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WEATHER DATA AROUND THE WORLD FOR DESIGN OF FIELD HOSPITAL HVAC

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ABSTRACT

Field hospital (FH) is a military mobile complex to be deployed in almost any climate around the world. Heating, ventilation and air-conditioning (HVAC) system for the Czech Republic FH units is being re-designed. Computer simulation software will be used for the design of HVAC under variety of specific outdoor conditions.

Simulation software requires weather data to calculate energy balance of buildings and HVAC systems. Currently there are several weather data sets available for this purpose. All contain weather data but they may differ significantly. Therefore they should be carefully selected prior to their use. Even though a lot of databases are available, there is poor access to proper data outside of U.S., Western Europe and Japan, and in non-typical regions in terms of simulation exercises (i.e. developing countries).

This paper reviews accessible weather data files and suggests which weather data should be used for design and long-term performance analysis of FH HVAC system in various non-typical geographical locations around the world.

INTRODUCTION

The Czech military FH is a mobile complex that provides most of the services found in common hospitals, i.e. operating room, laboratories, computer tomography, X-ray, etc. In the Czech FH these units are separated into individual containers which are typically 2.1 m high with floor area from 18 to 36 m^2. A central tent corridor connects all these single units. Unlike buildings usually simulated, containers are much smaller, have negligible thermal storage of walls and often have no windows. Field hospitals are to be deployed in almost any place around the world, i.e. climates ranging from cold (-19°C) to hot (45°C) including warm and humid tropics (32°C, 70% RH) regions.

Weather conditions are different every year. Mean opencast temperature on the north hemisphere fluctuates interannually by up to 0,4 K and the current tendency shows that increased by 1 K within the last century (Glick 2004). Therefore, weather data essential in the design of HVAC systems should be applied prudently.

The manual load calculation using simplified weather data overestimates cooling load compared to the simulation (Bowman et al. 2000). Moreover hospitals are dynamic buildings in terms of cooling load and occupancy which make the manual calculations more complicated. Hence energy simulations will be applied for energy calculations of the FH.

Accurate estimation of the building energy performance requires knowledge of weather to which a building is subjected. Modern design methods (i.e. building and system energy demand analysis) by computer simulations require one year of proper hourly meteorological data. These data files normally comprise of air temperature, solar radiation, humidity, wind velocity and wind direction. In some building simulations there is a need for additional weather data e.g. sky luminance, sky radiant temperature, snow cover, the concentration of gases (NO_x, CO, CO_2, O_3), pollen, etc. (Hensen 1999).

Meteorological data are usually measured by climatological agencies or other subjects at particular geographical locations with certain time-step of recording (e.g. hourly, daily). Extreme, near-extreme, average or typical values might be constituted and deduced from over 10 to 30 years of record. How these data are compiled what do they contain and how they should be used is reviewed in this paper. Weather data sets in terms of simulation exercises suitable for the FH buildings and HVAC systems are recommended.

WEATHER DATA SETS

Available weather data files differ in the process they were compiled, amount and type of offered data, accessibility of data from desired location, accuracy, availability, and applicability.

Long-term average data sets

A set of long-term average monthly values is the simplest type of a database. Usually 10 to 30-year period of record from measured data is employed.

These values are often taken as reference when new data sets for energy simulations are validated.

Near-Extreme data sets

Another way of processing and using measured data is to create near-extreme data sets. They are more appropriate to assist the design of a plant and building by simulation. Near-extreme data (i.e. dry bulb and dew point temperature) in period of 1, 2, 3, 5, and 7 days are available for North America (Colliver et al. 1998) and Europe (CIBSE 2002). However, the selection is often based just on near-extreme temperatures without accounting for solar and wind data (Levermore and Doylend 2002).

Typical years

North American locations

Only the most common weather data sets for the North America are summarized. The intention is to show different approach to creating typical years rather than complete detailed analysis.

One of the earliest hourly weather data sets specifically designed for use in building energy simulations is the Test Reference Year (TRY) (NCDC 1976). TRY's for 60 locations in the United States are available. However, basic data of TRY did not include any solar radiation. Another weakness was the data selection method. The TRY data are an actual historic year of weather from period of record (~1948-1975). The selection method excluded years with months with extremely high or low mean temperatures until one mild year remained.

