New-Trend Natural Ventilation Potential & Analytics for Various Climates in Canada

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Abstract

This paper is focussed on the natural ventilation potential of different weather data-sets used in Canada today. These weather data-sets have been compared against existing CWEC (Canadian Weather for Energy Calculations) weather data, which are based on 30 year weather data (pre-1995), against newer to the industry; TMY (15) and TMY (7) sets of weather data, which represents the last 15 and 7 years of weather data respectively, i.e. from, and *including* the year 2013.

One major goal of this paper was to raise awareness of the availability of newer useful weather data for building simulation and design.

Canadian multi-location TMY (Typical Meteorological Year) climate based natural ventilation analyses included comparisons of:

1. Natural Ventilation Potential (NVP); which accounted for the number of hours/year that *acceptable* outside air can be introduced into rooms during occupied hours.
2. Percentage People Dissatisfied (PPD) for the thermal comfort of occupants (ASHRAE 55).
3. Predictive energy-modelling of a small nature center building.

1 Introduction

There are various climate files and file-types used in our industry today. It has become apparent that during my years working with various consultancies in Canada, little or no thought is given to the selection of the appropriate weather file. Such selection is especially critical to the performance of naturally ventilated buildings, LEED ratings, local code compliance and provincial incentives offered to the buildings construction.

This paper has examined such impacts using appropriate files recognised by the Canadian Green Building Council and provincial governments for utility rebates and incentives. That is, CWEC and TMY files were examined, but TRY (Test Reference Year) data was not examined. TRY weather files are a UK-based weather file used for the calculation of building carbon emissions.

Two Canadian climates were examined in detail; Vancouver and Toronto. According to 2008 updated User Manual (Appendix D) of the CWEEDS (Canadian Weather Energy and Engineering Data Sets), the CWEC weather data for Toronto and Vancouver were created from actual weather data recorded between the years 1960-1989.

The *new-trend* TMY2 and TMY3 Canadian weather files used in this paper represent 30 year (TMY2) typical weather data; 15 year (TMY3-15) weather data and 7 year (TMY3-7) weather data. They all share the year of 2013 as the last recorded year for their respective 'typical' meteorological years. All of these TMY files were all constructed in accordance with the US-DOE (United States, Department of Energy) specified techniques by Weather Analytics. Further information of the TMY file composition can be found in ASHRAE 2013 Fundamentals Chapter 14 Climatic Data (ASHRAE).

2 Methodology

Various energy simulation and climatic tools were used to analyse, quantify and demonstrate the differences in climatic data. The analyses included;

- A Mahoney Analysis (Figure 3) of the climates under different time ranges.
- A Natural Ventilation Potential calculation (Figure 5) of the climates under different time ranges.
- A whole building energy simulation of a fictitious model building in the various climates using the different TMY ranges. Natural Ventilation strategies were incorporated to occupied zones and their levels of success have been quantified.
- Comparative studies include identification of inappropriately selected weather files.
- Thermal comfort analysis of occupied rooms.

For a consistent comparative study, the same simulation model was used for all climates and weather files. An architectural SketchUp model building is shown below in Figure 1.

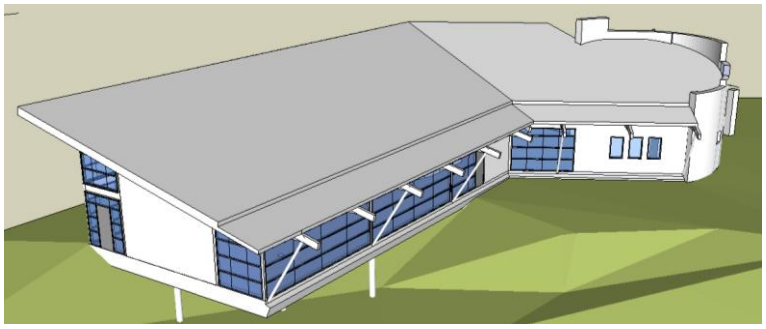


Figure 1: Architectural SketchUp Model

This SketchUp model was converted to a building performance model for predictive energy simulation and natural ventilation analysis.

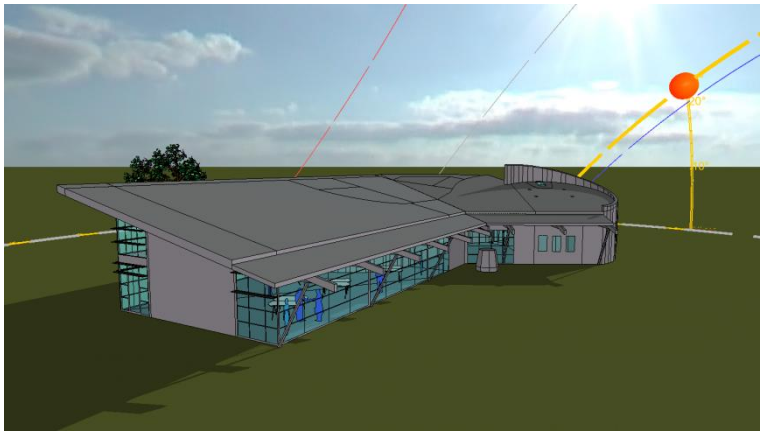


Figure 2: Analytical Energy Model

The architectural model is auto-transferred to the energy model using the veXML as defined by IES-VE (IES Ltd.). IES-VE is an ASHRAE 140 validate simulation tool.

