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Simulation of building energy and indoor environmental quality - some weather data issues

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Abstract

After elaborating that a building is a rather complicated dynamic system where many of the governing energy and mass transfer relationships are highly non-linear, this paper focuses on weather data as needed for computer simulation of buildings. The paper does not aim for completeness but rather to identify some issues of concern.
These issues are categorized under headings of weather data requirements, weather data information and availability, weather data generation, weather data reference years vs. recorded time series data, and micro climate issues. The paper finishes with some conclusions and possible directions for future work.

BACKGROUND

Building energy consumption and indoor environment is determined by a number of sources acting via various energy and mass transfer paths as shown in Figure 1. The main sources may be identified as:
- outdoor environment or weather (in a building context, the main variables are air temperature, sky radiant temperature, humidity, solar radiation, wind speed, and wind direction)
- occupants who cause casual heat gains by their metabolism, usage of various household or office appliances, lighting, etc.
- auxiliary system which may perform heating, cooling, and / or ventilating duties.

These sources act upon the indoor environment via various energy and mass transfer processes:
- conduction through the building envelope and partition walls
- radiation in the form of solar transmission through transparent parts of the building envelope, and in the form of long wave radiation exchange between surfaces
- convection causing heat exchange between surfaces and the air, and for instance heat exchange inside plant components
- air flow through the building envelope, inside the building, and within the heating, cooling, and / or ventilating system
- flow of fluids encapsulated within the plant system.

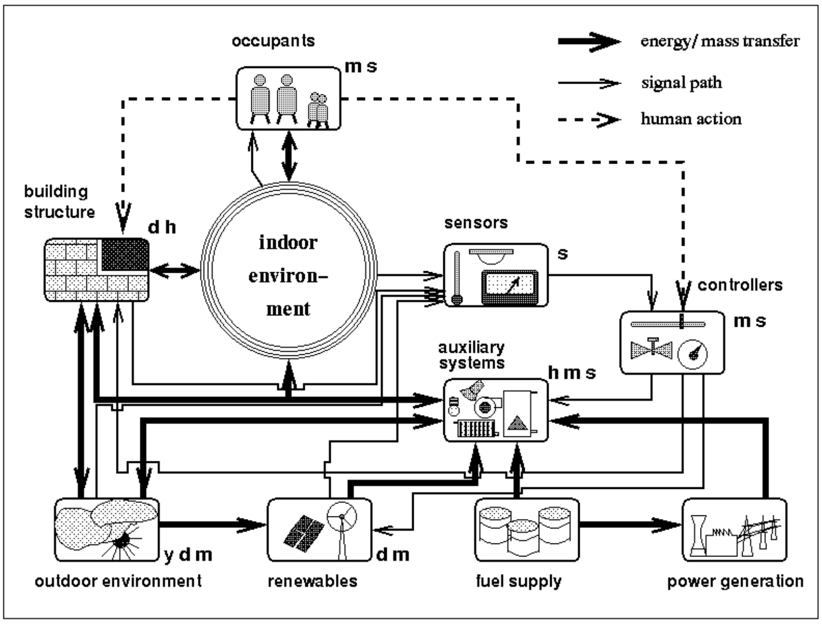

Figure 1 The building as an integration of dynamic sub-systems

The indoor climate may be controlled by the occupants basically via two mechanisms:
- altering the building envelope or inner partitions by for example opening doors, windows, or vents, or by closing curtains, lowering blinds, etc.
- scheduling or adjusting the set point of some controller device which may act upon the auxiliary systems or upon the building by automating tasks exemplified above.

Within the overall configuration as sketched in Figure 1, several sub-systems may be identified each with their own dynamic thermal characteristics:
- the occupants, who may be regarded as very complicated dynamic systems themselves.
- the building structure which incorporates elements with relatively large time constants, although some building related elements may have fairly small time constants (eg the enclosed air volume, furniture, etc.)
- the auxiliary system which embodies components having time constants varying by several orders of magnitude (eg from a few seconds up to many hours in case of for instance a hot water storage tank).

The cycle periods of the excitations acting upon the system are also highly diverse. They range from something in the order of seconds for the plant, via say minutes in case of the occupants, to variations in the order of minutes, hours, days and a year in case of the weather.

From the above it will be apparent that a building is a rather complicated dynamic system, where many of the governing relationships are highly non-linear.

