XV International Conference on Durability of Building Materials and Components
DBMC 2020, Barcelona
C. Serrat, J.R. Casas and V. Gibert (Eds)

# The Future Climate Moisture Susceptibility of Wall Assemblies: Analysis Based on Monte Carlo Simulation Using a Simplified Deterministic Hygrothermal Simulation Model

**Carl-Eric Hagentoft**[1] **and Pär Johansson**[1]

[1] Chalmers University of Technology, Department of Architecture and Civil Engineering,
SE-412 96 Göteborg, Sweden, carl-eric.hagentoft@chalmers.se

**Keywords:** *Climate, Driving Rain, Simplified Model, Risk Analysis, Monte Carlo Simulation.*

## 1 Introduction

The performances of buildings can vary quite a lot even if the design look identical in the drawings. The uncertainties are manifold and originate from the selection of the initial condition of materials, dimensions, and material properties. Obviously, weather conditions and the exposure to the external environment are sources of uncertainties. To make balanced and sound choices of design strategies and investment decisions, all these factors should be included. The results from the IEA EBC project RAP-RETRO (Annex 55) (Hagentoft, 2017) are used.

The scope of this paper is to investigate the possibility to use a simplified model for the heat and moisture transfer in a wall assembly. The model, intended to be used to assess moisture susceptibility of wall assemblies, is based on four material elements, each having resistances for vapor and heat between and at the surfaces, and includes rain intrusion. The investigated construction in this paper is an insulated wooden wall with an exterior air gap.

## 2 Weather Data

The historical and future climate data for the Canadian cities Toronto and Vancouver were selected. The data was provided by (Gaur *et al.*, 2019) who produced time-series of 30 consecutive years with hourly climate data corresponding to historical time-period (1986-2016) and future time-series corresponding to 2°C and 3.5°C increase in global temperature. In this paper the former climate scenario was selected.

## 3 Results

For simplicity in this study, the time of wetness was used as an indicator for the durability. This is the total time over the year that RH exceeds 80% for a specific susceptible element of the construction. Based on the previous study (Hagentoft and Johansson, 2019), the Monte Carlo simulations are based on a total number of 600 31-consecutive-year simulations using the simplified model. The results for the historical time-series for Toronto is presented in Figure 1. There is a clear trend, visible both in the cumulative distribution and histogram, for Toronto that the time of wetness was increasing the last 30 years. The average time of wetness for year 1 was 392 hours, while it was 1566 and 2146 hours for year 15 and 31 respectively.

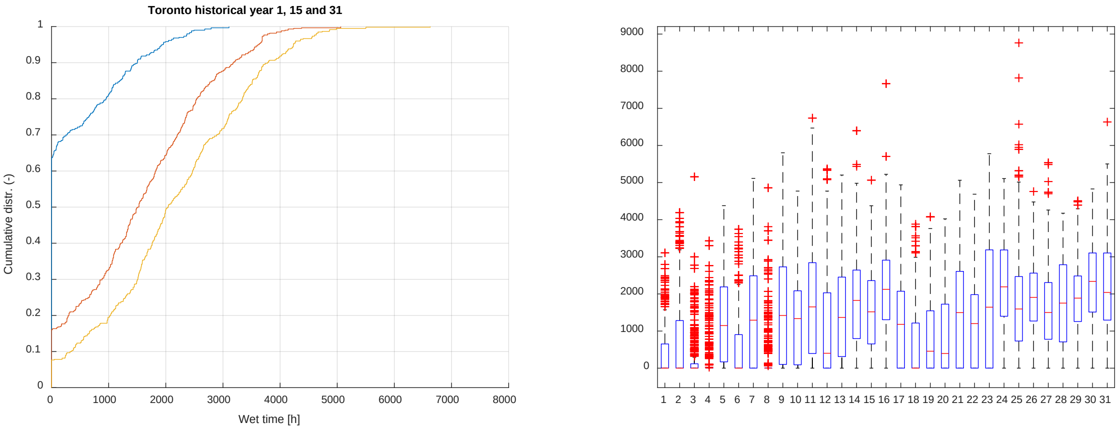


**Figure 1**. Results for the time of wetness for **Toronto historical** time-series.

## 4 Conclusions

A previously developed simplified model for heat and mass transfer across walls, based on a four-element discretization of a wall assembly has been used in the paper. The simplified model offers good flexibility for representing multi-layer wall constructions with various barriers and for moisture and heat transfer in between layers. As such, it is suitable to be used for the risk assessment of wall assemblies and similar constructions. In this paper additions to the model are presented that make it possible to analyze structures with a ventilated cladding.

For the case presented in this paper, the impact of rain leakage on the outermost part of the external wood layer of an insulated wooden wall was demonstrated. The risk analysis is based on Monte Carlo simulations of 600 runs of 31-consecutive-year historical and future climate scenarios for Toronto and Vancouver.

The time of wetness in the outermost part of the external wood layer was increasing with time in both Toronto and Vancouver. The expected time of wetness is 5 times higher in Toronto in 2016 compared to in 1986, and 1.5 times higher in 2064 compared to in 2034. In Vancouver the expected time of wetness is 4 times higher in 2016 compared to in 1986. However, for Toronto this may not be the most extreme case considering that south is not the predominant direction of wind driven rain in the future.

### ORCID

C-E. Hagentoft: http://orcid.org/0000-0002-1616-3619, P. Johansson: http://orcid.org/0000-0003-0935-7703

### References

Gaur, A.; Lacasse, M.; Armstrong, M. (2019). Climate Data to Undertake Hygrothermal and Whole Building Simulations Under Projected Climate Change Influences for 11 Canadian Cities. *Data*, 4, 72.

Hagentoft, C.-E. (2017). Reliability of energy efficient building retrofitting – probability assessment of performance and cost (Annex 55, RAP-RETRO). *Energy and Buildings*, 155: 166–171. doi: 10.1016/j.enbuild.2017.09.007.

Hagentoft, C.-E. and Johansson, P. (2019). Generic algorithm to assess moisture susceptibility of simplified wall assemblies. *Canadian Journal of Civil Engineering, special issue Durability and Climate Change*. doi: 10.1139/cjce-2018-0592.