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Climate effects of nuclear war in China*

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Abstract —By utilizing simulations of climatic respponse to nuclear smoke, which were made by the Lawrence Livermore National Laboratory, USA, climate change in China induced by a large-scale nuclear war is analysed. Remarkable climate change in China following nuclear smoke injections is found. The surface air temperature decreases dramatically around all China, surface cooling is 13 ℃ averaging over whole China in July and maximum cooling is 23. 4 ℃ , 3 ℃ cooling in January and maximum 8 ℃ for the 150 Tg smoke injection (equivalent to the base-line nuclear war). However, the change in temperature is unhomogeneous, implying that the rise in temperature happens over some parts of China. An averaging precipitation decrease in many of months of the experimental year. The precipitation defect is dependent on a scale of nuclear war, the deduction is 1.8mm/day averaging over China in July in the 150 Tg smoke injection, and 0.1 mm/d in January. Nevertheless, the precipitation enhancement in a few months over some regions is found. This dramatic climate change brings catastrophe to agriculture, ecology, as well as socio-economics.

Keywords: nuclear winter; climate simulation; precipitation change.

INTRODUCTION

Since the nuclear weapon exploded in 1945, people has pay more attention to climate effect of nuclear war. For a long time, it accounts for that much casualty and damage are limited within war parties, but small destruction meets with to non-parties of war. Crutzen and Birks proposed a view that global cooling is possible caused by a large-scale nuclear war, since then, the scientific hypothesis of "nuclear winter" has been of particular interest, leading many studies from various aspects. In 1988, the United Nation issued a report on casualties of 4 billion people killed possibly by a global nuclear war , it was a climax of the research topic and relevant political and environmental issues.

The gulf war and the following oil fire in Kuwait in January and February, 1991, stimulated people to study the "nuclear winter" again, because the oil fire in

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Kuwait, producing smoke even from a small area, impacts weather and climate over a large scale area. For example, Indian monsoon was influenced obviously, a global nuclear war must result in more serious and catastrophic consequences.

Cao and Liu (Cao, 1989) have studied the " nuclear winter" by using the one-dimensional energy balance model (EBM) with the smoke diffusion, whose results are only applicable to the global scale. For understanding the regional impact in China, we need the results simulated by the GCMs. Based on the Ghan's simulation by using the LLNL version of OSU (Oregon State University) GCM(Ghan, 1988; 1991), climate change induced by nuclear smoke injections is analysed in this paper.

MODEL AND EXPERIMENTS

The OSU climate model is a two-level general circulation model (400hPa and 800hPa, the atmopheric top being at 200hPa) with 4 latitude by 5 longitude grid (Ghan, 1982), land and ocean as well as topography are realistic, solar radiation has seasonal variation. Absorption and emission of infrared radiation by the aerosols are parameterized under the grey approximation. To permit the simulation of smoke transport and removal during the acute phase (the first month), this model is coupled with a Lagrangian trace species model as described by Walton *et al.* (1988). To treat interactions with the ocean mixed layer and sea ice, we have coupled the GCM with oceanic dynamical model (Pollard, 1983). This model solves the momentum, heat and mass balance equations for two layers, representing the ocean mixed layer and the thermocline, respectively. Besides, the GCM is also coupled to a sea-ice energy balance model.

For two reasons, the OSU/LLNL climate model was chosen. First, it is easy to work with and quite economical. Second, the treatment of several surface and subgrid-scale processes differs substantially from that in the other models which have been used in most other studies of "nuclear winter".

According to the recommendation by the SCOPE ENUWAR Committee (SCOPE, 1987) two smoke simulations have been performed. In the first case 50 Tg smoke (equivalent to the limit degree nuclear war) are injected into the troposphere over North American and Eurasia with a uniform mixing ratio in the vertical during the first three days of July. Second, high smoke case consists of 150 Tg smoke injected with a constant density within the troposphere and density decreasing linearly with altitude to zero at 3 km above the tropopause. Both the 50 Tg and the 150 Tg simulations are extended through the second July following the smoke injection. Global climate effects in the simulations has been studied (Ghan, 1991), and the main results are cited here as follows.