It is now generally accepted that the only way to make predictions regarding any future behaviour of a building is by using computer modelling and simulation. The remainder of this paper focuses on weather data as needed for computer simulation. The paper does not aim for completeness but rather to identify issues of concern.

WEATHER DATA REQUIREMENTS

Until recently the main weather data requirements constituted of representative time-series of hourly (averaged or integrated) values of air temperature, humidity, solar radiation, wind speed, and wind direction. Depending on the simulation objectives, the time-series should cover a representative heating season (for e.g. heating energy prediction), a representative cooling season (for e.g. cooling energy prediction, or summertime overheating assessment), an extreme cold period (for e.g. sizing of the heating system), an extreme warm period (for e.g. sizing of the cooling system), etc.

However, building simulation programmes have over the years evolved to a point where it is possible to simulate complex interactions of building components and systems way beyond the relatively simple heating/ cooling energy consumption calculations. (See e.g. Nakahara et al. 1999)

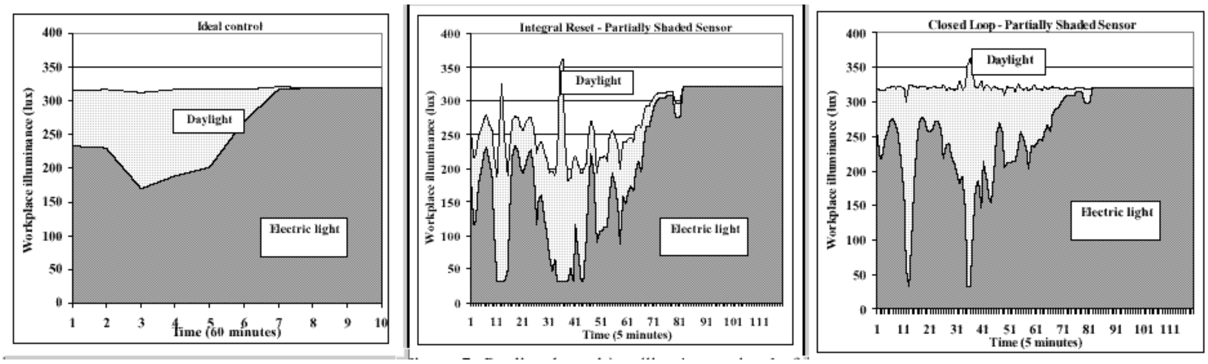

Figure 2 Predicted resulting illuminance levels for the case of ideal dimming control with typical hourly weather data resolution (left frame), for the case of integral reset dimming control with 5 minute weather data resolution (middle frame), and for the case of closed loop proportional dimming control with 5 minute weather data resolution (right frame). (Adapted from: Janak and MacDonald 1999)

For example, it is now possible to predict the performance of lighting controls based on daylight availability. (See e.g. Janak and MacDonald 1999.) However in order to do this there are additional weather data requirements because it is necessary to know the sky luminance distribution, and to have daylight availability data on a higher time resolution, say for each 5 minutes. This is demonstrated with Figure 2, which basically illustrates that realistic control can only be realistically simulated using small time-steps and high resolution weather data.

The way in which the original measured data is averaged over the hour is another problem. (Likewise in case the data is integrated over the hour, or in case instantaneous data is recorded on the hour.) The averaging is usually just algebraic, i.e. $\sum_{i=1}^{n} P_i/n$. However many of the processes in a building are not linear related to the weather variables. For example the output of ducted wind turbines embedded in a building (see e.g. Clarke et al. 1999) varies with the wind velocity to the third power. The relation between the output of photovoltaic cells and incident solar radiation is also non-linear. The main driving force for natural ventilation, wind pressure difference, varies with the wind velocity squared. There exist many more of such examples.

In order to accurately predict the performance of these non-linear systems there is a need for short time-step weather data, with the length of the time-step considerably shorter than the time constant of the systems being considered. In the case of ducted wind turbines and photovoltaic cells this is in the order of a few minutes or less.

