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AN UPDATE OF SOVIET RESEARCH ON AND EXPLOITATION OF "NUCLEAR WINTER," 1984-1986

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This study updates the author's technical report, "Soviet Exploitation of the 'Nuclear Winter' Hypothesis," DNA-TR-84-373, 5 June 1985. The study is based on Soviet open-source materials and papers given at various scientific seminars. It examines and analyzes Soviet published research on and propaganda uses of the "nuclear winter" phenomenon during the period of mid-1984 to mid-1986. In particular, the study seeks to ascertain the character, limitations, and degree of seriousness of Soviet research on nuclear winter, the validity of Soviet claims of having independently confirmed Western findings, and the extent to which Soviet work on nuclear winter is intended to serve political and propaganda rather than serious scientific objectives. The analysis of Soviet source materials shows that Soviet scientists have made only minimal contributions to nuclear winter research and that much of the published work has continued to be based on "worst case" war scenarios, parameters and values, and projections of climatic changes derived from seriously flawed 1983 —

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models and computations in the U.S. and Soviet Union. For political and propaganda reasons, most Soviet open sources on nuclear winter have continued to ignore new Western and even some Soviet projections of more moderate climatic effects. It appears that Soviet efforts to model nuclear winter have run their course and that more emphasis will be placed on the synergistic effects of nuclear war on the ecology and atmosphere.

SUMMARY

During 1983, Soviet scientists took an active part in the initial international modeling of a potential nuclear winter effect. Foremost in this effort was the work of V.V. Aleksandrov and G.L. Stenchikov of the Computing Center of the USSR Academy of Sciences, who published in September 1983 a paper in English, On the Modelling of the Climatic Consequences of the Nuclear War. The model was derived from an obsolete American model of atmospheric global circulation. The authors uncritically used a "worst case" war scenario (a 10,000 MT exchange) and assumptions about fires and key parameters of smoke, soot, and dust taken from the 1982 Crutzen-Birks and the 1983 TTAPS studies. They also greatly exaggerated the extent of absorption of incidental solar radiation by smoke and dust, resulting, therefore, in predictions of extremely large declines in global surface air temperatures. Nevertheless, the Soviet model provided a first coarse, three-dimensional, transient view of a nuclear winter simulation. Because of the predictable approximate correspondence of the Aleksandrov-Stenchikov and TTAPS projections of climatic effects for the first months of a post-exchange period, the Soviets claimed to have "independently" confirmed the nuclear winter effect and its probable severity. The Soviets made extensive use of these claims for propaganda purposes in support of their "peace" campaign and of Western anti-nuclear movements.

The pre-eminence of Soviet propaganda over objective scientific inquiry was reflected in various ways in subsequent Soviet treatment of and research on nuclear winter. During 1984, the Soviets made no new contribution to nuclear winter modeling and failed to provide the requested independent data on particle size distributions and fire experiments. Despite criticism by Western scientists, the errors in assumptions about the extent of absorption of solar radiation in the Aleksandrov-Stenchikov simulation were not corrected until 1985. The Soviets, however, were quick to model the TTAPS nuclear winter "threshold" scenario of a 100 MT urban-only attack, using the TTAPS parameters and assumptions. This allowed Soviet science spokesmen to claim that a limited nuclear war, said to be planned by the United States, would result in a devastating nuclear winter. The only innovation introduced in 1984 into the Soviet simulation was moving smoke from the Northern to the Southern Hemisphere, which,

given the model's assumptions, led to projections of extreme temperature declines in the Southern Hemisphere.

Although Soviet scientists recognized that the amount of smoke and dust injected into the atmosphere as a result of a nuclear exchange was uncertain, the general line, with a few exceptions, was that the existence of a severe nuclear winter effect had been proven. Soviet scientific papers on subjects relating to nuclear winter continued to make uncritical use of the Aleksandrov-Stenchikov and TTAPS studies for their basic assumptions.

The most significant change in Soviet modeling of nuclear winter occurred in 1985, when Stenchikov and P. Carl of the East German Academy of Sciences changed the assumed optical depth of smoke from 7 to 2.2, resulting, therefore, in the projection of less severe climatic effects. These computations were published in two English language publications. Significantly, however, they were ignored at the time and subsequently by all Soviet writings on the nuclear winter issue, which continued to use the results of the 1983 work. This was also true for Soviet inputs to the SCOPE-ENUWAR program, in particular the Computing Center's modeling of the ecological consequences of nuclear war.

In other aspects of global effects of a nuclear war, Soviet scientific publications placed great emphasis on the issue of large depletion of stratospheric ozone and on the effects of various gases released into the atmosphere by large urban and wild fires.

The analysis of Soviet open sources strongly suggests that the Soviets have continued to view the question of a nuclear winter effect primarily as a propaganda opportunity. Although Soviet scientists have indicated serious interest in and concern about this effect, the seriousness of the Soviet research effort is open to question because it is biased by propaganda requirements and the inability of Soviet scientists to use independent scenarios or parameters of smoke and dust.

The Soviet nuclear winter modeling effort may have run its course, especially as the Soviets are unwilling to simulate what they call the "nuclear optimism" of current

American findings on nuclear winter effects. The focus of Soviet research, which would also support the Soviet propaganda objectives, is likely to shift to questions of the consequences of small changes in ambient temperature and of synergistic effects of ionizing radiation, atmospheric aerosols, and increased UV radiation on the ecology.

PREFACE

The present study seeks to update the author's technical report on Soviet Exploitation of the "Nuclear Winter" Hypothesis, which was prepared for the Defense Nuclear Agency under Contract No. DNA 001-83-C-0195, published 5 June 1985. That report covered the period from 1983 to early 1984 when Soviet scientists first became active in modeling nuclear winter effects. The present report will cover developments in Soviet research on and exploitation of nuclear winter during the period from mid-1984 to mid-1986.

The present study has several purposes. First, it seeks to examine Soviet views and scientific research on the nuclear winter problem and to ascertain the changes which have taken place since 1983 in Soviet modeling and computations dealing with this phenomenon and its consequences. Second, it examines the question of the extent to which Soviet scientific work constitutes an "independent" confirmation of Western research and findings on nuclear winter, as is claimed by Soviet spokesmen. Third, it describes the political-propaganda use made by the Soviets of the nuclear winter phenomenon and of its claimed consequences. In the final analysis, the study seeks to determine whether the Soviets appear to be serious about their claimed concern over the threat of a nuclear winter occurring as a consequence of a nuclear war or see it primarily as a propaganda opportunity in support of their "peace" and "disarmament" campaign.

The report is based entirely on Soviet and Western open-source materials dealing with the nuclear winter issue. It includes reports on meetings of Soviet and U.S. scientists and Soviet papers given at various international scientific conferences, as well as published materials. While a significant portion of the Soviet scientific materials have not received wide notice in the Western mass media--even when they were published in English, they have been circulated in the international scientific community. In obtaining these Soviet materials and commentaries on them, this author is greatly indebted for the invaluable help given him by a number of American scientists--in particular, Dr. Joseph B. Knox and Dr. Michael C. MacCracken of the Lawrence Livermore National Laboratory, Dr. Alan Robock of the University of Maryland, and Dr. Alan D. Hecht of the National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

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SECTION 1
INTRODUCTION

The publication in 1982 in Ambio, the Journal of the Royal Swedish Academy of Sciences, of an article on "The Atmosphere After a Nuclear War: Twilight at Noon" led to a major international effort to study the possible climatic consequences of mass fires generated by a nuclear exchange. The authors of that article, Dr. Paul J. Crutzen of the Max Planck Institute for Chemistry (FRG) and Professor John W. Birks of the University of Colorado, drew attention to major climatic consequences which may result from the injection into the atmosphere of large amounts of smoke and soot from forest and urban fires in a nuclear war (Ref. 17). According to the authors, the smoke and soot particles could block and absorb from 50 to 99 percent of the sunlight, thus causing not only prolonged "twilight at noon" but also a significant lowering of ambient surface temperatures. In the United States the most noteworthy initial study of this question was carried out by a team of scientists: R.P. Turco, O.B. Toon, T.P. Ackerman, J.B. Pollack and C. Sagan, often collectively referred to as TTAPS, who introduced the so-called "nuclear winter" hypothesis. Some mention of their findings was initially reported in an abstract published in the November 1982 Transactions of the American Geophysical Union (EOS). These findings were subsequently presented first for review to a group of scientists in Cambridge, MA, in April 1983, then publicly discussed during 31 October - 1 November 1983 at a large, well publicized conference on "The World After Nuclear War" held in Washington, D.C. (Ref. 19), and finally were published in Science and Foreign Affairs in December 1983 (Refs. 62, 72).

The Soviet input to the study of nuclear winter was predominantly confined to climate modeling. The first and most widely publicized Soviet simulation of nuclear winter was developed by V.V. Aleksandrov and G.L. Stenchikov of the Computing Center of the USSR Academy of Sciences (CCAS) and presented to various Western audiences beginning in August 1983 (Refs. 2, 32). The computer model used by the Computing Center, under code name "GEA," had been developed during the 1970s to study problems of climatic change, such as those due to the increased greenhouse effect in the atmosphere, and to describe processes occurring in the biosphere (Refs. 49, 50). As was acknowledged by Aleksandrov and others, the model consisted of an atmospheric general circulation model based on a relatively obsolete two-level Mintz-Arakawa model of atmospheric circulation developed in the United States in 1971 and on a thermodynamic model of the upper ocean (Refs. 6, 25, 26). The model had a coarse horizontal geographic resolution of 12 degrees latitude by 15 degrees longitude, and two vertical layers of the troposphere to an altitude of about 12 km (Ref. 6). The simulation was performed on a BESM-6 computer, which was described as being "ten times faster but with less memory than an IBM personal computer" (Ref. 2).

The two most significant aspects of the Aleksandrov-Stenchikov model were that it gave a three-dimensional transient view of a nuclear winter simulation, while the TTAPS simulation was one-dimensional, and that it was somewhat interactive--in particular, allowing for the influence of changing ocean temperatures, while the initial American simulations assumed fixed sea surface temperatures. Beyond this, however, what Aleksandrov and Stenchikov did was to uncritically "play out" on their computer model the scenarios and assumptions about the critical parameters of smoke, soot, and dust injections into the atmosphere based on the Crutzen-Birks and the TTAPS studies, the latter having been obtained by Aleksandrov in April 1983 or even earlier (Refs. 6, 19, 32, 49). Indeed, in addition to using only Western inputs in their simulation, Aleksandrov-Stenchikov made an error by a factor of three in absorption optical depth by interpreting as absorption the TTAPS estimate of extinction optical depth, thereby treating dust as smoke and finding that the smoke and dust would absorb 100 percent of the incidental solar radiation, unlike the TTAPS determination of 50 percent for smoke/soot and 1 percent for dust. The result, as Dr. Michael C. MacCracken of the Lawrence Livermore National Laboratory (LLNL) has noted, was equivalent to assuming an injection of about 1,000 Tg of smoke into the atmosphere instead of the 225 Tg assumed by TTAPS (Ref. 46). This error led Aleksandrov-Stenchikov to project exceedingly large temperature decreases following a nuclear exchange to far below freezing for a period of up to one year throughout the Northern Hemisphere (Ref. 6). Despite persistent comments by Western scientists, this error was not corrected in published Soviet computations of the nuclear winter effect until 1985. It is also noteworthy that in 1983 the Soviet simulation used whatever available values of parameters that would lead to more significant effects, such as a 10,000 MT nuclear exchange scenario--i.e., the TTAPS study's "worst case" scenario, rather than its

5,000 MT exchange baseline scenario (Refs. 6, 19, 72); and the one million square kilometer forest fire scenario of the Crutzen-Birks paper instead of the 500 thousand square kilometers assumed in the TTAPS study. Aleksandrov explained his use of the 10,000 MT scenario on the ground that it had been the "first basic version" used in an early TTAPS draft war scenario (Ref. 3). Finally, in the Soviet model the upper layer of the smoke was assumed to extend as low as high mountain elevations. This led to the projection that the solar heating of this layer would result in the rapid melting of snow and ice at high elevations.

After the Washington Conference on "The World After Nuclear War," the Soviets made two basic public claims. First, that the results of the Aleksandrov-Stenchikov simulations, especially for the first 20 days following a 10,000 MT nuclear exchange, closely coincided with those of TTAPS and of the U.S. National Center for Atmospheric Research (NCAR) (Ref. 7). Second, that the Soviet and Western findings were arrived at "independently" of each other and consequently confirmed the correctness of the findings (Refs. 32, 44). Actually, the coincidence of the Soviet and Western initial calculations of nuclear winter effects was not surprising. Given that Aleksandrov-Stenchikov uncritically used Western "worst case" scenarios and values of essential parameters of smoke and soot, the results could be expected to coincide with those of early Western simulations, at least for an initial post-attack period. This, however, could not be considered as constituting "independent confirmation" of the validity of the findings. As far as Western scientists were concerned, the Aleksandrov-Stenchikov model, while characterized as being "seriously flawed" and "crude" (Refs. 62, 67, 73), was nevertheless credited with providing the first attempt at a three-dimensional simulation of nuclear winter.

