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Tropical cyclogenesis response to solar activity in the eastern Pacific region

Marni Pazos, Blanca Mendoza, and Luis Gimeno

***Abstract*—The relationship between tropical cyclogenesis and solar activity is addressed in this paper, analyzing the relationship between important parameters in the evolution of tropical cyclones as the CAPE, wind shear and relative vorticity, and the Dst geomagnetic index as a parameter of solar activity. The apparent relationship between all this phenomena has a different response depending on the phase of the solar cycles.**

***Keywords*—tropical cyclones, solar-earth relationship, climate change.**

I. Introduction

THE concern in the scientific community about the better understanding of the tropical cyclones is an important issue nowadays. Followed by drowns, tropical cyclones are the main cause of losses by natural phenomena in the world, resulting in deaths and damages mainly in developing countries, and the population increase, raises the vulnerability [1]; [2]. Such concern leads to try to understand the behavior of the tropical cyclones in a climate change background, whatever being the forcing: natural or anthropogenic. The hurricane season in 2005 in the Atlantic Ocean was remarkable, and such intense activity in tropical cyclones was attributed to the climate change [3].

Recent models attempt to provide the trend in tropical cyclones activity to evaluate the impact of climate change on them. Most of this models are focused on the intensity, but such models are not reliable enough as they do not simulate observed high intensity tropical cyclones and their results are still controversial, even though most of the models with higher resolution shows an increase of in the tropical cyclones number with greenhouse warming [4], [5], [6].

In this paper we focus on solar activity as one of the natural causes of the climate change, motivated by the AR 2007 of the IPCC, where the level of scientific understanding of the solar activity as a radiative forcing in the atmosphere is rated as ”low” [7]. There are many studies with global data and large-scale phenomena and its relationship with solar activity. Respect to tropical cyclones, many studies suggest that the solar activity might be acting as modulator (e. g. [8]; [9]; [10]). Hodges and Elsner (2010)[8] suggest that the total solar radiation could be affecting the tropical cyclone genesis through its effect in the sea surface temperature. In particular, Mendoza and Pazos (2009)[10] found that there is a statistically significant correlation, depending on the solar cycle phase, between the hurricanes occurrence in the Atlantic and Eastern Pacific basins and the 11 years solar cycle, in particular with the Dst geomagnetic index, which is a measure of the geomagnetic field disturbances in low latitudes. Here, we aim to find a possible mechanism where the Dst could be affecting not only the hurricanes, but all the tropical cyclones activity in general. Also, we focus only in the Eastern Pacific basin since there is less research in this area compared with other basins.

A. Data and Metodology

The approach to such a mechanism, will be considering the environmental conditions involved in the tropical cyclogenesis. According to Gray (1968)[11] there are six necessary conditions for the cyclogenesis:1) Sea surface temperature above to 26 °C in 60 m depth; 2) A raise in the relative moisture in the mid-troposphere; 3) Conditional instability; 4) Raise in the relative vorticity; 5) Weak vertical wind shear; 6) The pre-existing perturbation must be at 5° Lat. N far from the equator, allowing to the Coriolis Force to be sufficient. From all of these parameters, we choose those with enough time span data which coincide with the Dst time series (1957-2009). The parameters we used are the convective available potential energy (CAPE), relative vorticity and wind shear. The data were obtained from Earth System Research Laboratory, Physical Division, and the National Center for Atmospheric Research. Matlab, wgrib and PanoplyJ were necessary tools to work with the grib and netcdf files. The study area was a grid of 120°-90° W and 6°-37° N, which includes the cyclogenesis area of the Eastern Pacific tropical cyclones. The files contain eight daily data, then it was necessary to calculate the annual mean for each time-series, followed with the separation of data according to two types of solar cycle. Type 1: cycles formed by the descending part of an even solar cycle and the ascending part of an odd cycle; type 2: formed by the descending part of an odd cycle and the ascending part of an even cycle. The sunspot number is plotted between the years 1957 and 2010, corresponding to the 19th, 20th, 21th, 22th and 23th solar cycles and the beginning of the 24th cycle (Fig. 1). Gray shades correspond to the type 1 solar cycles, and white areas to the type 2 solar cycles. Table I shows the analyzed periods by type. The mean of all period was calculated by type to evaluate the main behavior of each data series in the corresponding type.

II. Results

The correlation coefficient was calculated between an atmospheric variable mean data by latitude and Dst. The correlation was performed with the common expression (1).

