International Best Track Archive for Climate Stewardship (IBTrACS) Technical Documentation

1. Intent of this Document and POC

1.1 Intent

This document is intended for users who wish to use IBTrACS 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:

IBTrACS version 04r01

1.2 Technical Point of Contact (POC) for this dataset

IBTrACS Science Team mailing list: IBTrACS.Team@noaa.gov
IBTrACS Q&A forum: https://groups.google.com/forum/#!forum/ibtracs-qa

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2. Revision History

2.1 Document Revision History

Rev 1 - April 2018

This is a new document based on the upcoming release of the IBTrACS version 04.

Rev 2 - June 2019

Added Appendix about DIST2LAND.

Rev 3 - April 2024

Updated for v04r01. Added Appendix about NATURE.

2.2 Dataset History

There have been three previous releases of IBTrACS. The primary characteristics and limitations are included below.

- **Version 04r01 -** Provided 2024 through present. Incorporates a new data source (Korea Meteorological Administration), makes available USA provisional and other center best track data at the same time in new TRACK_TYPE called US-PROVISIONAL, and improves quality control, including a reduction in spurs.
- **Version 04r00** - Provided from 2018 through 2024. Consolidates formats to three (netCDF, CSV and shapefile) and each format has identical variables. WMO data are now provided as variables in the IBTrACS files rather than a separate set. Information from multiple US agencies is combined into one set of variables.
- **Version 3 -** Available from 2010 to 2017. Provided each agency information individually. Wind speeds and central pressures were not provided as averages. Numerous formats (CSV, ATCF, WMO, cXML, and more) provided. Two datasets provided: WMO (with only the WMO-reported information) and ALL (all information from all agencies). Incorporated some new data sources.
- **Version 2 -** Available in 2009. Incorporated 2 new data sources. Fixed some bugs found in version 1 (corrected some wind speed unit conversions, etc.)
- **Version 1 -** Available in 2008. Provided average wind speeds and central pressures along with other statistics (maximum, minimum, standard deviation).

3. Data Field Description

3.1 Summary

Variable name, units	Maximum Sustained Wind Speed (knots) Minimum Central Pressure (mb) Storm Center of Circulation (degrees lat/lon) *See appendix for entire list of available variables*
Spatial resolution	0.1° (~10 km)
Temporal resolution	Interpolated to 3 hourly (most data reported at 6 hourly)
Coverage	70° N to 70° S and 180° W to 180° E 1841 - present (though not all storms are captured in earlier years. See sections 5.3, 6.8 and 7 for details)

3.2 Field definitions

There are two primary variables that need to be defined to better understand IBTrACS data. How these parameters are estimated is described in Section 7.

Maximum sustained wind speed

The following definition is a paraphrase from the NOAA AOML FAQ page:

The maximum sustained wind speeds for tropical cyclones are the highest surface winds occurring within the circulation of the system. These "surface" winds are those observed (or, more often, estimated) to occur at the standard meteorological height of 10 m (33 ft) in an unobstructed exposure (i.e., not blocked by buildings or trees).

The U.S. agencies (NOAA and JTWC) report a 1 min averaging time for the sustained (i.e. relatively long-lasting) winds. In most of the rest of the world, a 10 min averaging time is used for "sustained wind". It is possible to convert from peak 10 min wind to peak 1 min wind (roughly 12% higher for the latter) as a general rule. However, procedures can vary by agency, as do their available Tropical Cyclone (TC) observation data. When these agency differences are combined with the different averaging periods, interbasin comparisons of tropical cyclones around the world becomes problematic.

Maximum sustained wind speeds have been historically reported in knots (nautical miles per hour). Rather than converting to modern SI units, we retain this usage for historical clarity. One knot is 0.514 m s^{-1}.

Minimum central pressure

Minimum central pressure is the estimated lowest surface pressure in the tropical cyclone. This represents the pressure at the center of circulation reduced to sea level (though tropical cyclones almost always occur at sea level, so usually no reduction is necessary). Minimum central pressure is widely agreed as a parameter that is easily comparable between agencies, though observational differences still lead to discrepancies.

In contrast to maximum sustained winds, the minimum central pressure can generally be measured. In the past, observations were pressure measurements as a storm passed over a station or when a ship sailed through the system. Aircraft measure surface pressure using dropsondes or estimate it through calculations using aircraft pressure and altitude. However as of 2018, routine aircraft flights are limited mostly to the Western Hemisphere (North Atlantic and Eastern Pacific). For TCs outside the range of routine flights, surface pressure is estimated with both subjective and objective satellite analysis as well as automated buoys that may be present.

Knapp et al (2013) investigated TC minimum central pressures for the Western North Pacific from various agencies.

4. Data Origin

Tropical cyclone data were originally provided in atlases for international shipping, in an attempt to provide climatological speed and directions that the storms move (in order to help ships avoid them). During the late 1950s and 1960s, it became important to also understand their climatology for risk to land and coastal communities (e.g., insurance industry, the space program, etc.). Many tracks from the printed atlases were digitized in the 1960s and tracks and intensities were shared between agencies and countries. Now, basin-specific storm track data are widely available from numerous agencies. Nonetheless, there are few sources of global track data. IBTrACS provides a one-stop location for much of the tropical cyclone position and intensity information.

4.1 Best track data

During the lifetime of a tropical cyclone, a forecaster will maintain a record of the storm's historical position and intensity (along with other pertinent information). This is termed the "working best track" of the system. It is preliminary because forecasters have many additional responsibilities, viz. making a forecast of where it will be in the future and its intensity.

Therefore, after the storm has ended (usually after the TC season has ended), the forecasters gather all the available information (storm reports from land, buoy, ships, etc., radar data, aircraft data, satellites, and more). Much of this information was not available during the fast-paced forecast cycle. Forecasters (and sometimes researchers) use this information to produce a best estimate of the storm's track and intensity. Hence the term best track. More recently, other information has been made available during the reanalysis, such as storm wind structure. In some cases, older best tracks have been updated by agencies that reanalyzed all surviving data with modern understanding of these storms.

Best track data in IBTrACS has many source agencies and datasets (see Appendix A for the entire list).

4.2 Provisional data

The time between a storm's end and when its reanalysis is complete can be more than one year (especially for storms that occur early in a season). Hence, IBTrACS version 3 was generally available in September using reanalysis data for the previous year. IBTrACS was further delayed because of the need to collect data from all agencies: IBTrACS was released after the last agency's data was available.

The working best track data is made available by various entities. IBTrACS version 4 collects and assimilates the working best tracks from US sources as PROVISIONAL data. This allows users to analyze current storms in context of historical data. Provisional data have not been reanalyzed. The final best track data of the system such as position, intensity, storm type, etc. are subject to change. Also, some storms may be added or removed if analysis shows tropical characteristics and sufficient lifetime and intensity are not what was thought at forecast time.

