The study on modelled and measured weather data for building energy simulation programs for Malaysia.

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Abstract. This paper will study the usability of future weather data generated from climate model for Malaysia. Detailed future weather data is required for the building energy assessment as input parameters. The future weather data required is normally achieved from climate prediction models. The purpose of this study is to examine the gaps between weather data generated by climate model and the data measured by weather station in Bayan Lepas, Penang. Furthermore, this studies also to establish the modelled weather data for the use for future building energy simulation program. In order to achieve this purpose, simulated weather data sets HadCM3 were supplied by the Hadley Centre in the United Kingdom. The measured weather data was supplied by Malaysian Meteorological Department for Bayan Lepas, Penang. The period of analysed time was 18 years from 1990 to 2007 where the available data overlaps between HadCM3 and measured data. Several major weather variables were used in these studies such as Dry-bulb temperature, Solar radiation and Wind speed. The outcome from this studies shows a good match between HadCM3 data and measured data indicates that HadCM3 model is suitable for the purpose of future building energy simulation for Malaysia.

1. Introduction
Future building simulation requires simulated weather data from climate models. Currently, there are numbers of climate models used globally. Climate models are used for future predictions on climate changes and the study of climate dynamics. The development of climate models and their connection with climate change prediction was identified in the early 20th century as discussed by Edwards in his works ‘History of climate modeling’ [1] and Weart; ‘The development of general circulation models of climate’ [2].

Basically, there are two main categories of global climate models. Atmosphere General Circulation Models (AGCMs) and Ocean General Circulation Models (OGCMs) account the changes within the atmospheric and ocean changes respectively. These two types of models can be coupled together as Atmospheric-Ocean General Circulation Models (AOGCMs) giving a comprehensive model for future climate prediction [3].

AGCMs combine the atmosphere together with land surface models and impose the sea’s surface temperature. AGCMs normally consist of a ‘dynamical core’ that integrates the large-scale fluid motion usually to simulate surface pressure; temperature and water vapor in layers and so on. OGCM has basically the same concept as AGCMs. The difference is that OGCMs simulate the ocean together with the impose of fluxes from the atmosphere and can include the sea ice model [1].
The coupling of AOGCMs has meant progression towards a comprehensive model since 1980s [2]. There are two types of OAGCMs. Earth System Models (ESMs) OAGCMs models climate components such as land surface, cryosphere, hydrology (lakes, evaporation, rivers and rainfall), and vegetation. Meanwhile, Integrated Assessment Modes (IAMs) OAGCMs comprise the impact of climate change, economic responses, and policy scenarios in a single modeling structure [1].

Climate models require complicated computing processes and are usually developed at meteorological and research centers. There are a number of research centers developing climate models globally such as the Max Planck Institute in Germany, Japan’s Earth Simulator Centre, and the Goddard Institute for Space Studies in the United States [1]. In the United Kingdom, the Hadley Centre at the UK Met Office developed the Hadley Model which is used widely by various works such IPCC climate impact assessment. For this research, Hadley Coupled Model Version Three (HadCM3) data was employed. HadCM3 was the key model used in the development of IPCC Third Assessment Report (TAR) [4].

2. Weather data for building energy simulation

2.1. Special Report Emissions Scenarios (SRES)
The IPCCs Special Report Emissions Scenarios (2000) contained a set of new projections of future Green House Gases emissions. Each projection was a “storyline”, describing the manner of world population, political, economies and lifestyle changes over the next few decades [4]. The storylines are summarized into four scenario families with the severest scenario being A1. The scenario describes a very rapid economic growth with increasing globalization, an increase in general wealth, with convergence between regions and reduced differences in regional per capita income. The scenario also describes rapid technological change. In addition, the A1 scenario is divided into three variants: the emphasis of fossil fuels (A1F1), non-fossil fuels (A1T) or a balance across all sources (A1B).

The A2 scenario has slower economic growth than A1’s scenario but has a faster population growth due to less convergence of fertility rates. The scenario also portrays that economic and technological changes are regionally oriented.

The B1 scenario portrays the same rapid economic growth with the A1 scenario and the more integrated world, and is more environmentally sustainable. Clean and efficient technologies are introduced. Meanwhile, B2 scenarios have a lower population rate than A2 but it is still higher than A1 and B1. Future developments are locally oriented in terms of environmentally, economically and socially.

2.2. The Hadley Centre Model (HadCM3)
HadCM3 is a coupled AOGCM developed at the UK Hadley Centre in 1999. HadCM3 is a sophisticated climate model, a compilation of two models, the atmospheric model (HadAM3) and ocean model (HadOM3). It also contains the sea-ice model. The atmospheric component divides the global surface into 96 x 73 grid cell, where a grid cell has the resolution of 2.5 degrees of latitude and 3.75 degrees of longitude and also has 19 levels. The grid cell has a surface resolution of about 417 kilometres x 278 kilometres at the Equator, reducing to 295 kilometres x 278 kilometres at 45 degrees of latitude [5]. The oceanic model has 20 levels with a horizontal resolution of 1.25 x 1.25 degrees [6].

