TROPICAL HURRICANES

In the age of global warming

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About the author

Paul Homewood had a career as an accountant in industry. He has been writing on climate and energy issues since 2011.

Executive summary

2017 saw a particularly severe hurricane season in the North Atlantic. In addition, economic losses from hurricanes are much greater than even a few decades ago. Together with 24/7 news coverage, these observations have led to renewed claims that global warming is leading to more frequent and more intense hurricanes. This idea is based on the concept that hurricanes feed off warm waters: the warmer the waters, the more intense the hurricane. In addition, economic losses from hurricanes are much greater than even a few decades ago, simply because of greater wealth and urbanisation of vulnerable coastal areas. But what does the actual data tell us?

One of the problems in evaluating long-term hurricane trends is that there have been wholesale changes in observation methodology since the 19th century. Until the 1940s, there were only ships' logs and ad-hoc land observations. Aircraft reconnaissance began in the Atlantic in 1944, but there has only been full systematic coverage by satellites and buoys since the 1970s. As a result, many hurricanes in earlier decades were not recorded at all; others had their peak wind speeds underestimated. Several studies have been carried out to try to ascertain the real underlying trends, and these were carefully considered by the IPCC in their Fifth Assessment Report in 2013. Their verdict was clear:

> In summary, [there is] low confidence that any reported long-term (centennial) increases in tropical cyclone activity are robust, after accounting for past changes in observing capabilities. More recent assessments indicate that it is unlikely that annual numbers of tropical storms, hurricanes and major hurricanes counts have increased over the past 100 years in the North Atlantic basin. Evidence, however, is for a virtually certain increase in the frequency and intensity of the strongest tropical cyclones since the 1970s in that region.

Since 2013, observational evidence has continued to support this assessment, as has new studies.

The longest and most reliable database of hurricanes is of US landfalling ones. NOAA's Hurricane Research Division has carefully reanalysed the original records of all hurricanes up to 1960. Its HURDAT database shows that there has been no increase in the frequency of hurricanes or major hurricanes (Category 3 and over) since the start of the record in 1851. Prior to Harvey, no major hurricane had hit the US since Wilma in 2005, the longest such period on record. In 2017, for instance, two major landfalling hurricanes – Harvey and Irma – hit the US, but this is not unusual. In 1893, for instance, there were three, a number repeated in 1909. The record year for landfalling hurricanes was 1886, when there were seven. Only three Category 5 hurricanes have hit the US mainland: the Labor Day hurricane in 1935, Camille in 1969, and Andrew in 1992.

Data provided by HURDAT also shows that recent hurricane activity in the North Atlantic has not been unusual by historical standards. In 2017, there were six major Atlantic hurricanes, but the highest total recorded was eight in 1950. Of last year's six, two were Category 5 – Irma and Maria – but again, this is not unusual, having occurred five times previously, including in 1932 and 1933.

Historical data shows that Atlantic hurricanes, particularly major ones, were much more common between about 1930 and 1960 than in the following three decades. Since 1990, the numbers have returned to the earlier levels. It is widely accepted that this pattern is linked to the Atlantic Multidecadal Oscillation (AMO), a natural reoccurring cycle of temperature changes in the sea surface temperatures.

A database of global hurricanes is kept, with data going back to 1970. This shows an increase in the number of major hurricanes and their accumulated energy between 1970 and 1993. This is associated with the AMO cycle too. Since 1993, there has been a decline in the frequency of all hurricanes, major hurricanes and accumulated energy.

In summary, there is little evidence that global warming has resulted in more hurricanes, or more intense ones in recent years. On the contrary, available evidence confirms that hurricane and major hurricane frequency has been similar in many prior periods.

1 Introduction

Hurricanes are giant, spiralling tropical storms that can pack wind speeds of over 160 mph and unleash more than 2.4 trillion gallons of rain a day. The Atlantic Ocean's hurricane season peaks from mid-August to late October and averages five to six hurricanes per year. Centuries ago, the Spanish used the term *huracan*, an indigenous word for evil spirits and weather gods, for the storms that sank their ships in the Caribbean. Today 'hurricane' is one of three names for a rotating tropical storm with winds of at least 74 mph (64 knots). These storms are called 'hurricanes' when they develop over the Atlantic or eastern Pacific Oceans. They are 'cyclones' when they form over the Bay of Bengal and the northern Indian Ocean, and they are 'typhoons' when they develop in the western Pacific. All further references in this paper will be to 'hurricanes', rather than cyclones/typhoons, for the sake of clarity.

It is natural that hurricanes tend to get more attention than ever nowadays, purely because of 24/7 media. However, it is also important to note that ever more people are living in areas vulnerable to hurricanes, and that there is much more in the way of infrastructure, housing and general wealth at risk. Consequently, financial losses from these events, whether insured or not, appear to be growing ever greater, even when inflation and GDP growth are taken into account. But are hurricanes actually getting worse, either in terms of frequency or severity? This paper is intended to review scientific research on hurricane activity, including the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5), and examine observational evidence, in the light of changes in observational practices since the 19th century.

Basic theory suggests that, as the oceans and atmosphere become warmer, hurricane activity should become more intense, although projections of hurricane frequency are less certain. Section 2 looks at some of these arguments in more detail.

Section 3 summarises the findings of the IPCC in AR5, and also considers relevant papers published since.

Over the years, the way that hurricanes have been observed has changed radically. As a result, many hurricanes are now recorded that would have been missed in the past. Furthermore, satellites are now able to continually assess wind speeds, thus recording peak wind speeds that may have been missed in pre-satellite days. Section 4 discusses many of these changes and their implications.

The longest and most consistent database of hurricanes is that of US landfalling hurricanes, for which NOAA's Hurricane Research Division keeps data going back to 1851, and these are analysed in Section 5. Its data for Atlantic hurricanes are discussed in Section 6.

As the IPCC reported in AR5, evidence shows that there has been an increase in the frequency and intensity of the strongest hurricanes since the 1970s. Section 7 examines the role of the Atlantic Multidecadal Oscillation in the phenomenon.

Section 8 looks at global hurricane trends since 1970, whilst Section 9 reviews studies concerning trends in hurricane rainfall.

