Hurricanes and Tropical Storms: Are They Getting Worse?

Data Sources

Data is taken from the US National Hurricane Centre Data Archive, which is within the National Oceanic & Atmospheric Administration (NOAA), and hence is a US Government agency. There are two databases, the Atlantic HURDAT2 database, which contains data for the Atlantic ocean from 1851 to 2018, and the Northeast and North Central Pacific database, also confusingly referred to as HURDAT2, which contains Pacific ocean data from 1949 to 2018. For those wishing to carry out their own analyses, the format of these databases is explained here. They contain data for many storms, some of which are less severe than hurricanes or tropical storms.

In addition to analysing data taken directly from these numerical databases I have also used NOAA's own listing of the numbers of hurricanes per year, and their disaggregation into "severe hurricanes". The definition of "hurricane" which they deploy is that of the Saffir-Simpson Hurricane Scale at level 1 or higher. This means a sustained wind speed of 64 knots and higher. NOAA define "Major Hurricanes" as Saffir-Simpson Hurricane Scales 3, 4, or 5, which means sustained wind speeds of 96 knots and higher. I have also used directly NOAA's calculations of annual Accumulated Cyclone Energy (ACE). This is an index that combines the numbers of storm systems with how long they persisted and how intense they became. It is calculated by squaring the maximum sustained surface wind in the system every six hours that the cyclone is a Named Storm and summing it up for the season. It is expressed in 10^4 knots^2.

Data Shortcomings and Other Studies

Unfortunately the hurricane data all the way back to the mid-nineteenth century cannot be used in a naïve fashion to indicate long terms trends. The reason is that it is badly affected by observation bias. There were no planes (still less satellites) in the nineteenth century, and shipping was slow. Observations of severe storms were made incidentally. No one made it their business to go chasing storms, as was to occur later. This is how the NOAA express the problem,

"*Because tropical storms and hurricanes spend much of their lifetime over the open ocean - some never hitting land - many systems were "missed" during the late 19th and early 20th Centuries (Vecchi and Knutson 2008). Starting in 1944, systematic aircraft reconnaissance was commenced for monitoring both tropical cyclones and disturbances that had the potential to develop into tropical storms and hurricanes. This did provide much improved monitoring, but still about half of the Atlantic basin was not covered (Sheets 1990). Beginning in 1966, daily satellite imagery became available at the National Hurricane Center, and thus statistics from this time forward are most complete (McAdie et al. 2009).*"

I would add that satellite technology has improved significantly since 1966, so the increase in observational efficiency is likely to have continued well beyond that date.

The paper by Vecchi and Knutson 2008 attempts to correct the data for missing storms (Atlantic region), and then relate the corrected data to the "main development region sea surface temperature" (MDR SST). Their major conclusion is that whether there is a positive relationship between MDR SST and the annual number of tropical cyclones depends upon the time interval used. They note,

- *Using the base case adjustment for missed tropical cyclones leads to an 1878 – 2006 trend in the number of TCs that is weakly positive, though not statistically significant, with p ~ 0.2.*
- *The estimated trend for 1900 – 2006 is highly significant.*

However, they go on to note that "*the 1900–2006 trend is strongly influenced by a minimum in 1910–30, perhaps artificially enhancing significance*", and,

- *Thus, the evidence for a significant increase in Atlantic storm activity over the most recent 125 yr is mixed, even though MDR SST has warmed significantly.*

These authors also note a surprising trend towards storms of shorter duration, "*The trend in average TC duration (1878–2006) is negative and highly significant*".

Simple Data Analysis

Here I avoid the observational inadequacies in the earliest data by the simple expedient of not using it. Depending upon the dataset, the start of modern global warming occurred between early- and mid-twentieth century, and rises were most marked in the second half of that century, especially after ~1970. Consequently, concentrating on storm data which excludes the nineteenth and early twentieth century should still be sufficient to identify trends associated with global warming.

The method used is simple linear regression, calculating the best fit trend gradients together with the lower and upper 95% confidence limits for these gradients. The range between the 95%CL lower and upper defined the 90%CL range. Where this encompasses zero, I conclude there is no significant trend, i.e., any apparent trend is not statistically significant at the 90% level. In common with Vecchi and Knutson 2008 I note a marked dependence of the fitted trend on the period chosen for analysis. If a trend were to be claimed, this would reflect rather badly on its significance.