New with v04r01: track_type=US-Provisional. In v04r00 and prior, provisional and best track data could not coexist for a storm so as to ensure consistency of track quality. However, this resulted in a loss of data due to the various best track reanalysis schedules of institutes. For instance, if JMA BT data were updated in February it would supplant and remove all provisional data (e.g., US JTWC provisional tracks). Now with v04r01, US-PROVISIONAL denotes that the data from the US source is provisional while other tracks are reanalysis best tracks. This allows us to continue to report most sources closer to when it becomes available. For US-PROVISIONAL, the USA variables as well as system wide variables including merged position and dependent variables (landfall, storm speed and direction, etc.) and nature are subject to change with the same caveats as for the PROVISIONAL tracks described above.

4.3 IBTrACS data provenance

IBTrACS strives to provide data exactly as reported by the originating agency. There are very few changes made. Some of the units used are not SI units (e.g., knots vice m s^{-1}), but they represent units historically used by the community. These changes include:

- Conversion of some wind speeds to the widely accepted wind speed unit of knots.
- Conversion of some distances to nautical miles.
- Conversion of Hong Kong classifications (because they changed the definition of ST from Strong Tropical Storm to a Severe Typhoon, which are two very different categories that shouldn't be confused).

Information available in IBTrACS netCDF files allows one to trace the IBTrACS data back to the source data file.

5. Validation and Uncertainty Estimate

The best track data are not validated in the normal sense (e.g., where the intensity values would be compared to some independent reference dataset) because best tracks are the best estimates of storm intensity and position using all available storm information. Therefore, there is often no independent dataset for validation that has not already been used in the analysis. Therefore, this section will focus on uncertainty. See Landsea and Franklin (2013) for more details on the current state of best track uncertainty in the Atlantic with the caveat that these uncertainties vary widely through time and in other basins.

5.1 Intensity uncertainty

Forecasters estimate intensity in different ways based on the information available. Understandably, that information has changed over the years. Furthermore, different data and procedures were implemented at different times at each agency, therefore, the uncertainty varies in both time and space. Table 1 provides estimates of the level of uncertainty, which is based on input from attendees at the 3rd IBTrACS Workshop. The values are not quantitative but represent qualitative estimates of the measure of certainty. This table accounts for changes in aircraft reconnaissance in the Western Pacific and North Atlantic.

5.2 Position uncertainty

Storm positions are generally reported at a resolution of 0.1 degrees. This leads to an initial lower bound of the positional uncertainty of ~10 km. Kruk et al. (2010) also found that the spatial uncertainty varies with storm intensity, likely because weaker storms have centers of

Table 1 - Qualitative uncertainty level for intensity in wind speed (knots) for the South Indian (SI), North Indian (NI), South Pacific (SP), West Pacific (WP), East Pacific (EP), and North Atlantic (NA) ocean basins. Blank boxes imply the level of uncertainty is too difficult to quantify (and possibly larger than 30 knots).

Period	SI	NI	SP	WP	EP	NA
pre1950						±30
1950-1965				±30		±30
1965-1973	±30	±30	±30	±20		±20
1973-1978	±20	±20	±20	±20	±20	±20
1978-1984	±15	±20	±20	±20	±20	±15
1984-1987	±15	±20	±15	±10	±20	±10
1987-1995	±15	±15	±15	±15	±15	±10
1995-2000	±10	±15	±15	±10	±15	±10
2000- now	±10	±10	±10	±10	±10	± 7

It should be noted that in many basins, more than one agency provided input for their estimated uncertainty. This table attempts to combine those estimates into an amount consistent between all agencies in a given basin.

Table 2 - Uncertainty of TC position based on TC intensity

Approximate intensity of system	Approximate uncertainty of position
Weak TC (Winds < 60 kt)	~ 30-40 km (and larger before 1980)
Moderate TC (60 kt < Winds < 100 kt)	~ 20-25 km (and larger before 1980)
Strong TC (Winds > 100 kt)	~ 10-15 km (and larger before 1980)

Table 3 - Wind speed averaging period by agency.

1-min wind	2-min wind	3-min wind	10-min wind
US Agencies (NOAA and JTWC)	CMA (China)	IMD (India)	JMA (Japan) BoM (Australia) La Reunion Nadi (Fiji) Wellington (New Zealand) HKO (Hong Kong) KMA (South Korea)

circulation that are larger and more difficult to identify than strong systems that have well-defined eyes. Table 2 was calculated by comparing storm positions from different agencies and provides a measure of positional uncertainty. In places where aircraft reconnaissance is available (Western Pacific from 1950-1987 and the North Atlantic 1950-present) the position uncertainties are markedly less than the values provided in table 2.

5.3 Storm count uncertainty

Users should exercise care when counting storms in IBTrACS. Many issues are involved that may lead to inflated or wrong numbers. In many cases, these differences occur due to operational procedures that result from a decision, usually with the intent of improving forecast lead times, warning at the wind levels required by customers, etc. Understandably, these decisions can change as needs and capabilities change. These issues include (in no particular order):

- Tropical depressions - Some agencies include reporting on tropical depressions. These may occur in IBTrACS but may not be uniformly counted in space or time.
- Sub-tropical storms - In some years, these systems have been included in best tracks and in some years they haven't. It depended on the practices at the agency at the time. When possible, users can check the storm status (tropical or subtropical, etc.) in IBTrACS to ensure they are counting the storms they expect to count. However, those classifications have changed over time as well.
- Missed storms - Some storms far from regions of concern, or already moving to an area with no impact on operations, have led to a storm not being forecast or reported. This was more common before the advent of satellite monitoring in the 1960s, particularly over the open ocean or less populated coastlines (e.g., Landsea 2007).

- Storm spurs - Since IBTrACS is a collection of TC data from dozens of sources, there are numerous systems where those reports on position differ between agencies. In some cases, the differences are a result of the uncertainty in the observing system (e.g., difficulty in finding the center of circulation in an unorganized system of clouds). In these cases, the spurs are merely differences in opinion on a storm's location. IBTrACS software cannot determine which position is accurate, so both are maintained and alternate positions are given the title of spurs while the main track is labeled as a 'main' system. On the other hand, some storms can merge (Fujiwhara effect), in which case, spurs represent actual TCs. Recent updates to v04r01 have improved the quality control of spurs such that most of the Fujiwhara storms are classified as mains (and overall spurs have been reduced by about ⅔). See section 6.8 for more information. When counting TCs, spurs should be ignored in most cases.

In short, users should carefully consider these and other issues when counting TCs and comparing those counts through time. See Schreck et al. (2014) for examples of how these issues are dealt with.

6. Caveats for usage

Users should be aware of some important caveats when using IBTrACS data.

6.1 Caveats from the source agencies

IBTrACS is just a collection of other best track datasets. Users need to be aware of the comments on data quality from those who produce the data.

6.1.1 JTWC

The following are statements from the JTWC best track website:

> **"DISCLAIMER: JTWC does not consider all of its best track data to be of equal quality. Please read this report BEFORE using the data. The report details noted inconsistencies with our best track data."**

We highly recommend users familiarize themselves with the JTWC report linked above before using JTWC data. They also note on subsequent pages that:

> "Unless otherwise noted, final best tracks have been quality controlled for position and intensity only".

