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Special Edition

Wind farm: a new module for the BRAMS

“Fazendas de vento”: um novo módulo para o BRAMS

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ABSTRACT

A new module has been developed by the limited area model BRAMS to parameterize a wind farm power plant. BRAMS is developed to be a system for numerical weather prediction, and it is currently employed for operational environmental prediction by the CPTEC/INPE. The new module was able to simulate the impact from a set of wind turbines. The additional drag from turbines changes the turbulent kinetic energy

(TKE). Some simulations were carried out considering wind power plant installed on the Brazilian territory.
Keywords: Wind farm module; BRAMS; Wind turbine; Kinetic energy transfer.

RESUMO

Um novo módulo foi desenvolvido para o modelo BRAMS de área limitada para representar usinas eólicas. O modelo BRAMS foi desenvolvido para ser um sistema de previsão numérica de tempo e é atualmente empregado como o modelo operacional do CPTEC/INPE para previsão ambiental. O novo módulo foi capaz de simular o impacto de um conjunto de turbinas eólicas. O força de arraste adicional das turbinas altera a energia cinética turbulenta (ECT). Simulações foram realizadas com usinas eólicas instaladas no território brasileiro.
Palavras-chave: Usina eólica; BRAMS; Turbina eólica; Tranferência de energia cinética.

1 INTRODUCTION

Nowadays, there is a deep and strong discussion about sustainable forms of power generation. Thermoelectric plants, which burn carbon to produce energy, are under critical view – this is linked to the anthropogenic action associated with global warming. However, there are increasing energy demands by nations. Among the options for sustainable energy generation, the production of electricity by wind generators is a valid option. This energy production source will depend on the average wind speed. Therefore, it is essential to have record for a climatic atlas of wind. Thus, the climatology of the winds will determine the appropriate locations for the installation of wind power plants.

Wind power plants are installed inside the Planetary Boundary Layer (PBL), where turbulence is present. Energy to drive the propellers of the aero-generators is transferred from the Turbulent Kinetic Energy (TKE) within the PBL. A wind farm is structured by a set of turbines. This set of turbines has an impact on the TKE, and the TKE is depend on the wind speed – as already cited. Therefore, for valuating the efficiency of a wind farm, the estimation of TKE in the PBL is necessary. Mesoscale atmospheric models are able to estimate and/or to predict the wind speed, allowing to compute the TKE (FITCH et al., 2012).

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A new module has been developed for the mesoscale model BRAMS to parameterize a wind farm power plant. BRAMS is developed to be a system for numerical weather prediction, and it is currently employed for operational environmental prediction by the CPTEC/INPE (LONGO; FREITAS; AL., 2010). The new module was able to simulate the impact from a set of wind turbines and predicting the total energy generated. The additional drag from turbines changes the turbulent kinetic energy (TKE). Some simulations were carried out considering wind power plant installed on the South of Brazil - Chui and Santa Vitória do Palmar cities..

2 MESOSCALE ATMOSPHERIC MODEL: BRAMS

The BRAMS is the former system employed for the CPTEC (Portuguese acronym for Center for Weather Forecasting and Climate Studies), a division of the INPE (National Institute for Space Research, Brazil), as the operational model for numerical weather forecasting over South America (FREITAS et al., 2017). The prediction system operated with 5 km of horizontal resolution, executed on Cray XE6 massively parallel supercomputer, where the operational forecasting uses 9600 processing cores. BRAMS is also configured as the operational environmental prediction system - the old version of the environmental system was called as CCATT-BRAMS (LONGO; FREITAS; AL., 2010). The development for the BRAMS is a permanent feature (FREITAS; LONGO; AL., 2009; LONGO; FREITAS; AL., 2010; FREITAS et al., 2017).