Atlantic Region

Annual Numbers of Atlantic Hurricanes

Figure 1 shows the annual number of Atlantic hurricanes over the period 1944 – 2018 together with the regression best fit trend line and the 95%CL bounds on this trend. Although there is a small positive trend, it is not statistically significant, the 90%CL range encompassing zero gradient.

Figure 2 plots the number of major Atlantic hurricanes (level 3 and above, or sustained wind speeds of 96 knots or more) over the same period, 1944 - 2018. The mean trend is essentially zero.

Table 1 summaries the trend gradients and their 90%CL range for all the data presented here.

Figure 1: *Annual number of Atlantic hurricanes, 1944 – 2018, and trend line bounds*

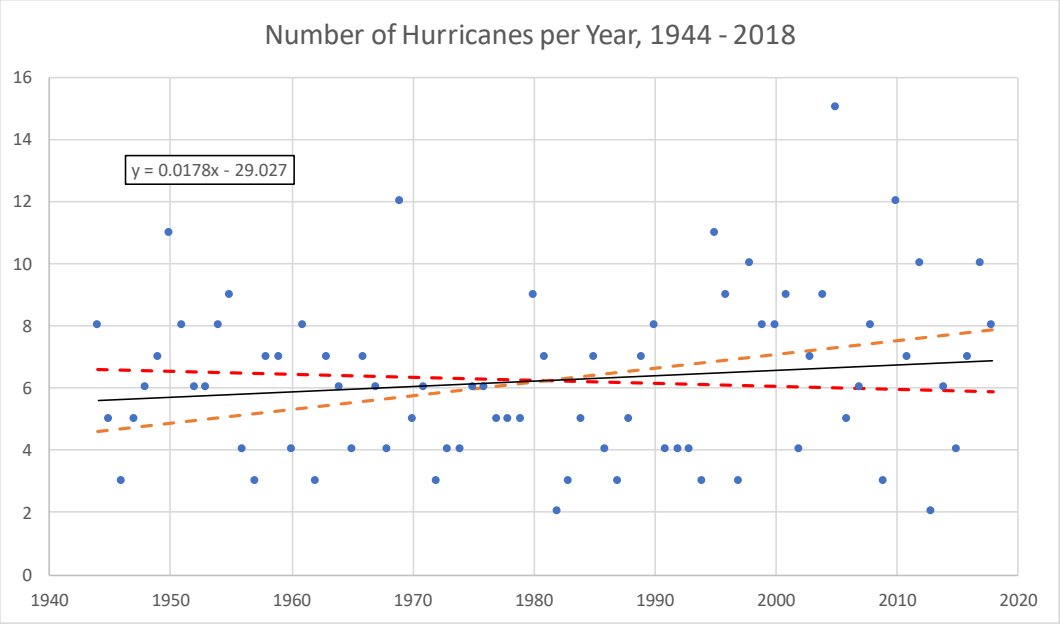


Figure 2: *Annual number of major Atlantic hurricanes, 1944 – 2018*

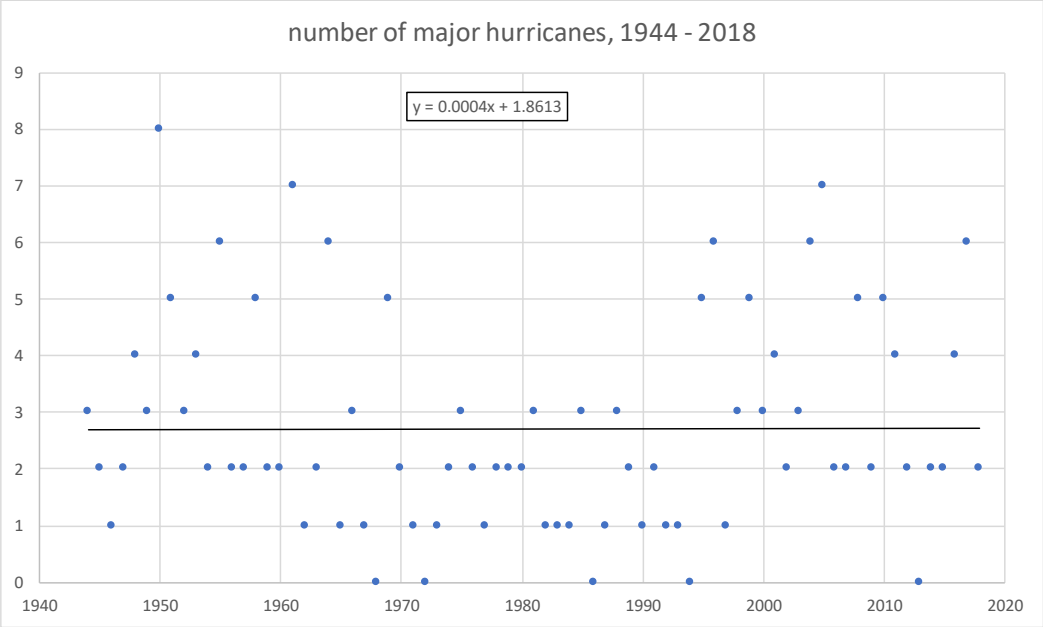
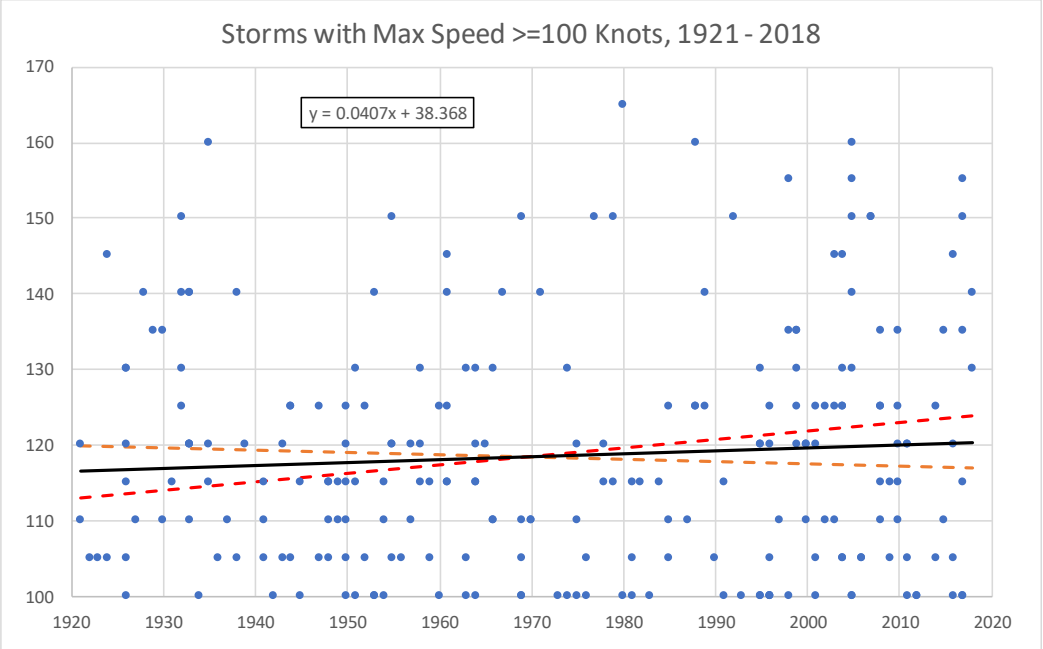


Figure 3 plots the number of Atlantic hurricanes with sustained wind speeds of 100 knots or more over a longer period, 1921 - 2018. There is a small positive trend, but it is not statistically significant, the 90%CL range again encompassing zero trend (see also Table 1).

Figure 3: *Annual number of Atlantic hurricanes with sustained wind speeds of 100 knots or more, 1921 - 2018*



Atlantic Storms' Severity: Duration, Wind Speed and ACE

Figure 4 displays the recorded storm duration, in days, for all storms recorded in the HURDAT2 database, plotted against the chronological storm number and includes all the HURDAT2 data from 1851 to 2018 (1,873 recorded storms in all). There is a positive trend towards storms of longer duration – directly the opposite conclusion of Vecchi and Knutson 2008 who reported more storms of

shorter duration. Note, however, that Figure 4 includes all storms, about half of which are below hurricane strength. (Over the period 1951 – 2018 there were an average of 11 reported Atlantic storms per year, of which an average of 5.5 were hurricane strength, and about 2 on average were major hurricanes of level 3 or higher).