In fact, the only specified deviation is that

> "Western North Pacific (WESTPAC) 34 knot best track wind radii (R34) have been quality controlled. 50- and 64- knot WESTPAC radii have been computed via linear regression from the R34 values."

6.2 Wind speed reporting differences

Wind speeds of tropical cyclones are reported very differently by many of the international agencies. Knapp and Kruk (2010) investigate many of these differences. They find that there is no simple global conversion between these wind speeds. While a multiplicative factor can describe the numerical differences (Harper et al, 2008), there are procedural and observational differences between agencies that can change through time, which confounds the simple multiplicative factor. This results in a difficulty with quantitative study of global wind speed values.

To be clear, wind speed values between one agency (e.g., JMA) are not convertible to wind speeds from another (e.g., JTWC) due to many issues. Some of these differences are well described but some are unknown, which means there is no simple way to convert values of wind speeds between various agencies.

6.3 WMO data

The WMO pressure and wind speed data provide storm reports from the WMO agency responsible for that location. It should be noted that there will be large discrepancies at boundaries where the procedural differences between the agencies are different. Most notably, this will occur at 180° West (between the USA agencies and JMA) because of differences in agency procedures. This can also occur at other boundaries but with less frequency and smaller differences. For example, Australia's area of responsibility boundaries are shared with 3 other agencies (La Reunion, Fiji and New Zealand) but the operational procedures of those agencies have more in common, which result in smaller differences.

Furthermore, the WMO data are the official data from the responsible agency. Thus, the data are not interpolated to 3 hourly since they represent official information.

6.4 Provisional data

Data provided in 'near real time' are provided as 'provisional' data. Generally, this includes most data of any current year as well as some tracks from the year prior and flagged as "PROVISIONAL" in IBTrACS version 4. This implies that the values are lower quality than the other best track data in IBTrACS (listed as 'main'). The intensity, position and storm categories are subject to change when the system is reanalyzed by agencies. Users should understand that provisional data are not final (See section 4.2 for details) and their uncertainties are larger than the values provided in Table 1.

6.5 3-hourly data can affect ACE and PDI

The data provided in IBTrACS is interpolated to 3-hourly data. ACE (Accumulated Cyclone Energy) and PDI (Power Dissipation Index) are sums of wind speed squared and cubed (respectively). Users should consider that these values are normally summed for 6-hourly data, instead of the 3-hourly data, so adjustments should be made to ACE and PDI calculated from 3-hourly IBTrACS data.

6.6 Position Interpolation

Positions were interpolated in time (to 3 hourly positions) using splines. The purpose of the interpolation was to provide a high-resolution dataset that provides easy comparison to other datasets (e.g., satellites) or allows further interpolation as needed.

6.7 Non-positional data interpolation

Parameters not related to position (e.g., wind speed, pressure, etc.) were interpolated linearly. This conserves maxima and minima (instead of spline interpolation, which can create new minima/maxima). That is, if the lifetime maximum intensity (LMI) of a system was 100 knots, linear interpolation ensures that the LMI remains unchanged.

WMO reports of wind speed and pressure are not interpolated.

6.8 Spurs and counting storms

Two tropical cyclones can merge and combine to form a larger system. Differences in storm positions (especially for weak systems) can be large and continuous such that we are unable to determine the actual center when two agencies significantly disagree on the center for the same system. In turn, these and other conditions cause there to be times when we are uncertain if tracks are from the same or different systems at some point in time. These uncertain tracks are then classified as a spur.

When counting storms, users should ignore spurs in the TRACK_TYPE variable, since these can be numerous (especially in early years when positions were far less accurate) and could cause overcounts. The processing algorithm has difficulty in determining when a system really is a merging of two separate systems (thus the spur is real) or when they represent differing opinions on the position of a storm (thus the spur track is a discrepancy and part of the same storm). Further quality control checks using agency source information have been added in v04r01 to reduce the number of spurs by about two-thirds. In particular, most of the storms undergoing Fujiwhara interactions that were previously spurs are now reclassified as main.

6.9 Counting storms in early years (before 1940)

Early storm tracks (e.g., prior to 1920) were often rescued by digitizing positions and times from atlases. These atlases often included tracks without dates. Instead, they compiled all storms occurring in a given month (thus, providing sailors with climatological directional storm movements). When these positions were digitized, the dates and times for each position were often estimated. That is, they knew that a storm occurred during a given month, but not exact start and end dates. The result is that some storms occur at different times in different datasets, resulting in duplication. While this is especially prevalent in the South Indian Ocean, it occurs in many of the basins prior to about 1930 and can affect storm counts by overcounting systems.

7. Overview of TC observation systems

Tropical cyclones have been observed using a multitude of observing systems. The following is a summary of the historical methods, with some references provided for the reader to obtain more detailed information. They are presented in the order of when they first became available.

7.1 Surface reports

Surface observations have the longest history for being used to understand TCs. They began with sparse observations on the surface as well as from ships that inadvertently strayed too close to them. Some work has gone into understanding how many TCs were missed due to the sparse observation network (Vecchi and Knutson, 2008).

In modern times, surface observations are numerous given the many global, national and regional observation networks with automated reporting. These are augmented by automated buoy observations. These networks can provide valuable reports on wind, pressure and rainfall in and around TCs.

7.2 Aircraft reconnaissance flights

Aircraft observations were first conducted in the late 1940s. By the 1950s, their value to ascertain inner core structure of TCs was understood and routine flights were made in the Western North Pacific and North Atlantic. Also, reconnaissance flights were made in TC-prone areas of the sparse oceans looking for TCs in an effort to forecast them earlier in their life. While aircraft continue to be used in the North Atlantic (and sometimes the Eastern North Pacific), routine reconnaissance flights ended in the Western North Pacific in 1987. No other basin has routine flights (though there have been some field experiments).

Aircraft routinely measured position, flight level pressure, altitude and flight winds. This provided a measure of central pressure and wind structure. However, surface winds were often estimated by observing the sea state through the node gunner window. This method is not the most accurate and leads to large uncertainty in the early years of flights, especially for higher intensities (Hagen et al. 2012). Improvements of instrumentation and navigation have allowed improved observations of storm conditions that are too lengthy to document here. Presently, flights can employ GPS dropsondes, drones, radar winds providing accurate surface wind conditions and more.

7.3 Satellite observations

Similar to aircraft observations, satellites have experienced an increasing capability to probe and understand TC environments and structure. Meteorological satellite observations began in the 1960s with merely identifying the systems from space. Researchers then developed a technique to estimate intensity from the storm cloud structure and lifetime. See Velden et al (2006) for a thorough history of satellite observations and their accuracy. However, the early observations at visible and infrared wavelengths were limited in that they could only observe cloud tops. Routine microwave imager satellites began in the late 1980s and became integrated into forecasting in the 1990s. Microwave satellites saw the rain structure of systems, the expanse of winds and could observe eyes before they became completely cloud free. Winds observations were once prominent and allowed observations of accurate observations of wind extent.

