Pernambuco Solarimetric Network

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Abstract

Internet services providing solar radiation data are not common nowadays. These resources, more likely ground-based data, are used for many applications such as calibration of satellite models, site adaptation, solar radiation, and energy forecasting. This article describes the Pernambuco solarimetric network (REDESOLPE), its geographical coverage, and a basic data quality analysis grouped by station owner. As results, all IFPE stations presented a lower percentage of suspected data, the APAC stations had a high percentage of anomalous data, and INMET stations presented percentages of physically possible and extremely rare values. The losses follow almost the same result, IFPE presented lower data loss. The APAC losses are always affected in the same year, which means that the problems had occurred in the same manner for a group of stations.

Keywords: Solar radiation resources, data quality analyses, solarimetric network.

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1. Introduction

A weather monitoring network provides long-term data on variables like temperature, rainfall patterns, and other climatic factors. This information supports decision-making in fields such as agriculture, livestock management, and hydropower generation (Cao et al., 2017).

Regarding solar energy resources, solarimetric data have diverse applications, including (1) calibration of satellite models (Perez et al., 2002), (2) adjustment of satellite-measured values for specific locations (site adaptation) (Bayasgalan et al., 2024), (3) solar radiation forecasting (Ye et al., 2022), and (4) power and energy forecasting in photovoltaic plants (Cervera-Gascó et al., 2022), as well as other related applications.

There are numerous sources of solar radiation data available worldwide. Paid services such as Meteonorm, SolarGIS, and PVGIS provide historical data with daily and hourly resolution (Kulesza et al., 2023). Free services like the BSRN (Baseline Surface Radiation Network), CAMS (Copernicus Atmosphere Monitoring Service), NSRDB (National Solar Radiation Database), SOLCAST, and Brazilian databases such as SONDA (Sistema de Organização Nacional de Dados Ambientais) and INMET (Instituto Nacional de Meteorologia) allow users to download historical solar radiation data at hourly and sub-hourly resolutions, including its direct and diffuse components.

To promote research and development activities in the state of Pernambuco, located in Brazil's Northeast Region, using solar energy resource data, a multiuser laboratory dedicated to measuring and organizing solar radiation data was established. This initiative is called the Pernambuco Solarimetric Network (REDESOLPE) (Pedrosa Filho, 2022).

This article describes REDESOLPE's implementation, geographical coverage, and operational data, focusing on data gaps and quality metrics based on standardized tests by Long and Dutton (2002).

2. REDESOLPE Description and Conception

The Pernambuco Solarimetric Network was conceived based on several key observations:

a) Research on solar energy resources and their diverse applications requires installation of a solarimetric station at the location of interest, which demands both financial resources and personnel for installation and operation. In most cases, these facilities only serve a limited number of researchers. When research funding ends, the station is typically decommissioned, resulting in location-specific data being available only for the duration of the particular research project.

b) Two public institutions operate measurement networks in Brazil: INMET (National Institute of Meteorology), with 578 stations nationwide but only 14 in Pernambuco, and INPE (National Institute for Space Research)

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via the SONDA network (National Environmental Data Organization System), which has 17 solarimetric stations across Brazil—only 1 located in Pernambuco state.
c) Since 2015, IFPE (Federal Institute of Education, Science and Technology of Pernambuco) has maintained 7 solarimetric stations throughout Pernambuco state.

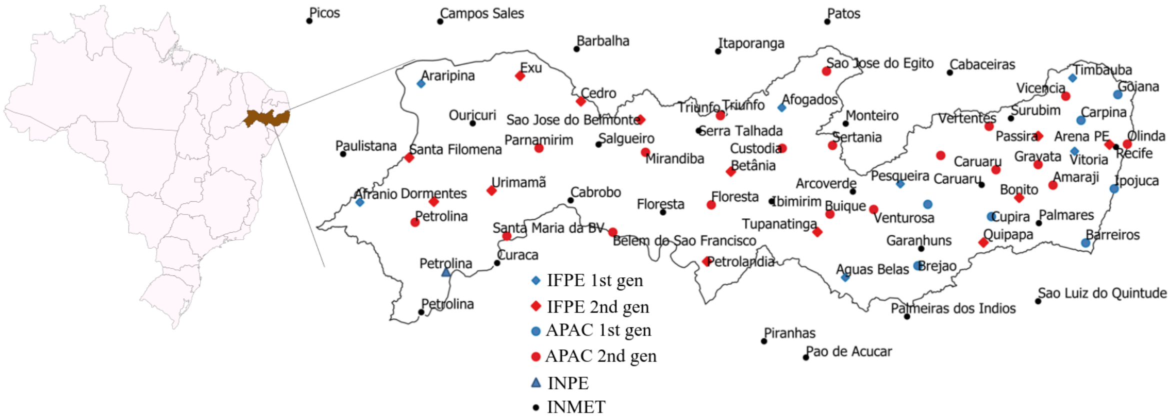

Figure 1: Solarimetric stations distribution.

