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Central
Intelligence

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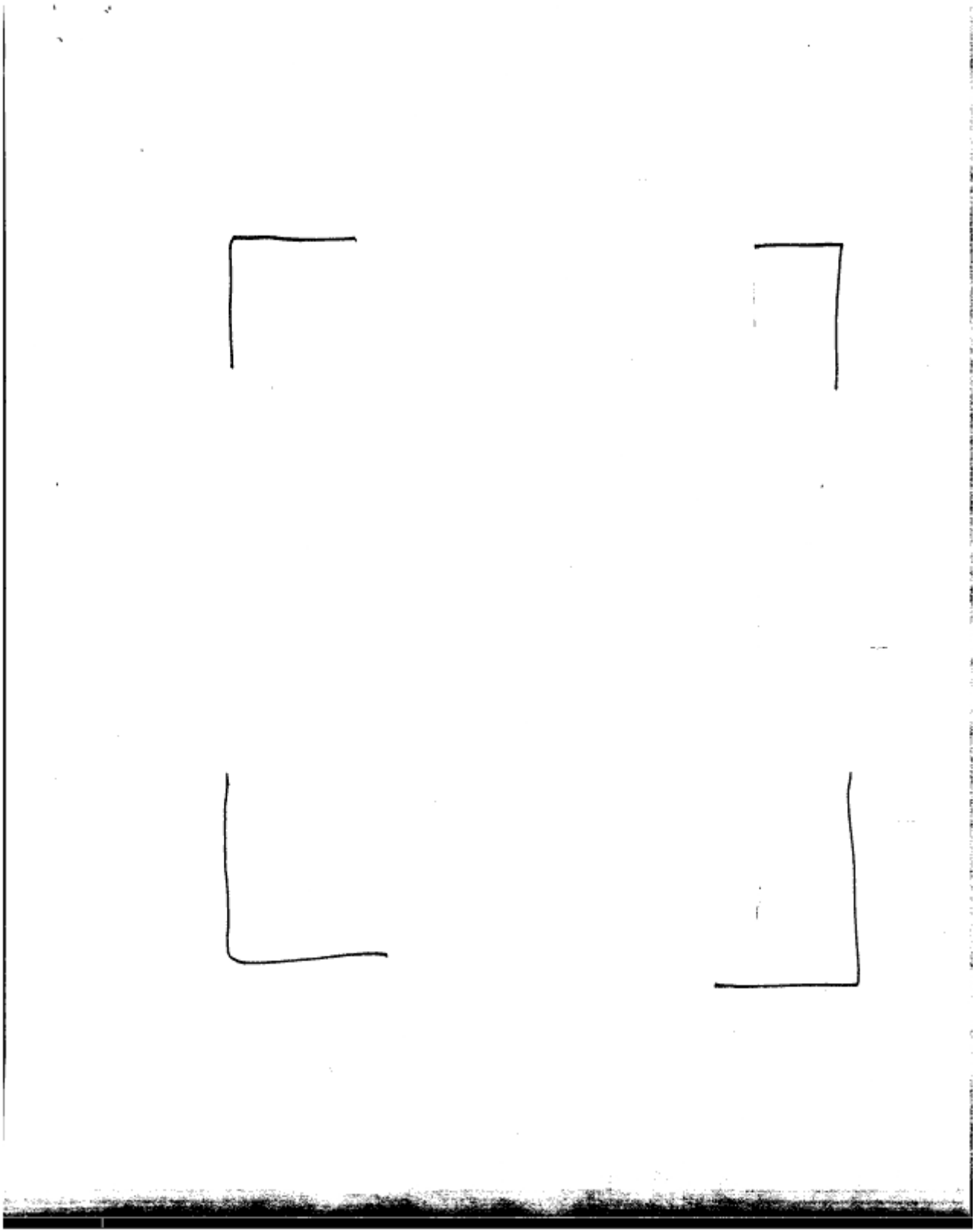
The Soviet Approach to Nuclear Winter

Interagency Intelligence Assessment

~~Secret~~

NI IIA 84-10006
December 1984



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THE SOVIET APPROACH TO NUCLEAR WINTER

Information available as of 10 December 1984 was used in the preparation of this Assessment.

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SCOPE NOTE

This Assessment looks at Soviet research on Nuclear Winter to determine what the Soviet leaders think of the hypothesis, the extent to which they are exploiting the subject for propaganda purposes, and the most likely implications from Moscow's perspective. It does not reach judgments about the scientific validity of the Nuclear Winter hypothesis. Most of the information on which this analysis is based is derived from the international scientific and diplomatic communities. This information is supplemented by foreign media reports. We also have debriefed a Soviet scientist who recently defected from the USSR and was knowledgeable of the capabilities of individuals and organizations involved in Soviet research in this field. From these sources, we believe that we have a relatively good understanding of Soviet Nuclear Winter research. We also know what Soviet leaders say publicly about Nuclear Winter. Their private, personal perceptions, however, are not known. We identify some possible military and political dilemmas, should Soviet leaders come to believe Nuclear Winter poses a serious danger, and note some possible indicators of increasing concern over possible adverse climatic consequences of nuclear war.

Note: This Assessment was prepared under the auspices of the National Intelligence Officer for Strategic Programs. It was coordinated at the working level by the Central Intelligence Agency, the Defense Intelligence Agency, and the intelligence component of the Department of Energy.

KEY JUDGMENTS

We do not anticipate any changes to Soviet nuclear weapons policies or programs solely as a result of Nuclear Winter research. Senior Soviet leaders are informed about Nuclear Winter. Reportedly, Foreign Minister Gromyko has been briefed on the subject. But the scientific evidence is not yet convincing, and, more important, Soviet leaders do not see any apparent response in US strategic programs to Nuclear Winter concerns. Lacking both of these conditions, we believe Moscow will continue to maintain a strategic force posture that supports their war-fighting strategy and depends primarily on missiles with large throw weights and large numbers of warheads. Consequently, we believe that there is little chance for major reductions in their nuclear arsenal as a direct result of published or ongoing research on Nuclear Winter.

We believe that there is a wide difference in what Soviet officials say publicly about Nuclear Winter and what they believe privately. The official Soviet party line is that Nuclear Winter is real and the effects are certain and severe, but Soviet scientists have privately acknowledged that substantial uncertainties remain. Despite these uncertainties, Soviet Nuclear Winter research remains concentrated among a small group of Computer Center scientists with little background in climatology. The research program does not appear to be well coordinated among other individuals and institutions in the Soviet Union that could make important contributions. Nor do we have any evidence that the research program is coordinated with the nuclear weapons design organizations at this time.

Soviet Nuclear Winter research began in 1983, when a few scientists moved quickly to conduct investigations and enter into the growing debate on the subject. Their findings were widely reported as independent confirmation of the hypothesis that nuclear war would lead to widespread and devastating climatic changes. On closer examination, however, Soviet research on Nuclear Winter is not convincing. Neither is it well documented. It is derived almost entirely from US ideas, data, and models. Early US climate models were greatly simplified and run with input data that grossly exaggerated the effects of smoke from burning cities, the key variable in the Nuclear Winter equation. Not surprisingly, Soviet scientists have consistently reported more severe climatic changes than are usually found in similar research in the West. Furthermore, Soviet reporting tends to stretch conclusions

well beyond what the research supports, often concluding that ". . . nuclear war of any dimension will signify either the disappearance of the human race or its degradation to a level lower than prehistoric." While Soviet scientists privately acknowledge errors in their work that produce more severe outcomes, they publicly continue to voice the party line. Western scientists have been amazed at this kind of intellectual dishonesty.

The location, nature, and findings of Soviet research suggest that the primary interest in Nuclear Winter thus far is for external political purposes. A large, well-coordinated propaganda campaign has been organized with the international scientific community as the primary target audience. The objective is to use these scientists to convince Western publics, and ultimately their political leaders, that arms reductions are necessary, that the US arsenal is already too large, and that new weapons are not needed. The themes usually emphasized at international scientific forums and widely reported in the media include:

— Nuclear war would have disastrous consequences for all mankind.

— There is no effective defense against nuclear attack.

— There is increasing danger of nuclear war due to the "arms race."

— US actions are the main cause of the "arms race."

The efforts have met with some success. In certain cases, Soviet scientists gain direct access to political leaders in the West. For example, Vladimir Aleksandrov, the leading Soviet writer on Nuclear Winter, has testified before the US Congress. In other cases, Soviet participation in international organizations has served to keep the horrors of nuclear war before the public. The UN World Health Organization, for example, has placed the study of Nuclear Winter on its agenda.

In addition to the potential for political influence, Soviet participation in Nuclear Winter research also contributes to continued Soviet access to US scientists, research, and computers. It also provides opportunities for Soviet scientists to develop new modeling techniques and improve global circulation models.

For all of these reasons, we expect Soviet research on Nuclear Winter will continue, but no substantial contributions are anticipated. Experimental research on large-scale fires, which could provide useful input data, has not been approved. Also, analysis will be limited by Soviet computers that lack the capacity to use advanced climate models. There will be continued Soviet interest in scientific exchanges with US

scientists, but Soviet agreement to joint research is unlikely because Moscow's public position is that the Nuclear Winter hypothesis has been adequately proved. Furthermore, it is important to Moscow that Soviet Nuclear Winter research be perceived as independent and original. In any event, unclassified Soviet research probably will be carefully circumscribed so that it does not cast any serious doubts on the Nuclear Winter hypothesis.

Classified analysis of Nuclear Winter is likely to be undertaken outside of the Computer Center. At a minimum, military planners would want to know to what extent their strike plans and US retaliatory strikes would cause adverse climatic conditions in the USSR. Another major issue is the possibility of asymmetrical damage in which the Soviet Union could experience somewhat more severe climatic consequences from a nuclear war than the United States because prevailing winds could move smoke from the United States and Europe to the Soviet Union more quickly than smoke from the Soviet cities would arrive over the United States.

Regardless of the climatic consequences of nuclear war, Nuclear Winter research has pointed out some additional problems that may have been insufficiently considered by Soviet military planners, including:

— Persistent smoke and dust could obscure targets from overhead reconnaissance and interfere with aircraft engines.

