Development of an Integrated Energy Simulation Tool for Buildings and MEP Systems, the BEST (Part 10)

# Characteristics of the weather data with different time intervals by the measurement data

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To improve the accuracy of the simulation, the calculation logic corresponding to the short time interval weather data was introduced in BEST. In this report, the property of the weather data with some different measurement intervals is described based on the measurement data in Osaka. And the considerations and the possibilities for the use of 1-minute interval weather data measured by Japan Meteorological Agency are described.

## 1. Introduction

To improve the accuracy of simulations, calculation logic handling data at intervals of less than an hour was introduced into BEST. Subsequently, studies to obtain weather data at shorter time intervals have been conducted. Before these studies, in spite of the demand for data at shorter time intervals, the only data available to the public was hourly weather data and based on this, missing data was complemented as needed. Our goal is to obtain one-minute interval weather data. One-minute interval data can further provide weather data at any time interval (e.g., 5 minutes, 10 minutes, etc.).

At present, the Japan Meteorological Agency (JMA) collects and publicly releases ten-minute interval data provided by the Automated Meteorological Data Acquisition System (AMeDAS) and one-minute interval data obtained from its meteorological observatories. Only a small amount of data has been accumulated until now, but the database is expected to be a useful source for research on weather data at shorter time intervals.

This report addresses the properties of various types of weather data at different time intervals, calculated on the basis of the data we measured. The problems with the one-minute interval data provided by JMA and the possibilities for its use are also discussed.

## 2. Comparison of weather data at different time intervals, using the data we measured

Regarding weather phenomena occurring within a short time (e.g., 1 minute, 10 minutes, etc.), it is not easy to obtain detailed and successively-recorded data. Each weather element shows different variability characteristics even in such a short time. Therefore, it is necessary to understand that we may need to estimate weather data at short time intervals from weather data measured at longer time intervals, based on our knowledge acquired by observing phenomenon, comparing it with the measured data and understanding its characteristics.

With the aim of improving weather data for environmental design and of reinforcing the next generation of weather data, “Expanded AMeDAS Weather Data” [1], we established the Solar Radiation and Daylight Measurement System at Osaka City University (Sumiyoshi-ku, Osaka; at 34°36´ N latitude and 135°30´ E longitude) and more than 30 weather elements have been measured at one-minute time intervals since January 1, 2006 [2]. We then introduced the measurement of ten-second interval data on October 30, 2006, so that it would be possible to investigate short time interval data. On the basis of the data we measured, the properties of weather data at short time intervals are described.

## 2.1 About the measurement of weather elements

Among the sensors and instruments used in the Solar Radiation and Daylight Measurement System, those related to this report are shown in Table 1.

Table 1 Sensors and instruments for measurements

| Quantities | Symbols | Instruments | Manufactures |
|---|---|---|---|
| Global irradiance | Eeg | MS-802 | EKO |
| Diffuse irradiance | Eed | MS-802 | |
| Direct Normal irradiance | Ees | MS-53 | |
| Temperature | T | THT-B4T | SHINYEI |
| Relative Humidity | RH | | |
| Wind Direction | Wd | SAT-530 | KAIJO Sonic |
| Wind Speed | Wv | | |
| Sun Tracker + Shadow Ball（for Ees and Eed） | | STR-22 | EKO |
| Data Logger（Interval: 1 minute, 10 seconds） | | CADAC-21 | ETO |

## 2.2 Data types and their definitions

Using data measured at intervals of 10 seconds or 1 minute, the values of one-minute data, ten-minute data and one-hour data are calculated and are defined as follows:

(1) One-minute data: the actual data measured every minute; or the data estimated every minute, calculated as the mean of the ten-second interval data measured during the 30 seconds before and after the point of time in question.

(2) Ten-minute data: data estimated every ten minutes, calculated as the mean of the one-minute data obtained during the five minutes before and after the point of time in question.

(3) One-hour data: data estimated every hour, calculated as the mean of the one-minute data obtained

during the 30 minutes before and after the point of time in question.

## 2.3 Comparison of data at different time intervals

For comparison, we selected two representative days: 3 May and 1 November. The former was a fine day and showed the most stable weather conditions of all days in 2006, while the latter had rather unstable weather conditions. The data on 3 May was measured every minute, while the data on 1 November was measured every 10 seconds. This section focuses on solar radiation, temperature, humidity, wind direction and speed. All of these weather elements are essential for the prediction of building environments and are also measured by JMA.

