The Impacts of Global Climate Changes on the Wind Power in Brazil

Enio Bueno Pereira

National Institute for Space Research - INPE

Center for Earth Science System - CCST

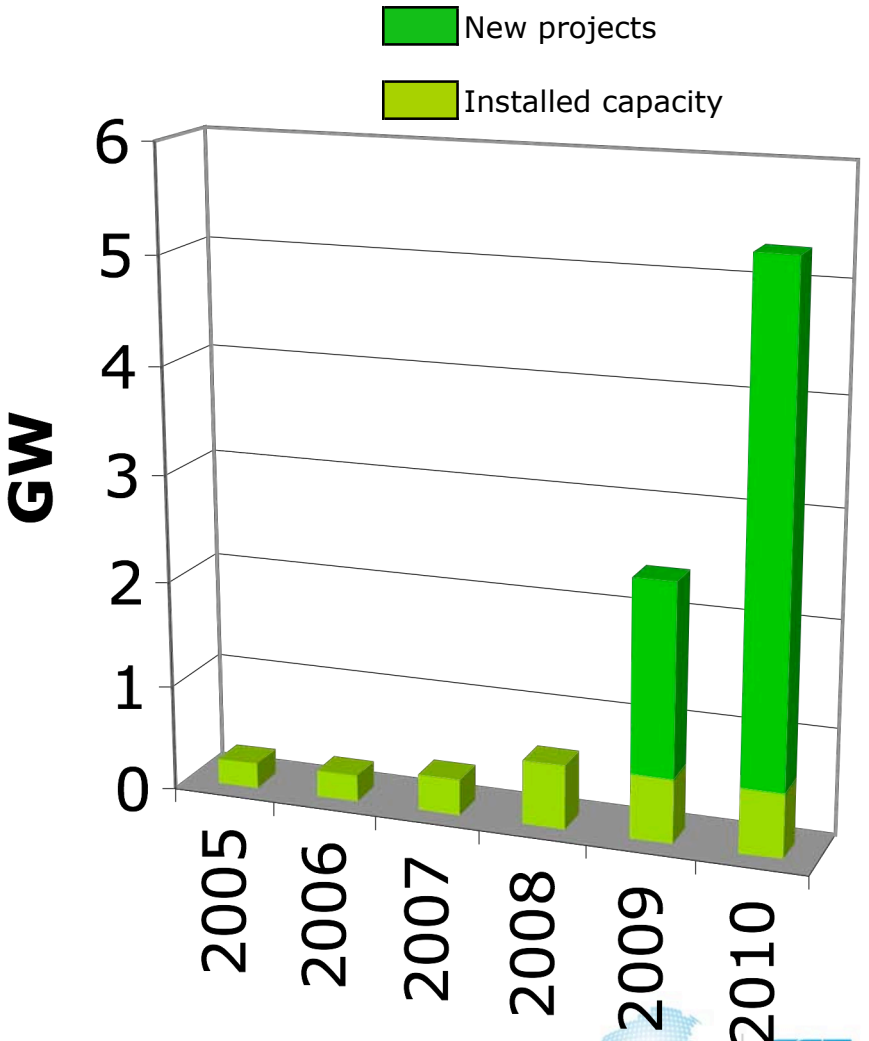
Brazil

XI World Renewable Energy Congress

25 -30 September, 2010 - Abu Dhabi, UAE

Wind Energy Growth in Brazil

- Annual auctions for wind energy since 2009
- Growth of 8-fold of its capacity after 2009
- This will represent a 2.5% share in the national electricity matrix
- Good for the national energy security
- The Brazilian wind market is now becoming attractive to investors
- Contracts are for 20 years
- **But what are the impacts of the Global Climate Changes on the national wind power?**