The BRAMS model was a joint project of several Brazilian institutions, including the CPTEC-INPE, and was initially funded by FINEP (a Brazilian Funding Agency). BRAMS is based on the Regional Atmospheric Modeling System (RAMS), with several new functionalities and parameterizations. BRAMS is a numerical model developed to simulate atmospheric circulations on many scales. It solves the time-split compressible nonhydrostatic equations described by Tripoli and Cotton (TRIPOLI; COTTON, 1982). Physical parameterizations in BRAMS are appropriate for simulating processes such as surface-air exchange, turbulence, convection, radiation and cloud micro-physics (BRAMS-2009). The BRAMS model includes an ensemble version of a deep and shallow cumulus scheme based on the mass flux approach (the GD scheme) (SANTOS et al., 1982; LUZ et al., 2015).

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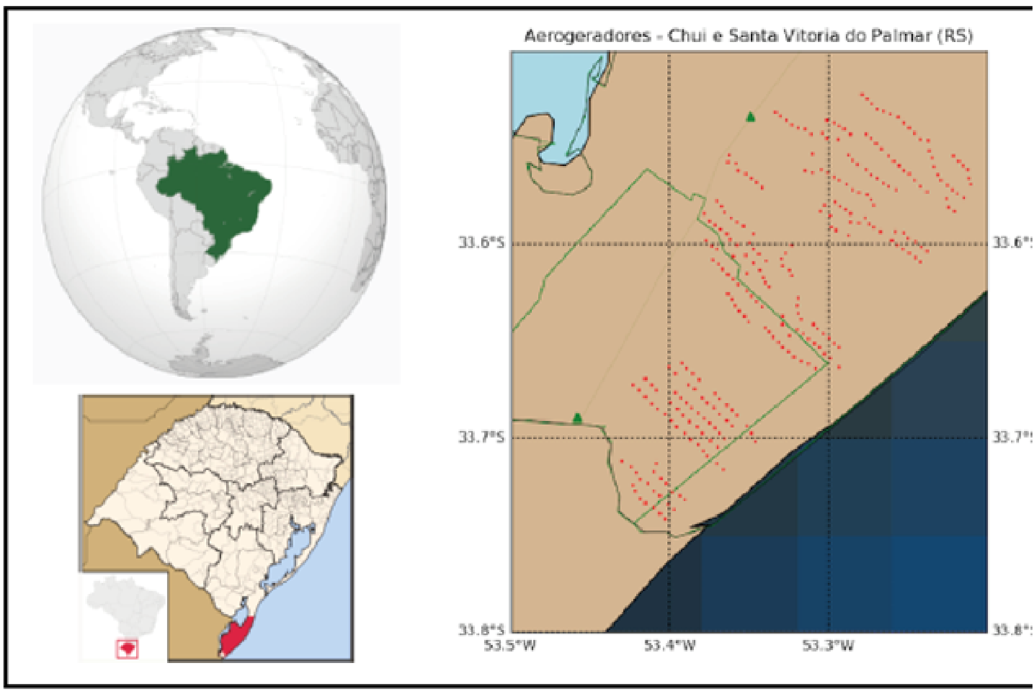
KEYWORDS

Amazon Arduino Biodiversity Contamination Ensino Environmental licensing Extension GeoGebra Geoprocessing Interdisciplinaridade Microorganisms Precipitation Remote sensing Soil moisture Solid waste Sustainability Temperature Thermal comfort Turbulence WRF Water pollution

3 TESTING THE NEW BRAMS MODULE: WIND FARM

As mentioned before, the test for the new BRAMS module was carried out for the wind farm placed in the Santa Vitoria do Palmar and Chui cities – see Figure 1 –, Rio grande do Sul state, Brazil. The Campos Neutrais Wind Complex is a set of three large parks: Geribatu (129 turbines - 258 MW) and Hermenegildo (101 turbines - 181 MW), in Santa Vitória do Palmar, and Chuí (72 - 144 MW), in Chuí - which total 583 megawatts of installed capacity. There are other two wind farms in the Rio Grande do Sul state: Osório city, close to the Atlantic ocean coast, and Santana do Livramento city - far from the Atlantic ocean (approximately 350 km) and at the border of the Uruguay[1].