(1) Solar radiation

Figure 1 shows the global irradiance (shown as Eeg in figure 1), diffuse irradiance (Eed) and direct normal irradiance (Ees) on 3 May (clear skies and stable weather conditions throughout the day). Each of the three weather elements has data at different time intervals. Figure 2 presents direct normal irradiance on 1 November (unstable weather conditions). In the graph legends, 1 m, 10 m ave. and 1 h ave. represents one-minute data (which is the actual data measured every minute), ten-minute data and one-hour data, respectively.

The one-minute data, ten-minute data and one-hour data are well matched with each other, suggesting that the estimation of values at shorter time intervals can be done accurately. Even on the day with unstable weather conditions, both the ten-minute data and one-hour data adequately represent the tendencies shown using the one-minute data.

Figure 3 shows the frequency of occurrence of standard deviations, using a data set that contains data selected every ten minutes from the one-minute data group (1 January to 31 December 2006). The range of standard deviations for diffuse irradiance is not wide. The standard deviations for direct normal irradiance are considerably wider in range, but the frequency of occurrence is not high. Similar tendencies are seen in the standard deviations for global radiation. It is relatively easy to estimate values at one-minute intervals, when ten-minute data is available.

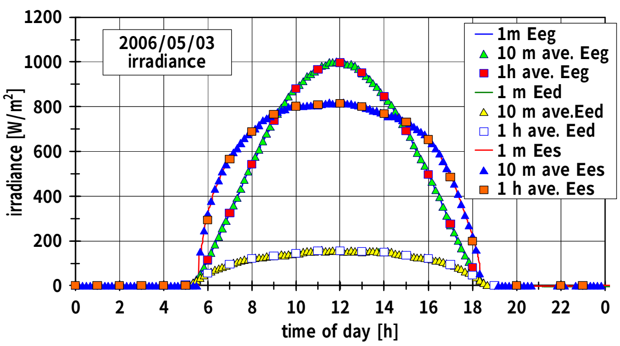


Figure 1: Solar radiation of a clear day, shown using data at different time intervals

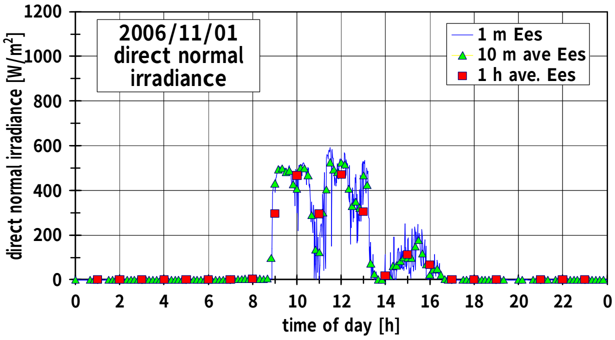


Figure 2: Direct normal irradiance of a day with unstable weather conditions, shown using data at different time intervals

(2) Temperature and relative humidity

It is considered that changes in temperature (shown as T in figure 4) and relative humidity (RH) are relatively slow and sudden large changes do not occur frequently. Figure 4 shows an example of changes in temperature and relative humidity throughout a day. Fluctuations in temperature and relative humidity are small and the data obtained at different time intervals correspond well to each other. Figure 5 represents the frequency of occurrence of standard deviations for temperature and relative humidity, using a data set that contains data selected every ten minutes from the one-minute data group. The standard deviations for temperature are mostly included at 0.4 °C or below and those for relative humidity are at 2% or below. Therefore, regarding temperature and relative humidity, values at short time intervals are expected to be estimated from long time interval data with very high accuracy.

(3) Wind direction and wind speed

Wind direction (shown as Wd in figure 6) and wind speed (Wv in figure 8) vary dramatically and it is necessary to have a good understanding of the relationship between long time interval data and short time interval data. An example of changes in wind direction throughout the day is given at levels of one-minute data, ten-minute data and one-hour data, which were estimated from data that was measured every minute, in figure 6. Figure 7 represents the frequency of occurrence of standard deviations, using a data set that contains data selected every ten minutes from the one-minute data group.

An example of change in wind speed throughout a day is given at levels of one-minute data, ten-minute data and one-hour data in figure 8. JMA defines one-minute data on wind speed, as the mean of data obtained during the 10 minutes before the point of time in question. The one-minute data obtained by the same calculation as JMA is shown using 1 m Wv b in figure 8.