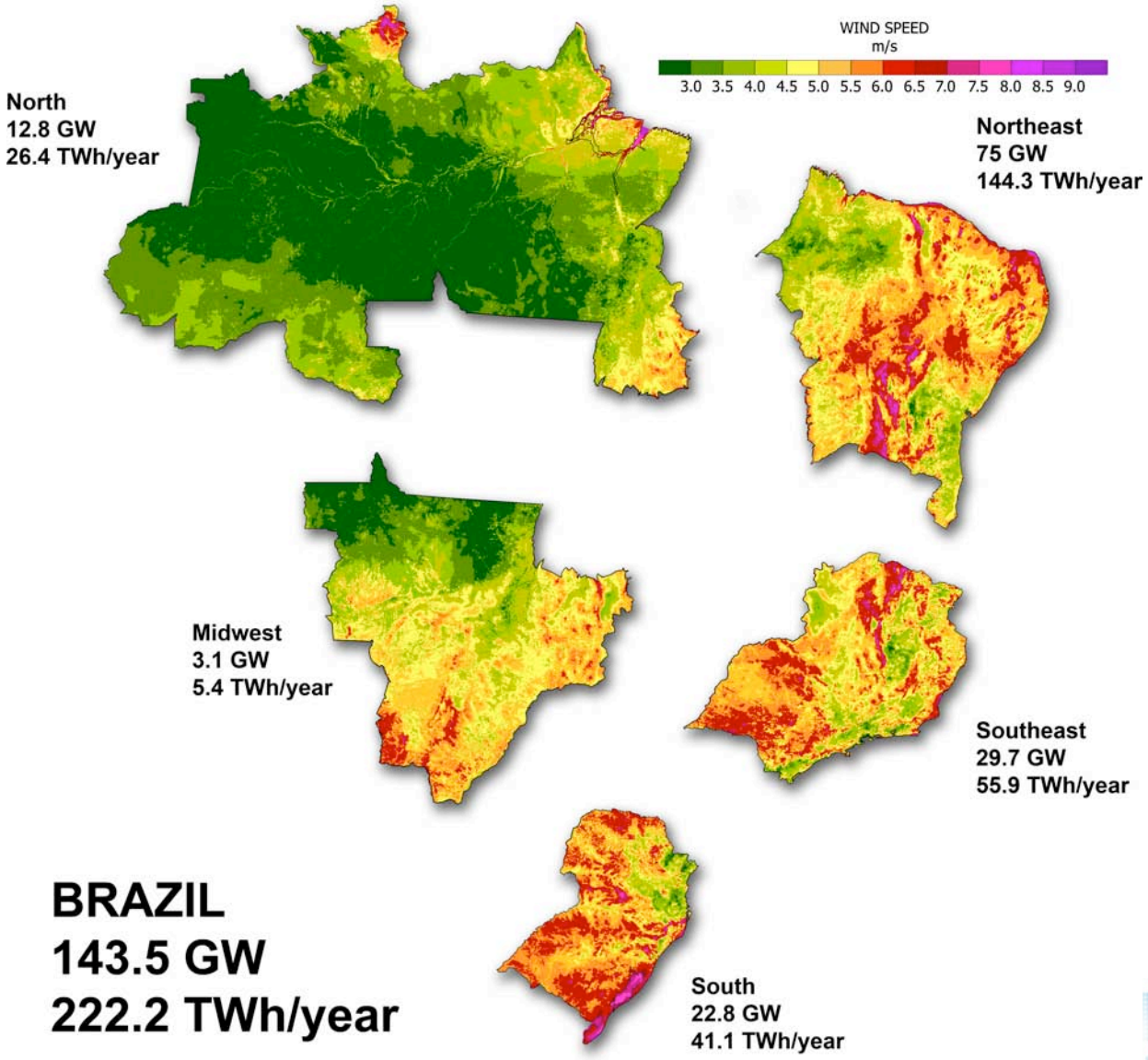


INPE

CST Centro de Ciência do Sistema Terrestre

Wind Power in Brazil

from CEPEL - 2001

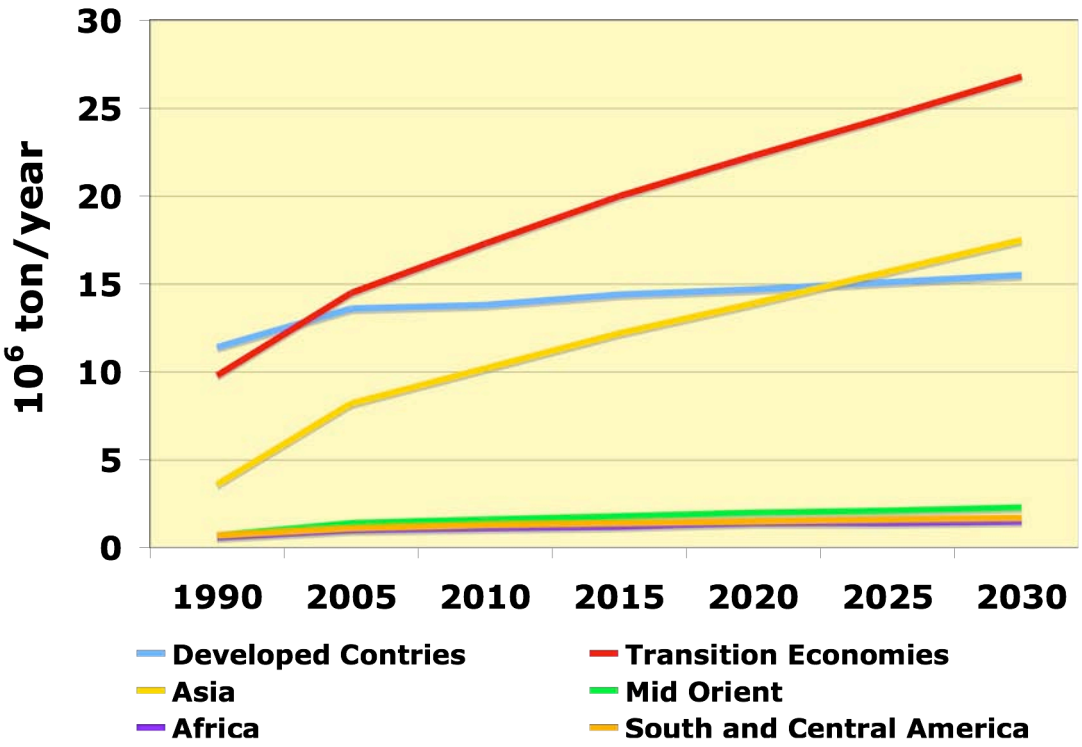


INPE

CST
Centro de Ciência do Sistema Terrestre

Premises

- Temperatures are already predicted to rise by almost 1.5C (2.7F) by the middle of the century
- Together with the temperature rise, changes in the wind circulation are also expected
- Developing economies will play a strategic role in the future scenarios of global warming as their development will demand increasingly energy resources



Previous Results

- Breslow and Sailor (2002), using outputs of the General Circulation Models (GCM's) of the Canadian Climate Center and Hadley Center, concluded that there is a reduction from 1.4 to 4.5% in surface wind speed in the USA for the next 100 years.

