

The impacts of global climate changes on the wind power density in Brazil

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ABSTRACT

Brazil's wind energy production has escalated up recently. However, the long-term wind projects do not include the yet unknown impacts of climate changes on wind power. This work is an assessment of these impacts by applying forecasts of a climate model and trend analysis over climatological time series from selected ground sites. Findings indicate a favourable scenario for wind power exploitation in Brazil on the long run.

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1. Introduction

Brazil's wind energy production has escalated up from 22 MW in 2003 to 602 MW in 2009 thanks to the Proinfa (Program for Incentive of Alternative Electric Energy Sources), which is a government program to encourage the use of wind power, biomass, and small hydroelectric power. An additional 256.4 MW is now under construction. Recently 71 additional projects have been approved as a result of the first wind-only bidding round for energy supply in Brazil of December 2009. The contracts, totalling 1800 MW, will start up in July 2012 with a supply period of for 20 years. Developing wind power in Brazil will help the country to meet its strategic objectives of enhancing energy security, creating more jobs and, at the same time, reducing the country's energy-related greenhouse gas emissions. The potential inland wind power resources in Brazil could reach more than 145,000 MW. In spite of this, the long-term growth of the national wind capacity depends not only on a more competitive price for this energy (today at US\$ 84.8 MWh) but also on the sustainable domestic development of this technology. Furthermore, since wind contracts are long term, the yet unknown impacts of climate changes on the wind power may possibly cast doubts and uncertainties on the revenues of investments in this area.

Eichelberger et al., 2008 [1] analysed the surface wind fields from a 14-member ensemble of GCM simulations to evaluate the impact of global climate change on near-surface wind speeds using the A1 and B2 scenarios from the IPCC. The models revealed globally the regions with the percentage of models showing increased annual-mean wind speed values in 2050. For North America, most models predicted increases in annual mean wind speed of up to 0.2 m/s on a broad North-South strip along the Eastern part of the continent, including the Yucatan

peninsula for the same period. The rest of the continent will see very little change, or very small decreases. According to these authors, the forecasted wind speed differences are large enough to affect the profitability of existing and future wind projects in this region. A study for the US [2] has pointed out that the effect of climate change will handicap the nascent wind industry in the US by slowing the winds. Pryor et al., 2009 [3], presented signs of overwhelming dominance of trends toward declining values of the 50th and 90th percentile and annual mean wind speeds based on two observational data sets, which is also the case for simulations conducted using MM5 with NCEP-2 boundary conditions. For the case of Brazil, a previous work [4] indicate that the wind potential in Brazil will be benefited by the expected climate changes of the next century as a result to of GCM models outputs using the IPCC A2 and B2 scenarios. Their results indicate increasing wind speed of up to 20% up to the year of 2100, particularly in the north and coastal northeast part of the country, and a strong decline in wind speeds in a large area located in the western Amazonian region.

This work intent to go deeper into this issue by refining the analysis of the impacts of the global climatic changes in the wind energy potentials in Brazil.

2. Methodology

As part of this study, we employed observational data time series from selected national weather stations between 1960 and 2007 to investigate for trends in wind speed. Two target areas were selected on basis of their greater wind energy potential in Brazil and their largest number of wind projects, the Northeast and the South. We first applied a quality-control data screening process to available sites. Only 15 out of the 41 available ground sites were selected based on the continuity of the data acquisition and data quality control. Then we applied the Kendall trend test at 95% confidence level on the selected ground data.

