NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT[1]

HURRICANE OLIVIA

(EP172018)

1–14 September 2018

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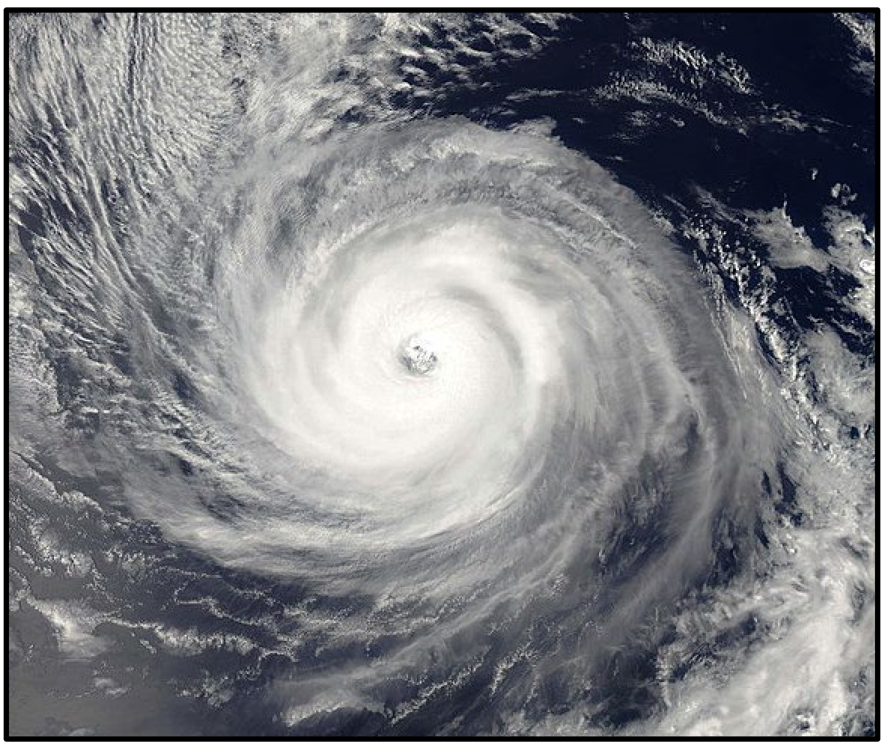

NASA MODIS VISIBLE SATELLITE IMAGE OF HURRICANE OLIVIA AT 2210 UTC 6 SEPTEMBER.

Olivia was a category 4 hurricane (on the Saffir-Simpson Hurricane Wind Scale) over the eastern Pacific Ocean. It weakened when it crossed into the north central Pacific basin and moved across the Hawaiian Islands as a tropical storm.

[1] Original report date 3 December 2018. Updated 25 July 2019 to include best track analysis, summary, verification, impacts, and damages from the Central Pacific Hurricane Center.

Hurricane Olivia

1–14 SEPTEMBER 2018

SYNOPTIC HISTORY

The genesis of Olivia can be traced back to a disturbance that formed over the southwestern Caribbean Sea on 26 August. This system moved westward across Central America and entered the far eastern North Pacific Ocean a couple of days later. Showers and thunderstorms gradually increased during the next few days, and a broad area of low pressure formed within the area of disturbed weather early on 31 August several hundred miles south of the southwestern coast of Mexico. Satellite images indicate that the low pressure system developed a well-defined center and sufficiently organized deep convection by 0000 UTC 1 September to mark the formation of a tropical depression about 350 n mi southwest of Manzanillo, Mexico. The "best track" chart of the tropical cyclone's path is given in Fig. 1, with the wind and pressure histories shown in Figs. 2 and 3, respectively. The best track positions and intensities are listed in Table 1[2].

Despite being over warm water, northeasterly vertical wind shear prevented the depression from strengthening during the next 18 h while the system moved west-northwestward on the southwestern side of a subtropical ridge.[3] Although the shear remained relatively strong, thunderstorm activity consolidated near and to the west of the center of the cyclone late on 1 September, and as a result, the system strengthened to a tropical storm by 0000 UTC 2 September when it was located about 450 n mi south of Cabo San Lucas, Mexico. Olivia then turned to the northwest, moving toward a weakness in the ridge, and strengthened only slowly due to the continued influence of northeasterly shear during the next day or so.

The shear relaxed significantly by early on 3 September, and Olivia began to rapidly intensify while it turned westward and accelerated due to a building subtropical ridge. Olivia reached hurricane intensity by 0000 UTC 4 September when it was located about 500 n mi southwest of Cabo San Lucas, and it reached its first peak intensity of 110 kt by 0000 UTC the following day. This period marked an impressive 70-kt increase in strength in 48 h. Shortly after that time, however, the northern eyewall began to collapse, likely due to an increase in northerly shear and dry air entrainment, and Olivia weakened. The hurricane's intensity decreased to 85 kt by 1800 UTC 5 September, at which time the eye was quite ragged, and the convective pattern was asymmetric.

Unexpectedly, the hurricane began to restrengthen on 6 September. The eye of Olivia became much more circular, and a ring of deep convection surrounded that feature throughout the day. The hurricane reached its maximum intensity as a category 4 hurricane on the Saffir-

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[2] A digital record of the complete best track, including wind radii, can be found on line at ftp://ftp.nhc.noaa.gov/atcf. Data for the current year's storms are located in the *btk* directory, while previous years' data are located in the *archive* directory.

Simpson Hurricane Wind Scale with peak winds of 115 kt (cover image) by 0000 UTC 7 September when it was located a little more than 1100 n mi west of Cabo San Lucas. While Olivia was strengthening, it was moving west-northwestward at about 13 kt on the south-southwestern periphery of a deep-layer ridge. Around the time of peak intensity, Olivia developed an annular appearance in satellite imagery, consisting of a well-organized inner core and a lack of outer banding features.

Shortly after obtaining category 4 intensity, cool 25–26°C sea-surface temperatures and dry and stable low- to mid-level air caused Olivia to weaken. However, this time the weakening trend persisted, and Olivia crossed 140°W into the central North Pacific basin just before 0000 UTC 9 September as a category 1 hurricane on the Saffir-Simpson Hurricane Wind Scale.

Olivia continued to gradually weaken over the next 24 h after entering the central North Pacific as it tracked westward across cool 25–26°C sea-surface temperatures while surrounded by dry mid-level air in a weak vertical wind shear environment. The tropical cyclone weakened to minimal hurricane strength of 65 kt by 1200 UTC 9 September. Deep convection began to increase around 1500 UTC 9 September as sea-surface temperatures became slightly more favorable, rising to around 26.5°C. A well-defined eye was re-established in satellite imagery around 1800 UTC 9 September, at the same time that the first aircraft from the U.S. Air Force Reserve 53rd Weather Reconnaissance Squadron (WRS) arrived and confirmed that Olivia remained a 65 kt hurricane.

Weak vertical wind shear in combination with marginally favorable sea-surface temperatures and increasing ocean heat content, allowed the tropical cyclone to intensify into a 75 kt hurricane by 0000 UTC 10 September, as the system continued to be steered westward by a large mid-level ridge to the distant northeast. Olivia maintained the 75-kt intensity for the next 12 h as the hurricane tracked westward at a slower pace. By 1800 UTC 10 September, increasing vertical wind shear began to impact the system, with the well-defined eye becoming cloud filled. This was the beginning of a slow and steady weakening trend that would last for the next couple of days as Olivia approached the main Hawaiian Islands from the east.

The tropical cyclone weakened to a tropical storm with an intensity of 60 kt by 0600 UTC 11 September and continued to weaken into a 40 kt tropical storm by 0600 UTC 12 September due to strong and relentless vertical wind shear. A rather abrupt increase in forward speed occurred when the strong vertical wind shear displaced the low-level circulation center of Olivia from the deep convection shortly after 1200 UTC 11 September, with the center of the tropical cyclone becoming exposed by 1800 UTC that day. This allowed Olivia to be steered by the low-level trade wind flow rapidly toward the west-southwest through 0000 UTC 12 September. This was followed by an abrupt decrease in the forward speed of the tropical cyclone by 0600 UTC 12 September as it approached the eastern end of the Hawaiian Island chain. Explosive convective development occurred over the low-level circulation center between 0600 and 1800 UTC 12 September as a deep upper-level trough digging north of the system provided cooler temperatures aloft, while the tropical cyclone was also moving over increasingly warm sea-surface temperatures of 27 to 28°C. The increase in deep convection allowed Olivia to maintain a 40-kt intensity through 1800 UTC 12 September, while being steered westward at a slower forward speed due to the digging upper-level trough to the north.

Olivia passed approximately 50 n mi to the north of the Big Island of Hawaii, and 10 n mi to the north of east Maui during the early morning of 12 September, making an initial landfall as a 40-kt tropical storm approximately 10 n mi northwest of Kahului, Maui at 1910 UTC 12 September. Olivia then went on to make a second landfall 6 n mi north-northwest of Lanai City, Lanai at 1954 UTC 12 September. Strong vertical wind shear and the interaction with the elevated terrain of Maui (peak elevation of 10,023 feet in east Maui, and 5,787 feet in west Maui), Molokai (peak elevation of 4,970 feet) and Lanai (peak elevation of 3,366 feet), likely led to the rapid loss of deep convection by 0000 UTC 13 September. The loss of deep convection resulted in Olivia weakening to minimal tropical storm intensity of 35 kt by 0000 UTC 13 September, along with a rapid acceleration to the west-southwest as the tropical cyclone was steered by the low-level trade wind flow. This rapid west-southwest motion continued as Olivia moved away from the main Hawaiian Islands, with the tropical cyclone weakening into a 30 kt tropical depression by 0600 UTC 13 September.

Olivia remained a tropical depression through 1200 UTC 13 September, then re-intensified into a 35 kt tropical storm at 1800 UTC 13 September as deep convection once again developed near the low-level circulation center. Olivia then tracked westward over the next 24 h, with the low-level center becoming exposed once again by 0000 UTC 14 September. Convection continued to pulse near the center of the system for the next couple of days, but the tropical cyclone was never able to re-organize after encountering the island terrain and being relentlessly hammered by strong vertical wind shear. Olivia weakened into a post-tropical remnant low by 0600 UTC 14 September, and became a trough 12 h later at 1800 UTC 14 September.