The ocean mixed layer cools by 3 – 6 ℃ within months following the smoke injection, and 1 – 2 ℃ thereafter. Land surface cooling is 10 – 20 ℃ in the acute phase and 2 – 5 ℃ in the chronic phase. Sea ice expands by up to 10 million km^2, or 2% of the global ocean area. Snow cover expands by more than 40 million km^2 (25% of global land area) briefly at high latitude, but by no more than 10 million km^2 thereafter.

The data in this study covers from 22°N to 46°N and from 85°E to 125°E, there are 56 grid points in China and adjacent area. Statistics of daily mean temperature and daily precipitation have made for from July following the smoke injection to second June.

CONTROL SIMULATION IN COMPARISON WITH OBSERVATION

The experimental work includes three simulations: the control simulation, i.e., the integration without smoke injection, the 50 Tg smoke injection and the 150 Tg smoke injection. The control simulation is equivalent to a scenario without a nuclear war, so the control simulation should be theoretically in agreement with observation. In order to verify the agreement we use t hypothesis test

$$t = (\bar{x}_1 - \bar{x}_2) / \left[\frac{(S_1 N_1 + S_2 N_2)(N_1 + N_2)}{N_1 N_2 (N_1 + N_2 - 2)} \right]^{1/2} ,$$

where $\bar{x}_i = \frac{1}{N_i} \sum_{j=1}^{N_i} x_{ij}$

$$S_i = \left(\frac{1}{N_{i-1}} \sum_{j=1}^{N_i} (x_{ij} - \bar{x}_i)^2 \right)^{1/2} , \quad i = 1,2 ,$$

where $N_1 = 56$ being the number of simulated grid, $N_2 = 56$ the number of observed grid.

When $t < t_a$, it indicates the difference between the simulated climate and the observed one at present-day is not significant. We take $a = 0.05$ then $t_a = 1.98$. The observations have read from CMB(1981).

The difference of 9 months from the tested 12 months for precipitation are not significant, i. e., the simulated precipitations are not different significantly from the observed, only in June, July and December it is different significantly from the observed, namely, precipitation simulations in many months are satisfactory. Because the climatic variability in precipitation is normally great, particularly in summer, it is pre-expected that the simulation of these three months will not be good. The difference of 11 months from the tested 12 months for the surface temperature is not significant, only in April it is different significantly from the observed, it means the simulation in temperature is better than precipitation. In light of months at 20/24=83% in both precipitation and temperature being well simulated, we account for that the simulations are confident overall.

Noting that as the OSU GCM is a global model with only two levels, we must employ this simulation for regional climate study. For example, though the simulated surface temperature Ts in January is in agreement with the observed via *t*-test as an ensemble, indicating there is no significant difference between *Ts* and observation T_0, the $\Delta T = T_s - T_0$ in many grid points is quite large, for example, in the point 30°N, 96°E, $\Delta t = -20$ ℃ being of the order-of-magnitude of cooling in July in "nuclear winter". It shows that the simulation by the OSU/LLNL model is not satisfactory to China But comparison is to do for the difference between the multi-year climatic mean and the simulated mean calculated from 30 days for same year or following year. Obviously, the different property of two sorts of data leads to unsatisfactory. Therefore, utilizing the simulation by a global climate model to study the regional climate, only can to understand the general climate change in a global scale rather than the detail changes in an individual point.

CHANGE IN TEMPERATURE FIELD

The change in surface air temperature following smoke injection and denote the difference are as follows:

$$\Delta T = T_s - T_c \ ,$$

where T_s is surface air temperature following smoke injection, being T_{50} for the 50 Tg smoke injection case, T_{150} for the 150 Tg case. Either in the 50 Tg case or in the 150 Tg case, the most remarkable cooling is in July, for all grid points, averaging cooling is 13 ℃ in the 150 Tg case, because it is in the acute phase of "nuclear winter". Cooling is 3 ℃ in the following January, maximum cooling is 8 ℃ . Cooling is minimum in the following April, i.e., for all grid points, the averaging difference $\overline{\Delta T} = -1$ ℃ in the 150Tg case as the "nuclear winter" is in the chronic phase. Cooling area in most months covers a half of China. In September and in October cooling is found in all parts of China. Maximum ΔT in July is -17.9 ℃ in the 50 Tg case, whereas maximum $\overline{\Delta T}$ in July in the 150 Tg case is -23.4 ℃ . Some parts of China appear warming following smoke injections. Noteworthily, warming area vary with different month, showing the change in temperature induced by the nuclear war is complicated.

