Gaborone peak shaving

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The climate data used in this study are estimates of land, marine, and atmosphere climate variables time-dependent at hourly through ECMWF Reanalysis v5 (ERA5), which covers the period from 1940 to the present. ERA5 spans the planet on a 31 km grid and resolves the atmosphere with 137 levels. It replaces the ERA-Interim reanalysis and offers hourly output and uncertainty estimates with a 31 km horizontal resolution (Hersbach et al., 2020; Ahamed & Alam, 2022).

The ERA5 data includes the main components needed to calculate optimal solar irradiance on an inclined plane: FDIR (direct solar irradiance at the surface), UV-visible albedo (surface albedo for direct irradiance), and SSRD (surface solar irradiance downwards) (Hogan, 2015).

Additionally, monthly cloud cover data (total, high, medium, and low clouds) derived from 24 hourly ERA5 and aerosol data derived from CAMS global reanalysis (EAC4) reanalysis data with horizontal resolutions of 0.25? x 0.25? and 0.75? x 0.75? were used to analyze their relationship to solar irradiance in Botswana from 1971 to 2020 and 2003 to 2020, respectively.

Figure 1. (a) The Botswana map shows the distribution of districts and observational stations; (b) Standardized annual mean direct solar irradiance at the surface anomalies averaged over all stations/grids of Botswana derived from the Botswana observational station data and ERA5 Reanalysis data, respectively. Also, the Pearson correlation coefficient and statistical significance were denoted at a 95% confidence interval.

Duffie and Beckman estimated the RD based on the angle difference f-S and latitude f, and its values were provided in their publication (Duffie & Beckman, 2013). Given a specific ratio RD, the direct sun irradiance on a tilted surface can be calculated using Equation (4).

where Id is the scattered/diffuse irradiance on a surface oriented horizontally. The formula for the irradiance reflected from the ground on the slanted surface I r,Σ is provided by

where ρ g denotes the diffuse reflectance of the ground (Bostan et al., 2011) and IT is the total solar irradiance on a surface oriented horizontally. The total solar irradiance on the surface tilted at a certain angle is combined into three components.

Utilizing ERA5 datasets, ID = direct solar radiation at the surface, denoted by the short name FDIR; IT = surface solar radiation downwards, denoted by the short name SSRD; and UV-visible surface albedo for direct radiation, is denoted by ALUVP. In addition, Id = diffuse/scatter radiation results from subtracting FDIR from SSRD.

EEMD helps process solar irradiance data, which is often nonlinear and nonstationary. It maintains critical

salient features and reduces noise by omitting measurement errors and atmospheric noise. EEMD allows for identifying the dominant modes of variability in the solar irradiance signal and, thus, primary oscillatory patterns. Additionally, it offers time-frequency localization, enabling the identification of transient events and localized changes in solar irradiance intensity.