Geography 586

Final Project

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ABSTRACT

The North Atlantic Hurricane Dataset (HURDAT) was examined to determine if certain Caribbean islands were more susceptible to hurricanes than others. It was determined that the Bahamian chain of islands is significantly more susceptible to hurricanes and in particular storms above Category 3 on the Saffir-Simpson scale.

INTRODUCTION

Atlantic Tropical Cyclones, or Hurricanes typically form a few hundred miles north of the Inter-Tropical Convergence Zone (ITCZ) off the western coast of Africa as tropical waves. At these latitudes the Coriolis force is insufficiently strong to cause circulation in the storms and they move west as tropical waves. Having moved sufficiently northwest they begin to circulate. Fed by warm Atlantic Ocean sea surface temperatures the storms begin a strong circulation pattern cycling up around the eye-wall out toward the margins then downwards and back toward the eye-wall. These storms can cause incredible economic damage and frequently loss of lives. (McAdie, 2009)

The North Atlantic Hurricane season formally begins in June 1st and ends in November 30th. During this period the Caribbean islands are at risk for the potentially devastating impact of a tropical cyclone (McAdie, 2009). As the impact of a hurricane can be damaging the comparative risk between each island is somewhat taboo in normal conversation. There remains however, a perception among the Caribbean community that certain island nations are at a higher risk than others for the impact of a hurricane. This paper aims to determine if there is any statistical basis for such an assumption. If such a spatial pattern does indeed exist, then the potential geophysical process that may be driving such a process will also be examined.

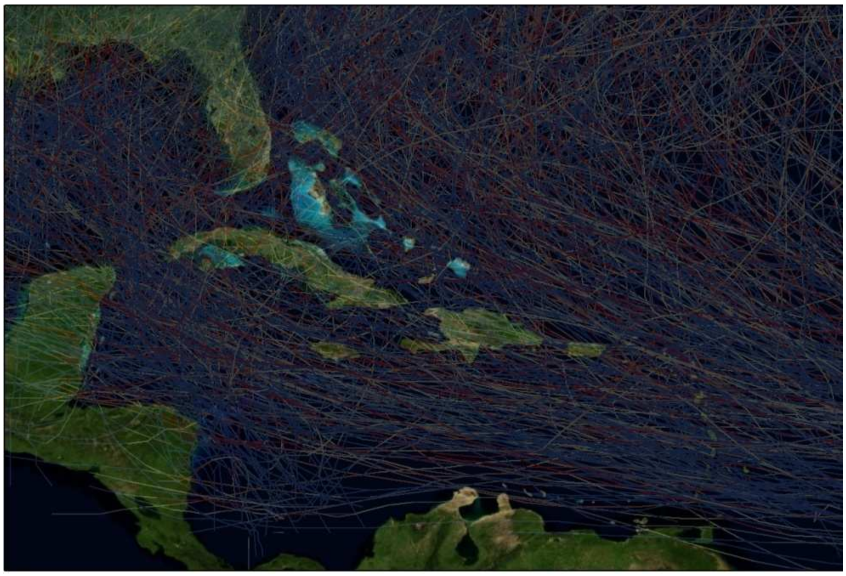

Figure 1. Historical Tropical Cyclone Tracks of the Caribbean, 1851-2009

DATA

NATIONAL HURRICANE CENTER'S HURDAT

The primary dataset for this analysis is the National Hurricane Centre's Hurricane Dataset, often referred to as The HURDAT. This dataset is offered in ESRI's shapefile format and consists of vector lines representing the track of the centre of eye movement of all known hurricanes from 1851 to 2009 (National Oceanic and Atmospheric Administration, 2005). In addition to line tracks the HURDAT dataset also provides the name of the storm, the date and time of the datapoint, the current maximum sustained winds and the Saffir-Simpson storm category. While the HURDAT dataset includes Pacific storms, for the purpose of this analysis they have been ignored.