- Sailor and Hart (2008), using outputs from GCM's for IPCC scenarios A1B and A2, found that the speed of winds in the northeastern U.S. may have a reduction from 50 to 10% in summer and a slight increase in winter.

- Eichelberger et al. (2008) using GCM's outputs applied globally for scenarios A1 and B1, forecast several areas with an increase in wind speed by 2050 and an overall influence of seasons

CST
Centro de Ciência do Sistema Terrestre

- The scenarios for South America have shown an increase in the wind regime in the north and central portions of the continent, including parts of Brazil, and regions of decreased winds mainly on the west coast of the continent, including part of the central-west Brazil

- The report "*Climate Change: Energy Report (2008)"* COPPE, forecasts high winds prevailing along the coast of the Brazilian northeast region while for the other regions of the country the wind speed should decrease significantly.

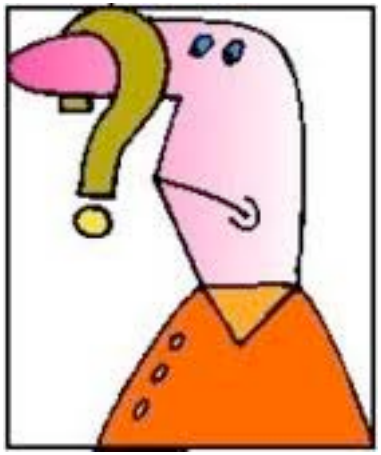
- This report indicates that the balance of these variations for different regions in Brazil will have a 31% decrease of the wind potential in 2100 compared with 2001 for the A2 scenario, and 60% for scenario B2.

- Lucena et al. (2010), have used the HadCM3 model predictions, with regionalization of 50 x 50 km by INPE made by the Hadley Centre PRECIS model, indicating an optimistic scenario for the wind sector mainly in the northeast.

Seemingly disparate results?

Uncertainties in the forecasts?

Need for models validation?



Project's goal

To study the impacts of the Global Climatic Changes on the wind regime in Brazil for this century

- ✓ Study of trends in available climatic data series of meteorological observations
- ✓ Use of the climatic data series to validate GCM models
- ✓ Applying GCM forecasts under distinct scenarios from the IPCC report
- ✓ Focus on the Brazilian Northeast and South (where most wind projects are located)

INPE

CST Centro de Ciência do Sistema Terrestre

Historical data series

- Meteorological data from the National Institute of Meteorology (INMET) between 1960 and 2007
- Additional historical time series from the Institute of Air Space Control (ICEA), and from the National Oceanographic Data (NODB) from the Brazilian Navy.
- 41 weather station were pre-selected based on a minimum of 20-year of data
- Only 15 out of the 41 pre-selected available meteorological stations were selected based on the continuity of the data acquisition and a data quality control

Selected (red) and rejected (black) weather stations

Testing time series for trends

Kendall method

- Most popular method to detect trends in environmental studies
- Non-parametric test to detect monotonic trends in time series
- The method consists of statistical tests on the sum of the number of terms in the series relative to given values x_i whose previous terms are less than x_i
- The test was applied to a confidence level of 95% for all data series
- The trends are ranked based on the null hypothesis H_0

  -1.96 < $u(t)$ < 1.96, obtained from the normal distribution table.
  - significant positive ($u(t)$ > 1.96)
  - significant negative ($u(t)$ < -1.96)
  - not significant (-1.96 < $u(t)$ < 1.96)

CST
Centro de Ciência do Sistema Terrestre

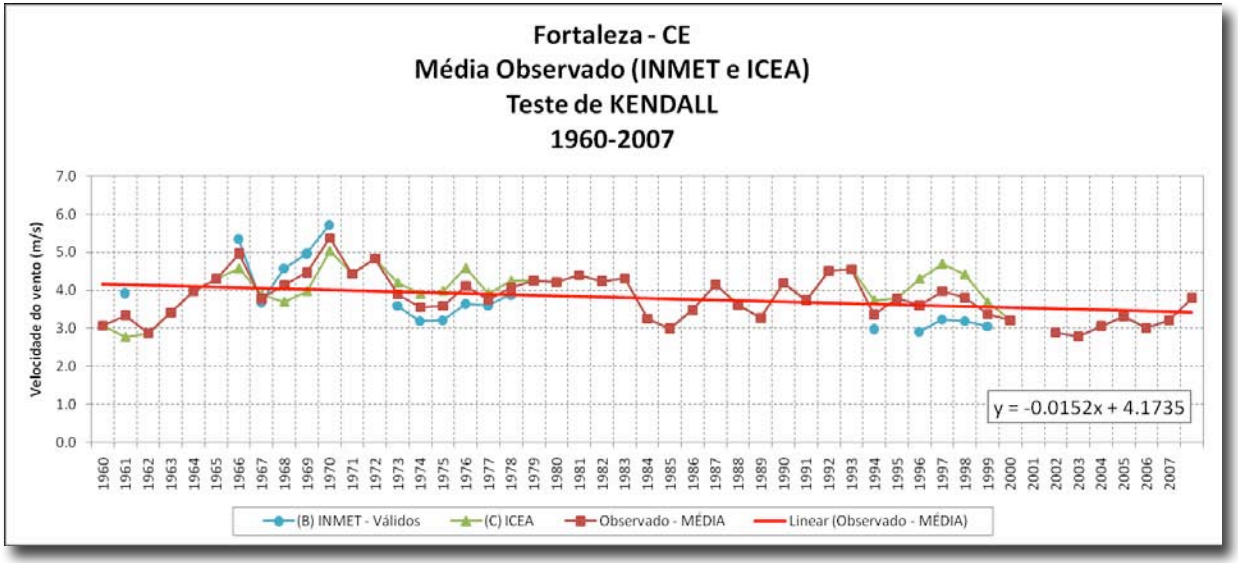
Northeast region

ground site	UF	avg. wind speed (m/s)	Kendall test	trend	period
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