2 Are hurricanes getting worse? – the theoretical case

The claim that hurricanes are becoming worse is made so frequently these days, both by scientists and media, that it seems to have been accepted as a universal truth. Only recently, the *MIT Technology Review* talked about 'hyperactive hurricanes', resulting from an 'altered world',[1] while MIT's Professor Kerry Emmanuel claimed that global warming increased the

of risk Hurricane Harvey-level rainfall.[2] Dr Michael Mann claimed that Harvey was almost certainly more intense than it would have been in the absence of human-caused warming, which means stronger winds, more wind damage and a larger storm surge.[3] And so on and so forth. Such claims revolve around the concept that hurricanes feed off warm waters. If seas are getting warmer as a result of climate change, so the argument goes, surely hurricanes must increase in intensity as a result.

However, in AR5, the IPCC found that there was low confidence in basin-scale and global projections of trends in hurricane frequency to the mid 20th century.[4] They also went on to say that although some studies project near-term increases in the frequency of the strongest (Category 4–5) hurricanes, there is low confidence in near-term intensity projections in all ocean basins.

As a specific exercise, Dr Roy Spencer compared major hurricane landfalls in Texas with Gulf of Mexico sea surface temperatures, and found little correlation (Figure 1).

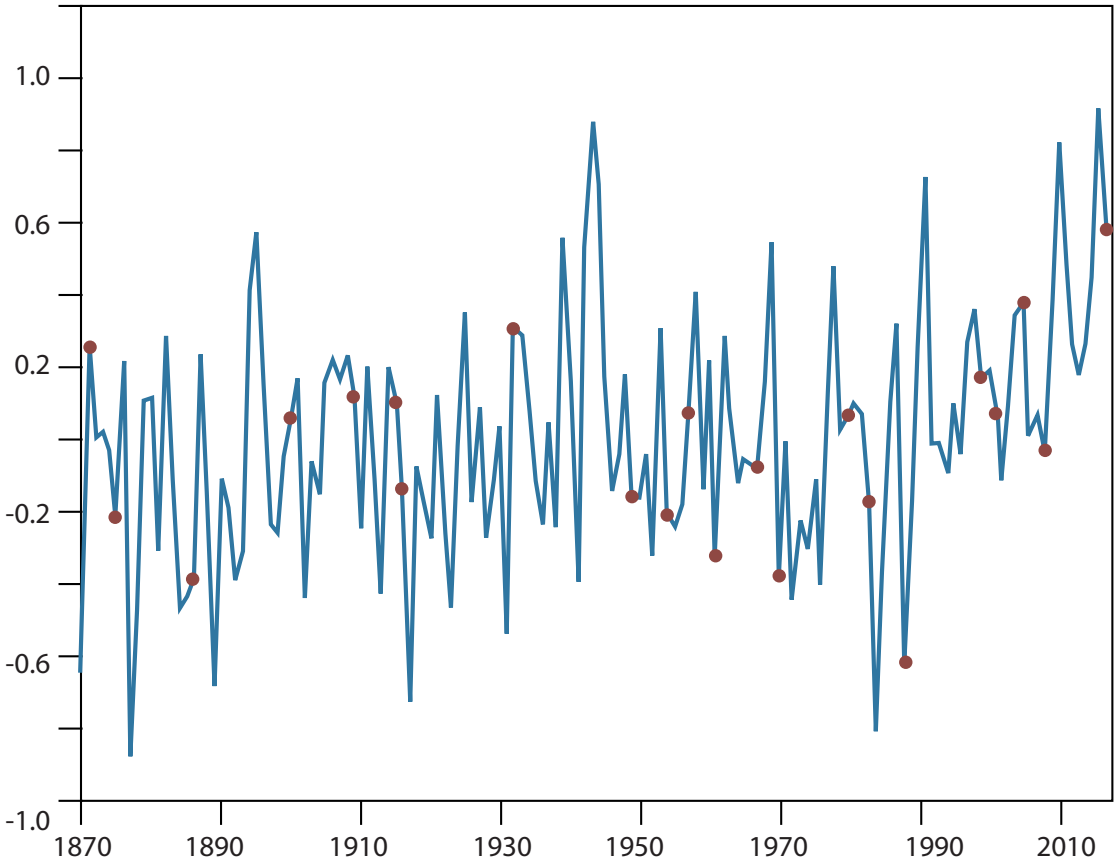


Figure 1: Sea surface temperatures and hurricanes.
Blue line: Sea surface temperature anomaly in western Gulf of Mexico (25–30°N, 90–100°W).
Red dots: years of major hurricane strikes in Texas. Source: Roy Spencer.

As he pointed out, the Gulf is warm enough every summer to produce a major hurricane. Many other factors are involved, and reasons why systems intensify are not well understood.[5] Many complex factors determine hurricane formation. Julian Heming, the Met Office's tropical prediction scientist, has offered some reasons why Irma became such a big hurricane in 2017:[6]

- The wind shear (change in wind with height) is low, meaning air can flow in up and out of the hurricane very efficiently, thus promoting intensification.
- There are no drying influences at present, such as pockets of Saharan dust which sometimes drift out over the Atlantic.
- Irma is moving fast enough to prevent cool water up-welled under the hurricane from having any impact on the continued feed of warm, moist air into the hurricane.
- Up until now there has been no interaction with large land masses that might disrupt intensification due to cutting off the moisture supply.

Research has revealed that periods of intense Atlantic hurricane activity coincide with abundant Sahel rainfall. And, of course, the reverse is true – Sahel droughts coincide with low hurricane-intense periods. These events are not coincidental; they are all part and parcel of the same climatic regime.[7]

What is apparent from even this small selection of observations is that the topic is an extremely complex one. But, of course, all of the discussion so far concerns the theory. But what do the actual observations tell us?

3 What does the IPCC say?

The IPCC Fifth Assessment Report considered the science in great detail, and concluded:

> [There is] low confidence that any reported long-term (centennial) increases in tropical cyclone activity are robust, after accounting for past changes in observing capabilities. More recent assessments indicate that it is unlikely that annual numbers of tropical storms, hurricanes and major hurricanes counts have increased over the past 100 years in the North Atlantic basin. Evidence, however, is for a virtually certain increase in the frequency and intensity of the strongest tropical cyclones since the 1970s in that region.[8]

Since AR5, there have been two papers of note. Msadek *et al.* (2015) reviewed past, present and future North Atlantic hurricane activity, based on an analysis of observational records and models projections. They stated that, when adjusted for likely missed tropical cyclones, the observational record shows no significant increase or decrease in North Atlantic hurricane frequency.[9] Then, in 2016, Walsh *et al.* reported as follows:

> …geological records of past climates have shown century-long variations in [hurricane] numbers. While no significant trends have been identified in the Atlantic since the late 19th century, significant observed trends in [hurricane] numbers and intensities have occurred in this basin over the past few decades, and trends in other basins are increasingly being identified. However, understanding of the causes of these trends is incomplete, and confidence in these trends continues to be hampered by a lack of consistent observations in some basins.[10]

The overall message is quite clear – that there is little evidence of long-term trends. Two specific issues emerge though:

- There have been changes in observation methods.
- There have been important North Atlantic trends since 1970.

