# NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

# TROPICAL STORM NADINE

(AL152018)

9–12 October 2018

Stacy R. Stewart
National Hurricane Center
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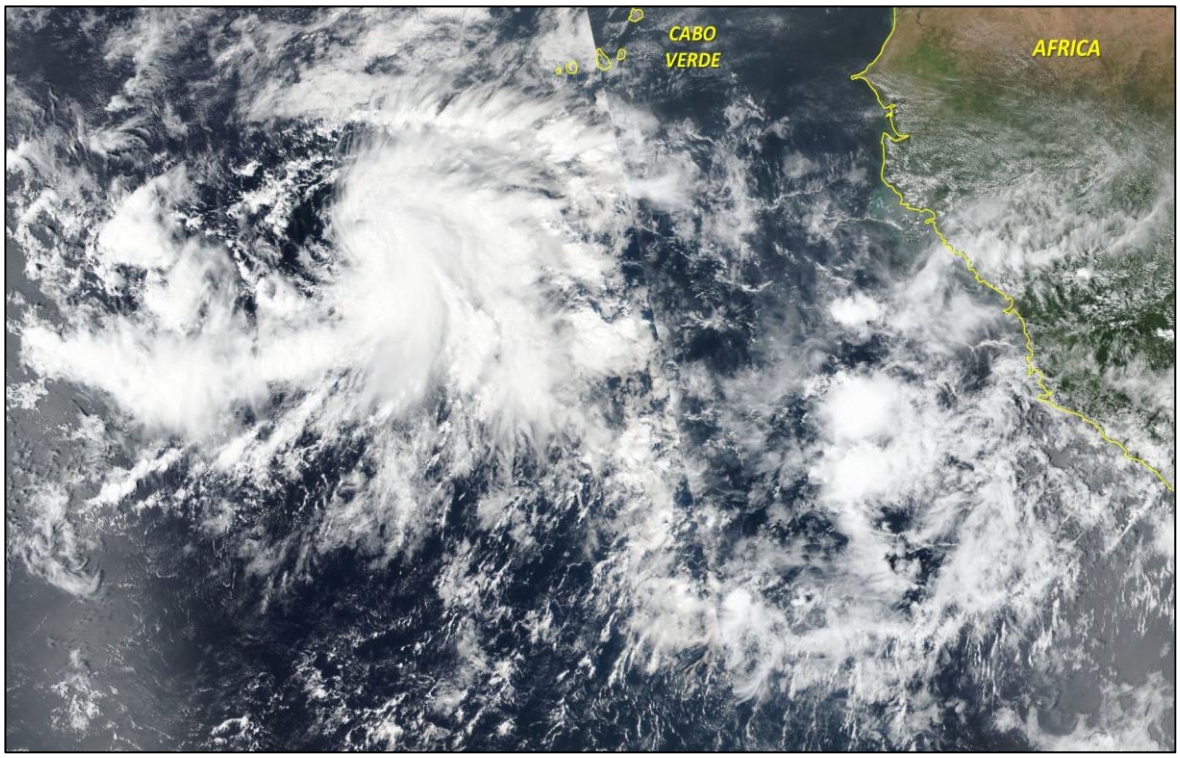


**VIIRS VISIBLE IMAGE FROM THE NASA-NOAA SUOMI NPP SATELLITE SHOWING NADINE SOUTHWEST OF THE CABO VERDE ISLANDS AT 1500Z 9 OCT 2018 SHORTLY AFTER BECOMING A TROPICAL STORM. IMAGE COURTESY OF NASA.**

Nadine was a small tropical storm that remained over the eastern tropical Atlantic Ocean and did not directly affect any land areas.

# Tropical Storm Nadine

**9–12 OCTOBER 2018**

## SYNOPTIC HISTORY

The origin of Nadine can be traced to a tropical wave that moved off the west coast of Africa early on 6 October. Accompanied by only modest convective activity, the wave fractured shortly after emerging over the far eastern tropical Atlantic, with the northern extent of the wave moving over anomalously cold water located north of 12°N latitude, while the southern end continued to move westward over much warmer water at an unusually low latitude south of 10°N. Convection associated with the northern portion of the wave dissipated over the colder water; in contrast, deep convection increased and became more concentrated along the southern extent of the wave axis, which helped to generate a well-defined mid- to upper-level circulation early on 7 October when the disturbance was located about 500 n mi south-southeast of the Cabo Verde archipelago. Thunderstorms slowly increased and became better organized over the next 24 h, and scatterometer wind data and ship observations indicated that a well-defined surface low pressure system had developed by 1200 UTC 8 October about 400 n mi south of the Cabo Verde Islands. Convective organization steadily improved with curved, spiral bands developing by late that day, and it is estimated that a tropical depression formed around 0600 UTC 9 October about 380 n mi southwest of the Cabo Verde Islands. The small cyclone strengthened into a tropical storm 6 h later. 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[1].