3 Results

The methodology details five areas of analytical results.

3.1 Mahoney Analyses

An example of a Mahoney Analysis (monthly average) for Toronto is shown below. The weather file used was a CWEC (Canadian Weather for Energy Calculations) file. A Mahoney analysis is used to examine swings between daytime and nighttime conditions for human comfort stresses (Upadhyay, Yoshida).

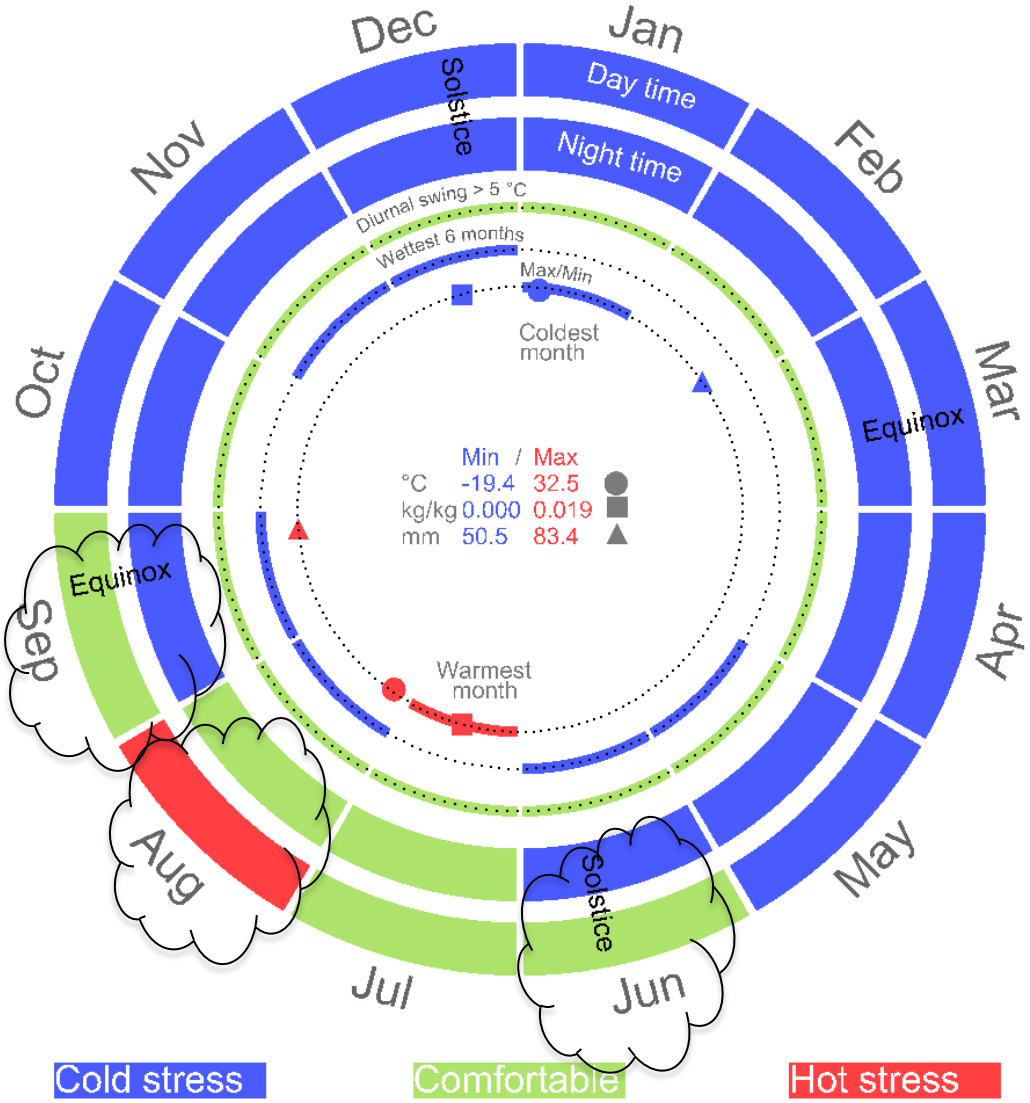


Figure 3: Mahoney Analysis of Toronto CWEC weather

The months of June, August and September are highlighted above in Figure 3 which demonstrate opportunities to night-purge a building with unconditioned air, so to cool the thermal mass of that building; thus lowering the peak internal operative temperatures of the occupied spaces. These monthly average results represent a diurnal swing of greater than 5°C.

Most importantly, this diurnal swing of external dry-bulb temperature occurs during the month where the peak external dry-bulb temperature (and daytime hot stress) occurs; August.

3.2 Natural Ventilation Potential

Examining all 8,760 hours/year in Toronto; restrictions were applied to the conditions that occupied spaces would potentially open windows to naturally ventilate the spaces. Figure 4 shows this test for all hours/year (left) and occupied hours/year (right).