8. Data Formats

8.1 Three formats

IBTrACS is provided in **three formats**. They are:

1. Comma Separated Value (CSV) - A text (i.e., ASCII) file for general use (e.g., in Excel, databases, etc.). The first two rows of the file provide column names and column units. A separate PDF provides a thorough description of information provided in each column.
2. Network common data format (netCDF) - A binary file that can be read by numerous programming languages. NetCDF is supported by Unidata.
3. Shapefiles - A set of files used by the geospatial community (e.g., ArcGIS). Shapefiles provide access to many mapping tools in use by emergency management, cartography, and other communities.

The storm data are identical in each format. The only difference is that the netCDF files contain more provenance information since that format is more flexible.

8.2 Data subsets

In addition to global data files that contain all storms available in IBTrACS, a few subsets are also provided:

- **Basin** - All storms that have at least one position in that basin. This allows analysis of a given basin but also means that different basin files should not be combined since some storms will be in both files. Basins included are:
    - NA - North Atlantic
    - SA - South Atlantic
    - EP - Eastern North Pacific (which includes the Central Pacific region)
    - WP - Western North Pacific
    - SP - South Pacific
    - SI - South Indian
    - NI - North Indian
- **Time subsets** - temporal subsets provide easier access to a set of storms in specific periods. Storms from the entire globe (all basins) are available in these sets.
    - Since 1980 - This is considered by many to be the modern era, since geostationary satellite coverage was nearly global and polar orbiting data (which does provide global coverage) was more widely available than in previous years.
    - Last 3 years - This provides access to the more recent storms.
    - Active - This provides access to storms active within the last 7 days.

9. References

9.1 IBTrACS website:

https://www.ncei.noaa.gov/products/international-best-track-archive

9.2 Primary Reference

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

Knapp, K. R., M. C. Kruk, D. H. Levinson, H. J. Diamond, and C. J. Neumann, 2010: The International Best Track Archive for Climate Stewardship (IBTrACS): Unifying tropical cyclone best track data. *Bulletin of the American Meteorological Society*, **91**, 363-376. doi:10.1175/2009BAMS2755.1

When using IBTrACS in any publication that doesn't have a bibliography (e.g., newsprint, blogs, etc.), please use this note:

"Data provided by NOAA IBTrACS (International Best Track Archive for Climate Stewardship), accessed on <*insert date data downloaded*> from https://www.ncei.noaa.gov/products/international-best-track-archive."

9.3 Other relevant references and websites

For a review of pressure and wind speeds in the Western North Pacific see:

Knapp, K.R., J.A. Knaff, C.R. Sampson, G.M. Riggio, and A.D. Schnapp, 2013: A Pressure-Based Analysis of the Historical Western North Pacific Tropical Cyclone Intensity Record. *Mon. Wea. Rev.,* **141**, 2611–2631, https://doi.org/10.1175/MWR-D-12-00323.1

For a description on how storm tracks are merged, see:

Kruk, M. C., K. R. Knapp, and D. H. Levinson, 2010: A technique for merging global tropical cyclone best track data. *Journal of Atmospheric and Oceanic Technology*, **27**,680-692. doi:10.1175/2009JTECHA1267.1

For generic information on best track data and tropical cyclones, see:

NOAA AOML Tropical Cyclone Frequently asked questions (TCFAQ): http://www.aoml.noaa.gov/hrd/tcfaq/tcfaqHED.html

For information on how changes in the TC observing systems likely affect storm counts:

Vecchi, G.A. and T.R. Knutson, 2008: On Estimates of Historical North Atlantic Tropical Cyclone Activity. *J. Climate,* **21**, 3580–3600, https://doi.org/10.1175/2008JCLI2178.1

For a history of the intensity estimates from satellite imagery (the Dvorak technique):

Velden, C., B. Harper, F. Wells, J.L. Beven, R. Zehr, T. Olander, M. Mayfield, C. Guard, M. Lander, R. Edson, L. Avila, A. Burton, M. Turk, A. Kikuchi, A. Christian, P. Caroff, and P. McCrone, 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

To see how IBTrACS information has been used to count storms and develop a global climatology:

Schreck III, C. J., K. R. Knapp, and J. P. Kossin, 2014: The Impact of Best Track Discrepancies on Global Tropical Cyclone Climatologies using IBTrACS, Monthly Weather Review, **142**, 3881-3899. doi:10.1175/MWR-D-14-00021.1

For more information on wind speed averaging periods, see:

Harper, B. A., J. D. Kepert and J. D. Ginger, 2008: Guidelines for converting between various wind averaging periods in tropical cyclone conditions, World Meteorological Organization. https://www.wmo.int/pages/prog/www/tcp/documents/WMO_TD_1555_en.pdf

List of Abbreviations

ACE -Accumulated Cyclone Energy
ATCF - Automated Tropical Cyclone Forecasting System (US format)
BOM - Bureau of Meteorology (Australia)
CMA - Chinese Meteorological Administration
CPHC - Central Pacific Hurricane Center (US)
CSV - Comma-Separated Values
GPS - Global Positioning System
HKO - Hong Kong Observatory
IBTrACS - International Best Track Archive for Climate Stewardship
IMD - India Meteorological Department
JMA - Japan Meteorological Agency
JTWC - Joint Typhoon Warning Center (US)
KMA - Korea Meteorological Administration (South Korea)
LMI - Lifetime Maximum Intensity
NA - North Atlantic
netCDF - Network common data format
NHC - National Hurricane Center (US)
NI - North Indian
NOAA - National Oceanic and Atmospheric Administration (US)
PDI - Power Dissipation Index
RSMC - Regional Specialised Meteorological Center
SI - South Indian
SP - South Pacific
TC - Tropical Cyclone
TCWC - Tropical Cyclone Warning Center
US - United States of America
WMO - World Meteorological Organization
WP - West Pacific

Appendix A. List of IBTrACS Variables

IBTrACS makes every effort to provide data exactly as it was provided by the agency (or source data). This is why there are so many columns (or variables): to ensure that the user can identify the source of each reported value. The following is a summary of the available data. They are provided in the order of the CSV columns.

The variable list is meant to give an idea of the variety of data from the different sources. Other IBTrACS documents provide a thorough description of each variable. More information about these is provided in the CSV column description file as well as the netCDF file metadata (global and variable attributes).

