Met Office

Verification

Verification of 2015 Seasonal Tropical Storm Forecasts for the Northern Hemisphere

December 2015

Contents

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Issued December 2015

1. Executive summary

Tropical cyclone activity in 2015 was characterised by slightly below-average activity in the North Atlantic and well above-average activity in the Eastern, Central and Western North Pacific. In the North Atlantic, the accumulated cyclone energy (ACE) index was the 4th lowest since 1995, and only 57% of the 1980–2010 average. In contrast, in the Northeast Pacific, the ACE index was the 2nd highest since records began in 1949 and over 200%[1] of average; similarly in the Northwest Pacific activity was 145% of average. For the tenth year in a row, no major hurricanes made landfall in the United States. This is the longest time that the U.S. has gone without a major hurricane landfall since records began in 1878.

The low activity in the Atlantic during 2015 was due in part to strong vertical wind shear and low mid-level humidity over the tropical Atlantic and Caribbean Sea (CSU 2015), which created unfavourable conditions for tropical cyclone development and intensification. However, the anomalously warm sea surface temperatures across the equatorial Central and Eastern Pacific, associated with the ongoing El Niño event, created favourable conditions across the North Pacific, resulting in a record number of major hurricanes in the Northern Hemisphere as a whole.

Monthly updated forecasts produced by the Met Office over the period March to September 2015 provided good guidance on the number of tropical storms, hurricanes and ACE index in the North Atlantic, with observed values falling within the predicted range for all forecasts issued. In the eastern and western North Pacific, forecasts of the number of tropical storms and hurricanes also performed well; however, forecasts of ACE index generally tended to under-predict activity.

In this report we provide an overview of tropical storm activity in the North Atlantic and the Eastern, Central and Western North Pacific during 2015, along with verification of the monthly updated seasonal forecasts.

2. Tropical cyclone activity in 2015

A list of tropical storms in the North Atlantic, Northeast Pacific and Northwest Pacific during 2015 and their characteristics can be found in Tables A1–A3 of the Appendix; corresponding storm tracks for each individual basin can be found in Figures A1–A3. An accompanying description of tropical storm activity for each basin can be found below. All statistics are calculated using observed data to 1st December 2015.

2.1 North Atlantic

The 2015 Atlantic hurricane season recorded 11 tropical storms (winds ≥ 39 mph), of which only 4 became hurricanes (winds ≥ 74 mph) and 2 of these major hurricanes (winds ≥ 111 mph). The accumulated cyclone energy (ACE) index—a measure of the combined strength and duration of tropical storms during the season—was 59.8[2]. This represents 57% of the 1980–2010 average annual ACE index of 105 and is the 4th lowest ACE index since 1995, the start of the current era of high activity in the North Atlantic.

The low ACE index can be attributed to strong vertical wind shear across the central tropical Atlantic and Caribbean Sea (CSU 2015). During June–October the average vertical wind shear in the Caribbean was the highest since records began in 1979 (CSU 2015). In

[1] Calculated throughout the lifetime of all storms with genesis in the Northeast Pacific basin. See Section 2.2 for further details.
[2] Based on preliminary ACE index values from http://models.weatherbell.com/tropical.php.

addition, mid-level relative humidity was also very low, particularly over the Caribbean Sea (CSU 2015), which further inhibited tropical storm genesis. As a result, the majority of tropical storms formed outside the Caribbean where conditions were slightly more favourable.

Two tropical storms (Ana and Bill) made landfall in the United States; the Caribbean was impacted by four storms (Danny, Erika, Joaquin, Kate); and parts of Mexico and Central America experienced heavy rains and flash flooding associated with the precursor disturbance to tropical storm Bill (NHC, 2015b). Hurricane Joaquin (October 2015) was the strongest storm of the Atlantic season, reaching category 4 intensity with winds of 155 mph. Joaquin devastated parts of the Bahamas (BBC, 2015a) and also caused significant flooding in South Carolina (WSJ, 2015).

For the tenth year in a row, no major hurricanes made landfall in the United States. This is the longest time that the U.S. has gone without a major hurricane landfall since relatively reliable landfall data became available in 1878 (the previous record was eight years 1861–1868; CSU 2015). The last major hurricane to make landfall in the U.S. was Wilma in October 2005. The low landfall activity in 2015 is likely due to anomalous troughing over the U.S. East Coast, which has been present for the last few years (particularly in 2012 and 2013). This causes storms to re-curve away from the U.S. and back out into the Atlantic.