— Cold and darkness could further stress personnel operating command and control systems.

— High-frequency communications links and satellite ground control stations could be affected by increased dust and water vapor in the atmosphere.

The Nuclear Winter hypothesis could pose potential dilemmas for the Soviet leadership and it could lead to contradictions between these new considerations, on the one hand, and Soviet doctrine and weapons employment policies on the other. Such contradictions would probably cause Soviet officials to demand exceptionally high standards of scientific proof for the Nuclear Winter hypothesis, standards that probably cannot be met.

Efforts to reduce the climatic consequences of nuclear war would run counter to Soviet war-fighting strategy, which emphasizes preemption and massive strikes. Responses to this dilemma would be difficult for Soviet strategic planners; they apparently are highly skeptical of concepts of escalation control and small-scale strike options. Nuclear Winter considerations also could result in more emphasis on conventional forces, biological weapons such as those achieved by genetic engineering, and directed-energy weapons.

Should Soviet leaders become convinced that steps must be taken to reduce the possibility of Nuclear Winter, these measures could affect Soviet research and development programs. This could reinforce existing trends toward lower yields and better accuracy. Nonnuclear warheads also could be considered for strategic targets. In addition, targeting planners might consider target combustibility along with other factors to reduce the amount of smoke and dust. Nuclear Winter considerations also could complicate Soviet ballistic missile defense (BMD) efforts. Should Moscow become concerned with using BMD both to protect military capabilities and to prevent an attack from triggering Nuclear Winter, then a much more extensive defense capability would be required.

Finally, Nuclear Winter also could influence Soviet thinking about civil defense. Because of the potential damage to food production, Soviet civil defense officials could be forced to extend their planning time frames for basic survival to about a year. Thus, substantial increases in civil defense food stockpiles might be an early indicator that Nuclear Winter was beginning to influence Soviet thinking at high levels.

DISCUSSION

The Scientific Debate

Background

1. The concept of "Nuclear Winter" could fundamentally change the way we think about nuclear war. The term refers to the possibility of catastrophic changes in climate due to nuclear war. This concept was first raised in 1982 and, in 1983, caught the attention of the scientific community with the publication of the "TTAPS" [1] study. The study concluded that nuclear war could trigger severe and widespread changes in climate that could have devastating global consequences. Other scientists have concluded that these climatic changes could lead to the extinction of human life on earth.[2]

2. Nuclear Winter studies raise the possibility that the longer term, global-scale, aftereffects of nuclear war may be even more serious than the immediate effects. Previous studies were primarily concerned with immediate effects, including blast, heat, and short-term radiation. Studies of longer term effects concentrated on fallout, residual radiation, and ozone depletion. But the climatic consequences of large amounts of smoke and dust were overlooked until recently; therefore the Nuclear Winter hypothesis has attracted considerable interest. Many scientists, however, do not agree that the effects would be as severe and widespread as indicated in early discussions, and thus a scientific debate has opened. This debate represents the latest in the long series of scientific concerns about nuclear war.

Nuclear Winter Hypothesis

The Nuclear Winter hypothesis essentially argues that a nuclear war would produce large quantities of smoke and dust that would absorb solar radiation, causing:

- — Darkness for several weeks or longer.
- — Cooling temperatures for several months or longer.
- — Circulation pattern changes that would bring similar, but less severe, climatic changes to the Southern Hemisphere.

The Process

3. Although smoke and dust were found to be the major contributors to Nuclear Winter, the TTAPS study considered four main physical effects of multiple nuclear explosions: *smoke* in the troposphere, *dust* in the stratosphere, *fallout* of radioactive debris, and depletion of the *ozone* layer. A single, 1-megaton (Mt) weapon detonated at ground level can generate 100,000 to 600,000 tons of fine dust that is propelled into the upper troposphere and stratosphere. In the TTAPS base-case scenario, about 960 million tons of fine dust was produced, about 80 percent of which reached the stratosphere. These particles would remain in the stratosphere for about a year, scattering sunlight. Airbursts over cities would likely start massive fires that could generate large quantities of smoke. Smoke particles could remain in the upper troposphere for weeks to months. In the TTAPS study, one scenario involved a 1,000-weapon attack using 100-

[1] R. P. Turco, O. B. Toon, R. P. Ackerman, J. B. Pollack, and Carl Sagan. "Nuclear Winter: Global Consequences of Multiple Nuclear Explosions," *Science*, vol. 222, No. 4630 (23 December 1983). The report is usually referred to as the "TTAPS" study, combining the initials of their last names. A less technical article on the subject by Carl Sagan appeared in *Foreign Affairs*, vol. 62, No. 2 (Winter 1983/84) and received widespread attention. The TTAPS study grew out of analysis of dust storms on Mars in connection with the US Mariner space exploration project in the early 1970s. Mariner data from Mars indicated that the widespread and persistent dust storms absorbed considerable solar radiation and resulted in temperatures much higher than normal at the polluted high altitudes and much lower temperatures on the surfaces that were masked from solar radiation. Similar changes on a much smaller scale have been noted on earth as a result of major volcanic eruptions that injected large quantities of ash particles into the atmosphere. In 1981, a group of American scientists decided to apply what had been learned about the effects of large quantities of dust in the atmosphere to the nuclear war context, in what eventually became the TTAPS report. A separate study in 1982 by Crutzen and Birks pointed out the potential significance of smoke from burning cities and forests in lowering surface temperatures after a nuclear attack. With this discovery, smoke data were added to the TTAPS research. Previously it had not been assumed that smoke would rise to high enough altitudes to cause significant, widespread climatic effects.

[2] Paul Ehrlich, "The Biological Consequences of Nuclear War," in *The Cold and the Dark* (1984), p. 59.

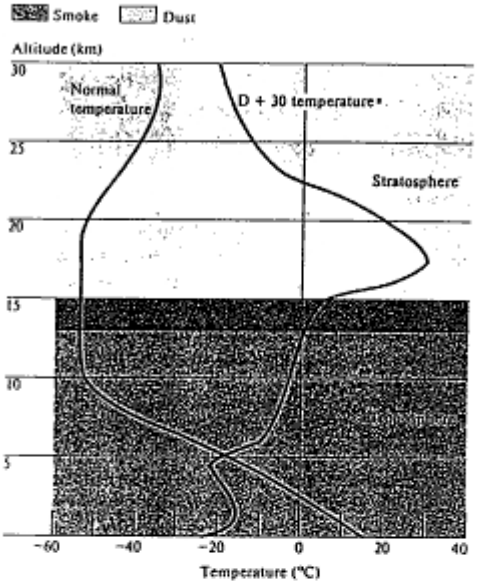
kiloton (kt) warheads against an urban area equivalent to about 100 cities. This scenario produced an estimated 130 million tons of smoke in the troposphere. In addition to dust and smoke, radioactive particles also are produced and carried aloft in the fireball or the updraft. Particles injected into the lower troposphere settle back to earth or are rained out in a matter of weeks. Those injected at higher altitudes, into the stratosphere, remain there for about a year, by which time most of the fission products have decayed to safer levels. The fourth effect, ozone depletion, results from nitrogen oxides produced by high-yield explosions and amounted to about a 30-percent maximum reduction in ozone in the TTAPS base case. This would produce about a twofold increase in ultraviolet radiation in the first year following a nuclear exchange, according to the TTAPS analysis. Other effects, including the generation of toxic gases, dioxins, and other dangerous products were noted but not evaluated.

Climate Changes

4. These physical effects could have a major impact on the global climate, due primarily to absorption of sunlight by thick clouds of smoke from burning cities. Local weather and precipitation could be seriously disturbed for up to a year. The severity of changes in climate would vary from region to region and depend on the season during which the attack occurred, but, even in the most extreme case considered in the TTAPS study, the climatic changes did not suggest that a long-term ice age would be triggered by nuclear war. This is primarily because of the tremendous quantities of heat stored in the oceans that would drive the climate back to normal ranges within, at most, a few years. Nevertheless, the combination of darkness and cooling for even one year could have disastrous consequences.

5. The normal temperature gradient could be radically changed by large quantities of smoke in the troposphere and dust in the stratosphere (figure 1). At the surface, when heated by the sun, the earth has an average annual temperature of 13°C (56°F). Nuclear effects (smoke and dust) in the atmosphere could reduce surface temperatures to about −17°C, well below freezing, within 30 days of a nuclear attack. At the same time, temperature changes in the stratosphere could be even larger, possibly rising by as much as 80°C as the smoke particles absorb solar energy. The impact of such temperature changes could be severe. An abrupt onset of cold may be damaging or fatal to plants, particularly if exposed during the growing season. Crop harvests could be destroyed or

Figure 1
Nuclear Winter: Atmospheric Effects



* TTAPS base case, 5,000-megaton scenario.

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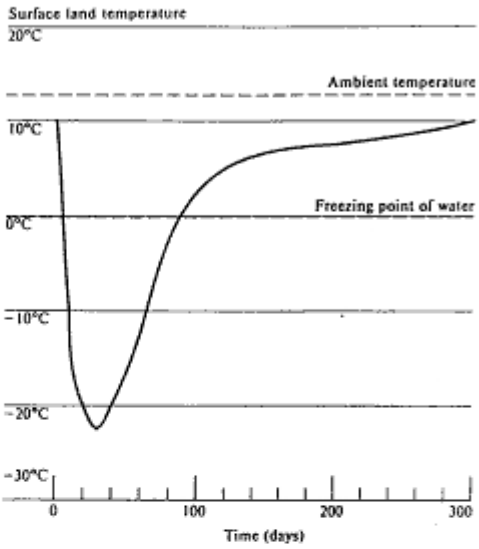
severely reduced in much of the Northern Hemisphere. In addition, the superheating of the stratosphere could affect circulation patterns, bringing the effects to the Southern Hemisphere rather quickly. Plants in the tropics are even more susceptible to damage from minor changes in climatic conditions.

