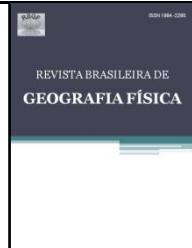




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## Intraseasonal Climate Forecast for the Alcântara Region in Northeastern Brazil

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### ABSTRACT

Global NCEP climate forecast system (CFSv2) was used as initial and boundary conditions for the Regional Climate Model (RegCM4.6) in order to produce intraseasonal forecasts (one month) for Alcântara Launch Center (ALC) in Maranhão State. The forecasts were carried out from June to October 2017 and the wind and air temperature at lower atmosphere were evaluated. For this reason, we used ERA-Interim reanalysis. In the ALC, the RegCM4.6 presented a good performance in representing the monthly means of the variables under study, but in some oceanic regions of the domain, it presented greater deviations.

Keywords: regional climate model (RegCM4.6); dynamical downscaling; CFSv2; Alcântara

## Previsão Climática Intrasazonal para a Região de Alcântara no Nordeste Brasileiro

### RESUMO

As saídas do sistema global de previsão climática do NCEP (CFSv2) foram utilizadas como condições iniciais e de fronteira no Modelo Regional Climático (RegCM4.6) a fim de produzir previsões intrasazonais (um mês) para o Centro de Lançamento de Alcântara (CLA) no estado do Maranhão. As previsões foram realizadas de junho a outubro de 2017 e o vento e a temperatura do ar na baixa atmosfera foram avaliados. Para tanto, foi utilizada a reanálise ERA-Interim. Na região de Alcântara, o RegCM4.6 teve uma boa performance em representar as médias mensais das variáveis em estudo, mas em setores oceânicos do domínio, apresentou maiores desvios.

Palavras-Chaves: modelo climático regional (RegCM4.6); *downscaling* dinâmico; CFSv2; Alcântara

### Introduction

Sub-seasonal to seasonal forecasts are growing rapidly their demands in operational prediction centers in order to fill in the gap between short-range weather and long-range or seasonal forecasts. For improving the skill of this kind of forecast (Robertson et al., 2015; Baggett et al., 2017; White et al., 2017; Vitart, 2017; Ardilouze, et al., 2017; Lin 2018; Batté et al., 2018), the Sub-seasonal to Seasonal (S2S) prediction research project (Brunet, et al., 2010 ; Weber and Mass, 2017 and Vitart et al., 2017) has been established by the World Weather Research Programme/World Climate Research Programme from the European Centre for Medium-Range Weather Forecasts (ECMWF).

S2S can be obtained through Regional Climate Models (RCMs). One regional climate model applied in studies in several globe regions is the Regional Climate Model (RegCM) from the Earth System Physics (ESP) -The International Center for Theoretical Physics (ICTP, Giorgi et al., 2015). RegCM can be initialized by different inputs from global datasets (e.g. reanalyses and model outputs). In this context, the Global NCEP Climate Forecast System (CFSv2), from National Centers for Environmental Prediction (NCEP; Saha, et al., 2014). Regarding the South America climate, there are several studies that employed RegCM: da Rocha, et al., 2012, de Souza, et al., 2014, Reboita, et al., 2017 and Reboita, et al., 2017b. It has been nested in RegCM to provide seasonal forecasts for

Brazil (Reboita et al., 2018), but not yet in operational mode.

S2S forecasts are very important for aerospace practices, such as rocket launching, in that the wind intensity is an atmospheric variable that more affects this activity. Brazil also has this activity in the Alcântara Launch Center, located in Maranhão State. For this reason, it is necessary to develop observational and numerical studies that support the aerospace activities.

Previous studies for ALC performed statistical analyzes from wind obtained in anemometric tower and/or radiosondes and in simulations with the Advanced Weather Research and Forecasting Model (WRF-ARW; Skamarock et al., 2008). Gomes da Silva and Fisch (2014) evaluated the WRF (version 3.2.1) ability in predicting the wind in the ALC, aiming to apply it operationally on rocket launching occasions. In general, the model overestimated the wind components up to  $3.0 \text{ ms}^{-1}$  compared to observations. de Jesus Reuter et al. (2015) used PSU/NCAR mesoscale model (MM5) to evaluate some meteorological parameters in the ALC. The authors observed that the model underestimated the zonal and meridional wind components by around 16% in the rainy season and overestimated them by on average 18% in the dry season. Corrêa et al. (2017) using the IPCC-AR5 scenarios and RegCM4 analyzed the average vertical wind profile, from August to December 2015. It was obtained oscillations from 3 to 5 days in the wind intensity. These results indicated great potential in the simulation of intraseasonal variations, which are important information to rocket launching activities at ALC.

