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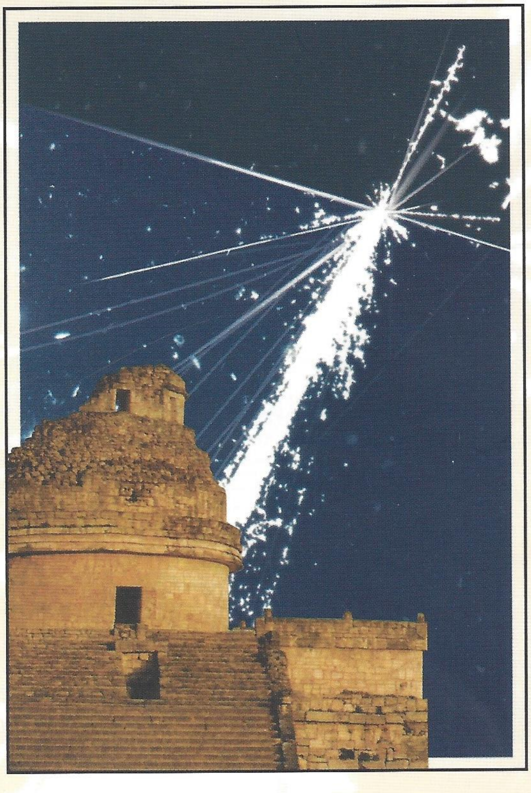

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Atlantic Hurricanes, Geomagnetic Changes and Cosmic Ray Variations. Part I. *Geomagnetic Disturbances and Hurricane Intensifications.*

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Abstract: In an earlier work we found a significant statistical relationship between geomagnetic activity as measured by the KP index and hurricane intensity as measured by the maximum wind speed for a certain type of higher-latitude hurricanes. 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 tropics and one over higher latitudes. The regions are chosen to control for effects of sea-surface temperature on hurricane genesis. Data are taken from all tropical cyclones passing through the regions during the period 1950-2006. We found that intensification is related with the geomagnetic disturbances mainly in the North Atlantic higher latitudes. It appears that the sharp Cosmic Ray intensity decreases have predominantly long time range influences.

Introduction

Lately some indications appeared that several purely meteorological processes in the terrestrial atmosphere are connected with the changes in the CR intensity, and influenced by solar activity, and magnetosphere variations [1, 2, 3].
Our interest was concentrated to find possible similar interconnection between the appearance and development of the hurricanes and changes in solar activity, geomagnetic disturbances and Cosmic Ray intensity. Up to now we generally presented the hurricanes by means of their rotational velocity [4, 5]. Here we describe them with the first derivative of that velocity. We assumed that the changes in the rotational speed reflects very well any energy impute in the robust hurricane dynamics.

Hurricanes

Powered by the intensive solar heating, producing fast evaporation and large upward hot air streams, high velocity circular winds are born over the hot equatorial waters of the oceans. These circular winds gradually gain velocity. Depending on the attained maximum of this velocity the hurricanes are classified in the Saffir-Simpson scale (Table 1) as Tropical Depression, Tropical Storm and five categories hurricanes

With the increase of the circular velocity, the whole vortex spread out to a gigantic ring with a diameter of several hundred kilometers (Table 2). In the center of this ring there is a relatively calm zone called Eye of the Hurricane. This huge system moves generally to the West and slightly to the North

Table 1: Saffir-Simpson scale

	MAX Rot. Wind Velocity		
	Range	Range	Range
Storm	Knots	km/h	m/s
TD	30-34	56-62	15-17
TS	35-64	63-118	18-32
H1	65-82	119-153	33-42
H2	83-95	154-177	43-49
H3	96-113	178-209	50-58
H4	114-135	210-249	59-69
H5	>135	>249	>70

Table 2: Average hurricane characteristics

Storm diameter:	**200- 1300 km**
Energy Source:	**Latent heat release**
Kinetic energy:	**4-8 TWh**
Eye diameter:	**16 – 70 km**
Lifespan:	**1 – 30 days**
Surface winds:	**> 33 m/sec**

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. In the United States hurricanes rank at the top of all natural hazards [6].