THE TROPICAL CYCLONE EXTENDED BEST TRACK DATASET (EBT)

Colorado State University produces an addendum to the HURDAT with additional data provided by the National Hurricane Center. This dataset includes information the storms structure, the radius of the outermost closed isobar, and the radius of hurricane force winds amongst others (DeMaria & Knaff, 2009). It is provided in comma delimited text and minor post-processing was required to achieve good compatibility with Microsoft's Excel.

REEFS AT RISK IN THE CARIBBEAN

The Reefs at Risk in the Caribbean project is an attempt to characterize the threats to the sustainability of the coral reefs In the Caribbean. In addition to the published report the authors host a web site which provides all spatial datasets produced during the creation of the report. For the purposes of this analysis the only dataset used was the Gulf Coast and Caribbean Coastline dataset. This dataset is 1:100,000 scale data (Burke & Maidens, 2004). Given that our analysis grids are all sampled to 1 kilometer cell sizes this should not be a problem.

Figure 2. The Reefs at Risk coastline dataset overlying Microsoft's Bing Maps Satellite Imagery

METHODOLOGY & DATA PREPERATION

The HURDAT dataset is a large collection of vector lines. Rather than simply use line density estimates for analyzing the data it was determined that a better approach would be to buffer the tracks and create swaths based on an estimate of the width of a hurricane swath.

BUFFERED LINE TRACKS

While the EBT dataset provides detailed information about the size of the swath of the hurricanes it is limited to hurricanes occurring during the 1997 onward. Additionally, the data provided by the EBT varies for each cardinal quadrant of the hurricane. This level of complexity was simply too great for the constraints of this analysis and clearly a compromise was required. That compromise came in the form of an average of averages. The quadrant data for each data point was averaged to create a radius to hurricane force winds. The average of those radii was determined and for the period from 1997 to 2009 the mean distance to hurricane force winds for an Atlantic basin hurricane was determined to be 47 nautical miles. While clearly this assumption limits the accuracy of the analysis, the sheer volume of information provided by the HURDAT dataset should help overcome this limitation.

The result of the buffer operation was a polygon dataset that contained many multipart and overlapping polygons. The multipart data are the result of hurricanes dropping down to tropical storm strength or lower and re-strengthening to hurricane status. The overlapping data is quite natural given the density of our line data. The data was converted to single part using the Multipart to Singlepart tool in ArcToolbox.

The overlaps required more attention. The data could not simply be converted using Spatial Analyst as it does not properly account for the overlapping polygons. Instead it would only apply the attribute value of the last polygon to the appropriate cell in the raster. To circumvent this problem a vector grid of 1km by 1km polygons was created at the extent of the HURDAT dataset. This rather unwieldy file made processing quite difficult, and intermediary files began overrunning physical memory and storage limits. Nevertheless, the HURDAT data was joined to these polygons, producing vector grids that contained the count of polygon intersections. The same procedure was repeated only for those hurricanes in the dataset that were above Category 3 on the Saffir-Simpson Scale. Having produced these pseudo-raster shapefiles the data were converted to true rasters using the Spatial Analyst tool Features to Raster using a 1km grid cell size.

The advantage of this approach is that it produces more tangible statistics. The number of storms to hit a given grid cell and the average wind speed of storms to hit that cell are far easier to discuss than the results of a density function. The cost here is in computational time and the weakness of the assumption of uniform storm swath size.

RATIO OF CAT3 STRIKES TO ALL STRIKES

Having produced strike count rasters for all hurricanes and only those hurricanes above category three it was decided that the ratio of the two could provide meaningful insight into the variation between very strong storms and more benign hurricanes. Using the Spatial Analyst Raster Calculator tool the ratio between Cat 3 storm strikes and all storm strikes was calculated.

ZONAL STATISTICS

Using the strike grids the average number of strikes per island can be evaluated using the Zonal Statistic tool as part of the Spatial Analyst package. The FID was used as the Zone field as the average was to be evaluated per polygon (not per island nation). The vector source was the Reefs at Risk coastal polygons and the two surfaces evaluated were the complete hurricane strike grid and the greater than category 3 strike grid. The result was a field appended to the coastline data that indicated how often that island had been struck.

