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Study on the future weather data considering the global and local climate change for building energy simulation

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ABSTRACT

Energy simulations are often used to evaluate the indoor thermal environment and energy consumption of buildings. In such simulations, it is common to use regional weather data that are typically based on current or past weather conditions. However, most buildings have a lifespan of several decades, during which climate can change gradually. Therefore, the design of energy conservation systems and energy simulations should incorporate climate change predictions to ensure that buildings are adaptable to future climatic conditions.

The present study aims to construct future (i.e., 2030s) standard weather data for use in architectural design using numerical meteorological models. For this purpose, we adopted a dynamical downscaling method, used global climate model (GCM) data as the initial and boundary conditions for input into a regional climate model (RCM), and physically downscaled the data using the RCM.

We constructed a prototype of the future (i.e., 2031–2035) standard weather data based on version 4 of the Model for Interdisciplinary Research on Climate (MIROC) and the Weather Research and Forecasting (WRF) model. The results confirm that the weather data generated via the dynamical downscaling method can predict local climate. Subsequently, we simulated building thermal load consumption using regional climate data. By comparing the results for the present (2007) and future (2034), we estimated the impact of climate change on the energy performance of a detached house. In particular, the sensible heat load for the house was predicted to increase by 15% under the conditions considered.

1. Introduction

During the building design process, energy simulation to adapt buildings to regional climate is typically conducted using regional weather data. There are two famous types of weather data for building energy simulation. One is the weather data to estimate peak loads which is so called “design weather data”. The other is the weather data to calculate annual loads, which is named “standard weather data” in this paper. Standard weather data have been generated by various groups in many countries (Cooperman & Dieckmann, 2010). For example, in Japan, the information observed by the Automated Meteorological Data Acquisition System (AMeDAS) was used to construct and publish Expanded AMeDAS Reference Weather Year (EA-RWY), which are commonly used as standard weather data (Kohri & Ishino, 2005). EA-RWY includes hourly data describing eight of the weather components required for standard weather data: temperature, humidity, direct solar radiation, atmospheric radiation, wind direction, wind speed, precipitation, and sunshine hours. There are some different points in way of making the standard weather data, but most of all ways are based on constructing a year from 12 individual months of real weather data, which represent average monthly weather over several years.

The weather data used for building energy simulations are typically based on current or past weather conditions. However, most buildings have a lifespan of several decades, during which climate can change gradually. The Intergovernmental Panel on Climate Change (IPCC) has summarized global warming predictions by using the observations and global climate model (GCM) simulations conducted by various groups globally. In particular, the IPCC Fifth Assessment Report (Intergovernmental panel on Climate Change, 2013) concluded that “Global mean surface air temperatures over

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land and oceans have increased over the last 100 years." Therefore, energy simulations should incorporate climate change predictions to ensure that buildings are adaptable to future climatic conditions. To achieve this, future weather data for building energy simulations based on future weather predictions are required.

Future climate predictions have long been conducted using GCMs, which undertake global simulations. GCMs typically solve sets of dominant equations that represent the characteristics of the global earth system (e.g., the atmosphere and oceans) and predict time series of future climate conditions under scenarios in which the concentrations of greenhouse gases (GHGs) and aerosols in the air are assumed. Recently, attempts have been made to evaluate the impact of climate change on building energy simulations and to produce future standard weather data using future climate data predicted by GCMs. Commonly used method is morphing approaches (Lisa Guan, 2009). In this method, current weather data base on observation is modified with climate change information, the difference of average and standard deviation between current and future climate predicted by GCMs. One of the most important merits of this method is to decrease the GCM's bias, due to the coarse resolution and the inaccuracy of parameterization or so, using the difference between current and future climate. In addition, the morphing approach is computationally cheap because this method is based on statistical manipulation.

