ADT-HURSAT

Technical Documentation

National Centers for
Environmental Information (NCEI)

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1. Intent of this Document and POC

1.1 Intent

This document is intended for users who wish to use the Advanced Dvorak Technique Hurricane Satellite (ADT-HURSAT) data. Users are not expected to be experts in tropical cyclone data. This document summarizes essential information needed to understand the context of the dataset observations and issues that affect its fitness for purpose. References at the end of this document provide additional information.

Dataset name:

NCEI ADT-HURSAT - version 01

1.2 Technical Point of Contact (POC) for this dataset

Contact Information: industryproving.grounds@noaa.gov

2. Revision History

2.1 Document Revision History

Revision 1 - August 2025

This is a new document based on the upcoming release of ADT-HURSAT version 01.

2.2 Dataset History

Version 01 is the first public release of the ADT-HURSAT dataset. Its primary characteristics and limitations are included below:

- **Version 01** - Provides data from **1978-2024.** Provides data on tropical cyclone (TC) intensity estimates using the ADT algorithm run on HURSAT Infrared (IR) imagery.

3. Dataset Description

3.1 Summary

The ADT-HURSAT dataset is a climatology of tropical cyclone intensity estimates. This dataset applies the Advanced Dvorak Technique (ADT) to Hurricane Satellite (HURSAT) website data, producing a record of climate-quality storm intensity estimates from 1978 through 2024. The ADT technique is a computer-based method for determining tropical cyclone intensity from satellite imagery, developed at the University of Wisconsin-Madison/Cooperative Institute for Meteorological Satellite Studies (UW/CIMSS).

The ADT algorithm uses objective techniques to determine the initial storm center and derives the intensity from a regression-based scheme for various phases of the TC lifecycle, from development to dissipation, using infrared imagery. The HURSAT-B1 (geostationary) dataset is derived from the International Satellite Cloud Climatology Project (ISCCP) and includes IR, visible, and spectral channels.

The HURSAT history files were created using HURSAT-B1 Version 07b netCDF files (which used International Best Track Archive for Climate Stewardship [IBTrACS] v04r01 to initially identify storms), and the ADT-Version 9.0 was employed to derive the intensity estimates in this dataset.

Additionally, if multiple HURSAT files existed at a specific time, the ADT will utilize the HURSAT image file with the smallest viewing angle. Time series plots of ADT history files' current intensity (CI#) values (converted to wind speed) versus the HURSAT Best Track Maximum Wind Speed (MWS) values are provided, with the ADT estimates color-coded by the ADT scene type utilized in the intensity estimation process for each HURSAT image. See Section 4.1, Summary (Data Field Description) for a full list of variables available in this dataset.

For more information on the ADT algorithm, please see:
Olander, T.L. and C.S. Velden, 2019: The Advanced Dvorak Technique (ADT) for estimating tropical cyclone intensity: update and new capabilities. Weather Forecast, 34, 905-922. https://doi.org/10.1175/WAF-D-19-0007.1

3.2 Google Cloud Data Bucket

The ADT-HURSAT dataset is stored in a Google Cloud Data Bucket.

This bucket contains:

- history_files - individual Network Common Data Format (netCDF) files for each storm.
- storm_plots - .jpg images of pre-generated plots showing the storm intensity, Dvorak T/CI #, and the dates the storm occurred.

4. Data Field Description

4.1 Summary

HURSAT Spatial Resolution: 8 km
Temporal Resolution: 3 hours
Coverage: Global
Variable Names and Units: See Appendix A for the full list.

4.2 Storm ID Definition

ADT-HURSAT data is provided in separate netCDF files for each storm, each named with its storm identification (SID) number, which comes from the IBTrACS v04r01.

Each file follows this naming convention: YyysJjjHLtLon.nc. The file name represents the IBTrACS SID number (YyysJjjHLtLon), where:

- Yyys is the year the tropical cyclone began.
- Jjj is the day of the year the tropical cyclone began.
- H refers to the hemisphere of the tropical cyclone, where S is for the Southern Hemisphere and N is for the Northern Hemisphere.