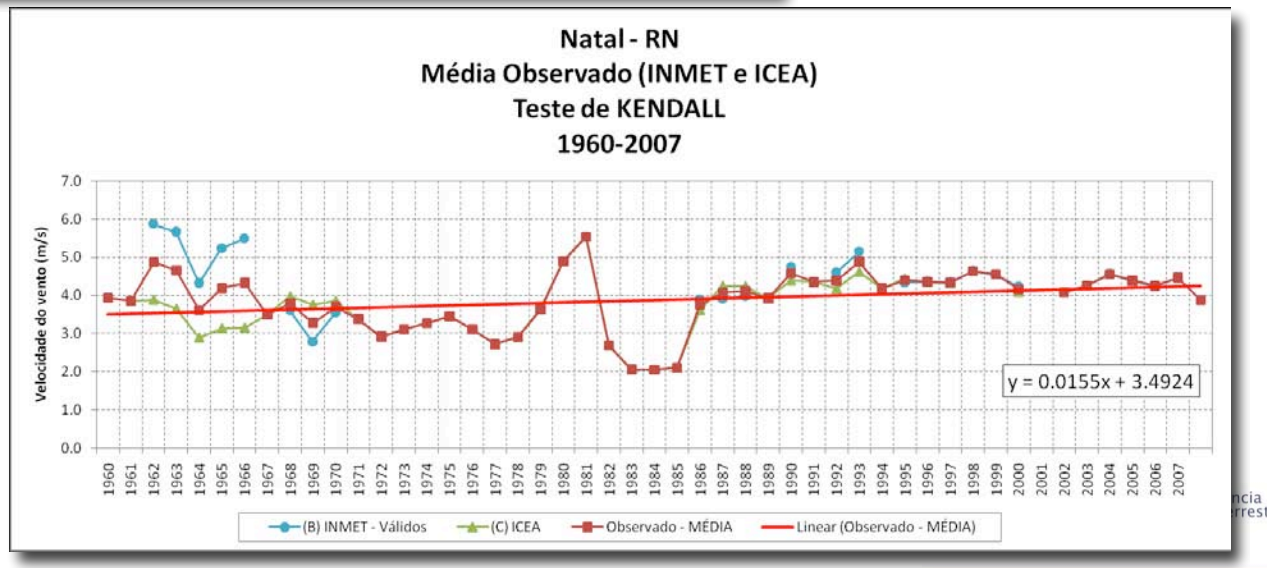
ground site	UF	avg. wind speed (m/s)	Kendall test	trend	period
Bagé	RS	2,89	2,43	increasing	1961-2007
Cruz Alta	RS	2,06	-1,35	non-significant	1961-2007
Curitiba	PR	2,18	-1,87	non-significant	1960-2007
Florianópolis	SC	3,25	-0,47	non-significant	1961-2007
Indaial	SC	1,42	-2,88	decreasing	1971-2007
Iratí	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

Time series



Negative significant

$u(t)$ = -2.5



Positive significant

$u(t)$ = +2.1

Conclusion for trend analysis

- 27% of the 15 valid time series presented statistically significant positive trend
- 33% time series with negative trends.
- The remaining 40% time series did not show statistically significant trends.
- The large number of non-significant results suggests that the number of valid time series in this study is not sufficient to achieve conclusive results