6. Furthermore, these conditions could persist for a long period of time (figure 2). The TTAPS base-case scenario produced subfreezing temperatures for about three months, and about a year was required before temperatures began to return to normal levels. The effects would be less severe in coastal areas, which are warmed by the oceans. Even there, however, severe storms would be common and in some areas further inland, there could be continuous snowfall for months. Water supplies could be frozen, and agriculture might be impossible for up to a year in many areas.

7. Darkness is the second major consequence of injecting large quantities of smoke and dust in the atmosphere. Virtually all life on earth depends on sunlight. If light levels were reduced by 5 percent,

Figure 2
Nuclear Winter: Range and Duration of Temperature Change*



* TTAPS base case, 5,000-megaton scenario.

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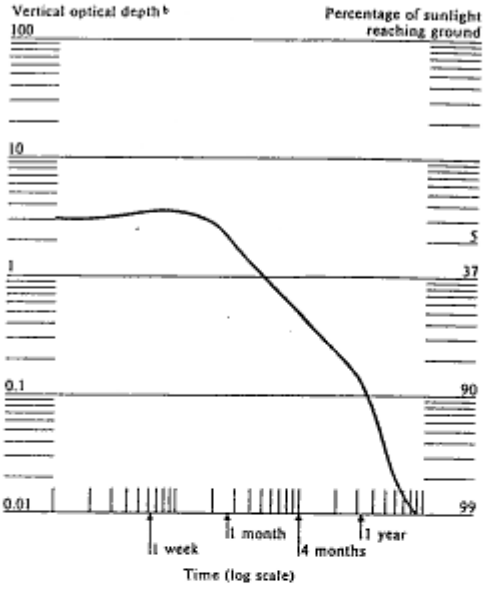
Figure 3
Nuclear Winter Darkness*



* TTAPS base case, 5,000-megaton scenario.

b The logarithm of the fraction of light that an atmosphere transmits. The normal, clear-sky optical depth is essentially zero; a light fog is about 0.5. An optical depth of 1 represents the transition between an atmosphere that is essentially transparent and one that is opaque.

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most plants would be unable to maintain net growth. In the TTAPS base case, smoke from urban fires and forest fires reduced the amount of sunlight reaching the earth's surface by over 95 percent for more than a week in the northern midlatitudes (figure 3). It could take a year or more for sunlight to reach normal levels (figure 4). Widespread disruption of photosynthesis, combined with radiation damage, severe cold, and other effects, could pose a serious danger to plants and ultimately to the animals and humans which depend on them.

Key Variables, Assumptions, and Uncertainties

8. Smoke is the key variable that determines the extent to which climatic change would occur, over the shorter term, while dust largely determines whether the effect will be long lasting. In particular, the amount of smoke produced, the altitude to which it rose, and the duration that it persisted are crucial factors in assessing resulting changes in the global climate. For example, in the TTAPS base case, 225 million tons of smoke were injected into the atmosphere and accounted for up to 90 percent of the reductions in the solar energy reaching the earth's surface and corresponding reductions in temperatures that in some cases amounted to 30 degrees centigrade. For such conditions to occur, however, there would have to be large numbers of urban fires generating intense heat that would carry some of the smoke into the stratosphere, where it would persist for much longer periods than commonly occurs at lower altitudes. The fireball of large-yield weapons, in the megaton range, also could inject smoke and dust into the stratosphere. Thus, the main smoke parameters—how much, how high, and how long—depend on several important assumptions. For example, the amount of smoke generated depends mainly upon the kind of fuel, the amount of oxygen available, weather

Figure 4
Nuclear Winter: Attenuation of Solar Energy

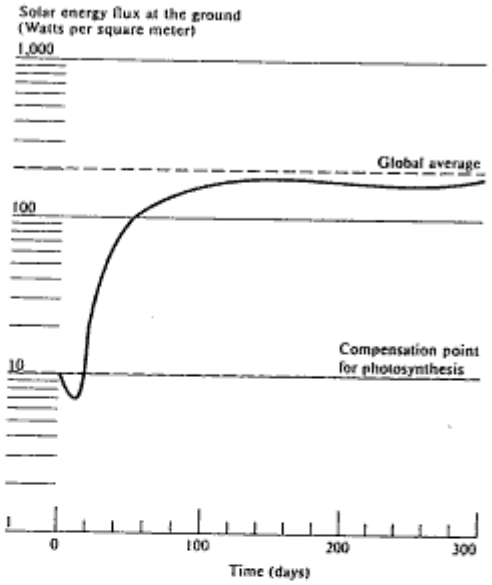

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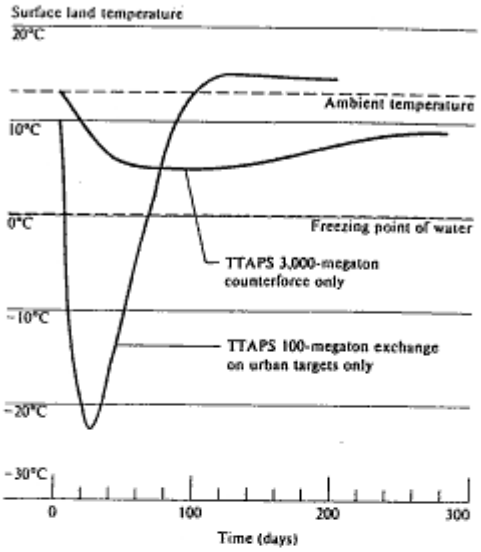
Figure 5
Nuclear Winter: Scenario Variations



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conditions, and the rate of burn. The total injected smoke in a nuclear war scenario may vary by a factor of 10 or more.

9. Variations in the assumed properties of smoke and dust generated by a nuclear war could change the climatological results significantly. For example, reasonable variations in estimates of dust and smoke particle parameters could vary the optical depth of resulting dust clouds from 0.02 to 3.0. Such a range in opacity would result in conditions that range from negligible haze to near-total darkness. Furthermore, the TTAPS study assumed instantaneous, uniform injection of smoke, whereas actual smoke and dust injections obviously would vary considerably from place to place and over time, so there would be corresponding variations in local temperatures. In some cases, surface temperatures would be unaffected, in others even a rise in temperatures is possible.

10. The assumed nuclear war scenarios also significantly affect research findings. The critical scenario variable is the extent of urban-industrial targeting, although the number of weapons used, their yield, height of burst, and timing also are important. The TTAPS base-case scenario involved a total yield of 5,000 Mt from 10,400 weapons ranging from 0.1 to 10.0 Mt each. About 20 percent of the yield was devoted to urban-industrial targets. This scenario is similar to those used by other researchers. Several other scenarios also were used in the TTAPS research to test the sensitivity of the outcome to variations in the postulated attacks. One of the major findings was that even a relatively small nuclear exchange—100 Mt on urban targets—could produce relatively large climatic effects. This scenario, however, used different smoke parameters from the base case. In a 3,000-Mt counterforce exchange, where cities were avoided, the climatic consequences were less severe (figure 5).

11. Another uncertainty is the extent to which smoke and dust will reach the Southern Hemisphere and cause substantial cooling. Research using various climate models suggests that typical circulation patterns (Hadley Cells) that would normally inhibit the

transport of smoke and dust to the Southern Hemisphere may be interrupted. This is due to warming of the stratosphere that could reduce precipitation in the tropical convergence zone that would be expected to prevent the spread of aerosols to the Southern Hemisphere. But the research is very preliminary at this point.

12. Combining the key assumptions about smoke, dust, and scenarios in a useful manner presents a difficult problem. In particular, translating the quantity of burnable fuels in cities and forests into appropriate smoke clouds that can be used in global climate models is the greatest source of uncertainty in Nuclear Winter research. Until more accurate data can be collected from actual large-scale fires, there will continue to be serious questions about the likelihood of severe and persistent climatic changes following a nuclear war.

Confidence in Findings

13. The Nuclear Winter hypothesis initially enjoyed considerable support in the scientific community. Early independent research using more complex climate models yielded similar results. Nevertheless, Nuclear Winter research has not been without criticism. For example, one argument challenges that rainout would substantially reduce the amount of smoke in the atmosphere within two weeks. Other meteorological effects, such as local winds and cloud caps, could further reduce the effects of smoke. Also, variations in the season selected for analysis can significantly affect the outcome. For example, some research has indicated relatively minor temperature declines might accompany a nuclear exchange occurring in the winter. As a result of these factors and uncertainties about the initial amount and properties of smoke generated, average temperature changes may be far less than those suggested in the TTAPS study. Furthermore, the areas adversely affected may be more restricted than suggested in the preliminary findings. However, even if the early Nuclear Winter research is in error by a factor of 10, the resulting temperature changes may still produce significant crop damage in certain areas.[3]

[3] Even though local temperature changes may frequently be large and rapid (in excess of 10°C in a matter of hours or days), the global climate, considered as a whole, is remarkably stable. For example, average annual temperatures have varied by only 0.5°C over the last hundred years. The stability of this huge, complex system is due to oceans acting as large energy reservoirs and many other complex interactive processes that store and redistribute solar energy. Because of the inherent stability of this system, it takes global-scale events to cause changes, and even relatively small changes to global averages can cause dramatic local consequences. For example, major volcanic eruptions inject large quantities of dust and ash into the atmosphere that spreads over much of the earth. The eruption of Tambora in Indonesia in 1815 produced an estimated 200 million tons of aerosol particles that subsequently caused about a 1°C reduction in the average global temperature. Yet, this seemingly small change produced "the year without a summer" in 1816. Severe and persistent freezes caused widespread loss of life and crop failure throughout the United States and Europe. Volcanic dust particles, because of their large size, are relatively inefficient in blocking sunlight. An injection of 200 million tons of smoke and dust resulting from a nuclear war could have a more severe impact than a 1°C temperature change.

14. Confidence in the Nuclear Winter hypothesis probably will have to await actual measurement of particles produced by large fires. This could involve monitoring forest fires, experimental fires, or quick-response measurement of actual large fires. Other important areas of study include the dynamics of smoke plumes, regional rather than global-scale meteorology, and calculations about the probability of black smoke reaching high altitudes. Even when the physical phenomenon are fairly well understood, however, there will continue to be substantial uncertainty about the biological consequences of climate changes.