Shortly after forming, Nadine turned toward the west-northwest and northwest, and quickly strengthened within a very favorable environment characterized by low 850–200-mb vertical wind shear (<10 kt), warm sea-surface temperatures (SST >28°C), and a rather moist mid-troposphere (RH >70%). At the time that Nadine first became a tropical depression, the cyclone was located very near the center of an upper-level anticyclone, which greatly reduced the shear across the system and also enhanced the upper-level outflow (Fig. 4), setting the stage for the 24-h period of strengthening that immediately followed. Nadine reached its peak intensity of 55 kt around 0600 UTC 10 October when the tropical storm was located about 400 n mi west-southwest of the Cabo Verde Islands, and maintained that intensity for another 6 h. A well-defined eye was evident in passive microwave satellite imagery throughout a deep layer of the troposphere (Fig. 5, top panels) at the time of peak intensity. However, strengthening was brought to an abrupt halt due to increasing westerly to west-southwesterly wind shear of 15–20 kt, which disrupted the eyewall convection (Fig. 5, bottom panels); by 1800 UTC that day, steady weakening was underway despite the otherwise favorable conditions of warm ocean temperatures and deep moisture (Fig. 4). At around 1200 UTC 12 October, Nadine turned sharply toward the west-northwest and moved

[1] 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.

into more hostile west-southwesterly wind shear conditions of more than 30 kt, which stripped away most of the deep convection, causing the cyclone to weaken to a tropical depression 6 h later. Now devoid of any latent heat to sustain the small tropical cyclone, the system quickly degenerated into an open wave by 0000 UTC 13 October about 750 n mi west of the Cabo Verde Islands. The sharp trough continued to move westward at forward speeds of 15–20 kt for the next several days, producing intermittent bursts of deep convection before finally dissipating just east of the Lesser Antilles early on 16 October.

## METEOROLOGICAL STATISTICS

Observations in Tropical Storm Nadine (Figs. 2 and 3) include subjective satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis Branch (SAB), 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 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 Nadine.

There were no ship reports of tropical-storm-force winds associated with Nadine.

Nadine's estimated peak intensity of 55 kt on 10 October at 0600 UTC and 1200 UTC is based on UW-CIMSS SATCON estimates of 54 kt, and were adjusted forward in time by 6 h to coincide with the well-defined eye feature noted in passive microwave imagery (Fig. 5).

The estimated minimum central pressure of 995 mb is based on blend of the Knaff-Zehr-Courtney (KZC) and SATCON pressure-wind relationships, coincident with the aforementioned eye feature.

## CASUALTY AND DAMAGE STATISTICS

There were no reports of damage or casualties associated with Tropical Storm Nadine.

## FORECAST AND WARNING CRITIQUE

The genesis of Nadine was not forecast very well. The wave from which the tropical storm developed was introduced in the Tropical Weather Outlook with a low probability (<40%) of formation only 30 h prior to genesis in both the 5-day and 2-day forecast periods (Table 2). Likewise, the probabilities were simultaneously raised into the medium (40–60%) and high (>60%) categories 18 h and 6 h prior to genesis, respectively. These extremely short lead times were due to uncertainly in what latitude the bulk of the tropical wave would move off of the African coast. Higher latitudes north of 12°N were characterized by colder-than-average SSTs and a very

dry Saharan Air Layer (SAL), while warmer SSTs and a more moist troposphere were present south of a sharp thermodynamic gradient that existed between 10°–12°N. After the wave fractured and it became apparent that the southern portion and not the northern portion of the wave would develop, genesis probabilities began to increase.

A verification of NHC official track forecasts for Nadine is given in Table 3a. Official forecast track errors (OFCL) were greater than the mean official errors for the previous 5-yr period at 12 h and 24 h, but they were lower than average by more than 30% in the 48–72 h period. A homogeneous comparison of the official track errors with selected guidance models is given in Table 3b. OFCL forecasts outperformed nearly every track forecast model at every time period except for the simple consensus model TVCX.

A verification of NHC official intensity forecasts for Nadine is given in Table 4a. Official forecast intensity errors were significantly lower — 35% to 65% less — than the mean official errors for the previous 5-yr period in the 24–72 h period; OFCL intensity errors were comparable to the 5-yr mean at 12 h. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 4b. Similar to the track errors, OFCL intensity forecasts outperformed nearly every model at most of the forecast time periods, except for GFS global model (GFSI) forecasts, which were about 60% better at 48 h and 72 h.