M. Pazos is in Posgrado en Ciencias de la Tierra, UNAM, Mexico City, 04510 Mexico.
B. Mendoza is in Instituto de Geofisica, UNAM, Mexico City, 04510 Mexico.
L. Gimeno is with the Environmental Physics Laboratory, Vigo University (Ourense Campus) - Science Faculty - 32004 - OURENSE - SPAIN.

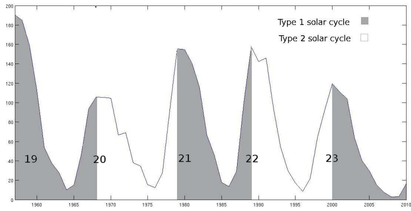

Fig. 1: Solar cyles by types 1 and 2. Shaded areas corresponds to type 1 solar cycles and white areas to type 2 cycles.

TABLE I: Periods for solar cycles types 1 and 2

Period	Solar cycle type
1958-1968	type 1
1969-1979	type 2
1980-1989	type 1
1990-2000	type 2
2001-2009	type 1

TABLE II: Correlation values of Dst and CAPE, wind shear and relative vorticity

Lat °C	Type 1	Type 2
33.33	0.20	0.18
31.43	-0.08	0.38
29.52	0.13	0.39
27.62	**0.62**	0.43
25.71	0.26	**0.68**
23.81	-0.07	0.26
21.90	-0.10	**-0.50**
20.00	0.07	**-0.57**
19.10	0.32	**-0.63**
16.19	0.37	**-0.50**
14.29	-0.19	-0.22
12.38	**-0.51**	**0.45**
10.48	**-0.67**	**0.69**
8.57	**-0.50**	0.05
6.67	0.18	-0.29

TABLE III: Correlation values of Dst and vertical wind shear.

Lat °C	Type 1	Type 2
37.50	0.37	0.39
35.00	0.37	0.35
32.50	0.29	0.48
30.00	-0.11	0.15
27.50	**-0.51**	-0.29
25.00	**-0.52**	-0.36
22.50	-0.43	-0.38
20.00	-0.47	-0.34
17.50	-0.45	-0.30
15.00	-0.34	**-0.53**
12.50	-0.16	**-0.75**
10.00	0.03	**-0.57**
7.50	-0.12	**-0.69**

$$R(i,j) = \frac{C(i,j)}{\sqrt{C(i,i)C(j,j)}} \quad (1)$$

where R is the resulting value and i and j are the values to be correlated. Correlations equal to 0.5 or higher or anti-correlations lower than -0.5, here are considered statistically significant. Tables II, III and IV show the values obtained analyzing the Dst time series with each one of the atmospheric variables data series. Statistically significant values are in bold font.

TABLE IV: Correlation values of Dst and relative vorticity.