METEOROLOGICAL STATISTICS

Observations in Hurricane Olivia (Figs. 3 and 4) include subjective satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB), the Satellite Analysis Branch (SAB), the Central Pacific Hurricane Center (CPHC/PHFO), the Joint Typhoon Warning Center (JTWC) and objective Advanced Dvorak Technique (ADT) estimates and Satellite Consensus (SATCON) estimates from the Cooperative Institute for Meteorological Satellite Studies/University of Wisconsin-Madison. Data and imagery from NOAA polar-orbiting satellites including the Advanced Microwave Sounding Unit (AMSU), the NASA Global Precipitation Mission (GPM), the European Space Agency's Advanced Scatterometer (ASCAT), and Defense Meteorological Satellite Program (DMSP) satellites, among others, were also useful in constructing the best track of Olivia.

Aircraft observations of Olivia include flight-level, stepped frequency microwave radiometer (SFMR), and dropwindsonde observations from missions flown by the U.S. Air Force Reserves 53rd Weather Reconnaissance Squadron (WRS). A total of 8 missions were flown by the WRS, including 2 synoptic sampling missions of the environment around Olivia which provided valuable data to numerical weather prediction models to improve the forecast track of the tropical cyclone as it approached the main Hawaiian Islands. A total of 16 center fixes were performed during 6 missions sampling the core of Olivia.

National Weather Service WSR-88D Doppler radar data from the PHKM radar near Upolu Point on the island of Hawaii, and the PHMO radar, near the Molokai airport on the island of Molokai were used to track the center of Olivia as it approached and moved through the main Hawaiian Islands.

Selected surface observations from land stations are given in Table 2. Only one land observation recorded tropical-storm-force winds. No ship reports or buoy observations of tropical-storm-force winds or greater were received in association with Olivia.

Winds and Pressure

Olivia reached a maximum intensity of 115 kt while located about 1465 n mi east of Hilo, Hawaii, at 0000 UTC 7 September. This intensity was based on Dvorak estimates of T6.0/115 kt from TAFB and SAB, and was slightly below the highest ADT values during that time period. The estimated minimum pressure of 951 mb is based on the Knaff-Zehr-Courtney pressure-wind relationship.

The maximum intensity Olivia reached in the central North Pacific was 75 kt, and this occurred several times as the tropical cyclone approached Hawaii from the east. The first instance was observed at 0000 UTC 9 September as the hurricane crossed 140°W, and this intensity was based on a blend of Dvorak estimates of T4.5 (77 kt) and T4.0 (65 kt) from PHFO and SAB respectively, as well as an ADT value of T4.4 (74.6 kt). After a brief period of weakening, Olivia once again reached an intensity of 75 kt for about 12 h starting at 0000 UTC 10 September. The Dvorak intensity estimates at each of these synoptic times were a unanimous T4.5 (77 kt) from PHFO, SAB, and JTWC. Additionally, the WRS flew a mission into Olivia and found a maximum flight-level (700 mb) wind of 85 kt (this is estimated to be 77 kt at the surface based on a standard NHC/CPHC flight-level to surface wind adjustment factor), and a maximum surface (SFMR) wind of 75 kt at 0725 UTC 10 September. The minimum central pressure of 980 mb was observed by the WRS aircraft at the same time, based on a dropsonde surface pressure of 981 mb and surface wind of 170/11 kt.

Olivia dropped below hurricane intensity at 0600 UTC 11 September, approximately 325 n mi east-northeast of Hilo, Hawaii. This was based on aircraft flight-level (700 mb) winds of 61 kt (estimated to be 55 kt at the surface) and SFMR winds of 56 kt at 0607 UTC 11 September, while taking into account the potential for under sampling of the strongest winds, and the unanimous Dvorak satellite intensity estimates of T4.0 (65 kt).

Aircraft data continued to show a gradually weakening of Olivia over the next 18 h and the WRS flew their final mission into the tropical cyclone around 0000 UTC 12 September. The low-level circulation center of the cyclone was becoming more ragged and elongated at this time, making the center more difficult to locate as it approached the main Hawaiian Islands from the east-northeast. The final center fix at 0150 UTC 12 September had maximum flight-level (700 mb) winds of 38 kt (estimated to be 34 kt at the surface) and SFMR winds of 42 kt. Based on a blend of these data, the intensity was lowered to 40 kt at 0600 UTC 12 September when Olivia was located around 85 n mi north-northeast of Hilo, Hawaii. The minimum central pressure at this same time was estimated to be 1005 mb based on a dropsonde pressure of 1007 mb and a surface wind of 150/18 kt.

Olivia tracked steadily westward, with the closest point of approach to the Big Island of Hawaii occurring around 1500 UTC 12 September, approximately 50 n mi to the north of the Upolu Point. The tropical storm made its first landfall approximately 10 n mi northwest of Kahului on the island of Maui, at 910 AM HST or 1910 UTC 12 September. Olivia then made a second landfall on the island of Lanai, approximately 6 n mi north-northwest of Lanai City at 954 AM HST or 1954 UTC 12 September. The maximum sustained winds at landfall were estimated to be 40 kt based on velocity data from the Molokai WSR-88D radar and standard flight-level to surface wind adjustment factors. The velocity data from the Molokai radar showed 50 kt winds at 5,000 feet (around the 850 mb level) and 45 kt winds at 10,000 feet (around the 700 mb level). The strongest sustained wind speed observed as Olivia moved through the islands of Maui County was 34 kt (39 mph) at the Lanai City Airport (PHNY), with a maximum wind gust of 48 kt (55 mph). This was the only observation of sustained tropical-storm-force winds, although many locations across the entire Hawaiian Island chain recorded tropical-storm-force wind gusts. The lowest observed surface pressure was also recorded at the Lanai City Airport (PHNY), and was 1007.5 mb. The estimated surface pressure at landfall was 1006 mb. A full listing of surface observations associated with Olivia as the tropical cyclone moved through the main Hawaiian Islands are listed in Table 2.

Rainfall and Flooding

Tropical Storm Olivia, which made landfall in Maui County 12 September, was responsible for very heavy rainfall and flash flooding across much of the state of Hawaii. Olivia was notable in that it impacted the main Hawaiian Islands from the east-northeast, when most of the direct tropical cyclone impacts in the state come from an easterly through southwesterly direction, and this resulted in an extended period of heavy rainfall across the state. The initial rain bands associated with the tropical storm started to affect the windward slopes of the Big Island of Hawaii, as well as the islands of Maui and Molokai on the morning of 11 September. Rainfall coverage and intensity increased on 12 September across Maui and Molokai as the center of Olivia made landfall, first in west Maui, and then shortly thereafter on the island of Lanai. As the center of Olivia moved toward the west-southwest away from the state, heavy rainfall spread westward over Oahu on the night of 12 September and into the morning of 13 September. Windward sections of Molokai, Maui and Oahu received the highest rainfall amounts (Figure 9), with peak totals in the 11 to 13 inch range for the 48-h period beginning at 6 AM HST 11 September and running through 6 AM HST 13 September.

The worst flooding occurred over the slopes of the west Maui Mountains in the Waihee River basin, Honokohau Stream basin (Figure 10), and the Napili area (Figure 11). Several homes in these areas were damaged by flood waters (Figure 12). Flash flooding at the Honolua Bridge on Honoapiilani Highway closed the road for a period of time and carried away several vehicles. On Molokai, the flooding resulted in the closure of Kamehameha V Highway (Highway 450) in several locations (Figure 13). Flash flooding on Oahu mainly affected drainages in the eastern half of the island. Kamehameha Highway (Highway 83) closed briefly when the Waikane Stream overflowed its banks, and the westbound lanes of Dillingham Boulevard in Honolulu were closed due to flooding from Kalihi Stream.

CASUALTY AND DAMAGE STATISTICS

On 11 September, Hawaii Governor David Ige requested a Presidential Disaster Declaration in anticipation of impacts associated with Tropical Storm Olivia. His request was granted on 12 September, when President Donald J. Trump signed an emergency declaration, authorizing federal emergency aid to the state of Hawaii to supplement state and local response efforts due to emergency conditions associated with Tropical Storm Olivia. Governor Ige activated around 300 members of the National Guard in support of emergency response activities on Oahu, Maui, and the Big Island of Hawaii in association with the tropical storm.

Damage associated with Olivia resulted from heavy rainfall, flash flooding as well as strong winds that occurred across the Hawaiian Islands. In addition, high surf affected many north and east facing shores of the individual isles, with breaking waves reported as high as 20 feet in some areas. Maui, where Olivia made its initial landfall, was the most severely impacted of the main Hawaiian Islands, where several vehicles and homes were reported swept away by flash flooding, muddy waters filled several properties, a taro farm was devastated, numerous trees were downed, several landslides occurred and dozens of power outages were reported. Thousands of electric customers were affected by the power outages, including 4,500 in the community of Makawao on the island of Maui. Maui was not the only island impacted by Olivia however, as trees were downed and power outages were also reported across Oahu. A downed tree caused the closure of Diamond Head Road in both directions near Makalei Place and the Pali Lookout was closed as a result of another fallen tree as well. Flash flooding also resulted in the closure of numerous roads across the state, and caused around 32,000 gallons of raw sewage to overflow into Kapalama Stream and Honolulu Harbor on the island of Oahu. No official estimate of damage in association with Olivia was available for this report.

There were no reports of casualties in association with Olivia.

FORECAST AND WARNING CRITIQUE

The genesis of Olivia was fairly well forecast, but the cyclone formed a little sooner than expected (Table 3). The possibility of tropical cyclone formation was introduced in NHC's 5-day Tropical Weather Outlook 102 h before genesis, and the chances were raised to the medium and high categories 66 h and 42 h before formation, respectively. The precursor disturbance was given a 2-day genesis probability in the low category 54 h before formation. The 48-h genesis potential was raised to the medium category 30 h before formation and the high category 12 h before development occurred. The NHC forecasts correctly anticipated the conducive environmental conditions that supported the genesis of Olivia.

A verification of NHC official track forecasts for Olivia is given in Table 4a. The official forecast track errors were much lower than the mean official errors for the previous 5-yr period at all forecast times. In fact, the 120-h error was about 60% smaller than the mean and the lowest

120-h average track forecast error on record in the eastern Pacific basin for tropical cyclones with 20 or more forecasts at this verifying time. A homogeneous comparison of the official track errors with selected guidance models is given in Table 4b. The only guidance that consistently beat the official forecast was the consensus model TVCE, though some of the other consensus aids (HCCA, TVCX, and GFEX) also beat the official forecast at the short lead times. Among the individual models, HMON (HMNI) was a strong performer for Olivia and it also had lower errors than the official forecast at 48 and 72 h.

