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Intraseasonal climate forecast of iba tropical cyclone in northeast Brazil using the regional climate model - a case study

Cleber Souza Corrêa[I], Gerson Luiz Camillo[II]

ABSTRACT

This study aimed to analyze the operationally stored simulations of the RegCM4.7 model using simulations performed by the National Center for Environmental Prediction (NCEP) coupled forecast system model version 2 (CFSv2) in downscaling. The South American domain, however, seeks to observe prevailing weather systems that may affect the Alcântara Rocket Launch Center in Maranhão. One case is analyzed with three different global initializations of the CFSv2 model. On March 25, 2019, the occurrence of Cyclone Iba on the southern coast of Bahia. The RegCM4.7 Regional Model was able to simulate tropical cyclone three months in advance. This performance is very important because the influence of these anomalous systems affect wind intensity and rainfall behavior in the Alcântara region because it would affect the convective processes on the continent in northeastern Brazil.

Keywords: Intraseasonal Climate Forecast; Regional Climate Model; Tropical Cyclone

1 INTRODUCTION

This case study sought to observe the simulation analysis of the Regional Climate Model (RegCM4.7) in use in the Atmospheric Sciences Division of the Institute of Aeronautics and Space (IAE). In which simulations are stored for monitoring and intraseasonal forecasting of the Alcântara Launch Center. In the operational activities of the Atmospheric Sciences Division, Corrêa, *et al,* 2017, was used the climate modeling (RegCM4 Climate Model) to provide a wind forecast average behavior at low levels, close to the surface. The model had used to generate an estimate of the average vertical wind profile lasting 5 months, from August to December 2015, attempting to observe intraseasonal variations, with the presence of persistence in the wind field. The results of climate modeling of the wind profile near the surface have the great potential for great operational significance during launch campaigns at

[I] Instituto de Aeronáutica e Espaço (IAE), Brasil- cleber.voy@gmail.com

[II] Instituto de Aeronáutica e Espaço (IAE), Brasil- gerson.camillo@gmail.com

the Centro de Lançamento de Alcântara. In the work's Corrêa *et al.,* 2019 using simulations performed by the CFSv2 / RegCM-4.6 model, which could be observed the information of the surface wind intensity through the analysis and comparison of the simulations performed in the Alcântara region, on the coast of Maranhão. These simulations were stored from February to June 2018. In their analysis, they sought to validate with ERA5 reanalysis data from the European Center for Medium-Range Weather Forecasts (ECMWF). The observed result showed great potential for the use of set prediction techniques since in the observed results the smallest anomalies were observed in the intraseasonal set prediction for the Alcântara region in wind intensity, compared to the simulation without being combined, which presented greater deviations. Ensemble's intraseasonal estimate eventually filtered out the high-frequency terms, being the best estimate and presenting the most balanced intraseasonal forecasts. Aiming to analyze the capacity of the RegCM4.7 model to observe mesoscale structures for the continental scale, it sought to use its results in the recognition of tropical cyclones in the northeast region of Brazil.