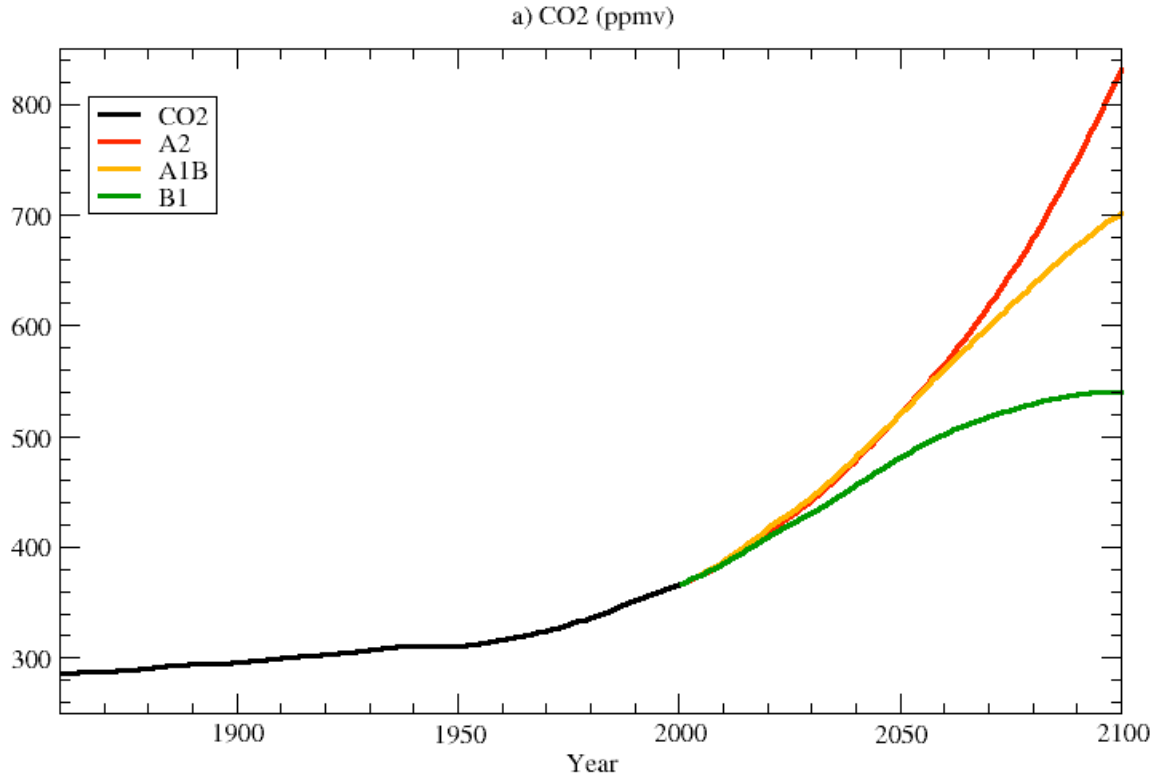
Use of GCM model

- The mesoscale model *Eta* provided downscaling of the Global Circulation Model (GCM) HADCM3 of the Hadley Centre - UK MetOffice from its global resolution of 2.5^{o} x 3.75^{o} down to 40km x 40km ground resolution and 38 vertical layers.
- The *Eta* model was updated every six hours with boundary conditions provided by the HadCM3 GCM.
- Model run for 31 years between 1960 and 1990 was employed as the baseline period in this study.
- Model runs for the 2010-2040, 2040-2070, and 2070-2100 were compared to the reference period.
- The model runs were performed at the INPE's supercomputing facilities

The climate scenario

Climate scenario A1B from the IPCC report

- Halfway between the pessimist A2 and the optimist B1 of the IPCC climate scenarios
- Assumes a more balanced use of the fossil and renewable energy resources
- And that there is no strong dependency on any specific energy resource