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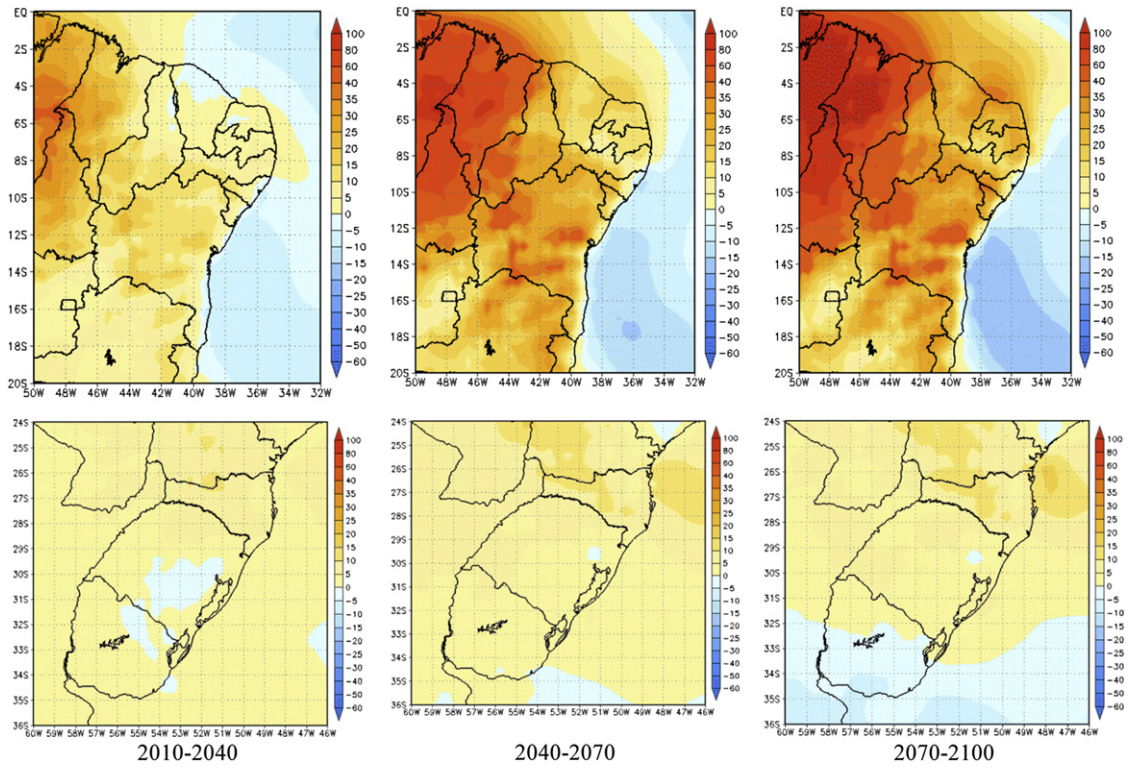


Fig. 1. Annual mean plots of the relative variation (%) of the Eta-HadCM3 model forecasts with respect to the reference period of 1962–1990 for the wind power densities in the Northeast (top row) and in the South (bottom row) regions.

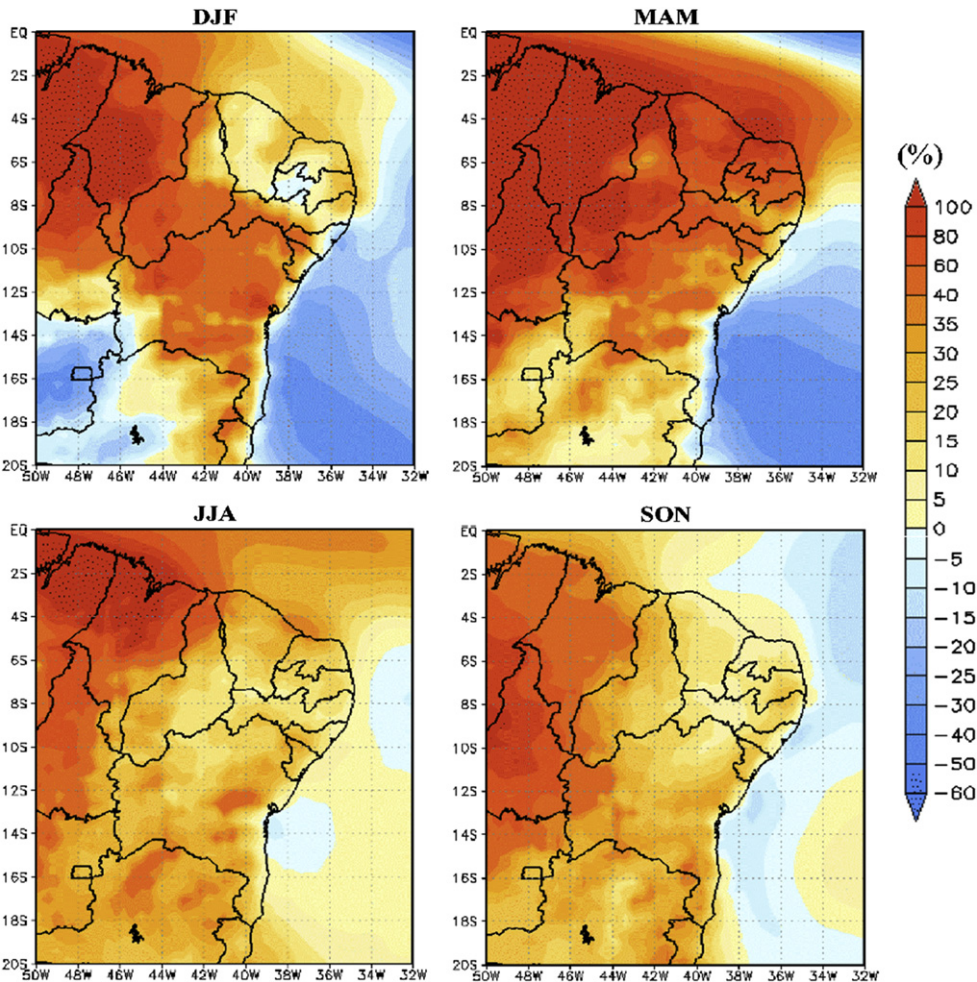


Fig. 2. Relative season variation in percentage of the Eta-HadCM3 model forecasts with respect to the reference period of 1962–1990 of the wind power density in the Northeast region for the forecasts for the period of 2070–2100.

