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Optimised method for estimating directional driving rain from synoptic observation data

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ABSTRACT

In this article, the annual directional exposure to driving rain and its characteristics are analysed and discussed at four Spanish sites that are characterised by different rainfall levels and topographical and wind conditions. For this study, the present weather observation method is used, which is based on average annual rainfall data and synoptic observations of the present weather. The results of this study are compared with those obtained by applying the ISO 15927-3:2009 standard, which is based on the semi-empirical analysis of hourly wind and rainfall data. This study identifies the intrinsic dependence of the aforementioned synoptic method on the weather conditions that exist at each site, which affect the reliability and accuracy of the estimates. Thus, corrective changes that would enable the synoptic method to generate more reliable approximations are proposed, and a new optimised methodology is presented; the precision of the new method relies on synoptic observations but is independent of weather conditions. The results, validated at four Spanish sites, suggest that in the absence of hourly data for implementing the ISO standard, this *optimised synoptic method* is able to generate reasonably accurate estimates of the annual directional exposure to driving rain, regardless of the particular site conditions.

1. Introduction

Atmospheric precipitation that is accompanied by gusts of wind is responsible for moistening building exteriors and penetrating these exteriors with water, which leads to damage and reduced performance of insulation and other energy-saving features of buildings (Del Coz et al., 2011, 2012; Sanders, 1996; Tang et al., 2004). An understanding of the level of exposure to wind-driven rain (WDR) that a building envelope component is exposed to is a fundamental requirement for establishing designs that minimise these moisture-related issues.

In recent years, the analysis of hourly climate data related to precipitation, wind speed, and wind direction has emerged as a standard method of determining the directional exposure of building envelopes to driving rain. Although the use of CFD models (Blocken and Carmeliet, 2002, 2007; Choi, 1991, 1993, 1994a, 1994b) has been shown to determine the exposure of the envelope to driving rain with precision and versatility (Blocken et al., 2010, 2011), alternative semi-empirical methods that are based on the analysis of weather data also continue to be employed for estimating this exposure, as these semi-empirical methods are considered to be reasonably reliable and easy to use (Blocken and Carmeliet, 2010).

One notable semi-empirical method is the ISO 15927-3:2009 standard (ISO, 2009), which provides an estimate model based on analysing hourly climate data to determine annual directional exposures under reference conditions ('… at a height of 10 m above ground level in the middle of an airfield, at the geographical location of the wall '). In the absence of WDR measurements or validated numerical simulations, the ISO standard results are the next best estimate. This standard also provides correction factors based on the surrounding terrain conditions that allow for the conversion of the free-field WDR intensity to the WDR intensity on a building façade.

However, the vast majority of countries do not have the hourly climate data that are necessary for the strict implementation of this standard, as the time period in which the available data was gathered is often insufficient, or the number of weather stations at which the data are collected are not representative (Chand and Bhargava, 2002; Giarma and Aravantinos, 2011; Pérez et al., 2012; Rydock et al., 2005). Given these frequent difficulties in applying the standard estimate model, several alternative semi-empirical methods are employed that estimate the directional exposure to driving rain from other available meteorological data.

A representative example of an alternative calculating method is specified by the ISO standard for countries in which simultaneous

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hourly rain and wind data are not available. However, this method, which uses 12-h wind data averages and qualitative recordings of the presence and intensity of rain to calculate the period during which the building exterior is moistened, is less accurate and reliable (due to its less quantitative nature) than the approach based on hourly data.

Another of the most representative alternative methods to quantitatively estimate directional exposure was introduced by Rydock et al. and is referred to in this article as the present weather observation method (Rydock et al., 2005). This method uses only mean annual precipitation values and synoptic observations of the present weather, encoded in accordance with an international standard (WMO, 2011). This method's application at certain Norwegian and British sites has been proved to be useful for providing reasonably accurate approximations of the directional distribution of annual driving rain at several of the locations that were examined (Rydock, 2007).

This article examines the synoptic weather and hourly data recorded at four Spanish weather stations to assess the accuracy of the present weather observation method at these sites relative to the ISO 15927-3:2009 standard. This analysis reveals the intrinsic dependence of the synoptic method on the particular climatology of each individual site. For certain rainfall conditions, this dependence produces significant errors, thereby affecting the reliability and accuracy of the overall results.