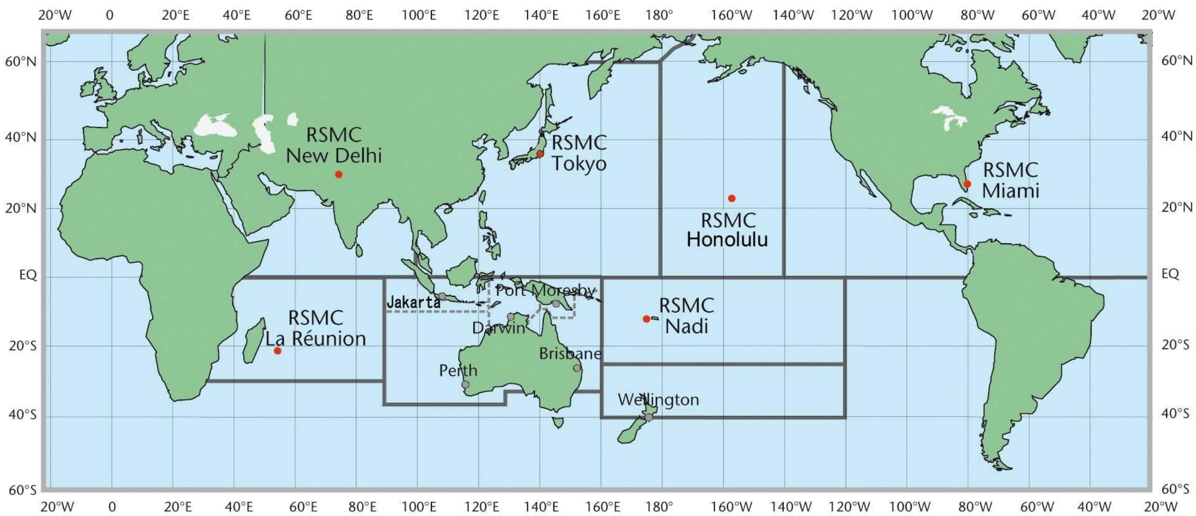

Figure - Depiction of the official WMO areas of responsibility for tropical cyclone forecasting for various global agencies. IBTrACS includes data from most of these agencies.

General Variables

These variables are primarily derived by the IBTrACS group and provide some broad descriptions of the data. The WMO (World Meteorological Organization) data are reports from the official WMO agency for that location. It should be noted, however, that there are differences in how different agencies prepare information and report on systems, so as systems cross boundaries of responsibility, there may be changes in how wind speed or structure is reported.

SID* A unique storm identifier (SID) assigned by IBTrACS algorithm
SEASON* Season (year) that the storm began. Due to how the Southern Hemisphere defines a season, storms after July 1 are classified with the following year.
NUMBER* Number of the storm for the year (restarts at 1 for each year)
BASIN* Basin of the current storm position
SUBBASIN* Sub-basin of the current storm position

NAME Name of system given by source (if available)
ISO_TIME Time of the observation in ISO format (YYYY-MM-DD hh:mm:ss)
NATURE* Type of storm (a combination of the various types from the available sources)
LAT* Mean position - latitude (a combination of the available positions)
LON* Mean position - longitude (a combination of the available positions)
WMO_WIND Maximum sustained wind speed assigned by the responsible WMO agency
WMO_PRES Minimum central pressure assigned by the responsible WMO agency
WMO_AGENCY The WMO agency responsible for warning on systems at the current position
TRACK_TYPE* Track type (main or spur; see section 5.8) and information about whether the track includes data that is PROVISIONAL (see Section 3.2).
DIST2LAND* Current distance to land from current position
LANDFALL* Minimum distance to land over next 3 hours (= 0 means landfall)
IFLAG* A flag identifying the type of interpolation used to fill the value at the given time
STORM_SPEED* Storm translation speed (knots)
STORM_DIR* Storm translation direction (in degrees east of north)
** Variables with an asterisk were assigned or derived by IBTrACS algorithm*

Variable overview

The following is a description of some of the variables listed below. They are provided in IBTrACS as provided by the agency, source dataset, etc.:
_LAT Latitude position (degrees north of Equator, negative is south)
_LON Longitude position (degrees east of Prime Meridian, where negative is west)
_WIND Wind speed units are knots, but the averaging period can vary by source.
_PRES Minimum central pressure
_R34_*(dir)* The radial extent of 34 knot winds in each quadrant (dir)
_R50_*(dir)* The radial extent of 50 knot winds in each quadrant (dir)
_POCI Pressure of the Outermost Closed Isobar
_ROCI Radius of the Outermost Closed Isobar
_RMW Radius of the Maximum Winds (distance from storm center)
_EYE Eye diameter
_GRADE/STAGE/CAT The type of storm as identified by the source (tropical, subtropical,...)
_CI The Dvorak technique current intensity (CI) measure

USA_agency information

The following variables are provided by agencies in the USA (NHC, JTWC, CPHC). This also includes data for the WMO Regional Specialised Meteorological Center at Miami and Honolulu (operated by NOAA). Most often, only one agency is providing information on the storm. However, in cases when there is information from more than one, then a priority list [HURDAT2, ATCF, JTWC, CPHC, NHC_WORKING_BT, TCVITALS, TCVIGHTALS, TCGP] is used to select information for a given segment of a storm. The selected source is provided in the USA_AGENCY column. In many cases, information from multiple sources are combined.

USA_AGENCY	USA_R34_SE	USA_R64_NW
USA_ATCF_ID	USA_R34_SW	USA_POCI
USA_LAT	USA_R34_NW	USA_ROCI
USA_LON	USA_R50_NE	USA_RMW
USA_RECORD	USA_R50_SE	USA_EYE
USA_STATUS	USA_R50_SW	USA_GUST
USA_WIND	USA_R50_NW	USA_SEAHGT
USA_PRES	USA_R64_NE	USA_SEARAD_NE
USA_SSHS	USA_R64_SE	USA_SEARAD_SE
USA_R34_NE	USA_R64_SW	USA_SEARAD_SW
		USA_SEARAD_NW

RSMC Tokyo (JMA)

The WMO Regional Specialised Meteorological Center at Tokyo (which is operated by the Japanese Meteorological Agency) is responsible for official Typhoon forecasts in the western North Pacific. Data from JMA spans 1951 to present.

TOKYO_LAT	TOKYO_PRES	TOKYO_R30_DIR
TOKYO_LON	TOKYO_R50_DIR	TOKYO_R30_LONG
TOKYO_GRADE	TOKYO_R50_LONG	TOKYO_R30_SHORT
TOKYO_WIND	TOKYO_R50_SHORT	TOKYO_LAND

Chinese Meteorological Administration (CMA) Shanghai Typhoon Institute

The CMA Shanghai Typhoon Institute provides information on typhoons in the western North Pacific. Data from CMA span 1949 to present.

CMA_LAT	CMA_CAT	CMA_PRES
CMA_LON	CMA_WIND	

Hong Kong Observatory (HKO)

The HKO provides information on typhoons in the western North Pacific with a focus on typhoons that approach Hong Kong. Data from HKO spans 1961 to present.

HKO_LAT	HKO_CAT	HKO_PRES
HKO_LON	HKO_WIND	

Korea Meteorological Administration (KMA)

The KMA provides information on typhoons occurring in the western North Pacific region. Data from KMA spans 2015 to present.

KMA_LAT	KMA_PRES	KMA_R30_DIR
KMA_LON	KMA_R50_DIR	KMA_R30_LONG
KMA_CAT	KMA_R50_LONG	KMA_R30_SHORT
KMA_WIND	KMA_R50_SHORT	

RSMC New Delhi (IMD)

The WMO Regional Specialised Meteorological Center at New Delhi (which is operated by the India Meteorological Department) is responsible for Tropical Cyclone forecasts in the North Indian Ocean. The data available from New Delhi begins in 1982[1] and is updated annually.