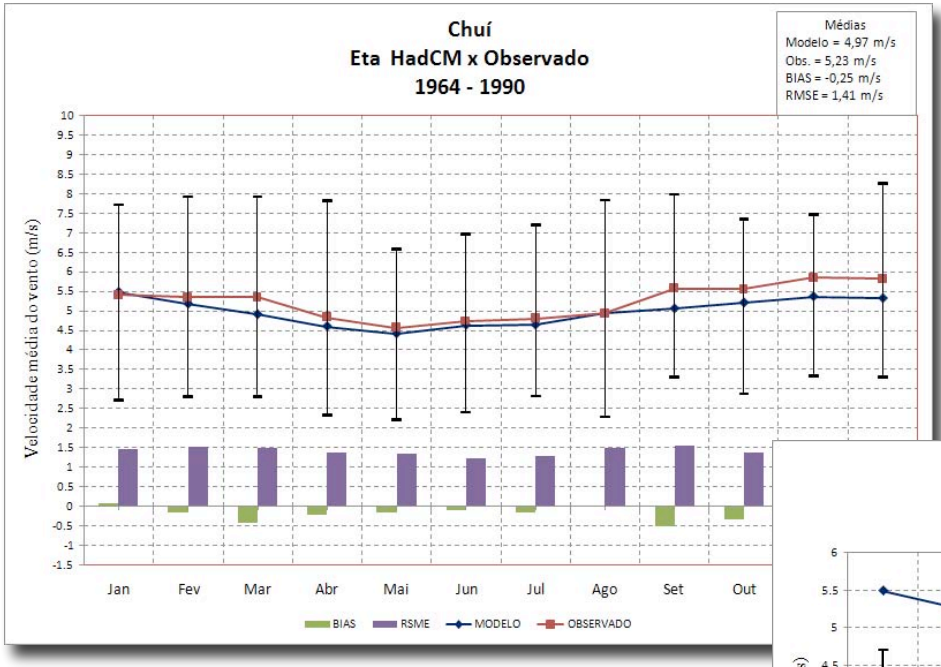


INPE

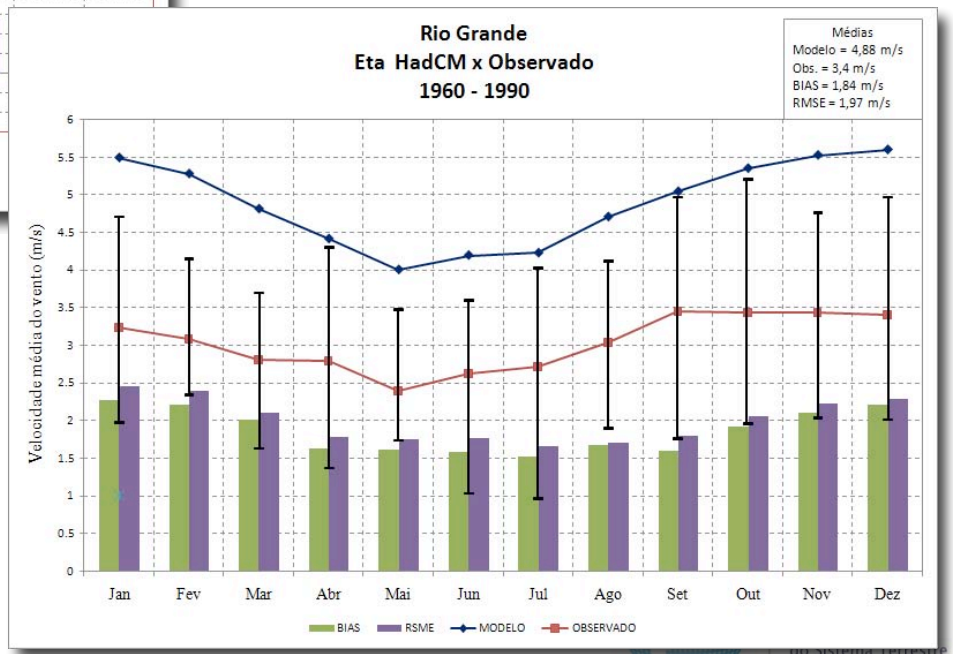
CST Centro de Ciência do Sistema Terrestre