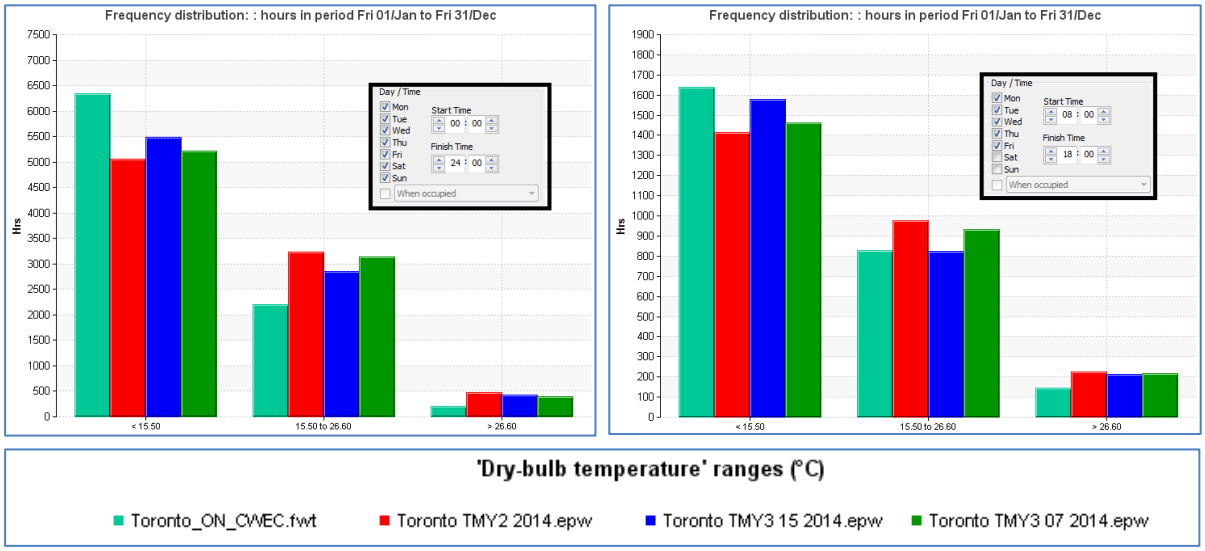


Figure 4: Comfortable Temperature Ranges in Toronto

Of course, Figure 4 demonstrates temperature only, and ignores other variables such as relative humidity (RH). A more appropriate NVP analysis would not examine the entire year, i.e. 8,760 hours, but rather for the occupied hours of the year, and account for relative humidity (RH) setpoint limits also. The occupied hours in this case was 2,490 hours, which represents Monday-Friday, 8am-6pm, and unoccupied periods during national holidays. Figure 5 was created and is demonstrating NVP for both TMY2 and AMY (Actual Meteorological Year) weather files in the United States of America and CWEC files in Canada.

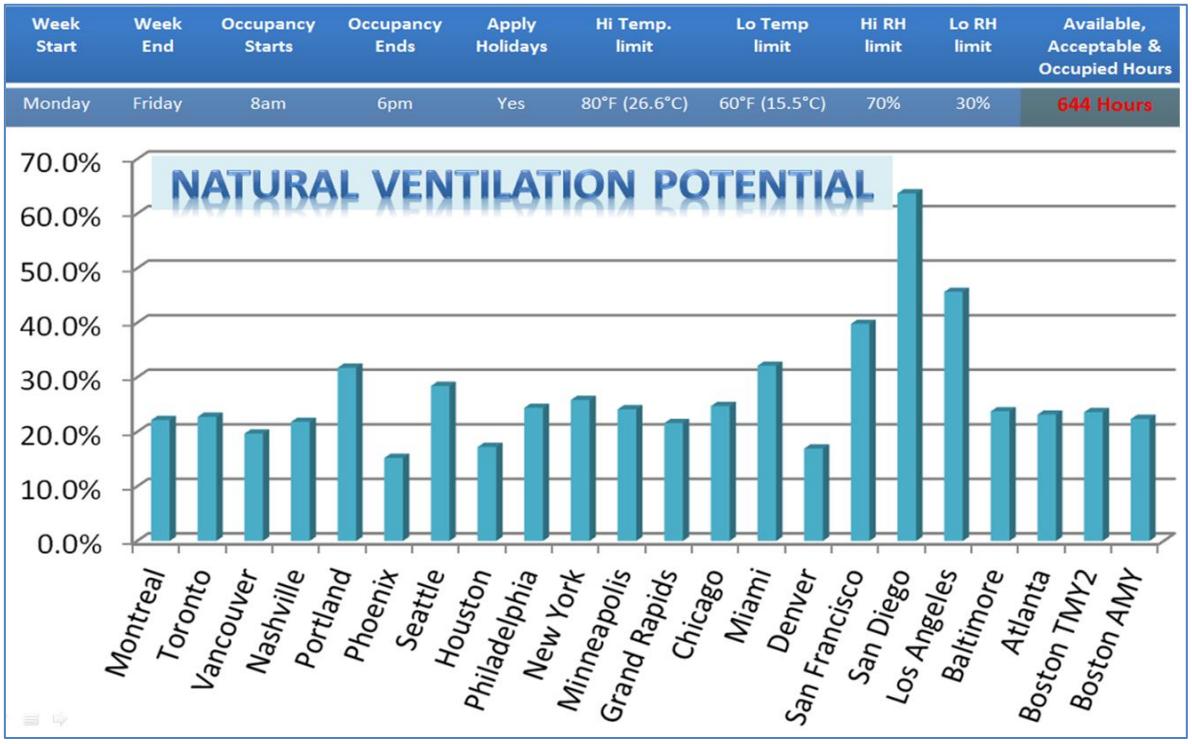


Figure 5: Natural Ventilation Potential in North America

The Canadian climates shown in Figure 5 were ranging between 19-22% NVP. The upper and lower limits were 26.6°C and 15.5°C; and 30%-70% relative humidity. These temperatures represent conditions that are acceptable by the building operators to open windows, using a red-light-green-light alert system.