As indicated above, the normally available weather data comprises air temperature, solar radiation, humidity, wind velocity and wind direction. However, in state-of-the-art building

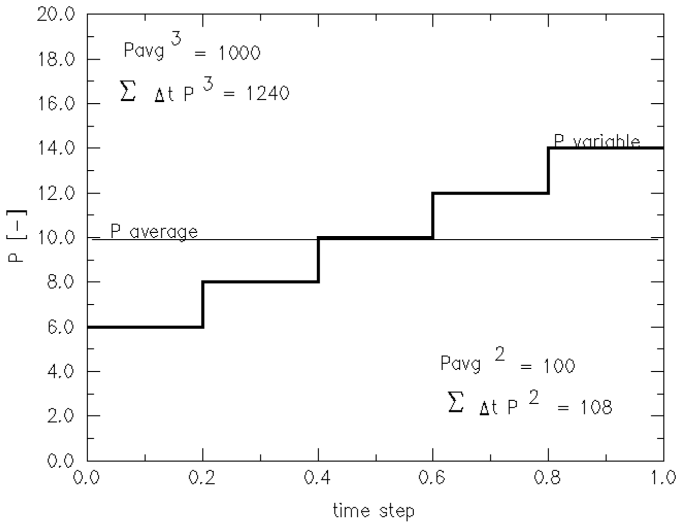

Figure 3 Illustration of the error resulting from using hourly averaged weather data instead of higher resolution time series data. In case the output of a system depends on the weather variable to the 3rd power, the error would be 24% in the example chosen. In case the output of a system depends on the weather variable squared, the error would be 8% in the example chosen.

simulation there is a definite need for additional weather data. The already mentioned sky luminance and sky distribution in an example. Other weather variables which impact the performance of a building are sky radiant temperature (until now this is rather crudely estimated from solar radiation and humidity data), snow cover (not taken into account, but important for e.g. daylighting), the level of CO2, CO, NO2, SO2, ozon and other components which influence the air quality. Extensions to this list are easily imagined.

As a way forward, Crawley et al. (1999) developed a new, generalized weather data format for use by energy simulation programs. This format has been adopted by both EnergyPlus (in the US) and ESP-r (in the UK).

Anticipating the need for data at time steps less than one hour, the format includes a minute field to facilitate the use of short time-step data. The data includes basic location identifiers such as location name, data source, latitude, longitude, time zone, elevation, peak design conditions, holidays, daylight saving period, typical and extreme periods, ground temperatures, time step data period(s) covered (not necessarily 365 days are included), time step data source and uncertainty flags. By including uncertainty and data source information users now can evaluate the potential impact of weather variability on the performance of the building. (See e.g. MacDonald et al. 1999.)

The time step data includes dry bulb temperature, dew point temperature, relative humidity, atmospheric pressure, radiation data, illuminance data, wind data, sky cover data, present weather data, precipitable water, aerosol optical depth and snow related data.

Although this format includes much more information than the traditional weather data for building energy simulation, it is very likely that in the near future there is a need for yet more data as indicated above in terms of air quality. Therefore it is highly desirable that the weather data format as proposed by Crawley et al. (1999) will be made flexible in order to be able to accommodate future extensions while remaining backward compatible.

WEATHER DATA INFORMATION & AVAILABILITY

Without even attempting to be complete, the following section describes some examples of information sources and availability of weather data for various regions around the world.

Most building related engineering associations have a current or ongoing interest in weather data. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) is one of the leading international societies in our field. ASHRAE has a technical committee focusing on weather information (TC 4.2). ASHRAE is currently revising the weather data section for the forthcoming ASHRAE Fundamentals Handbook. Of interest will be the selection of 1,3,5,7 day periods of semi extreme weather data to assist design of plant and buildings.

Table 1, adapted from (Harriman et al. 1999), identifies common use and sources of engineering weather data. The information focuses on the USA, however it is easy to imagine how similar information (should) exist in other countries.

Table 1 Common types and sources of engineering weather data mainly in the USA. (Adapted from: Harriman et al. 1999)