2.2 Northeast Pacific

Tropical storm activity in the Northeast Pacific was above-normal in 2015, with 19 tropical storms, making it the joint 5th most active season since records began in 1949[3]. Thirteen of these reached hurricane strength (only 1990 and 1992 have recorded more hurricanes) with 10 becoming major hurricanes, breaking the previous record of 9 set in 1992. The ACE index of 249.9 was the 2nd highest since 1949 (only 1992 has recorded a higher ACE index) and over 200% of the annual 1980–2010 average of 124. The ACE index for both observations and the long-term average is here calculated throughout the lifetime of all storms that formed in the Northeast Pacific basin. This includes portions of the storm track which may have moved outside of the region e.g. into the Central North Pacific.

It is interesting to note that a large portion of the observed ACE index in the Northeast Pacific was actually from storms that formed within the basin but later tracked into the Central North Pacific (encompassing the area between 140°W and the International Date Line). Indeed, of the total ACE index for the basin (249.9), around 36% (90.5) was accumulated in the Central North Pacific by the 7 storms that crossed into this region (Guillermo, Olaf, Nora, Ignacio, Hilda, Ela and Jimena). When calculating ACE index using the portions of the track which were *within* the Northeast Pacific region only, then the 2015 ACE index was 44% above the 1981–2010 median (NHC 2015a).

Hurricane Patricia (October 2015) was the strongest tropical cyclone of the season, and became the strongest storm on record in the Northeast Pacific and western hemisphere, reaching wind speeds of 200 mph and a central pressure of 879 hPa. Patricia later made landfall as a category 5 hurricane near Cuixmala, Jalisco, on the Pacific coast of Mexico: only the second category 5 hurricane on record to make landfall in the Northeast Pacific. However, the storm miraculously resulted in few fatalities, as the region of strongest winds around the eye covered only a small area and passed over areas of low population density.

[3] This includes Tropical Storm Ela, which formed as a tropical depression in the Northeast Pacific, but became a named storm in the central North Pacific.

2.3 Central North Pacific

The Central North Pacific experienced above-average activity in 2015, with 7 tropical storms forming in the region. This broke the previous record of 4 tropical storms set in 1982. The region also saw a record number of hurricanes (4) and the 3rd highest ACE index (78) since records began in 1949. The high level of activity is likely due to high sea surface temperatures and low vertical wind shear, both of which reached record levels during July—October in the North Central Pacific Main Development Region (7.5-20°N, 180-140°W) (Klotzbach, 2015).

2.4 Northwest Pacific

The Northwest Pacific also experienced above-average activity in 2015[4]. Since January a total of 25 tropical storms have formed in the region, of which 18 reached hurricane strength and 15 of these became major hurricanes – equalling the previous record for major hurricanes set in 1965. The number of tropical storms and hurricanes were near the long-term (1980–2010) annual average of 25.4 and 16.3, respectively; the ACE index of 419.2 was well-above the annual average of 289.

The strongest storm of the season was Typhoon Soudelor (note hurricanes are known regionally as typhoons in the Northwest Pacific), which reached estimated wind speeds of 180 mph and caused devastating flash floods across parts of Taiwan and southeast China (BBC, 2015b). In Taiwan, over 52 inches of rain fell in the southwest region of Taipingshan during the 72-hour passage of the storm (Weather, 2015).

The high levels of tropical storm activity throughout the tropical North Pacific in 2015 can be attributed to anomalously warm sea surface temperatures across the equatorial and eastern Pacific, associated with the current El Niño event, which created favourable conditions for tropical storm development and intensification

3. Forecast verification

A summary of observed and forecast numbers of tropical storms, hurricanes and ACE index is provided for the North Atlantic, Northeast Pacific and Northwest Pacific in Tables 1–3, respectively. The forecasts were run experimentally by the Met Office each month from March to September 2015 using information from the Met Office GloSea5 seasonal forecasting system, which has a total of 42 ensemble members. The May forecast for the North Atlantic was made publicly available on 21 May 2015 via the Met Office website[5].

Verification is performed using real-time observations from the National Hurricane Center (North Atlantic and Northeast Pacific) and the U.S. Navy's Joint Typhoon Warning Center (Northwest Pacific). Real-time values of ACE index are obtained from http://models.weatherbell.com/tropical.php.

