

Mapping of Solar Radiation Anomalies Based on Climate Change

Elison Eduardo Jardim Bierhals, Claudineia Brazil, Francisco Pereira, Elton Rossini

Abstract—The use of alternative energy sources to meet energy demand reduces environmental damage. To diversify an energy matrix and to minimize global warming, a solar energy is gaining space, being an important source of renewable energy, and its potential depends on the climatic conditions of the region. Brazil presents a great solar potential for a generation of electric energy, so the knowledge of solar radiation and its characteristics are fundamental for the study of energy use. Due to the above reasons, this article aims to verify the climatic variability corresponding to the variations in solar radiation anomalies, in the face of climate change scenarios. The data used in this research are part of the Intercomparison of Interconnected Models, Phase 5 (CMIP5), which contributed to the preparation of the fifth IPCC-AR5 report. The solar radiation data were extracted from The Australian Community Climate and Earth System Simulator (ACCESS) model using the RCP 4.5 and RCP 8.5 scenarios that represent an intermediate structure and a pessimistic framework, the latter being the most worrisome in all cases. In order to allow the use of solar radiation as a source of energy in a given location and/or region, it is important, first, to determine its availability, thus justifying the importance of the study. The results pointed out, for the 75-year period (2026-2100), based on a pessimistic scenario, indicate a drop in solar radiation of the approximately 12% in the eastern region of Rio Grande do Sul. Factors that influence the pessimistic prospects of this scenario should be better observed by the responsible authorities, since they can affect the possibility to produce electricity from solar radiation.

Keywords—Climate change, solar radiation, energy utilization.

I. INTRODUCTION

THE acceleration of climate change is related to industrial development, and consequently, to an increase in the demand for electricity. Looking for measures that minimize environmental impacts, the Brazilian energy matrix is gaining new formatting, becoming less and less dependent on non-renewable energy sources, such as oil and natural gas, while alternative sources of renewable energy increase its presence [4].

By opting for photovoltaic solar generation, the consumer also contributes to the mitigation of climate change, which is currently considered one of the biggest environmental problems.

The Intergovernmental Panel on Climate Change (IPCC) is the leading international scientific body for assessing climate change and was created to provide scientific information on the current state of knowledge of climate change and its possible socioeconomic and environmental impacts [6].

Elison Eduardo Jardim Bierhals is with the University State of Rio Grande Sul, Brazil (e-mail: bierhalseduardo@gmail.com).

The results from this program have been an important tool for policies implementation as responses to climate change.

The data are the results of global models simulations from several research centers, and simulations of global models represent numerical and physical approximations of equations governing the movements of the atmosphere and their interaction with the Earth's surface [7].

Since 1995, the IPCC reports have had an experimental framework to study the data provided by ocean-atmosphere general circulation models, the Coupled Model Intercomparison Project (CMIP). The combination of several readings of atmospheric data around the world makes it possible to evaluate certain patterns, which can predict events or evaluate deficiencies or even errors in the ways of analyzing these data [5].

The use of alternative sources of energy represents a major challenge in order to meet energy demand and reduce environmental damage. Faced with the need to diversify the energy matrix and try to minimize global warming, solar energy has been gaining space, being an important renewable source, even depending on the climatic conditions.

Compared to European level, Brazil presents a great solar potential for the generation of electric energy, having more sun hours per year. The sun is an inexhaustible source of energy, allowing one to obtain a clean energy [2]. Quality information about the solar resource is fundamental for the sizing of solar systems, since the generation of electric energy depends on the availability of the resource.

This work aims to analyze the projections of solar radiation for the south of Brazil and its correlation with a possible pessimistic scenario of climatic changes.

II. MATERIALS AND METHODS

A. Study Area

The state of Rio Grande do Sul (Fig. 1) is located in Brazil's extreme south, between latitudes 27 ° and 34 ° South (S) and longitudes 50 ° and 57 ° West (W). The state maintains borders to the West with Argentina, to the South with Uruguay, to the North with the Brazilian State of Santa Catarina, and to the east it is bathed by the Atlantic Ocean.

The territorial area of Rio Grande do Sul has 268,781,896 km², the average population density is 38 inhabitants per km². Among the states of Brazil, southern region is the one with the lowest density [3]. The predominant climate is subtropical.