3.3 Building Energy Usage

Building energy usage profiles were generated for each building, in each region, and for each climate file type. This followed a traditional ASHRAE 90.1-2010 Appendix G approach and also included the minimum ventilation requirements of ASHRAE Standard 62.1. One example is shown in Figure 6 for a fully air conditioned building.

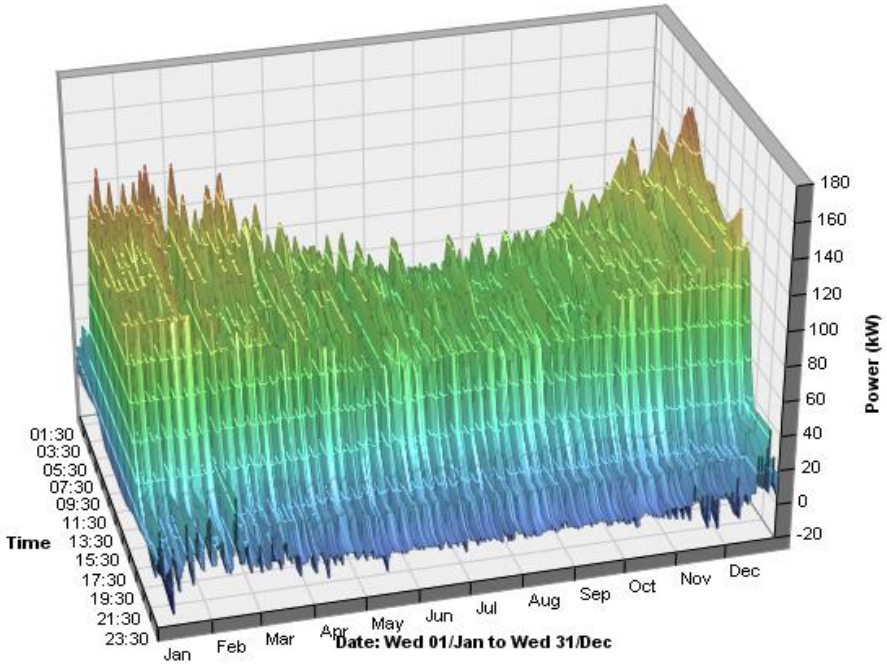


Figure 6: Building Total Energy Usage Profile

As expected in a Canadian climate, heating dominated the profile of 'total' energy consumption in Figure 6. This 'total' energy included a number of energy end-uses such as; space heating, service water heating, interior lighting, exterior lighting, space cooling, heat rejection, fans, pumps, plug loads, cooking and refrigeration.

Figure 6 above was useful in that it demonstrated both the seasonal annual energy usage and also what time of day those energy peaks occurred. This can generally allow a designer to target the causes of peak demands from one view. In this case, early-morning winter peaks have indicated that the heating equipment is spiking and that a better nighttime setback strategy should be implemented. This obviously required more investigation, but remains a useful visual tool.

3.4 Comparative Energy Studies

Examining one end-use; the chiller energy, for the building in Vancouver using different climate files, showed significant differences in chiller energy. See Figure 7 for a CWEC (red) and TMY(7) (blue) comparison.