RESULTS AND ANALYSIS

While there is a clear first order trend in hurricane movement, i.e. they generate in the West Atlantic and move eastward towards the Caribbean, this analysis intends to determine where that movement may be concentrated. Specifically whether or not there is a clustering of hurricanes along this general track. Having completed this analysis the focus will shift to the evaluation of the number of hits each island has received and whether or not this pattern shows any relationship to the patterns borne out in the first analysis.

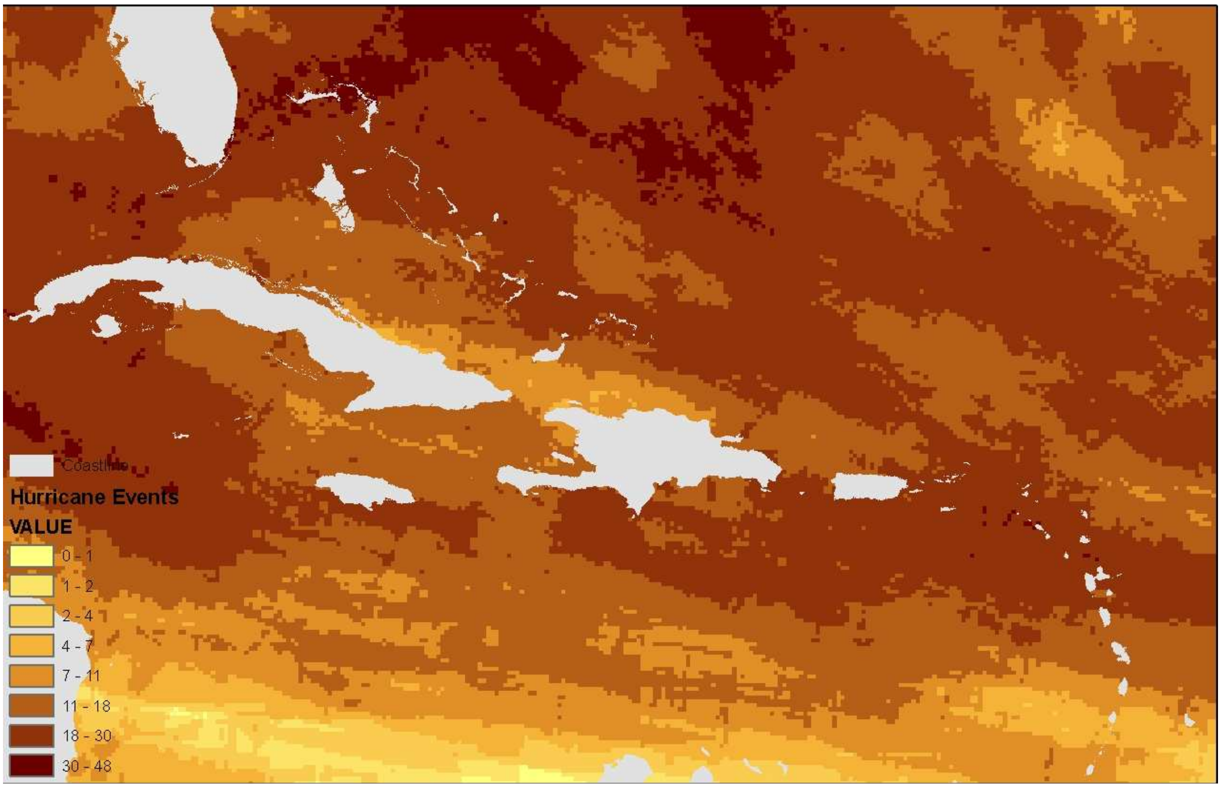

Figure 3. Surface representing the number of hurricane events per grid cell from 1851-2009