No coastal tropical cyclone watches or warnings were required with Nadine.

Table 1. Best track for Tropical Storm Nadine, 9–12 October 2018.

| Date/Time (UTC) | Latitude (°N) | Longitude (°W) | Pressure (mb) | Wind Speed (kt) | Stage |
|---|---|---|---|---|---|
| 08 / 1200 | 9.3 | 26.7 | 1009 | 25 | low |
| 08 / 1800 | 9.5 | 27.6 | 1009 | 25 | " |
| 09 / 0000 | 9.8 | 28.4 | 1009 | 25 | " |
| 09 / 0600 | 10.1 | 29.0 | 1008 | 30 | tropical depression |
| 09 / 1200 | 10.4 | 29.6 | 1006 | 35 | tropical storm |
| 09 / 1800 | 10.8 | 30.2 | 1004 | 40 | " |
| 10 / 0000 | 11.2 | 30.7 | 999 | 50 | " |
| 10 / 0600 | 11.8 | 30.9 | 995 | 55 | " |
| 10 / 1200 | 12.3 | 31.4 | 996 | 55 | " |
| 10 / 1800 | 12.8 | 32.0 | 998 | 50 | " |
| 11 / 0000 | 13.3 | 32.5 | 998 | 50 | " |
| 11 / 0600 | 13.6 | 33.1 | 1001 | 45 | " |
| 11 / 1200 | 13.9 | 33.8 | 1001 | 45 | " |
| 11 / 1800 | 14.3 | 34.6 | 1002 | 45 | " |
| 12 / 0000 | 14.8 | 35.0 | 1003 | 40 | " |
| 12 / 0600 | 15.3 | 35.3 | 1004 | 40 | " |
| 12 / 1200 | 15.8 | 35.7 | 1006 | 35 | " |
| 12 / 1800 | 16.2 | 37.0 | 1008 | 30 | tropical depression |
| 13 / 0000 | | | | | dissipated |
| 10 / 0600 | 11.8 | 30.9 | 995 | 55 | minimum pressure |

Table 2. 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%) | 30 | 30 |
| Medium (40%-60%) | 18 | 18 |
| High (>60%) | 6 | 6 |

Table 3a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Tropical Storm Nadine, 9–12 October 2018. 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 | 32.0 | 44.1 | **43.6** | **44.8** | **64.5** | | |
| OCD5 | 40.2 | 73.1 | 112.6 | 146.6 | 332.1 | | |
| Forecasts | 13 | 11 | 9 | 7 | 3 | | |
| OFCL (2013-17) | 24.1 | 37.4 | 50.5 | 66.6 | 98.4 | 137.4 | 180.7 |
| OCD5 (2013-17) | 44.7 | 95.8 | 153.2 | 211.2 | 318.7 | 416.2 | 490.6 |

Table 3b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Tropical Storm Nadine, 9–12 October 2018. 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 3a due to the homogeneity requirement.

| Model ID | Forecast Period (h) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 12 | 24 | 36 | 48 | 72 | 96 | 120 |
| OFCL | 31.1 | 41.9 | 44.3 | 43.7 | 74.9 | | |
| OCD5 | 31.3 | 54.0 | 81.9 | 104.9 | 332.0 | | |
| GFSI | 40.8 | 73.0 | 118.7 | 142.7 | 123.4 | | |
| EMXI | 33.2 | 46.5 | 60.2 | 63.8 | 109.8 | | |
| EGRI | **30.5** | 51.2 | 77.3 | 78.9 | **72.2** | | |
| CMCI | **28.6** | **32.1** | 58.8 | 98.6 | 283.1 | | |
| NVGI | 37.0 | 51.2 | 64.7 | 88.7 | 150.1 | | |
| AEMI | 34.1 | 56.0 | 88.2 | 108.1 | **70.7** | | |
| HWFI | 38.4 | 52.6 | 50.9 | **40.1** | 106.8 | | |
| HMNI | 31.3 | 45.6 | 51.6 | 46.7 | 130.2 | | |
| HCCA | 33.1 | **40.8** | **44.0** | 45.8 | 97.1 | | |
| FSSE | 36.0 | 45.8 | 62.1 | 70.3 | 78.0 | | |
| GFEX | 32.0 | 42.8 | 55.3 | 65.0 | 87.8 | | |
| TVCA | 33.0 | 41.9 | 47.9 | 54.5 | **53.2** | | |
| TVCX | **30.3** | **38.7** | **40.8** | **42.8** | **54.4** | | |
| TCON | 33.2 | 48.9 | 59.5 | 64.7 | **42.8** | | |
| TABD | 51.4 | 133.8 | 238.9 | 350.6 | 532.8 | | |
| TABM | 37.4 | 80.1 | 136.6 | 199.8 | 271.2 | | |
| TABS | 37.2 | 60.1 | 63.7 | 77.7 | 185.8 | | |
| Forecasts | 11 | 9 | 7 | 5 | 1 | | |

