Atlantic Hurricanes, Geomagnetic Disturbances and Cosmic Ray Intensity Changes.

S. Kavlakov

Abstract— **In some earlier work we found a significant statistical relationship between geomagnetic activity and hurricane intensity as measured by the maximum wind speed. Here we reexamine this relationship comparing changes in the hurricane intensification rates (time derivative of hurricane wind velocity) with sharp increases of KP and separately with sharp decreases of cosmic ray intensity. Intensification is computed using a filter especially designed for derivative calculations.**

We consider only hurricanes over the North Atlantic Ocean away from land for two regions: one over the hot waters around the 20th parallel and other one over higher latitudes. The regions are chosen to control of sea-surface temperature effects on hurricane genesis.

A statistically significant relationship is found between geomagnetic activity and tropical cyclone intensification over the tropical Atlantic where major hurricanes are borne. The result is consistent with one of our earlier study showing a connection between geomagnetic activity and tropical cyclone intensity. It appears possible that the sharp Cosmic Ray intensity decreases have predominantly long time range influences.

Key words: Nautical knots [kt] (kt = 1.853 km/h); Spline interpolation; Savitzky-Golay- smoothing; Forbush event (decrease); Geomagnetic KP index.

1. INTRODUCTION

The question that several purely meteorological processes of the terrestrial atmosphere are connected with the magnetosphere disturbances, CR intensity changes, and solar activity is now largely discussed **[1], [2],** and **[3].** We also noticed indications for similar connections between the hurricane development and these parameters in our earlier works **[4]** and **[5]**.

As it is well known the hurricane is high velocity circular wind born over the hot equatorial waters of the oceans. Its whole vortex generally spreads out to a gigantic ring with a diameter of several hundred kilometers. The energy accumulated during these processes is enormous. It could be compared with the energy of explosion of more than thousand Hiroshima type atomic bombs. That explains the disasters produced by a hurricane, when it touches a populated area. North Atlantic hurricanes frequently strike the Caribbean islands, Mexico, and the United States. Hurricanes rank at the top of all natural hazards in the United States. **[6].**

All that provoked our interest for a detailed study of a possible similar parallel between the appearance and development of the hurricanes and the geomagnetic disturbances and Cosmic Ray intensity. Finding statistically significant interconnection between them could help better hurricane predictions.

2. DATA

A. Hurricane data

All data for the cyclones (hurricanes and tropical storms) in the Atlantic Ocean, Gulf of Mexico, and the Caribbean Sea during the 55 year period 1951-2005 were derived from the HURricane DATa base (HURDAT or best track) **[7]** maintained by the National Hurricane Center (NHC). HURDAT consists of 6-hourly positions and intensities.

B. Geomagnetic data

The KP index is widely used in ionosphere and magnetosphere studies and is recognized as measuring the magnitude of worldwide geomagnetic activity. We used the 3-hour KP taken from the Web site of NOAA.

C. Cosmic Ray Data.

Earlier **[5]** we used data of several Neutron Monitors (NM), situated around the Atlantic Ocean. But the gain for the statistics, achieved in this way, was suppressed by the difficulties of combining together the different data, available in different intervals. So we accepted that the use of only one, but long running continuous CR measurement could be much more suitable.

That is why we took the whole set of Neutron Monitor 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 - 2005 with negligible instrumental changes, low percentage of missing data and wonderful stability. For the whole period of 55-years (20089 days) only 407 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 from practically all NM stations, measured on different geographical places, permit us to consider the CLIMAX data as globally representative.

Author is with the Bulgarian Academy of Sciences, Galileo Galilei Street 17. SOFIA 1113. BULGARIA. phone: +35928717685; e-mail: skavlakov@ gmail.com