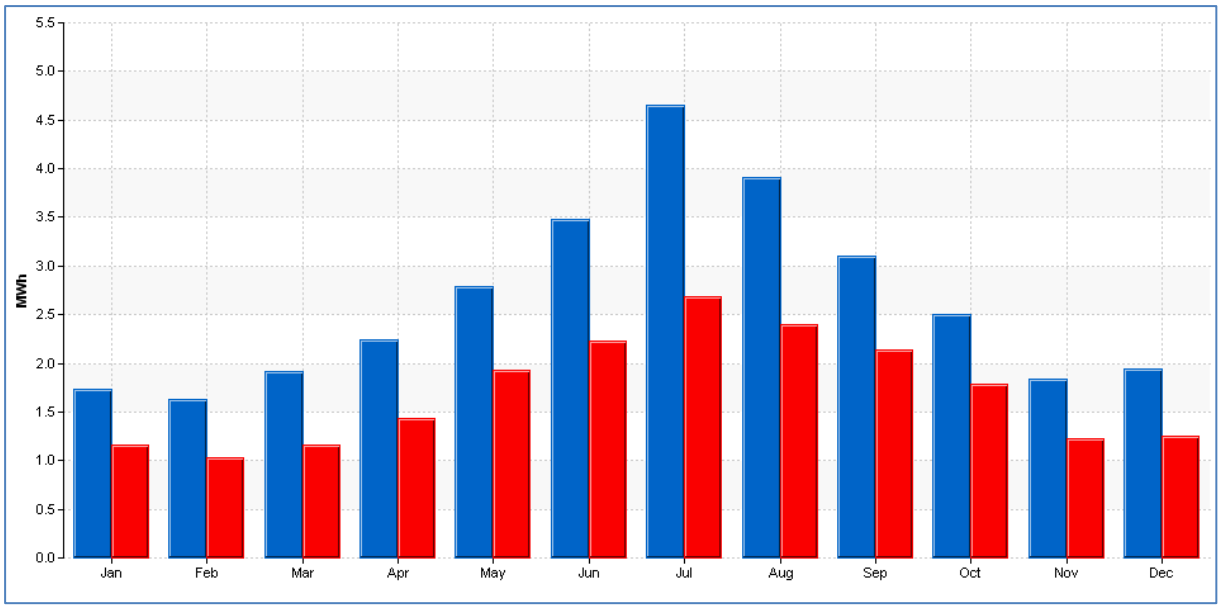


Figure 7: Chiller Energy for Office Building in Vancouver using different Vancouver weather files; CWEC [red] and TMY (7) [blue]

Note the significant difference shown for chiller energy, simply by using different climate data for the identical location.

3.5 Adaptive Thermal Comfort

Analysis of all buildings in all locations included a thermal comfort check (CIBSE). Occasionally, thermal comfort limits were exceeded, but upon further investigation, the uncomfortable conditions were occurring unoccupied times e.g. weekend evenings. This is shown in Figure 8. These custom graphical analytics were generated by the energy analytical software.

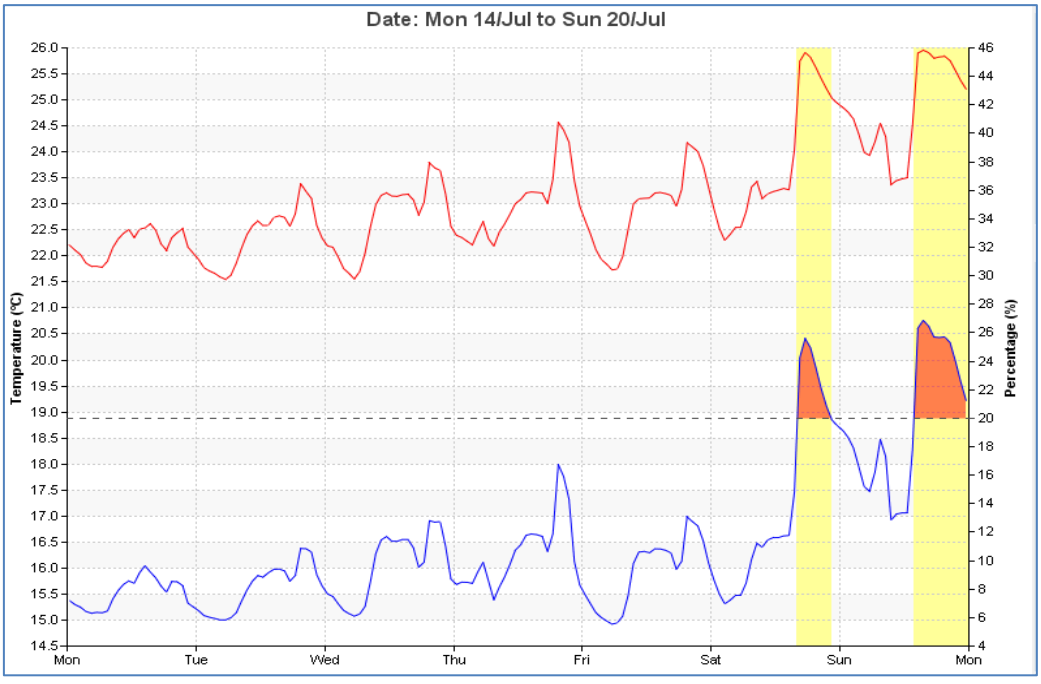


Figure 8: Operative Temperature (red) and Occupancy Thermal Comfort (blue)

Please note the above graph has two y-axis labels with the operative temperature (red) on the left Y-axis and the PPD (blue) of the right Y-axis.

4 Discussion

There were many areas of discussion related to the differences in weather data. Figure 7 showed the significant differences in chiller energy. These results correspond to the peak dry-bulb temperature for the CWEC and TMY(7) climates, as shown below in Figure 9 which shows a difference between peak external dry bulb temperature of 8 degrees between weather files. The Vancouver CWEC peaked at 34°C and the Vancouver TMY(7) peaked at 26.1°C.

Please note that peak external dry-bulb temperatures both occurred in July.