Another, less publicized Soviet model was developed by G.S. Golitsyn and A.S. Ginzburg of the Institute of Atmospheric Physics of the USSR Academy of Sciences (Refs. 30, 32). Their model drew heavily on their studies of Martian dust storms. It included a simple two-level model of atmospheric circulation. As in the case of the Aleksandrov-Stenchikov model, it also exclusively used Western scenarios and key parameters of injection of smoke and soot into the atmosphere, primarily those of Crutzen-Birks (Ref. 32). Based on Martian dust cloud analysis, the model was said to give "rather close" results to those of the "Sagan scenario" (Ref. 7).

At the Washington Conference on "The World After Nuclear War" the impression was given that the Soviet scientists would become important active participants in the international nuclear winter study effort. During the conference, which included a special Washington-Moscow television hookup to permit some direct exchange between select Soviet and American scientists, Sagan had asked Soviet scientists for data on the particle size distribution function of debris from Soviet atmospheric nuclear tests before 1963, on the particle size and absorption coefficient of smoke from large fires in the Soviet Union, and Soviet views on the more "likely" nuclear war scenarios (Ref. 19). However, the Soviet scientists failed to respond to this request. In two subsequent conferences--one held in Tallin, Estonia, in March 1984, and especially a meeting of a SCOPE workshop in Leningrad in May 1984--the Soviets offered nothing new. They also failed to provide data on fire experiments which Western scientists had expected to learn about (Refs. 32, 67). In September 1984, Richard Turco, the key author of the TTAPS study, noted that during the eight months following the Washington Conference "no substantial physical data and little evidence of objective scientific analyses were forthcoming" from the Soviet side (Ref. 73). Soviet scientists, including Aleksandrov, acknowledged that projections of nuclear winter effects on climate were fraught with many uncertainties, especially concerning the characteristics and amounts of soot and various aerosols injected into the atmosphere. Nevertheless, they made no independent contribution to the analysis of this problem. They also avoided becoming involved in the scientific debate in the West over the validity of the TTAPS and NCAR assumptions and findings and the nuclear winter hypothesis as a whole. Certainly, the Soviets gave no public evidence of a similar debate taking place within the Soviet scientific community or of serious questions being raised about the assumptions and computations of Aleksandrov and Stenchikov. The absence of a public debate, however, did not necessarily indicate general agreement among Soviet scientists concerning the nuclear winter hypothesis.

While there were grounds to question the validity of Soviet published findings on nuclear winter and even the seriousness with which the Soviet authorities and scientific community viewed this issue, there was little doubt that it was perceived by the Soviets as offering a major propaganda opportunity in the West. In addition, it constituted a very useful vehicle for expanding Soviet contacts and influence among the Western scientific community, especially its "anti-nuclear" activist element. The Soviet propaganda exploitation of the nuclear winter issue made it logical to choose "worst case" scenarios for the Soviet simulations and to make "worst case" predictions of climatic effects, even to the point of leaving uncorrected serious errors in assumptions despite criticism of them by Western scientists. The importance of the propaganda role of Soviet scientists and physicians, especially in dealing with foreign audiences in support of Soviet policy objectives, had been spelled out by Politburo candidate member Boris Ponomarev at a large meeting of Soviet scientists held in Moscow in May 1983 (Ref. 32). This meeting had also led to the organization of the Committee of Soviet Scientists for Peace, Against the Nuclear Threat, with the vice-president of the USSR Academy of Sciences, Ye.P. Velikhov, as its chairman, a sort of Soviet counterpart to the Union of Concerned Scientists.

Following the October-November 1983 Washington Conference, Aleksandrov, Velikhov, and other Soviet scientists became indefatigable travelers and lecturers in the West on the dire consequences of a nuclear winter and its implications for peace and disarmament. Although the initial Soviet simulation had not considered the TTAPS 100 MT city attack scenario, the Soviet spokesmen were quick to pick it up and cite it after the Washington Conference, especially given Sagan's claims that it constituted a sort of "nuclear winter" threshold as far as the total yield of a nuclear exchange was concerned. Thus, by December 8, 1983, Velikhov claimed at a public hearing in Washington that "estimates of Soviet and American scientists show that climatic changes, that is 'nuclear winter,' can arise on exploding 100 MT of nuclear equivalent" (Ref. 78). At the same hearing, Aleksandrov used the apocalyptic line, which he later often repeated, that "after a nuclear war, practically regardless of its scenario, the survivors of the first strike would find themselves in conditions of severe cold, lack of (drinking) water, food and fuel, affected by powerful radiation, pollution, and disease . . . in twilight and darkness" (Ref. 4).

While Soviet spokesmen gave full play in the West to the nuclear winter hypothesis, domestic treatment of this topic in the Soviet Union was noticeably more restrained. The Aleksandrov-Stenchikov study was first published in September 1983 but only in English. Although an abridged version of it was subsequently published in

1984 in a Soviet scientific journal in Russian (Ref. 8), popular Soviet articles on nuclear winter have generally continued to cite the English version. A report by Aleksandrov and Moiseyev on the 1983 Washington Conference "The World After Nuclear War" was published in the Herald of the USSR Academy of Sciences in November 1984, i.e., a year after the event (Ref. 7).

Not surprisingly, during 1983 and early 1984 the Soviet public, unlike its Western counterpart, received relatively little information about the nuclear winter "threat." Many of the articles on this topic appeared in Soviet foreign language publications or the news agency TASS' releases in English (Ref. 32). Nevertheless, a certain amount of brief commentary of a general character about the potential effects of nuclear detonations on the climate and the ecology and the dangers this could pose to human survival did appear in the Soviet national press following the Washington Conference (Ref. 32).

SECTION 2

SOVIET NUCLEAR WINTER RESEARCH 1984 - 1986

Following the development and wide presentation in the West of the initial Aleksandrov-Stenchikov computer simulation and calculations of nuclear winter, Soviet research into this effect essentially followed four directions: (a) elaborations on this model, (b) attempts to model and describe the fundamental consequences of a nuclear war, including the effects of nuclear winter on the ecology, agriculture and people, (c) eventual revisions of the Aleksandrov-Stenchikov computations and the running of a series of sensitivity calculations, and (d) discussions of research into other phenomena which could affect the post-exchange climate. The following provides an overview of these developments and changes in Soviet publicly acknowledged work on nuclear winter and related phenomena and issues.

2.1 THE 100 MT EXCHANGE CASE.

Although the Aleksandrov-Stenchikov 1983 model was based on the original TTAPS 10,000 MT exchange scenario, it became clear at the Washington Conference on "The World After Nuclear War" that the TTAPS 100 MT city-only attack scenario was especially interesting. It could be interpreted, as Sagan claimed, as constituting a rough indication of a "threshold" for a nuclear winter effect (Ref. 62). According to TTAPS, the initial temperature decline from an attack with 1,000 nuclear warheads with a yield of 100 KT each on several hundred large cities would be about the same as that in the 5,000 MT exchange case, although the decline would persist a significantly shorter time than in the latter case (Ref. 19). Thus, as Aleksandrov and Moiseyev later wrote, "After the [Washington] conference we also calculated this variant" (Ref. 7). The scenario was characterized by Aleksandrov as consisting of an aggregate yield of 100 MT airburst nuclear detonations on 100 "major cities all over the Northern Hemisphere" (Ref. 3).

As in the TTAPS study, Aleksandrov assumed that the optical depth of the smoke resulting from the burning cities alone would be 3, while in the 10,000 MT scenario he had projected it to be 7 (Ref. 3). Not surprisingly, the results of his simulation of the

100 MT scenario were similar to those of TTAPS (Refs. 3, 7). According to an article by Moiseyev published in August 1984 (Ref. 49):

> Conclusions drawn from our calculations indicate that if 100-150 megatons of nuclear explosives (i.e., 50 times less than in the Sagan scenario [i.e., the TTAPS baseline scenario of a 5,000 MT exchange]) were used in a nuclear exchange, the major cities of Europe, Asia and North America would be destroyed, and the nuclear winter would begin unabated. The only difference is that it would end within a few months instead of lasting a full year. But even this would be sufficient time to ensure the end of life on earth.

As one could expect, Soviet propagandists and science spokesmen were quick then and up to the present time to publicly adopt the concept of a nuclear winter "threshold" and to identify it with a 100 MT exchange scenario, often without any mention of the specific assumptions of this scenario. In particular, this was used by the Soviets to argue that the alleged U.S. concept of a "limited" nuclear war could result in a nuclear winter. At other times, Soviet spokesmen merely claimed the existence of a nuclear winter threshold as a result of a relatively small but unspecified nuclear exchange. For example, in April 1984 an article describing the U.S. and Soviet nuclear winter research asserted that "the climatic models of Soviet and American scientists have led us today to a realization of the threshold" of nuclear winter, which was said to be the " 'soft' scenario of 100 exploded megatons" (Ref. 44). As against this, an article in Izvestiya in July 1984 by Academician V. Goldanskiy and Professor S. Kapitza claimed the existence of a "definite threshold," but failed to specify its size because of uncertainties about the quantity of dust, smoke, soot, etc. which would be injected into the atmosphere (Ref. 29). These latter authors limited themselves to saying that the existing stockpiles of nuclear weapons "exceed the threshold beyond which a global geophysical reaction is triggered." They also came up with the following suggestion:

> Obviously, in estimating the quantity of the introduced admixtures [into the atmosphere], any additional data which will help to make the forecasts more accurate will be of value. Systems analysis methods can be of use here: these make it possible to study complex interrelated chains of phenomena when the accuracy of quantitative models constructed with the help of computers does not always adequately reflect the full range and the level of understanding and the accuracy of the initial data (Ref. 29).

2.2 THE MOSCOW TECHNICAL EXCHANGE MEETING, AUGUST 1984 (Ref. 37).

The Moscow meeting on 13-17 August 1984 was an outgrowth of an agreement between American and Soviet scientists reached at the 1983 session of the International Seminar on Nuclear War held in Erice, Italy. The agreement called for the sharing of updated assessments of nuclear winter and in general for collaboration in the study of simulations and the evaluations of the global consequences of a US-USSR nuclear confrontation. The agreement had been signed by Dr. E. Teller, Academician Ye.P. Velikhov, and Dr. A. Zichichi, director of the Center for Scientific Culture. The meeting in Moscow was hosted by N. Moiseyev at the Computing Center of the USSR Academy of Sciences. The American participants included Drs. J. B. Knox, F. Luther, M. MacCracken, and J. Penner from the LLNL, plus Dr. W. Parker of the Fire Research Laboratory, National Bureau of Standards. On the Soviet side, in addition to a large contingent of scientists from the CCAS, among them Aleksandrov, it also included scientists from various institutes of the USSR Academy of Sciences and from Goskomhydromet (State Committee for Hydro-Meteorology and Control of the Environment). It was, therefore, an occasion at which a largish group of Soviet scientists, 27 in all, from various disciplines could discuss issues relative to the climatic consequences of nuclear war. Both the American scientists and a number of Soviet scientists presented papers on various topics.

2.2.1 Large Fires.

According to the program two papers were to be presented on this topic, one by Dr. Y.A. Gostintsev of the Institute of Chemical Physics of the USSR Academy of Sciences on "The Hydrodynamic Aspects of Large Fires," and another by Dr. S.S. Grigoriyan of Moscow University on "The Theory of Mass Fires and Its Analogies." Both papers were canceled, however, presumably due to the nonavailability of these two scientists. Instead, Moiseyev indicated that a series of seminars had been held at the CCAS on the topic of the theory and modeling of mass fires, which had concluded that the modeling was very difficult because it involved a large number of interrelated parameters and processes. Moiseyev indicated that the CCAS had decided to defer further research on and experimentation with large fires because of the perceived difficulties in modeling them.

2.2.2 Nuclear Winter.

In his paper "On the Global Catastrophies" Moiseyev indicated that the scientists at the CCAS had done collaborative calculations with Sagan and with Dr. Stephen H. Schneider (NCAR), and that they considered the simulation as being essentially "right." He expressed the personal belief that the 100 MT scenario would be capable of triggering a "nuclear winter."

Stenchikov of the CCAS presented a paper "On 3D Nuclear Winter Modeling," in which he and Aleksandrov had rerun their previous simulations but, as a major innovation, included moving smoke. In this respect the simulation was ahead of similar American simulations (Ref. 47). Given the large amount of smoke assumed to be injected into the atmosphere in the Soviet model, the moving smoke made climatic cooling worse.

Two papers were given by Golitsyn and other members of Institute for Atmospheric Physics of the USSR Academy of Sciences. The first dealt with "The Evolution of the Heavy Turbid Boundary Layer," which presented an idealized analysis of the development of a turbid boundary layer, homogeneously mixed with an absorbing aerosol of optical depth 3. The study indicated that it would take approximately 13 days for the boundary layer to fill the normal troposphere if large forest and urban fires occurred. The paper was intended to show that there were reasons why the climatic effects portrayed in the TTAPS study could be worse. It was noteworthy, however, that the authors of the paper had used the more questionable assumptions of the TTAPS study, i.e., instantaneous spreading of the smoke over the hemisphere, smoke trapping on a hemispheric scale in the boundary layer the first day, and no plume-cloud-mesoscale processes of scavenging. The other paper was on "Theoretical and Laboratory Modeling of the Static Stability Influence on the Structure of the Atmospheric General Circulation." It examined the influence of large static vertical stability on the suppression of baroclinic instabilities in the general atmospheric circulation. It assumed the planetary scale inversion postulated in the TTAPS study and concluded that weather disturbances would essentially cease to exist in the post-war atmosphere.

