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# Influence of Atmospheric Nuclear Explosions on Climate Change

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## ABSTRACT

*This article suggests that the 0.5K stagnation in the global-mean surface temperature (GST) between 1945 and 1976 would be due to the atmospheric nuclear explosions, namely, Gadget, Little Boy, Fat Man and the succeeding at least 422 times nuclear weapons testing between 1946 and 1980. Estimation on GST drop due to the atmospheric nuclear explosions based on the published numerical simulation results was at least between 0.07K and 0.8K. The 0.5K GST stagnations was in the range of the estimation. Three supporting evidences, namely the radioactivity deposition volume in Tokyo, Japan, radioactivity concentration in livestock bones in Hokkaido, Japan and the diameter of the radionuclides from the Chernobyl accident were also shown. The accuracy of the simulation on GST in IPCC's AR4 would be significantly improved by including the influences of the particulate matters by the atmospheric nuclear explosions in their global climate model. A method to lower GST by injecting fine limestone powder to the upper troposphere and the stratosphere was proposed. A possibility of global warming deceleration was pointed out based on the observation and the estimated influence of the atmospheric nuclear explosions. Another possibility that we are suffering a "petit nuclear summer" was also pointed out.*

## 1. Introduction

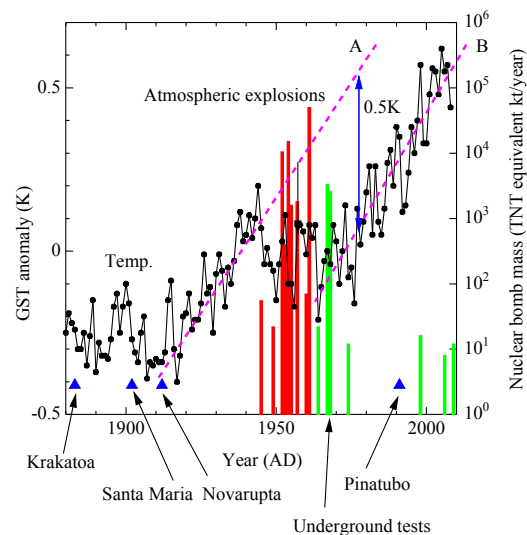
The global-mean surface temperature (GST) has been basically rising in this one hundred and several ten years (Fig. 1). The rise in GST looks stagnated around 1900. This is because of the biggest eruptions and the inactiveness of the sun (Fig. 2). The rise in GST looks stagnated again between 1945 and 1976. The difference before (Line A in Fig.1) and after (Line B in Fig. 1) the stagnation is approx. 0.5K. The stagnation was not simulated well in AR4 by IPCC and causes of this stagnation are still left unknown.

This article suggests that the stagnation was due to the atmospheric nuclear explosions, namely, Gadget, Little Boy for Hiroshima, Fat Man for Nagasaki and the succeeding nuclear weapons testing between 1945 and 1980. Supporting evidences including estimation on GST drop due to the atmospheric nuclear explosions based on the numerical simulation results will be described. The application of the GST stagnation to the global warming mitigation will be shown and the possibility of deceleration of the global warming will also be pointed out.

## 2. Possible cause of the GST stagnation between 1945 and 1976

The 0.5K stagnation cannot be explained by solar activity since it showed a maximum in 1957 (Fig. 2). There were no giant eruptions with VEI 6 between 1945 and 1976. It can be noted that the 0.5K stagnation began in 1945 when the atmospheric nuclear weapons testing of Gadget and the atomic bomb attacks by Little Boy against Hiroshima and Fat Man against Nagasaki were carried out. The stagnation lasted for the period in which the most atmospheric nuclear weapons testing were carried out. The temperature rise began again in 1977, 14 years after PTBT (Partial Test Ban Treaty) prohibited atmospheric nuclear weapons testing in 1963, at the almost the same rate (Line B in Fig. 1) as the

previous (Line A in Fig. 1).



*Fig. 1 Anomaly in global-mean surface temperature by NASA between 1880 and 2008 with the biggest eruptions whose VEI (volcanic explosivity index) is 6 (Wikipedia, "VEI") and TNT equivalent mass (Wikipedia Ja, "Nuclear Weapons Testing") of historic nuclear explosions only.*

The total TNT equivalent mass of the 425 times atmospheric nuclear explosions between 1945 and 1963 was 545 Mt (Hishida, 2001). France continued and China began atmospheric nuclear weapons testing after PTBT until the last one by China in 1980. This would be the cause why the stagnation continued to 1976. Detailed investigation should be done in future although the mass of the nuclear bombs after PTBT would be rather small.