These will be addressed later in this paper.

4 Changes in observation methodology

Since the 19th century, the way we observe, monitor and measure hurricanes has changed out of all recognition (Figure 2), as Hagen and Landsea summarised:[11]

> The Atlantic hurricane database (or HURDAT) extends back to 1851. However, 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). For hurricanes striking the USA Atlantic and Gulf coasts, one can go back further in time with relatively reliable counts of systems because enough people have lived along coastlines since 1900.[12]

In the Pacific and Indian Oceans, early coverage was even less comprehensive. Full satellite coverage may not have been available till around 1980.[13]

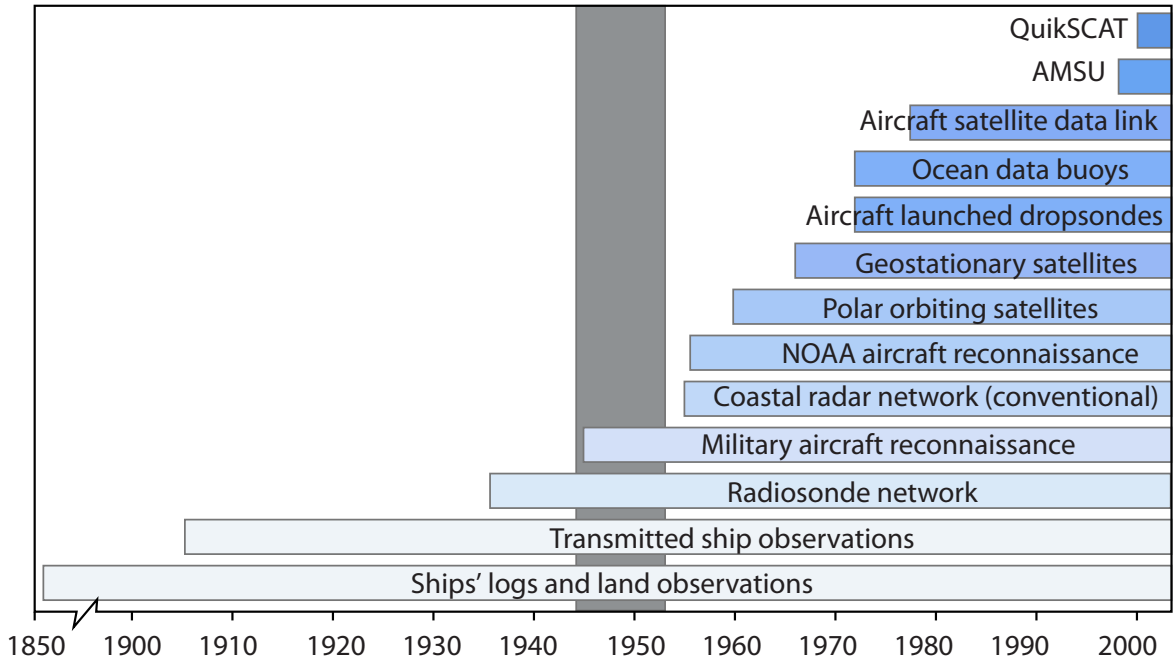


Figure 2: Changes in hurricane detection technologies.
The grey bar in the period 1944–53 is the baseline for period against which Category 5 activity is measured. Adapted from McAdie *et al.* (2009).

This lack of coverage has a particular impact on the reporting of short-lived storms, which would often have been 'missed' in earlier decades. Vecchi and Knutson made allowance for this, and concluded that (see Figure 3):

> …there is a small nominally positive upward trend in tropical storm occurrence from 1878–2006. But statistical tests reveal that this trend is so small, relative to the variability in the series, that it is not significantly distinguishable from zero…Thus the historical

tropical storm count record does not provide compelling evidence for a greenhouse warming induced long-term increase.[14]

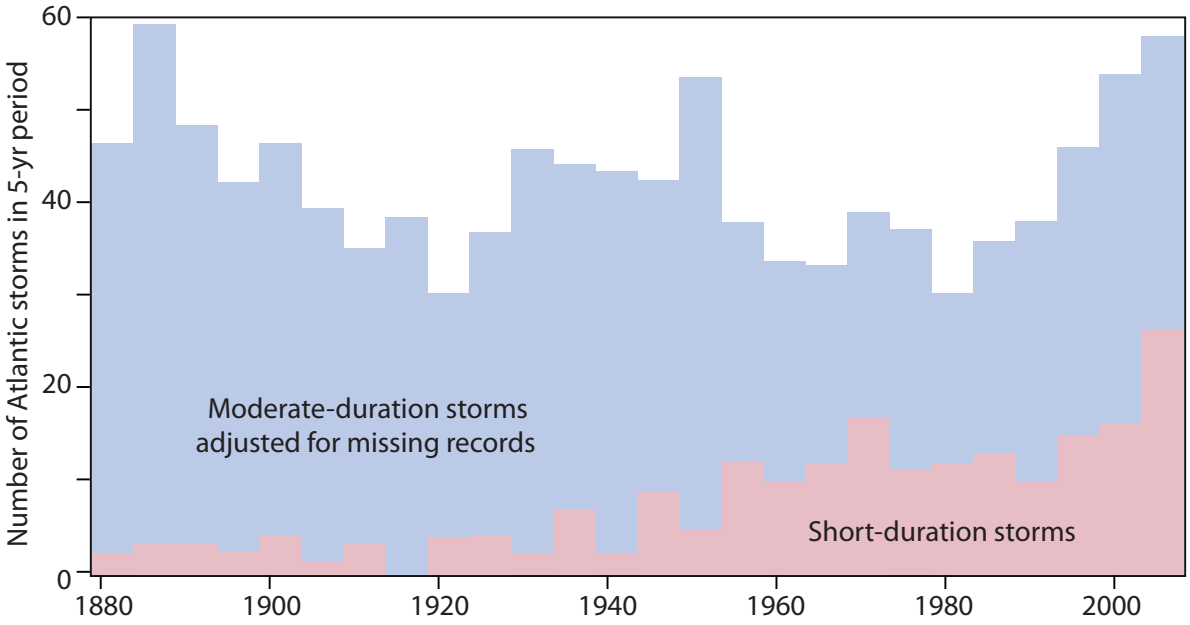


Figure 3: Effect of better observations.
Count of Atlantic hurricanes lasting more than 2 days is not increasing. Count of storms lasting less than 2 days has increased sharply, probably due to better observations. Adapted from Landsea *et al.* (2009).