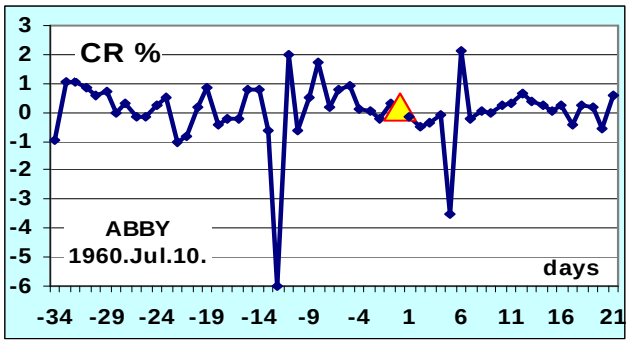
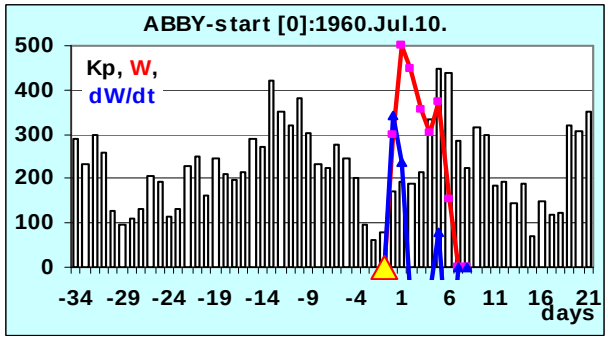


Fig. 1.



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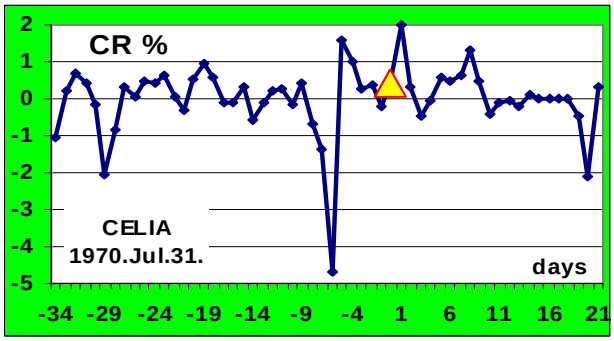

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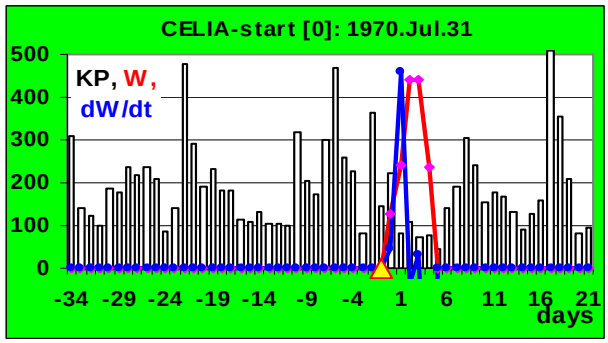

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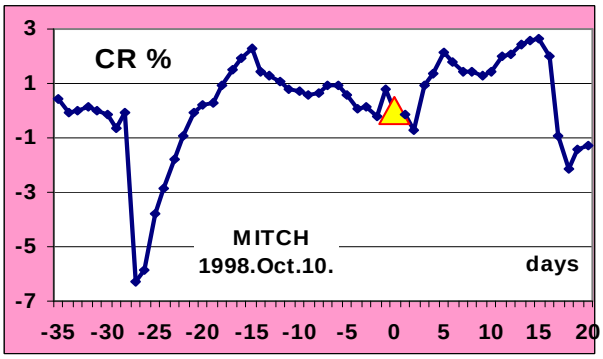

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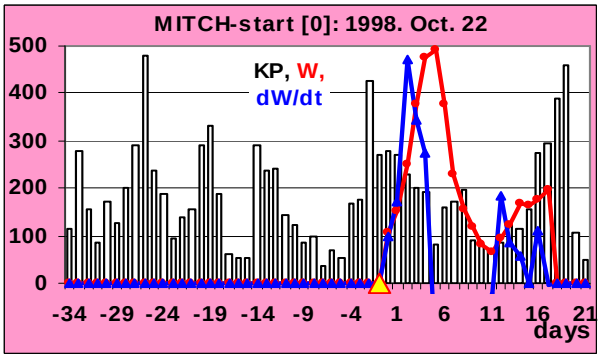

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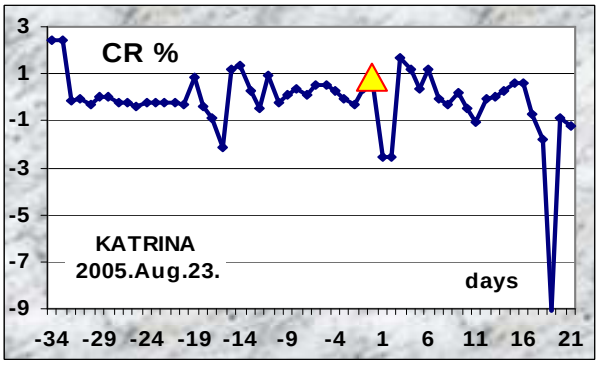

