO_2 into the atmosphere and how fast. It is necessary to review, compare, and further detail projections of future CO_2 injections into the atmosphere, primarily injections from fossil fuel combustion. Most studies have taken a "demand" approach to the problem, hypothesizing global demand for energy and then working back through fuel mix to CO_2 injection. It is also necessary to look at the supply side of the question. Who has the carbon reserves and resources? How quickly can these be extracted and converted to CO_2? To what extent can the information on "carbon wealth" (stocks of carbon convertible to atmospheric CO_2 on a time scale of about 100 years) be integrated with models of energy demand to give a picture of the geopolitical and economic structure of a CO_2 problem? What can we learn about the relative desirability and likelihood of preventive, compensatory, and adaptive strategies to CO_2-induced climatic change by clarifying possible quantities and sources of future injections? Are there issues of liability and distributive justice?

(3) Understanding the relationship of climate and human activities is inherently multidisciplinary. A problem oriented integration of sciences is required, but often the contributions of individual disciplines are such that they remain isolated and untranslatable or untranslated into terms of another discipline, much less into "political facts." (See the paper by Meyer-Abich in these proceedings.) For example, bringing together natural and socioeconomic models involves many problems. Existing models usually cover

subsystems. Present simulation models of the atmosphere at one extreme of the spectrum and econometric models at the other offer quite different approaches to modeling problems, and there is little possibility of interaction among them. Similarly, crop-climate models require more development and comparison of results before they can be reliably utilized in conjunction with either more sophisticated models of climate or of the agricultural sector. (See the paper by Biswas in these proceedings.) Issues involved in joining the various "physical" and "socioeconomic" models should be explored. The purpose of the explorations would be to develop methods for eventually linking socioeconomic models and empirical or dynamic models of climatic variability and change to study sensitivity, risk levels, and policy options in sound integrated assessments. New approaches may be needed. For example, it has been suggested that in studying the differential impact of drought on societies, recent structural theories, such as the theory of dissipative systems, may present a promising avenue to be explored. While some of the work in this area is theoretical, it may also be linked to concrete case studies. Finally, it should be pointed out that trying to grasp the functional circle of science and economy raises fundamental ethical issues in the philosophy of nature. Ultimately, this kind of research is not meant merely to help generate reliable numerical assessments, but also to help us judge what is good or bad with respect to nature.

(4) In certain respects it may be possible to arrive at the most concrete results by limiting the field of study to climate and one important natural or socioeconomic sector. Food and water appear to be the sectors with the highest priority, but interesting work might be undertaken with respect to ecology and other sectors. In this kind of work, for example, agricultural models might be used to test "climatic shocks" to the food system, or climatic variability might be explored as an environmental constraint to agriculture. Similarly, the connection of climatic variability and issues of water supply and quality have not been fully explored.

(5) Rather than a sectoral approach, it is also possible to undertake analysis of the interactions between climate and human activities from a national or regional perspective. Such studies offer a continuing source of ideas about the kind of problems and situations a model might be asked to represent, as well as offering concrete explorations of policy decisions. A number of these studies have been carried out, but no critical reviews, which would emphasize methods, theoretical frameworks, and underlying hypotheses, have been made. Subsequently, it might be useful to try to bring together researchers in this area, for example, by creation of a network of case studies in different geographical areas. An example of a specific topic is uses and limitations of crop-climate models in such studies.

SUMMARY OF CONTRIBUTIONS

In "Economics in the Air: An Introduction to Economic Issues of the Atmosphere and Climate," Ausubel suggests that for most purposes nations continue to treat the atmosphere as if it is endlessly assimilative and resilient. Because many of the consequences of the use of the atmosphere are felt far away in space and time, and because most of the uses of the atmosphere carry no price, the atmosphere remains one of a class of environmental goods that present economic systems encourage heavy use of. So, for example, households and firms normally dispose of their sulfur and carbon residuals not by scrubbing them from emissions but by pouring them freely into the atmosphere.

In the past 10 years, a series of "threats" to the atmosphere has been posed by the findings of natural scientists. Regardless of the seriousness of any particular issue at the present time, the outlook is that over the next 50 to 100 years, the atmosphere, including climate, will join the ranks of drastically altered aspects of the earth's environment. No such thing as a "forever wild" position can realistically be argued for the atmosphere. Societal choices with respect to the atmosphere will almost never be whether or not to have an activity, but to determine at what level an activity should be undertaken and how one activity should be balanced against another.