Specifying July, October, January and April as representative of summer, autumn, winter and spring, respectively, we seek maxima in warming and cooling from all grid points, thus statistics are given in Table 1.

Warming in some regions is quite great, because the land surface is heating following collapse of normal monsoon. The surface air temperature is exaggerated due to much sensitivity of the surface air temperature to the soil moisture. Warming areas found in the "nuclear winter" are attributed mainly to the defect of the climate model.

Table 1 Maxima in warming and cooling in July, October, January and April

Unit: ℃

	Scale and ΔT			
	50Tg		150Tg	
	Warming	Cooling	Warming	Cooling
July	8.3	−17.9	1.4	−23.4
October	no	−7.1	2.1	−13.0
January	5.7	−9.9	4.1	−8.9
April	4.0	−8.9	2.4	−9.6

Fig. 1 depicts the temperature differences in the 50 Tg injection (a) and the 150 Tg injection (b). Cooling is getting on greater from the 50 Tg to the 150Tg injection. In both smoke injections, the patterns of the cooling and warming distribution are similar to each other. There is a broad cooling zone extending from northeast China,

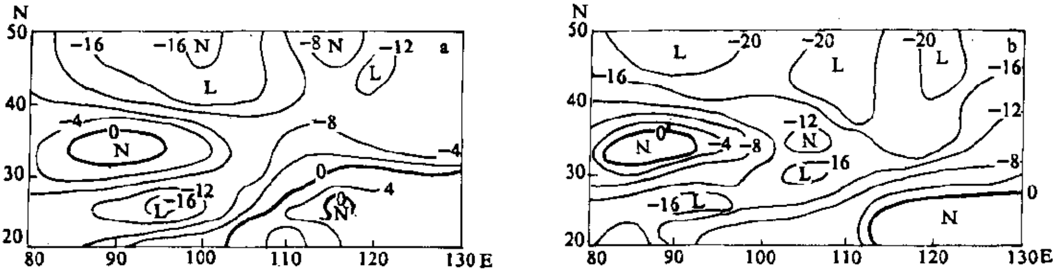

Fig. 1 Temperature difference between the smoke injections and the control simulations T_c in July

a. $T_{50}-T_c$, T_{50} is temperature in the 50 Tg injection;

b. $T_{150}-T_c$, T_{150} is temperature in the 150 Tg injection; *N* shows warmer; *L* shows colder north China to southwest China. A vast warming area covers from the north of the Tibet plateau to the southern part of Xinjiang autonomous region, the maximum warming is 2 ℃ in the 50 Tg case. The other area centralizes in Mt.Wuyi where the maximum warming is 8 ℃ .

Obviously, cooling in January is much smaller than in July (Fig.2), cooling in daily mean temperature in the 50 Tg case is 4 ℃ , in the 150 Tg case 8 ℃ . Besides, a weak warming area in the Tibet plateau is found. In view of the sustainability of human-being, the nuclear war with 50 Tg smoke injection causes calamity but not serious. Nevertheless, cooling in the 150 Tg case goes beyond the sustainability of human-being.

In order to investigate the impacts of the nuclear war on climatic zones, cooling values are calculated for the middle extratropics, the south extratropics, the plateau zone, the tropics and the subtropics in China (CMB, 1981). In the plateau zone cooling is small in the 50 Tg case whereas warming happens in March and April with the maximum warming 4 ℃ . Cooling in the subtropics and the tropics is significant in the 150 Tg case, However cooling happens in all months in the middle extratropics and the south tropics. Among them, cooling is 19.8 ℃ averaged in the middle extratropics in January. Warming in August, September and in March, April, July in the following year and cooling in the other months with a small amplitude are found in the plateau zone.