This work aims to analyze five S2S forecasts performed with RegCM version 4.6

nested in CFSv2. These predictions are being carried out and stored, since June 2017, by the Division of Atmospheric Sciences at the Aeronautics and Space Institute (ASI). Unfortunately, they are available only to that department (<http://www.iae.cta.intraer/cfs/>). The main focus here is to analyze the intraseasonal forecasts of the wind.

### Material and methods

CFSv2 forecasts were used as initial and boundary condition to drive RegCM version 4.6 (RegCM4.6; Giorgi et al., 2015). The regional climate model was initialized 30-days before the interest month. For example, to forecast June 2017, the model was initialized in the beginning of May 2017. We used four members of CFSv2 to perform each regional climate forecast. Therefore, the forecast presented in the results are an ensemble.

The simulation domain was configured with  $100 \times 120$  grid points (Figure 1), which is approximately 36 km of horizontal resolution, and the model was integrated with 23 sigma-pressure vertical levels. Table 1 shows a summary of the physical parameterization schemes used in the simulations.

The wind (direction and intensity) at 10 m and the air temperature at 2 m from five forecasts (months June, July, August, September and October 2017) were validated by comparisons with ERA-Interim reanalysis. These data have horizontal resolution of  $0.75^\circ \times 0.75^\circ$ . Moreover, RegCM4.6 forecasts of wind and air temperature were compared with mean values of the surface meteorological station in ALC.

Table 1 Configuration used in RegCM4.6.

Parameter	Value
Lateral boundary conditions scheme	Relaxation, exponential technique
Planetary Boundary Layer (PBL) scheme	Holtslag PBL
Cumulus Convection schemes	
Over land	Grell
Over ocean	Emanuel
Moisture scheme	Explicitmoisture (SUBEX)
Ocean Flux scheme	Zeng
Zeng Ocean model roughness formula to used	$1 \rightarrow (0.0065 * u_{star} * u_{star}) / e_{grav}$
Calendar	Gregorian
Globdatparam ssttyp	CFS01
Globdatparam dattyp	CFS01
Land surface model	Biosphere-Atmosphere Transfer scheme (BATS)

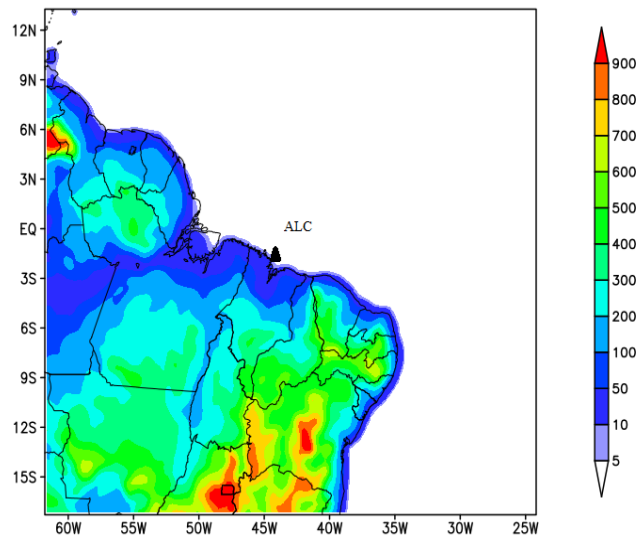


Figure 1. Topography (meters) and domain used in the RegCM4.6 simulations. The geographical location of the ALC is marked with a black dot.

**Results**

Figures 2 and 3 show the monthly averages, for each month from June to October, of the wind intensity in the domain presented in Figure 1, from simulation and reanalyses. Both datasets show a deceleration of the wind intensity monthly average between the ocean and the continent, with the intensity changing from  $7 \text{ m s}^{-1}$  over the sea to  $2 \text{ m s}^{-1}$  over the land. This allows us to conclude that the

RegCM4.6 has a good dynamic performance. The model has a difference of  $\sim 1 \text{ m s}^{-1}$  over the ALC when compared with ERA-Interim (Figure 4), while in the Tropical North Atlantic the deviations are higher ( $\sim 3 \text{ m s}^{-1}$ ).

