NATIONAL HURRICANE CENTER ANNUAL SUMMARY

2016 EASTERN NORTH PACIFIC HURRICANE SEASON

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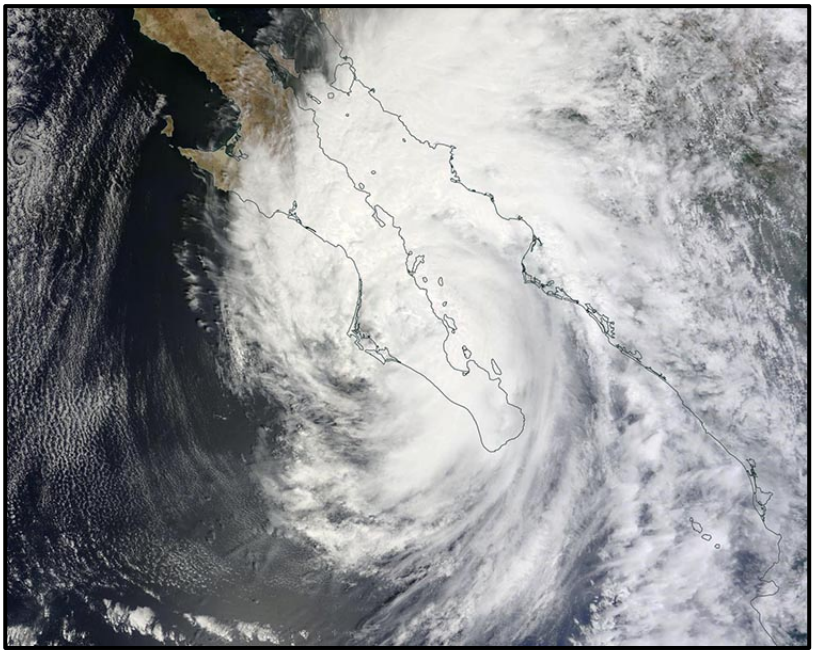

NASA Terra Modis image of Hurricane Newton at 1825 UTC 6 September moving through Baja California Sur.

ABSTRACT

The 2016 eastern North Pacific hurricane season was very active, with 21 named storms and 11 hurricanes, of which 5 reached major hurricane strength (category 3 or higher on the Saffir-Simpson Hurricane Wind Scale). The above-normal number of tropical cyclones in 2016 marked a continuation of the above normal activity observed in the basin since 2014.

Mexico was affected by a couple of tropical cyclones during the 2016 season. The most significant effects were from Hurricane Newton, which moved northward through Baja California Sur as a category 1 hurricane and made a second landfall in northwestern Mexico as a tropical storm. Moisture from Newton and Hurricane Paine caused locally heavy rainfall over portions of northwestern Mexico and the southwestern United States in September. About a month earlier Tropical Storm Javier produced minimal impacts when it made landfall in Baja California Sur.

OVERVIEW

The 2016 eastern North Pacific hurricane season was very active. Of the 21 cyclones that reached tropical storm strength, 11 became hurricanes and 5 became major hurricanes (category 3 or higher on the Saffir-Simpson Hurricane Wind Scale) within the basin. The number of named storms observed in 2016 was the second highest since reliable records began in 1971, behind only 1992. For comparison, the 1981-2010 seasonal averages are 15 tropical storms, 8 hurricanes and 4 major hurricanes. The Accumulated Cyclone Energy (ACE), which measures the combined strength and duration of tropical storms and hurricanes, was about 50 percent higher in 2016 than the 1981-2010 median value, and marked a continuation of the enhanced tropical cyclone activity seen in the eastern North Pacific since 2014. Interestingly, the formation of the season's first named storm did not occur until July, the second latest on record (after 1969). However, the period from July through September was especially busy with 18 named storms, the most since 1971 in any three-month period. There was one unnamed tropical depression that formed in June near the southern coast of Mexico. A tropical depression that formed over the extreme western part of the basin became a tropical storm (Ulika) in the central North Pacific, and returned to the eastern Pacific where it became a hurricane. Late-season Atlantic Hurricane Otto became the first basin-crosser into the eastern Pacific since Hurricane Cesar in 1996 and the first tropical cyclone to retain its Atlantic name while doing so. Although most of the tropical cyclones formed in association with tropical waves that moved westward from the Atlantic to the eastern North Pacific basin, a greater than average number of cyclones either had unknown origins or formed from Intertropical Disturbance Zone disturbances.