- Lt is the latitude (absolute value and rounded to the nearest integer) of the first observation of the cyclone (units=degrees).
- Lon is the longitude (rounded to the nearest integer) of the first observation of the cyclone (units=degrees east of the Prime Meridian ranging from 0 to 359).

Since the best track data in IBTrACS can be updated over time, IBTrACS SIDs may also be updated from those used in ADT-HURSAT. We provide a file to help keep track of the named storms included in ADT-HURSAT. ADT-HURSAT_list_of_storm_id.csv lists all SIDs used for ADT-HURSAT and the storms' alternative names, as described below:

- Column 1: SID used for ADT-HURSAT
- Column 2: Alternate SID used in the more recent version of IBTrACS
- Column 3: Automated Tropical Cyclone Forecasting System (ATCF) IDs (as provided by US agencies in IBTrACS) for the storm where available (marked as "none" where no ATCF ID exists for the storm)
- Column 4: Names from respective agencies formatted as NAME[source] in IBTrACS

Note that since provisional data was used for the 2024 data (and some of the Southern Hemisphere 2022/23 data), most of these storms have alternate SIDs in IBTrACS from when the best-tracked data was provided. Given the methods used in ADT-HURSAT with location centering, we do not expect the use of provisional data instead of best-tracked data to greatly influence the results in ADT-HURSAT.

In the case that a SID changes due to reanalysis in the IBTrACS record, it is possible that storms may not have a correct alternate ID listed. We recommend referring to the ATCF ID or the storm name and year to identify the storm in that case.

5. Data Access Notebook Description

A Data Access Notebook written in Python accompanies the dataset on the interface. Users with limited knowledge of data access via a Google Cloud Bucket can use this notebook to query the bucket for the data they are interested in. Additionally, the notebook offers preliminary statistical analysis and comparisons with the IBTrACS dataset. This can be used to investigate the data without needing additional coding knowledge or software.

The Data Access Notebook features the following:

- Querying for:
  - A subset of years
  - A specific basin
  - Storms that occurred during a specific month across many years (e.g., all storms that occurred in June between 2010 and 2020)
  - Storms that occurred during a specific month and year and within a specific basin
- Statistical Analysis:
  - The historical distribution of ADT values
  - Severity over time
- Climatological analysis
  - Comparison to IBTrACS

6. Caveats for Usage

Since HURSAT files are only available at an 8 km spatial resolution and a three-hour temporal resolution, certain limitations may exist with the ADT intensity estimates derived for each individual storm analysis. All of the above limitations are to advise against using this dataset to determine actual storm intensities.

Limitation 1. Due to the reduced resolution of data files, the determination of certain scene types could be affected- particularly Eye and Pinhole Eye scene types. In addition, the determination of the eye temperature value could be affected due to the reduced spatial sampling of each pixel within the eye.

- All of these could result in an underestimation of intensity.

Limitation 2. The application of the Dvorak Technique (Dvorak, 1984) Rule 8 and 9 intensity estimate adjustments will be affected within the ADT algorithm due to the relatively coarse three-hour temporal resolution of the HURSAT data.

- The Dvorak Rule 8 criteria control the rate of increase/decrease allowed for the Adjusted Raw T# intensity estimate values (and thus the Final T# and CI# values) over specified time periods. This will be more apparent in rapid intensification and weakening periods when the time-averaging scheme (used in the determination of the Final T# value) is implemented.
    - Derived for each ADT image analysis procedure, the derivation of the Final T# value utilizes a time-weighted average of intensity estimates over the past six hours. This calculation will be limited to the use of the current intensity estimate and the three-hour previous value (weighted at 0.5) in most cases. Thus, the Final T# value will fluctuate more rapidly than would normally be observed when using the 30-minute image resolution typically employed in operational ADT use.
- The Dvorak Rule 9 criteria specifically limits the decrease of the CI# value during the tropical cyclone weakening phase. This rule constrains the CI# value to the maximum Final T# value available within the past 6 hours. The use of the reduced temporal resolution HURSAT data will allow the CI# to decrease faster than would normally be allowed using the operational 30-minute imagery.

