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THE 80 CYCLONES MYTH

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1. Introduction

myth: A traditional story accepted as history and/or fact.

For the past several decades there has been a persistent myth that the annual global number of tropical cyclones is much more stable than would be expected given the large variability observed within the individual cyclone basins. Early references to the myth invoked it as evidence that there are important feedbacks between the storms and the global climate that imply global-scale limits on the number of cyclones that can form each year.

While this view remains popular, an alternative explanation has arisen based on recent studies showing correlations between some basins in the interannual variability of storm numbers. The alternative view is that negative correlations between basins (such as the well-known NEP-NAT dipole caused by the ENSO cycle) increase variability within the affected basins without affecting the global total significantly.

One reason that the myth has drawn interest is that it implies the existence of relationships between tropical cyclones and climate. For example, it could be evidence that tropical cyclones produce negative feedbacks to the general circulation that ultimately limit their numbers. It might also have important implications estimating the characteristics of tropical cyclones in past and future climates. Henderson-Sellers et al. (1998), in their post-IPCC assessment of tropical cyclones and climate change, noted this connection between the myth and the issue of hurricanes in future climates.

Whatever the cause of the observed storm climatology, the myth is based on the belief that if there is an above-average number of storms in one basin, then the sum of the storm numbers in the other global basins will usually be somewhat below average that year. We will refer to this as compensation. The myth is intriguing, and the lead author confesses that he is one of the many who has passed it on to a large number of students and other colleagues over the years. Alas, it also turns out to be false.

This study first examines the question of whether or not the myth is true. That is, is the global annual number of cyclones really less variable than would be expected from the observed variability within the individual storm basins? It then examines relationships between storm activities in the different basins in an effort to determine the modes of tropical cyclone variability.

2. Data

The average annual number of tropical cyclones (maximum winds of 17 m/s or more) is usually computed to be around 80, while the number that reach 33 m/s (called hurricanes, typhoons, or severe tropical cyclones, depending upon location) is around 43. Numbers vary slightly depending upon the period averaged and data sets used.

This study requires a global data set, and the primary sources of such data are the archives assembled by operational forecast centers around the world. The data available and procedures used to estimate tropical cyclone intensity have varied greatly between regions and in time, and considerable care should be taken with their use. These archives are one of the places where angels fear to tread.

The data used here are taken from archived tropical cyclone best track archives. They were downloaded from Kerry Emanuel's web page at MIT and were checked against

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original source files from warning centers. Data were grouped into five tropical cyclone basins to be consistent with recent studies of tropical cyclone climatology. These basins are: North Atlantic (NAT), Northeast Pacific (NEP), Northwest Pacific (NWP), North Indian Ocean (NIO), and Southern Hemisphere (SH). However, combining the Southwest Pacific and South Indian Ocean into a single basin may not be desirable for some studies.

After examining the data from each basin and the various published discourses on the data characteristics, we came to the conclusion that no intensity data should be used from years earlier than 1983. One can go back further in the NWP and NAT basins, but in the others (particularly the NIO and SH), there are too many missing or inaccurate intensities for this type of study. Further, since the Joint Typhoon Warning Center did not go back earlier than 1985 during its attempt to reconcile and correct earlier data sets, we chose that year as a more conservative starting point. Thus, our data are from the 19-year period from 1985-2003. Only data for systems with tropical storm or stronger intensities are used, as there are inconsistencies between the basins in the reporting of tropical depressions and disturbances.

During our analysis period the average global number of hurricane-strength storms was 49 with a standard deviation of 6.7. There was also an average of 38 tropical storms each year.

3. Methodology

The first task is to see whether the variance of the observed global storm number differs from the variance that would be expected if each basin varies independently of the others. If each of n basins had the same mean number of storms and the same variance pattern, then the variance of the sum of the five basins would simply be the square root of n times the variance of an individual basin.

The problem is somewhat more complex when each basin has different properties, so we adopted a Monte-Carlo method. We created 1000 annual storm totals by randomly drawing a yearly total from each of the five basins, summing them, and repeating the process 1000 times. These statistics were compared to the observed global storm totals.

If the myth is true, then the standard deviation of the observed global storm number should be smaller than the standard deviation of the number created from the random draws. This is because the implied compensation within the tropics (a negative correlation between any one basin and the sum of the other four) would reduce the variance of the observed global total relative to random draws.

Conversely, there could also be anti-compensation between basins. This would occur if the positive correlations in storm numbers between various storm basins were larger than any negative ones. In other words, an above-normal storm number in one basin would tend to be correlated with an above-normal sum of the numbers in the remaining four basins.

Note that if there is a long-term trend in the global storm numbers, this would create a positive correlation between storm numbers in the various basins that would have nothing to do with the issue of inter-basin compensation within a given year. Therefore, we removed the 19-year trend from each basin and repeated the analysis. Only the de-trended analyses are shown here. We also examined the effects of shifting the SH data set in time so that the total storm numbers for that basin were for a single season, rather than a calendar year. The effects of this shift were small and will not be discussed further in this paper.

