The Applicability of the Current Thermal Climate Zones for Building Energy-Saving Design of China

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Abstract. Climate has a great impact on the thermal performance of buildings. This study aims to provide a theoretical foundation for developing climate classification for building energy-saving in China. The current thermal climate zoning method was evaluated by using the mean deviation to assess its applicability on guiding building energy-saving design in China by using the latest weather data measured from 1988 to 2017. The analysis results indicate that current thermal climate zones cannot present the difference in atmospheric moisture and solar radiation in different regions. The current cold zone is unable to reveal the discrepancy of the monthly average temperature of hottest month in different regions. To provide an adequate guidance for the energy efficient design of HVAC systems as well as for passive building design, the main zoning criteria should be revised and the climate indices relating to air humidity and solar radiation should be considered in the future.

Keywords: Climate zoning, Building Energy-saving, Mean deviation, China

1. Introduction
Climate is a key issue in building energy efficiency design [1]. Plentiful research works have proved that climate-responsive design is an effective way to achieve building sustainable development, and the regional climate characteristics must be taken into account at first to achieve this object [2-4]. Climate classification, defined on account of climate variables, is generally viewed as a reliable approach to understand the climate features of different regions.

Climate classification has a long developmental history which concept can be traced to the 4th century B.C [5]. It was initially used to explain atmospheric phenomenon. With the development of the meteorological observation and the accumulate of meteorological data, a quantitative classification system, describing the diversity of climate rather than explanatory, was built in 1900. Since the mid of the 20th century, climate classification has been used for building projects in a lot of countries [6]. Nowadays, a lot of countries and regions have published building energy standards or policies according to the building climate zones defined by several climatic variables that has close relationship with building energy consumption [7-9].

The building energy consumption has rapidly increased in recent years in China due to the economic development. Chai and Zhang estimated that China’s PER would increase to 6200 Mtcce in 2050 [10]. To reduce the energy consumption and carbon emission, a range of building energy efficiency standards were published by government departments in China [11]. These standards should be implemented according to the thermal climate zones which developed by using the meteorological
data recorded from 1995 to 2004. Heat gain/loss of building envelopes and the corresponding thermal insulations was a major concern in this thermal climate zones [12]. In recent decade, more and more passive techniques including nocturnal ventilation cooling, passive solar heating and evaporative cooling are applied in building energy-saving design. With the increasing of the lifestyle levels, energy consumption by using Heating, Ventilation and Air Conditioning (HVAC) systems in residential and public buildings has sharply increased [13-15]. Several studies indicated that the current thermal climate zones in the standard cannot offer an adequate guidance for the building energy-saving design [16,17]. However, the way to build a comprehensive building climate classification to instruct building energy saving design in China is still obscure.

The object of this study is to analyse the applicability of the current thermal climate zones for building energy-saving design in China and provide a primary research foundation to build an adequate building climate classification for China in the future.

2. Method and Data

The first priority of building climate classification is to reveal regional climate characteristics and provide guidance for building energy efficiency design. Many studies indicated that several climate indices, including monthly average temperature in coldest month ($T_{\text{cold}}$), monthly average temperature in hottest month ($T_{\text{hot}}$), average vapour pressure during the winter ($V_{P_{\text{winter}}}$), average vapour pressure during the summer ($V_{P_{\text{summer}}}$), sunshine duration during the winter ($S_{T_{\text{winter}}}$), sunshine duration during the summer ($S_{T_{\text{summer}}}$), average diurnal temperature during the hottest month ($D_{T_{\text{hot}}}$), HDD 18°C and CDD26 ℃, have great connection with passive building design and HVAC system design [16,18]. Therefore, to reveal the regional climate characteristics, the mean deviation (MD), defined as the average value of the absolute deviation of a set of data with respect to the data’s mean, can be used to reveal quantitatively these regional distribution characteristics. The MD can be defined by the following equation.

$$MD = \frac{1}{N} \sum_{i=1}^{N} |x_i - \bar{x}|$$

where $N$ is the number of simple, $\bar{x}$ is the mean of simple located in same group, $x_i$ is the $i$th simple value.

In this study, an updated climate classification map was developed according to current thermal climate zoning method and the latest weather data at first. Afterwards, the MD was applied to quantitatively assess the feasibility of this updated thermal climate zones in China.

2.1. Meteorological Data

The meteorological data applied in this study comes from the National Climate Center of China. Totally 603 cities, measured from 1988 to 2017, were chosen from the dataset for this research. The daily mean value of each meteorological element in this dataset is calculated according to the recorded values measured 4 times each day.

