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Climatic parameters for building energy applications: A temporal-geospatial assessment of temperature indicators

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ABSTRACT

Understanding the climate and location aspects are usually the first step in energy applications – from buildings to renewable energy. With so many of the renewable energy sources being significantly dependent on weather, it is essential that the temporal and geospatial variability and distribution of climatic design parameters are investigated for effective planning and operation. ASHRAE-HOF is the most widely used climatic design conditions database for building energy and HVAC professionals, but gaps exist in the literature on the geospatial and temporal distributions of the HOF dataset. This research explored geospatial distributions of key HOF (2009) climatic parameters: temperature (dry-bulb, wet-bulb, dew-point and mean) and degree-days at various temporal scales. Identified spatial variability illustrate the effects of latitude, elevation, landuse and nearest coastline. Observed trends agree with conventional wisdom; however, sparse coverage in populated areas such as Africa and Asia diminish the versatility of the database. Variations in temperature exist, even between closely spaced sites – emphasizing the need to use location-specific data for enhancing the accuracy of the weather-related analysis. Moreover, latitudinal similarities in the distribution offer potential in identifying candidate locations for reciprocal transfer of knowledge on environmental design and operation.

1. Introduction

The need to reduce lifecycle carbon emissions from buildings to mitigate the impacts of climate change mandates that the efficiency of a building and its systems are optimized right from the beginning – at the earliest in the design process. Most of the decisions affecting a building's energy and environmental performance are taken during this stage. Mistakes and *less than optimum* design decisions are often carried forward in subsequent stages as early-stage decisions are difficult to alter. Complexities arise mainly due to the fragmented nature of the industry [1] and the involvement of many disciplines with varying understanding of the problem and work practices [2,3]. As one of the major boundary conditions of building design, the climate of a site plays a vital role in identifying and formulating design strategies [4]. An understanding of site climate and resulting climatic design conditions is, therefore, essential for effective design and operation of energy efficient buildings. Climatic design conditions, a summary of climate attributes and derived indicators, are routinely used to formulate and verify strategies for the design of building layout, form and fenestration – as well as for the design and operation of heating, refrigeration, ventilation and air-conditioning systems [5].

The analysis of precedents is an integral part of learning and practice of design [6–8]. Precedents are often exemplars that act as a benchmark and are used by designers (student/apprentice and practitioners) to glean concepts or ideas relevant to the problem they are trying to solve. Designers also learn from failures of their work or that of their peers. In this sense, precedents can also be negative ones, illustrating some failure [6]. In addition to having an understanding of the climate of the design site, it is also essential that the climatic features of the precedent site are understood, and its differences with the design site's climate are reconciled while gleaning relevant knowledge. Geospatial distributions of climatic parameters are useful in these circumstances where knowledge is often extracted from contextual observations of the effectiveness of a particular feature/strategy. Moreover, contextual observations are often carried out in situations where detailed information about buildings is not always available. Inference from observation and experience is, therefore, widely used and is more often than not the most effective strategy. The lack of knowledge of the distribution of

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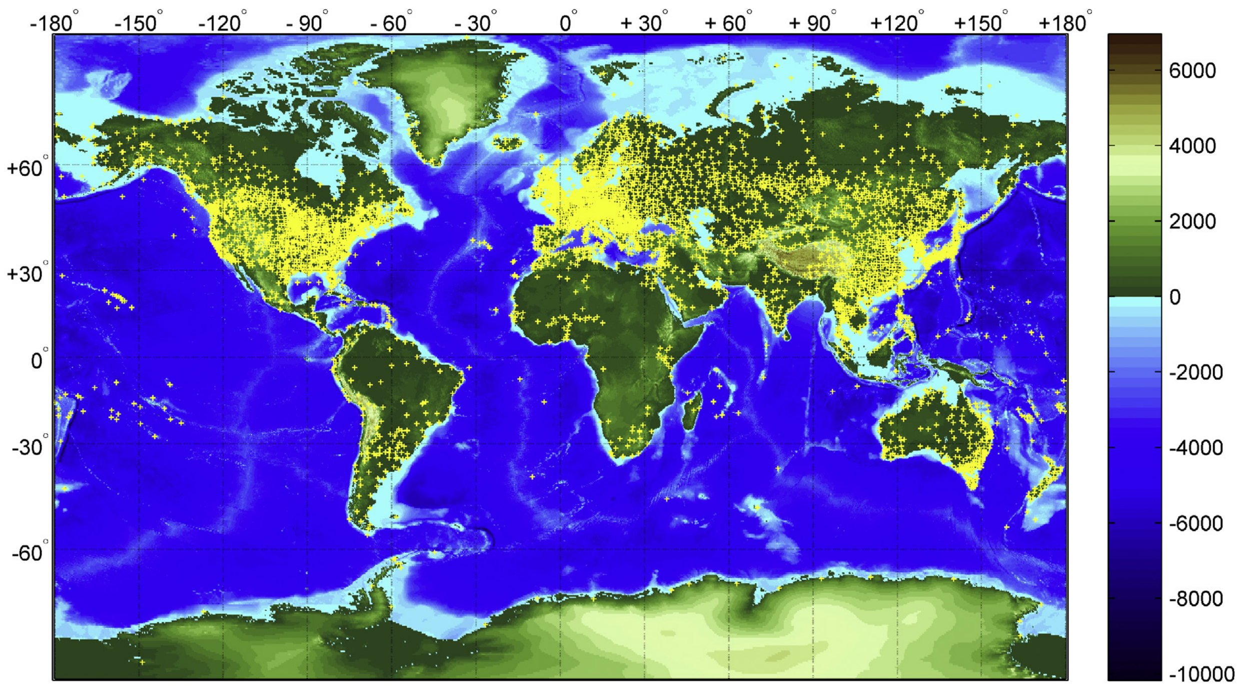