NEWDELHI_LAT	NEWDELHI_WIND	NEWDELHI_DP
NEWDELHI_LON	NEWDELHI_PRES	NEWDELHI_POCI
NEWDELHI_GRADE	NEWDELHI_CI	

RSMC La Reunion (MeteoFrance)

The WMO Regional Specialised Meteorological Center at La Reunion (which is operated by MeteoFrance) is responsible for Tropical Cyclone reports in the South Indian Ocean east of 100 degrees East. Earliest reported cyclones are from 1848 and data is provided annually.

REUNION_LAT	REUNION_RMW	REUNION_R50_SW
REUNION_LON	REUNION_R34_NE	REUNION_R50_NW
REUNION_TYPE	REUNION_R34_SE	REUNION_R64_NE
REUNION_WIND	REUNION_R34_SW	REUNION_R64_SE
REUNION_PRES	REUNION_R34_NW	REUNION_R64_SW
REUNION_TNUM	REUNION_R50_NE	REUNION_R64_NW
REUNION_CI	REUNION_R50_SE	REUNION_GUST
		REUNION_GUST_PER

Bureau of Meteorology (BoM)

The BoM operates as the WMO TCWC (Tropical Cyclone Warning Centers) at three BoM locations: Perth, Darwin, and Brisbane. The BoM combines reports from each of these centers into one consolidated dataset (provided as a CSV). The BoM provides data as early as 1907 and is updated annually. The BoM dataset has nearly 100 fields providing various parameters to describe the storm and its environment. Only a subset of those parameters is provided in IBTrACS. In general, we have included parameters that are common with other agencies.

BOM_LAT	BOM_R34_SE	BOM_R64_SW
BOM_LON	BOM_R34_SW	BOM_R64_NW
BOM_TYPE	BOM_R34_NW	BOM_ROCI
BOM_WIND	BOM_R50_NE	BOM_POCI
BOM_PRES	BOM_R50_SE	BOM_EYE
BOM_TNUM	BOM_R50_SW	BOM_POS_METHOD
BOM_CI	BOM_R50_NW	BOM_PRES_METHOD
BOM_RMW	BOM_R64_NE	BOM_GUST
BOM_R34_NE	BOM_R64_SE	BOM_GUST_PER

[1] IMD also provides a dataset called eAtlas, which has information on tropical cyclones from the late 1800s. However, many of the positions are missing dates or times or both. Data cannot be included in IBTrACS without a complete time stamp for each reported position.

TCWC Wellington (New Zealand MetService)

The New Zealand MetService at Wellington operates as the TCWC for the southern portion of the South Pacific (south of Nadi's area of responsibility). The first reported cyclone from Wellington is from 1968 and data are provided daily.

WELLINGTON_LAT	WELLINGTON_WIND	WELLINGTON_PRES
WELLINGTON_LON		

RSMC Nadi (Fiji)

The WMO Regional Specialised Meteorological Center at Nadi (operated by the Fiji Meteorological Service) is responsible for Tropical Cyclones in the northern portion of the South Pacific. Data from Nadi is updated annually with its first reports in 1992.

NADI_LAT	NADI_CAT	NADI_PRES
NADI_LON	NADI_WIND	

DataSet 824 (DS824)

The dataset 824 is a collection of storm data provided by the NCAR/UCAR Research Data Archive (RDA), which is denoted as 824.1. Data from ds824 is used for storms occurring between 1877 and 1980.

DS824_LAT	DS824_STAGE	DS824_PRES
DS824_LON	DS824_WIND	

TapeDeck (TD) 9636

The TD9636 dataset was constructed in the 1960s and 1970s by NOAA/National Climatic Center (now called NCEI). It represents a global collection of storms derived from multiple sources. It has not been updated since the 1980s. Data from TC 9636 is used in IBTrACS outside of the North Atlantic and before 1980.

TD9636_LAT	TD9636_STAGE	TD9636_PRES
TD9636_LON	TD9636_WIND	

TapeDeck (TD) 9635

The TD9635 is a joint Navy/NOAA dataset produced in the 1970s. The goal was to provide observations of storms that would aid forecast development. While it provides some information not listed in IBTrACS (e.g., latitude of ridge, etc.) it does provide an estimate of the ROCI (Radius of Outermost Closed Isobar, which is a measure of storm size) from surface analyses. TD9635 is a static dataset and provides information on storms from 1945 through 1976.

TD9635_LAT	TD9635_WIND	TD9635_ROCI
TD9635_LON	TD9635_PRES	

Neumann Southern Hemisphere Dataset

Charlie Neumann produced a consolidated best track dataset for the Southern Hemisphere which brought together information from dozens of sources. It is a static dataset; IBTrACS uses data from Neumann's data from 1960 through 2007.

NEUMANN_LAT	NEUMANN_CLASS	NEUMANN_PRES
NEUMANN_LON	NEUMANN_WIND	

Chenoweth Dataset

Michael L. Chenoweth compiled a reanalysis of historical hurricanes in the North Atlantic Ocean. The data is independent from the HURDAT analysis. It is a static dataset and spans 1851 through 1898.

MLC_LAT	MLC_CLASS	MLC_PRES
MLC_LON	MLC_WIND	

Appendix B. DIST2LAND and LANDFALL variables

New with IBTrACS version 4 are the two variables associated with land.

Purpose

The dist2land value was meant to be similar to the SHIPS (Statistical Hurricane Intensity Prediction System) variable of distance to land. A lower limit is placed on island sizes included since larger land masses have more impact on hurricane/tropical cyclone structure than smaller islands. In SHIPS, they limit islands to those larger than Trinidad (which is 4748 km^2). This seemed too large of a threshold as it removed some of the Hawaiian Islands. So, the IBTrACS land mask includes islands larger than 1400 km^2 (which just barely includes Kauai). The variable is not meant as a landfall flag for each and every island or area of interest. That is best accomplished with shapefiles and the coastline data of your choice. However, it does provide information on the larger landmasses with which a cyclone interacts.

Source

The coastline data used in the IBTrACS calculations are from:

Wessel, P., and Smith, W. H. F. (1996), A global, self-consistent, hierarchical, high-resolution shoreline database, *J. Geophys. Res.*, **101**(B4), 8741– 8743, doi:10.1029/96JB00104.

Definitions

DIST2LAND - DIST2LAND is described in the netCDF file as:

Distance to Land at current location

This value only uses the current center of circulation (i.e., position) to determine proximity to land.

Since DIST2LAND is a trailing indicator as far as landfall is concerned and since it can miss brief interactions with land (e.g., when a system crosses a coastline and remerges between IBTrACS reports), we included the LANDFALL variable.

LANDFALL - From the netCDF variable attribute:

Minimum distance to land between current location and next.

This variable represents the closest a system comes to land between the current position and the next reported position. If the value is zero, then it crosses a coastline during that time.

It has a useful relationship with DIST2LAND. For a given location, if DIST2LAND and LANDFALL are the same, then the cyclone is moving away from the coastline (because the current location is the closest the system is to land over the next three hours). Conversely, if the LANDFALL value is smaller than DIST2LAND, then the system is moving toward land.