Regarding wind direction, Figure 5 shows that RegCM4.6 has a systematic drift of anti-clockwise direction of approximately 30 to 60 degrees compared to ERA-Interim (Figure 6).

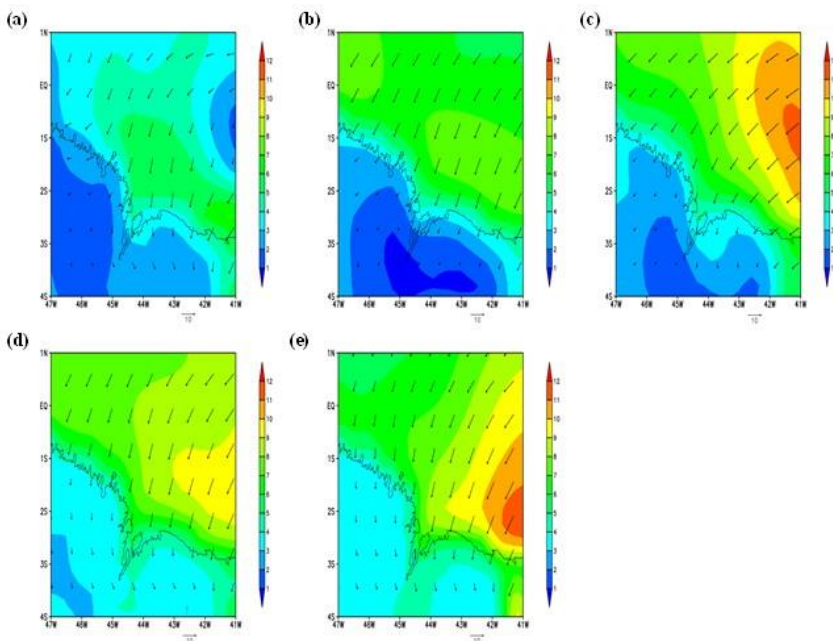


Figure 2. Monthly average of the wind intensity (meters per second) and direction (arrows) simulated by RegCM4.6 in June (a), July (b), August (c), September (d) and October (e) of the 2017-year.

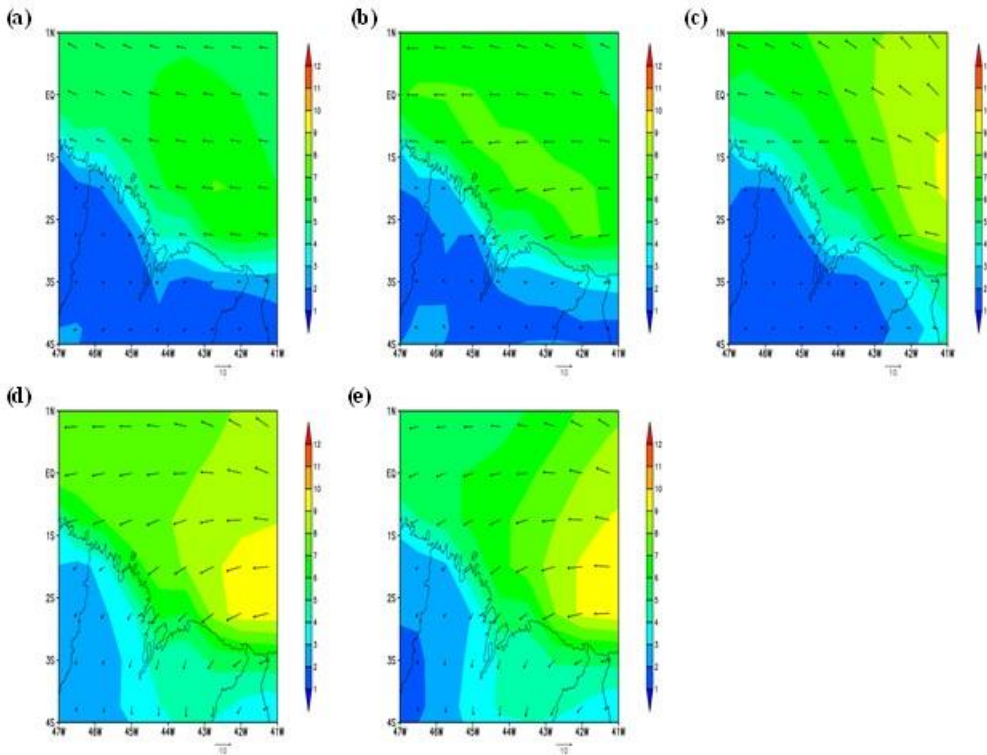


Figure 3. Similar to Figure 2, but to ERA-Interim reanalysis.