The fluctuations in wind direction are considerably large. As figure 7 suggests, the standard deviations obtained every ten minutes are also wide in range.

No extreme changes occur in wind speed, but it is necessary to develop a method to estimate of the range of fluctuation in order to calculate wind speed values at short time intervals. Regarding the standard deviations for wind speed using a data set that contains data selected every ten minutes from the one-minute data group, standard deviations with considerable frequency of occurrence extend to the level of approximately 1 m/s, which are wider in range than solar radiation, temperature and relative humidity.

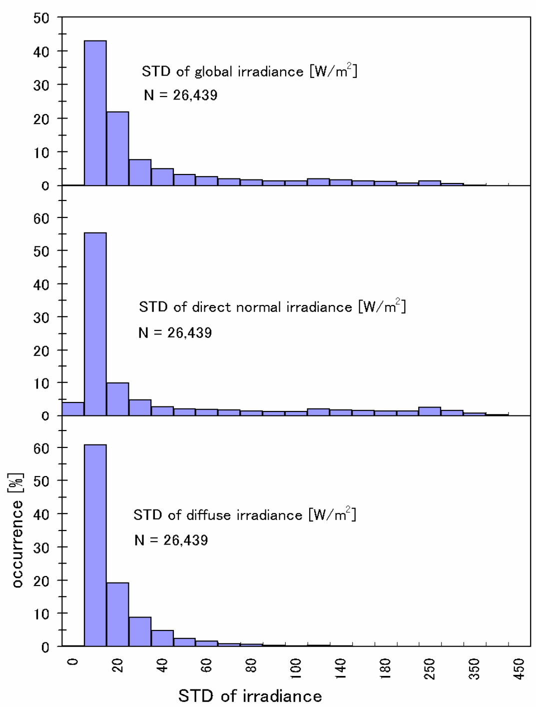


Figure 3: Frequency of occurrence of standard deviations for solar radiation, using data selected every ten minutes from the one-minute data group

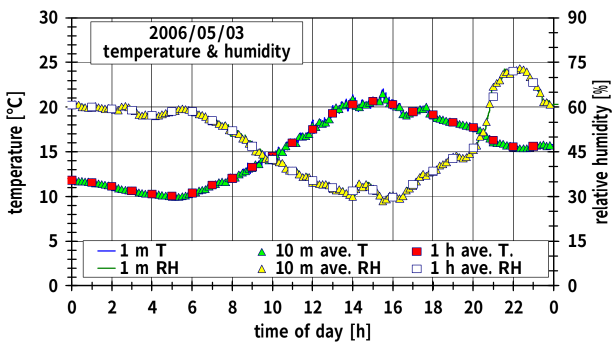


Figure 4: Temperature and relative humidity on a clear day, shown using data at different time intervals

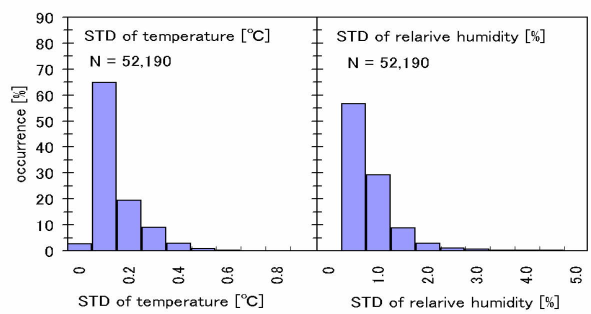


Figure 5: Frequency of occurrence of standard deviations for temperature and relative humidity, using data selected every ten minutes from the one-minute data group

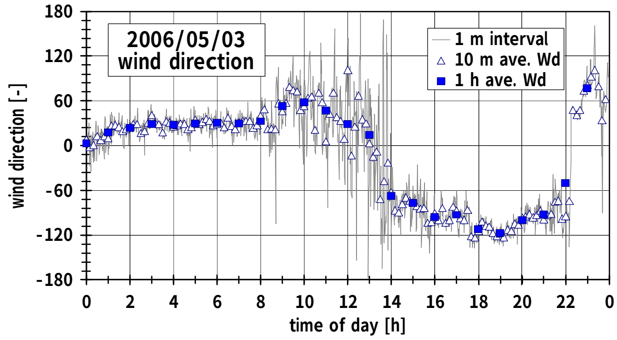


Figure 6: Wind direction, shown using data at different time intervals

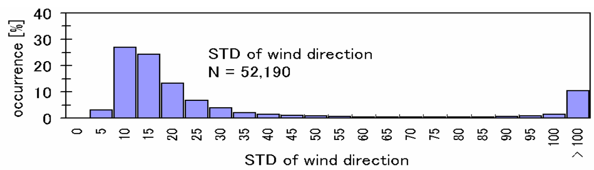


Figure 7: Frequency of occurrence of standard deviations for wind direction, using data selected every ten minutes from the one-minute data group