The active 2016 season marked a continuation of the enhanced tropical cyclone activity observed in the eastern Pacific since 2014. Although most of the season was marked by neutral El Niño-Southern Oscillation (ENSO) conditions, near-record warm waters extending from off the equator near Mexico into the central Pacific (Fig. 1) contributed to a large area of upper-level difluence and rising motion between 110º and 130º W that persisted during the most active months of the 2016 season (Fig. 2). The location of these conducive atmospheric and oceanic conditions for tropical cyclone genesis and intensification likely accounted for the abundance in and shift of tropical cyclone activity farther west than normal. Table 1 lists the tropical cyclones of the 2016 season, and the tracks of the season's tropical storms and hurricanes are shown in Figures 3a and 3b.

As in 2015, despite the above-average seasonal activity, most of the tropical cyclones intensified and moved away from land, and Newton was the only hurricane to make landfall in Mexico. The hurricane weakened to category 1 strength prior to moving onshore on the southern Baja California peninsula west of Cabo San Lucas, and brought strong winds and heavy rains to most of Baja California Sur and then to portions of northwestern Mexico after it weakened to a tropical storm. Tropical Storm Javier produced minimal effects after it moved onshore near Newton's point of landfall a month earlier. Moisture from Newton and from Hurricane Paine spread northward and northeastward, causing locally heavy rainfall over portions of northwestern Mexico and the southwestern United States in September.

The following section summarizes the tropical cyclones that affected land. More detailed information on the tropical cyclones of 2016 can be found at http://www.nhc.noaa.gov/2016epac.shtml .

SELECTED STORM SUMMARIES

Tropical Storm Javier

Javier formed from the remnants of Atlantic Hurricane Earl, which struck Belize as a category 1 hurricane (on the Saffir-Simpson Hurricane Wind Scale) early on 4 August. Earl's low-level circulation moved inland and dissipated over the mountains of eastern Mexico on 6 August. The remnant mid-to-upper-level circulation continued to move quickly westward across central Mexico while the southern portion of Earl's broad circulation began to interact with a disturbance within the Intertropical Convergence Zone (ITCZ), which was situated very near the coast of Mexico. By 1800 UTC that day, surface observations indicated that a small low pressure system had formed just west of Acapulco, Mexico. Convective activity associated with the low became better organized over the next 18 h, and it is estimated that Tropical Depression Eleven-E[1] formed by 0600 UTC 7 August about 105 n mi south-southeast of Manzanillo, Mexico.

The small tropical cyclone moved northwestward along the periphery of a deep-layer subtropical ridge for the next 48 h, remaining just offshore of the southwestern coast of Mexico. Sustained winds of 40 kt were reported at Manzanillo, indicating that the depression had intensified into a tropical storm around 1200 UTC 7 August when it was located about 45 n mi south of that city. Although environmental conditions were conducive for strengthening throughout Javier's lifetime, the cyclone struggled to intensify due to northeasterly to easterly mid-level shear of 15-20 kt, which caused the cyclone's circulation to acquire a westward tilt. However, a National Oceanic and Atmospheric Administration (NOAA) Hurricane Hunter aircraft found that Javier had still managed to strengthen to 55 kt around 1800 UTC 8 August, when the cyclone was located about 60 n mi southeast of Cabo San Lucas, Mexico. Shortly after reaching peak intensity, stronger easterly mid-level shear caused Javier's low-level and mid-level circulations to decouple, resulting in gradual weakening until landfall.

Javier made landfall around 0330 UTC 9 August along the southern tip of Baja California Sur near San Jose del Cabo, Mexico, as a 45-kt tropical storm and passed over or just east of Los Cabos International Airport, Mexico (MMSD), a short time later. Interaction with the mountainous terrain of the Baja California peninsula caused Javier to quickly weaken, with the cyclone becoming a depression by 1200 UTC and a remnant low 6 h later when the system was located about 45 n mi south of Cabo San Lazaro, Mexico. By 1800 UTC 10 August, Javier's remnant circulation dissipated just west of La Bocana, Mexico.