2.2. The Method of the Current Thermal Climate Zones in the Standard

The thermal climate zones were developed by the Ministry of Construction in 1993 and revised in 2016 [19]. The aim of this climate zones is to provide guidance for building envelope design that performed best in the winter and summer. The thermal climate zones contain five main climate zones, specifically Hot Summer and Cold Winter, Hot Summer and Warm Winter, Severe Cold, Cold and Mild which can be abbreviated to HSCW, HSWW, SCZ, CZ and MZ respectively, and 11 sub-zones. The zoning method of thermal climate zones was presented in table 1.
Table 1. Zoning method of thermal climate zones.

| Climate zone name | Zoning method | Sub-zone |
|-------------------|---------------|----------|
|                   | Primary zone  |          |
| SCZ               | A  $T_{\text{cold}} \leq 10 ^\circ \text{C}$ | HDD18 $^\circ \text{C} \geq 6000$ |
|                   | B  $D_5 \geq 145$ | 6000 > HDD18 $^\circ \text{C} \geq 5000$ |
|                   | C  $D_5 > 145$ | 5000 > HDD18 $^\circ \text{C} \geq 3800$ |
|                   | A  $T_{\text{cold}} = 0$--10 $^\circ \text{C}$ | 3800 > HDD18 $^\circ \text{C} \geq 2000$, 90 > CDD26 $^\circ \text{C}$ |
|                   | B  $D_5 = 145$--90 | 3800 > HDD18 $^\circ \text{C} \geq 2000$, 90 < CDD26 $^\circ \text{C}$ |
| CZ                | A  $T_{\text{cold}} = 0$--10 $^\circ \text{C}$, $T_{\text{hot}} = 25$--30 $^\circ \text{C}$ | 2000 > HDD18 $^\circ \text{C} \geq 1200$ |
|                   | B  $D_5 = 90$--0, $D_{25} = 40$--110 | 1200 > HDD18 $^\circ \text{C} \geq 700$ |
| HSCWZ             | A  $T_{\text{cold}} > 10$ $^\circ \text{C}$, $T_{\text{hot}} = 25$--29 $^\circ \text{C}$ | 700 > HDD18 $^\circ \text{C} \geq 500$ |
|                   | B  $D_5 = 100$--200 | 500 > HDD18 $^\circ \text{C}$ |
| HSWWZ             | A  $T_{\text{cold}} = 0$--13 $^\circ \text{C}$, $T_{\text{hot}} = 18$--25 $^\circ \text{C}$ | 10 > CDD26 $^\circ \text{C}$, 2000 > HDD18 $^\circ \text{C} \geq 700$ |
|                   | B  $D_5 = 90$--0 | 10 > CDD26 $^\circ \text{C}$, 700 > HDD18 $^\circ \text{C}$ |

Remarks: $D_5$ is the number of days which average temperature is below 5 $^\circ \text{C}$; $D_{25}$ is the number of days which average temperature is over 25 $^\circ \text{C}$.

3. Results and Analysis
The updated thermal climate zones for China developed according to the meteorological data measured from 1988 to 2017 is shown in figure 1. It can be found that the distribution of each climate zone is tangly, and the general location of each zone is similar to the one published in the Code for Thermal Design of Civil Building (GB 50176-2016).

![Figure 1. The climate zones for China based on the latest meteorological data.](image)

As the sub-zones in the thermal climate zones are determined by HDD18 $^\circ \text{C}$ and CDD26 $^\circ \text{C}$, the following analysis and discussion are mainly focused on the definition of the main zones. As shown in figure 2, the regional distribution characteristics of 7 climate indices which have been introduced in Section 2 in each main zone were revealed by MD.
Figure 2. Regional distribution characteristics of seven climate indices.

In figure 2a, the dispersion of $T_{\text{cold}}$, $T_{\text{hot}}$ and $DT_{\text{hot}}$ in SCZ and CZ is more obvious than that in other zones. It is worth noting that the dispersion of $T_{\text{hot}}$ in CZ which has reached to 4.6 ℃ is significantly greater than others. This phenomenon suggests that the current definition of CZ cannot well distinguish the difference of the average air temperature of the hottest month in this region. According to the analysis result shown in figure 2b and figure 2c, the current definition of SCZ and CZ cannot distinguish the difference of humidity in these regions, and the current definition of MZ cannot distinguish the different of solar radiation in this region. Humidity is a key factor in passive building design and has close relationship with several technical measures, such as radiant cooling, nocturnal ventilative cooling and evaporative cooling. And the intensity of solar radiation has crucial impact on the passive solar house design. In summary, the current definition of thermal climate zones cannot reveal adequately regional climate characteristics for building energy-saving design. The meteorological indices associated with air humidity and solar radiation need to considered on the basis of current thermal climate zoning method in the future.

4. Conclusions
Climate is one of the key factors affecting building energy-saving design. Defining an adequate building climate zones is the fundamental step towards building energy efficiency. This study quantitatively analysed the applicability of the current thermal climate zoning method of China in the standard for HVAC systems, as well as for passive building design by using the latest meteorological data from 1988 to 2017.

According to the analysis results, the dispersion of the monthly average temperature in hottest month of Cold Zone is obviously higher than other zones. The humidity characteristic in SCZ and CZ and solar radiation characteristic in MZ are unable to be distinguished by using the current method. It is indicated that current thermal climate zoning method cannot present comprehensively regional climate characteristics for building energy efficiency design. The main zoning criteria should be
revised and the climate indices relating to air humidity and solar radiation should be considered in the future.

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