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Characterization of the Campbell-Stokes sunshine duration recorder and its ability to derive direct solar radiation by using digital image processing

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The World Meteorological Organization defines the sunshine duration (SD) as the time that, along a given period, direct solar irradiance (DSI) exceeds the threshold level of 120 W/m2. Since the end of 19th century, the Campbell-Stokes sunshine recorder (CSSR) has been the most commonly used instrument used for measuring SD. Due to the large number of long records that exist worldwide, valuable climatic information can be extracted from them. Many authors have used the daily SD (as obtained from the measurement of the length of burn for a given card) to obtain additional information about solar radiation, by using Ångström-Prescott type formulas. Contrarily, the burn width has not been systematically used. Theoretically, the burn is wider (narrower) when the direct insolation is stronger (weaker). The aim of this research is to show the relationship between burn width and DSI, and to prove whether this relationship depends on the type of CSSR and burning card.

The research has been carried out in Girona (NE Spain) for a period of two years (from January 2012 to January 2014). Two different models of CSSR (which use different types of cards) and a pyrheliometer from Kipp&Zonen were used to measure SD and DSI, respectively. A semi-automatic method based on image processing of digital scanned images of burnt cards is presented. The method can be summarized in four steps: (i) scan each band on a green background; (ii) apply a digital process to increase the contrast of the burn; (iii) define two/three points in the image, depending of the geometry of the card, to point the center of the day (12.00 TST) on the image and define the trajectory of the sun with 1-minute intervals; and (iv) apply a program to make cross-sections every minute and measure the width of burn. So, after all of this process, we obtain a temporal evolution of the burn width with 1-minute resolution and distinguishing between morning and afternoon.

The results show that there is a good correlation between the burn widths obtained from the two types of CSSR. We also observe a quite good correlation with DSI, which is consistent with our hypothesis. However, if we study the threshold value, we obtain a wide range of values that are almost always higher than 120 W/m2, with a significant difference between the morning and afternoon records. Consequently, we consider that the behaviour of cards may also depend on other meteorological variables (temperature, humidity...) affecting the burn. The physical characteristics of the heliograph and of the cardboard from which the bands are made may also have an important role in this relationship. The method was applied to a limited series of cards, but could offer a practical way to exploit the worldwide sets of long-term CSSR data to create long time series of DSI. As there are methods to extract atmospheric aerosol content based on DSI (Linke turbidity factor, Ångström's turbidity coefficient, etc.), SD may become a proxy measurement for turbidity and atmospheric aerosol loading since the late 19th century.