Use	Item	Data Type	Coverage	Publisher
Sizing Equipment	1997 ASHRAE Handbook - Fundamentals	Long-term extremes	1459 U.S. and international locations	ASHRAE, GRI
	Sequences of extreme temperature and humidity		320 U.S. and Canadian locations	ASHRAE
Monitoring and Troubleshooting Installed Equipment	Hourly weather data archive	Current hourly DB and kg/kg	240 U.S. and Canadian locations	GRI
Estimating Long-term Behaviour and Energy Consumption	TMY-2 Typical meteorological years	Typical hourly observations	239 U.S. locations with Puerto Rico	GRI
	WYEC-2 Weather years for Energy Calculations		76 U.S. locations	ASHRAE
	CWEC Canadian Weather Year for Energy Calculations		145 Canadian locations	AES
	EWY Example Weather Year		15 locations in Great Britain	CIBSE
	TRY Test Reference Year and DRY Design Reference Year		156 locations in Europe, Russia and Turkey	CEC
Simulating Equipment Behaviour for a Specific Year	SAMSON Solar and Meteorological Surface Observational Network	Actual hourly observations for specific years	237 U.S. locations	NOAA
	CWEEDS Canadian Weather for Energy and Engineering		145 Canadian locations	AES
	INSWO International Surface Weather Observations		1500 worldwide locations	NOAA

In the UK, the Chartered Institution of Building Services Engineers (CIBSE) is currently preparing a new guide to weather and solar data, which will include the CIBSE TRY, new design guidance and a weather data toolkit. New for the CIBSE will be the use of hourly, real weather data as opposed to an admittance daily cyclic temperature and radiation wave as historically used in the manual CIBSE calculations, for example, for summertime cooling load predictions.

The Society of Heating, Air-conditioning and Sanitary Engineers of Japan (SHASE) has extensive Japanese weather data available for building simulation. They also produced a Standard Weather Year, SWY, for use in Japan.

Since 1997 the International Council for Research and Innovation in Building and Construction (Commission International du Batiment, CIB) has a task group (TG 21) devoted to climatic data for building services. The general aims of CIB TG 21 are to disseminate, discuss and to promote the awareness of climatic data for building services and simulation. The main objectives include: to collate and report on reports and documents from around the world on climatic change and its effect in various parts of the world; to collate sources of hourly weather data for all major cities around the world for simulation (if actual data cannot be identified then synthetic data parameters should be collated in order to enable synthesizing of weather data); to seek collaboration with ASHRAE, IEA, EU, ISO, CEN, IBPSA and BEPAC.

International experts collaborating within the Federation of European Heating and Air-Conditioning Associations (REHVA) are preparing a European HVAC Design Guide. The main goal of the work is to compare methods, data and tools for HVAC design and produce a manual on energy efficient design and to initiate further collaboration. The Guide will incorporate meteorological data, including solar irradiation and daylight data and algorithms

The activities within the European Committee for Standardization (CEN) includes work on weather data for building services engineering within CEN/TC89 Thermal Performance of Buildings and Building Components, working group WG9 Climatic Data. This group recommended choosing 1,3,5 and 7 day semi-extreme periods for design. This is as is being adopted by ASHRAE and also CIBSE.

Table 1 identifies several weather data toolkits - such as TMY, WYEC, CWEC, EWY, TRY, DRY, SAMSON, CWEEDS and INSWO - and the organizations which publish and or generated this data. Another weather data source is the European Solar Atlas (EU 1997), which contains tables and maps displaying monthly means of global, diffuse and beam solar radiation as well as sunhours for a large number of representative sites in Europe. Tables show radiation on both horizontal and inclined surfaces.

The world wide web should not be forgotten as a rich source for weather data. In an electronic article, Ku (1999) provides various pointers to freely available weather sources on the web, such as:

- Weather-specific sites
- Meteorological offices and weather/climate research institutes
- News and travel sites that contain weather information as part of the "need-to-know" package
- Internet directories and Internet service providers.

WEATHER DATA GENERATION

For many locations outside the USA, Canada, West Europe, Japan, etc. there is no weather data readily available for use in building simulation. However, for most locations the long-term (monthly) averages and other statistics of the major weather variables (typically dry-bulb temperature, humidity and global radiation) can be found in widely available atlas and meteorological publications around the world; for example in the case of Great Britain (Booth 1969, Page et al. 1986).

Such meteorological data can then be used to generate hourly weather data, for example by applying a methodology as described by Knight et al. (1991). It was essentially a similar methodology which was suggested by the current author to generate synthetic hourly weather data for Prague as reported by Dunovska (1993).

In a recent paper, Aguiar et al. (1999) report - on the basis of comparative simulations of test cells in the mid-latitude temperate climate of Lisbon - that the synthetic weather data seems more flexible and adequate than the typical meteorological years obtained from statistical analysis of meteorological records.