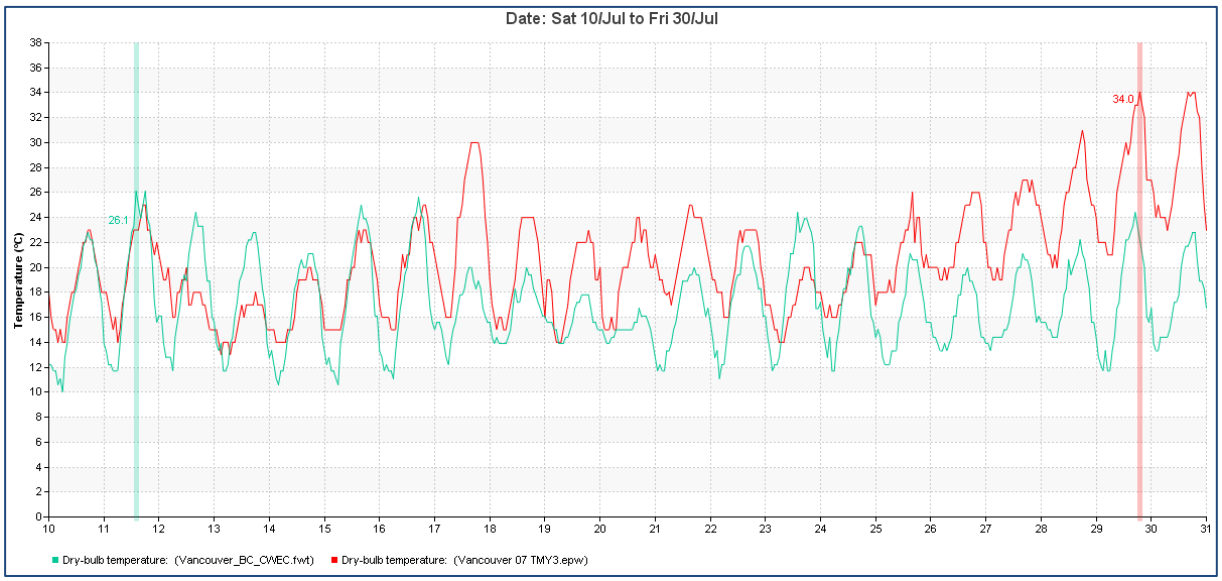


Figure 9: Peak External Dry-Bulb Temperatures in Vancouver for TMY(7) [red] and CWEC [green] Weather Files.

However, it is no longer sufficient to simply look at peak temperatures, but rather bins, trends and frequency of distribution of weather data. Figure 10 below examines Toronto in Winter (left) and Summer (right) and looks at the number of hours that exceed specific temperatures.

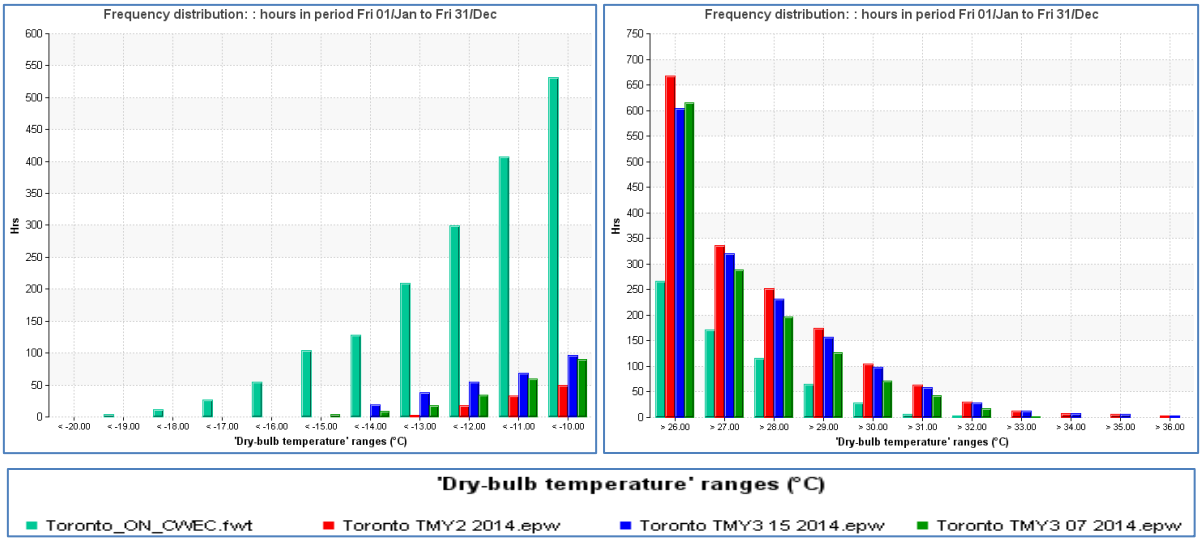


Figure 10: Frequency distribution of Toronto's Weather File Types.

The traditional or outdated CWEC weather file (in light green) for Toronto shows some compellingly out-of-sync data with respect to the other weather sets: TMY2(30), TMY(15) and TMY(7).

5 Conclusions

This paper intends to alert all members of design teams about the selection of weather data for their design of buildings. When considering which weather data files should be used for the simulation of buildings, it is not sufficient to "pick the closest one" due to the traditional weather data set being so outdated. We are not designing buildings for the last 50 years, but for the next ~100 years.

