Influence of Global Warming on Office Building Cooling Loads

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Abstract

The meteorological data incorporating future climate change were generated from the available predictions of the global warming, to be applied to thermal load calculation of air conditioning. Numerical simulations were subsequently carried out to predict changes in the thermal load of an air conditioned office building in 50 to 100 years. Compared to the current (Year 1991-2000) data, yearly cooling load was estimated to increase 60% in 50 years, while it would double by a century after. The results presented strongly suggest that proper attention be needed in the design process of an air-conditioning system of a building, in light of the fact that half a century is well within the lifespan of a building.

Key words: global warming, air-conditioning load, office building

1. INTRODUCTION

Simulation results on the global warming performed in a number of international research institutions have predicted a temperature increase by a few degrees in 50 to 100 years. Such a time scale of the temperature rise may be well within the lifespan of a building. Anthropogenic heat release from buildings is an important factor affecting urban heat balance and one of the main causes of heat island phenomena. Air conditioning-generated thermal load of buildings is proportional to the amount of heat release and influenced by outdoor climate.

Air conditioning design of the building is usually based on past weather data. It is, therefore, desirable from the standpoint of social management of the impact of the global warming and the mitigation of the warming process to start building design by accounting for predicted future climate change.

The present author has generated typical weather data in Tokyo to be employed for heat load calculation of air conditioning by taking influence of prediction for future warming into consideration. Using the data, possible changes in heat load required for air conditioning office buildings in 50-100 years have been predicted. Based on the simulation results of air conditioning load, its impact on building design has also been examined.

2. SUMMARY OF GLOBAL WARMING PREDICTION DATA

The simulation result of the K-1 Model Developers (2004; hereafter referred to as the 'K-1 model prediction') was applied to the present study, among the existing reports by a number of researchers on the global warming. The model analyzed global climate change by dividing the earth's atmospheric and ocean zones with a grid network. The size of lateral meshes in the atmospheric zone was approximately 100 km. The time period for simulation spanned over a century between 1900 and 2100. The prediction before Year 2000 was based on observational data on the greenhouse gas density, while that after 2001 followed future scenarios of gas concentrations published in the IPCC Special Report on Emissions Scenario (SRES, 2000).

Among the simulation results of the K-1 model prediction, Scenario A1B (focusing on balance among all energy sources) was adopted here. By targeting Tokyo as the region of thermal load calculation, data were extracted at the nearest grid point to the center of Tokyo.

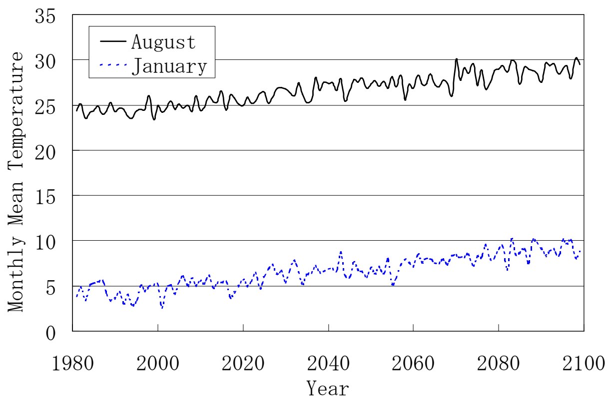

Fig. 1. Trend in ground-level air temperature in January and August near Tokyo based on the K-1 model prediction (K-1 Model Developers,2004).

Figure 1 shows monthly averaged surface air temperature prediction from 1980 to 2100. In both January and August, a remarkable temperature rise is seen to start at around 2020, which amounts to nearly 5°C by 2100. Also noticeable is yearly temperature fluctuations.

3. GENERATION OF TYPICAL WHETHER DATA FOR HEAT LOAD CALCULATION.

Since the spatial resolution in the horizontal direction of the K-1 model prediction is limited to the mesh size of about 100 km, the precise climate in Tokyo including the effects of geography and urbanization could not be predicted. Furthermore, the K-1 model prediction did not forecast future weather itself. In order to generate data to be employed for future heat load calculation and simultaneously minimizing prediction errors, an attempt was made to develop a method using typical weather data acquired from an extended AMEDAS (AIJ Research Subcommittee on Planning Weather Data, 2005).