3.1 North Atlantic

The 2015 Atlantic season recorded a total of 11 tropical storms (of which 4 reached hurricane strength) and an ACE index of 59.8. The number of tropical storms was near the long-term 1980–2010 annual average of 12.1; the number of hurricanes and ACE index

[4] We note the Northwest Pacific season is not yet complete as tropical storm activity can occur all year round.
[5] Met Office seasonal tropical storm forecast for the 2015 Atlantic hurricane season http://www.metoffice.gov.uk/weather/tropicalcyclone/seasonal/northatlantic2015

were both below the long-term average of 6.6 and 105, respectively. Forecasts of North Atlantic tropical storm activity provided good guidance during 2015, with observed values falling within the predicted range for all forecasts issued. This included the public forecast, which predicted 6–10 tropical storms, 3–7 hurricanes and an ACE index of 40–108 during *June–November* 2015. In the event, there were 10 tropical storms (Tropical Storm Ana formed outside the forecast period), of which 4 became hurricanes, and an ACE index of 57.7.

3.2 Northeast Pacific

The Northeast Pacific recorded a total of 19 tropical storms (13 reached hurricane strength) and an ACE index of 249.9 (note these values exclude storms which formed in the Central North Pacific: Halola, Iune, Kilo, Loke, Malia, Niala and Oho). The number of tropical storms, hurricanes and ACE index were well-above the 1980–2010 annual average of 15.6, 8.5 and 124, respectively. Forecasts for numbers of tropical storms and hurricanes in the Northeast Pacific provided good guidance of activity, with observations falling within the range predicted for all forecasts issued apart from August, which over-predicted the number of tropical storms. However, forecasts of ACE index generally under-predicted activity, with observations falling outside the predicted range in March, April, July and September.

3.3 Northwest Pacific

In the Northwest Pacific there were 25 tropical storms, of which 18 reached hurricane strength, and an ACE index of 419 (the ACE index is calculated for all named storms which *formed* in the Northwest Pacific basin i.e. west of the international dateline; it does not include storms that entered the basin from the Central North Pacific (Tropical Storm Halola and Hurricane Kilo). Overall, forecasts of tropical storm numbers provided good guidance with observations falling within the predicted range for all forecasts issued. For hurricane numbers, good guidance was provided from April to August. For ACE index, activity was under-predicted for forecasts issued between March and June, but performed well from July–September.

4. Long-term skill

The performance of GloSea5 to predict numbers of tropical storms, hurricanes and ACE index in each of the North Atlantic, Northeast Pacific and Northwest Pacific basins is shown in Tables A4–A6 of the Appendix, respectively. Here we measure skill as the Pearson linear correlation (r) between the model ensemble mean and observations for retrospective forecasts (or hindcasts) over the period 1996–2009.

Linear correlations between observed and predicted values of tropical storms, hurricanes and ACE index vary for each ocean basin and forecast start date. For the North Atlantic, skill is generally positive for each variable (tropical storms, hurricanes and ACE index) and each forecast start date, with the greatest skill shown for predictions of numbers of hurricanes.

In the Northeast Pacific skill is also positive, but generally lower, for the majority of start dates, with the greatest skill shown for predictions of ACE index. In the Northwest Pacific skill is much more variable across forecast start dates and variables. The greatest skill is generally found earlier in the season in March and April, with lower and negative skill in May and June. The greatest skill averaged across all forecast start dates is found for predictions of ACE index.

Forecast	Period of forecast	North Atlantic					
		Tropical storms		Hurricanes		ACE index	
		Forecast	Observed	Forecast	Observed	Forecast	Observed
March	April–September	7 (4–10)	10	4 (2-6)	3	85 (24-146)	56.4
April	May–October	8 (4-12)	10	4 (2-6)	3	78 (25-131)	56.4
May	June–November	8 (6-10)	10	5 (3-7)	4	74 (40-108)	57.7
June	July–November	8 (5-11)	9	6 (4-8)	4	80 (39-121)	56.6
July	August–November	7 (4-10)	8	5 (3-7)	4	63 (26-100)	55.5
August	September–November	6 (4-8)	5	4 (2-6)	2	62 (32-92)	37.7
September	October–November	3 (1-5)	1	1 (0-2)	1	7 (3-11)	3.4

Table 1. Observed and forecast numbers of tropical storms, hurricanes and ACE index issued monthly for the North Atlantic from March to September 2015. Forecast best-estimates are calculated from the mean of the 42-member Met Office GloSea5 ensemble. Values in brackets represent ±1 standard deviation about the ensemble mean. Colours refer to forecast verification: green - observed values were within the predicted range, amber - observed values were outside the predicted range.

