Meteorological Modeling Applications in Building Energy Simulations

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Introduction

Researchers use sophisticated computer models to predict building energy use. These models require extensive input data including building characteristics and dimensions, load schedules, and weather data. The typical source for weather data is the weather station at the nearest airport. Specifically, hourly values of ambient air temperature are necessary. The data obtained from local airports, however, may be significantly different from the actual weather experienced by a nearby residential building. Thus, using local airport data when simulating a residential building may yield inaccurate results. Furthermore, researchers interested in evaluating the potential for heat island mitigation schemes (such as urban tree planting programs) to decrease building air-conditioning energy use need a method for modifying the local airport data accordingly.

Weather Data

In order to investigate the applicability of airport data in building energy simulations, we analyzed dry-bulb temperature data from four airports and fifteen residential sites within Sacramento California. The data were taken from a heat island study conducted in the summer of 1987. Inter-comparison of these temperature data indicated that the peak temperatures at the sites often differed by 2 to 4°C. Occasionally airport and site temperatures differed by as much as 7 or 8°C. Figure 1 gives an indication of this variability by presenting temperature data for a site and nearby airport on a typical day. From these temperature data it is clear that airport weather data may differ significantly from nearby residential locations. The symbols on this figure are results from the method 1 simulations discussed later in this paper.

Meteorological Modeling

Meteorological models can play an important role in improving the airport weather data used in building energy simulations. These models are capable of predicting the impact that variable surface properties will have on local air temperatures.

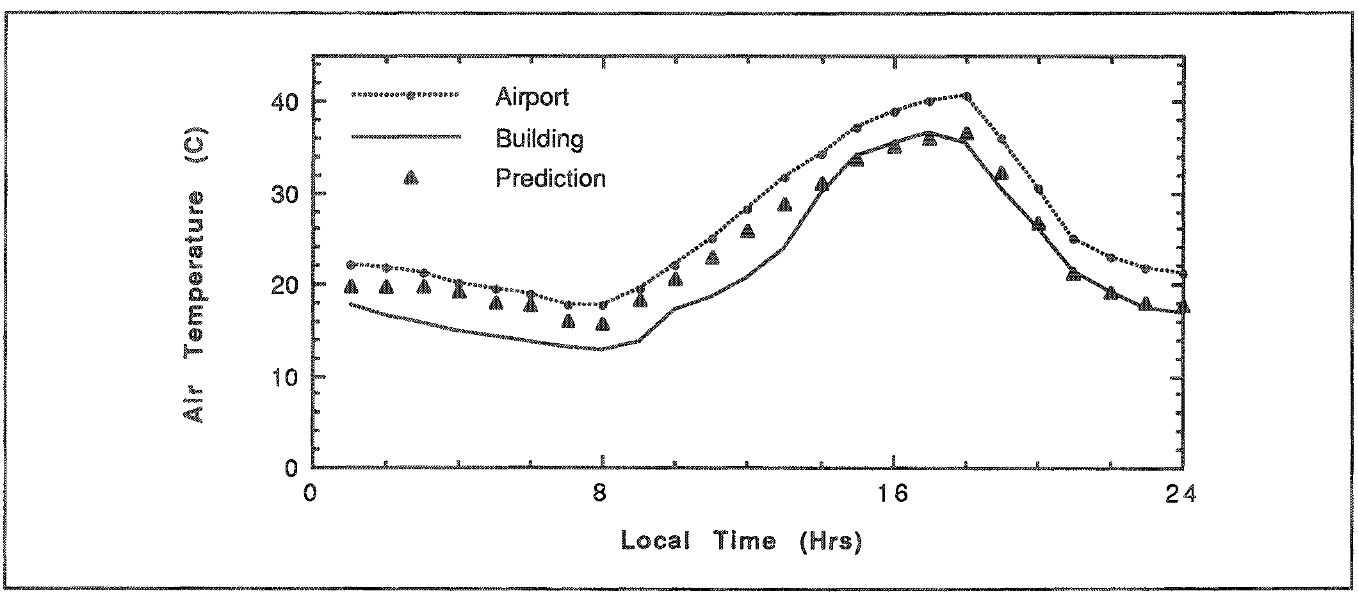

Figure 1. Diurnal Air Temperature Profiles Measured at a Residential Site and the Nearby Airport. Symbols represent Method 1 prediction of the residential site diurnal temperature profile.

Simple one-dimensional simulations are useful in that they can provide quick order-of-magnitude predictions of the impacts of changes in surface characteristics. Simulations have shown that in the absence of other effects, albedo and vegetation may independently be responsible for peak temperature variations on the order of 2 or 3°C. One-dimensional simulations are limited in applicability, however, since they assume homogeneous surface characteristics and do not take into account the effects of topographical variability and the impact of nearby areas of varying characteristics.