Limitation 3: Use of three-hour temporally spaced data could lead to delays in ADT-analyzed intensity changes, especially during periods of rapid intensification and weakening. For example, if an eye appears or disappears within the three-hour period between available HURSAT imagery, the ADT may not respond accordingly until the next available image analysis.

- If the eye feature is not apparent/clear in the imagery (a partially obscured eye, for example), the ADT may not be properly captured. This could result in the intensity response being delayed further, thus producing an intensity underestimate (during intensification) or overestimate (during weakening).

Limitation 4. The ADT only utilizes HURSAT IR imagery to derive intensity estimates. During normal operational use, the ADT will make use of available passive microwave (MW) imagery to help discern a possible emerging eye forming below the cirrus shield. The use of additional

imagery and related intensity derivation logic typically refines the derived ADT CI# intensity estimate values, improving ADT accuracy in such situations.

- This function and other intensity adjustment schemes (such as those implemented during Subtropical and Extratropical storm classifications) available in the ADT algorithm were also not utilized when determining the ADT intensity estimate values.

Limitation 5. MWS and mean sea level pressure (MSLP) estimates were calculated using the standard Dvorak Pressure/Wind relationships, which relate the CI# to MWS or a basin-dependent value estimate of MSLP. A latitude bias adjustment for the MSLP values was also applied, as provided in the ADT netCDF files. Use of the Courtney-Knaff equation to derive the current MSLP value was not utilized since the necessary R34 and Penv values were not available.

Limitation 6. For storms that start in one year and end in the next year, fixes in the new year get cut off (e.g., FREDA 2012362S08165).

- This mainly impacts Southern Hemisphere storms, and only a few storms yearly at most.

Full disclaimer: All of the above limitations are to advise against using this dataset to determine actual storm intensities. Peaks and valleys in storm intensity behavior will not be faithfully represented in individual cases due to the reduced spatiotemporal sampling of the HURSAT imagery. Instead, the ADT-HURSAT represents a consistently-derived, homogenized dataset that can faithfully represent trends in TC intensity over the period of the sampling.

7. Data Format

The ADT-HURSAT data is provided as a netCDF file, with the extension .nc. This is a binary file that can be read by numerous programming languages. NetCDF is supported by Unidata.

8. References

8.1 ADT-HURSAT website

https://www.ncei.noaa.gov/products/advanced-dvorak-technique-hurricane-satellite

8.2 Primary Reference

When using ADT-HURSAT in any publication with a bibliography (e.g., journals, books, etc.), please cite:

Knapp, Kenneth R.; Olander, Timothy L.; Velden, Christopher S.; Gahtan, Jennifer; Schreck, Carl J. (2025). Tropical Storm Wind Speed, Current Intensity Number, and other tropical storm related variables from the Advanced Dvorak Technique Hurricane Satellite (ADT-HURSAT) globally from May 30 1978 to December 31 2024 (NCEI Accession 0307249). [indicate subset used]. NOAA National Centers for Environmental Information. Dataset. https://doi.org/10.25921/n6va-0b18. Accessed [date].

When using ADT-HURSAT in any publication that doesn't have a bibliography (e.g., newsprint, blogs, etc.), please use this note:
"Data provided by NOAA ADT-HURSAT (Advanced Dvorak Technique Hurricane Satellite), accessed on <insert date data downloaded> from https://www.ncei.noaa.gov/products/advanced-dvorak-technique-hurricane-satellite."

