EMS Annual Meeting Abstracts
Vol. 9, EMS2012-152, 2012
12th EMS / 9th ECAC

Modeling circumsolar irradiance to adjust beam irradiances from radiative transfer models to measurements

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Radiative transfer models (RTMs) are increasingly used in the solar resource assessment community. They simulate the propagation of solar radiation through the atmosphere. As an example, the LibRadtran model has been used to develop the fast processing LUT-based McClear model predicting irradiance at ground level under clear skies.
The solar radiation reaches the top of the terrestrial atmosphere as a collimated beam, with a half angular aperture equals to 0.26°. During its path toward the ground, it is gradually scattered and exhibits hemispherical distribution. The beam irradiance normal to sun rays (BNI) originates from the sun direction and is modeled in RTMs as if the sun were a point source. On the contrary, pyrheliometers measure the radiation coming from the direction of the sun with an aperture equal to 5° according to WMO standards. Aperture angles or acceptance angles can be greater for systems converting solar energy into power and always facing the sun. Therefore, the measuring devices or power systems take into account the circumsolar irradiance, while RTM do not. The circumsolar irradiance (CSI) within the corresponding opening angle should therefore be added to the modeled BNI to derive the actual BNI.
There are very few methods in the literature for assessing CSI. Those existing are difficult to validate because CSI data are seldom available. In this work, we firstly make a comparison between CSI estimated with a published empirical method and that estimated from LibRadtran, and discuss the observed discrepancy. Both estimates are added to the BNI predicted by McClear for various states of the atmosphere. The results are then validated against ground measurements. The improvement of adding CSI to BNI is analyzed.