Figure 1 – Local for the Campos Neutrais Wind Complex: Santa Vitória do Palmar and Chui cities, in the Rio Grande do Sul state, Brazil, and the distribution of eolic turbines



For the simulations, BRAMS was configured with 250 m for horizontal resolution, with the first five vertical levels are: 0 m, 45 m, 90 m, 135 m, and 180 m, after that the standard vertical grid for the BRAMS was applied. The Runge-Kutta third and fifth order methods were employed for vertical and horizontal coordinates, respectively, with Δt = 1 second.

The characteristics from the turbine Wobben E92 were adopted in the simulations. For the BRAMS execution to consider the wind farm module, a new variable must be set-up as WINDFARM = 1 in the RAMSIN file.

BRAMS was executed for the date 07/Oct/2019, with the simulation starting at 00:00, local time. Figure 2a shows the TKE and wind lines without the set of wind turbines for the level z = 22 m with 3h for prediction ahead. Figure 2b is similar plot for the TKE at the level z = 22 m, for the same day and at the same time. Clearly, the wind farm has a significant impact on the TKE, mainly around the turbines.

Figure 2 – TKE field on the computational domain: (a) without wind turbines, (b) with wind turbines

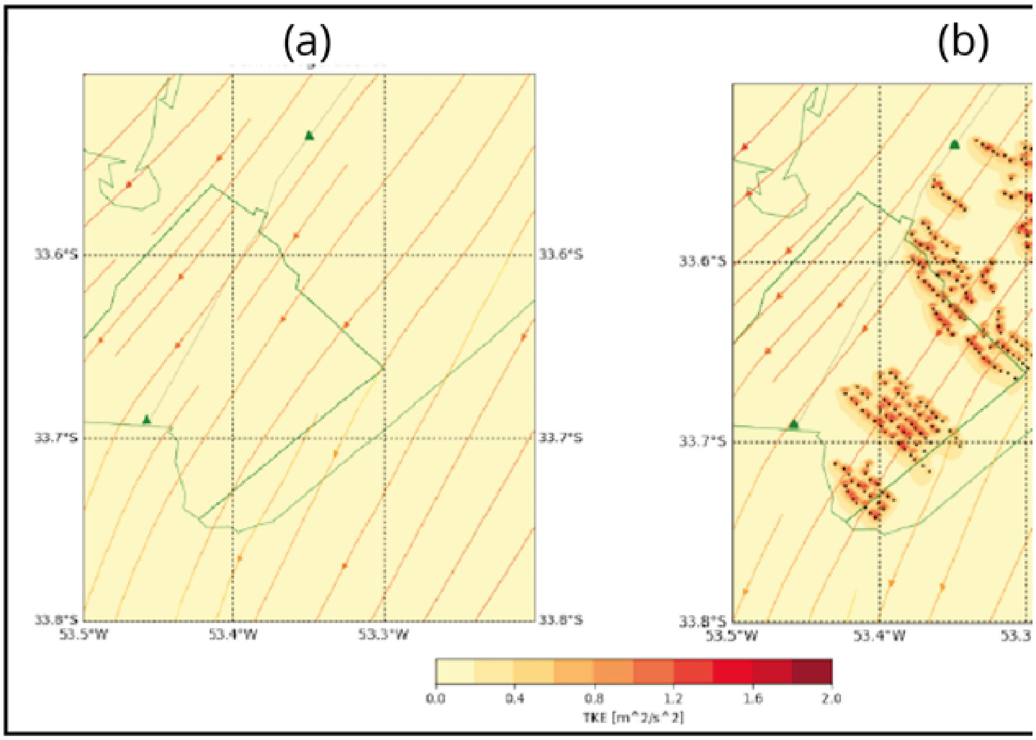


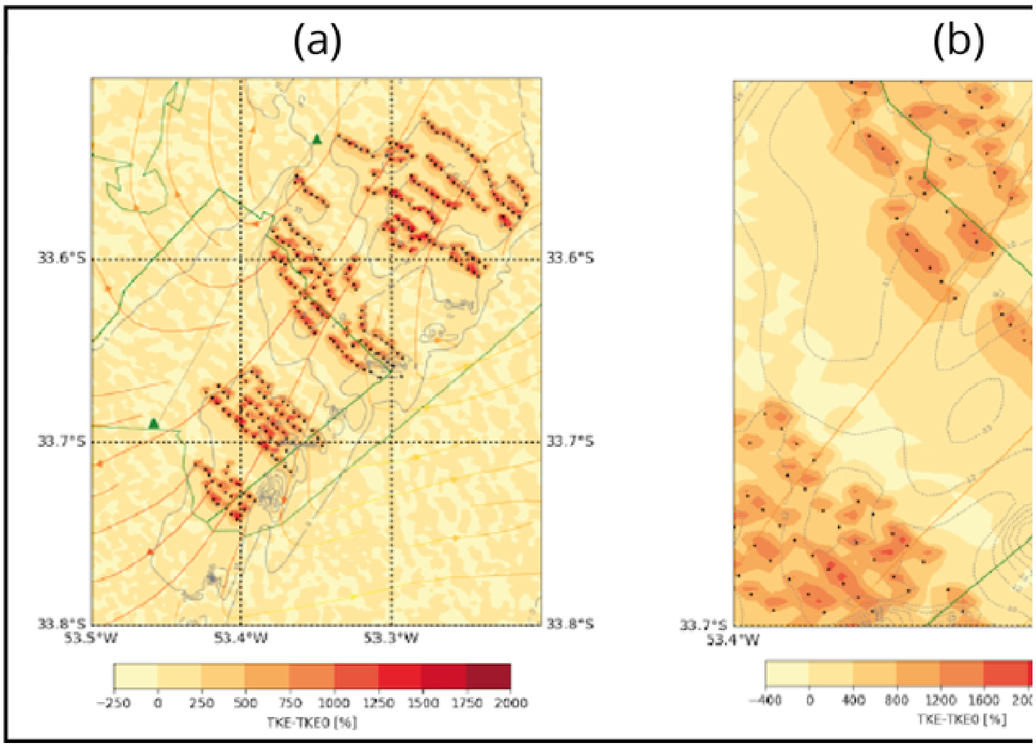