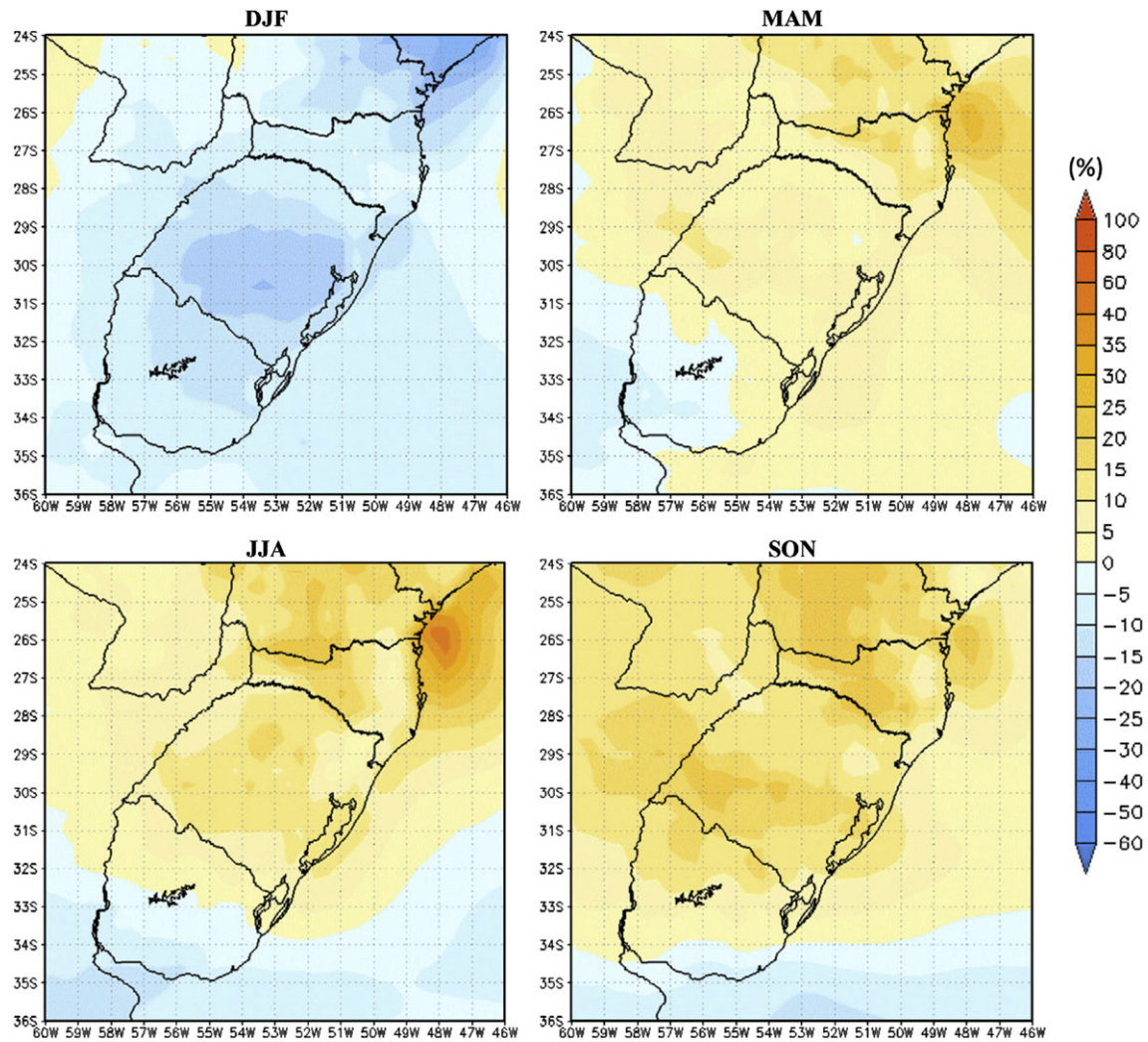


Fig. 3. Relative season variation in percentage of the Eta-HadCM3 model forecasts with respect to the reference period of 1962–1990 of the wind power density in the South region for the forecasts for the period of 2070–2100.

