30TH INTERNATIONAL COSMIC RAY CONFERENCE

Geomagnetic Disturbances and Atlantic Hurricane Intensification.

S. KAVLAKOV[1], J. ELSNER[2]
[1] *Bulgarian Academy of Sciences, Galileo Galilei Street 17/B. Sofia 1113.BULGARIA.*
[2] *Florida State University. Tallahassee. Florida.*
contact. ***skavlakov@gmail.com***

Abstract: Earlier we have 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 cosmic ray intensity and hurricane intensification rates (time derivative of hurricane intensity).

Introduction

Variations in geomagnetic activity in the magnetosphere have been statistically linked to hurricane intensity over the North Atlantic [1] A positive correlation between the averaged Kp index of global geomagnetic activity and hurricane intensity as measured by maximum sustained wind speed is identified. The results were based on daily hurricane intensity. Here we examine the relationship in more detail using hourly intensification rates**.**

Data

We consider the maximum wind speed (intensity) for all cyclones (hurricanes and tropical storms) over the North Atlantic, which includes the Atlantic Ocean, Gulf of Mexico, and the Caribbean Sea, during the period 1951-2005. The data are derived from the HURricane DATa base (HURDAT or best track) **[2]** 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 spline interpolation.
The Kp index is widely used in ionospheric and magnetospheric studies and is recognized as measuring the magnitude of worldwide geomagnetic activity. We used the Kp index data taken from the Web sight of NOAA.

Data processing

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. Hourly intensification rates are obtained for all hurricanes and tropical cyclones for a total of 105,638 values over the period 1951-2005.
As major geomagnetic disturbances day was defined when its daily Kp index exceeds 420 Kp units or more than 70% above the long-term average. . The monthly distribution of Kp days is fairly uniform with a maximum during September and a minimum in June. The annual distribution shows the well-known 22-year solar cycle. There is no significant long period trend in these counts. In contrast, the hurricane season is strongly peaked around the month of September and spread over the months from May till November In this hurricane season months we identify 224 Kp days over the period 1951-2005.

Statistical analysis

Some repeatedly observed coincidences between fast Hurricane intensifications and High Kp value (for example Hurricane KATRINA 2005 - **Fig.1**.) directed our interest to examine statistically the hurricane intensification rates around the time of a major geomagnetic disturbance and whether there is, on average, a statistically higher rate during these disturbances

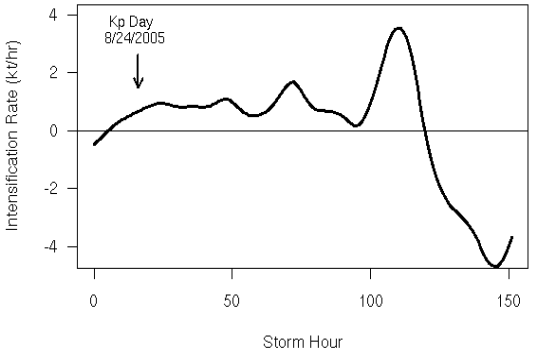

Figure.1. Intensification rate for Hurricane Katrina. The intensification rate in kt/hr is given every hour for the lifetime of the tropical cyclone until it passes north of 33 degrees N latitude. The arrow locates a Kp day. The location is 0900 UTC on 8/24/2005 when the Kp index reached a value of 8.7 steps.

So we analyze the relationship between geomagnetic disturbances and hurricane intensification by averaging intensification rates over 5 days centered on the Kp day and comparing this mean intensification with the overall average intensification. From all 105,628 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 or8.56 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. We note larger intensification rates surrounding the Kp day, on average, for tropical cyclones weaker and stronger than hurricane intensity (64 kt).

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 +0.0713 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 for all cyclones, 0.13 for weak cyclones, and 0.10 for strong cyclones. That permit to obtain a statistical error of 12 % while suggestive, the results are inconclusive regarding the relationship between geomagnetic disturbances and hurricane intensification.

Tropical cyclone intensification depends on many factors **[3]** 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 control for proximity to land by considering only storm hours far from land and control for ocean heat content by considering only storm hours 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.