It is not only the number of storms which has tended to be underestimated. Hagen and Landsea demonstrated that the strength of the most intense, Category 5 hurricanes were also underestimated prior to the satellite era:

> Observations of the peak intensity in strong hurricanes were much less common during the late 1940s/early 1950s when compared with recent years because the ability to measure the central pressure and peak winds in major hurricanes was very limited during the late 1940s/early 1950s. A Category 5 designation would be possible if a hurricane made landfall as a Category 5 at or very near a weather station, or if a ship passed through the center while at Category 5 intensity. Aircraft reconnaissance was generally only capable of recording Category 4 conditions at most because of the inability to penetrate intense hurricanes.[11]

They re-analysed ten Category 5 hurricanes, which occurred between 1992 and 2007, and found that, using 1940s' technology, only two would have been categorised as Category 5. Both of these, Andrew and Mitch, made landfall at Category 5. They concluded that, prior to the satellite era, several Category 4 and 5 hurricanes were probably misclassified as being weaker.

It is clear from all of the above that both the frequency and intensity of hurricanes were underestimated prior to the satellite era, making the measurement of long-term trends extremely difficult.

5 US landfalling hurricanes

The longest database of hurricanes is for those striking the USA Atlantic and Gulf Coasts. As the Hurricane Research Division (HURDAT) states:

> For hurricanes striking the USA Atlantic and Gulf coasts, one can go back further in time with relatively reliable counts of systems because enough people have lived along coastlines since 1900. Thus, the following records for the period of reliable data hold for the entire Atlantic basin (from 1966–2016) and for the USA coastline (1900–2016).[12]

HURDAT actually keep records going back to 1851, and have carefully reanalysed all hurricanes up to 1960, as original measurements of wind speeds may not have been accurate, particularly in the earlier years. The reanalysed data is shown in Figure 4a. There is no suggestion that hurricanes are becoming more frequent. The series average is 2.2 hurricanes per year. Since 2000, there have been 28, an average of 1.5 per year. The busiest year was 1886, when there were seven.

Again, with major hurricanes (Category 3 and stronger), there is no apparent trend (Figure 4b). The years of 2004 and 2005 were unusually busy ones, but the gap between those and the next major hurricane in 2017 is the longest period on record without a major hurricane. (Note that the categories refer to the wind speed at landfall). There is no evidence that either event is not due to natural factors.

Only three Category 5 storms have hit the US mainland:

- Labor Day – 1935
- Camille – 1969
- Andrew – 1992.

This number is too small to allow conclusions to be drawn.

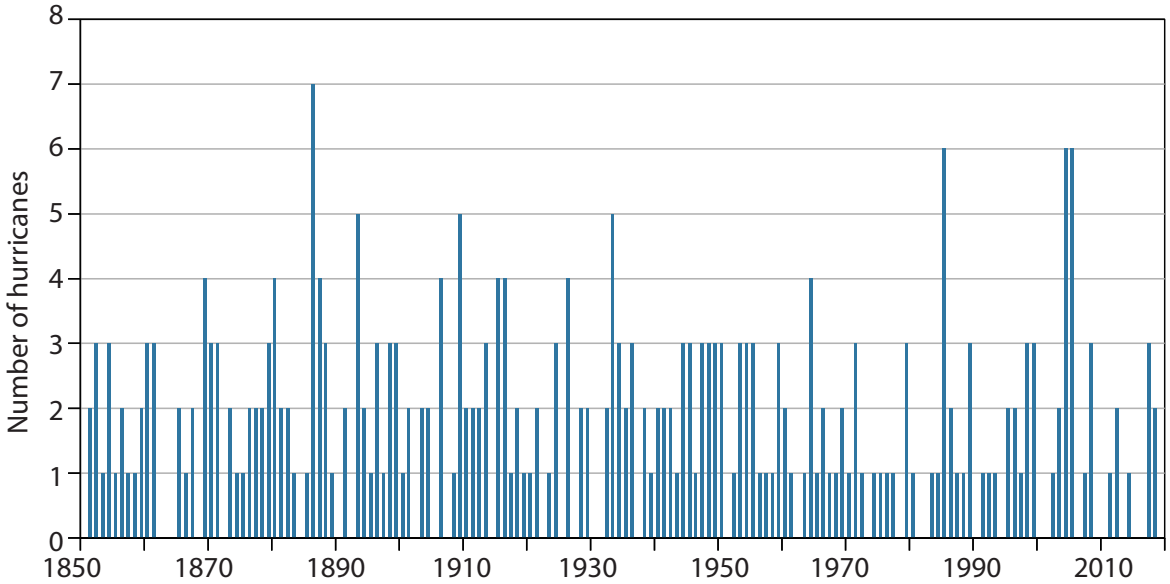
6 Atlantic hurricanes

According to HURDAT, the period of reliable data held for the entire Atlantic basin is 1966–2016.[12] Even though some hurricanes were missed prior to 1966, it is clear that earlier periods, such as the 1940s and 1950s, were comparable to the last two decades (Figure 5). For instance, between 2009 and 2018 there have been 69 hurricanes, of which 28 were major. During the 1950s, there were also 69 hurricanes, including 39 major ones. Although 2017 was a busy year, it was by no means unprecedented, either in total hurricanes or majors.