An example of public-domain software to automate the generation of synthetic weather years is reported by Degelman (1991). An example of commercial software which generates weather data is METEONORM. The latest version of this software (to be released late 1999) will include the climatological normals from the years 1961-90 from about 2500 stations around the world. These "normals" of the World Meteorological Organization (WMO) mainly contain monthly values of air temperature, humidity, rain, sunshine duration, and days with rain. Additional radiation data from this database and other sources will also be included, so that about 2400 stations will be directly accessible.

WEATHER DATA REFERENCE YEARS vs RECORDED TIME SERIES DATA

The need of accurate weather data reference years for building simulations has been well recognized over the years. Many different approaches and methods have been developed. These range from simply selecting - and agreeing to use as reference - a fixed continuous period of recorded data (examples are 1969 Kew data in the United Kingdom, and 1964/1965 De Bilt data in The Netherlands), or creating an artificial year consisting of "long-term average months" (e.g. Van der Bruggen 1978), to generating synthetic Short Reference Years (SRY) (e.g. Van Paassen 1981), and various other Test Reference Years (TRY). For a recent overview of the various TRY generation methodologies, see Argiriou et al. (1999).

There are some problems associated with TRY's. The main problem is that the weather includes several variables (temperature, solar radiation, wind, etc.) which are not necessarily correlated; i.e. it is possible to have both (relatively) warm and cold days with a lot of solar radiation, and you can have both (relatively) warm and cold days with very low solar radiation.
In establishing the TRY some statistical weighting is used to select which hours or days are going to be included into the TRY. This weighting favours, for example, temperature over solar radiation (or temperature and solar over wind, or ....). However, for a particular type of building (say a building without windows and without natural ventilation openings) only the temperature is relevant, so for that building the TRY should have been developed using a high weighting factor for the temperature. For another building (solar collector like) it might be the radiation which is much more dominant, and for yet another building (which completely depends on wind driven natural ventilation) the wind speed and wind direction might be the dominant variable. A TRY will somehow assume 'an average building'; whereas in reality

there are many non average buildings, which, ideally, should have their own TRY.

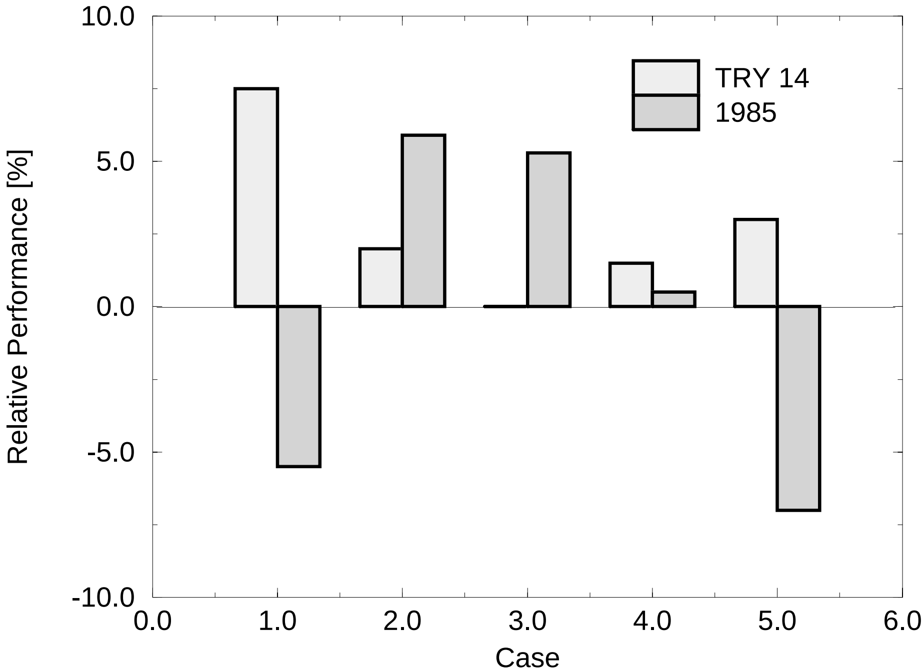

Figure 4 Relative performance of the best overall TRY and of an arbitrarily chosen year with respect to the average 20-year results (0% value), for the cases: 1 - building heating mode; 2 - building cooling mode; 3 - simple solar system; 4 - solar system with interseasonal storage; 5 - PV system. (Adapted from Argiriou et al. 1999)