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Tropical Storm Nadine, 9–12 October 2018. 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 | 5.8 | **5.0** | **3.3** | **5.0** | **5.0** | | |
| OCD5 | 9.9 | 13.5 | 16.7 | 19.0 | 16.3 | | |
| Forecasts | 13 | 11 | 9 | 7 | 3 | | |
| OFCL (2013-17) | 5.5 | 8.0 | 10.1 | 11.4 | 12.7 | 14.5 | 15.0 |
| OCD5 (2013-17) | 7.1 | 11.1 | 14.4 | 17.4 | 20.6 | 22.3 | 23.7 |

Table 4b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Tropical Storm Nadine, 9–12 October 2018. 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 | 5.4 | 3.5 | 2.5 | 5.0 | 5.0 | | |
| OCD5 | 9.7 | 12.3 | 16.6 | 20.8 | 22.5 | | |
| DSHP | 6.6 | 5.1 | 2.8 | **3.3** | 8.5 | | |
| LGEM | 8.0 | 6.4 | 5.2 | **4.3** | **4.5** | | |
| HWFI | 7.2 | 6.4 | 3.4 | 7.5 | 8.5 | | |
| HMNI | 5.7 | 8.7 | 8.9 | 10.5 | 10.5 | | |
| HCCA | 6.1 | 4.6 | 3.6 | 5.5 | 6.5 | | |
| FSSE | 6.2 | 4.5 | 2.5 | 5.7 | **4.5** | | |
| IVCN | 6.9 | 4.6 | 3.0 | **3.5** | 8.0 | | |
| ICON | 6.7 | 4.7 | 2.8 | **4.8** | 7.5 | | |
| GFSI | 6.9 | 6.1 | 6.1 | **1.8** | **2.0** | | |
| EMXI | 7.2 | 7.7 | 5.4 | 5.3 | **4.0** | | |
| Forecasts | 12 | 10 | 8 | 6 | 2 | | |