A verification of NHC official intensity forecasts for Olivia is given in Table 5a. Official forecast intensity errors were lower than the mean official errors for the previous 5-yr period at 36 h, but slightly higher than the mean at the remaining forecast times. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 5b. Unlike the track forecasts, no model consistently beat the official forecasts. However, HCCA, FSSE, and GFSI had slightly lower errors at some time periods from 12 to 72 h, and HWFI had slightly lower errors at 96 and 120 h. The largest contributor to the error of the official forecasts were low biases during the two intensification phases (Fig. 4).

A verification of CPHC official track forecasts for Olivia are given in Table 6a. The official forecast track errors were lower than the mean official errors for the previous 5-yr period at all forecast times except at 12 h, and much lower at 48 through 120 h. A homogenous comparison of the official track errors with selected guidance models is given in Table 6b. The only guidance that consistently beat the official forecast were the consensus models TVCX and TVCE, although the official forecast performed better then both at 72 and 96 h. Overall, the official forecast did not perform well at the 12 and 24 h forecast time periods when compared with the individual guidance, with most guidance beating the official forecast. The official forecast performed well compared to most individual guidance from 36 through 120 h. The larger official track errors at the 12 and 24-h forecast time periods were likely a result of the erratic motion of Olivia in the vicinity of the Hawaiian Islands. Other guidance that performed well overall include the FSSE and GFEX.

A verification of the CPHC official intensity forecasts for Olivia is given in Table 7a. The official forecast intensity errors were lower than the mean official errors for the previous 5-yr period at all forecast time periods. A homogenous comparison of the official track errors with selected guidance models is given in Table 7b. Despite the improvement over the mean official errors from the previous 5-yr period, individual guidance models performed rather well at many forecast time periods. The HMNI performed the best out of all of the guidance, beating the official forecast at all forecast time periods. The FSSE, IVCN, EMXI, GFSI, and DSHP also consistently beat the official forecast at most forecast time periods.

Watches and warnings associated with Olivia are given in Table 8. A Tropical Storm Watch was issued for the Big Island of Hawaii at 0300 UTC 10 September, and was upgraded to a Tropical Storm Warning at 1500 UTC 10 September. No locations on the Big Island of Hawaii observed tropical-storm-force winds, although Kohala Ranch (KHRH1) did observe a tropical-storm-force wind gust of 35 kt. No damage was reported on the Big Island of Hawaii. Therefore, the Tropical Storm Watch and Warning did not verify, as the strongest winds were on the north side of Olivia and the center of the tropical storm passed by approximately 50 n mi to the north of the Big Island of Hawaii.

A Tropical Storm Watch was issued for the islands of Maui County (Maui, Molokai, Lanai, and Kahoolawe) at 0300 UTC 10 September and was upgraded to a Tropical Storm Warning at 1500 UTC 10 September. The only observed tropical-storm-force wind was observed at Lanai City Airport (PHNY) at 0942Z 12 September, although numerous observation sites across Maui County recorded tropical-storm-force wind gusts. Estimating the arrival of tropical-storm-force winds is a bit more complicated however, due to the funneling and channeling of winds around the high terrain of Maui County. Based on damage reports and the strongest sustained winds and wind gusts from numerous sites across Maui County, it is estimated that the arrival of tropical-storm-force winds occurred around 1800 UTC 12 September. This results in a lead time of 63 h for the watch and 51 h for the warning.

A Tropical Storm Watch was issued for the island of Oahu at 0300 UTC 10 September and was upgraded to a Tropical Storm Warning at 0300 UTC 11 September. No locations on the island of Oahu observed tropical-storm-force winds, although the Bellows Air Force Station (BELH1) recorded a peak sustained wind of 30 kt with a tropical-storm-force wind gust of 40 kt, and several other observation sites also recorded tropical-storm-force wind gusts. Despite no sustained winds of tropical storm strength occurring at observations sites on the island of Oahu, several reports of downed trees occurred. Based on damage reports as well as the strongest sustained winds and wind gusts from numerous sites across the island of Oahu, it is estimated that the arrival of tropical-storm-force winds occurred around 2000 UTC 12 September. This results in a lead time of 65 h for the watch and 41 h for the warning.

A Tropical Storm Watch was issued for the islands of Kauai County (Kauai and Niihau) at 0300 UTC 11 September and upgraded to a Tropical Storm Warning at 2100 UTC 11 September. No locations on the islands of Kauai County observed tropical-storm-force winds, although the Lihue Airport (PHLI) recorded a sustained wind of 28 kt with a tropical-storm-force wind gust of 38 kt. No other locations recorded wind gusts of tropical-storm-force on the islands of Kauai County and no damage was reported. As a result, the Tropical Storm Watch and Warning did not verify.

Table 1. Best track for Hurricane Olivia, 1–14 September 2018.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
01 / 0000	14.3	107.8	1007	30	tropical depression
01 / 0600	14.5	108.7	1007	30	"
01 / 1200	14.7	109.6	1007	30	"
01 / 1800	15.0	110.5	1006	30	"
02 / 0000	15.4	111.2	1004	35	tropical storm
02 / 0600	15.9	111.7	1002	40	"
02 / 1200	16.5	112.1	1002	40	"
02 / 1800	16.8	112.8	1002	40	"
03 / 0000	16.9	113.4	1001	40	"
03 / 0600	16.8	114.0	999	45	"
03 / 1200	16.7	114.4	996	50	"
03 / 1800	16.7	114.9	991	60	"
04 / 0000	16.8	115.6	987	65	hurricane
04 / 0600	16.9	116.6	985	75	"
04 / 1200	16.9	117.6	971	90	"
04 / 1800	16.8	118.6	963	100	"
05 / 0000	16.8	119.6	954	110	"
05 / 0600	16.8	120.7	963	100	"
05 / 1200	17.0	121.8	966	95	"
05 / 1800	17.2	123.0	975	85	"
06 / 0000	17.5	124.1	976	85	"
06 / 0600	17.8	125.3	975	90	"
06 / 1200	18.1	126.6	959	100	"
06 / 1800	18.5	127.9	954	110	"
07 / 0000	18.9	129.2	951	115	"
07 / 0600	19.4	130.5	955	105	"
07 / 1200	19.9	131.8	965	95	"
07 / 1800	20.3	133.2	970	90	"
08 / 0000	20.7	134.5	975	85	"
08 / 0600	21.1	135.9	980	80	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
08 / 1200	21.4	137.3	983	75	"
08 / 1800	21.6	138.7	983	75	"
09 / 0000	21.8	140.2	982	75	"
09 / 0600	21.8	141.7	985	70	"
09 / 1200	21.7	143.1	989	65	"
09 / 1800	21.7	144.5	988	65	"
10 / 0000	21.7	145.6	982	75	"
10 / 0600	21.7	146.5	980	75	"
10 / 1200	21.7	147.4	980	75	"
10 / 1800	21.8	148.2	985	70	"
11 / 0000	21.8	149.1	989	65	"
11 / 0600	21.9	149.8	993	60	tropical storm
11 / 1200	21.9	150.7	997	55	"
11 / 1800	21.8	152.0	1000	50	"
12 / 0000	21.1	153.8	1003	45	"
12 / 0600	21.0	154.4	1005	40	"
12 / 1200	21.0	155.1	1005	40	"
12 / 1800	21.1	156.3	1005	40	"
13 / 0000	20.5	158.1	1007	35	"
13 / 0600	20.1	159.8	1008	30	tropical depression
13 / 1200	19.7	161.6	1008	30	"
13 / 1800	19.0	162.5	1007	35	tropical storm
14 / 0000	19.0	163.6	1007	35	"
14 / 0600	18.9	164.9	1007	35	low
14 / 1200	18.8	165.9	1007	35	"
14 / 1800					dissipated
07 / 0000	18.9	129.2	951	115	maximum wind and minimum pressure
12 / 1910	21.0	156.6	1006	40	Landfall 1 – 10 n mi NW of Kahului, Maui

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
12 / 1954	20.9	157.0	1006	40	Landfall 2 – 6 n mi NNW of Lanai City, Lanai

Table 2. Selected surface observations for Hurricane Olivia.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Hawaii									
International Civil Aviation Organization (ICAO) Sites									
Lanai City Airport (PHNY) (20.79N 156.95W)	12/1256	1007.5	12/0942	34	48				
Kahului Airport (PHOG) (20.89N 156.44W)	12/1815	1008.6	12/1040	28	35				1.16
Hilo International Airport (PHTO) (19.72N 155.06W)	12/1210	1008.7	12/0235	22	31				1.34
Keahole Airport Kona (PHKO) (19.74N 156.05W)	12/0120	1008.6	11/2355	25	30				T
Bradshaw Army Air Field (PHSF) (19.78N 155.55W)	12/1206	1009.5	12/0256	13	18				
Honolulu International Airport (PHNL) (21.33N 157.94W)	13/0053	1009.8	12/2220	25	36				1.31
Lahaina West Maui (PHJH) (20.96N 156.67W)	12/1945	1007.8	12/1848	17	32				
Lihue Airport (PHLI) (21.98N 159.34W)	13/0153	1012.0	12/2350	28	38				0.25
Molokai Airport Kaunakakai (PHMK) (21.15N 157.10W)	12/2035	1010.2	12/2115	30	42				2.47
Kalaeloa Airport (PHJR) (21.31N 158.07W)	13/0053	1010.5	12/2315	15	27				0.32
Kaneohe Marine Corps Air Station (PHNG) (21.45N 157.77W)	13/0157	1009.7	12/1957	21	32				
Barking Sands Kekaha (PHBK) (22.04N 159.79W)	13/0156	1010.8	13/0056	24	33				
Wheeler Air Force Base (PHHI) (21.48N 158.03W)	12/2356	1009.7	12/2129	23	30				
Hydrology-Surface Observing Instrumentation System (H-SOIS) Site									
Hana Airport (HNAH1) (20.79N 156.02W)			12/2130	16	34				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Maalaea Harbor (P36) (20.79N 156.51W)			12/0308	20	32				
Bellows AFS (BELH1) (21.37N 157.72W)			12/2130	30	40				
Hydrometeorological Automated Data System (HADS) Sites (NWS)									
Kohala Ranch (KHRH1) (20.09N 155.83W)			12/0035	19	35				
Kaneloa (KAOH1) (20.52N 156.57W)			12/1653	23	44				
Lanai 1 (LNIH1) (20.87N 157.01W)			12/1337	30	37				
Makapulapai (MKPH1) (21.20N 156.97W)			12/2015	30	42				
Molokai 1 (MLKH1) (21.12N 156.95W)			12/1737	16	39				
Kuaokala (KKRH1) (21.57N 158.26W)			13/0136	27	40				
Kahuku Training Area (KTAH1) (21.68N 157.99W)			12/2359	16	36				
PTA East (PTAH1) (19.68N 155.55W)			13/0259	20	30				
Kii (KFWH1) (21.69N 157.95W)			13/0045	25	34				
Kawailoa Training Area (KWLH1) (21.68N 157.99W)			12/2049	21	37				
Palehua (PLHH1) (21.38N 158.10W)			12/2336	16	33				
Puu Alii (PAFH1) (21.14N 156.90W)									12.03
Manoa Lyon Arboretum (MNLH1) (21.33N 157.80W)									10.31
Molokai 1 (MLKH1) (21.12N 156.95W)									7.81
Nuuanu Upper (NUUH1) (21.35N 157.82W)									7.41
Moanalua (MOGH1) (21.38N 157.84W)									6.60
Waiawa Correctional Fac (WAWH1) (21.44N 157.97W)									5.68