8.3 Other relevant references and websites

The methodology for this dataset is similar to the following references:
J.P. Kossin, K.R. Knapp, T.L. Olander, & C.S. Velden, Global increase in major tropical cyclone exceedance probability over the past four decades, Proc. Natl. Acad. Sci. U.S.A. 117 (22) 11975-11980, https://doi.org/10.1073/pnas.1920849117 (2020).

J. P. Kossin, T. L. Olander, K. R. Knapp, Trend analysis with a new global record of tropical cyclone intensity. J. Clim. 26, 9960–9976, https://doi.org/10.1175/JCLI-D-13-00262.1 (2013).

The ADT-HURSAT dataset builds on HURSAT data, which can be accessed at https://www.ncei.noaa.gov/products/hurricane-satellite-data.

The Storm IDs follow the IBTrACS syntax. IBTrACS can be accessed at https://www.ncei.noaa.gov/products/international-best-track-archive.

For more information on the ADT algorithm, please see:
Olander, T.L. and C.S. Velden, 2019: The Advanced Dvorak Technique (ADT) for estimating tropical cyclone intensity: update and new capabilities. Weather Forecast, 34, 905-922.

For more information on the Dvorak technique, please see:
Dvorak, V., 1984: Tropical cyclone intensity analysis using satellite data. NOAA Tech. Rep. NESDIS 11, NOAA, 47 pp., https://satepsanone.nesdis.noaa.gov/pub/Publications/Tropical/Dvorak_1984.pdf.

Velden, C., and Coauthors, 2006: The Dvorak Tropical Cyclone Intensity Estimation Technique: A Satellite-Based Method that Has Endured for over 30 Years. Bull. Amer. Meteor. Soc., 87, 1195–1210, https://doi.org/10.1175/BAMS-87-9-1195.

9. Acronyms

ADT - Advanced Dvorak Technique
ATCF - Automated Tropical Cyclone Forecasting
BD - Best Dvorak
CDO - Central Dense Overcast
CWT - Coldest-Warmest Temperature
EMBC - Embedded Center
HURSAT - Hurricane Satellite
IBTrACS - International Best Track Archive for Climate Stewardship
IR - Infrared
ISCCP - International Satellite Cloud Climatology Project
McIDAS - Man computer Interactive Data Access System
MSLP - Mean sea level pressure
MW - Microwave
MWS - Maximum wind speed
netCDF - Network Common Data Format
POC - Point of Contact
SID - Storm Identification
TC - Tropical Cyclone
UW/CIMSS - University of Wisconsin-Madison/Cooperative Institute for Meteorological Satellite Studies

Appendix A. Data Variables

Note: For the variables that include flags, some may have two zero flags available for different criteria. This is partly due to the nature of the flag descriptions, where they could both coincide together. For example, with the CloudScene designation, if there is a uniform cloud structure, the cloud top temperatures will be similar; likewise, if the storm is over land, the soil temperatures will be fairly uniform, thus resulting in providing the same flag of "0". Please refer to the Land variable to determine where 0 means over land for applicable variables.

Variable Name	Explanation	Units
Date	The date of the ADT analysis.	DayMonthYear
Time	The time of the ADT analysis. Times may not completely align with synoptic times (as provided in best track data), but are instead based on availability of times in HURSAT.	HHMMSS
FullDay	Day number and time of analysis in floating point notation.	
RawT	Raw T number. T-number is the "tropical number" to denote intensity. See Dvorak 1984, Velden et al. 2006. Range = [1. 9]; Missing Value = 0.0	
AdjT	Adjusted T number. T-number is the "tropical number" to denote intensity. Range = [1. 9]; Missing Value = 0.0	
FinalT	Final T number. T-number is the "tropical number" to denote intensity. Range = [1. 9]; Missing Value = 0.0	
CI	Current Intensity number. Range = [1. 9];	