Fig. 1. Locations of 5511 meteorological stations included in this study. The colormap represents altitude (m).

climate parameters may make it difficult, even impossible, to extract useful knowledge, if precedent and design sites are located in distinct climatic regions.

Projected changes in climate, in particular, global increases in temperature, are likely to alter the present-day climate characteristics of most locations. The magnitudes of the projected changes are uneven; i.e., not all places on earth will experience warming at the same rate [9]. An understanding of the distribution of changing parameters will help in identifying vulnerable regions and develop appropriate technologies and policies. While contemporary building regulations and policies are predominantly aimed at energy conservation and carbon emissions reduction, there is evidence of a gradual move towards adaptation to the inevitable changes in climate [10,11]. It is the identification of adaptation strategies where the investigations on distribution can offer significant leverage. The understanding of the behavior of buildings and occupants in future climates of a site can be thought of as an example. As the future climate is only a projection based on scenarios, it is difficult to ascertain how people will behave or adapt to the changes, as it does not exist yet. One can, however, get an idea of the physical and psychophysiological effect by studying a present-day climate of another location that is similar in characteristics to the projected future climate of a site. In climatological terms, this is known as an *analog* scenario/climate [12], which can be identified from distribution maps.

Climatic design information from professional bodies and governments are routinely used for the design and operational management of buildings that are responsible for 40% of global energy consumption and resulting greenhouse gas emissions [13]. Despite their routine use, design conditions database lag behind the state-of-the-art developments in climate and meteorology, both in terms of coverage and scope. The use of low resolution data averaged over a large geographic area is commonplace. For example, the underlying method of complying with the overarching European legislation, Energy Performance of Buildings Directive [14] on building energy efficiency relies on single degree-day quantity for large regions, ignoring the geospatial effects of temperature distribution. Such generalizations often result in significant discrepancies between the predicted (during design) and actual (operational) energy use. While, hypothetically, one can make use of detailed and robust climatic data from recognized sources such as IRENA Global Atlas for renewable energy [15], Meteonorm[1] [16] and CRU climate data,[2] in practice, however, there is a lack of evidence on the use of these data by the wider built environment community.

Existing research lacks an understanding of the distribution of climatic design parameters used by the built environment professionals. One of the reasons for this gap is that a *fine* resolution climate dataset covering the earth was not readily available until recently. Other reasons are related to the challenges associated with quality assurance of data and large-scale geospatial analysis. The recent release of a comprehensive climatic design information dataset by the American Society of Heating, Refrigerating and Air-Conditioning (ASHRAE) [5] enables us to construct geospatial distribution maps of climatic parameters and derived indicators, of interest to the built environment community. This paper investigates the geospatial distribution of key climatic design information: temperature and derived parameters at two temporal scales: annual and monthly. The rest of the paper is organized as follows. The source of data and methods for scattered data interpolation and the construction of distribution maps are discussed next, followed by a section on results and contextual discussions. The article ends with concluding remarks.

2. Methods

2.1. Data source

Several sources of data on climate parameters exist with varying

[1] Most of the data in meteonorm are taken from the Global Energy Balance Archive (GEBA), World Meteorological Organization (WMO); however, non-station data are mostly synthetic.

[2] Climatic Research Unit, University of East Anglia. http://cru.uea.ac.uk/data.