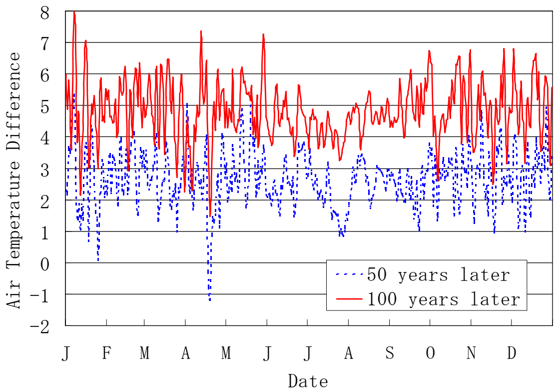

Fig. 2. The difference between the current and future daily mean temperature. (°C)

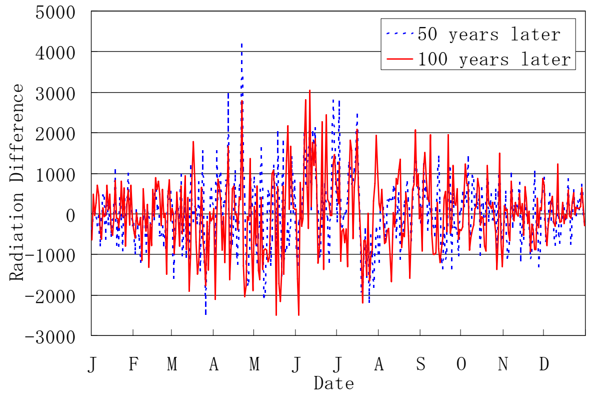

Fig. 3. The difference between the current and future daily accumulated global solar radiation. (W·h/m^2)

In the present work, an attempt was made to modify typical weather data using decade average of the K-1 model prediction. In order to calculate air conditioning heat load based on the climate data incorporating the global warming effects, data were processed as follows: decade averaged climate data of the 'present', 'half a century (50 years) after' and 'a century (100 years) after' were obtained during 1991-2000, 2041-2060 and 2091-2100, respectively.

Future typical weather data were generated first by taking the difference between individual physical factors, such as the current and (predicted) future temperature. It is then added to extended AMEDAS-based typical weather data in Tokyo for 1991-2000. The features of the present procedure are:

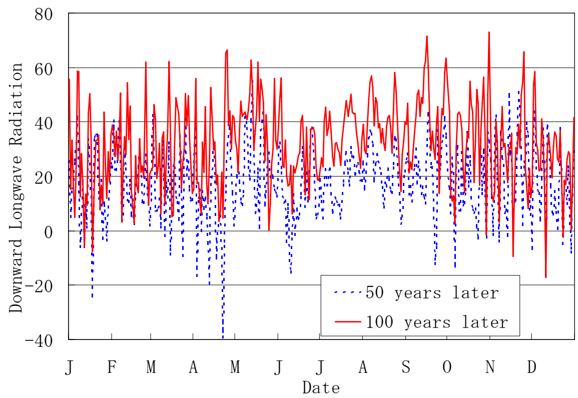

Fig.4. The difference between the current and future daily mean downward longwave radiation. (W/m^2)

1) Yearly fluctuations found in the K-1 model prediction were suppressed through the decade averaging.
2) Discrepancies between predicted and actual observational weather were minimized by taking the difference between the current data and future predictions.
3) Using typical weather data generated by extended AMEDAS, the influence of characteristics not reflected in the prediction, such as local climate, could be accounted for.