CHANGE IN PRECIPITATION FIELD

Statistics of reduction and enhancement in precipitation from July to following June has been made (Table 2). Hereby, the outline of change in monthly precipitation

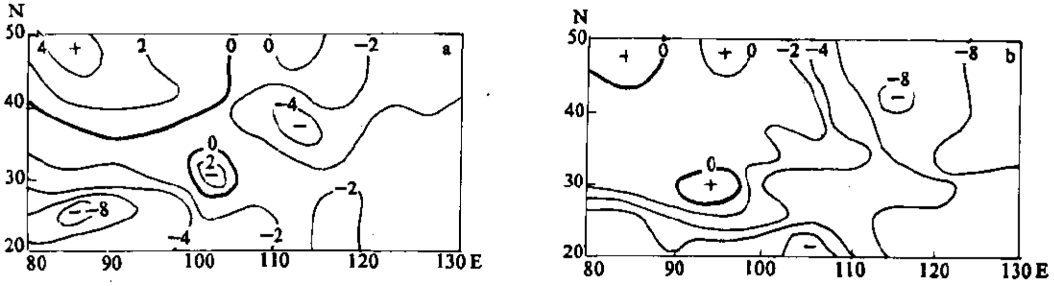

Fig. 2 Temperature difference between the smoke injections and the control simulations T_C in January

a. T_{50}-T_C; T_{50} is temperature in the 50Tg injection;

b. T_{150}-T_C; T_{150} is temperature in the 150 Tg injection can be inferred, the basic trend in precipitation following the nuclear war is to be reduced, but somewhere the precipitation increases and in the other places the precipitation decreases. The coverage of rainfall reduction in July and November is most large, being 45/56=80% reduction in the 150 Tg case and 70% in the 50 Tg case, as July is in the acute phase. Reduction grid points are 79% and 77% in the 150 Tg and 50 Tg case, respectively. The change in precipitation in January is in the other way, i.e., enhancement in precipitation is found in quite a lot of places, for example, the coverage of enhancement points is 45% in the 150 Tg case and 57% in the 50 Tg case.

Table 2 Statistics of monthly precipitation change in 50 Tg and 150 Tg smoke injections

Unit: mm/d

	150Tg				50Tg			
	Mean	Maximum enhancement	Maximum reduction	Number of reduction points	Mean	Maximum enhancement	Maximum reduction	Number of reduction points
July	−1.8	3.1	−8.5	45	−1.4	8.0	−8.5	40
October	0.3	6.4	−1.9	36	0.3	2.8	−1.3	24
January	−0.1	1.4	−2.6	31	0.0	2.0	−2.4	24
April	−0.1	5.2	−9.6	44	−0.5	5.2	−8.7	34
Anually average	−0.6	3.6	−5.1	37	−0.3	4.2	−4.0	32

The change pattern in precipitation in the 50 Tg smoke injection is rather similar to that in the 150 Tg smoke injection. In the eastern part of China in the 50Tg case there is a boundary along the Huaihe River-Mt. Qinling-Mt. Bayankelashan line. North of it there is a reduction zone with the maximum reduction in north China and south of it there is an enhancement zone with the maximum enhancement in the middle and lower Yangtze River.

The boundary migrates southward to the Yangtze River-Mt. Tanggulashan. The change in precipitation is almost the same in both the 50 Tg and the 150 Tg cases when CO_2 is doubled. The change in precipitation in July is not larger in comparison with the change in temperature. No significant change in the 50 Tg case is found, but in the 150 Tg case the change in precipitation become large, for example, the reduction in precipitation along Mt. Wuyishan-Mts. Nanling is remarkable.

In view of climatic zones, change in precipitation in the subtropics and the tropics is abnormal. The precipitation reduction in July and August in the 150 Tg smoke injection is noteworthy. The enhancement in precipitation during October to February is also remarkable. In the plateau zone, the precipitation reduction in all months in both the 50 Tg case and the 150 Tg case is found, reducing 2.6mm/d in July in the 150 Tg case. The precipitation reduction in most months in the middle extratropics and the south extratropics is found, but slight enhancement in a few months.