Javier produced minimal effects in Mexico. Sustained winds of 40 kt were reported at Playa de Oro International Airport, Manzanillo, Mexico (MMZO), at 1522 UTC and 1541 UTC 7 August. A sustained wind of 34 kt and a gust to 51 kt were reported at 0550 UTC 9 August by the Mexican National Meteorological Service CONAGUA (or La Comisión Nacional del Agua)

[1] Current operational policy is that tropical cyclones crossing into another basin retain their original name; since Earl had dissipated as a tropical cyclone prior to entering the eastern North Pacific basin, the new depression was named Eleven-E, rather than Earl.

observing station at Cabo Pulmo (elevation 26 m ASL) located on the southeastern tip of Baja California Sur, Mexico.

Rainfall amounts were generally less than 2 inches across western Mexico and less than one inch across Baja California Sur. These rains were beneficial to the region, and no significant flooding was reported.

Hurricane Newton

A tropical wave moving into the eastern Pacific basin merged with a pre-existing surface trough, likely triggered by an eastward-moving convectively coupled Kelvin wave, well south of the southern coast of Mexico by 3 September. The merger of the two disturbances resulted in an broad area of low pressure early on 4 September, with the deep convection becoming sufficiently organized to classify the system as a tropical depression at 1200 UTC that day. The depression strengthened into a tropical storm 6 h later at 1800 UTC while centered about 210 n mi south of Manzanillo, Mexico. When it formed, Newton was located between the southwestern periphery of a mid-tropospheric ridge that extended across the Gulf of Mexico and northern Mexico and a deep-layer trough covering the western United States and the adjacent eastern Pacific Ocean. This synoptic pattern caused the cyclone to move north-northwestward and northwestward for several days—slowly at first, and then faster as it gained latitude and felt the increasing effects of the trough. At the same time, Newton was located over very warm 30°C waters and in an environment of minimal deep-layer shear, which allowed it go through a 36-h period of rapid intensification (RI) from 1800 UTC 4 September through 0600 UTC 6 September while it approached the southern tip of the Baja California peninsula. During the period of RI, Newton became a hurricane by 1800 UTC 5 September about 115 n mi west-southwest of Cabo Corrientes, Mexico, and then reached its peak intensity of 80 kt at 0600 UTC 6 September when it was centered 50 n mi south-southeast of Cabo San Lucas. Newton's northeastern eyewall struck the southern tip of the Baja California peninsula a couple of hours later, and the cyclone's center passed offshore of Cabo San Lucas by just a few miles.

The hurricane weakened slightly while its eastern eyewall moved over the mountainous terrain of Baja California Sur, and made landfall near El Cuñaño on the western side of the peninsula around 1400 UTC 6 September with maximum winds of 75 kt. Newton gradually weakened through the day while its center moved north-northwestward up the center of the peninsula, and the convection became more asymmetric and displaced to the north of the center. However, Newton appears to have maintained hurricane intensity during its trek across the peninsula, with microwave images showing the redevelopment of a closed eyewall around 0000 UTC 7 September. Even though Newton's center subsequently emerged over the warm waters of the Gulf of California, deep-layer southerly shear increased and caused further weakening, with the cyclone becoming a tropical storm by 0600 UTC about 50 n mi west of Guaymas. Newton made a second landfall, with an intensity of 55 kt, around 0830 UTC 7 September just south of Bahía de Kino and then continued to weaken quickly over the state of Sonora due to the rugged terrain and increasing shear. Satellite images indicate that Newton lost all of its associated deep convection later that day, and it is estimated that the cyclone degenerated to a remnant low by

1800 UTC while it was centered just south of the United States-Mexico border about 35 n mi southwest of Nogales, Arizona. The remnant low turned northeastward and dissipated near the Arizona-New Mexico border soon after 0600 UTC 8 September.