The above analysis was carried out for each of six intensity categories (tropical storms and hurricanes in categories 1-5 of the Saffir-Simpson scale) and for various combinations of these categories. These analyses were performed for both storm numbers and storm days. Correlations of storm numbers/days between basins were analyzed. Factor analysis was used to determine patterns of variability, and the relationships between all of the above were correlated with three ENSO indices to determine the role of ENSO in the global patterns. For brevity, only the results of the storm count analyses will be presented here, but the storm day results are similar.

Results

There is no evidence of net compensation between basins of the annual storm number. For all hurricanes (categories 1-5) only 26% of the random draws produced annual totals with standard deviations as large as the observed standard deviation (SD) (Table 1). For there to be statistically significant net compensation between basins, the SD of the random draws would have to exceed the observed SD 95% of the time (50% of the time would be expected if the totals were totally random).

When only the most intense storms are analyzed (categories 4 and 5), only 6% of the random draws have SDs that exceed the observed SD. This indicates that the strongest storms actually appear to be exhibiting anti-compensation (that is, the basin counts are positively correlated, such that an above-normal intense storm number in one basin is likely to occur with above-normal numbers in the sum of the other basins as well). This result does not quite reach the 95% significance level, though that level is reached for the analysis of intense storm days (not shown).

Type:	TS to 5	1 to 5	4 to 5
Number	87.11	49.37	15.95
SD - OBS	8.33	6.69	5.36
SD - draw	8.56	6.09	4.26
% of draw over SD-OBS	55.30	26.60	6.00

TABLE 1: Annual global number of storms for three intensity groups, the SD of these means over the 19-year sample, the SD of the 1000 random draws for 19 years, and the percentage of the random draws whose SD exceeds the SD of the observed totals.

Correlations between annual storm numbers in the individual basins are shown in Table 2 for all hurricanes. There are strong negative correlations between total storm numbers in the NA and in both the EP and WP. There is also a large negative correlation between WP and IO storm activity. The WP, EP, and SH basins are all positively correlated with each other. When the analysis is restricted to category 4-5 storms, the pattern is generally similar, but the negative correlation between the AT and both the EP and WP increases to -.57 (not shown).

1 to 5					
Basin	AT	EP	IO	SH	WP
AT	1.00	-0.27	0.42	-0.09	-0.48
EP	-0.27	1.00	-0.06	0.16	0.44
IO	0.42	-0.06	1.00	0.24	-0.33
SH	-0.09	0.16	0.24	1.00	0.21
WP	-0.48	0.44	-0.33	0.21	1.00

TABLE 2: Correlations between annual storm numbers in the five basins (Categories 1-5).

In an effort to understand the inter-basin correlation patterns, observed storm numbers in each basin were correlated with each of three ENSO indices: SOI (Southern Oscillation Index), EQ-SOI (Equatorial SOI), and MEI (Multivariate ENSO Index). Each of the three indices produced very similar results, so only the EQ-SOI is discussed here.

A positive EQ-SOI is strongly correlated with above-normal storm activity in the AT and below-normal numbers of storms in the EP and WP, as has been shown in previous studies (e.g. – Gray et al., 1993).

Figures 1-3 show results of the factor analysis of hurricane numbers (categories 1-5). The three largest factors explain 76% of the total variance. Loading factors (scaled from 0.00-1.00) are shown in the boxes. The boxes are shaded to emphasize positive and negative correlations between basin storm numbers for each factor. Factor #2 is not related to ENSO. It appears to reflect an E. Hemisphere dipole between the NW Pacific and the N Indian Ocean, but this may be partially obscured by the merging of the SW Pacific and SIO into a single basin.

Conclusions

This study analyzes tropical cyclone interannual variability from 1985-2003. The variability of the total number of global storms with maximum winds greater than 17 m/s is found to be indistinguishable from the variability that would arise if the storms in each basin formed randomly in time with the variability observed in that basin. There is no observed tendency for above-normal cyclone activity in one basin to be compensated by net below-normal activity averaged over the remaining basins.

There is also a suggestion that interannual variability in the global number category 4-5 storms is greater than would be predicted from independent variations in the five basins.

There are positive and negative correlations between annual tropical cyclone numbers and storm days in various basins, with the strongest factor apparently being related to ENSO. There are also non-ENSO-related inter-basin correlations, some of which are intensity dependent.

The results suggest that tropical cyclones do not have the broad reaching effects on the global circulation required for storms in one basin to inhibit or enhance storm activity in another. Rather, they seem to form when conditions permit, and the occurrence of favorable conditions is modulated by larger-scale changes in the tropical circulation.

Perhaps this should not be too surprising. Earlier studies have indicated that within the atmosphere the larger-scale effects of a tropical cyclone are not dramatic (e.g. – Frank, 1977, 1982). They export kinetic energy in the upper troposphere, perhaps enough to account for a few percent of the total in limited zonal bands when they are active. They may increase total rainfall within the tropics by increasing the evaporation rate. (The anomalous rainfall does not increase the mass flux through the storm, but rather raises the outflow level. This probably affects the tropical tropopause.) They may have more significant and long-lasting effects within the ocean, but we suggest that these would probably be too slow to have strong effects upon the current storm season.