Figure 4: *The duration (in days) of all recorded Atlantic storms, 1851 – 2018. Note that the lower and upper bound trend lines are hard to distinguish from the mean trend line.*

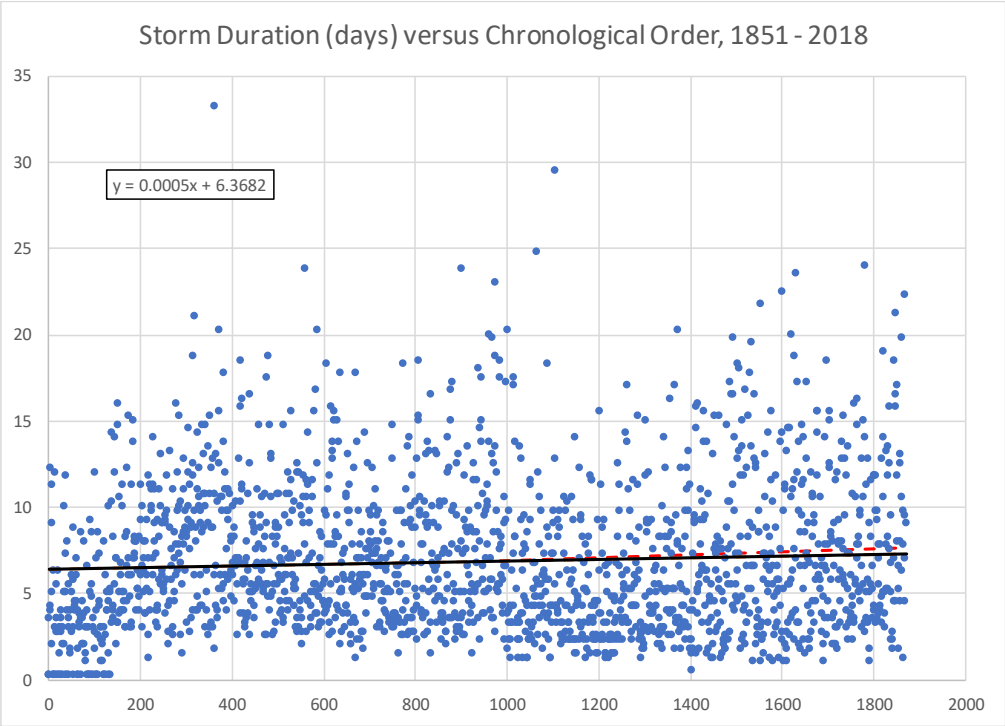
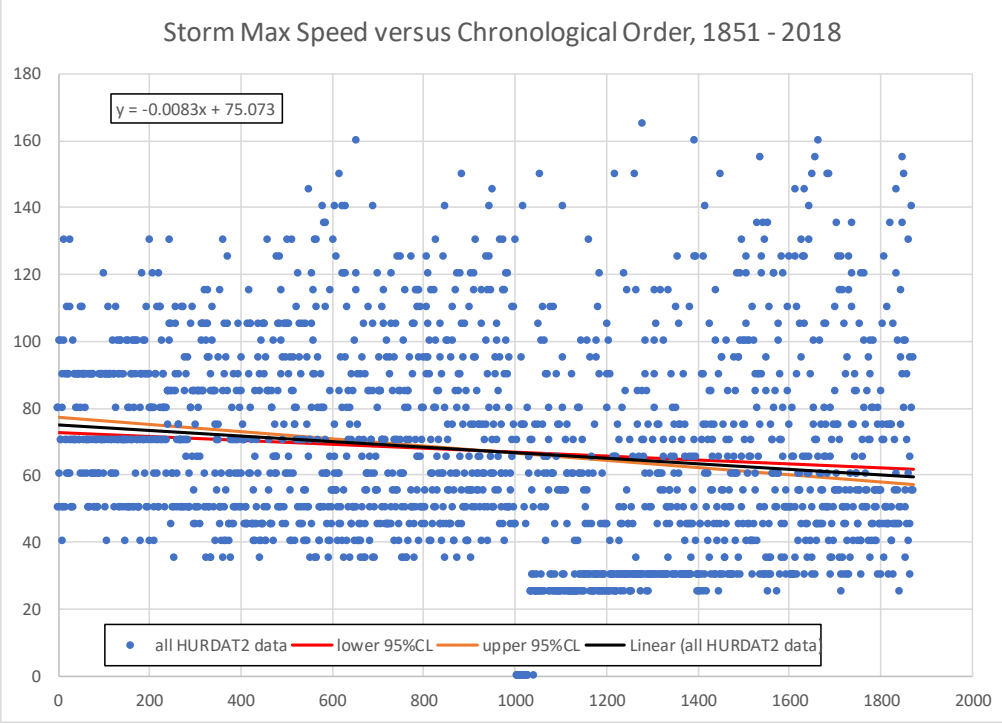