Soviet Views on Nuclear Winter

Leadership Perceptions

15. We do not know how seriously the Soviet political and military leadership takes the Nuclear Winter issue, although many senior Soviet officials probably are aware of the hypothesis. For example, Yevgeniy Velikhov, the main force behind Nuclear Winter research in the USSR, has told [redacted] that he personally has briefed Foreign Minister Gromyko, former Chief of the General Staff Ogarkov, and Defense Minister Ustinov on the subject of Nuclear Winter. However, we have not yet noted any significant Soviet military interest in Nuclear Winter.

16. If the Soviet leaders have been briefed on Nuclear Winter, and we believe they have, then they share essentially the same scientific basis for understanding the problem as do US leaders. Thus, at this time, Soviet leaders are likely to believe that nuclear war would cause varying degrees of increased cold and darkness in some regions, but the effects would not mean the end of life on earth. This view generally is consistent with what they have been saying publicly for over 20 years, that is, nuclear war would be a disaster of

unprecedented proportions. From this perspective, cold and darkness would further complicate the already difficult problem of survival in a nuclear war.

17. We believe Soviet leaders will remain interested in the subject because Nuclear Winter could have profound implications, if, as suggested in the TTAPS study, there is a "threshold"[4] beyond which the use of nuclear weapons would be self-destructive. In such a situation, a concept of deterrence that depended on the credibility of launching a retaliatory strike with a large number of nuclear weapons would be meaningless. The attractiveness of a disarming first strike also would be reduced because, even if a first strike were successful in totally destroying the retaliatory capability of the adversaries, it could exceed the "threshold," triggering Nuclear Winter, thus bringing about self-destruction. Furthermore, the nuclear inventories of France, the United Kingdom, and China also could independently represent a more significant minimum deterrent capability. Despite these considerations, Soviet scientists have not expressed an interest in the military scenarios[5] or the threshold concept, except to comment in line with their propaganda that the threshold is very low and even a limited nuclear war probably would trigger Nuclear Winter.

18. The threshold that could trigger Nuclear Winter is quite low according to the TTAPS study. Carl Sagan has suggested that, depending on yields and targeting, it may be somewhere between 500 and 2,000 nuclear warheads. Soviet scientists claim that their calculations indicate that a 100- to 150-Mt war—50 times less than the TTAPS base-case scenario—could cause a Nuclear Winter. Not all scientists agree, however, that such a self-destructive threshold exists. Nevertheless, such an idea has important implications for perceptions of the East-West military balance. From the Nuclear Winter viewpoint, a limited war in Europe conceivably could exceed the threshold. Thus perceptions of a low threshold could undermine the credibility of NATO's flexible response policy and place additional importance on the conventional force balance.

19. We believe that Soviet military planners are interested in the possible dangers of Nuclear Winter. At a minimum, they would want to know to what extent their strike plans and US retaliatory strikes would lead to adverse consequences in the USSR. To answer this kind of question, the basic relationship between nuclear weapons and Nuclear Winter will need to be better understood. In particular, how do variations in numbers, yields, and targets affect the extent and severity of cold and darkness?

Current Soviet Research

20. The logical place for Soviet climate research is the State Committee for Hydrometeorology and Environmental Control (usually called Hydromet), the government organization generally responsible for climate research and forecasting. Instead, Soviet research on Nuclear Winter until recently has been concentrated in the Academy of Sciences. Vladimir Aleksandrov, 46, is the leading Soviet scientist working on Nuclear Winter and appears to head an ad hoc group of about 20 scientists. Aleksandrov's work in this field grew out of Soviet interest in US high-speed computers. A mathematician specializing in computer science, Aleksandrov was directed in 1976 to shift his research from gas dynamics and plasma mechanics to climatology. He was sent to the United States in 1978 to study computer-based general weather circulation models and develop a computer program compatible with

Vladimir Aleksandrov

Leading Soviet scientist on Nuclear Winter

[4] The use of the term "threshold" in connection with Nuclear Winter has become controversial, mainly because it implies that there is some simple measure of warheads or yields that will trigger adverse global climate consequences. A more proper use of the term would be to indicate the mass of smoke injected into the atmosphere that would create globally significant temperature decreases. Smoke mass is a function of the number of weapons, their yield, and, most important, the combustibility of urban areas targeted. Also the local weather, the season, and other variables can affect the extent of climatic effects expected from a nuclear war. Another problem with the term "threshold" arises in its use in a strict scientific sense as designating a discrete point at which a phenomenon occurs, such as water boils at 100°C, but not at 99°C. By such use, Nuclear Winter would occur at a point where the addition of a single weapon would cause globally significant temperature drops. More realistically, there is a continuum of worsening effects.

[5] In joint scientific exchanges, Soviet scientists have urged Western scientists to use extreme scenarios, on the order of 20,000 Mt. By comparison the TTAPS base-case scenario was 5,000 Mt. A 10,000-Mt scenario also was tested, but generally is considered to be unrealistically large.

relatively slow-speed Soviet computers. He returned to the United States for further study and research in 1980 and 1982. During his visits he requested and was granted access to a Cray-1 computer at the National Center for Atmospheric Research. His travel to the United States has been under scientific exchange agreements on climate research signed in 1972, well before Nuclear Winter became an issue.

21. In 1983, Aleksandrov was directed to work on Nuclear Winter, probably by Yevgeniy Velikhov, a vice president of the Academy of Sciences. Among his several duties, Velikhov is secretary of the Department of Information Science, Computer Technology, and Automation. This department, created in 1984, oversees the Computer Center where the main Nuclear Winter research is conducted. Velikhov's interest in Nuclear Winter stems from his participation in international scientific forums and his responsibilities as director of the Soviet effort to develop supercomputers. He probably learned of Nuclear Winter at one of the numerous international conferences he attended and recognized its potential to contribute both to Soviet knowledge of computer science and to influence international public opinion on the nuclear "arms race." Velikhov is politically influential and a prime candidate to head the Soviet Academy of Sciences. He is heavily involved in all areas of nuclear disarmament, concentrating particularly on the issues of militarization of outer space and the US Strategic Defense Initiative. Velikhov will continue to be the key person in shaping Soviet Nuclear Winter research, and, under his direction, it will continue to serve Soviet political purposes.

Yevgeniy Velikhov

Key promoter of Soviet Nuclear Winter research

22. Velikhov took the lead on Nuclear Winter and tasked the Computer Center, which quickly produced the first Soviet research report on the subject. The speed with which the report was produced is a highly unusual accomplishment in Soviet science. In April 1983, the basic input information was probably obtained at the TTAPS "Peer Review" in Boston. By August, a report was completed, printed in English, and delivered at the International Seminar on Nuclear War held annually at Erice, Italy. Such work would normally take years in the Soviet Union because of inherent difficulties in the system—slow computers, lack of computer paper, and so forth. In this case, Velikhov was able to bring together the necessary resources and get the job done. This was possible mainly because Aleksandrov obtained two versions of a general circulation model (GCM) during his earlier visits to the United States—something Hydromet had been unable to do.

23. To date, Soviet Nuclear Winter research has primarily involved a simplified GCM, derived from a US model, and run on a BESM-6 computer. In a 1983 preprint describing his work, Aleksandrov mentioned a 40-hour modeling run on the BESM-6. This was for a single calculation, one year into the future, on his highly simplified model. He also noted that similar calculations using a Cray-1 computer would require only about eight minutes. In addition to three BESM-6's, a YeS-1060 computer has been installed at the Academy's Moscow Computer Center, but operational difficulties with the YeS-1060 have thus far prevented successful use of a more advanced GCM. Consequently, Aleksandrov and Stenchikov continue to rely on the more simplified GCM using the BESM-6.

24. The Computer Center facilities impose severe limitations on their abilities to do realistic Nuclear Winter climate modeling. State-of-the-art calculations require hours of time on Cray-class supercomputers. During a single modeling run in the West, about 100 billion arithmetic operations are performed, at a typical computational rate of about 20 million floating-point operations per second (Mflop). The YeS-1060 is capable of roughly 0.3 Mflop for high-precision scientific modeling problems. Even the fastest Soviet scientific computer, the El'brus-1, is still less than one-tenth the effective speed of a Cray.

25. There has not been any significant Soviet research on Nuclear Winter beyond the two reports by Aleksandrov and Stenchikov delivered at Erice in 1983 and 1984 and frequently repeated elsewhere. However, other Soviet studies related to nuclear effects have recently been presented at international conferences because they generally support the possibility of serious climatic changes due to multiple nuclear explosions. For the most part, these additional reports represent earlier research, completed before the idea of Nuclear Winter became popular. These additional reports also represent some internal competition among various institutes in the USSR as they attempt

to gain additional recognition. One report [6] by Hydromet scientists concluded that gaseous byproducts of nuclear explosions, especially ozone in the troposphere and nitrogen oxides in the stratosphere, would produce lower surface temperatures that would persist because these pollutants would remain in the atmosphere much longer than smoke and dust. Another unpublished Soviet report [7] noted that the atmospheric injection of nitrogen oxides from nuclear testing during the 1950-63 time frame may have contributed to about a 0.3°C drop in average temperature. Data from nuclear testing in the early 1960s were scaled up to a 10,000-Mt nuclear exchange, and it was estimated that there could be a corresponding 10°C temperature drop without considering the effects of smoke and dust.

26. We expect further bureaucratic competition within the USSR on Nuclear Winter research, rather than a coordinated approach to improve understanding of the phenomenon. Research funds and personal prestige are at stake, including election to the Academy of Sciences or a promotion from corresponding to full membership. The main competition involves the Academy of Sciences' Computer Center and Hydromet. Yuriy Izrael', as director of Hydromet, may seek a larger role in Nuclear Winter research, using scientists with more experience in climate research than those found at the Computer Center. Izrael' heads bilateral exchanges with the United States on environmental science, including Nuclear Winter, and could insert more of his scientists into the exchanges or attempt to block Aleksandrov, or others from the Computer Center, from future meetings. Among the possible scientists to look for outside of the Computer Center is Igor Karol, at the Main Geophysical Observatory of Hydromet, who has done climate research that includes nuclear effects. Within the Academy of Sciences but not yet associated with Aleksandrov's group at the Computer Center, there are other scientists who may become involved in Nuclear Winter research. Gostinstev, with the Chemical Physics Institute, has been mentioned to possibly head up some fire experiments in the USSR. But, if present relationships continue, most of the research will be conducted at the Computer Center and it will not be well coordinated with other work in the USSR. Increasing involvement of Hydromet would be an important indicator that Moscow was becoming more seriously interested in Nuclear Winter.

