

The Big Ice Age or The Big Steamy Age?

Syun-Ichi Akasofu

International Arctic Research Center, University of Alaska Fairbanks

Abstract

Shifting the present normal baseline ($+15^{\circ}\text{C}$) of temperature changes during the last 500,000 years to about the lowest recorded temperature ($+5^{\circ}\text{C}$), a somewhat different view of the temperature changes emerges. A rough radiative balance in the new view is estimated. We are at present in a peak steamy period, rather than an interglacial period.

In meteorology and climatology, there is no absolute standard or normal baseline from which anomalous deviations can be determined. In discussing the Big Ice Ages (BIAs), it is generally believed that these major ice ages begin rather gradually, cooling from the normal baseline temperature ($+15^{\circ}\text{C}$), and reach their minimum temperature ($\sim+5^{\circ}\text{C}$) in about 70,000 years. It is believed that the recovery is rather sudden, taking less than 10,000 years, and that the period between two BIAs, the interglacial period, lasts about 15,000 years. Figure 1 shows this cyclic trend by modifying a black and white version of the figure (Muller and MacDonald 2000), painting the period below the baseline blue and the period above the baseline red. Muller and MacDonald (2000) took the 1950 mean value as the baseline value ($+15^{\circ}$). The underlying consideration in this view is that the present condition is normal, the baseline or normal or standard temperature being $+15^{\circ}\text{C}$, which is shown as the baseline (the 0°C line) in Figure 1. All the radiative balance considerations are made on this basis (Graedel and Crutzen 1995, Ruddiman 2001, Burroughs 2001, Tsuchida 2008).

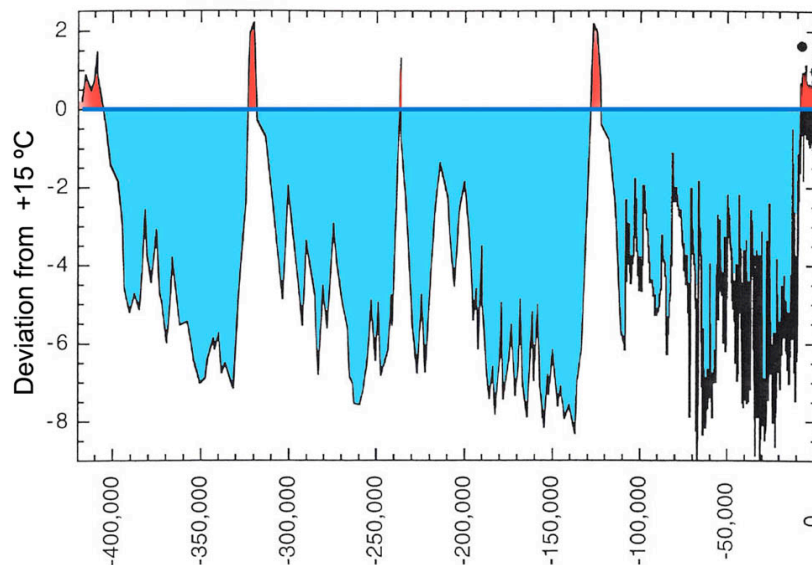


Figure 1. During the last 500,000 years, we had four successive Big Ice Ages (painted blue) and the intervening interglacial periods (painted red). The original figure in Muller and MacDonald (2000) has a black and white format.

However, glancing at temperature changes during the last four BIAs, other interpretations of the temperature changes may be possible. One of them is shown in Figure 2. The baseline temperature is taken to be 10°C lower than that described in the abovementioned view. In this new view, the earth experiences impulsive cyclic warm periods, from the baseline temperature, the lowest temperature level during the 500,000 years, namely about $+5^{\circ}\text{C}$ ($=15^{\circ}\text{C}-10^{\circ}\text{C}$). The warming occurs rather impulsively. The briefness of the heat input period can be judged by the sudden increase of the temperature and the sharpness of the peak period. Each input function is somewhat different. However, after reaching the peak value, the input warming process subsides quickly, so that the temperature begins to decrease gradually as the earth loses the input heat energy, taking 70,000 years to cool down to the baseline value ($+5^{\circ}\text{C}$). The interglacial period is simply a peak period in each warming. The new view is schematically shown in Figure 3.