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Hawaii Kai Golf Course (HAJH1) (21.30N 157.66W)									5.25
Mahinahina (MABH1) (20.96N 156.66W)									4.84
Kamalo (KMLH1) (21.05N 156.87W)									4.54
US Geological Survey (USGS)									
West Wailuaiki USGS (WWKH1) (20.82N 156.14W)									12.93
Puu Kukui USGS (PKKH1) (20.89N 156.59W)									11.86
National Ocean Service (NOS)									
Kahului Harbor (1615680) (20.90N 156.47W)			12/1106	26	33				
Offshore									
NOAA Buoys									
North Hawaii (51000) (23.54N 153.81W)	12/0150	1011.6	11/2150	25	33				
Southwest Hawaii (51002) (17.04N 157.56W)	13/0150	1009.0							
North Hawaii (51000) (23.54N 153.81W)	12/0150	1011.6	11/2150	25	33				
Southeast Hawaii (51004) (17.60N 152.40W)	12/0040	1009.9	11/1230	10	16				
Western Hawaii (51003) (19.29N 160.57W)	13/1350	1008.2	13/1550	23	29				

[a] Date/time is for sustained wind when both sustained and gust are listed.
[b] Except as noted, sustained wind averaging periods for land-based reports are 2 min; buoy averaging periods are 8 min.

Table 3. Number of hours in advance of formation associated with the first NHC Tropical Weather Outlook forecast in the indicated likelihood category. Note that the timings for the "Low" category do not include forecasts of a 0% chance of genesis.

	Hours Before Genesis	
	48-Hour Outlook	**120-Hour Outlook**
Low (<40%)	54	102
Medium (40%-60%)	30	66
High (>60%)	12	42

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Olivia. Mean errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	**17.5**	**26.7**	**32.3**	**38.1**	**49.4**	**57.0**	**61.3**
OCD5	28.6	58.8	95.9	137.1	227.3	323.0	441.3
Forecasts	32	32	32	32	32	32	32
OFCL (2013-17)	21.8	33.2	43.0	53.9	80.7	111.1	150.5
OCD5 (2013-17)	34.9	70.7	109.1	146.1	213.8	269.0	339.7

Table 4b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Olivia. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 4a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	16.2	22.9	28.9	37.1	50.2	55.8	58.7
OCD5	29.0	59.5	98.2	142.3	242.8	349.8	480.3
GFSI	18.1	27.7	34.2	42.0	62.4	89.1	115.9
HWFI	19.3	30.4	36.3	43.3	63.0	73.3	80.9
HMNI	18.0	27.6	32.0	**35.9**	**40.5**	61.1	89.4
EGRI	19.6	27.8	38.3	48.7	73.7	103.9	133.7
EMXI	17.8	28.6	43.9	58.4	83.6	95.0	99.5
CMCI	20.1	32.2	42.9	53.1	58.1	63.7	106.0
NVGI	25.5	42.0	62.2	79.8	104.7	126.8	148.2
AEMI	18.1	32.4	43.1	51.7	71.1	78.0	77.0
HCCA	**15.8**	**20.0**	**24.6**	**31.7**	51.7	57.8	63.5
FSSE	16.6	23.2	29.1	38.4	56.1	70.5	89.6
TVCX	**15.9**	**21.8**	**26.5**	**33.5**	50.8	60.0	59.3
TVCE	**15.6**	**21.7**	**24.6**	**31.2**	**44.4**	**53.4**	**51.9**
GFEX	**15.5**	**21.1**	**28.2**	37.9	56.9	73.1	81.1
TABS	34.7	73.7	110.9	144.7	202.8	227.5	233.6
TABM	20.2	30.2	36.9	45.3	71.5	94.0	118.0
TABD	20.1	29.2	34.1	42.3	62.2	100.7	151.6
Forecasts	28	28	28	28	28	28	28

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Olivia. Mean errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	8.0	10.6	**11.7**	13.8	**15.0**	16.2	16.2
OCD5	10.2	15.9	18.8	20.7	25.5	26.0	21.1
Forecasts	32	32	32	32	32	32	32
OFCL (2013-17)	5.8	9.6	11.8	13.2	15.1	15.1	14.6
OCD5 (2013-17)	7.6	12.4	15.6	17.7	19.8	20.8	19.6

Table 5b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Olivia. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 5a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	8.9	11.8	13.0	14.5	15.2	16.8	17.5
OCD5	10.9	17.6	20.3	22.3	25.9	24.2	18.4
HWFI	9.6	13.7	15.7	14.9	16.6	**15.1**	**15.8**
HMNI	9.4	13.8	15.4	18.2	21.8	24.1	21.9
DSHP	9.9	14.7	15.5	17.1	18.5	19.7	19.2
LGEM	9.3	14.4	16.8	20.1	24.0	26.4	26.4
HCCA	**7.9**	**11.4**	13.9	**13.8**	17.4	18.8	19.5
FSSE	**7.6**	11.8	13.4	15.4	19.6	21.9	21.7
IVCN	**7.7**	12.3	14.1	16.3	19.2	20.0	18.6
GFSI	**8.4**	13.0	13.5	**11.7**	**14.5**	19.8	22.0
EMXI	10.7	15.0	17.7	20.8	22.5	24.5	22.8
Forecasts	28	28	28	28	28	28	28

Table 6a. CPHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Olivia. Mean errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	29.8	**38.0**	**32.0**	**42.1**	**46.1**	**40.7**	**30.5**
OCD5	46.3	88.2	125.2	165.5	250.4	308.8	535.2
Forecasts	19	17	15	13	9	5	1
OFCL (2013-17)	28.2	43.2	58.0	75.6	121.0	163.2	208.4
OCD5 (2013-17)	44.7	95.8	153.2	211.2	318.7	416.2	490.6

Table 6b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Olivia. Errors smaller than the CPHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 6a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	29.8	38.0	32.0	42.1	46.1	40.7	30.5
OCD5	46.3	88.2	125.2	165.5	250.4	308.8	535.2
GFSI	**27.5**	38.2	37.4	64.5	125.7	125.7	88.1
HWFI	**26.3**	**33.2**	39.6	49.1	53.4	77.6	69.0
HMNI	**25.1**	**37.6**	42.2	45.3	59.9	67.9	70.7
EGRI	**29.6**	41.0	53.8	65.4	75.0	68.4	**12.8**
EMXI	**26.8**	**35.3**	37.3	43.3	46.2	47.9	78.2
CMCI	30.9	38.3	42.7	54.2	87.5	109.1	151.6
NVGI	41.1	53.8	53.6	66.2	76.8	102.7	217.4
AEMI	**28.0**	**37.9**	34.7	52.1	65.7	85.1	58.9
HCCA	**25.5**	**32.4**	35.3	46.7	54.6	64.2	**6.0**
FSSE	**27.3**	**33.1**	**26.3**	**38.5**	48.1	59.6	34.0
TVCX	**24.8**	**31.3**	**27.8**	**38.9**	47.6	49.8	**13.3**
TVCE	**25.0**	**32.7**	**29.8**	**37.8**	47.5	47.0	**0.0**
GFEX	**25.5**	**32.0**	**25.3**	**37.0**	58.0	59.5	36.1
TABS	42.0	72.8	97.6	127.7	202.6	237.4	187.1
TABM	35.1	64.8	96.3	112.7	169.8	215.7	290.0
TABD	49.4	116.9	195.0	250.9	361.0	465.3	585.6
Forecasts	19	17	15	13	9	5	1

Table 7a. CPHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Olivia. Mean errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	**5.0**	**6.5**	**9.0**	**9.6**	**11.7**	**12.0**	**5.0**
OCD5	6.5	8.5	9.4	9.0	9.8	8.4	8.0
Forecasts	19	17	15	13	9	5	1
OFCL (2013-17)	5.6	9.0	11.3	12.9	15.7	17.4	18.9
OCD5 (2013-17)	7.1	11.1	14.4	17.4	20.6	22.3	23.7

Table 7b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Olivia. Errors smaller than the CPHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 7a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	5.0	6.5	9.0	9.6	11.7	12.0	5.0
OCD5	6.5	8.5	9.4	**9.0**	**9.8**	**8.4**	8.0
HWFI	6.3	6.7	**5.5**	10.2	**8.9**	**4.6**	**2.0**
HMNI	**4.7**	**4.5**	**5.5**	**6.2**	**8.2**	**6.6**	**3.0**
DSHP	6.4	6.8	**8.9**	**8.8**	**8.0**	**4.8**	**3.0**
LGEM	6.2	8.1	10.1	10.5	13.8	12.0	6.0
HCCA	5.5	**6.3**	**7.7**	11.2	11.7	**8.6**	8.0
FSSE	**4.4**	**5.6**	**8.5**	11.2	**10.0**	**6.2**	**2.0**
IVCN	5.5	**6.1**	**6.5**	**8.2**	**10.0**	**6.0**	**1.0**
GFSI	**4.9**	6.5	**8.6**	**8.8**	**8.6**	**5.6**	11.0
EMXI	**4.6**	7.1	**6.5**	**7.5**	**8.3**	**5.2**	**1.0**
Forecasts	19	17	15	13	9	5	1

Table 8. Watch and warning summary for Hurricane Olivia.