27. We have not identified any secret research on Nuclear Winter in the USSR, but we believe that officials in the weapons development structure, at a minimum, are following the Nuclear Winter research being done by the Academy of Sciences. These officials would most likely include planners in the 12th Chief Directorate of the Ministry of Defense that formulate requirements for nuclear weapons. In addition, we would expect scientists at the two main nuclear weapons design centers at Sarova and Kasli also to be closely following Nuclear Winter research. These design centers fall under the management of the Ministry of Medium Machine Building. To date, we have no evidence of contacts between these organizations and Soviet scientists involved in the unclassified Nuclear Winter research.

Soviet Contributions

28. Soviet Nuclear Winter research is derived almost entirely from US ideas, data, and models. Because of pressure to produce results quickly, and given limited computer capabilities, Soviet research often is inaccurate and does not significantly advance the understanding of the Nuclear Winter phenomenon.

29. To date, there have been two main Soviet contributions to Nuclear Winter research. In 1983, the basic Nuclear Winter findings were tested using a three-dimensional GCM for the first time, whereas the original TTAPS study used a one-dimensional model.[8] In 1984, the effects of moving smoke were added to the Soviet GCM, whereas previous research had treated smoke in a static, uniform manner. These contributions are considered modest conceptual advances from the original TTAPS research. However, some internationally prominent scientists who have conducted research on Nuclear Winter have characterized the work as weak, crude, and seriously flawed. Nevertheless, it is currently the only national Nuclear Winter research program outside the United States. Regardless of the quality of the work, the USSR has effectively joined the scientific debate on Nuclear Winter.

[6] "Atmospheric Composition and Thermal Regime Model Changes After the Possible Nuclear War," by Izrael', Karol, Kiselev, and Rosanov of the Main Geophysical Observatory, Goskomgidromet, presented at Erice, August 1984.

[7] "Observational Evidence of the Impact of Nuclear Explosions in the Atmosphere," K. V. Kondrat'yev, presented in bilateral meeting with American scientists in Moscow, August 1984.

[8] The one dimension is altitude. The model used in the TTAPS study considers a single point on the ground as representing the average, year-round global temperature (15°C). The temperature at various levels of altitude above this point is then calculated for various changes in solar radiation corresponding to scattering and absorption of smoke and dust. A three-dimensional model includes longitude and latitude as well as altitude.

30. Soviet Nuclear Winter research consistently produces more severe results than similar research done in the West. For example, the original TTAPS study estimated a temperature decline of up to 30°C within a few weeks of a 5,000-Mt exchange. As would be expected, subsequent two- and three-dimensional studies that accounted for the moderating effects of the oceans noted less severe temperature declines of around 10°C. But Soviet research, using a three-dimensional model, found a temperature drop of about 40°C over the United States (figure 6). The addition of moving smoke to the Soviet GCM (figure 7) resulted in even more severe temperature drops than noted in the earlier Soviet research. These findings result from the unrealistically high input of smoke into the GCM. Soviet scientists have privately admitted their conceptual errors, but the results are nevertheless widely reported in the West without reservation or qualification.

31. Soviet scientists also tend to argue against factors that would moderate the effects of Nuclear Winter. For example, rainout may remove substantial quantities of smoke, but Soviet scientists argue that heating of the atmosphere would decrease its relative humidity and reduce turbulent convection that creates precipitation. In addition to discounting moderating effects, Soviet scientists note the relatively rapid movement of smoke into the Southern Hemisphere, thus bringing Nuclear Winter to Africa, Australia, and South America.

32. Soviet reporting on Nuclear Winter research often stretches conclusions well beyond what can be supported by research, most likely to further their propaganda effort. For example, the central conclusion of the 1983 Aleksandrov-Stenchikov Report was that a nuclear war would probably produce conditions under which man would not be likely to survive. (See inset.) Such conclusions have even been criticized within the Soviet scientific community. Dr. Budyko, with Hydromet, noted that small differences in parameters within various models can produce large differences in outcomes. In particular, he has pointed out that there has been too much duplication in Nuclear Winter research. He and others have called

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Soviet Scientists' Dramatic Portrayal of Nuclear Winter

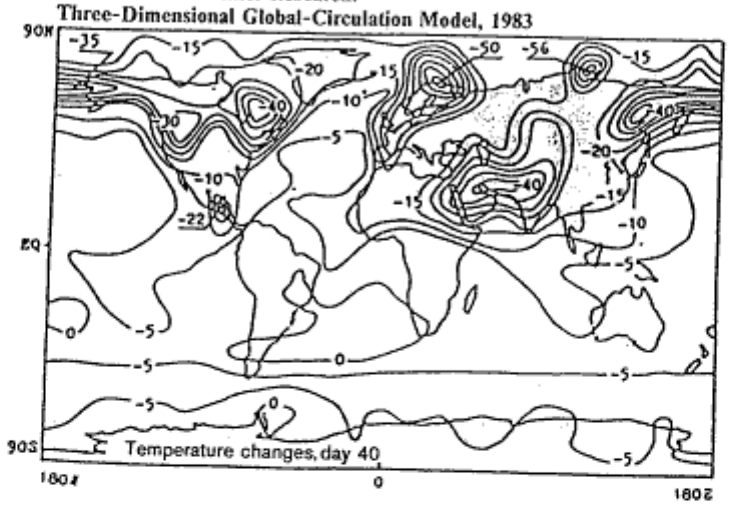
. . . Our three-dimensional hydrodynamic model of the climate shows that the Nuclear Winter will entail an avalanche of pernicious consequences. . . . This will generate severe storms along the coasts, causing enormous amounts of snowfall on land. This alone will evidently destroy life on the coastal zone. On the other hand, the changes in the atmosphere will completely change the hydrological cycle, and severe droughts will break out over the night-enveloped, frost-bound continents. In other words, everything living which hadn't been incinerated during the fires will freeze out. And if it survives in conditions of low temperatures, it will nevertheless die of thirst. But the earth's flora will not endure. . . . The forests of all middle latitudes will perish. . . . The planet's entire climatic system will pass into a new state . . . a new glacial period, possibly. . . . The temperatures over Tibet and the Cordilleras will be heated to such an extent that the giant masses of snow and glaciers will melt and precipitate inconceivable streams of water on the continents. It will be a deluge in conditions of severe cold . . . (Aleksandrov, 19 April 1984, on Moscow News in English)

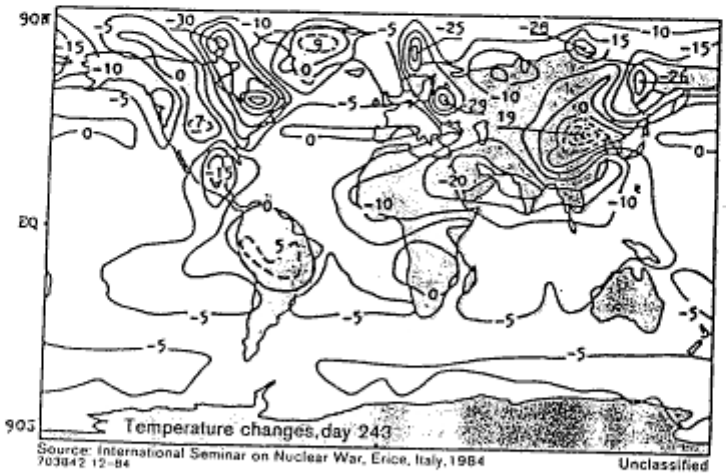
. . . Irrespective of the season of the year, a protracted Nuclear Winter will begin. In the hinterland of continents rainfalls will be almost zero, agricultural crops will perish, and domestic animals, even if they survive the cold, will die of thirst because fresh water for the most part will only be available in a frozen state. . . . The tropical forests, which are the main bearers of organic life on earth and the chief source of oxygen, will be killed . . . the biosphere will be left without its main source of oxygen. The effects I mentioned will arise practically in any nuclear war scenario. Even with an explosion of 100 megatons. . . . Therefore a nuclear war of any dimensions will signify either the disappearance of the human race or its degradation to a level lower than prehistoric. (Aleksandrov, 27 April 1984, in *Soviet Panorama*, No. 84, Novosti Press Agency Bulletin)

. . . The impenetrable black cover would spread from the northern hemisphere to the southern, and eventually enclose the entire planet. All sources of fresh water would freeze over, all ecological balances would be upset, and all harvests would fail. The total terrestrial biota, that is, the total population of various species of animals, plants, and microorganisms, would completely perish. . . . Conclusions drawn from our calculations indicated that if 100 to 150 megatons of nuclear fuel (that is, 50 times less than in the Sagan scenario) 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. . . . But even this would . . . ensure the end of life on earth. (Moiseyev, 3 August 1984, article "Scientists Warn: The World in the Aftermath of a Nuclear Strike: A Computer-Generated Prognosis," Novosti and Sovetskaya Kirgiziya)

Unclassified

Figure 6
Soviet Nuclear Winter Research:
Three-Dimensional Global-Circulation Model, 1983