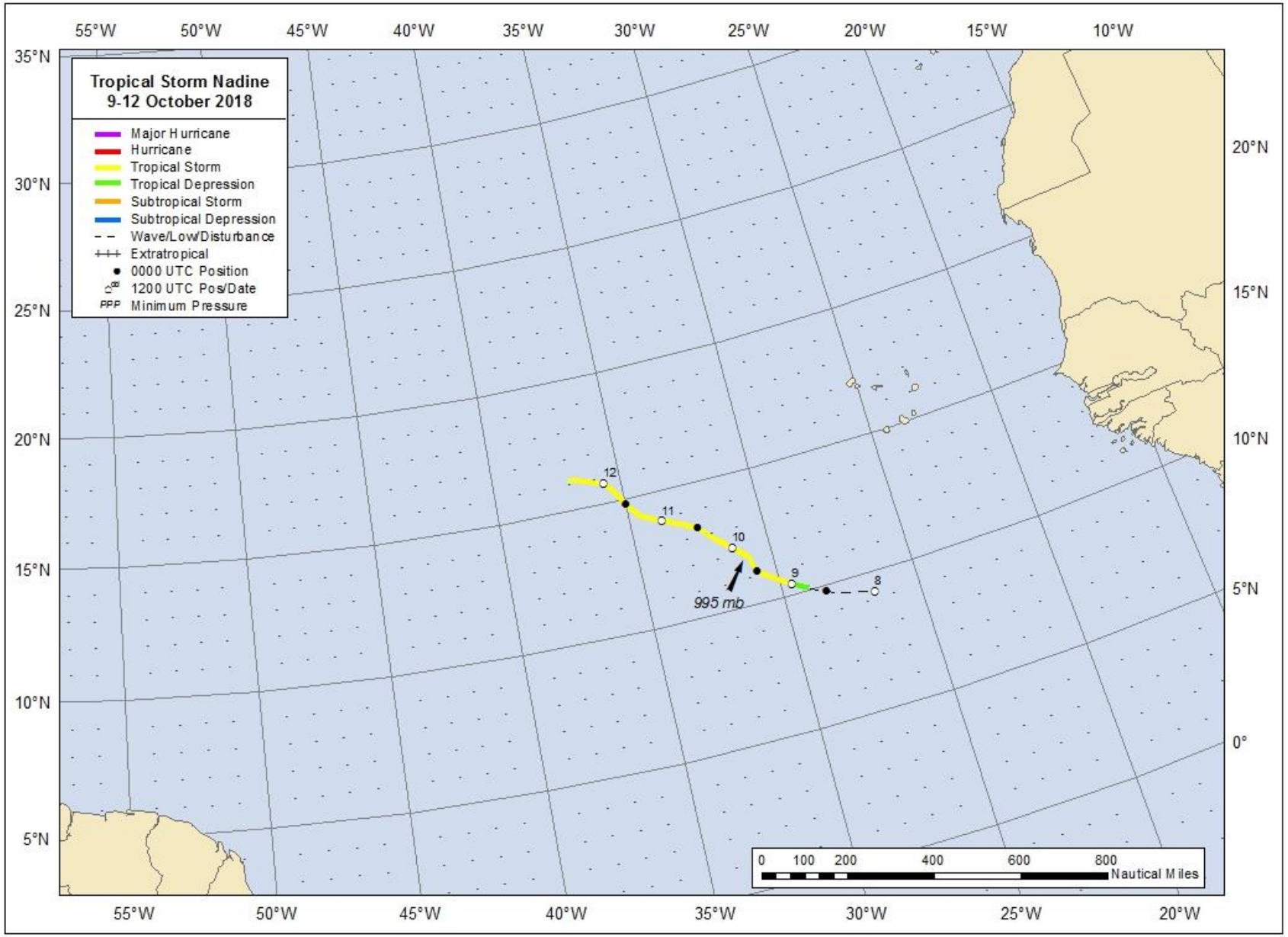


Figure 1. Best track positions for Tropical Storm Nadine, 9–12 October 2018.