At the Moscow meeting, Moiseyev claimed in effect the nuclear winter question to have been adequately resolved so the time had come to focus on other problems. The line taken appeared to be that while further refinement in the models and better data on the amount of injected smoke could firm up the initial calculations, there was no doubt that a nuclear exchange would have disastrous climatic consequences. The Soviets were obviously eager to use these conclusions for propaganda purposes. At the meeting Professor S. Kapitza of the Institute for Physical Problems of the USSR Academy of Sciences and a vice president of the Committee of Soviet Scientists for Peace, Against the Nuclear Threat, raised the question of how and when this message from the American-Soviet collaborative research could be taken to the peoples of the world. He noted that a special committee composed of Velikhov, Kapitza, and others had been constituted in the Soviet Union to deal with this question. Unfortunately, for him, the meeting reflected more disagreements than agreements among Soviet and American scientists. In this connection, it is noteworthy that in their July Izvestiya article Goldanskiy and Kapitza had warned against unnamed American scientists, but obviously meaning Dr. Edward Teller among others, who questioned the conclusions of the American and Soviet nuclear winter modeling efforts and projections. According to Goldanskiy and Kapitza:

> Now, when joint efforts, primarily on the part of Soviet and U.S. scientists, have firmly established the existence of such a global threshold phenomena and further detailed studies of the complex problems are urgently called for, the attempts of certain scientists - the developers and builders of U.S. nuclear weapons - to cast doubt on the conclusions reached and to subordinate the results of scientific research to the orders of aggressive politicians are arousing indignation. They are trying to discard the results of the work of conscientious researchers who are opening people's eyes to the danger threatening them (Ref. 29).

In this light, a paper by Dr. M.I. Budyko of the Main Hydrological Institute on "Empirical Studies Regarding Climatic Consequences" was of special interest. Unlike other Soviet participants, Budyko suggested that further research was needed before one could consider the nuclear winter projections to be final. He noted that small differences in model parameterization within separate models could lead to very large differences in assessments. He also perceived a need for independent methods of modeling climatic consequences, noting in particular that there had been too much duplication in regard to nuclear winter. Budyko suggested three empirical approaches: the study of seasonal differences in the climatic data base; the examination of data regarding the processes on periods of climate change during the past hundred years; and the study of mass extinctions which had occurred in various prehistoric times. At least Budyko's paper suggested the existence of divergent opinions on the question of the firmness of Soviet and American projections of nuclear winter effects. He also appeared to criticize the Computing Center for largely duplicating American "methods of modeling" the climatic consequences of a nuclear exchange and presumably for uncritically using the assumption and key parameters of U.S. simulations. Furthermore, Budyko suggested that various empirical studies could to some extent help to verify the nuclear winter calculations. This contradicted the general line that short of a war, nuclear winter projections could not be verified.

2.2.3 Other Effects.

Professor K.V. Kondratyev of the Institute of Lake Studies of the USSR Academy of Sciences, in his paper "Observational Evidence of the Impact of Nuclear Explosions on the Atmosphere and Climate," also suggested that some empirical verification of nuclear winter models was possible. He argued that data from large explosive volcanic eruption could be used to confirm (a) cloud or plume dispersion, (b) climatic effects, (c) perturbations in the ozone layer, and (d) gas-to-particle conversion processes. Kondratyev recognized the differences in the optical properties of volcanic aerosols and smoke emissions from urban and forest fires, but believed such studies to be helpful for identifying models or for assumptions about the spreading of aerosols. Beyond this, Kondratyev's group had also analyzed the effects on the ozone layer of the 1908 Tunguska meteorite explosion and had concluded that the ozone depletion had been 5 percent rather than the 30 percent assumed by the TTAPS group (Ref. 74). In 1983 Golitsyn had uncritically cited the latter conclusions (Ref. 63).

More interesting, Kondratyev reported on analyses conducted on the changes in average temperatures in the Northern Hemisphere from the late 1950's to the end of 1963, i.e., during U.S. and Soviet nuclear tests in the atmosphere, taking into account warming from injections of CO_2 and methane into the atmosphere and the cooling resulting from the injections of NO_2 and anthropogenic tropospheric aerosols. According to his analysis, the net impact had been a .3°C cooling. Scaled to the 10,000 MT scenario, Kondratyev predicted a 10°C cooling of surface temperatures as the result of the injection of NO_2 alone. Another interesting contribution by Kondratyev was the observation that the study of satellite data and probes of the earth's atmosphere indicated that atmospheric pollutants seldom extend above the natural cloud system, suggesting that the cloud layers are effective microphysical processors and scavengers of air pollutants.

2.3 THE AUGUST 1984 ERICE MEETING.

At the 4th session of the International Seminar on Nuclear War, held during 19-24 August 1984 in Erice, Aleksandrov presented a paper on "Update of Climatic Impacts of Nuclear Exchange" (Ref. 3). Essentially, this paper reviewed the newest Soviet simulation results carried out at the CCAS. These new results included the simulation of the 100 MT city-only attack scenario and of moving smoke. The model still assumed an instantaneous spread of smoke over the Northern Hemisphere in the same amount as in the 1983 study and only one size of smoke particles. However, the smoke and soot were now avected in the model rather than held fixed. Thus, in the Aleksandrov model the smoke moved from an initial uniform pall over the Northern Hemisphere into the Southern Hemisphere. As in his earlier model, Aleksandrov projected a maximum mean decline in surface air temperature over land in seven to ten days after the nuclear exchange of 15°C, while the temperature of the upper layer of the smoke cloud increased by 20°C. The new simulation predicted a change in the normal patterns of "zonally-averaged stream function of atmospheric circulation," the disappearance of the northern Hadley cell, and a dramatic expansion in the southern Hadley cell circulation, leading to transport of dust and soot from the Northern to the Southern Hemisphere. Given the large amount of dust and smoke assumed to be transported to the Southern Hemisphere in this model, Aleksandrov projected for Day 99 after the exchange a decline of about 60°C for Central America, 40°C for the northern part of Latin America, 50°C for Central Africa, and so on. The southward transport would also moderate somewhat the low temperatures in the Northern Hemisphere. As before, the new simulation did not include the moderating effects caused by scattering of solar radiation. Thus, it continued to project excessively large temperature declines. Aleksandrov concluded by noting that "nuclear war research is needed" in the study of large-scale fires and soot emissions, the behavior of pollutants in the atmosphere, and the removal-scavenging processes. Obviously, the answers to these questions could dramatically affect the projections of a nuclear winter effect.

2.4 THE PARIS SCOPE-ENUWAR WORKSHOP, 22-24 OCTOBER 1984.

The SCOPE-ENUWAR Workshop held in Paris in October 1984 dealt with two main research issues: the radiation effects on human and non-human climate and atmospheric chemistry and physics. Topics under the latter heading included atmospheric modeling and fires (Ref. 42). Among the participants was Moiseyev, the deputy director of the CCAS.

According to a summary of a statement made by Moiseyev (Ref. 12), he restated his view expressed at the already-cited Moscow meeting in August 1984 that the "easy" problems of nuclear winter had been done and that the credibility of the findings of the Aleksandrov-Stenchikov studies were enhanced by their agreement with those of NCAR. He said that the CCAS was working on improving the model. At the same time, he recognized that the hardest problem was to determine "how much soot will be in the atmosphere." As has been noted, the Soviet model had used the largest projection from the Crutzen-Birks and TTAPS studies.

Moiseyev also announced, contrary to his earlier statement in Moscow, that work was being done on developing a numerical model of big fires, which would include convergence of air flow, heating rates, and dynamic factors. This work was being done in cooperation with specialists in physical chemistry. Moiseyev acknowledged that the effort had met with considerable difficulties and that the calculations obtained were not stable. He also warned that this project would take several years. To date, the Soviets have not published a model of large fires and, given the limitations of their computer capabilities, it seems doubtful that they will develop such a model in the foreseeable future.

From the standpoint of fire experiments and studies of natural fires, Moiseyev pointed out that the Soviets could not experiment with large fires because of their high costs. If they were conducted, their size would likely be limited to forest areas of 100 x 100 meters. Moiseyev noted that large forest fires do occur accidentally, but that observations obtained from these are difficult to interpret. He mentioned that some measurements were made in 1984 in the region of a large fire in Siberia in which, he claimed, soot was found at an altitude of 5 to 6 kilometers and was not washed out by rain. However, the optical attenuation was "not different from the usual." Furthermore, no measurements on the optical properties of the smoke have been made. It should be noted that at the workshop, several American scientists cited new computations for estimating smoke emissions from non-urban fires developed by R.D. Small and B.W. Bush of the Pacific Sierra Corporation. The results of these computations showed that significantly smaller amounts of smoke-soot emissions (by a factor of $\geq$ 10) are likely to occur than had been previously assumed (Refs. 12, 66). There were no indications, however, that the Soviet scientists were taking these new estimates into account.

As to Soviet fire research and analysis, Moiseyev and his colleagues made no mention of any attempts to analyze the effects of the great forest and peat fires which had ravaged western Siberia during July - August 1915. These fires have been reported to have occurred in an area of some 1.8 million square kilometers, and to have destroyed up to 1.4×10^6 km^2 of timber and brush (Ref. 71). The resulting smoke is said to have covered an area of some 6.8 million square kilometers (Refs. 65, 66). According to observations carried out at that time, the smoke, which has been estimated by some to have been in the amount of 20-40 Tg (Ref. 31), reduced visibility in wide areas to less than 5-6 meters, and the average sunlight in August 1915 in Siberia by 35 percent (Ref. 65). This had a significant adverse effect on crop yields, but does not appear to have had an appreciable effect on average surface temperatures.

2.5 THE 1984 EDITION OF PEACE AND DISARMAMENT.

In the second half of 1984 appeared a book, Peace and Disarmament: Scientific Studies, edited by Academician P.N. Fedoseyev (Ref. 22). The book, consisting of a collection of papers by Soviet scientists, was prepared under the auspices of the Scientific Council for the Study of Problems of Peace and Disarmament, which in turn is sponsored by the USSR Academy of Sciences, the USSR State Committee for Science and Technology, and Soviet Committee for Defense of Peace. Among the contributors to the book were a number of prominent Soviet scientists, who discussed various aspects of the possible consequences of a nuclear war. As the title indicated, the primary purpose of the book was to make propaganda in which, according to the introductory article by candidate Politburo member Boris Ponomarev, scientists were called upon to play a very important role.

One of the contributed papers to the book was on the topic of "Nuclear War: Effects on the Atmosphere," authored by Academician A.M. Obukhov, director of the Institute for Atmospheric Physics of the USSR Academy of Sciences, and corresponding member of the USSR Academy of Sciences G.S. Golitsyn, a department head in the same institute (Ref. 56). For its initial scenario the article cited the 1982 Ambio study and the Crutzen-Birks paper in that same study and also the 1975 study on "Long-Term World-Wide Effects of Multiple Nuclear Detonations" by the U.S. National Academy of Sciences (NAS). The major portion of the article was devoted to the problem of the possible destruction of the ozone layer by nitrogen oxides. Citing the NAS study, the authors warned that a 10,000 MT exchange may, in principle, suffice to cause the total destruction of the ozone layer, but noted that further research was needed to precisely determine the effects of NO in the lower layers of the troposphere. In their discussion of the possible depletion of the ozone layer, the authors cited American studies on the effects of atmospheric nuclear tests in 1961-1962 and of the Tunguska meteorite fall in 1908. One may note that, unlike Kondratyev, the authors accepted uncritically the estimates of R.P. Turco et al. of the depletion of the ozone layer by the Tunguska meteorite explosion (Refs. 37, 74).

Obukhov and Golitsyn warned that Soviet theoretical and experimental research indicated that additional depletion of the ozone layer may result from the injection of large amounts of dust and other aerosols into the stratosphere, and that the absorption of sunlight by these aerosols may significantly slow the reconstitution of the depleted ozone. They also discussed the biological consequences of depletion of the ozone layer and the adverse effects of the possible increase in tropospheric ozone, which may cause a persistent smog poisonous to the ecology.

Finally, Obukhov and Golitsyn touched briefly on the effects of fires, again citing the Crutzen-Birks article in Ambio, and the possible effects of smoke, uncritically citing the findings of the TTAPS and Aleksandrov-Stenchikov computations. The authors, relying on their own studies of Martian dust storms, predicted a sharp increase of static stability of the atmosphere, the reduction of water vapor in it because of the heating of the smoke cloud, and raised the possibility of protracted droughts. At the same time, they called for further studies of the role of oceans and evaporation from them in the postulated scenarios, suggesting that most of the resulting atmosphere moisture may fall as rain over the oceans and would not be carried over land areas. According to the authors, more work was needed to refine "certain parameters of the atmosphere process and to develop models for quantitative calculations," which they said would be likely "to discover some new consequences which we do not as yet suspect."

