# Cosmic Ray, Solar and Geomagnetic Changes, Preceding Hurricane Formation.
## I. Size.
## II. Time distribution.

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*Abstract*—**Recently it was shown that there exist specific changes in the cosmic ray intensity and some solar and geomagnetic parameters during the days, preceding the hurricane appearances over the North Atlantic Ocean. To understand better these phenomena, data for all hurricanes born not only over the Atlantic but also over the Pacific waters in the last 55 years were elaborated. As basic hurricane parameters the maximum rotational velocity was used. To avoid any interference all hurricanes, overlapping the preceding ones with more than 20 days were not included. Then the behavior of the Cosmic Ray (CR) intensity, the Sunspot (SS) numbers, and the geomagnetic parameters (AP) and (KP) in 35 days prior and 20 days after of the cyclone start were investigated. All these parameters show intensive disturbances in the periods preceding and following the hurricane appearance. A characteristic peak in the CR intensity appears 5 – 20 days before the hurricane start. Specific changes were observed in the SS. The AP and the KP show series of bursts, spread over the whole period of 30 preceding days**

### I. Introduction

In the second part of the year high velocity circular winds are born over the hot equatorial waters of the oceans. Powered by the intensive solar heating, producing fast evaporation and large upward hot air streams, the circular winds gradually gain velocity of 65 nods (33 m/s). That is the speed, accepted to define the beginning of a hurricane over the Atlantic and a typhoon over the Pacific. With the further increase of the circular velocity, reaching sometimes150- 160 nodes (80 m/s), the whole vortex spread out to a gigantic ring with a diameter of several hundred kilometers. In the center of this ring there is a relatively calm zone called Eye of the Hurricane. Around it, the rotational velocity is the greatest and decreases out of the center. This huge system moves generally to the West and slightly to the North.

The energy accumulated during these processes is enormous. It could be compared with the energy of explosion of more than hundreds Hiroshima type atomic bombs. That explains the disasters produced by a hurricane, when it touches a populated area.

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All that provokes our interest for a detailed study of many collateral phenomena and their statistical comparison with the development of these formations, which sometimes give unexpected possibilities. Investigating data, recorded in the past, we could better foresee the hurricane appearances, to forecast their possible trajectory, to predict their probable devastations and most important: to warn on time the threatened population.

In our earlier work [1]-[4] we investigated the interconnections between some CR intensity changes Solar Activity variations and geomagnetic disturbances and possibilities of Atlantic hurricane appearance.

In the last years more and more investigations show that the solar activity [8]-[12] and [17], geomagnetic activity [5] and Cosmic Rays [5]-[7] and [13]-[16], have noticeable impact on the meteorological parameters. Now, continuing our earlier research we are trying to find more representative connections between all the parameters, mentioned above and all the processes of the cyclonal appearance and development**.**

So on the basis of a vast amount of data.

1. To evaluate the averaged time between the appearances of these specific CR, SS and AP changes and the cyclone start.
2. To determine the size and the time distribution of these changes and their interconnection.
3. To contribute to better cyclonical predictions.
4. To create a substantial basis for a future explanation of the physical interdependences between all these phenomena.

Results obtained on the first and on the second tasks are presented here. The evaluation of the obtained enormous amount of graphs coefficients and dependencies still continue. Our efforts to clarify the mechanism of all complicated interconnections between these phenomena are still in progress.

### II. Data.

#### *A. Hurricanes.*

Meteorologists have records of North Atlantic hurricanes that date back into the $19^{th}$ century. Over the last half-century, these records are based on a wide range of measurements including ship and land reports, upper-air balloon soundings, and aircraft reconnaissance. Lately, it was also included radar imaging and satellite photographs. The geographical position of the Eye center and the rotational velocity are measured and published every 12 and lately every 6 hours.

In this work data were used for all recorded cyclones in the Atlantic and in the Pacific Ocean from January 1, 1951 till December 31, 2004, which:

1. During their development their maximum rotational velocity $V_{max}$ reaches at least 35 knots (that means we include in our investigation not only the hurricanes, but also the Tropical Storms, as defined in the Saffir-Simpson scale). The hurricane velocity is traditionally measured in nautical knots [kt].
2. During their displacement they have touched either the Mexican coasts or the Mexican borders.