ALL HURRICANES – HIT ANALYSIS

This analysis attempts to quantify hurricane exposure in the Caribbean on a basin wide basis as well as an island by island analysis. As described in the Methodology section two surfaces were created that represented the exposure of each grid cell to hurricanes by all storms and only those storms category 3 or above on the Saffir-Simposon scale. Figure 3 shows the output of this analysis on all storms. It is immediately clear that there are two strong channels for hurricanes in the Caribbean. The northern most channel moves north over the Greater Antilles and across the Bahamas and eventually into South Florida. The southerly channel moves through across the Antilles (East to West) to the south of Puerto Rico and Hispaniola, just south of Jamaica across the Cayman Islands. These two channels tend are likely influenced by the absence of large land masses in them. This follows well with the expectations of climate science as large land masses would tend to decrease the strength of storms rapidly.

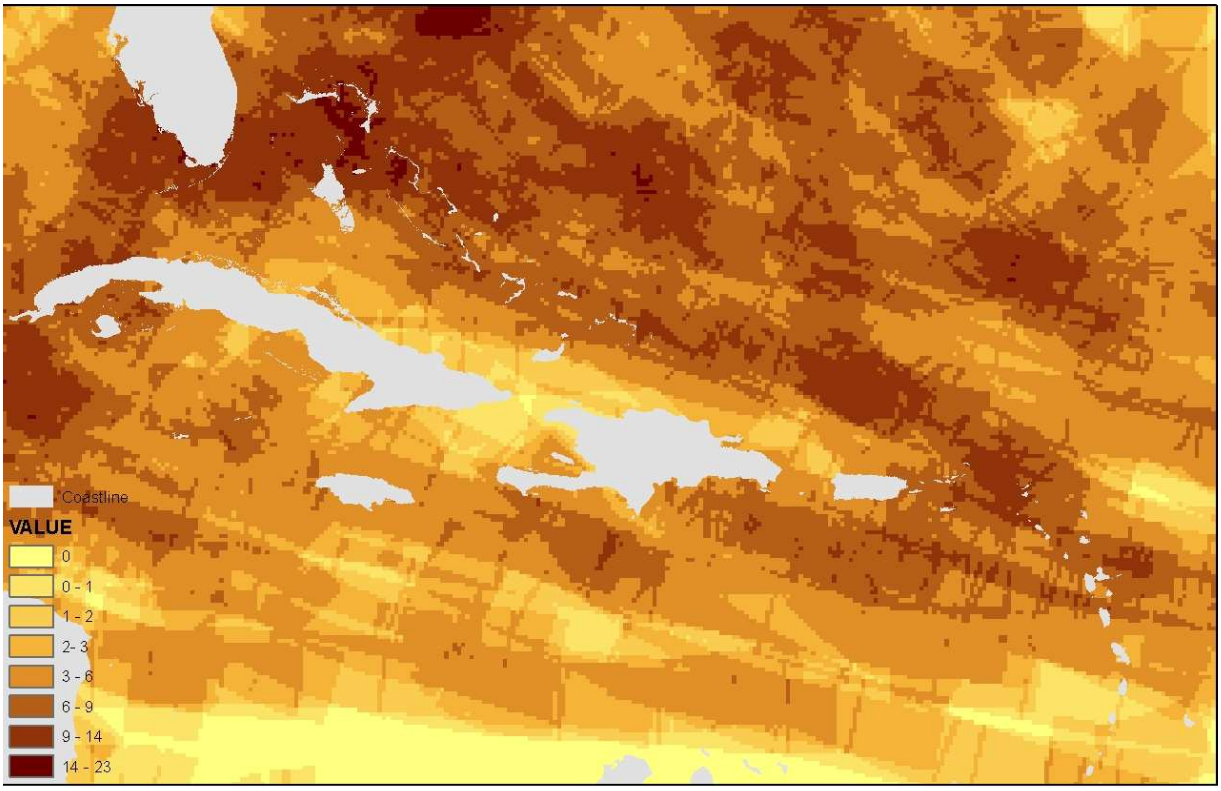

Figure 4. Surface representing the number of Category 3 or greater events per grid cell between 1851-2010 in the Caribbean