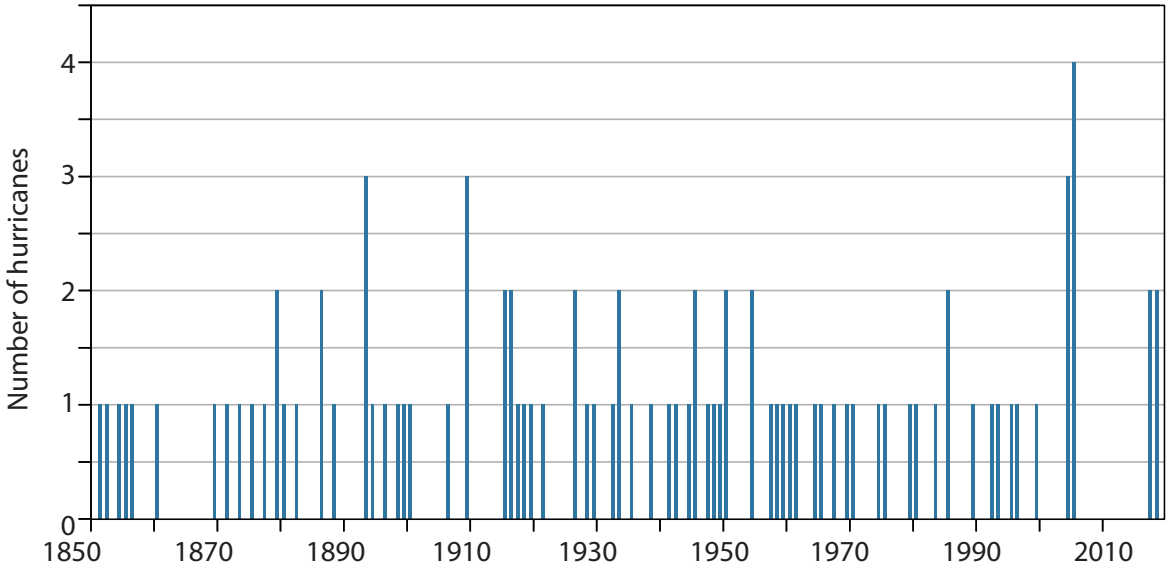
7 The Atlantic Multidecadal Oscillation

The increase in the frequency and intensity of hurricanes in the North Atlantic since the 1970s, as identified by the IPCC, is very clearly shown in Figure 5. But it is equally clear that this is part of a cyclical pattern, with greater frequency and intensity in the 1940s and 1950s. This is also borne out in the US landfalling data. This cycle corresponds closely with the Atlantic Multidecadal Oscillation (AMO; Figure 6). During the 1950s and 1960s, and again since around 1995, the AMO was in its warm phase. In contrast, the quiet hurricane years of the 1960s to 1980s marked the cold phase. NOAA explain the effects of the AMO on Atlantic hurricanes:

> …during warm phases of the AMO, the numbers of tropical storms that mature into severe hurricanes is much greater than during cool phases, at least twice as many. Since

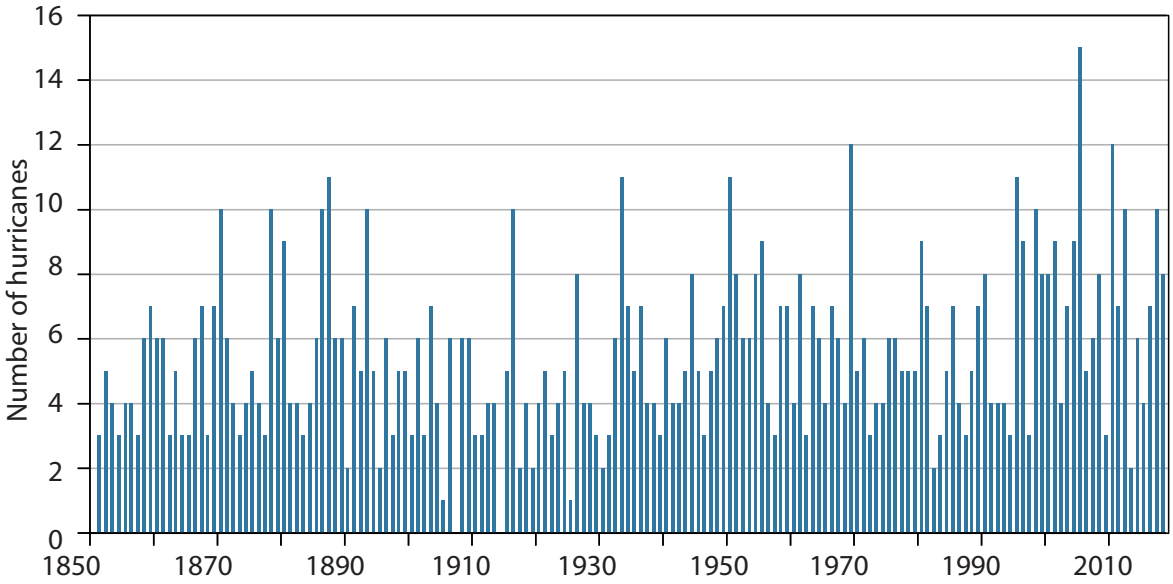


(a) All hurricanes

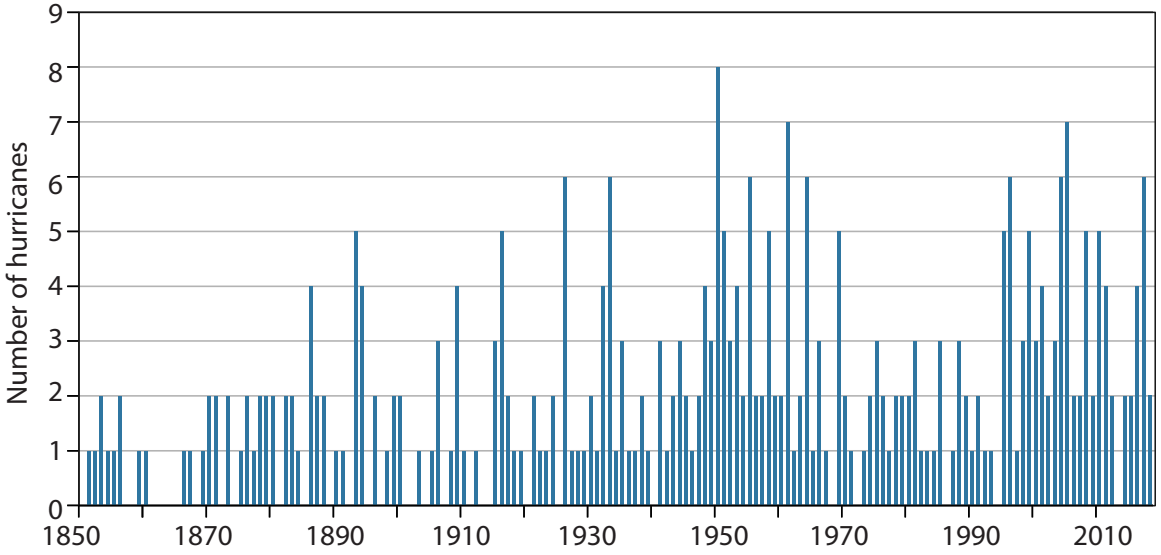


(b) Intense hurricanes (Category 3 and above)

Figure 4: Continental US landfalling hurricanes 1851–2018.
Source: Hurricane Research Division data.



