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Anisotropy limitations of the Drummond's model to correct the effect of shadow-rings for measuring solar diffuse radiation

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The study of solar radiation and its partitioning into direct and diffuse components is essential for the understanding the climatic alterations. The proportion in which diffuse and direct solar radiation reaches the Earth's surface is the result of its complex interaction with the atmosphere constituents (gases, aerosols, clouds, ...). Therefore, accurate measurements of the diffuse and direct components provide information on the composition of the atmosphere. Additionally, the study of solar radiation and, in particular, the partitioning into direct/diffuse radiation presents a high interest to design and get the highest performance of any solar energy system.
Diffuse irradiance is commonly measured using a shadow ring. This device consists of a U-profile ring parallel to the sun path that blocks the direct irradiance on the sensor. The shadow ring also removes the portion of diffuse radiation from perpendicular direction to the ring surface and, therefore, the diffuse measurements have to be corrected.
A first correction model was proposed by Drummond in 1956. This model is based on solar geometric calculations assuming an isotropic sky radiation distribution. It provides a good estimation of diffuse irradiance occluded by the ring and, therefore, it has been widely applied anywhere on earth and it is usually proposed by the shadow ring manufacturers. However, this model presents some limitations. For instance, the sky radiance is not isotropic since its distribution changes with sun elevation, atmospheric turbidity and cloudiness. Some studies determined that the additional corrections for anistropic conditions were between 14% and 30% of isotropic correction. Following these results, several models have been developed aimed at correcting the anisotropy radiance effect such as this proposed by Batlles et al. in 1995.
This study emphasizes the need to account the radiation anisotropy in order to correct shadow ring diffuse radiation measurements. In this study, the correction model proposed by Drummond has been compared with a modified version of the model proposed by Battles in 1995 with new coefficients adapted to our radiometric station of Badajoz, Spain (38° 52' 58" N; 7° 0' 38" W; 199 m a.s.l), has been used. The reliability of the two correction models has been analysed using as reference the diffuse measurements recorded with a pyranometer installed on a sun tracker. The comparison between the corrected diffuse data and the reference measurements gives a relative root mean square error (rRMSE) and a relative mean bias error (rMBE) of 3.7% and 0.2% for the Batlles's model and 4.4% and -1.2% for the Drummond's model, respectively. Therefore, this comparison shows that the model proposed by Batlles provides better correction of the diffuse measurements than the Drummond's model. This result is also confirmed by the Taylor diagram. The differences between the corrections applied by the two models can be up the 5% and they have been analysed versus the solar zenith angle and the parameters epsilon, ε, and delta, Δ, that characterize the sky's clearness and brightness, respectively. The higher differences between the models occur for situations with low ε values and high Δ values.