Source: International Seminar on Nuclear War, Erice, Italy, 1984
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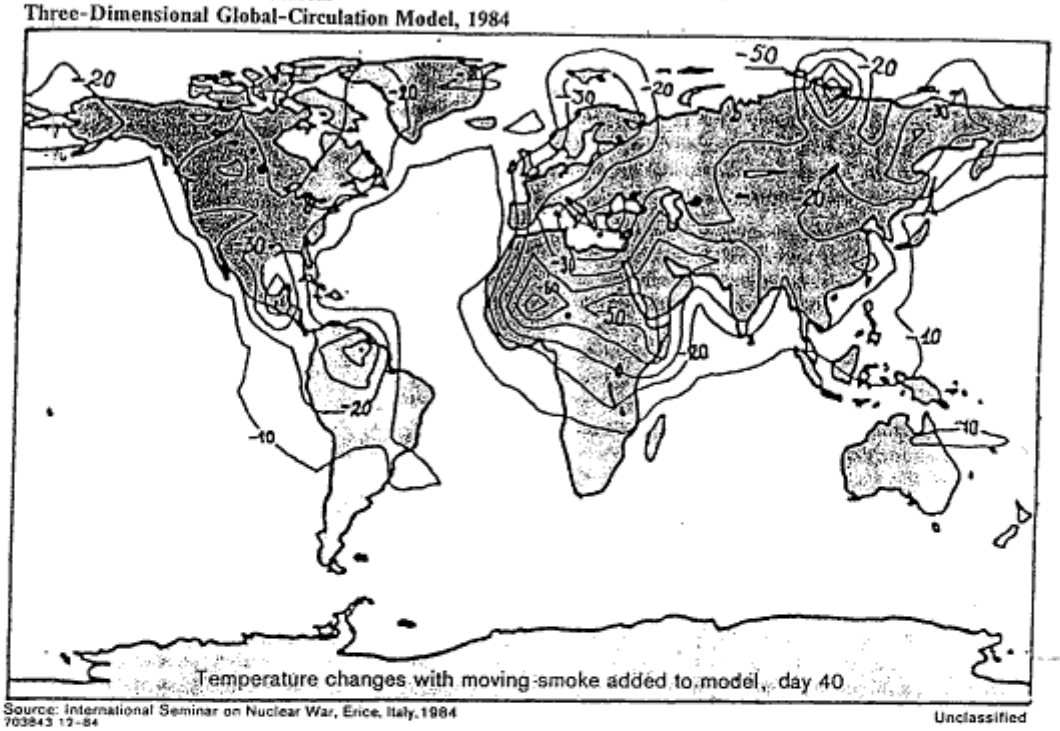
Figure 7
Soviet Nuclear Winter Research:
Three-Dimensional Global-Circulation Model, 1984



Source: International Seminar on Nuclear War, Erice, Italy, 1984
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Unclassified

for more independent research methods and more complete documentation of studies prior to their presentation at scientific meetings. Kirill Kondrat'yev, a Soviet specialist in atmospheric particles, has suggested that Aleksandrov and other "like-minded" scientists had reached conclusions far beyond what was justified by their limited work. Indeed, this frequently happens at international conferences, when Soviet scientists seem to stretch inferences. The tendency to overstate Nuclear Winter conclusions, however, is not limited to Soviet scientists.

33. Soviet research on Nuclear Winter does not stand up well to close examination. As noted, erroneous input data produced more severe climatic consequences. Soviet research, for example, used smoke parameters that were roughly equivalent to injecting about 700 million tons of smoke in the atmosphere—compared to 100-300 million tons estimated in the TTAPS study—and even these figures may be too high by a considerable margin. Although the Soviet scientists initially claimed that they were using data consistent with the TTAPS worst case scenario, they made some erroneous assumptions. They essentially treated dust and smoke equally, even though dust tends to scatter sunlight whereas smoke is more absorbent. Furthermore, they assumed that the combined smoke and dust absorbed all the sunlight, rather than a more reasonable estimate of 50 to 70 percent. Also, general hemispheric circulation patterns appear to be misplaced in Soviet reports.

34. Such basic errors are surprising for scientists of the caliber of Aleksandrov and Stenchikov[ ]does not believe the results of his large computer models because of the simplistic assumptions necessarily incorporated into the model[ ] they

publicly continue to voice the party line that Nuclear Winter is real and the effects are certain and severe. Western scientists have been amazed at this kind of intellectual dishonesty.

35. In addition to conceptual errors, Soviet research findings in many cases are not logically sound. These logical inconsistencies probably result from the limited data points used in the greatly simplified GCM, along with the limited knowledge of climatology among Soviet scientists at the Computer Center.

36. Research findings are quickly reported and not subjected to sensitivity tests. Soviet research on Nuclear Winter has not been documented in sufficient detail to understand clearly exactly what was done. Proposals to compare directly Soviet and US GCMs by using the same input data have not been favorably considered in the USSR. While these and other shortcomings become apparent to experts who take the time to inspect Soviet findings and question the scientists, the average participant at international conferences is only aware of the results of the Soviet research. And, in each case, the reported results amount to a severe Nuclear Winter.

37. While Soviet research has been cited as "independent verification" of the Nuclear Winter hypothesis, it falls far short of normal scientific standards for such claims. It represents more replication than verification because it lacks original Soviet data or models. When asked at scientific exchanges to provide data from Soviet atmospheric nuclear testing prior to the 1963 ban, Soviet scientists have not been able to respond. Early interest by Soviet scientists in joint experiments also apparently has been vetoed at higher political levels in the Soviet Union. Using data and models of US origin, it is not surprising that Soviet findings are similar to early studies in the United States.*

Technology Transfer

38. Soviet understanding of advanced computer modeling techniques probably has benefited from close cooperation with US scientists. For example, Aleksandrov has been able to use Cray computers in the United States and has demonstrated considerable skill in adapting complex models to a wide range of computers. At the same time, Aleksandrov has acquired advanced climatological models from the United States that could benefit Soviet theoretical science and provide practical applications in a variety of important fields such as agriculture. Soviet intelligence also could conceivably gain from contacts with US scientists.

39. At a minimum, frequent scientific exchanges enable the Soviet leadership to keep informed on the state of research in the West. In particular, we would expect Moscow to be interested in the prospects for asymmetrical damage—in which the USSR could incur somewhat more severe Nuclear Winter effects than the United States because the prevailing winds would move the smoke from the United States and Europe to the USSR more quickly than smoke from Soviet cities would arrive over the United States. To keep track of these and other developments, Soviet scientists will want to stay in close touch with Western scientists.

Implications

Political Benefits

40. In addition to technology transfer, Moscow derives several political benefits from a modest Nuclear Winter research program. The Soviet image as a responsible superpower is furthered by taking the Nuclear Winter issue seriously at international forums. Soviet officials have an informed position on Nuclear Winter that is not based solely on research conducted in the United States. Of course, it is no accident that Soviet Nuclear Winter research generally confirms longstanding Soviet pronouncements on the devastating nature of nuclear war.

41. Soviet interest in Nuclear Winter research also has the potential to influence arms reductions in the United States. Soviet leaders understand the American political process well, and by their active participation in conferences on nuclear war and arms control, they can support political forces that seek arms reductions and disarmament. As noted, Soviet presentations on Nuclear Winter consistently emphasize severe climatic consequences, and are widely interpreted as independent verification of the TTAPS study. Ongoing Soviet Nuclear Winter research ensures continued Soviet participation at international conferences (see figure 8).

42. We can already see widespread Soviet use of the Nuclear Winter theme abroad. The primary target audience is the international scientific community, because of its credibility and the "power of reason," with the ultimate goal of influencing Western political leaders. Direct face-to-face communication is emphasized because it is the most persuasive media. Thus, we note extensive Soviet participation in international scientific forums. These meetings also are widely

* A few Western scientists would disagree with these judgments and contend that Soviet Nuclear Winter research is original, independent, and contributes to further understanding of the phenomenon. They would further disagree with characterizing Soviet Nuclear Winter research as quick and careless.

publicized in the press, on radio, and on television. The themes that are generally emphasized in the Soviet media and often repeated in the West include:

— Nuclear war would have disastrous consequences for all mankind.

— There is no effective defense against a nuclear attack.

— There is increasing danger of nuclear war due to the "arms race."

— US actions are the main cause of the "arms race."

43. Nuclear Winter is appearing somewhat more frequently in the Soviet media aimed at foreign audiences. In the August to October 1984 time frame, for example, Nuclear Winter was discussed on about a weekly basis in Soviet foreign broadcasts and press releases. It also is appearing in a greater variety of Soviet media, including poetry and an article in the *Soviet Literary Gazette*. Much of the reporting is repetitive, citing foreign news sources, particularly from the United States and the United Kingdom. This lends credibility to the Nuclear Winter hypothesis by giving the impression of widespread, independent verification.

44. Nuclear Winter receives some attention in Soviet domestic media, largely in the context of the dangers of nuclear war. In such cases, the Soviet Union is characterized as leading the crusade for peace and disarmament. Contradictions between the Soviet concern with Nuclear Winter and Moscow's opposition to arms control agreements with deep cuts in strategic forces are not discussed.

Figure 8
Soviet Nuclear Winter Network

Research

- Computer Center

Scientific Comment

- Main Geophysical Observatory
- Institute of Problems of Mechanics
- Institute of Chemical Physics
- Institute of Physical Problems
- Institute of Atmospheric Physics
- Main Hydrological Institute

Political Comment

- Committee of Soviet Scientists in Defense of Peace and Against Nuclear War

International Forums

- International Seminar on Nuclear War (Erice, Italy)
- UN General Assembly, World Meteorological Organization, World Health Organization
- International Council of Scientific Unions, Scientific Committee on Problems of the Environment (SCOPE)
- International Physicians for the Prevention of Nuclear War
- World After Nuclear War Foundation
- Etc.

[a] Key individuals and organizations are discussed in annex A.

45. In addition to the public media, Soviet scientists continually stress the responsibility of all scientists to educate the public and the political leadership on the dangers of nuclear war in general. In particular, they argue that scientists should all work for peace by calling for a halt to the "arms race" and opposing the development of new weapons and the militarization of outer space. Clearly, Soviet leaders want US leaders to believe the Nuclear Winter hypothesis. On at least two occasions Soviet scientists have met with US Congressional leaders. On one of these occasions, Aleksandrov appeared before a Congressional subcommittee. Such access to the US political system is highly valuable to Moscow.

46. As part of this propaganda effort, ad hoc organizations have been created to produce reports, grant interviews, and sponsor exchanges (figure 8). For example, in 1983 the Committee of Soviet Scientists for Peace and Against Nuclear War was established with Velikhov as Chairman. One of the purposes of this organization is to:

> "mobilize the scientists' efforts in the struggle for preventing a nuclear holocaust, to draw a science-based and credible picture of the dangers of continuing along the route of the 'arms race,' which will lead mankind over the nuclear abyss, and to provide broad sections of the public and those who directly take political decisions with accurate scientific information."