2.6 THE 28–30 JANUARY 1985 US-USSR WORKING GROUP MEETING.

Although Moiseyev had mentioned at the Paris SCOPE-ENUWAR Workshop that efforts were underway to improve Soviet modeling of nuclear winter, in fact throughout the second half of 1984, he, Aleksandrov, and other Soviet scientists persisted in publicizing the Aleksandrov-Stenchikov model and its most dire projections of climatic effects (Refs. 5, 17, 23, 81). The publication in December 1984 by the U.S. National Research Council's long delayed report on "The Effects on the Atmosphere of a Major Nuclear Exchange" received scant public attention in the Soviet Union. No mention of it appeared in the main Soviet national newspaper. It was cited briefly, however, in the course of a Moscow Radio broadcast on 16 December 1984, which featured a roundtable discussion by a group of Soviet political commentators (Ref. 83). According to one participant who mentioned the NRC report, the study showed that a nuclear exchange of an unspecified magnitude would result in "a drop in temperature in most of the Northern Hemisphere of 18 or even 30 degrees centigrade." This would be the so-called nuclear winter, which really could lead to the destruction of all life on earth. This is also the view of American scientists and American politicians."

At a meeting of the U.S. and Soviet scientists, however, held in Boston on 28-30 January 1985 there were both signs of greater active interest in nuclear winter studies and of divergent views among Soviet scientists (Ref. 48). In this case the Soviet delegation included V. Boldyrev from the USSR Hydrometeorological Service, representing its director Yu. Izrael; V. Kapustin from the Institute of Atmospheric Physics of the USSR Academy of Sciences; Ye. Borisenko, head of the Main Geophysical Observatory in Leningrad; I. Karol of the Main Geophysical Observatory; and A. Velikhov of the Institute of Geography of the USSR Academy of Sciences. The discussion revealed uncertainty among Soviet scientists about who would be in direct charge of further research on nuclear winter and its potential effects in the Soviet Union, even while Velikhov was in overall control of it. There were speculations that it might be Dr. Ye. Izrael. The research program was held up by the failure of Velikhov to provide it with new funding. The Americans were told that field fire experiments were dormant. but that some work may be done on laboratory fire experiments. Low-level efforts were underway to measure the radiative properties, particle size distribution, and scavenging potential of nuclear winter related aerosols at the Institute of Atmospheric Physics. As one would expect, the Main Geophysical Observatory was still interested in the effect of NO and NO_2 on solar absorption. Karol called for more studies of the chemical modification of the troposphere following a nuclear exchange.

The conclusions of the American participants was that various Soviet scientists seemed to be interested in research in this general area but that funding for such work was uncertain, and that there was a certain amount of jockeying for position among senior scientists and institutions for being the national focus of and primary international contact for nuclear winter studies. Of particular interest was a comment by one Soviet scientist that in the opinion of Soviet military representatives at one of the institutes smaller exchange scenarios should be modeled to see if, as some scientists thought, they may only lead to regional climatic effects. This appeared to be a marked departure from the Soviet global conflict model and the line taken by Moiseyev and others, indeed from the standard Soviet public line, that any limited use of nuclear weapons was likely to generate a global nuclear winter.

2.7 ARTICLE BY GINZBURG, MARCH 1985.

The March 1985 issue of USA: Economics, Politics, Ideology, the monthly journal of the Institute for the Study of the USA and Canada of the USSR Academy of Sciences, contained an article "Nuclear Winter—A Real Threat to Mankind" by A.S. Ginzburg of the Institute for Atmospheric Physics of the USSR Academy of Sciences (Ref. 28). In 1983 Ginzburg had collaborated with Golitsyn in developing a crude model of nuclear winter (Ref. 32). Ginzburg's article offered nothing new. It provided a review of various past studies of the consequences of a nuclear war, in particular the 1982 Ambio study, the 1983 TTAPS, the Aleksandrov-Stenchikov and Obukhov-Golitsyn studies, and the 1984 study by Covey, Schneider, and Thompson in the United States. In his article, Ginzburg placed particular emphasis on the danger of a large depletion of the ozone layer and repeated the Obukhov-Golitsyn predictions of protracted drought on the continents. He also noted that the 1983 nuclear winter finds were followed by studies of their ecological consequences, and in 1984 by a study by Soviet scientists of the consequences of a nuclear war for the developing countries. The latter study claimed that although present scientific research could not fully assess the effects of nuclear winter and other nuclear effects on the ecosystem, what was already known sufficed to predict the "inevitable disappearance of tropical agriculture in Africa and also in countries of Asia and Latin America." In short, the paper predicted that a nuclear war would result in the death of the population of most developing countries. Ginzburg noted the difficulties in the modeling of large fires—yet he included his article claiming that the "parallel" studies conducted by American and Soviet scientists have "firmly determined the existence of global climatic consequences of a nuclear war." However, some American scientists, notably Dr. Edward Teller, were attempting to cast doubts on the conclusions reached about a nuclear winter effect. Ginzburg argued that claims of a rapid rain-out of the soot from the atmosphere were wrong because "along with the process of increased scavenging, there are processes in the atmosphere which accelerate the vertical and horizontal spread of the aerosols," especially in the presence of large amounts of smoke and soot in the atmosphere. Thus, while "work on the theory of 'nuclear winter' is not yet completed, even its opponents are forced to acknowledge that the possibility of the occurrence of a 'nuclear winter cannot be excluded."

Ginzburg noted that the U.S. Administration had been allegedly forced to allocate 50 million dollars to the study of nuclear winter over a period of five years. In this connection he cited the Goldanskiy-Kapitza's July 1984 Izvestiya article to the effect that such studies must be accompanied in the wide information of the public about the dire consequences of nuclear war be it limited or general.

2.8 THE KONDRATYEV ARTICLES IN SCIENCE IN THE USSR.

In the period March to June 1985, a two part article "Nuclear War, Atmosphere and Climate", appeared in issues No. 2 and 3 of Science in the USSR a journal primarily aimed at foreign audiences and published in several languages (Ref. 38). The article was jointly written by Academician K. Kondratyev, head of a laboratory of remote control measurements at the Institute of Lake Studies of the USSR Academy of Sciences, S. Baybakov, Director of the International Projects Center of the USSR State Committee for Science and Technology, and G. Nikolskiy, head of the Radiation Laboratory at the Physics Research Institute of Leningrad State University.

As Kondratyev had already indicated at the August 1984 meeting in Moscow, he and his colleagues had been analyzing data on the effects of the atmospheric nuclear tests in the period 1958 to 1962 on stratospheric ozone and climate. The data was said to have been obtained by means of high-altitude probes and observations from manned satellites. Thus, in their introduction to the first part of the article, the authors stated their basic conclusions, namely that

> A nuclear conflict can precipitate an ecological catastrophe and put an end to human civilization on this planet. That is the general conclusion drawn by experts who have analyzed atmospheric phenomena and changes in weather and climate over a period from 1958 to 1962, when there were frequent and extensive atmospheric nuclear weapon tests (Ref. 38).

Furthermore, it was claimed that "the authors offer a plethora of experimental data to support their conclusions." Essentially, this data was said to show that the atmospheric nuclear tests "produced an increase in infrared radiation in the thermosphere and further attenuation of incidental solar radiation in the stratosphere" as a result of injections of dust and oxides of nitrogen. According to the authors' computations, which took into account the warming effects of increased emissions of carbon dioxide following a nuclear exchange, the nuclear testing nonetheless produced a decline of .3°C in the average surface temperature of the Northern Hemisphere. They argued that analysis of temperatures in the Northern Hemisphere showed that the removal from the stratosphere and troposphere of the oxides of nitrogen and other aerosol produced by the nuclear tests, and the restoration of the resulting damage to the ozone layer, took many years. Extrapolating these findings to a 10,000 MT nuclear exchange scenario, the authors predicted "an unquestionable and very abrupt drop in the mean temperature approaching 9.5°K." In their projections, however, the authors largely drew their key assumptions from the U.S. National Academy of Sciences 1975 study of the long-term global consequence of a nuclear war, the 1982 Ambio scenario as well as the 1983 TTAPS study. As at the August Moscow Meeting, the main point of the paper was to add to other, largely American calculations of the climatic effects of a nuclear war, the effect of absorption of solar radiation by oxides of nitrogen in the stratosphere.

The second portion of the article was largely devoted to a critique of the 1982 assessments by Turco et al. of the effects, especially in the matter of release of oxides of nitrogen, of the Tunguska meteorite fall in Siberia in 1908 (Ref. 74). Kondratyev's studies of the effects of 1958-1962 atmospheric nuclear tests on the ozone layer were said to suggest that the American scientists had exaggerated the initial speed and energy release of the meteorite and the amount of the oxides of nitrogen generated by its explosion. It was claimed, therefore, that the explosion of the meteorite had not been equivalent to 6,000 MT (which generated 30 MT of oxides of nitrogen), as had been estimated by Turco et al., but to 300 MT. The Soviet authors claimed that these "errors" in the Americans' computations "have important political aspects" because they tended to reassure people about the consequences of a nuclear war and, consequently, must be rigorously countered. If the American computations had been correct, the Soviet authors insisted, the average temperature in the Northern Hemisphere should have declined by 5°C, which did not in fact occur.

Aside from this dispute with the American assessments of the effects of the Tunguska meteorite fall, the authors agreed that the evidence indicated the danger of detonating large-yield nuclear weapons at high altitude. Their finding, they claimed, could "influence the concepts of warfighting and the development of systems for protecting industrial centers and military installations."

While the article discussed in some detail the TTAPS and Aleksandrov-Stenchikov models and computations, it argued that they had paid insufficient attention to the "greenhouse" effects of the aerosols, especially CO_2, injected into the atmosphere in the course of a nuclear exchange. The article concluded by stating that while the existing models provide "firm conclusions about the inevitable global climatic collapse," it is essential to conduct further research which takes more "fully and reliably into account" all the factors which will affect the atmosphere and climate in the event of the detonation of a large number of nuclear weapons.

2.9 THE REVISED SOVIET SIMULATIONS.

As has been noted above, during 1983-1984 the Soviets failed to respond to Western criticism of the widely publicized Aleksandrov-Stenchikov "nuclear winter" model and to correct some of the more serious errors in their authors' computations. The necessary versions and corrections were finally made in 1985, largely as a result of the collaborative work of Stenchikov, from the CCAS and coauthor of the initial Soviet model, and P. Carl of the Central Institute for Electron Physics of the Academy of Sciences of the German Democratic Republic (GDR). The results appeared in two publications. The first was authored by Stenchikov alone in a chapter "Climatic Consequences of Nuclear War" in the book The Night After, edited by Velikhov, which also contained papers by other Soviet scientists (Ref. 79). The second was published jointly by Stenchikov and Carl as a manuscript or monograph Climatic Consequences of Nuclear War: Sensitivity Against Large-Scale Inhomogeneities in the Initial Atmospheric Pollutions in East Berlin (Ref. 68). Both were published in the second half of 1985. It should be noted that, unlike the second publication, the book The Night After was clearly intended to serve propaganda purposes. It is also noteworthy that apparently as a result of V. Aleksandrov's unexplained disappearance in Madrid on 31 March 1985, his name was deliberately omitted from all cited references and discussions in The Night After. However, his name did appear in the English text and citations of the Stenchikov-Carl study.

In his chapter in The Night After, Stenchikov devoted over half of its length (i.e. 19 pages of a total of 29 pages) to a review of the previous Computing Center model and its various computations. Only the latter third of the chapter was devoted to a summary of the sensitivity analysis of initial assumptions which were carried out jointly by Stenchikov and Carl and were treated in greater detail in their joint publication. The latter study included analysis of three key sensitivity test scenarios:

- A "belt-type injection" of smoke characterized by a constant mixing ratio and homogeneous distribution between 24°N and 72°N, a "washout" rate uniform with altitude.
- A "continental injection" scenario in which the oceans are excluded.
- A "lower layer injection" scenario, in which the smoke remains below the highest elevations and "washout" varies with the level of precipitation over 4 to 15 days.

The significant changes in these simulations from earlier ones were first of all a narrower initial latitudinal spread of aerosol. The Aleksandrov-Stenchikov model had assumed an initial uniform spread of smoke north of 12°N. Second, the smoke starts in the lower layer of the atmosphere. Third, the model allowed for various rates of "washout," i.e., scavenging. Fourth, the initial mean absorption optical depth was reduced in the new study from 7 in the earlier model to 2.2. This reduction, based on corrected application of optical properties, significantly mitigated the calculated temperature declines, bringing them more in line with those developed in more recent western studies. This reduction in initial absorption optical depth, based on correct application of optical properties of smoke and soot, significantly reduced the duration of temperature declines below ambient levels and also contributed to the mitigation of the calculated maximum average surface temperature decline in the Northern Hemisphere. The most significant difference, however, between the earlier Aleksandrov-Stenchikov and the TTAPS simulations and the new Stenchikov-Carl simulation was the lower level of initial pollution of the upper troposphere and the more rapid washout of pollutants.