Naturally all that provoked our interest for a detailed study of many collateral phenomena and their statistical comparison with these processes. Here we use simultaneously measured data to find statistical dependencies between the parameters of all recorded and the corresponding changes in the solar and geomagnetic activity and Cosmic rays.

Data

Hurricane data

All data for the cyclones (hurricane and tropical storms) in the Atlantic Ocean, Gulf of Mexico, and the Caribbean Sea during the 55 year period 1951-2005 ware 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. We convert the 6-hourly values to 1-hourly values using cubic spline interpolation.

Geomagnetic data

The KP index is widely used in ionospheric and magnetosphere studies and is recognized as measuring the magnitude of worldwide geomagnetic activity. We used the 3-hour KP and AP index data and the daily values of the Sun Spots, taken from the Web sight of NOAA.

Data Processing

Cyclone Intensification

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. Here we estimate the hourly intensification rate from an asymmetric 6-point (3 left, 2 right) 3-degree Savitzky-Golay first derivative filter that reduces the error [8]. Hourly intensification rates are obtained for all hurricanes and tropical cyclones for a total of 105,638 values over the period 1951-2005. Averaging these hourly values we derived the corresponding daily values.

Geographical Classification

Tropical cyclone intensification depends on many factors including oceanic heat content and proximity to land. These factors will confound our ability to identify a significant geomagnetic signal in the data. In order to provide some control, we repeat the analysis using cyclones confined to the open waters of the tropical Atlantic. In this way we consider only storm hours far from land over a fairly uniformly warm part of the basin. The control region we choose is part of the main development region for tropical cyclones and is bounded by 25 and 60 degrees W longitude and by 8 and 23 degrees N latitude (Fig. 1).

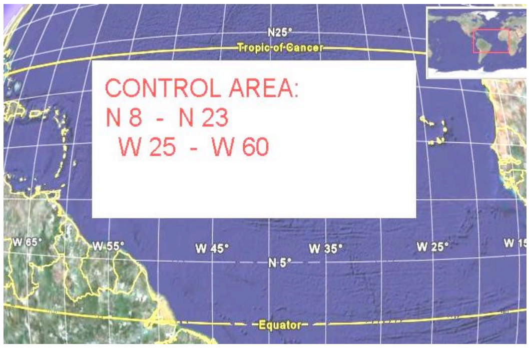

Figure 1: Control Geographic Area, where the water surface temperature is practically constant.

Cyclones around KP "0" day

Earlier (see for example [5]) we investigated the behavior of KP and some other parameters before the start day of the hurricane. In this work we re-arrange our basic position. We took as "0" days not the day when a hurricane starts, but the opposite – the day with a high KP peak.

As major geomagnetic disturbances "0" day was defined when its daily KP index exceeds 420 KP units or more than 70% above the long-term average.
The hurricane number is strongly peaked around the month of September and spread over the months from May till November (Fig. 2).

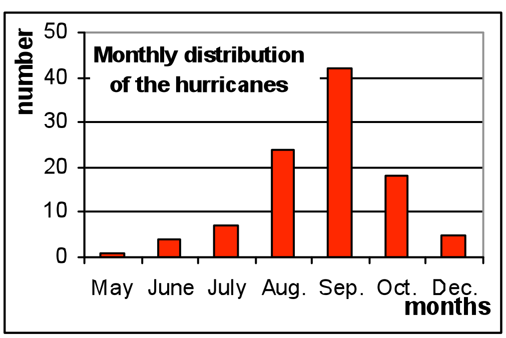

Figure 2: Monthly distribution of the KP "0" days.

The monthly distribution of KP "0" days in that period is more uniform (Fig. 3).
In the hurricane seasons of 1951-2005 we identify 224 KP "0" days overlapping active storm hours.
We analyze statistically the relationship between geomagnetic disturbances and hurricane

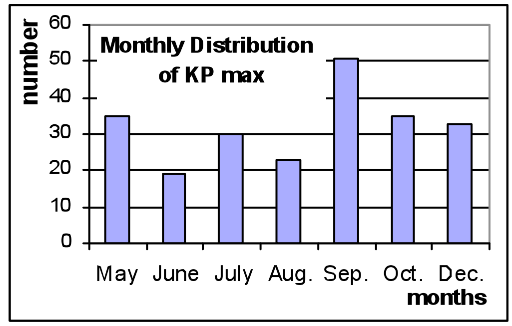

Figure 3: Monthly distribution of the KP "0" days.

intensification by averaging intensification rates over 5 days centered on the KP day and comparing this mean intensification with the overall average intensification.