47. The propaganda effort is well coordinated. In some cases, foreign attendees arrive at international conferences to find that the Soviet organizers have already prepared a draft final report, including a statement on the adverse consequences of Nuclear Winter. The subject has been raised in a variety of influential networks, such as the international medical profession. In this field, Soviet initiatives were in part responsible for the World Health Organization's adopting a resolution in May 1983 that "The role of physicians and other health workers in the preservation and promotion of peace is the most significant factor for the attainment of health for all." The World Health Assembly endorsed the conclusion that ". . . it is impossible to prepare health services to deal in any systematic way with a catastrophe resulting from nuclear warfare, and that nuclear weapons constitute the greatest immediate threat to the health and welfare of mankind." The Assembly recommended that the World Health Organization, in cooperation with other United Nations agencies, "continue the work of collecting, analysing, and regularly publishing accounts of activities and further studies on the effects of nuclear war on health and health services." Such efforts have met with considerable success in making the general public concerned about nuclear war.

Military Side Effects

48. Nuclear Winter research may raise some issues that Soviet military planners would want to consider, regardless of the climatic effects. For example, the smoke and dust generated by multiple nuclear explosions may obscure targets from overhead visual reconnaissance and could interfere with ground-to-satellite links. Reconnaissance may be precluded over large areas for long periods. Infrared sensors also may be degraded by the heat-absorbing aerosol particles. Radar imaging would be less affected except for a few hours and in areas where ground bursts produce very large quantities of dust. These considerations could affect the development of Soviet imaging systems. For example, we would expect added incentives to develop radar imaging systems for satellites, aircraft, and possibly the spaceplane.

49. Command and control systems also might be stressed by the effects of Nuclear Winter. High-frequency communications links and satellite ground control stations could be affected by increased dust and water vapor in the atmosphere. In addition, dust could interfere with aircraft engines, causing some degradation to flight operations. Also, the personnel that operate command and control systems may have difficulty functioning well during prolonged periods of cold and darkness. Thus Nuclear Winter concerns could reinforce existing efforts to improve capabilities for protracted war that include testing and training with prolonged occupation of underground command posts.

Outlook

The Base Case

50. We do not anticipate any changes to Soviet nuclear weapons policies or programs solely as a result of Nuclear Winter research. The scientific evidence is not yet convincing and, more important, Soviet leaders do not see any apparent response in US strategic programs to Nuclear Winter concerns. Lacking both of these conditions, we believe Moscow will continue to maintain a strategic force posture that supports their war-fighting strategy and depends primarily on missiles with large throw weights and on large numbers of

warheads. In addition, Soviet strategic planning will be further complicated by the prospective modernization of US, British, and French nuclear forces; NATO deployments of cruise missiles and Pershings IIs; and expanding Chinese strategic forces.

51. In any event, Soviet research on Nuclear Winter will continue, thus guaranteeing Soviet participation in the debate. But Soviet contributions are not likely to be significant. Analysis will be limited by the inadequate Soviet computer capacity to handle advanced climate modeling for at least the next several years. The prospects for new or original Soviet data also are poor. Individual Soviet scientists are interested in experimental research, but higher level approval will not be forthcoming, unless senior Soviet officials become more seriously concerned about Nuclear Winter. For present purposes, it appears that Soviet leaders are content to rely on US data. This will involve continued Soviet interest in scientific exchanges with the United States. Joint experimental research could provide access to US measurement technology, but there may continue to be reluctance to approve such work at high levels because the results could reduce the credibility of earlier Soviet research and Soviet scientists might eventually be put in an embarrassing position of agreeing to the possibility of much less severe climatic consequences.

52. The public presentation of Soviet views on Nuclear Winter has shifted from commentary on basic research to publicizing the policy implications. Soviet officials have noted that the main Nuclear Winter questions have been sufficiently resolved and there is a need to move on to dealing with the basic problem of superpower relations. Such views have been expressed by Moiseyev, Deputy Director of the Computer Center and a key administrator in the chain between Velikhov and Aleksandrov. Moiseyev wants to shift the focus to the larger context of "man in the biosphere," the subject of a forthcoming book he hopes to publish in the United States and the USSR. In linking the perils of Nuclear Winter to other serious environmental problems involving the superpowers, Moiseyev uses the analogy of passengers riding together in a small boat. In such a situation, any serious differences must be resolved to "mutual satisfaction." We can expect to see this theme associated with future Soviet reporting on Nuclear Winter.

53. Soviet scientists will seek to keep Nuclear Winter in front of the public, particularly in the United States and Western Europe. This will help keep pressure on Western governments to reduce their nuclear weapons inventories. We can expect to see the issue introduced into a wide variety of forums, especially the various United Nations agencies. Furthermore, Soviet officials will attempt to raise concerns about Nuclear Winter with members of the peace movement in Europe. In addition to the Soviet media, television documentaries on Nuclear Winter already have been produced in the United Kingdom and Japan. In the Third World, Soviet officials will exploit Nuclear Winter because research suggests that the consequences of nuclear war could extend to the Southern Hemisphere. All of these efforts will be part of a larger Soviet strategy to blame the United States for the "arms race" and get other countries to bring pressure on Washington to reduce the US strategic arms inventory.

54. We believe it is unlikely that Soviet positions on arms control will change dramatically solely as a result of Nuclear Winter research. Moscow will continue to oppose substantial reductions in their medium and heavy intercontinental ballistic missile force, other major alterations of their force structure, or serious limitations on their weapons modernization process. Pressures to retain a force large enough to carry out the major missions assigned to nuclear forces are likely to outweigh Nuclear Winter concerns.

Potential Dilemmas

55. The Nuclear Winter hypothesis is uncertain. While the Soviets will continue to exploit it for propaganda purposes, we believe that there is little chance for fundamental changes in Soviet nuclear weapons policies or major reductions in their nuclear arsenal as a direct result of published or ongoing research on this subject. If the Soviet leadership eventually were to accept Nuclear Winter effects as both credible and profound, it could lead to serious contradictions between these new considerations, on the one hand, and Soviet doctrine and weapons employment policies on the other. Such contradictions are obvious to the Soviets and would probably cause Soviet officials to demand exceptionally high standards of scientific proof for the Nuclear Winter hypothesis, standards that probably cannot be met.

56. The Soviets could be faced with several dilemmas if they had to reconcile the potential implications of the Nuclear Winter hypothesis with important tenets of their military doctrine. For example, Nuclear Winter would call into question those aspects of Soviet war-fighting strategy that emphasize preemptive, massive nuclear strikes, which, according to the hypothesis, would literally be suicidal for the Soviets even if US territory bore the brunt of the nuclear detonations.

Responses to this dilemma would be difficult for Soviet strategic planners; they apparently are highly skeptical of concepts of escalation control and small-scale strike options. Ultimately, increasing doubts that nuclear weapons would be used could undermine Soviet beliefs in the political utility of nuclear weapons. This, in turn, could result in more emphasis on conventional forces, biological weapons such as those achieved by genetic engineering, and directed-energy weapons.

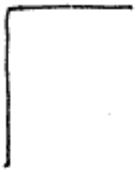
57. Nuclear Winter considerations also could pose dilemmas for Soviet research and development programs. In some respects, this could reinforce existing trends toward development of lower yields and better accuracy to reduce the climatic effects of strikes on critical targets. Nonnuclear warheads also could be considered for strategic targets. This might be especially attractive in the European Theater to reduce the possibility that effects from burning cities would extend to the USSR. In addition, targeting planners might consider target combustibility along with yield, height of bursts, timing, and other factors to reduce the amount of smoke and dust.

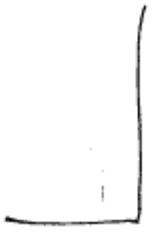
58. Nuclear Winter considerations also could complicate Soviet ballistic missile defense (BMD) planning. Large quantities of smoke, dust, and particulate matter in the atmosphere could degrade target detection, tracking, and intercept capabilities after the initial strikes. Also, more advanced BMD technologies may have to consider the effects of intercepts occurring in the boost phase, exoatmospheric, or terminal phase of missile flight in light of Nuclear Winter. Should Moscow become concerned with using BMD both to protect military capabilities and to prevent an attack from triggering Nuclear Winter, then a much more extensive defense capability would be required, including:

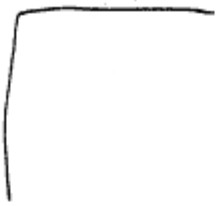
— Increased effectiveness to reduce leakage.

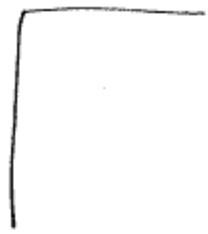
— Extended protection for urban areas, to reduce smoke and particulate matter.

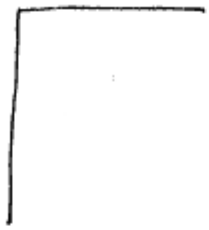
59. Nuclear Winter also could influence Soviet thinking about civil defense. Soviet agriculture may be more susceptible to damage than US crops because of weather patterns, greater geographical concentration, and less diversity of Soviet crops. Because of the potential damage to food production, Soviet civil defense officials could be forced to extend their planning time frames for basic survival to about a year, rather than about 30 days when fallout would be the major long-term consideration. Thus, substantial increases in civil defense food stockpiles might be an early indicator that Nuclear Winter was beginning to influence Soviet thinking at high levels.