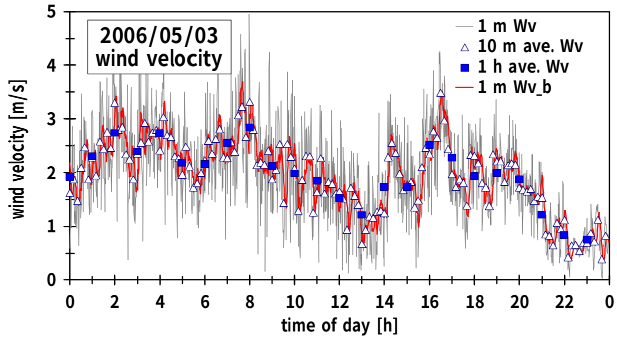


Figure 8: Wind speed, shown using data at different time intervals

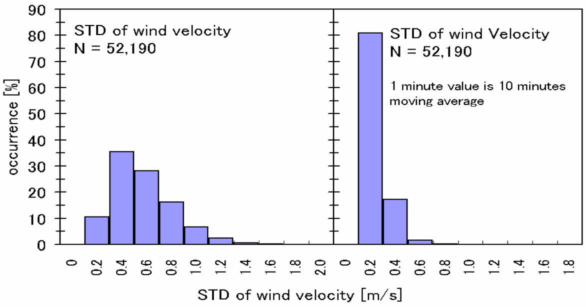


**Figure 9: Frequency of occurrence of standard deviations for wind speed, using data selected every ten minutes from the one-minute data group**

However, as figure 9 (right) indicates, when the one-minute data, as in JMA data and therefore as in the publicly available data, is estimated as the mean of the wind speed data obtained during the 10 minutes before the point of time in question, the standard deviations are included at 0.6 m/s or below. This indicates that wind direction and speed are much more difficult to estimate than solar radiation, temperature and relative humidity.

## 3. Validity of short time interval data, provided by JMA meteorological observatories

### 3.1 Weather data at short time intervals, made available by JMA

Table 2 shows a list of weather data publicly released by JMA.

Table 2: Weather data availability

| Year | JMA meteorological observatories | | | AMeDAS | |
|---|---|---|---|---|---|
| | SDP data | Original daily recorded data | One minute data | One hour data | Ten min data |
| 1981 | ○ | | | ○ | |
| 1982 | ○ | | | ○ | |
| 1983 | ○ | | | ○ | |
| 1984 | ○ | | | ○ | |
| 1985 | ○ | | | ○ | |
| 1986 | ○ | | | ○ | |
| 1987 | ○ | | | ○ | |
| 1988 | ○ | | | ○ | |
| 1989 | ○ | △From April | | ○ | |
| 1990 | ○ | ○ | | ○ | |
| 1991 | ○ | ○ | | ○ | |
| 1992 | ○ | ○ | | ○ | |
| 1993 | ○ | ○ | | ○ | |
| 1994 | ○ | ○ | | ○ | △From April |
| 1995 | ○ | ○ | | ○ | ○ |
| 1996 | ○ | ○ | Measurement started on 19 February | ○ | ○ |
| 1997 | ○ | ○ | 14 stations: Tokyo, Nagoya, Kanazawa, etc. | ○ | ○ |
| 1998 | ○ | ○ | 44 stations: Sapporo, Sendai, Yokohama, etc., were | ○ | ○ |
| 1999 | ○ | ○ | 72 stations: Kushiro, Akita, Chiba, etc., were added | ○ | ○ |
| 2000 | ○ | ○ | 103 stations: Osaka, Fukuoka, Naha, etc., were added | ○ | ○ |
| 2001 | ○ | ○ | 125 stations: Hiroshima, Kagoshima, etc., were added | ○ | ○ |
| 2002 | ○ | ○ | 138 stations: Himeji, Hita, etc., were added | ○ | ○ |
| 2003 | ○ | ○ | 148 stations: Katsuura, Nago, etc., were added | ○ | ○ |
| 2004 | ○ | ○ | 152 stations: Ishinomaki, Sakai, etc., were added | ○ | ○ |
| 2005 | ○ | ○ | 155 stations: Takeo, Kitamiesashi, etc., were added. | ○ | ○ |

*The column of one-minute data gives the total number of stations that measured data as of 1 January in the year concerned.
*Data on sunshine duration is not included in the ten-minute data provided by AMeDAS systems located on the premises of JMA meteorological observatories.

