Climatic maps for natural energy and passive cooling methods utilization in Thailand

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ABSTRACT

This paper aims to control energy conservation in a hot humid area such as Thailand by using natural energy for passive cooling methods. To promote the effective utilization, meteorological data arrangement, climatic and natural energy potential mapping have been made. They should be useful assist for thermal environment design in buildings.

INDEX TERMS

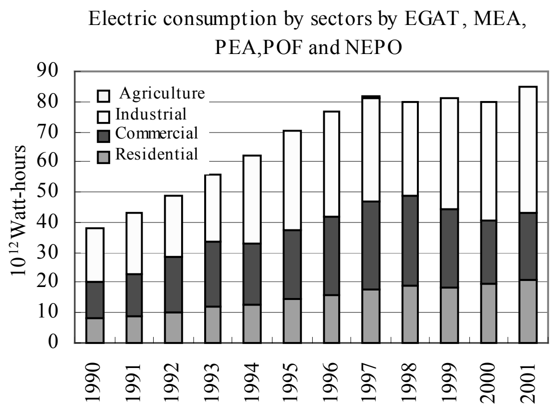
Passive cooling method; Meteorological data; Natural energy potential

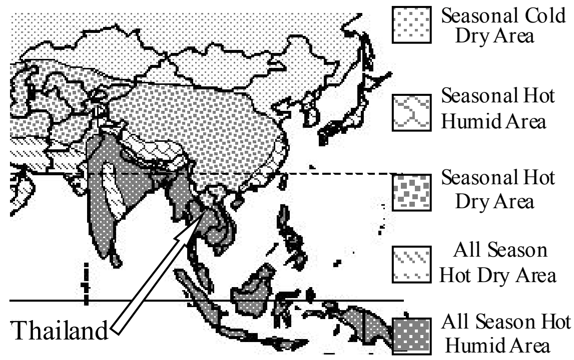
INTRODUCTION

Environmental protection movements have spread rapidly throughout the world in recent years. However, in developing countries, the reduction of emissions that have environmental impacts, such as carbon dioxide, is not straightforward because of the need to develop and expand economic growth while improving the environment.

Figure 1 shows electricity consumption by economic activities from 1990 to 2001 in Thailand. Consumption increases each year, especially by residences. Figure 2 shows the climatic characteristic zone (Kimura, 2000) and location of Thailand and surrounding countries. To apply energy conservation technologies effectively, it is necessary to understand the climatic characteristics of the area. Therefore, the present paper introduces a useful method that utilizes natural energies for cooling buildings.

METHODS





Preparation of Meteorological Data: In researching the present paper, the standard meteorological data was difficult to utilize; therefore, representative annual data were selected by standard deviation, the closest to the mean basic data for 1991–2000. Meteorological data for 1995, which included the altitude of observation points, were selected (Figure 3). Figure 4 shows the observation points, latitude–longitude and geographical map of Thailand (Information Service Division, Thai Meteorological Agency).

Drawing of the Climatic Maps

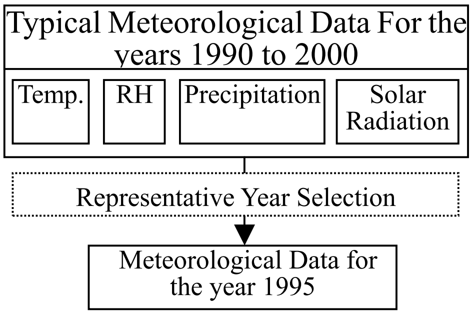


Figure 3 Selection of the representative year from standard deviation.