Figure 3a is showing the TKE field with wind turbines, displaying the difference [(TKE - TKE0)/TKE_0]× 100:] – the subscript zero is the field without turbines –, the difference for stream lines: (ψ_h - ψ_0) and the horizontal wind speed difference: [$(u,v)_h$ - $(u,v)_{h,0}$] at level z = 22 m for the same day and same time as Figures 1 and 2. A zoom from Figure 3a is presented in Figure 3b, but considering the level z = 69 m. The zoom is to have better details for the turbine influence, and also to have a better description and/or understanding on the meteorological variable behavior.

4 RESULTS AND DISCUSSION

This paper is focused on showing the execution the BRAMS module for the wind farm. The worked example was carried out for the Campos Neutrais Wind Complex, embracing three wind farms: Geribatu, Hermenegildo, and Chui; placed in the southernmost region of Brazil. Mesoscale models are able to describe atmospheric dynamics with finer resolution than global models, showing a better details for atmospheric dynamics. The results give a good idea about the impact on the TKE under the presence of a wind farm.

Now, BRAMS can be used for weather prediction system, enviromental prediction, and also can be used as a tool for the evaluation of wind farms.

Figure 3 – TKE field with wind turbines (a) – showing the differences: $[(TKE - TKE0)/TKE_0] \times 100]$, stream lines: $(\psi_h - \psi_0)$, and the wind speed: $[(u,v)_h - (u,v)_{h,0}]$; (b) a zoom of the same simulation at level z = 69 m



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[1] The cities Santana do Livramento (Brazil) and Rivera (Uruguay) established a conurbation between the two cities.

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