Three-dimensional simulations provide a much more accurate method for predicting the variability of air temperatures. This approach, however, requires a great deal more computer resources as well as a significant amount of data to accurately represent the surface characteristics within the computational domain. A further complication is that due to the common application of the hydrostatic assumption in these models, the horizontal grid spacing must be at least several kilometers for the model to remain stable. Thus, the micro-meteorological effects of very localized surface characteristics cannot be simulated with three-dimensional models. These models are, however, very useful in predicting the meteorological impact of large-scale characteristics such as topography and land-use.

Modifying Airport Weather Data: Method 1

A simple method for modifying airport temperature data consists of using one-dimensional meteorological simulations in order to estimate the temperature variation of a residential site relative to a nearby airport weather station. The first step is to estimate the surface characteristics for the airport and conduct a simulation for the day in question. The same should then be done for the building site at which local weather data is needed. The difference in temperature between these two cases (T_{site} - $T_{airport}$) should be computed at each hour. This difference represents the impact of local surface characteristics and should be added to the actual measured airport data to produce a new set of *modified* site temperature data (T_{site}). This process helps to account for synoptic weather patterns by using actual measured data rather than using the simulation predicted temperatures alone. This method was applied to one of the sites from the 1987 Sacramento study using rough estimates of the surface characteristics. The results are presented with the measured data in Figure 1. The air conditioning energy use for a typical building was then simulated using this temperature profile. For comparision, building energy simulations were also conducted using airport data and then using actual site measured data. Figure 2 presents a comparison of simulated air conditioning use for these three cases when applied to several typical houses. These results indicate that use of airport weather data in building energy simulations may result may result in errors as large as 50%. The use of temperature profiles derived using method 1 reduced this error to 29%.

Modifying Airport Weather Data: Method 2

The above method may be improved upon thorough use of a full three-dimensional simulation. The researcher should start with the *modified* site temperature data produced by method 1. These data represent the estimated impact of the difference between airport and building site local surface characteristics. In order to estimate the possible impact of effects due to topography and large scale land-use differences a full three-dimensional simulation must be conducted. This simulation will require detailed specification of surface characteristics. If the airport and building site are located in different computational grid cells, the predicted temperature difference between these cells will represent the above-mentioned non-local effects. This temperature difference is then added to the *modified* site temperature data (from Method 1) to produce an improved estimate of the diurnal profile of the outside air temperature at the building.

Conclusion

Existing meteorological data indicate that use of airport data in building energy simulations may be inappropriate

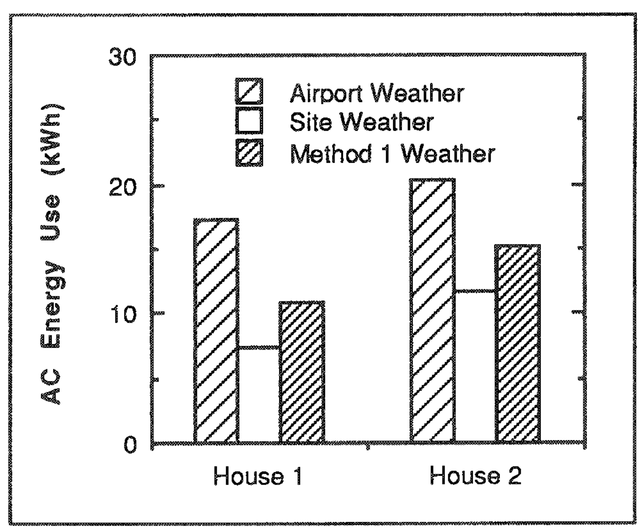

Figure 2. Building AC Energy Use for a Typical Summer Day Using Various Temperature Profiles

even in cases where the simulated building is very near the airport. The measured site air temperatures often differ by as much as 4°C. In some situations, simulations using airport temperature data yielded daily energy use estimates which were 50% higher than simulations which used site-measured temperature profiles. Two methods of differing complexity were proposed for the modification of airport temperature data for use in building energy simulations. The simpler method was illustrated by applying it to measured data. The use of this method reduced the error in the energy use estimate to roughly 29%. Method 2 is suggested as an improvement over method 1. The results presented here have shown the potential for meteorological models to improve upon weather data used in building energy simulations. In order to validate both of the proposed methods, however, a more sophisticated monitoring experiment is needed in which surface characteristics are thoroughly evaluated. These methods may then be proven to live up to their demonstrated potential.

Acknowledgements

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