Additionally, two data processing methods were examined for the decade average differentiation. In one method, a number of 365 average data are generated first from daily mean data stored every year and, then, the difference between current and future averages is added to typical weather data (called 'method A'). Whereas, in the other method, average is taken first using decade mean data for every year, followed by addition of the difference to typical weather data ('method B'). An increase in yearly average temperature from the present to 50 and 100 years later reaches 2.7°C and 4.8°C, respectively. Figure 2 shows seasonal variations of daily temperature difference between the present and the future. Compared to the results of summer months, more significant temperature rise is apparent for the rest of year. Similarly, the difference in daily accumulated global horizontal solar radiation increases by 33.8 Wh/m^2 to reach 4,380.3 Wh/m^2 after half a century, while in 100 years it falls to 4,345.4 W/m^2, i.e., a 1.1 Wh/m^2 drop. Seasonal variations of radiation are seen to be less prominent than those of temperature (compare Fig. 3 with 2).

Furthermore, after half a century downward longwave radiation increases by 17 W/m^2 to attain 335 W/m^2, whereas it hits 350 W/m^2, a 32 W/m^2 jump, by a century after — more than a 10 % rise from the current 318 W/m^2.

Figure 4 represents the results of daily mean downward longwave radiation, which clearly indicates a widening difference over time throughout the year.

In light of the results presented, the differences in temperature and downward longwave radiation are selected as influential physical parameters of meteorology for calculation of air conditioning heat load. Henceforth, typical weather data are modified according to temporal changes in these parameters.

4. CALCULATION OF AIR CONDITIONING HEAT LOAD

We now proceed to calculation of air conditioning heat load based on typical weather data with the modification referred to above. The computer program used is HASP/ACLD/8501 (Matsuo, 1985).

Property data of the building studied are taken from those used in a benchmark office building model of Takizawa (1985). The building model occupies a basement and eight upper floors with a total floor area of 7,583.44m^2, of which the air conditioned floor area is 5,331.76m^2. The office building is made of reinforced concrete. A representative floor of the office building studied is shown schematically in Fig. 5.

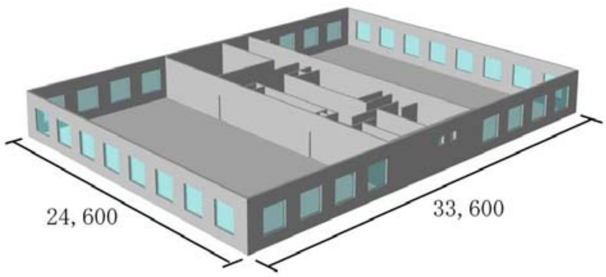

Fig.5. A schematic of a representative floor of the office building studied. (mm)

Although outputs from HASP/ACLD include continuous air conditioning load by both sensible and latent heat, only the former heat load is considered here since no modification is made to humidity data of typical weather data.

In heat load calculation, the reference temperature is generally taken to be 24°C, and deviations from the set temperature value in the positive and negative directions are respectively designated as cooling and heating load. However, the reference temperature chosen for the present work is 26°C, which may be more practical for cooling load calculation. Both Figs. 6 and 7 depict the calculated daily accumulated cooling load, which is the room- and time-wise summation of positive values. It is demonstrated that, in both 50 and 100 years, the load will invariably increase.

Figures 8 and 9 show the difference between daily accumulated cooling load of the present and the future. The difference occurred using method A based on daily averaging is found to be more prominent than that of method B (yearly averaging). The result presented reveals the influence of the data processing methods.

Annual cooling load by latent heat after half a century amounts to 245 MJ/m^2・in method A, while it is 220 MJ/m^2・ in method B, by taking 152 MJ/m^2・as the current baseline data. The prediction of method A is a 60% increase from the present. Furthermore, in 100 years, it will go up to 316 MJ/m^2・(method A) or 309 MJ/m^2 (method-B) — a two-fold surge from now.

5. CONCLUSION

The meteorological data incorporating future climate change were generated from the available predictions of the global warming, to be applied to thermal load calculation of air conditioning. Numerical simulations were subsequently carried out to predict changes in the thermal load of an air conditioned office building in 50 to 100 years. Compared to the current (Year 1991-2000) data, yearly cooling load was estimated to increase 60% in 50 years, while it would double by a century after. The results presented strongly suggest that proper attention be needed in the design process of an air-conditioning system of a building, in light of the fact that half a century is well within the lifespan of a building.