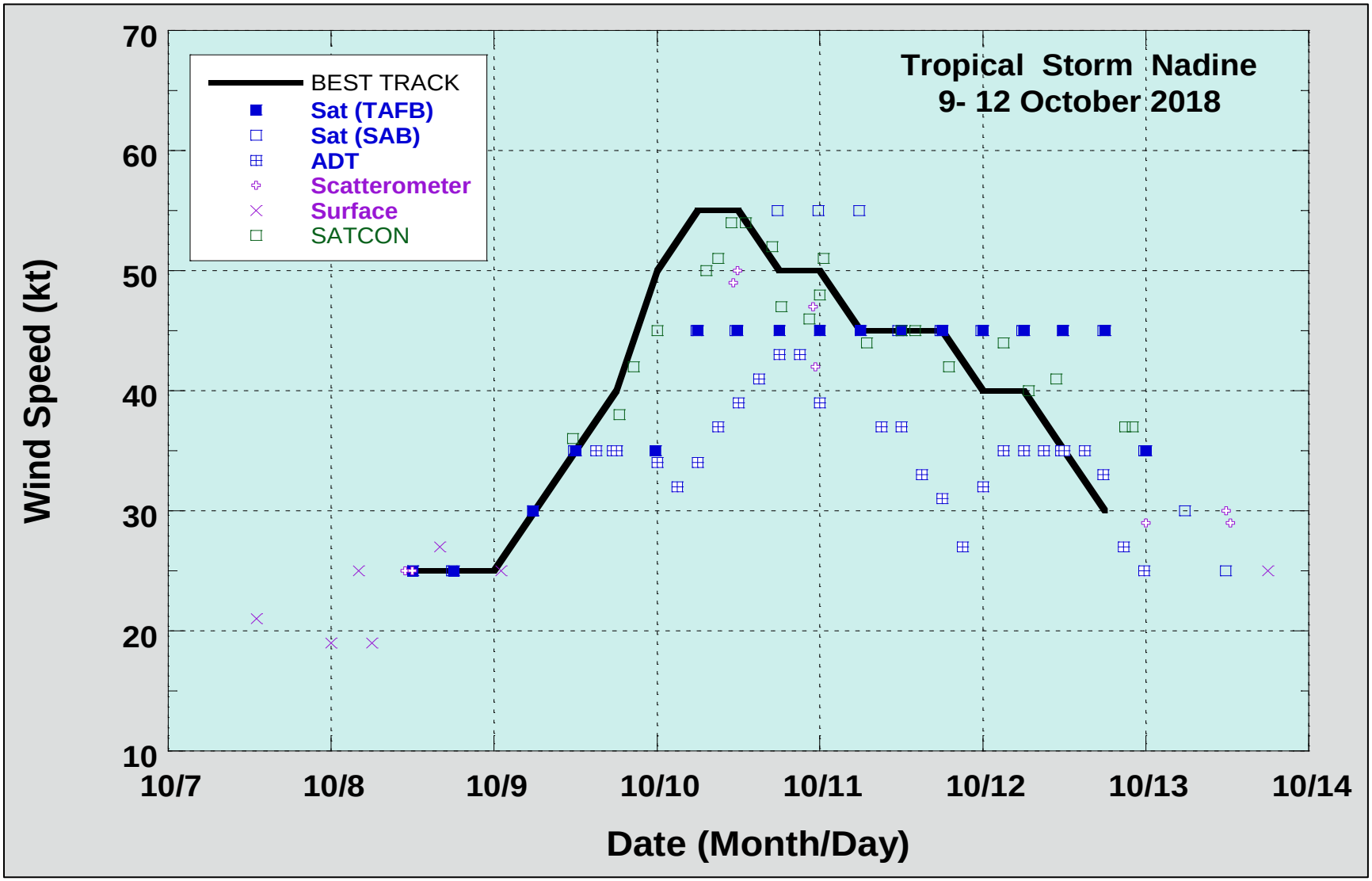


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Tropical Storm Nadine, 9–12 October 2018. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. Dashed vertical lines correspond to 0000 UTC.

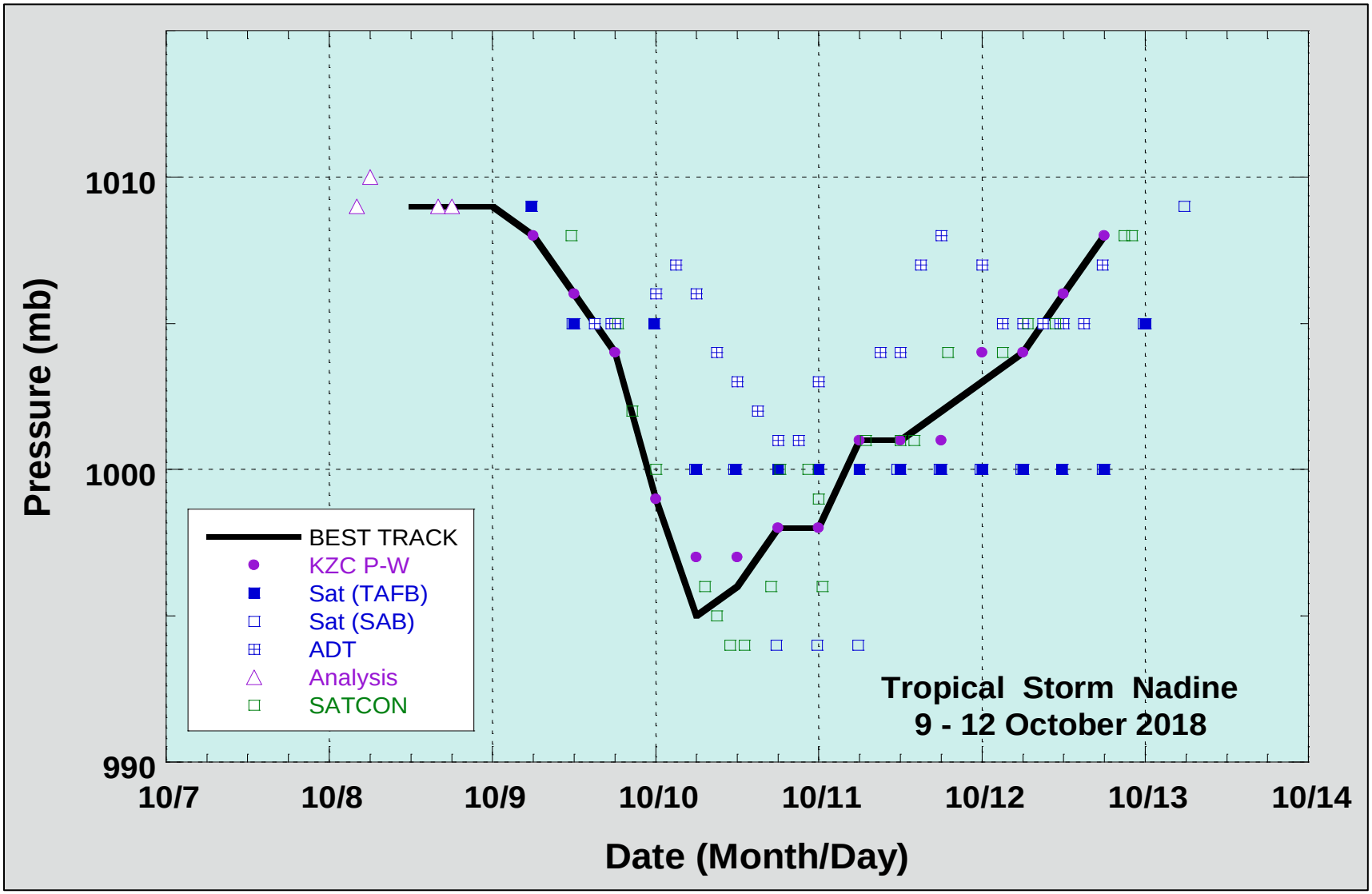


Figure 3. Selected pressure observations and best track minimum central pressure curve for Tropical Storm Nadine, 9–12 October 2018. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological 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.