Forecast	Period of forecast	Northeast Pacific					
		Tropical storms		Hurricanes		ACE index	
		Forecast	Observed	Forecast	Observed	Forecast	Observed
March	April–September	14 (10-18)	14	7 (4-10)	10	118 (76-160)	180.3
April	May–October	18 (14-22)	17	10 (7-13)	12	146 (108-184)	237.1
May	June–November	18 (14-22)	17	11 (8-14)	11	167 (119-215)	210.0
June	July–November	19 (15-23)	16	12 (9-15)	10	172 (128-216)	200.7
July	August–November	14 (11-17)	11	7 (5-9)	8	119 (84-154)	167.8
August	September–November	11 (9-13)	7	4 (3-5)	5	68 (48-89)	83.3
September	October–November	4 (2-6)	5	3 (1-5)	3	37 (19-55)	69.6

Table 2. As Table 1, but for the Northeast Pacific. Note the ACE index is calculated throughout the lifetime of the storms. This can include portions of the track which crossed into the Central North Pacific.

Forecast	Period of forecast	Northwest Pacific					
		Tropical storms		Hurricanes		ACE index	
		Forecast	Observed	Forecast	Observed	Forecast	Observed
March	April–September	19 (17-21)	17	13 (12-14)	11	221 (199-243)	292.8
April	May–October	19 (17-21)	19	13 (12-14)	14	241 (206-276)	347.4
May	June–November	19 (16-22)	18	13 (11-15)	13	254 (216-292)	310.0
June	July–November	17 (15-19)	16	12 (10-14)	12	248 (213-283)	285.5
July	August–November	14 (12-16)	12	9 (8-10)	9	178 (156-200)	199.0
August	September–November	8 (6-10)	9	6 (5-7)	7	118 (87-149)	117.6
September	October–November	4 (3-5)	4	2 (1-3)	4	62 (42-82)	79.0

Table 3. As Table 1, but for the Northwest Pacific. Note that although forecasts for this basin are verified using data up to 30th November. However, activity in this basin occurs all year round.

5. Conclusions

- 2015 was characterised by slightly below-normal activity in the North Atlantic and above-normal activity throughout the North Pacific. The Northern Hemisphere as a whole experienced record numbers of major hurricanes and the Northeast Pacific saw the formation of Hurricane Patricia (October 2015) which later became the strongest storm on record in the western hemisphere.

- The high levels of tropical cyclone activity across the North Pacific is likely due to anomalously warm sea surface temperatures (associated with the ongoing El Niño event), which created favourable conditions for tropical storm development and intensification. In contrast the low levels of activity in the Atlantic were due to record high levels of wind shear during June–October and dry air over the tropical Atlantic and Caribbean Sea, which inhibited tropical storm development. Both of these features are typically associated with El Niño events.

- Seasonal forecasts issued by the Met Office between March and September 2015 provided good guidance on the number of tropical storms, hurricanes and ACE index in the North Atlantic, with observed values falling within the predicted range for all forecasts issued. In the eastern and Northwest Pacific forecasts performed well for numbers of tropical storms and hurricanes; however, forecasts of ACE index generally under-predicted activity, particularly early in the season.

6. 2016 tropical storm forecast for the North Atlantic

The public forecast for the 2016 hurricane season will be released on the Met Office website in May 2016.

7. References

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Appendix

Storm name	Active dates	Lifetime (days)	Category	Maximum wind speed (mph)	Minimum central pressure (hPa)	ACE index (10^4 kt^2)
Ana	8–11 May	3	TS	60	998	2.12
Bill	16–18 June	2	TS	60	997	1.03
Claudette	13–14 July	1	TS	50	1003	1.13
Danny	18–24 August	6	C3	115	974	9.20
Erika	25–29 August	4	TS	50	1003	2.94
Fred	30 August–6 September	7	C1	85	986	5.65
Grace	5–9 September	4	TS	50	1002	1.73
Henri	8–11 September	3	TS	50	1003	0.98
Ida	18–27 September	9	TS	50	1001	3.39
Joaquin	28 September–8 October	10	C4	155	931	28.2
Kate	9–12 November	3	C1	75	983	3.42

Saffir–Simpson hurricane wind scale

Tropical depression (0–39 mph) Tropical storm (39–73 mph) Category 1 (74–95 mph) Category 2 (96–110 mph)
Category 3 (111–129 mph) Category 4 (130–156 mph) Category 5 (> 156 mph)

Table A1. Summary of North Atlantic tropical storm activity during 2015. Note that final details may change during post-analysis of the season and details of tropical depressions (wind speeds of approximately 30 mph) have been excluded. Colours refer to maximum storm intensity (based on the Saffir-Simpson hurricane wind scale). Wind speed values are given as 1-min averages. ACE index values are rounded from http://models.weatherbell.com/tropical.php and are calculated from real-time ATCF advisories. Data are from the National Hurricane Center.