Date/Time (UTC)	Action	Location
10 / 0300	Tropical Storm Watch issued	Islands of Hawaii, Maui, Molokai, Lanai, Kahoolawe, and Oahu
10 / 1500	Tropical Storm Watch changed to Tropical Storm Warning	Islands of Hawaii, Maui, Molokai, Lanai, and Kahoolawe
11 / 0300	Tropical Storm Watch issued	Islands of Kauai and Niihau
11 / 0300	Tropical Storm Watch changed to Tropical Storm Warning	Island of Oahu
11 / 2100	Tropical Storm Watch changed to Tropical Storm Warning	Islands of Kauai and Niihau
12 / 0900	Tropical Storm Warning discontinued	Islands of Kauai and Niihau
12 / 1500	Tropical Storm Warning discontinued	Island of Hawaii
13 / 0300	Tropical Storm Warning discontinued	All

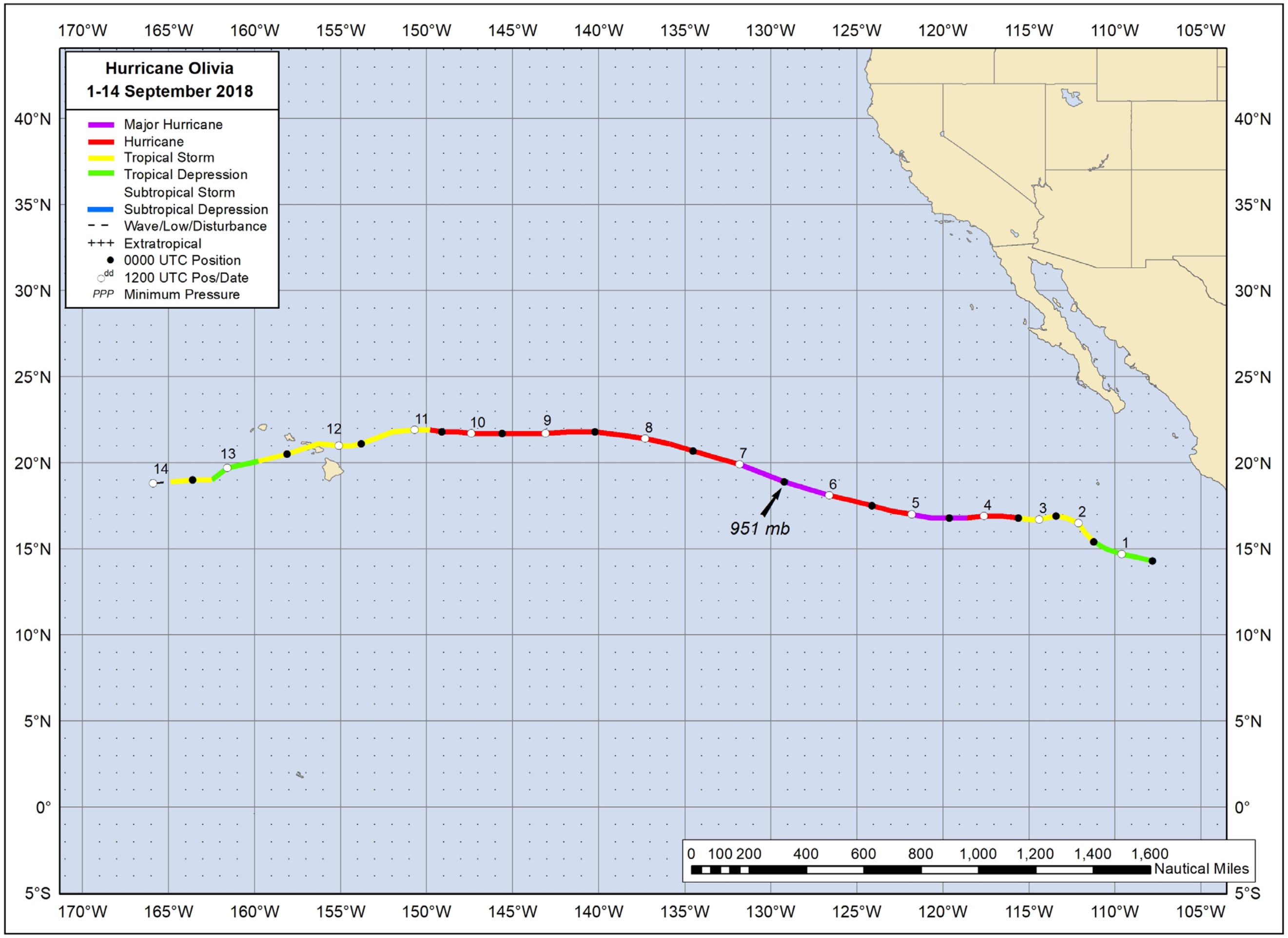

Figure 1. Best track positions for Hurricane Olivia, 1–14 September 2018.

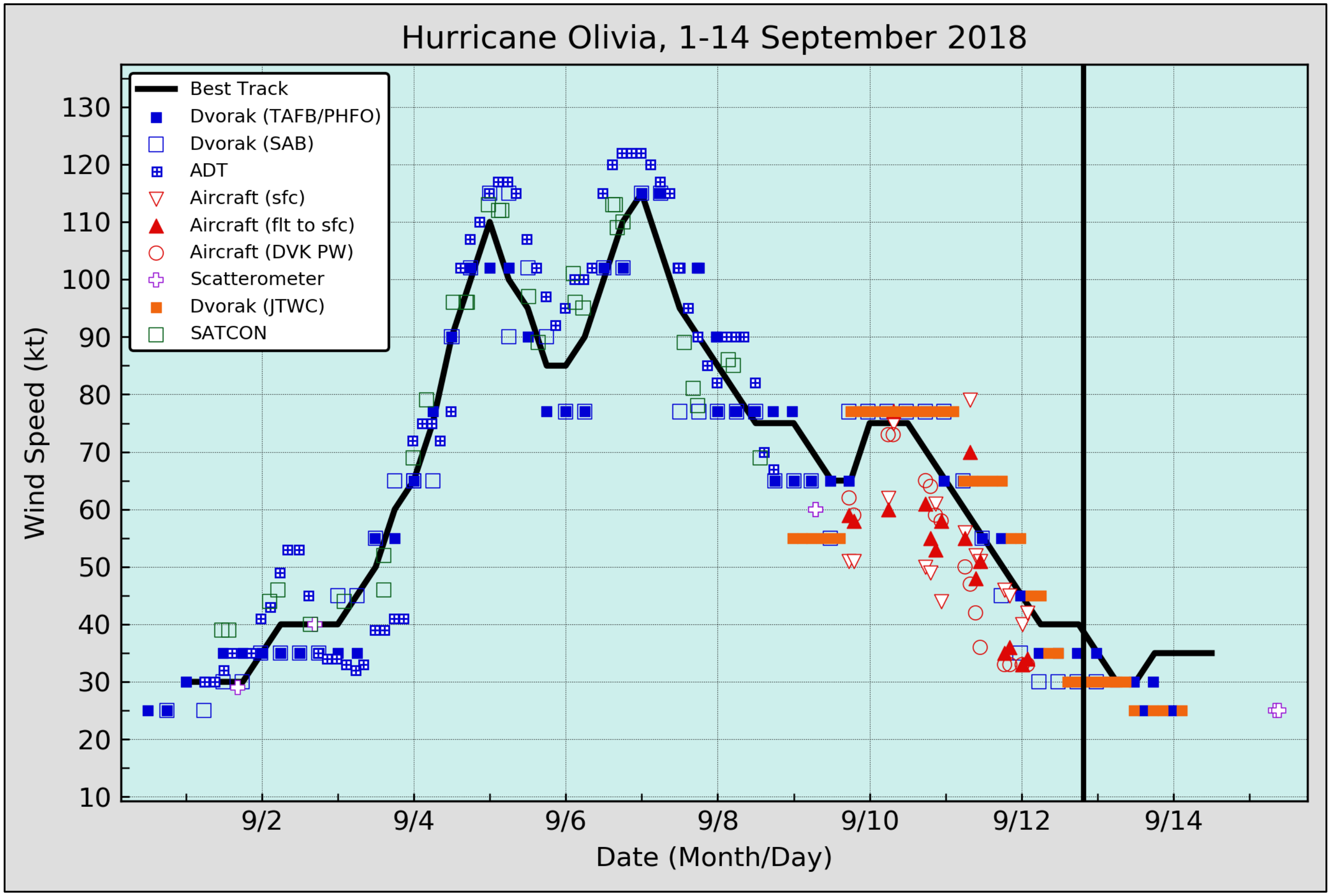

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Olivia, 1–14 September 2018. Aircraft observations have been adjusted for elevation using a 90% adjustment factor for observations from 700 mb. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. Dashed vertical lines correspond to 0000 UTC.