Kuo, 1965, described in his work that in observational studies show that tropical cyclones always originate from some large-scale pre-existing disturbance such as equatorial and easterly waves, noted that the formation and intensification of tropical cyclones occur by latent heat release of cumulus convection. Gray, 1998 showed that climatology presents different aspects of frequency and tropical seasonal characteristics in the formation of product-related cyclones of six parameters. It has: the Coriolis parameter, the low-level relative vorticity, the inverse vertical shear of the tropospheric wind, the thermal energy of the ocean, manifested as ocean temperatures over 26 centigrade and a depth of 60 meters, the difference in potential equivalent temperature between the surface and 500 hPa, and the relative humidity content of the half troposphere. In Emanuel's work (1986), derived a maximum potential intensity (MPI) that a Tropical Cyclone could achieve, its variability associated with the underlying sea surface temperature (SST) and the thermodynamic conditions of the atmospheric pressure environment. By this theory, a Tropical Cyclone is considered Carnot's ideal heat engine and can gain energy from the imbalance between the boundary layer atmosphere and the ocean surface and energy loss in the upper-level output layer. This air theory of the maritime interaction of the intensity of Tropical Cyclone later elaborated by Emanuel (1988, 1991, 1995). With a different approach, Holland, 1997 also described a theoretical MPI, which is determined solely by the thermodynamic conditions of the ocean and the atmospheric environment. The occurrence of tropical cyclones characterizes a spatial scale on the very strong (sub-synoptic) cyclone and these systems are associated with a very baroclinic atmospheric structure, Diniz & Kousky, 2004, Dias Pinto *et al*, 2013 and Reboita *et al*, 2017. Wang *et al.*, 2019 in their work, performed idealized simulations being conducted using Cloud Model version 1 (CM1) to explore the mechanism of tropical cyclone genesis from a pre-existing mid-tropospheric vortex that forms in convective-radiative equilibrium. With lower tropospheric air approaching near saturation during the genesis of Tropical Cyclone, convective cells become stronger, along with intensities of drafts and drafts and a larger coverage area of drafts relative to drafts. Consequently, the low-level vertical mass flow increases, inducing amplification of vorticity above the boundary layer, analyzing other physical and dynamic aspects that would influence the formation and intensification of a tropical cyclone.The formation of a tropical cyclone is very complex and may be associated with different baroclinic mechanisms. Sharmila & Walsh, 2018, showed in recent research indicates that the average annual location of tropical cyclones migrated to higher latitudes, using observational and reanalysis data, investigated how large-scale dynamic effects, combined with coherent changes in Hadley's regional circulation, explain recent changes in the regional genesis of the tropical cyclones between 1980 and 2014. They showed that the recent higher-level anomalous weakening of the growing branch of Hadley's circulation in the deep tropics, possibly induced by increased vertical stability, probably suppressed the low-latitude tropical cyclone genesis in most oceanic basins via anomalous subsidence on a large scale. The variations of the Hadley regional circulation also favored a change of climate favorable position to tropical cyclones by changing its extension towards the poleward shift of its meridional circulation. With projections indicating continued tropical expansion, these results indicate that the genesis of the tropical cyclone will also continue to shift to the opposite side, potentially increasing tropical cyclone-related risks in higher latitude regions. On the coast of Brazil have been observed the occurrence of cyclones in 2004 as the existence cyclone Catarina with hybrid characteristics; however on March 11, 2010, it was found in the South Atlantic, near the Brazilian coast the second tropical cyclone Anita. However, on March 25, 2019, tropical cyclone Iba occurred on the southern coast of the Bahia state. This situation shows a low frequency of occurrence of these types of tropical cyclones. However, the RegCM4.7 regional climate model would be able to represent such characteristics associated with tropical cyclones, and being initialized with global data from the global by the National Center for Environmental Prediction (NCEP) coupled forecast system model version 2 (CFSv2), would have the technical capacity to generate intraseasonal forecasts for periods of the order of two to five months. In which its use would be of great operational utility due to changes in the continental level of modulating cloudiness, rainfall, and the near-surface wind, in the northeast region of Brazil.

2. METHODOLOGY

This work adopted the CFSv2 as the initial and boundary condition from RegCM4.7 (Giorgi *et al*., 2015). The domain of the simulations carried out here was configured to have 212 x 222 grid points, with 23 sigma-pressure vertical levels and 36 km of horizontal resolution. In RegCM4.7 the surface processes can be solved through Surface-Atmosphere Processes scheme: The Community Land Model (CLM) model version 4.5 (Oleson *et al.* 2008 and Oleson *et al.* 2010). Table 1 shows a summary of the parameterization schemes defined in the *regcm.in* file.