Hishida (2001) pointed out that the bombing in World War

II and the atmospheric nuclear weapons testing might have influenced the regime shift between 1940 and 1975. However, the author would like to concentrate on the influence of the atmospheric nuclear explosions. Thompson et al. (2008) suggested that 0.3K GST drop in 1945 was due to the change in the method to measure temperature for SST (sea surface temperature) from engine room temperature (US ships) to uninsulated bucket measurement (UK ships). However, the author is not discussing the short-term GST drop in 1945 but the stagnation which lasted for 32 years from 1945 to 1976.

It is well known that nuclear wars can induce "nuclear winter" (Ehrlich et al., 1985). The smoke from nuclear war can reach the upper troposphere and rapidly spread with the jet streams. It can also reach the stratosphere to stay there for several months to years reflecting insolation. Temperature drop for a 3000 Mt nuclear war without smoke from cities is 10 K and lasts for approx. one year in the simulation. On the other hand, temperature drop for a 100 Mt nuclear war with smoke from cities is simulated as 32 K and lasts for several months. The climate model used in Ehrlich et al. (1985) was a simple one. However, recently, Robock et al. (2007) obtained similar results by using a modern climate model for only cases with smoke from cities.

The amount of radio activity deposition ( $^{90}\text{Sr}$ ,  $^{137}\text{Cs}$  and  $^{239,240}\text{Pu}$ ) in Tokyo was at a high level from the beginning of the monitoring in 1957 to 1963 and then decreased to approx. 1/1000 - 1/10000 in 1990 and it has kept the constant low level except for the short-term high levels of  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  due to the Chernobyl accident in 1986 (Igarashi et al., 2008, Fig. 3). Another research shows distinct peaks of  $^{90}\text{Sr}$  concentration in horse and cow bones in Hokkaido, Japan in 1965 and 1966, respectively (Takahashi et al., 1980, Fig. 4). There would be some delay for radioactive to be accumulated in livestock bones. The properties of smokes by atmospheric nuclear explosions were not clarified yet. However, the diameter of the most radionuclides from the Chernobyl accident sampled in Tokyo was less than  $1\ \mu\text{m}$  (Hirose et al., 1993, Fig. 5). This diameter is small enough to stay in the stratosphere for a long time as SPM2.5.

The above researches indicate that atmospheric nuclear explosion generated PM (particulate matters) at a high concentration till 1963 (PTBT year) and the concentration decreased to 1990 and now the concentration is at a very low level. The cause of the variations in radioactivity deposition amount is undoubtedly the atmospheric nuclear explosions. The author has a strong confidence that a significant amount of PM due to the atmospheric nuclear explosions was incessantly sprinkled to the upper troposphere and the stratosphere between 1945 and 1980 and the particulate matters caused the 0.5K GST stagnation.

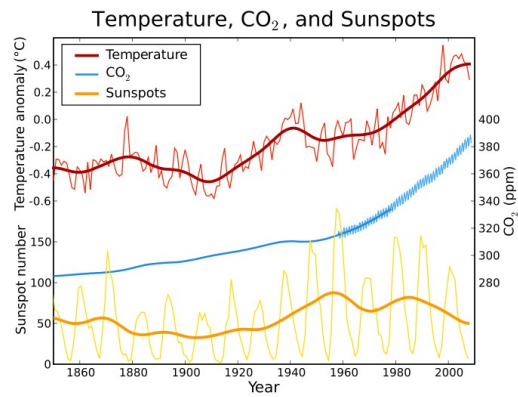


Fig. 2 Number of sunspot with GST anomaly and  $\text{CO}_2$  concentration (Wikipedia)

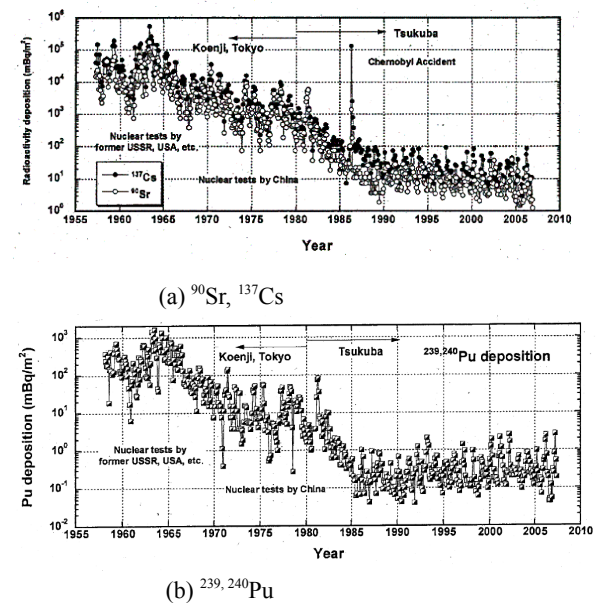


Fig. 3 Radioactive deposition in Tokyo (Igarashi et al., 2008)