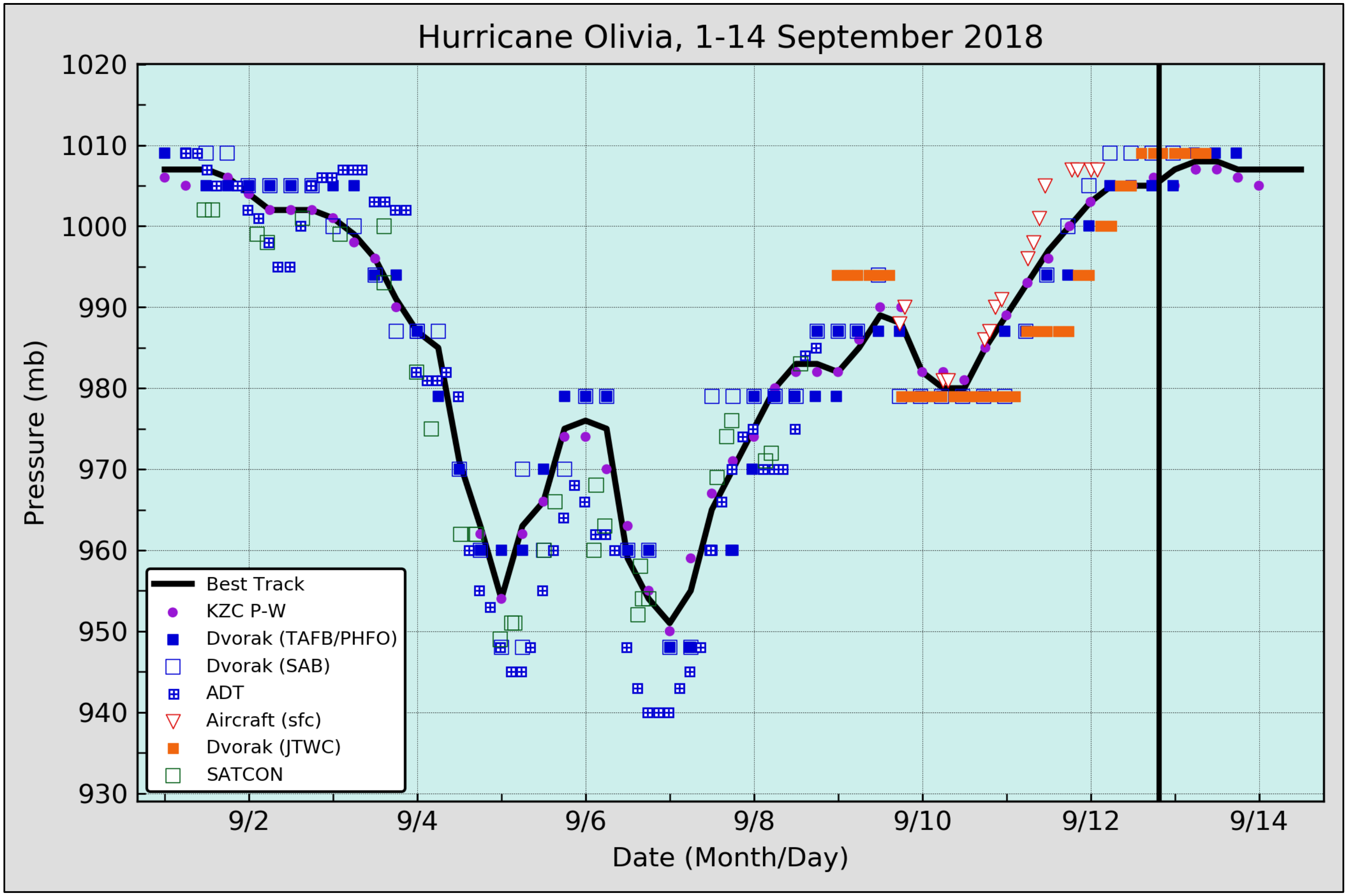

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Olivia, 1–14 September 2018. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship. Dashed vertical lines correspond to 0000 UTC.

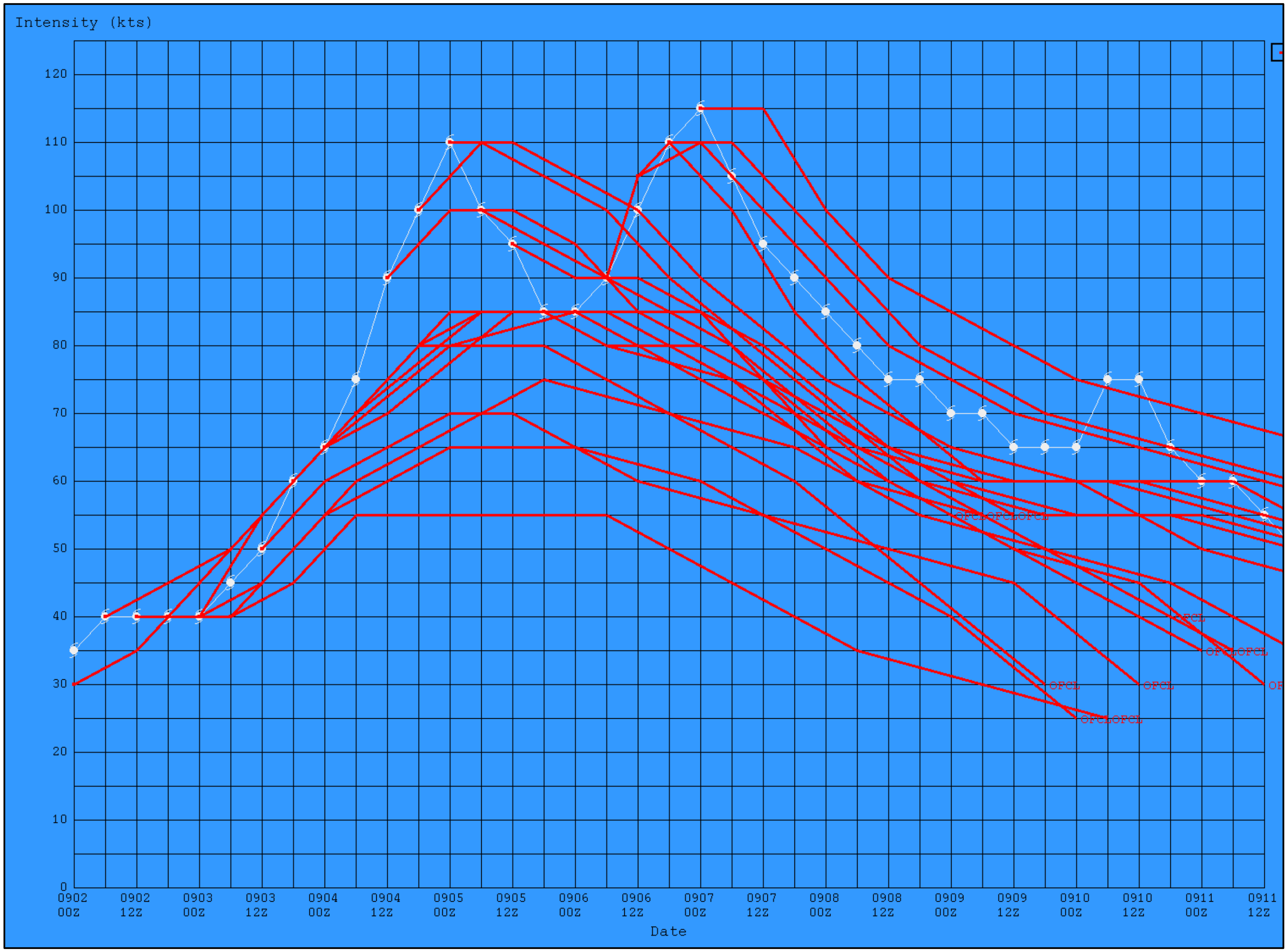

Figure 4. NHC official intensity forecasts (kt, red lines) from 0000 UTC 2 September to 0000 UTC 7 September 2018 for Hurricane Olivia. The verifying intensity is shown in white.

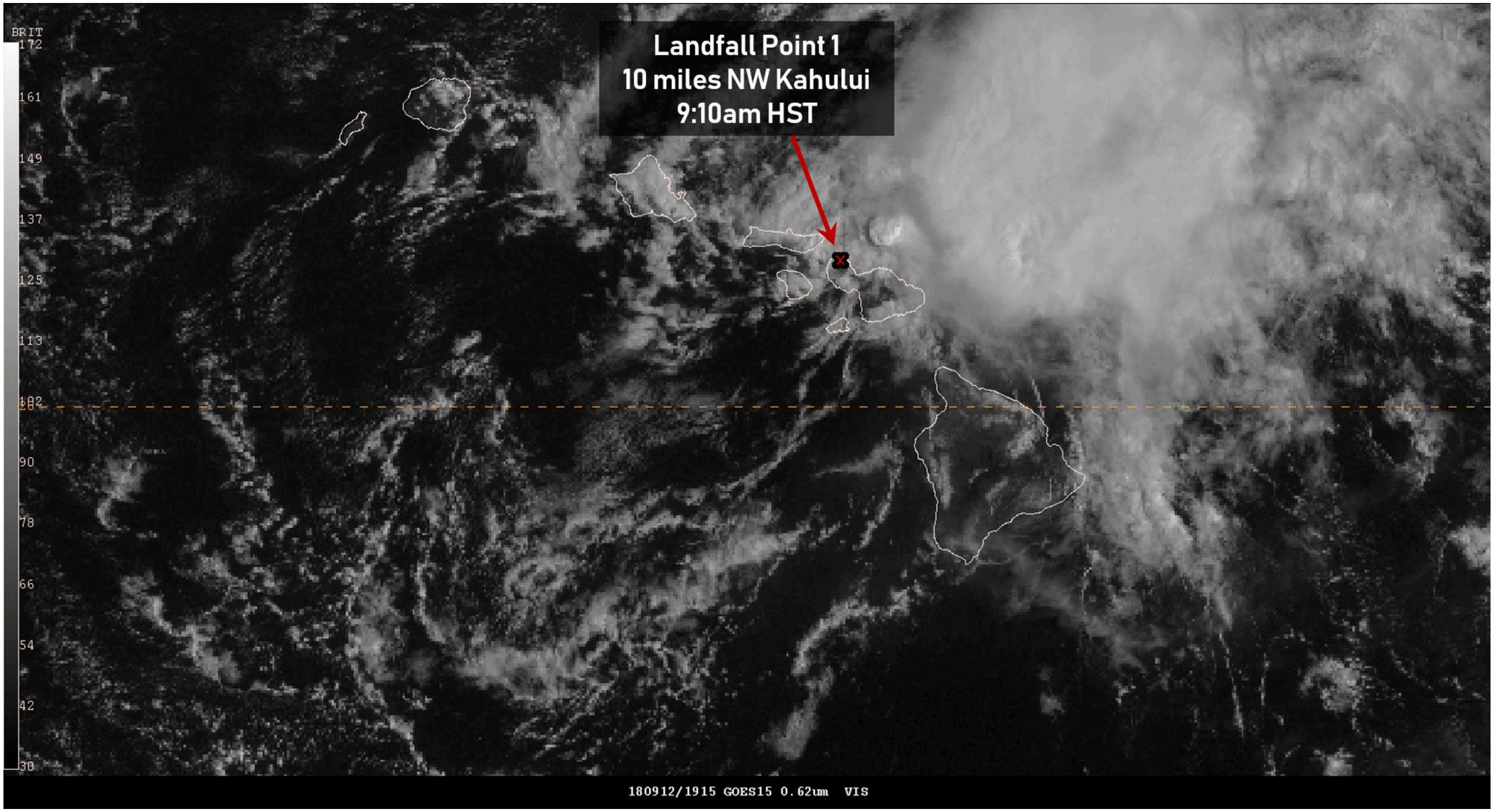

Figure 5. GOES-15 visible satellite image of initial landfall of Tropical Storm Olivia, 10 miles northwest of Kahului, Maui, Hawaii at 9:10 AM HST or 1910 UTC 12 September 2018.