On the Web there are a lot of cyclone data (WWW 1 - 5). We carefully examined all published data to create our basic hurricane data.

### B. *Sunspot Numbers (SS).*

Solar Activity generally is characterized with the daily Sun Spots number (SS). A full set of daily sunspot numbers for the period 1950-2004 was obtained from the web site of the National Geophysical Data Center in Boulder, Colorado, USA. (WWW-6, 7).

### C. *Cosmic Rays (CR).*

In our earlier investigation [1] we used data from several Neutron Monitors (NM), situated around the Atlantic Ocean. But the gain of the statistics, achieved in this way, was suppressed by the difficulties of sticking together the different data, available in different intervals. So we decided, that only one, but long running NM with more than 50 years continuous measurements could be much more suitable. That is why we took the whole set of Climax NM data received on Climax CR station, (39.37N; 106.18W; alt. 3400 m and 2.97 GeV cut-off rigidity). It appeared, that they covered the period 1951 - 2004 with negligible instrumental changes, low percentage of missing data and wonderful stability. For the whole period of 54-years (19724 days) only 399 days are without any data, or only 2.02 %. That is a 97.98 % of effective measured CR intensity. We carefully interpolated the missing data.

The general interconnection between the data of practically all NM data, measured on different geographical places, permit us to consider the CLIMAX data as globally representative. The CLIMAX data were taken from WWW- 8.

The values presented in counts per hour were transformed in daily percent deviation from the general 55 years average value (394,600 counts/hour, or 9,470,400 counts/day). The statistical error then is 0.032 % for a single day. In most cases we averaged over many days, and the error generally is below the size of the point, presented on the graph.

### D. *Geomagnetic Activity Index (KP) and (AP).*

The daily values of KP and AP indexes characterizing the geomagnetic activity used in this work are taken from the web page of GeoForschungs Zentrum, Potsdam and compared with those of National Geophysical Data Center in Boulder, Colorado, USA. Full data set for our 55-year long period ware available on both web sites (WWW 7, 8).

## III. Data Processing.

### A. *Cyclone Characteristics.*

We found 119 cyclone born over the Pacific and 59 cyclones born over the Atlantic Ocean, obeying the conditions shown in *II.A.* Every cyclone was characterized with:

1 Origin - Atlantic (A), or Pacific (P).
2. Start - (D0) [year, month day], when the circular wind velocity (V), measured on the ocean surface has reached 35 knots.
3. Geographical position - [B (φ, λ)] of the cyclone eye center, where the start occurs.
4. Maximum rotational speed $V_{max}$ reached during the whole cyclone development.
5. Hurricane rank after the Saffir-Simpson Scale, corresponding to the $V_{max}$ value
6. Duration in days (L).

### B. *The Cyclone Classification.*

If the start of the next cyclone occurs less than 20 days after the start of the previous one, the less powerful of them is defined as "overlapped". The overlapped cyclones were not included in our calculations.

So, 78 from all 119 Pacific and 44 from all 59 Atlantic cyclones (112 from all the 178 hurricanes) were classified as "not overlapped" in our 55 years period. Depending on their Safir-Simpson rank (Vmax) they were subdivided in: 6 separate groups (rank 5,4,3,2,1,TS), [Table. 1.].

TABLE I . Cyclones sorted depending on Vmax.

| Rank | H5 | H4 | H3 | H2 | H1 | TS | All |
|---|---|---|---|---|---|---|---|
| Vm [kt] | >135 | 114-135 | 96-113 | 83-95 | 65-82 | 35-64 | >35 |
| **Vm [km/h]** | >249 | 249-210 | 209-178 | 177-154 | 153-119 | 118-63 | >63 |
| Atl.+Pac. | 7 | 17 | 15 | 17 | 34 | 32 | 122 |
| Atl. | 6 | 7 | 7 | 4 | 11 | 9 | 44 |
| Pac. | 1 | 10 | 8 | 13 | 23 | 23 | 78 |

## IV. Days Preceding the Hurricane Start.

Several years ago we noticed an increased CR fluctuations during the days preceding the hurricane appearance. Mostly the high rank hurricanes were preceded with a well-expressed Forbush decrease. An increased disturbance in the SS and AP changes was also observed in the time interval of 35 days before and 20 days after the hurricane start As an example the changes in CR, SS, and AP around the start of the Hurricane ALLAN 1980 are shown on Fig. 1.A.; Fig. 1.B.; Fig. 1.C.; correspondingly.