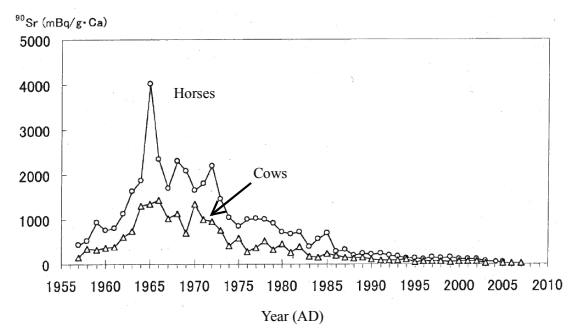


Fig. 4  $^{90}\text{Sr}$  concentration in horse and cow bones in Hokkaido, Japan in 1965 and 1966, respectively (Takahashi et al., 1980).

### 3. Estimation of GST drop by atmospheric nuclear explosions

Thompson et al. (2008) estimated that GST drop by only Little Boy (15 kt) and Fat Man (21 kt) was 0.03K based on Robock et al. (2007). GST drop by Gadget, Little Boy, Fat Man and the 422 times, 545 Mt atmospheric nuclear

weapons testing was estimated as follows.

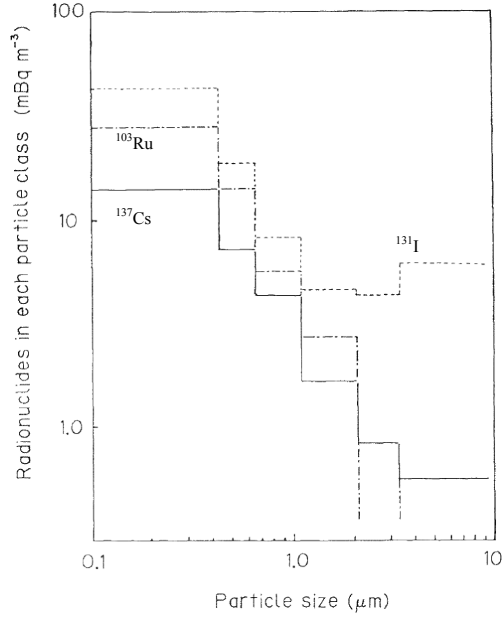


Fig. 5 Particle size distributions of  $^{131}\text{I}$ ,  $^{103}\text{Ru}$  and  $^{137}\text{Cs}$  observed at Tsukuba, Japan during the period of 6-10 May 1986 (Hirose et al., 1993).

Cumulative GST drop (*CGD*, Fig. 6a) for the cases with smoke from cities was roughly calculated based on the numerical results by Ehrlich et al. (1985) and Robock et al. (2007). *CGD* has an almost linear relationship with total TNT equivalent mass of nuclear bombs in a nuclear war on the log-log plot as shown in Fig. 7 and Eq. (1).

$$CGD = 0.43M^{0.59} \quad (1)$$

where *CGD* is in K yr and *M* is the TNT equivalent mass of nuclear bombs in Mt.

However, Eq. (1) should be corrected since atmospheric nuclear weapons testing did not induce smoke from cities except for Hiroshima and Nagasaki. *CGD* for a 3000 Mt nuclear war without smoke from cities can roughly be calculated as 6 K yr based on Ehrlich et al. (1985). On the other hand, *CGD* for a 3000 Mt nuclear war with smoke from cities can be estimated as 48.4 K yr based on Eq. (1). Namely, *CGD* becomes 8.1 times by smoke from cities. Therefore Eq. (2) for cases without smoke from cities can be derived dividing Eq. (1) by 8.1 as follows.

$$CGD = 0.053M^{0.59} \quad (2)$$

*CGD* for 545 Mt nuclear explosions without smoke from cities can be estimated as 2.2 K yr by Eq. (2). Assuming that the nuclear influence pattern has an isosceles triangle shape, the maximum temperature drop in 1976 can be estimated as 0.07K. *CGD* for 423 times of 1.3 Mt nuclear explosions is 26 K yr. The maximum temperature drop in 1976 would be 0.8K. In conclusion, temperature drop by Gadget, Little Boy, Fat Man and the 422 times nuclear weapons testing of total 545 Mt is estimated as between 0.07K and 0.8K. The influence of the atmospheric nuclear

explosions after PTBT should also be considered for more precise estimation. However, the observed 0.5 K stagnation is in this estimated range. This supports the idea that the 0.5K GST stagnation between 1945 and 1976 was induced by the atmospheric nuclear explosions.