Table 3: Intensification rates

	"0" days	Cyclones n	Cyclones h	Average (dW/dt) [kts/hour]	Average (dW/dt) [kts/5days]
	Over whole Atlantic region				
All		603	105638	0.0342+/-0.006	4.10+/-0.07
Kp_{max}	224	108	10995	0.0713+/-0.008	8.56+/-1.02
	Over hot waters				
All		131	17579	0.313+/-0.04	37.6+/-1.9
Kp_{max}	224	26	2230	0.543+/-0.12	65.1+/-14.4

The results are shown on Table 3. From all 105,638 hours of tropical cyclone activity, the mean intensification rate is +0.0342 kt/hr, which equals 4.1 kt over any 5-day period. This compares with a mean intensification rate of +0.0713 kt/hr or 8.56 kt over the 5-day period based on 10,995 hours of intensification (108 separate tropical cyclones) plus and minus 2 days of the KP day.
To test the significance of these differences we randomly assign days as KP days and compare the mean intensification rate (bootstrapped rate) over the 5 days centered on these random dates. We repeat this many times (200-1000) and count the number of bootstrapped rates that exceed +0.543 kt/hr. The number of times the rate is exceeded divided by the total number of bootstrapped rates is the p-value. We find a p-value of 0.12 (see Fig. 4).
The 2-day window surrounding the KP day is arbitrary so we also consider the mean hurricane

intensification for storms before, during, and after the KP day. Figure 5 shows the mean

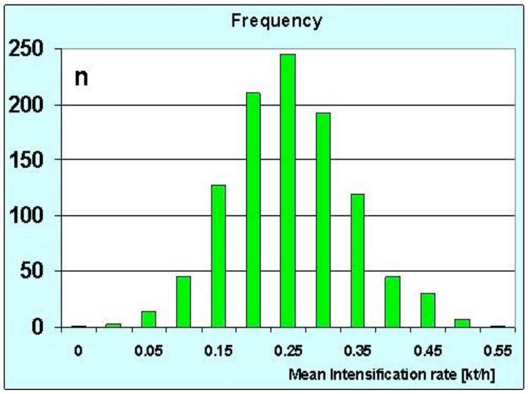

Figure 4: Distribution of "bootstrapped" rates.

intensification rate as a function of lag time from the KP "0" day.

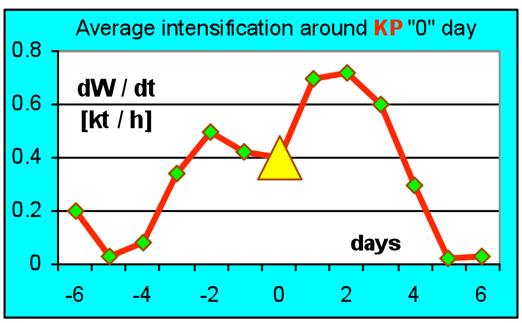

Figure 5: Hurricane intensification in [kt /h] around the average KP "0" day.

Obviously the effect appears most pronounced for lags from -3 to +3 days.

Conclusions

Here we find a statistically significant relationship between geomagnetic activity and hurricane intensification over the tropical Atlantic where major hurricanes are borne. The result is consistent with an earlier study in showing a connection between KP values and hurricane intensity. It expands on the earlier work by focusing on intensification rather than intensity. Results appear to be more general in that there is no need to separate the tropical cyclones by type.

It is understandable why the KP effect is less pronounced over the regions with overheated surface water, where more of the cyclones are born. There, the dominant factor is the energy extracted of the water surface. That reduces all other accompanying factors participating in the cyclone formation.

Over the whole basin, where generally the primary creating and supporting effect of water surface temperature is reduced, these other factors became more active.

Along the lines of our earlier study we suggest 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 to understand better this interesting result.

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