These observations revealed the potential for a multi-user laboratory to integrate disparate data sources, centralizing solar radiation and ancillary meteorological measurements. This initiative, the Pernambuco Solarimetric Network (REDESOLPE), standardizes access to ground-based data for researchers across Pernambuco and world wide. Initially deployed with 22 stations, REDESOLPE now operates 75 stations (IFPE: 20; APAC: 27; INMET: 27; INPE: 1), spatially distributed as shown in Figure 1.
The reliability of solar irradiance data within a monitoring network is directly contingent upon sensor technology and the rigor of maintenance protocols. In the REDESOLPE framework, stations operated by IFPE predominantly utilize high-precision thermopile pyranometers (Kipp & Zonen CMP3), with a smaller fraction equipped with photodiode sensors (SP Lite2), all of which undergo a biennial calibration cycle. In contrast, the APAC and INMET networks rely primarily on photovoltaic technology sensors, for which maintenance and calibration records are not uniformly documented.
Beyond instrumentation, data logging infrastructure varies between industrial-standard units, such as Campbell Scientific and Novus models, and proprietary systems like those from Hobeco, directly influencing time-series integrity and transmission failure rates. Table 1 details the technical specifications and operational practices for each participating institution within the network.

Table 1: Technical specifications and maintenance protocols of REDESOLPE networks.

Network	Sensor Technology	Pyranometer Model	Datalogger	Maintenance
IFPE	Thermopile (18) Photodiode (2)	K&Z CMP3 (18) K&Z SP Lite2 (2)	Campbell Scientific (12) Novus (8)	Calibration every 2 years
APAC	Photodiode	Photovoltaic type	Campbell CR1000X (20) Hobeco (7)	Not specified
INMET	Photodiode	Photovoltaic type	Not specified	Not specified

3. Description of qualification results

For the qualification of REDESOLPE data, the following considerations were initially made: the 20 stations operated by IFPE record measurements at 1-minute intervals. And the remaining 57 stations provide hourly data.
For quality control, we applied physically possible (eq. 1) and extremely rare (eq. 2) limits as described by Long and Dutton (2002).

$$GHI > I_{0eff} \times 1.5 \times cos(\theta_z)^{1.2} + 100 \quad \text{(eq. 1)}$$

$$GHI > I_{0eff} \times 1.2 \times cos(\theta_z)^{1.2} + 50 \quad \text{(eq. 2)}$$

For hourly data, these threshold values were integrated to produce hourly limits.
A third classification category was established for null or negative irradiance values (eq. 3) occurring within solar zenith angles $\theta_z < 80^o$. These values were flagged as anomalous.

$$\text{anomalous} = \begin{cases} 1, & \text{if } \theta_z < 80^\circ \text{ and } GHI \leq 0, \\ 0, & \text{otherwise.} \end{cases} \quad \text{(eq. 3)}$$

θ_z is the zenital angle, I_{0eff} is the extraterrestrial solar irradiance in W/m², and GHI is the global horizontal irradiance in W/m² (Rabl, 1985).
The results are presented in graphs organized by the operating institution of each station (Figure 2 and 3). All percentages are related to complete amount of data for each station.