(a) All hurricanes



(b) Intense hurricanes (Category 3 and above)

Figure 5: Atlantic hurricanes 1851–2018.
Source: Hurricane Research Division data.

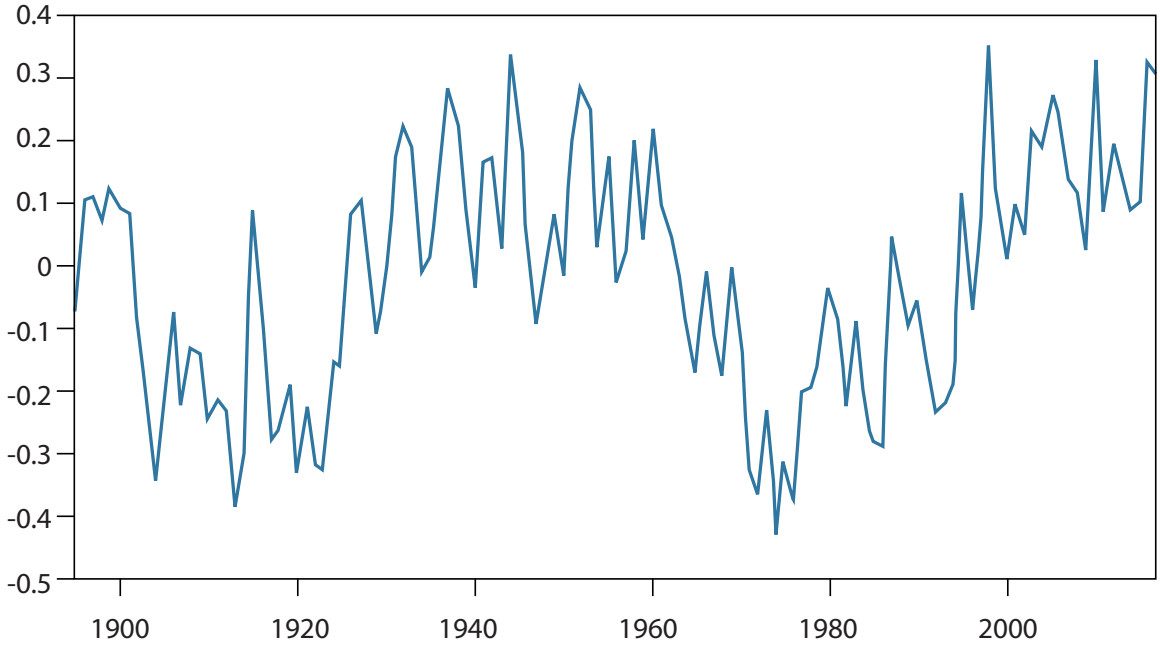


Figure 6: Atlantic Multidecadal Oscillation 1895–2017.
Jan–Dec average. *y*-axis is an anomaly scale.

> the AMO switched to its warm phase around 1995, severe hurricanes have become much more frequent and this has led to a crisis in the insurance industry.
>
> The frequency of weak-category storms – tropical storms and weak hurricanes – is not much affected by the AMO. However, the number of weak storms that mature into major hurricanes is noticeably increased. Thus, the intensity is affected, but, clearly, the frequency of major hurricanes is also affected. In that sense, it is difficult to discriminate between frequency and intensity and the distinction becomes somewhat meaningless.[15]

They also state that:

> …instruments have observed AMO cycles only for the last 150 years. However, studies of paleoclimate proxies, such as tree rings and ice cores, have shown that oscillations similar to those observed instrumentally have been occurring for at least the last millennium. This is clearly longer than modern man has been affecting climate, so the AMO is probably a natural climate oscillation.

Landsea also found that much of the multidecadal hurricane activity can be linked to the Atlantic Multidecadal Mode.[16] In 1991, he also noted that hurricane activity during different phases of the AMO were intrinsically tied in with Western Sahel rainfall patterns – low Atlantic hurricane activity and Sahel drought during the cold phase of the AMO were part of the same weather patterns, just as more intense hurricane activity and greater Sahel rainfall were associated during the warm phase.[17]

Walsh *et al.* also observe that the Atlantic basin has significant multidecadal variability in hurricane activity levels, with a more active period from the mid-1870s to the late 1890s as well as from the mid-1940s to the late 1960s. These periods may have had levels of activity similar to what has been observed since the mid-1990s.[10] Both of these earlier periods coincided with the warm phase of the AMO.

Wang *et al.* also showed that during the cold phase of the AMO, reduced rainfall in the Sahel led to a higher concentration of dust over the North Atlantic, which in turn led to fewer Atlantic hurricanes.[18]

Finally, a new study by Balaguru *et al.* has identified that in the last 30 years, rapid intensification of North Atlantic hurricanes has been occurring more frequently in the central and eastern Atlantic because of the AMO shift.[19]

As noted in Section 3, IPCC AR5 reported that there has been an increase in the frequency of very intense hurricanes in the North Atlantic since the 1970s. Whether this can be wholly explained by the AMO cannot be known at this stage. It would require several cycles of the AMO, with comprehensive availability of hurricane data, to be able to draw any conclusions with confidence.