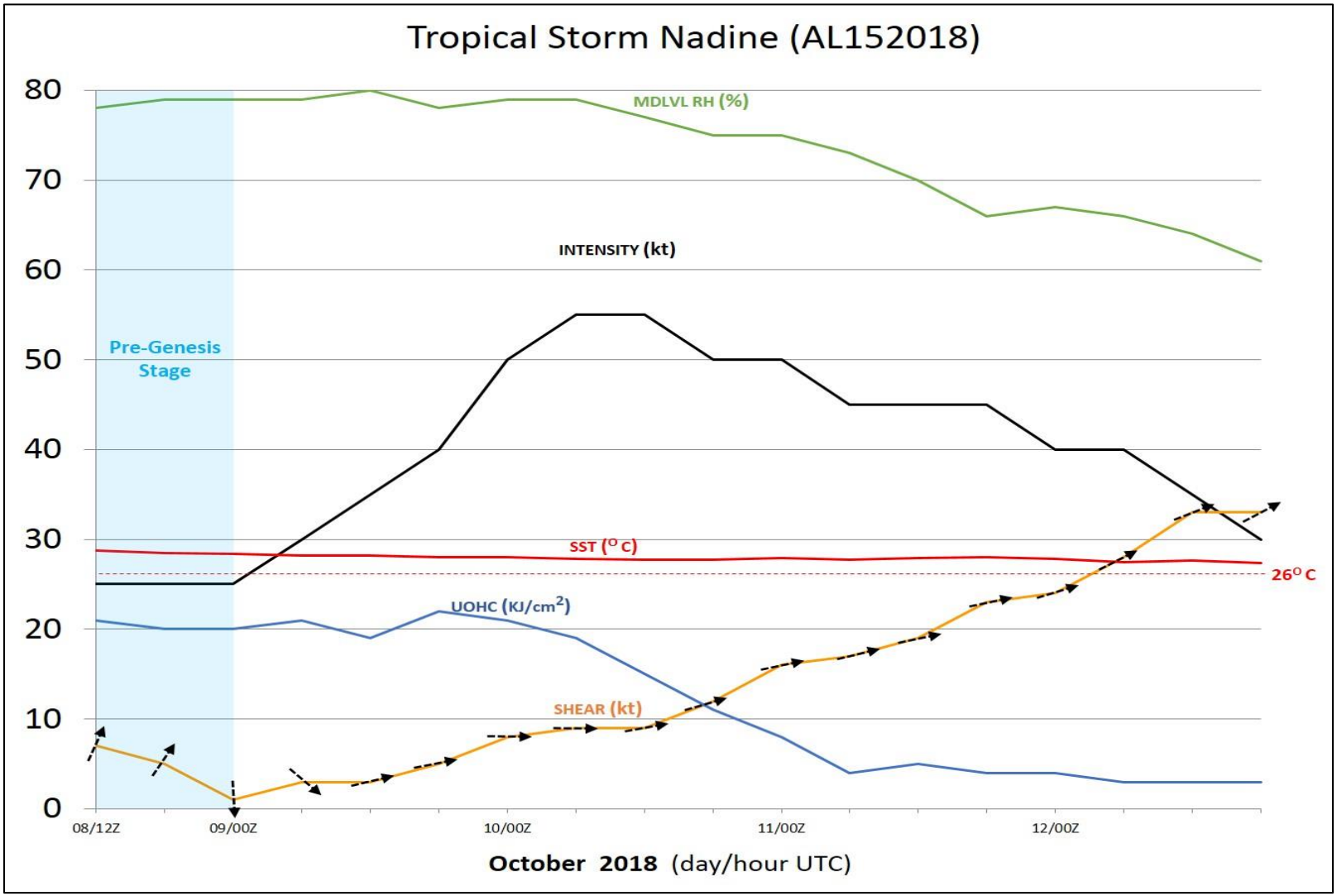


Figure 4. Graph of Tropical Storm Nadine's intensity versus GFS-based SHIPS model analyzed environmental parameters: 850−200-mb vertical wind shear (**SHEAR**, knots), sea-surface temperature (**SST**, °C), upper-ocean heat content (**UOHC**, kJ $cm^{-2}$), and 700−500-mb average relative humidity (**MDLVLRH**, percent). Direction of vertical wind shear vectors (black dashed arrows) is relative to true north, with north being at the top of the page. Time period covered is from 1200 UTC 8 October to 1800 UTC 12 October 2018, which includes the pre-genesis phase (blue shading).