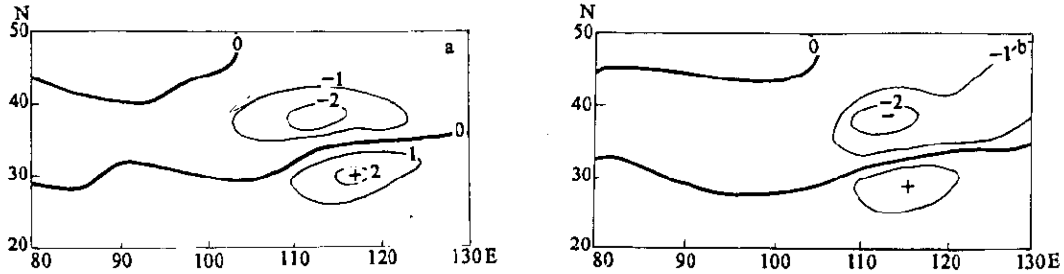

Fig. 3 Precipitation difference between the smoke injections and the control simulation Pc in January

a. P_{50}-Pc; P_{50} is precipitation in the 50 Tg injection;

b. P_{150}-Pc; P_{150} is precipitation in the 150 Tg injection;

+ shows a positive differene; − shows a negative difference

SEASONAL VARIATION

Fig. 4 depicts the seasonal variation in surface air temperature in the grid points (a) 22^0N, 110^0E (near Yulin, Guangxi Province); (b) 30^0N, 110^0E (near Enshi, Hubei Province); (c) 38^0N, 115^0E (near Baoding, Hebei Province), which represents the climate in south China, the middle Yangtze River, and north China, respectively. The model can better simulate subtropical climate into which south China is classified. Cooling in 22^0N, 110^0E in the 50 Tg case is not large, but larger in the 150 Tg case, maximum difference $T=T_{150}$-T_C is −9.3 ℃; nevertheless warming is not found in all months. The climate in the middle Yangtze River is characterized by prominent four seasons with a warm summer and cold winter, highest temperature being in July and August. Therefore, most cooling following the nuclear smoke injections happens in this period, cooling in August in the 150 Tg case being 16.2 ℃. Slight warming is found in May in the 50Tg case. Maximum cooling of 19℃ in surface air temperature following the 150 Tg smoke injection is found in July and slight warming happens in February, April and May in north China (Fig.4c).

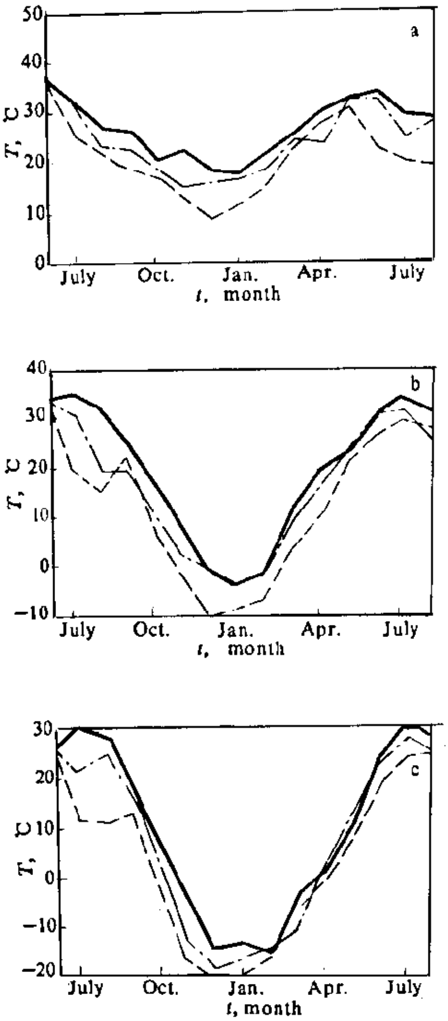

Fig. 4 Variation in surface air temperature with month in three grid points simulations
a. 22°N, 110°E; b. 30°N, 110°E;
c.38°N,115°E