Sustained hurricane-force winds likely occurred over a large portion of Baja California Sur, while elsewhere, sustained tropical-storm-force winds were reported in the states of Colima, Nayarit (Islas Marías), and Sonora, and also likely occurred in the states of Jalisco and Sinaloa. Near Newton's second landfall in Sonora, a sustained wind of 39 kt and a gust to 56 kt were reported at Bahía de Kino, and a sustained wind of 35 kt with a gust to 45 kt was reported at Hermosillo. Pressure readings from San Lucas and Todos Santos were as low as 979 mb when Newton's center made its closest approach. Reports from a storm chaser indicate that Newton's eye moved over Cabo San Lucas, with the wind going calm by 0915 UTC and the calm lasting until about 1050 UTC. This observation is corroborated by microwave imagery, which shows Cabo San Lucas located inside the eyewall within the northern and eastern portion of Newton's large eye from 0835 to 1012 UTC. The chaser's minimum reported pressure of 984.3 mb was nearly steady for about 35 minutes, and it was not as low as the pressure measurements from San Lucas and Todos Santos farther to the west and northwest. These data suggest that, although Cabo San Lucas was within the eastern portion of Newton's eye, the center of the cyclone likely missed Cabo San Lucas by a few miles to the west.

Although Newton did not cross the United States-Mexico border as a tropical cyclone, it did produce tropical-storm-force wind gusts in the elevated terrain of southern Arizona above 7,000 ft on the morning of 7 September before it became a remnant low. Heavy rains began falling across southern Arizona while Newton was still a tropical cyclone. More than an inch of rain fell in a swath extending across the far southeastern part of the state into southwestern New Mexico, and more than 6 inches occurred at locations in Cochise, Pima, and Graham Counties. The highest reported rainfall amount was 6.57 inches in the Rincon Mountains east of Tucson. The rainfall caused minor flash flooding in parts of southeastern Arizona. Flash flooding in southern Arizona affected U.S. Highway 92 in Cochise County and led to a swift-water rescue of two people and a dog in Hereford. Some roads in Tucson were barricaded near the Tanque Verde Wash.

Newton and its precursor disturbance caused heavy rains and flooding across southern Mexico, the coast of western Mexico, and the southern part of the Baja California peninsula. Rainfall accumulations as high 13.90 inches occurred near Acapulco, Mexico, between 31 August and 8 September. A storm total of 12.62 inches also occurred at Cihuatlán in the state of Jalisco, and 12.20 inches was measured at Mapastepec in the state of Chiapas. Up to 5 inches of rain fell in parts of Baja California Sur, especially in the municipality of Mulegé. Two to three inches occurred in the state of Sonora.

Newton caused five direct deaths while it was a tropical cyclone: five fisherman drowned when their shrimp boat, the *Mariano Pérez X*, capsized in rough seas in the Gulf of California while traveling between Ensenada and Mazatlán. Before Newton became a tropical cyclone, heavy rainfall and flooding caused another three deaths in the state of Chiapas, and one death occurred in Petatlán in the state of Guerrero when a person was swept away in a river.

The governor of Baja California Sur announced that Newton caused 700 million pesos (~37 million USD) in damage in the state. Although Newton knocked out power, blew out some windows, and caused some damage to homes in Cabo San Lucas, the resort areas at the southern tip of the Baja California peninsula escaped major damage. Most of the damage in Baja California Sur resulted from heavy rains in the municipality of Mulegé. In Santa Rosalía, rockslides and landslides buried dozens of houses and vehicles, and there was a lack of potable water due to damage to a water line. Communities such as Heroica Mulegé and San Ignacio had significant damage and were cut off due to debris on the Transpeninsular Highway.

On the other side of the Gulf of California, damage also occurred in the municipality of Guaymas in the state of Sonora to the south of Newton's second landfall. More than 3,000 homes and 50 business were damaged, and about 90% of Guaymas and San Carlos lost electricity. Total damage in Guaymas is estimated to be 1.1 billion pesos (~58 million USD).

Heavy rainfall and flooding from Newton's precursor disturbance caused some damage in the states of Guerrero and Chiapas. Approximately 2,000 homes were damaged in the two states, and over 200 people were rescued in the Campestre La Laguna neighborhood southeast of Acapulco when floodwaters rose to 60 cm (2 ft). In Chiapas, flooding occurred in the capital city of Tuxtla Gutiérrez, affecting about 3,500 people.

FORECAST VERIFICATION

The 2016 season had 391 official forecasts issued, which is above the long-term average of 331. The mean track errors ranged from 19 n mi at 12 h to 104 n mi at 120 h, and were notably lower (up to 35%) than the 5-yr means at all forecast times. However, the CLIPER5 errors were also lower than its 5-yr means, indicating that the season's storms were easier to forecast than average. Records for accuracy were set at all forecast periods in 2016, except at 120 h.. The official track forecast vector biases were small for all lead times. In a homogeneous sample, the official forecasts were very skillful and were comparable to the best models, the consensus aids. Among the consensus models, HCCA had the lowest errors, and it was the only aid that beat the official forecast at all time periods. The best-performing dynamical models were the GFSI and AEMI, with EMXI, HWFI, and CTCI not far behind.