The sensitivity tests showed that the "characteristic time" for the horizontal transport of smoke in the Northern Hemisphere took as long as had been projected in earlier Soviet simulations, i.e., approximately two weeks. However, aerosol transport to the Southern Hemisphere was significantly slower than in the earlier model, i.e., on the order of one to two months to be completed. In the matter of the vertical spread of smoke and soot, Stenchikov-Carl focused primarily on the scenario in which only the lower layer of the troposphere is assumed to be initially polluted and subjected to washout, with part of the pollutants then progressively rising to the upper troposphere as a result of solar heating. In this case, the calculated average maximum surface temperature decline over land in the Northern Hemisphere in the first 20 days was 8°-9°C, with temperature beginning to rise after that and returning to normal ambient levels after some 50 days following the exchange. In a scenario where some earlier injection of smoke into the upper troposphere is assumed, the calculated average maximum surface temperature decline in the Northern Hemisphere in the first 20 days is 10°C, and a return to ambient temperature levels was projected to occur in approximately 70 days from the exchange. The latter projection was closer to the earlier Aleksandrov 100 MT city-only attack simulation, which assumed an initial absorption optical depth of 3 and a return to ambient temperatures in some 90 days. However, in the earlier Aleksandrov-Stenchikov simulation, the average maximum surface temperature decline in the first 20 days in the Northern Hemisphere for both the 10,000 MT exchange and the 100 MT city-only exchange scenarios had been 15°C, and in the case of the 10,000 MT exchange, return to ambient temperatures was calculated to require approximately one year. With less soot loading of the upper troposphere in the new computation, there were also significantly less severe geographic variations of maximum declines of surface temperatures than in earlier Soviet simulations. Thus, in the new simulation projected temperature declines in most geographic regions of the Northern Hemisphere for the first 40 days were 10°C to 20°C less severe than in the 1983 Aleksandrov-Stenchikov model. The same was also generally true for the Southern Hemisphere. Even so, given the large amounts of smoke postulated in the Soviet scenarios, the new computation still projected large maximum temperature declines in the first 40 days (20°C to 40°C) over central North America, Eastern Europe, Scandinavia and Siberia. Of course, given the coarseness of the horizontal geographic gird in both the Aleksandrov-Stenchikov and the Stenchikov-Carl simulations (12° latitude by 15° longitude), the projected temperature contour lines were of dubious accuracy and value. Stenchikov still concluded that "the evidence suggested that even assuming a lower level of initial pollution of the upper troposphere and intensive aerosol washout, the extent of Northern Hemisphere cooling is sufficient to trigger dire ecological consequences" (Ref. 79).

In essence, the revised simulations did not bring any significant "independent" innovations to the study of nuclear winter. Rather they provided some necessary corrections of the Aleksandrov-Stenchikov computations, which were clearly out of line with the ongoing Western simulations and computations of the phenomena. Not surprisingly, when Stenchikov-Carl used a soot loading of the upper troposphere and washout rates comparable to those used in American models, the simulation became reasonably consistent with the latter. The Stenchikov-Carl computations developed no new war scenarios, nor any "independent" inputs to key parameters of smoke, soot and other aerosols. As a practical matter, the revised Soviet computations were soon made obsolete by new models and computations carried out by American scientists such as MacCracken at LLNL and Thompson and Schneider at NCAR.

2.10 SOME SOVIET SCIENTISTS' COMMENTARIES, OCTOBER 1985 - JUNE 1986.

It appears that at least up to mid-1986 the Stenchikov-Carl revised model and computations was the last Soviet attempt to model the climatic effects of injection of large amounts of smoke and soot into the atmosphere. It is interesting to note that the results of the Stenchikov-Carl simulations were subsequently largely ignored in public statements by Soviet scientists on nuclear winter effects, including those by Moiseyev, who is Stenchikov's superior.

In October 1985 Professor S. Kapitza published an article "A Soviet View of Nuclear Winter" in the Bulletin of the Atomic Scientists (Ref. 36). In it he argued for "worst case" analysis and projections of the risks of a nuclear winter. He cited the TTAPS study and the 1815 eruption of the Tambora volcano in Indonesia, to which he attributed the cholera epidemic in India and Persia which began in 1815. Kapitza warned that "we will face global climatic change, and there will be no safe haven on our small planet" and reminded of the extinction of the dinosaurs, 65 million years ago as a result of the presumed impact of a giant meteorite on the earth's surface. All this led Kapitza to engage in a polemic against SDI and further nuclear arms buildup.

In November 1985, Moiseyev spoke to some unidentified newsmen about the Computing Center's work on modeling and "predicting" the consequences of a nuclear war (Ref. 51). The interview was reported by TASS in English and does not appear to have been cited in the Soviet press. According to Moiseyev:

> . . . a nuclear conflict will bring about a global night that would last for about one year. Hundreds of millions tons of dust kicked into the atmosphere, the smoke and soot resulting from numerous fires will make the atmosphere impenetrable to sunlight. In the first weeks average temperatures in the Northern Hemisphere will drop 15-20 degrees (Centigrade) and in some places 30-40 degrees. The cold wave will effect southern regions as well . . . . The upper layer of the atmosphere will absorb much more solar energy and will be heated to a temperature of about 100 degrees (C), while sub-freezing temperatures will be registered near the earth's surface. Attacks on main cities of Europe, Asia and America with a total yield of 100 to 150 megatons will generate such an amount of soot that it will bring about a "nuclear winter" lasting for months on end.

Moiseyev went on to claim that Soviet and American scientists "working independently of one another, using different models and methodologies have arrived at a common understanding of the consequences of a nuclear war." Moiseyev made no mention of the Stenchikov-Carl computation, preferring instead to cite the earlier Soviet predictions of more severe average surface temperature declines.

In another interview published in a December 1985 issue of the Soviet newspaper Literary Gazette (Ref. 52) Moiseyev again predicted that the smoke and soot injected by nuclear detonations into the atmosphere would leave the global population suffering from "severe cold, twilight or total darkness, lack of water, food, fuel, under conditions of powerful radiation and pollutants, sickness, and extreme psychological stress." Because of the temperature differentials between the ocean and landmasses, the coastal areas will be subjected to fierce hurricanes and "gigantic" snowfalls, which will render them uninhabitable. In addition there would be a sharp increase in ultraviolet radiation and persistent clouds of toxic gases. Even in the case of a relatively small 5,000 MT exchange scenario, said Moiseyev, there will be continuous night for a year over the "battle field". Moiseyev also noted that while American scientists with their advanced computers were only able to simulate the effects of smoke and soot for a three-month period, the CCAS model did so for an entire year. In the same interview Moiseyev spoke of the disappearance of V. Aleksandrov, who, he said, was "irreplaceable" and suggested that he may have been "removed" by unnamed, but presumably Western, agencies because of his activities in bringing the consequences of a nuclear winter to the attention of the world's public.

In January 1986, Academician K. Ya. Kondratyev was reported to have given an interview to a TASS correspondent (Ref. 46). The interview also appears to have been publicized by TASS only in English and aimed at foreign audiences. In its somewhat garbled account, TASS reported Kondratyev as claiming that no serious researcher now doubts that a nuclear winter would follow a nuclear exchange. The mass urban and forest fires will release so much carbon particulate that the Northern Hemisphere will be plunged into darkness. According to Kondratyev, dark carbon aerosol will settle on the leaves of plants and crops and prevent sunlight from reaching them. At the same time, however, Kondratyev was said to claim that carbon aerosol will "sharply" enhance the greenhouse effect and, consequently, that "the heat from explosions and fires will lead to the onset of a 'nuclear summer' " in the regions subjected to nuclear strikes. Thus, according to Kondratyev, "in areas of concentration of products of nuclear explosions it will become warmer, while in the neighboring territories the temperature will drop." The sharp changes from warm to cold air masses would result in a global ecological catastrophe, in which "everything living on earth will perish."

Kondratyev's "nuclear summer" hypothesis appears to have been unique in Soviet discussions of climatic effects of nuclear war. It remained outside of the main stream of Soviet public scientific discussion of nuclear winter, and indeed, appeared to contradict Soviet models of nuclear winter.

Later in January 1986 Velikhov published an article in Literary Gazette, according to which the soot and ashes generated by vast fires following a nuclear exchange would result in the "so-called nuclear night" and, again citing the 1983 computation, would cause surface temperatures in the Northern Hemisphere to decline in the course of a few days by approximately 30-50°C, leading to a global climatic catastrophe (Ref. 80). Once again, in his article Velikhov chose to ignore the revised computations by Stenchikov and Carl, presumably, because from a propaganda standpoint on nuclear winter the latter were less extreme.

In February 1986, TASS announced in an English language release that according to Moiseyev, new computations carried out at the CCAS showed that a nuclear winter may set in as a result of the "use of conventional weapons whose capabilities are constantly increasing." According to TASS there findings were to be published in a forthcoming issue of the journal New Times. However, no such article was published.

At the All-Union Conference of Scientists on Problems of Peace and Prevention of Nuclear War held in Moscow during 27-29 May 1986, Golitsyn and Ginzburg gave a paper reexamining some of the large historic forest fires, including the 1915 Siberian forest fire, which they claimed had burned an area a factor of ten smaller than had been reported on the basis of data collected at that time (Ref. 31). They also recognized that the smoke generated by massive forest fires, while it could cover very large areas, did not have the same properties as smoke and soot from urban fires. In past Soviet publications, however, the Soviets often cited the 1×10^6 Km^2 forest fires projected by Crutzen and Birks as one of the factors causing a nuclear winter. There is no indication that the Golitsyn-Ginzburg work in this subject made any useful input to the study of nuclear winter.

Finally, an article in the June 1986 issue of New Times by L. Feoktiskov once again referred to the modeling carried out at the CCAS, from which he predicted "truly catastrophic climatic consequences" for a nuclear war as a result of the "heavy pollution of the atmosphere" (Ref. 24). Citing the CCAS computations, Feoktiskov wrote that "within 40 days of a nuclear conflict average air temperature in certain regions of the Northern Hemisphere will have dropped by tens of degrees (Centigrade); 'nuclear winter' will have set in."

2.11 SOME GENERAL OBSERVATIONS ON SOVIET RESEARCH ON CLIMATIC EFFECTS OF NUCLEAR WAR.

From 1983 to 1986 Soviet work on modeling global atmospheric circulation and the effects on climate of injection into the atmosphere of large amounts of smoke, soot, and other aerosol from mass fires was carried out in the Computing Center of the USSR Academy of Sciences. The Center had instituted a program of climate modeling in the 1970's to simulate small-scale changes of climate brought about by anthropogenic effects on the climate and to evaluate their ecological and economic implications (Ref. 79). Whether for purely scientific or political reasons or both, the publications of the 1982 article by Crutzen and Birks in Ambio and the early Soviet access to the TTAPS study results are acknowledged to have stimulated an attempt to apply the scenarios and key assumptions about smoke and dust to these CCAS models of atmospheric general circulations. The publication of the Aleksandrov-Stenchikov simulation results in 1983 led to Soviet claims of have "independently" of and in parallel with American modeling "confirmed" the existence of a nuclear winter effect and its dire consequences.

The Soviet work in 1983-1984 can be credited with some original contributions: first, the use of a crude three-dimensional model; second, an early attempt to incorporate moving smoke calculations; and third, calculations allowing for some changes in ocean temperatures. These legitimate Soviet credits, however, do not support Soviet claims of "independent" confirmation of the nuclear winter effect. Aside from the crudeness of the Soviet model, the Soviets then and subsequently used war scenarios, projections of sizes of fires, and the key parameters of smoke and dust injections exclusively from the Crutzen-Birks and TTAPS studies. Furthermore, the Soviet model suffered from the major error of greatly exaggerating the absorption optical depth of smoke-soot cloud, which led to projections of exceedingly large temperature decreases. One can surmise that the failure of the Soviets to correct their error in their publication until 1985, and, after the correction was made, the tendency of Soviet science spokesmen to fail to take these corrections into account in their public statements, was motivated by political and propaganda considerations. From the latter viewpoint the advantages of publicizing, especially in the West, "worst case" projections of nuclear winter effects in support of the Soviet anti-nuclear, peace and disarmament campaign are obvious and, in fact, are admitted by Soviet science spokesmen (Ref. 36). In this light, it would appear possible that the corrections introduced by Stenchikov and Carl may have been made more for the purpose of maintaining the Computing Center's credibility in the international nuclear winter study effort than for reasons of scientific objectivity.

Soviet scientists have acknowledged both in public and especially in private meetings that the modeling of nuclear winter was fraught with many uncertainties and that more research was needed on a wide number of questions, including on the more likely amounts of aerosol injected into the atmosphere. Yet in their public statements Moiseyev and other senior Soviet scientists have also argued that the nuclear winter effect was "firmly" determined and that further research could be expected to refine, but not fundamentally alter, the more extreme predictions of its consequences. Indeed, the Soviets have publicly denounced Western scientists who questioned these predictions and the models' initial assumptions for allegedly trying to mislead the public, i.e., western public, into believing that a nuclear war could be survivable.

It is interesting to note that Soviet publications in this period have continued to place considerable emphasis on the problem of the depletion of the ozone layer as a result of a nuclear exchange. Indeed, various Soviet scientists predicted a possible depletion of stratospheric ozone by 70 to 90 percent. Again it is not clear whether this reflected a serious Soviet concern or was merely for propaganda effect.

So far, Soviet scientists have made no contribution to the modeling of large fires and fire experiments. The former has been said to be too difficult to do and the latter to be economically too costly. However, the discounting of a significant effect on climate from non-urban fires in current Western models and calculations appears to have stimulated some Soviet scientists to try to challenge these Western conclusions. Again, the reasons for this challenge may reflect more of a Soviet propaganda interest in preserving a "worst case" image of the consequences of a nuclear war than a serious scientific difference of views.

Not surprisingly, the tendency in Western and even Soviet (i.e. Stenchikov-Carl) modeling of nuclear winter to arrive at predictions of significantly milder climatic effects from the injection of smoke and soot into the atmosphere has enhanced Soviet interest in the environmental and especially biological effects of the perturbation of the post-attack atmosphere.