Naturally, we deduced that such specific parameter changes during the days, preceding the cyclone appearance could be

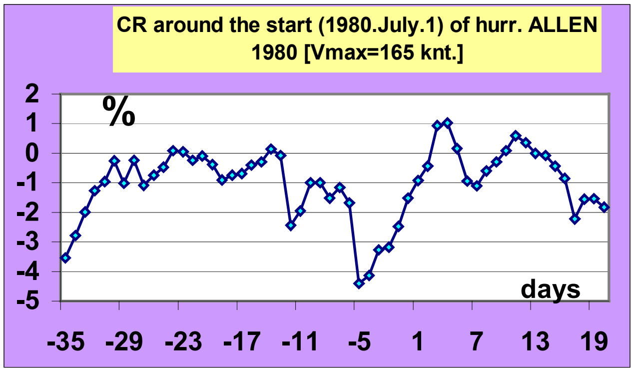


Fig. 1.A.

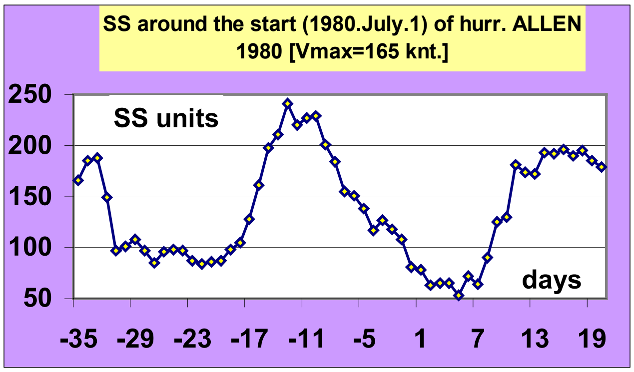


Fig. 1.B.

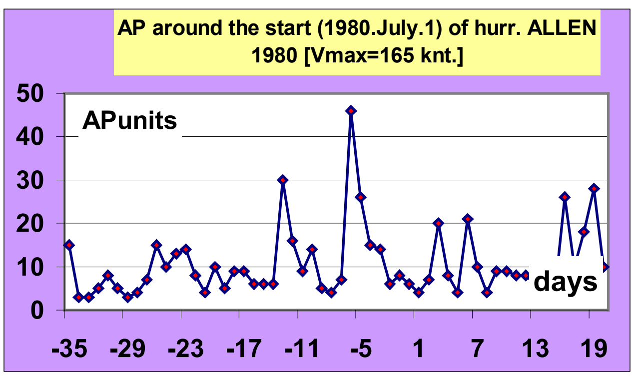


Fig. 1.C.

used as an indicative warning for an approaching dangerous event.

To have a detailed view on the behavior of all parameters (SS, CR, AP, KP) we investigated them separately 35 days before and 20 days after the cyclone start for every one of our 122 cyclones, creating 488 graphs. They generally confirm our preliminary suggestion that there exists an interconnection between these parameter specific changes and the cyclone appearance.

These parameters fluctuate considerably for every single case not only in size, but also in time of appearance toward the cyclone start. So an averaged parameter curve over all hurricanes did not enhance the peaks, but mostly reduce them. Nevertheless, the averaged behavior of these parameter changes, obtained for cyclones sorted depending their category, shows a slight connection with the cyclone rank. As an example the smoothed CR intensity changes, averaged

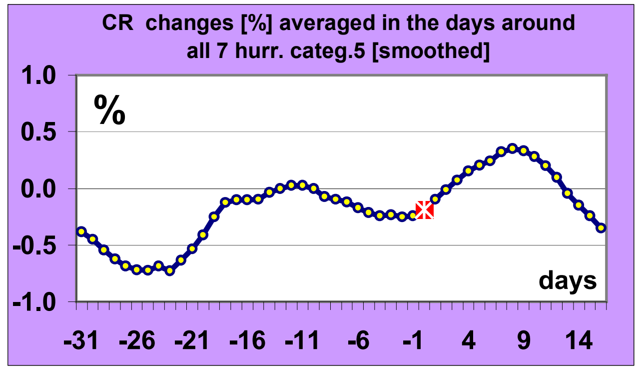


Fig. 2.A.