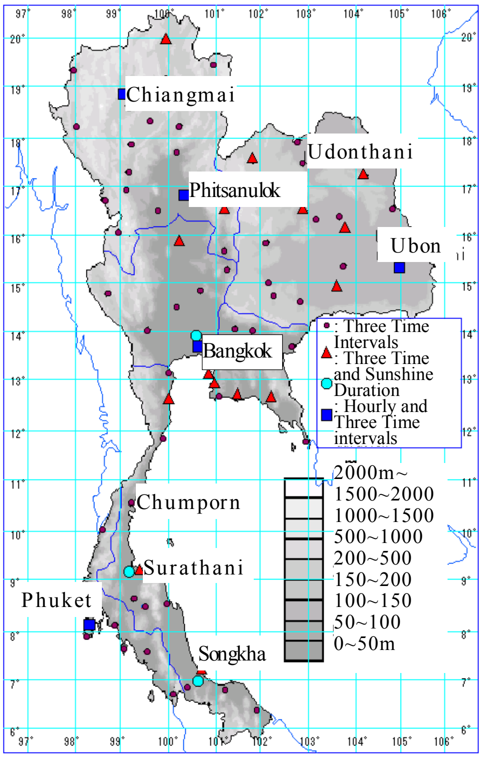


Figure 4 Observation points and altitude map of Thailand.

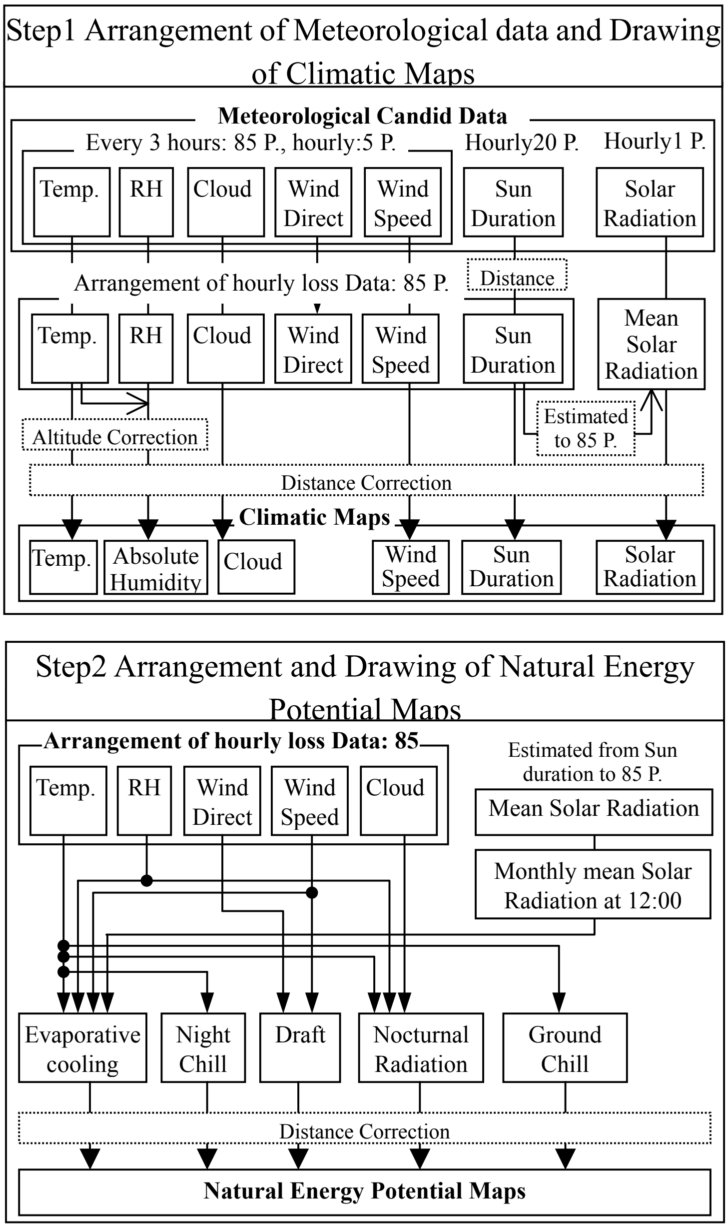


Figure 5 Steps for meteorological data arrangement and mapping of climatic and natural energy potential maps.