SECTION 3
SOVIET RESEARCH ON THE CLIMATIC-ATMOSPHERIC EFFECTS OF NUCLEAR WAR ON THE ENVIRONMENT AND ECOLOGY

Soviet scientific publications have sought to deal with all aspects of the consequences of a nuclear war. A considerable portion of these publications has dealt with the medical-biological effects of a nuclear exchange (Refs. 2, 6, 15, 32). Some others have addressed questions of the effects on climate and of aerosol injections into the atmosphere on the environment and ecology. Not surprisingly, the latter studies have suffered from the same "worst case" assumptions and the same dependence on Western war scenarios as have Soviet studies of climatic effects.

3.1 THE SVIREZHEV MODEL.

In 1984 the Computing Center of the USSR Academy of Sciences attempted to model and analyze the ecological and demographic consequences of a nuclear war. The principal author of this effort was Yu.M. Svirezhev, assisted by other staff members of the CCAS. The presentation of Svirezhev's findings appears to have occurred in three stages. First, a brief paper was presented at the SCOPE-ENUWAR Workshop held in Leningrad in May 1984 and then circulated to the SCOPE-ENUWAR Workshop held in Paris in September 1984. Second, a more elaborate paper was presented by him at the SCOPE-ENUWAR Workshop held in Toronto, Canada, in early 1985, and then, after being sponsored by Dr. Mark Harwell of Cornell University, was made an official input to the SCOPE-ENUWAR Workshop held in June 1985 in Essex, England. Apparently Svirezhev had hoped that his study would be included in and make up a major part of the final SCOPE report on the ecological and agricultural consequences of a nuclear war. However, there was so much criticism of it by Western scientists that the SCOPE committee decided that the paper deserved at best only minor consideration. Despite the criticism, the CCAS went ahead and published this paper in unaltered form, which Svirezhev then undertook to distribute at the SCOPE-ENUWAR Congress in Washington in September 1985.

The first paper circulated in 1984, "Ecological Consequences of a Nuclear War," stated that the authors' analysis of the possible ecological consequences of a nuclear war was based on the 1982 Ambio scenario and also on the climatic effects computations of the 1983 Aleksandrov-Stenchikov simulation of a 10,000 MT exchange, which had been derived from the TTAPS study (Ref. 70). Furthermore, the data on territories directly affected by the nuclear exchange were taken from the Ambio scenario, as were data on radiation levels on land surfaces and the amount of NO_x released by the nuclear detonations. Data on the radiosensitivity of plant seeds, plants and animals were taken from the 1983 article in Science by R.P. Ehrlich, J. Harte and M.N. Harwell, as were also projections of changes in UV radiation and the sensitivity of plants to them. The Soviet contribution to this basic data consisted of estimates of the amounts of nitrogen and sulphur oxides formed as a consequence of wild fires and were "calculated according to their amount in vegetation" (Ref. 43).

Essentially, the first paper provided a brief overview of the various factors which could be expected to degrade the ecological systems after a nuclear exchange, i.e., initial ionizing radiation doses, fires, nuclear winter, long-term radioactive contamination of soil and water, acid rain, and increase in UV radiation. The paper simply cited the Aleksandrov-Stenchikov estimates of temperature declines of "15^o to 50^{o}C," which "will cause the freezing of vegetation in vast areas" and the "death of many animal populations." In the matter of UV radiation "after the nuclear winter," the authors assumed a fourfold increase due to the partial destruction of the ozone layer, which would result in the "partial or total inhibition of photosynthesis for 2-3 years," some suppression of the immune system of animals, and the "deterioration of the reparation process in bacteria and the suppression of the bacterial flora in the upper soil layer." All this would also prevent the reconstitution of agriculture. The authors noted, however, that the severity of the effects of nuclear winter would depend on the season of the year when the nuclear conflict takes place.

The 1985 English language version of Svirezhev, et al. Ecological And Demographic Consequences of Nuclear War offered an extensive elaboration of their 1984 paper. (The later version is 267 pages long.) (Ref. 71). The model used was initially designed to describe the ecological, climatic, and demographic processes on earth in order to analyze "possible paths of the coevolution of human utilization and the biosphere" (Ref. 43). The authors, however, attempted to adapt it to modeling the ecological and demographic consequences of a nuclear war. In so doing, they cite three difficulties: the first is the difficulty of determining the environment after a nuclear conflict, i.e., its direct effect on nature, demography, and economic potentials. The second is the fact that little is known about the ability of the ecology to renew itself after a war. The third is the uncertainty about the social-economic situation after the war. According to the authors, while the possibility of extinction of mankind is high, the possibility of survival of old social institutions or the emergence of new ones cannot be ruled out.

For their scenario Svirezhev, et al. used the 1982 Ambio scenario, which postulated a nuclear exchange with a yield of 5,742 MT with strikes on 14,744 targets, of which 5,569 MT were detonated in the Northern Hemisphere and 173 MT in the Southern Hemisphere (Ref. 57). For their model, however, they delineated three basic regions: the USSR, Europe, and North America, and simply assumed that 1,800 MT of nuclear yield would be detonated in each of them. In dealing with non-urban fires, the authors assumed two sizes of total area burned directly after the war: (a) $1 \times 10^6 km^2$, first estimated by Crutzen and Birks, and (b) $4 \times 10^6 km^2$, based on the dubious assumptions that given that 35 percent of the three basic regions is forested, the number of targets in forested territories would be 4,853 (prorated from the Ambio scenario) and that a strike on each of these targets may ignite widespread fires, burning in each instance an area of 450 km^2. This was far in excess of fires assumed in the TTAPS study or in any later Western studies. According to Svirezhev, the fires would emit large amounts of various aerosol: smoke, carbon soot, CO, CO_2, nitrogen, and SO_2. By his estimate, the combined non-urban and urban fires would inject 10^{10} tons of carbon; also, for forest and urban fires, respectively, 10^8 tons and 7×10^8 tons of nitrogen and 1.3×10^7 tons and 3×10^8 tons of sulfur. The average solar radiation reading on the earth's surface during the summer at noon was projected to decrease by a factor of 150 as a "maximum estimate."

Svirezhev's assessment of the effects of nuclear winter was said to be based on the temperature and illumination calculations of the 1983 Aleksandrov-Stenchikov study, while the transport estimates of smoke to the Northern Hemisphere were based on the 1985 Stenchikov-Carl work. Thus, the scenario assumed a 10,000 MT exchange and predicted an initial average temperature decline of 15°C-20°C in the Northern Hemisphere and of 5-8°C in the "long term" in the middle latitudes of the Southern Hemisphere. However, according to Svirezhev, in a 10,000 MT exchange scenario "in a month the temperature in the tropics would fall to 0°C." Obviously this would lead to the predictable death of all vegetation sensitive to chilling damage. Svirezhev predicted, therefore, that a war in July would result in the death of all vegetation in the Northern Hemisphere and the partial dying out of vegetation in the Southern Hemisphere. Indeed, a world map in the study showed 100 percent destruction of vegetation north of the equator, 50 percent in the Central African and Amazon Basin region below the equator, with survival being largely confined to Australia, South Africa and the southern portions of Latin America. Furthermore, according to Svirezhev, the decay of this dead organic matter would result in large emissions of CO_2, which would seriously disturb the global cycle of carbon. Despite the predicted severity of temperature declines, Svirezhev assumed that many plant seeds would survive.

Another consequence of mass fires, predicted by Svirezhev, would be an increase of acid rain and the contamination of the soil by highly toxic elements such as mercury, lead, cadmium, arsenic, selenium, and zinc. In his computations, Svirezhev assumed the amount of "burned substances at 10^{10} tons" and considered the concentration of heavy metals and of nitrogen and sulfur for these substances to be the same as for coal, rather than wood. He concluded that the nuclear-generated fires would emit huge quantities of pollutants, including 12 times the current annual emissions of copper; 7 times the annual emissions of lead; and 3 times the annual emissions of mercury, arsenic, cadmium and zinc, as well as 6-10 times the annual emissions of oxides of nitrogen and sulfur.

In the matter of increase of UV radiation, the study assumed that "all nitrogen formed as a result of 'nuclear' fires would be emitted into the stratosphere in the form of oxides," or a total of 7×10^8 tons of NO_x, which, however, the authors elsewhere in the paper also assumed was used in producing "acid rain." There could be, therefore, up to a 21-times increase in UV radiation. One year after the nuclear exchange, the UV radiation was predicted to be 3 times the pre-war level.

In assessing the possible effect of the fire-generated injection of CO_2 after the burning of 20 percent of the forests in the Northern Hemisphere, the study projected an increase of 15 percent of CO_2 in the atmosphere "almost instantaneously." However, in five years after nuclear winter the burned areas would be overgrown with grass and shrubs, and in three years the process of decomposition of dead organic matter would be "completely restored." According to the computations, assuming only a 3 percent increase in CO_2 from fires, but with further additions due to the decay of dead organic matter, a greenhouse effect would occur which in 30 years would raise average temperatures by 1.3^{o}C, with a return to "normal" levels requiring "at least 100-150 years." Furthermore, the destruction of the forest ecology would make the climate less stable. Although Svirezhev anticipated progressive renewal of at least a portion of the ecology over many postwar years, this renewal would result in profound changes in the character of the ecology. As for agriculture, the study predicted its devastation for many years, which in turn would have a devastating effect on the world's demography. In addition, a major portion of the study dealt with the radiation effects on the ecology and also arrived at "worst case" projections of their consequences.

There is no doubt that the study's use of the Ambio scenario and fire predictions and of the results of the Aleksandrov-Stenchikov computations inevitably greatly biased the results, as did Svirezhev's "worst case" assumptions about the amounts of emissions of various aerosol. The calculated CO concentration in the atmosphere assumed that all fire-generated CO would be trapped in the lowest strata of the atmosphere over a city rather than be dispersed by the fire and winds, thus leading to Svirezhev's prediction of lethal levels of CO concentrations in targeted urban areas. Svirezhev also assumed the destruction of a major portion of the ozone layer and excessively high estimates of injection of heavy metal elements. The Svirezhev study's obvious preference for "worst case" analysis again raises the question to what extent the modeling and computations produced by the CCAS may have been deliberately biased to satisfy Soviet propaganda requirements.

3.2 THE 1985 PAPER BY YU. IZRAEL

Included in the book The Night After was a paper on "Changes in the Atmosphere Due to a Nuclear War" by Yu. Izrael, director of the Laboratory for Monitoring of

Climate and Natural Environment of the USSR Academy of Sciences, chairman of the USSR State Committee for Hydrometeorology and Control of the Natural Environment, and a corresponding member of the USSR Academy of Sciences (Ref. 35). Izrael is an internationally known and respected scientist.

In his paper, Izrael used a 5,000 MT exchange scenario—that is, the TTAPS baseline scenario—and assumed that half of this yield would be used in surface bursts. On the basis of this scenario, Izrael predicted a number of long-term effects which would result in "serious geophysical and ecological consequences," including pollution by radionuclides and the generation of large amounts of aerosol particles and gases by the nuclear explosions and resulting fires. Citing the TTAPS study, Izrael assumed that the nuclear detonations will inject a total of 960 Tg of materials into the atmosphere, 80 percent of which will go into the stratosphere. The amount of submicron particles in the stratosphere is estimated at 80 MT (Tg) for the scenario, as it was also by TTAPS. As to fires, the paper assumed that 1.9 g/cm^2 of combustible materials would burn in the urban areas and 0.5 g/cm^2 over a territory of $5x10^5$ km^2 in forests. Thus, the total amount of smoke generated was the same as in the TTAPS case. The initial absorption optical depth was said to be 4.0, of which 1.0 is for stratospheric dust. However, the optical depth cited by TTAPS pertaining to dust was for scattering and not for absorption. The resulting temperature declines were the same as those projected for the baseline case in the TTAPS study.

From this, Izrael went to discuss the increase of tropospheric ozone and CO and the possible depletion of the ozone layer by 30 to 70 percent. None of his computations and projections appeared to be new. Rather, they relied on earlier work, including some by Izrael himself. The article ends with a table of the short- and long-term ecological consequences of nuclear war. According to it, the short-term consequences include:

- Changes in precipitation because of "smudging" and changes in the electrical properties of the atmosphere.
- Rapid cooling of surface air temperatures.
- Atmospheric "smudging" and turbidity which would suppress photosynthesis in plants and slow bioproductivity.

The long-term consequences would include:

- The subsequent warming of the atmosphere would increase aridity and reduce bioproductivity.
- Increase in hard UV radiation flux.
- Mass elimination of plant and animal species would reduce genetic and species diversity.

Izrael, however, did not predict the inevitable extinction of mankind.