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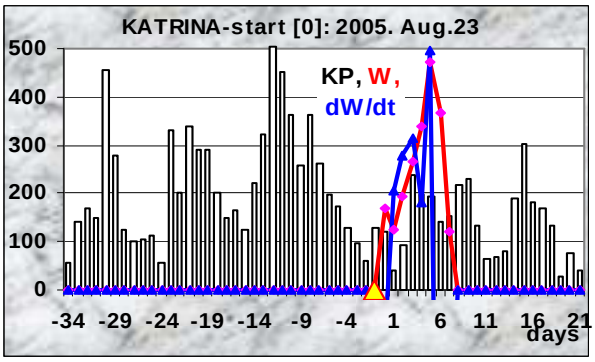

Fig. 8.

3. DATA PROCESSING

A. *Cyclone Intensification*

On the basis of all available cyclone data over the period 1951-2005 we estimated a total of 105,638 active cyclonic hours. To obtain a differentiable function from these data the SPLINE interpolation was used **[8].**

Tropical cyclone intensification is a time derivative quantity. While it is tempting to use a simple finite difference to approximate the derivative, the order of the error on this approximation is commensurate with the derivative value. To reduce such errors *the asymmetric 6-point Savitzky-Golay first derivative filter* **[9]** was used to calculate the hourly intensification rates. For all our 105,638 hours an average intensification rate of +0.0342kt/hr was found.

In our early study we found a persistent presence of at least one Forbush Decrease, in the time interval of about 3 to 16 days before the hurricane start **[Fig. 1, 3, 5, 7.]**. A sharp rise in the geomagnetic parameter KP **[Fig. 2, 4, 6, 8.]** was also noticed in the time intervals preceding the starts of many hurricanes.

On **Fig. 2, 4, 6, 8.** we can put now over the daily changes of the geomagnetic KP index (black bars) not only the corresponding hurricane rotational wind velocity (W) (red line) but also its derivative (dW/dt) (blue line). Thus we can depict clearly the hurricane behavior during or after high geomagnetic disturbances. Graphs are presented, using arbitrary units.

B. *Geomagnetic KP index*

A KP"0" day was defined when its daily KP index exceeds 420 KP units. That is chosen to be 70% above the long-term KP average.

All together 224 KP"0" days (from 108 separate tropical cyclones) overlapping active storms were found in the 1951-2005 period. Taking all the available hours for these KP"0" days, as well as the hours in the three preceding and three following days around KP"0" day we had all together 10995 hours.

Their average intensification was found to be +0.0713 kt/hr. That is more than twice (108%) higher than the intensification 0.0342 kt/h found in general case. Let us stress that to measure the acceleration dW/dt here, we used the traditionally units: **knots per hour** [kt/h].

One [kt/h] = 1.853 [km/h^2].

C. *Cosmic Ray Forbush Events*

The values presented in counts per hour were transformed in daily deviations 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 graphs.

Analogically we chose for "0" days these Forbush type events, when the daily decrease of the cosmic ray intensity is below -3 % from the adjacent intensity. We identify 166 Forbush Events (FE"0") days during the hurricane season months of May through November over the period 1951-2005. Applying the same procedure as for KP, we found 7691 hours.

Their average intensification was found to be +0.0546 kt/hr. That is more than 60 % higher than the intensification 0.0342kt/h found in general case

D. *Control area*

Tropical cyclone intensification depends on many factors **[10]**, specially, on surface oceanic temperature and proximity of land. These factors could confound our ability to identify a significant geomagnetic signal in the data. In order to provide some separation, we repeat our analysis using cyclones confined to the open waters of the tropical Atlantic. In such a way we consider only storm hours far from land over a fairly uniformly warm part of the basin. The control region we choose is a part of the main development region for tropical cyclones and is bounded by 25 and 60 degrees **West** longitude and by 8 and 23 degrees **North** latitude **[Fig. 9.]**.

Fig. 9.

We found 131 cyclones and counted 17579 hours, spread over the chosen area.

Correspondingly we found 2230 KP hours and 2104 FE hours covering hurricanes in the hot water area.