To map the climatic characteristics of Thailand, candid meteorological data observed by the Thai Meteorological Agency must be utilized. The process of data arrangement and mapping is shown in Figure 5. Step1, in which loss data, altitude and distance correction are used to estimate arbitrary points, not including observed data.

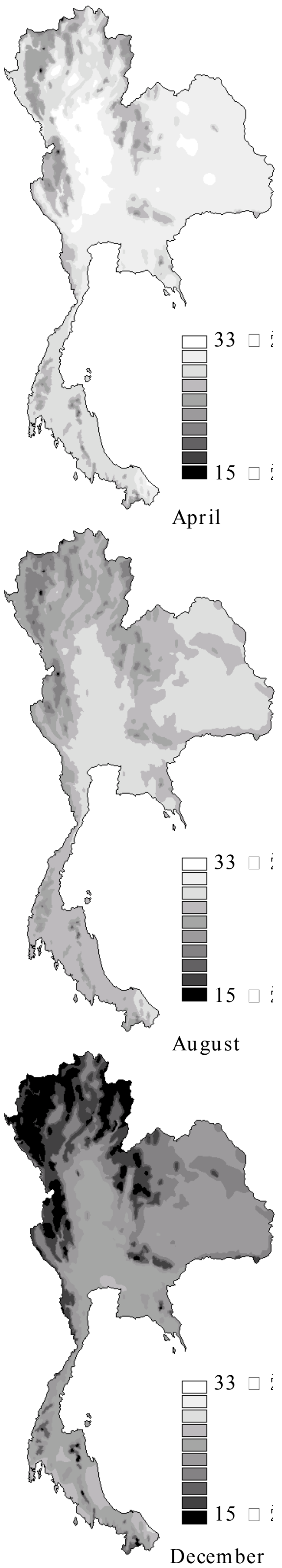


Figure 6 Air temperature.

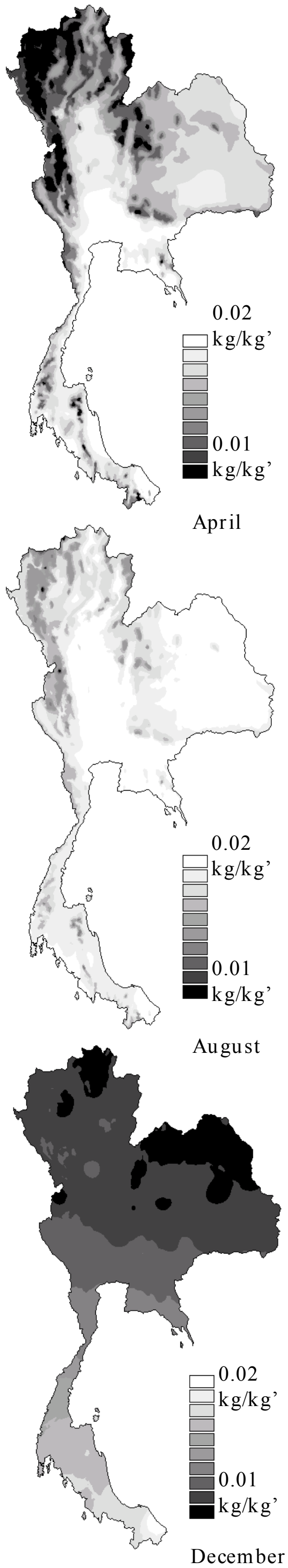


Figure 7 Absolute humidity.