B. Description of the Model Used

The database used in this research is part from the Phase 5 Intercomparison of Matching Models (CMIP5), and

contributed to the preparation of the fifth IPCC-AR5 report. The data were extracted from The Australian Community Climate and Earth System Simulator (ACCESS) model.

The AR5 scenarios are organized according to the RCPs. In this research, RCP 8.5 scenario was used which represents a scenario with a continuous population growth, resulting in

high carbon dioxide emissions, with an increase up to 4 °C [8].

In terms of greenhouse gas emissions, this scenario is considered to be the most pessimistic for the 21st century and is consistent with no policy change to reduce emissions and strong dependence on fossil fuels [6].

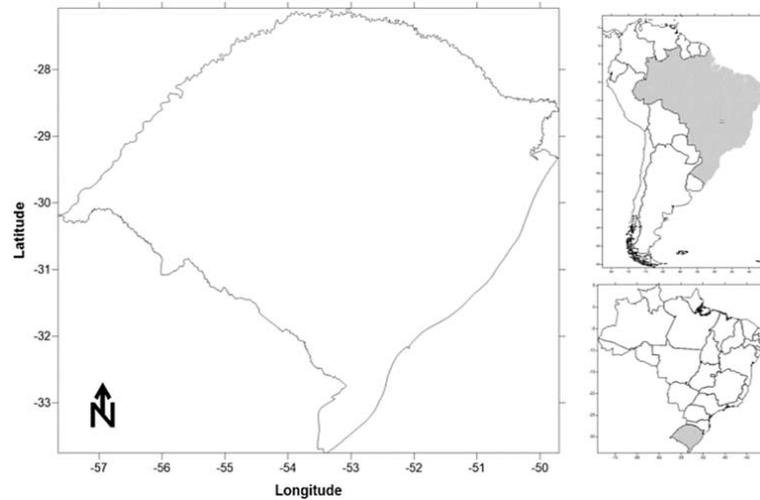


Fig. 1 Map of the study region

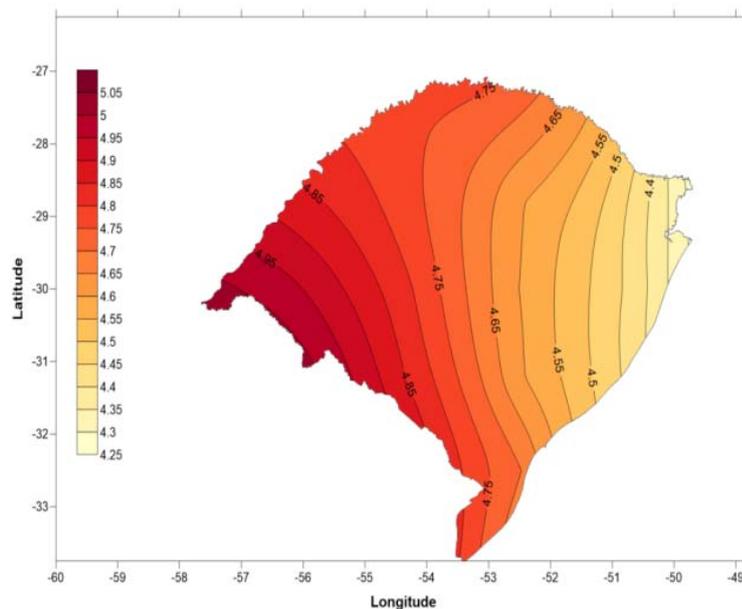


Fig. 2 Average solar radiation kWh/m² - Projections (2026 - 2100)

III. METHODOLOGY

The work was carried out in steps, the monthly data of Solar radiation in kWh/m² were extracted from the IPCC-AR5 data base, this work stage was performed through software Grid Analysis and Display System (GRADS).

GRADS is a data visualization and analysis system in grid points, working with binary data matrices, in which variables can have up to four dimensions (longitude, latitude, vertical

levels and time) [7].

After this stage, the historical data series and the data series with the climatic projections were organized. The projections were divided into three scenarios: Scenario-1 (2026-2050), Scenario-2 (2051-2075) and Scenario-3 (2076-2100).

The solar radiation anomaly was calculated from the following equation:

$$A_{Rad} (\%) = ((R_{MM} - R_{MN}) / R_{MN}) * 100 \quad (1)$$

At where: ARad (%) is the radiation anomaly in percentage; RMM is the average radiation of the month analyzed; NMR is the normal climatological correlation for the analyzed month.