Mean official intensity errors were lower than the 5-yr means from 12 to 48 h, but slightly higher than the means at the longer lead times. The Decay-SHIFOR5 forecast errors were slightly lower or similar to their 5-yr means, indicative that the season's storms were a little easier than normal to predict. A record for accuracy was set at 36 h in 2016. In a homogeneous sample, the official forecasts outperformed the models from 12 to 36 h, but were beaten by the best-performing models HWFI, HCCA, and IVCN at 48 h and beyond. FSSE was competitive with the other consensus aids at the shorter leads, but it trailed at longer range. It should be noted that the official forecast had smaller biases than the most of the guidance.

Table 1. 2016 eastern North Pacific hurricane season statistics.

Storm Name	Class[a]	Dates[b]	Max. Winds (kt)	Min. Pressure (mb)	Deaths	U.S. Damage ($million)
One	TD	June 6 – 7	30	1006		
Agatha	TS	July 2 – 5	45	1002		
Blas	MH	July 2 – 10	120	947		
Celia	H	July 6 – 15	85	972		
Darby	MH	July 11 – 25	105	958		
Estelle	TS	July 15 – 21	60	990		
Frank	H	July 21 – 28	75	979		
Georgette	MH	July 21 – 27	115	952		
Howard	TS	July 31 – Aug 3	50	998		
Ivette	TS	August 3 – 8	50	1000		
Javier	TS	August 7 – 9	55	997		
Kay	TS	August 18 – 23	45	1000		
Lester	MH	August 24 – September 7	125	944		
Madeline	MH	August 26 – September 2	115[c]	950[c]		
Newton	H	September 4 – 7	80	977	5	
Orlene	H	September 11 – 16	95	967		
Paine	H	September 18 – 20	80	979		
Roslyn	TS	September 25 – 29	45	999		
Ulika	H	September 26 – 30	65	992		
Seymour	MH	October 23 – 28	130	940		
Tina	TS	November 13 – 14	35	1004		
Otto	MH	November 20 – 26	100[d]	975[d]	18	

[a] Tropical depression (TD), maximum sustained winds 33 kt or less; tropical storm (TS), winds 34-63 kt; hurricane (H), winds 64-95 kt; major hurricane (MH), winds 96 kt or higher.

[b] Dates begin at 0000 UTC and include all tropical and subtropical cyclone stages; non-tropical stages are excluded.

[c] Peak intensity and minimum pressure were reached in the central Pacific hurricane basin.

[d] Originated in the Atlantic basin, where the peak intensity was also observed.