CAT3+ HURRICANES – HIT ANALYSIS

Figure 4 represents the same analysis as Figure 3 but only applied to those storms that are greater than category three on the Saffir-Simpson scale. The pattern is quite similar to the pattern seen in Figure 3, with two distinct channels. The difference appears to be in the concentration of the paths. It would appear that formation of strong hurricanes is favorable over a smaller region within the two channels. This follows from what is known about hurricanes growth and suggests that the strongest of hurricanes tend to occur in the most ideal of conditions which appear to happen most often in the two channels mentioned in the discussion of Figure 3. There is also appears to be a higher concentration of stronger storms in the northern channel which suggests more favorable conditions on average in this region.

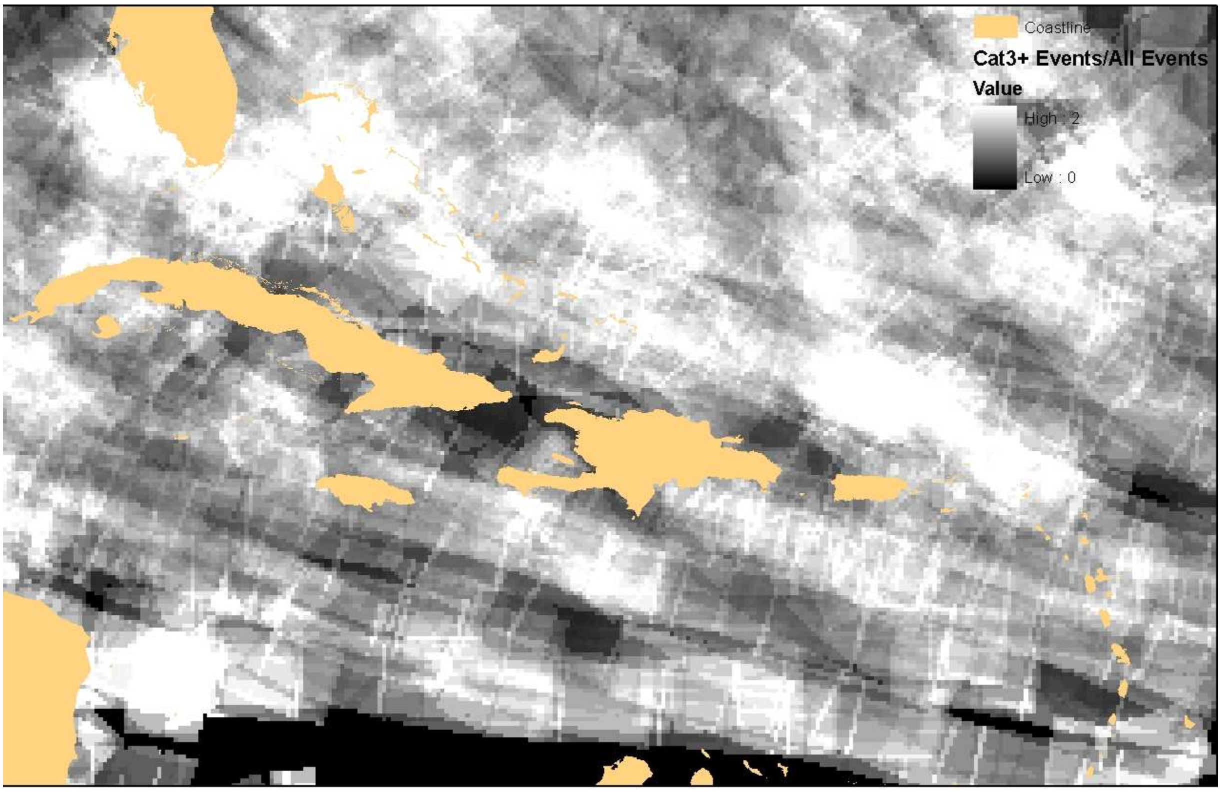

Figure 5. Surface representing the ratio of Category 3 or greater storms to all Hurricanes in the Caribbean between 1851-2010