Table 1 Parameters used in Physics *paramnamelist* (regcm.in) in RegCM4.7 model

Parameter	Value
Lateral boundary conditions scheme	Relaxation, exponential technique,

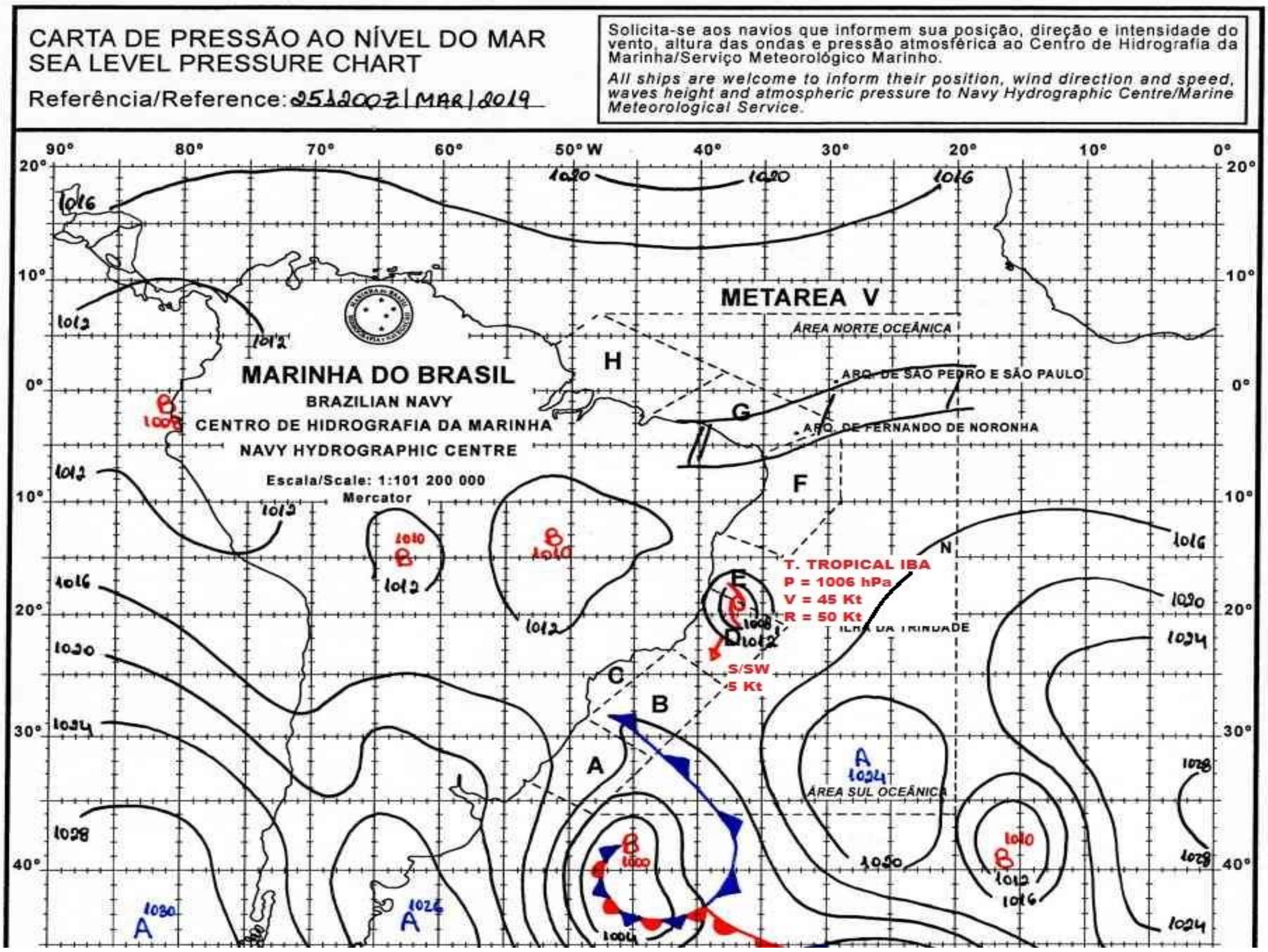
	Marbaix et al. (2003)
Planetary Boundary Layer (PBL) scheme	Holtslag PBL, Holtslag (1990)
Cumulus Convection schemes	
Over land	Kain & Fritsch, (1990) and Kain (2004)
Over ocean	Kain & Fritsch, (1990) and Kain (2004)
Moisture scheme	Explicit moisture (SUBEX, Pal et al, 2000)
Ocean Flux scheme	Zeng et al. (1998)
Zeng Ocean model roughness formula to used	1-> (0.0065*ustar*ustar)/egrav
Calendar	Gregorian
Globdatparam ssttyp	CFS01
Globdatparam dattyp	CFS01