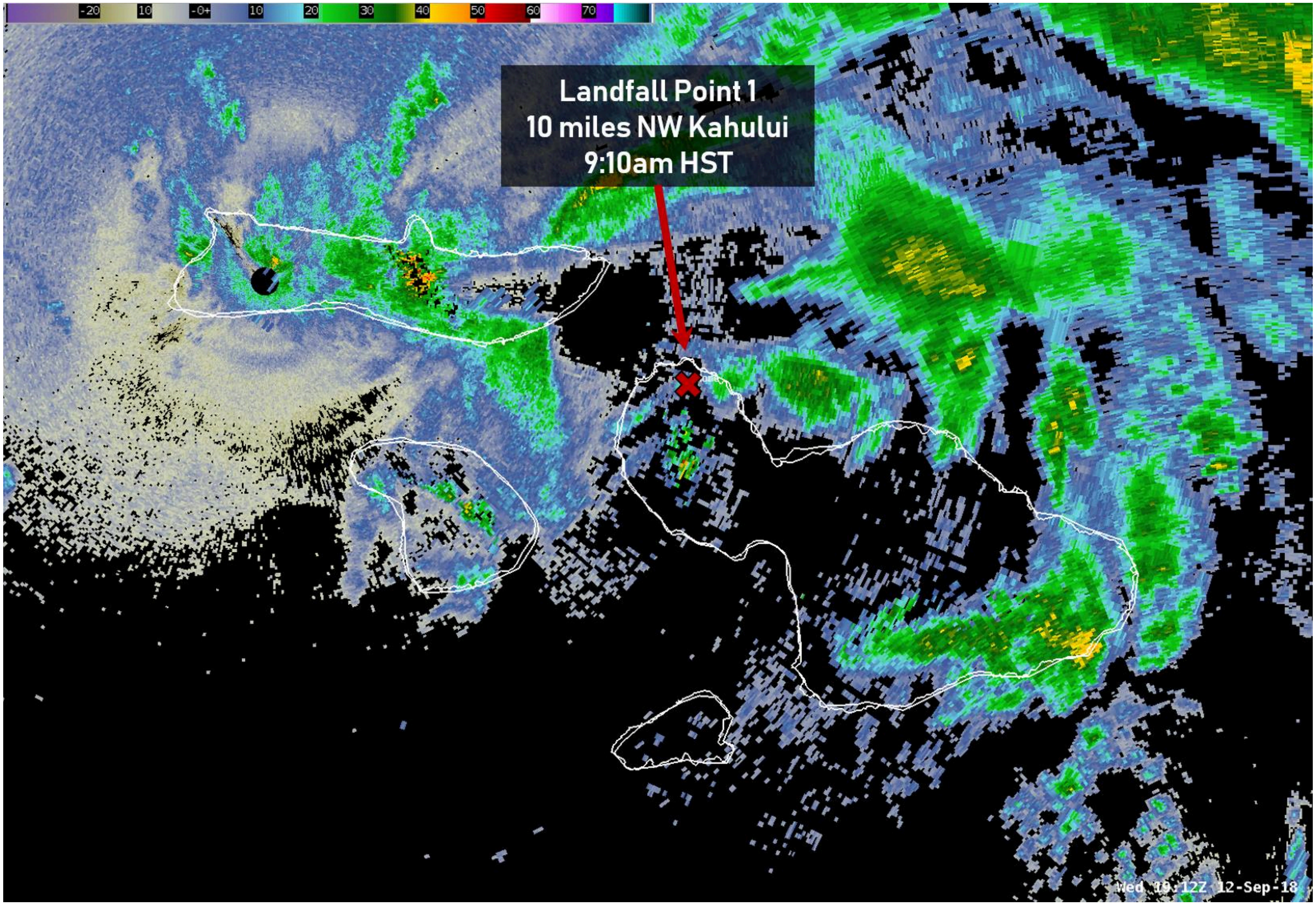

Figure 6. PHMO Nexrad radar image of initial landfall of Tropical Storm Olivia, 10 miles northwest of Kahului, Maui, Hawaii at 9:10 AM HST or 1910 UTC 12 September 2018.

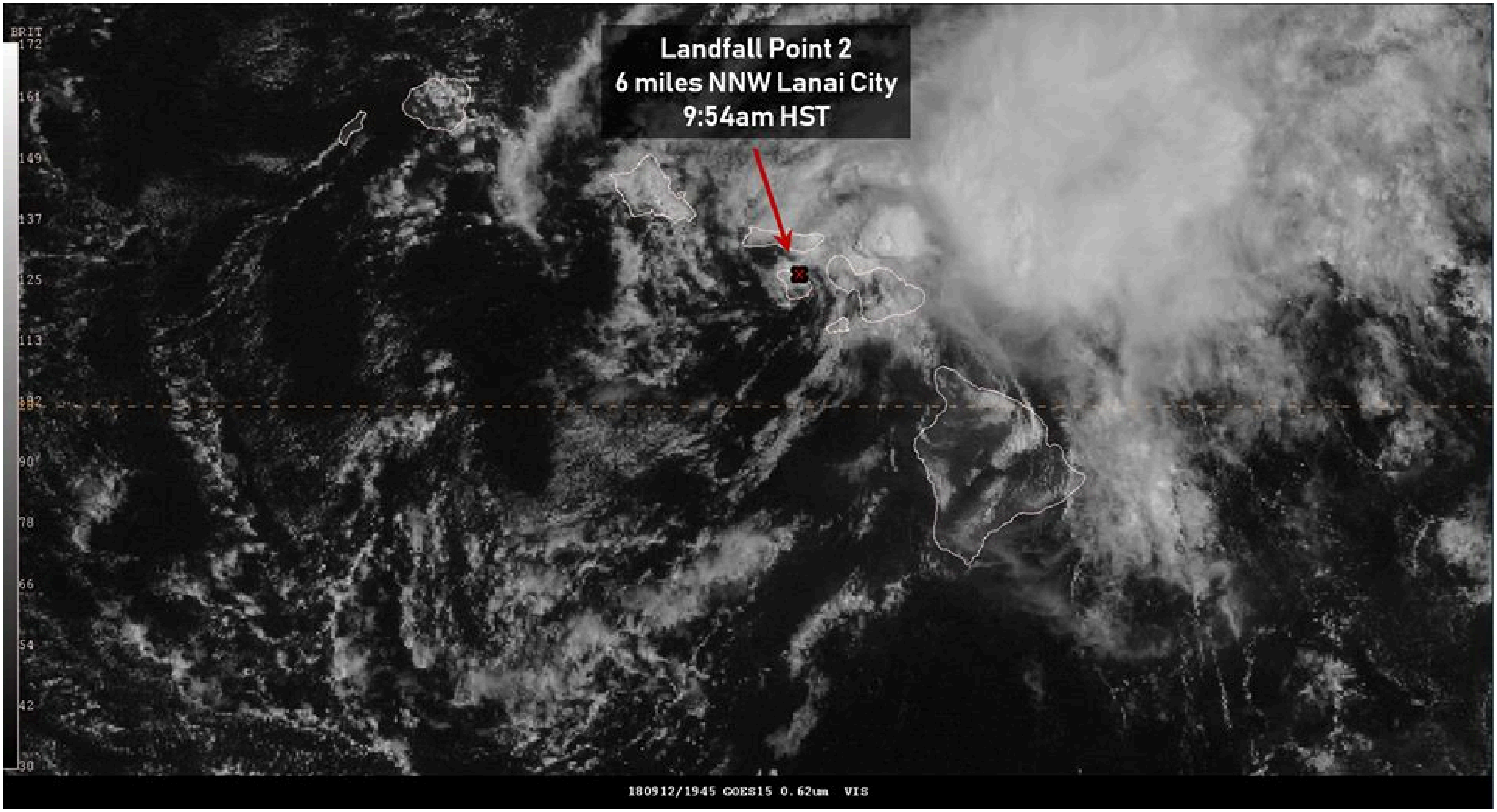

Figure 7. GOES-15 visible satellite image of secondary landfall of Tropical Storm Olivia, 6 miles north-northwest of Lanai City, Lanai, Hawaii at 9:54 AM HST or 1954 UTC 12 September 2018.