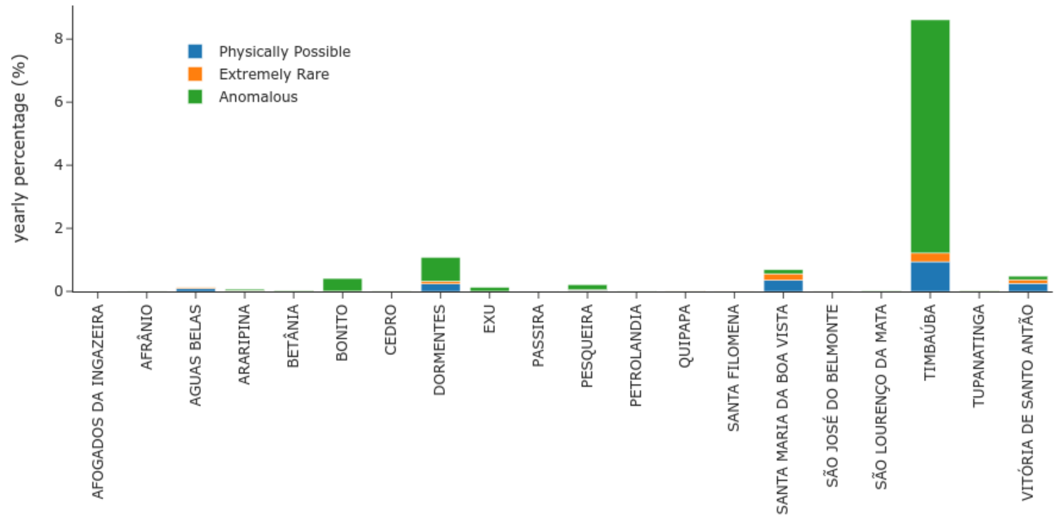

Figure 2: Yearly percentagem of physically possible, extremelly rare and anomalous ocurrences for IFPE stations.

The quality qualification results for REDESOLPE data are presented in Figures 2 and 3. As shown in Figure 2, all flag percentages for IFPE stations remained below 2%, with the exception of the Timbaúba station, where 7.3% of values were classified as anomalous. This specific deviation was caused by electrical issues near 2018, which led to significant data corruption. The high performance of the IFPE network is technically supported by the use of high-precision thermopile sensors (CMP3) and a rigorous biennial calibration protocol.
In contrast, anomalous values prevailed across all INMET stations (Figure 3, top). This lack of data quality is attributed to the absence of regular maintenance, such as battery replacement and sensor cleaning. Furthermore, since INMET utilizes photovoltaic-type sensors, they are more susceptible to spectral degradation and soiling in the absence of field interventions. Regarding the APAC stations (Figure 3, bottom), a significant number of sites exhibited high percentages of ”physically possible” and ”extremely rare” flags. This suggests that despite the use of modern Campbell CR1000X dataloggers, the sensors likely require deep calibration and maintenance to correct these measurement deviations.
The final analysis concerns the annual lack of data for observations where $\theta_z < 80^\circ$. Figure 4 reveals that IFPE stations experience punctual data gaps, with some locations like Santa Filomena and Afrânio maintaining very low loss rates. These distributed losses are typically caused by aleatory issues such as localized battery failure or datalogger resets.
An opposite trend was observed in the APAC network (Figure 5), where all stations presented high loss percentages synchronized in specific years. Significant losses occurred in 2017 for one group of stations, while the others were heavily affected in 2023 and 2024. This pattern indicates that the failures occurred in a group-wise manner, likely due to central telemetry or server-side issues rather than individual hardware malfunction. Interestingly, while INMET stations showed the lowest quality, they did not present a significant lack of data during the analyzed period, suggesting robust transmission despite the poor sensor maintenance.