8 Global trends

As noted, daily satellite imagery did not become available until 1966, and comprehensive coverage probably did not occur till around 1980. However, Dr Ryan Maue keeps track of global tropical cyclone data, going back to 1970 (Figure 7).[20] There is little evident trend in

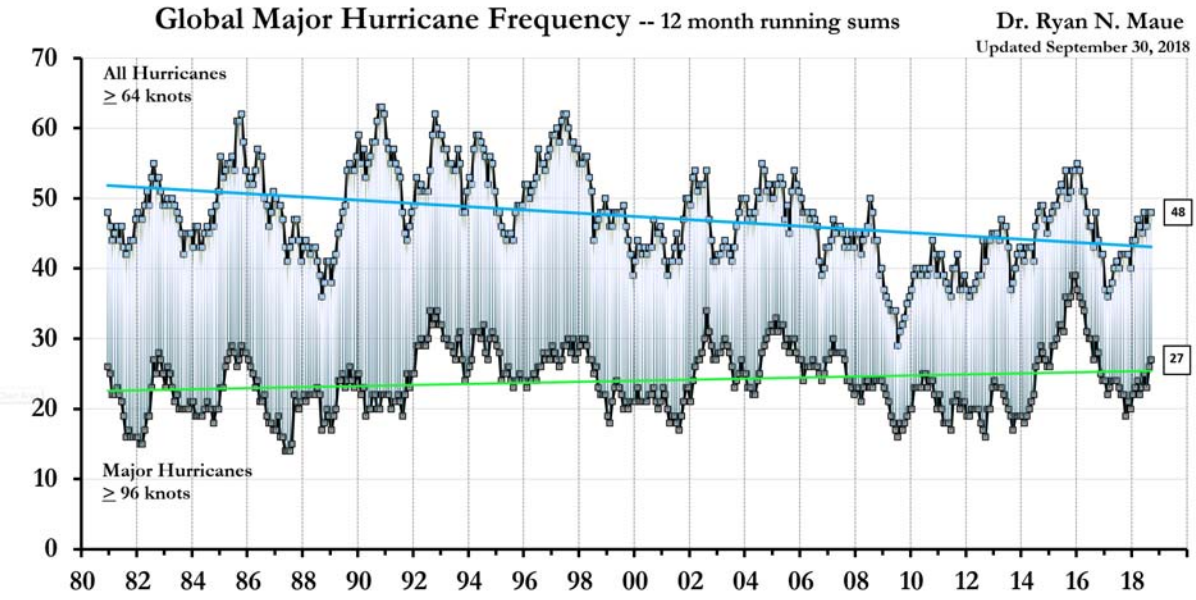


Figure 7: Global major hurricane frequency.
Source: Ryan Maue.[20]

the frequency of all hurricanes, but an apparent increase in the number of major ones.

Maue also monitors accumulated cyclone energy (ACE), a measure used by various agencies including NOAA, to express the activity of individual tropical cyclones and entire tropical cyclone seasons. It uses an approximation of the wind energy of a tropical system over its lifetime and is calculated every six hours. The ACE of a season is the sum of the ACEs for each storm and thus takes into account the number, strength, and duration of all the tropical storms in the season.

Figure 7 indicates that the increase in ACE since the 1970s has been confined to the Northern Hemisphere. We have seen in Figure 4 that the frequency of major hurricanes

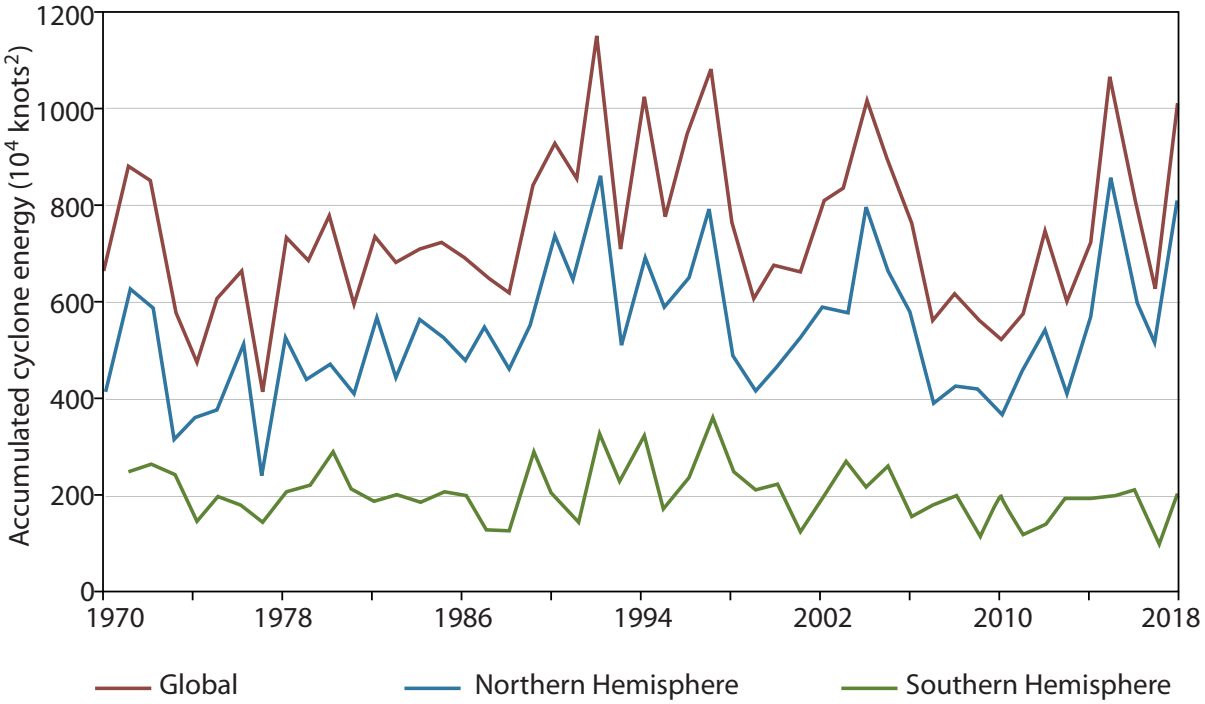


Figure 8: Global hurricane ACE.
Source: Ryan Maue.[20]

in the North Atlantic has increased significantly since the 1970s, correlating with the AMO cycle. Both the frequency of global major hurricanes and the increase in Northern Hemisphere ACE fit into this pattern. Both exhibit a step change in the 1990s, since when trends have changed little. Again, this fits in with the North Atlantic data. By contrast, trends in the Southern Hemisphere have been flat since 1970. Maue believes that the large-scale ocean cycles play a major role in the variability of ACE. His 2011 paper, 'Recent historically low global tropical cyclone activity' found evidence of considerable variability in tropical cyclone ACE, associated with the evolution of large-scale climate mechanisms including the El Niño Southern Oscillation and the Pacific Decadal Oscillation.[21]