Lat °C	Type 1	Type 2
33.33	0.20	0.18
31.43	-0.08	0.38
29.52	0.13	0.39
27.62	**0.62**	0.43
25.71	0.26	**0.68**
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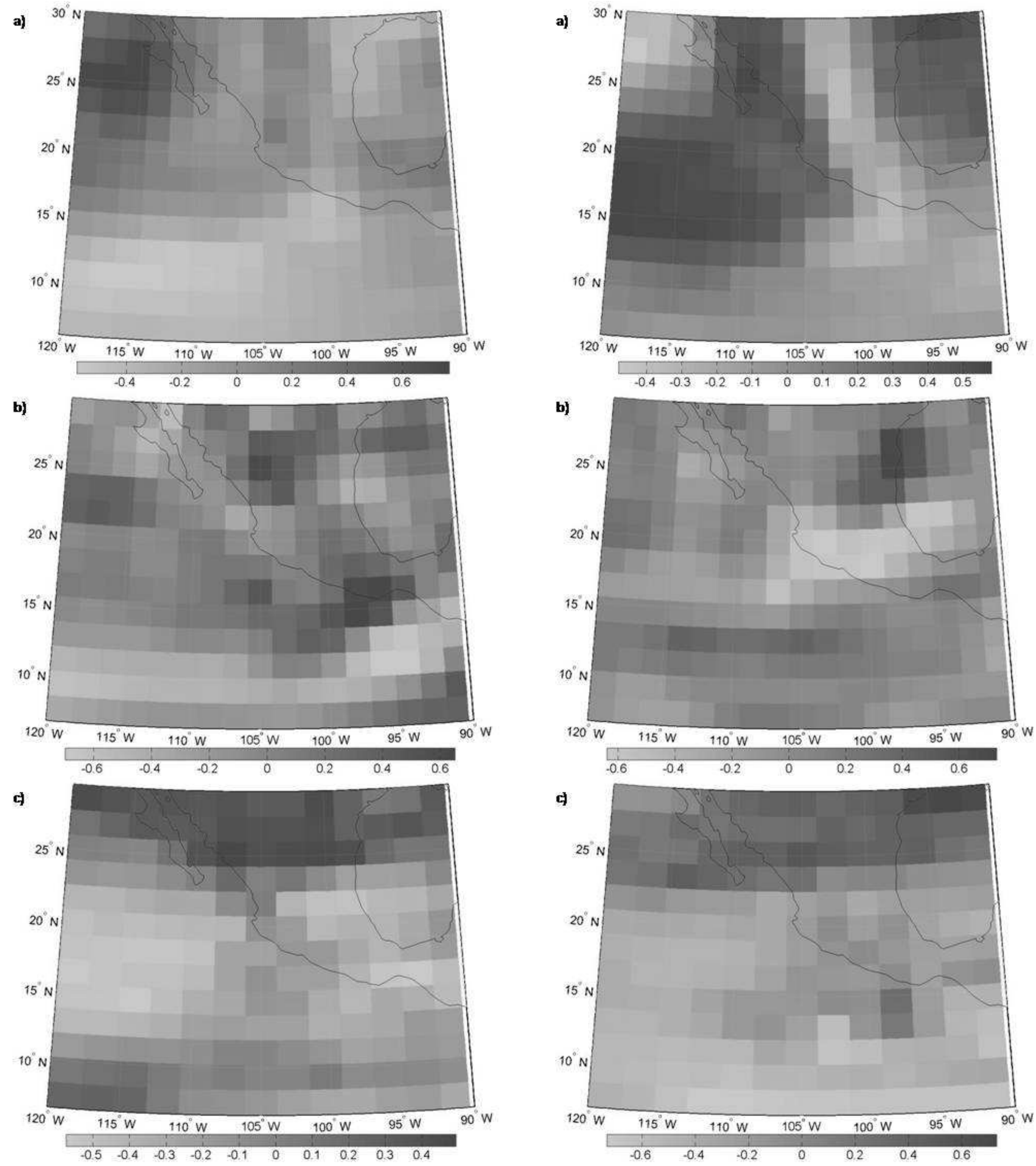
10.48	**-0.67**	**0.69**

Then, to have a better view of the response of each atmospheric variable, the correlation was performed for each coordinate inside the grid of the chosen area and the Dst. Fig. 2 shows the darker areas of higher correlation.

III. Discussion.

Performing the analysis by latitude, different zones show a better correlation depending on the cycle type. Then, the values of correlation vary with latitude and type of cycle. The coordinate analysis helps to visualize the higher or lower correlations in a most specific area. Better correlations are shown for Type 2 periods in all atmospheric variables and Dst. For CAPE, areas with higher correlations/anti-correlations, change their distribution in Type 2 solar cycles, respect to Type 1. A positive correlation might indicate that a geomagnetic disturbance could enhance the CAPE. For wind shear there is a higher anti-correlation in lowest latitudes in the type 2 cycle, and here, the anti-correlation might indicate that for higher disturbances, the wind shear is damped. This is a favorable condition for the tropical cyclone development. For relative vorticity, the highest correlations are on low latitudes for the type 1 cycle and for type 2 the area with highest correlation is on the east side and mid-latitudes, and also this results probably indicate that geomagnetic disturbances contribute to vorticity. The apparent sensitivity in different regions of the grid is not clear.



(a) Type 1

(b) Type 2

Fig. 2: Correlation results between the anual mean of the atmospheric variables by coordenate with the Dst anual mean. (a) are the correlations with CAPE, (b) are the correlations with relative vorticity, and (c) are the correlations with wind shear.

IV. Conclusion

All atmospheric variables has a response to different large-scale atmospheric mechanisms also present in the cyclogenesis process. Specifically for the Eastern Pacific are El Niño/Southern Oscillation, the Pacific Decadal Oscillation and the Madden-Julien Oscillation, as well as easterly waves, had a strong influence in the tropical cyclogenesis [12], [13], [14], [15], [16], [17], but it is also noticeable that the solar activity is playing a roll in the presence of tropical cyclones. From all these results the change of behavior is evident for both types of the solar cycle in to which all data was divided, so a possible response to the presence of the geomagnetic disturbance is present. Therefore, this probably shows a small advance in the understanding of the external causes affecting not only tropical cyclones, but climate in general, helping to improve the models and scenarios of climate change. CAPE and wind shear showing highest correlations, could be leading to the path to find the mechanism that we are looking for. Further investigation is definitely needed, focusing now in case studies and different basins, as this effect could be expected to be a global effect, as Elsner [8], Perez-Peraza et al [18] and others had pointed out.

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