It is this problem which is addressed and quantified in Argiriou et al. (1999). In this paper, the major TRY methodologies reported in literature (Hall et al. 1978, Lund and Eidorf 1980, and Festa and Ratto 1993) - in their original form and with some variations in the selection procedure - were applied to 20-year hourly recorded data from Athens, covering the period 1977 to 1996. Seventeen TRYs were produced in total. The simulation program TRNSYS was used to simulate various typical building energy systems (i.e. a solar water heater, a building, a large scale solar heating system with interseasonal storage and a photovoltaic system). The annual energy performance simulation results for each TRY were compared with the averaged results for the 20 year period. As implied above, the results confirm that it depends on the case considered which is the best performing TRY; i.e. TRY14 (the modified Festa-Ratto method) has the best overall performance and performs best for the simple solar system, TRY04 performs best for the building heating season, TRY05 for the building cooling season, TRY16 for the photovoltaic system, etc.

Figure 3 shows the differences, in terms of annual energy performance, obtained by TRY14 and by one year randomly chosen (1985) relative to averaged results for the 20-year simulations. The authors state that although the differences might be considered unimportant from the physical point of view, they may lead to erroneous conclusions on the performance, the sizing and feasibility assessment of certain building energy systems.
It should be noted that the comparison was made in terms of annual energy performance, which is an integrated value and as such has a tendency to obscure differences. It might well be possible that comparisons on the basis of for example peak loads would have led to different conclusions in terms of the best performing TRY.

It is that issue which is addressed in another recent, and again very extensive, study by Crawley (1998). Crawley compares simulation results using different reference years (TRY, TMY, TMY2, WYEC, WYEC2) to the results based on actual hourly weather data (SAMSON, 1961-1990, 30-year period of record). In this study, a prototype office building was simulated with the DOE-2.1E program for eight U.S. locations. Crawley reports the influence of the various weather data sets on simulated annual energy use and costs and annual peak electrical demand, heating load, and cooling load. Statistics for temperature, heating and cooling degree-days, and solar radiation for the different locations and data sets are also presented.
Table 2 shows, for example, some of the results for Washington, DC. From the table it is clear that, as implied above, the major differences are not in annual energy consumption but in the peak loads.

Table 2 Comparison of simulated annual energy consumption, energy costs, peak electric demand and peak loads for various weather data types and the SAMSON 30-year average, for Washington, DC. (Adapted from Crawley 1999)

Weather Data Type	Total Annual Energy		Annual Peak		
	Consumption, MJ/m^2-yr, (percent of SAMSON average)	Costs, USD/m^2-yr, (percent of SAMSON average)	Electric Demand, W/m^2-yr, (percent of SAMSON average)	Cooling Load, W/m^2, (percent of design size)	Heating Load, W/m^2, (percent of design size)
SAMSON Average	725	13.24	48.4	9.8%	-7.0%
Design Size	--	--	--	70.4	104
TRY	-2.3%	-1.3%	-1.4%	0.6%	-9.4%
TMY	0.2%	-0.3%	-0.7%	2.2%	-5.1%
TMY2	1.4%	0.7%	1.5%	19.6%	-7.3%
WYEC	-0.9%	0.1%	0.9%	23.6%	-12.0%
WYEC2 (TMY)	0.3%	-0.2%	-0.5%	4.4%	-5.0%
WYEC2 (WYEC)	-0.9%	-0.1%	0.7%	23.8%	-12.2%

The main recommendations from this study are that users of energy simulation programs should avoid using single year, TRY-type weather data. No single year can represent the typical long-term weather patterns. More comprehensive methods that attempt to produce a synthetic year to represent the temperature, solar radiation, and other variables within the period of record are more appropriate and will result in predicted energy consumption and energy costs that are closer to the long-term average. Both TMY2 and WYEC2 use this type of method, are based on improved solar models, and more closely match the long-term average climatic conditions.
For developers of future weather data sets, one of the recommendations is to create a typical weather file that has three years: typical (average), cold/cloudy, and hot/sunny. This would capture more than the average or typical conditions and provide simulation results that identify some of the uncertainty and variability inherent in weather.

To further remove the ambiguity of typical years and design weather in the present-day simulation approach, Hui and Cheung (1997) suggests a multi-year simulation approach, the advantages of which are demonstrated with a 17 year simulation study for a commercial building in Hong Kong. The obvious drawback of the multi-year approach is that many more data and computations are involved.