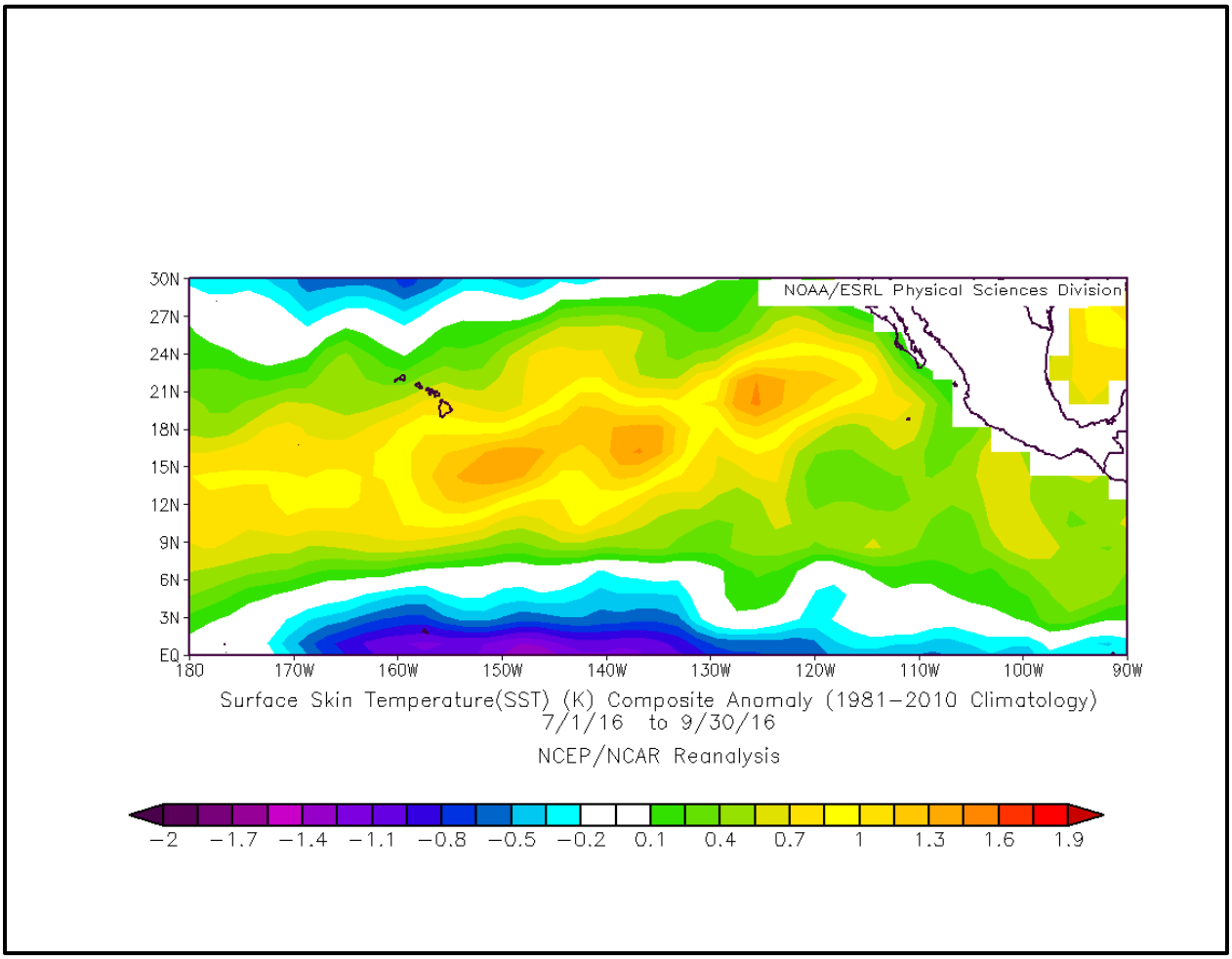

Figure 1. Sea surface temperatures from July to September 2016 (ºC). Anomalies computed relative to the 1981-2010 climatology from NCEP/NCAR reanalysis. Image courtesy of the NOAA/Earth Science Research Laboratory.