The strongest link between tropical cyclone frequency and the global circulation may be related to the time required to build up enough vorticity in a monsoon trough region to promote instability and hence cyclogenesis. Globally, the majority of tropical cyclones form in or near monsoon troughs. The authors speculate that understanding the temporal cycling of this portion of the Hadley circulation is the most promising avenue to better understanding of why the number of cyclones is around 80 per year.

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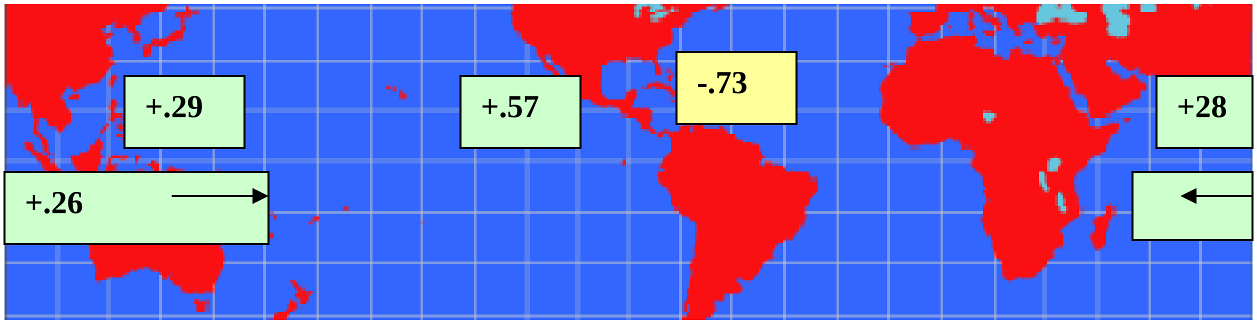

Figure 1: First factor of basin hurricane number variability, dominated by the ENSO signal. Numbers are factor loadings. Positive loadings are shaded green, while negative ones are shaded yellow. This factor explains 46 % of the variance.

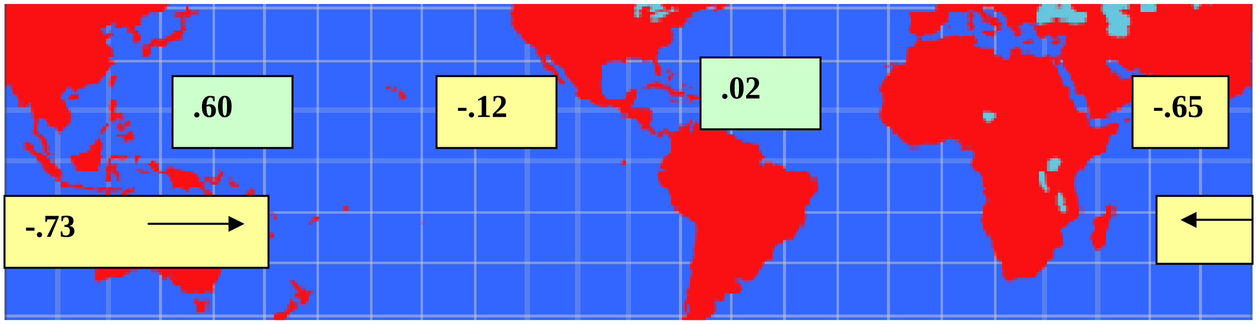

Figure 2: As in Fig. 1, but for factor #2, explaining 17 % of the variance.

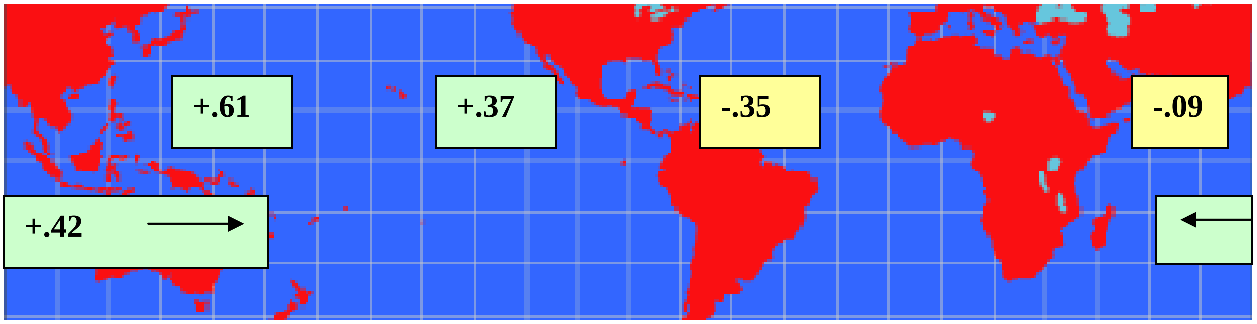

Figure 3: As in Fig. 1, but for factor #3, explaining 13 % of the variance, includes a moderate ENSO signal.