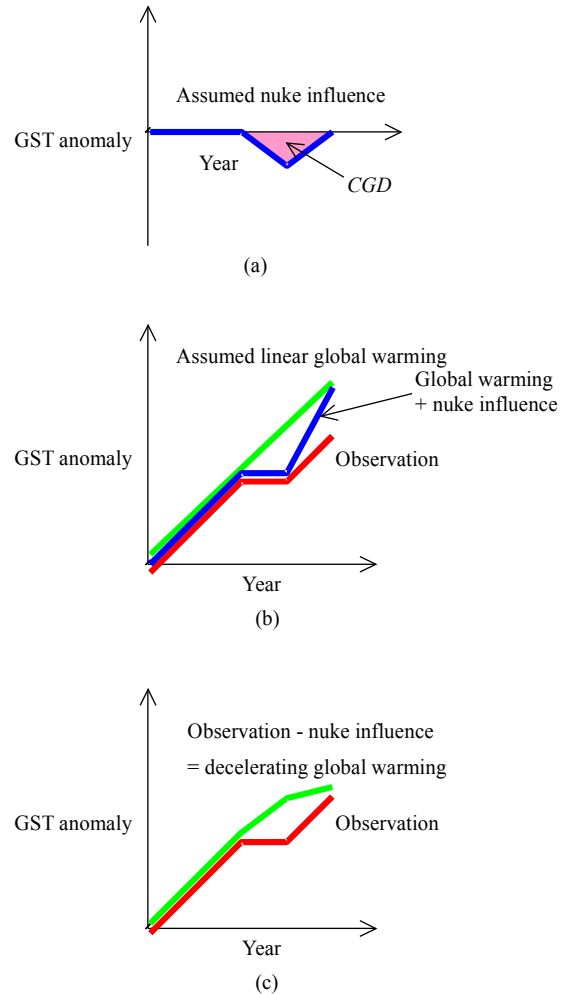


Fig. 6 (a) Assumed influence of atmospheric nuclear explosions, (b) discrepancy between observation and estimation assuming linear warming pattern and (c) estimated nonlinear warming pattern subtracting influence of nuclear explosions from observation.

#### 4. Application of the finding to the global warming mitigation

According to AR4 by IPCC, reduction of anthropogenic  $\text{CO}_2$  emission by 50% till 2050 will decrease 2.3K GST rise with 0%  $\text{CO}_2$  reduction to 1.7K inducing world GDP loss of more than 5.5%. The author does not think that the global warming of several degree centigrade is fatal for human future, however, he would like to point out that injection of PM to the upper troposphere and the stratosphere would be very effective to mitigate global warming.

The mass of the world biggest hydrogen bomb, Tsar Bomba (1961) by USSR was 50 Mt TNT equivalent. Mass of the crater created by the explosion can be evaluated as 400 Mt. Let's assume that a half the emitted PM, namely 4 times the

TNT equivalent mass reached the upper troposphere and the stratosphere. This leads that 0.5K GST drop is expected by injecting  $545 \times 4 / (1963-1945+1) = 114$  (Mt/year) of PM to the upper troposphere and the stratosphere for 19 years. For convenience, the contribution of the atmospheric nuclear explosions after PTBT was ignored in the above calculation.

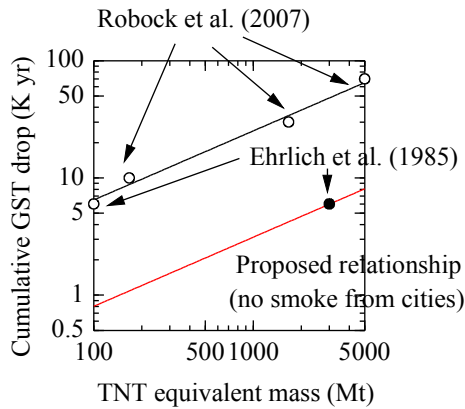


Fig. 7 Relationship between cumulative GST drop due to nuclear war and TNT equivalent mass of atomic bombs in a nuclear war based on Ehrlich et al. (1985) and Robock et al. (2007).