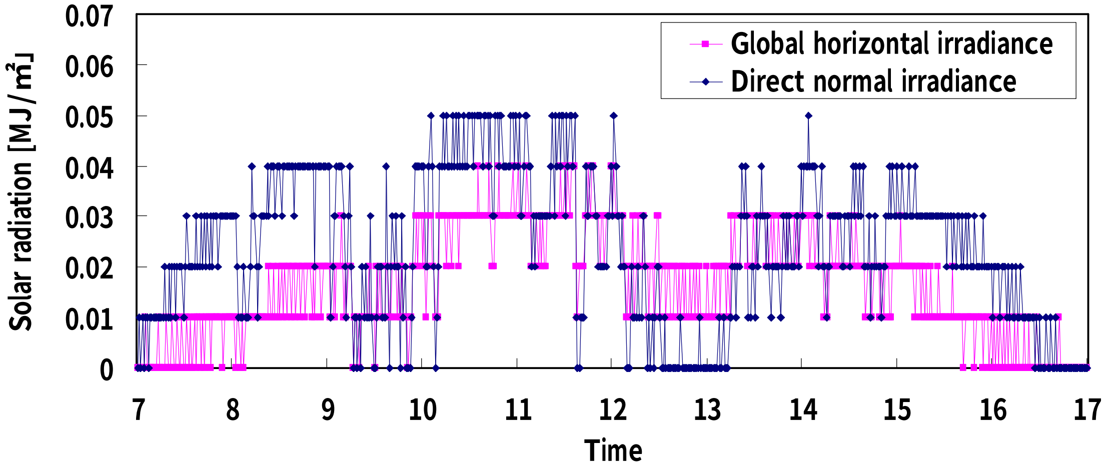


Figure 10: An example of one-minute data on global irradiance and direct irradiance (Tokyo district meteorological observatory; 23 January 1999)

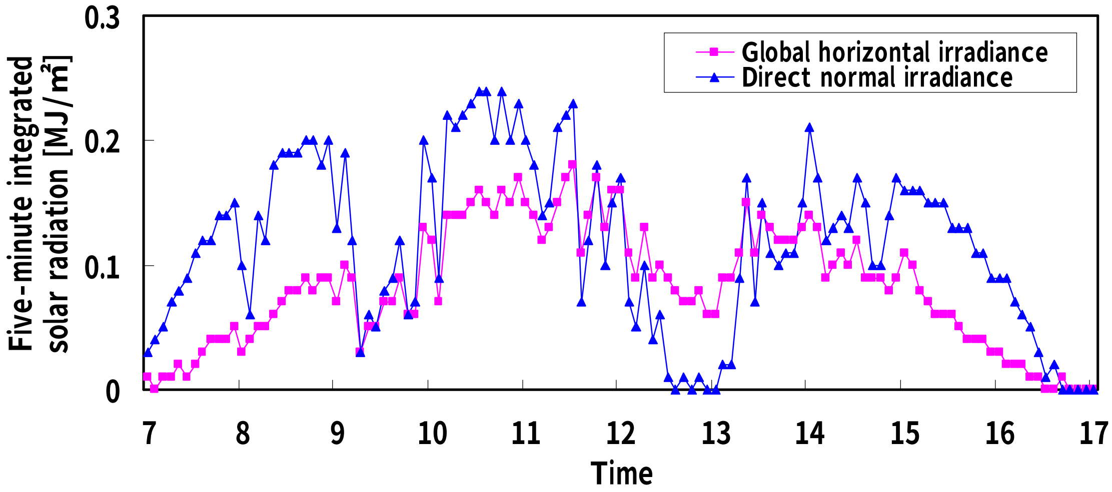


**Figure 11: Five-minute integrated values of global irradiance and direct irradiance**

The one-minute data obtained from JMA meteorological observatories has been accumulated and released to the public since the introduction of JMA-95 model surface weather observation devices: the earliest on 19 February 1996 in Tokyo and the latest on 1 October 2004 on Kume-jima Island. Therefore, data from all 155 JMA meteorological observatories has been available since 2005. The weather elements for which one-minute data is measured are wind direction and speed, amount of precipitation, temperature, humidity, sunshine duration, snow depth, global irradiance, direct irradiance and visibility. Global irradiance is obtained only from solar radiation observation stations (67 stations). Direct irradiance is measured by sun-tracking sunshine recorders and the measurement accuracy has not been verified.