Storm name	Active dates	Lifetime (days)	Category	Maximum wind speed (mph)	Minimum central pressure (hPa)	ACE index (10^4 kt^2)
Andres	28 May–4 June	7	C4	145	937	19.2
Blanca	31 May–9 June	9	C4	140	943	20.7
Carlos	10–17 June	7	C1	90	978	9.29
Ela	8–10 July	2	TS	40	1003	0.38
Dolores	11–19 July	8	C4	130	946	15.95
Enrique	12–18 July	6	TS	50	1000	2.44
Felicia	23–25 July	2	TS	40	1004	0.25
Guillermo	29 July–7 August	9	C2	110	967	13.9
Hilda	6–14 August	8	C4	140	946	16.4
Ignacio	25 August–5 September	11	C4	145	942	25.5
Jimena	26 August–10 September	15	C4	150	936	40.1
Kevin	31 August–5 September	5	TS	60	998	2.47
Linda	6–10 September	4	C3	125	950	9.75
Marty	26 September–1 October	5	C1	80	986	3.93
Nora	9–15 October	6	TS	70	993	3.80
Olaf	15–27 October	12	C4	150	938	35.1
Patricia	20–24 October	4	C5	200	879	17.9
Rick	18–22 November	4	TS	40	1002	1.26
Sandra	23–28 November	5	C4	145	935	11.6

Table A2. As Table A1, but for the Northeast Pacific. Note Ela formed as a depression in the Northeast Pacific, but was named once it reached tropical storm strength in the Central North Pacific. However, due to its location of genesis Ela is counted towards the Northeast Pacific storm count. Halola, Iune, Kilo, Loke, Malia, Niala and Oho formed in the Central North Pacific and therefore do not count towards the Northeast Pacific storm count.

Storm name	Active dates	Lifetime (days)	Category	Maximum wind speed (mph)	Minimum central pressure (hPa)	ACE index (10^4 kt^2)
Mekkhala	13–20 January	7	C1	80	975	3.21
Higos	6–12 February	6	C4	130	940	7.95
Bavi	10–21 March	11	TS	60	990	4.11
Maysak	26 March–7 April	12	C5	160	910	32.1
Haishen	2–6 April	4	TS	50	998	1.21
Noul	2–12 May	10	C5	160	920	28.6
Dolphin	6–20 May	14	C5	160	925	32.0
Kujira	19–25 June	6	TS	50	985	0.98
Chan-hom	29 June–13 July	14	C4	140	935	23.6
Linfa	1–10 July	9	C1	75	980	7.01
Nangka	2–18 July	16	C4	155	925	45.4
12W*	23–25 July	2	TS	45	1008	0.44
Soudelor	29 July–11 August	13	C5	180	900	33.7
Molave	6–14 August	8	TS	55	985	3.05
Goni	13–25 August	12	C4	130	930	40.7
Atsani	14–25 August	11	C5	160	925	37.6
Etau	1–11 September	10	TS	60	985	1.58
Vamco	13–15 September	2	TS	40	998	0.49
Krovanh	13–21 September	8	C3	120	945	10.9
Dujuan	19–30 September	11	C4	140	925	20.4
Mujigae	30 September–5 October	6	C4	130	950	5.22
Choi-wan	1–7 October	6	C1	80	965	6.91
Koppu	12–21 October	9	C4	150	925	16.8
Champi	13–25 October	12	C4	150	930	32.1
In-fa	17–26 November	9	C4	130	935	23.2

Table A3. As Table A1, but for the Northwest Pacific. Data are preliminary from the U.S. Navy's Joint Typhoon Warning Center (JTWC). *12W was classified as a tropical storm by JTWC only; the Japan Meteorological Agency (JMA) classified this storm as a tropical depression.