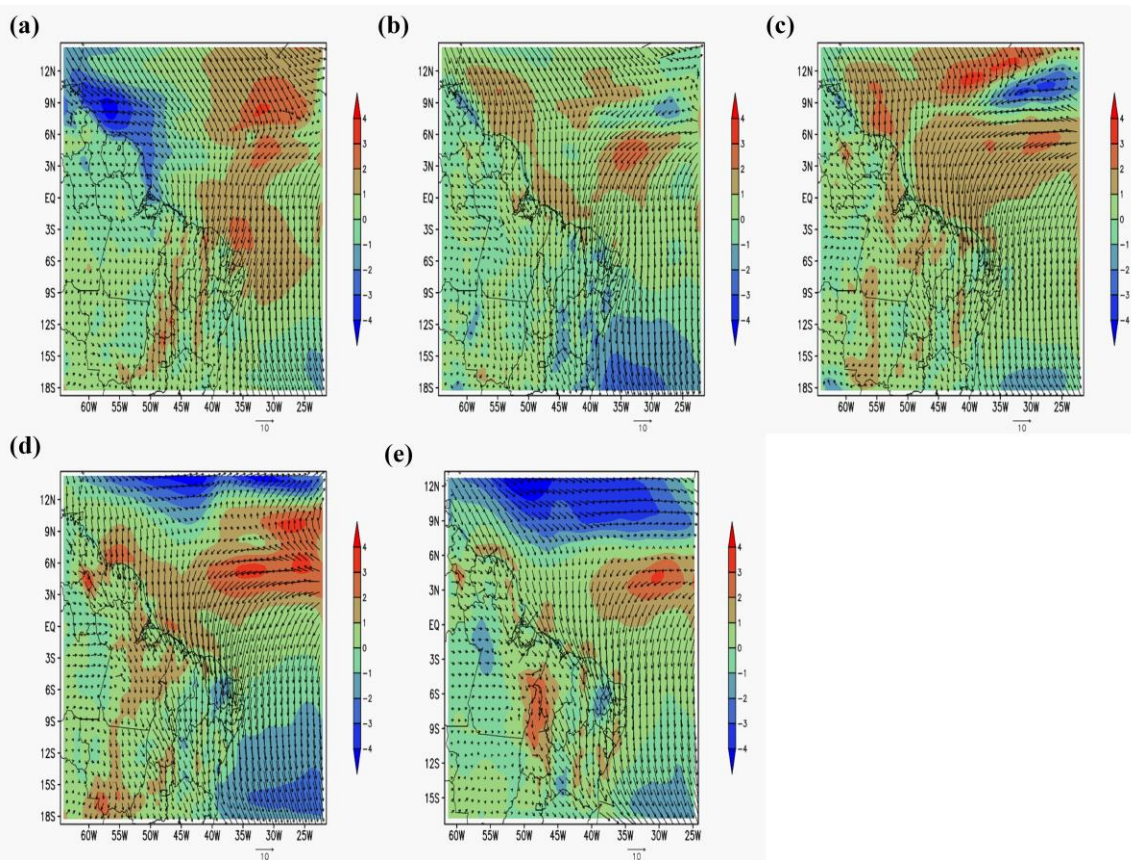


Figure 4. Difference between the monthly mean of the wind intensity (m/s, color) simulated by RegCM4.6 and ERA-Interim for the months of June (a), July (b), August (c), September (d) and October (e) in 2017. Arrows indicate the difference in the wind direction.