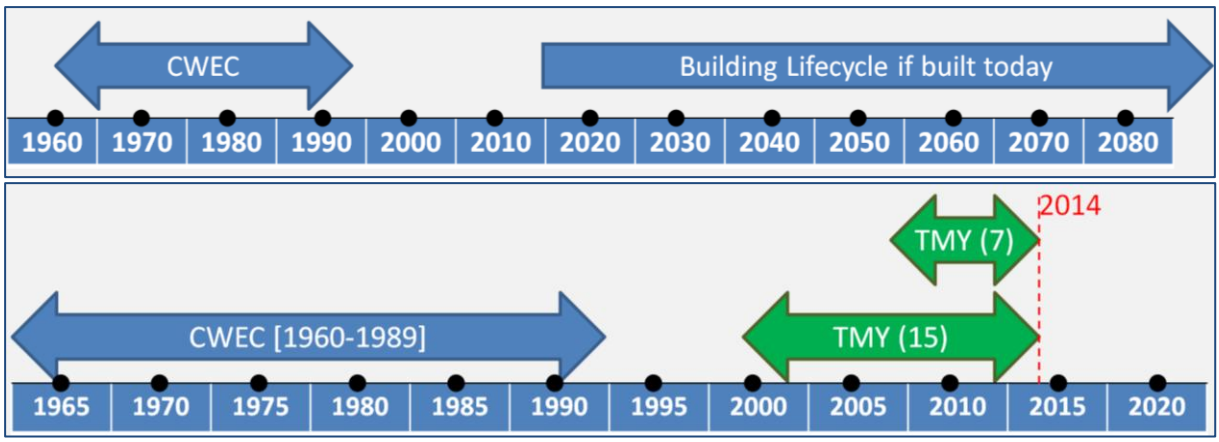


Figure 11: Building Lifecycle related to Outdated Weather Files.

Using old-trended weather data will result in relative catastrophic consequences for building commissioning, re-commissioning, retro-commissioning, and re-engineering due to the potential change-out of existing HVAC systems, especially if a commercial occupant cannot afford any downtime. These consequences yield large cost implications to building owners, potentially in the short term.

It is my recommendation to organisations such as the Canadian Green Building Council and the Ontario Power Authority that they should mandate that two weather files be provided with any submission of an energy model. The consultant should be required to provide a narrative upon why a certain weather file was selected over an alternative.

It is also my recommendation that at least one of these weather files be more representative of current climatic conditions e.g. TMY(7). It should be noted that the ASHRAE Handbook of Fundamentals makes "unpublished" references to having a minimum of 8 years of data recorded, to be used for hourly energy simulation. With this in mind, or until ASHRAE amend the fundamentals handbook, the next appropriate choice might be the TMY(10) or TMY(15). These new-trend weather files can be obtained from various sources, e.g. Weather Analytics.

6 Acknowledgements

This paper wishes to acknowledge Chuck Khuen; chair of the ASHRAE Climate Committee and Vice President of Weather Analytics for providing all TMY and AMY weather files for the purposes of this research paper.

7 References

ASHRAE 2013 Fundamentals (Chapter 14 Climatic Data)

American Society of Heating, Refrigeration and Air-Conditioning Engineers

www.ashrae.org

ASHRAE Standard 90.1-2010 Appendix G; Performance Rating Method.

American Society of Heating, Refrigeration and Air-Conditioning Engineers

www.ashrae.org

ASHRAE Standard ASHRAE 62.1: Ventilation for Acceptable Indoor Air Quality.

American Society of Heating, Refrigeration and Air-Conditioning Engineers

www.ashrae.org

ASHRAE Standard 55: Thermal Environmental Conditions for Human Occupancy.

American Society of Heating, Refrigeration and Air-Conditioning Engineers

www.ashrae.org

ASHRAE Standard 140: Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs.

American Society of Heating, Refrigeration and Air-Conditioning Engineers

www.ashrae.org

Canadian Weather Energy and Engineering Data Sets (CWEEDS); CWEC Weather Files. CWEEDS Appendix D.