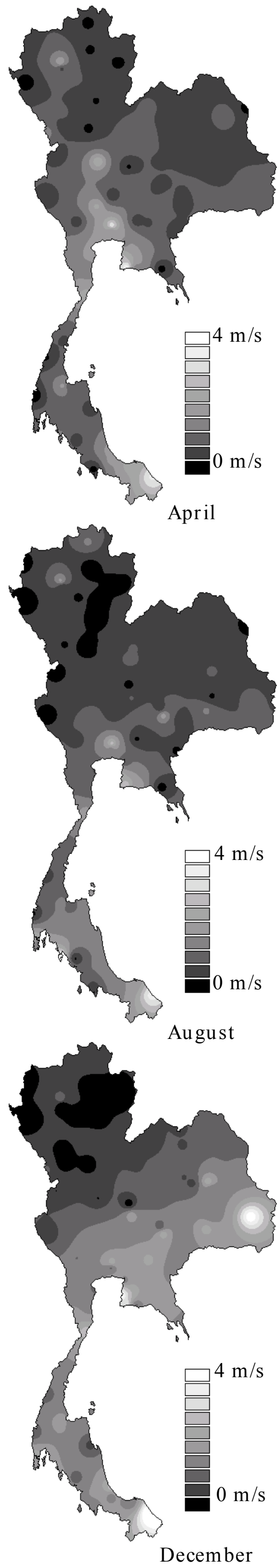


Figure 8 Wind speed.

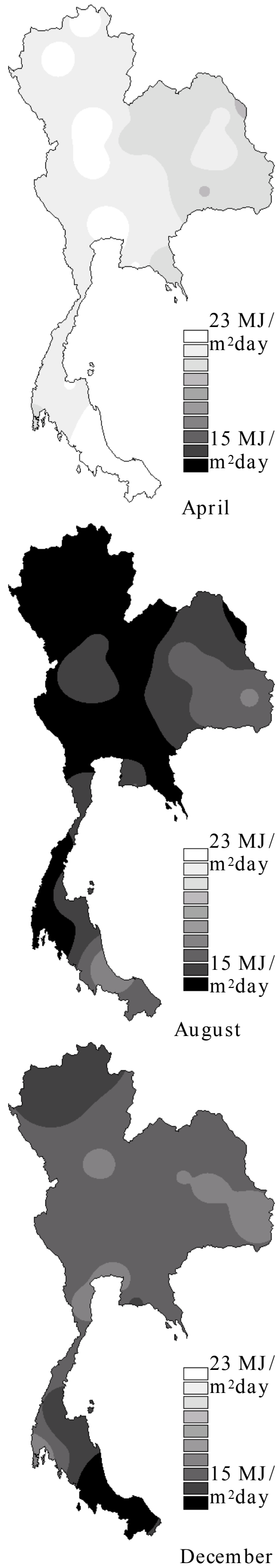


Figure 9 Solar radiation.

The climatic maps, showing temperature and absolute humidity in Figures 6 and 7, respectively, indicated that Thailand has remarkably seasonal differences, with hot dry, hot humid and cool seasons. Wind speed changes somewhat in specific parts of the area, as shown in Figure 8. Solar radiation (Figure 9) is estimated from only one observation point, however, the high correlation between predicted and observed values indicate that seasonal variations exist (Yoshida and Shinoki, 1978; Watanabe *et al.*, 1983). The climatic maps are the typical for hot dry-humid and cool seasons in Thailand.

Natural Energy Potential Mapping: The previous study and the current study (Saito and Ishihara, 1996; Nishikawa *et al.*, 1998) indicate that Thailand is located in a hot-humid region, obviously requiring cooling measures. In the present study, a passive cooling method would provide clean energy that meets energy conservation goals. To optimize natural energy available through passive cooling, each passive cooling method has been defined in the equations below. A natural energy potential map had been drawn utilizing the equations below based on passive cooling methods developed for hot-humid areas in Japan (Y. Urano, Passive Cooling of Houses). The process of mapping is shown in Figure 5, step 2.