9 Tropical cyclone rainfall

The purpose of this paper is to evaluate trends in the frequency and strength of tropical cyclones. However it is worth a quick look at rainfall from hurricanes. It is generally accepted that models project a tendency for hurricane rainfall to increase with greenhouse warming.[22] However, Walsh *et al.* concluded that there have not yet been any detected global trends in hurricane rainfall rates.[10] High rainfall rates often occur because of slow-moving weather systems, as with Hurricane Harvey last year. Chang *et al.* looked at this phenomenon with regard to hurricane systems affecting Taiwan, and could not find a mechanism that would attribute this trend to anthropogenic climate change.[23]

10 Conclusions

The IPCC AR5 made the following conclusions about hurricanes:

> [There is] low confidence that any reported long-term (centennial) increases in tropical cyclone activity are robust, after accounting for past changes in observing capabilities. More recent assessments indicate that it is unlikely that annual numbers of tropical storms, hurricanes and major hurricanes counts have increased over the past 100 years in the North Atlantic basin. Evidence, however, is for a virtually certain increase in the frequency and intensity of the strongest tropical cyclones since the 1970s in that region.

The evidence produced in this paper strongly supports this conclusion. In addition, the observational record since AR5 was published in 2013 is also consistent with this view. The data does show an increase in both the frequency and intensity of hurricanes in the North Atlantic. However, both observations and research find that there is little evidence of longer-term trends there. This paper refers to several studies which find a direct relationship between hurricane trends since 1970 and the Atlantic Multidecadal Oscillation.

Changes in the methods of observation, as well as the lack of any observations in many regions in earlier decades, make it difficult to come to any robust conclusions about global trends. It is clear though that actual observations have severely underestimated both the frequency and intensity of hurricanes prior to around 1970 in the North Atlantic, and maybe as late as 1980 for hurricanes in other parts of the world.

A more reliable longer-term record is available for US landfalling hurricanes, dating back to 1851. NOAA's Hurricane Research Division has carefully reanalysed all hurricane data between 1851 and 1960 in order to ensure wind speeds and intensity are as accurate as possible. Their database shows that there has been no increase in the number of hurricanes or major hurricanes over the period.

Globally, there is consistent data only since about 1970. There is little evidence of any increasing frequency of hurricanes since then. Major hurricane frequency increased during the 1970s and 1980s, due to North Atlantic hurricanes. However, since around 1990 major hurricane frequency and accumulated energy have remained essentially unchanged.

In summary, there is little evidence that global warming has resulted in more hurricanes, or more intense ones. On the contrary, available evidence confirms that hurricane and major hurricane frequency has been as great in many prior periods as it has been recently.

Notes

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About the Global Warming Policy Foundation

The Global Warming Policy Foundation is an all-party and non-party think tank and a registered educational charity which, while openminded on the contested science of global warming, is deeply concerned about the costs and other implications of many of the policies currently being advocated.

Our main focus is to analyse global warming policies and their economic and other implications. Our aim is to provide the most robust and reliable economic analysis and advice. Above all we seek to inform the media, politicians and the public, in a newsworthy way, on the subject in general and on the misinformation to which they are all too frequently being subjected at the present time.

The key to the success of the GWPF is the trust and credibility that we have earned in the eyes of a growing number of policy makers, journalists and the interested public. The GWPF is funded overwhelmingly by voluntary donations from a number of private individuals and charitable trusts. In order to make clear its complete independence, it does not accept gifts from either energy companies or anyone with a significant interest in an energy company.

GWPF BRIEFINGS

1	Andrew Turnbull	The Really Inconvenient Truth or 'It Ain't Necessarily So'
2	Philipp Mueller	The Greening of the Sahel
3	William Happer	The Truth about Greenhouse Gases
4	Gordon Hughes	The Impact of Wind Power on Household Energy Bills
5	Matt Ridley	The Perils of Confirmation Bias
6	Philipp Mueller	The Abundance of Fossil Fuels
7	Indur Goklany	Is Global Warming the Number One Threat to Humanity?
8	Andrew Montford	The Climate Model and the Public Purse
9	Philipp Mueller	UK Energy Security: Myth and Reality
10	Andrew Montford	Precipitation, Deluge and Flood
11	Susan Crockford	On the Beach
12	Madhav Khandekar	Floods and Droughts in the Indian Monsoon
13	Indur Goklany	Unhealthy Exaggeration
14	Susan Crockford	Twenty Good Reasons not to Worry about Polar Bears
15	Various	The Small Print
16	Susan Crockford	The Arctic Fallacy
17	Indur Goklany	The Many Benefits of Carbon Dioxide
18	Judith Curry	The Climate Debate in the USA
19	Indur Goklany	The Papal Academies' Broken Moral Compass
20	Donoughue and Forster	The Papal Encyclical: a Critical Christian Response
21	Andrew Montford	Parched Earth Policy: Drought, Heatwave and Conflict
22	David Campbell	The Paris Agreement and the Fifth Carbon Budget
23	Various	The Stern Review: Ten Years of Harm
24	Judith Curry	Climate Models for the Layman
25	Fritz Vahrenholt	Germany's *Energiewende*: a Disaster in the Making
26	Hughes, Aris, Constable	Offshore Wind Strike Prices
27	Michael Miersch	Truly Green?
28	Susan Crockford	20 Good Reasons not to Worry About Polar Bears: Update
29	Mikko Paunio	Sacrificing the Poor: *The Lancet* on 'pollution'
30	Mikko Paunio	Kicking Away the Energy Ladder
31	Bill Gray	Flaws in Applying Greenhouse Warming to Climate Variability
32	Mikko Paunio	Save the Oceans: Stop Recycling Plastic
33	Andy Dawson	Small Modular Nuclear: Crushed at Birth
34	Andrew Montford	Quakes, Pollution and Flaming Faucets
35	Paul Homewood	DEFRA vs Met Office: Factchecking the State of the UK Climate
36	J. Ray Bates	Deficiencies in the IPCC's Special Report on 1.5 Degrees
37	Paul Homewood	Tropical Hurricanes in the Age of Global Warming

For further information about the Global Warming Policy Foundation, please visit our website at www.thegwpf.org.

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