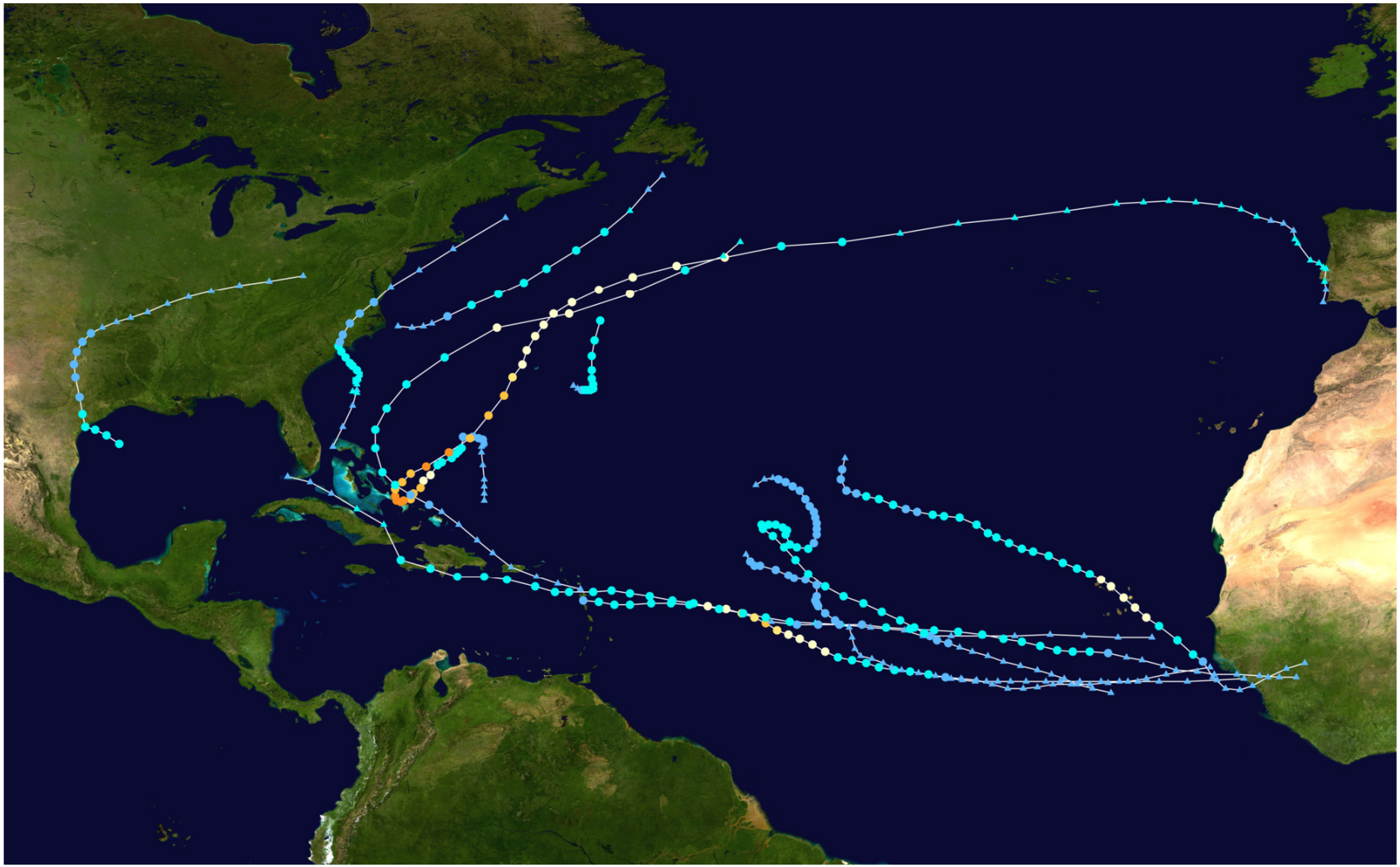

Figure A1. Tracks of all tropical depressions (wind speeds of approximately 30 mph) and named storms which formed in the North Atlantic during 2015. Colours refer to storm intensity (based on the Saffir–Simpson hurricane wind scale) at each 6 hour interval. Source: http://en.wikipedia.org/wiki/2015_Atlantic_hurricane_season.