Figure 5: *The maximum wind speed (knots) of all recorded Atlantic storms, 1851 – 2018.*

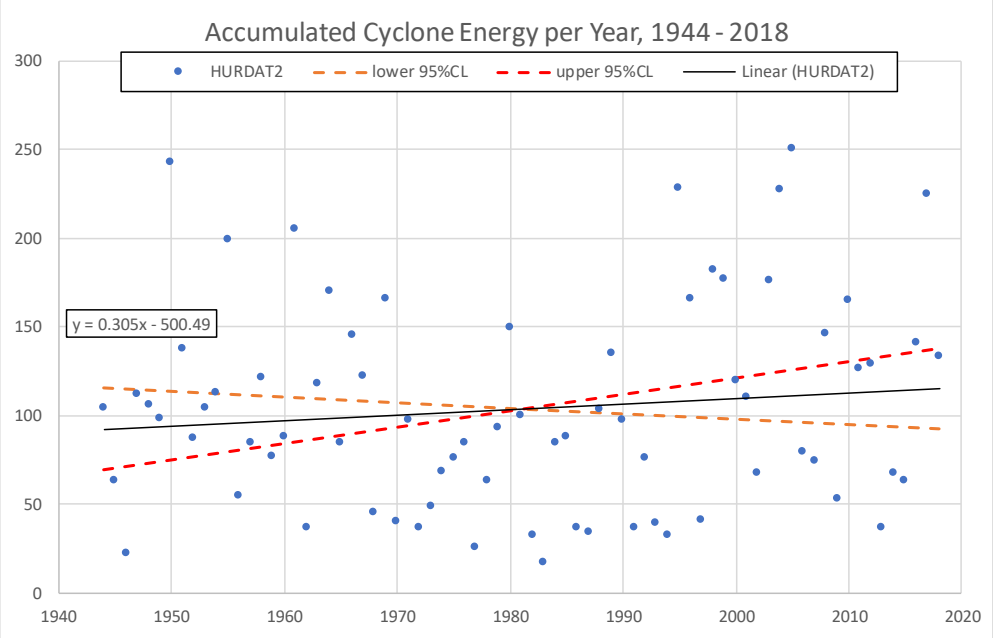


However, before the reader concludes that a “statistically significant” increase in recorded storm duration means that storms have become more severe, note that over the same period, and based on the same database of 1873 recorded storms, the maximum sustained wind speed has apparently decreased significantly (Figure 5).

It is almost certainly the case that the trends in Figures 4 and 5 are artefacts of observation bias. As the efficiency and detail of storm recording has improved one would expect that larger numbers of storms would be recorded, that there would be a tendency to record storms of somewhat lesser severity, and also to continue the record for longer (i.e., to longer durations).

Is there a way of combining the three variables - number of storms, storm duration, and storm maximum speed – into a single measure of the “storminess” of the Atlantic in a given year? Indeed there is, it is the ACE as defined above. Figure 6 plots the annual ACE over the period 1944 to 2018 (which I am taking as less affected by observation bias than periods starting earlier). There is a positive trend, but once again it is not statistically significant at the 90% confidence level, the lower-upper bounds of the trend line encompassing zero.

Figure 6: *Annual Accumulated Cyclone Energy (ACE), 1944 - 2018*



Conclusion for Atlantic Storms

> There is no statistically significant reason to believe that recorded Atlantic storms or hurricanes have become either more frequent or more severe over the last 76 years, or that the annual total storm-energy has significantly changed.

Table 1: *Summary of trend gradients and their 90%CL range, and hence significance*

Item	Mean Slope	Lower 95%CL Slope	Upper 95%CL Slope	Significant Trend?
Number of Atlantic hurricanes per year, 1944 - 2018	0.018	-0.010	0.045	No
Number of major Atlantic hurricanes per year, 1944 - 2018	~0	-0.020	0.020	No
Number of Atlantic hurricanes with wind speeds >=100 knots per year, 1921-2018	0.041	-0.030	0.111	No
Duration of all recorded Atlantic storms, 1851 – 2018 (1)	0.00050	0.00015	0.00088	Yes*
Maximum sustained wind speed of all recorded Atlantic storms, 1851 – 2018 (1)	-0.0083	-0.0058	-0.0107	Yes*
Annual Accumulate Cyclone Energy of all recorded Atlantic storms, 1944 - 2018	0.30	-0.31	0.92	No
Number of recorded NE/N Pacific storms, 1980 - 2018	0.036	-0.098	0.170	No
Maximum wind speed for all recorded NE/N Pacific storms, 1971 – 2018	-0.076	-0.232	0.079	No

** See text for interpretation.*

(1) Regressed x-axis in this case is the chronological storm number, which runs from 0 to 1873. In all other cases the regressed x-axis is the calendar year, ending in 2018.