The World Meteorological Organization (WMO) defines climatological normal as averages of climatological data calculated for consecutive periods of 30 years.

IV. RESULTS AND DISCUSSIONS

It is important, first of all, to determine its availability in order to enable the use of solar radiation as a source of energy in a given location and/or region.

Fig. 2 shows the average solar radiation based on the IPCC projections for the state of Rio Grande do Sul from 2026 to 2100. The highest values are found in the western half of the state of Rio Grande do Sul, in the region of the Uruguiana municipality with the maximum around 5 kWh/m², agreeing with the results obtained [1] that verified the availability of solar radiation from historical data. The lowest values of solar radiation are located in the state's eastern region.

From the historical series of Solar Radiation, the Climatic Radiation Norms were calculated, which are the long period averages of 1961-1990, for all months of the year. Based on this information, we recorded, for each period, the percentage of months that the Radiation was above or below Climatological Normal. According to Fig. 4, it was verified that, for all the scenarios analyzed that solar radiation has a tendency to decrease over the next few years, for example in the scenario of 2076-2100, the tendency is that the radiation is 60% of the months below the climatological normal.

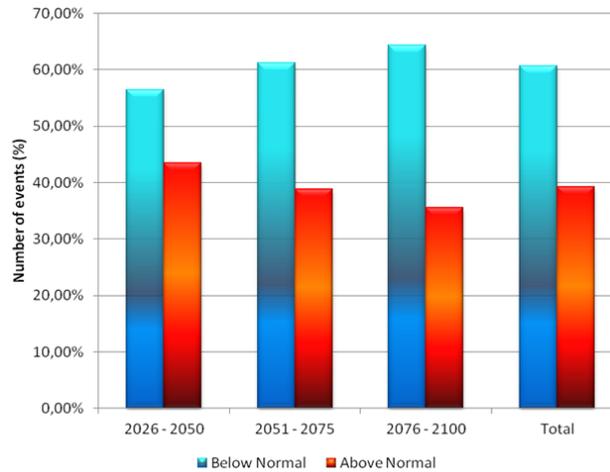


Fig. 3 Graph percentage of number of events above (red) and below (blue) the normal climatological

In order to verify the mean alteration trend over time, the anomalies of solar radiation that are the extreme fluctuations related to the historical averages were analyzed. Fig. 4 shows the solar radiation anomaly for scenario 1 (2026-2050). In the coastal region, in addition to presenting the lowest values of solar radiation, the trend is that for this scenario there will be a fall around 5% compared to historical data, verifying the scenario 2 (Fig. 5) and scenario 3 (Fig. 6), the tendency is to increase the fall of solar radiation, reaching a loss of 12% in the upper region of the East of the state of Rio Grande do Sul.

In general, negative anomalies were observed in the three scenarios, indicating a significant fall in radiation over the years, for the entire Gaucho territory.

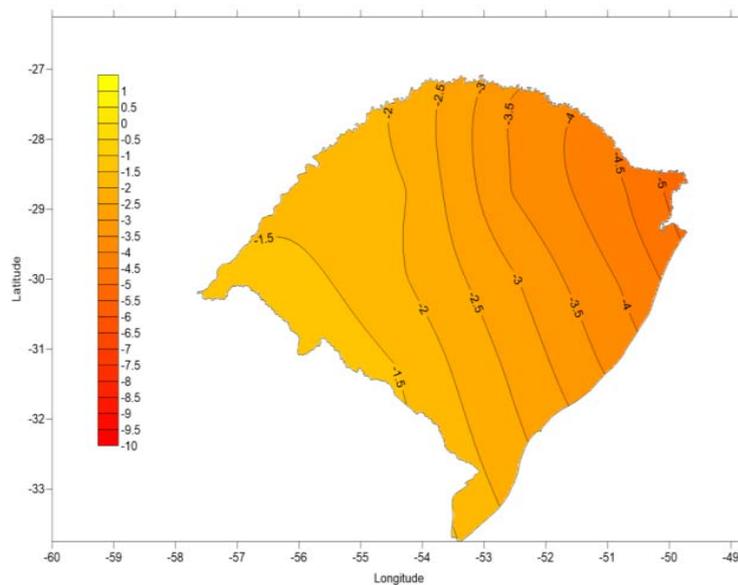


Fig. 4 Averages of solar radiation anomalies kWh / m² (%) Scenario 1 (2026 - 2050)