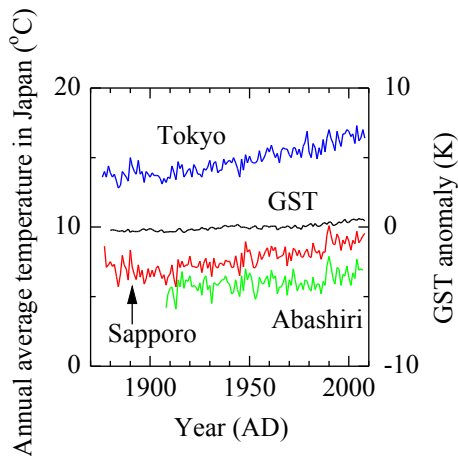


Fig. 8 Yearly average temperature for three cities in Japan (JMA data) with GST anomaly (NASA data).

The author admits that the radiative forcing of various PM should be investigated, however, fine limestone powder would be a candidate for the injection. 114 Mt/year is 3% the world limestone production (3800 Mt in 2001). Price of 114 Mt fine limestone powder whose average diameter is 2  $\mu\text{m}$  would be around 30 GUSD (Nishiyama, 2009, personal communication). Assuming that a flight of a transport plane can sprinkle 400 t of limestone powder and costs 10 kUSD, yearly cost would be 3 GUSD. Total yearly cost of 33 GUSD for the whole world is expensive but cheaper

than the cost for CO<sub>2</sub> reduction. It should be pointed out that CO<sub>2</sub> from 114 Mt limestone powder is negligible compared to 27 Gt world CO<sub>2</sub> emission. Neutralization of acid rain and a small economic contribution are also expected.

Deliberate considerations are of course required before the execution of injection, however, the author also would like to point that artificial rain fall is already often carried out in China by sprinkling silver iodide by missiles. This technique is apparently effective to mitigate the heat island phenomenon. For example, average temperature rise due to heat island phenomenon is approx. 2.3K in Tokyo (Fig. 8) for this 100 years. The artificial rainfall would also have some effects to lower GST if it is carried out in a very large scale.

### 5. Consideration on the true GST behavior

Assumed influence of atmospheric nuclear explosions was a triangle shape (Fig. 6a). Superposing a linear warming pattern and the triangle influence pattern does not make the observed pattern (Fig. 6b). On the other hand, subtracting the influence pattern from the observation derives a nonlinear, decelerating warming pattern (Fig. 6c).

Assuming that the global warming is decelerating, the causes would be the recent decay in solar activity and/or saturation of the green house effect. Assuming again that the nuclear influence pattern has an isosceles triangle shape, the nuclear influence should have ended in 2007 since it began in 1945 and showed the peak in 1976. This means that the warming pattern after 2008 might indicate the true warming pattern without the influence of the atmospheric nuclear explosions. GST after 2008 should be very carefully monitored.

### 6. Concluding remarks

It was pointed out that the cause of the 0.5K GST stagnation between 1945 and 1976 would be due to the atmospheric nuclear explosions including Gadget, Little Boy, Fat Man and the succeeding at least 422 times atmospheric nuclear weapons testing. The estimated GST drop by the atmospheric nuclear explosions based on the published simulation results were at least between 0.07 and 0.8K and the observed 0.5K stagnation is within the estimated range. Three more supporting evidences on radioactivity deposition volume in Tokyo, Japan, radioactivity concentration in livestock bones in Hokkaido, Japan and the diameter of the radionuclides from the Chernobyl accident were also shown.

The atmospheric nuclear explosions can be regarded as full-scale in-situ tests for "nuclear winter". Future precise analyses will be very useful to improve the accuracy of the global climate models. The accuracy of the simulation on GST in IPCC's AR4 would also be significantly improved by including the influences of PM by the atmospheric

nuclear explosions in their global climate model.

A method to lower GST by injecting fine limestone powder to the upper troposphere and the stratosphere was proposed. Many things are left to be investigated, however, there is a possibility that the method becomes practical and can be carried out with a reasonable cost inducing economic recovery and preventing the acid rain.

A possibility of global warming deceleration was pointed out based on the observation and the estimated influence of the atmospheric nuclear explosions. Very careful GST monitoring should be continued.

On the other hand, Ehrlich et al. (1985) also pointed out the possibility of "nuclear summer" which was gradual global warming by CO<sub>2</sub> concentration increase after the temporary "nuclear winter". There is a possibility that we are suffering a "*petit* nuclear summer" if the stagnation was a "*petit* nuclear winter". Those countries which have responsibilities to the atmospheric nuclear explosions should recognize that they might have been significantly influencing the world climate.

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