The Equation of Natural Energy Potential

Evaporative Cooling Potential ECP(MJ/m²h)

$$\mathbf{ECP} = L \cdot \frac{\alpha_{c12}}{C} (\overline{X}_{s12} - \overline{X}_{o12}) \quad (1)$$

L: evaporative latent heat (2427.9kJ/kg), C: humidity specific heat (kJ/kg°C)
$\overline{X}_{o12}$: mean monthly absolute humidity at 12:00 (kg/kg')
α_{c12}: mean monthly convective heat transfer at 12:00 (kJ/m²h°C)
(calculated utilizing Jurges equation from the mean monthly wind speed at 12:00)
$\overline{X}_{s12}$: mean monthly surface absolute humidity from SAT at 12:00 (kg/kg')

$$\overline{SAT}_{12} = \overline{T}_{12} + \frac{a}{\alpha_{c12} + \alpha_r} \overline{J}_{h12}$$

$\overline{T}_{12}$: mean monthly air temperature at 12:00 (°C)
$\overline{J}_{h12}$: mean monthly solar radiation at 12:00 (kJ/m²h)
a : solar absorptivity (0.5), α_r : radiative heat transfer coefficient (18.4 kJ/m²h°C)

Night Chill Potential NCP (°C)

$$\mathbf{NCP} = \sum_{i=1}^{days} (T_{maxi} - T_{mini})/days \quad (2)$$

T_{maxi}: maximum temperature (°C) , T_{mini}: minimum temperature(°C)

Nocturnal Radiation Potential NRP (kJ/m²h)

$$\mathbf{NRP} = \sum_{i=1}^{days} \varphi \cdot \sigma \cdot \overline{T}^4 (0.474 - 0.076\sqrt{\overline{f}}) \cdot \{1-(1-k)\overline{c}/10 \quad (3)$$

φ: sky factor
σ: Stefan-Bolzmann coefficient (20.43×10⁻⁸ kJ/m²hK⁴)
$\overline{T}^4$: mean monthly air temperature (°C), $\overline{f}$: mean monthly water vapor pressure (mmHg)
k: cloud height coefficient (0.3) , $\overline{c}$: mean monthly cloud cover

Ground Chill Potential GCP (°C)

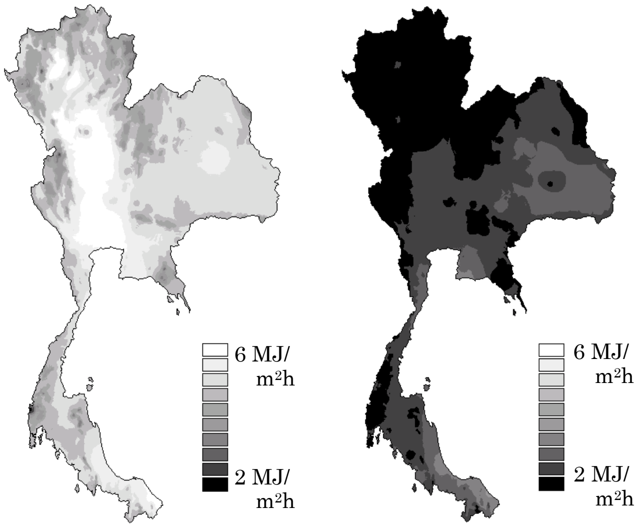
$$\mathbf{GCP} = (\overline{T}_{max} - \overline{T}) \quad (4)$$

$\overline{T}_{max}$: mean monthly maximum air temperature (°C), $\overline{T}$: mean annual air temperature (°C)

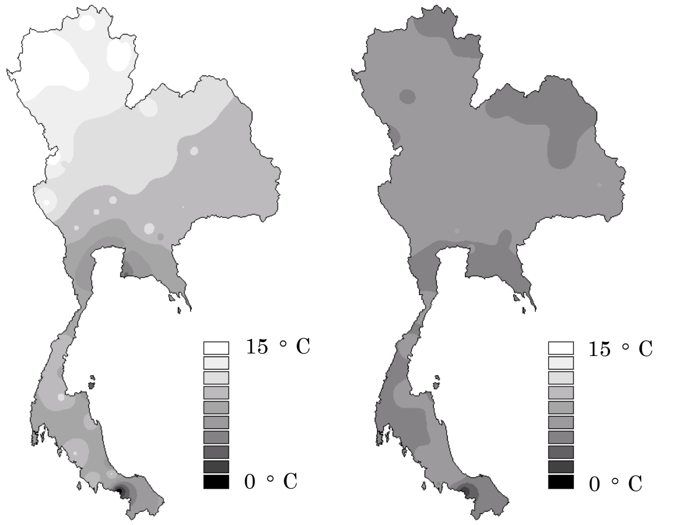
Draft Potential DP (%m/s)