Chartered Institute of Building Services Engineers

CIBSE AM-10: Natural Ventilation

www.cibse.org

EnergyPlus Weather Files

http://apps1.eere.energy.gov/buildings/energyplus/weatherdata_about.cfm

Integrated Environmental Solutions

VE-GAIA and VE-Pro Software

www.iesve.com

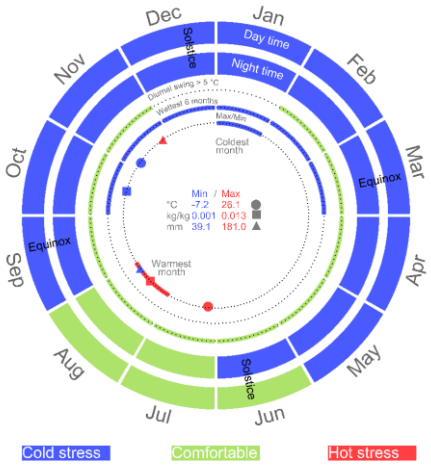
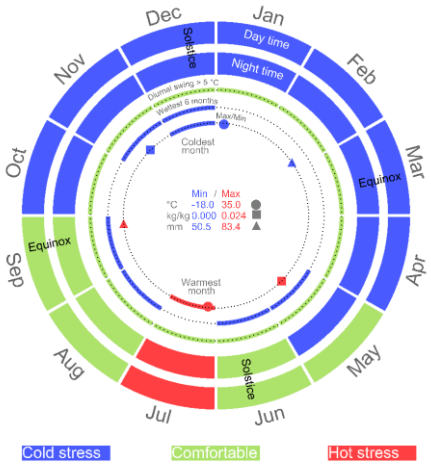
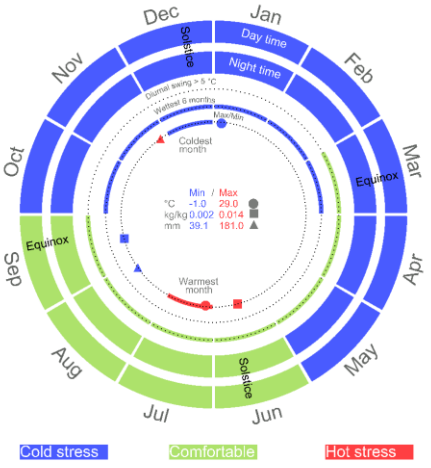
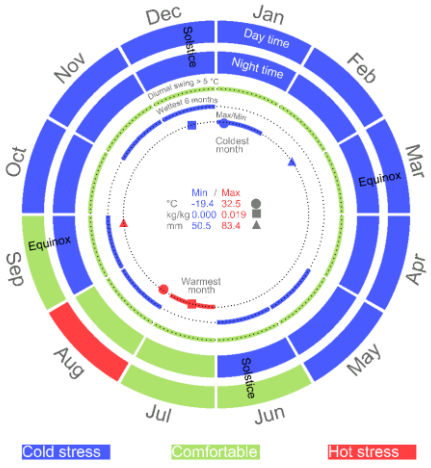
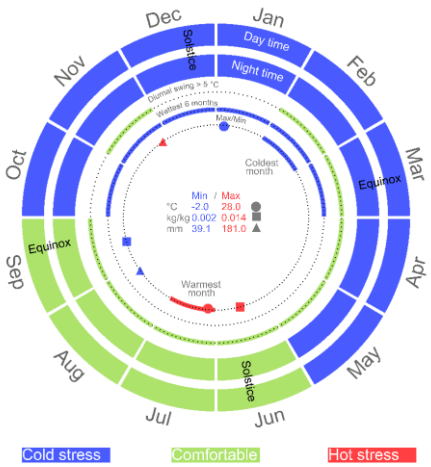
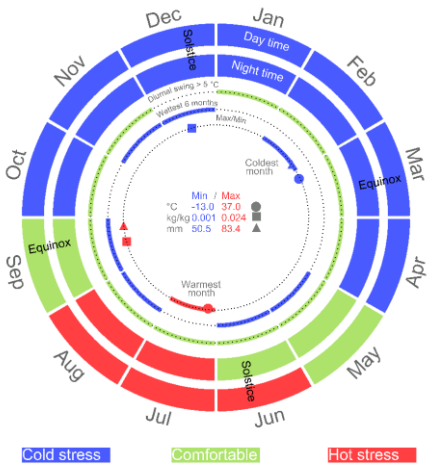
Upadhyay, A., Yoshida, J., Rajal, H., 2006. Journal of Asian Architecture and Building Engineering. May 2006.

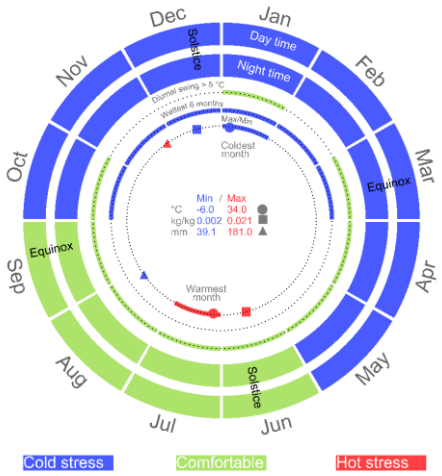
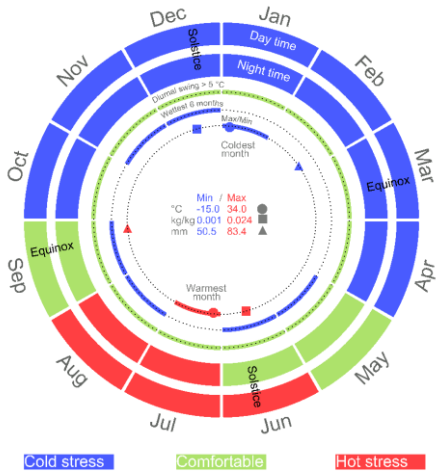
Paper: “Climate Responsive Building Design in the Kathmandu Valley”.

Weather Analytics: Source of all TMY -7, TMY-15 and TMY-30 weather files.

http://www.weatheranalytics.com

8 Appendix A – Mahoney Analysis for Vancouver and Toronto Weather Files

Vancouver	Toronto
CWEC (1960-1989)	CWEC (1960-1989)
	
TMY2 (30 year) from 2013	TMY2 (30 year) from 2013
	
TMY3 (15 year) from 2013	TMY3 (15 year) from 2013
	

TMY3 (7 year) from 2013 	TMY3 (7 year) from 2013
	AMY (Actual Meteorological Year) 2013  Note: AMY weather files are used to calibrate existing buildings against utility data.