Comparison of the results of temperature rise was made between yearly and daily averages of typical weather data with modification to accounting for the global warming. It was found that the yearly averaging resulted in larger load and seasonal fluctuations.

The results presented for the calculated heat load increase demonstrate the need for office building design to cope with the prediction as a future task.

In the future, more accurate and updated results may be obtained for the global warming simulation used in the present study. The calculation technique for air conditioning heat load discussed in the paper is also expected to work effectively to newly available data.

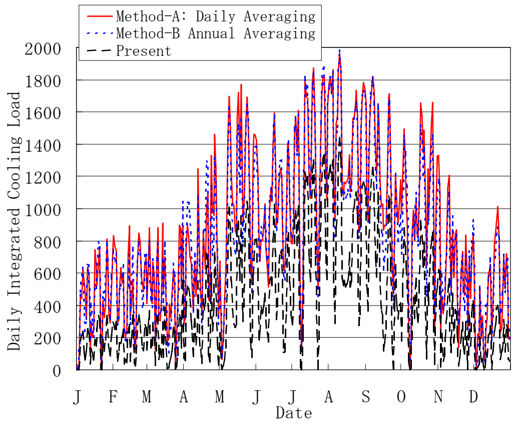

Fig.6. Comparison of the current and a century after daily accumulated cooling load. (kJ/m^2·day)

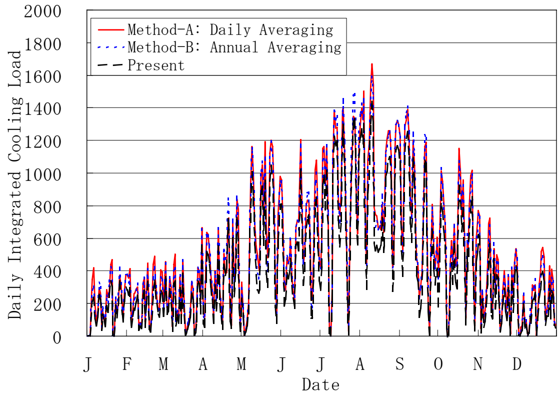

Fig. 7. Comparison of the current and a half-century after daily accumulated cooling load. (kJ/m^2·day)

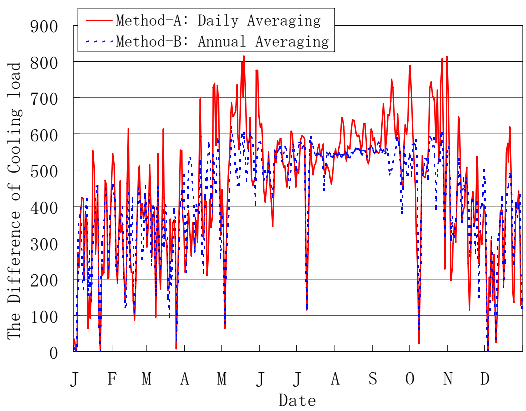

Fig. 8. The difference between the current and a century after daily accumulated cooling load. (kJ/m^2·day)

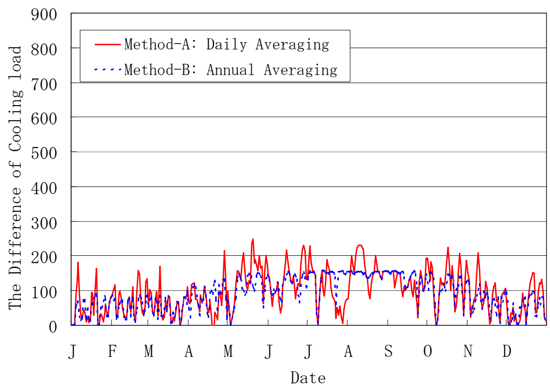

Fig. 9. The difference between the current and a half-century after daily accumulated cooling load. (kJ/m^2·day)

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