$$\mathbf{DP} = W_D \cdot W_{DS} \quad (5)$$

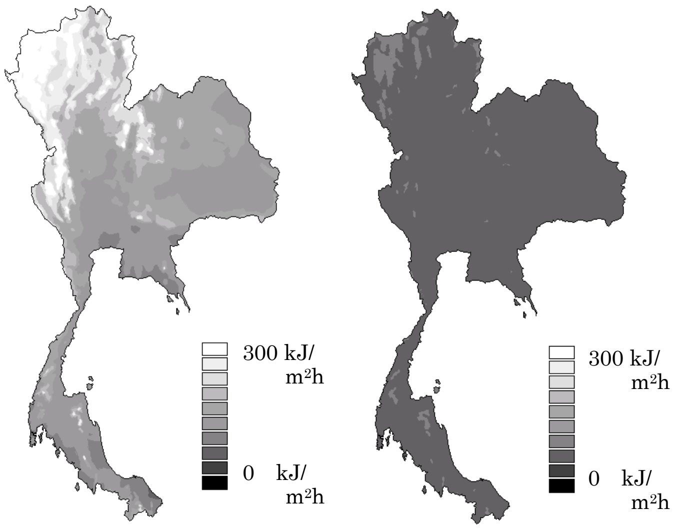
W_D: maximum 3 continuous wind direct (%), W_{DS}: maximum 3 continuous wind speed(m/s)



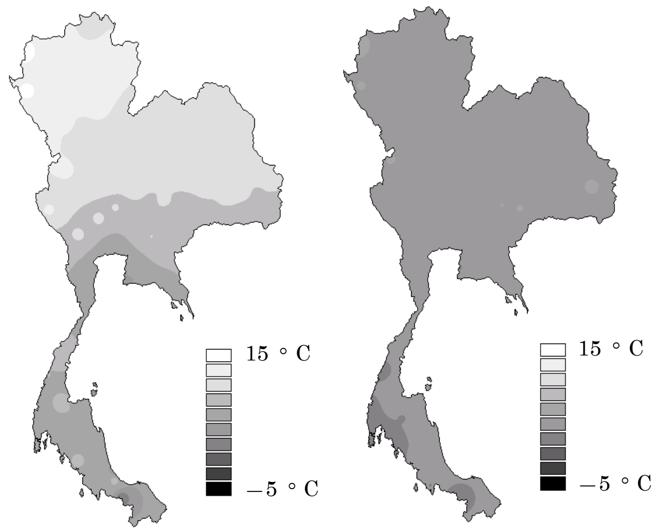
April August
Figure10 Evaporative cooling potential.



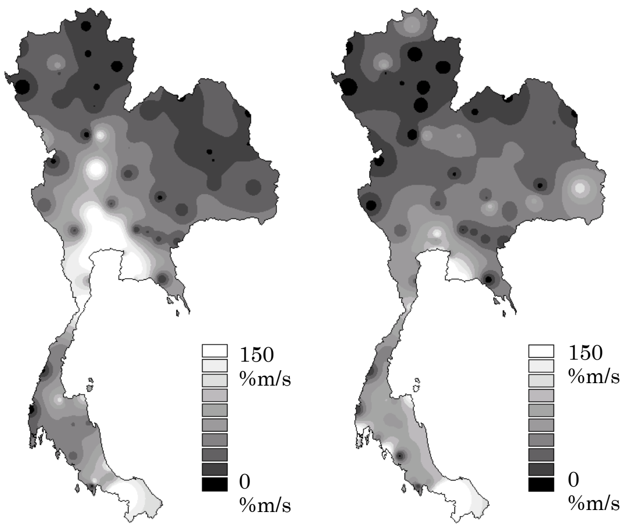
April August
Figure 11 Night chill potential.