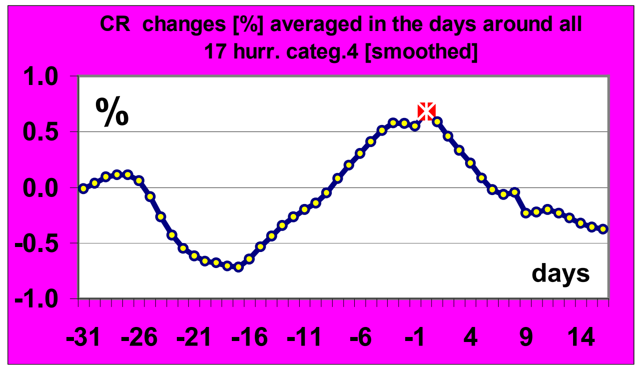


Fig. 2.B.

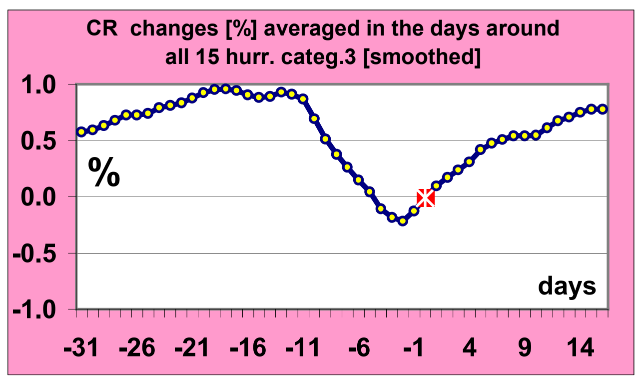


Fig. 2.C.

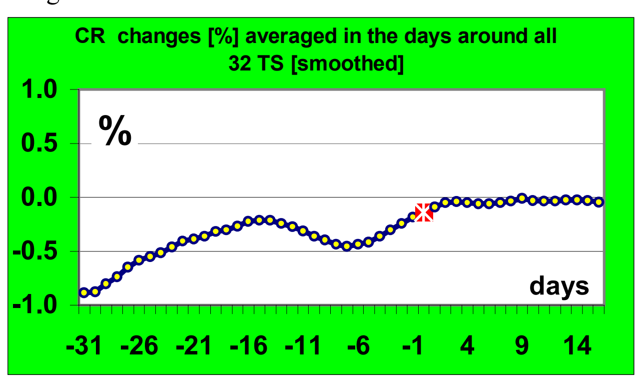


Fig. 2.D.

separately for cyclones rank 5, 4, 3 and for Thunder Storms are shown on Fig. 2.A.; Fig. 2.B.; Fig. 2.C. and Fig. 2.D. respectively

The same was done for SS, AP and KP. The graphs for them are not presented.

It is difficult from all these graphs to obtain directly either the averaged size or the averaged place of the preceding peak of the CR, SS and AP. It is even more uncertain to find the dependence of these peak parameters on the hurricane category

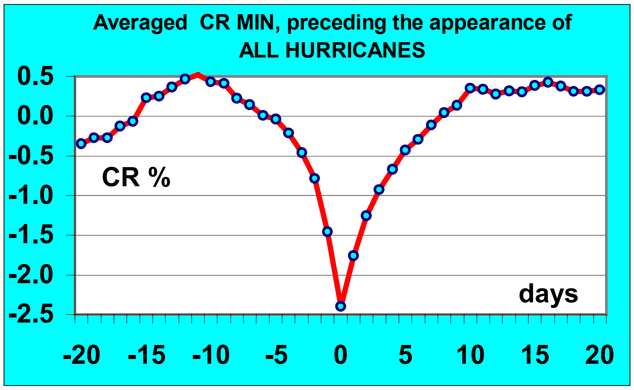


Fig. 3.A.