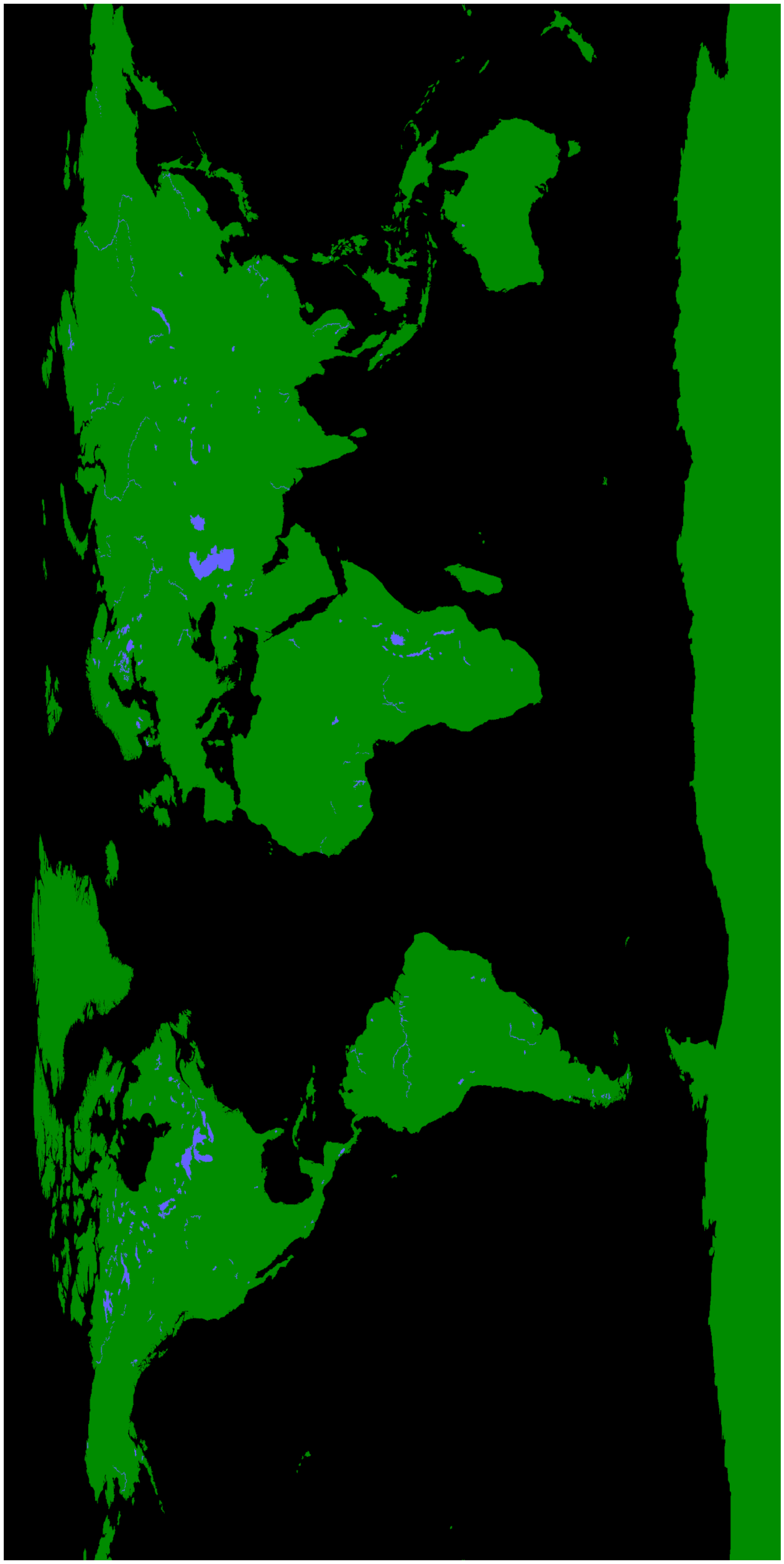

Figure - Landmasses used in the IBTrACS distance to land and landfall calculations.

Appendix C. Basin and subbasin definitions

The following provides definitions of the boundaries used for the basins and subbasins used in IBTrACS. All longitude values are listed in degrees West of the Prime Meridian.

Basin boundaries

Basin boundaries are generally on longitude boundaries.

<u>Southern Hemisphere basins (latitude < 0°)</u>

SI =	South Indian	10° < Longitude < 135°
SP =	South Pacific	135° < Longitude < 290°
SA =	South Atlantic	-70° < Longitude < 10°

<u>Northern Hemisphere basins (latitude > 0)</u>

Two basins are defined solely by longitude:

NI =	North Indian	30° < Longitude < 100°
WP =	Western Pacific	100° < Longitude < 180°

The boundary of the North Atlantic and Eastern Pacific overlap to allow storms to make landfall and move inland without crossing basins. A storm is said to change basins only if it emerges over the opposite ocean. For instance, an Eastern Pacific cyclone only changes basin if it makes landfall from the Pacific, is tracked continuously and emerges over the North Atlantic where the basin identifier changes when it emerges over the Atlantic. Conversely, a North Atlantic cyclone is deemed in the NA basin until it emerges (i.e. crosses the coastline) of the Pacific Ocean.

EP =	Eastern Pacific	
	Western Boundary of EP	180°
	Eastern Boundary of EP	Coastline of the North America on the North Atlantic
NA =	North Atlantic	
	Western Boundary of NA	Coastline of North America on the Eastern Pacific
	Eastern Boundary of NA	30°

Subbasin Boundaries

To facilitate analysis, some sub basins are provided for convenience. Some are defined by latitude and longitude boundaries while others were determined from their definitions at http://www.marineregions.org/ . If a cyclone is not in a predefined subbasin, then the subbasin is listed as a default value: MM (missing).

Southern Hemisphere subbasins:

Subbasin	Name	Definition
WA (SI)	Western Australia	In SI and Longitude > 90°
EA (SP)	Eastern Australia	In SP and Longitude < 160°

Northern Hemisphere subbasins:

Subbasin	Name	Definition
AS (NI)	Arabian Sea	in NI and Longitude < 78°
BB (NI)	Bay of Bengal	In NI and Longitude > 78°
CP (EP)	Central Pacific	In EP and Longitude < -140°
CS (NA)	Caribbean Sea	In NA and inside the boundary from: http://www.marineregions.org/gazetteer.php?p=details&id=4287
GM (NA)	Gulf of Mexico	In NA and inside the boundary from: http://www.marineregions.org/gazetteer.php?p=details&id=4288