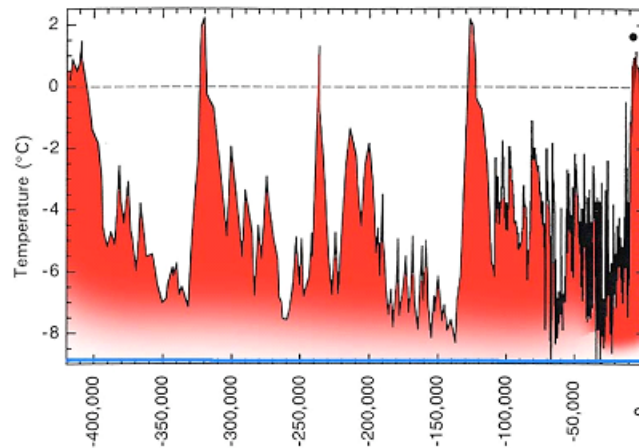


Figure 2. Big Steamy Age temperature changes, assuming that the warming (including the interglacial changes) occurs impulsively. The positive deviation from the baseline value ($+5^{\circ}\text{C}$) is painted red. The original figure in Muller and MacDonald (2000) has a black and white format.

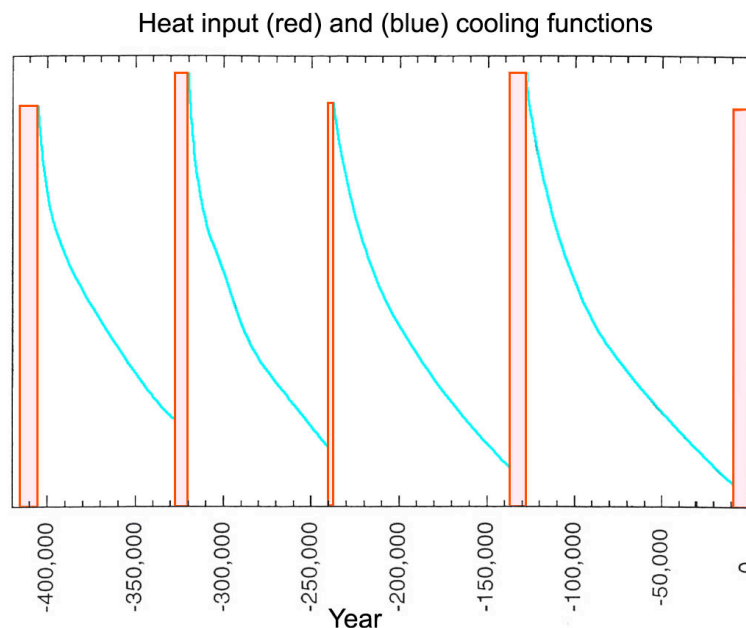


Figure 3. Schematic illustration of the heat input (red) and the cooling of the earth (blue).

The two views of temperature changes during the last 500,000 years are quite different. The former view seeks processes as to why the earth experiences cooling from the normal condition, namely why the cooling process begins. In the new view, an important question becomes why the warming process is impulsive and short-lived, rather than why the recovery from cooling is so sudden. The former view considers why the earth tries to recover abruptly from the abnormally cold condition. A new question is how the earth can respond to the heat input so quickly. In the new view, the development of the BIAs becomes simply relaxation from the impulsive warming; the earth cannot maintain the warm condition produced by the impulsive warming process. The time constant of the cooling after heating is about 70,000 years.

The basic physical process of warming and cooling may be the same or similar to those of the BIAs, but the new view might provide somewhat different ways of consideration. In the new view, there is nothing significant about the interglacial period; it is simply the peak period of the impulsive warming. The present radiative balance consideration based on 15°C as the baseline can be said to be “normal” only during the peak period of heat input. If we happen to live in a different part of the cycle, a different “normal” condition has to be considered. The differences of the individual interglacial periods depend on the differences in the heat input function. Characteristics of individual interglacial periods depend on characteristics of the heat input function, rather than those of the interglacial periods themselves.