Simulations were performed every 15 days in the case of Cyclone Iba. However, were analyzed simulations of January 01, 2019, January 15, 2019, and February 1, 2019, which generated figures in GRADS of three in three hours. These figures are qualitatively compared with the pressure charts on the surface of the Brazilian Navy hydrography service.

3. RESULTS AND DISCUSSION

The case of analysis took place on March 25, 2019, the tropical cyclone Iba, in the sea level pressure chart from the Brazilian Navy service presents the location of tropical cyclone Iba. The Navy Hydrographic Service maintained the symbolism of Cyclone Iba in its pressure surface chart until March 28, 2019, weakening its intensity.

Figure 1 - shows the sea level pressure chart on the surface with the tropical cyclone symbology on the southern coast of Bahia, chart from March 25, 2019, to 1200Z

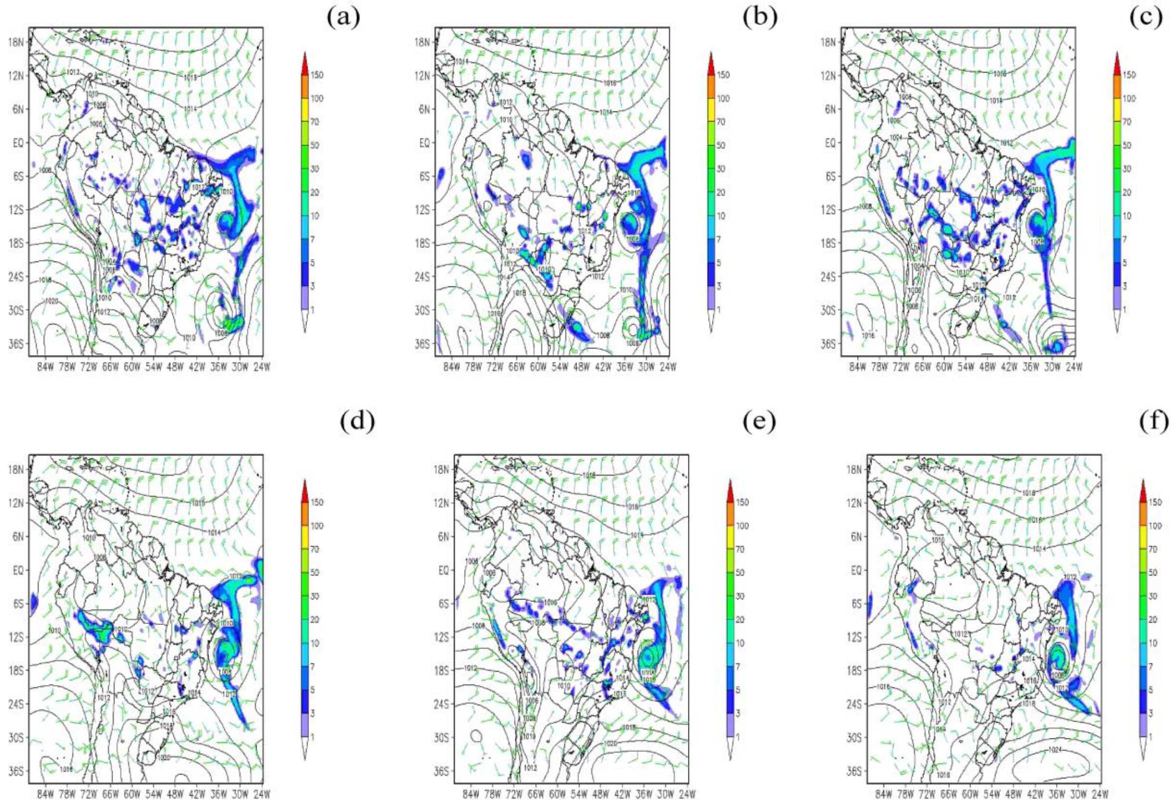


Source: https://www.marinha.mil.br/chm/dados-do-smm-cartas-sinoticas/cartas-sinoticas

Figure 2 presents the simulations RegCm4.7/CFSv2 every 12 hours that characterize the existence of tropical cyclone Iba. 2- (a) from March 25, 2019 to 1200Z, (b) March 26, 2019 to 0000Z (c) to 1200Z, (d) March 27, 2019 to 0000Z, (e) to 1200Z and (f) March 28, 2019 to 0000Z. These simulations CFSv2 were performed on January 1, 2019, when the existence of Cyclone Iba, three months in advance, has already appeared. The model was able to represent this baroclinic system with high spatial resolution. Figure 1 with the sea level pressure chart of the Brazilian Navy shows the main meteorological systems operating in the Brazilian coast, compared to the simulation performed on January 1, 2019, the RegCM4.7 model was very correct in simulating the main such as cyclone Iba and an extratropical cyclone off the coast of Rio Grande do Sul state. Figure 2 - (a) shows a great similarity between what is observed and what is predicted by the regional climate model. The historical description of the baroclinic process was that the low-pressure system shifted from the Inter-tropical Convergence Zone (ITCZ) to higher latitudes and also showed a certain degree of association with the passage of an extra-tropical system at 30 degrees latitude, creating the baroclinic conditions necessary for the appearance of cyclone Iba.