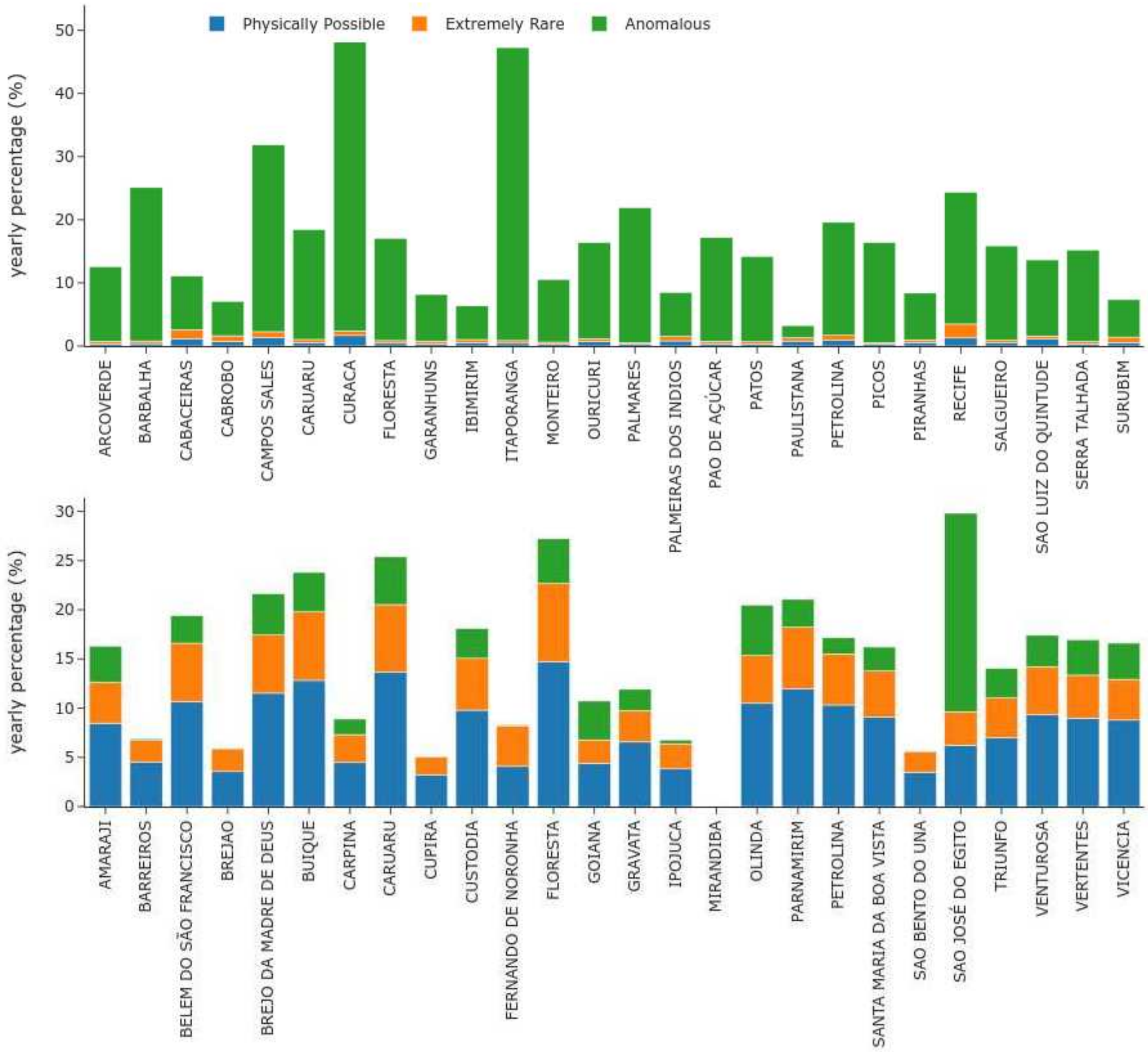

Figure 3: Yearly percentagem of physically possible, extremelly rare and anomalous ocurrences for INMET (above) and APAC (below) stations.