It is not too complicated to examine the relative balance for the proposed new base condition. It is assumed that the solar input has not changed during the last 500,000 years and is taken to be 100 in unit ($257 \text{ kcal/cm}^2/\text{year}$) at the top of the atmosphere, assuming that the solar output is constant throughout this period. The standard input-output relationship is shown in Figure 4. The various values are taken from Tsuchida (2008), but they are similar to those in most standard textbooks within ± 2 (Graedel and Crutzen 1995, Ruddiman 2001, Burroughs 2001). The main point in Figure 4 is that unit of 30 out of 100 is reflected back into space and 23 absorbed in the atmosphere, while the total input-output relationship balances with unit of 143, and 47 (=70-23) being absorbed by the earth's surface. The greenhouse effect is thus $143-47=96$. (The Stefan-Boltzman equation for the input 70 (=100-30) results in the earth's temperature of -18°C .)

• Solar Input to the top of the atmosphere = 100 (257 kcal/cm²/years)	
Reflection = 30	
Earth surface absorbs = 47	
Greenhouse effect = 96	
Total = 47 + 96 = 143	
• Output from the earth surface	
Evaporation = 24	
Transpiration = 6	
Surface radiation (15°C) = 113	
Total = 24 + 6 + 113 = 143	
• 100 – (30: Reflection) = 70	Stefan-Boltzman equation (T ⁴) → -18°C
• Total = 143	→ +31°C
	→ +28°C
• 137 – 24 (Evaporation) = 113	→ +15°C
• 100	→ +5°C

Figure 4. The present radiative balance (Tsuchida 2008). Most textbooks on this subject show similar numbers within ± 2 .

• Solar Input to the top of the atmosphere = 100 (257 kcal/cm²/years)	
Reflection = 30 20	
Earth surface absorbs = 47 57	
Greenhouse effect = 96 43	
Total = 47 + 96 = 143	
	57 43 100
• Output from the earth surface	
Evaporation = 24 0	
Transpiration = 6 0 (5°C)	
Surface radiation (15°C) = 113 100	
Total = 24 + 6 + 113 = 143	100
	0 0 100

Figure 5. The inferred radiative balance during the Big Ice Ages. The numbers are not based only on intuitive consideration. The changes in the figure are necessary because the balanced temperature of 5°C requires that the balanced input/output should be 100 in unit on the basis of the Stefan-Boltzman law.

However, if we suppose that the baseline temperature 10°C lower than the 1950 value (15°C), the Stefan-Boltzman equation indicates that for the earth's temperature of 5°C (=15°-10°C), the total input-output balances with unit of 100 must reach the earth's surface, instead of

143 (Figure 5). For this lower temperature, it is assumed that both evaporation and transpiration are very small. Since most of the greenhouse effect arises from water vapor, the reflection from the top of the atmosphere may be less than 30. Without a specific atmospheric model, let us assume that the reflection from the top of the atmosphere into space is 20 (a less cloudy condition). Further, since the transparency of the atmosphere (perhaps dusty) is not known, let us assume that the earth's surface receives 57 (=80-23) instead of 47. Then, the greenhouse effect will be 43 (=100-57), instead of 96. Therefore, the greenhouse effect is less than that of the present condition. In any case, the unit of 100 (the surface radiation of 5°C) limits choice of these numbers.

In this view, we are in the peak period of a steamy age, and the earth will return to the baseline temperature after the relaxation from the present humid condition, gradually losing water vapor. In the new view, the cooling back to 5°C is inevitable. It is suggested that the 5°C level is close to the absolute baseline condition which does not depend on the phase of the cycle.

If the base temperature of the earth's surface is 5°C instead of 15°C, we need to change our present view of climate change during the last 500,000 years from the view of successive Big Ice Ages (BIAs) to successive Big Steamy Ages (BSAs). We are now in the peak period of a Big Steamy Age.

References

- Burroughs, W.J. 2001. *Climate Change: A Multidisciplinary Approach*. Cambridge: Cambridge University Press.
- Graedel, T.E. and P.J. Crutzen. 1995. *Atmosphere, Climate, and Change*. New York: Scientific American Library.
- Muller, R.A. and G.J. MacDonald. 2000. *Ice Ages and Astronomical Causes: Data, Spectral Analysis and Mechanisms*. New York: Springer.
- Ruddiman, W.F. 2001. *Earth's Climate: Past and Future*. Macmillan.
- Tsuchida, A. 2008. Japanese textbook on meteorology.