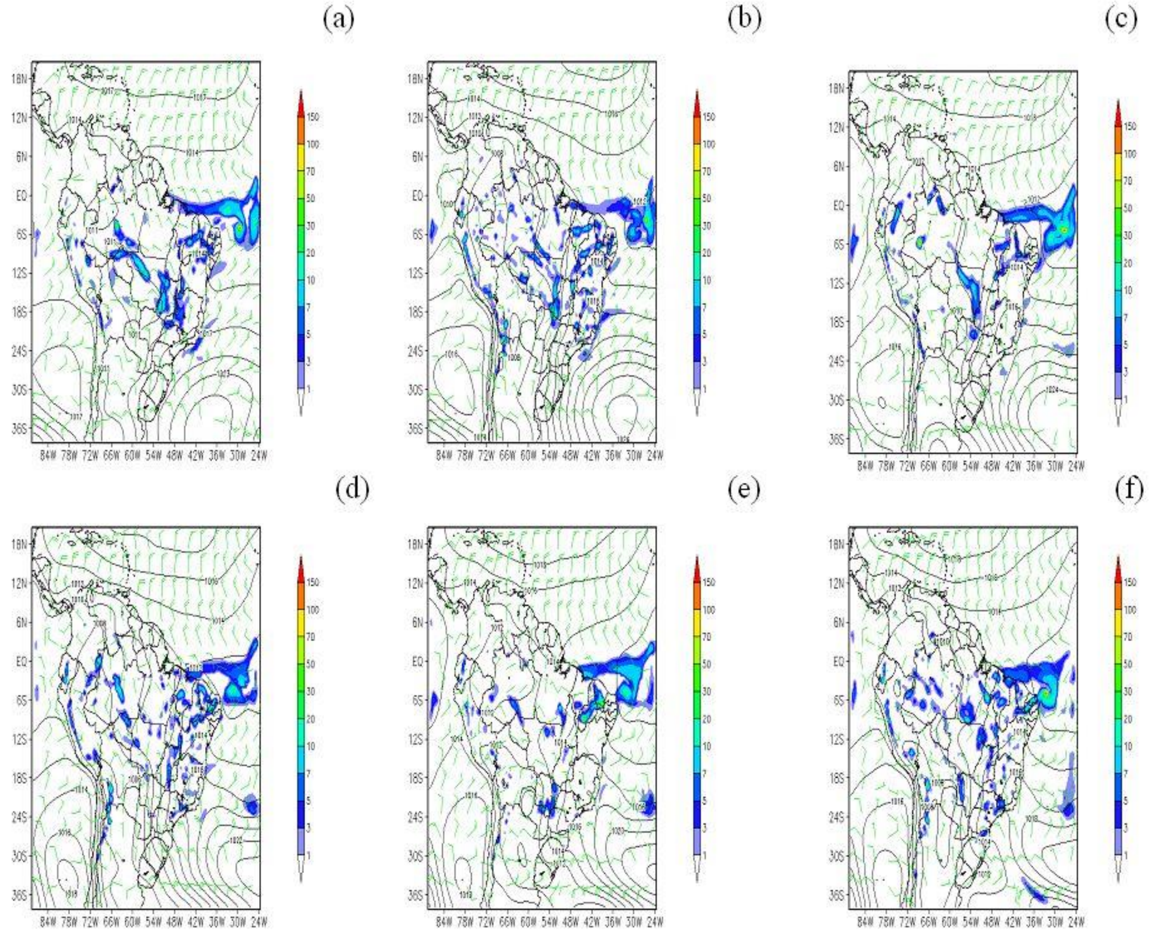
In Figures 3 and 4 analyzing the different simulations with a time difference of 15 days. However, the simulations observed in figures 3 and 4 did not present a similar result to the simulation of January 01, which represented to a high degree the systems observed from March 25 to 28, 2019. The simulations showed that there was a certain synchronism between the formation of convective systems in the northeast coast, tropical cyclones and the passage of a subtropical cyclonic vortex at the latitude of the order of 30 degrees, which helped in the process of baroclinic instability at lower latitude, it helps to create the conditions of instability for convection.

Figure 2 - Simulation conducted on January 1, 2019, of the RegCM4.7 / CFSv2 model for the period 25-28 March 2019, which shows the existence of a cyclone (Cyclone Iba) in the south of Bahia in the northeast of Brazil. - (a) March 25, 2019 to 1200Z, (b) March 26, 2019 to 0000Z, (c) to 1200Z, (d) March 27, 2019 to 0000Z, (e) to 1200Z, (f) March 28, 2019 to 0000Z. Showing rainfall in millimeters, wind in kts and surface pressure in hPa.