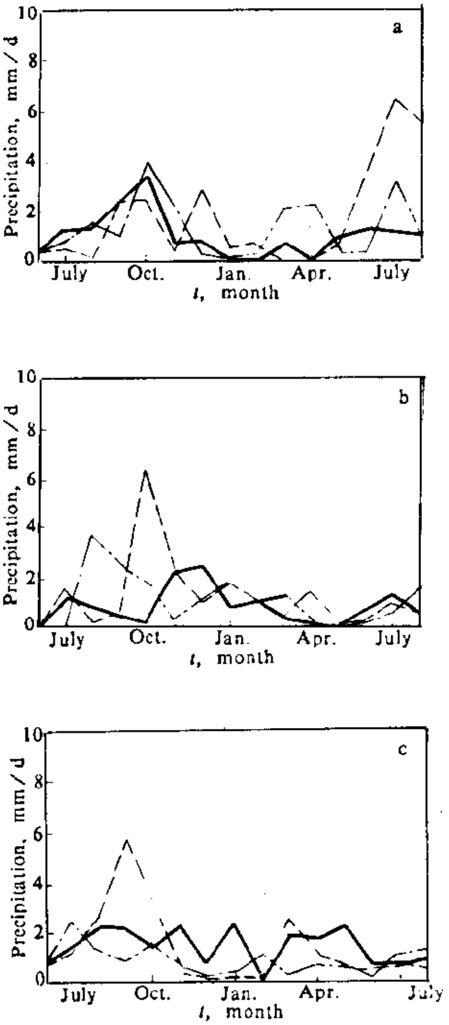

Fig. 5 Seasonal variation in precipitation in the three grid points
a. 22°N, 110°E; b. 30°N; 110°E;
c. 38°N,115°E

Control (solid line); 50Tg smoke(dotted line); 150Tg smoke (dashed line)

In general, the change in precipitation following the nuclear war is complicated, month to month variability is larger. Seasonal variation in the observed precipitation shows a bi-peak pattern with a pre-rainy season in September in south China (Fig.5a). The simulated pattern is in agreement with observation, though the simulated peak months lag at one month. The reduction in precipittation from July to October following the smoke injection is found, but the enhancement thereafter, Among them, the enhancement in precipitation in July of following year in the 150 Tg case is 5.9mm/d. The seasonal variation in precipitation in the middle Yangtze River is of one-peak pattern with maximum rainfall in June and July. The simulated pattern is in disagreement with the observed, particularly, the simulated maximum precipitation is wrong in December. The change in precipitation following the smoke injection is opposite to that in south China, namely, the precipitation enhances through first three months and thereafter reduces or enhances with small values. The enhancement in precipitation in October for the 150 Tg case is 6.4mm/d. Fig.5c presents the change in precipitation in north China. The simulated seasonal variation is in general agreement with the observation characterized by a concentrated rainfall in July and August, but scare precipitation in winter, namely an one-peak type. The basic characteristics in precipitation is an enhancement in the first couple of months and reduction thereafter in the "nuclear winter". The precipitation curve posses bi-peak type peaks with in September and in the following March, respectively. It reminds us that the climate change in north China is pronounced, therefore, crops, ecological system and human-being is difficult to adapt it.

CONCLUSIVE REMARKS

An attempt to study the "nuclear winter" in China simulated by the GCM is preliminarily made in this paper. There are several uncertainty in the nuclear war simulation, for example, smoke injection amount and smoke life-time. In addition, present GCMs are not sophisticated enough to simulate a regional climate. Therefore, high reliability of this sort of analysis is not to be expected. However, the main conclusion drawn from above work is that the "nuclear winter" causes mainly coldness and drought, i. e., dramatic cooling and a modest reduction in precipitation, but warming and enhancing in precipitation in some regions. In a word, the climate in China induced by the "nuclear winter" is complicated because China covers various climatic zone and various land surface.

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