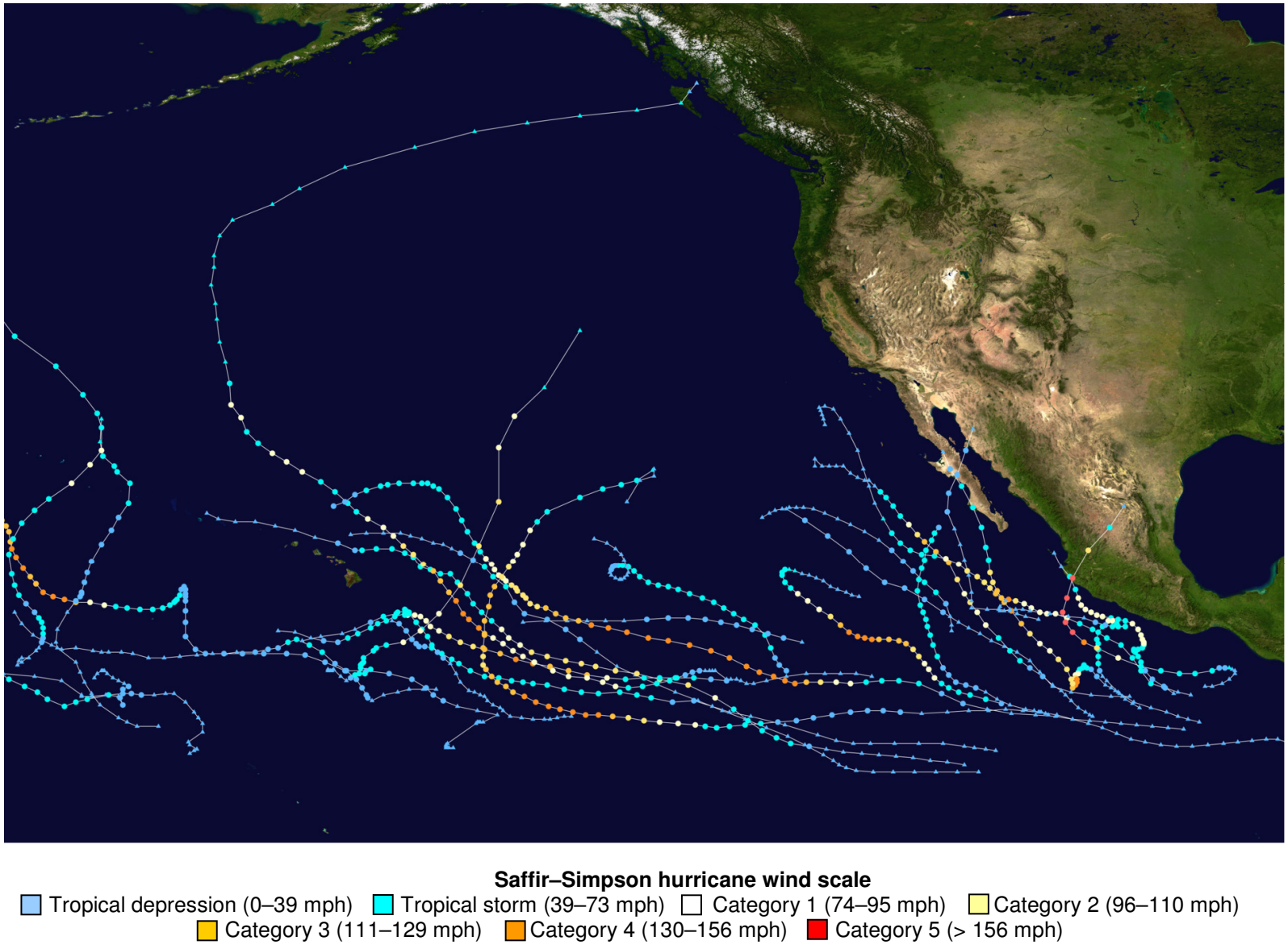

Figure A2. As Figure A1, but for the Eastern and Central North Pacific. Source: http://en.wikipedia.org/wiki/2015_Pacific_hurricane_season.