Pacific Region

The HURDAT2 Pacific database covers the period 1949 to 2018 at the time of writing. It covers the Northeast and North Central Pacific region only. Despite the far later starting year compared with the Atlantic database, the same caution regarding incompleteness applies in the first few decades. NOAA make this warning,

"*The database goes back to 1949, but it is far from being complete and accurate for the entire duration. Uncertainty estimates of the best track parameters are available from Torn and Snyder (2012) and Landsea and Franklin (2013) for the Atlantic, but may be relevant for the Northeast and North Central Pacific best tracks as well. The lack of completeness in the dataset before the satellite era (beginning around 1970) is well-recognized (e.g., Blake et al. 2008) and any long-term variability and trends so derived must be treated very cautiously. It should be noted that records for the most intense eastern North Pacific hurricanes are particularly uncertain prior to 1988*." (my emphasis)

Numbers of Pacific Storms

In view of the above note of caution, Figure 7 plots the annual number of recorded Northeast and North Central Pacific storms starting in year 1980. This remains a meaningful time period because the bulk of the approximately 1°C increase in global average temperature (GAT) has occurred since 1980 (see here). The slight upward trend is negligible and not statistically significant (see also Table 1 for the 90%CL range).

Severity of Pacific Storms

Figure 8 plots the maximum sustained wind speed for all recorded storms from 1971. There is no significant trend.

Conclusion for Pacific Region:

There is no statistically significant reason to believe that the frequency or the severity of NE/N Pacific storms has changed over the period in which GAT has increased.

Figure 7: *Number of recorded Pacific storms, 1980 - 2018*

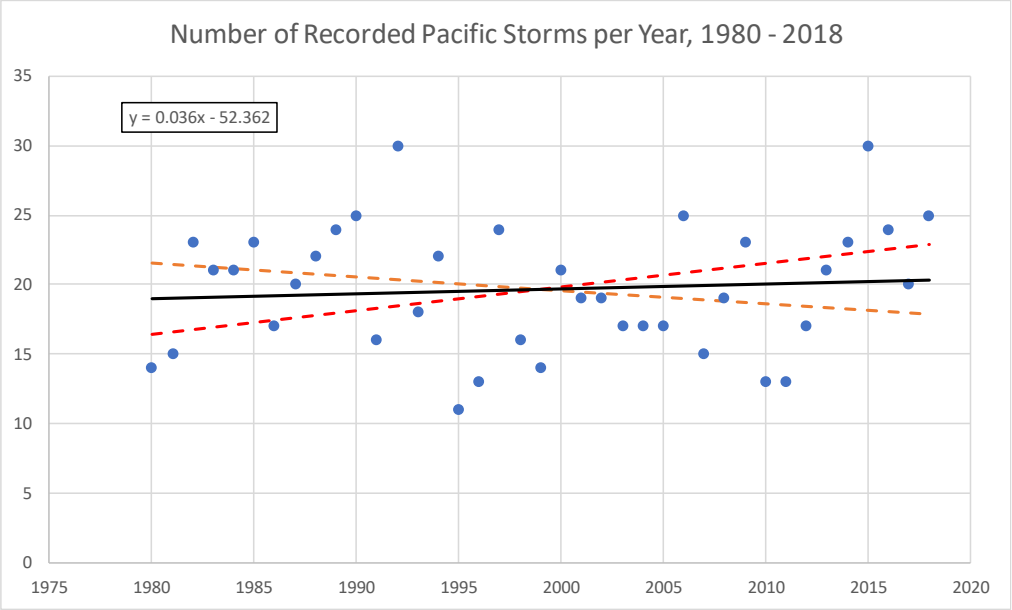


Figure 8: *Maximum wind speed for all recorded NE/N Pacific storms, 1971 - 2018*