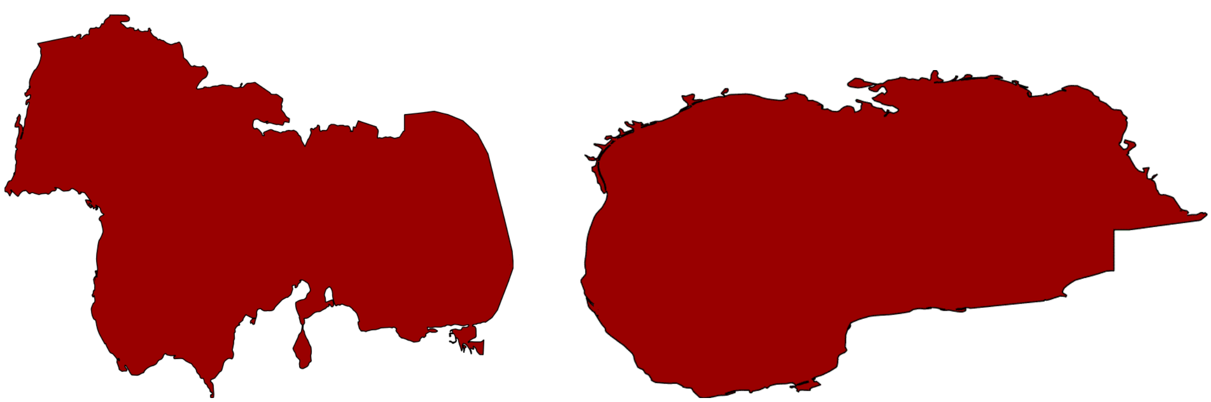

Figure - Outline of the (left) Caribbean Sea and (right) the Gulf of Mexico as defined by http://www.marineregions.org/

Appendix D. NATURE Assignments

The provided table shows the categorization of storm classifications from all of the available sources into the variable NATURE. NATURE represents the combined storm type, with options including:

DS - Disturbance
TS - Tropical
ET - Extratropical
SS - Subtropical
NR - Not reported
MX - Mixture (contradicting reports from different agencies)

Table D.1 - NATURE assignments for all available storm types. Disagreements between types (columns) other than NR for different sources (rows) at any given time step lead to MX classification. Lack of classification is NR.

NATURE Agency	DS- Disturbance	TS- Tropical	ET- Extratropical	SS- Subtropical	NR- Not reported
NHC	LO: A low that is neither a tropical cyclone, a subtropical cyclone, nor an extratropical cyclone (of any intensity) WV: Tropical Wave (of any intensity) DB: Disturbance (of any intensity)	TD: Tropical cyclone of tropical depression intensity (< 34 knots) TS: Tropical cyclone of tropical storm intensity (34-63 knots) HU: Tropical cyclone of hurricane intensity (> 64 knots)	EX: Extratropical cyclone (of any intensity)	SD: Subtropical cyclone of subtropical depression intensity (< 34 knots) SS: Subtropical cyclone of subtropical storm intensity (> 34 knots)	
ATCF	DB: disturbance, DS: dissipating, LO: low, WV: tropical wave, MD: monsoon depression	TD: tropical depression, TS: tropical storm, TY: typhoon, ST: super typhoon, TC: tropical cyclone, HU: hurricane	EX: extratropical systems, PT: post tropical	SD: subtropical depression, SS: subtropical storm	ET: extrapolated, XX: unknown IN: inland
JTWC	MD: monsoon depression, DS: dissipating, LO: low, WV: tropical wave	TD: tropical depression, TS: tropical storm, TY: typhoon, ST: super typhoon, TC: tropical cyclone, HU: hurricane	EX: extratropical systems	SD: subtropical depression, SS: subtropical storm	ET: extrapolated, XX: unknown. IN: inland
CPHC	LO: remnant low DS: Dissipated	TD: Tropical depression TS: Tropical storm HU: Hurricane	EX: extratropical	SD: subtropical depression, SS: subtropical storm	
Tokyo		2: Tropical Depression (TD), 3: Tropical Storm (TS), 4: Severe Tropical Storm (STS), 5: Typhoon (TY), 9: Tropical Cyclone of TS intensity or higher	6: Extratropical Cyclone (L)		7: Just entering into the responsible area of JMA

CMA	0: Weaker than Tropical Depression or unknown intensity;	1: Tropical Depression (TD: 10.8–17.1 m/s); 2: Tropical Storm (TS:17.2–24.4 m/s); 3: Severe Tropical Storm (STS: 24.5–32.6 m/s); 4: Typhoon (TY: 32.7–41.4 m/s); 5: Severe Typhoon (STY: 41.5–50.9 m/s); 6: Super Typhoon (SuperTY: ≥51.0 m/s);	9: Extratropical Cyclone (ET) stage		
HKO	LW: Low <22 kt	TD: Tropical Depression 22 – 33 kt TS: Tropical Storm 34 – 47 kt STS: Severe Tropical Storm 48 – 63 kt T: Typhoon 64 – 80 kt ST: Severe Typhoon 81 – 99 kt SuperT: Super Typhoon >= 100 kt			
KMA		TD: Tropical Depression 14 – 17 m/s TS: Tropical Storm 17 – 25 m/s STS: Severe Tropical Storm 25 – 33 m/s TY: Typhoon >= 33 m/s	L: Extratropical Cyclone		
New Delhi	L: Low pressure area <17 knots	D: Depression 17 – 27 kts DD: Deep Depression 28 – 33 kts CS: Cyclonic Storm 34 – 47 kts SCS: Severe Cyclonic Storm 48 – 63 kts VSCS: Very Severe Cyclonic Storm 64 – 89 kts ESCS: Extremely Severe Cyclonic Storm 90 – 119 kts SuCS: Super Cyclonic Storm>=120 knots			

Reunion	01: tropics; disturbance (no closed isobars) 06: dissipating	02: <34 kt winds and at least one closed isobar 03: 34 – 63 kts 04: >63 kts	05: extratropical	07: subtropical cyclone (nonfrontal, low pressure system that comprises initially baroclinic circulation developing over subtropical water)	08: overland 09: unknown 99: unknown
BOM	10: Tropics; disturbance (no closed isobars) 60: Dissipating (no gales)	20: <34 kts winds, and at least one closed isobar 21: 34 – 63 kts two or less quadrants 30: 34 – 63 kts more than two quadrants 40: >63 kts	50: Extra-tropical (no gales) 51: Extra-tropical (with gales) 52: Extra-tropical (max wind unknown)	70: Subtropical cyclone (non-frontal, low pressure system that comprises initially baroclinic circulation developing over subtropical water) (no gales) 71: Subtropical cyclone (with gales) 72: Subtropical cyclone (max wind unknown)	NULL: Default – unknown 80: Overland (no gales) 81: Overland (gales) 91: Tropical Cold-cored – Monsoon Low (with surrounding gales away from centre)
Nadi		1-5			
Ds824	DS WV	TC: Tropical cyclone	EX	SS	MM
TD9636	0: Tropical disturbance (1969 onward) 6: Dissipating	1: depression < 34 [some variation in definition for S Indian] 2: Storm 34-63 [with some variation in definition for S Indian] 3: point where wind reached 64 knots [except N Indian where it is wind 43-47 knots] 4: Hurricane > 64 [except in N Indian, Wind > 48]	5: Extratropical		7: Unknown Intensity or doubtful track
Neuman		TC: Tropical	EX: Extratropical		MM: Missing
Chenoweth	LO: Low WV: Open Wave	HU: Hurricane MH: Major Hurricane TS: Tropical Storm TD: Tropical Depression	EX: Extratropical	SD: Subtropical depression SS: Subtropical storm	TW