Since the number of independent weather variables of interest is increasing (i.e. in addition to air temperature, solar radiation, humidity, wind speed and wind direction, we now want to have information about sky temperature, sky luminance level and distribution, and possibly in the future the level of CO2, CO, NO2, SO2, ozon and other components which influence the air quality) it will become more and more difficult to generate test reference years.

MICRO CLIMATE ISSUES

An issue related to weather which is hardly researched until now concerns the differences between the "micro climate" surrounding a building and the assumed weather data which is usually representative of a location more or less distant from the building. These differences are most pronounced in terms of temperature and wind speed and direction; i.e. the main driving potential variables for the heat and mass transfer processes in buildings!

The temperature differences are very noticeable when walking about in the summer in an urban area. Yet it seems that hardly any research has been reported or done in this area.

There are some rough models to predict the wind speed reduction between the local wind speed and the wind speed at the meteorological measurement site. This so-called wind speed reduction factor accounts for any difference between measurement height and building height and for intervening terrain roughness. The reduction factor can be evaluated from some assumed wind speed profile. The wind speed profile depends on (upstream) terrain roughness and the vertical stability of the atmospheric boundary layer. The stability depends on the vertical heat flow through this boundary layer. Partly due to lack of information, in building engineering one usually assumes that there is no vertical heat flow, ie. a neutral atmospheric boundary layer. As an example, Hensen (1991) describes how ESP-r offers several user selectable wind profiles for evaluation of the wind speed reduction factor:

- power law wind profile (Liddament 1986); in this case the actual wind speed profile is approximated by an empirical exponential expression in which the coefficient and exponent account for terrain roughness differences between local site and measurement site:

$$\frac{U_l}{U_{10}} = K\ z_l^{\,a} \quad (-)$$

  where U_l is the local wind speed at a height z_l m above the ground (m/s), U_{10} the wind speed measured in open countryside (m/s) at a standard height of 10 m, and K, a are terrain dependent constants (see Table 0.4).

- logarithmic wind profile (Simiu & Scanlan 1986); it was found - both theoretically and experimental - that the wind speed is a logarithmic function of height:

$$\frac{U_l}{U_m} = \frac{U_{*,l}}{U_{*,m}} \left(\ln \frac{z_l - d_l}{z_{0,l}} \,/\, \ln \frac{z_m - d_m}{z_{0,m}} \right) \quad (-)$$

  where

$$\frac{U_{*,l}}{U_{*,m}} \approx \left(\frac{z_{0,l}}{z_{0,m}} \right)^{0.1} \quad (-)$$

where U_m is the wind speed as measured at the meteo site (m/s) at a height of z_m m above the ground, U_* is the atmospheric friction speed (m/s), z_0 is the terrain dependent roughness length (m), and d is the terrain dependent displacement length (m) (see Table 3).

- LBL model wind profile (also reported in Liddament 1986); for reasons of completeness the Lawrence Berkeley Laboratory (LBL) air infiltration model wind profile - basically a power law profile - is also available:

$$\frac{U_l}{U_m} = \frac{\alpha\,(z/10)^{\gamma}}{\alpha_m\,(z_m/10)^{\gamma_m}} \quad (-)$$

where α, γ are terrain dependent constants (see Table 3).

Table 3 Typical values for terrain dependent parameters (h = building height; source Liddament 1986)

Terrain	K	a	z_0	d	α	γ
Open flat country	0.68	0.17	0.03	0.0	1.00	0.15
Country with scattered wind breaks	0.52	0.20	0.1	0.0		
Rural			0.5	0.7 h	0.85	0.20
Urban	0.35	0.25	1.0	0.8 h	0.67	0.25
City	0.21	0.33	> 2.0	0.8 h	0.47	0.35