April August
Figure 12 Nocturnal radiation potential.



April August
Figure 13 Ground chill potential.



April August
Figure 14 Draft potential.

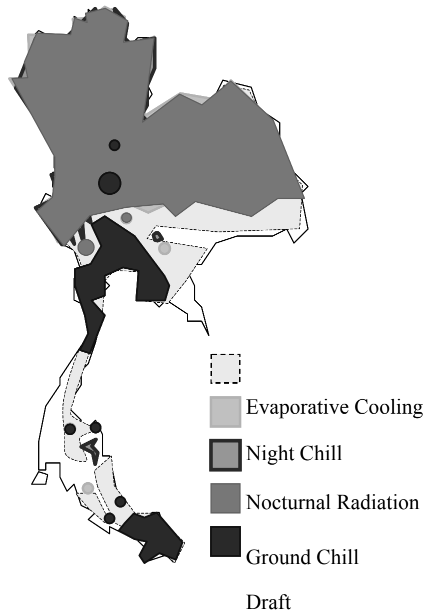


Figure 15 Optimal situation of passive cooling.

According to air temperature and absolute humidity of climatic maps, the cool season in December does not require cooling systems, and does not need consideration. Passive cooling methods would have to be implemented during the hottest season in April, and during the hot-humid season in August.

Evaporative cooling (Figure 10) utilization in Thailand would be more effective in the inland areas and in some parts of the south during hot dry season in April. Night chill potential (Figure 11) is increases with latitude in April, but in August, there is no variation across this small country. Nocturnal radiation (Figure 12) in April is higher with increased altitude. However, increases in nocturnal radiation observed in April, do not continue in August. In April, the ground chill potential (Figure 13), which increases with the latitude, could effectively be utilized in the upper regions. In August, this value is uniformly small throughout the country. Figure 14 shows that the draft potentials in April and August have similar distributions, which could be expected in the central coastal area and in some parts of the south. The distribution optimal passive cooling utilization in various areas in Thailand is shown in Figure 15.

CONCLUSIONS

Local meteorological data are needed to evaluate the indoor climate of buildings for environmental design. The present paper introduced a process of arranging meteorological data, obtained from the Thai Meteorological Agency, to visualize climatic characteristics and to utilize passive cooling methods in Thailand.

The results of climatic mapping in Thailand show that climatic maps differ by local area. Climatic elements were confirmed to change by geographical location and seasonal factors.

When applying natural energy to passive cooling methods in Thailand, evaporative cooling is the optimal method during hot-dry season in most areas of the country. During the hot-humid season, only drafts experienced in coastal areas could be utilized as a passive cooling method.

In the present study, the annual data used for analysis are not standardized meteorological data. Therefore, in the future, the standardization of meteorological data for environmental design should be considered.

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REFERENCES

Kimura, K. (2000). The technology of natural energy in folk dwellings. National Astronomical Observatory, Chronological Scientific Tables 2000.

Nishikawa, K., Saito, I., Ishihara, O. *et al.* (1998). Preparation of meteorological data and climate maps for natural energy utilization. *Journal of Architectural Planning and Environmental Engineering, AIJ* **509**, 15–20.

Saito, I. and Ishihara, O. (1996). A study on production of regional weather data for utilization of natural energy, Part1: Estimation of solar radiation. *Journal of REIMAN* **18**, 47–50.

Watanabe, T., Urano, Y. *et al.* (1983). Procedures for separating direct and diffuse insolation on a horizontal surface and prediction of insolation on tilted surfaces. *Journal of Architectural Planning and Environmental Engineering, AIJ* **330**, 96–108.

Yoshida, S. and Shinoki, S. (1978). Preparation of the maps of monthly mean global solar radiation and its year to year variability for the Japanese Islands. *TENKI* **25** (5), 61–75.