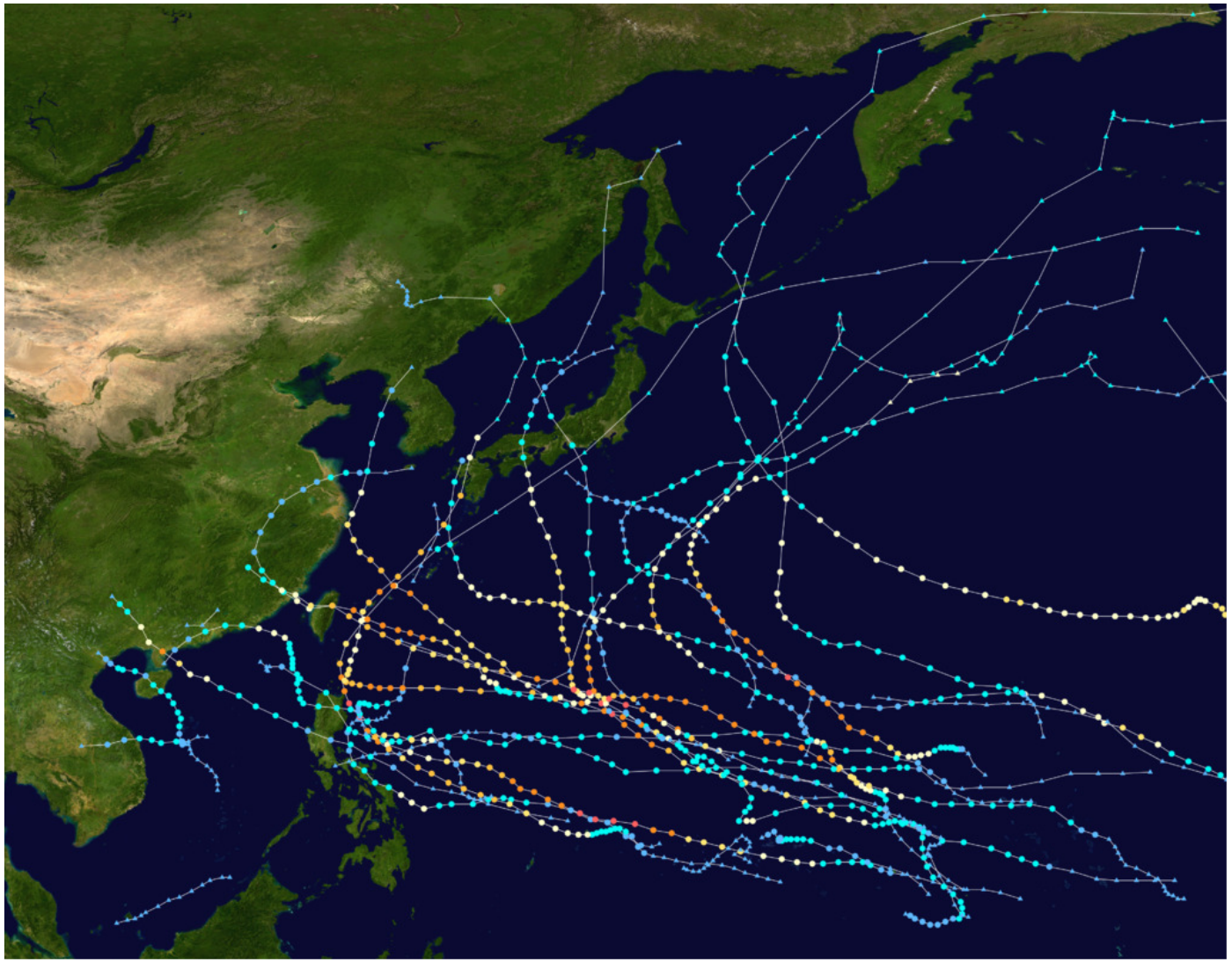

Figure A3. As Figure A1, but for the Northwest Pacific. Source: http://en.wikipedia.org/wiki/2015_Pacific_typhoon_season.

North Atlantic				
Forecast	Period of forecast	Forecast skill (linear correlation)		
		Tropical storms	Hurricanes	ACE index
March	April–September	0.54	0.30	0.15
April	May–October	0.32	0.49	0.30
May	June–November	0.33	0.49	-0.20
June	July–November	0.51	0.73	0.45
July	August–November	0.63	0.40	0.48
August	September–November	-0.06	0.33	0.56
September	October–November	0.24	0.48	0.31

Table A4. Forecast skill (Pearson's linear correlation) of Met Office GloSea5 tropical storm, hurricane and ACE index forecasts for the North Atlantic issued monthly from March to September 2015. Skill is measured over the corresponding forecast period using hindcasts for 1996–2009. Historical observations are obtained from the Atlantic hurricane database (HURDAT2).

Northeast Pacific				
Forecast	Period of forecast	Forecast skill (linear correlation)		
		Tropical storms	Hurricanes	ACE index
March	April–September	-0.43	0.36	0.32
April	May–October	0.05	0.10	0.52
May	June–November	0.29	0.10	0.54
June	July–November	0.05	0.28	0.55
July	August–November	0.31	-0.12	0.43
August	September–November	0.63	0.43	0.42
September	October–November	-0.26	0.42	0.28

Table A5. As Table A4, but for the Northeast Pacific.

Forecast	Period of forecast	Northwest Pacific		
		Forecast skill (linear correlation)		
		Tropical storms	Hurricanes	ACE index
March	April–September	0.54	0.21	0.62
April	May–October	0.56	0.29	0.75
May	June–November	-0.24	-0.14	0.41
June	July–November	-0.03	0.21	0.10
July	August–November	-0.51	-0.44	0.59
August	September–November	-0.52	-0.01	-0.52
September	October–November	0.42	-0.34	0.12

Table A6. As Table A4, but for the Northwest Pacific. Historical observations to calculate skill are obtained from the U.S. Navy's Joint Typhoon Warning Center (JTWC).

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