Conflicts tend to proliferate in a setting where no competing party or interest group is really informed about the scientific status or economic value of the resources in question. In trying to devise satisfactory long-term, international policies for a global commons such as the atmosphere, there is an urgent need for better information and analytical criteria and better sharing of these. Indeed, our knowledge needs to be dramatically improved, if we are ever to be able to apply efficiency criteria to the entire set of uses of the atmosphere in order to allow consideration of the welfare implications of trade-offs between alternative uses or groups of uses. In the past, the uses and users of the atmosphere have been independent enough so that they need not be considered in a holistic way. However, the subject of atmospheric policy is now maturing to the point where a comprehensive, long-term, integrated examination of the future relationship of the atmosphere and human activities may be warranted. In this respect, the atmosphere appears to be following the tendency in resource management to organize functionally defined units across spatial or physical regimes.

While it is true that the trade-offs which may eventually need to be made may be primarily functions of societal purpose (energy, food, and so forth) rather than competing uses of a natural system, the natural system probably still offers an excellent opportunity for applied research and policy analysis. Given the scientific and economic uncertainties about many of the uses of the atmosphere, and the structure of control and management of the atmosphere, or lack of it, both nationally and internationally, it is hard to believe that society will be able to come to grips in a decisive way with major atmospheric issues, such as climatic change, in the next decade. But, rather than accept this situation one may begin efforts to avoid an ever more irrationally exploited and degraded atmosphere.

In "Chalk on the White Wall? — On the Transformation of Climatological Facts into Political Facts," Meyer-Abich asks what kinds of political actions can be conceived in response to climatological developments so that facts about climate expressed in the language and terms of the sciences may change the political situation, and thereby become political facts. In principle, there are three options: prevention, compensation, and adaptation. While ultimately these options may be basically equivalent, Meyer-Abich shows that from a political point of view prevention and compensation (or abatement) are much less practical than adaptation. In particular, adaptation allows one to confine oneself to the least marginal action in the present and to defer expenses most distantly into the future. Adaptation also does not require long-term international cooperation or agreement on long-range goals. Adaptation, thus, for the time being is the most rational political option. Given this assessment of the issue of climatic change and the specific characteristics of an adaptive strategy, the climate problem, paradoxically, tends to fade out compared to the already existing extremely serious problems of the politics of development and industrial change.

Biswas, in "Crop-Climate Models: A Review of the State of the Art," looks at an area that is at the center of the issue of climate and human activities, since it is widely agreed that, barring a catastrophic occurrence like the collapse of the West Antarctic Ice Sheet, the most important and vulnerable human activity with respect to both climatic variability and change is agriculture. Biswas points out that there are two basic approaches to the question of the effects of climatic fluctuations on agricultural production. One is detailed ecological study which tries to understand the different determining physical processes involved and to assess the behavior of crops under different specific conditions. In contrast, "crop-climate models" attempt to relate climatic variables to production data through statistical techniques. Most crop-climate models developed so far are based on multiple regression and use empirical relationships derived from historical crop yield and climate data to predict potential future yields from different climate scenarios.

Following a review of the major models for different crops and geographical locations (Thompson, Haigh, Williams), Biswas points out some of the major problems. Among these problems are the black-box structure of the models, the fact that the coefficients derived are statistical estimates and not universal constants, the nonlinearity of the relations between crop yields and different climatic variables, the assumption that the independent meteorological variables are not closely related to one another, and the difficulty of separating factors of management, technology, and climate. While crop-climate models provide some interesting insights, Biswas concludes that further developments, both in terms of modeling sophistication and in our understanding of the interrelationships among the different processes involved (especially with respect to more specific time periods), are essential before the potential of the models can be fully realized and the models used in decision-making and planning processes.

Warrick's report, "Drought in the Great Plains: A Case Study of Research on Climate and Society in the U.S.," sets out an important hypothesis about the role of climate in relation to human activities and tests it with specific historical research offered in the framework of two models of climate-society interactions. The hypothesis states that persistent and adaptive societies, through their technology and social organization, *lessen* the impacts of recurrent climate fluctuations of similar magnitude on the resident population and indirectly on the entire society. This "lessening" hypothesis is investigated in relation to both a simple static model of climatic impacts in which a climatic event (drought) affects some sector of society (agricultural production) and "causes" societal impacts. A more sophisticated dynamic model is also discussed. In this model patterns of response alter either physical systems, social systems, or both, and in so doing transform the interaction of climate and society over time. Thus the social basis of vulnerability and the dynamics of adjustment may be explored.