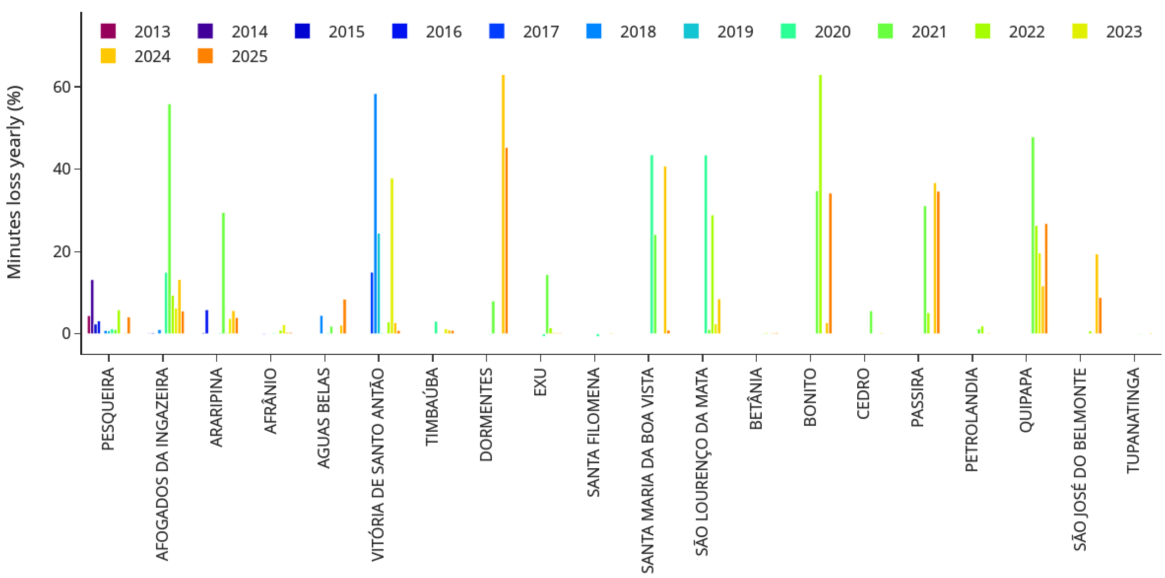

Figure 4: Yearly lack of data for IFPE stations.

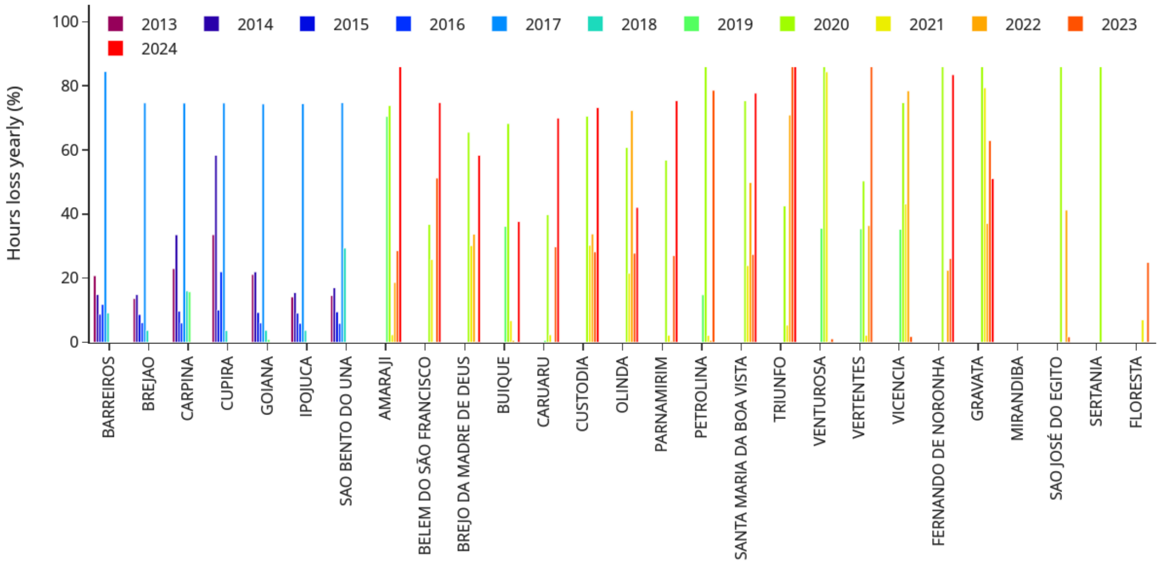

Figure 5: Yearly lack of data for APAC stations.

4. Conclusion

The analysis of the Pernambuco Solarimetric Network (REDESOLPE) reveals distinct performance profiles among the participating institutions, closely tied to their respective instrumentation and maintenance protocols. The IFPE stations demonstrated superior data quality, with low percentages of anomalous, physically possible, and extremely rare flags. This reliability is attributed to the use of thermopile sensors and a rigorous biennial calibration cycle, although these stations remain susceptible to sporadic data losses due to localized hardware or battery issues.

The APAC network exhibits significant data quality challenges, characterized by a high incidence of physically possible and extremely rare flags, likely stemming from the use of photovoltaic-type sensors without standardized calibration. Furthermore, the synchronized data losses observed in specific years (2017 and 2023–2024) suggest systemic failures in telemetry or central data management rather than individual station malfunctions.

Finally, the INMET stations presented a unique paradox: while they achieved the lowest data loss rates, they exhibited the poorest data quality due to a high prevalence of anomalous values. This indicates that while transmission infrastructure is robust, the lack of field maintenance, such as sensor cleaning and battery replacement—renders much of the collected data invalid for high-precision applications.

These findings underscore the necessity of establishing unified maintenance and calibration standards across multiuser laboratories to ensure the scientific utility of ground-based solar radiation data in Brazil's Northeast.

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