

Title: Assessment of the Impact of Synoptic Events on Photovoltaic Efficiency in North-Central Minas Gerais Using Random Forest

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Abstract: The increasing frequency of extreme climate events drives the energy transition in Brazil towards renewable sources. In this scenario, solar photovoltaic energy consolidates itself as a fundamental mitigation strategy. However, the thermodynamic efficiency of the panels is inherently vulnerable to atmospheric variability and extremes. Given this context, this study evaluates the impact of synoptic systems on photovoltaic generation in the North-Central region of Minas Gerais, Brazil, one of the main national generation hubs characterized by high irradiation levels, with a transitional climate domain highly susceptible to thermal and rainfall anomalies. This research utilizes daily ERA5 reanalysis data for surface air temperature and global solar radiation. These variables are first integrated into thermodynamic equations to estimate photovoltaic (PV) cell temperature and compute daily conversion efficiency. This efficiency metric is defined as the target variable for model training. A multivariate Random Forest predictive model is then developed to assess the impact of synoptic atmospheric phenomena on PV performance. The predictors include the occurrence and intensity of four key climate indices: Extreme Heatwaves, the South Atlantic Convergence Zone (SACZ), Atmospheric Blocking events, and the Standardized Precipitation Index (SPI). The model is trained and validated using historical data from 1960 to 2024, and feature importance metrics are extracted to quantify the relative contribution of each atmospheric driver to variations in PV efficiency. This approach allows us to isolate and compare thermally driven effects such as heatwaves and blocking induced subsidence with radiatively driven effects such as cloud cover associated with SACZ, as well as the role of precipitation anomalies.

Keywords: Machine Learning, Climate Extremes, South Atlantic Convergence Zone, Atmospheric Blocking, ERA5 Reanalysis.