There are 17,579 cyclone hours within the control region over the 55-year period (1951-2005). As expected the mean intensification rate is considerably higher at 0.313 kt/hr (37.6 kt/5 days). The mean intensification for the 5 days centered on a Kp day is 0.543 kt/hr (65.1 kt/5 days). This is based on 26 separate tropical cyclones, including Dog in 1952 and Iris in 2001. [Table 1.]

We repeat the bootstrap procedure as described above for determining the statistical significance. **Figure.2** shows the histogram of mean intensification rates for 1000 bootstrapped rates. The actual rate is noted with an arrow. The p-value is 0.007 indicating a significant increase in intensification around Kp days relative to the average.

Table 1. Intensification rates

Over whole Atlantic region				
	Cyclones		Average (dW/dt)gs [kts/hour]	Average (dW/dt)gs [kts/5days]
	n	h		
All Kp	603	105628	0.034+/0.006	4.10+/-0.07
$_m$	108	10995	0.071+/0.008	8.56+/-1.02
Over hot waters				
	Cyclones		Average (dW/dt)gs [kts/hour]	Average (dW/dt)gs [kts/5days]
	n	h		
All Kp	131	17579	0.313+/-0.04	37.6+/-1.9
$_m$	26	2230	0.543+/-0.12	65.1+/-14.4

Similar results are noted for tropical cyclones greater than and tropical cyclones less than 64 kt, although the significance is more pronounced for the weaker cyclones.

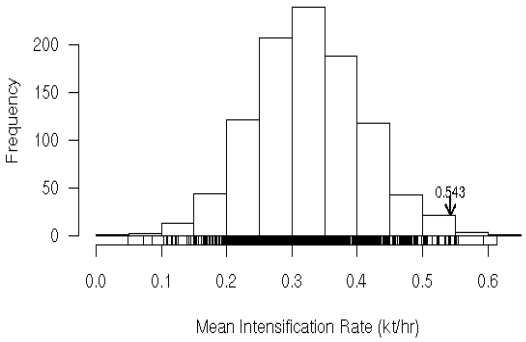

Figure.2. Histogram of bootstrapped intensification rates over the control region. The mean intensification rate +/- 2 days of the Kp day is 0.543 kt/day, which is greater than all but 7 of the 1000 bootstrapped rates.

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 3.** shows the mean intensification rate as a function of lag time from the Kp day. A lag of 0 represents the Kp day and minus days are days before the Kp day. We note that the affect appears most pronounced for lags from -3 to +3 days.

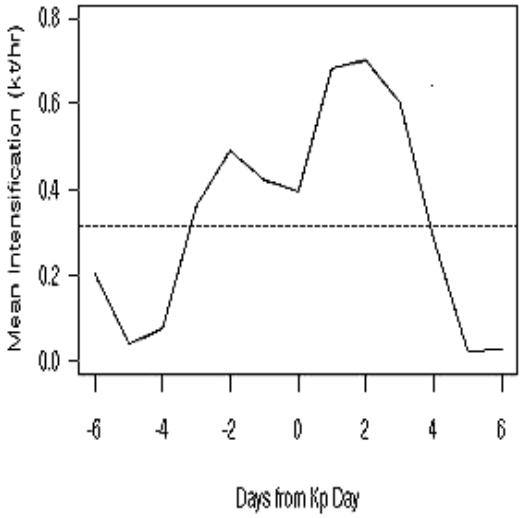

Figure 3. Lag plot of mean intensification. The influence of the geomagnetic disturbance appears most pronounced over a 7-day period centered on the Kp day.

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 better understand this interesting result.

Acknowledgements

We thank Dr. Thomas Jagger for his help with the hurricane data.

References

1. **Elsner, J.B., and Kavlakov, S.P., 2001** Hurricane intensity changes associated with geomagnetic variation. Atmospheric Science Letters, doi:10.1006/asle.2001.0040.

2. **Neumann, C.J., B.R.~Jarvinen, C.J.~McAdie, and G.R.~Hammer, 1999:** Tropical Cyclones of the North Atlantic Ocean, 1871--1998}. National Oceanic and Atmospheric Administration, 206 pp.

3. **DeMaria, M., and Kaplan, J., 1999**: An updated statistical hurricane intensity prediction scheme (SHIPS) for the Atlantic and eastern North Pacific basins. Weather and Forecasting, 14, 326-337.