Typical Meteorological Year (TMY) (NCDC 1981) data set was developed to deal with limitations of TRY. At 26 locations solar data were measured and for the other 208 locations solar data were calculated from cloud cover and type. The period of record consisted of 23 years (~1952-1975). TMY data files contain months from a number of different years. Months were selected based on monthly composite weighting of basic data. The months that were closest to the weighted long-term distribution were selected. This data set was later updated to TMY2 based on the new period of record (1961-1990) (NREL 1995).

To represent more typical weather patterns than either a single representative year or a grouping of months, ASHRAE commissioned a research project finished with the weather data set Weather Year for Energy Calculations (WYEC) (ASHRAE 1985). The basic method used to select data for WYEC was to determine for each month of the year, the single, real month of hourly data whose mean dry-bulb air temperature was closest to the average dry-bulb temperature for that month in the 30-year period of record. Then individual days from other months were substituted when those days helped bring the mean for the month closer to the 30-year mean. The database was competed in 1983 and consists of 51 sites in the North America.

WYEC data set was upgraded to WYEC2 by TMY format, adding hourly luminance data and data quality assessment flags (indicating the process of adjustment). An updated model for calculation of solar radiation from cloud cover data was used for solar radiation components and illuminance data. The National Renewable Energy Laboratory (NREL) working with ASHRAE processed the existing WYEC and TMY data to crate 77 WYEC2 format files (Stoffel and Rymes 1998).

Non-North American locations

ENISO15927-4 is a new international standard that should serve as a guideline to production of typical years from available meteorological data. “European” Test Reference Year (TRY) and Design Reference Year (DRY) were tested and the latter proposed to form a basis of this new standard.

The “European” TRY is similar to TMY (NCDC 1981). The “European” TRY selection process is specified to try to obtain (a) the mean, (b) the frequency distribution of individual variables, and (c) the implied correlations between the different variables within each month of the long-term data set. Selection method is based on dry-bulb temperature, solar radiation, and humidity but not wind speed. The month with the lowest deviation is selected as the month to be included.

DRY is an attempt to modify the TRY to be even more like year average months by adjusting the selected months. The parameters such as dry bulb temperature, solar radiation, and humidity, but not wind are adjusted by replacing certain days with the days from other years, but in the same month. Although this is referred to as a design reference year it is not a near-extreme year that could be used for HVAC design (Levermore and Doylend 2002).

SHASE developed new weather data file that is an expansion from the original Automated Meteorological Data Acquisition System (AMeDAS) for building energy calculations in Japan (Akasaka et al. 2000). Standard expanded AMeDAS is similar to TRY (European), DRY, and TMY. The data were compiled from 15-year record of weather data.

Typical Meteorological Year data set was developed for 69 Chinese locations (Zhang et al. 2002) using a methodology similar to that used for the TMY data. These TMYs were produced from 16 years weather history (1982-1997) reported from Chinese airports and obtained from the U.S. NCDC.

Few more typical years are currently being created from measured data sets e.g. in Czech Republic, Greece, Turkey, Egypt, Syria. They are Mostly based on the above mentioned principles.

Locations throughout the world

227 locations outside the U.S. are available in the International Weather for Energy Calculations (IWEC) weather files that were developed under the ASHRAE research project RP-1015 (Thevenard and Brunger 2002a). TMY procedure was chosen for selecting representative years from up to 18-year sequences of weather data. The 12 typical meteorological months were chosen from the set of available candidate months by comparing statistics for candidate months against corresponding long-term monthly statistics based on daily total global radiation, dry-bulb temperature, dew-point temperature, and wind speed. The selection was based on the weights for particular meteorological value. Emphasis was put on the daily solar radiation and the mean dry-bulb temperature (40% and 30 % respectively). Depending on how the solar radiation model performed compared with long-term data the IWEC files were divided into three Categories. Category 1 corresponded well, 2 poorly, and for Category 3 were no comparable data. Category 2 applies particularly to the sites around tropics in the sense that the model fails to predict the wide range of radiation conditions experienced at the site. A plot of the sites can be found in Figure 1 (Thevenard and Brunger 2002b).