3.3 SOME OBSERVATIONS.

The Soviet publications discussed above by no means cover all Soviet publications on the ecological and biological consequences of a nuclear war. This issue is discussed in various publications and papers, including Soviet inputs to the SCOPE-ENUWAR study on these effects. For example, in 1984 a team of Soviet scientists submitted a paper on "Lake Ecosystem Simulation Extreme Forcing" at the SCOPE-ENUWAR Workshop (Ref. 58). In their model, the authors used the variations of temperature and illumination from the 1983 Aleksandrov-Stenchikov study as external forcing parameters affecting lake ecosystems, while their assumed ionizing radiation levels were derived from the Ambio and TTAPS baseline scenarios. Some other Soviet scientists were also credited with having made contributions to the preparation of the second volume of the SCOPE study on Environmental Consequences of Nuclear Winter (Ref. 34). On the whole, however, their contributions appear to have been few and mostly of a marginal character, and dealt more with questions of the sensitivity of and effects on the ecosystem to ionizing radiation than with the consequences of a nuclear winter. The latter is also generally true for Soviet scientific writings on the ecological consequences of nuclear war. A good deal has also been published in Soviet literature about the global economic consequences of a nuclear war on the world economy and agriculture, the main point being that all countries, whether belligerents or neutrals, will greatly suffer from such a war and, therefore, should support the Soviet peace and disarmament programs (Refs. 10, 27, 33, 77).

SECTION 4
SOVIET DISSEMINATION AND PROPAGANDA USES OF THE NUCLEAR WINTER ISSUE

As one would expect, the extent and content of disseminated information on the nuclear winter issue by the Soviets depended on what audiences were being targeted. Domestic Soviet audiences included the scientific community and the general public. Similar audiences were also targeted abroad, with particular attention to the elements of the so-called antinuclear peace movement.

4.1 THE SOVIET SCIENTIFIC COMMUNITY.

One can assume that the Soviet scientific community generally had access to published Western materials on the nuclear winter issue and that at least a part of it had access to papers on this subject circulated at various U.S.-Soviet and international conferences and meetings. Soviet scientists also had representatives in the various SCOPE-ENUWAR committees and workshops dealing with various aspects of the consequences of nuclear war. It is interesting to note, therefore, that on the whole Soviet scientific publications on the nuclear winter issue made little use of Western work on this subject generated after mid-1984, generally preferring to continue to base their calculations on the 1982 Ambio and 1983 TTAPS and Aleksandrov-Stenchikov studies. One of the exceptions to this was the 1985 Stenchikov-Carl study, which revised the earlier Aleksandrov-Stenchikov computations but, as has been noted above, was largely ignored in other Soviet publications and public statements by Soviet science spokesmen.

The 1983 Aleksandrov-Stenchikov study, On the Modelling of the Climatic Consequences of the Nuclear War, was published in English and usually continued thereafter to be widely cited by its English title in Soviet writings on nuclear winter. As was noted, however, a Russian language version of it was eventually published in early 1984 (Ref. 8). A report in Russian on the discussions of the TTAPS study in October-November 1983 was published a year later in the Herald of the USSR Academy of Sciences by Aleksandrov and Moiseyev (Ref. 7). However, neither the

TTAPS report nor the 1984-1985 report of the U.S. National Research Council on The Effects on the Atmosphere of a Major Nuclear Exchange appear to have been translated into Russian. During 1984-1985, a number of scientific papers on nuclear winter in the Russian language were published by the Computing Center (Refs. 18, 69) and in publications of the USSR Academy of Sciences (Ref. 39). None of them, however, made any significant new additions to the study of nuclear winter.

As in the 1983-1984 period (Ref. 32), so during the 1984-1985 period there were no public indications that the apparent endorsement of the "worst case" nuclear winter hypothesis by Soviet scientists had any effect on the Soviet civil defense program or Soviet military strategy and targeting concepts. Both the Soviet civil defense and military literature simply continued to ignore the whole nuclear winter issue.

4.2 THE SOVIET PUBLIC.

On a number of occasions when addressing Western audiences, Soviet spokesmen have claimed that, just as its counterpart in the West, the Soviet public was being fully informed about the dangers of nuclear winter. Actually this was not the case. Far more of such information by the Soviets was aimed at foreign audiences than released to the public at home (Ref. 32). Nevertheless, a certain amount of such information did appear in the Soviet mass media, although irregularly and never in such detail and extent as it was discussed in the Western mass media. To the extent that it was publicly discussed in the Soviet Union, descriptions of nuclear winter tended to follow the general Soviet line of predicting very dire consequences. For example, according to a brief account in Pravda of the 1983 Washington Conference on "The World After Nuclear War,"

> The screen showed our planet, towards which a dark cloud was advancing, spreading over its entire surface. Diagrams showed how far the dust raised by a nuclear blast will cover the sky, blocking the sun's rays. Charts showed a sharp drop in the temperature on the Earth's surface and a steep increase in the level of radiation. The reports' language was precise, their conclusions were terrible. Those who do not die in the first minutes of a "nuclear exchange" can expect no better fate (Ref. 76).

After Senators Kennedy and Hatfield sponsored the "Joint American-Soviet Scientific Forum" in December 1983, Izvestiya spoke of the "catastrophic ecological consequences" of a nuclear war, which would "create a deadly threat to mankind," and stressed the "identity of opinions" of the American and Soviet participants on questions relating to the prevention of a nuclear war (Ref. 41).

Later Soviet domestic treatment of international conferences on nuclear winter and other consequences of a nuclear war, however, tended to be more infrequent and very sketchy, especially in comparison to the treatment of these issues in Soviet broadcasts addressed to foreign audiences. For example, the May 1984 Leningrad SCOPE-ENUWAR Workshop received extensive and detailed treatment in English language releases by the Soviet news agency TASS, particularly focused on the presentations by Crutzen and Aleksandrov (Refs. 32, 53). However, no mention of the meeting appeared in Pravda or Izvestiya. In connection with this meeting, the Moscow Radio domestic service only broadcast a brief interview with Moiseyev, in which he said:

> No matter where nuclear war starts and regardless of whether there is a retaliatory strike or not, the question of the possibility of mankind's existence on earth will clearly be unequivocally disposed of. This is the conclusion reached by scientists from different countries who made independent studies of the problem (Ref. 54).

Moiseyev argued that these scientific conclusions were bound to progressively influence the political situation.

The most extensive discussions of the nuclear winter issue in the Soviet mass media occurred in July and August of 1984. In July, Izvestiya published a lengthy article, "To Prevent a Catastrophe," by Academician V. Goldanskiy and Professor S. Kapitza (Ref. 29), and in August, Moiseyev published a discussion of nuclear winter effects in the newspaper Soviet Kirgizia, which, however, is not widely read outside of that Soviet republic (Ref. 49).

Following this, there appears to have been a decline in the public discussion of nuclear winter in the Soviet media during the rest of 1984. Possibly the reason for this was a growing concern that while it was all well and good for Soviet scientists and spokesmen "to bring the truth" about the consequences of a nuclear war to the attention of the world's public, too much of this at home risked to "morally disarm our people before the aggressor" and "contribute to panic" (Ref. 16). Thus, the international meeting in Bellagio, Italy, in November 1984 received mere mention in the Soviet press, with the comment that "recent scientific investigations demonstrate cogently that nuclear war could trigger uncontrollable climatic and other environmental changes over huge regions of the earth" (Ref. 61). In December, a lengthy article in Izvestiya criticizing SDI noted in passing that no defensive system could prevent "irreversible global consequences" in the event of the use of nuclear weapons (Ref. 20). There was also a brief reference to a nuclear winter effect by Moscow Radio on 16 December 1984 (Ref. 81).

As far as Soviet book publications in 1984 were concerned, the climatic effects of a nuclear war received mixed treatment. As was noted, the 1984 edition of Peace and Disarmament included a chapter by Academicians Oberkhov and Golitsyn, "Nuclear War: Effects on the Atmosphere" (Ref. 56). However, in another Soviet book, Scientists Against War, also published in 1984 for popular reading, none of the contributing scientists mentioned nuclear winter (Ref. 1). The same was true of the book, Ecological Consequences of the Arms Race, which included a discussion of the consequences of a nuclear war (Ref. 77).

During 1985-1986 the issue of the climatic consequences of a nuclear winter was again given somewhat greater, although erratic, public attention, primarily in journals with more limited readership. In addition to some brief references in the press in January 1985 (Ref. 9), a fairly detailed treatment was given to it in an article by Ginzburg in the March 1985 issue of the monthly journal USA: Economics, Politics, Ideology, which has a limited readership in the Soviet Union (Ref. 28). In July, the publication Arguments and Facts contained a brief article in answer to a reader's question on weather as a potential weapon. According to the article,

> The National Academy of Sciences of the U.S., in a report on possible long-term effects of mass use of nuclear weapons, arrived at the conclusion that explosion of [nuclear] charges totaling 10,000 megatons in the Northern

> Hemisphere would destroy more than half of the ozone there, thus subjecting the population of the countries located there to the threat of serious burns and causing a drop in temperature over wide areas (Ref. 60).

Surprisingly, the article made no reference to Soviet research and findings on this subject.

After the March 1985 article by Ginzburg, detailed public discussion of the climatic consequences of a nuclear war did not appear until December 1985 and January 1986, in two articles in the Literary Gazette. The December article was by Moiseyev (Ref. 52) and the January article by Velikhov (Ref. 80). Both articles discussed nuclear winter in terms of the 1983 computation and projections, and both sought to project an image of the suicidal consequences of any resort to nuclear weapons. In June 1986, an article in New Times by corresponding member of the USSR Academy of Sciences, L. Feoktistov, briefly mentioned the 1983 results of modeling nuclear winter by the CCAS (Ref. 24). This was followed in June by a lengthy article, " 'Nuclear Winter' and the U.S. Nuclear Course," in the specialized journal World Economics and International Relations (Ref. 76) of the Institute of World Economics and International Relations. While the article detailed the climatic consequences of nuclear war, it is noteworthy that it relied entirely on the 1983 American and Soviet models and computations and completely ignored later studies, including those by Stenchikov and Carl. Much space in the article was given to criticism of U.S. defense policies and praise for Soviet arms control proposals.

Thus, most of the public discussion of the nuclear winter issue in the Soviet media has been essentially limited, especially in the past two years, to various journals primarily read by elements of Soviet intelligentsia. As far as the Soviet mass press, radio, and television are concerned, since mid-1984 references to nuclear winter have been only occasional and brief.

4.3 NUCLEAR WINTER AND SDI IN SOVIET PUBLICATIONS.

Some attempt has been made in Soviet publications and broadcasts to link the SDI Program with the danger of a nuclear winter effect. In this connection, the

Soviets have pursued two themes: first, that the use of space-based lasers against ground targets could trigger a nuclear winter; second, that the inevitable leakage in any defensive systems could not preclude the occurrence of a nuclear winter. For the most part this has been aimed at foreign audiences.

For example, in April 1985 an article, "A Way to Nuclear Winter," in the English language publication Moscow News cited Professor C. Gruble, "a prominent U.S. scientist," to the effect that because space weapons also threaten targets on the earth's surface, they are "not a way to peace, but a way to a nuclear winter" (Ref. 14). Again, in an English language broadcast by Radio Moscow on 14 January 1986 about U.S. laser research, the broadcast quoted U.S. scientist (Caroline L. Herzenberger in Physics and Society) to the effect that "massive fires triggered by the lasers might generate smoke in amounts comparable to the amounts generated by a major nuclear exchange scenario" and cause a nuclear winter (Ref. 55).

In a different vein, an article, "Undermining Security" by L. Semeyko in Izvestiya, 31 January 1986, argued that any BMD system "cannot fail to leak." Consequently,

> A retaliatory strike, albeit reduced by several layers of ABM high defense, would be destructive for the aggressor. It is not just a question of the well-known medical and biological consequences of nuclear explosions for all life, but also the recently discovered and quite probable climatic consequences even with comparatively few [nuclear] explosions. Under these conditions it is truly blasphemous to talk about the security of the Americans, who would be condemned not only to incineration or contamination by radiation but also, as it now turns out, to be frozen in the intense cold of a "nuclear winter" (Ref. 64).

A similar argument was made in a Moscow Radio broadcast in English on 17 February 1986, which, citing the inevitable leakage in a U.S. BMD system, reminded that the detonation of 100-150 MT over the largest cities of Europe, Asia, and America would suffice to produce "an inevitable onset of nuclear winter for three months," which would "lead to the end of life on earth" (Ref. 13).

4.4 FOREIGN AUDIENCES.

As has been noted, the major part of Soviet statements on nuclear winter have been confined to Soviet foreign language publications, foreign language TASS releases, and radio broadcasts. The general line was to present a "worst case" nuclear winter scenario while claiming that these findings were "independently" confirmed by parallel Soviet and American researchers. As was noted, Soviet propaganda went to great pains to avoid mentioning the less extreme findings of American and even Soviet researchers and, indeed, criticized Western scientists who questioned the initial models and computations as warmongers and hirelings of the American militarist circles. No doubt the Soviets sought thereby to lend support to the anti-nuclear peace movement in the West, including its scientific members, and to influence Western public opinion. Typical of this was the Svirezhev et al. report on the ecological consequences of a nuclear war (Ref. 71) which, apparently the Soviets had hoped, would have its main parts and conclusions incorporated into the final SCOPE report.

Possibly the most skillful example of Soviet scientific propaganda addressed to Western audiences was Velikhov's introduction to the book The Night After (Ref. 79). One of his themes was the joint struggle of Soviet and American scientists for peace and disarmament as a result of scientific studies of the consequences of a nuclear war. Velikhov praised the "fruitful" cooperation of the Soviet Scientists' Committee for Peace and Against Nuclear Threat (SSC) with foreign scientists and scientific organizations in investigating the long-term climatic, ecological, and biological effects of a nuclear war. According to Velikhov,

> The program was maintained in parallel by workers at the Computing Center and The Institute of Physics of the Atmosphere of the USSR Academy of Sciences and by the research group of Professors C. Sagan and P. Ehrlich at the National Center for Atmospheric Research.