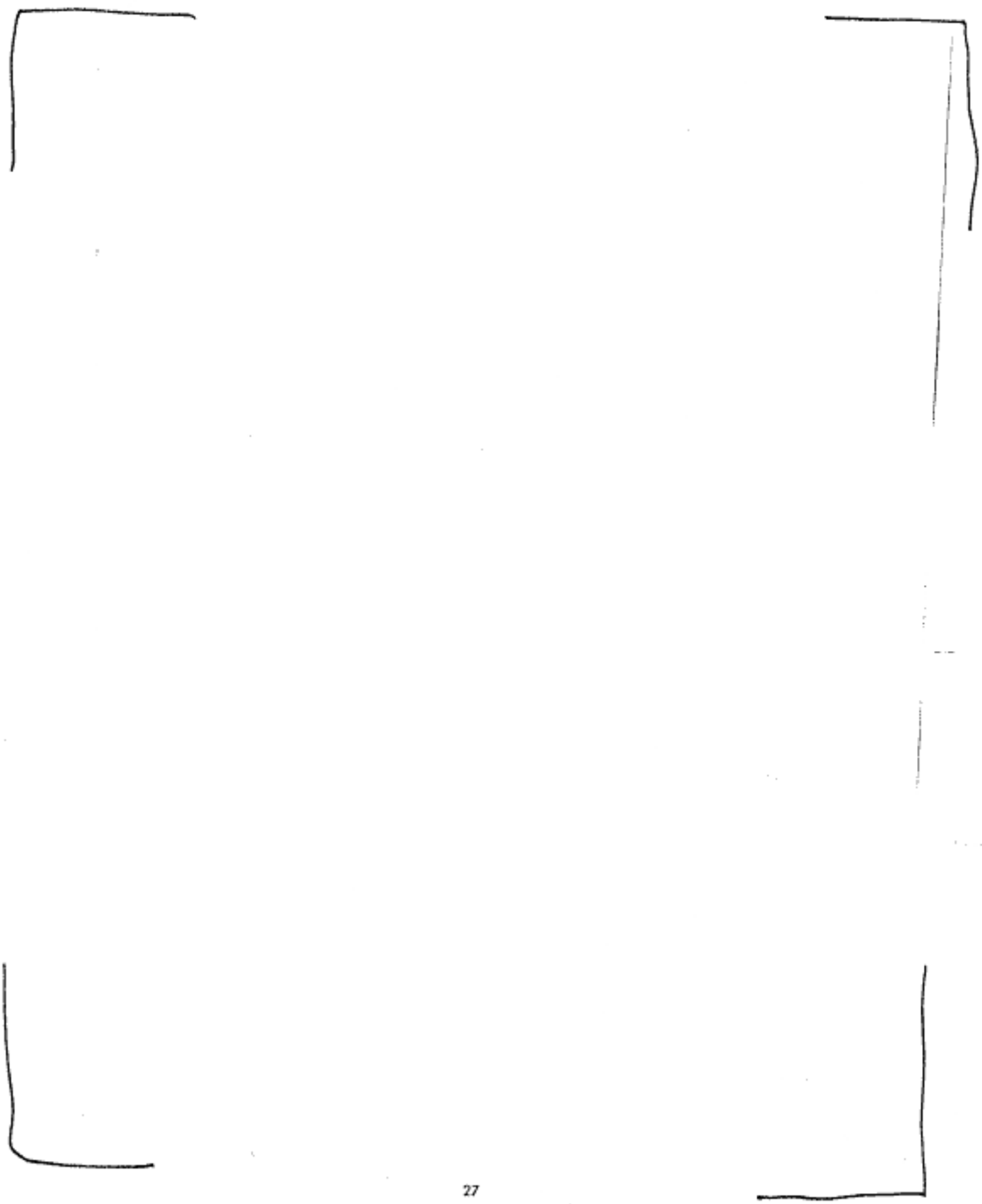


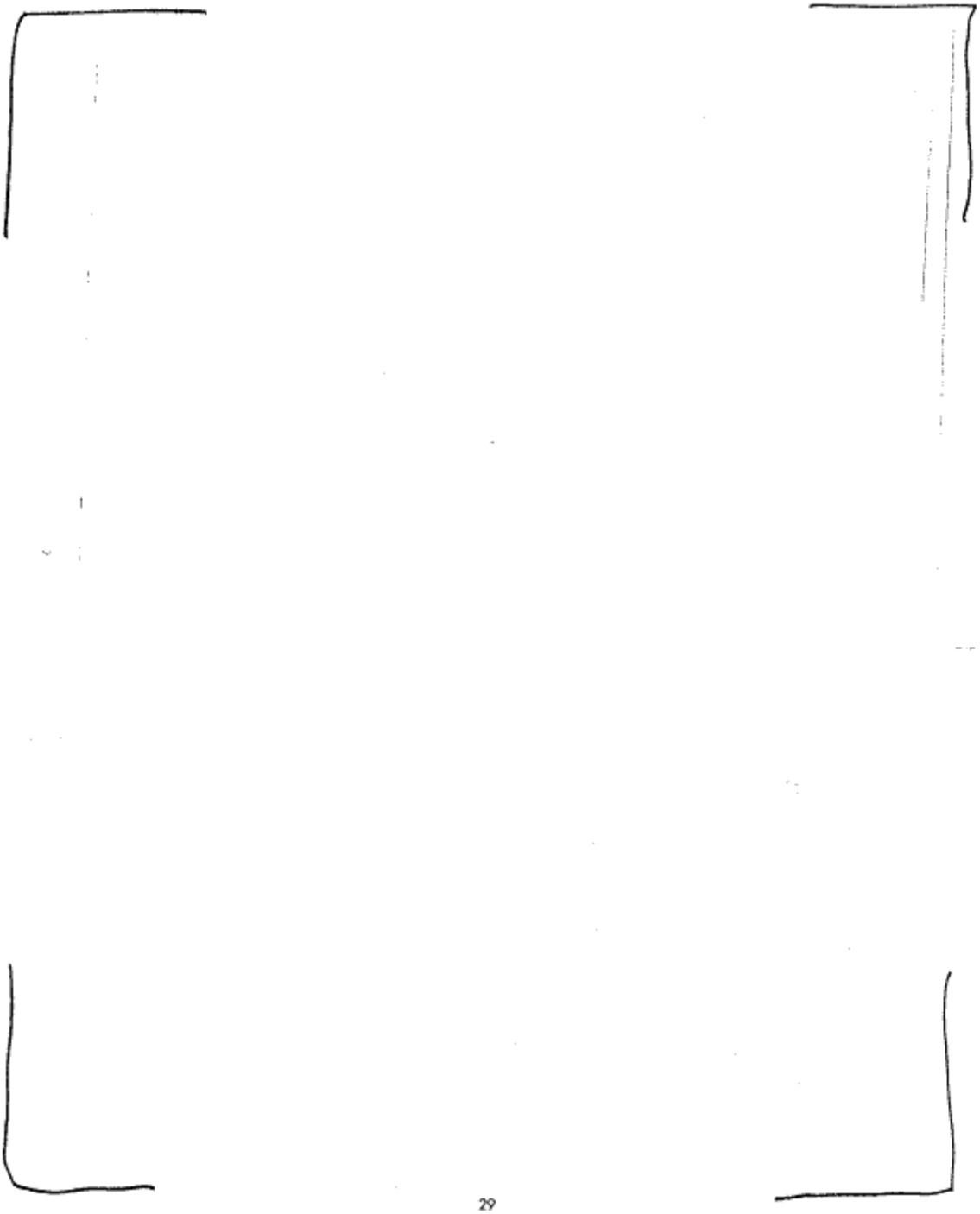












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Annex B

Selected Chronology of Nuclear Winter Discussions in International Forums

1983

April, Boston, TTAPS Peer Review. (Golitsyn)

17-19 May, Moscow, All-Union Conference of Scientists Against the Threat of Nuclear War, the Committee of Soviet Scientists in the Defense of Peace and Against Nuclear War established. (Velikhov, Golitsyn)

19-24 August, Erice, Italy, International Seminar on Nuclear War. (Velikhov, Aleksandrov)

October, Moscow, US-USSR Committee for International Security and Arms Control. (Velikhov, Skryabin, Blokhin, Bayer)

14-17 November, Second Vienna Dialogue for Disarmament and Detente, sponsored by International Liaison Forum of Peace Forces and World Peace Council. (Various Soviet scientists)

15-17 November, Stockholm, Sweden, Workshop on the Environmental Consequences of Nuclear War, sponsored by Scientific Community on Problems of the Environment (SCOPE), of International Council of Scientific Unions. (Various Soviet scientists)

16 November, Washington-Moscow TV hookup, Conference on World After Nuclear War. (Velikhov, Aleksandrov, Kondrat'yev)

23 November, Tbilisi, Georgia, USSR, Session of the Committee of Soviet Scientists in the Defense of Peace and Against Nuclear War, representatives of the Federation of American Scientists attend. (Velikhov, Golitsyn)

8 December, Washington, symposium of Soviet and American scientists, to discuss the effects of nuclear war. (Velikhov, Aleksandrov)

1984

January, Vatican meeting on the effects of nuclear explosions on the atmosphere, held at the Pontifical Academy of Sciences. (Aleksandrov)

7 March, Tallinn, Estonia, USSR, meeting of the Committee of Soviet Scientists in the Defense of Peace and Against Nuclear War. (Velikhov)

17 April, Ashkhabad, Turkmen Republic, USSR, meeting of the Committee of Soviet Scientists in the Defense of Peace and Against Nuclear War. (Velikhov)

9 May, Washington, conference between delegates of Committee of Soviet Scientists in the Defense of Peace and Against Nuclear War and representatives of the Federation of American Scientists. (Velikhov)

15 May, Leningrad, meeting of the Scientific Community on Problems of the Environment, International Council of Scientific Unions. (Aleksandrov, Golitsyn, Kondrat'yev)

June, Geneva, World Meteorological Organization, 36th seminar of Executive Committee. (Izrael')

4-8 June, Helsinki, Finland, International Physicians for the Prevention of Nuclear War. (Various Soviet scientists)

15 June, Leningrad, UN Regional Conference on World Disarmament. (Golitsyn)

19-24 August, Erice, Italy, International Seminar on Nuclear War. (Aleksandrov)

5-7 September, College Park, Maryland, Conference on Nuclear Deterrence. (Aleksandrov)

8 November, Glasgow, Scotland, conference on the effects of a nuclear attack. (Golitsyn)

18-20 November, Bellagio, Italy, International Conference on the Consequences of Nuclear War. (Skryabin)

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