Figure 1. IWEC stations worldwide (Adopted from Thevenard and Brunger 2002b)

<u>Databases of long-term measured data</u>

For many locations outside the U.S., Canada, Western Europe, Japan, there are no weather data readily available for building simulation (see e.g. IWEC stations in Figure 1). However, for most locations the long-term (monthly) averages and other statistics of the major weather variables could be found registers or meteorological publications.

Weatherbank is one of the companies offering paid hourly and daily climatic data. Hourly data are available since 1994. In some cases daily values reach back to the middle of the 19th century. Some of the incomplete data are compensated based on climate knowledge from particular region. Offered historical database consist of about 20 parameters.

National Oceanographic and Atmospheric Administration (NOAA) offers paid integrated hourly data deduced from the hourly data of NCDC, Navy surface hourly data, etc. This database called International Surface Weather Observations (INSWO) contains hourly synoptic data from the period of 1982-1997 from approximately 1500 worldwide locations.

An example of commercial software which generates weather data is METEONORM. The latest version (5.1) includes the climatological data from the years 1961-90 from about 7400 stations around the world, where 1000 measured also solar radiation. These data obtained also from the Global Energy Balance Archive (GEBA) and from the World Meteorological Organization (WMO) mainly contain average monthly values of air temperature, humidity, rain, sunshine duration, and days with rain. For remote locations (more that 300 km from the station) the solar radiation is interpolated with data from satellite observations.

<u>World Wide Web sources of weather data</u>

Another source of abundant weather data is freely available on the World Wide Web. Ku (1999) gives a summary of information sources dividing them into four categories: Weather - specific sites; Meteorological offices and weather/climate research institutes; News and travel sites; Internet directories and Internet service providers. Internet sites outnumber the paid databases however they offer no guarantee of accuracy, reliability, completeness, updates or wide range of locations, etc.

ASHRAE research project RP-1170 developed a new system, which provides its members with access to information on sources of international weather data on the Web. A Global Weather Data Source (GWDS) database enables users to select a country, choose a type of data (e.g. hourly, monthly) and climatic parameter of interest, and it then gives a list of data sources with information how to obtain these data (Plantico et al. 2002).

Even historical data with all required values including solar radiation could be found free on the Web for some U.S. locations. Other regions of the world have the data much less complete, e.g. only average month temperatures, precipitation, but further information is missing. Some of the sources, where the data from a large number of stations or from longer period could be found are listed below:

EnergyPlus – contains measured data from the past 5 years, often with missing data that additional program may substitute.

GCOS Surface Network (GSN) – daily, monthly, and annually averages, often from the past 40 years. Weather data from 439 stations in 52 countries excluding Western Africa and South Asia are available.

NOAA „Climates of the world“ is a document containing average and extreme daily temperatures for over 800 locations around the world. Average temperatures are presented for January, April, July, and October. Average monthly precipitation values are shown for each location.

Weatherbase provides climatic data from most of the countries around the world. Generally, several measured locations within one country are available. Data consist of annual and monthly average temperatures and precipitation deduced from about 30-year period.

DISCUSSION

Harriman et al. (1996) published a concise review of commonly used weather data types including their source and common application for various regions around the world (Table 2). Important are the first and the third column, where the type and use of particular weather data are shown. Table 2 further recommends using long-term extreme data for sizing of equipment and typical year of weather data for long-term behavior and energy consumption. For non-typical locations e.g. tropics in South America, locations in Africa generally, and south Asia (i.e. range of climatic zones where the deployment of FH is assumed) only long-term means or historical data (Meteonorm, INSWO) are available. These could be processed and used for the FH, i.e. near-extremes for sizing HVAC and long-term means for estimating long-term behavior and energy consumption.