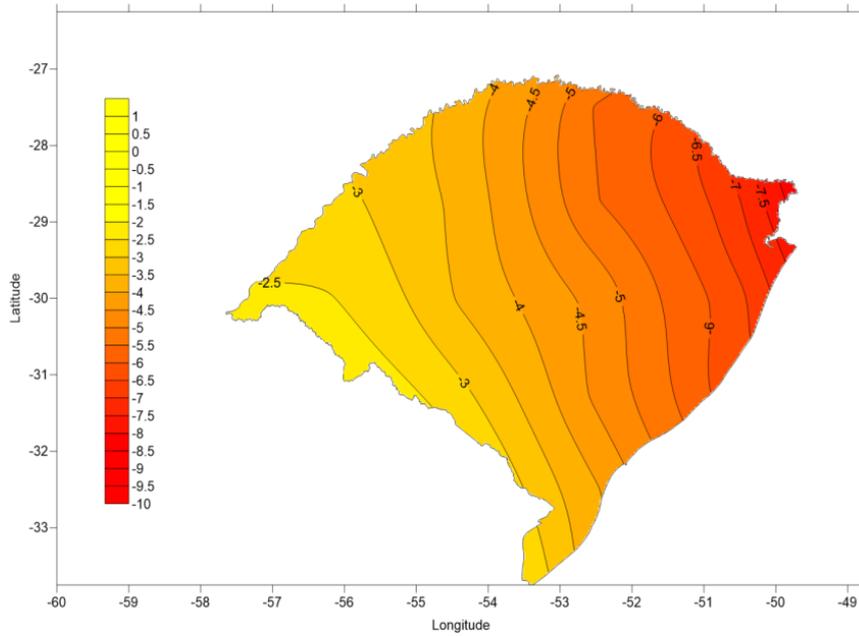


Fig. 5 Averages of solar radiation anomalies kWh / m² (%) Scenario 2 (2051 - 2075)

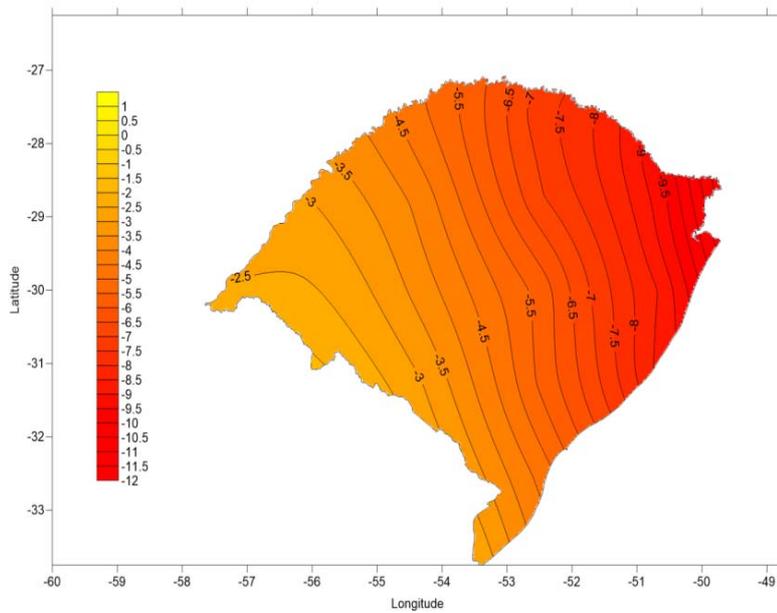


Fig. 6 Averages of solar radiation anomalies kWh / m² (%) Scenario 2 (2076 - 2100)

V. CONCLUSIONS

Renewable energies, for the most part, are dependent on weather conditions, so adequate energy planning requires climate change knowledge. The climatic projections, based on the pessimistic scenario, showed in all Rio Grande do Sul a solar radiation fall, reaching 12% in the eastern region of the state. These data demonstrate the need for a concern with the factors that influence the pessimistic perspectives of this scenario, as it will directly affect a possible production of electricity from solar radiation. In order to diversify the energy

matrix and minimize future climate impacts, it is important to invest in an energy policy considering renewable energy sources.

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