For example, using morphing approach, Urano (2009) attempted to construct a future weather dataset for Tokyo in Japan and conducted energy simulations to evaluate the impact of climate change on a general office building thermal load in this region. Urano produced future weather data for building energy simulations by incorporating a climate change value into EA-RWY; this climate change value was represented by the difference between the monthly mean present (1991–2000) and future (2041–2060, 2091–2100) weather data predicted by a GCM. This is one of the simplest examples using morphing approach, shifting only average of current standard weather data. The results of building energy simulations in the paper predicted that the sensible annual cooling load in future (2050s) would increase by 45–60% from current in a general office building in Japan. However, the resolutions of GCMs are typically so coarse (i.e., tens to hundreds of kilometers) that future weather data based on mean values predicted by GCMs cannot produce the regional-scale (i.e., resolution of several kilometers) climate change information required for building energy simulations. The Chartered Institution of Building Services Engineers (CIBSE) produced a future standard weather dataset by adding a regional climate change value based on regional climate change prediction (according to UKCIP02 and UKCP09) to a current standard weather dataset, Test Reference Years (TRYs) (Mylona, 2012). In Japan, Soga, Murakami, Akasaka, and Nimiya (2009) made future weather data using morphing approach to current EA weather data with the regional climate change information by Japan Meteorological Agency (JMA), Global warming prediction information vol. 6. Besides monthly mean value over decades, daily mean value and standard deviation of each weather component predicted in the global warming prediction information are used for making the future weather data. UKCIP02/UKCP09 by CIBSE and the global warming prediction information by JMA are the regional climate change information through dynamical downscaling of GCM with RCM, so these future weather data are expected to produce the local climate change information.

However, in all of these previous attempts to obtain future weather data, the weather datasets were created by modifying the current weather data based on observation with the future climate data predicted by GCMs. Therefore, for the future weather data in these ways, the synoptic variation which decides daily weather conditions is related to current rather than future weather and the information about synoptic variation predicted by GCM is lost. Moreover, information about the interactions between various weather components is lost because of statistical manipulation. These information of synoptic variation and interactions between weather components are of particular importance in the creation of regional weather data for building energy simulation. Particularly when utilizing the regional weather data to make the design weather data, which is based on extreme weather conditions and selected taking into consideration of some weather components, the properties of daily synoptic variation and the relationships between different weather components become very important.

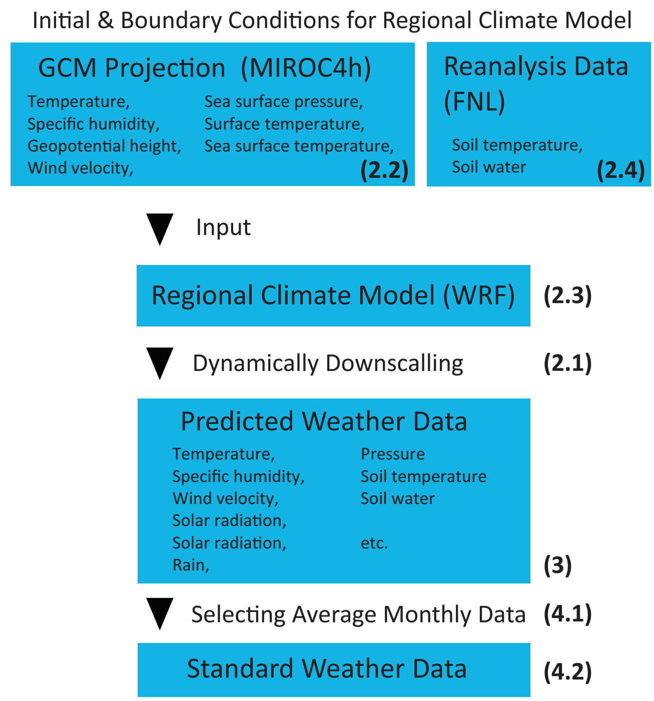

Fig. 1. Flowchart of making standard weather data.

The present study aims to construct a future (2030s) regional weather dataset for use in building energy simulation by using the direct dynamical downscaling method with a GCM. The regional weather data obtained according to this method contain the important information required for future weather data for building energy simulation, such as locality, future synoptic variation predicted by GCM, and interactions between weather components.

In this paper, we present the flow of making future weather data for building energy simulations. This paper is constructed as follows. In Section 2, we review the available downscaling methods and describe the characteristics of MIROC4h and WRF, which we used as the GCM and regional climate model (RCM), respectively. We document the analysis conditions and describe our simulation results in Section 3. Then, in Section 4, we discuss the adoption of the current and future standard weather data as a prototype and describe how we conducted building thermal load simulations to assess the impact of climate change on building energy simulations.

2. Methodology

We employ a dynamical downscaling method with the future (2031–2035) weather data predicted by a GCM to derive future weather data at a local scale; these data can be used to simulate the energy performance of buildings under future climate change scenarios. We adopted MIROC4h and WRF as the GCM and RCM, respectively. Fig. 1 shows a flowchart of making future weather