Compared with both the power law profile and the LBL wind profile, the logarithmic wind profile is to be preferred because it is based on physical laws rather than on a empirical formulation. It should be noted that all the wind profiles above are actually only valid for heights over $(20 * z_0 + d)$ and lower than $60 \cdots 100$ m; ie. for a building height of 10 m in a rural area, the profiles are only valid for heights above 17 m, in an urban area above 28 m and in a city area above 50 m. The layer below $(20 * z_0 + d)$ is often referred to as the urban canopy. Here the wind speed and direction is strongly influenced by individual obstacles, and can only be predicted through wind tunnel experiments or simulation with a CFD-model. If these are not available, it is advised to be **very cautious**, and to use - depending on the problem on hand - a high or low estimate of the wind speed reduction factor. For example, in case of an "energy consumption and infiltration problem" it is safer to use a high estimate of the wind speed reduction factor (eg. wind speed evaluated at a height of $(20 * z_0 + d)$). In case of for example an "air quality or overheating and ventilation problem" it is probably safer to use a low estimate (eg. wind speed evaluated at the actual building height).
To give a numerical example: assume a building with a height of 7.5 m which is located in an urban area (say $z_0 = 1.0$ m and $d = 6$ m; ie. the thickness of the urban canopy is approximately 26 m), and that the wind speed was measured at a height of 10 m in an open flat country. If we make lower and upper estimates as indicated above, then the following local wind speed reduction factors at building height will result:

power law:	0.58	...	0.79	(-)
logarithmic law:	0.10	...	0.73	(-)
LBL profile:	0.62	...	0.85	(-)

CONCLUSIONS & FUTURE WORK

It is clear that a building is a rather complicated dynamic system where many of the governing energy and mass transfer relationships are highly non-linear. Without even aiming for completeness, some issues of concern related to weather data as needed for computer simulation are identified.

In terms of weather data requirements there is an increasing need both for higher frequency data (due to their non-linear character many processes should be evaluated using time steps smaller than 1 hour) and for additional weather data (i.e. in addition to air temperature, solar radiation, humidity, wind speed and wind direction, we now want to have information about sky temperature, sky luminance level and distribution, and possibly in the future the level of CO2, CO, NO2, SO2, ozon and other components which influence the air quality).
There is a definite need for a general weather data file format which would be flexible enough to accommodate both of these requirements.

In terms of weather data information and availability, it appears that almost all building related engineering associations have a current or ongoing interest in weather data. Several sources of weather data information have been identified.

For many locations worldwide there is no weather data readily available for use in building simulation. Methodologies and several tools for weather data generation for such locations have been identified.

In terms of weather data reference years vs. recorded time series data, there is strong evidence that care is needed in when using reference years. The major problem is that each reference year is designed with a certain purpose in mind; say, to accurately predict the annual energy consumption of an "average" building. The validity of the reference year will deteriorate as soon as we want to do something else; e.g. establish peak loads, or predict the performance of a "non-average" building, etc.
Since, as indicated above, the number of independent weather variables of interest is increasing it will become more and more difficult to generate valid test reference years
Possibly the way forward is to revert to real time-series weather data, incorporating appropriate average and extreme periods, only!

A hardly researched issue concerns the differences in weather data between the area immediately surrounding a building and the weather data measurement site, usually at a considerable distance from the building. These differences are most pronounced in terms of temperature and wind speed and direction; i.e. the main driving potential variables for the heat and mass transfer processes in buildings!
This seems a very interesting and challenging area for future research.

Abbreviations

AES	Atmospheric Environment Service (CA)
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BEPAC	Building Environmental Performance Analysis Club (UK)
CEC	Commission of the European Community
CEC	California Energy Commission
CEN	Comite Europeen de Normalisation = European Committee for Standardization
CIB	Commission International du Batiment = International Council for Research and Innovation in Building and Construction

CIBSE	Chartered Institution of Building Services Engineers (UK)
CTZ	California Thermal Zones
CWEC	Canadian Weather for Energy Calculations
CWEEDS	Canadian Weather for Energy and Engineering
DRY	Design Reference Year
HVAC	Heating, Ventilation and Air-Conditioning
IBPSA	International Building Performance Simulation Association
INSWO	International Surface Weather Observations
EU	European Union
EWY	Example Weather Year (UK)
GRI	Gas Research Institute (USA)
IEA	International Energy Agency
ISO	International Organization for Standardization
NOAA	National Oceanographic and Atmospheric Administration (USA)
REHVA	Federation of European Heating and Air-Conditioning Associations
SAMSON	Solar and Meteorological Surface Observational Network (USA)
SHASE	Society of Heating, Air-conditioning and Sanitary Engineers of Japan
SRY	Short Reference Year (EU)
SWY	Standard Weather Year (Japan)
TRY	Test Reference Year (EU, USA)
TMY	Typical Meteorological Year (USA, EU)
WYEC	Weather Year for Energy Calculations (USA)

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