RATIO ANALYSIS

While there is clearly a correlation between the concentration of strong hurricanes and the concentration of all hurricanes, the ratio of the two, shown in Figure 5 indicates that there may be more to the relationship than a simple concentration of the effect. In particular there is a clearly a confluence of strong hurricanes along the channel to the north, over the Bahamas and near South Florida. This is likely due to the effects of the hurricane life cycle, i.e. it simply takes a persistence of ideal conditions to create a category three or higher hurricane and given that hurricanes move east to west along the channel those regions drawn out in Figures 3 and 4. It is especially interesting to note that the southerly channel does not appear to be nearly as effective a generator of strong storms, so in general it appears that islands in the north and east of the Caribbean appear to have the highest likelihood of strong hurricane susceptibility.

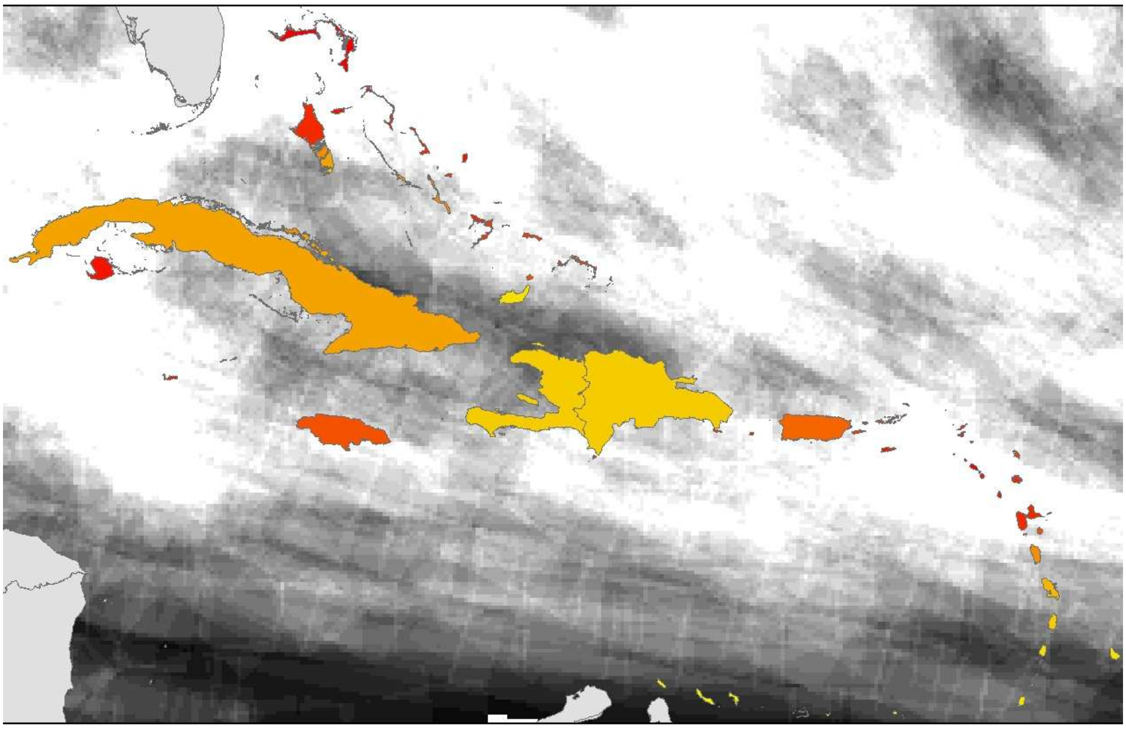

Figure 6. Chloropleth map illustrating the total number of storms to strike each island in the Caribbean from 185-2010. Higher frequencies appear as darker colors.