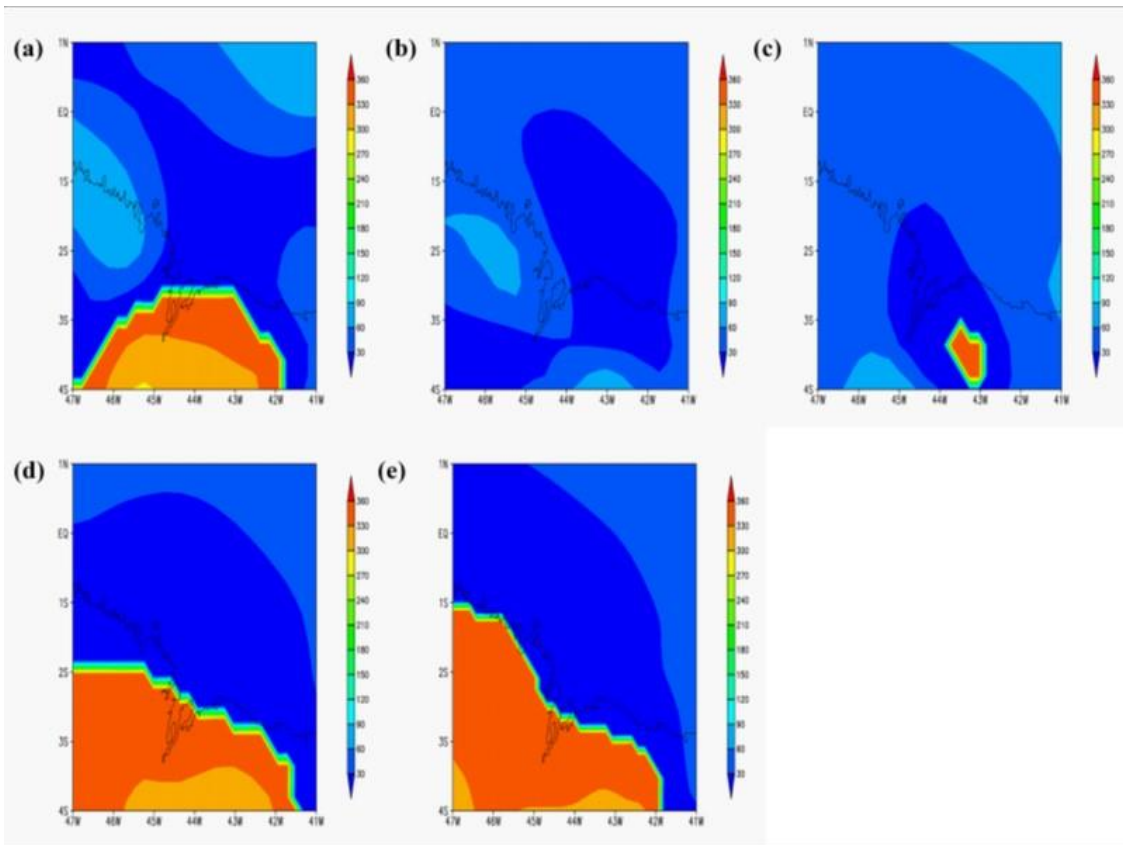


Figure 5. Monthly average of the wind direction (degrees, color) simulated by RegCM4.6 in June (a), July (b), August (c), September (d) and October (e) of the 2017-year.