The newly optimised methodology proposed in this study, which is also based on the analysis of synoptic observations, ensures that the accuracy of calculations is less influenced by site-specific weather conditions (wind speed during precipitation events and directional distribution, intensity and total amount of rainfall); thus, the optimised method estimates the annual directional exposure of building envelopes to driving rain with greater accuracy and reliability than the original synoptic method.

2. Background

The simultaneous measurement of rainfall intensity and wind speed during a precipitation event can allow the 'WDR Relationship' (Blocken and Carmeliet, 2004), to be used to calculate the amount of rain diverted onto a vertical surface by the wind. If the wind direction is known, the amount of water received by each building exterior can be directionally defined. In the 1950s and 1960s, Hoppestad (1955) and Lacy (1965) addressed the relationship between these climatic measurements and the driving rain received by buildings, and their research has become the starting point of the semi-empirical estimation methods that are currently used.

Currently, the ISO 15927-3:2009 standard provides a method for determining the annual directional exposure to driving rain I_A (mm/annum) in free-field conditions (assessed by the airfield index) that uses simultaneous hourly rain R_h (mm), wind U_{10} (m/s), and wind direction D (deg.) data. This method recommends using data collected over a period of at least 10 years (preferably 20 or 30 years).

The directional-type calculation (see Eq. (1)) of the standard method allows for moderately precise quantification of the amount of water that impacts at a particular orientation Θ (deg.) over the course of a year. In the equation below, which is used for this quantification, only positive results are considered, i.e., the sum below only incorporates the hours when the wind drives a nonzero amount of rain onto the envelope over the course of the N years that are analysed.

$$I_{A_\Theta} = \frac{2}{9}\frac{\sum U_{10}(R_h)^{8/9}\cos(D-\Theta)}{N} \tag{1}$$

2.1. Present weather observation method

In the absence of adequate hourly data in Norway, Rydock et al. (2005) defined the present weather observation method for estimating annual directional exposure to driving rain, which relies on synoptic observations that are commonly available in most countries. These synoptic observations include meteorological data collected at various times throughout each day (3–8 records/day), and the results are tabulated using an internationally standardised numerical code from the World Meteorological Organization WMO, 2011. As they are numerically coded, the resulting records are easily analysed in spreadsheet programmes and can be used to conduct weather forecasts.

This present weather observation method uses the $7wwW_1W_2$ data set of the coding (see Table 1), which is focused on the results of the present weather observation at the time of recording; specifically, the method employs the codes representing rain (codes 60–65) or rain showers (codes 80–82). The characterisation of the present weather by a specific code is subject to the judgment of the recording observer.

As the encoding group Nddff (see Table 2) encodes data that indicate the associated wind speed and direction at the recording time (averaged over the previous 10 min), it is possible to consider simultaneously the rain codes discussed above, the wind speed, and the wind direction (in increments of 10° and always referenced to the north) for a location. This process can determine both the number of rain events or rain showers that occur at the location in question for each wind direction D and the average wind speed U_D that is associated with each of these events. As the coded directions are tabulated in 10° intervals, subsequent estimates will always be made based on that tabulation.

Table 1
Encoding group $7wwW_1W_2$ for present weather (extract).
source: WMO manual on codes.

ww (code table 4677). *Numerals are in bold if they are used in the present weather observation method.*	
50–59	Drizzle
60	Rain, not freezing, intermittent, slight at time of observation
61	Rain, not freezing, continuous, slight at time of observation
62	Rain, not freezing, intermittent, moderate at time of observation
63	Rain, not freezing, continuous, moderate at time of observation
64	Rain, not freezing, intermittent, heavy at time of observation
65	Rain, not freezing, continuous, heavy at time of observation
66–69	Rain, freezing/ rain or drizzle and snow
70–79	Solid precipitation not in showers
80	Rain shower(s), slight
81	Rain shower(s), moderate or heavy
82	Rain shower(s), violent
83–89	Mixed showery precipitation and snow

Table 2
Nddff encoding group for wind direction and speed.
source: WMO manual on codes.

dd	True direction, in tens of degrees, from which wind is blowing (code table 0877)
00	Calm
01	5–14°
02	15–24°
***E*tc.**	*E*tc.
35	345–354°
36	355–4°
99	Variable or unknown
ff	Wind speed in units indicated (knot)