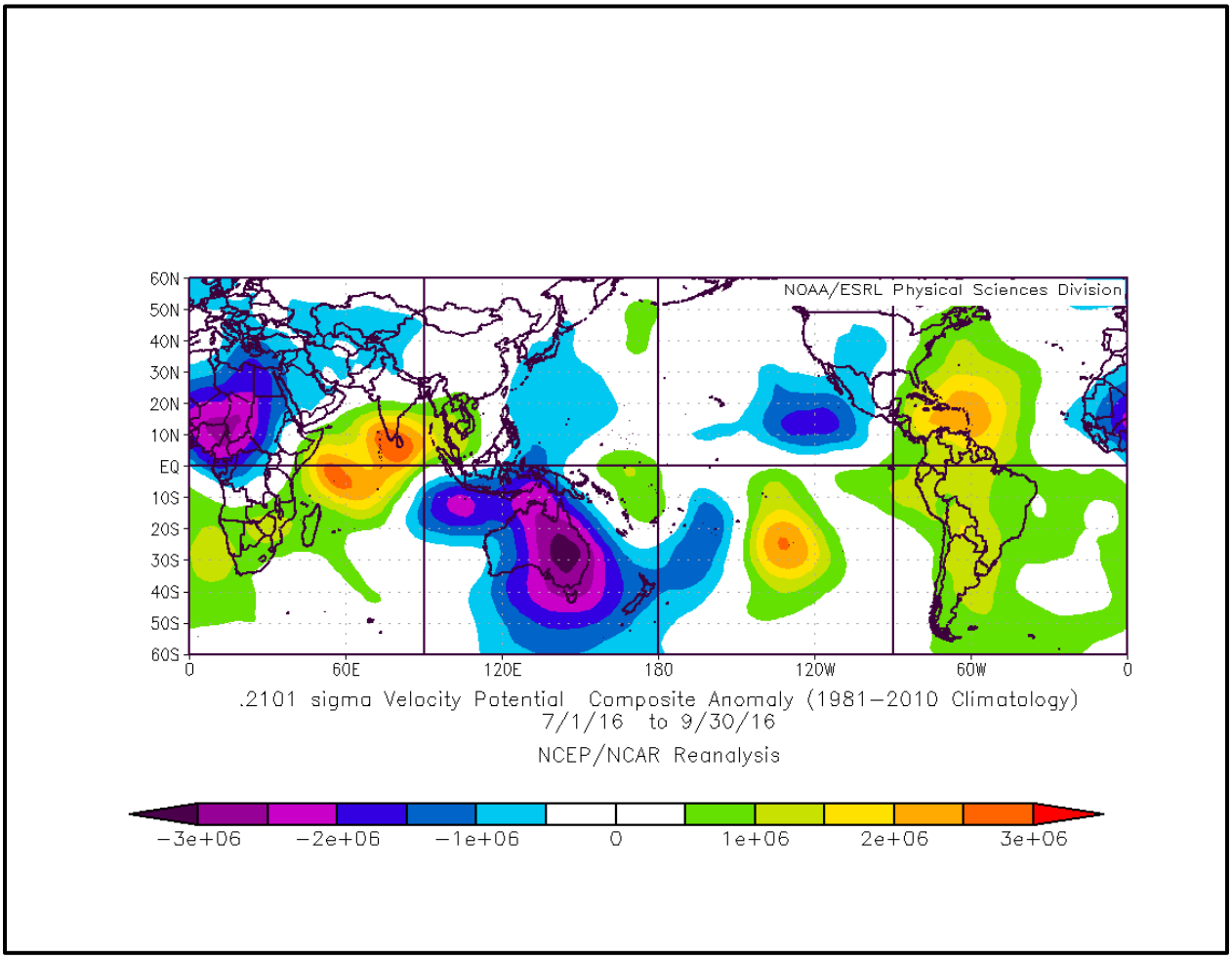

Figure 2. 200-mb velocity potential anomalies ($m^2 s^{-1}$) from July to September 2016. Negative values (blue or purple) are related to anomalous upper-level divergence or rising motion, and positive values (yellow or orange) are associated with anomalous upper-level convergence or sinking air. Anomalies computed relative to the 1981-2010 climatology from NCEP/NCAR reanalysis. Image courtesy of the NOAA/Earth Science Research Laboratory.