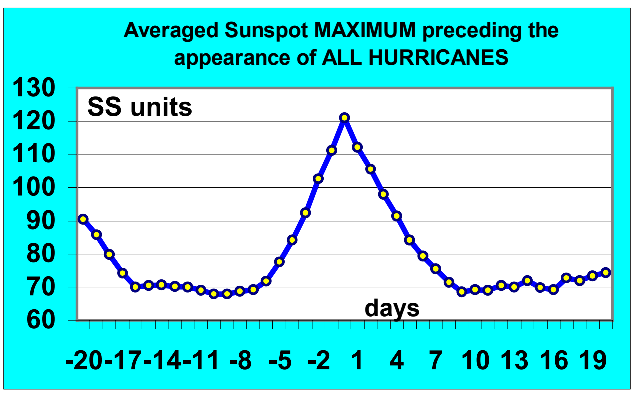


Fig. 3.B.

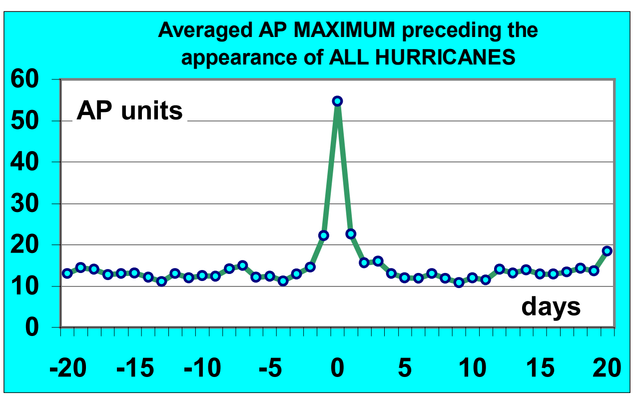


Fig. 3.C.

## V. SIZE OF THE PEAKS.

To avoid these difficulties we overlapped the highest peaks of CR, of SS and of AP in the 20 days intervals preceding the cyclone appearance for the 122 hurricanes.

The results are shown on Fig 3.A.; Fig 3.B.; Fig 3.C. The "relative" sizes of the peak here were measured toward the adjacent average values. So from the graphs we have:

For CR -2.5 – 0.3 = -2.8 %

For SS 120 - 70 = 50 SS units

For AP 55 – 12 = 43 AP units.

If we do the same, separately for every one of the hurricane categories, we could estimate roughly the sizes of the peaks there. These sizes as functions of the hurricane categories are

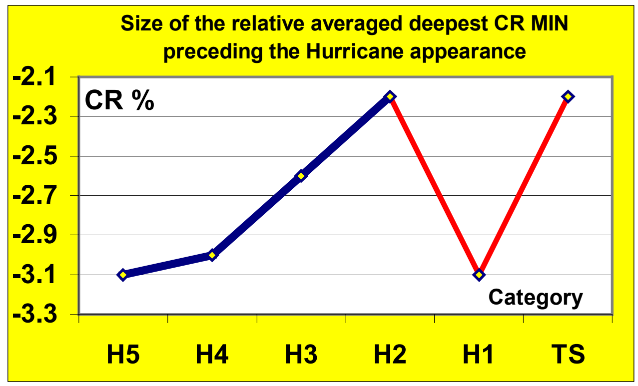


Fig. 4.A.

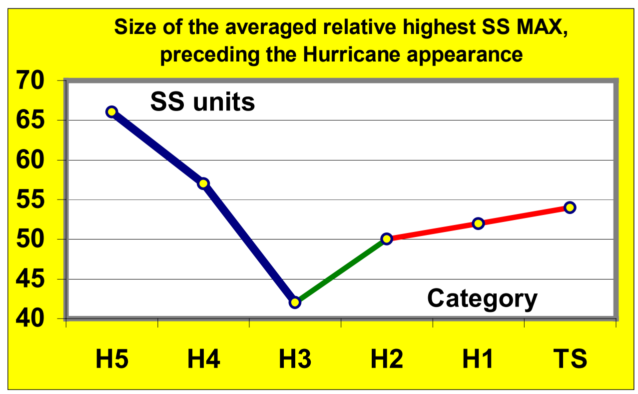


Fig. 4.B.