The ten-minute data provided by AMeDAS has been publicly available since April 1994. The following four weather elements are measured by AMeDAS: temperature, wind direction and speed, amount of precipitation and sunshine duration (in some areas, snow depth is also measured). However, if the AMeDAS system was located on the premises of a surface meteorological observatory, data on sunshine duration is not included in the ten-minute data provided.

### 3.2 Consideration of the possibilities of using the data at short time intervals

Figure 10 gives an example of the available one-minute data and presents changes in global irradiance and direct irradiance throughout the day. As the figure indicates, the one-minute data on solar radiation shows changes in a pattern of steps. Some global irradiance data indicates zero, even when direct irradiation is observed. The one-minute integrated value is estimated by subtracting the data for a specific time from the data obtained one minute before that time and the data used for the estimation is based on daily integrated values. One-minute integrated values are expressed in the unit of 0.01 $MJ/m^2$ and do not exceed the level of 0.08202 $MJ/m^2$ (solar constant: 1,367 $W/m^2 \cdot 60s$). The data accuracy is low, causing some global irradiance data to show zero even during daytime.

Although one-minute integrated values of solar radiation are not very accurate, setting a longer integration time allows us to reveal the amount of change in solar radiation. Figure 11 represents changes in solar radiation on the same day as in figure 10, using five-minute integrated values. Thus, it becomes possible to show changes in solar radiation throughout the day.

In conclusion, the one-minute data provided by JMA is basically a useful data source. Not all data can be directly used as one-minute data for BEST, but there is a strong possibility that the JMA data can be used if appropriate data-processing is applied.

## 4. Summary

For estimation of weather data at short time intervals, we specifically compared and examined the properties of weather data at short time intervals using the data we measured. The results suggest that, regarding solar radiation, temperature and humidity, any changes shown within a 10-minute period are small and short time interval data on these weather elements can be estimated using a simple method.

JMA weather data at short time intervals, which is available to the public, was examined to understand its validity. In particular, we discussed the problems and possibilities of use of the one-minute data on solar radiation.

If one-minute data obtained by JMA is available for the concerned area, one-minute data for use in BEST is created on the basis of the JMA data. Solar radiation data must be processed to some extent.

If the ten-minute data obtained by JMA is available for the concerned area (that is, the same area where an AMeDAS observation station is located), one-minute data for use in BEST is estimated from the AMeDAS ten-minute data, referring to data from another area where one-minute data is available and can be compared with the corresponding ten-minute data.

The relationship among one-minute data, ten-minute data and one-hour data is not specific. In spite of this problem, it may become possible to estimate short time interval data from long time interval data. If one-minute data can be estimated from ten-minute data more accurately, the ten-minute data obtained by AMeDAS can be used more effectively and BEST can be used in more fields.

## References

(1) Akasaka et al: Expanded AMeDAS Weather Data 1981-2000, Kagoshima TLO, 2005. (in Japanese)

(2) Igawa, N., Emura, K., Nimiya, H. and Kikuchi, T.: Solar Radiation and Daylight Measurement System in Osaka City University, Summaries of Technical Papers of Annual Meeting, AIJ, D1, pp. 285-286, 2006. (in Japanese)

## Acknowledgements

This report describes some of the project achievements conducted by the “Study Group for the Development and Promotion of BEST (Chairperson: Shuzo Murakami)”, the Architecture Study Group (Chairperson: Yuzo Sakamoto), and the Working Group on Weather Data (President: Hiroshi Akasaka), which were established in the Institute for Building Environment and Energy Conservation (IBEC). These groups aim to develop a comprehensive tool to calculate building energy consumption for the purpose of environmental load reduction in collaboration with industry, government and academia. We would like to express our gratitude to all of the parties involved.

This research is sponsored by the Grants-in-Aid for Scientific Research (B) of Ministry of Education, Culture, Sports, Science and Technology: “A study of methods for estimating weather elements and for monitoring weather conditions in order to improve the Expanded AMeDAS Weather Data” (Research director: Prof. Norio Igawa of Osaka City University). We appreciate their support.