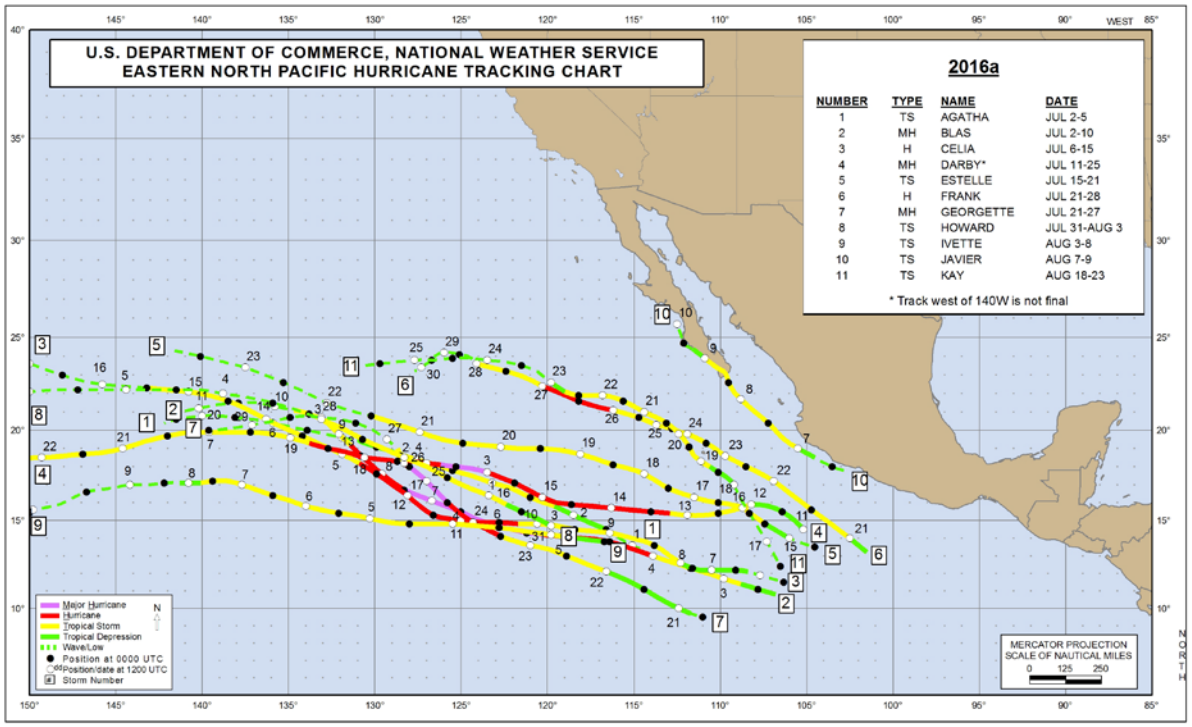

Figure 3a: Tracks of the tropical storms and hurricanes of the 2016 eastern North Pacific hurricane season for the first eleven named tropical cyclones.

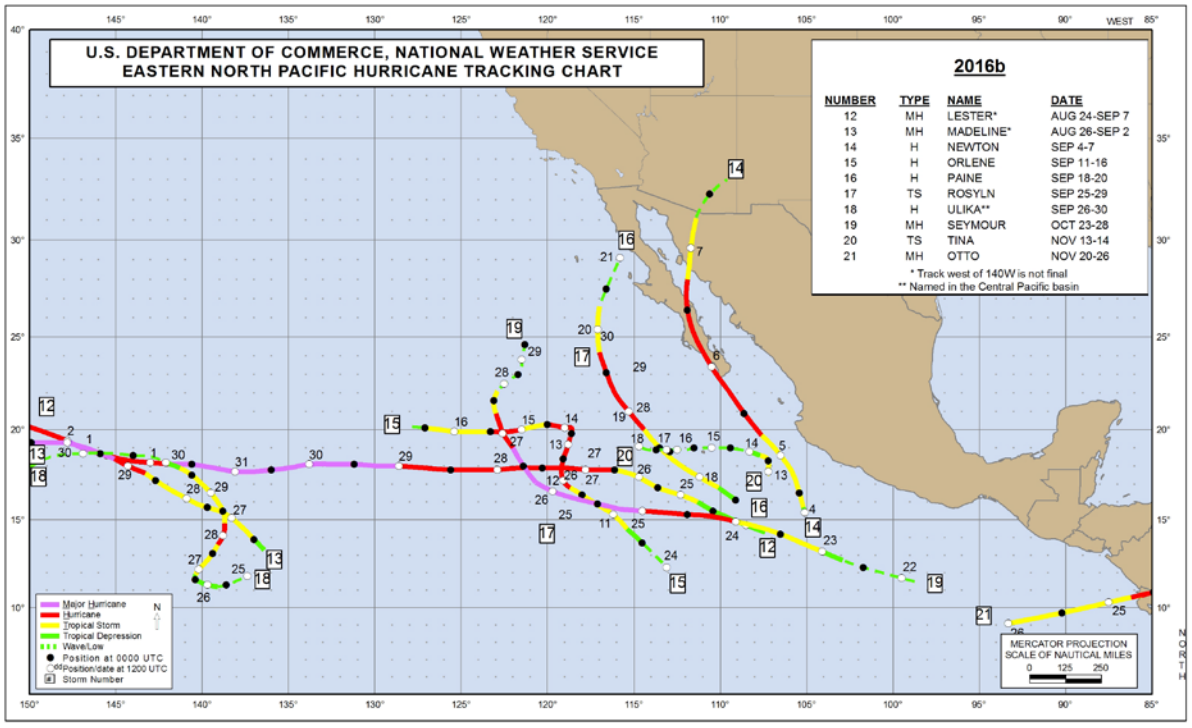

Figure 3b: Tracks of the tropical storms and hurricanes of the 2016 eastern North Pacific hurricane season the last ten named tropical cyclones.