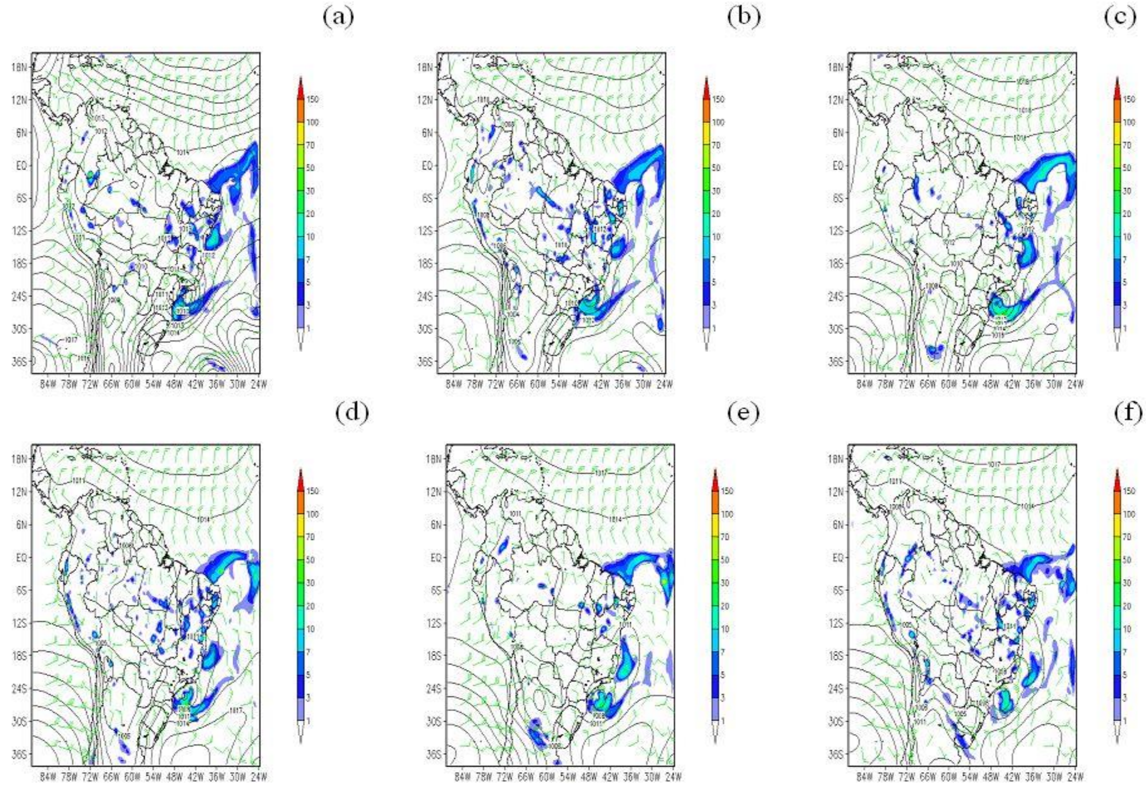
Fonte: acervo pessoal dos autores

Figure 3 - Simulation conducted on January 15, 2019, of the RegCM4.7 / CFSv2 model for the period 25-28Mach 2019, which shows the existence of a cyclone in the south of Bahia in the northeast of Brazil. - (a) March25, 2019 to 1200Z, (b) March26, 2019 to 0000Z, (c) to 1200Z, (d) March27, 2019 to 0000Z, (e) to 1200Z, and (f) March28, 2019 to 0000Z. Showing rainfall in millimeters, wind in kts and surface pressure in hPa.



Fonte: acervo pessoal dos autores

Figure 4 - Simulation conducted on February01, 2019, of the RegCM4.7 / CFSv2 model for the period 10-13 December 2019, which shows the existence of a cyclone in the south of Bahia in the northeast of Brazil. - (a) March25, 2019 to 1200Z, (b) March26, 2019 to 0000Z, (c) to 1200Z, (d) March 27, 2019 to 0000Z, (e) to 1200Z and (f) March 28, 2019 to 0000Z. Showing rainfall in millimeters, wind in kts and surface pressure in hPa.



Fonte: acervo pessoal dos autores

4. CONCLUSIONS

The observed results are important because Iba tropical cyclone was observed during the year of 2019, using a regional climate model. This has a low frequency of occurrence. The case study in this paper sought to record the occurrence of these phenomena and the ability of the RegCM4.7 model to simulate this situation at the intraseasonal forecast level, with a three-month antecedence. Other physical aspects will be studied of large-scale planetary turbulence associated with Hadley circulation, as their variations of Hadley regional circulation could be favorable for a change of climate position for tropical cyclones, changing their meridional extent, as well as the increase in the sea surface temperature value in the Atlantic Ocean of the coast of Brazil. Also, other low-frequency aspects, which may be associated with solar activity and the planet's orbit dynamics, their axis movements, and terrestrial orbit variability, have a time scale of 70 years or more. Which can modulate and delimit multi-decadal oscillations? Using the RegCM4.7 model allows important information to be generated at the strategic planning level for planning operations at the Alcântara rocket launch center.

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