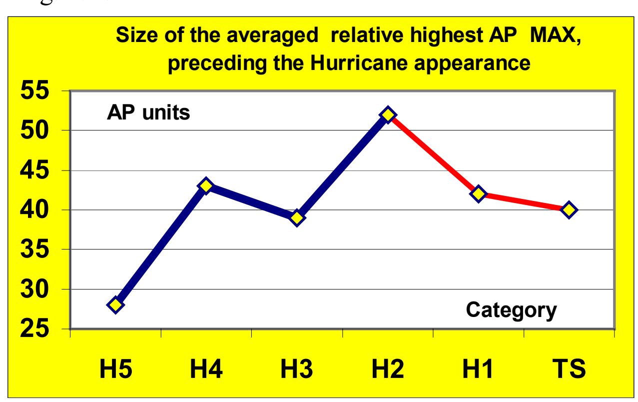


Fig. 4.C.

shown on Fig. 4.A.; Fig. 4.B. and Fig. 4.C.

There, the relative peak sizes in the hurricane category 5, 4, 3 and 2 show a well expressed, practically linear dependence on the hurricane category.

This dependence fades away for the lowest Category 1 and for the Thunder Storms (the lines in red in the graphs in yellow). It could be understood, accepting that the size of the peaks in the lowest categories is within the fluctuations.

The trend deeper MIN in CR intensity values as well as higher MAX in SS for higher Hurricane Categories is within our expectation.

Let us notice that the opposite trend for AP units seems rather unusual here.

## VI. Time distribution of the peaks, preceding the hurricane appearance.

We located the place of the highest MAX (for SS and AP) and the deepest MIN for CR in the interval of 20 days before the start of the cyclone.

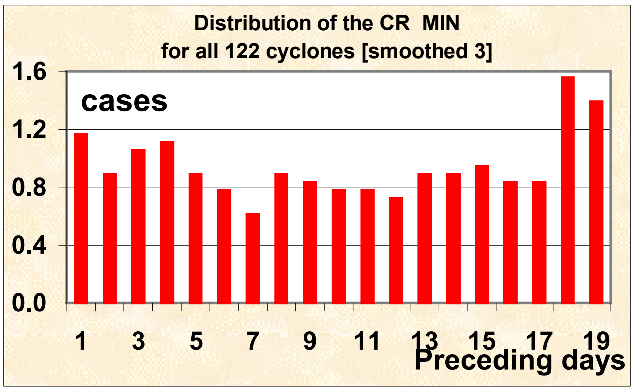


Fig. 5.A.

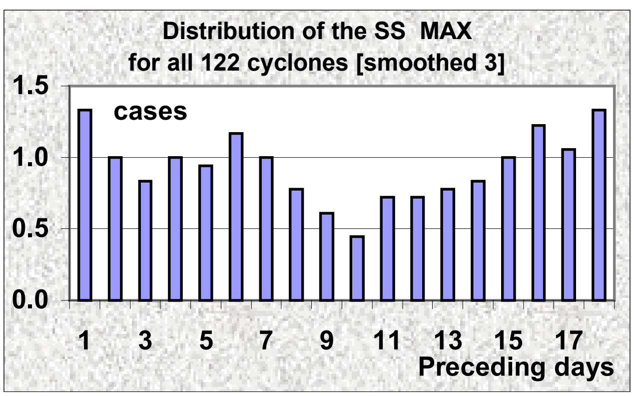


Fig. 5.B.