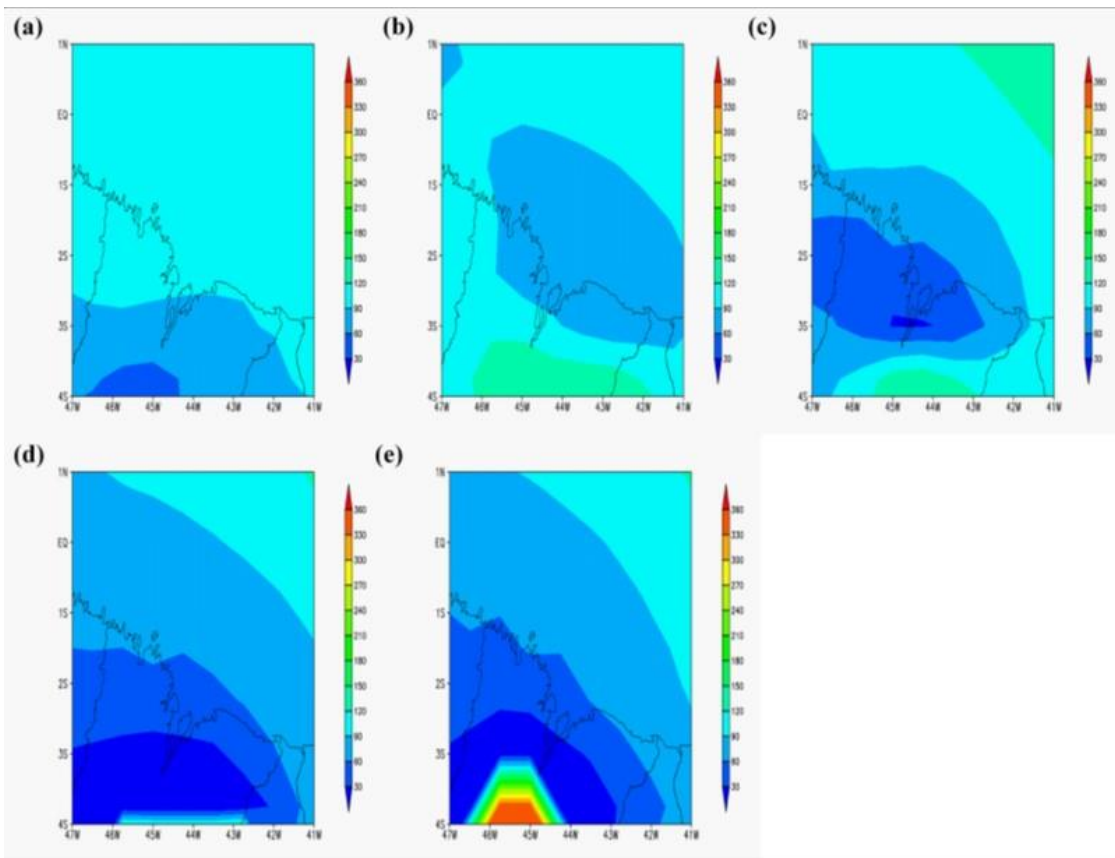


Figure 6. Similar to Figure 5, but to ERA-Interim reanalysis.

Figure 7 shows the difference between the air temperature simulated and that from ERA-Interim. In general, in the center-east of the continent the model underestimates the air temperature, while in the other parts including the ocean, it overestimates. Over ALC, it is registered a bias of 1 to 3 °C. June presented the smallest differences between the datasets.

Table 2 shows some comparisons of the RegCM4.6 forecasts with measured data in a meteorological station in ALC. Regarding the mean wind direction, RegCM4.6 simulated the wind with an anti-clockwise deviation from 20 to 50 degrees, and it agrees with the differences

obtained between the model and ERA-Interim (Figures 5 and 6).

While in ALC, RegCM4.6 has small differences compared with ERA-Interim, it is higher compared with the measured data in the meteorological station: an overestimate of 2 to 3  $\text{ms}^{-1}$ , the height in relation to sea level the ALC surface meteorological station is 49 meters and the wind intensity data is 10 meters high. For air temperature, RegCM4.6 presents a systematic underestimation of 1°C in relation to the observed values at the meteorological station.