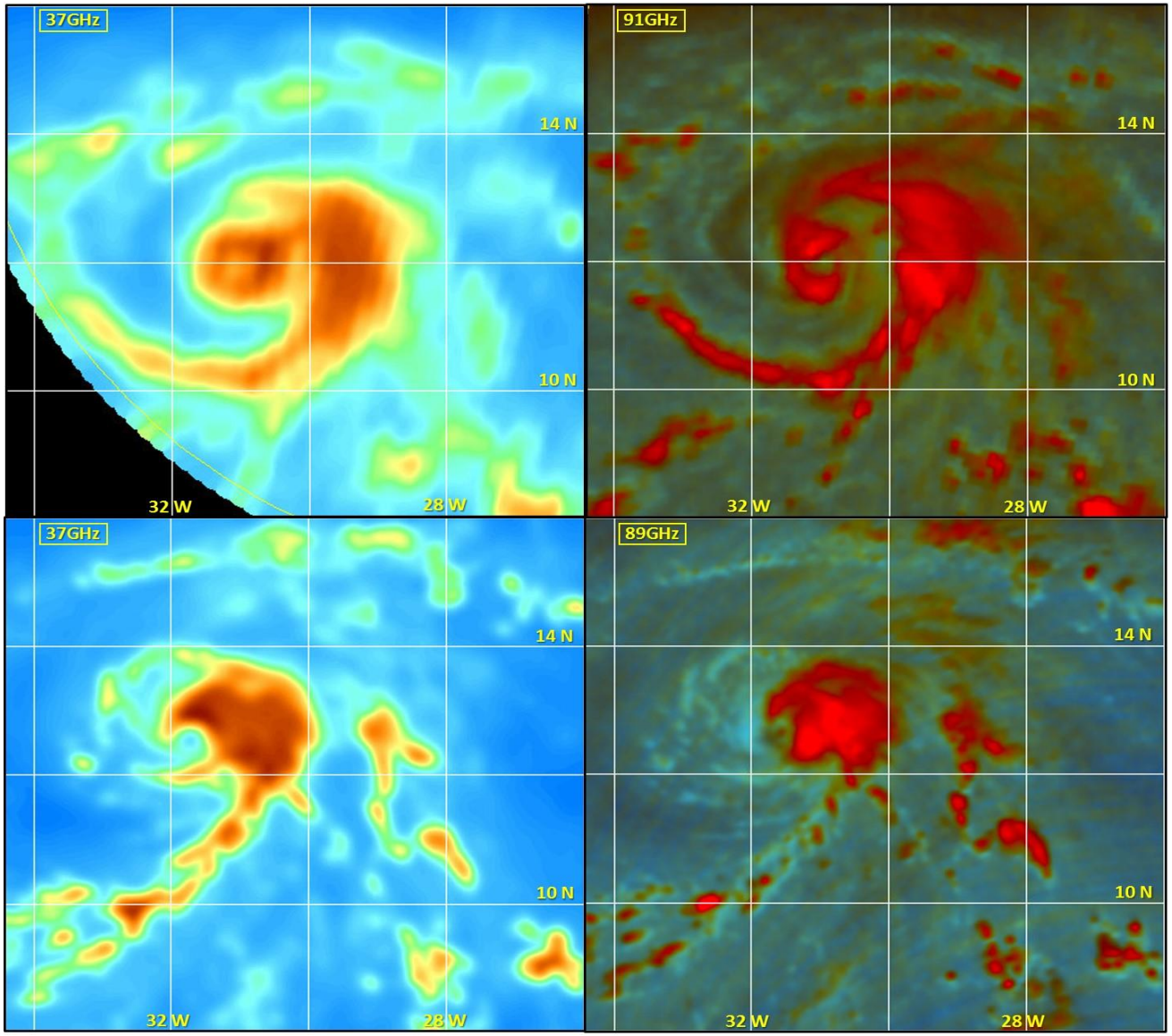


Figure 5. Passive microwave satellite imagery near the time of Nadine's peak intensity on 10 October 2018 showing a well-defined eye at 0739 UTC (top panels: SSMI/S). Strong westerly vertical wind shear induced steady weakening by 1514 UTC (bottom panels: AMSR2-GCOM). Images courtesy of Navy FNMOC, Monterey, CA.