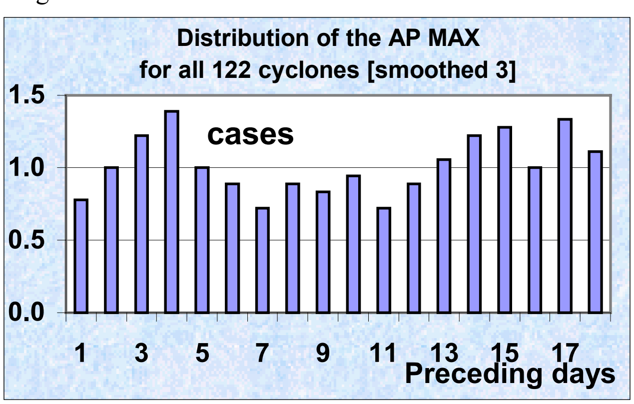


Fig. 5.C.

Distributions of the extreme values of CR, SS and AP in the 20 days interval, preceding the start of a cyclone averaged over all elaborated 122 cyclones are shown on Fig. 5.A.; Fig. 5.B. and Fig. 5.C. correspondingly.

The predominant minimum peaks for CR are concentrate at the beginning of this interval around the 18$^{th}$ - 19$^{th}$ day.

The maximum peaks for SS and also for AP are located around 5$^{th}$ - 7$^{th}$ day and around 16$^{th}$ - 19$^{th}$ day.

The same distributions made separately for different hurricane categories are poor in statistics. But even then in more of the cases their extremes show similar locations.

## VII. Results and Short Discussion.

Obviously our parameters are not the basic driving factor for hurricane appearance and development.

But the results obtained here confirmed our preliminary suggestion that there is interconnection between the changes in CR, SS, AP and the appearance of the cyclones - especially that of the most powerful of them.

The chosen long preceding period of 35 days permits to reveal the behavior of these parameters long before the cyclone appearance. Specific pre-cursors exist persistently before the cyclone start. During the time of major cyclone development specific changes are also noticeable. Obviously, a considerable change in the Solar activity and the depending on it CR intensity and Geomagnetic field disturbances, precede the appearance of intense cyclones.

Here an interesting dependence of the size of the preceding peaks on the hurricane category was established specially for major and moderate hurricanes. We still abstain to state the opposite: the dependence of Hurricane power on the preceding peaks size!

And we still cannot suggest an explanation of the unexpected opposite trend specially for AP peaks sizes

The distribution of these peaks over the 20 days interval preceding the hurricane appearance shows a stable form, which practically does not depends on the hurricane category. It is interesting to notice that the CR peaks are concentrated around the 19$^{th}$ day before the hurricane formation. That could be used as a well an advance warning for a coming treat.

It is difficult to suppose that the CR ionization of the upper atmosphere and the geomagnetic field disturbances, having billion times smaller energy than the oceanic thermal sources, could provoke atmospheric vortexes. Surely, they participate in the change of the atmospheric ionization together with the solar plasma. May be their effect could be defined as "triggering" for the hurricane formation. That change in the ion concentration in the upper layers either helps to go over certain threshold, or contributes continuously to attain a specific starting level. But it is still difficult to establish an acceptable mechanism unifying all these physical phenomena. Our farther efforts will be concentrated in that direction.

Going back to the main question:

Could we forecast the creation of a dangerous vortex on the basis of preceding CR, SS, AP peculiar data changes?

Well, we are still not able to do that firmly.

But, looking in our results we could be strongly alerted if a package of large SS and CR fluctuation, or a Forbush decrease appears at the end of the summer. Then investigating all the parallel atmospheric data we could be closer to a true prediction.

## ACKNOWLEDGMENT

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## WWW LINKS:

1. http://www.aoml.noaa.gov/hrd/hurdat/Track-Maps.htm
2. http://www.aoml.noaa.gov/hrd/hurdat/TrackMaps. ml
3. http://stormcarib.com/climatology/#links
4. http://weather.unisys.com/hurricane/atlantic/index.html
5. http://www.aoml.noaa.gov/hrd/hurdat/Track-Maps.htm
6. http://www.ngdc.noaa.gov/stp/SOLAR/ftpsunspot number.html#american
7. http://www.ngdc.noaa.gov/stp/SOLAR/ftpsunspotnumber. html#international
8. http://ulysses.sr.unh.edu/NeutronMonitor/00ClimaxCorr.html
9. http://www.gfz.potsdam.de/pb2/pb23/GeoMag/niemegk/kp_index/