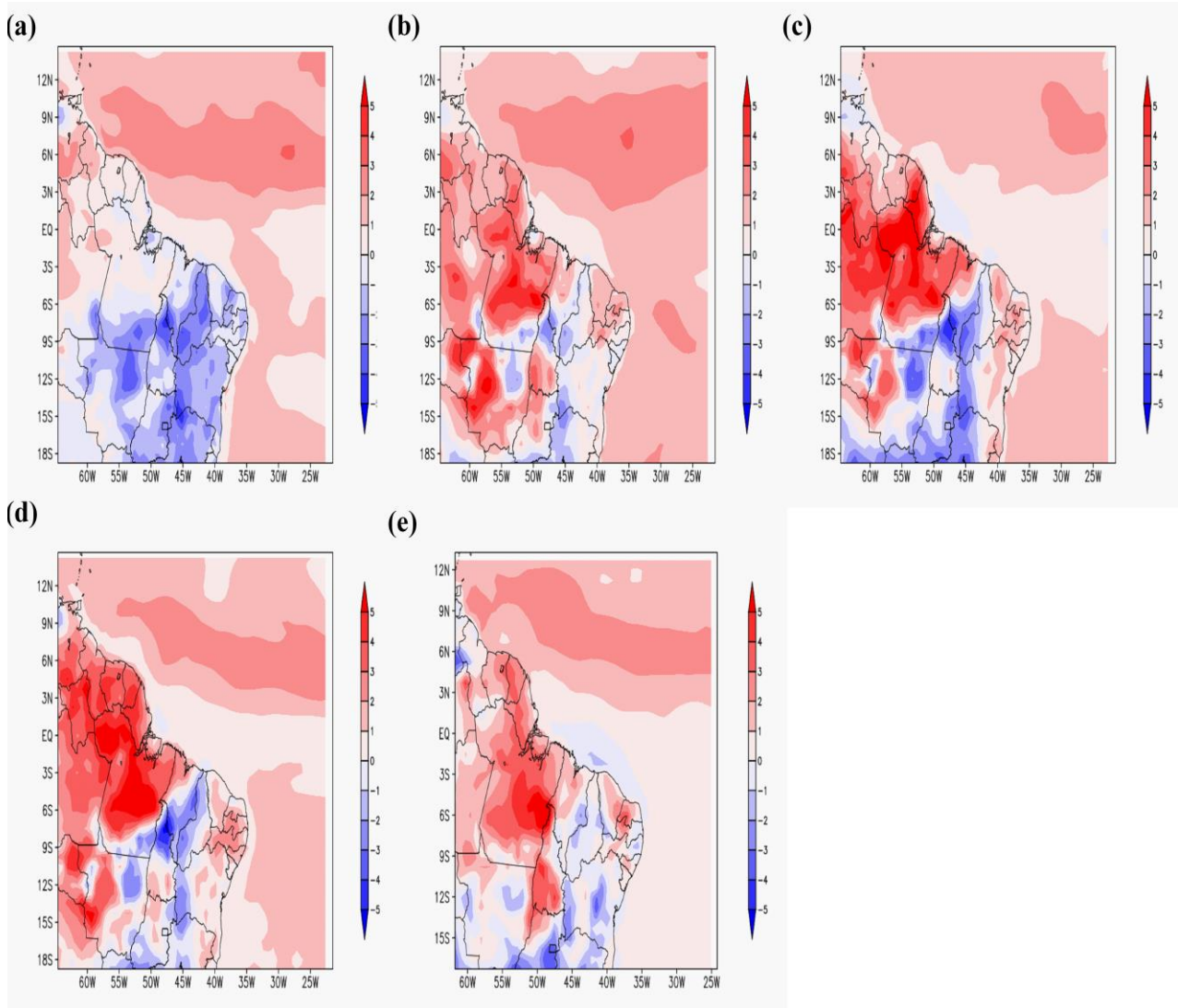


Figure 7. Difference between the monthly mean of the air temperature at 2 m (°C) simulated by RegCM4.6 and ERA-Interim for the months of June (a), July (b), August (c), September (d) and October (e) in 2017.

Table 2 Monthly average of the wind intensity and direction at 10 meters high and air temperature at 2 meters obtained from ALC surface meteorological station and RegCM4.6. S.D. means Standard Deviation.

Month	June	July	August	September	October
<b>Surface observation</b>					
Wind Direction (°)	73.4	48	59.4	63.3	65.2
Wind Direction S.D. (°)	30.5	23.9	34.3	31	21.1
Wind Intensity (m s <sup>-1</sup> )	2.7	2.2	3.2	3.7	3.7
Wind Inten. S.D. (m s <sup>-1</sup> )	1.1	1.3	1.4	1.3	1.3
Temperature (°C)	29.4	28.5	29	29.7	28.6
Temperature S.D. (°C)	1.3	1.6	2.4	1.4	1.7
<b>RegCM4.6</b>					
Wind Direction (°)	37.9	25.3	12.4	11.0	7.7
Wind Direction S.D. (°)	27.98	32.58	22.8	19.4	11.7
Wind Intensity (m s <sup>-1</sup> )	5.1	5.4	6.4	6.9	7.7
Wind Inten. S.D. (m s <sup>-1</sup> )	1.4	1.8	1.5	1.5	0.8
Temperature (°C)	28.0	27.8	27.4	27.5	26.8
Temperature S.D. (°C)	0.5	0.6	0.6	0.6	0.2

### Conclusions

Since June 2017 the Division of Atmospheric Sciences at the Aeronautics and Space Institute (ASI) has been produced S2S forecasts in operational mode for its internal use. For this reason, RegCM4.6 is nested in CFSv2 outputs. In this context, the goal of this work was to validate five forecasts performed in 2017. We focused on the wind once it is the most important variable to rocket launching. In terms of monthly averages, RegCM4.6 represented the main features of the lower-levels atmospheric circulation. The model presented a good performance in ALC in terms of wind intensity and direction and it is a important result once the model can be used to plan rocket launching.

### Acknowledgment

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