The weather data from HadCM3 is available from years 1860 to 2099, while every year is split conveniently into 360 days with 30 days in each month. In addition, HadCM3 is a first integrated model without flux adjustments. The flux adjustment was required for previous models in order to avoid the simulation drifting into unrealistic states of climate [6].

Meanwhile, HadCM3 simulates 28 weather components in a daily-average format. The variables accessible are such dry-bulb temperature (DB), maximum (Tmax) and minimum (Tmin) temperature, relative humidity (rH), Wind Speed, Down Short-Wave Flux (DSWF) and so on [7].

For this study, the data provided by the National Climatic Data Centre (NCDC) [8] were in ASCII data format. Data extraction for Malaysia’s grids was performed for these raw data sets.
2.2.1. HadCM3 grid on Malaysia.
Malaysia’s peninsular can be found between latitudes 1.5°N and 7°N and longitudes 99.5°E and 104°E. Moreover, there are two HadCM3 grid points situated in or near Malaysia’s peninsula, 101.25°E longitude and 5.0°N latitude, and 101.25°E longitude and 2.5°N latitude, with resolution of approximately 300 kilometres.

Figure 1 shows the HadCM3 grids that covering most of Malaysia’s peninsular. The first point, 101.25°E longitude and 5.0°N latitude is centred in Perak and covered most area of Northern region. It covers more land areas than the second grid point, 101.25°E longitude and 2.5°N latitude, which is centred on Malacca Strait (sea areas).

2.3. Result and Discussion
These analyses were undertaken to examine the gap or dissimilarities between HadCM3 and measured data supplied by the Malaysian Meteorological Department (MMD) [9]. The data used in these analyses for HadCM3 focused on grid 101.25°E, 5.0°N which is inland, whereas the measured data are for Bayan Lepas, Penang which is on coast as shown in Figure 1. There may therefore be some difference in climate between the two sites. The period of analysed time was 18 years from 1990 to 2007 where the available data overlaps between HadCM3 and measured data.

![Figure 1. HadCM3 Grids in Peninsular Malaysia.](image1)

Several major weather variables were used in these studies such as Dry-bulb temperature, Solar radiation and Wind speed. The annual means of Dry-bulb temperature analysis shows a consistent difference like that shown in figure 2. The average difference shows that the measured Dry-bulb temperature was 1.5°C warmer than HadCM3 data. The differences are expected as HadCM3 weather data summarised across the whole grid area while measured data supplied was station or point data.

![Figure 2. Comparison of measured and HadCM3 Dry-Bulb temperature from 1990 to 2007.](image2)

![Figure 3. Comparison of annual averages for measured and HadCM3 SOL from 1990 to 2007.](image3)

![Figure 4. Comparison of annual averages for measured and HadCM3 WS from 1990 to 2007.](image4)
On the other hand, the comparisons for Solar radiation (figure 3) and wind speed (figure 4) shows a close relation between measured and HadCM3 weather data. From Figure 3 it can be seen that the HadCM3 solar radiation shows close to measured data.

3. Conclusion
This paper discussed the background of weather data required for future building simulation. The weather data sets were obtained from simulated global climate models then compared with real weather data sets obtained from the Malaysian Met Office. The matching results show the similarity or close relation between modeled and real weather data. This result also established the usability of HadCM3 modeled weather data generated from Hadley Model for building energy simulation program.

References
[1] Edwards P N 2011 History of climate modeling Wiley Interdisciplinary Reviews: Climate Change 2 128
[2] Weart S 2010 The development of general circulation models of climate Studies in History and Philosophy of Modern Physics 41 208
[3] Solomon S Qin D Manning M Chen Z Marquis M Averyt K B Tignor M and Miller H L 2007 IPCC The Physical Science Basis: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, UK) (Cambridge University Press) pp 20
[4] Nakicenovic N and Swart Rob 2000 IPCC Emission Scenarios: A Special Report of Working Group II of the Intergovernmental Panel on Climate Change (Cambridge University Press)
[5] Hulme M Mitchell J Ingram W Lowe J Johns T New M Viner D 1999 Climate change scenarios for global impacts studies Global Environment Change 9 S3
[6] Met Office 2011 Hadley Centre at UK Met Office http://www.metoffice.gov.uk/climate-change/resources/hadley
[7] Gordon C Cooper C Senior C A Banks H Gregory J M Johns T C Mitchell J F B and Wood R A 2000 The simulation of SST, sea ice extents and ocean heat transports in a version of the Hadley Centre coupled model without flux adjustments Climate Dynamics 16 147-168
[8] More references National Climatic Data Centre 2011 US Department of Commerce Http://www.ncdc.noaa.gov/oa/ncdc.html.
[9] Malaysian Meteorological Department 2011 Official Portal of Malaysian Meteorological Department (MMD): Ministry of Science, Technology and Innovation (MOSTI) http://www.met.gov.my.
[10] More references Met Office (2011) Hadley Centre at UK Met Office http://www.metoffice.gov.uk/climate-change/resources/hadley.