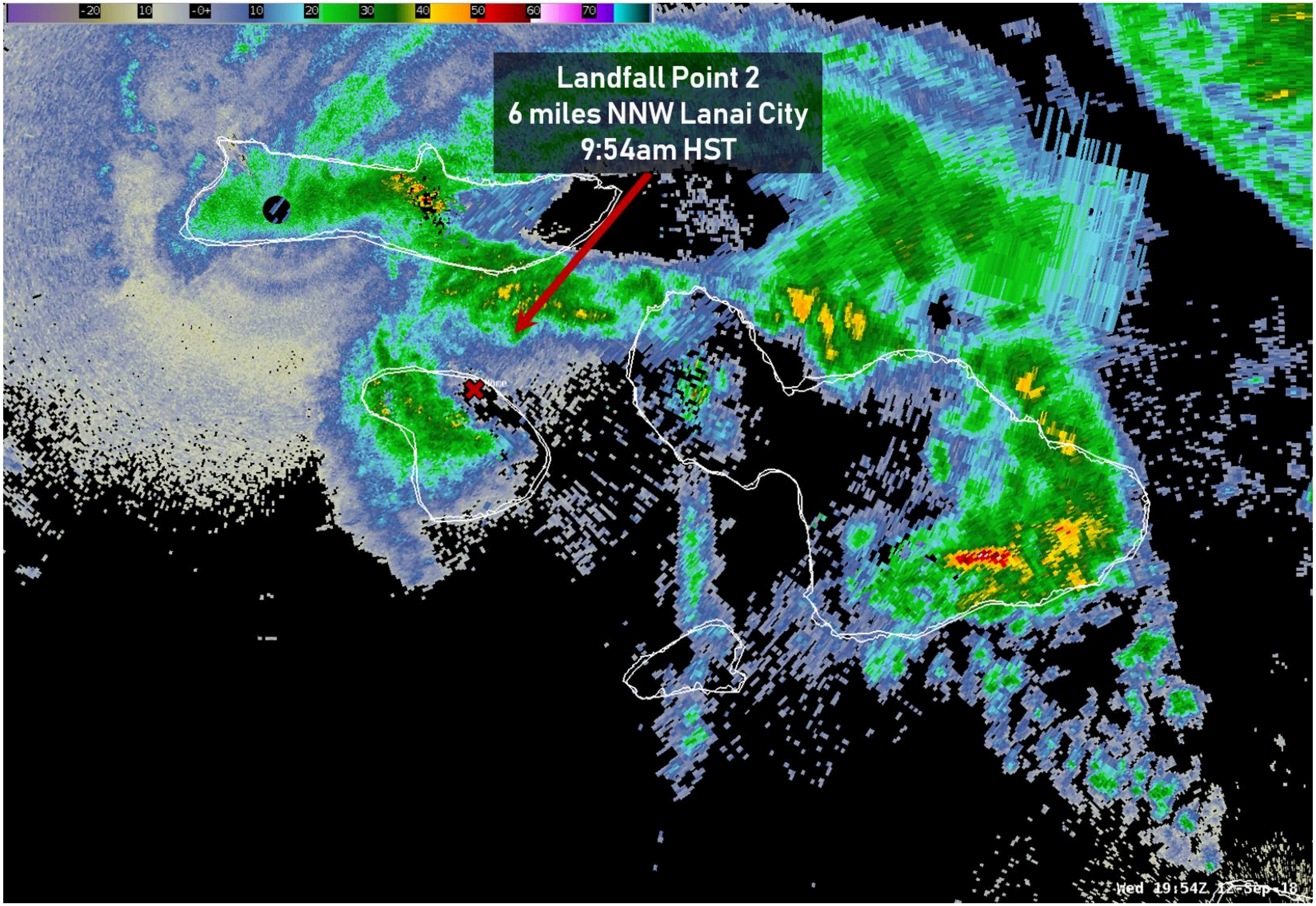

Figure 8. PHMO Nexrad radar image of secondary landfall of Tropical Storm Olivia, 6 miles north-northwest of Lanai City, Lanai, Hawaii at 9:54 AM HST or 1954 UTC 12 September 2018.

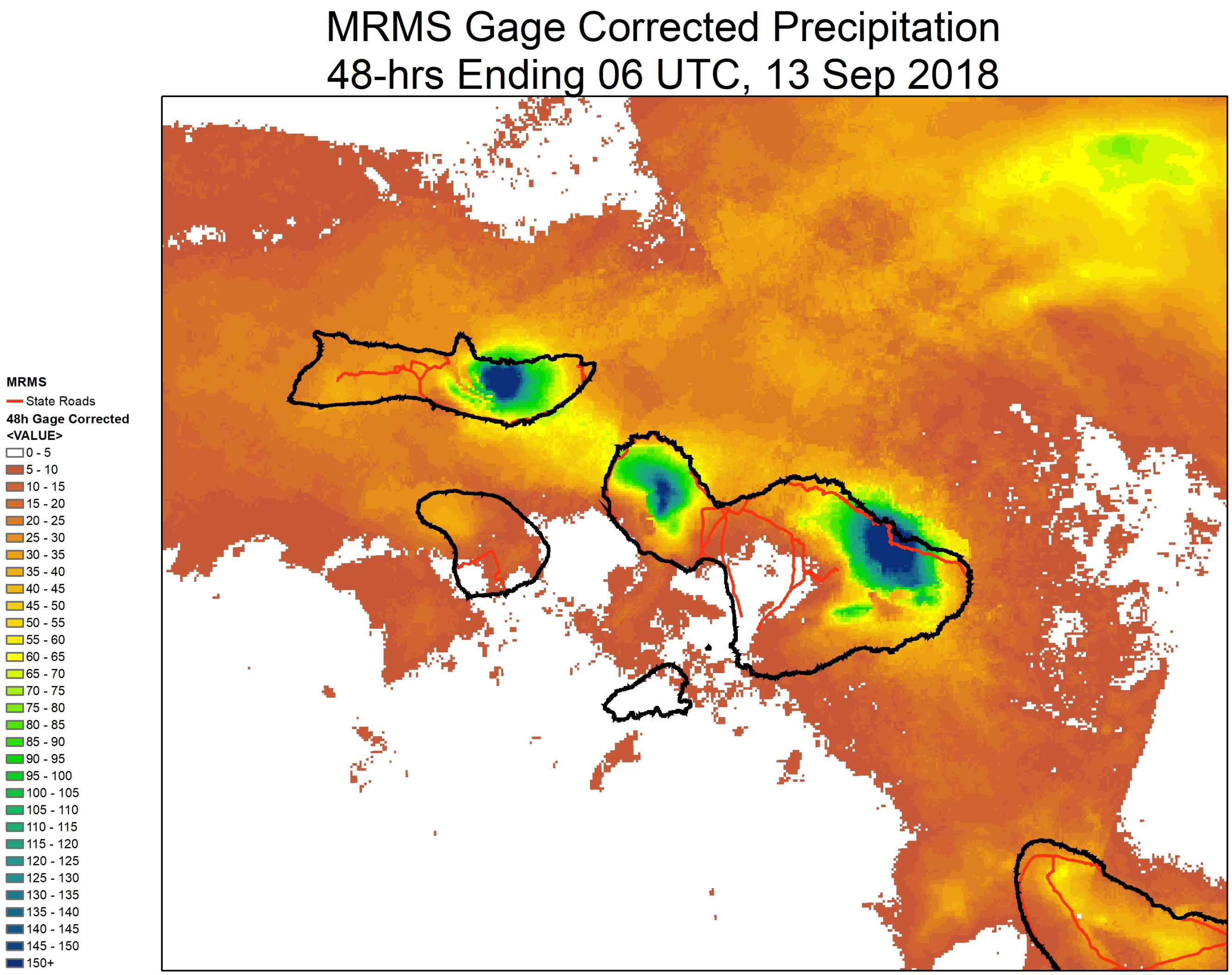

Figure 9. Multi-Radar, Multi-Sensor data showing the areas receiving the heaviest amounts of rainfall (mm) over windward sections of Maui and Molokai.

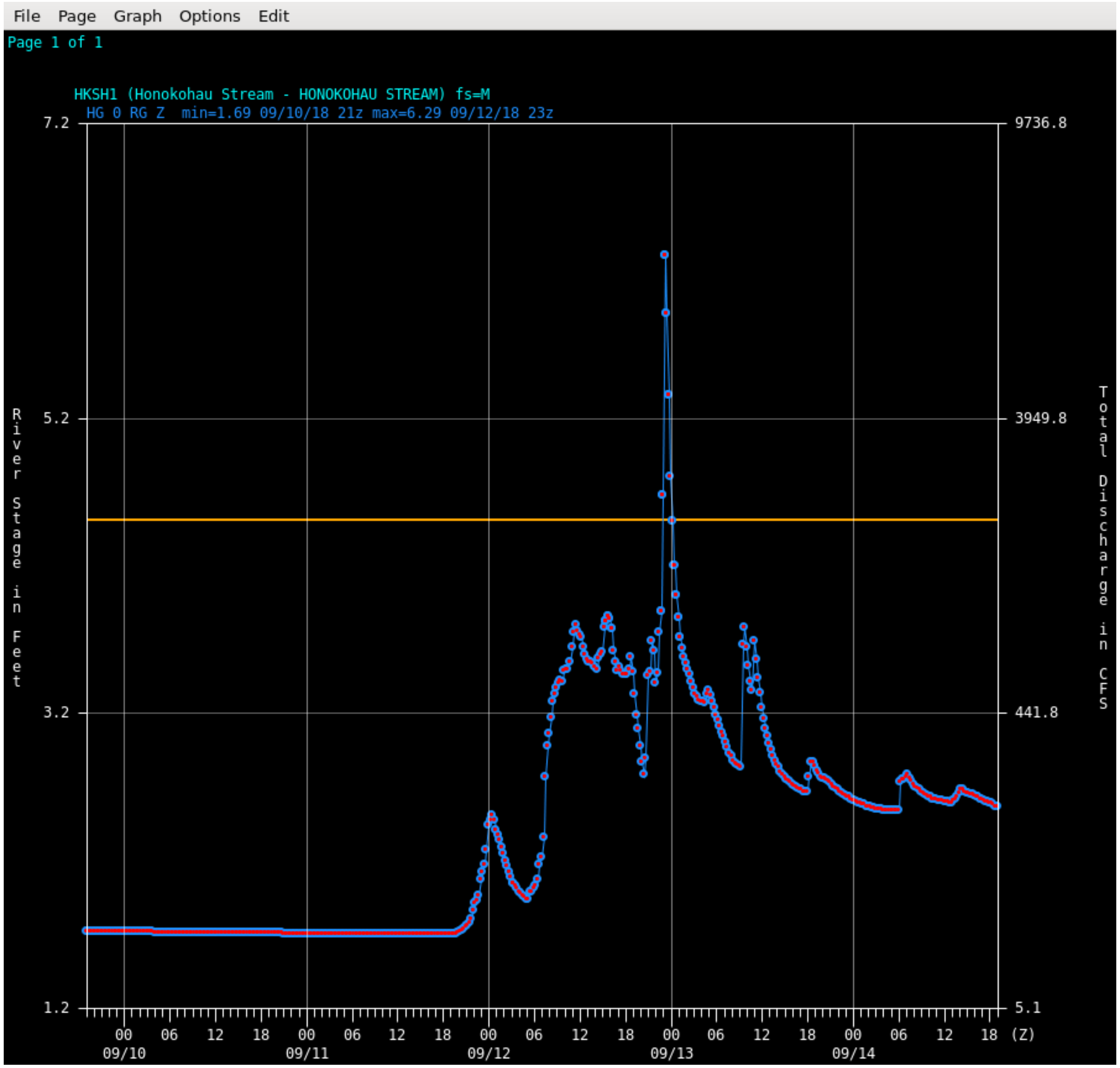

Figure 10. Hydrograph of the Honokohau Stream in west Maui on 12 September, which rose well above the level (orange line) that is known to produce flooding on 12 September.

Figure 11. Damage to Kahaha Road in Napili area (Credit: Maui Emergency Management Agency).

Figure 12. Home in Waihee River Basin with foundation damage (Credit: Maui Emergency Management Agency).

Figure 13. Flooding on Kamehameha V Highway at mile marker 10, near Kawalo Wharf Road (Credit: Hawaii DOT).