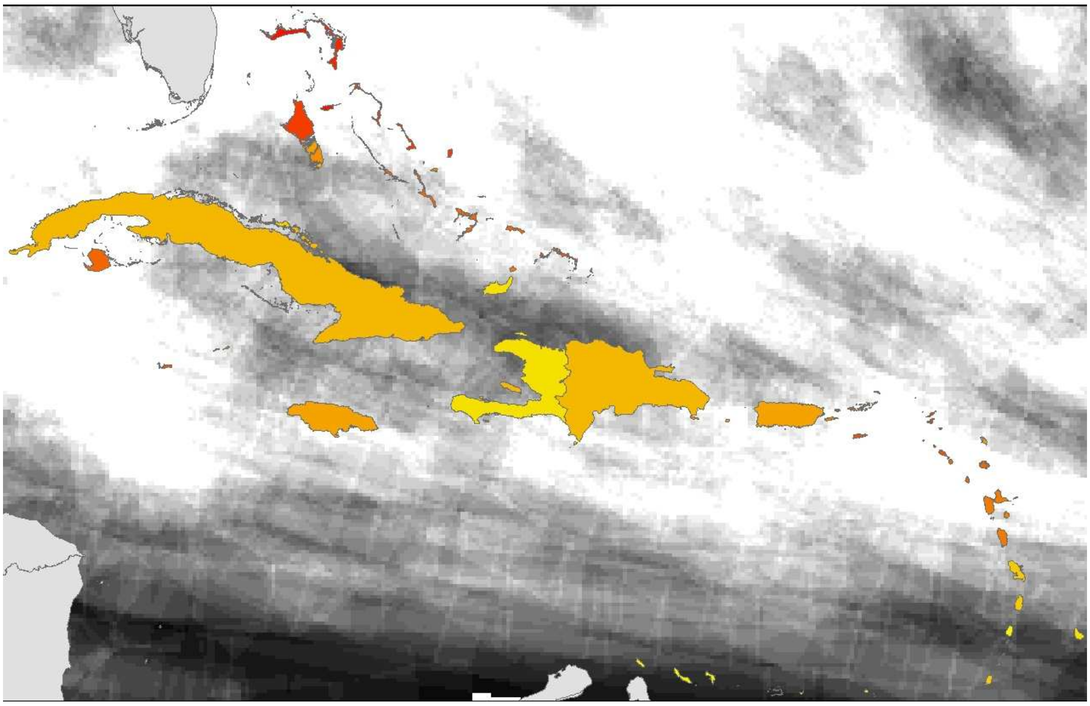

Figure 7. Chloropleth map illustrating the total number of Category 3 or greater storms to strike each island in the Caribbean from 1851-2010. . Higher frequencies appear as darker colors.

ZONAL STATISTICS

While the surface data provides good insight into the underlying physical processes and general channels of hurricane development the impact of a hurricane is non-existent if it never makes landfall. In order to determine the relative prevalence of actual landfall events the average number of strikes per islands was appended to the Reefs at Risk coastline polygon dataset. The results are quite striking in both cases. In particular there appears to be a strong concentration of hurricane land fall in the islands of the Bahamas. This is even stronger when considering intense storms only. Of particular interest here is the island of New Providence, home of the country's largest city Nassau. This island hasn't received a hurricane landfall of any significance since 1966 (Betsy) and is often considered one of the safer islands in the nation. It appears that the island is simply in a statistically anomalous lull and is in fact one of the recipients of the highest number of hurricane landfalls. This is in contrast with the island nation of Barbados, which, much like New Providence is often cited as being a low risk for hurricane landfall. Here we see perception being borne out in actual statistics, with a remarkable low 8 recorded hurricane landfalls since 1851.

CONCLUSION

While it was unsurprising to see a concentration of storm tracks it was particularly interesting to see that this concentration is split between two major channels. In hindsight the shape of the Caribbean chain of islands does provide hints to the likely pattern when the physical process of hurricane genesis and strengthening are considered. Future analysis would certainly better incorporate the data found in the EBT dataset to create more realistic buffers for the storm tracks. While the dataset is temporally limited in comparison it would be interesting to see if any new trends emerge given this level of detail. The analysis could also be broken up broken up to determine if there is any change over time in the nature of these patterns across the hurricane season and over the years.

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