As expected, the mean intensification rate 0.313 kt/hr, found over the hot water area is nearly 10 times higher than the corresponding 0.0342 kt/hr over the whole Atlantic area. The mean intensification for the 5 days centered on a KP"0"

Over all the Atlantic the intensifications **dW/dt** around KP "0" and FE "0" days are greater than during the quiet days. In the case of KP that difference is significant

Because of that and because of the large investigated interval of 55 years we could permit ourselves to suggest an interconnection between the geomagnetic disturbances and the hurricane intensification. This could be supported also with the fact that even over the hot water area, the intensification

Table 1..

	"0" days	Cyclones		Average (dW/dt)	Increase of (dW/dt)
		n	Cyclone hours	[kts/hour]	Around "0" points
			Over all Atlantic region		
All		603	105638	0.0342+/-0.006	
KP max	224	108	10995	0.0713+/-0.008	108 %
FE	166	96	7691	0.0546+/-0.0095	60 %
			Only over hot waters		
All		131	17579	0.313+/-0.04	
KP max	224	26	2230	0.543+/-0.12	73 %
FE	166	25	2104	0.363+/-0.216	16 %

day is 0.543 kt/hr or about 70 % higher than the general intensification 0.313kt/hr over the whole chosen hot water area. For FE days that is only 16 %.

All the results of our investigations over the whole Atlantic area and separately over the hot water area are shown on **Table 1.**

The statistical significance was estimated by means of "bootstrap" procedure **[**11**]**.

4. Intensification Around "0" days

The overlapping of the cyclone intensifications for all KP"0" day together with their adjacent days over the hot water area, is shown on **Fig. 10**.

The same was done for the FE"0" days. The results are shown on **Fig. 11.**

5. Results and Discussion

The slight rise of **dW/dt** around the KP and FE "0" days in the control area over hot waters is understandable. There, all the energy input to the storm intensification is mainly from the overheated water. All other influences are strongly suppressed.

dW/dt for KP "0" day is greater than that for the "calm" days.

The direct impact of the Forbush Decreases (FE) seems to be rather insignificant because of the slight changes of **dW/dt** around the FE "0" days and because the form of obtained curve on **Fig. 11**. But taking into account their persistent appearance before the hurricane start (**Fig. 1, 3, 5 and 7)** in the last half a century, their contribution to the storm intensification could be probably within a longer time range.

The fact that both curves on **Fig. 10. and 11**. reach their maximum immediately ***after*** the chosen "0" day, strongly support the supposition of an influence.

Here we find a statistically significant relationship between geomagnetic activity and hurricane intensification over the Atlantic Ocean where major hurricanes are borne.

The result is consistent with an earlier study **[4]** showing a connection between KP values and hurricane intensity. It suggests that a possible physical mechanism is related to increased ionization of the upper extent of the tropical cyclone vortex leading to increased condensation and additional warmth throughout the column. Obviously more work is needed for better understanding of this interesting interconnection.

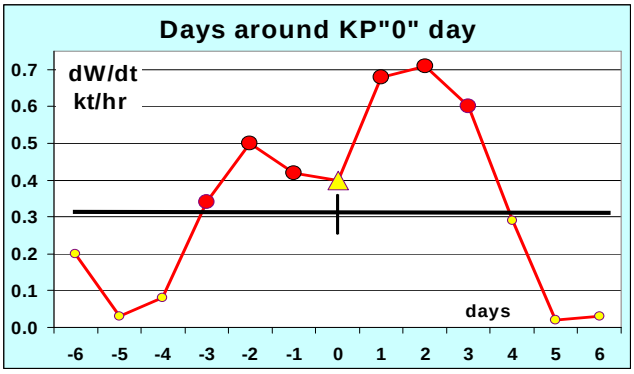

Fig. 10.

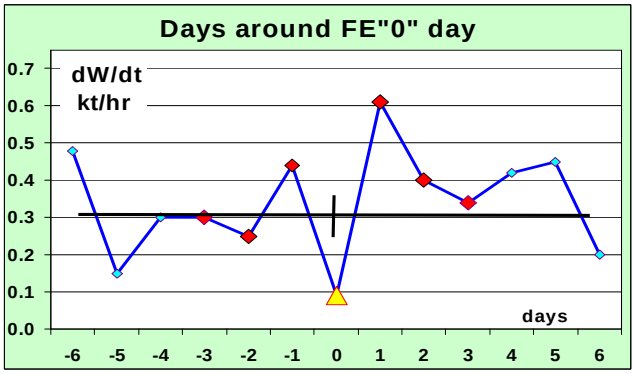

Fig. 11.

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