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Guidelines for the required time resolution of meteorological input data for wind-driven rain calculations on buildings

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Abstract

An important question in wind-driven rain (WDR) calculations on buildings, either with semi-empirical formulae or with Computational Fluid Dynamics (CFD), concerns the required time resolution of the meteorological input data: wind speed, wind direction and horizontal rainfall intensity. Earlier work has indicated that the use of 10 min input data can provide accurate results, while the use of arithmetically averaged hourly data can yield significant underestimations in the calculated WDR amounts. This paper builds further on this earlier work by providing a detailed investigation of the parameters that determine the required time resolution for WDR calculations on building facades: (1) the averaging technique, (2) the building geometry and the position at the building facade and (3) the type of the rain event. It is shown that all three parameters can have a large influence on the required time resolution. Depending on these parameters, hourly or even daily wind and rain input data could provide accurate results, while in other situations they can lead to very large errors. Finally, guidelines for the required time resolution as a function of the influencing parameters are provided.

Keywords: Wind-driven rain; Driving rain; Wind flow; Building; Computational Fluid Dynamics (CFD); Sample size; Time resolution; Data averaging; Climate data

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1. Introduction

Wind-driven rain (WDR) is one of the most important moisture sources for building facades, and it is expected to become even more important in the future (Sanders and Phillipson, 2003). WDR calculations on buildings are made with either the semi-empirical WDR relationship, or with numerical simulations based on Computational Fluid Dynamics (CFD). Both methods require standard wind and rain input data for the calculations: wind speed, wind direction and horizontal rainfall intensity. The horizontal rainfall intensity is the rainfall intensity through a horizontal plane, as measured by a traditional rain gauge with a horizontal orifice.

The semi-empirical WDR relationship was developed by Hoppestad (1955). It is a simple analytical formula that expresses that the WDR intensity is proportional to the product of the wind-velocity component normal to the wall and the horizontal rainfall intensity. The proportionality factor in the WDR relationship is called the WDR coefficient. The European Standard Draft for WDR calculation (CEN, 2002) is based on this method (Blocken and Carmeliet, 2004). In the past years, Choi (1991, 1993, 1994a, b) developed and applied a steady-state numerical simulation technique based on CFD. This technique has subsequently been adopted as the basic procedure in computational WDR studies and has been applied by many researchers since then. It is a steady-state simulation technique, allowing the determination of the spatial distribution of WDR on building facades for given (fixed) values of the wind speed, the wind direction and the horizontal rainfall intensity. Later, Choi's simulation technique was extended into the temporal domain by Blocken and Carmeliet (2002, 2007) and the extended simulation method was experimentally validated for low-rise and high-rise buildings (Blocken and Carmeliet, 2002, 2004, 2006; Tang and Davidson, 2004). The extension into the temporal domain allows this method to be applied for transient rain events, i.e. with time-varying meteorological input data (fluctuating values of wind speed, wind direction and horizontal rainfall intensity).

The extension into the temporal domain has raised an important question: "What is the required time resolution for the wind and rain input data in order to obtain accurate WDR calculation results?" The natural fluctuations in wind and rain characteristics suggest that the measurement samples of wind speed, wind direction and horizontal rainfall intensity should be available at a sufficiently high resolution in order to be "time-representative", i.e. to yield a good estimate of the corresponding WDR amount. In earlier papers (Blocken and Carmeliet, 2002, 2004, 2006; Tang and Davidson, 2004), time resolutions of 10 and 1 min have been used for WDR calculations, which yielded a good agreement with corresponding experimental WDR data. Earlier work has also shown that data at a lower time resolution (hourly) can give rise to significant errors (underestimations) in the calculated WDR amounts (Blocken and Carmeliet, 2007). In these publications, however, no detailed investigation of these errors and of their influencing parameters was made. A systematic investigation of the required time resolution has not yet been performed, and there are almost no guidelines for selecting an appropriate time resolution. Investigating this issue is quite important, because the use of hourly datasets for WDR calculations is generally accepted and current practice and there is hardly any information about the related errors. For example, the existing standards for WDR calculations (BSI British Standards Institution, 1992; CEN, 2002) request at best hourly averaged data. This is in contradiction with the statement by Sumner (1988) that hourly data are not appropriate where rain measurements are concerned, certainly not for the registration of