Variable Name	Explanation	Units
	Missing Value = 0.0	
WindSpeed	Dvorak Wind Speed Estimate from CI number. Range = [25. 200]; Missing Value = -99.5	knot
MSLP	Dvorak MSLP Estimate from CI Number (West/East of Dateline=West Pacific/Atlantic conversion). Range = [810. 1012]; Missing Value = -99.5	hPA
EyeT	Maximum eye region temperature. Range = [-100. 40]; Missing Value = 99.5	C
CloudT	Average temperature in an 80 km wide annulus centered on CloudCWdistance radius value. Range = [-100. 40]; Missing Value = 99.5	C
CWT	Coldest-Warmest Temperature. The coldest temperature in the array of warmest temperatures on each 4 km ring is between 24 km and 136 km from the storm center. Range = [-100. 40]; Missing Value = 99.5	C
Lat	Storm center latitude position. Range = [-90. 90]	degrees N
Lon	Storm center longitude position (+/- east/west). Range = [-180. 180]	degrees E
EyeSize	Eye diameter estimate when the eye scene is determined. Missing Value = -99.5	km

Variable Name	Explanation	Units
CDOSize	Central Dense Overcast (CDO) diameter estimate, when the CDO/EMBC scene is determined. Missing Value = -99.5	km
ShearDist	Shear distance. The distance from the storm position to the edge of the cloud shield when the shear scene is determined. Missing Value = -99.5	km
EyeStdv	Standard deviation of eye region temperature values (0-24 km from storm center). Missing Value = 0.0	C
CloudSym	Cloud Symmetry. Computed temp difference between the average temp of opposing 15-degree annulus sectors (80 km wide) in the cloud region. Symmetry value is the average of all difference values. Missing Value = 0.0	C
SatID	McIDAS sensor number. Satellite ID value using McIDAS sensor number designations (found in the McIDAS User Guide).	
SatIDChar	Satellite name corresponding to McIDAS sensor number designation.	
EyeScene	Eye scene designation value. 0-Eye, 1-Pinhole Eye, 2-Large Eye, 3-No Eye; 0 over land	
Scene	Scene Type is derived from the combination of Eye and Cloud Scene integer values.	
CloudScene	Cloud scene designation value. 0-CDO, 1-Embedded Center, 2-Irregular CDO, 3-Curved Band, 4-Shear; 0 over land	
Rule9	Dvorak Rule 9. Dvorak weakening Rule 9 designation flag values. 0-storm steady/intensifying (adjustment off); 1-storm weakening (adjustment on); 0 over land.	
Rule8	Dvorak Rule 8. Dvorak Rule 8 constraint flag values. 0 over land	

Variable Name	Explanation	Units
LatBias	Latitude Bias application flag. 0-Off, 1-On; 0 over land	
RapWeak	Rapid weakening application flag. 0-Off, 1-On; 0 over land	
Land	Land/Ocean Flag. Land or ocean designator flag. 1-Land, 2-Ocean	
EyeFFT	Eye region Fast Fourier Transform value. 0 over land.	
CloudFFT	Cloud region Fast Fourier Transform value. 0 over land.	
RingCBnum	Curved Band BD number. BD-enhancement ID value for Curved Band analysis. 2-DkGray, 3-MedGray, 4-LtGray, 5-Black, 6-White, 7-TopMed; 0 over land.	
RingCBval	Curved Band BD curvature. Amount of curvature on a 10-deg Log Spiral (out of 25 for 100%).	
CloudCWdist	CWT ring distance. Distance from storm center for CWT ring.	km
Position	Storm center determination method. 0-Manual, 1-Fcst Interp, 2-BT Interp, 3-ARCHER, 4-Spiral, 5-Ring/Spiral Combo, 6-Linear Extrap, 7-HURSAT	
MSLPAdj	MSLP adjustment to Dvorak Pressure/Wind/T# relationship using ADT latitude bias adjustment algorithm.	hPA
RMW	Radius of maximum wind value, when available. Missing value = -99.5	km
VZA	Viewing angle between storm center and sub-satellite position. Not available for ADT V8.1.3.	degrees

Variable Name	Explanation	Units
	Missing value = -99.5	

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