In addition to the study of time series trends of data from ground stations, we examined wind forecasts from the global circulation model (GCM) HADCM3 of the Hadley Centre - UK MetOffice. The mesoscale model Eta provided downscaling of the GCM forecasts from the original $2.5^\circ \times 3.75^\circ$ resolution down to $40 \text{ km} \times 40 \text{ km}$ ground resolution and 38 vertical layers. The Eta model was updated every 6 h with boundary conditions from the HadCM3 outputs. This new downscaled product will be referred to as Eta-HadCM3 throughout the remainder of this text. The model assumed the A1B scenario of the IPCC report. Time series observation data from ground stations were also employed to validate the Eta-HadCM3 model for the 1960–1990 period. This period was considered as a reference (baseline period) in this study. Next, we compared the model forecasts for the subsequent periods (2010–2040, 2040–2070, and 2070–2100) with the baseline period. These works were performed at the INPE's supercomputing facilities <http://www7.cptec.inpe.br/>.

3. Results

The analysis for trends on the selected time series of ground data shows that about 50% of the 15 selected time series present a statistically significant positive trend against 20% with negative

trends. The remaining validated time series did not show statistically significant trends. Although there are a slight larger percentage of positive trends as compared to negative trends, the large number of non-significant results suggests that there is a need

Table 1

Results of applied Kendall tests over observational data from the selected ground sites in the northeast and south regions of Brazil.

Ground site	UF	Avg. wind speed (m/s)	Kendall test	Trend	Period
Northeast region					
Caravelas	BA	3.00	-2.57	decreasing	1961–2007
Macau	RN	5.46	-1.63	non-significant	1961–2007
Maceió	AL	3.55	-4.41	decreasing	1961–2006
Parnaíba	PI	4.35	-3.71	decreasing	1971–2007
South region					
Bagé	RS	2.89	2.43	increasing	1961–2007
Cruz Alta	RS	2.06	-1.35	non-significant	1961–2007
Curitiba	PR	2.18	-1.87	non-significant	1960–2007
Florianópolis	SC	3.25	-0.47	non-significant	1961–2007
Indaial	SC	1.42	-2.88	decreasing	1971–2007
Iratí	PR	2.21	-5.62	decreasing	1967–2007
Lagoa Vermelha	RS	2.76	1.04	non-significant	1961–2006
Passo Fundo	RS	3.30	3.10	increasing	1961–2007
Vitória do Palmar	RS	3.88	2.18	increasing	1961–2007
São Joaquim	SC	2.44	1.10	non-significant	1961–2007
São Luiz Gonzaga	RS	2.40	5.58	increasing	1961–2007

to increase the number of ground sites time series in order to be able to achieve results that are more conclusive.

Fig. 1 depicts the relative changes in the annual mean wind power densities in percentage variation relative to the baseline period of 1962–1990 derived from the Eta-Hadcm3 model outputs. These plots were made by first calculating the power density on basis of the wind speed forecasts of the model. Next, the percentage change was calculated for each pixel for each of the period shown in the Fig. 1. Of course, there are pronounced variations also with respect to seasons. Fig. 2 depicts the same plots for each season for the period of 2070–2100 for the Northeast region and Fig. 3 for the South region (Table 1).

4. Conclusions

The search for trends in climatological time series of observational data did not produced conclusive results. The Eta-HadCM3 model forecasts for future climate scenario A1B indicate a tendency for an average of 15%–30% growth in the wind power density inland for most of the Northeast region of Brazil, with some regional intensification of more than 100% mainly in the north sector of this region. Except for the offshore area in the North and Northeast of the country, the Eta-HaDCM3 model pointed out a decreasing trend in wind power density for the future climate, particularly along the coast of Bahia state. The fall season (March–May) shows the largest increasing tendency for wind power density in the Northeast region. The largest contrast between the increasing wind power density in the North-Northeast offshore and the decreasing trend on the ocean off the coast of Bahia are observed during the fall season.

The South region of Brazil exhibited a mild growing trend for wind power density as compared to the Northeast region, about 10%, peaking to more than 20% in some areas. The central region of the state of Rio Grande do Sul extending down to the South of Uruguay has presented the smaller decreasing trend of wind power in this region. This region also exhibited the strongest inter-seasonal variability, with an overall minimum during the austral summer (Dec–Feb) and an increase during the rest of the year with respect to the baseline period.

From the above results, it is possible to expect that the overall impact of the global climate changes on the wind power in the Northeast and South regions of Brazil might be favourable to the profitability of existing and future wind projects in both regions. Nevertheless, this study is only preliminary. The large uncertainties associated with GCM models and scenarios remain open to further discussion. A more thorough study is necessary to reduce uncertainties, including time series of observation data from a much larger group of ground stations, and the inclusion of different scenarios for the GCM forecasts.

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