Velikhov claimed that scientists had "estimated fairly accurately possible alterations of the solar energy flux reaching the Earth due to the effects of a nuclear war" and that "even slight perturbations [of the atmosphere] can produce a global catastrophe." After discussing the various international meetings held in 1983 and

1984, at which Soviet and Western scientists were said to have essentially agreed on the nuclear winter projections, Velikhov asserted that the nuclear winter effect implied a lowering of the Earth's surface temperatures "by 20-50°C below the seasonal norm." Thus, "in virtually any scenario of a nuclear war the first strike survivors" would be left in such extreme conditions as to make their survival unlikely. These projections, he wrote, applied to the 10,000 MT exchange as well as to the "threshold" case of a 100 MT exchange, as worked out by Crutzen, TTAPS, and the Computing Center. (Incidentally, Soviet publications have tended not to mention J.W. Birks in connection with the 1982 Ambio paper and to credit the TTAPS study primarily to C. Sagan.) Along with this, Velikhov mentioned Svirezhev's studies of the effects of nuclear war on the ecological system, the work of Soviet geneticists such as A. Bayev and N. Blokhin on the biological effects of a nuclear war, and so on. As has been noted, however, he did not mention the Stenchikov paper included in the same book.

All this led Velikhov to his main point, namely, the "political importance of the obtained results," that is, that national security can no longer be based on the "quantitative buildup and qualitative improvements of armaments." From this he went on to describe and praise Soviet arms control proposals and to criticize U.S. resistance to accepting them, and especially condemned the U.S. SDI program.

It could be said that Soviet nuclear winter propaganda in the period under review suffered first from the increasing attention given by Velikhov and leading members of the Soviet Scientists' Committee for Peace, Against Nuclear War to countering and criticizing the SDI program, and second from the disappearance in March 1985 of its main public science spokesmen in the West, V. Aleksandrov, who had exceptionally good ties with the U.S. scientific community. Finally, the nuclear winter issue became superseded after 26 April 1986 by the accident at the Chernobyl nuclear power station, which led Soviet propaganda to emphasize the danger of ionizing radiation after a nuclear exchange rather than its climatic consequences.

Despite such books as The Night After and the revisions introduced in the Soviet simulations by Stenchikov and Carl, Soviet nuclear winter propaganda abroad is being rapidly overtaken and undermined by new Western models and findings which greatly moderate the projections and consequences of a nuclear winter effect (Ref. 75). So far, Soviet science-propaganda shows signs of finding it difficult to deal with these new findings. One article in the July 1986 issue of Moscow News (Ref. 59), in attempting a response, again restated the view that "independent" American and Soviet research had agreed that "even a comparatively small-scale" nuclear exchange would be likely to cause a nuclear winter. "Physicists have passed their judgment on nuclear illusions: the use of the Bomb means death for all!" Now, the article notes, citing the New York Times, American researchers have shown that the decline in temperature would measure "on the average 20°F instead of 45°F."

> Having thus confirmed the fundamental conclusion about the "nuclear winter," the official researchers commissioned by the U.S. government have, nonetheless, diminished its effect. Are we going to weather it, after all?

The author left the question unanswered, merely saying that the new temperature predictions will have to be verified by "experts." His recommendation was that "we should go by the assumption that 'nuclear winter' must be prevented at all cost, rather than speculate on the possibility of a thaw." According to the author, "nothing is more dangerous than 'nuclear optimism'," hence, the urgent need for the United States to agree to Soviet arms control proposals.

In a similar vein, two brief articles in Pravda (2 July 1986) and in Red Star (20 July 1986) have sought to cast doubt on the validity of the new American predictions of significantly more moderate temperature declines by suggesting that they were deliberately developed at the behest of the Pentagon in order to counter the growing opposition to U.S. defense programs. It is noteworthy that both articles made no mention of Soviet research on nuclear winter, instead crediting the nuclear winter hypothesis solely to the 1983 TTAPS study. The Red Star article targeted for criticism Thompson and Schneider of NCAR and McCracken of LLNL by name, claiming that in "their publications" in Foreign Affairs (Ref. 75), "they attempt in various ways, without in reality providing any evidence, to moderate, to 'warm up' the 'nuclear winter' " by "citing nebulous arguments about the 'stabilizing influence of oceans,' the 'scattering and washout effect of rain,' and so on" (Ref. 82). According to the author, a "mere" 11°C difference in predicted average temperature decline, i.e., 14°C vs. 25°C, does not invalidate the nuclear winter hypothesis, and no matter how much it is debated, "it is evident that the consequences of a nuclear war would be catastrophic for Earth and its inhabitants."

Finally, there has been some Soviet propaganda attempt to exploit V. Aleksandrov's disappearance to lend credibility to Soviet predictions of nuclear winter effects, by suggesting that he had been a victim of an American plot to silence him because of his effectiveness in bringing the "truth" about nuclear winter to the attention of the world's public.

SECTION 5
CONCLUSIONS

In principle, there should be ample reasons why the Soviets would have a serious interest in the study and analysis of possible climatic consequences of a nuclear war. Aside from purely scientific considerations, the political value of such studies, and the opportunity they offer to expand contacts with Western scientists and to participate in international scientific activities, the nuclear winter issue could have potentially important strategic implications for the Soviet Union. Specifically, it might affect Soviet views on nuclear warfighting, targeting, and war survival concepts, the possibility of achieving a favorable war outcome, as well as the credibility and utility of strategic nuclear forces and strategic deterrence. However, the publicly visible portion of Soviet study activities in this area cannot really be said to reflect such seriousness of purpose, even if due allowance is made for the honest dedication of some of the Soviet scientists working on this problem and their undoubted competence. Indeed, there is evidence that Soviet scientists have been genuinely interested in the nuclear winter problem. The apparent lack of real seriousness in the public Soviet effort appears to be due not so much to the limitations of Soviet computer capabilities--indeed the Soviets have better ones than those used at the CCAS to model nuclear winter, but primarily to the heavy politicalization and propaganda exploitation of the nuclear winter issue. The latter appear to have clearly superseded objective scientific inquiries when this was expedient to do so. The constraints on the seriousness of Soviet inquiries are also due to the inability of Soviet scientists to publicly discuss Soviet war scenarios and, consequently, to use independently arrived-at projections of nuclear generated fires and parameters of dust, smoke, soot, and other aerosol injected into the atmosphere as a result of a nuclear exchange. In the final analysis, Soviet contributions to the study of nuclear winter, despite some early innovations in modeling, have been marginal. The Soviet model was from the start very crude, and while this may have facilitated the incorporation of some additional features, its utility and the resulting computations quickly lost credibility.

Soviet politicalization of the nuclear winter issue tends to dictate that the focus be on "worst case" scenarios and predictions of extreme climatic effects. This was facilitated by the use of the *Ambio* and *TTAPS* scenarios and of their parameters of smoke in the CCAS initial atmospheric general circulation model, itself a derivation of an earlier American model. The approximate coincidence of the 1983 TTAPS and Aleksandrov-Stenchikov predictions of temperature declines, at least for the initial post-exchange weeks or months (in the case of a 10,000 MT exchange scenario rather than the *Ambio* or TTAPS baseline scenarios), allowed Soviet spokesmen to claim "independent" confirmation of an extremely severe nuclear winter effect. The subsequent adoption by Aleksandrov-Stenchikov of the TTAPS 100 MT city-only attack scenario became attractive when it was portrayed as representing a "threshold" for a nuclear winter effect. Soviet propaganda found this useful in its campaign against alleged U.S. plans to wage "limited" nuclear war.

Soviet political-propaganda exploitation of the nuclear winter issue is evident in the persistence with which Soviet science spokesmen, published scientific papers, and public discussions dealing with nuclear winter have continued to use and cite the *Ambio*, TTAPS and Aleksandrov-Stenchikov scenarios and projections long after their computations and predictions have been extensively altered by subsequent research. True, the Stenchikov-Carl 1985 paper, which included fully-interactive smoke calculations, did correct earlier Soviet errors in the matter of absorption optical depth of smoke and dust, but these new calculations have continued to be ignored in Soviet publications by Soviet science spokesmen. Indeed, it cannot be excluded that the primary reason for the publication of the Stenchikov-Carl computations was to lend much needed credibility to the Computing Center's modeling of nuclear winter and, thereby, allow it to remain a "player" in the international efforts to study this problem by bringing its findings somewhat closer in line with more recent computations by American scientists. Even so, it is noteworthy that the 1985 Svirezhev et al. work on modeling the ecological consequences of a nuclear war, carried out at the same Computing Center, ignored the Stenchikov-Carl simulations and instead chose to use the earlier "worst case" scenarios and projections of extreme temperature declines.

It is true that Soviet scientists have repeatedly noted that nuclear winter projections are fraught with many uncertainties, including those concerning the actual amount of dust, smoke, and soot likely to be injected into the atmosphere in a nuclear exchange. Yet, apparently for propaganda rather than scientific reasons, the Soviets are and probably will continue to try to publicly resist, or ignore, what they have dubbed as the current "nuclear optimism" of Western scientists in the matter of nuclear winter effects. In so doing, they have suggested that such findings were made in the interest of the "militaristic" policies of the United States and, therefore, were by definition suspect. In trying to counter these new Western computations and projections, the Soviets are hampered by the lack of a new model of nuclear winter, by being unable to model large fires, and by having no independent war scenarios or data to offer, such as from fire experiments or estimates of fire loading in the Soviet Union, Western Europe, and the United States. One tendency, therefore, is for Soviet scientists to fall back on the study of large volcanic eruptions and of historic large forest fires, such as the one in 1915 in Siberia. Another, and more important trend is to focus on the predictions of "worst case" synergistic consequences of the effects of a nuclear war: ionizing radiation and radioactive contamination, depletion of strato-sphere ozone, acid rain and pollution of the atmosphere with toxic chemicals, and widespread drought. Especially noteworthy is the continuing major attention paid in Soviet scientific publications to the danger of large depletions of stratospheric ozone and their consequences. It should be noted, however, that in non-publicized meetings of American and Soviet scientists, the latter have generally not challenged the revised American computations of nuclear winter effects and predictions of much milder climatic consequences of a nuclear war. It is possible that in such meetings, Soviet scientists do not necessarily feel obliged to play a propagandistic role.

At this time, the further direction of Soviet public research efforts into the climatic consequences of a nuclear war is not clear. In the past the level of this Soviet effort appears to have been quite modest and to have centered in only a few institutions, primarily the Computing Center and the Institute of Atmospheric Physics of the USSR Academy of Sciences, with secondary activities carried out in the laboratories of the State Hydrometeorological Service and the Institute for Lake Study of the USSR Academy of Sciences. For technical as well as political reasons, it would seem likely that the attempts of the Computing Center to model the effects of smoke on global climate may have run their course. In the competition for funds and influence in this area, the Computing Center--especially after V. Aleksandrov's disappearance in March 1985--may now lose out to the Institute of Atmospheric Physics or the laboratories of the Hydrometeorological Service, when the latter ceases to be heavily involved in dealing with the consequences of the Chernobyl accident.

From the Soviet scientific and political-propaganda standpoint, it would seem logical to expect increased focus on the study of the effects of various pollutants in the atmosphere and especially on the ecological consequences of a nuclear war, which may occur with relatively small long-term changes in average temperatures. If past experience can be used as a guide, one should expect Soviet propaganda and science spokesmen to make extensive use of both the 1985 Svirezhev et al. study, despite its serious flaws, and of the SCOPE report, which warns of the possibility of mass starvation and death in all countries of the Northern Hemisphere and Central Africa not only because of environmental effects of a nuclear war but also because of the likely widespread destruction and collapse of the infrastructure supporting agricultural production and transportation. As in the case of the TTAPS study, Soviet scientists have already begun to publicly praise the SCOPE report's estimates and projections and to claim to have made important contributions to them.

As far as Soviet open sources are concerned, there are no indications that Soviet nuclear winter research has had any influence on Soviet military concepts or the civil defense program. Indeed, the Soviet press continues to call for the latter's further "strengthening" and to assert its importance to the defense of the Soviet Union. This does not necessarily mean, however, that the Soviets are not conducting on behalf of Soviet defense planners classified research into all short- and long-term consequences of a nuclear war. Unfortunately, the results of such studies are unlikely to be made public. The only hint, unconfirmed at that, of a Soviet military interest in nuclear winter has been the alleged call for an analysis of possible regional climatic and other consequences of a limited use of nuclear weapons in a theater of operations. In Soviet open scientific publications one finds two mentions of military implications of some of the findings. The first appears to suggest the need to take steps to reduce the danger of large depletion of the ozone layer, presumably by the use of smaller-yield nuclear warheads. The second calls for avoidance of targeting nuclear power plants with either conventional or nuclear weapons. For the near-term at least, Soviet peace and disarmament propaganda will be trying--with the help of Soviet scientists--to capitalize on the Chernobyl reactor accident and consequently focus on the radiation effects of a nuclear war. It is also likely that the experience with the problems and costs of overcoming the consequences of the Chernobyl accident will have more influence on the Soviet leadership's and public's perceptions of the dangers of a nuclear war and the difficulties of surviving it than will the Soviet scientists' nuclear winter computations.

SECTION 6

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