Model validation

forecasting the past



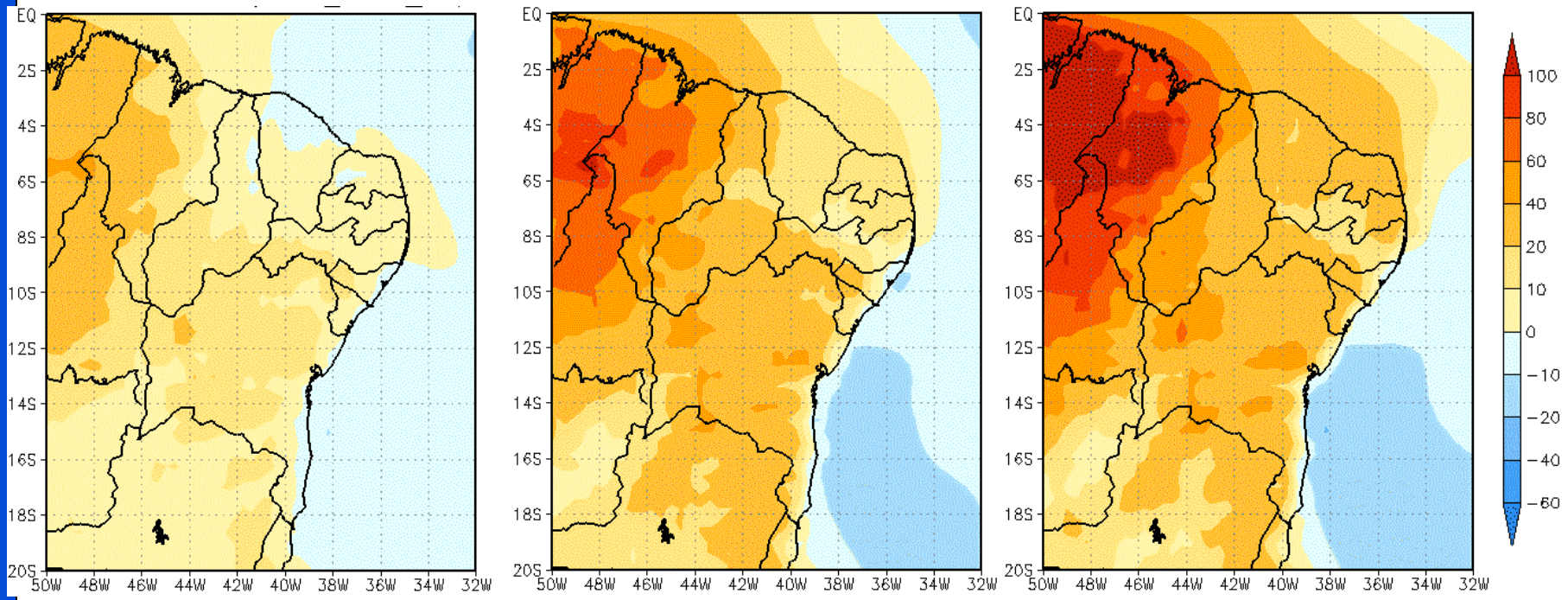
Good fits for some sites



Not so good fits for other sites

Northeast Region

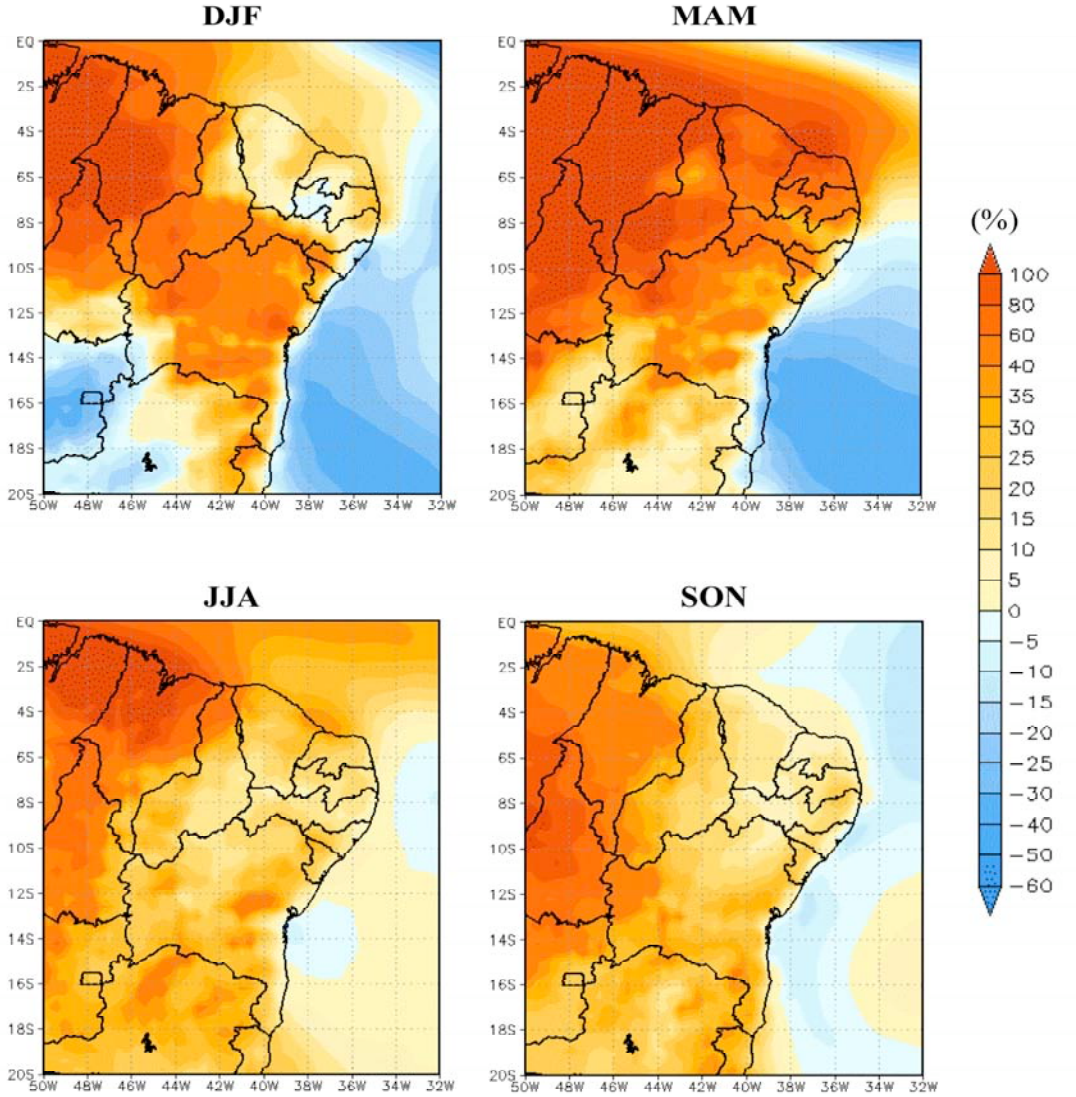
wind power density change in %



(2011-2040) - BASELINE **(2041-2070) - BASELINE** **(2071-2100) - BASELINE**

Northeast

Relative season variation in percentage forecasted for 2070-2100

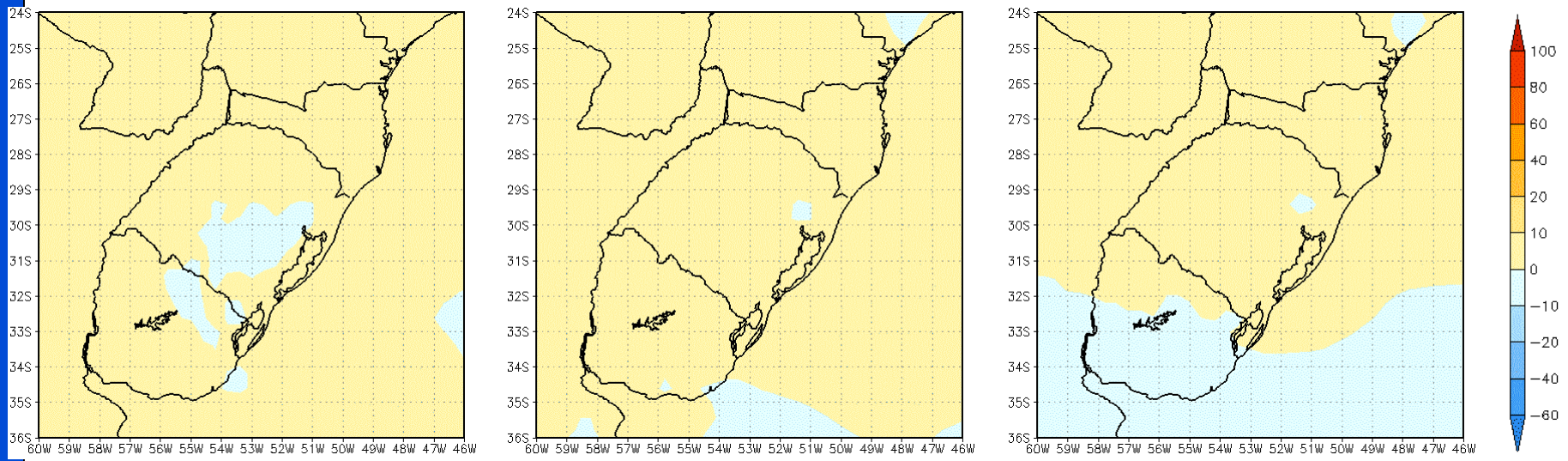


INPE

CST Centro de Ciência do Sistema Terrestre

South Region

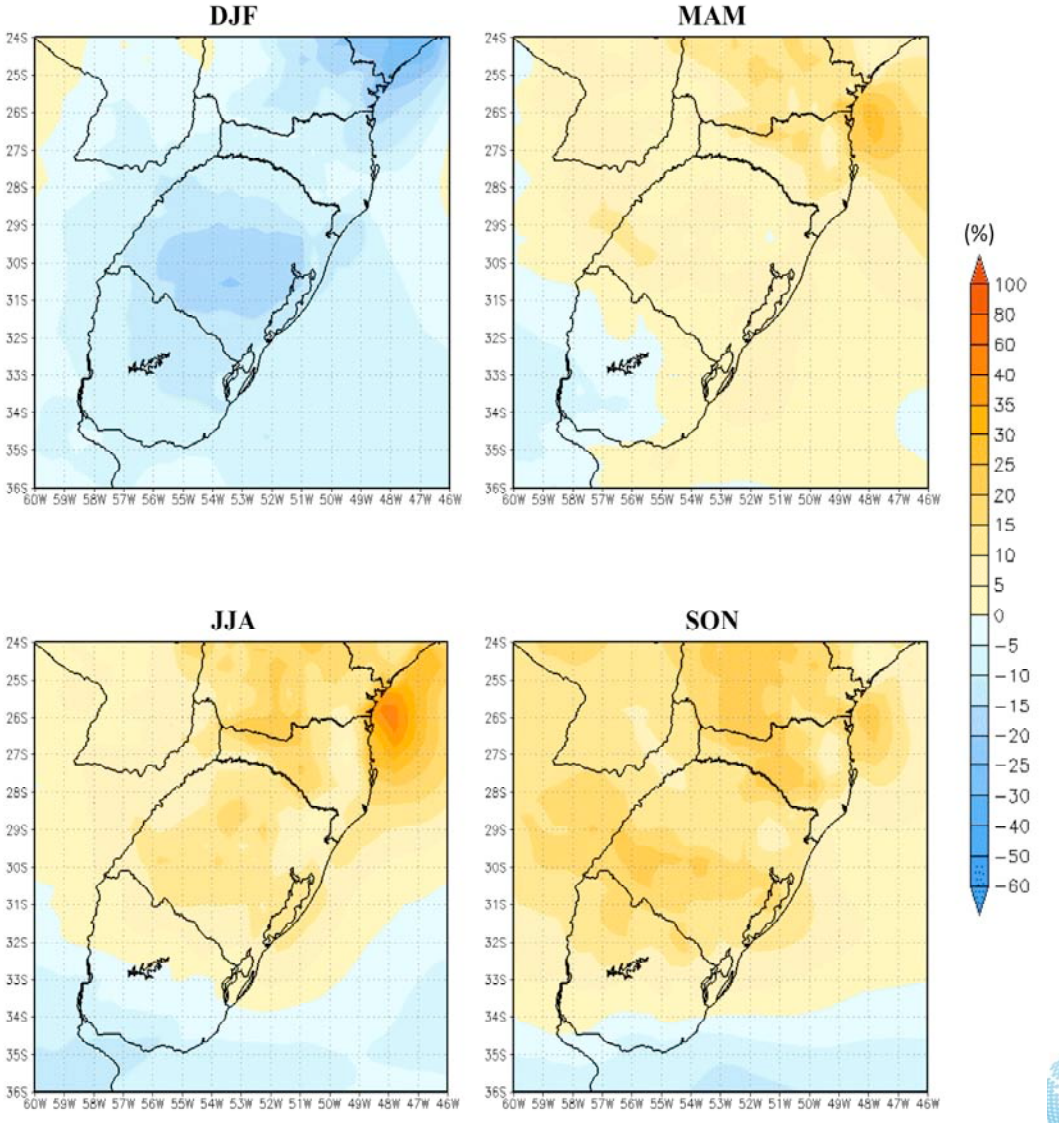
wind power density change in %



(2011-2040) - BASELINE **(2041-2070) - BASELINE** **(2071-2100) - BASELINE**

South Region

Relative season variation in percentage forecasted for 2070-2100



Concluding

- Historical time series form meteorological stations are inadequate for trend studies due to the bad quality of the available data;
- The future climate scenario A1B provided by Eta-HadCM3 models indicate a tendency for an average of 15% to 30% growth in the wind power density for most of the Northeast region of Brazil with regional intensifications of more than 100% in the north sector of this region;
- The South region of Brazil exhibited a mild growing trend for wind power as compared to the Northeast region, about 10%, peaking to more than 20% in some areas;
- The effect of seasons is more pronounced in the South region
- The overall impact of the global climate change on the wind power density in the Northeast and South regions of Brazil might be favourable to the existing and future wind projects in both regions.

CST
Centro de Ciência do Sistema Terrestre

END

Enio B. Pereira
<enio.pereira@inpe.br>

CST
Centro de Ciência
do Sistema Terrestre