The preliminary results of the Great Plains case study offer substantial evidence of support for the hypothesis of lessening impacts. Although there are difficulties in accounting for differences in the severity of drought and in separating its effects from more external economic effects, the overall picture which is emerging is one of progressively lessened impact upon local agricultural residents. Meanwhile, the pattern of impact has shifted to encompass a broader social network, as reduction of local stress has been accompanied by willingness to spread costs throughout society. However, while the societal impacts diminish, it is not clear that this reduction results from a lessening in the drought-yield linkage. The data are ambiguous, and this point invites connection with material in the papers by Biswas and Czelnai. Warrick suggests tentatively that the bulk of lessening has not occurred because of the technological mechanisms and changed farm operations that intervene between drought and yields, but rather it is more likely that lessening has occurred from intervention between yield declines and societal well-being, that is, through programs of reserves, insurance, and so forth.

While Warrick explores primarily effects changing through time, Spitz, in his paper "Drought and Self-Provisioning," looks at distributive effects of climatic variability on specific social groups. Spitz, drawing examples from Indian data, takes as his subject a social system of cereal production in which consumption by the producer, or self-provisioning, plays a major role. He examines the impact of shortfalls in production depending on the size of domestic stocks and relative strength of the forces of extraction of food from the household (food as a commodity) and the forces of retention of food in the household (food as a basic need). It is this dual nature of food, often ignored in microeconomic analysis, that in many poor areas accounts for the extreme sensitivity to variations in production and makes linear analysis of agricultural crises of little value. Moreover, those already relatively poor within the self-provisioning economy, namely those with small carry-over stocks, are affected most severely. The lower the nutritional level of a given group at the outset of a drought, the more it is likely to be reduced by the drought. In the case of a fall in production intended for self-provisioning and in the absence of any means of exchange for procuring a living, those without reserves are forced to emigrate, while those with greater and more diversified resources may find that drought enables changes to be made even more to their advantage through favorable prices for factors of production. The potential for conflict in a drought situation in a self-provisioning society is thus clear, as the vulnerability and resilience of different elements of the social and economic system are tested in the struggle for social control of reserves.

In "Climate and Society: The Great Plain of the Danube Basin," Czelnai explores this area as a possible candidate within eastern-central Europe for closer study of the interface between climate and human activities in developed countries. It appears to be an interesting choice for study because it is a food-surplus area with good availability of data and distinctive climatic features. Czelnai offers some general remarks about the stratification of climatic impacts, and reviews societal adjustment strategies in the light of a possible range of responses to a "single pulse" short-term climatic forcing. The environmental history of the Great Plain is briefly outlined with special regard to the factors that have shaped the hydroclimatic regime of the area. Czelnai then discusses some of the relationships of climate and economy in connection with agriculture, which he estimates contributes by itself 60% of the overall climatic sensitivity of the socioeconomic systems within the geographical area. It is shown that the prevailing negative water balance reduces the natural agro-climatic potential by some 50%. This means that an intensive agricultural system, with irrigation, could double the productivity. However, it appears that with present prices such a system would not be cost-effective and, moreover, would probably increase the climatic sensitivity of the area. Finally, it is suggested that a pervasive cooling, or an increasing of the recurrence of low temperatures, could be particularly detrimental to a broad range of plant culture.

As mentioned earlier, one of the needs in the area of research on climate and human activities is for improved information on plausible patterns of climatic change. Sergin's research on estimating climatic fields based on the similarity of seasonal and longer-term climatic variations offers a promising method for doing this, as well as some tentative results. The present state of development restricts the applicability of general circulation models for determining regional changes in the geographical pattern of temperature, precipitation, and winds. The use of past periods as analogues of the future, or a "similarity method" as Sergin describes his related approach, allows the possibility of using past instrumental records of climate to gain insight into possible futures. The similarity method does not offer a way of forecasting. However, the theory of similarity does provide a method for estimating fields of meteorological elements for new, given climatic states.

In his paper, Sergin outlines the theory of the similarity of states of global atmospheric circulation in the course of seasonal and longer-term climatic changes and shows that seasonal variations in the fields of meteorological elements can be taken as a physical model of climatic variations in the average annual field. If an atmosphere with a given seasonal course of boundary conditions is regarded as an experimental unit, then by applying the rules of the theory of similarity one can obtain basic quantitative estimates characterizing the average annual fields of various climatic states. A new state may be characterized by the specification of one pair of numbers, namely the average atmospheric temperature in the hemisphere and the temperature difference between the equator and the pole. Sergin makes experimental estimates for a warming and a cooling of the average annual surface temperature by 2 ^{o}C. While the average climate of the warmer epoch is characterized by greater humidity, cloudiness, and precipitation, the distribution of changes is uneven, and many arid areas become drier. In contrast, in the cooler epoch the amount of precipitation increases in most of the arid regions. Estimates such as these may prove useful in evaluating the significance of the effects of human activities upon the climate. However, we must keep in mind that in making use of natural fluctuations we are assuming that, given similar boundary conditions, there are broad similarities in the way the atmosphere responds to different types of forcing.