Table 2. Common types and sources of weather data. Adapted from Harriman et al. (1999)

Use	Source	Data type	Coverage	Publisher
Sizing Equipment	1997 ASHRAE Handbook – Fundamentals	Long-term extremes	1459 U.S. and int’l locations	ASHRAE, GRI
	Sequences of extreme temperature and humidity		320 U.S. and CAN locations	ASHRAE
Monitoring and Troubleshooting Installed Equipment	Hourly weather data archive	Current hourly dry bulb temp. and humidity	240 U.S. and Canadian locations	GRI
Estimating Long- term Behavior and Energy Consumption	Typical meteorological years – 2 (TMY-2)	Typical hourly observations	239 U.S. locations with Puerto Rico	GRI
	Weather years for Energy Calculations – 2 (WYEC-2)		76 U.S. locations	ASHRAE
	Canadian Weather Year for Energy Calculations (CWEC)		145 Canadian locations	AES
	Example Weather Year (EWY)		15 locations in Great Britain	CIBSE
	Test Reference Year (TRY) and Design Reference Year (DRY)		156 locations in Europe, Russia and Turkey	CEC
Simulating Equipment Behavior for a Specific Year	Solar and Meteorological Surface Observational Network (SAMSON)	Actual hourly observations for specific years	237 U.S. locations	NOAA
	Canadian Weather for Energy and Engineering (CWEEDS)		145 Canadian locations	AES
	Meteonorm		7405 worldwide locations	GEBA, WMO
	International Surface Weather Observations (INSWO)		1500 worldwide locations	NOAA

He concludes that, users of energy simulation programs should avoid using single-year, TRY-type weather data (i.e. NCDC 1976). No single-year can represent the typical long-term weather patterns (Crawley 1998, Huang 1998). TMY2 and WYEC2 were recommended since they better correspond to long-term averages.

In terms of weather data reference years vs. historic climatological data, there is strong evidence that care is needed when using reference years. The major problem is that each reference year is designed with a certain purpose in mind, i.e. to accurately predict the annual energy consumption of an "average" building.

For example, for a building simulation of particular type (i.e. a building without windows and without natural ventilation openings i.e. container of the FH) only the temperature is relevant, so a specific TRY should be developed using a high weighting factor for the temperature. In case of HVAC plant simulation, temperature and relative humidity are important. 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 variables. The European TRY (or TMY in U.S.) will somehow assume 'an average building'; whereas in reality there are many non average buildings, which, ideally, should have their own TRY. For a recent overview of the various TRY generation methodologies, see Argiriou et al. (1999).

Another approach would be 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 (Crawley 1998).

CONCLUSIONS

Objective of computer simulations and type and location of investigated building should be carefully considered prior to weather data selection.

Based on presented review the near-extreme measured data sets from INSWO or Meteonorm database are applicable for the field hospital HVAC sizing simulations.

Production of DRY from available meteorological data especially for units of FH seems to be the best but also the most difficult approach towards the energy simulations.

No worldwide database offering typical years in most of the non-typical regions was found. Moreover, there is poor access to national databases in non-typical regions in terms of simulation exercises. Therefore, long-term averages will be used for performance analysis of HAVC plant in these particular locations.

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NOMENCLATURE

AES - Atmospheric Environment Service (CA)
AMeDAS – Automated Meteorological Data Acquisition System (Jap)
ASHRAE - American Society of Heating, Refrigerating and Air-Conditioning Engineers
CEC - Commission of the European Community
CIBSE - Chartered Institution of Building Services Engineers (UK)
CWEC - Canadian Weather for Energy Calculations
DOE – Department of Energy
DRY - Design Reference Year
EWY - Example Weather Year (UK)
FH – field hospital
GEBA – Global Energy Balance Archive
GRI - Gas Research Institute (USA)
GSN – Global Surface Network
GWDS – Global Weather Data Source
HVAC - Heating, Ventilation and Air-Conditioning
INSWO - International Surface Weather Observations
IWEC – International Weather for Energy Calculations
NCDC - National Climatic Data Center
NOAA - National Oceanographic and Atmospheric Administration (USA)
SHASE - Society of Heating, Air-conditioning and Sanitary Engineers of Japan
TMY - Typical Meteorological Year (USA, EU)
TRY - Test Reference Year (EU, USA)
WMO – World Meteorological Organization
WRDC – World Radiation Data Centre
WYEC - Weather Year for Energy Calculations